# The Water Encyclopedia

THIRD EDITION

## Hydrologic Data and Internet Resources

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## Hydrologic Data and Internet Resources

Edited by
**Pedro Fierro, Jr.**
**Evan K. Nyer**

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# Preface

"Just do an Internet search." "It's on the Internet." How often have we said or been told that we could find it on the Internet. This third edition of *The Water Encyclopedia: Hydrologic Data and Internet Resources* started from a premise that most of the information provided within this publication could be found on the Internet. As our team of contributing authors started reviewing each section within each chapter, it soon became apparent that you cannot always find it on the internet. This edition represents many hours of effort to identify the most current information on a wide range of water-related topics whether it can be found on the internet or in other sources.

The *Encyclopedia* has retained many of the elements of the previous editions but has also been expanded to reflect the many changes within the environmental industry as well as the current and topical water-related matters of the last decade. Prepared by scientists and engineers, this publication is intended to serve as a valuable resource to all professionals dealing with water-related issues as well as the general public. The material presented has been footnoted to provide the user with the opportunity to return to the original source material for additional research. Where possible, an Internet URL address is provided to guide the user to the appropriate source.

The third edition of the *Encyclopedia* has been significantly expanded beyond the previous edition. The first two chapters of this edition are new and discuss data management and international data collection. Data management concepts are presented to review the use of databases, geographic information systems (GIS), data reporting and metadata. Data repositories and availability vary around the world and range in ease of access and usability. The international data collection provides some direction on potential data sources in less developed areas as well as case histories of actual project work and Internet sources for international water-related data.

This edition contains more than 1100 tables and 500 figures providing data related to weather, surface water, groundwater, water use, water quality, waste water, pollution, and water resource management. The pollution chapter alone has grown to contain some 450 plus tables and figures. Wastewater, previously included within the pollution chapter, is presented as a stand-alone chapter to facilitate use of this reference. A chapter of useful conversion factors and constants concludes this edition.

Whether you are looking for a specific piece of information or exploring one or more of the many topics related to water, this edition provides its users with a tremendous wealth of data whether on the Internet or not.

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# Acknowledgments

We want to extend our thanks and appreciation to the many individuals, publishers, and organizations that have made this third edition a reality. Without their time, cooperation, collaboration, this work would not have been possible. Most importantly, the support and access to resources for the management of this compilation provided by ARCADIS G&M was invaluable, and their on-going support and encouragement to undertake these efforts are deeply appreciated.

A number of individual contributors were involved in compiling the relevant information for each of the chapters and they are identified at the start of their chapters. Our thanks and appreciation to you and your families for the time committed to completing this task. Behind the scenes and the backbone of keeping everything organized, we want to extend a special thanks to Chris Worden and Carla Gerstner for their encouragement, patience, and the occasional stern word. Additionally, we want to acknowledge Barbara Kelly and Amanda Fierro for their efforts in preparing materials for the manuscript.

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Fierro received his bachelor's degree in geology from the University of Rochester, Rochester, New York and his master's degree in geology with an emphasis on groundwater studies from the University of Kentucky. He currently holds geological professional licenses/registrations in Alabama, Florida, Georgia, Kentucky, Pennsylvania, and Tennessee. He is a certified groundwater professional and a certified professional geologist. He was a contributing author to *In Situ Treatment Technology*.

**Evan K. Nyer** is a senior vice president with ARCADIS G&M, Inc., where he is responsible for maintaining and expanding the company's technical expertise in geology/hydrogeology, engineering, fate and transport, and remediation technologies. He has been active in the development of new treatment technologies for many years. He has been responsible for the strategies, technical designs and installations of more than 400 groundwater and soil remediation systems at contaminated sites throughout the United States. Nyer also lectures, provides expert testimony, and serves as the public spokesperson for one technically complicated site.

Nyer received his graduate degree in environmental engineering from Purdue University and has authored five books: *Practical Techniques for Groundwater and Soil Remediation*, published by Lewis Publishers, Inc.; *Groundwater Treatment Technology*, first and second edition, published by Van Nostrand Reinhold; *Groundwater and Soil Remediation*, and *In Situ Treatment Technology* (now in its second edition) published by CRC Press; and is co-author of *Bioremediation*, published by the American Academy of Environmental Engineers. Nyer is a regular contributor to *Groundwater Monitoring and Remediation* having had his own column "Treatment Technology" in the periodical for the past 20 years.

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CHAPTER 1

# Data Management

**Daniel J. McCarthy**

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## 1.1 INTRODUCTION

Data management encompasses many tasks, priorities, and decisions. Underlying these activities is the need for an accurate data from sampling and monitoring programs designed to measure the effects of operational activities. To understand the value of good data management, it is helpful to understand the nature of how this information is generated and used to support management decisions.

So what is data? The American Heritage Dictionary defines data as factual information, especially information organized for analysis or used to reason or make decisions, or values derived from scientific experiments. Scientific professionals generate huge quantities of data every day. It is estimated that scientists spend 80% of their time managing the data and 20% analyzing and interpreting. By establishing sound data management practices, more time can be spent in data analysis and interpretation.

Throughout this chapter, we will provide examples of data management practices within the context of an investigation of contaminated groundwater and surface water. These practices are directly applicable to managing other types of data, such as those found in this book.

## 1.2 DATABASE OVERVIEW

A discussion of data management would be incomplete without a general discussion of databases.

A very general definition of a database might be "*A collection of related items of information contained on*



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**Table 1.1 Groundwater and Surface Water Location Data**

| Location ID | Area of Concern | *x* | *y* | *z* |
|---|---|---|---|---|
| SW-01 | Upstream | 1,75,470.994 | 16,35,550.124 | 100.203 |
| SW-02 | Upstream | 1,77,126.487 | 16,35,925.814 | 100.102 |
| SW-03 | Outfall 1 | 1,77,047.029 | 16,35,676.853 | 100.00 |
| SW-04 | Downstream | 1,76,871.093 | 16,35,674.137 | 98.97 |
| SW-05 | Downstream | 1,75,790.418 | 16,35,597.208 | 97.96 |
| MW-01 | Background area | 1,74,345.077 | 16,32,431.087 | 96.597 |
| MW-02 | Oil storage area | 1,74,251.127 | 16,32,466.059 | 97.384 |
| MW-03 | Oil storage area | 1,74,690.942 | 16,31,435.707 | 97.384 |

*various media organized in a way that allows easy search and retrieval of subsets of the items of information*." Note that, strictly speaking, a database does not have to be electronic: Boxes containing recipes, telephone books, or paper address books are all databases. A database used for environmental purposes might be composed of a combination of paper copies of information along with items of information contained in electronic form, with perhaps some sort of paper or electronic index to or inventory list of all of the data.

Electronic data are nearly always organized into tables. Consider the example shown in Table 1.1.

Each row of this table represents a single data point; in this case the first row provides data about location SW-1, and only SW-1. Each column of this table represents a type of data that is stored for each row. In our example, the Area of Concern column identifies the spatial group that each location belongs to.

The rows in a database table are typically called "records," while the columns are called "fields." Thus, a useful definition of an electronic database is "A collection of related items of data organized into one or more tables." Each field is constrained to a single data type. Table 1.2 lists the most common data types.

Electronic databases are typically either "flat file databases," in which the entire database resides in a single table, or "relational databases," in which the data are distributed into more than one table, which are then linked together by a common key field. The tables will be related to one another according to a one-to-one (each record in one table has a single matching record in the other table) or one-to-many relationship (each record in one table may have one or more matching records in the other table, but not the reverse).

**Table 1.2 Common Data Types**

| Data Type | Description or Example |
|---|---|
| Integer | Typically stores numbers that relate to counts quantities, or, ID numbers |
| Decimal | Numbers with fractional parts such as percentages or rates |
| Floating point | Numbers with a scientific notation that can be calculated approximately, such as distance or weight |
| Fixed length character | Names, descriptions, addresses |
| Date/Time | Storage of date and/or time or intervals of dates or times |
| Boolean | Explicit constraints (Yes/No, True/False) or logical constraints (AND/OR) |
| Unstructured data | Images, video, audio |

One significant advantage of relational databases to flat-file databases is the ability to query the data in different ways. A query is defined as a statement to retrieve database records that match certain criteria. By structuring the query statement a certain way, different information can be returned from the data set.

The most popular general-purpose software for managing data is an electronic spreadsheet program such as Microsoft Excel. Electronic spreadsheets are excellent tools for managing electronic data that fit in a single table. However, spreadsheets are cumbersome or inadequate tools for managing relational data, where more than one table is required. For managing relational data, other more powerful data management programs should be used. There are many popular relational database management systems available, including Microsoft Access. It should be noted that, in contrast to flat-file databases, which typically can be managed by the casual computer user, large relational databases require management by trained individuals, and will usually be beyond the capabilities of the casual user.

The field of database management is continually in flux, and would have changed by the time this book is published. Thus, it is impossible to cover all the facets of data management and database theory here. However, it can be said that the relational database model overwhelmingly dominates large-scale data management and database theory. For further information about relational databases, the reader is directed to any of the numerous references on this subject. A particularly helpful book designed for the casual database user is by Michael J. Hernandez (2003) entitled *Database Design for Mere Mortals: A Hands-On Guide to Relational Database Design*, Addison–Wesley Developers Press.

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## 1.3 GEOGRAPHIC INFORMATION SYSTEMS OVERVIEW

Data are often presented in a tabular format. Sometimes, a visual representation is helpful in drawing conclusions, particularly if the data have a spatial component. A Geographical Information System (GIS) is a way to display information with a spatial component. GIS can be defined as a software package that manages and displays information in a database composed of data that are associated with spatial information. That is to say, there will be both tabular and spatial information in the database, it will be possible to query the database for specific data, and the user will be able to display the data spatially, as a map.

The software package comprising the GIS may be a single program, a set of programs from a single vendor, a combination of programs that together constitute the GIS, a custom-programmed software package, or any combination thereof.

In the groundwater arena, the tabular data could typically be depth to water data, water table elevation data, water chemistry data, and water quality data. In addition, the tabular data will have some spatial component in either two or three dimensions, as $x$–$y$–$z$ coordinates. Spatial data, in addition to the $x$–$y$–$z$ coordinates mentioned above, often will include digitally processed air or satellite photographs, computer-aided design (CAD) drawings, or other electronic spatial entities. Clearly, depth to water data and water chemistry data, which can be displayed in both plan view (two-dimensional) and side view (three-dimensional), are well suited to management using a GIS. Table 1.3 is an example of data from a GIS system representing depth to groundwater.

When generated in a GIS system in plan view, the view can look like Figure 1.1.

The primary attraction of a GIS is the ability to manage, query and display a large amount of data spatially, in real time. Using most GISs, the user can view the data on a map, query for a subset of the data while viewing the map, and then see the distribution of the subset data when the map is refreshed. This process can be repeated as many times as necessary to answer a question. For example, the temporary wells in the previous figure were not measured during the August sampling event. By querying the GIS system only for locations that were measured during the August event, we return a subset of the data, shown in Table 1.4.

From this set of data, our map would look like Figure 1.2.

The literature on GISs is voluminous. Because GISs have a wide applicability throughout many disciplines, the reader is directed to the internet, where search engines associated with any popular internet portal (Yahoo! or America Online, for example) may be used to find literally thousands of references on the subject.

**Table 1.3 Depth to Groundwater Data from GIS System**

| Well_Id | Loc_Type | X_Coord | Y_Coord | Date | Gwelev |
|---|---|---|---|---|---|
| MW131 | Monitor well | 25,48,766.73000 | 3,19,202.76570 | 8/17/2004 | 19.21000 |
| MW132 | Monitor well | 25,48,671.72700 | 3,19,228.04840 | 8/17/2004 | 20.38000 |
| MW133 | Monitor well | 25,48,677.58100 | 3,19,285.61010 | 8/17/2004 | 19.23000 |
| MW134 | Monitor well | 25,48,740.41300 | 3,19,287.73680 | 8/17/2004 | 18.13000 |
| MW135 | Monitor well | 25,48,668.82800 | 3,19,335.81440 | 8/17/2004 | 18.78000 |
| MW136 | Monitor well | 25,48,747.90500 | 3,19,346.29610 | 8/17/2004 | 16.71000 |
| MW137 | Monitor well | 25,48,704.97300 | 3,19,107.44400 | 8/17/2004 | 21.40000 |
| TW-161 | Temp monitor well | 25,48,677.70000 | 3,18,512.69000 | 8/17/2004 | NM |
| TW-162 | Temp monitor well | 25,49,393.00000 | 3,17,485.00000 | 8/17/2004 | NM |
| TW-163 | Temp monitor well | 25,49,412.00000 | 3,17,501.00000 | 8/17/2004 | NM |
| TW-164 | Temp monitor well | 25,48,775.80000 | 3,19,271.63000 | 8/17/2004 | NM |
| TW-165 | Temp monitor well | 25,48,788.62000 | 3,19,196.71000 | 8/17/2004 | NM |
| TW-166 | Temp monitor well | 25,48,656.95000 | 3,19,215.44000 | 8/17/2004 | NM |
| TW-167 | Temp monitor well | 25,48,690.37000 | 3,19,153.66000 | 8/17/2004 | NM |
| TW-168 | Temp monitor well | 25,48,618.73000 | 3,19,285.76000 | 8/17/2004 | NM |
| TW-169 | Temp monitor well | 25,48,672.29000 | 3,19,291.02000 | 8/17/2004 | NM |
| TW-170 | Temp monitor well | 25,48,722.90000 | 3,19,286.09000 | 8/17/2004 | NM |
| TW-171 | Temp monitor well | 25,48,745.57000 | 3,19,224.97000 | 8/17/2004 | NM |
| TW-172 | Temp monitor well | 25,48,758.72000 | 3,19,164.83000 | 8/17/2004 | NM |
| TW-173 | Temp monitor well | 25,48,304.43000 | 3,19,248.26000 | 8/17/2004 | NM |
| TW-174 | Temp monitor well | 25,48,314.10000 | 3,19,441.75000 | 8/17/2004 | NM |
| TW-175 | Temp monitor well | 25,48,247.26000 | 3,19,666.89000 | 8/17/2004 | NM |

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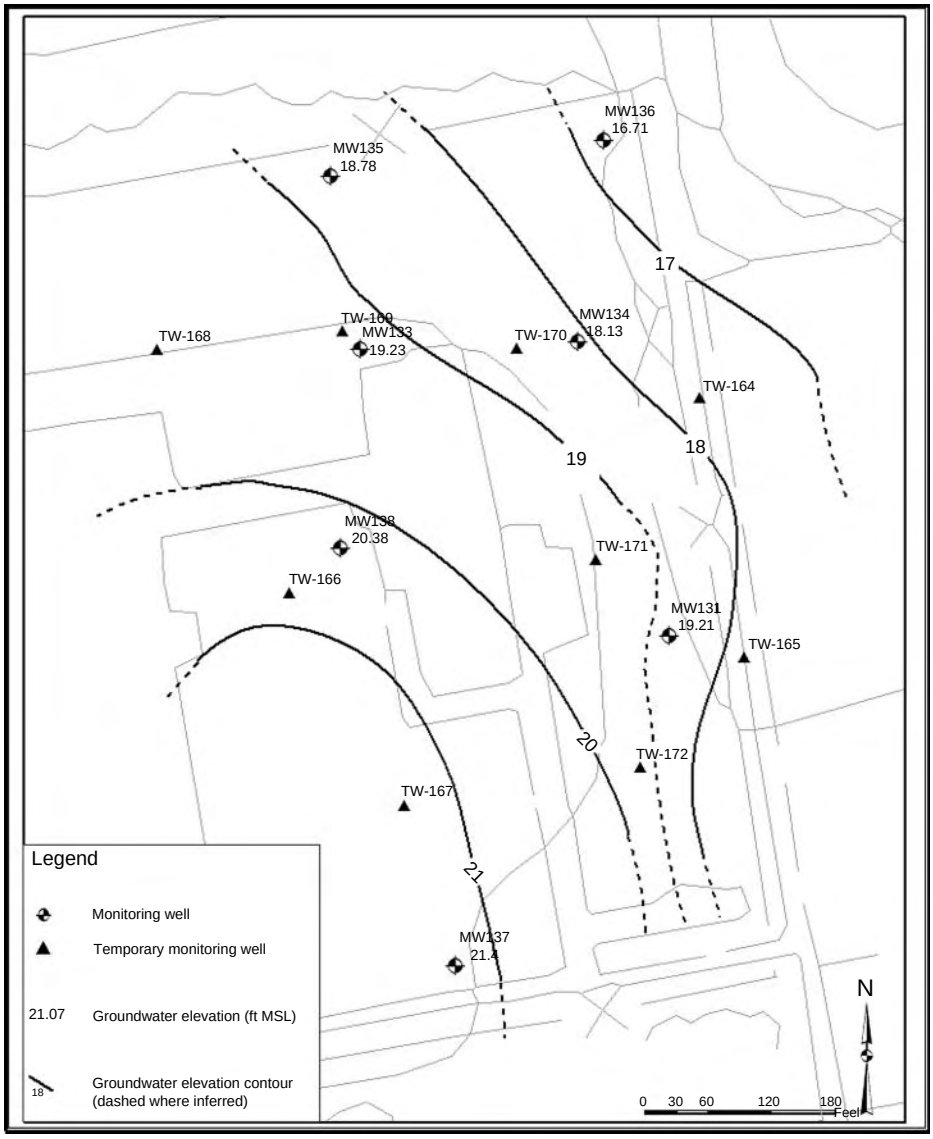


**Figure 1.1** Example of groundwater elevation data from GIS System.

## 1.4 UNDERSTANDING DATA MANAGEMENT NEEDS

Initially designing a data management program for an investigation or experiment requires significant scientific expertise. However, after design and implementation, the processes generally follow a well-defined and straightforward cycle. In our groundwater contamination example, samples are routinely collected and sent to laboratories where they are analyzed with the results reported in the form of a hard-copy analytical results report. From this point on, the data are put to multiple uses to meet a variety of needs. Some portion of the data are collected and reported under the requirements of environmental permits, while additional data are generated voluntarily to further the objectives of sound environmental management. Accountability for effectively managing the collection and utilization of this information according to well-defined processes within

**Table 1.4 Subset of Table 1.3 Data for August Events Only**

| Well_Id | Loc_Type | X_Coord | Y_Coord | Date | Gwelev |
|---|---|---|---|---|---|
| MW131 | Monitor well | 25,48,766.73000 | 3,19,202.76570 | 8/17/2004 | 19.21000 |
| MW132 | Monitor well | 25,48,671.72700 | 3,19,228.04840 | 8/17/2004 | 20.38000 |
| MW133 | Monitor well | 25,48,677.58100 | 3,19,285.61010 | 8/17/2004 | 19.23000 |
| MW134 | Monitor well | 25,48,740.41300 | 3,19,287.73680 | 8/17/2004 | 18.13000 |
| MW135 | Monitor well | 25,48,668.82800 | 3,19,335.81440 | 8/17/2004 | 18.78000 |
| MW136 | Monitor well | 25,48,747.90500 | 3,19,346.29610 | 8/17/2004 | 16.71000 |
| MW137 | Monitor well | 25,48,704.97300 | 3,19,107.44400 | 8/17/2004 | 21.40000 |

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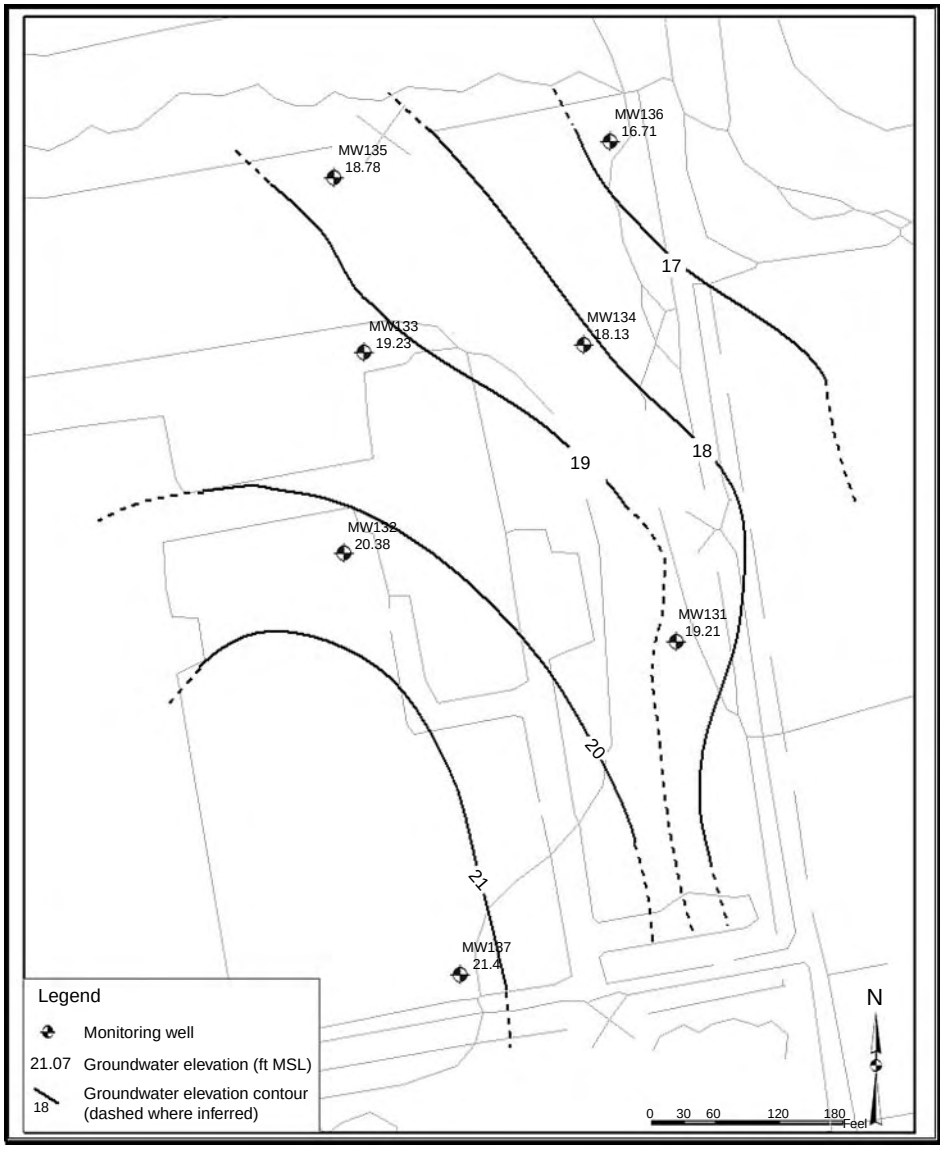


**Figure 1.2** Groundwater elevation data from August only.

standardized software environments is essential to effective environmental management.

Problems with data collection can be mitigated with a data management plan. This plan will typically specify how data are to be labeled and categorized, the format that the data are to be stored in, how to handle data collected over a period of time or over a significant geographic area, and procedures to account for changes in the investigation and experiment. The advantage to having a data management plan is that it allows the users to collect, label, and record data in a consistent manner. By doing so, retrieval of that data does not have to take into account bias on the part of the individual collecting the data. Consistent terms, units, methods and procedures, will allow any user to retrieve data accurately and quickly.

## 1.5 DATA CATEGORIZATION

### 1.5.1 Spatial Data

Data found in this book are often of two distinct types: data with a spatial representation and that of a temporal representation. Water quality, for example, can be represented as changing over an area based on land use, and can also be represented as changing over time due to urban development changing the drainage pathways.

It is often helpful to have a defined nomenclature when collecting and categorizing data. This nomenclature makes it easy to glean basic information from the raw data, as well as expediting queries from the data management system. As an example, consider the following spatial data, shown in Table 1.5.

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**Table 1.5 Spatial Data for Groundwater and Surface Water Locations**

| Location ID | Area of Concern | *x* | *y* | *z* |
|---|---|---|---|---|
| SW-01 | Upstream | 1,75,470.994 | 16,35,550.124 | 100.203 |
| SW-02 | Upstream | 1,77,126.487 | 16,35,925.814 | 100.102 |
| SW-03 | Outfall 1 | 1,77,047.029 | 16,35,676.853 | 100.00 |
| SW-04 | Downstream | 1,76,871.093 | 16,35,674.137 | 98.97 |
| SW-05 | Downstream | 1,75,790.418 | 16,35,597.208 | 97.96 |
| MW-01 | Background area | 1,74,345.077 | 16,32,431.087 | 96.597 |
| MW-02 | Oil storage area | 1,74,251.127 | 16,32,466.059 | 97.384 |
| MW-03 | Oil storage area | 1,74,690.942 | 16,31,435.707 | 97.384 |

Consistent nomenclature for identifying spatial locations is crucial to maintaining data integrity, particularly where there is sensitivity to geographic, political, and physical boundaries. In addition, each location should be unique in order to maintain referential integrity within the data management system. This unique value in this table is referred to as a *primary key*. The location IDs are coded in such a way to let the reader know at a glance what type of location it is. Acceptable locations types in this example include:

| Location Type Identifier | Location Type Description |
|---|---|
| MW | Monitoring well |
| SW | Surface water |

The Area of Concern column provides a general categorization of where the location occurs within the context of the immediate surroundings. This is useful for queries that would ask for all data found in a particular site-specific area.

The example table also presents spatial data in the form of *x*, *y*, and *z* coordinates. Spatial data for each location should be collected in a form that is consistent with use at the site, but that can also reference features that are located nearby, such as surface water bodies, wetland areas, or other physiographic features. Use of a consistent coordinate system will make sure that all the data can be compared to each other.

Examples of coordinate systems include latitude, longitude and height, Universal Transverse Mercator (UTM), Earth Centered, Earth Fixed Cartesian (ECEF), and State Plane coordinates. In our example, the coordinates are in State Plane Coordinates. In the United States, the State Plane System was developed in the 1930s and was based on the North American Datum 1927 (NAD27), which are based on the foot. A more recent variation is the NAD83 system, which is based on the North American 1983 datum and is based on the meter. The State Plane System was developed to provide local references tied to a national datum. Most USGS 7.5 Minute Quadrangles use several coordinate system grids including latitude and longitude, UTM kilometer tic marks, and applicable State Plane coordinates.

## 1.6 TEMPORAL DATA

With the establishment of the spatial locations, data collected over time can be collected and referenced. Consider Table 1.6, which summarizes data from samples collected from our groundwater and surface water locations.

Consistent nomenclature for sample identifications is crucial to maintaining data integrity. And sample identifications should be unique in order to maintain referential integrity. Character limits are often in place in database management systems; therefore, care should be taken in minimizing spaces, dashes, or parentheses. In our example, the date of collection is captured in the sample ID in parentheses, which allows each sample to be unique.

By including the Location ID in this table, we establish a relationship to the previous table. This relationship allows us to query the data in different ways. Because the relationship is of one location to many samples, this is referred to as a *one-to-many relationship*. The Location ID in this table is referred to as a *foreign key* because it matches primary key values in our spatial data table presented earlier. Together the primary and foreign keys create a parent/child relationship, which is at the heart of relational database systems.

The Sample Type column provides an identifier to discriminate individual samples from each other based on quality assurance needs. In this example, all of the samples have a normal "N" type. If duplicate samples were required for quality assurance purpose to check on the validity of the data set, one could identify the sample type as a "D" for duplicate.

The Sample Matrix column identifies what the medium collected for each sample was, through

**Table 1.6 Sample Information from Groundwater and Surface Water Locations**

| Sample ID | Location ID | Sample Type | Sample Matrix | Sample Date | Sample Time |
|---|---|---|---|---|---|
| SW-1(081602) | SW-1 | N | WS | 8/16/2002 | 13:00 |
| SW-2(081602) | SW-2 | N | WS | 8/16/2002 | 13:10 |
| SW-3(081602)) | SW-3 | N | WS | 8/16/2002 | 13:20 |
| SW-4(081602) | SW-4 | N | WS | 8/16/2002 | 13:30 |
| SW-5(081602) | SW-5 | N | WS | 8/16/2002 | 14:31 |
| MW-01(111301) | MW-01 | N | WG | 11/13/2001 | 15:22 |
| MW-01(111401) | MW-01 | N | WG | 11/14/2001 | 16:31 |
| MW-01(111501) | MW-01 | N | WG | 11/15/2001 | 11:00 |

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an abbreviated two-digit code. Examples of these kinds of matrices are:

| Sample Matrix | Matrix Description |
|---|---|
| WB | Water collected from borehole or during geoprobe investigation |
| WE | Estuary water |
| WG | Ground water |
| WL | Leachate |
| WO | Ocean water |
| WP | Drinking water |
| WQ | Water quality control matrix |
| WS | Surface water |
| WW | Waste water |

The sample date and time columns allow the data to be sorted from more recent to historical and can provide a context for how the data changes over time.

Continuing with our groundwater contamination example, consider Table 1.7, which summarizes the data obtained from an analytical laboratory.

The primary key (Sample ID) is present again to establish the relationship back to the other tables. The other columns relate information related to the analyses performed on the samples and the results.

Each of these records represents a concentration of a given chemical at a given location for a specific point in time. As chemical concentrations, detection limits and detections change, those data points would be represented as new records in the database. This can be illustrated in the following query result, shown in Table 1.8.

## 1.7 DATA VALIDATION AND VERIFICATION

Once data are collected into the database, steps must be taken to ensure that it was collected accurately and is representative of the source. Data verification checks the compliance of the collected data against known requirements of the experiment or investigation. For example, using the data set shown above, we would verify with the analytical laboratory that the groundwater samples were analyzed according to specific methods, such as the use of the calibration samples for laboratory equipment. If a verification check fails, then the data may be considered suspect.

Data validation, by contrast, must take into account the suitability of the data, and must take into account how the data were collected, how the data were analyzed, and finally, based on the results of the review of the collection and analysis processes, how the data should be used. If the collection process is found to be flawed, the data might be discarded or used for qualitative purposes only. The United States Environmental Protection Agency has provided guidance documents on validating data, which can be found at www.epa.gov/superfund/programs/clp/guidance.htm.

## 1.8 DATA REPORTING

Once the data have been collected and validated into the data management system, it is time to retrieve the data and make some conclusions about its meaning. Data retrieval usually takes the form of querying the data and then reporting the data.

### 1.8.1 Querying Data

A query is a programmatic statement that asks a question about the data. Each query usually specifies a criterion, which is a condition or test that must be met in order for a given record to be selected. Queries produce subsets of data, which are the records that match the conditions of the query. For example, a query might request the locations where a certain chemical, e.g. carbon tetrachloride, exceeds a certain concentration, e.g. 500 µg/L. This query would produce a result like the one presented below in Table 1.9.

**Table 1.7 Analytical Data Summary**

| Sample ID | Matrix | SDG | Lab Method | Chemical | Result | RDL | Detect | Unit |
|---|---|---|---|---|---|---|---|---|
| SW-1(081602) | WG | 884825 | SW8260 | Carbon disulfide | | 2.5 | N | µg/L |
| SW-1(081602) | WG | 884825 | SW8260 | Xylene (total) | | 2.5 | N | µg/L |
| SW-1(081602) | WG | 884825 | SW8260 | Ethylbenzene | | 0.2 | N | µg/lL |
| SW-1(081602) | WG | 884825 | SW8260 | Carbon tetrachloride | 670 | 25 | Y | µg/L |

**Table 1.8 Additional Analytical Data**

| Sample ID | Matrix | SDG | Sample Date | Lab Method | Chemical | Result | RDL | Detect | Unit |
|---|---|---|---|---|---|---|---|---|---|
| SW-1(081602) | WG | 884825 | 8/16/2002 | SW8260 | Carbon tetrachloride | 670 | 25 | Y | µg/L |
| SW-1(111602) | WG | 884825 | 11/16/2002 | SW8260 | Carbon tetrachloride | 340 | 25 | Y | µg/L |
| SW-1(011603) | WG | 884825 | 01/16/2003 | SW8260 | Carbon tetrachloride | 100 | 5 | Y | µg/L |
| SW-1(031603) | WG | 884825 | 03/16/2003 | SW8260 | Carbon tetrachloride | | 5 | N | µg/L |

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**Table 1.9 Query Results for Carbon Tetrachloride Concentrations over 500 μg/L**

| Sample ID | Matrix | SDG | Lab Method | Chemical | Result | RDL | Detect | Unit |
|---|---|---|---|---|---|---|---|---|
| SW-1(081602) | WG | 884825 | SW8260 | Carbon tetrachloride | 670 | 25 | Y | μg/L |

**Table 1.10 Data Summary for Crosstab Query**

| Loc ID | AoC | Nitrate | Iron | Sulfate Concentration |
|---|---|---|---|---|
| SW-01 | Upstream | 200 | 599 | 100.203 |
| SW-02 | Upstream | 250 | 342 | 100.102 |
| SW-03 | Background area | 300 | 105 | 100 |
| SW-04 | Downstream | 100 | 20 | 98.97 |
| SW-05 | Downstream | 50 | 40 | 97.96 |
| MW-01 | Background area | 75 | 50 | 96.597 |
| MW-02 | Oil storage area | 60 | 65 | 97.384 |
| MW-03 | Oil storage area | 35 | 10 | 97.384 |

This type of query is referred to a selection query; it returns the selection based on the criteria. Other types of queries, available in Microsoft Access for example, include action queries and crosstab queries. Action queries change record information by specifying criteria and changing the values in given fields based on those criteria. An example of an action query would be the application of data qualifiers following a rigorous validation of the collected data. For example, in our surface water example, the data validation process might uncover that the analytical laboratory initially reported the reported detection limit of carbon tetrachloride as 25 μg/L but in fact it should have been 100 μg/L. An action query could be used to specify the criteria (Sample SW-1(081602) and carbon tetrachloride) and correct the reported detection limit (RDL) from 25 to 100.

Crosstab queries perform aggregate calculations on the value of a field, using one or more other fields as rows and one field's data as columns. For example, consider the data set shown in Table 1.10.

An analysis of this data might help refine a remedial course of action for impacted groundwater. Useful calculations to perform would be the average and the maximum values of each of the constituents. A crosstab query of this data would generate the following results, shown in Table 1.11.

### 1.8.2 Reporting Data

Once data have been retrieved through a query process, it can be reported in tabular format, like those found in this chapter and elsewhere in this book, graphically in the form of charts and graphs, or if there is a spatial representation to the data, as a figure in a GIS system.

**Table 1.11 Crosstab Query Results**

| | Area of Concern | | | |
|---|---|---|---|---|
| Data | Background Area | Downstream | Oil Storage Area | Upstream |
| Average of nitrate | 187.5 | 75 | 47.5 | 225 |
| Average of iron | 77.5 | 30 | 37.5 | 470.5 |
| Average of sulfate concentration | 98.2985 | 98.465 | 97.384 | 100.1525 |
| Max of nitrate | 300 | 100 | 60 | 250 |
| Max of iron | 105 | 40 | 65 | 599 |
| Max of sulfate concentration | 100 | 98.97 | 97.384 | 100.203 |

## 1.9 METADATA

The formal definition of metadata is simply "data about data." Metadata is the information about a data source, for example, a book contains information, but there is also information about that book such as the author and publisher—this is the metadata.

Metadata in the context of this book can be used to describe how a particular data table was assembled, who collected the data, what method was used to collect and aggregate the data, the sources of the data. In our groundwater contamination example, metadata might include who did the surveying for the locations, the date of that survey, and the coordinate system specification.

For the sample data, the metadata might consist of the following components, shown in Table 1.12.

**Table 1.12 Examples of Metadata Components**

| Field Name | Field Description |
|---|---|
| $COC^{num}$ | Chain of custody identifier |
| Sent_to_lab_date | Date sample was sent to lab |
| Sample_receipt_date | Date that sample was received at laboratory |
| Sampler | Name or initials of sampler |
| Sampling_company | Name or initials of sampling company |
| Sampling_reason | Reason for sampling |
| Sampling_technique | Sampling technique |
| Task_code | Code used to identify the task under which sample was retrieved |
| Collection_quarter | Quarter of the year sample was collected (e.g., "1Q96") |
| Composite_yn | Boolean field used to indicate whether a sample is a composite sample |
| Composite_desc | Description of composite sample (if composite_yn is YES) |

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Within the context of GISs, metadata almost always refers to "data about digital geospatial data." Throughout this discussion, the term "metadata" is used under this restricted definition to refer to the *content, quality, condition, and other characteristics of digital geospatial data*.

Metadata for electronic images should include, as a minimum:

- How the image was created
- Who created it originally
- What has been done to enhance the image
- Coordinate system to which the image has been rectified
- Projection system to which the image has been rectified
- Other information unique to these particular images

With regard to electronic spatial data, in the United States, efforts are being made to try to develop a universal standard format for metadata for GIS systems. This would make accessing and using metadata much easier than it is today. Toward this end, the Federal Geographic Data Committee (FGDC) has approved a standard for metadata. Development of the standard was a part of the development of the National Spatial Data Infrastructure.

The standard is known as the Content Standard for Digital Geospatial Metadata (Version 2). It may be downloaded as a pdf file from the FGDC web site (www.fgdc.gov/standards/documents/standards/metadata/v2_0698.pdf).

While this standard is intended to facilitate the use of metadata and associated data (particularly images), it appears to not have been universally accepted outside of U.S. government bodies. Accordingly, within this definition metadata may take many forms, ranging from simple (on the paper map, the map legend is the metadata) to separate electronic text files, often multi-page, associated with a specific electronic aerial or satellite photo image.

The primary use of metadata is to correlate spatial image information, particularly aerial photos, satellite photos, and computer aided design (CAD) images, in three-dimensional space, with tabular data obtained in the field. There are, thus, two aspects to this process.

The first aspect is the creation of an electronic base map image on which tabular data may be electronically posted. Typically, the user will need to overlay images together (a CAD image superimposed on an aerial photo, for example) or combine smaller images together to create larger maps, or some combination of both. In this process, it is often possible to obtain access to additional tabular data already associated with (i.e. linked to, or posted on) images.

The second aspect is creating or obtaining the tabular data, and orienting it in two- or three-dimensional space. Tabular data are usually oriented in three-dimensional space according to surveys taken by hand on the ground, either using traditional surveying methods (compass, transit, etc) or global positioning satellite data. Because of the availability of extremely inexpensive receivers, GPS is rapidly becoming the dominate tool to obtain two- and three-dimensional positioning data in the field.

Typically the orientation metadata associated with the spatial data must be used to convert (reproject or recoordinate) the spatial data to conform to the orientation data associated with the tabular data, or vice-versa, or both. This process of correlation is called "rectification." Metadata are thus typically used to rectify the spatial image data to the tabular data.

## 1.10 CONCLUSIONS

The data management process is intended to reduce the amount of time spent on manipulating data and increase the level of utility of the data to the end users. The goals of the data management process should be as follows:

- Understand your data needs and how you are collecting it;
- Have a plan to accurately categorize all facets of your data;
- Promote accuracy of data through validation and verification;
- Promote consistency of data querying and reporting; and
- Understand the role of metadata in GIS.

The data presented in this book are categorized in a way to facilitate effective data management, and through querying and reporting, would be a verifiable and validated source of data for experimentation and investigation purposes.

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CHAPTER 2

# International Data Collection

**Daniel Zell**

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In developing countries, dams, irrigation schemes, watershed management plans, water and wastewater systems, and flood mitigation works have grown in both number and complexity. Because these data intensive approaches, such as river basin planning, are being embraced worldwide and funded by multilateral and bilateral organizations, the need for data has increased. China, for example, has undertaken massive water resources projects on a scale never seen before, and vast irrigation rehabilitation projects are underway in Afghanistan. In many Latin American countries, water management projects are a top priority. With the demand for such types of projects comes the need for data, information, knowledge management, and, in particular, people who fall under the broad category of water resources engineers. This need is made sharper given the imminent retirement of the seasoned professionals of the post-WWII generation who have spent their lives in water resources, leaving a younger, less experienced cohort of engineers to tackle the future.

## 2.1 INTRODUCTION

When, as often happens, engineers and other technical professionals in the water resources field are asked to render a technical judgment, they usually need a large set of data to analyze the issue. In the United States, general information such as precipitation, topography, streamflow, and other related data is usually readily available from standard sources: previous studies are usually on-hand with the implementing agency, e.g., state government, military, and the private sector. But sometimes, data are harder to find, less reliable, maybe even lost. This latter case is the normal starting point for water resources projects in less developed countries. The engineer will have to invest a good deal of time, effort,



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and sometimes money to get the sort of data that are, usually, freely available in developed countries. This chapter gives engineers an idea of what to expect, some approaches to gathering data, and international internet data sources.

There has been and always will be a need for rapid and complete data collection for water resources projects in the developing world, a process made even more challenging since data are fragmented among various government and private organizations. Due to both varied organizational arrangements and cultural factors, procedures for data collection vary from region to region and country to country, and it is not possible within the confines of this chapter to give a comprehensive step-by-step method for accomplishing it. Here, we present a brief picture of the challenges of data collection through some selected examples, an outline of a brief process, and a listing of sources of data for international water resources projects. This chapter, then, will be most useful for those with little experience in water resources projects in developing nations.

Now, before getting into the details, a few definitions and explanations.

1. *Less developed countries* is a term of convenience, generally meaning any country except the United States, the former Soviet Union, Canada, Western Europe, Australia, New Zealand, and Japan. But even though such a simple dichotomy does not really exist—other countries undoubtedly deserve to be considered developed and may indeed boast superior data repositories—this term, because of its widespread acceptance, will be used throughout this chapter.
2. *Engineer* is defined here as a person responsible for technical aspects of a water-related project. Although the engineer is normally an outsider to the country or region under study and perhaps initially unfamiliar with its cultural norms and practices, he or she engineer understands not only the data collection need but also its intended application and eventual output. In some cases engineers will be scientists, economists, even policymakers. The term, again, is chosen out of convenience.
3. To make the chapter as useful as possible to the widest audience, it generally refers to data in the generic sense, rather than, for example, average precipitation and uses illustrative examples rather than an analytical examination.

Without digressing too much into the world of development economics, we note that the engineer needs to understand the stage or level of development. In general, there is a positive correlation between wealth, or Gross Domestic Product per capita, and the centralization and quality of water resources data. In Afghanistan, one of the poorest countries in the world, for example, where data sources are widely scattered, the results are incomplete, with much historical data, and studies lost in the warfare over the past few decades. Climate also plays a factor, as natural disasters, humidity, and even rodents often destroy hard copies in countries with limited computerized archives. The overall lesson is that even in the relatively more developed countries of Central and South America, the engineer will need to search for secondary sources of data *outside* of the government, such as previous consultants' reports, private water companies' data, and others (see the list of websites at the end of this chapter). An outside engineer's local contacts will be essential in setting appointments, identifying possible resources, and even collecting data themselves.

But—a word of caution—it is unlikely that this task can be accomplished without the involvement of the engineer. If you are not willing to travel to the country of assignment, then you should probably find somebody else to do the job. Both the credibility and realism of the outputs will suffer from a lack of field presence. Besides, as an outsider, typically seen as immune to local politics and prejudices, the engineer who is willing to travel and spend enough time in country can surmount obstacles that an indigenous assistant could not.

## 2.2 DATA SOURCES

For general purposes, let us consider a simple dichotomy in terms of data availability:

- Initial Conditions (given data), and
- Needs (data objectives).

Initial data may be given by your client or employer or may be found through some cursory searching of the internet resources listed in this chapter. Data needs or objectives depend on the particular assignment and will likely evolve throughout the problem solving process. In any case, it is well worth taking the time to explore most, if not all, of the websites listed at the end of the chapter with a high-speed internet connection. You will spend much less time than trying to find data from alternate sources, such as government departments, previous and/or current projects, and well-known experts in the field. And the websites listed are generally regarded as reliable.

But website searches are not the only route. I recommend a variety of methods, especially if the

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country and region are unfamiliar to the engineer. Before arriving in a country, establish primary contacts and introductions through the employer or client. Email, however convenient, is no substitute for phone calls in building relationships. These contacts may, if sufficiently motivated, be in a much better position to collect the required data. Unfortunately, due primarily to the long and frequently inconclusive history of most local water resources projects with international engineers, it will be a difficult task convincing someone unknown to you, that your cause is worthwhile. This is yet another reason why you should use your in-country network, even if it is only your employer or client, as a foundation for collecting data. The social ties and relationships that locals have established are a resource you should not ignore.

A frequent issue when working in an unfamiliar region and culture is payment. How much do things cost? From CAD and GIS operators, to internet usage, to maps, most, if not all, goods and services have a value. In my experience, the issue is not whether or not to pay, but rather, "what is the correct price?" This is not to say that you can not get data for free; indeed, that is how I got most of mine. The engineer will have to rely on his or her in-country network and awareness of local social norms to determine whether or not a payment is required. In general, if work is required beyond normal hours or duties, then a payment is more likely to be required.

Another thing to be prepared for is equipment and procedures that do not work. Copiers, for example, are usually broken because of a lack of basic supplies and/or maintenance. Or it may not exist or be available to anyone except the senior staff. Regulations may not let you take records from the office for off-site duplication. Unless you have a penchant for data entry, this is another case where it may be appropriate to pay the correct fee for the data to be digitally entered. I suggest offering an electronic copy of the records by email to both the department and data entry person. By making them part of the process, rather than a cog in a wheel, you may use these people as resources for a long time to come, as I did with a local hydrologist in Afghanistan months after my return. (It did, however, take much longer than expected and required several phone calls and visits by contacts in Afghanistan.)

## 2.3 CASE STUDIES

The following case studies will give the engineer a general perspective of the operational aspects of data collection in a few developing nations. Let me note at once, however, the enormous importance of learning about and paying attention to the unique cultures, conditions, and particularly the values of each nation or region. Ignoring them will imperil both the engineer and the project itself.

### 2.3.1 Latin America

Overall, although collecting water resources data in Latin America is like working in developing countries worldwide,* the relatively higher income in Latin America can make the work easier, as education level generally correlates with income. Because hydropower is a highly developed sector in Latin America, its organizations often have the best data. However, the data are often considered proprietary and, being tightly controlled, take concerted and time-consuming effort by the engineer and local counterparts to get it.

As in other regions, engineers should rely on their counterparts, local staff, or client by insisting that reasonable efforts be expended to gather data in advance. Due to the culture of Latin America, counterparts can be relied on quite heavily, and will likely be highly competent. In this manner, the engineer's time can be best and efficiently used to address the remaining obstacles, like analyzing the data and writing reports.

Still, the engineer should be prepared to complete an assignment with much less data in both quantity and quality than is the norm in developed countries. When no data are found for a specific basin, data for a similar region—in combination with field interviews, maps, and surveys—is used to build a model. The uncertainties resulting from using such data should be plainly and simply stated in the engineer's work.

According to Dr Molina, the process of cleaning data—searching for errors—although time consuming and tedious, has repeatedly proved itself to be worth the trouble. Common errors include converting units, converting gauge readings to flow, and a myriad of other possibilities. These errors, if unchecked and corrected, will skew the results of an analysis. On the other hand, careful advance planning can minimize delays, for example, by contracting a local firm or consultants to carefully screen the data for anomalies and enter it into a useful format.

* According to a June 25, 2004, interview with Dr Medardo Molina, a Peruvian-born water resources expert who has been active in water resources since 1965 as an international consultant and professor. Dr Molina has published numerous papers in both Spanish and English.

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### 2.3.2 Central Asia

In Afghanistan, collecting water resources data were quite complicated, based on my personal experiences in 2003. What little historical data existed was fragmented and incomplete. Thirty years of instability destroyed critical records and the hydrological network. The language barrier, with data sometimes recorded in Dari, Pashto, or Russian, further complicated data collection.

The assigned task—to construct a national water balance and determine water availability for rehabilitating irrigation—necessitated casting a wide net to collect all sources of data. Before visiting Afghanistan, my thorough search of libraries and databases yielded only few results, but one of them, a previous water balance study, was quite useful. Although I made contacts in advance, scheduling appointments from outside of Afghanistan did not work. I now understand that the local custom is to pay a brief introductory visit, without an appointment. Then, a later appointment can be scheduled where the useful work will be accomplished.

This introductory visit may seem full of pleasantries and even a bit useless. To the novice it may seem not along the critical path. Quite to the contrary, the visits are used to evaluate the engineer, to understand what the engineer is doing, and to understand if the engineer is worthy of help. Besides, since data are rarely immediately available, the first meeting gives the local source time to prepare.

The team conducted initial and follow-up visits to the following organizations:

> *Ministries*: Irrigation and Water Resources and Environment, Rehabilitation and Rural Development, Agriculture and Animal Husbandry, and the Central Statistics Office
> *United Nations*: Food and Agriculture Organization and World Food Program, in particular the Vulnerability Analysis Mapping Unit for socio-economic data, and the Development Program
> *Others*: ICARDA (International Center for Agricultural Research in the Dry Areas), the U.S. Agency for International Development, and various private consultants, firms, and non-government organizations

From these and subsequent visits over a 12-month period, the consultant team gathered the hydrological station data. We hired a local professional consultant to both construct and digitize a map of the monitoring stations. More importantly, the team was able to persuade a wide range of policy makers and water resources professionals of the report's thoroughness and usefulness by conducting follow-up visits to the data repositories, courtesy calls to government officials to present the report and findings, and formal presentations.

The United Nations' organizations provided the most accurate satellite and agricultural data, and previous consultants' reports were essential in constructing the overall water balance. Although we still had to do careful fact checking based on the newly available data, the efforts of independent and knowledgeable local staff helped us get data not only more rapidly but also with a higher degree of reliability than would have otherwise been possible.

It is important to note that the local staff's efforts had to be supplemented with continual phone calls and emails by the consultants as well as periodic visits to Afghanistan. As outsiders, foreign consultants can often bypass the social norms and traditions that hamper local staff. At the same time, continued communication and visits let the team more completely understand the extent of the problem or issues to be addressed and more importantly, convey the engineers' recommended solution to the client as it evolved. This served two purposes:

1. By avoiding the "parachute in" approach where a consultant works rapidly and alone, often behind a closed door, the team won a sense of buy-in and respect from the client, which ensured that the client would actually understand the results of the work.
2. By working hand-in-hand with a client who lacked basic institutional capacity, the consultant team was able to increase the client's capacity to use the team's results.

With so many people interested in the report, the team decided to circulate a draft copy. The resulting informal peer review process increased the credibility of the findings, and although it led to a series of revisions, in the end, it was the only way to accomplish the task.

### 2.3.3 South Asia

In contrast to the situation in Afghanistan, data availability was relatively high during a 2004 assignment to the Indian State of Orissa. At the state water resources agency, I saw many rooms with neatly bound papers stacked literally from floor to ceiling. More remarkably, when motivated by the department head, almost everything we asked for was quickly found. And because the information requested was relatively recent,

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we did not encounter the issue of deteriorating paper records in a humid environment without climate control. The main problems were poor database design and data entry, and resistance to improving quality control standards.

To make sure that our primary data on average daily flow from reservoirs were accurate, my team went to one of the more remote locations to look at primary records. This entailed a journey across the small rice paddies that characterize the regions, a courtesy call to the local supervisor, and even more driving to where the road literally ended at the reservoir. The water resources department had told the reservoir about our trip, and the records were ready. However, local customs dictated a long, slow, and quite good meal as well as an exchanging of pleasantries before the ledger was produced. Then, we asked the data recorders how they recorded the gate height and translated that measurement into a daily flow. Spot checking a few calculations for accuracy, we found no mistakes.

A universal issue when dealing with government agencies is territorialism. This issue nearly derailed the entire project in India. An agency insisted that a task was within their realm of authority but showed neither the will nor the capacity to perform the work as required. Rather the agency did the bare minimum and strongly resisted any efforts at improvement. The lesson the engineer should take from this is that relying on someone or some agency out of your control is risky. In hindsight, the solution would have been to accept the agency as a partner, then help them, as cooperatively and diligently as possible, to complete the project.

## 2.4 GENERAL PROCESS FOR DATA COLLECTION

The following process serves as a guideline for engineers unfamiliar with international water resources engineering. It is highly likely that additional steps will be needed in any actual project depending on the requirements and country.

1. Learn key features of the country's culture norms and values by both talking to someone from the country and reading appropriate articles and even the literature.
2. Identify the problem.
   This step consists of more than simply reading the terms of reference. The engineer should plan on conducting one-to-one discussions with senior and mid-level staff at the local or client agency.
3. Identify data requirements.
4. Identify local staff requirements such as cartographers, hydrologists, statisticians, field surveyors, etc.
5. Contact the client or local agency.
   5.1. Contact made well in advance of the initial visit so that the staff are aware of the planned work and can plan accordingly.
   5.2. Contact at regular intervals, at least weekly. Contact by phone and email is recommended.
6. Make initial visit.
   Prearranged visits with organizations should be conducted. Social outings, while exhausting, may prove useful for particularly difficult data collection situations.
7. Collect the data.
8. Review data collected.
   Determine what steps need to be taken to ensure the data are both accurate and in a usable format.
9. Conduct field validation if required.
10. Make more visits.
    These visits will supplement initial data gatherings and present initial findings.
11. Perform analysis.
12. Prepare and circulate draft report.
13. Incorporate comments as appropriate.
14. Prepare report.

## 2.5 INTERNET SOURCES

The following addresses give access to a lot of data. The descriptions of the 2006 websites come directly from the web pages themselves.

AQUASTAT is the Food and Agricultural Organization's (FAO) global information system of water and agriculture developed by the Land and Water Development Division of FAO. AQUASTAT is FAO's global information system of water and agriculture developed by the Land and Water Development Division of FAO. The objective of AQUASTAT is to provide users with comprehensive information on the state of agricultural water management across the world, with emphasis on developing countries and countries in transition (www.fao.org/WAICENT/FAOINFO/AGRICULT/AGL/AGLW/aquastat/main/index.stm).

The following is an excerpt from the AQUASTAT country profile of Afghanistan

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### Water Resources

Based on the hydrographic systems, the country can be divided into four zones:

- the northern basin (24% of the territory) with the Amu Darya and its tributaries (14%), which drain toward the Aral sea, and the rivers of northern Afghanistan (10%), which disappear within the country before joining the Amu Darya;
- the western region (12%) consisting of the Hari Rud river basin (6%) and the Murgab river basin (6%), both rivers disappearing in Turkmenistan;
- the south-western basin (52%) with the Helmand river flowing toward the Sistan swamps, located on the border of Iran and Afghanistan. In 1972, a document was signed between Afghanistan and Iran to allocate a discharge of 26 m/s of Helmand river water to Iran all year round;
- the eastern Kabul basin (12%), which is the only river system having an outlet to the sea, joining the Indus at Attock in Pakistan.

Internal renewable water resources are estimated at 55 $km^3yr^{-1}$. The Kunar river, which originates in Pakistan, crosses the border with an average annual flow of 10 $km^3$ and joins the Kabul river at Jalalabad about 180 km further downstream. The Kabul river flows again into Pakistan 80 km further downstream.

Total water withdrawal was estimated at 26.11 $km^3$ in 1987, of which 99% for agricultural purposes. Recently, there has been a large development of groundwater use in some provinces.

In 1986, there were two dams higher than 15 m. The installed capacity of the hydroelectric plants was 281 MW in 1992, which is about 70% of total installed capacity. There is considerable potential for the generation of hydropower, by both large dams and microhydropower stations.

FAOSTAT is an on-line and multilingual database currently containing over 3 million time-series records covering international statistics in the following areas:

| | | |
|---|---|---|
| Production | Land use and irrigation | Fertilizer and pesticides |
| Trade | Forest products | Agricultural machinery |
| Food balance sheets | Fishery products | Food aid shipments |
| Producer prices | Population | Exports by destination |
| Forestry trade flow | Food quality control | |

faostat.fao.org/default.jsp?language=EN.

| | Year | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** |
| *Population-estimates rural (1000)* | | | | | | | | | | | |
| Africa developing | 428,145 | 435,774 | 443,382 | 450,948 | 458,471 | 465,941 | 473,370 | 480,738 | 488,033 | 495,224 | 502,287 |
| AGG_COUNTRIES | 428,145 | 435,774 | 443,382 | 450,948 | 458,471 | 465,941 | 473,370 | 480,738 | 488,033 | 495,224 | 502,287 |
| *Population-estimates urban (1000)* | | | | | | | | | | | |
| Africa developing | 205,568 | 214,269 | 223,156 | 232,235 | 241,525 | 251,050 | 260,846 | 270,932 | 281,347 | 292,111 | 303,245 |
| AGG_COUNTRIES | 205,568 | 214,269 | 223,156 | 232,235 | 241,525 | 251,050 | 260,846 | 270,932 | 281,347 | 292,111 | 303,245 |

The tables above are an example of the output produced by FAO STAT, in this case rural and urban populations in African Developing Nations from 1993 to 2003. The output is also available in .csv format.

GRDC (Global Runoff Data Center) The GRDC makes the unique offer to the international research and science community of easy and universal access to river flow information on a global scale. On request, data

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products are developed and specialized databases are assembled for projects on both regional and global scale. The GRDC serves as a communication platform between institutions, advisors, and scientists and also transfers information about other relevant databases with a hydrological content such as the Global Precipitation Climatology Centre (GPCC) and the Programme Office of the Global Environment Monitoring System—Water (GWPO) of UNEP. It also maintains close ties to the UNESCO Water project "Flow Regimes from International Experimental and Network Data" (FRIEND).

The GRDC contains long-term mean annual freshwater surface water fluxes into the world oceans. Estimates are based on 251 discharge stations of major rivers. Data available include mean, minimum, maximum monthly discharges, and time series of mean, minimum, maximum annual discharge for 3035 stations. UNH-GRDC Global Composite Runoff Fields combines observed river discharge information with a climate-driven Water Balance Model (http://grdc.bafg.de).

The following is a sample output:

```
# GRDC-No.:          2903425
# River:             LENA
# Station:           UST-KUT
# Country:           RU
# Lat (dec. degree):    56.7700
# Lon (dec. degree):   105.6500
# Area (km**2):       71400.000
#
#
# General procedure to calculate the statistics:
# Original monthly values are used whenever available.
# In order to extend the time series, monthly data derived from daily values
# is added where applicable. Then the calculation of a monthly value
# allows a maximum to 5 missing daily values per month
#
# -999 indicates missing value or insufficient data
#
# Time series: 1936 - 1948
#
# Missing original monthly values (%): 17.00
# Missing original daily values (%):    not available
#
Number of values used for calc.:     |   127.000
Absolute minimum discharge (m**3/s): |    37.800
Absolute maximum discharge (m**3/s): |  1790.000
Average annual discharge (m**3/s):   |   402.554
Average annual volume (km**3/yr):    |    12.695
Average annual runoff (mm/yr):       |   177.801
#
# Long-term monthly characteristics (m**3/s)
# (Calculation requires at least 5 years of data)
Mo|Min       |Year|Max       |Year|Mean      |S. deviation|No. values
01|    45.800|1944|   171.000|1938|   101.200|    37.64067|   9
02|    39.700|1944|   149.000|1938|    85.222|    32.85977|   9
03|    37.800|1944|   149.000|1938|    81.589|    33.89430|   9
04|    79.600|1936|   693.000|1939|   281.422|   231.32462|   9
05|   594.000|1943|  1790.000|1941|  1141.818|   355.42926|  11
06|   211.000|1943|  1250.000|1942|   641.308|   360.34299|  13
07|   129.000|1943|  1480.000|1948|   607.000|   359.37097|  13
08|    97.000|1943|  1140.000|1948|   468.692|   252.89140|  13
09|   103.000|1943|  1010.000|1948|   457.462|   224.95651|  13
10|    85.800|1943|   383.000|1947|   267.380|   104.19906|  10
11|    56.000|1943|   242.000|1944|   158.633|    65.03188|   9
12|    50.500|1943|   215.000|1937|   138.878|    53.44971|   9
#
# Annual characteristics (m**3/s)
# (Calculation requires at least 9 months per year)
Year|Min       |Mo|Max       |Mo|Mean      |No. values
1936|    71.000|03|  1180.000|06|   410.442| 12
1937|    93.900|03|  1600.000|05|   379.933| 12
1938|   149.000|02|  1250.000|05|   499.833| 12
1939|    87.500|12|   694.000|05|   260.883| 12
1940|    52.400|03|  1010.000|07|   350.800| 12
1941|    79.000|03|  1790.000|05|   408.250| 12
1942|    80.900|12|  1360.000|05|   405.358| 12
```

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CGIAR is a global link to research on agriculture, hunger, poverty, and the environment. CGIAR (Consultative Group on International Agricultural Research) is a good starting point for international water issues related to agriculture (www.cigar.org).

To access any of CGIARs publications published by the 15 research centers, go to the CGIAR Library Gateway (www.cgiar.org/publications/library/index.html).

CGIAR Reefbase—ReefBase is the world's premier online information system on coral reefs, and provides information services to coral reef professionals involved in management, research, monitoring, conservation, and education. Its goal is to facilitate sustainable management of coral reefs and related coastal/marine environments, in order to benefit poor people in developing countries whose livelihoods depend on these natural resources. ReefBase's Online Geographic Information System (GIS) allows you to display coral reef related data and information on interactive maps. You can zoom, search, and query datalayers, and save or bookmark the map (www.reefbase.org).

ICARDA (International Center for Research in the Dry Areas) is one of the research centers of CGIAR, whose mission is to improve and integrate the management of soil, water, nutrients, plants, and animals in ways that optimize sustainable agricultural production. There are many relevant articles, publications, and datasets on on-farm water use and water efficiency (www.icarda.cgiar.org).

IWMI's (International Water Management Institute) on-line publication section contains several thousand pages of peer reviewed research on water management. All research outputs and publications produced by IWMI are international public goods, freely available to partners in developing countries and to members of the international development, academic and research communities (www.iwmi.cgiar.org/pubs/mindex.htm).

The Remote Sensing and GIS Unit (RS GIS Unit) of the International Water Management Institute (IWMI), is a centralized facility for all spatial data-related activities of IWMI at the headquarters in Sri Lanka and Regional Offices located in different parts of the world.

Currently, the RS GIS Unit holds over 1 terabyte of data. Although the emphasis is on IWMI benchmark river basins, large volumes of data are also available at National, Regional, and Global levels. These data are catalogued, streamlined, and released to the public through the IWMI Data Storehouse Pathway (DSP). Much of the river basin and other datasets are composed as single mega files of hundreds or sometimes thousands of bands consisting of continuous streams of 8-day or monthly time series data in several wavebands and/or indices.

Large volumes of multitemporal data from multiple satellite sensors are used in several IWMI research projects. These projects include: (a) Global Irrigated Area Mapping (GIAM) at global to local scales, (b) the Wetland project in the Limpopo river basin of four Southern African Nations, (c) the Krishna river basin project in India, (d) the Indo-Gangetic river basin project in India and Pakistan, (e) the Drought Assessment and Mitigation project in Afghanistan, Pakistan, and parts of India, and (f) the biodiversity project in Sri Lanka.

More information on the RS GIS Unit and its activities can be found in several areas of this web site (www.iwmidsp.org/iwmi/info/centerprofile.asp).

Hydrological Processes is a relevant international journal with abstracts freely accessible on the web. Of particular interest are the past articles on mathematical and methodological aspects of hydrological processes and modeling.

Accessed through Wiley Intersciences (www.interscience.wiley.com).

Although traditionally thought of as a repository of United States data sets only, the United States Geological Survey (USGS) has a notably thorough database on selected countries that will likely grow over time. In particular, datasets for Jordan and Israel can be found through their project websites (www.watercare.org and www.exact-me.org).

Also on USGS, a general homepage with linkages to Ukraine, United Arab Emirates, Bangladesh, and Cyprus (international.usgs.gov/disciplines/water.htm).

Winrock Water is both a discussion forum and data clearinghouse that includes an annotated bibliography. Winrock water has selected leading reference materials, research and discussions of major issues in the water resources field through the internet. The links section is of particular interest to those in data collection (www.winrockwater.org).

Sakia.org is an information and communication service in the area of "land and water". Sakia.org hosts several services such as the email discussion list IRRIGATION-L the WWW Virtual Library Irrigation & Hydrology (content filling stage), the WWW Database on Irrigation & Hydrology Software—IRRISOFT (under revision), the e-Journal of Land and Water, an open access and peer reviewed international scientific journal for research and developments and the *Journal of Applied Irrigation Science*. Sakia.org is fostering the open and free access to knowledge in support of the "land and water" community (www.sakia.org).

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CHAPTER 3

# Climate and Precipitation

**Pedro Fierro, Jr.**

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## SECTION 3A CLIMATIC DATA — UNITED STATES

**Figure 3A.1** U.S. standard regions for temperature and precipitation. (From U.S. National Oceanic and Atmospheric Administration.)

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**Table 3A.1 Normal Daily Mean Temperature — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham AP | 30 | 42.6 | 46.8 | 54.5 | 61.3 | 69.3 | 76.4 | 80.2 | 79.6 | 73.8 | 62.9 | 53.1 | 45.6 | 62.2 |
| | Huntsville | 30 | 39.8 | 44.3 | 52.3 | 60.4 | 68.6 | 76.0 | 79.5 | 78.6 | 72.4 | 61.3 | 51.2 | 43.1 | 60.6 |
| | Mobile | 30 | 50.1 | 53.5 | 60.2 | 66.1 | 73.5 | 79.3 | 81.5 | 81.3 | 77.2 | 67.7 | 58.9 | 52.3 | 66.8 |
| | Montgomery | 30 | 46.6 | 50.5 | 57.9 | 64.3 | 72.3 | 78.9 | 81.8 | 81.2 | 76.3 | 65.4 | 56.1 | 49.0 | 65.1 |
| AK | Anchorage | 30 | 15.8 | 18.7 | 25.9 | 36.3 | 46.9 | 54.7 | 58.4 | 56.4 | 48.2 | 34.1 | 21.8 | 17.5 | 36.3 |
| | Annette | 30 | 35.1 | 37.1 | 39.5 | 43.8 | 49.4 | 54.3 | 58.2 | 58.6 | 53.8 | 46.5 | 39.7 | 36.4 | 46.1 |
| | Barrow | 30 | −13.7 | −15.9 | −13.7 | −0.5 | 20.1 | 35.0 | 40.4 | 38.7 | 31.2 | 14.6 | −0.9 | −10.6 | 10.4 |
| | Bethel | 30 | 6.6 | 7.6 | 14.5 | 25.9 | 41.3 | 51.4 | 56.0 | 53.6 | 45.4 | 30.0 | 17.4 | 9.4 | 29.9 |
| | Bettles | 30 | −11.2 | −7.9 | 4.2 | 22.4 | 44.3 | 57.8 | 60.2 | 53.5 | 41.0 | 18.7 | −0.8 | −7.4 | 22.9 |
| | Big Delta | 30 | −2.6 | 2.3 | 14.2 | 32.1 | 47.8 | 57.5 | 60.8 | 55.5 | 44.4 | 24.1 | 6.4 | 0.1 | 28.6 |
| | Cold Bay | 30 | 28.2 | 27.6 | 30.0 | 33.5 | 39.8 | 45.9 | 50.6 | 51.8 | 47.8 | 40.0 | 34.5 | 31.0 | 38.4 |
| | Fairbanks | 30 | −9.7 | −3.8 | 11.1 | 31.7 | 48.8 | 59.7 | 62.4 | 56.2 | 44.5 | 23.5 | 2.3 | −5.9 | 26.8 |
| | Gulkana | 30 | −4.7 | 3.2 | 15.3 | 31.1 | 43.9 | 53.1 | 57.0 | 53.1 | 43.1 | 26.4 | 5.5 | −1.6 | 27.1 |
| | Homer | 30 | 23.4 | 24.9 | 29.4 | 36.4 | 43.7 | 50.0 | 54.1 | 53.8 | 47.9 | 37.8 | 29.4 | 25.8 | 38.1 |
| | Juneau | 30 | 25.7 | 28.9 | 33.7 | 40.8 | 47.9 | 53.9 | 56.8 | 55.7 | 50.0 | 42.3 | 33.3 | 28.7 | 41.5 |
| | King Salmon | 30 | 15.4 | 15.6 | 23.5 | 33.1 | 43.5 | 50.9 | 55.7 | 54.8 | 47.6 | 33.3 | 23.2 | 17.2 | 34.5 |
| | Kodiak | 30 | 29.7 | 29.9 | 32.6 | 37.3 | 43.5 | 49.2 | 54.1 | 55.0 | 49.4 | 40.3 | 34.0 | 30.6 | 40.5 |
| | Kotzebue | 30 | −2.5 | −3.5 | −0.3 | 11.5 | 31.6 | 44.8 | 54.7 | 52.1 | 41.8 | 23.2 | 8.3 | −0.2 | 21.8 |
| | Mcgrath | 30 | −6.7 | −0.9 | 11.8 | 29.1 | 46.2 | 56.7 | 59.8 | 54.9 | 44.7 | 25.3 | 5.8 | −3.8 | 26.9 |
| | Nome | 30 | 5.8 | 5.7 | 9.4 | 19.6 | 37.1 | 47.3 | 52.6 | 50.6 | 42.9 | 28.5 | 16.9 | 8.4 | 27.1 |
| | St. Paul Island | 30 | 25.7 | 23.3 | 24.2 | 28.4 | 35.7 | 41.9 | 46.7 | 48.4 | 45.0 | 38.3 | 33.1 | 28.8 | 35.0 |
| | Talkeetna | 30 | 11.0 | 15.4 | 22.6 | 34.3 | 45.8 | 55.3 | 58.9 | 55.6 | 46.2 | 31.4 | 17.5 | 13.0 | 33.9 |
| | Unalakleet | 30 | 3.3 | 4.3 | 10.7 | 22.7 | 39.5 | 49.0 | 55.5 | 53.1 | 43.6 | 26.5 | 12.6 | 6.1 | 27.2 |
| | Valdez | 30 | 21.9 | 24.8 | 29.8 | 37.7 | 45.8 | 52.2 | 55.2 | 53.6 | 47.1 | 38.2 | 28.3 | 24.7 | 38.3 |
| | Yakutat | 30 | 25.8 | 28.4 | 31.5 | 37.2 | 43.6 | 49.7 | 53.6 | 53.3 | 48.2 | 41.1 | 32.4 | 28.6 | 39.5 |
| AZ | Flagstaff | 30 | 29.7 | 32.2 | 36.6 | 42.9 | 50.8 | 60.1 | 66.1 | 64.4 | 57.8 | 47.1 | 36.5 | 30.2 | 46.2 |
| | Phoenix | 30 | 54.2 | 58.2 | 62.7 | 70.2 | 79.1 | 88.6 | 92.8 | 91.4 | 86.0 | 74.6 | 61.6 | 54.3 | 72.9 |
| | Tucson | 30 | 51.7 | 55.0 | 59.2 | 66.0 | 74.5 | 84.1 | 86.5 | 84.9 | 80.9 | 70.5 | 58.7 | 51.9 | 68.7 |
| | Winslow | 30 | 34.2 | 40.0 | 46.3 | 53.4 | 62.2 | 72.1 | 77.5 | 75.6 | 68.2 | 55.9 | 43.2 | 34.1 | 55.2 |
| | Yuma | 30 | 58.1 | 62.0 | 66.5 | 72.7 | 79.9 | 88.8 | 94.1 | 93.5 | 88.2 | 77.2 | 64.8 | 57.4 | 75.3 |
| AR | Fort Smith | 30 | 40.1 | 45.2 | 53.4 | 61.4 | 70.1 | 78.4 | 82.4 | 81.3 | 74.4 | 63.3 | 51.7 | 43.2 | 62.1 |
| | Little Rock | 30 | 40.2 | 45.6 | 54.3 | 63.0 | 70.9 | 78.8 | 83.2 | 82.1 | 75.0 | 64.5 | 52.5 | 43.4 | 62.8 |
| | North Little Rock | 30 | 38.0 | 43.7 | 52.6 | 61.1 | 69.5 | 77.5 | 82.2 | 81.5 | 73.9 | 62.8 | 50.5 | 41.0 | 61.2 |
| CA | Bakersfield | 30 | 47.8 | 53.3 | 57.3 | 62.7 | 70.3 | 77.7 | 83.1 | 81.9 | 76.7 | 67.2 | 54.8 | 47.2 | 65.0 |
| | Bishop | 30 | 38.0 | 42.4 | 47.7 | 54.1 | 62.5 | 71.1 | 76.8 | 74.8 | 67.3 | 56.6 | 44.8 | 38.0 | 56.2 |
| | Eureka | 30 | 47.9 | 48.9 | 49.2 | 50.7 | 53.6 | 56.3 | 58.1 | 58.7 | 57.4 | 54.5 | 51.0 | 47.9 | 52.9 |
| | Fresno | 30 | 46.0 | 51.4 | 55.5 | 61.2 | 68.8 | 76.1 | 81.4 | 79.9 | 74.6 | 65.0 | 52.7 | 45.2 | 63.2 |
| | Long Beach | 30 | 57.0 | 58.3 | 59.7 | 63.0 | 65.9 | 69.8 | 73.8 | 75.1 | 73.4 | 68.6 | 61.8 | 57.1 | 65.3 |
| | Los Angeles AP | 30 | 57.1 | 58.0 | 58.3 | 60.8 | 63.1 | 66.4 | 69.3 | 70.7 | 70.1 | 66.9 | 61.6 | 57.6 | 63.3 |
| | Los Angeles CO | 30 | 58.3 | 60.0 | 60.7 | 63.8 | 66.2 | 70.5 | 74.2 | 75.2 | 74.0 | 69.5 | 62.9 | 58.5 | 66.2 |
| | Mount Shasta | 30 | 35.3 | 38.2 | 41.2 | 46.3 | 53.2 | 60.2 | 66.1 | 65.1 | 59.5 | 50.5 | 39.9 | 34.8 | 49.2 |
| | Redding | 30 | 45.5 | 49.1 | 52.5 | 57.8 | 66.2 | 75.2 | 81.3 | 78.9 | 73.4 | 63.2 | 51.1 | 45.3 | 61.6 |
| | Sacramento | 30 | 46.3 | 51.2 | 54.5 | 58.9 | 65.5 | 71.5 | 75.4 | 74.8 | 71.7 | 64.4 | 53.3 | 45.8 | 61.1 |

*(Continued)*



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**Table 3A.1 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | San Diego | 30 | 57.8 | 58.9 | 60.0 | 62.6 | 64.6 | 67.4 | 70.9 | 72.5 | 71.6 | 67.6 | 61.8 | 57.6 | 64.4 |
| | San Francisco AP | 30 | 49.4 | 52.4 | 54.0 | 56.2 | 58.7 | 61.4 | 62.8 | 63.6 | 63.9 | 61.0 | 54.7 | 49.5 | 57.3 |
| | San Francisco CO | 30 | 52.3 | 55.0 | 55.9 | 57.3 | 58.4 | 60.5 | 61.3 | 62.4 | 63.7 | 62.5 | 57.5 | 52.7 | 58.3 |
| | Santa Barbara | 30 | 53.1 | 55.2 | 56.7 | 58.9 | 60.9 | 64.2 | 67.0 | 68.6 | 67.4 | 63.5 | 57.5 | 53.2 | 60.5 |
| | Santa Maria | 30 | 51.6 | 53.1 | 53.8 | 55.5 | 57.8 | 60.9 | 63.5 | 64.2 | 63.9 | 61.1 | 55.5 | 51.6 | 57.7 |
| | Stockton | 30 | 46.0 | 51.1 | 54.9 | 60.0 | 66.7 | 73.2 | 77.3 | 76.5 | 72.8 | 64.6 | 53.1 | 45.3 | 61.8 |
| CO | Alamosa | 30 | 14.7 | 22.5 | 32.7 | 40.8 | 50.4 | 59.4 | 64.1 | 62.1 | 54.5 | 42.8 | 28.4 | 17.1 | 40.8 |
| | Colorado Springs | 30 | 28.1 | 31.7 | 37.8 | 45.3 | 54.6 | 64.4 | 69.6 | 67.6 | 59.8 | 48.9 | 36.2 | 29.0 | 47.8 |
| | Denver | 30 | 29.2 | 33.2 | 39.6 | 47.6 | 57.2 | 67.6 | 73.4 | 71.7 | 62.4 | 51.0 | 37.5 | 30.3 | 50.1 |
| | Grand Junction | 30 | 26.1 | 34.1 | 43.4 | 50.9 | 60.5 | 71.1 | 76.8 | 74.7 | 65.4 | 52.7 | 38.1 | 28.2 | 51.8 |
| | Pueblo | 30 | 29.3 | 34.6 | 41.8 | 49.9 | 59.7 | 69.8 | 75.4 | 73.5 | 64.8 | 52.4 | 38.4 | 30.3 | 51.7 |
| CT | Bridgeport | 30 | 29.9 | 31.9 | 39.5 | 48.9 | 59.0 | 68.0 | 74.0 | 73.1 | 65.7 | 54.7 | 45.1 | 35.1 | 52.1 |
| | Hartford | 30 | 25.7 | 28.8 | 38.0 | 48.9 | 59.9 | 68.5 | 73.7 | 71.6 | 63.2 | 51.9 | 41.8 | 30.8 | 50.2 |
| DE | Wilmington | 30 | 31.5 | 34.2 | 42.7 | 52.4 | 62.5 | 71.5 | 76.6 | 75.0 | 67.7 | 55.8 | 45.9 | 36.4 | 54.4 |
| DE | Washington Dulles AP | 30 | 31.7 | 34.8 | 43.4 | 53.1 | 62.3 | 70.9 | 75.7 | 74.4 | 67.3 | 55.0 | 45.2 | 36.0 | 54.2 |
| | Washington Nat'l AP | 30 | 34.9 | 38.1 | 46.5 | 56.1 | 65.6 | 74.5 | 79.2 | 77.4 | 70.5 | 58.8 | 48.7 | 39.5 | 57.5 |
| FL | Apalachicola | 30 | 52.7 | 55.3 | 60.7 | 66.8 | 74.1 | 80.0 | 81.9 | 81.7 | 79.1 | 70.2 | 62.0 | 55.2 | 68.3 |
| | Daytona Beach | 30 | 58.4 | 60.0 | 64.7 | 68.9 | 74.8 | 79.7 | 81.7 | 81.5 | 79.9 | 74.0 | 67.0 | 60.8 | 71.0 |
| | Fort Myers | 30 | 64.9 | 66.0 | 69.9 | 73.6 | 78.8 | 82.2 | 83.0 | 83.1 | 82.1 | 77.5 | 71.7 | 66.4 | 74.9 |
| | Gainesville | 30 | 54.3 | 57.0 | 62.5 | 67.6 | 74.3 | 79.2 | 80.9 | 80.4 | 77.8 | 70.1 | 62.8 | 56.3 | 68.6 |
| | Jacksonville | 30 | 53.1 | 55.8 | 61.6 | 66.6 | 73.4 | 79.1 | 81.6 | 80.8 | 77.8 | 69.4 | 61.7 | 55.0 | 68.0 |
| | Key West | 30 | 70.3 | 70.8 | 73.8 | 77.0 | 80.7 | 83.4 | 84.5 | 84.4 | 83.4 | 80.2 | 76.3 | 72.0 | 78.1 |
| | Miami | 30 | 68.1 | 69.1 | 72.4 | 75.7 | 79.6 | 82.4 | 83.7 | 83.6 | 82.4 | 78.8 | 74.4 | 69.9 | 76.7 |
| | Orlando | 30 | 60.9 | 62.6 | 67.4 | 71.5 | 77.1 | 81.2 | 82.4 | 82.5 | 81.1 | 75.3 | 68.8 | 63.0 | 72.8 |
| | Pensacola | 30 | 52.0 | 54.9 | 61.0 | 66.9 | 74.6 | 80.6 | 82.6 | 82.2 | 78.7 | 69.5 | 60.7 | 54.1 | 68.2 |
| | Tallahassee | 30 | 51.8 | 54.8 | 61.1 | 66.4 | 74.4 | 80.4 | 82.4 | 82.1 | 78.9 | 69.1 | 60.4 | 53.7 | 68.0 |
| | Tampa | 30 | 61.3 | 62.7 | 67.4 | 71.5 | 77.6 | 81.5 | 82.5 | 82.7 | 81.6 | 75.8 | 69.3 | 63.3 | 73.1 |
| | Vero Beach | 30 | 63.0 | 63.9 | 67.7 | 71.5 | 76.2 | 80.4 | 81.7 | 81.6 | 80.7 | 76.4 | 70.5 | 64.7 | 73.2 |
| | West Palm Beach | 30 | 66.2 | 67.2 | 70.6 | 73.8 | 78.2 | 81.2 | 82.5 | 82.8 | 81.7 | 78.1 | 73.1 | 68.3 | 75.3 |
| GA | Athens | 30 | 42.2 | 46.0 | 53.5 | 60.9 | 69.1 | 76.3 | 79.8 | 78.4 | 72.6 | 61.8 | 52.7 | 44.8 | 61.5 |
| | Atlanta | 30 | 42.7 | 46.7 | 54.3 | 61.6 | 69.8 | 76.8 | 80.0 | 78.9 | 73.3 | 62.8 | 53.4 | 45.4 | 62.2 |
| | Augusta | 30 | 44.8 | 48.4 | 55.9 | 62.4 | 70.5 | 77.5 | 80.8 | 79.3 | 73.8 | 63.1 | 54.4 | 46.9 | 63.2 |
| | Columbus | 30 | 46.8 | 50.3 | 57.6 | 64.2 | 72.3 | 79.2 | 82.0 | 81.3 | 76.2 | 65.8 | 56.7 | 49.1 | 65.1 |
| | Macon | 30 | 45.5 | 48.9 | 56.2 | 62.7 | 71.0 | 78.0 | 81.1 | 80.0 | 74.5 | 63.9 | 55.1 | 47.8 | 63.8 |
| | Savannah | 30 | 49.2 | 52.5 | 59.3 | 65.3 | 72.8 | 78.8 | 82.1 | 80.8 | 76.7 | 67.1 | 58.7 | 51.4 | 66.2 |
| HI | Hilo | 30 | 71.4 | 71.5 | 72.0 | 72.5 | 73.7 | 75.1 | 75.9 | 76.3 | 76.2 | 75.6 | 74.0 | 72.2 | 73.9 |
| | Honolulu | 30 | 73.0 | 73.0 | 74.3 | 75.6 | 77.2 | 79.5 | 80.8 | 81.8 | 81.5 | 80.2 | 77.7 | 74.8 | 77.5 |
| | Kahului | 30 | 71.8 | 71.9 | 73.1 | 74.2 | 75.7 | 77.6 | 78.8 | 79.5 | 79.1 | 78.1 | 76.0 | 73.4 | 75.8 |
| | Lihue | 30 | 71.7 | 71.7 | 72.7 | 73.9 | 75.4 | 77.7 | 79.0 | 79.7 | 79.5 | 78.2 | 75.9 | 73.3 | 75.7 |
| ID | Boise | 30 | 30.2 | 36.7 | 43.8 | 50.6 | 58.6 | 67.2 | 74.7 | 73.9 | 64.2 | 52.8 | 39.9 | 30.6 | 52.0 |
| | Lewiston | 30 | 33.7 | 38.4 | 44.7 | 51.1 | 58.5 | 65.8 | 73.5 | 73.4 | 63.8 | 51.6 | 40.4 | 33.9 | 52.4 |
| | Pocatello | 30 | 24.4 | 30.0 | 37.9 | 45.6 | 53.5 | 62.0 | 69.2 | 68.4 | 58.8 | 47.7 | 34.7 | 25.3 | 46.5 |
| IL | Chicago | 30 | 22.0 | 27.0 | 37.3 | 47.8 | 58.7 | 68.2 | 73.3 | 71.7 | 63.8 | 52.1 | 39.3 | 27.4 | 49.1 |
| | Moline | 30 | 21.1 | 26.9 | 38.7 | 50.5 | 61.7 | 71.2 | 75.3 | 73.2 | 65.0 | 53.0 | 39.1 | 26.4 | 50.2 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Peoria | 30 | 22.5 | 28.2 | 39.8 | 51.2 | 61.9 | 71.1 | 75.1 | 73.1 | 65.4 | 53.4 | 40.1 | 27.8 | 50.8 |
| | Rockford | 30 | 19.0 | 24.7 | 36.1 | 47.9 | 59.6 | 68.8 | 72.9 | 70.9 | 62.8 | 51.0 | 37.2 | 24.4 | 48.0 |
| | Springfield | 30 | 25.1 | 30.6 | 41.8 | 52.8 | 63.6 | 72.6 | 76.3 | 74.2 | 67.0 | 55.5 | 42.3 | 30.3 | 52.7 |
| IN | Evansville | 30 | 31.0 | 35.8 | 45.8 | 55.5 | 65.6 | 74.8 | 78.6 | 76.5 | 69.1 | 57.3 | 45.9 | 35.6 | 56.0 |
| | Fort Wayne | 30 | 23.6 | 27.3 | 38.1 | 49.0 | 60.4 | 69.7 | 73.4 | 71.1 | 64.1 | 52.4 | 40.6 | 29.0 | 49.9 |
| | Indianapolis | 30 | 26.5 | 31.2 | 41.7 | 52.0 | 62.6 | 71.7 | 75.4 | 73.5 | 66.3 | 54.6 | 42.9 | 31.6 | 52.5 |
| | South Bend | 30 | 23.4 | 27.3 | 37.5 | 48.3 | 59.6 | 69.0 | 73.0 | 71.0 | 63.4 | 52.1 | 40.1 | 28.7 | 49.5 |
| IA | Des Moines | 30 | 20.4 | 26.6 | 38.4 | 50.6 | 61.9 | 71.4 | 76.1 | 73.9 | 65.1 | 52.8 | 37.9 | 24.9 | 50.0 |
| | Dubuque | 30 | 17.0 | 23.1 | 34.8 | 47.5 | 59.1 | 68.3 | 72.3 | 70.0 | 61.8 | 50.4 | 35.7 | 22.5 | 46.9 |
| | Sioux City | 30 | 18.6 | 25.1 | 36.5 | 49.5 | 61.2 | 70.5 | 74.6 | 72.1 | 63.1 | 50.8 | 34.8 | 22.3 | 48.3 |
| | Waterloo | 30 | 16.1 | 22.6 | 35.0 | 47.8 | 60.2 | 69.9 | 73.6 | 71.2 | 62.6 | 50.2 | 35.1 | 21.6 | 47.2 |
| KS | Concordia | 30 | 26.6 | 32.4 | 42.5 | 52.8 | 63.0 | 73.4 | 79.1 | 77.0 | 68.0 | 56.0 | 40.8 | 30.2 | 53.5 |
| | Dodge City | 30 | 30.1 | 36.0 | 44.3 | 53.9 | 63.8 | 74.3 | 79.8 | 78.2 | 69.3 | 57.1 | 42.4 | 33.1 | 55.2 |
| | Goodland | 30 | 27.6 | 32.4 | 39.8 | 48.8 | 58.7 | 69.6 | 75.1 | 73.2 | 64.0 | 51.8 | 37.4 | 29.6 | 50.7 |
| | Topeka | 30 | 27.2 | 33.4 | 44.2 | 54.5 | 64.4 | 73.9 | 78.4 | 76.7 | 68.1 | 56.6 | 42.6 | 31.4 | 54.3 |
| | Wichita | 30 | 30.2 | 36.3 | 45.9 | 55.3 | 65.0 | 75.5 | 81.0 | 79.8 | 70.8 | 58.6 | 44.2 | 33.6 | 56.4 |
| KY | Greater Cincinnati AP | 30 | 29.7 | 34.1 | 43.9 | 53.7 | 63.7 | 72.0 | 76.3 | 74.5 | 67.4 | 55.7 | 44.7 | 34.6 | 54.2 |
| | Jackson | 30 | 33.9 | 37.9 | 47.1 | 56.3 | 64.1 | 71.4 | 75.0 | 73.8 | 67.9 | 57.5 | 47.7 | 38.3 | 55.9 |
| | Lexington | 30 | 32.0 | 36.4 | 45.6 | 54.6 | 63.8 | 72.2 | 76.1 | 74.8 | 68.0 | 56.6 | 45.9 | 36.3 | 55.2 |
| | Louisville | 30 | 33.0 | 37.6 | 46.9 | 56.4 | 65.8 | 74.2 | 78.4 | 77.0 | 70.1 | 58.5 | 47.6 | 37.6 | 57.0 |
| | Paducah | 30 | 32.9 | 38.1 | 47.6 | 57.0 | 65.9 | 74.5 | 78.2 | 76.2 | 69.1 | 58.0 | 46.8 | 36.9 | 56.8 |
| LA | Baton Rouge | 30 | 50.1 | 53.5 | 60.3 | 66.6 | 74.0 | 79.7 | 81.7 | 81.4 | 77.5 | 68.1 | 59.0 | 52.4 | 67.0 |
| | Lake Charles | 30 | 50.9 | 54.4 | 61.0 | 67.3 | 74.9 | 80.5 | 82.6 | 82.4 | 78.4 | 69.5 | 60.1 | 53.3 | 68.0 |
| | New Orleans | 30 | 52.6 | 55.7 | 62.4 | 68.2 | 75.6 | 80.7 | 82.7 | 82.5 | 78.9 | 70.0 | 61.4 | 55.1 | 68.8 |
| | Shreveport | 30 | 46.4 | 51.2 | 58.5 | 65.2 | 73.0 | 79.9 | 83.4 | 82.9 | 77.0 | 66.7 | 56.1 | 48.4 | 65.7 |
| ME | Caribou | 30 | 9.5 | 13.0 | 24.6 | 38.1 | 51.6 | 60.8 | 65.6 | 63.4 | 53.8 | 42.8 | 30.6 | 16.4 | 39.2 |
| | Portland | 30 | 21.7 | 24.8 | 33.7 | 43.7 | 53.8 | 62.9 | 68.7 | 67.2 | 58.7 | 47.7 | 38.3 | 27.6 | 45.8 |
| MD | Baltimore | 30 | 32.3 | 35.5 | 43.7 | 53.2 | 62.9 | 71.8 | 76.5 | 74.5 | 67.4 | 55.4 | 45.5 | 36.7 | 54.6 |
| MA | Blue Hill | 30 | 26.0 | 28.3 | 36.3 | 46.3 | 57.0 | 65.7 | 71.6 | 69.9 | 62.1 | 51.6 | 41.8 | 31.2 | 49.0 |
| | Boston | 30 | 29.3 | 31.5 | 38.9 | 48.3 | 58.5 | 68.0 | 73.9 | 72.3 | 64.7 | 54.1 | 44.9 | 34.8 | 51.6 |
| | Worcester | 30 | 23.6 | 26.0 | 34.3 | 45.0 | 56.3 | 64.7 | 70.1 | 68.3 | 60.2 | 49.6 | 39.6 | 28.9 | 47.2 |
| MI | Alpena | 30 | 17.8 | 19.0 | 28.0 | 40.3 | 52.2 | 61.3 | 66.7 | 64.5 | 56.3 | 45.6 | 34.6 | 24.0 | 42.5 |
| | Detroit | 30 | 24.5 | 27.2 | 36.9 | 48.1 | 59.8 | 69.0 | 73.5 | 71.8 | 63.9 | 51.9 | 40.7 | 29.6 | 49.8 |
| | Flint | 30 | 21.3 | 23.8 | 33.7 | 45.4 | 57.1 | 66.2 | 70.6 | 68.5 | 60.7 | 49.2 | 38.1 | 26.7 | 46.8 |
| | Grand Rapids | 30 | 22.4 | 25.0 | 34.6 | 46.3 | 58.1 | 67.1 | 71.4 | 69.4 | 61.3 | 49.9 | 38.4 | 27.6 | 47.7 |
| | Houghton Lake | 30 | 17.8 | 19.9 | 29.3 | 41.8 | 53.9 | 62.2 | 66.7 | 64.6 | 56.8 | 46.1 | 34.8 | 23.7 | 43.2 |
| | Lansing | 30 | 21.6 | 24.0 | 33.9 | 45.5 | 57.1 | 66.2 | 70.3 | 68.4 | 60.5 | 49.2 | 38.0 | 26.9 | 46.8 |
| | Marquette | 30 | 11.5 | 14.8 | 23.7 | 36.4 | 50.3 | 59.3 | 64.4 | 62.3 | 53.5 | 42.5 | 28.9 | 17.2 | 38.7 |
| | Muskegon | 30 | 23.5 | 25.4 | 34.0 | 44.9 | 56.1 | 64.9 | 69.9 | 68.5 | 60.5 | 49.7 | 38.7 | 28.6 | 47.1 |
| | Sault Ste. Marie | 30 | 13.2 | 15.6 | 24.9 | 38.4 | 51.3 | 58.6 | 63.9 | 63.3 | 54.8 | 44.4 | 32.4 | 20.2 | 40.1 |
| MN | Duluth | 30 | 8.4 | 14.8 | 25.4 | 39.0 | 51.8 | 59.9 | 65.5 | 63.7 | 54.7 | 43.5 | 28.0 | 14.0 | 39.1 |
| | International Falls | 30 | 2.7 | 10.9 | 23.6 | 39.3 | 53.3 | 61.6 | 66.1 | 63.8 | 53.2 | 41.6 | 24.4 | 8.5 | 37.5 |
| | Minneapolis-St. Paul | 30 | 13.1 | 20.1 | 32.1 | 46.6 | 59.3 | 68.4 | 73.2 | 70.6 | 61.0 | 48.7 | 32.5 | 18.7 | 45.4 |
| | Rochester | 30 | 11.8 | 18.4 | 30.6 | 44.7 | 56.9 | 66.1 | 70.1 | 67.7 | 58.9 | 47.0 | 31.2 | 17.3 | 43.4 |
| | Saint Cloud | 30 | 8.8 | 16.1 | 28.4 | 43.6 | 56.6 | 65.1 | 69.8 | 67.2 | 57.4 | 45.3 | 28.8 | 14.4 | 41.8 |
| MS | Jackson | 30 | 45.0 | 49.2 | 56.8 | 63.4 | 71.5 | 78.5 | 81.4 | 80.9 | 75.5 | 64.4 | 54.8 | 47.6 | 64.1 |

*(Continued)*



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**Table 3A.1 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Meridian | 30 | 46.1 | 50.2 | 57.3 | 63.8 | 71.7 | 78.5 | 81.7 | 81.4 | 76.1 | 64.8 | 55.7 | 48.9 | 64.7 |
| | Tupelo | 30 | 40.4 | 44.8 | 53.1 | 60.9 | 69.4 | 76.9 | 80.6 | 79.6 | 73.3 | 61.9 | 51.5 | 43.4 | 61.3 |
| MO | Columbia | 30 | 27.8 | 33.7 | 44.0 | 54.4 | 63.7 | 72.7 | 77.4 | 75.7 | 67.3 | 56.0 | 43.2 | 32.0 | 54.0 |
| | Kansas City | 30 | 26.9 | 33.0 | 43.8 | 54.4 | 64.3 | 73.6 | 78.5 | 76.6 | 68.1 | 56.8 | 42.7 | 31.3 | 54.2 |
| | St. Louis | 30 | 29.6 | 35.4 | 45.8 | 56.6 | 66.5 | 75.6 | 80.2 | 78.2 | 70.2 | 58.3 | 45.3 | 33.9 | 56.3 |
| | Springfield | 30 | 31.7 | 37.1 | 46.3 | 55.6 | 64.7 | 73.4 | 78.5 | 77.6 | 69.3 | 58.4 | 45.9 | 35.7 | 56.2 |
| MT | Billings | 30 | 24.0 | 29.8 | 37.0 | 46.1 | 55.7 | 65.2 | 72.0 | 70.9 | 59.5 | 48.1 | 34.1 | 26.1 | 47.4 |
| | Glasgow | 30 | 10.8 | 19.1 | 30.9 | 44.5 | 55.5 | 64.4 | 70.2 | 69.5 | 57.3 | 45.0 | 27.9 | 15.6 | 42.6 |
| | Great Falls | 30 | 21.7 | 26.4 | 33.4 | 42.6 | 51.5 | 60.0 | 66.2 | 65.6 | 55.4 | 45.5 | 32.3 | 24.3 | 43.8 |
| | Havre | 30 | 14.6 | 21.9 | 32.5 | 44.3 | 54.5 | 62.7 | 68.3 | 67.6 | 56.3 | 44.6 | 29.1 | 19.0 | 43.0 |
| | Helena | 30 | 20.2 | 26.4 | 35.1 | 44.1 | 52.9 | 61.2 | 67.8 | 66.7 | 56.1 | 44.8 | 30.9 | 21.4 | 44.0 |
| | Kalispell | 30 | 21.4 | 26.8 | 34.9 | 43.4 | 51.3 | 57.7 | 63.5 | 63.2 | 53.1 | 41.9 | 30.9 | 23.1 | 42.6 |
| | Missoula | 30 | 23.5 | 29.0 | 37.6 | 45.2 | 52.7 | 60.2 | 66.9 | 66.3 | 56.1 | 44.4 | 32.0 | 23.4 | 44.8 |
| NE | Grand Island | 30 | 22.4 | 28.2 | 38.3 | 49.9 | 60.6 | 71.1 | 75.8 | 73.6 | 64.4 | 52.0 | 36.4 | 25.6 | 49.9 |
| | Lincoln | 30 | 22.4 | 28.3 | 39.4 | 51.2 | 62.0 | 72.7 | 77.8 | 75.4 | 66.0 | 53.5 | 38.1 | 26.5 | 51.1 |
| | Norfolk | 30 | 20.4 | 26.4 | 37.0 | 49.1 | 60.3 | 70.1 | 74.8 | 72.7 | 63.4 | 51.0 | 35.1 | 23.7 | 48.7 |
| | North Platte | 30 | 23.2 | 29.4 | 38.0 | 48.1 | 58.3 | 68.4 | 74.3 | 72.6 | 62.4 | 49.7 | 34.6 | 25.7 | 48.7 |
| | Omaha Eppley AP | 30 | 21.7 | 28.0 | 39.3 | 51.4 | 62.2 | 72.2 | 76.7 | 74.5 | 65.4 | 53.2 | 38.0 | 25.6 | 50.7 |
| | Omaha (North) | 30 | 22.4 | 28.5 | 39.8 | 52.0 | 62.3 | 71.5 | 75.6 | 74.0 | 65.7 | 53.9 | 38.4 | 26.2 | 50.9 |
| | Scottsbluff | 30 | 24.5 | 30.0 | 37.3 | 46.2 | 56.8 | 67.2 | 73.0 | 70.9 | 60.5 | 47.8 | 34.0 | 25.7 | 47.9 |
| | Valentine | 30 | 20.8 | 26.6 | 35.3 | 46.1 | 57.5 | 67.6 | 73.7 | 72.1 | 61.5 | 48.3 | 33.0 | 23.6 | 47.2 |
| NV | Elko | 30 | 25.6 | 31.3 | 38.6 | 44.6 | 52.7 | 61.7 | 69.1 | 67.6 | 58.2 | 46.7 | 34.5 | 26.0 | 46.4 |
| | Ely | 30 | 25.2 | 29.8 | 35.9 | 42.2 | 50.4 | 59.9 | 67.4 | 65.8 | 56.7 | 45.4 | 33.5 | 25.8 | 44.8 |
| | Las Vegas | 30 | 47.0 | 52.2 | 58.3 | 66.0 | 75.4 | 85.6 | 91.2 | 89.3 | 81.3 | 68.7 | 55.0 | 47.0 | 68.1 |
| | Reno | 30 | 33.6 | 38.5 | 43.3 | 48.6 | 56.4 | 64.7 | 71.3 | 69.9 | 62.4 | 52.0 | 40.9 | 33.6 | 51.3 |
| | Winnemucca | 30 | 30.1 | 36.1 | 41.1 | 46.7 | 55.2 | 64.3 | 72.0 | 69.9 | 60.3 | 48.8 | 37.4 | 29.6 | 49.3 |
| NH | Concord | 30 | 20.1 | 23.3 | 33.3 | 44.6 | 56.0 | 64.9 | 70.0 | 68.2 | 59.4 | 47.8 | 37.6 | 25.9 | 45.9 |
| | Mt. Washington | 30 | 5.2 | 6.6 | 13.6 | 22.9 | 35.6 | 44.4 | 48.7 | 47.6 | 40.4 | 30.2 | 20.6 | 10.1 | 27.2 |
| NJ | Atlantic City AP | 30 | 32.1 | 34.2 | 41.8 | 50.6 | 60.5 | 69.7 | 75.3 | 73.5 | 66.3 | 55.1 | 45.9 | 36.8 | 53.5 |
| | Atlantic City CO | 30 | 35.2 | 36.9 | 43.3 | 51.4 | 60.5 | 69.4 | 75.2 | 74.8 | 68.9 | 58.5 | 49.0 | 40.2 | 55.3 |
| | Newark | 30 | 31.3 | 33.8 | 42.2 | 52.3 | 62.7 | 71.9 | 77.2 | 75.5 | 67.8 | 56.4 | 46.4 | 36.4 | 54.5 |
| NM | Albuquerque | 30 | 35.7 | 41.4 | 48.1 | 55.6 | 64.7 | 74.8 | 78.5 | 76.1 | 69.1 | 57.3 | 44.4 | 36.1 | 56.8 |
| | Clayton | 30 | 33.9 | 37.6 | 43.7 | 51.7 | 60.5 | 69.9 | 73.8 | 72.2 | 64.7 | 54.6 | 42.2 | 34.8 | 53.3 |
| | Roswell | 30 | 40.0 | 45.7 | 52.9 | 60.5 | 69.6 | 78.0 | 80.8 | 78.9 | 72.0 | 61.4 | 48.9 | 40.7 | 60.8 |
| NY | Albany | 30 | 22.2 | 25.0 | 35.0 | 46.6 | 58.1 | 66.3 | 71.1 | 69.0 | 60.6 | 49.3 | 39.2 | 28.0 | 47.6 |
| | Binghamton | 30 | 21.7 | 23.8 | 32.7 | 44.1 | 55.9 | 63.9 | 68.7 | 66.6 | 58.8 | 48.1 | 37.6 | 27.1 | 45.8 |
| | Buffalo | 30 | 24.5 | 25.9 | 34.3 | 45.3 | 57.0 | 65.8 | 70.8 | 69.1 | 61.5 | 50.7 | 40.2 | 29.8 | 48.0 |
| | Islip | 30 | 30.9 | 32.4 | 39.8 | 49.1 | 59.2 | 68.5 | 74.6 | 73.1 | 65.8 | 54.3 | 44.9 | 35.7 | 52.4 |
| | New York C.Park | 30 | 32.1 | 34.6 | 42.5 | 52.5 | 62.6 | 71.2 | 76.5 | 75.1 | 67.5 | 56.6 | 47.1 | 37.3 | 54.6 |
| | New York (JFK AP) | 30 | 31.8 | 33.5 | 40.9 | 50.1 | 59.7 | 68.8 | 74.8 | 74.1 | 67.2 | 56.5 | 46.8 | 37.2 | 53.5 |
| | New York (Laguardia AP) | 30 | 32.6 | 34.8 | 42.3 | 52.2 | 62.4 | 71.5 | 77.1 | 75.9 | 68.6 | 57.7 | 47.6 | 37.9 | 55.1 |
| | Rochester | 30 | 23.9 | 25.3 | 33.9 | 45.3 | 57.0 | 65.8 | 70.7 | 68.9 | 61.2 | 50.4 | 39.9 | 29.4 | 47.7 |
| | Syracuse | 30 | 22.7 | 24.5 | 33.6 | 45.3 | 57.1 | 65.8 | 70.9 | 69.2 | 61.3 | 50.1 | 39.7 | 28.6 | 47.4 |
| NC | Asheville | 30 | 35.8 | 39.0 | 46.3 | 54.1 | 62.0 | 69.2 | 73.0 | 71.8 | 65.7 | 55.2 | 46.4 | 39.0 | 54.8 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cape Hatteras | 30 | 46.1 | 46.8 | 52.4 | 59.8 | 67.6 | 74.8 | 79.2 | 78.6 | 74.8 | 65.7 | 57.6 | 50.0 | 62.8 |
| | Charlotte | 30 | 41.7 | 45.2 | 52.8 | 60.9 | 69.0 | 76.5 | 80.3 | 78.9 | 72.7 | 61.7 | 52.3 | 44.4 | 61.4 |
| | Greensboro-Wnstn-Slm-HPT | 30 | 37.7 | 41.2 | 49.1 | 57.6 | 65.8 | 73.6 | 77.9 | 76.2 | 69.8 | 58.5 | 49.2 | 41.0 | 58.2 |
| | Raleigh | 30 | 39.7 | 43.0 | 50.7 | 59.1 | 67.0 | 74.7 | 78.8 | 77.2 | 71.2 | 60.0 | 51.0 | 43.0 | 59.6 |
| | Wilmington | 30 | 46.1 | 48.5 | 55.0 | 62.7 | 70.2 | 77.0 | 81.1 | 79.7 | 75.0 | 64.8 | 56.5 | 48.9 | 63.8 |
| ND | Bismarck | 30 | 10.2 | 18.1 | 29.7 | 43.3 | 56.0 | 64.7 | 70.4 | 69.0 | 57.7 | 45.2 | 28.0 | 15.2 | 42.3 |
| | Fargo | 30 | 6.8 | 14.1 | 27.2 | 43.5 | 57.4 | 66.0 | 70.6 | 69.0 | 58.0 | 45.3 | 27.0 | 12.5 | 41.5 |
| | Grand Forks | 30 | 5.3 | 13.1 | 25.7 | 42.3 | 56.8 | 65.2 | 69.4 | 67.8 | 57.0 | 44.3 | 25.8 | 11.3 | 40.3 |
| | Williston | 30 | 8.0 | 16.8 | 28.7 | 42.5 | 54.6 | 63.7 | 69.3 | 68.3 | 56.1 | 43.6 | 25.6 | 13.0 | 40.9 |
| OH | Akron | 30 | 25.2 | 28.3 | 37.7 | 48.1 | 58.8 | 67.5 | 71.8 | 70.3 | 63.0 | 51.6 | 41.1 | 30.7 | 49.5 |
| | Cleveland | 30 | 25.7 | 28.4 | 37.5 | 47.6 | 58.5 | 67.5 | 71.9 | 70.2 | 63.3 | 52.2 | 41.8 | 31.1 | 49.7 |
| | Columbus | 30 | 28.3 | 32.0 | 42.0 | 52.0 | 62.6 | 71.2 | 75.1 | 73.5 | 66.5 | 54.7 | 43.7 | 33.5 | 52.9 |
| | Dayton | 30 | 26.3 | 30.3 | 40.2 | 50.6 | 61.2 | 70.2 | 74.3 | 72.3 | 65.1 | 53.5 | 42.2 | 31.4 | 51.5 |
| | Mansfield | 30 | 24.3 | 27.3 | 36.7 | 47.2 | 58.0 | 66.8 | 71.0 | 69.3 | 62.6 | 51.5 | 40.5 | 29.6 | 48.8 |
| | Toledo | 30 | 23.9 | 27.0 | 37.2 | 48.3 | 59.6 | 68.8 | 73.0 | 70.8 | 63.5 | 51.8 | 40.5 | 29.2 | 49.5 |
| | Youngstown | 30 | 24.9 | 27.7 | 36.7 | 47.4 | 57.6 | 65.9 | 69.9 | 68.4 | 61.5 | 50.8 | 40.7 | 30.4 | 48.5 |
| OK | Oklahoma City | 30 | 36.7 | 42.3 | 51.0 | 59.7 | 68.4 | 76.8 | 82.0 | 81.2 | 73.2 | 62.0 | 48.9 | 39.5 | 60.1 |
| | Tulsa | 30 | 36.4 | 42.0 | 51.4 | 60.8 | 69.3 | 78.0 | 83.5 | 82.2 | 73.5 | 62.6 | 49.7 | 39.7 | 60.8 |
| OR | Astoria | 30 | 42.4 | 44.2 | 46.0 | 48.5 | 52.7 | 56.7 | 60.1 | 60.8 | 58.5 | 52.6 | 46.6 | 42.8 | 51.0 |
| | Burns | 30 | 24.4 | 30.0 | 37.0 | 43.0 | 50.9 | 58.1 | 65.9 | 64.2 | 55.0 | 44.4 | 32.7 | 24.9 | 44.2 |
| | Eugene | 30 | 39.8 | 42.8 | 46.3 | 49.8 | 54.8 | 60.2 | 66.2 | 66.4 | 61.7 | 52.6 | 44.7 | 39.5 | 52.1 |
| | Medford | 30 | 39.1 | 43.5 | 47.1 | 51.6 | 58.1 | 65.6 | 72.7 | 72.5 | 65.9 | 55.1 | 43.9 | 38.1 | 54.5 |
| | Pendleton | 30 | 33.8 | 38.7 | 45.1 | 51.0 | 58.1 | 65.4 | 72.6 | 72.0 | 63.4 | 52.3 | 41.2 | 33.9 | 52.3 |
| | Portland | 30 | 39.9 | 43.1 | 47.2 | 51.2 | 57.1 | 62.7 | 68.1 | 68.5 | 63.6 | 54.3 | 45.8 | 40.2 | 53.5 |
| | Salem | 30 | 40.3 | 43.0 | 46.5 | 50.0 | 55.6 | 61.2 | 66.8 | 67.0 | 62.2 | 52.9 | 45.2 | 40.2 | 52.6 |
| | Sexton Summit | 30 | 37.5 | 38.6 | 39.6 | 43.4 | 49.9 | 56.5 | 63.7 | 64.2 | 60.1 | 51.3 | 40.5 | 37.3 | 48.6 |
| PC | Guam | 30 | 77.6 | 77.6 | 78.4 | 79.5 | 80.3 | 80.5 | 79.8 | 79.5 | 79.7 | 79.5 | 79.6 | 78.9 | 79.2 |
| | Johnston Island | 30 | 77.5 | 77.7 | 77.9 | 78.7 | 79.8 | 81.2 | 82.0 | 82.6 | 82.5 | 81.9 | 79.9 | 78.3 | 80.0 |
| | Koror | 30 | 81.4 | 81.2 | 81.8 | 82.3 | 82.6 | 81.8 | 81.4 | 81.6 | 82.0 | 82.1 | 82.5 | 82.0 | 81.9 |
| | Kwajalein, Marshall IS | 30 | 81.6 | 81.8 | 82.3 | 82.2 | 82.4 | 82.2 | 82.1 | 82.3 | 82.3 | 82.4 | 82.1 | 81.9 | 82.1 |
| | Majuro, Marshall IS | 30 | 80.8 | 81.1 | 81.2 | 81.1 | 81.3 | 81.2 | 81.1 | 81.4 | 81.5 | 81.5 | 81.4 | 80.9 | 81.2 |
| | Pago Pago, Amer Samoa | 30 | 81.5 | 81.8 | 82.0 | 81.6 | 80.9 | 80.3 | 79.7 | 79.8 | 80.3 | 80.7 | 81.2 | 81.7 | 81.0 |
| | Pohnpei, Caroline IS | 30 | 80.8 | 81.1 | 81.4 | 81.2 | 81.2 | 81.0 | 80.7 | 80.7 | 80.7 | 80.7 | 81.0 | 80.9 | 81.0 |
| | Chuuk, E. Caroline IS | 30 | 81.5 | 81.3 | 81.6 | 81.8 | 81.9 | 81.6 | 81.4 | 80.9 | 81.3 | 81.4 | 82.1 | 81.5 | 81.5 |
| | Wake Island | 30 | 77.8 | 77.3 | 78.2 | 79.2 | 80.8 | 82.6 | 83.3 | 83.3 | 83.6 | 82.6 | 81.0 | 79.3 | 80.8 |
| | Yap, W Caroline IS | 30 | 80.1 | 80.3 | 80.8 | 81.5 | 81.7 | 81.0 | 80.6 | 80.4 | 80.6 | 80.7 | 80.9 | 80.6 | 80.8 |
| PA | Allentown | 30 | 27.1 | 29.9 | 38.8 | 49.0 | 59.6 | 68.5 | 73.3 | 71.2 | 63.4 | 52.0 | 42.0 | 32.0 | 50.6 |
| | Erie | 30 | 26.9 | 28.2 | 36.5 | 46.8 | 58.1 | 67.4 | 72.1 | 70.9 | 64.0 | 53.3 | 42.9 | 32.7 | 50.0 |
| | Harrisburg | 30 | 30.3 | 32.8 | 41.7 | 52.1 | 62.0 | 70.7 | 75.9 | 74.0 | 66.2 | 54.5 | 44.3 | 34.8 | 53.3 |
| | Middletown/ Harrisburg AP | 30 | 30.3 | 32.8 | 41.7 | 52.1 | 62.0 | 70.7 | 75.9 | 74.0 | 66.2 | 54.5 | 44.3 | 34.8 | 53.3 |
| | Philadelphia | 30 | 32.3 | 34.8 | 43.2 | 53.1 | 63.5 | 72.3 | 77.6 | 76.3 | 68.8 | 57.2 | 47.1 | 37.4 | 55.3 |
| | Pittsburgh | 30 | 27.5 | 30.5 | 39.8 | 49.9 | 60.0 | 68.4 | 72.6 | 71.0 | 64.0 | 52.5 | 42.3 | 32.5 | 51.0 |
| | Avoca | 30 | 26.3 | 28.9 | 37.9 | 48.7 | 59.6 | 67.5 | 72.1 | 70.3 | 62.5 | 51.5 | 41.5 | 31.4 | 49.9 |

*(Continued)*



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**Table 3A.1 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Williamsport | 30 | 25.5 | 28.5 | 38.0 | 49.0 | 59.5 | 67.8 | 72.4 | 70.9 | 63.1 | 51.3 | 40.8 | 30.7 | 49.9 |
| RI | Providence | 30 | 28.7 | 30.9 | 38.8 | 48.6 | 58.7 | 67.6 | 73.3 | 71.9 | 64.0 | 53.0 | 43.8 | 33.8 | 51.1 |
| SC | Charleston AP | 30 | 47.9 | 50.7 | 57.7 | 64.2 | 72.1 | 78.2 | 81.7 | 80.5 | 76.1 | 66.2 | 58.0 | 50.5 | 65.3 |
| | Charleston CO | 30 | 49.8 | 52.4 | 58.7 | 65.9 | 73.5 | 79.4 | 82.8 | 81.6 | 77.6 | 68.5 | 60.5 | 52.8 | 67.0 |
| | Columbia | 30 | 44.6 | 47.9 | 55.4 | 63.2 | 71.6 | 78.5 | 82.0 | 80.3 | 74.7 | 63.7 | 54.7 | 47.0 | 63.6 |
| | Greenville-Spartanburg | 30 | 40.8 | 44.4 | 51.6 | 59.0 | 67.2 | 74.7 | 78.8 | 77.5 | 71.4 | 60.5 | 51.1 | 43.5 | 60.1 |
| SD | Aberdeen | 30 | 11.0 | 18.7 | 30.7 | 45.4 | 57.9 | 66.8 | 72.2 | 70.5 | 59.8 | 46.8 | 29.3 | 16.0 | 43.8 |
| | Huron | 30 | 14.2 | 21.0 | 32.6 | 46.1 | 58.2 | 67.9 | 73.4 | 71.5 | 61.0 | 47.9 | 31.3 | 18.6 | 45.4 |
| | Rapid City | 30 | 22.4 | 27.3 | 34.9 | 44.7 | 55.0 | 64.6 | 71.7 | 71.1 | 60.6 | 48.2 | 33.4 | 24.7 | 46.6 |
| | Sioux Falls | 30 | 14.0 | 20.8 | 32.6 | 45.7 | 57.8 | 67.5 | 73.0 | 70.8 | 60.9 | 48.0 | 31.3 | 18.3 | 45.1 |
| TN | Bristol-JhnCty-Kgsprt | 30 | 34.2 | 38.0 | 46.5 | 54.6 | 63.0 | 70.7 | 74.2 | 72.8 | 66.6 | 55.0 | 45.5 | 37.3 | 54.9 |
| | Chattanooga | 30 | 39.4 | 43.4 | 51.4 | 59.6 | 67.7 | 75.4 | 79.6 | 78.5 | 72.1 | 60.4 | 50.3 | 42.4 | 60.0 |
| | Knoxville | 30 | 37.6 | 41.8 | 49.7 | 57.8 | 66.0 | 73.8 | 77.7 | 76.9 | 70.8 | 58.8 | 49.0 | 40.9 | 58.4 |
| | Memphis | 30 | 39.9 | 44.9 | 53.5 | 62.1 | 70.6 | 78.7 | 82.5 | 81.2 | 74.8 | 63.8 | 52.3 | 43.3 | 62.4 |
| | Nashville | 30 | 36.8 | 41.3 | 50.1 | 58.5 | 67.1 | 75.1 | 79.1 | 77.9 | 71.3 | 59.9 | 49.3 | 40.5 | 58.9 |
| | Oak Ridge | 30 | 36.6 | 40.6 | 48.8 | 57.2 | 65.6 | 73.3 | 77.3 | 76.2 | 70.0 | 58.4 | 47.7 | 39.4 | 57.6 |
| TX | Abilene | 30 | 43.5 | 48.6 | 56.4 | 64.6 | 72.8 | 79.8 | 83.5 | 82.6 | 75.5 | 66.0 | 53.7 | 45.4 | 64.4 |
| | Amarillo | 30 | 35.8 | 40.6 | 47.9 | 56.2 | 65.2 | 74.3 | 78.2 | 76.3 | 69.1 | 58.2 | 45.1 | 37.0 | 57.0 |
| | Austin/City | 30 | 50.2 | 54.6 | 61.7 | 68.3 | 75.1 | 81.0 | 84.2 | 84.5 | 79.5 | 70.6 | 59.7 | 52.1 | 68.5 |
| | Austin/Bergstrom | 30 | 48.1 | 52.6 | 59.9 | 67.1 | 74.7 | 80.1 | 82.8 | 82.1 | 77.5 | 68.6 | 57.8 | 49.8 | 66.8 |
| | Brownsville | 30 | 59.6 | 62.7 | 68.8 | 73.8 | 79.3 | 82.7 | 83.9 | 84.0 | 81.0 | 75.0 | 67.7 | 61.1 | 73.3 |
| | Corpus Christi | 30 | 56.1 | 59.5 | 66.0 | 71.5 | 77.5 | 81.9 | 83.8 | 83.9 | 80.8 | 73.8 | 65.1 | 58.1 | 71.5 |
| | Dallas-Fort Worth | 30 | 44.1 | 49.4 | 57.4 | 65.0 | 73.1 | 80.9 | 85.0 | 84.4 | 77.5 | 67.2 | 55.1 | 46.7 | 65.5 |
| | Dallas-Love Field | 30 | 45.9 | 51.0 | 58.8 | 66.3 | 74.4 | 82.2 | 86.5 | 86.1 | 78.9 | 68.4 | 56.4 | 48.0 | 66.9 |
| | Del Rio | 30 | 51.3 | 56.1 | 63.8 | 70.6 | 77.7 | 82.9 | 85.3 | 85.1 | 80.0 | 71.1 | 60.1 | 52.4 | 69.7 |
| | El Paso | 30 | 45.1 | 50.5 | 57.0 | 64.6 | 73.7 | 82.1 | 83.3 | 81.1 | 75.4 | 64.9 | 52.7 | 45.4 | 64.7 |
| | Galveston | 30 | 55.8 | 58.0 | 64.1 | 70.0 | 76.9 | 82.2 | 84.3 | 84.4 | 81.1 | 74.1 | 65.4 | 58.1 | 71.2 |
| | Houston | 30 | 51.8 | 55.4 | 62.3 | 68.5 | 75.8 | 81.3 | 83.6 | 83.3 | 78.9 | 70.4 | 60.9 | 53.7 | 68.8 |
| | Lubbock | 30 | 38.1 | 43.3 | 51.2 | 60.0 | 69.2 | 77.1 | 79.8 | 78.0 | 70.9 | 60.7 | 48.1 | 39.7 | 59.7 |
| | Midland-Odessa | 30 | 43.2 | 48.6 | 55.9 | 63.7 | 72.8 | 79.6 | 81.7 | 80.4 | 73.9 | 64.4 | 52.3 | 44.8 | 63.4 |
| | Port Arthur | 30 | 52.2 | 55.6 | 62.2 | 68.2 | 75.4 | 80.9 | 82.7 | 82.5 | 78.7 | 70.1 | 60.9 | 54.2 | 68.6 |
| | San Angelo | 30 | 44.9 | 49.7 | 57.2 | 65.0 | 73.1 | 79.2 | 82.4 | 81.3 | 74.8 | 65.4 | 54.0 | 46.4 | 64.5 |
| | San Antonio | 30 | 50.3 | 54.7 | 62.1 | 68.6 | 75.8 | 81.5 | 84.3 | 84.2 | 79.4 | 70.7 | 60.0 | 52.4 | 68.7 |
| | Victoria | 30 | 53.2 | 56.7 | 63.7 | 69.7 | 76.6 | 81.8 | 84.2 | 84.2 | 80.1 | 72.3 | 62.7 | 55.2 | 70.0 |
| | Waco | 30 | 46.1 | 50.8 | 58.5 | 65.9 | 74.1 | 81.3 | 85.4 | 85.2 | 78.6 | 68.6 | 56.8 | 48.3 | 66.6 |
| | Wichita Falls | 30 | 40.5 | 45.7 | 54.2 | 62.4 | 71.4 | 79.7 | 84.8 | 83.5 | 75.6 | 64.7 | 51.9 | 42.9 | 63.1 |
| UT | Milford | 30 | 28.1 | 33.7 | 41.6 | 48.3 | 56.6 | 66.7 | 74.2 | 72.6 | 63.1 | 50.6 | 37.6 | 28.6 | 50.1 |
| | Salt Lake City | 30 | 29.2 | 34.5 | 43.1 | 50.0 | 58.8 | 69.0 | 77.0 | 75.6 | 65.0 | 52.5 | 39.6 | 30.2 | 52.0 |
| VT | Burlington | 30 | 18.0 | 19.9 | 30.7 | 43.5 | 56.5 | 65.6 | 70.6 | 68.2 | 59.4 | 47.7 | 37.1 | 24.8 | 45.2 |
| VA | Lynchburg | 30 | 34.5 | 37.8 | 46.0 | 55.3 | 63.4 | 71.0 | 75.1 | 73.8 | 67.1 | 56.1 | 46.6 | 38.2 | 55.4 |
| | Norfolk | 30 | 40.1 | 42.0 | 49.0 | 57.4 | 66.3 | 74.5 | 79.1 | 77.4 | 72.1 | 61.1 | 52.3 | 44.2 | 59.6 |
| | Richmond | 30 | 36.4 | 39.5 | 47.7 | 57.1 | 65.4 | 73.5 | 77.9 | 76.3 | 69.8 | 58.3 | 49.0 | 40.4 | 57.6 |
| | Roanoke | 30 | 35.8 | 39.1 | 47.2 | 56.1 | 64.1 | 71.9 | 76.2 | 74.7 | 67.7 | 56.6 | 47.3 | 39.1 | 56.3 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WA | Olympia | 30 | 38.1 | 40.5 | 43.6 | 47.4 | 53.3 | 58.2 | 62.8 | 63.3 | 58.3 | 49.7 | 42.4 | 38.0 | 49.7 |
| | Quillayute | 30 | 40.6 | 42.2 | 43.8 | 46.7 | 51.2 | 54.9 | 58.6 | 59.3 | 56.5 | 50.1 | 44.2 | 40.6 | 49.1 |
| | Seattle CO | 30 | 41.5 | 43.8 | 46.9 | 50.9 | 56.6 | 61.1 | 65.5 | 66.0 | 61.3 | 53.4 | 46.0 | 41.3 | 52.9 |
| | Seattle Sea-Tac AP | 30 | 40.9 | 43.3 | 46.2 | 50.2 | 55.8 | 60.7 | 65.3 | 65.6 | 61.1 | 52.7 | 45.2 | 40.7 | 52.3 |
| | Spokane | 30 | 27.3 | 32.5 | 39.5 | 46.5 | 54.4 | 61.6 | 68.6 | 68.6 | 59.2 | 47.2 | 34.9 | 27.2 | 47.3 |
| | Walla Walla | 30 | 34.7 | 39.7 | 46.5 | 52.7 | 59.8 | 67.3 | 75.3 | 75.2 | 66.1 | 54.7 | 43.1 | 35.1 | 54.2 |
| | Yakima | 30 | 29.1 | 35.2 | 42.5 | 48.7 | 56.2 | 62.9 | 69.1 | 68.3 | 60.0 | 48.6 | 37.0 | 28.8 | 48.9 |
| PR | San Juan | 30 | 76.6 | 76.9 | 77.6 | 79.1 | 80.6 | 82.1 | 82.2 | 82.4 | 82.2 | 81.6 | 79.6 | 77.7 | 79.9 |
| WV | Beckley | 30 | 30.4 | 33.9 | 42.1 | 51.5 | 59.9 | 67.0 | 70.7 | 69.3 | 63.1 | 52.8 | 43.4 | 34.8 | 51.6 |
| | Charleston | 30 | 33.4 | 36.9 | 45.3 | 54.3 | 62.4 | 69.9 | 73.9 | 72.6 | 66.2 | 55.1 | 45.9 | 37.5 | 54.5 |
| | Elkins | 30 | 28.6 | 31.6 | 40.0 | 48.9 | 57.9 | 65.6 | 69.6 | 68.5 | 62.1 | 50.6 | 41.0 | 32.7 | 49.8 |
| | Huntington | 30 | 32.7 | 36.8 | 45.9 | 55.2 | 63.6 | 71.3 | 75.3 | 73.9 | 66.9 | 55.6 | 45.9 | 37.1 | 55.0 |
| WI | Green Bay | 30 | 15.6 | 20.5 | 31.3 | 44.2 | 56.4 | 65.4 | 69.9 | 67.5 | 58.8 | 47.4 | 34.0 | 21.2 | 44.4 |
| | La Crosse | 30 | 15.9 | 22.6 | 34.6 | 48.4 | 60.6 | 69.6 | 74.0 | 71.6 | 62.7 | 50.6 | 35.5 | 21.8 | 47.3 |
| | Madison | 30 | 17.3 | 22.6 | 33.7 | 45.9 | 57.7 | 67.0 | 71.6 | 69.1 | 60.7 | 49.3 | 35.5 | 23.0 | 46.1 |
| | Milwaukee | 30 | 20.7 | 25.4 | 34.9 | 45.2 | 56.1 | 66.3 | 72.0 | 70.6 | 63.0 | 51.4 | 38.4 | 26.2 | 47.5 |
| WY | Casper | 30 | 22.3 | 26.7 | 35.0 | 42.7 | 52.1 | 62.7 | 70.0 | 68.6 | 57.6 | 45.7 | 32.0 | 23.8 | 44.9 |
| | Cheyenne | 30 | 25.9 | 28.8 | 34.2 | 41.6 | 51.3 | 61.5 | 67.7 | 65.9 | 56.6 | 45.4 | 33.3 | 27.1 | 45.0 |
| | Lander | 30 | 20.3 | 25.6 | 35.5 | 43.9 | 53.4 | 63.7 | 70.9 | 69.4 | 58.7 | 46.4 | 30.3 | 21.3 | 45.0 |
| | Sheridan | 30 | 21.3 | 26.9 | 35.3 | 43.9 | 52.5 | 61.6 | 68.8 | 68.2 | 57.1 | 45.1 | 31.0 | 22.4 | 44.6 |

*Note:* In Fahrenheit degrees, based on 30-year average values 1971–2000; Temperature data are the normal daily values for each month.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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**Table 3A.2 Normal Daily Minimum Temperature — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham AP | 30 | 32.3 | 35.4 | 42.4 | 48.4 | 57.6 | 65.4 | 69.7 | 68.9 | 63.0 | 50.9 | 41.8 | 35.2 | 50.9 |
| | Huntsville | 30 | 30.7 | 34.0 | 41.2 | 48.4 | 57.5 | 65.4 | 69.5 | 68.1 | 61.7 | 49.6 | 40.7 | 33.8 | 50.1 |
| | Mobile | 30 | 39.5 | 42.4 | 49.2 | 54.8 | 62.8 | 69.2 | 71.8 | 71.7 | 67.6 | 56.3 | 47.8 | 41.6 | 56.2 |
| | Montgomery | 30 | 35.5 | 38.6 | 45.4 | 51.2 | 60.1 | 67.3 | 70.9 | 70.1 | 64.9 | 52.2 | 43.5 | 37.6 | 53.1 |
| AK | Anchorage | 30 | 9.3 | 11.7 | 18.2 | 28.7 | 38.9 | 47.0 | 51.5 | 49.4 | 41.4 | 28.3 | 15.9 | 11.4 | 29.3 |
| | Annette | 30 | 30.4 | 32.3 | 34.2 | 37.7 | 43.1 | 48.3 | 52.4 | 52.6 | 48.0 | 41.7 | 35.1 | 32.1 | 40.7 |
| | Barrow | 30 | −19.6 | −22.0 | −20.0 | −7.3 | 15.3 | 30.4 | 34.3 | 33.8 | 27.5 | 9.8 | −6.4 | −16.4 | 5.0 |
| | Bethel | 30 | 0.7 | 1.3 | 7.2 | 18.4 | 33.1 | 43.3 | 48.8 | 47.5 | 39.1 | 24.7 | 11.7 | 3.2 | 23.3 |
| | Bettles | 30 | −19.2 | −17.7 | −8.0 | 10.6 | 33.7 | 46.9 | 49.5 | 43.7 | 32.8 | 11.9 | −8.0 | −15.1 | 13.4 |
| | Big Delta | 30 | −9.6 | −6.4 | 3.2 | 21.7 | 37.7 | 47.6 | 51.1 | 46.1 | 35.6 | 17.0 | −0.8 | −7.1 | 19.7 |
| | Cold Bay | 30 | 23.5 | 22.9 | 24.9 | 28.8 | 34.8 | 41.1 | 46.1 | 47.4 | 43.0 | 35.1 | 29.9 | 26.5 | 33.7 |
| | Fairbanks | 30 | −19.0 | −15.6 | −2.7 | 19.8 | 36.9 | 48.5 | 51.9 | 46.2 | 34.7 | 15.6 | −6.6 | −15.2 | 16.3 |
| | Gulkana | 30 | −12.9 | −7.4 | 2.3 | 19.7 | 32.2 | 41.1 | 45.4 | 41.7 | 32.8 | 18.4 | −2.2 | −9.5 | 16.8 |
| | Homer | 30 | 17.5 | 18.3 | 22.5 | 29.3 | 36.7 | 43.0 | 47.2 | 46.7 | 41.0 | 31.4 | 23.5 | 20.0 | 31.4 |
| | Juneau | 30 | 20.7 | 23.5 | 27.8 | 33.4 | 40.1 | 46.1 | 49.2 | 48.3 | 43.8 | 37.7 | 28.9 | 24.4 | 35.3 |
| | King Salmon | 30 | 8.0 | 7.4 | 15.1 | 24.9 | 34.8 | 42.2 | 47.5 | 47.4 | 40.3 | 26.0 | 15.9 | 9.3 | 26.6 |
| | Kodiak | 30 | 24.6 | 24.3 | 26.8 | 31.8 | 38.2 | 43.9 | 48.5 | 48.6 | 43.2 | 34.3 | 28.9 | 25.3 | 34.9 |
| | Kotzebue | 30 | −8.6 | −9.9 | −7.7 | 3.3 | 25.3 | 38.8 | 49.4 | 47.4 | 37.2 | 18.8 | 3.2 | −6.4 | 15.9 |
| | Mcgrath | 30 | −15.6 | −12.5 | −1.8 | 17.7 | 35.5 | 45.7 | 49.8 | 45.7 | 35.9 | 18.3 | −2.2 | −12.3 | 17.0 |
| | Nome | 30 | −1.8 | −2.3 | 1.0 | 12.4 | 31.1 | 40.6 | 46.6 | 45.2 | 37.2 | 22.9 | 10.8 | 0.9 | 20.4 |
| | St. Paul Island | 30 | 21.5 | 18.9 | 19.5 | 24.0 | 31.5 | 37.6 | 43.0 | 45.1 | 40.7 | 34.1 | 29.1 | 24.7 | 30.8 |
| | Talkeetna | 30 | 2.3 | 5.0 | 11.1 | 23.9 | 34.9 | 45.1 | 49.9 | 46.5 | 37.3 | 23.6 | 9.4 | 4.8 | 24.5 |
| | Unalakleet | 30 | −3.9 | −4.2 | 1.8 | 13.8 | 32.1 | 42.7 | 48.9 | 46.5 | 35.8 | 19.4 | 5.0 | −1.4 | 19.7 |
| | Valdez | 30 | 17.2 | 19.6 | 23.8 | 30.9 | 38.6 | 45.0 | 48.0 | 46.4 | 40.9 | 33.4 | 23.9 | 20.2 | 32.3 |
| | Yakutat | 30 | 19.4 | 21.0 | 23.6 | 29.2 | 36.1 | 42.7 | 47.1 | 46.2 | 40.6 | 34.8 | 26.3 | 22.9 | 32.5 |
| AZ | Flagstaff | 30 | 16.5 | 18.8 | 22.8 | 27.3 | 34.0 | 41.4 | 49.9 | 49.1 | 41.7 | 31.1 | 22.1 | 16.6 | 30.9 |
| | Phoenix | 30 | 43.4 | 47.0 | 51.1 | 57.5 | 66.3 | 75.2 | 81.4 | 80.4 | 74.5 | 62.9 | 50.0 | 43.5 | 61.1 |
| | Tucson | 30 | 38.9 | 41.6 | 45.1 | 50.5 | 58.6 | 68.0 | 73.4 | 72.4 | 67.7 | 57.0 | 45.1 | 39.2 | 54.8 |
| | Winslow | 30 | 21.3 | 25.5 | 31.1 | 36.9 | 45.3 | 54.2 | 62.0 | 61.1 | 52.9 | 40.1 | 28.7 | 21.0 | 40.0 |
| | Yuma | 30 | 46.2 | 48.8 | 52.8 | 58.1 | 65.1 | 73.2 | 80.8 | 80.8 | 75.3 | 64.0 | 52.2 | 45.8 | 61.9 |
| AR | Fort Smith | 30 | 27.8 | 32.6 | 40.9 | 49.0 | 58.9 | 67.2 | 71.4 | 70.3 | 62.9 | 50.5 | 39.5 | 31.1 | 50.2 |
| | Little Rock | 30 | 30.8 | 34.8 | 42.6 | 50.0 | 59.2 | 67.8 | 72.0 | 70.5 | 63.6 | 51.5 | 41.5 | 33.9 | 51.5 |
| | North Little Rock | 30 | 31.3 | 36.1 | 44.5 | 52.7 | 61.2 | 68.9 | 72.9 | 71.5 | 64.9 | 54.1 | 43.4 | 34.9 | 53.0 |
| CA | Bakersfield | 30 | 39.3 | 43.0 | 46.2 | 49.6 | 56.8 | 63.7 | 69.2 | 68.4 | 63.9 | 54.9 | 44.2 | 38.2 | 53.1 |
| | Bishop | 30 | 22.4 | 26.4 | 31.0 | 36.0 | 43.7 | 50.7 | 55.7 | 53.7 | 46.9 | 37.1 | 27.1 | 21.6 | 37.7 |
| | Eureka | 30 | 40.8 | 41.8 | 42.2 | 44.0 | 47.6 | 50.7 | 52.8 | 53.4 | 51.2 | 47.7 | 43.9 | 40.6 | 46.4 |
| | Fresno | 30 | 38.4 | 41.4 | 44.9 | 48.4 | 54.9 | 61.2 | 66.1 | 64.9 | 60.4 | 51.9 | 42.3 | 37.0 | 51.0 |
| | Long Beach | 30 | 46.0 | 48.1 | 50.4 | 53.2 | 57.8 | 61.3 | 64.6 | 65.6 | 63.7 | 58.3 | 50.1 | 45.3 | 55.4 |
| | Los Angeles AP | 30 | 48.6 | 50.1 | 51.3 | 53.6 | 56.9 | 60.1 | 63.3 | 64.5 | 63.6 | 59.4 | 52.7 | 48.5 | 56.1 |
| | Los Angeles CO | 30 | 48.5 | 50.3 | 51.6 | 54.4 | 57.9 | 61.4 | 64.6 | 65.6 | 64.6 | 59.9 | 52.6 | 48.3 | 56.6 |
| | Mount Shasta | 30 | 26.4 | 28.7 | 30.3 | 33.3 | 39.0 | 44.9 | 48.9 | 47.5 | 42.9 | 36.6 | 29.9 | 25.8 | 36.2 |
| | Redding | 30 | 35.5 | 38.1 | 41.1 | 44.9 | 51.6 | 59.6 | 64.1 | 60.8 | 56.5 | 48.0 | 39.8 | 35.0 | 47.9 |
| | Sacramento | 30 | 38.8 | 41.9 | 44.2 | 46.3 | 50.9 | 55.5 | 58.3 | 58.1 | 55.8 | 50.6 | 42.8 | 37.7 | 48.4 |
| | San Diego | 30 | 49.7 | 51.5 | 53.6 | 56.4 | 59.8 | 62.6 | 65.9 | 67.4 | 66.1 | 61.2 | 53.6 | 48.9 | 58.1 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | San Francisco AP | 30 | 42.9 | 45.5 | 46.8 | 48.1 | 50.5 | 52.9 | 54.5 | 55.5 | 55.1 | 52.4 | 47.5 | 43.0 | 49.6 |
| | San Francisco CO | 30 | 46.4 | 48.5 | 49.2 | 50.1 | 51.4 | 53.2 | 54.4 | 55.6 | 56.1 | 54.6 | 50.8 | 46.7 | 51.4 |
| | Santa Barbara | 30 | 40.8 | 44.0 | 46.0 | 47.6 | 50.5 | 53.9 | 57.3 | 58.4 | 56.6 | 51.6 | 44.0 | 39.9 | 49.2 |
| | Santa Maria | 30 | 39.3 | 41.4 | 42.7 | 43.4 | 46.9 | 50.4 | 53.5 | 54.2 | 52.9 | 48.2 | 41.8 | 38.2 | 46.1 |
| | Stockton | 30 | 38.1 | 41.0 | 43.6 | 46.7 | 52.1 | 57.5 | 60.8 | 60.3 | 57.4 | 50.5 | 42.1 | 36.7 | 48.9 |
| CO | Alamosa | 30 | −3.7 | 4.7 | 15.8 | 22.8 | 32.4 | 40.4 | 46.4 | 45.2 | 36.5 | 23.9 | 11.1 | −0.7 | 22.9 |
| | Colorado Springs | 30 | 14.5 | 18.0 | 23.9 | 31.4 | 40.7 | 49.5 | 54.8 | 53.6 | 45.4 | 34.3 | 22.6 | 15.6 | 33.7 |
| | Denver | 30 | 15.2 | 19.1 | 25.4 | 34.2 | 43.8 | 53.0 | 58.7 | 57.4 | 47.3 | 35.9 | 23.5 | 16.4 | 35.8 |
| | Grand Junction | 30 | 15.6 | 22.7 | 31.0 | 37.5 | 46.4 | 55.3 | 61.4 | 59.7 | 50.4 | 38.6 | 26.3 | 17.5 | 38.5 |
| | Pueblo | 30 | 14.0 | 18.8 | 26.3 | 34.5 | 44.8 | 53.5 | 59.4 | 58.1 | 48.7 | 35.3 | 22.5 | 15.1 | 35.9 |
| CT | Bridgeport | 30 | 22.9 | 24.9 | 32.0 | 40.7 | 50.6 | 59.6 | 66.0 | 65.4 | 57.7 | 46.3 | 37.5 | 28.0 | 44.3 |
| | Hartford | 30 | 17.2 | 19.9 | 28.3 | 37.9 | 48.1 | 57.0 | 62.4 | 60.7 | 52.1 | 40.6 | 32.6 | 22.6 | 40.0 |
| DE | Wilmington | 30 | 23.7 | 25.8 | 33.4 | 42.1 | 52.4 | 61.8 | 67.3 | 65.8 | 58.1 | 45.6 | 36.9 | 28.4 | 45.1 |
| DC | Washington Dulles AP | 30 | 21.9 | 24.1 | 31.8 | 40.2 | 49.9 | 59.0 | 64.0 | 62.8 | 55.6 | 42.3 | 33.8 | 26.0 | 42.6 |
| | Washington Nat'l AP | 30 | 27.3 | 29.7 | 37.3 | 45.9 | 55.8 | 65.0 | 70.1 | 68.6 | 61.8 | 49.6 | 40.0 | 32.0 | 48.6 |
| FL | Apalachicola | 30 | 43.0 | 45.8 | 51.4 | 57.6 | 65.1 | 71.6 | 73.9 | 74.0 | 71.2 | 60.5 | 52.0 | 45.3 | 59.3 |
| | Daytona Beach | 30 | 47.1 | 48.8 | 53.7 | 58.0 | 64.5 | 70.6 | 72.4 | 72.8 | 71.9 | 65.3 | 57.0 | 50.1 | 61.0 |
| | Fort Myers | 30 | 54.5 | 55.4 | 59.3 | 62.7 | 68.4 | 73.1 | 74.2 | 74.4 | 73.9 | 68.6 | 62.1 | 56.2 | 65.2 |
| | Gainesville | 30 | 42.4 | 44.7 | 49.9 | 54.7 | 62.0 | 68.4 | 70.8 | 70.6 | 68.1 | 59.2 | 51.1 | 44.4 | 57.2 |
| | Jacksonville | 30 | 41.9 | 44.3 | 49.8 | 54.6 | 62.5 | 69.4 | 72.4 | 72.2 | 69.4 | 59.7 | 50.8 | 44.1 | 57.6 |
| | Key West | 30 | 65.2 | 65.7 | 68.8 | 72.1 | 75.9 | 78.7 | 79.6 | 79.2 | 78.5 | 75.7 | 71.9 | 67.3 | 73.2 |
| | Miami | 30 | 59.6 | 60.5 | 64.0 | 67.6 | 72.0 | 75.2 | 76.5 | 76.5 | 75.7 | 72.2 | 67.5 | 62.2 | 69.1 |
| | Orlando | 30 | 49.9 | 51.3 | 55.9 | 59.9 | 65.9 | 71.3 | 72.6 | 73.0 | 71.9 | 65.5 | 58.7 | 52.6 | 62.4 |
| | Pensacola | 30 | 42.7 | 45.4 | 51.7 | 57.6 | 65.8 | 72.1 | 74.5 | 74.2 | 70.4 | 59.6 | 51.1 | 44.7 | 59.2 |
| | Tallahassee | 30 | 39.7 | 42.1 | 48.2 | 52.8 | 62.3 | 69.8 | 72.7 | 72.7 | 69.2 | 56.9 | 47.9 | 41.6 | 56.3 |
| | Tampa | 30 | 52.4 | 53.8 | 58.5 | 62.4 | 68.9 | 74.0 | 75.3 | 75.4 | 74.3 | 67.6 | 60.7 | 54.7 | 64.8 |
| | Vero Beach | 30 | 52.7 | 53.6 | 57.8 | 61.6 | 67.2 | 71.8 | 73.0 | 72.9 | 72.7 | 68.5 | 61.9 | 54.7 | 64.0 |
| | West Palm Beach | 30 | 57.3 | 58.2 | 61.9 | 65.4 | 70.5 | 73.8 | 75.0 | 75.4 | 74.7 | 71.2 | 65.8 | 60.1 | 67.4 |
| GA | Athens | 30 | 32.9 | 35.4 | 42.3 | 48.7 | 57.6 | 65.3 | 69.3 | 68.5 | 62.7 | 50.7 | 42.2 | 35.3 | 50.9 |
| | Atlanta | 30 | 33.5 | 36.5 | 43.6 | 50.4 | 59.5 | 67.1 | 70.6 | 69.9 | 64.3 | 52.8 | 43.5 | 36.2 | 52.3 |
| | Augusta | 30 | 33.1 | 35.5 | 42.5 | 48.1 | 57.2 | 65.4 | 69.6 | 68.4 | 62.4 | 49.6 | 40.9 | 34.7 | 50.6 |
| | Columbus | 30 | 36.6 | 39.0 | 45.7 | 51.8 | 61.3 | 68.8 | 72.3 | 71.5 | 66.4 | 54.5 | 45.7 | 39.0 | 54.4 |
| | Macon | 30 | 34.5 | 37.0 | 43.8 | 49.5 | 58.6 | 66.6 | 70.5 | 69.5 | 63.7 | 51.1 | 42.5 | 36.3 | 52.0 |
| | Savannah | 30 | 38.0 | 40.9 | 47.5 | 52.9 | 61.3 | 68.1 | 71.8 | 71.3 | 67.3 | 56.1 | 46.9 | 40.1 | 55.2 |
| HI | Hilo | 30 | 63.6 | 63.5 | 64.7 | 65.6 | 66.7 | 68.0 | 69.2 | 69.4 | 69.0 | 68.5 | 67.2 | 64.9 | 66.7 |
| | Honolulu | 30 | 65.7 | 65.4 | 66.9 | 68.2 | 69.6 | 72.1 | 73.8 | 74.7 | 74.2 | 73.2 | 71.1 | 67.8 | 70.2 |
| | Kahului | 30 | 63.3 | 63.1 | 64.6 | 66.0 | 67.0 | 69.3 | 70.8 | 71.0 | 70.0 | 69.4 | 67.9 | 65.1 | 67.3 |
| | Lihue | 30 | 65.4 | 65.5 | 67.3 | 68.9 | 70.3 | 72.7 | 74.0 | 74.5 | 74.0 | 72.8 | 70.8 | 67.6 | 70.3 |
| ID | Boise | 30 | 23.6 | 28.8 | 34.0 | 39.4 | 46.6 | 54.2 | 60.3 | 59.8 | 51.2 | 41.3 | 32.4 | 24.1 | 41.3 |
| | Lewiston | 30 | 28.0 | 31.2 | 35.6 | 40.6 | 47.0 | 53.6 | 59.3 | 59.3 | 50.9 | 41.2 | 34.1 | 28.5 | 42.5 |
| | Pocatello | 30 | 16.3 | 20.9 | 27.3 | 32.6 | 39.2 | 45.7 | 50.9 | 49.9 | 41.8 | 33.3 | 24.9 | 16.8 | 33.3 |
| IL | Chicago | 30 | 14.3 | 19.2 | 28.5 | 37.6 | 47.5 | 57.2 | 63.2 | 62.2 | 53.7 | 42.1 | 31.6 | 20.4 | 39.8 |
| | Moline | 30 | 12.3 | 18.2 | 29.0 | 39.3 | 50.0 | 59.7 | 64.5 | 62.4 | 53.4 | 41.6 | 30.1 | 18.3 | 39.9 |
| | Peoria | 30 | 14.3 | 19.7 | 30.2 | 40.3 | 50.8 | 60.1 | 64.6 | 62.6 | 54.0 | 42.3 | 31.4 | 20.1 | 40.9 |
| | Rockford | 30 | 10.8 | 16.3 | 26.7 | 36.8 | 47.9 | 57.6 | 62.6 | 60.9 | 51.8 | 40.1 | 29.0 | 16.9 | 38.1 |
| | Springfield | 30 | 17.1 | 22.2 | 32.4 | 42.2 | 52.7 | 61.9 | 66.0 | 63.9 | 55.4 | 44.4 | 33.7 | 22.6 | 42.9 |

*(Continued)*



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**Table 3A.2 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN | Evansville | 30 | 22.6 | 26.2 | 35.2 | 43.8 | 54.0 | 63.5 | 67.8 | 65.1 | 57.0 | 44.6 | 36.0 | 27.0 | 45.2 |
| | Fort Wayne | 30 | 16.1 | 19.2 | 28.8 | 38.2 | 49.1 | 58.8 | 62.5 | 60.4 | 52.8 | 41.8 | 32.7 | 22.3 | 40.2 |
| | Indianapolis | 30 | 18.5 | 22.5 | 32.0 | 41.2 | 51.8 | 61.3 | 65.2 | 63.3 | 55.2 | 43.6 | 34.1 | 24.0 | 42.7 |
| | South Bend | 30 | 15.7 | 19.0 | 28.2 | 37.7 | 48.4 | 58.3 | 62.8 | 61.3 | 53.3 | 42.3 | 32.6 | 21.7 | 40.1 |
| IA | Des Moines | 30 | 11.7 | 17.8 | 28.7 | 39.9 | 51.4 | 61.0 | 66.1 | 63.9 | 54.3 | 42.2 | 29.0 | 16.7 | 40.2 |
| | Dubuque | 30 | 9.2 | 15.4 | 26.2 | 37.5 | 48.8 | 57.9 | 62.4 | 60.2 | 51.7 | 40.5 | 27.8 | 15.2 | 37.7 |
| | Sioux City | 30 | 8.5 | 15.3 | 25.7 | 37.3 | 49.2 | 58.5 | 62.9 | 60.6 | 50.1 | 38.0 | 24.8 | 12.8 | 37.0 |
| | Waterloo | 30 | 6.3 | 13.2 | 24.9 | 35.8 | 48.1 | 58.1 | 62.2 | 59.5 | 49.8 | 37.8 | 25.1 | 12.5 | 36.1 |
| KS | Concordia | 30 | 16.9 | 21.9 | 31.1 | 41.2 | 51.9 | 61.8 | 67.4 | 65.6 | 56.1 | 44.0 | 30.5 | 20.8 | 42.4 |
| | Dodge City | 30 | 18.7 | 23.6 | 31.2 | 40.7 | 51.7 | 61.6 | 66.8 | 65.6 | 56.5 | 43.8 | 30.2 | 21.7 | 42.7 |
| | Goodland | 30 | 15.8 | 19.7 | 26.4 | 34.8 | 45.7 | 55.5 | 61.1 | 59.6 | 50.0 | 37.5 | 25.2 | 17.8 | 37.4 |
| | Topeka | 30 | 17.2 | 23.0 | 32.9 | 42.9 | 53.4 | 63.2 | 67.7 | 65.4 | 55.9 | 44.3 | 32.1 | 21.8 | 43.3 |
| | Wichita | 30 | 20.3 | 25.3 | 34.4 | 43.7 | 54.0 | 63.9 | 69.1 | 67.9 | 59.3 | 46.9 | 33.9 | 24.0 | 45.2 |
| KY | Greater Cincinnati AP | 30 | 21.3 | 25.0 | 33.8 | 42.7 | 52.9 | 61.6 | 66.1 | 64.2 | 56.8 | 44.9 | 35.7 | 26.4 | 44.3 |
| | Jackson | 30 | 25.7 | 28.9 | 37.4 | 45.8 | 54.3 | 61.9 | 65.7 | 64.3 | 58.4 | 47.4 | 38.9 | 30.2 | 46.6 |
| | Lexington | 30 | 24.1 | 27.7 | 35.9 | 44.1 | 53.6 | 62.2 | 66.4 | 64.9 | 57.9 | 46.4 | 37.3 | 28.4 | 45.7 |
| | Louisville | 30 | 24.9 | 28.5 | 37.1 | 46.0 | 56.1 | 65.1 | 69.8 | 68.2 | 60.9 | 48.5 | 39.3 | 29.9 | 47.9 |
| | Paducah | 30 | 23.9 | 28.2 | 37.1 | 45.6 | 55.0 | 63.8 | 67.7 | 64.9 | 57.1 | 45.2 | 36.5 | 27.5 | 46.1 |
| LA | Baton Rouge | 30 | 40.2 | 43.1 | 49.6 | 55.8 | 64.1 | 70.2 | 72.7 | 71.9 | 67.5 | 56.4 | 47.9 | 42.1 | 56.8 |
| | Lake Charles | 30 | 41.2 | 44.3 | 50.8 | 57.2 | 65.7 | 72.1 | 74.3 | 73.6 | 69.1 | 58.6 | 49.7 | 43.3 | 58.3 |
| | New Orleans | 30 | 43.4 | 46.1 | 52.7 | 58.4 | 66.4 | 72.0 | 74.2 | 73.9 | 70.6 | 60.2 | 51.8 | 45.6 | 59.6 |
| | Shreveport | 30 | 36.5 | 40.3 | 47.2 | 53.8 | 62.7 | 69.9 | 73.4 | 72.3 | 66.4 | 55.0 | 45.3 | 38.3 | 55.1 |
| ME | Caribou | 30 | −0.3 | 2.9 | 15.2 | 29.2 | 40.7 | 49.9 | 54.8 | 52.6 | 43.6 | 34.1 | 23.7 | 8.0 | 29.6 |
| | Portland | 30 | 12.5 | 15.6 | 25.2 | 34.7 | 44.2 | 52.9 | 58.6 | 57.2 | 48.5 | 37.4 | 29.5 | 18.7 | 36.3 |
| MD | Baltimore | 30 | 23.5 | 26.1 | 33.6 | 42.0 | 51.8 | 60.8 | 65.8 | 63.9 | 56.6 | 43.7 | 34.7 | 27.3 | 44.2 |
| MA | Blue Hill | 30 | 18.1 | 20.3 | 27.8 | 37.1 | 47.0 | 55.9 | 62.0 | 60.9 | 53.2 | 42.9 | 34.2 | 23.8 | 40.3 |
| | Boston | 30 | 22.1 | 24.2 | 31.5 | 40.5 | 50.2 | 59.4 | 65.5 | 64.5 | 56.8 | 46.4 | 37.9 | 27.8 | 43.9 |
| | Worcester | 30 | 15.8 | 17.8 | 25.6 | 35.5 | 46.2 | 55.0 | 60.8 | 59.5 | 51.3 | 40.7 | 32.0 | 21.6 | 38.5 |
| MI | Alpena | 30 | 9.5 | 9.7 | 18.7 | 30.2 | 40.0 | 48.8 | 54.5 | 52.9 | 45.2 | 35.6 | 27.0 | 16.9 | 32.4 |
| | Detroit | 30 | 17.8 | 20.0 | 28.5 | 38.4 | 49.4 | 58.9 | 63.6 | 62.2 | 54.1 | 42.5 | 33.5 | 23.4 | 41.0 |
| | Flint | 30 | 13.3 | 15.3 | 24.3 | 34.6 | 45.2 | 54.6 | 59.1 | 57.4 | 49.4 | 38.6 | 29.8 | 19.1 | 36.7 |
| | Grand Rapids | 30 | 15.6 | 17.4 | 25.9 | 36.1 | 46.6 | 55.8 | 60.5 | 59.0 | 51.0 | 40.2 | 31.2 | 21.4 | 38.4 |
| | Houghton Lake | 30 | 9.7 | 10.5 | 19.2 | 30.6 | 40.7 | 48.9 | 53.4 | 52.2 | 45.3 | 36.2 | 27.6 | 16.8 | 32.6 |
| | Lansing | 30 | 13.9 | 15.4 | 24.3 | 34.5 | 44.8 | 54.3 | 58.4 | 57.0 | 48.9 | 38.6 | 30.1 | 19.7 | 36.7 |
| | Marquette | 30 | 3.3 | 5.4 | 14.3 | 26.9 | 39.1 | 48.3 | 53.5 | 52.0 | 43.8 | 34.0 | 22.4 | 10.2 | 29.4 |
| | Muskegon | 30 | 17.1 | 18.3 | 25.4 | 35.1 | 45.1 | 54.2 | 59.8 | 58.8 | 50.7 | 40.6 | 31.8 | 22.6 | 38.3 |
| | Sault Ste. Marie | 30 | 4.9 | 6.6 | 16.1 | 28.8 | 39.3 | 46.5 | 52.0 | 52.4 | 44.8 | 36.0 | 25.9 | 13.1 | 30.5 |
| MN | Duluth | 30 | −1.2 | 5.1 | 16.5 | 28.9 | 40.2 | 48.5 | 54.6 | 53.5 | 44.8 | 34.5 | 20.7 | 5.6 | 29.3 |
| | International Falls | 30 | −8.4 | −0.7 | 12.3 | 27.1 | 40.0 | 49.1 | 53.6 | 51.3 | 41.6 | 31.5 | 16.4 | −1.1 | 26.1 |
| | Minneapolis-St. Paul | 30 | 4.3 | 11.8 | 23.5 | 36.2 | 48.5 | 57.8 | 63.0 | 60.8 | 50.8 | 38.9 | 24.8 | 10.9 | 35.9 |
| | Rochester | 30 | 3.7 | 10.6 | 22.6 | 34.6 | 46.1 | 55.6 | 60.1 | 58.0 | 48.7 | 37.1 | 23.7 | 10.1 | 34.3 |
| | Saint Cloud | 30 | −1.2 | 6.4 | 19.1 | 32.2 | 44.1 | 52.9 | 57.9 | 55.5 | 45.7 | 34.3 | 20.4 | 5.5 | 31.1 |
| MS | Jackson | 30 | 35.0 | 38.2 | 45.4 | 51.7 | 61.0 | 68.1 | 71.4 | 70.3 | 64.6 | 52.0 | 43.4 | 37.3 | 53.2 |
| | Meridian | 30 | 34.7 | 37.7 | 44.3 | 50.4 | 59.5 | 66.8 | 70.5 | 69.8 | 64.2 | 51.3 | 42.8 | 37.2 | 52.4 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tupelo | 30 | 30.5 | 33.5 | 41.4 | 48.2 | 57.7 | 65.7 | 69.8 | 68.2 | 61.7 | 48.8 | 40.0 | 33.2 | 49.9 |
| MO | Columbia | 30 | 18.2 | 23.4 | 33.0 | 42.9 | 52.8 | 61.8 | 66.3 | 64.0 | 55.4 | 44.1 | 33.0 | 22.5 | 43.1 |
| | Kansas City | 30 | 17.8 | 23.3 | 33.2 | 43.5 | 53.9 | 63.2 | 68.2 | 66.1 | 57.2 | 45.9 | 33.4 | 22.5 | 44.0 |
| | St. Louis | 30 | 21.2 | 26.5 | 36.2 | 46.5 | 56.6 | 65.9 | 70.6 | 68.6 | 60.3 | 48.2 | 36.7 | 25.8 | 46.9 |
| | Springfield | 30 | 21.8 | 26.4 | 34.9 | 43.6 | 53.4 | 62.2 | 67.1 | 65.6 | 57.4 | 46.1 | 35.3 | 25.9 | 45.0 |
| MT | Billings | 30 | 15.1 | 20.1 | 26.4 | 34.7 | 44.0 | 52.5 | 58.3 | 57.3 | 47.1 | 37.2 | 25.6 | 17.7 | 36.3 |
| | Glasgow | 30 | 1.8 | 9.9 | 20.6 | 32.2 | 43.0 | 51.6 | 56.6 | 55.7 | 44.1 | 33.0 | 18.5 | 6.4 | 31.1 |
| | Great Falls | 30 | 11.3 | 15.1 | 21.5 | 29.7 | 38.3 | 46.0 | 50.4 | 49.9 | 41.2 | 33.0 | 22.5 | 14.4 | 31.1 |
| | Havre | 30 | 3.7 | 10.4 | 20.0 | 30.0 | 40.2 | 48.0 | 52.0 | 51.3 | 40.7 | 29.8 | 17.3 | 7.8 | 29.3 |
| | Helena | 30 | 9.9 | 15.6 | 23.5 | 31.2 | 39.8 | 47.5 | 52.3 | 50.8 | 41.2 | 31.2 | 20.3 | 11.3 | 31.2 |
| | Kalispell | 30 | 13.8 | 18.4 | 24.8 | 30.8 | 37.9 | 43.5 | 46.7 | 45.8 | 37.1 | 28.4 | 23.2 | 16.1 | 30.5 |
| | Missoula | 30 | 16.2 | 20.5 | 27.1 | 32.4 | 39.3 | 45.9 | 50.2 | 49.3 | 40.6 | 31.4 | 24.0 | 16.5 | 32.8 |
| NE | Grand Island | 30 | 12.2 | 17.7 | 27.0 | 37.8 | 49.3 | 59.1 | 64.4 | 62.3 | 51.8 | 39.3 | 25.9 | 15.9 | 38.6 |
| | Lincoln | 30 | 11.5 | 17.2 | 27.5 | 38.8 | 50.1 | 60.4 | 65.9 | 63.7 | 53.2 | 40.4 | 27.0 | 16.2 | 39.3 |
| | Norfolk | 30 | 9.6 | 15.5 | 25.4 | 36.8 | 48.3 | 58.0 | 63.0 | 61.0 | 50.4 | 38.0 | 24.7 | 13.7 | 37.1 |
| | North Platte | 30 | 9.9 | 15.4 | 23.8 | 33.4 | 44.5 | 54.2 | 60.2 | 58.4 | 46.7 | 33.7 | 20.7 | 12.1 | 34.4 |
| | Omaha Eppley AP | 30 | 11.6 | 18.0 | 28.1 | 39.6 | 50.7 | 60.6 | 65.9 | 63.8 | 53.5 | 41.1 | 28.1 | 16.4 | 39.8 |
| | Omaha (North) | 30 | 12.6 | 19.0 | 28.8 | 40.3 | 51.3 | 60.5 | 65.5 | 64.1 | 55.0 | 43.1 | 29.2 | 17.2 | 40.6 |
| | Scottsbluff | 30 | 11.0 | 15.8 | 23.0 | 31.4 | 42.4 | 52.1 | 57.4 | 54.9 | 43.7 | 31.3 | 19.7 | 11.6 | 32.9 |
| | Valentine | 30 | 7.8 | 13.7 | 22.1 | 32.4 | 43.7 | 53.2 | 59.1 | 57.3 | 45.8 | 33.1 | 20.1 | 10.5 | 33.2 |
| NV | Elko | 30 | 14.1 | 19.7 | 25.9 | 29.9 | 36.8 | 43.5 | 48.6 | 47.0 | 38.1 | 28.3 | 20.9 | 13.8 | 30.6 |
| | Ely | 30 | 10.4 | 15.6 | 21.9 | 26.4 | 33.4 | 40.6 | 47.4 | 46.4 | 37.5 | 27.8 | 18.2 | 10.6 | 28.0 |
| | Las Vegas | 30 | 36.8 | 41.4 | 47.0 | 53.9 | 62.9 | 72.3 | 78.2 | 76.7 | 68.8 | 56.5 | 44.0 | 36.6 | 56.3 |
| | Reno | 30 | 21.8 | 25.4 | 29.3 | 33.2 | 40.2 | 46.5 | 51.4 | 49.9 | 43.1 | 34.0 | 26.4 | 20.7 | 35.2 |
| | Winnemucca | 30 | 18.5 | 23.6 | 27.0 | 30.7 | 38.4 | 45.8 | 51.8 | 49.2 | 40.2 | 30.2 | 23.3 | 17.0 | 33.0 |
| NH | Concord | 30 | 9.7 | 12.6 | 22.7 | 32.2 | 42.4 | 51.8 | 57.1 | 55.6 | 46.6 | 35.1 | 27.6 | 16.2 | 34.1 |
| | Mt. Washington | 30 | −3.7 | −1.7 | 5.9 | 16.4 | 29.5 | 38.5 | 43.3 | 42.1 | 34.6 | 24.0 | 13.6 | 1.7 | 20.4 |
| NJ | Atlantic City AP | 30 | 22.8 | 24.5 | 31.7 | 39.8 | 49.8 | 59.3 | 65.4 | 63.7 | 56.0 | 43.9 | 35.7 | 27.1 | 43.3 |
| | Atlantic City CO | 30 | 29.0 | 30.6 | 37.0 | 45.2 | 54.8 | 63.9 | 69.8 | 69.7 | 63.6 | 52.5 | 42.9 | 34.0 | 49.4 |
| | Newark | 30 | 24.4 | 26.6 | 34.2 | 43.7 | 54.1 | 63.5 | 69.1 | 67.7 | 59.9 | 48.2 | 39.1 | 29.8 | 46.7 |
| NM | Albuquerque | 30 | 23.8 | 28.2 | 33.7 | 40.5 | 49.7 | 59.4 | 64.7 | 63.2 | 56.0 | 43.8 | 31.6 | 24.2 | 43.2 |
| | Clayton | 30 | 20.3 | 23.7 | 29.2 | 37.2 | 46.7 | 55.9 | 60.2 | 59.2 | 51.5 | 40.6 | 28.7 | 21.6 | 39.6 |
| | Roswell | 30 | 24.4 | 29.3 | 35.7 | 43.3 | 53.2 | 62.0 | 66.7 | 65.5 | 58.3 | 46.3 | 33.3 | 25.1 | 45.3 |
| NY | Albany | 30 | 13.3 | 15.7 | 25.4 | 35.9 | 46.5 | 55.0 | 60.0 | 58.3 | 49.9 | 38.8 | 30.8 | 20.1 | 37.5 |
| | Binghamton | 30 | 15.0 | 16.7 | 24.7 | 35.1 | 46.2 | 54.4 | 59.2 | 57.4 | 49.9 | 39.6 | 30.9 | 20.8 | 37.5 |
| | Buffalo | 30 | 17.8 | 18.6 | 26.1 | 36.4 | 47.7 | 56.9 | 62.1 | 60.5 | 52.9 | 42.6 | 33.7 | 23.6 | 39.9 |
| | Islip | 30 | 22.6 | 24.3 | 31.1 | 40.0 | 49.4 | 59.6 | 65.9 | 64.5 | 56.6 | 44.6 | 36.1 | 27.5 | 43.5 |
| | New York C.Park | 30 | 26.2 | 28.1 | 35.1 | 44.2 | 54.2 | 63.3 | 68.8 | 67.7 | 60.3 | 49.6 | 41.0 | 31.6 | 47.5 |
| | New York (JFK AP) | 30 | 24.7 | 26.1 | 32.9 | 41.6 | 51.2 | 60.4 | 66.7 | 66.3 | 59.5 | 48.7 | 39.8 | 30.5 | 45.7 |
| | New York (Laguardia AP) | 30 | 26.5 | 28.3 | 35.1 | 44.4 | 54.3 | 63.7 | 69.5 | 68.7 | 61.6 | 50.9 | 41.6 | 32.0 | 48.1 |
| | Rochester | 30 | 16.6 | 17.3 | 25.2 | 35.3 | 46.1 | 55.0 | 60.0 | 58.7 | 51.3 | 41.1 | 32.6 | 22.7 | 38.5 |
| | Syracuse | 30 | 14.0 | 15.5 | 24.2 | 34.9 | 45.8 | 54.6 | 60.1 | 58.8 | 51.1 | 40.4 | 32.0 | 20.9 | 37.7 |
| NC | Asheville | 30 | 25.8 | 28.0 | 34.9 | 41.8 | 50.6 | 58.3 | 62.7 | 61.8 | 55.4 | 43.3 | 35.3 | 28.8 | 43.9 |
| | Cape Hatteras | 30 | 38.6 | 39.0 | 44.5 | 51.8 | 60.2 | 68.1 | 72.9 | 72.3 | 68.5 | 58.8 | 50.3 | 42.6 | 55.6 |
| | Charlotte | 30 | 32.1 | 34.4 | 41.6 | 49.1 | 58.2 | 66.5 | 70.6 | 69.3 | 63.0 | 50.9 | 41.8 | 34.9 | 51.0 |

*(Continued)*



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**Table 3A.2 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Greensboro-Wnstn-Slm-HPT | 30 | 28.2 | 30.6 | 37.8 | 45.5 | 54.7 | 63.5 | 68.1 | 66.8 | 60.1 | 47.5 | 38.6 | 31.4 | 47.7 |
| | Raleigh | 30 | 29.6 | 31.9 | 38.9 | 46.4 | 55.3 | 63.8 | 68.5 | 67.2 | 61.0 | 48.2 | 39.5 | 32.6 | 48.6 |
| | Wilmington | 30 | 35.8 | 37.5 | 43.7 | 51.2 | 59.8 | 67.6 | 72.3 | 71.0 | 65.9 | 53.9 | 45.1 | 38.1 | 53.5 |
| ND | Bismarck | 30 | −0.6 | 7.8 | 19.1 | 30.6 | 42.8 | 51.6 | 56.4 | 54.7 | 43.7 | 32.1 | 17.8 | 4.8 | 30.1 |
| | Fargo | 30 | −2.3 | 5.4 | 19.0 | 32.4 | 45.3 | 54.5 | 59.0 | 57.0 | 46.1 | 34.4 | 18.7 | 4.2 | 31.1 |
| | Grand Forks | 30 | −4.3 | 3.7 | 17.1 | 31.0 | 43.5 | 52.8 | 56.8 | 54.5 | 44.3 | 33.0 | 17.4 | 2.5 | 29.4 |
| | Williston | 30 | −3.3 | 5.9 | 17.2 | 29.1 | 40.9 | 50.1 | 55.2 | 53.8 | 42.2 | 30.2 | 14.9 | 2.1 | 28.2 |
| OH | Akron | 30 | 17.4 | 19.8 | 27.9 | 37.1 | 47.8 | 56.8 | 61.3 | 60.2 | 53.1 | 42.1 | 33.4 | 23.6 | 40.0 |
| | Cleveland | 30 | 18.8 | 21.0 | 28.9 | 37.9 | 48.3 | 57.7 | 62.3 | 61.2 | 54.3 | 43.7 | 34.9 | 24.9 | 41.2 |
| | Columbus | 30 | 20.3 | 23.5 | 32.2 | 41.2 | 51.8 | 60.7 | 64.9 | 63.2 | 55.9 | 44.0 | 34.9 | 25.9 | 43.2 |
| | Dayton | 30 | 19.0 | 22.4 | 31.2 | 40.4 | 51.1 | 60.2 | 64.4 | 62.2 | 54.6 | 43.5 | 34.3 | 24.4 | 42.3 |
| | Mansfield | 30 | 16.2 | 18.7 | 26.8 | 36.1 | 46.7 | 55.8 | 60.3 | 58.9 | 52.1 | 41.3 | 32.2 | 22.0 | 38.9 |
| | Toledo | 30 | 16.4 | 18.9 | 27.9 | 37.7 | 48.6 | 58.2 | 62.6 | 60.7 | 52.9 | 41.6 | 32.6 | 22.3 | 40.0 |
| | Youngstown | 30 | 17.4 | 19.3 | 27.1 | 36.5 | 46.2 | 54.6 | 58.7 | 57.5 | 50.9 | 40.9 | 33.0 | 23.4 | 38.8 |
| OK | Oklahoma City | 30 | 26.2 | 31.1 | 39.4 | 48.1 | 57.9 | 66.4 | 70.8 | 69.8 | 62.2 | 50.6 | 38.2 | 29.2 | 49.2 |
| | Tulsa | 30 | 26.3 | 31.1 | 40.3 | 49.5 | 59.0 | 67.9 | 73.1 | 71.2 | 62.9 | 51.1 | 39.3 | 29.8 | 50.1 |
| OR | Astoria | 30 | 36.7 | 37.6 | 38.6 | 40.8 | 45.4 | 49.8 | 52.9 | 53.2 | 49.5 | 44.1 | 40.1 | 37.1 | 43.8 |
| | Burns | 30 | 14.0 | 19.4 | 24.9 | 28.6 | 35.6 | 41.1 | 46.4 | 43.9 | 35.0 | 26.4 | 20.6 | 14.6 | 29.2 |
| | Eugene | 30 | 33.0 | 34.9 | 36.7 | 38.9 | 42.7 | 47.0 | 50.8 | 50.8 | 46.7 | 40.5 | 37.2 | 33.3 | 41.0 |
| | Medford | 30 | 30.9 | 33.1 | 35.9 | 39.0 | 44.0 | 50.1 | 55.2 | 54.9 | 48.3 | 40.2 | 35.0 | 31.0 | 41.5 |
| | Pendleton | 30 | 27.4 | 30.9 | 35.4 | 39.7 | 45.9 | 52.0 | 57.5 | 57.3 | 49.7 | 40.7 | 33.8 | 27.7 | 41.5 |
| | Portland | 30 | 34.2 | 35.9 | 38.6 | 41.9 | 47.5 | 52.6 | 56.9 | 57.3 | 52.5 | 45.2 | 39.8 | 35.0 | 44.8 |
| | Salem | 30 | 33.5 | 34.7 | 36.6 | 38.8 | 43.6 | 48.4 | 52.0 | 52.1 | 47.7 | 41.3 | 37.9 | 33.9 | 41.7 |
| | Sexton Summit | 30 | 32.5 | 33.0 | 32.5 | 34.9 | 39.6 | 45.4 | 51.8 | 52.7 | 49.8 | 43.3 | 35.2 | 32.5 | 40.3 |
| PC | Guam | 30 | 71.2 | 71.1 | 71.7 | 72.7 | 73.2 | 73.5 | 72.8 | 72.8 | 72.8 | 72.7 | 73.6 | 73.1 | 72.6 |
| | Johnston Island | 30 | 73.1 | 73.2 | 73.4 | 74.2 | 75.2 | 76.6 | 77.4 | 78.0 | 77.9 | 77.5 | 75.7 | 73.9 | 75.5 |
| | Koror | 30 | 75.1 | 74.9 | 75.2 | 75.8 | 76.0 | 75.4 | 75.3 | 75.7 | 76.0 | 75.8 | 75.9 | 75.6 | 75.6 |
| | Kwajalein, Marshall IS | 30 | 77.5 | 77.5 | 77.9 | 77.8 | 78.0 | 77.8 | 77.6 | 77.6 | 77.5 | 77.8 | 77.7 | 77.9 | 77.7 |
| | Majuro, Marshall IS | 30 | 76.3 | 76.6 | 76.5 | 76.4 | 76.5 | 76.3 | 76.2 | 76.3 | 76.4 | 76.3 | 76.4 | 76.3 | 76.4 |
| | Pago Pago, Amer Samoa | 30 | 76.1 | 76.3 | 76.6 | 76.3 | 76.2 | 76.1 | 75.5 | 75.5 | 75.8 | 76.2 | 76.5 | 76.4 | 76.1 |
| | Pohnpei, Caroline IS | 30 | 74.8 | 75.1 | 75.2 | 74.7 | 74.6 | 74.2 | 73.2 | 72.8 | 72.6 | 72.6 | 73.3 | 74.5 | 74.0 |
| | Chuuk, E. Caroline IS | 30 | 75.9 | 76.2 | 76.4 | 76.4 | 76.1 | 76.0 | 75.0 | 74.3 | 74.7 | 74.5 | 75.8 | 75.3 | 75.6 |
| | Wake Island | 30 | 73.1 | 72.4 | 73.1 | 73.9 | 75.3 | 77.1 | 77.8 | 77.9 | 78.4 | 77.4 | 76.3 | 74.7 | 75.6 |
| | Yap, W Caroline IS | 30 | 73.7 | 73.8 | 74.0 | 74.6 | 74.9 | 74.3 | 74.0 | 73.7 | 73.7 | 73.8 | 74.0 | 74.2 | 74.1 |
| PA | Allentown | 30 | 19.1 | 21.0 | 28.9 | 37.8 | 48.3 | 57.7 | 62.6 | 60.7 | 52.7 | 41.1 | 32.7 | 24.0 | 40.6 |
| | Erie | 30 | 20.3 | 20.9 | 28.2 | 37.9 | 48.7 | 58.5 | 63.7 | 62.7 | 55.9 | 45.5 | 36.4 | 26.8 | 42.1 |
| | Harrisburg | 30 | 23.1 | 24.7 | 32.5 | 41.5 | 51.4 | 60.6 | 66.0 | 64.2 | 56.7 | 44.6 | 36.1 | 27.8 | 44.1 |
| | Middletown/ Harrisburg AP | 30 | 23.1 | 24.7 | 32.5 | 41.5 | 51.4 | 60.6 | 66.0 | 64.2 | 56.7 | 44.6 | 36.1 | 27.8 | 44.1 |
| | Philadelphia | 30 | 25.5 | 27.5 | 35.1 | 44.2 | 54.8 | 64.0 | 69.7 | 68.5 | 60.9 | 48.7 | 39.5 | 30.6 | 47.4 |
| | Pittsburgh | 30 | 19.9 | 22.3 | 30.1 | 39.1 | 49.2 | 57.7 | 62.4 | 61.0 | 53.9 | 42.5 | 34.2 | 25.3 | 41.5 |
| | Avoca | 30 | 18.5 | 20.4 | 28.4 | 38.1 | 48.4 | 56.7 | 61.5 | 60.1 | 52.6 | 41.7 | 33.7 | 24.2 | 40.4 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Williamsport | 30 | 17.9 | 19.9 | 28.2 | 37.8 | 47.8 | 56.8 | 61.7 | 60.4 | 52.8 | 40.9 | 32.7 | 23.7 | 40.1 |
| RI | Providence | 30 | 20.3 | 22.5 | 30.0 | 39.1 | 48.8 | 57.9 | 64.1 | 62.8 | 54.5 | 43.1 | 35.1 | 25.6 | 42.0 |
| SC | Charleston AP | 30 | 36.9 | 39.1 | 46.0 | 52.2 | 61.3 | 68.5 | 72.5 | 71.6 | 67.1 | 55.3 | 46.4 | 39.3 | 54.7 |
| | Charleston CO | 30 | 42.4 | 44.9 | 51.5 | 58.8 | 67.4 | 73.8 | 77.0 | 76.1 | 72.2 | 61.9 | 53.4 | 45.5 | 60.4 |
| | Columbia | 30 | 34.0 | 36.3 | 43.5 | 50.7 | 60.0 | 67.9 | 71.8 | 70.6 | 64.6 | 51.5 | 42.6 | 36.1 | 52.5 |
| | Greenville-Spartanburg AP | 30 | 31.4 | 33.9 | 40.5 | 47.0 | 56.2 | 64.3 | 68.7 | 67.9 | 61.7 | 49.7 | 41.0 | 34.3 | 49.7 |
| SD | Aberdeen | 30 | 0.6 | 8.8 | 21.2 | 33.4 | 45.6 | 54.8 | 59.7 | 57.4 | 46.5 | 34.4 | 19.7 | 6.3 | 32.4 |
| | Huron | 30 | 3.5 | 10.8 | 22.3 | 33.9 | 45.8 | 55.4 | 60.7 | 58.6 | 47.3 | 34.9 | 21.1 | 8.4 | 33.6 |
| | Rapid City | 30 | 11.3 | 15.9 | 23.2 | 32.3 | 42.7 | 51.8 | 57.9 | 56.6 | 46.0 | 34.7 | 22.1 | 13.3 | 34.0 |
| | Sioux Falls | 30 | 2.9 | 10.1 | 21.3 | 32.5 | 44.6 | 54.5 | 60.3 | 58.4 | 47.6 | 34.8 | 20.7 | 7.8 | 33.0 |
| TN | Bristol-JhnCty-Kgsprt | 30 | 24.3 | 27.0 | 34.6 | 42.0 | 51.0 | 59.5 | 63.5 | 61.7 | 54.7 | 41.8 | 33.6 | 26.8 | 43.4 |
| | Chattanooga | 30 | 29.9 | 32.6 | 40.0 | 47.0 | 56.2 | 64.6 | 69.4 | 68.3 | 61.7 | 48.5 | 39.5 | 32.7 | 49.2 |
| | Knoxville | 30 | 28.9 | 31.8 | 39.1 | 46.6 | 55.6 | 63.9 | 68.5 | 67.3 | 60.8 | 47.7 | 38.9 | 31.9 | 48.4 |
| | Memphis | 30 | 31.3 | 35.5 | 43.7 | 51.9 | 60.8 | 68.8 | 72.9 | 71.2 | 64.3 | 52.5 | 42.6 | 34.5 | 52.5 |
| | Nashville | 30 | 27.9 | 31.2 | 39.4 | 47.1 | 56.7 | 65.0 | 69.5 | 68.0 | 61.0 | 48.6 | 39.5 | 31.5 | 48.8 |
| | Oak Ridge | 30 | 27.2 | 29.5 | 36.6 | 43.8 | 53.4 | 61.7 | 66.4 | 65.2 | 58.8 | 45.7 | 36.4 | 29.8 | 46.2 |
| TX | Abilene | 30 | 31.8 | 36.5 | 43.8 | 51.8 | 61.0 | 68.5 | 72.3 | 71.4 | 64.4 | 54.4 | 42.3 | 33.9 | 52.7 |
| | Amarillo | 30 | 22.6 | 27.0 | 33.6 | 41.7 | 51.7 | 61.1 | 65.3 | 63.8 | 56.3 | 44.6 | 31.8 | 24.1 | 43.6 |
| | Austin/City | 30 | 40.0 | 44.0 | 50.9 | 57.6 | 65.4 | 71.1 | 73.4 | 73.3 | 68.8 | 59.8 | 49.3 | 41.9 | 58.0 |
| | Austin/Bergstrom | 30 | 37.3 | 41.0 | 48.4 | 56.3 | 65.1 | 70.2 | 71.5 | 70.3 | 65.3 | 56.3 | 45.9 | 38.2 | 55.5 |
| | Brownsville | 30 | 50.5 | 53.3 | 59.5 | 65.2 | 71.6 | 74.9 | 75.4 | 75.3 | 72.6 | 65.9 | 58.6 | 52.0 | 64.6 |
| | Corpus Christi | 30 | 46.2 | 49.3 | 56.2 | 62.3 | 69.5 | 73.5 | 74.4 | 74.5 | 71.6 | 64.0 | 55.4 | 48.1 | 62.1 |
| | Dallas-Fort Worth | 30 | 34.0 | 38.7 | 46.4 | 54.0 | 63.0 | 70.7 | 74.6 | 74.0 | 67.2 | 56.4 | 45.1 | 36.8 | 55.1 |
| | Dallas-Love Field | 30 | 36.4 | 41.0 | 48.5 | 56.1 | 64.9 | 72.7 | 76.8 | 76.4 | 69.2 | 58.2 | 46.8 | 38.6 | 57.1 |
| | Del Rio | 30 | 39.7 | 44.1 | 51.6 | 58.5 | 66.7 | 72.1 | 74.3 | 74.1 | 69.4 | 60.5 | 49.2 | 41.2 | 58.5 |
| | El Paso | 30 | 32.9 | 37.5 | 43.7 | 51.1 | 60.6 | 68.8 | 72.0 | 70.2 | 63.7 | 51.8 | 39.8 | 33.4 | 52.1 |
| | Galveston | 30 | 49.7 | 51.5 | 58.2 | 64.7 | 72.3 | 77.8 | 79.8 | 79.5 | 75.6 | 68.4 | 59.4 | 51.8 | 65.7 |
| | Houston | 30 | 41.2 | 44.3 | 51.3 | 57.9 | 66.1 | 71.8 | 73.5 | 73.0 | 68.4 | 58.8 | 49.8 | 42.8 | 58.2 |
| | Lubbock | 30 | 24.4 | 28.9 | 36.2 | 45.4 | 55.6 | 64.1 | 67.7 | 66.0 | 58.4 | 47.0 | 34.5 | 26.1 | 46.2 |
| | Midland-Odessa | 30 | 29.6 | 34.1 | 40.8 | 48.6 | 58.8 | 66.4 | 69.1 | 67.9 | 61.6 | 51.3 | 38.8 | 31.2 | 49.9 |
| | Port Arthur | 30 | 42.9 | 45.9 | 52.4 | 58.6 | 66.4 | 72.3 | 73.8 | 73.2 | 69.4 | 59.6 | 50.8 | 44.5 | 59.2 |
| | San Angelo | 30 | 31.8 | 36.0 | 43.3 | 51.0 | 60.6 | 67.6 | 70.4 | 69.4 | 63.0 | 53.0 | 41.4 | 33.5 | 51.8 |
| | San Antonio | 30 | 38.6 | 42.4 | 49.9 | 56.9 | 65.5 | 71.6 | 74.0 | 73.6 | 68.8 | 59.4 | 48.6 | 40.8 | 57.5 |
| | Victoria | 30 | 43.6 | 46.7 | 53.9 | 60.1 | 68.1 | 73.3 | 75.0 | 74.6 | 70.3 | 61.6 | 52.3 | 45.2 | 60.4 |
| | Waco | 30 | 35.1 | 39.3 | 46.8 | 54.2 | 63.3 | 70.6 | 74.1 | 73.5 | 67.0 | 56.7 | 45.8 | 37.5 | 55.3 |
| | Wichita Falls | 30 | 28.9 | 33.4 | 41.1 | 49.3 | 59.3 | 67.8 | 72.4 | 71.3 | 63.7 | 52.4 | 40.1 | 31.3 | 50.9 |
| UT | Milford | 30 | 15.5 | 20.2 | 26.4 | 31.6 | 38.9 | 47.1 | 55.4 | 54.5 | 44.9 | 33.1 | 23.0 | 15.0 | 33.8 |
| | Salt Lake City | 30 | 21.3 | 25.5 | 33.4 | 39.0 | 46.9 | 55.8 | 63.4 | 62.4 | 52.4 | 41.0 | 30.4 | 22.4 | 41.2 |
| VT | Burlington | 30 | 9.3 | 10.9 | 21.8 | 33.6 | 45.2 | 54.7 | 59.8 | 58.1 | 49.9 | 38.9 | 30.3 | 17.3 | 35.8 |
| VA | Lynchburg | 30 | 24.5 | 26.9 | 34.4 | 42.6 | 51.2 | 59.5 | 63.7 | 62.4 | 55.9 | 43.7 | 35.2 | 27.9 | 44.0 |
| | Norfolk | 30 | 32.3 | 33.6 | 40.1 | 47.8 | 57.6 | 66.2 | 71.4 | 70.1 | 64.8 | 52.8 | 43.7 | 36.1 | 51.4 |
| | Richmond | 30 | 27.6 | 29.7 | 37.0 | 45.3 | 54.6 | 63.3 | 68.3 | 66.8 | 59.9 | 47.2 | 38.4 | 31.1 | 47.4 |
| | Roanoke | 30 | 26.6 | 29.0 | 36.5 | 44.2 | 52.3 | 60.4 | 64.9 | 63.4 | 56.6 | 44.6 | 36.6 | 29.6 | 45.4 |

*(Continued)*



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**Table 3A.2 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WA | Olympia | 30 | 31.8 | 32.6 | 34.1 | 36.5 | 42.0 | 46.4 | 49.6 | 49.5 | 44.9 | 38.9 | 35.3 | 32.1 | 39.5 |
| | Quillayute | 30 | 34.6 | 35.1 | 35.7 | 37.6 | 41.9 | 46.0 | 49.0 | 49.2 | 45.7 | 40.9 | 37.5 | 34.6 | 40.7 |
| | Seattle CO | 30 | 36.0 | 37.1 | 39.2 | 42.5 | 48.2 | 52.7 | 56.4 | 57.1 | 52.6 | 46.4 | 40.4 | 36.1 | 45.4 |
| | Seattle Sea-Tac AP | 30 | 35.9 | 37.2 | 39.1 | 42.1 | 47.2 | 51.7 | 55.3 | 55.7 | 51.9 | 45.7 | 39.9 | 35.9 | 44.8 |
| | Spokane | 30 | 21.7 | 25.7 | 30.4 | 35.5 | 42.6 | 49.2 | 54.6 | 54.5 | 45.9 | 35.8 | 28.7 | 21.6 | 37.2 |
| | Walla Walla | 30 | 28.8 | 32.5 | 36.9 | 41.3 | 47.6 | 54.3 | 60.7 | 61.2 | 52.9 | 43.6 | 36.0 | 29.3 | 43.8 |
| | Yakima | 30 | 20.5 | 24.7 | 28.9 | 33.2 | 40.0 | 46.2 | 50.9 | 50.1 | 42.3 | 32.9 | 26.3 | 20.5 | 34.7 |
| PR | San Juan | 30 | 70.8 | 70.9 | 71.7 | 73.2 | 74.9 | 76.6 | 76.9 | 77.0 | 76.5 | 75.6 | 74.0 | 72.1 | 74.2 |
| WV | Beckley | 30 | 22.1 | 24.9 | 32.4 | 40.6 | 49.2 | 57.0 | 61.1 | 59.8 | 53.5 | 42.4 | 34.4 | 26.5 | 42.0 |
| | Charleston | 30 | 24.2 | 26.7 | 34.0 | 41.8 | 50.3 | 58.3 | 62.9 | 61.7 | 55.0 | 43.1 | 35.3 | 28.2 | 43.5 |
| | Elkins | 30 | 18.0 | 19.7 | 26.9 | 34.6 | 44.1 | 52.7 | 57.6 | 56.7 | 50.1 | 37.0 | 29.3 | 21.9 | 37.4 |
| | Huntington | 30 | 24.5 | 27.5 | 35.5 | 43.7 | 52.6 | 60.9 | 65.4 | 64.1 | 56.8 | 44.8 | 36.6 | 28.9 | 45.1 |
| WI | Green Bay | 30 | 7.1 | 12.1 | 22.6 | 33.9 | 44.7 | 54.0 | 58.6 | 56.5 | 47.5 | 36.9 | 25.6 | 13.3 | 34.4 |
| | La Crosse | 30 | 6.3 | 12.8 | 24.5 | 37.1 | 48.7 | 57.9 | 62.8 | 60.7 | 51.7 | 40.1 | 27.4 | 13.6 | 37.0 |
| | Madison | 30 | 9.3 | 14.3 | 24.6 | 35.2 | 46.0 | 55.7 | 61.0 | 58.7 | 49.9 | 38.9 | 27.7 | 15.8 | 36.4 |
| | Milwaukee | 30 | 13.4 | 18.3 | 27.3 | 36.4 | 46.2 | 56.3 | 62.9 | 62.1 | 54.1 | 42.6 | 31.0 | 19.4 | 39.2 |
| WY | Casper | 30 | 12.2 | 16.4 | 23.1 | 29.3 | 37.9 | 46.6 | 53.2 | 51.8 | 41.7 | 31.8 | 21.3 | 14.0 | 31.6 |
| | Cheyenne | 30 | 14.8 | 17.2 | 22.0 | 28.7 | 38.3 | 47.5 | 53.4 | 52.0 | 42.9 | 32.5 | 22.1 | 16.1 | 32.3 |
| | Lander | 30 | 8.7 | 13.9 | 23.5 | 31.3 | 40.3 | 48.9 | 55.4 | 54.1 | 44.4 | 33.2 | 18.9 | 9.9 | 31.9 |
| | Sheridan | 30 | 9.7 | 14.9 | 22.5 | 30.4 | 38.6 | 46.8 | 52.4 | 51.5 | 41.0 | 30.3 | 18.5 | 10.4 | 30.6 |

*Note:* In Fahrenheit degrees, based on 30-year average values 1971–2000.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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**Table 3A.3 Normal Daily Maximun Temperature — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham AP | 30 | 52.8 | 58.3 | 66.5 | 74.1 | 81.0 | 87.5 | 90.6 | 90.2 | 84.6 | 74.9 | 64.5 | 56.0 | 73.4 |
| | Huntsville | 30 | 48.9 | 54.6 | 63.4 | 72.3 | 79.6 | 86.5 | 89.4 | 89.0 | 83.0 | 72.9 | 61.6 | 52.4 | 71.1 |
| | Mobile | 30 | 60.7 | 64.5 | 71.2 | 77.4 | 84.2 | 89.4 | 91.2 | 90.8 | 86.8 | 79.2 | 70.1 | 62.9 | 77.4 |
| | Montgomery | 30 | 57.6 | 62.4 | 70.5 | 77.5 | 84.6 | 90.6 | 92.7 | 92.2 | 87.7 | 78.7 | 68.7 | 60.3 | 77.0 |
| AK | Anchorage | 30 | 22.2 | 25.8 | 33.6 | 43.9 | 54.9 | 62.3 | 65.3 | 63.3 | 55.0 | 40.0 | 27.7 | 23.7 | 43.1 |
| | Annette | 30 | 39.7 | 41.9 | 44.7 | 49.8 | 55.7 | 60.3 | 64.1 | 64.6 | 59.6 | 51.4 | 44.2 | 40.7 | 51.4 |
| | Barrow | 30 | −7.7 | −9.8 | −7.4 | 6.3 | 24.9 | 39.5 | 46.5 | 43.6 | 34.8 | 19.3 | 4.6 | −4.7 | 15.8 |
| | Bethel | 30 | 12.4 | 13.9 | 21.8 | 33.3 | 49.4 | 59.4 | 63.1 | 59.7 | 51.7 | 35.3 | 23.1 | 15.6 | 36.6 |
| | Bettles | 30 | −3.1 | 2.0 | 16.4 | 34.1 | 54.9 | 68.7 | 70.8 | 63.2 | 49.1 | 25.4 | 6.4 | 0.4 | 32.4 |
| | Big Delta | 30 | 4.4 | 10.9 | 25.1 | 42.5 | 57.8 | 67.3 | 70.4 | 64.8 | 53.2 | 31.1 | 13.5 | 7.2 | 37.4 |
| | Cold Bay | 30 | 32.8 | 32.3 | 35.1 | 38.2 | 44.9 | 50.8 | 55.1 | 56.2 | 52.5 | 45.0 | 39.1 | 35.5 | 43.1 |
| | Fairbanks | 30 | −0.3 | 8.0 | 25.0 | 43.6 | 60.6 | 70.9 | 73.0 | 66.3 | 54.3 | 31.4 | 11.2 | 3.3 | 37.3 |
| | Gulkana | 30 | 3.5 | 13.8 | 28.2 | 42.4 | 55.6 | 65.0 | 68.5 | 64.5 | 53.4 | 34.3 | 13.2 | 6.4 | 37.4 |
| | Homer | 30 | 29.3 | 31.4 | 36.3 | 43.4 | 50.6 | 57.0 | 61.0 | 60.8 | 54.8 | 44.1 | 35.2 | 31.6 | 44.6 |
| | Juneau | 30 | 30.6 | 34.3 | 39.5 | 48.1 | 55.7 | 61.6 | 64.3 | 63.1 | 56.1 | 46.9 | 37.6 | 33.0 | 47.6 |
| | King Salmon | 30 | 22.8 | 23.8 | 32.0 | 41.3 | 52.1 | 59.5 | 63.8 | 62.2 | 54.9 | 40.5 | 30.5 | 25.1 | 42.4 |
| | Kodiak | 30 | 34.7 | 35.5 | 38.3 | 42.7 | 48.8 | 54.5 | 59.6 | 61.4 | 55.6 | 46.2 | 39.0 | 35.8 | 46.0 |
| | Kotzebue | 30 | 3.7 | 3.0 | 7.2 | 19.6 | 37.8 | 50.8 | 60.0 | 56.7 | 46.4 | 27.5 | 13.3 | 6.0 | 27.7 |
| | Mcgrath | 30 | 2.3 | 10.7 | 25.3 | 40.5 | 56.8 | 67.6 | 69.7 | 64.1 | 53.4 | 32.2 | 13.8 | 4.8 | 36.8 |
| | Nome | 30 | 13.4 | 13.6 | 17.7 | 26.8 | 43.0 | 53.9 | 58.6 | 56.0 | 48.6 | 34.0 | 23.0 | 15.8 | 33.7 |
| | St. Paul Island | 30 | 29.8 | 27.6 | 28.8 | 32.8 | 39.8 | 46.2 | 50.3 | 51.6 | 49.2 | 42.5 | 37.1 | 32.9 | 39.1 |
| | Talkeetna | 30 | 19.6 | 25.7 | 34.0 | 44.6 | 56.7 | 65.4 | 67.9 | 64.6 | 55.1 | 39.1 | 25.6 | 21.2 | 43.3 |
| | Unalakleet | 30 | 10.5 | 12.7 | 19.6 | 31.5 | 46.9 | 55.2 | 62.0 | 59.6 | 51.3 | 33.6 | 20.2 | 13.6 | 34.7 |
| | Valdez | 30 | 26.6 | 30.0 | 35.8 | 44.4 | 52.9 | 59.4 | 62.3 | 60.8 | 53.3 | 43.0 | 32.7 | 29.1 | 44.2 |
| | Yakutat | 30 | 32.1 | 35.7 | 39.3 | 45.1 | 51.1 | 56.6 | 60.1 | 60.4 | 55.7 | 47.3 | 38.4 | 34.3 | 46.3 |
| AZ | Flagstaff | 30 | 42.9 | 45.6 | 50.3 | 58.4 | 67.6 | 78.7 | 82.2 | 79.7 | 73.8 | 63.1 | 50.8 | 43.7 | 61.4 |
| | Phoenix | 30 | 65.0 | 69.4 | 74.3 | 83.0 | 91.9 | 102.0 | 104.2 | 102.4 | 97.4 | 86.4 | 73.3 | 65.0 | 84.5 |
| | Tucson | 30 | 64.5 | 68.4 | 73.3 | 81.5 | 90.4 | 100.2 | 99.6 | 97.4 | 94.0 | 84.0 | 72.3 | 64.6 | 82.5 |
| | Winslow | 30 | 47.1 | 54.4 | 61.5 | 69.8 | 79.0 | 90.0 | 93.0 | 90.1 | 83.5 | 71.7 | 57.7 | 47.1 | 70.4 |
| | Yuma | 30 | 69.9 | 75.2 | 80.1 | 87.2 | 94.7 | 104.4 | 107.3 | 106.1 | 101.0 | 90.3 | 77.3 | 69.0 | 88.5 |
| AR | Fort Smith | 30 | 48.1 | 54.8 | 64.2 | 73.2 | 80.0 | 87.7 | 92.9 | 92.6 | 84.9 | 75.0 | 61.4 | 50.9 | 72.1 |
| | Little Rock | 30 | 49.5 | 55.6 | 64.2 | 72.9 | 81.0 | 89.0 | 92.8 | 92.1 | 85.1 | 75.1 | 62.0 | 52.5 | 72.7 |
| | North Little Rock | 30 | 49.1 | 55.1 | 64.1 | 73.2 | 80.5 | 88.6 | 93.5 | 92.6 | 85.0 | 74.8 | 61.6 | 51.9 | 72.5 |
| CA | Bakersfield | 30 | 56.3 | 63.5 | 68.3 | 75.7 | 83.8 | 91.6 | 96.9 | 95.4 | 89.4 | 79.5 | 65.3 | 56.1 | 76.8 |
| | Bishop | 30 | 53.6 | 58.4 | 64.3 | 72.1 | 81.2 | 91.5 | 97.9 | 95.8 | 87.6 | 76.0 | 62.4 | 54.3 | 74.6 |
| | Eureka | 30 | 55.0 | 55.9 | 56.1 | 57.4 | 59.6 | 61.8 | 63.3 | 63.9 | 63.6 | 61.3 | 58.0 | 55.1 | 59.3 |
| | Fresno | 30 | 53.6 | 61.3 | 66.1 | 74.0 | 82.7 | 90.9 | 96.6 | 94.8 | 88.8 | 78.1 | 63.0 | 53.4 | 75.3 |
| | Long Beach | 30 | 68.0 | 68.5 | 68.9 | 72.7 | 74.0 | 78.3 | 82.9 | 84.6 | 83.1 | 78.9 | 73.4 | 68.8 | 75.2 |
| | Los Angeles AP | 30 | 65.6 | 65.8 | 65.3 | 68.0 | 69.3 | 72.6 | 75.3 | 76.8 | 76.5 | 74.3 | 70.4 | 66.7 | 70.6 |
| | Los Angeles CO | 30 | 68.1 | 69.6 | 69.8 | 73.1 | 74.5 | 79.5 | 83.8 | 84.8 | 83.3 | 79.0 | 73.2 | 68.7 | 75.6 |
| | Mount Shasta | 30 | 44.2 | 47.6 | 52.1 | 59.2 | 67.3 | 75.5 | 83.2 | 82.6 | 76.0 | 64.4 | 49.9 | 43.8 | 62.2 |
| | Redding | 30 | 55.4 | 60.1 | 63.9 | 70.6 | 80.7 | 90.7 | 98.5 | 96.9 | 90.2 | 78.4 | 62.4 | 55.6 | 75.3 |
| | Sacramento | 30 | 53.8 | 60.5 | 64.7 | 71.4 | 80.0 | 87.4 | 92.4 | 91.4 | 87.5 | 78.2 | 63.7 | 53.9 | 73.7 |

*(Continued)*



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**Table 3A.3 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | San Diego | 30 | 65.8 | 66.3 | 66.3 | 68.7 | 69.3 | 72.2 | 75.8 | 77.5 | 77.0 | 74.0 | 69.9 | 66.3 | 70.8 |
| | San Francisco AP | 30 | 55.9 | 59.3 | 61.2 | 64.3 | 66.8 | 69.9 | 71.1 | 71.7 | 72.7 | 69.7 | 62.0 | 56.1 | 65.1 |
| | San Francisco CO | 30 | 58.1 | 61.4 | 62.5 | 64.5 | 65.4 | 67.7 | 68.2 | 69.2 | 71.3 | 70.4 | 64.1 | 58.6 | 65.1 |
| | Santa Barbara | 30 | 65.4 | 66.3 | 67.4 | 70.1 | 71.2 | 74.4 | 76.7 | 78.7 | 78.2 | 75.4 | 71.0 | 66.4 | 71.8 |
| | Santa Maria | 30 | 63.9 | 64.8 | 64.8 | 67.6 | 68.6 | 71.4 | 73.5 | 74.2 | 74.9 | 74.0 | 69.2 | 64.9 | 69.3 |
| | Stockton | 30 | 53.8 | 61.2 | 66.1 | 73.3 | 81.3 | 88.9 | 93.8 | 92.6 | 88.2 | 78.6 | 64.0 | 53.8 | 74.6 |
| CO | Alamosa | 30 | 33.1 | 40.2 | 49.6 | 58.7 | 68.3 | 78.4 | 81.7 | 78.9 | 72.5 | 61.7 | 45.7 | 34.8 | 58.6 |
| | Colorado Springs | 30 | 41.7 | 45.4 | 51.6 | 59.2 | 68.4 | 79.2 | 84.4 | 81.6 | 74.1 | 63.4 | 49.8 | 42.4 | 61.8 |
| | Denver | 30 | 43.2 | 47.2 | 53.7 | 60.9 | 70.5 | 82.1 | 88.0 | 86.0 | 77.4 | 66.0 | 51.5 | 44.1 | 64.2 |
| | Grand Junction | 30 | 36.6 | 45.4 | 55.7 | 64.3 | 74.5 | 86.9 | 92.1 | 89.6 | 80.3 | 66.7 | 49.8 | 38.9 | 65.1 |
| | Pueblo | 30 | 44.6 | 50.4 | 57.3 | 65.3 | 74.6 | 86.1 | 91.4 | 88.8 | 80.8 | 69.4 | 54.3 | 45.4 | 67.4 |
| CT | Bridgeport | 30 | 36.9 | 38.8 | 46.9 | 57.0 | 67.4 | 76.4 | 81.9 | 80.7 | 73.6 | 63.1 | 52.6 | 42.1 | 59.8 |
| | Hartford | 30 | 34.1 | 37.7 | 47.7 | 59.9 | 71.7 | 80.0 | 84.9 | 82.5 | 74.3 | 63.1 | 50.9 | 39.0 | 60.5 |
| DE | Wilmington | 30 | 39.3 | 42.5 | 51.9 | 62.6 | 72.5 | 81.1 | 86.0 | 84.1 | 77.2 | 65.9 | 55.0 | 44.4 | 63.6 |
| DC | Washington Dulles AP | 30 | 41.4 | 45.5 | 55.0 | 65.9 | 74.6 | 82.8 | 87.4 | 85.9 | 78.9 | 67.7 | 56.5 | 45.9 | 65.6 |
| | Washington Nat'l AP | 30 | 42.5 | 46.5 | 55.7 | 66.3 | 75.4 | 83.9 | 88.3 | 86.3 | 79.3 | 68.0 | 57.3 | 47.0 | 66.4 |
| FL | Apalachicola | 30 | 62.4 | 64.8 | 69.9 | 76.0 | 83.0 | 88.3 | 89.8 | 89.4 | 87.0 | 79.9 | 72.0 | 65.0 | 77.3 |
| | Daytona Beach | 30 | 69.7 | 71.1 | 75.6 | 79.8 | 85.0 | 88.8 | 91.0 | 90.1 | 87.9 | 82.6 | 76.9 | 71.4 | 80.8 |
| | Fort Myers | 30 | 75.3 | 76.5 | 80.5 | 84.5 | 89.1 | 91.2 | 91.7 | 91.7 | 90.3 | 86.3 | 81.3 | 76.6 | 84.6 |
| | Gainesville | 30 | 66.2 | 69.3 | 75.1 | 80.4 | 86.5 | 89.9 | 90.9 | 90.1 | 87.4 | 81.0 | 74.4 | 68.1 | 79.9 |
| | Jacksonville | 30 | 64.2 | 67.3 | 73.4 | 78.6 | 84.3 | 88.7 | 90.8 | 89.4 | 86.1 | 79.1 | 72.5 | 65.8 | 78.4 |
| | Key West | 30 | 75.3 | 75.9 | 78.8 | 81.9 | 85.4 | 88.1 | 89.4 | 89.5 | 88.2 | 84.7 | 80.6 | 76.7 | 82.9 |
| | Miami | 30 | 76.5 | 77.7 | 80.7 | 83.8 | 87.2 | 89.5 | 90.9 | 90.6 | 89.0 | 85.4 | 81.2 | 77.5 | 84.2 |
| | Orlando | 30 | 71.8 | 73.9 | 78.8 | 83.0 | 88.2 | 91.0 | 92.2 | 92.0 | 90.3 | 85.0 | 78.9 | 73.3 | 83.2 |
| | Pensacola | 30 | 61.2 | 64.4 | 70.2 | 76.2 | 83.4 | 89.0 | 90.7 | 90.1 | 87.0 | 79.3 | 70.3 | 63.4 | 77.1 |
| | Tallahassee | 30 | 63.8 | 67.4 | 74.0 | 80.0 | 86.5 | 90.9 | 92.0 | 91.5 | 88.5 | 81.2 | 72.9 | 65.8 | 79.5 |
| | Tampa | 30 | 70.1 | 71.6 | 76.3 | 80.6 | 86.3 | 88.9 | 89.7 | 90.0 | 89.0 | 84.1 | 78.0 | 72.0 | 81.4 |
| | Vero Beach | 30 | 73.3 | 74.1 | 77.6 | 81.4 | 85.2 | 89.0 | 90.4 | 90.2 | 88.7 | 84.3 | 79.1 | 74.7 | 82.3 |
| | West Palm Beach | 30 | 75.1 | 76.3 | 79.2 | 82.1 | 85.9 | 88.5 | 90.1 | 90.1 | 88.7 | 85.0 | 80.4 | 76.4 | 83.2 |
| GA | Athens | 30 | 51.4 | 56.5 | 64.7 | 73.0 | 80.5 | 87.2 | 90.2 | 88.2 | 82.5 | 72.9 | 63.2 | 54.2 | 72.0 |
| | Atlanta | 30 | 51.9 | 56.8 | 65.0 | 72.9 | 80.0 | 86.5 | 89.4 | 87.9 | 82.3 | 72.9 | 63.3 | 54.6 | 72.0 |
| | Augusta | 30 | 56.5 | 61.3 | 69.2 | 76.7 | 83.9 | 89.6 | 92.0 | 90.2 | 85.3 | 76.5 | 67.8 | 59.1 | 75.7 |
| | Columbus | 30 | 56.9 | 61.6 | 69.4 | 76.5 | 83.2 | 89.5 | 91.7 | 91.0 | 86.0 | 77.0 | 67.6 | 59.2 | 75.8 |
| | Macon | 30 | 56.6 | 60.9 | 68.5 | 75.9 | 83.4 | 89.5 | 91.8 | 90.5 | 85.4 | 76.8 | 67.8 | 59.2 | 75.5 |
| | Savannah | 30 | 60.4 | 64.1 | 71.0 | 77.7 | 84.3 | 89.5 | 92.3 | 90.3 | 86.0 | 78.1 | 70.5 | 62.6 | 77.2 |
| HI | Hilo | 30 | 79.2 | 79.4 | 79.2 | 79.3 | 80.6 | 82.2 | 82.5 | 83.2 | 83.4 | 82.7 | 80.7 | 79.5 | 81.0 |
| | Honolulu | 30 | 80.4 | 80.7 | 81.7 | 83.1 | 84.9 | 86.9 | 87.8 | 88.9 | 88.9 | 87.2 | 84.3 | 81.7 | 84.7 |
| | Kahului | 30 | 80.3 | 80.8 | 81.5 | 82.5 | 84.3 | 86.0 | 86.9 | 87.9 | 88.1 | 86.9 | 84.1 | 81.7 | 84.3 |
| | Lihue | 30 | 77.9 | 77.9 | 78.1 | 78.8 | 80.6 | 82.7 | 83.9 | 84.9 | 85.0 | 83.5 | 81.0 | 79.0 | 81.1 |
| ID | Boise | 30 | 36.7 | 44.5 | 53.6 | 61.7 | 70.7 | 80.3 | 89.2 | 88.0 | 77.2 | 64.3 | 47.5 | 37.2 | 62.6 |
| | Lewiston | 30 | 39.4 | 45.6 | 53.8 | 61.6 | 70.0 | 78.0 | 87.6 | 87.6 | 76.7 | 62.0 | 46.8 | 39.2 | 62.4 |
| | Pocatello | 30 | 32.5 | 39.0 | 48.5 | 58.5 | 67.7 | 78.3 | 87.5 | 86.8 | 75.7 | 62.0 | 44.5 | 33.8 | 59.6 |
| IL | Chicago | 30 | 29.6 | 34.7 | 46.1 | 58.0 | 69.9 | 79.2 | 83.5 | 81.2 | 73.9 | 62.1 | 47.1 | 34.4 | 58.3 |
| | Moline | 30 | 29.8 | 35.6 | 48.3 | 61.7 | 73.3 | 82.7 | 86.1 | 83.9 | 76.5 | 64.4 | 48.0 | 34.5 | 60.4 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Peoria | 30 | 30.7 | 36.6 | 49.4 | 62.0 | 73.0 | 82.2 | 85.7 | 83.6 | 76.7 | 64.4 | 48.8 | 35.5 | 60.7 |
| | Rockford | 30 | 27.2 | 33.0 | 45.5 | 59.1 | 71.2 | 79.9 | 83.1 | 80.9 | 73.9 | 61.8 | 45.5 | 32.0 | 57.8 |
| | Springfield | 30 | 33.1 | 38.9 | 51.1 | 63.4 | 74.4 | 83.3 | 86.5 | 84.5 | 78.5 | 66.6 | 50.9 | 38.0 | 62.4 |
| IN | Evansville | 30 | 39.5 | 45.4 | 56.4 | 67.2 | 77.1 | 86.1 | 89.4 | 87.8 | 81.3 | 70.0 | 55.7 | 44.1 | 66.7 |
| | Fort Wayne | 30 | 31.0 | 35.4 | 47.4 | 59.8 | 71.6 | 80.6 | 84.3 | 81.8 | 75.4 | 63.0 | 48.5 | 35.8 | 59.6 |
| | Indianapolis | 30 | 34.5 | 39.9 | 51.4 | 62.9 | 73.5 | 82.1 | 85.6 | 83.7 | 77.4 | 65.6 | 51.6 | 39.2 | 62.3 |
| | South Bend | 30 | 31.0 | 35.5 | 46.8 | 58.9 | 70.7 | 79.6 | 83.1 | 80.7 | 73.6 | 61.8 | 47.7 | 35.6 | 58.8 |
| IA | Des Moines | 30 | 29.1 | 35.4 | 48.2 | 61.3 | 72.3 | 81.8 | 86.0 | 83.9 | 75.9 | 63.5 | 46.7 | 33.1 | 59.8 |
| | Dubuque | 30 | 24.8 | 30.8 | 43.3 | 57.4 | 69.3 | 78.6 | 82.1 | 79.8 | 71.9 | 60.3 | 43.6 | 29.7 | 56.0 |
| | Sioux City | 30 | 28.7 | 35.0 | 47.3 | 61.7 | 73.2 | 82.5 | 86.2 | 83.7 | 76.0 | 63.7 | 44.8 | 31.7 | 59.6 |
| | Waterloo | 30 | 25.8 | 31.9 | 45.0 | 59.7 | 72.2 | 81.7 | 85.0 | 82.8 | 75.3 | 62.5 | 45.0 | 30.7 | 58.1 |
| KS | Concordia | 30 | 36.3 | 42.9 | 53.9 | 64.4 | 74.0 | 85.0 | 90.7 | 88.4 | 79.9 | 67.9 | 51.0 | 39.6 | 64.5 |
| | Dodge City | 30 | 41.4 | 48.3 | 57.3 | 67.1 | 75.9 | 86.9 | 92.8 | 90.8 | 82.0 | 70.4 | 54.5 | 44.4 | 67.7 |
| | Goodland | 30 | 39.4 | 45.0 | 53.2 | 62.7 | 71.7 | 83.6 | 89.1 | 86.7 | 78.0 | 66.0 | 49.6 | 41.3 | 63.9 |
| | Topeka | 30 | 37.2 | 43.8 | 55.5 | 66.1 | 75.3 | 84.5 | 89.1 | 87.9 | 80.3 | 68.9 | 53.1 | 40.9 | 65.2 |
| | Wichita | 30 | 40.1 | 47.2 | 57.3 | 66.9 | 76.0 | 87.1 | 92.9 | 91.6 | 82.2 | 70.2 | 54.5 | 43.1 | 67.4 |
| KY | Greater Cincinnati AP | 30 | 38.0 | 43.1 | 53.9 | 64.7 | 74.4 | 82.4 | 86.4 | 84.8 | 78.0 | 66.4 | 53.6 | 42.7 | 64.0 |
| | Jackson | 30 | 42.0 | 46.8 | 56.8 | 66.8 | 73.8 | 80.8 | 84.2 | 83.3 | 77.4 | 67.5 | 56.4 | 46.3 | 65.2 |
| | Lexington | 30 | 39.9 | 45.2 | 55.3 | 65.1 | 74.0 | 82.3 | 85.9 | 84.6 | 78.1 | 66.9 | 54.5 | 44.3 | 64.7 |
| | Louisville | 30 | 41.0 | 46.6 | 56.8 | 66.8 | 75.4 | 83.3 | 87.0 | 85.8 | 79.4 | 68.4 | 55.9 | 45.4 | 66.0 |
| | Paducah | 30 | 41.9 | 48.0 | 58.1 | 68.4 | 76.9 | 85.2 | 88.6 | 87.4 | 81.2 | 70.8 | 57.2 | 46.3 | 67.5 |
| LA | Baton Rouge | 30 | 60.0 | 63.9 | 71.0 | 77.3 | 84.0 | 89.2 | 90.7 | 90.9 | 87.4 | 79.7 | 70.1 | 62.8 | 77.3 |
| | Lake Charles | 30 | 60.6 | 64.5 | 71.3 | 77.4 | 84.1 | 88.9 | 91.0 | 91.3 | 87.7 | 80.5 | 70.6 | 63.3 | 77.6 |
| | New Orleans | 30 | 61.8 | 65.3 | 72.1 | 78.0 | 84.8 | 89.4 | 91.1 | 91.0 | 87.1 | 79.7 | 71.0 | 64.5 | 78.0 |
| | Shreveport | 30 | 56.2 | 62.0 | 69.7 | 76.6 | 83.2 | 89.8 | 93.3 | 93.4 | 87.6 | 78.3 | 66.8 | 58.5 | 76.3 |
| ME | Caribou | 30 | 19.3 | 23.2 | 34.1 | 47.0 | 62.6 | 71.8 | 76.3 | 74.2 | 64.1 | 51.4 | 37.4 | 24.8 | 48.9 |
| | Portland | 30 | 30.9 | 34.1 | 42.2 | 52.8 | 63.3 | 72.8 | 78.8 | 77.3 | 68.9 | 57.9 | 47.1 | 36.4 | 55.2 |
| MD | Baltimore | 30 | 41.2 | 44.8 | 53.9 | 64.5 | 73.9 | 82.7 | 87.2 | 85.1 | 78.2 | 67.0 | 56.3 | 46.0 | 65.1 |
| MA | Blue Hill | 30 | 33.8 | 36.3 | 44.8 | 55.5 | 67.0 | 75.5 | 81.2 | 78.9 | 71.0 | 60.3 | 49.3 | 38.6 | 57.7 |
| | Boston | 30 | 36.5 | 38.7 | 46.3 | 56.1 | 66.7 | 76.6 | 82.2 | 80.1 | 72.5 | 61.8 | 51.8 | 41.7 | 59.3 |
| | Worcester | 30 | 31.4 | 34.1 | 43.0 | 54.4 | 66.3 | 74.4 | 79.3 | 77.1 | 69.0 | 58.4 | 47.1 | 36.2 | 55.9 |
| MI | Alpena | 30 | 26.1 | 28.2 | 37.3 | 50.3 | 64.3 | 73.8 | 79.0 | 76.1 | 67.4 | 55.6 | 42.2 | 31.2 | 52.6 |
| | Detroit | 30 | 31.1 | 34.4 | 45.2 | 57.8 | 70.2 | 79.0 | 83.4 | 81.4 | 73.7 | 61.2 | 47.8 | 35.9 | 58.4 |
| | Flint | 30 | 29.2 | 32.3 | 43.1 | 56.2 | 69.0 | 77.7 | 82.0 | 79.5 | 71.9 | 59.7 | 46.3 | 34.2 | 56.8 |
| | Grand Rapids | 30 | 29.3 | 32.6 | 43.3 | 56.6 | 69.6 | 78.4 | 82.3 | 79.7 | 71.7 | 59.6 | 45.5 | 33.7 | 56.9 |
| | Houghton Lake | 30 | 25.9 | 29.3 | 39.4 | 53.0 | 67.2 | 75.5 | 80.0 | 77.1 | 68.3 | 56.0 | 41.9 | 30.5 | 53.7 |
| | Lansing | 30 | 29.4 | 32.6 | 43.5 | 56.6 | 69.4 | 78.1 | 82.1 | 79.7 | 72.0 | 59.8 | 46.0 | 34.1 | 56.9 |
| | Marquette | 30 | 19.7 | 24.2 | 33.1 | 45.8 | 61.5 | 70.3 | 75.2 | 72.6 | 63.2 | 50.9 | 35.4 | 24.1 | 48.0 |
| | Muskegon | 30 | 29.8 | 32.5 | 42.5 | 54.6 | 67.0 | 75.6 | 80.0 | 78.1 | 70.3 | 58.7 | 45.6 | 34.6 | 55.8 |
| | Sault Ste. Marie | 30 | 21.5 | 24.5 | 33.6 | 48.0 | 63.2 | 70.7 | 75.7 | 74.1 | 64.8 | 52.8 | 38.9 | 27.2 | 49.6 |
| MN | Duluth | 30 | 17.9 | 24.4 | 34.2 | 49.0 | 63.4 | 71.2 | 76.3 | 73.9 | 64.5 | 52.5 | 35.2 | 22.3 | 48.7 |
| | International Falls | 30 | 13.8 | 22.4 | 34.9 | 51.5 | 66.6 | 74.2 | 78.6 | 76.3 | 64.7 | 51.7 | 32.5 | 18.1 | 48.8 |
| | Minneapolis-St. Paul | 30 | 21.9 | 28.4 | 40.6 | 57.0 | 70.1 | 79.0 | 83.3 | 80.4 | 71.1 | 58.4 | 40.1 | 26.4 | 54.7 |
| | Rochester | 30 | 19.9 | 26.2 | 38.7 | 54.8 | 67.7 | 76.6 | 80.1 | 77.5 | 69.2 | 56.9 | 38.7 | 24.5 | 52.6 |
| | Saint Cloud | 30 | 18.7 | 25.7 | 37.7 | 54.9 | 69.0 | 77.3 | 81.7 | 78.9 | 69.0 | 56.3 | 37.2 | 23.2 | 52.5 |
| MS | Jackson | 30 | 55.1 | 60.3 | 68.1 | 75.0 | 82.1 | 88.9 | 91.4 | 91.4 | 86.4 | 76.8 | 66.3 | 57.9 | 75.0 |

*(Continued)*



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**Table 3A.3 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Meridian | 30 | 57.5 | 62.6 | 70.3 | 77.1 | 83.9 | 90.1 | 92.9 | 92.9 | 88.0 | 78.3 | 68.5 | 60.5 | 76.9 |
| | Tupelo | 30 | 50.3 | 56.0 | 64.8 | 73.5 | 81.0 | 88.0 | 91.4 | 90.9 | 84.9 | 74.9 | 63.0 | 53.6 | 72.7 |
| MO | Columbia | 30 | 37.4 | 43.9 | 55.1 | 65.9 | 74.6 | 83.6 | 88.6 | 87.3 | 79.1 | 68.0 | 53.4 | 41.5 | 64.9 |
| | Kansas City | 30 | 36.0 | 42.6 | 54.4 | 65.2 | 74.6 | 83.9 | 88.8 | 87.1 | 79.0 | 67.6 | 52.0 | 40.0 | 64.3 |
| | St. Louis | 30 | 37.9 | 44.3 | 55.4 | 66.7 | 76.5 | 85.3 | 89.8 | 87.9 | 80.1 | 68.3 | 53.8 | 42.0 | 65.7 |
| | Springfield | 30 | 41.6 | 47.7 | 57.8 | 67.7 | 75.9 | 84.6 | 89.9 | 89.5 | 81.2 | 70.6 | 56.4 | 45.5 | 67.4 |
| MT | Billings | 30 | 32.8 | 39.5 | 47.6 | 57.5 | 67.4 | 78.0 | 85.8 | 84.5 | 71.8 | 58.9 | 42.7 | 34.5 | 58.4 |
| | Glasgow | 30 | 19.9 | 28.3 | 41.3 | 56.7 | 67.9 | 77.1 | 83.8 | 83.3 | 70.4 | 57.1 | 37.4 | 24.8 | 54.0 |
| | Great Falls | 30 | 32.1 | 37.7 | 45.3 | 55.6 | 64.7 | 73.9 | 82.0 | 81.2 | 69.6 | 58.0 | 42.1 | 34.2 | 56.4 |
| | Havre | 30 | 25.5 | 33.4 | 44.9 | 58.5 | 68.8 | 77.4 | 84.6 | 83.9 | 71.9 | 59.4 | 40.8 | 30.1 | 56.6 |
| | Helena | 30 | 30.5 | 37.3 | 46.8 | 56.9 | 65.9 | 75.0 | 83.4 | 82.5 | 71.0 | 58.4 | 41.5 | 31.5 | 56.7 |
| | Kalispell | 30 | 28.9 | 35.2 | 44.9 | 56.0 | 64.7 | 71.9 | 80.2 | 80.5 | 69.0 | 55.3 | 38.6 | 30.1 | 54.6 |
| | Missoula | 30 | 30.8 | 37.4 | 48.1 | 58.0 | 66.1 | 74.5 | 83.6 | 83.2 | 71.5 | 57.4 | 40.0 | 30.3 | 56.7 |
| NE | Grand Island | 30 | 32.6 | 38.6 | 49.5 | 61.9 | 71.9 | 83.0 | 87.1 | 84.8 | 76.9 | 64.6 | 46.8 | 35.3 | 61.1 |
| | Lincoln | 30 | 33.2 | 39.3 | 51.2 | 63.5 | 73.8 | 84.9 | 89.6 | 87.1 | 78.8 | 66.5 | 49.1 | 36.8 | 62.8 |
| | Norfolk | 30 | 31.2 | 37.3 | 48.5 | 61.3 | 72.3 | 82.3 | 86.5 | 84.4 | 76.4 | 64.0 | 45.5 | 33.6 | 60.3 |
| | North Platte | 30 | 36.5 | 43.3 | 52.1 | 62.7 | 72.0 | 82.6 | 88.4 | 86.8 | 78.0 | 65.6 | 48.5 | 39.2 | 63.0 |
| | Omaha Eppley AP | 30 | 31.7 | 37.9 | 50.4 | 63.2 | 73.7 | 83.7 | 87.4 | 85.2 | 77.3 | 65.2 | 47.8 | 34.8 | 61.5 |
| | Omaha (North) | 30 | 32.1 | 38.0 | 50.8 | 63.6 | 73.3 | 82.4 | 85.6 | 83.9 | 76.3 | 64.6 | 47.5 | 35.1 | 61.1 |
| | Scottsbluff | 30 | 38.0 | 44.3 | 51.7 | 61.0 | 71.1 | 82.2 | 88.7 | 86.8 | 77.3 | 64.4 | 48.2 | 39.8 | 62.8 |
| | Valentine | 30 | 33.8 | 39.4 | 48.4 | 59.8 | 71.2 | 81.9 | 88.3 | 86.9 | 77.2 | 63.5 | 45.9 | 36.7 | 61.1 |
| NV | Elko | 30 | 37.1 | 42.9 | 51.2 | 59.3 | 68.6 | 79.9 | 89.6 | 88.1 | 78.2 | 65.0 | 48.1 | 38.2 | 62.2 |
| | Ely | 30 | 40.0 | 44.0 | 49.9 | 57.9 | 67.3 | 79.2 | 87.3 | 85.1 | 75.8 | 63.0 | 48.8 | 41.0 | 61.6 |
| | Las Vegas | 30 | 57.1 | 63.0 | 69.5 | 78.1 | 87.8 | 98.9 | 104.1 | 101.8 | 93.8 | 80.8 | 66.0 | 57.3 | 79.9 |
| | Reno | 30 | 45.5 | 51.7 | 57.2 | 64.1 | 72.6 | 82.8 | 91.2 | 89.9 | 81.7 | 69.9 | 55.3 | 46.4 | 67.4 |
| | Winnemucca | 30 | 41.6 | 48.5 | 55.1 | 62.6 | 72.0 | 82.7 | 92.2 | 90.6 | 80.4 | 67.3 | 51.4 | 42.2 | 65.6 |
| NH | Concord | 30 | 30.6 | 34.1 | 43.8 | 56.9 | 69.6 | 77.9 | 82.9 | 80.8 | 72.1 | 60.5 | 47.6 | 35.6 | 57.7 |
| | Mt. Washington | 30 | 14.0 | 14.8 | 21.3 | 29.4 | 41.6 | 50.3 | 54.1 | 53.0 | 46.1 | 36.4 | 27.6 | 18.5 | 33.9 |
| NJ | Atlantic City AP | 30 | 41.4 | 43.9 | 51.9 | 61.3 | 71.1 | 80.0 | 85.1 | 83.3 | 76.6 | 66.3 | 56.0 | 46.4 | 63.6 |
| | Atlantic City CO | 30 | 41.4 | 43.2 | 49.5 | 57.5 | 66.1 | 74.8 | 80.6 | 79.8 | 74.1 | 64.5 | 55.0 | 46.3 | 61.1 |
| | Newark | 30 | 38.1 | 41.1 | 50.1 | 60.8 | 71.4 | 80.2 | 85.2 | 83.2 | 75.7 | 64.7 | 53.7 | 43.0 | 62.3 |
| NM | Albuquerque | 30 | 47.6 | 54.6 | 62.4 | 70.6 | 79.7 | 90.2 | 92.3 | 89.0 | 82.2 | 70.7 | 57.1 | 47.9 | 70.4 |
| | Clayton | 30 | 47.4 | 51.5 | 58.2 | 66.1 | 74.2 | 83.9 | 87.4 | 85.1 | 77.9 | 68.5 | 55.7 | 48.0 | 67.0 |
| | Roswell | 30 | 55.6 | 62.0 | 70.0 | 77.7 | 86.0 | 94.0 | 94.8 | 92.3 | 85.7 | 76.5 | 64.5 | 56.3 | 76.3 |
| NY | Albany | 30 | 31.1 | 34.3 | 44.5 | 57.3 | 69.8 | 77.5 | 82.2 | 79.7 | 71.3 | 59.7 | 47.5 | 36.0 | 57.6 |
| | Binghamton | 30 | 28.4 | 30.9 | 40.6 | 53.1 | 65.6 | 73.4 | 78.1 | 75.8 | 67.8 | 56.7 | 44.3 | 33.4 | 54.0 |
| | Buffalo | 30 | 31.1 | 33.2 | 42.5 | 54.1 | 66.4 | 74.8 | 79.6 | 77.8 | 70.1 | 58.9 | 46.7 | 36.0 | 55.9 |
| | Islip | 30 | 39.1 | 40.5 | 48.5 | 58.1 | 68.9 | 77.4 | 83.2 | 81.7 | 74.9 | 64.0 | 53.7 | 43.9 | 61.2 |
| | New York C.Park | 30 | 38.0 | 41.0 | 49.8 | 60.7 | 70.9 | 79.0 | 84.2 | 82.4 | 74.7 | 63.5 | 53.1 | 42.9 | 61.7 |
| | New York (JFK AP) | 30 | 38.8 | 40.9 | 48.9 | 58.6 | 68.3 | 77.2 | 82.9 | 81.8 | 74.9 | 64.3 | 53.8 | 44.0 | 61.2 |
| | New York (Laguardia AP) | 30 | 38.6 | 41.2 | 49.6 | 60.0 | 70.6 | 79.3 | 84.7 | 83.1 | 75.6 | 64.5 | 53.6 | 43.7 | 62.1 |
| | Rochester | 30 | 31.2 | 33.2 | 42.7 | 55.2 | 67.9 | 76.6 | 81.4 | 79.1 | 71.1 | 59.7 | 47.2 | 36.1 | 56.8 |
| | Syracuse | 30 | 31.4 | 33.5 | 43.1 | 55.7 | 68.5 | 77.0 | 81.7 | 79.6 | 71.4 | 59.8 | 47.4 | 36.3 | 57.1 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NC | Asheville | 30 | 45.9 | 50.0 | 57.7 | 66.5 | 73.5 | 80.0 | 83.3 | 81.7 | 76.0 | 67.1 | 57.4 | 49.3 | 65.7 |
| | Cape Hatteras | 30 | 53.6 | 54.6 | 60.2 | 67.7 | 74.9 | 81.5 | 85.4 | 84.8 | 81.1 | 72.6 | 64.8 | 57.3 | 69.9 |
| | Charlotte | 30 | 51.3 | 55.9 | 64.1 | 72.8 | 79.7 | 86.6 | 90.1 | 88.4 | 82.3 | 72.6 | 62.8 | 54.0 | 71.7 |
| | Greensboro-Wnstn-Slm-HPT | 30 | 47.2 | 51.7 | 60.3 | 69.7 | 76.9 | 83.8 | 87.6 | 85.7 | 79.4 | 69.6 | 59.9 | 50.6 | 68.5 |
| | Raleigh | 30 | 49.8 | 54.0 | 62.5 | 71.8 | 78.7 | 85.5 | 89.1 | 87.2 | 81.3 | 71.8 | 62.4 | 53.3 | 70.6 |
| | Wilmington | 30 | 56.3 | 59.5 | 66.2 | 74.1 | 80.6 | 86.4 | 89.9 | 88.3 | 84.1 | 75.6 | 67.8 | 59.6 | 74.0 |
| ND | Bismarck | 30 | 21.1 | 28.5 | 40.2 | 55.9 | 69.1 | 77.8 | 84.5 | 83.3 | 71.6 | 58.2 | 38.2 | 25.7 | 54.5 |
| | Fargo | 30 | 15.9 | 22.8 | 35.3 | 54.5 | 69.5 | 77.4 | 82.2 | 81.0 | 69.9 | 56.1 | 35.2 | 20.8 | 51.7 |
| | Grand Forks | 30 | 14.9 | 22.4 | 34.3 | 53.6 | 70.0 | 77.6 | 81.9 | 81.0 | 69.7 | 55.6 | 34.1 | 20.1 | 51.3 |
| | Williston | 30 | 19.4 | 27.6 | 40.1 | 56.0 | 68.2 | 77.3 | 83.4 | 82.8 | 70.0 | 57.0 | 36.2 | 24.0 | 53.5 |
| OH | Akron | 30 | 32.9 | 36.8 | 47.5 | 59.0 | 69.8 | 78.2 | 82.3 | 80.3 | 72.8 | 61.1 | 48.7 | 37.7 | 58.9 |
| | Cleveland | 30 | 32.6 | 35.8 | 46.1 | 57.3 | 68.6 | 77.4 | 81.4 | 79.2 | 72.3 | 60.8 | 48.7 | 37.4 | 58.1 |
| | Columbus | 30 | 36.2 | 40.5 | 51.7 | 62.9 | 73.3 | 81.6 | 85.3 | 83.8 | 77.1 | 65.4 | 52.4 | 41.0 | 62.6 |
| | Dayton | 30 | 33.7 | 38.2 | 49.3 | 60.7 | 71.2 | 80.1 | 84.2 | 82.3 | 75.6 | 63.5 | 50.1 | 38.5 | 60.6 |
| | Mansfield | 30 | 32.4 | 35.9 | 46.6 | 58.4 | 69.3 | 77.8 | 81.8 | 79.7 | 73.0 | 61.7 | 48.7 | 37.2 | 58.6 |
| | Toledo | 30 | 31.4 | 35.1 | 46.5 | 58.9 | 70.7 | 79.5 | 83.4 | 81.0 | 74.0 | 62.1 | 48.3 | 36.0 | 58.9 |
| | Youngstown | 30 | 32.4 | 36.0 | 46.3 | 58.2 | 69.0 | 77.1 | 81.0 | 79.3 | 72.1 | 60.7 | 48.4 | 37.3 | 58.2 |
| OK | Oklahoma City | 30 | 47.1 | 53.5 | 62.5 | 71.2 | 78.9 | 87.2 | 93.1 | 92.5 | 84.1 | 73.4 | 59.6 | 49.8 | 71.1 |
| | Tulsa | 30 | 46.5 | 52.9 | 62.4 | 72.1 | 79.6 | 88.0 | 93.8 | 93.2 | 84.1 | 74.0 | 60.0 | 49.6 | 71.4 |
| OR | Astoria | 30 | 48.1 | 50.8 | 53.3 | 56.1 | 60.0 | 63.6 | 67.2 | 68.3 | 67.5 | 61.0 | 53.1 | 48.4 | 58.1 |
| | Burns | 30 | 34.7 | 40.5 | 49.0 | 57.4 | 66.1 | 75.1 | 85.4 | 84.5 | 75.0 | 62.4 | 44.8 | 35.1 | 59.2 |
| | Eugene | 30 | 46.5 | 50.7 | 55.9 | 60.6 | 66.8 | 73.3 | 81.5 | 81.9 | 76.6 | 64.6 | 52.1 | 45.7 | 63.0 |
| | Medford | 30 | 47.3 | 53.8 | 58.3 | 64.3 | 72.2 | 81.2 | 90.2 | 90.1 | 83.5 | 70.0 | 52.8 | 45.2 | 67.4 |
| | Pendleton | 30 | 40.1 | 46.5 | 54.8 | 62.2 | 70.2 | 78.7 | 87.7 | 86.6 | 77.1 | 63.8 | 48.5 | 40.0 | 63.0 |
| | Portland | 30 | 45.6 | 50.3 | 55.7 | 60.5 | 66.7 | 72.7 | 79.3 | 79.7 | 74.6 | 63.3 | 51.8 | 45.4 | 62.1 |
| | Salem | 30 | 47.0 | 51.2 | 56.3 | 61.1 | 67.5 | 74.0 | 81.5 | 81.9 | 76.6 | 64.5 | 52.4 | 46.4 | 63.4 |
| | Sexton Summit | 30 | 42.5 | 44.1 | 46.7 | 51.9 | 60.1 | 67.5 | 75.5 | 75.7 | 70.3 | 59.3 | 45.7 | 42.0 | 56.8 |
| PC | Guam | 30 | 84.0 | 84.0 | 85.0 | 86.2 | 87.3 | 87.4 | 86.8 | 86.1 | 86.5 | 86.3 | 85.6 | 84.7 | 85.8 |
| | Johnston Island | 30 | 81.9 | 82.1 | 82.3 | 83.1 | 84.3 | 85.8 | 86.5 | 87.2 | 87.0 | 86.2 | 84.1 | 82.6 | 84.4 |
| | Koror | 30 | 87.6 | 87.5 | 88.3 | 88.8 | 89.1 | 88.1 | 87.5 | 87.5 | 88.0 | 88.3 | 89.0 | 88.4 | 88.2 |
| | Kwajalein, Marshall IS | 30 | 85.6 | 86.1 | 86.7 | 86.5 | 86.7 | 86.5 | 86.6 | 86.9 | 87.0 | 86.9 | 86.5 | 85.8 | 86.5 |
| | Majuro, Marshall IS | 30 | 85.2 | 85.6 | 85.9 | 85.7 | 86.0 | 86.0 | 85.9 | 86.4 | 86.6 | 86.6 | 86.3 | 85.5 | 86.0 |
| | Pago Pago, Amer Samoa | 30 | 86.8 | 87.2 | 87.3 | 86.9 | 85.6 | 84.5 | 83.8 | 84.0 | 84.8 | 85.2 | 85.8 | 86.9 | 85.7 |
| | Pohnpei, Caroline IS | 30 | 86.8 | 87.0 | 87.5 | 87.6 | 87.8 | 87.8 | 88.2 | 88.6 | 88.8 | 88.7 | 88.6 | 87.3 | 87.9 |
| | Chuuk, E. Caroline IS | 30 | 87.0 | 86.4 | 86.7 | 87.1 | 87.6 | 87.2 | 87.7 | 87.4 | 87.8 | 88.3 | 88.3 | 87.7 | 87.4 |
| | Wake Island | 30 | 82.4 | 82.1 | 83.3 | 84.5 | 86.2 | 88.1 | 88.8 | 88.7 | 88.7 | 87.8 | 85.7 | 83.9 | 85.9 |
| | Yap, W Caroline IS | 30 | 86.5 | 86.7 | 87.5 | 88.3 | 88.5 | 87.7 | 87.2 | 87.1 | 87.4 | 87.6 | 87.7 | 87.0 | 87.4 |
| PA | Allentown | 30 | 35.0 | 38.7 | 48.7 | 60.1 | 70.9 | 79.3 | 83.9 | 81.7 | 74.0 | 62.9 | 51.2 | 40.0 | 60.5 |
| | Erie | 30 | 33.5 | 35.4 | 44.7 | 55.6 | 67.4 | 76.2 | 80.4 | 79.0 | 72.0 | 61.0 | 49.3 | 38.6 | 57.8 |
| | Harrisburg | 30 | 37.5 | 40.9 | 50.9 | 62.6 | 72.6 | 80.8 | 85.7 | 83.7 | 75.7 | 64.3 | 52.5 | 41.7 | 62.4 |
| | Middletown/ Harrisburg AP | 30 | 37.5 | 40.9 | 50.9 | 62.6 | 72.6 | 80.8 | 85.7 | 83.7 | 75.7 | 64.3 | 52.5 | 41.7 | 62.4 |
| | Philadelphia | 30 | 39.0 | 42.1 | 51.3 | 62.0 | 72.1 | 80.6 | 85.5 | 84.0 | 76.7 | 65.7 | 54.8 | 44.2 | 63.2 |

*(Continued)*



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**Table 3A.3 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pittsburgh | 30 | 35.1 | 38.8 | 49.5 | 60.7 | 70.8 | 79.1 | 82.7 | 81.1 | 74.2 | 62.5 | 50.5 | 39.8 | 60.4 |
| | Avoca | 30 | 34.1 | 37.3 | 47.3 | 59.2 | 70.8 | 78.2 | 82.6 | 80.5 | 72.4 | 61.2 | 49.3 | 38.6 | 59.3 |
| | Williamsport | 30 | 33.2 | 37.1 | 47.8 | 60.2 | 71.3 | 78.9 | 83.2 | 81.4 | 73.3 | 61.8 | 49.0 | 37.8 | 59.6 |
| RI | Providence | 30 | 37.1 | 39.3 | 47.7 | 58.1 | 68.5 | 77.3 | 82.6 | 80.9 | 73.4 | 62.9 | 52.4 | 42.1 | 60.2 |
| SC | Charleston AP | 30 | 58.9 | 62.3 | 69.3 | 76.1 | 82.9 | 87.9 | 90.9 | 89.4 | 85.0 | 77.0 | 69.6 | 61.6 | 75.9 |
| | Charleston CO | 30 | 57.1 | 59.8 | 65.8 | 72.9 | 79.6 | 84.9 | 88.5 | 87.1 | 83.0 | 75.1 | 67.6 | 60.0 | 73.5 |
| | Columbia | 30 | 55.1 | 59.5 | 67.4 | 75.7 | 83.1 | 89.1 | 92.1 | 90.0 | 84.8 | 75.8 | 66.7 | 57.8 | 74.8 |
| | Greenville-Spartanburg | 30 | 50.2 | 54.8 | 62.7 | 71.0 | 78.2 | 85.1 | 88.8 | 87.1 | 81.1 | 71.4 | 61.3 | 52.7 | 70.4 |
| SD | Aberdeen | 30 | 21.4 | 28.5 | 40.2 | 57.4 | 70.2 | 78.7 | 84.7 | 83.5 | 73.0 | 59.2 | 38.8 | 25.7 | 55.1 |
| | Huron | 30 | 24.8 | 31.3 | 43.0 | 58.3 | 70.5 | 80.3 | 86.1 | 84.4 | 74.7 | 60.9 | 41.4 | 28.8 | 57.1 |
| | Rapid City | 30 | 33.6 | 38.6 | 46.6 | 57.1 | 67.2 | 77.4 | 85.5 | 85.5 | 75.2 | 61.7 | 44.8 | 36.1 | 59.1 |
| | Sioux Falls | 30 | 25.2 | 31.6 | 43.8 | 58.8 | 71.0 | 80.6 | 85.6 | 83.2 | 74.2 | 61.1 | 41.9 | 28.8 | 57.2 |
| TN | Bristol-JhnCty-Kgsprt | 30 | 44.1 | 48.9 | 58.4 | 67.1 | 74.9 | 81.8 | 84.8 | 83.9 | 78.5 | 68.2 | 57.4 | 47.8 | 66.3 |
| | Chattanooga | 30 | 48.8 | 54.1 | 62.8 | 72.1 | 79.1 | 86.2 | 89.8 | 88.7 | 82.5 | 72.3 | 61.1 | 52.0 | 70.8 |
| | Knoxville | 30 | 46.3 | 51.7 | 60.3 | 69.0 | 76.3 | 83.6 | 86.9 | 86.4 | 80.7 | 69.9 | 59.0 | 49.8 | 68.3 |
| | Memphis | 30 | 48.6 | 54.4 | 63.3 | 72.4 | 80.4 | 88.5 | 92.1 | 91.2 | 85.3 | 75.1 | 62.1 | 52.2 | 72.1 |
| | Nashville | 30 | 45.6 | 51.4 | 60.7 | 69.8 | 77.5 | 85.1 | 88.7 | 87.8 | 81.5 | 71.1 | 59.0 | 49.4 | 69.0 |
| | Oak Ridge | 30 | 45.9 | 51.6 | 61.0 | 70.5 | 77.8 | 84.9 | 88.1 | 87.2 | 81.1 | 71.1 | 59.0 | 49.0 | 68.9 |
| TX | Abilene | 30 | 55.2 | 60.7 | 69.1 | 77.3 | 84.7 | 91.1 | 94.8 | 93.7 | 86.7 | 77.6 | 65.1 | 56.9 | 76.1 |
| | Amarillo | 30 | 48.9 | 54.1 | 62.2 | 70.6 | 78.6 | 87.4 | 91.0 | 88.7 | 81.8 | 71.8 | 58.4 | 49.8 | 70.3 |
| | Austin/City | 30 | 60.3 | 65.1 | 72.5 | 78.9 | 84.8 | 90.9 | 95.0 | 95.6 | 90.1 | 81.4 | 70.1 | 62.3 | 78.9 |
| | Austin/Bergstrom | 30 | 58.9 | 64.1 | 71.4 | 77.8 | 84.3 | 89.9 | 94.0 | 94.0 | 89.7 | 80.8 | 69.7 | 61.3 | 78.0 |
| | Brownsville | 30 | 68.7 | 72.2 | 78.0 | 82.3 | 86.9 | 90.5 | 92.4 | 92.6 | 89.4 | 84.0 | 76.8 | 70.2 | 82.0 |
| | Corpus Christi | 30 | 66.0 | 69.7 | 75.8 | 80.7 | 85.6 | 90.2 | 93.2 | 93.4 | 89.9 | 83.6 | 74.9 | 68.0 | 80.9 |
| | Dallas-Fort Worth | 30 | 54.1 | 60.1 | 68.3 | 75.9 | 83.2 | 91.1 | 95.4 | 94.8 | 87.7 | 77.9 | 65.1 | 56.5 | 75.8 |
| | Dallas-Love Field | 30 | 55.4 | 61.0 | 69.1 | 76.5 | 83.8 | 91.6 | 96.1 | 95.8 | 88.5 | 78.6 | 66.0 | 57.4 | 76.7 |
| | Del Rio | 30 | 62.8 | 68.0 | 76.0 | 82.7 | 88.7 | 93.7 | 96.2 | 96.0 | 90.6 | 81.7 | 70.9 | 63.5 | 80.9 |
| | El Paso | 30 | 57.2 | 63.4 | 70.2 | 78.1 | 86.7 | 95.3 | 94.5 | 92.0 | 87.1 | 77.9 | 65.5 | 57.4 | 77.1 |
| | Galveston | 30 | 61.9 | 64.4 | 70.0 | 75.2 | 81.4 | 86.6 | 88.7 | 89.3 | 86.5 | 79.7 | 71.3 | 64.3 | 76.6 |
| | Houston | 30 | 62.3 | 66.5 | 73.3 | 79.1 | 85.5 | 90.7 | 93.6 | 93.5 | 89.3 | 82.0 | 72.0 | 64.6 | 79.4 |
| | Lubbock | 30 | 51.9 | 57.8 | 66.2 | 74.7 | 82.8 | 90.0 | 91.9 | 90.0 | 83.4 | 74.4 | 61.6 | 53.2 | 73.2 |
| | Midland-Odessa | 30 | 56.8 | 63.0 | 70.9 | 78.8 | 86.8 | 92.7 | 94.3 | 92.8 | 86.1 | 77.4 | 65.8 | 58.4 | 77.0 |
| | Port Arthur | 30 | 61.5 | 65.3 | 72.0 | 77.8 | 84.3 | 89.4 | 91.6 | 91.7 | 88.0 | 80.5 | 70.9 | 63.9 | 78.1 |
| | San Angelo | 30 | 57.9 | 63.5 | 71.1 | 79.0 | 85.6 | 90.8 | 94.4 | 93.1 | 86.6 | 77.8 | 66.5 | 59.3 | 77.2 |
| | San Antonio | 30 | 62.1 | 67.1 | 74.3 | 80.4 | 86.0 | 91.4 | 94.6 | 94.7 | 90.0 | 82.0 | 71.4 | 64.0 | 79.8 |
| | Victoria | 30 | 62.8 | 66.6 | 73.4 | 79.2 | 85.1 | 90.3 | 93.4 | 93.7 | 89.9 | 83.0 | 73.0 | 65.2 | 79.6 |
| | Waco | 30 | 57.0 | 62.3 | 70.2 | 77.6 | 84.8 | 92.0 | 96.7 | 96.9 | 90.1 | 80.4 | 67.8 | 59.1 | 77.9 |
| | Wichita Falls | 30 | 52.1 | 58.1 | 67.2 | 75.5 | 83.5 | 91.7 | 97.2 | 95.8 | 87.5 | 77.1 | 63.7 | 54.5 | 75.3 |
| UT | Milford | 30 | 40.6 | 47.1 | 56.7 | 65.0 | 74.2 | 86.2 | 92.9 | 90.7 | 81.3 | 68.0 | 52.2 | 42.2 | 66.4 |
| | Salt Lake City | 30 | 37.0 | 43.4 | 52.8 | 60.9 | 70.6 | 82.2 | 90.6 | 88.7 | 77.6 | 64.0 | 48.7 | 38.0 | 62.9 |
| VT | Burlington | 30 | 26.7 | 29.0 | 39.6 | 53.3 | 67.8 | 76.5 | 81.4 | 78.4 | 68.9 | 56.4 | 44.0 | 32.3 | 54.5 |
| VA | Lynchburg | 30 | 44.5 | 48.6 | 57.6 | 68.0 | 75.5 | 82.5 | 86.4 | 85.1 | 78.3 | 68.4 | 58.0 | 48.4 | 66.8 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Norfolk | 30 | 47.8 | 50.3 | 57.8 | 67.0 | 74.9 | 82.8 | 86.8 | 84.7 | 79.4 | 69.4 | 60.9 | 52.3 | 67.8 |
| | Richmond | 30 | 45.3 | 49.3 | 58.4 | 68.9 | 76.2 | 83.6 | 87.5 | 85.7 | 79.7 | 69.3 | 59.7 | 49.7 | 67.8 |
| | Roanoke | 30 | 45.0 | 49.1 | 57.9 | 68.0 | 75.9 | 83.3 | 87.5 | 86.0 | 78.8 | 68.6 | 58.0 | 48.6 | 67.2 |
| WA | Olympia | 30 | 44.4 | 48.3 | 53.0 | 58.2 | 64.6 | 70.0 | 76.1 | 77.0 | 71.7 | 60.4 | 49.6 | 43.8 | 59.8 |
| | Quillayute | 30 | 46.6 | 49.2 | 51.8 | 55.7 | 60.4 | 63.8 | 68.2 | 69.3 | 67.3 | 59.2 | 50.8 | 46.5 | 57.4 |
| | Seattle CO | 30 | 46.9 | 50.5 | 54.5 | 59.3 | 64.9 | 69.5 | 74.5 | 74.9 | 69.9 | 60.3 | 51.5 | 46.5 | 60.3 |
| | Seattle Sea-Tac AP | 30 | 45.8 | 49.5 | 53.2 | 58.2 | 64.4 | 69.6 | 75.3 | 75.6 | 70.2 | 59.7 | 50.5 | 45.5 | 59.8 |
| | Spokane | 30 | 32.8 | 39.3 | 48.6 | 57.5 | 66.2 | 73.9 | 82.5 | 82.6 | 72.5 | 58.5 | 41.1 | 32.8 | 57.4 |
| | Walla Walla | 30 | 40.6 | 46.9 | 56.0 | 64.1 | 72.0 | 80.3 | 89.9 | 89.1 | 79.3 | 65.8 | 50.1 | 40.8 | 64.6 |
| | Yakima | 30 | 37.7 | 45.6 | 56.0 | 64.1 | 72.4 | 79.6 | 87.2 | 86.5 | 77.6 | 64.3 | 47.7 | 37.1 | 63.0 |
| PR | San Juan | 30 | 82.4 | 82.8 | 83.4 | 84.9 | 86.3 | 87.6 | 87.4 | 87.8 | 87.8 | 87.5 | 85.1 | 83.2 | 85.5 |
| WV | Beckley | 30 | 38.8 | 42.8 | 51.9 | 62.5 | 70.6 | 77.0 | 80.2 | 78.9 | 72.6 | 63.1 | 52.4 | 43.1 | 61.2 |
| | Charleston | 30 | 42.6 | 47.0 | 56.6 | 66.7 | 74.6 | 81.5 | 84.9 | 83.5 | 77.3 | 67.1 | 56.4 | 46.8 | 65.4 |
| | Elkins | 30 | 39.3 | 43.5 | 53.2 | 63.2 | 71.7 | 78.5 | 81.7 | 80.4 | 74.1 | 64.1 | 52.8 | 43.5 | 62.2 |
| | Huntington | 30 | 41.0 | 46.1 | 56.3 | 66.6 | 74.6 | 81.7 | 85.1 | 83.7 | 77.0 | 66.4 | 55.1 | 45.3 | 64.9 |
| WI | Green Bay | 30 | 24.1 | 28.9 | 40.0 | 54.6 | 68.0 | 76.8 | 81.2 | 78.5 | 70.2 | 57.9 | 42.4 | 29.0 | 54.3 |
| | La Crosse | 30 | 25.5 | 32.4 | 44.6 | 59.7 | 72.5 | 81.3 | 85.2 | 82.5 | 73.7 | 61.1 | 43.6 | 29.9 | 57.7 |
| | Madison | 30 | 25.2 | 30.8 | 42.8 | 56.6 | 69.4 | 78.3 | 82.1 | 79.4 | 71.4 | 59.6 | 43.3 | 30.2 | 55.8 |
| | Milwaukee | 30 | 28.0 | 32.5 | 42.6 | 53.9 | 66.0 | 76.3 | 81.1 | 79.1 | 71.9 | 60.2 | 45.7 | 33.1 | 55.9 |
| WY | Casper | 30 | 32.3 | 37.0 | 46.9 | 56.1 | 66.4 | 78.8 | 86.8 | 85.3 | 73.4 | 59.5 | 42.6 | 33.6 | 58.2 |
| | Cheyenne | 30 | 37.1 | 40.5 | 46.4 | 54.4 | 64.4 | 75.4 | 81.9 | 79.8 | 70.3 | 58.2 | 44.5 | 38.1 | 57.6 |
| | Lander | 30 | 31.9 | 37.4 | 47.5 | 56.5 | 66.5 | 78.5 | 86.3 | 84.8 | 73.0 | 59.5 | 41.8 | 32.6 | 58.0 |
| | Sheridan | 30 | 33.0 | 39.0 | 48.2 | 57.5 | 66.4 | 76.4 | 85.2 | 84.9 | 73.1 | 59.8 | 43.4 | 34.4 | 58.5 |

*Note:* In Fahrenheit degrees, based on 30-year average values 1971–2000.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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**Table 3A.4 Mean Number of Days with Minimum Temperature 32 ° or Less — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham CO | 11 | 18 | 11 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | — | 4 | 14 | 52 |
| | Birmingham AP | 39 | 17 | 12 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | — | 6 | 14 | 57 |
| | Huntsville | 35 | 18 | 13 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | — | 8 | 16 | 63 |
| | Mobile | 40 | 8 | 5 | 1 | — | 0 | 0 | 0 | 0 | 0 | — | 1 | 6 | 22 |
| | Montgomery | 39 | 13 | 8 | 3 | — | 0 | 0 | 0 | 0 | 0 | — | 4 | 10 | 39 |
| AK | Anchorage | 38 | 31 | 27 | 29 | 20 | 3 | 0 | 0 | — | 3 | 20 | 28 | 30 | 191 |
| | Annette | 42 | 17 | 13 | 12 | 4 | — | 0 | 0 | 0 | 0 | 2 | 10 | 14 | 72 |
| | Barrow | 82 | 31 | 28 | 31 | 30 | 31 | 24 | 14 | 15 | 25 | 31 | 30 | 31 | 321 |
| | Barter IS | 41 | 31 | 28 | 31 | 30 | 31 | 23 | 9 | 11 | 25 | 31 | 30 | 31 | 310 |
| | Bethel | 44 | 30 | 28 | 31 | 28 | 16 | 1 | — | — | 6 | 26 | 29 | 30 | 224 |
| | Bettles | 50 | 31 | 28 | 31 | 29 | 14 | — | — | 2 | 15 | 30 | 30 | 31 | 240 |
| | Big Delta | 57 | 31 | 28 | 30 | 26 | 8 | — | — | 1 | 10 | 28 | 30 | 31 | 222 |
| | Cold Bay | 59 | 24 | 23 | 25 | 21 | 9 | — | 0 | 0 | — | 9 | 19 | 24 | 154 |
| | Fairbanks | 39 | 31 | 28 | 31 | 27 | 7 | 0 | 0 | 1 | 9 | 29 | 30 | 31 | 222 |
| | Gulkana | 54 | 31 | 28 | 31 | 29 | 15 | 1 | — | 3 | 14 | 27 | 30 | 31 | 238 |
| | Homer | 61 | 28 | 25 | 27 | 22 | 9 | — | 0 | — | 3 | 18 | 25 | 28 | 185 |
| | Juneau | 58 | 25 | 22 | 23 | 14 | 3 | — | 0 | — | 1 | 7 | 18 | 23 | 137 |
| | King Salmon | 39 | 28 | 26 | 27 | 24 | 11 | — | 0 | — | 5 | 22 | 25 | 28 | 197 |
| | Kodiak | 40 | 22 | 20 | 21 | 13 | 3 | — | 0 | 0 | 1 | 12 | 18 | 23 | 134 |
| | Kotzebue | 59 | 31 | 28 | 31 | 30 | 25 | 6 | — | — | 7 | 28 | 30 | 31 | 248 |
| | Mcgrath | 60 | 31 | 28 | 31 | 28 | 11 | — | 0 | 1 | 10 | 28 | 30 | 31 | 229 |
| | Nome | 36 | 31 | 28 | 31 | 29 | 19 | 3 | — | 1 | 10 | 25 | 29 | 31 | 238 |
| | St. Paul Island | 85 | 26 | 26 | 29 | 27 | 18 | 3 | — | — | 2 | 11 | 19 | 25 | 187 |
| | Talkeetna | 62 | 31 | 28 | 31 | 28 | 13 | — | 0 | 1 | 8 | 25 | 29 | 31 | 223 |
| | Unalakleet | 30 | 31 | 28 | 31 | 29 | 18 | 2 | — | 1 | 8 | 27 | 30 | 31 | 236 |
| | Valdez | 30 | 30 | 27 | 29 | 17 | 1 | — | 0 | — | 1 | 12 | 26 | 30 | 172 |
| | Yakutat | 38 | 25 | 23 | 24 | 21 | 8 | — | 0 | — | 5 | 11 | 22 | 25 | 163 |
| AZ | Flagstaff | 53 | 30 | 28 | 30 | 25 | 13 | 3 | — | — | 3 | 19 | 28 | 30 | 208 |
| | Phoenix | 42 | 3 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 5 |
| | Tucson | 62 | 6 | 4 | 1 | — | 0 | 0 | 0 | 0 | 0 | — | 1 | 5 | 17 |
| | Winslow | 42 | 28 | 23 | 19 | 8 | 1 | 0 | 0 | 0 | — | 5 | 21 | 28 | 135 |
| | Yuma | 31 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| AR | Fort Smith | 38 | 23 | 16 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 19 | 74 |
| | Little Rock | 42 | 19 | 12 | 5 | — | 0 | 0 | 0 | 0 | 0 | — | 5 | 15 | 56 |
| | North Little Rock | 24 | 17 | 10 | 4 | — | 0 | 0 | 0 | 0 | 0 | — | 4 | 12 | 46 |
| CA | Bakersfield | 39 | 5 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 5 | 11 |
| | Bishop | 54 | 29 | 24 | 20 | 8 | 1 | — | 0 | 0 | — | 7 | 24 | 29 | 143 |
| | Blue Canyon | 54 | 18 | 16 | 18 | 11 | 4 | — | 0 | 0 | — | 2 | 10 | 15 | 95 |
| | Eureka | 92 | 2 | 1 | — | — | 0 | 0 | 0 | 0 | 0 | — | — | 1 | 4 |
| | Fresno | 39 | 7 | 3 | 1 | — | 0 | 0 | 0 | 0 | 0 | — | 2 | 8 | 20 |
| | Long Beach | 42 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 |
| | Los Angeles AP | 43 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 |
| | Los Angeles CO | 61 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 |
| | Mount Shasta | 42 | 26 | 21 | 22 | 14 | 4 | — | — | 0 | 1 | 6 | 18 | 25 | 136 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Redding | 16 | 11 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 12 | 33 |
| | Sacramento | 52 | 6 | 2 | 0 | — | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 16 |
| | San Diego | 42 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | San Francisco AP | 43 | 1 | — | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| | San Francisco CO | 65 | — | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 |
| | Santa Barbara | 66 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 3 | 7 |
| | Santa Maria | 39 | 5 | 3 | 1 | — | — | 0 | 0 | 0 | 0 | — | 2 | 6 | 17 |
| | Stockton | 43 | 8 | 2 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 21 |
| CO | Alamosa | 57 | 31 | 28 | 31 | 27 | 14 | 2 | 0 | — | 8 | 27 | 30 | 31 | 227 |
| | Colorado Springs | 42 | 30 | 27 | 26 | 14 | 2 | 0 | 0 | 0 | 1 | 9 | 24 | 29 | 162 |
| | Denver | 35 | 30 | 26 | 24 | 11 | 1 | 0 | 0 | 0 | 1 | 8 | 24 | 29 | 156 |
| | Grand Junction | 39 | 30 | 25 | 17 | 6 | — | 0 | 0 | 0 | — | 4 | 21 | 30 | 133 |
| | Pueblo | 37 | 30 | 27 | 25 | 11 | 1 | 0 | 0 | 0 | 1 | 11 | 26 | 30 | 162 |
| CT | Bridgeport | 37 | 26 | 23 | 17 | 3 | — | 0 | 0 | 0 | 0 | 1 | 8 | 21 | 98 |
| | Hartford | 43 | 28 | 25 | 22 | 8 | 1 | 0 | 0 | 0 | — | 6 | 16 | 27 | 133 |
| DE | Wilmington | 55 | 25 | 22 | 15 | 3 | — | 0 | 0 | 0 | 0 | 1 | 10 | 22 | 99 |
| DC | Washington Dulles AP | 40 | 26 | 22 | 17 | 5 | — | 0 | 0 | 0 | — | 5 | 14 | 23 | 113 |
| | Washington Nat'l AP | 42 | 22 | 18 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | — | 4 | 15 | 68 |
| FL | Apalachicola | 42 | 3 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 2 | 6 |
| | Daytona Beach | 59 | 2 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 5 |
| | Fort Myers | 59 | — | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 |
| | Gainesville | 19 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 14 |
| | Jacksonville | 61 | 6 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 15 |
| | Key West | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Miami | 38 | — | 0 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 |
| | Orlando | 39 | 2 | — | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 2 |
| | Pensacola | 39 | 6 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 4 | 15 |
| | Tallahassee | 41 | 11 | 7 | 3 | — | 0 | 0 | 0 | 0 | 0 | — | 4 | 9 | 34 |
| | Tampa | 39 | 1 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 3 |
| | Vero Beach | 19 | — | 0 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 |
| | West Palm Beach | 38 | — | — | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 |
| GA | Athens | 59 | 15 | 11 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | — | 6 | 13 | 50 |
| | Atlanta | 42 | 15 | 11 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | — | 5 | 12 | 48 |
| | Augusta | 38 | 16 | 12 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | 14 | 55 |
| | Columbus | 57 | 13 | 8 | 3 | — | 0 | 0 | 0 | 0 | 0 | — | 4 | 11 | 39 |
| | Macon | 38 | 14 | 10 | 4 | — | 0 | 0 | 0 | 0 | 0 | — | 5 | 12 | 44 |
| | Savannah | 38 | 10 | 6 | 2 | — | 0 | 0 | 0 | 0 | 0 | — | 2 | 8 | 28 |
| HI | Hilo | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Honolulu | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Kahului | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lihue | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ID | Boise | 63 | 26 | 21 | 17 | 8 | 2 | — | 0 | 0 | 0 | 6 | 17 | 26 | 122 |
| | Lewiston | 56 | 21 | 16 | 12 | 3 | — | 0 | 0 | 0 | — | 3 | 12 | 21 | 87 |
| | Pocatello | 39 | 28 | 25 | 25 | 15 | 4 | — | 0 | — | 3 | 15 | 24 | 28 | 168 |
| IL | Cairo | 45 | 21 | 15 | 7 | — | 0 | 0 | 0 | 0 | 0 | — | 6 | 17 | 66 |
| | Chicago | 44 | 29 | 25 | 21 | 7 | 1 | 0 | 0 | 0 | — | 5 | 16 | 26 | 130 |

*(Continued)*



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**Table 3A.4 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Moline | 42 | 29 | 25 | 21 | 7 | 1 | 0 | 0 | 0 | — | 6 | 18 | 27 | 134 |
| | Peoria | 43 | 29 | 25 | 19 | 6 | — | 0 | 0 | 0 | — | 4 | 17 | 27 | 127 |
| | Rockford | 39 | 29 | 26 | 23 | 9 | 1 | 0 | 0 | 0 | 0 | 7 | 19 | 28 | 143 |
| | Springfield | 43 | 28 | 23 | 17 | 4 | — | 0 | 0 | 0 | — | 4 | 15 | 25 | 115 |
| IN | Evansville | 41 | 25 | 20 | 13 | 3 | — | 0 | 0 | 0 | 0 | 3 | 12 | 21 | 97 |
| | Fort Wayne | 41 | 28 | 24 | 21 | 8 | 1 | 0 | 0 | 0 | — | 5 | 16 | 26 | 128 |
| | Indianapolis | 43 | 27 | 23 | 17 | 5 | — | 0 | 0 | 0 | — | 4 | 14 | 24 | 114 |
| | South Bend | 39 | 28 | 24 | 20 | 8 | 1 | 0 | 0 | 0 | — | 3 | 14 | 25 | 124 |
| IA | Des Moines | 41 | 30 | 25 | 21 | 6 | — | 0 | 0 | 0 | — | 5 | 19 | 29 | 134 |
| | Dubuque | 35 | 31 | 26 | 23 | 8 | 1 | 0 | 0 | 0 | 0 | 7 | 21 | 30 | 147 |
| | Sioux City | 43 | 31 | 27 | 23 | 9 | 1 | 0 | 0 | 0 | 1 | 8 | 23 | 30 | 152 |
| | Waterloo | 43 | 31 | 27 | 24 | 10 | 1 | 0 | 0 | 0 | 1 | 9 | 22 | 30 | 155 |
| KS | Concordia | 40 | 29 | 24 | 19 | 5 | — | 0 | 0 | 0 | — | 3 | 17 | 28 | 125 |
| | Dodge City | 39 | 29 | 23 | 18 | 5 | — | 0 | 0 | 0 | — | 4 | 17 | 28 | 125 |
| | Goodland | 36 | 30 | 27 | 24 | 12 | 1 | 0 | 0 | 0 | 1 | 8 | 24 | 30 | 157 |
| | Topeka | 38 | 29 | 22 | 16 | 4 | — | 0 | 0 | 0 | — | 4 | 16 | 27 | 118 |
| | Wichita | 49 | 28 | 22 | 15 | 3 | — | 0 | 0 | 0 | — | 1 | 14 | 26 | 109 |
| KY | Greater Cincinnati AP | 40 | 26 | 22 | 16 | 5 | — | 0 | 0 | 0 | — | 3 | 13 | 22 | 106 |
| | Jackson | 22 | 23 | 16 | 12 | 3 | — | 0 | 0 | 0 | 0 | 1 | 9 | 17 | 81 |
| | Lexington | 39 | 24 | 20 | 14 | 3 | — | 0 | 0 | 0 | 0 | 2 | 11 | 20 | 93 |
| | Louisville | 42 | 24 | 19 | 12 | 2 | — | 0 | 0 | 0 | 0 | 1 | 9 | 20 | 86 |
| | Paducah | 19 | 23 | 16 | 11 | 3 | 0 | 0 | 0 | 0 | 0 | 2 | 11 | 19 | 85 |
| LA | Baton Rouge | 43 | 9 | 5 | 1 | — | 0 | 0 | 0 | 0 | 0 | — | 2 | 6 | 22 |
| | Lake Charles | 38 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 4 | 14 |
| | New Orleans | 56 | 5 | 3 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 12 |
| | Shreveport | 50 | 12 | 7 | 3 | — | 0 | 0 | 0 | 0 | 0 | — | 3 | 10 | 35 |
| ME | Caribou | 63 | 31 | 28 | 29 | 22 | 5 | — | 0 | 0 | 3 | 14 | 25 | 30 | 187 |
| | Portland | 62 | 30 | 27 | 26 | 14 | 2 | 0 | 0 | 0 | 1 | 9 | 19 | 28 | 155 |
| MD | Baltimore | 52 | 25 | 21 | 14 | 3 | — | 0 | 0 | 0 | 0 | 2 | 11 | 21 | 97 |
| MA | Blue Hill | 117 | 28 | 26 | 23 | 9 | — | 0 | 0 | 0 | — | 3 | 14 | 26 | 129 |
| | Boston | 38 | 26 | 23 | 16 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 21 | 96 |
| | Worcester | 47 | 29 | 26 | 25 | 10 | 1 | 0 | 0 | 0 | — | 5 | 17 | 28 | 141 |
| MI | Alpena | 43 | 30 | 27 | 28 | 19 | 7 | 1 | 0 | — | 2 | 11 | 22 | 29 | 176 |
| | Detroit | 44 | 29 | 25 | 22 | 9 | 1 | 0 | 0 | 0 | — | 4 | 16 | 26 | 132 |
| | Flint | 39 | 29 | 26 | 24 | 11 | 2 | 0 | 0 | 0 | — | 6 | 17 | 27 | 140 |
| | Grand Rapids | 39 | 29 | 26 | 24 | 12 | 2 | 0 | 0 | 0 | — | 6 | 17 | 28 | 143 |
| | Houghton Lake | 38 | 31 | 28 | 28 | 17 | 5 | — | 0 | — | 2 | 9 | 22 | 30 | 171 |
| | Lansing | 39 | 29 | 26 | 25 | 13 | 3 | — | 0 | 0 | 1 | 8 | 18 | 27 | 150 |
| | Marquette | 24 | 31 | 28 | 29 | 22 | 8 | 0 | 0 | 0 | 2 | 16 | 26 | 30 | 194 |
| | Muskegon | 42 | 29 | 26 | 24 | 11 | 2 | — | 0 | 0 | — | 5 | 16 | 26 | 138 |
| | Sault Ste. Marie | 61 | 31 | 28 | 29 | 21 | 7 | 1 | 0 | — | 2 | 9 | 22 | 30 | 179 |
| MN | Duluth | 41 | 31 | 28 | 29 | 20 | 5 | — | 0 | — | 2 | 12 | 26 | 31 | 184 |
| | International Falls | 63 | 31 | 28 | 30 | 22 | 7 | — | 0 | — | 4 | 16 | 28 | 31 | 197 |
| | Minneapolis-St. Paul | 43 | 31 | 27 | 25 | 11 | 1 | 0 | 0 | 0 | 0 | 7 | 23 | 30 | 155 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rochester | 42 | 31 | 27 | 26 | 12 | 2 | 0 | 0 | 0 | 1 | 10 | 24 | 30 | 163 |
| | Saint Cloud | 62 | 31 | 28 | 28 | 17 | 3 | — | 0 | 0 | 2 | 13 | 26 | 31 | 178 |
| MS | Jackson | 39 | 14 | 10 | 4 | — | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 12 | 47 |
| | Meridian | 38 | 15 | 11 | 5 | — | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 13 | 51 |
| | Tupelo | 19 | 16 | 10 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | — | 6 | 14 | 53 |
| MO | Columbia | 33 | 27 | 21 | 15 | 3 | — | 0 | 0 | 0 | — | 2 | 14 | 25 | 107 |
| | Kansas City | 30 | 28 | 21 | 15 | 4 | — | 0 | 0 | 0 | — | 2 | 14 | 26 | 110 |
| | St. Louis | 42 | 26 | 20 | 13 | 2 | — | 0 | 0 | 0 | 0 | 1 | 11 | 23 | 96 |
| | Springfield | 42 | 26 | 20 | 13 | 3 | — | 0 | 0 | 0 | — | 2 | 12 | 23 | 100 |
| MT | Billings | 43 | 28 | 24 | 23 | 13 | 2 | — | 0 | 0 | 1 | 8 | 22 | 28 | 147 |
| | Glasgow | 38 | 31 | 28 | 28 | 16 | 3 | 0 | 0 | 0 | 2 | 14 | 27 | 31 | 179 |
| | Great Falls | 41 | 27 | 24 | 26 | 17 | 4 | — | 0 | — | 3 | 12 | 22 | 27 | 160 |
| | Helena | 39 | 30 | 27 | 27 | 18 | 4 | — | 0 | — | 3 | 17 | 27 | 30 | 181 |
| | Kalispell | 43 | 29 | 26 | 27 | 18 | 6 | 1 | — | — | 6 | 21 | 25 | 29 | 189 |
| | Missoula | 42 | 29 | 26 | 26 | 17 | 5 | — | — | — | 4 | 18 | 26 | 30 | 181 |
| NE | Grand Island | 41 | 31 | 26 | 23 | 8 | 1 | 0 | 0 | 0 | 0 | 7 | 23 | 30 | 148 |
| | Lincoln | 31 | 30 | 26 | 22 | 8 | 1 | 0 | 0 | 0 | 0 | 6 | 22 | 30 | 144 |
| | Norfolk | 57 | 31 | 27 | 24 | 10 | 1 | 0 | 0 | 0 | 1 | 7 | 24 | 30 | 155 |
| | North Platte | 38 | 31 | 28 | 27 | 13 | 3 | — | 0 | 0 | 2 | 14 | 28 | 31 | 177 |
| | Omaha Eppley AP | 38 | 30 | 26 | 22 | 7 | — | 0 | 0 | 0 | — | 6 | 20 | 29 | 139 |
| | Omaha (North) | 39 | 30 | 26 | 21 | 7 | — | 0 | 0 | 0 | — | 4 | 19 | 29 | 137 |
| | Scottsbluff | 38 | 30 | 27 | 27 | 14 | 2 | — | 0 | 0 | 2 | 13 | 27 | 30 | 172 |
| | Valentine | 47 | 31 | 28 | 27 | 15 | 3 | — | 0 | 0 | 2 | 14 | 27 | 31 | 177 |
| NV | Elko | 38 | 29 | 26 | 26 | 20 | 8 | 1 | — | — | 7 | 22 | 26 | 29 | 195 |
| | Ely | 64 | 31 | 27 | 29 | 24 | 13 | 4 | — | 0 | 8 | 23 | 28 | 30 | 218 |
| | Las Vegas | 42 | 11 | 4 | 1 | — | 0 | 0 | 0 | 0 | 0 | — | 2 | 10 | 27 |
| | Reno | 39 | 27 | 24 | 22 | 16 | 5 | 0 | 0 | — | 3 | 14 | 24 | 28 | 163 |
| | Winnemucca | 53 | 28 | 24 | 25 | 19 | 8 | 1 | — | — | 6 | 21 | 25 | 28 | 186 |
| NH | Concord | 37 | 30 | 27 | 26 | 17 | 5 | — | 0 | — | 2 | 14 | 21 | 29 | 171 |
| | Mt. Washington | 70 | 31 | 28 | 31 | 28 | 20 | 6 | 2 | 3 | 12 | 23 | 28 | 31 | 243 |
| NJ | Atlantic City AP | 38 | 25 | 22 | 17 | 6 | — | 0 | 0 | 0 | — | 3 | 13 | 22 | 109 |
| | Atlantic City CO | 40 | 21 | 17 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | — | 4 | 15 | 69 |
| | Newark | 37 | 23 | 20 | 12 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 19 | 83 |
| NM | Albuquerque | 42 | 28 | 21 | 14 | 4 | — | 0 | 0 | 0 | 0 | 2 | 15 | 28 | 113 |
| | Clayton | 54 | 29 | 25 | 22 | 9 | 1 | 0 | 0 | 0 | — | 5 | 20 | 28 | 139 |
| | Roswell | 30 | 25 | 16 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 12 | 24 | 88 |
| NY | Albany | 37 | 29 | 26 | 24 | 12 | 1 | 0 | 0 | 0 | 0 | 8 | 18 | 27 | 146 |
| | Binghamton | 51 | 29 | 26 | 25 | 12 | 1 | 0 | 0 | 0 | — | 6 | 18 | 27 | 145 |
| | Buffalo | 42 | 28 | 26 | 24 | 10 | 1 | 0 | 0 | 0 | — | 3 | 14 | 25 | 130 |
| | Islip | 19 | 25 | 21 | 17 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 21 | 99 |
| | New York C.Park | 89 | 22 | 20 | 12 | 1 | — | 0 | 0 | 0 | 0 | — | 5 | 18 | 78 |
| | New York (JFK AP) | 41 | 23 | 20 | 12 | 1 | 0 | 0 | 0 | 0 | 0 | — | 4 | 17 | 77 |
| | New York (Laguardia AP) | 40 | 22 | 19 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | — | 3 | 15 | 70 |
| | Rochester | 39 | 28 | 25 | 23 | 11 | 1 | 0 | 0 | 0 | — | 4 | 15 | 25 | 133 |
| | Syracuse | 39 | 28 | 25 | 24 | 11 | 1 | 0 | 0 | 0 | — | 5 | 15 | 26 | 135 |

*(Continued)*



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**Table 3A.4 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NC | Asheville | 38 | 23 | 19 | 13 | 4 | — | 0 | 0 | 0 | — | 4 | 13 | 21 | 97 |
| | Cape Hatteras | 45 | 9 | 8 | 3 | — | 0 | 0 | 0 | 0 | 0 | — | 1 | 6 | 27 |
| | Charlotte | 42 | 18 | 14 | 7 | 1 | — | 0 | 0 | 0 | 0 | 1 | 6 | 15 | 63 |
| | Greensboro-Wnstn-Slm-HPT | 39 | 22 | 18 | 10 | 2 | — | 0 | 0 | 0 | 0 | 1 | 9 | 18 | 80 |
| | Raleigh | 38 | 20 | 16 | 9 | 2 | — | 0 | 0 | 0 | 0 | 1 | 9 | 17 | 75 |
| | Wilmington | 39 | 13 | 10 | 4 | — | 0 | 0 | 0 | 0 | 0 | — | 3 | 10 | 40 |
| ND | Bismarck | 43 | 31 | 28 | 29 | 18 | 4 | — | 0 | 0 | 3 | 15 | 28 | 31 | 186 |
| | Fargo | 43 | 31 | 28 | 27 | 16 | 4 | — | 0 | 0 | 2 | 13 | 27 | 31 | 179 |
| | Williston | 41 | 31 | 28 | 29 | 18 | 5 | — | 0 | 0 | 3 | 17 | 29 | 31 | 189 |
| OH | Akron | 39 | 28 | 24 | 21 | 9 | 1 | — | 0 | 0 | 0 | 4 | 14 | 25 | 125 |
| | Cleveland | 42 | 28 | 24 | 21 | 9 | 1 | — | 0 | 0 | 0 | 2 | 12 | 24 | 121 |
| | Columbus | 43 | 27 | 23 | 18 | 6 | 0 | 0 | 0 | 0 | — | 3 | 13 | 23 | 115 |
| | Dayton | 39 | 27 | 23 | 18 | 6 | — | 0 | 0 | 0 | — | 3 | 14 | 24 | 115 |
| | Mansfield | 37 | 28 | 24 | 21 | 9 | 1 | 0 | 0 | 0 | 0 | 4 | 15 | 25 | 126 |
| | Toledo | 47 | 29 | 25 | 23 | 10 | 1 | — | 0 | 0 | — | 6 | 17 | 26 | 137 |
| | Youngstown | 59 | 28 | 25 | 23 | 11 | 2 | — | 0 | — | — | 4 | 16 | 26 | 134 |
| OK | Oklahoma City | 37 | 23 | 15 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 20 | 75 |
| | Tulsa | 42 | 23 | 16 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | — | 8 | 19 | 76 |
| OR | Astoria | 49 | 9 | 6 | 6 | 2 | — | 0 | 0 | 0 | 0 | — | 4 | 7 | 34 |
| | Burns | 18 | 30 | 26 | 27 | 21 | 9 | 3 | — | 1 | 8 | 24 | 27 | 30 | 207 |
| | Eugene | 60 | 14 | 10 | 7 | 2 | — | — | 0 | 0 | — | 2 | 7 | 11 | 54 |
| | Medford | 41 | 19 | 14 | 11 | 5 | 1 | 0 | 0 | 0 | — | 4 | 10 | 16 | 80 |
| | Pendleton | 67 | 21 | 16 | 10 | 3 | — | 0 | 0 | 0 | — | 3 | 12 | 20 | 84 |
| | Portland | 62 | 12 | 8 | 4 | 1 | — | 0 | 0 | 0 | 0 | 1 | 5 | 9 | 40 |
| | Salem | 40 | 13 | 11 | 9 | 5 | 1 | — | 0 | 0 | — | 3 | 7 | 13 | 62 |
| | Sexton Summit | 40 | 19 | 16 | 20 | 15 | 7 | — | 0 | 0 | — | 3 | 11 | 17 | 107 |
| PC | Guam | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Johnston Island | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Koror | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Kwajalein, Marshall IS | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Majuro, Marshall IS | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Pago Pago, Amer Samoa | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Pohnpei, Caroline IS | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Chuuk, E. Caroline IS | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Wake Island | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Yap, W Caroline IS | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PA | Allentown | 59 | 28 | 25 | 20 | 6 | — | 0 | 0 | 0 | — | 4 | 15 | 26 | 123 |
| | Erie | 37 | 27 | 25 | 23 | 10 | 1 | — | 0 | 0 | 0 | 1 | 11 | 24 | 122 |
| | Harrisburg | 37 | 26 | 23 | 17 | 4 | — | 0 | 0 | 0 | — | 2 | 11 | 23 | 106 |
| | Middletown/Harrisburg AP | 64 | 26 | 23 | 17 | 3 | — | 0 | 0 | 0 | — | 2 | 11 | 23 | 105 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Philadelphia | 43 | 25 | 21 | 14 | 2 | — | 0 | 0 | 0 | 0 | 1 | 8 | 20 | 92 |
| | Pittsburgh | 43 | 27 | 24 | 19 | 8 | 1 | 0 | 0 | 0 | 0 | 4 | 14 | 24 | 121 |
| | Avoca | 47 | 28 | 25 | 22 | 8 | 1 | 0 | 0 | 0 | — | 4 | 14 | 25 | 127 |
| | Williamsport | 58 | 28 | 25 | 21 | 8 | 1 | 0 | 0 | 0 | — | 5 | 15 | 25 | 128 |
| RI | Block IS | 39 | 24 | 21 | 16 | 3 | 0 | 0 | 0 | 0 | 0 | — | 5 | 17 | 86 |
| | Providence | 39 | 28 | 24 | 19 | 5 | — | 0 | 0 | 0 | 0 | 3 | 13 | 24 | 116 |
| SC | Charleston AP | 60 | 10 | 7 | 3 | — | 0 | 0 | 0 | 0 | 0 | — | 3 | 9 | 32 |
| | Charleston CO | 27 | 4 | 2 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 9 |
| | Columbia | 36 | 16 | 12 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | 14 | 57 |
| | Greenville-Spartanburg AP | 40 | 18 | 14 | 7 | 1 | — | 0 | 0 | 0 | 0 | 1 | 7 | 15 | 63 |
| SD | Aberdeen | 41 | 31 | 28 | 27 | 15 | 3 | 0 | 0 | — | 2 | 14 | 27 | 31 | 178 |
| | Huron | 43 | 31 | 27 | 26 | 14 | 2 | — | 0 | 0 | 1 | 12 | 26 | 31 | 170 |
| | Rapid City | 60 | 30 | 27 | 27 | 15 | 3 | — | 0 | 0 | 2 | 11 | 25 | 30 | 169 |
| | Sioux Falls | 39 | 31 | 27 | 26 | 13 | 2 | 0 | 0 | 0 | 1 | 12 | 26 | 31 | 168 |
| TN | Bristol-JhnCty-Kgsprt | 41 | 23 | 19 | 13 | 4 | — | 0 | 0 | 0 | 0 | 3 | 13 | 21 | 96 |
| | Chattanooga | 62 | 19 | 15 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 17 | 71 |
| | Knoxville | 42 | 20 | 16 | 9 | 2 | — | 0 | 0 | 0 | 0 | 1 | 8 | 17 | 72 |
| | Memphis | 61 | 17 | 12 | 5 | — | 0 | 0 | 0 | 0 | 0 | — | 5 | 14 | 53 |
| | Nashville | 37 | 21 | 16 | 9 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 17 | 74 |
| | Oak Ridge | 37 | 21 | 17 | 12 | 3 | — | 0 | 0 | 0 | 0 | 2 | 12 | 19 | 86 |
| TX | Abilene | 39 | 17 | 10 | 4 | — | 0 | 0 | 0 | 0 | 0 | — | 5 | 14 | 50 |
| | Amarillo | 41 | 27 | 22 | 15 | 4 | — | 0 | 0 | 0 | — | 2 | 15 | 27 | 111 |
| | Austin | 40 | 8 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 5 | 18 |
| | Brownsville | 36 | 1 | — | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 2 |
| | Corpus Christi | 38 | 3 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | — | — | 1 | 5 |
| | Dallas-Fort Worth | 39 | 14 | 8 | 3 | — | 0 | 0 | 0 | 0 | 0 | — | 3 | 10 | 37 |
| | Del Rio | 39 | 6 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 5 | 16 |
| | El Paso | 42 | 18 | 11 | 5 | 1 | — | 0 | 0 | 0 | 0 | — | 7 | 18 | 59 |
| | Galveston | 42 | 2 | 1 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 3 |
| | Houston | 33 | 7 | 4 | 1 | — | 0 | 0 | 0 | 0 | 0 | — | 1 | 5 | 18 |
| | Lubbock | 55 | 25 | 18 | 11 | 2 | — | 0 | 0 | 0 | 0 | 1 | 11 | 24 | 92 |
| | Midland-Odessa | 39 | 20 | 13 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | — | 7 | 18 | 63 |
| | Port Arthur | 42 | 6 | 3 | 1 | — | 0 | 0 | 0 | 0 | 0 | — | 1 | 4 | 14 |
| | San Angelo | 42 | 17 | 10 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | — | 5 | 14 | 51 |
| | San Antonio | 60 | 8 | 4 | 2 | — | 0 | 0 | 0 | 0 | 0 | — | 2 | 6 | 21 |
| | Victoria | 41 | 5 | 2 | — | 0 | 0 | 0 | 0 | 0 | 0 | — | 1 | 3 | 10 |
| | Waco | 39 | 12 | 7 | 2 | — | 0 | 0 | 0 | 0 | 0 | — | 3 | 9 | 33 |
| | Wichita Falls | 42 | 21 | 13 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | — | 6 | 17 | 64 |
| UT | Milford | 39 | 30 | 26 | 27 | 18 | 6 | 1 | 0 | 0 | 3 | 15 | 26 | 30 | 180 |
| | Salt Lake City | 43 | 27 | 22 | 15 | 6 | 1 | 0 | 0 | 0 | — | 4 | 18 | 27 | 122 |
| VT | Burlington | 38 | 30 | 26 | 26 | 15 | 2 | 0 | 0 | 0 | 1 | 8 | 18 | 28 | 154 |
| VA | Lynchburg | 39 | 23 | 20 | 12 | 3 | — | 0 | 0 | 0 | 0 | 3 | 11 | 20 | 92 |
| | Norfolk | 54 | 16 | 13 | 6 | — | 0 | 0 | 0 | 0 | 0 | — | 3 | 13 | 51 |
| | Richmond | 73 | 21 | 19 | 10 | 2 | — | 0 | 0 | 0 | 0 | 2 | 10 | 20 | 83 |

*(Continued)*



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**Table 3A.4 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Roanoke | 38 | 23 | 19 | 12 | 2 | — | 0 | 0 | 0 | 0 | 2 | 10 | 19 | 88 |
| | Wallops Island | 28 | 21 | 17 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | — | 6 | 17 | 72 |
| | Olympia | 43 | 15 | 14 | 14 | 8 | 2 | — | 0 | 0 | 1 | 5 | 10 | 15 | 84 |
| WA | Quillayute | 36 | 13 | 10 | 9 | 6 | — | 0 | 0 | 0 | — | 3 | 7 | 12 | 61 |
| | Seattle CO | 48 | 7 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | — | 2 | 5 | 19 |
| | Seattle Sea-Tac AP | 43 | 9 | 6 | 3 | — | 0 | 0 | 0 | 0 | 0 | — | 3 | 8 | 29 |
| | Spokane | 43 | 26 | 23 | 21 | 10 | 2 | 0 | 0 | 0 | 1 | 10 | 20 | 27 | 139 |
| | Walla Walla | 43 | 19 | 14 | 6 | 0 | 0 | 0 | 0 | 0 | — | 2 | 9 | 22 | 73 |
| | Yakima | 56 | 28 | 24 | 21 | 12 | 3 | — | 0 | 0 | 1 | 12 | 22 | 28 | 149 |
| PR | San Juan | 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WV | Beckley | 39 | 25 | 21 | 17 | 7 | 1 | — | 0 | 0 | — | 5 | 14 | 22 | 112 |
| | Charleston | 55 | 23 | 20 | 15 | 5 | — | 0 | 0 | 0 | 0 | 3 | 13 | 21 | 99 |
| | Elkins | 58 | 26 | 24 | 22 | 12 | 3 | — | — | 0 | 1 | 11 | 20 | 26 | 144 |
| | Huntington | 41 | 23 | 20 | 13 | 4 | — | 0 | 0 | 0 | — | 3 | 11 | 20 | 95 |
| WI | Green Bay | 41 | 31 | 27 | 27 | 14 | 2 | 0 | 0 | 0 | 1 | 9 | 22 | 29 | 161 |
| | La Crosse | 50 | 30 | 27 | 25 | 9 | 1 | 0 | 0 | 0 | — | 6 | 21 | 29 | 149 |
| | Madison | 43 | 30 | 27 | 26 | 13 | 3 | — | 0 | 0 | 1 | 9 | 21 | 29 | 159 |
| | Milwaukee | 42 | 29 | 26 | 23 | 9 | 1 | 0 | 0 | 0 | — | 4 | 17 | 27 | 136 |
| WY | Casper | 38 | 29 | 26 | 27 | 19 | 7 | — | — | 0 | 4 | 16 | 25 | 29 | 181 |
| | Cheyenne | 43 | 29 | 26 | 27 | 18 | 4 | 0 | 0 | 0 | 2 | 13 | 24 | 29 | 172 |
| | Lander | 56 | 31 | 28 | 28 | 18 | 5 | — | 0 | 0 | 3 | 14 | 28 | 31 | 184 |
| | Sheridan | 38 | 30 | 27 | 27 | 18 | 5 | — | 0 | 0 | 3 | 16 | 28 | 30 | 186 |

The mean number of days with a minimum temperature of 32°F or lower indicates the frequency of occurrence of days with freezing temperatures.
The annual value is the total of the unrounded monthly values, it may not agree with the sum of the rounded monthly values.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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**Table 3A.5 Mean Number of Days with Maximum Temperature 90° F or More — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham | 11 | 0 | 0 | 0 | — | 1 | 10 | 18 | 17 | 5 | 0 | 0 | 0 | 52 |
| | Birmingham AP | 39 | 0 | 0 | 0 | — | 2 | 11 | 18 | 16 | 7 | — | 0 | 0 | 54 |
| | Huntsville | 35 | 0 | 0 | 0 | — | 1 | 9 | 17 | 15 | 6 | — | 0 | 0 | 48 |
| | Mobile | 40 | 0 | 0 | 0 | — | 4 | 16 | 22 | 21 | 10 | 1 | 0 | 0 | 74 |
| | Montgomery | 39 | 0 | 0 | 0 | — | 4 | 17 | 22 | 21 | 12 | 1 | 0 | 0 | 78 |
| AK | Anchorage | 38 | 0 | 0 | 0 | 0 | 1 | 4 | 6 | 3 | — | 0 | 0 | 0 | 14 |
| | Annette | 42 | 0 | 0 | 0 | — | 2 | 4 | 6 | 6 | 2 | — | 0 | 0 | 19 |
| | Barrow | 29 | 0 | 0 | 0 | 0 | 0 | — | 1 | — | 0 | 0 | 0 | 0 | 1 |
| | Barter IS | 41 | 0 | 0 | 0 | 0 | 0 | 0 | — | — | 0 | 0 | 0 | 0 | 0 |
| | Bethel | 44 | 0 | 0 | 0 | 0 | 1 | 3 | 6 | 2 | — | 0 | 0 | 0 | 12 |
| | Bettles | 50 | 0 | 0 | 0 | 0 | 1 | 13 | 16 | 5 | — | 0 | 0 | 0 | 36 |
| | Big Delta | 58 | 0 | 0 | 0 | — | 2 | 11 | 15 | 8 | 1 | 0 | 0 | 0 | 37 |
| | Cold Bay | 58 | 0 | 0 | 0 | 0 | 0 | — | — | — | — | 0 | 0 | 0 | 0 |
| | Fairbanks | 39 | 0 | 0 | 0 | — | 4 | 17 | 21 | 10 | 1 | 0 | 0 | 0 | 54 |
| | Gulkana | 54 | 0 | 0 | 0 | 0 | 1 | 9 | 13 | 7 | — | 0 | 0 | 0 | 30 |
| | Homer | 62 | 0 | 0 | 0 | 0 | — | — | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| | Juneau | 58 | 0 | 0 | 0 | — | 1 | 5 | 7 | 6 | — | 0 | 0 | 0 | 19 |
| | King Salmon | 39 | 0 | 0 | 0 | 0 | 1 | 3 | 6 | 4 | — | 0 | 0 | 0 | 13 |
| | Kodiak | 40 | 0 | 0 | 0 | 0 | — | 1 | 2 | 3 | — | 0 | 0 | 0 | 7 |
| | Kotzebue | 59 | 0 | 0 | 0 | 0 | — | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 4 |
| | Mcgrath | 60 | 0 | 0 | 0 | 0 | 2 | 11 | 14 | 6 | — | 0 | 0 | 0 | 32 |
| | Nome | 36 | 0 | 0 | 0 | 0 | — | 2 | 3 | 1 | — | 0 | 0 | 0 | 6 |
| | St. Paul Island | 85 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Talkeetna | 62 | 0 | 0 | 0 | 0 | 2 | 10 | 13 | 7 | — | 0 | 0 | 0 | 32 |
| | Unalakleet | 30 | 0 | 0 | 0 | 0 | — | 1 | 3 | 2 | — | 0 | 0 | 0 | 6 |
| | Valdez | 30 | 0 | 0 | 0 | 0 | — | 2 | 4 | 3 | — | 0 | 0 | 0 | 9 |
| | Yakutat | 38 | 0 | 0 | 0 | — | — | 1 | 1 | 1 | — | 0 | 0 | 0 | 3 |
| AZ | Flagstaff | 53 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | — | — | 0 | 0 | 0 | 3 |
| | Phoenix | 42 | 0 | — | 2 | 10 | 23 | 29 | 31 | 31 | 28 | 15 | — | 0 | 168 |
| | Tucson | 62 | 0 | — | 0 | 5 | 18 | 28 | 29 | 29 | 24 | 9 | — | 0 | 144 |
| | Winslow | 42 | 0 | 0 | 0 | — | 3 | 17 | 24 | 19 | 5 | — | 0 | 0 | 68 |
| | Yuma | 31 | 0 | — | 3 | 12 | 23 | 29 | 31 | 31 | 28 | 18 | 1 | 0 | 175 |
| AR | Fort Smith | 38 | 0 | 0 | — | 1 | 2 | 13 | 23 | 22 | 10 | 1 | 0 | 0 | 72 |
| | Little Rock | 42 | 0 | 0 | — | — | 3 | 16 | 23 | 21 | 9 | 1 | 0 | 0 | 73 |
| | North Little Rock | 24 | 0 | 0 | 0 | — | 2 | 13 | 22 | 21 | 8 | — | 0 | 0 | 67 |
| CA | Bakersfield | 39 | 0 | 0 | — | 2 | 10 | 19 | 28 | 26 | 17 | 5 | — | 0 | 108 |
| | Bishop | 55 | 0 | 0 | 0 | — | 5 | 19 | 29 | 27 | 14 | 1 | 0 | 0 | 95 |
| | Blue Canyon | 55 | 0 | 0 | 0 | 0 | 0 | — | — | 0 | — | 0 | 0 | 0 | 0 |
| | Eureka | 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Fresno | 39 | 0 | 0 | — | 2 | 10 | 19 | 28 | 27 | 18 | 4 | 0 | 0 | 108 |
| | Long Beach | 42 | — | — | — | 1 | 1 | 2 | 3 | 5 | 6 | 3 | 1 | 0 | 22 |
| | Los Angeles AP | 43 | 0 | — | — | — | — | — | — | — | 1 | 1 | — | — | 3 |
| | Los Angeles CO | 62 | — | — | — | 1 | 1 | 1 | 4 | 5 | 6 | 3 | 1 | — | 22 |

*(Continued)*



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**Table 3A.5 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mount Shasta | 42 | 0 | 0 | 0 | 0 | — | 2 | 9 | 7 | 3 | — | 0 | 0 | 21 |
| | Redding | 16 | 0 | 0 | 0 | 1 | 7 | 16 | 28 | 25 | 18 | 5 | 0 | 0 | 100 |
| | Sacramento | 52 | 0 | 0 | 0 | — | 5 | 12 | 22 | 19 | 13 | 3 | 0 | 0 | 74 |
| | San Diego | 42 | 0 | — | — | — | — | — | — | — | 1 | 1 | — | 0 | 2 |
| | San Francisco AP | 43 | 0 | 0 | 0 | — | — | 1 | 1 | — | 1 | — | 0 | 0 | 3 |
| | San Francisco CO | 65 | 0 | 0 | 0 | — | — | — | — | — | 1 | — | 0 | 0 | 1 |
| | Santa Barbara | 66 | 0 | 0 | — | — | — | — | 0 | — | 1 | 1 | — | 0 | 2 |
| | Santa Maria | 39 | 0 | 0 | — | — | — | 1 | — | — | 1 | 1 | — | 0 | 3 |
| | Stockton | 43 | 0 | 0 | 0 | 1 | 7 | 14 | 23 | 21 | 14 | 3 | 0 | 0 | 83 |
| CO | Alamosa | 57 | 0 | 0 | 0 | 0 | 0 | — | 1 | — | 0 | 0 | 0 | 0 | 1 |
| | Colorado Springs | 42 | 0 | 0 | 0 | 0 | — | 4 | 9 | 3 | 1 | 0 | 0 | 0 | 16 |
| | Denver | 35 | 0 | 0 | 0 | — | — | 7 | 15 | 10 | 2 | 0 | 0 | 0 | 34 |
| | Grand Junction | 39 | 0 | 0 | 0 | 0 | 1 | 15 | 25 | 19 | 4 | 0 | 0 | 0 | 64 |
| | Pueblo | 37 | 0 | 0 | 0 | — | 3 | 15 | 23 | 18 | 7 | — | 0 | 0 | 65 |
| CT | Bridgeport | 37 | 0 | 0 | 0 | — | — | 1 | 3 | 2 | — | 0 | 0 | 0 | 6 |
| | Hartford | 43 | 0 | 0 | 0 | — | 1 | 4 | 7 | 5 | 1 | — | 0 | 0 | 18 |
| DE | Wilmington | 55 | 0 | 0 | 0 | — | 1 | 4 | 8 | 5 | 2 | — | 0 | 0 | 20 |
| DC | Washington Dulles AP | 40 | 0 | 0 | 0 | — | 1 | 5 | 11 | 9 | 3 | — | 0 | 0 | 29 |
| | Washington Nat'l AP | 42 | 0 | 0 | 0 | — | 2 | 7 | 14 | 10 | 4 | — | 0 | 0 | 37 |
| FL | Apalachicola | 42 | 0 | 0 | 0 | — | 1 | 6 | 8 | 8 | 4 | — | 0 | 0 | 26 |
| | Daytona Beach | 59 | 0 | 0 | — | 2 | 6 | 11 | 17 | 14 | 6 | 1 | 0 | 0 | 57 |
| | Fort Myers | 59 | 0 | — | 0 | 3 | 14 | 20 | 25 | 25 | 19 | 6 | — | — | 113 |
| | Gainesville | 19 | 0 | 0 | 0 | 2 | 10 | 17 | 22 | 20 | 10 | 1 | 0 | 0 | 81 |
| | Jacksonville | 61 | 0 | 0 | — | 1 | 8 | 16 | 24 | 21 | 10 | 1 | 0 | 0 | 81 |
| | Key West | 54 | 0 | 0 | 0 | — | 1 | 7 | 16 | 17 | 8 | 1 | 0 | 0 | 48 |
| | Miami | 38 | 0 | 0 | — | 2 | 4 | 10 | 17 | 17 | 10 | 2 | 0 | 0 | 62 |
| | Orlando | 39 | 0 | 0 | — | 4 | 12 | 19 | 25 | 25 | 18 | 3 | 0 | — | 106 |
| | Pensacola | 39 | 0 | 0 | 0 | — | 2 | 13 | 18 | 16 | 9 | — | 0 | 0 | 59 |
| | Tallahassee | 41 | 0 | 0 | — | 1 | 9 | 19 | 23 | 22 | 15 | 2 | 0 | 0 | 92 |
| | Tampa | 39 | 0 | 0 | 0 | 1 | 9 | 17 | 21 | 22 | 16 | 3 | — | 0 | 87 |
| | Vero Beach | 19 | 0 | 0 | — | 1 | 4 | 10 | 17 | 18 | 10 | 2 | — | 0 | 63 |
| | West Palm Beach | 38 | 0 | 0 | — | 2 | 4 | 10 | 18 | 19 | 10 | 2 | — | 0 | 65 |
| GA | Athens | 59 | 0 | 0 | 0 | — | 3 | 11 | 17 | 14 | 5 | — | 0 | 0 | 51 |
| | Atlanta | 42 | 0 | 0 | 0 | — | 1 | 8 | 13 | 10 | 3 | 0 | 0 | 0 | 36 |
| | Augusta | 38 | 0 | 0 | 0 | 1 | 6 | 15 | 23 | 19 | 9 | 1 | 0 | 0 | 74 |
| | Columbus | 57 | 0 | 0 | 0 | — | 6 | 17 | 22 | 21 | 10 | 1 | 0 | 0 | 76 |
| | Macon | 38 | 0 | 0 | — | 1 | 6 | 17 | 23 | 21 | 10 | 1 | 0 | 0 | 80 |
| | Savannah | 38 | 0 | 0 | — | 1 | 6 | 14 | 22 | 18 | 7 | 1 | 0 | 0 | 70 |
| HI | Hilo | 57 | — | — | — | 0 | — | — | 0 | — | — | — | — | — | 0 |
| | Honolulu | 33 | 0 | 0 | 0 | 0 | — | 2 | 5 | 11 | 10 | 4 | 0 | 0 | 33 |
| | Kahului | 38 | 0 | 0 | — | — | 1 | 2 | 3 | 6 | 7 | 5 | 1 | — | 25 |
| | Lihue | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | — | — | 0 | 0 | 0 |
| ID | Boise | 63 | 0 | 0 | 0 | — | 1 | 5 | 19 | 16 | 4 | — | 0 | 0 | 45 |
| | Lewiston | 56 | 0 | 0 | 0 | — | 1 | 4 | 16 | 14 | 4 | 0 | 0 | 0 | 40 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pocatello | 39 | 0 | 0 | 0 | 0 | 0 | 4 | 14 | 13 | 2 | — | 0 | 0 | 34 |
| IL | Cairo | 45 | 0 | 0 | 0 | — | 2 | 11 | 17 | 13 | 4 | — | 0 | 0 | 48 |
| | Chicago | 44 | 0 | 0 | 0 | — | 1 | 4 | 7 | 4 | 2 | — | 0 | 0 | 17 |
| | Moline | 42 | 0 | 0 | 0 | — | 1 | 6 | 9 | 6 | 2 | — | 0 | 0 | 23 |
| | Peoria | 43 | 0 | 0 | 0 | — | — | 5 | 8 | 5 | 2 | — | 0 | 0 | 20 |
| | Rockford | 39 | 0 | 0 | 0 | — | 0 | 3 | 6 | 3 | 1 | — | 0 | 0 | 14 |
| | Springfield | 43 | 0 | 0 | 0 | — | 1 | 7 | 10 | 6 | 3 | — | 0 | 0 | 28 |
| IN | Evansville | 41 | 0 | 0 | 0 | — | 2 | 9 | 15 | 11 | 4 | — | 0 | 0 | 41 |
| | Fort Wayne | 41 | 0 | 0 | 0 | 0 | 1 | 4 | 6 | 4 | 1 | 0 | 0 | 0 | 15 |
| | Indianapolis | 43 | 0 | 0 | 0 | 0 | 0 | 4 | 7 | 5 | 2 | 0 | 0 | 0 | 18 |
| | South Bend | 39 | 0 | 0 | 0 | 0 | 1 | 3 | 5 | 3 | 1 | 0 | 0 | 0 | 13 |
| IA | Des Moines | 41 | 0 | 0 | — | — | — | 4 | 9 | 6 | 2 | — | 0 | 0 | 22 |
| | Dubuque | 35 | 0 | 0 | 0 | — | — | 1 | 4 | 2 | 1 | 0 | 0 | 0 | 8 |
| | Sioux City | 43 | 0 | 0 | — | 0 | 1 | 6 | 9 | 6 | 2 | — | 0 | 0 | 24 |
| | Waterloo | 43 | 0 | 0 | 0 | — | 1 | 4 | 6 | 4 | 1 | — | 0 | 0 | 16 |
| KS | Concordia | 40 | 0 | 0 | 0 | — | 1 | 9 | 18 | 14 | 5 | 1 | 0 | 0 | 49 |
| | Dodge City | 39 | 0 | 0 | — | 1 | 3 | 13 | 22 | 19 | 8 | 1 | — | 0 | 66 |
| | Goodland | 36 | 0 | 0 | 0 | — | 1 | 9 | 17 | 14 | 6 | — | 0 | 0 | 47 |
| | Topeka | 38 | 0 | 0 | 0 | — | 1 | 7 | 16 | 14 | 5 | — | 0 | 0 | 43 |
| | Wichita | 49 | 0 | 0 | 0 | — | 2 | 12 | 21 | 19 | 8 | 1 | 0 | 0 | 63 |
| KY | Greater Cincinnati AP | 40 | 0 | 0 | 0 | 0 | — | 4 | 8 | 6 | 2 | 0 | 0 | 0 | 19 |
| | Jackson | 22 | 0 | 0 | 0 | — | — | 2 | 6 | 5 | 1 | 0 | 0 | 0 | 14 |
| | Lexington | 39 | 0 | 0 | 0 | 0 | — | 3 | 8 | 7 | 2 | 0 | 0 | 0 | 20 |
| | Louisville | 42 | 0 | 0 | 0 | — | — | 6 | 12 | 10 | 3 | 0 | 0 | 0 | 32 |
| | Paducah | 19 | 0 | 0 | 0 | — | 1 | 11 | 18 | 14 | 6 | 0 | 0 | 0 | 50 |
| LA | Baton Rouge | 43 | 0 | 0 | — | — | 6 | 19 | 24 | 22 | 12 | 2 | 0 | 0 | 84 |
| | Lake Charles | 38 | 0 | 0 | 0 | — | 2 | 14 | 23 | 23 | 12 | 1 | 0 | 0 | 75 |
| | New Orleans | 56 | 0 | 0 | 0 | — | 4 | 16 | 21 | 21 | 9 | 1 | 0 | 0 | 72 |
| | Shreveport | 50 | 0 | 0 | — | — | 4 | 18 | 26 | 25 | 14 | 2 | 0 | 0 | 90 |
| ME | Caribou | 63 | 0 | 0 | 0 | 0 | — | — | 1 | — | — | 0 | 0 | 0 | 1 |
| | Portland | 62 | 0 | 0 | 0 | 0 | — | 1 | 2 | 1 | — | 0 | 0 | 0 | 5 |
| MD | Baltimore | 52 | 0 | 0 | 0 | — | 2 | 6 | 12 | 8 | 3 | — | 0 | 0 | 30 |
| MA | Blue Hill | 117 | 0 | 0 | 0 | — | — | 1 | 3 | 2 | — | 0 | 0 | 0 | 5 |
| | Boston | 38 | 0 | 0 | 0 | — | — | 3 | 6 | 3 | 1 | 0 | 0 | 0 | 13 |
| | Worcester | 47 | 0 | 0 | 0 | — | — | 1 | 2 | 1 | — | 0 | 0 | 0 | 3 |
| MI | Alpena | 43 | 0 | 0 | 0 | — | — | 2 | 3 | 1 | — | 0 | 0 | 0 | 6 |
| | Detroit | 44 | 0 | 0 | 0 | 0 | — | 3 | 5 | 3 | 1 | — | 0 | 0 | 12 |
| | Flint | 39 | 0 | 0 | 0 | 0 | — | 2 | 3 | 2 | — | 0 | 0 | 0 | 7 |
| | Grand Rapids | 39 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 2 | — | 0 | 0 | 0 | 10 |
| | Houghton Lake | 38 | 0 | 0 | 0 | 0 | — | 1 | 2 | 1 | — | 0 | 0 | 0 | 3 |
| | Lansing | 39 | 0 | 0 | 0 | 0 | — | 2 | 4 | 2 | 1 | 0 | 0 | 0 | 10 |
| | Marquette | 24 | 0 | 0 | 0 | — | — | 1 | 2 | 1 | — | 0 | 0 | 0 | 3 |
| | Muskegon | 42 | 0 | 0 | 0 | 0 | — | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| | Sault Ste. Marie | 61 | 0 | 0 | 0 | 0 | 0 | — | 1 | 1 | — | 0 | 0 | 0 | 1 |
| MN | Duluth | 41 | 0 | 0 | 0 | 0 | — | — | 1 | 1 | — | 0 | 0 | 0 | 2 |
| | International Falls | 63 | 0 | 0 | 0 | — | — | 1 | 2 | 1 | — | 0 | 0 | 0 | 4 |

*(Continued)*



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**Table 3A.5 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minneapolis-St. Paul | 43 | 0 | 0 | 0 | — | 1 | 3 | 6 | 3 | 1 | 0 | 0 | 0 | 14 |
| | Rochester | 42 | 0 | 0 | 0 | — | — | 2 | 3 | 1 | — | 0 | 0 | 0 | 6 |
| | Saint Cloud | 62 | 0 | 0 | 0 | — | — | 2 | 4 | 3 | 1 | — | 0 | 0 | 10 |
| MS | Jackson | 39 | 0 | 0 | 0 | — | 5 | 18 | 24 | 23 | 12 | 1 | 0 | 0 | 82 |
| | Meridian | 38 | 0 | 0 | — | — | 4 | 16 | 24 | 23 | 12 | 1 | 0 | 0 | 81 |
| | Tupelo | 19 | 0 | 0 | 0 | — | 2 | 13 | 22 | 20 | 9 | — | 0 | 0 | 66 |
| MO | Columbia | 33 | 0 | 0 | 0 | — | — | 5 | 14 | 12 | 4 | — | 0 | 0 | 35 |
| | Kansas City | 30 | 0 | 0 | 0 | — | — | 6 | 15 | 12 | 4 | — | 0 | 0 | 36 |
| | St. Louis | 42 | 0 | 0 | 0 | — | 1 | 8 | 15 | 12 | 4 | — | 0 | 0 | 41 |
| | Springfield | 42 | 0 | 0 | 0 | — | — | 6 | 16 | 15 | 4 | — | 0 | 0 | 40 |
| MT | Billings | 43 | 0 | 0 | 0 | — | — | 4 | 12 | 11 | 2 | — | 0 | 0 | 29 |
| | Glasgow | 38 | 0 | 0 | 0 | — | 1 | 3 | 9 | 9 | 2 | — | 0 | 0 | 23 |
| | Great Falls | 41 | 0 | 0 | 0 | 0 | — | 2 | 8 | 8 | 1 | — | 0 | 0 | 19 |
| | Helena | 39 | 0 | 0 | 0 | 0 | — | 2 | 8 | 8 | 1 | 0 | 0 | 0 | 19 |
| | Kalispell | 43 | 0 | 0 | 0 | 0 | — | 1 | 6 | 6 | — | 0 | 0 | 0 | 13 |
| | Missoula | 42 | 0 | 0 | 0 | 0 | — | 2 | 9 | 9 | 1 | 0 | 0 | 0 | 22 |
| NE | Grand Island | 41 | 0 | 0 | — | 1 | 2 | 8 | 14 | 11 | 4 | — | 0 | 0 | 39 |
| | Lincoln | 31 | 0 | 0 | 0 | 0 | 1 | 9 | 15 | 12 | 4 | — | 0 | 0 | 42 |
| | Norfolk | 57 | 0 | 0 | 0 | 1 | 1 | 7 | 12 | 9 | 3 | — | 0 | 0 | 33 |
| | North Platte | 38 | 0 | 0 | 0 | — | 1 | 6 | 13 | 11 | 4 | — | 0 | 0 | 35 |
| | Omaha Eppley AP | 38 | 0 | 0 | 0 | 0 | 2 | 7 | 13 | 8 | 3 | — | 0 | 0 | 33 |
| | Omaha (North) | 39 | 0 | 0 | 0 | — | 1 | 5 | 9 | 7 | 2 | — | 0 | 0 | 24 |
| | Scottsbluff | 38 | 0 | 0 | 0 | — | 1 | 8 | 16 | 13 | 5 | — | 0 | 0 | 43 |
| | Valentine | 47 | 0 | 0 | 0 | — | 1 | 7 | 14 | 13 | 5 | 1 | 0 | 0 | 41 |
| NV | Elko | 38 | 0 | 0 | 0 | 0 | — | 5 | 19 | 15 | 3 | 0 | 0 | 0 | 42 |
| | Ely | 64 | 0 | 0 | 0 | 0 | 0 | 3 | 11 | 6 | 1 | 0 | 0 | 0 | 20 |
| | Las Vegas | 42 | 0 | 0 | — | 3 | 16 | 26 | 30 | 30 | 22 | 6 | 0 | 0 | 133 |
| | Reno | 39 | 0 | 0 | 0 | 0 | 1 | 7 | 20 | 18 | 5 | — | 0 | 0 | 52 |
| | Winnemucca | 53 | 0 | 0 | 0 | — | 1 | 9 | 22 | 19 | 6 | — | 0 | 0 | 57 |
| NH | Concord | 37 | 0 | 0 | 0 | — | 1 | 2 | 5 | 3 | — | 0 | 0 | 0 | 11 |
| | Mt. Washington | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NJ | Atlantic City AP | 38 | 0 | 0 | 0 | — | 1 | 4 | 7 | 5 | 1 | 0 | 0 | 0 | 18 |
| | Atlantic City CO | 40 | 0 | 0 | 0 | — | — | 1 | 2 | 1 | — | 0 | 0 | 0 | 4 |
| | Newark | 37 | 0 | 0 | 0 | — | 2 | 5 | 9 | 7 | 1 | 0 | 0 | 0 | 24 |
| NM | Albuquerque | 42 | 0 | 0 | 0 | 0 | 3 | 17 | 23 | 16 | 4 | — | 0 | 0 | 62 |
| | Clayton | 54 | 0 | 0 | 0 | — | 1 | 9 | 14 | 9 | 3 | — | 0 | 0 | 36 |
| | Roswell | 30 | 0 | 0 | — | 2 | 10 | 22 | 25 | 23 | 11 | 2 | 0 | 0 | 94 |
| NY | Albany | 37 | 0 | 0 | 0 | — | — | 2 | 4 | 2 | — | 0 | 0 | 0 | 8 |
| | Binghamton | 51 | 0 | 0 | 0 | 0 | 0 | — | 1 | 1 | — | 0 | 0 | 0 | 2 |
| | Buffalo | 42 | 0 | 0 | 0 | — | — | 1 | 1 | 1 | — | 0 | 0 | 0 | 3 |
| | Islip | 19 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 2 | — | 0 | 0 | 0 | 7 |
| | New York C.Park | 89 | 0 | 0 | 0 | — | 1 | 3 | 7 | 5 | 1 | — | 0 | 0 | 17 |
| | New York (JFK AP) | 41 | 0 | 0 | 0 | — | — | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 10 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | New York (Laguardia AP) | 40 | 0 | 0 | 0 | — | 1 | 3 | 6 | 4 | 1 | 0 | 0 | 0 | 16 |
| | Rochester | 39 | 0 | 0 | 0 | — | — | 2 | 4 | 2 | 1 | 0 | 0 | 0 | 8 |
| | Syracuse | 39 | 0 | 0 | 0 | — | — | 2 | 4 | 2 | — | 0 | 0 | 0 | 7 |
| NC | Asheville | 38 | 0 | 0 | 0 | 0 | — | 2 | 4 | 2 | — | 0 | 0 | 0 | 8 |
| | Cape Hatteras | 45 | 0 | 0 | 0 | 0 | — | 1 | 2 | 2 | — | 0 | 0 | 0 | 5 |
| | Charlotte | 42 | 0 | 0 | 0 | — | 2 | 8 | 14 | 11 | 4 | — | 0 | 0 | 39 |
| | Greensboro-Wnstn-Slm-HPT | 39 | 0 | 0 | 0 | — | 1 | 6 | 12 | 8 | 2 | — | 0 | 0 | 29 |
| | Raleigh | 38 | 0 | 0 | — | 1 | 2 | 8 | 14 | 11 | 3 | — | 0 | 0 | 38 |
| | Wilmington | 39 | 0 | 0 | 0 | 1 | 2 | 8 | 16 | 12 | 4 | — | 0 | 0 | 44 |
| ND | Bismarck | 43 | 0 | 0 | 0 | — | 1 | 3 | 8 | 8 | 2 | — | 0 | 0 | 21 |
| | Fargo | 43 | 0 | 0 | 0 | — | 1 | 2 | 5 | 5 | 1 | — | 0 | 0 | 14 |
| | Williston | 41 | 0 | 0 | 0 | — | 1 | 3 | 8 | 9 | 2 | — | 0 | 0 | 23 |
| OH | Akron | 39 | 0 | 0 | 0 | 0 | — | 2 | 4 | 2 | — | 0 | 0 | 0 | 7 |
| | Cleveland | 42 | 0 | 0 | 0 | 0 | — | 2 | 4 | 2 | 1 | 0 | 0 | 0 | 9 |
| | Columbus | 43 | 0 | 0 | 0 | 0 | 1 | 4 | 6 | 4 | 1 | 0 | 0 | 0 | 16 |
| | Dayton | 39 | 0 | 0 | 0 | 0 | — | 4 | 7 | 4 | 1 | 0 | 0 | 0 | 16 |
| | Mansfield | 37 | 0 | 0 | 0 | 0 | — | 1 | 3 | 2 | — | 0 | 0 | 0 | 6 |
| | Toledo | 47 | 0 | 0 | 0 | 0 | 1 | 4 | 6 | 3 | 1 | — | 0 | 0 | 15 |
| | Youngstown | 59 | 0 | 0 | 0 | 0 | — | 1 | 3 | 2 | 0 | 0 | 0 | 0 | 7 |
| OK | Oklahoma City | 37 | 0 | 0 | — | — | 2 | 11 | 23 | 23 | 9 | 1 | 0 | 0 | 68 |
| | Tulsa | 42 | 0 | 0 | — | 1 | 2 | 13 | 24 | 22 | 9 | 1 | 0 | 0 | 72 |
| OR | Astoria | 49 | 0 | 0 | 0 | 0 | 0 | — | — | — | — | 0 | 0 | 0 | 0 |
| | Burns | 18 | 0 | 0 | 0 | 0 | — | 2 | 9 | 9 | 1 | 0 | 0 | 0 | 21 |
| | Eugene | 60 | 0 | 0 | 0 | 0 | — | 1 | 6 | 5 | 2 | — | 0 | 0 | 15 |
| | Medford | 41 | 0 | 0 | 0 | — | 2 | 7 | 18 | 17 | 9 | 1 | 0 | 0 | 55 |
| | Pendleton | 67 | 0 | 0 | 0 | — | 1 | 4 | 14 | 11 | 3 | — | 0 | 0 | 33 |
| | Portland | 62 | 0 | 0 | 0 | 0 | — | 1 | 4 | 4 | 2 | — | 0 | 0 | 10 |
| | Salem | 40 | 0 | 0 | 0 | 0 | — | 2 | 6 | 6 | 2 | — | 0 | 0 | 16 |
| | Sexton Summit | 40 | 0 | 0 | 0 | 0 | — | — | 1 | 1 | — | 0 | 0 | 0 | 2 |
| PC | Guam | 44 | 0 | 0 | — | — | 3 | 4 | 2 | 1 | 1 | — | — | 0 | 10 |
| | Johnston Island | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | 0 | 0 | 0 |
| | Koror | 51 | 4 | 3 | 5 | 10 | 14 | 8 | 4 | 4 | 6 | 9 | 12 | 7 | 86 |
| | Kwajalein, Marshall IS | 50 | — | — | 1 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | — | 10 |
| | Majuro, Marshall IS | 48 | 0 | 0 | 0 | 0 | — | 0 | — | — | 1 | 1 | — | — | 1 |
| | Pago Pago, Amer Samoa | 43 | 4 | 5 | 5 | 3 | — | — | 0 | — | 0 | — | 2 | 4 | 22 |
| | Pohnpei, Caroline IS | 51 | 1 | 1 | 3 | 4 | 6 | 5 | 8 | 10 | 12 | 12 | 9 | 3 | 74 |
| | Chuuk, E. Caroline IS | 51 | — | — | — | 1 | 3 | 2 | 3 | 3 | 3 | 3 | 2 | — | 21 |
| | Wake Island | 50 | 0 | 0 | — | — | 1 | 3 | 6 | 8 | 7 | 3 | — | — | 29 |
| | Yap, W Caroline IS | 54 | — | — | — | 4 | 7 | 5 | 3 | 4 | 4 | 5 | 4 | 1 | 37 |
| PA | Allentown | 59 | 0 | 0 | 0 | — | 1 | 3 | 7 | 4 | 1 | — | 0 | 0 | 16 |
| | Erie | 37 | 0 | 0 | 0 | 0 | — | 1 | 1 | 1 | — | 0 | 0 | 0 | 2 |
| | Harrisburg | 37 | 0 | 0 | 0 | — | 1 | 5 | 9 | 6 | 2 | — | 0 | 0 | 23 |

*(Continued)*



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**Table 3A.5 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Middletown/ Harrisburg AP | 64 | 0 | 0 | 0 | — | 1 | 5 | 9 | 6 | 2 | — | 0 | 0 | 23 |
| | Philadelphia | 43 | 0 | 0 | 0 | — | 1 | 5 | 9 | 7 | 2 | 0 | 0 | 0 | 24 |
| | Pittsburgh | 43 | 0 | 0 | 0 | 0 | — | 2 | 4 | 2 | 1 | 0 | 0 | 0 | 8 |
| | Avoca | 47 | 0 | 0 | 0 | — | — | 2 | 4 | 2 | — | 0 | 0 | 0 | 7 |
| | Williamsport | 58 | 0 | 0 | 0 | — | 1 | 3 | 6 | 3 | 1 | — | 0 | 0 | 14 |
| RI | Block IS | 39 | 0 | 0 | 0 | — | 0 | — | — | — | 0 | 0 | 0 | 0 | 0 |
| | Providence | 39 | 0 | 0 | 0 | — | 1 | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 10 |
| SC | Charleston AP | 60 | 0 | 0 | — | 1 | 4 | 11 | 17 | 15 | 5 | — | 0 | 0 | 53 |
| | Charleston CO | 27 | 0 | 0 | 0 | — | 1 | 6 | 13 | 10 | 3 | — | 0 | 0 | 34 |
| | Columbia | 36 | 0 | 0 | — | 2 | 6 | 16 | 23 | 18 | 8 | 1 | 0 | 0 | 73 |
| | Greenville-Spartanburg | 40 | 0 | 0 | 0 | — | 2 | 8 | 14 | 10 | 3 | — | 0 | 0 | 37 |
| SD | Aberdeen | 41 | 0 | 0 | 0 | — | — | 3 | 8 | 7 | 2 | — | 0 | 0 | 20 |
| | Huron | 43 | 0 | 0 | 0 | — | 1 | 4 | 11 | 9 | 3 | — | 0 | 0 | 28 |
| | Rapid City | 60 | 0 | 0 | 0 | — | 0 | 3 | 11 | 12 | 4 | — | 0 | 0 | 31 |
| | Sioux Falls | 39 | 0 | 0 | 0 | — | 1 | 4 | 10 | 6 | 2 | 0 | 0 | 0 | 22 |
| TN | Bristol-JhnCty-Kgsprt | 41 | 0 | 0 | 0 | 0 | — | 3 | 6 | 4 | 2 | 0 | 0 | 0 | 14 |
| | Chattanooga | 62 | 0 | 0 | 0 | — | 2 | 10 | 17 | 15 | 5 | — | 0 | 0 | 49 |
| | Knoxville | 42 | 0 | 0 | 0 | — | 1 | 5 | 11 | 9 | 3 | 0 | 0 | 0 | 29 |
| | Memphis | 61 | 0 | 0 | 0 | — | 3 | 14 | 22 | 19 | 8 | 1 | 0 | 0 | 67 |
| | Nashville | 37 | 0 | 0 | 0 | — | 1 | 9 | 17 | 13 | 5 | — | 0 | 0 | 45 |
| | Oak Ridge | 37 | 0 | 0 | 0 | — | 1 | 7 | 13 | 10 | 4 | — | 0 | 0 | 35 |
| TX | Abilene | 39 | 0 | 0 | 1 | 3 | 8 | 19 | 26 | 25 | 12 | 2 | — | 0 | 96 |
| | Amarillo | 41 | 0 | 0 | — | 1 | 5 | 13 | 21 | 17 | 7 | 1 | 0 | 0 | 65 |
| | Austin | 41 | — | — | 1 | 2 | 7 | 21 | 28 | 28 | 17 | 4 | 0 | 0 | 109 |
| | Brownsville | 36 | — | — | 1 | 4 | 12 | 24 | 28 | 28 | 19 | 6 | — | — | 122 |
| | Corpus Christi | 38 | — | — | 1 | 2 | 5 | 20 | 28 | 27 | 18 | 5 | — | — | 106 |
| | Dallas-Fort Worth | 39 | 0 | 0 | — | 1 | 5 | 20 | 28 | 27 | 14 | 3 | 0 | 0 | 97 |
| | Del Rio | 39 | 0 | — | 2 | 7 | 15 | 25 | 28 | 28 | 20 | 5 | — | — | 130 |
| | El Paso | 42 | 0 | 0 | 0 | 2 | 14 | 26 | 27 | 24 | 13 | 2 | 0 | 0 | 108 |
| | Galveston | 42 | 0 | 0 | 0 | — | — | 1 | 4 | 5 | 2 | — | 0 | 0 | 12 |
| | Houston | 33 | 0 | — | — | 1 | 6 | 20 | 27 | 26 | 16 | 3 | 0 | 0 | 99 |
| | Lubbock | 55 | 0 | 0 | — | 2 | 9 | 18 | 23 | 20 | 9 | 1 | 0 | 0 | 81 |
| | Midland-Odessa | 39 | 0 | — | — | 4 | 12 | 21 | 26 | 23 | 11 | 2 | 0 | 0 | 101 |
| | Port Arthur | 42 | 0 | 0 | 0 | — | 2 | 17 | 24 | 24 | 13 | 2 | 0 | 0 | 83 |
| | San Angelo | 42 | — | — | 1 | 5 | 12 | 21 | 27 | 26 | 13 | 3 | — | 0 | 109 |
| | San Antonio | 60 | 0 | — | 1 | 2 | 9 | 22 | 28 | 28 | 18 | 4 | — | — | 113 |
| | Victoria | 41 | 0 | — | — | 1 | 6 | 20 | 28 | 28 | 18 | 5 | — | 0 | 106 |
| | Waco | 39 | 0 | — | — | 1 | 7 | 22 | 29 | 28 | 17 | 4 | — | 0 | 109 |
| | Wichita Falls | 42 | 0 | — | 1 | 2 | 8 | 20 | 28 | 27 | 14 | 4 | 0 | 0 | 104 |
| UT | Milford | 39 | 0 | 0 | 0 | 0 | 1 | 10 | 24 | 18 | 5 | — | 0 | 0 | 57 |
| | Salt Lake City | 43 | 0 | 0 | 0 | 0 | 1 | 9 | 23 | 20 | 4 | 0 | 0 | 0 | 57 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VT | Burlington | 38 | 0 | 0 | 0 | — | 0 | 1 | 3 | 1 | — | 0 | 0 | 0 | 6 |
| VA | Lynchburg | 39 | 0 | 0 | 0 | — | 1 | 4 | 9 | 7 | 2 | — | 0 | 0 | 23 |
| | Norfolk | 54 | 0 | 0 | 0 | 0 | 2 | 7 | 12 | 9 | 3 | — | 0 | 0 | 33 |
| | Richmond | 73 | 0 | 0 | — | 1 | 3 | 9 | 14 | 11 | 4 | — | 0 | 0 | 42 |
| | Roanoke | 38 | 0 | 0 | 0 | — | 1 | 5 | 11 | 8 | 2 | 0 | 0 | 0 | 27 |
| | Wallops Island | 28 | 0 | 0 | 0 | — | 1 | 3 | 7 | 4 | 1 | 0 | 0 | 0 | 15 |
| WA | Olympia | 43 | 0 | 0 | 0 | 0 | — | 1 | 2 | 2 | 1 | — | 0 | 0 | 6 |
| | Quillayute | 36 | 0 | 0 | 0 | 0 | — | — | — | — | — | 0 | 0 | 0 | 0 |
| | Seattle CO | 48 | 0 | 0 | 0 | 0 | — | — | 1 | — | — | 0 | 0 | 0 | 1 |
| | Seattle Sea-Tac AP | 43 | 0 | 0 | 0 | 0 | — | — | 1 | 1 | — | 0 | 0 | 0 | 2 |
| | Spokane | 43 | 0 | 0 | 0 | — | — | 2 | 8 | 7 | 1 | 0 | 0 | 0 | 19 |
| | Walla Walla | 43 | 0 | 0 | 0 | 0 | 2 | 7 | 16 | 15 | 4 | 0 | 0 | 0 | 44 |
| | Yakima | 56 | 0 | 0 | 0 | — | 1 | 4 | 14 | 11 | 2 | 0 | 0 | 0 | 33 |
| PR | San Juan | 47 | — | 1 | 2 | 3 | 6 | 9 | 8 | 10 | 11 | 9 | 2 | 1 | 62 |
| WV | Beckley | 39 | 0 | 0 | 0 | 0 | 0 | — | 0 | — | 0 | 0 | 0 | 0 | 1 |
| | Charleston | 55 | 0 | 0 | 0 | — | 1 | 5 | 8 | 5 | 2 | — | 0 | 0 | 21 |
| | Elkins | 58 | 0 | 0 | 0 | 0 | — | — | 1 | 1 | — | 0 | 0 | 0 | 2 |
| | Huntington | 41 | 0 | 0 | 0 | — | 1 | 4 | 8 | 6 | 2 | 0 | 0 | 0 | 21 |
| WI | Green Bay | 41 | 0 | 0 | 0 | 0 | — | 2 | 3 | 1 | — | 0 | 0 | 0 | 6 |
| | La Crosse | 49 | 0 | 0 | 0 | — | 1 | 4 | 7 | 4 | 1 | — | 0 | 0 | 17 |
| | Madison | 43 | 0 | 0 | 0 | — | — | 3 | 5 | 3 | 1 | — | 0 | 0 | 11 |
| | Milwaukee | 42 | 0 | 0 | 0 | — | — | 2 | 4 | 2 | 1 | 0 | 0 | 0 | 9 |
| WY | Casper | 38 | 0 | 0 | 0 | 0 | — | 5 | 13 | 11 | 2 | 0 | 0 | 0 | 31 |
| | Cheyenne | 43 | 0 | 0 | 0 | 0 | — | 1 | 6 | 3 | — | 0 | 0 | 0 | 10 |
| | Lander | 56 | 0 | 0 | 0 | 0 | — | 3 | 11 | 7 | 1 | 0 | 0 | 0 | 21 |
| | Sheridan | 38 | 0 | 0 | 0 | 0 | — | 3 | 11 | 11 | 3 | — | 0 | 0 | 28 |

*Note:* Through 2002. For Alaska, the reported values are 70° F. The annual value is the total of the unrounded monthly values, it may not agree with the sum of the rounded monthly values.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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**Table 3A.6 Normal Monthly Heating Degree Days — Selected Cities of the United States**

| State | Station | Years | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham AP | 30 | 0 | 0 | 11 | 133 | 359 | 590 | 691 | 514 | 339 | 154 | 31 | 1 | 2823 |
| | Huntsville | 30 | 0 | 0 | 18 | 165 | 417 | 669 | 780 | 587 | 404 | 180 | 41 | 1 | 3262 |
| | Mobile | 30 | 0 | 0 | 2 | 51 | 204 | 387 | 455 | 326 | 182 | 57 | 3 | 0 | 1667 |
| | Montgomery | 30 | 0 | 0 | 3 | 84 | 278 | 487 | 568 | 415 | 250 | 98 | 9 | 0 | 2192 |
| AK | Anchorage | 30 | 206 | 268 | 505 | 957 | 1297 | 1472 | 1526 | 1295 | 1212 | 861 | 560 | 311 | 10470 |
| | Annette | 30 | 215 | 206 | 337 | 572 | 760 | 885 | 928 | 781 | 791 | 637 | 484 | 321 | 6917 |
| | Barrow | 30 | 763 | 815 | 1016 | 1564 | 1978 | 2346 | 2440 | 2267 | 2443 | 1967 | 1391 | 903 | 19893 |
| | Bethel | 30 | 280 | 355 | 587 | 1085 | 1428 | 1724 | 1813 | 1608 | 1566 | 1175 | 738 | 410 | 12769 |
| | Bettles | 30 | 170 | 366 | 721 | 1437 | 1975 | 2245 | 2365 | 2041 | 1888 | 1280 | 642 | 227 | 15357 |
| | Big Delta | 30 | 144 | 308 | 620 | 1270 | 1761 | 2016 | 2097 | 1759 | 1576 | 987 | 536 | 228 | 13302 |
| | Cold Bay | 30 | 447 | 409 | 518 | 774 | 915 | 1054 | 1142 | 1048 | 1085 | 945 | 780 | 573 | 9690 |
| | Fairbanks | 30 | 121 | 283 | 615 | 1287 | 1882 | 2199 | 2315 | 1926 | 1670 | 999 | 504 | 179 | 13980 |
| | Gulkana | 30 | 250 | 370 | 658 | 1199 | 1786 | 2064 | 2163 | 1733 | 1543 | 1018 | 655 | 358 | 13797 |
| | Homer | 30 | 338 | 349 | 514 | 844 | 1069 | 1215 | 1290 | 1125 | 1103 | 860 | 663 | 451 | 9821 |
| | Juneau | 30 | 257 | 288 | 453 | 704 | 953 | 1125 | 1219 | 1010 | 973 | 728 | 529 | 335 | 8574 |
| | King Salmon | 30 | 290 | 317 | 521 | 984 | 1254 | 1481 | 1538 | 1384 | 1286 | 957 | 667 | 425 | 11104 |
| | Kodiak | 30 | 339 | 310 | 468 | 766 | 931 | 1067 | 1096 | 983 | 1007 | 833 | 667 | 474 | 8941 |
| | Kotzebue | 30 | 327 | 407 | 696 | 1297 | 1703 | 2022 | 2092 | 1918 | 2023 | 1606 | 1037 | 607 | 15735 |
| | Mcgrath | 30 | 174 | 318 | 611 | 1233 | 1779 | 2132 | 2223 | 1847 | 1653 | 1078 | 583 | 256 | 13887 |
| | Nome | 30 | 387 | 446 | 664 | 1134 | 1444 | 1756 | 1836 | 1663 | 1727 | 1361 | 867 | 533 | 13818 |
| | St. Paul Island | 30 | 569 | 518 | 603 | 828 | 957 | 1122 | 1220 | 1174 | 1267 | 1097 | 911 | 693 | 10959 |
| | Talkeetna | 30 | 193 | 294 | 563 | 1043 | 1425 | 1613 | 1676 | 1391 | 1317 | 923 | 596 | 293 | 11327 |
| | Unalakleet | 30 | 297 | 373 | 644 | 1192 | 1572 | 1826 | 1915 | 1703 | 1685 | 1271 | 791 | 481 | 13750 |
| | Valdez | 30 | 306 | 353 | 537 | 832 | 1101 | 1251 | 1336 | 1126 | 1091 | 821 | 596 | 383 | 9733 |
| | Yakutat | 30 | 353 | 364 | 506 | 742 | 980 | 1129 | 1216 | 1027 | 1040 | 837 | 664 | 460 | 9318 |
| AZ | Flagstaff | 30 | 33 | 56 | 224 | 554 | 850 | 1085 | 1099 | 930 | 880 | 668 | 446 | 174 | 6999 |
| | Phoenix | 30 | 0 | 0 | 0 | 11 | 117 | 305 | 304 | 174 | 99 | 29 | 1 | 0 | 1040 |
| | Tucson | 30 | 0 | 0 | 0 | 33 | 195 | 397 | 401 | 275 | 194 | 76 | 7 | 0 | 1578 |
| | Winslow | 30 | 0 | 1 | 31 | 290 | 649 | 965 | 961 | 713 | 580 | 357 | 133 | 12 | 4692 |
| | Yuma | 30 | 0 | 0 | 0 | 5 | 90 | 246 | 228 | 114 | 73 | 23 | 3 | 0 | 782 |
| AR | Fort Smith | 30 | 0 | 0 | 23 | 145 | 448 | 745 | 854 | 619 | 410 | 172 | 34 | 1 | 3451 |
| | Little Rock | 30 | 0 | 0 | 13 | 124 | 400 | 666 | 775 | 563 | 369 | 150 | 24 | 0 | 3084 |
| | North Little Rock | 30 | 0 | 0 | 8 | 99 | 383 | 669 | 770 | 549 | 343 | 128 | 31 | 0 | 2980 |
| CA | Bakersfield | 30 | 0 | 0 | 2 | 51 | 283 | 534 | 521 | 324 | 236 | 119 | 31 | 3 | 2104 |
| | Bishop | 30 | 1 | 1 | 46 | 276 | 609 | 847 | 843 | 643 | 545 | 344 | 138 | 21 | 4314 |
| | Eureka | 30 | 216 | 198 | 232 | 326 | 423 | 532 | 530 | 451 | 491 | 430 | 354 | 263 | 4446 |
| | Fresno | 30 | 0 | 0 | 3 | 70 | 344 | 597 | 578 | 377 | 283 | 140 | 37 | 4 | 2433 |
| | Long Beach | 30 | 0 | 0 | 1 | 16 | 128 | 265 | 268 | 205 | 186 | 99 | 39 | 5 | 1212 |
| | Los Angeles AP | 30 | 1 | 0 | 2 | 21 | 121 | 234 | 252 | 205 | 212 | 141 | 78 | 19 | 1286 |
| | Los Angeles CO | 30 | 0 | 0 | 1 | 11 | 91 | 201 | 206 | 149 | 144 | 83 | 36 | 5 | 927 |
| | Mount Shasta | 30 | 66 | 65 | 196 | 451 | 753 | 936 | 921 | 753 | 738 | 563 | 374 | 175 | 5991 |
| | Redding | 30 | 0 | 0 | 13 | 131 | 420 | 611 | 606 | 445 | 390 | 239 | 99 | 7 | 2961 |
| | Sacramento | 30 | 0 | 0 | 11 | 84 | 359 | 595 | 580 | 387 | 335 | 208 | 97 | 10 | 2666 |
| | San Diego | 30 | 0 | 0 | 1 | 12 | 109 | 231 | 227 | 176 | 160 | 90 | 47 | 10 | 1063 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | San Francisco AP | 30 | 77 | 56 | 62 | 131 | 298 | 476 | 482 | 354 | 339 | 266 | 201 | 120 | 2862 |
| | San Francisco CO | 30 | 133 | 107 | 95 | 100 | 232 | 383 | 396 | 283 | 288 | 233 | 214 | 150 | 2614 |
| | Santa Barbara | 30 | 22 | 23 | 54 | 92 | 234 | 368 | 369 | 277 | 263 | 193 | 151 | 75 | 2121 |
| | Santa Maria | 30 | 68 | 49 | 70 | 141 | 288 | 422 | 419 | 337 | 350 | 291 | 230 | 135 | 2800 |
| | Stockton | 30 | 0 | 0 | 5 | 76 | 348 | 609 | 592 | 391 | 313 | 169 | 54 | 6 | 2563 |
| CO | Alamosa | 30 | 47 | 91 | 302 | 675 | 1082 | 1475 | 1551 | 1189 | 983 | 719 | 451 | 169 | 8734 |
| | Colorado Springs | 30 | 11 | 20 | 163 | 471 | 827 | 1082 | 1114 | 915 | 816 | 568 | 306 | 76 | 6369 |
| | Denver | 30 | 1 | 9 | 136 | 436 | 826 | 1078 | 1111 | 892 | 788 | 524 | 267 | 60 | 6128 |
| | Grand Junction | 30 | 1 | 1 | 59 | 342 | 766 | 1118 | 1194 | 860 | 643 | 397 | 151 | 20 | 5552 |
| | Pueblo | 30 | 1 | 3 | 88 | 381 | 779 | 1058 | 1092 | 843 | 694 | 431 | 172 | 24 | 5566 |
| CT | Bridgeport | 30 | 2 | 4 | 68 | 320 | 591 | 918 | 1089 | 944 | 803 | 489 | 207 | 32 | 5467 |
| | Hartford | 30 | 3 | 12 | 120 | 413 | 697 | 1054 | 1218 | 1024 | 844 | 486 | 195 | 38 | 6104 |
| DE | Wilmington | 30 | 1 | 2 | 49 | 297 | 564 | 871 | 1029 | 864 | 687 | 376 | 132 | 15 | 4887 |
| DC | Washington Dulles AP | 30 | 1 | 4 | 60 | 323 | 589 | 882 | 1025 | 847 | 670 | 362 | 139 | 21 | 4923 |
| | Washington Nat'l AP | 30 | 0 | 1 | 19 | 202 | 467 | 755 | 906 | 741 | 562 | 269 | 72 | 5 | 3999 |
| FL | Apalachicola | 30 | 0 | 0 | 0 | 32 | 152 | 328 | 408 | 285 | 169 | 42 | 3 | 0 | 1419 |
| | Daytona Beach | 30 | 0 | 0 | 0 | 6 | 67 | 185 | 245 | 183 | 99 | 29 | 1 | 0 | 815 |
| | Fort Myers | 30 | 0 | 0 | 0 | 1 | 16 | 76 | 103 | 75 | 28 | 3 | 0 | 0 | 302 |
| | Gainesville | 30 | 0 | 0 | 0 | 21 | 121 | 268 | 321 | 208 | 123 | 40 | 2 | 0 | 1104 |
| | Jacksonville | 30 | 0 | 0 | 0 | 30 | 148 | 314 | 374 | 272 | 155 | 55 | 5 | 0 | 1353 |
| | Key West | 30 | 0 | 0 | 0 | 0 | 0 | 14 | 26 | 18 | 6 | 0 | 0 | 0 | 64 |
| | Miami | 30 | 0 | 0 | 0 | 0 | 4 | 38 | 58 | 39 | 15 | 1 | 0 | 0 | 155 |
| | Orlando | 30 | 0 | 0 | 0 | 2 | 40 | 142 | 220 | 128 | 57 | 9 | 0 | 0 | 598 |
| | Pensacola | 30 | 0 | 0 | 1 | 35 | 175 | 352 | 416 | 299 | 171 | 48 | 1 | 0 | 1498 |
| | Tallahassee | 30 | 0 | 0 | 1 | 49 | 193 | 369 | 428 | 315 | 185 | 71 | 5 | 0 | 1616 |
| | Tampa | 30 | 0 | 0 | 0 | 4 | 46 | 144 | 187 | 136 | 63 | 13 | 0 | 0 | 593 |
| | Vero Beach | 30 | 0 | 0 | 0 | 0 | 18 | 101 | 166 | 114 | 48 | 8 | 0 | 0 | 455 |
| | West Palm Beach | 30 | 0 | 0 | 0 | 0 | 10 | 58 | 83 | 60 | 27 | 4 | 0 | 0 | 242 |
| GA | Athens | 30 | 0 | 0 | 10 | 133 | 353 | 597 | 687 | 522 | 349 | 152 | 28 | 1 | 2832 |
| | Atlanta | 30 | 0 | 0 | 11 | 126 | 352 | 600 | 692 | 523 | 346 | 150 | 26 | 1 | 2827 |
| | Augusta | 30 | 0 | 0 | 5 | 112 | 313 | 540 | 617 | 469 | 301 | 129 | 21 | 1 | 2508 |
| | Columbus | 30 | 0 | 0 | 3 | 78 | 263 | 481 | 559 | 415 | 252 | 94 | 8 | 0 | 2153 |
| | Macon | 30 | 0 | 0 | 4 | 91 | 277 | 494 | 570 | 427 | 262 | 104 | 12 | 0 | 2241 |
| | Savannah | 30 | 0 | 0 | 1 | 56 | 204 | 403 | 472 | 350 | 202 | 72 | 6 | 0 | 1766 |
| HI | Hilo | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Honolulu | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Kahului | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lihue | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ID | Boise | 30 | 12 | 16 | 126 | 408 | 769 | 1088 | 1102 | 819 | 675 | 460 | 254 | 80 | 5809 |
| | Lewiston | 30 | 10 | 10 | 102 | 401 | 717 | 951 | 962 | 742 | 616 | 411 | 218 | 71 | 5211 |
| | Pocatello | 30 | 21 | 26 | 201 | 536 | 907 | 1240 | 1274 | 1003 | 842 | 584 | 353 | 129 | 7116 |
| IL | Chicago | 30 | 5 | 9 | 112 | 401 | 759 | 1147 | 1333 | 1075 | 858 | 513 | 232 | 49 | 6493 |
| | Moline | 30 | 3 | 8 | 108 | 394 | 782 | 1191 | 1374 | 1090 | 831 | 450 | 172 | 19 | 6422 |
| | Peoria | 30 | 2 | 7 | 94 | 368 | 738 | 1136 | 1316 | 1045 | 788 | 423 | 159 | 19 | 6095 |
| | Rockford | 30 | 5 | 14 | 136 | 444 | 832 | 1244 | 1430 | 1150 | 912 | 522 | 215 | 36 | 6940 |
| | Springfield | 30 | 1 | 4 | 77 | 319 | 674 | 1060 | 1239 | 980 | 726 | 376 | 126 | 14 | 5596 |

*(Continued)*



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**Table 3A.6 (Continued)**

| State | Station | Years | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN | Evansville | 30 | 0 | 1 | 45 | 262 | 565 | 891 | 1047 | 825 | 591 | 295 | 85 | 5 | 4612 |
| | Fort Wayne | 30 | 3 | 11 | 105 | 394 | 722 | 1094 | 1275 | 1063 | 835 | 479 | 188 | 29 | 6198 |
| | Indianapolis | 30 | 2 | 4 | 77 | 335 | 659 | 1020 | 1192 | 957 | 724 | 394 | 141 | 16 | 5521 |
| | South Bend | 30 | 6 | 13 | 114 | 392 | 721 | 1090 | 1270 | 1055 | 844 | 498 | 213 | 41 | 6257 |
| IA | Des Moines | 30 | 1 | 6 | 103 | 386 | 804 | 1223 | 1385 | 1090 | 826 | 439 | 153 | 16 | 6432 |
| | Dubuque | 30 | 8 | 21 | 158 | 465 | 879 | 1307 | 1492 | 1192 | 949 | 536 | 226 | 40 | 7273 |
| | Sioux City | 30 | 3 | 10 | 128 | 434 | 888 | 1308 | 1439 | 1131 | 885 | 473 | 172 | 25 | 6896 |
| | Waterloo | 30 | 7 | 20 | 155 | 478 | 903 | 1343 | 1538 | 1221 | 948 | 528 | 205 | 29 | 7375 |
| KS | Concordia | 30 | 1 | 2 | 76 | 307 | 722 | 1068 | 1195 | 927 | 702 | 380 | 131 | 13 | 5524 |
| | Dodge City | 30 | 1 | 2 | 65 | 273 | 674 | 978 | 1087 | 826 | 647 | 351 | 121 | 12 | 5037 |
| | Goodland | 30 | 5 | 10 | 117 | 407 | 807 | 1079 | 1147 | 916 | 776 | 490 | 224 | 35 | 6013 |
| | Topeka | 30 | 1 | 1 | 73 | 287 | 665 | 1030 | 1174 | 898 | 647 | 336 | 106 | 7 | 5225 |
| | Wichita | 30 | 0 | 0 | 49 | 235 | 620 | 965 | 1087 | 819 | 594 | 302 | 89 | 5 | 4765 |
| KY | Greater Cincinnati AP | 30 | 1 | 3 | 68 | 326 | 626 | 953 | 1110 | 899 | 684 | 373 | 138 | 19 | 5200 |
| | Jackson | 30 | 0 | 4 | 44 | 263 | 522 | 830 | 966 | 761 | 557 | 273 | 128 | 10 | 4358 |
| | Lexington | 30 | 1 | 2 | 53 | 284 | 574 | 877 | 1026 | 819 | 616 | 332 | 119 | 13 | 4716 |
| | Louisville | 30 | 0 | 1 | 36 | 240 | 527 | 838 | 992 | 779 | 569 | 280 | 84 | 6 | 4352 |
| | Paducah | 30 | 0 | 0 | 38 | 229 | 516 | 833 | 978 | 750 | 529 | 250 | 67 | 2 | 4192 |
| LA | Baton Rouge | 30 | 0 | 0 | 2 | 49 | 211 | 386 | 456 | 325 | 179 | 55 | 2 | 0 | 1665 |
| | Lake Charles | 30 | 0 | 0 | 1 | 38 | 191 | 363 | 434 | 304 | 163 | 47 | 1 | 0 | 1542 |
| | New Orleans | 30 | 0 | 0 | 0 | 30 | 169 | 332 | 403 | 288 | 150 | 44 | 1 | 0 | 1417 |
| | Shreveport | 30 | 0 | 0 | 6 | 78 | 296 | 522 | 597 | 416 | 250 | 89 | 8 | 0 | 2262 |
| ME | Caribou | 30 | 58 | 103 | 344 | 691 | 1039 | 1505 | 1719 | 1466 | 1254 | 805 | 417 | 159 | 9560 |
| | Portland | 30 | 19 | 37 | 199 | 523 | 790 | 1152 | 1346 | 1145 | 988 | 649 | 361 | 116 | 7325 |
| MD | Baltimore | 30 | 0 | 1 | 41 | 279 | 549 | 839 | 986 | 816 | 647 | 345 | 119 | 12 | 4634 |
| MA | Blue Hill | 30 | 9 | 22 | 138 | 422 | 698 | 1040 | 1207 | 1034 | 894 | 562 | 271 | 74 | 6371 |
| | Boston | 30 | 4 | 8 | 84 | 344 | 604 | 932 | 1104 | 951 | 815 | 503 | 233 | 48 | 5630 |
| | Worcester | 30 | 9 | 20 | 158 | 478 | 764 | 1119 | 1284 | 1094 | 952 | 601 | 278 | 74 | 6831 |
| MI | Alpena | 30 | 46 | 78 | 260 | 583 | 894 | 1244 | 1447 | 1285 | 1133 | 723 | 394 | 150 | 8237 |
| | Detroit | 30 | 5 | 12 | 121 | 429 | 742 | 1099 | 1270 | 1084 | 894 | 527 | 221 | 45 | 6449 |
| | Flint | 30 | 13 | 28 | 163 | 474 | 781 | 1149 | 1329 | 1147 | 957 | 577 | 267 | 66 | 6951 |
| | Grand Rapids | 30 | 10 | 24 | 159 | 471 | 793 | 1147 | 1317 | 1135 | 956 | 571 | 255 | 58 | 6896 |
| | Houghton Lake | 30 | 41 | 74 | 250 | 577 | 901 | 1271 | 1468 | 1283 | 1115 | 685 | 338 | 117 | 8120 |
| | Lansing | 30 | 17 | 35 | 179 | 493 | 805 | 1167 | 1341 | 1160 | 970 | 585 | 277 | 69 | 7098 |
| | Marquette | 30 | 92 | 134 | 348 | 700 | 1083 | 1484 | 1659 | 1405 | 1280 | 859 | 468 | 200 | 9712 |
| | Muskegon | 30 | 15 | 27 | 168 | 476 | 784 | 1117 | 1288 | 1124 | 968 | 602 | 296 | 78 | 6943 |
| | Sault Ste. Marie | 30 | 91 | 107 | 320 | 642 | 979 | 1383 | 1606 | 1405 | 1253 | 798 | 434 | 212 | 9230 |
| MN | Duluth | 30 | 69 | 106 | 331 | 682 | 1124 | 1587 | 1772 | 1435 | 1248 | 787 | 421 | 180 | 9742 |
| | International Falls | 30 | 55 | 102 | 360 | 723 | 1217 | 1744 | 1946 | 1551 | 1304 | 775 | 378 | 140 | 10295 |
| | Minneapolis-St. Paul | 30 | 7 | 20 | 178 | 516 | 978 | 1428 | 1616 | 1279 | 1034 | 560 | 222 | 44 | 7882 |
| | Rochester | 30 | 23 | 50 | 208 | 558 | 1014 | 1479 | 1650 | 1305 | 1066 | 609 | 281 | 65 | 8308 |
| | Saint Cloud | 30 | 19 | 49 | 253 | 604 | 1077 | 1551 | 1742 | 1381 | 1135 | 637 | 285 | 79 | 8812 |
| MS | Jackson | 30 | 0 | 0 | 7 | 100 | 305 | 516 | 607 | 440 | 272 | 110 | 11 | 0 | 2368 |
| | Meridian | 30 | 0 | 0 | 6 | 106 | 303 | 506 | 598 | 435 | 274 | 111 | 14 | 0 | 2353 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tupelo | 30 | 0 | 0 | 14 | 150 | 400 | 639 | 750 | 559 | 368 | 160 | 29 | 1 | 3070 |
| MO | Columbia | 30 | 1 | 2 | 72 | 291 | 642 | 1004 | 1153 | 891 | 656 | 336 | 115 | 10 | 5173 |
| | Kansas City | 30 | 0 | 7 | 58 | 269 | 668 | 1047 | 1182 | 897 | 658 | 331 | 124 | 8 | 5249 |
| | St. Louis | 30 | 0 | 1 | 46 | 246 | 583 | 943 | 1097 | 845 | 613 | 294 | 83 | 6 | 4757 |
| | Springfield | 30 | 1 | 1 | 62 | 248 | 578 | 899 | 1034 | 790 | 581 | 300 | 100 | 8 | 4602 |
| MT | Billings | 30 | 20 | 25 | 205 | 516 | 909 | 1195 | 1280 | 1001 | 876 | 575 | 312 | 90 | 7004 |
| | Glasgow | 30 | 22 | 38 | 253 | 609 | 1088 | 1506 | 1671 | 1290 | 1055 | 610 | 308 | 91 | 8541 |
| | Great Falls | 30 | 48 | 64 | 275 | 579 | 952 | 1237 | 1323 | 1063 | 948 | 639 | 389 | 158 | 7675 |
| | Havre | 30 | 33 | 49 | 270 | 622 | 1067 | 1410 | 1546 | 1201 | 999 | 613 | 324 | 113 | 8247 |
| | Helena | 30 | 42 | 56 | 283 | 631 | 1018 | 1348 | 1397 | 1093 | 932 | 634 | 384 | 157 | 7975 |
| | Kalispell | 30 | 85 | 94 | 341 | 705 | 1014 | 1297 | 1359 | 1079 | 933 | 640 | 411 | 213 | 8171 |
| | Missoula | 30 | 55 | 62 | 276 | 637 | 985 | 1287 | 1291 | 1019 | 852 | 596 | 384 | 178 | 7622 |
| NE | Grand Island | 30 | 3 | 7 | 114 | 401 | 835 | 1192 | 1310 | 1031 | 819 | 452 | 175 | 23 | 6362 |
| | Lincoln | 30 | 1 | 5 | 100 | 377 | 806 | 1188 | 1328 | 1043 | 799 | 425 | 154 | 16 | 6242 |
| | Norfolk | 30 | 4 | 11 | 130 | 432 | 879 | 1266 | 1388 | 1099 | 872 | 478 | 180 | 28 | 6767 |
| | North Platte | 30 | 6 | 14 | 158 | 481 | 902 | 1222 | 1316 | 1026 | 853 | 519 | 240 | 46 | 6783 |
| | Omaha Eppley AP | 30 | 1 | 6 | 105 | 384 | 806 | 1211 | 1349 | 1053 | 805 | 424 | 151 | 17 | 6312 |
| | Omaha (North) | 30 | 4 | 15 | 83 | 349 | 800 | 1204 | 1323 | 1022 | 783 | 400 | 154 | 16 | 6153 |
| | Scottsbluff | 30 | 7 | 11 | 157 | 489 | 885 | 1183 | 1233 | 969 | 837 | 544 | 257 | 53 | 6625 |
| | Valentine | 30 | 11 | 19 | 175 | 516 | 952 | 1285 | 1386 | 1101 | 932 | 571 | 260 | 57 | 7265 |
| NV | Elko | 30 | 53 | 57 | 237 | 569 | 916 | 1208 | 1222 | 943 | 820 | 612 | 383 | 161 | 7181 |
| | Ely | 30 | 26 | 48 | 258 | 605 | 938 | 1220 | 1240 | 996 | 903 | 690 | 459 | 178 | 7561 |
| | Las Vegas | 30 | 0 | 0 | 1 | 57 | 320 | 581 | 583 | 380 | 247 | 90 | 16 | 1 | 2276 |
| | Reno | 30 | 12 | 22 | 130 | 416 | 732 | 987 | 984 | 757 | 683 | 502 | 285 | 91 | 5601 |
| | Winnemucca | 30 | 12 | 23 | 173 | 509 | 829 | 1101 | 1088 | 820 | 742 | 554 | 315 | 105 | 6271 |
| NH | Concord | 30 | 22 | 44 | 212 | 548 | 835 | 1220 | 1402 | 1188 | 999 | 623 | 302 | 90 | 7485 |
| | Mt. Washington | 30 | 504 | 542 | 740 | 1079 | 1333 | 1702 | 1857 | 1639 | 1594 | 1262 | 914 | 619 | 13785 |
| NJ | Atlantic City AP | 30 | 1 | 6 | 69 | 323 | 573 | 868 | 1019 | 873 | 725 | 437 | 187 | 32 | 5113 |
| | Atlantic City CO | 30 | 0 | 0 | 20 | 228 | 481 | 772 | 924 | 787 | 674 | 409 | 167 | 18 | 4480 |
| | Newark | 30 | 1 | 2 | 41 | 264 | 541 | 863 | 1030 | 869 | 697 | 371 | 120 | 13 | 4812 |
| NM | Albuquerque | 30 | 0 | 0 | 29 | 248 | 614 | 898 | 914 | 670 | 525 | 294 | 85 | 4 | 4281 |
| | Clayton | 30 | 1 | 7 | 85 | 325 | 685 | 937 | 964 | 767 | 661 | 407 | 179 | 27 | 5045 |
| | Roswell | 30 | 0 | 0 | 18 | 144 | 485 | 755 | 775 | 542 | 378 | 182 | 51 | 2 | 3332 |
| NY | Albany | 30 | 10 | 26 | 168 | 484 | 772 | 1142 | 1330 | 1136 | 938 | 553 | 240 | 62 | 6861 |
| | Binghamton | 30 | 22 | 43 | 200 | 514 | 812 | 1160 | 1331 | 1156 | 997 | 617 | 292 | 90 | 7234 |
| | Buffalo | 30 | 8 | 21 | 149 | 442 | 737 | 1081 | 1256 | 1111 | 961 | 594 | 268 | 65 | 6693 |
| | Islip | 30 | 0 | 1 | 49 | 339 | 604 | 909 | 1060 | 913 | 782 | 479 | 197 | 24 | 5357 |
| | New York C.Park | 30 | 1 | 2 | 43 | 261 | 524 | 841 | 1009 | 853 | 695 | 372 | 127 | 16 | 4744 |
| | New York (JFK AP) | 30 | 1 | 2 | 42 | 264 | 532 | 838 | 1007 | 868 | 723 | 420 | 166 | 19 | 4882 |
| | New York (Laguardia AP) | 30 | 1 | 1 | 40 | 249 | 524 | 836 | 1008 | 861 | 713 | 392 | 136 | 16 | 4777 |
| | Rochester | 30 | 10 | 24 | 154 | 447 | 741 | 1085 | 1263 | 1117 | 958 | 582 | 266 | 66 | 6713 |
| | Syracuse | 30 | 10 | 25 | 158 | 460 | 748 | 1108 | 1294 | 1131 | 959 | 572 | 254 | 66 | 6785 |
| NC | Asheville | 30 | 1 | 2 | 52 | 285 | 531 | 769 | 872 | 708 | 550 | 302 | 116 | 15 | 4203 |
| | Cape Hatteras | 30 | 0 | 0 | 2 | 72 | 244 | 464 | 587 | 518 | 400 | 187 | 44 | 3 | 2521 |
| | Charlotte | 30 | 0 | 0 | 16 | 165 | 404 | 655 | 747 | 585 | 409 | 180 | 44 | 3 | 3208 |

*(Continued)*



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**Table 3A.6 (Continued)**

| State | Station | Years | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Greensboro-Wnstn-Slm-HPT | 30 | 0 | 1 | 32 | 232 | 480 | 742 | 851 | 679 | 501 | 245 | 77 | 8 | 3848 |
| | Raleigh | 30 | 0 | 1 | 20 | 194 | 425 | 679 | 783 | 627 | 456 | 214 | 61 | 5 | 3465 |
| | Wilmington | 30 | 0 | 0 | 3 | 95 | 277 | 497 | 589 | 474 | 331 | 134 | 28 | 1 | 2429 |
| ND | Bismarck | 30 | 19 | 44 | 256 | 625 | 1112 | 1539 | 1711 | 1335 | 1110 | 660 | 305 | 93 | 8809 |
| | Fargo | 30 | 17 | 37 | 245 | 614 | 1137 | 1610 | 1808 | 1446 | 1185 | 652 | 271 | 73 | 9095 |
| | Grand Forks | 30 | 27 | 53 | 276 | 655 | 1186 | 1660 | 1860 | 1484 | 1233 | 689 | 294 | 88 | 9505 |
| | Williston | 30 | 22 | 43 | 274 | 645 | 1146 | 1567 | 1734 | 1336 | 1104 | 646 | 315 | 90 | 8922 |
| OH | Akron | 30 | 7 | 16 | 120 | 412 | 704 | 1040 | 1220 | 1026 | 836 | 498 | 219 | 50 | 6148 |
| | Cleveland | 30 | 7 | 13 | 110 | 385 | 677 | 1023 | 1205 | 1025 | 847 | 516 | 235 | 54 | 6097 |
| | Columbus | 30 | 3 | 7 | 81 | 354 | 656 | 982 | 1154 | 954 | 742 | 421 | 165 | 27 | 5546 |
| | Dayton | 30 | 2 | 7 | 90 | 358 | 669 | 1016 | 1185 | 973 | 760 | 427 | 167 | 24 | 5678 |
| | Mansfield | 30 | 8 | 19 | 122 | 407 | 714 | 1066 | 1236 | 1045 | 852 | 509 | 227 | 53 | 6258 |
| | Toledo | 30 | 6 | 18 | 129 | 431 | 745 | 1107 | 1281 | 1087 | 878 | 517 | 224 | 45 | 6468 |
| | Youngstown | 30 | 15 | 26 | 148 | 439 | 723 | 1063 | 1243 | 1057 | 879 | 530 | 252 | 71 | 6446 |
| OK | Oklahoma City | 30 | 0 | 0 | 30 | 152 | 482 | 780 | 884 | 648 | 446 | 197 | 43 | 1 | 3663 |
| | Tulsa | 30 | 0 | 0 | 29 | 152 | 468 | 781 | 898 | 658 | 437 | 179 | 38 | 1 | 3641 |
| OR | Astoria | 30 | 151 | 130 | 197 | 386 | 542 | 688 | 695 | 583 | 585 | 492 | 375 | 244 | 5068 |
| | Burns | 30 | 89 | 96 | 313 | 638 | 968 | 1245 | 1259 | 982 | 869 | 661 | 439 | 226 | 7785 |
| | Eugene | 30 | 40 | 31 | 115 | 370 | 594 | 780 | 769 | 615 | 564 | 443 | 308 | 152 | 4781 |
| | Medford | 30 | 10 | 7 | 69 | 316 | 632 | 837 | 804 | 610 | 550 | 402 | 233 | 69 | 4539 |
| | Pendleton | 30 | 14 | 15 | 115 | 400 | 711 | 962 | 971 | 747 | 623 | 433 | 247 | 83 | 5321 |
| | Portland | 30 | 21 | 15 | 78 | 318 | 558 | 756 | 765 | 605 | 529 | 393 | 234 | 94 | 4366 |
| | Salem | 30 | 39 | 34 | 116 | 376 | 592 | 771 | 765 | 623 | 574 | 452 | 301 | 141 | 4784 |
| | Sexton Summit | 30 | 127 | 101 | 211 | 440 | 737 | 860 | 853 | 741 | 788 | 648 | 470 | 267 | 6243 |
| PC | Guam | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Johnston Island | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Koror | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Kwajalein, Marshall IS | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Majuro, Marshall IS | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Pago Pago, Amer Samoa | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Pohnpei, Caroline IS | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Chuuk, E. Caroline IS | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Wake Island | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Yap, W Caroline IS | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PA | Allentown | 30 | 3 | 8 | 95 | 374 | 657 | 985 | 1147 | 966 | 784 | 450 | 176 | 26 | 5671 |
| | Erie | 30 | 13 | 18 | 123 | 398 | 684 | 1016 | 1209 | 1074 | 926 | 585 | 288 | 75 | 6409 |
| | Harrisburg | 30 | 0 | 1 | 52 | 338 | 621 | 937 | 1076 | 901 | 723 | 390 | 148 | 14 | 5201 |
| | Middletown/ Harrisburg AP | 30 | 0 | 1 | 52 | 338 | 621 | 937 | 1076 | 901 | 723 | 390 | 148 | 14 | 5201 |
| | Philadelphia | 30 | 1 | 2 | 39 | 269 | 545 | 857 | 1020 | 858 | 681 | 362 | 113 | 12 | 4759 |
| | Pittsburgh | 30 | 6 | 13 | 105 | 397 | 677 | 996 | 1163 | 979 | 788 | 462 | 200 | 43 | 5829 |
| | Avoca | 30 | 9 | 18 | 138 | 431 | 711 | 1047 | 1214 | 1040 | 866 | 512 | 219 | 53 | 6258 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Williamsport | 30 | 5 | 12 | 116 | 417 | 708 | 1033 | 1201 | 1014 | 824 | 471 | 196 | 38 | 6035 |
| RI | Providence | 30 | 3 | 9 | 101 | 377 | 637 | 961 | 1125 | 965 | 817 | 494 | 221 | 44 | 5754 |
| SC | Charleston AP | 30 | 0 | 0 | 2 | 68 | 222 | 428 | 510 | 394 | 242 | 95 | 11 | 1 | 1973 |
| | Charleston CO | 30 | 0 | 0 | 0 | 47 | 183 | 390 | 489 | 362 | 224 | 57 | 3 | 0 | 1755 |
| | Columbia | 30 | 0 | 0 | 8 | 121 | 325 | 552 | 628 | 485 | 321 | 131 | 23 | 1 | 2595 |
| | Greenvile-Spartanbrg AP | 30 | 0 | 0 | 19 | 178 | 417 | 655 | 750 | 586 | 420 | 197 | 47 | 3 | 3272 |
| SD | Aberdeen | 30 | 11 | 27 | 206 | 569 | 1066 | 1506 | 1678 | 1318 | 1072 | 591 | 251 | 59 | 8354 |
| | Huron | 30 | 8 | 21 | 180 | 530 | 996 | 1417 | 1572 | 1242 | 1004 | 567 | 242 | 49 | 7828 |
| | Rapid City | 30 | 16 | 21 | 190 | 521 | 934 | 1233 | 1314 | 1061 | 925 | 595 | 313 | 88 | 7211 |
| | Sioux Falls | 30 | 7 | 20 | 175 | 519 | 986 | 1417 | 1563 | 1236 | 988 | 558 | 231 | 46 | 7746 |
| TN | Bristol-JhnCty-Kgsprt | 30 | 1 | 2 | 44 | 279 | 541 | 810 | 919 | 744 | 556 | 303 | 108 | 11 | 4318 |
| | Chattanooga | 30 | 0 | 0 | 16 | 180 | 442 | 697 | 797 | 618 | 432 | 195 | 48 | 2 | 3427 |
| | Knoxville | 30 | 0 | 0 | 22 | 210 | 470 | 732 | 841 | 652 | 467 | 223 | 65 | 3 | 3685 |
| | Memphis | 30 | 0 | 0 | 13 | 121 | 381 | 651 | 770 | 565 | 366 | 144 | 22 | 0 | 3033 |
| | Nashville | 30 | 0 | 0 | 24 | 189 | 457 | 730 | 858 | 664 | 462 | 217 | 56 | 1 | 3658 |
| | Oak Ridge | 30 | 0 | 0 | 30 | 230 | 518 | 787 | 882 | 696 | 510 | 254 | 80 | 6 | 3993 |
| | Abilene | 30 | 0 | 0 | 18 | 93 | 353 | 608 | 678 | 477 | 299 | 113 | 20 | 0 | 2659 |
| TX | Amarillo | 30 | 1 | 1 | 56 | 239 | 594 | 874 | 920 | 706 | 542 | 291 | 94 | 7 | 4325 |
| | Austin/City | 30 | 0 | 0 | 2 | 32 | 205 | 406 | 475 | 319 | 163 | 44 | 2 | 0 | 1648 |
| | Austin/Bergstrom | 30 | 0 | 0 | 1 | 38 | 248 | 480 | 532 | 360 | 180 | 45 | 5 | 0 | 1889 |
| | Brownsville | 30 | 0 | 0 | 0 | 6 | 64 | 170 | 206 | 123 | 45 | 8 | 0 | 0 | 622 |
| | Corpus Christi | 30 | 0 | 0 | 0 | 12 | 103 | 246 | 299 | 191 | 77 | 19 | 0 | 0 | 947 |
| | Dallas-Fort Worth | 30 | 0 | 0 | 2 | 52 | 312 | 571 | 650 | 448 | 248 | 74 | 13 | 0 | 2370 |
| | Dallas-Love Field | 30 | 0 | 0 | 7 | 62 | 281 | 527 | 605 | 415 | 238 | 75 | 9 | 0 | 2219 |
| | Del Rio | 30 | 0 | 0 | 2 | 24 | 183 | 384 | 423 | 262 | 111 | 27 | 1 | 0 | 1417 |
| | El Paso | 30 | 0 | 0 | 9 | 96 | 388 | 626 | 641 | 435 | 285 | 113 | 11 | 0 | 2604 |
| | Galveston | 30 | 0 | 0 | 0 | 6 | 112 | 245 | 316 | 220 | 94 | 15 | 0 | 0 | 1008 |
| | Houston | 30 | 0 | 0 | 1 | 37 | 189 | 367 | 427 | 298 | 156 | 48 | 2 | 0 | 1525 |
| | Lubbock | 30 | 0 | 0 | 33 | 158 | 472 | 744 | 800 | 588 | 409 | 178 | 38 | 2 | 3422 |
| | Midland-Odessa | 30 | 0 | 0 | 19 | 103 | 380 | 622 | 680 | 472 | 302 | 120 | 18 | 0 | 2716 |
| | Port Arthur | 30 | 0 | 0 | 1 | 34 | 181 | 349 | 411 | 286 | 143 | 41 | 1 | 0 | 1447 |
| | San Angelo | 30 | 0 | 0 | 12 | 82 | 325 | 558 | 617 | 427 | 258 | 92 | 13 | 0 | 2384 |
| | San Antonio | 30 | 0 | 0 | 2 | 33 | 197 | 390 | 455 | 303 | 149 | 42 | 1 | 0 | 1572 |
| | Victoria | 30 | 0 | 0 | 1 | 22 | 145 | 314 | 372 | 249 | 113 | 28 | 1 | 0 | 1245 |
| | Waco | 30 | 0 | 0 | 6 | 58 | 271 | 512 | 589 | 409 | 235 | 77 | 7 | 0 | 2164 |
| | Wichita Falls | 30 | 0 | 0 | 18 | 106 | 395 | 676 | 762 | 550 | 354 | 140 | 23 | 0 | 3024 |
| UT | Milford | 30 | 1 | 4 | 112 | 451 | 821 | 1129 | 1144 | 879 | 726 | 503 | 280 | 66 | 6116 |
| | Salt Lake City | 30 | 2 | 3 | 87 | 370 | 737 | 1067 | 1108 | 857 | 665 | 448 | 215 | 48 | 5607 |
| VT | Burlington | 30 | 17 | 38 | 203 | 538 | 834 | 1240 | 1457 | 1273 | 1063 | 642 | 283 | 77 | 7665 |
| VA | Lynchburg | 30 | 1 | 1 | 43 | 268 | 526 | 798 | 918 | 749 | 572 | 288 | 102 | 13 | 4279 |
| | Norfolk | 30 | 0 | 0 | 8 | 150 | 368 | 623 | 758 | 638 | 487 | 240 | 66 | 4 | 3342 |
| | Richmond | 30 | 0 | 1 | 27 | 224 | 464 | 736 | 863 | 705 | 526 | 250 | 75 | 7 | 3878 |
| | Roanoke | 30 | 1 | 2 | 48 | 276 | 528 | 798 | 911 | 745 | 569 | 290 | 107 | 13 | 4288 |
| WA | Olympia | 30 | 90 | 78 | 195 | 465 | 666 | 829 | 819 | 678 | 644 | 511 | 347 | 201 | 5523 |
| | Quillayute | 30 | 193 | 174 | 250 | 460 | 626 | 762 | 758 | 646 | 656 | 548 | 421 | 296 | 5790 |

*(Continued)*



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**Table 3A.6 (Continued)**

| State | Station | Years | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seattle CO | 30 | 52 | 50 | 139 | 362 | 571 | 735 | 729 | 593 | 564 | 423 | 266 | 131 | 4615 |
| | Seattle Sea-Tac AP | 30 | 55 | 45 | 138 | 383 | 592 | 754 | 747 | 613 | 582 | 447 | 291 | 150 | 4797 |
| | Spokane | 30 | 44 | 42 | 196 | 554 | 897 | 1168 | 1169 | 916 | 790 | 557 | 338 | 149 | 6820 |
| | Walla Walla | 30 | 9 | 9 | 99 | 323 | 659 | 928 | 939 | 709 | 574 | 373 | 191 | 69 | 4882 |
| | Yakima | 30 | 28 | 28 | 155 | 487 | 813 | 1100 | 1090 | 821 | 671 | 463 | 258 | 98 | 6012 |
| PR | San Juan | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WV | Beckley | 30 | 10 | 16 | 115 | 388 | 647 | 926 | 1068 | 882 | 714 | 414 | 199 | 48 | 5427 |
| | Charleston | 30 | 1 | 3 | 56 | 300 | 558 | 837 | 977 | 794 | 604 | 319 | 122 | 18 | 4589 |
| | Elkins | 30 | 15 | 23 | 134 | 456 | 719 | 996 | 1133 | 959 | 792 | 498 | 251 | 70 | 6046 |
| | Huntington | 30 | 1 | 2 | 55 | 292 | 557 | 843 | 991 | 796 | 596 | 308 | 116 | 14 | 4571 |
| WI | Green Bay | 30 | 19 | 38 | 208 | 540 | 925 | 1350 | 1537 | 1270 | 1065 | 638 | 301 | 85 | 7976 |
| | La Crosse | 30 | 6 | 17 | 152 | 467 | 893 | 1347 | 1545 | 1225 | 975 | 526 | 204 | 38 | 7395 |
| | Madison | 30 | 12 | 33 | 183 | 504 | 892 | 1298 | 1490 | 1209 | 978 | 576 | 261 | 63 | 7499 |
| | Milwaukee | 30 | 13 | 18 | 134 | 443 | 808 | 1200 | 1384 | 1132 | 949 | 611 | 318 | 86 | 7096 |
| WY | Casper | 30 | 15 | 24 | 229 | 581 | 961 | 1252 | 1309 | 1073 | 921 | 661 | 393 | 115 | 7534 |
| | Cheyenne | 30 | 28 | 39 | 238 | 574 | 914 | 1145 | 1187 | 1000 | 928 | 686 | 414 | 136 | 7289 |
| | Lander | 30 | 16 | 24 | 220 | 580 | 1027 | 1355 | 1397 | 1122 | 921 | 643 | 373 | 116 | 7794 |
| | Sheridan | 30 | 27 | 33 | 238 | 581 | 979 | 1293 | 1351 | 1078 | 925 | 628 | 374 | 129 | 7636 |

*Note:* Based on 30-year average values 1971–2000. Degree-day data are used to estimate amounts of energy required to maintain comfortable indoor temperature levels. Each degree that a day's mean temperature is below 65°F is counted as one heating degree day.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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**Table 3A.7 Normal Monthly Cooling Degree Days — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham AP | 30 | 1 | 3 | 16 | 51 | 167 | 351 | 476 | 455 | 280 | 69 | 9 | 3 | 1881 |
| | Huntsville | 30 | 0 | 1 | 8 | 40 | 142 | 326 | 446 | 417 | 238 | 47 | 5 | 1 | 1671 |
| | Mobile | 30 | 9 | 11 | 45 | 108 | 282 | 450 | 529 | 520 | 384 | 151 | 41 | 18 | 2548 |
| | Montgomery | 30 | 2 | 4 | 24 | 73 | 225 | 415 | 519 | 502 | 350 | 106 | 23 | 9 | 2252 |
| AK | Anchorage | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| | Annette | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 8 | 0 | 0 | 0 | 0 | 13 |
| | Barrow | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bethel | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | Bettles | 30 | 0 | 0 | 0 | 0 | 0 | 11 | 20 | 7 | 0 | 0 | 0 | 0 | 38 |
| | Big Delta | 30 | 0 | 0 | 0 | 0 | 0 | 1 | 12 | 12 | 2 | 0 | 0 | 0 | 27 |
| | Cold Bay | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Fairbanks | 30 | 0 | 0 | 0 | 0 | 0 | 20 | 42 | 11 | 1 | 0 | 0 | 0 | 74 |
| | Gulkana | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Homer | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Juneau | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | King Salmon | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Kodiak | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Kotzebue | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 0 | 0 | 12 |
| | Mcgrath | 30 | 0 | 0 | 0 | 0 | 0 | 4 | 11 | 6 | 0 | 0 | 0 | 0 | 21 |
| | Nome | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| | St. Paul Island | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Talkeetna | 30 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 5 |
| | Unalakleet | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 3 |
| | Valdez | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Yakutat | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AZ | Flagstaff | 30 | 0 | 0 | 0 | 0 | 0 | 23 | 64 | 36 | 3 | 0 | 0 | 0 | 126 |
| | Phoenix | 30 | 2 | 15 | 71 | 223 | 473 | 744 | 900 | 859 | 664 | 350 | 53 | 1 | 4355 |
| | Tucson | 30 | 0 | 3 | 25 | 107 | 300 | 577 | 672 | 625 | 477 | 211 | 20 | 0 | 3017 |
| | Winslow | 30 | 0 | 0 | 0 | 3 | 39 | 221 | 384 | 327 | 124 | 6 | 0 | 0 | 1104 |
| | Yuma | 30 | 12 | 29 | 118 | 251 | 466 | 714 | 900 | 882 | 694 | 381 | 82 | 11 | 4540 |
| AR | Fort Smith | 30 | 0 | 0 | 8 | 43 | 155 | 364 | 520 | 491 | 275 | 59 | 5 | 1 | 1921 |
| | Little Rock | 30 | 1 | 1 | 14 | 52 | 188 | 408 | 542 | 502 | 296 | 72 | 8 | 2 | 2086 |
| | North Little Rock | 30 | 0 | 6 | 10 | 66 | 212 | 412 | 564 | 528 | 307 | 83 | 8 | 0 | 2196 |
| CA | Bakersfield | 30 | 0 | 1 | 7 | 56 | 205 | 392 | 580 | 541 | 374 | 144 | 4 | 0 | 2304 |
| | Bishop | 30 | 0 | 0 | 0 | 3 | 45 | 191 | 357 | 293 | 106 | 8 | 0 | 0 | 1003 |
| | Blue Canyon | 30 | 0 | 0 | 0 | 1 | 15 | 41 | 129 | 125 | 84 | 28 | 0 | 0 | 423 |
| | Eureka | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 0 | 0 | 0 | 7 |
| | Fresno | 30 | 0 | 0 | 3 | 40 | 170 | 351 | 530 | 483 | 316 | 97 | 1 | 0 | 1991 |
| | Long Beach | 30 | 3 | 5 | 10 | 28 | 55 | 135 | 260 | 302 | 244 | 119 | 20 | 2 | 1183 |
| | Los Angeles AP | 30 | 6 | 7 | 6 | 15 | 19 | 58 | 135 | 175 | 154 | 81 | 22 | 4 | 682 |
| | Los Angeles CO | 30 | 15 | 23 | 26 | 58 | 84 | 178 | 295 | 325 | 281 | 164 | 44 | 13 | 1506 |
| | Mount Shasta | 30 | 0 | 0 | 0 | 0 | 7 | 31 | 100 | 66 | 29 | 2 | 0 | 0 | 235 |
| | Redding | 30 | 0 | 0 | 3 | 22 | 133 | 310 | 504 | 430 | 263 | 74 | 2 | 0 | 1741 |

*(Continued)*



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**Table 3A.7 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sacramento | 30 | 0 | 0 | 6 | 24 | 110 | 204 | 320 | 303 | 210 | 66 | 5 | 0 | 1248 |
| | San Diego | 30 | 2 | 4 | 5 | 17 | 32 | 81 | 183 | 230 | 199 | 97 | 15 | 1 | 866 |
| | San Francisco AP | 30 | 0 | 0 | 0 | 4 | 10 | 21 | 23 | 26 | 38 | 20 | 0 | 0 | 142 |
| | San Francisco CO | 30 | 0 | 2 | 4 | 3 | 9 | 14 | 19 | 26 | 56 | 22 | 5 | 0 | 160 |
| | Santa Barbara | 30 | 0 | 0 | 5 | 8 | 23 | 50 | 84 | 133 | 125 | 45 | 9 | 0 | 482 |
| | Santa Maria | 30 | 0 | 1 | 1 | 4 | 5 | 10 | 23 | 25 | 33 | 18 | 3 | 0 | 123 |
| | Stockton | 30 | 0 | 0 | 0 | 18 | 111 | 254 | 390 | 363 | 247 | 73 | 0 | 0 | 1456 |
| CO | Alamosa | 30 | 0 | 0 | 0 | 0 | 0 | 7 | 27 | 10 | 0 | 0 | 0 | 0 | 44 |
| | Colorado Springs | 30 | 0 | 0 | 0 | 1 | 5 | 86 | 184 | 131 | 35 | 1 | 0 | 0 | 443 |
| | Denver | 30 | 0 | 0 | 0 | 2 | 23 | 135 | 261 | 217 | 57 | 0 | 0 | 0 | 695 |
| | Grand Junction | 30 | 0 | 0 | 0 | 3 | 45 | 247 | 414 | 350 | 119 | 4 | 0 | 0 | 1182 |
| | Pueblo | 30 | 0 | 0 | 0 | 2 | 31 | 191 | 343 | 276 | 91 | 2 | 0 | 0 | 936 |
| CT | Bridgeport | 30 | 0 | 0 | 0 | 1 | 21 | 125 | 286 | 258 | 91 | 7 | 0 | 0 | 789 |
| | Hartford | 30 | 0 | 0 | 1 | 5 | 38 | 144 | 277 | 220 | 68 | 5 | 1 | 0 | 759 |
| DE | Wilmington | 30 | 0 | 0 | 2 | 9 | 62 | 215 | 368 | 317 | 135 | 16 | 1 | 0 | 1125 |
| DC | Washington Dulles AP | 30 | 0 | 0 | 4 | 11 | 60 | 203 | 345 | 302 | 132 | 15 | 3 | 0 | 1075 |
| | Washington Nat'l AP | 30 | 0 | 0 | 4 | 21 | 108 | 307 | 464 | 410 | 210 | 32 | 4 | 0 | 1560 |
| FL | Apalachicola | 30 | 25 | 14 | 35 | 95 | 284 | 448 | 522 | 517 | 423 | 193 | 63 | 23 | 2642 |
| | Daytona Beach | 30 | 36 | 40 | 86 | 150 | 306 | 441 | 513 | 502 | 436 | 277 | 122 | 52 | 2961 |
| | Fort Myers | 30 | 97 | 99 | 174 | 260 | 423 | 516 | 564 | 568 | 518 | 394 | 222 | 122 | 3957 |
| | Gainesville | 30 | 17 | 17 | 70 | 131 | 308 | 439 | 507 | 498 | 408 | 207 | 74 | 26 | 2702 |
| | Jacksonville | 30 | 15 | 21 | 58 | 116 | 277 | 437 | 535 | 509 | 400 | 183 | 64 | 21 | 2636 |
| | Key West | 30 | 189 | 183 | 277 | 361 | 485 | 552 | 604 | 600 | 550 | 473 | 340 | 233 | 4847 |
| | Miami | 30 | 155 | 154 | 236 | 315 | 442 | 510 | 568 | 568 | 517 | 433 | 291 | 194 | 4383 |
| | Orlando | 30 | 91 | 60 | 129 | 201 | 373 | 485 | 539 | 543 | 484 | 319 | 154 | 79 | 3457 |
| | Pensacola | 30 | 11 | 11 | 42 | 107 | 296 | 466 | 541 | 529 | 412 | 174 | 48 | 19 | 2656 |
| | Tallahassee | 30 | 9 | 12 | 44 | 96 | 273 | 440 | 515 | 509 | 400 | 162 | 49 | 16 | 2525 |
| | Tampa | 30 | 56 | 59 | 124 | 204 | 393 | 501 | 550 | 549 | 489 | 323 | 157 | 76 | 3481 |
| | Vero Beach | 30 | 104 | 83 | 132 | 202 | 347 | 462 | 517 | 513 | 471 | 354 | 183 | 92 | 3460 |
| | West Palm Beach | 30 | 122 | 121 | 195 | 266 | 408 | 485 | 544 | 549 | 499 | 408 | 255 | 160 | 4012 |
| GA | Athens | 30 | 0 | 1 | 8 | 46 | 164 | 351 | 471 | 430 | 257 | 54 | 7 | 1 | 1790 |
| | Atlanta | 30 | 0 | 1 | 11 | 52 | 170 | 354 | 463 | 430 | 262 | 58 | 8 | 1 | 1810 |
| | Augusta | 30 | 1 | 2 | 15 | 52 | 191 | 385 | 511 | 468 | 296 | 77 | 15 | 3 | 2016 |
| | Columbus | 30 | 1 | 4 | 25 | 77 | 234 | 429 | 533 | 511 | 349 | 107 | 21 | 6 | 2297 |
| | Macon | 30 | 1 | 3 | 23 | 73 | 227 | 418 | 528 | 495 | 325 | 95 | 19 | 6 | 2213 |
| | Savannah | 30 | 6 | 11 | 39 | 101 | 267 | 435 | 547 | 506 | 367 | 141 | 40 | 11 | 2471 |
| HI | Hilo | 30 | 198 | 180 | 215 | 223 | 268 | 303 | 336 | 350 | 336 | 328 | 268 | 223 | 3228 |
| | Honolulu | 30 | 249 | 225 | 288 | 319 | 379 | 436 | 490 | 521 | 497 | 472 | 382 | 303 | 4561 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kahului | 30 | 210 | 195 | 250 | 277 | 330 | 379 | 429 | 448 | 422 | 407 | 329 | 260 | 3936 |
| | Lihue | 30 | 207 | 188 | 239 | 266 | 323 | 382 | 433 | 455 | 435 | 408 | 327 | 257 | 3920 |
| ID | Boise | 30 | 0 | 0 | 0 | 3 | 30 | 116 | 281 | 260 | 75 | 4 | 0 | 0 | 769 |
| | Lewiston | 30 | 0 | 0 | 0 | 3 | 29 | 105 | 283 | 285 | 84 | 3 | 0 | 0 | 792 |
| | Pocatello | 30 | 0 | 0 | 0 | 0 | 3 | 51 | 167 | 143 | 23 | 0 | 0 | 0 | 387 |
| IL | Chicago | 30 | 0 | 0 | 1 | 9 | 48 | 159 | 283 | 234 | 91 | 10 | 0 | 0 | 835 |
| | Moline | 30 | 0 | 0 | 1 | 12 | 62 | 205 | 322 | 254 | 101 | 12 | 0 | 0 | 969 |
| | Peoria | 30 | 0 | 0 | 1 | 11 | 64 | 210 | 325 | 263 | 112 | 12 | 0 | 0 | 998 |
| | Rockford | 30 | 0 | 0 | 1 | 7 | 49 | 162 | 263 | 205 | 74 | 7 | 0 | 0 | 768 |
| | Springfield | 30 | 0 | 0 | 2 | 17 | 84 | 249 | 358 | 291 | 140 | 23 | 1 | 0 | 1165 |
| IN | Evansville | 30 | 0 | 0 | 4 | 23 | 108 | 304 | 425 | 356 | 173 | 27 | 2 | 0 | 1422 |
| | Fort Wayne | 30 | 0 | 0 | 1 | 7 | 53 | 183 | 278 | 212 | 88 | 8 | 0 | 0 | 830 |
| | Indianapolis | 30 | 0 | 0 | 2 | 10 | 69 | 221 | 331 | 272 | 122 | 14 | 1 | 0 | 1042 |
| | South Bend | 30 | 0 | 0 | 1 | 10 | 53 | 172 | 268 | 214 | 86 | 9 | 0 | 0 | 813 |
| IA | Des Moines | 30 | 0 | 0 | 1 | 12 | 60 | 219 | 353 | 285 | 110 | 12 | 0 | 0 | 1052 |
| | Dubuque | 30 | 0 | 0 | 0 | 6 | 37 | 138 | 233 | 175 | 61 | 6 | 0 | 0 | 656 |
| | Sioux City | 30 | 0 | 0 | 0 | 11 | 53 | 198 | 311 | 246 | 87 | 8 | 0 | 0 | 914 |
| | Waterloo | 30 | 0 | 0 | 0 | 7 | 47 | 168 | 261 | 198 | 70 | 7 | 0 | 0 | 758 |
| KS | Concordia | 30 | 0 | 0 | 2 | 15 | 63 | 265 | 436 | 366 | 163 | 22 | 1 | 0 | 1333 |
| | Dodge City | 30 | 0 | 0 | 2 | 18 | 79 | 291 | 462 | 407 | 193 | 28 | 1 | 0 | 1481 |
| | Goodland | 30 | 0 | 0 | 0 | 4 | 26 | 173 | 320 | 266 | 99 | 6 | 0 | 0 | 894 |
| | Topeka | 30 | 0 | 0 | 3 | 22 | 85 | 278 | 419 | 357 | 166 | 26 | 1 | 0 | 1357 |
| | Wichita | 30 | 0 | 0 | 2 | 19 | 93 | 330 | 503 | 454 | 221 | 35 | 1 | 0 | 1658 |
| KY | Greater Cincinnati AP | 30 | 0 | 0 | 3 | 13 | 71 | 209 | 334 | 280 | 126 | 16 | 1 | 0 | 1053 |
| | Jackson | 30 | 0 | 0 | 0 | 11 | 100 | 201 | 310 | 277 | 130 | 29 | 1 | 0 | 1059 |
| | Lexington | 30 | 0 | 0 | 3 | 16 | 80 | 228 | 350 | 307 | 147 | 21 | 2 | 0 | 1154 |
| | Louisville | 30 | 0 | 0 | 6 | 24 | 109 | 287 | 421 | 374 | 189 | 29 | 3 | 1 | 1443 |
| | Paducah | 30 | 0 | 0 | 6 | 33 | 122 | 320 | 444 | 377 | 191 | 37 | 3 | 0 | 1533 |
| LA | Baton Rouge | 30 | 12 | 15 | 55 | 128 | 303 | 462 | 538 | 523 | 389 | 157 | 48 | 22 | 2652 |
| | Lake Charles | 30 | 9 | 13 | 49 | 126 | 312 | 467 | 544 | 534 | 399 | 178 | 54 | 20 | 2705 |
| | New Orleans | 30 | 15 | 19 | 62 | 136 | 320 | 466 | 538 | 534 | 413 | 182 | 62 | 29 | 2776 |
| | Shreveport | 30 | 5 | 7 | 31 | 87 | 242 | 436 | 553 | 532 | 353 | 119 | 24 | 7 | 2396 |
| ME | Caribou | 30 | 0 | 0 | 0 | 0 | 7 | 39 | 80 | 56 | 9 | 0 | 0 | 0 | 191 |
| | Portland | 30 | 0 | 0 | 0 | 0 | 7 | 51 | 144 | 120 | 24 | 1 | 0 | 0 | 347 |
| MD | Baltimore | 30 | 0 | 0 | 4 | 13 | 71 | 236 | 390 | 332 | 153 | 19 | 2 | 0 | 1220 |
| MA | Blue Hill | 30 | 0 | 0 | 1 | 3 | 21 | 93 | 215 | 173 | 49 | 3 | 0 | 0 | 558 |
| | Boston | 30 | 0 | 0 | 1 | 4 | 32 | 139 | 282 | 235 | 76 | 7 | 1 | 0 | 777 |
| | Worcester | 30 | 0 | 0 | 0 | 0 | 7 | 64 | 166 | 122 | 12 | 0 | 0 | 0 | 371 |
| MI | Alpena | 30 | 0 | 0 | 0 | 3 | 13 | 54 | 117 | 83 | 22 | 1 | 0 | 0 | 293 |
| | Detroit | 30 | 0 | 0 | 0 | 6 | 41 | 144 | 252 | 204 | 75 | 5 | 0 | 0 | 727 |
| | Flint | 30 | 0 | 0 | 1 | 5 | 33 | 110 | 199 | 151 | 52 | 4 | 0 | 0 | 555 |
| | Grand Rapids | 30 | 0 | 0 | 1 | 6 | 38 | 124 | 218 | 165 | 56 | 5 | 0 | 0 | 613 |
| | Houghton Lake | 30 | 0 | 0 | 0 | 3 | 20 | 64 | 127 | 89 | 24 | 1 | 0 | 0 | 328 |
| | Lansing | 30 | 0 | 0 | 1 | 6 | 34 | 113 | 195 | 151 | 53 | 5 | 0 | 0 | 558 |
| | Marquette | 30 | 0 | 0 | 0 | 0 | 12 | 30 | 72 | 50 | 3 | 0 | 0 | 0 | 167 |

*(Continued)*



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**Table 3A.7 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Muskegon | 30 | 0 | 0 | 0 | 4 | 24 | 86 | 181 | 145 | 44 | 3 | 0 | 0 | 487 |
| | Sault Ste. Marie | 30 | 0 | 0 | 0 | 1 | 6 | 20 | 56 | 50 | 12 | 0 | 0 | 0 | 145 |
| MN | Duluth | 30 | 0 | 0 | 0 | 0 | 7 | 28 | 82 | 60 | 12 | 0 | 0 | 0 | 189 |
| | International Falls | 30 | 0 | 0 | 0 | 1 | 17 | 47 | 91 | 67 | 10 | 0 | 0 | 0 | 233 |
| | Minneapolis-St. Paul | 30 | 0 | 0 | 0 | 4 | 41 | 146 | 259 | 190 | 56 | 3 | 0 | 0 | 699 |
| | Rochester | 30 | 0 | 0 | 0 | 1 | 30 | 99 | 181 | 135 | 26 | 1 | 0 | 0 | 473 |
| | Saint Cloud | 30 | 0 | 0 | 0 | 2 | 26 | 90 | 172 | 121 | 31 | 1 | 0 | 0 | 443 |
| MS | Jackson | 30 | 5 | 8 | 32 | 83 | 232 | 424 | 525 | 505 | 340 | 101 | 25 | 10 | 2290 |
| | Meridian | 30 | 4 | 6 | 26 | 70 | 213 | 400 | 509 | 495 | 331 | 91 | 20 | 8 | 2173 |
| | Tupelo | 30 | 0 | 1 | 14 | 50 | 171 | 364 | 488 | 453 | 274 | 60 | 8 | 2 | 1885 |
| MO | Columbia | 30 | 0 | 0 | 3 | 18 | 70 | 245 | 396 | 341 | 152 | 20 | 1 | 0 | 1246 |
| | Kansas City | 30 | 0 | 0 | 0 | 12 | 101 | 264 | 418 | 367 | 151 | 12 | 0 | 0 | 1325 |
| | St. Louis | 30 | 0 | 0 | 7 | 32 | 114 | 316 | 461 | 396 | 196 | 36 | 3 | 0 | 1561 |
| | Springfield | 30 | 0 | 0 | 3 | 20 | 83 | 258 | 415 | 379 | 179 | 27 | 1 | 0 | 1365 |
| MT | Billings | 30 | 0 | 0 | 0 | 2 | 13 | 90 | 227 | 204 | 44 | 3 | 0 | 0 | 583 |
| | Glasgow | 30 | 0 | 0 | 0 | 1 | 17 | 80 | 185 | 182 | 28 | 1 | 0 | 0 | 494 |
| | Great Falls | 30 | 0 | 0 | 0 | 1 | 7 | 47 | 126 | 121 | 22 | 2 | 0 | 0 | 326 |
| | Havre | 30 | 0 | 0 | 0 | 1 | 10 | 59 | 146 | 141 | 19 | 1 | 0 | 0 | 377 |
| | Helena | 30 | 0 | 0 | 0 | 0 | 3 | 39 | 122 | 100 | 13 | 0 | 0 | 0 | 277 |
| | Kalispell | 30 | 0 | 0 | 0 | 0 | 3 | 17 | 62 | 63 | 4 | 0 | 0 | 0 | 149 |
| | Missoula | 30 | 0 | 0 | 0 | 0 | 3 | 33 | 111 | 99 | 10 | 0 | 0 | 0 | 256 |
| NE | Grand Island | 30 | 0 | 0 | 1 | 11 | 48 | 218 | 349 | 285 | 107 | 8 | 0 | 0 | 1027 |
| | Lincoln | 30 | 0 | 0 | 1 | 13 | 56 | 244 | 390 | 315 | 123 | 12 | 0 | 0 | 1154 |
| | Norfolk | 30 | 0 | 0 | 0 | 11 | 48 | 202 | 324 | 261 | 93 | 7 | 0 | 0 | 946 |
| | North Platte | 30 | 0 | 0 | 0 | 4 | 22 | 139 | 279 | 230 | 70 | 2 | 0 | 0 | 746 |
| | Omaha Eppley AP | 30 | 0 | 0 | 1 | 14 | 60 | 233 | 365 | 296 | 114 | 12 | 0 | 0 | 1095 |
| | Omaha (North) | 30 | 0 | 0 | 0 | 8 | 71 | 209 | 330 | 295 | 101 | 5 | 0 | 0 | 1019 |
| | Scottsbluff | 30 | 0 | 0 | 0 | 2 | 19 | 138 | 279 | 225 | 63 | 1 | 0 | 0 | 727 |
| | Valentine | 30 | 0 | 0 | 0 | 5 | 27 | 141 | 286 | 242 | 75 | 3 | 0 | 0 | 779 |
| NV | Elko | 30 | 0 | 0 | 0 | 0 | 2 | 62 | 181 | 135 | 31 | 1 | 0 | 0 | 412 |
| | Ely | 30 | 0 | 0 | 0 | 0 | 0 | 22 | 98 | 69 | 7 | 0 | 0 | 0 | 196 |
| | Las Vegas | 30 | 0 | 1 | 17 | 93 | 310 | 597 | 792 | 734 | 470 | 150 | 4 | 0 | 3168 |
| | Reno | 30 | 0 | 0 | 0 | 0 | 11 | 72 | 204 | 164 | 41 | 1 | 0 | 0 | 493 |
| | Winnemucca | 30 | 0 | 0 | 0 | 0 | 11 | 81 | 232 | 174 | 28 | 0 | 0 | 0 | 526 |
| NH | Concord | 30 | 0 | 0 | 0 | 2 | 18 | 82 | 173 | 133 | 33 | 1 | 0 | 0 | 442 |
| | Mt. Washington | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NJ | Atlantic City AP | 30 | 0 | 0 | 1 | 5 | 44 | 168 | 322 | 269 | 110 | 15 | 1 | 0 | 935 |
| | Atlantic City CO | 30 | 0 | 0 | 0 | 0 | 25 | 147 | 316 | 302 | 136 | 25 | 0 | 0 | 951 |
| | Newark | 30 | 0 | 0 | 2 | 10 | 70 | 240 | 403 | 350 | 146 | 19 | 2 | 0 | 1242 |
| NM | Albuquerque | 30 | 0 | 0 | 0 | 6 | 70 | 297 | 417 | 343 | 148 | 9 | 0 | 0 | 1290 |
| | Clayton | 30 | 0 | 0 | 0 | 6 | 37 | 173 | 274 | 228 | 77 | 2 | 0 | 0 | 797 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Roswell | 30 | 0 | 0 | 1 | 47 | 194 | 391 | 488 | 431 | 228 | 32 | 2 | 0 | 1814 |
| NY | Albany | 30 | 0 | 0 | 1 | 3 | 27 | 102 | 206 | 157 | 46 | 2 | 0 | 0 | 544 |
| | Binghamton | 30 | 0 | 0 | 1 | 4 | 23 | 74 | 158 | 115 | 32 | 2 | 0 | 0 | 409 |
| | Buffalo | 30 | 0 | 0 | 0 | 4 | 28 | 101 | 203 | 158 | 50 | 4 | 0 | 0 | 548 |
| | Islip | 30 | 0 | 0 | 0 | 0 | 15 | 129 | 296 | 251 | 72 | 7 | 0 | 0 | 770 |
| | New York C. Park | 30 | 0 | 0 | 2 | 10 | 63 | 214 | 379 | 335 | 138 | 17 | 2 | 0 | 1160 |
| | New York (JFK AP) | 30 | 0 | 0 | 0 | 2 | 31 | 162 | 335 | 306 | 125 | 13 | 1 | 0 | 975 |
| | New York (Laguardia AP) | 30 | 0 | 0 | 1 | 6 | 54 | 209 | 377 | 336 | 141 | 17 | 1 | 0 | 1142 |
| | Rochester | 30 | 0 | 0 | 1 | 5 | 32 | 109 | 210 | 162 | 54 | 4 | 0 | 0 | 577 |
| | Syracuse | 30 | 0 | 0 | 1 | 4 | 29 | 105 | 203 | 158 | 48 | 3 | 0 | 0 | 551 |
| NC | Asheville | 30 | 0 | 0 | 0 | 6 | 47 | 165 | 278 | 243 | 104 | 8 | 0 | 0 | 851 |
| | Cape Hatteras | 30 | 1 | 1 | 5 | 29 | 122 | 297 | 440 | 422 | 297 | 96 | 24 | 4 | 1738 |
| | Charlotte | 30 | 0 | 1 | 7 | 40 | 142 | 323 | 451 | 405 | 226 | 43 | 5 | 1 | 1644 |
| | Greensboro-Wnstn-Slm-HPT | 30 | 0 | 0 | 4 | 25 | 97 | 263 | 398 | 345 | 172 | 24 | 3 | 1 | 1332 |
| | Raleigh | 30 | 0 | 1 | 9 | 38 | 119 | 293 | 429 | 379 | 206 | 39 | 6 | 2 | 1521 |
| | Wilmington | 30 | 3 | 4 | 17 | 65 | 187 | 361 | 501 | 455 | 304 | 90 | 25 | 5 | 2017 |
| ND | Bismarck | 30 | 0 | 0 | 0 | 2 | 18 | 80 | 180 | 161 | 30 | 0 | 0 | 0 | 471 |
| | Fargo | 30 | 0 | 0 | 0 | 3 | 33 | 104 | 191 | 162 | 38 | 2 | 0 | 0 | 533 |
| | Grand Forks | 30 | 0 | 0 | 0 | 2 | 30 | 85 | 148 | 127 | 27 | 1 | 0 | 0 | 420 |
| | Williston | 30 | 0 | 0 | 0 | 1 | 20 | 82 | 177 | 166 | 24 | 1 | 0 | 0 | 471 |
| OH | Akron | 30 | 0 | 0 | 1 | 7 | 41 | 136 | 232 | 189 | 69 | 4 | 0 | 0 | 679 |
| | Cleveland | 30 | 0 | 0 | 2 | 7 | 40 | 140 | 239 | 195 | 80 | 8 | 1 | 0 | 712 |
| | Columbus | 30 | 0 | 0 | 2 | 9 | 61 | 188 | 296 | 251 | 106 | 11 | 1 | 0 | 925 |
| | Dayton | 30 | 0 | 0 | 2 | 9 | 62 | 194 | 305 | 246 | 105 | 11 | 1 | 0 | 935 |
| | Mansfield | 30 | 0 | 0 | 1 | 7 | 39 | 136 | 228 | 181 | 73 | 7 | 0 | 0 | 672 |
| | Toledo | 30 | 0 | 0 | 1 | 7 | 42 | 148 | 248 | 190 | 73 | 6 | 0 | 0 | 715 |
| | Youngstown | 30 | 0 | 0 | 1 | 8 | 33 | 112 | 190 | 154 | 57 | 5 | 1 | 0 | 561 |
| OK | Oklahoma City | 30 | 0 | 1 | 7 | 38 | 145 | 360 | 527 | 497 | 271 | 58 | 3 | 0 | 1907 |
| | Tulsa | 30 | 0 | 1 | 10 | 50 | 163 | 385 | 568 | 524 | 277 | 64 | 6 | 1 | 2049 |
| OR | Astoria | 30 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 7 | 7 | 1 | 0 | 0 | 22 |
| | Burns | 30 | 0 | 0 | 0 | 0 | 0 | 19 | 117 | 70 | 12 | 0 | 0 | 0 | 218 |
| | Eugene | 30 | 0 | 0 | 0 | 0 | 5 | 21 | 95 | 93 | 32 | 1 | 0 | 0 | 247 |
| | Medford | 30 | 0 | 0 | 0 | 2 | 24 | 90 | 253 | 240 | 95 | 7 | 0 | 0 | 711 |
| | Pendleton | 30 | 0 | 0 | 0 | 2 | 23 | 86 | 243 | 224 | 63 | 3 | 0 | 0 | 644 |
| | Portland | 30 | 0 | 0 | 0 | 1 | 15 | 44 | 138 | 145 | 53 | 2 | 0 | 0 | 398 |
| | Salem | 30 | 0 | 0 | 0 | 0 | 7 | 25 | 95 | 98 | 31 | 1 | 0 | 0 | 257 |
| | Sexton Summit | 30 | 0 | 0 | 0 | 0 | 0 | 11 | 84 | 76 | 62 | 15 | 0 | 0 | 248 |
| PC | Guam | 30 | 390 | 350 | 414 | 435 | 473 | 463 | 458 | 449 | 439 | 449 | 439 | 431 | 5190 |
| | Johnston Island | 30 | 389 | 354 | 399 | 409 | 457 | 485 | 526 | 545 | 523 | 522 | 448 | 412 | 5469 |
| | Koror | 30 | 507 | 454 | 518 | 518 | 545 | 503 | 509 | 515 | 509 | 527 | 524 | 526 | 6155 |
| | Kwajalein, Marshall IS | 30 | 512 | 470 | 536 | 515 | 538 | 515 | 529 | 534 | 518 | 537 | 513 | 522 | 6239 |

*(Continued)*



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**Table 3A.7 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Majuro, Marshall IS | 30 | 487 | 451 | 502 | 482 | 504 | 485 | 498 | 507 | 496 | 510 | 490 | 493 | 5905 |
| | Pago Pago, Amer Samoa | 30 | 511 | 469 | 526 | 498 | 493 | 460 | 454 | 457 | 460 | 486 | 485 | 515 | 5814 |
| | Pohnpei, Caroline IS | 30 | 490 | 449 | 506 | 485 | 501 | 480 | 486 | 487 | 471 | 486 | 477 | 493 | 5811 |
| | Chuuk, E. Caroline IS | 30 | 510 | 456 | 513 | 501 | 522 | 497 | 506 | 492 | 488 | 508 | 511 | 511 | 6015 |
| | Wake Island | 30 | 396 | 344 | 409 | 427 | 488 | 527 | 567 | 567 | 556 | 546 | 480 | 443 | 5750 |
| | Yap, W Caroline IS | 30 | 467 | 428 | 488 | 493 | 518 | 479 | 484 | 478 | 466 | 486 | 476 | 484 | 5747 |
| PA | Allentown | 30 | 0 | 0 | 1 | 6 | 45 | 164 | 292 | 235 | 83 | 7 | 0 | 0 | 833 |
| | Erie | 30 | 0 | 0 | 1 | 5 | 30 | 105 | 197 | 166 | 63 | 6 | 0 | 0 | 573 |
| | Harrisburg | 30 | 0 | 0 | 0 | 1 | 54 | 186 | 337 | 279 | 87 | 11 | 0 | 0 | 955 |
| | Middletown/ Harrisburg AP | 30 | 0 | 0 | 0 | 1 | 54 | 186 | 337 | 279 | 87 | 11 | 0 | 0 | 955 |
| | Philadelphia | 30 | 0 | 0 | 2 | 10 | 70 | 234 | 395 | 351 | 152 | 19 | 2 | 0 | 1235 |
| | Pittsburgh | 30 | 0 | 0 | 2 | 8 | 41 | 143 | 244 | 203 | 78 | 6 | 1 | 0 | 726 |
| | Avoca | 30 | 0 | 0 | 1 | 5 | 35 | 113 | 220 | 174 | 57 | 4 | 0 | 0 | 609 |
| | Williamsport | 30 | 0 | 0 | 0 | 6 | 39 | 135 | 251 | 206 | 68 | 4 | 0 | 0 | 709 |
| RI | Block IS | 30 | 0 | 0 | 0 | 0 | 1 | 51 | 184 | 177 | 48 | 5 | 0 | 0 | 466 |
| | Providence | 30 | 0 | 0 | 0 | 3 | 25 | 122 | 265 | 223 | 71 | 5 | 0 | 0 | 714 |
| SC | Charleston AP | 30 | 3 | 7 | 29 | 85 | 242 | 408 | 532 | 494 | 348 | 122 | 35 | 8 | 2313 |
| | Charleston CO | 30 | 16 | 7 | 27 | 83 | 266 | 431 | 551 | 514 | 377 | 156 | 47 | 11 | 2486 |
| | Columbia | 30 | 2 | 4 | 20 | 69 | 206 | 388 | 515 | 467 | 296 | 76 | 15 | 5 | 2063 |
| | Greenville-Spartanburg | 30 | 0 | 0 | 5 | 30 | 127 | 304 | 430 | 384 | 207 | 35 | 3 | 1 | 1526 |
| SD | Aberdeen | 30 | 0 | 0 | 0 | 3 | 29 | 112 | 235 | 196 | 49 | 2 | 0 | 0 | 626 |
| | Huron | 30 | 0 | 0 | 0 | 4 | 29 | 138 | 273 | 228 | 66 | 3 | 0 | 0 | 741 |
| | Rapid City | 30 | 0 | 0 | 0 | 2 | 13 | 86 | 227 | 208 | 59 | 3 | 0 | 0 | 598 |
| | Sioux Falls | 30 | 0 | 0 | 0 | 5 | 37 | 151 | 278 | 217 | 65 | 4 | 0 | 0 | 757 |
| TN | Bristol-JhnCty-Kgsprt | 30 | 0 | 0 | 1 | 10 | 61 | 200 | 309 | 274 | 128 | 11 | 1 | 0 | 995 |
| | Chattanooga | 30 | 0 | 0 | 5 | 32 | 124 | 312 | 450 | 418 | 229 | 35 | 2 | 1 | 1608 |
| | Knoxville | 30 | 0 | 1 | 5 | 27 | 110 | 282 | 408 | 381 | 205 | 28 | 3 | 0 | 1450 |
| | Memphis | 30 | 1 | 2 | 15 | 72 | 210 | 428 | 554 | 504 | 307 | 84 | 11 | 2 | 2190 |
| | Nashville | 30 | 0 | 0 | 9 | 37 | 136 | 321 | 455 | 416 | 230 | 46 | 5 | 1 | 1656 |
| | Oak Ridge | 30 | 0 | 0 | 2 | 19 | 95 | 254 | 380 | 347 | 180 | 23 | 1 | 0 | 1301 |
| TX | Abilene | 30 | 0 | 5 | 28 | 94 | 253 | 442 | 568 | 535 | 327 | 118 | 15 | 1 | 2386 |
| | Amarillo | 30 | 0 | 0 | 2 | 18 | 90 | 285 | 405 | 345 | 173 | 26 | 0 | 0 | 1344 |
| | Austin/City | 30 | 7 | 18 | 59 | 147 | 323 | 495 | 605 | 610 | 439 | 207 | 51 | 13 | 2974 |
| | Austin/Bergstrom | 30 | 8 | 11 | 23 | 107 | 307 | 453 | 551 | 532 | 377 | 148 | 32 | 8 | 2557 |
| | Brownsville | 30 | 60 | 76 | 180 | 292 | 463 | 551 | 607 | 608 | 497 | 338 | 170 | 82 | 3924 |
| | Corpus Christi | 30 | 32 | 43 | 121 | 229 | 402 | 520 | 594 | 598 | 485 | 300 | 123 | 51 | 3498 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dallas-Fort Worth | 30 | 2 | 11 | 10 | 72 | 265 | 478 | 621 | 601 | 376 | 118 | 15 | 2 | 2571 |
| | Dallas-Love Field | 30 | 2 | 9 | 39 | 110 | 290 | 511 | 659 | 646 | 417 | 162 | 28 | 5 | 2878 |
| | Del Rio | 30 | 2 | 18 | 86 | 207 | 401 | 545 | 630 | 622 | 453 | 217 | 41 | 4 | 3226 |
| | El Paso | 30 | 0 | 1 | 8 | 65 | 238 | 481 | 535 | 473 | 293 | 69 | 2 | 0 | 2165 |
| | Galveston | 30 | 30 | 23 | 65 | 163 | 367 | 515 | 596 | 601 | 482 | 286 | 122 | 30 | 3280 |
| | Houston | 30 | 15 | 21 | 63 | 147 | 328 | 485 | 573 | 563 | 412 | 196 | 65 | 25 | 2893 |
| | Lubbock | 30 | 0 | 0 | 7 | 48 | 180 | 382 | 472 | 413 | 225 | 49 | 1 | 0 | 1777 |
| | Midland-Odessa | 30 | 0 | 2 | 15 | 77 | 254 | 438 | 512 | 473 | 281 | 83 | 4 | 0 | 2139 |
| | Port Arthur | 30 | 11 | 16 | 55 | 140 | 324 | 480 | 553 | 546 | 417 | 195 | 63 | 23 | 2823 |
| | San Angelo | 30 | 1 | 4 | 30 | 107 | 277 | 446 | 554 | 519 | 322 | 113 | 16 | 1 | 2390 |
| | San Antonio | 30 | 7 | 19 | 68 | 161 | 344 | 505 | 607 | 601 | 439 | 215 | 57 | 15 | 3038 |
| | Victoria | 30 | 18 | 26 | 84 | 181 | 368 | 514 | 601 | 597 | 454 | 248 | 83 | 29 | 3203 |
| | Waco | 30 | 2 | 8 | 39 | 111 | 292 | 497 | 637 | 628 | 416 | 170 | 34 | 6 | 2840 |
| | Wichita Falls | 30 | 0 | 2 | 19 | 66 | 220 | 448 | 618 | 574 | 339 | 99 | 10 | 1 | 2396 |
| UT | Milford | 30 | 0 | 0 | 0 | 1 | 18 | 115 | 286 | 239 | 54 | 2 | 0 | 0 | 715 |
| | Salt Lake City | 30 | 0 | 0 | 0 | 4 | 34 | 184 | 395 | 355 | 111 | 6 | 0 | 0 | 1089 |
| VT | Burlington | 30 | 0 | 0 | 0 | 3 | 23 | 96 | 192 | 139 | 35 | 1 | 0 | 0 | 489 |
| VA | Lynchburg | 30 | 0 | 0 | 3 | 20 | 72 | 218 | 348 | 308 | 141 | 19 | 2 | 0 | 1131 |
| | Norfolk | 30 | 1 | 2 | 8 | 35 | 119 | 303 | 456 | 403 | 240 | 50 | 11 | 2 | 1630 |
| | Richmond | 30 | 0 | 1 | 8 | 33 | 107 | 282 | 428 | 374 | 193 | 33 | 6 | 1 | 1466 |
| | Roanoke | 30 | 0 | 0 | 4 | 20 | 74 | 217 | 355 | 309 | 136 | 17 | 2 | 0 | 1134 |
| WA | Olympia | 30 | 0 | 0 | 0 | 0 | 2 | 10 | 38 | 40 | 7 | 0 | 0 | 0 | 97 |
| | Quillayute | 30 | 0 | 0 | 0 | 0 | 1 | 3 | 7 | 8 | 4 | 0 | 0 | 0 | 23 |
| | Seattle CO | 30 | 0 | 0 | 0 | 0 | 4 | 15 | 67 | 79 | 27 | 0 | 0 | 0 | 192 |
| | Seattle Sea-TAC AP | 30 | 0 | 0 | 0 | 0 | 5 | 19 | 65 | 65 | 19 | 0 | 0 | 0 | 173 |
| | Spokane | 30 | 0 | 0 | 0 | 1 | 11 | 46 | 155 | 154 | 26 | 1 | 0 | 0 | 394 |
| | Walla Walla | 30 | 0 | 0 | 0 | 4 | 29 | 138 | 329 | 323 | 131 | 3 | 0 | 0 | 957 |
| | Yakima | 30 | 0 | 0 | 0 | 1 | 18 | 68 | 187 | 163 | 28 | 0 | 0 | 0 | 465 |
| PR | San Juan | 30 | 360 | 332 | 388 | 421 | 484 | 513 | 533 | 539 | 515 | 513 | 436 | 392 | 5426 |
| WV | Beckley | 30 | 0 | 0 | 1 | 8 | 29 | 99 | 183 | 149 | 56 | 4 | 0 | 0 | 529 |
| | Charleston | 30 | 0 | 0 | 7 | 25 | 77 | 204 | 324 | 280 | 125 | 18 | 3 | 1 | 1064 |
| | Elkins | 30 | 0 | 0 | 0 | 2 | 16 | 76 | 153 | 126 | 41 | 2 | 0 | 0 | 416 |
| | Huntington | 30 | 0 | 0 | 8 | 25 | 82 | 218 | 341 | 300 | 135 | 19 | 3 | 1 | 1132 |
| WI | Green Bay | 30 | 0 | 0 | 0 | 3 | 24 | 95 | 177 | 126 | 36 | 2 | 0 | 0 | 463 |
| | La Crosse | 30 | 0 | 0 | 0 | 8 | 49 | 162 | 272 | 208 | 70 | 6 | 0 | 0 | 775 |
| | Madison | 30 | 0 | 0 | 0 | 6 | 33 | 123 | 214 | 154 | 48 | 4 | 0 | 0 | 582 |
| | Milwaukee | 30 | 0 | 0 | 0 | 5 | 27 | 114 | 222 | 180 | 63 | 5 | 0 | 0 | 616 |
| WY | Casper | 30 | 0 | 0 | 0 | 0 | 3 | 64 | 186 | 154 | 28 | 0 | 0 | 0 | 435 |
| | Cheyenne | 30 | 0 | 0 | 0 | 0 | 1 | 41 | 126 | 92 | 20 | 0 | 0 | 0 | 280 |
| | Lander | 30 | 0 | 0 | 0 | 0 | 3 | 70 | 190 | 153 | 29 | 0 | 0 | 0 | 445 |
| | Sheridan | 30 | 0 | 0 | 0 | 1 | 4 | 52 | 165 | 154 | 30 | 1 | 0 | 0 | 407 |

*Note:* Based on 30-year average values 1971–2000. Degree-day data are used to estimate amounts of energy required to maintain comfortable indoor temperature levels. Each degree that a day's mean temperature is above 65°F is counted as one cooling degree day.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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**Table 3A.8 Average Wind Speed (MPH) — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham AP | 59 | 8.1 | 8.7 | 9.0 | 8.2 | 6.8 | 6.0 | 5.7 | 5.4 | 6.3 | 6.2 | 7.2 | 7.7 | 7.1 |
| | Huntsville | 35 | 9.0 | 9.4 | 9.8 | 9.2 | 7.9 | 6.9 | 6.0 | 5.8 | 6.7 | 7.3 | 8.1 | 9.0 | 7.9 |
| | Mobile | 54 | 10.1 | 10.3 | 10.7 | 10.1 | 8.7 | 7.5 | 6.9 | 6.7 | 7.7 | 8.0 | 8.9 | 9.6 | 8.8 |
| | Montgomery | 58 | 7.7 | 8.2 | 8.3 | 7.3 | 6.1 | 5.8 | 5.7 | 5.2 | 5.9 | 5.7 | 6.5 | 7.1 | 6.6 |
| AK | Anchorage | 49 | 6.4 | 6.8 | 7.1 | 7.3 | 8.5 | 8.4 | 7.3 | 6.9 | 6.7 | 6.7 | 6.4 | 6.3 | 7.1 |
| | Annette | 38 | 11.6 | 11.8 | 10.5 | 10.6 | 9.0 | 8.5 | 7.7 | 8.1 | 8.8 | 11.2 | 11.7 | 12.0 | 10.1 |
| | Barrow | 69 | 11.9 | 11.3 | 11.3 | 11.5 | 12.0 | 11.5 | 11.7 | 12.4 | 13.2 | 13.3 | 12.5 | 11.7 | 12.0 |
| | Barter IS | 33 | 15.1 | 14.4 | 13.7 | 12.0 | 12.7 | 11.6 | 10.9 | 11.8 | 13.2 | 14.8 | 14.9 | 13.9 | 13.2 |
| | Bethel | 44 | 14.5 | 14.7 | 13.7 | 12.9 | 11.5 | 11.0 | 10.6 | 11.0 | 11.6 | 12.3 | 13.2 | 13.6 | 12.6 |
| | Bettles | 27 | 5.8 | 6.3 | 7.0 | 7.4 | 7.2 | 6.8 | 6.5 | 6.2 | 6.4 | 6.4 | 5.8 | 5.6 | 6.5 |
| | Big Delta | 26 | 11.2 | 10.2 | 8.8 | 8.0 | 8.2 | 6.9 | 6.1 | 6.6 | 7.6 | 8.7 | 10.2 | 10.0 | 8.5 |
| | Cold Bay | 47 | 17.5 | 17.9 | 17.4 | 17.5 | 16.2 | 15.8 | 15.6 | 16.2 | 16.2 | 16.6 | 17.5 | 17.5 | 16.8 |
| | Fairbanks | 51 | 3.0 | 3.9 | 5.3 | 6.6 | 7.7 | 7.1 | 6.6 | 6.1 | 6.0 | 5.3 | 3.8 | 3.0 | 5.4 |
| | Gulkana | 14 | 5.0 | 4.9 | 6.3 | 8.5 | 8.7 | 8.1 | 7.7 | 7.7 | 7.3 | 6.0 | 4.1 | 3.3 | 6.5 |
| | Homer | 28 | 7.8 | 7.7 | 7.8 | 8.1 | 8.2 | 7.8 | 7.1 | 6.6 | 7.0 | 7.3 | 7.7 | 7.8 | 7.6 |
| | Juneau | 57 | 8.1 | 8.2 | 8.4 | 8.5 | 8.3 | 7.7 | 7.5 | 7.4 | 8.0 | 9.5 | 8.4 | 8.8 | 8.2 |
| | King Salmon | 47 | 10.5 | 11.0 | 11.3 | 10.9 | 11.0 | 10.5 | 9.9 | 10.0 | 10.4 | 10.3 | 10.4 | 10.1 | 10.5 |
| | Kodiak | 49 | 12.7 | 12.5 | 12.5 | 11.6 | 10.6 | 9.3 | 7.7 | 8.4 | 9.7 | 11.4 | 12.5 | 12.6 | 11.0 |
| | Kotzebue | 56 | 13.9 | 13.0 | 11.9 | 12.0 | 10.7 | 11.9 | 12.7 | 13.2 | 13.2 | 13.5 | 14.4 | 12.9 | 12.8 |
| | Mcgrath | 52 | 3.2 | 4.2 | 5.3 | 6.5 | 6.7 | 6.4 | 5.9 | 5.8 | 5.9 | 5.4 | 3.7 | 3.2 | 5.2 |
| | Nome | 55 | 10.8 | 11.0 | 10.1 | 10.1 | 9.9 | 9.7 | 9.7 | 10.4 | 11.0 | 10.5 | 11.5 | 10.3 | 10.4 |
| | St. Paul Island | 28 | 19.9 | 20.0 | 18.8 | 17.4 | 14.9 | 13.6 | 12.1 | 13.7 | 15.4 | 17.4 | 20.0 | 20.1 | 16.9 |
| | Talkeetna | 19 | 6.0 | 5.5 | 5.5 | 4.7 | 4.9 | 5.1 | 4.2 | 3.7 | 3.7 | 3.8 | 5.0 | 4.9 | 4.8 |
| | Valdez | 22 | 7.5 | 7.8 | 6.7 | 5.2 | 5.8 | 5.9 | 4.9 | 4.2 | 4.3 | 6.3 | 7.5 | 7.0 | 6.1 |
| | Yakutat | 54 | 7.2 | 7.3 | 7.0 | 7.1 | 7.5 | 6.9 | 6.6 | 6.3 | 6.9 | 7.8 | 7.2 | 7.8 | 7.1 |
| AZ | Flagstaff | 35 | 6.5 | 6.6 | 7.1 | 7.6 | 7.3 | 7.0 | 5.5 | 5.0 | 5.6 | 5.8 | 6.6 | 6.6 | 6.4 |
| | Phoenix | 57 | 5.3 | 5.8 | 6.6 | 6.9 | 7.0 | 6.7 | 7.1 | 6.6 | 6.3 | 5.8 | 5.3 | 5.1 | 6.2 |
| | Tucson | 57 | 7.9 | 8.1 | 8.6 | 8.9 | 8.8 | 8.7 | 8.4 | 7.9 | 8.3 | 8.2 | 8.1 | 7.8 | 8.3 |
| | Winslow | 42 | 7.1 | 8.5 | 10.3 | 11.3 | 10.7 | 10.6 | 9.0 | 8.4 | 8.1 | 7.6 | 7.3 | 6.7 | 8.8 |
| | Yuma | 28 | 7.3 | 7.4 | 7.9 | 8.3 | 8.3 | 8.5 | 9.5 | 8.9 | 7.3 | 6.6 | 6.9 | 7.2 | 7.8 |
| AR | Fort Smith | 57 | 8.2 | 8.5 | 9.4 | 8.9 | 7.7 | 6.7 | 6.3 | 6.3 | 6.6 | 6.8 | 7.8 | 8.1 | 7.6 |
| | Little Rock | 60 | 8.4 | 8.9 | 9.6 | 9.0 | 7.6 | 7.1 | 6.7 | 6.3 | 6.6 | 6.8 | 8.0 | 8.1 | 7.8 |
| CA | Bakersfield | 50 | 5.2 | 5.8 | 6.5 | 7.1 | 7.9 | 7.9 | 7.2 | 6.8 | 6.2 | 5.5 | 5.1 | 5.0 | 6.4 |
| | Blue Canyon | 50 | 7.8 | 7.7 | 7.4 | 6.5 | 6.5 | 6.3 | 5.8 | 5.9 | 6.4 | 6.8 | 6.6 | 6.7 | 6.7 |
| | Eureka | 54 | 6.9 | 7.2 | 7.6 | 8.0 | 7.9 | 7.4 | 6.8 | 5.8 | 5.5 | 5.6 | 6.0 | 6.4 | 6.8 |
| | Fresno | 53 | 5.2 | 5.7 | 6.7 | 7.4 | 8.1 | 8.3 | 7.4 | 6.8 | 6.1 | 5.2 | 4.7 | 4.9 | 6.4 |
| | Long Beach | 33 | 5.2 | 6.0 | 6.7 | 7.4 | 7.1 | 7.0 | 6.8 | 6.6 | 6.2 | 5.6 | 5.2 | 5.0 | 6.2 |
| | Los Angeles AP | 54 | 6.7 | 7.4 | 8.1 | 8.5 | 8.4 | 8.0 | 7.9 | 7.7 | 7.3 | 6.9 | 6.7 | 6.6 | 7.5 |
| | Los Angeles CO | 28 | 6.2 | 6.4 | 6.5 | 6.3 | 6.0 | 5.4 | 5.0 | 4.9 | 5.1 | 5.2 | 5.8 | 5.8 | 5.7 |
| | Mount Shasta | 3 | 5.0 | 5.2 | 5.8 | 6.2 | 5.4 | 5.4 | 4.4 | 4.2 | 4.6 | 4.2 | 5.2 | 5.4 | 5.1 |
| | Redding | 16 | 6.2 | 7.1 | 7.3 | 7.0 | 7.3 | 7.5 | 6.6 | 6.1 | 6.0 | 6.0 | 5.7 | 6.4 | 6.6 |
| | Sacramento | 52 | 7.1 | 7.3 | 8.4 | 8.6 | 9.0 | 9.6 | 8.9 | 8.4 | 7.4 | 6.4 | 6.0 | 6.4 | 7.8 |
| | San Diego | 62 | 6.0 | 6.6 | 7.5 | 7.8 | 7.9 | 7.8 | 7.5 | 7.4 | 7.1 | 6.5 | 5.9 | 5.6 | 7.0 |
| | San Francisco AP | 75 | 7.2 | 8.6 | 10.5 | 12.2 | 13.4 | 14.0 | 13.6 | 12.8 | 11.1 | 9.4 | 7.5 | 7.1 | 10.6 |
| | San Francisco CO | 28 | 6.7 | 7.5 | 8.5 | 9.5 | 10.4 | 10.9 | 11.2 | 10.5 | 9.1 | 7.6 | 6.3 | 6.5 | 8.7 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Santa Barbara | 31 | 5.1 | 5.9 | 6.7 | 7.6 | 7.0 | 6.7 | 6.5 | 6.1 | 5.5 | 5.5 | 5.2 | 4.4 | 6.0 |
| | Santa Maria | 22 | 6.4 | 7.2 | 8.1 | 8.0 | 8.2 | 7.8 | 6.5 | 6.3 | 5.9 | 6.0 | 6.4 | 6.2 | 6.9 |
| | Stockton | 42 | 6.7 | 7.0 | 7.7 | 8.4 | 9.2 | 9.2 | 8.2 | 7.7 | 7.1 | 6.4 | 5.8 | 6.4 | 7.5 |
| C0 | Alamosa | 11 | 5.6 | 6.6 | 8.4 | 10.3 | 9.7 | 9.0 | 7.0 | 6.2 | 6.5 | 6.4 | 5.6 | 4.9 | 7.2 |
| | Colorado Springs | 54 | 9.4 | 10.0 | 11.1 | 11.6 | 11.2 | 10.4 | 9.3 | 8.9 | 9.4 | 9.6 | 9.5 | 9.4 | 10.0 |
| | Denver | 47 | 8.6 | 8.7 | 9.6 | 10.0 | 9.3 | 8.8 | 8.3 | 8.0 | 7.9 | 7.8 | 8.2 | 8.4 | 8.6 |
| | Grand Junction | 56 | 5.7 | 6.7 | 8.4 | 9.4 | 9.6 | 9.8 | 9.4 | 9.1 | 9.0 | 7.9 | 6.8 | 6.0 | 8.2 |
| | Pueblo | 47 | 7.8 | 8.5 | 9.6 | 10.3 | 9.7 | 9.3 | 8.7 | 7.9 | 7.9 | 7.4 | 7.5 | 7.7 | 8.5 |
| CT | Bridgeport | 30 | 12.5 | 12.9 | 13.0 | 12.4 | 11.1 | 9.9 | 9.4 | 9.5 | 10.5 | 11.3 | 12.0 | 12.1 | 11.4 |
| | Hartford | 48 | 8.9 | 9.4 | 9.9 | 9.8 | 8.7 | 8.0 | 7.3 | 7.0 | 7.3 | 7.8 | 8.4 | 8.7 | 8.4 |
| DE | Wilmington | 54 | 9.8 | 10.3 | 11.0 | 10.4 | 9.0 | 8.3 | 7.8 | 7.4 | 7.8 | 8.1 | 9.2 | 9.3 | 9.0 |
| DC | Washington Dulles AP | 40 | 8.1 | 8.6 | 9.0 | 8.8 | 7.4 | 6.8 | 6.2 | 5.8 | 6.2 | 6.6 | 7.6 | 7.7 | 7.4 |
| | Washington Nat'l AP | 54 | 10.0 | 10.3 | 10.9 | 10.5 | 9.3 | 8.9 | 8.3 | 8.1 | 8.3 | 8.7 | 9.4 | 9.6 | 9.4 |
| FL | Apalachicola | 54 | 8.3 | 8.7 | 8.9 | 8.5 | 7.7 | 7.1 | 6.4 | 6.4 | 7.8 | 8.0 | 8.0 | 8.0 | 7.8 |
| | Daytona Beach | 57 | 8.8 | 9.3 | 9.8 | 9.4 | 8.9 | 8.0 | 7.3 | 7.0 | 8.0 | 8.9 | 8.3 | 8.3 | 8.5 |
| | Fort Myers | 57 | 8.3 | 8.9 | 9.3 | 8.8 | 8.0 | 7.2 | 6.6 | 6.7 | 7.4 | 8.4 | 8.1 | 7.9 | 8.0 |
| | Gainesville | 19 | 6.9 | 7.4 | 7.8 | 7.2 | 6.9 | 6.1 | 5.6 | 5.4 | 5.8 | 6.3 | 6.2 | 6.0 | 6.5 |
| | Jacksonville | 53 | 8.1 | 8.7 | 9.1 | 8.5 | 7.9 | 7.7 | 7.0 | 6.7 | 7.4 | 7.8 | 7.6 | 7.6 | 7.8 |
| | Key West | 49 | 11.8 | 12.0 | 12.1 | 12.2 | 10.5 | 9.6 | 9.4 | 9.2 | 9.6 | 10.8 | 12.0 | 11.8 | 10.9 |
| | Miami | 53 | 9.5 | 10.0 | 10.5 | 10.5 | 9.5 | 8.3 | 7.9 | 7.9 | 8.2 | 9.2 | 9.7 | 9.1 | 9.2 |
| | Orlando | 54 | 9.0 | 9.6 | 9.9 | 9.4 | 8.8 | 8.0 | 7.3 | 7.2 | 7.6 | 8.6 | 8.6 | 8.5 | 8.5 |
| | Pensacola | 38 | 9.0 | 9.3 | 9.8 | 9.5 | 8.6 | 7.6 | 6.9 | 6.7 | 7.6 | 7.9 | 8.2 | 8.8 | 8.3 |
| | Tallahassee | 41 | 6.7 | 7.1 | 7.5 | 6.8 | 6.2 | 5.7 | 5.0 | 5.0 | 5.9 | 6.3 | 5.9 | 6.3 | 6.2 |
| | Tampa | 56 | 8.6 | 9.1 | 9.4 | 9.2 | 8.6 | 7.9 | 7.1 | 6.9 | 7.6 | 8.3 | 8.2 | 8.3 | 8.3 |
| | Vero Beach | 19 | 8.7 | 9.0 | 9.9 | 9.5 | 9.1 | 7.7 | 6.9 | 6.5 | 7.3 | 8.6 | 8.6 | 8.0 | 8.3 |
| | West Palm Beach | 60 | 10.1 | 10.5 | 11.0 | 10.9 | 9.9 | 8.3 | 7.7 | 7.7 | 8.7 | 10.0 | 10.4 | 10.0 | 9.6 |
| GA | Athens | 47 | 8.3 | 8.6 | 8.7 | 8.3 | 7.1 | 6.6 | 6.3 | 5.8 | 6.4 | 6.6 | 7.3 | 8.0 | 7.3 |
| | Atlanta | 64 | 10.4 | 10.6 | 10.9 | 10.1 | 8.7 | 8.1 | 7.7 | 7.3 | 8.0 | 8.5 | 9.1 | 9.8 | 9.1 |
| | Augusta | 51 | 6.9 | 7.5 | 7.9 | 7.4 | 6.4 | 6.0 | 5.8 | 5.3 | 5.4 | 5.6 | 5.9 | 6.5 | 6.4 |
| | Columbus | 44 | 7.2 | 7.7 | 8.0 | 7.2 | 6.6 | 6.1 | 5.8 | 5.5 | 6.4 | 6.3 | 6.4 | 6.9 | 6.7 |
| | Macon | 54 | 8.0 | 8.4 | 8.8 | 8.3 | 7.4 | 7.0 | 6.7 | 6.2 | 6.7 | 6.5 | 6.9 | 7.5 | 7.4 |
| | Savannah | 52 | 8.2 | 8.6 | 9.1 | 8.6 | 7.6 | 7.4 | 6.9 | 6.7 | 7.2 | 7.3 | 7.2 | 7.6 | 7.7 |
| HI | Hilo | 53 | 7.4 | 7.7 | 7.7 | 7.5 | 7.4 | 7.1 | 6.9 | 6.8 | 6.8 | 6.7 | 6.8 | 7.2 | 7.2 |
| | Honolulu | 53 | 9.4 | 10.1 | 11.3 | 11.6 | 11.6 | 12.6 | 13.1 | 12.8 | 11.2 | 10.5 | 10.7 | 10.4 | 11.3 |
| | Kahului | 30 | 10.8 | 11.2 | 12.2 | 13.4 | 13.0 | 14.9 | 15.5 | 14.7 | 13.0 | 12.2 | 11.8 | 11.3 | 12.8 |
| | Lihue | 52 | 11.1 | 11.7 | 12.7 | 13.5 | 12.8 | 13.2 | 13.7 | 13.1 | 11.7 | 11.8 | 12.4 | 12.0 | 12.5 |
| ID | Boise | 63 | 7.9 | 8.9 | 9.9 | 9.9 | 9.4 | 9.0 | 8.4 | 8.2 | 8.2 | 8.3 | 8.4 | 8.1 | 8.7 |
| | Pocatello | 50 | 10.5 | 10.5 | 11.1 | 11.6 | 10.5 | 10.1 | 9.1 | 8.9 | 9.0 | 9.5 | 10.1 | 9.9 | 10.1 |
| IL | Cairo | 22 | 9.8 | 9.8 | 10.6 | 10.2 | 8.2 | 7.4 | 6.5 | 6.2 | 7.0 | 7.3 | 9.1 | 9.3 | 8.5 |
| | Chicago | 44 | 11.6 | 11.4 | 11.8 | 11.9 | 10.5 | 9.3 | 8.4 | 8.2 | 8.9 | 10.1 | 11.1 | 11.0 | 10.3 |
| | Moline | 59 | 10.7 | 10.6 | 11.7 | 11.8 | 10.1 | 8.8 | 7.5 | 7.1 | 8.0 | 9.2 | 10.6 | 10.3 | 9.7 |
| | Peoria | 59 | 10.9 | 10.9 | 11.7 | 11.6 | 9.9 | 8.9 | 7.8 | 7.3 | 8.3 | 9.3 | 10.6 | 10.6 | 9.8 |
| | Rockford | 52 | 10.5 | 10.6 | 11.6 | 11.8 | 10.4 | 9.3 | 8.1 | 7.7 | 8.4 | 9.5 | 10.6 | 10.4 | 9.9 |
| | Springfield | 55 | 12.2 | 12.2 | 13.2 | 13.0 | 11.1 | 9.6 | 8.3 | 7.9 | 8.7 | 10.1 | 12.2 | 12.0 | 10.9 |
| IN | Evansville | 62 | 9.2 | 9.3 | 10.0 | 9.6 | 7.9 | 7.1 | 6.2 | 5.8 | 6.4 | 6.9 | 8.7 | 8.9 | 8.0 |

*(Continued)*



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**Table 3A.8 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fort Wayne | 56 | 11.5 | 11.0 | 11.7 | 11.6 | 10.0 | 8.9 | 8.0 | 7.3 | 8.2 | 9.1 | 10.9 | 11.1 | 9.9 |
| | Indianapolis | 54 | 10.9 | 10.8 | 11.6 | 11.2 | 9.6 | 8.5 | 7.5 | 7.2 | 7.9 | 8.9 | 10.5 | 10.5 | 9.6 |
| | South Bend | 54 | 11.9 | 11.2 | 11.9 | 11.6 | 10.2 | 9.1 | 8.1 | 7.7 | 8.5 | 9.5 | 11.0 | 11.2 | 10.2 |
| IA | Des Moines | 53 | 11.4 | 11.2 | 12.4 | 12.6 | 11.0 | 10.1 | 8.9 | 8.6 | 9.4 | 10.3 | 11.3 | 11.1 | 10.7 |
| | Sioux City | 61 | 11.4 | 11.2 | 12.3 | 13.2 | 11.8 | 10.7 | 9.2 | 9.1 | 9.9 | 10.5 | 11.4 | 11.0 | 11.0 |
| | Waterloo | 46 | 11.4 | 11.4 | 12.1 | 12.6 | 11.1 | 9.8 | 8.4 | 8.3 | 9.0 | 10.2 | 11.0 | 11.0 | 10.5 |
| KS | Concordia | 40 | 11.7 | 12.1 | 13.4 | 13.8 | 12.1 | 11.7 | 11.3 | 10.9 | 11.2 | 11.6 | 11.8 | 11.5 | 11.9 |
| | Dodge City | 60 | 13.5 | 13.9 | 15.5 | 15.5 | 14.6 | 14.0 | 13.1 | 12.5 | 13.5 | 13.5 | 13.7 | 13.4 | 13.9 |
| | Goodland | 54 | 12.4 | 12.4 | 14.0 | 14.4 | 13.5 | 12.7 | 11.9 | 11.5 | 12.0 | 11.9 | 11.9 | 11.9 | 12.5 |
| | Topeka | 53 | 9.7 | 10.2 | 11.5 | 11.7 | 10.2 | 9.4 | 8.4 | 8.0 | 8.5 | 9.0 | 9.7 | 9.5 | 9.6 |
| | Wichita | 49 | 12.0 | 12.5 | 13.8 | 14.0 | 12.3 | 12.2 | 11.3 | 11.1 | 11.6 | 11.9 | 12.1 | 11.7 | 12.2 |
| KY | Greater Cincinnati AP | 55 | 10.4 | 10.4 | 11.0 | 10.6 | 8.7 | 7.9 | 7.2 | 6.8 | 7.4 | 8.1 | 9.7 | 10.0 | 9.0 |
| | Jackson | 21 | 7.3 | 7.4 | 7.6 | 7.7 | 6.0 | 5.3 | 5.0 | 4.6 | 5.3 | 6.0 | 7.0 | 7.1 | 6.4 |
| | Lexington | 55 | 10.6 | 10.6 | 10.9 | 10.4 | 8.6 | 7.9 | 7.2 | 6.8 | 7.6 | 8.1 | 9.9 | 10.3 | 9.1 |
| | Louisville | 55 | 9.5 | 9.5 | 10.1 | 9.7 | 8.0 | 7.4 | 6.8 | 6.4 | 6.8 | 7.2 | 8.9 | 9.1 | 8.3 |
| | Paducah | 18 | 8.8 | 8.9 | 9.4 | 8.9 | 7.4 | 6.2 | 5.7 | 5.1 | 5.6 | 6.5 | 8.2 | 8.4 | 7.4 |
| LA | Baton Rouge | 51 | 8.7 | 9.1 | 9.1 | 8.7 | 7.6 | 6.5 | 5.9 | 5.6 | 6.4 | 6.6 | 7.4 | 8.1 | 7.5 |
| | Lake Charles | 41 | 9.8 | 10.0 | 10.2 | 9.8 | 8.6 | 7.5 | 6.1 | 6.1 | 7.1 | 7.8 | 8.8 | 9.3 | 8.4 |
| | New Orleans | 54 | 9.3 | 9.8 | 9.9 | 9.4 | 8.1 | 6.8 | 6.1 | 5.9 | 7.3 | 7.6 | 8.7 | 9.0 | 8.2 |
| | Shreveport | 50 | 9.2 | 9.6 | 10.0 | 9.6 | 8.3 | 7.6 | 7.1 | 6.6 | 7.2 | 7.4 | 8.3 | 8.8 | 8.3 |
| ME | Caribou | 22 | 11.1 | 10.8 | 11.7 | 10.9 | 10.3 | 9.3 | 8.6 | 8.1 | 9.2 | 10.0 | 10.0 | 10.4 | 10.0 |
| | Portland | 62 | 9.0 | 9.4 | 10.0 | 9.9 | 9.1 | 8.2 | 7.6 | 7.5 | 7.8 | 8.4 | 8.8 | 9.0 | 8.7 |
| MD | Baltimore | 52 | 9.4 | 9.9 | 10.7 | 10.2 | 8.9 | 8.2 | 7.6 | 7.5 | 7.7 | 8.1 | 8.8 | 8.9 | 8.8 |
| MA | Blue Hill | 61 | 17.2 | 17.2 | 17.2 | 16.4 | 14.6 | 13.8 | 12.9 | 12.6 | 13.5 | 15.2 | 16.2 | 16.7 | 15.3 |
| | Boston | 45 | 13.7 | 13.7 | 13.6 | 13.1 | 12.0 | 11.4 | 11.0 | 10.8 | 11.3 | 11.9 | 12.7 | 13.4 | 12.4 |
| | Worcester | 36 | 11.7 | 11.6 | 11.5 | 11.0 | 10.0 | 8.9 | 8.4 | 8.3 | 8.6 | 9.4 | 10.4 | 10.9 | 10.1 |
| MI | Alpena | 42 | 8.8 | 8.4 | 8.9 | 9.2 | 8.3 | 7.5 | 7.0 | 6.7 | 7.1 | 7.8 | 8.5 | 8.4 | 8.1 |
| | Detroit | 44 | 11.9 | 11.4 | 11.7 | 11.3 | 10.1 | 9.2 | 8.5 | 8.1 | 8.7 | 9.7 | 11.2 | 11.3 | 10.3 |
| | Flint | 61 | 11.8 | 11.2 | 11.8 | 11.5 | 10.1 | 9.0 | 8.1 | 7.8 | 8.8 | 9.8 | 11.2 | 11.3 | 10.2 |
| | Grand Rapids | 39 | 11.4 | 10.6 | 11.1 | 11.0 | 9.7 | 8.9 | 8.3 | 7.9 | 8.3 | 9.4 | 10.5 | 10.7 | 9.8 |
| | Houghton Lake | 21 | 9.7 | 9.1 | 9.1 | 9.5 | 8.8 | 7.8 | 7.5 | 7.0 | 7.8 | 8.8 | 9.6 | 9.3 | 8.7 |
| | Lansing | 43 | 11.7 | 10.9 | 11.2 | 11.1 | 9.9 | 8.8 | 8.0 | 7.5 | 8.2 | 9.4 | 10.7 | 11.0 | 9.9 |
| | Muskegon | 41 | 12.2 | 11.6 | 11.6 | 11.5 | 9.9 | 9.3 | 8.8 | 8.6 | 9.3 | 10.7 | 11.9 | 11.7 | 10.6 |
| | Sault Ste. Marie | 61 | 9.6 | 9.3 | 10.0 | 10.3 | 9.7 | 8.5 | 7.8 | 7.7 | 8.6 | 9.2 | 9.7 | 9.6 | 9.2 |
| MN | Duluth | 53 | 11.6 | 11.3 | 11.8 | 12.3 | 11.6 | 10.4 | 9.4 | 9.4 | 10.3 | 11.2 | 11.6 | 11.2 | 11.0 |
| | International Falls | 50 | 8.9 | 8.8 | 9.4 | 9.9 | 9.4 | 8.5 | 7.7 | 7.5 | 8.5 | 9.3 | 9.4 | 8.8 | 8.8 |
| | Minneapolis-St. Paul | 64 | 10.5 | 10.4 | 11.3 | 12.2 | 11.1 | 10.4 | 9.4 | 9.2 | 10.0 | 10.6 | 11.0 | 10.4 | 10.5 |
| | Rochester | 42 | 14.2 | 13.7 | 14.1 | 14.3 | 13.2 | 12.1 | 10.8 | 10.4 | 11.5 | 12.7 | 13.6 | 13.7 | 12.9 |
| | Saint Cloud | 16 | 8.4 | 8.4 | 9.0 | 9.8 | 9.2 | 8.3 | 7.1 | 6.5 | 7.2 | 8.4 | 8.6 | 8.2 | 8.3 |
| MS | Jackson | 39 | 8.2 | 8.4 | 8.7 | 8.0 | 6.8 | 6.1 | 5.2 | 5.3 | 6.1 | 6.2 | 6.9 | 7.8 | 7.0 |
| | Meridian | 43 | 7.1 | 7.5 | 7.9 | 7.1 | 6.0 | 5.2 | 4.9 | 4.6 | 5.3 | 5.2 | 6.1 | 6.9 | 6.2 |
| | Tupelo | 19 | 7.6 | 8.2 | 8.3 | 7.8 | 6.6 | 5.7 | 5.3 | 5.2 | 6.1 | 6.0 | 6.9 | 7.5 | 6.8 |
| MO | Columbia | 32 | 10.7 | 10.8 | 11.7 | 11.5 | 9.1 | 8.7 | 8.2 | 7.9 | 8.6 | 9.3 | 10.6 | 10.6 | 9.8 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kansas City | 30 | 11.1 | 11.1 | 12.3 | 12.3 | 10.3 | 9.9 | 9.2 | 8.8 | 9.6 | 10.5 | 11.2 | 10.9 | 10.6 |
| | St. Louis | 53 | 10.6 | 10.8 | 11.6 | 11.3 | 9.4 | 8.8 | 8.0 | 7.6 | 8.2 | 8.9 | 10.2 | 10.3 | 9.6 |
| | Springfield | 57 | 11.4 | 11.5 | 12.5 | 12.0 | 10.2 | 9.3 | 8.4 | 8.4 | 9.1 | 10.1 | 11.0 | 11.2 | 10.4 |
| MT | Billings | 63 | 13.0 | 12.3 | 11.4 | 11.4 | 10.7 | 10.1 | 9.5 | 9.5 | 10.2 | 11.0 | 12.2 | 13.0 | 11.2 |
| | Glasgow | 33 | 9.8 | 10.1 | 11.2 | 12.3 | 12.2 | 11.1 | 10.5 | 10.9 | 10.9 | 10.6 | 9.5 | 9.7 | 10.7 |
| | Great Falls | 61 | 14.9 | 13.9 | 12.8 | 12.6 | 11.3 | 11.1 | 10.0 | 10.1 | 11.2 | 12.9 | 14.5 | 15.2 | 12.5 |
| | Havre | 3 | 8.8 | 9.4 | 10.2 | 11.6 | 12.4 | 10.8 | 9.8 | 9.0 | 9.4 | 9.1 | 10.6 | 10.8 | 10.2 |
| | Helena | 62 | 6.7 | 7.3 | 8.2 | 9.1 | 8.8 | 8.5 | 7.8 | 7.4 | 7.4 | 7.1 | 7.1 | 6.7 | 7.7 |
| | Kalispell | 40 | 5.6 | 5.6 | 6.7 | 7.7 | 7.4 | 6.9 | 6.3 | 6.3 | 6.1 | 5.1 | 5.3 | 5.1 | 6.2 |
| | Missoula | 58 | 5.1 | 5.6 | 6.7 | 7.6 | 7.4 | 7.2 | 6.9 | 6.7 | 6.0 | 5.1 | 5.0 | 4.7 | 6.2 |
| NE | Grand Island | 53 | 11.7 | 11.7 | 13.1 | 14.0 | 12.6 | 11.8 | 10.5 | 10.3 | 11.0 | 11.2 | 11.8 | 11.6 | 11.8 |
| | Lincoln | 30 | 9.6 | 10.0 | 11.3 | 12.1 | 10.5 | 9.8 | 9.3 | 9.1 | 9.5 | 9.9 | 9.9 | 9.6 | 10.1 |
| | Norfolk | 26 | 11.6 | 11.5 | 12.5 | 13.1 | 11.5 | 10.8 | 9.7 | 9.5 | 10.3 | 11.0 | 11.4 | 11.3 | 11.2 |
| | North Platte | 50 | 9.2 | 9.8 | 11.5 | 12.6 | 11.5 | 10.4 | 9.5 | 9.2 | 9.7 | 9.6 | 9.5 | 9.0 | 10.1 |
| | Omaha Eppley AP | 66 | 10.9 | 11.1 | 12.2 | 12.6 | 10.9 | 10.1 | 8.8 | 8.8 | 9.4 | 9.8 | 10.9 | 10.7 | 10.5 |
| | Omaha (North) | 9 | 9.9 | 9.2 | 10.5 | 10.2 | 8.9 | 8.3 | 7.5 | 7.6 | 8.6 | 9.0 | 9.7 | 9.8 | 9.1 |
| | Scottsbluff | 51 | 10.6 | 11.1 | 12.0 | 12.5 | 11.8 | 10.5 | 9.3 | 8.9 | 9.4 | 9.7 | 10.2 | 10.4 | 10.5 |
| | Valentine | 34 | 9.3 | 9.4 | 10.4 | 11.1 | 11.0 | 9.9 | 9.1 | 9.2 | 9.7 | 9.5 | 9.7 | 9.2 | 9.8 |
| NV | Elko | 47 | 5.2 | 5.7 | 6.6 | 7.2 | 6.8 | 6.7 | 6.2 | 5.9 | 5.4 | 5.0 | 5.1 | 5.0 | 5.9 |
| | Ely | 61 | 10.1 | 10.3 | 10.7 | 10.9 | 10.7 | 10.6 | 10.3 | 10.4 | 10.3 | 10.0 | 9.9 | 9.9 | 10.3 |
| | Las Vegas | 54 | 7.4 | 8.5 | 10.1 | 11.0 | 11.0 | 11.0 | 10.2 | 9.6 | 9.0 | 8.1 | 7.8 | 7.3 | 9.2 |
| | Reno | 60 | 5.6 | 6.2 | 7.8 | 8.2 | 8.0 | 7.7 | 7.2 | 6.6 | 5.8 | 5.4 | 5.5 | 5.3 | 6.6 |
| | Winnemucca | 46 | 7.6 | 8.0 | 8.6 | 8.6 | 8.6 | 8.5 | 8.4 | 7.8 | 7.6 | 7.3 | 7.2 | 7.4 | 8.0 |
| NH | Concord | 60 | 7.2 | 7.9 | 8.1 | 7.8 | 7.0 | 6.5 | 5.7 | 5.4 | 5.6 | 6.0 | 6.6 | 7.0 | 6.7 |
| | Mt. Washington | 67 | 46.1 | 44.3 | 41.4 | 35.8 | 29.7 | 27.3 | 25.3 | 24.7 | 28.8 | 33.8 | 39.5 | 44.5 | 35.1 |
| NJ | Atlantic City AP | 44 | 10.7 | 11.1 | 11.8 | 11.4 | 10.1 | 9.1 | 8.3 | 7.9 | 8.3 | 8.7 | 9.9 | 10.3 | 9.8 |
| | Newark | 58 | 11.2 | 11.5 | 11.9 | 11.2 | 10.0 | 9.5 | 8.9 | 8.7 | 9.0 | 9.4 | 10.2 | 10.8 | 10.2 |
| NM | Albuquerque | 63 | 8.0 | 8.8 | 9.9 | 10.7 | 10.5 | 9.8 | 8.9 | 8.1 | 8.4 | 8.2 | 7.9 | 7.6 | 8.9 |
| | Clayton | 10 | 11.9 | 12.4 | 13.1 | 14.4 | 13.2 | 12.9 | 11.2 | 10.2 | 11.3 | 11.8 | 11.8 | 12.1 | 12.2 |
| | Roswell | 29 | 7.7 | 8.6 | 10.1 | 10.2 | 9.9 | 9.7 | 8.6 | 7.9 | 8.0 | 7.9 | 7.7 | 7.6 | 8.7 |
| NY | Albany | 64 | 9.8 | 10.1 | 10.6 | 10.5 | 9.0 | 8.3 | 7.5 | 7.0 | 7.4 | 8.0 | 9.1 | 9.3 | 8.9 |
| | Binghamton | 51 | 11.3 | 11.3 | 11.5 | 11.2 | 9.9 | 9.3 | 8.4 | 8.2 | 8.8 | 9.7 | 10.8 | 11.0 | 10.1 |
| | Buffalo | 63 | 14.0 | 13.3 | 13.1 | 12.3 | 11.4 | 10.8 | 10.2 | 9.7 | 10.2 | 11.1 | 12.6 | 13.1 | 11.8 |
| | Islip | 19 | 9.6 | 10.1 | 10.5 | 9.8 | 9.0 | 8.4 | 7.7 | 7.4 | 7.7 | 8.3 | 9.4 | 9.3 | 8.9 |
| | New York C. Park | 65 | 10.6 | 10.7 | 11.0 | 10.2 | 8.8 | 8.1 | 7.6 | 7.5 | 8.1 | 8.8 | 9.8 | 10.1 | 9.3 |
| | New York (JFK AP) | 44 | 13.0 | 13.3 | 13.5 | 12.7 | 11.6 | 10.7 | 10.2 | 10.0 | 10.4 | 11.0 | 12.2 | 12.7 | 11.8 |
| | New York (Laguardia AP) | 54 | 13.7 | 13.8 | 13.9 | 12.9 | 11.6 | 11.0 | 10.4 | 10.3 | 11.0 | 11.6 | 12.8 | 13.4 | 12.2 |
| | Rochester | 62 | 11.6 | 11.1 | 11.0 | 10.7 | 9.3 | 8.6 | 8.0 | 7.7 | 8.1 | 8.8 | 10.2 | 10.7 | |

*Note:* Through 2002. The average wind speed is based on the speed of the wind regardless of direction.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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## Table 3A.9 Maximum Wind Speed (MPH) — Selected Cities of the United States

| | | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **State** | **Station** | **Years** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** |
| AL | Birmingham AP | 39 | W | 49 | SE | 59 | SW | 65 | SW | 56 | NW | 65 | SW | 56 | SW | 57 | NW | 50 | SE | 50 | W | 43 | N | 52 | SE | 41 | SW | 65 |
| | Huntsville | 35 | 26 | 44 | 08 | 43 | 12 | 46 | 18 | 44 | 24 | 46 | 24 | 56 | 10 | 52 | 02 | 63 | 23 | 43 | 01 | 43 | 27 | 40 | 30 | 40 | 02 | 63 |
| | Mobile | 44 | 18 | 44 | 23 | 46 | 10 | 40 | 01 | 44 | 32 | 51 | 16 | 45 | 21 | 60 | 14 | 63 | 09 | 63 | 36 | 46 | 17 | 38 | 22 | 43 | 14 | 63 |
| | Montgomery | 17 | 30 | 32 | 26 | 38 | 28 | 46 | 32 | 39 | 36 | 35 | 29 | 44 | 26 | 35 | 10 | 44 | 70 | 35 | 08 | 52 | 30 | 39 | 30 | 35 | 08 | 52 |
| AK | Anchorage (G) | 23 | E | 64 | NE | 61 | NE | 75 | SE | 43 | S | 43 | SE | 46 | SE | 40 | N | 44 | S | 48 | S | 55 | NE | 55 | SE | 55 | NE | 75 |
| | Annette | 50 | 16 | 58 | 16 | 50 | 14 | 48 | 14 | 60 | 14 | 44 | 16 | 44 | 16 | 35 | 16 | 40 | 11 | 51 | 16 | 55 | 13 | 51 | 16 | 58 | 14 | 60 |
| | Barrow (G) | 22 | E | 58 | SW | 74 | E | 56 | 26 | 51 | NE | 41 | W | 43 | W | 55 | 27 | 55 | SW | 66 | W | 54 | E | 53 | SW | 61 | SW | 74 |
| | Barter IS. (G) | 9 | W | 75 | W | 69 | W | 66 | E | 49 | W | 56 | E | 53 | W | 48 | NW | 58 | E | 58 | W | 69 | E | 61 | W | 70 | W | 75 |
| | Bethel (G) | 23 | S | 61 | NE | 59 | S | 56 | S | 51 | S | 53 | S | 59 | S | 46 | NW | 56 | SE | 69 | S | 77 | W | 66 | S | 67 | S | 77 |
| | Bettles | 10 | 11 | 30 | 08 | 25 | 08 | 29 | 23 | 28 | 11 | 31 | 01 | 28 | 24 | 30 | 25 | 32 | 24 | 25 | 24 | 25 | 26 | 38 | 24 | 40 | 24 | 40 |
| | Big Delta | 29 | 29 | 74 | 18 | 67 | 20 | 63 | 18 | 60 | 20 | 55 | 16 | 51 | 18 | 63 | 16 | 47 | 18 | 66 | 18 | 58 | 11 | 56 | 11 | 63 | 29 | 74 |
| | Cold Bay | 47 | 17 | 71 | 16 | 73 | 15 | 71 | 15 | 61 | 14 | 60 | 11 | 63 | 17 | 54 | 16 | 64 | 17 | 75 | 21 | 60 | 14 | 66 | 11 | 64 | 17 | 75 |
| | Fairbanks | 51 | 25 | 31 | 26 | 36 | 22 | 40 | 24 | 32 | 23 | 32 | 25 | 40 | 27 | 32 | 27 | 34 | 08 | 33 | 25 | 40 | 25 | 35 | 24 | 37 | 22 | 40 |
| | Gulkana | 9 | 04 | 52 | 16 | 44 | 15 | 35 | 18 | 46 | 19 | 35 | 15 | 38 | 15 | 40 | 16 | 30 | 16 | 36 | 19 | 46 | 19 | 33 | 16 | 49 | 04 | 52 |
| | Homer | 30 | 28 | 39 | 07 | 39 | 20 | 35 | 90 | 38 | 11 | 44 | 90 | 35 | 16 | 29 | 28 | 32 | 36 | 49 | 80 | 41 | 08 | 44 | 40 | 69 | 40 | 69 |
| | Juneau | 32 | 12 | 45 | 12 | 46 | 11 | 40 | 11 | 40 | 12 | 40 | 12 | 35 | 12 | 32 | 12 | 38 | 12 | 48 | 12 | 49 | 11 | 58 | 11 | 55 | 11 | 58 |
| | King Salmon (G) | 23 | E | 69 | E | 69 | E | 62 | S | 59 | S | 63 | E | 58 | E | 47 | SW | 56 | E | 71 | E | 67 | E | 67 | E | 66 | E | 71 |
| | Kodiak (G) | 23 | NW | 75 | NW | 67 | NW | 82 | E | 67 | W | 59 | NE | 52 | NW | 52 | NW | 67 | NW | 78 | NW | 70 | W | 82 | NW | 83 | NW | 83 |
| | Kotzebue (G) | 23 | E | 72 | E | 63 | E | 66 | 80 | 56 | NE | 49 | SE | 46 | SE | 45 | S | 53 | NE | 54 | SE | 60 | SE | 63 | E | 68 | E | 72 |
| | Mcgrath (G) | 23 | S | 59 | SW | 47 | SE | 46 | S | 46 | S | 45 | NW | 62 | S | 46 | S | 49 | S | 49 | E | 40 | S | 53 | SW | 52 | NW | 62 |
| | Nome | 45 | 09 | 54 | 04 | 51 | 02 | 44 | 05 | 45 | 09 | 44 | 04 | 35 | 24 | 35 | 15 | 41 | 18 | 44 | 20 | 52 | 24 | 55 | 05 | 54 | 24 | 55 |
| | St. Paul Island (G) | 23 | | 63 | N | 72 | N | 67 | SE | 67 | SW | 74 | S | 53 | SE | 47 | N | 58 | N | 61 | W | 70 | SW | 84 | E | 79 | SW | 84 |
| | Talkeetna | 35 | 04 | 38 | 03 | 35 | 03 | 39 | 34 | 29 | 18 | 32 | 19 | 29 | 17 | 22 | 40 | 28 | 30 | 35 | 20 | 32 | 02 | 31 | 36 | 35 | 03 | 39 |
| | Unalakleet (G) | 6 | E | 63 | E | 71 | E | 60 | E | 43 | E | 46 | E | 37 | SW | 39 | S | 44 | S | 45 | SE | 53 | E | 62 | E | 61 | E | 71 |
| | Valdez (G) | 23 | N | 94 | NE | 83 | NE | 82 | N | 55 | N | 44 | W | 38 | N | 41 | N | 56 | SW | 69 | NE | 66 | N | 77 | N | 75 | N | 94 |
| | Yakutat (G) | 23 | SE | 81 | SE | 62 | SE | 64 | SE | 64 | SE | 48 | SE | 45 | SE | 44 | SE | 60 | SE | 63 | SE | 60 | SE | 70 | SE | 63 | SE | 81 |
| AZ | Flagstaff | 18 | SW | 38 | SW | 34 | 21 | 38 | SW | 40 | SW | 46 | SW | 35 | NW | 39 | SW | 30 | W | 33 | 40 | 38 | SW | 39 | NE | 38 | SW | 46 |
| | Phoenix | 17 | 25 | 36 | 26 | 30 | 24 | 43 | 30 | 51 | 11 | 35 | 40 | 33 | 13 | 43 | 14 | 37 | 15 | 39 | 24 | 36 | 25 | 30 | 29 | 39 | 30 | 51 |
| | Tucson | 54 | E | 40 | E | 59 | SE | 41 | SW | 46 | SE | 43 | SE | 50 | SE | 71 | NE | 54 | SE | 54 | SE | 47 | E | 55 | W | 44 | SE | 71 |
| | Winslow | 37 | 23 | 56 | 22 | 63 | 22 | 61 | 25 | 56 | 25 | 53 | 20 | 52 | 16 | 59 | 21 | 45 | 31 | 45 | 22 | 49 | 22 | 46 | 22 | 52 | 22 | 63 |
| | Yuma | 40 | NW | 41 | W | 50 | N | 43 | NW | 47 | NW | 38 | SW | 42 | NE | 61 | SE | 60 | E | 57 | S | 47 | N | 47 | W | 47 | NE | 61 |
| AR | Fort Smith | 20 | 30 | 43 | 30 | 39 | 34 | 45 | 26 | 45 | 30 | 49 | 28 | 57 | 09 | 51 | 09 | 46 | 31 | 45 | 29 | 51 | 26 | 40 | 22 | 44 | 28 | 57 |
| | Little Rock | 41 | S | 44 | SW | 57 | SE | 56 | NW | 65 | NW | 61 | NE | 60 | NW | 56 | NW | 54 | NW | 50 | SSW | 58 | SW | 49 | SW | 48 | NW | 65 |
| | North Little Rock | 3 | NW | 25 | SW | 25 | S | 28 | NE | 30 | SW | 30 | NE | 21 | W | 30 | W | 28 | NE | 24 | SE | 24 | SW | 27 | SW | 25 | NE | 30 |
| CA | Bakersfield | 53 | 19 | 36 | 13 | 49 | 17 | 40 | 29 | 40 | 32 | 40 | 15 | 41 | 29 | 25 | 14 | 33 | 14 | 35 | 08 | 38 | 30 | 35 | 13 | 46 | 13 | 49 |
| | Bishop (G) | 17 | | 60 | W | 63 | | 58 | | 62 | | 62 | | 54 | | 60 | | 70 | | 47 | | 52 | | 66 | | 68 | | 70 |
| | Blue Canyon | 33 | 20 | 67 | 17 | 76 | 07 | 67 | 20 | 50 | 23 | 37 | 07 | 49 | 09 | 32 | 07 | 30 | 09 | 49 | 05 | 70 | 19 | 54 | 07 | 51 | 17 | 76 |
| | Eureka | 83 | S | 54 | SW | 48 | SW | 48 | N | 49 | NW | 40 | NW | 39 | N | 35 | N | 34 | N | 44 | SW | 56 | S | 55 | S | 56 | SW | 56 |
| | Fresno | 24 | 14 | 39 | 13 | 36 | 29 | 30 | 29 | 36 | 32 | 32 | 29 | 28 | 32 | 23 | 31 | 28 | 31 | 29 | 31 | 26 | 28 | 30 | 14 | 29 | 14 | 39 |
| | Long Beach | 33 | 17 | 37 | 18 | 40 | 11 | 39 | 29 | 44 | 27 | 30 | 29 | 24 | 18 | 23 | 16 | 23 | 10 | 26 | 30 | 37 | 25 | 44 | 32 | 39 | 29 | 44 |
| | Los Angeles AP (G) | 52 | NE | 51 | N | 57 | W | 62 | N | 59 | W | 49 | W | 40 | SW | 31 | SE | 33 | E | 39 | W | 46 | W | 60 | NW | 49 | W | 62 |
| | Los Angeles CO | 40 | N | 49 | NW | 40 | NW | 47 | NW | 40 | NW | 39 | N | 32 | W | 21 | E | 24 | NW | 27 | N | 48 | N | 42 | SE | 44 | N | 49 |
| | Mount Shasta | 6 | 34 | 23 | 36 | 22 | 35 | 21 | 34 | 24 | 32 | 21 | 31 | 18 | 36 | 20 | 34 | 15 | 35 | 20 | 30 | 17 | 34 | 20 | 32 | 21 | 34 | 24 |
| | Redding (G) | 16 | S | 70 | S | 64 | S | 74 | S | 47 | S | 54 | N | 60 | N | 36 | S | 46 | | 44 | S | 66 | S | 58 | S | 85 | S | 85 |
| | Sacramento | 53 | SE | 60 | SE | 51 | S | 66 | SW | 45 | SW | 74 | SW | 47 | SW | 36 | SW | 38 | NW | 42 | SE | 68 | SE | 70 | SE | 70 | SW | 74 |
| | San Diego | 58 | SE | 56 | S | 45 | SW | 46 | S | 37 | S | 30 | S | 26 | NW | 23 | NW | 23 | S | 31 | N | 31 | SE | 51 | NW | 39 | SE | 56 |
| | San Francisco AP | 53 | 16 | 58 | 22 | 55 | 26 | 46 | 18 | 47 | 26 | 46 | 28 | 44 | 28 | 40 | 26 | 37 | 28 | 38 | 25 | 44 | 18 | 51 | 22 | 54 | 16 | 58 |
| | San Francisco CO | 36 | SE | 47 | SW | 47 | S | 44 | W | 38 | W | 38 | W | 40 | W | 38 | W | 34 | W | 32 | SE | 43 | S | 41 | SE | 45 | SE | 47 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Santa Maria | 13 | 13 | 36 | 13 | 46 | 16 | 35 | 30 | 44 | 30 | 35 | 29 | 36 | 29 | 32 | 29 | 30 | 29 | 32 | 17 | 37 | 26 | 31 | 16 | 36 | 13 | 46 |
| | Stockton | 39 | 14 | 46 | 16 | 41 | 33 | 39 | 35 | 37 | 35 | 41 | 29 | 35 | 27 | 31 | 26 | 30 | 34 | 33 | 33 | 37 | 15 | 47 | 15 | 44 | 15 | 47 |
| CO | Alamosa (G) | 19 | SW | 58 | 23 | 62 | 23 | 60 | 24 | 71 | 22 | 63 | 20 | 69 | 30 | 66 | 34 | 51 | SW | 54 | W | 62 | 21 | 63 | 26 | 54 | 24 | 71 |
| | Colorado Springs | 52 | 29 | 55 | 28 | 61 | 29 | 60 | 28 | 61 | 27 | 52 | 20 | 55 | 22 | 49 | 34 | 45 | 30 | 44 | 27 | 59 | 34 | 52 | 27 | 60 | 28 | 61 |
| | Denver | 14 | 32 | 44 | 30 | 36 | 30 | 41 | 33 | 46 | 36 | 43 | 21 | 38 | 29 | 46 | 33 | 33 | 29 | 36 | 01 | 36 | 36 | 36 | 32 | 38 | 33 | 46 |
| | Grand Junction | 23 | 25 | 36 | 20 | 41 | 34 | 53 | 27 | 49 | 20 | 46 | 30 | 57 | 35 | 45 | 24 | 45 | 28 | 49 | 21 | 44 | 31 | 39 | 26 | 35 | 30 | 57 |
| | Pueblo | 18 | 29 | 51 | 29 | 46 | 36 | 52 | 35 | 52 | 35 | 60 | 29 | 48 | 30 | 58 | 22 | 48 | 01 | 46 | 30 | 47 | 04 | 48 | 27 | 47 | 35 | 60 |
| CT | Bridgeport | 42 | 34 | 67 | 34 | 65 | 08 | 58 | 32 | 55 | 34 | 50 | 35 | 39 | 29 | 40 | 04 | 58 | 18 | 74 | 09 | 58 | 14 | 58 | 25 | 53 | 18 | 74 |
| | Hartford | 17 | 24 | 46 | 30 | 46 | 30 | 43 | 05 | 41 | 28 | 39 | 36 | 45 | 27 | 39 | 18 | 40 | 17 | 43 | 29 | 38 | 17 | 44 | 26 | 41 | 24 | 46 |
| DE | Wilmington | 54 | 15 | 51 | 29 | 46 | 28 | 45 | 33 | 46 | 24 | 48 | 34 | 43 | 27 | 48 | 35 | 46 | 07 | 40 | 20 | 58 | 16 | 46 | 32 | 46 | 20 | 58 |
| DC | Washington Dulles AP | 39 | 20 | 39 | 30 | 37 | 28 | 44 | 32 | 46 | 35 | 40 | 31 | 55 | 30 | 48 | 34 | 43 | 25 | 35 | 29 | 38 | 29 | 35 | 30 | 40 | 31 | 55 |
| | Washington Nat'l AP | 17 | 29 | 41 | 33 | 39 | 33 | 44 | 31 | 39 | 32 | 46 | 31 | 49 | 50 | 47 | 34 | 37 | 32 | 39 | 23 | 39 | 32 | 37 | 34 | 38 | 31 | 49 |
| FL | Apalachicola | 48 | E | 48 | E | 42 | E | 54 | SE | 51 | SE | 47 | E | 55 | N | 63 | NE | 59 | E | 67 | NW | 56 | SE | 47 | SE | 42 | E | 67 |
| | Daytona Beach | 54 | 26 | 43 | 20 | 44 | 24 | 58 | 18 | 46 | 28 | 46 | 33 | 40 | 25 | 40 | 11 | 50 | 11 | 58 | 05 | 53 | 50 | 39 | 34 | 40 | 24 | 58 |
| | Fort Myers | 51 | 25 | 40 | 25 | 39 | 35 | 46 | 20 | 39 | 32 | 44 | 31 | 48 | 18 | 45 | 25 | 44 | 05 | 92 | 23 | 45 | 30 | 32 | 33 | 35 | 05 | 92 |
| | Jacksonville | 22 | 30 | 38 | 30 | 39 | 22 | 44 | 32 | 46 | 29 | 34 | 28 | 39 | 26 | 57 | 11 | 38 | 25 | 36 | 21 | 31 | 33 | 38 | 31 | 40 | 26 | 57 |
| | Key West | 26 | 27 | 41 | 12 | 57 | 22 | 54 | 01 | 58 | 13 | 46 | 18 | 40 | 12 | 33 | 19 | 41 | 12 | 43 | 35 | 46 | 12 | 47 | 26 | 39 | 01 | 58 |
| | Miami | 45 | 24 | 46 | 19 | 55 | 04 | 46 | 24 | 35 | 32 | 52 | 13 | 37 | 25 | 43 | 12 | 86 | 06 | 69 | 90 | 59 | 07 | 38 | 32 | 38 | 12 | 86 |
| | Orlando | 53 | 25 | 42 | 25 | 46 | 24 | 46 | 02 | 50 | 35 | 51 | 32 | 64 | 14 | 46 | 32 | 50 | 24 | 46 | 05 | 48 | 26 | 46 | 20 | 35 | 32 | 64 |
| | Pensacola | 30 | 31 | 40 | 13 | 40 | 16 | 39 | 32 | 35 | 12 | 39 | 29 | 46 | 20 | 37 | 20 | 40 | 16 | 54 | 22 | 39 | 21 | 35 | 20 | 36 | 16 | 54 |
| | Tallahassee | 43 | 23 | 46 | 09 | 40 | 27 | 48 | 19 | 35 | 29 | 40 | 03 | 44 | 22 | 39 | 02 | 58 | 08 | 46 | 20 | 32 | 16 | 40 | 28 | 37 | 02 | 58 |
| | Tampa | 50 | 32 | 44 | 32 | 50 | 29 | 43 | 28 | 44 | 36 | 46 | 31 | 67 | 32 | 58 | 11 | 38 | 34 | 56 | 21 | 40 | 25 | 40 | 36 | 45 | 31 | 67 |
| | West Palm Beach | 53 | 29 | 48 | 11 | 48 | 27 | 51 | 32 | 55 | 27 | 45 | 09 | 71 | 34 | 46 | 13 | 86 | 36 | 58 | 16 | 74 | 10 | 39 | 36 | 38 | 13 | 86 |
| GA | Athens | 47 | 25 | 52 | 20 | 52 | 24 | 50 | 23 | 47 | 31 | 35 | 18 | 43 | 13 | 35 | 35 | 47 | 15 | 37 | 05 | 35 | 24 | 41 | 10 | 48 | 25 | 52 |
| | Atlanta | 26 | 23 | 46 | 29 | 52 | 31 | 49 | 30 | 44 | 27 | 54 | 24 | 51 | 30 | 60 | 32 | 41 | 27 | 37 | 09 | 35 | 29 | 39 | 30 | 33 | 30 | 60 |
| | Augusta | 51 | 25 | 40 | 30 | 40 | 23 | 52 | 32 | 39 | 28 | 48 | 08 | 62 | 33 | 48 | 18 | 45 | 04 | 36 | 18 | 40 | 27 | 40 | 28 | 35 | 08 | 62 |
| | Columbus | 44 | 29 | 46 | 20 | 52 | 27 | 44 | 28 | 40 | 23 | 39 | 29 | 55 | 36 | 52 | 18 | 47 | 36 | 38 | 12 | 40 | 31 | 37 | 33 | 35 | 29 | 55 |
| | Macon | 20 | 32 | 37 | 27 | 46 | 70 | 35 | 33 | 45 | 31 | 47 | 27 | 44 | 30 | 44 | 12 | 38 | 36 | 37 | 18 | 33 | 30 | 40 | 30 | 35 | 31 | 47 |
| | Savannah | 22 | 31 | 30 | 09 | 31 | 32 | 46 | 23 | 35 | 22 | 44 | 05 | 43 | 04 | 45 | 34 | 37 | 10 | 40 | 31 | 35 | 23 | 40 | 30 | 29 | 32 | 46 |
| HI | Hilo | 23 | 36 | 35 | 34 | 39 | 10 | 29 | 34 | 26 | 35 | 29 | 11 | 25 | 05 | 25 | 36 | 25 | 04 | 25 | 34 | 29 | 02 | 28 | 36 | 29 | 34 | 39 |
| | Honolulu | 22 | 70 | 36 | 07 | 35 | 06 | 32 | 50 | 35 | 13 | 30 | 70 | 30 | 05 | 30 | 70 | 31 | 13 | 38 | 60 | 29 | 20 | 46 | 70 | 35 | 20 | 46 |
| | Kahului | 28 | SW | 44 | NE | 40 | N | 43 | E | 36 | E | 34 | 40 | 38 | 60 | 38 | NE | 35 | E | 33 | E | 36 | SW | 41 | 21 | 40 | SW | 44 |
| | Lihue | 23 | 40 | 38 | 23 | 41 | 06 | 39 | 05 | 36 | 06 | 33 | 90 | 35 | 70 | 31 | 05 | 31 | 15 | 84 | 04 | 33 | 18 | 65 | 40 | 41 | 15 | 84 |
| ID | Boise | 61 | SE | 50 | W | 56 | W | 52 | W | 50 | W | 50 | SW | 50 | W | 61 | SE | 56 | SE | 50 | SE | 56 | NW | 57 | NW | 56 | W | 61 |
| | Lewiston (G) | 31 | | 72 | | 64 | | 60 | | 58 | | 54 | | 54 | 29 | 59 | | 51 | | 59 | | 59 | | 59 | | 63 | | 72 |
| | Pocatello | 51 | SE | 61 | W | 57 | W | 72 | S | 61 | W | 61 | W | 50 | W | 57 | SW | 54 | W | 57 | SW | 54 | W | 67 | NW | 57 | W | 72 |
| IL | Cairo | 45 | SW | 50 | SW | 68 | NW | 60 | SW | 59 | SW | 63 | SW | 60 | NW | 49 | S | 45 | SW | 47 | SW | 40 | SW | 53 | SW | 63 | SW | 68 |
| | Chicago | 44 | 28 | 47 | 25 | 45 | 01 | 54 | 24 | 54 | 34 | 52 | 24 | 41 | 36 | 55 | 32 | 46 | 23 | 58 | 20 | 48 | 23 | 51 | 26 | 46 | 23 | 58 |
| | Moline | 13 | 29 | 40 | 26 | 40 | 23 | 46 | 26 | 49 | 30 | 40 | 24 | 49 | 27 | 37 | 20 | 57 | 26 | 36 | 26 | 40 | 26 | 49 | 22 | 45 | 20 | 57 |
| | Peoria | 17 | 23 | 38 | 27 | 39 | 23 | 54 | 24 | 45 | 20 | 36 | 30 | 44 | 26 | 40 | 30 | 37 | 29 | 35 | 27 | 44 | 20 | 48 | 06 | 46 | 23 | 54 |
| | Rockford | 52 | 27 | 40 | 22 | 49 | 25 | 46 | 11 | 54 | 27 | 52 | 20 | 47 | 30 | 53 | 29 | 57 | 20 | 52 | 21 | 40 | 20 | 46 | 06 | 46 | 29 | 57 |
| | Springfield | 23 | 25 | 39 | 29 | 51 | 24 | 56 | 30 | 61 | 28 | 46 | 16 | 43 | 40 | 52 | 33 | 44 | 18 | 39 | 20 | 40 | 24 | 46 | 25 | 36 | 30 | 61 |
| IN | Evansville | 17 | 26 | 34 | 26 | 43 | 25 | 40 | 28 | 44 | 33 | 46 | 28 | 46 | 32 | 35 | 27 | 37 | 28 | 36 | 23 | 36 | 31 | 41 | 24 | 41 | 28 | 46 |
| | Fort Wayne | 53 | SW | 59 | W | 61 | S | 65 | W | 63 | S | 57 | SE | 65 | NW | 61 | N | 55 | W | 52 | SW | 46 | SW | 57 | SW | 52 | S | 65 |
| | Indianapolis | 23 | 19 | 45 | 23 | 46 | 21 | 54 | 25 | 47 | 30 | 40 | 29 | 46 | 28 | 49 | 29 | 45 | 26 | 46 | 27 | 44 | 23 | 44 | 26 | 41 | 28 | 49 |
| | South Bend | 53 | 22 | 52 | 20 | 47 | 20 | 51 | 27 | 55 | 27 | 68 | 27 | 50 | 34 | 45 | 32 | 63 | 25 | 36 | 25 | 56 | 22 | 58 | 23 | 43 | 27 | 68 |
| IA | Des Moines | 47 | NW | 66 | W | 56 | S | 66 | W | 76 | W | 70 | NW | 76 | W | 73 | SSE | 60 | NW | 55 | W | 56 | W | 72 | SW | 61 | W | 76 |
| | Dubuque (G) | 19 | | 58 | | 52 | | 62 | | 68 | | 74 | | 55 | NW | 74 | 32 | 66 | NW | 58 | | 54 | | 55 | E | 56 | | 74 |
| | Sioux City | 58 | NW | 56 | NW | 54 | N | 61 | W | 68 | W | 80 | W | 91 | NW | 66 | NW | 56 | S | 66 | W | 70 | NW | 59 | NW | 53 | W | 91 |

*(Continued)*



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**Table 3A.9 (Continued)**

| State | Station | Years | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP | DR | SP |
| | Waterloo | 42 | 29 | 46 | 28 | 44 | 23 | 46 | 25 | 52 | 18 | 52 | 33 | 60 | 35 | 58 | 21 | 46 | 28 | 38 | 29 | 43 | 22 | 53 | 32 | 39 | 33 | 60 |
| KS | Concordia | 21 | 32 | 46 | 21 | 41 | 35 | 46 | 24 | 55 | 30 | 41 | 24 | 54 | 25 | 58 | 06 | 44 | 17 | 44 | 26 | 46 | 34 | 46 | 35 | 40 | 25 | 58 |
| | Dodge City | 16 | 34 | 56 | 34 | 47 | 35 | 63 | 21 | 53 | 30 | 52 | 29 | 60 | 36 | 56 | 32 | 63 | 14 | 51 | 34 | 49 | 20 | 44 | 32 | 46 | 32 | 63 |
| | Goodland | 53 | 34 | 53 | 36 | 51 | 33 | 62 | 29 | 62 | 27 | 61 | 33 | 66 | 30 | 64 | 23 | 60 | 34 | 51 | 27 | 61 | 33 | 52 | 34 | 52 | 33 | 66 |
| | Topeka | 17 | 31 | 39 | 31 | 36 | 18 | 55 | 08 | 51 | 34 | 47 | 34 | 48 | 34 | 44 | 27 | 38 | 32 | 43 | 23 | 39 | 31 | 45 | 30 | 37 | 18 | 55 |
| | Wichita | 21 | 35 | 48 | 20 | 44 | 24 | 49 | 23 | 56 | 18 | 61 | 30 | 51 | 34 | 70 | 04 | 52 | 19 | 44 | 31 | 49 | 33 | 48 | 32 | 44 | 34 | 70 |
| KY | Greater Cincinnati AP | 39 | 28 | 46 | 29 | 40 | 27 | 45 | 25 | 46 | 31 | 37 | 27 | 41 | 32 | 45 | 29 | 41 | 31 | 36 | 29 | 48 | 28 | 43 | 21 | 40 | 29 | 48 |
| | Jackson | 21 | 23 | 37 | 19 | 39 | 31 | 33 | 27 | 43 | 28 | 39 | 29 | 31 | 33 | 32 | 28 | 37 | 29 | 26 | 25 | 28 | 19 | 30 | 30 | 30 | 27 | 43 |
| | Lexington | 41 | 18 | 47 | 32 | 46 | 27 | 36 | 32 | 46 | 22 | 35 | 30 | 44 | 29 | 37 | 22 | 39 | 29 | 41 | 17 | 40 | 27 | 45 | 22 | 39 | 18 | 47 |
| | Louisville | 17 | 16 | 38 | 23 | 44 | 19 | 43 | 22 | 56 | 23 | 40 | 04 | 54 | 32 | 46 | 21 | 47 | 29 | 39 | 29 | 40 | 23 | 44 | 27 | 40 | 22 | 56 |
| | Paducah | 18 | 30 | 41 | 25 | 40 | 19 | 37 | 24 | 38 | 24 | 51 | 29 | 45 | 34 | 51 | 10 | 33 | 18 | 35 | 24 | 43 | 21 | 44 | 22 | 35 | 34 | 51 |
| LA | Baton Rouge | 40 | 24 | 39 | 17 | 39 | 27 | 38 | 23 | 39 | 17 | 48 | 03 | 40 | 03 | 41 | 14 | 46 | 06 | 58 | 33 | 40 | 22 | 33 | 29 | 60 | 29 | 60 |
| | Lake Charles | 41 | 32 | 58 | 25 | 40 | 18 | 40 | 06 | 44 | 31 | 43 | 19 | 53 | 33 | 36 | 11 | 46 | 36 | 40 | 33 | 38 | 21 | 46 | 33 | 36 | 32 | 58 |
| | New Orleans | 43 | 27 | 48 | 26 | 43 | 16 | 38 | 10 | 40 | 36 | 55 | 25 | 49 | 13 | 44 | 33 | 42 | 09 | 69 | 17 | 40 | 22 | 38 | 28 | 46 | 09 | 69 |
| | Shreveport | 40 | 30 | 41 | 30 | 43 | 29 | 54 | 28 | 52 | 32 | 63 | 36 | 46 | 29 | 46 | 11 | 40 | 19 | 44 | 25 | 37 | 31 | 46 | 32 | 43 | 32 | 63 |
| ME | Caribou | 13 | 31 | 36 | 25 | 41 | 33 | 37 | 31 | 33 | 33 | 37 | 34 | 35 | 32 | 32 | 33 | 28 | 30 | 26 | 30 | 40 | 32 | 41 | 31 | 39 | 32 | 41 |
| | Portland | 17 | 16 | 38 | 08 | 45 | 11 | 41 | 29 | 40 | 28 | 37 | 28 | 35 | 29 | 37 | 28 | 57 | 29 | 33 | 14 | 37 | 10 | 41 | 30 | 44 | 28 | 57 |
| MD | Baltimore | 50 | NE | 63 | W | 68 | SE | 80 | W | 70 | SW | 65 | SW | 80 | NW | 57 | NE | 54 | W | 56 | SE | 73 | E | 58 | W | 57 | SE | 80 |
| MA | Blue Hill | 39 | S | 76 | S | 77 | ENE | 72 | NW | 66 | S | 65 | NW | 61 | NW | 78 | SSW | 67 | SSE | 92 | S | 62 | S | 67 | SSE | 68 | SSE | 92 |
| | Boston | 17 | 17 | 46 | 08 | 43 | 06 | 54 | 28 | 43 | 24 | 43 | 28 | 45 | 26 | 46 | 08 | 47 | 23 | 47 | 04 | 47 | 11 | 48 | 05 | 51 | 06 | 54 |
| | Worcester | 46 | 25 | 60 | 32 | 76 | 29 | 76 | 05 | 54 | 31 | 51 | 25 | 39 | 31 | 46 | 36 | 44 | 32 | 41 | 25 | 43 | 20 | 54 | 23 | 51 | 32 | 76 |
| MI | Alpena | 22 | 80 | 30 | 35 | 37 | 20 | 35 | 16 | 38 | 21 | 35 | 21 | 35 | 14 | 37 | 31 | 35 | 19 | 38 | 33 | 31 | 20 | 38 | 26 | 33 | 19 | 38 |
| | Detroit | 23 | 22 | 48 | 22 | 51 | 21 | 46 | 22 | 47 | 23 | 43 | 23 | 37 | 28 | 53 | 29 | 35 | 28 | 35 | 24 | 47 | 24 | 45 | 29 | 49 | 28 | 53 |
| | Flint | 47 | 26 | 45 | 28 | 40 | 27 | 58 | 24 | 44 | 32 | 81 | 29 | 52 | 29 | 41 | 27 | 37 | 27 | 46 | 25 | 39 | 23 | 46 | 27 | 40 | 32 | 81 |
| | Grand Rapids | 23 | 24 | 45 | 24 | 55 | 25 | 47 | 24 | 52 | 26 | 47 | 24 | 39 | 26 | 51 | 31 | 41 | 18 | 40 | 24 | 47 | 23 | 49 | 24 | 39 | 19 | 52 |
| | Houghton Lake | 25 | 26 | 40 | 24 | 37 | 28 | 36 | 24 | 37 | 26 | 40 | 19 | 51 | 13 | 37 | 25 | 29 | 23 | 32 | 16 | 35 | 27 | 40 | 32 | 33 | 19 | 51 |
| | Lansing | 41 | SW | 54 | SW | 56 | W | 59 | W | 61 | W | 46 | SE | 63 | NE | 56 | SW | 47 | N | 57 | SW | 48 | W | 56 | SW | 56 | SE | 63 |
| | Marquette | 6 | NW | 44 | NW | 31 | NW | 40 | NW | 44 | N | 34 | NW | 38 | NW | 35 | NW | 37 | W | 35 | SE | 38 | NW | 31 | SW | 35 | NW | 44 |
| | Muskegon | 43 | 31 | 44 | 34 | 41 | 25 | 41 | 22 | 48 | 27 | 44 | 24 | 44 | 33 | 40 | 26 | 43 | 20 | 40 | 22 | 40 | 23 | 52 | 23 | 40 | 23 | 52 |
| | Sault Ste. Marie | 31 | NW | 47 | W | 47 | SE | 42 | SE | 42 | E | 49 | S | 37 | SE | 44 | NW | 35 | W | 43 | NW | 42 | NW | 60 | NW | 45 | NW | 60 |
| MN | Duluth | 17 | 30 | 45 | 29 | 44 | E | 57 | 20 | 43 | 28 | 44 | 27 | 46 | 31 | 41 | 26 | 48 | 26 | 33 | 32 | 46 | 08 | 44 | 32 | 41 | E | 57 |
| | International Falls | 47 | 30 | 35 | 26 | 36 | 29 | 42 | 23 | 52 | 20 | 52 | 18 | 46 | 29 | 46 | 30 | 43 | 34 | 38 | 30 | 47 | 27 | 35 | 31 | 36 | 23 | 52 |
| | Minneapolis-St. Paul | 23 | 32 | 51 | 34 | 37 | 32 | 37 | 18 | 45 | 22 | 49 | 33 | 48 | 35 | 43 | 20 | 44 | 29 | 39 | 31 | 43 | 25 | 41 | 32 | 38 | 32 | 51 |
| | Rochester | 40 | 30 | 48 | 28 | 45 | 23 | 58 | 30 | 53 | 25 | 69 | 13 | 53 | 17 | 51 | 34 | 46 | 24 | 44 | 30 | 47 | 29 | 47 | 32 | 47 | 25 | 69 |
| | Saint Cloud | 13 | 1 | 36 | 30 | 46 | 30 | 43 | 30 | 44 | 27 | 41 | 32 | 62 | 22 | 49 | 22 | 45 | 32 | 34 | 31 | 43 | 30 | 39 | 31 | 39 | 32 | 62 |
| MS | Jackson | 26 | 35 | 46 | 13 | 43 | 16 | 44 | 14 | 44 | 22 | 35 | 35 | 40 | 33 | 44 | 17 | 37 | 06 | 55 | 31 | 30 | 14 | 41 | 15 | 41 | 06 | 55 |
| | Meridian | 43 | 33 | 41 | 02 | 35 | 34 | 39 | 19 | 48 | 17 | 35 | 22 | 46 | 40 | 51 | 34 | 38 | 02 | 45 | 02 | 35 | 19 | 41 | 80 | 37 | 40 | 51 |
| | Tupelo | 19 | 24 | 39 | 25 | 35 | 24 | 39 | 10 | 33 | 31 | 41 | 20 | 41 | 35 | 48 | 01 | 41 | 30 | 32 | 25 | 38 | 23 | 37 | 11 | 38 | 35 | 48 |
| MO | Columbia | 14 | NW | 49 | 24 | 41 | 26 | 46 | 23 | 54 | 36 | 39 | 26 | 49 | 31 | 46 | 19 | 52 | 35 | 38 | 25 | 47 | 19 | 45 | 06 | 37 | 23 | 54 |
| | Kansas City | 18 | 32 | 39 | 20 | 40 | 23 | 46 | 20 | 48 | 24 | 46 | 10 | 51 | 20 | 58 | 31 | 40 | 14 | 41 | 21 | 40 | 22 | 37 | 20 | 39 | 20 | 58 |
| | St. Louis | 23 | 29 | 40 | 30 | 45 | 27 | 48 | 27 | 49 | 34 | 46 | 27 | 48 | 36 | 46 | 31 | 40 | 25 | 41 | 28 | 52 | 11 | 41 | 29 | 39 | 28 | 52 |
| | Springfield | 17 | NW | 39 | 15 | 39 | 25 | 39 | 34 | 41 | 10 | 43 | 36 | 47 | 28 | 46 | 36 | 48 | 10 | 40 | 22 | 35 | 10 | 43 | 13 | 37 | 36 | 48 |
| MT | Billings | 59 | W | 66 | W | 72 | NW | 61 | NW | 72 | NN | 68 | NW | 79 | N | 73 | NW | 69 | NW | 61 | NW | 68 | NW | 63 | NW | 66 | NW | 79 |
| | Glasgow | 34 | 33 | 41 | 29 | 46 | 10 | 41 | 30 | 54 | 32 | 44 | 30 | 54 | 30 | 69 | 23 | 66 | 30 | 46 | 29 | 54 | 27 | 48 | 29 | 54 | 30 | 69 |
| | Great Falls | 54 | SW | 65 | W | 72 | W | 73 | W | 70 | SW | 65 | NW | 70 | W | 73 | SW | 71 | NW | 73 | W | 73 | SW | 73 | SW | 82 | SW | 82 |
| | Havre | 3 | 29 | 46 | 24 | 46 | 27 | 46 | 28 | 58 | 10 | 51 | 27 | 47 | 28 | 55 | 25 | 46 | 33 | 45 | 26 | 69 | 33 | 46 | 29 | 45 | 26 | 69 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Helena | 62 | SW | 73 | W | 73 | SW | 61 | W | 52 | SW | 56 | W | 56 | SW | 65 | S | 65 | NW | 54 | W | 62 | SW | 56 | NW | 59 | SW | 73 |
| | Kalispell | 36 | 04 | 52 | 01 | 40 | 03 | 41 | 23 | 43 | 23 | 40 | 03 | 38 | 31 | 38 | 15 | 43 | 22 | 36 | 32 | 38 | 03 | 35 | 03 | 52 | 04 | 52 |
| | Missoula | 57 | S | 52 | NW | 47 | SW | 50 | NW | 51 | SW | 57 | S | 51 | SE | 72 | SW | 58 | 16 | 48 | SW | 51 | SW | 42 | W | 56 | SE | 72 |
| NE | Grand Island | 40 | 34 | 54 | 33 | 53 | 34 | 55 | 21 | 52 | 29 | 59 | 30 | 68 | 29 | 59 | 22 | 52 | 25 | 40 | 33 | 51 | 34 | 51 | 31 | 52 | 30 | 68 |
| | Lincoln | 30 | 33 | 48 | NW | 48 | N | 54 | NW | 52 | W | 51 | NE | 67 | SW | 52 | NW | 65 | 32 | 44 | 30 | 47 | NW | 48 | 34 | 46 | NE | 67 |
| | Norfolk | 21 | 33 | 46 | 32 | 44 | 30 | 44 | 32 | 51 | 07 | 44 | 28 | 46 | 21 | 58 | 32 | 60 | 30 | 55 | 18 | 46 | 31 | 51 | 35 | 46 | 32 | 60 |
| | North Platte | 23 | 31 | 45 | 36 | 52 | 02 | 47 | 28 | 49 | 31 | 48 | 32 | 52 | 24 | 55 | 31 | 56 | 30 | 46 | 31 | 53 | 29 | 46 | 02 | 52 | 31 | 56 |
| | Omaha Eppley AP | 14 | 33 | 45 | 33 | 39 | 33 | 40 | 20 | 51 | 16 | 57 | 24 | 40 | 28 | 58 | 30 | 46 | 19 | 36 | 11 | 48 | 28 | 45 | 34 | 39 | 28 | 58 |
| | Omaha (North) | 15 | NW | 41 | NW | 38 | NW | 38 | NW | 46 | N | 34 | SW | 39 | SW | 50 | NW | 39 | NW | 35 | NW | 34 | NW | 38 | NW | 37 | SW | 50 |
| | Scottsbluff | 52 | 34 | 53 | 29 | 60 | 29 | 62 | 31 | 55 | 32 | 80 | 29 | 80 | 05 | 52 | 35 | 52 | 32 | 46 | 31 | 48 | 29 | 56 | 32 | 47 | 32 | 80 |
| | Valentine | 20 | 32 | 43 | 30 | 52 | 33 | 43 | 30 | 49 | 33 | 49 | 29 | 53 | 26 | 51 | 20 | 53 | 31 | 40 | 29 | 51 | 30 | 45 | 31 | 41 | 20 | 53 |
| NV | Elko | 39 | 23 | 40 | 27 | 39 | 29 | 41 | 25 | 48 | 34 | 55 | 27 | 61 | 23 | 45 | 16 | 35 | 27 | 58 | 29 | 35 | 20 | 40 | 27 | 50 | 27 | 61 |
| | Ely | 57 | SE | 66 | S | 56 | SW | 65 | S | 59 | S | 74 | SW | 63 | S | 50 | E | 57 | S | 57 | S | 65 | S | 51 | SE | 61 | S | 74 |
| | Las Vegas | 17 | 23 | 45 | 23 | 50 | 23 | 51 | 22 | 49 | 22 | 56 | 34 | 48 | 30 | 45 | 32 | 43 | 16 | 41 | 31 | 47 | 21 | 43 | 34 | 48 | 22 | 56 |
| | Reno | 13 | 16 | 45 | 15 | 44 | 21 | 49 | SW | 50 | 17 | 46 | 23 | 37 | 18 | 41 | 19 | 40 | 23 | 43 | 15 | 41 | 19 | 52 | 19 | 67 | 19 | 67 |
| | Winnemucca | 51 | W | 56 | W | 59 | W | 66 | W | 52 | N | 61 | W | 57 | W | 56 | W | 51 | W | 57 | NE | 54 | 22 | 48 | SW | 61 | W | 66 |
| NH | Concord | 57 | NW | 44 | N | 42 | NE | 71 | NW | 52 | NW | 48 | SW | 44 | SW | 45 | E | 56 | E | 42 | NW | 39 | NE | 72 | NW | 52 | NE | 72 |
| | Mt. Washington (G) | 63 | NW | 173 | E | 166 | W | 180 | SE | 231 | W | 164 | NW | 136 | NW | 110 | ENE | 142 | SE | 174 | W | 161 | NW | 163 | NW | 178 | SE | 231 |
| NJ | Atlantic City AP | 43 | 29 | 47 | 27 | 43 | 24 | 46 | 07 | 46 | 70 | 40 | 30 | 41 | 31 | 41 | 12 | 35 | 32 | 60 | 29 | 41 | 28 | 47 | 36 | 55 | 32 | 60 |
| | Atlantic City CO | 11 | 4 | 43 | 04 | 43 | 07 | 63 | 19 | 37 | 01 | 37 | 05 | 30 | 19 | 44 | 35 | 30 | 07 | 32 | 04 | 44 | 04 | 36 | 11 | 45 | 07 | 63 |
| | Newark | 54 | 30 | 52 | 23 | 46 | 30 | 45 | 29 | 55 | 32 | 50 | 26 | 58 | 35 | 52 | 09 | 46 | 05 | 51 | 11 | 48 | 09 | 82 | 32 | 55 | 09 | 82 |
| NM | Albuquerque | 18 | 09 | 52 | 27 | 47 | 19 | 49 | 11 | 47 | 25 | 48 | 27 | 48 | 36 | 52 | 80 | 51 | 34 | 43 | 26 | 48 | 27 | 48 | 06 | 51 | 09 | 52 |
| | Roswell | 16 | NW | 47 | NW | 56 | NW | 52 | 25 | 49 | NW | 60 | NW | 73 | 19 | 49 | NW | 44 | 35 | 43 | 22 | 44 | NE | 65 | SW | 58 | NW | 73 |
| NY | Albany | 19 | 30 | 40 | 29 | 44 | 30 | 46 | 17 | 35 | 32 | 55 | 23 | 43 | 29 | 41 | 30 | 47 | 32 | 35 | 28 | 39 | 28 | 41 | 29 | 43 | 32 | 55 |
| | Binghamton | 17 | 27 | 40 | 25 | 41 | 24 | 39 | 24 | 32 | 28 | 33 | 26 | 40 | 30 | 35 | 32 | 43 | 34 | 33 | 26 | 33 | 27 | 41 | 24 | 43 | 24 | 43 |
| | Buffalo | 54 | SW | 91 | SW | 70 | W | 68 | W | 67 | SW | 63 | NW | 56 | NW | 59 | SW | 56 | SW | 59 | SW | 63 | SW | 66 | S | 60 | SW | 91 |
| | New York C. Park | 19 | 7 | 40 | 08 | 34 | 8 | 37 | 80 | 35 | 30 | 29 | 08 | 28 | 35 | 29 | 30 | 33 | 90 | 29 | 33 | 28 | 32 | 30 | 05 | 39 | 7 | 40 |
| | New York (JFK AP) | 39 | 26 | 52 | 25 | 46 | 06 | 46 | 31 | 46 | 16 | 44 | 28 | 43 | 29 | 51 | 30 | 46 | 28 | 47 | 26 | 44 | 30 | 44 | 26 | 49 | 26 | 52 |
| | New York (Laguardia AP) | 23 | 5 | 40 | 01 | 43 | 06 | 52 | 29 | 55 | 17 | 41 | 29 | 38 | 35 | 53 | 28 | 46 | 33 | 51 | 10 | 52 | 30 | 55 | 05 | 52 | 29 | 55 |
| | Rochester | 17 | 24 | 45 | 25 | 59 | 25 | 55 | 25 | 41 | 18 | 45 | 36 | 39 | 20 | 52 | 27 | 40 | 27 | 68 | 25 | 43 | 25 | 46 | 24 | 45 | 27 | 68 |
| | Syracuse | 53 | W | 60 | W | 62 | SE | 56 | NW | 52 | 30 | 52 | NW | 49 | 28 | 54 | NW | 43 | 32 | 59 | SE | 63 | E | 59 | W | 52 | SE | 63 |
| NC | Asheville | 38 | 34 | 45 | 34 | 60 | 33 | 48 | 22 | 44 | 34 | 40 | 36 | 40 | 35 | 43 | 30 | 41 | 36 | 45 | 33 | 35 | 32 | 40 | 34 | 44 | 34 | 60 |
| | Cape Hatteras | 32 | 24 | 44 | 16 | 44 | 19 | 52 | 21 | 40 | 18 | 35 | 29 | 37 | 15 | 52 | 33 | 60 | 11 | 60 | 22 | 47 | 15 | 58 | 16 | 46 | 33 | 60 |
| | Charlotte | 23 | 31 | 30 | 32 | 33 | 30 | 32 | 19 | 32 | 35 | 34 | 20 | 32 | 20 | 38 | 28 | 46 | 12 | 46 | 21 | 37 | 24 | 30 | 16 | 38 | 28 | 46 |
| | Greensboro-Wnstn-Slm-HPT | 22 | 19 | 41 | 07 | 38 | 30 | 49 | 26 | 37 | 27 | 62 | 27 | 43 | 35 | 50 | 19 | 30 | 26 | 46 | 30 | 46 | 20 | 38 | 24 | 34 | 27 | 62 |
| | Raleigh | 49 | 27 | 41 | 23 | 45 | 24 | 46 | 25 | 40 | 20 | 54 | 33 | 39 | 23 | 69 | 33 | 46 | 04 | 53 | 29 | 73 | 32 | 35 | 22 | 40 | 29 | 73 |
| | Wilmington | 22 | 26 | 38 | 25 | 44 | 29 | 58 | 28 | 47 | 27 | 44 | 23 | 46 | 4 | 53 | 06 | 56 | 07 | 67 | 01 | 35 | 24 | 38 | 26 | 43 | 07 | 67 |
| ND | Bismarck | 23 | 29 | 44 | 30 | 52 | 36 | 43 | 31 | 55 | 27 | 54 | 34 | 52 | 22 | 64 | 30 | 54 | 15 | 46 | 32 | 44 | 31 | 47 | 33 | 45 | 22 | 64 |
| | Fargo | 17 | 34 | 49 | 33 | 51 | 34 | 49 | 32 | 49 | 24 | 45 | 14 | 43 | 33 | 74 | 34 | 51 | 31 | 45 | 33 | 49 | 31 | 47 | 30 | 45 | 33 | 74 |
| | Grand Forks | 5 | 17 | 39 | 27 | 47 | 35 | 48 | 31 | 49 | 15 | 53 | 31 | 51 | 12 | 40 | 30 | 62 | 29 | 43 | 31 | 46 | 31 | 54 | 34 | 45 | 30 | 62 |
| | Williston | 23 | 32 | 44 | 30 | 46 | 29 | 46 | 30 | 55 | 27 | 46 | 30 | 56 | 26 | 63 | 29 | 53 | 27 | 40 | 28 | 55 | 29 | 52 | 30 | 48 | 26 | 63 |
| OH | Akron | 41 | 22 | 44 | 25 | 51 | 26 | 49 | 30 | 40 | 32 | 46 | 31 | 67 | 23 | 44 | 17 | 51 | 36 | 40 | 24 | 43 | 25 | 41 | 24 | 48 | 31 | 67 |
| | Cleveland | 25 | 22 | 53 | 24 | 45 | 27 | 46 | 23 | 44 | 20 | 42 | 28 | 41 | 23 | 43 | 24 | 39 | 29 | 35 | 24 | 46 | 18 | 40 | 25 | 46 | 22 | 53 |
| | Columbus | 21 | 24 | 40 | 27 | 43 | 26 | 47 | 26 | 47 | 25 | 52 | 31 | 40 | 33 | 47 | 29 | 43 | 23 | 44 | 24 | 40 | 27 | 45 | 26 | 47 | 25 | 52 |
| | Dayton | 17 | 25 | 43 | 28 | 45 | 27 | 49 | 25 | 49 | 24 | 54 | 24 | 43 | 29 | 61 | 26 | 33 | 22 | 43 | 26 | 43 | 22 | 44 | 25 | 46 | 29 | 61 |
| | Mansfield | 36 | 24 | 46 | 24 | 44 | 26 | 44 | 33 | 46 | 25 | 37 | 23 | 40 | 26 | 39 | 17 | 41 | 33 | 34 | 32 | 40 | 23 | 39 | 18 | 46 | 24 | 46 |
| | Toledo | 45 | W | 47 | SW | 56 | W | 56 | SW | 72 | 25 | 46 | W | 50 | NW | 54 | W | 47 | NW | 47 | 24 | 45 | SW | 65 | 30 | 48 | SW | 72 |
| | Youngstown | 53 | 25 | 48 | 27 | 58 | 25 | 55 | 33 | 51 | 24 | 46 | 23 | 45 | 27 | 58 | 27 | 44 | 36 | 40 | 23 | 44 | 25 | 52 | 25 | 46 | 27 | 58 |
| OK | Oklahoma City | 21 | 34 | 45 | 32 | 45 | 24 | 52 | 32 | 67 | 23 | 53 | 35 | 48 | 31 | 74 | 05 | 46 | 21 | 52 | 30 | 43 | 19 | 46 | 33 | 44 | 31 | 74 |
| | Tulsa | 25 | 18 | 37 | 20 | 41 | 18 | 46 | 34 | 55 | 30 | 41 | 04 | 49 | 19 | 51 | 29 | 38 | 27 | 39 | 25 | 40 | 29 | 44 | 33 | 36 | 34 | 55 |

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**Table 3A.9 (Continued)**

| | | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **State** | **Station** | **Years** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** | **DR** | **SP** |
| OR | Astoria | 49 | 17 | 55 | 19 | 47 | 18 | 47 | 20 | 52 | 22 | 37 | 18 | 30 | 19 | 29 | 20 | 30 | 17 | 36 | 20 | 44 | 20 | 46 | 25 | 52 | 17 | 55 |
| | Eugene | 46 | 20 | 58 | 19 | 60 | 18 | 48 | 18 | 44 | 25 | 46 | 27 | 29 | 32 | 37 | 11 | 32 | 20 | 32 | 18 | 63 | 23 | 46 | 18 | 40 | 18 | 63 |
| | Medford | 53 | 23 | 50 | 25 | 46 | 16 | 55 | 14 | 35 | 12 | 38 | 17 | 37 | 07 | 44 | 16 | 48 | 14 | 47 | 20 | 40 | 19 | 40 | 14 | 44 | 16 | 55 |
| | Pendleton | 47 | 24 | 52 | 25 | 54 | 29 | 63 | 27 | 77 | 27 | 48 | 29 | 62 | 31 | 49 | 23 | 43 | 27 | 47 | 25 | 49 | 27 | 62 | 29 | 63 | 27 | 77 |
| | Portland | 48 | S | 54 | SW | 61 | S | 57 | S | 60 | SW | 42 | SW | 40 | SW | 33 | SW | 29 | S | 61 | S | 88 | SW | 56 | S | 57 | S | 88 |
| | Salem | 53 | 18 | 43 | 18 | 46 | 19 | 40 | 18 | 44 | 20 | 31 | 23 | 28 | 24 | 26 | 18 | 25 | 19 | 34 | 18 | 58 | 17 | 49 | 17 | 46 | 18 | 58 |
| | Sexton Summit | 15 | 16 | 60 | 19 | 53 | 21 | 60 | 20 | 50 | 20 | 44 | 18 | 42 | 35 | 39 | 20 | 45 | 12 | 45 | 14 | 51 | 19 | 59 | 20 | 63 | 20 | 63 |
| PC | Guam | 38 | W | 64 | NE | 36 | 70 | 35 | SW | 64 | NE | 76 | E | 32 | 22 | 74 | SE | 43 | E | 35 | W | 44 | NE | 80 | 27 | 106 | 27 | 106 |
| | Johnston Island | 5 | 33 | 31 | 09 | 38 | 08 | 35 | 09 | 35 | 07 | 32 | 08 | 31 | 06 | 33 | 08 | 32 | 07 | 35 | 08 | 32 | 03 | 33 | 06 | 43 | 06 | 43 |
| | Koror | 13 | 20 | 35 | 06 | 23 | 36 | 26 | 10 | 25 | 15 | 46 | 30 | 33 | 26 | 33 | 08 | 28 | 27 | 37 | 29 | 31 | 25 | 52 | 09 | 31 | 25 | 52 |
| | Kwajalein, Marshall IS | 42 | 22 | 55 | 18 | 35 | 90 | 39 | 08 | 37 | 11 | 44 | 12 | 41 | 09 | 41 | 70 | 44 | 07 | 44 | 20 | 40 | 12 | 60 | 09 | 45 | 12 | 60 |
| | Majuro, Marshall IS | 13 | 06 | 36 | 70 | 35 | 07 | 25 | 07 | 26 | 07 | 25 | 09 | 29 | 23 | 30 | 32 | 29 | 22 | 29 | 06 | 33 | 22 | 31 | 09 | 35 | 06 | 36 |
| | Pago Pago, Amer Samoa | 23 | 34 | 46 | 36 | 63 | 32 | 37 | 35 | 35 | 08 | 35 | 08 | 43 | 09 | 32 | 17 | 33 | 06 | 38 | 18 | 35 | 09 | 39 | 21 | 81 | 21 | 81 |
| | Pohnpei, Caroline IS | 14 | 29 | 28 | 10 | 21 | 23 | 20 | 29 | 26 | 10 | 23 | 90 | 18 | 30 | 18 | 25 | 32 | 23 | 21 | 22 | 23 | 24 | 35 | 27 | 23 | 24 | 35 |
| | Chuuk, E. Caroline IS | 13 | 34 | 30 | 50 | 28 | 33 | 33 | 8 | 29 | 09 | 29 | 40 | 29 | 24 | 33 | 23 | 39 | 21 | 32 | 22 | 35 | 24 | 35 | 24 | 46 | 24 | 46 |
| | Wake Island | 8 | 08 | 39 | 02 | 36 | 06 | 37 | 06 | 38 | 09 | 30 | 08 | 28 | 10 | 41 | 19 | 51 | 16 | 30 | 08 | 33 | 07 | 40 | 03 | 39 | 19 | 51 |
| | Yap, W Caroline IS | 13 | 05 | 23 | 04 | 23 | 12 | 39 | 13 | 23 | 08 | 20 | 23 | 23 | 28 | 28 | 22 | 25 | 09 | 23 | 16 | 26 | 09 | 36 | 26 | 41 | 26 | 41 |
| PA | Allentown | 54 | 29 | 55 | 25 | 58 | 29 | 58 | 29 | 60 | 30 | 58 | 27 | 81 | 27 | 55 | 23 | 58 | 25 | 46 | 14 | 49 | 30 | 58 | 29 | 52 | 27 | 81 |
| | Erie | 45 | 20 | 53 | 29 | 52 | 14 | 55 | 21 | 46 | 25 | 37 | 36 | 37 | 32 | 46 | 25 | 36 | 17 | 45 | 24 | 43 | 31 | 41 | 24 | 40 | 14 | 55 |
| | Harrisburg | 10 | 27 | 44 | 30 | 35 | 28 | 37 | 28 | 35 | 29 | 47 | 33 | 58 | 29 | 35 | 35 | 46 | 28 | 31 | 25 | 30 | 31 | 40 | 31 | 46 | 33 | 58 |
| | Middletown/ Harrisburg AP | 20 | 34 | 46 | 29 | 51 | 29 | 46 | 33 | 46 | 29 | 47 | 33 | 58 | 16 | 52 | 29 | 49 | 28 | 40 | 32 | 37 | 33 | 40 | 31 | 46 | 33 | 58 |
| | Philadelphia | 60 | NE | 61 | NW | 59 | NW | 56 | SW | 59 | SW | 56 | NW | 73 | SW | 49 | E | 67 | NE | 49 | SW | 66 | SW | 60 | NW | 48 | NW | 73 |
| | Pittsburgh | 50 | 23 | 52 | 26 | 58 | 25 | 48 | 30 | 51 | 30 | 48 | 34 | 53 | 25 | 51 | 29 | 46 | 20 | 38 | 31 | 39 | 29 | 45 | 25 | 48 | 26 | 58 |
| | Avoca | 45 | SW | 52 | W | 60 | S | 49 | NW | 47 | SW | 46 | W | 43 | NW | 43 | NE | 50 | SW | 47 | E | 40 | NW | 49 | SW | 47 | W | 60 |
| | Williamsport | 49 | 27 | 66 | 14 | 60 | 11 | 58 | 18 | 62 | 18 | 55 | 29 | 62 | 20 | 78 | 29 | 60 | 16 | 59 | 11 | 75 | 09 | 77 | 16 | 58 | 20 | 78 |
| RI | Block IS | 12 | 27 | 36 | 36 | 46 | 05 | 45 | 04 | 29 | 15 | 29 | 18 | 28 | 30 | 28 | 04 | 29 | 16 | 53 | 08 | 37 | 28 | 38 | 25 | 40 | 16 | 53 |
| | Providence | 49 | 20 | 46 | 16 | 46 | 18 | 60 | 20 | 51 | 20 | 42 | 20 | 40 | 14 | 39 | 11 | 90 | 18 | 58 | 14 | 41 | 18 | 52 | 14 | 48 | 11 | 90 |
| SC | Charleston AP | 27 | 20 | 40 | 30 | 38 | 21 | 46 | 20 | 38 | 24 | 33 | 17 | 44 | 28 | 40 | 27 | 38 | 21 | 52 | 21 | 39 | 15 | 37 | 24 | 39 | 21 | 52 |
| | Columbia | 49 | 28 | 46 | 20 | 40 | 27 | 60 | 33 | 44 | 28 | 47 | 27 | 47 | 32 | 40 | 30 | 48 | 30 | 48 | 27 | 29 | 35 | 35 | 26 | 41 | 27 | 60 |
| | Greenville-Spartanburg AP | 12 | 25 | 36 | 22 | 37 | 25 | 39 | 29 | 39 | 36 | 43 | 30 | 43 | 17 | 49 | 24 | 36 | 23 | 30 | 12 | 31 | 25 | 32 | 35 | 29 | 17 | 49 |
| SD | Aberdeen | 33 | 34 | 58 | 06 | 52 | 35 | 52 | 31 | 55 | 16 | 46 | 10 | 47 | 31 | 63 | 33 | 46 | 32 | 41 | 33 | 49 | 34 | 46 | 33 | 43 | 31 | 63 |
| | Huron | 60 | NW | 57 | NW | 56 | NW | 68 | SE | 73 | NW | 70 | SE | 65 | NW | 77 | NW | 72 | NW | 64 | W | 72 | NW | 73 | NW | 59 | NW | 77 |
| | Rapid City | 19 | 32 | 59 | 33 | 59 | 33 | 54 | 32 | 61 | 32 | 57 | 25 | 54 | 21 | 69 | 32 | 54 | 32 | 52 | 32 | 55 | 33 | 57 | 33 | 52 | 21 | 69 |
| | Sioux Falls | 54 | 32 | 47 | 31 | 45 | 02 | 60 | 31 | 51 | 11 | 46 | 23 | 70 | 36 | 69 | 31 | 58 | 16 | 50 | 27 | 60 | 36 | 52 | 36 | 46 | 23 | 70 |
| TN | Bristol-JhnCty-Kgsprt | 47 | 25 | 40 | 25 | 46 | 25 | 40 | 25 | 41 | 32 | 50 | 27 | 39 | 23 | 40 | 34 | 46 | 31 | 29 | 27 | 36 | 26 | 37 | 24 | 40 | 32 | 50 |
| | Chattanooga | 27 | 31 | 30 | 25 | 37 | 32 | 44 | 18 | 32 | 18 | 35 | 24 | 37 | 30 | 44 | 06 | 43 | 29 | 33 | 29 | 35 | 30 | 38 | 22 | 29 | 30 | 44 |
| | Knoxville | 28 | 27 | 43 | 25 | 39 | 24 | 43 | 28 | 64 | 20 | 40 | 07 | 35 | 24 | 43 | 30 | 38 | 24 | 29 | 26 | 43 | 25 | 49 | 20 | 39 | 28 | 64 |
| | Memphis | 23 | 34 | 35 | 24 | 38 | 16 | 40 | 24 | 46 | 34 | 40 | 29 | 51 | 34 | 37 | 30 | 37 | 36 | 39 | 28 | 40 | 23 | 40 | 30 | 36 | 29 | 51 |
| | Nashville | 27 | 26 | 38 | 20 | 36 | 13 | 41 | 25 | 40 | 36 | 41 | 10 | 38 | 36 | 38 | 02 | 40 | 34 | 33 | 17 | 35 | 15 | 39 | 23 | 41 | 13 | 41 |
| TX | Abilene | 22 | 19 | 38 | 31 | 45 | 27 | 41 | 27 | 55 | 31 | 54 | 21 | 49 | 30 | 48 | 19 | 55 | 35 | 43 | 31 | 46 | 33 | 39 | 32 | 40 | 27 | 55 |
| | Amarillo | 28 | 25 | 45 | 25 | 48 | 34 | 58 | 25 | 53 | 13 | 47 | 35 | 60 | 30 | 48 | 02 | 46 | 80 | 41 | 31 | 58 | 31 | 46 | 32 | 51 | 35 | 60 |
| | Austin/City | 23 | 35 | 37 | 34 | 39 | 33 | 36 | 27 | 46 | 20 | 52 | 34 | 41 | 28 | 40 | 03 | 35 | 02 | 52 | 35 | 33 | 30 | 36 | 31 | 44 | 20 | 52 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Austin/Bergstrom | 61 | 29 | 73 | 23 | 59 | 20 | 73 | 25 | 60 | 32 | 78 | 29 | 80 | 11 | 62 | 36 | 66 | 02 | 63 | 36 | 51 | 32 | 62 | 34 | 76 | 29 | 80 |
| | Brownsville | 23 | 18 | 40 | 23 | 36 | 28 | 44 | 17 | 41 | 17 | 38 | 30 | 41 | 12 | 36 | 19 | 48 | 30 | 51 | 36 | 35 | 17 | 39 | 17 | 38 | 30 | 51 |
| | Corpus Christi | 26 | 30 | 43 | 06 | 45 | 17 | 45 | 30 | 45 | 10 | 56 | 01 | 41 | 02 | 46 | 11 | 55 | 30 | 49 | 28 | 49 | 90 | 41 | 18 | 38 | 10 | 56 |
| | Dallas-Fort Worth | 49 | 36 | 55 | 36 | 51 | 29 | 55 | 32 | 55 | 14 | 55 | 32 | 52 | 36 | 65 | 36 | 73 | 11 | 53 | 23 | 46 | 34 | 50 | 32 | 53 | 36 | 73 |
| | Dallas-Love Field | 3 | 30 | 41 | 17 | 40 | 29 | 47 | 35 | 43 | 28 | 47 | 16 | 40 | 02 | 35 | 33 | 35 | 10 | 35 | 14 | 43 | 03 | 38 | 33 | 45 | 29 | 47 |
| | Del Rio | 23 | 31 | 45 | 31 | 39 | 33 | 52 | 15 | 41 | 32 | 48 | 28 | 51 | 16 | 39 | 14 | 60 | 32 | 45 | 33 | 46 | 32 | 36 | 29 | 43 | 14 | 60 |
| | El Paso | 27 | 26 | 64 | 24 | 51 | 28 | 52 | 26 | 56 | 25 | 45 | 32 | 51 | 30 | 45 | 26 | 54 | 35 | 41 | 23 | 41 | 23 | 52 | 26 | 44 | 26 | 64 |
| | Galveston | 124 | S | 53 | N | 60 | SE | 50 | NW | 68 | W | 66 | SE | 62 | NW | 68 | E | 91 | NE | 100 | SE | 66 | NW | 72 | NW | 50 | NE | 100 |
| | Houston | 33 | 33 | 32 | 26 | 46 | 25 | 35 | 14 | 45 | 23 | 46 | 30 | 45 | 10 | 46 | 08 | 51 | 05 | 37 | 27 | 41 | 33 | 37 | 14 | 46 | 08 | 51 |
| | Lubbock | 54 | 28 | 59 | 25 | 58 | 34 | 69 | 25 | 58 | 36 | 70 | 05 | 63 | 25 | 64 | 30 | 46 | 36 | 45 | 25 | 65 | 25 | 59 | 25 | 58 | 36 | 70 |
| | Midland-Odessa | 49 | 28 | 44 | 25 | 67 | 27 | 53 | 30 | 53 | 20 | 52 | 24 | 58 | 05 | 58 | 16 | 55 | 23 | 53 | 14 | 46 | 25 | 48 | 26 | 47 | 25 | 67 |
| | Port Arthur | 23 | 06 | 39 | 16 | 39 | 10 | 43 | 30 | 46 | 29 | 52 | 14 | 55 | 05 | 44 | 01 | 44 | 06 | 38 | 33 | 36 | 34 | 38 | 25 | 41 | 14 | 55 |
| | San Angelo | 54 | 26 | 45 | 29 | 48 | 27 | 58 | 28 | 75 | 02 | 60 | 02 | 57 | 17 | 46 | 02 | 44 | 34 | 52 | 29 | 60 | 29 | 66 | 30 | 43 | 28 | 75 |
| | San Antonio | 26 | 29 | 39 | 31 | 42 | 33 | 46 | 35 | 39 | 28 | 46 | 90 | 38 | 09 | 48 | 11 | 39 | 25 | 43 | 31 | 35 | 33 | 37 | 33 | 33 | 09 | 48 |
| | Victoria (G) | 19 | N | 49 | N | 54 | N | 54 | N | 62 | N | 68 | N | 60 | E | 54 | N | 54 | S | 44 | NW | 75 | N | 55 | N | 45 | NW | 75 |
| | Waco | 54 | 32 | 49 | 36 | 58 | 27 | 65 | 36 | 62 | 36 | 60 | 09 | 69 | 36 | 60 | 05 | 60 | 32 | 60 | 34 | 52 | 29 | 62 | 32 | 52 | 09 | 69 |
| | Wichita Falls | 54 | 32 | 49 | 29 | 57 | 27 | 59 | 14 | 52 | 20 | 59 | 36 | 69 | 33 | 60 | 34 | 55 | 01 | 53 | 29 | 60 | 32 | 56 | 29 | 55 | 36 | 69 |
| UT | Milford | 18 | SW | 44 | W | 56 | SW | 52 | SW | 52 | SW | 57 | SW | 57 | NW | 45 | SW | 52 | SW | 47 | NW | 45 | SW | 56 | SW | 53 | SW | 57 |
| | Salt Lake City | 66 | NW | 59 | SE | 56 | NW | 71 | NW | 57 | NW | 57 | W | 63 | NW | 51 | SW | 58 | W | 61 | NW | 67 | NW | 63 | S | 54 | NW | 71 |
| VT | Burlington | 19 | 16 | 38 | 17 | 39 | 16 | 33 | 33 | 36 | 29 | 35 | 29 | 39 | 30 | 37 | 36 | 35 | 19 | 36 | 13 | 32 | 18 | 35 | 27 | 35 | 29 | 39 |
| VA | Lynchburg | 58 | W | 45 | S | 50 | S | 43 | NE | 43 | N | 56 | SW | 56 | NW | 43 | W | 48 | NE | 40 | N | 41 | NW | 43 | SE | 45 | N | 56 |
| | Norfolk | 30 | 20 | 43 | 36 | 44 | 22 | 46 | 02 | 41 | 70 | 40 | 30 | 46 | 34 | 46 | 35 | 46 | 30 | 46 | 04 | 48 | 21 | 40 | 01 | 39 | 04 | 48 |
| | Richmond | 17 | 22 | 38 | 23 | 39 | 27 | 41 | 33 | 46 | 23 | 46 | 26 | 45 | 23 | 40 | 36 | 44 | 10 | 40 | 10 | 37 | 23 | 36 | 15 | 40 | 33 | 46 |
| | Roanoke | 41 | 30 | 53 | 31 | 40 | 32 | 52 | 32 | 58 | 36 | 46 | 28 | 46 | 34 | 46 | 30 | 44 | 10 | 38 | 30 | 36 | 34 | 52 | 30 | 40 | 32 | 58 |
| | Wallops Island | 16 | NNE | 70 | SSW | 66 | W | 68 | NE | 69 | S | 52 | W | 69 | WNW | 67 | WNW | 75 | WNW | 70 | W | 60 | WNW | 60 | E | 73 | WNW | 75 |
| WA | Olympia | 54 | 18 | 55 | 18 | 45 | 23 | 40 | 23 | 46 | 29 | 39 | 25 | 32 | 18 | 29 | 27 | 26 | 18 | 35 | 23 | 58 | 18 | 60 | 16 | 45 | 18 | 60 |
| | Quillayute | 34 | 21 | 35 | SE | 46 | 23 | 38 | SW | 32 | W | 28 | SE | 23 | NE | 23 | SE | 27 | SE | 33 | SE | 42 | SE | 37 | SW | 39 | SE | 46 |
| | Seattle CO (G) | 11 | SSE | 51 | SSW | 40 | WSW | 54 | SW | 44 | WSW | 46 | SW | 37 | SW | 39 | S | 33 | S | 33 | SSW | 41 | SSW | 63 | SW | 46 | SSW | 63 |
| | Seattle Sea-Tac AP | 34 | S | 47 | S | 51 | SW | 44 | SW | 38 | SW | 32 | SW | 29 | SW | 26 | SW | 29 | 20 | 36 | SW | 38 | S | 66 | S | 49 | S | 66 |
| | Spokane | 53 | SW | 59 | SW | 54 | SW | 54 | SW | 52 | W | 49 | SW | 44 | SW | 43 | SW | 50 | SW | 38 | SW | 56 | SW | 54 | SW | 51 | SW | 59 |
| | Yakima | 48 | 25 | 44 | 28 | 48 | 23 | 48 | 29 | 46 | 18 | 46 | 20 | 47 | 24 | 43 | 20 | 37 | 30 | 38 | 31 | 41 | 29 | 45 | 23 | 48 | 28 | 48 |
| PR | San Juan | 17 | 50 | 28 | 06 | 29 | 07 | 32 | 60 | 31 | 60 | 28 | 12 | 35 | 32 | 49 | 04 | 34 | 05 | 79 | 40 | 37 | 36 | 33 | 70 | 30 | 05 | 79 |
| WV | Beckley | 39 | 24 | 46 | 26 | 40 | 27 | 58 | 27 | 44 | 24 | 41 | 27 | 40 | 36 | 46 | 32 | 40 | 30 | 46 | 26 | 32 | 16 | 44 | 28 | 41 | 27 | 58 |
| | Charleston | 53 | 25 | 45 | 19 | 40 | 32 | 46 | 27 | 45 | 25 | 55 | 32 | 50 | 29 | 46 | 29 | 50 | 20 | 35 | 25 | 45 | 29 | 40 | 25 | 55 | 25 | 55 |
| | Elkins | 19 | 27 | 46 | 25 | 55 | 32 | 46 | 27 | 50 | 30 | 46 | 27 | 40 | 30 | 37 | 32 | 40 | 26 | 35 | 29 | 46 | 30 | 33 | 27 | 40 | 25 | 55 |
| | Huntington | 40 | 26 | 43 | 26 | 41 | 25 | 37 | 18 | 44 | 29 | 47 | 24 | 35 | 34 | 35 | 24 | 35 | 34 | 29 | 30 | 38 | 23 | 35 | 26 | 36 | 29 | 47 |
| WI | Green Bay | 17 | 40 | 39 | 27 | 37 | 29 | 44 | 22 | 41 | 29 | 46 | 16 | 41 | 24 | 36 | 28 | 35 | 32 | 37 | 28 | 36 | 20 | 45 | 26 | 38 | 29 | 46 |
| | La Crosse | 21 | 32 | 45 | 34 | 37 | 34 | 40 | 25 | 53 | 09 | 58 | 34 | 63 | 27 | 52 | 32 | 63 | 27 | 40 | 34 | 39 | 18 | 46 | 34 | 43 | 34 | 63 |
| | Madison | 53 | E | 68 | W | 57 | SW | 70 | SW | 73 | SW | 77 | W | 59 | NW | 72 | W | 47 | W | 52 | SW | 73 | SE | 56 | SW | 65 | SW | 77 |
| | Milwaukee | 20 | 80 | 44 | 27 | 52 | 26 | 41 | 24 | 48 | 30 | 46 | 31 | 47 | 30 | 54 | 02 | 47 | 70 | 41 | 24 | 43 | 23 | 52 | 04 | 40 | 30 | 54 |
| WY | Casper | 49 | 20 | 58 | 23 | 58 | 25 | 81 | 25 | 54 | 32 | 58 | 26 | 54 | 25 | 52 | 25 | 50 | 32 | 53 | 25 | 55 | 25 | 51 | 20 | 63 | 25 | 81 |
| | Cheyenne | 21 | 25 | 55 | 27 | 59 | 28 | 52 | 30 | 58 | 26 | 48 | 29 | 71 | 25 | 46 | 25 | 56 | 28 | 48 | 26 | 53 | 27 | 59 | 27 | 63 | 29 | 71 |
| | Lander | 13 | 26 | 44 | 20 | 46 | 23 | 68 | 25 | 62 | 17 | 52 | 19 | 53 | 22 | 47 | 18 | 39 | 20 | 52 | 26 | 55 | 27 | 44 | 24 | 55 | 23 | 68 |
| | Sheridan | 17 | 30 | 53 | 24 | 45 | 31 | 49 | 30 | 61 | 31 | 60 | 31 | 47 | 20 | 52 | 32 | 58 | 31 | 46 | 29 | 46 | 32 | 55 | 31 | 48 | 31 | 60 |

*Note:* Through 2002. This table expresses both a maximum wind speed and where available, the direction (referenced to true North) from which it blew. Short gusts are listed only for stations denoted with a (G). If the direction is expressed as one of the 16 compass points (N, NNE, NE, etc) the maximum speed is calculated from the minimum time during which one mile of wind passed the station. If the direction is expressed numerically, the maximum speed is the highest one-minute average value recorded by the observer. Direction is given in tens of degrees clockwise from true North.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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**Table 3A.10 Average Percentage of Possible Sunshine — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham CO | 10 | 48 | 48 | 62 | 61 | 64 | 63 | 60 | 62 | 57 | 63 | 49 | 52 | 57 |
| | Birmingham AP | 34 | 42 | 50 | 54 | 63 | 66 | 65 | 59 | 63 | 61 | 66 | 55 | 46 | 58 |
| | Montgomery | 45 | 47 | 52 | 59 | 65 | 63 | 62 | 61 | 63 | 62 | 64 | 55 | 49 | 58 |
| AK | Anchorage | 40 | 34 | 42 | 50 | 50 | 50 | 46 | 43 | 39 | 38 | 36 | 32 | 27 | 41 |
| | Juneau | 33 | 32 | 32 | 37 | 39 | 39 | 34 | 31 | 32 | 26 | 19 | 23 | 20 | 30 |
| | Nome | 40 | 40 | 55 | 54 | 54 | 50 | 43 | 37 | 32 | 36 | 34 | 31 | 34 | 42 |
| AZ | Flagstaff | 15 | 77 | 73 | 76 | 82 | 88 | 86 | 75 | 76 | 81 | 79 | 75 | 73 | 78 |
| | Phoenix | 101 | 78 | 80 | 84 | 89 | 93 | 94 | 85 | 85 | 89 | 88 | 83 | 77 | 85 |
| | Tucson | 53 | 80 | 82 | 86 | 90 | 92 | 93 | 78 | 80 | 87 | 88 | 84 | 79 | 85 |
| | Yuma | 42 | 84 | 87 | 90 | 94 | 95 | 97 | 91 | 91 | 93 | 92 | 87 | 82 | 90 |
| AR | Fort Smith | 51 | 50 | 55 | 56 | 60 | 62 | 69 | 73 | 72 | 66 | 65 | 54 | 50 | 61 |
| | Little Rock | 32 | 46 | 54 | 57 | 62 | 68 | 73 | 71 | 73 | 68 | 69 | 56 | 48 | 62 |
| | North Little Rock | 24 | 61 | 62 | 72 | 77 | 74 | 81 | 82 | 79 | 81 | 75 | 62 | 57 | 72 |
| CA | Eureka | 84 | 43 | 46 | 52 | 57 | 58 | 59 | 55 | 51 | 55 | 50 | 44 | 41 | 51 |
| | Fresno | 46 | 47 | 65 | 77 | 85 | 90 | 95 | 97 | 96 | 94 | 88 | 66 | 46 | 79 |
| | Los Angeles CO | 32 | 69 | 72 | 73 | 70 | 66 | 65 | 82 | 83 | 79 | 73 | 74 | 71 | 73 |
| | Redding | 10 | 72 | 82 | 85 | 90 | 91 | 94 | 97 | 97 | 94 | 92 | 84 | 73 | 88 |
| | Sacramento | 46 | 48 | 65 | 74 | 82 | 90 | 94 | 97 | 96 | 93 | 86 | 66 | 49 | 78 |
| | San Diego | 56 | 72 | 71 | 70 | 68 | 59 | 58 | 68 | 70 | 69 | 68 | 75 | 73 | 68 |
| | San Francisco CO | 38 | 56 | 62 | 69 | 73 | 72 | 73 | 66 | 65 | 72 | 70 | 62 | 53 | 66 |
| CO | Denver | 46 | 71 | 69 | 69 | 67 | 64 | 70 | 71 | 71 | 74 | 72 | 64 | 67 | 69 |
| | Grand Junction | 56 | 61 | 65 | 65 | 70 | 73 | 81 | 79 | 77 | 79 | 74 | 63 | 61 | 71 |
| | Pueblo | 61 | 75 | 74 | 74 | 74 | 73 | 78 | 79 | 78 | 80 | 79 | 72 | 71 | 76 |
| CT | Hartford | 42 | 53 | 56 | 57 | 55 | 57 | 60 | 62 | 62 | 59 | 57 | 45 | 47 | 56 |
| DC | Washington Nat'l AP | 50 | 46 | 50 | 55 | 57 | 58 | 64 | 62 | 62 | 61 | 59 | 51 | 46 | 56 |
| FL | Apalachicola | 57 | 58 | 61 | 65 | 74 | 77 | 71 | 64 | 64 | 66 | 74 | 67 | 57 | 66 |
| | Jacksonville | 50 | 58 | 62 | 68 | 73 | 70 | 66 | 65 | 64 | 58 | 60 | 60 | 54 | 63 |
| | Key West | 38 | 74 | 77 | 82 | 84 | 82 | 76 | 77 | 76 | 72 | 71 | 71 | 70 | 76 |
| | Miami | 20 | 66 | 68 | 74 | 76 | 72 | 68 | 72 | 71 | 70 | 70 | 67 | 63 | 70 |
| | Pensacola | 5 | 48 | 53 | 61 | 63 | 67 | 67 | 57 | 58 | 60 | 71 | 64 | 49 | 60 |
| | Tampa | 50 | 63 | 65 | 71 | 75 | 75 | 67 | 62 | 61 | 61 | 65 | 64 | 61 | 66 |
| GA | Atlanta | 65 | 49 | 54 | 58 | 66 | 68 | 67 | 63 | 64 | 62 | 66 | 58 | 50 | 60 |
| | Macon | 48 | 56 | 61 | 65 | 73 | 71 | 70 | 67 | 71 | 67 | 69 | 64 | 57 | 66 |
| | Savannah | 46 | 54 | 57 | 62 | 71 | 68 | 65 | 64 | 62 | 58 | 63 | 61 | 55 | 62 |
| HI | Hilo | 52 | 46 | 46 | 42 | 37 | 37 | 44 | 41 | 42 | 43 | 39 | 33 | 37 | 41 |
| | Honolulu | 46 | 65 | 68 | 72 | 70 | 72 | 74 | 76 | 77 | 77 | 70 | 65 | 63 | 71 |
| | Kahului | 37 | 64 | 64 | 64 | 63 | 68 | 72 | 71 | 71 | 73 | 68 | 62 | 63 | 67 |
| | Lihue | 51 | 55 | 57 | 56 | 55 | 61 | 63 | 62 | 65 | 67 | 59 | 49 | 49 | 58 |
| ID | Boise | 60 | 40 | 50 | 62 | 68 | 70 | 75 | 87 | 85 | 82 | 69 | 43 | 38 | 64 |
| | Pocatello | 53 | 40 | 53 | 61 | 66 | 67 | 75 | 83 | 81 | 80 | 72 | 47 | 40 | 64 |
| IL | Cairo | 45 | 45 | 50 | 56 | 62 | 65 | 72 | 74 | 75 | 69 | 67 | 51 | 44 | 61 |
| | Chicago | 16 | 44 | 49 | 51 | 50 | 58 | 67 | 66 | 62 | 59 | 55 | 38 | 43 | 54 |
| | Moline | 53 | 48 | 50 | 50 | 53 | 57 | 63 | 68 | 66 | 62 | 58 | 42 | 40 | 55 |
| | Peoria | 52 | 47 | 50 | 51 | 55 | 60 | 67 | 69 | 67 | 64 | 61 | 43 | 42 | 56 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Springfield | 48 | 48 | 52 | 51 | 56 | 63 | 68 | 71 | 70 | 68 | 63 | 48 | 44 | 58 |
| IN | Evansville | 56 | 42 | 48 | 55 | 60 | 64 | 71 | 73 | 73 | 69 | 65 | 48 | 42 | 59 |
| | Fort Wayne | 52 | 46 | 51 | 55 | 60 | 68 | 74 | 75 | 74 | 68 | 62 | 42 | 38 | 59 |
| | Indianapolis | 53 | 40 | 49 | 50 | 54 | 60 | 65 | 66 | 68 | 65 | 61 | 41 | 38 | 55 |
| IA | Des Moines | 50 | 51 | 54 | 57 | 56 | 61 | 68 | 72 | 70 | 66 | 62 | 49 | 46 | 59 |
| | Sioux City | 55 | 57 | 56 | 57 | 59 | 61 | 67 | 73 | 70 | 66 | 63 | 51 | 50 | 61 |
| KS | Concordia | 34 | 64 | 63 | 63 | 65 | 67 | 76 | 78 | 76 | 70 | 68 | 59 | 57 | 67 |
| | Dodge City | 59 | 67 | 65 | 65 | 68 | 67 | 74 | 79 | 78 | 74 | 73 | 67 | 65 | 70 |
| | Topeka | 53 | 56 | 55 | 57 | 58 | 61 | 66 | 71 | 70 | 66 | 64 | 54 | 52 | 61 |
| | Wichita | 49 | 58 | 61 | 62 | 63 | 64 | 69 | 76 | 75 | 68 | 65 | 58 | 57 | 65 |
| KY | Greater Cincinnati AP | 13 | 33 | 40 | 48 | 56 | 57 | 61 | 61 | 61 | 61 | 54 | 36 | 31 | 50 |
| | Louisville | 48 | 41 | 48 | 51 | 56 | 60 | 66 | 67 | 66 | 64 | 61 | 46 | 40 | 56 |
| | Paducah | 18 | 45 | 48 | 54 | 61 | 63 | 60 | 70 | 70 | 63 | 64 | 50 | 42 | 58 |
| LA | Lake Charles | 19 | 62 | 66 | 74 | 71 | 72 | 78 | 83 | 81 | 78 | 75 | 67 | 59 | 72 |
| | New Orleans | 22 | 46 | 50 | 56 | 62 | 62 | 63 | 58 | 61 | 61 | 64 | 54 | 48 | 57 |
| | Shreveport | 50 | 51 | 57 | 58 | 60 | 63 | 71 | 75 | 74 | 70 | 69 | 60 | 54 | 64 |
| ME | Portland | 55 | 56 | 59 | 56 | 54 | 54 | 59 | 63 | 63 | 62 | 58 | 48 | 53 | 57 |
| MD | Baltimore | 40 | 51 | 55 | 56 | 56 | 56 | 62 | 64 | 62 | 60 | 58 | 51 | 49 | 57 |
| MA | Blue Hill | 112 | 46 | 50 | 48 | 49 | 52 | 55 | 57 | 58 | 56 | 55 | 47 | 46 | 52 |
| | Boston | 61 | 53 | 56 | 57 | 56 | 58 | 63 | 65 | 65 | 63 | 60 | 50 | 52 | 58 |
| MI | Alpena | 37 | 36 | 45 | 53 | 52 | 59 | 63 | 65 | 59 | 51 | 42 | 28 | 28 | 48 |
| | Detroit | 31 | 40 | 46 | 52 | 54 | 61 | 66 | 68 | 67 | 61 | 51 | 35 | 31 | 53 |
| | Grand Rapids | 36 | 28 | 39 | 46 | 51 | 56 | 62 | 64 | 61 | 54 | 44 | 27 | 23 | 46 |
| | Lansing | 42 | 36 | 44 | 49 | 52 | 61 | 65 | 69 | 64 | 59 | 50 | 31 | 29 | 51 |
| | Marquette | 21 | 35 | 41 | 49 | 51 | 61 | 64 | 66 | 62 | 54 | 45 | 35 | 34 | 50 |
| | Sault Ste. Marie | 55 | 36 | 47 | 55 | 54 | 57 | 58 | 62 | 58 | 45 | 38 | 24 | 27 | 47 |
| MN | Duluth | 48 | 48 | 53 | 55 | 56 | 57 | 58 | 65 | 61 | 52 | 46 | 35 | 39 | 52 |
| | Minneapolis-St.Paul | 58 | 53 | 59 | 57 | 58 | 61 | 66 | 72 | 69 | 62 | 55 | 39 | 42 | 58 |
| MS | Jackson | 33 | 49 | 54 | 60 | 66 | 63 | 70 | 66 | 67 | 65 | 70 | 57 | 49 | 61 |
| | Tupelo | 13 | 53 | 53 | 61 | 73 | 72 | 74 | 75 | 73 | 72 | 62 | 51 | 46 | 64 |
| MO | Columbia | 27 | 50 | 49 | 50 | 55 | 57 | 64 | 67 | 64 | 60 | 59 | 47 | 45 | 56 |
| | Kansas City | 23 | 58 | 55 | 58 | 62 | 61 | 66 | 72 | 67 | 66 | 60 | 49 | 49 | 60 |
| | St. Louis | 37 | 50 | 52 | 54 | 56 | 59 | 66 | 68 | 65 | 63 | 60 | 46 | 43 | 57 |
| MT | Billings | 57 | 47 | 53 | 61 | 60 | 61 | 64 | 76 | 75 | 68 | 61 | 46 | 45 | 60 |
| | Great Falls | 46 | 49 | 56 | 66 | 62 | 62 | 65 | 79 | 76 | 67 | 61 | 46 | 44 | 61 |
| | Helena | 55 | 46 | 55 | 61 | 59 | 60 | 64 | 78 | 74 | 67 | 60 | 44 | 42 | 59 |
| | Missoula | 57 | 33 | 44 | 54 | 57 | 59 | 63 | 81 | 77 | 69 | 55 | 34 | 29 | 55 |
| NE | Lincoln | 40 | 58 | 57 | 57 | 58 | 61 | 69 | 73 | 70 | 66 | 63 | 53 | 52 | 61 |
| | North Platte | 50 | 63 | 62 | 62 | 64 | 65 | 71 | 77 | 75 | 72 | 70 | 60 | 61 | 67 |
| | Omaha (North) | 57 | 55 | 53 | 54 | 58 | 61 | 67 | 74 | 70 | 68 | 65 | 51 | 48 | 60 |
| | Valentine | 29 | 63 | 62 | 59 | 59 | 62 | 69 | 76 | 76 | 71 | 68 | 60 | 60 | 65 |
| NV | Ely | 56 | 68 | 68 | 71 | 70 | 72 | 80 | 80 | 81 | 82 | 75 | 67 | 67 | 73 |
| | Las Vegas | 47 | 77 | 81 | 83 | 87 | 88 | 93 | 88 | 88 | 91 | 87 | 81 | 78 | 85 |
| | Reno | 45 | 65 | 68 | 75 | 80 | 81 | 85 | 92 | 92 | 91 | 83 | 70 | 64 | 79 |
| | Winnemucca | 42 | 51 | 56 | 60 | 66 | 72 | 77 | 86 | 85 | 82 | 74 | 54 | 52 | 68 |
| NH | Concord | 58 | 52 | 55 | 53 | 53 | 55 | 58 | 62 | 60 | 56 | 53 | 42 | 47 | 54 |

*(Continued)*



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**Table 3A.10 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mt. Washington | 64 | 32 | 35 | 34 | 34 | 36 | 32 | 30 | 31 | 35 | 38 | 29 | 30 | 33 |
| NJ | Atlantic City AP | 36 | 50 | 53 | 55 | 56 | 56 | 60 | 61 | 65 | 61 | 59 | 51 | 47 | 56 |
| NM | Albuquerque | 63 | 72 | 72 | 73 | 77 | 79 | 83 | 76 | 75 | 79 | 79 | 76 | 71 | 76 |
| | Roswell | 7 | 60 | 68 | 75 | 77 | 80 | 83 | 77 | 73 | 72 | 77 | 73 | 71 | 74 |
| NY | Albany | 61 | 46 | 52 | 54 | 54 | 56 | 60 | 64 | 61 | 57 | 52 | 37 | 39 | 53 |
| | Binghamton | 51 | 37 | 42 | 46 | 50 | 56 | 62 | 64 | 61 | 55 | 49 | 32 | 29 | 49 |
| | Buffalo | 59 | 31 | 38 | 46 | 51 | 56 | 65 | 67 | 64 | 57 | 50 | 29 | 27 | 48 |
| | New York C.Park | 109 | 51 | 55 | 57 | 58 | 61 | 64 | 65 | 64 | 62 | 61 | 52 | 49 | 58 |
| | Rochester | 57 | 35 | 41 | 49 | 53 | 59 | 66 | 69 | 66 | 59 | 49 | 31 | 30 | 51 |
| | Syracuse | 53 | 33 | 39 | 46 | 49 | 55 | 59 | 63 | 59 | 53 | 44 | 26 | 25 | 46 |
| NC | Asheville | 32 | 55 | 59 | 61 | 66 | 61 | 62 | 60 | 54 | 56 | 61 | 58 | 55 | 59 |
| | Cape Hatteras | 33 | 48 | 52 | 60 | 67 | 65 | 65 | 65 | 65 | 64 | 60 | 56 | 48 | 60 |
| | Charlotte | 48 | 54 | 58 | 61 | 68 | 67 | 67 | 67 | 65 | 64 | 65 | 58 | 55 | 62 |
| | Greensboro-Wnstn-Slm-HPT | 68 | 51 | 56 | 60 | 63 | 63 | 64 | 62 | 61 | 62 | 64 | 57 | 53 | 60 |
| | Raleigh | 42 | 52 | 56 | 60 | 63 | 59 | 60 | 60 | 58 | 58 | 60 | 57 | 53 | 58 |
| | Wilmington | 51 | 56 | 59 | 64 | 70 | 67 | 66 | 64 | 62 | 61 | 64 | 63 | 59 | 63 |
| ND | Bismarck | 63 | 53 | 53 | 58 | 58 | 61 | 64 | 73 | 72 | 65 | 58 | 43 | 47 | 59 |
| | Fargo | 54 | 50 | 56 | 58 | 60 | 61 | 62 | 71 | 69 | 60 | 54 | 40 | 43 | 57 |
| | Williston | 39 | 51 | 57 | 61 | 60 | 62 | 66 | 74 | 74 | 67 | 59 | 45 | 50 | 60 |
| OH | Cleveland | 59 | 30 | 37 | 45 | 52 | 58 | 65 | 67 | 63 | 60 | 52 | 31 | 25 | 49 |
| | Columbus | 45 | 36 | 42 | 44 | 51 | 56 | 60 | 60 | 60 | 61 | 56 | 37 | 31 | 50 |
| | Dayton | 53 | 40 | 44 | 48 | 52 | 58 | 66 | 66 | 67 | 65 | 59 | 40 | 36 | 53 |
| | Toledo | 41 | 41 | 46 | 50 | 52 | 60 | 64 | 65 | 63 | 61 | 54 | 37 | 33 | 52 |
| OK | Oklahoma City | 42 | 60 | 60 | 65 | 68 | 66 | 75 | 79 | 79 | 72 | 70 | 61 | 58 | 68 |
| | Tulsa | 55 | 53 | 56 | 58 | 60 | 60 | 66 | 74 | 73 | 66 | 64 | 56 | 53 | 62 |
| OR | Portland | 46 | 28 | 38 | 48 | 52 | 57 | 56 | 69 | 66 | 62 | 44 | 28 | 23 | 48 |
| PC | Guam | 39 | 47 | 52 | 57 | 57 | 56 | 52 | 40 | 36 | 38 | 38 | 40 | 38 | 46 |
| | Johnston Island | 22 | 70 | 74 | 74 | 70 | 74 | 78 | 79 | 76 | 73 | 65 | 59 | 62 | 71 |
| | Koror | 42 | 54 | 54 | 63 | 61 | 54 | 44 | 45 | 44 | 52 | 47 | 50 | 49 | 51 |
| | Majuro, Marshall IS | 42 | 61 | 64 | 66 | 59 | 58 | 55 | 56 | 61 | 59 | 55 | 53 | 53 | 58 |
| | Pago Pago, Amer Samoa | 34 | 45 | 45 | 45 | 40 | 34 | 34 | 40 | 43 | 51 | 42 | 46 | 45 | 42 |
| | Pohnpei, Caroline IS | 44 | 38 | 41 | 45 | 42 | 41 | 40 | 44 | 44 | 44 | 40 | 39 | 36 | 41 |
| | Chuuk, E. Caroline IS | 42 | 50 | 55 | 56 | 50 | 47 | 44 | 47 | 48 | 44 | 42 | 44 | 42 | 47 |
| | Wake Island | 28 | 68 | 71 | 76 | 75 | 75 | 76 | 72 | 68 | 68 | 68 | 65 | 64 | 70 |
| | Yap, W Caroline IS | 43 | 59 | 61 | 68 | 67 | 65 | 52 | 47 | 45 | 50 | 47 | 52 | 49 | 55 |
| PA | Allentown | 12 | 43 | 48 | 53 | 46 | 53 | 62 | 57 | 61 | 58 | 57 | 49 | 45 | 53 |
| | Harrisburg | 53 | 49 | 54 | 58 | 59 | 60 | 65 | 68 | 67 | 62 | 58 | 47 | 44 | 58 |
| | Middletown/Harrisburg AP | 62 | 48 | 54 | 57 | 58 | 59 | 64 | 67 | 66 | 61 | 58 | 47 | 44 | 57 |
| | Philadelphia | 60 | 49 | 53 | 55 | 56 | 57 | 62 | 61 | 62 | 59 | 60 | 52 | 49 | 56 |
| | Pittsburgh | 49 | 32 | 36 | 43 | 46 | 50 | 55 | 57 | 56 | 55 | 51 | 36 | 28 | 45 |
| | Avoca | 41 | 41 | 47 | 50 | 53 | 57 | 61 | 62 | 61 | 55 | 52 | 36 | 34 | 51 |
| RI | Providence | 42 | 56 | 58 | 58 | 57 | 58 | 61 | 63 | 62 | 62 | 61 | 50 | 52 | 58 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SC | Charleston AP | 39 | 56 | 59 | 66 | 72 | 68 | 66 | 67 | 64 | 61 | 63 | 59 | 56 | 63 |
| | Columbia | 46 | 55 | 59 | 64 | 70 | 68 | 67 | 67 | 66 | 65 | 67 | 63 | 59 | 64 |
| | Greenville-Spartanburg | 39 | 54 | 57 | 63 | 66 | 62 | 62 | 60 | 61 | 62 | 66 | 58 | 54 | 60 |
| SD | Huron | 55 | 57 | 59 | 59 | 61 | 65 | 70 | 76 | 74 | 69 | 63 | 50 | 49 | 63 |
| | Rapid City | 55 | 57 | 60 | 63 | 62 | 60 | 65 | 73 | 74 | 70 | 66 | 55 | 55 | 63 |
| TN | Chattanooga | 65 | 43 | 49 | 53 | 61 | 65 | 65 | 62 | 63 | 64 | 63 | 53 | 44 | 57 |
| | Knoxville | 57 | 40 | 47 | 53 | 63 | 64 | 65 | 64 | 63 | 61 | 61 | 49 | 40 | 56 |
| | Memphis | 35 | 50 | 54 | 56 | 64 | 69 | 74 | 74 | 75 | 69 | 70 | 58 | 50 | 64 |
| | Nashville | 54 | 41 | 47 | 52 | 59 | 60 | 65 | 63 | 63 | 62 | 62 | 50 | 42 | 56 |
| TX | Abilene | 49 | 62 | 64 | 70 | 72 | 70 | 78 | 80 | 78 | 71 | 72 | 67 | 62 | 70 |
| | Amarillo | 61 | 69 | 68 | 72 | 74 | 71 | 78 | 79 | 77 | 73 | 75 | 72 | 67 | 73 |
| | Austin/City | 58 | 49 | 51 | 55 | 54 | 56 | 69 | 75 | 74 | 66 | 64 | 54 | 49 | 60 |
| | Austin/Bergstrom | 60 | 49 | 51 | 55 | 54 | 56 | 69 | 75 | 74 | 66 | 63 | 56 | 49 | 60 |
| | Brownsville | 59 | 41 | 48 | 53 | 58 | 63 | 73 | 80 | 76 | 68 | 65 | 51 | 42 | 60 |
| | Corpus Christi | 60 | 44 | 49 | 54 | 56 | 59 | 72 | 80 | 76 | 68 | 67 | 54 | 43 | 60 |
| | Dallas-Fort Worth | 17 | 52 | 54 | 58 | 61 | 57 | 67 | 75 | 73 | 67 | 63 | 57 | 52 | 61 |
| | El Paso | 54 | 78 | 82 | 86 | 89 | 90 | 90 | 82 | 81 | 83 | 84 | 83 | 77 | 84 |
| | Galveston | 103 | 48 | 51 | 56 | 61 | 67 | 75 | 73 | 71 | 68 | 71 | 59 | 48 | 62 |
| | Houston | 27 | 45 | 50 | 54 | 58 | 62 | 68 | 70 | 68 | 66 | 64 | 52 | 51 | 59 |
| | Lubbock | 25 | 65 | 66 | 73 | 74 | 71 | 76 | 77 | 76 | 71 | 75 | 69 | 65 | 72 |
| | Midland-Odessa | 22 | 66 | 69 | 73 | 78 | 78 | 81 | 81 | 77 | 77 | 72 | 74 | 65 | 74 |
| | Port Arthur | 26 | 42 | 52 | 52 | 52 | 64 | 69 | 65 | 63 | 62 | 67 | 57 | 47 | 58 |
| | San Antonio | 53 | 47 | 50 | 57 | 56 | 56 | 67 | 74 | 74 | 67 | 64 | 54 | 48 | 60 |
| UT | Milford | 16 | 58 | 64 | 63 | 69 | 73 | 82 | 77 | 79 | 80 | 76 | 62 | 60 | 70 |
| | Salt Lake City | 64 | 45 | 54 | 64 | 68 | 72 | 80 | 83 | 82 | 82 | 72 | 53 | 42 | 66 |
| VT | Burlington | 59 | 41 | 48 | 51 | 49 | 56 | 59 | 64 | 60 | 54 | 47 | 31 | 33 | 49 |
| VA | Lynchburg | 52 | 52 | 56 | 58 | 62 | 62 | 65 | 62 | 62 | 61 | 62 | 56 | 53 | 59 |
| | Norfolk | 32 | 53 | 56 | 60 | 63 | 62 | 67 | 62 | 62 | 61 | 59 | 56 | 54 | 60 |
| | Richmond | 46 | 54 | 58 | 62 | 66 | 66 | 70 | 68 | 66 | 65 | 63 | 59 | 54 | 63 |
| WA | Quillayute | 30 | 22 | 30 | 34 | 35 | 37 | 35 | 43 | 44 | 47 | 34 | 21 | 19 | 33 |
| | Seattle CO | 31 | 28 | 34 | 42 | 47 | 52 | 49 | 63 | 56 | 53 | 37 | 28 | 23 | 43 |
| | Seattle Sea-Tac AP | 30 | 28 | 40 | 50 | 52 | 56 | 56 | 65 | 65 | 62 | 43 | 28 | 23 | 47 |
| | Spokane | 48 | 28 | 41 | 55 | 61 | 65 | 67 | 80 | 78 | 72 | 55 | 29 | 23 | 54 |
| PR | San Juan | 47 | 69 | 70 | 76 | 72 | 64 | 65 | 69 | 68 | 62 | 64 | 60 | 61 | 67 |
| WV | Elkins | 11 | 29 | 32 | 39 | 46 | 44 | 48 | 44 | 44 | 45 | 46 | 37 | 28 | 40 |
| WI | Green Bay | 53 | 49 | 52 | 53 | 55 | 61 | 65 | 66 | 63 | 56 | 47 | 38 | 40 | 54 |
| | Madison | 50 | 47 | 51 | 52 | 52 | 58 | 64 | 67 | 64 | 60 | 54 | 39 | 40 | 54 |
| | Milwaukee | 55 | 44 | 47 | 50 | 53 | 60 | 65 | 69 | 66 | 59 | 54 | 39 | 38 | 54 |
| WY | Cheyenne | 63 | 64 | 67 | 67 | 63 | 61 | 67 | 69 | 68 | 70 | 69 | 61 | 60 | 66 |
| | Lander | 50 | 65 | 68 | 70 | 66 | 64 | 72 | 75 | 75 | 72 | 67 | 58 | 61 | 68 |
| | Sheridan | 55 | 57 | 60 | 63 | 60 | 60 | 65 | 75 | 75 | 68 | 62 | 53 | 55 | 63 |

*Note:* Through 2002. The total time that sunshine reaches the surface of the earth is expressed as the percentage of the maximum amount possible from sunrise to sunset with clear sky conditions.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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## Table 3A.11 Mean Number of Cloudy Days (Clear, Partly Cloudy, Cloudy) — Selected Cities of the United States (Through 2002)

| State | Station | Years | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | | Jul | | | Aug | | | Sep | | | Oct | | | Nov | | | Dec | | | Annual | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD |
| AL | Birmingham AP | 37 | 7 | 6 | 18 | 7 | 6 | 15 | 7 | 8 | 16 | 9 | 8 | 13 | 8 | 11 | 12 | 7 | 13 | 10 | 5 | 14 | 12 | 7 | 15 | 10 | 9 | 9 | 11 | 14 | 8 | 9 | 10 | 7 | 13 | 8 | 7 | 16 | 99 | 111 | 155 |
| | Huntsville | 27 | 7 | 6 | 18 | 7 | 6 | 16 | 7 | 8 | 17 | 9 | 7 | 14 | 8 | 10 | 14 | 8 | 11 | 11 | 7 | 13 | 11 | 9 | 13 | 10 | 9 | 9 | 12 | 12 | 7 | 12 | 9 | 7 | 14 | 8 | 6 | 18 | 100 | 101 | 164 |
| | Mobile | 47 | 8 | 6 | 17 | 8 | 7 | 14 | 9 | 8 | 14 | 9 | 9 | 12 | 9 | 11 | 11 | 7 | 14 | 9 | 4 | 15 | 12 | 6 | 15 | 10 | 9 | 10 | 11 | 14 | 8 | 9 | 11 | 7 | 12 | 9 | 6 | 16 | 102 | 116 | 147 |
| | Montgomery | 51 | 7 | 6 | 17 | 8 | 6 | 14 | 8 | 8 | 15 | 10 | 8 | 12 | 9 | 10 | 12 | 8 | 12 | 10 | 6 | 14 | 11 | 8 | 14 | 9 | 10 | 9 | 11 | 14 | 7 | 10 | 11 | 6 | 13 | 9 | 6 | 16 | 107 | 107 | 151 |
| AK | Anchorage | 44 | 7 | 5 | 19 | 6 | 4 | 18 | 8 | 5 | 18 | 6 | 6 | 18 | 4 | 7 | 20 | 3 | 7 | 20 | 3 | 6 | 22 | 3 | 6 | 22 | 4 | 5 | 21 | 5 | 5 | 21 | 6 | 5 | 20 | 6 | 4 | 21 | 61 | 65 | 239 |
| | Annette | 41 | 4 | 4 | 23 | 3 | 4 | 21 | 4 | 5 | 23 | 3 | 6 | 21 | 4 | 7 | 21 | 2 | 6 | 21 | 4 | 6 | 21 | 4 | 6 | 21 | 4 | 6 | 21 | 2 | 4 | 25 | 3 | 3 | 24 | 3 | 4 | 24 | 40 | 60 | 265 |
| | Barrow | 54 | 6 | 2 | 3 | 12 | 6 | 11 | 14 | 7 | 10 | 11 | 7 | 12 | 3 | 5 | 23 | 3 | 6 | 21 | 3 | 7 | 21 | 1 | 4 | 26 | 1 | 3 | 26 | 2 | 4 | 25 | 6 | 3 | 11 | 4 | 0 | 0 | 66 | 52 | 187 |
| | Barter IS | 34 | 4 | 3 | 8 | 10 | 6 | 12 | 12 | 8 | 12 | 9 | 8 | 13 | 3 | 6 | 22 | 3 | 7 | 20 | 3 | 9 | 19 | 1 | 6 | 23 | 2 | 4 | 24 | 2 | 5 | 24 | 5 | 4 | 15 | 0 | 0 | 0 | 53 | 66 | 192 |
| | Bethel | 34 | 8 | 5 | 18 | 10 | 4 | 14 | 9 | 5 | 16 | 6 | 6 | 17 | 4 | 8 | 20 | 2 | 7 | 21 | 2 | 5 | 24 | 2 | 4 | 26 | 2 | 5 | 23 | 4 | 5 | 22 | 6 | 5 | 19 | 8 | 5 | 18 | 62 | 65 | 239 |
| | Bettles | 5 | 15 | 5 | 11 | 10 | 4 | 14 | 9 | 5 | 16 | 7 | 10 | 13 | 7 | 11 | 13 | 4 | 13 | 13 | 2 | 10 | 19 | 2 | 8 | 21 | 7 | 7 | 16 | 5 | 6 | 21 | 9 | 6 | 14 | 9 | 7 | 15 | 86 | 93 | 187 |
| | Big Delta | 3 | 14 | 8 | 9 | 5 | 7 | 17 | 8 | 8 | 15 | 2 | 9 | 20 | 2 | 11 | 18 | 4 | 9 | 17 | — | 8 | 22 | 2 | 8 | 21 | 5 | 7 | 18 | 4 | 5 | 23 | 7 | 6 | 17 | 7 | 7 | 17 | 60 | 93 | 212 |
| | Cold Bay | 42 | 2 | 5 | 23 | 2 | 5 | 22 | 2 | 6 | 23 | 1 | 4 | 26 | — | 3 | 27 | — | 3 | 27 | — | 2 | 28 | — | 2 | 29 | — | 4 | 26 | 1 | 5 | 25 | 1 | 6 | 23 | 2 | 5 | 24 | 10 | 50 | 304 |
| | Fairbanks | 45 | 9 | 6 | 16 | 8 | 6 | 14 | 10 | 7 | 14 | 7 | 8 | 16 | 5 | 11 | 15 | 3 | 10 | 17 | 3 | 9 | 19 | 3 | 7 | 21 | 4 | 6 | 20 | 4 | 5 | 22 | 7 | 5 | 18 | 7 | 6 | 18 | 70 | 86 | 210 |
| | Gulkana | 5 | 15 | 4 | 12 | 6 | 4 | 18 | 9 | 6 | 15 | 5 | 10 | 15 | 3 | 10 | 18 | 2 | 10 | 18 | 4 | 9 | 18 | 3 | 9 | 19 | 6 | 8 | 17 | 3 | 7 | 21 | 5 | 5 | 21 | 7 | 7 | 17 | 67 | 89 | 209 |
| | Homer | 15 | 8 | 4 | 19 | 7 | 4 | 17 | 6 | 6 | 19 | 5 | 6 | 18 | 4 | 7 | 20 | 4 | 8 | 18 | 3 | 9 | 19 | 5 | 8 | 18 | 5 | 7 | 18 | 5 | 5 | 21 | 6 | 5 | 19 | 7 | 5 | 18 | 65 | 75 | 225 |
| | Juneau | 47 | 6 | 3 | 23 | 4 | 3 | 21 | 4 | 3 | 23 | 4 | 4 | 22 | 4 | 4 | 23 | 3 | 4 | 22 | 3 | 5 | 23 | 4 | 5 | 22 | 3 | 3 | 24 | 2 | 2 | 27 | 4 | 2 | 24 | 3 | 2 | 25 | 44 | 41 | 280 |
| | King Salmon | 42 | 8 | 5 | 18 | 7 | 5 | 16 | 8 | 6 | 18 | 4 | 7 | 20 | 3 | 6 | 22 | 1 | 5 | 24 | 1 | 5 | 25 | 1 | 5 | 25 | 2 | 6 | 22 | 4 | 7 | 20 | 6 | 5 | 19 | 7 | 6 | 19 | 51 | 69 | 245 |
| | Kodiak | 25 | 5 | 6 | 20 | 6 | 5 | 18 | 6 | 7 | 18 | 4 | 6 | 19 | 3 | 5 | 22 | 3 | 6 | 21 | 3 | 6 | 22 | 4 | 7 | 20 | 4 | 7 | 19 | 6 | 8 | 17 | 7 | 7 | 16 | 6 | 6 | 19 | 59 | 74 | 232 |
| | Kotzebue | 52 | 11 | 4 | 16 | 12 | 3 | 13 | 12 | 6 | 13 | 10 | 7 | 13 | 8 | 9 | 14 | 6 | 10 | 14 | 4 | 8 | 19 | 4 | 6 | 21 | 6 | 5 | 19 | 8 | 5 | 19 | 9 | 4 | 17 | 11 | 4 | 16 | 100 | 72 | 193 |
| | McGrath | 55 | 9 | 5 | 17 | 9 | 4 | 15 | 9 | 6 | 15 | 7 | 7 | 15 | 4 | 8 | 19 | 2 | 9 | 19 | 2 | 8 | 21 | 2 | 5 | 23 | 3 | 5 | 22 | 4 | 5 | 22 | 6 | 4 | 19 | 8 | 5 | 19 | 67 | 72 | 226 |
| | Nome | 51 | 10 | 4 | 17 | 12 | 4 | 13 | 11 | 5 | 14 | 9 | 6 | 14 | 7 | 8 | 16 | 6 | 9 | 15 | 4 | 7 | 20 | 3 | 6 | 22 | 5 | 6 | 20 | 7 | 6 | 18 | 7 | 4 | 18 | 10 | 4 | 17 | 91 | 69 | 205 |
| | St. Paul Island | 66 | 2 | 6 | 23 | 3 | 6 | 20 | 3 | 7 | 21 | 2 | 6 | 22 | 1 | 4 | 26 | 1 | 3 | 26 | 1 | 2 | 28 | 1 | 3 | 28 | 1 | 5 | 24 | 1 | 7 | 23 | 1 | 6 | 22 | 1 | 5 | 24 | 18 | 61 | 287 |
| | Talkeetna | 10 | 6 | 4 | 21 | 8 | 4 | 16 | 9 | 4 | 18 | 5 | 5 | 18 | 6 | 6 | 19 | 1 | 12 | 17 | 5 | 7 | 19 | 3 | 11 | 17 | 5 | 4 | 19 | 6 | 5 | 20 | 7 | 3 | 19 | 5 | 2 | 22 | 67 | 67 | 225 |
| | Unalakleet | 4 | 8 | 4 | 20 | 10 | 3 | 15 | 10 | 6 | 15 | 9 | 5 | 16 | 5 | 9 | 17 | 5 | 7 | 18 | 2 | 8 | 21 | 6 | 6 | 20 | 4 | 7 | 19 | 6 | 5 | 21 | 8 | 5 | 18 | 11 | 4 | 16 | 83 | 67 | 215 |
| | Valdez | 23 | 5 | 4 | 22 | 5 | 3 | 20 | 8 | 4 | 19 | 6 | 5 | 19 | 4 | 6 | 21 | 3 | 6 | 21 | 3 | 5 | 23 | 4 | 6 | 21 | 3 | 5 | 22 | 5 | 4 | 23 | 6 | 4 | 20 | 5 | 3 | 23 | 57 | 55 | 253 |
| | Yakutat | 48 | 5 | 3 | 22 | 4 | 3 | 21 | 5 | 4 | 22 | 4 | 5 | 21 | 2 | 5 | 24 | 2 | 5 | 24 | 2 | 4 | 25 | 3 | 4 | 24 | 3 | 4 | 24 | 3 | 3 | 25 | 4 | 3 | 23 | 4 | 3 | 24 | 41 | 46 | 278 |
| AZ | Flagstaff | 43 | 12 | 6 | 12 | 11 | 6 | 11 | 12 | 8 | 12 | 12 | 9 | 9 | 15 | 9 | 7 | 18 | 8 | 4 | 9 | 13 | 9 | 10 | 13 | 8 | 16 | 10 | 5 | 17 | 7 | 7 | 15 | 7 | 8 | 14 | 6 | 11 | 162 | 102 | 102 |
| | Phoenix | 57 | 14 | 7 | 10 | 13 | 7 | 9 | 14 | 8 | 8 | 17 | 7 | 6 | 21 | 7 | 3 | 23 | 5 | 2 | 17 | 10 | 4 | 18 | 10 | 4 | 22 | 5 | 3 | 20 | 6 | 4 | 18 | 6 | 6 | 15 | 6 | 9 | 211 | 85 | 70 |
| | Tucson | 55 | 14 | 7 | 10 | 13 | 7 | 9 | 15 | 7 | 9 | 17 | 7 | 6 | 20 | 7 | 4 | 21 | 6 | 3 | 10 | 12 | 9 | 12 | 12 | 7 | 19 | 7 | 4 | 20 | 6 | 5 | 18 | 6 | 6 | 15 | 6 | 10 | 193 | 91 | 81 |
| | Winslow | 37 | 12 | 7 | 12 | 12 | 7 | 10 | 13 | 9 | 9 | 15 | 9 | 7 | 17 | 9 | 5 | 20 | 7 | 4 | 11 | 12 | 8 | 12 | 13 | 6 | 18 | 8 | 4 | 19 | 7 | 6 | 16 | 6 | 8 | 14 | 7 | 10 | 177 | 99 | 89 |
| | Yuma | 32 | 15 | 7 | 9 | 15 | 7 | 6 | 17 | 7 | 6 | 21 | 6 | 4 | 24 | 5 | 2 | 25 | 4 | 1 | 20 | 8 | 3 | 22 | 6 | 3 | 24 | 4 | 2 | 23 | 5 | 3 | 19 | 6 | 5 | 17 | 7 | 8 | 242 | 71 | 52 |
| AR | Fort Smith | 49 | 9 | 6 | 16 | 9 | 6 | 14 | 9 | 7 | 15 | 9 | 7 | 14 | 8 | 10 | 13 | 10 | 10 | 10 | 12 | 11 | 8 | 12 | 11 | 8 | 12 | 8 | 10 | 14 | 7 | 11 | 11 | 6 | 13 | 10 | 7 | 15 | 123 | 95 | 147 |
| | Little Rock | 35 | 9 | 6 | 16 | 9 | 6 | 13 | 9 | 7 | 15 | 9 | 7 | 14 | 8 | 11 | 12 | 9 | 12 | 9 | 9 | 13 | 9 | 12 | 11 | 9 | 11 | 9 | 10 | 14 | 7 | 9 | 11 | 6 | 13 | 9 | 6 | 16 | 119 | 100 | 147 |
| CA | Bakersfield | 55 | 7 | 8 | 17 | 7 | 8 | 13 | 10 | 9 | 12 | 12 | 9 | 9 | 18 | 9 | 5 | 23 | 5 | 2 | 26 | 3 | 1 | 26 | 4 | 1 | 24 | 4 | 2 | 19 | 7 | 5 | 12 | 8 | 10 | 7 | 8 | 16 | 191 | 81 | 93 |
| | Bishop | 29 | 11 | 8 | 12 | 11 | 8 | 10 | 13 | 9 | 9 | 14 | 9 | 7 | 15 | 10 | 6 | 20 | 7 | 3 | 22 | 7 | 2 | 23 | 6 | 2 | 23 | 5 | 2 | 20 | 7 | 5 | 15 | 8 | 7 | 14 | 7 | 9 | 201 | 89 | 75 |
| | Blue Canyon | 31 | 9 | 5 | 17 | 8 | 5 | 15 | 9 | 6 | 17 | 10 | 7 | 13 | 12 | 8 | 11 | 18 | 5 | 6 | 26 | 4 | 1 | 25 | 4 | 2 | 22 | 4 | 3 | 17 | 6 | 9 | 10 | 5 | 15 | 9 | 5 | 17 | 174 | 64 | 126 |
| | Eureka | 92 | 6 | 6 | 19 | 5 | 6 | 17 | 6 | 8 | 17 | 6 | 8 | 16 | 6 | 10 | 15 | 7 | 10 | 13 | 6 | 11 | 14 | 6 | 11 | 15 | 9 | 9 | 13 | 8 | 9 | 14 | 6 | 7 | 17 | 6 | 7 | 18 | 77 | 101 | 187 |
| | Fresno | 46 | 5 | 7 | 19 | 8 | 8 | 13 | 11 | 8 | 12 | 14 | 8 | 8 | 18 | 8 | 5 | 23 | 5 | 2 | 27 | 3 | 1 | 26 | 3 | 1 | 24 | 4 | 2 | 20 | 6 | 5 | 12 | 7 | 11 | 7 | 6 | 18 | 194 | 73 | 98 |
| | Long Beach | 38 | 12 | 8 | 11 | 10 | 7 | 11 | 11 | 9 | 11 | 12 | 10 | 8 | 10 | 13 | 8 | 12 | 12 | 6 | 18 | 11 | 2 | 19 | 10 | 2 | 15 | 11 | 4 | 13 | 11 | 7 | 13 | 8 | 8 | 13 | 8 | 10 | 159 | 119 | 87 |
| | Los Angeles AP | 60 | 12 | 8 | 11 | 11 | 6 | 11 | 12 | 9 | 11 | 11 | 9 | 9 | 10 | 11 | 10 | 10 | 11 | 9 | 13 | 13 | 5 | 14 | 12 | 5 | 13 | 10 | 6 | 13 | 10 | 8 | 15 | 8 | 8 | 13 | 8 | 10 | 147 | 116 | 103 |
| | Los Angeles CO | 34 | 14 | 8 | 9 | 12 | 7 | 9 | 13 | 9 | 9 | 12 | 10 | 8 | 11 | 12 | 8 | 14 | 10 | 6 | 21 | 9 | 1 | 22 | 7 | 1 | 18 | 8 | 3 | 16 | 9 | 6 | 16 | 7 | 6 | 15 | 8 | 8 | 186 | 106 | 73 |
| | Mount Shasta | 22 | 9 | 6 | 16 | 8 | 7 | 13 | 8 | 8 | 15 | 10 | 10 | 10 | 12 | 8 | 10 | 16 | 7 | 7 | 25 | 5 | 2 | 24 | 4 | 2 | 21 | 5 | 4 | 14 | 7 | 9 | 9 | 7 | 13 | 7 | 8 | 16 | 164 | 83 | 118 |
| | Redding | 9 | 8 | 5 | 18 | 8 | 6 | 14 | 8 | 7 | 17 | 8 | 8 | 13 | 11 | 9 | 10 | 17 | 8 | 5 | 25 | 4 | 1 | 25 | 5 | 2 | 22 | 4 | 3 | 18 | 7 | 6 | 11 | 8 | 11 | 10 | 5 | 16 | 172 | 77 | 116 |
| | Sacramento | 49 | 7 | 6 | 19 | 8 | 7 | 13 | 10 | 9 | 12 | 12 | 10 | 8 | 17 | 9 | 5 | 22 | 6 | 2 | 27 | 3 | 1 | 26 | 4 | 1 | 24 | 4 | 2 | 19 | 6 | 6 | 10 | 8 | 12 | 8 | 6 | 17 | 188 | 77 | 100 |
| | San Diego | 55 | 12 | 7 | 11 | 10 | 8 | 10 | 11 | 9 | 11 | 10 | 10 | 10 | 8 | 11 | 11 | 9 | 12 | 9 | 13 | 13 | 5 | 15 | 12 | 4 | 15 | 10 | 6 | 14 | 10 | 8 | 15 | 8 | 7 | 14 | 8 | 10 | 146 | 117 | 102 |
| | San Francisco AP | 68 | 9 | 8 | 15 | 8 | 7 | 13 | 10 | 9 | 13 | 11 | 9 | 10 | 14 | 10 | 8 | 16 | 9 | 5 | 21 | 8 | 3 | 19 | 9 | 3 | 18 | 8 | 4 | 16 | 9 | 7 | 11 | 8 | 11 | 9 | 8 | 14 | 160 | 100 | 105 |
| | Santa Maria | 45 | 13 | 7 | 11 | 12 | 6 | 10 | 13 | 8 | 10 | 13 | 9 | 8 | 14 | 10 | 7 | 15 | 11 | 4 | 17 | 12 | 2 | 17 | 13 | 2 | 16 | 10 | 4 | 17 | 9 | 5 | 15 | 7 | 8 | 14 | 7 | 10 | 176 | 110 | 80 |
| | Stockton | 46 | 5 | 6 | 19 | 7 | 7 | 15 | 10 | 8 | 13 | 12 | 9 | 10 | 17 | 8 | 5 | 22 | 6 | 3 | 27 | 3 | 1 | 26 | 4 | 1 | 23 | 4 | 2 | 19 | 6 | 6 | 9 | 8 | 12 | 7 | 7 | 18 | 184 | 77 | 104 |
| CO | Alamosa | 33 | 13 | 10 | 8 | 11 | 10 | 7 | 10 | 11 | 9 | 10 | 13 | 8 | 9 | 14 | 8 | 14 | 12 | 4 | 9 | 17 | 6 | 11 | 14 | 6 | 15 | 10 | 5 | 17 | 8 | 6 | 14 | 9 | 7 | 14 | 10 | 7 | 148 | 137 | 81 |
| | Alamosa | 2 | 16 | 6 | 6 | 8 | 6 | 7 | 8 | 4 | 3 | 8 | 8 | 8 | 11 | 7 | 6 | 14 | 6 | 5 | 16 | 6 | 1 | 5 | 10 | 9 | 10 | 2 | 2 | 10 | 6 | 3 | 6 | 6 | 4 | 12 | 8 | 2 | 124 | 75 | 54 |
| | Colorado Springs | 44 | 12 | 8 | 11 | 9 | 8 | 11 | 9 | 9 | 13 | 8 | 10 | 12 | 7 | 12 | 12 | 10 | 12 | 8 | 9 | 15 | 7 | 10 | 13 | 8 | 14 | 8 | 7 | 15 | 8 | 8 | 12 | 8 | 10 | 12 | 8 | 11 | 127 | 120 | 118 |
| | Colorado Springs | 3 | 5 | 2 | 2 | 8 | 5 | 7 | 8 | 6 | 7 | 5 | 6 | 8 | 1 | 5 | 2 | 3 | 4 | 2 | 7 | 4 | 2 | 6 | 8 | 8 | 11 | 4 | 6 | 10 | 1 | 5 | 6 | 2 | 2 | 11 | 4 | 1 | 82 | 51 | 50 |
| | Denver | 61 | 10 | 9 | 11 | 8 | 9 | 11 | 8 | 10 | 13 | 7 | 11 | 13 | 6 | 12 | 13 | 10 | 12 | 8 | 9 | 16 | 6 | 10 | 14 | 8 | 13 | 9 | 8 | 13 | 9 | 9 | 10 | 10 | 10 | 11 | 10 | 10 | 115 | 130 | 120 |
| | Grand Junction | 49 | 9 | 7 | 15 | 8 | 7 | 13 | 8 | 8 | 15 | 8 | 9 | 13 | 10 | 11 | 11 | 15 | 9 | 6 | 14 | 11 | 6 | 13 | 11 | 6 | 16 | 8 | 5 | 15 | 8 | 8 | 11 | 7 | 12 | 10 | 8 | 13 | 136 | 106 | 122 |
| | Pueblo | 50 | 12 | 9 | 10 | 10 | 8 | 11 | 10 | 9 | 12 | 9 | 10 | 11 | 9 | 12 | 11 | 12 | 11 | 7 | 11 | 14 | 5 | 12 | 12 | 7 | 15 | 8 | 6 | 15 | 8 | 8 | 12 | 9 | 9 | 12 | 9 | 10 | 139 | 119 | 107 |
| | Pueblo | 3 | 11 | 4 | 3 | 9 | 5 | 6 | 7 | 2 | 5 | 10 | 8 | 5 | 4 | 7 | 4 | 11 | 4 | 2 | 15 | 6 | 2 | 8 | 11 | 5 | 9 | 2 | 2 | 11 | 4 | 5 | 10 | 2 | 2 | 15 | 4 | 2 | 120 | 59 | 44 |
| CT | Bridgeport | 46 | 8 | 8 | 15 | 8 | 7 | 13 | 8 | 9 | 14 | 7 | 9 | 14 | 7 | 10 | 14 | 8 | 10 | 12 | 7 | 12 | 12 | 9 | 11 | 12 | 10 | 9 | 12 | 11 | 8 | 12 | 8 | 8 | 14 | 8 | 8 | 15 | 99 | 107 | 159 |
| | Hartford | 41 | 8 | 8 | 15 | 7 | 8 | 14 | 7 | 8 | 16 | 6 | 9 | 15 | 6 | 10 | 16 | 6 | 10 | 14 | 6 | 12 | 13 | 7 | 11 | 13 | 8 | 9 | 13 | 9 | 9 | 13 | 6 | 8 | 16 | 7 | 7 | 17 | 82 | 108 | 175 |
| DE | Wilmington | 47 | 7 | 7 | 17 | 7 | 7 | 14 | 8 | 8 | 15 | 7 | 8 | 14 | 7 | 10 | 14 | 8 | 11 | 12 | 8 | 11 | 12 | 9 | 10 | 12 | 10 | 8 | 12 | 11 | 8 | 12 | 8 | 8 | 14 | 8 | 7 | 16 | 97 | 104 | 164 |
| DC | Washington Dulles AP | 33 | 7 | 7 | 17 | 7 | 6 | 15 | 7 | 8 | 16 | 7 | 9 | 14 | 7 | 10 | 14 | 6 | 12 | 12 | 8 | 11 | 12 | 8 | 11 | 12 | 9 | 9 | 12 | 11 | 8 | 12 | 7 | 8 | 15 | 7 | 7 | 17 | 92 | 105 | 168 |
| | Washington Nat'l AP | 48 | 7 | 7 | 16 | 7 | 7 | 15 | 7 | 8 | 15 | 7 | 9 | 14 | 7 | 10 | 14 | 7 | 11 | 11 | 7 | 12 | 12 | 9 | 10 | 12 | 10 | 8 | 12 | 11 | 8 | 12 | 8 | 8 | 14 | 8 | 7 | 16 | 96 | 106 | 164 |

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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FL | Apalachicola | 62 | 10 | 8 | 5 | 10 | 7 | 12 | 11 | 8 | 12 | 12 | 9 | 9 | 13 | 10 | 8 | 9 | 13 | 8 | 6 | 13 | 11 | 7 | 13 | 11 | 10 | 10 | 10 | 16 | 7 | 7 | 13 | 8 | 9 | 10 | 8 | 13 | 128 | 113 | 116 |
| | Daytona Beach | 52 | 9 | 9 | 13 | 9 | 8 | 12 | 10 | 10 | 12 | 11 | 11 | 9 | 10 | 11 | 10 | 6 | 13 | 12 | 5 | 14 | 12 | 5 | 15 | 11 | 5 | 13 | 12 | 9 | 10 | 11 | 10 | 10 | 10 | 9 | 9 | 13 | 97 | 132 | 136 |
| | Fort Myers | 54 | 11 | 12 | 9 | 10 | 11 | 7 | 11 | 12 | 8 | 11 | 13 | 6 | 10 | 15 | 6 | 5 | 16 | 10 | 2 | 18 | 11 | 2 | 19 | 10 | 4 | 16 | 11 | 11 | 13 | 8 | 11 | 12 | 7 | 11 | 12 | 8 | 98 | 168 | 99 |
| | Jacksonville | 47 | 9 | 8 | 14 | 9 | 7 | 12 | 9 | 9 | 13 | 10 | 10 | 9 | 9 | 12 | 10 | 5 | 13 | 12 | 5 | 14 | 12 | 5 | 15 | 11 | 5 | 12 | 13 | 10 | 9 | 12 | 10 | 9 | 11 | 9 | 8 | 14 | 94 | 127 | 144 |
| | Key West | 43 | 11 | 11 | 9 | 12 | 10 | 7 | 13 | 11 | 6 | 13 | 11 | 6 | 10 | 13 | 8 | 5 | 14 | 11 | 3 | 16 | 11 | 3 | 17 | 11 | 3 | 15 | 12 | 9 | 13 | 9 | 10 | 11 | 8 | 11 | 11 | 9 | 104 | 155 | 107 |
| | Miami | 46 | 9 | 13 | 9 | 8 | 12 | 8 | 9 | 14 | 8 | 8 | 15 | 7 | 6 | 15 | 9 | 3 | 14 | 13 | 3 | 17 | 11 | 2 | 18 | 11 | 2 | 15 | 12 | 7 | 14 | 10 | 8 | 14 | 9 | 9 | 13 | 9 | 74 | 175 | 115 |
| | Orlando | 47 | 9 | 10 | 12 | 9 | 9 | 11 | 9 | 10 | 12 | 10 | 11 | 9 | 9 | 14 | 9 | 4 | 14 | 12 | 3 | 17 | 11 | 3 | 17 | 11 | 4 | 15 | 12 | 9 | 11 | 11 | 10 | 10 | 10 | 10 | 9 | 12 | 89 | 147 | 130 |
| | Pensacola | 29 | 8 | 7 | 16 | 9 | 7 | 13 | 9 | 8 | 14 | 10 | 9 | 11 | 9 | 11 | 11 | 7 | 15 | 8 | 4 | 17 | 10 | 6 | 15 | 10 | 10 | 11 | 9 | 13 | 9 | 9 | 11 | 8 | 11 | 9 | 7 | 16 | 105 | 123 | 137 |
| | Tallahassee | 34 | 8 | 7 | 15 | 8 | 7 | 13 | 9 | 9 | 13 | 11 | 10 | 9 | 9 | 13 | 10 | 6 | 14 | 10 | 4 | 17 | 10 | 5 | 16 | 10 | 8 | 12 | 10 | 13 | 8 | 10 | 11 | 8 | 11 | 9 | 8 | 14 | 102 | 129 | 134 |
| | Tampa | 49 | 10 | 10 | 12 | 9 | 9 | 10 | 11 | 10 | 10 | 11 | 11 | 8 | 11 | 13 | 8 | 6 | 14 | 10 | 3 | 16 | 12 | 3 | 17 | 11 | 5 | 14 | 11 | 11 | 10 | 9 | 12 | 10 | 9 | 10 | 10 | 11 | 101 | 143 | 121 |
| | West Palm Beach | 48 | 8 | 11 | 12 | 8 | 11 | 10 | 8 | 13 | 10 | 9 | 13 | 8 | 8 | 14 | 10 | 4 | 13 | 13 | 4 | 14 | 13 | 3 | 16 | 12 | 3 | 14 | 13 | 6 | 14 | 11 | 7 | 13 | 10 | 9 | 12 | 10 | 75 | 159 | 131 |
| | West Palm Beach | 1 | 1 | 6 | 6 | 8 | 3 | 2 | 7 | 6 | 4 | 9 | 13 | 8 | 5 | 6 | 8 | 6 | 8 | 9 | 4 | 14 | 13 | 3 | 16 | 12 | 3 | 14 | 13 | 6 | 14 | 11 | 7 | 13 | 10 | 2 | 3 | 10 | 30 | 32 | 29 |
| GA | Athens | 52 | 9 | 7 | 15 | 9 | 6 | 13 | 9 | 7 | 14 | 10 | 8 | 11 | 9 | 10 | 12 | 8 | 12 | 10 | 7 | 13 | 11 | 8 | 13 | 10 | 10 | 9 | 11 | 14 | 7 | 10 | 12 | 6 | 12 | 10 | 6 | 15 | 113 | 105 | 147 |
| | Atlanta | 61 | 8 | 6 | 16 | 8 | 6 | 14 | 9 | 8 | 15 | 10 | 8 | 12 | 9 | 11 | 11 | 8 | 12 | 10 | 6 | 13 | 12 | 7 | 13 | 10 | 10 | 10 | 10 | 14 | 7 | 10 | 12 | 6 | 12 | 9 | 6 | 15 | 110 | 107 | 149 |
| | Augusta | 44 | 9 | 6 | 16 | 9 | 6 | 13 | 9 | 8 | 14 | 11 | 8 | 11 | 8 | 11 | 12 | 8 | 11 | 11 | 6 | 13 | 12 | 7 | 14 | 10 | 9 | 9 | 11 | 14 | 7 | 10 | 12 | 6 | 12 | 10 | 6 | 15 | 112 | 106 | 147 |
| | Columbus | 49 | 8 | 6 | 17 | 8 | 6 | 14 | 9 | 7 | 15 | 10 | 9 | 11 | 9 | 10 | 12 | 8 | 12 | 10 | 5 | 13 | 12 | 8 | 14 | 10 | 10 | 9 | 11 | 14 | 7 | 10 | 12 | 6 | 12 | 9 | 6 | 16 | 110 | 104 | 151 |
| | Macon | 46 | 8 | 7 | 16 | 8 | 7 | 13 | 9 | 8 | 14 | 11 | 8 | 11 | 9 | 11 | 11 | 8 | 11 | 11 | 6 | 13 | 12 | 8 | 12 | 10 | 9 | 10 | 11 | 14 | 7 | 10 | 12 | 6 | 12 | 9 | 7 | 15 | 112 | 107 | 147 |
| | Savannah | 45 | 9 | 6 | 16 | 8 | 6 | 14 | 9 | 9 | 13 | 11 | 9 | 11 | 9 | 10 | 12 | 7 | 11 | 12 | 6 | 14 | 12 | 6 | 14 | 12 | 7 | 10 | 13 | 12 | 8 | 11 | 11 | 7 | 12 | 9 | 7 | 15 | 104 | 110 | 152 |
| HI | Hilo | 50 | 6 | 11 | 13 | 5 | 10 | 13 | 3 | 10 | 18 | 1 | 9 | 20 | 1 | 11 | 19 | 2 | 11 | 17 | 1 | 12 | 18 | 2 | 12 | 17 | 3 | 12 | 15 | 3 | 12 | 16 | 3 | 10 | 17 | 5 | 11 | 15 | 36 | 132 | 197 |
| | Honolulu | 47 | 9 | 13 | 9 | 8 | 12 | 8 | 8 | 14 | 9 | 6 | 14 | 10 | 7 | 16 | 9 | 6 | 17 | 6 | 7 | 18 | 5 | 8 | 17 | 6 | 8 | 16 | 6 | 7 | 15 | 8 | 7 | 14 | 9 | 8 | 14 | 9 | 90 | 181 | 94 |
| | Kahului | 37 | 13 | 10 | 8 | 11 | 9 | 7 | 11 | 11 | 9 | 8 | 12 | 10 | 10 | 14 | 8 | 11 | 13 | 6 | 11 | 15 | 5 | 12 | 14 | 5 | 12 | 13 | 6 | 11 | 13 | 8 | 11 | 11 | 8 | 12 | 11 | 8 | 131 | 145 | 90 |
| | Lihue | 46 | 8 | 13 | 10 | 7 | 12 | 9 | 5 | 14 | 12 | 3 | 14 | 13 | 3 | 17 | 11 | 3 | 17 | 9 | 3 | 19 | 10 | 4 | 18 | 9 | 5 | 18 | 7 | 5 | 16 | 10 | 4 | 14 | 12 | 6 | 14 | 11 | 56 | 184 | 125 |
| ID | Boise | 56 | 4 | 5 | 22 | 5 | 6 | 17 | 6 | 7 | 18 | 6 | 9 | 15 | 8 | 10 | 13 | 12 | 10 | 8 | 20 | 7 | 3 | 19 | 8 | 4 | 17 | 7 | 6 | 12 | 8 | 11 | 6 | 6 | 18 | 5 | 6 | 20 | 120 | 90 | 155 |
| | Lewiston | 42 | 3 | 4 | 24 | 3 | 5 | 21 | 4 | 6 | 21 | 5 | 6 | 19 | 6 | 9 | 16 | 8 | 9 | 13 | 18 | 7 | 6 | 16 | 8 | 7 | 13 | 7 | 9 | 9 | 7 | 15 | 3 | 6 | 22 | 3 | 4 | 24 | 91 | 78 | 196 |
| | Pocatello | 46 | 3 | 7 | 22 | 4 | 6 | 18 | 5 | 8 | 18 | 6 | 8 | 16 | 7 | 10 | 14 | 12 | 9 | 9 | 17 | 9 | 5 | 16 | 11 | 5 | 15 | 8 | 7 | 12 | 8 | 11 | 5 | 7 | 18 | 3 | 7 | 21 | 106 | 98 | 162 |
| IL | Cairo | 30 | 8 | 6 | 17 | 8 | 6 | 14 | 9 | 8 | 15 | 8 | 9 | 13 | 8 | 10 | 13 | 8 | 12 | 10 | 9 | 13 | 10 | 12 | 11 | 8 | 12 | 9 | 9 | 15 | 7 | 9 | 9 | 8 | 13 | 8 | 7 | 16 | 113 | 104 | 149 |
| | Chicago | 37 | 7 | 6 | 18 | 6 | 6 | 16 | 5 | 8 | 18 | 6 | 8 | 16 | 7 | 10 | 14 | 7 | 11 | 11 | 8 | 12 | 10 | 9 | 11 | 11 | 9 | 10 | 11 | 9 | 9 | 14 | 5 | 6 | 18 | 6 | 6 | 19 | 84 | 105 | 176 |
| | Moline | 62 | 8 | 7 | 16 | 7 | 6 | 15 | 6 | 8 | 17 | 7 | 9 | 15 | 8 | 9 | 14 | 7 | 11 | 12 | 10 | 12 | 9 | 10 | 11 | 10 | 12 | 8 | 11 | 12 | 8 | 12 | 7 | 7 | 16 | 7 | 6 | 18 | 101 | 100 | 164 |
| | Peoria | 52 | 7 | 6 | 18 | 7 | 6 | 16 | 6 | 7 | 18 | 6 | 8 | 16 | 7 | 10 | 14 | 7 | 11 | 12 | 9 | 12 | 10 | 10 | 10 | 10 | 11 | 9 | 10 | 11 | 8 | 12 | 7 | 6 | 17 | 7 | 6 | 19 | 95 | 97 | 172 |
| | Rockford | 45 | 7 | 7 | 17 | 7 | 6 | 15 | 6 | 8 | 17 | 6 | 8 | 16 | 8 | 9 | 14 | 7 | 11 | 12 | 9 | 12 | 10 | 9 | 11 | 11 | 10 | 9 | 12 | 10 | 7 | 13 | 6 | 6 | 18 | 7 | 6 | 19 | 93 | 98 | 174 |
| | Springfield | 48 | 7 | 6 | 17 | 7 | 6 | 15 | 6 | 7 | 18 | 7 | 8 | 15 | 8 | 9 | 14 | 8 | 9 | 12 | 10 | 11 | 10 | 11 | 10 | 10 | 12 | 8 | 10 | 12 | 7 | 12 | 8 | 6 | 16 | 7 | 6 | 18 | 104 | 94 | 167 |
| IN | Evansville | 55 | 7 | 5 | 19 | 7 | 6 | 15 | 7 | 8 | 16 | 7 | 8 | 15 | 8 | 9 | 14 | 8 | 11 | 10 | 9 | 12 | 9 | 11 | 11 | 9 | 11 | 8 | 10 | 13 | 7 | 11 | 8 | 7 | 15 | 7 | 6 | 18 | 102 | 100 | 163 |
| | Fort Wayne | 49 | 5 | 6 | 20 | 5 | 7 | 17 | 5 | 7 | 19 | 6 | 7 | 17 | 7 | 9 | 15 | 6 | 12 | 12 | 8 | 12 | 11 | 9 | 12 | 11 | 9 | 9 | 12 | 10 | 8 | 14 | 5 | 6 | 19 | 4 | 6 | 21 | 78 | 102 | 186 |
| | Indianapolis | 64 | 6 | 6 | 19 | 6 | 6 | 16 | 6 | 7 | 18 | 6 | 7 | 17 | 7 | 9 | 15 | 7 | 11 | 12 | 8 | 12 | 10 | 9 | 12 | 10 | 11 | 9 | 11 | 11 | 8 | 12 | 6 | 7 | 17 | 5 | 6 | 20 | 88 | 99 | 179 |
| | South Bend | 56 | 3 | 6 | 22 | 4 | 6 | 19 | 5 | 7 | 19 | 6 | 8 | 17 | 7 | 10 | 14 | 7 | 10 | 12 | 8 | 13 | 10 | 9 | 12 | 10 | 9 | 9 | 12 | 9 | 8 | 14 | 4 | 6 | 20 | 3 | 6 | 22 | 73 | 100 | 193 |
| IA | Des Moines | 46 | 8 | 7 | 16 | 8 | 6 | 15 | 7 | 7 | 17 | 7 | 8 | 15 | 8 | 8 | 15 | 8 | 10 | 11 | 10 | 11 | 9 | 11 | 10 | 10 | 12 | 8 | 11 | 12 | 7 | 12 | 7 | 7 | 16 | 7 | 7 | 17 | 105 | 97 | 164 |
| | Dubuque | 21 | 7 | 7 | 17 | 8 | 6 | 15 | 6 | 8 | 17 | 6 | 8 | 16 | 7 | 9 | 16 | 6 | 11 | 13 | 8 | 12 | 10 | 9 | 10 | 11 | 10 | 8 | 12 | 10 | 8 | 13 | 7 | 6 | 17 | 7 | 6 | 18 | 92 | 99 | 175 |
| | Sioux City | 55 | 8 | 8 | 15 | 7 | 7 | 14 | 7 | 8 | 17 | 7 | 9 | 15 | 7 | 9 | 15 | 8 | 11 | 11 | 11 | 12 | 8 | 12 | 11 | 9 | 12 | 8 | 11 | 12 | 8 | 12 | 7 | 7 | 16 | 7 | 7 | 16 | 104 | 104 | 157 |
| | Waterloo | 35 | 8 | 7 | 16 | 7 | 6 | 15 | 6 | 7 | 18 | 6 | 8 | 16 | 7 | 9 | 14 | 7 | 11 | 12 | 9 | 12 | 11 | 9 | 11 | 11 | 10 | 8 | 12 | 10 | 8 | 14 | 5 | 7 | 18 | 7 | 6 | 18 | 91 | 100 | 174 |
| KS | Concordia | 30 | 11 | 7 | 13 | 9 | 7 | 13 | 9 | 7 | 15 | 9 | 8 | 13 | 8 | 9 | 13 | 10 | 10 | 10 | 14 | 10 | 7 | 13 | 10 | 8 | 13 | 7 | 10 | 13 | 7 | 11 | 10 | 7 | 13 | 10 | 7 | 14 | 131 | 95 | 140 |
| | Concordia | 3 | 6 | 2 | 0 | 8 | 4 | 0 | 10 | 3 | 0 | 7 | 4 | 0 | 11 | 4 | 0 | 13 | 6 | 0 | 11 | 8 | 0 | 16 | 3 | 0 | 8 | 2 | 0 | 10 | 4 | 0 | 7 | 4 | 0 | 9 | 4 | 0 | 116 | 48 | 2 |
| | Dodge City | 50 | 11 | 8 | 12 | 9 | 8 | 12 | 9 | 8 | 14 | 9 | 9 | 12 | 9 | 10 | 12 | 11 | 10 | 8 | 13 | 12 | 7 | 14 | 10 | 7 | 14 | 7 | 9 | 15 | 7 | 9 | 12 | 8 | 11 | 11 | 7 | 12 | 137 | 104 | 124 |
| | Dodge City | 3 | 6 | 3 | 9 | 5 | 6 | 6 | 10 | 5 | 5 | 9 | 4 | 8 | 12 | 4 | 5 | 14 | 5 | 3 | 16 | 4 | 3 | 16 | 5 | 3 | 9 | 1 | 2 | 10 | 6 | 4 | 8 | 4 | 4 | 13 | 3 | 5 | 128 | 51 | 57 |
| | Goodland | 72 | 12 | 9 | 10 | 10 | 9 | 10 | 9 | 10 | 12 | 9 | 10 | 11 | 9 | 11 | 11 | 12 | 11 | 6 | 14 | 12 | 5 | 13 | 12 | 6 | 14 | 9 | 7 | 15 | 8 | 7 | 12 | 8 | 9 | 12 | 9 | 10 | 143 | 117 | 105 |
| | Goodland | 3 | 6 | 4 | 9 | 8 | 4 | 8 | 7 | 4 | 5 | 8 | 3 | 11 | 8 | 5 | 6 | 14 | 4 | 4 | 13 | 5 | 2 | 14 | 4 | 6 | 9 | 9 | 3 | 12 | 3 | 6 | 8 | 4 | 5 | 14 | 2 | 5 | 121 | 42 | 69 |
| | Topeka | 46 | 10 | 6 | 15 | 8 | 6 | 14 | 7 | 7 | 16 | 8 | 8 | 14 | 7 | 10 | 14 | 8 | 10 | 11 | 11 | 11 | 9 | 12 | 10 | 9 | 12 | 8 | 10 | 13 | 7 | 11 | 10 | 7 | 14 | 9 | 7 | 15 | 114 | 97 | 154 |
| | Topeka | 3 | 4 | 4 | 10 | 9 | 3 | 7 | 7 | 5 | 6 | 8 | 4 | 10 | 11 | 4 | 6 | 11 | 6 | 5 | 6 | 9 | 6 | 12 | 7 | 4 | 7 | 1 | 4 | 10 | 2 | 8 | 6 | 2 | 8 | 10 | 3 | 8 | 102 | 51 | 83 |
| | Wichita | 39 | 11 | 6 | 14 | 8 | 7 | 13 | 9 | 7 | 15 | 9 | 8 | 13 | 8 | 10 | 13 | 9 | 11 | 10 | 13 | 11 | 7 | 13 | 10 | 8 | 13 | 7 | 10 | 13 | 7 | 11 | 11 | 7 | 13 | 10 | 7 | 14 | 128 | 97 | 140 |
| | Wichita | 3 | 6 | 5 | 8 | 7 | 6 | 8 | 7 | 4 | 8 | 6 | 2 | 9 | 11 | 8 | 6 | 10 | 7 | 3 | 15 | 4 | 3 | 16 | 5 | 2 | 6 | 3 | 2 | 10 | 4 | 5 | 7 | 2 | 8 | 11 | 4 | 8 | 114 | 55 | 70 |
| KY | Greater Cincinnati AP | 44 | 5 | 6 | 20 | 5 | 6 | 17 | 5 | 7 | 19 | 6 | 8 | 17 | 6 | 10 | 15 | 7 | 10 | 13 | 8 | 12 | 12 | 8 | 12 | 11 | 10 | 9 | 11 | 10 | 7 | 13 | 6 | 6 | 18 | 5 | 6 | 20 | 81 | 98 | 186 |
| | Jackson | 14 | 4 | 5 | 22 | 4 | 5 | 19 | 6 | 7 | 18 | 6 | 8 | 16 | 6 | 8 | 17 | 6 | 12 | 13 | 7 | 12 | 12 | 7 | 12 | 12 | 8 | 9 | 12 | 9 | 8 | 14 | 6 | 6 | 18 | 5 | 5 | 21 | 73 | 97 | 195 |
| | Lexington | 51 | 6 | 6 | 20 | 6 | 6 | 17 | 6 | 7 | 18 | 6 | 9 | 15 | 7 | 10 | 14 | 7 | 12 | 11 | 8 | 12 | 11 | 9 | 12 | 10 | 10 | 8 | 11 | 12 | 7 | 12 | 7 | 7 | 17 | 6 | 6 | 19 | 89 | 101 | 174 |
| | Louisville | 47 | 6 | 6 | 20 | 6 | 6 | 16 | 6 | 7 | 18 | 6 | 9 | 15 | 8 | 9 | 14 | 8 | 11 | 11 | 8 | 13 | 10 | 10 | 11 | 9 | 10 | 9 | 11 | 12 | 8 | 12 | 7 | 6 | 16 | 6 | 6 | 19 | 93 | 102 | 171 |
| | Paducah | 11 | 7 | 6 | 18 | 6 | 8 | 15 | 7 | 8 | 16 | 8 | 8 | 14 | 7 | 9 | 15 | 7 | 12 | 11 | 10 | 11 | 10 | 11 | 11 | 8 | 11 | 8 | 11 | 11 | 7 | 13 | 9 | 4 | 17 | 7 | 6 | 17 | 101 | 97 | 167 |
| LA | Baton Rouge | 42 | 7 | 6 | 18 | 8 | 6 | 15 | 8 | 8 | 15 | 8 | 9 | 13 | 8 | 11 | 12 | 7 | 14 | 9 | 5 | 15 | 11 | 7 | 15 | 9 | 9 | 11 | 10 | 14 | 8 | 8 | 10 | 8 | 13 | 8 | 7 | 16 | 99 | 119 | 147 |
| | Baton Rouge | 1 | 10 | 4 | 14 | 10 | 6 | 15 | 8 | 3 | 8 | 7 | 6 | 9 | 13 | 6 | 16 | 7 | 18 | 10 | 9 | 7 | 9 | 10 | 8 | 4 | 3 | 2 | 10 | 5 | 3 | 8 | 6 | 3 | 7 | 2 | 2 | 5 | 90 | 67 | 106 |
| | Lake Charles | 34 | 7 | 6 | 19 | 8 | 6 | 15 | 7 | 8 | 16 | 7 | 9 | 15 | 7 | 11 | 12 | 8 | 13 | 9 | 6 | 14 | 10 | 7 | 15 | 9 | 10 | 11 | 9 | 13 | 9 | 9 | 10 | 8 | 13 | 8 | 7 | 17 | 98 | 115 | 152 |
| | New Orleans | 47 | 7 | 7 | 17 | 8 | 6 | 14 | 8 | 8 | 15 | 8 | 10 | 12 | 9 | 11 | 11 | 8 | 13 | 9 | 5 | 15 | 12 | 7 | 14 | 10 | 10 | 11 | 10 | 14 | 8 | 9 | 10 | 8 | 12 | 8 | 7 | 16 | 101 | 118 | 146 |
| | Shreveport | 43 | 8 | 5 | 18 | 8 | 5 | 15 | 8 | 6 | 16 | 8 | 8 | 14 | 8 | 10 | 13 | 9 | 13 | 9 | 10 | 12 | 9 | 11 | 12 | 8 | 11 | 9 | 10 | 13 | 7 | 10 | 11 | 6 | 13 | 9 | 6 | 16 | 114 | 100 | 151 |
| ME | Caribou | 54 | 7 | 7 | 17 | 6 | 6 | 16 | 7 | 7 | 17 | 5 | 7 | 18 | 4 | 9 | 18 | 3 | 10 | 17 | 3 | 13 | 15 | 5 | 11 | 15 | 5 | 9 | 15 | 5 | 8 | 18 | 3 | 6 | 21 | 6 | 7 | 19 | 59 | 100 | 206 |
| | Portland | 54 | 10 | 7 | 14 | 9 | 7 | 13 | 9 | 7 | 15 | 7 | 7 | 16 | 6 | 9 | 15 | 7 | 10 | 13 | 7 | 11 | 13 | 9 | 11 | 11 | 10 | 8 | 12 | 10 | 8 | 13 | 7 | 7 | 15 | 9 | 7 | 15 | 101 | 99 | 165 |
| | Baltimore | 45 | 8 | 8 | 15 | 8 | 7 | 14 | 8 | 9 | 14 | 8 | 9 | 13 | 8 | 10 | 13 | 8 | 11 | 10 | 9 | 12 | 10 | 9 | 11 | 11 | 11 | 9 | 11 | 12 | 8 | 11 | 8 | 8 | 13 | 8 | 7 | 16 | 105 | 108 | 152 |
| MA | Boston | 60 | 9 | 7 | 15 | 8 | 7 | 13 | 8 | 8 | 15 | 7 | 8 | 15 | 6 | 10 | 15 | 7 | 10 | 13 | 7 | 12 | 12 | 9 | 11 | 11 | 10 | 8 | 12 | 11 | 8 | 12 | 8 | 7 | 15 | 9 | 7 | 15 | 98 | 103 | 164 |
| | Worcester | 40 | 9 | 8 | 14 | 8 | 7 | 14 | 8 | 8 | 16 | 7 | 9 | 15 | 6 | 10 | 15 | 6 | 11 | 13 | 6 | 12 | 13 | 8 | 11 | 12 | 9 | 9 | 12 | 10 | 8 | 13 | 7 | 8 | 15 | 8 | 8 | 16 | 90 | 107 | 168 |
| MI | Alpena | 36 | 3 | 7 | 21 | 4 | 7 | 17 | 6 | 8 | 17 | 6 | 8 | 16 | 7 | 10 | 14 | 8 | 11 | 12 | 8 | 13 | 10 | 9 | 11 | 12 | 6 | 10 | 14 | 5 | 8 | 18 | 2 | 6 | 22 | 2 | 6 | 23 | 67 | 104 | 194 |
| | Detroit | 37 | 4 | 7 | 20 | 5 | 7 | 17 | 6 | 7 | 18 | 6 | 8 | 16 | 7 | 10 | 14 | 8 | 11 | 11 | 9 | 12 | 10 | 9 | 11 | 11 | 8 | 10 | 12 | 8 | 9 | 15 | 4 | 7 | 19 | 3 | 6 | 22 | 75 | 105 | 185 |

*(Continued)*



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**Table 3A.11 (Continued)**

| State | Station | Years | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | | Jul | | | Aug | | | Sep | | | Oct | | | Nov | | | Dec | | | Annual | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD |
| | Flint | 54 | 4 | 6 | 21 | 4 | 7 | 17 | 5 | 7 | 19 | 6 | 7 | 17 | 6 | 10 | 15 | 6 | 12 | 12 | 7 | 13 | 11 | 8 | 12 | 11 | 7 | 10 | 13 | 7 | 9 | 15 | 3 | 6 | 21 | 3 | 6 | 22 | 66 | 105 | 195 |
| | Grand Rapids | 32 | 3 | 5 | 23 | 3 | 6 | 19 | 5 | 7 | 19 | 6 | 7 | 17 | 7 | 9 | 15 | 7 | 11 | 12 | 8 | 12 | 11 | 8 | 11 | 12 | 7 | 9 | 14 | 6 | 8 | 17 | 3 | 5 | 22 | 2 | 4 | 25 | 64 | 96 | 205 |
| | Houghton Lake | 30 | 3 | 6 | 22 | 4 | 7 | 17 | 6 | 7 | 18 | 6 | 7 | 17 | 7 | 9 | 14 | 7 | 11 | 12 | 7 | 13 | 10 | 8 | 11 | 12 | 6 | 9 | 14 | 5 | 8 | 18 | 2 | 5 | 23 | 2 | 6 | 23 | 65 | 100 | 200 |
| | Lansing | 41 | 3 | 7 | 21 | 4 | 7 | 17 | 5 | 8 | 18 | 6 | 7 | 17 | 7 | 10 | 14 | 7 | 11 | 11 | 8 | 13 | 10 | 8 | 12 | 11 | 8 | 9 | 13 | 7 | 9 | 15 | 4 | 6 | 21 | 3 | 6 | 23 | 71 | 104 | 191 |
| | Muskegon | 53 | 2 | 3 | 26 | 3 | 5 | 21 | 5 | 7 | 18 | 7 | 7 | 16 | 8 | 9 | 14 | 9 | 10 | 12 | 11 | 11 | 9 | 11 | 11 | 10 | 9 | 9 | 12 | 7 | 8 | 15 | 2 | 4 | 23 | 2 | 4 | 26 | 75 | 88 | 202 |
| | Sault Ste. Marie | 54 | 4 | 6 | 22 | 5 | 6 | 17 | 7 | 7 | 17 | 6 | 7 | 16 | 7 | 9 | 15 | 7 | 10 | 13 | 8 | 11 | 12 | 8 | 11 | 13 | 5 | 9 | 17 | 5 | 7 | 19 | 2 | 4 | 24 | 3 | 4 | 23 | 66 | 90 | 209 |
| MN | Duluth | 47 | 7 | 7 | 17 | 7 | 6 | 15 | 7 | 7 | 17 | 6 | 8 | 16 | 6 | 10 | 15 | 5 | 11 | 14 | 7 | 13 | 11 | 7 | 12 | 11 | 6 | 9 | 15 | 7 | 8 | 17 | 5 | 6 | 20 | 6 | 6 | 19 | 77 | 102 | 187 |
| | International Falls | 56 | 7 | 7 | 16 | 8 | 6 | 14 | 8 | 8 | 16 | 7 | 8 | 15 | 7 | 9 | 15 | 5 | 11 | 14 | 6 | 13 | 11 | 7 | 12 | 12 | 6 | 9 | 15 | 6 | 7 | 18 | 4 | 5 | 21 | 6 | 6 | 19 | 76 | 101 | 188 |
| | Minneapolis-St. Paul | 57 | 8 | 7 | 15 | 8 | 7 | 14 | 7 | 7 | 17 | 7 | 8 | 15 | 7 | 9 | 15 | 7 | 10 | 12 | 10 | 12 | 9 | 10 | 11 | 10 | 10 | 8 | 12 | 10 | 7 | 14 | 5 | 6 | 18 | 6 | 6 | 18 | 95 | 101 | 169 |
| | Rochester | 35 | 7 | 7 | 16 | 7 | 6 | 15 | 6 | 7 | 18 | 6 | 7 | 16 | 7 | 9 | 15 | 7 | 11 | 13 | 8 | 12 | 11 | 9 | 11 | 11 | 9 | 7 | 14 | 8 | 8 | 15 | 5 | 6 | 19 | 6 | 6 | 19 | 86 | 97 | 182 |
| | Saint Cloud | 50 | 8 | 8 | 15 | 8 | 7 | 13 | 7 | 7 | 17 | 7 | 7 | 16 | 7 | 10 | 14 | 7 | 11 | 12 | 10 | 12 | 9 | 10 | 11 | 10 | 10 | 9 | 12 | 10 | 8 | 13 | 6 | 6 | 18 | 7 | 7 | 18 | 97 | 102 | 166 |
| MS | Jackson | 30 | 8 | 6 | 17 | 8 | 6 | 14 | 9 | 7 | 15 | 9 | 7 | 13 | 8 | 10 | 12 | 9 | 12 | 9 | 8 | 13 | 10 | 9 | 13 | 9 | 10 | 9 | 10 | 15 | 7 | 10 | 10 | 7 | 13 | 9 | 6 | 16 | 111 | 104 | 150 |
| | Jackson | 2 | 8 | 4 | 15 | 12 | 4 | 13 | 10 | 4 | 10 | 12 | 6 | 5 | 16 | 8 | 12 | 14 | 12 | 9 | 9 | 4 | 14 | 9 | 7 | 5 | 5 | 9 | 1 | 6 | 7 | 12 | 5 | 1 | 7 | 3 | 3 | 5 | 110 | 52 | 108 |
| | Meridian | 50 | 7 | 7 | 17 | 7 | 6 | 15 | 8 | 7 | 15 | 9 | 8 | 13 | 9 | 11 | 12 | 8 | 13 | 9 | 6 | 15 | 10 | 9 | 13 | 9 | 10 | 9 | 11 | 14 | 7 | 10 | 10 | 7 | 13 | 9 | 7 | 16 | 108 | 110 | 148 |
| | Tupelo | 10 | 8 | 6 | 17 | 7 | 6 | 15 | 8 | 7 | 16 | 10 | 8 | 12 | 8 | 10 | 13 | 9 | 11 | 9 | 11 | 11 | 8 | 12 | 12 | 8 | 13 | 9 | 8 | 14 | 6 | 11 | 9 | 6 | 15 | 8 | 6 | 18 | 119 | 97 | 150 |
| | Tupelo | 2 | 10 | 3 | 14 | 9 | 4 | 14 | 10 | 7 | 8 | 14 | 4 | 5 | 18 | 4 | 8 | 7 | 11 | 6 | 8 | 7 | 11 | 10 | 7 | 3 | 4 | 1 | 1 | 7 | 2 | 9 | 5 | 1 | 9 | 3 | 3 | 7 | 104 | 47 | 96 |
| MO | Columbia | 26 | 8 | 6 | 16 | 7 | 6 | 15 | 7 | 7 | 17 | 8 | 7 | 15 | 7 | 8 | 16 | 7 | 11 | 12 | 11 | 10 | 10 | 11 | 10 | 10 | 11 | 8 | 12 | 12 | 7 | 13 | 8 | 6 | 16 | 8 | 6 | 17 | 104 | 91 | 169 |
| | Kansas City | 23 | 10 | 6 | 14 | 8 | 6 | 14 | 8 | 8 | 16 | 9 | 7 | 14 | 8 | 9 | 14 | 10 | 10 | 11 | 13 | 11 | 7 | 12 | 11 | 8 | 12 | 8 | 10 | 13 | 7 | 11 | 9 | 7 | 14 | 10 | 6 | 15 | 120 | 96 | 149 |
| | St. Louis | 47 | 7 | 7 | 17 | 7 | 6 | 15 | 6 | 8 | 16 | 7 | 8 | 15 | 7 | 9 | 14 | 7 | 11 | 12 | 9 | 11 | 10 | 10 | 11 | 10 | 11 | 8 | 10 | 12 | 7 | 11 | 9 | 7 | 15 | 7 | 7 | 17 | 101 | 101 | 164 |
| | Springfield | 50 | 8 | 7 | 16 | 7 | 6 | 15 | 8 | 8 | 16 | 8 | 8 | 14 | 7 | 10 | 14 | 8 | 10 | 11 | 12 | 10 | 9 | 12 | 10 | 9 | 12 | 7 | 11 | 13 | 7 | 11 | 10 | 6 | 14 | 9 | 6 | 16 | 115 | 96 | 155 |
| MT | Billings | 56 | 6 | 8 | 18 | 4 | 8 | 16 | 4 | 9 | 18 | 4 | 9 | 17 | 6 | 10 | 15 | 7 | 12 | 11 | 13 | 12 | 6 | 14 | 11 | 7 | 10 | 9 | 10 | 9 | 9 | 13 | 6 | 8 | 17 | 6 | 8 | 17 | 89 | 112 | 164 |
| | Glasgow | 39 | 5 | 7 | 18 | 5 | 7 | 16 | 5 | 9 | 17 | 5 | 8 | 16 | 6 | 11 | 15 | 7 | 12 | 11 | 12 | 12 | 7 | 12 | 11 | 8 | 9 | 9 | 11 | 8 | 9 | 15 | 6 | 7 | 17 | 5 | 8 | 18 | 86 | 111 | 168 |
| | Great Falls | 57 | 5 | 6 | 19 | 4 | 6 | 18 | 4 | 9 | 18 | 4 | 8 | 18 | 5 | 10 | 17 | 5 | 11 | 14 | 13 | 12 | 6 | 12 | 11 | 8 | 10 | 9 | 11 | 7 | 9 | 15 | 5 | 7 | 18 | 5 | 8 | 18 | 79 | 106 | 180 |
| | Helena | 54 | 5 | 6 | 20 | 4 | 7 | 17 | 4 | 8 | 19 | 4 | 9 | 18 | 5 | 10 | 16 | 6 | 11 | 13 | 14 | 11 | 6 | 13 | 11 | 7 | 11 | 9 | 11 | 8 | 9 | 14 | 5 | 7 | 18 | 4 | 7 | 20 | 82 | 104 | 179 |
| | Kalispell | 45 | 2 | 4 | 25 | 2 | 5 | 21 | 3 | 6 | 21 | 4 | 6 | 20 | 5 | 9 | 17 | 6 | 10 | 14 | 14 | 9 | 7 | 12 | 9 | 9 | 10 | 8 | 12 | 6 | 7 | 18 | 2 | 5 | 23 | 2 | 3 | 26 | 70 | 81 | 214 |
| | Missoula | 51 | 2 | 4 | 24 | 3 | 5 | 21 | 3 | 6 | 22 | 4 | 7 | 20 | 5 | 9 | 17 | 6 | 9 | 14 | 15 | 10 | 6 | 14 | 10 | 8 | 10 | 8 | 11 | 7 | 7 | 17 | 2 | 5 | 23 | 2 | 4 | 25 | 75 | 83 | 208 |
| NE | Grand Island | 54 | 9 | 8 | 14 | 7 | 7 | 13 | 8 | 8 | 15 | 8 | 9 | 13 | 8 | 9 | 14 | 10 | 10 | 9 | 13 | 11 | 7 | 13 | 10 | 8 | 14 | 7 | 9 | 13 | 8 | 10 | 9 | 7 | 13 | 10 | 7 | 14 | 123 | 102 | 140 |
| | Grand Island | 2 | 5 | 3 | 11 | 7 | 4 | 7 | 7 | 4 | 7 | 6 | 6 | 9 | 9 | 3 | 9 | 12 | 4 | 5 | 11 | 8 | 4 | 14 | 4 | 5 | 8 | 2 | 3 | 9 | 3 | 6 | 9 | 4 | 6 | 10 | 2 | 10 | 106 | 48 | 81 |
| | Lincoln | 28 | 10 | 7 | 15 | 8 | 7 | 13 | 8 | 8 | 15 | 8 | 8 | 14 | 8 | 10 | 13 | 10 | 10 | 10 | 12 | 10 | 9 | 12 | 10 | 9 | 13 | 8 | 10 | 12 | 8 | 12 | 9 | 7 | 15 | 8 | 7 | 15 | 117 | 99 | 149 |
| | Lincoln | 3 | 3 | 2 | 5 | 5 | 1 | 6 | 4 | 3 | 4 | 8 | 8 | 14 | 3 | 2 | 7 | 6 | 4 | 4 | 4 | 2 | 4 | 10 | 5 | 4 | 9 | 5 | 5 | 12 | 2 | 7 | 6 | 2 | 4 | 6 | 6 | 12 | 71 | 35 | 62 |
| | Norfolk | 50 | 9 | 8 | 15 | 8 | 7 | 14 | 7 | 8 | 16 | 8 | 8 | 14 | 8 | 10 | 14 | 10 | 10 | 10 | 13 | 11 | 7 | 13 | 10 | 8 | 13 | 8 | 10 | 12 | 8 | 11 | 8 | 7 | 14 | 9 | 8 | 15 | 117 | 103 | 146 |
| | North Platte | 43 | 9 | 9 | 14 | 7 | 7 | 14 | 7 | 8 | 16 | 7 | 9 | 14 | 7 | 10 | 14 | 10 | 11 | 9 | 12 | 12 | 7 | 12 | 11 | 8 | 13 | 8 | 9 | 12 | 8 | 10 | 9 | 8 | 13 | 10 | 8 | 13 | 115 | 109 | 141 |
| | Omaha Eppley AP | 49 | 9 | 8 | 14 | 7 | 7 | 14 | 7 | 8 | 16 | 7 | 8 | 14 | 7 | 10 | 14 | 8 | 11 | 11 | 11 | 12 | 8 | 12 | 10 | 9 | 12 | 8 | 10 | 13 | 8 | 10 | 9 | 7 | 14 | 8 | 8 | 15 | 111 | 105 | 149 |
| | Omaha (North) | 18 | 9 | 8 | 14 | 8 | 6 | 15 | 8 | 8 | 16 | 8 | 8 | 14 | 7 | 10 | 14 | 9 | 11 | 10 | 11 | 10 | 10 | 10 | 11 | 9 | 13 | 8 | 9 | 11 | 8 | 12 | 8 | 7 | 15 | 8 | 7 | 15 | 110 | 102 | 153 |
| | Scottsbluff | 52 | 8 | 8 | 14 | 7 | 8 | 13 | 6 | 10 | 15 | 7 | 9 | 15 | 6 | 11 | 14 | 10 | 11 | 9 | 13 | 12 | 6 | 13 | 11 | 7 | 14 | 8 | 8 | 13 | 8 | 10 | 8 | 8 | 14 | 9 | 9 | 14 | 115 | 112 | 138 |
| | Valentine | 40 | 9 | 8 | 14 | 7 | 7 | 13 | 7 | 8 | 15 | 8 | 8 | 14 | 8 | 10 | 13 | 11 | 10 | 9 | 14 | 12 | 6 | 14 | 11 | 6 | 14 | 7 | 9 | 12 | 8 | 10 | 9 | 8 | 13 | 10 | 7 | 14 | 123 | 105 | 136 |
| NV | Elko | 56 | 7 | 8 | 17 | 6 | 7 | 15 | 6 | 8 | 17 | 6 | 9 | 15 | 8 | 10 | 13 | 13 | 10 | 7 | 17 | 10 | 4 | 18 | 9 | 4 | 18 | 7 | 5 | 14 | 8 | 9 | 8 | 7 | 15 | 8 | 7 | 16 | 130 | 99 | 136 |
| | Ely | 56 | 9 | 8 | 15 | 7 | 7 | 14 | 7 | 8 | 15 | 7 | 9 | 13 | 7 | 11 | 12 | 13 | 10 | 6 | 15 | 11 | 5 | 15 | 12 | 5 | 17 | 8 | 5 | 14 | 8 | 9 | 10 | 8 | 12 | 9 | 8 | 14 | 131 | 109 | 125 |
| | Las Vegas | 47 | 14 | 6 | 11 | 12 | 7 | 9 | 14 | 8 | 9 | 16 | 8 | 7 | 18 | 8 | 5 | 22 | 5 | 3 | 20 | 7 | 3 | 22 | 7 | 3 | 22 | 5 | 2 | 20 | 6 | 4 | 16 | 7 | 7 | 15 | 7 | 10 | 210 | 82 | 73 |
| | Reno | 53 | 8 | 7 | 16 | 7 | 7 | 14 | 8 | 9 | 14 | 8 | 10 | 12 | 12 | 10 | 10 | 16 | 8 | 6 | 22 | 6 | 3 | 22 | 6 | 3 | 21 | 6 | 4 | 16 | 8 | 8 | 9 | 8 | 13 | 8 | 8 | 15 | 158 | 93 | 114 |
| | Winnemucca | 45 | 7 | 7 | 18 | 6 | 6 | 16 | 7 | 7 | 17 | 6 | 9 | 14 | 9 | 10 | 12 | 14 | 9 | 8 | 20 | 7 | 4 | 19 | 8 | 4 | 18 | 6 | 5 | 14 | 7 | 9 | 8 | 7 | 15 | 8 | 6 | 16 | 138 | 89 | 138 |
| NH | Concord | 54 | 9 | 7 | 15 | 8 | 8 | 13 | 8 | 8 | 15 | 7 | 8 | 15 | 6 | 10 | 15 | 6 | 12 | 12 | 7 | 12 | 12 | 8 | 11 | 12 | 9 | 9 | 12 | 9 | 9 | 13 | 6 | 8 | 16 | 8 | 8 | 15 | 90 | 109 | 166 |
| | Mt. Washington | 70 | 5 | 6 | 21 | 4 | 5 | 19 | 4 | 5 | 21 | 4 | 6 | 20 | 3 | 7 | 20 | 2 | 7 | 21 | 1 | 8 | 22 | 3 | 8 | 20 | 4 | 7 | 19 | 6 | 6 | 19 | 3 | 5 | 22 | 4 | 5 | 22 | 44 | 76 | 245 |
| NJ | Atlantic City AP | 37 | 8 | 8 | 15 | 8 | 7 | 14 | 8 | 8 | 15 | 7 | 9 | 14 | 6 | 11 | 14 | 7 | 12 | 12 | 7 | 12 | 13 | 8 | 11 | 12 | 10 | 8 | 12 | 11 | 9 | 12 | 8 | 9 | 13 | 8 | 8 | 15 | 94 | 111 | 160 |
| | Newark | 53 | 8 | 8 | 16 | 7 | 8 | 13 | 8 | 8 | 15 | 7 | 9 | 14 | 6 | 11 | 14 | 7 | 11 | 12 | 7 | 12 | 12 | 8 | 12 | 12 | 10 | 9 | 12 | 11 | 8 | 12 | 8 | 8 | 14 | 8 | 8 | 15 | 93 | 112 | 160 |
| NM | Albuquerque | 56 | 13 | 8 | 10 | 11 | 8 | 10 | 11 | 10 | 10 | 13 | 10 | 8 | 14 | 10 | 7 | 17 | 9 | 4 | 12 | 14 | 5 | 13 | 13 | 5 | 17 | 8 | 6 | 17 | 8 | 6 | 15 | 8 | 7 | 14 | 7 | 10 | 167 | 111 | 87 |
| | Clayton | 28 | 13 | 7 | 12 | 11 | 7 | 10 | 11 | 9 | 11 | 12 | 9 | 10 | 11 | 9 | 10 | 13 | 10 | 6 | 12 | 12 | 7 | 15 | 10 | 6 | 17 | 6 | 7 | 18 | 7 | 7 | 15 | 6 | 9 | 14 | 7 | 10 | 162 | 99 | 104 |
| | Roswell | 9 | 11 | 9 | 11 | 12 | 8 | 8 | 14 | 9 | 8 | 14 | 9 | 7 | 13 | 12 | 6 | 17 | 10 | 3 | 11 | 15 | 5 | 13 | 12 | 6 | 13 | 8 | 9 | 18 | 6 | 7 | 16 | 7 | 7 | 15 | 9 | 7 | 168 | 113 | 84 |
| NY | Albany | 57 | 5 | 8 | 18 | 6 | 7 | 15 | 6 | 8 | 17 | 5 | 8 | 16 | 5 | 9 | 16 | 5 | 11 | 13 | 6 | 13 | 12 | 7 | 12 | 13 | 8 | 10 | 12 | 8 | 9 | 14 | 4 | 8 | 18 | 5 | 7 | 19 | 69 | 111 | 185 |
| | Binghamton | 44 | 3 | 7 | 22 | 3 | 6 | 19 | 4 | 7 | 20 | 5 | 7 | 18 | 5 | 9 | 17 | 5 | 11 | 14 | 6 | 13 | 13 | 5 | 12 | 14 | 6 | 10 | 14 | 6 | 8 | 17 | 3 | 6 | 21 | 2 | 6 | 23 | 52 | 102 | 212 |
| | Buffalo | 52 | 1 | 6 | 24 | 2 | 6 | 20 | 4 | 8 | 19 | 5 | 8 | 17 | 6 | 10 | 16 | 6 | 12 | 12 | 7 | 13 | 11 | 7 | 12 | 12 | 6 | 10 | 14 | 6 | 8 | 16 | 2 | 5 | 23 | 1 | 6 | 24 | 54 | 103 | 208 |
| | New York C. Park | 42 | 8 | 9 | 14 | 8 | 9 | 11 | 9 | 10 | 12 | 8 | 11 | 12 | 8 | 12 | 11 | 8 | 12 | 10 | 8 | 13 | 10 | 9 | 12 | 10 | 11 | 10 | 9 | 12 | 10 | 9 | 9 | 10 | 12 | 9 | 9 | 13 | 107 | 127 | 132 |
| | New York (JFK AP) | 37 | 8 | 8 | 15 | 8 | 8 | 13 | 8 | 9 | 14 | 8 | 9 | 13 | 7 | 11 | 13 | 7 | 11 | 12 | 7 | 12 | 11 | 8 | 13 | 10 | 10 | 9 | 11 | 11 | 9 | 11 | 8 | 8 | 14 | 8 | 8 | 15 | 98 | 116 | 152 |
| | New York (Laguardia AP) | 47 | 8 | 8 | 15 | 8 | 7 | 13 | 8 | 9 | 14 | 7 | 9 | 13 | 7 | 11 | 13 | 7 | 11 | 11 | 7 | 13 | 11 | 8 | 12 | 11 | 10 | 9 | 11 | 11 | 9 | 11 | 7 | 8 | 14 | 8 | 9 | 15 | 96 | 117 | 153 |
| | Rochester | 55 | 2 | 7 | 22 | 2 | 7 | 19 | 5 | 8 | 18 | 6 | 8 | 16 | 6 | 10 | 15 | 7 | 11 | 12 | 8 | 12 | 11 | 8 | 12 | 12 | 7 | 10 | 13 | 6 | 8 | 16 | 2 | 6 | 22 | 2 | 6 | 23 | 61 | 104 | 200 |
| | Syracuse | 44 | 3 | 7 | 22 | 3 | 6 | 19 | 5 | 7 | 19 | 6 | 7 | 17 | 6 | 10 | 15 | 7 | 11 | 12 | 8 | 12 | 11 | 7 | 11 | 13 | 7 | 10 | 13 | 6 | 8 | 17 | 2 | 6 | 22 | 2 | 5 | 24 | 63 | 98 | 205 |
| | Syracuse | 0 | 3 | 7 | 3 | 3 | 6 | 5 | 3 | 7 | 11 | 6 | 7 | 17 | 5 | 6 | 9 | 3 | 10 | 6 | 8 | 12 | 11 | 7 | 11 | 13 | 7 | 10 | 13 | 6 | 8 | 17 | 2 | 6 | 22 | 2 | 5 | 24 | 11 | 23 | 34 |
| NC | Asheville | 31 | 9 | 7 | 15 | 9 | 6 | 13 | 9 | 8 | 14 | 10 | 8 | 12 | 7 | 10 | 13 | 6 | 12 | 12 | 5 | 14 | 12 | 5 | 13 | 13 | 7 | 11 | 13 | 12 | 8 | 11 | 11 | 7 | 12 | 10 | 7 | 14 | 99 | 113 | 153 |
| | Cape Hatters | 38 | 9 | 7 | 16 | 9 | 5 | 14 | 10 | 7 | 14 | 10 | 9 | 11 | 9 | 10 | 13 | 7 | 10 | 12 | 7 | 10 | 14 | 8 | 10 | 13 | 10 | 9 | 11 | 11 | 8 | 12 | 10 | 8 | 12 | 10 | 7 | 14 | 109 | 101 | 156 |
| | Charlotte | 49 | 9 | 6 | 16 | 8 | 6 | 14 | 9 | 8 | 14 | 10 | 9 | 12 | 8 | 10 | 13 | 7 | 11 | 12 | 7 | 12 | 12 | 7 | 13 | 11 | 9 | 9 | 11 | 13 | 8 | 10 | 11 | 6 | 12 | 10 | 6 | 15 | 109 | 105 | 152 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Greensboro-Wnstn-Slm-HPT | 67 | 9 | 7 | 15 | 9 | 6 | 13 | 9 | 8 | 14 | 10 | 8 | 12 | 8 | 11 | 12 | 7 | 12 | 11 | 7 | 13 | 12 | 7 | 12 | 11 | 10 | 9 | 12 | 13 | 7 | 10 | 11 | 7 | 12 | 10 | 6 | 15 | 109 | 107 | 150 |
| | Raleigh | 47 | 9 | 7 | 15 | 9 | 6 | 14 | 9 | 7 | 14 | 10 | 9 | 11 | 8 | 10 | 13 | 8 | 12 | 11 | 7 | 12 | 12 | 7 | 12 | 11 | 10 | 9 | 11 | 13 | 7 | 11 | 11 | 7 | 11 | 10 | 7 | 14 | 111 | 106 | 149 |
| | Wilmington | 44 | 10 | 6 | 15 | 9 | 6 | 13 | 10 | 8 | 14 | 11 | 8 | 11 | 8 | 11 | 12 | 7 | 11 | 12 | 6 | 12 | 13 | 7 | 12 | 12 | 8 | 10 | 12 | 12 | 7 | 11 | 12 | 7 | 11 | 10 | 7 | 14 | 111 | 104 | 150 |
| ND | Bismarck | 56 | 7 | 8 | 17 | 6 | 8 | 15 | 6 | 8 | 17 | 6 | 9 | 15 | 6 | 10 | 14 | 7 | 10 | 12 | 11 | 13 | 7 | 12 | 11 | 8 | 10 | 9 | 11 | 9 | 8 | 14 | 6 | 7 | 17 | 7 | 7 | 17 | 93 | 107 | 165 |
| | Fargo | 53 | 7 | 7 | 17 | 6 | 7 | 15 | 5 | 9 | 17 | 6 | 9 | 15 | 7 | 10 | 14 | 6 | 11 | 13 | 10 | 13 | 8 | 10 | 12 | 9 | 9 | 9 | 12 | 9 | 8 | 14 | 5 | 6 | 18 | 6 | 7 | 18 | 88 | 109 | 168 |
| | Williston | 34 | 6 | 8 | 17 | 6 | 8 | 15 | 7 | 8 | 16 | 6 | 9 | 15 | 6 | 11 | 13 | 8 | 11 | 11 | 12 | 12 | 7 | 11 | 12 | 8 | 10 | 9 | 11 | 9 | 8 | 14 | 6 | 7 | 16 | 7 | 7 | 17 | 93 | 112 | 160 |
| OH | Akron | 47 | 3 | 6 | 22 | 3 | 6 | 19 | 5 | 6 | 20 | 5 | 8 | 18 | 6 | 9 | 16 | 6 | 11 | 13 | 7 | 13 | 11 | 8 | 12 | 11 | 8 | 9 | 12 | 9 | 8 | 14 | 4 | 6 | 20 | 3 | 5 | 23 | 68 | 99 | 198 |
| | Cleveland | 54 | 3 | 5 | 24 | 3 | 6 | 20 | 5 | 6 | 20 | 5 | 8 | 17 | 6 | 10 | 15 | 7 | 11 | 12 | 8 | 12 | 11 | 9 | 11 | 11 | 8 | 10 | 12 | 8 | 8 | 15 | 3 | 6 | 21 | 3 | 5 | 24 | 66 | 97 | 202 |
| | Columbus | 46 | 4 | 6 | 21 | 4 | 6 | 18 | 5 | 7 | 19 | 5 | 8 | 17 | 6 | 10 | 15 | 6 | 11 | 13 | 7 | 13 | 11 | 7 | 13 | 11 | 9 | 9 | 12 | 10 | 8 | 13 | 5 | 7 | 19 | 4 | 6 | 21 | 72 | 103 | 190 |
| | Dayton | 52 | 5 | 6 | 20 | 5 | 6 | 17 | 5 | 7 | 19 | 5 | 7 | 17 | 6 | 9 | 16 | 6 | 10 | 13 | 7 | 12 | 11 | 8 | 12 | 11 | 9 | 9 | 12 | 10 | 8 | 13 | 5 | 7 | 18 | 4 | 6 | 21 | 77 | 100 | 188 |
| | Mansfield | 30 | 4 | 6 | 21 | 4 | 6 | 18 | 5 | 7 | 19 | 6 | 8 | 16 | 7 | 10 | 15 | 7 | 12 | 11 | 8 | 13 | 10 | 8 | 11 | 11 | 9 | 9 | 12 | 9 | 8 | 14 | 4 | 6 | 20 | 3 | 5 | 23 | 73 | 101 | 191 |
| | Toledo | 40 | 5 | 7 | 20 | 5 | 7 | 17 | 5 | 7 | 19 | 6 | 8 | 17 | 7 | 10 | 14 | 7 | 12 | 12 | 8 | 13 | 10 | 8 | 12 | 11 | 8 | 10 | 12 | 8 | 9 | 14 | 4 | 7 | 19 | 3 | 6 | 22 | 73 | 107 | 185 |
| | Youngstown | 52 | 3 | 5 | 23 | 3 | 5 | 20 | 5 | 6 | 20 | 5 | 7 | 18 | 6 | 9 | 17 | 6 | 11 | 12 | 7 | 13 | 11 | 7 | 12 | 12 | 7 | 10 | 13 | 8 | 8 | 15 | 3 | 6 | 21 | 3 | 5 | 23 | 63 | 97 | 205 |
| OK | Oklahoma City | 44 | 11 | 6 | 14 | 9 | 7 | 13 | 10 | 8 | 13 | 9 | 8 | 13 | 9 | 10 | 12 | 10 | 11 | 9 | 15 | 10 | 7 | 14 | 10 | 7 | 13 | 8 | 9 | 14 | 7 | 10 | 12 | 7 | 11 | 12 | 6 | 13 | 139 | 96 | 130 |
| | Oklahoma City | 3 | 4 | 5 | 7 | 10 | 3 | 10 | 8 | 3 | 7 | 10 | 2 | 8 | 9 | 6 | 6 | 13 | 5 | 3 | 16 | 4 | 2 | 15 | 4 | 3 | 7 | 3 | 2 | 12 | 4 | 5 | 6 | 4 | 6 | 8 | 5 | 8 | 119 | 49 | 68 |
| | Tulsa | 54 | 10 | 7 | 14 | 9 | 6 | 13 | 9 | 8 | 14 | 8 | 9 | 13 | 8 | 10 | 13 | 9 | 11 | 10 | 13 | 11 | 7 | 13 | 11 | 7 | 12 | 8 | 10 | 14 | 7 | 10 | 11 | 7 | 12 | 10 | 7 | 13 | 127 | 103 | 136 |
| | Tulsa | 3 | 5 | 4 | 8 | 8 | 3 | 7 | 8 | 1 | 9 | 10 | 1 | 10 | 10 | 4 | 9 | 11 | 8 | 4 | 14 | 6 | 4 | 15 | 5 | 4 | 8 | 4 | 4 | 10 | 4 | 6 | 7 | 1 | 10 | 9 | 5 | 7 | 113 | 45 | 83 |
| OR | Astoria | 40 | 3 | 4 | 24 | 3 | 3 | 22 | 3 | 5 | 23 | 3 | 6 | 21 | 3 | 8 | 20 | 3 | 7 | 19 | 6 | 10 | 15 | 6 | 10 | 15 | 8 | 7 | 14 | 5 | 7 | 19 | 3 | 5 | 22 | 3 | 4 | 24 | 50 | 76 | 239 |
| | Astoria | 1 | 5 | 8 | 15 | 6 | 4 | 15 | 3 | 5 | 2 | 3 | 5 | 19 | 8 | 6 | 14 | 2 | 7 | 12 | 5 | 9 | 10 | 6 | 6 | 8 | 1 | 2 | 2 | 2 | 4 | 5 | 1 | 2 | 8 | 3 | 2 | 3 | 38 | 55 | 114 |
| | Burns | 11 | 5 | 8 | 18 | 6 | 6 | 17 | 6 | 7 | 18 | 5 | 10 | 15 | 9 | 10 | 12 | 12 | 9 | 9 | 19 | 7 | 5 | 20 | 8 | 3 | 16 | 8 | 6 | 12 | 7 | 12 | 6 | 7 | 17 | 5 | 7 | 18 | 120 | 94 | 151 |
| | Eugene | 53 | 2 | 4 | 25 | 3 | 4 | 21 | 3 | 6 | 22 | 4 | 7 | 19 | 6 | 9 | 17 | 8 | 8 | 14 | 16 | 8 | 7 | 14 | 9 | 8 | 12 | 8 | 9 | 5 | 9 | 17 | 2 | 6 | 23 | 1 | 4 | 26 | 75 | 82 | 209 |
| | Medford | 67 | 3 | 5 | 24 | 4 | 6 | 19 | 5 | 7 | 19 | 6 | 8 | 16 | 9 | 9 | 13 | 13 | 8 | 9 | 23 | 5 | 3 | 22 | 6 | 4 | 18 | 6 | 6 | 10 | 8 | 12 | 3 | 6 | 21 | 2 | 4 | 25 | 117 | 79 | 169 |
| | Pendleton | 60 | 2 | 5 | 24 | 3 | 6 | 20 | 5 | 8 | 19 | 5 | 10 | 15 | 8 | 11 | 13 | 10 | 10 | 10 | 19 | 8 | 4 | 18 | 8 | 5 | 15 | 8 | 7 | 10 | 8 | 13 | 4 | 6 | 20 | 3 | 5 | 24 | 101 | 91 | 173 |
| | Portland | 47 | 3 | 4 | 24 | 3 | 4 | 21 | 3 | 5 | 23 | 3 | 6 | 21 | 5 | 7 | 19 | 6 | 8 | 16 | 13 | 8 | 10 | 11 | 10 | 10 | 10 | 8 | 12 | 5 | 8 | 18 | 3 | 4 | 23 | 2 | 3 | 26 | 68 | 74 | 222 |
| | Salem | 58 | 3 | 5 | 24 | 3 | 4 | 21 | 4 | 6 | 21 | 4 | 7 | 19 | 6 | 8 | 18 | 7 | 8 | 15 | 15 | 8 | 8 | 14 | 9 | 9 | 11 | 8 | 10 | 6 | 8 | 17 | 3 | 5 | 22 | 2 | 4 | 25 | 77 | 80 | 208 |
| | Sexton Summit | 30 | 5 | 5 | 21 | 4 | 4 | 20 | 5 | 5 | 21 | 6 | 7 | 17 | 9 | 7 | 14 | 13 | 7 | 10 | 23 | 5 | 3 | 21 | 6 | 4 | 17 | 6 | 7 | 11 | 6 | 14 | 6 | 5 | 20 | 5 | 4 | 22 | 126 | 68 | 172 |
| PC | Guam | 20 | 3 | 13 | 15 | 2 | 10 | 16 | 3 | 15 | 13 | 1 | 15 | 14 | 1 | 16 | 15 | 1 | 11 | 19 | — | 9 | 22 | 0 | 5 | 26 | — | 6 | 23 | — | 10 | 21 | 2 | 13 | 15 | 3 | 12 | 16 | 16 | 134 | 215 |
| | Johnston Island | 24 | 13 | 14 | 4 | 11 | 13 | 4 | 11 | 14 | 6 | 7 | 12 | 11 | 6 | 13 | 12 | 7 | 15 | 8 | 7 | 16 | 9 | 6 | 14 | 11 | 6 | 13 | 11 | 7 | 12 | 12 | 7 | 12 | 12 | 11 | 13 | 7 | 99 | 159 | 107 |
| | Koror | 50 | — | 7 | 24 | — | 6 | 21 | 1 | 9 | 21 | 1 | 9 | 20 | 1 | 9 | 21 | — | 5 | 25 | — | 5 | 26 | — | 5 | 26 | — | 6 | 23 | 1 | 7 | 23 | — | 8 | 22 | — | 7 | 24 | 4 | 83 | 276 |
| | Kwajalein, Marshall IS | 41 | 2 | 7 | 21 | 3 | 6 | 19 | 2 | 7 | 21 | 2 | 6 | 23 | 1 | 6 | 24 | 1 | 6 | 23 | 1 | 6 | 24 | 1 | 6 | 24 | 1 | 5 | 24 | 1 | 5 | 26 | 1 | 6 | 23 | 2 | 6 | 23 | 18 | 72 | 276 |
| | Majuro, Marshall IS | 46 | 1 | 7 | 23 | 1 | 8 | 19 | 1 | 8 | 22 | 1 | 7 | 22 | 1 | 7 | 23 | — | 7 | 23 | 0 | 7 | 24 | 1 | 8 | 22 | 1 | 7 | 22 | 1 | 7 | 23 | 0 | 7 | 23 | 1 | 6 | 24 | 8 | 85 | 272 |
| | Pago Pago, Amer Samoa | 36 | 1 | 10 | 21 | 0 | 9 | 18 | 1 | 12 | 18 | 1 | 12 | 17 | 1 | 13 | 17 | 2 | 14 | 14 | 2 | 15 | 14 | 2 | 16 | 14 | 2 | 14 | 14 | 1 | 13 | 17 | 1 | 11 | 18 | 1 | 10 | 20 | 13 | 148 | 204 |
| | Pohnpei, Caroline IS | 50 | — | 5 | 26 | — | 5 | 24 | — | 5 | 26 | — | 5 | 25 | — | 5 | 25 | — | 5 | 25 | 0 | 6 | 24 | 1 | 7 | 24 | 1 | 6 | 24 | 0 | 6 | 24 | — | 6 | 24 | — | 5 | 26 | 2 | 65 | 296 |
| | Chuuk, E. Caroline IS | 51 | — | 4 | 27 | — | 3 | 25 | — | 4 | 27 | — | 4 | 26 | — | 4 | 27 | — | 4 | 26 | — | 4 | 27 | — | 4 | 27 | — | 4 | 26 | — | 4 | 27 | — | 4 | 26 | — | 3 | 28 | 0 | 45 | 318 |
| | Wake Island | 43 | 12 | 13 | 5 | 12 | 11 | 5 | 12 | 14 | 5 | 11 | 14 | 6 | 10 | 14 | 6 | 10 | 13 | 7 | 7 | 11 | 13 | 6 | 11 | 14 | 7 | 11 | 12 | 9 | 12 | 10 | 12 | 13 | 5 | 14 | 13 | 4 | 121 | 149 | 94 |
| | Yap, W Caroline IS | 53 | 1 | 8 | 22 | 0 | 8 | 20 | 1 | 9 | 21 | 1 | 10 | 19 | 1 | 10 | 20 | — | 6 | 24 | 0 | 4 | 26 | — | 4 | 27 | — | 6 | 24 | 0 | 7 | 23 | — | 8 | 21 | 0 | 8 | 22 | 5 | 88 | 271 |
| PA | Allentown | 52 | 7 | 8 | 16 | 7 | 8 | 13 | 8 | 8 | 15 | 7 | 9 | 14 | 7 | 11 | 14 | 8 | 11 | 11 | 8 | 12 | 11 | 9 | 11 | 11 | 9 | 9 | 12 | 10 | 9 | 12 | 7 | 8 | 15 | 7 | 7 | 17 | 94 | 110 | 161 |
| | Erie | 40 | 2 | 4 | 25 | 3 | 6 | 20 | 5 | 7 | 19 | 6 | 8 | 17 | 7 | 10 | 14 | 8 | 11 | 11 | 8 | 13 | 10 | 8 | 12 | 11 | 7 | 10 | 14 | 6 | 8 | 17 | 3 | 5 | 23 | 1 | 4 | 26 | 63 | 97 | 205 |
| | Harrisburg | 53 | 7 | 7 | 17 | 7 | 7 | 14 | 7 | 8 | 16 | 6 | 9 | 15 | 6 | 10 | 15 | 7 | 12 | 12 | 7 | 12 | 12 | 8 | 11 | 12 | 9 | 9 | 12 | 10 | 8 | 13 | 6 | 8 | 15 | 6 | 8 | 17 | 87 | 109 | 169 |
| | Middletown/Harrisburg AP | 61 | 7 | 8 | 17 | 7 | 7 | 14 | 7 | 8 | 16 | 7 | 9 | 15 | 6 | 11 | 14 | 6 | 12 | 12 | 7 | 12 | 12 | 8 | 12 | 12 | 9 | 10 | 12 | 10 | 9 | 13 | 6 | 8 | 15 | 6 | 8 | 17 | 85 | 112 | 168 |
| | Philadelpia | 55 | 7 | 8 | 16 | 7 | 7 | 14 | 8 | 8 | 15 | 7 | 9 | 14 | 6 | 11 | 14 | 7 | 11 | 12 | 7 | 12 | 12 | 8 | 11 | 11 | 10 | 9 | 11 | 11 | 9 | 12 | 7 | 9 | 14 | 7 | 8 | 15 | 93 | 112 | 160 |
| | Pittsburgh | 43 | 3 | 6 | 22 | 3 | 6 | 19 | 4 | 7 | 20 | 4 | 8 | 17 | 5 | 9 | 17 | 5 | 12 | 13 | 5 | 13 | 13 | 7 | 12 | 13 | 7 | 10 | 13 | 8 | 9 | 14 | 4 | 6 | 20 | 3 | 6 | 23 | 59 | 103 | 203 |
| | Avoca | 40 | 4 | 7 | 20 | 5 | 7 | 17 | 5 | 8 | 18 | 6 | 8 | 16 | 6 | 10 | 16 | 7 | 11 | 12 | 6 | 13 | 12 | 7 | 12 | 12 | 7 | 10 | 13 | 8 | 8 | 14 | 4 | 7 | 19 | 4 | 7 | 20 | 70 | 106 | 189 |
| | Williamsport | 51 | 5 | 7 | 19 | 5 | 7 | 16 | 6 | 8 | 17 | 6 | 8 | 16 | 5 | 10 | 15 | 6 | 12 | 12 | 6 | 13 | 12 | 6 | 13 | 12 | 6 | 11 | 14 | 7 | 9 | 15 | 4 | 7 | 19 | 4 | 7 | 20 | 67 | 110 | 188 |
| RI | Block Is | 19 | 8 | 9 | 14 | 8 | 8 | 12 | 9 | 9 | 13 | 8 | 8 | 13 | 7 | 11 | 13 | 8 | 10 | 12 | 7 | 11 | 13 | 7 | 11 | 13 | 10 | 9 | 11 | 11 | 8 | 12 | 7 | 10 | 14 | 7 | 10 | 14 | 98 | 113 | 155 |
| | Providence | 42 | 10 | 7 | 15 | 8 | 7 | 13 | 8 | 8 | 15 | 7 | 8 | 14 | 6 | 10 | 15 | 7 | 10 | 13 | 7 | 12 | 12 | 8 | 10 | 12 | 9 | 8 | 12 | 11 | 8 | 12 | 8 | 7 | 15 | 8 | 8 | 15 | 98 | 103 | 164 |
| SC | Charleston AP | 47 | 9 | 6 | 16 | 9 | 6 | 13 | 9 | 8 | 14 | 11 | 8 | 11 | 8 | 11 | 12 | 6 | 11 | 13 | 5 | 12 | 13 | 6 | 13 | 13 | 7 | 10 | 13 | 11 | 8 | 11 | 12 | 7 | 12 | 9 | 7 | 14 | 102 | 109 | 155 |
| | Columbia | 48 | 9 | 6 | 16 | 9 | 6 | 13 | 9 | 8 | 14 | 11 | 8 | 11 | 9 | 10 | 11 | 8 | 11 | 11 | 7 | 13 | 12 | 8 | 12 | 11 | 10 | 9 | 12 | 13 | 7 | 11 | 12 | 6 | 12 | 10 | 6 | 15 | 115 | 103 | 147 |
| | Greenville-Spartanburg AP | 33 | 10 | 6 | 15 | 10 | 5 | 13 | 10 | 8 | 13 | 11 | 8 | 11 | 8 | 10 | 13 | 8 | 11 | 11 | 7 | 13 | 11 | 8 | 12 | 11 | 10 | 9 | 11 | 14 | 7 | 10 | 12 | 6 | 12 | 11 | 6 | 14 | 121 | 100 | 145 |
| SD | Aberdeen | 28 | 8 | 8 | 16 | 7 | 6 | 15 | 6 | 7 | 17 | 7 | 7 | 16 | 8 | 10 | 14 | 9 | 10 | 11 | 11 | 13 | 7 | 12 | 11 | 8 | 11 | 8 | 11 | 10 | 8 | 13 | 6 | 6 | 18 | 7 | 7 | 17 | 101 | 101 | 163 |
| | Huron | 56 | 8 | 8 | 15 | 6 | 8 | 14 | 6 | 8 | 17 | 7 | 9 | 15 | 8 | 10 | 14 | 9 | 11 | 10 | 12 | 12 | 7 | 12 | 11 | 7 | 12 | 8 | 10 | 11 | 8 | 12 | 7 | 7 | 16 | 7 | 7 | 16 | 104 | 107 | 154 |
| | Rapid City | 53 | 8 | 8 | 15 | 6 | 8 | 14 | 6 | 9 | 15 | 6 | 10 | 15 | 7 | 11 | 13 | 9 | 11 | 10 | 13 | 13 | 5 | 14 | 12 | 5 | 13 | 9 | 8 | 12 | 8 | 11 | 8 | 8 | 14 | 8 | 8 | 14 | 111 | 115 | 139 |
| | Sioux Falls | 50 | 8 | 8 | 15 | 7 | 7 | 15 | 6 | 8 | 17 | 7 | 8 | 15 | 7 | 10 | 14 | 9 | 11 | 11 | 12 | 12 | 8 | 12 | 11 | 9 | 12 | 8 | 10 | 11 | 8 | 12 | 7 | 7 | 16 | 8 | 7 | 16 | 105 | 103 | 157 |
| TN | Bristol-JhnCty-Kgsprt | 58 | 6 | 7 | 18 | 6 | 7 | 16 | 7 | 8 | 17 | 8 | 9 | 14 | 7 | 11 | 14 | 6 | 13 | 11 | 6 | 13 | 12 | 7 | 14 | 11 | 10 | 10 | 11 | 12 | 8 | 11 | 8 | 7 | 14 | 7 | 7 | 17 | 88 | 112 | 165 |
| | Chattanooga | 65 | 7 | 7 | 17 | 7 | 6 | 15 | 8 | 8 | 16 | 9 | 8 | 13 | 9 | 10 | 12 | 8 | 12 | 10 | 7 | 13 | 11 | 8 | 13 | 10 | 10 | 10 | 11 | 13 | 8 | 10 | 10 | 7 | 13 | 8 | 6 | 17 | 104 | 106 | 155 |
| | Knoxville | 53 | 6 | 7 | 18 | 7 | 6 | 16 | 7 | 7 | 16 | 8 | 9 | 13 | 8 | 10 | 13 | 7 | 12 | 10 | 7 | 13 | 11 | 8 | 12 | 10 | 10 | 9 | 11 | 12 | 8 | 11 | 9 | 7 | 14 | 7 | 7 | 17 | 97 | 107 | 162 |
| | Memphis | 43 | 8 | 6 | 17 | 8 | 6 | 15 | 8 | 7 | 17 | 9 | 7 | 14 | 8 | 10 | 13 | 10 | 11 | 9 | 10 | 12 | 9 | 12 | 12 | 7 | 12 | 8 | 10 | 14 | 7 | 10 | 10 | 6 | 14 | 9 | 6 | 16 | 118 | 96 | 151 |
| | Nashville | 54 | 6 | 6 | 18 | 7 | 6 | 15 | 8 | 7 | 16 | 8 | 8 | 13 | 8 | 10 | 13 | 8 | 12 | 10 | 8 | 13 | 10 | 10 | 12 | 9 | 11 | 9 | 10 | 13 | 8 | 10 | 9 | 7 | 14 | 7 | 7 | 17 | 102 | 106 | 156 |
| | Oak Ridge | 42 | 7 | 7 | 17 | 8 | 6 | 15 | 8 | 7 | 16 | 10 | 7 | 13 | 9 | 9 | 13 | 9 | 10 | 10 | 8 | 12 | 11 | 9 | 11 | 10 | 10 | 9 | 11 | 14 | 7 | 10 | 9 | 7 | 14 | 8 | 6 | 17 | 109 | 98 | 158 |
| TX | Abilene | 56 | 11 | 6 | 14 | 10 | 6 | 12 | 11 | 7 | 12 | 12 | 8 | 11 | 10 | 10 | 11 | 13 | 11 | 7 | 14 | 10 | 7 | 14 | 10 | 7 | 14 | 8 | 8 | 15 | 7 | 9 | 13 | 6 | 11 | 12 | 6 | 13 | 149 | 95 | 121 |
| | Amarillo | 51 | 13 | 7 | 11 | 10 | 7 | 10 | 12 | 9 | 11 | 12 | 9 | 9 | 11 | 10 | 10 | 13 | 11 | 6 | 13 | 12 | 5 | 14 | 10 | 7 | 15 | 7 | 8 | 17 | 7 | 8 | 15 | 7 | 9 | 13 | 7 | 10 | 157 | 104 | 104 |
| | Amarillo | 3 | 8 | 5 | 5 | 10 | 4 | 6 | 11 | 3 | 3 | 12 | 4 | 5 | 11 | 5 | 6 | 18 | 5 | 2 | 17 | 3 | 2 | 16 | 2 | 4 | 10 | 1 | 2 | 12 | 2 | 4 | 10 | 3 | 4 | 13 | 5 | 4 | 146 | 43 | 44 |
| | Austin | 54 | 9 | 6 | 16 | 8 | 6 | 14 | 9 | 8 | 15 | 8 | 8 | 15 | 6 | 11 | 13 | 8 | 15 | 7 | 12 | 13 | 6 | 12 | 14 | 5 | 11 | 11 | 9 | 12 | 9 | 9 | 11 | 7 | 12 | 10 | 6 | 15 | 115 | 114 | 136 |

*(Continued)*



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**Table 3A.11 (Continued)**

| State | Station | Years | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | | Jul | | | Aug | | | Sep | | | Oct | | | Nov | | | Dec | | | Annual | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD | CL | PC | CD |
| | Brownsville | 52 | 6 | 7 | 18 | 7 | 6 | 15 | 7 | 8 | 16 | 5 | 10 | 15 | 6 | 14 | 11 | 8 | 15 | 6 | 11 | 14 | 6 | 11 | 14 | 7 | 9 | 13 | 8 | 11 | 12 | 7 | 9 | 9 | 12 | 7 | 7 | 17 | 96 | 131 | 138 |
| | Corpus Christi | 53 | 7 | 7 | 17 | 7 | 6 | 15 | 7 | 8 | 16 | 6 | 9 | 15 | 5 | 12 | 13 | 9 | 14 | 7 | 11 | 14 | 6 | 11 | 13 | 7 | 10 | 12 | 8 | 12 | 10 | 8 | 9 | 9 | 12 | 8 | 6 | 17 | 102 | 121 | 142 |
| | Dallas-Fort Worth | 42 | 10 | 6 | 16 | 10 | 6 | 13 | 10 | 8 | 14 | 9 | 8 | 13 | 8 | 10 | 13 | 11 | 12 | 8 | 15 | 10 | 6 | 15 | 10 | 6 | 13 | 9 | 9 | 14 | 7 | 10 | 12 | 6 | 12 | 11 | 6 | 14 | 135 | 97 | 133 |
| | Del Rio | 16 | 10 | 7 | 14 | 10 | 7 | 11 | 11 | 8 | 13 | 8 | 7 | 14 | 6 | 9 | 16 | 8 | 13 | 9 | 12 | 11 | 8 | 11 | 12 | 8 | 9 | 11 | 10 | 12 | 8 | 10 | 12 | 7 | 11 | 11 | 6 | 14 | 121 | 106 | 138 |
| | El Paso | 53 | 14 | 7 | 10 | 14 | 7 | 7 | 15 | 8 | 7 | 17 | 8 | 5 | 19 | 8 | 4 | 20 | 7 | 3 | 12 | 13 | 5 | 14 | 12 | 5 | 18 | 7 | 5 | 19 | 7 | 5 | 18 | 6 | 6 | 15 | 7 | 9 | 193 | 100 | 72 |
| | Houston | 26 | 7 | 5 | 18 | 7 | 5 | 16 | 7 | 6 | 18 | 7 | 7 | 16 | 6 | 11 | 14 | 7 | 13 | 9 | 7 | 16 | 8 | 6 | 17 | 8 | 9 | 11 | 10 | 11 | 9 | 11 | 9 | 7 | 14 | 7 | 6 | 18 | 90 | 114 | 161 |
| | Lubbock | 49 | 12 | 6 | 12 | 11 | 7 | 10 | 12 | 9 | 11 | 12 | 9 | 9 | 11 | 11 | 9 | 14 | 11 | 6 | 14 | 11 | 6 | 15 | 10 | 6 | 14 | 8 | 8 | 17 | 7 | 8 | 15 | 7 | 9 | 13 | 7 | 11 | 160 | 102 | 103 |
| | Midland-Odessa | 47 | 12 | 6 | 12 | 11 | 7 | 10 | 13 | 8 | 10 | 13 | 8 | 9 | 13 | 10 | 8 | 15 | 9 | 5 | 13 | 11 | 7 | 14 | 10 | 6 | 14 | 8 | 8 | 17 | 6 | 8 | 15 | 6 | 9 | 14 | 6 | 11 | 165 | 96 | 104 |
| | Port Arthur | 42 | 7 | 6 | 18 | 8 | 6 | 15 | 7 | 7 | 17 | 6 | 8 | 16 | 7 | 12 | 12 | 8 | 14 | 8 | 7 | 15 | 9 | 7 | 15 | 9 | 9 | 11 | 10 | 12 | 10 | 9 | 10 | 7 | 13 | 8 | 6 | 17 | 95 | 117 | 153 |
| | San Angelo | 47 | 12 | 6 | 13 | 11 | 6 | 11 | 12 | 8 | 11 | 11 | 8 | 11 | 11 | 10 | 10 | 14 | 10 | 6 | 15 | 10 | 7 | 15 | 10 | 6 | 13 | 8 | 8 | 15 | 7 | 8 | 14 | 6 | 10 | 12 | 7 | 12 | 154 | 97 | 114 |
| | San Antonio | 53 | 9 | 6 | 16 | 8 | 6 | 14 | 9 | 7 | 15 | 7 | 8 | 15 | 6 | 11 | 14 | 7 | 15 | 8 | 9 | 15 | 7 | 10 | 15 | 6 | 9 | 12 | 9 | 11 | 10 | 9 | 10 | 7 | 13 | 10 | 6 | 16 | 105 | 119 | 141 |
| | Victoria | 34 | 7 | 6 | 18 | 7 | 6 | 16 | 7 | 7 | 18 | 5 | 8 | 17 | 5 | 11 | 15 | 6 | 15 | 9 | 7 | 15 | 8 | 7 | 15 | 9 | 8 | 12 | 10 | 11 | 10 | 10 | 9 | 7 | 14 | 7 | 6 | 19 | 86 | 118 | 162 |
| | Waco | 50 | 9 | 6 | 16 | 9 | 6 | 14 | 10 | 7 | 14 | 9 | 7 | 14 | 8 | 10 | 13 | 10 | 12 | 8 | 14 | 10 | 6 | 14 | 11 | 6 | 12 | 9 | 8 | 13 | 8 | 9 | 12 | 6 | 12 | 11 | 6 | 15 | 130 | 98 | 136 |
| | Waco | 3 | 5 | 2 | 6 | 9 | 1 | 8 | 9 | 3 | 7 | 7 | 4 | 4 | 6 | 5 | 5 | 10 | 3 | 2 | 10 | 4 | 2 | 14 | 3 | 2 | 5 | 3 | 2 | 8 | 2 | 4 | 3 | 2 | 6 | 4 | 4 | 6 | 89 | 36 | 53 |
| | Wichita Falls | 50 | 11 | 6 | 14 | 10 | 6 | 12 | 11 | 8 | 12 | 11 | 8 | 11 | 11 | 9 | 11 | 13 | 11 | 7 | 15 | 9 | 7 | 15 | 9 | 6 | 15 | 7 | 8 | 15 | 7 | 9 | 13 | 6 | 11 | 12 | 6 | 13 | 151 | 93 | 120 |
| | Wichita Falls | 2 | 12 | 6 | 11 | 15 | 4 | 8 | 9 | 3 | 4 | 10 | 6 | 4 | 18 | 6 | 12 | 24 | 10 | 2 | 19 | 6 | 1 | 16 | 4 | 2 | 3 | 2 | 1 | 12 | 3 | 3 | 1 | 3 | 8 | 1 | 5 | 5 | 140 | 58 | 60 |
| UT | Milford | 40 | 9 | 8 | 14 | 8 | 8 | 12 | 9 | 8 | 13 | 10 | 10 | 11 | 11 | 10 | 9 | 17 | 8 | 5 | 16 | 10 | 5 | 16 | 10 | 5 | 18 | 7 | 4 | 17 | 7 | 7 | 11 | 8 | 11 | 10 | 8 | 13 | 151 | 104 | 111 |
| | Salt Lake City | 69 | 6 | 6 | 19 | 5 | 7 | 16 | 7 | 8 | 16 | 7 | 9 | 14 | 9 | 10 | 12 | 14 | 10 | 6 | 17 | 10 | 4 | 16 | 11 | 4 | 16 | 8 | 5 | 14 | 8 | 9 | 8 | 7 | 15 | 6 | 6 | 18 | 125 | 101 | 139 |
| VT | Burlington | 52 | 5 | 6 | 20 | 4 | 7 | 17 | 6 | 7 | 18 | 5 | 8 | 17 | 5 | 9 | 17 | 5 | 11 | 14 | 5 | 13 | 13 | 6 | 12 | 13 | 6 | 10 | 14 | 6 | 8 | 17 | 3 | 5 | 22 | 3 | 6 | 22 | 58 | 101 | 206 |
| VA | Lynchburg | 49 | 9 | 7 | 15 | 8 | 7 | 13 | 9 | 9 | 13 | 9 | 9 | 12 | 8 | 10 | 13 | 8 | 12 | 10 | 8 | 12 | 11 | 9 | 11 | 11 | 10 | 9 | 11 | 13 | 7 | 11 | 10 | 7 | 13 | 10 | 7 | 14 | 112 | 107 | 147 |
| | Norfolk | 47 | 9 | 7 | 16 | 8 | 6 | 14 | 9 | 8 | 15 | 9 | 9 | 12 | 8 | 10 | 13 | 7 | 12 | 11 | 7 | 12 | 12 | 8 | 12 | 11 | 9 | 9 | 11 | 12 | 7 | 12 | 10 | 8 | 12 | 9 | 7 | 15 | 106 | 107 | 153 |
| | Richmond | 50 | 8 | 7 | 16 | 8 | 6 | 14 | 8 | 8 | 15 | 8 | 9 | 13 | 7 | 10 | 14 | 7 | 12 | 12 | 7 | 12 | 12 | 7 | 12 | 12 | 9 | 9 | 12 | 12 | 7 | 12 | 9 | 8 | 13 | 9 | 6 | 15 | 100 | 106 | 160 |
| | Roanoke | 48 | 8 | 8 | 15 | 8 | 7 | 14 | 8 | 8 | 14 | 9 | 9 | 13 | 7 | 11 | 13 | 7 | 12 | 11 | 7 | 13 | 11 | 8 | 12 | 11 | 10 | 9 | 12 | 13 | 7 | 11 | 9 | 8 | 13 | 9 | 8 | 14 | 102 | 112 | 151 |
| WA | Olympia | 54 | 2 | 4 | 25 | 2 | 4 | 22 | 3 | 6 | 22 | 3 | 7 | 20 | 4 | 9 | 18 | 5 | 8 | 16 | 10 | 10 | 11 | 9 | 10 | 12 | 8 | 10 | 13 | 3 | 8 | 20 | 2 | 5 | 23 | 2 | 4 | 26 | 52 | 84 | 228 |
| | Quillayute | 29 | 3 | 3 | 24 | 4 | 4 | 21 | 4 | 6 | 22 | 3 | 6 | 21 | 3 | 8 | 20 | 4 | 7 | 20 | 6 | 9 | 16 | 6 | 9 | 16 | 8 | 8 | 14 | 5 | 7 | 19 | 3 | 5 | 22 | 4 | 4 | 24 | 51 | 75 | 239 |
| | Seattle CO | 24 | 3 | 5 | 23 | 3 | 6 | 19 | 4 | 8 | 19 | 5 | 9 | 16 | 7 | 10 | 14 | 7 | 8 | 15 | 12 | 10 | 9 | 10 | 10 | 11 | 9 | 8 | 13 | 5 | 8 | 18 | 3 | 6 | 21 | 3 | 5 | 23 | 71 | 93 | 201 |
| | Seattle Sea-Tac AP | 51 | 3 | 4 | 24 | 3 | 4 | 21 | 3 | 6 | 22 | 3 | 7 | 20 | 4 | 9 | 18 | 5 | 8 | 17 | 10 | 10 | 11 | 9 | 10 | 12 | 8 | 9 | 13 | 4 | 7 | 19 | 2 | 4 | 23 | 2 | 4 | 25 | 58 | 82 | 226 |
| | Spokane | 48 | 3 | 4 | 24 | 3 | 5 | 20 | 5 | 8 | 19 | 4 | 8 | 17 | 6 | 10 | 15 | 7 | 10 | 12 | 16 | 8 | 6 | 15 | 9 | 7 | 12 | 8 | 9 | 8 | 8 | 15 | 3 | 5 | 22 | 3 | 4 | 24 | 86 | 88 | 191 |
| | Yakima | 49 | 4 | 5 | 22 | 4 | 6 | 18 | 6 | 8 | 17 | 6 | 9 | 14 | 8 | 11 | 12 | 10 | 10 | 10 | 19 | 8 | 4 | 18 | 8 | 6 | 15 | 8 | 7 | 9 | 8 | 13 | 5 | 6 | 19 | 4 | 5 | 22 | 109 | 92 | 164 |
| PR | San Juan | 40 | 9 | 18 | 4 | 7 | 16 | 4 | 9 | 17 | 4 | 7 | 17 | 6 | 4 | 16 | 12 | 4 | 16 | 10 | 5 | 17 | 9 | 5 | 17 | 8 | 4 | 17 | 9 | 5 | 17 | 9 | 5 | 18 | 7 | 7 | 18 | 6 | 73 | 203 | 89 |
| WV | Beckley | 32 | 5 | 5 | 21 | 4 | 5 | 18 | 5 | 6 | 20 | 5 | 7 | 17 | 5 | 9 | 17 | 3 | 10 | 16 | 3 | 12 | 16 | 4 | 12 | 16 | 6 | 9 | 15 | 9 | 8 | 14 | 5 | 7 | 18 | 5 | 6 | 21 | 60 | 95 | 210 |
| | Charleston | 47 | 4 | 6 | 21 | 4 | 6 | 18 | 5 | 8 | 19 | 6 | 8 | 16 | 6 | 10 | 15 | 5 | 13 | 12 | 5 | 13 | 13 | 5 | 14 | 12 | 7 | 11 | 12 | 9 | 9 | 13 | 5 | 7 | 18 | 5 | 6 | 20 | 65 | 111 | 189 |
| | Elkins | 49 | 3 | 6 | 22 | 3 | 6 | 19 | 4 | 6 | 20 | 4 | 8 | 18 | 4 | 9 | 17 | 3 | 11 | 16 | 2 | 13 | 16 | 3 | 14 | 15 | 4 | 11 | 15 | 7 | 8 | 13 | 5 | 6 | 19 | 4 | 5 | 21 | 48 | 103 | 212 |
| | Huntington | 34 | 4 | 6 | 21 | 4 | 5 | 19 | 5 | 7 | 19 | 5 | 8 | 17 | 6 | 9 | 17 | 5 | 11 | 14 | 5 | 12 | 14 | 5 | 12 | 14 | 7 | 9 | 14 | 9 | 8 | 14 | 5 | 6 | 19 | 5 | 5 | 21 | 63 | 99 | 203 |
| WI | Green Bay | 46 | 8 | 7 | 17 | 7 | 7 | 15 | 7 | 8 | 16 | 6 | 8 | 16 | 7 | 10 | 14 | 8 | 11 | 12 | 8 | 12 | 11 | 8 | 11 | 12 | 8 | 9 | 13 | 7 | 8 | 15 | 5 | 6 | 19 | 6 | 6 | 19 | 85 | 102 | 178 |
| | La Crosse | 17 | 7 | 7 | 17 | 8 | 7 | 13 | 7 | 7 | 17 | 7 | 7 | 16 | 7 | 9 | 15 | 7 | 10 | 12 | 10 | 11 | 10 | 9 | 11 | 11 | 9 | 9 | 12 | 11 | 7 | 13 | 6 | 6 | 18 | 7 | 6 | 18 | 95 | 97 | 173 |
| | Madison | 49 | 7 | 6 | 17 | 7 | 6 | 15 | 6 | 7 | 17 | 6 | 8 | 16 | 7 | 9 | 15 | 7 | 10 | 13 | 9 | 11 | 11 | 9 | 10 | 12 | 9 | 8 | 12 | 9 | 7 | 14 | 5 | 6 | 18 | 6 | 6 | 19 | 89 | 96 | 180 |
| | Milwaukee | 55 | 7 | 6 | 18 | 6 | 6 | 15 | 6 | 8 | 17 | 6 | 8 | 16 | 7 | 10 | 14 | 8 | 10 | 12 | 10 | 11 | 10 | 10 | 11 | 10 | 9 | 9 | 12 | 9 | 8 | 13 | 5 | 6 | 18 | 6 | 6 | 19 | 90 | 100 | 175 |
| WY | Casper | 45 | 7 | 8 | 16 | 6 | 8 | 14 | 6 | 9 | 16 | 5 | 9 | 16 | 6 | 11 | 15 | 10 | 11 | 9 | 14 | 11 | 6 | 13 | 11 | 7 | 13 | 9 | 8 | 11 | 8 | 12 | 7 | 8 | 14 | 8 | 8 | 15 | 107 | 111 | 147 |
| | Cheyenne | 60 | 9 | 10 | 13 | 7 | 9 | 12 | 7 | 10 | 14 | 6 | 10 | 14 | 5 | 12 | 14 | 9 | 12 | 9 | 10 | 15 | 7 | 10 | 13 | 8 | 13 | 9 | 9 | 13 | 9 | 9 | 10 | 9 | 11 | 9 | 9 | 13 | 106 | 127 | 133 |
| | Lander | 49 | 8 | 10 | 13 | 7 | 10 | 12 | 7 | 10 | 14 | 6 | 10 | 14 | 6 | 11 | 14 | 10 | 11 | 9 | 14 | 11 | 6 | 13 | 12 | 6 | 14 | 9 | 8 | 12 | 9 | 10 | 8 | 10 | 12 | 10 | 10 | 12 | 114 | 122 | 129 |
| | Sheridan | 55 | 6 | 8 | 17 | 5 | 8 | 15 | 5 | 9 | 17 | 5 | 9 | 16 | 6 | 10 | 15 | 8 | 12 | 11 | 13 | 12 | 6 | 14 | 11 | 6 | 12 | 9 | 9 | 10 | 9 | 12 | 6 | 8 | 16 | 7 | 8 | 17 | 95 | 113 | 157 |

*Note:* This table shows the mean number of days per category of cloudiness. The categories are determined for daylight hours only. Clear denotes zero to 3/10 average sky cover. Partly cloudy denotes 4/10 to 7/10 average sky cover. Cloudy denotes 8/10 to 10/10 average sky cover.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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## Table 3A.12 Average Relative Humidity: Morning (M), Afternoon (A) — Selected Cities of the United States (Through 2002)

| State | Station | Years | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A |
| AL | Birmingham AP | 39 | 39 | 80 | 64 | 79 | 60 | 79 | 57 | 83 | 57 | 86 | 60 | 84 | 59 | 86 | 62 | 86 | 61 | 87 | 62 | 87 | 58 | 83 | 60 | 81 | 63 | 83 | 60 |
| | Huntsville | 35 | 35 | 82 | 68 | 80 | 63 | 80 | 60 | 82 | 57 | 86 | 60 | 88 | 61 | 90 | 64 | 91 | 63 | 89 | 63 | 87 | 59 | 84 | 62 | 82 | 67 | 85 | 62 |
| | Mobile | 40 | 40 | 83 | 65 | 83 | 61 | 85 | 60 | 88 | 58 | 88 | 60 | 89 | 61 | 90 | 66 | 91 | 66 | 90 | 65 | 87 | 59 | 86 | 62 | 85 | 66 | 87 | 62 |
| | Montgomery | 39 | 39 | 82 | 64 | 80 | 60 | 82 | 57 | 86 | 57 | 88 | 60 | 88 | 60 | 90 | 64 | 91 | 64 | 89 | 62 | 89 | 58 | 87 | 60 | 84 | 64 | 86 | 61 |
| AK | Anchorage | 49 | 49 | 75 | 73 | 75 | 68 | 70 | 57 | 66 | 53 | 63 | 49 | 67 | 56 | 74 | 63 | 78 | 65 | 80 | 64 | 78 | 66 | 78 | 74 | 77 | 76 | 73 | 64 |
| | Annette | 37 | 37 | 81 | 77 | 80 | 73 | 77 | 69 | 76 | 66 | 76 | 66 | 79 | 69 | 81 | 71 | 84 | 73 | 86 | 75 | 85 | 78 | 83 | 79 | 83 | 80 | 81 | 73 |
| | Barrow | 51 | 51 | 69 | 69 | 66 | 67 | 67 | 68 | 75 | 74 | 85 | 82 | 87 | 84 | 88 | 84 | 92 | 86 | 91 | 87 | 85 | 84 | 78 | 79 | 73 | 73 | 80 | 78 |
| | Barter IS | 40 | 40 | 70 | 70 | 69 | 67 | 67 | 67 | 73 | 74 | 86 | 84 | 89 | 87 | 89 | 86 | 91 | 88 | 90 | 87 | 84 | 83 | 75 | 75 | 70 | 70 | 79 | 78 |
| | Bethel | 52 | 52 | 78 | 77 | 76 | 74 | 80 | 75 | 83 | 72 | 80 | 62 | 78 | 60 | 86 | 68 | 91 | 73 | 92 | 71 | 88 | 76 | 84 | 81 | 78 | 78 | 83 | 72 |
| | Bettles | 52 | 52 | 69 | 68 | 67 | 64 | 67 | 60 | 66 | 60 | 62 | 50 | 60 | 47 | 69 | 53 | 79 | 61 | 79 | 62 | 78 | 72 | 73 | 72 | 70 | 70 | 70 | 62 |
| | Big Delta | 43 | 43 | 65 | 64 | 68 | 61 | 64 | 52 | 57 | 44 | 50 | 38 | 57 | 44 | 64 | 49 | 69 | 51 | 70 | 53 | 74 | 66 | 69 | 67 | 68 | 68 | 65 | 55 |
| | Cold Bay | 33 | 33 | 85 | 83 | 85 | 81 | 85 | 78 | 84 | 77 | 84 | 75 | 87 | 77 | 90 | 82 | 91 | 82 | 88 | 79 | 84 | 77 | 84 | 81 | 84 | 83 | 86 | 79 |
| | Fairbanks | 50 | 50 | 70 | 71 | 68 | 65 | 68 | 53 | 60 | 45 | 53 | 37 | 60 | 43 | 70 | 50 | 78 | 55 | 79 | 55 | 80 | 68 | 75 | 74 | 72 | 73 | 69 | 57 |
| | Gulkana | 50 | 50 | 72 | 71 | 73 | 67 | 70 | 54 | 64 | 45 | 58 | 40 | 60 | 42 | 68 | 48 | 71 | 49 | 75 | 52 | 79 | 65 | 76 | 75 | 73 | 73 | 70 | 57 |
| | Homer | 53 | 53 | 78 | 75 | 78 | 70 | 75 | 65 | 72 | 63 | 70 | 63 | 71 | 64 | 76 | 69 | 79 | 69 | 80 | 68 | 79 | 66 | 77 | 72 | 78 | 76 | 76 | 68 |
| | Juneau | 36 | 36 | 78 | 74 | 81 | 71 | 79 | 66 | 77 | 61 | 75 | 61 | 75 | 61 | 79 | 67 | 82 | 70 | 86 | 74 | 84 | 76 | 81 | 77 | 81 | 79 | 80 | 70 |
| | King Salmon | 54 | 54 | 79 | 76 | 78 | 71 | 78 | 67 | 77 | 62 | 73 | 56 | 77 | 59 | 83 | 64 | 86 | 67 | 86 | 66 | 85 | 68 | 83 | 77 | 79 | 77 | 80 | 68 |
| | Kodiak | 55 | 55 | 79 | 76 | 79 | 73 | 76 | 69 | 74 | 69 | 76 | 72 | 79 | 75 | 82 | 77 | 80 | 74 | 81 | 73 | 78 | 68 | 78 | 72 | 77 | 74 | 78 | 73 |
| | Kotzebue | 39 | 39 | 73 | 73 | 73 | 73 | 73 | 71 | 78 | 75 | 82 | 78 | 81 | 77 | 83 | 77 | 85 | 77 | 83 | 74 | 82 | 77 | 78 | 77 | 75 | 75 | 79 | 75 |
| | McGrath | 48 | 48 | 73 | 72 | 73 | 64 | 73 | 53 | 68 | 49 | 63 | 44 | 66 | 47 | 75 | 56 | 83 | 62 | 84 | 61 | 84 | 70 | 79 | 76 | 76 | 75 | 75 | 61 |
| | Nome | 39 | 39 | 74 | 74 | 73 | 72 | 73 | 70 | 76 | 74 | 76 | 73 | 76 | 73 | 82 | 78 | 83 | 79 | 81 | 73 | 80 | 71 | 77 | 75 | 74 | 74 | 77 | 74 |
| | St. Paul Island | 24 | 24 | 84 | 83 | 86 | 84 | 87 | 83 | 86 | 81 | 89 | 81 | 92 | 83 | 95 | 89 | 95 | 89 | 90 | 83 | 83 | 78 | 82 | 80 | 84 | 83 | 88 | 83 |
| | Talkeetna | 51 | 51 | 73 | 69 | 74 | 64 | 71 | 57 | 67 | 52 | 65 | 49 | 70 | 53 | 79 | 61 | 84 | 64 | 84 | 64 | 80 | 67 | 75 | 71 | 73 | 73 | 75 | 62 |
| | Unalakleet | 10 | 10 | 67 | 69 | 71 | 73 | 71 | 70 | 76 | 74 | 76 | 71 | 80 | 74 | 81 | 75 | 82 | 73 | 80 | 69 | 77 | 71 | 74 | 73 | 68 | 69 | 75 | 72 |
| | Valdez | 30 | 30 | 75 | 74 | 74 | 68 | 72 | 64 | 71 | 61 | 73 | 61 | 78 | 64 | 84 | 71 | 85 | 72 | 87 | 74 | 78 | 70 | 74 | 70 | 76 | 75 | 77 | 69 |
| | Yakutat | 38 | 38 | 85 | 82 | 86 | 77 | 83 | 71 | 78 | 69 | 78 | 71 | 81 | 74 | 85 | 78 | 86 | 79 | 89 | 78 | 89 | 79 | 87 | 82 | 86 | 85 | 84 | 77 |
| AZ | Flagstaff | 45 | 45 | 74 | 50 | 74 | 45 | 72 | 41 | 67 | 32 | 63 | 27 | 54 | 21 | 67 | 37 | 77 | 44 | 74 | 37 | 72 | 36 | 70 | 43 | 72 | 51 | 70 | 39 |
| | Phoenix | 42 | 42 | 64 | 32 | 59 | 27 | 56 | 24 | 42 | 17 | 34 | 14 | 30 | 12 | 43 | 20 | 50 | 23 | 48 | 23 | 49 | 22 | 56 | 27 | 65 | 33 | 50 | 23 |
| | Tucson | 62 | 62 | 62 | 32 | 58 | 27 | 53 | 23 | 42 | 16 | 34 | 13 | 32 | 13 | 56 | 28 | 65 | 33 | 55 | 27 | 52 | 25 | 54 | 28 | 62 | 34 | 52 | 25 |
| | Winslow | 25 | 25 | 76 | 47 | 68 | 33 | 61 | 25 | 52 | 20 | 43 | 16 | 37 | 14 | 58 | 27 | 65 | 30 | 65 | 29 | 60 | 26 | 66 | 33 | 75 | 47 | 60 | 29 |
| | Yuma | 14 | 14 | 57 | 28 | 56 | 24 | 52 | 21 | 47 | 17 | 44 | 15 | 41 | 13 | 49 | 22 | 55 | 24 | 57 | 24 | 54 | 23 | 56 | 27 | 58 | 32 | 52 | 22 |
| AR | Fort Smith | 38 | 38 | 82 | 65 | 80 | 60 | 79 | 57 | 82 | 56 | 88 | 62 | 89 | 62 | 88 | 60 | 88 | 58 | 89 | 60 | 87 | 57 | 84 | 61 | 83 | 65 | 85 | 60 |
| | Little Rock | 38 | 38 | 80 | 65 | 79 | 61 | 78 | 59 | 82 | 60 | 87 | 62 | 85 | 58 | 86 | 58 | 85 | 58 | 86 | 59 | 84 | 55 | 81 | 60 | 79 | 63 | 83 | 60 |
| CA | Bakersfield | 26 | 26 | 85 | 63 | 80 | 53 | 74 | 44 | 67 | 33 | 57 | 27 | 52 | 24 | 49 | 23 | 53 | 25 | 57 | 28 | 62 | 34 | 77 | 50 | 83 | 61 | 66 | 39 |
| | Bishop | 7 | 7 | 67 | 32 | 68 | 31 | 58 | 20 | 53 | 17 | 49 | 15 | 39 | 14 | 46 | 14 | 45 | 14 | 50 | 16 | 50 | 16 | 63 | 24 | 64 | 29 | 54 | 20 |
| | Blue Canyon | 13 | 13 | 56 | 58 | 61 | 61 | 66 | 61 | 61 | 54 | 55 | 47 | 47 | 38 | 41 | 34 | 42 | 34 | 48 | 42 | 50 | 48 | 57 | 60 | 55 | 59 | 53 | 50 |
| | Fresno | 39 | 39 | 91 | 68 | 89 | 56 | 86 | 47 | 80 | 35 | 71 | 27 | 65 | 24 | 61 | 22 | 66 | 24 | 71 | 28 | 77 | 35 | 87 | 54 | 91 | 68 | 78 | 41 |
| | Long Beach | 32 | 32 | 76 | 53 | 78 | 54 | 80 | 55 | 80 | 51 | 81 | 55 | 82 | 56 | 82 | 54 | 82 | 53 | 83 | 54 | 81 | 54 | 79 | 53 | 77 | 52 | 80 | 54 |
| | Los Angeles AP | 43 | 43 | 71 | 61 | 75 | 64 | 79 | 66 | 80 | 65 | 83 | 67 | 85 | 68 | 86 | 69 | 85 | 69 | 84 | 68 | 80 | 66 | 72 | 62 | 68 | 60 | 79 | 65 |
| | Los Angeles CO | 43 | 43 | 64 | 50 | 70 | 52 | 74 | 52 | 79 | 54 | 80 | 55 | 80 | 54 | 80 | 52 | 79 | 53 | 75 | 52 | 72 | 54 | 59 | 47 | 59 | 48 | 73 | 52 |
| | Mount Shasta | 13 | 13 | 76 | 66 | 75 | 60 | 75 | 52 | 71 | 43 | 69 | 39 | 67 | 36 | 64 | 28 | 65 | 29 | 66 | 33 | 71 | 46 | 78 | 62 | 77 | 67 | 71 | 47 |
| | Redding | 16 | 16 | 84 | 61 | 82 | 51 | 78 | 46 | 76 | 38 | 72 | 33 | 63 | 25 | 60 | 20 | 60 | 19 | 61 | 23 | 68 | 30 | 82 | 51 | 83 | 59 | 72 | 38 |
| | Sacramento | 16 | 16 | 91 | 70 | 89 | 61 | 86 | 53 | 83 | 44 | 82 | 38 | 78 | 32 | 77 | 30 | 78 | 29 | 77 | 31 | 79 | 37 | 87 | 57 | 88 | 67 | 83 | 46 |
| | San Diego | 42 | 42 | 72 | 58 | 74 | 60 | 76 | 61 | 76 | 60 | 78 | 65 | 81 | 67 | 82 | 67 | 83 | 67 | 81 | 67 | 77 | 65 | 73 | 62 | 71 | 59 | 77 | 63 |
| | San Francisco AP | 43 | 43 | 86 | 68 | 85 | 66 | 82 | 63 | 82 | 60 | 83 | 60 | 84 | 59 | 86 | 60 | 87 | 61 | 85 | 59 | 82 | 59 | 84 | 64 | 85 | 68 | 84 | 62 |
| | San Francisco CO | 8 | 8 | 81 | 63 | 83 | 63 | 80 | 61 | 82 | 61 | 88 | 68 | 78 | 63 | 80 | 65 | 80 | 64 | 75 | 58 | 70 | 52 | 71 | 55 | 69 | 55 | 78 | 61 |
| | Santa Barbara | 6 | 6 | 80 | 57 | 79 | 58 | 83 | 60 | 76 | 58 | 83 | 60 | 88 | 62 | 90 | 64 | 90 | 64 | 86 | 63 | 81 | 62 | 77 | 52 | 81 | 55 | 83 | 60 |
| | Santa Maria | 26 | 26 | 82 | 61 | 85 | 62 | 86 | 65 | 89 | 61 | 91 | 61 | 92 | 61 | 89 | 62 | 90 | 62 | 92 | 63 | 85 | 62 | 80 | 62 | 80 | 59 | 87 | 62 |
| | Stockton | 26 | 26 | 90 | 71 | 89 | 61 | 84 | 50 | 80 | 41 | 74 | 34 | 71 | 29 | 68 | 28 | 69 | 29 | 71 | 32 | 75 | 38 | 83 | 57 | 91 | 71 | 79 | 45 |
| CO | Alamosa | 45 | 45 | 78 | 57 | 78 | 48 | 74 | 36 | 71 | 30 | 72 | 28 | 74 | 25 | 83 | 35 | 85 | 38 | 81 | 33 | 76 | 34 | 78 | 47 | 77 | 56 | 77 | 39 |
| | Colorado Springs | 42 | 42 | 58 | 46 | 59 | 40 | 62 | 39 | 63 | 35 | 68 | 37 | 67 | 35 | 69 | 39 | 71 | 43 | 67 | 38 | 59 | 37 | 61 | 46 | 57 | 49 | 63 | 40 |
| | Denver | 35 | 35 | 63 | 49 | 67 | 44 | 67 | 40 | 67 | 35 | 70 | 38 | 69 | 35 | 68 | 34 | 69 | 35 | 68 | 34 | 65 | 36 | 68 | 49 | 65 | 52 | 67 | 40 |
| | Grand Junction | 39 | 39 | 78 | 62 | 73 | 47 | 64 | 35 | 58 | 28 | 54 | 25 | 44 | 19 | 48 | 22 | 52 | 24 | 53 | 27 | 59 | 33 | 71 | 47 | 77 | 59 | 61 | 36 |
| | Pueblo | 23 | 23 | 69 | 49 | 66 | 37 | 68 | 34 | 68 | 31 | 70 | 32 | 70 | 28 | 74 | 32 | 76 | 35 | 72 | 32 | 69 | 33 | 74 | 46 | 69 | 51 | 70 | 37 |
| CI | Bridgeport | 36 | 36 | 70 | 59 | 70 | 57 | 70 | 55 | 69 | 53 | 75 | 59 | 78 | 61 | 78 | 60 | 79 | 61 | 82 | 61 | 80 | 59 | 77 | 60 | 74 | 60 | 75 | 59 |
| | Hartford | 43 | 43 | 72 | 57 | 72 | 53 | 73 | 51 | 70 | 45 | 74 | 48 | 77 | 51 | 79 | 51 | 83 | 53 | 86 | 55 | 84 | 51 | 79 | 56 | 76 | 59 | 77 | 52 |
| DE | Wilmington | 55 | 55 | 76 | 60 | 75 | 56 | 74 | 53 | 73 | 50 | 76 | 54 | 78 | 54 | 79 | 54 | 83 | 56 | 85 | 56 | 85 | 54 | 80 | 56 | 77 | 59 | 78 | 55 |
| DC | Washington Dulles AP | 33 | 33 | 77 | 58 | 78 | 54 | 78 | 52 | 77 | 49 | 83 | 55 | 84 | 56 | 86 | 55 | 88 | 55 | 90 | 56 | 89 | 54 | 83 | 54 | 79 | 58 | 83 | 55 |
| | Washington Nat'l AP | 42 | 42 | 71 | 56 | 71 | 53 | 70 | 50 | 70 | 49 | 75 | 53 | 76 | 53 | 76 | 53 | 80 | 55 | 82 | 56 | 80 | 54 | 76 | 54 | 72 | 57 | 75 | 54 |

*(Continued)*



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**Table 3A.12 (Continued)**

| State | Station | Years | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A |
| FL | Apalachicola | 42 | 42 | 85 | 66 | 86 | 65 | 86 | 65 | 86 | 64 | 85 | 65 | 85 | 67 | 86 | 71 | 88 | 75 | 88 | 69 | 86 | 62 | 85 | 63 | 86 | 67 | 86 | 66 |
| | Daytona Beach | 58 | 58 | 88 | 59 | 87 | 57 | 87 | 55 | 86 | 54 | 85 | 57 | 87 | 63 | 89 | 64 | 91 | 67 | 90 | 67 | 87 | 63 | 88 | 60 | 88 | 61 | 88 | 61 |
| | Fort Myers | 58 | 58 | 89 | 57 | 88 | 54 | 89 | 52 | 88 | 48 | 88 | 50 | 89 | 58 | 89 | 60 | 91 | 60 | 92 | 61 | 90 | 57 | 90 | 56 | 89 | 57 | 89 | 56 |
| | Gainesville | 19 | 19 | 90 | 60 | 90 | 56 | 91 | 53 | 91 | 50 | 91 | 50 | 88 | 56 | 89 | 59 | 91 | 60 | 96 | 64 | 94 | 61 | 93 | 60 | 91 | 61 | 91 | 58 |
| | Jacksonville | 66 | 66 | 88 | 58 | 87 | 54 | 87 | 50 | 87 | 48 | 86 | 51 | 88 | 57 | 89 | 59 | 91 | 61 | 92 | 63 | 91 | 59 | 90 | 57 | 89 | 59 | 89 | 56 |
| | Key West | 54 | 54 | 82 | 69 | 81 | 67 | 80 | 66 | 77 | 64 | 77 | 65 | 78 | 68 | 77 | 67 | 78 | 67 | 81 | 70 | 82 | 69 | 83 | 69 | 83 | 70 | 80 | 68 |
| | Miami | 38 | 38 | 84 | 60 | 84 | 58 | 82 | 56 | 79 | 54 | 80 | 58 | 84 | 65 | 83 | 63 | 85 | 65 | 87 | 67 | 86 | 63 | 85 | 62 | 84 | 60 | 83 | 61 |
| | Orlando | 39 | 39 | 88 | 57 | 88 | 53 | 89 | 50 | 88 | 47 | 88 | 49 | 90 | 58 | 91 | 59 | 93 | 60 | 92 | 61 | 90 | 57 | 90 | 56 | 89 | 58 | 90 | 55 |
| | Pensacola | 39 | 39 | 82 | 65 | 82 | 61 | 84 | 62 | 86 | 60 | 87 | 62 | 84 | 61 | 86 | 65 | 87 | 66 | 85 | 63 | 82 | 57 | 82 | 61 | 81 | 65 | 84 | 62 |
| | Tallahassee | 41 | 41 | 87 | 58 | 87 | 54 | 89 | 51 | 91 | 47 | 90 | 50 | 91 | 56 | 94 | 61 | 95 | 61 | 93 | 58 | 91 | 53 | 90 | 55 | 88 | 57 | 90 | 55 |
| | Tampa | 39 | 39 | 87 | 60 | 86 | 57 | 87 | 55 | 86 | 52 | 85 | 53 | 86 | 60 | 87 | 64 | 90 | 65 | 91 | 63 | 89 | 58 | 88 | 58 | 88 | 60 | 88 | 59 |
| | Vero Beach | 39 | 39 | 88 | 60 | 88 | 56 | 86 | 56 | 84 | 55 | 84 | 58 | 80 | 60 | 83 | 59 | 85 | 60 | 82 | 59 | 81 | 58 | 79 | 56 | 81 | 56 | 83 | 58 |
| | West Palm Beach | 38 | 38 | 84 | 59 | 83 | 57 | 82 | 56 | 79 | 55 | 80 | 59 | 84 | 66 | 85 | 64 | 86 | 64 | 87 | 66 | 84 | 63 | 84 | 61 | 84 | 60 | 83 | 61 |
| GA | Athens | 47 | 47 | 81 | 58 | 80 | 54 | 81 | 53 | 83 | 50 | 86 | 54 | 88 | 56 | 90 | 58 | 92 | 59 | 92 | 59 | 89 | 55 | 85 | 54 | 82 | 58 | 86 | 56 |
| | Atlanta | 42 | 42 | 79 | 59 | 77 | 55 | 77 | 52 | 79 | 50 | 82 | 53 | 84 | 56 | 88 | 59 | 89 | 60 | 88 | 59 | 84 | 54 | 82 | 56 | 80 | 59 | 82 | 56 |
| | Augusta | 38 | 38 | 84 | 54 | 83 | 49 | 84 | 48 | 86 | 45 | 87 | 49 | 87 | 52 | 89 | 55 | 92 | 57 | 92 | 55 | 91 | 50 | 89 | 50 | 85 | 53 | 87 | 51 |
| | Columbus | 57 | 57 | 84 | 59 | 83 | 54 | 84 | 51 | 85 | 48 | 85 | 50 | 85 | 53 | 89 | 57 | 90 | 56 | 89 | 56 | 88 | 52 | 87 | 54 | 84 | 58 | 86 | 54 |
| | Macon | 38 | 38 | 84 | 58 | 84 | 54 | 86 | 52 | 88 | 49 | 88 | 50 | 88 | 54 | 90 | 57 | 93 | 57 | 93 | 58 | 90 | 52 | 88 | 53 | 85 | 57 | 88 | 54 |
| | Savannah | 38 | 38 | 83 | 55 | 82 | 51 | 84 | 49 | 84 | 46 | 86 | 51 | 88 | 56 | 89 | 58 | 91 | 60 | 91 | 60 | 89 | 54 | 87 | 53 | 84 | 55 | 87 | 54 |
| HI | Hilo | 53 | 53 | 79 | 67 | 78 | 66 | 80 | 67 | 81 | 69 | 80 | 68 | 79 | 66 | 81 | 68 | 81 | 69 | 80 | 68 | 80 | 69 | 82 | 71 | 81 | 69 | 80 | 68 |
| | Honolulu | 33 | 33 | 81 | 61 | 78 | 59 | 74 | 57 | 70 | 56 | 68 | 54 | 67 | 52 | 68 | 52 | 68 | 52 | 69 | 53 | 71 | 56 | 75 | 59 | 79 | 61 | 72 | 56 |
| | Kahului | 38 | 38 | 83 | 62 | 81 | 60 | 77 | 59 | 75 | 58 | 71 | 56 | 68 | 53 | 71 | 56 | 72 | 56 | 71 | 55 | 74 | 57 | 77 | 60 | 80 | 61 | 75 | 58 |
| | Lihue | 53 | 53 | 82 | 67 | 80 | 66 | 78 | 66 | 77 | 67 | 75 | 66 | 75 | 66 | 76 | 66 | 76 | 66 | 77 | 65 | 78 | 68 | 80 | 69 | 81 | 69 | 78 | 67 |
| ID | Boise | 63 | 63 | 80 | 70 | 79 | 60 | 73 | 44 | 70 | 36 | 69 | 34 | 66 | 29 | 54 | 21 | 52 | 22 | 58 | 29 | 66 | 38 | 77 | 60 | 81 | 71 | 69 | 43 |
| | Lewiston | 44 | 44 | 80 | 70 | 79 | 61 | 76 | 50 | 74 | 43 | 75 | 40 | 73 | 36 | 60 | 25 | 57 | 25 | 66 | 32 | 78 | 49 | 82 | 68 | 81 | 74 | 74 | 48 |
| | Pocatello | 39 | 39 | 80 | 71 | 80 | 62 | 76 | 50 | 71 | 38 | 71 | 35 | 71 | 32 | 65 | 25 | 62 | 23 | 66 | 28 | 70 | 37 | 77 | 60 | 80 | 72 | 72 | 44 |
| IL | Cairo | 22 | 22 | 80 | 67 | 79 | 64 | 78 | 59 | 77 | 54 | 82 | 57 | 83 | 57 | 84 | 59 | 87 | 59 | 87 | 57 | 85 | 53 | 80 | 58 | 79 | 66 | 82 | 59 |
| | Chicago | 44 | 44 | 78 | 70 | 78 | 67 | 79 | 63 | 77 | 58 | 77 | 57 | 79 | 58 | 82 | 60 | 86 | 61 | 85 | 61 | 81 | 59 | 80 | 66 | 80 | 71 | 80 | 63 |
| | Moline | 42 | 42 | 76 | 69 | 77 | 67 | 78 | 63 | 78 | 58 | 80 | 57 | 82 | 58 | 85 | 62 | 89 | 64 | 87 | 62 | 81 | 59 | 80 | 66 | 79 | 71 | 81 | 63 |
| | Peoria | 43 | 43 | 80 | 71 | 81 | 69 | 81 | 65 | 78 | 59 | 81 | 60 | 82 | 60 | 86 | 63 | 89 | 65 | 87 | 63 | 84 | 61 | 83 | 69 | 83 | 73 | 83 | 65 |
| | Rockford | 39 | 39 | 81 | 73 | 81 | 69 | 81 | 65 | 80 | 60 | 80 | 58 | 82 | 60 | 86 | 62 | 91 | 64 | 90 | 63 | 85 | 61 | 83 | 69 | 83 | 74 | 83 | 65 |
| | Springfield | 43 | 43 | 80 | 71 | 80 | 70 | 81 | 66 | 79 | 60 | 81 | 58 | 83 | 59 | 86 | 63 | 89 | 64 | 88 | 61 | 83 | 59 | 82 | 67 | 83 | 73 | 83 | 64 |
| IN | Evansville | 41 | 41 | 79 | 69 | 79 | 66 | 79 | 62 | 78 | 58 | 82 | 59 | 83 | 59 | 86 | 61 | 88 | 61 | 88 | 60 | 84 | 57 | 80 | 64 | 80 | 70 | 82 | 62 |
| | Fort Wayne | 41 | 41 | 81 | 72 | 81 | 69 | 81 | 63 | 79 | 57 | 80 | 55 | 81 | 55 | 85 | 56 | 89 | 59 | 89 | 57 | 86 | 58 | 84 | 68 | 83 | 75 | 83 | 62 |
| | Indianapolis | 43 | 43 | 81 | 71 | 81 | 67 | 80 | 61 | 79 | 56 | 82 | 57 | 83 | 57 | 87 | 60 | 90 | 60 | 90 | 57 | 87 | 57 | 84 | 66 | 83 | 72 | 84 | 62 |
| | South Bend | 39 | 39 | 82 | 73 | 81 | 68 | 80 | 61 | 78 | 56 | 79 | 54 | 81 | 55 | 84 | 57 | 89 | 59 | 89 | 59 | 84 | 60 | 83 | 68 | 83 | 75 | 83 | 62 |
| IA | Des Moines | 41 | 41 | 77 | 70 | 79 | 67 | 78 | 63 | 77 | 58 | 78 | 59 | 80 | 60 | 83 | 61 | 85 | 63 | 84 | 62 | 79 | 59 | 79 | 66 | 80 | 72 | 80 | 63 |
| | Dubuque | 35 | 35 | 78 | 72 | 79 | 69 | 79 | 65 | 77 | 60 | 79 | 61 | 83 | 64 | 86 | 65 | 89 | 66 | 87 | 65 | 81 | 62 | 81 | 69 | 82 | 74 | 82 | 66 |
| | Sioux City | 43 | 43 | 78 | 71 | 80 | 69 | 80 | 66 | 78 | 57 | 79 | 58 | 82 | 61 | 86 | 63 | 89 | 66 | 86 | 63 | 81 | 58 | 82 | 67 | 82 | 73 | 82 | 64 |
| | Waterloo | 43 | 43 | 78 | 72 | 80 | 71 | 82 | 68 | 81 | 59 | 81 | 58 | 84 | 60 | 87 | 63 | 90 | 64 | 89 | 63 | 83 | 61 | 83 | 69 | 82 | 74 | 83 | 65 |
| KS | Concordia | 40 | 40 | 78 | 67 | 79 | 64 | 78 | 59 | 80 | 57 | 84 | 61 | 84 | 59 | 81 | 56 | 83 | 59 | 82 | 58 | 78 | 55 | 80 | 63 | 79 | 67 | 80 | 61 |
| | Dodge City | 39 | 39 | 76 | 61 | 76 | 58 | 76 | 54 | 76 | 51 | 81 | 56 | 80 | 53 | 76 | 50 | 79 | 52 | 79 | 53 | 75 | 51 | 77 | 57 | 76 | 60 | 77 | 55 |
| | Goodland | 36 | 36 | 76 | 61 | 77 | 53 | 78 | 48 | 78 | 43 | 84 | 48 | 82 | 42 | 82 | 40 | 83 | 42 | 79 | 41 | 75 | 45 | 76 | 59 | 75 | 61 | 79 | 48 |
| | Topeka | 38 | 38 | 78 | 66 | 78 | 64 | 78 | 60 | 80 | 58 | 84 | 62 | 86 | 63 | 85 | 63 | 87 | 62 | 87 | 61 | 83 | 58 | 81 | 64 | 80 | 67 | 82 | 62 |
| | Wichita | 49 | 49 | 79 | 65 | 78 | 62 | 77 | 57 | 78 | 56 | 83 | 60 | 83 | 56 | 79 | 53 | 79 | 53 | 81 | 57 | 80 | 56 | 79 | 60 | 80 | 65 | 80 | 58 |
| KY | Greater Cincinnati | 40 | 40 | 80 | 69 | 78 | 64 | 78 | 59 | 77 | 54 | 81 | 56 | 84 | 57 | 86 | 58 | 89 | 58 | 89 | 57 | 84 | 56 | 80 | 63 | 81 | 69 | 82 | 60 |
| | Jackson | 21 | 21 | 78 | 64 | 76 | 60 | 73 | 53 | 71 | 48 | 82 | 57 | 86 | 62 | 90 | 63 | 91 | 62 | 89 | 60 | 83 | 55 | 76 | 58 | 79 | 65 | 81 | 59 |
| | Lexington | 39 | 39 | 81 | 69 | 79 | 64 | 77 | 58 | 76 | 55 | 81 | 58 | 84 | 58 | 86 | 59 | 88 | 59 | 88 | 58 | 85 | 57 | 81 | 63 | 81 | 68 | 82 | 60 |
| | Louisville | 42 | 42 | 78 | 65 | 77 | 61 | 76 | 57 | 76 | 52 | 82 | 56 | 83 | 57 | 85 | 58 | 87 | 57 | 88 | 57 | 85 | 55 | 80 | 61 | 79 | 66 | 81 | 59 |
| | Paducah | 18 | 18 | 81 | 71 | 80 | 68 | 77 | 65 | 80 | 62 | 87 | 66 | 88 | 67 | 90 | 69 | 92 | 69 | 91 | 67 | 86 | 65 | 82 | 68 | 82 | 71 | 85 | 67 |
| LA | Baton Rouge | 43 | 43 | 85 | 67 | 84 | 62 | 86 | 61 | 89 | 60 | 91 | 62 | 92 | 63 | 92 | 66 | 92 | 66 | 91 | 64 | 89 | 59 | 89 | 63 | 87 | 66 | 89 | 63 |
| | Lake Charles | 38 | 38 | 87 | 72 | 87 | 67 | 89 | 67 | 90 | 65 | 93 | 67 | 93 | 68 | 94 | 69 | 94 | 68 | 92 | 67 | 91 | 62 | 89 | 66 | 89 | 70 | 91 | 67 |
| | New Orleans | 54 | 54 | 85 | 68 | 84 | 65 | 84 | 63 | 87 | 62 | 89 | 62 | 90 | 65 | 91 | 68 | 91 | 68 | 89 | 67 | 87 | 62 | 86 | 64 | 85 | 68 | 87 | 65 |
| | Shreveport | 50 | 50 | 83 | 66 | 82 | 62 | 83 | 60 | 86 | 60 | 90 | 63 | 90 | 62 | 90 | 61 | 90 | 59 | 89 | 60 | 88 | 59 | 86 | 62 | 85 | 65 | 87 | 62 |
| ME | Caribou | 58 | 58 | 75 | 67 | 75 | 63 | 76 | 60 | 76 | 56 | 74 | 52 | 78 | 56 | 83 | 58 | 86 | 59 | 88 | 61 | 86 | 62 | 85 | 71 | 80 | 71 | 80 | 61 |
| | Portland | 62 | 62 | 76 | 61 | 76 | 57 | 75 | 58 | 73 | 55 | 75 | 58 | 78 | 60 | 80 | 59 | 83 | 59 | 86 | 60 | 84 | 59 | 82 | 62 | 79 | 61 | 79 | 59 |
| MD | Baltimore | 49 | 49 | 73 | 57 | 72 | 54 | 72 | 51 | 72 | 49 | 77 | 52 | 77 | 52 | 80 | 53 | 84 | 55 | 85 | 55 | 84 | 54 | 79 | 54 | 75 | 57 | 78 | 54 |
| MA | Blue Hill | 49 | 49 | 76 | 62 | 75 | 59 | 75 | 57 | 72 | 52 | 75 | 55 | 78 | 58 | 80 | 56 | 82 | 58 | 83 | 59 | 80 | 56 | 79 | 60 | 75 | 61 | 78 | 58 |
| | Boston | 38 | 38 | 69 | 58 | 68 | 56 | 70 | 57 | 69 | 55 | 72 | 59 | 73 | 58 | 74 | 57 | 77 | 59 | 79 | 61 | 77 | 58 | 74 | 59 | 70 | 59 | 73 | 58 |
| | Worcester | 47 | 47 | 73 | 60 | 72 | 57 | 71 | 55 | 68 | 50 | 70 | 51 | 75 | 57 | 77 | 58 | 79 | 59 | 82 | 61 | 78 | 56 | 78 | 61 | 75 | 62 | 75 | 57 |
| MI | Alpena | 43 | 43 | 81 | 71 | 80 | 66 | 83 | 61 | 80 | 54 | 78 | 52 | 80 | 52 | 85 | 54 | 90 | 58 | 91 | 61 | 87 | 61 | 84 | 69 | 83 | 73 | 83 | 61 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Detroit | 44 | 44 | 80 | 70 | 79 | 65 | 79 | 60 | 78 | 54 | 78 | 53 | 79 | 54 | 82 | 54 | 86 | 57 | 87 | 57 | 84 | 57 | 82 | 65 | 81 | 70 | 81 | 60 |
| | Flint | 39 | 39 | 81 | 72 | 80 | 68 | 80 | 61 | 78 | 56 | 78 | 54 | 81 | 56 | 84 | 55 | 89 | 58 | 90 | 59 | 85 | 60 | 83 | 68 | 82 | 74 | 83 | 62 |
| | Grand Rapids | 39 | 39 | 82 | 73 | 81 | 68 | 81 | 63 | 79 | 57 | 79 | 53 | 82 | 56 | 84 | 56 | 89 | 59 | 89 | 60 | 86 | 62 | 83 | 70 | 83 | 75 | 83 | 63 |
| | Houghton Lake | 38 | 38 | 84 | 73 | 83 | 68 | 84 | 62 | 80 | 54 | 78 | 50 | 82 | 55 | 86 | 55 | 91 | 60 | 92 | 62 | 88 | 64 | 87 | 73 | 85 | 76 | 85 | 63 |
| | Lansing | 39 | 39 | 82 | 73 | 81 | 68 | 81 | 62 | 79 | 56 | 78 | 54 | 82 | 57 | 86 | 57 | 91 | 60 | 91 | 61 | 88 | 63 | 85 | 70 | 85 | 76 | 84 | 63 |
| | Muskegon | 42 | 42 | 81 | 75 | 81 | 70 | 80 | 63 | 77 | 57 | 76 | 55 | 81 | 58 | 84 | 59 | 89 | 62 | 89 | 63 | 84 | 65 | 81 | 70 | 81 | 75 | 82 | 64 |
| | Sault Ste. Marie | 61 | 61 | 81 | 74 | 81 | 70 | 82 | 66 | 80 | 59 | 79 | 55 | 85 | 62 | 88 | 62 | 92 | 63 | 92 | 67 | 89 | 67 | 86 | 75 | 84 | 77 | 85 | 66 |
| MN | Duluth | 41 | 41 | 78 | 72 | 77 | 68 | 78 | 66 | 76 | 59 | 76 | 56 | 82 | 63 | 85 | 63 | 88 | 66 | 88 | 67 | 82 | 65 | 81 | 72 | 80 | 75 | 81 | 66 |
| | International Falls | 60 | 60 | 75 | 70 | 74 | 66 | 76 | 62 | 76 | 55 | 77 | 53 | 83 | 59 | 88 | 60 | 91 | 63 | 90 | 66 | 85 | 65 | 84 | 75 | 80 | 75 | 82 | 64 |
| | Minneapolis-St.Paul | 43 | 43 | 76 | 69 | 76 | 67 | 76 | 64 | 74 | 55 | 75 | 55 | 78 | 58 | 81 | 59 | 84 | 61 | 84 | 63 | 80 | 61 | 80 | 68 | 78 | 71 | 78 | 63 |
| | Rochester | 42 | 42 | 81 | 76 | 81 | 74 | 82 | 71 | 80 | 63 | 80 | 60 | 83 | 62 | 86 | 65 | 89 | 67 | 88 | 67 | 83 | 64 | 84 | 73 | 84 | 78 | 83 | 68 |
| | Saint Cloud | 50 | 50 | 78 | 71 | 79 | 68 | 81 | 65 | 80 | 55 | 80 | 54 | 85 | 59 | 88 | 59 | 91 | 62 | 90 | 63 | 85 | 61 | 83 | 70 | 80 | 73 | 83 | 63 |
| MS | Jackson | 39 | 39 | 86 | 68 | 86 | 63 | 86 | 60 | 90 | 58 | 91 | 60 | 91 | 61 | 93 | 64 | 94 | 63 | 93 | 62 | 92 | 59 | 90 | 62 | 87 | 66 | 90 | 62 |
| | Meridian | 38 | 38 | 86 | 65 | 86 | 61 | 87 | 58 | 90 | 58 | 91 | 61 | 91 | 61 | 92 | 64 | 93 | 63 | 91 | 62 | 91 | 58 | 89 | 60 | 87 | 64 | 89 | 61 |
| | Tupelo | 19 | 19 | 82 | 70 | 80 | 67 | 80 | 61 | 84 | 61 | 88 | 65 | 89 | 65 | 90 | 66 | 91 | 66 | 90 | 65 | 88 | 63 | 85 | 67 | 83 | 70 | 86 | 66 |
| MO | Columbia | 33 | 33 | 80 | 69 | 80 | 67 | 78 | 62 | 78 | 59 | 85 | 65 | 87 | 65 | 87 | 63 | 88 | 63 | 87 | 63 | 84 | 62 | 81 | 66 | 81 | 70 | 83 | 64 |
| | Kansas City | 30 | 30 | 77 | 67 | 78 | 66 | 77 | 62 | 77 | 59 | 83 | 63 | 85 | 64 | 85 | 64 | 86 | 64 | 85 | 64 | 80 | 60 | 79 | 66 | 79 | 68 | 81 | 64 |
| | St. Louis | 42 | 42 | 81 | 68 | 80 | 65 | 79 | 61 | 77 | 58 | 81 | 59 | 82 | 59 | 83 | 60 | 86 | 60 | 86 | 61 | 82 | 59 | 81 | 65 | 82 | 69 | 82 | 62 |
| | Springfield | 42 | 42 | 78 | 65 | 78 | 63 | 77 | 59 | 79 | 59 | 85 | 63 | 87 | 64 | 87 | 62 | 87 | 60 | 87 | 63 | 82 | 59 | 80 | 63 | 80 | 66 | 82 | 62 |
| MT | Billings | 43 | 43 | 65 | 57 | 66 | 51 | 68 | 46 | 69 | 42 | 70 | 42 | 72 | 39 | 64 | 32 | 61 | 30 | 65 | 37 | 64 | 43 | 65 | 54 | 65 | 57 | 66 | 44 |
| | Glasgow | 38 | 38 | 77 | 73 | 79 | 70 | 80 | 58 | 75 | 42 | 74 | 40 | 77 | 41 | 74 | 35 | 69 | 32 | 72 | 37 | 75 | 47 | 80 | 65 | 79 | 73 | 76 | 51 |
| | Great Falls | 41 | 41 | 67 | 61 | 67 | 55 | 69 | 49 | 69 | 42 | 71 | 41 | 72 | 41 | 68 | 31 | 66 | 30 | 68 | 37 | 65 | 44 | 65 | 56 | 65 | 60 | 68 | 46 |
| | Helena | 37 | 37 | 72 | 64 | 73 | 54 | 73 | 46 | 70 | 39 | 71 | 38 | 73 | 38 | 67 | 30 | 68 | 30 | 72 | 35 | 73 | 43 | 74 | 58 | 73 | 66 | 72 | 45 |
| | Kalispell | 38 | 38 | 82 | 76 | 82 | 67 | 81 | 54 | 78 | 43 | 80 | 44 | 85 | 46 | 84 | 36 | 82 | 35 | 84 | 42 | 85 | 53 | 84 | 73 | 83 | 79 | 82 | 54 |
| | Missoula | 42 | 42 | 85 | 76 | 85 | 66 | 83 | 51 | 80 | 42 | 81 | 42 | 83 | 42 | 78 | 31 | 75 | 30 | 82 | 38 | 85 | 50 | 86 | 71 | 86 | 80 | 82 | 52 |
| NE | Grand Island | 41 | 41 | 77 | 66 | 78 | 64 | 79 | 60 | 79 | 54 | 82 | 57 | 82 | 56 | 83 | 58 | 85 | 59 | 84 | 57 | 79 | 53 | 80 | 61 | 79 | 66 | 81 | 59 |
| | Lincoln | 30 | 30 | 78 | 68 | 80 | 66 | 80 | 63 | 80 | 58 | 83 | 61 | 83 | 59 | 83 | 60 | 86 | 63 | 84 | 61 | 81 | 58 | 81 | 64 | 81 | 68 | 82 | 62 |
| | Norfolk | 57 | 57 | 76 | 66 | 79 | 66 | 80 | 63 | 78 | 53 | 80 | 54 | 82 | 56 | 83 | 57 | 86 | 59 | 83 | 56 | 79 | 53 | 79 | 61 | 79 | 67 | 80 | 59 |
| | North Platte | 38 | 38 | 80 | 66 | 79 | 63 | 80 | 58 | 80 | 53 | 83 | 57 | 83 | 58 | 83 | 57 | 85 | 58 | 83 | 54 | 81 | 52 | 81 | 60 | 80 | 64 | 81 | 58 |
| | Omaha Eppley AP | 38 | 38 | 79 | 68 | 77 | 64 | 78 | 61 | 77 | 57 | 80 | 59 | 82 | 61 | 85 | 63 | 87 | 65 | 86 | 63 | 81 | 59 | 81 | 66 | 81 | 70 | 81 | 63 |
| | Omaha (North) | 9 | 9 | 75 | 63 | 77 | 63 | 78 | 59 | 76 | 53 | 79 | 55 | 79 | 56 | 85 | 63 | 86 | 62 | 84 | 60 | 78 | 55 | 79 | 65 | 77 | 67 | 79 | 60 |
| | Scottsbluff | 37 | 37 | 74 | 58 | 75 | 48 | 77 | 44 | 76 | 41 | 80 | 42 | 80 | 39 | 81 | 37 | 83 | 39 | 80 | 37 | 76 | 42 | 77 | 53 | 75 | 58 | 78 | 45 |
| | Valentine | 35 | 35 | 76 | 63 | 77 | 64 | 79 | 61 | 77 | 54 | 78 | 54 | 79 | 54 | 78 | 53 | 79 | 53 | 77 | 51 | 75 | 52 | 76 | 59 | 75 | 62 | 77 | 57 |
| NV | Elko | 35 | 35 | 78 | 60 | 79 | 52 | 77 | 41 | 72 | 33 | 71 | 30 | 63 | 24 | 54 | 18 | 53 | 19 | 59 | 22 | 64 | 27 | 74 | 47 | 76 | 58 | 68 | 36 |
| | Ely | 50 | 50 | 73 | 55 | 75 | 50 | 72 | 42 | 69 | 34 | 67 | 30 | 58 | 23 | 52 | 21 | 55 | 23 | 59 | 24 | 64 | 31 | 71 | 46 | 72 | 54 | 65 | 36 |
| | Las Vegas | 42 | 42 | 55 | 32 | 51 | 28 | 45 | 23 | 35 | 16 | 32 | 14 | 24 | 11 | 28 | 15 | 33 | 17 | 34 | 17 | 36 | 20 | 45 | 27 | 53 | 32 | 39 | 21 |
| | Reno | 39 | 39 | 79 | 50 | 74 | 40 | 69 | 33 | 65 | 28 | 64 | 25 | 62 | 22 | 60 | 18 | 61 | 19 | 66 | 22 | 70 | 27 | 74 | 40 | 77 | 50 | 68 | 31 |
| | Winnemucca | 53 | 53 | 79 | 58 | 77 | 47 | 73 | 38 | 67 | 30 | 64 | 27 | 58 | 22 | 46 | 16 | 45 | 16 | 53 | 20 | 62 | 28 | 74 | 46 | 79 | 58 | 65 | 34 |
| NH | Concord | 37 | 37 | 76 | 59 | 76 | 55 | 77 | 53 | 75 | 46 | 77 | 47 | 81 | 52 | 84 | 51 | 88 | 52 | 90 | 55 | 88 | 52 | 84 | 59 | 80 | 61 | 81 | 53 |
| | Mt. Washington | 34 | 34 | 83 | 83 | 81 | 83 | 84 | 84 | 85 | 84 | 84 | 81 | 86 | 82 | 88 | 84 | 87 | 85 | 82 | 83 | 80 | 79 | 82 | 82 | 82 | 82 | 84 | 83 |
| NJ | Atlantic City AP | 38 | 38 | 79 | 59 | 79 | 55 | 77 | 54 | 77 | 52 | 79 | 55 | 81 | 56 | 83 | 57 | 87 | 58 | 88 | 58 | 88 | 56 | 84 | 57 | 79 | 59 | 82 | 56 |
| | Newark | 37 | 37 | 73 | 59 | 72 | 54 | 70 | 51 | 66 | 48 | 70 | 51 | 71 | 52 | 72 | 51 | 76 | 53 | 78 | 55 | 79 | 53 | 76 | 56 | 74 | 58 | 73 | 53 |
| NM | Albuquerque | 42 | 42 | 68 | 39 | 63 | 31 | 55 | 24 | 48 | 19 | 47 | 19 | 46 | 18 | 59 | 27 | 65 | 31 | 61 | 30 | 60 | 30 | 64 | 36 | 69 | 43 | 59 | 29 |
| | Clayton | 45 | 45 | 64 | 48 | 65 | 42 | 65 | 37 | 64 | 32 | 70 | 37 | 71 | 35 | 76 | 41 | 77 | 42 | 72 | 40 | 65 | 41 | 64 | 47 | 62 | 53 | 68 | 41 |
| | Roswell | 29 | 29 | 71 | 41 | 65 | 33 | 58 | 26 | 54 | 22 | 58 | 24 | 65 | 27 | 68 | 32 | 73 | 35 | 74 | 38 | 69 | 36 | 69 | 39 | 69 | 42 | 66 | 33 |
| NY | Albany | 37 | 37 | 78 | 64 | 77 | 58 | 76 | 54 | 72 | 49 | 75 | 53 | 79 | 56 | 81 | 55 | 86 | 58 | 89 | 59 | 86 | 58 | 82 | 63 | 80 | 65 | 80 | 58 |
| | Binghamton | 51 | 51 | 80 | 71 | 79 | 66 | 79 | 62 | 76 | 56 | 78 | 56 | 83 | 59 | 84 | 58 | 89 | 60 | 90 | 63 | 85 | 62 | 82 | 69 | 82 | 73 | 82 | 63 |
| | Buffalo | 42 | 42 | 79 | 73 | 79 | 69 | 80 | 65 | 77 | 58 | 76 | 56 | 78 | 57 | 79 | 55 | 83 | 58 | 84 | 60 | 82 | 60 | 80 | 68 | 81 | 72 | 80 | 63 |
| | Islip | 42 | 42 | 76 | 62 | 76 | 58 | 77 | 57 | 76 | 55 | 76 | 56 | 71 | 53 | 74 | 56 | 77 | 56 | 79 | 56 | 78 | 54 | 74 | 55 | 70 | 54 | 75 | 56 |
| | New York C.Park | 68 | 68 | 68 | 60 | 68 | 57 | 68 | 54 | 67 | 51 | 71 | 53 | 74 | 56 | 75 | 55 | 78 | 57 | 79 | 57 | 76 | 55 | 73 | 59 | 69 | 60 | 72 | 56 |
| | New York (JFK AP) | 41 | 41 | 71 | 60 | 71 | 57 | 71 | 56 | 70 | 55 | 73 | 59 | 75 | 60 | 75 | 59 | 78 | 60 | 80 | 60 | 78 | 57 | 76 | 59 | 72 | 60 | 74 | 58 |
| | New York (Laguardia AP) | 40 | 40 | 67 | 58 | 65 | 55 | 67 | 53 | 67 | 51 | 71 | 53 | 72 | 54 | 72 | 53 | 75 | 55 | 76 | 57 | 74 | 55 | 71 | 58 | 68 | 59 | 70 | 55 |
| | Rochester | 39 | 39 | 78 | 69 | 79 | 66 | 79 | 62 | 77 | 55 | 77 | 54 | 80 | 56 | 83 | 55 | 87 | 58 | 88 | 61 | 85 | 60 | 81 | 67 | 81 | 72 | 81 | 61 |
| | Syracuse | 39 | 39 | 77 | 69 | 78 | 64 | 78 | 60 | 76 | 53 | 76 | 55 | 79 | 56 | 81 | 56 | 86 | 58 | 87 | 61 | 84 | 61 | 81 | 67 | 81 | 71 | 80 | 61 |
| NC | Asheville | 38 | 38 | 85 | 59 | 83 | 55 | 84 | 53 | 85 | 50 | 91 | 56 | 94 | 60 | 95 | 62 | 97 | 62 | 97 | 62 | 93 | 56 | 88 | 56 | 85 | 59 | 90 | 57 |
| | Cape Hatteras | 45 | 45 | 80 | 68 | 80 | 65 | 80 | 63 | 78 | 60 | 81 | 65 | 83 | 68 | 85 | 70 | 86 | 70 | 84 | 68 | 82 | 65 | 81 | 65 | 80 | 67 | 82 | 66 |
| | Charlotte | 42 | 42 | 78 | 55 | 76 | 52 | 78 | 49 | 78 | 46 | 82 | 52 | 84 | 55 | 86 | 56 | 88 | 57 | 89 | 57 | 86 | 53 | 83 | 53 | 79 | 55 | 82 | 53 |
| | Greensboro-Wnstn-Slm-HPT | 39 | 39 | 78 | 56 | 76 | 52 | 77 | 50 | 78 | 48 | 82 | 54 | 84 | 56 | 87 | 59 | 90 | 60 | 90 | 59 | 88 | 54 | 83 | 53 | 79 | 56 | 83 | 55 |
| | Raleigh | 38 | 38 | 80 | 55 | 78 | 52 | 80 | 49 | 81 | 46 | 85 | 54 | 87 | 56 | 89 | 58 | 91 | 59 | 92 | 59 | 90 | 53 | 85 | 52 | 81 | 55 | 85 | 54 |
| | Wilmington | 39 | 39 | 81 | 56 | 80 | 52 | 82 | 52 | 81 | 48 | 84 | 55 | 85 | 60 | 87 | 63 | 90 | 64 | 90 | 62 | 89 | 56 | 85 | 53 | 82 | 55 | 85 | 56 |
| ND | Bismarck | 43 | 43 | 76 | 71 | 79 | 70 | 81 | 66 | 79 | 55 | 79 | 53 | 84 | 57 | 84 | 53 | 83 | 52 | 82 | 54 | 79 | 55 | 81 | 67 | 79 | 72 | 81 | 61 |
| | Fargo | 43 | 43 | 76 | 73 | 78 | 74 | 82 | 72 | 79 | 59 | 76 | 53 | 82 | 59 | 85 | 59 | 86 | 58 | 84 | 61 | 80 | 62 | 82 | 72 | 79 | 75 | 81 | 65 |
| | Williston | 41 | 41 | 79 | 74 | 81 | 73 | 83 | 67 | 79 | 55 | 77 | 52 | 81 | 54 | 80 | 51 | 77 | 51 | 79 | 55 | 79 | 58 | 82 | 71 | 81 | 75 | 80 | 61 |
| OH | Akron | 39 | 39 | 80 | 71 | 79 | 66 | 78 | 60 | 76 | 54 | 78 | 56 | 81 | 57 | 84 | 56 | 88 | 59 | 88 | 60 | 84 | 59 | 80 | 66 | 80 | 71 | 81 | 61 |

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**Table 3A.12 (Continued)**

| State | Station | Years | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A | M | A |
| | Cleveland | 42 | 42 | 79 | 70 | 78 | 68 | 79 | 63 | 77 | 58 | 78 | 58 | 80 | 58 | 82 | 57 | 86 | 60 | 85 | 60 | 81 | 60 | 78 | 66 | 78 | 71 | 80 | 62 |
| | Columbus | 43 | 43 | 78 | 68 | 77 | 64 | 76 | 57 | 76 | 53 | 79 | 55 | 81 | 55 | 84 | 56 | 87 | 57 | 87 | 57 | 83 | 55 | 80 | 63 | 79 | 69 | 81 | 59 |
| | Dayton | 39 | 39 | 79 | 70 | 79 | 66 | 79 | 61 | 77 | 55 | 78 | 55 | 80 | 55 | 82 | 56 | 87 | 57 | 87 | 56 | 83 | 57 | 81 | 65 | 81 | 71 | 81 | 60 |
| | Mansfield | 36 | 36 | 82 | 73 | 81 | 69 | 80 | 63 | 78 | 57 | 79 | 57 | 81 | 58 | 83 | 58 | 88 | 61 | 88 | 60 | 83 | 59 | 81 | 67 | 83 | 74 | 82 | 63 |
| | Toledo | 47 | 47 | 81 | 70 | 80 | 66 | 81 | 60 | 79 | 54 | 80 | 53 | 82 | 54 | 85 | 55 | 91 | 59 | 91 | 57 | 86 | 57 | 83 | 66 | 83 | 73 | 84 | 60 |
| | Youngstown | 55 | 55 | 81 | 72 | 80 | 68 | 80 | 63 | 77 | 56 | 79 | 54 | 82 | 56 | 85 | 56 | 89 | 57 | 89 | 59 | 85 | 58 | 82 | 67 | 82 | 72 | 83 | 61 |
| OK | Oklahoma City | 37 | 37 | 78 | 62 | 77 | 60 | 76 | 57 | 77 | 56 | 83 | 62 | 84 | 61 | 80 | 55 | 80 | 55 | 83 | 59 | 80 | 57 | 80 | 60 | 78 | 62 | 80 | 59 |
| | Tulsa | 42 | 42 | 78 | 63 | 76 | 59 | 75 | 56 | 77 | 55 | 85 | 62 | 85 | 63 | 81 | 57 | 82 | 56 | 85 | 62 | 82 | 57 | 80 | 61 | 79 | 63 | 81 | 60 |
| OR | Astoria | 49 | 49 | 87 | 78 | 86 | 74 | 88 | 71 | 89 | 70 | 89 | 70 | 90 | 71 | 90 | 70 | 91 | 71 | 91 | 70 | 90 | 73 | 87 | 78 | 86 | 81 | 89 | 73 |
| | Eugene | 45 | 45 | 92 | 80 | 92 | 72 | 91 | 65 | 90 | 58 | 91 | 55 | 90 | 50 | 87 | 39 | 88 | 39 | 89 | 43 | 93 | 62 | 93 | 78 | 92 | 84 | 91 | 60 |
| | Medford | 41 | 41 | 90 | 70 | 88 | 57 | 86 | 50 | 84 | 45 | 83 | 39 | 78 | 33 | 74 | 26 | 74 | 26 | 78 | 29 | 86 | 42 | 91 | 67 | 91 | 76 | 84 | 47 |
| | Pendleton | 61 | 61 | 80 | 75 | 78 | 65 | 74 | 50 | 71 | 42 | 70 | 38 | 66 | 33 | 55 | 24 | 54 | 26 | 61 | 32 | 72 | 47 | 80 | 70 | 81 | 78 | 70 | 48 |
| | Portland | 62 | 62 | 85 | 76 | 85 | 67 | 85 | 60 | 86 | 55 | 85 | 53 | 83 | 49 | 82 | 45 | 83 | 45 | 86 | 48 | 90 | 62 | 88 | 74 | 86 | 78 | 85 | 59 |
| | Salem | 40 | 40 | 87 | 76 | 88 | 68 | 88 | 61 | 88 | 57 | 88 | 53 | 87 | 49 | 85 | 41 | 85 | 40 | 87 | 45 | 90 | 60 | 90 | 77 | 89 | 80 | 88 | 59 |
| | Sexton Summit | 7 | 7 | 80 | 72 | 78 | 70 | 84 | 68 | 84 | 63 | 73 | 53 | 73 | 49 | 65 | 40 | 66 | 42 | 65 | 45 | 70 | 58 | 81 | 75 | 79 | 75 | 75 | 59 |
| PC | Guam | 9 | 9 | 87 | 73 | 87 | 72 | 86 | 70 | 88 | 70 | 89 | 72 | 88 | 73 | 90 | 77 | 91 | 78 | 92 | 79 | 90 | 77 | 88 | 77 | 87 | 76 | 89 | 74 |
| | Johnston Island | 23 | 23 | 76 | 68 | 77 | 68 | 78 | 70 | 79 | 71 | 78 | 70 | 77 | 69 | 78 | 69 | 79 | 71 | 80 | 72 | 80 | 72 | 79 | 73 | 78 | 72 | 78 | 70 |
| | Koror | 51 | 51 | 80 | 76 | 80 | 75 | 78 | 73 | 78 | 74 | 79 | 77 | 81 | 78 | 81 | 78 | 80 | 77 | 79 | 76 | 79 | 77 | 79 | 77 | 80 | 77 | 80 | 76 |
| | Kwajalein, Marshall IS | 42 | 42 | 79 | 72 | 78 | 70 | 79 | 71 | 81 | 74 | 83 | 77 | 81 | 75 | 84 | 77 | 83 | 77 | 83 | 76 | 83 | 76 | 83 | 76 | 81 | 75 | 81 | 75 |
| | Majuro, Marshall IS | 47 | 47 | 80 | 75 | 79 | 74 | 80 | 75 | 83 | 77 | 83 | 78 | 84 | 78 | 84 | 78 | 83 | 77 | 82 | 76 | 82 | 76 | 83 | 77 | 82 | 77 | 82 | 76 |
| | Pago Pago, Amer Samoa | 34 | 34 | 88 | 75 | 88 | 75 | 89 | 75 | 89 | 76 | 87 | 76 | 85 | 76 | 83 | 74 | 84 | 74 | 84 | 74 | 84 | 76 | 84 | 76 | 85 | 75 | 86 | 75 |
| | Pohnpei, Caroline IS | 32 | 32 | 85 | 78 | 84 | 76 | 85 | 77 | 88 | 79 | 90 | 81 | 92 | 80 | 94 | 79 | 95 | 79 | 95 | 79 | 94 | 79 | 93 | 80 | 87 | 79 | 90 | 79 |
| | Chuuk, E. Caroline IS | 32 | 32 | 81 | 76 | 81 | 75 | 82 | 75 | 84 | 77 | 85 | 78 | 86 | 78 | 88 | 78 | 88 | 77 | 88 | 77 | 87 | 78 | 86 | 78 | 83 | 79 | 85 | 77 |
| | Wake Island | 45 | 45 | 77 | 66 | 78 | 66 | 80 | 67 | 81 | 68 | 82 | 68 | 82 | 68 | 82 | 70 | 83 | 71 | 83 | 71 | 82 | 71 | 80 | 69 | 78 | 67 | 81 | 69 |
| | Yap, W Caroline IS | 54 | 54 | 79 | 76 | 78 | 74 | 77 | 73 | 76 | 73 | 78 | 75 | 80 | 77 | 81 | 77 | 82 | 78 | 81 | 78 | 81 | 78 | 80 | 78 | 80 | 77 | 79 | 76 |
| PA | Allentown | 52 | 52 | 76 | 62 | 76 | 57 | 75 | 53 | 74 | 50 | 78 | 53 | 80 | 54 | 82 | 53 | 86 | 56 | 88 | 57 | 87 | 55 | 82 | 59 | 79 | 62 | 80 | 56 |
| | Erie | 37 | 37 | 78 | 72 | 77 | 70 | 77 | 65 | 75 | 62 | 76 | 62 | 79 | 64 | 80 | 64 | 82 | 65 | 82 | 65 | 77 | 63 | 76 | 68 | 77 | 72 | 78 | 66 |
| | Harrisburg | 49 | 49 | 72 | 58 | 71 | 55 | 72 | 52 | 70 | 49 | 74 | 52 | 77 | 53 | 79 | 52 | 83 | 55 | 85 | 56 | 82 | 54 | 77 | 57 | 73 | 58 | 76 | 54 |
| | Middletown/Harrisburg AP | 37 | 37 | 73 | 59 | 72 | 55 | 72 | 53 | 71 | 50 | 75 | 52 | 76 | 52 | 78 | 52 | 81 | 54 | 84 | 55 | 81 | 54 | 76 | 56 | 72 | 58 | 76 | 54 |
| | Philadelphia | 43 | 43 | 74 | 60 | 72 | 55 | 72 | 53 | 71 | 50 | 75 | 53 | 77 | 53 | 78 | 54 | 81 | 54 | 83 | 56 | 83 | 54 | 78 | 56 | 74 | 59 | 76 | 55 |
| | Pittsburgh | 42 | 42 | 77 | 66 | 75 | 62 | 76 | 57 | 74 | 51 | 77 | 52 | 80 | 53 | 83 | 54 | 86 | 56 | 87 | 57 | 82 | 55 | 79 | 62 | 78 | 67 | 79 | 58 |
| | Avoca | 47 | 47 | 76 | 66 | 75 | 61 | 74 | 57 | 72 | 52 | 76 | 52 | 82 | 56 | 83 | 55 | 86 | 58 | 88 | 60 | 84 | 58 | 79 | 63 | 77 | 67 | 79 | 59 |
| | Williamsport | 57 | 57 | 77 | 62 | 76 | 58 | 77 | 53 | 75 | 49 | 80 | 51 | 84 | 54 | 87 | 55 | 90 | 57 | 92 | 59 | 89 | 57 | 82 | 61 | 78 | 63 | 82 | 57 |
| RI | Block IS | 15 | 15 | 73 | 65 | 73 | 65 | 75 | 65 | 79 | 65 | 80 | 66 | 83 | 69 | 87 | 72 | 86 | 71 | 84 | 70 | 80 | 66 | 76 | 65 | 72 | 65 | 79 | 67 |
| | Providence | 39 | 39 | 72 | 57 | 71 | 54 | 72 | 53 | 70 | 49 | 73 | 53 | 76 | 56 | 77 | 56 | 80 | 56 | 82 | 57 | 81 | 54 | 78 | 57 | 74 | 58 | 75 | 55 |
| SC | Charleston AP | 60 | 60 | 83 | 56 | 82 | 52 | 83 | 50 | 84 | 49 | 85 | 53 | 86 | 59 | 88 | 62 | 90 | 63 | 90 | 62 | 89 | 56 | 86 | 53 | 84 | 55 | 86 | 56 |
| | Columbia | 36 | 36 | 83 | 54 | 82 | 49 | 84 | 48 | 84 | 44 | 85 | 48 | 86 | 51 | 88 | 53 | 91 | 56 | 92 | 55 | 91 | 51 | 89 | 51 | 84 | 53 | 86 | 51 |
| | Greenville-Spartanburg AP | 40 | 40 | 77 | 55 | 76 | 51 | 76 | 50 | 78 | 48 | 83 | 53 | 85 | 54 | 87 | 56 | 89 | 58 | 89 | 59 | 86 | 53 | 82 | 53 | 79 | 55 | 82 | 54 |
| SD | Aberdeen | 34 | 34 | 79 | 73 | 80 | 74 | 83 | 70 | 82 | 59 | 81 | 57 | 84 | 61 | 86 | 59 | 87 | 58 | 85 | 58 | 82 | 59 | 83 | 71 | 81 | 74 | 83 | 65 |
| | Huron | 43 | 43 | 77 | 70 | 80 | 71 | 83 | 68 | 82 | 59 | 83 | 59 | 85 | 61 | 86 | 58 | 88 | 59 | 86 | 58 | 81 | 58 | 82 | 66 | 80 | 71 | 83 | 63 |
| | Rapid City | 52 | 52 | 69 | 64 | 71 | 61 | 75 | 54 | 73 | 47 | 76 | 48 | 78 | 49 | 74 | 41 | 72 | 37 | 68 | 39 | 67 | 46 | 69 | 60 | 69 | 64 | 72 | 51 |
| | Sioux Falls | 39 | 39 | 78 | 71 | 80 | 71 | 82 | 67 | 81 | 59 | 81 | 58 | 81 | 60 | 84 | 60 | 86 | 62 | 85 | 61 | 81 | 60 | 83 | 69 | 81 | 73 | 82 | 64 |
| TN | Bristol-JhnCty-Kgsprt | 41 | 41 | 81 | 62 | 80 | 58 | 80 | 52 | 82 | 50 | 89 | 55 | 90 | 58 | 92 | 61 | 93 | 60 | 93 | 57 | 90 | 53 | 85 | 56 | 82 | 62 | 86 | 57 |
| | Chattanooga | 72 | 72 | 82 | 62 | 81 | 57 | 81 | 53 | 82 | 49 | 86 | 53 | 87 | 55 | 89 | 57 | 91 | 57 | 91 | 56 | 90 | 53 | 85 | 56 | 83 | 61 | 86 | 56 |
| | Knoxville | 42 | 42 | 82 | 64 | 80 | 59 | 80 | 55 | 82 | 52 | 87 | 57 | 89 | 59 | 90 | 61 | 92 | 60 | 92 | 59 | 90 | 56 | 85 | 59 | 83 | 64 | 86 | 59 |
| | Memphis | 63 | 63 | 78 | 65 | 77 | 61 | 76 | 58 | 77 | 56 | 81 | 58 | 82 | 59 | 84 | 60 | 85 | 59 | 85 | 58 | 82 | 54 | 79 | 58 | 78 | 64 | 80 | 59 |
| | Nashville | 37 | 37 | 79 | 66 | 79 | 62 | 77 | 57 | 79 | 56 | 85 | 60 | 86 | 60 | 88 | 61 | 89 | 61 | 89 | 62 | 86 | 58 | 81 | 62 | 80 | 66 | 83 | 61 |
| TX | Abilene | 39 | 39 | 72 | 56 | 72 | 56 | 70 | 51 | 72 | 50 | 78 | 55 | 78 | 54 | 71 | 49 | 72 | 50 | 76 | 56 | 75 | 54 | 75 | 56 | 73 | 56 | 74 | 54 |
| | Amarillo | 41 | 41 | 71 | 53 | 72 | 52 | 69 | 46 | 68 | 42 | 75 | 48 | 77 | 49 | 73 | 46 | 77 | 50 | 79 | 52 | 73 | 48 | 73 | 50 | 71 | 52 | 73 | 49 |
| | Austin | 41 | 41 | 78 | 63 | 78 | 61 | 79 | 59 | 82 | 60 | 88 | 64 | 88 | 61 | 87 | 56 | 85 | 55 | 85 | 59 | 83 | 59 | 82 | 62 | 79 | 63 | 83 | 60 |
| | Brownsville | 36 | 36 | 88 | 70 | 89 | 66 | 88 | 63 | 89 | 64 | 90 | 65 | 90 | 64 | 91 | 60 | 91 | 61 | 91 | 65 | 90 | 64 | 87 | 66 | 87 | 69 | 89 | 65 |
| | Corpus Christi | 38 | 38 | 87 | 70 | 87 | 68 | 87 | 65 | 89 | 66 | 92 | 70 | 93 | 67 | 93 | 62 | 92 | 62 | 90 | 65 | 89 | 63 | 87 | 66 | 86 | 68 | 89 | 66 |
| | Dallas-Fort Worth | 39 | 39 | 79 | 63 | 78 | 61 | 79 | 59 | 81 | 59 | 86 | 63 | 85 | 59 | 79 | 53 | 78 | 53 | 82 | 59 | 82 | 58 | 81 | 61 | 80 | 63 | 81 | 59 |
| | Del Rio | 23 | 23 | 74 | 60 | 72 | 57 | 70 | 54 | 74 | 57 | 78 | 61 | 78 | 60 | 74 | 57 | 75 | 59 | 80 | 62 | 80 | 63 | 80 | 63 | 75 | 59 | 76 | 60 |
| | El Paso | 42 | 42 | 65 | 34 | 55 | 27 | 47 | 21 | 39 | 17 | 41 | 17 | 45 | 19 | 61 | 29 | 65 | 33 | 66 | 33 | 63 | 30 | 61 | 33 | 65 | 38 | 56 | 27 |
| | Galveston | 96 | 96 | 85 | 77 | 84 | 74 | 85 | 74 | 86 | 75 | 84 | 73 | 81 | 70 | 81 | 70 | 81 | 69 | 81 | 68 | 80 | 65 | 83 | 72 | 85 | 76 | 83 | 72 |
| | Houston | 33 | 33 | 85 | 68 | 86 | 65 | 87 | 65 | 89 | 64 | 91 | 66 | 92 | 65 | 92 | 63 | 92 | 63 | 92 | 64 | 91 | 62 | 89 | 65 | 87 | 67 | 89 | 65 |
| | Lubbock | 55 | 55 | 72 | 52 | 71 | 52 | 67 | 44 | 67 | 42 | 74 | 47 | 76 | 48 | 73 | 49 | 76 | 52 | 79 | 54 | 77 | 51 | 73 | 49 | 72 | 51 | 73 | 49 |
| | Midland-Odessa | 39 | 39 | 71 | 51 | 71 | 48 | 65 | 40 | 66 | 38 | 73 | 43 | 75 | 46 | 70 | 45 | 73 | 47 | 78 | 53 | 78 | 49 | 75 | 49 | 72 | 49 | 72 | 46 |
| | Port Arthur | 42 | 42 | 88 | 71 | 87 | 67 | 88 | 66 | 90 | 66 | 92 | 68 | 93 | 68 | 94 | 70 | 94 | 69 | 92 | 68 | 91 | 63 | 89 | 66 | 89 | 70 | 91 | 68 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | San Angelo | 42 | 42 | 75 | 56 | 75 | 53 | 71 | 48 | 73 | 47 | 79 | 53 | 80 | 54 | 75 | 48 | 76 | 50 | 82 | 58 | 81 | 56 | 80 | 56 | 78 | 56 | 77 | 53 |
| | San Antonio | 60 | 60 | 80 | 61 | 80 | 59 | 79 | 57 | 82 | 59 | 87 | 62 | 87 | 60 | 86 | 55 | 85 | 54 | 85 | 57 | 84 | 57 | 81 | 59 | 80 | 60 | 83 | 58 |
| | Victoria | 41 | 41 | 87 | 69 | 87 | 66 | 87 | 63 | 89 | 64 | 91 | 66 | 92 | 65 | 92 | 62 | 92 | 62 | 92 | 65 | 90 | 62 | 89 | 64 | 87 | 68 | 90 | 65 |
| | Waco | 39 | 39 | 83 | 66 | 82 | 64 | 82 | 62 | 84 | 62 | 88 | 65 | 86 | 60 | 81 | 53 | 79 | 51 | 84 | 58 | 84 | 59 | 84 | 63 | 83 | 65 | 83 | 61 |
| | Wichita Falls | 42 | 42 | 79 | 59 | 78 | 58 | 78 | 54 | 80 | 53 | 85 | 57 | 84 | 55 | 76 | 48 | 77 | 49 | 83 | 56 | 82 | 55 | 82 | 57 | 80 | 59 | 80 | 55 |
| UT | Salt Lake City | 43 | 43 | 79 | 69 | 78 | 60 | 70 | 46 | 66 | 39 | 65 | 34 | 59 | 26 | 52 | 22 | 53 | 24 | 61 | 30 | 68 | 41 | 75 | 59 | 79 | 71 | 67 | 43 |
| VI | Burlington | 37 | 37 | 73 | 64 | 74 | 61 | 75 | 58 | 73 | 52 | 73 | 51 | 77 | 54 | 78 | 53 | 83 | 56 | 86 | 60 | 81 | 60 | 78 | 65 | 77 | 67 | 77 | 59 |
| VA | Lynchburg | 39 | 39 | 73 | 54 | 73 | 50 | 73 | 48 | 73 | 45 | 81 | 52 | 83 | 55 | 86 | 57 | 86 | 56 | 88 | 57 | 86 | 52 | 80 | 52 | 76 | 54 | 80 | 53 |
| | Norfolk | 54 | 54 | 75 | 59 | 75 | 57 | 74 | 54 | 74 | 51 | 77 | 56 | 79 | 57 | 81 | 59 | 84 | 61 | 84 | 61 | 83 | 59 | 79 | 57 | | | | |

*Note:* The relative humidity is expressed as a percentage measure of the amount of moisture in the air compared to the maximum amount of moisture the air can hold at the same temperature and pressure. Average humidity values are given for selected morning and afternoon observations. Maximum relative humidity values usually occur during morning hours. In this publication, the Local Standard Time (LST) of morning and afternoon humidity is shown below. Atlantic, Alaskan (M morning 8 A.M.) (Afternoon 2 P.M.), Eastern, Bering, 165W Meridian (M morning 7 A.M.) (Afternoon 1 P.M.), Central, 180E Meridian (M morning 6 A.M.) (Afternoon NOON), Mountain, 165E Meridian (M morning 5 A.M.) (Afternoon 5 P.M.), Pacific, 150E Meridian (M morning 4 A.M.) (Afternoon 4 P.M.), 135E Meridian (M morning 9 A.M.) (Afternoon 3 P.M.).

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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## SECTION 3B CLIMATIC DATA — WORLD

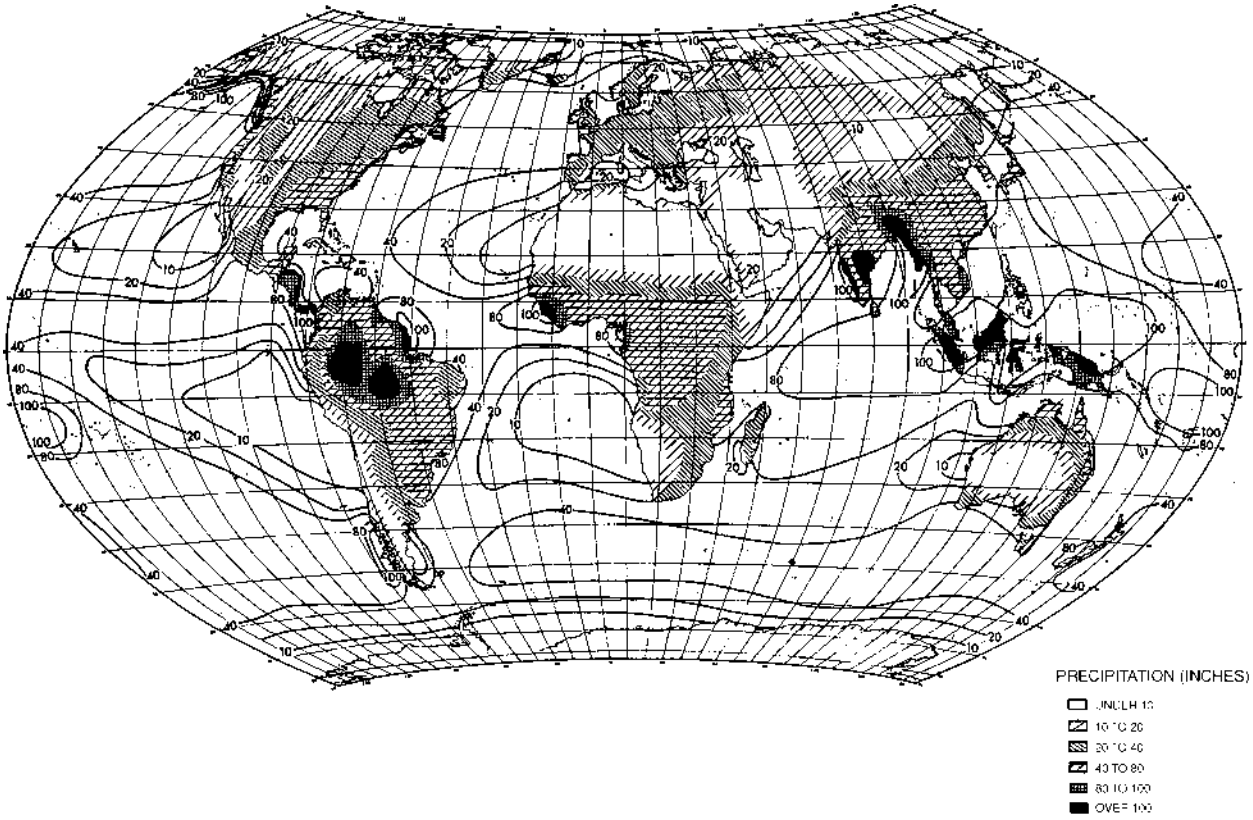


**Figure 3B.2** General Pattern of Annual World Precipitation. (From Environmental Science Service: Administration, *Climates of the World*, 1969. www.noaa.gov.)

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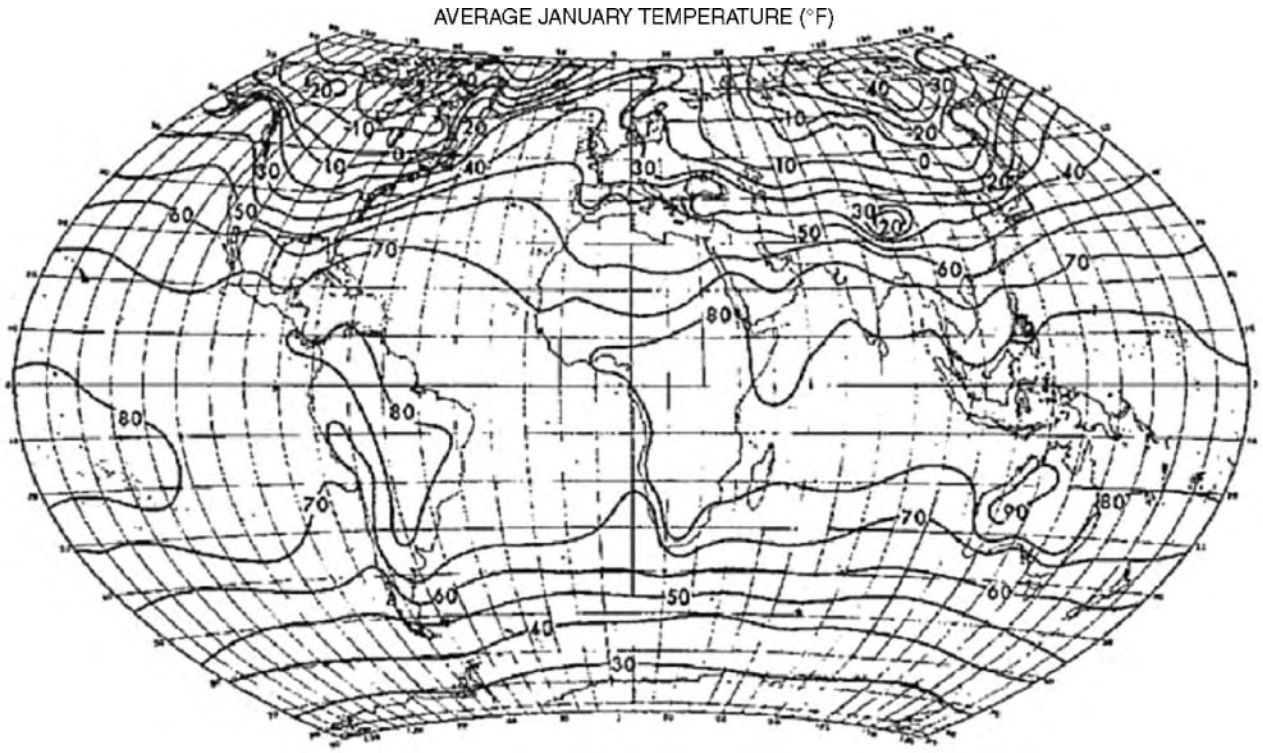


**Figure 3B.3** Average January World Temperature. (From *Climates of the World*, Historical Climatology Series 6–14, 1991. www.noaa.gov.)

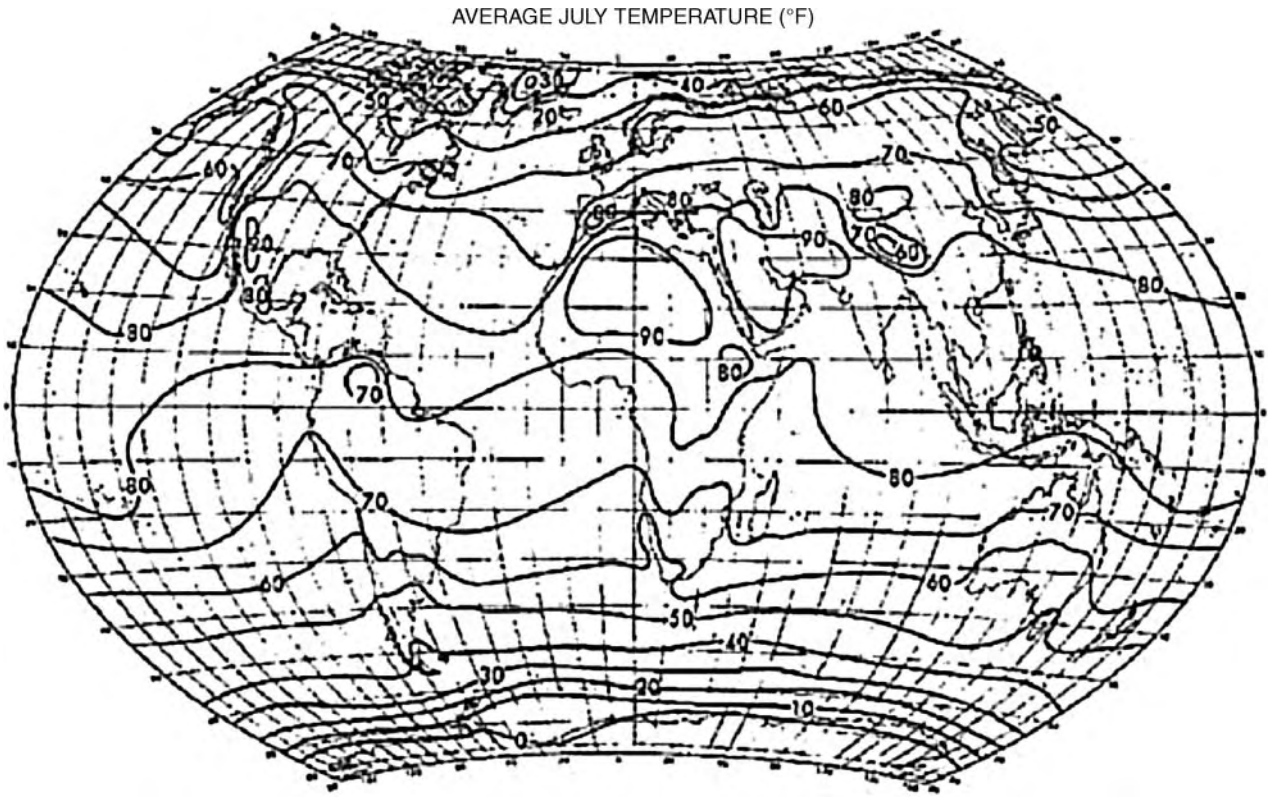


**Figure 3B.4** Average July World Temperatures. (From *Climates of the World*, Historical Climatology Series 6–14, 1991. www.noaa.gov.)

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## Table 3B.13 Temperature and Precipitation Data for Representative World-Wide Stations

| Country and Station | Latitude | Longitude | Elevation | Temperature | | | | | | | | | | | | Average Precipitation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Average Daily | | | | | | | | | | Extreme | | | | | | | | | | | | | | | |
| | | | | | Jan | | Apr | | July | | Oct | | | | | | | | | | | | | | | | | | | |
| | | | | Length of Record | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Length of Record | January | February | March | April | May | June | July | August | September | October | November | December | Year |
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| **North America** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| United States | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Albuquerque, NM | 35 03N | 106 37W | 5,311 | 30 | 46 | 24 | 69 | 42 | 91 | 66 | 71 | 45 | 104 | −16 | 30 | 0.4 | 0.4 | 0.5 | 0.5 | 0.8 | 0.6 | 1.2 | 1.3 | 1.0 | 0.8 | 0.4 | 0.5 | 8.4 |
| Asheville, NC | 35 26N | 82 32W | 2,140 | 30 | 48 | 28 | 67 | 42 | 84 | 61 | 68 | 45 | 99 | −7 | 30 | 4.2 | 4.0 | 4.8 | 4.0 | 3.7 | 3.5 | 5.9 | 4.9 | 3.6 | 3.1 | 2.8 | 3.6 | 48.1 |
| Atlanta, GA | 33 39N | 84 26W | 1,010 | 30 | 52 | 37 | 70 | 50 | 87 | 71 | 72 | 52 | 103 | −9 | 30 | 4.4 | 4.5 | 5.4 | 4.5 | 3.2 | 3.8 | 4.7 | 3.6 | 3.3 | 2.4 | 3.0 | 4.4 | 47.2 |
| Austin, TX | 30 18N | 97 42W | 597 | 30 | 60 | 41 | 78 | 57 | 95 | 74 | 82 | 60 | 109 | −2 | 30 | 2.4 | 2.6 | 2.1 | 3.6 | 3.7 | 3.2 | 2.2 | 1.9 | 3.4 | 2.8 | 2.1 | 2.5 | 32.5 |
| Birmingham, AL | 33 34N | 86 45W | 620 | 30 | 57 | 36 | 76 | 50 | 93 | 71 | 79 | 52 | 107 | −10 | 30 | 5.0 | 5.3 | 6.0 | 4.5 | 3.4 | 4.0 | 5.2 | 4.9 | 3.3 | 3.0 | 3.5 | 5.0 | 53.1 |
| Bismark, ND | 46 46N | 100 45W | 1,647 | 30 | 20 | 0 | 55 | 32 | 86 | 58 | 59 | 34 | 114 | −45 | 30 | 0.4 | 0.4 | 0.8 | 1.2 | 2.0 | 3.4 | 2.2 | 1.7 | 1.2 | 0.9 | 0.6 | 0.4 | 15.2 |
| Boise, ID | 43 34N | 116 13W | 2,838 | 30 | 36 | 22 | 63 | 37 | 91 | 59 | 65 | 38 | 112 | −28 | 30 | 1.3 | 1.3 | 1.3 | 1.2 | 1.3 | 0.9 | 0.2 | 0.2 | 0.4 | 0.8 | 1.2 | 1.3 | 11.4 |
| Brownsville, TX | 25 54N | 97 26W | 16 | 30 | 71 | 52 | 82 | 66 | 93 | 76 | 85 | 67 | 104 | 12 | 30 | 1.4 | 1.5 | 1.0 | 1.6 | 2.4 | 3.0 | 1.7 | 2.8 | 5.0 | 3.5 | 1.3 | 1.7 | 26.9 |
| Buffalo, NY | 42 56N | 78 44W | 705 | 30 | 31 | 18 | 53 | 34 | 80 | 59 | 60 | 41 | 99 | −21 | 30 | 2.8 | 2.7 | 3.2 | 3.0 | 3.0 | 2.5 | 2.6 | 3.1 | 3.1 | 3.0 | 3.6 | 3.0 | 35.6 |
| Cheyenne, WY | 41 09N | 104 49W | 6,126 | 30 | 37 | 14 | 56 | 30 | 85 | 55 | 63 | 32 | 100 | −38 | 30 | 0.5 | 0.6 | 1.2 | 1.9 | 2.5 | 2.1 | 1.8 | 1.4 | 1.1 | 0.8 | 0.6 | 0.5 | 15.0 |
| Chicago, IL | 41 47N | 87 45W | 607 | 30 | 33 | 19 | 57 | 41 | 84 | 67 | 63 | 47 | 105 | −23 | 30 | 1.9 | 1.6 | 2.7 | 3.0 | 3.7 | 4.1 | 3.4 | 3.2 | 2.7 | 2.8 | 2.2 | 1.9 | 33.2 |
| Des Moines, IO | 41 32N | 93 39W | 938 | 30 | 29 | 11 | 59 | 38 | 87 | 65 | 66 | 43 | 110 | −30 | 30 | 1.3 | 1.1 | 2.1 | 2.5 | 4.1 | 4.7 | 3.1 | 3.7 | 2.9 | 2.1 | 1.8 | 1.1 | 30.5 |
| Dodge City, KS | 37 46N | 99 58W | 2,582 | 30 | 42 | 20 | 66 | 41 | 93 | 68 | 71 | 46 | 109 | −26 | 30 | 0.6 | 0.7 | 1.2 | 1.8 | 3.2 | 3.0 | 2.3 | 2.4 | 1.5 | 1.4 | 0.6 | 0.5 | 19.2 |
| El Paso, TX | 31 48N | 106 24W | 3,918 | 30 | 56 | 30 | 78 | 49 | 95 | 69 | 79 | 50 | 109 | −8 | 30 | 0.5 | 0.4 | 0.4 | 0.3 | 0.4 | 0.7 | 1.3 | 1.2 | 1.1 | 0.9 | 0.3 | 0.5 | 8.0 |
| Indianapolis, IN | 39 44N | 86 17W | 792 | 30 | 37 | 21 | 61 | 40 | 86 | 64 | 67 | 44 | 107 | −25 | 30 | 3.1 | 2.3 | 3.4 | 3.7 | 4.0 | 4.6 | 3.5 | 3.0 | 3.2 | 2.6 | 3.1 | 2.7 | 39.2 |
| Jacksonville, FL | 30 25N | 81 39W | 20 | 30 | 67 | 45 | 80 | 58 | 92 | 73 | 80 | 62 | 105 | 10 | 30 | 2.5 | 2.9 | 3.5 | 3.6 | 3.5 | 6.3 | 7.7 | 6.9 | 7.6 | 5.2 | 1.7 | 2.2 | 53.6 |
| Kansas City, MO | 39 07N | 94 36W | 742 | 30 | 40 | 23 | 66 | 46 | 92 | 71 | 72 | 49 | 113 | −22 | 30 | 1.4 | 1.2 | 2.5 | 3.6 | 4.4 | 4.6 | 3.2 | 3.8 | 3.3 | 2.9 | 1.8 | 1.5 | 34.2 |
| Las Vegas, NV | 36 05N | 115 10W | 2,162 | 30 | 54 | 32 | 78 | 51 | 104 | 76 | 80 | 53 | 117 | 8 | 30 | 0.5 | 0.4 | 0.4 | 0.2 | 0.1 | — | 0.5 | 0.5 | 0.3 | 0.2 | 0.3 | 0.4 | 3.8 |
| Los Angeles, CA | 33 56N | 118 23W | 97 | 30 | 64 | 45 | 67 | 52 | 76 | 62 | 73 | 57 | 110 | 23 | 30 | 2.7 | 2.9 | 1.8 | 1.1 | 0.1 | 0.1 | — | — | 0.2 | 0.4 | 1.1 | 2.4 | 12.8 |
| Louisville, KY | 38 11N | 85 44W | 477 | 30 | 44 | 27 | 66 | 43 | 89 | 67 | 70 | 46 | 107 | −20 | 30 | 4.1 | 3.3 | 4.6 | 3.8 | 3.9 | 4.0 | 3.4 | 3.0 | 2.6 | 2.3 | 3.2 | 3.2 | 41.4 |
| Miami, FL | 25 48N | 80 16W | 7 | 30 | 76 | 58 | 83 | 66 | 89 | 75 | 85 | 71 | 100 | 28 | 30 | 2.0 | 1.9 | 2.3 | 3.9 | 6.4 | 7.4 | 6.8 | 7.0 | 9.5 | 8.2 | 2.8 | 1.7 | 59.9 |
| Minneapolis, MN | 44 53N | 93 13W | 834 | 30 | 22 | 2 | 56 | 33 | 84 | 61 | 61 | 37 | 108 | −34 | 30 | 0.7 | 0.8 | 1.5 | 1.9 | 3.2 | 4.0 | 3.3 | 3.2 | 2.4 | 1.6 | 1.4 | 0.9 | 24.9 |
| Missoula, MT | 46 55N | 114 05W | 3,190 | 30 | 28 | 10 | 57 | 31 | 85 | 49 | 58 | 30 | 105 | −33 | 30 | 0.9 | 0.9 | 0.7 | 1.0 | 1.9 | 1.9 | 0.9 | 0.7 | 1.0 | 1.0 | 0.9 | 1.1 | 12.9 |
| Nashville, TN | 36 07N | 86 41W | 590 | 30 | 49 | 31 | 71 | 48 | 91 | 70 | 74 | 49 | 107 | −15 | 30 | 5.5 | 4.5 | 5.2 | 3.7 | 3.7 | 3.3 | 3.7 | 2.9 | 2.9 | 2.3 | 3.3 | 4.2 | 45.2 |
| New Orleans, LA | 29 59N | 90 15W | 3 | 30 | 64 | 45 | 78 | 58 | 91 | 73 | 80 | 61 | 102 | 7 | 30 | 3.8 | 4.0 | 5.3 | 4.6 | 4.4 | 4.4 | 6.7 | 5.3 | 5.0 | 2.8 | 3.3 | 4.1 | 53.7 |
| New York, NY | 40 47N | 73 58W | 132 | 30 | 40 | 27 | 60 | 43 | 85 | 68 | 66 | 50 | 106 | −15 | 30 | 3.3 | 2.8 | 4.0 | 3.4 | 3.7 | 3.3 | 3.7 | 4.4 | 3.9 | 3.1 | 3.4 | 3.3 | 42.3 |
| Oklahoma City, OK | 35 24N | 97 36W | 1,285 | 30 | 46 | 28 | 71 | 49 | 93 | 72 | 74 | 52 | 113 | −17 | 30 | 1.3 | 1.4 | 2.0 | 3.1 | 5.2 | 4.5 | 2.4 | 2.5 | 3.0 | 2.5 | 1.6 | 1.4 | 30.9 |
| Phoenix, AZ | 33 26N | 112 01W | 1,117 | 30 | 64 | 35 | 84 | 50 | 105 | 75 | 87 | 55 | 118 | 16 | 30 | 0.7 | 0.9 | 0.7 | 0.3 | 0.1 | 0.1 | 0.8 | 1.1 | 0.7 | 0.5 | 0.5 | 0.9 | 7.3 |
| Pittsburgh, PA | 40 27N | 80 00W | 747 | 30 | 40 | 25 | 63 | 42 | 85 | 65 | 65 | 45 | 103 | −20 | 30 | 2.8 | 2.3 | 3.5 | 3.4 | 3.8 | 4.0 | 3.6 | 3.5 | 2.7 | 2.5 | 2.3 | 2.5 | 36.9 |
| Portland, ME | 43 39N | 70 19W | 47 | 30 | 32 | 12 | 53 | 32 | 80 | 57 | 60 | 37 | 103 | −39 | 30 | 4.4 | 3.8 | 4.3 | 3.7 | 3.4 | 3.2 | 2.9 | 2.4 | 3.5 | 3.2 | 4.2 | 3.9 | 42.9 |
| Portland, OR | 45 36N | 122 36W | 21 | 30 | 44 | 33 | 62 | 42 | 79 | 56 | 63 | 45 | 107 | −3 | 30 | 5.4 | 4.2 | 3.8 | 2.1 | 2.0 | 1.7 | 0.4 | 0.7 | 1.6 | 3.6 | 5.3 | 6.4 | 37.2 |
| Reno, NV | 39 30N | 119 47W | 4,404 | 30 | 45 | 16 | 65 | 31 | 89 | 46 | 69 | 29 | 106 | −19 | 30 | 1.2 | 1.0 | 0.7 | 0.5 | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 | 0.5 | 0.6 | 1.1 | 7.2 |
| Salt Lake City, UT | 40 46N | 111 58W | 4,220 | 30 | 37 | 18 | 63 | 36 | 94 | 60 | 65 | 38 | 107 | −30 | 30 | 1.4 | 1.2 | 1.6 | 1.8 | 1.4 | 1.0 | 0.6 | 0.9 | 0.5 | 1.2 | 1.3 | 1.2 | 14.1 |
| San Francisco, CA | 37 37N | 122 23W | 8 | 30 | 55 | 42 | 64 | 47 | 72 | 54 | 71 | 51 | 106 | 20 | 30 | 4.0 | 3.5 | 2.7 | 1.3 | 0.5 | 0.1 | — | — | 0.2 | 0.7 | 1.6 | 4.1 | 18.7 |
| Sault Ste. Marie, MI | 46 28N | 84 22W | 721 | 30 | 23 | 8 | 46 | 30 | 76 | 54 | 55 | 38 | 98 | −37 | 30 | 2.1 | 1.5 | 1.8 | 2.2 | 2.8 | 3.3 | 2.5 | 2.9 | 3.8 | 2.8 | 3.3 | 2.3 | 31.3 |
| Seattle, WA | 47 27N | 122 18W | 400 | 30 | 44 | 33 | 58 | 40 | 76 | 54 | 60 | 44 | 100 | 0 | 30 | 5.7 | 4.2 | 3.8 | 2.4 | 1.7 | 1.6 | 0.8 | 1.0 | 2.1 | 4.0 | 5.4 | 6.3 | 39.0 |
| Sheridan, WY | 44 46N | 106 58W | 3,964 | 30 | 34 | 9 | 56 | 31 | 87 | 56 | 62 | 33 | 106 | −41 | 30 | 0.6 | 0.7 | 1.4 | 2.2 | 2.6 | 2.6 | 1.2 | 0.9 | 1.2 | 1.1 | 0.8 | 0.6 | 15.9 |
| Spokane, WA | 47 38N | 117 32W | 2,356 | 30 | 31 | 19 | 59 | 36 | 86 | 55 | 60 | 38 | 108 | −30 | 30 | 2.4 | 1.9 | 1.5 | 0.9 | 1.2 | 1.5 | 0.4 | 0.4 | 0.8 | 1.6 | 2.2 | 2.4 | 17.2 |
| Washington, DC | 38 51N | 77 03W | 14 | 30 | 44 | 30 | 66 | 46 | 87 | 69 | 68 | 50 | 106 | −15 | 30 | 3.0 | 2.5 | 3.2 | 3.2 | 4.1 | 3.2 | 4.2 | 4.9 | 3.8 | 3.1 | 2.8 | 2.8 | 40.8 |
| Wilmington, NC | 34 16N | 77 55W | 28 | 30 | 58 | 37 | 74 | 51 | 89 | 71 | 76 | 55 | 104 | 5 | 30 | 2.9 | 3.4 | 4.0 | 2.9 | 3.5 | 4.3 | 7.7 | 6.9 | 6.3 | 3.0 | 3.1 | 3.4 | 51.4 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| United States, Alaska | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Anchorage | 61 13N | 149 52W | 85 | 30 | 21 | 4 | 44 | 28 | 65 | 50 | 42 | 28 | 86 | −38 | 30 | 0.8 | 0.7 | 0.5 | 0.4 | 0.5 | 1.0 | 1.9 | 2.6 | 2.5 | 1.9 | 1.0 | 0.9 | 14.7 |
| Annette | 55 02N | 131 34W | 110 | 30 | 38 | 30 | 50 | 37 | 63 | 51 | 51 | 42 | 90 | −4 | 30 | 11.4 | 8.5 | 9.6 | 9.1 | 7.1 | 5.7 | 6.0 | 7.5 | 9.9 | 16.9 | 14.7 | 12.1 | 118.5 |
| Barrow | 71 18N | 156 47W | 31 | 30 | −9 | −23 | 7 | −7 | 45 | 33 | 21 | 12 | 78 | −56 | 30 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.4 | 0.8 | 0.9 | 0.6 | 0.5 | 0.2 | 0.2 | 4.3 |
| Bethel | 60 47N | 161 48W | 125 | 30 | 11 | −4 | 34 | 18 | 62 | 48 | 38 | 25 | 90 | −52 | 30 | 1.1 | 1.1 | 1.0 | 0.6 | 1.0 | 1.2 | 2.0 | 4.2 | 2.6 | 1.5 | 1.1 | 1.0 | 18.4 |
| Cold Bay | 55 12N | 162 43W | 96 | 30 | 33 | 23 | 38 | 28 | 54 | 45 | 45 | 36 | 78 | −9 | 30 | 2.3 | 3.2 | 1.8 | 1.5 | 2.3 | 2.0 | 1.8 | 4.3 | 4.3 | 4.6 | 3.8 | 2.6 | 34.5 |
| Fairbanks | 64 49N | 147 52W | 436 | 30 | −1 | −21 | 42 | 17 | 72 | 48 | 35 | 17 | 99 | −66 | 30 | 0.9 | 0.5 | 0.4 | 0.3 | 0.7 | 1.4 | 1.8 | 2.2 | 1.1 | 0.9 | 0.6 | 0.5 | 11.3 |
| Juneau | 58 22N | 134 35W | 12 | 30 | 30 | 20 | 45 | 31 | 63 | 48 | 47 | 37 | 89 | −21 | 30 | 4.0 | 3.1 | 3.3 | 2.9 | 3.2 | 3.4 | 4.5 | 5.0 | 6.7 | 8.3 | 6.1 | 4.2 | 54.7 |
| King Salmon | 58 41N | 156 39W | 49 | 30 | 21 | 6 | 41 | 25 | 63 | 47 | 43 | 29 | 88 | −40 | 30 | 1.1 | 1.0 | 1.0 | 0.6 | 1.0 | 1.4 | 2.1 | 3.4 | 3.1 | 2.2 | 1.5 | 1.0 | 19.4 |
| Nome | 64 30N | 165 26W | 13 | 30 | 12 | −3 | 28 | 14 | 55 | 44 | 35 | 24 | 84 | −47 | 30 | 1.0 | 0.9 | 0.9 | 0.8 | 0.7 | 0.9 | 2.3 | 3.8 | 2.7 | 1.7 | 1.2 | 1.0 | 17.9 |
| St. Paul Island | 57 09N | 170 13W | 22 | 30 | 30 | 21 | 33 | 24 | 49 | 42 | 41 | 33 | 64 | −26 | 30 | 1.8 | 1.2 | 1.1 | 1.0 | 1.3 | 1.2 | 2.3 | 3.3 | 3.1 | 3.2 | 2.5 | 1.8 | 23.8 |
| Shemya | 52 43N | 174 06E | 122 | 30 | 34 | 29 | 38 | 33 | 49 | 44 | 42 | 38 | 63 | 16 | 30 | 2.5 | 2.3 | 2.6 | 2.1 | 2.4 | 1.3 | 2.2 | 2.1 | 2.3 | 2.8 | 2.7 | 2.1 | 27.4 |
| Yakutat | 59 31N | 139 40W | 28 | 30 | 34 | 20 | 45 | 29 | 61 | 48 | 49 | 35 | 86 | −24 | 30 | 10.9 | 8.2 | 8.7 | 7.2 | 8.0 | 5.1 | 8.4 | 10.9 | 16.6 | 19.6 | 16.1 | 12.3 | 132.0 |
| Canada | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aklavik, NWT | 68 14N | 135 00W | 30 | 22 | −10 | −26 | 19 | −2 | 66 | 47 | 25 | 15 | 93 | −62 | 22 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 | 0.8 | 1.4 | 1.4 | 0.9 | 0.9 | 0.8 | 0.4 | 9.0 |
| Alert, NWT | 82 31N | 62 20W | 95 | 9 | −19 | −29 | −8 | −18 | 44 | 36 | 2 | −7 | 67 | −53 | 10 | 0.2 | 0.3 | 0.3 | 0.3 | 0.5 | 0.6 | 0.5 | 1.1 | 1.0 | 0.9 | 0.2 | 0.4 | 6.3 |
| Calgary, Alta | 51 06N | 114 01W | 3,540 | 55 | 24 | 2 | 53 | 27 | 76 | 47 | 54 | 29 | 97 | −49 | 55 | 0.5 | 0.5 | 0.8 | 1.0 | 2.3 | 3.1 | 2.5 | 2.3 | 1.5 | 0.7 | 0.7 | 0.6 | 16.7 |
| Charlottetown, PEI | 46 17N | 63 08W | 181 | 65 | 26 | 10 | 43 | 30 | 73 | 58 | 54 | 41 | 98 | −27 | 65 | 3.8 | 3.0 | 3.2 | 2.8 | 2.7 | 2.6 | 3.0 | 3.4 | 3.4 | 4.1 | 3.8 | 4.0 | 39.8 |
| Chatham, NB | 47 00N | 65 27W | 109 | 50 | 23 | 2 | 47 | 28 | 77 | 56 | 55 | 37 | 102 | −43 | 50 | 3.4 | 2.7 | 3.3 | 3.0 | 3.2 | 3.6 | 3.9 | 4.0 | 3.1 | 4.0 | 3.4 | 3.2 | 40.8 |
| Churchhill, Man | 58 45N | 94 04W | 94 | 30 | −11 | −27 | 24 | 4 | 64 | 43 | 34 | 20 | 96 | −57 | 30 | 0.5 | 0.6 | 0.9 | 0.9 | 0.9 | 1.9 | 2.2 | 2.7 | 2.3 | 1.4 | 1.0 | 0.7 | 16.0 |
| Edmonton, Alta | 53 34N | 113 31W | 2,219 | 71 | 16 | −3 | 52 | 28 | 74 | 50 | 51 | 30 | 99 | −57 | 71 | 0.9 | 0.7 | 0.7 | 1.0 | 1.9 | 3.2 | 3.3 | 2.4 | 1.3 | 0.8 | 0.9 | 0.9 | 18.0 |
| Fort Nelson, BC | 58 50N | 122 35W | 1,253 | 12 | 1 | −15 | 47 | 25 | 74 | 51 | 43 | 25 | 98 | −61 | 13 | 0.9 | 1.2 | 0.7 | 0.8 | 1.4 | 2.5 | 2.4 | 1.5 | 1.3 | 1.0 | 1.4 | 1.2 | 16.3 |
| Fort Simpson, NWT | 61 45N | 121 14W | 554 | 42 | −10 | −27 | 38 | 14 | 74 | 50 | 36 | 21 | 97 | −70 | 42 | 0.7 | 0.7 | 0.5 | 0.7 | 1.4 | 1.5 | 2.0 | 1.5 | 1.3 | 1.1 | 0.9 | 0.8 | 13.1 |
| Frobisher Bay, NWT | 63 45N | 68 33W | 110 | 18 | −9 | −23 | 16 | −1 | 53 | 39 | 29 | 18 | 76 | −49 | 10 | 0.7 | 0.9 | 0.8 | 0.8 | 0.7 | 0.9 | 1.5 | 2.0 | 1.8 | 1.1 | 1.1 | 1.0 | 13.3 |
| Gander, Nfld | 48 57N | 54 34W | 496 | 14 | 27 | 13 | 40 | 27 | 71 | 52 | 51 | 37 | 96 | −17 | 14 | 2.6 | 3.3 | 2.8 | 2.6 | 2.6 | 2.8 | 3.6 | 3.6 | 3.7 | 4.1 | 4.2 | 3.7 | 39.6 |
| Halifax, NS | 44 39N | 63 34W | 83 | 75 | 32 | 15 | 47 | 31 | 74 | 55 | 57 | 41 | 99 | −21 | 71 | 5.4 | 4.4 | 4.9 | 4.5 | 4.1 | 4.0 | 3.8 | 4.4 | 4.1 | 5.4 | 5.3 | 5.4 | 55.7 |
| Kapuskasing, Ont | 49 25N | 82 28W | 743 | 19 | 10 | −14 | 43 | 19 | 75 | 50 | 47 | 31 | 101 | −53 | 19 | 2.0 | 1.1 | 1.6 | 1.8 | 2.1 | 2.3 | 3.4 | 2.9 | 3.5 | 2.5 | 2.4 | 1.9 | 27.5 |
| Knob Lake, Que | 54 48N | 66 49W | 1,712 | 30 | −3 | −21 | 30 | 12 | 64 | 46 | 37 | 25 | 88 | −59 | 10 | 1.9 | 1.9 | 1.4 | 1.6 | 1.7 | 3.3 | 3.3 | 4.4 | 3.4 | 2.9 | 2.4 | 1.5 | 29.7 |
| Montreal, Que | 45 30N | 73 34W | 187 | 67 | 21 | 6 | 50 | 33 | 78 | 61 | 54 | 40 | 97 | −35 | 77 | 3.8 | 3.0 | 3.5 | 2.6 | 3.1 | 3.4 | 3.7 | 3.5 | 3.7 | 3.4 | 3.5 | 3.6 | 40.8 |
| North Bay, Ont | 46 21N | 79 25W | 1,216 | 17 | 22 | 2 | 48 | 28 | 78 | 56 | 49 | 36 | 99 | −46 | 23 | 2.0 | 1.5 | 1.8 | 2.2 | 2.5 | 3.2 | 3.2 | 2.7 | 3.7 | 3.2 | 2.7 | 2.1 | 30.8 |
| Ottawa, Ont | 45 19N | 75 40W | 374 | 65 | 21 | 3 | 51 | 31 | 81 | 58 | 54 | 37 | 102 | −38 | 65 | 2.9 | 2.2 | 2.8 | 2.7 | 2.5 | 3.5 | 3.4 | 2.6 | 3.2 | 2.9 | 3.0 | 2.6 | 34.3 |
| Penticton, BC | 49 28N | 119 36W | 1,129 | 32 | 32 | 21 | 61 | 35 | 84 | 53 | 59 | 38 | 105 | −16 | 32 | 1.0 | 0.7 | 0.7 | 0.7 | 1.1 | 1.2 | 0.8 | 0.8 | 1.0 | 0.8 | 0.9 | 1.1 | 10.8 |
| Port Arthur, Ont | 48 22N | 89 19W | 644 | 62 | 17 | −4 | 44 | 26 | 74 | 52 | 50 | 34 | 104 | −42 | 59 | 0.9 | 0.8 | 1.0 | 1.5 | 2.1 | 2.8 | 3.6 | 2.8 | 3.4 | 2.5 | 1.5 | 0.9 | 23.8 |
| Prince George, BC | 53 53N | 122 41W | 2,218 | 27 | 23 | 3 | 54 | 27 | 75 | 44 | 52 | 30 | 102 | −58 | 27 | 1.8 | 1.2 | 1.4 | 0.8 | 1.3 | 2.1 | 1.6 | 1.9 | 2.0 | 2.0 | 1.9 | 1.9 | 19.9 |
| Prince Rupert, BC | 54 17N | 130 23W | 170 | 26 | 39 | 30 | 50 | 37 | 62 | 49 | 53 | 42 | 90 | −3 | 26 | 9.8 | 7.6 | 8.4 | 6.7 | 5.3 | 4.1 | 4.8 | 5.1 | 7.7 | 12.2 | 12.3 | 11.3 | 95.3 |
| Quebec, Que | 46 48N | 71 23W | 239 | 72 | 18 | 2 | 44 | 29 | 76 | 57 | 51 | 37 | 97 | −34 | 72 | 3.5 | 2.7 | 3.0 | 2.4 | 3.1 | 3.7 | 4.0 | 4.0 | 3.6 | 3.4 | 3.2 | 3.2 | 39.8 |
| Regina, Sask | 50 26N | 104 40W | 1,884 | 55 | 10 | −11 | 50 | 26 | 79 | 51 | 52 | 27 | 110 | −56 | 49 | 0.5 | 0.3 | 0.7 | 0.7 | 1.8 | 3.3 | 2.4 | 1.8 | 1.3 | 0.9 | 0.6 | 0.4 | 14.7 |
| Resolute, NWT | 74 43N | 94 59W | 220 | 13 | −20 | −33 | −1 | −16 | 45 | 35 | 11 | 0 | 61 | −61 | 7 | 0.1 | 0.1 | 0.2 | 0.2 | 0.5 | 0.8 | 0.9 | 1.1 | 0.8 | 0.5 | 0.2 | 0.1 | 5.5 |
| St. John, NB | 45 17N | 66 04W | 119 | 61 | 28 | 11 | 43 | 32 | 69 | 54 | 54 | 41 | 93 | −24 | 61 | 4.1 | 3.1 | 3.7 | 3.2 | 3.1 | 3.2 | 3.1 | 3.6 | 3.7 | 4.1 | 3.9 | 3.8 | 42.6 |
| St. Johns, Nfld | 47 32N | 52 44W | 211 | 68 | 30 | 18 | 41 | 29 | 69 | 51 | 53 | 40 | 93 | −21 | 58 | 5.3 | 5.1 | 4.6 | 3.8 | 3.9 | 3.1 | 3.1 | 4.0 | 3.7 | 4.8 | 5.7 | 6.0 | 53.1 |
| Saskatoon, Sask | 52 08N | 106 38W | 1,690 | 38 | 9 | −11 | 49 | 26 | 77 | 52 | 51 | 27 | 104 | −55 | 38 | 0.9 | 0.5 | 0.7 | 0.7 | 1.4 | 2.6 | 2.4 | 1.9 | 1.5 | 0.9 | 0.5 | 0.6 | 14.6 |
| The Pas, Man | 53 49N | 101 15W | 890 | 27 | 1 | −18 | 45 | 21 | 75 | 54 | 45 | 26 | 100 | −54 | 27 | 0.6 | 0.5 | 0.7 | 0.8 | 1.4 | 2.2 | 2.2 | 2.1 | 2.0 | 1.2 | 1.0 | 0.8 | 15.5 |
| Toronto, Ont | 43 40N | 79 24W | 379 | 105 | 30 | 16 | 50 | 34 | 79 | 59 | 56 | 40 | 105 | −26 | 105 | 2.7 | 2.4 | 2.6 | 2.5 | 2.9 | 2.7 | 3.0 | 2.7 | 2.9 | 2.4 | 2.8 | 2.6 | 32.2 |
| Vancouver, BC | 49 17N | 123 05W | 127 | 43 | 41 | 32 | 58 | 40 | 74 | 54 | 57 | 44 | 92 | 2 | 41 | 8.6 | 5.8 | 5.0 | 3.3 | 2.8 | 2.5 | 1.2 | 1.7 | 3.6 | 5.8 | 8.3 | 8.8 | 57.4 |
| Whitehorse, YT | 60 43N | 135 04W | 2,303 | 10 | 13 | −3 | 41 | 22 | 67 | 45 | 41 | 28 | 91 | −62 | 10 | 0.6 | 0.5 | 0.6 | 0.4 | 0.6 | 1.0 | 1.6 | 1.5 | 1.3 | 0.7 | 1.0 | 0.8 | 10.6 |
| Winnipeg, Man | 49 54N | 97 14W | 783 | 66 | 7 | −13 | 48 | 27 | 79 | 55 | 51 | 31 | 108 | −54 | 66 | 0.9 | 0.9 | 1.2 | 1.4 | 2.3 | 3.1 | 3.1 | 2.5 | 2.3 | 1.5 | 1.1 | 0.9 | 21.2 |
| Yellow Knife, NWT | 62 28N | 114 27W | 674 | 13 | −8 | −23 | 29 | 9 | 69 | 52 | 36 | 26 | 90 | −60 | 13 | 0.8 | 0.6 | 0.7 | 0.4 | 0.7 | 0.6 | 1.5 | 1.4 | 1.0 | 1.3 | 1.0 | 0.8 | 10.8 |
| Greenland | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Angmagssalik | 65 36N | 37 33W | 95 | 30 | 23 | 10 | 35 | 16 | 54 | 37 | 35 | 25 | 77 | −26 | 38 | 2.9 | 2.4 | 2.6 | 2.1 | 2.0 | 1.8 | 1.5 | 2.1 | 3.3 | 4.7 | 3.0 | 2.7 | 31.1 |
| Denmarkshaven | 76 46N | 19 00W | 7 | 2 | −1 | −15 | 6 | −13 | 47 | 34 | 13 | 2 | 63 | −42 | 2 | 1.2 | 0.7 | 0.7 | 0.1 | 0.2 | 0.2 | 0.5 | 0.6 | 0.3 | 0.3 | 1.0 | 0.7 | 6.0 |
| Elsmitte | 70 53N | 40 42W | 9,843 | 1 | −33 | −53 | −14 | −37 | 19 | 1 | −23 | −42 | 27 | −85 | 1 | 0.6 | 0.2 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.4 | 0.3 | 0.5 | 0.5 | 1.0 | 4.3 |
| Godthaab | 64 10N | 51 43W | 66 | 40 | 19 | 10 | 31 | 20 | 52 | 38 | 35 | 26 | 76 | −20 | 45 | 1.4 | 1.7 | 1.6 | 1.2 | 1.7 | 1.4 | 2.2 | 3.1 | 3.3 | 2.5 | 1.9 | 1.5 | 23.5 |
| Ivigtut | 61 12N | 48 10W | 98 | 48 | 24 | 12 | 38 | 24 | 57 | 42 | 40 | 29 | 86 | −20 | 50 | 3.3 | 2.6 | 3.4 | 2.5 | 3.5 | 3.2 | 3.1 | 3.7 | 5.9 | 5.7 | 4.6 | 3.1 | 44.6 |
| Jacobshavn | 69 13N | 51 02W | 104 | 32 | 8 | −7 | 24 | 6 | 51 | 40 | 31 | 20 | 71 | −46 | 52 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.8 | 1.2 | 1.4 | 1.3 | 0.9 | 0.7 | 0.5 | 9.2 |
| Nord | 81 36N | 16 40W | 118 | 8 | −15 | −28 | −5 | −18 | 44 | 35 | 3 | −6 | 61 | −60 | 8 | 0.8 | 0.8 | 0.5 | 0.3 | 0.1 | 0.3 | 1.0 | 1.4 | 1.2 | 0.6 | 1.4 | 0.5 | 8.9 |
| Scoresbysund | 70 29N | 21 58W | 56 | 12 | 12 | −3 | 22 | 6 | 49 | 36 | 25 | 15 | 63 | −42 | 12 | 1.8 | 1.4 | 0.9 | 1.4 | 0.4 | 0.8 | 1.5 | 0.7 | 1.7 | 1.4 | 1.1 | 1.9 | 15.0 |
| Thule | 76 31N | 68 44W | 251 | 12 | −4 | −17 | 10 | −7 | 46 | 38 | 19 | 8 | 63 | −44 | 12 | 0.4 | 0.3 | 0.2 | 0.2 | 0.3 | 0.2 | 0.7 | 0.6 | 0.6 | 0.7 | 0.5 | 0.2 | 4.9 |
| Upernivik | 72 47N | 56 07W | 59 | 40 | −1 | −13 | 15 | −1 | 48 | 35 | 29 | 21 | 69 | −44 | 50 | 0.4 | 0.5 | 0.7 | 0.6 | 0.6 | 0.5 | 0.9 | 1.1 | 1.1 | 1.1 | 1.1 | 0.6 | 9.2 |

*(Continued)*



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**Table 3B.13 (Continued)**

| Country and Station | Latitude | Longitude | Elevation | Temperature: Length of Record | Temperature: Average Daily: Jan: Maximum | Temperature: Average Daily: Jan: Minimum | Temperature: Average Daily: Apr: Maximum | Temperature: Average Daily: Apr: Minimum | Temperature: Average Daily: July: Maximum | Temperature: Average Daily: July: Minimum | Temperature: Average Daily: Oct: Maximum | Temperature: Average Daily: Oct: Minimum | Temperature: Extreme: Maximum | Temperature: Extreme: Minimum | Average Precipitation: Length of Record | Average Precipitation: January | Average Precipitation: February | Average Precipitation: March | Average Precipitation: April | Average Precipitation: May | Average Precipitation: June | Average Precipitation: July | Average Precipitation: August | Average Precipitation: September | Average Precipitation: October | Average Precipitation: November | Average Precipitation: December | Average Precipitation: Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| Mexico | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acapulco | 16 50N | 99 56W | 10 | 8 | 85 | 70 | 87 | 71 | 89 | 75 | 88 | 74 | 97 | 60 | 40 | 0.3 | — | 0.0 | — | 1.4 | 12.8 | 9.1 | 9.3 | 13.9 | 6.7 | 1.2 | 0.4 | 55.1 |
| Chihuahua | 28 42N | 105 57W | 4,429 | 9 | 65 | 36 | 81 | 51 | 89 | 66 | 79 | 51 | 102 | 12 | 22 | 0.2 | 0.4 | 0.3 | 0.2 | 0.2 | 1.7 | 3.6 | 3.7 | 3.3 | 0.9 | 0.5 | 0.4 | 15.4 |
| Guadalajara | 20 41N | 103 20W | 5,194 | 26 | 73 | 45 | 85 | 53 | 79 | 60 | 78 | 56 | 101 | 26 | 33 | 0.4 | 0.2 | 0.2 | 0.2 | 1.1 | 8.8 | 9.4 | 8.5 | 7.2 | 2.2 | 0.8 | 0.7 | 39.7 |
| Guaymas | 27 57N | 110 55W | 58 | 9 | 74 | 57 | 84 | 65 | 96 | 82 | 91 | 75 | 117 | 41 | 41 | 0.5 | 0.2 | 0.2 | 0.1 | — | 0.1 | 1.7 | 2.7 | 2.1 | 0.7 | 0.3 | 0.8 | 9.4 |
| La Paz | 24 07N | 110 17W | 85 | 9 | 74 | 54 | 86 | 58 | 96 | 73 | 90 | 68 | 108 | 31 | 12 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.2 | 0.4 | 1.2 | 1.4 | 0.6 | 0.5 | 1.1 | 5.7 |
| Lerdo | 25 30N | 103 32W | 3,740 | 10 | 72 | 45 | 86 | 57 | 90 | 68 | 82 | 58 | 105 | 23 | 14 | 0.4 | 0.1 | 0.2 | 0.3 | 0.8 | 1.5 | 1.5 | 1.3 | 2.0 | 0.8 | 0.8 | 0.5 | 10.2 |
| Manzanillo | 19 04N | 104 20W | 26 | 17 | 86 | 68 | 87 | 67 | 93 | 76 | 91 | 76 | 103 | 54 | 17 | 0.1 | 0.2 | — | 0.0 | 0.1 | 4.7 | 5.7 | 6.4 | 14.5 | 5.1 | 0.9 | 1.8 | 39.5 |
| Mazatan | 23 11N | 106 25W | 256 | 10 | 71 | 61 | 76 | 65 | 86 | 77 | 85 | 76 | 93 | 52 | 46 | 0.8 | 0.5 | 0.2 | 0.1 | 0.1 | 1.5 | 5.9 | 8.3 | 8.0 | 2.6 | 0.9 | 1.3 | 30.2 |
| Merida | 20 58N | 89 38W | 72 | 22 | 83 | 62 | 92 | 69 | 92 | 73 | 87 | 71 | 106 | 51 | 40 | 1.2 | 0.9 | 0.7 | 0.8 | 3.2 | 5.6 | 5.2 | 5.6 | 6.8 | 3.8 | 1.3 | 1.3 | 36.5 |
| Mexico City | 19 26N | 99 04W | 7,340 | 42 | 66 | 42 | 78 | 52 | 74 | 54 | 70 | 50 | 92 | 24 | 48 | 0.2 | 0.3 | 0.5 | 0.7 | 1.9 | 4.1 | 4.5 | 4.3 | 4.1 | 1.6 | 0.5 | 0.3 | 23.0 |
| Monterrey | 25 40N | 100 18W | 1,732 | 11 | 68 | 48 | 84 | 62 | 90 | 71 | 80 | 64 | 107 | 25 | 33 | 0.6 | 0.7 | 0.8 | 1.3 | 1.3 | 3.0 | 2.3 | 2.4 | 5.2 | 3.0 | 1.5 | 0.8 | 22.9 |
| Salina Cruz | 16 12N | 95 12W | 184 | 10 | 85 | 72 | 88 | 76 | 89 | 76 | 87 | 75 | 98 | 62 | 22 | * | 0.4 | 0.6 | 0.5 | 3.3 | 11.6 | 4.5 | 5.5 | 7.1 | 4.0 | 0.9 | 0.1 | 38.5 |
| Tampico | 22 16N | 97 51W | 78 | 12 | 75 | 59 | 83 | 69 | 89 | 75 | 85 | 71 | 104 | 34 | 12 | 1.5 | 1.2 | 1.0 | 1.5 | 1.9 | 8.7 | 4.9 | 4.8 | 10.8 | 5.0 | 2.0 | 1.6 | 44.9 |
| Vera Cruz | 19 12N | 96 08W | 52 | 10 | 77 | 66 | 83 | 72 | 87 | 74 | 85 | 73 | 98 | 53 | 40 | 0.9 | 0.6 | 0.6 | 0.8 | 2.6 | 10.4 | 4.1 | 11.1 | 13.9 | 6.9 | 3.0 | 1.0 | 65.7 |
| **Central America** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Belize | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Belize | 17 31N | 88 11W | 17 | 27 | 81 | 67 | 86 | 74 | 87 | 75 | 86 | 72 | 97 | 49 | 33 | 5.4 | 2.4 | 1.5 | 2.2 | 4.3 | 7.7 | 6.4 | 6.7 | 9.6 | 12.0 | 8.9 | 7.3 | 74.4 |
| Canal Zone | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Balboa Heights | 08 57N | 79 33W | 118 | 34 | 88 | 71 | 90 | 74 | 87 | 74 | 85 | 73 | 97 | 63 | 46 | 1.0 | 0.4 | 0.7 | 2.9 | 8.0 | 8.4 | 7.1 | 7.9 | 8.2 | 10.1 | 10.2 | 4.8 | 69.7 |
| Cristobal | 09 21N | 79 54W | 35 | 36 | 84 | 76 | 86 | 77 | 85 | 76 | 86 | 75 | 97 | 66 | 73 | 3.4 | 1.5 | 1.5 | 4.1 | 12.5 | 13.9 | 15.6 | 15.3 | 12.7 | 15.8 | 22.3 | 11.7 | 130.3 |
| Costa Rica | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Jose | 09 56N | 84 08W | 3,760 | 8 | 75 | 58 | 79 | 62 | 77 | 62 | 77 | 60 | 92 | 49 | 34 | 0.6 | 0.2 | 0.8 | 1.8 | 9.0 | 9.5 | 8.3 | 9.5 | 12.0 | 11.8 | 5.7 | 1.6 | 70.8 |
| El Salvador | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Salvador | 13 42N | 89 13W | 2,238 | 39 | 90 | 60 | 93 | 65 | 89 | 65 | 87 | 65 | 105 | 45 | 39 | 0.3 | 0.2 | 0.4 | 1.7 | 7.7 | 12.9 | 11.5 | 11.7 | 12.1 | 9.5 | 1.6 | 0.4 | 70.0 |
| Guatemala | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Guatemala City | 14 37N | 90 31W | 4,855 | 6 | 73 | 53 | 82 | 58 | 78 | 60 | 76 | 60 | 90 | 41 | 29 | 0.3 | 0.1 | 0.5 | 1.2 | 6.0 | 10.8 | 8.0 | 7.8 | 9.1 | 6.8 | 0.9 | 0.3 | 51.8 |
| Honduras | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tela | 15 46N | 87 27W | 41 | 4 | 82 | 67 | 87 | 72 | 88 | 73 | 86 | 71 | 96 | 58 | 20 | 8.9 | 5.1 | 2.6 | 3.3 | 4.3 | 5.0 | 6.4 | 9.4 | 7.7 | 13.5 | 15.9 | 14.0 | 96.1 |
| **West Indies** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bridgetown, Barbados | 13 08N | 59 36W | 181 | 35 | 83 | 70 | 86 | 72 | 86 | 74 | 86 | 73 | 95 | 61 | 22 | 2.6 | 1.1 | 1.3 | 1.4 | 2.3 | 4.4 | 5.8 | 5.8 | 6.7 | 7.0 | 8.1 | 3.8 | 50.3 |
| Camp Jacob, Guadaloupe | 16 01N | 61 42W | 1,750 | 19 | 77 | 64 | 79 | 65 | 81 | 68 | 81 | 68 | 92 | 54 | 21 | 9.2 | 6.1 | 8.1 | 7.3 | 11.5 | 14.1 | 17.6 | 15.3 | 16.4 | 12.4 | 12.3 | 10.1 | 140.4 |
| Fort-de-France, Martinique | 14 37N | 61 05W | 13 | 22 | 83 | 69 | 86 | 71 | 86 | 74 | 87 | 73 | 96 | 56 | 31 | 4.7 | 4.3 | 2.9 | 3.9 | 4.7 | 7.4 | 9.4 | 10.3 | 9.3 | 9.7 | 7.9 | 5.9 | 80.4 |
| Hamilton, Bermuda | 32 17N | 64 46W | 151 | 59 | 68 | 58 | 71 | 59 | 85 | 73 | 79 | 69 | 99 | 40 | 62 | 4.4 | 4.7 | 4.8 | 4.1 | 4.6 | 4.4 | 4.5 | 5.4 | 5.2 | 5.8 | 5.0 | 4.7 | 57.6 |
| Havana, Cuba | 23 08N | 82 21W | 80 | 25 | 79 | 65 | 84 | 69 | 89 | 75 | 85 | 73 | 104 | 43 | 72 | 2.8 | 1.8 | 1.8 | 2.3 | 4.7 | 6.5 | 4.9 | 5.3 | 5.9 | 6.8 | 3.1 | 2.3 | 48.2 |
| Kingston, Jamaica | 17 58N | 76 48W | 110 | 33 | 86 | 67 | 87 | 70 | 90 | 73 | 88 | 73 | 97 | 56 | 59 | 0.9 | 0.6 | 0.9 | 1.2 | 4.0 | 3.5 | 1.5 | 3.6 | 3.9 | 7.1 | 2.9 | 1.4 | 31.5 |
| La Guerite, St. Christopher (St. Kitts) | 17 20N | 62 45W | 157 | 19 | 80 | 71 | 83 | 73 | 86 | 76 | 85 | 75 | 91 | 61 | 21 | 4.1 | 2.0 | 2.3 | 2.3 | 3.8 | 3.6 | 4.4 | 5.2 | 6.0 | 5.4 | 7.3 | 4.5 | 50.9 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nassau, Bahamas | 25 05N | 77 21W | 12 | 35 | 77 | 65 | 81 | 69 | 88 | 75 | 85 | 73 | 94 | 41 | 57 | 1.4 | 1.5 | 1.4 | 2.5 | 4.6 | 6.4 | 5.8 | 5.3 | 6.9 | 6.5 | 2.8 | 1.3 | 46.4 |
| Port-au-Prince, Haiti | 18 33N | 72 20W | 121 | 42 | 87 | 68 | 89 | 71 | 94 | 74 | 90 | 72 | 101 | 58 | 70 | 1.3 | 2.3 | 3.4 | 6.3 | 9.1 | 4.0 | 2.9 | 5.7 | 6.9 | 6.7 | 3.4 | 1.3 | 53.3 |
| Saint Clair, Trinidad | 10 40N | 61 31W | 67 | 49 | 87 | 69 | 90 | 69 | 88 | 71 | 89 | 71 | 101 | 52 | 97 | 2.7 | 1.6 | 1.8 | 2.1 | 3.7 | 7.6 | 8.6 | 9.7 | 7.6 | 6.7 | 7.2 | 4.9 | 64.2 |
| Saint Thomas, Virgin Is | 18 20N | 64 58W | 11 | 9 | 82 | 71 | 85 | 74 | 88 | 77 | 87 | 76 | 92 | 63 | 9 | 2.5 | 1.9 | 1.7 | 2.2 | 4.6 | 3.2 | 3.2 | 4.1 | 6.9 | 5.6 | 3.9 | 3.9 | 43.7 |
| San Juan, Puerto Rico | 18 26N | 66 00W | 13 | 30 | 81 | 67 | 84 | 69 | 87 | 74 | 87 | 73 | 94 | 60 | 30 | 4.7 | 2.9 | 2.2 | 3.7 | 7.1 | 5.7 | 6.3 | 7.1 | 6.8 | 5.8 | 6.5 | 5.4 | 64.2 |
| Santo Domingo, Dom. Rep | 18 29N | 69 54W | 57 | 26 | 84 | 66 | 85 | 69 | 88 | 72 | 87 | 72 | 98 | 59 | 25 | 2.4 | 1.4 | 1.9 | 3.9 | 6.8 | 6.2 | 6.4 | 6.3 | 7.3 | 6.0 | 4.8 | 2.4 | 55.8 |
| **South America** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Argentina | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bahia Blanca | 38 43S | 62 16W | 95 | 33 | 88 | 62 | 71 | 51 | 57 | 39 | 71 | 48 | 109 | 18 | 46 | 1.7 | 2.2 | 2.5 | 2.3 | 1.2 | 0.9 | 1.0 | 1.0 | 1.6 | 2.2 | 2.1 | 1.9 | 20.6 |
| Buenos Aires | 34 35S | 58 29W | 89 | 23 | 85 | 63 | 72 | 53 | 57 | 42 | 69 | 50 | 104 | 22 | 70 | 3.1 | 2.8 | 4.3 | 3.5 | 3.0 | 2.4 | 2.2 | 2.4 | 3.1 | 3.4 | 3.3 | 3.9 | 37.4 |
| Cipolletti | 38 57S | 67 59W | 889 | 9 | 89 | 56 | 72 | 40 | 55 | 29 | 72 | 43 | 107 | 9 | 24 | 0.4 | 0.4 | 0.7 | 0.4 | 0.6 | 0.6 | 0.5 | 0.3 | 0.6 | 0.9 | 0.5 | 0.5 | 6.4 |
| Corrientes | 27 28S | 58 50W | 177 | 39 | 93 | 71 | 81 | 63 | 71 | 53 | 82 | 60 | 112 | 30 | 40 | 4.7 | 4.5 | 5.3 | 5.6 | 3.3 | 1.9 | 1.7 | 1.5 | 2.8 | 4.7 | 5.2 | 5.2 | 46.4 |
| La Quiaca | 22 06S | 65 36W | 11,345 | 23 | 70 | 41 | 69 | 32 | 60 | 16 | 71 | 32 | 95 | 0 | 25 | 3.5 | 2.6 | 1.8 | 0.3 | — | 0.0 | — | — | 0.1 | 0.3 | 1.0 | 2.7 | 12.3 |
| Mendoza | 32 53S | 68 49W | 2,625 | 23 | 90 | 60 | 73 | 47 | 59 | 35 | 76 | 50 | 109 | 15 | 46 | 0.9 | 1.2 | 1.1 | 0.5 | 0.4 | 0.3 | 0.2 | 0.3 | 0.5 | 0.7 | 0.7 | 0.7 | 7.5 |
| Parana | 31 44S | 60 31W | 210 | 12 | 91 | 67 | 77 | 58 | 62 | 45 | 75 | 54 | 113 | 21 | 23 | 3.1 | 3.1 | 3.9 | 4.9 | 2.6 | 1.2 | 1.2 | 1.6 | 2.1 | 2.8 | 3.7 | 4.5 | 35.0 |
| Puerto Madryn | 42 47S | 65 01W | 26 | 50 | 81 | 57 | 70 | 46 | 55 | 36 | 68 | 45 | 104 | 10 | 50 | 0.4 | 0.6 | 0.7 | 0.5 | 0.9 | 0.6 | 0.6 | 0.4 | 0.6 | 0.7 | 0.4 | 0.6 | 7.0 |
| Santa Cruz | 50 01S | 68 32W | 39 | 12 | 70 | 48 | 57 | 39 | 41 | 28 | 58 | 39 | 94 | 1 | 20 | 0.6 | 0.3 | 0.3 | 0.6 | 0.4 | 0.5 | 0.4 | 0.5 | 0.3 | 0.3 | 0.4 | 0.7 | 5.3 |
| Santiago del Estero | 27 46S | 64 18W | 653 | 28 | 97 | 69 | 82 | 59 | 70 | 44 | 87 | 59 | 116 | 19 | 20 | 3.4 | 3.0 | 3.0 | 1.3 | 0.6 | 0.3 | 0.2 | 0.2 | 0.5 | 1.4 | 2.5 | 4.1 | 20.4 |
| Ushulaia | 54 50S | 68 20W | 26 | 16 | 57 | 41 | 48 | 33 | 39 | 25 | 52 | 35 | 85 | 6 | 21 | 2.0 | 2.6 | 1.9 | 2.1 | 1.5 | 1.2 | 1.2 | 1.1 | 1.3 | 1.6 | 1.5 | 1.9 | 19.9 |
| Bollvia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Concepcion | 16 15S | 62 03W | 1,607 | 5 | 85 | 66 | 86 | 62 | 81 | 54 | 88 | 62 | 101 | 32 | 16 | 7.2 | 4.7 | 4.4 | 1.8 | 2.0 | 1.5 | 1.1 | 0.9 | 1.2 | 2.9 | 5.0 | 5.9 | 38.6 |
| La Paz | 16 30S | 68 08W | 12,001 | 31 | 63 | 43 | 65 | 40 | 62 | 33 | 66 | 40 | 80 | 26 | 50 | 4.5 | 4.2 | 2.6 | 1.3 | 0.5 | 0.3 | 0.4 | 0.5 | 1.1 | 1.6 | 1.9 | 3.7 | 22.6 |
| Sucre | 19 03S | 65 17W | 9,344 | 5 | 63 | 48 | 63 | 45 | 61 | 37 | 65 | 46 | 88 | 25 | 52 | 7.3 | 4.9 | 3.7 | 1.6 | 0.2 | 0.1 | 0.2 | 0.3 | 1.0 | 1.6 | 2.6 | 4.3 | 27.8 |
| Brazil | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Barra do Corda | 05 35S | 45 28W | 266 | 9 | 89 | 71 | 89 | 71 | 92 | 64 | 94 | 72 | 103 | 45 | 9 | 6.7 | 8.7 | 8.0 | 6.1 | 2.3 | 1.0 | 0.7 | 0.7 | 1.0 | 2.5 | 3.9 | 5.7 | 47.2 |
| Bela Vista | 22 06S | 56 22W | 525 | 13 | 91 | 67 | 85 | 61 | 77 | 49 | 87 | 61 | 108 | 20 | 20 | 6.6 | 4.9 | 4.4 | 4.3 | 5.0 | 2.8 | 1.3 | 1.8 | 2.9 | 5.4 | 5.8 | 7.0 | 52.2 |
| Belem | 01 27S | 48 29W | 42 | 16 | 87 | 72 | 87 | 73 | 88 | 71 | 89 | 71 | 98 | 61 | 20 | 12.5 | 14.1 | 14.1 | 12.6 | 10.2 | 6.7 | 5.9 | 4.4 | 3.5 | 3.3 | 2.6 | 6.1 | 96.0 |
| Brasilia | 15 51S | 47 56W | 3,481 | 3 | 80 | 65 | 82 | 62 | 78 | 51 | 82 | 64 | 93 | 46 | 3 | 9.0 | 7.8 | 4.8 | 3.4 | 1.4 | — | 0.0 | — | 1.3 | 4.9 | 9.7 | 11.7 | 54.0 |
| Conceicao do Araguaia | 08 15S | 49 12W | 53 | 5 | 88 | 70 | 91 | 68 | 95 | 63 | 93 | 68 | 102 | 55 | 5 | 14.9 | 12.1 | 10.8 | 4.1 | 1.9 | 0.4 | — | 0.5 | 1.5 | 6.6 | 4.9 | 8.6 | 66.2 |
| Corumba | 19 00S | 57 39W | 381 | 8 | 94 | 73 | 92 | 73 | 84 | 64 | 93 | 70 | 106 | 33 | 11 | 7.3 | 5.9 | 5.1 | 4.6 | 2.9 | 1.9 | 0.3 | 1.2 | 2.6 | 4.0 | 5.6 | 7.1 | 48.5 |
| Florianopolis | 27 35S | 48 33W | 96 | 17 | 83 | 72 | 74 | 64 | 68 | 57 | 73 | 63 | 102 | 32 | 25 | 7.6 | 5.6 | 6.3 | 4.1 | 3.6 | 6.5 | 2.2 | 3.7 | 4.3 | 5.1 | 3.5 | 4.3 | 53.1 |
| Goias | 15 58S | 50 04W | 1,706 | 11 | 86 | 63 | 91 | 63 | 89 | 56 | 94 | 63 | 104 | 41 | 11 | 12.5 | 9.9 | 10.2 | 4.6 | 0.4 | 0.3 | 0.0 | 0.3 | 2.3 | 5.3 | 9.4 | 9.5 | 64.8 |
| Guarapuava | 25 16S | 51 30W | 3,592 | 10 | 79 | 61 | 73 | 55 | 66 | 47 | 74 | 53 | 94 | 23 | 5 | 8.7 | 5.8 | 5.4 | 4.5 | 4.6 | 6.5 | 2.7 | 3.6 | 4.6 | 6.9 | 6.6 | 6.1 | 65.8 |
| Manaus | 03 08S | 60 01W | 144 | 11 | 88 | 75 | 87 | 75 | 89 | 75 | 92 | 76 | 101 | 63 | 25 | 9.8 | 9.1 | 10.3 | 8.7 | 6.7 | 3.3 | 2.3 | 1.5 | 1.8 | 4.2 | 5.6 | 8.0 | 71.3 |
| Natal | 05 46S | 35 12W | 52 | 18 | 87 | 76 | 86 | 73 | 82 | 69 | 85 | 75 | 100 | 61 | 18 | 1.9 | 4.8 | 7.0 | 9.2 | 7.1 | 8.7 | 7.7 | 3.8 | 1.4 | 0.8 | 0.7 | 1.1 | 54.2 |
| Parana | 12 26S | 48 06W | 853 | 19 | 90 | 58 | 90 | 58 | 91 | 48 | 94 | 58 | 105 | 37 | 19 | 11.3 | 9.3 | 9.4 | 4.0 | 0.5 | * | 0.1 | 0.2 | 1.1 | 5.0 | 9.1 | 12.2 | 62.3 |
| Porto Alegre | 30 02S | 51.13W | 33 | 22 | 87 | 67 | 78 | 60 | 66 | 49 | 74 | 57 | 105 | 25 | 22 | 3.5 | 3.2 | 3.9 | 4.1 | 4.5 | 5.1 | 4.5 | 5.0 | 5.2 | 3.4 | 3.1 | 3.5 | 49.1 |
| Quixeramobim | 05 12S | 39 18W | 653 | 9 | 92 | 79 | 86 | 76 | 88 | 74 | 93 | 77 | 100 | 63 | 13 | 0.7 | 5.0 | 6.6 | 5.0 | 7.0 | 1.7 | 0.7 | 0.6 | 0.4 | 0.6 | 0.7 | 0.6 | 29.6 |
| Recife | 08 04S | 34 53W | 97 | 27 | 86 | 77 | 85 | 75 | 80 | 71 | 84 | 75 | 94 | 50 | 56 | 2.1 | 3.3 | 6.3 | 8.7 | 10.5 | 10.9 | 10.0 | 6.0 | 2.5 | 1.0 | 1.0 | 1.1 | 63.4 |
| Rio de Janeiro | 22 55S | 43 12W | 201 | 38 | 84 | 73 | 80 | 69 | 75 | 63 | 77 | 66 | 102 | 46 | 84 | 4.9 | 4.8 | 5.1 | 4.2 | 3.1 | 2.1 | 1.6 | 1.7 | 2.6 | 3.1 | 4.1 | 5.4 | 42.6 |
| Salvador (Bahia) | 13 00S | 38 30W | 154 | 25 | 86 | 74 | 84 | 74 | 79 | 69 | 83 | 71 | 100 | 50 | 20 | 2.6 | 5.3 | 6.1 | 11.2 | 10.8 | 9.4 | 7.2 | 4.8 | 3.3 | 4.0 | 4.5 | 5.6 | 74.8 |
| Santarem | 02 30S | 54 42W | 66 | 22 | 86 | 73 | 85 | 73 | 87 | 71 | 91 | 73 | 99 | 65 | 22 | 6.8 | 10.9 | 13.2 | 12.9 | 11.3 | 6.9 | 4.1 | 1.7 | 1.5 | 1.9 | 2.3 | 4.1 | 77.9 |
| Sao Paulo | 23 37S | 46 39W | 2,628 | 44 | 77 | 63 | 73 | 59 | 66 | 53 | 68 | 57 | 100 | 32 | 24 | 8.8 | 7.8 | 6.0 | 2.2 | 3.0 | 2.4 | 1.5 | 2.1 | 3.5 | 4.6 | 6.0 | 9.4 | 57.3 |
| Sena Madureira | 09 04S | 68 39W | 443 | 12 | 92 | 69 | 91 | 68 | 91 | 63 | 93 | 69 | 100 | 41 | 17 | 11.2 | 11.3 | 10.2 | 9.4 | 4.1 | 2.2 | 1.1 | 1.5 | 4.0 | 7.0 | 7.5 | 11.7 | 81.2 |
| Uaupes | 00 08S | 67 05W | 272 | 15 | 88 | 72 | 88 | 72 | 85 | 70 | 89 | 71 | 100 | 52 | 10 | 10.3 | 7.7 | 10.0 | 10.6 | 12.0 | 9.2 | 8.8 | 7.2 | 5.1 | 6.9 | 7.2 | 10.4 | 105.4 |
| Uruguaiana | 29 46S | 57 07W | 246 | 15 | 91 | 69 | 78 | 59 | 66 | 48 | 77 | 55 | 108 | 27 | 12 | 3.6 | 3.6 | 5.6 | 5.1 | 3.7 | 4.2 | 3.2 | 2.8 | 3.6 | 4.1 | 2.9 | 4.1 | 46.6 |
| Chile | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ancud | 41 47S | 73 52W | 184 | 30 | 62 | 51 | 57 | 47 | 50 | 42 | 55 | 45 | 82 | 30 | 46 | 3.1 | 3.7 | 5.3 | 7.4 | 9.9 | 11.0 | 10.3 | 9.4 | 6.5 | 4.2 | 4.7 | 4.6 | 80.1 |
| Antofagasta | 26 42S | 70 24W | 308 | 22 | 76 | 63 | 70 | 58 | 63 | 51 | 66 | 55 | 86 | 37 | 32 | 0.0 | 0.0 | 0.0 | — | — | 0.1 | 0.2 | 0.1 | — | 0.1 | — | 0.0 | 0.5 |
| Arica | 18 28S | 70 20W | 95 | 15 | 78 | 64 | 74 | 60 | 66 | 54 | 69 | 58 | 93 | 39 | 25 | — | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — | 0.0 | 0.0 | 0.0 | — | — |
| Cabo Raper | 46 50S | 75 38W | 131 | 8 | 58 | 46 | 54 | 44 | 47 | 38 | 51 | 40 | 72 | 28 | 10 | 7.8 | 5.8 | 7.1 | 7.7 | 7.5 | 7.9 | 9.5 | 7.5 | 5.6 | 7.0 | 6.7 | 7.0 | 87.1 |
| Los Evangelistas | 52 23S | 75 07W | 190 | 16 | 50 | 44 | 48 | 41 | 43 | 36 | 45 | 39 | 66 | 19 | 27 | 11.7 | 10.0 | 11.3 | 11.4 | 9.6 | 9.4 | 9.4 | 8.6 | 9.2 | 8.8 | 9.9 | 10.1 | 119.4 |
| Potrerillos | 26 30S | 69 27W | 9,350 | 7 | 65 | 49 | 63 | 47 | 57 | 40 | 61 | 44 | 75 | 20 | 7 | — | — | 0.3 | — | 0.7 | — | 0.5 | 0.3 | 0.2 | 0.2 | 0.0 | — | 2.2 |
| Puerto Aisen | 42 24S | 72 42W | 33 | 8 | 63 | 50 | 55 | 43 | 45 | 37 | 55 | 42 | 93 | 18 | 11 | 7.8 | 7.8 | 8.3 | 7.5 | 14.7 | 10.4 | 11.1 | 11.1 | 6.5 | 7.8 | 7.0 | 7.9 | 107.9 |

*(Continued)*



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**Table 3B.13 (Continued)**

| Country and Station | Latitude | Longitude | Elevation | Temperature | | | | | | | | | | | Average Precipitation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Average Daily | | | | | | | | | | Extreme | | | | | | | | | | | | | | | | |
| | | | | Jan | | Apr | | July | | Oct | | | | | | | | | | | | | | | | | | | | |
| | | | | Length of Record | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Length of Record | January | February | March | April | May | June | July | August | September | October | November | December | Year |
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| Punta Arenas | 53 10S | 70 54W | 26 | 15 | 58 | 45 | 50 | 39 | 40 | 31 | 51 | 38 | 86 | 11 | 15 | 1.5 | 0.9 | 1.3 | 1.4 | 1.3 | 1.6 | 1.1 | 1.2 | 0.9 | 1.1 | 0.7 | 1.4 | 14.4 |
| Santiago | 33 27S | 70 42W | 1,706 | 14 | 85 | 53 | 74 | 45 | 59 | 37 | 72 | 45 | 99 | 24 | 58 | 0.1 | 0.1 | 0.2 | 0.5 | 2.5 | 3.3 | 3.0 | 2.2 | 1.2 | 0.6 | 0.3 | 0.2 | 14.2 |
| Valdivia | 39 48S | 73 14W | 16 | 29 | 73 | 52 | 62 | 46 | 52 | 41 | 63 | 44 | 97 | 19 | 60 | 2.6 | 2.9 | 5.2 | 9.2 | 14.2 | 17.7 | 15.5 | 12.9 | 8.2 | 5.0 | 4.9 | 4.1 | 102.4 |
| Valparaiso | 33 01S | 71 38W | 135 | 30 | 72 | 56 | 67 | 52 | 60 | 47 | 65 | 50 | 94 | 32 | 41 | 0.1 | — | 0.3 | 0.6 | 4.1 | 5.9 | 3.9 | 2.9 | 1.3 | 0.4 | 0.2 | 0.2 | 19.9 |
| Colombia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Andagoya | 05 06N | 76 40W | 197 | 8 | 90 | 75 | 90 | 75 | 89 | 74 | 90 | 74 | 97 | 62 | 15 | 25.0 | 21.4 | 19.5 | 26.1 | 25.5 | 25.8 | 23.3 | 25.3 | 24.6 | 22.7 | 22.4 | 19.5 | 281.1 |
| Bogota | 04 42N | 74 08W | 8,355 | 10 | 67 | 48 | 67 | 51 | 64 | 50 | 66 | 50 | 75 | 30 | 49 | 2.3 | 2.6 | 4.0 | 5.8 | 4.5 | 2.4 | 2.0 | 2.2 | 2.4 | 6.3 | 4.7 | 2.6 | 41.8 |
| Cartagena | 10 28N | 75 30W | 39 | 6 | 84 | 73 | 87 | 76 | 88 | 78 | 87 | 77 | 98 | 61 | 10 | 0.4 | 0.0 | 0.4 | 0.9 | 3.4 | 3.4 | 3.0 | 0.6 | 0.5 | 10.8 | 8.9 | 4.5 | 36.8 |
| Ipiales | 00 50N | 77 42W | 9,680 | 9 | 61 | 50 | 60 | 49 | 57 | 42 | 62 | 49 | 77 | 32 | 13 | 3.1 | 2.3 | 3.5 | 3.5 | 2.8 | 1.9 | 1.3 | 1.1 | 1.4 | 3.1 | 3.3 | 2.6 | 29.9 |
| Tumaco | 01 49N | 78 45W | 7 | 10 | 82 | 75 | 84 | 76 | 82 | 75 | 82 | 75 | 90 | 64 | 10 | 16.9 | 11.7 | 9.6 | 14.6 | 17.4 | 12.0 | 7.7 | 7.3 | 7.3 | 5.9 | 4.9 | 7.0 | 122.3 |
| Ecuador | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cuenca | 02 53S | 78 39W | 8,301 | 7 | 69 | 50 | 69 | 50 | 65 | 47 | 70 | 49 | 81 | 29 | 10 | 2.0 | 1.8 | 3.2 | 4.3 | 4.3 | 1.7 | 0.9 | 1.1 | 1.6 | 3.1 | 1.8 | 2.5 | 28.3 |
| Guayaquil | 02 10S | 79 53W | 20 | 5 | 87 | 72 | 88 | 72 | 84 | 67 | 86 | 68 | 98 | 52 | 10 | 8.3 | 11.4 | 11.5 | 8.1 | 2.1 | 0.4 | 0.2 | — | — | — | 0.1 | 1.1 | 43.2 |
| Quito | 00 08S | 78 29W | 9,222 | 54 | 67 | 46 | 69 | 47 | 71 | 44 | 71 | 46 | 86 | 25 | 33 | 3.9 | 4.4 | 5.6 | 6.9 | 5.4 | 1.7 | 0.8 | 1.2 | 2.7 | 4.4 | 3.8 | 3.1 | 43.9 |
| French Guiana | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cayenne | 04 56N | 52 27W | 20 | 38 | 84 | 74 | 86 | 75 | 88 | 73 | 91 | 74 | 97 | 65 | 51 | 14.4 | 12.3 | 15.8 | 18.9 | 21.7 | 15.5 | 6.9 | 2.8 | 1.2 | 1.3 | 4.6 | 10.7 | 126.1 |
| Guyana | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Georgetown | 06 50N | 58 12W | 6 | 54 | 84 | 74 | 85 | 76 | 85 | 75 | 87 | 76 | 93 | 68 | 35 | 8.0 | 4.5 | 6.9 | 5.5 | 11.4 | 11.9 | 10.0 | 6.9 | 3.2 | 3.0 | 6.1 | 11.3 | 88.7 |
| Lethem | 03 24N | 59 38W | 270 | 3 | 91 | 73 | 91 | 74 | 87 | 73 | 92 | 76 | 97 | 63 | 9 | 1.2 | 1.4 | 1.3 | 5.7 | 11.5 | 11.9 | 14.8 | 9.4 | 3.4 | 2.3 | 4.3 | 1.3 | 68.5 |
| Paraguay | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Asuncion | 25 17S | 57 30W | 456 | 15 | 95 | 71 | 84 | 65 | 74 | 53 | 86 | 62 | 110 | 29 | 30 | 5.5 | 5.1 | 4.3 | 5.2 | 4.6 | 2.7 | 2.2 | 1.5 | 3.1 | 5.5 | 5.9 | 6.2 | 51.8 |
| Bahia Negra | 20 14S | 58 10W | 318 | 20 | 92 | 74 | 87 | 68 | 79 | 61 | 90 | 69 | 106 | 35 | 20 | 5.4 | 5.3 | 4.9 | 2.9 | 2.3 | 1.6 | 1.5 | 0.6 | 2.3 | 4.2 | 5.3 | 4.3 | 40.6 |
| Peru | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Arequipa | 16 21S | 71 34W | 8,460 | 13 | 67 | 49 | 67 | 48 | 67 | 47 | 68 | 47 | 82 | 25 | 37 | 1.3 | 1.8 | 0.7 | 0.2 | — | — | — | — | 0.0 | — | — | 0.4 | 4.4 |
| Cajamarca | 07 09S | 78 30W | 8,662 | 9 | 71 | 48 | 70 | 47 | 70 | 41 | 71 | 47 | 79 | 25 | 9 | 3.6 | 4.2 | 4.6 | 3.4 | 1.7 | 9.5 | 9.2 | 9.3 | 2.3 | 2.3 | 1.9 | 3.2 | 28.2 |
| Cusco | 13 33S | 71 59W | 10,866 | 13 | 68 | 45 | 71 | 40 | 70 | 31 | 72 | 43 | 86 | 16 | 12 | 6.4 | 5.9 | 4.3 | 2.0 | 0.6 | 0.2 | 0.2 | 0.4 | 1.0 | 2.6 | 3.0 | 5.4 | 32.0 |
| Iquitos | 03 45S | 73 13W | 384 | 5 | 90 | 71 | 87 | 71 | 88 | 68 | 90 | 70 | 100 | 54 | 5 | 9.1 | 10.4 | 9.4 | 13.6 | 10.7 | 5.7 | 6.4 | 5.2 | 10.5 | 7.3 | 9.1 | 10.3 | 107.7 |
| Lima | 12 05S | 77 03W | 394 | 15 | 82 | 66 | 80 | 63 | 67 | 57 | 71 | 58 | 93 | 49 | 15 | 0.1 | — | — | — | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.1 | 0.1 | — | 1.6 |
| Mollendo | 17 00S | 72 07W | 80 | 10 | 79 | 66 | 76 | 63 | 67 | 57 | 70 | 59 | 90 | 50 | 10 | — | 0.1 | — | — | 0.1 | 0.1 | — | 0.2 | 0.2 | 0.1 | 0.1 | — | 0.9 |
| Surinam | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Paramaribo | 05 49N | 55 09W | 12 | 35 | 85 | 72 | 86 | 73 | 87 | 73 | 91 | 73 | 99 | 62 | 75 | 8.4 | 6.5 | 7.9 | 9.0 | 12.2 | 11.9 | 9.1 | 6.2 | 3.1 | 3.0 | 4.9 | 8.8 | 91.0 |
| Uruguay | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Artigas | 30 24S | 56 23W | 384 | 13 | 91 | 65 | 77 | 55 | 65 | 45 | 75 | 54 | 107 | 24 | 50 | 4.3 | 3.9 | 4.7 | 5.1 | 4.1 | 4.1 | 2.8 | 3.0 | 4.0 | 4.7 | 3.8 | 4.1 | 48.6 |
| Montevideo | 34 52S | 56 12W | 72 | 56 | 83 | 62 | 71 | 53 | 58 | 43 | 68 | 49 | 109 | 25 | 56 | 2.9 | 2.6 | 3.9 | 3.9 | 3.3 | 3.2 | 2.9 | 3.1 | 3.0 | 2.6 | 2.9 | 3.1 | 37.4 |
| Venezuela | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Caracas | 10 30N | 66 56W | 3,418 | 30 | 75 | 56 | 81 | 60 | 78 | 61 | 79 | 61 | 91 | 45 | 46 | 0.9 | 0.4 | 0.6 | 1.3 | 3.1 | 4.0 | 4.3 | 4.3 | 4.2 | 4.3 | 3.7 | 1.8 | 32.9 |
| Ciudad Bolivar | 08 07N | 63 32W | 197 | 10 | 90 | 72 | 93 | 75 | 90 | 75 | 93 | 75 | 100 | 64 | 10 | 1.4 | 0.8 | 0.7 | 1.0 | 3.8 | 5.5 | 6.3 | 7.1 | 3.6 | 4.0 | 2.8 | 1.3 | 38.3 |
| Maracaibo | 10 39N | 71 36W | 20 | 12 | 90 | 73 | 92 | 76 | 94 | 76 | 92 | 76 | 102 | 66 | 36 | 0.1 | — | 0.3 | 0.8 | 2.7 | 2.2 | 1.8 | 2.2 | 2.8 | 5.9 | 3.3 | 0.6 | 22.7 |
| Merida | 08 36N | 71 10W | 5,293 | 14 | 73 | 56 | 75 | 60 | 76 | 59 | 75 | 60 | 90 | 48 | 14 | 2.5 | 1.5 | 3.6 | 6.7 | 9.8 | 7.3 | 4.7 | 5.7 | 6.7 | 9.5 | 8.2 | 3.4 | 69.7 |
| Santa Elena | 04 36N | 61 07W | 2,976 | 10 | 82 | 61 | 82 | 63 | 81 | 61 | 84 | 61 | 95 | 48 | 10 | 3.2 | 3.2 | 3.2 | 5.7 | 9.6 | 9.5 | 9.1 | 7.6 | 5.3 | 4.9 | 4.9 | 4.5 | 70.7 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pacific Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Easter Is. (Isla de Pascua) | 27 10S | 109 26W | 98 | 4 | 77 | 64 | 78 | 63 | 70 | 58 | 73 | 58 | 88 | 46 | 10 | 4.8 | 3.7 | 4.6 | 4.2 | 4.6 | 4.3 | 3.5 | 3.0 | 2.7 | 3.7 | 4.6 | 4.9 | 48.6 |
| Mas a Tierra (Juan Fernandez) | 33 37S | 78 52W | 20 | 25 | 72 | 60 | 68 | 57 | 60 | 50 | 61 | 51 | 86 | 39 | 29 | 0.8 | 1.2 | 1.6 | 3.4 | 5.9 | 6.4 | 5.8 | 4.4 | 2.9 | 1.9 | 1.6 | 1.0 | 36.9 |
| Seymour Is. (Galapagos Is.) | 00 28S | 90 18W | 36 | 3 | 86 | 72 | 87 | 75 | 81 | 69 | 81 | 67 | 93 | 58 | 3 | 0.8 | 1.4 | 1.1 | 0.7 | — | — | — | — | — | — | — | — | 4.0 |
| Atlantic Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fernando de Noronha | 03 50S | 32 25W | 148 | 32 | 84 | 75 | 82 | 75 | 81 | 73 | 82 | 75 | 93 | 63 | 32 | 1.7 | 4.7 | 7.4 | 10.5 | 10.5 | 7.3 | 5.4 | 1.9 | 0.7 | 0.3 | 0.4 | 0.5 | 51.3 |
| Cumberland Bay, South Georgia | 54 16S | 36 30W | 8 | 23 | 48 | 35 | 42 | 29 | 34 | 23 | 41 | 28 | 84 | −3 | 24 | 3.3 | 4.3 | 5.3 | 5.4 | 5.2 | 4.9 | 5.5 | 5.3 | 3.5 | 2.6 | 3.4 | 3.0 | 51.7 |
| Laurie Is., South Orkneys | 60 44S | 44 44W | 13 | 48 | 35 | 29 | 31 | 21 | 20 | 4 | 30 | 19 | 54 | −40 | 46 | 1.4 | 1.5 | 1.9 | 1.6 | 1.2 | 1.0 | 1.3 | 1.3 | 1.1 | 1.1 | 1.3 | 1.0 | 15.7 |
| Stanley, Falkland Isles | 51 42S | 57 51W | 6 | 25 | 56 | 42 | 49 | 37 | 40 | 31 | 48 | 35 | 76 | 12 | 41 | 2.8 | 2.3 | 2.5 | 2.6 | 2.6 | 2.1 | 2.0 | 2.0 | 1.5 | 1.6 | 2.0 | 2.8 | 26.8 |
| **Europe** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Albania | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Durres | 41 19N | 19 28E | 23 | 10 | 51 | 42 | 63 | 55 | 83 | 74 | 68 | 58 | 95 | 21 | 10 | 3.0 | 3.3 | 3.9 | 2.2 | 1.6 | 1.9 | 0.5 | 1.9 | 1.7 | 7.1 | 8.5 | 7.3 | 42.9 |
| Andorra | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Les Escaldes | 42 30N | 01 31E | 3,543 | 5 | 43 | 29 | 59 | 39 | 78 | 55 | 61 | 42 | 91 | 0 | 9 | 1.5 | 1.7 | 2.9 | 2.4 | 4.7 | 3.1 | 2.2 | 3.4 | 3.1 | 3.5 | 3.3 | 2.5 | 34.3 |
| Austria | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Innsbruck | 47 16N | 11 24E | 1,909 | 34 | 34 | 20 | 60 | 39 | 78 | 55 | 58 | 40 | 97 | −16 | 35 | 2.1 | 1.8 | 1.5 | 2.2 | 2.9 | 4.1 | 5.1 | 4.5 | 3.1 | 2.4 | 2.2 | 1.9 | 33.8 |
| Vienna | 48 15N | 16 22E | 664 | 50 | 34 | 26 | 57 | 41 | 75 | 59 | 55 | 44 | 98 | −14 | 100 | 1.5 | 1.4 | 1.8 | 2.0 | 2.8 | 2.7 | 3.0 | 2.7 | 2.0 | 2.0 | 1.9 | 1.8 | 25.6 |
| Bulgaria | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sofia | 42 42N | 23 20E | 1,805 | 30 | 34 | 22 | 62 | 41 | 82 | 57 | 63 | 42 | 99 | −17 | 27 | 1.3 | 1.1 | 1.7 | 2.3 | 3.3 | 3.2 | 2.4 | 2.0 | 2.3 | 2.1 | 1.9 | 1.4 | 25.0 |
| Varna | 43 12N | 27 55E | 115 | 30 | 40 | 30 | 59 | 43 | 84 | 63 | 67 | 50 | 107 | −12 | 20 | 1.5 | 0.9 | 1.2 | 1.2 | 1.8 | 2.6 | 1.9 | 1.2 | 1.5 | 1.9 | 1.9 | 2.0 | 19.6 |
| Cyprus | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nicosia | 35 09N | 33 17E | 716 | 40 | 58 | 42 | 74 | 50 | 97 | 69 | 81 | 58 | 116 | 23 | 64 | 2.9 | 2.0 | 1.3 | 0.8 | 1.1 | 0.4 | — | — | 0.2 | 0.9 | 1.7 | 3.0 | 14.6 |
| Czechoslovakia | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Prague | 50 05N | 14 25E | 662 | 40 | 34 | 25 | 55 | 40 | 74 | 58 | 54 | 44 | 98 | −16 | 70 | 0.9 | 0.8 | 1.1 | 1.5 | 2.4 | 2.8 | 2.6 | 2.2 | 1.7 | 1.2 | 1.2 | 0.9 | 19.3 |
| Prerov | 49 27N | 17 27E | 702 | 20 | 34 | 25 | 57 | 38 | 77 | 55 | 56 | 40 | 100 | −23 | 21 | 1.3 | 1.1 | 1.1 | 2.0 | 2.4 | 2.9 | 3.5 | 3.2 | 2.0 | 2.4 | 1.5 | 1.4 | 24.8 |
| Denmark | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Copenhagen | 55 41N | 12 33E | 43 | 30 | 36 | 29 | 50 | 37 | 72 | 55 | 53 | 42 | 91 | −3 | 30 | 1.6 | 1.3 | 1.2 | 1.7 | 1.7 | 2.1 | 2.2 | 3.2 | 1.9 | 2.1 | 2.2 | 2.1 | 23.3 |
| Aarhus | 56 08N | 10 12E | 161 | 21 | 35 | 27 | 51 | 37 | 70 | 54 | 53 | 42 | 87 | −12 | 21 | 2.3 | 1.5 | 1.4 | 1.8 | 1.2 | 2.2 | 2.5 | 3.3 | 3.2 | 2.6 | 2.5 | 2.1 | 26.6 |
| Finland | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Helsinki | 60 10N | 24 57E | 30 | 20 | 27 | 17 | 43 | 31 | 71 | 57 | 45 | 37 | 89 | −23 | 50 | 2.2 | 1.7 | 1.7 | 1.7 | 1.9 | 2.0 | 2.3 | 3.3 | 2.8 | 2.9 | 2.7 | 2.4 | 27.6 |
| Kuusamo | 65 57N | 29 12E | 843 | 20 | 17 | 2 | 35 | 18 | 68 | 50 | 36 | 27 | 90 | −40 | 20 | 1.1 | 1.1 | 1.1 | 1.1 | 1.4 | 2.3 | 2.8 | 3.0 | 2.1 | 2.1 | 1.6 | 1.1 | 20.8 |
| Vaasa | 63 05N | 21 36E | 13 | 18 | 26 | 16 | 41 | 28 | 69 | 55 | 44 | 36 | 89 | −29 | 19 | 1.1 | 0.8 | 0.8 | 1.0 | 1.4 | 1.8 | 2.4 | 2.5 | 2.7 | 2.3 | 1.7 | 1.1 | 19.6 |
| France | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ajaccio (Corsica) | 41 52N | 08 35E | 243 | 46 | 56 | 40 | 66 | 48 | 85 | 64 | 72 | 55 | 103 | 23 | 86 | 3.0 | 2.3 | 2.6 | 2.2 | 1.6 | 0.9 | 2.8 | 0.7 | 1.7 | 3.8 | 4.4 | 3.1 | 29.1 |
| Bordeaux | 44 50N | 00 43W | 157 | 51 | 48 | 35 | 63 | 44 | 80 | 58 | 66 | 47 | 102 | 9 | 47 | 2.7 | 2.8 | 2.9 | 2.6 | 2.5 | 2.3 | 2.0 | 1.9 | 2.2 | 3.0 | 3.9 | 3.9 | 32.7 |
| Brest | 48 19N | 04 47W | 56 | 56 | 49 | 40 | 57 | 44 | 70 | 56 | 61 | 49 | 95 | 7 | 56 | 3.5 | 3.0 | 2.5 | 2.5 | 1.9 | 2.0 | 2.0 | 2.2 | 2.3 | 3.6 | 4.2 | 4.4 | 34.1 |
| Cherbourg | 49 39N | 01 38W | 30 | 47 | 47 | 40 | 54 | 43 | 67 | 57 | 59 | 50 | 91 | 14 | 47 | 3.3 | 2.9 | 2.7 | 2.0 | 1.9 | 1.8 | 1.9 | 3.0 | 2.9 | 4.6 | 5.1 | 5.2 | 37.3 |
| Lille | 50 35N | 03 05W | 141 | 40 | 42 | 33 | 58 | 40 | 75 | 55 | 59 | 45 | 96 | 0 | 40 | 2.5 | 1.9 | 2.5 | 2.0 | 2.4 | 2.2 | 2.8 | 2.3 | 2.6 | 3.0 | 3.0 | 3.2 | 30.3 |
| Lyon | 45 42N | 04 47E | 938 | 70 | 41 | 30 | 61 | 42 | 80 | 58 | 61 | 45 | 105 | −13 | 70 | 1.4 | 1.4 | 1.8 | 2.1 | 2.8 | 2.9 | 2.8 | 2.9 | 3.1 | 3.1 | 2.6 | 1.9 | 28.8 |
| Marseille | 43 18N | 05 23E | 246 | 72 | 53 | 38 | 59 | 41 | 78 | 58 | 76 | 57 | 101 | 9 | 102 | 1.9 | 1.5 | 1.8 | 2.0 | 1.9 | 1.0 | 0.6 | 0.9 | 2.6 | 3.7 | 3.1 | 2.2 | 23.2 |
| Paris | 48 49N | 02 29E | 164 | 66 | 42 | 32 | 60 | 41 | 76 | 55 | 59 | 44 | 105 | 1 | 118 | 1.5 | 1.3 | 1.5 | 1.7 | 2.0 | 2.1 | 2.1 | 2.0 | 2.0 | 2.2 | 2.0 | 1.9 | 22.3 |
| Strasbourg | 48 35N | 07 46E | 465 | 20 | 40 | 31 | 59 | 41 | 78 | 57 | 58 | 43 | 101 | −8 | 20 | 1.6 | 1.4 | 1.7 | 2.6 | 2.6 | 3.1 | 3.4 | 3.4 | 3.1 | 2.7 | 2.0 | 1.9 | 29.5 |
| Toulouse | 43 33N | 01 23E | 538 | 47 | 47 | 35 | 62 | 43 | 82 | 59 | 66 | 48 | 111 | 1 | 47 | 1.9 | 1.7 | 2.3 | 2.7 | 2.9 | 2.4 | 1.5 | 2.1 | 2.3 | 2.2 | 2.4 | 2.3 | 26.7 |
| Germany | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Berlin | 52 27N | 13 18E | 187 | 50 | 35 | 26 | 55 | 38 | 74 | 55 | 55 | 41 | 96 | −15 | 40 | 1.9 | 1.3 | 1.5 | 1.7 | 1.9 | 2.3 | 3.1 | 2.2 | 1.9 | 1.7 | 1.7 | 1.9 | 23.1 |
| Bremen | 53 05N | 08 47E | 52 | 50 | 37 | 30 | 53 | 38 | 71 | 55 | 54 | 43 | 94 | −7 | 80 | 1.9 | 1.6 | 1.8 | 1.5 | 2.1 | 2.6 | 3.2 | 2.8 | 2.1 | 2.2 | 2.0 | 2.2 | 26.0 |
| Frankfurt A/M | 50 07N | 08 40E | 338 | 50 | 37 | 29 | 58 | 41 | 75 | 56 | 56 | 43 | 100 | −7 | 80 | 1.7 | 1.3 | 1.6 | 1.5 | 2.0 | 2.5 | 2.8 | 2.6 | 1.9 | 2.2 | 2.0 | 2.0 | 24.1 |
| Hamburg | 53 33N | 09 58E | 66 | 50 | 35 | 28 | 51 | 39 | 69 | 56 | 53 | 44 | 92 | −4 | 80 | 2.1 | 1.9 | 2.0 | 1.8 | 2.1 | 2.7 | 3.4 | 3.2 | 2.5 | 2.6 | 2.1 | 2.5 | 28.9 |
| Munich | 48 09N | 11 34E | 1,739 | 50 | 33 | 23 | 54 | 37 | 72 | 54 | 53 | 40 | 92 | −14 | 80 | 1.7 | 1.4 | 1.9 | 2.7 | 3.7 | 4.6 | 4.7 | 4.2 | 3.2 | 2.2 | 1.9 | 1.9 | 34.1 |
| Munster | 51 58N | 07 38E | 207 | 50 | 39 | 29 | 56 | 38 | 73 | 54 | 56 | 42 | 96 | −17 | 40 | 2.6 | 1.9 | 2.2 | 2.0 | 2.2 | 2.7 | 3.3 | 3.1 | 2.5 | 2.7 | 2.4 | 2.9 | 30.5 |
| Numberg | 49 27N | 11 03E | 1,050 | 50 | 35 | 26 | 56 | 38 | 74 | 55 | 55 | 41 | 99 | −18 | 80 | 1.5 | 1.2 | 1.3 | 1.7 | 2.2 | 2.5 | 3.1 | 3.1 | 2.1 | 2.1 | 1.9 | 1.7 | 24.4 |
| Gibraltar | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Windmill Hill | 36 06N | 05 21W | 400 | 12 | 58 | 50 | 64 | 55 | 77 | 66 | 70 | 61 | 97 | 35 | 12 | 4.6 | 3.4 | 3.7 | 2.5 | 1.4 | 0.2 | — | 0.1 | 0.8 | 3.5 | 4.1 | 5.4 | 29.7 |
| Greece | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Athens | 37 58N | 23 43E | 351 | 72 | 54 | 42 | 67 | 52 | 90 | 72 | 74 | 60 | 109 | 20 | 80 | 2.2 | 1.6 | 1.4 | 0.8 | 0.8 | 0.6 | 0.2 | 0.4 | 0.6 | 1.7 | 2.8 | 2.8 | 15.8 |
| Iraklion (Crete) | 35 20N | 25 08E | 98 | 21 | 60 | 48 | 70 | 54 | 85 | 72 | 77 | 62 | 114 | 32 | 22 | 3.7 | 3.0 | 1.6 | 0.9 | 0.7 | 0.1 | — | 0.1 | 0.7 | 1.7 | 2.8 | 2.8 | 15.8 |

*(Continued)*



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**Table 3B.13 (Continued)**

| Country and Station | Latitude | Longitude | Elevation | Temperature | | | | | | | | | | | Average Precipitation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Average Daily | | | | | | | | Extreme | | | | | | | | | | | | | | | | |
| | | | | | Jan | | Apr | | July | | Oct | | | | | | | | | | | | | | | | | | |
| | | | | Length of Record | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Length of Record | January | February | March | April | May | June | July | August | September | October | November | December | Year |
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| Rhodes | 36 26N | 28 15E | 289 | 10 | 59 | 51 | 67 | 59 | 83 | 74 | 76 | 68 | 104 | 30 | 6 | 5.7 | 3.9 | 2.6 | 1.7 | 0.5 | 0.3 | 0.0 | — | 0.4 | 1.7 | 5.2 | 6.7 | 28.5 |
| Thessaloniki | 40 37N | 22 57E | 78 | 9 | 49 | | | | | | | | | | | | | | | | | | | | | | | |
| Hungary | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Budapest | 47 31N | 19 02E | 394 | 50 | 35 | 26 | 62 | 44 | 82 | 61 | 61 | 45 | 103 | −10 | 50 | 1.5 | 1.5 | 1.7 | 2.0 | 2.7 | 2.6 | 2.0 | 1.9 | 1.8 | 2.1 | 2.4 | 2.0 | 24.2 |
| Debrecen | 47 36N | 21 39E | 430 | 50 | 33 | 21 | 61 | 39 | 81 | 57 | 60 | 41 | 102 | −22 | 80 | 1.2 | 1.1 | 1.4 | 1.8 | 2.4 | 2.8 | 2.5 | 2.3 | 1.8 | 2.2 | 2.0 | 1.6 | 23.1 |
| Iceland | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Akureyri | 65 41N | 18 05W | 16 | 23 | 34 | 26 | 40 | 30 | 57 | 47 | 43 | 34 | 83 | −8 | 26 | 1.7 | 1.5 | 1.7 | 1.3 | 0.6 | 0.9 | 1.3 | 1.6 | 1.9 | 2.3 | 1.9 | 1.9 | 18.6 |
| Reykjavik | 64 09N | 21 56W | 92 | 25 | 36 | 28 | 43 | 33 | 58 | 48 | 44 | 36 | 74 | 4 | 30 | 4.0 | 3.1 | 3.0 | 2.1 | 1.6 | 1.7 | 2.0 | 2.6 | 3.1 | 3.4 | 3.6 | 3.7 | 33.9 |
| Ireland | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cork | 51 54N | 08 29W | 56 | 27 | 48 | 38 | 55 | 41 | 68 | 53 | 58 | 44 | 85 | 15 | 35 | 4.9 | 3.6 | 3.3 | 2.6 | 2.9 | 2.0 | 2.9 | 3.1 | 2.9 | 3.9 | 4.5 | 4.7 | 41.3 |
| Dublin | 53 22N | 06 21W | 155 | 30 | 47 | 35 | 54 | 38 | 67 | 51 | 57 | 43 | 86 | 8 | 35 | 2.7 | 2.2 | 2.0 | 1.9 | 2.3 | 2.0 | 2.8 | 3.0 | 2.8 | 2.7 | 2.7 | 2.6 | 29.7 |
| Shannon Airport | 52 41N | 08 55W | 8 | 9 | 46 | 36 | 55 | 41 | 66 | 53 | 58 | 45 | 87 | 12 | 12 | 3.8 | 3.0 | 2.0 | 2.2 | 2.4 | 2.1 | 3.1 | 3.0 | 3.0 | 3.4 | 4.2 | 4.3 | 36.5 |
| Italy | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ancona | 43 37N | 13 32E | 52 | 30 | 46 | 36 | 62 | 50 | 83 | 68 | 67 | 55 | 102 | 18 | 30 | 2.6 | 1.7 | 1.6 | 2.3 | 2.1 | 1.9 | 1.5 | 1.5 | 3.5 | 3.7 | 2.5 | 3.0 | 28.0 |
| Cagliari (Sardinia) | 39 15N | 09 03E | 3 | 30 | 56 | 43 | 66 | 50 | 86 | 67 | 72 | 58 | 102 | 25 | 25 | 2.2 | 1.5 | 1.5 | 1.2 | 1.5 | 0.5 | 0.1 | 0.4 | 1.0 | 3.0 | 1.8 | 2.3 | 17.0 |
| Genoa | 44 24N | 08 55E | 318 | 10 | 50 | 41 | 65 | 53 | 82 | 70 | 73 | 58 | 100 | 18 | 10 | 3.9 | 4.0 | 3.3 | 3.4 | 4.6 | 1.4 | 1.6 | 2.3 | 4.7 | 6.1 | 7.2 | 4.1 | 46.6 |
| Naples | 40 51N | 14 15E | 82 | 30 | 54 | 40 | 65 | 52 | 84 | 70 | 71 | 60 | 101 | 24 | 30 | 3.7 | 3.2 | 3.0 | 2.6 | 1.8 | 1.8 | 0.6 | 0.7 | 2.8 | 5.1 | 4.5 | 5.4 | 35.2 |
| Palermo (Sicily) | 38 07N | 13 19E | 354 | 10 | 58 | 47 | 67 | 53 | 86 | 71 | 75 | 62 | 113 | 31 | 30 | 3.8 | 3.4 | 2.4 | 1.9 | 1.1 | 0.6 | 0.2 | 0.6 | 0.2 | 3.7 | 4.1 | 4.5 | 28.3 |
| Rome | 41 48N | 12 36E | 377 | 10 | 54 | 39 | 68 | 46 | 88 | 64 | 73 | 53 | 104 | 20 | 30 | 3.3 | 2.9 | 2.0 | 2.0 | 1.9 | 0.7 | 0.4 | 0.7 | 2.8 | 4.3 | 4.4 | 4.1 | 29.5 |
| Taranto | 40 28N | 17 17E | 56 | 10 | 55 | 43 | 59 | 50 | 89 | 70 | 73 | 58 | 108 | 26 | 10 | 1.6 | 0.9 | 1.3 | 0.8 | 1.0 | 0.6 | 0.4 | 0.7 | 1.0 | 2.2 | 1.8 | 1.9 | 14.2 |
| Venice | 45 26N | 12 23E | 82 | 10 | 43 | 33 | 63 | 49 | 82 | 67 | 65 | 52 | 97 | 14 | 30 | 2.0 | 2.1 | 2.4 | 2.8 | 3.2 | 3.3 | 2.6 | 2.6 | 2.6 | 3.7 | 3.5 | 2.6 | 33.4 |
| Luxembourg | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Luxembourg | 49 37N | 06 03E | 1,096 | 7 | 36 | 29 | 58 | 40 | 74 | 55 | 56 | 43 | 99 | −10 | 100 | 2.3 | 2.0 | 1.9 | 2.1 | 2.4 | 2.5 | 2.8 | 2.6 | 2.4 | 2.7 | 2.7 | 2.8 | 29.2 |
| Malta | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Valletta | 35 54N | 14 31E | 233 | 90 | 59 | 51 | 66 | 56 | 84 | 72 | 76 | 66 | 105 | 34 | 90 | 3.3 | 2.3 | 1.5 | 0.8 | 0.4 | 0.4 | * | 0.2 | 1.3 | 2.7 | 3.6 | 3.9 | 20.3 |
| Monaco | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monaco | 43 44N | 07 25E | 180 | 60 | 54 | 46 | 61 | 53 | 77 | 70 | 67 | 60 | 93 | 27 | 60 | 2.4 | 2.3 | 3.1 | 2.2 | 2.1 | 1.4 | 0.7 | 1.1 | 2.3 | 4.7 | 4.3 | 3.5 | 30.1 |
| Netherlands | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Amsterdam | 52 23N | 04 55E | 5 | 29 | 40 | 34 | 52 | 43 | 69 | 59 | 56 | 48 | 95 | 3 | 29 | 2.0 | 1.4 | 1.3 | 1.6 | 1.8 | 1.8 | 2.6 | 2.7 | 2.8 | 2.8 | 2.6 | 2.2 | 25.6 |
| Norway | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bergen | 60 24N | 05 19E | 141 | 49 | 43 | 27 | 55 | 34 | 72 | 51 | 57 | 38 | 89 | 3 | 75 | 7.9 | 6.0 | 5.4 | 4.4 | 3.9 | 4.2 | 5.2 | 7.3 | 9.2 | 9.2 | 8.0 | 8.1 | 78.8 |
| Kristiansand | 58 10N | 07 59E | 175 | 11 | 32 | 25 | 50 | 35 | 71 | 53 | 53 | 39 | 90 | −14 | 56 | 5.0 | 3.6 | 3.6 | 2.7 | 2.5 | 2.8 | 3.5 | 5.3 | 4.7 | 6.2 | 5.7 | 6.4 | 52.0 |
| Oslo | 59 56N | 10 44E | 308 | 44 | 30 | 20 | 50 | 34 | 73 | 56 | 49 | 37 | 93 | −21 | 56 | 1.7 | 1.3 | 1.4 | 1.6 | 1.8 | 2.4 | 2.9 | 3.8 | 2.5 | 2.9 | 2.3 | 2.3 | 26.9 |
| Tromoso | 69 39N | 18 57E | 335 | 47 | 30 | 22 | 37 | 27 | 69 | 48 | 40 | 33 | 83 | −1 | 75 | 4.1 | 3.8 | 3.3 | 2.4 | 2.1 | 2.1 | 2.3 | 2.9 | 4.7 | 4.5 | 4.0 | 3.9 | 40.1 |
| Trondheim | 63 25N | 10 27E | 417 | 44 | 31 | 22 | 45 | 32 | 66 | 51 | 46 | 36 | 95 | −22 | 65 | 3.1 | 2.7 | 2.6 | 2.0 | 1.7 | 1.9 | 2.4 | 3.0 | 3.4 | 3.7 | 2.8 | 2.8 | 32.1 |
| Vardo | 70 22N | 31 06E | 43 | 40 | 27 | 19 | 34 | 26 | 53 | 44 | 38 | 32 | 80 | −11 | 56 | 2.5 | 2.5 | 2.3 | 1.5 | 1.3 | 1.3 | 1.5 | 1.7 | 1.9 | 2.5 | 2.1 | 2.4 | 23.5 |
| Poland | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Danzig | 54 24N | 18 40E | 36 | 36 | 33 | 25 | 49 | 37 | 70 | 56 | 53 | 42 | 94 | −16 | 35 | 1.2 | 1.0 | 1.3 | 1.5 | 1.8 | 2.3 | 2.8 | 2.6 | 2.1 | 1.8 | 1.8 | 1.5 | 21.7 |
| Krakow | 50 04N | 19 57E | 723 | 35 | 32 | 22 | 55 | 38 | 76 | 57 | 56 | 41 | 97 | −28 | 35 | 1.1 | 1.3 | 1.4 | 1.8 | 2.8 | 4.0 | 4.5 | 3.8 | 2.7 | 2.2 | 1.7 | 1.3 | 28.6 |
| Warsaw | 52 13N | 21 02E | 294 | 25 | 30 | 21 | 54 | 38 | 75 | 56 | 54 | 41 | 98 | −22 | 113 | 1.2 | 1.1 | 1.3 | 1.5 | 1.9 | 2.6 | 3.0 | 3.0 | 1.9 | 1.7 | 1.4 | 1.4 | 22.0 |
| Wroclaw (Breslau) | 51 07N | 17 05E | 482 | 50 | 35 | 25 | 55 | 39 | 74 | 57 | 55 | 42 | 98 | −26 | 40 | 1.5 | 1.1 | 1.5 | 1.7 | 2.4 | 2.4 | 3.4 | 2.7 | 1.8 | 1.7 | 1.5 | 1.5 | 23.2 |
| Portugal | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Braganca | 41 49N | 06 47W | 2,395 | 11 | 46 | 31 | 59 | 39 | 80 | 54 | 62 | 42 | 103 | 10 | 11 | 11.9 | 6.9 | 7.7 | 3.7 | 3.0 | 1.6 | 0.5 | 0.6 | 1.5 | 3.0 | 6.3 | 7.1 | 53.8 |
| Lagos | 37 06N | 08 38W | 46 | 21 | 61 | 47 | 67 | 52 | 83 | 64 | 73 | 58 | 107 | 28 | 17 | 3.2 | 2.6 | 2.8 | 1.4 | 0.8 | 0.2 | * | * | 0.4 | 1.5 | 2.6 | 2.8 | 18.3 |
| Lisbon | 38 43N | 09 08W | 313 | 75 | 56 | 46 | 64 | 52 | 79 | 63 | 69 | 57 | 103 | 29 | 75 | 3.3 | 3.2 | 3.1 | 2.4 | 1.7 | 0.7 | 0.2 | 0.2 | 1.4 | 3.1 | 4.2 | 3.6 | 27.0 |
| Romania | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bucharest | 44 25N | 26 06E | 269 | 41 | 33 | 20 | 63 | 41 | 86 | 61 | 65 | 44 | 105 | −18 | 41 | 1.5 | 1.1 | 1.7 | 1.6 | 2.5 | 3.8 | 2.3 | 1.8 | 1.5 | 1.6 | 1.9 | 1.5 | 22.8 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cluj | 46 47N | 23 40E | 1,286 | 15 | 31 | 18 | 58 | 38 | 79 | 56 | 60 | 41 | 100 | −26 | 16 | 1.3 | 1.2 | 1.0 | 2.1 | 3.3 | 3.3 | 2.6 | 3.3 | 2.0 | 1.7 | 1.0 | 1.2 | 24.0 |
| Constanta | 44 11N | 28 39E | 13 | 20 | 37 | 25 | 55 | 42 | 79 | 63 | 62 | 49 | 101 | −13 | 39 | 1.2 | 1.2 | 1.1 | 1.1 | 1.3 | 1.7 | 1.3 | 1.1 | 1.1 | 1.4 | 1.2 | 1.4 | 15.1 |
| Spain | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Almeria | 36 51N | 02 28W | 213 | 20 | 61 | 47 | 69 | 54 | 85 | 69 | 76 | 62 | 108 | 34 | 20 | 0.9 | 1.0 | 0.7 | 0.9 | 0.7 | 0.2 | * | 0.1 | 0.6 | 0.9 | 1.5 | 1.1 | 8.6 |
| Barcelona | 41 24N | 02 09E | 312 | 20 | 56 | 42 | 64 | 51 | 81 | 69 | 71 | 58 | 98 | 24 | 30 | 1.2 | 2.1 | 1.9 | 1.8 | 1.8 | 1.3 | 1.2 | 1.7 | 2.6 | 3.4 | 2.7 | 1.8 | 23.5 |
| Burgos | 42 20N | 03 42W | 2,825 | 29 | 42 | 30 | 57 | 38 | 77 | 53 | 61 | 43 | 99 | 0 | 29 | 1.5 | 1.5 | 2.1 | 1.9 | 2.4 | 1.7 | 0.8 | 0.7 | 1.4 | 2.0 | 2.2 | 2.0 | 20.2 |
| Madrid | 40 25N | 03 41W | 2,188 | 30 | 47 | 33 | 64 | 44 | 87 | 62 | 66 | 48 | 102 | 14 | 30 | 1.1 | 1.7 | 1.7 | 1.7 | 1.5 | 1.2 | 0.4 | 0.3 | 1.2 | 1.9 | 2.2 | 1.6 | 16.5 |
| Sevilla | 37 29N | 05 59W | 98 | 26 | 59 | 41 | 73 | 51 | 96 | 67 | 78 | 57 | 117 | 27 | 26 | 2.2 | 2.9 | 3.3 | 2.3 | 1.3 | 0.9 | 0.1 | 0.1 | 1.1 | 2.6 | 3.7 | 2.8 | 23.3 |
| Valencia | 39 28N | 00 23W | 79 | 26 | 58 | 41 | 67 | 51 | 83 | 68 | 73 | 57 | 107 | 20 | 29 | 0.9 | 1.5 | 0.9 | 1.2 | 1.1 | 1.3 | 0.4 | 0.5 | 2.2 | 1.6 | 2.5 | 1.3 | 15.4 |
| Sweden | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Abisko | 68 21N | 18 49E | 1,273 | 11 | 20 | 6 | 33 | 19 | 61 | 45 | 35 | 24 | 82 | −30 | 11 | 0.7 | 0.6 | 0.5 | 0.5 | 0.7 | 1.8 | 1.6 | 1.8 | 1.2 | 1.0 | 0.6 | 0.6 | 11.7 |
| Goteberg | 57 42N | 11 58E | 55 | 39 | 35 | 27 | 48 | 36 | 69 | 56 | 51 | 42 | 88 | −13 | 61 | 2.5 | 2.0 | 2.0 | 1.7 | 1.9 | 2.2 | 2.8 | 3.7 | 3.1 | 3.1 | 2.7 | 2.8 | 30.5 |
| Haparanda | 65 50N | 24 09E | 30 | 20 | 22 | 10 | 38 | 23 | 71 | 53 | 39 | 30 | 89 | −34 | 20 | 2.2 | 1.6 | 1.2 | 1.5 | 1.4 | 1.7 | 2.1 | 2.8 | 2.6 | 2.8 | 2.5 | 2.0 | 24.4 |
| Karlstad | 59 23N | 13 30E | 164 | 30 | 30 | 20 | 49 | 32 | 73 | 56 | 49 | 38 | 93 | −21 | 30 | 1.9 | 1.2 | 1.2 | 1.4 | 1.9 | 1.9 | 2.6 | 3.1 | 2.9 | 2.4 | 2.4 | 1.9 | 24.8 |
| Sarna | 61 41N | 13 07E | 1,504 | 20 | 19 | 4 | 42 | 23 | 69 | 46 | 42 | 28 | 91 | −51 | 20 | 1.6 | 0.8 | 0.9 | 1.2 | 1.6 | 2.8 | 3.6 | 3.3 | 2.6 | 2.3 | 1.8 | 1.8 | 24.3 |
| Stockholm | 59 21N | 18 04E | 146 | 30 | 31 | 23 | 45 | 32 | 70 | 55 | 48 | 39 | 97 | −26 | 30 | 1.5 | 1.1 | 1.1 | 1.5 | 1.6 | 1.9 | 2.8 | 3.1 | 2.1 | 2.1 | 1.9 | 1.9 | 22.4 |
| Visby (Gotland) | 57 39N | 18 18E | 36 | 30 | 35 | 28 | 44 | 33 | 67 | 55 | 50 | 41 | 88 | 1 | 30 | 1.7 | 1.1 | 1.2 | 1.4 | 1.1 | 1.4 | 2.0 | 2.7 | 1.7 | 1.9 | 2.1 | 2.0 | 20.3 |
| Switzerland | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Berne | 46 57N | 07 26E | 1,877 | 30 | 35 | 26 | 56 | 39 | 74 | 56 | 55 | 42 | 96 | −9 | 77 | 1.9 | 2.0 | 2.6 | 3.0 | 3.7 | 4.4 | 4.4 | 4.3 | 3.5 | 3.5 | 2.7 | 2.5 | 38.5 |
| Geneva | 46 12N | 06 09E | 1,329 | 30 | 39 | 29 | 58 | 41 | 77 | 58 | 58 | 44 | 101 | −1 | 125 | 1.9 | 1.8 | 2.2 | 2.5 | 3.0 | 3.1 | 2.9 | 3.6 | 3.6 | 3.8 | 3.1 | 2.4 | 33.9 |
| Zurich | 47 23N | 08 33E | 1,617 | 23 | 38 | 28 | 57 | 39 | 76 | 55 | 57 | 42 | 98 | −12 | 23 | 2.3 | 1.9 | 2.9 | 3.4 | 4.0 | 4.9 | 5.0 | 4.6 | 3.3 | 3.2 | 2.5 | 2.9 | 40.9 |
| Turkey | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Edirne | 41 39N | 26 34E | 154 | 18 | 41 | 28 | 66 | 44 | 88 | 63 | 70 | 49 | 107 | −8 | 18 | 2.2 | 1.9 | 1.7 | 1.9 | 1.7 | 2.1 | 1.5 | 1.1 | 1.1 | 2.1 | 2.9 | 3.0 | 23.2 |
| Istanbul | 40 58N | 28 50E | 59 | 18 | 45 | 36 | 61 | 45 | 81 | 65 | 67 | 54 | 100 | 17 | 18 | 3.7 | 2.3 | 2.6 | 1.9 | 1.4 | 1.3 | 1.7 | 1.5 | 2.3 | 3.8 | 4.1 | 4.9 | 31.5 |
| United Kingdom | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Belfast | 54 35N | 05 56W | 57 | 7 | 42 | 34 | 53 | 38 | 65 | 52 | 55 | 44 | 82 | 14 | 30 | 4.2 | 2.8 | 2.3 | 2.4 | 2.3 | 2.5 | 3.5 | 3.5 | 3.4 | 3.8 | 3.6 | 3.9 | 38.2 |
| Birmingham | 52 29N | 01 56W | 535 | 30 | 42 | 35 | 53 | 40 | 69 | 54 | 55 | 45 | 92 | 11 | 30 | 2.9 | 2.1 | 1.7 | 2.2 | 2.5 | 1.8 | 2.8 | 2.7 | 2.3 | 2.9 | 3.2 | 2.6 | 29.7 |
| Cardiff | 51 28N | 03 10W | 203 | 30 | 45 | 36 | 55 | 41 | 69 | 54 | 57 | 45 | 91 | 2 | 30 | 4.6 | 3.0 | 2.3 | 2.5 | 3.0 | 2.2 | 3.4 | 3.9 | 3.6 | 4.5 | 4.6 | 4.3 | 41.9 |
| Dublin | 53 22N | 06 21W | 155 | 30 | 47 | 35 | 54 | 38 | 67 | 51 | 57 | 43 | 86 | 8 | 35 | 2.7 | 2.2 | 2.0 | 1.9 | 2.3 | 2.0 | 2.8 | 3.0 | 2.8 | 2.7 | 2.7 | 2.6 | 29.7 |
| Edinburgh | 55 55N | 03 11W | 441 | 30 | 43 | 35 | 50 | 39 | 65 | 52 | 53 | 44 | 83 | 15 | 30 | 2.5 | 1.6 | 1.6 | 1.6 | 2.2 | 1.9 | 3.1 | 3.1 | 2.6 | 2.9 | 2.4 | 2.1 | 27.6 |
| London | 51 29N | 00 00 | 149 | 30 | 44 | 35 | 56 | 40 | 73 | 55 | 58 | 44 | 99 | 9 | 30 | 2.0 | 1.5 | 1.4 | 1.8 | 1.8 | 1.6 | 2.0 | 2.2 | 1.8 | 2.3 | 2.5 | 2.0 | 22.9 |
| Liverpool | 53 24N | 03 04W | 198 | 30 | 44 | 36 | 52 | 41 | 66 | 55 | 55 | 46 | 87 | 15 | 30 | 2.7 | 1.9 | 1.5 | 1.6 | 2.2 | 2.0 | 2.8 | 3.1 | 2.6 | 3.0 | 3.0 | 2.5 | 28.9 |
| Perth | 56 24N | 03 27W | 77 | 30 | 43 | 32 | 53 | 38 | 68 | 51 | 55 | 41 | 89 | 0 | 30 | 3.1 | 2.2 | 1.9 | 1.7 | 2.3 | 2.0 | 3.1 | 2.9 | 2.8 | 3.3 | 2.7 | 2.7 | 30.7 |
| Plymouth | 50 21N | 04 07W | 87 | 30 | 47 | 40 | 54 | 43 | 66 | 55 | 58 | 49 | 88 | 16 | 30 | 4.3 | 3.0 | 2.6 | 2.3 | 2.5 | 2.0 | 2.6 | 2.9 | 2.8 | 3.8 | 4.6 | 4.4 | 37.8 |
| Wick | 58 26N | 03 04W | 119 | 30 | 42 | 35 | 48 | 38 | 59 | 50 | 52 | 43 | 80 | 8 | 30 | 2.9 | 2.1 | 1.8 | 2.1 | 1.8 | 2.0 | 2.6 | 2.6 | 2.9 | 3.2 | 3.1 | 2.9 | 30.0 |
| U.S.S.R. | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Arkhangelsk | 64 33N | 40 32E | 22 | 23 | 9 | 2 | 36 | 23 | 64 | 51 | 36 | 30 | 91 | −49 | 25 | 1.2 | 1.1 | 1.1 | 0.7 | 1.3 | 1.9 | 2.6 | 2.7 | 2.2 | 1.9 | 1.6 | 1.3 | 19.8 |
| Astrakhan | 46 21N | 48 02E | 45 | 10 | 23 | 14 | 57 | 40 | 85 | 69 | 56 | 40 | 99 | −22 | 25 | 0.5 | 0.5 | 0.4 | 0.6 | 0.6 | 0.7 | 0.5 | 0.4 | 0.6 | 0.4 | 0.6 | 0.6 | 6.4 |
| Dnepropetrovsk | 48 27N | 35 04E | 259 | 18 | 25 | 16 | 53 | 39 | 80 | 62 | 56 | 40 | 101 | −25 | 17 | 1.4 | 1.1 | 1.2 | 1.4 | 1.8 | 3.0 | 1.9 | 1.6 | 1.0 | 1.8 | 1.6 | 1.6 | 19.4 |
| Kaunas | 54 54N | 23 53E | 118 | 19 | 26 | 18 | 49 | 34 | 72 | 53 | 50 | 38 | 96 | −23 | 19 | 1.6 | 1.3 | 1.3 | 1.8 | 2.0 | 3.2 | 3.3 | 3.5 | 1.9 | 1.9 | 1.6 | 1.6 | 25.0 |
| Kirov | 58 36N | 49 41E | 594 | 20 | 6 | −2 | 41 | 27 | 72 | 55 | 37 | 29 | 92 | −43 | 29 | 1.2 | 1.0 | 0.9 | 0.9 | 1.9 | 2.5 | 2.1 | 2.9 | 2.3 | 2.0 | 1.6 | 1.3 | 20.6 |
| Kursk | 51 45N | 36 12E | 773 | 15 | 19 | 11 | 47 | 35 | 74 | 58 | 48 | 36 | 91 | −23 | 20 | 1.5 | 1.3 | 1.2 | 1.5 | 2.2 | 2.5 | 3.2 | 2.3 | 1.6 | 1.8 | 1.5 | 1.7 | 22.3 |
| Leningrad | 59 56N | 30 16E | 16 | 26 | 23 | 12 | 45 | 31 | 71 | 57 | 45 | 37 | 91 | −36 | 95 | 1.0 | 0.9 | 0.9 | 1.0 | 1.6 | 2.0 | 2.5 | 2.8 | 2.1 | 1.8 | 1.4 | 1.2 | 19.2 |
| Lvov | 49 50N | 24 01E | 978 | 9 | 31 | 22 | 53 | 38 | 77 | 59 | 55 | 43 | 97 | −29 | 35 | 1.3 | 1.5 | 1.8 | 2.0 | 2.8 | 3.7 | 4.1 | 3.1 | 2.4 | 2.1 | 0.8 | 1.6 | 28.2 |
| Minsk | 53 54N | 27 33E | 738 | 12 | 22 | 13 | 47 | 33 | 70 | 54 | 47 | 36 | 92 | −27 | 20 | 1.4 | 1.5 | 1.3 | 1.5 | 2.0 | 2.8 | 3.0 | 3.1 | 1.6 | 1.5 | 1.5 | 1.7 | 22.9 |
| Moscow | 55 46N | 37 40E | 505 | 15 | 21 | 9 | 47 | 31 | 76 | 55 | 46 | 34 | 96 | −27 | 11 | 1.5 | 1.4 | 1.1 | 1.9 | 2.2 | 2.9 | 3.0 | 2.9 | 1.9 | 2.7 | 1.7 | 1.6 | 24.8 |
| Odessa | 46 29N | 30 44E | 214 | 20 | 28 | 22 | 52 | 41 | 79 | 65 | 57 | 47 | 99 | −13 | 15 | 1.0 | 0.7 | 0.7 | 1.1 | 1.1 | 1.9 | 1.6 | 1.4 | 1.1 | 1.4 | 1.1 | 1.1 | 14.3 |
| Riga | 56 57N | 24 06E | 67 | 30 | 29 | 20 | 48 | 35 | 72 | 56 | 49 | 39 | 93 | −20 | 57 | 1.3 | 1.0 | 1.1 | 1.2 | 1.7 | 2.4 | 3.0 | 3.0 | 2.1 | 2.0 | 1.9 | 1.5 | 22.2 |
| Saratov | 51 32N | 46 03E | 197 | 14 | 15 | 7 | 50 | 35 | 82 | 64 | 48 | 36 | 102 | −27 | 15 | 1.0 | 1.0 | 0.8 | 1.0 | 1.3 | 1.8 | 1.2 | 1.3 | 1.1 | 1.4 | 1.4 | 1.2 | 14.5 |
| Sevastopol | 44 37N | 33 31E | 75 | 20 | 39 | 30 | 55 | 42 | 79 | 65 | 63 | 50 | 97 | −4 | 30 | 1.1 | 1.1 | 1.1 | 0.9 | 0.6 | 1.1 | 0.8 | 0.6 | 1.1 | 1.5 | 1.2 | 1.1 | 12.2 |
| Stalingrad | 48 42N | 44 31E | 136 | 8 | 15 | 4 | 52 | 36 | 84 | 65 | 53 | 37 | 106 | −30 | 12 | 0.9 | 1.0 | 0.6 | 0.6 | 1.0 | 1.9 | 0.9 | 0.8 | 0.7 | 1.0 | 1.5 | 1.3 | 12.2 |
| Stavropol | 45 02N | 41 58E | 1,886 | 18 | 26 | 17 | 50 | 37 | 76 | 60 | 55 | 42 | 95 | −22 | 41 | 1.4 | 1.1 | 1.5 | 2.4 | 3.0 | 4.1 | 3.0 | 2.0 | 2.5 | 2.3 | 1.8 | 1.8 | 26.9 |
| Tallin | 59 26N | 24 48E | 146 | 15 | 27 | 18 | 42 | 31 | 70 | 55 | 47 | 38 | 89 | −19 | 63 | 1.1 | 1.0 | 0.9 | 1.1 | 1.7 | 1.9 | 2.1 | 2.7 | 2.3 | 2.1 | 1.9 | 1.5 | 20.2 |
| Tbilisi | 41 43N | 44 48E | 1,325 | 10 | 39 | 26 | 61 | 44 | 83 | 65 | 64 | 48 | 95 | 6 | 10 | 0.7 | 0.8 | 1.3 | 1.6 | 3.6 | 3.1 | 2.2 | 1.7 | 1.9 | 1.3 | 2.0 | 1.2 | 21.4 |
| Ust'Shchugor | 64 16N | 57 34E | 279 | 15 | 4 | −14 | 35 | 17 | 65 | 49 | 33 | 23 | 90 | −67 | 15 | 1.1 | 0.8 | 0.8 | 0.7 | 1.4 | 2.2 | 3.0 | 3.2 | 2.4 | 2.2 | 1.5 | 1.3 | 20.6 |
| Ufy | 54 43N | 55 56E | 571 | 20 | 6 | −3 | 44 | 30 | 75 | 58 | 41 | 31 | 99 | −42 | 23 | 1.6 | 1.3 | 1.2 | 0.9 | 1.6 | 2.4 | 2.6 | 2.2 | 1.8 | 2.3 | 2.2 | 2.3 | 22.5 |
| Yugoslavia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Belgrade | 44 48N | 20 28E | 453 | 16 | 37 | 27 | 64 | 45 | 84 | 61 | 65 | 47 | 107 | −14 | 16 | 1.6 | 1.3 | 1.6 | 2.2 | 2.6 | 2.8 | 1.9 | 2.5 | 1.7 | 2.7 | 1.8 | 1.9 | 24.6 |
| Skopje | 41 59N | 21 28E | 787 | 10 | 40 | 26 | 67 | 42 | 88 | 60 | 65 | 43 | 105 | −11 | 10 | 1.5 | 1.2 | 1.3 | 1.5 | 1.9 | 1.9 | 1.3 | 1.1 | 1.1 | 2.6 | 2.3 | 1.8 | 19.5 |
| Split | 43 31N | 16 26E | 420 | 14 | 51 | 29 | 65 | 50 | 87 | 68 | 69 | 55 | 100 | 17 | 51 | 3.1 | 2.5 | 3.2 | 3.0 | 2.5 | 2.1 | 1.2 | 1.6 | 2.9 | 4.4 | 4.2 | 4.4 | 35.1 |

*(Continued)*



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**Table 3B.13 (Continued)**

| Country and Station | Latitude | Longitude | Elevation | Temperature: Length of Record | Temperature: Average Daily: Jan: Maximum | Temperature: Average Daily: Jan: Minimum | Temperature: Average Daily: Apr: Maximum | Temperature: Average Daily: Apr: Minimum | Temperature: Average Daily: July: Maximum | Temperature: Average Daily: July: Minimum | Temperature: Average Daily: Oct: Maximum | Temperature: Average Daily: Oct: Minimum | Temperature: Extreme: Maximum | Temperature: Extreme: Minimum | Average Precipitation: Length of Record | Average Precipitation: January | Average Precipitation: February | Average Precipitation: March | Average Precipitation: April | Average Precipitation: May | Average Precipitation: June | Average Precipitation: July | Average Precipitation: August | Average Precipitation: September | Average Precipitation: October | Average Precipitation: November | Average Precipitation: December | Average Precipitation: Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| Ocean Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bjornoya, Bear Island | 74 31N | 19 01E | 49 | 10 | 26 | 17 | 27 | 16 | 44 | 36 | 36 | 29 | 71 | −25 | 25 | 1.6 | 1.3 | 1.3 | 0.9 | 0.8 | 0.7 | 0.8 | 1.2 | 1.8 | 1.7 | 1.4 | 1.6 | 15.1 |
| Gronfjorden, Spitzbergen | 78 02N | 14 15E | 23 | 19 | 10 | −4 | 15 | −3 | 46 | 38 | 25 | 17 | 60 | −57 | 15 | 1.4 | 1.3 | 1.1 | 0.9 | 0.5 | 0.4 | 0.6 | 0.9 | 1.0 | 1.2 | 0.9 | 1.5 | 11.7 |
| Horta, Azores | 38 32N | 28 38W | 200 | 30 | 62 | 54 | 64 | 55 | 76 | 65 | 71 | 62 | 88 | 38 | 30 | 4.5 | 4.1 | 4.2 | 3.0 | 2.9 | 2.0 | 1.5 | 1.9 | 3.2 | 4.4 | 4.1 | 4.5 | 40.3 |
| Jan Mayen | 77 01N | 08 28W | 131 | 5 | 31 | 21 | 31 | 22 | 46 | 38 | 39 | 29 | 60 | −18 | 29 | 2.1 | 1.7 | 1.6 | 1.4 | 0.9 | 0.9 | 1.4 | 1.8 | 2.5 | 2.5 | 2.2 | 2.2 | 21.2 |
| Lerwick, Shetland Island | 60 08N | 01 11W | 269 | 30 | 42 | 35 | 46 | 37 | 58 | 49 | 50 | 42 | 71 | 17 | 30 | 4.5 | 3.4 | 2.9 | 2.7 | 2.2 | 2.2 | 2.7 | 2.9 | 3.7 | 4.3 | 4.5 | 4.5 | 40.5 |
| Matochikin Shar, Novaya Zemlya | 73 16N | 56 24E | 61 | 9 | 8 | −6 | 13 | −1 | 47 | 36 | 30 | 21 | 68 | −41 | 9 | 0.6 | 0.6 | 0.6 | 0.4 | 0.3 | 0.4 | 1.4 | 1.5 | 1.5 | 0.6 | 0.6 | 0.4 | 8.9 |
| Ponta Delgada, Azores | 37 45N | 25 40W | 118 | 30 | 62 | 54 | 64 | 55 | 76 | 64 | 71 | 61 | 85 | 37 | 30 | 4.0 | 3.5 | 3.5 | 2.5 | 2.3 | 1.4 | 1.0 | 1.2 | 2.9 | 3.6 | 3.7 | 3.0 | 32.6 |
| Stornoway, Hebrides | 58 11N | 06 21W | 34 | 30 | 44 | 37 | 49 | 39 | 61 | 51 | 53 | 44 | 78 | 11 | 15 | 6.4 | 3.2 | 3.2 | 3.1 | 2.5 | 2.4 | 3.0 | 4.3 | 4.7 | 6.2 | 4.6 | 5.5 | 49.1 |
| Thorshavn, Faeroes | 62 02N | 06 45W | 82 | 50 | 42 | 33 | 45 | 36 | 56 | 47 | 58 | 40 | 70 | 8 | 50 | 6.6 | 5.2 | 4.8 | 3.6 | 3.4 | 2.5 | 3.1 | 3.5 | 4.7 | 5.9 | 6.3 | 6.6 | 56.2 |
| **Africa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Algeria | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Adrar | 27 52N | 00 17W | 948 | 15 | 69 | 39 | 92 | 60 | 115 | 82 | 92 | 63 | 124 | 25 | 15 | * | * | 0.1 | * | * | * | * | * | * | 0.2 | 0.2 | * | 0.6 |
| Algiers | 36 46N | 03 03E | 194 | 25 | 59 | 49 | 68 | 55 | 83 | 70 | 74 | 63 | 107 | 32 | 25 | 4.4 | 3.3 | 2.9 | 1.6 | 1.8 | 0.6 | * | 0.2 | 1.6 | 3.1 | 5.1 | 5.4 | 30.0 |
| Annaba | 36 54N | 07 46E | 66 | 26 | 59 | 46 | 67 | 52 | 85 | 69 | 75 | 61 | 115 | 32 | 26 | 5.6 | 4.1 | 2.9 | 2.2 | 1.5 | 0.6 | 0.1 | 0.3 | 1.2 | 3.0 | 4.3 | 5.2 | 31.0 |
| Bordj Omar Driss | 28 06N | 06 42E | 1,224 | 15 | 67 | 38 | 90 | 59 | 110 | 78 | 92 | 63 | 124 | 19 | 15 | 0.3 | 0.1 | 0.1 | 0.2 | * | * | 0.0 | * | * | * | 0.2 | 0.2 | 1.1 |
| El Golea | 30 35N | 02 53E | 1,247 | 15 | 63 | 37 | 84 | 56 | 107 | 79 | 87 | 60 | 120 | 23 | 15 | 0.1 | 0.3 | 0.5 | * | * | * | * | * | * | 0.3 | 0.4 | 0.3 | 1.9 |
| Tamanrasset | 22 42N | 05 31E | 4,593 | 15 | 67 | 39 | 86 | 56 | 95 | 71 | 85 | 59 | 102 | 20 | 15 | 0.2 | * | * | 0.2 | 0.4 | 0.1 | 0.1 | 0.4 | 0.1 | * | * | * | 1.5 |
| Touggourt | 33 07N | 06 04E | 226 | 26 | 62 | 38 | 83 | 55 | 107 | 77 | 84 | 59 | 122 | 26 | 26 | 0.2 | 0.4 | 0.5 | 0.2 | 0.2 | 0.2 | * | * | 0.1 | 0.3 | 0.5 | 0.3 | 2.9 |
| Angola | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cangamba | 13 41S | 19 52E | 4,331 | 6 | 84 | 62 | 89 | 58 | 82 | 46 | 87 | 59 | 109 | 20 | 7 | 8.9 | 7.4 | 6.8 | 1.8 | 0.1 | 0.0 | 0.0 | 0.2 | 0.2 | 1.6 | 5.1 | 8.5 | 40.6 |
| Huambo | 12 48S | 15 45E | 5,577 | 14 | 78 | 58 | 78 | 57 | 77 | 47 | 81 | 58 | 90 | 36 | 14 | 8.7 | 7.8 | 9.8 | 5.7 | 0.4 | 0.0 | * | * | 0.6 | 5.5 | 9.6 | 8.9 | 57.0 |
| Luanda | 08 49S | 13 13E | 194 | 27 | 83 | 74 | 85 | 75 | 74 | 65 | 79 | 71 | 98 | 58 | 59 | 1.0 | 1.4 | 3.0 | 4.6 | 0.5 | * | * | * | 0.1 | 0.2 | 1.1 | 0.8 | 12.7 |
| Moçâmedes | 15 12S | 12 09E | 10 | 15 | 79 | 65 | 82 | 66 | 68 | 56 | 74 | 61 | 102 | 44 | 21 | 0.3 | 0.4 | 0.7 | 0.5 | * | * | * | * | * | * | 0.1 | 0.1 | 2.1 |
| Benin | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cotonou | 06 21N | 02 26E | 23 | 5 | 80 | 74 | 83 | 78 | 78 | 74 | 80 | 75 | 95 | 65 | 10 | 1.3 | 1.3 | 4.6 | 4.9 | 10.0 | 14.4 | 3.5 | 1.5 | 2.6 | 5.3 | 2.3 | 0.5 | 52.4 |
| Botswana | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Francistown | 21 13S | 27 30E | 3,294 | 20 | 88 | 65 | 83 | 56 | 75 | 41 | 90 | 61 | 107 | 24 | 28 | 4.2 | 3.1 | 2.8 | 0.7 | 0.2 | 0.1 | * | * | * | 0.9 | 2.3 | 3.4 | 17.7 |
| Maun | 19 59S | 23 25E | 3,091 | 20 | 90 | 66 | 87 | 58 | 77 | 42 | 95 | 64 | 110 | 24 | 20 | 4.3 | 3.8 | 3.5 | 1.1 | 0.2 | * | 0.0 | 0.0 | * | 0.5 | 1.9 | 2.8 | 18.2 |
| Tsabong | 26 03S | 22 27E | 3,156 | 10 | 94 | 65 | 83 | 51 | 71 | 34 | 88 | 54 | 107 | 15 | 14 | 2.0 | 1.9 | 1.9 | 1.3 | 0.4 | 0.4 | 0.1 | * | 0.2 | 0.7 | 1.1 | 1.5 | 11.5 |
| Burkina Faso | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bobo Dioulasso | 11 10N | 04 15W | 1,411 | 11 | 92 | 58 | 99 | 71 | 87 | 69 | 90 | 70 | 115 | 46 | 10 | 0.1 | 0.2 | 1.1 | 2.1 | 4.6 | 4.8 | 9.8 | 12.0 | 8.5 | 2.5 | 0.7 | 0.0 | 46.4 |
| Ouagadougou | 12 22N | 01 31W | 991 | 10 | 92 | 60 | 103 | 79 | 91 | 74 | 95 | 74 | 118 | 48 | 15 | * | 0.1 | 0.5 | 0.6 | 3.3 | 4.8 | 8.0 | 10.9 | 5.7 | 1.3 | * | 0.0 | 35.2 |
| Cameroon | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ngaoundere | 07 17N | 13 19E | 3,601 | 9 | 87 | 55 | 87 | 64 | 82 | 63 | 82 | 61 | 102 | 46 | 10 | * | * | 1.1 | 5.5 | 7.0 | 8.4 | 10.6 | 9.6 | 9.2 | 5.3 | 0.5 | * | 57.2 |
| Yaounde | 03 53N | 11 32E | 2,526 | 11 | 85 | 67 | 85 | 66 | 80 | 66 | 81 | 65 | 96 | 57 | 11 | 0.9 | 2.6 | 5.8 | 6.7 | 7.7 | 6.0 | 2.9 | 3.1 | 8.4 | 11.6 | 4.6 | 0.9 | 61.2 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Central African Republic | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bangui | 04 22N | 18 34E | 1,270 | 5 | 90 | 68 | 91 | 71 | 85 | 69 | 87 | 69 | 101 | 57 | 5 | 1.0 | 1.7 | 5.0 | 5.3 | 7.4 | 4.5 | 8.9 | 8.1 | 5.9 | 7.9 | 4.9 | 0.2 | 60.8 |
| Ndele | 08 24N | 20 39E | 1,939 | 3 | 99 | 67 | 98 | 73 | 86 | 69 | 90 | 68 | 109 | 58 | 3 | 0.2 | 1.3 | 0.6 | 1.7 | 8.4 | 6.1 | 8.3 | 10.1 | 10.7 | 7.8 | 0.6 | 0.0 | 55.8 |
| Chad | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Am Timan | 11 02N | 20 17E | 1,430 | 3 | 98 | 56 | 105 | 68 | 89 | 70 | 96 | 67 | 113 | 43 | 3 | 0.0 | 0.0 | 0.1 | 1.2 | 4.3 | 5.0 | 7.3 | 12.3 | 5.8 | 1.2 | 0.0 | 0.0 | 37.2 |
| Fort Lamy | 12 07N | 15 02E | 968 | 5 | 93 | 57 | 107 | 74 | 92 | 72 | 97 | 70 | 114 | 47 | 5 | 0.0 | 0.0 | 0.0 | 0.1 | 1.2 | 2.6 | 6.7 | 12.6 | 4.7 | 1.4 | 0.0 | 0.0 | 29.3 |
| Largeau (Faya) | 18 00N | 19 10E | 837 | 5 | 84 | 54 | 104 | 69 | 109 | 76 | 103 | 72 | 121 | 37 | 5 | 0.0 | 0.0 | 0.0 | 0.0 | * | 0.0 | * | 0.7 | * | 0.0 | 0.0 | 0.0 | 0.7 |
| Congo | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brazzaville | 04 15S | 15 15E | 1,043 | 15 | 88 | 69 | 91 | 71 | 82 | 63 | 89 | 70 | 98 | 54 | 18 | 6.3 | 4.9 | 7.4 | 7.0 | 4.3 | 0.6 | * | * | 2.2 | 5.4 | 11.5 | 8.4 | 58.0 |
| Ouesso | 01 37N | 16 04E | 1,132 | 4 | 88 | 69 | 91 | 71 | 85 | 69 | 87 | 69 | 106 | 60 | 4 | 2.4 | 3.6 | 6.4 | 3.2 | 5.8 | 4.6 | 2.9 | 3.7 | 7.9 | 10.0 | 5.7 | 2.4 | 58.6 |
| Pointe Noire (Loango) | 04 39S | 11 48E | 164 | 7 | 85 | 73 | 87 | 74 | 78 | 66 | 83 | 72 | 93 | 59 | 7 | 5.4 | 6.7 | 6.4 | 8.0 | 3.9 | 0.0 | 0.0 | 0.0 | 0.4 | 4.1 | 6.6 | 6.6 | 48.1 |
| Djibouti | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Djibouti | 11 36N | 43 09E | 23 | 16 | 84 | 73 | 90 | 79 | 106 | 87 | 92 | 80 | 117 | 63 | 46 | 0.4 | 0.5 | 1.0 | 0.5 | 0.2 | * | 0.1 | 0.3 | 0.3 | 0.4 | 0.9 | 0.5 | 46.0 |
| Egypt | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Alexandria | 31 12N | 29 53E | 105 | 45 | 65 | 51 | 74 | 59 | 85 | 73 | 83 | 68 | 111 | 37 | 61 | 1.9 | 0.9 | 0.4 | 0.1 | * | * | * | * | * | 0.2 | 1.3 | 2.2 | 7.0 |
| Aswan | 24 02N | 32 53E | 366 | 46 | 74 | 50 | 96 | 66 | 106 | 79 | 98 | 71 | 124 | 35 | 11 | * | * | * | * | * | * | 0.0 | 0.0 | 0.0 | * | * | * | * |
| Cairo | 29 52N | 31 20E | 381 | 42 | 65 | 47 | 83 | 57 | 96 | 70 | 86 | 65 | 117 | 34 | 42 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | * | 0.0 | 0.0 | * | * | 0.1 | 0.2 | 1.1 |
| Ethiopia | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Addis Ababa | 09 20N | 38 45E | 8,038 | 15 | 75 | 43 | 77 | 50 | 69 | 50 | 75 | 45 | 94 | 32 | 37 | 0.5 | 1.5 | 2.6 | 3.4 | 3.4 | 5.4 | 11.0 | 11.8 | 7.5 | 0.8 | 0.6 | 0.2 | 48.7 |
| Asmara | 15 17N | 38 55E | 7,628 | 9 | 74 | 44 | 78 | 51 | 71 | 53 | 72 | 53 | 88 | 31 | 17 | * | * | 0.4 | 1.5 | 1.5 | 1.3 | 6.7 | 5.0 | 1.3 | 0.3 | 0.4 | * | 18.4 |
| Diredawa | 09 02N | 41 45E | 3,937 | 8 | 81 | 58 | 91 | 69 | 90 | 68 | 89 | 67 | 100 | 49 | 8 | 0.8 | 0.8 | 3.3 | 3.0 | 2.8 | 1.5 | 4.3 | 3.8 | 2.2 | 0.5 | 0.3 | 0.8 | 24.1 |
| Gambela | 08 15N | 34 35E | 1,345 | 26 | 98 | 64 | 98 | 71 | 87 | 69 | 92 | 67 | 111 | 48 | 30 | 0.2 | 0.4 | 1.4 | 3.2 | 5.9 | 6.7 | 8.5 | 9.5 | 7.3 | 3.5 | 1.8 | 0.4 | 48.8 |
| Gabon | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Libreville | 00 23N | 09 26E | 115 | 11 | 87 | 73 | 89 | 73 | 83 | 68 | 86 | 71 | 99 | 62 | 21 | 9.8 | 9.3 | 13.2 | 13.4 | 9.6 | 0.5 | 0.1 | 0.7 | 4.1 | 13.6 | 14.7 | 9.8 | 98.8 |
| Mayoumba | 03 25S | 10 38E | 200 | 8 | 84 | 73 | 86 | 73 | 78 | 68 | 82 | 72 | 91 | 60 | 8 | 6.5 | 9.3 | 6.2 | 10.2 | 2.3 | 0.1 | 0.0 | 0.2 | 2.6 | 9.3 | 10.7 | 4.6 | 62.0 |
| Gambia | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Banjul | 13 21N | 16 40W | 90 | 9 | 88 | 59 | 91 | 65 | 86 | 74 | 89 | 72 | 106 | 45 | 9 | 0.1 | 0.1 | * | * | 0.4 | 2.3 | 11.1 | 19.7 | 12.2 | 4.3 | 0.7 | 0.1 | 51.0 |
| Ghana | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Accra | 05 33N | 00 12W | 88 | 17 | 87 | 73 | 88 | 76 | 81 | 73 | 85 | 74 | 100 | 59 | 65 | 0.6 | 1.3 | 2.2 | 3.2 | 5.6 | 7.0 | 1.8 | 0.6 | 1.4 | 2.5 | 1.4 | 0.9 | 28.5 |
| Kumasi | 06 40N | 01 37W | 942 | 10 | 88 | 66 | 89 | 71 | 82 | 70 | 86 | 70 | 100 | 51 | 10 | 0.8 | 2.3 | 5.7 | 5.1 | 7.5 | 7.9 | 4.3 | 3.1 | 6.8 | 7.1 | 3.7 | 0.8 | 55.2 |
| Guinea | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Conakry | 09 31N | 13 43W | 23 | 7 | 88 | 72 | 90 | 73 | 83 | 72 | 87 | 73 | 96 | 63 | 10 | 0.1 | 0.1 | 0.4 | 0.9 | 6.2 | 22.0 | 51.1 | 41.5 | 26.9 | 14.6 | 4.8 | 0.4 | 169.0 |
| Kouroussa | 10 39N | 09 53W | 1,217 | 9 | 93 | 60 | 99 | 73 | 87 | 69 | 90 | 69 | 109 | 39 | 10 | 0.4 | 0.3 | 0.9 | 2.8 | 5.3 | 9.7 | 11.7 | 13.6 | 13.4 | 6.6 | 1.3 | 0.4 | 66.4 |
| Guinea-Bissau | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bolama | 11 34N | 15 26W | 62 | 31 | 88 | 67 | 91 | 73 | 84 | 74 | 87 | 74 | 106 | 59 | 37 | * | * | * | * | 0.8 | 7.8 | 23.1 | 27.6 | 16.9 | 8.0 | 1.6 | 0.1 | 85.9 |
| Ifni (Now in Morocco) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sidi Ifni | 29 27N | 10 11W | 148 | 14 | 66 | 52 | 71 | 59 | 75 | 64 | 75 | 62 | 124 | 40 | 14 | 1.0 | 0.6 | 0.5 | 0.6 | 0.1 | 0.1 | * | * | 0.4 | 0.1 | 0.9 | 1.8 | 6.1 |
| Ivory Coast | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Abidjan | 05 19N | 04 01W | 65 | 13 | 88 | 73 | 90 | 75 | 83 | 73 | 85 | 74 | 96 | 59 | 10 | 1.6 | 2.1 | 3.9 | 4.9 | 14.2 | 19.5 | 8.4 | 2.1 | 2.8 | 6.6 | 7.9 | 3.1 | 77.1 |
| Bouake | 07 42N | 05 00W | 1,194 | 12 | 91 | 68 | 92 | 70 | 85 | 68 | 89 | 68 | 104 | 57 | 10 | 0.4 | 1.5 | 4.1 | 5.8 | 5.3 | 6.0 | 3.1 | 4.6 | 8.2 | 5.2 | 1.5 | 1.0 | 46.7 |
| Kenya | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mombasa | 04 03S | 39 39E | 52 | 45 | 87 | 75 | 86 | 76 | 81 | 71 | 84 | 74 | 96 | 61 | 54 | 1.0 | 0.7 | 2.5 | 7.7 | 12.6 | 4.7 | 3.5 | 2.5 | 2.5 | 3.4 | 3.8 | 2.4 | 47.3 |
| Nairobi | 01 16S | 36 48E | 5,971 | 15 | 77 | 54 | 75 | 58 | 69 | 51 | 76 | 55 | 87 | 41 | 17 | 1.5 | 2.5 | 4.9 | 8.3 | 6.2 | 1.8 | 0.6 | 0.9 | 1.2 | 2.1 | 4.3 | 3.4 | 37.7 |
| Liberia | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monrovia | 06 18N | 10 48W | 75 | 6 | 89 | 71 | 90 | 72 | 80 | 72 | 86 | 72 | 97 | 62 | 4 | 0.2 | 0.1 | 4.4 | 11.7 | 13.4 | 36.1 | 24.2 | 18.6 | 29.9 | 25.2 | 8.2 | 2.9 | 174.9 |
| Libya | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Benghazi | 32 06N | 20 04E | 82 | 46 | 63 | 50 | 74 | 58 | 84 | 71 | 80 | 66 | 109 | 37 | 46 | 2.6 | 1.6 | 0.8 | 0.2 | 0.1 | * | * | * | 0.1 | 0.7 | 1.8 | 2.6 | 10.5 |
| Kufra | 24 12N | 23 21E | 1,276 | 7 | 69 | 43 | 90 | 62 | 101 | 75 | 90 | 64 | 122 | 26 | 7 | * | 0.0 | 0.0 | 0.0 | * | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | * | * |
| Sabhah | 27 01N | 14 26E | 1,457 | 3 | 64 | 41 | 89 | 60 | 102 | 74 | 91 | 64 | 120 | 24 | 10 | * | * | * | * | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | * | * | * | 0.3 |
| Tripoli | 32 54N | 13 11E | 72 | 47 | 61 | 47 | 72 | 57 | 85 | 71 | 80 | 65 | 114 | 33 | 56 | 3.2 | 1.8 | 1.1 | 0.4 | 0.2 | 0.1 | * | * | 0.4 | 1.6 | 2.6 | 3.7 | 15.1 |
| Malagasy Republic | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diego Suarez | 12 17S | 49 17E | 100 | 11 | 88 | 75 | 88 | 75 | 84 | 69 | 86 | 72 | 98 | 63 | 31 | 10.6 | 9.5 | 7.6 | 2.2 | 0.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.7 | 1.1 | 5.8 | 38.7 |
| Tananarive | 18 55S | 47 33E | 4,500 | 44 | 79 | 61 | 76 | 58 | 68 | 48 | 80 | 54 | 95 | 34 | 62 | 11.8 | 11.0 | 7.0 | 2.1 | 0.7 | 0.3 | 0.3 | 0.4 | 0.7 | 2.4 | 5.3 | 11.3 | 53.4 |
| Tulear | 23 20S | 43 41E | 20 | 27 | 92 | 72 | 89 | 64 | 81 | 58 | 86 | 65 | 108 | 43 | 15 | 3.1 | 3.2 | 1.4 | 0.3 | 0.7 | 0.4 | 0.1 | 0.2 | 0.3 | 0.7 | 1.4 | 1.7 | 13.5 |
| Malawi | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Karonga | 09 57S | 33 56E | 1,596 | 8 | 86 | 71 | 85 | 70 | 81 | 59 | 91 | 66 | 99 | 51 | 8 | 7.1 | 7.0 | 10.8 | 6.2 | 1.7 | 0.1 | * | * | 0.0 | 0.3 | 0.3 | 4.7 | 38.3 |
| Zomba | 15 23S | 35 19E | 3,141 | 27 | 80 | 65 | 78 | 62 | 72 | 53 | 85 | 64 | 95 | 41 | 29 | 12.1 | 9.9 | 10.1 | 2.7 | 0.7 | 0.4 | 0.3 | 0.3 | 0.2 | 1.0 | 4.3 | 10.9 | 52.9 |
| Mali | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Araouane | 18 54N | 03 33W | 935 | 8 | 81 | 48 | 110 | 67 | 111 | 79 | 103 | 70 | 130 | 37 | 10 | * | * | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.5 | 0.6 | 0.1 | 0.1 | * | 1.7 |
| Bamako | 12 39N | 07 58W | 1,116 | 11 | 91 | 61 | 103 | 76 | 89 | 71 | 93 | 71 | 117 | 47 | 10 | * | * | 0.1 | 0.6 | 2.9 | 5.4 | 11.0 | 13.7 | 8.1 | 1.7 | 0.6 | * | 44.1 |
| Gao | 16 16N | 00 03W | 902 | 15 | 83 | 58 | 105 | 77 | 97 | 80 | 100 | 78 | 116 | 44 | 19 | * | 0.0 | * | 0.1 | 0.4 | 1.0 | 2.9 | 5.4 | 1.5 | 0.2 | * | 0.0 | 11.5 |
| Mauritania | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Atar | 20 31N | 13 04W | 761 | 7 | 84 | 54 | 97 | 67 | 106 | 81 | 98 | 72 | 117 | 39 | 10 | * | 0.0 | * | * | * | 0.1 | 0.3 | 1.2 | 1.1 | 0.1 | * | * | 2.8 |
| Nema | 16 36N | 07 16W | 883 | 9 | 86 | 62 | 105 | 79 | 99 | 78 | 101 | 79 | 120 | 47 | 10 | 0.1 | * | * | * | 0.7 | 1.1 | 2.3 | 4.7 | 2.1 | 0.7 | * | 0.1 | 11.6 |

*(Continued)*



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**Table 3B.13 (Continued)**

| Country and Station | Latitude | Longitude | Elevation | Temperature | | | | | | | | | | | Average Precipitation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Average Daily | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Jan | | Apr | | July | | Oct | | Extreme | | | | | | | | | | | | | | | |
| | | | | Length of Record | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Length of Record | January | February | March | April | May | June | July | August | September | October | November | December | Year |
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| Nouakchott | 18 07N | 15 36W | 69 | 5 | 85 | 57 | 90 | 64 | 89 | 74 | 91 | 71 | 115 | 44 | 10 | * | 0.1 | * | * | * | 0.1 | 0.5 | 4.1 | 0.9 | 0.4 | 0.1 | * | 6.2 |
| Morocco | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Casablanca | 33 35N | 07 39W | 164 | 48 | 63 | 45 | 69 | 52 | 79 | 65 | 76 | 58 | 110 | 31 | 40 | 2.1 | 1.9 | 2.2 | 1.4 | 0.9 | 0.2 | 0.0 | * | 0.3 | 1.5 | 2.6 | 2.8 | 15.9 |
| Marrakech | 31 36N | 08 01W | 1,509 | 35 | 65 | 40 | 79 | 52 | 101 | 67 | 83 | 57 | 120 | 27 | 31 | 1.0 | 1.1 | 1.3 | 1.2 | 0.6 | 0.3 | 0.1 | 0.1 | 0.4 | 0.9 | 1.2 | 1.2 | 9.4 |
| Rabat | 34 00N | 06 50W | 213 | 35 | 63 | 46 | 71 | 52 | 82 | 63 | 77 | 58 | 118 | 32 | 29 | 2.6 | 2.5 | 2.6 | 1.7 | 1.1 | 0.3 | * | * | 0.4 | 1.9 | 3.3 | 3.4 | 19.8 |
| Tangier | 35 48N | 05 49W | 239 | 35 | 60 | 47 | 65 | 51 | 80 | 64 | 72 | 59 | 106 | 28 | 35 | 4.5 | 4.2 | 4.8 | 3.5 | 1.7 | 0.6 | * | * | 0.9 | 3.9 | 5.8 | 5.4 | 35.3 |
| Mozambique | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Beira | 19 50S | 34 51E | 28 | 37 | 89 | 75 | 86 | 71 | 77 | 61 | 87 | 71 | 109 | 48 | 39 | 10.9 | 8.4 | 10.1 | 4.2 | 2.2 | 1.3 | 1.2 | 1.1 | 0.8 | 5.2 | 5.3 | 9.2 | 59.9 |
| Chicoa | 15 36S | 32 21E | 899 | 8 | 96 | 65 | 93 | 63 | 86 | 55 | 101 | 68 | 117 | 32 | 8 | 7.8 | 5.7 | 4.4 | 0.6 | * | * | * | * | * | 1.1 | 2.6 | 5.2 | 27.4 |
| Maputo | 25 58S | 32 36E | 194 | 42 | 86 | 71 | 83 | 66 | 76 | 55 | 82 | 64 | 114 | 45 | 42 | 5.1 | 4.9 | 4.9 | 2.1 | 1.1 | 0.8 | 0.5 | 0.5 | 1.1 | 1.9 | 3.2 | 3.8 | 29.9 |
| Namibia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Keetmanshoop | 26 35S | 18 08E | 3,295 | 17 | 95 | 65 | 85 | 57 | 70 | 42 | 87 | 55 | 108 | 26 | 45 | 0.8 | 1.1 | 1.4 | 0.6 | 0.2 | * | * | * | 0.1 | 0.2 | 0.3 | 0.4 | 5.2 |
| Windhoek | 22 34S | 17 06E | 5,669 | 30 | 85 | 63 | 77 | 55 | 68 | 43 | 84 | 59 | 97 | 25 | 60 | 3.0 | 2.9 | 3.1 | 1.6 | 0.3 | * | * | * | 0.1 | 0.4 | 0.9 | 1.9 | 14.3 |
| Niger | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Agades | 16 59N | 07 59E | 1,706 | 8 | 86 | 50 | 105 | 70 | 104 | 75 | 101 | 68 | 115 | 40 | 10 | 0.0 | 0.0 | * | * | 0.2 | 0.3 | 1.9 | 3.7 | 0.7 | 0.0 | 0.0 | 0.0 | 6.8 |
| Bilma | 18 41N | 12 55E | 1,171 | 9 | 81 | 45 | 101 | 63 | 108 | 75 | 101 | 62 | 116 | 29 | 10 | 0.0 | 0.0 | 0.0 | * | * | 0.0 | 0.1 | 0.5 | 0.3 | 0.0 | 0.0 | 0.0 | 0.9 |
| Niamey | 13 31N | 02 06E | 709 | 10 | 93 | 58 | 108 | 77 | 94 | 74 | 101 | 74 | 114 | 47 | 10 | * | * | 0.2 | 0.3 | 1.3 | 3.2 | 5.2 | 7.4 | 3.7 | 0.5 | * | 0.0 | 21.6 |
| Nigeria | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Enugu | 06 27N | 07 29E | 763 | 11 | 90 | 72 | 91 | 74 | 83 | 71 | 87 | 71 | 99 | 55 | 33 | 0.7 | 1.1 | 2.6 | 5.9 | 10.4 | 11.4 | 7.6 | 6.7 | 12.8 | 9.8 | 2.1 | 0.5 | 71.5 |
| Kaduna | 10 35N | 06 26E | 2,113 | 18 | 89 | 59 | 95 | 72 | 83 | 68 | 89 | 66 | 105 | 46 | 34 | * | 0.1 | 0.5 | 2.5 | 5.9 | 7.1 | 8.5 | 11.9 | 10.6 | 2.9 | 0.1 | * | 50.1 |
| Lagos | 06 27N | 03 24E | 10 | 32 | 88 | 74 | 89 | 77 | 83 | 74 | 85 | 74 | 104 | 60 | 47 | 1.1 | 1.8 | 4.0 | 5.9 | 10.6 | 18.1 | 11.0 | 2.5 | 5.5 | 8.1 | 2.7 | 1.0 | 72.3 |
| Maiduguri | 11 51N | 13 05E | 1,162 | 15 | 90 | 54 | 104 | 72 | 90 | 73 | 96 | 68 | 112 | 43 | 40 | * | * | * | 0.3 | 1.6 | 2.7 | 7.1 | 8.7 | 4.2 | 0.7 | * | 0.0 | 25.3 |
| Senegal | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Dakar | 14 42N | 17 29W | 131 | 25 | 79 | 64 | 81 | 65 | 88 | 76 | 89 | 76 | 109 | 53 | 26 | * | * | * | * | * | 0.7 | 3.5 | 10.0 | 5.2 | 1.5 | 0.1 | 0.3 | 21.3 |
| Kaolack | 14 08N | 16 04W | 20 | 9 | 93 | 60 | 103 | 68 | 91 | 75 | 93 | 74 | 114 | 48 | 10 | * | 0.0 | * | * | 0.3 | 2.6 | 6.9 | 10.7 | 7.0 | 2.7 | 0.1 | * | 30.3 |
| Sierra Leone | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Freetown/Lungi | 08 37N | 13 12W | 92 | 8 | 87 | 73 | 88 | 76 | 82 | 73 | 85 | 72 | 98 | 62 | 8 | 0.4 | 0.2 | 1.2 | 3.1 | 9.5 | 14.3 | 29.2 | 36.5 | 22.3 | 14.2 | 5.5 | 1.2 | 137.6 |
| Somalia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Berbera | 10 26N | 45 02E | 45 | 30 | 84 | 68 | 89 | 77 | 107 | 88 | 92 | 76 | 117 | 58 | 30 | 0.3 | 0.1 | 0.2 | 0.5 | 0.3 | * | * | 0.1 | * | 0.1 | 0.2 | 0.2 | 2.0 |
| Mogadiscio | 02 02N | 45 21E | 39 | 13 | 86 | 73 | 90 | 78 | 83 | 73 | 86 | 76 | 97 | 59 | 21 | * | * | * | 2.3 | 2.3 | 3.8 | 2.5 | 1.9 | 1.0 | 0.9 | 1.6 | 0.5 | 16.9 |
| South Africa, Republic of | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cape Town | 33 54S | 18 32E | 56 | 19 | 78 | 60 | 72 | 53 | 63 | 45 | 70 | 52 | 103 | 28 | 18 | 0.6 | 0.3 | 0.7 | 1.9 | 3.1 | 3.3 | 3.5 | 2.6 | 1.7 | 1.2 | 0.7 | 0.4 | 20.0 |
| Durban | 29 50S | 31 02E | 16 | 15 | 81 | 69 | 78 | 64 | 72 | 52 | 75 | 62 | 107 | 39 | 78 | 4.3 | 4.8 | 5.1 | 3.0 | 2.1 | 1.3 | 1.1 | 1.5 | 2.8 | 4.3 | 4.8 | 4.7 | 39.7 |
| Kimberley | 28 48S | 24 46E | 3,927 | 19 | 91 | 64 | 77 | 52 | 65 | 36 | 83 | 54 | 103 | 20 | 57 | 2.4 | 2.5 | 3.1 | 1.5 | 0.7 | 0.2 | 0.2 | 0.3 | 0.6 | 1.0 | 1.6 | 2.0 | 16.1 |
| Port Elizabeth | 33 59S | 25 36E | 190 | 14 | 78 | 61 | 73 | 55 | 67 | 45 | 70 | 54 | 104 | 31 | 84 | 1.2 | 1.3 | 1.9 | 1.8 | 2.4 | 1.8 | 1.9 | 2.0 | 2.3 | 2.2 | 2.2 | 1.7 | 22.7 |
| Port Nolloth | 29 14S | 16 52E | 23 | 20 | 67 | 53 | 66 | 50 | 62 | 45 | 64 | 49 | 107 | 31 | 64 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 2.3 |
| Pretoria | 25 45S | 28 14E | 4,491 | 13 | 81 | 60 | 75 | 50 | 66 | 37 | 80 | 55 | 96 | 24 | 12 | 5.0 | 4.3 | 4.5 | 1.7 | 0.9 | 0.6 | 0.3 | 0.2 | 0.8 | 2.2 | 5.2 | 5.2 | 30.9 |
| Walvis Bay | 22 56S | 14 30E | 24 | 20 | 73 | 59 | 75 | 55 | 70 | 47 | 67 | 51 | 104 | 25 | 20 | * | 0.2 | 0.3 | 0.1 | 0.1 | * | * | 0.1 | * | * | * | *. | 0.9 |
| Sudan | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| El Fasher | 13 38N | 25 21E | 2,395 | 17 | 88 | 50 | 102 | 64 | 96 | 70 | 99 | 64 | 113 | 33 | 17 | * | 0.0 | * | * | 0.3 | 0.7 | 4.5 | 5.3 | 1.2 | 0.2 | 0.0 | 0.0 | 12.2 |
| Khartoum | 15 37N | 32 33E | 1,279 | 46 | 90 | 59 | 105 | 72 | 101 | 77 | 104 | 75 | 118 | 41 | 46 | * | * | * | * | 0.1 | 0.3 | 2.1 | 2.8 | 0.7 | 0.2 | * | 0.0 | 6.2 |
| Port Sudan | 19 37N | 37 13E | 18 | 30 | 81 | 68 | 89 | 71 | 106 | 83 | 93 | 76 | 117 | 50 | 40 | 0.2 | 0.1 | * | * | * | * | 0.3 | 0.1 | * | 0.4 | 1.7 | 0.9 | 3.7 |
| Wadi Halfa | 21 55N | 31 20E | 410 | 39 | 75 | 46 | 98 | 62 | 106 | 74 | 98 | 67 | 127 | 28 | 39 | * | * | * | * | * | 0.0 | * | * | * | * | * | 0.0 | * |
| Wau | 07 42N | 28 03E | 1,443 | 38 | 96 | 64 | 99 | 72 | 89 | 69 | 93 | 69 | 115 | 50 | 38 | * | 0.2 | 0.9 | 2.6 | 5.3 | 6.5 | 7.5 | 8.2 | 6.6 | 4.9 | 0.6 | * | 43.3 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tanzania | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Dares Salaam | 06 50S | 39 18E | 47 | 44 | 83 | 77 | 86 | 73 | 83 | 66 | 85 | 69 | 96 | 59 | 49 | 2.6 | 2.6 | 5.1 | 11.4 | 7.4 | 1.3 | 1.2 | 1.0 | 1.2 | 1.6 | 2.9 | 3.6 | 41.9 |
| Iringa | 07 47S | 35 42E | 5,330 | 14 | 76 | 59 | 75 | 59 | 72 | 52 | 80 | 57 | 90 | 42 | 24 | 6.8 | 5.1 | 7.1 | 3.5 | 0.5 | * | * | * | 0.1 | 0.2 | 1.5 | 4.5 | 29.3 |
| Kigoma | 04 53S | 29 38E | 2,903 | 26 | 80 | 67 | 81 | 67 | 83 | 63 | 84 | 69 | 100 | 53 | 18 | 4.8 | 5.0 | 5.9 | 5.1 | 1.7 | 0.2 | 0.1 | 0.2 | 0.7 | 1.9 | 5.6 | 5.3 | 36.5 |
| Togo | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lome | 06 10N | 01 15E | 72 | 5 | 85 | 72 | 86 | 74 | 80 | 71 | 83 | 72 | 94 | 58 | 15 | 0.6 | 0.9 | 1.9 | 4.6 | 5.7 | 8.8 | 2.8 | 0.4 | 1.4 | 2.4 | 1.1 | 0.4 | 31.0 |
| Tunisia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gabes | 33 53N | 10 07E | 7 | 50 | 61 | 43 | 74 | 54 | 89 | 71 | 81 | 62 | 122 | 27 | 50 | 0.9 | 0.7 | 0.8 | 0.4 | 0.3 | * | * | 0.1 | 0.5 | 1.2 | 1.2 | 0.6 | 6.7 |
| Tunis | 36 47N | 10 12E | 217 | 50 | 58 | 43 | 70 | 51 | 90 | 68 | 77 | 59 | 118 | 30 | 50 | 2.5 | 2.0 | 1.6 | 1.4 | 0.7 | 0.3 | 0.1 | 0.3 | 1.3 | 2.0 | 1.9 | 2.4 | 16.5 |
| Uganda | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kampala | 00 20N | 32 36E | 4,304 | 15 | 83 | 65 | 79 | 64 | 77 | 62 | 81 | 63 | 97 | 53 | 15 | 1.8 | 2.4 | 5.1 | 6.9 | 5.8 | 2.9 | 1.8 | 3.4 | 3.6 | 3.8 | 4.8 | 3.9 | 46.2 |
| Lira | 02 15N | 32 54E | 3,560 | 14 | 91 | 61 | 86 | 64 | 81 | 61 | 86 | 61 | 100 | 50 | 14 | 0.7 | 1.0 | 3.5 | 6.9 | 7.9 | 4.9 | 6.4 | 10.0 | 8.3 | 6.1 | 3.2 | 1.8 | 60.7 |
| Western Sahara | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Semara | 26 46N | 11 31W | 1,509 | 6 | 73 | 47 | 88 | 58 | 99 | 66 | 88 | 61 | 121 | 37 | 6 | 0.1 | * | 0.0 | * | * | 0.0 | 0.0 | * | 1.0 | * | 0.4 | 0.0 | 1.5 |
| Villa Cisneros | 23 42N | 15 52W | 35 | 12 | 71 | 56 | 74 | 60 | 78 | 65 | 80 | 65 | 107 | 48 | 14 | * | * | * | * | 0.1 | 0.0 | * | 0.2 | 1.4 | 0.1 | 0.2 | 1.0 | 3.0 |
| Zaire | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kalemie | 05 54S | 29 12E | 2,493 | 5 | 85 | 66 | 83 | 67 | 82 | 58 | 87 | 67 | 92 | 50 | 20 | 4.2 | 4.7 | 6.3 | 8.4 | 3.3 | 0.3 | 0.1 | 0.3 | 0.8 | 2.8 | 7.9 | 6.3 | 45.4 |
| Kinshasa | 04 20S | 15 18E | 1,066 | 8 | 87 | 70 | 89 | 71 | 81 | 64 | 88 | 70 | 97 | 58 | 12 | 5.3 | 5.7 | 7.7 | 7.7 | 6.2 | 0.3 | 0.1 | 0.1 | 1.2 | 4.7 | 8.7 | 5.6 | 53.3 |
| Kisangani | 00 26N | 25 14E | 1,370 | 8 | 88 | 69 | 88 | 70 | 84 | 67 | 86 | 68 | 97 | 61 | 14 | 2.1 | 3.3 | 7.0 | 6.2 | 5.4 | 4.5 | 5.2 | 6.5 | 7.2 | 8.6 | 7.8 | 3.3 | 67.1 |
| Luluabourg | 05 54S | 22 25E | 2,198 | 3 | 85 | 68 | 86 | 68 | 85 | 63 | 85 | 68 | 94 | 57 | 14 | 5.4 | 5.6 | 7.7 | 7.6 | 3.3 | 0.8 | 0.5 | 2.3 | 4.6 | 6.5 | 9.1 | 8.9 | 62.3 |
| Zambia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Balovale | 13 34S | 23 06E | 3,577 | 8 | 82 | 65 | 84 | 61 | 81 | 47 | 91 | 64 | 108 | 38 | 9 | 8.5 | 6.9 | 5.8 | 1.2 | * | 0.0 | 0.0 | * | 0.3 | 2.3 | 4.4 | 8.9 | 38.3 |
| Kasama | 10 12S | 31 11E | 4,544 | 10 | 79 | 61 | 79 | 60 | 76 | 50 | 87 | 62 | 95 | 39 | 10 | 10.7 | 9.9 | 10.9 | 2.8 | 0.5 | * | * | * | * | 0.8 | 6.4 | 9.5 | 51.5 |
| Lusaka | 15 25S | 28 19E | 4,191 | 10 | 78 | 63 | 79 | 59 | 73 | 49 | 88 | 64 | 100 | 39 | 10 | 9.1 | 7.5 | 5.6 | 0.7 | 0.1 | * | * | 0.0 | * | 0.4 | 3.6 | 5.9 | 32.9 |
| Zimbabwe | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bulawayo | 20 09S | 28 37E | 4,405 | 15 | 81 | 61 | 79 | 56 | 70 | 45 | 85 | 59 | 99 | 28 | 50 | 5.6 | 4.3 | 3.3 | 0.7 | 0.4 | 0.1 | * | * | 0.2 | 0.8 | 3.2 | 4.8 | 23.4 |
| Salisbury | 17 50S | 31 08E | 4,831 | 15 | 78 | 60 | 78 | 55 | 70 | 44 | 83 | 58 | 95 | 32 | 50 | 7.7 | 7.0 | 4.6 | 1.1 | 0.5 | 0.1 | * | 0.1 | 0.2 | 1.1 | 3.8 | 6.4 | 32.6 |
| Atlantic Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Funchal, Madeira Island | 32 38N | 16 55W | 82 | 30 | 66 | 56 | 67 | 58 | 75 | 66 | 74 | 65 | 103 | 40 | 30 | 2.5 | 2.9 | 3.1 | 1.3 | 0.7 | 0.2 | * | * | 1.0 | 3.0 | 3.5 | 3.3 | 21.5 |
| Georgetown, Ascension Island | 07 56S | 14 25W | 55 | 29 | 85 | 73 | 88 | 75 | 84 | 72 | 83 | 71 | 95 | 65 | 45 | 0.2 | 0.4 | 0.7 | 1.1 | 0.5 | 0.5 | 0.5 | 0.4 | 0.3 | 0.3 | 0.2 | 0.1 | 5.2 |
| Hutts Gate, St. Helena | 15 57S | 05 40W | 2,062 | 30 | 68 | 60 | 69 | 61 | 62 | 55 | 61 | 54 | 82 | 50 | 30 | 2.1 | 3.1 | 4.2 | 3.1 | 2.8 | 3.2 | 4.3 | 2.6 | 2.2 | 1.7 | 1.2 | 1.6 | 32.1 |
| Las Palmas, Canary Islands | 28 11N | 15 28W | 20 | 45 | 70 | 58 | 71 | 61 | 77 | 67 | 79 | 67 | 99 | 46 | 48 | 1.4 | 0.9 | 0.9 | 0.5 | 0.2 | * | * | * | 0.2 | 1.1 | 2.1 | 1.6 | 8.6 |
| Porto da Praia, Cape Verde Is | 14 54N | 23 31W | 112 | 25 | 77 | 68 | 79 | 69 | 83 | 75 | 85 | 76 | 94 | 56 | 25 | 0.1 | * | * | * | 0.0 | * | 0.2 | 3.8 | 4.5 | 1.2 | 0.3 | 0.1 | 10.2 |
| Porto da Praia, Cape Verde Is | 14 54N | 23 31W | 112 | 25 | 77 | 68 | 79 | 69 | 83 | 75 | 85 | 76 | 94 | 56 | 25 | 0.1 | * | * | * | 0.0 | * | 0.2 | 3.8 | 4.5 | 1.2 | 0.3 | 0.1 | 10.2 |
| Santa Isabel, Fernando Po | 03 46N | 08 46E | — | 2 | 87 | 67 | 89 | 70 | 84 | 69 | 86 | 70 | 102 | 61 | 16 | 1.3 | 2.5 | 4.2 | 7.2 | 9.4 | 11.1 | 7.4 | 6.6 | 9.6 | 10.4 | 3.5 | 1.7 | 74.9 |
| Sao Tome, Sao Tome | 00 20N | 06 43E | 16 | 10 | 86 | 73 | 86 | 73 | 82 | 69 | 84 | 71 | 91 | 56 | 10 | 3.2 | 4.2 | 5.9 | 5.0 | 5.3 | 1.1 | * | * | 0.9 | 4.3 | 4.6 | 3.5 | 38.0 |
| Tristan da Cunha | 37 03S | 12 19W | 75 | 5 | 66 | 59 | 64 | 57 | 57 | 50 | 59 | 51 | 75 | 38 | 5 | 3.5 | 3.5 | 6.4 | 4.7 | 7.1 | 5.9 | 6.1 | 6.9 | 7.9 | 5.8 | 4.3 | 4.0 | 66.1 |
| Indian Ocean Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Agalega Island | 10 26S | 56 40E | 10 | 3 | 86 | 77 | 87 | 77 | 83 | 75 | 84 | 75 | 91 | 69 | 2 | 5.9 | 10.1 | 4.9 | 6.9 | 13.2 | 8.9 | 8.7 | 3.2 | 1.8 | 4.2 | 7.0 | 10.0 | 84.7 |
| Cocos (Keeling) Island | 12 05S | 96 53E | 15 | 36 | 86 | 77 | 85 | 78 | 82 | 76 | 84 | 76 | 94 | 68 | 38 | 5.4 | 7.7 | 8.5 | 10.4 | 7.9 | 9.0 | 8.7 | 4.8 | 3.7 | 3.3 | 4.2 | 4.6 | 78.2 |
| Heard Island | 53 01S | 73 23E | 16 | 5 | 41 | 35 | 39 | 33 | 34 | 27 | 35 | 28 | 58 | 13 | 5 | 5.8 | 5.8 | 5.7 | 6.1 | 5.8 | 3.9 | 3.6 | 2.2 | 2.5 | 3.7 | 4.0 | 5.1 | 54.3 |
| Hellburg, Reunion Island | 21 04S | 55 22E | 3,070 | 5 | 74 | 59 | 73 | 56 | 65 | 48 | 69 | 51 | 84 | 40 | 11 | 22.4 | 8.0 | 16.4 | 7.2 | 5.3 | 4.4 | 3.1 | 3.0 | 2.0 | 2.3 | 3.5 | 12.9 | 90.5 |
| Port Victoria, Seychelles | 04 37S | 55 27E | 15 | 60 | 83 | 76 | 86 | 77 | 81 | 75 | 83 | 75 | 92 | 67 | 64 | 15.2 | 10.5 | 9.2 | 7.2 | 6.7 | 4.0 | 3.3 | 2.7 | 5.1 | 6.1 | 9.1 | 13.4 | 92.5 |
| Royal Alfred Observatory, Mauritius | 20 06S | 57 32E | 181 | 40 | 86 | 73 | 82 | 70 | 75 | 62 | 80 | 64 | 95 | 50 | 43 | 8.5 | 7.8 | 8.7 | 5.0 | 3.8 | 2.6 | 2.3 | 2.5 | 1.4 | 1.6 | 1.8 | 4.6 | 50.6 |
| Asia-Far East | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| China | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Canton | 23 10N | 113 20E | 59 | 26 | 65 | 49 | 77 | 65 | 91 | 77 | 85 | 67 | 101 | 31 | 36 | 0.9 | 1.9 | 4.2 | 6.8 | 10.6 | 10.6 | 8.1 | 8.5 | 6.5 | 3.4 | 1.2 | 0.9 | 63.6 |
| Chanasha | 28 15N | 112 58E | 161 | 14 | 45 | 35 | 70 | 56 | 94 | 78 | 75 | 59 | 109 | 16 | 26 | 1.9 | 3.7 | 5.3 | 5.7 | 8.2 | 8.7 | 4.4 | 4.3 | 2.7 | 3.0 | 2.7 | 1.5 | 52.1 |
| Chungking | 29 30N | 106 33E | 855 | 27 | 51 | 42 | 73 | 59 | 93 | 76 | 71 | 61 | 111 | 28 | 60 | 0.7 | 0.8 | 1.5 | 3.8 | 5.7 | 7.1 | 5.6 | 4.7 | 5.8 | 4.3 | 1.9 | 0.8 | 42.9 |

*(Continued)*



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**Table 3B.13 (Continued)**

| Country and Station | Latitude | Longitude | Elevation | Temperature: Length of Record | Temperature: Average Daily: Jan: Maximum | Temperature: Average Daily: Jan: Minimum | Temperature: Average Daily: Apr: Maximum | Temperature: Average Daily: Apr: Minimum | Temperature: Average Daily: July: Maximum | Temperature: Average Daily: July: Minimum | Temperature: Average Daily: Oct: Maximum | Temperature: Average Daily: Oct: Minimum | Temperature: Extreme: Maximum | Temperature: Extreme: Minimum | Average Precipitation: Length of Record | Average Precipitation: January | Average Precipitation: February | Average Precipitation: March | Average Precipitation: April | Average Precipitation: May | Average Precipitation: June | Average Precipitation: July | Average Precipitation: August | Average Precipitation: September | Average Precipitation: October | Average Precipitation: November | Average Precipitation: December | Average Precipitation: Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| Hankow | 30 35N | 114 17E | 75 | 29 | 46 | 34 | 69 | 55 | 93 | 78 | 74 | 60 | 108 | 9 | 55 | 1.8 | 1.9 | 3.6 | 5.8 | 7.0 | 9.0 | 7.0 | 4.1 | 3.0 | 3.1 | 1.9 | 1.2 | 49.4 |
| Harbin | 45 45N | 126 38E | 476 | 35 | 7 | −14 | 54 | 31 | 84 | 65 | 54 | 31 | 102 | −43 | 38 | 0.2 | 0.2 | 0.4 | 0.9 | 1.7 | 3.7 | 6.6 | 4.7 | 2.3 | 1.2 | 0.5 | 0.2 | 22.6 |
| Kashgar | 39 24N | 76 07E | 4,296 | 27 | 33 | 12 | 71 | 48 | 92 | 68 | 71 | 43 | 106 | −15 | 18 | 0.6 | 0.1 | 0.5 | 0.2 | 0.3 | 0.2 | 0.4 | 0.3 | 0.1 | 0.1 | 0.2 | 0.3 | 3.2 |
| Kunming | 25 02N | 102 43E | 6,211 | 32 | 61 | 37 | 76 | 51 | 77 | 62 | 70 | 53 | 91 | 22 | 31 | 0.4 | 0.5 | 0.7 | 0.8 | 4.3 | 6.3 | 8.8 | 8.6 | 5.0 | 3.0 | 1.7 | 0.4 | 40.5 |
| Lanchow | 36 06N | 103 55E | 5,105 | 8 | 33 | 7 | 65 | 40 | 84 | 61 | 62 | 39 | 100 | −3 | 4 | 0.2 | 0.2 | 0.2 | 0.5 | 0.8 | 0.7 | 3.3 | 5.1 | 2.2 | 0.6 | 0.0 | 0.3 | 14.1 |
| Mukden | 41 47N | 123 24E | 138 | 40 | 20 | −2 | 60 | 36 | 87 | 69 | 62 | 39 | 103 | −28 | 42 | 0.2 | 0.2 | 0.7 | 1.2 | 2.6 | 3.8 | 7.0 | 6.3 | 2.9 | 1.7 | 0.9 | 0.4 | 28.2 |
| Shanghai | 31 12N | 121 26E | 16 | 56 | 47 | 32 | 67 | 49 | 91 | 75 | 75 | 56 | 104 | 10 | 81 | 1.9 | 2.4 | 3.3 | 3.6 | 3.8 | 7.0 | 5.8 | 5.5 | 5.2 | 2.9 | 2.1 | 1.5 | 45.0 |
| Tientsin | 39 10N | 117 10E | 13 | 24 | 33 | 16 | 68 | 45 | 90 | 73 | 68 | 48 | 109 | −3 | 25 | 0.2 | 0.1 | 0.4 | 0.5 | 1.1 | 2.4 | 7.6 | 6.0 | 1.7 | 0.6 | 0.4 | 0.2 | 21.0 |
| Urumchi | 43 45N | 87 40E | 2,972 | 6 | 13 | −7 | 60 | 36 | 82 | 58 | 50 | 31 | 112 | −30 | 6 | 0.6 | 0.3 | 0.5 | 1.5 | 1.1 | 1.5 | 0.7 | 1.0 | 0.6 | 1.7 | 1.6 | 0.4 | 11.5 |
| Hong Kong | 22 18N | 114 10E | 109 | 50 | 64 | 56 | 75 | 67 | 87 | 78 | 81 | 73 | 97 | 32 | 50 | 1.3 | 1.8 | 2.9 | 5.4 | 11.5 | 15.5 | 15.0 | 14.2 | 10.1 | 4.5 | 1.7 | 1.2 | 85.1 |
| Japan | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kushiro | 43 02N | 144 12E | 315 | 41 | 30 | 8 | 44 | 31 | 66 | 55 | 58 | 40 | 87 | −19 | 41 | 1.8 | 1.4 | 2.8 | 3.6 | 3.8 | 4.1 | 4.4 | 4.9 | 6.6 | 4.0 | 3.1 | 2.0 | 42.9 |
| Miyako | 39 38N | 141 59E | 98 | 30 | 43 | 23 | 58 | 37 | 77 | 62 | 66 | 46 | 99 | 1 | 30 | 2.9 | 3.0 | 3.2 | 3.5 | 4.5 | 5.0 | 5.0 | 7.2 | 9.5 | 6.8 | 3.0 | 2.6 | 56.2 |
| Nagasaki | 32 44N | 129 53E | 436 | 59 | 49 | 36 | 66 | 50 | 85 | 73 | 72 | 58 | 98 | 22 | 59 | 2.8 | 3.3 | 4.9 | 7.3 | 6.7 | 12.3 | 10.1 | 6.9 | 9.8 | 4.5 | 3.7 | 3.2 | 75.5 |
| Osaka | 34 47N | 135 26E | 49 | 60 | 47 | 32 | 65 | 47 | 87 | 73 | 72 | 55 | 102 | 19 | 60 | 1.7 | 2.3 | 3.8 | 5.2 | 4.9 | 7.4 | 5.9 | 4.4 | 7.0 | 5.1 | 3.0 | 1.9 | 52.6 |
| Tokyo | 35 41N | 139 46E | 19 | 60 | 47 | 29 | 63 | 46 | 83 | 70 | 69 | 55 | 101 | 17 | 60 | 1.9 | 2.9 | 4.2 | 5.3 | 5.8 | 6.5 | 5.6 | 6.0 | 9.2 | 8.2 | 3.8 | 2.2 | 61.6 |
| Korea | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pusan | 35 10N | 129 07E | 6 | 36 | 43 | 29 | 62 | 47 | 81 | 71 | 70 | 54 | 97 | 7 | 36 | 1.7 | 1.4 | 2.7 | 5.5 | 5.2 | 7.9 | 11.6 | 5.1 | 6.8 | 2.9 | 1.6 | 1.2 | 53.6 |
| Pyongyang | 39 01N | 125 49E | 94 | 43 | 27 | 8 | 61 | 38 | 84 | 69 | 65 | 43 | 100 | −19 | 43 | 0.6 | 0.4 | 1.0 | 1.8 | 2.6 | 3.0 | 9.3 | 9.0 | 4.4 | 1.8 | 1.6 | 0.8 | 36.4 |
| Seoul | 37 31N | 126 55E | 34 | 22 | 32 | 15 | 62 | 41 | 84 | 70 | 67 | 45 | 99 | −12 | 22 | 1.2 | 0.8 | 1.5 | 3.0 | 3.2 | 5.1 | 14.8 | 10.5 | 4.7 | 1.6 | 1.8 | 1.0 | 49.2 |
| Mongolia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ulan Bator | 47 54N | 106 56E | 4,287 | 13 | −2 | −27 | 45 | 18 | 71 | 50 | 44 | 17 | 97 | −48 | 15 | * | * | 0.1 | 0.2 | 0.3 | 1.0 | 2.9 | 1.9 | 0.8 | 0.2 | 0.2 | 0.1 | 7.7 |
| Taiwan | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tainan | 22 57N | 120 12E | 53 | 13 | 72 | 55 | 82 | 67 | 89 | 77 | 86 | 70 | 95 | 39 | 13 | 0.7 | 0.7 | 1.1 | 3.2 | 6.3 | 15.6 | 16.0 | 15.8 | 8.4 | 1.2 | 0.9 | 0.6 | 70.5 |
| Taipei | 25 04N | 121 32E | 21 | 12 | 66 | 53 | 77 | 64 | 92 | 76 | 80 | 68 | 101 | 32 | 12 | 3.8 | 5.3 | 4.3 | 5.3 | 6.9 | 8.8 | 8.8 | 8.7 | 8.2 | 5.5 | 4.2 | 2.9 | 72.7 |
| Union of Soviet Socialist Republics | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Alma-Ata | 43 16N | 76 53E | 2,543 | 19 | 23 | 7 | 56 | 38 | 81 | 60 | 55 | 35 | 100 | −30 | 27 | 1.3 | 0.9 | 2.2 | 4.0 | 3.7 | 2.6 | 1.4 | 1.2 | 1.0 | 2.0 | 1.9 | 1.3 | 23.5 |
| Chita | 52 02N | 113 30E | 2,218 | 10 | −10 | −27 | 42 | 19 | 75 | 51 | 38 | 18 | 99 | −52 | 24 | 0.1 | 0.1 | 0.1 | 0.4 | 1.1 | 1.8 | 3.3 | 3.3 | 1.2 | 0.5 | 0.2 | 0.2 | 12.3 |
| Dubinka | 69 07N | 87 00E | 141 | 5 | −23 | −31 | 6 | −10 | 59 | 47 | 19 | 11 | 84 | −62 | 5 | 0.3 | 0.4 | 0.2 | 0.3 | 0.6 | 1.9 | 1.5 | 2.1 | 1.8 | 0.9 | 0.4 | 0.3 | 10.7 |
| Irkutsk | 52 16N | 104 19E | 1,532 | 10 | 3 | −15 | 42 | 20 | 70 | 50 | 41 | 21 | 98 | −58 | 38 | 0.5 | 0.4 | 0.3 | 0.6 | 1.3 | 2.2 | 3.1 | 2.8 | 1.7 | 0.7 | 0.6 | 0.6 | 14.9 |
| Kazalinsk | 45 46N | 62 06E | 207 | 10 | 16 | 5 | 58 | 27 | 90 | 65 | 57 | 35 | 108 | −27 | 19 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.6 | 4.9 |
| Khabarovsk | 48 28N | 135 03E | 165 | 7 | −2 | −13 | 41 | 28 | 75 | 63 | 48 | 34 | 91 | −46 | 8 | 0.3 | 0.2 | 0.3 | 0.7 | 2.0 | 3.5 | 4.1 | 3.3 | 3.0 | 0.7 | 0.6 | 0.5 | 19.2 |
| Kirensk | 57 47N | 108 07E | 938 | 18 | −14 | −28 | 38 | 15 | 74 | 51 | 10 | −4 | 95 | −71 | 19 | 0.8 | 0.5 | 0.5 | 0.5 | 1.0 | 1.8 | 2.1 | 2.1 | 1.7 | 1.0 | 1.0 | 1.0 | 14.0 |
| Krasnoyarsk | 56 01N | 92 52E | 498 | 10 | 3 | −10 | 34 | 23 | 67 | 55 | 34 | 26 | 103 | −47 | 8 | 0.1 | 0.2 | 0.1 | 0.2 | 1.0 | 1.4 | 1.2 | 2.1 | 1.7 | 0.9 | 0.5 | 0.4 | 9.8 |
| Markovo | 64 45N | 170 50E | 85 | 15 | −19 | −29 | 5 | −8 | 59 | 47 | 16 | 9 | 84 | −72 | 16 | 0.2 | 0.2 | 0.3 | 0.1 | 0.3 | 0.8 | 1.0 | 1.9 | 1.1 | 0.4 | 0.4 | 0.3 | 7.0 |
| Narym | 58 50N | 81 39E | 197 | 13 | −7 | −18 | 35 | 19 | 71 | 56 | 35 | 25 | 94 | −61 | 14 | 0.8 | 0.5 | 0.8 | 0.5 | 1.3 | 2.6 | 2.4 | 2.7 | 1.7 | 1.4 | 1.1 | 0.9 | 16.8 |
| Okhotsk | 59 21N | 143 17E | 18 | 19 | −6 | −17 | 29 | 10 | 57 | 48 | 33 | 21 | 78 | −50 | 25 | 0.1 | 0.1 | 0.2 | 0.4 | 0.9 | 1.6 | 2.2 | 2.6 | 2.4 | 1.0 | 0.2 | 0.1 | 11.8 |
| Omsk | 54 58N | 73 20E | 279 | 19 | −1 | −14 | 39 | 21 | 74 | 56 | 40 | 27 | 102 | −56 | 22 | 0.6 | 0.3 | 0.3 | 0.5 | 1.2 | 2.0 | 2.0 | 2.0 | 1.1 | 1.0 | 0.7 | 0.8 | 12.5 |
| Petropavlovsk | 52 53N | 158 42E | 286 | 7 | 23 | 11 | 35 | 25 | 56 | 47 | 46 | 34 | 84 | −29 | 35 | 3.0 | 2.2 | 3.4 | 2.5 | 2.2 | 2.0 | 3.1 | 3.2 | 3.8 | 3.9 | 3.6 | 3.0 | 35.9 |
| Salehkard | 66 31N | 66 35E | 60 | 18 | −13 | −21 | 18 | 4 | 61 | 49 | 26 | 20 | 85 | −65 | 27 | 0.3 | 0.3 | 0.3 | 0.3 | 0.7 | 1.3 | 1.9 | 2.0 | 1.5 | 0.7 | 0.5 | 0.4 | 10.2 |
| Semipalatinsk | 50 24N | 80 13E | 709 | 10 | 8 | −7 | 45 | 26 | 81 | 57 | 46 | 30 | 101 | −47 | 10 | 0.9 | 0.5 | 0.5 | 0.6 | 1.2 | 1.5 | 1.1 | 1.3 | 0.7 | 1.2 | 1.1 | 1.0 | 11.6 |
| Sverdlovsk | 56 49N | 60 38E | 894 | 21 | 6 | −5 | 42 | 26 | 70 | 54 | 37 | 28 | 94 | −45 | 29 | 0.5 | 0.4 | 0.5 | 0.7 | 1.9 | 2.7 | 2.6 | 2.7 | 1.6 | 1.2 | 1.1 | 0.8 | 16.7 |
| Tashkent | 41 20N | 69 18E | 1,569 | 19 | 37 | 21 | 65 | 47 | 92 | 64 | 65 | 41 | 106 | −19 | 19 | 2.1 | 1.1 | 2.6 | 2.3 | 1.4 | 0.5 | 0.2 | 0.1 | 0.1 | 1.2 | 1.5 | 1.6 | 14.7 |
| Verkhoyansk | 67 34N | 133 51E | 328 | 24 | −54 | −63 | 19 | −10 | 66 | 47 | 12 | −3 | 98 | −90 | 44 | 0.2 | 0.2 | 0.1 | 0.2 | 0.3 | 0.9 | 1.1 | 1.0 | 0.5 | 0.3 | 0.3 | 0.2 | 5.3 |
| Vladivostok | 43 07N | 131 55E | 94 | 14 | 13 | 0 | 46 | 34 | 71 | 60 | 55 | 41 | 92 | −22 | 53 | 0.3 | 0.4 | 0.7 | 1.2 | 2.1 | 2.9 | 3.3 | 4.7 | 4.3 | 1.9 | 1.2 | 0.6 | 23.6 |
| Yakutsk | 62 01N | 129 43E | 535 | 19 | −45 | −53 | 27 | 6 | 73 | 54 | 23 | 11 | 97 | −84 | 22 | 0.3 | 0.2 | 0.1 | 0.3 | 0.4 | 1.1 | 1.6 | 1.3 | 1.1 | 0.5 | 0.4 | 0.3 | 7.4 |

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Asia-Southeast

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brunel | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brunel | 04 55N | 114 55E | 10 | 5 | 85 | 76 | 87 | 77 | 87 | 76 | 86 | 77 | 99 | 70 | 12 | 14.6 | 7.6 | 7.8 | 9.8 | 10.9 | 9.5 | 9.0 | 7.3 | 11.8 | 14.5 | 15.2 | 13.0 | 131.0 |
| Burma | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mandalay | 21 59N | 96 06E | 252 | 20 | 82 | 55 | 1.1 | 77 | 93 | 78 | 89 | 73 | 111 | 44 | 20 | 0.1 | 0.1 | 0.2 | 1.2 | 5.8 | 6.3 | 2.7 | 4.1 | 5.4 | 4.3 | 2.0 | 0.4 | 32.6 |
| Moulmein | 16 26N | 97 39E | 150 | 43 | 89 | 65 | 95 | 77 | 83 | 74 | 88 | 75 | 103 | 52 | 60 | 0.2 | 0.2 | 0.5 | 3.0 | 19.9 | 37.1 | 47.5 | 44.2 | 27.1 | 8.5 | 1.7 | 0.3 | 190.2 |
| Cambodia | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Phanom Penh | 11 33N | 104 51E | 39 | 37 | 88 | 71 | 95 | 76 | 90 | 76 | 87 | 76 | 105 | 55 | 49 | 0.3 | 0.4 | 1.4 | 3.1 | 5.7 | 5.8 | 6.0 | 6.1 | 8.9 | 9.9 | 5.5 | 1.7 | 54.8 |
| Indonesia | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Jakarta | 06 11S | 106 50E | 26 | 80 | 84 | 74 | 87 | 75 | 87 | 73 | 87 | 74 | 98 | 66 | 78 | 11.8 | 11.8 | 8.3 | 5.8 | 4.5 | 3.8 | 2.5 | 1.7 | 2.6 | 4.4 | 5.6 | 8.0 | 70.8 |
| Manokwari | 00 53S | 134 03E | 10 | 5 | 86 | 73 | 86 | 74 | 86 | 74 | 87 | 74 | 93 | 68 | 40 | 12.0 | 9.4 | 13.2 | 11.1 | 7.8 | 7.2 | 5.4 | 5.6 | 4.9 | 4.7 | 6.5 | 10.3 | 98.1 |
| Mapanget | 01 32N | 124 55E | 264 | 21 | 85 | 73 | 86 | 73 | 87 | 73 | 89 | 72 | 97 | 65 | 63 | 18.6 | 13.8 | 12.2 | 8.0 | 6.4 | 6.5 | 4.8 | 4.0 | 3.3 | 4.9 | 8.9 | 14.7 | 106.1 |
| Penfui | 10 10S | 123 39E | 335 | 21 | 87 | 75 | 89 | 72 | 88 | 70 | 92 | 72 | 101 | 58 | 63 | 15.2 | 13.7 | 9.2 | 2.6 | 1.2 | 0.4 | 0.2 | 0.0 | 0.0 | 0.7 | 3.3 | 9.1 | 55.7 |
| Pontianak | 00 00N | 109 20E | 13 | 20 | 87 | 74 | 89 | 75 | 89 | 74 | 89 | 75 | 96 | 68 | 63 | 10.8 | 8.2 | 9.5 | 10.9 | 11.1 | 8.7 | 6.5 | 8.0 | 9.0 | 14.4 | 15.3 | 12.7 | 125.1 |
| Tabing | 00 52S | 100 21E | 19 | 21 | 87 | 74 | 87 | 75 | 87 | 74 | 86 | 74 | 94 | 68 | 63 | 13.9 | 10.1 | 12.2 | 14.5 | 12.8 | 11.7 | 10.5 | 13.7 | 16.2 | 20.1 | 20.5 | 19.2 | 175.4 |
| Tarakan | 03 19N | 117 33E | 20 | 19 | 85 | 73 | 86 | 75 | 87 | 74 | 87 | 74 | 94 | 67 | 31 | 10.9 | 10.2 | 14.0 | 13.9 | 13.5 | 12.6 | 10.3 | 12.4 | 11.6 | 14.3 | 15.2 | 13.4 | 152.3 |
| Laos | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vientiane | 17 58N | 102 34E | 559 | 13 | 83 | 58 | 95 | 73 | 89 | 75 | 88 | 71 | 108 | 32 | 27 | 0.2 | 0.6 | 1.5 | 3.9 | 10.5 | 11.9 | 10.5 | 11.5 | 11.9 | 4.3 | 0.6 | 0.1 | 67.5 |
| Malaysia | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kuala Lumpur | 03 06N | 101 42E | 111 | 19 | 90 | 72 | 91 | 74 | 90 | 72 | 89 | 73 | 99 | 64 | 19 | 6.2 | 7.9 | 10.2 | 11.5 | 8.8 | 5.1 | 3.9 | 6.4 | 8.6 | 9.8 | 10.2 | 7.5 | 96.1 |
| North Borneo | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sandakan | 05 54N | 118 03E | 38 | 45 | 85 | 74 | 89 | 76 | 89 | 75 | 88 | 75 | 99 | 70 | 46 | 19.0 | 10.9 | 8.6 | 4.5 | 6.2 | 7.4 | 6.7 | 7.9 | 9.3 | 10.2 | 14.5 | 18.5 | 123.7 |
| Philippine Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Davao | 07 07N | 125 38E | 88 | 15 | 87 | 72 | 91 | 73 | 88 | 73 | 89 | 73 | 97 | 65 | 34 | 4.8 | 4.5 | 5.2 | 5.8 | 9.2 | 9.1 | 6.5 | 6.5 | 6.7 | 7.9 | 5.3 | 6.1 | 77.6 |
| Manila | 14 31N | 121 00E | 49 | 61 | 86 | 69 | 93 | 73 | 88 | 75 | 88 | 74 | 101 | 58 | 75 | 0.9 | 0.5 | 0.7 | 1.3 | 5.1 | 10.0 | 17.0 | 16.6 | 14.0 | 7.6 | 5.7 | 2.6 | 82.0 |
| Sarawak: | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kuching | 01 29N | 110 20E | 85 | 5 | 85 | 72 | 90 | 73 | 90 | 72 | 89 | 73 | 98 | 64 | 19 | 24.0 | 20.1 | 12.9 | 11.0 | 10.3 | 7.1 | 7.7 | 9.2 | 8.6 | 10.5 | 14.1 | 18.2 | 153.7 |
| Singapore | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Singapore | 01 18N | 103 50E | 33 | 39 | 86 | 73 | 88 | 75 | 88 | 75 | 87 | 74 | 97 | 66 | 64 | 9.9 | 6.8 | 7.6 | 7.4 | 6.8 | 6.8 | 6.7 | 7.7 | 7.0 | 8.2 | 10.0 | 10.1 | 95.0 |
| Thailand | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bangkok | 13 44N | 100 30E | 53 | 10 | 89 | 67 | 95 | 78 | 90 | 76 | 88 | 76 | 104 | 50 | 10 | 0.2 | 1.1 | 1.1 | 2.3 | 5.2 | 6.0 | 6.9 | 9.2 | 14.0 | 9.9 | 1.8 | 0.1 | 57.8 |
| Viet Nam Hanoi | 21 03N | 105 52E | 20 | 12 | 68 | 58 | 80 | 70 | 92 | 79 | 84 | 72 | 108 | 41 | 12 | 0.8 | 1.2 | 2.5 | 3.6 | 4.1 | 11.2 | 11.9 | 15.2 | 10.0 | 3.5 | 2.6 | 2.8 | 69.4 |
| Saigon | 10 49N | 106 39E | 33 | 31 | 89 | 70 | 95 | 76 | 88 | 75 | 88 | 74 | 104 | 57 | 33 | 0.6 | 0.1 | 0.5 | 1.7 | 8.7 | 13.0 | 12.4 | 10.6 | 13.2 | 10.6 | 4.5 | 2.2 | 78.1 |

Asia-Middle East

| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aden | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Riyan | 14 39N | 49 19E | 83 | 13 | 82 | 67 | 88 | 74 | 92 | 77 | 88 | 72 | 111 | 57 | 13 | 0.3 | 0.1 | 0.6 | 0.2 | * | 0.1 | 0.1 | 0.1 | * | * | 0.7 | 0.3 | 2.5 |
| Afghanistan | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kabul | 34 30N | 69 13E | 5,955 | 9 | 36 | 18 | 66 | 43 | 92 | 61 | 73 | 42 | 104 | −6 | 45 | 1.3 | 1.5 | 3.6 | 3.3 | 0.9 | 0.2 | 0.1 | 0.1 | * | 0.4 | 0.6 | 0.6 | 12.6 |
| Kandhar | 31 36N | 65 40E | 3,462 | 7 | 56 | 31 | 83 | 50 | 102 | 66 | 85 | 44 | 111 | 14 | 7 | 3.1 | 1.7 | 0.8 | 0.3 | 0.2 | * | 0.1 | * | 0.0 | * | * | 0.8 | 7.0 |
| Bangladesh | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Dacca | 23 46N | 90 23E | 24 | 60 | 77 | 56 | 92 | 74 | 88 | 79 | 88 | 75 | 108 | 43 | 61 | 0.3 | 1.2 | 2.4 | 5.4 | 9.6 | 12.4 | 13.0 | 13.3 | 9.8 | 5.3 | 1.0 | 0.2 | 73.9 |
| India | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ahmadabad | 23 03N | 72 37E | 180 | 45 | 85 | 58 | 104 | 75 | 93 | 79 | 97 | 73 | 118 | 36 | 45 | * | 0.1 | 0.1 | * | 0.4 | 3.7 | 12.2 | 8.1 | 4.2 | 0.4 | 0.1 | * | 29.3 |
| Bangalore | 12 57N | 77 40E | 2,937 | 60 | 80 | 57 | 93 | 69 | 81 | 66 | 82 | 65 | 102 | 46 | 60 | 0.2 | 0.3 | 0.4 | 1.6 | 4.2 | 2.9 | 3.9 | 5.0 | 6.7 | 5.9 | 2.7 | 0.4 | 34.2 |
| Bombay | 19 06N | 72 51E | 27 | 60 | 88 | 62 | 93 | 74 | 88 | 75 | 93 | 73 | 110 | 46 | 60 | 0.1 | 0.1 | 0.1 | * | 0.7 | 19.1 | 24.3 | 13.4 | 10.4 | 2.5 | 0.5 | 0.1 | 71.2 |
| Calcutta | 22 32N | 88 20E | 21 | 60 | 80 | 55 | 97 | 76 | 90 | 79 | 89 | 74 | 111 | 44 | 60 | 0.4 | 1.2 | 1.4 | 1.7 | 5.5 | 11.7 | 12.8 | 12.9 | 9.9 | 4.5 | 0.8 | 0.2 | 63.0 |
| Cherrapunji | 25 15N | 91 44E | 4,309 | 35 | 60 | 46 | 71 | 59 | 72 | 65 | 72 | 61 | 87 | 33 | 35 | 0.7 | 2.1 | 7.3 | 26.2 | 50.4 | 6.1 | 96.3 | 70.1 | 43.3 | 19.4 | 2.7 | 0.5 | 425.1 |
| Hyderabad | 17 27N | 78 28E | 1,741 | 50 | 85 | 59 | 101 | 75 | 87 | 73 | 88 | 68 | 112 | 43 | 45 | 0.3 | 0.4 | 0.5 | 1.2 | 1.1 | 4.4 | 6.0 | 5.3 | 6.5 | 2.5 | 1.1 | 0.3 | 29.6 |
| Jalpaiguri | 26 32N | 88 43E | 272 | 50 | 74 | 50 | 90 | 68 | 89 | 77 | 87 | 70 | 104 | 36 | 55 | 0.3 | 0.7 | 1.3 | 3.7 | 11.8 | 25.9 | 32.2 | 25.3 | 21.2 | 5.6 | 0.5 | 0.2 | 128.7 |
| Lucknow | 26 45N | 80 52E | 400 | 60 | 74 | 47 | 101 | 71 | 92 | 80 | 91 | 67 | 119 | 34 | 60 | 0.8 | 0.7 | 0.3 | 0.3 | 0.8 | 4.5 | 12.0 | 11.5 | 7.4 | 1.3 | 0.2 | 0.3 | 40.1 |
| Madras | 13 04N | 80 15E | 51 | 60 | 85 | 67 | 95 | 78 | 96 | 79 | 90 | 75 | 113 | 57 | 60 | 1.4 | 0.4 | 0.3 | 0.6 | 1.0 | 1.9 | 3.6 | 4.6 | 4.7 | 12.0 | 14.0 | 5.5 | 50.0 |
| Mormugao | 15 22N | 73 49E | 157 | 10 | 86 | 70 | 88 | 79 | 83 | 75 | 86 | 75 | 98 | 59 | 30 | * | * | * | 0.7 | 2.6 | 29.6 | 31.2 | 15.9 | 9.5 | 3.8 | 1.3 | 0.2 | 94.8 |
| New Delhi | 28 35N | 77 12E | 695 | 10 | 71 | 43 | 97 | 68 | 95 | 80 | 93 | 64 | 115 | 31 | 75 | 0.9 | 0.7 | 0.5 | 0.3 | 0.5 | 2.9 | 7.1 | 6.8 | 4.6 | 0.4 | 0.1 | 0.4 | 25.2 |
| Silchar | 24 49N | 92 48E | 95 | 60 | 78 | 52 | 88 | 69 | 90 | 77 | 88 | 72 | 103 | 41 | 53 | 0.8 | 2.1 | 7.9 | 14.3 | 15.6 | 21.7 | 19.7 | 19.7 | 14.4 | 6.5 | 1.4 | 0.4 | 124.5 |
| Indian Ocean Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port Blair, Andaman Is | 11 40N | 92 43E | 261 | 60 | 84 | 72 | 89 | 75 | 84 | 75 | 84 | 74 | 97 | 62 | 60 | 1.8 | 1.1 | 1.1 | 2.4 | 15.1 | 21.7 | 15.4 | 16.3 | 17.4 | 12.5 | 10.5 | 7.9 | 123.2 |

*(Continued)*



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**Table 3B.13 (Continued)**

| Country and Station | Latitude | Longitude | Elevation | Temperature | | | | | | | | | | | Average Precipitation | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Average Daily | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Jan | | Apr | | July | | Oct | | Extreme | | | | | | | | | | | | | | | | |
| | | | | Length of Record | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Length of Record | January | February | March | April | May | June | July | August | September | October | November | December | Year |
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| Amini Divi, Laccadive Is | 11 07N | 72 44E | 13 | 29 | 86 | 74 | 92 | 80 | 86 | 77 | 86 | 77 | 99 | 65 | 30 | 0.7 | * | * | 1.5 | 3.7 | 14.3 | 12.0 | 7.7 | 6.3 | 5.8 | 2.6 | 1.3 | 56.0 |
| Minicoy, Maldive Is | 08 18N | 73 00E | 9 | 20 | 85 | 73 | 87 | 80 | 85 | 76 | 85 | 76 | 98 | 63 | 50 | 1.8 | 0.7 | 0.9 | 2.3 | 7.0 | 11.6 | 8.9 | 7.8 | 6.3 | 7.3 | 5.5 | 3.4 | 63.5 |
| Car Nicobar, Nicobar Is | 09 09N | 92 49E | 47 | 13 | 86 | 77 | 90 | 77 | 86 | 77 | 85 | 75 | 95 | 66 | 30 | 3.9 | 1.2 | 2.1 | 3.5 | 12.5 | 12.4 | 9.3 | 10.2 | 12.9 | 11.6 | 11.4 | 7.8 | 98.8 |
| Iran | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Abadan | 30 21N | 48 13E | 10 | 12 | 64 | 44 | 90 | 62 | 112 | 81 | 98 | 63 | 127 | 24 | 10 | 1.5 | 1.7 | 0.6 | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 1.0 | 1.8 | 7.6 |
| Isfahan | 32 37N | 51 41E | 5,238 | 45 | 47 | 25 | 72 | 46 | 98 | 67 | 78 | 47 | 108 | −4 | 45 | 0.7 | 0.6 | 0.8 | 0.6 | 0.3 | * | 0.1 | * | * | 0.1 | 0.4 | 0.7 | 4.4 |
| Kermanshah | 34 19N | 47 07E | 4,331 | 15 | 45 | 23 | 68 | 38 | 99 | 56 | 79 | 38 | 108 | −3 | 15 | 2.6 | 2.3 | 2.8 | 2.2 | 1.6 | * | * | * | * | 0.4 | 2.0 | 2.4 | 16.4 |
| Rezaiyeh | 37 32N | 45 05E | 4,364 | 3 | 32 | 17 | 67 | 45 | 91 | 64 | 67 | 47 | 99 | −11 | 3 | 1.9 | 2.3 | 2.0 | 1.7 | 1.2 | 0.5 | * | 0.1 | 0.2 | 1.5 | 0.8 | 1.6 | 13.8 |
| Tehran | 35 41N | 51 19E | 3,937 | 24 | 45 | 27 | 71 | 49 | 99 | 72 | 76 | 53 | 109 | −5 | 33 | 1.8 | 1.5 | 1.8 | 1.4 | 0.5 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.8 | 1.2 | 9.7 |
| Iraq | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Baghdad | 33 20N | 44 24E | 111 | 15 | 60 | 39 | 85 | 57 | 110 | 76 | 92 | 61 | 121 | 18 | 15 | 0.9 | 1.0 | 1.1 | 0.5 | 0.1 | * | * | * | * | 0.1 | 0.8 | 1.0 | 5.5 |
| Basra | 30 34N | 47 47E | 8 | 10 | 64 | 45 | 85 | 63 | 104 | 81 | 94 | 64 | 123 | 24 | 10 | 1.4 | 1.1 | 1.2 | 1.2 | 0.2 | 0.0 | * | * | * | * | 1.4 | 0.8 | 7.3 |
| Mosul | 36 19N | 43 09E | 730 | 26 | 54 | 35 | 77 | 49 | 109 | 72 | 88 | 51 | 124 | 12 | 29 | 2.8 | 3.1 | 2.1 | 1.9 | 0.7 | * | * | * | * | 0.2 | 1.9 | 2.4 | 15.2 |
| Israel | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Haifa | 32 48N | 35 02E | 23 | 16 | 65 | 49 | 77 | 58 | 88 | 75 | 85 | 68 | 112 | 27 | 30 | 6.9 | 4.3 | 1.6 | 1.0 | 0.2 | * | * | * | 0.1 | 1.0 | 3.7 | 7.3 | 26.2 |
| Jerusalem | 31 47N | 35 13E | 2,654 | 19 | 55 | 41 | 73 | 50 | 87 | 63 | 81 | 59 | 107 | 26 | 50 | 5.1 | 4.7 | 2.9 | 0.9 | 0.1 | * | 0.0 | 0.0 | * | 0.3 | 2.2 | 3.5 | 19.7 |
| Tel Aviv | 32 06N | 34 46E | 33 | 10 | 64 | 50 | 70 | 57 | 82 | 72 | 79 | 65 | 102 | 34 | 10 | 4.9 | 2.7 | 2.0 | 0.7 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 4.1 | 6.1 | 21.1 |
| Jammu/Kashmir | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Srinagar | 33 58N | 74 46E | 5,458 | 50 | 41 | 24 | 67 | 45 | 88 | 64 | 74 | 41 | 106 | −4 | 50 | 2.9 | 2.8 | 3.6 | 3.7 | 2.4 | 1.4 | 2.3 | 2.4 | 1.5 | 1.2 | 0.4 | 1.3 | 25.9 |
| Jordan | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Amman | 31 58N | 35 59E | 2,547 | 25 | 54 | 39 | 73 | 49 | 89 | 65 | 81 | 57 | 109 | 21 | 25 | 2.7 | 2.9 | 1.2 | 0.6 | 0.2 | 0.0 | 0.0 | 0.0 | * | 0.2 | 1.3 | 1.8 | 10.9 |
| Kuwait | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kuwait | 29 21N | 48 00E | 16 | 14 | 61 | 49 | 83 | 68 | 103 | 86 | 91 | 73 | 119 | 33 | 10 | 0.9 | 0.9 | 1.1 | 0.2 | * | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.6 | 1.1 | 5.1 |
| Lebanon | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Beirut | 33 54N | 35 28E | 111 | 62 | 62 | 51 | 72 | 58 | 87 | 73 | 81 | 69 | 107 | 30 | 71 | 7.5 | 6.2 | 3.7 | 2.2 | 0.7 | 0.1 | * | * | 0.2 | 2.0 | 5.2 | 7.3 | 35.1 |
| Nepal | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Katmandu | 27 42N | 85 22E | 4,423 | 27 | 65 | 36 | 84 | 53 | 84 | 69 | 80 | 56 | 99 | 27 | 9 | 0.6 | 1.6 | 0.9 | 2.3 | 4.8 | 9.7 | 14.7 | 13.6 | 6.1 | 1.5 | 0.3 | 0.1 | 56.2 |
| Oman and Muscat | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Muscat | 23 37N | 58 35E | 15 | 23 | 77 | 66 | 90 | 78 | 97 | 87 | 93 | 80 | 116 | 51 | 38 | 1.1 | 0.7 | 0.4 | 0.4 | * | 0.1 | * | * | 0.0 | 0.1 | 0.4 | 0.7 | 3.9 |
| Pakistan | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Karachi | 24 48N | 66 59E | 13 | 43 | 77 | 55 | 90 | 73 | 91 | 81 | 91 | 72 | 118 | 39 | 59 | 0.5 | 0.4 | 0.3 | 0.1 | 0.1 | 0.7 | 3.2 | 1.6 | 0.5 | 0.1 | 0.1 | 0.2 | 7.8 |
| Multan | 30 11N | 71 25E | 400 | 60 | 68 | 42 | 95 | 68 | 102 | 86 | 94 | 64 | 122 | 29 | 60 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.6 | 2.0 | 1.8 | 0.5 | 0.1 | 0.1 | 0.2 | 7.1 |
| Rawalpindi | 33 35N | 73 03E | 1,676 | 60 | 62 | 38 | 86 | 59 | 98 | 77 | 89 | 57 | 118 | 25 | 60 | 2.5 | 2.5 | 2.7 | 1.9 | 1.3 | 2.3 | 8.1 | 9.2 | 3.9 | 0.6 | 0.3 | 1.2 | 36.5 |
| Saudi Arabia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Dhahran | 26 16N | 50 10E | 78 | 10 | 69 | 54 | 90 | 69 | 107 | 86 | 95 | 73 | 120 | 40 | 10 | 1.1 | 0.6 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.9 | 3.5 |
| Jidda | 21 28N | 39 10E | 20 | 5 | 84 | 66 | 91 | 70 | 99 | 79 | 95 | 73 | 117 | 49 | 5 | 0.2 | * | * | * | * | 0.0 | * | * | * | * | 1.0 | 1.2 | 2.5 |
| Riyadh | 24 39N | 46 42E | 1,938 | 3 | 70 | 46 | 89 | 64 | 107 | 78 | 94 | 61 | 113 | 19 | 3 | 0.1 | 0.8 | 0.9 | 1.0 | 0.4 | * | 0.0 | * | 0.0 | 0.0 | * | * | 3.2 |
| Sri Lanka | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Colombo | 06 54N | 79 52E | 22 | 25 | 86 | 72 | 88 | 76 | 85 | 77 | 85 | 75 | 99 | 59 | 40 | 3.5 | 2.7 | 5.8 | 9.1 | 14.6 | 8.8 | 5.3 | 4.3 | 6.3 | 13.7 | 12.4 | 5.8 | 92.3 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Syria | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Deir Ez Zor | 35 21N | 40 09E | 699 | 5 | 53 | 35 | 80 | 52 | 105 | 78 | 86 | 56 | 114 | 16 | 8 | 1.6 | 0.8 | 0.3 | 0.8 | 0.1 | * | 0.0 | 0.0 | 0.0 | 0.2 | 1.5 | 0.9 | 6.2 |
| Damascus | 33 30N | 36 20E | 2,362 | 13 | 53 | 36 | 75 | 49 | 96 | 64 | 81 | 54 | 113 | 21 | 7 | 1.7 | 1.7 | 0.3 | 0.5 | 0.1 | * | * | 0.0 | 0.7 | 0.4 | 1.6 | 1.6 | 8.6 |
| Aleppo | 36 14N | 37 08E | 1,280 | 8 | 50 | 34 | 75 | 48 | 97 | 69 | 81 | 54 | 117 | 9 | 10 | 3.5 | 2.5 | 1.5 | 1.1 | 0.3 | 0.1 | 0.0 | * | * | 1.0 | 2.2 | 3.3 | 15.5 |
| Turkey | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Adana | 36 59N | 35 18E | 82 | 21 | 57 | 39 | 74 | 51 | 93 | 71 | 84 | 58 | 109 | 19 | 31 | 4.3 | 4.0 | 2.5 | 1.6 | 2.0 | 0.7 | 0.2 | 0.2 | 0.7 | 1.9 | 2.4 | 3.8 | 24.3 |
| Ankara | 39 57N | 32 53E | 2,825 | 26 | 39 | 24 | 63 | 40 | 86 | 59 | 69 | 44 | 104 | −13 | 24 | 1.3 | 1.2 | 1.3 | 1.3 | 1.9 | 1.0 | 0.5 | 0.4 | 0.7 | 0.9 | 1.2 | 1.9 | 13.6 |
| Erzurum | 39 54N | 41 16E | 6,402 | 16 | 24 | 8 | 50 | 32 | 78 | 53 | 59 | 37 | 93 | −22 | 16 | 1.4 | 1.6 | 2.0 | 2.5 | 3.1 | 2.1 | 1.3 | 0.9 | 1.1 | 2.3 | 1.8 | 1.1 | 21.2 |
| Izmir | 38 27N | 27 15E | 92 | 39 | 55 | 39 | 70 | 49 | 92 | 69 | 76 | 55 | 108 | 12 | 58 | 4.4 | 3.3 | 3.0 | 1.7 | 1.3 | 0.6 | 0.2 | 0.2 | 0.8 | 2.1 | 3.3 | 4.8 | 25.5 |
| Samsun | 41 17N | 36 19E | 131 | 24 | 50 | 38 | 59 | 45 | 79 | 65 | 69 | 56 | 103 | 20 | 27 | 2.9 | 2.6 | 2.7 | 2.3 | 1.8 | 1.5 | 1.5 | 1.3 | 2.4 | 3.2 | 3.5 | 2.4 | 29.1 |
| United Arab Emirates | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sharjah | 25 20N | 55 24E | 18 | 11 | 74 | 54 | 86 | 65 | 100 | 82 | 92 | 71 | 118 | 37 | 12 | 0.9 | 0.9 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 1.4 | 4.2 |
| Yemen | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kamaran I | 15 20N | 42 37E | 20 | 26 | 82 | 74 | 89 | 79 | 98 | 85 | 93 | 82 | 105 | 66 | 21 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | * | 0.5 | 0.7 | 0.1 | 0.1 | 0.4 | 0.9 | 3.4 |
| Australia & Pacific Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Australia | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Adelaide | 34 57S | 138 32E | 20 | 86 | 86 | 61 | 73 | 55 | 59 | 45 | 73 | 51 | 118 | 32 | 104 | 0.8 | 0.7 | 1.0 | 1.8 | 2.7 | 3.0 | 2.6 | 2.6 | 2.1 | 1.7 | 1.1 | 1.0 | 21.1 |
| Alice Springs | 23 48S | 133 53E | 1,791 | 62 | 97 | 70 | 81 | 54 | 67 | 39 | 88 | 58 | 111 | 19 | 30 | 1.7 | 1.3 | 1.1 | 0.4 | 0.6 | 0.5 | 0.3 | 0.3 | 0.3 | 0.7 | 1.2 | 1.5 | 9.9 |
| Bourke | 30 05S | 145 58E | 361 | 63 | 99 | 70 | 82 | 55 | 65 | 40 | 85 | 56 | 125 | 25 | 72 | 1.4 | 1.5 | 1.1 | 1.1 | 1.0 | 1.1 | 0.9 | 0.8 | 0.8 | 0.9 | 1.2 | 1.4 | 13.2 |
| Brisbane | 27 25S | 153 05E | 17 | 53 | 85 | 69 | 79 | 61 | 68 | 49 | 80 | 60 | 110 | 35 | 91 | 6.4 | 6.3 | 5.7 | 3.7 | 2.8 | 2.6 | 2.2 | 1.9 | 1.9 | 2.5 | 3.7 | 5.0 | 44.7 |
| Broome | 17 57S | 122 13E | 56 | 41 | 92 | 79 | 93 | 72 | 82 | 58 | 91 | 72 | 113 | 40 | 50 | 6.3 | 5.8 | 3.9 | 1.2 | 0.6 | 0.9 | 0.2 | 0.1 | * | * | 0.6 | 3.3 | 22.9 |
| Burketown | 17 45S | 139 33E | 30 | 31 | 93 | 77 | 91 | 69 | 82 | 55 | 93 | 70 | 110 | 40 | 53 | 8.2 | 6.3 | 5.2 | 1.0 | 0.2 | 0.3 | * | * | * | 0.4 | 1.5 | 4.4 | 27.5 |
| Canberra | 35 18S | 149 11E | 1,886 | 23 | 82 | 55 | 67 | 44 | 52 | 33 | 68 | 43 | 109 | 14 | 25 | 1.9 | 1.7 | 2.2 | 1.6 | 1.8 | 2.1 | 1.8 | 2.2 | 1.6 | 2.2 | 1.9 | 2.0 | 23.0 |
| Carnarvon | 24 53S | 113 40E | 13 | 43 | 88 | 72 | 84 | 66 | 71 | 51 | 78 | 61 | 118 | 37 | 57 | 0.4 | 0.7 | 0.7 | 0.6 | 1.5 | 2.4 | 1.6 | 0.7 | 0.2 | 0.1 | * | 0.2 | 9.1 |
| Cloncurry | 20 40S | 140 30E | 622 | 32 | 99 | 77 | 90 | 67 | 77 | 51 | 95 | 68 | 127 | 35 | 59 | 4.4 | 4.2 | 2.4 | 0.7 | 0.5 | 0.6 | 0.3 | 0.1 | 0.3 | 0.5 | 1.3 | 2.7 | 18.0 |
| Esperance | 33 50S | 121 55E | 14 | 44 | 77 | 60 | 72 | 54 | 62 | 45 | 68 | 50 | 117 | 31 | 60 | 0.7 | 0.7 | 1.2 | 1.8 | 3.3 | 4.1 | 4.0 | 3.8 | 2.7 | 2.2 | 1.0 | 0.9 | 26.4 |
| Laverton | 28 40S | 122 23E | 1,510 | 30 | 96 | 69 | 81 | 57 | 64 | 41 | 82 | 55 | 115 | 25 | 30 | 0.8 | 0.8 | 1.6 | 0.8 | 0.9 | 0.7 | 0.6 | 0.5 | 0.2 | 0.3 | 0.8 | 0.8 | 8.8 |
| Melbourne | 37 49S | 144 58E | 115 | 88 | 78 | 57 | 68 | 51 | 56 | 42 | 67 | 48 | 114 | 27 | 88 | 1.9 | 1.8 | 2.2 | 2.3 | 2.1 | 2.1 | 1.9 | 1.9 | 2.3 | 2.6 | 2.3 | 2.3 | 25.7 |
| Mundiwindi | 23 52S | 120 10E | 1,840 | 15 | 101 | 64 | 87 | 61 | 70 | 41 | 89 | 58 | 112 | 22 | 15 | 1.0 | 1.9 | 2.0 | 0.8 | 0.6 | 0.9 | 0.1 | 0.3 | 0.3 | 0.5 | 0.5 | 1.2 | 10.1 |
| Perth | 31 56S | 115 58E | 64 | 44 | 85 | 63 | 76 | 57 | 63 | 48 | 70 | 53 | 112 | 31 | 63 | 0.3 | 0.4 | 0.8 | 1.7 | 5.1 | 7.1 | 6.7 | 5.7 | 3.4 | 2.2 | 0.8 | 0.5 | 34.7 |
| Port Darwin | 12 25S | 130 52E | 104 | 58 | 90 | 77 | 92 | 76 | 87 | 67 | 93 | 77 | 105 | 55 | 70 | 15.2 | 12.3 | 10.0 | 3.8 | 0.6 | 0.1 | * | 0.1 | 0.5 | 2.0 | 4.7 | 9.4 | 58.7 |
| Sydney | 33 52S | 151 02E | 62 | 87 | 78 | 65 | 71 | 58 | 60 | 46 | 71 | 56 | 114 | 35 | 87 | 3.5 | 4.0 | 5.0 | 5.3 | 5.0 | 4.6 | 4.6 | 3.0 | 2.9 | 2.8 | 2.9 | 2.9 | 46.5 |
| Thursday Island | 10 35S | 142 13E | 200 | 31 | 87 | 77 | 86 | 77 | 82 | 73 | 86 | 76 | 98 | 64 | 49 | 18.2 | 15.8 | 13.9 | 8.0 | 1.6 | 0.5 | 0.4 | 0.2 | 0.1 | 0.3 | 1.5 | 7.0 | 67.5 |
| Townsville | 19 15S | 146 46E | 18 | 31 | 87 | 76 | 84 | 70 | 75 | 59 | 83 | 71 | 110 | 39 | 67 | 10.9 | 11.2 | 7.2 | 3.3 | 1.3 | 1.4 | 0.6 | 0.5 | 0.7 | 1.3 | 1.9 | 5.4 | 45.7 |
| William Creek | 28 55S | 136 21E | 247 | 39 | 96 | 69 | 80 | 55 | 65 | 41 | 84 | 56 | 119 | 25 | 30 | 0.5 | 0.6 | 0.3 | 0.3 | 0.3 | 0.5 | 0.2 | 0.3 | 0.3 | 0.5 | 0.5 | 0.7 | 5.0 |
| Windorah | 25 26S | 142 36E | 390 | 29 | 101 | 74 | 86 | 59 | 70 | 43 | 91 | 61 | 116 | 26 | 50 | 1.4 | 1.6 | 1.6 | 0.9 | 0.8 | 0.8 | 0.5 | 0.4 | 0.5 | 0.6 | 0.9 | 1.4 | 11.4 |
| Tasmania | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hobart | 42 53S | 147 20E | 177 | 70 | 71 | 53 | 63 | 48 | 52 | 40 | 63 | 46 | 105 | 28 | 100 | 1.9 | 1.5 | 1.8 | 1.9 | 1.8 | 2.2 | 2.1 | 1.9 | 2.1 | 2.3 | 2.4 | 2.1 | 24.0 |
| New Zealand | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Auckland | 37 00S | 174 47E | 23 | 36 | 73 | 60 | 67 | 56 | 56 | 46 | 63 | 52 | 90 | 33 | 92 | 3.1 | 3.7 | 3.2 | 3.8 | 5.0 | 5.4 | 5.7 | 4.6 | 4.0 | 4.0 | 3.5 | 3.1 | 49.1 |
| Christchurch | 43 29S | 172 32E | 118 | 52 | 70 | 53 | 62 | 45 | 50 | 35 | 62 | 44 | 96 | 21 | 64 | 2.2 | 1.7 | 1.9 | 1.9 | 2.6 | 2.6 | 2.7 | 1.9 | 1.8 | 1.7 | 1.9 | 2.2 | 25.1 |
| Dunedin | 45 55S | 170 12E | 4 | 77 | 66 | 50 | 59 | 45 | 48 | 37 | 59 | 42 | 94 | 23 | 77 | 3.4 | 2.8 | 3.0 | 2.8 | 3.2 | 3.2 | 3.1 | 3.0 | 2.7 | 3.0 | 3.2 | 3.5 | 36.9 |
| Wellington | 41 17S | 174 46E | 415 | 66 | 69 | 56 | 63 | 51 | 53 | 42 | 60 | 48 | 88 | 29 | 79 | 3.2 | 3.2 | 3.2 | 3.8 | 4.6 | 4.6 | 5.4 | 4.6 | 3.8 | 4.0 | 3.5 | 3.5 | 47.4 |
| Pacific Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Canton, Phoenix Is | 02 46S | 171 43W | 9 | 12 | 88 | 78 | 89 | 78 | 89 | 78 | 90 | 78 | 98 | 70 | 30 | 2.6 | 2.2 | 2.5 | 3.6 | 4.3 | 2.6 | 2.6 | 2.5 | 1.2 | 1.1 | 1.6 | 2.6 | 29.4 |
| Guam, Marianas Is | 13 33N | 144 50E | 361 | 30 | 84 | 72 | 86 | 73 | 87 | 72 | 86 | 73 | 95 | 54 | 30 | 4.6 | 3.5 | 2.6 | 3.0 | 4.2 | 5.9 | 9.0 | 12.8 | 13.4 | 13.1 | 10.3 | 6.1 | 88.5 |
| Honolulu, Hawaii | 21 20N | 157 55W | 7 | 30 | 79 | 66 | 80 | 68 | 85 | 73 | 84 | 72 | 93 | 56 | 30 | 3.8 | 3.3 | 2.9 | 1.3 | 1.0 | 0.3 | 0.4 | 0.9 | 1.0 | 1.8 | 2.2 | 3.0 | 21.9 |
| Iwo Jima, Bonin Is | 24 47N | 141 19E | 353 | 15 | 71 | 64 | 77 | 69 | 86 | 78 | 84 | 76 | 95 | 46 | 17 | 3.2 | 2.5 | 2.1 | 3.7 | 4.9 | 4.0 | 6.4 | 6.5 | 4.6 | 5.9 | 4.8 | 4.3 | 52.8 |
| Madang, New Guinea | 05 12S | 145 47E | 19 | 12 | 87 | 75 | 88 | 74 | 88 | 74 | 88 | 75 | 98 | 62 | 20 | 12.1 | 11.9 | 14.9 | 16.9 | 15.1 | 10.8 | 7.6 | 4.8 | 5.3 | 10.0 | 13.3 | 14.5 | 137.2 |
| Midway Is | 28 13N | 177 23W | 29 | 21 | 69 | 62 | 71 | 64 | 81 | 74 | 79 | 72 | 92 | 46 | 20 | 4.6 | 3.7 | 3.1 | 2.5 | 1.9 | 1.3 | 2.9 | 3.9 | 3.7 | 3.7 | 3.6 | 4.2 | 40.7 |
| Naha, Okinawa | 26 12N | 127 39F | 96 | 30 | 67 | 56 | 76 | 64 | 89 | 77 | 81 | 69 | 96 | 41 | 30 | 5.3 | 5.4 | 6.1 | 6.1 | 8.9 | 10.0 | 7.1 | 10.0 | 7.1 | 6.6 | 5.9 | 4.3 | 82.8 |
| Noumea, New Caledonia | 22 16S | 166 27E | 246 | 24 | 86 | 72 | 83 | 70 | 76 | 62 | 80 | 65 | 99 | 52 | 52 | 3.7 | 5.1 | 5.7 | 5.2 | 4.4 | 3.7 | 3.6 | 2.6 | 2.5 | 2.0 | 2.4 | 2.6 | 43.5 |
| Pago Pago, Samoa | 14 19S | 170 43W | 29 | 2 | 87 | 75 | 87 | 76 | 83 | 74 | 85 | 75 | 98 | 67 | 41 | 24.5 | 20.5 | 19.2 | 16.5 | 15.4 | 12.3 | 10.0 | 8.2 | 13.1 | 14.9 | 19.2 | 19.8 | 193.6 |
| Ponape, Caroline Is | 06 58N | 158 13E | 123 | 30 | 86 | 75 | 86 | 75 | 87 | 73 | 87 | 72 | 96 | 67 | 30 | 11.1 | 9.7 | 14.6 | 20.0 | 20.3 | 16.7 | 16.2 | 16.3 | 15.8 | 16.0 | 16.9 | 18.3 | 191.9 |

*(Continued)*



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**Table 3B.13 (Continued)**

| Country and Station | Latitude | Longitude | Elevation | Temperature: Average Daily: Jan: Length of Record | Jan: Maximum | Jan: Minimum | Apr: Maximum | Apr: Minimum | July: Maximum | July: Minimum | Oct: Maximum | Oct: Minimum | Extreme: Maximum | Extreme: Minimum | Average Precipitation: Length of Record | January | February | March | April | May | June | July | August | September | October | November | December | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | Feet | Year | °F | °F | °F | °F | °F | °F | °F | °F | °F | °F | Year | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. | IN. |
| Port Moresby, New Guinea | 09 29S | 147 09E | 126 | 20 | 89 | 76 | 87 | 75 | 83 | 73 | 86 | 75 | 98 | 64 | 38 | 7.0 | 7.6 | 6.7 | 4.2 | 2.5 | 1.3 | 1.1 | 0.7 | 1.0 | 1.4 | 1.9 | 4.4 | 39.8 |
| Rabaul, New Guinea | 04 13S | 152 11E | 28 | 19 | 90 | 73 | 90 | 73 | 89 | 73 | 92 | 73 | 100 | 65 | 24 | 14.8 | 10.4 | 10.2 | 10.0 | 5.2 | 3.3 | 5.4 | 3.7 | 3.5 | 5.1 | 7.1 | 10.1 | 88.8 |
| Suva, Fiji Is | 18 08S | 178 26E | 20 | 43 | 86 | 74 | 84 | 73 | 79 | 68 | 81 | 70 | 98 | 55 | 43 | 11.4 | 10.7 | 14.5 | 12.2 | 10.1 | 6.7 | 4.9 | 8.3 | 7.7 | 8.3 | 9.8 | 12.5 | 117.1 |
| Tahiti, Society Is | 17 33S | 149 36W | 7 | 23 | 89 | 72 | 89 | 72 | 86 | 68 | 87 | 70 | 93 | 61 | 27 | 13.2 | 11.5 | 6.5 | 6.8 | 4.9 | 3.2 | 2.6 | 1.9 | 2.3 | 3.4 | 6.5 | 11.9 | 74.7 |
| Tulagi, Solomon Is | 09 05S | 160 10E | 8 | 20 | 88 | 76 | 88 | 76 | 86 | 76 | 87 | 76 | 96 | 68 | 37 | 14.3 | 15.8 | 15.0 | 10.8 | 8.1 | 6.8 | 7.6 | 8.7 | 8.0 | 8.7 | 10.0 | 10.4 | 123.4 |
| Wake Is | 19 17N | 166 39E | 11 | 30 | 82 | 73 | 83 | 74 | 87 | 77 | 86 | 77 | 92 | 64 | 30 | 1.1 | 1.4 | 1.5 | 1.9 | 2.0 | 1.9 | 4.6 | 7.1 | 5.2 | 5.3 | 3.1 | 1.8 | 36.9 |
| Yap, Caroline Is | 9 31N | 138 08E | 62 | 30 | 85 | 76 | 87 | 77 | 88 | 75 | 88 | 75 | 97 | 69 | 30 | 7.9 | 4.6 | 5.4 | 6.4 | 9.5 | 10.7 | 13.8 | 14.7 | 14.0 | 13.2 | 11.2 | 10.2 | 121.6 |
| **Antarctica** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Byrd Station | 80 01S | 119 32W | 5,095 | 6 | 10 | −2 | −11 | −30 | −25 | −45 | −15 | −33 | 31 | −82 | 6 | 0.4 | 0.4 | 0.2 | 0.3 | 0.4 | 0.5 | 0.7 | 0.7 | 0.3 | 0.7 | 0.0 | 0.3 | 4.9 |
| Elisworth | 77 44S | 41 07W | 139 | 6 | 22 | 12 | −10 | −25 | −21 | −35 | −2 | −15 | 36 | −70 | 6 | 0.3 | 0.2 | 0.3 | 0.6 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.2 | 3.6 |
| McMurdo Station | 77 53S | 166 48W | 8 | 10 | 30 | 21 | −1 | −13 | −9 | −24 | 2 | −12 | 42 | −59 | 10 | 0.5 | 0.7 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 0.3 | 0.4 | 0.2 | 0.2 | 0.3 | 4.3 |
| South Pole Station | 89 59S | 000 00W | 9,186 | 5 | −16 | −23 | −66 | −79 | −67 | −81 | −55 | −64 | 6 | −107 | 5 | * | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | * | 0.0 | * | 0.1 |
| Wilkes | 66 16S | 110 31E | 31 | 7 | 34 | 28 | 17 | 9 | 8 | −3 | 16 | 6 | 46 | −35 | 7 | 0.5 | 0.4 | 1.7 | 1.1 | 1.4 | 1.2 | 1.3 | 0.8 | 1.5 | 1.2 | 0.8 | 0.3 | 12.2 |

*Note:* 1. "Length of Record" refers to average daily maximum and minimum temperatures and precipitation. A standard period of the 30 years from 1931–1960 had been used for locations in the United States and some other countries. The length of record of extreme maximum and minimum temperatures includes all available years of data for a given location and is usually for a longer period. 2. * = Less than 0.05″. 3. Except for Antarctica, amounts of solid precipitation such as snow or hail have been converted to their water equivalent. Because of the frequent occurrence of blowing snow, it has not been possible to determine the precise amount of precipitation actually falling in Antarctica. The values shown are the average amounts of solid snow accumulating in a given period as determined by snow markers. The liquid content of the accumulation is undetermined.

*Source*: From Environmental Science Services Administration, *Climates of the World*, 1969. Geographic names revised by editors in accordance with 1987 usage.

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## SECTION 3C WEATHER EXTREMES

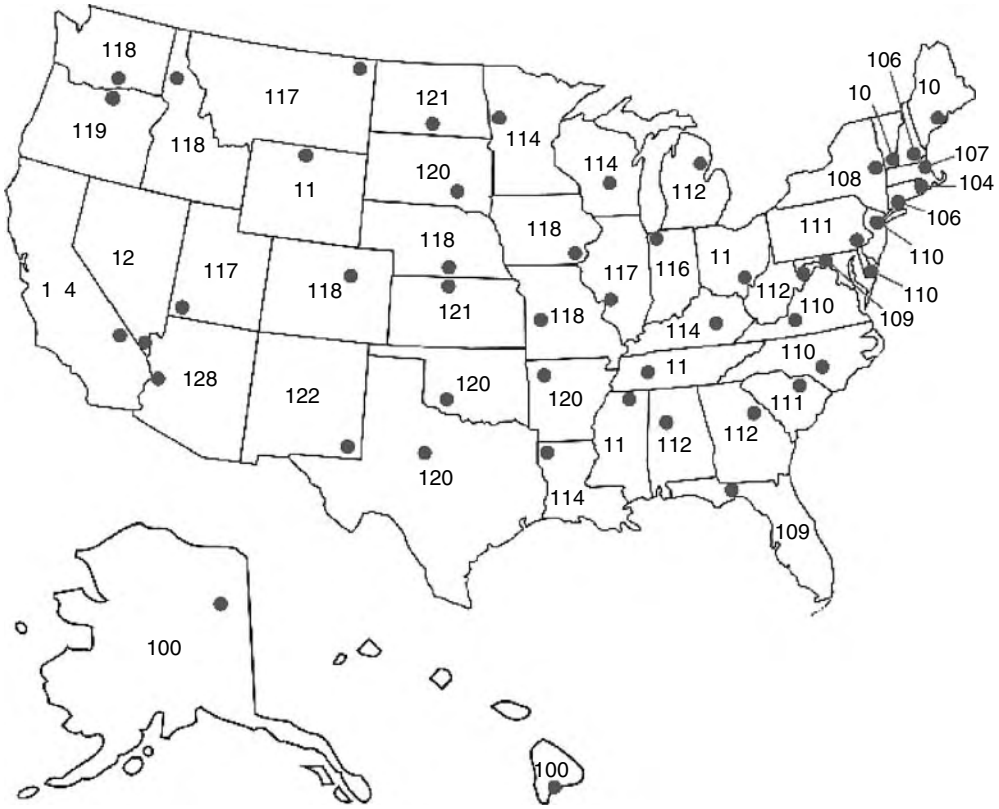


**Figure 3C.5** Record highest temperature (°F) (through 2000). (From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*. www.noaa.gov.)

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**Table 3C.14 Record Highest Temperatures by State**

| State | Temperature (°F) | Date | Station | Elevation (ft) |
|---|---|---|---|---|
| Alabama | 112 | Sep 5, 1925 | Centerville | 345 |
| Alaska | 100 | Jun 27, 1915 | Fort Yukon | est. 420 |
| Arizona | 128 | Jun 29, 1994 | Lake Havasu City | 505 |
| Arkansas | 120 | Aug 10, 1936 | Ozark | 396 |
| California | 134 | Jul 10, 1913 | Greenland Ranch | −178 |
| Colorado | 118 | Jul 11, 1888 | Bennett | 5,484 |
| Connecticut | 106 | Jul 15, 1995 | Danbury | 450 |
| Delaware | 110 | Jul 21, 1930 | Millsboro | 20 |
| Florida | 109 | Jun 29, 1931 | Monticello | 207 |
| Georgia | 112 | Aug 20, 1983 | Grenville | 860 |
| Hawaii | 100 | Apr 27, 1931 | Pahala | 850 |
| Idaho | 118 | Jul 28, 1934 | Orofino | 1,027 |
| Illinois | 117 | Jul 14, 1954 | East St. Louis | 410 |
| Indiana | 116 | Jul 14, 1936 | Collegeville | 672 |
| Iowa | 118 | Jul 20, 1934 | Keokuk | 614 |
| Kansas | 121 | Jul 24, 1936[a] | Alton (Near) | 1,651 |
| Kentucky | 114 | Jul 28, 1930 | Greensburg | 581 |
| Louisiana | 114 | Aug 10, 1936 | Plain Dealing | 268 |
| Maine | 105 | Jul 10, 1911 | North Bridgton | 450 |
| Maryland | 109 | Jul 10, 1936[a] | Cumberland & Frederick | 623; 325 |
| Massachusetts | 107 | Aug 2, 1975 | New Bedford & Chester | 120; 640 |
| Michigan | 112 | Jul 13, 1936 | Mio | 963 |
| Minnesota | 114 | Jul 6, 1936[a] | Moorhead | 904 |
| Mississippi | 115 | Jul 29, 1930 | Holly Springs | 600 |
| Missouri | 118 | Jul 14, 1954[a] | Warsaw & Union | 705; 560 |
| Montana | 117 | Jul 5, 1937 | Medicine Lake | 1,950 |
| Nebraska | 118 | Jul 24, 1936[a] | Minden | 2,169 |
| Nevada | 125 | Jun 29, 1994[a] | Laughlin | 605 |
| New Hampshire | 106 | Jul 4, 1911 | Nashua | 125 |
| New Jersey | 110 | Jul 10, 1936 | Runyon | 18 |
| New Mexico | 122 | Jun 27, 1994 | Waste Isolat. Pilot Plt | 3,418 |
| New York | 108 | Jul 22, 1926 | Troy | 35 |
| North Carolina | 110 | Aug 21, 1983 | Fayetteville | 213 |
| North Dakota | 121 | Jul 6, 1936 | Steele | 1,857 |
| Ohio | 113 | Jul 21, 1934[a] | Gallipolis (Near) | 673 |
| Oklahoma | 120 | Jun 27, 1994[a] | Tipton | 1,350 |
| Oregon | 119 | Aug 10, 1898[a] | Pendleton | 1,074 |
| Pennsylvania | 111 | Jul 10, 1936[a] | Phoenixville | 100 |
| Rhode Island | 104 | Aug 2, 1975 | Providence | 51 |
| South Carolina | 111 | Jun 28, 1954[a] | Camden | 170 |
| South Dakota | 120 | Jul 5, 1936 | Gannvalley | 1,750 |
| Tennessee | 113 | Aug 9, 1930[a] | Perryville | 377 |
| Texas | 120 | Jun 28, 1994[a] | Monahans | 2,660 |
| Utah | 117 | Jul 5, 1985 | Saint George | 2,880 |
| Vermont | 105 | Jul 4, 1911 | Vernon | 310 |
| Virginia | 110 | Jul 15, 1954 | Balcony Falls | 725 |
| Washington | 118 | Aug 5, 1961 | Ice Harbor Dam | 475 |
| West Virginia | 112 | Jul 10, 1936[a] | Martinsburg | 435 |
| Wisconsin | 114 | Jul 13, 1936 | Wisconsin Dells | 900 |
| Wyoming | 115 | Aug 8, 1983 | Basin | 3,500 |

[a] Also on earlier dates at the same or other places.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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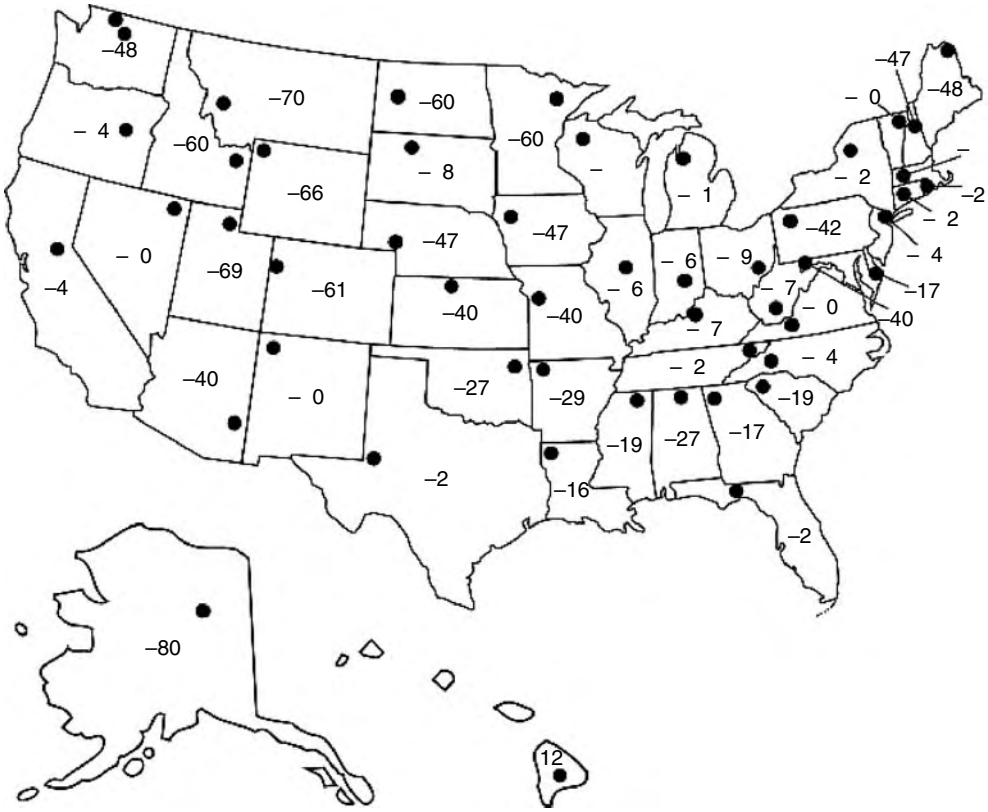


**Figure 3C.6** Record lowest temperature (°F) (through 2000). (From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*. www.noaa.gov.)

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**Table 3C.15 Record Lowest Temperatures by State**

| State | Temperature (°F) | Date | Station | Elevation (ft) |
|---|---|---|---|---|
| Alabama | −27 | Jan 30, 1966 | New Market | 760 |
| Alaska | −80 | Jan 23, 1971 | Prospect Creek Camp | 1,100 |
| Arizona | −40 | Jan 7, 1971 | Hawley Lake | 8,180 |
| Arkansas | −29 | Feb 13, 1905 | Pond | 1,250 |
| California | −45 | Jan 20, 1937 | Boca | 5,532 |
| Colorado | −61 | Feb 1, 1985 | Maybell | 5,920 |
| Connecticut | −32 | Jan 22, 1961[a] | Coventry | 480 |
| Delaware | −17 | Jan 17, 1893 | Millsboro | 20 |
| Florida | −2 | Feb 13, 1899 | Tallahassee | 193 |
| Georgia | −17 | Jan 27, 1940 | CCC Camp F-16 | est. 1,000 |
| Hawaii | 12 | May 17, 1979 | Mauna Kea Obs 111.2 | 13,770 |
| Idaho | −60 | Jan 18, 1943 | Island Park Dam | 6,285 |
| Illinois | −36 | Jan 5, 1999 | Congerville | 635 |
| Indiana | −36 | Jan 19, 1994 | New Whiteland | 785 |
| Iowa | −47 | Feb 3, 1996[a] | Elkader | 770 |
| Kansas | −40 | Feb 13, 1905 | Lebanon | 1,812 |
| Kentucky | −37 | Jan 19, 1994 | Shelbyville | 730 |
| Louisiana | −16 | Feb 13, 1899 | Minden | 194 |
| Maine | −48 | Jan 19, 1925 | Van Buren | 510 |
| Maryland | −40 | Jan 13, 1912 | Oakland | 2,461 |
| Massachusetts | −35 | Jan 12, 1981 | Chester | 640 |
| Michigan | −51 | Feb 9, 1934 | Vanderbilt | 785 |
| Minnesota | −60 | Feb 2, 1996 | Tower | 1,460 |
| Mississippi | −19 | Jan 30, 1966 | Corinth | 420 |
| Missouri | −40 | Feb 13, 1905 | Warsaw | 700 |
| Montana | −70 | Jan 20, 1954 | Rogers Pass | 5,470 |
| Nebraska | −47 | Dec 22, 1989[a] | Oshkosh | 3,379 |
| Nevada | −50 | Jan 8, 1937 | San Jacinto | 5,200 |
| New Hampshire | −47 | Jan 29, 1934 | Mt. Washington | 6,262 |
| New Jersey | −34 | Jan 5, 1904 | River Vale | 70 |
| New Mexico | −50 | Feb 1, 1951 | Gavilan | 7,350 |
| New York | −52 | Feb 18, 1979[a] | Old Forge | 1,720 |
| North Carolina | −34 | Jan 21, 1985 | Mt. Michell | 6,525 |
| North Dakota | −60 | Feb 15, 1936 | Parshall | 1,929 |
| Ohio | −39 | Feb 10, 1899 | Milligan | 800 |
| Oklahoma | −27 | Jan 18, 1930[a] | Watts | 958 |
| Oregon | −54 | Feb 10, 1933[a] | Seneco | 4,700 |
| Pennsylvania | −42 | Jan 5, 1904 | Smethport | est. 1,500 |
| Rhode Island | −25 | Feb 5, 1996 | Greene | 425 |
| South Carolina | −19 | Jan 21, 1985 | Caesars Head | 3,115 |
| South Dakota | −58 | Feb 17, 1936 | McIntosh | 2,277 |
| Tennessee | −32 | Dec 30, 1917 | Mountain City | 2,471 |
| Texas | −23 | Feb 8, 1933[a] | Seminole | 3,275 |
| Utah | −69 | Feb 1, 1985 | Peter's Sink | 8,092 |
| Vermont | −50 | Dec 30, 1933 | Bloomfield | 915 |
| Virginia | −30 | Jan 22, 1985 | Mtn. Lake Bio. Stn. | 3,870 |
| Washington | −48 | Dec 30, 1968 | Mazama & Winthrop | 2,120; 1,755 |
| West Virginia | −37 | Dec 30, 1917 | Lewisburg | 2,200 |
| Wisconsin | −55 | Feb 4, 1996 | Couderay | 1,300 |
| Wyoming | −66 | Feb 9, 1933 | Riverside R.S. | 6,500 |

[a] Also on earlier dates at the same or other places.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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**Table 3C.16 Temperature — Highest of Record — Selected Cities of the United States**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham CO | 11 | 74 | 80 | 87 | 91 | 95 | 99 | 106 | 102 | 99 | 89 | 82 | 76 | 106 |
| | Birmingham AP | 59 | 81 | 83 | 89 | 92 | 99 | 102 | 106 | 103 | 100 | 94 | 85 | 80 | 106 |
| | Huntsville | 35 | 77 | 83 | 85 | 90 | 96 | 101 | 104 | 103 | 101 | 90 | 84 | 79 | 104 |
| | Mobile | 61 | 84 | 82 | 90 | 94 | 100 | 102 | 104 | 105 | 99 | 93 | 87 | 81 | 105 |
| | Montgomery | 58 | 83 | 85 | 89 | 91 | 98 | 105 | 105 | 104 | 101 | 100 | 87 | 85 | 105 |
| AK | Anchorage | 49 | 50 | 48 | 51 | 65 | 77 | 85 | 82 | 82 | 73 | 61 | 54 | 48 | 85 |
| | Annette | 55 | 61 | 65 | 64 | 82 | 88 | 89 | 89 | 90 | 82 | 71 | 67 | 62 | 90 |
| | Barrow | 82 | 36 | 36 | 34 | 42 | 47 | 72 | 79 | 76 | 62 | 43 | 39 | 34 | 79 |
| | Barter IS | 39 | 39 | 37 | 36 | 43 | 52 | 68 | 78 | 72 | 66 | 46 | 37 | 37 | 78 |
| | Bethel | 44 | 48 | 46 | 46 | 60 | 80 | 86 | 83 | 84 | 72 | 58 | 51 | 45 | 86 |
| | Bettles | 52 | 48 | 40 | 49 | 63 | 86 | 92 | 93 | 88 | 79 | 53 | 45 | 38 | 93 |
| | Big Delta | 58 | 48 | 51 | 58 | 72 | 90 | 92 | 91 | 90 | 79 | 66 | 52 | 55 | 92 |
| | Cold Bay | 58 | 51 | 50 | 56 | 60 | 67 | 72 | 77 | 78 | 76 | 69 | 59 | 54 | 78 |
| | Fairbanks | 51 | 50 | 47 | 56 | 74 | 89 | 96 | 94 | 93 | 84 | 65 | 49 | 45 | 96 |
| | Gulkana | 55 | 46 | 46 | 50 | 67 | 85 | 90 | 91 | 86 | 74 | 65 | 48 | 49 | 91 |
| | Homer | 59 | 51 | 51 | 53 | 63 | 71 | 80 | 81 | 78 | 69 | 64 | 55 | 51 | 81 |
| | Juneau | 58 | 57 | 57 | 61 | 72 | 82 | 86 | 90 | 83 | 73 | 61 | 56 | 54 | 90 |
| | King Salmon | 60 | 53 | 57 | 56 | 65 | 80 | 88 | 86 | 84 | 74 | 67 | 56 | 49 | 88 |
| | Kodiak | 54 | 54 | 56 | 57 | 64 | 80 | 86 | 82 | 83 | 73 | 62 | 54 | 56 | 86 |
| | Kotzebue | 60 | 39 | 40 | 39 | 48 | 74 | 85 | 85 | 80 | 69 | 51 | 38 | 37 | 85 |
| | McGrath | 60 | 54 | 55 | 55 | 67 | 82 | 90 | 89 | 89 | 76 | 61 | 49 | 49 | 90 |
| | Nome | 56 | 43 | 48 | 43 | 51 | 78 | 81 | 86 | 81 | 71 | 59 | 47 | 43 | 86 |
| | St. Paul Island | 85 | 48 | 44 | 50 | 49 | 59 | 62 | 63 | 66 | 61 | 54 | 50 | 52 | 66 |
| | Talkeetna | 63 | 45 | 51 | 54 | 69 | 85 | 91 | 90 | 89 | 78 | 68 | 51 | 54 | 91 |
| | Unalakleet | 30 | 47 | 44 | 47 | 62 | 78 | 86 | 87 | 85 | 71 | 57 | 48 | 41 | 87 |
| | Valdez | 31 | 46 | 52 | 53 | 62 | 78 | 86 | 85 | 82 | 74 | 58 | 50 | 52 | 86 |
| | Yakutat | 56 | 55 | 54 | 59 | 71 | 79 | 87 | 84 | 86 | 77 | 63 | 55 | 52 | 87 |
| AZ | Flagstaff | 53 | 66 | 71 | 73 | 80 | 89 | 96 | 97 | 92 | 90 | 85 | 74 | 68 | 97 |
| | Phoenix | 65 | 88 | 92 | 100 | 105 | 113 | 122 | 121 | 116 | 118 | 107 | 95 | 88 | 122 |
| | Tucson | 62 | 87 | 92 | 99 | 104 | 108 | 117 | 114 | 112 | 107 | 102 | 93 | 84 | 117 |
| | Winslow | 71 | 75 | 78 | 85 | 92 | 101 | 106 | 109 | 103 | 99 | 93 | 80 | 74 | 109 |
| | Yuma | 45 | 88 | 97 | 100 | 107 | 116 | 122 | 124 | 120 | 116 | 112 | 98 | 86 | 124 |
| AR | Fort Smith | 57 | 81 | 86 | 94 | 95 | 98 | 105 | 111 | 110 | 109 | 96 | 86 | 82 | 111 |
| | Little Rock | 61 | 83 | 85 | 91 | 95 | 98 | 105 | 112 | 109 | 106 | 97 | 86 | 80 | 112 |
| | North Little Rock | 24 | 78 | 83 | 87 | 94 | 97 | 102 | 110 | 111 | 105 | 92 | 83 | 78 | 111 |
| CA | Bakersfield | 65 | 82 | 87 | 92 | 101 | 107 | 114 | 115 | 112 | 112 | 103 | 91 | 83 | 115 |
| | Bishop | 55 | 77 | 81 | 87 | 93 | 101 | 109 | 110 | 107 | 112 | 97 | 84 | 78 | 112 |
| | Blue Canyon | 55 | 71 | 73 | 72 | 82 | 88 | 92 | 95 | 97 | 93 | 88 | 78 | 75 | 97 |
| | Eureka | 92 | 78 | 85 | 78 | 80 | 84 | 85 | 76 | 82 | 86 | 87 | 78 | 77 | 87 |
| | Fresno | 53 | 78 | 80 | 90 | 100 | 107 | 110 | 112 | 112 | 111 | 102 | 89 | 76 | 112 |
| | Long Beach | 50 | 91 | 91 | 98 | 105 | 103 | 109 | 107 | 105 | 110 | 111 | 101 | 92 | 111 |
| | Los Angeles AP | 67 | 88 | 92 | 95 | 102 | 97 | 104 | 97 | 98 | 110 | 106 | 101 | 94 | 110 |
| | Los Angeles CO | 62 | 95 | 95 | 98 | 106 | 102 | 112 | 107 | 105 | 110 | 108 | 100 | 91 | 112 |
| | Mount Shasta | 42 | 65 | 71 | 80 | 86 | 94 | 98 | 100 | 105 | 103 | 93 | 80 | 72 | 105 |
| | Redding | 16 | 77 | 83 | 88 | 94 | 104 | 111 | 118 | 115 | 116 | 105 | 88 | 78 | 118 |
| | Sacramento | 52 | 70 | 76 | 88 | 95 | 105 | 115 | 114 | 110 | 108 | 104 | 87 | 72 | 115 |
| | San Diego | 62 | 88 | 90 | 93 | 98 | 96 | 101 | 95 | 98 | 111 | 107 | 97 | 88 | 111 |
| | San Francisco AP | 75 | 72 | 78 | 85 | 92 | 97 | 106 | 105 | 100 | 103 | 99 | 85 | 75 | 106 |
| | San Francisco CO | 65 | 79 | 81 | 83 | 94 | 101 | 103 | 103 | 98 | 101 | 102 | 86 | 76 | 103 |
| | Santa Barbara | 66 | 86 | 85 | 90 | 96 | 92 | 109 | 109 | 101 | 102 | 103 | 97 | 83 | 109 |
| | Santa Maria | 60 | 86 | 89 | 95 | 103 | 100 | 102 | 104 | 103 | 103 | 108 | 93 | 90 | 108 |
| | Stockton | 43 | 71 | 78 | 87 | 100 | 107 | 111 | 114 | 109 | 108 | 101 | 84 | 72 | 114 |
| CO | Alamosa | 57 | 62 | 66 | 73 | 80 | 90 | 95 | 96 | 91 | 87 | 81 | 71 | 61 | 96 |
| | Colorado Springs | 54 | 73 | 76 | 81 | 87 | 94 | 100 | 100 | 99 | 94 | 86 | 78 | 77 | 100 |
| | Denver | 61 | 73 | 76 | 84 | 90 | 96 | 104 | 104 | 101 | 97 | 89 | 79 | 75 | 104 |
| | Grand Junction | 56 | 60 | 68 | 81 | 89 | 101 | 105 | 105 | 103 | 100 | 88 | 75 | 64 | 105 |
| | Pueblo | 61 | 81 | 81 | 86 | 93 | 102 | 108 | 106 | 104 | 101 | 94 | 84 | 82 | 108 |
| CT | Bridgeport | 54 | 68 | 67 | 84 | 91 | 97 | 96 | 103 | 100 | 99 | 86 | 78 | 76 | 103 |
| | Hartford | 48 | 66 | 73 | 89 | 96 | 99 | 100 | 102 | 102 | 99 | 91 | 81 | 76 | 102 |
| DE | Wilmington | 55 | 75 | 78 | 86 | 94 | 96 | 100 | 102 | 101 | 100 | 91 | 85 | 75 | 102 |
| DC | Washington Dulles AP | 40 | 75 | 79 | 89 | 93 | 97 | 100 | 104 | 104 | 99 | 90 | 84 | 79 | 104 |
| | Washington Nat'l AP | 61 | 79 | 82 | 89 | 95 | 99 | 101 | 104 | 105 | 101 | 94 | 86 | 79 | 105 |
| FL | Apalachicola | 61 | 79 | 80 | 85 | 90 | 98 | 101 | 102 | 99 | 96 | 93 | 87 | 82 | 102 |
| | Daytona Beach | 59 | 87 | 89 | 92 | 96 | 100 | 102 | 102 | 100 | 99 | 95 | 89 | 88 | 102 |
| | Fort Myers | 59 | 88 | 92 | 93 | 96 | 99 | 103 | 101 | 100 | 96 | 95 | 95 | 90 | 103 |

*(Continued)*

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**Table 3C.16 (Continued)**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gainesville | 19 | 83 | 87 | 89 | 95 | 98 | 102 | 108 | 99 | 97 | 92 | 88 | 84 | 108 |
| | Jacksonville | 61 | 85 | 88 | 91 | 95 | 100 | 103 | 105 | 102 | 100 | 96 | 88 | 84 | 105 |
| | Key West | 50 | 86 | 85 | 88 | 90 | 91 | 94 | 95 | 95 | 94 | 93 | 89 | 86 | 95 |
| | Miami | 60 | 88 | 89 | 92 | 96 | 96 | 98 | 98 | 98 | 97 | 95 | 91 | 87 | 98 |
| | Orlando | 60 | 87 | 90 | 92 | 96 | 102 | 100 | 101 | 100 | 98 | 95 | 89 | 90 | 102 |
| | Pensacola | 39 | 80 | 82 | 86 | 96 | 98 | 101 | 106 | 104 | 98 | 92 | 85 | 81 | 106 |
| | Tallahassee | 42 | 82 | 86 | 90 | 95 | 100 | 103 | 103 | 103 | 99 | 94 | 88 | 84 | 103 |
| | Tampa | 56 | 86 | 88 | 91 | 93 | 98 | 99 | 97 | 98 | 96 | 94 | 90 | 86 | 99 |
| | Vero Beach | 19 | 88 | 89 | 91 | 94 | 99 | 99 | 99 | 98 | 97 | 94 | 92 | 87 | 99 |
| | West Palm Beach | 66 | 89 | 90 | 94 | 99 | 96 | 98 | 101 | 98 | 97 | 95 | 91 | 90 | 101 |
| GA | Athens | 59 | 80 | 81 | 88 | 93 | 97 | 104 | 104 | 107 | 99 | 98 | 86 | 79 | 107 |
| | Atlanta | 54 | 79 | 80 | 89 | 93 | 95 | 101 | 105 | 102 | 98 | 95 | 84 | 79 | 105 |
| | Augusta | 52 | 82 | 86 | 89 | 96 | 99 | 105 | 107 | 108 | 101 | 97 | 90 | 82 | 108 |
| | Columbus | 57 | 83 | 83 | 89 | 93 | 97 | 104 | 104 | 104 | 100 | 96 | 86 | 82 | 104 |
| | Macon | 54 | 84 | 85 | 95 | 96 | 99 | 106 | 108 | 105 | 102 | 100 | 88 | 82 | 108 |
| | Savannah | 52 | 84 | 86 | 91 | 95 | 100 | 104 | 105 | 104 | 98 | 97 | 89 | 83 | 105 |
| HI | Hilo | 56 | 92 | 92 | 93 | 89 | 94 | 90 | 89 | 93 | 92 | 91 | 92 | 93 | 94 |
| | Honolulu | 33 | 88 | 88 | 88 | 91 | 93 | 92 | 94 | 93 | 95 | 94 | 93 | 89 | 95 |
| | Kahului | 38 | 89 | 89 | 90 | 91 | 92 | 94 | 95 | 97 | 96 | 96 | 93 | 90 | 97 |
| | Lihue | 52 | 86 | 86 | 88 | 88 | 88 | 89 | 89 | 90 | 90 | 90 | 89 | 86 | 90 |
| ID | Boise | 63 | 63 | 71 | 81 | 92 | 98 | 109 | 111 | 110 | 102 | 94 | 78 | 65 | 111 |
| | Lewiston | 56 | 66 | 72 | 76 | 97 | 100 | 107 | 110 | 115 | 103 | 89 | 77 | 65 | 115 |
| | Pocatello | 53 | 57 | 65 | 75 | 86 | 93 | 103 | 104 | 104 | 98 | 91 | 75 | 64 | 104 |
| IL | Cairo | 45 | 75 | 77 | 85 | 91 | 98 | 104 | 104 | 103 | 103 | 92 | 82 | 79 | 104 |
| | Chicago | 44 | 65 | 72 | 88 | 91 | 93 | 104 | 104 | 101 | 99 | 91 | 78 | 71 | 104 |
| | Moline | 70 | 69 | 71 | 88 | 93 | 104 | 104 | 105 | 106 | 100 | 93 | 80 | 71 | 106 |
| | Peoria | 63 | 70 | 72 | 86 | 92 | 93 | 105 | 103 | 103 | 100 | 90 | 81 | 71 | 105 |
| | Rockford | 52 | 63 | 70 | 85 | 91 | 95 | 101 | 103 | 104 | 102 | 90 | 76 | 67 | 104 |
| | Springfield | 55 | 71 | 74 | 87 | 90 | 95 | 103 | 112 | 103 | 101 | 93 | 83 | 74 | 112 |
| IN | Evansville | 62 | 76 | 79 | 84 | 91 | 95 | 104 | 105 | 102 | 103 | 94 | 83 | 77 | 105 |
| | Fort Wayne | 56 | 69 | 73 | 82 | 88 | 94 | 106 | 103 | 101 | 100 | 90 | 79 | 71 | 106 |
| | Indianapolis | 63 | 71 | 76 | 85 | 89 | 93 | 102 | 104 | 102 | 100 | 90 | 81 | 74 | 104 |
| | South Bend | 63 | 68 | 74 | 85 | 91 | 95 | 104 | 102 | 103 | 99 | 92 | 82 | 70 | 104 |
| IA | Des Moines | 63 | 65 | 73 | 91 | 93 | 98 | 103 | 105 | 108 | 101 | 95 | 81 | 69 | 108 |
| | Dubuque | 50 | 60 | 66 | 85 | 93 | 91 | 100 | 101 | 100 | 97 | 90 | 75 | 67 | 101 |
| | Sioux City | 62 | 71 | 71 | 91 | 97 | 102 | 108 | 108 | 104 | 103 | 94 | 81 | 70 | 108 |
| | Waterloo | 54 | 65 | 66 | 87 | 100 | 94 | 103 | 105 | 105 | 98 | 95 | 80 | 67 | 105 |
| | Concordia | 41 | 74 | 86 | 88 | 98 | 102 | 109 | 109 | 108 | 109 | 96 | 84 | 82 | 109 |
| KS | Dodge City | 60 | 80 | 85 | 93 | 100 | 105 | 110 | 109 | 107 | 106 | 96 | 91 | 86 | 110 |
| | Goodland | 82 | 79 | 81 | 89 | 96 | 104 | 109 | 111 | 110 | 105 | 96 | 87 | 83 | 111 |
| | Topeka | 56 | 73 | 84 | 89 | 95 | 97 | 107 | 110 | 110 | 109 | 96 | 85 | 73 | 110 |
| | Wichita | 50 | 75 | 87 | 89 | 96 | 100 | 110 | 113 | 110 | 108 | 95 | 85 | 83 | 113 |
| KY | Greater Cincinnati AP | 41 | 69 | 75 | 84 | 89 | 93 | 102 | 103 | 102 | 98 | 88 | 81 | 75 | 103 |
| | Jackson | 22 | 78 | 79 | 87 | 92 | 90 | 99 | 101 | 101 | 95 | 86 | 81 | 79 | 101 |
| | Lexington | 58 | 76 | 80 | 83 | 88 | 92 | 101 | 103 | 103 | 103 | 91 | 83 | 75 | 103 |
| | Louisville | 55 | 77 | 77 | 86 | 91 | 95 | 102 | 106 | 101 | 104 | 92 | 84 | 76 | 106 |
| | Paducah | 19 | 70 | 77 | 84 | 90 | 94 | 103 | 102 | 104 | 100 | 89 | 83 | 74 | 104 |
| LA | Baton Rouge | 52 | 84 | 85 | 91 | 92 | 98 | 103 | 101 | 105 | 104 | 94 | 87 | 85 | 105 |
| | Lake Charles | 38 | 82 | 83 | 86 | 95 | 96 | 99 | 102 | 107 | 105 | 94 | 87 | 82 | 107 |
| | New Orleans | 56 | 83 | 85 | 89 | 92 | 96 | 100 | 101 | 102 | 101 | 94 | 87 | 84 | 102 |
| | Shreveport | 50 | 84 | 89 | 92 | 94 | 102 | 102 | 107 | 109 | 109 | 97 | 88 | 84 | 109 |
| ME | Caribou | 63 | 53 | 59 | 73 | 86 | 96 | 96 | 95 | 95 | 91 | 79 | 68 | 58 | 96 |
| | Portland | 62 | 64 | 64 | 88 | 85 | 94 | 98 | 99 | 103 | 95 | 88 | 74 | 71 | 103 |
| MD | Baltimore | 52 | 75 | 79 | 89 | 94 | 98 | 101 | 104 | 105 | 100 | 92 | 83 | 77 | 105 |
| | Milton | 117 | 68 | 68 | 89 | 94 | 93 | 99 | 100 | 101 | 99 | 88 | 81 | 74 | 101 |
| MA | Boston | 51 | 66 | 70 | 89 | 94 | 95 | 100 | 102 | 102 | 100 | 90 | 79 | 76 | 102 |
| | Worcester | 47 | 60 | 67 | 84 | 91 | 92 | 94 | 96 | 96 | 91 | 85 | 78 | 72 | 96 |
| MI | Alpena | 44 | 52 | 65 | 80 | 90 | 94 | 103 | 102 | 102 | 94 | 88 | 76 | 65 | 103 |
| | Detroit | 44 | 62 | 70 | 81 | 89 | 93 | 104 | 102 | 100 | 98 | 91 | 77 | 69 | 104 |
| | Flint | 46 | 61 | 68 | 80 | 87 | 93 | 101 | 101 | 98 | 94 | 89 | 76 | 70 | 101 |
| | Grand Rapids | 39 | 62 | 69 | 78 | 88 | 92 | 98 | 100 | 100 | 93 | 87 | 77 | 69 | 100 |
| | Houghton Lake | 38 | 54 | 59 | 76 | 86 | 90 | 103 | 98 | 96 | 92 | 85 | 70 | 64 | 103 |
| | Lansing | 44 | 66 | 69 | 79 | 86 | 94 | 99 | 100 | 100 | 97 | 89 | 77 | 69 | 100 |

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**Table 3C.16 (Continued)**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Marquette | 24 | 46 | 61 | 71 | 92 | 93 | 96 | 99 | 96 | 93 | 87 | 73 | 59 | 99 |
| | Muskegon | 63 | 63 | 67 | 80 | 86 | 93 | 98 | 96 | 99 | 95 | 83 | 76 | 64 | 99 |
| | Sault Ste. Marie | 62 | 45 | 49 | 75 | 85 | 89 | 93 | 97 | 98 | 95 | 80 | 67 | 62 | 98 |
| MN | Duluth | 61 | 52 | 55 | 78 | 88 | 90 | 94 | 97 | 97 | 95 | 86 | 71 | 55 | 97 |
| | International Falls | 63 | 48 | 58 | 76 | 93 | 95 | 99 | 98 | 95 | 95 | 88 | 73 | 57 | 99 |
| | Minneapolis-St.Paul | 64 | 58 | 61 | 83 | 95 | 96 | 102 | 105 | 102 | 98 | 90 | 77 | 68 | 105 |
| | Rochester | 43 | 55 | 63 | 79 | 91 | 92 | 101 | 102 | 99 | 95 | 93 | 75 | 62 | 102 |
| | Saint Cloud | 62 | 55 | 55 | 79 | 96 | 97 | 102 | 103 | 103 | 98 | 90 | 75 | 61 | 103 |
| MS | Jackson | 39 | 83 | 85 | 89 | 94 | 99 | 105 | 106 | 107 | 104 | 95 | 88 | 84 | 107 |
| | Meridian | 57 | 83 | 85 | 90 | 95 | 99 | 104 | 107 | 106 | 105 | 97 | 87 | 84 | 107 |
| | Tupelo | 19 | 77 | 84 | 85 | 93 | 94 | 101 | 105 | 106 | 103 | 92 | 86 | 79 | 106 |
| MO | Columbia | 33 | 74 | 82 | 85 | 90 | 92 | 103 | 111 | 110 | 101 | 93 | 83 | 76 | 111 |
| | Kansas City | 30 | 69 | 77 | 86 | 93 | 95 | 105 | 107 | 109 | 106 | 92 | 82 | 74 | 109 |
| | St. Louis | 45 | 76 | 85 | 89 | 93 | 94 | 102 | 107 | 107 | 104 | 94 | 85 | 76 | 107 |
| | Springfield | 57 | 76 | 81 | 87 | 93 | 93 | 101 | 113 | 106 | 104 | 93 | 81 | 77 | 113 |
| MT | Billings | 68 | 68 | 72 | 79 | 92 | 96 | 105 | 108 | 105 | 103 | 90 | 77 | 69 | 108 |
| | Glasgow | 47 | 61 | 71 | 79 | 91 | 102 | 108 | 104 | 108 | 103 | 90 | 79 | 59 | 108 |
| | Great Falls | 65 | 67 | 70 | 78 | 89 | 93 | 101 | 105 | 106 | 98 | 91 | 76 | 69 | 106 |
| | Havre | 3 | 62 | 64 | 77 | 91 | 96 | 99 | 103 | 109 | 96 | 82 | 78 | 61 | 109 |
| | Helena | 62 | 72 | 69 | 77 | 86 | 93 | 100 | 105 | 105 | 99 | 87 | 75 | 64 | 105 |
| | Kalispell | 53 | 53 | 64 | 72 | 84 | 94 | 96 | 104 | 105 | 99 | 86 | 69 | 57 | 105 |
| | Missoula | 58 | 59 | 66 | 75 | 87 | 95 | 98 | 105 | 105 | 99 | 85 | 73 | 60 | 105 |
| NE | Grand Island | 57 | 76 | 80 | 90 | 96 | 101 | 107 | 109 | 110 | 104 | 96 | 82 | 76 | 110 |
| | Lincoln | 31 | 73 | 84 | 89 | 97 | 99 | 107 | 108 | 107 | 106 | 93 | 85 | 70 | 108 |
| | Norfolk | 57 | 74 | 76 | 88 | 95 | 103 | 106 | 113 | 107 | 101 | 95 | 82 | 71 | 113 |
| | North Platte | 51 | 73 | 79 | 86 | 98 | 97 | 107 | 112 | 105 | 102 | 94 | 82 | 75 | 112 |
| | Omaha Eppley AP | 66 | 69 | 78 | 89 | 97 | 99 | 105 | 114 | 110 | 104 | 96 | 83 | 72 | 114 |
| | Omaha (North) | 39 | 66 | 76 | 88 | 96 | 100 | 104 | 107 | 106 | 103 | 93 | 79 | 66 | 107 |
| | Scottsbluff | 60 | 74 | 77 | 87 | 93 | 97 | 106 | 109 | 104 | 102 | 92 | 80 | 77 | 109 |
| | Valentine | 48 | 72 | 78 | 85 | 100 | 99 | 110 | 114 | 108 | 104 | 96 | 86 | 74 | 114 |
| NV | Elko | 72 | 64 | 70 | 77 | 86 | 92 | 104 | 107 | 107 | 99 | 88 | 78 | 65 | 107 |
| | Ely | 64 | 68 | 67 | 73 | 82 | 90 | 99 | 101 | 97 | 93 | 84 | 75 | 67 | 101 |
| | Las Vegas | 54 | 77 | 87 | 91 | 99 | 109 | 115 | 116 | 116 | 113 | 103 | 87 | 77 | 116 |
| | Reno | 61 | 70 | 75 | 83 | 89 | 96 | 103 | 108 | 105 | 101 | 91 | 77 | 70 | 108 |
| | Winnemucca | 53 | 68 | 74 | 81 | 90 | 97 | 106 | 109 | 108 | 103 | 91 | 77 | 67 | 109 |
| NH | Concord | 61 | 68 | 67 | 89 | 95 | 97 | 98 | 102 | 101 | 98 | 90 | 80 | 73 | 102 |
| | Mt. Washington | 70 | 47 | 43 | 54 | 60 | 66 | 71 | 71 | 72 | 69 | 59 | 52 | 47 | 72 |
| NJ | Atlantic City AP | 59 | 78 | 75 | 87 | 94 | 99 | 106 | 104 | 103 | 99 | 90 | 84 | 77 | 106 |
| | Atlantic City CO | 41 | 70 | 72 | 82 | 91 | 94 | 97 | 101 | 102 | 92 | 89 | 78 | 74 | 102 |
| | Newark | 61 | 74 | 76 | 89 | 97 | 99 | 102 | 105 | 105 | 105 | 92 | 85 | 76 | 105 |
| MN | Albuquerque | 63 | 69 | 76 | 85 | 89 | 98 | 107 | 105 | 101 | 100 | 91 | 77 | 72 | 107 |
| | Clayton | 55 | 80 | 81 | 86 | 91 | 99 | 104 | 102 | 102 | 99 | 93 | 85 | 83 | 104 |
| | Roswell | 30 | 82 | 85 | 93 | 99 | 107 | 114 | 111 | 107 | 103 | 99 | 88 | 81 | 114 |
| | Albany | 56 | 65 | 68 | 89 | 92 | 94 | 99 | 100 | 99 | 100 | 89 | 82 | 71 | 100 |
| NY | Binghamton | 51 | 63 | 66 | 82 | 88 | 89 | 94 | 98 | 95 | 96 | 82 | 77 | 65 | 98 |
| | Buffalo | 59 | 72 | 71 | 81 | 94 | 90 | 96 | 97 | 99 | 98 | 87 | 80 | 74 | 99 |
| | Islip | 19 | 69 | 67 | 82 | 94 | 98 | 96 | 102 | 100 | 92 | 86 | 78 | 77 | 102 |
| | New York C.Park | 134 | 72 | 75 | 86 | 96 | 99 | 101 | 106 | 104 | 102 | 94 | 84 | 75 | 106 |
| | New York (JFK AP) | 42 | 69 | 71 | 85 | 90 | 99 | 99 | 104 | 100 | 98 | 88 | 77 | 75 | 104 |
| | New York (Laguardia AP) | 41 | 68 | 73 | 83 | 94 | 97 | 99 | 107 | 104 | 96 | 87 | 80 | 75 | 107 |
| | Rochester | 62 | 74 | 73 | 84 | 93 | 94 | 100 | 98 | 99 | 99 | 91 | 81 | 72 | 100 |
| | Syracuse | 53 | 70 | 69 | 87 | 92 | 96 | 98 | 98 | 101 | 97 | 87 | 81 | 72 | 101 |
| NC | Asheville | 38 | 80 | 78 | 83 | 89 | 93 | 96 | 96 | 100 | 92 | 86 | 81 | 78 | 100 |
| | Cape Hatteras | 45 | 75 | 76 | 81 | 89 | 91 | 95 | 96 | 94 | 92 | 89 | 81 | 78 | 96 |
| | Charlotte | 63 | 79 | 81 | 90 | 93 | 100 | 103 | 103 | 103 | 104 | 98 | 85 | 78 | 104 |
| | Greensboro-Wnstn-Slm-HPT | 74 | 78 | 81 | 90 | 94 | 98 | 102 | 102 | 103 | 100 | 95 | 85 | 78 | 103 |
| | Raleigh | 58 | 80 | 84 | 92 | 95 | 97 | 104 | 105 | 105 | 104 | 98 | 88 | 80 | 105 |
| | Wilmington | 51 | 82 | 85 | 89 | 95 | 98 | 104 | 102 | 103 | 98 | 95 | 87 | 82 | 104 |
| ND | Bismarck | 63 | 63 | 69 | 81 | 93 | 98 | 111 | 109 | 109 | 105 | 95 | 79 | 65 | 111 |
| | Fargo | 50 | 52 | 66 | 78 | 100 | 98 | 100 | 106 | 106 | 102 | 93 | 74 | 57 | 106 |
| | Grand Forks | 5 | 47 | 67 | 64 | 87 | 88 | 96 | 93 | 95 | 96 | 77 | 73 | 50 | 96 |

*(Continued)*

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**Table 3C.16 (Continued)**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Williston | 41 | 53 | 66 | 78 | 92 | 106 | 106 | 109 | 107 | 104 | 93 | 76 | 58 | 109 |
| OH | Akron | 54 | 70 | 72 | 81 | 88 | 93 | 100 | 101 | 98 | 99 | 86 | 80 | 76 | 101 |
| | Cleveland | 61 | 73 | 74 | 83 | 88 | 92 | 104 | 103 | 102 | 101 | 90 | 82 | 77 | 104 |
| | Columbus | 63 | 74 | 75 | 85 | 89 | 94 | 102 | 100 | 101 | 100 | 90 | 80 | 76 | 102 |
| | Dayton | 59 | 71 | 73 | 82 | 89 | 93 | 102 | 102 | 102 | 101 | 89 | 79 | 72 | 102 |
| | Mansfield | 43 | 65 | 71 | 82 | 86 | 92 | 101 | 100 | 97 | 93 | 85 | 78 | 73 | 101 |
| | Toledo | 47 | 65 | 71 | 81 | 88 | 95 | 104 | 104 | 99 | 98 | 91 | 78 | 70 | 104 |
| | Youngstown | 59 | 71 | 73 | 82 | 88 | 92 | 99 | 100 | 97 | 99 | 87 | 80 | 76 | 100 |
| OK | Oklahoma City | 49 | 80 | 92 | 93 | 100 | 104 | 105 | 110 | 110 | 108 | 96 | 87 | 86 | 110 |
| | Tulsa | 64 | 79 | 90 | 96 | 102 | 96 | 103 | 112 | 110 | 109 | 98 | 87 | 80 | 112 |
| OR | Astoria | 49 | 67 | 72 | 73 | 83 | 87 | 93 | 100 | 96 | 95 | 85 | 71 | 64 | 100 |
| | Burns | 18 | 55 | 67 | 71 | 84 | 94 | 98 | 107 | 100 | 97 | 86 | 70 | 57 | 107 |
| | Eugene | 60 | 67 | 72 | 77 | 86 | 93 | 102 | 105 | 108 | 103 | 94 | 76 | 68 | 108 |
| | Medford | 73 | 71 | 79 | 86 | 93 | 103 | 111 | 115 | 114 | 110 | 99 | 77 | 72 | 115 |
| | Pendleton | 67 | 70 | 75 | 79 | 91 | 100 | 108 | 110 | 113 | 102 | 92 | 80 | 67 | 113 |
| | Portland | 62 | 63 | 71 | 80 | 90 | 100 | 100 | 107 | 107 | 105 | 92 | 73 | 65 | 107 |
| | Salem | 65 | 65 | 72 | 80 | 88 | 100 | 105 | 108 | 108 | 104 | 93 | 72 | 68 | 108 |
| | Sexton Summit | 65 | 66 | 67 | 74 | 82 | 91 | 95 | 100 | 97 | 97 | 87 | 77 | 66 | 100 |
| PC | Guam | 44 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 91 | 95 | 91 | 90 | 89 | 95 |
| | Johnston Island | 29 | 88 | 87 | 85 | 86 | 87 | 88 | 89 | 89 | 89 | 90 | 89 | 86 | 90 |
| | Koror | 53 | 93 | 93 | 94 | 94 | 94 | 95 | 93 | 94 | 92 | 93 | 93 | 94 | 95 |
| | Kwajalein, Marshall IS | 50 | 90 | 90 | 90 | 90 | 91 | 90 | 91 | 91 | 92 | 92 | 91 | 89 | 92 |
| | Majuro, Marshall IS | 47 | 89 | 89 | 90 | 89 | 90 | 90 | 90 | 91 | 90 | 91 | 91 | 90 | 91 |
| | Pago Pago, Amer Samoa | 43 | 95 | 96 | 95 | 95 | 93 | 91 | 91 | 92 | 92 | 94 | 95 | 94 | 96 |
| | Pohnpei, Caroline IS | 52 | 93 | 93 | 95 | 94 | 93 | 94 | 94 | 97 | 96 | 95 | 95 | 95 | 97 |
| | Chuuk, E. Caroline IS | 52 | 92 | 91 | 94 | 93 | 94 | 93 | 92 | 92 | 93 | 92 | 91 | 91 | 94 |
| | Wake Island | 50 | 89 | 88 | 90 | 91 | 92 | 93 | 94 | 95 | 95 | 92 | 90 | 91 | 95 |
| | Yap, W Caroline IS | 54 | 90 | 92 | 90 | 97 | 93 | 94 | 96 | 93 | 93 | 93 | 93 | 94 | 97 |
| PA | Allentown | 59 | 72 | 76 | 87 | 93 | 97 | 100 | 105 | 100 | 99 | 90 | 81 | 72 | 105 |
| | Erie | 49 | 68 | 75 | 82 | 89 | 90 | 100 | 99 | 94 | 94 | 88 | 80 | 75 | 100 |
| | Harrisburg | 49 | 73 | 75 | 86 | 93 | 97 | 100 | 107 | 101 | 102 | 97 | 84 | 75 | 107 |
| | Middletown/Harrisburg AP | 64 | 73 | 78 | 87 | 93 | 97 | 100 | 107 | 101 | 102 | 97 | 84 | 75 | 107 |
| | Philadelphia | 61 | 74 | 74 | 87 | 95 | 97 | 100 | 104 | 101 | 100 | 96 | 81 | 73 | 104 |
| | Pittsburgh | 50 | 72 | 76 | 82 | 89 | 91 | 98 | 103 | 100 | 97 | 87 | 82 | 74 | 103 |
| PA | Avoca | 47 | 67 | 71 | 85 | 92 | 93 | 97 | 101 | 98 | 95 | 84 | 80 | 69 | 101 |
| | Williamsport | 58 | 69 | 71 | 87 | 92 | 96 | 102 | 103 | 100 | 102 | 91 | 83 | 69 | 103 |
| RI | Block IS | 39 | 58 | 62 | 74 | 92 | 83 | 90 | 91 | 91 | 87 | 80 | 70 | 64 | 92 |
| | Providence | 49 | 69 | 72 | 85 | 98 | 95 | 97 | 102 | 104 | 100 | 86 | 78 | 77 | 104 |
| SC | Charleston AP | 60 | 83 | 87 | 90 | 95 | 98 | 103 | 104 | 105 | 99 | 94 | 88 | 83 | 105 |
| | Charleston CO | 17 | 80 | 82 | 88 | 94 | 96 | 104 | 103 | 103 | 98 | 93 | 84 | 81 | 104 |
| | Columbia | 55 | 84 | 84 | 91 | 94 | 101 | 107 | 107 | 107 | 101 | 101 | 90 | 83 | 107 |
| | Greenville-Spartanburg AP | 40 | 79 | 81 | 89 | 93 | 97 | 100 | 104 | 103 | 96 | 92 | 85 | 76 | 104 |
| SD | Aberdeen | 41 | 60 | 62 | 82 | 98 | 96 | 108 | 110 | 112 | 103 | 96 | 78 | 62 | 112 |
| | Huron | 61 | 63 | 71 | 89 | 97 | 99 | 109 | 112 | 110 | 106 | 102 | 86 | 66 | 112 |
| | Rapid City | 60 | 76 | 75 | 82 | 93 | 98 | 109 | 110 | 106 | 104 | 94 | 83 | 75 | 110 |
| | Sioux Falls | 57 | 66 | 70 | 87 | 94 | 100 | 110 | 108 | 108 | 104 | 94 | 81 | 63 | 110 |
| TN | Bristol-JhnCty-Kgsprt | 57 | 79 | 80 | 85 | 89 | 92 | 97 | 102 | 101 | 100 | 90 | 81 | 78 | 102 |
| | Chattanooga | 63 | 78 | 79 | 87 | 93 | 99 | 104 | 106 | 105 | 102 | 94 | 84 | 78 | 106 |
| | Knoxville | 61 | 77 | 83 | 86 | 92 | 94 | 102 | 103 | 102 | 103 | 91 | 84 | 80 | 103 |
| | Memphis | 61 | 79 | 81 | 85 | 94 | 99 | 104 | 108 | 107 | 103 | 95 | 86 | 81 | 108 |
| | Nashville | 63 | 78 | 84 | 86 | 91 | 97 | 106 | 107 | 104 | 105 | 94 | 84 | 79 | 107 |
| | Oak Ridge | 63 | 75 | 79 | 86 | 92 | 93 | 101 | 105 | 103 | 102 | 90 | 83 | 78 | 105 |
| TX | Abilene | 63 | 89 | 93 | 97 | 99 | 109 | 109 | 110 | 109 | 107 | 103 | 92 | 89 | 110 |
| | Amarillo | 62 | 81 | 88 | 94 | 98 | 103 | 108 | 105 | 106 | 103 | 99 | 87 | 81 | 108 |
| | Austin/City | 61 | 90 | 99 | 98 | 98 | 102 | 108 | 109 | 107 | 112 | 98 | 91 | 90 | 112 |
| | Austin/Bergstrom | 61 | 89 | 101 | 98 | 99 | 102 | 109 | 106 | 107 | 112 | 98 | 90 | 91 | 112 |
| | Brownsville | 64 | 93 | 94 | 106 | 102 | 102 | 102 | 102 | 102 | 105 | 96 | 97 | 94 | 106 |
| | Corpus Christi | 64 | 91 | 98 | 102 | 102 | 103 | 106 | 104 | 103 | 109 | 98 | 98 | 91 | 109 |

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**Table 3C.16 (Continued)**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dallas-Fort Worth | 49 | 88 | 95 | 96 | 95 | 103 | 113 | 110 | 108 | 111 | 102 | 89 | 88 | 113 |
| | Dallas-Love Field | 3 | 80 | 81 | 86 | 92 | 96 | 97 | 104 | 106 | 110 | 93 | 86 | 80 | 110 |
| | Del Rio | 40 | 90 | 99 | 101 | 106 | 109 | 112 | 108 | 109 | 110 | 106 | 96 | 90 | 112 |
| | El Paso | 63 | 80 | 83 | 89 | 98 | 104 | 114 | 112 | 108 | 104 | 96 | 87 | 80 | 114 |
| | Galveston | 63 | 78 | 83 | 85 | 92 | 94 | 99 | 101 | 100 | 96 | 94 | 85 | 80 | 101 |
| | Houston | 33 | 84 | 91 | 91 | 95 | 99 | 103 | 104 | 107 | 109 | 96 | 89 | 85 | 109 |
| | Lubbock | 56 | 83 | 87 | 95 | 100 | 109 | 114 | 108 | 106 | 103 | 100 | 88 | 81 | 114 |
| | Midland-Odessa | 55 | 84 | 90 | 95 | 101 | 108 | 116 | 112 | 107 | 107 | 101 | 90 | 85 | 116 |
| | Port Arthur | 49 | 82 | 85 | 87 | 94 | 97 | 100 | 103 | 108 | 105 | 95 | 88 | 84 | 108 |
| | San Angelo | 55 | 90 | 97 | 97 | 103 | 109 | 110 | 111 | 109 | 107 | 100 | 93 | 91 | 111 |
| | San Antonio | 61 | 89 | 100 | 100 | 101 | 103 | 107 | 106 | 108 | 111 | 99 | 94 | 90 | 111 |
| | Victoria | 42 | 88 | 95 | 97 | 98 | 101 | 106 | 104 | 107 | 111 | 99 | 93 | 88 | 111 |
| | Waco | 60 | 88 | 96 | 100 | 101 | 102 | 109 | 109 | 112 | 111 | 101 | 92 | 91 | 112 |
| | Wichita Falls | 56 | 87 | 93 | 100 | 102 | 110 | 117 | 114 | 113 | 111 | 102 | 89 | 88 | 117 |
| UT | Milford | 53 | 66 | 75 | 80 | 87 | 94 | 105 | 104 | 102 | 98 | 90 | 76 | 65 | 105 |
| | Salt Lake City | 74 | 62 | 69 | 78 | 86 | 96 | 104 | 107 | 106 | 100 | 89 | 75 | 69 | 107 |
| VT | Burlington | 59 | 66 | 62 | 84 | 91 | 93 | 100 | 100 | 101 | 98 | 85 | 75 | 67 | 101 |
| VA | Lynchburg | 58 | 80 | 79 | 87 | 94 | 93 | 100 | 103 | 102 | 101 | 93 | 83 | 79 | 103 |
| | Norfolk | 54 | 80 | 82 | 88 | 97 | 100 | 101 | 103 | 104 | 99 | 95 | 86 | 80 | 104 |
| | Richmond | 73 | 81 | 83 | 93 | 96 | 100 | 104 | 105 | 102 | 103 | 99 | 86 | 81 | 105 |
| | Roanoke | 55 | 79 | 80 | 87 | 95 | 96 | 100 | 104 | 105 | 101 | 93 | 83 | 80 | 105 |
| | Wallops Island | 28 | 79 | 79 | 86 | 93 | 97 | 96 | 101 | 100 | 96 | 90 | 82 | 77 | 101 |
| WA | Olympia | 61 | 63 | 73 | 76 | 87 | 96 | 101 | 103 | 104 | 98 | 90 | 74 | 64 | 104 |
| | Quillayute | 36 | 65 | 73 | 72 | 83 | 92 | 96 | 97 | 99 | 97 | 83 | 69 | 64 | 99 |
| | Seattle CO | 65 | 66 | 74 | 75 | 87 | 92 | 100 | 100 | 97 | 92 | 82 | 73 | 65 | 100 |
| | Seattle Sea-Tac AP | 58 | 64 | 70 | 75 | 85 | 93 | 96 | 100 | 99 | 98 | 89 | 74 | 64 | 100 |
| | Spokane | 55 | 59 | 63 | 71 | 90 | 96 | 101 | 103 | 108 | 98 | 86 | 67 | 56 | 108 |
| | Walla Walla | 55 | 67 | 75 | 77 | 87 | 99 | 107 | 112 | 109 | 99 | 87 | 81 | 65 | 112 |
| | Yakima | 56 | 68 | 69 | 80 | 92 | 102 | 105 | 108 | 110 | 100 | 88 | 73 | 67 | 110 |
| PR | San Juan | 48 | 92 | 96 | 96 | 97 | 96 | 97 | 95 | 97 | 97 | 98 | 96 | 94 | 98 |
| WV | Beckley | 39 | 73 | 74 | 81 | 86 | 89 | 90 | 94 | 96 | 92 | 81 | 78 | 73 | 96 |
| | Charleston | 55 | 79 | 79 | 89 | 94 | 93 | 98 | 104 | 101 | 102 | 92 | 85 | 80 | 104 |
| | Elkins | 58 | 76 | 75 | 84 | 89 | 93 | 93 | 99 | 95 | 97 | 86 | 80 | 76 | 99 |
| | Huntington | 42 | 78 | 79 | 86 | 92 | 93 | 100 | 102 | 100 | 97 | 87 | 82 | 80 | 102 |
| WI | Green Bay | 53 | 53 | 61 | 78 | 89 | 91 | 98 | 103 | 99 | 95 | 88 | 74 | 64 | 103 |
| WI | La Crosse | 50 | 57 | 64 | 84 | 93 | 94 | 102 | 108 | 105 | 100 | 93 | 75 | 67 | 108 |
| | Madison | 63 | 56 | 64 | 82 | 94 | 93 | 101 | 104 | 102 | 99 | 90 | 76 | 64 | 104 |
| | Milwaukee | 62 | 62 | 68 | 82 | 91 | 93 | 101 | 103 | 103 | 98 | 89 | 77 | 68 | 103 |
| WY | Casper | 52 | 60 | 68 | 74 | 84 | 92 | 102 | 104 | 102 | 97 | 87 | 72 | 63 | 104 |
| | Cheyenne | 67 | 66 | 71 | 74 | 83 | 91 | 100 | 100 | 96 | 95 | 83 | 75 | 69 | 100 |
| | Lander | 56 | 63 | 68 | 76 | 82 | 91 | 100 | 101 | 101 | 94 | 85 | 70 | 64 | 101 |
| | Sheridan | 62 | 70 | 76 | 77 | 87 | 95 | 105 | 107 | 106 | 103 | 92 | 81 | 72 | 107 |

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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**Table 3C.17 Temperature — Lowest of Record — Selected Cities of the United States**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham CO | 11 | −6 | 11 | 13 | 29 | 42 | 48 | 60 | 57 | 41 | 32 | 21 | −1 | −6 |
| | Birmingham AP | 59 | −6 | 3 | 2 | 26 | 35 | 42 | 51 | 51 | 37 | 27 | 5 | 1 | −6 |
| | Huntsville | 35 | −11 | 1 | 6 | 26 | 36 | 45 | 54 | 52 | 38 | 29 | 15 | −3 | −11 |
| | Mobile | 61 | 3 | 11 | 21 | 32 | 43 | 49 | 60 | 59 | 42 | 30 | 22 | 8 | 3 |
| | Montgomery | 58 | 0 | 10 | 17 | 28 | 40 | 49 | 59 | 56 | 39 | 26 | 13 | 5 | 0 |
| AK | Anchorage | 49 | −34 | −28 | −24 | −4 | 17 | 33 | 38 | 31 | 19 | −5 | −21 | −30 | −34 |
| | Annette | 55 | 1 | 2 | 1 | 21 | 31 | 37 | 40 | 40 | 33 | 18 | −3 | 1 | −3 |
| | Barrow | 82 | −53 | −56 | −52 | −42 | −19 | 4 | 22 | 20 | 1 | −32 | −40 | −55 | −56 |
| | Barter IS | 41 | −54 | −59 | −51 | −44 | −16 | 13 | 24 | 20 | 4 | −26 | −51 | −51 | −59 |
| | Bethel | 44 | −48 | −39 | −39 | −22 | 4 | 28 | 31 | 28 | 18 | −6 | −24 | −37 | −48 |
| | Bettles | 52 | −70 | −64 | −56 | −37 | −10 | 27 | 29 | 22 | 0 | −35 | −57 | −59 | −70 |
| | Big Delta | 58 | −63 | −60 | −49 | −37 | −1 | 30 | 32 | 22 | −2 | −39 | −47 | −62 | −63 |
| | Cold Bay | 59 | −13 | −9 | −13 | 4 | 18 | 29 | 33 | 32 | 26 | 6 | 1 | −1 | −13 |
| | Fairbanks | 51 | −61 | −58 | −49 | −24 | −1 | 31 | 35 | 27 | 3 | −27 | −46 | −62 | −62 |
| | Gulkana | 55 | −60 | −65 | −48 | −42 | 5 | 26 | 29 | 20 | 2 | −23 | −44 | −58 | −65 |
| | Homer | 59 | −24 | −19 | −21 | −9 | 6 | 29 | 34 | 31 | 20 | 2 | −7 | −16 | −24 |
| | Juneau | 58 | −22 | −22 | −15 | 6 | 25 | 31 | 36 | 27 | 23 | 11 | −5 | −21 | −22 |
| | King Salmon | 60 | −48 | −41 | −42 | −15 | 4 | 29 | 33 | 25 | 15 | −12 | −28 | −38 | −48 |
| | Kodiak | 54 | −16 | −12 | −6 | 7 | 20 | 30 | 37 | 34 | 26 | 10 | 0 | −2 | −16 |
| | Kotzebue | 60 | −49 | −52 | −48 | −44 | −18 | 20 | 30 | 29 | 13 | −19 | −36 | −47 | −52 |
| | McGrath | 60 | −75 | −64 | −51 | −40 | −2 | 30 | 33 | 25 | 2 | −28 | −53 | −67 | −75 |
| | Nome | 56 | −54 | −42 | −46 | −30 | −11 | 23 | 30 | 26 | 9 | −10 | −39 | −41 | −54 |
| | St. Paul Island | 85 | −26 | −16 | −19 | −8 | 8 | 16 | 28 | 29 | 22 | 12 | 4 | −5 | −26 |
| | Talkeetna | 63 | −48 | −46 | −43 | −37 | −5 | 28 | 33 | 25 | 11 | −21 | −41 | −45 | −48 |
| | Unalakleet | 30 | −48 | −50 | −50 | −30 | −6 | 25 | 32 | 28 | 6 | −20 | −47 | −50 | −50 |
| | Valdez | 31 | −20 | −10 | −6 | 5 | 21 | 31 | 33 | 32 | 25 | 8 | 1 | −6 | −20 |
| | Yakutat | 56 | −22 | −20 | −20 | 3 | 21 | 29 | 35 | 29 | 21 | 6 | −6 | −24 | −24 |
| AZ | Flagstaff | 53 | −22 | −23 | −16 | −2 | 14 | 22 | 32 | 24 | 23 | −2 | −13 | −23 | −23 |
| | Phoenix | 65 | 17 | 22 | 25 | 32 | 40 | 50 | 61 | 60 | 47 | 34 | 25 | 22 | 17 |
| | Tucson | 62 | 16 | 20 | 20 | 27 | 38 | 47 | 59 | 61 | 44 | 26 | 24 | 16 | 16 |
| | Winslow | 71 | −18 | −7 | −2 | 16 | 23 | 35 | 44 | 41 | 31 | 13 | −1 | −12 | −18 |
| | Yuma | 45 | 24 | 28 | 32 | 41 | 46 | 54 | 63 | 63 | 53 | 35 | 30 | 27 | 24 |
| AR | Fort Smith | 57 | −10 | −9 | 7 | 22 | 35 | 47 | 50 | 51 | 33 | 22 | 8 | −5 | −10 |
| | Little Rock | 61 | −4 | −5 | 11 | 28 | 40 | 46 | 54 | 52 | 37 | 29 | 17 | −1 | −5 |
| | North Little Rock | 24 | −6 | 4 | 14 | 30 | 40 | 52 | 60 | 53 | 41 | 27 | 19 | −2 | −6 |
| CA | Bakersfield | 65 | 20 | 25 | 31 | 33 | 37 | 45 | 52 | 52 | 45 | 29 | 28 | 19 | 19 |
| | Bishop | 55 | −7 | −2 | 9 | 15 | 25 | 29 | 34 | 37 | 26 | 16 | 5 | −8 | −8 |
| | Blue Canyon | 55 | 5 | 6 | 9 | 17 | 21 | 28 | 36 | 35 | 27 | 17 | 13 | 3 | 3 |
| | Eureka | 92 | 25 | 27 | 29 | 32 | 35 | 40 | 45 | 44 | 41 | 32 | 29 | 21 | 21 |
| | Fresno | 53 | 19 | 24 | 26 | 32 | 36 | 44 | 50 | 49 | 37 | 27 | 26 | 18 | 18 |
| | Long Beach | 50 | 25 | 33 | 33 | 38 | 40 | 47 | 51 | 52 | 50 | 39 | 34 | 28 | 25 |
| | Los Angeles AP | 67 | 23 | 32 | 34 | 39 | 43 | 48 | 49 | 51 | 47 | 41 | 34 | 32 | 23 |
| | Los Angeles CO | 62 | 28 | 34 | 26 | 39 | 5 | 49 | 54 | 53 | 51 | 41 | 38 | 30 | 5 |
| | Mount Shasta | 42 | −2 | 1 | 11 | 14 | 21 | 25 | 31 | 34 | 25 | 19 | 9 | −5 | −5 |
| | Redding | 16 | 19 | 21 | 28 | 28 | 34 | 42 | 53 | 51 | 40 | 33 | 23 | 17 | 17 |
| | Sacramento | 52 | 23 | 23 | 26 | 31 | 36 | 41 | 48 | 49 | 43 | 36 | 26 | 18 | 18 |
| | San Diego | 62 | 29 | 36 | 39 | 41 | 48 | 51 | 55 | 57 | 51 | 43 | 38 | 34 | 29 |
| | San Francisco AP | 75 | 24 | 25 | 30 | 31 | 36 | 41 | 43 | 42 | 38 | 34 | 25 | 20 | 20 |
| | San Francisco CO | 65 | 30 | 31 | 38 | 40 | 44 | 47 | 47 | 48 | 48 | 45 | 40 | 28 | 28 |
| | Santa Barbara | 66 | 26 | 25 | 34 | 36 | 38 | 42 | 49 | 47 | 45 | 36 | 30 | 20 | 20 |
| | Santa Maria | 60 | 20 | 22 | 24 | 31 | 31 | 36 | 43 | 43 | 36 | 26 | 25 | 20 | 20 |
| | Stockton | 43 | 19 | 22 | 27 | 32 | 38 | 45 | 49 | 50 | 43 | 33 | 25 | 17 | 17 |
| CO | Alamosa | 57 | −50 | −35 | −20 | −6 | 11 | 24 | 30 | 29 | 15 | −10 | −30 | −42 | −50 |
| | Colorado Springs | 54 | −26 | −27 | −11 | −3 | 21 | 32 | 42 | 39 | 22 | 5 | −8 | −24 | −27 |
| | Denver | 61 | −25 | −30 | −11 | −2 | 22 | 30 | 43 | 41 | 17 | 3 | −8 | −25 | −30 |
| | Grand Junction | 56 | −23 | −18 | 5 | 11 | 26 | 34 | 44 | 43 | 29 | 18 | −2 | −17 | −23 |
| | Pueblo | 61 | −29 | −31 | −20 | 2 | 25 | 36 | 44 | 40 | 21 | 4 | −17 | −25 | −31 |
| CT | Bridgeport | 54 | −7 | −5 | 4 | 18 | 31 | 41 | 49 | 44 | 36 | 26 | 16 | −4 | −7 |
| | Hartford | 48 | −26 | −21 | −6 | 9 | 28 | 35 | 44 | 36 | 30 | 17 | 1 | −14 | −26 |
| DE | Wilmington | 55 | −14 | −6 | 2 | 18 | 30 | 41 | 48 | 43 | 36 | 24 | 14 | −7 | −14 |
| DC | Washington Dulles AP | 40 | −18 | −14 | −1 | 17 | 28 | 36 | 41 | 38 | 30 | 15 | 9 | −4 | −18 |
| | Washington Nat'l AP | 61 | −5 | 4 | 11 | 24 | 34 | 47 | 54 | 49 | 39 | 29 | 16 | 1 | −5 |
| FL | Apalachicola | 61 | 9 | 21 | 22 | 36 | 47 | 48 | 63 | 62 | 50 | 37 | 24 | 13 | 9 |
| | Daytona Beach | 59 | 15 | 24 | 26 | 35 | 44 | 52 | 60 | 65 | 52 | 41 | 27 | 19 | 15 |
| | Fort Myers | 59 | 28 | 30 | 33 | 39 | 50 | 60 | 66 | 65 | 63 | 45 | 34 | 26 | 26 |
| | Gainesville | 19 | 10 | 18 | 26 | 34 | 42 | 50 | 62 | 61 | 52 | 33 | 25 | 16 | 10 |
| | Jacksonville | 61 | 7 | 19 | 23 | 34 | 45 | 47 | 61 | 59 | 48 | 36 | 21 | 11 | 7 |

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**Table 3C.17 (Continued)**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Key West | 50 | 41 | 45 | 47 | 48 | 64 | 68 | 69 | 68 | 69 | 60 | 49 | 44 | 41 |
| | Miami | 60 | 30 | 32 | 32 | 46 | 53 | 60 | 69 | 68 | 68 | 51 | 39 | 30 | 30 |
| | Orlando | 60 | 19 | 26 | 25 | 38 | 48 | 53 | 64 | 64 | 56 | 43 | 29 | 20 | 19 |
| | Pensacola | 39 | 5 | 15 | 22 | 33 | 48 | 56 | 61 | 62 | 43 | 32 | 25 | 11 | 5 |
| | Tallahassee | 42 | 6 | 14 | 20 | 29 | 34 | 46 | 57 | 57 | 40 | 30 | 13 | 10 | 6 |
| | Tampa | 56 | 21 | 24 | 29 | 40 | 49 | 53 | 63 | 67 | 57 | 40 | 23 | 18 | 18 |
| | Vero Beach | 19 | 21 | 28 | 32 | 42 | 47 | 57 | 67 | 64 | 64 | 46 | 38 | 23 | 21 |
| | West Palm Beach | 66 | 27 | 32 | 30 | 43 | 51 | 61 | 66 | 65 | 66 | 46 | 36 | 28 | 27 |
| GA | Athens | 59 | −4 | 5 | 11 | 26 | 37 | 45 | 55 | 54 | 36 | 24 | 7 | 2 | −4 |
| | Atlanta | 54 | −8 | 5 | 10 | 26 | 37 | 46 | 53 | 55 | 36 | 28 | 3 | 0 | −8 |
| | Augusta | 52 | −1 | 9 | 12 | 26 | 35 | 47 | 55 | 54 | 36 | 22 | 15 | 5 | −1 |
| | Columbus | 57 | −2 | 10 | 16 | 28 | 39 | 44 | 59 | 57 | 38 | 24 | 10 | 4 | −2 |
| | Macon | 54 | −6 | 9 | 14 | 29 | 40 | 46 | 54 | 55 | 35 | 26 | 10 | 5 | −6 |
| | Savannah | 52 | 3 | 14 | 20 | 32 | 39 | 51 | 61 | 57 | 43 | 28 | 15 | 9 | 3 |
| HI | Hilo | 56 | 54 | 53 | 54 | 56 | 58 | 60 | 62 | 63 | 61 | 62 | 58 | 55 | 53 |
| | Honolulu | 33 | 53 | 53 | 55 | 57 | 60 | 65 | 66 | 67 | 66 | 61 | 57 | 54 | 53 |
| | Kahului | 38 | 48 | 50 | 52 | 54 | 57 | 58 | 58 | 61 | 60 | 58 | 55 | 52 | 48 |
| | Lihue | 52 | 50 | 52 | 51 | 56 | 58 | 61 | 62 | 66 | 65 | 61 | 57 | 52 | 50 |
| ID | Boise | 63 | −17 | −15 | 6 | 19 | 22 | 31 | 35 | 34 | 23 | 11 | −3 | −25 | −25 |
| | Lewiston | 56 | −22 | −15 | 2 | 20 | 23 | 34 | 41 | 41 | 28 | 15 | −3 | −22 | −22 |
| | Pocatello | 53 | −30 | −33 | −12 | 13 | 20 | 28 | 34 | 30 | 19 | 10 | −14 | −29 | −33 |
| IL | Cairo | 45 | −12 | −5 | 6 | 28 | 38 | 51 | 54 | 50 | 40 | 27 | 5 | −4 | −12 |
| | Chicago | 44 | −27 | −19 | −8 | 7 | 24 | 36 | 40 | 41 | 28 | 17 | 1 | −25 | −27 |
| | Moline | 70 | −27 | −28 | −19 | 7 | 26 | 39 | 46 | 40 | 24 | 16 | −9 | −24 | −28 |
| | Peoria | 63 | −25 | −19 | −10 | 14 | 25 | 39 | 47 | 41 | 26 | 19 | −2 | −23 | −25 |
| | Rockford | 52 | −27 | −24 | −11 | 5 | 24 | 37 | 43 | 41 | 27 | 15 | −10 | −24 | −27 |
| | Springfield | 55 | −21 | −22 | −12 | 19 | 28 | 40 | 48 | 43 | 32 | 17 | −3 | −21 | −22 |
| IN | Evansville | 62 | −21 | −23 | −9 | 23 | 28 | 41 | 47 | 43 | 31 | 21 | −3 | −15 | −23 |
| | Fort Wayne | 56 | −22 | −18 | −10 | 7 | 27 | 38 | 44 | 38 | 29 | 19 | −1 | −18 | −22 |
| | Indianapolis | 63 | −27 | −21 | −7 | 16 | 28 | 37 | 44 | 41 | 28 | 17 | −2 | −23 | −27 |
| | South Bend | 63 | −22 | −17 | −13 | 11 | 24 | 35 | 42 | 40 | 29 | 20 | −7 | −16 | −22 |
| IA | Des Moines | 63 | −24 | −26 | −22 | 9 | 30 | 38 | 47 | 40 | 26 | 14 | −4 | −22 | −26 |
| | Dubuque | 50 | −28 | −27 | −20 | 11 | 24 | 36 | 44 | 40 | 28 | 13 | −17 | −25 | −28 |
| | Sioux City | 62 | −26 | −26 | −22 | −2 | 25 | 38 | 42 | 37 | 24 | 12 | −9 | −24 | −26 |
| | Waterloo | 54 | −33 | −31 | −34 | −4 | 25 | 38 | 42 | 38 | 22 | 11 | −17 | −29 | −34 |
| KS | Concordia | 41 | −17 | −15 | −7 | 14 | 26 | 41 | 48 | 45 | 29 | 14 | −4 | −26 | −26 |
| | Dodge City | 60 | −13 | −15 | −15 | 14 | 26 | 41 | 46 | 47 | 29 | 14 | 0 | −21 | −21 |
| | Goodland | 82 | −26 | −22 | −20 | 0 | 21 | 31 | 42 | 38 | 19 | 7 | −12 | −27 | −27 |
| | Topeka | 56 | −20 | −23 | −7 | 10 | 26 | 43 | 43 | 41 | 29 | 19 | 2 | −26 | −26 |
| | Wichita | 50 | −12 | −21 | −2 | 15 | 31 | 43 | 51 | 48 | 31 | 18 | 1 | −16 | −21 |
| KY | Greater Cincinnati AP | 41 | −25 | −11 | −11 | 15 | 27 | 39 | 47 | 43 | 31 | 16 | 1 | −20 | −25 |
| | Jackson | 22 | −18 | −8 | 7 | 20 | 32 | 44 | 52 | 45 | 34 | 26 | 13 | −13 | −18 |
| | Lexington | 58 | −21 | −15 | −2 | 18 | 26 | 39 | 47 | 42 | 34 | 20 | −3 | −19 | −21 |
| | Louisville | 55 | −22 | −19 | −1 | 22 | 31 | 42 | 50 | 46 | 33 | 23 | −1 | −15 | −22 |
| | Paducah | 19 | −15 | −8 | 11 | 24 | 35 | 44 | 53 | 44 | 35 | 24 | 10 | −10 | −15 |
| LA | Baton Rouge | 52 | 9 | 15 | 20 | 32 | 44 | 53 | 58 | 59 | 43 | 30 | 21 | 8 | 8 |
| | Lake Charles | 38 | 15 | 17 | 23 | 34 | 49 | 56 | 61 | 59 | 47 | 30 | 23 | 11 | 11 |
| | New Orleans | 56 | 14 | 16 | 25 | 32 | 41 | 50 | 60 | 60 | 42 | 35 | 24 | 11 | 11 |
| | Shreveport | 50 | 3 | 12 | 17 | 31 | 42 | 52 | 58 | 53 | 42 | 28 | 16 | 5 | 3 |
| ME | Caribou | 63 | −33 | −41 | −28 | −2 | 18 | 30 | 36 | 34 | 23 | 14 | −8 | −31 | −41 |
| | Portland | 62 | −26 | −39 | −21 | 8 | 23 | 33 | 40 | 33 | 23 | 15 | 3 | −21 | −39 |
| | Baltimore | 52 | −7 | −3 | 6 | 20 | 32 | 40 | 50 | 45 | 35 | 25 | 13 | 0 | −7 |
| MA | Blue Hill | 117 | −16 | −21 | −5 | 6 | 27 | 36 | 44 | 39 | 28 | 21 | 5 | −19 | −21 |
| | Boston | 51 | −12 | −4 | 6 | 16 | 34 | 45 | 50 | 47 | 38 | 28 | 15 | −7 | −12 |
| | Worcester | 47 | −19 | −12 | −4 | 11 | 28 | 36 | 43 | 38 | 30 | 20 | 6 | −13 | −19 |
| MI | Alpena | 44 | −28 | −37 | −27 | 0 | 20 | 28 | 34 | 30 | 25 | 16 | −6 | −18 | −37 |
| | Detroit | 44 | −21 | −15 | −4 | 10 | 25 | 36 | 41 | 38 | 29 | 17 | 9 | −10 | −21 |
| | Flint | 46 | −25 | −22 | −12 | 6 | 22 | 33 | 40 | 37 | 26 | 19 | 6 | −13 | −25 |
| | Grand Rapids | 39 | −22 | −19 | −8 | 3 | 22 | 33 | 41 | 39 | 27 | 18 | 5 | −18 | −22 |
| | Houghton Lake | 38 | −26 | −34 | −23 | 3 | 21 | 29 | 33 | 29 | 21 | 16 | −5 | −21 | −34 |
| | Lansing | 44 | −29 | −25 | −15 | −2 | 19 | 30 | 37 | 35 | 22 | 15 | 4 | −18 | −29 |
| | Marquette | 24 | −27 | −34 | −23 | −5 | 17 | 28 | 36 | 34 | 24 | 14 | −5 | −28 | −34 |
| | Muskegon | 63 | −13 | −19 | −10 | 1 | 22 | 31 | 39 | 36 | 27 | 21 | −14 | −15 | −19 |
| | Sault Ste. Marie | 62 | −36 | −35 | −24 | −2 | 18 | 26 | 36 | 29 | 25 | 16 | −10 | −31 | −36 |
| MN | Duluth | 61 | −39 | −39 | −29 | −5 | 17 | 27 | 35 | 32 | 22 | 8 | −23 | −34 | −39 |
| | International Falls | 63 | −46 | −45 | −38 | −14 | 11 | 23 | 34 | 30 | 20 | 2 | −32 | −41 | −46 |
| | Minneapolis-St.Paul | 64 | −34 | −32 | −32 | 2 | 18 | 34 | 43 | 39 | 26 | 13 | −17 | −29 | −34 |

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**Table 3C.17 (Continued)**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rochester | 43 | −32 | −35 | −31 | 5 | 21 | 35 | 42 | 37 | 23 | 11 | −20 | −33 | −35 |
| | Saint Cloud | 62 | −43 | −40 | −32 | −3 | 19 | 32 | 40 | 33 | 18 | 5 | −20 | −41 | −43 |
| MS | Jackson | 39 | 2 | 10 | 15 | 27 | 38 | 47 | 51 | 55 | 35 | 26 | 17 | 4 | 2 |
| | Meridian | 57 | 0 | 8 | 15 | 28 | 38 | 42 | 55 | 53 | 34 | 24 | 16 | 2 | 0 |
| | Tupelo | 19 | −6 | 4 | 16 | 29 | 40 | 49 | 58 | 52 | 40 | 29 | 19 | −3 | −6 |
| MO | Columbia | 33 | −19 | −15 | −5 | 19 | 29 | 40 | 48 | 42 | 32 | 22 | 0 | −20 | −20 |
| | Kansas City | 30 | −17 | −19 | −10 | 12 | 30 | 42 | 51 | 43 | 31 | 17 | 1 | −23 | −23 |
| | St. Louis | 45 | −18 | −12 | −5 | 22 | 31 | 43 | 51 | 47 | 36 | 23 | 1 | −16 | −18 |
| | Springfield | 57 | −13 | −17 | −3 | 18 | 30 | 42 | 44 | 44 | 31 | 18 | 4 | −16 | −17 |
| MT | Billings | 68 | −30 | −38 | −19 | −5 | 14 | 32 | 41 | 35 | 22 | −7 | −22 | −32 | −38 |
| | Glasgow | 47 | −47 | −38 | −27 | −3 | 20 | 32 | 41 | 37 | 15 | −6 | −26 | −38 | −47 |
| | Great Falls | 65 | −37 | −35 | −29 | −6 | 15 | 31 | 36 | 30 | 16 | −11 | −25 | −43 | −43 |
| | Havre | 3 | −23 | −23 | −27 | 4 | 17 | 38 | 39 | 34 | 21 | 4 | −6 | −30 | −30 |
| | Helena | 62 | −42 | −42 | −30 | 1 | 17 | 30 | 36 | 28 | 18 | −8 | −39 | −38 | −42 |
| | Kalispell | 53 | −38 | −36 | −29 | 10 | 19 | 26 | 30 | 30 | 16 | −3 | −28 | −35 | −38 |
| | Missoula | 58 | −33 | −27 | −13 | 14 | 21 | 30 | 31 | 30 | 20 | 0 | −23 | −30 | −33 |
| NE | Grand Island | 57 | −28 | −19 | −21 | 7 | 23 | 38 | 42 | 40 | 23 | 9 | −11 | −26 | −28 |
| | Lincoln | 31 | −33 | −24 | −19 | 3 | 24 | 39 | 42 | 41 | 26 | 8 | −5 | −27 | −33 |
| | Norfolk | 57 | −27 | −26 | −20 | 2 | 24 | 38 | 42 | 40 | 26 | 11 | −15 | −30 | −30 |
| | North Platte | 51 | −23 | −22 | −22 | 7 | 19 | 29 | 39 | 35 | 17 | 10 | −13 | −34 | −34 |
| | Omaha Eppley AP | 66 | −23 | −21 | −16 | 5 | 27 | 38 | 44 | 43 | 25 | 13 | −9 | −23 | −23 |
| | Omaha (North) | 39 | −22 | −20 | −16 | 7 | 25 | 41 | 44 | 44 | 28 | 15 | −11 | −25 | −25 |
| | Scottsbluff | 60 | −32 | −28 | −27 | −8 | 15 | 30 | 40 | 39 | 19 | −6 | −13 | −42 | −42 |
| | Valentine | 48 | −30 | −31 | −29 | 3 | 19 | 30 | 38 | 34 | 17 | −1 | −22 | −39 | −39 |
| NV | Elko | 72 | −43 | −37 | −9 | −2 | 10 | 23 | 30 | 20 | 9 | 1 | −12 | −38 | −43 |
| | Ely | 64 | −27 | −30 | −13 | −5 | 7 | 18 | 28 | 24 | 15 | −3 | −15 | −29 | −30 |
| | Las Vegas | 54 | 8 | 16 | 23 | 31 | 40 | 48 | 60 | 56 | 46 | 26 | 21 | 11 | 8 |
| | Reno | 61 | −16 | −16 | −2 | 13 | 18 | 25 | 33 | 24 | 20 | 8 | 1 | −16 | −16 |
| | Winnemucca | 53 | −24 | −28 | −3 | 6 | 10 | 23 | 29 | 28 | 12 | −2 | −8 | −37 | −37 |
| NH | Concord | 61 | −33 | −37 | −16 | 8 | 21 | 30 | 35 | 29 | 21 | 10 | −5 | −22 | −37 |
| | Mt. Washington | 70 | −47 | −46 | −38 | −20 | −2 | 8 | 24 | 20 | 9 | −5 | −20 | −46 | −47 |
| NJ | Atlantic City AP | 59 | −10 | −11 | 5 | 12 | 25 | 37 | 42 | 40 | 32 | 20 | 10 | −7 | −11 |
| | Atlantic City CO | 41 | −3 | 1 | 2 | 22 | 36 | 45 | 53 | 50 | 42 | 27 | 8 | 4 | −3 |
| | Newark | 61 | −8 | −7 | 6 | 16 | 33 | 43 | 52 | 45 | 35 | 28 | 15 | −1 | −8 |
| NM | Albuquerque | 63 | −17 | −5 | 8 | 19 | 16 | 40 | 52 | 50 | 37 | 21 | −7 | −7 | −17 |
| | Clayton | 55 | −21 | −17 | −11 | 9 | 23 | 37 | 45 | 45 | 26 | 12 | −10 | −14 | −21 |
| | Roswell | 30 | −9 | 3 | 9 | 23 | 34 | 47 | 59 | 54 | 40 | 14 | 4 | −8 | −9 |
| NY | Albany | 56 | −28 | −21 | −21 | 10 | 26 | 36 | 40 | 34 | 24 | 16 | 5 | −22 | −28 |
| | Binghamton | 51 | −20 | −15 | −7 | 9 | 25 | 33 | 39 | 37 | 25 | 17 | 3 | −18 | −20 |
| | Buffalo | 59 | −16 | −20 | −7 | 12 | 26 | 35 | 43 | 38 | 32 | 20 | 9 | −10 | −20 |
| | Islip | 19 | −7 | 1 | 8 | 24 | 34 | 43 | 50 | 45 | 38 | 28 | 11 | 7 | −7 |
| | New York C.Park | 134 | −6 | −15 | 3 | 12 | 32 | 44 | 52 | 50 | 39 | 28 | 5 | −13 | −15 |
| | New York (JFK AP) | 42 | −2 | −2 | 7 | 20 | 34 | 45 | 55 | 46 | 40 | 25 | 19 | 2 | −2 |
| | New York (Laguardia AP) | 41 | −3 | −2 | 8 | 22 | 38 | 46 | 56 | 51 | 44 | 30 | 18 | −1 | −3 |
| | Rochester | 62 | −17 | −19 | −7 | 13 | 26 | 35 | 42 | 36 | 28 | 20 | 5 | −16 | −19 |
| | Syracuse | 53 | −26 | −26 | −16 | 9 | 25 | 35 | 45 | 40 | 28 | 19 | 5 | −22 | −26 |
| NC | Asheville | 38 | −16 | −2 | 2 | 22 | 28 | 35 | 44 | 42 | 30 | 21 | 8 | −7 | −16 |
| | Cape hatteras | 45 | 6 | 14 | 19 | 26 | 39 | 44 | 54 | 56 | 45 | 32 | 22 | 12 | 6 |
| | Charlotte | 63 | −5 | 5 | 4 | 24 | 32 | 45 | 53 | 53 | 39 | 24 | 11 | 2 | −5 |
| | Greensboro-Wnstn-Slm-HPT | 74 | −8 | −4 | 5 | 21 | 32 | 42 | 48 | 45 | 35 | 20 | 10 | 0 | −8 |
| | Raleigh | 58 | −9 | 0 | 11 | 23 | 31 | 38 | 48 | 46 | 37 | 19 | 11 | 4 | −9 |
| | Wilmington | 51 | 5 | 11 | 9 | 30 | 38 | 48 | 55 | 55 | 44 | 27 | 20 | 0 | 0 |
| ND | Bismarck | 63 | −44 | −43 | −31 | −12 | 15 | 30 | 35 | 33 | 11 | −10 | −30 | −43 | −44 |
| | Fargo | 50 | −35 | −39 | −23 | −7 | 20 | 30 | 36 | 33 | 19 | 7 | −24 | −32 | −39 |
| | Grand Forks | 5 | −29 | −22 | −14 | 6 | 22 | 33 | 37 | 40 | 28 | 12 | −9 | −24 | −29 |
| | Williston | 41 | −40 | −41 | −28 | −15 | 17 | 26 | 34 | 34 | 17 | −9 | −27 | −50 | −50 |
| OH | Akron | 54 | −25 | −13 | −3 | 10 | 24 | 32 | 43 | 41 | 32 | 20 | −1 | −16 | −25 |
| | Cleveland | 61 | −20 | −15 | −5 | 10 | 25 | 31 | 41 | 38 | 32 | 19 | 3 | −15 | −20 |
| | Columbus | 63 | −22 | −13 | −6 | 14 | 25 | 35 | 43 | 39 | 31 | 20 | 5 | −17 | −22 |
| | Dayton | 59 | −25 | −16 | −7 | 15 | 27 | 40 | 44 | 39 | 32 | 21 | −2 | −20 | −25 |
| | Mansfield | 43 | −22 | −11 | −6 | 8 | 25 | 37 | 43 | 40 | 33 | 20 | 2 | −17 | −22 |
| | Toledo | 47 | −20 | −14 | −6 | 8 | 25 | 32 | 40 | 34 | 26 | 15 | 2 | −19 | −20 |
| | Youngstown | 59 | −22 | −14 | −10 | 11 | 24 | 30 | 40 | 32 | 29 | 20 | 1 | −12 | −22 |
| OK | Oklahoma City | 49 | −4 | −3 | 3 | 20 | 37 | 47 | 53 | 51 | 36 | 16 | 11 | −8 | −8 |
| | Tulsa | 64 | −8 | −11 | −3 | 22 | 35 | 49 | 51 | 52 | 35 | 18 | 10 | −8 | −11 |

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**Table 3C.17 (Continued)**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OR | Astoria | 49 | 11 | 9 | 22 | 29 | 30 | 37 | 39 | 39 | 33 | 26 | 15 | 6 | 6 |
| | Burns | 18 | −27 | −28 | −14 | 10 | 15 | 21 | 25 | 22 | 17 | −7 | −13 | −20 | −28 |
| | Eugene | 60 | −4 | −3 | 20 | 27 | 28 | 32 | 39 | 38 | 31 | 17 | 12 | −12 | −12 |
| | Medford | 73 | −3 | 6 | 16 | 21 | 28 | 31 | 38 | 39 | 29 | 18 | 10 | −6 | −6 |
| | Pendleton | 67 | −22 | −18 | 1 | 18 | 25 | 35 | 42 | 40 | 30 | 11 | −12 | −19 | −22 |
| | Portland | 62 | −2 | −3 | 19 | 29 | 29 | 39 | 43 | 44 | 34 | 26 | 13 | 6 | −3 |
| | Salem | 65 | −10 | −4 | 12 | 23 | 25 | 32 | 37 | 36 | 26 | 20 | 9 | −12 | −12 |
| | Sexton Summit | 65 | −2 | 9 | 15 | 19 | 22 | 27 | 36 | 36 | 26 | 20 | 11 | 2 | −2 |
| PC | Guam | 44 | 56 | 59 | 54 | 59 | 62 | 63 | 64 | 63 | 61 | 64 | 62 | 61 | 54 |
| | Johnston Island | 29 | 65 | 64 | 67 | 65 | 68 | 69 | 70 | 70 | 71 | 66 | 63 | 62 | 62 |
| | Koror | 53 | 69 | 71 | 69 | 69 | 71 | 70 | 70 | 70 | 70 | 71 | 70 | 71 | 69 |
| | Kwajalein, Marshall IS | 50 | 68 | 71 | 70 | 71 | 71 | 71 | 70 | 71 | 68 | 71 | 70 | 69 | 68 |
| | Majuro, Marshall IS | 47 | 69 | 70 | 70 | 70 | 70 | 70 | 70 | 71 | 70 | 70 | 68 | 70 | 68 |
| | Pago Pago, Amer Samoa | 43 | 67 | 67 | 67 | 68 | 66 | 64 | 62 | 64 | 63 | 67 | 67 | 67 | 62 |
| | Pohnpei,Caroline IS | 52 | 61 | 63 | 65 | 61 | 61 | 67 | 66 | 63 | 62 | 63 | 64 | 65 | 61 |
| | Chuuk,E.Caroline IS | 52 | 68 | 67 | 68 | 68 | 67 | 68 | 67 | 69 | 67 | 64 | 66 | 69 | 64 |
| | Wake Island | 50 | 65 | 65 | 65 | 65 | 69 | 71 | 69 | 68 | 69 | 68 | 65 | 64 | 64 |
| | Yap,W. Caroline IS | 54 | 67 | 67 | 64 | 66 | 67 | 65 | 66 | 65 | 66 | 66 | 63 | 65 | 63 |
| PA | Allentown | 59 | −15 | −8 | −1 | 16 | 28 | 39 | 46 | 41 | 30 | 21 | 11 | −8 | −15 |
| | Erie | 49 | −18 | −17 | −9 | 12 | 26 | 32 | 44 | 37 | 33 | 24 | 7 | −6 | −18 |
| | Harrisburg | 49 | −9 | −5 | 5 | 19 | 31 | 40 | 49 | 45 | 30 | 23 | 13 | −8 | −9 |
| | Middletown/ Harrisburg AP | 64 | −22 | −5 | 5 | 19 | 31 | 40 | 49 | 45 | 30 | 23 | 13 | −8 | −22 |
| | Philadelphia | 61 | −7 | −4 | 7 | 19 | 28 | 44 | 51 | 44 | 35 | 25 | 15 | 1 | −7 |
| | Pittsburgh | 50 | −22 | −12 | −1 | 14 | 26 | 34 | 42 | 39 | 31 | 16 | −1 | −12 | −22 |
| | Avoca | 47 | −21 | −16 | −4 | 14 | 27 | 34 | 43 | 38 | 29 | 19 | 9 | −9 | −21 |
| | Williamsport | 58 | −20 | −13 | −2 | 15 | 28 | 36 | 43 | 38 | 28 | 20 | 8 | −15 | −20 |
| RI | Block IS | 39 | −2 | −2 | 8 | 18 | 34 | 41 | 51 | 45 | 40 | 30 | 16 | −4 | −4 |
| | Providence | 49 | −13 | −7 | 1 | 14 | 29 | 41 | 48 | 40 | 33 | 20 | 6 | −10 | −13 |
| SC | Charleston A | 60 | 6 | 12 | 15 | 29 | 36 | 50 | 58 | 56 | 42 | 27 | 15 | 8 | 6 |
| | Charleston CO | 17 | 10 | 22 | 22 | 36 | 13 | 58 | 65 | 59 | 55 | 40 | 35 | 5 | 5 |
| | Columbia | 55 | −1 | 5 | 4 | 26 | 34 | 44 | 54 | 53 | 40 | 23 | 12 | 4 | −1 |
| | Greenville-Spartanburg AP | 40 | −6 | 8 | 11 | 25 | 31 | 40 | 54 | 52 | 36 | 25 | 12 | 5 | −6 |
| SD | Aberdeen | 41 | −35 | −45 | −32 | −2 | 19 | 33 | 39 | 32 | 20 | 8 | −27 | −39 | −45 |
| | Huron | 61 | −37 | −41 | −24 | −2 | 17 | 32 | 37 | 36 | 19 | 8 | −21 | −30 | −41 |
| | Rapid City | 60 | −27 | −31 | −21 | 1 | 18 | 31 | 39 | 38 | 18 | −2 | −19 | −30 | −31 |
| | Sioux Falls | 57 | −36 | −31 | −23 | 5 | 17 | 33 | 38 | 34 | 22 | 9 | −17 | −28 | −36 |
| TN | Bristol-JhnCty -Kgsprt | 57 | −21 | −15 | −2 | 21 | 30 | 38 | 45 | 43 | 34 | 20 | 5 | −9 | −21 |
| | Chattanooga | 63 | −10 | 1 | 8 | 25 | 34 | 41 | 51 | 50 | 36 | 22 | 4 | −2 | −10 |
| | Knoxville | 61 | −24 | −8 | 1 | 22 | 32 | 43 | 49 | 49 | 36 | 25 | 5 | −6 | −24 |
| | Memphis | 61 | −4 | −11 | 12 | 29 | 38 | 48 | 52 | 48 | 36 | 25 | 9 | −13 | −13 |
| | Nashville | 63 | −17 | −13 | 2 | 23 | 34 | 42 | 51 | 47 | 36 | 26 | −1 | −10 | −17 |
| | Oak Ridge | 63 | −17 | −13 | 1 | 20 | 30 | 39 | 49 | 50 | 33 | 21 | 0 | −7 | −17 |
| TX | Abilene | 63 | −9 | −7 | 7 | 25 | 36 | 47 | 55 | 50 | 35 | 23 | 14 | −7 | −9 |
| | Amarillo | 62 | −11 | −14 | −3 | 14 | 28 | 41 | 51 | 49 | 30 | 12 | 0 | −8 | −14 |
| | Austin City | 61 | −2 | 7 | 18 | 35 | 43 | 53 | 64 | 61 | 41 | 30 | 20 | 4 | −2 |
| | Brownsville | 64 | 19 | 22 | 32 | 38 | 52 | 60 | 68 | 63 | 55 | 35 | 31 | 16 | 16 |
| | Corpus Christi | 64 | 14 | 18 | 24 | 33 | 47 | 58 | 64 | 64 | 50 | 28 | 28 | 13 | 13 |
| | Dallas-Fort Worth | 49 | 4 | 7 | 15 | 29 | 41 | 51 | 59 | 56 | 43 | 29 | 20 | −1 | −1 |
| | Dallas-Love Field | 3 | 19 | 21 | 17 | 41 | 50 | 62 | 69 | 70 | 49 | 39 | 29 | 21 | 17 |
| | Del Rio | 40 | 15 | 14 | 21 | 33 | 45 | 55 | 64 | 64 | 48 | 28 | 22 | 10 | 10 |
| | El Paso | 63 | −8 | 8 | 14 | 23 | 31 | 46 | 57 | 56 | 41 | 25 | 1 | 5 | −8 |
| | Galveston | 63 | 11 | 8 | 26 | 38 | 52 | 57 | 66 | 67 | 52 | 39 | 26 | 14 | 8 |
| | Houston | 33 | 12 | 20 | 22 | 31 | 44 | 52 | 62 | 60 | 48 | 29 | 19 | 7 | 7 |
| | Lubbock | 56 | −16 | −8 | 2 | 22 | 30 | 44 | 51 | 52 | 33 | 18 | −1 | −2 | −16 |
| | Midland-Odessa | 55 | −8 | −11 | 9 | 20 | 34 | 47 | 53 | 54 | 36 | 24 | 11 | −1 | −11 |
| | Port Arthur | 49 | 14 | 20 | 23 | 32 | 46 | 56 | 61 | 60 | 45 | 30 | 22 | 12 | 12 |
| | San Angelo | 55 | 5 | −1 | 8 | 25 | 35 | 48 | 56 | 54 | 37 | 26 | 13 | −4 | −4 |
| | San Antonio | 61 | 0 | 6 | 19 | 31 | 43 | 53 | 62 | 61 | 41 | 27 | 21 | 6 | 0 |
| | Victoria | 42 | 14 | 19 | 21 | 33 | 49 | 59 | 62 | 62 | 48 | 31 | 24 | 9 | 9 |
| | Waco | 60 | −5 | 4 | 15 | 27 | 37 | 52 | 60 | 53 | 40 | 25 | 17 | −4 | −5 |
| | Wichita Falls | 56 | −5 | −8 | 8 | 24 | 36 | 51 | 54 | 53 | 38 | 25 | 14 | −7 | −8 |
| UT | Milford | 53 | −28 | −29 | −14 | 9 | 17 | 24 | 38 | 34 | 23 | −2 | −13 | −32 | −32 |
| | Salt Lake City | 74 | −22 | −30 | 2 | 14 | 25 | 35 | 40 | 37 | 27 | 16 | −14 | −21 | −30 |
| VT | Burlington | 59 | −30 | −30 | −20 | 2 | 24 | 33 | 39 | 35 | 25 | 15 | −2 | −26 | −30 |

*(Continued)*

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**Table 3C.17 (Continued)**

| Data | Through 2002 | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VA | Lynchburg | 58 | −10 | −10 | 7 | 20 | 31 | 40 | 49 | 45 | 35 | 21 | 8 | −4 | −10 |
| | Norfolk | 54 | −3 | 8 | 18 | 28 | 36 | 45 | 54 | 49 | 45 | 27 | 20 | 7 | −3 |
| | Richmond | 73 | −12 | −10 | 11 | 23 | 31 | 40 | 51 | 46 | 35 | 21 | 10 | −1 | −12 |
| | Roanoke | 55 | −11 | −1 | 9 | 20 | 31 | 39 | 47 | 42 | 34 | 22 | 9 | −4 | −11 |
| | Wallops Island | 28 | 0 | 10 | 14 | 27 | 37 | 44 | 53 | 48 | 43 | 31 | 20 | 4 | 0 |
| WA | Olympia | 61 | −8 | −1 | 9 | 23 | 25 | 30 | 35 | 33 | 25 | 14 | −1 | −7 | −8 |
| | Quillayute | 36 | 7 | 11 | 19 | 23 | 29 | 33 | 38 | 36 | 28 | 24 | 5 | 7 | 5 |
| | Seattle CO | 65 | 11 | 11 | 22 | 31 | 35 | 42 | 47 | 48 | 40 | 30 | 13 | 9 | 9 |
| | Seattle Sea-Tac AP | 58 | 0 | 1 | 11 | 29 | 28 | 38 | 43 | 44 | 35 | 28 | 6 | 6 | 0 |
| | Spokane | 55 | −22 | −24 | −7 | 17 | 24 | 33 | 37 | 35 | 22 | 7 | −21 | −25 | −25 |
| | Walla Walla | 55 | −4 | −13 | 4 | 29 | 34 | 39 | 46 | 42 | 32 | 15 | −11 | −14 | −14 |
| | Yakima | 56 | −21 | −25 | −1 | 20 | 25 | 30 | 34 | 35 | 24 | 4 | −13 | −17 | −25 |
| PR | San Juan | 48 | 61 | 62 | 60 | 64 | 66 | 69 | 69 | 70 | 69 | 46 | 66 | 59 | 46 |
| WV | Beckley | 39 | −22 | −16 | −5 | 11 | 23 | 32 | 41 | 36 | 30 | 18 | 4 | −18 | −22 |
| | Charleston | 55 | −16 | −12 | 0 | 19 | 26 | 33 | 46 | 41 | 34 | 17 | 6 | −12 | −16 |
| | Elkins | 58 | −24 | −22 | −15 | 3 | 20 | 25 | 32 | 34 | 27 | 11 | 0 | −24 | −24 |
| | Huntington | 42 | −21 | −9 | −2 | 20 | 27 | 40 | 46 | 43 | 31 | 16 | 8 | −13 | −21 |
| WI | Green Bay | 53 | −31 | −28 | −29 | 7 | 21 | 32 | 40 | 38 | 24 | 15 | −9 | −27 | −31 |
| | La Crosse | 51 | −37 | −36 | −28 | 7 | 26 | 37 | 33 | 40 | 28 | 14 | −9 | −30 | −37 |
| | Madison | 63 | −37 | −29 | −29 | 0 | 19 | 31 | 36 | 35 | 25 | 13 | −11 | −25 | −37 |
| | Milwaukee | 62 | −26 | −26 | −10 | 12 | 21 | 33 | 40 | 44 | 28 | 18 | −5 | −20 | −26 |
| WY | Casper | 52 | −40 | −29 | −21 | −6 | 16 | 28 | 30 | 33 | 16 | −3 | −21 | −41 | −41 |
| | Cheyenne | 67 | −29 | −34 | −21 | −8 | 16 | 25 | 38 | 36 | 8 | −1 | −16 | −28 | −34 |
| | Lander | 56 | −37 | −28 | −16 | −2 | 18 | 25 | 39 | 35 | 10 | −3 | −18 | −37 | −37 |
| | Sheridan | 62 | −35 | −32 | −23 | −2 | 13 | 27 | 35 | 32 | 6 | −9 | −25 | −37 | −37 |

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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**Table 3C.18 World-Wide Extremes of Temperature and Precipitation**

**Temperature**

A. *Highest*

World, 58°C (136°F), El Azizia, Libya, 13 September 1922
Western Hemisphere, 57°C (134°F), Death Valley, California, 10 July 1913
Antarctica, −13.6°C (7.5°F), 27 December 1978
Asia, 54°C (129°F), Tirat Tsvi, Israel, 21 June 1942
Australia, 53°C (128°F), Cloncurry, Queensland, 16 January 1889
Europe, 50°C (122°F), Seville, Spain, 4 August 1881
South America, 49°C (120°F), Rivadavia, Argentina, 11 December 1905
Canada, 45°C (113°F), Midale and Yellow Grass, Saskatchewan, 5 July 1937
Vanda Station, Antarctica, had a 15°C (59°F) maximum, 5 January 1974 (possibly Antarctica's highest)
South Pole, −14°C (7.5°F), 27 December 1978
Persian Gulf had a 36°C (96°F) sea-surface, 5 August 1924
Annual Mean, 34.4°C (94°F), Dallol, Ethiopia

B. *Lowest*

World, −89°C (−129°F), Vostok, Antarctica, 21 July 1983
Northern Hemisphere, −68°C (−90°F), Verkhoyansk, U.S.S.R., 5 and 7 February 1892 and Oimekon, U.S.S.R., 6 February 1933
Greenland, −66°C (−87°F), Northice, 9 January 1954
North America, excluding Greenland, −63°C (−81°F), Snag, Yukon Territory, 3 February 1947
U.S., −62°C (−80°F), Prospect Creek, Endicott Mts., Alaska, 23 January 1971
U.S., excluding Alaska, −56.5°C (−70°F), Rogers Pass, Montana, 20 January 1954
Europe, −55°C (−67°F), Ust 'Shchugor, U.S.S.R., January (date not known, lowest in 15-year period)
South America, −33°C (−27°F), Sarmiento, Argentina, 1 June 1907
Africa, −24°C (−11°F), Ifrane, Morocco, 11 February 1935
Antarctica, annual mean temperature −57°C, (−71°F), Sovietskaya, Antarctica
Australia, −23°C (−9°F), Charlotte Pass, New South Wales, 29 June 1994
Upper Air, −153°C (−243°F) at 93 km (58 mi) above Point Barrow, AK

**Precipitation**

A. *Greatest Rainfall*

World, 1-minute, 3.1 cm (1.23″), Unionville, Maryland, 4 July 1956
World, 20-minute, 20.5 cm (8″), Curtea-de-Arges, Romania, 7 July 1889
World, 42-minute, 30.5 cm (12″), Holt, Missouri, 22 June 1947
World, 60-minute, 30.5 cm (12″), Holt, Missouri, 22 June 1947 and Kilauea Sugar Plantaion 24–25 January 1956
World, 12-hour, 117 cm (46″), Grand Ilet, La R'eunion Island, 28 January 1980
World, 24-hour, 183 cm (72″), Foc-Foc, La R'eunion Island, 7–8 January 1966
World, 5-day, 430 cm (169″), Commerson, La R'eunion Island, 23–28 January 1980
World, 1-month, 930 cm (366″), Cherrapunji, India, July 1861
World, 12-month, 2,647 cm (1042″), Cherrapunji, India, August 1860–1861
Northern Hemisphere, 24-hour, 125 cm (49″), Paishih, Taiwan, 10–11 September 1963
Australia, 24-hour, 114 cm (44″), Bellenden Ker, Queensland, 4 January 1979
Canada, 24-hour, 49 cm (19″), Ucluelet Brynnor Mines, British Columbia, 6 October 1967
United States, 24-hour, 109 cm (43″), Alvin, Texas, 25–26 July 1979
United States, 12-month, 1878 cm (793″), Kukui, Maui, Hawaii, December 1981–1982

B. *Greatest Average Yearly Precipitation*

World, 1,168 cm (460i″), Mount Waialeale, Kauai, HI (1931–1960), 1187 cm (467 Mawsynram,India (1941–1979), 1330 cm (524″), Lloro, Colombia (1932–1960)
Asia, 1187 cm (467″) during a 38-year period, Mawsynrami, India
Africa, 1029 cm (405″) during a 32-year period, Debundscha, Cameroon
South America, 899 cm (354″) during a 10–16 year period, Quibdo, Colombia
North America, 650 cm (256″) during a 14-year period Henderson Lake, British Columbia
Europe, 465 cm (183″) during a 22-year period, Crkvice, Yugoslavia
Australia, average yearly, 864 cm (340″), Bellenden Ker, Queensland
Bahia Felix, Chile, averages 325 days/year with rain
Canada, highest frequency of days with precipitation, 242 per year average, Langara, Queen Charlotte Islands, British Columbia

C. *Least Precipitation*

Arica, Chile, had no rain for more than 14 consecutive years, October 1903 to January 1918
U.S., longest dry period, 767 days from 3 October 1912 to 8 November 1914, Bagdad, California
Canada, least precipitation during a calendar year, 1.27 cm (0.05″), Arctic Bay, Northwest Territories, 1949 Canada, lowest frequency of days with precipitation, 8 per year average, Rea Point, Northwest Territories

D. *Lowest Average Yearly Precipitation*

World, 0.08 cm (0.03″) during a 59-year period, Arica, Chile

*(Continued)*

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**Table 3C.18 (Continued)**

Africa, <0.25 cm (<0.1″> during a 39-year period, Wadi Haifa, Sudan
North America, 3.0 cm (1.2″) during a 14-year period, Bataques, Mexico
United States, 4.1 cm (1.63″) during a 42-year period, Death Valley, California
Asia, 4.6 cm (1.8″) during a 50-year period, Aden, South Yemen
Australia, 10 cm (4.05″) during a 42-year period, Troudaninna, South Australia
Europe, 16 cm (6.4″) during a 25-year period, Astrakhan, U.S.S.R.

E. *Hailstones*
U.S., largest hailstone, 44.5 cm (17.5″) circumference, Coffeyville, Kansas, 3 September 1979 Canada, heaviest hailstone, 290 gm (10.23 oz),
Cedoux, Saskatchewan, 27 August 1973 Canada, highest frequency of days with hail, 7 per year average, Edson and Red Deer, Alberta
United States, highest frequency of days with hail, 9.4 per year average, Cheyenne, Wyoming
World, heaviest hailstone, 1.02 kg (2.25 lbs) in the Gopalganj district, Bangladesh, 14 April 1986

F. *Greatest Snowfall*
North America, 24-hour, 192.5 cm (76″), Silver Lake, Colorado, 14–15 April 1921
Bessans, France, had a snowfall of 172 cm (68″) in 19 hours, 5–6 April 1969
Canada, climatological day, 118 cm (46″), Lakelse Lake, British Columbia, 17 January 1974
North America, one storm, 480 cm (189″), Mt. Shasta Ski Bowl, California, 13–19 February 1959
North America, one season, 2850 cm (1122″), Rainier Paradise Ranger Station, Washington, 1971–1972
Canada, one season, 2446.5 cm (964″), Revelstoke Mt. Copeland, British Columbia, 1971–1972
Canada, highest frequency of days with snow, 142 per year average, Old Glory Mountain, British Columbia
North America, greatest depth of snow on the ground, 1145.5 cm (451″), Tamarack, California, 11 March 1911
Canada, greatest depth of snow on the ground, 775 cm (305″), Loch Lomond, British Columbia

**Other Elements**

A. *Thunderstorms*
Kampala, Uganda, averages 242 days/year with thunderstorms, during a 10-year period
Bogor, Indonesia, averaged 322 days/year with thunderstorms from 1916 to 1920
Canada, highest frequency of days with thunderstorms, 34 per year average, Windsor, Ontario
North America, highest average annual days with thunderstorms, 100 per year average, Tampa, Florida

B. *Fog Frequency*
U.S. West Coast, highest average, 2552 hours per year during a 10-year period or more, Cape Disappointment, Washington U.S. East Coast, highest average, 1580 hours per year during a 10-year period or more, Moose Peak Lighthouse, Mistake Island, Maine
Canada, highest average, 158 days per year, Cape Race, Newfoundland

*Source*: From Krause, P. and Flood, K., 1997, Weather and climate extremes, U.S. Army Corps of Engineers, Topographic Engineering Center, Alexandria, VA 22315.

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**Table 3C.19 World Record Point Rainfall**

| Duration | Units | Rainfall (mm) | Location | Date |
|---|---|---|---|---|
| 1 | min | 38 | Barot, Guadeloupe | 26 Nov 1970 |
| 8 | | 126 | Fussen, Bavaria | 25 May 1920 |
| 15 | | 198 | Plumb Point, Jamaica | 12 May 1916 |
| 20 | | 206 | Curtea-de-Arges, Romania | 7 Jul 1889 |
| 42 | | 305 | Holt, U.S.A. | 22 Jun 1947 |
| 60 | | 401 | Shangdi, Nei Monggol, China | 3 Jul 1975 |
| 2.17 | hours | 483 | Rockport, U.S.A. | 18 Jul 1889 |
| 2.75 | | 559 | D'Hanis, U.S.A. | 31 May 1935 |
| 4.5 | | 782 | Smethport, U.S.A. | 18 Jul 1942 |
| 6 | | 840 | Muduocaidang, China | 1 Aug 1977 |
| 9 | | 1,087 | Belouve, La Réunion | 28 Feb 1964 |
| 10 | | 1,400 | Muduocaidang, China | 1 Aug 1977 |
| 18.5 | | 1,689 | Belouve, La Réunion | 28–89 Feb 1964 |
| 24 | | 1,825 | Foc Foc, La Réunion | 7–8 Jan 1966 |
| 2 | days | 2,467 | Aurere, La Réunion | 7–9 Apr 1958 |
| 3 | | 3,130 | Aurere, La Réunion | 6–9 Apr 1958 |
| 4 | | 3,721 | Cherrapunji, India | 12–15 Sep 1974 |
| 5 | | 4,301 | Commerson, La Réunion | 23–27 Jan 1980 |
| 6 | | 4,653 | Commerson, La Réunion | 22–27 Jan 1980 |
| 7 | | 5,003 | Commerson, La Réunion | 21–27 Jan 1980 |
| 8 | | 5,286 | Commerson, La Réunion | 20–27 Jan 1980 |
| 9 | | 5,692 | Commerson, La Réunion | 19–27 Jan 1980 |
| 10 | | 6,028 | Commerson, La Réunion | 18–27 Jan 1980 |
| 11 | | 6,299 | Commerson, La Réunion | 17–27 Jan 1980 |
| 12 | | 6,401 | Commerson, La Réunion | 16–27 Jan 1980 |
| 13 | | 6,422 | Commerson, La Réunion | 15–27 Jan 1980 |
| 14 | | 6,432 | Commerson, La Réunion | 15–28 Jan 1980 |
| 15 | | 6,433 | Commerson, La Réunion | 14–28 Jan 1980 |
| 31 | | 9,300 | Cherrapunji, India | 1–31 Jul 1861 |
| 2 | months | 12,767 | Cherrapunji, India | Jun–Jul 1861 |
| 3 | | 16,369 | Cherrapunji, India | May–Jul 1861 |
| 4 | | 18,738 | Cherrapunji, India | Apr–Jul 1861 |
| 5 | | 20,412 | Cherrapunji, India | Apr–Aug 1861 |
| 6 | | 22,454 | Cherrapunji, India | Apr–Sep 1861 |
| 11 | | 22,990 | Cherrapunji, India | Jan–Nov 1861 |
| 12 | | 26,461 | Cherrapunji, India | Aug 1860–Jul 1861 |
| 2 | years | 40,768 | Cherrapunji, India | 1860–1861 |

*Source*: From World Meteorological Organization and are published in the *Guide to Hydrological Practices 1994, 5th Edition*, WMO No. 168, www.noaa.gov.

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## SECTION 3D PRECIPITATION DATA

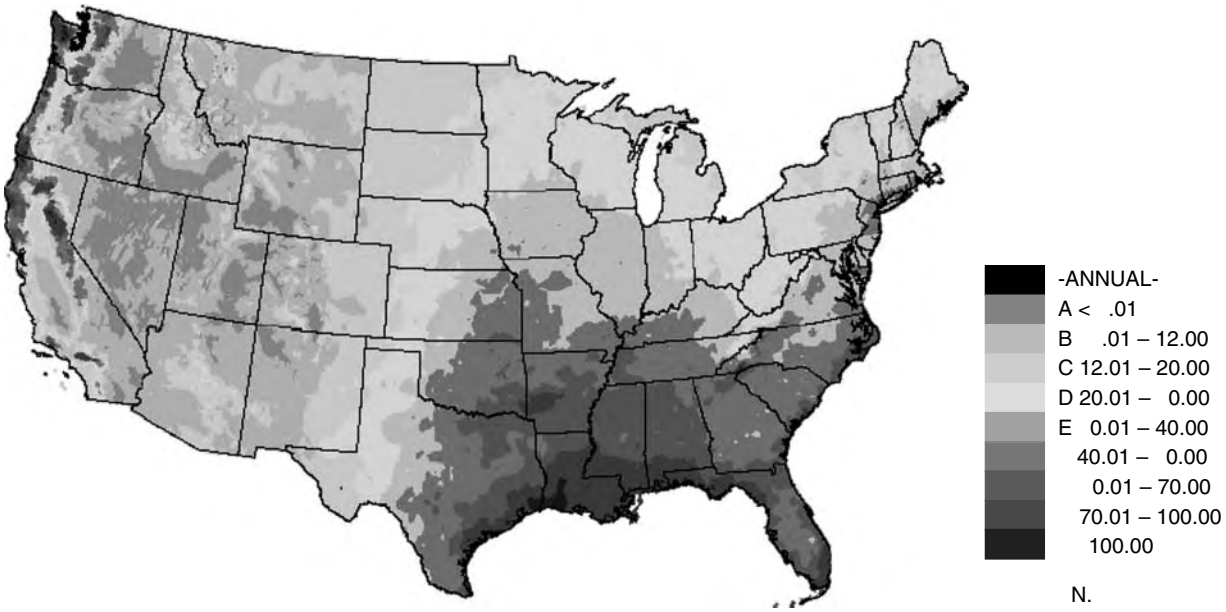


**Figure 3D.7** U.S. annual mean total precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

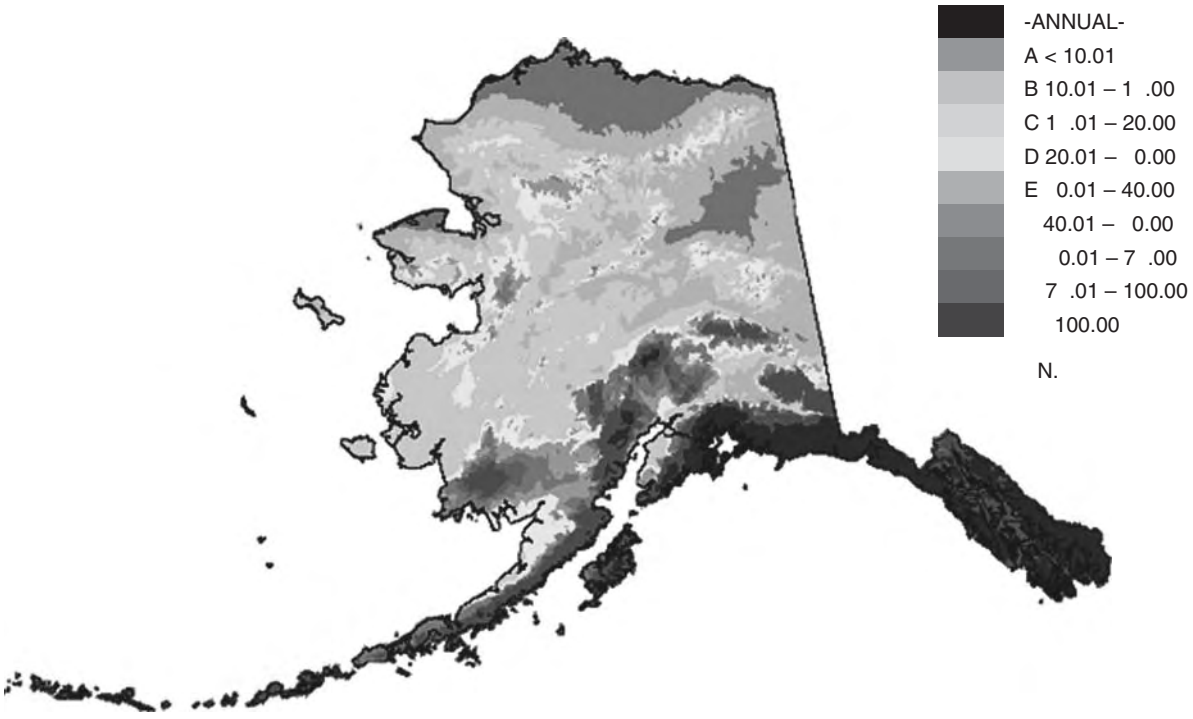


**Figure 3D.8** Alaska annual mean total precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

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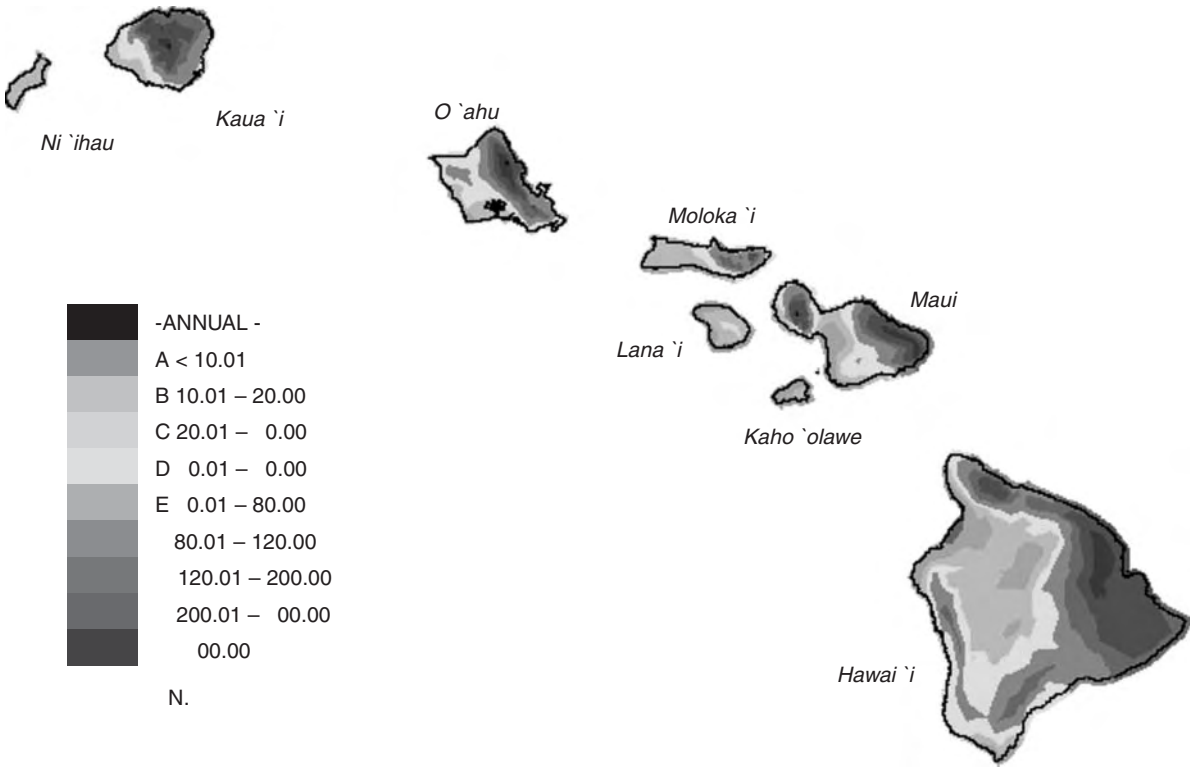


**Figure 3D.9** Hawaii annual mean total precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

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**Table 3D.20 Normal Monthly Precipitation (inches) — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham | 30 | 5.45 | 4.21 | 6.10 | 4.67 | 4.83 | 3.78 | 5.09 | 3.48 | 4.05 | 3.23 | 4.63 | 4.47 | 53.99 |
| | Huntsville | 30 | 5.52 | 4.95 | 6.68 | 4.54 | 5.24 | 4.22 | 4.40 | 3.32 | 4.29 | 3.54 | 5.22 | 5.59 | 57.51 |
| | Mobile | 30 | 5.75 | 5.10 | 7.20 | 5.06 | 6.10 | 5.01 | 6.54 | 6.20 | 6.01 | 3.25 | 5.41 | 4.66 | 66.29 |
| | Montgomery | 30 | 5.04 | 5.45 | 6.39 | 4.38 | 4.14 | 4.13 | 5.31 | 3.63 | 4.22 | 2.58 | 4.53 | 4.97 | 54.77 |
| AK | Anchorage | 30 | 0.68 | 0.74 | 0.65 | 0.52 | 0.69 | 1.06 | 1.70 | 2.93 | 2.87 | 2.08 | 1.09 | 1.05 | 16.08 |
| | Annette | 30 | 9.67 | 8.05 | 7.96 | 7.37 | 5.73 | 4.72 | 4.26 | 6.12 | 9.49 | 13.86 | 12.21 | 11.39 | 100.83 |
| | Barrow | 30 | 0.12 | 0.12 | 0.09 | 0.12 | 0.12 | 0.32 | 0.87 | 1.04 | 0.69 | 0.39 | 0.16 | 0.12 | 4.16 |
| | Bethel | 30 | 0.62 | 0.51 | 0.67 | 0.65 | 0.85 | 1.60 | 2.03 | 3.02 | 2.31 | 1.43 | 1.37 | 1.12 | 16.18 |
| | Bettles | 30 | 0.84 | 0.61 | 0.55 | 0.38 | 0.85 | 1.43 | 2.10 | 2.54 | 1.82 | 1.08 | 0.90 | 0.87 | 13.97 |
| | Big Delta | 30 | 0.34 | 0.41 | 0.22 | 0.20 | 0.77 | 2.38 | 2.77 | 2.11 | 1.03 | 0.73 | 0.59 | 0.39 | 11.94 |
| | Cold Bay | 30 | 3.08 | 2.59 | 2.48 | 2.30 | 2.65 | 2.89 | 2.53 | 3.59 | 4.51 | 4.54 | 4.79 | 4.33 | 40.28 |
| | Fairbanks | 30 | 0.56 | 0.36 | 0.28 | 0.21 | 0.60 | 1.40 | 1.73 | 1.74 | 1.12 | 0.92 | 0.68 | 0.74 | 10.34 |
| | Gulkana | 30 | 0.45 | 0.52 | 0.36 | 0.22 | 0.59 | 1.54 | 1.82 | 1.80 | 1.44 | 1.02 | 0.67 | 0.97 | 11.40 |
| | Homer | 30 | 2.61 | 2.04 | 1.82 | 1.21 | 1.07 | 0.96 | 1.45 | 2.28 | 3.37 | 2.77 | 2.87 | 3.00 | 25.45 |
| | Juneau | 30 | 4.81 | 4.02 | 3.51 | 2.96 | 3.48 | 3.36 | 4.14 | 5.37 | 7.54 | 8.30 | 5.43 | 5.41 | 58.33 |
| | King Salmon | 30 | 1.03 | 0.72 | 0.79 | 0.94 | 1.35 | 1.70 | 2.15 | 2.89 | 2.81 | 2.09 | 1.54 | 1.39 | 19.41 |
| | Kodiak | 30 | 8.17 | 5.72 | 5.22 | 5.48 | 6.31 | 5.38 | 4.12 | 4.48 | 7.84 | 8.36 | 6.63 | 7.64 | 75.35 |
| | Kotzebue | 30 | 0.55 | 0.42 | 0.38 | 0.41 | 0.33 | 0.57 | 1.43 | 2.00 | 1.70 | 0.95 | 0.71 | 0.60 | 10.05 |
| | Mcgrath | 30 | 1.04 | 0.74 | 0.81 | 0.66 | 1.02 | 1.45 | 2.32 | 2.75 | 2.36 | 1.46 | 1.46 | 1.44 | 17.51 |
| | Nome | 30 | 0.92 | 0.75 | 0.60 | 0.65 | 0.74 | 1.14 | 2.15 | 3.23 | 2.51 | 1.58 | 1.28 | 1.01 | 16.56 |
| | St. Paul Island | 30 | 1.74 | 1.25 | 1.12 | 1.12 | 1.21 | 1.41 | 1.91 | 2.96 | 2.79 | 2.70 | 2.87 | 2.13 | 23.21 |
| | Talkeetna | 30 | 1.45 | 1.28 | 1.26 | 1.22 | 1.64 | 2.41 | 3.24 | 4.53 | 4.35 | 3.06 | 1.78 | 1.96 | 28.18 |
| | Unalakleet | 30 | 0.40 | 0.31 | 0.39 | 0.35 | 0.55 | 1.25 | 2.15 | 2.92 | 2.10 | 0.89 | 0.66 | 0.47 | 12.44 |
| | Valdez | 30 | 6.02 | 5.53 | 4.49 | 3.55 | 3.08 | 3.01 | 3.84 | 6.62 | 9.59 | 8.58 | 5.51 | 7.59 | 67.41 |
| | Yakutat | 30 | 13.18 | 10.99 | 11.41 | 10.80 | 9.78 | 7.17 | 7.88 | 13.27 | 20.88 | 24.00 | 15.17 | 15.85 | 160.38 |
| AZ | Flagstaff | 30 | 2.18 | 2.56 | 2.62 | 1.29 | 0.80 | 0.43 | 2.40 | 2.89 | 2.12 | 1.93 | 1.86 | 1.83 | 22.91 |
| | Phoenix | 30 | 0.83 | 0.77 | 1.07 | 0.25 | 0.16 | 0.09 | 0.99 | 0.94 | 0.75 | 0.79 | 0.73 | 0.92 | 8.29 |
| | Tucson | 30 | 0.99 | 0.88 | 0.81 | 0.28 | 0.24 | 0.24 | 2.07 | 2.30 | 1.45 | 1.21 | 0.67 | 1.03 | 12.17 |
| | Winslow | 30 | 0.46 | 0.53 | 0.61 | 0.27 | 0.36 | 0.30 | 1.18 | 1.31 | 1.02 | 0.90 | 0.55 | 0.54 | 8.03 |
| | Yuma | 30 | 0.38 | 0.28 | 0.27 | 0.09 | 0.05 | 0.02 | 0.23 | 0.61 | 0.26 | 0.26 | 0.14 | 0.42 | 3.01 |
| AR | Fort Smith | 30 | 2.37 | 2.59 | 3.94 | 3.91 | 5.29 | 4.28 | 3.19 | 2.56 | 3.61 | 3.94 | 4.80 | 3.39 | 43.87 |
| | Little Rock | 30 | 3.61 | 3.33 | 4.88 | 5.47 | 5.05 | 3.95 | 3.31 | 2.93 | 3.71 | 4.25 | 5.73 | 4.71 | 50.93 |
| | North Little Rock | 30 | 3.37 | 3.27 | 4.88 | 5.03 | 5.40 | 3.51 | 3.15 | 2.97 | 3.53 | 3.81 | 5.74 | 4.53 | 49.19 |
| CA | Bakersfield | 30 | 1.18 | 1.21 | 1.41 | 0.45 | 0.24 | 0.12 | 0.00 | 0.08 | 0.15 | 0.30 | 0.59 | 0.76 | 6.49 |
| | Bishop | 30 | 0.88 | 0.97 | 0.62 | 0.24 | 0.26 | 0.21 | 0.17 | 0.13 | 0.28 | 0.20 | 0.44 | 0.62 | 5.02 |
| | Eureka | 30 | 5.97 | 5.51 | 5.55 | 2.91 | 1.62 | 0.65 | 0.16 | 0.38 | 0.86 | 2.36 | 5.78 | 6.35 | 38.10 |
| | Fresno | 30 | 2.16 | 2.12 | 2.20 | 0.76 | 0.39 | 0.23 | 0.01 | 0.01 | 0.26 | 0.65 | 1.10 | 1.34 | 11.23 |
| | Long Beach | 30 | 2.95 | 3.01 | 2.43 | 0.60 | 0.23 | 0.08 | 0.02 | 0.10 | 0.24 | 0.40 | 1.12 | 1.76 | 12.94 |
| | Los Angeles AP | 30 | 2.98 | 3.11 | 2.40 | 0.63 | 0.24 | 0.08 | 0.03 | 0.14 | 0.26 | 0.36 | 1.13 | 1.79 | 13.15 |
| | Los Angeles CO | 30 | 3.33 | 3.68 | 3.14 | 0.83 | 0.31 | 0.06 | 0.01 | 0.13 | 0.32 | 0.37 | 1.05 | 1.91 | 15.14 |
| | Mount Shasta | 30 | 7.06 | 6.45 | 5.81 | 2.65 | 1.87 | 0.99 | 0.39 | 0.43 | 0.87 | 2.21 | 5.08 | 5.35 | 39.16 |
| | Redding | 30 | 6.50 | 5.49 | 5.15 | 2.40 | 1.66 | 0.69 | 0.05 | 0.22 | 0.48 | 2.18 | 4.03 | 4.67 | 33.52 |
| | Sacramento | 30 | 3.84 | 3.54 | 2.80 | 1.02 | 0.53 | 0.20 | 0.05 | 0.06 | 0.36 | 0.89 | 2.19 | 2.45 | 17.93 |
| | San Diego | 30 | 2.28 | 2.04 | 2.26 | 0.75 | 0.20 | 0.09 | 0.03 | 0.09 | 0.21 | 0.44 | 1.07 | 1.31 | 10.77 |
| | San Francisco AP | 30 | 4.45 | 4.01 | 3.26 | 1.17 | 0.38 | 0.11 | 0.03 | 0.07 | 0.20 | 1.04 | 2.49 | 2.89 | 20.11 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | San Francisco CO | 30 | 4.72 | 4.15 | 3.40 | 1.25 | 0.54 | 0.13 | 0.04 | 0.09 | 0.28 | 1.19 | 3.31 | 3.18 | 22.28 |
| | Santa Barbara | 30 | 3.57 | 4.28 | 3.51 | 0.63 | 0.23 | 0.05 | 0.03 | 0.11 | 0.42 | 0.52 | 1.32 | 2.26 | 16.93 |
| | Santa Maria | 30 | 2.64 | 3.23 | 2.94 | 0.91 | 0.32 | 0.05 | 0.03 | 0.05 | 0.31 | 0.45 | 1.24 | 1.84 | 14.01 |
| | Stockton | 30 | 2.71 | 2.46 | 2.28 | 0.96 | 0.50 | 0.09 | 0.05 | 0.05 | 0.33 | 0.82 | 1.77 | 1.82 | 13.84 |
| CO | Alamosa | 30 | 0.25 | 0.21 | 0.46 | 0.54 | 0.70 | 0.59 | 0.94 | 1.19 | 0.89 | 0.67 | 0.48 | 0.33 | 7.25 |
| | Colorado Springs | 30 | 0.28 | 0.35 | 1.06 | 1.62 | 2.39 | 2.34 | 2.85 | 3.48 | 1.23 | 0.86 | 0.52 | 0.42 | 17.40 |
| | Denver | 30 | 0.51 | 0.49 | 1.28 | 1.93 | 2.32 | 1.56 | 2.16 | 1.82 | 1.14 | 0.99 | 0.98 | 0.63 | 15.81 |
| | Grand Junction | 30 | 0.60 | 0.50 | 1.00 | 0.86 | 0.98 | 0.41 | 0.66 | 0.84 | 0.91 | 1.00 | 0.71 | 0.52 | 8.99 |
| | Pueblo | 30 | 0.33 | 0.26 | 0.97 | 1.25 | 1.49 | 1.33 | 2.04 | 2.27 | 0.84 | 0.64 | 0.58 | 0.39 | 12.39 |
| CT | Bridgeport | 30 | 3.73 | 2.92 | 4.15 | 3.99 | 4.03 | 3.57 | 3.77 | 3.75 | 3.58 | 3.54 | 3.65 | 3.47 | 44.15 |
| | Hartford | 30 | 3.84 | 2.96 | 3.88 | 3.86 | 4.39 | 3.85 | 3.67 | 3.98 | 4.13 | 3.94 | 4.06 | 3.60 | 46.16 |
| DE | Wilmington | 30 | 3.43 | 2.81 | 3.97 | 3.39 | 4.15 | 3.59 | 4.28 | 3.51 | 4.01 | 3.08 | 3.19 | 3.40 | 42.81 |
| DC | Washington Dulles AP | 30 | 3.05 | 2.77 | 3.55 | 3.22 | 4.22 | 4.07 | 3.57 | 3.78 | 3.82 | 3.37 | 3.31 | 3.07 | 41.80 |
| | Washington Nat'l AP | 30 | 3.21 | 2.63 | 3.60 | 2.77 | 3.82 | 3.13 | 3.66 | 3.44 | 3.79 | 3.22 | 3.03 | 3.05 | 39.35 |
| FL | Apalachicola | 30 | 4.87 | 3.76 | 4.95 | 3.00 | 2.62 | 4.30 | 7.31 | 7.29 | 7.10 | 4.18 | 3.62 | 3.51 | 56.51 |
| | Daytona Beach | 30 | 3.13 | 2.74 | 3.84 | 2.54 | 3.26 | 5.69 | 5.17 | 6.09 | 6.61 | 4.48 | 3.03 | 2.71 | 49.29 |
| | Fort Myers | 30 | 2.23 | 2.10 | 2.74 | 1.67 | 3.42 | 9.77 | 8.98 | 9.54 | 7.86 | 2.59 | 1.71 | 1.58 | 54.19 |
| | Gainesville | 30 | 3.51 | 3.39 | 4.26 | 2.86 | 3.23 | 6.78 | 6.10 | 6.63 | 4.37 | 2.50 | 2.17 | 2.56 | 48.36 |
| | Jacksonville | 30 | 3.69 | 3.15 | 3.93 | 3.14 | 3.48 | 5.37 | 5.97 | 6.87 | 7.90 | 3.86 | 2.34 | 2.64 | 52.34 |
| | Key West | 30 | 2.22 | 1.51 | 1.86 | 2.06 | 3.48 | 4.57 | 3.27 | 5.40 | 5.45 | 4.34 | 2.64 | 2.14 | 38.94 |
| | Miami | 30 | 1.88 | 2.07 | 2.56 | 3.36 | 5.52 | 8.54 | 5.79 | 8.63 | 8.38 | 6.19 | 3.43 | 2.18 | 58.53 |
| | Orlando | 30 | 2.43 | 2.35 | 3.54 | 2.42 | 3.74 | 7.35 | 7.15 | 6.25 | 5.76 | 2.73 | 2.32 | 2.31 | 48.35 |
| | Pensacola | 30 | 5.34 | 4.68 | 6.40 | 3.89 | 4.40 | 6.39 | 8.02 | 6.85 | 5.75 | 4.13 | 4.46 | 3.97 | 64.28 |
| | Tallahassee | 30 | 5.36 | 4.63 | 6.47 | 3.59 | 4.95 | 6.92 | 8.04 | 7.03 | 5.01 | 3.25 | 3.86 | 4.10 | 63.21 |
| | Tampa | 30 | 2.27 | 2.67 | 2.84 | 1.80 | 2.85 | 5.50 | 6.49 | 7.60 | 6.54 | 2.29 | 1.62 | 2.30 | 44.77 |
| | Vero Beach | 30 | 2.89 | 2.45 | 4.20 | 2.88 | 3.80 | 6.03 | 6.53 | 6.04 | 6.84 | 5.04 | 3.04 | 2.19 | 51.93 |
| | West Palm Beach | 30 | 3.75 | 2.55 | 3.68 | 3.57 | 5.39 | 7.58 | 5.97 | 6.65 | 8.10 | 5.46 | 5.55 | 3.14 | 61.39 |
| GA | Athens | 30 | 4.69 | 4.39 | 4.99 | 3.35 | 3.86 | 3.94 | 4.41 | 3.78 | 3.53 | 3.47 | 3.71 | 3.71 | 47.83 |
| | Atlanta | 30 | 5.02 | 4.68 | 5.38 | 3.62 | 3.95 | 3.63 | 5.12 | 3.67 | 4.09 | 3.11 | 4.10 | 3.82 | 50.20 |
| | Augusta | 30 | 4.50 | 4.11 | 4.61 | 2.94 | 3.07 | 4.19 | 4.07 | 4.48 | 3.59 | 3.20 | 2.68 | 3.14 | 44.58 |
| | Columbus | 30 | 4.78 | 4.48 | 5.75 | 3.84 | 3.62 | 3.51 | 5.04 | 3.78 | 3.07 | 2.33 | 3.97 | 4.40 | 48.57 |
| | Macon | 30 | 5.00 | 4.55 | 4.89 | 3.14 | 2.98 | 3.54 | 4.32 | 3.79 | 3.26 | 2.37 | 3.22 | 3.93 | 45.00 |
| | Savannah | 30 | 3.95 | 2.92 | 3.64 | 3.32 | 3.61 | 5.49 | 6.04 | 7.20 | 5.08 | 3.12 | 2.40 | 2.81 | 49.58 |
| HI | Hilo | 30 | 9.74 | 8.86 | 14.35 | 12.54 | 8.07 | 7.36 | 10.71 | 9.78 | 9.14 | 9.64 | 15.58 | 10.50 | 126.27 |
| | Honolulu | 30 | 2.73 | 2.35 | 1.89 | 1.11 | 0.78 | 0.43 | 0.50 | 0.46 | 0.74 | 2.18 | 2.26 | 2.85 | 18.29 |
| | Kahului | 30 | 3.74 | 2.36 | 2.35 | 1.75 | 0.66 | 0.23 | 0.49 | 0.53 | 0.39 | 1.05 | 2.17 | 3.08 | 18.80 |
| | Lihue | 30 | 4.59 | 3.26 | 3.58 | 3.00 | 2.87 | 1.82 | 2.12 | 1.91 | 2.69 | 4.25 | 4.70 | 4.78 | 39.57 |
| ID | Boise | 30 | 1.39 | 1.14 | 1.41 | 1.27 | 1.27 | 0.74 | 0.39 | 0.30 | 0.76 | 0.76 | 1.38 | 1.38 | 12.19 |
| | Lewiston | 30 | 1.14 | 0.95 | 1.12 | 1.30 | 1.56 | 1.16 | 0.72 | 0.75 | 0.80 | 0.96 | 1.21 | 1.05 | 12.74 |
| | Pocatello | 30 | 1.14 | 1.01 | 1.38 | 1.18 | 1.51 | 0.91 | 0.70 | 0.66 | 0.89 | 0.97 | 1.13 | 1.10 | 12.58 |
| IL | Chicago | 30 | 1.75 | 1.63 | 2.65 | 3.68 | 3.38 | 3.63 | 3.51 | 4.62 | 3.27 | 2.71 | 3.01 | 2.43 | 36.27 |
| | Moline | 30 | 1.58 | 1.51 | 2.92 | 3.82 | 4.25 | 4.63 | 4.03 | 4.41 | 3.16 | 2.80 | 2.73 | 2.20 | 38.04 |
| | Peoria | 30 | 1.50 | 1.67 | 2.83 | 3.56 | 4.17 | 3.84 | 4.02 | 3.16 | 3.12 | 2.76 | 2.99 | 2.40 | 36.03 |
| | Rockford | 30 | 1.41 | 1.34 | 2.39 | 3.62 | 4.02 | 4.80 | 4.10 | 4.21 | 3.47 | 2.57 | 2.63 | 2.06 | 36.63 |
| | Springfield | 30 | 1.62 | 1.80 | 3.15 | 3.36 | 4.06 | 3.77 | 3.53 | 3.41 | 2.83 | 2.62 | 2.87 | 2.54 | 35.56 |

*(Continued)*



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**Table 3D.20 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IN | Evansville | 30 | 2.91 | 3.10 | 4.29 | 4.48 | 5.01 | 4.10 | 3.75 | 3.14 | 2.99 | 2.78 | 4.18 | 3.54 | 44.27 |
| | Fort Wayne | 30 | 2.05 | 1.94 | 2.86 | 3.54 | 3.75 | 4.04 | 3.58 | 3.60 | 2.81 | 2.63 | 2.98 | 2.77 | 36.55 |
| | Indianapolis | 30 | 2.48 | 2.41 | 3.44 | 3.61 | 4.35 | 4.13 | 4.42 | 3.82 | 2.88 | 2.76 | 3.61 | 3.03 | 40.95 |
| | South Bend | 30 | 2.27 | 1.98 | 2.89 | 3.62 | 3.50 | 4.19 | 3.73 | 3.98 | 3.79 | 3.27 | 3.39 | 3.09 | 39.70 |
| IA | Des Moines | 30 | 1.03 | 1.19 | 2.21 | 3.58 | 4.25 | 4.57 | 4.18 | 4.51 | 3.15 | 2.62 | 2.10 | 1.33 | 34.72 |
| | Dubuque | 30 | 1.28 | 1.42 | 2.57 | 3.49 | 4.12 | 4.08 | 3.73 | 4.59 | 3.56 | 2.50 | 2.49 | 1.69 | 35.52 |
| | Sioux City | 30 | 0.59 | 0.62 | 2.00 | 2.75 | 3.75 | 3.61 | 3.30 | 2.90 | 2.42 | 1.99 | 1.40 | 0.66 | 25.99 |
| | Waterloo | 30 | 0.84 | 1.05 | 2.13 | 3.23 | 4.15 | 4.82 | 4.20 | 4.08 | 2.95 | 2.49 | 2.10 | 1.11 | 33.15 |
| KS | Concordia | 30 | 0.66 | 0.73 | 2.35 | 2.45 | 4.20 | 3.95 | 4.20 | 3.24 | 2.50 | 1.84 | 1.45 | 0.86 | 28.43 |
| | Dodge City | 30 | 0.62 | 0.66 | 1.84 | 2.25 | 3.00 | 3.15 | 3.17 | 2.73 | 1.70 | 1.45 | 1.01 | 0.77 | 22.35 |
| | Goodland | 30 | 0.43 | 0.44 | 1.20 | 1.51 | 3.46 | 3.30 | 3.54 | 2.49 | 1.12 | 1.05 | 0.82 | 0.40 | 19.76 |
| | Topeka | 30 | 0.95 | 1.18 | 2.56 | 3.14 | 4.86 | 4.88 | 3.83 | 3.81 | 3.71 | 2.99 | 2.31 | 1.42 | 35.64 |
| | Wichita | 30 | 0.84 | 1.02 | 2.71 | 2.57 | 4.16 | 4.25 | 3.31 | 2.94 | 2.96 | 2.45 | 1.82 | 1.35 | 30.38 |
| KY | Greater Cincinnati AP | 30 | 2.92 | 2.75 | 3.90 | 3.96 | 4.59 | 4.42 | 3.75 | 3.79 | 2.82 | 2.96 | 3.46 | 3.28 | 42.60 |
| | Jackson | 30 | 3.56 | 3.68 | 4.38 | 3.79 | 5.16 | 4.67 | 4.59 | 4.13 | 3.77 | 3.18 | 4.20 | 4.27 | 49.38 |
| | Lexington | 30 | 3.34 | 3.27 | 4.41 | 3.67 | 4.78 | 4.58 | 4.80 | 3.77 | 3.11 | 2.70 | 3.44 | 4.03 | 45.91 |
| | Louisville | 30 | 3.28 | 3.25 | 4.41 | 3.91 | 4.88 | 3.76 | 4.30 | 3.41 | 3.05 | 2.79 | 3.80 | 3.69 | 44.54 |
| | Paducah | 30 | 3.47 | 3.93 | 4.27 | 4.95 | 4.75 | 4.51 | 4.45 | 2.99 | 3.56 | 3.45 | 4.53 | 4.38 | 49.24 |
| LA | Baton Rouge | 30 | 6.19 | 5.10 | 5.07 | 5.56 | 5.34 | 5.33 | 5.96 | 5.86 | 4.84 | 3.81 | 4.76 | 5.26 | 63.08 |
| | Lake Charles | 30 | 5.52 | 3.28 | 3.54 | 3.64 | 6.06 | 6.07 | 5.12 | 4.85 | 5.95 | 3.94 | 4.61 | 4.60 | 57.19 |
| | New Orleans | 30 | 5.87 | 5.47 | 5.24 | 5.02 | 4.62 | 6.83 | 6.20 | 6.15 | 5.55 | 3.05 | 5.09 | 5.07 | 64.16 |
| | Shreveport | 30 | 4.60 | 4.21 | 4.18 | 4.42 | 5.25 | 5.05 | 3.99 | 2.71 | 3.21 | 4.45 | 4.68 | 4.55 | 51.30 |
| ME | Caribou | 30 | 2.97 | 2.06 | 2.57 | 2.64 | 3.27 | 3.31 | 3.89 | 4.15 | 3.27 | 2.99 | 3.12 | 3.19 | 37.44 |
| | Portland | 30 | 4.09 | 3.14 | 4.14 | 4.26 | 3.82 | 3.28 | 3.32 | 3.05 | 3.37 | 4.40 | 4.72 | 4.24 | 45.83 |
| MD | Baltimore | 30 | 3.47 | 3.02 | 3.93 | 3.00 | 3.89 | 3.43 | 3.85 | 3.74 | 3.98 | 3.16 | 3.12 | 3.35 | 41.94 |
| MA | Blue Hill | 30 | 4.78 | 4.06 | 4.79 | 4.32 | 3.79 | 3.93 | 3.74 | 4.06 | 4.13 | 4.42 | 4.64 | 4.56 | 51.22 |
| | Boston | 30 | 3.92 | 3.30 | 3.85 | 3.60 | 3.24 | 3.22 | 3.06 | 3.37 | 3.47 | 3.79 | 3.98 | 3.73 | 42.53 |
| | Worcester | 30 | 4.07 | 3.10 | 4.23 | 3.92 | 4.35 | 4.02 | 4.19 | 4.09 | 4.27 | 4.67 | 4.34 | 3.80 | 49.05 |
| MI | Alpena | 30 | 1.76 | 1.35 | 2.13 | 2.31 | 2.61 | 2.53 | 3.17 | 3.50 | 2.80 | 2.33 | 2.08 | 1.83 | 28.40 |
| | Detroit | 30 | 1.91 | 1.88 | 2.52 | 3.05 | 3.05 | 3.55 | 3.16 | 3.10 | 3.27 | 2.23 | 2.66 | 2.51 | 32.89 |
| | Flint | 30 | 1.57 | 1.35 | 2.22 | 3.13 | 2.74 | 3.07 | 3.17 | 3.43 | 3.76 | 2.34 | 2.65 | 2.18 | 31.61 |
| | Grand Rapids | 30 | 2.03 | 1.53 | 2.59 | 3.48 | 3.35 | 3.67 | 3.56 | 3.78 | 4.28 | 2.80 | 3.35 | 2.70 | 37.13 |
| | Houghton Lake | 30 | 1.61 | 1.25 | 2.05 | 2.29 | 2.57 | 2.93 | 2.75 | 3.72 | 3.11 | 2.26 | 2.14 | 1.75 | 28.43 |
| | Lansing | 30 | 1.61 | 1.45 | 2.33 | 3.09 | 2.71 | 3.60 | 2.68 | 3.46 | 3.48 | 2.29 | 2.66 | 2.17 | 31.53 |
| | Marquette | 30 | 2.60 | 1.85 | 3.13 | 2.79 | 3.07 | 3.21 | 3.01 | 3.55 | 3.74 | 3.66 | 3.27 | 2.43 | 36.31 |
| | Muskegon | 30 | 2.22 | 1.58 | 2.36 | 2.91 | 2.95 | 2.58 | 2.32 | 3.77 | 3.52 | 2.80 | 3.23 | 2.64 | 32.88 |
| | Sault Ste. Marie | 30 | 2.64 | 1.60 | 2.41 | 2.57 | 2.50 | 3.00 | 3.14 | 3.47 | 3.71 | 3.32 | 3.40 | 2.91 | 34.67 |
| MN | Duluth | 30 | 1.12 | 0.83 | 1.69 | 2.09 | 2.95 | 4.25 | 4.20 | 4.22 | 4.13 | 2.46 | 2.12 | 0.94 | 31.00 |
| | International Falls | 30 | 0.84 | 0.64 | 0.96 | 1.38 | 2.55 | 3.98 | 3.37 | 3.14 | 3.03 | 1.98 | 1.36 | 0.70 | 23.93 |
| | Minneapolis-St. Paul | 30 | 1.04 | 0.79 | 1.86 | 2.31 | 3.24 | 4.34 | 4.04 | 4.05 | 2.69 | 2.11 | 1.94 | 1.00 | 29.41 |
| | Rochester | 30 | 0.94 | 0.75 | 1.88 | 3.01 | 3.53 | 4.00 | 4.61 | 4.33 | 3.12 | 2.20 | 2.01 | 1.02 | 31.40 |
| | Saint Cloud | 30 | 0.76 | 0.59 | 1.50 | 2.13 | 2.97 | 4.51 | 3.34 | 3.93 | 2.93 | 2.24 | 1.54 | 0.69 | 27.13 |
| MS | Jackson | 30 | 5.67 | 4.50 | 5.74 | 5.98 | 4.86 | 3.82 | 4.69 | 3.66 | 3.23 | 3.42 | 5.04 | 5.34 | 55.95 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Meridian | 30 | 5.92 | 5.35 | 6.93 | 5.62 | 4.87 | 3.99 | 5.45 | 3.34 | 3.64 | 3.28 | 4.95 | 5.31 | 58.65 |
| | Tupelo | 30 | 5.14 | 4.68 | 6.30 | 4.94 | 5.80 | 4.82 | 3.65 | 2.67 | 3.35 | 3.38 | 5.01 | 6.12 | 55.86 |
| MO | Columbia | 30 | 1.73 | 2.20 | 3.21 | 4.16 | 4.87 | 4.02 | 3.80 | 3.75 | 3.42 | 3.18 | 3.47 | 2.47 | 40.28 |
| | Kansas City | 30 | 1.15 | 1.31 | 2.44 | 3.38 | 5.39 | 4.44 | 4.42 | 3.54 | 4.64 | 3.33 | 2.30 | 1.64 | 37.98 |
| | St. Louis | 30 | 2.14 | 2.28 | 3.60 | 3.69 | 4.11 | 3.76 | 3.90 | 2.98 | 2.96 | 2.76 | 3.71 | 2.86 | 38.75 |
| | Springfield | 30 | 2.11 | 2.28 | 3.82 | 4.31 | 4.57 | 5.02 | 3.56 | 3.37 | 4.83 | 3.47 | 4.46 | 3.17 | 44.97 |
| MT | Billings | 30 | 0.81 | 0.57 | 1.12 | 1.74 | 2.48 | 1.89 | 1.28 | 0.85 | 1.34 | 1.26 | 0.75 | 0.67 | 14.77 |
| | Glasgow | 30 | 0.35 | 0.26 | 0.47 | 0.75 | 1.72 | 2.20 | 1.78 | 1.25 | 0.98 | 0.71 | 0.39 | 0.37 | 11.23 |
| | Great Falls | 30 | 0.68 | 0.51 | 1.01 | 1.40 | 2.53 | 2.24 | 1.45 | 1.65 | 1.23 | 0.93 | 0.59 | 0.67 | 14.89 |
| | Havre | 30 | 0.47 | 0.36 | 0.70 | 0.87 | 1.84 | 1.90 | 1.51 | 1.20 | 1.03 | 0.62 | 0.45 | 0.51 | 11.46 |
| | Helena | 30 | 0.52 | 0.38 | 0.63 | 0.91 | 1.78 | 1.82 | 1.34 | 1.29 | 1.05 | 0.66 | 0.48 | 0.46 | 11.32 |
| | Kalispell | 30 | 1.47 | 1.15 | 1.11 | 1.22 | 2.04 | 2.30 | 1.41 | 1.25 | 1.20 | 0.96 | 1.45 | 1.65 | 17.21 |
| | Missoula | 30 | 1.06 | 0.77 | 0.96 | 1.09 | 1.95 | 1.73 | 1.09 | 1.15 | 1.08 | 0.83 | 0.96 | 1.15 | 13.82 |
| | Grand Island | 30 | 0.54 | 0.68 | 2.04 | 2.61 | 4.07 | 3.72 | 3.14 | 3.08 | 2.43 | 1.51 | 1.41 | 0.66 | 25.89 |
| NE | Lincoln | 30 | 0.67 | 0.66 | 2.21 | 2.90 | 4.23 | 3.51 | 3.54 | 3.35 | 2.92 | 1.94 | 1.58 | 0.86 | 28.37 |
| | Norfolk | 30 | 0.57 | 0.76 | 1.97 | 2.59 | 3.92 | 4.25 | 3.74 | 2.80 | 2.25 | 1.72 | 1.44 | 0.65 | 26.66 |
| | North Platte | 30 | 0.39 | 0.51 | 1.24 | 1.97 | 3.34 | 3.17 | 3.17 | 2.15 | 1.32 | 1.24 | 0.76 | 0.40 | 19.66 |
| | Omaha Eppley AP | 30 | 0.77 | 0.80 | 2.13 | 2.94 | 4.44 | 3.95 | 3.86 | 3.21 | 3.17 | 2.21 | 1.82 | 0.92 | 30.22 |
| | Omaha (North) | 30 | 0.76 | 0.77 | 2.25 | 3.07 | 4.57 | 3.84 | 3.75 | 2.93 | 3.03 | 2.49 | 1.67 | 0.95 | 30.08 |
| | Scottsbluff | 30 | 0.54 | 0.58 | 1.16 | 1.79 | 2.70 | 2.65 | 2.13 | 1.19 | 1.22 | 1.01 | 0.80 | 0.56 | 16.33 |
| | Valentine | 30 | 0.30 | 0.48 | 1.11 | 1.97 | 3.20 | 3.01 | 3.37 | 2.20 | 1.61 | 1.22 | 0.72 | 0.33 | 19.52 |
| NV | Elko | 30 | 1.14 | 0.88 | 0.98 | 0.81 | 1.08 | 0.67 | 0.30 | 0.36 | 0.68 | 0.71 | 1.05 | 0.93 | 9.59 |
| | Ely | 30 | 0.74 | 0.75 | 1.05 | 0.90 | 1.29 | 0.66 | 0.60 | 0.91 | 0.94 | 1.00 | 0.63 | 0.50 | 9.97 |
| | Las Vegas | 30 | 0.59 | 0.69 | 0.59 | 0.15 | 0.24 | 0.08 | 0.44 | 0.45 | 0.31 | 0.24 | 0.31 | 0.40 | 4.49 |
| | Reno | 30 | 1.06 | 1.06 | 0.86 | 0.35 | 0.62 | 0.47 | 0.24 | 0.27 | 0.45 | 0.42 | 0.80 | 0.88 | 7.48 |
| | Winnemucca | 30 | 0.83 | 0.62 | 0.86 | 0.85 | 1.06 | 0.69 | 0.27 | 0.35 | 0.53 | 0.66 | 0.80 | 0.81 | 8.33 |
| | Concord | 30 | 2.97 | 2.36 | 3.04 | 3.07 | 3.33 | 3.10 | 3.37 | 3.21 | 3.16 | 3.46 | 3.57 | 2.96 | 37.60 |
| | Mt. Washington | 30 | 8.52 | 7.33 | 9.42 | 8.43 | 8.21 | 8.36 | 8.02 | 8.08 | 8.55 | 7.66 | 10.49 | 8.84 | 101.91 |
| NJ | Atlantic City AP | 30 | 3.60 | 2.85 | 4.06 | 3.45 | 3.38 | 2.66 | 3.86 | 4.32 | 3.14 | 2.86 | 3.26 | 3.15 | 40.59 |
| | Atlantic City CO | 30 | 3.44 | 2.88 | 3.79 | 3.25 | 3.16 | 2.46 | 3.36 | 4.16 | 3.02 | 2.71 | 2.96 | 3.18 | 38.37 |
| | Newark | 30 | 3.98 | 2.96 | 4.21 | 3.92 | 4.46 | 3.40 | 4.68 | 4.02 | 4.01 | 3.16 | 3.88 | 3.57 | 46.25 |
| NM | Albuquerque | 30 | 0.49 | 0.44 | 0.61 | 0.50 | 0.60 | 0.65 | 1.27 | 1.73 | 1.07 | 1.00 | 0.62 | 0.49 | 9.47 |
| | Clayton | 30 | 0.30 | 0.27 | 0.62 | 0.99 | 2.08 | 2.21 | 2.81 | 2.69 | 1.56 | 0.74 | 0.54 | 0.32 | 15.13 |
| | Roswell | 30 | 0.39 | 0.41 | 0.35 | 0.58 | 1.30 | 1.62 | 1.99 | 2.31 | 1.98 | 1.29 | 0.53 | 0.59 | 13.34 |
| NY | Albany | 30 | 2.71 | 2.27 | 3.17 | 3.25 | 3.67 | 3.74 | 3.50 | 3.68 | 3.31 | 3.23 | 3.31 | 2.76 | 38.60 |
| | Binghamton | 30 | 2.58 | 2.46 | 2.97 | 3.49 | 3.55 | 3.80 | 3.49 | 3.35 | 3.59 | 3.02 | 3.32 | 3.03 | 38.65 |
| | Buffalo | 30 | 3.16 | 2.42 | 2.99 | 3.04 | 3.35 | 3.82 | 3.14 | 3.87 | 3.84 | 3.19 | 3.92 | 3.80 | 40.54 |
| | Islip | 30 | 4.27 | 3.33 | 4.76 | 4.13 | 3.90 | 3.71 | 2.93 | 4.48 | 3.39 | 3.63 | 3.86 | 4.13 | 46.52 |
| | New York C. Park | 30 | 4.13 | 3.15 | 4.37 | 4.28 | 4.69 | 3.84 | 4.62 | 4.22 | 4.23 | 3.85 | 4.36 | 3.95 | 49.69 |
| | New York (JFK AP) | 30 | 3.62 | 2.70 | 3.78 | 3.75 | 4.13 | 3.59 | 3.92 | 3.64 | 3.50 | 3.03 | 3.48 | 3.31 | 42.46 |
| | New York (Laguardia AP) | 30 | 3.56 | 2.75 | 3.93 | 3.68 | 4.16 | 3.57 | 4.41 | 4.09 | 3.77 | 3.26 | 3.67 | 3.51 | 44.36 |
| | Rochester | 30 | 2.34 | 2.04 | 2.58 | 2.75 | 2.82 | 3.36 | 2.93 | 3.54 | 3.45 | 2.60 | 2.84 | 2.73 | 33.98 |
| | Syracuse | 30 | 2.60 | 2.12 | 3.02 | 3.39 | 3.39 | 3.71 | 4.02 | 3.56 | 4.15 | 3.20 | 3.77 | 3.12 | 40.05 |
| NC | Asheville | 30 | 4.06 | 3.83 | 4.59 | 3.50 | 4.41 | 4.38 | 3.87 | 4.30 | 3.72 | 3.17 | 3.82 | 3.39 | 47.07 |
| | Cape Hatteras | 30 | 5.84 | 3.94 | 4.95 | 3.29 | 3.92 | 3.82 | 4.95 | 6.56 | 5.68 | 5.31 | 4.93 | 4.56 | 57.75 |

*(Continued)*



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**Table 3D.20 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Charlotte | 30 | 4.00 | 3.55 | 4.39 | 2.95 | 3.66 | 3.42 | 3.79 | 3.72 | 3.83 | 3.66 | 3.36 | 3.18 | 43.51 |
| | Greensboro-Wnstn-Slm-HPT | 30 | 3.54 | 3.10 | 3.85 | 3.43 | 3.95 | 3.53 | 4.44 | 3.71 | 4.29 | 3.27 | 2.96 | 3.06 | 43.14 |
| | Raleigh | 30 | 4.02 | 3.47 | 4.03 | 2.80 | 3.79 | 3.42 | 4.29 | 3.78 | 4.26 | 3.18 | 2.97 | 3.04 | 43.05 |
| | Wilmington | 30 | 4.52 | 3.66 | 4.22 | 2.94 | 4.40 | 5.36 | 7.62 | 7.31 | 6.79 | 3.21 | 3.26 | 3.78 | 57.07 |
| ND | Bismarck | 30 | 0.45 | 0.51 | 0.85 | 1.46 | 2.22 | 2.59 | 2.58 | 2.15 | 1.61 | 1.28 | 0.70 | 0.44 | 16.84 |
| | Fargo | 30 | 0.76 | 0.59 | 1.17 | 1.37 | 2.61 | 3.51 | 2.88 | 2.52 | 2.18 | 1.97 | 1.06 | 0.57 | 21.19 |
| | Grand Forks | 30 | 0.68 | 0.58 | 0.89 | 1.23 | 2.21 | 3.03 | 3.06 | 2.72 | 1.96 | 1.70 | 0.99 | 0.55 | 19.60 |
| | Williston | 30 | 0.54 | 0.39 | 0.74 | 1.05 | 1.88 | 2.36 | 2.28 | 1.48 | 1.35 | 0.87 | 0.65 | 0.57 | 14.16 |
| OH | Akron | 30 | 2.49 | 2.28 | 3.15 | 3.39 | 3.96 | 3.55 | 4.02 | 3.65 | 3.43 | 2.53 | 3.04 | 2.98 | 38.47 |
| | Cleveland | 30 | 2.48 | 2.29 | 2.94 | 3.37 | 3.50 | 3.89 | 3.52 | 3.69 | 3.77 | 2.73 | 3.38 | 3.14 | 38.71 |
| | Columbus | 30 | 2.53 | 2.20 | 2.89 | 3.25 | 3.88 | 4.07 | 4.61 | 3.72 | 2.92 | 2.31 | 3.19 | 2.93 | 38.52 |
| | Dayton | 30 | 2.60 | 2.29 | 3.29 | 4.03 | 4.17 | 4.21 | 3.75 | 3.49 | 2.65 | 2.72 | 3.30 | 3.08 | 39.58 |
| | Mansfield | 30 | 2.63 | 2.17 | 3.36 | 4.17 | 4.42 | 4.52 | 4.22 | 4.60 | 3.44 | 2.68 | 3.76 | 3.26 | 43.24 |
| | Toledo | 30 | 1.93 | 1.88 | 2.62 | 3.24 | 3.14 | 3.80 | 2.80 | 3.19 | 2.84 | 2.35 | 2.78 | 2.64 | 33.21 |
| | Youngstown | 30 | 2.34 | 2.03 | 3.05 | 3.33 | 3.45 | 3.91 | 4.10 | 3.43 | 3.89 | 2.46 | 3.07 | 2.96 | 38.02 |
| OK | Oklahoma City | 30 | 1.28 | 1.56 | 2.90 | 3.00 | 5.44 | 4.63 | 2.94 | 2.48 | 3.98 | 3.64 | 2.11 | 1.89 | 35.85 |
| | Tulsa | 30 | 1.60 | 1.95 | 3.57 | 3.95 | 6.11 | 4.72 | 2.96 | 2.85 | 4.76 | 4.05 | 3.47 | 2.43 | 42.42 |
| OR | Astoria | 30 | 9.62 | 7.87 | 7.37 | 4.93 | 3.28 | 2.57 | 1.16 | 1.21 | 2.61 | 5.61 | 10.50 | 10.40 | 67.13 |
| | Burns | 30 | 1.18 | 1.11 | 1.24 | 0.85 | 1.05 | 0.66 | 0.40 | 0.45 | 0.50 | 0.72 | 1.11 | 1.30 | 10.57 |
| | Eugene | 30 | 7.65 | 6.35 | 5.80 | 3.66 | 2.66 | 1.53 | 0.64 | 0.99 | 1.54 | 3.35 | 8.44 | 8.29 | 50.90 |
| | Medford | 30 | 2.47 | 2.10 | 1.85 | 1.31 | 1.21 | 0.68 | 0.31 | 0.52 | 0.78 | 1.31 | 2.93 | 2.90 | 18.37 |
| | Pendleton | 30 | 1.45 | 1.22 | 1.26 | 1.13 | 1.22 | 0.78 | 0.41 | 0.56 | 0.63 | 0.99 | 1.63 | 1.48 | 12.76 |
| | Portland | 30 | 5.07 | 4.18 | 3.71 | 2.64 | 2.38 | 1.59 | 0.72 | 0.93 | 1.65 | 2.88 | 5.61 | 5.71 | 37.07 |
| | Salem | 30 | 5.84 | 5.09 | 4.17 | 2.76 | 2.13 | 1.45 | 0.57 | 0.68 | 1.43 | 3.03 | 6.39 | 6.46 | 40.00 |
| | Sexton Summit | 30 | 4.71 | 4.29 | 3.92 | 2.38 | 1.35 | 0.94 | 0.35 | 0.61 | 1.20 | 2.93 | 5.32 | 5.18 | 33.18 |
| PC | Guam | 30 | 5.58 | 5.11 | 4.24 | 4.16 | 6.39 | 6.28 | 11.66 | 16.17 | 13.69 | 11.88 | 9.34 | 6.11 | 100.61 |
| | Johnston Island | 30 | 1.64 | 1.29 | 2.01 | 1.86 | 1.14 | 0.87 | 1.40 | 2.07 | 2.46 | 2.78 | 4.78 | 2.70 | 25.00 |
| | Koror | 30 | 11.20 | 9.65 | 8.79 | 9.45 | 11.27 | 17.54 | 16.99 | 14.47 | 11.65 | 13.41 | 11.62 | 12.33 | 148.37 |
| | Kwajalein, Marshall IS | 30 | 5.12 | 3.73 | 3.82 | 7.63 | 8.62 | 8.86 | 10.24 | 10.42 | 11.82 | 11.46 | 10.74 | 7.94 | 100.40 |
| | Majuro, Marshall IS | 30 | 8.09 | 6.86 | 8.43 | 11.30 | 11.53 | 11.09 | 12.41 | 11.95 | 11.96 | 13.73 | 12.81 | 11.50 | 131.66 |
| | Pago Pago, Amer Samoa | 30 | 14.02 | 12.14 | 11.15 | 11.16 | 10.43 | 5.94 | 5.76 | 6.43 | 7.36 | 10.03 | 11.16 | 13.38 | 118.96 |
| | Pohnpei, Caroline IS | 30 | 12.52 | 9.78 | 13.96 | 16.94 | 19.41 | 17.06 | 16.72 | 16.37 | 14.94 | 16.30 | 14.74 | 15.87 | 184.61 |
| | Chuuk, E. Caroline IS | 30 | 8.58 | 8.77 | 8.15 | 10.94 | 11.29 | 12.82 | 12.45 | 15.09 | 13.12 | 10.69 | 11.09 | 10.98 | 133.97 |
| | Wake Island | 30 | 1.40 | 1.89 | 2.38 | 2.11 | 1.70 | 1.95 | 3.44 | 5.62 | 4.82 | 4.27 | 2.78 | 1.87 | 34.23 |
| | Yap, W Caroline IS | 30 | 7.24 | 5.45 | 6.14 | 5.58 | 8.15 | 13.46 | 13.25 | 14.41 | 13.53 | 12.25 | 8.82 | 9.34 | 117.62 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PA | Allentown | 30 | 3.50 | 2.75 | 3.56 | 3.49 | 4.47 | 3.99 | 4.27 | 4.35 | 4.37 | 3.33 | 3.70 | 3.39 | 45.17 |
| | Erie | 30 | 2.53 | 2.28 | 3.13 | 3.38 | 3.34 | 4.28 | 3.28 | 4.21 | 4.73 | 3.92 | 3.96 | 3.73 | 42.77 |
| | Harrisburg | 30 | 3.18 | 2.88 | 3.58 | 3.31 | 4.60 | 3.99 | 3.21 | 3.24 | 3.65 | 3.06 | 3.53 | 3.22 | 41.45 |
| | Middletown/ Harrisburg AP | 30 | 3.18 | 2.88 | 3.58 | 3.31 | 4.60 | 3.99 | 3.21 | 3.24 | 3.65 | 3.06 | 3.53 | 3.22 | 41.45 |
| | Philadelphia | 30 | 3.52 | 2.74 | 3.81 | 3.49 | 3.88 | 3.29 | 4.39 | 3.82 | 3.88 | 2.75 | 3.16 | 3.31 | 42.05 |
| | Pittsburgh | 30 | 2.70 | 2.37 | 3.17 | 3.01 | 3.80 | 4.12 | 3.96 | 3.38 | 3.21 | 2.25 | 3.02 | 2.86 | 37.85 |
| | Avoca | 30 | 2.46 | 2.08 | 2.69 | 3.28 | 3.69 | 3.97 | 3.74 | 3.10 | 3.86 | 3.02 | 3.12 | 2.55 | 37.56 |
| | Williamsport | 30 | 2.85 | 2.61 | 3.21 | 3.49 | 3.79 | 4.45 | 4.08 | 3.38 | 3.98 | 3.19 | 3.62 | 2.94 | 41.59 |
| RI | Block IS | 30 | 3.68 | 3.04 | 3.99 | 3.72 | 3.40 | 2.77 | 2.62 | 3.00 | 3.19 | 3.04 | 3.77 | 3.57 | 39.79 |
| | Providence | 30 | 4.37 | 3.45 | 4.43 | 4.16 | 3.66 | 3.38 | 3.17 | 3.90 | 3.70 | 3.69 | 4.40 | 4.14 | 46.45 |
| SC | Charleston AP | 30 | 4.08 | 3.08 | 4.00 | 2.77 | 3.67 | 5.92 | 6.13 | 6.91 | 5.98 | 3.09 | 2.66 | 3.24 | 51.53 |
| | Charleston CO | 30 | 3.62 | 2.62 | 3.83 | 2.44 | 2.77 | 4.96 | 5.50 | 6.54 | 6.13 | 3.02 | 2.18 | 2.78 | 46.39 |
| | Columbia | 30 | 4.66 | 3.84 | 4.59 | 2.98 | 3.17 | 4.99 | 5.54 | 5.41 | 3.94 | 2.89 | 2.88 | 3.38 | 48.27 |
| | Greenville-Spartanburg AP | 30 | 4.41 | 4.24 | 5.31 | 3.53 | 4.59 | 3.92 | 4.65 | 4.08 | 3.96 | 3.88 | 3.79 | 3.86 | 50.24 |
| SD | Aberdeen | 30 | 0.48 | 0.48 | 1.34 | 1.83 | 2.69 | 3.49 | 2.92 | 2.42 | 1.81 | 1.63 | 0.75 | 0.38 | 20.22 |
| | Huron | 30 | 0.48 | 0.57 | 1.67 | 2.29 | 3.00 | 3.28 | 2.86 | 2.07 | 1.80 | 1.59 | 0.89 | 0.39 | 20.90 |
| | Rapid City | 30 | 0.37 | 0.46 | 1.03 | 1.86 | 2.96 | 2.83 | 2.03 | 1.61 | 1.10 | 1.37 | 0.61 | 0.40 | 16.64 |
| | Sioux Falls | 30 | 0.51 | 0.51 | 1.81 | 2.65 | 3.39 | 3.49 | 2.93 | 3.01 | 2.58 | 1.93 | 1.36 | 0.52 | 24.69 |
| TN | Bristol-JhnCty-Kgsprt | 30 | 3.52 | 3.40 | 3.91 | 3.23 | 4.32 | 3.89 | 4.21 | 3.00 | 3.08 | 2.30 | 3.08 | 3.39 | 41.33 |
| | Chattanooga | 30 | 5.40 | 4.85 | 6.19 | 4.23 | 4.28 | 3.99 | 4.73 | 3.59 | 4.31 | 3.26 | 4.88 | 4.81 | 54.52 |
| | Knoxville | 30 | 4.57 | 4.01 | 5.17 | 3.99 | 4.68 | 4.04 | 4.71 | 2.89 | 3.04 | 2.65 | 3.98 | 4.49 | 48.22 |
| | Memphis | 30 | 4.24 | 4.31 | 5.58 | 5.79 | 5.15 | 4.30 | 4.22 | 3.00 | 3.31 | 3.31 | 5.76 | 5.68 | 54.65 |
| | Nashville | 30 | 3.97 | 3.69 | 4.87 | 3.93 | 5.07 | 4.08 | 3.77 | 3.28 | 3.59 | 2.87 | 4.45 | 4.54 | 48.11 |
| | Oak Ridge | 30 | 5.13 | 4.50 | 5.72 | 4.32 | 5.14 | 4.64 | 5.16 | 3.39 | 3.75 | 3.02 | 4.86 | 5.42 | 55.05 |
| TX | Abilene | 30 | 0.97 | 1.13 | 1.41 | 1.67 | 2.83 | 3.06 | 1.69 | 2.63 | 2.91 | 2.90 | 1.30 | 1.27 | 23.78 |
| | Amarillo | 30 | 0.63 | 0.55 | 1.13 | 1.33 | 2.50 | 3.28 | 2.68 | 2.94 | 1.88 | 1.50 | 0.68 | 0.61 | 19.71 |
| | Austin/City | 30 | 1.89 | 1.99 | 2.14 | 2.51 | 5.03 | 3.81 | 1.97 | 2.31 | 2.91 | 3.97 | 2.68 | 2.44 | 33.65 |
| | Austin/ Bergstrom | 30 | 2.20 | 1.73 | 1.98 | 2.77 | 5.87 | 3.38 | 1.61 | 1.48 | 2.63 | 2.70 | 2.61 | 2.39 | 31.36 |
| | Brownsville | 30 | 1.36 | 1.18 | 0.93 | 1.96 | 2.48 | 2.93 | 1.77 | 2.99 | 5.31 | 3.78 | 1.75 | 1.11 | 27.55 |
| | Corpus Christi | 30 | 1.62 | 1.84 | 1.73 | 2.05 | 3.48 | 3.53 | 2.00 | 3.54 | 5.03 | 3.94 | 1.74 | 1.75 | 32.26 |
| | Dallas-Fort Worth | 30 | 1.90 | 2.37 | 3.06 | 3.20 | 5.15 | 3.23 | 2.12 | 2.03 | 2.42 | 4.11 | 2.57 | 2.57 | 34.73 |
| | Dallas-Love Field | 30 | 1.89 | 2.31 | 3.13 | 3.46 | 5.30 | 3.92 | 2.43 | 2.17 | 2.65 | 4.65 | 2.61 | 2.53 | 37.05 |
| | Del Rio | 30 | 0.57 | 0.96 | 0.96 | 1.71 | 2.31 | 2.34 | 2.02 | 1.59 | 2.06 | 2.00 | 0.96 | 0.75 | 18.23 |
| | El Paso | 30 | 0.45 | 0.39 | 0.26 | 0.23 | 0.38 | 0.87 | 1.49 | 1.75 | 1.61 | 0.81 | 0.42 | 0.77 | 9.43 |
| | Galveston | 30 | 4.08 | 2.61 | 2.76 | 2.56 | 3.70 | 4.04 | 3.45 | 4.22 | 5.76 | 3.49 | 3.64 | 3.53 | 43.84 |
| | Houston | 30 | 3.68 | 2.98 | 3.36 | 3.60 | 5.15 | 5.35 | 3.18 | 3.83 | 4.33 | 4.50 | 4.19 | 3.69 | 47.84 |
| | Lubbock | 30 | 0.50 | 0.71 | 0.76 | 1.29 | 2.31 | 2.98 | 2.13 | 2.35 | 2.57 | 1.70 | 0.71 | 0.67 | 18.69 |
| | Midland-Odessa | 30 | 0.53 | 0.58 | 0.42 | 0.73 | 1.79 | 1.71 | 1.89 | 1.77 | 2.31 | 1.77 | 0.65 | 0.65 | 14.80 |
| | Port Arthur | 30 | 5.69 | 3.35 | 3.75 | 3.84 | 5.83 | 6.58 | 5.23 | 4.85 | 6.10 | 4.67 | 4.75 | 5.25 | 59.89 |
| | San Angelo | 30 | 0.81 | 1.18 | 0.99 | 1.60 | 3.09 | 2.52 | 1.10 | 2.05 | 2.95 | 2.57 | 1.10 | 0.94 | 20.91 |

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**Table 3D.20 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | San Antonio | 30 | 1.66 | 1.75 | 1.89 | 2.60 | 4.72 | 4.30 | 2.03 | 2.57 | 3.00 | 3.86 | 2.58 | 1.96 | 32.92 |
| | Victoria | 30 | 2.44 | 2.04 | 2.25 | 2.97 | 5.12 | 4.96 | 2.90 | 3.05 | 5.00 | 4.26 | 2.64 | 2.47 | 40.10 |
| | Waco | 30 | 1.90 | 2.43 | 2.48 | 2.99 | 4.46 | 3.08 | 2.23 | 1.85 | 2.88 | 3.67 | 2.61 | 2.76 | 33.34 |
| | Wichita Falls | 30 | 1.12 | 1.57 | 2.27 | 2.62 | 3.92 | 3.69 | 1.58 | 2.38 | 3.19 | 3.11 | 1.68 | 1.68 | 28.83 |
| UT | Milford | 30 | 0.73 | 0.77 | 1.21 | 0.99 | 0.94 | 0.44 | 0.76 | 1.04 | 0.92 | 1.12 | 0.77 | 0.58 | 10.27 |
| | Salt Lake City | 30 | 1.37 | 1.33 | 1.91 | 2.02 | 2.09 | 0.77 | 0.72 | 0.76 | 1.33 | 1.57 | 1.40 | 1.23 | 16.50 |
| VT | Burlington | 30 | 2.22 | 1.67 | 2.32 | 2.88 | 3.32 | 3.43 | 3.97 | 4.01 | 3.83 | 3.12 | 3.06 | 2.22 | 36.05 |
| VA | Lynchburg | 30 | 3.54 | 3.10 | 3.83 | 3.46 | 4.11 | 3.79 | 4.39 | 3.41 | 3.88 | 3.39 | 3.18 | 3.23 | 43.31 |
| | Norfolk | 30 | 3.93 | 3.34 | 4.08 | 3.38 | 3.74 | 3.77 | 5.17 | 4.79 | 4.06 | 3.47 | 2.98 | 3.03 | 45.74 |
| | Richmond | 30 | 3.55 | 2.98 | 4.09 | 3.18 | 3.95 | 3.54 | 4.67 | 4.18 | 3.98 | 3.60 | 3.06 | 3.12 | 43.91 |
| | Roanoke | 30 | 3.23 | 3.08 | 3.84 | 3.61 | 4.24 | 3.68 | 4.00 | 3.74 | 3.85 | 3.15 | 3.21 | 2.86 | 42.49 |
| WA | Olympia | 30 | 7.54 | 6.17 | 5.29 | 3.58 | 2.27 | 1.78 | 0.82 | 1.10 | 2.03 | 4.19 | 8.13 | 7.89 | 50.79 |
| | Quillayute | 30 | 13.65 | 12.35 | 10.98 | 7.44 | 5.51 | 3.50 | 2.34 | 2.67 | 4.15 | 9.81 | 14.82 | 14.50 | 101.72 |
| | Seattle CO | 30 | 5.24 | 4.09 | 3.92 | 2.75 | 2.03 | 1.55 | 0.93 | 1.16 | 1.61 | 3.24 | 5.67 | 6.06 | 38.25 |
| | Seattle Sea-Tac AP | 30 | 5.13 | 4.18 | 3.75 | 2.59 | 1.77 | 1.49 | 0.79 | 1.02 | 1.63 | 3.19 | 5.90 | 5.62 | 37.07 |
| | Spokane | 30 | 1.82 | 1.51 | 1.53 | 1.28 | 1.60 | 1.18 | 0.76 | 0.68 | 0.76 | 1.06 | 2.24 | 2.25 | 16.67 |
| | Walla Walla | 30 | 2.25 | 1.97 | 2.20 | 1.83 | 1.95 | 1.15 | 0.73 | 0.84 | 0.83 | 1.77 | 2.85 | 2.51 | 20.88 |
| | Yakima | 30 | 1.17 | 0.80 | 0.70 | 0.53 | 0.51 | 0.62 | 0.22 | 0.36 | 0.39 | 0.53 | 1.05 | 1.38 | 8.26 |
| PR | San Juan | 30 | 3.02 | 2.30 | 2.14 | 3.71 | 5.29 | 3.52 | 4.16 | 5.22 | 5.60 | 5.06 | 6.17 | 4.57 | 50.76 |
| WV | Beckley | 30 | 3.23 | 2.96 | 3.63 | 3.42 | 4.39 | 3.92 | 4.78 | 3.45 | 3.23 | 2.64 | 2.88 | 3.09 | 41.63 |
| | Charleston | 30 | 3.25 | 3.19 | 3.90 | 3.25 | 4.30 | 4.09 | 4.86 | 4.11 | 3.45 | 2.67 | 3.66 | 3.32 | 44.05 |
| | Elkins | 30 | 3.43 | 3.20 | 3.92 | 3.53 | 4.77 | 4.61 | 4.83 | 4.26 | 3.82 | 2.86 | 3.42 | 3.44 | 46.11 |
| | Huntington | 30 | 3.21 | 3.09 | 3.83 | 3.33 | 4.41 | 3.88 | 4.46 | 3.88 | 2.80 | 2.73 | 3.32 | 3.37 | 42.31 |
| WI | Green Bay | 30 | 1.21 | 1.01 | 2.06 | 2.56 | 2.75 | 3.43 | 3.44 | 3.77 | 3.11 | 2.17 | 2.27 | 1.41 | 29.19 |
| | La Crosse | 30 | 1.19 | 0.99 | 2.00 | 3.38 | 3.38 | 4.00 | 4.25 | 4.28 | 3.40 | 2.16 | 2.10 | 1.23 | 32.36 |
| | Madison | 30 | 1.25 | 1.28 | 2.28 | 3.35 | 3.25 | 4.05 | 3.93 | 4.33 | 3.08 | 2.18 | 2.31 | 1.66 | 32.95 |
| | Milwaukee | 30 | 1.85 | 1.65 | 2.59 | 3.78 | 3.06 | 3.56 | 3.58 | 4.03 | 3.30 | 2.49 | 2.70 | 2.22 | 34.81 |
| WY | Casper | 30 | 0.58 | 0.64 | 0.90 | 1.52 | 2.38 | 1.43 | 1.29 | 0.73 | 0.98 | 1.14 | 0.82 | 0.62 | 13.03 |
| | Cheyenne | 30 | 0.45 | 0.44 | 1.05 | 1.55 | 2.48 | 2.12 | 2.26 | 1.82 | 1.43 | 0.75 | 0.64 | 0.46 | 15.45 |
| | Lander | 30 | 0.52 | 0.54 | 1.24 | 2.07 | 2.38 | 1.15 | 0.84 | 0.57 | 1.14 | 1.37 | 0.99 | 0.61 | 13.42 |
| | Sheridan | 30 | 0.77 | 0.57 | 1.00 | 1.77 | 2.41 | 2.02 | 1.11 | 0.80 | 1.38 | 1.41 | 0.80 | 0.68 | 14.72 |

*Note:* Based on 30-year average values 1971–2000. The normal precipitation is the arithmetic mean for each month over the 30-year period and includes the liquid water equivalent of snowfall. The annual value is the total of the unrounded monthly values and may not agree with the sum of the rounded monthly values.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.

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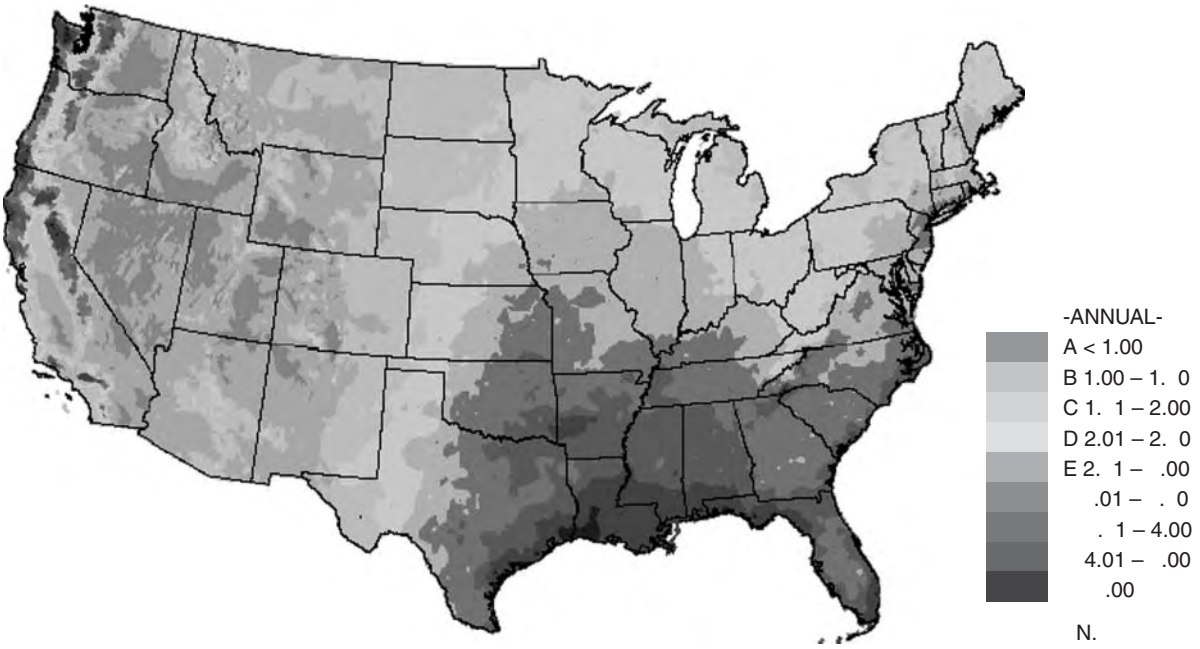


**Figure 3D.10** U.S. mean maximum daily precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

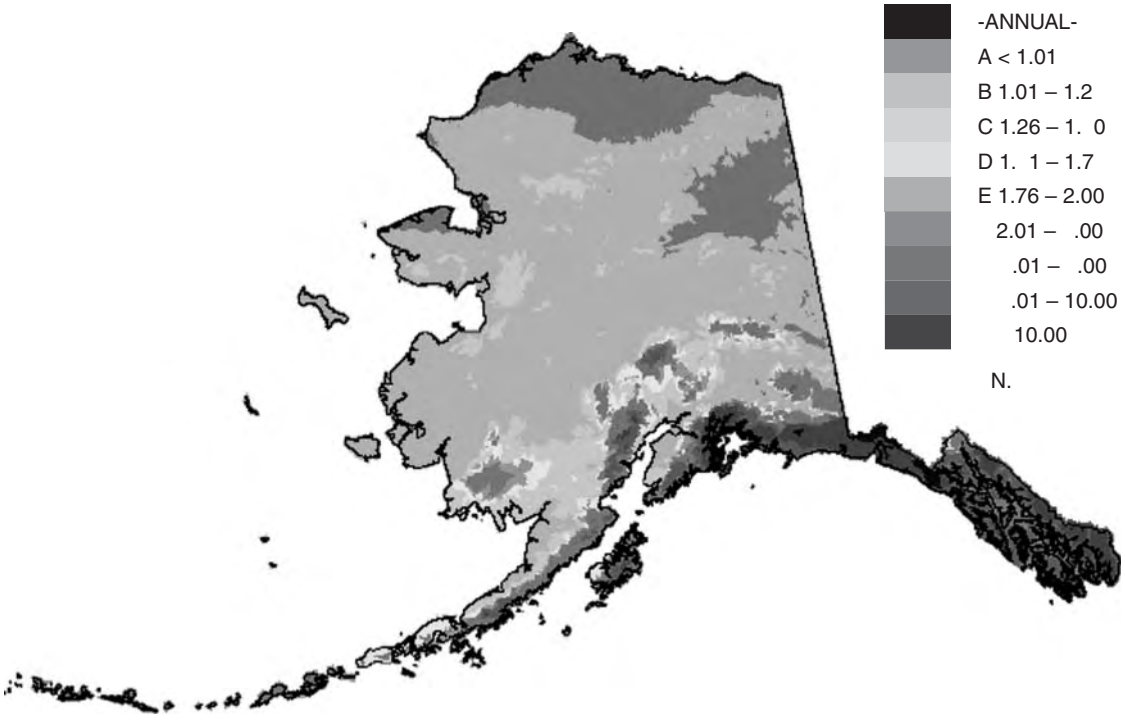


**Figure 3D.11** Alaska mean maximum daily precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

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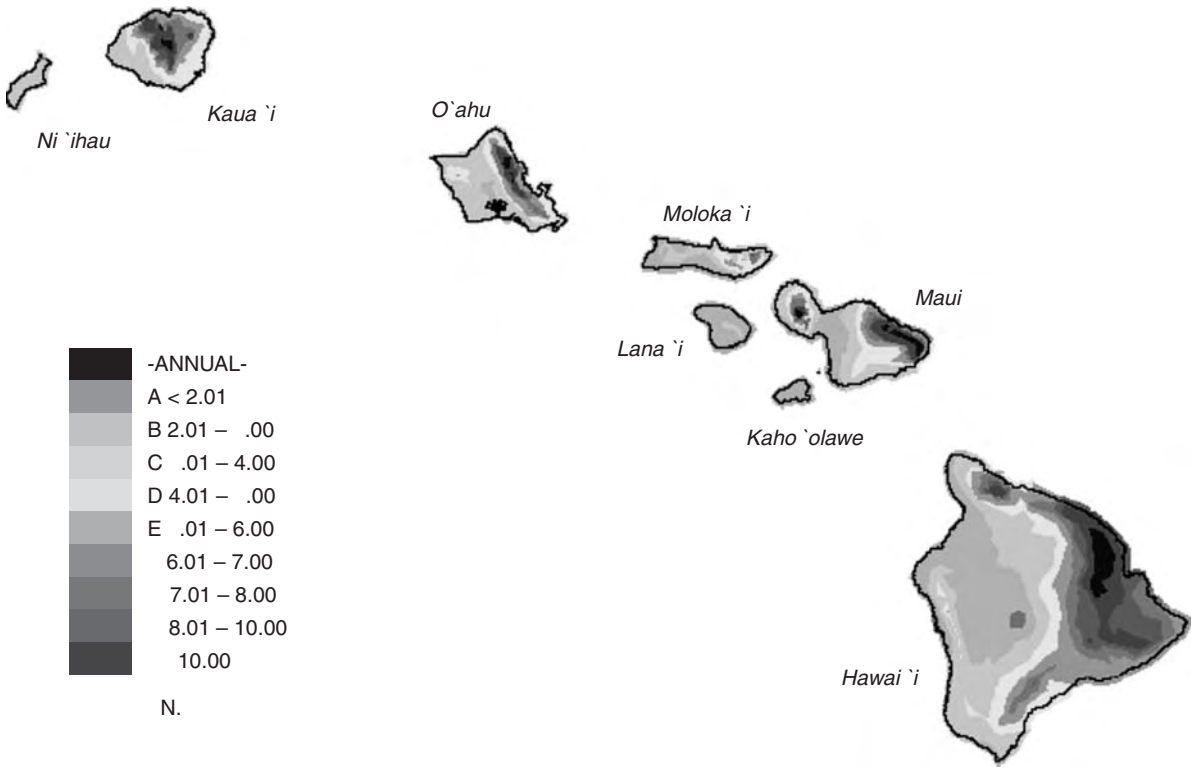


**Figure 3D.12** Hawaii mean maximum daily precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

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**Table 3D.21 Record Maximum Annual Precipitation by State**

| State | Precipitation (inches) | Date | Station | Elevation (ft) |
|---|---|---|---|---|
| Alabama | 98.22 | 1961 | Citronelle | 331 |
| Alaska | 332.29 | 1976 | MacLeod Harbor | 40 |
| Arizona | 58.92 | 1978 | Hawley Lake | 8,180 |
| Arkansas | 98.55 | 1957 | Newhope | 2,420 |
| California | 153.54 | 1909 | Monumental | 2,420 |
| Colorado | 92.84 | 1897 | Ruby | est.10,000 |
| Connecticut | 78.53[a] | 1955 | Burlington | 460 |
| Delaware | 72.75 | 1948 | Lewes | 10 |
| Florida | 112.43[a] | 1966 | Wewahitchka | 50 |
| Georgia | 122.16 | 1959 | Flat Top | est. 3,600 |
| Hawaii | 704.83 | 1982 | Kukui | 5,788 |
| Idaho | 81.05 | 1933 | Roland | 4,150 |
| Illinois | 74.58 | 1950 | New Burnside | 560 |
| Indiana | 97.38 | 1890 | Marengo | 570 |
| Iowa | 74.50 | 1851 | Muscatine | 680 |
| Kansas | 68.55[a] | 1993 | Blaine | 1,530 |
| Kentucky | 79.68 | 1950 | Russelville | 590 |
| Louisiana | 113.74[a] | 1991 | New Orleans (Audubon) | 6 |
| Maine | 75.64 | 1845 | Brunswick | 70 |
| Maryland | 76.52 | 1971 | Towson | 390 |
| Massachusetts | 76.49[a] | 1996 | New Salem | 845 |
| Michigan | 64.01 | 1881 | Adrian | 770 |
| Minnesota | 52.36 | 1993 | Fairmont | 1,187 |
| Mississippi | 104.36[a] | 1991 | Waveland | 8 |
| Missouri | 92.77 | 1957 | Portageville | 280 |
| Montana | 55.51 | 1953 | Summit | 5,210 |
| Nebraska | 64.52 | 1896 | Omaha | 980 |
| Nevada | 59.03 | 1969 | Mt. Rose Resort | est. 7,300 |
| New Hampshire | 130.14 | 1969 | Mount Washington | 6,260 |
| New Jersey | 85.99 | 1882 | Paterson | 100 |
| New Mexico | 62.45 | 1941 | White Tail | 7,450 |
| New York | 90.97 | 1996 | Slide Mountain | 2,649 |
| North Carolina | 129.60 | 1964 | Rosman | 2,220 |
| North Dakota | 37.98 | 1944 | Milnor | 2,600 |
| Ohio | 70.82 | 1870 | Little Mountain | 1,187 |
| Oklahoma | 84.47 | 1957 | Kiamichi Tower | 2,350 |
| Oregon | 204.04 | 1996 | Laurel Mountain | 3,590 |
| Pennsylvania | 81.64 | 1952 | Mt. Pocono | 1,910 |
| Rhode Island | 70.21 | 1983 | Kingston | 100 |
| South Carolina | 110.79 | 1994 | Jocassee | 2,500 |
| South Dakota | 48.42 | 1946 | Deadwood | 4,550 |
| Tennessee | 114.88 | 1957 | Haw Knob | 4,900 |
| Texas | 109.38 | 1873 | Clarksville | 440 |
| Utah | 108.54 | 1983 | Alta | 8,760 |
| Vermont | 100.96[a] | 1996 | Mt. Mansfield | 3,950 |
| Virginia | 83.70[a] | 1996 | Philpott Dam | 1,123 |
| Washington | 184.56 | 1931 | Wynoochee Oxbow | 670 |
| West Virginia | 89.01 | 1926 | Bayard | 2,381 |
| Wisconsin | 62.07 | 1884 | Embarrass | 808 |
| Wyoming | 55.46 | 1945 | Grassy Lake Dam | 7,240 |

[a] At least one month estimated.

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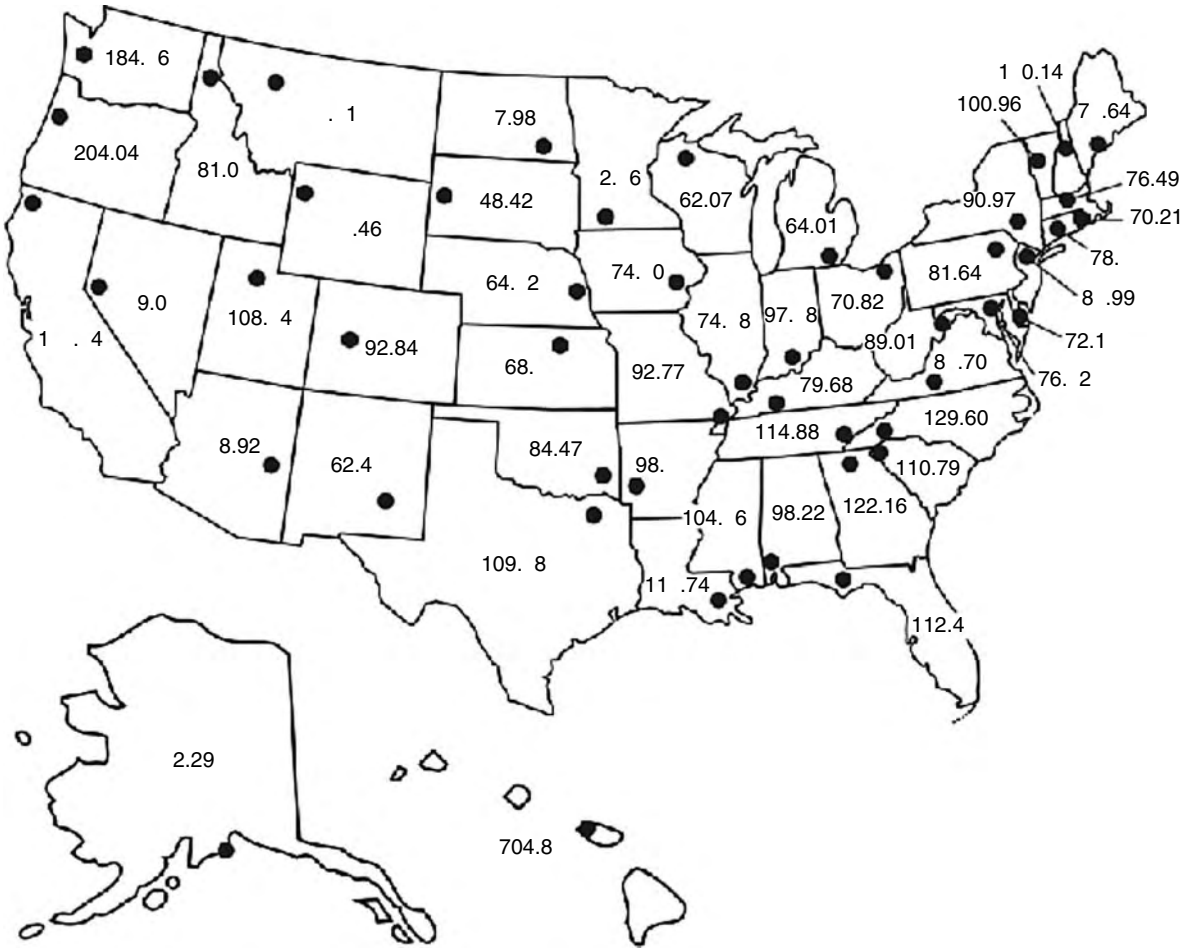


**Figure 3D.13** Record maximum annual precipitation (in.) (through 1998) (*at least one month estimate). (From U.S. National Oceanic and Atmospheric Administration, *Comparative Climate Data for the United States Through 2000*. www.noaa.gov.)

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**Table 3D.22 Record Maximum 24-hour Precipitation by State**

| State | Precip. (inches) | Date | Station | Elevation (feet) |
|---|---|---|---|---|
| Alabama | 32.52 | Jul 19–20, 1997 | Dauphin Is Sea Lab | 8 |
| Alaska | 15.20 | Oct 12, 1982 | Angoon | 15 |
| Arizona | 11.40 | Sep 4–5, 1970 | Workman Creek | 6,970 |
| Arkansas | 14.06 | Dec 3, 1982 | Big Fork | 1,100 |
| California | 26.12 | Jan 22–23, 1943 | Hoegees Camp | 2,760 |
| Colorado | 11.08 | Jun 17, 1965 | Holly | 3,390 |
| Connecticut | 12.77 | Aug 19, 1955 | Burlington | 460 |
| Delaware | 8.50 | Jul 13, 1975 | Dover | 30 |
| Florida | 38.70 | Sep 5, 1950 | Yankeetown | 5 |
| Georgia | 21.10 | Jul 6, 1994 | Americus | 490 |
| Hawaii | 38.00 | Jan 24–25, 1956 | Kilauea Plantation | 180 |
| Idaho | 7.17 | Nov 23, 1909 | Rattlesnake Creek | 4,000 |
| Illinois | 16.91 | Jul 18, 1996 | Aurora | 640 |
| Indiana | 10.50 | Aug 6, 1905 | Princeton | 480 |
| Iowa | 16.70 | Aug 5–6, 1959 | Decatur Co. | 1,110 |
| Kansas | 12.59 | May 31–Jun 1, 1941 | Burlington | 1,010 |
| Kentucky | 10.40 | Jun 28, 1960 | Dunmor | 610 |
| Louisiana | 22.00 | Aug 28–29, 1962 | Hackberry | 10 |
| Maine | 13.32 | Oct 20–21, 1996 | Portland | 45 |
| Maryland | 14.75 | Jul 26–27, 1897 | Jewell | 165 |
| Massachusetts | 18.15 | Aug 18–19, 1955 | Westfield | 220 |
| Michigan | 9.78 | Aug 31–Sep. 1, 1914 | Bloomingdale | 750 |
| Minnesota | 10.84 | Jul 21–22, 1972 | Fort Ripley | 1,140 |
| Mississippi | 15.68 | Jul 9, 1968 | Columbus | 190 |
| Missouri | 18.18 | Jul 20, 1965 | Edgarton | 856 |
| Montana | 11.50 | Jun 20, 1921 | Circle | 2,440 |
| Nebraska | 13.15 | Jul 8–9, 1950 | York | 1,610 |
| Nevada | 7.13 | Jan 31, 1963 | Mt. Rose Hwy. Stn. | 7,360 |
| New Hampshire | 10.38 | Feb 10–11, 1970 | Mount Washington | 6,262 |
| New Jersey | 14.81 | Aug 19, 1939 | Tuckerton | 20 |
| New Mexico | 11.28 | May 18–19, 1955 | Lake Maloya | 7,400 |
| New York | 11.17 | Oct 9, 1903 | NYC Central Park | 130 |
| North Carolina | 22.22 | Jul 15–16, 1916 | Altapass | 2,600 |
| North Dakota | 8.10 | Jun 29, 1975 | Litchville | 1,470 |
| Ohio | 10.75 | Aug 7–8, 1995 | Lockington Dam | 950 |
| Oklahoma | 15.68 | Oct 11, 1973 | Enid | 1,245 |
| Oregon | 11.65 | Nov 19, 1996 | Port Orford | 150 |
| Pennsylvania | 34.50[a] | Jul 17, 1942 | Smethport | 1,510 |
| Rhode Island | 12.13 | Sept 16–17, 1932 | Westerly | 40 |
| South Carolina | 17.00 | Aug 27, 1995 | Antreville | 700 |
| South Dakota | 8.00 | Sep 10, 1900 | Elk Point | 1,127 |
| Tennessee | 11.00 | Mar 28, 1902 | McMinnville | 900 |
| Texas | 43.00[a] | Jul 25–26, 1979 | Alvin | 50 |
| Utah | 6.00[a] | Sept 5, 1970 | Bug Point | 6,600 |
| Vermont | 8.77 | Nov 3–4, 1927 | Somerset | 2,080 |
| Virginia | 27.00[a] | Aug 20 1969 | Nelson Co. | Est 500 |
| Washington | 14.26 | Nov 23–24, 1986 | Mt. Mitchell #2 | 3,600 |
| West Virginia | 19.00[a] | Jul 18, 1889 | Rockport | 700 |
| Wisconsin | 11.72 | Jun 24, 1946 | Mellen | 1,150 |
| Wyoming | 6.06 | Aug 1, 1985 | Cheyenne | 6,126 |

[a] Estimated.

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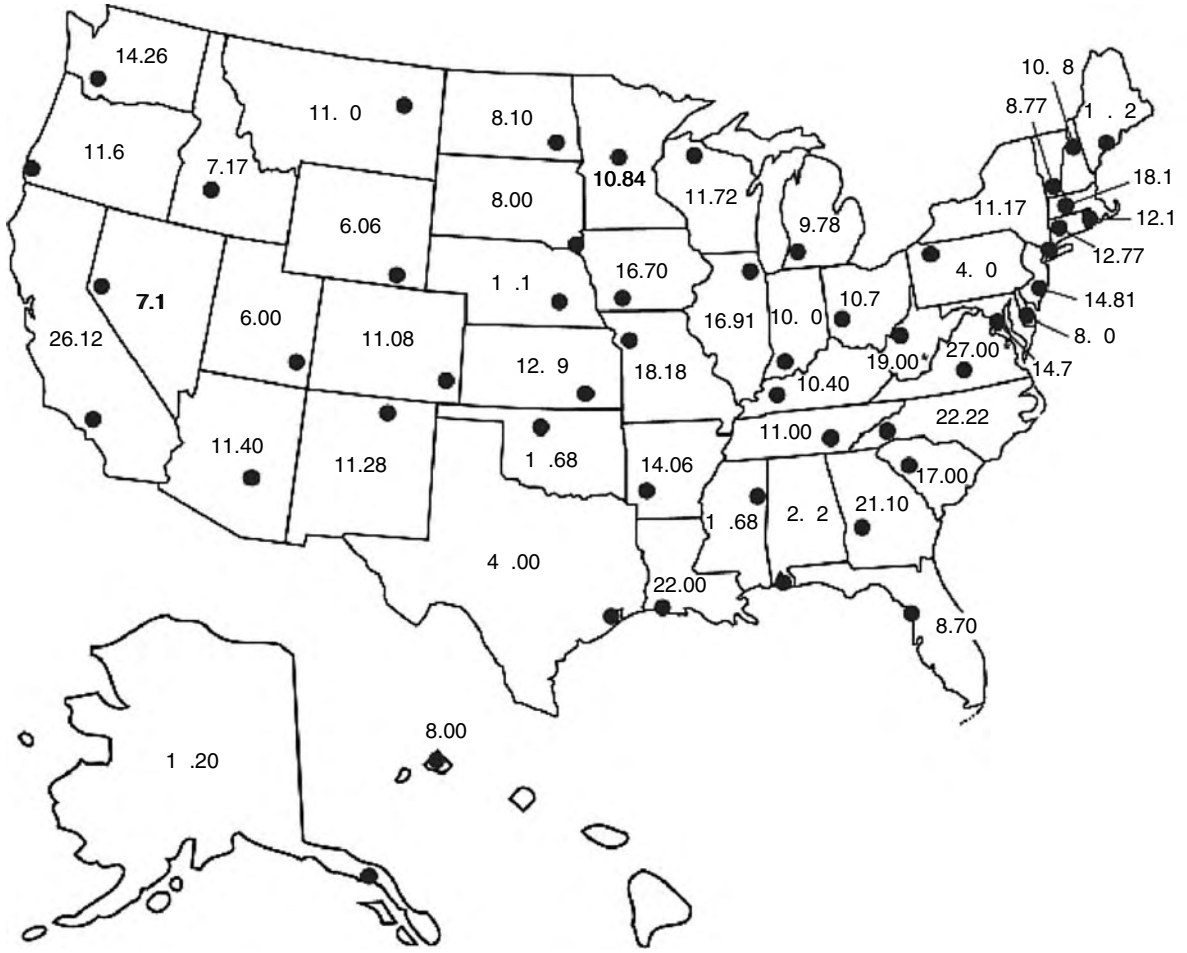


**Figure 3D.14** Record maximum 24-h precipitation (in.) (through 1998) (*estimated). (From U.S. National Oceanic and Atmospheric Administration, *Comparative Climate Data for the United States Through 2000*, www.noaa.gov.)

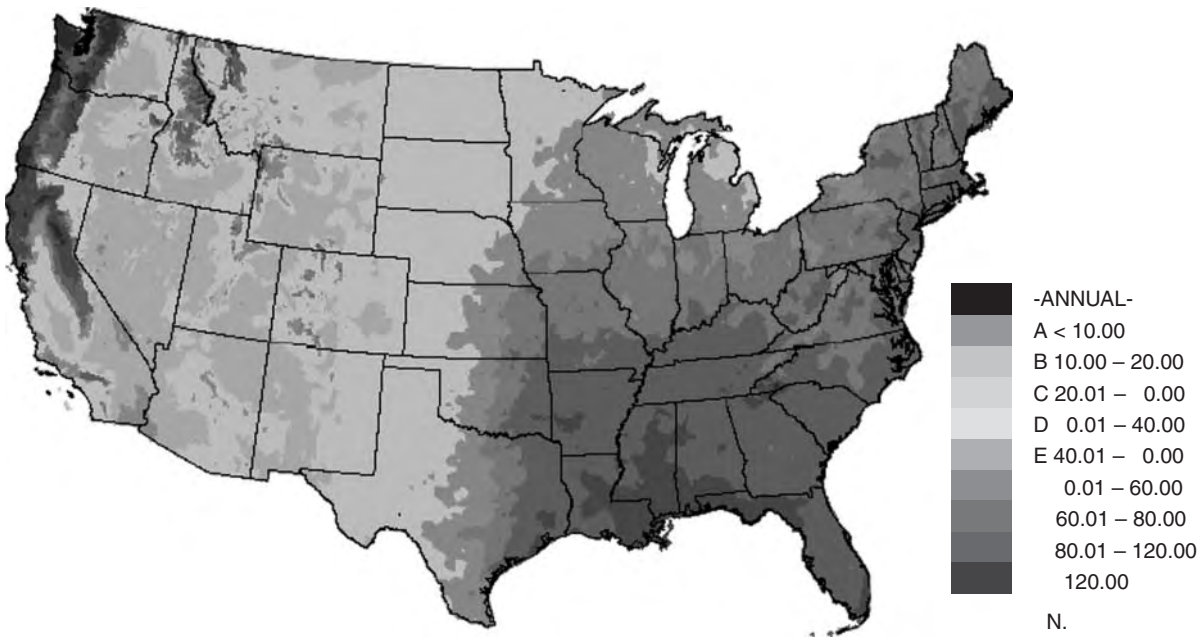


**Figure 3D.15** U.S. record total precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

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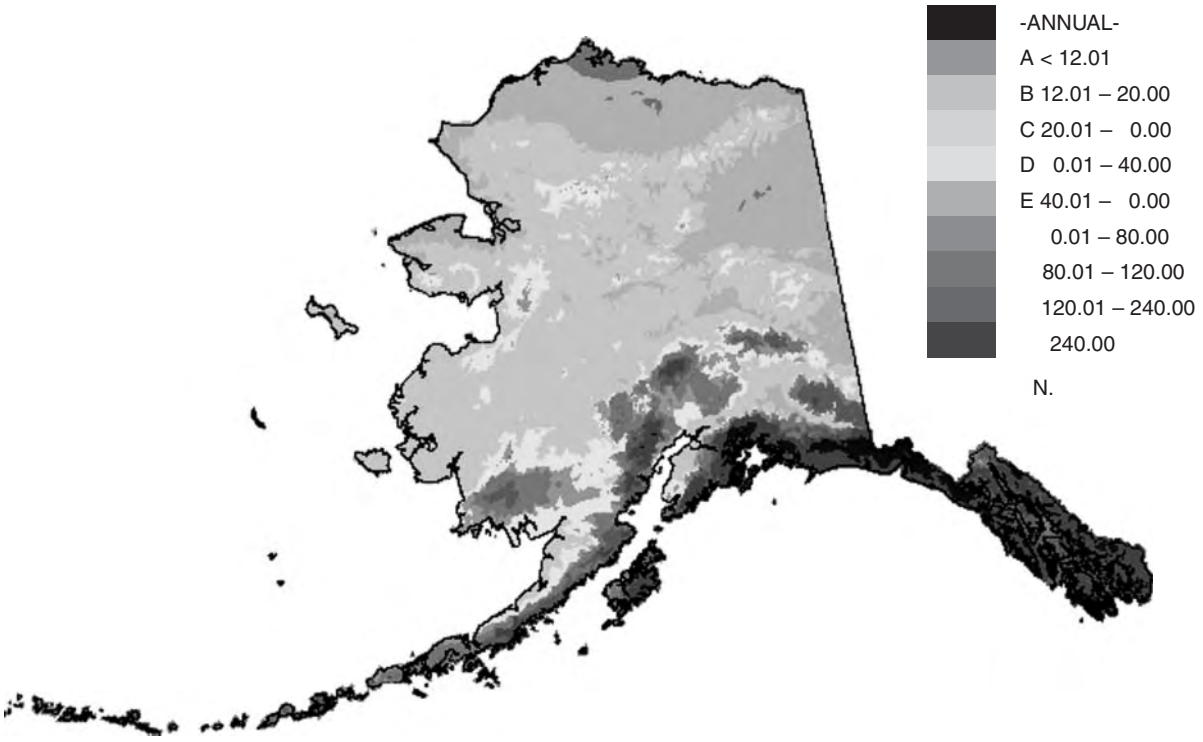


**Figure 3D.16** Alaska record total precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

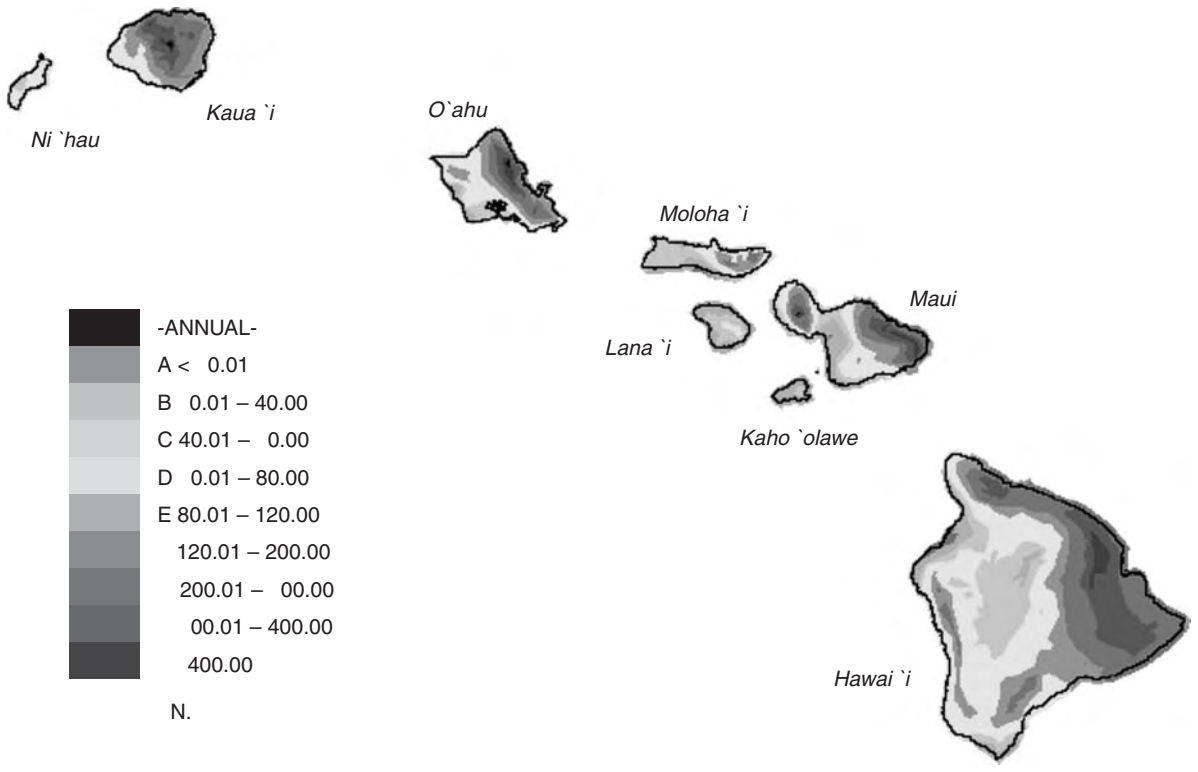


**Figure 3D.17** Hawaii record total precipitation. (From Climate Atlas of the United States, updated 8/27/02.)

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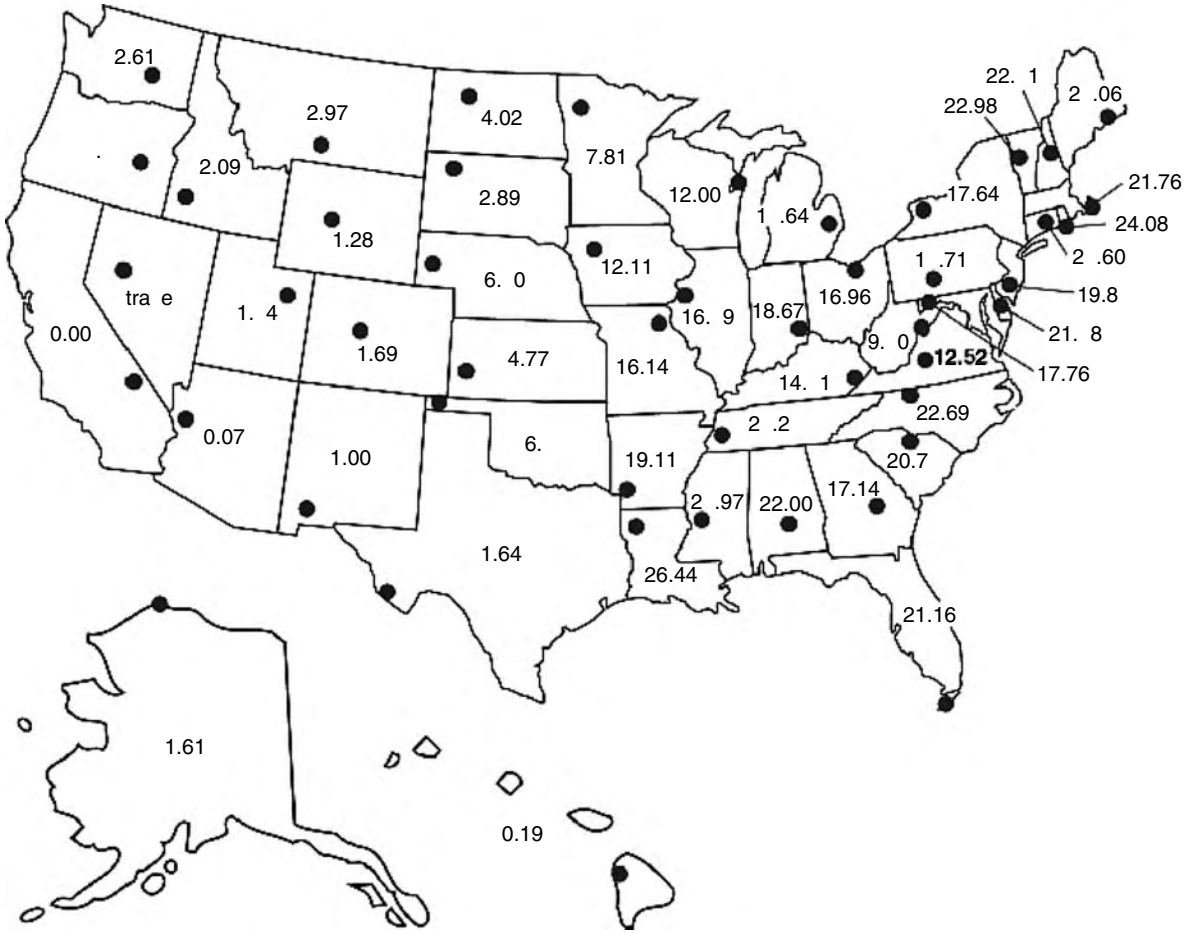


**Figure 3D.18** Record minimum annual precipitation (in.) (through 1998) (*at least one month estimate). (From U.S. National Oceanic and Atmospheric Administration, *Comparative Climate Data for the United States Through 2000*, www.noaa.gov.)

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**Table 3D.23 Mean Number of Days with Precipitation 0.01 in. or More — Selected Cities of the United States**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | Birmingham CO | 11 | 10 | 10 | 11 | 9 | 10 | 9 | 12 | 10 | 9 | 8 | 10 | 9 | 117 |
| | Birmingham AP | 59 | 11 | 10 | 11 | 9 | 10 | 10 | 12 | 10 | 8 | 6 | 9 | 11 | 117 |
| | Huntsville | 35 | 12 | 10 | 12 | 10 | 10 | 10 | 11 | 9 | 8 | 7 | 10 | 11 | 118 |
| | Mobile | 61 | 11 | 9 | 10 | 7 | 8 | 11 | 16 | 14 | 10 | 6 | 8 | 10 | 121 |
| | Montgomery | 58 | 11 | 9 | 10 | 8 | 8 | 9 | 12 | 9 | 8 | 6 | 8 | 10 | 108 |
| AK | Anchorage | 38 | 8 | 8 | 7 | 6 | 7 | 8 | 12 | 14 | 14 | 12 | 9 | 11 | 115 |
| | Annette | 55 | 20 | 19 | 20 | 18 | 17 | 15 | 14 | 15 | 18 | 24 | 22 | 23 | 226 |
| | Barrow | 82 | 4 | 4 | 4 | 4 | 4 | 5 | 9 | 11 | 11 | 11 | 6 | 5 | 78 |
| | Barter IS | 39 | 5 | 5 | 5 | 6 | 6 | 6 | 8 | 12 | 10 | 12 | 8 | 5 | 87 |
| | Bethel | 44 | 9 | 7 | 9 | 9 | 11 | 13 | 15 | 18 | 16 | 12 | 11 | 10 | 141 |
| | Bettles | 43 | 8 | 7 | 7 | 5 | 7 | 10 | 12 | 14 | 12 | 11 | 10 | 10 | 114 |
| | Big Delta | 42 | 6 | 4 | 4 | 4 | 7 | 12 | 14 | 13 | 9 | 9 | 7 | 6 | 93 |
| | Cold Bay | 57 | 19 | 18 | 18 | 17 | 17 | 16 | 17 | 20 | 21 | 23 | 22 | 21 | 229 |
| | Fairbanks | 51 | 8 | 6 | 6 | 4 | 7 | 11 | 12 | 13 | 10 | 11 | 10 | 9 | 106 |
| | Gulkana | 44 | 7 | 6 | 5 | 3 | 5 | 10 | 13 | 12 | 11 | 9 | 7 | 8 | 94 |
| | Homer | 46 | 14 | 12 | 11 | 9 | 10 | 9 | 11 | 13 | 16 | 15 | 13 | 15 | 147 |
| | Juneau | 58 | 19 | 17 | 18 | 17 | 17 | 16 | 17 | 18 | 21 | 24 | 20 | 21 | 223 |
| | King Salmon | 57 | 11 | 9 | 10 | 10 | 12 | 13 | 15 | 17 | 17 | 13 | 12 | 12 | 152 |
| | Kodiak | 53 | 17 | 16 | 17 | 16 | 17 | 15 | 15 | 14 | 16 | 17 | 17 | 18 | 195 |
| | Kotzebue | 59 | 8 | 7 | 7 | 7 | 6 | 6 | 11 | 14 | 12 | 10 | 10 | 9 | 108 |
| | McGrath | 60 | 10 | 8 | 9 | 7 | 9 | 12 | 15 | 17 | 14 | 12 | 12 | 12 | 138 |
| | Nome | 56 | 11 | 9 | 9 | 9 | 8 | 9 | 12 | 16 | 14 | 11 | 12 | 10 | 130 |
| | St. Paul Island | 84 | 18 | 15 | 15 | 14 | 14 | 12 | 15 | 18 | 20 | 22 | 22 | 20 | 205 |
| | Talkeetna | 48 | 9 | 9 | 9 | 7 | 12 | 13 | 15 | 17 | 16 | 13 | 10 | 11 | 139 |
| | Unalakleet | 17 | 6 | 5 | 6 | 6 | 6 | 8 | 12 | 16 | 12 | 10 | 8 | 8 | 103 |
| | Valdez | 30 | 17 | 15 | 15 | 14 | 16 | 15 | 17 | 17 | 21 | 19 | 15 | 18 | 200 |
| | Yakutat | 56 | 19 | 18 | 19 | 18 | 19 | 17 | 18 | 18 | 21 | 24 | 21 | 22 | 235 |
| AZ | Flagstaff | 53 | 7 | 7 | 8 | 6 | 4 | 3 | 11 | 12 | 7 | 5 | 5 | 6 | 82 |
| | Phoenix | 63 | 4 | 4 | 4 | 2 | 1 | 1 | 4 | 5 | 3 | 3 | 2 | 4 | 36 |
| | Tucson | 62 | 4 | 4 | 4 | 2 | 2 | 2 | 10 | 9 | 5 | 3 | 3 | 4 | 53 |
| | Winslow | 71 | 4 | 4 | 5 | 3 | 3 | 2 | 7 | 9 | 5 | 4 | 3 | 4 | 54 |
| | Yuma | 45 | 3 | 2 | 2 | 1 | — | — | 1 | 2 | 1 | 1 | 1 | 2 | 17 |
| AR | Fort Smith | 57 | 8 | 8 | 9 | 10 | 11 | 9 | 7 | 7 | 7 | 7 | 7 | 8 | 97 |
| | Little Rock | 60 | 10 | 9 | 10 | 10 | 10 | 8 | 8 | 7 | 7 | 7 | 8 | 9 | 104 |
| | North Little Rock | 24 | 10 | 9 | 10 | 10 | 11 | 9 | 8 | 7 | 8 | 8 | 9 | 10 | 107 |
| CA | Bakersfield | 65 | 6 | 6 | 6 | 4 | 2 | 1 | — | — | 1 | 2 | 4 | 5 | 37 |
| | Bishop | 55 | 4 | 3 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 3 | 29 |
| | Blue Canyon | 55 | 12 | 12 | 13 | 10 | 7 | 3 | 1 | 1 | 3 | 6 | 10 | 12 | 90 |
| | Eureka | 92 | 16 | 14 | 16 | 12 | 9 | 5 | 2 | 3 | 4 | 9 | 13 | 16 | 119 |
| | Fresno | 53 | 8 | 8 | 7 | 4 | 2 | 1 | — | — | 1 | 2 | 5 | 7 | 45 |
| | Long Beach | 58 | 6 | 5 | 5 | 3 | 1 | — | — | — | 1 | 2 | 3 | 5 | 31 |
| | Los Angeles AP | 67 | 6 | 6 | 6 | 3 | 1 | 1 | 1 | — | 1 | 2 | 3 | 5 | 35 |
| | Los Angeles CO | 62 | 6 | 6 | 6 | 3 | 1 | 1 | — | 1 | 1 | 2 | 3 | 5 | 35 |

*(Continued)*



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**Table 3D.23 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mount Shasta | 42 | 12 | 11 | 12 | 9 | 7 | 5 | 2 | 2 | 3 | 6 | 10 | 12 | 93 |
| | Redding | 16 | 14 | 11 | 12 | 8 | 7 | 4 | 1 | 1 | 2 | 4 | 9 | 11 | 83 |
| | Sacramento | 63 | 10 | 9 | 9 | 5 | 3 | 1 | — | — | 1 | 3 | 7 | 9 | 58 |
| | San Diego | 62 | 7 | 6 | 7 | 5 | 2 | 1 | — | 0 | 1 | 2 | 4 | 6 | 42 |
| | San Francisco AP | 75 | 11 | 10 | 10 | 6 | 3 | 1 | — | — | 1 | 4 | 7 | 10 | 63 |
| | San Francisco CO | 65 | 11 | 10 | 11 | 6 | 3 | 1 | — | 1 | 2 | 4 | 8 | 10 | 69 |
| | Santa Barbara | 66 | 6 | 6 | 6 | 2 | 1 | 1 | 1 | — | 1 | 2 | 3 | 5 | 33 |
| | Santa Maria | 60 | 8 | 8 | 8 | 5 | 2 | 1 | — | — | 1 | 2 | 5 | 6 | 46 |
| | Stockton | 60 | 9 | 9 | 8 | 5 | 3 | 1 | — | — | 1 | 3 | 7 | 7 | 52 |
| CO | Alamosa | 56 | 4 | 4 | 5 | 5 | 6 | 5 | 9 | 10 | 6 | 5 | 4 | 4 | 67 |
| | Colorado Springs | 54 | 5 | 5 | 7 | 8 | 10 | 10 | 13 | 12 | 7 | 5 | 4 | 4 | 90 |
| | Denver | 61 | 6 | 6 | 9 | 9 | 11 | 9 | 9 | 9 | 6 | 5 | 6 | 5 | 89 |
| | Grand Junction | 56 | 7 | 6 | 8 | 7 | 6 | 4 | 5 | 7 | 6 | 6 | 6 | 6 | 73 |
| | Pueblo | 60 | 4 | 4 | 6 | 6 | 8 | 7 | 9 | 9 | 5 | 4 | 4 | 4 | 71 |
| CT | Bridgeport | 54 | 11 | 10 | 11 | 11 | 11 | 10 | 8 | 9 | 9 | 7 | 10 | 11 | 118 |
| | Hartford | 48 | 11 | 10 | 12 | 11 | 12 | 11 | 10 | 10 | 10 | 9 | 11 | 12 | 127 |
| DE | Wilmington | 55 | 11 | 9 | 11 | 11 | 11 | 10 | 9 | 9 | 8 | 8 | 9 | 10 | 117 |
| DC | Washington Dulles AP | 39 | 10 | 9 | 10 | 10 | 12 | 10 | 11 | 10 | 9 | 8 | 9 | 10 | 117 |
| | Washington Nat'l AP | 61 | 10 | 9 | 11 | 10 | 11 | 10 | 10 | 9 | 8 | 7 | 8 | 9 | 112 |
| FL | Apalachicola | 61 | 9 | 8 | 8 | 6 | 5 | 10 | 15 | 14 | 11 | 5 | 6 | 8 | 105 |
| | Daytona Beach | 59 | 7 | 7 | 8 | 6 | 8 | 13 | 13 | 14 | 14 | 11 | 7 | 7 | 115 |
| | Fort Myers | 59 | 6 | 5 | 6 | 4 | 8 | 15 | 18 | 18 | 16 | 8 | 4 | 5 | 112 |
| | Gainesville | 19 | 9 | 7 | 8 | 6 | 7 | 15 | 16 | 16 | 12 | 7 | 7 | 7 | 116 |
| | Jacksonville | 61 | 8 | 8 | 8 | 6 | 8 | 13 | 14 | 15 | 13 | 9 | 6 | 8 | 116 |
| | Key West | 54 | 6 | 5 | 5 | 5 | 8 | 12 | 12 | 15 | 16 | 11 | 7 | 7 | 109 |
| | Miami | 60 | 7 | 6 | 6 | 6 | 10 | 15 | 16 | 18 | 17 | 14 | 8 | 7 | 131 |
| | Orlando | 60 | 6 | 7 | 7 | 6 | 8 | 14 | 17 | 16 | 14 | 9 | 6 | 6 | 116 |
| | Pensacola | 39 | 10 | 9 | 9 | 6 | 7 | 10 | 14 | 13 | 9 | 5 | 8 | 9 | 110 |
| | Tallahassee | 41 | 10 | 9 | 9 | 6 | 8 | 13 | 17 | 14 | 9 | 5 | 7 | 8 | 115 |
| | Tampa | 56 | 7 | 7 | 7 | 5 | 6 | 12 | 16 | 16 | 13 | 7 | 5 | 6 | 106 |
| | Vero Beach | 19 | 9 | 7 | 8 | 6 | 8 | 14 | 14 | 14 | 16 | 13 | 9 | 8 | 126 |
| | West Palm Beach | 60 | 8 | 7 | 8 | 7 | 11 | 15 | 15 | 16 | 17 | 13 | 9 | 8 | 133 |
| GA | Athens | 59 | 11 | 9 | 11 | 9 | 9 | 10 | 11 | 9 | 8 | 7 | 8 | 10 | 111 |
| | Atlanta | 68 | 12 | 10 | 11 | 9 | 9 | 10 | 12 | 9 | 8 | 7 | 9 | 10 | 115 |
| | Augusta | 52 | 10 | 9 | 10 | 8 | 9 | 10 | 11 | 10 | 8 | 6 | 7 | 9 | 107 |
| | Columbus | 57 | 10 | 9 | 10 | 8 | 8 | 10 | 13 | 10 | 8 | 6 | 8 | 9 | 109 |
| | Macon | 54 | 11 | 9 | 10 | 8 | 9 | 10 | 12 | 10 | 8 | 6 | 7 | 9 | 110 |
| | Savannah | 52 | 9 | 8 | 9 | 7 | 8 | 12 | 13 | 13 | 10 | 6 | 7 | 8 | 110 |
| HI | Hilo | 60 | 17 | 17 | 23 | 25 | 25 | 25 | 27 | 27 | 24 | 24 | 23 | 21 | 279 |
| | Honolulu | 53 | 9 | 9 | 9 | 9 | 7 | 6 | 7 | 6 | 7 | 8 | 9 | 10 | 96 |
| | Kahului | 44 | 10 | 9 | 10 | 10 | 6 | 5 | 7 | 6 | 5 | 7 | 10 | 11 | 98 |
| | Lihue | 52 | 15 | 13 | 16 | 17 | 16 | 17 | 20 | 18 | 16 | 18 | 18 | 18 | 200 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Boise | 63 | 12 | 10 | 10 | 8 | 8 | 6 | 2 | 2 | 4 | 6 | 10 | 11 | 89 |
| | Lewiston | 56 | 11 | 9 | 11 | 10 | 10 | 9 | 5 | 4 | 5 | 8 | 11 | 11 | 104 |
| | Pocatello | 53 | 12 | 10 | 10 | 8 | 9 | 7 | 4 | 4 | 5 | 5 | 9 | 11 | 95 |
| IL | Cairo | 45 | 10 | 9 | 12 | 11 | 11 | 9 | 9 | 8 | 7 | 7 | 9 | 10 | 112 |
| | Chicago | 44 | 11 | 9 | 12 | 13 | 11 | 10 | 10 | 9 | 9 | 9 | 11 | 11 | 125 |
| | Moline | 70 | 9 | 8 | 11 | 11 | 12 | 10 | 10 | 9 | 9 | 8 | 9 | 9 | 115 |
| | Peoria | 63 | 9 | 8 | 11 | 12 | 12 | 10 | 9 | 8 | 8 | 8 | 9 | 10 | 114 |
| | Rockford | 52 | 9 | 8 | 11 | 12 | 12 | 10 | 10 | 9 | 9 | 9 | 9 | 10 | 117 |
| | Springfield | 55 | 9 | 8 | 11 | 12 | 11 | 10 | 9 | 8 | 8 | 8 | 9 | 10 | 113 |
| IN | Evansville | 62 | 10 | 9 | 12 | 12 | 11 | 10 | 9 | 7 | 7 | 8 | 9 | 10 | 115 |
| | Fort Wayne | 56 | 12 | 10 | 13 | 13 | 12 | 10 | 10 | 9 | 9 | 9 | 11 | 12 | 132 |
| | Indianapolis | 63 | 12 | 10 | 13 | 12 | 12 | 10 | 10 | 9 | 8 | 8 | 10 | 12 | 126 |
| | South Bend | 63 | 16 | 12 | 14 | 13 | 12 | 11 | 9 | 9 | 9 | 10 | 13 | 15 | 144 |
| IA | Des Moines | 63 | 7 | 7 | 10 | 11 | 12 | 11 | 9 | 9 | 9 | 8 | 7 | 8 | 108 |
| | Dubuque | 50 | 9 | 8 | 11 | 12 | 12 | 11 | 10 | 9 | 9 | 9 | 9 | 10 | 117 |
| | Sioux City | 62 | 7 | 6 | 9 | 10 | 11 | 11 | 9 | 9 | 8 | 7 | 6 | 7 | 99 |
| | Waterloo | 52 | 7 | 7 | 9 | 10 | 12 | 10 | 9 | 9 | 9 | 7 | 7 | 7 | 104 |
| KS | Concordia | 40 | 5 | 5 | 8 | 9 | 11 | 10 | 9 | 9 | 8 | 6 | 5 | 5 | 89 |
| | Dodge City | 60 | 5 | 5 | 7 | 7 | 10 | 9 | 9 | 8 | 6 | 5 | 4 | 4 | 78 |
| | Goodland | 82 | 4 | 5 | 6 | 7 | 10 | 9 | 9 | 8 | 6 | 5 | 4 | 4 | 77 |
| | Topeka | 56 | 6 | 6 | 9 | 10 | 12 | 11 | 9 | 8 | 8 | 7 | 6 | 6 | 97 |
| | Wichita | 49 | 5 | 5 | 8 | 8 | 11 | 9 | 8 | 7 | 8 | 6 | 5 | 6 | 86 |
| KY | Greater Cincinnati AP | 55 | 12 | 11 | 13 | 13 | 12 | 11 | 10 | 9 | 8 | 8 | 11 | 12 | 130 |
| | Jackson | 22 | 14 | 13 | 14 | 12 | 14 | 12 | 12 | 9 | 9 | 9 | 12 | 14 | 143 |
| | Lexington | 58 | 12 | 11 | 13 | 12 | 12 | 11 | 11 | 9 | 8 | 8 | 11 | 12 | 130 |
| | Louisville | 55 | 11 | 10 | 13 | 12 | 12 | 10 | 10 | 8 | 8 | 7 | 10 | 12 | 124 |
| | Paducah | 19 | 10 | 9 | 11 | 11 | 11 | 9 | 8 | 7 | 7 | 8 | 10 | 10 | 110 |
| LA | Baton Rouge | 51 | 10 | 9 | 9 | 7 | 8 | 10 | 13 | 12 | 9 | 6 | 8 | 10 | 110 |
| | Lake Charles | 41 | 10 | 8 | 8 | 7 | 8 | 9 | 11 | 11 | 9 | 6 | 8 | 9 | 104 |
| | New Orleans | 54 | 10 | 9 | 9 | 7 | 8 | 11 | 14 | 13 | 10 | 6 | 8 | 10 | 114 |
| | Shreveport | 50 | 9 | 8 | 10 | 8 | 9 | 8 | 8 | 7 | 7 | 7 | 9 | 9 | 99 |
| ME | Caribou | 63 | 15 | 12 | 13 | 13 | 14 | 14 | 14 | 13 | 12 | 13 | 14 | 14 | 160 |
| | Portland | 62 | 11 | 10 | 11 | 12 | 12 | 11 | 10 | 9 | 9 | 9 | 12 | 11 | 129 |
| MD | Baltimore | 52 | 10 | 9 | 11 | 11 | 11 | 10 | 9 | 9 | 8 | 7 | 9 | 9 | 114 |
| MA | Blue Hill | 117 | 12 | 11 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 10 | 11 | 12 | 134 |
| | Boston | 51 | 12 | 10 | 12 | 11 | 12 | 11 | 9 | 10 | 9 | 9 | 11 | 12 | 126 |
| | Worcester | 47 | 12 | 11 | 12 | 12 | 13 | 11 | 10 | 10 | 10 | 9 | 12 | 12 | 134 |
| MI | Alpena | 43 | 15 | 11 | 12 | 12 | 12 | 11 | 10 | 11 | 12 | 13 | 14 | 15 | 146 |
| | Detroit | 44 | 13 | 11 | 13 | 13 | 11 | 10 | 10 | 10 | 10 | 10 | 12 | 13 | 135 |
| | Flint | 61 | 13 | 11 | 12 | 13 | 11 | 10 | 9 | 9 | 10 | 10 | 12 | 13 | 134 |
| | Grand Rapids | 39 | 16 | 12 | 12 | 13 | 11 | 10 | 9 | 9 | 11 | 11 | 13 | 16 | 144 |
| | Houghton Lake | 38 | 15 | 11 | 12 | 12 | 11 | 11 | 9 | 10 | 12 | 12 | 13 | 14 | 141 |
| | Lansing | 48 | 14 | 11 | 13 | 13 | 11 | 11 | 10 | 10 | 10 | 10 | 13 | 14 | 139 |
| | Marquette | 24 | 18 | 13 | 15 | 12 | 11 | 12 | 11 | 11 | 14 | 15 | 16 | 17 | 165 |
| | Muskegon | 62 | 17 | 13 | 13 | 12 | 11 | 9 | 9 | 9 | 10 | 11 | 14 | 16 | 143 |

*(Continued)*



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**Table 3D.23 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sault Ste. Marie | 61 | 19 | 14 | 13 | 11 | 11 | 11 | 10 | 11 | 13 | 14 | 17 | 19 | 165 |
| MN | Duluth | 61 | 12 | 9 | 11 | 11 | 12 | 13 | 12 | 11 | 12 | 10 | 11 | 11 | 134 |
| | International Falls | 63 | 11 | 9 | 10 | 9 | 12 | 13 | 12 | 11 | 12 | 10 | 11 | 11 | 130 |
| | Minneapolis-St.Paul | 64 | 9 | 7 | 10 | 10 | 11 | 12 | 10 | 10 | 10 | 8 | 8 | 9 | 116 |
| | Rochester | 42 | 9 | 8 | 10 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 120 |
| | Saint Cloud | 62 | 9 | 7 | 9 | 9 | 11 | 12 | 10 | 10 | 9 | 8 | 8 | 8 | 109 |
| MS | Jackson | 39 | 11 | 9 | 10 | 8 | 9 | 9 | 11 | 10 | 8 | 7 | 9 | 10 | 110 |
| | Meridian | 57 | 11 | 9 | 10 | 9 | 9 | 9 | 11 | 9 | 8 | 6 | 8 | 10 | 107 |
| | Tupelo | 19 | 11 | 10 | 11 | 9 | 11 | 10 | 8 | 7 | 6 | 7 | 9 | 11 | 111 |
| MO | Columbia | 33 | 8 | 8 | 11 | 11 | 12 | 9 | 8 | 8 | 8 | 9 | 9 | 9 | 112 |
| | Kansas City | 30 | 7 | 7 | 10 | 11 | 12 | 10 | 9 | 9 | 8 | 8 | 7 | 7 | 105 |
| | St. Louis | 45 | 9 | 8 | 11 | 11 | 11 | 9 | 9 | 8 | 8 | 8 | 9 | 9 | 111 |
| | Springfield | 57 | 8 | 8 | 10 | 11 | 11 | 10 | 8 | 8 | 8 | 8 | 9 | 9 | 109 |
| MT | Billings | 68 | 8 | 7 | 9 | 10 | 11 | 11 | 8 | 6 | 7 | 6 | 6 | 7 | 96 |
| | Glasgow | 47 | 8 | 6 | 7 | 7 | 10 | 11 | 8 | 7 | 6 | 5 | 6 | 7 | 90 |
| | Great Falls | 65 | 9 | 8 | 9 | 9 | 11 | 12 | 8 | 8 | 7 | 6 | 7 | 7 | 100 |
| | Helena | 62 | 8 | 6 | 8 | 8 | 11 | 12 | 8 | 8 | 6 | 6 | 7 | 8 | 95 |
| | Kalispell | 53 | 15 | 12 | 11 | 10 | 12 | 12 | 7 | 8 | 8 | 9 | 13 | 15 | 131 |
| | Missoula | 58 | 14 | 10 | 11 | 10 | 12 | 12 | 7 | 7 | 8 | 8 | 11 | 13 | 123 |
| NE | Grand Island | 64 | 5 | 6 | 7 | 9 | 11 | 10 | 9 | 8 | 7 | 5 | 5 | 5 | 87 |
| | Lincoln | 31 | 6 | 5 | 8 | 10 | 12 | 9 | 9 | 9 | 8 | 6 | 6 | 6 | 93 |
| | Norfolk | 57 | 6 | 6 | 8 | 9 | 11 | 10 | 9 | 8 | 8 | 6 | 5 | 5 | 91 |
| | North Platte | 50 | 5 | 5 | 7 | 8 | 11 | 10 | 10 | 8 | 7 | 5 | 5 | 4 | 84 |
| | Omaha Eppley AP | 66 | 6 | 7 | 8 | 10 | 12 | 10 | 9 | 9 | 8 | 6 | 6 | 6 | 99 |
| | Omaha (North) | 18 | 5 | 6 | 10 | 10 | 12 | 10 | 10 | 9 | 8 | 7 | 6 | 7 | 101 |
| | Scottsbluff | 59 | 5 | 5 | 7 | 9 | 12 | 11 | 8 | 7 | 7 | 5 | 5 | 5 | 86 |
| | Valentine | 47 | 4 | 5 | 7 | 9 | 11 | 10 | 9 | 8 | 7 | 5 | 4 | 4 | 83 |
| NV | Elko | 72 | 9 | 9 | 9 | 8 | 8 | 6 | 3 | 3 | 4 | 5 | 7 | 9 | 79 |
| | Ely | 64 | 7 | 7 | 8 | 8 | 7 | 5 | 5 | 6 | 4 | 5 | 5 | 6 | 73 |
| | Las Vegas | 54 | 3 | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 2 | 2 | 2 | 3 | 26 |
| | Reno | 60 | 6 | 6 | 6 | 4 | 4 | 3 | 2 | 2 | 3 | 3 | 5 | 6 | 51 |
| | Winnemucca | 53 | 8 | 7 | 8 | 7 | 7 | 5 | 2 | 2 | 3 | 4 | 7 | 8 | 69 |
| NH | Concord | 61 | 11 | 9 | 11 | 11 | 12 | 11 | 10 | 10 | 9 | 9 | 11 | 11 | 127 |
| | Mt. Washington | 70 | 19 | 18 | 19 | 18 | 17 | 16 | 16 | 15 | 15 | 15 | 19 | 20 | 209 |
| NJ | Atlantic City AP | 59 | 11 | 10 | 11 | 11 | 10 | 9 | 9 | 9 | 8 | 7 | 9 | 10 | 113 |
| | Atlantic City CO | 40 | 10 | 9 | 10 | 10 | 10 | 8 | 9 | 8 | 8 | 7 | 9 | 10 | 109 |
| | Newark | 61 | 11 | 10 | 11 | 11 | 12 | 10 | 10 | 9 | 9 | 8 | 10 | 11 | 122 |
| NM | Albuquerque | 63 | 4 | 4 | 5 | 3 | 4 | 4 | 9 | 10 | 6 | 5 | 4 | 4 | 61 |
| | Clayton | 53 | 3 | 3 | 5 | 5 | 8 | 8 | 10 | 9 | 6 | 4 | 3 | 3 | 68 |
| | Roswell | 30 | 4 | 3 | 3 | 3 | 4 | 5 | 6 | 8 | 7 | 5 | 3 | 4 | 55 |
| NY | Albany | 56 | 13 | 11 | 12 | 12 | 13 | 11 | 10 | 10 | 10 | 9 | 12 | 12 | 135 |
| | Binghamton | 51 | 17 | 14 | 15 | 14 | 13 | 12 | 11 | 11 | 11 | 12 | 15 | 17 | 161 |
| | Buffalo | 59 | 20 | 17 | 16 | 14 | 13 | 11 | 10 | 10 | 11 | 12 | 16 | 19 | 168 |
| | Islip | 19 | 11 | 9 | 11 | 12 | 11 | 9 | 9 | 9 | 9 | 8 | 10 | 10 | 118 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | New York C. Park | 133 | 11 | 10 | 11 | 11 | 11 | 10 | 10 | 10 | 8 | 8 | 9 | 10 | 121 |
| | New York (JFK AP) | 44 | 10 | 10 | 11 | 11 | 11 | 10 | 9 | 9 | 8 | 8 | 10 | 11 | 118 |
| | New york (Laguardia AP) | 62 | 11 | 10 | 11 | 11 | 11 | 10 | 9 | 9 | 8 | 8 | 10 | 11 | 118 |
| | Rochester | 62 | 18 | 16 | 15 | 13 | 12 | 11 | 10 | 10 | 11 | 12 | 15 | 18 | 160 |
| | Syracuse | 53 | 19 | 16 | 17 | 14 | 13 | 11 | 11 | 11 | 11 | 13 | 17 | 19 | 171 |
| NC | Asheville | 38 | 11 | 9 | 12 | 10 | 11 | 12 | 12 | 12 | 10 | 8 | 9 | 10 | 125 |
| | Cape Hatteras | 45 | 11 | 10 | 11 | 9 | 10 | 9 | 12 | 11 | 9 | 9 | 9 | 10 | 120 |
| | Charlotte | 63 | 10 | 9 | 11 | 9 | 9 | 10 | 11 | 10 | 7 | 7 | 8 | 10 | 111 |
| | Greensboro-Wnstn-Slm-HPT | 74 | 10 | 9 | 11 | 9 | 10 | 10 | 12 | 10 | 8 | 7 | 8 | 9 | 115 |
| | Raleigh | 58 | 10 | 10 | 10 | 9 | 10 | 10 | 11 | 10 | 8 | 7 | 8 | 9 | 113 |
| | Wilmington | 51 | 11 | 10 | 10 | 8 | 9 | 10 | 13 | 12 | 10 | 7 | 8 | 9 | 117 |
| ND | Bismarck | 63 | 8 | 7 | 8 | 8 | 10 | 12 | 9 | 8 | 7 | 6 | 6 | 7 | 96 |
| | Fargo | 60 | 9 | 7 | 8 | 8 | 10 | 11 | 10 | 9 | 8 | 7 | 6 | 8 | 101 |
| | Williston | 41 | 8 | 6 | 8 | 8 | 10 | 11 | 9 | 7 | 7 | 6 | 7 | 8 | 95 |
| OH | Akron | 54 | 16 | 14 | 15 | 14 | 13 | 11 | 11 | 10 | 10 | 10 | 14 | 16 | 154 |
| | Cleveland | 61 | 16 | 14 | 15 | 15 | 13 | 11 | 10 | 10 | 10 | 11 | 14 | 16 | 155 |
| | Columbus | 63 | 13 | 11 | 13 | 13 | 13 | 11 | 11 | 9 | 8 | 9 | 11 | 13 | 137 |
| | Dayton | 59 | 13 | 11 | 13 | 13 | 12 | 11 | 10 | 9 | 8 | 9 | 11 | 12 | 132 |
| | Mansfield | 43 | 14 | 12 | 14 | 14 | 13 | 11 | 10 | 10 | 9 | 10 | 13 | 14 | 144 |
| | Toledo | 47 | 13 | 11 | 13 | 13 | 12 | 10 | 9 | 9 | 10 | 9 | 12 | 14 | 134 |
| | Youngstown | 59 | 17 | 15 | 15 | 15 | 13 | 12 | 11 | 10 | 10 | 11 | 15 | 17 | 160 |
| OK | Oklahoma City | 63 | 5 | 6 | 7 | 8 | 10 | 9 | 6 | 6 | 7 | 7 | 5 | 6 | 83 |
| | Tulsa | 63 | 6 | 7 | 8 | 9 | 11 | 9 | 6 | 7 | 7 | 7 | 6 | 7 | 91 |
| OR | Astoria | 49 | 22 | 19 | 21 | 18 | 16 | 13 | 8 | 8 | 10 | 16 | 21 | 22 | 193 |
| | Burns | 18 | 11 | 10 | 11 | 9 | 9 | 6 | 3 | 3 | 4 | 6 | 12 | 11 | 95 |
| | Eugene | 60 | 18 | 15 | 17 | 13 | 10 | 7 | 3 | 4 | 6 | 11 | 17 | 18 | 139 |
| | Medford | 73 | 14 | 11 | 12 | 10 | 8 | 5 | 2 | 2 | 4 | 7 | 13 | 14 | 101 |
| | Pendleton | 67 | 12 | 10 | 11 | 9 | 8 | 7 | 3 | 3 | 4 | 7 | 12 | 12 | 98 |
| | Portland | 62 | 18 | 16 | 17 | 15 | 12 | 9 | 4 | 5 | 7 | 12 | 18 | 19 | 152 |
| | Salem | 65 | 18 | 16 | 17 | 14 | 11 | 8 | 3 | 4 | 7 | 12 | 18 | 19 | 147 |
| | Sexton Summit | 65 | 16 | 15 | 16 | 12 | 9 | 6 | 2 | 3 | 5 | 9 | 16 | 17 | 126 |
| PC | Guam | 45 | 20 | 18 | 19 | 20 | 20 | 24 | 26 | 26 | 25 | 25 | 25 | 24 | 271 |
| | Johnston Island | 28 | 11 | 12 | 15 | 14 | 13 | 12 | 12 | 13 | 14 | 16 | 15 | 16 | 162 |
| | Koror | 51 | 23 | 19 | 20 | 19 | 23 | 25 | 24 | 22 | 20 | 23 | 22 | 24 | 265 |
| | Kwajalein, Marshall IS | 50 | 16 | 13 | 15 | 17 | 21 | 23 | 24 | 23 | 22 | 24 | 23 | 19 | 240 |
| | Majuro, Marshall IS | 48 | 18 | 16 | 18 | 20 | 23 | 24 | 24 | 23 | 23 | 23 | 23 | 22 | 258 |
| | Pago Pago, Amer Samoa | 36 | 24 | 21 | 23 | 22 | 20 | 19 | 19 | 18 | 17 | 21 | 20 | 23 | 247 |
| | Pohnpei, Caroline IS | 51 | 22 | 20 | 23 | 24 | 27 | 27 | 27 | 26 | 24 | 25 | 25 | 24 | 294 |
| | Chuuk, E. Caroline IS | 51 | 19 | 16 | 19 | 20 | 24 | 24 | 24 | 24 | 22 | 23 | 23 | 23 | 264 |
| | Wake Island | 50 | 11 | 10 | 12 | 14 | 15 | 15 | 19 | 19 | 19 | 19 | 15 | 13 | 180 |

*(Continued)*



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**Table 3D.23 (Continued)**

| State | Station | Years | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yap, W Caroline IS | 54 | 21 | 18 | 18 | 18 | 21 | 24 | 24 | 24 | 23 | 24 | 23 | 22 | 258 |
| PA | Allentown | 59 | 11 | 10 | 11 | 12 | 12 | 11 | 10 | 10 | 9 | 8 | 10 | 11 | 124 |
| | Erie | 49 | 19 | 15 | 15 | 14 | 12 | 10 | 10 | 11 | 11 | 13 | 16 | 19 | 163 |
| | Harrisburg | 49 | 11 | 10 | 11 | 13 | 13 | 11 | 10 | 9 | 9 | 9 | 10 | 10 | 126 |
| | Middletown/ Harrisburg AP | 24 | 11 | 10 | 11 | 12 | 13 | 10 | 10 | 9 | 9 | 8 | 10 | 10 | 122 |
| | Philadelphia | 62 | 11 | 9 | 11 | 11 | 11 | 10 | 9 | 9 | 8 | 8 | 9 | 10 | 117 |
| | Pittsburgh | 50 | 16 | 14 | 15 | 14 | 13 | 12 | 11 | 10 | 10 | 10 | 13 | 16 | 152 |
| | Avoca | 47 | 12 | 11 | 13 | 12 | 13 | 12 | 11 | 11 | 10 | 10 | 12 | 12 | 139 |
| | Williamsport | 58 | 12 | 11 | 12 | 13 | 13 | 12 | 11 | 11 | 10 | 10 | 12 | 12 | 139 |
| RI | Block IS | 36 | 10 | 9 | 11 | 10 | 10 | 9 | 7 | 8 | 7 | 8 | 10 | 11 | 110 |
| | Providence | 49 | 11 | 10 | 12 | 11 | 11 | 11 | 9 | 9 | 9 | 9 | 10 | 12 | 124 |
| SC | Charleston AP | 60 | 10 | 9 | 10 | 7 | 9 | 11 | 14 | 13 | 10 | 6 | 7 | 9 | 114 |
| | Charleston CO | 27 | 10 | 8 | 8 | 7 | 8 | 10 | 11 | 11 | 10 | 6 | 7 | 9 | 104 |
| | Columbia | 55 | 10 | 9 | 10 | 8 | 8 | 10 | 12 | 11 | 8 | 6 | 7 | 9 | 109 |
| | Greenville-Spartanburg AP | 40 | 11 | 9 | 11 | 9 | 10 | 10 | 12 | 10 | 9 | 7 | 9 | 10 | 117 |
| SD | Aberdeen | 71 | 6 | 6 | 7 | 8 | 10 | 10 | 9 | 8 | 7 | 5 | 6 | 6 | 89 |
| | Huron | 63 | 6 | 7 | 8 | 9 | 10 | 11 | 9 | 8 | 7 | 6 | 6 | 6 | 92 |
| | Rapid City | 60 | 6 | 7 | 8 | 10 | 12 | 12 | 9 | 8 | 6 | 6 | 6 | 6 | 95 |
| | Sioux Falls | 57 | 6 | 7 | 9 | 10 | 11 | 11 | 10 | 9 | 8 | 6 | 7 | 6 | 98 |
| TN | Bristol-JhnCty-Kgsprt | 57 | 14 | 12 | 13 | 11 | 12 | 11 | 12 | 10 | 8 | 8 | 10 | 12 | 133 |
| | Chattanooga | 72 | 12 | 10 | 12 | 10 | 10 | 11 | 12 | 10 | 8 | 7 | 9 | 11 | 121 |
| | Knoxville | 60 | 12 | 11 | 13 | 11 | 11 | 11 | 11 | 9 | 8 | 8 | 10 | 11 | 127 |
| | Memphis | 52 | 10 | 9 | 11 | 10 | 9 | 9 | 9 | 7 | 7 | 6 | 9 | 10 | 107 |
| | Nashville | 61 | 11 | 10 | 12 | 11 | 11 | 10 | 10 | 9 | 8 | 7 | 9 | 11 | 119 |
| | Oak Ridge | 61 | 12 | 11 | 13 | 11 | 11 | 11 | 12 | 10 | 8 | 8 | 10 | 11 | 128 |
| TX | Abilene | 63 | 5 | 5 | 5 | 6 | 8 | 6 | 5 | 6 | 6 | 6 | 5 | 5 | 67 |
| | Amarillo | 61 | 4 | 4 | 5 | 5 | 8 | 8 | 8 | 8 | 6 | 5 | 4 | 4 | 69 |
| | Austin | 61 | 8 | 8 | 8 | 7 | 9 | 7 | 5 | 5 | 7 | 7 | 7 | 8 | 85 |
| | Brownsville | 60 | 7 | 6 | 4 | 4 | 5 | 6 | 4 | 7 | 10 | 7 | 6 | 7 | 73 |
| | Corpus Christi | 63 | 8 | 7 | 5 | 5 | 6 | 6 | 5 | 6 | 9 | 7 | 6 | 7 | 77 |
| | Dallas-Fort Worth | 49 | 7 | 7 | 8 | 8 | 9 | 7 | 5 | 5 | 6 | 6 | 6 | 7 | 79 |
| | Del Rio | 39 | 5 | 5 | 5 | 5 | 7 | 5 | 4 | 4 | 6 | 5 | 5 | 5 | 62 |
| | El Paso | 63 | 4 | 3 | 2 | 2 | 2 | 3 | 8 | 8 | 5 | 4 | 3 | 4 | 49 |
| | Galveston | 63 | 10 | 8 | 8 | 6 | 6 | 7 | 9 | 9 | 9 | 7 | 8 | 10 | 96 |
| | Houston | 33 | 10 | 8 | 9 | 7 | 8 | 10 | 9 | 9 | 9 | 8 | 8 | 9 | 105 |
| | Lubbock | 56 | 4 | 4 | 4 | 5 | 7 | 7 | 7 | 7 | 6 | 5 | 3 | 4 | 63 |
| | Midland-Odessa | 55 | 4 | 4 | 3 | 3 | 6 | 5 | 5 | 6 | 6 | 5 | 3 | 3 | 51 |
| | Port Arthur | 49 | 10 | 9 | 8 | 7 | 7 | 9 | 11 | 12 | 10 | 7 | 8 | 9 | 105 |
| | San Angelo | 55 | 5 | 5 | 4 | 5 | 7 | 5 | 4 | 5 | 6 | 5 | 4 | 4 | 59 |
| | San Antonio | 60 | 8 | 7 | 8 | 7 | 8 | 7 | 4 | 5 | 7 | 6 | 7 | 8 | 82 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Victoria | 41 | 8 | 7 | 7 | 6 | 7 | 8 | 7 | 9 | 10 | 7 | 7 | 8 | 91 |
| | Waco | 59 | 7 | 7 | 8 | 7 | 9 | 6 | 4 | 5 | 6 | 6 | 7 | 6 | 80 |
| | Wichita Falls | 59 | 5 | 5 | 6 | 7 | 9 | 7 | 5 | 6 | 6 | 6 | 5 | 5 | 71 |
| UT | Milford | 56 | 7 | 7 | 8 | 6 | 5 | 3 | 5 | 6 | 4 | 4 | 5 | 6 | 67 |
| | Salt Lake City | 74 | 10 | 9 | 10 | 10 | 8 | 5 | 4 | 6 | 5 | 6 | 8 | 9 | 91 |
| VT | Burlington | 59 | 15 | 11 | 13 | 12 | 14 | 13 | 12 | 12 | 12 | 12 | 14 | 15 | 154 |
| VA | Lynchburg | 58 | 11 | 9 | 11 | 10 | 12 | 10 | 11 | 10 | 8 | 7 | 9 | 9 | 118 |
| | Norfolk | 54 | 11 | 10 | 11 | 10 | 10 | 9 | 11 | 10 | 8 | 7 | 8 | 9 | 116 |
| | Richmond | 65 | 10 | 9 | 11 | 9 | 11 | 9 | 11 | 9 | 8 | 7 | 8 | 9 | 113 |
| | Roanoke | 55 | 10 | 10 | 11 | 10 | 12 | 10 | 12 | 10 | 9 | 7 | 9 | 9 | 119 |
| | Wallops Island | 28 | 11 | 10 | 11 | 10 | 10 | 9 | 11 | 8 | 8 | 8 | 9 | 10 | 115 |
| WA | Olympia | 61 | 20 | 17 | 18 | 15 | 11 | 9 | 5 | 6 | 8 | 14 | 19 | 21 | 163 |
| | Quillayute | 36 | 23 | 19 | 21 | 19 | 17 | 14 | 11 | 10 | 12 | 18 | 22 | 23 | 209 |
| | Seattle CO | 48 | 18 | 15 | 17 | 14 | 11 | 9 | 5 | 6 | 8 | 11 | 18 | 18 | 151 |
| | Seattle Sea-Tac AP | 58 | 19 | 16 | 17 | 14 | 11 | 9 | 5 | 6 | 9 | 13 | 18 | 19 | 155 |
| | Spokane | 55 | 14 | 11 | 11 | 9 | 9 | 8 | 5 | 5 | 6 | 8 | 13 | 14 | 112 |
| | Walla Walla | 55 | 13 | 10 | 12 | 10 | 9 | 7 | 4 | 3 | 4 | 7 | 15 | 12 | 106 |
| | Yakima | 56 | 10 | 7 | 6 | 5 | 5 | 5 | 2 | 3 | 3 | 5 | 8 | 10 | 69 |
| PR | San Juan | 47 | 17 | 13 | 12 | 13 | 16 | 15 | 19 | 19 | 18 | 17 | 19 | 19 | 197 |
| WV | Beckley | 39 | 16 | 14 | 15 | 15 | 14 | 13 | 13 | 11 | 11 | 10 | 12 | 15 | 159 |
| | Charleston | 55 | 15 | 14 | 15 | 14 | 13 | 12 | 13 | 11 | 9 | 9 | 12 | 14 | 151 |
| | Elkins | 58 | 18 | 16 | 17 | 15 | 15 | 13 | 14 | 12 | 11 | 11 | 13 | 17 | 171 |
| | Huntington | 41 | 13 | 12 | 14 | 13 | 13 | 11 | 11 | 10 | 8 | 9 | 11 | 13 | 139 |
| WI | Green Bay | 53 | 10 | 8 | 11 | 11 | 11 | 11 | 10 | 11 | 10 | 9 | 10 | 10 | 121 |
| | La Crosse | 50 | 9 | 7 | 10 | 11 | 11 | 11 | 10 | 10 | 10 | 8 | 8 | 9 | 114 |
| | Madison | 54 | 10 | 8 | 11 | 12 | 12 | 11 | 10 | 10 | 9 | 9 | 10 | 10 | 120 |
| | Milwaukee | 62 | 11 | 10 | 12 | 12 | 12 | 11 | 10 | 9 | 9 | 9 | 10 | 11 | 125 |
| WY | Casper | 52 | 7 | 8 | 9 | 10 | 11 | 9 | 8 | 6 | 7 | 7 | 7 | 7 | 95 |
| | Cheyenne | 67 | 6 | 6 | 9 | 10 | 12 | 11 | 11 | 10 | 8 | 6 | 6 | 6 | 100 |
| | Lander | 56 | 4 | 5 | 7 | 8 | 9 | 6 | 6 | 5 | 6 | 5 | 5 | 4 | 71 |
| | Sheridan | 62 | 9 | 8 | 11 | 11 | 12 | 11 | 8 | 6 | 7 | 8 | 8 | 8 | 106 |

*Note:* Through 2002. This table shows mean number of days per month with at least 0.01 in. of precipitation. This is the smallest amount of precipitation numerically recorded, and includes the liquid water equivalent of frozen precipitation. The frequency of days with precipitation should not be considered as frequency of cloudy days.

*Source*: From U.S. National Oceanic and Atmospheric Administration, *Comparative Climatic Data for the United States Through 2000*, www.noaa.gov.



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**Table 3D.24 Record Minimum Annual Precipitation by State**

| State | Precipitation (in.) | Date | Station | Elevation (ft) |
|---|---|---|---|---|
| Alabama | 22.00 | 1954 | Primrose Farm | 180 |
| Alaska | 1.61 | 1935 | Barrow | 31 |
| Arizona | 0.07 | 1956 | Davis Dam | 660 |
| Arkansas | 19.11 | 1936 | Index | 300 |
| California | 0.00 | 1929 | Death Valley | −282 |
| Colorado | 1.69 | 1939 | Buena Vista | 7,980 |
| Connecticut | 23.60[a] | 1965 | Baltic | 140 |
| Delaware | 21.38 | 1965 | Dover | 30 |
| Florida | 21.16 | 1989 | Conch Key | 6 |
| Georgia | 17.14 | 1954 | Swainsboro | 320 |
| Hawaii | 0.19 | 1953 | Kawaihae | est. 75 |
| Idaho | 2.09 | 1947 | Grand View | 2,360 |
| Illinois | 16.59[a] | 1956 | Keithsburg | 540 |
| Indiana | 18.67 | 1934 | Brooksville | 630 |
| Iowa | 12.11 | 1958 | Cherokee | 1,360 |
| Kansas | 4.77 | 1956 | Johnson | 3,270 |
| Kentucky | 14.51 | 1968 | Jeremiah | 1,160 |
| Louisiana | 26.44 | 1936 | Shreveport | 170 |
| Maine | 23.06 | 1930 | Machias | 30 |
| Maryland | 17.76 | 1930 | Picardy | 1,030 |
| Massachusetts | 21.76[a] | 1965 | Chatham L.S. | 20 |
| Michigan | 15.64 | 1936 | Croswell | 730 |
| Minnesota | 7.81 | 1936 | Angus | 870 |
| Mississippi | 25.97 | 1936 | Yazoo City | 120 |
| Missouri | 16.14[a] | 1956 | La Belle | 770 |
| Montana | 2.97 | 1960 | Belfry | 4,040 |
| Nebraska | 6.30 | 1931 | Hull | 4,400 |
| Nevada | T | 1898 | Hot Springs | 4,072 |
| New Hampshire | 22.31 | 1930 | Bethlehem | 1,440 |
| New Jersey | 19.85 | 1965 | Canton | 20 |
| New Mexico | 1.00 | 1910 | Hermanas | 4,540 |
| New York | 17.64 | 1941 | Lewiston | 320 |
| North Carolina | 22.69 | 1930 | Mount Airy | 1,070 |
| North Dakota | 4.02 | 1934 | Parshall | 1,930 |
| Ohio | 16.96 | 1963 | Elyria | 730 |
| Oklahoma | 6.53 | 1956 | Regnier | 4,280 |
| Oregon | 3.33 | 1939 | Warm Springs Reservoir | 3,330 |
| Pennsylvania | 15.71 | 1965 | Breezewood | 1,350 |
| Rhode Island | 24.08 | 1965 | Block Island | 40 |
| South Carolina | 20.73 | 1954 | Rock Hill | 667 |
| South Dakota | 2.89 | 1936 | Ludlow | 2,850 |
| Tennessee | 25.23 | 1941 | Halls | 310 |
| Texas | 1.64[a] | 1956 | Presidio | 2,580 |
| Utah | 1.34 | 1974 | Myton | 5,080 |
| Vermont | 22.98 | 1941 | Burlington | 330 |
| Virginia | 12.52 | 1941 | Moores Creek Dam | 1,950 |
| Washington | 2.61 | 1930 | Wahluke | 416 |
| West Virginia | 9.50 | 1930 | Upper Tract | 1,540 |
| Wisconsin | 12.00 | 1937 | Plum Is. | 590 |
| Wyoming | 1.28 | 1960 | Lysite | 5,260 |

[a] At least one month estimated.

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**Table 3D.25 Velocity of Fall, Number of Drops, and Kinetic Energy for Rainfall of Various Intensities**

| | Intensity (in./hr) | Median Diameter (mm) | Velocity of Fall (ft/sec) | Drops per Square Foot (no./sec) | Kinetic Energy (ft-lbs.per sq. ft/hr) |
|---|---|---|---|---|---|
| Fog | 0.005 | 0.01 | 0.01 | 6,264,000 | $4.043\times10^{-8}$ |
| Mist | 0.002 | 0.1 | 0.7 | 2.510 | $7.937\times10^{-5}$ |
| Drizzle | 0.01 | 0.96 | 13.5 | 14 | 0.148 |
| Light Rain | 0.04 | 1.24 | 15.7 | 26 | 0.797 |
| Moderate Rain | 0.15 | 1.60 | 18.7 | 46 | 4.241 |
| Heavy Rain | 0.60 | 2.05 | 22.0 | 46 | 23.47 |
| Excessive Rain | 1.60 | 2.40 | 24.0 | 76 | 74.48 |
| Cloudburst | 4.00 | 2.85 | 25.9 | 113 | 216.9 |
| Do | 4.00 | 4.00 | 29.2 | 41 | 275.8 |
| Do | 4.00 | 6.00 | 30.5 | 12 | 300.7 |

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## SECTION 3E SNOW AND SNOW MELT

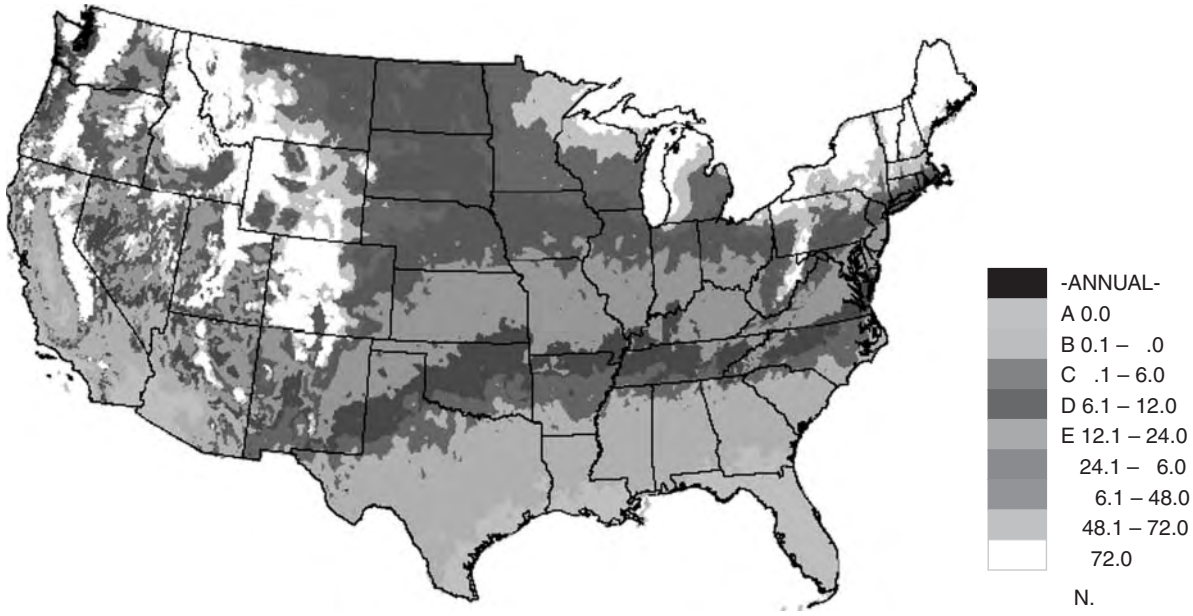


**Figure 3E.19** U.S. mean total snow. (From Climate Atlas of the United States, updated 8/27/02.)

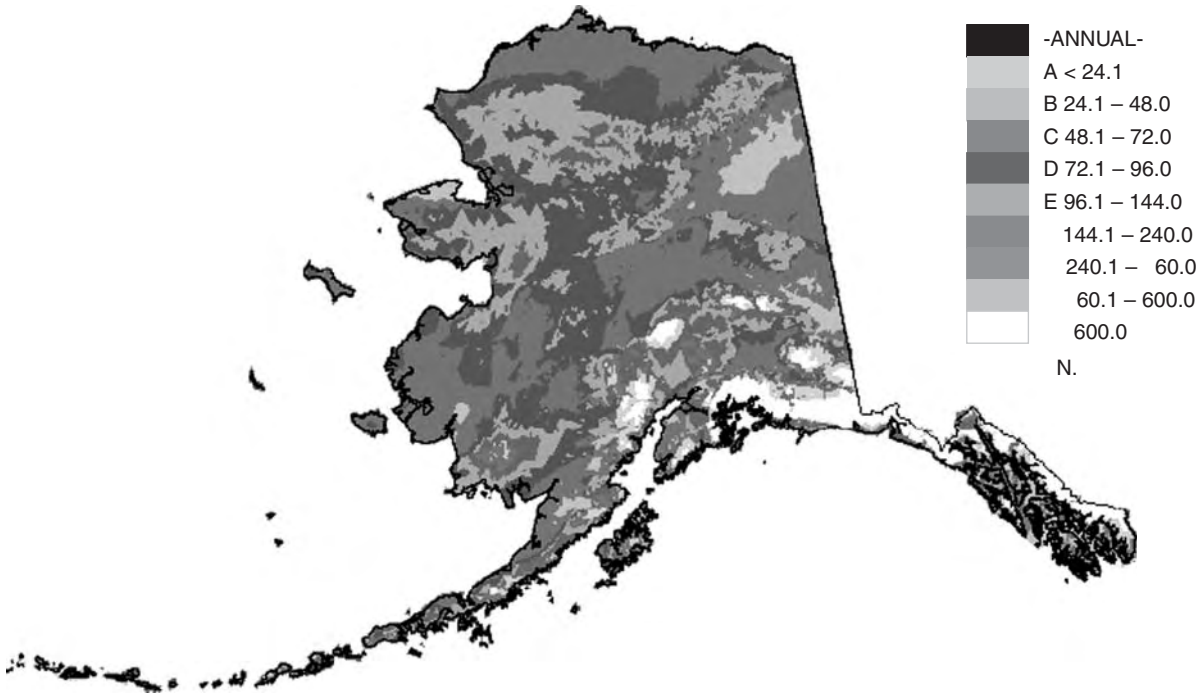


**Figure 3E.20** Alaska mean total snow. (From Climate Atlas of the United States, updated 8/27/02.)

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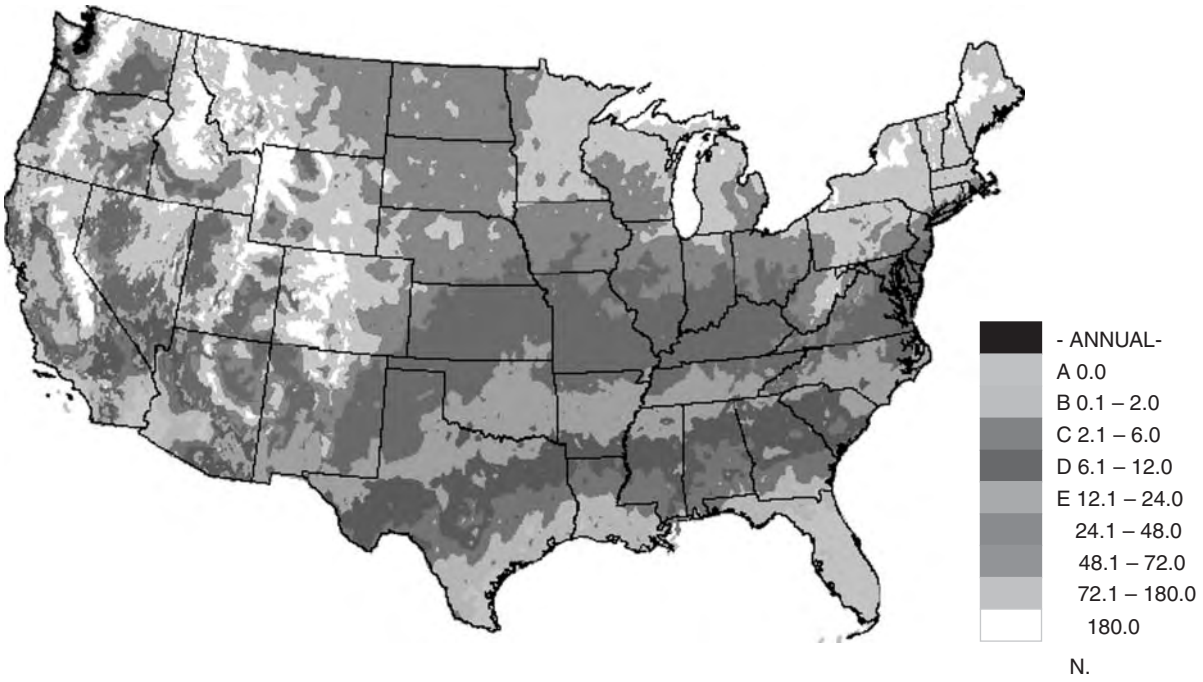


**Figure 3E.21** U.S. annual (Aug–Jul) record total snowfall. (From Climate Atlas of the United States, updated 8/27/02.)

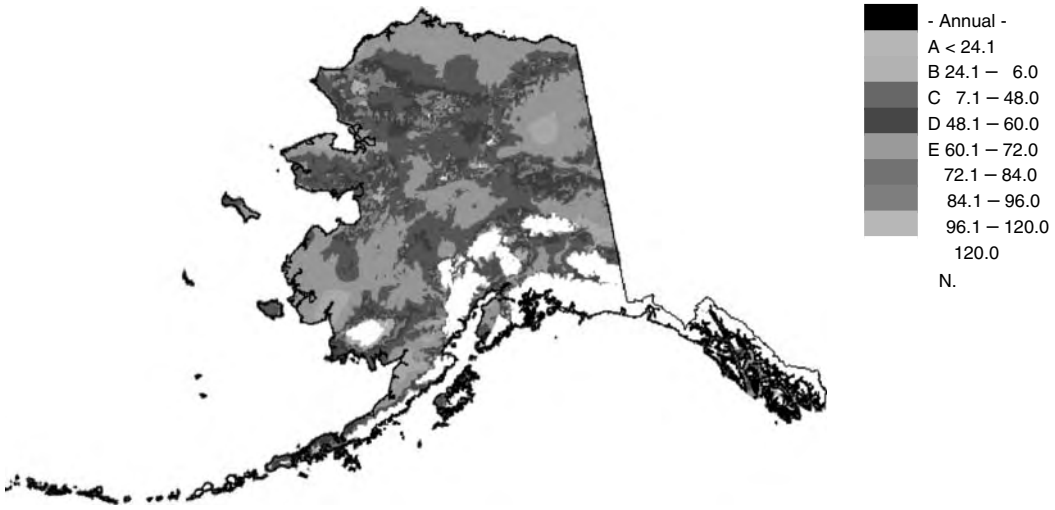


**Figure 3E.22** General Pattern of Annual World Precipitation. (Form Environmental Science Service: Administration, *Climates of the World*, 1969, www.noaa.gov.)

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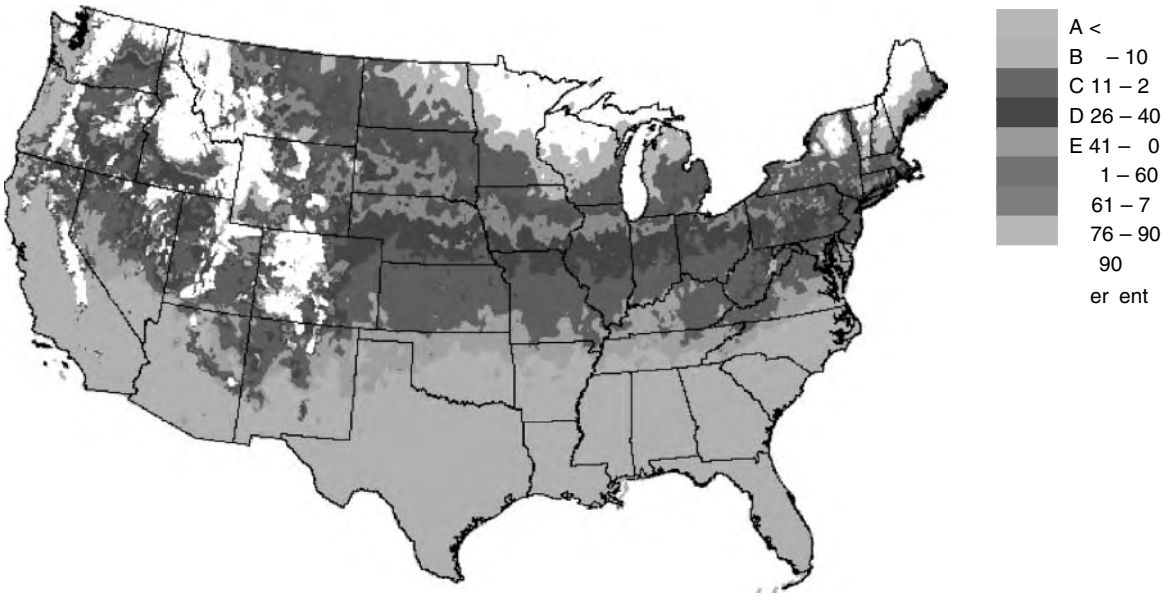


**Figure 3E.23** Average January world temperature. (From *Climates of the World*, Historical Climatology Series 6–14, 1991, www.noaa.gov.)

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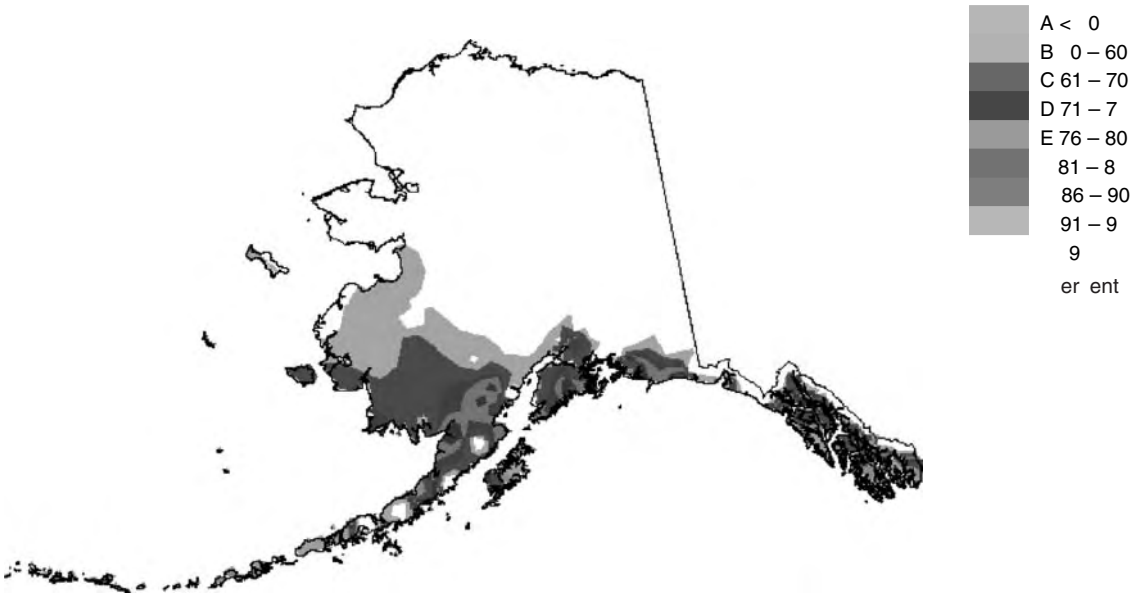


**Figure 3E.24** Average July world temperature. (From *Climates of the World*, Historical Climatology Series 6–14, 1991, www.noaa.gov.)

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**Table 3E.26 Physical Properties of Snow and Ice**

| | Density ($g/cm^3$) | Porosity (percent) | Air Permeability ($g/cm^3/sec$) | Grain Size (mm) |
|---|---|---|---|---|
| New Snow | 0.01–0.3 | 99–67 | >400–40 | 0.01–5 |
| Old Snow | 0.2–0.6 | 78–35 | 100–20 | 0.5–3 |
| Firm[a] | 0.4–0.84 | 56–8 | 40–0 | 0.5–5 |
| Glacier Ice | 0.84–0.917 | 8–0 | 0 | 1–100 |

[a] Firm is snow which has been modified into a dense compact material by deformation, refreezing, recrystallization, and other processes.

**Table 3E.27 Heat Supplied to Melting Snow by Different Processes**

| Heat Supply | Extreme Conditions | Approximate Heat Supplied[a] |
|---|---|---|
| Convection from turbulent air | 70° dry bulb, 20-mile wind | 600 |
| Condensation of atmospheric moisture | 60° dew point, 20-mile wind | 600 |
| Absorption of solar radiation | Very moist air, cloudy at night | 200 |
| Warm rain | 4 in., 50° wet bulb | 100 |
| Conduction from soil | New snow | 20 |

[a] Calories per square centimeter per day.

**Table 3E.28 Relation of Snow Melt to Snow Evaporation**

| Air Temperature (°C) | Relative Humidity (%) | Snow Evaporated ($g\ cm^{-2}\ day^{1}$) | Heat Transfer from Air to Snow ($cal\ cm^{-2}\ day^{1}$) | Heat Required in Evaporation Process[a] ($cal\ cm^{-2}\ day^{1}$) | Heat Available to Melt Snow ($cal\ cm^{-2}\ day^{1}$) | Melted Snow ($g\ cm^{-2}\ day^{1}$) | Melt/Evaporation |
|---|---|---|---|---|---|---|---|
| 5 | 20 | 2.02 | 900 | 1,370 | 0 | 0 | |
| 10 | 20 | 1.69 | 1,790 | 1,150 | 640 | 8.0 | 4.7 |
| 15 | 20 | 1.25 | 2,690 | 850 | 1,840 | 23.0 | 18.4 |
| 20 | 20 | 0.67 | 3,590 | 460 | 3,130 | 39.1 | 58.4 |

[a] Heat required in evaporation process is equal to heat transfer from air to snow plus heat obtained by lowering of snow-surface temperature.

**Table 3E.29 Melting Constant for Snow**

| Location | Descriptive Notes | Melting Period | Melting Constant |
|---|---|---|---|
| Albany, NY | Tests of small cylinders | 8–12 hours | 0.04–0.06 |
| Donner Summit, CA | Observations in 1917 | Apr 1–May 6 | 0.071 |
| Gooseberry Creek, UT | Field measurements | Apr 23–May 9 | 0.091 |
| Gooseberry Creek, UT | Tests of cores | 6–9 hr | 0.05–0.07 |
| Finland | All basins, 1934–1937 | Apr | 0.108 |
| Soda Springs, CA | Average, 1936–1941 | Apr | 0.051 |
| New England floods | Studies by Boston Soc. C.E. | 1–14 days | 0.01–0.04 |
| NY and PA basins | Flood runoff studies | Mar or Apr | 0.04–0.07 |
| LaGrange Brook, NY | Basin area, 36 acres | Mar 28–Apr 6 | 0.09 |
| New England floods, 1936 | Geol. Survey, average values | Mar 9–22 | 0.03–0.05 |
| Permigewasset Basin, NH | Flood of March 1936 | Mar 17–20 | 0.16 |
| Crater Lake, OR | Small test plots | Mar 3–Jun 9 | 0.153 |
| Crater Lake, OR | Small test plots | May 26–Jun 2 | 0.658 |

*Note:* The melting constant is the depth of water in inches melted per degree day. A degree day is a unit of heat resulting from a day with a mean temperature one degree Fahrenheit above 32°F.

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**Table 3E.30 Snow Survey Reports — Western United States**

SNOTEL (SNOWpack Telemetry) is an extensive system operated by the Natural Resources Conservation Services (NRCS). The system supports the Congressional mandate from the mid-1930's "to measure snow pack in the mountains of the West and forecast the water supply." SNOTEL has been in operation since 1980 replacing manual measurements and provides the data necessary to support the data needs of the NRCS and others

Specific products (data) supported include

- Climate Information
- Data Collection Technology
- Snow Survey Information
- Water Supply Forecasting
  - Colorado River Basin
  - Columbia River Basin/Alaska
  - Great Basin/California/Pacific Coastal
  - Missouri River Basin
- Hydraulics and Hydrology
- Irrigation and Water Management
- Water and Wind Erosion
- Water Quality Assessment and Monitoring
- Wetlands and Drainage

**Regional**

Water and Climate Monitoring
Natural Resources Conservation Service
Unites States Department of Agriculture
101 SW Main, Suite 1600
Portland, OR 97204-3224

Water and Climate Services
Natural Resources Conservation Service
Unites States Department of Agriculture
101 SW Main, Suite 1600
Portland, OR 97204-3224

**States**

**Alaska**
Data Collection Officer, Natural Resources Conservation Service, 949 E. 36th Ave., Suite 400, Anchorage, AK 99508-4362, (907) 271-2424

**Arizona**
Water Supply Specialist, Natural Resources Conservation Service, 3003 N. Central Ave., Suite 800, Phoenix, AZ 85012-2945

**California**
Water Supply Specialist, 430 G Street, #4164, Davis, CA 95616, (530) 792-5624, (530) 792-5791 (fax)

**Colorado**
Snow Survey Supervisor, USDA Natural Resources Conservation Service, Snow Survey Office, 655 Parfet St., Rm. E200C, Lakewood, CO 80215-5517, (303)236-2910 Ext. 235

**Idaho**
Water Supply Specialist, Natural Resources Conservation Service, Snow Survey Office, 9173 West Barnes Drive, Suite C, Boise, Idaho 83709-1574

**Montana**
Water Supply Specialist, Natural Resources Conservation Service, 10 E. Babcock, Room 443, Bozeman, Montana 59715

**Nevada**
Water Supply Specialist, Natural Resources Conservation Service, 5301 Longley Lane, Building F, Suite 201, Reno, NV 89511

**New Mexico**
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**Oregon**
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**Utah**
Snow Survey Supervisor, USDA–NRCS, Snow Surveys, 245 N. Jimmy Doolittle Road, Salt Lake City, UT 84116

**Washington**
Water Supply Specialist, Washington Snow Survey Office, 2021 E. College Way, Suite 214, Mount Vernon, WA 98273

**Wyoming**
Water Supply Specialist, Federal Building, Room 3124, 100 East B Street Casper, Wyoming 82601-1911

http://www.wcc.nrcs.usda.gov

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**Table 3E.31 Greatest Snowfalls in North America**

| | Place | Date | In. | Cm |
|---|---|---|---|---|
| 24 hr | Silver Lake, CO | Apr 14–15, 1921 | 76 | 195.6 |
| 1 month | Tamarack, CA | Jan 1911 | 390 | 991 |
| 1 storm | Mt. Shasta Ski Bowl, CA | Feb 13–19, 1959 | 189 | 480 |
| 1 season | Mount Baker, WA | 1998–1999 | 1,140 | 2,895.6 |

**Table 3E.32 National Snowfall and Snow Depth Extremes**

| | | Location | | | | | |
|---|---|---|---|---|---|---|---|
| Coop Station Number | Snow Amount (in.) | Station Name | State | | Ending Date | Number of Years of Non-Missing Data | Data Period Analyzed |
| Greatest daily snowfall | 62.0 | 509146 | Thompson Pass | AK | 12/29/1955 | 19 | 1952–1973 |
| Greatest 2-day snowfall (snowed both days) | 120.6 | 509146 | Thompson Pass | AK | 12/30/1955 | 19 | 1952–1073 |
| Greatest 3-day snowfall (snowed all 3 days) | 147.0 | 509146 | Thompson Pass | AK | 12/30/1955 | 19 | 1952–1973 |
| Greatest 4-day snowfall (snowed all 4 days) | 163.0 | 509146 | Thompson Pass | AK | 12/30/1955 | 19 | 1952–1973 |
| Greatest 5-day snowfall (snowed all 5 days) | 175.4 | 509146 | Thompson Pass | AK | 12/31/1955 | 19 | 1952–1973 |
| Greatest 6-day snowfall (snowed all 6 days) | 172.6 | 509146 | Thompson Pass | AK | 2/24/1953 | 19 | 1952–1973 |
| Greatest 7-day snowfall (snowed all 7 days) | 186.9 | 509146 | Thompson Pass | AK | 2/25/1993 | 19 | 1952–1973 |
| Greatest monthly snowfall total | 297.9 | 509146 | Thompson Pass | AK | 2/1953 | 17 | 1952–1973 |
| Greatest Aug–July snowfall total | 1069.8 | 456898 | Rainier Paradise Rangers | WA | 1974 | 17 | 1948–2000 |
| Greatest daily snow depth | 293.0 | 456898 | Rainier Paradise Rangers | WA | 4/12/1974 | 11 | 1948–2000 |

*Note:* Missing data may cause apparent discrepancies between the daily extreme, monthly total, and seasonal total snowfall values. The monthly and seasonal totals were based on complete data; if any days were missing, then the monthly or seasonal total could not be computed for that year. Daily snowfall extremes were not as susceptible to missing data. Consequently, it may be possible for a 1-day extreme to be greater than a multiple-day extreme, a daily extreme to be greater than a monthly total, and a monthly total to be greater than a seasonal total. Checking the "number of years with non-missing data" parameter is an important part of using this snow climatology.

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CHAPTER 4

# Hydrologic Elements

**Brian Burke**

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## SECTION 4A HYDROLOGIC CYCLE

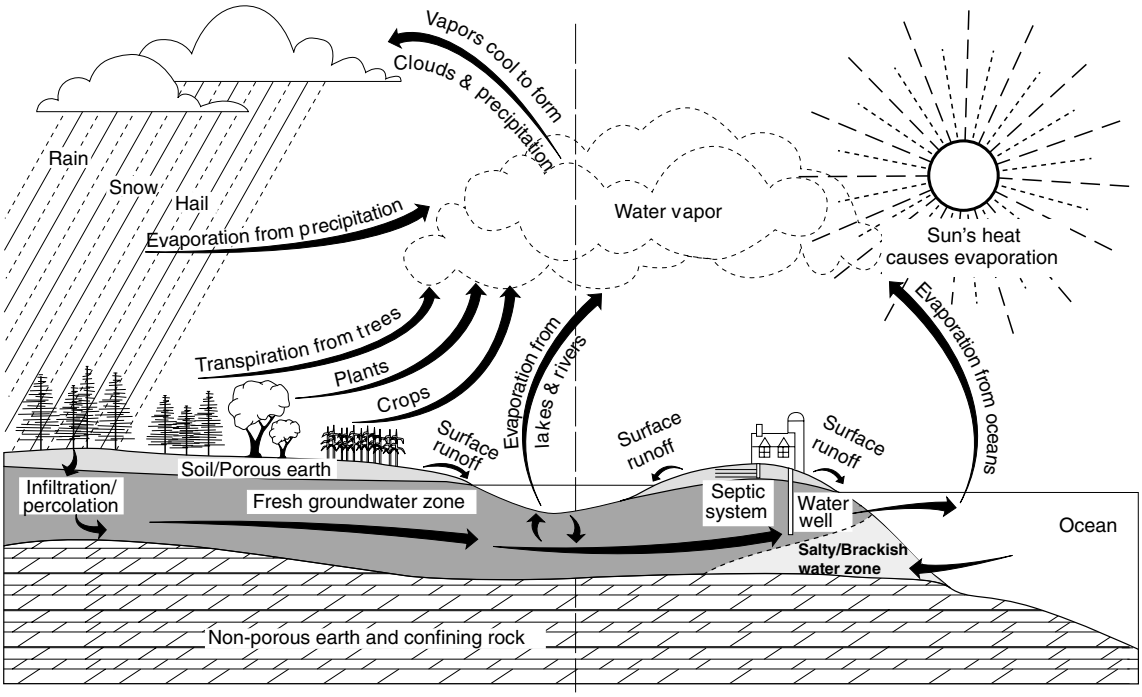


**Figure 4A.1** The hydrologic cycle. (From www.dnr.ohio.gov.)

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**Table 4A.1 Hydrologic Effects of Urbanization**

| Change in Land or Water Use | Possible Hydrologic Effect |
|---|---|
| **Transition from Pre-Urban to Early-Urban Stage:** | |
| Removal of trees or vegetation | Decrease in transpiration and increase in storm flow |
| Construction of scattered city-type houses and limited water and sewage facilities | Increased sedimentation of streams |
| Drilling of wells | Some lowering of water table |
| Construction of septic tanks and sanitary drains | Some increase in soil moisture and perhaps a rise in water table. Perhaps some waterlogging of land and contamination of nearby wells or streams from overloaded sanitary drain system |
| **Transition from Early-Urban to Middle-Urban State:** | |
| Bulldozing of land for mass housing, some topsoil removed, farm ponds filled in | Accelerated land erosion and stream sedimentation and aggradation. Increased flood flows. Elimination of smallest streams |
| Mass construction of houses, paving of streets, building of culverts | Decreased infiltration, resulting in increased flood flows and lowered groundwater levels. Occasional flooding at channel constrictions (culverts) on remaining small streams. Occasional overtopping or undermining of banks of artificial channels on small streams |
| Discontinued use and abandonment of some shallow wells | Rise in water table |
| Diversion of nearby streams for public water supply | Decrease in runoff between points of diversion and disposal |
| Untreated or inadequately treated sewage discharged into streams or disposal wells | Pollution of stream or wells. Death of fish and other aquatic life. Inferior quality of water available for supply and recreation at downstream populated areas |
| **Transition from Middle-Urban to Late-Urban Stage:** | |
| Urbanization of area completed by addition of more houses and streets and of public, commercial, and industrial buildings | Reduced infiltration and lowered water table. Streets and gutters act as storm drains, creating higher flood peaks and lower base flow of local streams |
| Larger quantities of untreated waste discharged into local streams | Increased pollution of streams and concurrent increased loss of aquatic life. Additional degradation of water available to downstream users |
| Abandonment of remaining shallow wells because of pollution | Rise in water table |
| Increase in population requires establishment of new water-supply and distribution systems, construction of distant reservoirs diverting water from upstream sources within or outside basin | Increase in local streamflow if supply is from outside basin |
| Channels of streams restricted at least in part to artificial channels and tunnels | Increased flood damage (higher stage for a given flow). Changes in channel geometry and sediment load. Aggradation |
| Construction of sanitary drainage system and treatment plant for sewage | Removal of additional water from the area, further reducing infiltration and recharge of aquifer |
| Improvement of storm drainage system | A definite effect is alleviation or elimination of flooding of basements, streets, and yards, with consequent reduction in damages, particularly with respect to frequency of flooding |
| Drilling of deeper, large-capacity industrial wells | Lowered water-pressure surface of artesian aquifer; perhaps some local overdrafts (withdrawal from storage) and land subsidence. Overdraft of aquifer may result in salt-water encroachment in coastal areas and in pollution or contamination by inferior or brackish waters |
| Increased use of water for air conditioning | Overloading of sewers and other drainage facilities. Possibly some recharge to water table, due to leakage of disposal lines |
| Drilling of recharge wells | Raising of water-pressure surface |
| Waste-water reclamation and utilization | Recharge to groundwater aquifers. More efficient use of water resources |

*Note:* A selected sequence of changes in land and water use associated with urbanization.

*Source*: U.S. Geological Survey.

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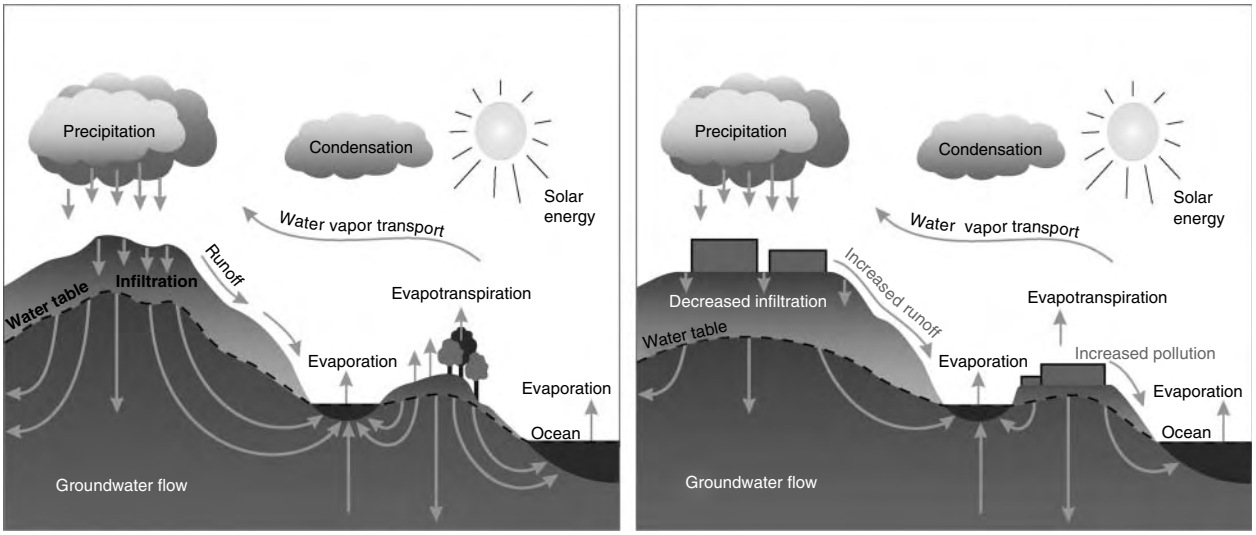


**Figure 4A.2** Water cycle before and after urbanization. (From www.unce.unr.edu.)

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## SECTION 4B WATER RESOURCES — UNITED STATES

**Table 4B.2 Distribution of Water in the Continental United States**

| | Volume | | Annual Circulation | Replacement Period |
|---|---|---|---|---|
| | $\times 10^9$ m$^3$ | % | ($\times 10^9$ m$^3$/yr) | (yr) |
| Liquid water | | | | |
| Groundwater | | | | |
| Shallow (<800 m deep) | 63,000 | 43.2 | 310 | >200 |
| Deep (>800 m deep) | 63,000 | 43.2 | 6.2 | >10,000 |
| Freshwater lakes | 19,000 | 13.0 | 190 | 100 |
| Soil moisture (1-m root zone) | 630 | 0.43 | 3,100 | 0.2 |
| Salt lakes | 58 | 0.04 | 5.7 | >10 |
| Average in stream channels | 50 | 0.03 | 1,900 | <0.03 |
| Water vapor in atmosphere | 190 | 0.13 | 6,200 | >0.03 |
| Frozen water, glaciers | 67 | 0.05 | 1.6 | >40 |

*Source*: From Ad Hoc Panel on Hydrology, *Scientific Hydrology*, Washington, DC: Federal Council for Science and Technology, 1962.

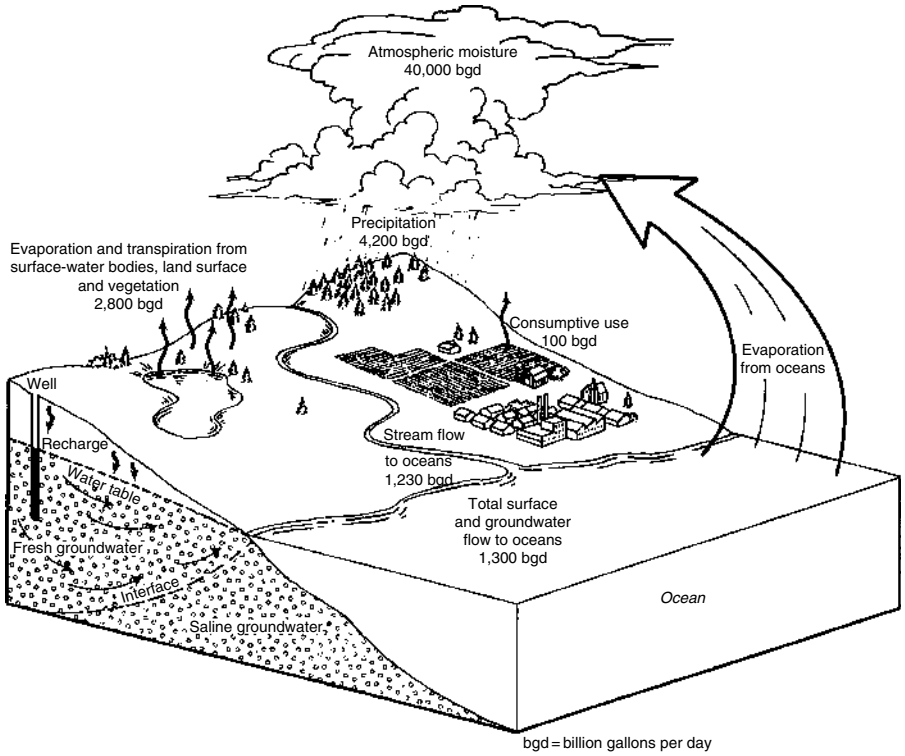


**Figure 4B.3** Hydrologic cycle showing the gross water budget of the conterminous United States. (From U.S. Geological Survey, *National Water Summary 1983 — Hydrologic Events and Issues*, Water-Supply Paper 2250, 1984.)

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**Table 4B.3 Some Purposes of Water-Resources Development**

| Purpose | Description | Type of Works and Measures |
|---|---|---|
| Flood control | Flood-damage abatement or reduction, protection of economic development, conservation storage, river regulation, recharging of groundwater, water supply, development of power, protection of life | Dams, storage reservoirs, levees, floodwalls, channel improvement, floodways, pumping stations, floodplain zoning, flood forecasting |
| Irrigation | Agricultural production | Dams, reservoirs, walls, canals, pumps and pumping plants, weed-control and desilting works, distribution systems, drainage facilities, farmland grading |
| Hydroelectricity | Provision of power for economic development and improved living standards | Dams, reservoirs, penstocks, power plants, transmission lines |
| Navigation | Transportation of goods and passengers | Dams, reservoirs, canals, locks, open-channel improvements, harbor improvements |
| Domestic and industrial water supply | Provision of water for domestic, industrial, commercial, municipal, and other uses | Dams, reservoirs, walls, conduits, pumping plants, treatment plants, saline-water conversion, distribution systems |
| Watershed management | Conservation and improvement of the soil, sediment abatement, runoff retardation, forests and grassland improvement, and protection of water supply | Soil-conservation practices, forest and range management practices, headwater-control structures, debris-detention dams, small reservoirs, and farm ponds |
| Recreational use of water | Increased well-being and health of the people | Reservoirs, facilities for recreational use, works for pollution control, preservation of scenic and wilderness areas |
| Fish and wildlife | Improvement of habitat for fish and wildlife, reduction or prevention of fish or wildlife losses associated with man's works, enhancement of sports opportunities, provision for expansion of commercial fishing | Wildlife refuges, fish hatcheries, fish ladders and screens, reservoir storage, regulation of streamflows, stocking of streams and reservoirs with fish, pollution control, and land management |
| Pollution abatement | Protection or improvement of water supplies for municipal, domestic, industrial and agricultural uses and for aquatic life and recreation | Treatment facilities, reservoir storage for augmenting low flows, sewage-collection systems, legal control measures |
| Insect control | Public health, protection of recreational values, protection of forests and crops | Proper design and operation of reservoirs and associated works, drainage, and extermination measures |
| Drainage | Agricultural production, urban development and protection of public health | Ditches, tile drains, levees, pumping stations, soil treatment |
| Sediment control | Reduction or control of slit load in streams and protection of reservoirs | Soil conservation, sound forest practices, proper highway and railroad construction, desilting works, channel and revetment works, bank stabilization, special dam construction and reservoir operations |
| Salinity control | Abatement or prevention of salt-water contamination of agricultural, industrial, and municipal water supplies | Reservoirs for augmenting low stream-flow, barriers, groundwater recharge, coastal jetties |

*Source*: From Chow, V.T., Water as a World Resource, *Water International*, 4, 6, 1979. With permission.

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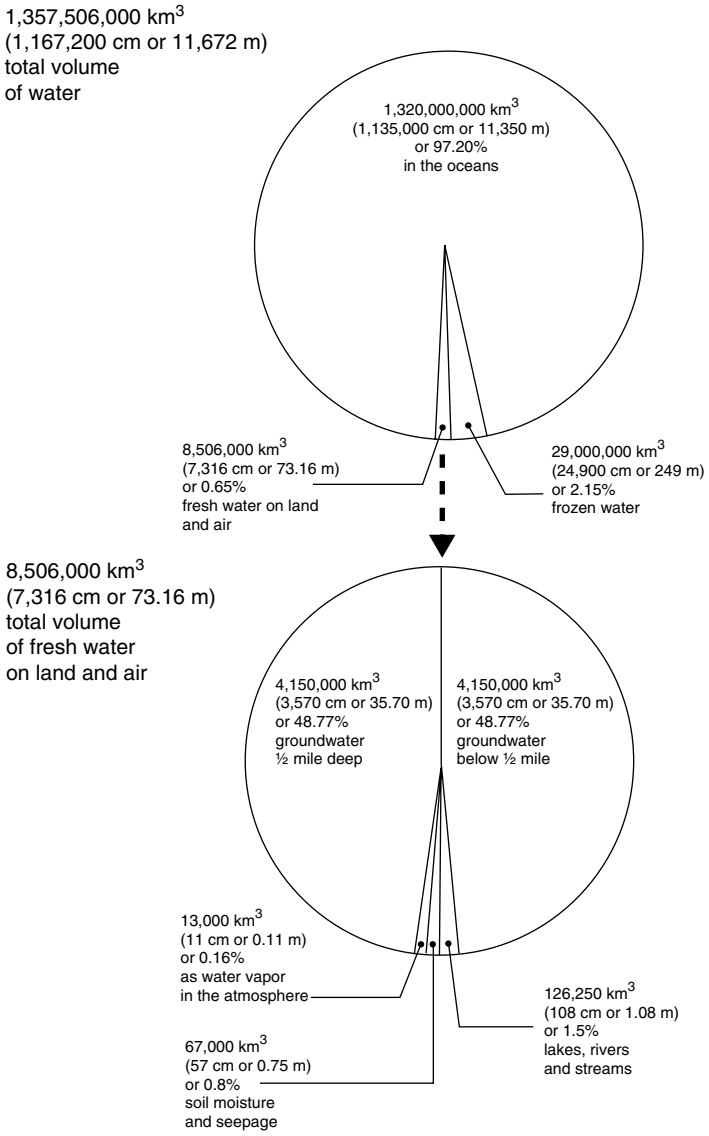
## SECTION 4C WORLD WATER BALANCE




Note: figures in brackets indicate the height that the relevant quantites of water would reach if they were placed on the whole non-frozen land area of the earth which is 116,400,000 km$^3$

**Figure 4C.4** Water availability on earth. (From Doxiadis, C.A., *Water and Environment International Conference on Water for Peace*, Washington, DC, 1967.)

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**Table 4C.4 Estimated Global Water Cycle**

| Type of Water | Location | Volume | | Percent of Total Volume |
|---|---|---|---|---|
| | | Millions of cu. Miles | Millions of cu Kilometer | |
| Salt Water | | | | 97.00 |
| | Oceans | 314.2 | 1308.0 (96.4%) | |
| | Saline bodies | 2.1 | 8.7 (0.6%) | |
| Fresh Water | | | | 2.90 |
| | Ice & snow | 6.9 | 28.7 (2.1%) | |
| | Lakes | 0.5 | 2.1 (0.15%) | |
| | Rivers | 0.01 | 0.04 (0.003%) | |
| | Accessible groundwater | 1.0 | 4.2 (0.31%) | |
| Atmospheric | | | | 0.10 |
| | Sea evaporation | 0.1 | 0.42 (0.03%) | |
| | Land evaporation | 0.05 | 0.21 (0.015%) | |
| | Precipitation over sea | 0.09 | 0.37 (0.03%) | |
| | Precipitation over land | 0.03 | 0.12 (0.01%) | |
| | Water vapor | 0.005 | 0.02 (0.002%) | |
| Rounded Total | | 326.00 | 1357.00 | 100.0 |

*Source*: From National Weather Service Northwest River Forecast Center, www.nwrfc.noaa.gov.

**Table 4C.5 World Water Balance, by Continent**

| Water Balance Elements | Europe[a] | Asia | Africa | North America[b] | South America | Australia[c] | Total Land Area[d] |
|---|---|---|---|---|---|---|---|
| Area, millions of $km^2$ | 9.8 | 45.0 | 30.3 | 20.7 | 17.8 | 8.7 | 132.3 |
| **in mm** | | | | | | | |
| Precipitation (P) | 734 | 726 | 686 | 670 | 1,648 | 736 | 834 |
| Total river runoff (R) | 319 | 293 | 139 | 287 | 583 | 226 | 294 |
| Groundwater runoff (U) | 109 | 76 | 48 | 84 | 210 | 54 | 90 |
| Surface water runoff (S) | 210 | 217 | 91 | 203 | 373 | 172 | 204 |
| Total infiltration and soil moisture (W) | 524 | 509 | 595 | 467 | 1,275 | 564 | 630 |
| Evaporation (E) | 415 | 433 | 547 | 383 | 1,065 | 510 | 540 |
| **in $km^3$** | | | | | | | |
| Precipitation | 7,165 | 32,690 | 20,780 | 13,910 | 29,355 | 6,405 | 110,303 |
| Total river runoff | 3,110 | 13,190 | 4,225 | 5,960 | 10,380 | 1,965 | 38,830 |
| Groundwater runoff | 1,065 | 3,410 | 1,465 | 1,740 | 3,740 | 465 | 11,885 |
| Surface water runoff | 2,045 | 9,780 | 2,760 | 4,220 | 6,640 | 1,500 | 26,945 |
| Total infiltration and soil moisture | 5,120 | 22,910 | 18,020 | 9,690 | 22,715 | 4,905 | 83,360 |
| Evaporation | 4,055 | 19,500 | 16,555 | 7,950 | 18,975 | 4,440 | 71,475 |
| **Relative values** | | | | | | | |
| Groundwater runoff as percent of total runoff | 34 | 26 | 35 | 32 | 36 | 24 | 31 |
| Coefficient of groundwater discharge into rivers | 0.21 | 0.15 | 0.08 | 0.18 | 0.16 | 0.10 | 0.14 |
| Coefficient of runoff | 0.43 | 0.40 | 0.23 | 0.31 | 0.35 | 0.31 | 0.36 |

[a] Including Iceland.
[b] Excluding the Canadian archipelago and including Central America.
[c] Including Tasmania, New Guinea and New Zealand, only within the limits of the continent: P-440 mm; R-47 mm; U-7 mm; S-40 mm; W-400 mm; E-393 mm.
[d] Excluding Greenland, Canadian archipelago and Antarctica.

*Source*: From Lvovitch, M.I., *EOS*, 54, 1973. With permission. Copyright by American Geophysical Union.

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**Table 4C.6 World Water Resources by Region**

| | Region | Total Area ($km^2$) (FAOSTATE, 1999) (1) | Total Population (FAOSTAT, 2000) (2) | Average Precipitation 1961–1990 ($km^3$/yr) (IPCC) (3) | Internal Resources: Total ($km^3$/yr) (4) | External Resources: Natural ($km^3$/yr) | External Resources: Actual ($km^3$/yr) | Total Resources: Natural ($km^3$/yr) | Total Resources: Natural ($km^3$/yr) | % of World Resources | IRWR/inhab. ($m^3$/yr) | TRWR (actual)/inhab. ($m^3$/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Northern America | 21,899,600 | 409,895,363 | 13,384 | 6,662 | 47 (5) | 47 | 6,709 | 6,709 | 15.2% | 16,253 | 16,368 |
| 2 | Central America and Caribbean | 749,120 | 72,430,000 | 1,506 | 781 | 6 (6) | 6 | 787 | 787 | 1.8% | 10,784 | 10,867 |
| 3 | Southern America | 17,853,960 | 345,737,000 | 28,635 | 12,380 | 0 | 0 | 12,380 | 12,380 | 28.3% | 35,808 | 35,808 |
| 4 | Western and Central Europe | 4,898,416 | 510,784 | 4,096 | 2,170 | 11 | 11 | 2,181 | 2,181 | 5.0% | 4,249 | 4,270 |
| 5 | Eastern Europe | 18,095,450 | 217,051,000 | 8,452 | 4,449 | 244 | 244 | 4,693 | 4,693 | 10.2% | 20,498 | 21,622 |
| 6 | Africa | 30,044,850 | 793,288,000 | 20,415 | 3,950 | 0 | 0 | 3,950 | 3,950 | 9.0% | 4,980 | 4,980 |
| 7 | Near East | 6,347,970 | 257,114,000 | 1,378 | 488 | 3 | 3 | 491 | 491 | 1.1% | 1,897 | 1,909 |
| 8 | Central Asia | 4,655,490 | 78,563,000 | 1,270 | 261 | 28 | 28 | 289 | 289 | 0.6% | 3,321 | 3,681 |
| 9 | Southern and Eastern Asia | 21,191,290 | 3,331,938 000 | 24,017 | 11,712 | 8 | 8 | 11,720 | 11,720 | 26.8% | 3,515 | 3,518 |
| 10 | Oceania and Pacific | 8,058,920 | 25,388,537 | 4,772 | 911 | 0 | 0 | 911 | 911 | 2.1% | 35,869 | 35,869 |
| | World | 133,795,066 | 6,042,188,900 | 107,924 | 43,764 | 0 | 0 | 43,764 | 43,764 | 100.0% | 7,243 | 7,243 |

*Notes:* (1) No FAOSTAT data for Spilsbergen (Norway); (2) No FAOSTAT data for West Bank (Palestinian authority); data from Margat and Vallée (2000); (3) No IPCC data on Near East (Saudi Arabia, West Bank (Palestinian Authority); Gaza strip (Palestinian Authority)), South Asia (Taiwan Province of China, east Timor), Caribbean (Aruba). Pacific (Polynesia, Guam) so not included in total. For Europe: no IPCC data for Spilsbergen (Norway), Luxembourg and Belgium; national data source used; (4) No data for various islands in Caribbean (Aruba, Bermuda, Grenada, Guadeloupe, Martinique, St. Lucia. St. Vincent, Dominica) Pacific (French Polynesia, Guam, New Caledonia, Samoa, Tonga), Asia (Macao, Hong Kong); so not included in regional and global totals; (5) 47 $km^3$/year from Guatemala to Mexico; (6) 6 $km^3$/year from North America region (Mexico).

*Source*: www.fao.org.



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**Table 4C.7 Water Poor Countries**

| FAO Code | Country | Average Precipitation 1961–1990 ($km^3$/yr) | Internal Resources Surface ($km^3$/yr) | Internal Resources Groundwater ($km^3$/yr) | Internal Resources Overlap ($km^3$/yr) | Internal Resources Total ($km^3$/yr) | External Resources Natural ($km^3$/yr) | External Resources Actual ($km^3$/yr) | Total Resources Natural ($km^3$/yr) | Total Resources Actual ($km^3$/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| 105 | Israel | 9.16 | 0.25 | 0.50 | 0.00 | 0.75 | 0.92 | 0.92 | 1.67 | 1.67 |
| 112 | Jordan | 9.93 | 0.40 | 0.50 | 0.22 | 0.68 | 0.20 | 0.20 | 0.88 | 0.88 |
| 124 | Libyan Arab Jamahiriya | 98.53 | 0.20 | 0.50 | 0.10 | 0.60 | 0.00 | 0.00 | 0.60 | 0.60 |
| 136 | Mauritania | 94.66 | 0.10 | 0.30 | 0.00 | 0.40 | 11.00 | 11.00 | 11.40 | 11.40 |
| 35 | Cape Verde | 1.70 | 0.18 | 0.12 | 0.00 | 0.30 | 0.00 | 0.00 | 0.30 | 0.30 |
| 72 | Djibouti | 5.12 | 0.30 | 0.02 | 0.02 | 0.30 | 0.00 | 0.00 | 0.30 | 0.30 |
| 225 | United Arab Emirates | 6.53 | 0.15 | 0.12 | 0.12 | 0.15 | 0.00 | 0.00 | 0.15 | 0.15 |
| 179 | Qatar | 0.81 | 0.00 | 0.05 | 0.00 | 0.05 | 0.00 | 0.00 | 0.05 | 0.05 |
| 134 | Malta | 0.12 | 0.00 | 0.05 | 0.00 | 0.05 | 0.00 | 0.00 | 0.05 | 0.05 |
| 76 | Gaza Strip (Palestinian Authority) | 0.00 | 0.00 | 0.05 | 0.00 | 0.05 | 0.01 | 0.01 | 0.06 | 0.06 |
| 13 | Bahrain | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.11 | 0.12 | 0.12 |
| 118 | Kuwait | 2.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 | 0.02 |

*Source*: From Review of World Water Resources by Country, www.fao.org/documents.

**Table 4C.8 Water Rich Countries**

| FAO Code | Country | Average Precipitation 1961–1990 ($km^3$/yr) | Internal Resources Surface ($km^3$/yr) | Internal Resources Groundwater ($km^3$/yr) | Internal Resources Overlap ($km^3$/yr) | Internal Resources Total ($km^3$/yr) | External Resources Natural ($km^3$/yr) | External Resources Actual ($km^3$/yr) | Total Resources Natural ($km^3$/yr) | Total Resources Actual ($km^3$/yr) | IRWR/inhab. ($m^3$/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | Brazil | 15,236 | 5,418 | 1,874 | 1,874 | 5,418 | 2,815 | 2,815 | 8,233 | 8,233 | 31,795 |
| 185 | Russian Federation | 7,855 | 4,037 | 788 | 512 | 4,313 | 195 | 195 | 4,507 | 4,507 | 29,642 |
| 33 | Canada | 5,352 | 2,840 | 370 | 360 | 2,850 | 52 | 52 | 2,902 | 2,902 | 92,662 |
| 101 | Indonesia | 5,147 | 2,793 | 455 | 410 | 2,838 | 0 | 0 | 2,838 | 2,838 | 13,381 |
| 41 | China, Mainland | 5,995 | 2,712 | 829 | 728 | 2,812 | 17 | 17 | 2,830 | 2,830 | 2,245 |
| 44 | Colombia | 2,975 | 2,112 | 510 | 510 | 2,112 | 20 | 20 | 2,132 | 2,132 | 50,160 |
| 231 | United States of America (Cont.) | 5,800 | 1,862 | 1,300 | 1,162 | 2,000 | 71 | 71 | 2,071 | 2,071 | 7,153 |
| 170 | Peru | 1,919 | 1,616 | 303 | 303 | 1,616 | 297 | 297 | 1,913 | 1,913 | 62,973 |
| 100 | India | 3,559 | 1,222 | 419 | 380 | 1,261 | 647 | 636 | 1,908 | 1,897 | 1,249 |

*Source*: From Review of World Water Resources by Country, www.fao.org/documents.

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## SECTION 4D HYDROLOGIC DATA

*The networks included 63 HBN stations from 1962-95 and 618 NASQAN stations from 1973-95. Stations located outside of the conterminous United States for NASQAN included 13 in Alaska. 8 in Hawaii, 6 in Puerto Rico, and 1 in Guam; HBN stations included 1 each in Alaska and Hawaii.*

**Figure 4D.5** Locations of NASQAN and national hydrologic bench-mark stations in the United States. (From http://water.usgs.gov.)

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**Table 4D.9 National Stream Water Quality Accounting Network (NASQAN) — Stations Operated by NASQAN 1996–2000**

| USGA Station ID | Station Name | USGS Office Sampling Station | Latitude | Longitude | Hydrologic Unit Code | Location of Stream Gage and Sampling Site | Drainage Area | Remarks |
|---|---|---|---|---|---|---|---|---|
| **Mississippi River Basin** | | | | | | | | |
| 03216600 | Ohio River at Greenup Dam near Greenup, KY | Louisville, KY | 38°38′48″ | 82°51′38″ | 05090103 | At left bank at downstream end of lock guidewall in lower poolat Greenup locks, 1.1 mi upstream from Grays Branch, 4.7 mi downstream from Little Sandy River, 5.0 mi north of Greenup and at mile 341.5 | 62,000 sq. mi., approximately | |
| 03303280 | Ohio River at Cannelton Dam at Cannelton, IN | Louisville, KY | 37°53′58″ | 86°42′20″ | 05140201 | At Cannelton Dam, 0.7 mi upstream from Indian Creek, 3.3 mi upstream from Lead Creek, and at mile 720.8. Water-quality samples are collected 2.0 mi upstream from discharge station | 97,000 sq. mi, approximately | |
| 03378500 | Wabash River at New Harmony, IN | Paducah, KY | 38°07′55″ | 87°56′25″ | 05120113 | At bridge on U.S. Highway 66 at New Harmony and at mile 51.5 | 29,234 sq. mi | Water discharge obtained from station Wabash river at Mount Carmel, IL (03377500) |
| 03609750 | Tennessee River at Highway 60 near Paducah, KY | Paducah, KY | 37°02′16″ | 88°31′46″ | 06040006 | At auxiliary gaging station at bridge on U.S. Highway 60, 16.3 mi downstream from gagin station, 2.4 mi east of Paducah, and at mile 5.3 | 40,330 sq. mi., 40,200 sq. mi. at gage | Records of daily discharge are taken from gaging station near Paducah (03609500). Flow completely regulated. Barkley-Kentucky Cannal (03438190) diverts water from and to Lake Barkley in the Cumberland River Basin |
| 03612500 | Ohio River at Dam 53 near Grand Chain, IL | Paducah, KY | 37°12′11″ | 89°02′30″ | 05140206 | At auxiliary gaging station, 0.5 mi upstream from Gar Creek, 3.0 mi southwest of Grand Chain, 18.1 mi downstream from gaging station at Metropolis, and at mile 962.2 | 203,100 sq. mi, approximately | Water discharge obtained from Ohio River at Metropolis, IL (03611500). Flow regulated by many dams and reservoirs |
| 05420500 | Mississippi River at Clinton, IA | Iowa City, IA | 41°46′50″ | 90°15′07″ | 07080101 | At river end of 3rd St., at downstream end of ADM repair dock, 10.3 miles upstream from Wapsipinicon River, 4.8 mi upstream from Camanche gage, 5.9 mi downstream from Lock and Dam 13, and at mile 516.6 upstream from Ohio River. Water-quality samples collected at Fulton-Lyons Bridge, 6.4 mi upstream of discharge station | 85,600 sq. mi., approximately, at Fulton-Lyons Bridge in Clinton | |
| 05587455 | Mississippi River below Grafton, IL | Rolla, MO | 38°58′05″ | 90°25′42″ | 07110009 | On left bank 0.2 mi downstream from the mouth of the Illinois River, 15.3 mi above Lock and Dam 26, 23.0 mi above mouth of Missouri River and at mile 218.6 upstream of the mouth o the Ohio River. Water-quality samples collected 4 mi downstream of discharge station | 171,300 sq. mi., approximately | |
| 06185500 | Missouri River near Culbertson, MT | Fort Peck, MT | 48°07′30″ | 104°28′20″ | 10060005 | On right bank at upstream side of bridge on State Highway 16, 2.5 mi southeast of Culbertson, 10 mi downstream from Big Muddy Creek and at river mile 1,620.76 | 91,557 sq. mi | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 06329500 | Yellowstone River near Sidney, MT | Fort Peck, MT | 47°40′42″ | 104°09′22″ | 10100004 | On left bank at Montana-Dakota Utilities Company powerplant, 0.2 mi downstream from bridge on State Highway 23, 2.5 mi south of Sidney, 3.0 mi downstream from Fox Creek, and at river mile 29.2 | 69,103 sq. mi; | |
| 06338490 | Missouri River at Garrison Dam, ND | Bismark, ND | 47°30′08″ | 101°25′50″ | 10130101 | In control structure of Garrison Dam, 2.5 mi west of Riverdale, 14 mi upstream from Knife River, and at mile 1,389.9 | 181,400 sq. mi., approximately | |
| 06440000 | Missouri River at Pierre SD | Pierre, SD | 44°22′23″ | 100°22′03″ | 10140101 | On left bank downstream from Dakota Minnesota and Eastern Railroad bridge, 1.3 mi upstream from Bad River, 5.8 mi downstream from Oahe Dam, and at mile 1066.5. Water-quality samples collected 0.25 mile below Oahe Dam, about 5.55 mile upstream from gaging station. Inflow between these two locations generally are negligible | 243,500 sq. mi., approximately | |
| 06610000 | Missouri River at Omaha, NE | Council Bluffs, IA | 41°15′32″ | 95°55′20″ | 10230006 | On right bank on left side of concrete floodwall, at foot of Douglas Street, 275 ft downstream of Interstate 480 Highway bridge in Omaha and at mile 615.9 Water-quality samples are collected at Interstate-80 bridge, 2.0 miles downstream of gaging station | 322,800 sq. mi. approximately. The 3,959 sq. mi. in the Great Divide basin are not included | Flow regulated by upstream mainstem reservoirs. US Army Corps of Engineers raingage and satellite data collection platform at station |
| 06805500 | Platte River at Louisville, NE | Linclon, NE | 41°00′55″ | 96°09′28″ | 10200202 | On the left bank at the upstream side of bridge on Nebraska Highway 50, 1 mi north of Louisville, and at mile 16.5 | 85,370 sq. mi., appoximately, of which about 71,000 sq. mi., contributes directly to surface runoff | |
| 06934500 | Missouri River at Hermann, MO | Rolla, MO | 38°42′36″ | 91°26′21″ | 10300300 | On downstream side of third pier from right abutment of bridge on State Highway 19 at Hermann, and at mile 97.9 | 524,200 sq. mi., approximately | |
| 07022000 | Mississippi River at Thebes, IL | Rolla, MO | 37°13′00″ | 89°27′50″ | 07140105 | Near center span on downstream side of railroad bridge at Thebes, 5.0 mi downstream from Headwater Diversion Channel and at mile 43.7 above Ohio River | 713,200 sq. mi., approximately | |
| 07263620 | Arkansas River at David D. Terry Lock & Dam below Little Rock, AR | Little Rock, AR | 34°40′07″ | 92°09′18″ | 11110207 | At upper end of upstream wall at David D. Terry Lock and Dam. 10.7 mi downstream from Main Street bridge at Little Rock, and at mile 124.2 | 158,288 sq. mi., of which 22,241 sq. mi. is probably non-contributing | Discharge is from station 07263450, 16.8 mi. upstream |
| 07373420 | Mississippi River near St. Francisville, LA | Baton Rouge, LA | 30°45′30″ | 91°23′45″ | 08070100 | At State Highway 10 ferry crossing, 2.0 mi southwest of St. Francisville and at mile 266.0 | 1,125,300 sq. mi. contributing | Discharge is from Mississippi River at Tarbert Landing, MS, station 07295100 |
| 07381495 | Atchafalaya River at Melville, LA | Baton Rouge, LA | 30°41′26″ | 91°44′10″ | 08080101 | At bridge on Texas and Pacific Railroad in Melville | 93,316 sq. mi | Discharge is from station 07381490, Atachafalaya river at Simmesport, LA |

*(Continued)*



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**Table 4D.9 (Continued)**

| USGA Station ID | Station Name | USGS Office Sampling Station | Latitude | Longitude | Hydrologic Unit Code | Location of Stream Gage and Sampling Site | Drainage Area | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Rio Grande Basin** | | | |
| 08364000 | Rio Grand at El Paso, TX | Albuquerque, NM | 31°48′10″ | 106°32′25″ | 13030102 | At gaging stati on the downstream side of the Courchesne Bridge, 5.6 mi upstream from the Santa Fe Street-Juarez Avenue bridge betwen El Paso, Tx, and Cd. Juarez, Chihuahua at mile 1,249 and 1.7 mi upstream from the American Dam | 29,267 sq. mi | Discharge measured by International Boundary and Water Commission |
| 08377200 | Rio Grande at Foster Ranch, near Langtry, TX | San Angelo, TX | 29°46′50″ | 101°45′20″ | 13040212 | At gaging station 0.1 mi downstream from Terrell-Val Verde Country line, 16.9 mi from Langtry, and 597.2 midownstream from the American Dam at El Paso | 80,742 sq. mi | Discharge measured by International Boundary and Water Commission |
| 08447410 | Pecos River near Langtry, TX | San Angelo, TX | 29°48′10″ | 101°26′45″ | 13040212 | At gaging station 7.4 mi east of Langtry and 15.0 mi upstream from confluence with Rio Grande | 35,179 sq. mi | Discharge measured by International Boundary and Water Commission |
| 08450900 | Rio Grande below Amistad Dam near Del Rio, TX | San Angelo, TX | 29°25′30″ | 101°02′27″ | 13080001 | 2.2 mi downstream from Amistad Dam and 10 mi northwest of Del Rio | 123,143 sq. mi | Discharge measured by International Boundary and Water Commission |
| 08459200 | Rio Grande at Pipeline Crossing below Laredo, TX | San Angelo, TX | 27°24′01″ | 99°29′18″ | 13080002 | 8.7 Mi (14.0 km) downstream from Texas-Mexican Railway Bridge near Laredo, and at mile 352.69 (567.48 km) | 132,578 | Discharge measured by International Boundary and Water Commission |
| 08461300 | Rio Grande below Falcon Dam, TX | San Angelo, TX | 26°33′25″ | 99°10′05″ | 13090001 | U.S. tailrace at Falcon Dam | 159,270 sq. mi | Discharge measured by International Boundary and Water Commission |
| 08470400 | Arroyo Colorado at Harlingen, TX map of lower basin | San Angelo, TX | 26°10′24″ | 97°42′01″ | 13090002 | On downstream side of northbound service road on U.S. Highways 83&77, about 18 mi from point of main floodway that divides into North Floodway and Arroyo Colorado | 182 sq. mi | Discharge measured by International Boundary and Water Commission |
| 08475000 | Rio Grande near Brownsville, TX map of lower basin | San Angelo, TX | 25°52′35″ | 97°27′15″ | 13090002 | At International Boundary and Water Commission gaging station, 1000 ft downstream from El Jardin pumping plant, 6.8 mi below International bridge between Brownsville and Matamoras, Tamps., Mex. And 48.8 miles above the Gulf of Mexico | 176,333 sq. mi | Discharge measured by International Boundary and Water Commission |
| | | | | | **Colorado River Basin** | | | |
| 09180500 | Colorado River near Cisco, UT | Moab, UT | 38°48′38″ | 109°17′34″ | 14030005 | On left bank 1 mi downstream from Dolores River, 11 mi south of Cisco, 36 mi downstream from Colorado-Utah state line, 97 mi upstream from Green River and 235 mi upstream from San Juan River, at mile 1022.3 from Arizona-Sonora | 24,100 sq. mi., approximately | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 09315000 | Green River at Green River, UT | Moab, UT | 38°59′10″ | 110°09′02″ | 14060008 | On right bank, 1,400 ft upstream from railroad bridge, 0.9 mi southeast of town of Green River, 22.7 mi upstream from San Rafael River, at mile 117.6 upstream from mouth | 44,850 sq. mi. of which about 4,260 sq. mi. (including 3,959 sq. mi. in Great Divide Basin in southern Wyoming) i noncontributing | Flow regulated by Flaming gorge Reservoir (09234400) |
| 09379500 | San Juan River near Bluff, UT | Moab UT | 37°08′49″ | 109°51′52″ | 14080205 | On left bank, 1,600 ft downstream from Gypsum Creek, 1,800 ft upstream from highway bridge, 20 mi southwest of Bluff, at mile 113.5 | 23,000 sq. mi., approximately | No diversions between station and mouth of river. Flow regulated by Navajo Reservoir, NM (09355100) |
| 09380000 | Colorado River at Lees Ferry, AZ | Flagstaff, AZ | 36°51′53″ | 111°35′15″ | 14070006 | In Navajo Indian Reservation, on left bank at head of Marble gorge at lees ferry, just upstream from Paria River, 16 mi downstream of Glen Canyon Dam, 28 mi downstream from UT-AZ state line, and 61.5 mi upstream from Little Colorado River | 111,800 sq. mi., approximately, including 3,959 sq. mi. in Great Divide basin in southern Wyoming, which is noontributing | Many diversions above Lake Powell for irrigation, municipal, and industrial use. No diversion or inflow between Lake Powell and the gage |
| 09404200 | Colorado River above Diamond Creek near Peach Springs, AZ | Flagstaff, AZ | 36°46′25″ | 113°21′46″ | 15010002 | In Lake Mead NRA, on the right bank, 0.6 mi upstream from Diamond Creek, 138 mi downstream from Phantom Ranch, 25 mi north of Peach Springs, 242 mi downstream from Glen Canyon Dam, and 130 mi upstream from Hoover Dam | 149,316 sq. mi., including 3,959 sq. mi. in Great Divide Basin in southern Wyoming nand 697 sq. mi. on the Colorado Plateau | Several unregulated tributaries below Glen Canyon Dam |
| 09421500 | Colorado River below Hoover Dam, AZ-NV | Las Vegas, NV | 36°00′55″ | 114°44′16″ | 15030101 | In powerhouse at downstream side of Hoover Dam. Water-quality samples collected at gaging station 0.3 mi downstream from Hoover Dam | 171,700 sq. mi., approximately, included 3,959 sq. mi. in Great Divide Basin in southern Wyoming, which is non-contributing | |
| 09429490 | Colorado River above Imperial Dam, CA-AZ. schematic map of Lower Colorado River | Yuma, AZ | 32°52′59″ | 114°27′55″ | 15030104 | Imperial Dam is 5 mi upstream from Laguna Dam, 15 mi northeast of Yuma, 90 mi downstream from Palo Verde Dam and 147 mi downstream from Parker Dam. Water-quality samples collected below trash racks at All-American Canal headworks at west end of Imperial Dam | 188,500 sq. mi., approximately, including 3,959 sq. mi. in Great Divide basin in southern Wyoming, which is non-contributing | Records show flow of Colorado River reaching Imperial Dam and are synthesized from records of several other stations |

*(Continued)*



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**Table 4D.9 (Continued)**

| USGA Station ID | Station Name | USGS Office Sampling Station | Latitude | Longitude | Hydrologic Unit Code | Location of Stream Gage and Sampling Site | Drainage Area | Remarks |
|---|---|---|---|---|---|---|---|---|
| 09522000 | Colorado River at Northerly International Boundary (NIB), above Morelos Dam, near Andrade, CA schematic map of Lower Colorado River | Yuma, AZ | 32°43′07″ | 114°43′05″ | 15030108 | On left bank at northerly international boundary, 0.5 mi east of Andrade. 1.1 mi upstream from Morelos Dam, 1.1 mi downstream from Rockwood Gate, and 6.4 mi downstream from gaging station on Colorado River below Yuma Main Canal wasteway | 246,700 sq. mi., approximately, including all closed basins entirely within the drainage boundary, also 3,959 sq. mi. in Great divide basin in southern Wyoming, which is non-contributing | |
| | | | | | **Columbia River Basin** | | | |
| 12400520 | Columbia River at Northport, WA | Spokane, WA | 48°55′08″ | 117°47′11″ | 17020001 | 0.4 mi downstream from State Highway 25 bridge at Northport, 10.3 mi downstream from gaging station at boundary, and at mile 735.1 | 60,200 sq. mi., approximately | Discharge is routed from gaging station at international boundary (12399500) |
| 12472900 | Columbia River at Vernita Bridge, near Priest Rapids Dam WA | Pasco, WA | 46°38′34″ | 119°43′54″ | 17020016 | At State Highway 24 Vernita Bridge crossing, 9.0 mi downstream from Priest Rapids Dam and at mile 388.1 | 96,000 sq. mi., approximately | Discharge determined by routing flows from the gaging station below Priest Rapids Dam (12472800) 6.4 mi upstream |
| 13353200 | Snake River at Burbank, WA | Pasco, WA | 46°15′00″ | 118°53′45″ | 17060110 | Approximately 1.0 mi downstream from Ice Harbor Dam | 108,800 sq. mi | Discharge is obtained and routed from Ice Harbor Dam, 1.0 mi upstream |
| 14128910 | Columbia River at Warrendale, OR | Portland, OR | 45°36′45″ | 122°01′35″ | 17080001 | On left bank 0.1 mi downstream from Tumult Creek, 1.0 mi west of Warrendale, 5.1 mi downstream from Bonneville Dam, and at mile 141.0 | 240,000 sq. mi., approximately | Stream discharge taken from Columbia River at the Dalles, OR (14105700) at river mile 188.9 |
| 14211720 | Willamette River at Portland, OR | Portland, OR | 45°31′07″ | 122°40′00″ | 17090012 | In pier at east end of drawspan, on upstream side of Morrison bridge in Portland, and at mile 12.8 | 11,100 sq. mi., approximately | Water discharge records obtained by flow routing procedures usg sta records |
| 14246900 | Columbia river at Beaver Army Terminal, near Quincy, OR | Portland, OR | 46°10′55″ | 123°10′50″ | 17080003 | On left bank, 0.7 mi downstream from Crims Island, 3.0 mi northwest of Qunicy, and at mile 53.8 | 256,900 sq. mi., approximately | |

*Source*: From http://water.usgs.gov

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**Figure 4D.6** NASQAN stations, 1996–2000. (From http://water.usgs.gov.)

**Table 4D.10 Water Quality Characteristics Are Measured as NASQAN Stations**

| Code | Parameter | Description |
|---|---|---|
| 4S | 5S | 75S |
| MAJ | 00010 | Water temperature (degree Celsius) |
| MAJ | 00061 | Discharge, instantaneous (cubic feet per second) |
| MAJ | 00076 | Turbidity (nephelometric turbidity units, NTU) |
| MAJ | 00095 | Specific conconductance (microsiemens per centimeter at 25 Celsius) |
| MAJ | 00300 | Oxygen, dissolved (milligrams per liter) |
| MAJ | 00400 | Ph, field (standard units) |
| MAJ | 00452 | Carbonate, filtered (milligrams per liter as $CO_3$) |
| MAJ | 00453 | Bicarbonate, filtered (milligrams per liter as $HCO_3$) |
| MAJ | 00608 | Ammonia–nitrogen (milligrams per liter as N) |
| MAJ | 00613 | Nitrite–nitrogen (milligrams per liter as N) |
| MAJ | 00623 | Ammonia-plus-organic-nitrogen, dissolved (milligrams per liter as N) |
| MAJ | 00625 | Ammonia-plus-organic-nitrogen (milligrams per liter as N) |
| MAJ | 00631 | Nitrite-plus-nitrate-nitrogen, dissolved (milligrams per liter as N) |
| MAJ | 00665 | Phosphorus, total (milligrams per liter as P) |
| MAJ | 00666 | Phosphorus, dissolved (milligrams per liter as P) |
| MAJ | 00671 | Orthophosphate-phosphorus (milligrams per liter as P) |
| MAJ | 00681 | Carbon, organic, dissolved (milligrams per liter as C) |
| MAJ | 00689 | Carbon, organic, suspended (milligrams per liter as C) |
| MAJ | 00915 | Calcium, dissolved (milligrams per liter as Ca) |
| MAJ | 00925 | Magnesium, dissolved (milligrams per liter as Mg) |
| MAJ | 00930 | Sodium, dissolved milligrams per liter as Na) |
| MAJ | 00935 | Potassium, dissolved (milligrams per liter as K) |
| MAJ | 00940 | Chloride, dissolved (milligrams per liter as Cl) |
| MAJ | 00945 | Sulfate, dissolved (milligrams per liter as $SO_4$) |

*(Continued)*

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**Table 4D.10 (Continued)**

| Code | Parameter | Description |
|---|---|---|
| MAJ | 00950 | Fluoride, dissolved (milligrams per liter as F) |
| MAJ | 00955 | Silica, dissolved (milligrams per liter as $SiO_2$) |
| MAJ | 39086 | Alkalinity, filtered (milligrams per liter as $CaCO_3$) |
| MAJ | 70300 | Residue on evaporation (180 Celsius) (milligrams per liter) |
| MAJ | 70331 | Sediment, finer than 63 microns (percent) |
| MAJ | 80154 | Sediment, suspended (milligrams per liter) |
| SEDCHEM | 29816 | Antimony, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29818 | Arsenic, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29820 | Barium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29822 | Beryllium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29826 | Cadmium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29829 | Chromium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29832 | Copper, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29836 | Lead, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29839 | Manganese, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29841 | Mercury, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29843 | Molybdenum, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29846 | Nickel, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29847 | Selenium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29850 | Silver, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29853 | Vanadium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 29855 | Zinc, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 30221 | Aluminum, sediment, suspended, total (percent) |
| SEDCHEM | 30244 | Carbon, sediment, suspended, total (percent) |
| SEDCHEM | 30269 | Iron, sediment, suspended, total (percent) |
| SEDCHEM | 30292 | Phosphorus, sediment, suspended, total (percent) |
| SEDCHEM | 30308 | Sulfur, sediment, suspended (percent) |
| SEDCHEM | 30317 | Titanium, sediment, suspended, total (percent) |
| SEDCHEM | 35031 | Cobalt, sediment suspended, total (micrograms per gram) |
| SEDCHEM | 35040 | Strontium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 35046 | Uranium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 35050 | Lithium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 49955 | Thallium, sediment, suspended, total (micrograms per gram) |
| SEDCHEM | 50279 | Sediment, suspended (milligrams per liter) |
| SEDCHEM | 50465 | Carbon, organic, suspended, total (percent) |
| TE | 01000 | Arsenic, dissolved (milligrams per liter as As) |
| TE | 01005 | Barium, dissolved (milligrams per liter as Ba) |
| TE | 01010 | Beryllium, dissolved (milligrams per liter as Be) |
| TE | 01020 | Boron, dissolved (micrograms per liter as B) |
| TE | 01025 | Cadmium, dissolved (micrograms per liter as Cd) |
| TE | 01030 | Chromium, dissolved (micrograms per liter as Cr) |
| TE | 01035 | Cobalt, dissolved (micrograms per liter as Co) |
| TE | 01040 | Copper, dissolved (micrograms per liter as Cu) |
| TE | 01046 | Iron, dissolved (micrograms per liter as Fe) |
| TE | 01049 | Lead, dissolved (micrograms per liter as Pb) |
| TE | 01056 | Manganese, dissolved (micrograms per liter as Mn) |
| TE | 01057 | Thallium, dissolved (micrograms per liter as Tl) |
| TE | 01060 | Molybdenum, dissolved (micrograms per liter as Mo) |
| TE | 01065 | Nickel, dissolved (micrograms per liter as Ni) |
| TE | 01075 | Silver, dissolved (micrograms per liter as Ag) |
| TE | 01080 | Strontium, dissolved (micrograms per liter as Sr) |
| TE | 01085 | Vanadium, dissolved (micrograms per liter as V) |
| TE | 01090 | Zinc, dissolved (micrograms per liter as Zn) |
| TE | 01095 | Antimony, dissolved (micrograms per liter as Sb) |
| TE | 01106 | Aluminum, dissolved (micrograms per liter as Al) |
| TE | 01130 | Lithium, dissolved (micrograms per liter as Li) |
| TE | 01145 | Selenium, dissolved (micrograms per liter as Se) |
| PEST | 04024 | Propachlor, dissolved (micrograms per liter) |
| PEST | 04028 | Butylate, dissolved (micrograms per liter) |
| PEST | 04035 | Simazine, dissolved (micrograms per liter) |

*(Continued)*

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**Table 4D.10 (Continued)**

| Code | Parameter | Description |
|---|---|---|
| PEST | 04037 | Prometon, dissolved (micrograms per liter) |
| PEST | 04040 | Desethyl atrazine, dissolved (micrograms per liter) |
| PEST | 04041 | Cyanazine, dissolved (micrograms per liter) |
| PEST | 04095 | Fonofos, dissolved (micrograms per liter) |
| PEST | 22703 | Uranium, natural, dissolved (micrograms per liter) |
| PEST | 34253 | Alpha BHC, dissolved (micrograms per liter) |
| PEST | 34653 | P, P′ DDE, dissolved (micrograms per liter) |
| PEST | 38933 | Chlorpyrifos, dissolved (micrograms per liter) |
| PEST | 39341 | Lindane, dissolved (micrograms per liter) |
| PEST | 39381 | Dieldrin, dissolved (micrograms per liter) |
| PEST | 39415 | Metolachlor, dissolved (micrograms per liter) |
| PEST | 39532 | Malathion, dissolved (micrograms per liter) |
| PEST | 39542 | Parathion, dissolved (micrograms per liter) |
| PEST | 39572 | Diazinon, dissolved (micrograms per liter) |
| PEST | 39632 | Atrazine, dissolved (micrograms per liter) |
| PEST | 46342 | Alachlor, dissolved (micrograms per liter) |
| PEST | 49260 | Acetochlor, dissolved (micrograms per liter) |
| PEST | 82630 | Metribuzin, dissolved (micrograms per liter) |
| PEST | 82660 | Diethylanilene, dissolved (micrograms per liter) |
| PEST | 82661 | Trifluralin, dissolved (micrograms per liter) |
| PEST | 82663 | Ethalfluralin, dissolved (micrograms per liter) |
| PEST | 82664 | Phorate, dissolved (micrograms per liter) |
| PEST | 82665 | Terbacil, dissolved (micrograms per liter) |
| PEST | 82666 | Linuron, dissolved (micrograms per liter) |
| PEST | 82667 | Methyl parathion, dissolved (micrograms per liter) |
| PEST | 82668 | EPTC, dissolved (micrograms per liter) |
| PEST | 82669 | Pebulate, dissolved (micrograms per liter) |
| PEST | 82670 | Tebuthiuron, dissolved (micrograms per liter) |
| PEST | 82671 | Molinate, dissolved (micrograms per liter) |
| PEST | 82672 | Ethoprop, dissolved (micrograms per liter) |
| PEST | 82673 | Benfluralin, dissolved (micrograms per liter) |
| PEST | 82674 | Carbofuran, dissolved (micrograms per liter) |
| PEST | 82675 | Terbufos, dissolved (micrograms per liter) |
| PEST | 82676 | Pronamide, dissolved (micrograms per liter) |
| PEST | 82677 | Disultoton, dissolved (micrograms per liter) |
| PEST | 82678 | Triallate, dissolved (micrograms per liter) |
| PEST | 82679 | Propanil, dissolved (micrograms per liter) |
| PEST | 82680 | Carbaryl, dissolved (micrograms per liter) |
| PEST | 82681 | Thiobencarb, dissolved (micrograms per liter) |
| PEST | 82682 | DCPA, dissolved (micrograms per liter) |
| PEST | 82683 | Pendimethalin, dissolved (micrograms per liter) |
| PEST | 82684 | Napropamide, dissolved (micrograms per liter) |
| PEST | 82685 | Propargite, dissolved (micrograms per liter) |
| PEST | 82686 | Azinphos-methyl, dissolved (micrograms per liter) |
| PEST | 82687 | Permethrin, dissolved (micrograms per liter) |
| PEST | 91063 | Diazinon, D-10 surrogate (percent) |
| PEST | 91065 | HCH, alpha, D-6 surrogate (percent) |
| PEST | 99108 | Spike volume (milliters) |
| PEST | 99856 | Sample volume (milliters) |

*Note:* ASCII text file containing parameter code definitions for constituents.
Analyzed by the USGS National Stream Quality Accounting Network (1996–2000).
File is tab-delimited.
The first header contains column names.
The second header contains column formats.
Code = Constituent group, defined as follows:
MAJ = instantaneous Q, field parameters, major ions, nutrients, suspended sediment
SEDCHEM = sediment chemistry
TE = trace elements (dissolved)
PEST = pesticides
Parameter = WATSTORE code
Description = Constituent name (units of measure)

*Source*: http://water.usgs.gov.

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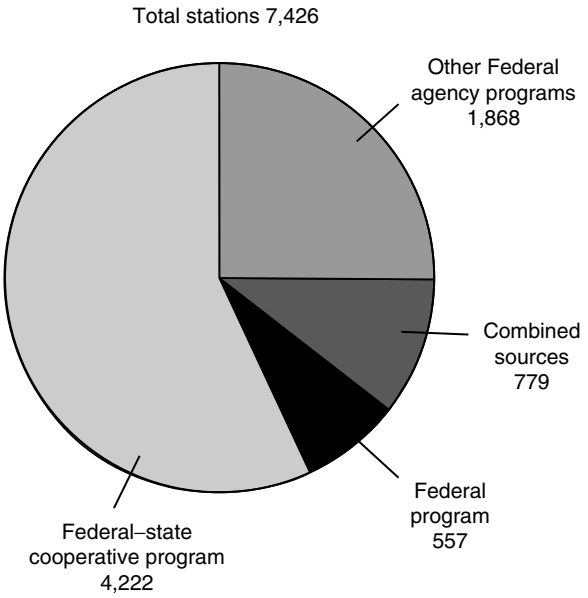


**Figure 4D.7** Sources of funds for operation of continuous surface-water discharge stations. (From U.S. Geological Survey Water Data Program, http://water.usgs.gov.)

**Table 4D.11 Hydrologic and Related Data Collection Networks in the United States**

| Type of Network | Number of Stations |
|---|---|
| Automatic meterological observing stations (full parameter); temperature, dew point, wind, pressure, precipitation) | 92 |
| National weather service synoptic and basic observation stations (high quality observations for basic weather program) | 67 |
| Cooperative station services (observations by lay persons): | |
| Temperature and precipitation | 5,568 |
| Precipitation only — daigeoly | 3,200 |
| Precipitation only — storage | 32 |
| Hourly precipitation stations equipped with recording precipitation gages | 3,205 |
| Cooperative stations equipped with both recording and nonrecording precipitations gages | 1,995 |
| Crop reporting stations | 566 |
| River and/or rainfall reporting stations | |
| River stage reports only | 998 |
| Rainfall reports only | 3,656 |
| River stage and rainfall reports | 1,069 |
| Evaporation storage | 448 |
| Reference Climatological Stations | 21 |
| Automated Hydrologic Observing System (AHOS) — river and rainfall data for flood forecasting | |
| AHOS/T[a] | 506 |
| AHOS/S[b] | 75 |
| Special reporting stations | 293 |
| Cooperative station data published | |
| Temperature and precipitation | 8,256 |
| Precipitation only | 3,055 |
| Evaporation | 431 |
| Soil temperature | 308 |
| Miscellaneous (snow density, special meteorological, etc) | 473 |

[a] Data transmitted by telephone.
[b] Data transmitted by satellite.

*Source*: From National Weather Service, *Operations of the National Weather Service*, 1985.

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**Table 4D.12 USGS Programs Managed by the Water Resources Discipline**

- *Cooperative Water Program* — The Cooperative Program, a partnership between the USGS and state and local agencies, provides information that forms the foundation for many of the Nation's water resources management and planning activities
- *National Streamflow Information Program* (NSIP) — The National Streamflow Information Program (NSIP) is a conceptual plan developed by the USGS for a new approach to the acquisition and delivery of streamflow information
- *National Water Quality Assessment Program* (NAWQA) — Since 1991, USGS scientists with the NAWQA program have been collecting and analyzing data and information in more than 50 major river basins and aquifers across the Nation. The goal is to develop long-term consistent and comparable information on streams, groundwater, and aquatic ecosystems to support sound management and policy decisions. The NAWQA program is designed to answer these questions:
  1. What is the condition of our Nation's streams and groundwater?
  2. How are these conditions changing over time?
  3. How do natural features and human activities affect these conditions?
- *Toxic Substances Hydrology (Toxics) Program* — provides unbiased earth science information on the behavior of toxic substances in the Nation's hydrologic environments. The information is used to avoid human exposure, to develop effective cleanup strategies, and to prevent further contamination
- *Groudwater Resources Program* — The Groundwater Resources Program encompasses regional studies of groundwater systems, multidisciplinary studies of critical groundwater issues, access to groundwater data, and research and methods development. The program provides unbiased scientific information and many of the tools that are used by Federal, State, and local management and regulatory agencies to make important decisions about the Nation's groundwater resources
- *Hydrologic Research and Development* — Hydrologic Research and Development focuses on long-term investigations that integrate hydrological, geological, chemical, climatic, and biological information related to water resources issues. The program provides the primary support for the *National Research Program* (NRP) in the hydrologic sciences and for *Water, Energy, and Biogeochemical Budgets (WEBB) program*
- *State Water Resoruces Research Institute Program* — A matching grant program to support water resources research, education, and information transfer at the 54 university based Water Resources Research Institutes. This program includes the National Institutes for Water Resources USGS *Student Internship Program*

Subprograms:

- *Water Information Coordination Program* (WICP) — ensures the availability of water information required for effective decision making for natural resources management and environmental protection and to do it cost effectively
- *Drinking Water Programs* — The wide range of monitoring, assessment, and research activities conducted by the USGS to help understand the protect the quality of our drinking water resources is described on these pages. These studies are often done in collaboration with other federal, state, tribal, and local agencies
- *National Stream Quality Accounting Network* (NASQAN) — Focus is on monitoring the water quality of four of the Nation's largest river systems — the Mississippi (including the Missouri and Ohio), the Columbia, the Colorado, and the Rio Grande
- *Hydrologic Benchmark Network* (HBN) — was established in 1963 to provide long-term measurements of streamflow and water quality in areas that are minimally affected by human activities. These data were to be used to study time trends and to serve as controls for separating natural from artificial changes in other streams. The network has consisted of as many as 58 drainage basins in 39 State
- *National Atmospheric Deposition Program/National Trends Network* (NADP/NTN) — A nationwide network of precipitation monitoring sites. The first sites in the network were established in 1978. The network currently consists of approximately 200 sites
- *National Research Program* (NRP) — conducts basic and problem-oriented hydrologic research in support of the mission of the U.S. Geological Survey (USGS)
- *National Water Summary Program* — a series of publications designed to increase public understanding of the nature, geographic distribution, magnitude, and trends of the Nation's water resources. It is often referred to as the USGS "encyclopedia of water"
- *National Water-Use Program* — examines the withdrawal, use, and return flow of water on local, state, and national levels
- *USGS Environmental Affairs Program* — provides guidance and information on the National Environmental Policy Act and other environmental issues
- *Water, Energy, and Biogeochemical Budgets* (WEBB) — understands the processes controlling water, energy, and biogeochemical fluxes over a range of temporal and spatial scales and to understand the interactions of these processes, including the effect of atmospheric and climatic variables
- *National Irrigation Water Quality Program* — A Department of Interior program to identify and address irrigation-induced water quality and contamination problems related to Department of Interior water projects in the west

International Programs:

- *Cyprus Water Resources Database Development* — This project met the USGS goal of supporting U.S. foreign policy. It was requested by the U.S. Ambassador to Cyprus and coordinated closely through the U.S. Department of State. It took 5 years of negotiations with senior Cypriot officials, Embassy staff, U.S. Department of State, and selected United Nations offices to design and implement this project. This project enabled water managers on Cyprus to manage their limited water resources, which will directly contribute to enhancement and protection of the quality of life for Cypriot citizens
- *Public Awareness and Water Conservation* — The project, which began in 1996, is part of the Middle East Peace Process and is one of several projects sponsored by the Multilateral Working Group on Water Resources. The U.S. Department of State requested the USGS to undertake this activity and has provided political guidance throughout the project. The project meets the USGS goal of supporting U.S. foreign policy and fostering outreach and public awareness activities

*(Continued)*

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**Table 4D.12 (Continued)**

- *Regional Water Data Banks* — The Executive Action Team Multilateral Working Group on Water Resoruces, Water Data Banks Project consists of a series of specific actions to be taken by the Israelis, Jordanians, and Palestinians that are designed to foster the adoption of common, standardized data collection and storage techniques among the Parties, improve the quality of the water resources data collected in the region, and to improve communication among the scientific community in the region
- *Ukraine Streamflow Project* — Floods are among the most frequent and costly natural disasters in terms of human hardship and economic loss. In Ukraine, two major floods (one in 1998 and one in 2001) have occurred in the Tisa River Basin in the last 5 years. Both floods caused several fatalities, damaged or destroyed several thousand homes, destroyed bridges and roads, and created severe personal and economic hardship for the residents of Zakarpattia Oblast in western Ukraine. Near real-time streamflow data can be used to forecast and manage floods and improve public safety
- *Groundwater Research Program for the Emirate of Abu Dhabi, United Arab Emirates* — Since 1988 the USGS has been partnering with the National Drilling Company (NDC) of the Abu Dhabi Emirate to collect information on the groundwater resources of the Emirate, to conduct research on the hydrology of the arid environment, to provide training in water resources investigations, and to document the results of the cooperative work in scientific publications
- *Geologic, Hydrologic, and Geochemical Characterization of the Deep Groundwater Aquifer System In the Bengal Delta of Bangladesh* — The USGS is currently conducting research on the deeper aquifer system in Bangladesh in areas associated with high levels of arsenic in the shallow groundwater. This work is an integral step in the characterization of the hydrogeolocial framework needed to define the potential for developing safe and sustainable groundwater sources
- *Botswana–Village Flood Watch* — The Village Flood Watch project, which was completed in 2002, was designed to help establish an early-warning system for potential flooding events by adding or upgrading six gauging stations to near real-time capabilities and providing training on hydrologic runoff modeling
- *Jordan Groundwater Management* — The project objective is to enhance current Jordanian technical capacities for hydrogeologic data and information development, management and analysis; development and use of groundwater management models; and joint design and conduct of outreach workshops and meetings to increase public understanding of the benefits of local efforts in groundwater management and conservation
- *Summary of Palestinian Hydrologic Data 2000* — The project provides a critical tool to the USAID Water Resources Program including several investigative, development, and construction projects, in the West Bank and Gaza, designed to comprehensively develop, manage, and protect water resources. This activity demonstrates the USGS leadership role in the natural sciences and confirms the mission of providing scientific information to manage natural resources to enhance and protect the quality of life

*Source*: From Water Resources of the United States, http://water.usgs.gov.

**Table 4D.13 Number of USGS Data-Collection Stations Operated in 1994, by Source of Funds**

| Types of Stations | Federal Program | Federal-State Cooperative Program | Other Federal Agency Program | Combined Support | Total |
|---|---|---|---|---|---|
| Surface water: | | | | | |
| Discharge | 638 | 6,419 | 2,219 | 964 | 10,240 |
| Stage-only — streams, lakes and reservoirs | 47 | 968 | 850 | 183 | 2,048 |
| Quality | 778 | 1,666 | 426 | 228 | 3,098 |
| Groundwater: | | | | | |
| Water levels | 2,344 | 27,029 | 2,421 | 237 | 32,031 |
| Quality | 691 | 4,602 | 1,347 | 216 | 6,856 |

*Source*: From U.S. Geological Survey Water Data Program, http://water.usgs.gov.

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**Table 4D.14 Increasing Global Data Coverage**

| Regions | Number of Stations | Number of Data Point | Physical/Chemical | Major Loans | Metals | Nutrients | Organic Contaminants | Microbiology | Date Range |
|---|---|---|---|---|---|---|---|---|---|
| Africa | 138 | 206907 | 26712 | 79889 | 6439 | 41289 | 370 | 832 | 1977–2004 |
| Americas | 682 | 417994 | 47198 | 73210 | 88124 | 47284 | 3583 | 10401 | 1965–2004 |
| Asia | 332 | 641940 | 118868 | 159329 | 83005 | 98796 | 6794 | 32018 | 1971–2004 |
| Europe | 318 | 823323 | 146747 | 136392 | 154742 | 108815 | 14539 | 27260 | 1978–2003 |
| Oceania | 94 | 206650 | 31678 | 12237 | 2535 | 46992 | 1438 | 1383 | 1979–2004 |
| Total | 1544 | 2296814 | 371203 | 461087 | 334845 | 343176 | 26734 | 71894 | 1965–2004 |

*Source*: From GEMS Water, *State of the UNEP GEMS/Water Global Network and Annual Report*, United Nations Environment Programme, Global Environment Monitoring System (GEMS) Water Programme, 2004, www.gemswater.org.



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## SECTION 4E INTERCEPTION

**Table 4E.15 Interception by Trees**

| Type or Species | Age or Size | Place in Succession | Locality | Interception (Percent) |
|---|---|---|---|---|
| Hemlock | Mature | Climax | Connecticut | 48 |
| Douglas fir | 25 yr | Climax | Washington | 43 |
| Hemlock | Mature | Climax | New Hampshire | 38 |
| Spruce-fir | Mature | Climax | Maine | 37 |
| Hemlock | Mature | Climax | Adirondacks, New York | 34 |
| Douglas fir | Mature | Climax | Washington | 34 |
| Hemlock | Mature | Climax | Ithaca, New York | 31 |
| Spruce — fir — paper birch | Mature | Climax | Maine | 26 |
| White pine — hemlock | Mature | Climax | Massachusetts | 24 |
| Western white pine — western hemlock | Overmature | Climax | Idaho | 21 |
| Maple — beech | Mature | Climax | New York | 43 |
| Mixed | Mature | Climax | New York | 40 |
| Maple — hemlock | Mature, cutover | Climax | Wisconsin | 25 |
| Beech — birch — maple | Mature | Climax | Ontario | 21 |
| Ponderosa pine | Mature | Preclimax | Arizona | 40 |
| Lodgepole pine | Mature | Preclimax | Colorado | 32 |
| Ponderosa pine | Mature | Preclimax | Idaho | 27 |
| Jeffrey pine | Mature | Preclimax | Southern California | 26 |
| Lodgepole pine | 32 yr | Preclimax | Colorado | 23 |
| Ponderosa pine | Mature | Preclimax | Idaho | 22 |
| Ponderosa pine | Young | Pioneer | Colorado | 18 |
| Calif, scrub oak | 6 ft | — | Southern California | 31 |
| Mixed brush | Mature | Preclimax | North Fork, California | 19 |
| White pine — red pine | 40 yr | Preclimax | Ontario | 37 |
| Jack pine | 50 yr | Pioneer | Wisconsin | 21 |
| Shortleaf pine | 45 yr | Pioneer | North Carolina | 16 |
| Quaking aspen | 32 yr | Pioneer | Colorado | 16 |
| Chaparral, mixed | 6 ft | | Southern California | 17 |
| Maple — hemlock | Mature (after leaf fall) | Climax (under-stocked) | Wisconsin | 16 |
| Hemlock | Mature | Climax | New York | 13 |
| Oak-pine | Open, second growth | Preclimax | New Jersey | 13 |
| Ponderosa — lodgepole pine | 25 ft | Preclimax | Idaho | 8 |
| Beech — maple | Mature | Climax | New York | 6 |
| Chamise | 6 ft | Pioneer | Southern California | 3 |

*Note:* Interception includes stemflow and is expressed as a percentage of annual precipitation.

*Source*: From Compilation of data from various references, Kittredge, *Forest Influences*, McGraw-Hill, Copyright 1948. With permission.

**Table 4E.16 Interception by Various Forest Types**

| | Gross Interception | | Stemflow | | Net Interception | | Net Snow Interception (%) |
|---|---|---|---|---|---|---|---|
| Forest Type | With Leaves (%) | Without Leaves (%) | With Leaves (%) | Without Leaves (%) | With Leaves (%) | Without Leaves (%) | |
| Northern hardwood | 20 | 17 | 5 | 10 | 15 | 7 | 10 |
| Aspen — birch | 15 | 12 | 5 | 8 | 10 | 4 | 7 |
| Spruce — spruce-fir | 35 | — | 3 | — | 32 | — | 35 |
| White pine | 30 | — | 4 | — | 26 | — | 25 |
| Hemlock | 30 | — | 2 | — | 28 | — | 25 |
| Red pine | 32 | — | 3 | — | 29 | — | 30 |

*Source*: U.S. Forest Service.

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**Table 4E.17 Interception by Various Crops**

| Description | Alfalfa | Corn | Soybean | Oats |
|---|---|---|---|---|
| During growing season: | | | | |
| Rainfall (in.) | 10.81 | 7.12 | 6.25 | 6.77 |
| Canopy penetration (in.) | 6.18 | 4.84 | 4.06 | 6.30 |
| Stemflow (in.) | 0.76 | 1.18 | 1.28 | |
| Interception (in.) | 3.87 | 1.10 | 0.91 | 0.47 |
| Interception (%) | 35.8 | 15.5 | 14.6 | 6.9 |
| During low-vegetation development (%) | 21.9 | 3.4 | 9.1 | 3.1 |

*Source*: U.S. Department of Agriculture.

## SECTION 4F INFILTRATION

**Figure 4F.8** Total annual infiltration and soil moisture in the world (in mm). (From Lvovitch, M.I., *EOS*, 54, 1973, Copyright by American Geophysical Union. With permission.)

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**Table 4F.18 Seepage Rates for Canals**

| Canal Soil Material | Seepage (Feet per Day) | Canal Soil Material | Seepage (Feet per Day) |
|---|---|---|---|
| Sandy loam | 8.2 | Loam and adobe | 1.4 |
| Gravelly loam | 5.3 | Loam | 1.1 |
| Fine sandy loam and adobe | 3.8 | Silty clay | 0.9 |
| Sand and sandy loam | 3.4 | Sand and silty clay | 0.4 |
| Loam and sandy loam | 3.3 | Sand and clay | 0.1 |
| Adobe | 3.0 | Loam and gravelly loam | 0.1 |
| Fine sandy loam | 2.1 | | |

*Note:* Values are average maximum rates through the wetted area.

*Source*: From Rohwer and Stout, Colo, *Agric. Exp. Sta. Bull.*, 1948. With permission.

**Table 4F.19 Infiltration Rate and Land Use**

| | |
|---|---|
| 1. Fallow | 8. Pasture, fair |
| 2. Row crops, poor rotation[a] | 9. Woods, poor |
| 3. Row crops, good rotation[b] | 10. Pasture, good |
| 4. Pasture, poor | 11. Woods, fair |
| 5. Legumes after row crops | 12. Meadows |
| 6. Small grains, poor rotation | 13. Woods, good |
| 7. Small grains, good rotation | |

*Notes:* Rank of land uses in order of infiltration rate; first use listed has lowest rate

[a] One-fourth or less in hay or sod.
[b] More than one-fourth of rotation in hay or sod.

*Source*: U.S. Soil Conservation Service.

**Table 4F.20 Infiltration Model Classification**

| Category | Model Selected | Reference |
|---|---|---|
| Semi-empirical | SCS model | USDA-SCS (1972) |
| Homogeneous | Philip's two-term model | Philip (1957) |
| Nonhomogeneous | Green-Ampt model for layered systems | Flerchinger *et al.* (1988) |
| Ponding | Green-Ampt explicit model | Salvucci and Entekhabi (1994) |
| Non-ponding | Constant Flux Green-Ampt model | Swartzendruber (1974) |
| Wetting and drying | Infiltration/Exfiltration model | Eagleson (1978) |

*Source*: From USEPA *Estimation of Infiltration Rate in the Vadose Zone: Application of Selected Mathematical Models — Volume II*, EPA/600/R-97/128b, 1998.

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**Table 4F.21 Concentrations of Compounds in Highway Runoff Prior to and after Infiltration through the Second Batch of Medium Formulation Number 9: 90-Percent Sand, 5-Percent Clay, and 5-Percent Mulch**

| | | Effluent After Infiltration | | |
|---|---|---|---|---|
| **Analyte** | **Influent Prior to Infiltration** | **Halfway Through Experiment** | **End of Experiment** | **Percent Change[a]** |
| Calcium, dissolved (mg/L) | 6.3 | 5.2 | 5.1 | −19 |
| Magnesium, dissolved (mg/L) | 1.2 | 1.9 | 1.8 | 50 |
| Potassium, dissolved (mg/L) | 1.2 | 1.6 | 1.6 | 33 |
| Sodium, dissolved (mg/L) | 3.2 | 3.5 | 3.4 | 6 |
| Chloride, dissolved (mg/L) | 2.8 | 3.0 | 3.0 | 7 |
| Fluoride, dissolved (mg/L) | <0.2 | e0.1 | e0.1 | — |
| Silica, dissolved (mg/L) | 7.6 | 8.3 | 7.9 | 4 |
| Sulfate, dissolved (mg/L) | 11 | 11 | 11 | 0 |
| Nitrate+nitrite (mg/L) | 0.83 | 0.83 | 0.80 | −4 |
| Suspended solids (mg/L) | 13 | 42 | 65 | 400 |
| Dissolved solids (mg/L) | 48 | 55 | 52 | 8 |
| Arsenic, dissolved (μg/L) | 0.3 | 0.5 | 0.7 | 133 |
| Arsenic, total (μg/L) | <2 | e2 | e1 | — |
| Cadmium, dissolved (μg/L) | 0.1 | e0.02 | e0.02 | e−80 |
| Cadmium, total (μg/L) | 0.28 | 0.17 | 0.16 | −43 |
| Copper, dissolved (μg/L) | 6 | 4 | 4 | −33 |
| Copper, total (μg/L) | 10.5 | 16.9 | 12.9 | 23 |
| Iron, dissolved (μg/L) | 48 | 79 | 19 | −60 |
| Lead, dissolved (μg/L) | 0.4 | 0.09 | e0.06 | e-85 |
| Lead, total (μg/L) | 2.8 | 8.1 | 6.4 | 129 |
| Manganese, dissolved (μg/L) | 17 | e2 | <3 | >−82 |
| Zinc, dissolved (μg/L) | 20 | 2 | 2 | −90 |
| Zinc, total (μg/L) | 55.3 | 54.0 | 54.7 | −1 |
| Total petroleum hydrocarbons (mg/L) | 4 | <2 | <2 | >−50 |
| Calcium, dissolved (mg/L) | 6.3 | 5.2 | 5.1 | −19 |
| Magnesium, dissolved (mg/L) | 1.2 | 1.9 | 1.8 | 50 |
| Potassium, dissolved (mg/L) | 1.2 | 1.6 | 1.6 | 33 |
| Sodium, dissolved (mg/L) | 3.2 | 3.5 | 3.4 | 6 |

*Note:* mg/L, milligrams per liter; μg/L, micrograms per liter; <, less than; >, greater than; e, estimated value; — , not computed.

[a] Percent change was calculated using the prior-to-infiltration and end-of-experiment values.

*Source*: From Kenneth, C. Ames, Emily L., Inkpen, Lonna M., Frans, William R., Bidlake, Technical Report WARD 5122, Wahington State Department of Transportation.

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## SECTION 4G RUNOFF

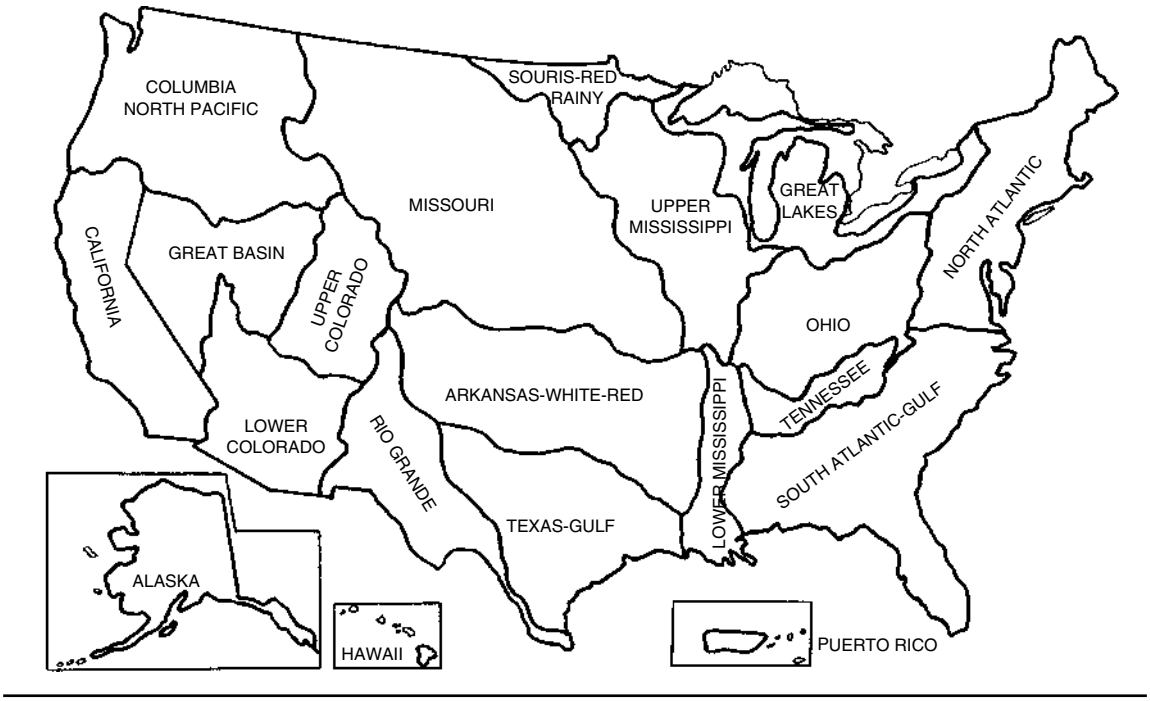


**Figure 4G.9** Water resources regions of the United States. (From U.S. Water Resources Council, 1968.)

**Table 4G.22 World-Wide Stable Runoff, by Continent**

| | Stable Runoff[a] ($km^2$) | | | | | |
|---|---|---|---|---|---|---|
| | Of Underground Origin | Regulated by Lakes | Regulated by Water Reservoirs | Total | Total River Runoff[b] | Total Stable Runoff as Present of Total River Runoff |
| Europe | 1,065 | 60 | 200 | 1,325 | 3,110 | 43 |
| Asia | 3,410 | 35 | 560 | 4,005 | 13,190 | 30 |
| Africa | 1,465 | 40 | 400 | 1,905 | 4,225 | 45 |
| North America | 1,740 | 150 | 490 | 2,380 | 5,960 | 40 |
| South America | 3,740 | — | 160 | 3,900 | 10,380 | 38 |
| Australia[c] | 465 | — | 30 | 495 | 1,965 | 25 |
| Total land area except polar zones | 11,885 | 285 | 1,840 | 14,010 | 38,830 | 36 |

[a] Excluding flood flows.
[b] Including flood flow.
[c] Including Tasmania, New Guinea, and New Zealand.

*Source*: From Lvovitch, M.I., *EOS*, 54, 1, 1973.

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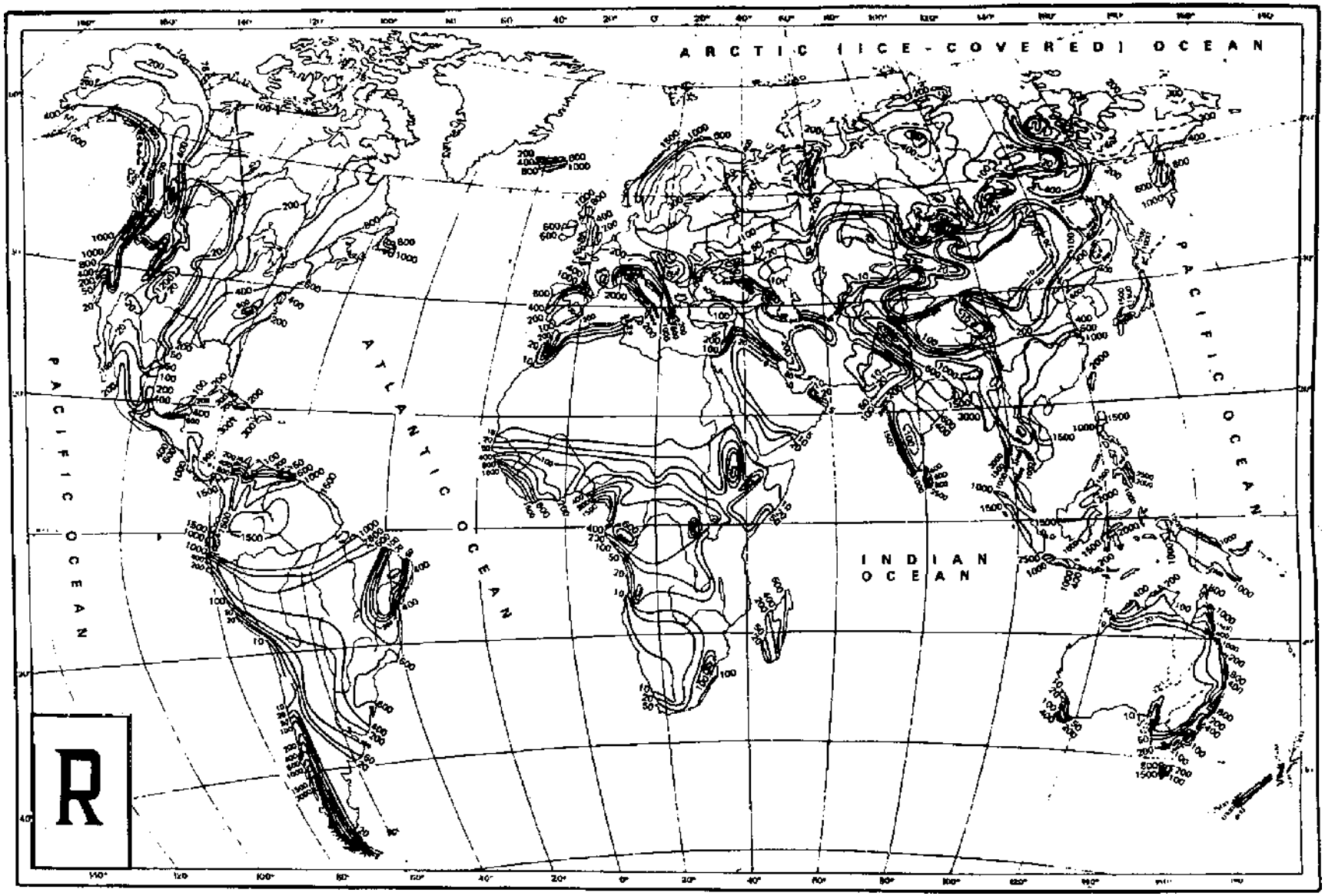


**Figure 4G.10** Annual total river runoff in the world (includes groundwater discharge to rivers; in mm). (From Lvovitch, M.I., *EOS*, 54, 1973. Copyright by American Geophysical Union. With permission.)



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**Table 4G.23 Runoff in the United States**

| Region | Mean | 50%[a] | 90%[a] | 95%[a] |
|---|---|---|---|---|
| North Atlantic[b] | 163 | 163 | 123 | 112 |
| South Atlantic-Gulf | 197 | 188 | 131 | 116 |
| Great Lakes[b,c] | 63.2 | 61.4 | 46.3 | 42.4 |
| Ohio[d] | 125 | 125 | 80.0 | 67.5 |
| Tennessee | 41.5 | 41.5 | 28.2 | 24.4 |
| Upper Mississippi[d] | 64.6 | 64.6 | 36.4 | 28.5 |
| Lower Mississippi[d] | 48.4 | 48.4 | 29.7 | 24.6 |
| Souris-Red-Rainy[b] | 6.17 | 5.95 | 2.60 | 1.91 |
| Missouri[b] | 54.1 | 53.7 | 29.9 | 23.9 |
| Arkansas-White–Red | 95.8 | 93.4 | 44.3 | 33.4 |
| Texas-Gulf | 39.1 | 37.5 | 15.8 | 11.4 |
| Rio Grande[e] | 4.9 | 4.9 | 2.6 | 2.1 |
| Upper Colorado[e] | 13.45 | 13.45 | 8.82 | 7.50 |
| Lower Colorado[d,e] | 3.19 | 2.51 | 1.07 | 0.85 |
| Great Basin[d] | 5.89 | 5.82 | 3.12 | 2.46 |
| Columbia-North Pacific[b] | 210 | 210 | 154 | 138 |
| California[f] | 65.1 | 64.1 | 32.8 | 25.6 |
| Conterminous United States[g] | 1,201 | | | |
| Alaska[b] | 580 | —[h] | —[h] | —[h] |
| Hawaii | 13.3 | —[h] | —[h] | —[h] |
| United States[g] | 1,794 | | | |

*Note:* Annual natural runoff in billions of gallons per day; regions are shown in Figure 4G.9.

[a] Flow exceeded in indicated percent of years.
[b] Does not include runoff from Canada.
[c] Does not include net precipitation on the lakes.
[d] Does not include runoff from upstream regions.
[e] Does not include runoff from Mexico.
[f] Virgin flow. Mean annual natural runoff estimated to be 13.7 bgd.
[g] Rounded.
[h] Not available.

*Source*: U.S. Water Resources Council, 1968.

**Table 4G.24 Runoff Distribution in the United States**

| Range in Runoff (Inches per Year) | Area (Square Miles) | Percent of Total Area | Percent of Total Runoff |
|---|---|---|---|
| 0–0.25 | 306,000 | 10.1 | 0.1 |
| 0.25–0.5 | 380,000 | 12.6 | .5 |
| 0.5–1.0 | 266,000 | 8.8 | .8 |
| 1.0–2.5 | 413,000 | 13.7 | 2.8 |
| 2.5–5 | 247,000 | 8.2 | 3.6 |
| 5–10 | 258,000 | 8.5 | 7.4 |
| 10–20 | 830,000 | 27.4 | 44.8 |
| 20–40 | 290,000 | 9.6 | 32.4 |
| 40–80 | 30,000 | 1.0 | 6.9 |
| Over 80 | 2,000 | 0.1 | 0.7 |
| Total | 3,022,000 | 100 | 100 |

*Source*: House of Representatives, U.S. Congress.

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**Table 4G.25 Seasonal Variation of Natural Runoff by Regions of the United States**

| Region | Months of High Flow | Months of Low Flow |
|---|---|---|
| North Atlantic | March, April | August, September |
| South Atlantic-Gulf | February, March | September, October |
| Great Lakes | April | January, August, September |
| Ohio | March | September, October |
| Tennessee | March | October |
| Upper Mississippi | March, April | January, September, October |
| Lower Mississippi | March | October |
| Souris-Red-Rainy | April | January, February |
| Missouri | March, June | January |
| Arkansas-White–Red | April, May, June | January, September |
| Texas-Gulf | March, May | August, October |
| Rio Grande | May | June |
| Upper Colorado | June | January, February |
| Lower Colorado | March, April | June, November |
| Great Basin | June | September, January |
| Columbia-North Pacific | February, April, May | January, February, August, September |
| California | April, May | September, October, December |

*Source*: U.S. Water Resources Council, 1968.

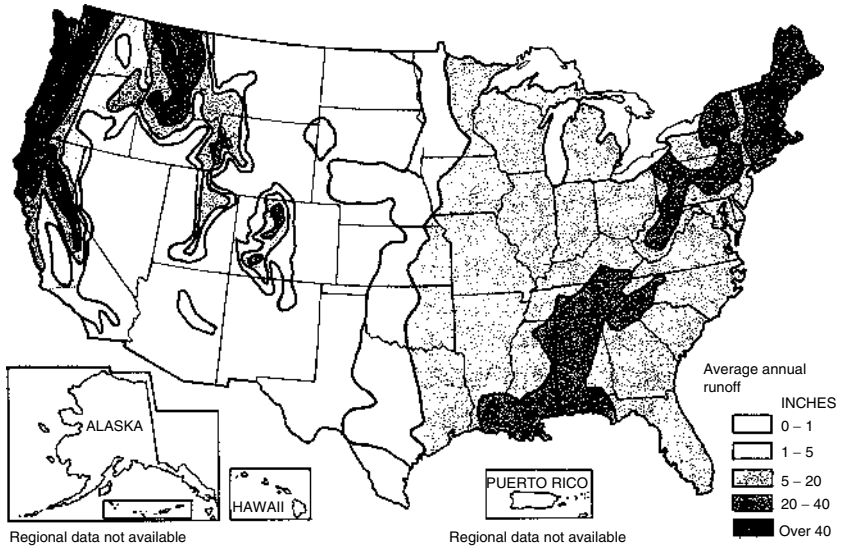


**Figure 4G.11** Average annual runoff in the United States. (From U.S. Water Resources Council 1968, The Nation's Water Resources.)

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**Table 4G.26 Runoff for National Forest and Non-National Forest Areas in Selected Western Drainage Basins**

| | Area | | Average Annual Water Production | | | | |
|---|---|---|---|---|---|---|---|
| | | | | NF | | Outside NF | |
| Drainage Basin or Area | NF (Percent) | Outside NF (Percent) | Whole Area (Inches) | Inches | Percent of Total Volume | Inches | Percent of Total Volume |
| Columbia (in U.S.) | 37 | 63 | 10.4 | 16.7 | 59 | 6.7 | 41 |
| Colorado (in U.S.) | 19 | 81 | 2.5 | 7.2 | 56 | 1.3 | 44 |
| Rio Grande above El Paso | 25 | 75 | 1.7 | 3.8 | 58 | 0.9 | 42 |
| Central Valley (California only) | 32 | 68 | 11.8 | 23.5 | 63 | 6.4 | 37 |
| Rogue-Umpqua Area | 40 | 60 | 35.5 | 37.0 | 42 | 34.2 | 58 |
| Northwest Washington (State less Columbia) | 32 | 68 | 39.3 | 51.4 | 41 | 33.7 | 59 |
| Southern California Coast (Los Angeles watershed to Mexican border) | 25 | 75 | 3.7 | 6.3 | 43 | 2.8 | 57 |
| North Platte and South Platte | 11 | 89 | 1.7 | 6.2 | 41 | 1.2 | 59 |
| Missouri above Fort Randall Dam | 9 | 91 | 1.7 | 6.9 | 37 | 1.2 | 63 |
| Arkansas above Dodge City | 9 | 91 | 1.2 | 4.7 | 38 | 0.7 | 62 |

*Source*: U.S. Geological Survey.

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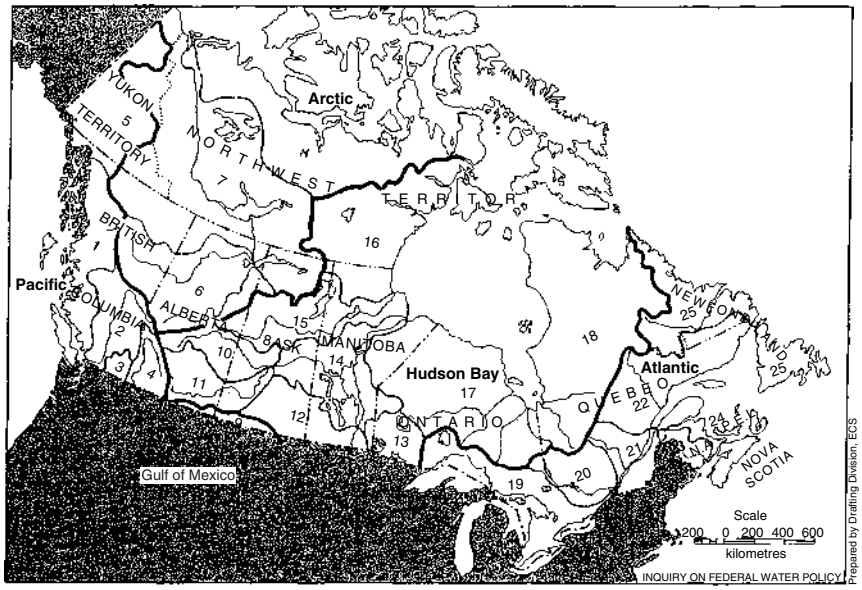


| Ocean basin region | | River basin region | Area in 000s km$^2$ | Population in 000s 1981 |
|---|---|---|---|---|
| | 1 | Pacific Coastal | 352 | 616 |
| | 2 | Fraser-Lower Mainland | 234 | 1 722 |
| Pacific | 3 | Okanagan-Similkameen[a] | 14 | 189 |
| | 4 | Columbia[a] | 90 | 161 |
| | 5 | Yukon[a] | 328 | 23 |
| | 6 | Peace-Athabasca | 487 | 286 |
| Arctic | 7 | Lower Mackenzie | 1 300 | 43 |
| | 8 | Arctic Coast-Islands | 2 025 | 13 |
| Gulf of Mexico | 9 | Missouri[a] | 26 | 14 |
| | 10 | North Saskatchewan | 146 | 1 084 |
| | 11 | South Saskatchewan[a] | 170 | 1 282 |
| | 12 | Assiniboine-Red[a] | 190 | 1 300 |
| | 13 | Winnipeg[a] | 107 | 77 |
| Hudson Bay | 14 | Lower Saskatchewan-Nelson | 363 | 224 |
| | 15 | Churchill | 298 | 68 |
| | 16 | Keewatin | 689 | 5 |
| | 17 | Northern Oontario | 694 | 157 |
| | 18 | Northern Quebec | 950 | 109 |
| | 19 | Great Lakes[a] | 319 | 7 579 |
| | 20 | Ottawa | 146 | 1 270 |
| | 21 | St. Lawrence[a] | 116 | 5 193 |
| Atlantic | 22 | North Shore-Gaspé | 403 | 653 |
| | 23 | St. John-St. Croix[a] | 37 | 393 |
| | 24 | Maritime Coastal | 114 | 1 314 |
| | 25 | Newfoundland-Labrador | 376 | 568 |
| CANADA | | | 9 974 | 24 343 |

[a]Canadian portion only; area and population on U.S. side of international basin regions are excluded from totals.

**Figure 4G.12** Drainage regions of Canada. (From Pearse, P.H., Currents of change, *Final Report Inquiry on Federal Water Policy*, Ottawa, Canada, 1985.)

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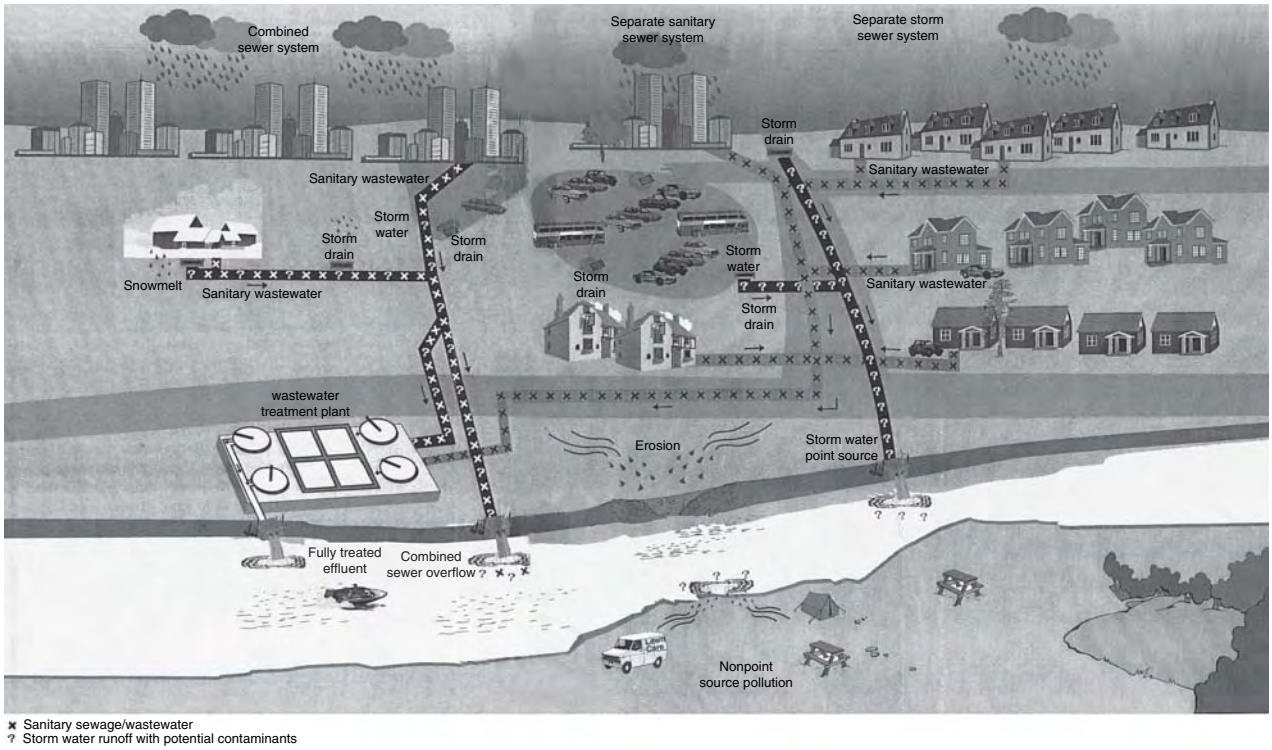


**Figure 4G.13** Urban runoff flows in different types of sewer systems. (From www.gao.gov. GAO water quality — better data and evaluation of urban runoff programs needed to assess effectiveness — report to Congressional requesters, U.S. General Accounting Office.)

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**Table 4G.27 Projections of Average Water Availability in the United States[a]**

| Region | 1965 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| North Atlantic | 163 | 163 | 163 | 163 |
| South Atlantic-Gulf | 197 | 197 | 197 | 197 |
| Great Lakes[b] | 80.3 | 80.3 | 80.3 | 80.3 |
| Ohio | 125 | 125 | 125 | 125 |
| Tennessee | 41.5 | 41.5 | 41.5 | 41.5 |
| Upper Mississippi[c] | 66.7 | 66.7 | 66.7 | 66.7 |
| Lower Mississippi[d] | 408 | 401 | 395 | 390 |
| Souris-Red-Rainy[e] | 6.2 | 6.4 | 6.8 | 6.8 |
| Missouri[f] | 54.5 | 54.6 | 54.8 | 54.9 |
| Arkansas-White–Red[f] | 95.8 | 95.9 | 96.0 | 96.0 |
| Texas-Gulf[g] | 39.1 | 39.2 | 39.2 | 39.2 |
| Rio Grande[h] | 5.2 | 5.3 | 5.3 | 5.3 |
| Upper Colorado[i] | 13.5 | 13.5 | 13.5 | 13.5 |
| Lower Colorado[j] | 14.1 | 12.6 | 11.9 | 11.6 |
| Great Basin[k] | 6.9 | 7.0 | 7.1 | 7.2 |
| Columbia-North Pacific[l] | 258 | 258 | 258 | 258 |
| California[m] | 69.7 | 69.4 | 69.3 | 69.2 |
| Alaska[l] | 710 | 710 | 710 | 710 |
| Hawaii | 13.3 | 13.3 | 13.3 | 13.3 |

*Note:* Values in billion gallons per day; for regions, see Figure 4G.9.

[a] Nature runoff adjusted for imports and upstream runoff where appropriate, values rounded.
[b] Includes net precipitation of U.S. portion of Great Lakes.
[c] Includes import from Great Lakes Region.
[d] Includes net upstream runoff and imports.
[e] Includes import from Missouri Region.
[f] Includes imports from Upper Colorado Region.
[g] Includes import from Arkansas-White–Red Region.
[h] Includes imports from Upper Colorado Region and Mexican Treaty deliveries.
[i] Virgin flow at Lee Ferry Compact point.
[j] Includes net upstream runoff.
[k] Includes imports from Upper Colorado Region and nature runoff from California Region.
[l] Includes natural runoff from Canada.
[m] Includes imports from Lower Colorado Region.

*Source*: U.S. Water Resources Council, 1968.

**Table 4G.28 Values of Runoff Coefficient in the Rational Formula**

| Types of Drainage Area | Runoff Coefficient (*C*) | Type of Drainage Area | Runoff Coefficient (*C*) |
|---|---|---|---|
| Lawns: | | Industrial: | |
| Sandy soil, flat, 2% | 0.05–0.10 | Light areas | 0.50–0.80 |
| Sandy soil, average, 2–7% | 0.10–0.15 | Heavy areas | 0.60–0.90 |
| Sandy soil, steep, 7% | 0.15–0.20 | Parks, cemeteries | 0.10–0.25 |
| Heavy soil, flat, 2% | 0.13–0.17 | Playgrounds | 0.20–0.35 |
| Heavy soil, average, 2–7% | 0.18–0.22 | Railroad yard areas | 0.20–0.40 |
| Heavy soil, steep, 7% | 0.25–0.35 | Unimproved areas | 0.10–0.30 |
| Business: | | Streets: | |
| Downtown areas | 0.70–0.95 | Asphaltic | 0.70–0.95 |
| Neighborhood areas | 0.50–0.70 | Concrete | 0.80–0.95 |
| Residential: | | Brick: | 0.70–0.85 |
| Single-family areas | 0.30–0.50 | Drives and walks | 0.75–0.85 |
| Multi units, detached | 0.40–0.60 | Roofs | 0.75–0.95 |
| Multi units, attached | 0.60–0.75 | | |
| Suburban | 0.25–0.40 | | |
| Apartment dwelling areas | 0.50–0.70 | | |

*Note:* Formula is applicable to drainage areas less than about 5000 acres and has the form $Q = CiA$ where $Q$ is peak discharge in cfs, $C$ is a dimensionless runoff coefficient, $i$ is rainfall intensity for the time of concentration in inches per hour, and $A$ is drainage area in acres.

*Source*: *Amer. Soc. Civil Engrs.*

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**Table 4G.29 Watershed Characteristics for Determining Runoff Coefficient in the Rational Formula**

| Designation of Watershed Characteristics | Runoff-Producing Characteristics | | | |
|---|---|---|---|---|
| | **100 Extreme** | **75 High** | **50 Normal** | **25 Low** |
| Relief | (40) Steep, rugged terrain, with average slopes generally above 30% | (30) Hilly, with average slopes of 10–30% | (20) Rolling, with average slopes of 5–10% | (10) Relatively flat land, with average slopes of 0–5% |
| Soil infiltration | (20) No effective soil cover, either rock or thin soil mantle of negligible infiltration capacity | (15) Slow to take up water; clay or other soil of low infiltration capacity, such as heavy gumbo | (10) Normal; deep loam with infiltration about equal to that of typical prairie soil | (5) High; deep sand or other soil that takes up water readily and rapidly |
| Vegetal cover | (20) No effective plant cover; bare or very sparse cover | (15) Poor to fair; clean-cultivated crops or poor natural cover; less than 10% of drainage area under good cover | (10) Fair to good; about 50% of drainage area in good grassland, woodland, or equivalent cover; not more than 50% of area in clean-cultivated crops | (5) Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover |
| Surface storage | (20) Negligible; surface depressions few and shallow; drainage-ways steep and small; no ponds or marshes | (15) Low; well-defined system of small drainage-ways; no ponds or marshes | (10) Normal; considerable surface-depression storage; drainage system similar to that of typical prairie lands; lakes, ponds and marshes less than 2% of drainage area | (5) High; surface-depression storage high; drainage system not sharply defined; large flood-plain storage or a large number of lakes, ponds, or marshes |

*Note:* For each watershed characteristic in left column select appropriate descriptive box; add four numerical values given in parentheses to obtain runoff coefficient as a percentage.

*Source*: U.S. Soil Conservation Service.

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**Table 4G.30 Time of Concentration of a Watershed**

| | Height (Feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Length (Feet)** | **5** | **10** | **20** | **40** | **60** | **100** | **200** | **400** | **600** | **800** | **1000** |
| 200 | 2 | 2 | 1 | 1 | 1 | 1 | | | | | |
| 400 | 5 | 4 | 3 | 2 | 2 | 1 | 1 | | | | |
| 600 | 8 | 6 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | | |
| 800 | 10 | 8 | 6 | 5 | 4 | 3 | 2 | 2 | 2 | 1 | |
| 1,000 | 14 | 10 | 8 | 6 | 5 | 4 | 3 | 2 | 2 | 2 | 2 |
| 2,000 | 28 | 21 | 17 | 13 | 10 | 9 | 7 | 5 | 4 | 4 | 3 |
| 3,000 | 48 | 35 | 27 | 20 | 17 | 13 | 10 | 8 | 7 | 6 | 5 |
| 4,000 | 65 | 50 | 36 | 28 | 24 | 19 | 14 | 11 | 9 | 8 | 7 |
| 5,000 | 100 | 65 | 48 | 35 | 28 | 22 | 19 | 14 | 12 | 11 | 9 |
| 7,000 | 150 | 100 | 70 | 52 | 42 | 34 | 27 | 20 | 17 | 15 | 13 |
| 10,000 | 240 | 180 | 120 | 85 | 70 | 54 | 40 | 28 | 25 | 22 | 20 |
| 15,000 | 330 | 270 | 210 | 150 | 120 | 90 | 60 | 46 | 44 | 34 | 30 |
| 20,000 | 430 | 350 | 280 | 210 | 180 | 140 | 95 | 65 | 54 | 48 | 43 |
| 30,000 | 600 | 500 | 450 | 320 | 280 | 230 | 170 | 120 | 100 | 90 | 75 |
| 40,000 | 870 | 660 | 510 | 420 | 360 | 300 | 240 | 180 | 150 | 130 | 120 |
| 50,000 | 1080 | 840 | 600 | 480 | 430 | 360 | 300 | 230 | 190 | 160 | 150 |

*Note:* Values are time in minutes for water to travel from the most distant point in a watershed to the watershed outlet. Length is distance along the main stream from the watershed outlet to the most distant ridge; height is difference in elevation between the watershed outlet and the most distant ridge.

*Source*: From Kirpich, *Civil Eng*, 1940.



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**Table 4G.31 Total Impervious Area for Specific Land-Use Categories**

| | Typical Values of Total Impervious Area (Precent) | | |
|---|---|---|---|
| **Land-Use Category** | **Low** | **Intermediate** | **High** |
| Single-family residential[a] | 16 | 27 | 45 |
| Multifamily residential[b] | 50 | 60 | 70 |
| Commercial[c] | 80 | 88 | 95 |
| Industrial[d] | 50 | 75 | 90 |
| Public facilities[e] | 50 | 60 | 75 |
| Parks and undeveloped land[f] | 0 | 1 | 3 |

[a] Single-family residential — Single-family dwellings predominate.
[b] Multifamily residential — Multiple-family units predominate. These include duplexes, apartment buildings, and condominiums.
[c] Commercial — Zone consisting of various types of business.
[d] Industrial — Manufacturing complexes, railroad yards, and large utilities.
[e] Public facilities — School, hospitals, churches, airports, and other public buildings.
[f] Parks and undeveloped land-parks, forests, and open undeveloped land.

*Source*: From Conger, D.H., Estimating magnitude and frequency of floods for wisconsin urban streams, *U.S. Geological Survey Water-Resources investigations Report 86-4005*, 1986.

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## SECTION 4H EROSION AND SEDIMENTATION

**Table 4H.32 Drainage Area, Water and Suspended Sediment Discharges for Major Rivers of the World**

| River | Drainage Area ($\times 10^6$ km$^2$) | Water Discharge (km$^3$ yr) | Sediment Discharge Millions of Tons per Year | | |
|---|---|---|---|---|---|
| | | | Strakhov (1961) and Lisitzin (1972) | Holeman (1968) | Milliman and Meade (1983) |
| North America | | | | | |
| St. Lawrence (Canada) | 1.03 | 447 | 4 | 4 | 4 |
| Hudson (U.S.A.) | 0.02 | 12 | 36 | — | 1 |
| Mississippi (U.S.A.) (including Atchafalaya) | 3.27 | 580 | 500 | 349 | 210 |
| Brazos (U.S.A.) | 0.11 | 7 | 32 | 32 | 16 |
| Colorado (Mexico) | 0.64 | 20 | 135 | 135 | 0.1 |
| Eel (U.S.A.) | 0.008 | — | — | 16 | 14 |
| Columbia (U.S.A.) | 0.67 | 251 | 36 | 9 | 8 |
| Fraser (Canada) | 0.22 | 112 | — | — | 20 |
| Yukon (U.S.A.) | 0.84 | 195 | 88 | — | 60 |
| Copper (U.S.A.) | 0.06 | 39 | — | — | 70 |
| Susitna (U.S.A.) | 0.05 | 40 | — | — | 25 |
| MacKenzie (Canada) | 1.81 | 306 | 15 | — | 100 |
| Total North America | 9.57 | | | | 528 |
| South America | | | | | |
| Chira (Peru) | 0.02 | 5 | — | — | 4-75 |
| Magdalena (Colombia) | 0.24 | 237 | — | — | 220 |
| Orinoco (Venezuela) | 0.99 | 1100 | 86 | 86 | 210 |
| Amazon (Brazil) | 6.15 | 6300 | 498 | 364 | 900 |
| Sao Francisco (Brazil) | 0.64 | 97 | — | — | 6 |
| La Plata (Argentina) | 2.83 | 470 | 129 | 82 | 92 |
| Negro (Argentina) | 0.10 | 30 | — | — | 13 |
| Total South America | 10.85 | | | | 1420 |
| Europe | | | | | |
| Rhone (France) | 0.09 | 49 | 31 | — | 10 |
| Po (Italy) | 0.07 | 46 | 18 | 15 | 15 |
| Danube (Romania) | 0.81 | 206 | 67 | 19 | 67 |
| Semani (Albania) | — | — | — | 22 | ? |
| Drini (Albania) | 0.01 | — | — | 15 | ? |
| Total Europe | 0.97 | | | | 92 |
| Eurasian Arctic | | | | | |
| Yana (U.S.S.R.) | 0.22 | 29 | 3 | — | 3 |
| Ob (U.S.S.R.) | 2.50 | 385 | 16 | 15 | 16 |
| Yenisei (U.S.S.R.) | 2.58 | 560 | 13 | — | 13 |
| Severnay Dvina (U.S.S.R.) | 0.35 | 106 | 4.5 | — | 4.5 |
| Lena (U.S.S.R.) | 2.50 | 514 | 15 | — | 12 |
| Kolyma (U.S.S.R.) | 0.64 | 71 | 6 | — | 6 |
| Indigirka (U.S.S.R.) | 0.36 | 55 | 14 | — | 14 |
| Total Euras. Arctic | 9.15 | | | | 68 |
| Asia | | | | | |
| Amur (U.S.S.R.) | 1.85 | 325 | 25 | — | 52 |
| Liaohe (China) | 0.17 | 6 | — | — | 41 |
| Daling (China) | 0.02 | 1 | — | — | 36 |
| Haiho (China) | 0.05 | 2 | — | — | 81 |
| Yellow (Huangho) (China) | 0.77 | 49 | 1890 | 1890 | 1080 |
| Yangtze (China) | 1.94 | 900 | 500 | 502 | 478 |
| Huaihe (China) | 0.26 | — | — | — | 14 |
| Pearl (Zhu Jiang) (China) | 0.44 | 302 | — | 27 | 69 |
| Hungho (Vietnam) | 0.12 | 123 | 130 | 130 | 130 |
| Mekong (Vietnam) | 0.79 | 470 | 170 | 170 | 160 |
| Irrawaddy (Burma) | 0.43 | 428 | 299 | 300 | 265 |
| Ganges/Brahmaputra (Bangladesh) | 1.48 | 971 | 2180 | 2180 | 1670 |
| Mehandi (India) | 0.13 | 67 | — | 62 | 2 |

*(Continued)*

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**Table 4H.32 (Continued)**

| River | Drainage Area ($\times 10^6$ km$^2$) | Water Discharge (km$^3$ yr) | Sediment Discharge Millions of Tons per Year | | |
|---|---|---|---|---|---|
| | | | Strakhov (1961) and Lisitzin (1972) | Holeman (1968) | Milliman and Meade (1983) |
| Damodar (India) | 0.02 | 10 | — | 28 | ? |
| Godavari (India) | 0.31 | 84 | — | — | 96 |
| Indus (Pakistan) | 0.97 | 238 | 435 | 440 | 100 |
| Tigris-Euphrates (Iraq) | 1.05 | 46 | 105 | 53 | ? |
| Total Asia | 9.74 | | | | 4334 |
| Africa | | | | | |
| Nile (Egypt) | 2.96 | 30 | 110 | 111 | 0 |
| Niger (Nigeria) | 1.21 | 192 | 67 | 4 | 40 |
| Zaire (Zaire) | 3.82 | 1250 | 65 | 64 | 43 |
| Orange (S. Africa) | 1.02 | 11 | 153 | — | 17 |
| Zambesi (Mozambique) | 1.20 | 223 | 100 | — | 20 |
| Limpopo (Mozambique) | 0.41 | 5 | — | — | 33 |
| Rufiji (Tanzania) | 0.18 | 9 | — | — | 17 |
| Tana (Kenya) | 0.032 | — | — | — | 32 |
| Total Africa (minus Nile) | 7.48 | | | | 175 |
| Oceania | | | | | |
| Murray (Aust.) | 1.06 | 22 | 32 | 32 | 30 |
| Waiapu (N.Z.) | — | — | — | — | 28 |
| Haast (N.Z.) | 0.001 | 6 | — | — | 13 |
| Fly (New Guinea) | 0.061 | 77 | | | 30 |
| Purari (New Guinea) | 0.031 | 77 | | | 80 |
| Choshui (Taiwan) | 0.003 | 6 | — | — | 66 |
| Kaoping (Taiwan) | 0.003 | 9 | — | — | 39 |
| Tsengwen (Taiwan) | 0.001 | 2 | — | — | 28 |
| Hualien (Taiwan) | 0.002 | 4 | — | — | 19 |
| Peinan (Taiwan) | 0.002 | 4 | — | — | 17 |
| Hsiukuluan (Taiwan) | 0.002 | 4 | — | — | 16 |
| Total Oceania (excluding Murray) | 1.074 | 39 | | | 336 |

*Source*: From Milliman, J.D., and Meade, R.H., World-wide Delivery of River sediment to oceans Copyright. *J. Geol.*, 91, 1, 1983. With permission.

**Table 4H.33 Losses of Land by Riverbank Erosion in the United States**

| Region | Areas of Significant Erosion | Average Land Losses |
|---|---|---|
| | *River-miles* | *Acres/yr* |
| North Atlantic | Not significant | Not significant |
| South Atlantic-Gulf | 5,100 | 350 |
| Great Lakes | Not significant | Not significant |
| Ohio | Not significant | Not significant |
| Tennessee | Not significant | Not significant |
| Upper Mississippi | Not available | Not available |
| Lower Mississippi | 1,044 | 4,705 |
| Souris-Red-Rainy | Not available | Not available |
| Missouri | 1,692 | 5,000 |
| Arkansas-White–Red | 2,300 | 7,300 |
| Texas-Gulf | 1,698 | 1,045 |
| Rio Grande | 250 | 150 |
| Upper Colorado | Not available | Not available |
| Lower Colorado | Not available | Not available |
| Great Basin | 265 | 150 |
| Columbia-North Pacific | 13,500 | 1,300 |
| California | 2,600 | 3,837 |
| Alaska | 80,000 | 5,000 |
| Hawaii | Not significant | Not significant |
| Puerto Rico | Not available | Not available |

*Note:* Estimated average annual losses as of 1966; for regions see Figure 4G.9.

*Source*: U.S. Water Resources Council, 1968.

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**Table 4H.34 Losses of Land by Erosion of Beaches and Estuary Shores in the United States**

| Region | Average Annual Land Losses |
|---|---|
| | *Acres/mile* |
| North Atlantic | 0.12 |
| South Atlantic-Gulf | 0.11 |
| Great Lakes | 0.07 |
| Lower Mississippi | — |
| Texas-Gulf | 0.27 |
| Columbia-North Pacific | 0.02 |
| California | 0.13 |
| Alaska | 0.06 |
| Hawaii | 0.24 |
| Puerto Rico | — |

*Note:* Estimated average annual losses as of 1966; for regions see Figure 4G.9.

*Source*: U.S. Water Resources Council, 1968.

**Table 4H.35 Erosion Problems in the Public Domain of the United States**

| | Extent of Erosion | | | |
|---|---|---|---|---|
| **Region** | **Slight** | **Moderate** | **Critical** | **Total** |
| Missouri | 7.5 | 9.0 | 5.2 | 21.7 |
| Arkansas-White–Red | 0.1 | 0.4 | 0.2 | 0.7 |
| Rio Grande | 1.3 | 6.4 | 3.6 | 11.3 |
| Upper Colorado | 4.1 | 14.4 | 8.3 | 26.8 |
| Lower Colorado | 2.4 | 13.8 | 7.9 | 24.1 |
| Great Basin | 15.4 | 20.1 | 11.6 | 47.1 |
| Columbia-North Pacific | 14.6 | 8.5 | 5.0 | 28.1 |
| California | 6.8 | 5.4 | 3.2 | 15.4 |
| Total | 52.2 | 78.0 | 45.0 | 175.2 |

*Note:* Values in millions of acres; conterminous United States only; for regions see Figure 4G.9.

*Source*: U.S. Water Resources Council, 1968.

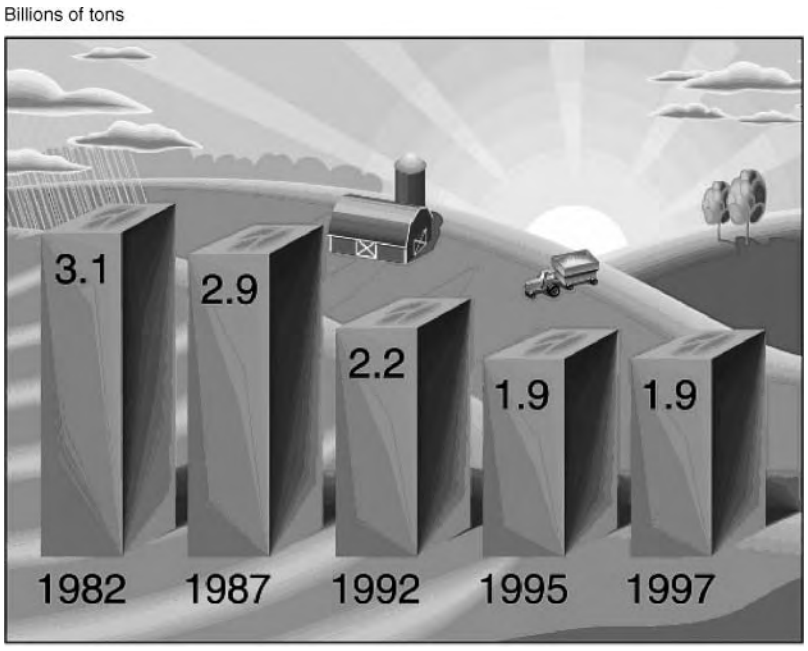


**Figure 4H.14** Total erosion on cropland and Conservation Reserve Program Land. (From USDA, Natural Resources Conservation Service, 1997 National Resources Inventory, revised December 2000, www.nrcs.usda.gov.)

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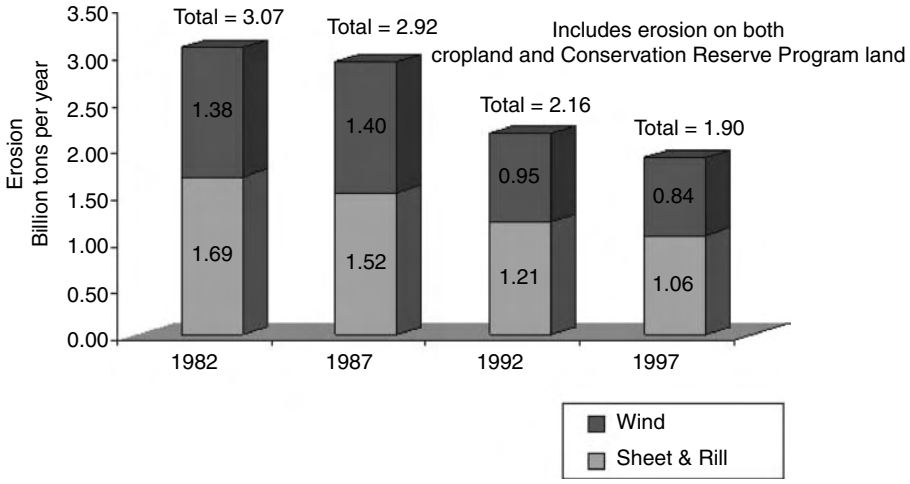


**Figure 4H.15** Changes in erosion, 1982–1997. (From www.nrcs.usda.gov.)

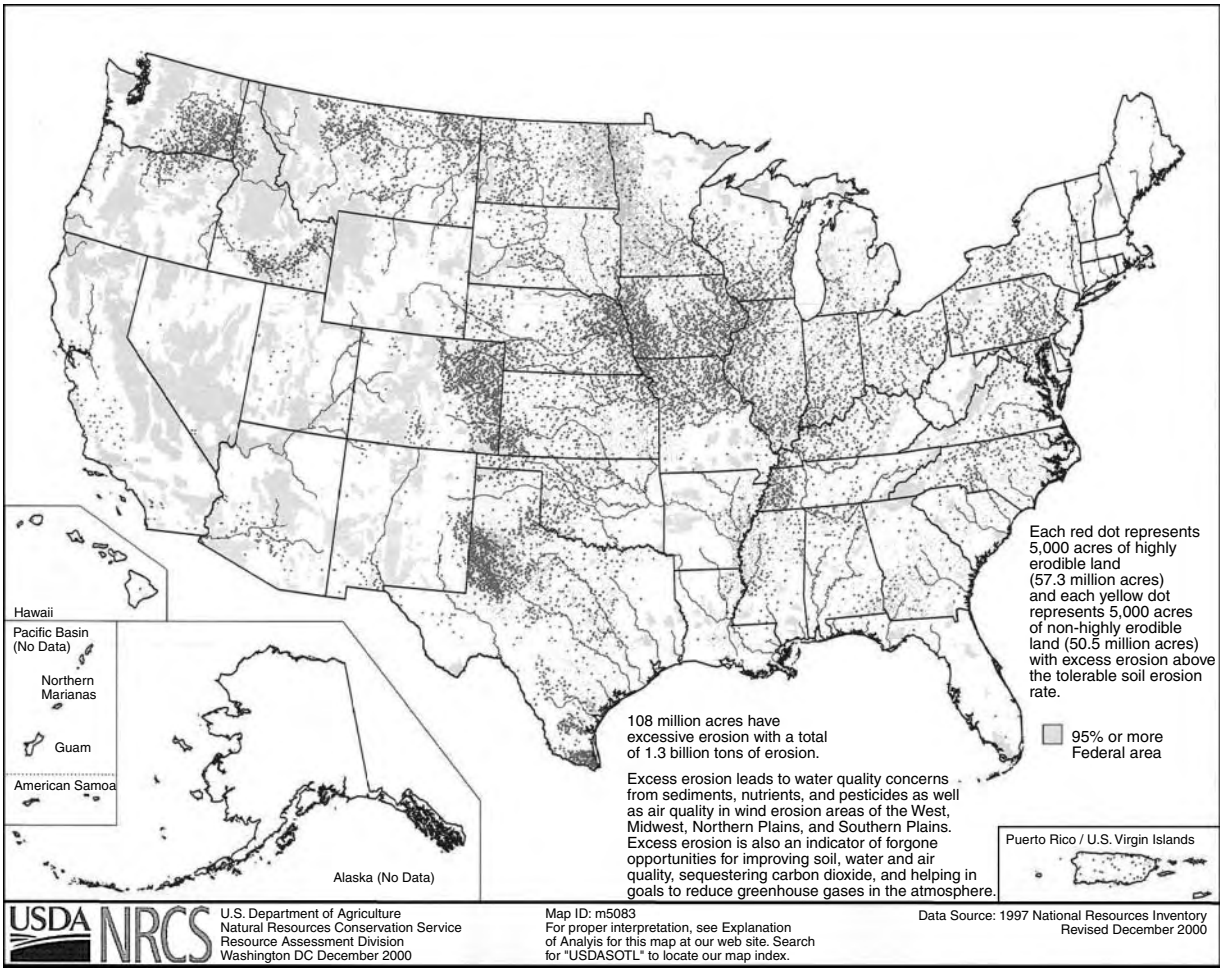


**Figure 4H.16** Excessive erosion on cropland, 1997. (From www.nrcs.usda.gov.)

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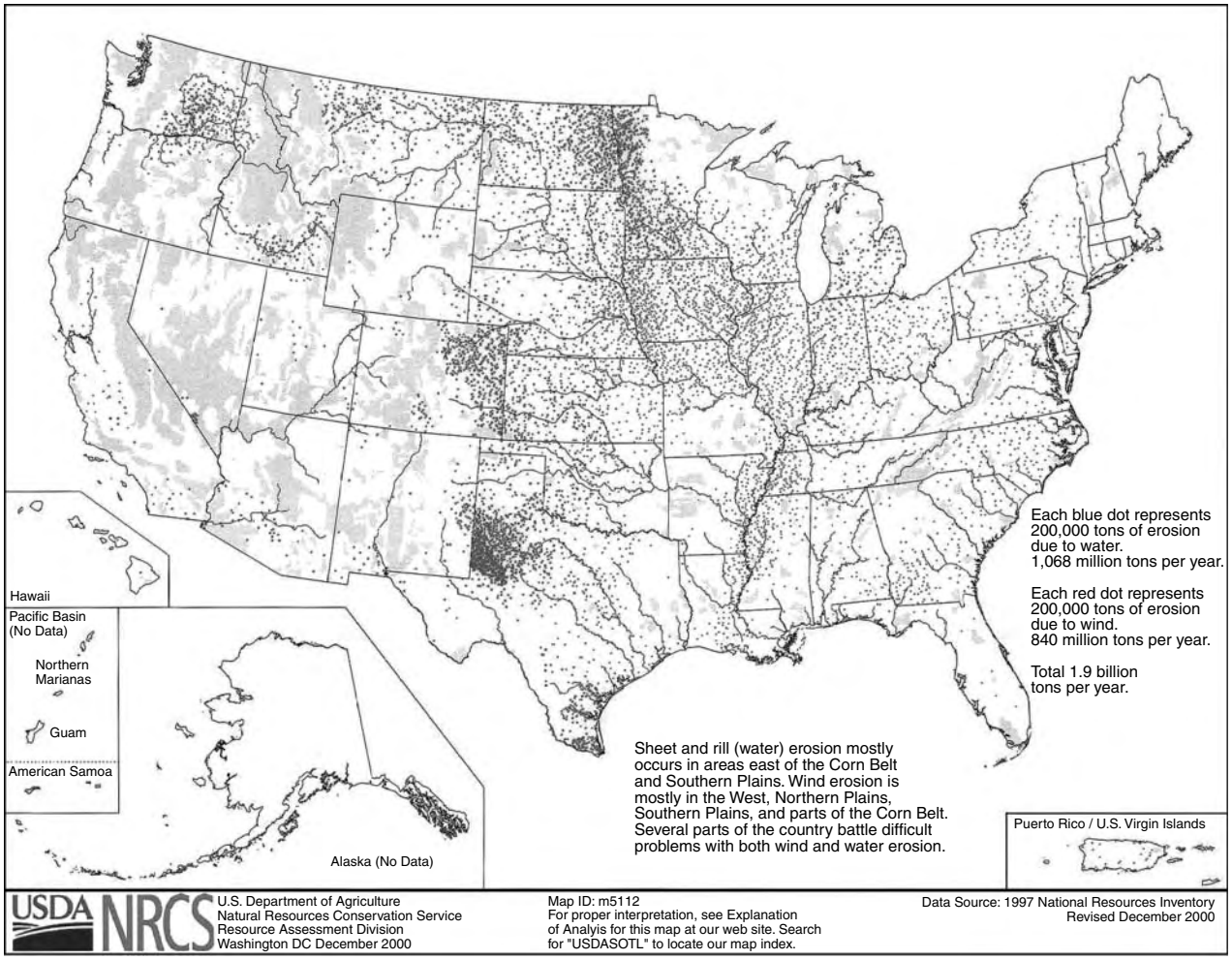


**Figure 4H.17** Total wind and water erosion, 1997. (From www.nrcs.usda.gov.)

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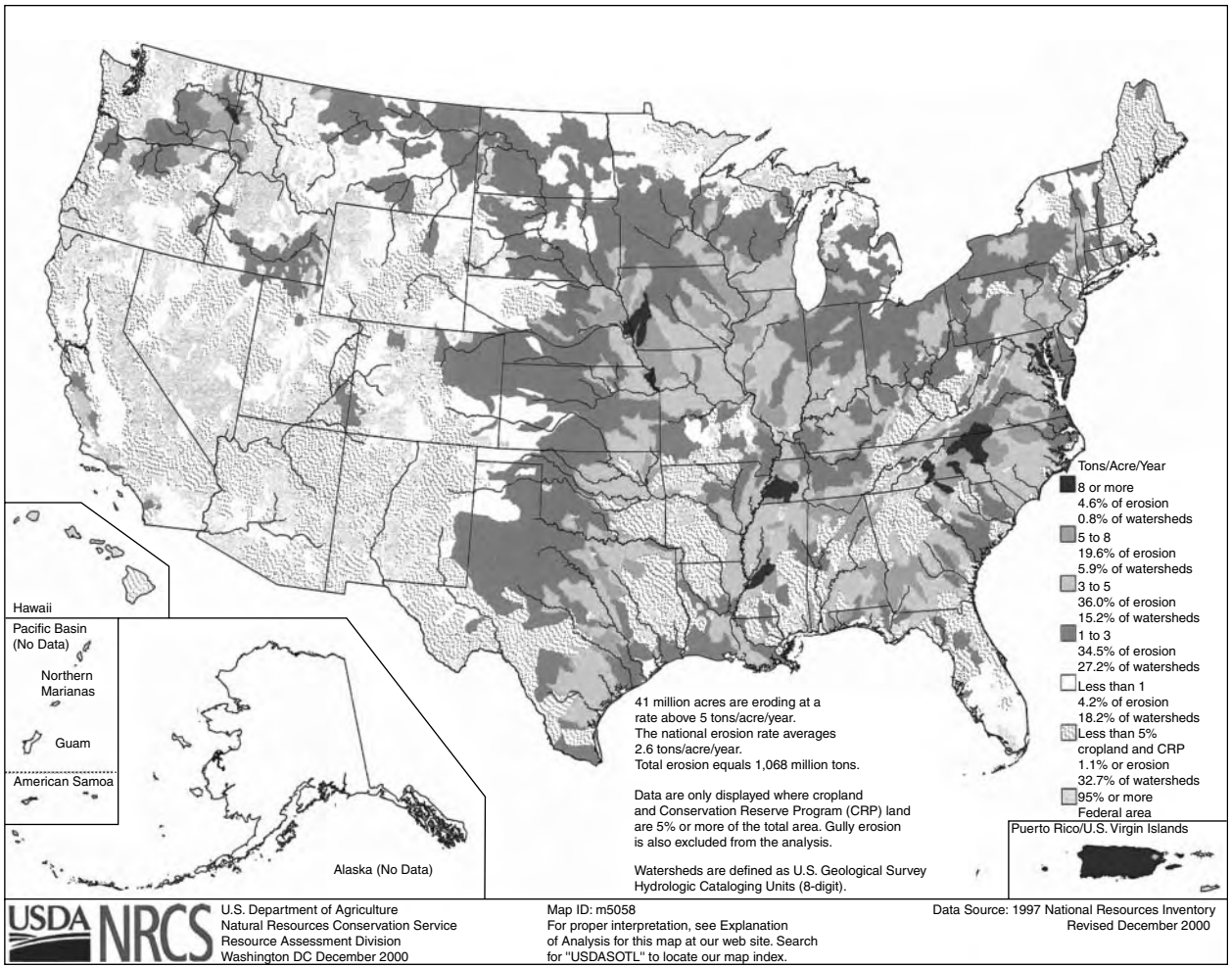


**Figure 4H.18** Average annual soil erosion by water on cropland and Conservation Reserve Program land, 1997. (From www.nrcs.usda.gov.)

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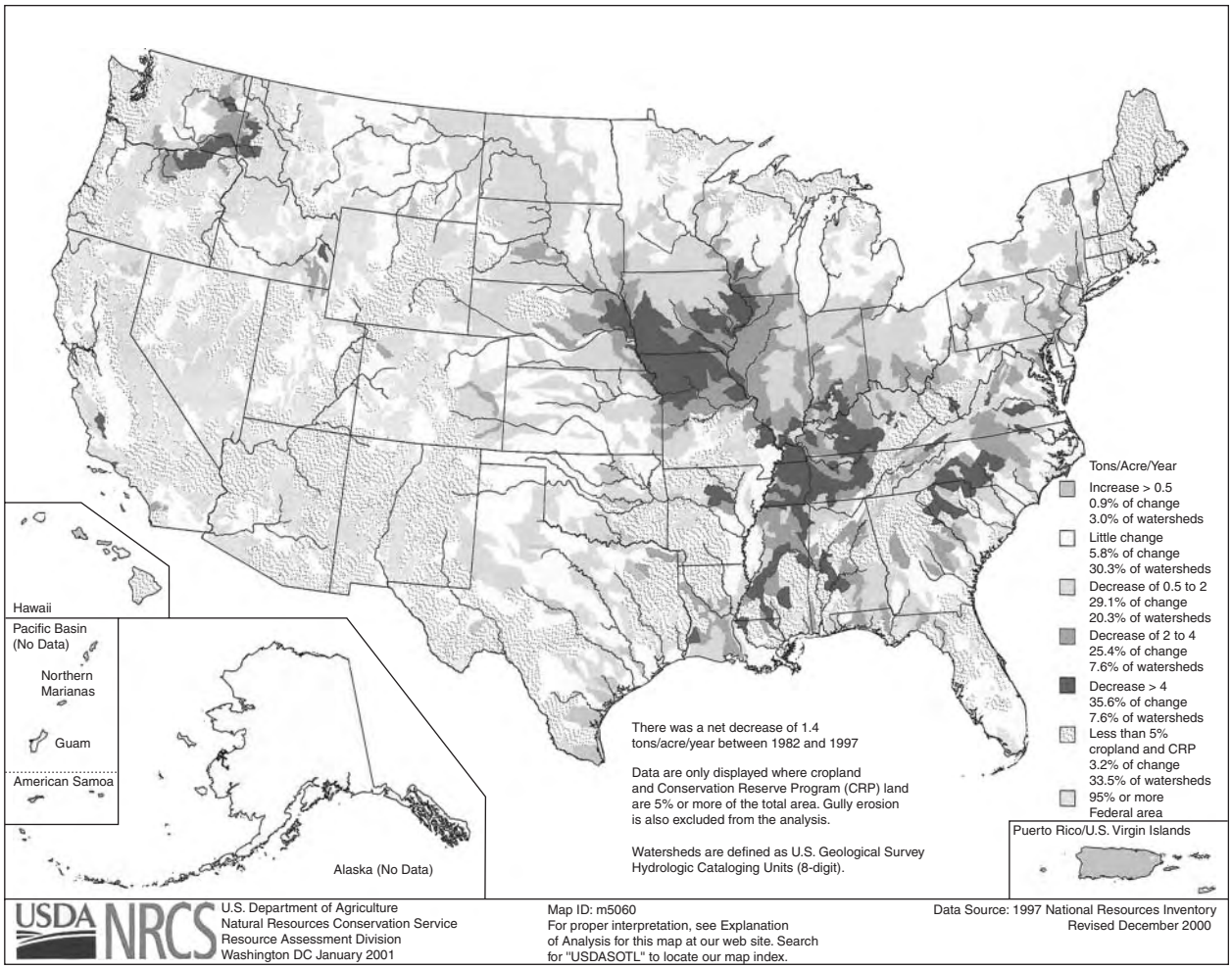


**Figure 4H.19** Change in average annual soil erosion by water on cropland and Conservation Reserve Program land, 1982–1997. (From www.nrcs.usda.gov.)

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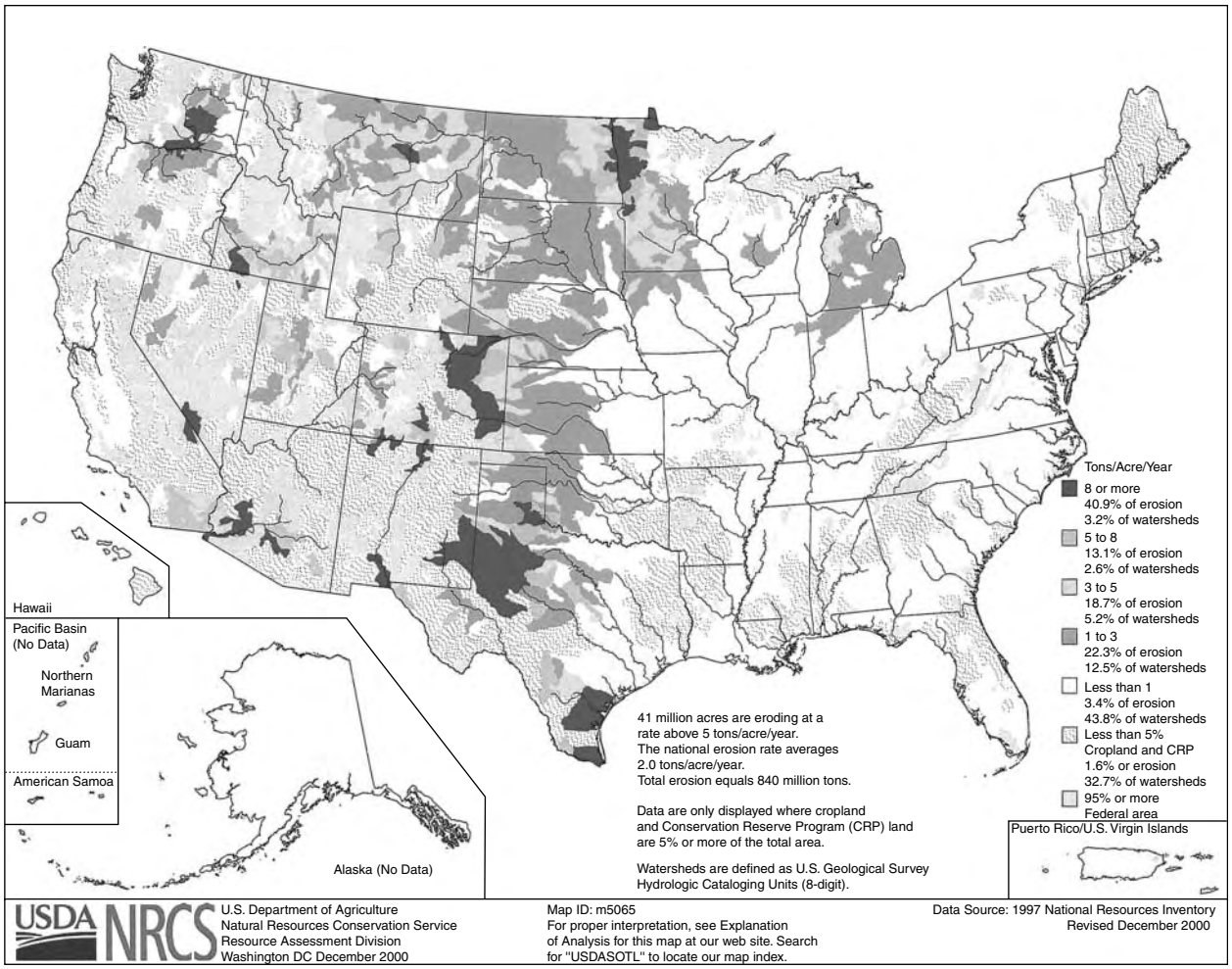


**Figure 4H.20** Average annual soil erosion by wind on cropland and Conservation Reserve Program land, 1997. (From www.nrcs.usda.gov.)

**Table 4H.36 Selected Quantitative Effects of Man's Activities on Surface Erosion**

| Initial Status of Land Use | Type of Disturbance | Magnitude of Specific Disturbance[a] |
|---|---|---|
| Forestland | Planting row crops | 100 to 1,000 Times |
| Grassland | Planting row crops | 20 to 100 Times |
| Forestland | Building logging roads | 220 Times |
| Forestland | Woodcutting and skidding | 1.6 Times |
| Forestland | Fire | 7 to 1,500 Times |
| Forestland | Mining | 1,000 Times |
| Row crop | Construction | 10 Times |
| Pastureland | Construction | 200 Times |
| Forestland | Construction | 2,000 Times |

[a] Relative magnitude of surface erosion from disturbed surface, assuming "I" for the initial status. The first row of the table, for example, indicates that transforming a forestland into row crops may increase surface erosion 100 to 1000 times.

*Source*: U.S. Environmental Protection Agency, Loading Functions for Assessments of Water Pollution from Non-Point Sources, *Environmental Protection Technology Series*, Washington, DC, 1976.

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**Table 4H.37 Representative Rates of Erosion from Various Land Uses**

| Land Use | Amount of Erosion (Tons/Square Mile/Year) | Rate of Erosion Relative to Forest = 1 |
|---|---|---|
| Forest | 24 | 1 |
| Grassland | 240 | 10 |
| Abandoned Surface Mines | 2,400 | 100 |
| Cropland | 4,800 | 200 |
| Harvested Forest | 12,000 | 500 |
| Active Surface Mines | 48,000 | 2,000 |
| Construction | 48,000 | 2,000 |

*Source*: U.S. Environmental Protection Agency. *Methods For Identifying and Evaluating the Nature and Extent of Nonpoint Source of Pollutants*, EPA 430/9-73-014, Washington, DC, 1973.

**Table 4H.38 Estimated Average Annual Sheet and Rill Erosion on Nonfederal Land, by State and Year (Data in tons/acre/year)**

| | | Cropland | | | | |
|---|---|---|---|---|---|---|
| State | Year | Cultivated | Noncultivated | Total | CRP Land | Pastureland |
| Alabama | 1982 | 7.6 | 0.8 | 7.2 | — | 0.6 |
| | 1987 | 6.5 | 0.5 | 6.0 | 3.0 | 0.5 |
| | 1992 | 7.0 | 0.5 | 6.3 | 0.6 | 0.5 |
| | 1997 | 6.7 | 0.5 | 6.0 | 1.0 | 0.5 |
| Arizona | 1982 | 0.6 | 0.3 | 0.5 | — | 0.2 |
| | 1987 | 0.6 | 0.2 | 0.6 | — | 0.1 |
| | 1992 | 0.6 | 0.2 | 0.6 | — | 0.1 |
| | 1997 | 0.7 | 0.2 | 0.6 | — | 0.1 |
| Arkansas | 1982 | 3.8 | 0.8 | 3.7 | — | 1.1 |
| | 1987 | 3.8 | 0.6 | 3.7 | 0.7 | 1.1 |
| | 1992 | 3.5 | 0.6 | 3.4 | 0.7 | 1.2 |
| | 1997 | 3.5 | 0.6 | 3.4 | 0.6 | 1.1 |
| California | 1982 | 1.2 | 0.7 | 1.1 | — | 0.2 |
| | 1987 | 1.1 | 0.8 | 1.0 | 2.4 | 0.2 |
| | 1992 | 1.0 | 0.5 | 0.8 | 1.1 | 0.1 |
| | 1997 | 0.7 | 0.5 | 0.6 | 0.3 | 0.1 |
| Colorado | 1982 | 2.2 | 0.2 | 1.9 | — | 0.3 |
| | 1987 | 2.2 | 0.2 | 2.0 | 2.2 | 0.3 |
| | 1992 | 2.0 | 0.2 | 1.8 | 0.8 | 0.3 |
| | 1997 | 1.7 | 0.2 | 1.5 | 0.4 | 0.3 |
| Connecticut | 1982 | 4.8 | 0.6 | 2.6 | — | 0.2 |
| | 1987 | 5.7 | 1.2 | 3.1 | — | 0.2 |
| | 1992 | 6.1 | 1.4 | 3.3 | — | 0.2 |
| | 1997 | 5.6 | 0.7 | 2.7 | — | 0.1 |
| Delaware | 1982 | 2.1 | 0.2 | 2.0 | — | 0.4 |
| | 1987 | 2.0 | 0.4 | 2.0 | — | 0.4 |
| | 1992 | 2.1 | 0.7 | 2.1 | 0.1 | 0.5 |
| | 1997 | 2.0 | 0.4 | 2.0 | 0.1 | 0.6 |
| Florida | 1982 | 2.4 | 0.5 | 1.8 | — | 0.1 |
| | 1987 | 2.1 | 0.4 | 1.4 | 0.5 | 0.1 |
| | 1992 | 1.8 | 0.4 | 1.2 | 0.6 | 0.1 |
| | 1997 | 1.8 | 0.5 | 1.2 | 0.4 | 0.1 |
| Georgia | 1982 | 6.2 | 0.4 | 5.9 | — | 0.5 |
| | 1987 | 6.1 | 1.0 | 5.7 | 2.1 | 0.4 |
| | 1992 | 5.5 | 0.6 | 5.0 | 0.5 | 0.4 |
| | 1997 | 5.9 | 0.3 | 5.2 | 0.2 | 0.4 |
| Hawaii | 1982 | 5.3 | 3.0 | 5.0 | — | 0.8 |
| | 1987 | 5.1 | 2.8 | 4.8 | — | 0.7 |
| | 1992 | 4.6 | 2.8 | 4.3 | — | 0.7 |
| | 1997 | 2.5 | 3.3 | 2.7 | — | 0.8 |
| Idaho | 1982 | 5.0 | 0.4 | 4.3 | — | 0.4 |
| | 1987 | 4.4 | 0.3 | 3.7 | 2.9 | 0.4 |

*(Continued)*

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**Table 4H.38 (Continued)**

| State | Year | Cropland | | | | |
|---|---|---|---|---|---|---|
| | | Cultivated | Noncultivated | Total | CRP Land | Pastureland |
| | 1992 | 3.5 | 0.4 | 2.9 | 1.5 | 0.4 |
| | 1997 | 3.4 | 0.4 | 2.8 | 1.3 | 0.5 |
| Illinois | 1982 | 6.3 | 1.2 | 6.2 | — | 1.6 |
| | 1987 | 5.3 | 1.5 | 5.2 | 4.3 | 1.3 |
| | 1992 | 4.4 | 1.6 | 4.3 | 1.2 | 1.0 |
| | 1997 | 4.1 | 0.6 | 4.0 | 0.5 | 1.0 |
| Indiana | 1982 | 4.8 | 1.1 | 4.7 | — | 1.0 |
| | 1987 | 4.4 | 0.9 | 4.2 | 1.7 | 0.8 |
| | 1992 | 3.4 | 1.1 | 3.3 | 0.4 | 0.8 |
| | 1997 | 3.0 | 0.9 | 2.9 | 0.3 | 0.7 |
| Iowa | 1982 | 7.7 | 1.8 | 7.5 | — | 1.3 |
| | 1987 | 6.5 | 1.5 | 6.3 | 0.8 | 1.3 |
| | 1992 | 5.6 | 1.1 | 5.4 | 0.5 | 1.2 |
| | 1997 | 4.9 | 0.8 | 4.7 | 0.5 | 1.1 |
| Kansas | 1982 | 2.7 | 0.4 | 2.5 | — | 0.8 |
| | 1987 | 2.6 | 0.5 | 2.5 | 2.3 | 0.8 |
| | 1992 | 2.3 | 0.4 | 2.2 | 0.4 | 0.7 |
| | 1997 | 2.2 | 0.4 | 2.1 | 0.3 | 0.7 |
| Kentucky | 1982 | 8.3 | 1.0 | 6.9 | — | 2.4 |
| | 1987 | 8.2 | 1.1 | 6.6 | 4.2 | 2.4 |
| | 1992 | 5.8 | 1.2 | 4.5 | 0.9 | 2.5 |
| | 1997 | 4.4 | 1.2 | 3.4 | 0.9 | 2.0 |
| Louisiana | 1982 | 4.7 | 0.6 | 4.6 | — | 0.2 |
| | 1987 | 4.1 | 0.3 | 4.0 | 0.6 | 0.2 |
| | 1992 | 3.5 | 0.6 | 3.4 | 0.2 | 0.2 |
| | 1997 | 3.3 | 0.6 | 3.2 | 0.6 | 0.2 |
| Maine | 1982 | 3.6 | 0.2 | 1.7 | — | 0.2 |
| | 1987 | 4.0 | 0.4 | 1.8 | — | 0.2 |
| | 1992 | 3.1 | 0.3 | 1.3 | 0.1 | 0.2 |
| | 1997 | 3.9 | 0.3 | 1.7 | 0.2 | 0.2 |
| Maryland | 1982 | 5.6 | 1.3 | 5.2 | — | 1.1 |
| | 1987 | 5.3 | 2.0 | 5.1 | 1.0 | 1.1 |
| | 1992 | 5.0 | 1.8 | 4.6 | 1.3 | 1.0 |
| | 1997 | 4.4 | 1.2 | 4.0 | 1.0 | 0.7 |
| Massachusetts | 1982 | 5.7 | 0.2 | 1.7 | — | 0.2 |
| | 1987 | 5.9 | 0.1 | 1.7 | — | 0.1 |
| | 1992 | 4.1 | 0.2 | 1.3 | — | 0.2 |
| | 1997 | 4.5 | 0.1 | 1.2 | — | 0.1 |
| Michigan | 1982 | 2.5 | 0.6 | 2.2 | — | 0.3 |
| | 1987 | 2.5 | 0.7 | 2.2 | 3.8 | 0.2 |
| | 1992 | 2.3 | 0.6 | 1.9 | 0.6 | 0.2 |
| | 1997 | 2.0 | 0.5 | 1.6 | 0.2 | 0.2 |
| Minnesota | 1982 | 2.6 | 0.6 | 2.4 | — | 0.4 |
| | 1987 | 2.6 | 0.4 | 2.5 | 1.3 | 0.3 |
| | 1992 | 2.3 | 0.3 | 2.2 | 0.3 | 0.3 |
| | 1997 | 2.1 | 0.3 | 2.0 | 0.2 | 0.3 |
| Mississippi | 1982 | 7.7 | 2.8 | 7.6 | — | 1.3 |
| | 1987 | 6.6 | 2.3 | 6.5 | 4.4 | 1.2 |
| | 1992 | 5.7 | 1.3 | 5.5 | 2.6 | 1.2 |
| | 1997 | 5.3 | 1.2 | 5.0 | 1.1 | 1.2 |
| Missouri | 1982 | 10.9 | 1.0 | 9.6 | — | 2.0 |
| | 1987 | 8.4 | 0.7 | 7.4 | 6.3 | 1.7 |
| | 1992 | 6.6 | 0.7 | 5.5 | 1.1 | 1.6 |
| | 1997 | 5.6 | 0.7 | 4.5 | 0.7 | 1.3 |
| Montana | 1982 | 2.1 | 0.2 | 1.8 | — | 0.2 |
| | 1987 | 2.3 | 0.2 | 2.0 | 0.8 | 0.2 |
| | 1992 | 2.0 | 0.2 | 1.7 | 0.2 | 0.2 |
| | 1997 | 1.9 | 0.3 | 1.6 | 0.2 | 0.2 |
| Nebraska | 1982 | 4.8 | 0.7 | 4.5 | — | 0.9 |

*(Continued)*

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**Table 4H.38 (Continued)**

| State | Year | Cropland | | | CRP Land | Pastureland |
|---|---|---|---|---|---|---|
| | | Cultivated | Noncultivated | Total | | |
| | 1987 | 4.2 | 0.5 | 3.9 | 1.5 | 0.8 |
| | 1992 | 3.5 | 0.5 | 3.3 | 0.7 | 0.7 |
| | 1997 | 2.9 | 0.5 | 2.7 | 0.5 | 0.7 |
| Nevada | 1982 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 |
| | 1987 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 |
| | 1992 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 |
| | 1997 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 |
| New Hampshire | 1982 | 4.1 | 0.4 | 1.4 | — | 0.5 |
| | 1987 | 4.4 | 0.4 | 1.3 | — | 0.5 |
| | 1992 | 3.7 | 0.4 | 0.8 | — | 0.4 |
| | 1997 | 3.5 | 0.4 | 0.9 | — | 0.5 |
| New Jersey | 1982 | 6.7 | 1.0 | 5.5 | — | 0.5 |
| | 1987 | 6.7 | 1.1 | 5.7 | — | 0.6 |
| | 1992 | 5.5 | 0.8 | 4.3 | 0.3 | 0.5 |
| | 1997 | 5.6 | 0.6 | 4.3 | 0.3 | 0.4 |
| New Mexico | 1982 | 1.2 | 0.1 | 1.0 | — | 0.1 |
| | 1987 | 0.9 | 0.1 | 0.7 | 1.0 | 0.1 |
| | 1992 | 1.0 | 0.2 | 0.8 | 0.4 | 0.1 |
| | 1997 | 0.9 | 0.1 | 0.7 | 0.2 | 0.1 |
| New York | 1982 | 4.0 | 0.7 | 2.6 | — | 0.4 |
| | 1987 | 4.1 | 0.9 | 2.7 | 3.8 | 0.4 |
| | 1992 | 4.0 | 0.8 | 2.4 | 0.5 | 0.3 |
| | 1997 | 3.9 | 0.7 | 2.3 | 0.3 | 0.3 |
| North Carolina | 1982 | 6.4 | 1.5 | 6.1 | — | 1.1 |
| | 1987 | 6.3 | 1.0 | 6.0 | 15.7 | 1.0 |
| | 1992 | 5.6 | 1.4 | 5.3 | 4.5 | 1.0 |
| | 1997 | 5.0 | 1.0 | 4.6 | 1.2 | 1.7 |
| North Dakota | 1982 | 1.9 | 0.4 | 1.8 | — | 0.4 |
| | 1987 | 2.0 | 0.5 | 1.8 | 1.1 | 0.5 |
| | 1992 | 1.5 | 0.3 | 1.4 | 0.3 | 0.5 |
| | 1997 | 1.4 | 0.3 | 1.3 | 0.2 | 0.4 |
| Ohio | 1982 | 3.8 | 1.1 | 3.6 | — | 2.3 |
| | 1987 | 3.7 | 1.1 | 3.5 | 3.4 | 1.7 |
| | 1992 | 3.3 | 1.2 | 3.1 | 0.5 | 1.7 |
| | 1997 | 2.6 | 1.4 | 2.5 | 0.3 | 1.7 |
| Oklahoma | 1982 | 2.7 | 0.6 | 2.6 | — | 0.9 |
| | 1987 | 3.0 | 0.6 | 2.9 | 1.1 | 0.7 |
| | 1992 | 2.9 | 0.5 | 2.8 | 0.4 | 0.7 |
| | 1997 | 2.8 | 0.5 | 2.8 | 0.3 | 0.6 |
| Oregon | 1982 | 4.6 | 0.7 | 3.8 | — | 0.6 |
| | 1987 | 3.4 | 0.5 | 2.6 | 2.9 | 0.5 |
| | 1992 | 3.2 | 0.4 | 2.5 | 0.4 | 0.5 |
| | 1997 | 3.1 | 0.4 | 2.3 | 0.4 | 0.5 |
| Pennsylvania | 1982 | 7.0 | 0.7 | 4.8 | — | 1.1 |
| | 1987 | 6.9 | 1.2 | 5.0 | 1.7 | 1.0 |
| | 1992 | 5.8 | 1.2 | 4.2 | 1.0 | 1.0 |
| | 1997 | 5.1 | 1.2 | 3.8 | 0.3 | 0.8 |
| Rhode Island | 1982 | 7.0 | 1.1 | 3.0 | — | 0.1 |
| | 1987 | 5.0 | 2.2 | 2.9 | — | 0.1 |
| | 1992 | 4.8 | 1.6 | 2.5 | — | 0.1 |
| | 1997 | 3.5 | 1.8 | 2.2 | — | 0.1 |
| South Carolina | 1982 | 4.0 | 1.9 | 3.9 | — | 0.4 |
| | 1987 | 3.9 | 1.4 | 3.8 | 3.9 | 0.4 |
| | 1992 | 3.3 | 1.0 | 3.1 | 1.7 | 0.4 |
| | 1997 | 3.2 | 0.7 | 3.0 | 0.5 | 0.4 |
| South Dakota | 1982 | 2.8 | 0.3 | 2.5 | — | 0.3 |
| | 1987 | 2.6 | 0.3 | 2.3 | 2.6 | 0.3 |
| | 1992 | 2.2 | 0.3 | 2.0 | 0.4 | 0.3 |
| | 1997 | 2.0 | 0.2 | 1.7 | 0.1 | 0.2 |

*(Continued)*

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**Table 4H.38 (Continued)**

| State | Year | Cropland | | | CRP Land | Pastureland |
|---|---|---|---|---|---|---|
| | | Cultivated | Noncultivated | Total | | |
| Tennessee | 1982 | 11.0 | 0.9 | 9.4 | — | 0.8 |
| | 1987 | 10.8 | 1.0 | 9.1 | 9.5 | 0.7 |
| | 1992 | 9.1 | 0.9 | 7.1 | 0.8 | 0.7 |
| | 1997 | 7.7 | 0.6 | 5.6 | 0.7 | 0.8 |
| Texas | 1982 | 2.6 | 0.9 | 2.6 | — | 0.7 |
| | 1987 | 2.6 | 1.2 | 2.5 | 0.6 | 0.6 |
| | 1992 | 2.6 | 0.7 | 2.6 | 0.3 | 0.5 |
| | 1997 | 2.6 | 0.8 | 2.6 | 0.2 | 0.5 |
| Utah | 1982 | 1.4 | 0.2 | 0.9 | — | 0.1 |
| | 1987 | 1.5 | 0.2 | 0.8 | 3.2 | 0.1 |
| | 1992 | 1.4 | 0.2 | 0.8 | 1.3 | 0.1 |
| | 1997 | 1.6 | 0.2 | 0.8 | 0.9 | 0.2 |
| Vermont | 1982 | 4.6 | 0.2 | 1.3 | — | 0.3 |
| | 1987 | 4.2 | 0.2 | 1.4 | — | 0.2 |
| | 1992 | 3.4 | 0.5 | 1.2 | — | 0.1 |
| | 1997 | 3.1 | 0.7 | 1.2 | — | 0.1 |
| Virginia | 1982 | 6.6 | 1.5 | 5.3 | — | 3.4 |
| | 1987 | 6.4 | 1.6 | 4.9 | 0.8 | 3.4 |
| | 1992 | 6.4 | 1.4 | 4.5 | 0.8 | 3.4 |
| | 1997 | 5.9 | 1.5 | 3.9 | 0.5 | 3.3 |
| Washington | 1982 | 6.1 | 0.5 | 5.5 | — | 0.2 |
| | 1987 | 7.0 | 0.4 | 6.2 | 2.4 | 0.4 |
| | 1992 | 5.0 | 0.5 | 4.4 | 0.5 | 0.4 |
| | 1997 | 4.7 | 0.6 | 4.0 | 0.6 | 0.3 |
| West Virginia | 1982 | 7.3 | 0.7 | 2.5 | — | 4.2 |
| | 1987 | 9.2 | 0.9 | 2.8 | 0.7 | 5.4 |
| | 1992 | 4.7 | 0.8 | 1.7 | 0.3 | 6.1 |
| | 1997 | 4.3 | 0.8 | 1.4 | 0.0 | 6.0 |
| Wisconsin | 1982 | 4.7 | 1.5 | 4.1 | — | 0.6 |
| | 1987 | 4.1 | 2.0 | 3.7 | 4.5 | 0.6 |
| | 1992 | 3.8 | 0.7 | 3.2 | 0.7 | 0.5 |
| | 1997 | 3.7 | 1.2 | 3.3 | 0.6 | 0.6 |
| Wyoming | 1982 | 1.5 | 0.2 | 0.9 | — | 0.3 |
| | 1987 | 1.4 | 0.1 | 0.8 | 1.6 | 0.2 |
| | 1992 | 1.3 | 0.2 | 0.7 | 0.6 | 0.3 |
| | 1997 | 1.1 | 0.1 | 0.6 | 0.2 | 0.3 |
| Caribbean | 1982 | 11.1 | 11.9 | 11.2 | — | 7.0 |
| | 1987 | 11.2 | 13.1 | 11.5 | — | 7.3 |
| | 1992 | 12.1 | 15.4 | 12.9 | — | 8.0 |
| | 1997 | 12.2 | 13.2 | 12.7 | — | 6.4 |
| National average | 1982 | 4.4 | 0.7 | 4.0 | — | 1.1 |
| | 1987 | 4.0 | 0.7 | 3.7 | 2.0 | 1.0 |
| | 1992 | 3.5 | 0.6 | 3.1 | 0.6 | 1.0 |
| | 1997 | 3.1 | 0.7 | 2.8 | 0.4 | 0.9 |

*Source*: www.nrcs.usda.gov.

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**Table 4H.39 Dissolved and Suspended Sediment Loads in Selected Rivers of the United States**

| River and Location | Elevation (ft) | Drainage Area (sq mi) | Average Discharge, *Q* (cfs) | Discharge + Drainage Area (cfs/sq mi) | Years of Record in Sample[a] | Average Suspended Load | Average Dissolved Load (millions of tons/yr) | Total Average Suspended and Dissolved Load | Total Average Load + Drainage Area (tons sq mi/yr) | Dissolved Load as Percent of Total Load (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Little Colorado at Woodruff, Arizona | 5,129 | 8,100 | 63.3 | 0.0078 | 6 | 1.6 | 0.02 | 1.62 | 199 | 1.2 |
| Canadian River near Amarillo, Texas | 2,989 | 19,445 | 621 | 0.032 | 1 | 6.41 | 0.124 | 6.53 | 336 | 1.9 |
| Colorado River near San Saba, Texas | 1,096 | 30,600 | 1,449 | 0.047 | 5 | 3.02 | 0.208 | 3.23 | 105 | 6.4 |
| Bighorn River at Kane, Wyoming | 3,609 | 15,900 | 2,391 | 0.150 | 1 | 1.60 | 0.217 | 1.82 | 114 | 12 |
| Green River at Green River, Utah | 4,040 | 40,600 | 6,737 | 0.166 | 26–20 | 19 | 2.5 | 21.5 | 530 | 12 |
| Colorado River near Cisco, Utah | 4,090 | 24,100 | 8,457 | 0.351 | 25–20 | 15 | 4.4 | 19.4 | 808 | 23 |
| Iowa River at Iowa City, Iowa | 627 | 3,271 | 1,517 | 0.464 | 3 | 1.184 | 0.485 | 1.67 | 510 | 29 |
| Mississippi River at Red River Landing, Louisiana | | 1,144,500[b] | 569,500[b] | 0.497 | 3 | 284 | 101.8 | 385.8 | 337 | 26 |
| Sacramento River at Sacramento, California | 0 | 27,000[c] | 25,000[c] | 0.926 | 3 | 2.85 | 2.29 | 5.14 | 190 | 44 |
| Flint River near Montezuma, Georgia | 256 | 2,900 | 3,528 | 1.22 | 1 | 0.400 | 0.132 | 0.53 | 183 | 25 |
| Juniata River near New Port, Pennsylvania | 364 | 3,354 | 4,329 | 1.29 | 7 | 0.322 | 0.566 | 0.89 | 265 | 64 |
| Delaware River at Trenton, New Jersey | 8 | 6,780 | 11,730 | 1.73 | 9–4 | 1.003 | 0.830 | 1.83 | 270 | 45 |

[a] Computation of load, dissolved or suspended, depends on discharge for same period. Years of record pertain to number of years used for related values of discharge and of suspended and dissolved load. Where two figures are shown, the first is for suspended load and the second is for dissolved load.
[b] From USGS records for Vicksburg, Mississippi station.
[c] Estimated.

*Source*: From Leopold, Wolman, and Miller, *Fluvial Processes in Geomorphology*, W.H. Freeman and Company, 1964. With permission.



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**Table 4H.40 Discharge of Suspended Sediment to the Coastal Zone by 10 Major rivers of the United States, About 1980**

| Rivers | Average Annual Sediment Discharge (million ton/yr) |
|---|---|
| Rivers that discharge the largest sediment loads: | |
| Mississippi | 230[a] |
| Copper | 80 |
| Yukon | 65 |
| Susitna | 25 |
| Eel | 15 |
| Brazos | 11 |
| Columbia: | |
| Before Mount St. Helens eruption | 10 |
| Since Mount St. Helens eruption-approximate | 40 |
| Rivers with large drainage areas: | |
| St. Lawrence | 1.5 |
| Rio Grande | 0.8 |
| Colorado | 0.1 |

[a] Includes Atchafalaya River.

*Source*: From Meade, R.H., Parker, R.S., Sediment in rivers of the United States, *U.S. Geological Survey Water-Supply Paper 2275*, National Water Summary 1984, 1985.

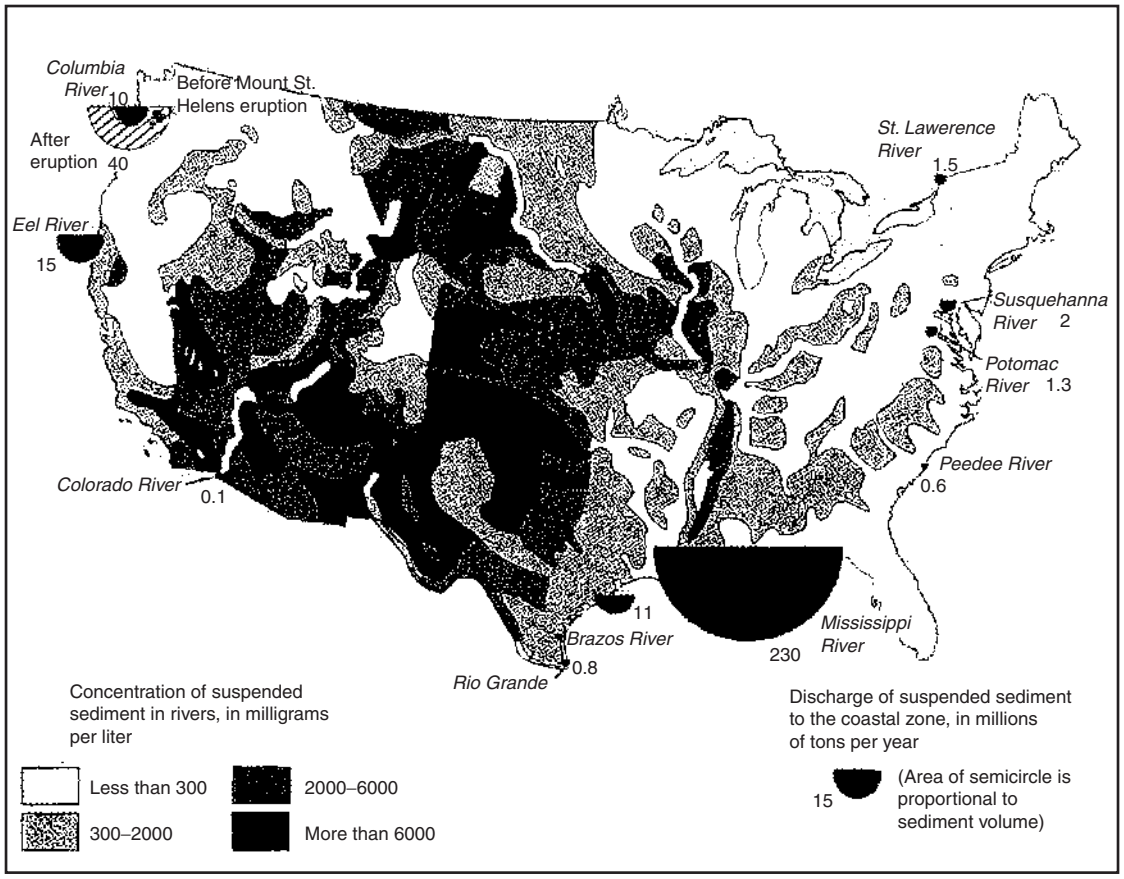


**Figure 4H.21** Concentration of suspended sediment in rivers and discharge of suspended sediment to the coastal zone in the conterminous United States. (From Meade, R.H., Parker, R.S., Sediment in the rivers of the United States, National Water Summary 1984, *U.S. Geological Survey Water-Supply Paper 2275*, 1984.)

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**Table 4H.41 Dimension and Rate of Formation of Modern Deltas**

| River | Dimension of Subaerial Delta, Statute Mi | | Amount of Sediment Discharged | | Annual Extension of Subaerial Delta | |
|---|---|---|---|---|---|---|
| | Length | Breadth | River Water by Weight (avg), ppm | Annual Volume of Sediment ($mi^3$) | Measurement Period (yr) | Approximate Distance (ft) |
| Mississippi's present bird-foot delta | 12 | 30 | 550 | 0.068 | 1838–1947 | 250 |
| Hwang-Ho | 300 | 470[a] | 50,000[b] | | 1870–1937 | 950 |
| Ganges-Brahmaputra | 220 | 200 | 870 | 0.043 (Ganges only) | | |
| Rhone into Mediterranean Sea | 30 | 47 | 400–590 | 0.005 | 1737–1870 | 190 |
| Danube | 46 | 46 | 310 | 0.008 | | 40 |
| Nile (prior to barrages) | 96 | 145 | 1600 | 0.001 | 1100–1870 | 45 |
| Colorado above Hoover Dam | 43 | 0.05–0.6 | 8300 | 0.032 | 1936–1948 | 3.6 mi (gorge) |
| Euphrates Tigris | 350 | 90 | | | 1793–1853 | 180 |

[a] Includes 100 ml of nondeltaic Shantung Peninsula.
[b] Maximum is 400,000 ppm.

*Source*: From *McGraw-Hill Encyclopedia of the Geological Sciences*. Copyright 1978. With permission.

**Table 4H.42 Water Storage Capacity and the Capacity Lost Annually Due to Sedimentation in the Conterminous United States**

| Farm Production Region | Total Water Storage Capacity (million ac-ft) | Usable Water Storage Capacity (million ac-ft) | Estimated Water Storage Capacity Lost (%) | Estimated Water Storage Capacity Lost (thousand ac-ft) | Stream Sediment Originating on Cropland (%) | Reservoir Sedimentation from Cropland (thousand ac-ft) |
|---|---|---|---|---|---|---|
| Northeast | 36.5 | 25.2 | 0.08 | 28.1 | 29 | 8.2 |
| Appalachian | 59.5 | 30.6 | 0.13 | 75.5 | 29 | 21.9 |
| Southeast | 73.6 | 47.6 | 0.17 | 127.3 | 33 | 42.0 |
| Lake States | 29.3 | 19.5 | 0.27 | 79.1 | 64 | 50.6 |
| Corn Belt | 39.7 | 15.2 | 0.26 | 104.8 | 63 | 66.0 |
| Delta States | 42.7 | 20.1 | 0.21 | 87.5 | 41 | 35.9 |
| Northern Plains | 78.9 | 54.4 | 0.23 | 184.6 | 36 | 66.5 |
| Southern Plains | 110.3 | 46.6 | 0.19 | 207.4 | 19 | 39.4 |
| Mountain | 167.1 | 138.1 | 0.18 | 302.5 | 8 | 24.2 |
| Pacific | 90.7 | 74.7 | 0.49 | 441.6 | 9 | 39.7 |
| United States (Lower 48) | 728.3 | 472.1 | 0.22 | 1,638.5 | | 394.4 |

*Note:* Reservoirs with 5000 acre-feet or more total capacity.

*Source*: From Crowder, B.M., *J Soil Water Conserv., Soil Conserv. Soc. Am.*, 1987.

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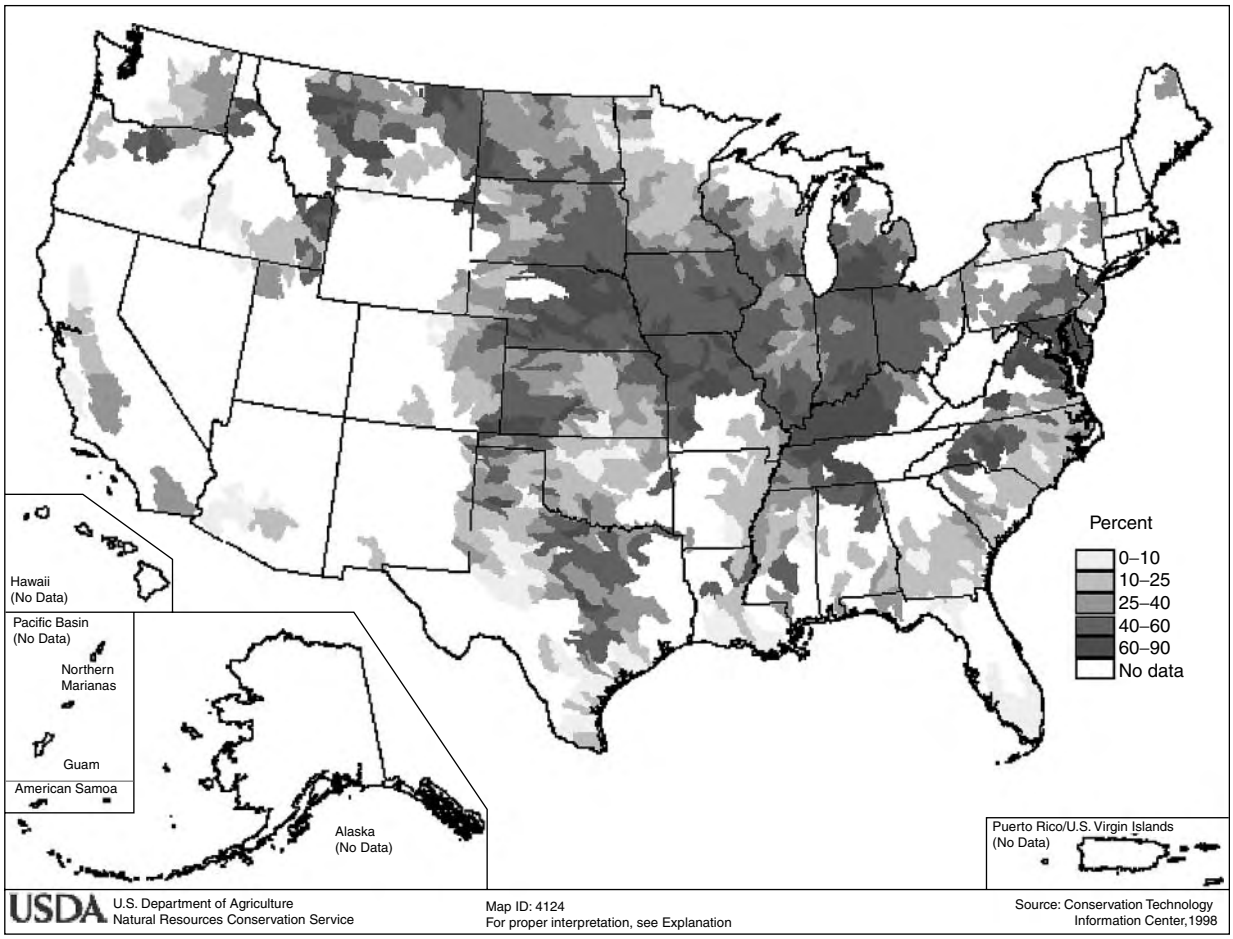


**Figure 4H.22** Percent conservation tillage. (From www.epa.gov.)

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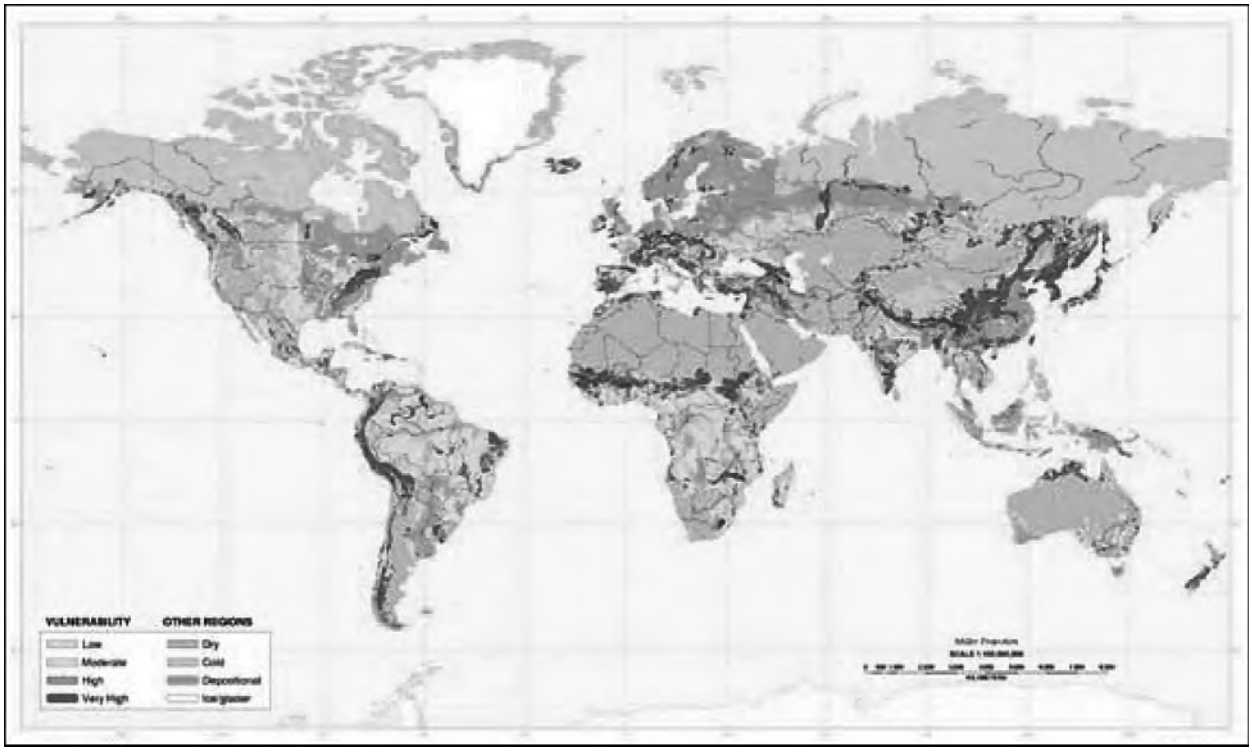


**Figure 4H.23** Water erosion vulnerability. (From www.soils.usda.gov.)

**Table 4H.43 Matrix of Laws Relating to Beach Nourishment**

| Law | Provisions | Relevance |
|---|---|---|
| P.L. 71-520 of 1930 | Authorized the USACE to conduct shoreline erosion control studies (not construction) in cooperation with state governments; the Beach Erosion Board (BEB) was also established | First federal involvement in shoreline protection activities |
| P.L. 79-727 of 1946 | Expanded the use of federal funds to now include one third of construction costs in addition to the studies for projects along publicly owned shores | Expanded federal involvement as a result of major hurricanes |
| Submerged Lands Act of 1953 (43 USC 1301 and following) | Gave coastal states authority over the resources of submerged lands from the shore out to three miles seaward | Affected the availability of offshore sand for beach nourishment |
| Outer Continental Shelf Lands Act of 1953 (43 USC 1331 and following) | Provided for the federal government to manage the mineral resources of the OCS lying on or under the seabed that extends seaward from state waters out to the edge of the shelf | Affected the availability of offshore sand for beach nourishment |
| P.L. 84-826 of 1956 | Expanded the authority for federal shore protection to include privately owned shores where substantial public benefits would result; also defined periodic renourishment as construction for the protection of shores for a period of usually ten years | Federal authority now included shore protection on privately owned shores where public benefits result |
| River and Harbor Act (33 USC 401 and following) of 1962 (P.L. 87-874) and 1968 (P.L. 980-483) | Under Section 103 (33 USC 426g), the Corps was authorized to participate in the cost of protecting the shores of publicly owned property and private property where public benefits result; increased federal aid from one third to 100 percent for shore protection study costs leading to authorization; also increased federal participation in the cost of beach erosion and shore protection to 50 percent of the construction cost when the beaches were publicly owned or used, and 70 percent for seashore parks and conservation areas when certain conditions of ownership and use of the beaches were met | Resulted in a large number of studies and subsequent authorizations in the 1950's and 60's; Required USACE to fund mitigation for downdrift erosion caused by federal navigation works |

*(Continued)*

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**Table 4H.43 (Continued)**

| Law | Provisions | Relevance |
|---|---|---|
| | Under Section 111 (33 USC 426i), mitigation could be conducted for shoreline erosion that results from federal navigation works | |
| P.L. 88-172 of 1963 | Established the Coastal Engineering Research Board (CERB) and the Coastal Engineering Research Center (CERC), replacing the Beach Erosion Board | Resulted from increased need for additional engineering and study in the area of beach erosion, coupled with increased beach development and more demand for erosion relief from the federal government |
| Coastal Zone Management Act of 1972 (16 USC 1451 and following) (P.L. 92-583) | Required all federal agencies with activities directly affecting the coastal zone, or with development projects within the zone, to assure that those activities or projects are consistent with the approved state Coastal Zone Management Program | Established a national program to assist the states in comprehensively managing the nation's coastal resources through wise management practices. Encouraged coastal zone management and provided grants (Section 306A) for maintaining coastal areas |
| Coastal Barrier Resources Act of 1982 (16 USC 3501 and following) (P.L. 97-384) | Established the Coastal Barrier Resources System (CBRS); areas in the CBRS may no longer receive federal financial assistance for new construction or improvements. The CBRS was greatly expanded with the passage of the Coastal Barrier Improvement Act (CBIA) of 1990 (P.L. 101-591) | The intent of the law was to discourage development. The law applied only to areas within the defined CBRS |
| Water Resources Development Act (33 USC 2201 and following) of 1976 (P.L. 94-587), 1986 (P.L. 99-662), 1988 (P.L. 100-676), 1992 (P.L. 102-580), 1996 (P.L. 104-303), 1999 (P.L. 106-53), and 2000 (P.L. 106-541) | Established a broad congressional policy to encourage conservation efforts among federal, state, and local governments. Authorized the Secretary of the Army to construct, operate, and maintain any water resource development project. The resource development projects over which the USACE currently maintains jurisdiction are navigation, flood control, shore protection, and beach renourishment projects | Authorized beach nourishment projects. Set cost-sharing percentage, with a general trend to reduce federal percentage and increase non-federal percentage (will be 50/50 by 2003) |
| Shore Protection Act of 1996 (Section 227 of the WRDA of 1996) (33 USC 2601 and following) | Recommended funding for shore protection project studies and construction | Rejected the Administration's position of not authorizing funding for new projects |
| National Environmental Policy Act of 1969 (42 USC 4321 and following) | Required federal agencies to evaluate the environmental impacts associated with major actions they fund, support, permit, or implement | Required that actions be the least environmentally damaging practicable alternative. Most beach nourishment projects have the potential for adverse impacts and will trigger a required NEPA analysis |
| Clean Water Act (33 USC 1251 and following) | Under section 404, a permit was required for the discharge of dredged or fill materials into the waters of the U.S. The USACE has the permitting authority for the 404 program | Proponents of beach nourishment projects must obtain a Section 404 permit |
| Endangered Species Act (16 USC 1531 and following) | Federal agencies must review actions they undertake or support to determine whether they may affect endangered species or their habitats; agency must consult with the USFWS | Significant impacts on beach nourishment projects; limitations on construction typically exclude construction in certain seasons, for example, the nesting season for sea turtles on the Atlantic and Gulf Coasts. There are short-term environmental impacts associated with both removing the sand from the source and depositing it onto the beach |
| National Historic Preservation Act (16 USC 470 and following) | Federal agencies must consider the effects of their undertakings (including the issuance of permits, the expenditure of federal funding, and the initiation of federal projects) on historic resources that the either eligible for listing or are listed on the National Register of Historic Places | Areas worthy of historic preservation must be avoided in the beach nourishment site selection process |

*Source*: csc.noaa.gov/beachnourishment.

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**Table 4H.44 Atlantic and Gulf Coast State Beach Nourishment Program Summary**

| State | Beach Nourishment Policy | Related Policies | State Funding Program |
|---|---|---|---|
| Alabama | Yes | A B C D E | No |
| Connecticut | Yes | B C D E | Yes |
| Delaware | Yes | A B C D E | Yes |
| Florida | Yes | B C D E | Yes |
| Georgia | Yes | A B C D E | Case-by-Case |
| Louisiana | Yes | A B C D | Yes |
| Maine | No | A B C D | No |
| Maryland | No | A B C | Yes |
| Massachusetts | Yes | A B C D E | Yes |
| Mississippi | Yes | A B C | Yes |
| New Hampshire | Yes | A B C D E | Case-by-Case |
| New Jersey | Yes | A B C D E | Yes |
| New York | Yes | A B C D E | Case-by-Case |
| North Carolina | Yes | A B C D E | Case-by-Case |
| Rhode Island | Yes | A B C D E | No |
| South Carolina | Yes | B C D E | Case-by-Case |
| Texas | Yes | A B D E | Case-by-Case |
| Virginia | Yes | A B C | Yes |

*Note:* Policies related to beach nourishment. A = near shore sand mining; B = dredge and fill; C = sand scraping/dune reshaping; D = dune creation/restoration; E = public access.

*Source*: NOAA 2000, csc.noaa.gov.

**Table 4H.45 Riverbank Treatment in the United States**

| Region | Mattress | Jetties | Training Walls | Riprap | Revetment | Dikes | Other | Total Treated |
|---|---|---|---|---|---|---|---|---|
| North Atlantic | — | 18 | 18 | — | — | — | — | 36 |
| South Atlantic-Gulf | 35 | 67 | — | — | — | — | — | 102 |
| Great Lakes | — | — | — | — | — | — | — | — |
| Ohio | — | — | — | 50 | 10 | — | — | 60 |
| Tennessee | — | — | — | — | — | — | — | — |
| Upper Mississippi | — | — | — | — | — | — | — | — |
| Lower Mississippi | 573 | — | — | — | — | 75 | 5836 | 6484 |
| Souris-Red-Rainy | — | — | — | — | — | — | — | — |
| Missouri | — | 735 | — | — | 735 | — | — | 1470 |
| Arkansas-White–Red | 250 | 1 | 80 | — | — | 140 | — | 471 |
| Texas-Gulf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bio Grande | — | 250 | — | — | — | — | — | 250 |
| Upper Colorado | — | — | — | — | — | — | — | — |
| Lower Colorado | — | — | — | — | — | — | — | — |
| Great Basin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Columbia-North Pacific | — | — | — | 261 | — | — | — | 261 |
| California | — | — | — | — | — | — | 19 | 19 |
| Alaska | — | — | 6 | — | — | — | — | 6 |
| Hawaii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Puerto Rico | — | — | — | — | — | — | — | — |

*Note:* Value in miles as of 1966; Corps of Engineers projects only; for regions see Fig. 4G.9.

*Source*: U.S. Water Resources Council, 1968.

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**Table 4H.46 Sediment Yield from Drainage Areas of 100 Square Miles or Less of the United States**

| Region | Estimated Sediment Yield | | | Region | Estimated Sediment Yield | | |
|---|---|---|---|---|---|---|---|
| | High | Low | Average | | High | Low | Average |
| | tons/sq/mi/yr | | | | tons/sq/mi/yr | | |
| North Atlantic | 1210 | 30 | 250 | Arkansas-White–Red | 8210 | 260 | 2200 |
| South Atlantic-Gulf | 1850 | 100 | 800 | Texas-Gulf | 3180 | 90 | 1800 |
| Great Lakes | 800 | 10 | 100 | Rio Grande | 3340 | 150 | 1300 |
| Ohio | 2110 | 160 | 850 | Upper Colorado | 3340 | 150 | 1800 |
| Tennessee | 1560 | 460 | 700 | Lower Colorado | 1620 | 150 | 600 |
| Upper Mississippi | 3900 | 10 | 800 | Great Basin | 1780 | 100 | 400 |
| Lower Mississippi | 8210 | 1560 | 5200 | Columbia-North Pacific | 1100 | 30 | 400 |
| Souris-Red-Rainy | 470 | 10 | 50 | California | 5570 | 80 | 1300 |
| Missouri | 6700 | 10 | 1500 | | | | |

*Note:* For regions see Fig. 4G.9.

*Source*: U.S. Water Resources Council, 1968.

**Table 4H.47 Permissible Velocities for Channels Lined with Vegetation**

| Cover | Slope Range[a] (Percent) | Permissible Velocity | |
|---|---|---|---|
| | | Erosion Resistant Soils (ft/sec) | Easily Eroded Soils (ft/sec) |
| | 0–5 | 8 | 6 |
| Bermudagrass | 5–10 | 7 | 5 |
| | over 10 | 6 | 4 |
| Buffalograss | 0–5 | 7 | 5 |
| Kentucky bluegrass | 5–10 | 6 | 4 |
| Smooth brome | over 10 | 5 | 3 |
| Blue grama | | | |
| Grass mixture | 0–5[a] | 5 | 4 |
| | 5–10 | 4 | 3 |
| Lespedeza sericea | | | |
| Weeping lovegrass | | | |
| Yellow bluestem | | | |
| Kudzu | 0–5[b] | 3.5 | 2.5 |
| Alfalfa | | | |
| Crabgrass | | | |
| Common lespedeza[c] | | | |
| Sudangrass[c] | 0–5[d] | 3.5 | 2.5 |

*Note:* Use velocities exceeding 5 feet per second only where good covers and proper maintenance can be obtained. Values apply to average, uniform stands of each type of cover.

[a] Do not use on slopes steeper than 10 percent except for side slopes in a combination channel.
[b] Do not use on slopes steeper than 5 percent except for side slopes in a combination channel.
[c] Annuals — used on mild slopes or as temporary protection until permanent covers are established.
[d] Use on slopes steeper than 5 percent is not recommended.

*Source*: U.S. Soil Conservation Service.

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**Table 4H.48 Permissible Velocities for Channels with Linings Other Than Vegetation**

| Original Material Excavated | Clear Water, No Detritus (ft/sec) | Water Transporting Colloidal Silts (ft/sec) | Water Transporting Noncolloidal Silts, Sands, Gravels, or Rock Fragments (ft/sec) |
|---|---|---|---|
| Fine sand, noncolloidal | 1.50 | 2.50 | 1.50 |
| Sandy loam, noncolloidal | 1.75 | 2.50 | 2.00 |
| Silt loam, noncolloidal | 2.00 | 3.00 | 2.00 |
| Alluvial silts, noncolloidal | 2.00 | 3.50 | 2.00 |
| Ordinary firm loam | 2.50 | 3.50 | 2.25 |
| Volcanic ash | 2.50 | 3.50 | 2.00 |
| Fine gravel | 2.50 | 5.00 | 3.75 |
| Stiff clay, very colloidal | 3.75 | 5.00 | 3.00 |
| Graded, loam to cobbles, noncolloidal | 3.75 | 5.00 | 5.00 |
| Alluvial silts, colloidal | 3.75 | 5.00 | 3.00 |
| Graded, silt to cobbles, colloidal | 4.00 | 5.50 | 5.00 |
| Coarse gravel, noncolloidal | 4.00 | 6.00 | 6.50 |
| Cobbles and shingles | 5.00 | 5.50 | 6.50 |
| Shales and hardpans | 6.00 | 6.00 | 5.00 |

*Note:* Values apply to aged straight channels with mild bed slopes.

*Source*: From Fortier and Scobey, *Trans. Am. Soc. Civil Eng.*, 1926. With permission.

**Table 4H.49 Settling Velocities of Sand and Silt in Still Water**

| Diameter of Particle (mm) | Order of Size | Setting Velocity (mm/sec) | Time Required to Settle 1 Foot |
|---|---|---|---|
| 10.0 | Gravel | 1000 | 0.3 sec |
| 1.0 | | 100 | 3.0 sec |
| 0.8 | | 83 | |
| 0.6 | | 63 | |
| 0.5 | Coarse sand | 53 | |
| 0.4 | | 42 | |
| 0.3 | | 32 | |
| 0.2 | | 21 | |
| 0.15 | | 15 | |
| 0.10 | Fine sand | 8 | 38.0 sec |
| 0.08 | | 6 | |
| 0.06 | | 3.8 | |
| 0.05 | | 2.9 | |
| 0.04 | | 2.1 | |
| 0.03 | | 1.3 | |
| 0.02 | | 0.62 | |
| 0.015 | | 0.35 | |
| 0.010 | Silt | 0.154 | 33.0 min |
| 0.008 | | 0.098 | |
| 0.006 | | 0.065 | |
| 0.005 | | 0.0385 | |
| 0.004 | | 0.0247 | |
| 0.003 | | 0.0138 | |
| 0.002 | | 0.0062 | |
| 0.0015 | | 0.0035 | |
| 0.001 | Bacteria | 0.00154 | 55.0 h |
| 0.0001 | Clay particles | 0.000154 | 230.0 d |
| 0.00001 | Colloidal particles | 0.000000154 | 63.0 yr |

*Note:* Temperature 50 °F; all particles assumed to have a specific gravity of 2.65.

*Source*: Amer. Water Works Assoc.

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**Table 4H.50 Classification of Alluvial Channels Based on Channel Stability and on Mode of Sediment Transport**

| Mode of Sediment Transport | Silt-Clay in Channel Sediment, Percent[a] | Proportion of Total Sediment Load | | Channel Stability | | |
|---|---|---|---|---|---|---|
| | | Suspended Load Percent | Bedload, Percent | Stable (Graded Stream) | Depositing (Excess Load) | Eroding (Deficiency of Load) |
| Suspended load | 30–100 | 85–100 | 0–15 | Stable suspended-load channel. Width-depth ratio less than 7; sinuosity greater than 2.1; gradient relatively gentle | Depositing suspended load channel. Major deposition on banks cause narrowing of channel; streambed deposition minor | Eroding suspended-load channel. Streambed erosion predominant; channel widening minor |
| Mixed load | 8–30 | 65–85 | 15–35 | Stable mixed-load channel. Width-depth ratio greater than 7 less than 25; sinuosity, less than 2.1 greater than 1.5; gradient moderate | Depositing mixed-load channel. Initial major deposition on banks followed by streambed deposition | Eroding mixed-load channel. Initial streambed erosion followed by channel widening |
| Bedload | 0–8 | 30–65 | 35–70 | Stable bedload channel. Width-depth ratio greater than 25; sinuosity, less than 1.5; gradient relatively steep | Depositing badload channel. Streambed deposition and island formation | Eroding bedload channel. Little streambed erosion; channel widening predominant |

[a] The percentage of sediment finer than 0.074 mm in the perimeter of the channel.

*Source*: U.S. Geological Survey.

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## SECTION 4I TRANSPIRATION

**Table 4I.51 Transpiration Ratios for Crops**

| Crop | Varieties Tested, No | Transpiration Ratio | |
|---|---|---|---|
| | | Range | Mean |
| Grains | | | |
| Proso | 2 | 531–603 | 567 |
| Millet | 3 | 863–1117 | 959 |
| Buckwheat | 1 | — | 969 |
| Sorgo | 3 | 863–1804 | 1237 |
| Grain sorghum | 4 | 750–1050 | 868 |
| Barley | 4 | 1128–1464 | 1241 |
| Corn | 2 | 821–1998 | 1405 |
| Oats | 4 | 1379–1915 | 1627 |
| Wheat, emmer | 1 | — | 1167 |
| Wheat, durum | 6 | 1365–1622 | 1475 |
| Wheat, common | 11 | 1244–3398 | 1872 |
| Wheat, hybrids | 2 | 1995–2163 | 2079 |
| Rye | 1 | — | 2142 |
| Flax | 6 | 2010–5162 | 3252 |
| Legumes | | | |
| Clover | 2 | 636–759 | 698[a] |
| Clover, sweet | 1 | — | 731[a] |
| Vetch | 5 | 562–899 | 708[a] |
| Alfalfa | 10 | 626–920 | 844[a] |
| Cowpeas | 1 | — | 1632 |
| Beans | 2 | 1583–1815 | 1699 |
| Beans, soy | 1 | — | 1974 |
| Chickpeas | 1 | — | 1685 |
| Peas, Canadian field | 1 | — | 2153 |
| Lupinus albus | 1 | — | 4734 |
| Grassses | | | |
| Sudan grass | 1 | — | 380[a] |
| Wheat grass | 1 | — | 678[a] |
| Brome grass | 1 | — | 977[a] |
| Miscellaneous | | | |
| Cotton | 1 | — | 568[a] |
| Sugar beets | 1 | — | 629 |
| Potatoes | 2 | 1325–2877 | 2101 |
| Cabbage | 1 | — | 518[a] |
| Rape | 1 | — | 714[a] |
| Watermelons | 1 | — | 1102 |
| Cantaloupes | 1 | — | 1754 |
| Turnips | 1 | — | 1471 |
| Cucumbers | 1 | — | 1549 |

*Note:* Transpiration ratios are weighted values in pounds of water per pound of crop product. Data measured at Akron, Colorado.

[a] Based on total dry matter

*Source*: From Shantz and Piemeisel, *J. Agric. Res.*, 1927.

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**Table 4I.52 Transpiration Ratios for Weeds and Native Plants**

| Weeds or Native Plants | Transpiration Ratio | Weeds or Native Plants | Transpiration Ratio |
|---|---|---|---|
| Weeds | | Native weeds (continued) | |
| Tumbleweed | 260 | Sunflower | 623 |
| Pigweed | 305 | Mountain sage | 654 |
| Russian thistle | 314 | Verbena | 702 |
| Lamb's quarters | 658 | Fetid marigold | 847 |
| Polygonum | 678 | | |
| Native weeds | | Native plants | |
| Purslane | 281 | Buffalo grass | 296 |
| Cocklebur | 415 | Buffalo and grama grass | 338 |
| Nightshade | 487 | Clammyweed | 483 |
| Buffalo bur | 536 | Iva | 534 |
| Gumweed | 585 | Western ragweed | 912 |
| | | Western wheat grass | 1035 |
| | | Franseria | 1131 |

*Note:* Transpiration ratios are weighted values in pounds of water per pound of dry matter. Data measured at Akron, Colorado.

*Source*: From Shantz and Piemeisel, *J. Agric. Res.*, 1927.

**Table 4I.53 Transpiration Ratios for Trees**

| Tree | Scientific Name | Transpiration Ratio |
|---|---|---|
| Ash | *Fraxinus excelsior* | 981 |
| White birch | *Betula alba* | 849 |
| Beech | *Fagus sylvatica* | 1043 |
| Hornbeam | *Carpinus betulus* | 787 |
| Field elm | *Ulmus campestris* | 738 |
| Stiel oak | *Quercus pedunculus* | 454 |
| Traubean oak | *Quercus sessilifolia* | 790 |
| Zerr oak | *Quercus cerris* | 669 |
| Black alder | *Alnus glutinosa* | 840 |
| Gray alder | *Alnus incana* | 678 |
| Sycamore maple | *Acer platanoides* | 520 |
| Mountain maple | *Acer pseudoplat* | 635 |
| Field maple | *Acer campestria* | 1281 |
| Linden | *Tilia grandifolia* | 1038 |
| Aspen | *Populus tremula* | 873 |
| Service berry | *Sorbus tormin* | 1748 |
| Larch | *Larix europea* | 1165 |
| Spruce | *Abies excelsa* | 242 |
| Fir | *Abies pectinata* | 96 |
| Scotch white pine | *Pinus silvestris* | 110 |
| Black Austrian pine | *Pinus larico* | 123 |

*Note:* Transpiration ratios are expressed as pounds of water per pound of dry-leaf matter. Data measured by Hohnel (1879–1880).

*Source*: U.S. Weather Bureau.

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# SECTION 4J EVAPORATION

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**Table 4J.54 Reservoir Evaporation at Selected Stations in the United States**

| | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Station** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Annual** |
| AZ, Yuma | 3.9 | 4.6 | 6.5 | 8.0 | 9.8 | 11.5 | 13.4 | 12.9 | 10.7 | 8.0 | 6.1 | 4.5 | 100 |
| CA, Sacramento | 0.8 | 1.4 | 2.5 | 3.6 | 5.0 | 7.1 | 8.9 | 8.6 | 7.1 | 4.8 | 2.6 | 1.2 | 54 |
| CO, Denver | 1.6 | 1.8 | 2.5 | 3.7 | 5.0 | 7.4 | 8.8 | 8.4 | 6.7 | 4.6 | 3.0 | 1.9 | 55 |
| FL, Miami | 3.0 | 3.4 | 4.1 | 4.9 | 5.0 | 4.8 | 5.3 | 5.1 | 4.3 | 4.1 | 4.3 | 2.7 | 51 |
| GA, Macon | 1.7 | 2.2 | 3.1 | 4.3 | 5.1 | 6.2 | 6.3 | 5.8 | 5.2 | 4.2 | 2.8 | 1.8 | 49 |
| ME, Eastport | 0.8 | 0.7 | 0.9 | 1.1 | 1.4 | 1.7 | 2.0 | 2.1 | 2.0 | 1.6 | 1.1 | 0.7 | 16 |
| MN, Minneapolis | 0.3 | 0.4 | 0.9 | 1.7 | 3.2 | 4.4 | 6.0 | 5.8 | 4.6 | 3.0 | 1.3 | 0.4 | 32 |
| MS, Vicksburg | 1.3 | 1.9 | 2.9 | 4.2 | 5.0 | 5.7 | 5.8 | 5.5 | 5.2 | 4.4 | 2.9 | 1.6 | 46 |
| MO, Kansas City | 0.9 | 1.1 | 1.7 | 3.1 | 4.4 | 6.1 | 8.0 | 7.8 | 6.0 | 4.5 | 2.5 | 1.0 | 47 |
| MT, Havre | 0.5 | 0.5 | 1.1 | 2.5 | 4.5 | 6.1 | 8.2 | 8.3 | 5.6 | 3.3 | 1.5 | 0.7 | 43 |
| NE, North Platte | 0.8 | 1.1 | 2.2 | 3.7 | 5.0 | 6.5 | 8.6 | 8.4 | 6.9 | 4.6 | 2.6 | 1.1 | 51 |
| NM, Roswell | 2.1 | 3.2 | 4.9 | 6.8 | 8.3 | 9.8 | 9.4 | 8.3 | 6.9 | 5.5 | 3.5 | 2.5 | 71 |
| NY, Albany | 0.6 | 0.7 | 1.1 | 2.0 | 3.2 | 4.3 | 5.2 | 4.7 | 3.4 | 2.4 | 1.4 | 0.8 | 30 |
| ND, Bismarck | 0.4 | 0.5 | 1.0 | 2.3 | 4.0 | 5.3 | 7.3 | 7.7 | 5.8 | 3.3 | 1.3 | 0.5 | 39 |
| OH, Columbus | 0.6 | 0.8 | 1.1 | 2.3 | 3.5 | 4.6 | 5.6 | 5.1 | 4.1 | 3.0 | 1.6 | 0.6 | 33 |
| OK, Oklahoma City | 1.5 | 1.9 | 3.1 | 4.7 | 5.5 | 7.8 | 10.2 | 10.7 | 8.8 | 6.3 | 3.5 | 2.0 | 66 |
| OR, Baker | 0.5 | 0.7 | 1.4 | 2.5 | 3.4 | 4.4 | 6.9 | 7.3 | 4.9 | 2.9 | 1.5 | 0.6 | 37 |
| SC, Columbia | 1.6 | 2.4 | 3.2 | 4.5 | 5.4 | 6.3 | 6.6 | 6.0 | 5.5 | 4.4 | 3.0 | 1.9 | 51 |
| TN, Nashville | 0.9 | 1.3 | 1.9 | 3.3 | 4.1 | 5.1 | 5.8 | 5.4 | 4.9 | 3.7 | 2.1 | 1.1 | 39 |
| TX, Galveston | 0.9 | 1.3 | 1.6 | 2.6 | 4.1 | 5.6 | 6.2 | 6.1 | 5.7 | 4.6 | 2.7 | 1.3 | 43 |
| TX, San Antonio | 2.2 | 3.1 | 4.5 | 5.6 | 6.5 | 8.4 | 9.4 | 9.4 | 7.6 | 5.8 | 3.7 | 2.4 | 69 |
| UT, Salt Lake City | 0.8 | 1.0 | 2.0 | 3.5 | 5.1 | 7.9 | 10.6 | 10.4 | 7.3 | 3.9 | 2.0 | 1.0 | 55 |
| VA, Richmond | 1.3 | 1.7 | 2.2 | 3.5 | 4.1 | 5.0 | 5.6 | 4.9 | 4.1 | 3.2 | 2.4 | 1.5 | 39 |
| WA, Seattle | 0.8 | 0.8 | 1.4 | 2.1 | 2.7 | 3.4 | 3.9 | 3.4 | 2.6 | 1.6 | 1.1 | 0.7 | 24 |
| WI, Milwaukee | 0.6 | 0.7 | 0.9 | 1.3 | 2.1 | 3.2 | 5.0 | 5.4 | 4.7 | 3.2 | 1.6 | 0.6 | 29 |
| Gulf off Texas Coast | 4.0 | 4.0 | 3.5 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.5 | 6.5 | 6.0 | 5.0 | 58 |
| Gulf Stream off Cape Hatteras, NC | 9.0 | 9.5 | 8.5 | 7.0 | 5.5 | 3.5 | 3.5 | 3.5 | 5.5 | 9.0 | 9.5 | 10.0 | 84 |
| Ocean off Massachusetts | 3.0 | 2.5 | 2.0 | 1.5 | 1.0 | 1.5 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 28 |

*Note:* Mean monthly computed values in inches.

*Source*: Minnesota Resources Commission.

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**Table 4J.55 Evaporation Equations**

For pan evaporation, the expression is

$$E_P = \{\exp[(T_a - 212)(0.1024 - 0.01066\ln R)] - 0.0001 + 0.025(e_s - e_a)^{0.88}(0.37 + 0.0041U_p)\} \times \{0.025 + (T_a + 398.36)^{-2}4.7988 \times 10^{10}\exp[-7482.6/(T_a + 398.36)]\}^{-1}$$

For lake evaporation, the expression is

$$E_L = \{\exp[(T_a - 212)(0.1024 - 0.01066\ln R)] - 0.0001 + 0.0105(e_s - e_a)^{0.88}(0.37 - 0.0041U_P)\} \times \{0.015 + (T_a + 398.36)^{-2}6.8554 \times 10^{10}\exp[-7482.6/(T_a + 398.36)]\}^{-1}$$

The terms in these expressions are

$E_P$ = pan evaporation, inches
$E_L$ = lake evaporation, inches
$T_a$ = air temperature, degrees Fahrenheit
$e_a$ = vapor pressure, inches of mercury at temperature $T_a$
$e_s$ = vapor pressure, inches of mercury at temperature $T_d$
$T_d$ = dew point temperature, degrees Fahrenheit
$R$ = solar radiation, langleys per day
$U_P$ = wind movement, miles per day

*Notes*: The equations enable pan and lake evaporation to be computed from climatic data at first-order weather stations. Daily values of evaporation are obtained using mean daily temperature and vapor pressure data together with data on solar radiation and wind movement as specified.

*Source*: U.S. Weather Bureau, 1962.



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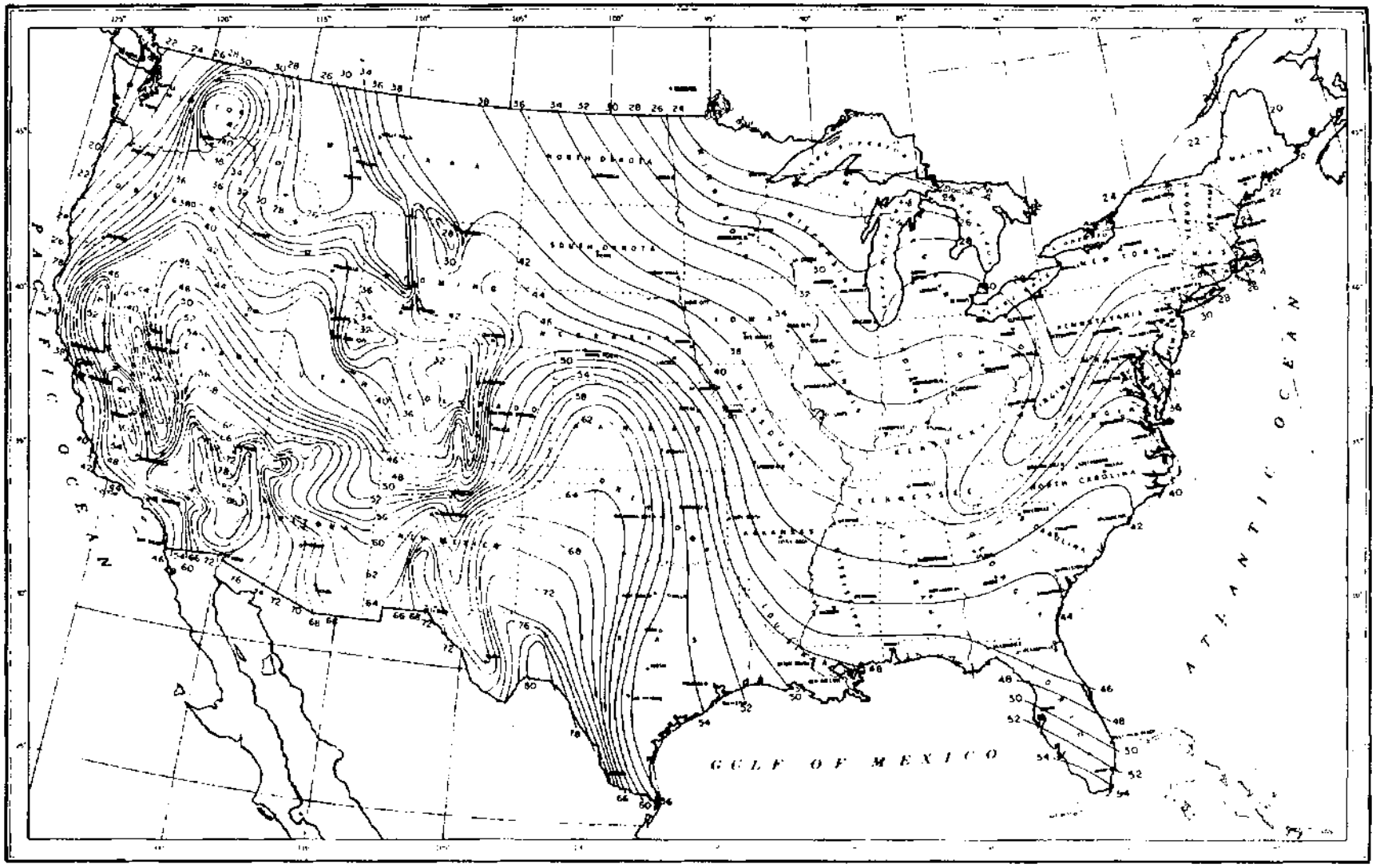


**Figure 4J.24** Mean annual lake evaporation in the United States (values in inches for period 1946–1955). (From U.S. Weather Bureau.)

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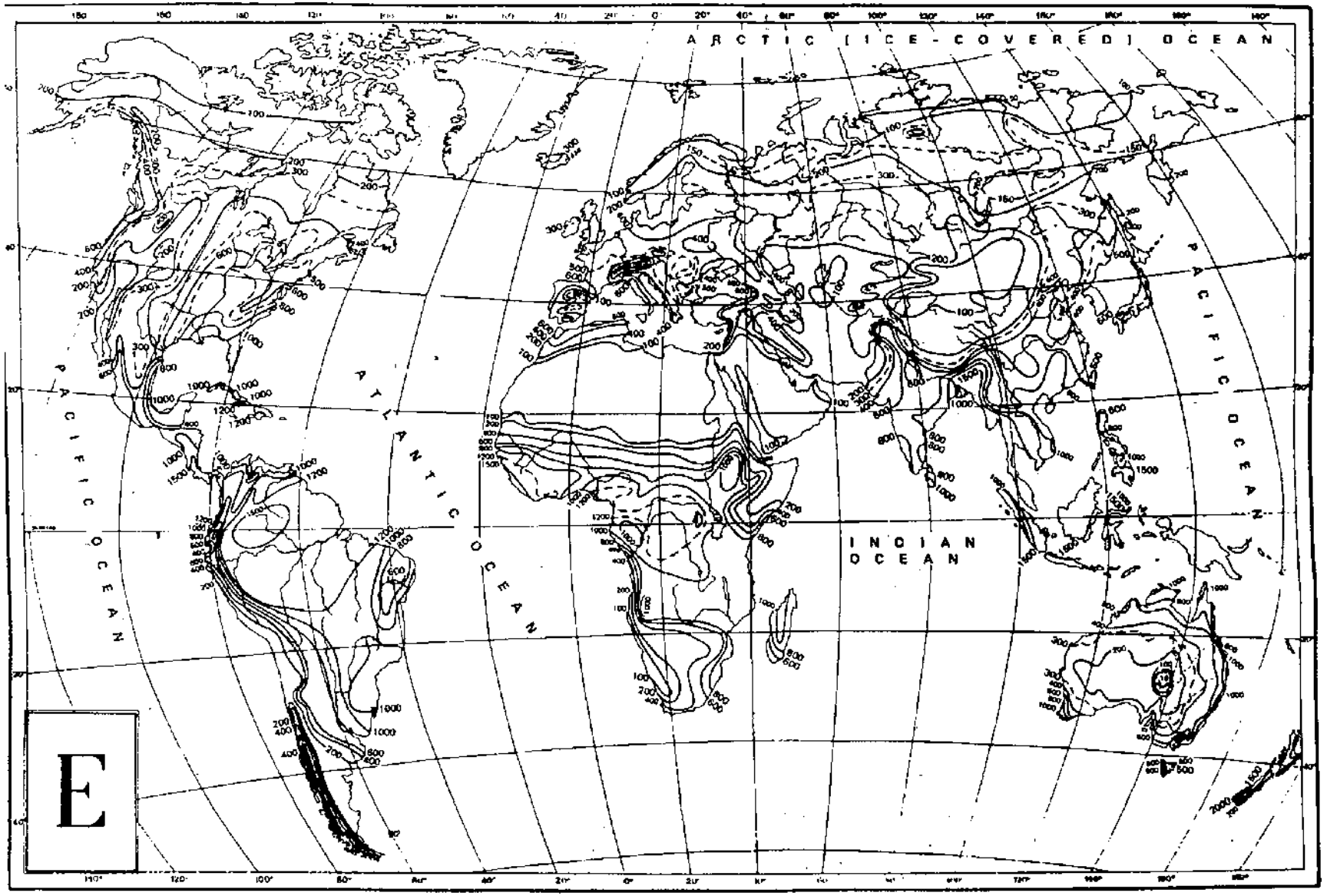


**Figure 4J.25** Annual evaporation in the world (in mm). (From Lvovitch, M.I., *EOS*, 54, 1973, Copyright by American Geophysical Union.)



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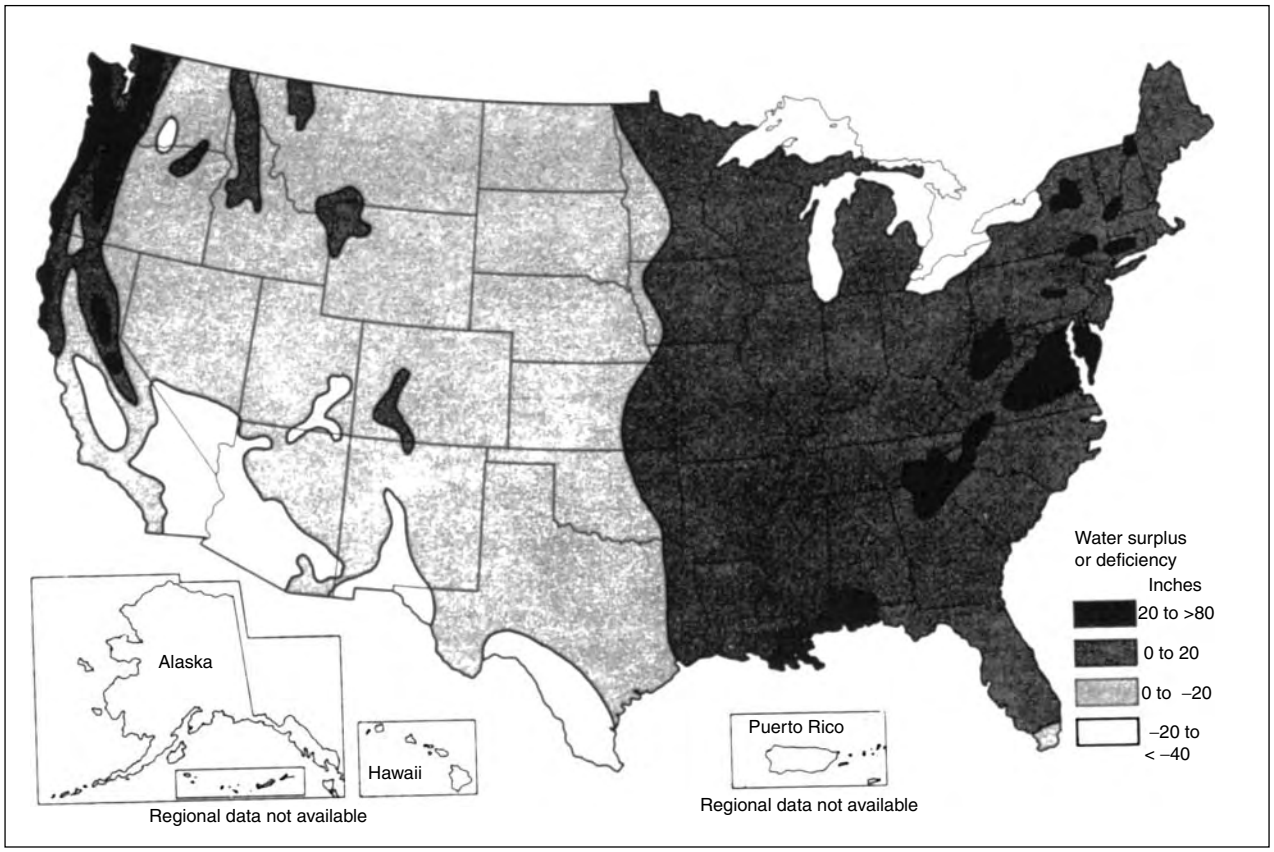


**Figure 4J.26** Areas of natural water surplus and natural water deficiency (computed by subtracting values of potential evapotranspiration from average precipitation). (From U.S. Water Resources Council, 1968, The Nation's Water Resources.)

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## SECTION 4K CONSUMPTIVE USE

**Table 4K.56 Consumptive Use by Irrigated Crops in the Western United States**

| | | Consumptive Use (Evapotranspiration), (in.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Crop** | **Apr** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Total** |
| Arizona, Mesa | Alfalfa | 5.0 | 6.5 | 9.0 | 12.0 | 10.0 | 6.0 | 4.0 | 52.5 |
| | Dates | 6.2 | 7.6 | 8.3 | 9.2 | 8.4 | 7.2 | 5.7 | 52.6 |
| California | | | | | | | | | |
| Los Angeles[a] | Lemons | 2.1 | 2.6 | 3.3 | 3.9 | 3.7 | 3.4 | 2.8 | 21.8 |
| | Oranges | 2.2 | 2.2 | 3.1 | 3.4 | 3.7 | 3.1 | 2.9 | 20.6 |
| | Walnuts | 3.8 | 5.0 | 5.9 | 6.1 | 5.0 | 2.8 | 2.0 | 30.6 |
| | Alfalfa | 3.3 | 6.7 | 5.4 | 7.8 | 4.2 | 5.6 | 4.4 | 37.4 |
| Coastal | Alfalfa | 4.9 | 4.9 | 4.3 | 5.2 | 5.9 | 5.5 | 4.7 | 35.4 |
| Ontario | Peaches | 1.0 | 3.5 | 6.7 | 8.0 | 6.5 | 2.7 | 1.4 | 29.8 |
| Shafter | Cotton | 0.5 | 1.0 | 4.0 | 8.5 | 9.7 | 5.8 | 3.2 | 32.7 |
| Firebaugh | Cotton | — | 0.8 | 1.1 | 7.3 | 7.8 | 3.6 | 2.0 | 22.6 |
| | Cotton | — | 0.4 | 0.7 | 8.4 | 9.5 | 3.0 | 2.5 | 24.5 |
| Delta[b] | Alfalfa | 3.6 | 4.8 | 6.0 | 7.8 | 6.6 | 6.0 | 1.2 | 36.0 |
| | Potatoes | — | 1.8 | 4.6 | 6.2 | 3.6 | 1.8 | — | 18.0 |
| | Truck | 1.2 | 3.0 | 6.0 | 5.4 | 5.4 | 3.6 | 1.8 | 26.4 |
| | Sugar beets | 1.6 | 3.8 | 6.1 | 7.3 | 6.4 | 2.4 | — | 27.6 |
| | Beans | 1.9 | 2.4 | 1.7 | 2.9 | 6.9 | 4.4 | — | 20.2 |
| | Fruit | 2.2 | 3.8 | 6.0 | 6.8 | 4.8 | 2.8 | 0.8 | 27.2 |
| | Onions | 1.6 | 3.2 | 5.9 | 5.2 | 2.4 | 1.9 | — | 19.8 |
| Davis | Sugar beets | — | 5.2 | 5.7 | 7.1 | 5.8 | — | — | 23.8 |
| | Tomatoes | — | — | 3.2 | 6.2 | 4.9 | 4.7 | — | 22.3 |
| | Alfalfa | — | 6.8 | 7.9 | 8.3 | 7.1 | 4.3 | — | — |
| | Prunes | — | 5.8 | 6.0 | 7.6 | 6.5 | 5.0 | — | — |
| | Peaches | — | 5.4 | 6.4 | 7.9 | 7.2 | 5.0 | — | — |
| | Walnuts | — | 6.6 | 6.7 | 8.4 | 7.2 | 4.8 | — | — |
| | Grapes | — | 4.6 | 4.9 | 6.2 | 5.3 | 4.3 | — | — |
| Winters | Apricots | — | — | 5.6 | 6.8 | 6.5 | 4.9 | — | — |
| Nebraska, Scottsbluff | Alfalfa | 1.4 | 4.0 | 7.0 | 7.1 | 6.4 | 3.0 | — | 28.9 |
| | Beets | 1.9 | 3.3 | 5.2 | 6.9 | 5.8 | 1.1 | — | 24.2 |
| | Potatoes | — | — | — | 3.4 | 5.8 | 4.4 | — | — |
| | Oats | — | 3.0 | 6.1 | 5.1 | — | — | — | 14.2 |

*Notes:* Data for irrigation season only.

[a] In San Fernando Valley, City of Los Angeles, California.
[b] In Sacramento–San Joaquin Delta, California.

*Source*: U.S. Dept. of Agriculture.

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**Table 4K.57 Consumptive Use by Principal Crops in the Central Valley, California**

| Month | Improved Pasture | Alfalfa | Sugar Beets | | Cotton | | Deciduous Orchard | Rice S.V. |
|---|---|---|---|---|---|---|---|---|
| | | | S.V. | S.J.V. | a | b | | |
| January | 1.0 | 1.0 | 0.9 | — | — | — | — | (0.8)[c] |
| February | 1.8 | 1.8 | 1.2 | — | — | — | — | (1.5) |
| March | 3.0 | 2.8 | — | 1.6 | — | — | 1.8 | (1.4) |
| April | 4.7 | 4.2 | — | 3.6 | — | — | 3.3 | 4.8 |
| May | 6.1 | 5.4 | 1.8 | 5.6 | 1.0 | 0.6 | 4.9 | 7.6 |
| June | 7.8 | 7.0 | 6.0 | 7.7 | 6.0 | 3.6 | 6.7 | 9.6 |
| July | 8.2 | 7.6 | 8.5 | 8.5 | 9.7 | 8.8 | 7.5 | 10.0 |
| August | 7.1 | 6.8 | 7.3 | 5.1 | 8.5 | 7.8 | 6.4 | 8.5 |
| September | 5.2 | 5.1 | 5.6 | 1.9 | 5.5 | 5.3 | 4.5 | 6.4 |
| October | 3.5 | 3.5 | 3.5 | — | 2.1 | 1.8 | 2.7 | 3.2 |
| November | 1.6 | 1.6 | 1.6 | — | — | — | — | (1.4) |
| December | 0.8 | 0.8 | 0.8 | — | — | — | — | (0.8) |
| Total | 50.8 | 47.6 | 37.2 | 34.0 | 32.8 | 27.9 | 37.8 | 56.0 |

*Note:* Values in inches; S.V. is Sacramento Valley, and S.J.V. is San Joaquin Valley.

[a] Solid planting or one row skipped in three.
[b] Planting of two rows skipped in four.
[c] Values in parentheses are for nongrowing season. Values may change with differences in rainfall.

*Source*: Calif. Dept. of Water Resources, 1967.

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**Table 4K.58 Consumptive Use by Crops in the Sacramento-San Joaquin Delta, California**

| Month | Alfalfa | Asparagus | Beans | Beets | Celery | Corn | Fruit | Grain and Hay | Onions | Potatoes |
|---|---|---|---|---|---|---|---|---|---|---|
| January | (0.06) | 0.05 | (0.06) | (0.06) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.06) |
| February | (0.08) | 0.05 | (0.08) | (0.08) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.08) |
| March | 0.10 | 0.05 | (0.08) | (0.08) | (0.04) | (0.04) | (0.04) | 0.07 | 0.08 | (0.08) |
| April | 0.30 | 0.05 | (0.16) | 0.13 | (0.08) | (0.08) | 0.18 | 0.60 | 0.13 | (0.16) |
| May | 0.40 | 0.08 | (0.20) | 0.32 | (0.10) | (0.10) | 0.32 | 0.83 | 0.27 | 0.15 |
| June | 0.50 | 0.14 | 0.14 | 0.51 | 0.10 | 0.24 | 0.50 | 0.20 | 0.49 | 0.38 |
| July | 0.65 | 0.40 | 0.24 | 0.61[a] | 0.10 | 0.85 | 0.57 | (0.14) | 0.43 | 0.52 |
| August | 0.55 | 0.68 | 0.58 | 0.53[a] | 0.20 | 0.84[a] | 0.40 | (0.23) | 0.20 | 0.30 |
| September | 0.50 | 0.55 | 0.37 | 0.20[a] | 0.25 | 0.40[a] | 0.23 | (0.21) | (0.16) | 0.15 |
| October | 0.20 | 0.42 | (0.09) | (0.13) | 0.30 | 0.10 | 0.07 | (0.14) | (0.13) | (0.09) |
| November | (0.10) | 0.12 | (0.07) | (0.10) | 0.20 | (0.10) | (0.07) | (0.07) | (0.10) | (0.07) |
| December | (0.07) | 0.10 | (0.05) | (0.07) | 0.05 | (0.07) | (0.05) | (0.05) | (0.07) | (0.05) |
| Growing season | 3.20 | 2.69 | 1.33 | 2.30 | 1.20 | 2.43 | 2.27 | 1.70 | 1.60 | 1.50 |
| Year | 3.51 | 2.69 | 2.12 | 2.82 | 1.50 | 2.90 | 2.51 | 2.62 | 2.14 | 2.09 |

*Note:* Depth in feet. Figures in parentheses show estimated losses by soil evaporation and weed transpiration.

[a] Including additional use of water by weeds.

*Source*: California Department of Public Works.



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**Table 4K.59 Total Consumptive Use and Peak Daily Use, Western United States**

| | Southern Coastal | | | | South Pacific Coastal Interior and North Coastal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 300 Days Plus | | 250–300 Days | | 250–300 Days | | 210–250 Days | | 180–210 Days | | 150–180 Days | |
| Crops | Season Use (in.) | Daily Use (in./d) | Season Use (in.) | Daily Use (in./d) | Season Use (in.) | Daily Use (in./d) | Season Use (in.) | Daily Use (in./d) | Season Use (in.) | Daily Use (in./d) | Season Use (in.) | Daily Use (in./d) |
| Alfalfa | 36.0 | 0.20 | 30.0 | 0.17 | 37.0 | 0.27 | 32.0 | 0.22 | 26.0 | 0.20 | 22.0 | 0.18 |
| Pasture | 33.5 | 0.20 | 28.0 | 0.17 | 33.0 | 0.27 | 30.0 | 0.22 | 24.0 | 0.20 | 20.0 | 0.18 |
| Grain — small | 16.0 | 0.18 | 14.0 | 0.16 | 17.0 | 0.22 | 14.5 | 0.20 | 12.0 | 0.20 | 10.0 | 0.18 |
| Beets — sugar | 29.0 | 0.20 | 25.0 | 0.18 | 30.0 | 0.27 | 26.0 | 0.22 | — | — | — | — |
| Beans — field | 12.0 | 0.18 | 10.0 | 0.16 | 13.0 | 0.22 | 11.0 | 0.18 | — | — | — | — |
| Corn — field | — | — | — | — | — | — | 19.0 | 0.25 | 16.0 | 0.22 | 14.0 | 0.20 |
| Potatoes | — | — | — | — | 24.0 | 0.20 | 20.0 | 0.18 | — | — | — | — |
| Peas — green | 10.0 | 0.18 | 8.0 | 0.16 | 11.0 | 0.20 | 9.0 | 0.18 | 8.0 | 0.16 | 7.0 | 0.16 |
| Legume seed | 25.0 | 0.20 | 22.0 | 0.18 | 26.0 | 0.25 | 22.0 | 0.22 | 20.0 | 0.20 | 18.0 | 0.18 |
| Tomatoes | 18.0 | 0.16 | 15.0 | 0.16 | 19.0 | 0.20 | 16.0 | 0.18 | 13.0 | 0.16 | 11.0 | 0.16 |
| Vegetable seed | 16.0 | 0.16 | 14.0 | 0.16 | 18.0 | 0.18 | 16.0 | 0.18 | 14.0 | 0.16 | 12.0 | 0.16 |
| Beans — pole | — | — | — | — | 18.0 | 0.20 | 16.0 | 0.20 | 14.0 | 0.18 | 12.0 | 0.16 |
| Corn — sweet | 16.0 | 0.18 | 14.0 | 0.16 | 16.0 | 0.20 | 14.0 | 0.18 | 12.0 | 0.18 | 11.0 | 0.16 |
| Apples | — | — | — | — | 24.0 | 0.20 | 22.0 | 0.20 | 20.0 | 0.18 | 18.0 | 0.18 |
| Cherries | — | — | — | — | 24.0 | 0.20 | 22.0 | 0.20 | — | — | — | — |
| Peaches | — | — | — | — | 24.0 | 0.20 | 22.0 | 0.20 | — | — | — | — |
| Prunes | — | — | — | — | 22.0 | 0.20 | 20.0 | 0.20 | — | — | — | — |
| Apricots | — | — | — | — | 22.0 | 0.20 | 20.0 | 0.20 | — | — | — | — |
| Oranges | 20.0 | 0.16 | 18.0 | 0.16 | 22.0 | 0.18 | — | — | — | — | — | — |
| Avocados | 18.0 | 0.16 | — | — | — | — | — | — | — | — | — | — |
| Walnuts | 22.0 | 0.20 | 18.0 | 0.18 | 24.0 | 0.25 | 22.0 | 0.22 | 20.0 | 0.20 | — | — |
| Strawberries | 22.0 | 0.20 | 18.0 | 0.18 | 23.0 | 0.25 | 18.0 | 0.22 | 16.0 | 0.20 | 14.0 | 0.18 |
| Lettuce | 4.0 | 0.16 | 4.0 | 0.16 | 6.0 | 0.18 | 5.0 | 0.18 | — | — | — | — |
| Mint | — | — | — | — | 23.0 | 0.24 | 21.0 | 0.22 | 19.0 | 0.20 | 17.0 | 0.18 |
| Hops | — | — | — | — | 20.0 | 0.22 | 20.0 | 0.20 | — | — | — | — |

| | Central Valley—California and Valleys East Side of Cascade Mountains | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 250–300 Days | | 210–250 Days | | 180–210 Days | | 150–180 Days | | 120–150 Days | | 90–120 Days | |
| Alfalfa | 40.0 | 0.30 | 34.0 | 0.28 | 30.0 | 0.25 | 26.0 | 0.22 | 20.0 | 0.20 | 14.0 | 0.18 |
| Pasture | 36.0 | 0.30 | 30.0 | 0.28 | 28.0 | 0.25 | 24.0 | 0.22 | 18.0 | 0.20 | 13.0 | 0.18 |
| Grain — small | 18.0 | 0.22 | 16.0 | 0.22 | 15.0 | 0.20 | 14.0 | 0.18 | 13.0 | 0.18 | 12.0 | 0.16 |
| Beets — sugar | 33.0 | 0.30 | 28.0 | 0.25 | 24.0 | 0.22 | 20.0 | 0.20 | 18.0 | 0.18 | — | — |
| Beans — field | 17.0 | 0.22 | 13.0 | 0.20 | 13.0 | 0.20 | 12.0 | 0.18 | 12.0 | 0.18 | — | — |
| Corn — field | 26.0 | 0.35 | 22.0 | 0.32 | 22.0 | 0.30 | 20.0 | 0.25 | 18.0 | 0.22 | 17.0 | 0.20 |
| Potatoes — summer | 12.0 | 0.16 | — | — | — | — | — | — | — | — | — | — |
| Potatoes — fall | — | — | 19.0 | 0.25 | 18.0 | 0.22 | 18.0 | 0.20 | 17.0 | 0.18 | 16.0 | 0.16 |
| Peas — green | — | — | 8.0 | 0.18 | 7.0 | 0.18 | 7.0 | 0.18 | 7.0 | 0.16 | 6.0 | 0.15 |
| Peas — field | — | — | 10.0 | 0.18 | 9.0 | 0.18 | 9.0 | 0.18 | 8.0 | 0.16 | 8.0 | 0.15 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tomatoes | 20.0 | 0.20 | 18.0 | 0.18 | 18.0 | 0.18 | 17.0 | 0.17 | 16.0 | 0.16 | — | — |
| Cotton | 26.0 | 0.30 | 22.0 | 0.28 | — | — | — | — | — | — | — | — |
| Grain — sorghum | 15.0 | 0.20 | 13.0 | 0.18 | 12.0 | 0.17 | 10.0 | 0.16 | 9.0 | 0.15 | 8.0 | 0.15 |
| Apples | — | — | 26.0 | 0.20 | 23.0 | 0.20 | 21.0 | 0.18 | — | — | — | — |
| Cherries | — | — | 24.0 | 0.20 | 21.0 | 0.20 | 19.0 | 0.18 | — | — | — | — |
| Peaches | 22.0 | 0.22 | 22.0 | 0.20 | 20.0 | 0.20 | 18.0 | 0.18 | — | — | — | — |
| Apricots | 20.0 | 0.22 | 17.0 | 0.20 | 15.0 | 0.20 | — | — | — | — | — | — |
| Oranges | 28.0 | 0.18 | — | — | — | — | — | — | — | — | — | — |
| Strawberries | 24.0 | 0.20 | 20.0 | 0.20 | 18.0 | 0.18 | — | — | — | — | — | — |
| Lettuce — winter | 4.0 | 0.20 | — | — | — | — | — | — | — | — | — | — |
| Mint | — | — | 20.0 | 0.22 | 18.0 | 0.20 | — | — | — | — | — | — |
| Hops | — | — | 18.0 | 0.20 | 16.0 | 0.18 | — | — | — | — | — | — |
| Grapes | 30.0 | 0.25 | 25.0 | 0.22 | 22.0 | 0.20 | — | — | — | — | — | — |
| Walnuts | 24.0 | 0.22 | 20.0 | 0.20 | — | — | — | — | — | — | — | — |
| Almonds | 22.0 | 0.25 | 20.0 | 0.22 | — | — | — | — | — | — | — | — |

**Central Intermountain, Desert, and Western High Plains**

| | 250–300 Days | | 210–250 Days | | 180–210 Days | | 150–180 Days | | 120–150 Days | | 90–120 Days | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alfalfa | 52.0 | 0.40 | 44.0 | 0.32 | 36.0 | 0.29 | 30.0 | 0.26 | 24.0 | 0.22 | 19.0 | 0.20 |
| Pasture | 48.0 | 0.40 | 40.0 | 0.30 | 33.0 | 0.28 | 28.0 | 0.25 | 22.0 | 0.22 | 17.0 | 0.20 |
| Grain — small | 21.0 | 0.25 | 18.0 | 0.22 | 16.0 | 0.20 | 16.0 | 0.20 | 16.0 | 0.20 | 14.0 | 0.18 |
| Beets — sugar | 37.0 | 0.30 | 32.0 | 0.30 | 30.0 | 0.28 | 26.0 | 0.25 | 24.0 | 0.22 | 18.0 | 0.20 |
| Beans — field | 22.0 | 0.25 | 17.0 | 0.20 | 14.0 | 0.20 | 14.0 | 0.18 | 14.0 | 0.17 | 12.0 | 0.15 |
| Corn — field | — | — | 30.0 | 0.35 | 26.0 | 0.30 | 24.0 | 0.28 | 22.0 | 0.24 | — | — |
| Potatoes — fall | — | — | 23.0 | 0.30 | 21.0 | 0.28 | 20.0 | 0.25 | 19.0 | 0.22 | 17.0 | 0.20 |
| Peas — field | — | — | — | — | 10.0 | 0.19 | 10.0 | 0.18 | 10.0 | 0.17 | 9.0 | 0.15 |
| Tomatoes | — | — | 20.0 | 0.22 | 18.0 | 0.20 | 17.0 | 0.18 | 16.0 | 0.17 | — | — |
| Cotton | 32.0 | 0.30 | 30.0 | 0.28 | | — | — | — | — | — | — | — |
| Grain — sorghum | 19.0 | 0.25 | 18.0 | 0.20 | 16.0 | 0.20 | 14.0 | 0.18 | 12.0 | 0.17 | — | — |
| Apples | — | — | — | — | 28.0 | 0.22 | 24.0 | 0.20 | 20.0 | 0.18 | — | — |
| Cherries | — | — | — | — | 26.0 | 0.22 | — | — | — | — | — | — |
| Peaches | — | — | 29.0 | 0.25 | 27.0 | 0.22 | — | — | — | — | — | — |
| Apricots | 26.0 | 0.25 | 24.0 | 0.25 | 25.0 | 0.20 | — | — | — | — | — | — |
| Almonds | 22.0 | 0.25 | 20.0 | 0.25 | — | — | — | — | — | — | — | — |
| Vineyards | 40.0 | 0.27 | 32.0 | 0.25 | 26.0 | 0.22 | — | — | — | — | — | — |
| Legume seed | — | — | — | — | — | — | — | — | 16.0 | 0.18 | 14.0 | 0.16 |
| Grass seed | — | — | — | — | — | — | — | — | 14.0 | 0.14 | 12.0 | 0.14 |
| Potatoes — seed | — | — | — | — | — | — | — | — | 16.0 | 0.16 | 14.0 | 0.15 |
| Grapefruit | 45.0 | 0.20 | — | — | — | — | — | — | — | — | — | — |
| Oranges | 36.0 | 0.18 | — | — | — | — | — | — | — | — | — | — |
| Lettuce — winter | 6.0 | 0.18 | — | — | — | — | — | — | — | — | — | — |
| Melons | 22.0 | 0.25 | 20.0 | 0.22 | 18.0 | 0.20 | 16.0 | 0.18 | — | — | — | — |
| Palm dates | 60.0 | 0.30 | — | — | — | — | — | — | — | — | — | — |
| Truck crops | 20.0 | 0.25 | 18.0 | 0.22 | 14.0 | 0.20 | 12.0 | 0.18 | 12.0 | 0.16 | 10.0 | 0.15 |

*Source*: From Woodward, *Sprinkler Irrigation*, Sprinkler Irrigation Assoc., 1959. With permission.



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**Table 4K.60 Accumulated Use of Water by Crops with Various Planting to Maturity Periods**

| | | Total Period of Growth | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 Month | | 3 Month | | 4 Month | | 5 Month | | 6 Month | |
| Percentage of Growing Period[a] | Accumulated Consumptive Use of Water in Percentage of Total Use | Days Since Planting | Accum. Water Use (in.) | Days Since Planting | Accum. Water Use (in.) | Days Since Planting | Accum. Water Use (in.) | Days Since Planting | Accum. Water Use (in.) | Days Since Planting | Accum. Water Use (in.) |
| 10 | 6.0 | 6 | 0.3 | 9 | 0.4 | 12 | 0.6 | 15 | 0.8 | 18 | 0.9 |
| 20 | 13.8 | 12 | 0.7 | 18 | 1.0 | 24 | 1.4 | 30 | 1.7 | 36 | 2.0 |
| 30 | 23.5 | 18 | 1.1 | 27 | 1.9 | 36 | 2.3 | 45 | 2.9 | 54 | 3.5 |
| 40 | 34.5 | 24 | 1.7 | 36 | 2.6 | 48 | 3.4 | 60 | 4.3 | 72 | 5.1 |
| 50 | 46.5 | 30 | 2.3 | 45 | 3.4 | 60 | 4.6 | 75 | 5.7 | 90 | 6.8 |
| 60 | 59.4 | 36 | 2.9 | 54 | 4.4 | 72 | 5.8 | 90 | 7.3 | 108 | 8.7 |
| 70 | 72.3 | 42 | 3.5 | 63 | 5.3 | 84 | 7.1 | 105 | 8.9 | 126 | 10.6 |
| 80 | 84.3 | 48 | 4.1 | 72 | 6.2 | 96 | 8.3 | 120 | 10.3 | 144 | 12.4 |
| 90 | 94.5 | 54 | 4.7 | 81 | 7.0 | 108 | 9.3 | 135 | 11.6 | 162 | 13.9 |
| 100 | 100.0 | 60 | 4.9 | 90 | 7.4 | 120 | 9.8 | 150 | 12.3 | 180 | 14.7 |

[a] Growing Period refers to the entire time from planting to the time the plant dies, which is usually longer than the period from planting to harvesting. Flowering will occur at about 50 to 60 percent of the growing period and fruiting after 60 percent.

*Source*: From Israelson and Hansen, *Irrigation Principles and Practices*, John Wiley & Sons, 1962. With permission.

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**Table 4K.61 Variations in Consumptive Use by Crops**

| Crop | No. of Tests | Range in Water Requirements (ft) |
|---|---|---|
| **(A) Farm crops in the southwest** | | |
| Alfalfa | 369 | 3.47–5.08 |
| Rhodes grass | 12 | 3.49–4.43 |
| Sudan grass | 25 | 2.88–3.16 |
| Barley | 3 | 1.24–1.83 |
| Oats | 2 | 1.90–2.09 |
| Wheat | 46 | 1.46–2.24 |
| Corn | 42 | 1.44–1.99 |
| Kafir | 16 | 1.32–1.54 |
| Flax | 3 | 1.23–1.59 |
| Broomcorn | 9 | 0.97–1.15 |
| Emmer | 6 | 1.19–1.87 |
| Feterita | 8 | 0.97–1.10 |
| Millet | 5 | 0.91–1.09 |
| Milo | 35 | 0.96–1.67 |
| Sorghum | 34 | 1.69–2.08 |
| Cotton | 103 | 2.35–3.51 |
| Potatoes | 12 | 1.59–2.04 |
| Soybeans | 36 | 1.66–2.81 |
| Sugar beets | 5 | 1.77–2.72 |
| Sugar cane[a] | 41 | 3.48–4.56 |
| **(B) Vegetable crops in the southwest** | | |
| Beans, snap | 9 | 0.83–1.44 |
| Beets, table | 28 | 0.87–1.37 |
| Cabbage | 21 | 0.94–1.49 |
| Carrots | 6 | 1.27–1.60 |
| Cauliflower | 6 | 1.43–1.77 |
| Lettuce | 49 | 0.72–1.35 |
| Onions | 4 | 0.73–1.52 |
| Peas | 8 | 1.21–1.56 |
| Melons | 3 | 0.80–1.07 |
| Spinach | 12 | 0.80–1.07 |
| Sweet potatoes | 3 | 1.77–2.25 |
| Tomatoes | 17 | 0.95–1.42 |
| **(C) Crops in the Missouri and Arkansas Basins** | | |
| Forage, including alfalfa | 648 | 1.94–2.62 |
| Barley | 335 | 1.33–1.82 |
| Oats | 409 | 1.35–1.81 |
| Wheat | 542 | 1.36–1.80 |
| Corn | 70 | 1.23–1.83 |
| Kafir corn | 15 | 1.43–1.57 |
| Flax | 50 | 1.47–1.85 |
| Millet | 14 | 0.81–0.94 |
| Milo maize | 27 | 1.09–1.70 |
| Sorghum | 26 | 1.06–1.47 |
| Apples | 4 | 2.10–2.60 |
| Beans | 4 | 1.30–1.60 |
| Buckwheat | 3 | 1.05–1.30 |
| Cantaloupes | 10 | 1.50–2.30 |
| Peas | 168 | 1.36–1.94 |
| Potatoes | 350 | 1.38–1.70 |
| Sugar beets | 128 | 1.60–2.50 |
| Sunflowers | 16 | 1.20–1.40 |
| Tomatoes | 6 | 2.10–2.80 |
| Cucumbers | 7 | 1.73–3.75 |

[a] Not commonly produced in the Southwest.

*Source*: U.S. Dept. of Agriculture.

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**Table 4K.62 Consumptive Use of Water by Crops in Florida**

| Month | Citrus | Pasture[a] | Sugarcane | Rice[b] | Rainfall | Pan Evapotranspiration[c] |
|---|---|---|---|---|---|---|
| January | 2.09 | 2.01 | 1.42 | 0 | 1.97 | 3.39 |
| February | 2.60 | 2.52 | 1.10 | 0 | 1.97 | 4.00 |
| March | 3.58 | 3.35 | 2.52 | 0 | 3.21 | 5.70 |
| April | 4.49 | 4.21 | 3.39 | 1.63 | 2.96 | 6.54 |
| May | 5.31 | 5.20 | 4.80 | 3.07 | 4.74 | 7.06 |
| June | 4.41 | 4.25 | 5.98 | 5.82 | 9.08 | 6.24 |
| July | 4.88 | 4.80 | 6.50 | 8.43 | 8.58 | 6.36 |
| August | 4.80 | 4.80 | 6.69 | 3.05 | 8.21 | 6.12 |
| September | 4.02 | 3.86 | 5.12 | (5.00) | 8.82 | 5.31 |
| October | 3.59 | 3.43 | 5.20 | (3.00) | 5.65 | 4.82 |
| November | 2.72 | 2.48 | 3.19 | 0 | 1.74 | 3.71 |
| December | 2.09 | 1.93 | 2.59 | 0 | 1.80 | 3.19 |
| Total | 44.58 | 42.84 | 48.50 | 22.00 | 58.76 | 62.44 |

*Note:* Everglades agricultural area; in inches.

[a] Mean monthly values averaged over 5 years and averaged over water table depth of 12, 24, and 36 inches maintained in lysimeters at Ft. Lauderdale. These turfgrass evapotranspiration values are assumed to be valid for pastures adequately supplied with water.

[b] Assuming planting date of April 15 which is approximately the middle of the planting season. Values in parentheses are estimates for a ratoon crop. Rice is not always ratoon cropped.

[c] Pan evapotranspiration is a measure of the capability of the air to evaporate water. A relatively higher indicates relatively high consumptive use of water.

*Source*: From Bajwa, R.S., *Analysis of Irrigation Potential in the Southeast: Florida, A Special Report*, U.S. Department of Agriculture, 1985.

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**Table 4K.63 Economic Irrigation Requirements in the Western United States**

| Div. No | Division Description | State | Irrigation Season, Inclusive | Total Depth (ft) |
|---|---|---|---|---|
| | **(A) Columbia River basin** | | | |
| 1 | Snake River Valley | Idaho | Apr–Oct | 2.5 |
| 2 | Upper Snake River Valley | Idaho | Apr–Sept | 2.3 |
| 3 | Jackson Lake and Upper Snake basin | Idaho and Wyoming | May–Sept | 1.7 |
| 4 | Southwest Idaho and north Nevada | Idaho and Nevada | Apr–Sept | 1.9 |
| 5 | Salmon River basin | Idaho | May–Aug | 2.0 |
| 6 | North Idaho | Idaho | May–Sept | 1.5 |
| 7 | Bitterroot and Missoula River basins | Montana | Apr–Nov | 2.1 |
| 8 | Flathead Lake and River basins | Montana | Apr–Sept | 1.8 |
| 9 | Owyhee and Malheur River basins | Oregon | Apr–Sept | 2.4 |
| 10 | Northeast Oregon | Oregon | Apr–Sept | 2.0 |
| 11 | Umatilla, John Day, Deschutes, and Hood basins | Oregon | Apr–Oct | 2.5 |
| 12 | Central Oregon | Oregon | May–Aug | 2.4 |
| 13 | Yakima and Wenatchee river basins | Washington | Apr–Nov | 2.6 |
| 14 | Southeast Washington | Washington | Apr–Oct | 2.1 |
| 15 | Northeast Washington | Washington | Apr–Oct | 2.2 |
| 16 | Okanogan River basin | Washington | Apr–Nov | 2.3 |
| 17 | Lower Columbia River basin | Washington | May–Sept | 1.3 |
| 18 | Willamette River basin | Oregon | May–Sept | 1.2 |
| 19 | Puget Sound region[a] | Washington | May–Sept | 1.4 |
| | **(B) Pacific Slope basins** | | | |
| 1 | Umpqua, Coquill, and Lower Rogue basins | Oregon | Apr–Sept | 0.85 |
| 2 | Upper Rogue River basin | Oregon | Mar–Sept | 1.50 |
| 3 | Klamath Lake and River basins | Oregon and California | Apr–Sept | 2.00 |
| 4 | Northwest California | California | Apr–Oct | 1.40 |
| 5 | Pit River basin | California | Apr–Sept | 1.60 |
| 6 | Feather, Yuba, and American River basins | California | Mar–Nov | 1.50 |
| 7 | Sacramento Valley | California | Mar–Oct | 2.10 |
| 8 | Sacramento-San Joaquin Delta | California | May–Sept | 2.00 |
| 9 | San Francisco Bay basin | California | Mar–Nov | 1.50 |
| 10 | Salinas River basin | California | Mar–Oct | 1.70 |
| 11 | Santa Maria, Santa Inez, and Santa Clara basins | California | Jan–Dec | 1.60 |
| 12 | San Joaquin Valley | California | Feb–Oct | 2.30 |
| 13 | West slope of Sierras | California | Feb–Nov | 1.70 |
| 14 | East slope of Coast Range | California | Feb–Oct | 1.80 |
| 15 | Antelope and Victor Valleys | California | Mar–Oct | 1.90 |
| 16 | Los Angeles, San Gabriel, and Santa Ana basins | California | Jan–Dec | 1.70 |
| 17 | Upper Santa Ana River Valley | California | Jan–Dec | 1.80 |
| 18 | San Diego County | California | Jan–Dec | 1.40 |
| | **(C) Southwest** | | | |
| 1 | Imperial Valley | California | Jan–Dec | 3.10 |
| 2 | South Nevada | Nevada | Jan–Dec | 2.90 |
| 3 | Southwest Arizona | Arizona | Jan–Dec | 3.00 |
| 4 | Northwest Arizona | Arizona | Mar–Oct | 2.30 |
| 5 | Navajo country | Arizona | Mar–Oct | 2.30 |
| 6 | Southeast Arizona | Arizona | Feb–Nov | 2.60 |
| 7 | San Juan basin | New Mexico | Apr–Sept | 2.20 |
| 8 | West New Mexico | New Mexico | Apr–Oct | 1.70 |
| 9 | Rio Grande basin | New Mexico | Jan–Dec | 2.60 |
| 10 | Pecos River basin | New Mexico | Jan–Dec | 2.40 |
| 11 | Northeast New Mexico | New Mexico | Feb–Nov | 1.60 |
| 12 | Central Rio Grande basin | Texas | Jan–Nov | 2.40 |
| 13 | Pecos River basin | Texas | Jan–Nov | 2.25 |
| 14 | West Central Texas | Texas | Jan–Dec | 1.60 |
| 15 | Lower Rio Grande basin | Texas | Jan–Dec | 1.75 |
| 16 | Upper Nueces and Colorado River basins | Texas | Jan–Dec | 1.30 |
| 17 | Upper Brazos and Red River basins | Texas | Jan–Dec | 1.10 |
| 18 | Eastern Panhandle | Texas | Mar–Oct | 1.35 |

*(Continued)*

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**Table 4K.63 (Continued)**

| Div. No | Division Description | State | Irrigation Season, Inclusive | Total Depth (ft) |
|---|---|---|---|---|
| 19 | Western Panhandle | Texas | Mar–Oct | 1.65 |
| 20 | Panhandle | Oklahoma | Apr–Oct | 1.25 |
| 21 | West Oklahoma | Oklahoma | Apr–Oct | 1.00 |
| 22 | San Luis basin | Colorado | May–Sept | 1.80 |
| 23 | San Juan basin | Colorado | Apr–Sept | 1.90 |
| 24 | Yampa and White River basins | Colorado | May–Aug | 1.35 |
| 25 | Upper Colorado River basin | Colorado | Apr–Sept | 1.70 |
| 26 | Virgin River basin | Utah | Feb–Nov | 2.25 |
| 27 | San Juan basin | Utah | Apr–Sept | 2.10 |
| 28 | Green River basin | Utah | Apr–Oct | 2.00 |
| 29 | Uintah basin | Utah | Apr–Sept | 1.75 |
| 30 | Green River basin | Wyoming | May–Aug | 1.60 |
| | **(D) Great basin** | | | |
| 1 | Bear River basin | Idaho and Utah | May–Oct | 2.0 |
| 2 | Utah Lake and Great Salt Lake Valleys[b] | Utah | May–Oct | 2.2 |
| 3 | Sevier River basin | Utah | May–Oct | 2.1 |
| 4 | Irrigable lands, southwest Utah | Utah | Apr–Oct | 1.8 |
| 5 | Irrigable lands, southern Nevada | Nevada | Apr–Oct | 1.7 |
| 6 | Antelope Valley and Mohave River areas | California and Nevada | Mar–Oct | 1.8 |
| 7 | Mono, Owens, and Inyo-Kern valleys | California | Mar–Oct | 2.1 |
| 8 | Walker River basin | California and Nevada | Apr–Oct | 2.0 |
| 9 | Truckee and Carson River basins | California and Nevada | May–Oct | 2.1 |
| 10 | Humboldt, Quinn, and White River basins | Nevada | May–Sept | 2.0 |
| 11 | Honey Lake basin | California and Nevada | Apr–Sept | 1.7 |
| 12 | Malheur Lake, Harney Lake, and other basins | Oregon | Apr–Sept | 1.5 |
| | **(E) Missouri and Arkansas basins** | | | |
| 1 | Northeast Montana | Montana | May–Aug | 1.40 |
| 2 | North central Montana | Montana | May–Aug | 1.50 |
| 3 | Central Montana | Montana | May–Aug | 1.70 |
| 4 | Upper Missouri River basin | Montana | May–Aug | 1.60 |
| 5 | Upper Yellowstone River basin | Montana | May–Aug | 1.90 |
| 6 | Southeast Montana | Montana | May–Sept | 1.95 |
| 7 | Big Horn River basin | Wyoming | May–Sept | 1.65 |
| 8 | Yellowstone and Missouri River basins | Wyoming | May–Sept | 1.70 |
| 9 | Upper Platte River basin | Wyoming | May–Sept | 1.60 |
| 10 | Northeast Colorado | Colorado | Apr–Sept | 2.05 |
| 11 | North central Colorado | Colorado | Apr–Sept | 2.20 |
| 12 | South central Colorado | Colorado | Apr–Sept | 2.10 |
| 13 | Southeast Colorado | Colorado | Apr–Oct | 2.30 |
| 14 | West Kansas | Kansas | Apr–Oct | 1.75 |
| 15 | Central Nebraska | Nebraska | Apr–Oct | 1.25 |
| 16 | West Nebraska | Nebraska | Apr–Oct | 2.00 |
| 17 | Western South Dakota | South Dakota | May–Sept | 1.50 |
| 18 | Western North Dakota | North Dakota | May–Sept | 1.35 |

*Note:* Estimated minimum quantities of irrigation water required, assuming optimal irrigation practices.

[a] Not in the Columbia River Basin.
[b] South of Weber River basin.

*Source*: U.S. Department of Agriculture.

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**Table 4K.64 Estimated Evapotranspiration for Types of Vegetation in the Western United States**

| Vegetation Type | Annual Evapotranspiration (in.) |
|---|---|
| Forest | |
| Lodgepole pine | 19 |
| Engelmann spruce-fir | 15 |
| White pine-larch-fir | 22 |
| Mixed conifer | 22 |
| True fir | 24 |
| Aspen | 23 |
| Pacific Douglas-fir-hemlock-redwood | 30 |
| Interior ponderosa pine | 17 |
| Interior Douglas-fir | 21 |
| Chaparral and woodland | |
| Southern California chaparral | 20 |
| California woodland-grass | 18 |
| Arizona chaparral | 17.5 |
| Pinon-juniper | 14.5 |
| Semiarid grass and shrub | 10.6 |
| Alpine | 20 |

*Source*: Select Committee on National Water Resources, U.S. Senate, 1960.

**Table 4K.65 Consumptive Use in a Municipal Area**

| Cultural Classification | Consumptive Use (ft) | Cultural Classification | Consumptive Use (ft) |
|---|---|---|---|
| Estates | 2.07 | Reservoir sites | 1.34 |
| Class A residential | 1.92 | Park | 2.40 |
| Class B residential | 1.88 | Schools | 1.63 |
| Rural residential | 1.78 | River wash | 0.99 |
| Semicommercial | 1.32 | | |

*Note:* Data for Raymond Basin, Los Angeles County, California.

*Source*: California Department of Water Resources.

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## Blaney-Criddle Consumptive Use Formula

The consumptive use of an irrigated crop in which ample water supply is available can be estimated by the Blaney-Criddle formula. For a given month the consumptive use is given by

$$u = k(tp) \tag{4.1}$$

where $u$ is the monthly consumptive use measured in inches, $k$ is a monthly consumptive use coefficient dependent on the crop and location, $t$ is the mean monthly temperature in degrees Fahrenheit, and $p$ is the monthly percentage of daytime hours of the year.

Because $t$ and $p$ can be found from climatic data at a given location, they are often combined into a monthly consumptive use factor $f$, so that Equation 4.1 becomes simply

$$u = kf \tag{4.2}$$

For an entire growing season the consumptive use is given by

$$U = KF \tag{4.3}$$

where $U$ is the seasonal consumptive use measured in inches, $K$ is a seasonal consumptive use coefficient, and $F$ is the sum of the monthly consumptive use factors.

Values for the Western United States of $k$ are given in Table 4K.66, $K$ in Table 4K.67, $p$ in Table 4K.69, and $f$ in Table 4K.70.

**Table 4K.66 Monthly Consumptive Use Coefficients ($k$) for Irrigated Crops in the Western United States**

| Crop | Location | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|
| Alfalfa | California, coastal | 0.60 | 0.65 | 0.70 | 0.80 | 0.85 | 0.85 | 0.80 | 0.70 | 0.60 |
| | California, interior | 0.65 | 0.70 | 0.80 | 0.90 | 1.10 | 1.00 | 0.85 | 0.80 | 0.70 |
| | North Dakota | — | 0.84 | 0.89 | 1.00 | 0.86 | 0.78 | 0.72 | | |
| | Utah, St. George | — | 0.88 | 1.15 | 1.24 | 0.97 | 0.87 | 0.81 | | |
| Corn (maize) | North Dakota | — | — | 0.47 | 0.63 | 0.78 | 0.79 | 0.70 | | |
| Cotton | Arizona | — | 0.27 | 0.30 | 0.49 | 0.86 | 1.04 | 1.03 | 0.81 | |
| | Texas | 0.24 | 0.22 | 0.61 | 0.42 | 0.50 | | | | |
| Orchard, citrus | Arizona | 0.57 | 0.60 | 0.60 | 0.64 | 0.64 | 0.68 | 0.68 | 0.65 | 0.62 |
| | California, coastal | — | 0.40 | 0.42 | 0.52 | 0.55 | 0.55 | 0.55 | 0.50 | 0.45 |
| Pasture | California, Murrieta | — | — | 0.84 | 0.84 | 0.77 | 0.82 | 1.09 | 0.70 | |
| Potatoes | North Dakota | — | — | 0.45 | 0.74 | 0.87 | 0.75 | 0.54 | | |
| | South Dakota | — | — | 0.69 | 0.60 | 0.80 | 0.89 | 0.39 | | |
| Small grain | North Dakota | — | 0.19 | 0.55 | 1.13 | 0.77 | 0.30 | | | |
| Wheat | Texas | 0.64 | 1.16 | 1.26 | 0.87 | | | | | |
| Sorghum | Arizona | — | — | — | — | 0.34 | 0.72 | 0.97 | 0.62 | 0.60 |
| | Kansas | — | — | — | 0.80 | 0.94 | 1.17 | 0.86 | 0.47 | |
| | Texas | — | — | — | 0.26 | 0.73 | 1.20 | 0.85 | 0.49 | |
| Soy beans | Arizona | — | — | — | 0.26 | 0.58 | 0.92 | 0.92 | 0.55 | |
| Sugar beets | California, coastal | — | 0.39 | 0.38 | 0.36 | 0.37 | 0.35 | 0.38 | | |
| | California, interior | — | 0.30 | 0.60 | 0.86 | 0.96 | 0.91 | 0.41 | | |
| | Montana | — | — | — | — | 0.83 | 1.05 | 1.02 | | |
| Truck crops | California, interior | 0.19 | 0.26 | 0.38 | 0.55 | 0.71 | 0.82 | 0.69 | 0.37 | 0.35 |

*Note:* For use with the Blaney-Criddle consumptive use formula.

*Source*: U.S. Department of Agriculture.

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**Table 4K.67 Seasonal Consumptive Use Coefficients (*k*) for Irrigated Crops in the Western United States**

| Crop | Length of Normal Growing Season or Period[a] | Consumptive Use Coefficient (*K*)[b] |
|---|---|---|
| Alfalfa | Between frosts | 0.80 to 0.90 |
| Bananas | Full year | 0.80 to 1.00 |
| Beans | 3 months | 0.60 to 0.70 |
| Cocoa | Full year | 0.70 to 0.80 |
| Coffee | Full year | 0.70 to 0.80 |
| Corn (Maize) | 4 months | 0.75 to 0.85 |
| Cotton | 7 months | 0.60 to 0.70 |
| Dates | Full year | 0.65 to 0.80 |
| Flax | 7 to 8 months | 0.70 to 0.80 |
| Grains, small | 3 months | 0.75 to 0.85 |
| Grain, sorghums | 4 to 5 months | 0.70 to 0.80 |
| Oilseeds | 3 to 5 months | 0.65 to 0.75 |
| Orchard crops | | |
| Avocado | Full year | 0.50 to 0.55 |
| Grapefruit | Full year | 0.55 to 0.65 |
| Orange and lemon | Full year | 0.45 to 0.55 |
| Walnuts | Between frosts | 0.60 to 0.70 |
| Deciduous | Between frosts | 0.60 to 0.70 |
| Pasture crops | | |
| Grass | Between frosts | 0.75 to 0.85 |
| Ladino whiteclover | Between frosts | 0.80 to 0.85 |
| Potatoes | 3 to 5 months | 0.65 to 0.75 |
| Rice | 3 to 5 months | 1.00 to 1.10 |
| Sisal | Full year | 0.65 to 0.70 |
| Sugar beets | 6 months | 0.65 to 0.75 |
| Sugarcane | Full year | 0.80 to 0.90 |
| Tobacco | 4 months | 0.70 to 0.80 |
| Tomatoes | 4 months | 0.65 to 0.70 |
| Truck crops, small | 2 to 4 months | 0.60 to 0.70 |
| Vineyard | 5 to 7 months | 0.50 to 0.60 |

*Note:* For use with the Blaney-Criddle consumptive use formula.

[a] Length of season depends largely on variety and time of year when the crop is grown. Annual crops grown during the winter period may take much longer than if grown in the summertime.

[b] The lower values of *K* for use in the Blaney-Criddle formula, $U = KF$, are for the more humid areas, and the higher values are for the more arid climates.

*Source*: U.S. Department of Agriculture.

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**Table 4K.68 Monthly and Seasonal Consumptive Use Coefficients (*k*) for Mature Urban Landscape Plantings**

| Planting Type | Monthly (Maximum K) | Seasonal (Average) |
|---|---|---|
| Warm-season grass (Bermuda, buffalo), Mesa and Tempe, Arizona (elevation 1200 ft) | 1.17 | 0.97 |
| Warm-season grass (Bermuda, buffalo), Laramie and Wheatland, Colorado (elevation 7200 and 4700 ft) | 1.08 | 0.79 |
| Cool-season grass (Kentucky bluegrass), Mesa and Tempe, Arizona (elevation 1200 ft) | 1.41 | 1.20 |
| Cool-season grass (Kentucky bluegrass), Laramie and Wheatland, Colorado (elevation 7200 and 4700 ft) | 1.30 | 0.95 |
| Deciduous fruit or nut tree in bare soil, Mulch, or Paved Area | 0.90 | 0.70 |
| Deciduous fruit or nut tree with cover crop (turf, ground cover, etc) | 1.25 | 1.00 |
| Grapefruit in bare soil, mulch, or paved area | 0.75 | 0.65 |
| Lemon, orange | 0.65 | 0.55 |
| Other trees | 0.90 | 0.80 |
| Grapevine, Mesa and Tempe, Arizona (elevation 1200 ft) | 0.80 | 0.70 |
| Grapevine, elsewhere | 0.75 | 0.60 |
| Other vines | 0.80 | 0.70 |
| Shrubs over 4 ft diameter | 0.80 | 0.70 |
| Shrubs under 4 ft diameter | 1.00 | 0.90 |
| Ground cover plants, other small plants | 1.00 | 0.90 |
| Arid climate native plants | 0.35 | 0.25 |
| Pavements, mulches, nonliving soil covers | 0.00 | 0.00 |

*Note:* For use with the Blaney-Criddle consumptive use formula; the higher the monthly or seasonal factor, the greater the planting's water demand in that time period.

*Source*: From Ferguson, B.K., Water conservation methods in urban landscape irrigation: an exploratory overview, *Water Res. Bull.*, 23, 147, 1987. With permission.

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**Table 4K.69 Monthly Percentage of Daytime Hours of the Year (*p*)**

| Latitude | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **North** | | | | | | | | | | | | |
| 0 | 8.50 | 7.66 | 8.49 | 8.21 | 8.50 | 8.22 | 8.50 | 8.49 | 8.21 | 8.50 | 8.22 | 8.50 |
| 5 | 8.32 | 7.57 | 8.47 | 8.29 | 8.65 | 8.41 | 8.67 | 8.60 | 8.23 | 8.42 | 8.07 | 8.30 |
| 10 | 8.13 | 7.47 | 8.45 | 8.37 | 8.81 | 8.60 | 8.86 | 8.71 | 8.25 | 8.34 | 7.91 | 8.10 |
| 15 | 7.94 | 7.36 | 8.43 | 8.44 | 8.98 | 8.80 | 9.05 | 8.83 | 8.28 | 8.26 | 7.75 | 7.88 |
| 20 | 7.74 | 7.25 | 8.41 | 8.52 | 9.15 | 9.00 | 8.25 | 8.96 | 8.30 | 8.18 | 7.58 | 7.66 |
| 25 | 7.53 | 7.14 | 8.39 | 8.61 | 9.33 | 9.23 | 9.45 | 9.09 | 8.32 | 8.09 | 7.40 | 7.42 |
| 30 | 7.30 | 7.03 | 8.38 | 8.72 | 9.53 | 9.49 | 9.67 | 9.22 | 8.33 | 7.99 | 7.19 | 7.15 |
| 32 | 7.20 | 6.97 | 8.37 | 8.76 | 9.62 | 9.59 | 9.77 | 9.27 | 8.34 | 7.95 | 7.11 | 7.05 |
| 34 | 7.10 | 6.91 | 8.36 | 8.80 | 9.72 | 9.70 | 9.88 | 9.33 | 8.36 | 7.90 | 7.02 | 6.92 |
| 36 | 6.99 | 6.85 | 8.35 | 8.85 | 9.82 | 9.82 | 9.99 | 9.40 | 8.37 | 7.85 | 6.92 | 6.79 |
| 38 | 6.87 | 6.79 | 8.34 | 8.90 | 9.92 | 9.95 | 10.10 | 9.47 | 8.38 | 7.80 | 6.82 | 6.66 |
| 40 | 6.76 | 6.72 | 8.33 | 8.95 | 10.02 | 10.08 | 10.22 | 9.54 | 8.39 | /7.75 | 6.72 | 7.52 |
| 42 | 6.63 | 6.65 | 8.31 | 9.00 | 10.14 | 10.22 | 10.35 | 9.62 | 8.40 | 7.69 | 6.62 | 6.37 |
| 44 | 6.49 | 6.58 | 8.30 | 9.06 | 10.26 | 10.38 | 10.49 | 9.70 | 8.41 | 7.63 | 6.49 | 6.21 |
| 46 | 6.34 | 6.50 | 8.29 | 9.12 | 10.39 | 10.54 | 10.64 | 9.79 | 8.42 | 7.57 | 6.36 | 6.04 |
| 48 | 6.17 | 6.41 | 8.27 | 9.18 | 10.53 | 10.71 | 10.80 | 9.89 | 8.44 | 7.51 | 6.23 | 5.86 |
| 50 | 5.98 | 6.30 | 8.24 | 9.24 | 10.68 | 10.91 | 10.99 | 10.00 | 8.46 | 7.45 | 6.10 | 5.65 |
| 52 | 5.77 | 6.19 | 8.21 | 9.29 | 10.85 | 11.13 | 11.20 | 10.12 | 8.49 | 7.39 | 5.93 | 5.43 |
| 54 | 5.55 | 6.08 | 8.18 | 9.36 | 11.03 | 11.38 | 11.43 | 10.26 | 8.51 | 7.30 | 5.74 | 5.18 |
| 56 | 5.30 | 5.95 | 8.15 | 9.45 | 11.22 | 11.67 | 11.69 | 10.40 | 8.53 | 7.21 | 5.54 | 4.89 |
| 58 | 5.01 | 5.81 | 8.12 | 9.55 | 11.46 | 12.00 | 11.98 | 10.55 | 8.55 | 7.10 | 5.31 | 4.56 |
| 60 | 4.67 | 5.65 | 8.08 | 9.65 | 11.74 | 12.39 | 12.31 | 10.70 | 8.57 | 6.98 | 5.04 | 4.22 |
| **South** | | | | | | | | | | | | |
| 0 | 8.50 | 7.66 | 8.49 | 8.21 | 8.50 | 8.22 | 8.50 | 8.49 | 8.21 | 8.50 | 8.22 | 8.50 |
| 5 | 8.68 | 7.76 | 8.51 | 8.15 | 8.34 | 8.05 | 8.33 | 8.38 | 8.19 | 8.56 | 8.37 | 8.68 |
| 10 | 8.86 | 7.87 | 8.53 | 8.09 | 8.18 | 7.86 | 8.14 | 8.27 | 8.17 | 8.62 | 8.53 | 8.88 |
| 15 | 9.05 | 7.98 | 8.55 | 8.02 | 8.02 | 7.65 | 7.95 | 8.15 | 8.15 | 8.68 | 8.70 | 9.10 |
| 20 | 9.24 | 8.09 | 8.57 | 7.94 | 7.85 | 7.43 | 7.76 | 8.03 | 8.13 | 8.76 | 8.87 | 9.33 |
| 25 | 9.46 | 8.21 | 8.60 | 7.84 | 7.66 | 7.20 | 7.54 | 7.90 | 8.11 | 8.86 | 9.04 | 9.58 |
| 30 | 9.70 | 8.33 | 8.62 | 7.73 | 7.45 | 6.96 | 7.31 | 7.76 | 8.07 | 8.97 | 9.24 | 9.85 |
| 32 | 9.81 | 8.39 | 8.63 | 7.69 | 7.36 | 6.85 | 7.21 | 7.70 | 8.06 | 9.01 | 9.33 | 9.96 |
| 34 | 9.92 | 8.45 | 8.64 | 7.64 | 7.27 | 6.74 | 7.10 | 7.63 | 8.05 | 9.06 | 9.42 | 10.08 |
| 36 | 10.03 | 8.51 | 8.65 | 7.59 | 7.18 | 6.62 | 6.99 | 7.56 | 8.04 | 9.11 | 9.51 | 10.21 |
| 38 | 10.15 | 8.57 | 8.66 | 7.54 | 7.08 | 6.50 | 6.87 | 7.49 | 8.03 | 9.16 | 9.61 | 10.34 |
| 40 | 10.27 | 8.63 | 8.67 | 7.49 | 6.97 | 6.37 | 6.76 | 7.41 | 8.02 | 9.21 | 9.71 | 10.49 |
| 42 | 10.40 | 8.70 | 8.68 | 7.44 | 6.85 | 6.23 | 6.64 | 7.33 | 8.01 | 9/9.26 | 9.82 | 10.64 |
| 44 | 10.54 | 8.78 | 8.69 | 7.38 | 6.73 | 6.08 | 6.51 | 7.25 | 7.99 | 9.31 | 9.94 | 10.80 |
| 46 | 10.69 | 8.86 | 8.70 | 7.32 | 6.61 | 5.92 | 6.37 | 7.16 | 7.96 | 9.37 | 10.07 | 10.97 |

*Note:* Latitudes 60°N to 46°S. For use with the Blaney-Criddle consumptive use formula.

*Source*: U.S. Dept. of Agriculture.



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**Table 4K.70 Monthly Consumptive Use Factors (*f*) for Locations in the Western United States and Hawaii**

| | Arizona | | | California |
|---|---|---|---|---|
| Month | Phoenix *f* | Safford *f* | Yuma *f* | Bakersfield *f* |
| January | 3.64 | 3.14 | 3.90 | 3.33 |
| February | 3.82 | 3.40 | 4.07 | 3.58 |
| March | 5.07 | 4.51 | 5.36 | 4.74 |
| April | 5.89 | 5.35 | 6.10 | 5.55 |
| May | 7.28 | 6.73 | 7.36 | 6.87 |
| June | 8.17 | 7.61 | 8.16 | 7.61 |
| July | 8.85 | 8.20 | 8.91 | 8.38 |
| August | 8.25 | 7.52 | 8.41 | 7.69 |
| September | 6.91 | 6.26 | 6.98 | 6.20 |
| October | 5.58 | 5.04 | 5.81 | 5.13 |
| November | 4.20 | 3.67 | 4.42 | 3.68 |
| December | 3.62 | 3.15 | 3.87 | 3.38 |
| Total | 71.28 | 64.58 | 73.35 | 65.84 |
| Frost-free period | 2/5 to 12/6 | 4/5 to 11/4 | 1/12 to 12/26 | 2/21 to 11/25 |

| | California | | | |
|---|---|---|---|---|
| Month | El Centro *f* | Escondido *f* | Merced *f* | Red Bluff *f* |
| January | 3.88 | 3.70 | 3.16 | 3.06 |
| February | 4.00 | 3.70 | 3.38 | 3.35 |
| March | 5.37 | 4.72 | 4.45 | 4.53 |
| April | 6.17 | 5.26 | 5.27 | 5.33 |
| May | 7.58 | 6.20 | 6.57 | 6.70 |
| June | 8.20 | 6.49 | 7.35 | 7.58 |
| July | 9.07 | 7.22 | 8.08 | 8.34 |
| August | 8.56 | 6.93 | 7.39 | 7.61 |
| September | 7.19 | 5.95 | 6.06 | 6.14 |
| October | 5.95 | 5.14 | 4.95 | 4.98 |
| November | 4.44 | 4.06 | 3.67 | 3.60 |
| December | 3.93 | 3.73 | 3.14 | 3.20 |
| Total | 74.34 | 63.10 | 53.47 | 64.24 |
| Frost-free period | 1/29 to 12/9 | 3/9 to 11/25 | 3/9 to 11/20 | 3/5 to 12/5 |

| | California | | Colorado | |
|---|---|---|---|---|
| Month | Sacramento *f* | Santa Ana *f* | Fort Collins *f* | Grand Junction *f* |
| January | 3.13 | 3.77 | 1.76 | 1.72 |
| February | 3.39 | 3.78 | 1.89 | 2.29 |
| March | 4.52 | 4.77 | 3.02 | 3.57 |
| April | 5.18 | 5.27 | 4.10 | 4.67 |
| May | 6.30 | 6.17 | 5.49 | 6.20 |
| June | 6.93 | 6.50 | 6.45 | 7.22 |
| July | 7.42 | 7.05 | 7.11 | 7.98 |
| August | 6.92 | 6.71 | 6.50 | 7.19 |
| September | 5.81 | 5.81 | 4.98 | 5.60 |
| October | 4.89 | 5.11 | 3.73 | 4.22 |
| November | 3.64 | 4.15 | 2.42 | 2.71 |
| December | 3.06 | 3.80 | 1.81 | 1.92 |
| Total | 61.19 | 62.89 | 49.26 | 55.29 |
| Frost-free period | 2/6 to 12/10 | 2/7 to 12/7 | 5/7 to 9/29 | 4/13 to 10/25 |

| | Colorado | | Idaho | |
|---|---|---|---|---|
| Month | Montrose *f* | Boise *f* | Idaho Falls *f* | Lewiston *f* |
| January | 1.68 | 1.82 | 1.26 | 2.09 |
| February | 2.15 | 2.22 | 1.55 | 2.42 |
| March | 3.32 | 3.44 | 2.79 | 3.77 |

*(Continued)*

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**Table 4K.70 (Continued)**

| | | | | |
|---|---|---|---|---|
| April | 4.32 | 4.44 | 4.05 | 4.84 |
| May | 5.70 | 5.74 | 5.45 | 6.25 |
| June | 6.64 | 6.68 | 6.26 | 7.12 |
| July | 7.31 | 7.58 | 7.19 | 8.13 |
| August | 6.62 | 6.87 | 6.45 | 8.01 |
| September | 5.20 | 5.15 | 4.79 | 5.40 |
| October | 3.89 | 3.83 | 3.60 | 4.02 |
| November | 2.56 | 2.58 | 2.18 | 2.64 |
| December | 1.77 | 1.90 | 1.45 | 2.12 |
| Total | 51.16 | 52.25 | 47.02 | 56.81 |
| Frost-free period | 5/6 to 10/9 | 4/23 to 10/17 | 5/15 to 9/19 | 4/5 to 10/26 |

| | **Idaho** | **Kansas** | | **Montana** |
|---|---|---|---|---|
| | **Twin Falls** | **Garden City** | **Wichita** | **Agricultural College** |
| **Month** | ***f*** | ***f*** | ***f*** | ***f*** |
| January | 1.77 | 2.12 | 2.21 | 1.30 |
| February | 2.16 | 2.32 | 2.39 | 1.48 |
| March | 3.35 | 3.65 | 3.80 | 2.50 |
| April | 4.39 | 4.81 | 4.98 | 3.76 |
| May | 5.75 | 6.32 | 6.45 | 5.15 |
| June | 6.53 | 7.30 | 7.45 | 6.03 |
| July | 7.57 | 7.97 | 8.10 | 6.87 |
| August | 6.67 | 7.37 | 7.53 | 6.21 |
| September | 5.00 | 5.83 | 5.99 | 4.53 |
| October | 3.93 | 4.41 | 4.65 | 3.35 |
| November | 2.48 | 2.93 | 3.13 | 2.03 |
| December | 9.84 | 2.17 | 2.32 | 1.41 |
| Total | 51.44 | 57.20 | 59.00 | 44.63 |
| Frost-free period | 5/18 to 9/26 | 4/25 to 10/16 | 4/10 to 10/27 | 5/24 to 9/16 |

| | **Montana** | **Nebraska** | | **New Mexico** |
|---|---|---|---|---|
| | **Missoula** | **McCook** | **Scottsbluff** | **Albuquerque** |
| **Month** | ***f*** | ***f*** | ***f*** | ***f*** |
| January | 1.16 | 1.85 | 1.72 | 2.40 |
| February | 1.54 | 2.11 | 1.88 | 2.69 |
| March | 2.77 | 3.34 | 3.02 | 3.85 |
| April | 4.01 | 4.59 | 4.20 | 4.87 |
| May | 5.46 | 6.14 | 5.71 | 6.23 |
| June | 6.34 | 7.17 | 6.79 | 7.09 |
| July | 7.17 | 7.97 | 7.58 | 7.65 |
| August | 6.32 | 7.25 | 6.87 | 6.98 |
| September | 4.51 | 5.56 | 5.19 | 5.65 |
| October | 3.26 | 4.20 | 3.83 | 4.46 |
| November | 1.98 | 2.64 | 2.45 | 3.01 |
| December | 1.27 | 1.91 | 1.81 | 2.54 |
| Total | 45.79 | 54.73 | 51.05 | 57.39 |
| Frost-free period | 5/18 to 9/23 | 5/3 to 10/6 | 5/11 to 9/26 | 4/13 to 10/28 |

| | **New Mexico** | | **Nevada** | |
|---|---|---|---|---|
| | **Carlsbad** | **State College** | **Carson City** | **Yerington** |
| **Month** | ***f*** | ***f*** | ***f*** | ***f*** |
| January | 3.18 | 2.96 | 2.20 | 2.06 |
| February | 3.37 | 3.12 | 2.40 | 2.46 |
| March | 4.64 | 4.29 | 3.45 | 3.56 |
| April | 5.56 | 5.15 | 4.25 | 4.40 |
| May | 6.89 | 6.29 | 5.49 | 5.65 |
| June | 7.61 | 7.29 | 6.23 | 6.37 |
| July | 7.93 | 7.72 | 7.04 | 7.17 |
| August | 7.55 | 7.17 | 6.42 | 6.63 |

*(Continued)*

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**Table 4K.70 (Continued)**

| | | | | |
|---|---|---|---|---|
| September | 6.15 | 5.94 | 5.00 | 5.09 |
| October | 5.04 | 4.77 | 3.87 | 3.95 |
| November | 3.70 | 3.45 | 2.69 | 2.67 |
| December | 3.06 | 2.85 | 2.24 | 2.11 |
| Total | 64.68 | 61.00 | 51.28 | 52.12 |
| Frost-free period | 3/29 to 11/4 | 4/6 to 10/31 | 5/23 to 9/19 | 5/23 to 9/18 |
| | **Oklahoma** | | **Oregon** | |
| **Month** | **Altus** ***f*** | **Baker** ***f*** | **Hood River** ***f*** | **Medford** ***f*** |
| January | 2.75 | 1.60 | 2.09 | 2.50 |
| February | 3.09 | 1.90 | 2.40 | 2.81 |
| March | 4.43 | 3.12 | 3.61 | 3.90 |
| April | 5.49 | 4.10 | 4.57 | 4.69 |
| May | 6.86 | 5.33 | 5.83 | 5.91 |
| June | 7.78 | 6.11 | 6.47 | 6.74 |
| July | 8.33 | 6.92 | 7.15 | 7.54 |
| August | 7.82 | 6.26 | 6.50 | 6.85 |
| September | 6.34 | 4.72 | 5.04 | 5.33 |
| October | 5.07 | 3.55 | 3.92 | 4.12 |
| November | 3.65 | 2.32 | 2.65 | 2.90 |
| December | 2.88 | 1.68 | 2.15 | 2.42 |
| Total | 64.48 | 47.64 | 52.38 | 55.71 |
| Frost-free period | 3/28 to 11/9 | 5/12 to 10/3 | 4/20 to 10/20 | 5/6 to 10/4 |
| | | **Texas** | | **Utah** |
| | **Amarillo** ***f*** | **Fort Stockton** ***f*** | **Lubbock** ***f*** | **Logan** ***f*** |
| January | 2.33 | 3.45 | 2.85 | 1.59 |
| February | 2.48 | 3.61 | 3.09 | 1.86 |
| March | 3.78 | 4.87 | 4.28 | 3.05 |
| April | 4.75 | 5.74 | 5.25 | 4.28 |
| May | 6.07 | 7.08 | 6.57 | 5.63 |
| June | 6.98 | 7.69 | 7.37 | 6.53 |
| July | 7.54 | 7.94 | 7.80 | 7.53 |
| August | 6.98 | 7.47 | 7.28 | 6.86 |
| September | 5.67 | 6.25 | 5.95 | 5.19 |
| October | 4.39 | 5.25 | 4.83 | 3.87 |
| November | 2.87 | 3.93 | 3.47 | 2.46 |
| December | 2.43 | 3.39 | 2.84 | 1.69 |
| Total | 56.27 | 66.67 | 61.58 | 50.54 |
| Frost-free period | 4/11 to 11/2 | 4/1 to 11/3 | 4/12 to 11/3 | 5/7 to 10/11 |
| | **Utah** | **Washington** | | **Wyoming** |
| **Month** | **Salt Lake City** ***f*** | **Prosser** ***f*** | **Yakima** ***f*** | **Cheyenne** ***f*** |
| January | 1.96 | 1.95 | 1.72 | 1.70 |
| February | 2.26 | 2.36 | 2.22 | 1.82 |
| March | 3.47 | 3.80 | 3.71 | 2.75 |
| April | 4.45 | 4.82 | 4.64 | 3.67 |
| May | 5.77 | 6.21 | 6.06 | 5.08 |
| June | 6.83 | 7.03 | 6.88 | 6.13 |
| July | 7.77 | 7.74 | 7.63 | 6.87 |

*(Continued)*

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**Table 4K.70 (Continued)**

| | | | | |
|---|---|---|---|---|
| August | 7.13 | 6.92 | 6.79 | 6.29 |
| September | 5.40 | 5.24 | 5.21 | 4.78 |
| October | 4.06 | 3.97 | 3.91 | 3.46 |
| November | 2.75 | 2.55 | 2.41 | 2.32 |
| December | 2.06 | 2.01 | 1.92 | 1.84 |
| Total | 53.91 | 54.55 | 53.11 | 46.71 |
| Frost-free period | 4/13 to 10/22 | 4/28 to 10/4 | 4/15 to 10/22 | 5/14 to 10/2 |

| | Wyoming | Hawaii | |
|---|---|---|---|
| **Month** | **Worland** ***f*** | **Honolulu W.B. Airport** ***f*** | **Waianai** ***f*** |
| January | 0.97 | 5.62 | 5.57 |
| February | 1.40 | 5.15 | 5.16 |
| March | 2.79 | 6.04 | 6.08 |
| April | 4.08 | 6.26 | 6.45 |
| May | 5.57 | 6.87 | 7.05 |
| June | 6.58 | 6.98 | 7.23 |
| July | 7.41 | 7.20 | 7.49 |
| August | 6.60 | 7.02 | 7.35 |
| September | 4.87 | 6.49 | 6.65 |
| October | 3.57 | 6.27 | 6.43 |
| November | 2.07 | 5.67 | 5.74 |
| December | 1.19 | 5.54 | 5.61 |
| Total | 47.10 | 75.07 | 76.81 |
| Frost-free period | 5/10–9/27 | — | — |

*Note:* For use with the Blaney-Criddle consumptive use formula.

*Source*: U.S. Department of Agriculture.

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**Table 4K.71 Estimated Oat Yields[a] Based on Stored Soil Water and Growing Season Precipitation[a]**

| Consumptive Use Area | Stored Soil Water + Growing Season Precipitation (in.) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | Bushels per acre[b,c] | | | | | | | | | | | | | | |
| 1 High | 0 | 2 | 11 | 21 | 30 | 39 | 49 | 58 | 68 | 77 | 86 | 96 | 105 | 115 | 124 |
| 2 Moderate high | 0 | 2 | 12 | 23 | 33 | 43 | 54 | 64 | 74 | 84 | 95 | 105 | 115 | 126 | 136 |
| 3 Moderate | 0 | 2 | 14 | 26 | 37 | 49 | 61 | 72 | 84 | 96 | 108 | 119 | 131 | 143 | 154 |
| 4 Moderate low | 0 | 2 | 15 | 28 | 40 | 52 | 65 | 78 | 90 | 102 | 115 | 128 | 140 | 152 | 165 |

[a] Estimated yields reflect consumptive use data from Huntley, Havre, Sidney, Conrad, Kalispell, Bozeman, and Moccasin.
[b] Yields may vary from estimates due to climatic conditions, weeds, disease, insects, lodging, or stand density.
[c] When rooting depths are limited by rocks, gravel, or impermeable layers such as shale, yields may vary.

*Source*: From NRCS, MT July 2002, Specification MT590-5.

**Table 4K.72 Estimated Safflower Yields[a] Based on Stored Soil Water and Growing Season Precipitation[a]**

| Consumptive Use Area | Stored Soil Water + Growing Season Precipitation (in.) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 228 |
| | Pounds per acre[b,c] | | | | | | | | | | | | | | |
| 2 Moderate high | 115 | 279 | 443 | 607 | 771 | 935 | 1,099 | 1,263 | 1,427 | 1,591 | 1,755 | 1,919 | 2,083 | 2,247 | 2,411 |

[a] Estimated yields reflect consumptive use data from Huntley, Havre, Sidney, Conrad, Kalispell, Bozeman, and Moccasin.
[b] Yields may vary from estimates due to climatic conditions, weeds, disease, insects, lodging, or stand density.
[c] When rooting depths are limited by rocks, gravel, or impermeable layers such as shale, yields may vary.

*Source*: From NRCS, MT July 2002, Specification MT590-5.

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**Table 4K.73 Estimated Spring Wheat Yields[a] Based on Stored Soil Water and Growing Season Precipitation[a]**

| Consumptive Use Area | Stored Soil Water + Growing Season Precipitation (in.) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | Bushels per acre[b,c] | | | | | | | | | | | | | | |
| 1 High | 0 | 6 | 10 | 15 | 20 | 24 | 29 | 34 | 39 | 43 | 48 | 53 | 57 | 62 | 67 |
| 2 Moderate high | 0 | 6 | 11 | 16 | 21 | 27 | 32 | 37 | 42 | 47 | 52 | 57 | 62 | 67 | 72 |
| 3 Moderate | 0 | 7 | 13 | 19 | 24 | 30 | 36 | 42 | 48 | 53 | 59 | 65 | 71 | 77 | 82 |
| 4 Moderate low | 0 | 7 | 13 | 20 | 26 | 32 | 38 | 44 | 50 | 56 | 62 | 68 | 74 | 80 | 87 |

[a] Estimated yields reflect consumptive use data from Huntley, Havre, Sidney, Conrad, Kalispell, Bozeman, and Moccasin.
[b] Yields may vary from estimates due to climatic conditions, weeds, disease, insects, lodging, or stand density.
[c] When rooting depths are limited by rocks, gravel, or impermeable layers such as shale, yields may vary.

*Source*: From NRCS, MT July 2002, Specification MT590-5.

**Table 4K.74 Estimated Barley Yields[a] Based on Stored Soil Water and Growing Season Precipitation[a]**

| Consumptive Use Area | Stored Soil Water + Growing Season Precipitation (in.) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | Bushels per acre[b,c] | | | | | | | | | | | | | | |
| 1 High | 6 | 13 | 20 | 27 | 34 | 41 | 48 | 55 | 62 | 69 | 76 | 83 | 90 | 97 | 104 |
| 2 Moderate high | 7 | 14 | 22 | 30 | 37 | 45 | 52 | 60 | 68 | 75 | 83 | 90 | 98 | 106 | 113 |
| 3 Moderate | 8 | 16 | 25 | 33 | 42 | 50 | 59 | 67 | 76 | 84 | 93 | 101 | 110 | 118 | 127 |
| 4 Moderate low | 8 | 17 | 26 | 35 | 44 | 53 | 62 | 71 | 80 | 89 | 98 | 107 | 116 | 125 | 134 |

[a] Estimated yields reflect consumptive use data from Huntley, Havre, Sidney, Conrad, Kalispell, Bozeman, and Moccasin.
[b] Yields may vary from estimates due to climatic conditions, weeds, disease, insects, lodging, or stand density.
[c] When rooting depths are limited by rocks, gravel, or impermeable layers such as shale, yields may vary.

*Source*: From NRCS, MT July 2002, Specification MT590-5.



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**Table 4K.75 Estimated Winter Wheat Yields[a] Based on Stored Soil Water and Growing Season Precipitation[a]**

| Consumptive Use Area | Stored Soil Water + Growing Season Precipitation (in.) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | Bushels per acre[b,c] | | | | | | | | | | | | | | |
| 1 High | 0 | 6 | 11 | 17 | 22 | 28 | 33 | 38 | 44 | 49 | 55 | 60 | 65 | 71 | 76 |
| 2 Moderate high | 0 | 6 | 12 | 18 | 24 | 30 | 35 | 41 | 47 | 53 | 59 | 64 | 70 | 76 | 82 |
| 3 Moderate | 0 | 7 | 14 | 20 | 27 | 34 | 40 | 47 | 53 | 60 | 67 | 73 | 80 | 86 | 93 |
| 4 Moderate low | 0 | 8 | 15 | 22 | 29 | 36 | 43 | 50 | 57 | 64 | 71 | 78 | 85 | 92 | 99 |

[a] Estimated yields reflect consumptive use data from Huntley, Havre, Sidney, Conrad, Kalispell, Bozeman, and Moccasin.
[b] Yields may vary from estimates due to climatic conditions, weeds, disease, insects, lodging, or stand density.
[c] When rooting depths are limited by rocks, gravel, or impermeable layers such as shale, yields may vary.

*Source*: From NRCS, MT July 2002, Specification MT590-5.

**Table 4K.76 Irrigated Land in Farms, 1889–1994, by Region and Crop**

| Region | 1889[a,b] | 1949[a] | 1969[a] | 1974[a] | 1978[a] | 1982[a] | 1987[a] | 1992[c] | 1993[c] | 1994[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1000 acres | | | | | | | | | |
| USDA production region | | | | | | | | | | |
| Atlantic[e] | — | 500 | 1,800 | 2,000 | 2,900 | 2,700 | 3,000 | 3,500 | 3,600 | 3,700 |
| North Central[f] | — | — | 500 | 600 | 1,400 | 1,700 | 2,000 | 2,600 | 2,400 | 2,700 |
| Northern Plains | — | 1,100 | 4,600 | 6,200 | 8,800 | 9,300 | 8,700 | 10,200 | 9,800 | 10,300 |
| Delta States | — | 1,000 | 1,900 | 1,800 | 2,700 | 3,100 | 3,700 | 5,400 | 5,200 | 5,300 |
| Southern Plains | — | 3,200 | 7,400 | 7,100 | 7,500 | 6,100 | 4,700 | 5,300 | 5,500 | 5,300 |
| Mountain States | 2,300 | 11,600 | 12,800 | 12,700 | 14,800 | 14,100 | 13,300 | 13,600 | 13,900 | 14,300 |
| Pacific Coast | 1,200 | 8,300 | 10,000 | 10,600 | 12,000 | 11,900 | 10,800 | 10,500 | 10,100 | 10,300 |
| United States[g] | 3,600 | 25,800 | 39,100 | 41,200 | 50,400 | 49,000 | 46,400 | 51,300 | 50,600 | 52,000 |
| Crop | | | | | | | | | | |
| Corn for grain | NA | NA | 3,300 | 5,600 | 8,700 | 8,500 | 8,000 | 10,300 | 9,800 | 10,600 |
| Wheat | NA | NA | 2,000 | 3,300 | 3,000 | 4,600 | 3,700 | 4,100 | 3,900 | 3,900 |
| Rice | NA | NA | 2,200 | 2,600 | 3,000 | 3,200 | 2,400 | 3,500 | 3,100 | 3,400 |
| Soybeans | NA | NA | 700 | 500 | 1,300 | 2,300 | 2,600 | 3,100 | 3,200 | 3,200 |
| Cotton | NA | NA | 3,100 | 3,700 | 4,700 | 3,400 | 3,500 | 3,700 | 4,400 | 4,300 |
| Hay | NA | NA | 7,900 | 8,000 | 8,900 | 8,500 | 8,600 | 8,400 | 8,600 | 8,900 |

*Note:* — Indicated > 50,0000 acres. NA = not applicable.

[a] Census of agriculture.
[b] Excludes rice, which was grown on 342,000 acres in South Atlantic and Gulf States in 1899.
[c] Preliminary estimates constructed from unpublished USDA sources and the Census. Partial returns from 1992 Census were incorporated.
[d] Forecast based on March Planting Intentions (NASS).
[e] Northeast, Appalachian, and Southeast farm production regions.
[f] Lake States and Corn Belt production regions. Remaining regions correspond to single farm production regions.
[g] Includes Alaska and Hawaii.

*Source*: USDA, ERS data.

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**Table 4K.77 Average Depth of Irrigation Water Applied Per Season, 1969–94, by Region and Crop**

| Item | 1969[a] | 1974[a] | 1979[b] | 1984[b] | 1988[b] | 1990[c] | 1991[c] | 1992[c] | 1993[c] | 1994[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inches[e] | | | | | |
| Region | | | | | | | | | | |
| Atlantic[f] | 8.5 | 11.5 | 15.0 | 16.5 | 15.5 | 15.5 | 16.0 | 16.0 | 16.5 | 16.5 |
| North Central[g] | 7.5 | 8.0 | 9.5 | 9.5 | 10.5 | 9.0 | 9.5 | 10.0 | 8.0 | 10.0 |
| Northern Plains | 16.0 | 17.0 | 15.5 | 13.5 | 14.5 | 14.0 | 14.0 | 13.5 | 11.5 | 14.5 |
| Delta States | 15.5 | 17.5 | 26.0 | 17.5 | 18.0 | 16.5 | 15.5 | 16.5 | 15.5 | 15.5 |
| Southern Plains | 18.0 | 18.5 | 17.0 | 16.5 | 17.0 | 16.5 | 15.0 | 16.0 | 16.0 | 16.0 |
| Mountain States | 30.5 | 28.5 | 24.0 | 24.5 | 24.5 | 24.0 | 24.0 | 24.0 | 23.0 | 24.0 |
| Pacific Coast | 33.0 | 34.0 | 32.0 | 34.0 | 34.5 | 34.5 | 34.5 | 34.5 | 33.0 | 35.0 |
| United States[h] | 25.5 | 25.0 | 22.5 | 22.5 | 22.5 | 22.5 | 21.5 | 21.5 | 20.0 | 21.5 |
| Crop | | | | | | | | | | |
| Corn for grain | 18.5 | 19.5 | 17.0 | 16.0 | 16.0 | 15.5 | 15.0 | 15.0 | 13.5 | 15.5 |
| Wheat | 23.0 | 24.0 | 20.5 | 16.5 | 16.0 | 15.5 | 14.5 | 14.5 | 14.0 | 14.5 |
| Rice | 28.0 | 28.5 | 33.5 | 33.5 | 32.5 | 31.5 | 30.5 | 30.0 | 30.5 | 30.5 |
| Soybeans | 12.0 | 11.5 | 14.0 | 9.5 | 10.0 | 8.5 | 7.0 | 8.0 | 6.5 | 7.5 |
| Cotton | 23.0 | 25.5 | 24.0 | 25.0 | 24.5 | 23.0 | 21.0 | 23.0 | 20.0 | 21.5 |
| Alfalfa hay | 32.5 | 30.5 | 26.0 | 28.0 | 29.0 | 28.5 | 27.5 | 27.5 | 26.5 | 27.5 |

[a] Census of Agriculture.
[b] Estimates constructed by State, by crop, from Farm and Ranch Irrigation Surveys (FRIS) (USDC, 1990, 1986, and 1982a) and ERS estimates of irrigated area.
[c] Aggregated from FRIS State/crop application rates adjusted to reflect annual changes in precipitation. Sensitivity to precipitation is estimated as a function of average precipitation and soil hydrologic group.
[d] Forecast using precipitation records through May 1994.
[e] Values rounded to nearest 0.5 inches.
[f] Northeast, Appalachian, and Southeast production regions.
[g] Lake States and Corn Belt farm production regions.
[h] Includes Alaska and Hawaii.

*Source*: USDA, ERS data.

**Table 4K.78 Irrigated Area, 1992 Census of Agriculture**

| State | 1987 | 1992 | Change |
|---|---|---|---|
| | 1,000 acres | | Percent |
| Colorado | 3,014 | 3,170 | 5 |
| Connecticut | 7 | 6 | −19 |
| Delaware | 61 | 62 | 2 |
| Florida | 1,623 | 1,783 | 10 |
| Idaho | 3,219 | 3,260 | 1 |
| Illinois | 208 | 328 | 58 |
| Indiana | 170 | 241 | 42 |
| Iowa | 92 | 116 | 25 |
| Kansas | 2,463 | 2,680 | 9 |
| Maine | 6 | 10 | 69 |
| Maryland | 51 | 57 | 12 |
| Massachusetts | 20 | 20 | −1 |
| Michigan | 315 | 368 | 17 |
| Missouri | 535 | 709 | 33 |
| New Hampshire | 3 | 2 | −41 |
| New Jersey | 91 | 80 | −12 |
| Ohio | 32 | 29 | −9 |
| Oregon | 1,648 | 1,622 | −2 |
| Rhode Island | 3 | 3 | −15 |
| Vermont | 2 | 2 | 16 |
| Virginia | 79 | 62 | −22 |
| Washington | 1,519 | 1,641 | 8 |
| West Virginia | 3 | 3 | −12 |
| Wisconsin | 285 | 331 | 16 |
| Wyoming | 1,518 | 1,465 | −4 |
| Total, 25 states | 16,967 | 18,050 | 6 |

*Note:* The table includes 1992 data on States released by the Bureau of the Census by June 20, 1994.

*Source*: USDC, 1994.

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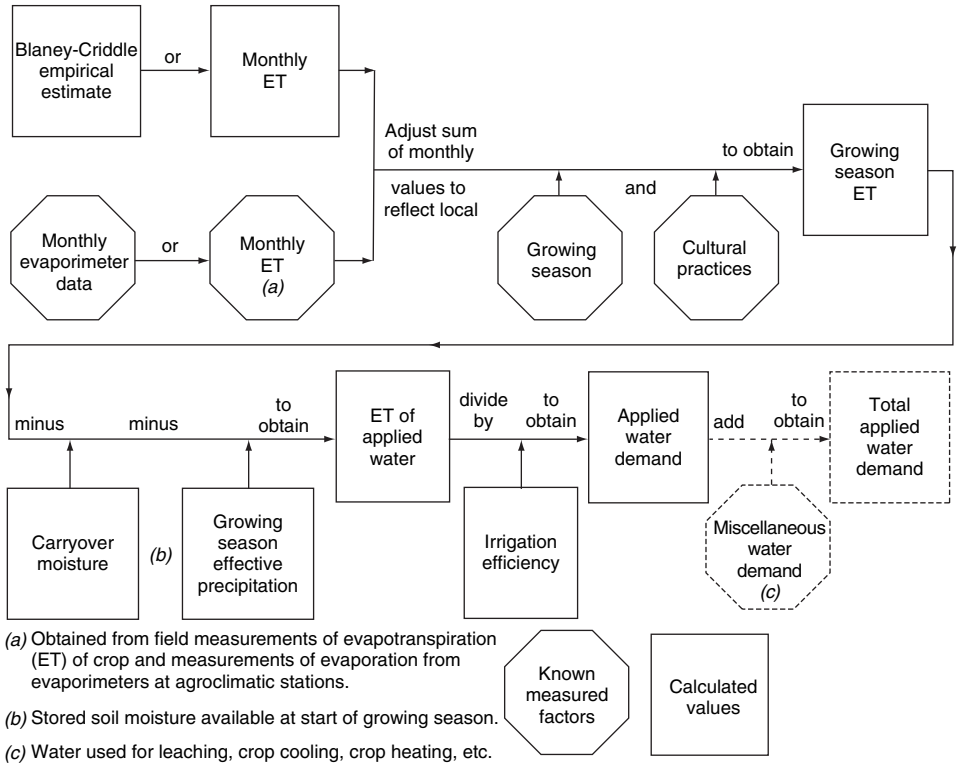


**Figure 4K.27** Steps in determining agricultural applied water demand. (From American Society of Civil Engineers, 1972, Copyright, Groundwater Management.)

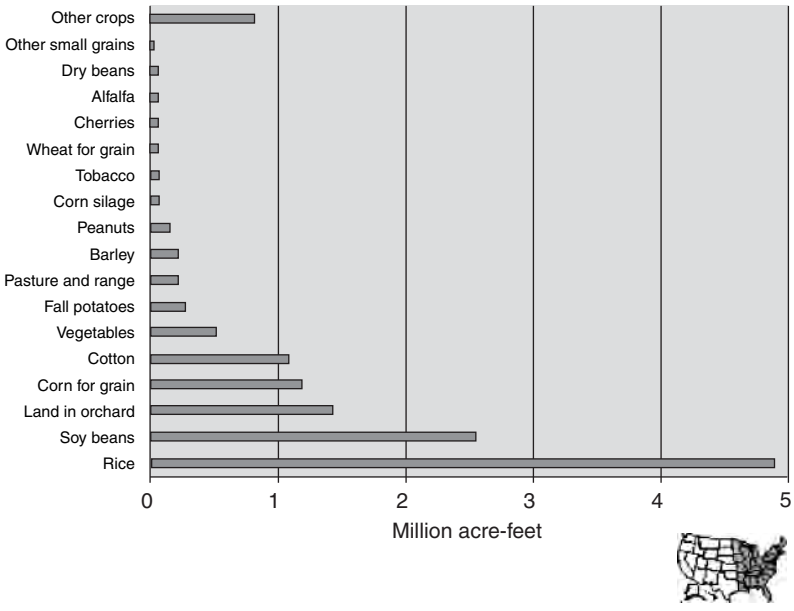


**Figure 4K.28** Eastern water applications by crop, 1998. (From ERS, 1998 Farm and Ranch Irrigation Survey, USDA, www.ers.usda.gov.)

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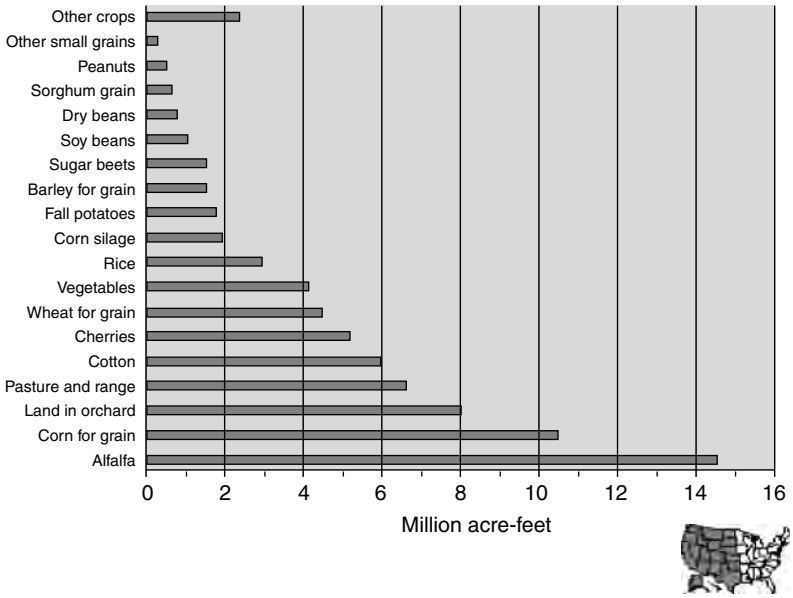


**Figure 4K.29** Western water applications by crop, 1998. (From ERS, 1998 Farm and Ranch Irrigation Survey, USDA, http://ers.usda.gov.)

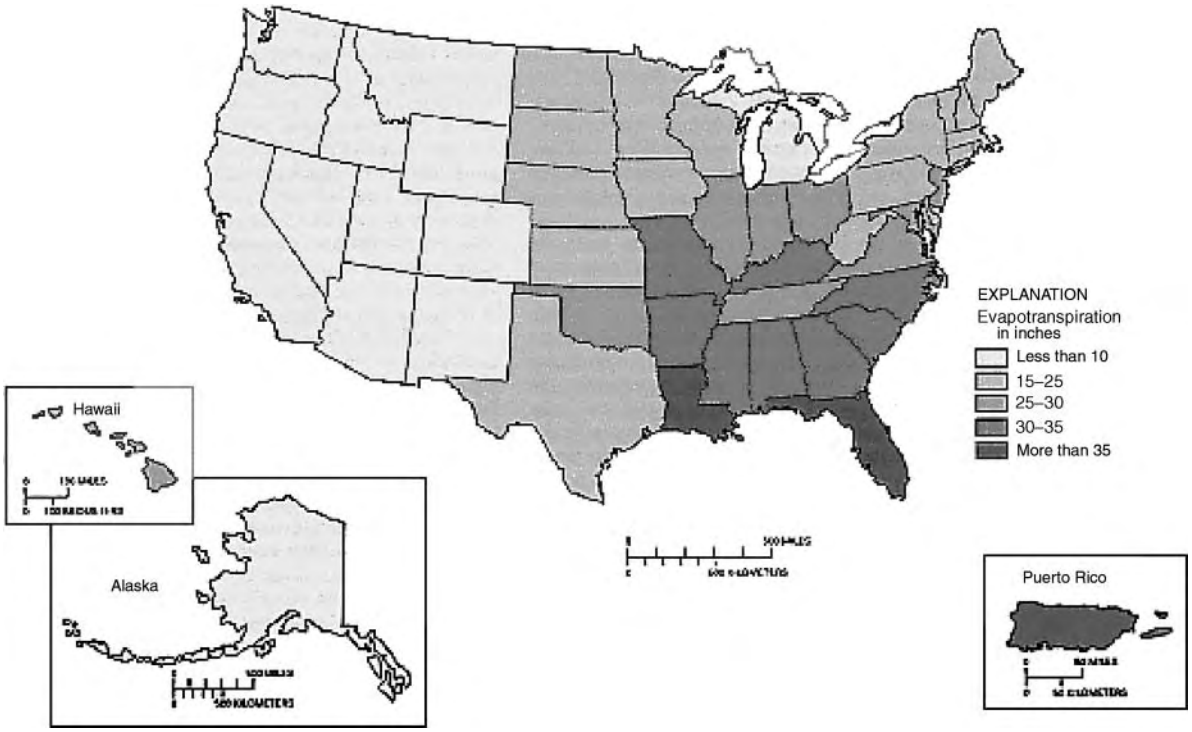


**Figure 4K.30** Estimated mean annual evapotranspiration in the United States and Puerto Rico. (From U.S. Geological Survey, 1990, http://geochange.er.usgs.gov.)

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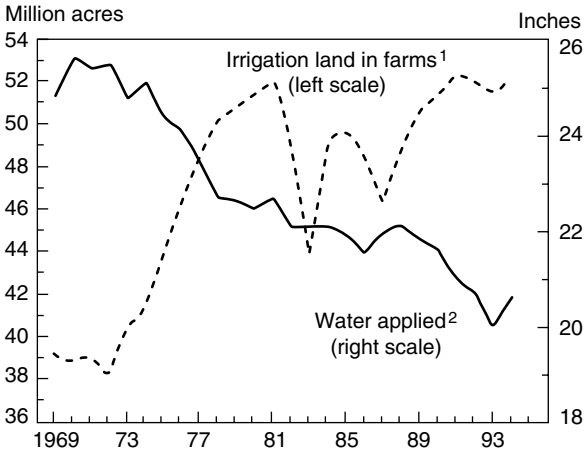


**Figure 4K.31** Irrigation trends, 1969–1994. (From USDA, ERS data, www.ers.usda.gov.)

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# SECTION 4L PHREATOPHYTES

**Table 4L.79 Phreatophyte Areas and Their Consumptive Use in Selected Western States (Estimates as of 1953)**

| State | Area (Acres) | Annual Use (Acre-Feet) |
|---|---|---|
| Arizona | 405,000 | 1,280,000 |
| California[a] | 317,000 | 1,150,000 |
| Colorado[a] | 737,000 | 1,056,000 |
| Idaho | 500,000 | 1,000,000 |
| Montana | 1,600,000 | 3,200,000 |
| Nebraska[a] | 515,000 | 709,000 |
| Nevada | 2,801,000 | 1,500,000 |
| New Mexico | 300,000 | 900,000 |
| North Dakota | 1,035,000 | 1,660,000 |
| Oregon[a] | 40,800 | 21,200 |
| South Dakota | 850,000 | 1,240,000 |
| Texas[a] | 262,000 | 436,500 |
| Utah | 1,200,000 | 1,500,000 |
| Wyoming | 527,000 | 1,100,000 |
| Total (approximate)[b] | 11,090,000 | 16,750,000 |

[a] Partial data, from published reports on areas within the state.
[b] Partial data.

*Source*: U.S. Geological Survey.

**Table 4L.80 Consumptive Use by Some Common Phreatophytes in the Western United States**

| Plant | Annual Rate Including Precipitation | Volume Density | Depth to Water | Locality |
|---|---|---|---|---|
| | Acre-feet per acre | Percent | Feet | |
| Alder | 5.3 | — | — | Santa Ana River, CA |
| Batamote or seepwillow | 4.7 | 100 | 6 | Safford Valley, AZ |
| Cottonwood | 7.6–5.2 | 100 | 3–4 | San Luis Rey River, CA |
| Do | 6.0 | 100 | 6 | Safford Valley, AZ |
| Greasewood | 2.5–0.08 | — | — | Escalante Valley, UT |
| Mesquaite | 3.3 | 100 | 10 | Safford Valley, AZ |
| Sacaton | 4.0–3.5 | — | — | Pecos River Valley, NM |
| Saltcedar | 5.5–4.7 | — | — | Do |
| Do | 9.2–7.3 | 100 | 4–7 | Safford Valley, AZ |
| Saltgrass | 4.1–1.1 | — | 1.5–5 | Owens Valley, CA |
| Do | 2.9–1.1 | — | 2–4 | Santa Ana, CA |
| Do | 2.3–1.1 | — | 0.3–2.1 | San Luis Valley, CO |
| Do | 4.5 | — | 2.0 | Carlsbad, NM |
| Do | 2.6 | — | 0.65 | Isleta, NM |
| Do | 4.0–0.8 | — | 0.4–3.1 | Los Griegos, NM |
| Do | 1.9 | — | 2.2 | Mesilla Dam, NM |
| Do | 2.3–1.6 | — | 1.9–2.6 | Escalante Valley, UT |
| Do | 2.0 | — | 2.0 | Vernal, UT |
| Willow | 4.4 | — | 2.0 | Santa Ana, CA |
| Do | 2.5 | — | 1.1 | Isleta, NM |

*Source*: From Select Committee on National Water Resources U.S. Senate, 1960.

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**Table 4L.81 Phreatophyte Areas and their Consumptive Use in River Basins of the Western United States**

| State and River or Valley | Area in Acres | Estimated Annual Water Use in Acre-Feet | Year of Survey or Estimate | Principal Species of Phreatophytes |
|---|---|---|---|---|
| Arizona | | | | |
| Little Colorado River | | | | |
| Main stem only St. Johns to mouth | 49,560 | 64,720 | 1951 | Saltcedar, cottonwood, willow, brush |
| Total Little Colorado including Zuni and Puerco Rivers | 65,310 | 74,360 | 1951 | Saltcedar, cottonwood, willow, brush |
| Gila River | | | | |
| Virden, NM to Clifton, AZ | 5,600 | 6,310 | 1951 | Cottonwood, willow, seepwillow |
| Head of Safford Valley to Coolidge Dam | 25,520 | 61,500 | 1951 | Saltcedar, mesquite, willow, seepwillow, cotton wood, arrowweed |
| Coolidge Dam to Kelvin | 3,970 | 7,460 | 1951 | Saltcedar, mesquite, willow, seepwillow, cotton wood, arrowweed |
| Kelvin to Gillespie Dam downstream from Granite Reef Dam on Salt River, Rillito on Santa Cruz River and Lake Pleasant on Agua Fria River | 142,880 | 282,770 | 1951 | Saltcedar, mesquite, willow, seepwillow, cotton wood, arrowweed |
| Gillespie Dam to Dome | 51,270 | 69,220 | 1951 | Saltcedar, mesquite, seepwillow |
| Total Gila River including San Pedro River, Palominas to mouth, Verde River, Bartlett Dam to mouth, Salt River, Stewart Mountain Dam to Granite Reef Dam | 300,710 | 522,510 | 1951 | |
| Salt River: Stewart Mountain Dam to Granite Reef Dam | 2,710 | 2,070 | 1951 | Saltcedar, mesquite |
| San Pedro River: Palominas to Gila at mouth | 42,510 | 69,420 | 1951 | Saltcedar, mesquite |
| Verde River: Bartlett to Gila at mouth | 3,790 | 5,720 | 1951 | Saltcedar, mesquite, seepwillow |
| California | | | | |
| San Luis Rey River: IN San Diego County | 6,390 | 17,800 | 1945 | Cottonwood, willow |
| Santa Anna River: Below Prado Dam | 1,071 | 3,000 | 1946 | Cottonwood, willow |
| Kings River: Kings River Soil Conservation District | 1,080 | 6,500 | 1958 | Cottonwood, willow |
| Idaho: Malad Valley | 10,900 | 32,400 | 1953 | Grasses and rushes |
| New Mexico | | | | |
| Pecos River: Alamogordo Dam to Texas State line | 42,500 | 117,000 | 1956 | Saltcedar |
| Rio Grande: Bernardo to San Marcial | 52,000 | 77,800 | 1955 | Saltcedar |
| Nevada | | | | |
| Little Humboldt River: Paradise Valley | 36,500 | 23,000 | 1947 | Greasewood, saltgrass, willows |
| Muddy River: To mouth | 4,900 | 10,330 | 1951 | Saltcedar |
| Nevada-Utah-Arizona-California | | | | |
| Virgin River: Littlefield to mouth | 7,360 | 27,160 | 1951 | Saltcedar |
| Lower Colorado River: | | | | |
| Main stem | | | | |
| Lee Ferry to Hoover Dam | 1,480 | 5,920 | 1951 | Saltcedar, willow |
| Hoover Dam to Davis Dam | 4,500 | 11,450 | 1951 | Saltcedar, willow |
| Davis Dam to Parker Dam | 57,490 | 209,290 | 1950 | Saltcedar, willow |
| Parker Dam to Laguna Dam | 191,890 | 314,360 | 1951 | Saltcedar, willow |
| Laguna Dam to International Boundary | 33,510 | 54,210 | 1951 | Saltcedar, willow |
| Total main stem | 288,920 | 595,230 | 1951 | |
| Total Lower Colorado River Basin, including Little Colorado River, Virgin River, and Gila River Basins | 667,200 | 1,230,090 | 1951 | |

*Source*: Select Committee on National Water Resources, U.S. Senate, 1960.

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**Table 4L.82 Phreatophytes in the Western United States**

| Scientific Name | Common Name | Occurrence as a Phreatophyte | Relation to Groundwater: Depth to Water Below Land Surface (ft) | Relation to Groundwater: Quality | Relation to Groundwater: Use (acre feet/acre) | Remarks |
|---|---|---|---|---|---|---|
| *Acacia greggii* A. Gray | Catclaw, devilsclaw, una de gato | Southern California to western Texas | — | 1 | — | Uses more water than mesquite. Forms thickets along streams and washes |
| *Acer negundo* Linnacus | Boxelder | Canada to Oklahoma and Arizona | — | — | — | Occurs in moist places and along streams, chiefly in mountains. Observed in the flood plain of the North Canadian River near Oklahoma City, Okla. Widely used as a shade tree |
| *Alhagi camelorum* Fischer | Camelthorn | Arizona | — | — | — | Introduced into Southwestern United States from Asia Minor. Poor browse plant. Observed growing as a phreatophyte along Little Colorado River between Holbrook and Winslow, AZ, in localities where the depth to water ranged from 4 to 6 ft. Aggressive and thicket forming, root system deep and extensive |
| *Allenrolfea occidentalis* (S. Watson) Kuntze | Pickleweed, iodinebush | California to western Texas | 1–20 | 3 | — | |
| *Alnus* | Alder | — | — | — | 5.3 | Occurs along streams, river bottom land, and other wet sites. The use of 5.3 ft was for the period May to October 1932 in Cold-water Canyon, altitude 2400 ft, San Bernardino Mountains, CA, where alder constituted 82 percent of the vegetation |
| *Anemopsis californica* (Nuttall) Hooker and Arnott | Yerba mansa | So. California, So. Nevada to Utah and Texas | Shallow | 3 | — | Used by Pima Indians as a herbal remedy. Common in saline and wet lowlands |
| *Aster spinosus* Bentham | Spiny aster | Arizona | — | — | — | Identified as phreatophyte in bottom land of lower Safford Valley, AZ |
| *Atriplex canescens* (Pursh) Nuttall | Fourwing saltbush, Chamiso, chamiza | South Dakota to Oregon, south to Mexico | 8–62 | 1–2 | — | Tolerates alkali. Valuable browse plant. Useful in erosion control. Taproots 30–40 ft deep. May not always occur as a phreatophyte |
| *hastata* Linnaeus | — | Oregon and California to Kansas and New Mexico | — | 3 | — | Occurs in saline soils, especially around alkaline lakes, in salt marshes, and in other water-soaked soils |
| *lentiformis* (Torrey) Watson | Quailbrush, lenscale Nevada saltbush | Southern Utah and Nevada to California and Sonora, Mexico | 6–15 | 3 | — | High tolerance for alkali and saline soil. Fair browse plant. Reaches height of 10 ft where water table is shallow |

*(Continued)*



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**Table 4L.82 (Continued)**

| Scientific Name | Common Name | Occurrence as a Phreatophyte | Relation to Groundwater: Depth to Water Below Land Surface (ft) | Relation to Groundwater: Quality | Relation to Groundwater: Use (acre feet/acre) | Remarks |
|---|---|---|---|---|---|---|
| *Baccharis emoryi* A. Gray | Emory baccharis | Texas to southern California and southern Utah | — | 2 | | |
| *glutinosa* Persoon | Batamote, seepwillow, water motie, waterwillow | Colorado and Texas to California and Mexico | 2–15 | 2 | 4.7 | Evapotranspiration for plants grown in tanks ranged from 10.3 ft with water level at 2 ft to 4.6 ft with water level of 6 ft. Safford Valley, AZ |
| *sarothroides* A. Gray | Broom baccharis, desertbroom, rosinbrush | Southern California, Arizona, southwestern New Mexico | — | — | — | Occurs along streams in draws, in canyon bottoms and wet alkaline sites |
| *sergiloides* A. Gray | Squaw baccharis, waterweed | Arizona, southern California, southern Nevada, southwestern Utah | — | 2 | — | Occurs as a phreatophyte in lower Safford Valley, AZ |
| *viminea* Crandolle | Mulefat | Southwestern Utah, southern California, Nevada, Arizona | — | — | — | Useful in erosion control |
| *Bigelovia hartwegii,* probably *Aplopappus heterophyllus* A. Gray | Rayless goldenrod | | — | — | — | Will grow in dry places but thrives where groundwater is within reach |
| *Celtis reticulata* Torrey | Hackberry, cumaru, kom | Arizona | — | — | — | A large tree that may reach 3 ft in diameter and 50 ft in height. Usually occurs along streams |
| *Cercidium floridum* Bentham | Blue palo verde | Southwestern Arizona, southeastern California | — | — | — | Common along washes, canyons, valleys, alluvial plains, grassland at sites where groundwater is plentiful |
| *Chilopsis linearis* Sweet | Desertwillow | Western Texas to southern Nevada, Arizona, southern California | To 50 | — | — | May not always occur as a phreatophyte |
| *Chrysothamnus pumilus* (Nuttall) | Rabbitbrush | Mud Lake, Idaho | — | — | — | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| *nauseosus consimilis* (Greene) | Rubber rabbitbrush | Nevada, Utah, Idaho, Wyoming | — | 2–3 | — | |
| *nauseosus graveolens* (Nuttall) | Rubber rabbitbrush | Montana, Idaho, Utah, Nevada, New Mexico | 2.5–15 | 2–3 | — | |
| *nauseosus mohavensis* (Greene) | Rubber rabbitbrush | Northern California, Nevada | — | 2–3 | — | |
| *nauseosus oreophilus* (Al Nelson) | Rubber rabbitbrush | Wyoming, Colorado, Utah | — | — | — | |
| *nauseosus viridulus* | Rubber rabbitbrush | Colorado to Oregon; Nevada, New Mexico | — | — | — | |
| *Cowania stansburiana* (Torrey) | Vanadium bush | Arizona, Idaho, Utah | — | — | — | Used as an indicator of vanadium–uranium deposits by prospectors in the Colorado Plateau. Able to grow in highly mineralized ground and to absorb large amounts of uranium |
| *Dalea spinosa* Gray | Smoketree, smokethorn | Southeastern California, southwestern Arizona | — | — | — | Its persistent occurrence in gravelly and sandy washes suggests it depends upon groundwater underflow and occurs as a phreatophyte |
| *Dasiphora fruticosa* Linnaeus | Bush or shrubby cinquefoil | Locally in Idaho but widespread in Oregon, Washington, Utah, Nevada and Arizona | Shallow | — | — | Occurs as a phreatophyte in Pahsimeroi Valley, Idaho. Grows on subalpine meadows, along streams, about cold springs in peaty, sandy, or clayey loams |
| *Distichlis spicata* (Linnaeus) Greene | Seashore saltgrass | Western United States | — | — | — | |
| *stricta* (Torrey) Rydberg | Saltgrass, or desert saltgrass | All Western States | 2–14 | 1–3 | — | |
| *Elymus condensatus* Presl | Giant wildrye | All Western States except New Mexico | 1–12 | 1–2 | — | Fair forage, Killed by overgrazing. Extensive root system |
| *triticoides* Buckley | Creeping wildrye | Western United States | — | 1–2 | — | Good forage. Frequently cut for hay. Associated with giant wild-rye along Humboldt River, Nev |
| *Eragrostis obtusiflora* (Fournier) Scribner | Mexican saltgrass, alkali lovegrass | Southeastern Arizona, southwestern New Mexico | 4–15 | 2–3 | — | Commonly locally in saline soil near Wilcox, AZ. Observed growing in Sulphur Springs Valley, AZ, where depth to water table was from 4–15 ft |

*(Continued)*



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**Table 4L.82 (Continued)**

| Scientific Name | Common Name | Occurrence as a Phreatophyte | Relation to Groundwater: Depth to Water Below Land Surface (ft) | Relation to Groundwater: Quality | Relation to Groundwater: Use (acre feet/acre) | Remarks |
|---|---|---|---|---|---|---|
| *Fraxinus velutina* Torrey | Velvet ash, Arizona ash | Southwestern Utah, southern Nevada, California, Arizona, New Mexico, and western Texas | — | 1 | — | Prominent stream-bank and canyon tree; restricted to areas with a permanent groundwater supply. Popular as a shade tree in Arizona and California |
| *Hedysarum boreale* Nuttall | Sweet vetch | Colorado, Utah | — | — | — | Deep tap root. Identified as a phreatophyte in Colorado |
| *Heliotropium curassavicum* Linnaeus | Heliotrope, Chinese pusley | Southwestern Utah to southern California | Shallow | 2–3 | — | High tolerance for alkali. Occurs on moist saline soil |
| *Hymenoclea monogyra* Torrey and Gray | Burrobush | Western Texas to southern California | Shallow | 1–2 | — | Occurs largely along streams, washes, and in bottom lands; aggressive. Often forming thickets. Unpalatable to livestock |
| *salsola* Torrey and Gray | White burrobush | Utah to Arizona and California | — | — | — | Occurs in sandy desert |
| *Juglans microcarpa* Berlandier | Walnut, nogal, butternut | Arizona, New Mexico | 2–20 | 1 | — | Occurs along watercourses and washes; intolerant of shade. Deep tap root |
| *Juncus balticus* Willdenow | Wirerush, wiregrass | Western United States | — | — | 7.8 | Grows in wet sites where groundwater is shallow, also in shallow ponds. Appears to occur both as phreatophyte and hydrophyte. Deep root system. Fair to good forage |
| *Juncus cooperi* Engelmann | Desertrush | Southern Utah to California | — | 2–3 | — | Occurs on the margins of salt marshes and alkaline meadows, common in Death Valley, CA, along the edge of the playa often associated with saltgrass |
| *Juniperus scopulorum?* | Rocky Mountain juniper; locally "swampcedar." | Nevada | 10 | 1–2 | — | Occurs locally as a phreatophyte in White River and Spring Valleys, Nev. May be a hybrid between *J. scopulorum* and *J. utahensis.* |
| *Leptochola fascicularis* (Lamarck) A. Gray | Sprangletop | Western United States | — | 1–3 | — | Occurs along ditches and in moist waste places, often in brackish marshes; most places in alkali plains. Often invades rice fields |
| *Medicago sativa* Linnaeus | Alfalfa | Western United States | 4+ | 1–2 | — | |
| *Phragmites communis* Trinius | Reed, giant reed-grass, carrizo | Western United States | 0–8± | 1–2 | — | Occurs also as a hydrophyte in the shallow water of streams, lakes, ponds, and marshes |
| *Picea engelmanni* Parry | Engelmann spruce | Mountain areas of western United States | — | 1 | — | Requires a good water supply and depends upon groundwater in many localities. Shallow root system |

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| | | | | | | |
|---|---|---|---|---|---|---|
| *Platanus wrightil* Watson | Arizona sycamore | Southern Arizona, southeastern and southwestern California, New Mexico | — | 1 | — | Common along stream and rocky canyons, in foothills and mountains, upper desert, desert grassland, and oak woodland zones. Valuable in erosion control |
| *Pluchea sericea* Coville | Arrowweed | Texas to southern Utah and southern California | 0–10± | 1–2 | — | Occurs along streams and flood plains. Abundant along lower reaches of Colorado River and tributaries. Arrowweed may grow where depth to water is 25 ft |
| *Populus* | Cottonwood | Western United States | — | 1–2 | — | |
| *tremuloides aurea* Tidestorm | Quaking aspen | Mountainous areas of Western United States | — | 1 | — | Considered a phreatophyte when it grows along streams, around springs, and in other wet areas. Shallow root system |
| *Prosopis juliflora* (Swartz.) | Mesquite, honey mesquite | Southern Kansas to southeastern California and Mexico | — | 1–2 | — | Extensive root development. Reported to penetrate 60 ft below surface |
| *velutina* Wooton | Velvet mesquite | Southern Arizona | 10+ | 1–2 | 3.3 | Occurs in bottom lands. Extensive root development |
| *pubescens* Bentham | Screwbean mesquite, tornillo | Western Texas to southern Nevada and southern California | — | — | — | Characteristic of bottom lands along desert streams and water holes of Mojave and Colorado Deserts |
| *Quercus agrifolia* Nee | California live oak | California | 35± | 1 | — | Occurrence related to depth to water table |
| *lobata* Nee | Roble oak | California | 10–20 | — | — | |
| *Salicornia europaea* Linnaeus | Glasswort | — | — | 3 | — | Frequently occurs in salt flats with salts approximately 1.0 percent of weight of soil |
| *rubra* Linnaeus | Glasswort | Colorado, New Mexico, Nevada, Utah | — | 3 | — | Some value as waterfowl feed. In Nevada occurs along edges of channels draining into playas |
| *utahensis* Tidestrom | Glasswort | Utah | — | 3 | — | Occurs on borders of salt lakes and alkaline places |
| *Salix* | Willow | Western United States | — | — | — | |
| *Sambucus* | Elder, elderberry | Western United States | — | 1 | — | Eleven species reported to grow in Western United States. Grows along streams, in canyons and in moist sites |
| *Sarcobatus vermiculatus* (Hook). Torrey | Big greasewood | Western United States | 60± | — | — | |
| *Sequoia gigantea* (Lindley) | Giant or bigtree sequoia | California | — | 1 | — | Appears to prefer localities where a water table is within reach of its roots but will grow elsewhere |
| *Sesuvium* portulocostrum | Lowland purslane | Southern Nevada and California | — | 3 | — | Reported as a plant that grows on moist alkaline soils. Indicative of groundwater but usually of poor quality. Alkali resistant |

*(Continued)*



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**Table 4L.82 (Continued)**

| Scientific Name | Common Name | Occurrence as a Phreatophyte | Relation to Groundwater: Depth to Water Below Land Surface (ft) | Relation to Groundwater: Quality | Relation to Groundwater: Use (acre feet/acre) | Remarks |
|---|---|---|---|---|---|---|
| *verrucosum* Rafinesque | Warty sesuvium, sea purslane | Southern Arizona, California, and New Mexico | Shallow | 3 | — | |
| *Shepherdia* | Buffalo berry | Arizona, New Mexico, Nevada, Oregon, Black Hills | — | 1 | — | Fruit edible. Grows in moist sites and along streams and river bottoms. One species reported growing as a phreatophyte in Big Smoky Valley, Nev. Occurs also as a phreatophyte in Mason Valley, Nev. |
| *Sporobolus airoides* Torrey | Alkali sacaton | Western United States | 5–25± | 1–3 | 3.7 | Most common in the Southwest where it is important as forage; deep, coarse root system. Prefers moist alkali flats. Grows in very saline or saline-alkali soils. Soil salinity may range from 0.3 to 3.0 percent. Grows best in range 0.3 to 0.5 percent |
| *wrightii* Munro | Sacaton | Arizona to western Texas | — | 1–2 | — | Occurs in alluvial flats and bottom lands. Will not grow on highly alkaline soils |
| *Suaeda depressa* Watson | Seepweed, saltwort | Southwest | — | 3 | — | Browsed when other forage is scarce. Occurs on saline or saline-alkali soils with salt content in first foot as much as 3.2 percent |
| *Suaeda suffrutescens* Watson | Desert seepweed | Western Texas, New Mexico, Arizona | — | 3 | — | Browsed when other forage is scarce. Occurs on saline or saline-alkali soils with salt content in first foot as much as 3.2 percent |
| *torreyana* Watson | Torrey seepweed, iodineweed, inkweed | Eastern Oregon to New Mexico and California | 4–15 | 3 | — | Browsed when other forage is scarce. Occurs on saline or saline-alkali soils with salt content in first foot as much as 3.2 percent |
| *Tamarix aphylla* Linnaeus | Athel tree | Southwest | — | 1–3 | — | |
| *Gallica* Linnaeus | Saltcedar, French tamarisk | Southwest | — | 1–3 | — | |
| *Washingtonia filifera* Wendland | Fan palm, California palm | Southern Arizona, California, SE New Mexico | — | 1–3 | — | Highly tolerant to alkali. Generally grows where groundwater is at shallow depth |

*Note:* The quality of the groundwater with respect to its suitability for crop growth is indicated by numerals as follows: 1 = excellent to good; 2 = good to poor; 3 = poor to unsatisfactory. The use of groundwater, including precipitation, unless otherwise stated is presumed to be for a plant growth of 100-percent volume density.

*Source*: U.S. Geological Survey.

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CHAPTER 5

# Surface Water

**Christopher Spooner**

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## SECTION 5A RIVERS

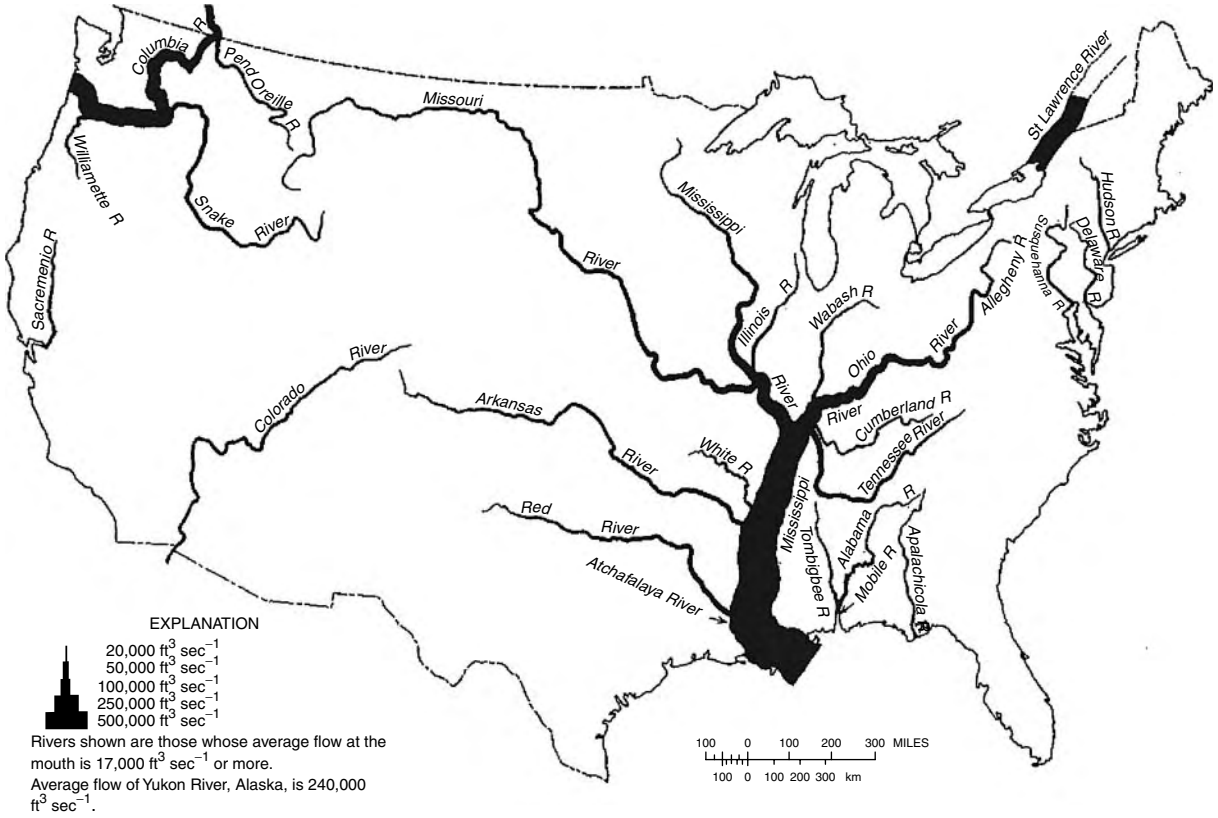


**Figure 5A.1** Large rivers in the United States. (From Iseri, K.T., and W.B. Langbein, *Large Rivers of the United States*, U.S. Geol. Survey Circular 686, 1974.)

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**Table 5A.1 Average Discharge at Downstream Gaging Stations on Large Rivers of the United States, 1931–1960, and 1941–1970**

| River | Gaging-Station Location | Drainage Area (Square Miles) | Average Discharge (1931–1960) ($ft^3$/sec) | Average Discharge (1941–1970) ($ft^3$/sec) |
|---|---|---|---|---|
| Alabama | At Claiborne, AL | 22,000 | 31,140 | 31,510 |
| Allegheny | At Natrona, PA | 11,410 | 19,200 | 18,810 |
| Apalachicola | At Chattahoochee, FL | 17,200 | 20,700 | 21,700 |
| Arkansas | At Little Rock, AR | 158,000 | 41,300 | 42,130 |
| Atchafalaya[a] | At Krotz Springs, LA | 93,320 | 160,800[b] | 180,800[b] |
| Colorado | Below Hoover Dam, AZ–NV[c] | 167,800 | 14,580[d] | 14,530 |
| Columbia | At The Dalles, OR | 237,000 | 183,000 | 189,000 |
| Cumberland | Near Grand Rivers, KY | 17,598 | 26,900 | 28,030[e] |
| Delaware | At Trenton, NJ[f] | 9,397 | 16,100 | 14,500[g] |
| Hudson | At Green Island, NY | 8,090 | — | 12,520[h] |
| Illinois | At Merdosia, IL | 25,300 | 20,500 | 20,670 |
| Mississippi | At Alton, IL | 171,500 | 91,300 | 98,300 |
| Mississippi | At Vicksburg, MS | 1,144,500 | 554,000 | 565,300 |
| Missouri | At Hermann, MO | 528,200 | 69,200 | 76,200 |
| Ohio | At Metropolis, IL | 203,000 | 257,000 | 257,200 |
| Pend Oreille | At international boundary | 25,200 | 26,900 | 28,420 |
| Red | At Alexandria, LA | 67,412 | 32,470 | 32,100 |
| Sacramento | At Verona, CA[i] | — | 25,700 | 27,200 |
| St. Lawrence | At Cornwall, Ontario-near Massena, NY[j] | 299,000 | 233,000[k] | 239,000[k] |
| Snake | Near Clarkston, WA | 103,200 | 48,600 | 48,960 |
| Susquehanna | At Marietta, PA | 25,990 | 36,100 | 35,060 |
| Tennessee | Near Paducah, KY | 40,200 | 63,400 | 64,050[f] |
| Tombigbee | At Jackson Lock and Dam near Coffeeville, AL | 18,500 | 25,200 | 25,130 |
| Wabash | At Mount Carmel, IL | 28,600 | 26,400 | 26,600 |
| White | At Clarendon, AR | 25,497 | 29,490 | 29,360 |
| Willamette | At Salem, OR | 7,280 | 23,870 | 24,780 |
| Yukon | At Ruby, AK | 259,000 | — | 170,000[l] |

[a] Continuation of Red River.
[b] Includes diversion from Mississippi River through Old River or Old River diversion channel.
[c] Very little tributary flow downstream. Downstream station located at Yuma, AZ., drainage area 242,900 square miles. The greater part of the natural flow is diverted for irrigation and other uses in the basin above Yuma. Average flow at Yuma, 1963–1970, is less than 1,000 $ft^3sec^{-1}$.
[d] For the period 1934–1960.
[e] Interbasin diversion beginning June 1966 between Lake Barkley on Cumberland River and Lake Kentucky on Tennessee River through Barkley–Kentucky Canal.
[f] Five tributaries below Trenton have been added.
[g] Unadjusted for diversion by New York City reservoirs since 1954.
[h] October 1946 to September 1970 (24 years).
[i] American River and Yolo bypass have been added.
[j] Formerly at Ogdensburg, NY
[k] Furnished by the U.S. Army Corps of Engineers through International St. Lawrence River Board of Control.
[l] Average is for 1957–1970; station operated only since 1956.

*Source*: From Iseri, K.T., and W.B. Langbein, 1974, *Large Rivers of the United States*, U.S. Geol. Survey Circular 686.

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**Table 5A.2 Flow of Selected Streams in the United States**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | **Alabama** | | | | | |
| | **South Atlantic–Gulf Region Choctawhatcheee-Wseambia Subregion** | | | | | |
| 1. | Choctawhatchee River, Newton | 686 | 1923–1926 | 88 | 983 | 40,900 |
| | | | 1937–1983 | | | |
| 2. | Conecuh River, Brantley | 500 | 1937–1983 | 31 | 680 | 27,300 |
| | **Alabama Subregion** | | | | | |
| 3. | Coosa River, Childersburg | 8,392 | 1915–1968 | 2,000 | 13,860 | 157,600 |
| | | | 1969–1978 | 1,330 | 13,860 | 144,900 |
| 4. | Tallapoosa River, Wadley | 1,675 | 1923–1983 | 140 | 2,594 | 73,800 |
| 5. | Alabama River, Montgomery | 15,087 | 1927–1968 | 5,240 | 24,260 | 317,000 |
| | | | 1969–1983 | 3,860 | 24,260 | 219,500 |
| | **Mobile–Tombigbee Subregion** | | | | | |
| 6. | Cahaba River, Centreville | 1,027 | 1902–1907 | 143 | 1,633 | 117,000 |
| | | | 1931 | | | |
| | | | 1937–1983 | | | |
| 7. | Mulberry Fork, Garden City | 365 | 1928–1983 | 4.9 | 681 | 51,300 |
| 8. | Black Warrior River, Northport | 4,820 | 1895–1902 | 90 | 8,041 | 221,000 |
| | | | 1929–1960 | | | |
| | | | 1961–1983 | 504 | 8,041 | 305,400 |
| 9. | Tombigbee River, Coatopa | 15,385 | 1928–1983 | 685 | 23,500 | |
| | **Tennessee Region** | | | | | |
| | **Middle Tennessee-Elk Subregion** | | | | | |
| 10. | Flint River, Chase | 342 | 1930–1983 | 66 | 554 | 75,200 |
| 11. | Tennessee River, Florence | 30,810 | 1984–1983 | 7,490 | 51,900 | — |
| | **Alaska** | | | | | |
| | **Alaska Region** | | | | | |
| | **Southeast Alaska Subregion** | | | | | |
| 1. | Stikine River, Wrangell | 19,920 | 1976–1983 | 4,500[a] | 56,674 | 299,600[a] |
| 2. | Fish Creek, Ketchikan | 32.1 | 1915–1936[b] | 31 | 421 | 5,420 |
| | | | 1938–1983 | | | |
| | **South-Central Alaska Subregion** | | | | | |
| 3. | Copper River, Chitina | 20,600 | 1955–1983 | 3,040 | 37,670 | 321,000 |
| 4. | Susitna River, Gold Creek | 6,160 | 1949–1983 | 723 | 9,724 | 115,000 |
| 5. | Susitna River, Susitna Station | 19,400 | 1974–1983 | 5,000[a] | 49,940 | 230,000[a] |
| | **Southwest Alaska Subregion** | | | | | |
| 6. | Kvichak River, Igiugig | 6,500 | 1967–1983 | 7,380 | 18,060 | 66,500 |
| 7. | Nuyakuk River, Dillingham | 1,490 | 1953–1983 | 1,100 | 6,156 | 36,200 |
| 8. | Nushagak River, Ekwok | 9,850 | 1977–1983 | 6,000[a] | 23,840 | 89,200[a] |
| 9. | Kuskokwim River, Crooked Creek | 31,100 | 1951–1983 | 7,850 | 41,220 | 445,000 |
| | **Yukon Subregion** | | | | | |
| 10. | Yukon, River, Eagle | 113,500 | 1911–1913[b] | 10,500 | 82,660 | 605,000 |
| | | | 1950–1983 | | | |
| 11. | Porcupine River, Fort Yukon | 29,500 | 1964–1979 | 6[b] | 14,230 | 476,000 |
| 12. | Chena River, Fairbanks | 1,980 | 1948–1983 | 150 | 1,384 | 38,800[c] |
| 13. | Tanana River, Nenana | 25,600 | 1962–1983 | 4,740 | 23,550 | 153,000[d] |
| 14. | Koyukuk River, Hughes | 18,700 | 1960–1982 | 267 | 14,540 | 332,000[e] |
| 15. | Yukon River, Pilot Station | 321,000 | 1975–1983 | 37,000[a] | 219,600 | 751,000[a] |
| | **Northwest Alaska Subregion** | | | | | |
| 16. | Kobuk River, Kiana | 9,520 | 1976–1983 | 1,300[a] | 15,270 | 152,000[a] |
| | **Arctic Subregion** | | | | | |
| 17. | Kaparuk River, Deadhorse | 3,130 | 1971–1983 | No flow | 1,367 | 218,000 |
| | **Arizona** | | | | | |
| | **Lower Colorado River Basin** | | | | | |
| 1. | Colorado River, Lees Ferry | 111,800 | 1912–1962 | 1,670 | 17,850 | 189,500 |
| | | | 1965–1984 | — | — | — |
| 2. | Colorado River, below Hoover Dam | 171,700 | 1935–1984 | 2,550 | 13,590 | — |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 3. | Bill Williams River, below Alamo Dam | 4,730 | 1940–1968 | 0.72 | 92.3 | 325,000 |
| 4. | Colorado River, above Morelos Dam | 246,700 | 1950–1984 | 541 | — | — |
| | **Little Colorado Subregion** | | | | | |
| 5. | Little Colorado River, Cameron | 26,500 | 1974–1984 | — | 244 | 32,800 |
| | **Upper Gila Subregion** | | | | | |
| 6. | Gila River, Clifton | 4,010 | 1928–1984 | 8.15 | 192 | 30,600 |
| 7. | Gila River, Solomon | 7,896 | 1914–1984 | 22.0 | 468 | 86,800 |
| | **Middle Gila Subregion** | | | | | |
| 8. | San Pedro River, Palominas | 741 | 1950–1981 | 0.03 | 32.1 | 21,800 |
| 9. | San Pedro River, Winkelman | 4,471 | 1966–1979 | — | 57.1 | — |
| 10. | Gila River, Kelvin | 18,011 | 1912–1984 | 0.82 | 494 | 244,000 |
| 11. | Santa Cruz River, Tucson | 2,222 | 1915–1981 | — | 22.7 | 20,300 |
| | **Salt Subregion** | | | | | |
| 12. | Black River, Fort Apache | 1,232 | 1958–1984 | 16.7 | 412 | 56,100 |
| 13. | White River, Fort Apache | 632 | 1958–1984 | 4.80 | 201 | 11,900 |
| 14. | Salt River, Roosevelt | 4,306 | 1925–1984 | 81.9 | 888 | 164,000 |
| 15. | Verde River, above Horseshoe Dam | 5,872 | 1945–1984 | 72.5 | 564 | 158,000 |
| | **Arkansas** | | | | | |
| | **Lower Mississippi Region** | | | | | |
| | **Mississippi River Main Stem** | | | | | |
| 1. | Mississippi River, Memphis, TN | 932,800 | 1933–1981 | 99,000 | 474,200 | 1,860,000 |
| | **Lower Mississippi–St. Francis Subregion** | | | | | |
| | **St. Francis River Basin** | | | | | |
| 2. | St. Francis Bay, Riverfront | — | 1936–1975 | 57 | 5,274 | — |
| | | | 1978–1981 | | | |
| | | | 1944–1975 | 83 | — | — |
| | | | 1978–1981 | | | |
| | **Lower Red–Ouachita Subregion** | | | | | |
| 3. | Ouachita River, Malvern | 1,585 | 1928–1984 | 105 | 2,380 | 194,000 |
| | | | 1954–1984 | 244 | | |
| 4. | Ouachita River, Camden | 5,357 | 1928–1984 | 236 | 7,490 | 299,000 |
| | | | 1954–1984 | 548 | — | — |
| 5. | Smackover Creek, Smackover | 385 | 1961–1983 | 0.35 | 374 | 39,700 |
| 6. | Saline River, Rye | 2,102 | 1937–1983 | 12.6 | 2,590 | 102,000 |
| 7. | Bayou Bartholomew, McGehee | 576 | 1939–1942 | 6.5 | 676 | 6,930 |
| | | | 1946–1984 | | | |
| | **Arkansas–White–Red Region** | | | | | |
| | **Upper White Subregion** | | | | | |
| | **White River Basin** | | | | | |
| 8. | Buffalo River, St. Joe | 829 | 1939–1984 | 16.5 | 1,027 | 176,000 |
| 9. | White River, Calico Rock | 9,978 | 1939–1983 | 894 | 9,830 | 352,000 |
| | | | 1945–1983 | 973 | — | — |
| | | | 1958–1983 | 1,120 | — | — |
| 10. | Spring River, Imboden | 1,183 | 1936–1983 | 279 | 1,360 | 163,000 |
| 11. | Black River, Black Rock | 7,369 | 1929–1931 | 1,980 | 8,410 | 176,000 |
| | | | 1939–1983 | | | |
| | | | 1950–1983 | 1,990 | — | — |
| 12. | Middle Fork Little Red River, Shirley | 302 | 1939–1983 | $<0.19$ | 467 | 140,000 |
| 13. | White River, Clarendon | 25,555 | 1928–1981 | 4,090 | 29,510 | 291,000 |
| | | | 1945–1981 | 5,050 | — | — |
| | | | 1958–1981 | 6,020 | — | — |
| | **Lower Arkansas Subregion** | | | | | |
| | **Arkansas River Basin** | | | | | |
| 14. | Poteau River, Cauthron | 203 | 1939–1983 | $<0.1$ | 215 | 47,100 |
| | | | 1950–1983 | $<0.1$ | — | — |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 15. | Mulberry River, Mulberry | 373 | 1938–1983 | <0.16 | 534 | 82,400 |
| 16. | Big Piney Creek, Dover | 274 | 1950–1983 | 0.15 | 398 | 112,000 |
| 17. | Petit Jean River, Danville | 764 | 1916–1984 | 0.74 | 809 | 91,900 |
| | | | 1949–1984 | 1.9 | — | — |
| 18. | Arkansas River, Murray Dam | 158,030 | 1927–1984 | 1,230 | 40,290 | 588,000 |
| | **Red–Sulphur Subregion** | | | | | |
| | **Red River Basin** | | | | | |
| 19. | Red River, Index | 48,030 | 1936–1984 | 812 | 11,170 | 190,000 |
| | | | 1945–1984 | 934 | — | — |
| | | | 1969–1984 | 1,110 | — | — |
| | **California** | | | | | |
| | **California Region** | | | | | |
| | **Sacramento Subregion** | | | | | |
| 1. | Feather River, Nicolaus | 5,921 | 1944–1969 | 169 | 7,957 | 521,000 |
| | | | 1970–1983 | 1,061 | 9,424 | 332,000 |
| 2. | Sacramento River, Verona | 21,251 | 1930–1969 | 1,618 | 18,240 | 77,700[f] |
| | | | 1970–1983 | 5,732 | 22,680 | 94,700[f] |
| 3. | American River Fair Oaks | 1,888 | 1906–1955 | 64 | 3,735 | 257,000 |
| | | | 1956–1983 | 426 | 3,942 | 150,000 |
| | **Tulare–Buena Vista Lakes and San Joaquin Subregions** | | | | | |
| 4. | Kern River, Kernville | 846 | 1912–1984 | 104 | 762 | 45,800 |
| 5. | Kings River, Trimmer | 1,342 | 1953–1983 | 111 | 2,177 | 135,000 |
| 6. | Merced River, Stevinson | 1,273 | 1941–1983 | 52 | 733 | 14,400 |
| 7. | San Joaquin River, Vernalis | 13,536 | 1930–1983 | 241 | 4,783 | 99,900 |
| | **Southern California Coastal Subregion** | | | | | |
| 8. | San Diego River, Santee | 377 | 1914–1943 | 0.1 | 42.3 | 54,900 |
| | | | 1944–1982 | 1.0 | 13.7 | 5,400 |
| 9. | Santa Margarita River, Ysidora | 740 | 1924–1948 | 0 | 43.3 | 46,000 |
| | | | 1949–1983 | 0 | 31.0 | 32,000 |
| 10. | Santa Ana River, Santa Ana | 1,700 | 1942–1984 | 0 | 52.8 | 33,800 |
| 11. | Los Angeles River, at Long Beach | 827 | 1930–1940 | 0.1 | 110 | 192,000 |
| | | | 1941–1982 | 3.8 | 222 | 118,000 |
| 12. | Santa Clara River, Los Angeles–Ventura County Line | 625 | 1953–1971 | 0.1 | 36.2 | 161,000 |
| | | | 1972–1984 | 2.9 | 67.8 | 58,500 |
| | **Central California Coastal Subregion** | | | | | |
| 13. | Salinas River, Spreckels | 4,156 | 1930–1941 | 0.1 | 659 | 145,000[g] |
| | | | 1942–1965 | 0.5 | 262 | 145,000[g] |
| | | | 1966–1984 | 0.6 | 590 | 145,000[g] |
| 14. | San Lorenzo River, Big Trees | 106 | 1937–1984 | 9.2 | 140 | 39,600 |
| | **Klamath–Northern California Coastal Subregion** | | | | | |
| 15. | Russian River, Guerneville | 1,338 | 1940–1958 | 77 | 2,230 | 108,000 |
| | | | 1959–1983 | 40 | 2,435 | 93,400 |
| 16. | Eel River, Scotia | 3,113 | 1911–1984 | 43 | 7,412 | 608,000 |
| 17. | Klamath River, Klamath | 12,100 | 1911–1984 | 1,859 | 18,110 | 556,000 |
| 18. | Smith River, Crescent City | 609 | 1932–1984 | 191 | 3,891 | 231,000 |
| | **Great Basin Region** | | | | | |
| | **Central Lahontan Subregion** | | | | | |
| 19. | Truckee River, Tahoe City | 507 | 1910–1984 | 2.4 | 240 | 2,830 |
| | **Colorado** | | | | | |
| | **Missouri Region** | | | | | |
| | **North and South Platte Subregions** | | | | | |
| 1. | North Platte River, Northgate | 1,431 | 1915–1984 | 35 | 440 | 7,870 |
| 2. | South Platte River, Hartsel | 880 | 1933–1984 | 3.3 | 79.1 | 2,410 |
| 3. | South Platte River, Kersey | 9,598 | 1901–1984 | 51 | 834 | 40,400 |
| 4. | South Platte River, Julesburg | 23,138 | 1902–1984 | 7.6 | 524 | 62,300 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | **Arkansas–White–Red Region** | | | | |
| | | **Upper Arkansas Subregion** | | | | |
| 5. | Arkansas River, Canon City | 3,117 | 1888–1981 | 129 | 715 | 14,300 |
| 6. | Arkansas River, La Junta | 12,210 | 1912–1973 | 4.8 | 244 | 96,300 |
| | | | 1974–1984 | 3.8 | 233 | 19,300 |
| 7. | Purgatoire River, Trinidad | 795 | 1895–1976 | 2.7 | 83.3 | 34,400 |
| | | | 1977–1981 | — | 64.3 | — |
| 8. | Purgatoire River, Las Animas | 3,503 | 1922–1931 | 0.34 | 116 | 94,000 |
| | | | 1948–1976 | | | |
| | | | 1977–1984 | — | 81.0 | — |
| 9. | Arkansas River Lamar | 19,780 | 1913–1942 | 1.1 | 301 | 131,000 |
| | | | 1948–1984 | 0.63 | 93.6 | 35,500 |
| | | **Rio Grande Region** | | | | |
| | | **Rio Grande Headwaters Subregion** | | | | |
| 10. | Rio Grande, Del Norte | 1,320 | 1889–1984 | 107 | 901 | 13,400 |
| 11. | Rio Grande, Lobatos | 7,700 | 1899–1984 | 7.1 | 575 | 19,900 |
| | | **Upper Colorado Region** | | | | |
| | | **Colorado Headwaters Subregion** | | | | |
| 12. | Colorado River, near Dotsero | 4,394 | 1940–1984 | 536 | 2,136 | 23,800 |
| 13. | Colorado River, Cameo | 8,050 | 1933–1984 | 997 | 3,900 | 41,900 |
| | | **Gunnison Subregion** | | | | |
| 14. | Gunnison River, Gunnison | 1,012 | 1940–1928 | 148 | 888 | 11,500 |
| | | | 1944–1984 | 115 | 709 | 9,000 |
| 15. | Gunnison River Grand Junction | 7,928 | 1896–1965 | 265 | 2,611 | 38,100 |
| | | | 1968–1984 | 495 | 2,659 | 30,500 |
| | | **White–Yampa Subregion** | | | | |
| 16. | Yampa River, Maybell | 3,410 | 1916–1984 | 39 | 1,573 | 19,900 |
| 17. | White River, Meeker | 755 | 1901–1984 | 179 | 626 | 6,570 |
| | | **San Juan Subregion** | | | | |
| 18. | Animas River, Durango | 692 | 1912–1984 | 128 | 819 | 15,500 |
| | | **Connecticut** | | | | |
| | | **New England Region** | | | | |
| | | **Connecticut Subregion** | | | | |
| | | **Connecticut River Basin** | | | | |
| 1. | Connecticut River, Thompsonville | 9,661 | 1928–1983 | 2,200 | 16,400 | 209,000 |
| 2. | Burlington Brook, Burlington | 4.10 | 1931–1983 | 0.7 | 8.3 | 1,250 |
| 3. | Farmington River, Rainbow | 590 | 1928–1960 | 144 | 1,030 | 44,000 |
| | | | 1961–1983 | 101 | 1,040 | 24,000 |
| 4. | Salmon Silver, East Hampton | 100 | 1928–1983 | 5.2 | 184 | 16,600 |
| | | **Connecticut Coastal Subregion** | | | | |
| | | **Thames River Basin** | | | | |
| 5. | Mount Hope River, Warrenville | 28.6 | 1940–1983 | 0.9 | 51.2 | 5,620 |
| 6. | Shetucket River, Willimantic | 404 | 1928–1952 | 46.5 | 667 | 25,000 |
| | | | 1953–1983 | 44.2 | 734 | 22,500 |
| 7. | Quinebaug River, Jewett City | 713 | 1918–1958 | 119 | 1,250 | 29,500 |
| | | | 1959–1983 | 90.0 | 1,330 | 26,500 |
| 8. | Yantic River, Yantic | 89.3 | 1930–1983 | 5.2 | 165 | 10,800 |
| | | **Quinnipiac River Basin** | | | | |
| 9. | Quinnipiac River, Wallingford | 115 | 1930–1983 | 32.6 | 211 | 6,340 |
| | | **Housatonic River Basin** | | | | |
| 10. | Housatonic River, Falls Village | 634 | 1912–1983 | 119 | 1,090 | 24,000 |
| 11. | Shepaug River, Roxbury | 132 | 1930–1971 | 6.2 | 236 | 24,000 |
| 12. | Pomperaug River, Southbury | 75.1 | 1932–1983 | 6.0 | 128 | 19,900 |
| 13. | Housatonic River, Stevenson | 1,544 | 1928–1983 | 160 | 2,600 | 95,100 |
| 14. | Naugatuck River, Beacon Falls | 260 | 1928–1959 | 61.2 | 484 | 46,000 |
| | | | 1960–1983 | 59.4 | 557 | 23,000 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | | **Saugatuck River Basin** | | | |
| 15. | Saugatuck River, Westport | 79.8 | 1932–1967 | 2.25 | 119 | 13,400 |
| | | | **Delaware** | | | |
| | | | **Mid-Atlantic Region** | | | |
| | | | **Delaware Subregion** | | | |
| | | | **Christina River Basin** | | | |
| 1. | Christina River, Coochs Bridge | 20.5 | 1943–1984 | 1.5 | 28.8 | 4,840 |
| 2. | Brandywine Creek, Wilmington | 314 | 1946–1984 | 75 | 488 | 34,300 |
| | | | **Upper Chesapeake Subregion** | | | |
| | | | **Indian River Basin** | | | |
| 3. | Stockley Branch, Stockley | 5.24 | 1943–1984 | 0.66 | 7.04 | 200 |
| | | | **Nanticoke River Basin** | | | |
| 4. | Nanticoke River, Bridgeville | 75.4 | 1943–1984 | 15 | 92.8 | 3,570 |
| | | | **Florida** | | | |
| | | | **South Atlantic–Gulf Region** | | | |
| | | | **Altamaha–St. Marys Subregion** | | | |
| 1. | St. Marys River, Macclenny | 700 | 1927–1983 | 18 | 672 | 40,500 |
| | | | **St. Johns Subregion** | | | |
| 2. | St. Johns River, Christmas | 1,539 | 1934–1983 | 24 | 1,310 | 18,500 |
| 3. | St. Johns River, DeLand | 3,066 | 1934–1983 | 0 | 3,120 | 21,900 |
| 4. | Oklawaha River, | 2,747 | 1944–1968 | 788 | 2,020 | 12,900 |
| | Rodman Dam | | 1969–1983 | — | 1,550 | — |
| | | | **Southern Florida Subregion** | | | |
| 5. | Fisheating Creek, Palmdale | 311 | 1932–1983 | 0 | 257 | 21,400 |
| 6. | Kissimmee River, | 2,886 | 1929–1962 | 809 | 2,190 | 29,800 |
| | S-65E near Okeechobee | | 1964–1983 | 36 | 1,390 | |
| | | | **Peace–Tampa Bay Subregion** | | | |
| 7. | Peace River, Acradia | 1,367 | 1932–1983 | 57 | 1,150 | 34,400 |
| 8. | Hillsborough River, Zephyrhills | 220 | 1940–1983 | 53 | 259 | 10,300 |
| 9. | Withlacoochee River, Holder | 1,825 | 1932–1983 | 158 | 1,090 | 9,750 |
| | | | **Suwannee Subregion** | | | |
| 10. | Suwannee River, Branford | 7,880 | 1932–1983 | 1,790 | 6,940 | 68,000 |
| 11. | Santa Fe River, Fort White | 1,017 | 1928–1929 | 730 | 1,610 | 16,400 |
| | | | 1933–1983 | | | |
| 12. | Suwannee River, Wilcox | 9,640 | 1931 | 4,020 | 10,400 | 66,400 |
| | | | 1942–1983 | | | |
| | | | **Ochlockonee Subregion** | | | |
| 13. | Ochlockonee River, Havana | 1,140 | 1927–1983 | 30 | 1,030 | 41,200 |
| | | | **Apalachicola Subregion** | | | |
| 14. | Apalachicola River, Chattahoochee | 17,200 | 1929–1983 | 7,000 | 22,400 | 264,000 |
| | | | **Choctawhatchee–Escambia Subregion** | | | |
| 15. | Choctawhatchee River, Bruce | 4,384 | 1931–1983 | 1,630 | 7,140 | 128,000 |
| 16. | Yellow River, Milligan | 624 | 1939–1983 | 184 | 1,170 | 45,900 |
| 17. | Shoal River, Crestview | 474 | 1939–1983 | 291 | 1,100 | 33,600 |
| 18. | Escambia River, Century | 3,817 | 1935–1983 | 777 | 6,360 | 179,000 |
| 19. | Perdido River, Barrineau Park | 394 | 1942–1983 | 221 | 766 | 34,200 |
| | | | **Georgia** | | | |
| | | | **South Atlantic–Gulf Region** | | | |
| | | | **Ogeechee–Savannah Subregion** | | | |
| 1. | Broad River, Bell | 1,430 | 1927–1932 | 200 | 1,809 | 60,400 |
| | | | 1937 | | | — |
| 2. | Savannah River, Augusta | 7,508 | 1960–1981 | 5,500 | 10,200 | — |
| | | | **Altamaha–St. Marys Subregion** | | | |
| 3. | Oconee River, Greensboro | 1,090 | 1903–1932 | 150 | 1,446 | 50,700 |
| | | | 1936–1978 | | | |
| 4. | Altamaha River, Doctortown | 13,600 | 1931–1983 | 2,250 | 13,770 | 225,000 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 5. | Penholoway Creek, Jesup | 210 | 1958–1983 | 0 | 201 | 7,180 |
| | **Suwannee Subregion** | | | | | |
| 6. | Alapaha River, Statenville | 1,400 | 1931–1983 | 25 | 1,044 | 24,200 |
| | **Apalachicola Subregion** | | | | | |
| 7. | Chattahoochee River, Atlanta | 1,450 | 1959–1981 | 860 | 2,840 | — |
| 8. | Flint River, Culloden | 1,850 | 1911–1923<br>1928–1931<br>1937–1983 | 180 | 2,402 | 99,100 |
| 9. | Flint River, Albany | 5,310 | 1901–1921<br>1929–1983 | 1,000 | 6,303 | 94,600 |
| | **Alabama Subregion** | | | | | |
| 10. | Etowah River, Allatoona Dam | 1,120 | 1950–1981 | 240 | 1,944 | — |
| | **Tennessee Region** | | | | | |
| | **Middle Tennessee–Hiawassee Subregion** | | | | | |
| 11. | Toccoa River, Dial | 177 | 1912–1983 | 125 | 498 | 16,600 |
| | **Hawaii** | | | | | |
| | **Hawaii Region** | | | | | |
| | **Kauai Subregion** | | | | | |
| 1. | East Branch of North Fork Wailua River near Lihue | 6.27 | 1916–1983 | 10.4 | 48.6 | 10,400 |
| | **Oahu Subregion** | | | | | |
| 2. | Kalihi Stream, near Honolulu | 2.61 | 1917–1983 | 0.29 | 6.74 | 10,400 |
| | **Maui Subregion** | | | | | |
| 3. | Honopou Stream near Huolo | 0.64 | 1911–1983 | 0.26 | 4.69 | 4,410 |
| | **Hawaii Subregion** | | | | | |
| 4. | Waiakea Stream near Mountain View | 17.4 | 1931–1983 | 0.10 | 11.8 | 1,140 |
| | **Idaho** | | | | | |
| | **Great Basin Region** | | | | | |
| | **Bear Subregion** | | | | | |
| | **Bear River Basin** | | | | | |
| 1. | Bear River, Preston | 4,545 | 1944–1984 | 80 | 937 | 8,190 |
| | **Pacific Northwest Region** | | | | | |
| | **Kootenai–Pond Oreille–Spokane Subregion** | | | | | |
| | **Pend Oreille River Basin** | | | | | |
| 2. | Priest River, Priest River | 902 | 1904<br>1930–1984 | 200 | 1,686 | 11,500 |
| | **Spokane River Basin** | | | | | |
| 3. | Spokane River, Post Falls | 3,340 | 1913–1984 | 180 | 6,297 | 46,000 |
| | **Upper Snake Subregion** | | | | | |
| 4. | Snake River, Irwin | 5,225 | 1950–1984 | 560 | 6,691 | 31,700 |
| 5. | Henrys Fork, Rexburg | 2,920 | 1910–1984 | 400 | 2,088 | 12,100 |
| 6. | Portneuf River, Pocatello | 1,250 | 1913–1916<br>1918–1984 | 14 | 280 | 2,650 |
| 7. | Snake River, Milner | 17,180 | 1910–1926<br>1927–1984 | 5<br>— | 2,711<br>— | 42,400<br>28,300 |
| 8. | Big Lost River, below Mackay Reservoir, Mackay | 813 | 1905<br>1913–1914<br>1920–1984 | 36 | 314 | 3,280 |
| 9. | Big Wood River below Magic Dam, Richfield | 1,600 | 1913–1984 | 2 | 480 | 10,400 |
| | **Middle Snake Subregion** | | | | | |
| 10. | Snake River, King Hill | 35,800 | 1910–1926<br>1927–1984 | 6,000<br>— | 10,910<br>— | 54,600<br>39,100 |
| 11. | Bruneau River, Hot Spring | 2,630 | 1904–1914<br>1943–1984 | 47 | 409 | 7,500 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 12. | Boise River, Boise | 2,680 | 1953–1984 | 1 | 2,951 | 10,000 |
| 13. | Payette River, Payette | 3,240 | 1936–1984 | 400 | 3,183 | 10,000 |
| 14. | Weiser River, Weiser | 1,460 | 1953–1984 | 54 | 1,132 | 26,000 |
| 15. | Snake River, Weiser | 69,200 | 1911–1984 | 6,600 | 18,490 | 10,000 |
| | **Lower Snake Subregion** | | | | | |
| 16. | Salmon River, White Bird | 13,550 | 1911–1917 | 2,400 | 11,420 | 126,000 |
| | | | 1920–1984 | | | |
| 17. | Clearwater River, Spalding | 9,570 | 1910–1913 | 1,500 | 15,550 | 188,000 |
| | | | 1925–1984 | | | |
| | **Illinois** | | | | | |
| | **Upper Mississippi Region** | | | | | |
| | **Upper and Lower Illinois Subregions** | | | | | |
| | **Illinois River Main Stem** | | | | | |
| 1. | Illinois River, Marseilles | 8,259 | 1919–1983 | — | — | 91,100 |
| | | | 1940–1983 | 3,180 | 9,791 | — |
| 2. | Illinois River, Meredosia | 26,028 | 1921–1983 | — | — | 132,300 |
| | | | 1940–1983 | 3,630 | 21,976 | — |
| | **Illinois River Basin–Tributaries** | | | | | |
| 3. | Kankakee River, Wilmington | 5,150 | 1915–1983 | 463 | 4,233 | 68,100 |
| 4. | Des Plaines, River Riverside | 630 | 1914–1983 | — | — | 7,830 |
| | | | 1943–1983 | 6.0 | 471 | — |
| | | | 1974–1983 | 48 | — | — |
| 5. | Fox River, Dayton | 2,642 | 1915–1983 | 176 | 1,703 | 37,400 |
| | | | 1974–1983 | 366 | — | — |
| 6. | Vermillion River, Leonore | 1,251 | 1931–1983 | — | 822 | 40,700 |
| | | | 1973–1983 | 9.6 | — | — |
| 7. | Mackinaw River, Congerville | 767 | 1945–1983 | 1.3 | 511 | 43,900 |
| 8. | Spoon River, Seville | 1,636 | 1914–1983 | 20 | 1,054 | 37,600 |
| 9. | Sangamon River, Oakford | 5,093 | 1910–1983 | 147 | 3,335 | 82,800 |
| | | | 1974–1983 | 263 | — | — |
| 10. | La Moine River, Ripley | 1,293 | 1921–1983 | 10 | 802 | 27,500 |
| | **Rock Subregion** | | | | | |
| | **Rock River Basin** | | | | | |
| 11. | Pecatonica River, Freeport | 1,326 | 1914–1983 | 191 | 900 | 21,300 |
| 12. | Kishwaukee River, Perryville | 1,099 | 1940–1983 | 68 | 713 | 25,000 |
| 13. | Rock River, Joslin | 9,549 | 1940–1983 | 1,270 | 6,020 | 58,800 |
| 14. | Green River, Geneseo | 1,003 | 1936–1983 | 40 | 610 | 13,000 |
| | **Upper Mississippi–Kaskaskia–Meramec Subregion** | | | | | |
| | **Kaskaskia and Big Muddy River Basins** | | | | | |
| 15. | Kaskaskia River, Vandalia | 1,940 | 1908–1969 | 14 | 1,412 | 33,000 |
| | | | 1970–1983 | 34 | 1,769 | 30,400 |
| 16. | Big Muddy River, Murphysboro | 2,169 | 1916–1970 | — | — | 39,300 |
| | | | 1931–1970 | 2.3 | 1,788 | — |
| | | | 1971–1983 | 47 | 1,888 | 41,000 |
| | **Ohio Region** | | | | | |
| | **Wabash and Lower Ohio Subregions** | | | | | |
| | **Embarras and Little Wabash River Basins** | | | | | |
| 17. | Embarras River, Ste. Marie | 1,516 | 1910–1983 | 14 | 1,224 | 53,700 |
| 18. | Little Wabash, River, Carmi | 3,102 | 1940–1983 | 6.2 | 2,529 | 45,300 |
| | **Indiana** | | | | | |
| | **Ohio Region** | | | | | |
| | **Great Miami Subregion** | | | | | |
| | **Whitewater River Basin** | | | | | |
| 1. | Whitewater River, Alpine | 522 | 1928–1983 | 48 | 551 | 49,000 |
| | **Wabash Subregion** | | | | | |
| | **Wabash River Main Stem–White River Basin–Patoka River Basin** | | | | | |
| 2. | Muscatatuck River, Deputy | 293 | 1947–1983 | 0.0 | 348 | 41,200 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 3. | South Fork Patoka River, Spurgeon | 42.8 | 1964–1983 | 2.2 | 51.9 | 5,990 |
| 4. | Eagle Creek, Indianapolis | 174 | 1938–1968 | 0.5 | 148 | 18,400 |
| | | | 1969–1983 | 6.0 | 168 | 11,800 |
| 5. | Driftwood River, Edinburgh | 1,060 | 1940–1983 | 91 | 1,144 | 49,500 |
| 6. | Wabash River, Peru | 2,686 | 1943–1967 | 92 | 2,290 | 74,300 |
| | | | 1970–1983 | 155 | 2,500 | 31,000 |
| 7. | Wabash River, Mount Carmel, IL | 28,635 | 1927–1983 | 2,280 | 27,440 | 315,000 |
| | **Upper Mississippi Region** | | | | | |
| | **Upper Illinois Subregion** | | | | | |
| | **Kankakee River Basin** | | | | | |
| 8. | Kankakee River, Shelby | 1,779 | 1922–1983 | 417 | 1,619 | 6,950 |
| 9. | Iroquois River, Foresman | 449 | 1948–1983 | 11 | 383 | 5,660 |
| | **Great Lakes Region** | | | | | |
| | **Southeastern Lake Michigan Subregion** | | | | | |
| | **St. Joseph River Basin** | | | | | |
| 10. | St. Joseph River, Elkhart | 3,370 | 1947–1983 | 818 | 3,177 | 21,500 |
| 11. | Pigeon Creek Angola | 106 | 1947–1983 | 5.8 | 78.5 | 843 |
| | **Western Lake Erie Subregion** | | | | | |
| | **Maumee River Basin** | | | | | |
| 12. | Muamee River, New Haven | 1,967 | 1956–1983 | 72 | 1,645 | 25,600 |
| | **Iowa** | | | | | |
| | **Upper Mississippi Region** | | | | | |
| | **Mississippi River Main Stem** | | | | | |
| 1. | Mississippi River, Clinton | 85,600 | 1873–1983 | 10,050 | 47,390 | 295,000[h] |
| | **Northeast Iowa River Basin[i]** | | | | | |
| 2. | Upper Iowa River, Decorah | 511 | 1951–1983 | 32 | 327 | 22,400 |
| 3. | Turkey River, Garber | 1,545 | 1913–1916 | 81 | 949 | 33,100 |
| | | | 1919–1927 | | | |
| | | | 1929–1930 | | | |
| | | | 1932–1983 | | | |
| 4. | Maquoketa River, Maquoketa | 1,553 | 1913–1983 | 160 | 1,027 | 47,700 |
| 5. | Wapsipinicon River, De Witt | 2,330 | 1934–1983 | 98 | 1,537 | 31,600 |
| | **Iowa–Cedar River Basin[j]** | | | | | |
| 6. | Iowa River, Iowa City | 3,271 | 1903–1958 | 60 | 1,470 | 43,700 |
| | | | 1959–1983 | 93 | 2,180 | 17,400 |
| 7. | English River, Kalona | 573 | 1939–1983 | 2.3 | 370 | 25,300 |
| 8. | Shell Rock River, Shell Rock | 1,746 | 1953–1983 | 64 | 974 | 42,800 |
| 9. | Cedar River, Waterloo | 5,146 | 1940–1983 | 284 | 2,984 | 98,900 |
| 10. | Cedar River, Cedar Rapids | 6,510 | 1902–1983 | 347 | 3,414 | 83,500 |
| 11. | Iowa River, Wapello | 12,499 | 1914–1958 | 555 | 5,950 | 102,000 |
| | | | 1959–1983 | 893 | 8,650 | 116,000 |
| | **Skunk River Basin[j]** | | | | | |
| 12. | South Skunk River, Oskaloosa | 1,635 | 1945–1983 | 10 | 916 | 25,800 |
| 13. | North Skunk River, Sigourney | 730 | 1945–1983 | 2.3 | 436 | 27,400 |
| 14. | Skunk River, Augusta | 4,303 | 1914–1983 | 31 | 2,407 | 55,200 |
| | **Des Moines River Basin[k]** | | | | | |
| 15. | Des Moines River, Stratford | 5,452 | 1920–1983 | 40 | 1,882 | 54,600 |
| 16. | North Raccoon River, Jefferson | 1,619 | 1940–1983 | 8.3 | 708 | 27,200 |
| 17. | South Raccoon River, Redfield | 988 | 1940–1983 | 26 | 449 | 32,200 |
| 18. | Raccoon River, Van Meter | 3,441 | 1915–1983 | 34 | 1,346 | 46,500 |
| 19. | Des Moines River, Keosauqua | 14,038 | 1903–1906 | 143 | 5,160 | 123,000 |
| | | | 1911–1968 | | | |
| | | | 1969–1983 | 245 | 7,860 | 90,600 |
| | **Missouri Region** | | | | | |
| | **Missouri River Main Stem[l]** | | | | | |
| 20. | Missouri River, Sioux City | 314,600 | 1897–1956[m] | 3,810 | 30,000 | 437,000 |
| | | | 1957–1983 | 6,570 | 28,700 | 144,500[n] |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | | **Western Iowa River Basin[o]** | | | |
| 21. | Big Sioux River, Akron | 9,030 | 1928–1983 | 19 | 901 | 71,000 |
| 22. | Floyd River, James | 886 | 1934–1983 | 2.7 | 197 | 34,300 |
| 23. | Little Sioux River, Correctionville | 2,500 | 1918–1925<br>1928–1932<br>1936–1983 | 14 | 766 | 32,600 |
| 24. | Boyer River, Logan | 871 | 1918–1925<br>1937–1983 | 6.5 | 315 | 31,800 |
| | | | **Southern Iowa River Basin[p]** | | | |
| 25. | Nishnabotna River, Hamburg | 2,806 | 1922–1923<br>1928–1983 | 28 | 1,057 | 40,700 |
| 26. | Nodaway River, Clarinda | 762 | 1918–1925<br>1936–1983 | 5.8 | 338 | 37,900 |
| 27. | Thompson River, Davis City | 701 | 1918–1925<br>1941–1983 | 1.6 | 370 | 25,500 |
| 28. | Chariton River, Rathbun | 549 | 1956–1969<br>1970–1983 | 0.25<br>4.0 | 303<br>382 | 40,327<br>2,130 |
| | | | **Kansas** | | | |
| | | | **Missouri Region** | | | |
| | | | **Republican and Smoky Hill Subregions** | | | |
| | | | **Republican and Smoky Hill River Basins** | | | |
| 1. | Republic River, Clay Center | 24,542 | 1917–1983 | 75[q] | 990 | 76,000[q] |
| 2. | Smoky Hill River, Elkader | 3,555 | 1940–1983 | 0.0 | 30 | 70,000 |
| 3. | Solomon River, Niles | 6,770 | 1897–1903<br>1917–1983 | 33[q] | 550 | 51,000[r] |
| 4. | Smoky Hill River Enterprise | 19,260 | 1935–1983 | 120[q] | 1,600 | 85,000[r] |
| | | | **Kansas, Gasconade–Osage, and Missouri–Nishnabotna Subregions** | | | |
| | | | **Kansas, Osage, and Missouri River Basins** | | | |
| 5. | Kansas River, Fort Riley | 44,870 | 1964–1983 | 240[q] | 2,600 | 140,000[r] |
| 6. | Big Blue River, Manhattan | 9,640 | 1955–1983 | 18[q] | 2,000 | 50,000[r] |
| 7. | Kansas River, De Soto | 59,756 | 1917–1983 | 800[q] | 7,000 | 300,000[r] |
| 8. | Marais des Cygnes River, Kansas–Missouri State line | 3,230 | 1959–1983 | 2.5[q] | 2,000 | 67,000[q] |
| 9. | Missouri River, St. Joseph, MO | 420,300 | 1929–1983 | 6,100[q] | 42,000 | — |
| | | | **Arkansas–White–Red Regions** | | | |
| | | | **Middle Arkansas, Upper Cimarron, and Arkansas–Keystone Subregions** | | | |
| | | | **Arkansas River Basin** | | | |
| 10. | Arkansas River, Syracuse | 25,763 | 1902–1906<br>1921–1983 | 0.3[q] | 310 | 130,000[q] |
| 11. | Little Arkansas River, Valley Center | 1,327 | 1922–1983 | 10 | 280 | 43,000 |
| 12. | Arkansas River, Arkansas City | 43,713 | 1902–1906<br>1922–1983 | 170[q] | 1,800 | 99,000[r] |
| | | | **Middle Arkansas and Neosho–Verdigris Subregions** | | | |
| | | | **Walnut, Verdigris, and Neosho River Basins** | | | |
| 13. | Verdigris River, Independence | 2,892 | 1895–1904<br>1921–1983 | 9.0[q] | 1,700 | 72,000[r] |
| 14. | Neosho River, Parsons | 4,905 | 1922–1983 | 7.5[q] | 2,500 | 56,000[q] |
| | | | **Kentucky** | | | |
| | | | **Ohio Region** | | | |
| | | | **Middle and Lower Ohio Subregions** | | | |
| | | | **Ohio River Main Stem** | | | |
| 1. | Ohio River, Greenup Dam | 62,000 | 1968–1983 | 7,400 | 92,530 | 699,000 |
| 2. | Ohio River, Louisville | 91,170 | 1928–1983 | 8,200 | 115,700 | 862,000 |
| 3. | Ohio River, Metropolis, IL | 203,000 | 1928–1983 | 46,000 | 271,000 | 1,580,000 |
| | | | **Salt River Basin** | | | |
| 4. | Salt River, Shepherdsville | 1,197 | 1938–1983 | 0.22 | 1,572 | 61,900 |
| 5. | Rolling Fork, Boston | 1,299 | 1938–1983 | 2.3 | 1,801 | 65,600 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | **Big Sandy–Guyandotte Subregion** | | | | |
| 6. | Levisa Fork, Pikeville | 1,232 | 1937–1983 | 5.8 | 1,474 | 76,400 |
| | | **Kentucky–Licking Subregion** | | | | |
| | | **Licking River Basin** | | | | |
| 7. | Licking River, Catawba | 3,300 | 1914–1983 | 13 | 4,143 | 84,900 |
| | | **Kentucky River Basin** | | | | |
| 8. | Middle Fork Kentucky River, Tallega | 537 | 1930–1983 | 0.64 | 730 | 51,400 |
| 9. | Kentucky River, Salvisa | 5,102 | 1925–1983 | 136 | 6,737 | 125,000 |
| | | **Green Subregion** | | | | |
| | | **Green River Basin** | | | | |
| 10. | Green River, Munfordville | 1,673 | 1915–1983 | 73 | 2,722 | 70,300 |
| 11. | Pond River, Apex | 194 | 1940–1983 | 0 | 267 | 25,800 |
| | | **Cumberland Subregion** | | | | |
| | | **Cumberland River Basin** | | | | |
| 12. | Cumberland River, Williamsburg | 1,607 | 1959–1983 | 22 | 2,736 | 54,000 |
| 13. | Little River, Cadiz | 244 | 1940–1983 | 11 | 349 | 18,200 |
| | | **Tennessee Region** | | | | |
| | | **Lower Tennessee Subregion** | | | | |
| 14. | Tennessee River, Paducah | 40,200 | 1889–1983 | 8,190 | 64,060[s] | — |
| | | | | — | 65,450[t] | — |
| | | **Louisiana** | | | | |
| | | **South Atlantic–Gulf Region** | | | | |
| | | **Pearl Subregion** | | | | |
| | | **Pearl River Basin** | | | | |
| 1. | Pearl River, Bogalusa | 6,573 | 1939–1983 | 1,320 | 9,887 | 129,000 |
| 2. | Bogue Chitto, Bush | 1,213 | 1938–1983 | 460 | 1,915 | 93,200 |
| | | **Lower Mississippi Region** | | | | |
| | | **Mississippi River Main Stem[u]** | | | | |
| 3. | Mississippi River, Vicksburg, MO | 1,118,160 | 1929–1983 | 127,000 | 578,800 | 2,203,000 |
| 4. | Mississippi River, Tarbert Landing, MO | 1,124,900 | 1939–1983 | 142,000 | 514,200 | — |
| | | **Lower Red–Ouachita Subregion** | | | | |
| | | **Ouachita River Basin** | | | | |
| 5. | Big Creek, Pollock | 51 | 1943–1983 | 7.4 | 61.4 | 37,200 |
| | | **Lower Mississippi–Lake Maurepas Subregion** | | | | |
| 6. | Amite River, Denham Springs | 1,280 | 1939–1983 | 304 | 2,021 | 136,000 |
| 7. | Tangipahoa River, Robert | 646 | 1939–1983 | 284 | 1,154 | 81,900 |
| | | **Louisiana Coastal Subregion** | | | | |
| | | **Atchafalaya–Teche–Vermillion and Calcasieu–Mermentau River Basin** | | | | |
| 8. | Atchafalaya River, Simmesport | 87,570 | 1939–1983 | 26,000 | 196,700 | — |
| 9. | Calcasieu River, Oberlin | 753 | 1923–1924<br>1939–1983 | 37 | 1,147 | 58,900 |
| 10. | Calcasieu River, Kinder | 1,700 | 1923–1924<br>1939–1957<br>1962–1983 | 202 | 2,568 | 121,000 |
| | | **Arkansas–White–Red Region** | | | | |
| | | **Red–Sulphur Subregion** | | | | |
| | | **Red River Basin** | | | | |
| 11. | Red River, Shreveport | 60,613 | 1929–1983 | 1,150 | 24,030 | 297,000 |
| 12. | Red River, Alexandria | 67,500 | 1929–1983 | 1,650 | 30,870 | 251,000 |
| 13. | Saline Bayou, Lucky | 154 | 1941–1983 | 4.5 | 162 | 17,200 |
| | | **Texas–Gulf Region** | | | | |
| | | **Sabine Subregion** | | | | |
| | | **Sabine River Basin** | | | | |
| 14. | Sabine River, Ruliff, TX | 9,329 | 1925–1983 | 432 | 7,491 | 90,700 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | | **Maine** | | | |
| | | | **New England Region** | | | |
| | | | **St. John Subregion** | | | |
| 1. | St. John River, Ninemile Bridge | 1,341 | 1950–1985 | 96 | 2,330 | 47,900 |
| 2. | St. John River, Fort Kent | 5,665 | 1926–1985 | 747 | 9,730 | 167,000 |
| 3. | Aroostook River, Washburn | 1,654 | 1930–1985 | 143 | 2,670 | 51,500 |
| | | | **Maine Coastal Subregion** | | | |
| 4. | St. Croix River, Baring | 1,374 | 1958–1985 | 484 | 2,760 | 31,000 |
| 5. | Narraguagus River, Cherryfield | 227 | 1948–1985 | 29 | 503 | 11,300 |
| 6. | Sheepscot River, North Whitefield | 148 | 1938–1985 | 8.8 | 249 | 7,080 |
| | | | **Penobscot Subregion** | | | |
| 7. | Penobscot River, Dover–Foxcroft | 298 | 1902–1985 | 19 | 603 | 25,400 |
| 8. | Penobscot River, West Enfield | 6,71 | 1901–1985 | 2,970 | 11,960 | 150,000 |
| | | | **Kennebec Subregion** | | | |
| 9. | Kennebec River, Bingham | 2,715 | 1907–1910<br>1930–1985 | 1,310 | 4,450 | 59,200 |
| 10. | Carrabassett River, North Anson | 353 | 1902–1907<br>1925–1985 | 45 | 717 | 39,500 |
| | | | **Androscoggin Subregion** | | | |
| 11. | Swift River, Roxbury | 96.9 | 1929–1985 | 6.9 | 199 | 21,100 |
| 12. | Little Androscoggin River, South Paris | 75.8 | 1913–1924<br>1931–1985 | 2.6 | 139 | 6,700 |
| 13. | Androscoggin River, Auburn | 3,263 | 1928–1985 | 1,690 | 6,140 | 99,700 |
| | | | **Saco Subregion** | | | |
| 14. | Royal River, Yarmouth | 141 | 1949–1985 | 24 | 275 | 11,000 |
| 15. | Saco River, Cornish | 1,293 | 1916–1985 | 386 | 2,710 | 36,800 |
| | | | **Maryland (and the District of Columbia)** | | | |
| | | | **Mid-Atlantic Region** | | | |
| | | | **Potomac Subregion** | | | |
| 1. | Conoccocheague Creek, Fairview | 494 | 1928–1983 | 53 | 590 | 26,800 |
| 2. | Antietam Creek, Sharpsburg | 281 | 1899–1983 | 66 | 275 | 14,400 |
| 3. | Monocacy River, Frederick | 817 | 1929–1983 | 50 | 926 | 65,900 |
| | | | **Upper Chesapeake Subregion** | | | |
| 4. | Pocomoke River, Willards | 60.5 | 1949–1983 | 3.4 | 71 | 1,830 |
| 5. | Choptank River, Greensboro | 113 | 1948–1983 | 5.4 | 132 | 9,360 |
| 6. | Patuxent River, Unity | 34.8 | 1944–1983 | 2.8 | 39 | 26,900 |
| | | | **Susquehanna Subregion** | | | |
| 7. | Susquehanna River, Conowingo | 27,100 | 1968–1983 | — | 42,180 | — |
| | | | **Ohio Region** | | | |
| | | | **Monongahela Subregion** | | | |
| 8. | Youghiogheny River, Oakland | 134 | 1941–1983 | 5.9 | 297 | 12,800 |
| | | | **Massachusetts** | | | |
| | | | **New England Region** | | | |
| | | | **Connecticut Subregion** | | | |
| 1. | Millers River, Erving | 372 | 1915–1983 | 47 | 630 | — |
| 2. | North River, Shattuckville | 89.0 | 1940–1983 | 8.1 | 183 | 17,000 |
| 3. | Deerfield River, West Deerfield | 557 | 1941–1983 | 97 | 1,285 | 56,000 |
| 4. | Connecticut River, Montague City | 7,860 | 1905–1983 | 1,700 | 13,760 | — |
| 5. | Ware River, Barre | 96.3 | 1929–1983 | 6.4 | 167 | — |
| 6. | East Branch Swift River, Hardwick | 43.7 | 1938–1983 | 0.2 | 69.5 | 3,100 |
| 7. | Chicopee River, Indian Orchard | 689 | 1929–1983 | 130 | 903 | — |
| 8. | West Branch Westfield River, Huntington | 94.0 | 1936–1983 | 5.7 | 190 | 29,000 |
| 9. | Westfield River, Westfield | 497 | 1915–1983 | 84 | 921 | — |
| | | | **Merrimack Subregion** | | | |
| 10. | Nashua River, East Pepperell | 316 | 1936–1983 | 46 | 568 | 16,000 |
| 11. | Concord River, Lowell | 307 | 1937–1983 | 33 | 630 | 6,000 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 12. | Merrimack River, Lowell | 4,423 | 1924–1983 | 937 | 7,530 | — |
| | **Massachusetts–Rhode Island Coastal Subregion** | | | | | |
| 13. | Parker River, Byfield | 21.3 | 1946–1983 | 0.2 | 36.7 | 610 |
| 14. | Ipswich River, Ipswich | 125 | 1931–1983 | 2.0 | 187 | 3,120 |
| 15. | Charles River, Dover | 183 | 1938–1983 | 13 | 302 | 3,800 |
| 16. | Indian Head River, Hanover | 30.2 | 1967–1983 | 1.4 | 62.4 | 1,800 |
| 17. | Wading River, Norton | 43.3 | 1926–1983 | 2.3 | 73.3 | 1,500 |
| | **Connecticut Coastal Subregion** | | | | | |
| 18. | Housatonic River, Great Barrington | 280 | 1914–1983 | 69 | 526 | 11,000 |
| | **Michigan** | | | | | |
| | **Great Lakes Region** | | | | | |
| | **Northwestern Lake Michigan and Southeastern Lake Michigan Subregions** | | | | | |
| 1. | St. Joseph River, Niles | 3,666 | 1931–1984 | 945 | 3,260 | 20,400 |
| 2. | Kalamazoo River, Fennville | 1,600 | 1930–1936<br>1938–1984 | 335 | 1,420 | 12,300 |
| 3. | Red Cedar River, East Lansing | 355 | 1903<br>1932–1984 | 9.79 | 205 | 6,890 |
| 4. | Grand River, Lansing | 1,230 | 1902–1906<br>1935–1984 | 80.2 | 833 | 8,800 |
| 5. | Grand River, Grand Rapids | 4,900 | 1902–1905<br>1931–1984 | 721 | 3,570 | 53,000 |
| 6. | Escanaba River, Cornell | 870 | 1904–1912<br>1951–1984 | 168 | 892 | 13,000 |
| | **Northeastern Lake Michigan–Lake Michigan Subregion** | | | | | |
| 7. | Muskegon River, Evart | 1,450 | 1931<br>1934–1984 | 314 | 998 | 9,060 |
| 8. | Muskegon River, Newaygo | 2,350 | 1910–1914<br>1917–1919<br>1931–1984 | 672 | 1,970 | 14,100 |
| 9. | Manistee River, Manistee | 1,780 | 1952–1984 | 1,210 | 2,000 | 8,240 |
| | **Southwestern Lake Huron–Lake Huron Subregion** | | | | | |
| 10. | Shiawassee River, Fergus | 637 | 1940–1984 | 42.1 | 420 | 9,330 |
| 11. | Flint River, Fosters | 1,188 | 1940–1984 | 66.4 | 743 | 16,700 |
| 12. | Cass River, Frankenmuth | 841 | 1936<br>1940–1984 | 20.4 | 490 | 20,800 |
| 13. | Tittabawassee River, Midland | 2,400 | 1937–1984 | 187 | 1,680 | 44,600 |
| | **Southern Lake Superior–Lake Superior and St. Clair–Detroit Subregions** | | | | | |
| 14. | Ontonagon River, Rockland | 1,340 | 1943–1984 | 308 | 1,430 | 32,400 |
| 15. | Sturgeon River, Sidnaw | 171 | 1913–1915<br>1944–1984 | 8.19 | 216 | 4,830 |
| 16. | Tahquamenon River, Paradise | 790 | 1954–1984 | 196 | 936 | 7,660 |
| 17. | Clinton River, Mt. Clemens | 734 | 1935–1984 | 61.4 | 531 | 23,200 |
| 18. | Huron River, Ann Arbor | 729 | 1905–1984 | 43.6 | 456 | 5,940 |
| | **Minnesota** | | | | | |
| | **Upper Mississippi Region** | | | | | |
| | **Mississippi River Basin**[v] | | | | | |
| 1. | Mississippi River, Anoka | 19,000 | 1932–1983 | 1,194 | 7,655 | 98,000 |
| 2. | Crow Wing River, Pillager | 3,300 | 1968–1983 | 173 | 1,264 | 15,300 |
| 3. | Sauk River, St. Cloud | 925 | 1910–1912<br>1931<br>1935–1981 | 13.1 | 276 | 10,000 |
| 4. | Crow River, Rockford | 2,520 | 1910–1917<br>1931<br>1935–1983 | 14.7 | 664 | 19,000 |
| 5. | Rum River, St. Francis | 1,360 | 1931<br>1934–1983 | 64.4 | 602 | 14,000 |
| 6. | Cannon River, Welch | 1,320 | 1911–1913<br>1931–1971 | 61.6 | 501 | 34,000 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 7. | Zumbro River, Zumbro Falls | 1,130 | 1910–1917<br>1931–1980 | 77.7 | 517 | 40,200 |
| 8. | Root River, Houston | 1,270 | 1910–1917<br>1931–1983 | 178 | 696 | 51,500 |
| | Minnesota Subregion | | | | | |
| 9. | Minnesota River, Jordan | 16,200 | 1935–1983 | 171 | 3,520 | 115,000 |
| 10. | Lac qui Parle River, Lac qui Parle | 983 | 1913<br>1932<br>1934–1983 | 0.20 | 120 | 19,300 |
| 11. | Chippewa River, Milan | 1,870 | 1938–1983 | 2.90 | 269 | 12,400 |
| 12. | Cottonwood River, New Ulm | 1,280 | 1912–1913<br>1936–1937<br>1939–1983 | 2.77 | 289 | 33,000 |
| 13. | Blue Earth River, Rapidan | 2,430 | 1940–1945<br>1950–1983 | 14.9 | 895 | 34,600 |
| | **St. Croix Subregion** | | | | | |
| 14. | St. Croix River, St. Croix Falls | 6,240 | 1903–1983 | 1,099 | 4,235 | 61,000 |
| | **Souris–Red–Rainy Region** | | | | | |
| | **Red Subregion Red Lake River Basin** | | | | | |
| 15. | Otter Tail River, Orwell Dam Fergus Falls | 1,830 | 1931–1983 | 12.3 | 304 | 4,800 |
| 16. | Red River of the North, Grand Forks | 30,100 | 1883–1983 | 71.4 | 2,558 | 89,000 |
| 17. | Red Lake River, Crookston | 5,280 | 1902–1983 | 31.6 | 1,130 | 31,000 |
| | **Rainy Subregion** | | | | | |
| | **Little Fork and Big Fork River Basins** | | | | | |
| 18. | Rainy River, Manitou Rapids | 19,400 | 1929–1983 | 3,597 | 12,830 | 80,000 |
| 19. | Little Fork River, Littlefork | 1,730 | 1912–1916<br>1929–1983 | 40.3 | 1,053 | 27,400 |
| 20. | Big Fork River, Big Falls | 1,460 | 1929–1979<br>1983 | 33.7 | 715 | 21,800 |
| | **Great Lakes Region** | | | | | |
| | **Western Lake Superior Subregion** | | | | | |
| 21. | Pigeon River, Grand Portage | 600 | 1924–1983 | 44.5 | 506 | 13,600 |
| 22. | Baptism River, Beaver Bay | 140 | 1928–1983 | 3.45 | 169 | 8,820 |
| 23 | St. Louis River, Scanlon | 3,430 | 1909–1983 | 316 | 2,313 | 38,000 |
| | **Mississippi** | | | | | |
| | **Lower Mississippi Region** | | | | | |
| | **Lower Mississippi–Yazoo Subregion** | | | | | |
| | **Yazoo River Basin** | | | | | |
| 1. | Yazoo River, Greenwood[w] | 7,450 | 1907–1912<br>1927–1939<br>1940–1984 | 831<br>741 | 9,330<br>10,900 | —<br>45,000 |
| 2. | Big Sunflower River, Sunflower[w] | 767 | 1935–1984 | 87 | 1,070 | 14,100 |
| | **Lower Mississippi–Big Black Subregion** | | | | | |
| | **Big Black River Basin** | | | | | |
| 3. | Big Black River, Bovina | 2,810 | 1936–1984 | 84 | 3,800 | 73,400 |
| | **South Atlantic–Gulf Region** | | | | | |
| | **Pearl Subregion** | | | | | |
| | **Pearl River Basin** | | | | | |
| 4. | Pearl River, Monticello | 4,993 | 1938–1960<br>1961–1984 | 324<br>365 | 6,110<br>7,530 | —<br>97,100 |
| | **Mobile–Tombigbee Subregion** | | | | | |
| | **Tombigbee River Basin** | | | | | |
| 5. | Tombigbee River, Columbus | 4,463 | 1899–1912<br>1928–1982 | 233 | 6,520 | 223,000 |
| | **Pascagoula Subregion** | | | | | |
| | **Pascagoula River Basin** | | | | | |
| 6. | Pascagoula River, Merrill | 6,590 | 1930–1968 | 865 | 9,350 | — |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | | 1969–1984 | 1,080 | 11,800 | 221,000 |
| | | **Missouri** | | | | |
| | | **Upper Mississippi Region** | | | | |
| | | **Upper Mississippi–Kaskaskia–Meramec Subregion** | | | | |
| 1. | Salt River, New London | 2,480 | 1922–1983 | 1.7 | 1,700 | 87,000 |
| 2. | Mississippi River, St. Louis | 697,000 | 1951–1983 | 43,000 | 183,000 | 1,000,000 |
| 3. | Meramec River, Eureka | 3,788 | 1921–1983 | 280 | 3,100 | 144,000 |
| 4. | Mississippi River, Thebes, IL | 713,200 | 1951–1983 | 47,100 | 198,000 | 1,100,000 |
| | | **Lower Mississippi Region** | | | | |
| | | **Lower Mississippi–St. Francis Subregion** | | | | |
| | | **St. Francis River Basin** | | | | |
| 5. | St. Francis River, Patterson | 956 | 1920–1983 | 15 | 1,100 | 89,000 |
| 6. | Little River, Morehouse | 450 | 1945–1983 | 33 | 530 | 11,000 |
| | | **Missouri Region** | | | | |
| | | **Gasconade–Osage and Chariton–Grand Subregions** | | | | |
| | | **Osage and Grand River Basins** | | | | |
| 7. | Missouri River, Kansas City | 485,200 | 1955–1983 | 6,400 | 51,000 | — |
| 8. | Grand River, Gallatin | 2,250 | 1921–1983 | 4.0 | 1,200 | 72,000 |
| 9. | Osage River, St. Thomas | 14,500 | 1931–1983 | 480 | 9,900 | — |
| 10. | Gasconade River, Jerome | 2,840 | 1923–1983 | 320 | 2,500 | 106,000 |
| 11. | Missouri River, Hermann | 524,200 | 1955–1983 | 11,000 | 72,000 | — |
| | | **Arkansas–White–Red Region** | | | | |
| | | **Upper White Subregion** | | | | |
| | | **White River Basin** | | | | |
| 12. | James River, Galena | 987 | 1921–1983 | 38 | 940 | 69,000 |
| 13. | White River, Branson | 4,020 | 1956–1983 | 78 | 3,500 | — |
| 14. | Current River, Doniphan | 2,038 | 1918–1983 | 940 | 2,700 | 104,000 |
| 15. | Spring River, Waco | 1,164 | 1924–1983 | 18 | 840 | 80,000 |
| | | **Montana** | | | | |
| | | **Missouri Region** | | | | |
| | | **Missouri River Basin[x]** | | | | |
| 1. | Beaverhead River, Barretts | 2,737 | 1907–1983 | 122 | 430 | 3,040 |
| 2. | Missouri River, Fort Benton | 24,749 | 1890–1983 | 2,230 | 7,827 | 96,000 |
| 3. | Marias River, Shelby | 3,242 | 1902–1904 | 65 | 940 | — |
| | | | 1905–1906 | | | |
| | | | 1907–1908 | | | |
| | | | 1911–1983 | | | |
| 4. | Musselshell River, Mosby | 7,846 | 1929 | 0.00 | 301 | 34,600 |
| | | | 1932–1983 | | | |
| | | | 1934–1930 | | | |
| 5. | Milk River, Nashua | 22,332 | 1939–1983 | 13 | 710 | 36,600 |
| 6. | Missouri River, Culbertson | 91,557 | 1941–1951 | 1,520 | 11,000 | 54,900 |
| | | | 1958–1983 | | | |
| | | **Yellowstone River Basin[y]** | | | | |
| 7. | Yellowstone River, Billings | 11,795 | 1928–1983 | 1,090 | 7,074 | 80,000 |
| 8. | Bighorn River, Bighorn | 22,885 | 1945–1983 | 767 | 3,939 | 41,700 |
| 9. | Tongue River, Miles City | 5,379 | 1938–1942 | 3.3 | 440 | 17,800 |
| | | | 1946–1983 | | | |
| 10. | Powder River, Locate | 13,194 | 1938–1983 | 1.6 | 612 | 48,100 |
| 11. | Yellowstone River, Sidney | 69,103 | 1910–1931 | 1,410 | 13,080 | 156,000 |
| | | | 1933–1983 | | | |
| | | **Pacific Northwest Region** | | | | |
| | | **Clark Fork Basin[z]** | | | | |
| 12. | Clark Fork, St. Regis | 10,709 | 1910–1983 | 1,440 | 7,583 | 79,800 |
| 13. | Bitterroot River, Darby | 1,049 | 1937–1983 | 123 | 931 | 13,200 |
| 14. | Flathead River, Columbia Falls | 4,464 | 1928–1983 | 1,090 | 9,737 | 84,000 |
| 15. | Clark Fork, Plains | 19,958 | 1910–1983 | 4,440 | 20,010 | 145,000 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | **Kootenai River Basin[z]** | | | | |
| 16. | Kootenai River, Libby | 10,240 | 1911–1970 | 1,610 | 12,100 | 116,000 |
| | | | 1973–1983 | 2,560 | 11,740 | 76,300 |
| | | **Nebraska** | | | | |
| | | **Missouri Region** | | | | |
| | | **Missouri River Main Stem[aa]** | | | | |
| 1. | Missouri River, Fort Randall Dam, SD | 263,500 | 1947–1983 | 1,450[bb] | 25,230[bb] | 99,000[bb] |
| 2. | Missouri River, Rulo | 414,900 | 1950–1983 | 6,210[bb] | 40,190[bb] | 241,000[bb] |
| | | **Niobrara Subregion** | | | | |
| 3. | Niobrara River, Norden | 8,390 | 1953–1963 | 516 | 952 | 10,900 |
| | | | 1964–1983 | 398 | 810 | |
| | | **North Platte Subregion** | | | | |
| 4. | Pumpkin Creek, Bridgeport | 1,020 | 1932–1983 | 0.35 | 28.3 | 3,320 |
| 5. | North Platte River, North Platte | 30,900 | 1896–1940 | 135 | 2,720 | 36,700 |
| | | | 1941–1983 | | 713 | 10,700 |
| | | **South Plate Subregion** | | | | |
| 6. | South Platte River, North Platte | 24,300 | 1918–1946 | 78 | 435 | 77,300 |
| | | | 1947–1983 | | 402 | 57,300 |
| | | **Platte Subregion** | | | | |
| 7. | Platte River, Overton | 57,700 | 1915–1940 | 46 | 2,860 | 60,700 |
| | | | 1941–1983 | | 1,470 | 32,800 |
| 8. | Platte River, Louisville | 85,800 | 1954–1983 | 430 | 5,980 | 169,000 |
| | | **Loup Subregion** | | | | |
| 9. | Middle Loup River, Dunning | 1,850 | 1946–1983 | 260 | 401 | 1,100 |
| 10. | Loup River, Genoa | 14,400 | 1943–1983 | 0.96 | 574 | 130,000 |
| | | **Elkhorn Subregion** | | | | |
| 11. | Elkhorn River, Waterloo | 6,900 | 1929–1983 | 119 | 1,120 | 83,500 |
| | | **Missouri–Nishnabotna Subregion** | | | | |
| 12. | Big Nemaha River, Falls City | 1,340 | 1945–1983 | 11.4 | 587 | 80,700 |
| | | **Republican Subregion** | | | | |
| 13. | Medicine River, Harry Strunk Lake | 770 | 1951–1983 | 16.0 | 65.9 | 23,700 |
| 14. | Republican River, Cambridge | 14,520 | 1950–1983 | 18.0[cc] | 279[cc] | 16,800[cc] |
| | | **Kansas Subregion** | | | | |
| | | **Blue River Basin** | | | | |
| 15. | Big Blue River, Barneston | 4,447 | 1933–1983 | 35.1 | 787 | 50,100 |
| 16. | Little Blue River, Fairbury | 2,350 | 1911–1915 | 48.3 | 369 | 48,500 |
| | | | 1930–1983 | | | |
| | | **Nevada** | | | | |
| | | **Lower Colorado Regions** | | | | |
| | | **Lower Colorado–Lake Mead Subregion** | | | | |
| 1. | Virgin River, Littlefield, AZ | 5,090 | 1929–1983 | 48 | 243 | 35,300 |
| 2. | Muddy River, Moapa | 3,820 | 1913–1915 | 31 | 41.5 | 5,000 |
| | | | 1916–1918 | | | |
| | | | 1928–1931 | | | |
| | | | 1944–1983 | | | |
| 3. | Lee Canyon, Charleston Park | 9.20 | 1963–1983 | 0 | 0.025 | 4,300 |
| 4. | Las Vegas Wash, Henderson | 2,125 | 1957–1983 | — | 46.6 | 6,500 |
| | | **Great Basin Region** | | | | |
| | | **Black Rock Desert–Humboldt Subregion** | | | | |
| | | **Humboldt River Basin** | | | | |
| 5. | Humboldt River, Palisade | 5,010 | 1902–1906 | 8.9 | 385 | 7,700 |
| | | | 1911–1983 | | | |
| 6. | Humboldt River, Imlay | 15,700 | 1911–1983 | 0.3 | 235 | 5,700 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | | **Central Lahontan Subregion** | | | |
| | | | **Walker Lake Basin** | | | |
| 7. | Walker River, Wabuska | 2,600 | 1902–1904<br>1920–1924<br>1925–1935<br>1939–1941<br>1942–1943<br>1944–1983 | 3.8 | 170 | 6,700 |
| | | | **Carson River Basin** | | | |
| 8. | Carson River, Carson City | 886 | 1939–1983 | 4.8 | 418 | 28,300 |
| | | | **Truckee River Basin** | | | |
| 9. | Truckee River, Nixon | 1,827 | 1957–1983 | 14 | 538 | 28,300 |
| | | | **Central Nevada Desert Basins Subregions** | | | |
| 10. | Newark Valley tributary, Hamilton | 157 | 1962–1983 | 0 | 0.325 | 1,100 |
| 11. | South Twin River, Round Mountain | 20 | 1965–1983 | 0.78 | 7.06 | 260 |
| | | | **New Hampshire** | | | |
| | | | **New England Region** | | | |
| | | | **Androscoggin Subregion** | | | |
| 1. | Androscoggin River, Gorham | 1,361 | 1913–1983[cc] | 1,280 | 2,465 | 20,900 |
| | | | **Saco Subregion** | | | |
| 2. | Saco River, Conway | 385 | 1903–1909<br>1929–1983 | 93 | 933 | 53,800 |
| 3. | Lamprey River, Newmarket | 183 | 1934–1983 | 4.9 | 282 | 6,310 |
| | | | **Merrimack Subregion** | | | |
| 4. | Pemigewasset River, Plymouth | 622 | 1903–1983 | 115 | 1,358 | 60,800 |
| 5. | Blackwater River, Webster | 129 | 1918–1920<br>1927–1983 | 13 | 213 | — |
| 6. | Soucook River, Concord | 76.8 | 1951–1983 | 3.7 | 112 | 4,080 |
| 7. | Merrimack River, Goffs Falls Manchester | 3,092 | 1936–1983 | 663 | 5,280 | — |
| | | | **Connecticut Subregion** | | | |
| 8. | Connecticut River, Pittsburg | 254 | 1956–1983 | 35 | 571 | — |
| 9. | Upper Ammonoosuc River, Groveton | 232 | 1940–1980<br>1982–1983 | 49 | 473 | 10,800 |
| 10. | Ammonoosuc River, Bethlehem Junction | 87.6 | 1939–1983 | 27 | 208 | 13,600 |
| 11. | Connecticut River, Wells River, VT | 2,644 | 1949–1983 | 632 | 4,731 | — |
| 12. | Sugar River, West Claremont | 269 | 1928–1983 | 40 | 404 | 13,800 |
| 13. | Connecticut River, North Walpole | 5,493 | 1942–1983 | 993 | 9,380 | — |
| 14. | Ashuelot River, Hinsdale | 420 | 1907–1911<br>1914–1983 | 46 | 671 | — |
| | | | **New Jersey** | | | |
| | | | **Lower Hudson–Long Island Subregion** | | | |
| | | | **Hackensack and Passaic River Basins** | | | |
| 1. | Hackensack River, New Milford | 113 | 1922–1984 | 0 | 103 | 5,570 |
| 2. | Passaic River, Chatham | 100 | 1904–1984[dd] | 3.7 | 172 | 3,730 |
| 3. | Passaic River, Little Falls | 762 | 1898–1984 | 32 | 1,168 | 22,500 |
| 4. | Saddle River, Lodi | 54.6 | 1924–1984 | 13 | 102 | 5,750 |
| | | | **Raritan River Basin** | | | |
| 5. | South Branch Raritan River, High Bridge | 65.3 | 1919–1984 | 22 | 123 | 6,600 |
| 6. | Stony Brook, Princeton | 44.5 | 1954–1984 | 0.1 | 65.1 | 8,390 |
| 7. | Raritan River below Calco Dam Bound Brook | 785 | 1904–1984[dd] | 72 | 1,293 | 40,800 |
| 8. | Green Brook, Plainfield | 9.75 | 1939–1984 | 0 | 12.9 | 3,280 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | **Delaware and Lower Hudson–Long Island Subregions** | | | | | |
| | **Atlantic Coastal Basins** | | | | | |
| 9. | Swimming River, Red Bank | 49.2 | 1923–1984 | 0 | 80.8[ee] | 11,000 |
| 10. | Manasquan River, Squankum | 44.0 | 1932–1984 | 18 | 75.9 | 2,870 |
| 11. | Oyster Creek, Brookville | 7.43 | 1968–1984 | 13 | 28.7 | 514 |
| 12. | Great Egg Harbor River, Folsom | 57.1 | 1926–1984 | 22 | 86.8 | 1,230 |
| | **Delaware Subregion** | | | | | |
| | **Delaware River Basin and Streams Tributary to Delaware Bay** | | | | | |
| 13. | Maurice River, Norma | 112 | 1933–1984 | 37 | 168 | 2,880 |
| 14. | Flat Brook, Flatbrookville | 64.0 | 1924–1984 | 7.8 | 110 | 7,070 |
| 15. | Delaware River, Trenton | 6,780 | 1914–1984 | 1,800[ff] | 11,740 | 217,000[ff] |
| 16. | Crosswicks Creek, Extonville | 81.5 | 1941–1984[gg] | 24 | 136 | 5,800 |
| 17. | McDonalds Branch, Lebanon State Forest | 2.35 | 1954–1984 | 0.9 | 2.32 | 49 |
| 18. | Cooper River, Haddonfield | 17.0 | 1964–1984 | 8.6 | 36.3 | 3,840 |
| | **New Mexico** | | | | | |
| | **Arkansas–White–Red Region[hh]** | | | | | |
| | **Upper Canadian Subregion** | | | | | |
| | **Canadian River Basin** | | | | | |
| 1. | Canadian River, Logan | 11,141 | 1904–1983 | 0.0 | 392[ii] | 333,000 |
| | **Rio Grande Region** | | | | | |
| | **Upper and Lower Pecos Subregions** | | | | | |
| | **Pecos River Basin** | | | | | |
| 2. | Pecos River, Pecos | 189 | 1919–1983 | 12.0 | 98.1 | 3,070 |
| 3. | Delaware River, Red Bluff, TX | 689 | 1912–83 | 0.0 | 13.0 | 82,500 |
| | **Rio Grande River Basin (main stem)[ll]** | | | | | |
| 4. | Rio Grande, Albuquerque | 117,440 | 1941–1983 | 0.3 | 1,068[mm] | 22,000 |
| | | | | 1,232[nn] | — | — |
| | **Upper Colorado Region** | | | | | |
| | **San Juan Subregion** | | | | | |
| 5. | San Juan River, Shiprock | 12,900 | 1927–1983 | 53.6 | 2,181 | 67,200 |
| | **Lower Colorado Region[oo]** | | | | | |
| 6. | Gila River, Gila | 1,864 | 1927–1983 | 19.7 | 141 | 24,900 |
| | **New York** | | | | | |
| | **Mid-Atlantic Region** | | | | | |
| | **Upper Hudson Subregion** | | | | | |
| 1. | Sacandaga River, Stewarts Bridge | 1,055 | 1907–1929 | 106 | 2,230 | 30,400 |
| | | | 1931–1984 | 757 | 2,090 | 14,800 |
| 2. | Mohawk River, Cohoes | 3,456 | 1917–1984 | 772 | 5,750 | 128,000 |
| 3. | Hudson River, Green Island | 8,090 | 1946–1984 | 2,810 | 13,700 | 191,000 |
| 4. | Wappinger Creek, Wappingers Falls | 181 | 1928–1984 | 6.5 | 253 | 18,500 |
| | **Delaware Subregion** | | | | | |
| 5. | East Branch Delaware River, Fishs Eddy | 784 | 1912–1954 | 89 | 1,670 | 73,700 |
| | | | 1955–1984 | 111 | 1,100 | 40,100 |
| 6. | Delaware River, Port Jervis | 3,070 | 1904–1954 | 416 | 5,570 | 184,000 |
| | | | 1963–1984 | 832 | 4,750 | 170,000 |
| | **Susquehanna Subregion** | | | | | |
| 7. | Susquehanna River, Waverly | 4,773 | 1937–1984 | 385 | 7,580 | 139,000 |
| 8. | Chemung River, Chemung | 2,506 | 1903–1984 | 104 | 2,530 | 143,000 |
| | **Great Lakes Region** | | | | | |
| | **Southwestern and Southeastern Lake Ontario Subregions** | | | | | |
| 9. | Genesee River, Rochester | 2,467 | 1919–1951 | 511 | 2,780 | 44,100 |
| | | | 1952–1984 | 311 | 2,880 | 30,600 |
| 10. | Oswego River, Oswego | 5,100 | 1933–1984 | 980 | 6,690 | 38,600 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | **Northeastern Lake Ontario–Lake Ontario–St. Lawrence Subregion** | | | | | |
| 11. | Black River, Watertown | 1,874 | 1920–1984 | 825 | 4,020 | 41,000 |
| 12. | West Branch Oswegatchie River, Harrisville | 244 | 1916–1984 | 43 | 515 | 7,290 |
| 13. | St. Lawrence River, Massena | 298,000 | 1860–1984 | 179,000 | 243,000 | 358,000 |
| | **North Carolina** | | | | | |
| | **South Atlantic–Gulf Region** | | | | | |
| | **Chowan–Roanoke Subregion** | | | | | |
| 1. | Roanoke River, Roanoke Rapids | 8,386 | 1911–1949 | 1,010 | 8,085 | 215,000 |
| | | | 1950–1984 | 1,310 | 7,700 | 66,800 |
| | **Neuse–Pamlico Subregion** | | | | | |
| 2. | Tar River, Tarboro | 2,183 | 1896–1900 | 90 | 2,234 | 45,500 |
| | | | 1931–1984 | | | |
| 3. | Neuse River, Kinston | 2,692 | 1930–1981 | 210 | 2,892 | 43,100 |
| | | | 1981–1984 | — | — | 33,000 |
| | **Cape Fear Subregion** | | | | | |
| 4. | Cape Fear River, Lillington | 3,464 | 1923–1975 | 75 | 3,300 | 117,000 |
| | | | 1975–1981 | 600 | 3,300 | 80,000 |
| | **Pee Dee Subregion** | | | | | |
| 5. | South Yadkin River, Mocksville | 306 | 1939–1984 | 61 | 340 | 15,700 |
| | **Tennessee Region** | | | | | |
| | **Tennessee Subregion** | | | | | |
| 6. | French Broad River, Asheville | 945 | 1896–1984 | 455 | 2,093 | 49,100 |
| | **North Dakota** | | | | | |
| | **Souris–Red–Rainy Region** | | | | | |
| | **Souris and Red Subregions** | | | | | |
| | **Souris River and Red River of the North Basins** | | | | | |
| 1. | Souris River, Minot | 10,600[pp] | 1904–1983 | <0.1 | 171 | 11,500 |
| | | 6,700[qq] | | | | |
| 2. | Red River of the North, Wahpeton | 4,010[pp] | 1943–1983 | 12.3 | 519 | 11,000 |
| 3. | Big Coulee, Churchs Ferry | 2,510[pp] | 1951–1979 | 0 | 44.1 | 3,370 |
| | | 690[qq] | | | | |
| 4. | Sheyenne River, West Fargo | 8,870[pp] | 1904–1905 | 12.9 | 176 | 5,280 |
| | | 5,780[qq] | 1930–1983 | | | |
| 5. | Red River of the North Grand | 30,100[pp] | 1883–1983 | 69.1 | 2,558 | 89,000 |
| | | 3,800[qq] | | | | |
| | **Missouri Region** | | | | | |
| | **Missouri–Little Missouri and Missouri–Oahe Subregions** | | | | | |
| | **Missouri River Main Stem and Tributary River Basins** | | | | | |
| 6. | Little Missouri River, Watford City | 8,310[pp] | 1935–1983 | <0.1 | 593 | 78,700 |
| 7. | Knife River, Hazen | 2,240[pp] | 1930–1933 | 2.7 | 181 | 36,200 |
| | | | 1938–1983 | | | |
| 8. | Missouri River, Bismarck | 186,400[pp] | 1921–1983 | 6,570 | 22,740 | 63,700 |
| 9. | Heart River, Mandan | 3,310[pp] | 1929–1932 | <0.3 | 268 | 49,500 |
| | | | 1938–1983 | | | |
| 10. | Cannonball River, Breien | 4,100[pp] | 1935–1983 | <0.1 | 256 | 60,000 |
| 11. | James River, Jamestown | 2,820[pp] | 1929–1934 | 1.1 | 62.2 | 4,800 |
| | | 1,650[qq] | | | | |
| | **Ohio** | | | | | |
| | **Ohio Region** | | | | | |
| | **Muskingum Subregion** | | | | | |
| 1. | Tuscarawas River, Massillon | 518 | 1937–1984 | 71 | 441 | 8,670 |
| 2. | Tuscarawas River, Newcomerstown | 2,443 | 1921–1937 | 253 | 2,541 | 66,900 |
| | | | 1938–1984 | | | 23,000 |
| 3. | Muskingum River, McConnelsville | 7,422 | 1921–1937 | 641 | 7,596 | 183,000 |
| | | | 1938–1984 | | | 97,100 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | | **Scioto Subregion** | | | |
| 4. | Scioto River, Prospect | 567 | 1925–1932 | 9.3 | 454 | 13,900 |
| | | | 1939–1984 | | | |
| 5. | Olentangy River, Delaware | 393 | 1923–1934 | 5.2 | 351 | 22,000 |
| | | | 1938–1951 | | | 6,280 |
| | | | 1951–1984 | | | |
| 6. | Scioto River, Higby | 5,131 | 1930–1984 | 296 | 4,579 | 184,000 |
| | | | **Great Miami Subregion** | | | |
| 7. | Great Miami River, Sidney | 541 | 1914–1984 | 21 | 477 | 27,300 |
| 8. | Stillwater River, Englewood | 650 | 1925–1984 | 15 | 579 | 10,500 |
| 9. | Mad River, Dayton | 635 | 1914–1984 | 131 | 629 | 21,100 |
| 10. | Great Miami River, Hamilton | 3,630 | 1907–1918 | 284 | 3,279 | 140,000 |
| | | | 1927–1984 | | | 95,900 |
| | | | **Great Lakes Region** | | | |
| | | | **Western Lake Erie Subregion** | | | |
| | | | **Maumee River Basin** | | | |
| 11. | Blanchard River, Findlay | 346 | 1923–1935 | 2.3 | 251 | 14,300 |
| | | | 1940–1984 | | | |
| 12. | Auglaize River, Defiance | 2,318 | 1915–1984 | 11 | 1,718 | 62,700 |
| 13. | Maumee River, Waterville | 6,330 | 1898–1901 | 95 | 4,926 | 97,800 |
| | | | 1921–1935 | | | |
| | | | 1939–1984 | | | |
| | | | **Southern Lake Erie Subregion** | | | |
| | | | **Cuyahoga River Basin** | | | |
| 14. | Cuyahoga River, Hiram Rapids | 151 | 1927–1935 | 16 | 207 | 4,410 |
| | | | 1944–1984 | | | 3,690 |
| 15. | Cuyahoga River, Independence | 707 | 1921–1923 | 63 | 817 | 18,000 |
| | | | 1927–1935 | | | |
| | | | 1940–1984 | | | |
| | | | **Oklahoma** | | | |
| | | | **Arkansas–White–Red Region** | | | |
| | | | **Arkansas River Basin, Salt Fork Arkansas River and Cimarron River Basin, Verdigris River and Grand (Neosho) River Basins, and Canadian River Basins[rr]** | | | |
| 1. | Salt Fork Arkansas River, Tonkawa | 4,528 | 1942–1982 | 6.68 | 730 | 69,400 |
| 2. | Cimarron River Perkins | 17,852 | 1940–1982 | 8.73 | 1,180 | 174,000 |
| 3. | Arkansas River, Tulsa | 74,615 | 1926–1964 | 155 | 6,550 | 324,000 |
| | | | 1965–1982 | 346 | 6,940 | 165,000 |
| 4. | Verdigris River, Claremore | 6,534 | 1936–1962 | 3.06 | 3,720 | 178,000 |
| | | | 1965–1982 | 15.4 | 3,720 | 46,400 |
| 5. | Illinois River, Tahlequah | 959 | 1936–1982 | 16.8 | 867 | 141,000 |
| 6. | Little River, Sasakawa | 865 | 1943–1965 | 0.69 | 398 | 66,800 |
| | | | 1966–1982 | 0.08 | 242 | 23,300 |
| 7. | Beaver River, Beaver | 7,955 | 1938–1982 | 0.03 | 95.9 | 68,100 |
| 8. | Fourche Maline, Red Oak | 122 | 1939–1963 | 0.10 | 126 | 51,400 |
| | | | 1966–1982 | 0.12 | 133 | 17,900 |
| | | | **Red River Basin[ss], Washita River Basin** | | | |
| 9. | North Fork Red River, Headrick | 4,244 | 1946–1982 | 0.39 | 266 | 54,200 |
| 10. | Red River, Gainesville | 30,782 | 1947–1982 | 97.6 | 2,750 | 180,000 |
| 11. | Washita River, Dickson | 7,202 | 1929–1960 | 33.7 | 1,540 | 117,000 |
| | | | 1962–1982 | 4.87 | 1,140 | 64,200 |
| 12. | Muddy Boggy Creek, Farris | 1,087 | 1938–1982 | 0.14 | 880 | 61,200 |
| 13. | Red River, Arthur City, TX | 44,531 | 1945–1982 | 375 | 7,890 | 174,000 |
| | | | **Oregon** | | | |
| | | | **Pacific Northwest Region** | | | |
| | | | **Oregon Closed Basins Subregion** | | | |
| 1. | Silvies River, Burns | 934 | 1928–1983 | 1.5 | 175 | 4,900 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 2. | Donner und Blitzen River, Burns | 200 | 1912–1913<br>1915–1916<br>1918–1921<br>1939–1983 | 20 | 125 | 4,200 |
| | | **Middle Snake Subregion** | | | | |
| 3. | Owyhee River, Owyhee Reservoir | 11,160 | 1930–1983 | 1.7 | 380 | — |
| | | **Middle Columbia Subregion** | | | | |
| 4. | Umatilla River, Umatilla | 2,290 | 1928–1983 | 1.3 | 456 | 19,700 |
| 5. | John Day River, McDonald Ferry | 7,580 | 1906–1983 | 28 | 2,036 | 37,800 |
| 6. | Deschutes River, Moody | 10,500 | 1897–1999<br>1907–1983 | 3,610 | 5,846 | — |
| | | **Willamette Subregion** | | | | |
| 7. | Santiam River, Jefferson | 1,790 | 1909–1953<br>1967–1982 | 323<br>1,150 | 7,821<br>7,821 | —<br>— |
| 8. | Willamette River, Salem | 7,280 | 1911–1941<br>1969–1982 | 2,720<br>5,160 | 23,650 | |
| | | **Oregon–Washington Coastal Subregion** | | | | |
| | | **Rogue River Basin** | | | | |
| 9. | Wilson River, Tillamook | 161 | 1932–1983 | 51 | 1,205 | 36,700 |
| 10. | Umpqua River, Elkton | 3,683 | 1906–1983 | 797 | 7,517 | 276,000 |
| 11. | Rogue River, Raygold | 2,053 | 1905–1983 | 870 | 2,978 | 139,000 |
| | | **California Region** | | | | |
| | | **Klamath–Northern California Coastal Subregion** | | | | |
| | | **Klamath River Basin** | | | | |
| 12. | Sprague River, Chiloquin | 1,580 | 1922–1983 | 127 | 584 | 13,300 |
| 13. | Williamson River, Chiloquin | 3,000 | 1918–1982 | 414 | 1,049 | 14,100 |
| 14. | Klamath River, Keno | 3,920 | 1905–1912<br>1930–1983 | 165 | 1,684 | 13,000 |
| | | **Pennsylvania** | | | | |
| | | **Mid-Atlantic Region** | | | | |
| | | **Delaware Subregion** | | | | |
| | | **Delaware River Main Stem** | | | | |
| 1. | Bush Kill Shoemakers | 117 | 1908–1983 | 7.6 | 235 | 10,800 |
| 2. | Delaware River, Belvidere, NJ | 4,535 | 1922–1983 | 920 | 7,890 | 220,000 |
| 3. | Delaware River Trenton, NJ | 6,780 | 1913–1983 | — | 11,685 | 270,000 |
| | | **Schuylkill River Basin** | | | | |
| 4. | Schuylkill River, Landingville | 133 | 1947–1983 | 28 | 292 | 14,600 |
| 5. | Schuylkill River, Pottstown | 1,147 | 1926–1983 | 260 | 1,891 | 74,000 |
| | | **Susquehanna Subregion** | | | | |
| | | **Susquehanna River Main Stem** | | | | |
| 6. | Susquehanna River, Towanda | 7,797 | 1913–1983 | 550 | 10,600 | 105,000 |
| 7. | Susquehanna River, Danville | 1,220 | 1899–1983 | 980 | 15,320 | 260,000 |
| 8. | Susquehanna River, Sunbury | 18,300 | 1937–1983 | 1,600 | 26,520 | 530,000 |
| 9. | Susquehanna River, Harrisburg | 24,100 | 1890–1983 | 2,556 | 34,350 | 750,000 |
| | | **West Branch Susquehanna River Basin** | | | | |
| 10. | West Branch Susquehanna River, Lewisburg | 6,847 | 1939–1983 | 655 | 10,810 | 280,000 |
| | | **Juniata River Basin** | | | | |
| 11. | Juniata River, Newport | 3,354 | 1899–1983 | 380 | 4,295 | 145,000 |
| | | **Potomac Subregion** | | | | |
| 12. | Tonoloway Creek, Needmore | 10.7 | 1965–1983 | 0.27 | 12.4 | 1,590 |
| | | **Ohio Region** | | | | |
| | | **Allegheny Subregion** | | | | |
| 13. | Allegheny River, Port Allegany | 248 | 1974–1983 | 24 | 476 | 9,300 |
| 14. | Oil Creek Rouseville | 300 | 1932–1983 | 29 | 535 | 19,800 |
| 15. | Allegheny River, Franklin | 5,982 | 1914–1983 | 511 | 10,470 | 125,000 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | | **Monongahela Subregion** | | | | |
| 16. | Monongahela River, Elizabeth | 5,340 | 1933–1983 | 698 | 9,109 | 170,000 |
| 17. | Monongahela River, Braddock | 7,337 | 1938–1983 | 1,150 | 12,460 | 230,000 |
| | | **Upper Ohio Subregion** | | | | |
| | | **Ohio River Main Stem** | | | | |
| 18. | Connoquenessing Creek, Zelienople | 356 | 1919–1983 | 11 | 464 | 19,450 |
| | | **Puerto Rico** | | | | |
| | | **Caribbean Region** | | | | |
| | | **Puerto Rico Subregion** | | | | |
| | | **North Coast Area** | | | | |
| 1. | Rio Culebrinas, Moca | 71.2 | 1967–1985 | 20.0 | 299 | 111,000 |
| 2. | Rio Grande de Arecibo, Central Cambalache | 200[tt] | 1969–1984 | 90.0 | 510 | — |
| 3. | Rio Grande de Manati, Manati | 197[uu] | 1970–1985 | 60.0 | 375 | 255,000 |
| 4. | Rio Cibuco, Vega Baja | 99.1[vv] | 1973–1985 | 8.2[tt] | 125 | 45,800 |
| 5. | Rio de la Plata, Toa Alta | 200[ww] | 1960–1985 | 7.8 | 276 | 202,000 |
| 6. | Rio Grande de Loiza, Caguas | 89.8 | 1960–1985 | 14.0 | 219 | 131,000 |
| 7. | Rio Herrera, Colonia Dolores | 2.75 | 1966–1973 | 1.4[tt] | 9.47 | 5,430[tt] |
| 8. | Rio Espiritu Santo, Rio Grande | 8.62 | 1966–1985 | 5.0 | 57.0 | 22,400 |
| | | **East Coast Area** | | | | |
| 9. | Rio Fajardo, Fajardo | 14.9 | 1961–1985 | 3.5 | 68.9 | 45,400 |
| | | **South Coast Area** | | | | |
| 10. | Rio Grande de Patillas, Patillas | 18.3 | 1966–1985 | 5.4 | 60.9 | 40,500 |
| 11. | Rio Inabon, Real Abajo | 9.70 | 1964–1970<br>1971–1985 | 1.3 | 18.6 | 15,100 |
| 12. | Rio Cerrillos, Ponce | 17.8 | 1964–1985 | 3.1 | 35.8 | 22,200 |
| 13. | Rio Portugues, Ponce | 8.82 | 1964–1985 | 1.5 | 18.2 | 21,800 |
| | | **West Coast Area** | | | | |
| 14. | Rio Guanajibo, Hormigueros | 120 | 1973–1985 | 5.9[tt] | 220 | 160,000[tt] |
| 15. | Rio Grande de Anasco, San Sebastian | 134[xx] | 1963–1985 | 38.0 | 304 | 83,600 |
| | | **Rhode Island** | | | | |
| | | **New England Region** | | | | |
| | | **Massachusetts–Rhode Island Coastal Subregion** | | | | |
| | | **Blackstone River Basin** | | | | |
| 1. | Branch River, Forestdale | 91.2 | 1941–1983 | 13 | 171 | 7,110 |
| 2. | Blackstone River, Woonsocket | 416 | 1930–1983 | 100 | 763 | 19,200 |
| 3. | South Branch Pawtuxet River, Washington | 63.8 | 1942–1983 | 16 | 130 | 2,890 |
| 4. | Pawtuxet River, Cranston | 200 | 1941–1983 | 73 | 345 | 5,220 |
| | | **Pawcatuck River Basin** | | | | |
| 5. | Pawcatuck River, Wood River Jct. | 100 | 1942–1983 | 28 | 194 | 2,090 |
| 6. | Wood River, Hope Valley | 72.4 | 1942–1983 | 20 | 156 | 2,630 |
| 7. | Pawcatuck River, Westerly | 295 | 1942–1983 | 67 | 576 | 6,850 |
| | | **South Carolina** | | | | |
| | | **South Atlantic–Gulf Region** | | | | |
| | | **Pee Dee Subregion** | | | | |
| | | **Lower Pee Dee River Basin** | | | | |
| 1. | Pee Dee River, Pee Dee | 8,830 | 1938–1983 | 1,500[yy] | 9,850 | 160,000[yy] |
| 2. | Lynches River, Effingham | 1,030 | 1925–1983 | 132 | 1,035 | 22,100 |
| 3. | Little Pee Dee River, Galivants Ferry | 2,790 | 1943–1983 | 315 | 3,243 | 31,300 |
| 4. | Black River, Kingstree | 1,252 | 1920–1983 | 5.7 | 942 | 39,100 |
| 5. | Waccamaw River, Longs | 1,110 | 1950–1983 | 0.99 | 1,223 | 17,300 |
| | | **Edisto–Santee Subregion** | | | | |
| | | **Santee River Basin** | | | | |
| 6. | North Pacolet River, Fingerville | 116 | 1931–1983 | 43 | 215 | 13,100 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 7. | Broad River, Richtex | 4,850 | 1925–1983 | 970[yy] | 6,250 | 210,000[yy] |
| 8. | Saluda River, Columbia | 2,520 | 1925–1983 | 260[yy] | 2,929 | 70,000[yy] |
| 9. | Wateree River, Carnden | 5,070 | 1904–1910<br>1925–1983 | 490[yy] | 6,444 | 225,000[yy] |
| 10. | Congaree River, Columbia | 7,850 | 1939–1983 | 1,800[yy] | 9,425 | 220,000[yy] |
| 11. | Lake Marlon–Moultrie Diversion Canal | — | 1943–1983 | 2,320 | 15,125 | — |
| | **Edisto–South Carolina Coastal Basin** | | | | | |
| 12. | Edisto River, Givhans | 2,730 | 1939–1983 | 442 | 2,711 | 29,200 |
| 13. | Salkehatchie River, Miley | 341 | 1951–1983 | 33 | 356 | 4,390 |
| | **Ogeechee–Savannah Subregion** | | | | | |
| | **Savannah River Basin** | | | | | |
| 14. | Savannah River, Augusta, GA | 7,508 | 1883–1891<br>1896–1906<br>1925–1983 | 4,700[yy] | 10,300 | — |
| | **South Dakota** | | | | | |
| | **Missouri Region** | | | | | |
| | **Missouri River Main Stem[zz]** | | | | | |
| 1. | Missouri River, Mobridge | 208,700 | 1928–1962[aaa] | 3,500 | 21,560 | 471,000 |
| 2. | Missouri River, Pierre | 243,500 | 1929–1965 | 2,100[bbb] | 21,860 | 97,500[bbb] |
| 3. | Missouri River, Fort Randall Dam | 263,500 | 1947–1983 | 1,450[bbb] | 25,230 | 99,000[bbb] |
| 4. | Missouri River, Yankton | 279,500 | 1930–1983 | 5,980[bbb] | 26,430 | 92,400[bbb] |
| 5. | Missouri River, Sioux City, IA | 314,600 | 1929–1983 | 6,380[bbb] | 29,360 | 115,000[bbb] |
| | **Western Tributaries[ccc]** | | | | | |
| 6. | Little Missouri River, Camp Crook | 1,970 | 1903–1983[ddd] | 0.2 | 136 | 13,300 |
| 7. | Grand River, Little Eagle | 5,370 | 1958–1983 | 0.3[bbb] | 238 | 24,400[bbb] |
| 8. | Moreau River, Whitehorse | 4,880 | 1954–1983 | 0.0 | 202 | 44,900 |
| 9. | Cheyenne River, Cherry Creek | 23,900 | 1960–1983 | 26.1[bbb] | 827 | 84,600[bbb] |
| 10. | Bad River, Fort Pierre | 3,107 | 1928–1983 | 0.0 | 147 | 47,000 |
| 11. | White River, Oacoma | 10,200 | 1928–1983 | 0.5 | 531 | 49,200 |
| 12. | Keya Paha River, Wewela | 1,070 | 1937–1983[ddd] | 3.6 | 68.9 | 8,680 |
| | **Eastern Tributaries[eee]** | | | | | |
| 13. | James River, Scotland | 20,300 | 1928–1983 | 1.5 | 372 | 23,600 |
| 14. | Vermillion River, Wakonda | 1,680 | 1945–1983 | 0.9 | 125 | 6,050 |
| 15. | Big Sioux River, Akron, IA | 8,360 | 1928–1983 | 18.8 | 901 | 73,200 |
| | **Tennessee** | | | | | |
| | **Ohio Region** | | | | | |
| | **Cumberland Subregion** | | | | | |
| | **Cumberland Basin** | | | | | |
| 1. | New River, New River | 382 | 1934–1985 | 0.47 | 741 | 63,500 |
| 2. | Wolf River, Byrdstown | 106 | 1942–1985 | 5.19 | 192 | 31,400 |
| 3. | Cumberland River, Celina | 7,307 | 1924–1985 | 850 | 11,830 | 78,000 |
| 4. | West Fork Stones River, Smyrna | 237 | 1965–1985 | 9.0 | 440 | 57,400 |
| 5. | Harpeth River, Kingston Springs | 681 | 1924–1985 | 25.4 | 986 | 69,700 |
| 6. | Red River, Port Royal | 935 | 1961–1985 | 66.6 | 1,351 | 18,000 |
| | **Tennessee Region** | | | | | |
| | **Upper Tennessee, Middle Tennessee–Hiwassee, Middle Tennessee–Elk, and Lower Tennessee Subregions** | | | | | |
| | **Tennessee Basin** | | | | | |
| 7. | Nolichucky River, Embreeville | 805 | 1919–1985 | 224 | 1,370 | 72,600 |
| 8. | Little River, Maryville | 269 | 1951–1985 | 54.8 | 535 | 37,200 |
| 9. | Obed River, Lancing | 518 | 1958–1968<br>1974–1985 | 1.3 | 1,062 | 84,400 |
| 10. | South Chickamauga Creek, Chickamauga | 428 | 1928–1978<br>1980–1985 | 88.3 | 698 | 35,100 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| 11. | Tennessee River, Chattanooga | 21,400 | 1874–1985 | 10,000 | 37,100 | 257,000 |
| 12. | Elk River, Prospect | 1,784 | 1905–1907<br>1920–1985 | 330 | 3,076 | 128,000 |
| 13. | Duck River, Hurricane Mills | 2,557 | 1925–1985 | 303 | 4,121 | 114,000 |
| 14. | Buffalo River, Lobelville | 707 | 1927–1985 | 174 | 1,196 | 88,900 |
| 15. | Big Sandy River, Bruceton | 205 | 1929–1985 | 35.5 | 294 | 18,900 |
| | **Lower Mississippi Region** | | | | | |
| | **Lower Mississippi–Hatchie Subregion** | | | | | |
| | **Lower Mississippi Basin** | | | | | |
| 16. | Obion River, Obion | 1,852 | 1929–1958<br>1966–1985 | 266 | 2,702 | 92,800 |
| 17. | Hatchie River, Bolivar | 1,480 | 1929–1985 | 126 | 2,428 | 68,000 |
| 18. | Loosahatchie River, Arlington | 262 | 1969–1985 | 71 | 364 | 24,000 |
| 19. | Wolf River, Germantown | 699 | 1969–1985 | 200 | 1,040 | 42,100 |
| | **Arkansas–White–Red Region** | | | | | |
| | **Canadian–Red River Basin[fff]** | | | | | |
| 1. | Canadian River, Amarillo | 15,376 | 1939–1983 | 0.3 | 331 | 135,000 |
| 2. | Red River Terral, OK | 22,787 | 1939–1983 | 76.4 | 2,117 | — |
| | **Texas–Gulf Region** | | | | | |
| | **Sabine–Neches–Trinity–San Jacinto River Basin[ggg]** | | | | | |
| 3. | Trinity River, Dallas | 6,106 | 1903–1983 | 20.5 | 1,530 | — |
| 4. | Trinity River, Romayor | 17,186 | 1969–1983 | 64 | 7,417 | — |
| 5. | Neches River, Rockland | 3,636 | 1962–1983 | 27.6 | 1,974 | 68,400 |
| | **Brazos–Colorado River Basin[hhh]** | | | | | |
| 6. | Salt Fork Brazos River, Aspermont | 2,496 | 1940–1983 | 0.0 | 108 | 52,900 |
| 7. | Brazos River, South Bend | 13,107 | 1939–1983 | 0.0 | 836 | — |
| 8. | North Bosque River, Clifton | 968 | 1968–1983 | 0.0 | 167 | 73,200 |
| 9. | Colorado River, Colorado City | 1,585 | 1953–1983 | 0.0 | 38.9 | — |
| 10. | Llano River, Junction | 1,849 | 1916–1983 | 17.8 | 194 | 363,000 |
| 11. | Colorado River, Wharton | 30,600 | 1939–1983 | 224 | 2,685 | — |
| | **Lavaca–Guadalupe–Nueces River Basin[iii]** | | | | | |
| 12. | Guadalupe River, Spring Branch | 1,315 | 1923–1983 | 0.1 | 311 | 158,000 |
| 13. | Nueces River, Laguna | 737 | 1924–1983 | 9.6 | 148 | 408,000 |
| 14. | Nueces River, Three Rivers | 15,427 | 1916–1983 | 0.0 | 848 | 116,000 |
| | **Rio Grande Region** | | | | | |
| | **Rio Grande Basin[jjj]** | | | | | |
| 15. | Pecos River, Girvin | 29,560 | 1940–1983 | 3.3 | 84.2 | 23,300 |
| | **U.S. Virgin Islands** | | | | | |
| | **Caribbean Region** | | | | | |
| | **U.S. Virgin Islands Subregion** | | | | | |
| | **St. Thomas** | | | | | |
| 1. | Bonne Resolution Gut, Bonne Resolution | 0.49 | 1963–1968<br>1979–1981<br>1982 | 0 | 0.24 | [kkk]1,650 |
| 2. | Turpentine Run, Mariendal | 2.97 | 1963–1969<br>1979–1980<br>1982 | 0 | 1.07 | [kkk]9,710 |
| | **St. John** | | | | | |
| 3. | Guinea Gut, Bethany | 0.37 | 1963–1967<br>1983 | 0 | 0.08 | [kkk]946 |
| | **St. Croix** | | | | | |
| 4. | Jolly Hill Gut, Jolly Hill | 2.10 | 1963–1969<br>1983 | 0 | 0.02 | [lll]223 |

*(Continued)*

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**Table 5A.2 (Continued)**

| | Gaging Station | | | Streamflow Characteristics | | |
|---|---|---|---|---|---|---|
| | Name | Drainage Area ($mL^2$) | Period of Analysis | 7-Day, 10-Year Low Flow ($ft^3$/sec) | Average Discharge ($ft^3$/sec) | 100-Year Flood ($ft^3$/sec) |
| | **Guam, American Samoa, and the Trust Territory of the Pacific Islands** | | | | | |
| | **Aipan** | | | | | |
| 1. | S. F. Talofofo Stream | 0.64 | 1968–1984 | 0.0 | 1.35 | — |
| | **Guam** | | | | | |
| 2. | Ugum River | 5.76 | 1977–1984 | 3.6 | 23.3 | — |
| 3. | Ylig River | 6.48 | 1952–1984 | 0.2 | 28.0 | 5,980 |
| 4. | Pago River | 5.67 | 1951–1982 | 0.2 | 26.3 | 12,300 |
| | **Palau** | | | | | |
| 5. | Diongradid River | 4.45 | 1969–1984 | 3.2 | 32.4 | 2,870 |
| 6. | Tabecheding River | 6.07 | 1970–1984 | 1.7 | 48.4 | 4,910 |
| | **Yap** | | | | | |
| 7. | Oaringeel Stream | 0.24 | 1968–1984 | 0.1 | 1.07 | 696 |
| | **Truk** | | | | | |
| 8. | Wichen River | 0.57 | 1968–1983 | 0.02 | 3.05 | 1,060 |
| | **Pohnpei** | | | | | |
| 9. | Nanpil River | 3.00 | 1970–1984 | 1.8 | 44.6 | 10,000 |
| | **Kosrae** | | | | | |
| 10. | Malem River | 0.76 | 1971–1981<br>1982–1984 | 0.3 | 6.71 | 2,760 |
| | **American Samoa** | | | | | |
| 11. | Aasu Stream | 1.03 | 1958–1984 | 0.4 | 6.05 | 586 |
| 12. | Afuelo Stream | 0.25 | 1958–1984 | 0.03 | 1.45 | 683 |
| | **Utah** | | | | | |
| | **Upper Colorado Region** | | | | | |
| | **Colorado River Main Stem[mmm]** | | | | | |
| 1. | Colorado River, Cisco | 24,100[nnn] | 1895–1984 | 1,100 | 7,563 | 87,600 |
| | **Upper–Coloradodolores Subregion** | | | | | |
| | **Dolores River Basin** | | | | | |
| 2. | Dolores River, Cisco | [nnn]4,580 | 1951–1984 | 19 | 785 | 23,600 |
| | **Great Divide–Upper Green and Lower Green Subregions** | | | | | |
| | **Green River Basin** | | | | | |
| 3. | Green River, Jensen | [nnn]29,660 | [ooo]1904–1984 | 480[ppp]<br>743 | 4,396[ppp]<br>4,456 | 38,200 |

Gaging station: Period of analysis is for the water years used to compute average discharge and may differ from that used to compute other streamflow characteristics. Streamflow characteristics: The 7-day, 10-year low flow is a discharge statistic; the lowest average discharge during 7 consecutive days of a year will be equal to or less than this value, on the average, once every 10 years. The average discharge is the arithmetic average annual discharges during the period of analysis. The 100-year flood is the peak flow that has a 1-percent chance of being equaled or exceeded in a given year. The degree of regulation is the effect of dams on the natural flow of the river. Abbreviations: Do = ditto; $mi^2$ = square miles; $ft^3$/sec = cubic feet per second; … = insufficient data or not applicable.

[a] Less than 10 years of record. Minimum discharge and maximum instantaneous discharge for period of record are shown.
[b] Record interrupted.
[c] Adjusted for no-flow periods.
[d] Adjusted for high-outlier in period of record. Did not use 1981 peak because it was regulated.
[e] Adjusted for high-outlier in period of record.
[f] Sutter and Yolo Bypasses Carry Much of Floodflow Past Verona gage.
[g] Regulation has Little Effect on High Floodflows.
[h] From Upper Mississippi River Basin Commission, 1978.
[i] Within the Upper Mississippi–Black–Root, Upper Mississippi–Maquoketa–Plum, and Upper Mississippi–Iowa–Skunk–Wapsipinicon Subregion (Seaber and Others, 1984).
[j] Within the Upper Mississippi–Iowa–Skunk–Wapsipinicon Subregions (Seaber and Others, 1984).
[k] Within the Minnesota Des Moines Subregions(Seaber and Others, 1984).
[l] Within the Missouri–Big Sioux, Missouri–Little Sioux, and Missouri–Nishnabotna Subregions (Seaber and Others, 1984).
[m] Flow Parameters Based Only on 1929–1931 and 1939–1956 Water Years.
[n] From U.S. Army Corps of Engineers, February 1978.
[o] Within the Missouri–Big Sioux, Missouri–Little Sioux, and Missouri–Nishnabotna Subregions (Seaber and Others, 1984).
[p] Within the Missouri–Nishnabotna, Chariton–Grand, and Upper Mississippi–Salt Subregions (Seaber and Others, 1984).
[q] Based on period of analysis since regulation began. These values are not based on detailed analyses, are approximate estimates, and are for information purposes only.

*(Continued)*

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**Table 5A.2 (Continued)**

| | |
|---|---|
| r | From flood-insurance hydrology study. Based on detailed analyses of regulated-flow conditions. |
| s | Prior to opening of Barkley–Kentucky Canal (1889–1965). |
| t | Since the opening of Barkley–Kentucky Canal (1965–1983). |
| u | Includes all or parts of the Lower Mississippi–Yazoo, Lower Mississippi–Big Black, Lower Mississippi–Lake Maurepas, and the Lower Mississippi Subregions (Seaber, Kapinos, and Knapp, 1984). |
| v | Includes the Mississippi Headwaters and the Upper Mississippi Black-Roof Subregions. |
| w | Data furnished by U.S. Army Corps of Engineers. |
| x | Includes the Saskatchewan, the Missouri Headwaters, the Missouri–Marias, the Missouri–Musselshell, the Milk, and the Missouri–Polar Subregions. |
| y | Includes the upper Yellowstone, the Big Horn, the Powder–Tongue, the lower Yellowstone, and the Missouri–Little Missouri Subregions. |
| z | Contained within the Kootenai–Pend Oreille–Spokane Subregion. |
| aa | Within the Missouri–Big Sioux, Missouri–Little Sioux, and Missouri–Nishnabotna Subregions. |
| bb | Analysee based on period of record since regulation began. |
| cc | Based on record to 1981. |
| dd | Period of record not continuous. |
| ee | Adjusted for diversion and change in reservoir contents. |
| ff | Analysis based no regulated period 1955–1984. |
| gg | Period of record not continuous. |
| hh | Also includes parts of the Upper Arkansas, Upper Cimarron, Lower Canadian, North Canadian, and Red Headwaters Subregions. |
| ii | Fifteen years, prior to completion of Conchas Dam. |
| jj | Twenty-four years, prior to completion of Ute dam. |
| kk | Twenty-one years (1963–1983), subsequent to completion of Ute Dam. |
| ll | Includes all or parts of Rio Grande Headwaters, Rio Grande–Elephant–Butte, Rio Grande–Mimbres, and Rio Grande Closed basins Subregions. |
| mm | Thirty-two years, prior to closure of Cochiti Dam. |
| nn | Ten years (1974–1983), subsequent to closure of Cochiti Dam. |
| oo | Includes parts of the Little Colorado, Upper Gila and Sonora Subregions. |
| pp | Approximate. |
| qq | Noncontributing. |
| rr | Includes parts or all of the Upper Cimarron, Arkansas–Keystone, Lower Cimarron, Lower Arkansas, Neosho–Verdigris, Lower Canadian and North Canadian Subregions. |
| ss | Includes parts or all of the Red Headwaters, Red–Washita, and Red–Sulphur Subregions. |
| tt | Estimated. |
| uu | Drainage area includes 38 $mi^2$ which are partly or entirely noncontributing and excludes 6.0 $mi^2$ upstream from Lago El Guinea and Lago de Matrullas. |
| vv | Drainage area includes 25.4 $mi^2$ which do not contribute directly to surface runoff. |
| ww | Drainage area excludes 8.2 $mi^2$ upstream form Lago Carite, flow from which is diverted to the Rio Guamani. |
| xx | Drainage area includes 39.7 $mi^2$ from headwaters of Lago Yahuecas (17.05 $mi^2$), Lago Guayo (9.67 $mi^2$), Lago prieto (9.50 $mi^2$), and Lago Toro (3.5 $mi^3$) which does not contribute to surface runoff except at high stages. |
| yy | Analysis based on records collected since regulation began. |
| zz | Within the Missouri–Oahe, Missouri–White, and Missouri–Big Sioux Subregions. |
| aaa | Station discontinued subsequent to construction of Oahe Dam in 1962. |
| bbb | Analysis based on period of record after regulation began. |
| ccc | Within the Missouri–Oahe, Missouri–Little Missouri, Cheyenne, Missouri–White, and Niobrara Subregions. |
| ddd | Period of record not continuous. |
| eee | Within the James and Missouri–Big Sioux Subregions. |
| fff | Within the Upper Canadian, Lower Canadian, North Canadian, Red Headwaters, Red–Washita, and Red–Sulphur Subregions. |
| ggg | Within the Sabine, neches, Triniy, and Galveston Bay–San Subregions. |
| hhh | Within the Brazos Headwaters, Middle Brazos, Lower Brazos, Upper Colorado, and Lower Colorado–San Bernard Coastal Subregions. |
| iii | Within the Central Texas Coastal and Nueces–Southwestern Texas Coastal Subregions. |
| jjj | Within the Rio Grande–Mimbres, Rio Grande Amistad, Rio Grande Closed Basins, Upper Pecos, Lower Pecos, Rio Grande–Falcon, and Lower Rio Grande Subregions. |
| kkk | Discharge represents highest recorded. Data available are not adequate to determine a discharge–frequency relation, but it is estimated to have exceeded the 100-year flood. |
| lll | Discharge represents highest recorded. |
| mmm | Within the Upper Colorado–Dolores and Upper Colorado–Dirty Devil Subregions. |
| nnn | Approximate. |
| ooo | Period of analysis not continuous. |
| ppp | Since completion of Flaming Gorge Reservoir in 1963. |
| qqq | Based on record to 1981. |

*Source*: From U.S. Geological Survey, *National Water Summary 1985—Hydrologic Events and Surface-Water Resources, Water-Supply Paper 2300*.

*Original Source*: Reports of the U.S. Geological Survey and State agencies.

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**Table 5A.3 Monthly Discharge of Principal Rivers in the United States**

| River and Station | Basin Area ($km^2$) | Mean Monthly Discharge ($m^3$/sec) Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year | Period of Record |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Penobscot, West Enfield, ME | 17,000 | 214 | 186 | 290 | 809 | 685 | 345 | 221 | 181 | 176 | 224 | 328 | 282 | 327 | 1902–65 |
| Kennebec, Bingham, ME | 7,040 | 94.4 | 99.5 | 116 | 202 | 259 | 136 | 94.8 | 89.6 | 89.0 | 88.2 | 93.3 | 92.9 | 121 | 1907–10 |
| Androscoggin, Auburn, ME | 8,436 | 123 | 111 | 194 | 428 | 336 | 161 | 93.5 | 81.7 | 93.4 | 107 | 149 | 137 | 168 | 1929–65 |
| Merrimack, Lowell, MA | 12,000 | 187 | 188 | 348 | 542 | 320 | 165 | 86.6 | 71.3 | 90.8 | 98.4 | 171 | 193 | 205 | 1923–65 |
| Connecticut, Thompsonville, CT | 25,020 | 385 | 341 | 677 | 1,300 | 763 | 365 | 194 | 172 | 202 | 237 | 390 | 393 | 451[1] | 1928–65 |
| Delaware, Trenton, NJ | 17,600 | 351 | 353 | 611 | 653 | 387 | 235 | 197 | 170 | 157 | 179 | 292 | 334 | 327 | 1912–65 |
| Susquehanna, Harrisburg, PA | 62,400 | 1,070 | 1,100 | 2,210 | 2,090 | 1,290 | 703 | 422 | 332 | 306 | 457 | 696 | 877 | 963[1] | 1890–1965 |
| Potomac, Washington, DC | 29,940 | 369 | 461 | 642 | 552 | 379 | 221 | 132 | 143 | 110 | 150 | 161 | 245 | 296 | 1930–65 |
| James, Richmond, VA | 17,500 | 260 | 300 | 358 | 316 | 192 | 126 | 83.5 | 106 | 85.1 | 95.3 | 105 | 185 | 184 | 1934–65 |
| Roanoke, Roanoke Rapids, NC | 21,800 | 304 | 329 | 362 | 315 | 233 | 182 | 175 | 183 | 158 | 155 | 153 | 221 | 230 | 1911–65 |
| Cape Fear, Lillington, NC | 8,910 | 143 | 181 | 169 | 140 | 66.6 | 49.7 | 64.9 | 61.3 | 72.7 | 59.0 | 57.6 | 87.7 | 95.9 | 1923–65 |
| Pee Dee, Pee Dee, SC | 22,900 | 316 | 431 | 471 | 396 | 241 | 179 | 190 | 183 | 210 | 182 | 171 | 224 | 265 | 1938–65 |
| Santee, Pineville, SC | 38,100 | 58.6 | 123 | 161 | 139 | 47.8 | 24.8 | 22.2 | 18.8 | 63.6 | 72.9 | 31.6 | 43.0 | 67.0 | 1942–65 |
| Savannah, Clyo, GA | 25,500 | 418 | 438 | 519 | 520 | 338 | 240 | 244 | 253 | 222 | 277 | 249 | 313 | 336 | 1929–33, 37–65 |
| Altamaha, Doctortown, GA | 35,200 | 477 | 636 | 795 | 782 | 388 | 239 | 231 | 214 | 177 | 177 | 162 | 295 | 385 | 1931–65 |
| St. Johns, De Land, FL | 8,080 | 78.8 | 69.0 | 73.4 | 70.8 | 46.2 | 46.8 | 80.2 | 100 | 124 | 168 | 144 | 103 | 92.2 | 1933–65 |
| Suwannee, Branford, FL | 20,000 | 169 | 203 | 287 | 316 | 207 | 145 | 148 | 180 | 185 | 175 | 141 | 142 | 191 | 1931–65 |
| Apalachicola, Chattahoochee, FL | 44,300 | 752 | 876 | 1,150 | 1,040 | 652 | 465 | 477 | 429 | 341 | 361 | 359 | 550 | 620[1] | 1928–65 |
| Escambia, Century, FL | 9,886 | 223 | 246 | 339 | 337 | 166 | 108 | 120 | 123 | 95.6 | 74.6 | 90.5 | 160 | 173 | 1934–65 |
| Alabama, Claiborne, AL | 57,000 | 1,280 | 1,550 | 1,830 | 1,770 | 899 | 531 | 519 | 484 | 369 | 367 | 433 | 834 | 902[1] | 1930–65 |
| Tombigbee, Leroy, AL | 49,500 | 1,190 | 1,580 | 1,750 | 1,530 | 714 | 318 | 330 | 208 | 175 | 162 | 347 | 661 | 742[1] | 1928–60 |
| Pascagoula, Merrill, MS | 17,000 | 381 | 492 | 561 | 515 | 279 | 140 | 170 | 124 | 100 | 78.5 | 133 | 269 | 269 | 1930–65 |
| Pearl, Bogalusa, LA | 17,200 | 332 | 483 | 554 | 502 | 298 | 138 | 144 | 103 | 74.8 | 70.0 | 101 | 222 | 250 | 1938–65 |
| Ohio, Louisville, KY | 236,100 | 4,880 | 5,470 | 7,210 | 6,020 | 3,730 | 2,280 | 1,610 | 1,190 | 743 | 738 | 1,500 | 2,780 | 3,120[1] | 1928–65 |
| Wabash, Mount Carmel, IL | 74,100 | 1,130 | 1,110 | 1,370 | 1,380 | 1,130 | 742 | 528 | 270 | 194 | 217 | 332 | 537 | 744[1] | 1928–65 |
| Cumberland, Smithland, KY | 46,395 | 1,210 | 1,580 | 1,740 | 1,390 | 718 | 446 | 348 | 272 | 217 | 188 | 383 | 809 | 779 | 1939–65 |
| Tennessee, Paducah, KY | 104,000 | 2,890 | 3,590 | 3,160 | 2,100 | 1,520 | 1,170 | 1,140 | 1,080 | 1,050 | 987 | 1,370 | 2,130 | 1,820[1] | 1939–65 |
| Ohio, Metropolis, IL | 526,000 | 10,900 | 13,400 | 14,900 | 13,400 | 8,650 | 5,480 | 4,070 | 3,040 | 2,300 | 2,180 | 3,640 | 6,200 | 7,300[1] | 1928–65 |
| Fox, Wrightstown, WS | 15,900 | 109 | 112 | 132 | 199 | 171 | 143 | 95.4 | 76.2 | 73.1 | 86.4 | 99.8 | 105 | 117 | 1896–1965 |
| Grand, Grand Rapids, MI | 12,700 | 90.7 | 111 | 213 | 185 | 128 | 88.9 | 54.4 | 41.0 | 46.0 | 54.0 | 64.8 | 70.9 | 95.2 | 1904–65 |
| Maumee, Waterville, OH | 16,350 | 197 | 203 | 317 | 268 | 157 | 92.4 | 47.4 | 22.7 | 22.4 | 31.5 | 58.7 | 108 | 127 | 1899–1901 |
| St. Lawrence, Ogdensburg, NY | 764,600 | 6,230 | 6,150 | 6,430 | 6,970 | 7,230 | 7,340 | 7,290 | 7,100 | 6,860 | 6,630 | 6,510 | 6,450 | 6,760 | 1860–1965 |
| Red of the North, Grand Forks, ND | 78,000 | 19.5 | 18.0 | 48.1 | 238 | 138 | 108 | 80.3 | 44.1 | 36.0 | 35.2 | 31.4 | 24.8 | 68.5 | 1882–1965 |
| Mississippi, Clinton, IA | 222,000 | 677 | 730 | 1,330 | 2,420 | 2,280 | 1,990 | 1,560 | 1,030 | 1,040 | 1,100 | 1,030 | 708 | 1,330[1] | 1874–1965 |
| Mississippi, Alton, IL | 444,200 | 1,790 | 2,120 | 3,540 | 4,870 | 4,290 | 3,680 | 2,840 | 1,740 | 1,650 | 1,660 | 1,790 | 1,530 | 2,620[1] | 1927–65 |
| Missouri, Culbertson, MT | 237,130 | 187 | 171 | 212 | 259 | 205 | 184 | 236 | 363 | 389 | 377 | 249 | 197 | 252 | 1941–51; 58–65 |
| Yellowstone, Sidney, MT | 178,220 | 143 | 173 | 307 | 310 | 527 | 1,200 | 690 | 257 | 197 | 228 | 197 | 153 | 365[1] | 1910–31; 33–65 |
| Missouri, Yankton, SD | 723,900 | 267 | 299 | 600 | 1,120 | 829 | 1,250 | 1,060 | 737 | 696 | 663 | 485 | 263 | 689[1] | 1930–65 |
| Platte, South Bend | 221,000 | 84.7 | 148 | 249 | 233 | 218 | 267 | 134 | 88.6 | 93.7 | 87.6 | 109 | 93.4 | 150 | 1953–65 |
| Missouri, Nebraska City, NE | 1,073,000 | 374 | 532 | 1,060 | 1,540 | 1,200 | 1,690 | 1,360 | 918 | 848 | 807 | 674 | 384 | 948[1] | 1929–65 |
| Kansas, Bonner Springs, | 155,100 | 67.0 | 106 | 161 | 221 | 261 | 426 | 332 | 169 | 180 | 136 | 99.1 | 67.5 | 185 | 1917–65 |

*(Continued)*



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**Table 5A.3 (Continued)**

| River and Station | Basin Area ($km^2$) | Mean Monthly Discharge ($m^3$/sec) Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year | Period of Record |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Missouri, Herman, MO | 1,368,000 | 1,080 | 1,420 | 2,430 | 3,360 | 3,020 | 4,160 | 3,390 | 1,930 | 1,820 | 1,600 | 1,440 | 1,050 | 2,220[1] | 1897–1965 |
| White, DeValls Bluff, AR | 60,686 | 850 | 943 | 1,140 | 1,270 | 1,230 | 829 | 505 | 339 | 291 | 305 | 402 | 542 | 720[1] | 1928–45; 50–65 |
| Arkansas, Tulsa, OK | 193,250 | 73.6 | 90.9 | 118 | 261 | 375 | 368 | 277 | 151 | 164 | 185 | 116 | 82.6 | 188 | 1925–65 |
| Canadian, Whitefield, OK | 123,220 | 61.5 | 102 | 147 | 255 | 430 | 291 | 164 | 69.0 | 88.6 | 117 | 87.0 | 76.9 | 157 | 1938–65 |
| Arkansas, Little Rock, AR | 409,741 | 987 | 1,160 | 1,330 | 1,810 | 2,320 | 1,780 | 1,070 | 545 | 555 | 762 | 695 | 721 | 1,140[1] | 1927–65 |
| Mississippi, Vicksburg, MS | 2,964,300 | 16,200 | 21,100 | 24,800 | 27,900 | 23,600 | 18,500 | 14,600 | 9,340 | 7,320 | 7,090 | 8,220 | 11,100 | 15,800[1] | 1928–65 |
| Red, Alexandria, LA | 175,000 | 1,100 | 1,330 | 1,380 | 1,350 | 1,600 | 1,150 | 555 | 305 | 260 | 342 | 432 | 673 | 880[1] | 1928–65 |
| Ouachita, Monroe, LA | 39,622 | 627 | 879 | 1,010 | 1,039 | 940 | 524 | 272 | 103 | 90.1 | 109 | 174 | 316 | 507[1] | 1932–65 |
| Mississippi, Tarbert Landing | 3,923,800 | 17,900 | 23,000 | 27,800 | 30,800 | 27,900 | 21,400 | 16,500 | 10,500 | 8,100 | 7,930 | 8,750 | 12,100 | 17,700[1] | 1928–65 |
| Sabine, Ruliff, TX | 24,160 | 399 | 416 | 406 | 366 | 381 | 252 | 120 | 82.9 | 57.5 | 55.5 | 116 | 221 | 239 | 1927–65 |
| Neches, Evadale, TX | 20,590 | 273 | 297 | 308 | 308 | 325 | 188 | 73.4 | 37.3 | 28.2 | 36.6 | 81.1 | 164 | 176 | 1904–06; 21–65 |
| Trinity, Romayor, TX | 44,512 | 247 | 262 | 291 | 278 | 439 | 295 | 118 | 41.4 | 53.6 | 86.4 | 122 | 185 | 202 | 1924–65 |
| Brazos, Richmond, TX | 114,000 | 200 | 234 | 231 | 257 | 459 | 303 | 145 | 68.9 | 99.2 | 153 | 140 | 188 | 207 | 1903–06; 22–65 |
| Colorado, Wharton, TX | 107,200 | 67.6 | 79.5 | 67.5 | 101 | 133 | 131 | 82.8 | 47.0 | 72.2 | 77.2 | 80.6 | 69.8 | 80.7 | 1919–25; 38–65 |
| Nueces, Mathis, TX | 43,150 | 8.6 | 12.0 | 11.4 | 15.0 | 43.5 | 38.9 | 29.5 | 6.9 | 42.7 | 38.2 | 10.8 | 4.2 | 21.9 | 1939–65 |
| Pecos, Shumla, TX | 91,069 | 5.42 | 5.28 | 4.82 | 6.57 | 13.4 | 9.84 | 7.23 | 5.28 | 16.6 | 12.7 | 6.31 | 5.44 | 8.24 | 1954–65 |
| Rio Grande, Laredo, TX | 352,178 | 73.7 | 72.2 | 61.9 | 69.7 | 121 | 158 | 136 | 143 | 269 | 188 | 96.8 | 82.5 | 123 | 1900–14; 22–65 |
| Green, Green River, UT | 105,000 | 49.3 | 64.8 | 124 | 222 | 485 | 600 | 250 | 108 | 76.8 | 77.4 | 68.5 | 50.6 | 181 | 1895–99; 1905–65 |
| Colorado, Lees Ferry, AZ | 279,500 | 150 | 192 | 274 | 561 | 1,280 | 1,600 | 657 | 313 | 236 | 245 | 210 | 163 | 489[1] | 1911–65 |
| Colorado, Yuma, AZ | 629,100 | 222 | 262 | 293 | 367 | 665 | 1,040 | 586 | 306 | 230 | 214 | 200 | 213 | 383 | 1902–65 |
| Sevier, Juab, UT | 13,300 | 0.67 | 0.35 | 1.28 | 6.86 | 20.4 | 13.6 | 14.2 | 9.13 | 5.98 | 2.36 | 1.05 | 0.38 | 6.36 | 1911–65 |
| Humboldt, Imlay, NV | 40,700 | 2.09 | 3.53 | 6.60 | 9.83 | 14.2 | 13.9 | 10.8 | 2.54 | 1.05 | 0.71 | 0.92 | 1.71 | 5.66 | 1935–41; 45–65 |
| San Joaquin, Vernalis, CA | 35,070 | 126 | 181 | 187 | 199 | 239 | 212 | 64.9 | 28.1 | 33.8 | 46.8 | 58.6 | 99.2 | 124 | 1922–65 |
| Sacramento, Sacramento, CA | 60,940 | 940 | 1,180 | 1,020 | 960 | 850 | 501 | 299 | 289 | 323 | 320 | 419 | 681 | 647[1] | 1948–65 |
| Eel, Scotia, CA | 8,063 | 508 | 566 | 349 | 262 | 108 | 35.3 | 9.42 | 4.08 | 3.57 | 22.1 | 121 | 370 | 200 | 1910–65 |
| Klamath, Klamath, CA | 31,300 | 806 | 1,050 | 749 | 793 | 648 | 381 | 162 | 94.2 | 93.6 | 148 | 348 | 629 | 486 | 1910–26; 50–65 |
| Chehalis, Porter, WA | 3,351 | 279 | 251 | 182 | 131 | 64.5 | 31.0 | 15.8 | 10.9 | 12.4 | 38.9 | 176 | 239 | 119 | 1952–65 |
| Pend Oreille, Newport, WA | 62,700 | 377 | 382 | 439 | 723 | 1,540 | 2,060 | 1,210 | 505 | 339 | 340 | 402 | 391 | 726[1] | 1903–41; 52–65 |
| Columbia International Bdry. | 155,000 | 1,080 | 1,110 | 1,200 | 1,930 | 5,040 | 8,140 | 5,920 | 3,130 | 1,940 | 1,600 | 1,430 | 1,190 | 2,810 | 1937–65 |
| Snake, Clarkston, WA | 267,300 | 866 | 1,010 | 1,320 | 2,300 | 3,540 | 3,140 | 1,130 | 555 | 549 | 666 | 777 | 887 | 1,390[1] | 1915–65 |
| Columbia, Dalles, OR | 614,000 | 2,750 | 3,020 | 3,590 | 5,700 | 10,300 | 14,000 | 9,630 | 5,270 | 3,470 | 2,810 | 2,800 | 2,820 | 5,520[1] | 1878–1965 |
| Willamette, Salem, OR | 18,900 | 1,300 | 1,250 | 971 | 824 | 624 | 412 | 205 | 134 | 147 | 253 | 772 | 1,130 | 665[1] | 1909–16; 23–65 |
| Cowlitz, Castle Rock, WA | 5,796 | 371 | 354 | 297 | 323 | 345 | 291 | 150 | 76.3 | 65.2 | 122 | 302 | 415 | 259 | 1927–65 |
| Umpqua,Elkton, OR | 9,539 | 443 | 450 | 350 | 278 | 191 | 113 | 50.9 | 33.6 | 33.4 | 55.8 | 194 | 361 | 212 | 1905–65 |
| Rogue, Agness, OR | 10,200 | 312 | 352 | 260 | 229 | 181 | 94.2 | 46.7 | 37.1 | 35.9 | 64.1 | 154 | 427 | 182 | 1960–65 |
| Copper, Chitina, AK | 53,300 | 160 | 130 | 124 | 147 | 848 | 2,320 | 3,250 | 2,920 | 1,460 | 615 | 303 | 200 | 1,040[1] | 1955–65 |
| Kuskokwim, Crooked Creek, AK | 80,500 | 385 | 328 | 284 | 315 | 2,080 | 2,740 | 2,000 | 2,420 | 2,470 | 1,300 | 599 | 457 | 1,280 | 1951–65 |
| Yukon, Eagle, AK | 294,000 | 475 | 433 | 394 | 408 | 3,220 | 6,160 | 5,130 | 3,980 | 2,980 | 1,930 | 980 | 598 | 2,220[1] | 1911–14; 50–65 |
| Yukon, Rampart, AK | 516,400 | 674 | 591 | 502 | 517 | 5,420 | 11,500 | 7,950 | 6,480 | 5,090 | 2,780 | 1,220 | 799 | 3,630[1] | 1955–65 |
| Yukon, Kaltag, AK | 767,000 | 1,320 | 1,100 | 915 | 930 | 7,980 | 18,300 | 13,100 | 11,800 | 9,820 | 5,400 | 2,350 | 1,490 | 6,210[1] | 1956–65 |

[1] Monthly and yearly averages rounded to three significant figures.

*Source*: From UNESCO, 1971.

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**Table 5A.4 Length of Principal Rivers in the United States and Canada**

| River/Outflow | Length | |
|---|---|---|
| | Miles | km |
| Alabama/Mobile River | 735 | 1,183 |
| Albany/James Bay | 610 | 981 |
| Arkansas/Mississippi River | 1,459 | 2,348 |
| Black/Chantrey Inlet | 600 | 965 |
| Brazos/Gulf of Mexico | 870 | 1,400 |
| Canadian/Arkansas River | 906 | 1,458 |
| Churchill/Hudson Bay | 1,000 | 1,609 |
| Cimarron/Arkansas River | 600 | 965 |
| Colorado (U.S.-Mex.)/Gulf of California | 1,450 | 2,333 |
| Colorado (Texas)/Matagorda Bay | 840 | 1,352 |
| Columbia/Pacific Ocean | 1,243 | 2,000 |
| Columbia, Upper Mouth of Snake River | 890 | 1,432 |
| Cumberland/Ohio River | 720 | 1,158 |
| Fraser/Strait of Georgia | 850 | 1,368 |
| Gila/Colorado River | 630 | 1,014 |
| Green (UT–WY)/Colorado River | 730 | 1,175 |
| Hamilton/Atlantic Ocean | 600 | 965 |
| James (ND–SD)/Missouri River | 710 | 1,142 |
| Kuskokwim/Kuskokwim Bay | 680 | 1,094 |
| Liard/Mackenzie River | 693 | 1,115 |
| Mackenzie/Arctic Ocean | 900 | 1,448 |
| Milk/Missouri River | 625 | 1,006 |
| Mississippi/Mouth of SW Pass | 2,348 | 3,778 |
| Mississippi, Upper/to Mouth of Missouri River | 1,171 | 1,884 |
| Mississippi–Missouri–Red Rock/Mouth of SW Pass | 3,710 | 5,969 |
| Missouri/Mississippi River | 2,315 | 3,725 |
| Missouri–Red Rock/Mississippi River | 2,533 | 4,076 |
| Mobile-Alabama–Coosa/Mobile Bay | 780 | 1,255 |
| North Canadian/Canadian River | 760 | 1,223 |
| North Platte/Platte River | 618 | 994 |
| Ohio/Mississippi River | 981 | 1,578 |
| Ohio–Allegheny/Mississippi River | 1,306 | 2,101 |
| Ottawa/St. Lawrence | 790 | 1,271 |
| Ouachita/Red River | 605 | 973 |
| Peace/Slave River | 1,195 | 1,923 |
| Pecos/Rio Grande | 735 | 1,183 |
| Red (OK–TX–LA)/Mississippi River | 1,270 | 2,043 |
| Rio Grande/Gulf of Mexico | 1,885 | 3,033 |
| St. Lawrence/Lake Ontario | 800 | 1,287 |
| Saskatchewan N./Lake Winnipeg | 1,100 | 1,770 |
| Saskatchewan S./Lake Winnipeg | 1,205 | 1,939 |
| Severn (Ontario)/Hudson Bay | 610 | 981 |
| Snake/Columbia River | 1,038 | 1,670 |
| Tanana/Yukon River | 620 | 998 |
| Tennessee/Ohio River | 652 | 1,049 |
| Tennessee–French Broad/Ohio River | 900 | 1,448 |
| White (AR–MO)/Mississippi River | 720 | 1,158 |
| Yellowstone/Missouri River | 671 | 1,080 |
| Yukon/Bering Sea | 1,979 | 3,185 |

*Note:* Comprises rivers 600 miles or more in length. Length represents distance to designated outflow from (a) original headwater of named river where name applies to entire length of channel, or (b) upper limit of channel so named, usually the junction of two tributaries or headwater streams.

*Source*: From Statistical Abstract of the United States 1986.

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**Table 5A.5 Flowing Water Resources of the United States**

| Stream Order[a] | Number Streams | Average Length Miles | Total Length Miles (L) | Drainage Area Sq. Miles ($A_d$) | Mean Flow For Area Drained (CFS) | Mean Width Feet (W) | Mean Depth Feet (D) | Mean Velocity ft/sec (V) | Calculated Discharge CFS = WDV | Total Surface Area, $A_s$Sq. Miles (thousands) | Total Channel Storage Acre Feet (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,570,000 | 1 | 1,570,000 | 1 | 0.65 | 4 | 0.15 | 1.0 | 0.60 | 1.2 | 0.11 |
| 2 | 350,000 | 2.1 | 810,000 | 4.7 | 3.1 | 10 | 0.29 | 1.3 | 3.7 | 1.5 | 0.29 |
| 3 | 80,000 | 5.3 | 420,000 | 23 | 15.0 | 18 | 0.58 | 1.5 | 15.6 | 1.4 | 0.53 |
| 4 | 18,000 | 12 | 220,000 | 109 | 71.0 | 37 | 1.10 | 1.8 | 73 | 1.5 | 1.1 |
| 5 | 4,200 | 28 | 116,000 | 518 | 340 | 75 | 2.20 | 2.3 | 380 | 1.6 | 2.4 |
| 6 | 950 | 64 | 61,000 | 2,500 | 1,600 | 160 | 4.1 | 2.7 | 1,800 | 1.8 | 4.9 |
| 7 | 200 | 147 | 30,000 | 12,000 | 7,600 | 320 | 8.0 | 3.3 | 8,500 | 1.8 | 9.3 |
| 8 | 41 | 338 | 14,000 | 56,000 | 36,000 | 650 | 15.0 | 3.9 | 38,000 | 1.7 | 16.5 |
| 9 | 8 | 777 | 6,200 | 260,000 | 171,000 | 1,300 | 29.0 | 5.6 | 211,000 | 1.5 | 28.3 |
| 10 | 1 | 1,800 | 1,800 | 1,250,000 | 810,000 | 2,800 | 55.0 | 5.9 | 900,000 | 1.0 | 34.3 |
| Total | 2,023,000 | | 3,249,000 | | | | | | | 15.0 | 97.0 |

*Note:* Based on stream order and channel morphology.

[a] Stream order classification based on river characteristics. A first order stream has no tributary channels; a second order stream is formed when two first order streams merge. When two second order streams merge, a third order stream is formed, and so on, downstream in the drainage basin until the water is discharged to the sea.

*Source*: From Keup, L.E., Flowing Water Resources, *Water Resources Bulletin*, V.21, no.2, 1985. Reprinted with permission.

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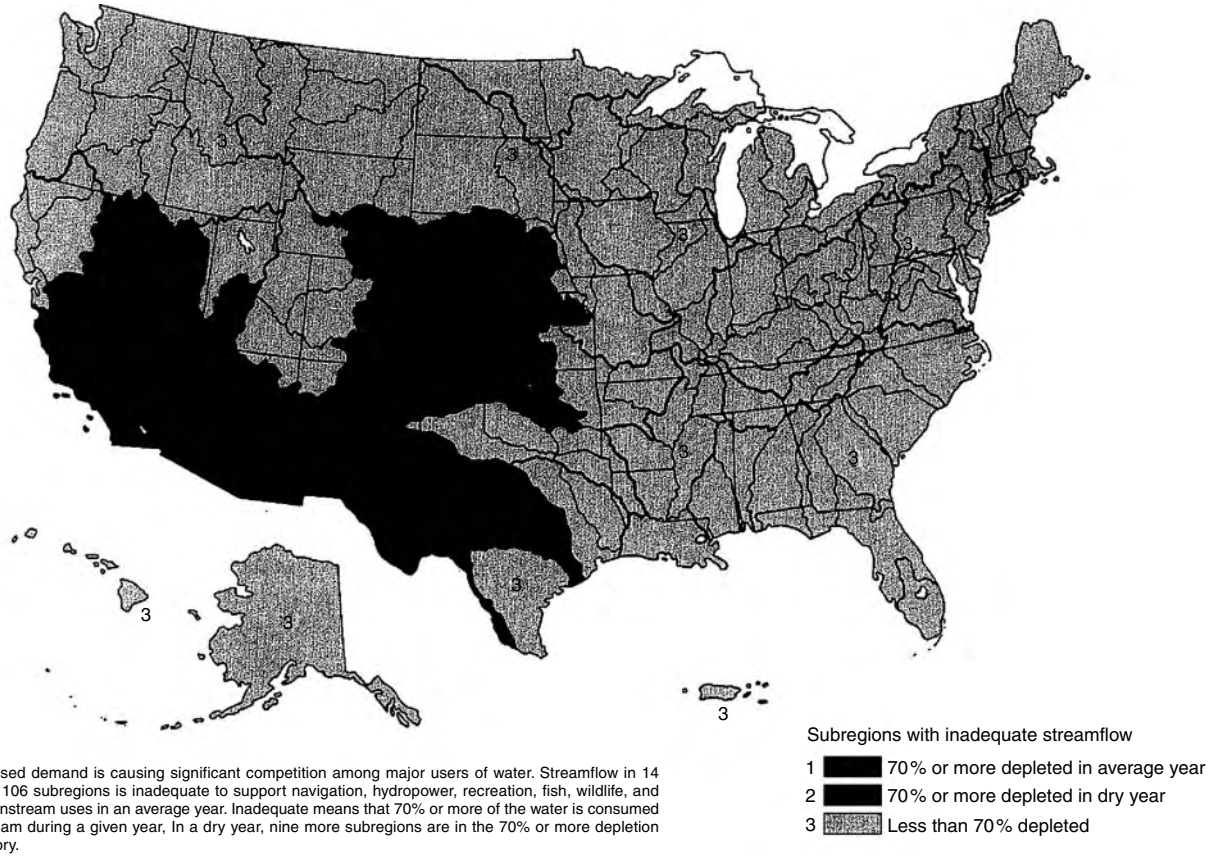


**Figure 5A.2** Inadequate surface water supply for instream use in the United States. (From COUNCIL on Environmental Quality, 1981, Environmental Trends.)

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**Table 5A.6 Velocity of Low Flows and Average Length of Streams in the United States**

| Water Resource Region | Mean Velocity (mi/hour) | Average Stream Length (miles) | Mean Depth at Velocities Given in Col. 1 (ft) | Mean Flow at Velocity Given in Col. 1 ($ft^3$/sec) |
|---|---|---|---|---|
| New England | 1½ | 100 | 4.0 | 1,500 |
| Delaware-Hudson | 1½ | 75 | 3.0 | 500 |
| Eastern Great Lakes | 1½ | 50 | 3.0 | 800 |
| Western Great Lakes | 1½ | 50 | 3.0 | 800 |
| Chesapeake Bay | 1½ | 75 | 5.0 | 2,500 |
| Ohio | 1 | 100 | 4.0 | 1,500 |
| Cumberland | 1½ | 100 | 3.0 | 500 |
| Tennessee | 1½ | 75 | 4.0 | 1,200 |
| Southeast | 1½ | 150 | 5.0 | 2,500 |
| Upper Mississippi | 1 | 150 | 3.0 | 500 |
| Lower Mississippi | 1½ | 150 | 4.0 | 1,200 |
| Upper Missouri | 1½ | 250 | 3.0 | 500 |
| Lower Missouri | 1 | 125 | 3.5 | 900 |
| Upper Arkansas, Red | 1½ | 200 | 2.0 | 200 |
| Lower Arkansas, Red, and White | 1½ | 175 | 3.5 | 1,000 |
| Western Gulf | 1 | 300 | 4.0 | 1,500 |
| Rio Grande and Pecos | 1½ | 150 | 1.5 | 100 |
| Colorado | 1 | 150 | 2.0 | 300 |
| Great Basin | 1 | 100 | 1.0 | 50 |
| Pacific Northwest | 1 | 150 | 4.0 | 1,500 |
| Central Pacific | 1½ | 100 | 4.0 | 1,500 |
| South Pacific | | 50 | 0.5 | 20 |

*Note:* Velocities are estimated for discharges which are exceeded 95 percent of the time. Stream lengths are estimated for representative streams in each region. For location of river basins see Figure 2.6.

*Source*: From U.S. Geological Survey.

**Table 5A.7 Annual River Flow Rates in Canada**

| | | Annual Flow Rates[a] ($m^3$/sec) | | |
|---|---|---|---|---|
| Ocean Basin Region | River Basin Region | Reliable[b] (Low) | Mean | High[c] |
| Pacific | 1. Pacific Coastal | 12,570 | 16,390 | 20,200 |
| | 2. Fraser-Lower Mainland[d] | 3,044 | 3,972 | 4,900 |
| | 3. Okanagan-Similkameen[d] | 31 | 74 | 116 |
| | 4. Columbia[e] | 1,644 | 2,009 | 2,373 |
| | 5. Yukon[e] | 1,806 | 2,506 | 3,206 |
| Arctic | 6. Peace-Athabasca | 1,862 | 2,903 | 3,946 |
| | 7. Lower Mackenzie[f] | 6,114 | 7,337 | 8,561 |
| | 8. Arctic Coast-Islands | 5,920 | 10,251 | 14,582 |
| Gulf of Mexico | 9. Missouri[e] | 3 | 12 | 41 |
| Hudson Bay | 10. North Saskatchewan | 160 | 234 | 373 |
| | 11. South Saskatchewan | 147 | 239 | 418 |
| | 12. Assiniboine-Red[e] | 16 | 50 | 188 |
| | 13. Winnipeg[d,e] | 382 | 758 | 1,137 |
| | 14. Lower Saskatchewan-Nelsone[f] | 1,108 | 1,911 | 2,714 |
| | 15. Churchill[d] | 323 | 701 | 1,070 |
| | 16. Keewatin | 2,945 | 3,876 | 4,806 |
| | 17. Northern Ontario[d] | 3,733 | 5,995 | 8,258 |
| | 18. Northern Quebec[d] | 12,820 | 16,830 | 20,830 |
| Atlantic | 19. Great Lakes | 2,403 | 3,067 | 3,733 |
| | 20. Ottawa | 1,390 | 1,990 | 2,590 |
| | 21. St. Lawrence[e,f] | 1,504 | 2,140 | 2,777 |
| | 22. North Shore-Gaspé | 6,437 | 8,706 | 10,980 |
| | 23. St. John-St. Croix[e] | 507 | 779 | 1,050 |
| | 24. Maritime Coastal | 2,079 | 3,081 | 4,085 |
| | 25. Newfoundland-Labrador | 6,908 | 9,324 | 11,739 |
| Canada | | 75,856 | 105,135 | 134,674 |

*Note:* For map of river basin regions see Figure 2.8.

[a] From recorded flows except in Prairie basins where natural flows have been estimated.
[b] Flow equalled or exceeded in 19 years out of 20.
[c] Flow equalled or exceeded in 1 year out of 20.
[d] Excludes flow transferred into neighboring basin region; because this flow is recorded in importing basin, transfers have little effect on national total.
[e] Excludes inflow from United States portion of basin region.
[f] Excludes inflow from upper basin region.

*Source*: From Pearse, P.H., Currents of change, *Final Report Inquiry on Federal Water Policy*, Ottawa, Canada, 1985.

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**Table 5A.8 Longest Rivers of the World**

| Name | Outflow | Length[a] Miles | Length[a] km | Rank in World (first 100) |
|---|---|---|---|---|
| **World** | | | | |
| Nile | Mediterranean Sea | 4,132 | 6,650 | 1 |
| Amazon | South Atlantic Ocean | 4,000 | 6,400 | 2 |
| Yantze | East China Sea | 3,915 | 6,300 | 3 |
| Mississippi | Gulf of Mexico | 3,710 | 5,971 | 4 |
| Yenisey | Kara Sea | 3,442 | 5,540 | 5 |
| Huang Ho (Yellow) | Gulf of Cihli | 3,395 | 5,464 | 6 |
| Ob | Gulf of Ob | 3,362 | 5,410 | 7 |
| Paraná | Rio de la Plata | 3,032 | 4,880 | 8 |
| Congo | South Atlantic Ocean | 2,900 | 4,700 | 9 |
| Amur | Sea of Okhotak | 2,761 | 4,444 | 10 |
| **Africa** | | | | |
| Nile | Mediterranean Sea | 4,132 | 6,650 | 1 |
| Congo | South Atlantic Ocean | 2,900 | 4,700 | 9 |
| Niger | Bight of Blafra | 2,600 | 4,200 | 16 |
| Zambezi | Mozambique Channel | 2,200 | 3,500 | 24 |
| Kasai | Congo River | 1,338 | 2,153 | 63 |
| Orange | South Atlantic Ocean | 1,300 | 2,100 | 66 |
| White Nile (al-Bahr al-Abyad) | Nile River | 1,295 | 2,084 | 67 |
| Lualaba | Congo River | 1,100 | 1,800 | 87 |
| Limpopo | Mozambique Channel | 1,100 | 1,800 | 87 |
| Jubba (Juba) | Indian Ocean | 1,030 | 1,658 | 94 |
| Sénégal | South Atlantic Ocean | 1,020 | 1,641 | 95 |
| Okavango (Kubango) | Okavango Swamp | 1,000 | 1,600 | 100 |
| Lomami | Congo River | 830 | 1,500 | |
| Blue Nile (al-Bahr al-Azraq) | White Nile River | 907 | 1,460 | |
| Chari (Shari) | Lake Chad | 870 | 1,400 | |
| Ubangi-Uele | Congo River | 870 | 1,400 | |
| Awash | Lake Abe | 750 | 1,200 | |
| **America, North** | | | | |
| Mississippi-Missouri-Red Rock | Gulf of Mexico | 3,710 | 5,971 | 4 |
| Mackenzie-Slave-Peace | Beaufort Sea | 2,635 | 4,241 | 15 |
| Missouri-Red Rock | Mississippi River | 2,533 | 4,076 | 17 |
| St. Lawrence-Great Lakes | Gulf of Saint Lawrence | 2,500 | 4,000 | 19 |
| Mississippi | Gulf of Mexico | 2,348 | 3,779 | 20 |
| Missouri | Mississippi River | 2,315 | 3,726 | 21 |
| Yukon–Nisutlin | Bering Sea | 1,979 | 3,185 | 28 |
| Rio Grande | Gulf of Mexico | 1,885 | 3,034 | 29 |
| Yukon | Bering Sea | 1,875 | 3,018 | 31 |
| Nelson Saskatchewan | Hudson Bay | 1,600 | 2,575 | 46 |
| Arkansas | Mississippi River | 1,459 | 2,348 | 55 |
| Colorado | Gulf of California | 1,450 | 2,333 | 56 |
| Ohio–Allegheny | Mississippi River | 1,306 | 2,102 | 65 |
| Red | Mississippi River | 1,270 | 2,044 | 68 |
| Columbia | North Pacific Ocean | 1,243 | 2,000 | 71 |
| Saskatchewan | Lake Winnipeg | 1,205 | 1,939 | 76 |
| Peace | Slave River | 1,195 | 1,923 | 79 |
| Snake | Columbia River | 1,038 | 1,670 | 93 |
| Churchill | Hudson Bay | 1,000 | 1,609 | 99 |
| Ohio | Mississippi River | 981 | 1,579 | |
| Canadian | Arkansas River | 906 | 1,456 | |
| Tennessee–French Broad | Ohio River | 900 | 1,448 | |
| Upper Columbia | Columbia River | 890 | 1,432 | |
| Brazos | Gulf of Mexico | 870 | 1,400 | |
| South Saskatchewan | Saskatchewan River | 865 | 1,392 | |
| Fraser | Strait of Georgia | 850 | 1,368 | |
| Colorado (of Texas) | Matagorda Bay | 840 | 1,352 | |
| St. Lawrence | Lake Ontario | 800 | 1,287 | |
| North Saskatchewan | Saskatchewan River | 800 | 1,287 | |
| Ottawa | St. Lawrence | 790 | 1,271 | |

*(Continued)*

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**Table 5A.8 (Continued)**

| Name | Outflow | Length[a] Miles | Length[a] km | Rank in World (first 100) |
|---|---|---|---|---|
| North Canadian | Canadian River | 760 | 1,223 | |
| Pecos | Rio Grande River | 735 | 1,183 | |
| Kuskokwim | Bering Sea | 680 | 1,094 | |
| **America, South** | | | | |
| Amazon-Ucayali-Apurimac | South Atlantic Ocean | 4,000 | 6,400 | 2 |
| Paraná | Rio de la Plata | 3,032 | 4,880 | 8 |
| Madeira-Mamoré-Guaporé | Amazon River | 2,082 | 3,350 | 25 |
| Jurua | Amazon River | 2,040 | 3,283 | 26 |
| Purus | Amazon River | 1,995 | 3,211 | 27 |
| Sáo Francisco | South Atlantic Ocean | 1,811 | 2,914 | 33 |
| Japurá (Caquetá) | Amazon River | 1,750 | 2,816 | 37 |
| Ucayali-Apurimac | Amazon River | 1,701 | 2,738 | 40 |
| Orinoco | South Atlantic Ocean | 1,700 | 2,736 | 41 |
| Tocantins | Pará River | 1,677 | 2,699 | 42 |
| Araguaia | Tocantins River | 1,632 | 2,627 | 44 |
| Paraguay | Paraná River | 1,584 | 2,550 | 47 |
| Pilcomayo | Paraguay River | 1,550 | 2,500 | 51 |
| Negro (Guainia) | Amazon River | 1,400 | 2,253 | 59 |
| Xingu | Amazon River | 1,300 | 2,100 | 66 |
| Tapajos-Teles Pires | Amazon River | 1,238 | 1,992 | 72 |
| Mamoré | Guaporé River | 1,200 | 1,931 | 77 |
| Marañón-Hualiaga | Amazon River | 1,184 | 1,905 | 80 |
| Guaporé (Iténez) | Mamore River | 1,087 | 1,749 | 90 |
| Parnaiba | South Atlantic Ocean | 1,056 | 1,700 | 92 |
| Madre de Dios | Beni River | 1,056 | 1,700 | 92 |
| Putumayo (Içа) | Amazon River | 1,000 | 1,609 | 99 |
| Solimões | Amazon River | 1,000 | 1,609 | 99 |
| Uruguay | Río de la Plata | 990 | 1,593 | |
| Magdalena | Caribbean Sea | 930 | 1,497 | |
| Guaviare | Orinoco River | 930 | 1,497 | |
| Ucayali | Marañón River | 910 | 1,465 | |
| Teles Pires | Tapajós River | 870 | 1,400 | |
| Grande | Mamoré River | 845 | 1,360 | |
| Cauca | Magdalena River | 838 | 1,349 | |
| Iguaçu | Paraná River | 808 | 1,300 | |
| **Asia** | | | | |
| Yangtze | East China Sea | 3,915 | 6,300 | 3 |
| Yenisey-Balkal-Selenga | Kara Sea | 3,442 | 5,540 | 5 |
| Huang Ho (Yellow) | Gulf of Chihli | 3,395 | 5,464 | 6 |
| Oh-Irtysh | Gulf of Ob | 3,362 | 5,410 | 7 |
| Amur-Argun | Sea of Okhotsk | 2,761 | 4,444 | 10 |
| Lena | Laptev Sea | 2,734 | 4,400 | 11 |
| Mekong | South China Sea | 2,700 | 4,350 | 12 |
| Ob-Katun | Gulf of Ob | 2,696 | 4,338 | 13 |
| Irtysh–Chorny Irtysh | Ob River | 2,640 | 4,248 | 14 |
| Yenisey | Kara Sea | 2,549 | 4,102 | 18 |
| Ob | Gulf of Ob | 2,268 | 3,650 | 22 |
| Syrdarya–Arabelsu | Aral Sea | 1,876 | 3,019 | 30 |
| Nizhnyaya Tunguska | Yenisey River | 1,857 | 2,989 | 32 |
| Brahmaputra | Jamuna River | 1,800 | 2,900 | 34 |
| Indus | Arabian Sea | 1,800 | 2,900 | 34 |
| Amur | Sea of Okhotak | 1,755 | 2,824 | 36 |
| Euphrates | Shatt-al-Arab | 1,740 | 2,800 | 38 |
| Vilyuy | Lena River | 1,647 | 2,650 | 43 |
| Amu Darya–Pyandzh | Aral Sea | 1,578 | 2,540 | 48 |
| Kolyma–Kulu | East Siberian Sea | 1,562 | 2,513 | 49 |
| Ganges | Padma River | 1,560 | 2,510 | 50 |
| Ishim | Irtysh River | 1,522 | 2,450 | 52 |
| Salween | Gulf of Martaban | 1,500 | 2,400 | 54 |
| Olenyok | Laptev Sea | 1,424 | 2,292 | 57 |
| Aldan | Lena River | 1,412 | 2,273 | 58 |
| Syrdarya | Aral Sea | 1,374 | 2,212 | 60 |
| Chu Chiang (Pearl)-Hsi | South China Sea | 1,365 | 2,197 | 62 |

*(Continued)*

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**Table 5A.8 (Continued)**

| Name | Outflow | Length[a] Miles | Length[a] km | Rank in World (first 100) |
|---|---|---|---|---|
| Kolyma (Kolima) | East Siberian Sea | 1,323 | 2,129 | 64 |
| Tarim | Lop Nor Basin | 1,261 | 2,030 | 69 |
| Chulym-Bely Iyus | Ob River | 1,257 | 2,023 | 70 |
| Irrawaddy | Andaman Sea | 1,238 | 1,992 | 72 |
| Vitim-Vitimkan | Lena River | 1,229 | 1,978 | 73 |
| Indigirka-Khastakh | East Siberian Sea | 1,228 | 1,977 | 74 |
| Hsi | South China Sea | 1,216 | 1,957 | 75 |
| Sungari | Amur River | 1,197 | 1,927 | 78 |
| Tigris | Shatt-al-Arab | 1,180 | 1,900 | 81 |
| Podkamennaya Tunguska | Yenisey River | 1,159 | 1,865 | 83 |
| Vitim | Lena River | 1,141 | 1,837 | 84 |
| Chulym | Ob River | 1,118 | 1,799 | 88 |
| Angara | Yanisey River | 1,105 | 1,779 | 89 |
| Indigirka | East Siberian Sea | 1,072 | 1,726 | 91 |
| Khatanga-Kotuy | Laptev Sea | 1,017 | 1,636 | 96 |
| Ket | Ob River | 1,007 | 1,621 | 97 |
| Argun | Amur River | 1,007 | 1,620 | 98 |
| Shilka-Onon | Amur River | 989 | 1,592 | |
| Tobol-Kokpektysay | Irtysh River | 989 | 1,591 | |
| Alazeya–Kadylchan | East Siberian Sea | 988 | 1,590 | |
| Han Shui | Yangtze River | 952 | 1,532 | |
| Yana-Sartang | Laptev Sea | 927 | 1,492 | |
| Godavari | Bay of Bengal | 910 | 1,465 | |
| Amga | Aldan River | 908 | 1,462 | |
| Sutleg | Indus River | 900 | 1,450 | |
| Ili-Tekes | Lake Balkhash | 894 | 1,439 | |
| Olyokma | Lena River | 892 | 1,436 | |
| Amu Darya | Aral Sea | 879 | 1,415 | |
| Taz | Gulf of Taz | 871 | 1,401 | |
| Yamuna | Ganges River | 855 | 1,376 | |
| Kura | Caspian Sea | 848 | 1,364 | |
| Tavda-Lozva | Tobol River | 843 | 1,356 | |
| Liao | Gulf of Liaotung | 836 | 1,345 | |
| Taseyeva-Chuna | Angara River | 820 | 1,319 | |
| Vyatka | Kama River | 817 | 1,314 | |
| Krishna | Bay of Bengal | 800 | 1,290 | |
| Narmada | Gulf of Cambay | 800 | 1,290 | |
| Zeya | Amur River | 772 | 1,242 | |
| Chu | Betpak Dala Plateau | 663 | 1,067 | |
| **Europe** | | | | |
| Volga | Caspian Sea | 2,193 | 3,530 | 23 |
| Danube | Black Sea | 1,770 | 2,850 | 35 |
| Ural | Caspian Sea | 1,509 | 2,428 | 53 |
| Dnepr | Black Sea | 1,367 | 2,200 | 61 |
| Don | Sea of Azov | 1,162 | 1,870 | 82 |
| Pechora | Barents Sea | 1,124 | 1,809 | 85 |
| Kama | Volga River | 1,122 | 1,805 | 86 |
| Oka | Vola River | 932 | 1,500 | |
| Belaya | Kama River | 889 | 1,430 | |
| Rhine | North Sea | 865 | 1,392 | |
| Dnestr | Black Sea | 840 | 1,352 | |
| Northern Dvina-Sukhona | White Sea | 809 | 1,302 | |
| **Oceania** | | | | |
| Darling | Murray River | 1,702 | 2,739 | 39 |
| Murray | Great Australian Bight | 1,609 | 2,589 | 45 |
| Murrumbidgee | Murray River | 981 | 1,579 | |
| Lachlan | Murrumidgee River | 992 | 1,484 | |

[a] Conversions of rounded figures are rounded to nearest hundred miles or kilometres.

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**Table 5A.9 Large Rivers of the World**

| River | Country | Drainage Area (Thousands of sq mi) | Average Discharge at Mouth (Thousands of cfs) | Rank |
|---|---|---|---|---|
| | | **North America** | | |
| Mississippi[a] | U.S.A. and Canada | 1,244 | 611 | 7 |
| St. Lawrence | U.S.A. and Canada | 498 | 500 | 11 |
| Mackenzie | Canada | 697 | 280 | 17 |
| Columbia | U.S.A. and Canada | 258 | 256 | 19 |
| Yukon | Canada | 360 | 180 | 24 |
| Frazer | Canada | 92 | 113 | 32 |
| Nelson | Canada | 414 | 80 | 37 |
| Mobile | U.S.A. | 42 | 58 | 43 |
| Susquehanna | U.S.A. | 28 | 38 | 48 |
| | | **South America** | | |
| Amazon | Brazil | 2,231 | 7,500[b] | 1 |
| Orinoco | Venezuela | 340 | 600 | 8 |
| Parana | Argentina | 890 | 526 | 10 |
| Tocantins | Brazil | 350 | 360 | 16 |
| Magdalena | Colombia | 93 | 265 | 18 |
| Uruguay | [c] | 90 | 136 | 26 |
| Sao Francisco | Brazil | 260 | 100 | 34 |
| | | **Africa** | | |
| Congo | Congo | 1,550 | 1,400 | 2 |
| Zambezi | Mozambique | 500 | 250 | 20 |
| Niger | Nigeria | 430 | 215 | 22 |
| Nile | Egypt | 1,150 | 100 | 33 |
| | | **Asia** | | |
| Yangtze | China | 750 | 770 | 3 |
| Brahmaputra | Bangladesh | 361 | 700 | 4 |
| Ganges | India | 409 | 660 | 5 |
| Yenisel | U.S.S.R. | 1,000 | 614 | 6 |
| Lena | U.S.S.R. | 936 | 547 | 9 |
| Irrawaddy | Burma | 166 | 479 | 12 |
| Ob | U.S.S.R. | 959 | 441 | 13 |
| Mekong | Thailand | 310 | 390 | 14 |
| Amur | U.S.S.R. | 712 | 388 | 15 |
| Indus | Pakistan | 358 | 196 | 23 |
| Kolyma | U.S.S.R. | 249 | 134 | 27 |
| Sankai (Si) | China | 46 | 127 | 28 |
| Godavari | India | 115 | 127 | 29 |
| Hwang Ho (Yellow) | China | 260 | 116 | 31 |
| Pyasina | U.S.S.R. | 74 | 90 | 36 |
| Krishna | India | 119 | 69 | 39 |
| Indigirka | U.S.S.R. | 139 | 64 | 40 |
| Salween | Burma | 108 | 53 | 44 |
| Shatt-al Arab[d] | Iraq | 209 | 51 | 45 |
| Yana | U.S.S.R. | 95 | 35 | 49 |
| | | **Europe** | | |
| Danube | Romania | 315 | 218 | 21 |
| Pechora | U.S.S.R. | 126 | 144 | 25 |
| Dvina (Northern) | U.S.S.R. | 139 | 124 | 30 |
| Neva | U.S.S.R. | 109 | 92 | 36 |
| Rhine | Netherlands and Germany | 56 | 78 | 38 |
| Dnepr | U.S.S.R. | 194 | 59 | 41 |
| Rhone | France | 37 | 59 | 42 |
| Po | Italy | 27 | 51 | 46 |
| Vistula | Poland | 76 | 38 | 47 |

[a] Includes Atchafalaya River.
[b] Department of Interior News Release, Feb. 24, 1964.
[c] Argentina and Uruguay.
[d] Tigris, Euphrates and Karun.

*Source*: From Young, L.L., U.S. Geological Survey, 1964.

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## SECTION 5B LAKES

**Table 5B.10 Natural Fresh-Water Lakes of the United States of 10 sq. mi or More**

| Name | Latitude | Longitude | Area (sq. mi) |
|---|---|---|---|
| **Alaska** | | | |
| Iliamna | 59°35 | 155°00 | 1,000 |
| Becharof | 57°50 | 156°25 | 458 |
| Teshekpuk | 70°35 | 153°30 | 315 |
| Naknek | 58°35 | 156°00 | 242 |
| Tustumena | 60°25 | 150°20 | 117 |
| Clark | 60°10 | 154°00 | 110 |
| Dall | 60°15 | 163°45 | 100 |
| Inland[a] | 66°30 | 159°50 | 95 |
| Imuruk Basin[a] | 65°05 | 165°40 | 80 |
| Upper Ugashik | 57°50 | 156°25 | 75 |
| Kukaklek | 59°35 | 155°00 | 72 |
| Lower Ugashik | 57°30 | 156°55 | 72 |
| Nerka | 59°20 | 158°45 | 69 |
| Nuyakuk | 59°50 | 158°50 | 64 |
| Aropuk | 61°10 | 163°45 | 57 |
| Tazlina | 61°50 | 146°30 | 57 |
| Nanwhyenuk or Nonvianuk | 59°00 | 155°25 | 56 |
| Nunavakpak | 60°45 | 162°40 | 53 |
| Kaghasuk[a] | 60°55 | 163°40 | 52 |
| Skilak | 60°25 | 150°20 | 38 |
| Chauekuktuli | 60°05 | 158°50 | 34 |
| Chikuminuk | 60°15 | 158°55 | 34 |
| Beverly | 59°40 | 158°45 | 33 |
| Whitefish | 61°20 | 160°00 | 33 |
| Aleknagik | 59°20 | 158°45 | 31 |
| Brooks | 58°30 | 155°55 | 31 |
| Kgun | 61°35 | 163°50 | 31 |
| Nonvianuk | 59°00 | 155°30 | 31 |
| Takslesluk | 61°05 | 162°55 | 31 |
| George | 61°15 | 148°35 | 29 |
| Nunavak Anukslak | 61°05 | 162°30 | 29 |
| Unnamed | 60°55 | 164°00 | 28 |
| Grosvenor | 58°40 | 155°15 | 27 |
| Tetlin | 63°05 | 142°45 | 27 |
| Chakachamna | 61°10 | 152°30 | 26 |
| Imuruk | 65°35 | 163°10 | 26 |
| Nunavakanuk | 62°05 | 164°40 | 25 |
| Louise | 62°20 | 146°30 | 23 |
| Minchumina | 63°55 | 152°15 | 23 |
| Klutina | 61°40 | 145°30 | 22 |
| Unnamed | 61°30 | 164°30 | 22 |
| Unnamed | 71°05 | 156°30 | 21 |
| Beluga | 61°25 | 151°30 | 20 |
| Unnamed | 60°05 | 164°00 | 20 |
| Unnamed | 61°40 | 160°25 | 20 |
| Kenai | 60°25 | 149°35 | 19 |
| Kyigayalik | 61°00 | 162°30 | 19 |
| Tikchik | 59°55 | 158°20 | 19 |
| Bering | 60°20 | 144°20 | 17 |
| Kulik | 59°50 | 158°50 | 17 |
| Upnuk | 60°05 | 158°55 | 17 |
| Unnamed slough | 62°40 | 163°30 | 17 |
| Teloquana | 60°55 | 153°55 | 16 |
| Unnamed | 60°30 | 161°40 | 16 |
| Unnamed | 61°00 | 163°45 | 16 |
| Unnamed | 61°30 | 164°55 | 16 |
| Five Day Slough | 62°05 | 162°00 | 15 |
| Togiak | 59°35 | 159°35 | 15 |
| Unnamed | 59°55 | 163°15 | 15 |
| Black | 56°25 | 159°00 | 14 |
| Ualik | 59°05 | 159°30 | 14 |

*(Continued)*

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**Table 5B.10 (Continued)**

| Name | Latitude | Longitude | Area (sq. mi) |
|---|---|---|---|
| Walker | 67°05 | 154°25 | 14 |
| Unnamed | 60°20 | 164°25 | 14 |
| Unnamed | 60°50 | 163°30 | 14 |
| Unnamed | 59°50 | 163°30 | 14 |
| Amanka | 59°05 | 159°10 | 13 |
| Whitefish | 60°55 | 154°55 | 13 |
| Unnamed | 71°00 | 156°00 | 13 |
| Crosswind | 62°20 | 146°00 | 12 |
| Kakhomak | 59°30 | 154°10 | 12 |
| Karluk | 57°20 | 154°05 | 12 |
| Mother Goose | 57°10 | 157°20 | 12 |
| Unnamed | 60°25 | 164°10 | 12 |
| Unnamed | 59°50 | 163°25 | 12 |
| Unnamed | 62°15 | 162°20 | 12 |
| Unnamed | 70°50 | 153°30 | 12 |
| Coleville | 58°45 | 155°40 | 11 |
| Harlequin | 59°25 | 138°55 | 11 |
| Unnamed | 60°25 | 164°10 | 11 |
| Unnamed | 60°55 | 162°20 | 11 |
| Bear | 56°00 | 160°15 | 10 |
| Chignik | 56°15 | 158°50 | 10 |
| Ewan | 62°25 | 145°50 | 10 |
| Kontrashibuna | 60°10 | 154°00 | 10 |
| Kukaklik | 61°40 | 160°30 | 10 |
| Kulik | 58°55 | 155°00 | 10 |
| Unnamed | 61°45 | 160°40 | 10 |
| Miles | 60°40 | 144°45 | 10 |
| Susitna | 62°25 | 146°40 | 10 |
| Unnamed | 60°20 | 162°00 | 10 |
| Unnamed | 60°25 | 162°00 | 10 |
| Unnamed | 60°55 | 162°10 | 10 |
| Unnamed | 59°55 | 163°15 | 10 |
| Unnamed | 62°00 | 162°00 | 10 |

| Name | County | Area (sq. mi) |
|---|---|---|
| **California** | | |
| Tahoe[b] | Placer, Eldorado | 193 |
| Clear | Lake | 65 |
| Eagle[c] | Lassen | 41 |
| **Florida** | | |
| Okeechobee | Hendry, Glades, Okeechobee, Martin, Palm Beach | 700 |
| George | Putnam, Marion, Volusia, Lake | 70 |
| Kissimmee | Osceola, Polk | 55 |
| Apopka | Orange | 48 |
| Istokpoga | Highlands | 43 |
| Tsala Apopka | Citrus | 30 |
| Tohopekaliga | Osceola | 29 |
| Harris | Lake | 27 |
| Orange | Alachua, Marion | 26 |
| East Tohopekaliga | Osceola | 19 |
| Griffin | Lake | 14 |
| Monroe | Seminole, Volusia | 14 |
| Jessup | Seminole | 13 |
| Weohyakapka | Polk | 12 |
| Talquin | Gadsden, Leon | 11 |
| Eustis | Lake | 11 |
| Blue Cypress | Osceola, Indian River | 10 |
| Hatchineha | Polk, Osceola | 10 |
| Lochloosa | Alachua | 10 |
| **Idaho** | | |
| Pend Oreille | Bonner | 148 |
| Bear[d] | Bear Lake | 110[d] |
| Coeur d'Alene | Kootenai | 50 |
| Priest | Bonner | 37 |
| Grays[f] | Bonneville, Caribou | 34 |
| Henrys | Fremont | 10 |

*(Continued)*

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**Table 5B.10 (Continued)**

| Name | County | Area (sq. mi) |
|---|---|---|
| **Iowa** | | |
| Spirit | Dickinson | 12 |
| **Louisiana** | | |
| White[g] | Vermilion | 83 |
| Grand | Iberia, St. Mary, St. Martin | 64 |
| Caddo[h] | DeSoto | 60 |
| Catahoula[i] | LaSalle | 32 |
| Grand | Cameron | 32 |
| Six Mile | St. Martin, St. Mary | 30 |
| Fausse Pointe | St. Mary, Iberia | 24 |
| Lac des Allemands | St. John the Baptist | 23 |
| Verret | Assumption | 22 |
| Polourde | St. Martin, St. Mary, Assumption | 18 |
| **Maine** | | |
| Moosehead | Piscataquis, Somerset | 117 |
| Sebago | Cumberland | 45 |
| Chesuncook[j] | Piscataquis | 43 |
| West Grand | Washington | 37 |
| Flagstaff | Somerset, Franklin | 28 |
| Spednik[k] | Washington | 28 |
| Grand Falls[k] | Washington | 27 |
| East Grand[k] | Washington, Aroostook | 26 |
| Mooselookmeguntic | Oxford, Franklin | 26 |
| Twin | Penobscot, Piscataquis | 25 |
| Chamberlain and Telos | Piscataquis | 22 |
| Graham | Hancock | 19 |
| Churchill and Eagle | Piscataquis | 17 |
| Baskahegan | Washington | 16 |
| Umbagog[l] | Oxford | 16 |
| Brassua | Somerset | 15 |
| Square | Aroostook | 14 |
| Millinocket | Penobscot, Piscataquis | 14 |
| Great | Kennebec | 13 |
| Richardson | Oxford | 13 |
| Schoodic | Piscataquis | 11 |
| Sebec | Piscataquis | 11 |
| Aziscohos | Oxford | 10 |
| Canada Falls | Somerset | 10 |
| Rangeley | Oxford | 10 |
| **Michigan** | | |
| St. Clair[m] | | 460 |
| Houghton | Roscommon | 31 |
| Torch | Antrim, Kalkaska | 29 |
| Charlevoix[n] | Charlevoix | 27 |
| Burt | Cheboygan | 27 |
| Mullet | Cheboygan | 26 |
| Gogebic | Ontonagon, Gogebic | 21 |
| Manistique | Mackinac, Luce | 16 |
| Black | Cheboygan, Presque Isle | 16 |
| Crystal | Benzie | 15 |
| Portage | Houghton | 15 |
| Higgins | Crawford, Roscommon | 15 |
| Hubbard | Alcona | 14 |
| Leelanau | Leelanau | 13 |
| Indian | Schoolcraft | 12 |
| Elk | Antrim, Grand Traverse | 12 |
| Glen | Leelanau | 10 |
| **Minnesota** | | |
| Lake of the Woods[o] | Lake of the Woods | 1,485 |
| Upper and Lower Red | Beltrami | 451 |
| Rainy[o] | Koochiching, St. Louis | 345 |
| Mille Lacs | Aitken, Crow Wing, Mille Lacs | 207 |
| Leech | Cass | 176 |
| Winnibigoshish | Itasca, Cass | 109 |
| Vermilion | St. Louis | 77 |
| Lac La Croix[o] | St. Louis | 53 |
| Cass | Cass, Beltrami | 46 |

*(Continued)*

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**Table 5B.10 (Continued)**

| Name | County | Area (sq. mi) |
|---|---|---|
| Basswood[o] | Lake | 46 |
| Namakan[o] | St. Louis | 44 |
| Kabetogama | Itasca | 40 |
| Pepin[p] | Goodhue, Wabasha | 39 |
| Mud | Marshall | 37 |
| Saganaga[o] | Cook | 32 |
| Pokegama | Itasca | 24 |
| Minnetonka | Hennepin, Carver | 22 |
| Otter Tail | Otter Tail | 22 |
| Gull | Cass, Crow Wing | 20 |
| Pelican | St. Louis | 19 |
| Traverse[q] | Traverse | 18 |
| Big Stone[q] | Big Stone | 17 |
| Crooked[o] | St. Louis, Lake | 17 |
| Sandy | Aitkin | 15 |
| Swan | Nicollet | 15 |
| Island | St. Louis | 14 |
| Bowstring | Itaska | 14 |
| Burntside | St. Louis | 14 |
| Sand Point[o] | St. Louis | 14 |
| Trout | St. Louis | 14 |
| St. Croix[p] | Washington | 13 |
| Lac qui Parle | Chippewa, Lac qui Parle | 13 |
| Pelican | Crow Wing | 13 |
| Dead | Otter Tail | 12 |
| Minnewaska | Pope | 12 |
| Thief | Marshall | 12 |
| Nett | St. Louis, Koochiching | 12 |
| Osakis | Douglas, Todd | 10 |
| Bemidji | Beltrami | 10 |
| Lida | Otter Tail | 10 |
| **Montana** | | |
| Flathead | Lake, Flathead | 197[r] |
| Medicine | Sheridan | 15[s] |
| McDonald | Flathead | 10 |
| **Nevada** | | |
| Tahoe[b] | Ormsby, Douglas | 193 |
| **New Hampshire** | | |
| Winnipesaukee | Belknap, Carroll | 72 |
| Umbagog[l] | Coos | 16 |
| Squam | Gafton, Carroll | 11 |
| **New York** | | |
| Champlain[t] | Clinton, Essex | 490[u] |
| Oneida | Oswego, Oneida | 80 |
| Seneca | Seneca, Schuyler | 67 |
| Cayuga | Cayuga, Seneca, Tompkins | 66 |
| George | Warren | 44 |
| Chautauqua | Chautauqua | 21 |
| Black | St. Lawrence | 17 |
| Canandaigua | Ontario, Yates | 17 |
| Skaneateles | Onondaga, Cayuga | 14 |
| Owasco | Cayuga | 10 |
| **North Carolina** | | |
| Mattamuskeet[v] | Hyde | 67 |
| Phelps | Washington | 25 |
| Waccamaw | Columbus | 14 |
| **Oregon** | | |
| Upper Klamath | Klamath | 142[w] |
| Crater | Klamath | 21 |
| **South Dakota** | | |
| Traverse[q] | Roberts | 18 |
| Big Stone[q] | Roberts | 17 |
| **Tennessee** | | |
| Reelfoot | Lake, Obion | 22 |
| **Texas** | | |
| Caddo[h] | Marion | 60 |

*(Continued)*

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**Table 5B.10 (Continued)**

| Name | County | Area (sq. mi) |
|---|---|---|
| **Utah** | | |
| Utah | Utah | 140 |
| Bear[d] | Rich | 110 |
| **Vermont** | | |
| Champlain[t] | Chittenden, Franklin | 490[u] |
| **Washington** | | |
| Chelan | Chelan | 55 |
| Washington | King | 35 |
| Ozette | Clallam | 12 |
| **Wisconsin** | | |
| Winnebago | Winnebago, Calumet, Fond du Lac | 215 |
| Pepin[p] | Pierce, Pepin | 39 |
| Poygan | Winnebago | 17 |
| Koshkonong | Jefferson | 16 |
| Mendota | Dane | 15 |
| St. Croix[p] | St. Croix | 12 |
| Green | Green Lake | 11 |
| **Wyoming** | | |
| Yellowstone | Yellowstone National Park | 37[x] |
| Jackson | Teton | 39[y] |
| Shoshone | Yellowstone National Park | 11 |

*Note:* Lakes are arranged by states; the Great Lakes are excluded.

[a] May be salt water.
[b] California and Nevada.
[c] Mildly saline, less than 1,000 ppm.
[d] Idaho and Utah.
[e] 136 sq. mi including Mud Lake.
[f] Submerged marsh.
[g] Originally brackish; now kept fresh by controls on salt water intrusion.
[h] Louisiana and Texas.
[i] Shrinks to small area at extremely low stages.
[j] Includes Ripogenus and Caribou.
[k] Maine and Quebec.
[l] Maine and New Hampshire.
[m] Michigan and Ontario.
[n] Formerly called Pine.
[o] Minnesota and Ontario.
[p] Minnesota and Wisconsin.
[q] Minnesota and South Dakota.
[r] At normal high water; 188 sq. mi at medium low water; lake regulated for power between these limits.
[s] Includes 4 islands having area of about 1 sq. mi.
[t] New York, Vermont, and Quebec.
[u] Includes islands totaling about 55 sq. mi.
[v] The lake originally landlocked, was drained and provided with outlet and is fresh water; level regulated to some extent by control works on canals draining the area.
[w] At upper level; dam at outlet allows regulation so that area varies between 93 and 142 sq. mi.
[x] Includes islands totaling 3 sq. mi.
[y] Enlarged by dam; original area, 30 sq. mi.

*Source*: From U.S. Geological Survey.

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**Table 5B.11 Natural Fresh-Water Lakes of the United States of 100 sq. mi or More**

| Name | Location | Area (sq. mi) |
|---|---|---|
| Lake of the Woods | Minnesota and Ontario | 1,485 |
| Iliamna | Alaska | 1,000 |
| Okeechobee | Florida | 700 |
| Champlain | New York, Vermont, and Quebec | 490 |
| St. Clair | Michigan and Ontario | 460 |
| Becharof | Alaska | 458 |
| Upper and Lower Red | Minnesota | 451 |
| Rainy | Minnesota and Ontario | 345 |
| Teshekpuk | Alaska | 315 |
| Naknek | Alaska | 242 |
| Winnebago | Wisconsin | 215 |
| Mille Lacs | Minnesota | 207 |
| Flathead | Montana | 197 |
| Tahoe | California and Nevada | 193 |
| Leech | Minnesota | 176 |
| Pend Oreille | Idaho | 148 |
| Upper Klamath | Oregon | 142 |
| Utah | Utah | 140 |
| Yellowstone | Wyoming | 137 |
| Tustumena | Alaska | 117 |
| Moosehead | Maine | 117 |
| Clark | Alaska | 110 |
| Bear | Idaho and Utah | 110 |
| Winnibigoshish | Minnesota | 109 |
| Dall | Alaska | 100 |

*Note:* The Great Lakes are excluded.

*Source*: From U.S. Geological Survey.

**Table 5B.12 Natural Fresh-Water Lakes of the United States, 250 ft Deep or More**

| Name | Location | Depth (ft) |
|---|---|---|
| Crater | Oregon | 1,932 |
| Tahoe | California and Nevada | 1,645 |
| Chelan | Washington | 1,605 |
| Pend Oreille | Idaho | 1,200 |
| Nuyakuk | Alaska | 930 |
| Deer | Alaska | 877 |
| Chauekuktuli | Alaska | 700 |
| Crescent | Washington | 624 |
| Seneca | New York | 618 |
| Clark | Alaska | 606 |
| Beverley | Alaska | 500 |
| Nerka | Alaska | 475 |
| Tokatz | Alaska | 474 |
| Long | Alaska | 470 |
| Lower Sweetheart | Alaska | 459 |
| Cayuga | New York | 435 |
| Crater | Alaska | 414 |
| Cooper | Alaska | >400 |
| Champlain | New York, Vermont, and Quebec | 400 |
| Kasnyku | Alaska | 393 |

*(Continued)*

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**Table 5B.12 (Continued)**

| Name | Location | Depth (ft) |
|---|---|---|
| Chakachamna | Alaska | 380 |
| Ozette | Washington | 331 |
| Aleknagik | Alaska | 330 |
| Sebago | Maine | 316 |
| Swan | Alaska | >314 |
| Baranoff | Alaska | 303 |
| Payette | Idaho | >300 |
| Quinault | Washington | About 300 |
| Crescent | Alaska | 291 |
| Wallowa | Oregon | 283 |
| Chilkoot | Alaska | 282 |
| Odell | Oregon | 279 |
| Silver | Alaska | 278 |
| Grant | Alaska | >250 |

*Note:* The Great Lakes are excluded.

*Source*: From U.S. Geological Survey.

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**Table 5B.13 Largest Lake in Each State of the United States**

| State | Largest Entirely Within State | Largest Partly in Another State | Shared With | Origin | Area sq. mi | Feet Above Sea Level | Maximum Depth (ft) | Shoreline Length (miles) |
|---|---|---|---|---|---|---|---|---|
| AL | Wheeler | | | Man-made | 104.84 | 556 | 58 | 1,063 |
| | | Guntersville | TN | Man-made | 107.97 | 595 | 60 | 962 |
| AK | Illamna | | | Natural | 1,033 | 50 | — | 188 |
| AZ | San Carlos[a] | | | Man-made | 30.6 | 2,523 | 249 | — |
| | | Powell | UT | Man-made | 252 | 3,700 | 580 | — |
| AR | Ouachita | | | Man-made | 62.65 | 578 | 207 | 690 |
| | | Bull Shoals | MO | Man-made | 111.31 | 695 | 243 | 1,050 |
| CA | Salton Sea | | | Natural | 360 | −231 | 46 | — |
| | | Tahoe | NV | Natural | 192 | 6,229 | 1,685 | 71 |
| CO | John Martin[a] | | | Man-made | 28.72 | 3,765 | 118 | 86 |
| CT | Candlewood | | | Man-made | 8.46 | 429 | 85 | 65 |
| DE | Lum's Pond | | | Man-made | 0.31 | 44 | 12 | 3.5 |
| FL | Okeechobee | | | Natural | 700 | 18.7 | — | 110 |
| GA | Sidney Lanier | | | Man-made | 57.96 | 1,035 | 180 | 540 |
| | | Clark Hill[a] | SC | Man-made | 111.09 | 330 | 190 | 1,057 |
| HI | Koloa[a] | | | Man-made | 0.66 | 233 | 22.5 | 3.3 |
| ID | Pend Oreille | | | Natural | 133 | 2,063 | 1,150 | 111.3 |
| | | Bear | UT | Natural | 136 | 5,930 | 30 | 51.5 |
| IL | Crab Orchard | | | Man-made | 10.96 | 405 | 33 | 103 |
| | | Michigan | WI, IN, MI | Natural | 22,400 | 578.8 | 923 | 1,660 |
| IN | Wawasee | | | Natural | 4.09 | 859 | 68 | 18 |
| | | Michigan | WI, IL, MI | Natural | 22,400 | 578.8 | 923 | 1,660 |
| IA | Spirit | | | Natural | 8.84 | 1,402 | — | — |
| KS | Tuttle Creek[a] | | | Man-made | 24.68 | 1,075 | 56 | 112 |
| KY | Cumberland | | | Man-made | 78.51 | 723 | — | 1,255 |
| | | Kentucky | TN | Man-made | 247.34 | 375 | 145 | 2,380 |
| LA | Pontchartrain | | | Natural | 630 | S.L | 15 | 113 |
| ME | Moosehead | | | Natural | 117 | 1,028 | 246 | — |
| MD | Deep Creek | | | Man-made | 7.03 | 2,462 | — | — |
| MA | Quabbin[a] | | | Man-made | 38.6 | 530 | 150 | 118 |
| MI | Houghton | | | Natural | 31.3 | 1,139 | 20 | 30 |
| | | Superior | WI, Ont, MN | Natural | 31,800 | 600 | 1,333 | 2,980 |
| MN | Red | | | Natural | 451 | 1,175 | 31 | 123 |
| | | Superior | WI, Ont, MI | Natural | 31,800 | 600 | 1,333 | 2,980 |
| MS | Sardis | | | Man-made | 15.31 | 234 | — | 60 |
| MO | Lake of the Ozarks | | | Man-made | 93.75 | — | 125 | 1,375 |
| | | Bull Shoals | AR | Man-made | 111.31 | 695 | 243 | 1,050 |
| MT | Fort Peck[a] | | | Man-made | 382.81 | 2,250 | 220 | 1,600 |
| NE | McConaughy | | | Man-made | 55 | 3,276 | 150 | 50 |
| NV | Pyramid | | | Natural | 187.5 | 3,800 | 330 | 70 |
| | | Mead | AZ | Man-made | 247 | 1,221 | 589 | 550 |
| NH | Winnipesaukee | | | Natural | 71.55 | 504 | 120 | 128 |
| NJ | Hopatcong | | | Man-made | 4.19 | 924 | 58 | 35 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NM | Elephant Butte[a] | | | Man-made | 58.85 | 4,450 | 193 | 250 |
| NY | Oneida | | | Natural | 80 | 370 | 50 | 52 |
| | | Erie | MI, PA, OH, Ont | Natural | 9,910 | 570 | 210 | 856 |
| NC | Norman | | | Man-made | 50.78 | 760 | 115 | 520 |
| | | John H. Kerr[a] | VA | Man-made | 76.4 | 300 | 100 | 800 |
| ND | Garrison[a] | | | Man-made | 609.38 | 1,850 | 200 | 1,600 |
| OH | Grand | | | Man-made | 20 | 869 | 12 | 60 |
| | | Erie | MI, PA, NY, Ont | Natural | 9,910 | 570 | 210 | 856 |
| OK | Eufaula[a] | | | Man-made | 160.16 | 585 | 87 | 600 |
| | | Texoma | TX | Man-made | 149.06 | 617 | 94 | 540 |
| OR | Upper Klamath (incl. Agency Lake) | | | Natural | 140.63 | 4,139 | 40 | 105 |
| PA | Wallenpaupack | | | Man-made | 9 | 1,182 | 50 | 45 |
| | | Erie | MI, NY, OH, Ont | Natural | 9,910 | 570 | 210 | 856 |
| RI | Scituate[a] | | | Man-made | 5.68 | 284 | 80 | 38 |
| SC | Marion | | | Man-made | 157.03 | 75 | 35 | 299 |
| | | Clark Hill[a] | GA | Man-made | 111.09 | 330 | 190 | 1,057 |
| SD | Francis Case | | | Man-made | 160.31 | 1,375 | 140 | 540 |
| TN | Watts Bar | | | Man-made | 60.31 | 745 | 80 | 783 |
| | | Kentucky | KY | Man-made | 247.34 | 375 | 145 | 2,380 |
| TX | Texarkana | | | Man-made | 46.56 | 225 | 39 | 141 |
| | | Texoma | OK | Man-made | 149.06 | 617 | 94 | 540 |
| UT | Great Salt | | | Natural | 1,500 | 4,200 | 48 | 350 |
| | | Powell | AZ | Man-made | 252 | 3,700 | 580 | — |
| VT | Bomoseen | | | Natural | 3.69 | 411 | — | — |
| | | Champlain | NY Que | Natural | 430 | 100 | 399 | — |
| VA | Smith Mountain | | | Man-made | 31.25 | 795 | 200 | 500 |
| | | John H. Kerr[a] | NC | Man-made | 76.4 | 300 | 100 | 800 |
| WA | F.D. Roosevelt | | | Man-made | 123.44 | 1,288 | 375 | 302 |
| WV | Tygart | | | Man-made | 5.37 | 1,010 | | 106 |
| | | Bluestone[a] | VA | Man-made | 3.07 | 1,409 | 42 | 33 |
| WI | Winnebago | | | Natural | 215.26 | — | 21.6 | 91.96 |
| | | Superior | MN, MI, Ont | Natural | 31,800 | 600 | 1,333 | 2,980 |
| WY | Yellowstone | | | Natural | 137 | 7,735 | — | — |

[a] Reservoir.

*Source*: From National Geographic Society.



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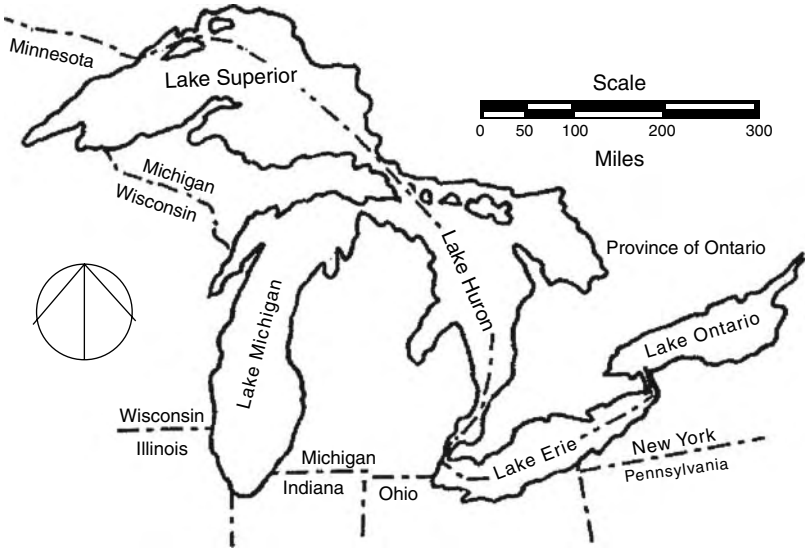


**Figure 5B.3** The Great Lakes. (From U.S. Geological Survey, *National Water Summary 1985—Hydrologic Events and Surface-Water Resources, Water-Supply Paper 2300.*)

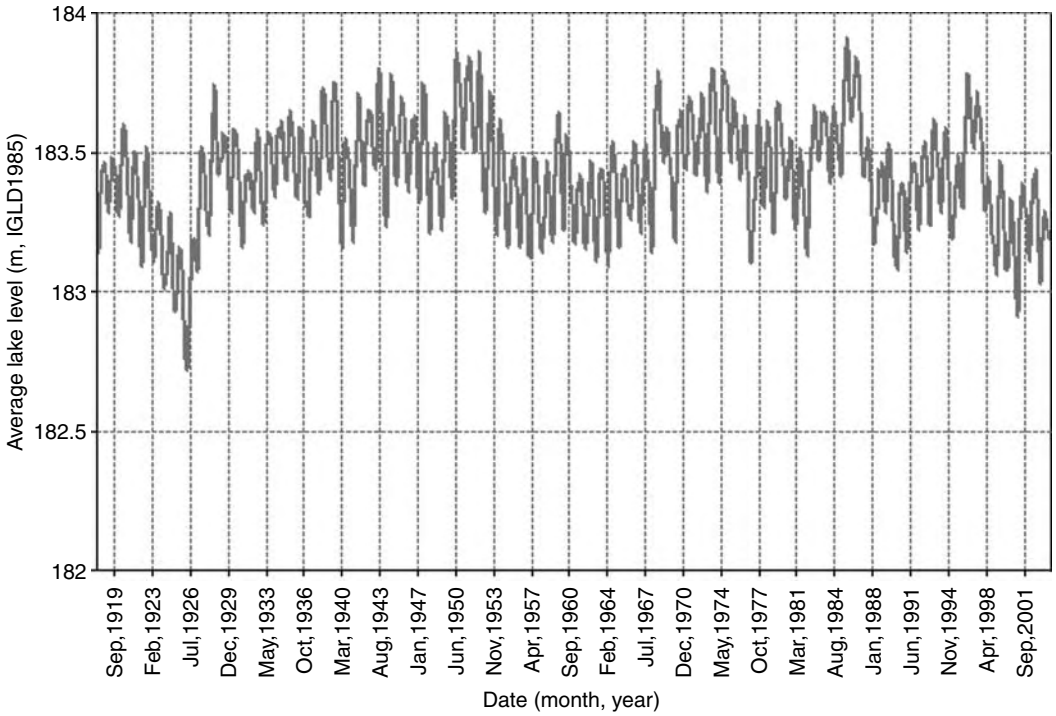


**Figure 5B.4** Great Lakes water levels for Lake Superior graphed for consecutive years, Lake Superior: 1918–2003. (From www.usace.army.mil.)

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**Table 5B.14 Selected Facts about the Great Lakes System**

| Outlet | Remarks |
|---|---|
| St. Marys River to Lake Huron | Largest surface area of all the freshwater lakes in the world. Outflow controlled by St. Marys River Compensating works |
| Straits of Mackinac to Lake Huron | Sixth largest surface area of world's freshwater lakes |
| St. Clair River to Lake St. Clair | Fifth largest surface area of world's freshwater lakes |
| Detroit River to Lake Erie | Shallowest lake in the Great Lakes system |
| Niagara River and Falls to Lake Ontario | Eleventh largest surface area of world's freshwater lakes |
| St. Lawrence River to Atlantic Ocean | Outflow controlled by St. Lawrence Seaway and Power Project |

*Source*: From U.S. Geological Survey, *National Water Summary 1985—Hydrologic Events and Surface-Water Resources, Water-Supply Paper 2300*, 1985.

**Table 5B.15 Great Lakes Physical Features and Population**

| | | Superior | Michigan | Huron | Erie | Ontario | Totals |
|---|---|---|---|---|---|---|---|
| Elevation[a] | (ft)[f] | 600 | 577 | 577 | 569 | 243 | |
| | (m) | 183 | 176 | 176 | 173 | 74 | |
| Length | (mi)[e] | 350 | 307 | 206 | 241 | 193 | |
| | (km) | 563 | 494 | 332 | 388 | 311 | |
| Breadth | (mi)[e] | 160 | 118 | 183 | 57 | 53 | |
| | (km) | 257 | 190 | 245 | 92 | 85 | |
| Average Depth[a] | (ft)[f] | 483 | 279 | 195 | 62 | 283 | |
| | (m) | 147 | 85 | 59 | 19 | 86 | |
| Maximum Depth[a] | (ft)[e] | 1,332 | 925 | 750 | 210 | 802 | |
| | (m) | 406 | 282 | 229 | 64 | 244 | |
| Volume[a] | (cu. mi.)[e] | 2,900 | 1,180 | 850 | 116 | 393 | 5,439 |
| | ($km^3$) | 12,100 | 4,920 | 3,540 | 484 | 1,640 | 22,684 |
| Water Area | (sq. mi)[e] | 31,700 | 22,300 | 23,000 | 9,910 | 7,340 | 94,250 |
| | ($km^2$) | 82,100 | 57,800 | 59,600 | 25,700 | 18,960 | 244,160 |
| Land Drainage Area[b] | (sq. mi)[e] | 49,300 | 45,600 | 51,700 | 30,140 | 24,720 | 201,460 |
| | ($km^2$) | 127,700 | 118,000 | 134,100 | 78,000 | 64,030 | 521,830 |
| Total Area | (sq. mi)[e] | 81,000 | 67,900 | 74,700 | 40,050 | 32,060 | 295,710 |
| | ($km^2$) | 209,800 | 175,800 | 193,700 | 103,700 | 82,990 | 765,990 |
| Shoreline Length[c] | (mi)[e] | 2,726 | 1,638 | 3,827 | 871 | 712 | 10,210d |
| | (km) | 4,385 | 2,633 | 6,157 | 1,402 | 1,146 | 17,017d |
| Retention Time | (yr)[f] | 191 | 99 | 22 | 2.6 | 6 | |
| Population:U.S | (1990)[g] | 425,548 | 10,057,026 | 1,502,687 | 10,017,530 | 2,704,284 | 24,707,075 |
| | Canada (1991) | 181,573 | | 1,191,467 | 1,664,639 | 5,446,611 | 8,484,290 |
| | Totals | 607,121 | 10,057,026 | 2,694,154 | 11,682,169 | 8,150,895 | 33,191,365 |
| | Outlet | St. Marys River | Straits of Mackinac | St. Clair River | Niagara River/ Welland Canal | St. Lawrence River | |

*Note:* [a]Measured at low water datum; [b]Land Drainage Area for Lake Huron includes St. Marys River. Lake Erie includes the St. Clair-Detroit system. Lake Ontario includes the Niagara River; [c]Including islands; [d]These totals are greater than the sum of the shoreline length for the lakes because they include the connecting channels (excluding the St. Lawrence River).

*Source*: From www.epa.gov.

*Original Source*: [e]Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, Coordinated Great Lakes Physical Data. May, 1992; [f]Extension Bulletins E-1866-70, Michigan Sea Grant College Program, Cooperative Extension Service, Michigan State University, E. Lansing, Michigan, 1985; [g]1990–1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years.

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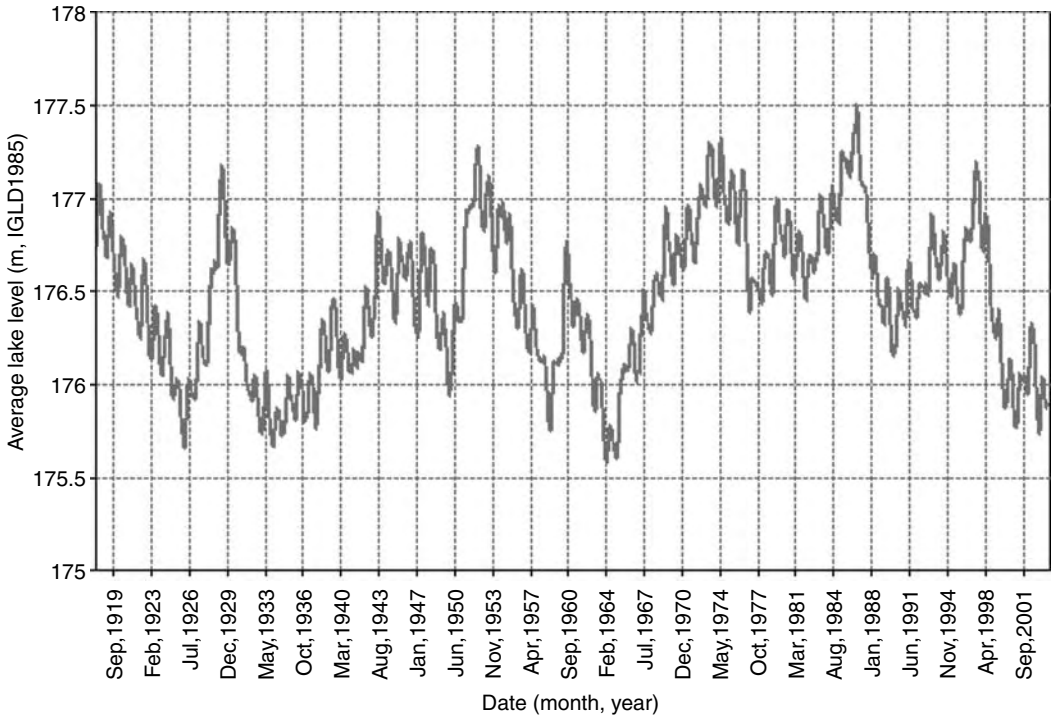


**Figure 5B.5** Great Lakes water levels for Lake Michigan/Huron graphed for consecutive years, Lake Michigan/Huron: 1918–2003. (From www.usace.army.mil.)

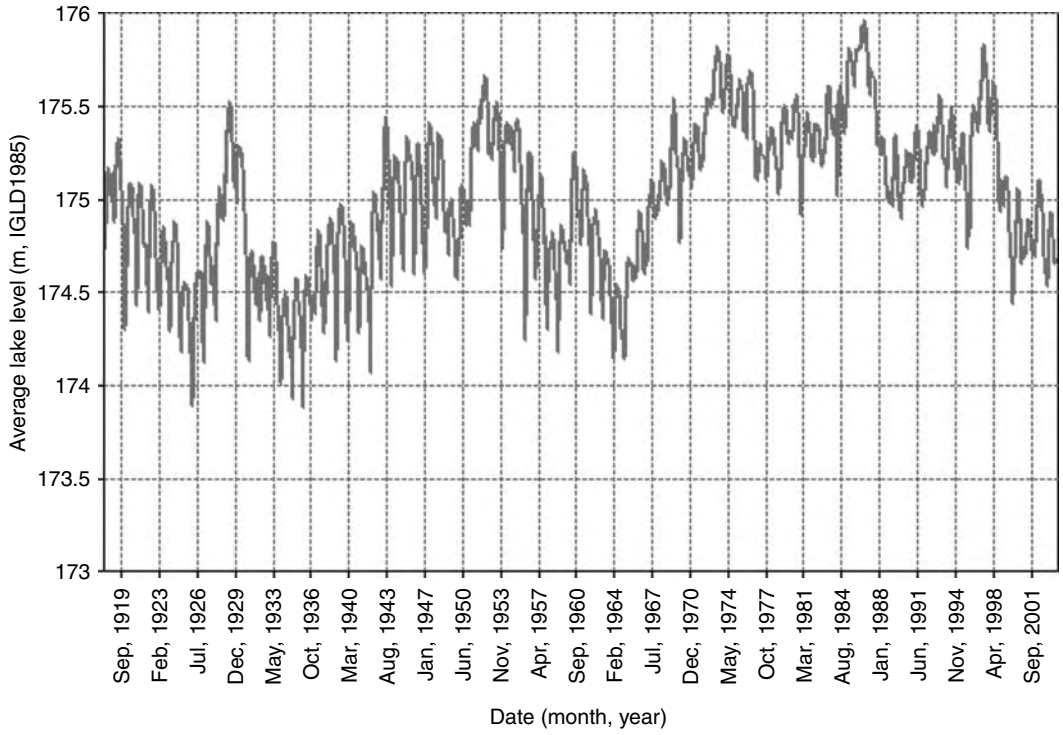


**Figure 5B.6** Great Lakes water levels for Lake St. Clair graphed for consecutive years, Lake St. Clair: 1918–2003. (From www.usace.army.mil.)

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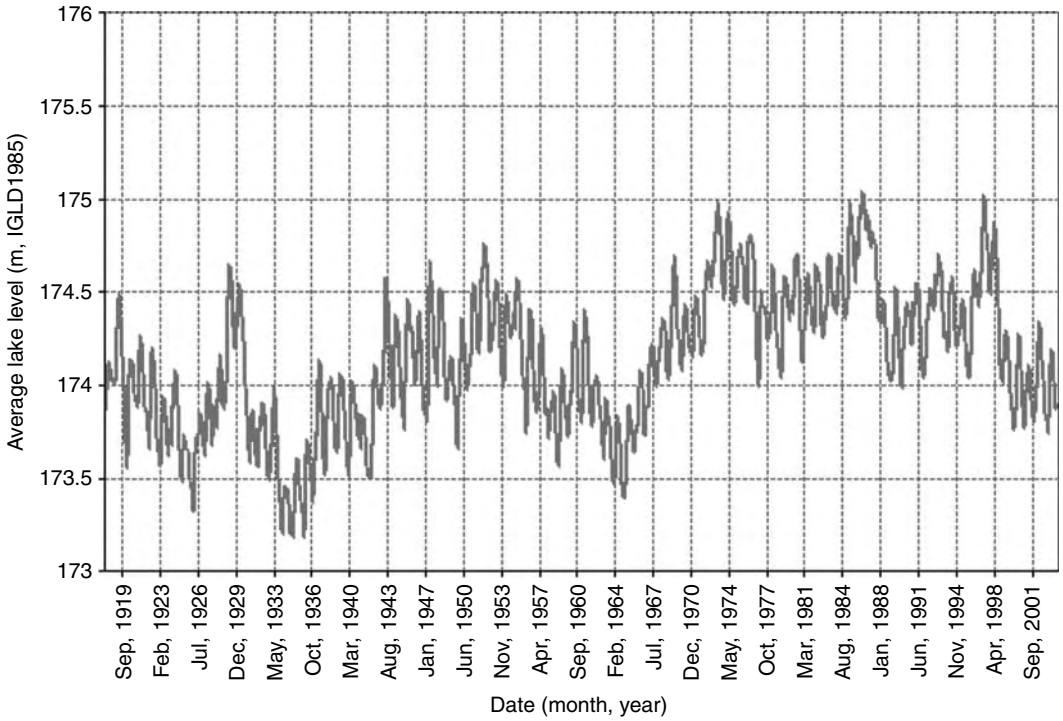


**Figure 5B.7** Great Lakes water levels for Lake Erie graphed for consecutive years, Lake Erie: 1918–2003. (From www.usace.army.mil.)

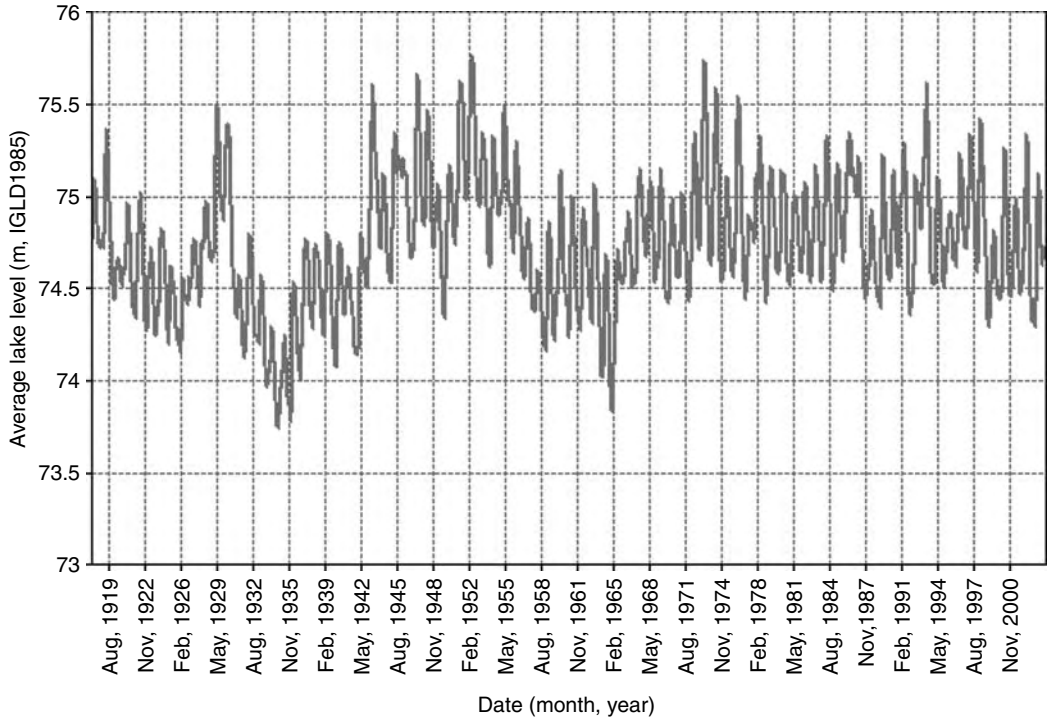


**Figure 5B.8** Great Lakes water levels for Lake Ontario graphed for consecutive years, Lake Ontario: 1918–2003. (From www.usace.army.mil.)

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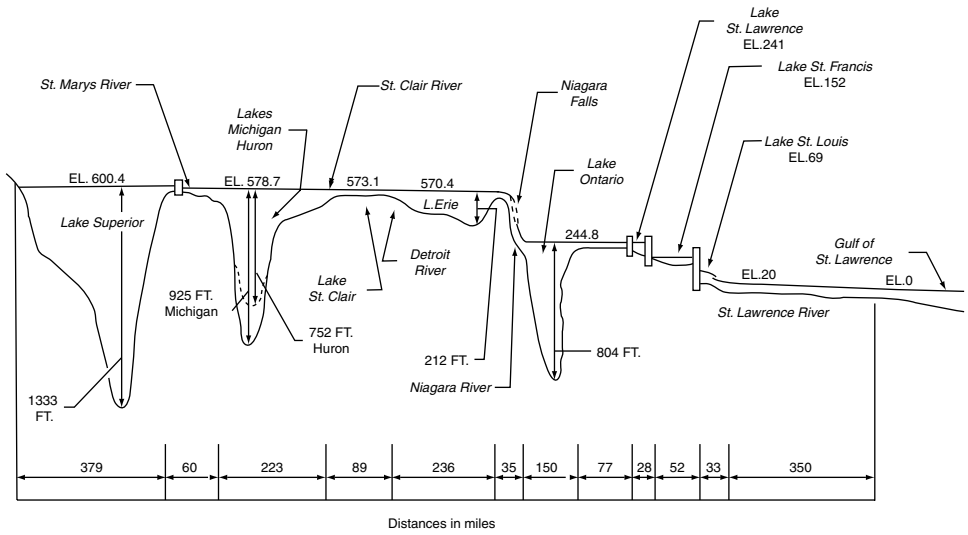


**Figure 5B.9** Profile of the Great Lakes—St. Lawrence River Drainage System. (From International great lakes levels board. Regulation of Great Lakes water levels, Report to the international joint commission, Washington, 1973. With permission.)

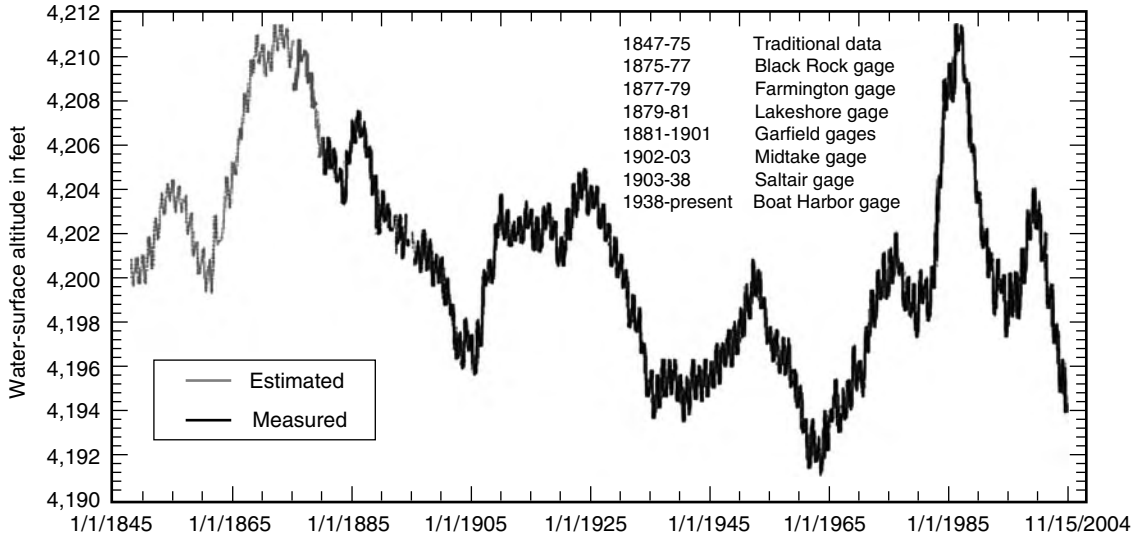


**Figure 5B.10** Fluctuation in water-surface altitude of Gilbert Bay (south part), Great Salt Lake, 1847 to present. (From www.usgs.gov.)

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**Table 5B.16 Hydrologic Characteristics of the Great Lakes**

| | Lake Surface Elevation, in Feet, 1900–1984 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monthly Mean | | | Monthly Range (From Winter Low to Summer High) | | | Total Dissolved Solids, | Mean Discharge |
| Lake | Average | Maximum | Minimum | Average | Maximum | Minimum | 1986 ppm | ($m^2$/sec) |
| Superior | 600.59 | 602.02 | 598.23 | 1.2 | 2.1 | 0.4 | 52 | 2,076 |
| Michigan–Huron | 578.27 | 581.04 | 575.35 | 1.2 | 2.1 | 0.4 | — | — |
| Michigan | — | — | — | — | — | — | 150 | 1,558 |
| Huron | — | — | — | — | — | — | 118 | 5,038 |
| St. Clair | 573.34 | 576.23 | 569.86 | 1.7 | 3.3 | 0.6 | — | — |
| Erie | 570.44 | 573.51 | 567.49 | 1.6 | 2.8 | 0.9 | 198 | 5,545 |
| Ontario | 244.71 | 248.06 | 241.45 | 2.0 | 3.6 | 0.7 | 194 | 6,624 |

*Note:* Levels referenced to international Great Lakes datum 1955.

*Source*: From U.S. Geological Survey, *National Water Summary 1985—Hydrologic Events and Surface-Water Resources, Water-Supply Paper 2300* and U.S. Army Corps of Engineers data.

**Table 5B.17 Principal Saline Lakes of the United States**

| Lake | Present Area (sq. mi) | Remarks |
|---|---|---|
| **California** | | |
| Salton Sea | 350 | About 650 sq. mi at highest stage in 1905–07 |
| Owens | Dry at times each year since 1943 | 110 sq. mi in 1872, prior to diversions from Owens River; 35 sq. mi in 1943 |
| Mono | 76 | Maximum, 89 sq. mi in 1919 |
| Goose (in California and Oregon) | About 100 | Maximum, 186 sq. mi, 125 in California and 61 in Oregon; overflowed into Pitt River in 1869 and 1881; dry in 1930; 150 sq. mi in 1958 |
| Eagle | 41 | Some question as to whether Eagle Lake should be considered saline or fresh water. It has no surface outlet (Martin, 1962), but since 1924 it has been tapped by tunnel to Willow Creek. Salinity is considerably less than 1,000 ppm, according to California Dept. of Water Resources. During period 1895–1925 lake rose to highest level since at least 1650 (Harding, 1935); rise believed due to closing of subterranean outlet by earthquake in 1890 (Antevs, 1938) |
| Honey | Dry | 90 sq. mi in 1867, possibly higher in 1890; dry in 1903; high in 1904; dry in 1924. Contained some water April 1958 to September 1960, and early in 1962 |
| **Louisiana** | | |
| Pontchartrain | 625 | These lakes are connected with the Gulf of Mexico, and are subject to tidal fluctuation |
| Sabine (Louisiana and Texas) | 95 | As above |
| Calcasieu | 90 | As above |
| Maurepas | 90 | As above |
| Salvador | 70 | As above |
| **Nevada** | | |
| Pyramid | 180 | Maximum size, 220 sq. mi. Low until 1860; reached extreme high level in 1862 and 1868 or 1869; nearly as high in 1890; began to drop in 1917 (Hardman and Venstrom, 1941) |
| Walker | 107 | Maximum size, 125 sq. mi |
| Winnemucca | Dry | Maximum size, 180 sq. mi. Dry in 1840, but began to fill shortly thereafter (Zones, 1961). According to Russell (1885) the lake rose more than 50 ft and approximately doubled its area between 1867 and 1882. Was 87 ft deep in 1882. Dry since 1945 |
| Carson | Nearly dry | Maximum size, 41 sq. mi. A few water-filled pot holes remain. Once called South Carson Lake; received flow of Carson River before Lahontan Reservoir was built |

*(Continued)*

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**Table 5B.17 (Continued)**

| Lake | Present Area (sq. mi) | Remarks |
|---|---|---|
| Carson Sink | Dry | A shallow playa some 250 sq. mi in area shown on some maps as a body of water. Russell (1885) called it North Carson Lake. Dry in 1882, but probably has had some water at times since. Once received water from both Carson and Humboldt Rivers |
| Ruby | | Maximum size, 37 sq. mi. Shown as swamp on recent maps of Army Map Service and Nevada Dept. of Highways |
| Franklin | | Maximum size, 32 sq. mi. Shown as swamp on recent maps of the Army Map Service and Nevada Dept. of Highways |
| **North Dakota** | | |
| Devils | 24 | 140 sq. mi in 1867; 70 sq. mi in 1883; 45 sq. mi in 1900; 10 sq. mi in 1940. Since 1940 lake has been rising |
| **Oregon** | | |
| Malheur and Harney | Probably dry | Malheur, the larger of the two lakes, overflows into Harney, which has no outlet. Maximum combined size, 125 sq. mi. Reported dry in 1931; high in late 1950s; about 1 sq. mi in 1961, and expected to go dry in 1962 |
| Goose (see California) | | |
| Abert | 52 | Maximum size, 60 sq. mi. Dry in 1930 or thereabouts, but fairly high in 1958 |
| Summer | Probably dry | Maximum size, 70 sq. mi. Nearly dry in 1961 |
| Silver | Dry | Maximum size, 15 sq. mi. Dry in 1961. Because of the transient nature of the lake, the water—whenever there is any—is relatively fresh; hay is raised on the dry lake bed |
| Warner | Probably less than 10 | A series of shallow lakes; combined area about 30 sq. mi in 1953, a wet year, estimated from Army Map Service map based on aerial photograph taken in 1953. Present lakes are all that is left of Pleistocene Warner Lake, which covered about 300 sq. mi and was about 270 ft deep |
| **Utah** | | |
| Great Salt | About 1,000 | Maximum size since 1851, 2,400 sq. mi in 1870s; minimum, 950 sq. mi in October 1961; seasonal high in 1962 was 1,050 sq. mi in June |
| Sevier | Dry | Maximum size, 125 sq. mi; has been dry for several years |

*Source*: From U.S. Geological Survey, 1963.

**Table 5B.18 Hydrologic Data for Great Salt Lake and West Desert Pumping Project**

| | |
|---|---|
| **Great Salt Lake** | |
| Dimensions | 80×35 mi |
| Average depth | 22 ft |
| Maximum depth | 42 ft |
| Contents in dissolved minerals (mainly chloride, sodium, sulfate, magnesium, potassium with lesser amounts of calcium, lithium, bromium and boron[a]) | 4–5 billion tons |
| **West Desert Pumping Project** | |
| Flood control project by State of Utah to lower water level of Great Salt Lake | |
| Start of construction July 1986 | |
| Cost of construction and 1st year of operation | 71.7 million |
| Projected volume of diversion | 2.73 million acre ft total |
| Water is lifted by 3 large pumps (capacity 1,000 cfs each) through 4.1 mi long outlet canal to evaporation pond (west pond) | |
| Surface area of west pond | 500 sq. mi |
| Rate of evaporation from west pond | 825,000 acre-ft/yr |
| Salinity of water in west pond | 350 g/L |

Rock and earthfill Southern Pacific Transportation Co. railroad causeway separates the lake into two parts, Southern part of lake (60% of total area) receives 90% of lake's freshwater inflow, Total annual inflow 1931–76 averaged 2.9 million acre-ft, Northern part of lake receives most of its water as brine flowing through culverts and causeway from southern part of lake, Lake salinity varies with lake level, Northern lake is 16% salt and about 3 times saltier than southern lake (June 1987).

[a] For chemical analysis of brine see Chapter 6 Table 6.8.

*Source*: From Compiled from information provided by Utah Division of Water-Resources, 1987 and U.S. Geological Survey Circular 913.

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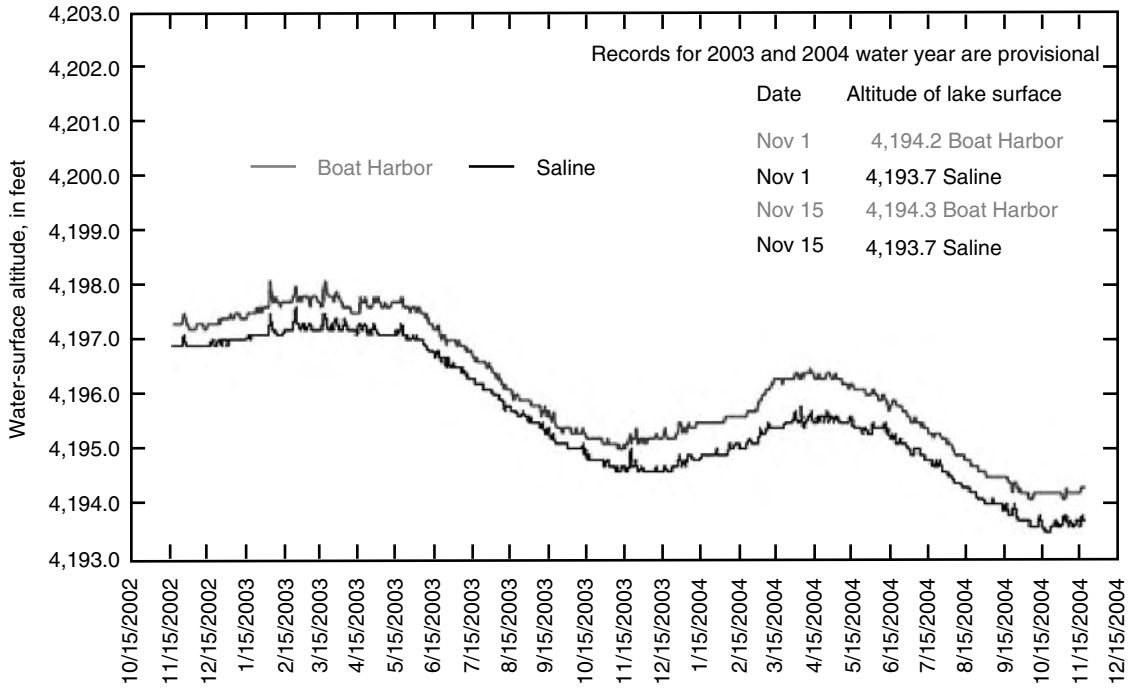


**Figure 5B.11** Fluctuation in water-surface altitude of both parts of Great Salt Lake during last 2 years. (From www.usgs.gov.)

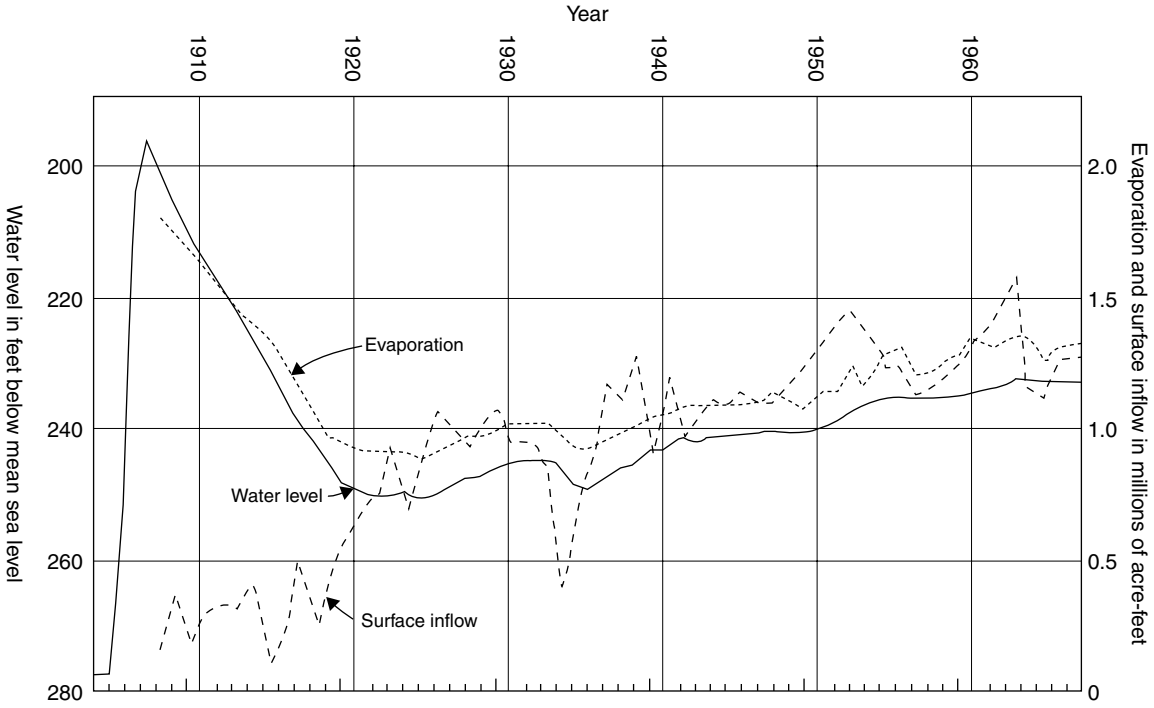


**Figure 5B.12** Water levels, evaporation and surface inflow of the Salton Sea, California. (From U.S. Geological survey, professional paper 486-C and California department of water resources bulletin 143-7, geothermal wastes and the water resources of the salton sea area, 1966. With permission.)

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**Table 5B.19 Long Term Average Min-Max Water Levels**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake Superior[a]** | | | | | | | | | | | | |
| Mean | 601.51 | 601.31 | 601.21 | 601.31 | 601.64 | 601.90 | 602.13 | 602.20 | 602.23 | 602.13 | 602.00 | 601.77 |
| Max | 602.69<br>1986 | 602.46<br>1986 | 602.40<br>1986 | 602.62<br>1986 | 602.82<br>1986 | 602.89<br>1986 | 603.08<br>1950 | 603.22<br>1952 | 603.22<br>1985 | 603.38<br>1985 | 603.31<br>1985 | 603.05<br>1985 |
| Min | 599.84<br>1926 | 599.61<br>1926 | 599.54<br>1926 | 599.48<br>1926 | 599.61<br>1926 | 599.90<br>1926 | 600.26<br>1926 | 600.46<br>1926 | 600.79<br>1926 | 600.72<br>1925 | 600.43<br>1925 | 600.13<br>1925 |
| **Lakes Michigan–Huron[a]** | | | | | | | | | | | | |
| Mean | 578.54 | 578.48 | 578.54 | 578.81 | 579.13 | 579.33 | 579.43 | 579.36 | 579.20 | 579.00 | 578.81 | 578.64 |
| Max | 581.30<br>1987 | 581.07<br>1986 | 581.10<br>1986 | 581.46<br>1986 | 581.63<br>1986 | 581.79<br>1986 | 581.99<br>1986 | 581.99<br>1986 | 581.99<br>1986 | 582.35<br>1986 | 581.96<br>1986 | 581.56<br>1986 |
| Min | 576.12<br>1965 | 576.08<br>1964 | 576.05<br>1964 | 576.15<br>1964 | 576.57<br>1964 | 576.64<br>1964 | 576.71<br>1964 | 576.67<br>1964 | 576.64<br>1964 | 576.44<br>1964 | 576.28<br>1964 | 576.18<br>1964 |
| **Lake St. Clair[a]** | | | | | | | | | | | | |
| Mean | 573.62 | 573.43 | 573.82 | 574.31 | 574.57 | 574.70 | 574.77 | 574.67 | 574.44 | 574.15 | 573.88 | 573.88 |
| Max | 576.77<br>1986 | 576.77<br>1986 | 576.77<br>1986 | 576.84<br>1986 | 576.87<br>1986 | 577.17<br>1986 | 577.20<br>1986 | 577.10<br>1986 | 576.90<br>1986 | 577.30<br>1986 | 576.84<br>1986 | 576.77<br>1986 |
| Min | 570.47<br>1936 | 570.51<br>1926 | 571.03<br>1934 | 571.92<br>1926 | 572.24<br>1934 | 572.34<br>1934 | 572.51<br>1934 | 572.21<br>1934 | 571.98<br>1934 | 571.75<br>1934 | 571.46<br>1934 | 571.65<br>1964 |
| **Lake Erie[a]** | | | | | | | | | | | | |
| Mean | 570.83 | 570.80 | 571.10 | 571.59 | 571.85 | 571.95 | 571.92 | 571.69 | 571.39 | 571.06 | 570.83 | 570.83 |
| Max | 573.69<br>1987 | 573.43<br>1987 | 573.75<br>1986 | 574.08<br>1985 | 574.05<br>1986 | 574.28<br>1986 | 574.25<br>1986 | 573.95<br>1986 | 573.59<br>1986 | 573.95<br>1986 | 573.65<br>1986 | 573.82<br>1986 |
| Min | 568.27<br>1935 | 568.18<br>1936 | 568.24<br>1934 | 568.83<br>1934 | 569.03<br>1934 | 569.06<br>1934 | 569.06<br>1934 | 569.00<br>1934 | 568.83<br>1934 | 568.57<br>1934 | 568.24<br>1934 | 568.21<br>1934 |
| **Lake Ontario[a]** | | | | | | | | | | | | |
| Mean | 244.59 | 244.69 | 244.98 | 245.64 | 246.10 | 246.19 | 246.03 | 245.67 | 245.18 | 244.78 | 244.55 | 244.49 |
| Max | 246.59<br>1946 | 246.95<br>1952 | 247.28<br>1952 | 248.20<br>1973 | 248.46<br>1973 | 248.56<br>1952 | 248.23<br>1947 | 247.97<br>1947 | 247.41<br>1947 | 246.78<br>1945 | 246.65<br>1945 | 246.72<br>1945 |
| Min | 246.16<br>1935 | 242.06<br>1936 | 242.59<br>1935 | 242.88<br>1935 | 243.14<br>1935 | 243.41<br>1935 | 243.24<br>1934 | 242.78<br>1934 | 242.49<br>1934 | 242.19<br>1934 | 241.96<br>1934 | 241.93<br>1934 |
| **Lake Superior[b]** | | | | | | | | | | | | |
| Mean | 183.34 | 183.28 | 183.25 | 183.28 | 183.38 | 183.46 | 183.53 | 183.55 | 186.56 | 183.53 | 183.49 | 183.42 |
| Max | 183.70<br>1986 | 183.63<br>1986 | 183.61<br>1986 | 183.68<br>1986 | 183.74<br>1986 | 183.76<br>1986 | 183.82<br>1950 | 183.86<br>1952 | 183.86<br>1985 | 183.91<br>1985 | 183.89<br>1985 | 183.81<br>1985 |
| Min | 182.83<br>1926 | 182.76<br>1926 | 182.74<br>1926 | 182.72<br>1926 | 182.76<br>1926 | 182.85<br>1926 | 182.96<br>1926 | 183.02<br>1926 | 183.12<br>1926 | 183.10<br>1925 | 183.01<br>1925 | 182.92<br>1925 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lakes Michigan–Huron[b]** | | | | | | | | | | | | |
| Mean | 176.34 | 176.32 | 176.34 | 176.42 | 176.52 | 176.58 | 176.61 | 176.59 | 176.54 | 176.48 | 176.42 | 176.37 |
| Max | 177.18<br>1987 | 177.11<br>1986 | 177.12<br>1986 | 177.23<br>1986 | 177.28<br>1986 | 177.33<br>1986 | 177.39<br>1986 | 177.39<br>1986 | 177.38<br>1986 | 177.50<br>1986 | 177.38<br>1986 | 177.26<br>1986 |
| Min | 175.60<br>1965 | 175.59<br>1964 | 175.58<br>1964 | 175.61<br>1964 | 175.74<br>1964 | 175.76<br>1964 | 175.78<br>1964 | 175.77<br>1964 | 175.76<br>1964 | 175.70<br>1964 | 175.65<br>1964 | 175.62<br>1964 |
| **Lake St. Clair[b]** | | | | | | | | | | | | |
| Mean | 174.84 | 174.78 | 174.80 | 175.05 | 175.13 | 175.17 | 175.19 | 175.16 | 175.09 | 175.00 | 174.92 | 174.92 |
| Max | 175.80<br>1986 | 175.80<br>1986 | 175.80<br>1986 | 175.82<br>1986 | 175.83<br>1986 | 175.92<br>1986 | 175.93<br>1986 | 175.90<br>1986 | 175.84<br>1986 | 175.96<br>1986 | 175.82<br>1986 | 175.80<br>1986 |
| Min | 173.88<br>1936 | 173.89<br>1926 | 174.05<br>1934 | 174.32<br>1926 | 174.42<br>1934 | 174.45<br>1934 | 174.50<br>1934 | 174.41<br>1934 | 174.34<br>1934 | 174.27<br>1934 | 174.18<br>1934 | 174.24<br>1964 |
| **Lake Erie[b]** | | | | | | | | | | | | |
| Mean | 173.99 | 173.98 | 174.07 | 174.22 | 174.30 | 174.33 | 174.32 | 174.25 | 174.16 | 174.06 | 173.99 | 173.99 |
| Max | 174.86<br>1987 | 174.78<br>1987 | 174.88<br>1986 | 174.98<br>1985 | 174.97<br>1986 | 175.04<br>1986 | 175.03<br>1986 | 174.94<br>1986 | 174.83<br>1986 | 174.94<br>1986 | 174.85<br>1986 | 174.90<br>1986 |
| Min | 173.21<br>1935 | 173.18<br>1936 | 173.20<br>1934 | 173.38<br>1934 | 173.44<br>1934 | 173.45<br>1934 | 173.45<br>1934 | 173.43<br>1934 | 173.38<br>1934 | 173.30<br>1934 | 173.20<br>1934 | 173.19<br>1934 |
| **Lake Ontario[b]** | | | | | | | | | | | | |
| Mean | 74.55 | 74.58 | 74.67 | 74.87 | 75.01 | 75.04 | 74.99 | 74.88 | 74.73 | 74.61 | 74.54 | 75.52 |
| Max | 75.16<br>1946 | 75.27<br>1952 | 75.37<br>1952 | 75.65<br>1973 | 75.73<br>1973 | 75.76<br>1952 | 75.66<br>1947 | 75.58<br>1947 | 75.41<br>1947 | 75.22<br>1945 | 75.18<br>1945 | 75.20<br>1945 |
| Min | 73.81<br>1935 | 73.78<br>1936 | 73.94<br>1935 | 74.03<br>1935 | 74.11<br>1935 | 74.19<br>1935 | 74.14<br>1934 | 74.00<br>1934 | 73.91<br>1934 | 73.82<br>1934 | 73.75<br>1934 | 73.74<br>1934 |

*Note:* Period of Records: 1918–2003. All levels in this table are referenced to the International Great Lakes Datum of 1985 (IGLD85).

[a] English Units (ft).
[b] Metric Units (m).

*Source*: From www.usace.army.mil.



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**Table 5B.20 Hydrologic Data for Closed Lakes**

| Lake | Drainage Area (sq. mi) | Evaporation (ft/yr) | | Coeff-cient of Variation of Lake Area[a] | Response Time[b] (yr) | Overflow Expressed as Depth Over Tributary Area (ft) | Salinity | | Mean Depth (ft) | Lake Area (sq. mi) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Gross | Net[c] | | | | Date | ppm | | |
| Devils Lake, ND | 3,000 | 2.5 | 1.2 | 0.40 | 14 | 2.5 | 1899 | 8,470 | 13 | 45 |
| | | | | | | | 1923 | 15,210 | 10 | 26 |
| | | | | | | | 1948 | 25,000 | 4.5 | 14 |
| | | | | | | | 1952 | 8,680 | 10 | 20 |
| Basin, Lake, Saskatchewan | 105 | 2.25 | 1.0 | 0.07 | 25 | — | 1938–41 | 11,900 | 20 | 16 |
| Quill Lakes, Saskatchewan | 2,700 | 2.0 | 0.75 | 0.15 | 20 | — | 1938–41 | 25,000 | 10 | 230 |
| Redberry Lake, Saskatchewan | 120 | 2.25 | 1.0 | 0.038 | 50 | — | 1938–41 | 14,000 | 43 | 27 |
| Great Salt Lake, UT | 21,000 | 3.3 | 2.7 | 0.125 | 9 | 1.0 | 1877 | 138,000 | 18 | 2,200 |
| | | | | | | | 1932 | 276,000 | 13 | 1,300 |
| Sevier Lake, UT | 16,000 | 3.7 | 3.2 | 0.35 | 3 | 4 | 1872 | 86,400 | 8 | 188 |
| Pyramid Lake, NV | 2,650 | 4.2 | 3.7 | 0.04 | 65 | 9 | 1882 | 3,486 | 167 | 200 |
| Walker Lake, NV | 3,500 | 4.2 | 3.8 | 0.075 | 45 | 13 | 1882 | 2,500 | 120 | 110 |
| Mono Lake, CA | 600 | 4.1 | 3.3 | 0.043 | 35 | 200 | 1882 | 51,170 | 61 | 85 |
| Elsinore Lake, CA | 717 | 4.5 | 3.2 | 0.68 | 3.0 | 0.3 | 1949 | 8,880 | 5 | 5 |
| Owens Lake, CA | 2,900 | 5.5 | 5.0 | 0.10 | 10 | 12 | 1876 | 60,000 | 24 | 105 |
| | | | | | | | 1905 | 213,700 | 11 | 76 |
| Omak Lake, WA | 100 | 3.2 | 2.2 | 0.067 | 30 | 19 | [d] | 5,704 | 50 | 5.5 |
| Lake Abert, OR | 900 | 3.5 | 2.5 | 0.5 | 6 | 11 | 1902 | 76,000 | 5 | 50 |
| | | | | | | | 1912 | 30,000 | | – |
| | | | | | | | 1956—59 | 20,000 | 10 | 60 |
| Summer Lake, OR | 330 | 3.5 | 2.5 | 1.0 | 2 | 61 | 1901 | 36,000 | 3 | 30 |
| | | | | | | | 1912 | 18,000 | | – |
| Harney Lake, OR | 5,300 | 3.3 | 2.5 | 0.8 | 2 | 1.0 | 1912 | 22,380 | 4.8 | 47 |
| Lake Eyre, Australia | 550,000 | 7.5 | 7.0 | 2.5 | 1.5 | 10 | 1950 | [e]40,000 | 8.5 | 3,100 |
| | | | | | | | 1951 | [e]240,000 | 2.8 | 740 |
| Lake Corangamite, Australia | 1,300 | 4.0 | 2.0 | 0.30 | 10 | 3.8 | 1933 | 105,000 | 3.5 | 74 |
| | | | | | | | 1950 | 50,000 | 6.0 | 88 |
| | | | | | | | 1956 | 12,000 | 12 | 140 |
| Aral Sea, U.S.S.R. | 625,000 | 3.0 | 2.6 | 0.10 | 35 | 10 | — | 10,700 | 52 | 25,000 |
| Caspian Sea, Asia | 1,400,000 | 3.3 | 2.8 | 0.015 | 300 | 22 | — | 11,000 | 600 | 170,000 |
| Dead Sea, Palestine | 12,000 | 5.1 | 4.8 | 0.03 | 40 | 175 | — | 220,000 | 460 | 390 |
| Lake of Urmia, Iran | 20,000 | 3.0 | 2.5 | 0.11 | 9 | | — | 148,000 | 16 | 1,800 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Lake Van, Turkey | 6,000 | 3.3 | 2.0 | 0.02 | 150 | 53 | 1944 | [e]22,400 | 175 | 1,450 |
| Tuz Golu, Turkey | 4,400 | 3.4 | 2.4 | 0.5 | 1 | 86 | 1959 | 250,000 | 2 | 650 |
| Elton Lake, U.S.S.R. | — | — | 3.0 | 1.0 | 1.0 | — | — | 300,000 | 2.3 | 110 |
| Baskuntschak Lake, U.S.S.R. | — | — | 3.0 | 2.0 | 0.5 | — | — | 260,000 | 1.15 | 50 |

*Note:* These lakes occupy topographic sinks with no discharges by surface streams or seepage and with a groundwater gradient toward the lake.

[a] Coefficient of variation of lake area is equal to the standard deviation of lake volume divided by the area of the lake.
[b] Response time is the ratio of a change in lake volume to the corresponding change in rate of discharge.
[c] Net evaporation is gross evaporation minus precipitation.
[d] Before 1924.
[e] Milligrams per liter.

*Source*: From U.S. Geological Survey.



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**Table 5B.21 Water Balance of the Major Lakes of the World**

| Lake | Observation Period | Volume ($km^3$) | Inflow ($km^3/yr$) | Precipitation (mm/yr) | Outflow ($km^3/yr$) | Evaporation (mm/yr) | Inflow Factor[a] | Outflow Factor[b] | Retentions Time (yr) |
|---|---|---|---|---|---|---|---|---|---|
| Caspian Sea | 1940–1966 | 78200 | 289 | 246 | 10.8 | 994 | 0.76 | 0.03 | 204 |
| Michigan and Huron | 1959–1966 | 8200 | 142 | 780 | 161 | 750 | 0.61 | 0.65 | 33 |
| Superior | 1959–1966 | 11600 | 47.6 | 760 | 69.7 | 470 | 0.43 | 0.64 | 107 |
| Victoria | 1925–1959 | 2700 | 17.9 | 1630 | 21.9 | 1570 | 0.14 | 0.17 | 21 |
| Aral Sea | 1959–1969 | 1020 | 49.5 | 173 | 0 | 1050 | 0.82 | 0 | 15 |
| Tanganyika | Long-term | 18900 | 25.8 | 1000 | 3.0 | 1690 | 0.44 | 0.05 | 322 |
| Baikai | 1901–1970 | 23000 | 60.3 | 405 | 59.5 | 416 | 0.82 | 0.82 | 317 |
| Nyasa | Long-term | 7720 | 34.2 | 1220 | 6.3 | 2130 | 0.48 | 0.09 | 107 |
| Great Slave | Long-term | 1070 | 136 | 350 | 141 | 166 | 0.93 | 0.97 | 7.4 |
| Erie | 1959–1966 | 545 | 190 | 860 | 182 | 920 | 0.90 | 0.88 | 2.6 |
| Ontario | 1959–1966 | 1710 | 210 | 900 | 210 | 800 | 0.93 | 0.94 | 7.6 |
| Balkhash | 1911–1966 | 112 | 15.7 | 154 | 0 | 1020 | 0.85 | 0 | 6.0 |
| Ladoga | 1932–1958 | 908 | 69.1 | 606 | 73.7 | 344 | 0.87 | 0.92 | 11 |
| Chad | 1954–1962 | 44 | 45.8 | 378 | 0 | 2260 | 0.85 | 0 | 0.9 |
| Eyre | Long-term | — | 4.2 | 150 | 0 | Dries up | 0.77 | 0 | — |
| Maracaibo | Long-term | — | 19.6 | 977 | 4.9 | 2080 | 0.60 | 0.15 | — |
| Onega | Long-term | 295 | 15.9 | 575 | 18.0 | 350 | 0.74 | 0.84 | 14 |
| Rudolf | Long-term | — | 16.0 | 750 | 0.0 | 2610 | 0.71 | 0 | — |
| Titicaca | Long-term | 710 | 7.7 | 625 | 0.6 | 1500 | 0.60 | 0.05 | 55 |

[a] Percentage of inflow of the sum of inflow and lake precipitation.
[b] Percentage of outflow of the sum of outflow and lake evaporation.

*Source*: From Kuusisto, E.E., *Lakes Their Physical Aspects, in Facets of Hydrology II*, John C. Rodda, Editor, John Wiley and Sons 1985. Reproduced with permission.

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**Table 5B.22 Major Lakes in the World**

| Lake | Country | Surface Area ($km^2$) | Maximum Depth (m) | Volume ($km^3$) |
|---|---|---|---|---|
| | | **Europe** | | |
| Caspian Sea[a] | U.S.S.R. Iran | 374,000 | 1,025 | 78,200 |
| Ladozskoje | U.S.S.R. | 17,700 | 230 | 908 |
| Onezskoje | U.S.S.R. | 9,630 | 127 | 295 |
| Vänern | Sweden | 5,550 | 100 | 180 |
| Cudskoje with Pskovskoje | U.S.S.R. | 3,550 | 15 | 25 |
| Vättern | Sweden | 1,900 | 119 | 72 |
| Saimaa | Finland | 1,800 | 58 | 36 |
| Beloje | U.S.S.R. | 1,290 | 20 | 5.2 |
| Vygozero | U.S.S.R. | 1,140 | 18 | 7.1 |
| Mälaren | Sweden | 1,140 | 64 | 10 |
| Il'men' | U.S.S.R. | 1,100 | 10 | 12 |
| Päyänne | Finland | 1,065 | 93 | — |
| Inari | Finland | 1,000 | 80 | 28 |
| Imandra | U.S.S.R. | 900 | 67 | 11 |
| Balaton | Hungary | 596 | 12 | 1.9 |
| Lac de Geneve | Switzerland, France | 581 | 310 | 90 |
| Bodensee | German Federal Republic, Switzerland, Austria | 538 | 252 | 48 |
| Hälmaren | Sweden | 484 | 22 | — |
| Stor Sjön | Sweden | 464 | 74 | 8.0 |
| Kubenskoje | U.S.S.R. | 407 | 13 | 1.7 |
| Loch Ness | Great Britain | 396 | 31 | — |
| Garda | Italy | 370 | 346 | 50 |
| Mjøsa | Norway | 363 | 434 | 56 |
| Skadarsko | Albania, Yugoslavia | 362 | 10 | 2.2 |
| Ohridsko | Albania, Yugoslavia | 350 | 256 | 61 |
| Sniardwy | Poland | 331 | 47 | 2.8 |
| Torne Träsk | Sweden | 330 | 168 | 17 |
| Neusieler See | Austria, Hungary | 323 | 2 | — |
| Prespansko | Greece, Albania, Yugoslavia | 288 | 54 | 4.0 |
| Neuchâtel | Switzerland | 216 | 152 | — |
| Lago Maggiore | Italy, Switzerland | 214 | 372 | — |
| Femund | Norway | 202 | 131 | 6.0 |
| Como | Italy | 146 | 410 | — |
| | | **Asia** | | |
| Aral'skoje More[a] | U.S.S.R. | 64,100 | 68 | 1,020 |
| Bajkali | U.S.S.R. | 31,500 | 1,741 | 23,000 |
| Balchas | U.S.S.R. | 18,200 | 26 | 112 |
| Tonle Sap | Cambodia | 10,000[b] | 12 | 40 |
| Issyk-Kul' | U.S.S.R. | 6,200 | 702 | 1,730 |
| Dongtinghu | China | 6,000[c] | 10 | — |
| Rizaiyeh (Urumiyeh)[a] | Iran | 5,800 | 16 | 45 |
| Zajsan | U.S.S.R. | 5,510 | 8.5 | 53 |
| Tajmyr | U.S.S.R. | 4,560 | 26 | 13 |
| Kukunor[a] | China | 4,220 | 38 | — |
| Chanka | U.S.S.R. China | 4,190 | 10.6 | 18.5 |
| Van[a] | Turkey | 3,760 | 145 | — |
| Lob Nor[a] | China | 3,500 | 5 | (5) |
| Ubsa Nor[a] | Mongolia | 3,350 | — | — |
| Poyanghu | China | 2,700 | 20 | — |
| Alakol' | U.S.S.R. | 2,650 | 54 | 58.6 |
| Chövsgöl Nuur | Mongolia | 2,620 | 270 | 480 |
| Cany | U.S.S.R. | 2,500 | 10 | 4.5 |
| Tuz[a] | Turkey | 2,500 | — | — |
| Namru Tso[a] | China | 2,460 | — | — |
| Taihu | China | 2,210 | — | — |
| Char Us Nuur | Mongolia | 1,760 | — | — |
| Tengiz[a] | U.S.S.R. | 1,590 | 8 | — |

*(Continued)*

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**Table 5B.22 (Continued)**

| Lake | Country | Surface Area ($km^2$) | Maximum Depth (m) | Volume ($km^3$) |
|---|---|---|---|---|
| Ebi Nor[a] | China | 1,420 | — | — |
| Chirgis Nuur | Mongolia | 1,480 | — | — |
| Sevan | U.S.S.R. | 1,230 | 86 | 38 |
| Dalai Nur | China | 1,100 | — | — |
| Ulyunger Nor | China | 1,000 | — | — |
| Dead Sea[a] | Israel, Jordan | 940 | 400 | 188 |
| Seletyteniz | U.S.S.R. | 777 | 3.2 | 1.5 |
| Sasykkol' | U.S.S.R. | 736 | — | — |
| P'asino | U.S.S.R. | 735 | 10 | — |
| Kulundinskoje[a] | U.S.S.R. | 728 | 4.9 | — |
| Biwa ko | Japan | 688 | 103 | 27.5 |
| Gandhi | India | 663 | 64 | 39.2 |
| Karnaphuli | Bangladesh, India | 656 | 33 | 13.8 |
| Buir Nuur | Mongolia | 610 | 11 | — |
| Markakol' | U.S.S.R. | 449 | 30 | — |
| Ubinskoje | U.S.S.R. | 440 | 3 | — |
| Karakul'[a] | U.S.S.R. | 380 | 238 | — |
| Tungabharda | India | 378 | 47 | 12.4 |
| Fumibhal | Thailand | 300 | 123 | 29.7 |
| Kronockoje | U.S.S.R. | 245 | 128 | — |
| Teleckoje | U.S.S.R. | 223 | 325 | 40 |
| | **Africa** | | | |
| Victoria | Tanzania, Kenya, Uganda | 69,000 | 92 | 2,700 |
| Tanganyika | Tanazania, Zaire, Zambia, Burundi, Rwanda | 32,900 | 1,435 | 18,900 |
| Nyasa | Malawi, Mozambique, Tanzania | 30,900 | 706 | 7,725 |
| Chad | Chad, Niger, Nigeria | 16,600[d] | 12 | 44.4 |
| Rudolf | Kenya | 8,660 | 73 | — |
| Mobutu Sese Seko | Uganda, Zaire | 5,300 | 57 | 64.0 |
| Mweru | Zambia, Zaire | 5,100 | 15 | 32.0 |
| Bangweulu | Zambia | 4,920[e] | 5 | 5.00 |
| Rukwa | Tanzania | 4,500 | — | — |
| Tana | Ethiopia | 3,150 | 14 | 28.0 |
| Idi Amin Dada | Zaire, Uganda | 2,500 | 131 | 78.2 |
| Kivu | Zaire, Rwanda | 2,370 | 496 | 569 |
| Mai Ndombe | Zaire | 2,325 | 6 | — |
| Kamnit | Nigeria | 1,270 | 60 | 14.0 |
| Abaya | Ethiopia | 1,160 | 13 | 8.20 |
| Shirwa | Malawi | 1,040 | 2.6 | 45.0 |
| Tumba | Zaire | 765 | — | — |
| Faguibine | Mali | 620 | 14 | 3.72 |
| Gab el Aulia | Sudan | 600 | 12 | — |
| Chamo | Ethiopia | 551 | 12.7 | — |
| Upemba | Zaire | 530 | 3.5 | 0.90 |
| Zwai | Ethiopia | 434 | 7 | 1.10 |
| Shala | Ethiopia | 409 | 266 | 37.0 |
| Langana | Ethiopia | 230 | 46.2 | 3.82 |
| L. de Guiers | Senegal | 213 | 7 | 0.64 |
| Hora Abyata | Ethiopia | 205 | 14.2 | 1.56 |
| Naivasha | Kenya | 140 | — | — |
| Awusa | Ethiopia | 130 | 21 | 1.34 |
| | **North America** | | | |
| Superior | Canada, U.S.A. | 82,680 | 406 | 11,600 |
| Huron | Canada, U.S.A. | 59,800 | 229 | 3,580 |
| Michigan | U.S.A. | 58,100 | 281 | 4,680 |
| Great Bear | Canada | 30,200 | 137 | 1,010 |
| Great Slave | Canada | 27,200 | 156 | 1,070 |
| Erie | Canada, U.S.A. | 25,700 | 64 | 545 |

*(Continued)*

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**Table 5B.22 (Continued)**

| Lake | Country | Surface Area ($km^2$) | Maximum Depth (m) | Volume ($km^3$) |
|---|---|---|---|---|
| Winnipeg | Canada | 24,600 | 19 | 127 |
| Ontario | Canada, U.S.A. | 19,000 | 236 | 1,710 |
| Nicaragua | Nicaragua | 8,430 | 70 | 108 |
| Athabaska | Canada | 7,900 | 60 | 110 |
| Dear Lake | Canada | 6,300 | — | — |
| Winnipegosis | Canada | 5,470 | 12 | 16 |
| Nipigon | Canada | 4,800 | 162 | |
| Manitoba | Canada | 4,720 | 28 | 17 |
| Great Salt[a] | U.S.A. | 4,660 | 14 | 19 |
| Forest | Canada, U.S.A. | 4,410 | 21 | — |
| Dubawant | Canada | 4,160 | — | — |
| Mistassini | Canada | 2,190 | 120 | — |
| Managua | Nicaragua | 1,490 | 80 | — |
| Saint Clair | Canada | 1,200 | 7.2 | 5.3 |
| Lesser Slave | Canada | 1,190 | 3 | — |
| Chapala | Mexico | 1,080 | 10 | 10.2 |
| Winnibago | U.S.A. | 818 | 6 | 4.1 |
| Marion | U.S.A. | 465 | — | 2.8 |
| Winnipesaukee | U.S.A. | 181 | 55 | 3.8 |
| | **South America** | | | |
| Maracaibo | Venezuela | 13,300 | 35 | — |
| Titicaca | Peru, Bolivia | 8,110 | 230 | 710 |
| Poopó[a] | Bolivia | 2,530 | 3 | 2 |
| Buenos-Aires | Chile, Argentina | 2,400 | — | — |
| Lago Argentina | Argentina | 1,400 | 300 | — |
| Valencia | Venezuela | 350 | — | — |
| | **Australia** | | | |
| Eyre[a] | | up to 15,000 | 20 | — |
| Amadeus[a] | | 8,000 | — | — |
| Torrens[a] | | 5,800 | — | — |
| Gairdner[a] | | 4,780 | — | — |
| George | | 145 | 3 | 0.3 |
| | **New Zealand** | | | |
| Taupo | | 611 | 159 | — |
| Te Anau | | 352 | 276 | — |
| Wakatipu | | 293 | 378 | — |
| Wanaka | | 194 | — | — |
| Manapouri | | 130 | — | — |
| Hawea | | 119 | — | — |

[a] Salt lakes.
[b] At low levels 3000 $km^2$, at high levels 30,000 $km^2$.
[c] At low levels 4000 $km^2$, at high levels 12,000 $km^2$.
[d] At low levels 7000–10,000 $km^2$, at high levels 18,000–22,000 $km^2$.
[e] At low levels 4000 $km^2$, at high levels 15,000 $km^2$.

*Source*: From U.S.S.R. National Committee for the International Hydrological Decade, Atlas of World Balance UNESCO, 1977.

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## SECTION 5C WATERFALLS

**Table 5C.23 Major Waterfalls of the World**

| Name and Location | ft |
|---|---|
| **Africa** | |
| **Angola** | |
| Duque de Braganca, Lucala R | 344 |
| Ruacana, Cunene R | 406 |
| **Ethiopia** | |
| Baratieri, Ganale Dorya R | 459 |
| Dal Verme, Ganale Dorya R | 98 |
| Fincha | 508 |
| Tesissat, Blue Nile R[b] | 140 |
| **Lesotho** | |
| Maletsunyane | 630 |
| **Rhodesia-Zambia** | |
| Victoria, Zambezi R[b] | 355 |
| **South Africa** | |
| Aughrabies, Orange R[b] | 400 |
| Howick, Umgeni R | 311 |
| Tugela (5 falls)[a] | 3,110 |
| Highest fall | 1,350 |
| **Tanzania-Zambia** | |
| Kalambo[b] | 726 |
| **Uganda** | |
| Murchison, Victoria Nile R | 130 |
| **Zambia** | |
| Chirombo, Leisa R | 880 |
| **Asia** | |
| **India** | |
| Cauvery[c] | 330 |
| Gersoppa (Jog), Sharavati R[a,c] | 830 |
| **Japan** | |
| Kegon, L. Chuzenji[c] | 330 |
| Yudaki, L. Yuno | 335 |
| **Australasia** | |
| **Australia** | |
| New South Wales | |
| Wentworth[a] | 518 |
| Highest fall | 360 |
| Wollomombi | 1,100 |
| Queensland | |
| Coomera | 210 |
| Tully | 450 |
| **New Zealand** | |
| Bowen (from Glaciers)[b] | 540 |
| Helena | 890 |
| Sterling | 505 |
| Sutherland, Arthur R[a] | 1,904 |
| **Europe** | |
| **Austria** | |
| Upper Gastein | 207 |
| Lower Gastein (Both on Ache R.) | 280 |
| Golling, Schwarzbach R[a] | 200 |
| Krimml (Krimmler) | 1,250 |
| **France** | 1,385 |
| Gavarnie (C)[a] | |
| **Great Britain**–Wales | |
| Pistyll Cain, Afon Gain R | 150 |
| Pistyll Rhaiadr | 240 |
| Scotland Glomach | 370 |

*(Continued)*

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**Table 5C.23 (Continued)**

| Name and Location | ft |
|---|---|
| **Iceland** | |
| Detti, Jokul R | 144 |
| Gull, Hvita R | 101 |
| **Italy** | |
| Toce (C) | 470 |
| **Norway** | |
| Eastern Mardalsfoss[a] | 1,696 |
| Highest fall | 974 |
| Western Mardalsfoss (Both on L. Eikesdal) | 1,535 |
| Skjeggedal | 525 |
| Skykkje, Skykkjua R | 820 |
| Vettis, Morkedöla R | 1,214 |
| Highest fall | 889 |
| Vöring, Bjoreia R | 597 |
| **Sweden** | |
| Handöl, Handöl Cr[a] | 345 |
| Stora Sjöfallet, Lule R[a,b] | 130 |
| Tannforsen, Are R | 120 |
| **Switzerland** | |
| Giétroz (Glacier) (C)[a] | 1,640 |
| Diesbach[a] | 394 |
| Giessbach[a] | 1,312 |
| Handegg, Aare R | 151 |
| Iffigen | 394 |
| Pissevache, La Salanfe R | 213 |
| Reichenbach[a] | 656 |
| Rhine | 65 |
| Simmen, Simme R[a] | 459 |
| Stäuber | 590 |
| Staubbach | 984 |
| Trümmelbach[a] | 1,312 |
| **North America** | |
| **Canada** | |
| British Columbia | |
| Takakkaw (Daly Glacier)[a] | 1,650 |
| Highest fall | 1,200 |
| Panther, Nigel Cr | 600 |
| Labrador | |
| Churchill Falls, Churchill R | 245 |
| Mackenzie District | |
| Virginia, S. Nahanni R | 315 |
| Quebec | |
| Montmorency | 251 |
| **Canada-United States** | |
| Ontario-New York | |
| Niagara: American | 193 |
| Horseshoe | 186 |
| **United States** | |
| Arizona | |
| Mooney, Havasu Cr | 220 |
| California | |
| Feather, Fall R | 640 |
| Illilouette | 370 |
| Nevada, Merced R | 594 |
| Ribbon[c] | 1,612 |
| Silver Strand | 1,170 |
| Vernal, Merced R | 317 |
| Yosemite[a] | 2,425 |
| Bridalveil | 620 |
| Yosemite (upper)[b] | 1,430 |

*(Continued)*

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**Table 5C.23 (Continued)**

| Name and Location | ft |
|---|---|
| Yosemite (lower)[b] | 320 |
| Colorado | |
| Seven | 266 |
| Georgia | |
| Tallulah[a] | 251 |
| Idaho | |
| Henry's Fork (upper) | 96 |
| Henry's Fork (lower) | 70 |
| Shoshone, Snake R[c] | 195 |
| Twin, Snake R[c] | 125 |
| Kentucky | |
| Cumberland | 68 |
| Maryland | |
| Great Potomac R (C) | 90 |
| Minnesota | |
| Minnehaha[c] | 54 |
| Montana | |
| Missouri | 75 |
| New Jersey | |
| Passaic[c] | 70 |
| New York | |
| Taughannock | 215 |
| Oregon | |
| Multnomah[a] | 620 |
| Highest fall | 542 |
| Tennessee | |
| Fall Creek | 256 |
| Rock House Creek | 125 |
| Washington | |
| Fairy Falls | 700 |
| Mt. Rainer National Pk | |
| Narada, Paradise R | 168 |
| Sluiskin, Paradise R | 300 |
| Palouse | 198 |
| Snoqualmie | 270 |
| Wisconsin | |
| Manitou, Black R | 165 |
| Wyoming | |
| Yellowstone National Pk | |
| Tower | 132 |
| Yellowstone (upper) | 109 |
| Yellowstone (lower) | 308 |
| **Mexico** | |
| El Salto | |
| Juanacatlán, Rio Grande de Santiago[c] | 66 |
| **South America** | |
| **Argentina-Brazil** | |
| Iguazú[a] | 230 |
| **Brazil** | |
| Glass | 1,325 |
| Herval | 400 |
| Paulo Afonso, São Francisco R | 275 |
| Patos-Maribondo, Rio Grande | 115 |
| Urubupunga, Alto Paraná R | 40 |
| **Brazil-Paraguay** | |
| Sete Quedas, or Guaira Alto Paraná R | 130 |
| **Colombia** | |
| Tequendama | |
| Bogotá R | 427 |

*(Continued)*

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**Table 5C.23 (Continued)**

| Name and Location | ft |
|---|---|
| Catarata de Candelas, Cusiana R | 984 |
| **Ecuador** | |
| Agoyan, Pastaza R | 200 |
| **Guyana** | |
| Kaieteur, Potaro R | 741 |
| King Edward VIII, Semang R | 840 |
| King George VI, Utshi R | 1,600 |
| Marina, Ipobe R[a] | 500 |
| Highest fall | 300 |
| **Venezuela** | |
| Angel | 3,212 |
| Highest fall | 2,648 |
| Cuquenán | 2,000 |

*Note:* Height-total drop in one or more leaps. If river names not shown, they are same as the falls. R—river; L—lake; (C)—Cascade-type.

[a] Falls of more than one leap.
[b] Falls that diminish greatly seasonally.
[c] Falls that reduce to a trickle or are dry for part of each year.

*Source*: From National Geographic Society.

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## SECTION 5D GLACIERS AND ICE

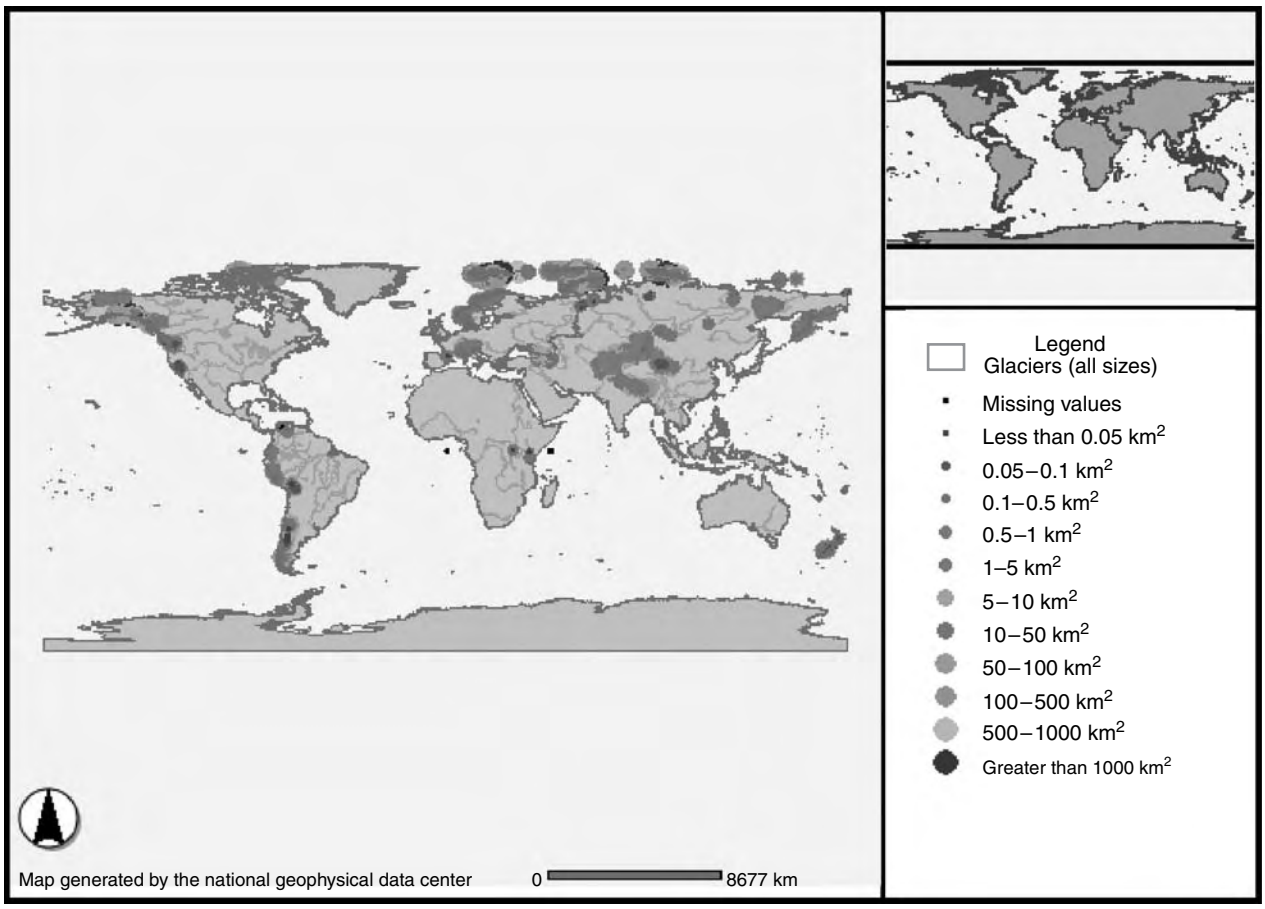


**Figure 5D.13** World glacier inventory. (From www.ngdc.noaa.gov.)

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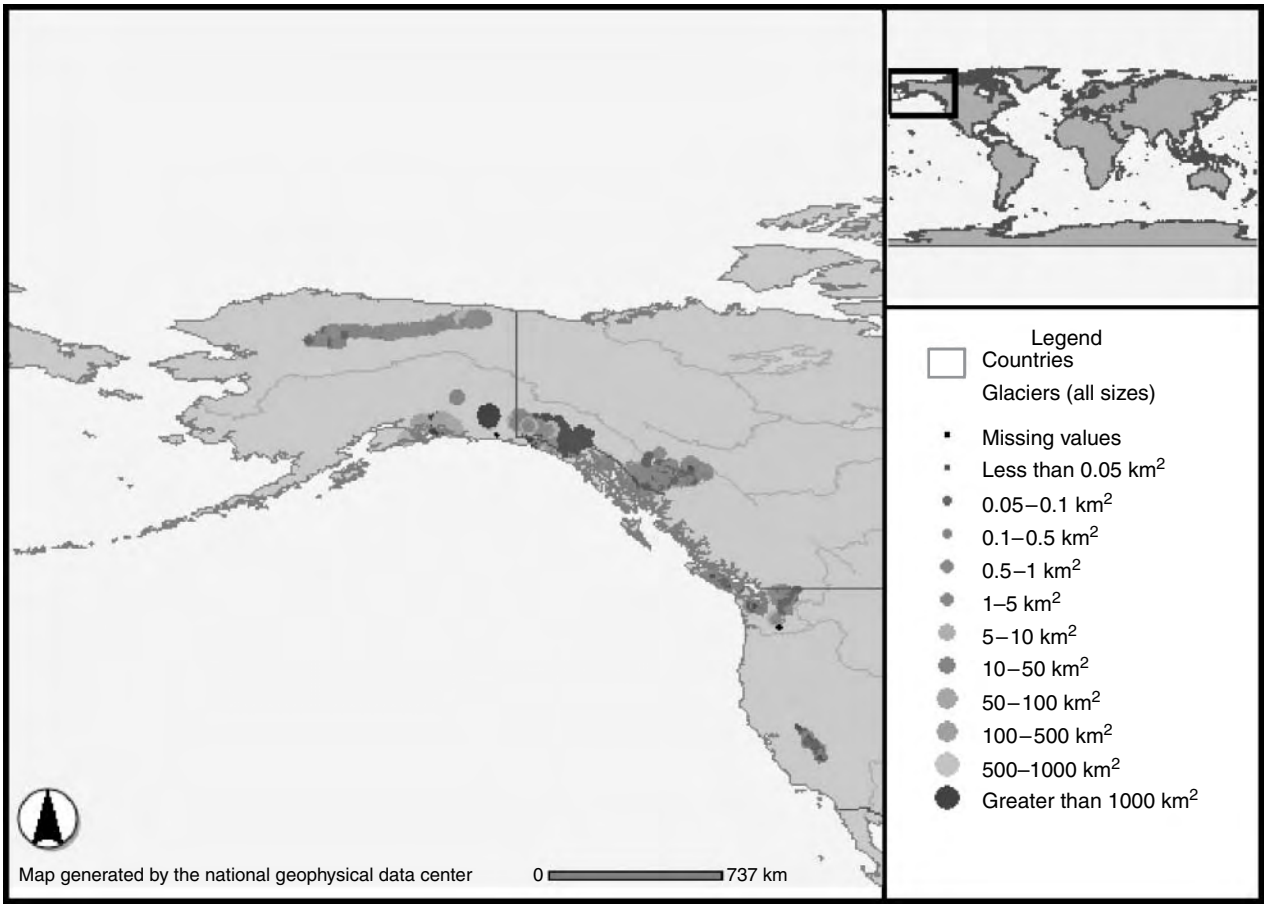


**Figure 5D.14** Glacier inventory of western North America. (From www.ngdc.noaa.gov.)

**Table 5D.24 Glacial Ice Coverage of the World**

| Land Area | sq. mi |
|---|---|
| Continental Europe | 3,880 |
| Continental Asia | 43,270 |
| Continental North America | 30,900 |
| Continental South America | 9,600 |
| South polar regions | 5,020,450 |
| North polar regions | 721,150 |
| Africa | 8 |
| New Zealand | 386 |
| New Guinea | 6 |
| Total | 5,829,650 |

*Source*: From Huberty and Flock, Natural Resources, McGraw-Hill, Copyright 1959. Reproduced with permission.

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**Table 5D.25 Glaciers in the United States**

| State | Approximate Number of Glaciers | Total Glaciated Area (sq. mi) | Glacier Contribution to July–August Streamflow (Estimated) | |
|---|---|---|---|---|
| | | | Thousand Acre-feet | Million Gallons |
| Alaska | (unknown) | 29,000 | 150,000 | 49,000,000 |
| Washington | 950 | 160 | 870 | 280,000 |
| California | 290 | 19 | 65 | 21,000 |
| Wyoming | 100 | 19 | 80 | 26,000 |
| Montana | 200 | 16 | 65 | 21,000 |
| Oregon | 60 | 8 | 40 | 13,000 |
| Colorado | 25 | 0.6 | 2 | 650 |
| Idaho | 20 | 0.6 | 2 | 650 |
| Nevada | 5 | 0.1 | 0.4 | 130 |
| Utah | 1 | 0.04 | 0.1 | 33 |

*Source*: From U.S. Geological Survey, *National Water Summary 1985—Hydrologic Perspectives. Water-Supply Paper 2300*.

**Table 5D.26 Areas of Glaciers in the Western Conterminous United States**

| Location | Area (sq. km) | |
|---|---|---|
| | Meier (1961a) | More Recent Source, Where Available |
| Washington | | |
| 1. North Cascades (northern Cascade Range)[a] | 251.7 | 267.0[b] |
| 2. Olympic Mountains | 33.0 | 45.9[c] |
| 3. Mount Rainier | 87.8 | 92.1[d] |
| 4. Goat Rocks area | 1.5 | 1.5 |
| 5. Mount Adams | 16.1* | 16.1* |
| 6. Mount St. Helens | 7.3 | 5.92/2.16[e] |
| Total | 397.4 | 428.5/424.8 |
| Oregon | | |
| 7. Mount Hood | 9.9 | 13.5[d] |
| 8. Mount Jefferson | 3.2 | 3.2 |
| 9. Three Sisters area | 7.6 | 8.3[d] |
| 10. Wallowa Mountains | — | *0.1 |
| Total | 20.7 | 25.1 |
| California | | |
| 11. Mount Shasta | 5.5 | 6.9[d] |
| 12. Salmon-Trinity Mountains | 0.3 | 0.3 |
| 13. Sierra Nevada | 13.1 | 50.0/63.0[f] |
| Total | 18.9 | 57.2/70.2 |
| Montana | | |
| 14. Glacier National Park | 13.8 | 28.4[g] |
| 15. Cabinet Range | 0.5 | 0.5[g] |
| 16. Flathead-Mission-Swan Ranges | *1.2 | *2.3[g] |
| 17. Crazy Mountains | *0.5 | *0.4[g] |
| 18. Beartooth Mountains | 10.8 | 10.9[g] |
| Total | 26.8 | 42.5 |
| Wyoming | | |
| 19. Big Horn Mountains | 0.3 | 1.0[g] |
| 20. Absaroka Range | 0.7* | .7*[g] |
| 21. Teton Range | 2.0 | 1.7[g] |
| 22. Wind River Range | 44.5 | 31.6[g] |
| Total | 47.5 | 37.5 |
| Colorado | | |
| 23. Rocky Mountain Park-Front Range, others | 1.7 | 1.5[g] |

*(Continued)*

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**Table 5D.26 (Continued)**

| Location | Area (sq. km) | |
|---|---|---|
| | Meier (1961a) | More Recent Source, Where Available |
| Idaho | | |
| 24. Sawtooth Mountains | — | 1.0[h]* |
| Utah | | |
| 25. Wasatch Mountains | — | 0.2[i] |
| Nevada | | |
| 26. Wheeler Peak | 0.2 | 0.2 |

*Note:* Glacier areas in the first column are taken from Meier (1961a); dashes mean not determined by Meier. Glacier areas in the second column are from Meier (1961a) where a more recent source is not available. The change in area between 1961 and the more recent source is normally due to a more complete data set rather than a true change. An asterisk indicates that the value is estimated.

[a] The region bounded by the Canadian border on the north, Snoqualmie Pass on the south, the Puget Lowlands on the west, and the Columbia and Okanogan Rivers on the east.
[b] Post and Others, 1971.
[c] Spicer, 1986.
[d] Driedger and Kennard, 1986.
[e] Brugman and Meier, 1981. Before/after eruption of 18 May 1980.
[f] Raub and Others, 1980; unpub. data. The 50 $km^2$area includes glaciers plus moraine-covered ice; the 63 $km^2$ area includes glaciers, moraine-covered ice, and small ice bodies not large enough to be considered glaciers.
[g] Graf, 1977.
[h] Estimated; various observers have reported numerous small glaciers.
[i] Timpanogos Cave, Utah, USGS 1:24,000-scale topographic map.

*Source*: From www.usgs.gov.

**Table 5D.27 Variations in the Position of Glacier Fronts Addenda from Earlier Years**

| NR | Glacier Name | PSFG NR | Method | 1st Survey DMY | 2nd Survey DMY | Variations (m) |
|---|---|---|---|---|---|---|
| | **Colombia** | | | | | |
| 1 | Alfombralese | CO0013B | A | 13.1.1945 | 10.2.1959 | −50.0 |
| | | | | 10.2.1959 | 11.1.1975 | −50.0 |
| | | | | 11.1.1975 | 10.12.1985 | −80.0 |
| | | | | 10.12.1985 | 19.1.1987 | −20.0 |
| 2 | Azufradoe | CO0005B | A | 13.1.1945 | 10.2.1959 | 60.0 |
| | | | | 10.2.1959 | 11.1.1975 | −20.0 |
| | | | | 11.1.1975 | 10.12.1985 | −130.0 |
| | | | | 10.12.1985 | 19.1.1987 | ST |
| 3 | Azufradow | CO0005A | A | 13.1.1945 | 10.2.1959 | −70.0 |
| | | | | 10.2.1959 | 11.1.1975 | −20.0 |
| | | | | 11.1.1975 | 10.12.1985 | −80.0 |
| | | | | 10.12.1985 | 19.1.1987 | ST |
| 4 | Lacabana | CO00007 | A | 10.2.1959 | 11.1.1975 | −200.0 |
| | | | | 11.1.1975 | 10.12.1985 | −200.0 |
| | | | | 10.12.1985 | 19.1.1987 | −20.0 |
| 5 | Laplazuela | CO00006 | A | 13.1.1945 | 10.2.1959 | −20.0 |
| | | | | 10.2.1959 | 11.1.1975 | −30.0 |
| | | | | 11.1.1975 | 19.1.1987 | −220.0 |
| 6 | Lagunillas | CO00008 | A | 13.1.1945 | 10.2.1959 | 0.0 |
| | | | | 10.2.1959 | 11.1.1975 | 0.0 |
| | | | | 11.1.1975 | 10.12.1985 | −50.0 |
| | | | | 10.12.1985 | 19.1.1987 | −10.0 |
| 7 | Leonera alta | CO00009 | A | 13.1.1945 | 10.2.1959 | −330.0 |
| | | | | 10.2.1959 | 11.1.1975 | −180.0 |
| | | | | 11.1.1975 | 10.12.1985 | −100.0 |
| | | | | 10.12.1985 | 19.1.1987 | −30.0 |

*(Continued)*

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**Table 5D.27 (Continued)**

| NR | Glacier Name | PSFG NR | Method | 1st Survey DMY | 2nd Survey DMY | Variations (m) |
|---|---|---|---|---|---|---|
| 8 | Nereidas | CO00014 | C | 1958 | 6.3.1986 | −644.5 |
| | | | | 6.3.1986 | 5.5.1987 | −40.0 |
| | | | | 5.5.1987 | 18.3.1988 | −50.0 |
| | | | | 18.3.1988 | 27.12.1990 | −150.0 |
| | **Chile** | | | | | |
| 9 | Amalia | RC00056 | A | 1945 | 1986 | −6000.0 |
| 10 | Asia | RC00055 | A | 1945 | 1984 | −195.0 |
| | | | | 1984 | 1986 | −96.0 |
| 11 | Balmaceda | RC00060 | A | 1945 | 1984 | −2496.0 |
| | | | | 1984 | 1986 | −80.0 |
| 12 | Bernardo | RC00037 | A | 1945 | 1976 | −837.0 |
| | | | | 1976 | 1984 | −304.0 |
| 13 | Calvo | RC00053 | A | 1945 | 1984 | 0.0 |
| | | | | 1984 | 1986 | 0.0 |
| 14 | Dickson | RC00063 | A | 1945 | 1984 | −3120.0 |
| 15 | EUROPA | RC00049 | A | 1945 | 1981 | −504.0 |
| | | | | 1981 | 1986 | −234.0 |
| 16 | GREVE | RC00040 | A | 1945 | 1976 | −3317.0 |
| | | | | 1976 | 1981 | −215.0 |
| | | | | 1981 | 1984 | −102.0 |
| | | | | 1984 | 1986 | −22.0 |
| | | | | 1986 | 1987 | −80.0 |
| 17 | GREY | RC00062 | A | 1945 | 1967 | −550.0 |
| | | | | 1967 | 1975 | − 350.0 |
| 18 | HPS12 | RC00043 | A | 1981 | 1984 | −180.0 |
| | | | | 1984 | 1986 | 0.0 |
| 19 | HPS13 | RC00045 | A | 1945 | 1984 | 0.0 |
| | | | | 1984 | 1986 | 0.0 |
| 20 | HPS15 | RC00046 | A | 1945 | 1984 | 0.0 |
| | | | | 1984 | 1986 | 0.0 |
| 21 | HPS19 | RC00047 | A | 1981 | 1986 | −400.0 |
| 22 | HPS28 | RC00051 | A | 1945 | 1984 | −351.0 |
| | | | | 1984 | 1986 | −1028.0 |
| 23 | HPS29 | RC00052 | A | 1945 | 1984 | −234.0 |
| | | | | 1984 | 1986 | −120.0 |
| 24 | HPS31 | RC00050 | A | 1945 | 1970 | −975.0 |
| | | | | 1970 | 1984 | −252.0 |
| 25 | HPS34 | RC00054 | A | 1945 | 1984 | −39.0 |
| | | | | 1984 | 1986 | 0.0 |
| 26 | HPS38 | RC00057 | A | 1945 | 1984 | − 468.0 |
| | | | | 1984 | 1986 | 240.0 |
| 27 | HPS41 | RC00058 | A | 1945 | 1984 | −360.0 |
| | | | | 1984 | 1986 | 0.0 |
| 28 | HPS8 | RC00041 | A | 1945 | 1976 | −1240.0 |
| | | | | 1976 | 1979 | −60.0 |
| | | | | 1979 | 1984 | −265.0 |
| | | | | 1984 | 1986 | 66.0 |
| 29 | HPS9 | RC00042 | A | 1976 | 1979 | −30.0 |
| | | | | 1979 | 1984 | −35.0 |
| | | | | 1984 | 1986 | −134.0 |
| 30 | OCCIDENTAL | RC00039 | A | 1945 | 1976 | −93.0 |
| | | | | 1976 | 1984 | −592.0 |
| | | | | 1984 | 1987 | − 462.0 |
| 31 | FHIDRO | RC00036 | A | 1945 | 1976 | −1643.0 |
| | | | | 1976 | 1984 | −216.0 |
| | | | | 1984 | 1986 | 134.0 |
| 32 | PENGUIN | RC00048 | A | 1981 | 1986 | −60.0 |
| 33 | PINGO | RC00061 | A | 1945 | 1984 | −1326.0 |
| | | | | 1984 | 1986 | 0.0 |

*(Continued)*

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**Table 5D.27 (Continued)**

| NR | Glacier Name | PSFG NR | Method | 1st Survey DMY | 2nd Survey DMY | Variations (m) |
|---|---|---|---|---|---|---|
| 34 | Pio XI | RC00044 | A | 1925 | 9.1926 | 1000.0 |
| | | | | 9.1926 | 12.1928 | 400.0 |
| | | | | 12.1928 | 1945 | −2500.0 |
| | | | | 1945 | 1951 | 5400.0 |
| | | | | 1951 | 1963 | 600.0 |
| | | | | 1963 | 1969 | 500.0 |
| | | | | 1969 | 1976 | 2400.0 |
| | | | | 1976 | 1981 | 310.0 |
| | | | | 1981 | 1986 | −400.0 |
| 35 | Snowy | RC00059 | A | 1945 | 1984 | −936.0 |
| | | | | 1984 | 1986 | 0.0 |
| 36 | Tempano | RC00038 | A | 1945 | 1976 | −1178.0 |
| | | | | 1976 | 1984 | −1264.0 |
| | | | | 1984 | 1986 | −694.0 |
| | **Argentina** | | | | | |
| 37 | Frias | RA00064 | A | 1984 | 1986 | 0.0 |
| | **Sweden** | | | | | |
| 38 | Hyllglaciaeren | S00780 | C | 16.8.1984 | 15.9.1988 | −38.0 |
| | **Kenya** | | | | | |
| 39 | Cesar | KN00004 | A | 1899 | 21.2.1947 | −120.0 |
| | | | | 3.9.1947 | 3.9.1987 | −95.0 |
| 40 | Darwin | KN00006 | A | 21.2.1947 | 3.9.1987 | −60.0 |
| 41 | Diamond | KN00010 | A | 21.2.1947 | 3.9.1987 | −40.0 |
| 42 | Forel | KN00011 | A | 21.2.1947 | 3.9.1987 | −9.0 |
| 43 | Gregory | KN00009 | A | 21.2.1947 | 3.9.1987 | −120.0 |
| | | | | 13.3.1986 | 1.9.1990 | −25.0 |
| 44 | Heim | KN00012 | A | 21.2.1947 | 3.9.1987 | −9.0 |
| 45 | Joseph | KN00003 | A | 21.2.1947 | 3.9.1987 | −250.0 |
| 46 | Krapf | KN00001 | A | 1899 | 21.2.1947 | −150.0 |
| 47 | Lewis | KN00008 | A | 1.5.1934 | 21.2.1947 | −130.0 |
| | | | | 1.1.1974 | 13.2.1978 | −25.0 |
| | | | | 21.2.1947 | 3.9.1987 | −245.0 |
| 48 | Melhuish | KN00014 | A | 21.2.1947 | 3.9.1987 | −220.0 |
| 49 | Northey | KN00013 | A | 21.2.1947 | 3.9.1987 | −230.0 |
| 50 | Tyndall | KN00005 | A | 1899 | 21.2.1947 | −250.0 |
| | | | | 21.2.1947 | 3.9.1987 | −70.0 |
| | **Poland** | | | | | |
| 51 | Pod Bula | PL00111 | C | 9.9.1980 | 26.9.1981 | −32.6 |
| | | | | 26.9.1981 | 25.9.1982 | −7.0 |
| | | | | 25.9.1982 | 10.10.1983 | 13.0 |
| | | | | 10.10.1983 | 30.9.1984 | −.3 |
| | | | | 30.9.1984 | 30.9.1985 | −20.7 |
| | | | | 30.9.1985 | 29.9.1985 | 24.3 |
| | | | | 29.9.1986 | 10.10.1987 | −10.3 |
| | | | | 10.10.1987 | 25.9.1988 | 17.7 |
| | | | | 25.9.1988 | 8.10.1989 | 3.3 |
| | | | | 8.10.1989 | 27.9.1990 | −33.0 |
| | **C.I.S** | | | | | |
| 52 | Dzhelo | SU07106 | C | 6.9.1985 | 1986 | −X |
| | | | | 1986 | 1987 | −X |
| | | | | 1987 | 3.9.1988 | −50.7 |
| | | | | 3.9.1988 | 6.9.1989 | −19.6 |
| | | | | 6.9.1989 | 3.9.1990 | −8.7 |
| 53 | Leviy Karagemsk | SU07107 | C | 6.9.1985 | 2.9.1986 | −19.0 |
| | | | | 2.9.1986 | 5.9.1987 | 1.1 |
| | | | | 5.9.1987 | 3.9.1988 | −12.6 |
| | | | | 3.9.1988 | 6.9.1989 | −11.0 |
| | | | | 6.9.1989 | 5.9.1990 | −8.7 |
| 54 | Mizhirgichiran | SU03043 | C | 6.9.1989 | 7.9.1990 | 12.9 |

*(Continued)*

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**Table 5D.27 (Continued)**

| NR | Glacier Name | PSFG NR | Method | 1st Survey DMY | 2nd Survey DMY | Variations (m) |
|---|---|---|---|---|---|---|
| 55 | Muravlev | SU06002 | C | 3.9.1989 | 26.8.1990 | −3.3 |
| 56 | NO. 122 (UNIV.) | SU07108 | C | 6.9.1985 | 2.9.1986 | −15.6 |
| | | | | 2.9.1986 | 5.9.1987 | −6.4 |
| | | | | 5.9.1987 | 3.9.1988 | −4.9 |
| | | | | 3.9.1988 | 6.9.1989 | −5.5 |
| | | | | 6.9.1989 | 5.9.1990 | −13.1 |
| 57 | Praviy Karagems | SU07109 | C | 6.9.1985 | 2.9.1986 | −18.6 |
| | | | | 2.9.1986 | 5.9.1987 | −.5 |
| | | | | 5.9.1987 | 3.9.1988 | 2.3 |
| | | | | 3.9.1988 | 5.9.1990 | −7.5 |
| 58 | Shumskiy | SU06001 | C | 8.9.1989 | 27.8.1990 | −9.4 |
| | **Pakistan** | | | | | |
| 59 | Aling | PK00035 | | 1970 | 1989 | −X |
| 60 | Bualtar | PK00004 | | 1939 | 1988 | +X |
| | **Nepal** | | | | | |
| 61 | Thulagi | NP00013 | A | 1958 | 1.11.1972 | −50.0 |
| | | | | 1.11.1972 | 1.11.1977 | −50.0 |
| | | | | 1.11.1977 | 1.11.1984 | −150.0 |
| | | | | 1.11.1984 | 1.11.1988 | −850.0 |

*Note:*
- NR: Record number
- Glacier Name: 15 alphabetic or numeric digits
- PSFG Number: 5 digits identifying glacier with alphabetic prefix denoting country
- Method:
  - A = aerial photogrammetry
  - B = terrestrial photogrammetry
  - C = geodetic ground survey (theodolite, tape etc.)
  - D = combination of a, b, or c
  - E = other methods or no information
- 1ST Survey: Day, month, and year of survey
- 2ND Survey: Day, month, and year of following survey
- Variation in Meters: Variation in the position of the glacier front in horizontal projection expressed as the change in length between the surveys
- Key to Symbols:
  - +X: Glacier in advance
  - −X: Glacier in retreat
  - ST: Glacier stationary
  - SN: Glacier front covered by snow

*Source*: From World Glacier Monitoring Service by Wilfried Haeberli, Martin Hoelzle, Stephan Suter and Regula Frauenfelder. www.wgms.ch.

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**Table 5D.28 Variations in the Postion of Glacier Fronts 1990–1995**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| | **Canada** | | | | | | | | | |
| 1 | Overlord | CD01590 | 1928 | 1990 | C | | −27.3 | 0.8 | | −50.0 |
| 2 | Wedgemount | CD02333 | 1928 | 1990 | A | | | | −39.0 | −14.5 |
| | **U.S.A.** | | | | | | | | | |
| 3 | Blue Glacier | US02126 | 1938 | 1990 | C | −14.0 | −42.0 | −6.0 | −25.0 | 8.0 |
| 4 | Cantwell | US00320 | 1950 | 1950 | C | | | −98.0 | | |
| 5 | Mccall | US00001 | 1957 | 1971 | C | | | −285.0 | −5.4 | −19.0 |
| 6 | Middle Toklat | US00315 | 1954 | 1954 | C | | −769.0 | | | |
| 7 | South Cascade | US02013 | 1957 | 1990 | A | −30.0 | −38.0 | −22.0 | −29.0 | −23.0 |
| | **Colombia** | | | | | | | | | |
| 8 | Nereidas | CO00014 | 1958 | 1990 | C | −50.0 | −80.0 | −X | −X | −260.0 |
| | **Peru** | | | | | | | | | |
| 9 | Broggi | PE00003 | 1968 | 1990 | C | −36.7 | −54.5 | −22.2 | −7.8 | −17.4 |
| 10 | Uruashraju | PE00005 | 1968 | 1990 | C | −25.8 | −32.7 | −24.2 | −24.1 | −34.7 |
| 11 | Yanamarey | PE00004 | 1972 | 1990 | C | −7.2 | −4.0 | −22.0 | −21.7 | −35.8 |
| | **Bolivia** | | | | | | | | | |
| 12 | Chacaltaya | RB05180 | | 1991 | C | | −5.2 | −4.7 | −4.6 | −17.6 |
| 13 | Zongo | RB05150 | | 1991 | C | | −12.3 | 1.1 | −10.2 | −6.4 |
| | **Chile** | | | | | | | | | |
| 14 | Bernardo | RC00037 | 1945 | 1984 | A | | 226.0 | | | |
| 15 | Grey | RC00062 | 1945 | 1975 | A | −352.0 | | | | −80.0 |
| 16 | PIO XI | RC00044 | 1925 | 1986 | A | | 500.0 | 400.0 | 700.0 | −600.0 |
| | **Iceland** | | | | | | | | | |
| 17 | Breidamjok EA | IS1126A | 1932 | 1990 | C | −X | | | | |
| 18 | Briedamjok EB | IS1126B | 1932 | 1990 | C | −40.0 | −24.0 | −25.0 | | |
| 19 | Breidamjok WA | IS1125A | 1932 | 1990 | C | −62.0 | −57.0 | −40.0 | −18.0 | 0.0 |
| 20 | Breidamjok WC | IS1125C | 1932 | 1990 | C | −70.0 | −69.0 | −16.0 | −20.0 | −30.0 |
| 21 | Brokarjokull | IS01427 | | 1990 | C | −12.0 | | −18.0 | 11.0 | |
| 22 | Falljokull | IS01021 | 1932 | 1990 | C | −3.0 | −14.0 | −3.0 | −14.0 | −1.0 |
| 23 | Fjallsfitjar | IS1024B | 1948 | 1990 | C | −9.0 | −39.0 | −67.0 | 10.0 | 5.0 |
| 24 | Fjallsj. Brmfj | IS1024A | 1948 | 1987 | C | −21.0 | −22.0 | −15.0 | −20.0 | −5.0 |
| 25 | Fjallsj.G-Sel | IS1024C | 1948 | 1990 | C | −25.0 | −25.0 | −30.0 | −X | 25.0 |
| 26 | Flaajokull | IS1930A | | 1972 | C | 5.0 | 6.0 | −7.0 | −5.0 | |
| 27 | Gigjokull | IS00112 | 1930 | 1990 | C | | | 7.0 | 22.0 | |
| 28 | Gljufurarjokull | IS00103 | 1939 | 1989 | C | | | | −X | −4.0 |
| 29 | Hagafellsjok E | IS00306 | 1934 | 1990 | C | | | −149.0 | | |
| 30 | Hagafellsjok W | IS00204 | 1934 | 1990 | C | | | −86.0 | | |
| 31 | Halsjokull | IS00117 | 1972 | 1990 | C | 3.0 | 5.0 | SN | | |
| 32 | Hoffellsj W | IS02031 | 1930 | 1990 | C | | −2.0 | | | |
| 33 | Hrutarjokull | IS00923 | 1948 | 1990 | C | −5.0 | −X | −X | −28.0 | 5.0 |
| 34 | Hyrningsjokull | IS00100 | 1931 | 1990 | C | 2.0 | 9.0 | 20.0 | 16.0 | 28.0 |
| 35 | Jokulkrokur | IS00007 | 1965 | 1985 | C | 3.0 | | | | |
| 36 | Kaldalonsjokull | IS00102 | 1931 | 1988 | C | SN | −4.0 | −6.0 | −3.0 | 12.0 |
| 37 | Kverkjokull | IS02500 | 1963 | 1989 | C | | | 13.0 | | |
| 38 | Kviarjokull | IS00822 | 1934 | 1990 | C | −14.0 | −X | −X | −11.0 | 6.0 |
| 39 | Leirufjjokull | IS00200 | 1966 | 1990 | C | −22.0 | 0.0 | −37.0 | −32.0 | 39.0 |
| 40 | Morsarjokull | IS00318 | 1932 | 1990 | C | −3.0 | −52.0 | 31.0 | 0.0 | 0.0 |
| 41 | Mulajokulls | IS0311A | 1933 | 1990 | C | −91.0 | 49.0 | 153.0 | −15.0 | −52.0 |
| 42 | Nauthagajokull | IS00210 | 1932 | 1990 | C | −8.0 | 1.0 | 3.0 | −9.3 | −2.0 |
| 43 | Oldufellsjokull | IS00114 | 1967 | 1989 | C | | | 57.0 | | |
| 44 | Reykjafjardarj | IS00300 | 1931 | 1990 | C | −47.0 | −10.0 | SN | −25.0 | −8.0 |
| 45 | Satujokull | IS00530 | | 1990 | C | −11.0 | −8.0 | 0.0 | −X | |
| 46 | Sidujok EM177 | IS0015B | 1964 | 1990 | C | −95.0 | −27.0 | −63.0 | 1117.0 | −3.0 |
| 47 | Skaftafellsj. | IS00419 | 1932 | 1990 | C | −12.0 | 0.0 | −6.0 | −46.0 | −56.0 |
| 48 | Skalafellsjokul | IS1728A | | 1990 | C | | 2.0 | 5.0 | | 2.0 |
| 49 | Skeidararj E1 | IS0117A | 1932 | 1990 | C | 147.0 | −28.0 | −9.0 | −33.0 | −31.0 |
| 50 | Skeidararj E2 | IS0117B | 1932 | 1990 | C | 64.0 | −10.0 | −16.0 | −11.0 | −7.0 |
| 51 | Skeidararj E3 | IS0117C | 1932 | 1990 | C | 0.0 | −3.0 | −1.0 | −4.0 | −3.0 |
| 52 | Skeidararj W | IS00116 | 1932 | 1990 | C | 429.0 | 86.0 | −X | −X | −77.0 |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 53 | Solheimajok W | IS0113A | 1930 | 1990 | C | 2.0 | 13.0 | 12.0 | −3.0 | 13.0 |
| 54 | Svinafellsj | IS0520A | 1932 | 1990 | C | 11.0 | 7.0 | −11.0 | −7.0 | 5.0 |
| 55 | Tungnaarjokull | IS02214 | 1955 | 1990 | C | −81.0 | −9.0 | −31.0 | −17.0 | 1175.0 |
| 56 | Virkisjokull | IS00721 | 1932 | 1990 | C | −X | −X | −X | −22.0 | −X |
| | **Norway** | | | | | | | | | |
| 57 | Austerdalsbreen | N31220 | 1906 | 1990 | C | 0.0 | 5.0 | 7.0 | 15.0 | 15.0 |
| 58 | Brigsdalsbreen | N37110 | 1901 | 1990 | C | 10.0 | 35.0 | 75.0 | 80.0 | 65.0 |
| 59 | Engabreen | N67011 | 1903 | 1990 | C | −24.0 | | 18.0 | | 115.0 |
| 60 | Faabergstoelsb. | N31015 | 1907 | 1990 | C | −18.0 | −6.0 | 10.0 | 34.0 | 44.0 |
| 61 | Hansbreen | N12419 | 1936 | 1990 | B | −309.0 | 56.0 | −64.0 | 45.0 | 42.0 |
| 62 | Hellstugubreen | N00511 | 1902 | 1990 | C | −7.0 | −9.0 | −3.0 | −9.0 | −6.0 |
| 60 | Leirbreen | N00548 | 1910 | 1990 | C | | | −16.5 | | −14.5 |
| 64 | Nigardsbreen | N31014 | 1907 | 1990 | C | 10.0 | 21.0 | 14.0 | 36.0 | 50.0 |
| 65 | Stegholtbreen | N31021 | 1907 | 1990 | C | −7.0 | −5.0 | −3.0 | −10.0 | −5.0 |
| 66 | Storbreen | N00541 | 1904 | 1990 | C | | | | −1.5 | 0.0 |
| 67 | Styggedalsbreen | N30720 | 1903 | 1992 | C | | | 0.0 | 4.0 | 2.0 |
| | **Sweden** | | | | | | | | | |
| 68 | Hyllglaciaeren | S00780 | 1965 | 1990 | C | 0.0 | 0.0 | 0.0 | −4.0 | 0.0 |
| 69 | Isfallsglac | S00787 | 1897 | 1990 | C | 0.0 | 5.0 | 3.0 | 2.0 | 5.0 |
| 70 | Karsojietna | S00798 | 1905 | 1990 | C | | 0.0 | 0.0 | −2.0 | |
| 71 | Mikkajekna | S00766 | 1896 | 1990 | C | −8.0 | −10.0 | −15.0 | −12.5 | −13.5 |
| 72 | Partejekna | S00763 | 1965 | 1990 | C | 0.0 | −4.0 | −5.0 | −12.0 | −9.0 |
| 73 | Passusjietna E | S00797 | 1968 | 1990 | C | | 0.0 | 0.0 | | |
| 74 | Passusjietna W | S00796 | 1968 | 1990 | C | | −2.0 | −4.0 | −2.0 | 0.0 |
| 75 | Rabots Glaciaer | S00785 | 1946 | 1990 | C | −11.0 | −14.0 | −15.0 | | −18.6 |
| 76 | Riukojietna | S00790 | 1963 | 1990 | C | | 0.0 | 0.0 | 0.0 | 0.0 |
| 77 | Ruopsokjekna | S00764 | 1965 | 1989 | C | | −10.0 | −11.0 | −3.9 | −3.4 |
| 78 | Ruotesjekna | S00767 | 1965 | 1990 | C | −14.0 | −7.0 | −4.0 | −10.0 | |
| 79 | Salajekna | S00759 | 1897 | 1990 | C | | −10.0 | | −14.0 | −12.5 |
| 80 | SE Kaskasatj GL | S00789 | 1910 | 1989 | C | 0.0 | 3.0 | 1.0 | 2.0 | 5.0 |
| 81 | Storglaciaeren | S00788 | 1897 | 1990 | C | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 82 | Stour Raetta GL | S00784 | 1963 | 1990 | C | | 0.0 | −5.0 | −3.0 | −1.0 |
| 83 | Suottasjekna | S00768 | 1964 | 1990 | C | −2.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 84 | Unnaraeita GL | S00783 | 1963 | 1990 | C | | 0.0 | 0.0 | 0.0 | 0.0 |
| 85 | Vartasjekna | S00765 | 1964 | 1990 | C | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | **France** | | | | | | | | | |
| 86 | Argentiere | F00002 | 1878 | 1990 | C | −11.0 | −13.0 | −25.0 | −10.0 | −22.0 |
| 87 | Blanc | F00031 | 1871 | 1990 | C | −15.5 | −18.0 | −26.0 | −27.0 | −23.5 |
| 88 | Bossons | F00004 | 1861 | 1990 | C | −110.0 | −66.0 | −81.0 | −74.0 | −18.0 |
| 89 | Gebroulaz | F00009 | 1730 | 1990 | C | −6.0 | −21.0 | ST | ST | ST |
| 90 | Mer De Glace | F00003 | 1879 | 1990 | C | 5.0 | ST | ST | ST | ST |
| 91 | Saint Sorlin | F00015 | 1904 | 1990 | C | −2.7 | −6.2 | −1.8 | 2.6 | −3.4 |
| | **Switzerland** | | | | | | | | | |
| 92 | Allalin | CH00011 | 1880 | 1990 | A | −35.0 | −63.0 | −20.0 | −11.0 | −24.0 |
| 93 | Alpetli (Kander) | CH00109 | 1893 | 1990 | C | −2.0 | −9.0 | −6.0 | −3.0 | −3.0 |
| 94 | Ammerten | CH00111 | 1969 | 1990 | C | −6.0 | −4.0 | −1.0 | −4.0 | −2.0 |
| 95 | Arolla (BAS) | CH00027 | 1884 | 1990 | C | −26.0 | −10.0 | −15.0 | −6.0 | −11.0 |
| 96 | Basodino | CH00104 | 1893 | 1990 | C | −2.0 | −3.0 | +X | 6.0 | −25.0 |
| 97 | Bella Tola | CH00021 | 1945 | 1990 | C | −13.0 | −1.0 | −5.0 | −9.0 | −39.0 |
| 98 | Biferten | CH00077 | 1893 | 1990 | C | −4.0 | | | −39.0 | −7.0 |
| 99 | BIS | CH00107 | 1883 | 1990 | E | −X | −X | | −X | −X |
| 100 | Bluemlisalp | CH00064 | 1893 | 1990 | C | −11.0 | −6.0 | −17.0 | −7.0 | −3.0 |
| 101 | Boveyre | CH00041 | 1889 | 1990 | C | −25.0 | −37.0 | | −13.0 | |
| 102 | Breney | CH00036 | 1892 | 1990 | C | −11.0 | −24.0 | −27.0 | −8.0 | −2.0 |
| 103 | Bresciana | CH00103 | 1896 | 1990 | C | −12.0 | SN | −17.0 | −8.0 | −14.0 |
| 104 | Brunegg | CH00020 | 1941 | 1990 | C | −5.0 | −3.0 | −4.0 | −8.0 | −5.0 |
| 105 | Brunni | CH00072 | 1882 | 1990 | C | | | | −X | |
| 106 | Calderas | CH00095 | 1920 | 1990 | C | −17.0 | −9.0 | −8.0 | −4.0 | −7.0 |
| 107 | Cambrena | CH00099 | 1889 | 1990 | C | −5.0 | −12.0 | −X | −17.0 | −9.0 |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 108 | Cavagnoli | CH00119 | 1893 | 1990 | C | −16.0 | −21.0 | −X | −12.0 | 0.0 |
| 109 | Cheillon | CH00029 | 1919 | 1990 | C | −79.0 | −60.0 | | 11.0 | −7.0 |
| 110 | Corbassiere | CH00038 | 1889 | 1990 | C | −15.0 | −14.0 | 9.0 | | |
| 111 | Corno | CH00120 | 1893 | 1990 | C | −7.0 | −13.0 | −X | −16.0 | 1.0 |
| 112 | Damma | CH00070 | 1920 | 1990 | C | 2.0 | −9.0 | −X | −9.0 | −16.0 |
| 113 | Eiger | CH00059 | 1893 | 1990 | C | −28.0 | −16.0 | −17.0 | −13.0 | −8.0 |
| 114 | EN Darrey | CH00030 | 1929 | 1990 | C | | −8.0 | | −65.0 | −2.0 |
| 115 | FEE North | CH00013 | 1879 | 1990 | C | −10.0 | −5.0 | | −55.0 | −38.0 |
| 116 | Ferpecle | CH00025 | 1891 | 1990 | C | −19.0 | −8.0 | −7.0 | −23.0 | −12.0 |
| 117 | Fiescher | CH00004 | 1891 | 1990 | C | −6.0 | 7.0 | −16.0 | −21.0 | −16.0 |
| 118 | Findelen | CH00016 | 1892 | 1990 | D | −61.0 | −22.0 | | −32.0 | −35.0 |
| 119 | Firnalpeli | CH00075 | 1894 | 1990 | C | | −15.0 | −X | −8.0 | −5.0 |
| 120 | Forno | CH00102 | 1894 | 1990 | C | −19.0 | −22.0 | −16.0 | −24.0 | −21.0 |
| 121 | Gamchi | CH00061 | 1893 | 1990 | C | −3.0 | −6.0 | −12.0 | −9.0 | −1.0 |
| 122 | Gauli | CH00052 | 1886 | 1990 | C | −11.0 | −21.0 | −9.0 | −30.0 | −12.0 |
| 123 | Gietro | CH00037 | 1889 | 1990 | A | −X | −X | −X | −X | −X |
| 124 | Glaernisch | CH00080 | 1923 | 1990 | C | −5.0 | | −22.0 | −9.0 | −35.0 |
| 125 | Gorner | CH00014 | 1883 | 1990 | C | −4.0 | −52.0 | −12.0 | −34.0 | −10.0 |
| 126 | Grand Desert | CH00031 | 1892 | 1989 | C | −73.0 | −7.0 | | −11.0 | −4.0 |
| 127 | Grand Plan Neve | CH00045 | 1893 | 1990 | C | −10.0 | 0.0 | | 4.0 | 6.0 |
| 128 | Gries (Aegina) | CH00003 | 1961 | 1990 | A | −9.0 | −18.0 | −X | −17.0 | −11.0 |
| 129 | Griess (Klausen) | CH00074 | 1929 | 1990 | C | −34.0 | −2.0 | | −18.0 | 0.0 |
| 130 | Griessen (OBWA) | CH00076 | 1894 | 1990 | C | | −9.0 | −2.0 | −5.0 | ST |
| 131 | Grosser Aletsch | CH00005 | 1886 | 1990 | A | −9.0 | −18.0 | −26.0 | −37.0 | −60.0 |
| 132 | Huefi | CH00073 | 1882 | 1990 | C | | −26.0 | | −33.0 | −33.0 |
| 133 | Kaltwasser | CH00007 | 1891 | 1990 | C | 4.0 | 1.0 | −X | −8.0 | −4.0 |
| 134 | Kehlen | CH00068 | 1893 | 1990 | C | −14.0 | −12.0 | −X | −41.0 | −29.0 |
| 135 | Kessjen | CH00012 | 1928 | 1990 | A | −28.0 | 12.0 | | | +X |
| 136 | Laemmern | CH00063 | 1917 | 1990 | C | −10.0 | −8.0 | −6.0 | −6.0 | −5.0 |
| 137 | Lang | CH00018 | 1888 | 1990 | C | −7.0 | −3.0 | −7.0 | −1.0 | −8.0 |
| 138 | Lavaz | CH00082 | 1899 | 1989 | C | | | −386.0 | | +X |
| 139 | Lenta | CH00084 | 1895 | 1990 | C | | −92.0 | | −11.0 | −11.0 |
| 140 | Limmern | CH00078 | 1964 | 1990 | C | −5.0 | −2.0 | | −6.0 | −2.0 |
| 141 | Lischana | CH00098 | 1895 | 1990 | C | −5.0 | −7.0 | −2.0 | −5.0 | −6.0 |
| 142 | Martinets | CH00046 | 1894 | 1986 | E | | −X | | | |
| 143 | Mittelaletsch | CH00106 | 1970 | 1990 | C | −16.0 | −8.0 | −X | −X | −X |
| 144 | Moiry | CH00024 | 1891 | 1990 | C | −6.0 | −4.0 | −2.0 | −1.0 | 0.0 |
| 145 | Moming | CH00023 | 1911 | 1990 | C | −10.0 | −30.0 | −81.0 | −32.0 | −16.0 |
| 146 | Mont Durand | CH00035 | 1885 | 1990 | C | 23.0 | 6.0 | 20.0 | 8.0 | 8.0 |
| 147 | Mont Fort | CH00032 | 1892 | 1988 | C | −221.0 | −8.0 | | 5.0 | 23.0 |
| 148 | Mont Mine | CH00026 | 1956 | 1990 | C | −25.0 | −5.0 | −7.0 | −58.0 | −18.0 |
| 149 | Morteratsch | CH00094 | 1879 | 1990 | C | −5.0 | −6.0 | −24.0 | −12.0 | −24.0 |
| 150 | Mutt | CH00002 | 1918 | 1990 | D | −5.0 | −7.0 | −X | 0.0 | |
| 151 | OB. Grindelwald | CH00057 | 1880 | 1990 | C | −53.0 | −50.0 | −60.0 | −62.0 | −7.0 |
| 152 | Oberaar | CH00050 | 1920 | 1990 | A | −4.0 | −18.0 | −3.0 | −20.0 | −10.0 |
| 153 | Ofental | CH00009 | 1922 | 1990 | D | | −42.0 | | | +X |
| 154 | Otemma | CH00034 | 1887 | 1990 | C | −13.0 | −13.0 | −40.0 | −32.0 | −13.0 |
| 155 | Palue | CH00100 | 1894 | 1990 | C | −12.0 | −7.0 | −7.0 | −9.0 | −8.0 |
| 156 | Paneyrosse | CH00044 | 1893 | 1990 | C | −7.0 | 0.0 | | −4.0 | 6.0 |
| 157 | Paradies | CH00086 | 1898 | 1990 | C | −21.0 | −81.0 | −1.0 | −10.0 | 12.0 |
| 158 | Paradisino | CH00101 | 1955 | 1990 | C | −12.0 | 3.0 | 4.0 | −3.0 | 0.0 |
| 159 | Pierredar | CH00049 | 1921 | 1990 | E | −X | −X | | −X | −X |
| 160 | Pizol | CH00081 | 1894 | 1990 | C | −22.0 | 5.0 | | −14.0 | SN |
| 161 | Plattalva | CH00114 | 1969 | 1990 | C | −10.0 | 1.0 | | −8.0 | −4.0 |
| 162 | Porchabella | CH00088 | 1893 | 1990 | C | −9.0 | −10.0 | | −15.0 | −6.0 |
| 163 | Prapio | CH00048 | 1898 | 1990 | C | −15.0 | −10.0 | −5.0 | 0.0 | ST |
| 164 | Punteglias | CH00083 | 1895 | 1989 | C | −22.0 | −X | | −38.0 | −22.0 |
| 165 | Raetzli | CH00065 | 1924 | 1990 | C | −20.0 | −X | −56.0 | 0.0 | −16.0 |
| 166 | Rhone | CH00001 | 1970 | 1990 | A | −31.0 | −10.0 | −12.0 | −7.0 | 1.0 |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 167 | Ried | CH00017 | 1895 | 1990 | C | −6.0 | −12.0 | −X | −X | −X |
| 168 | Roseg | CH00092 | 1894 | 1990 | C | 0.0 | −12.0 | −47.0 | −30.0 | −84.0 |
| 169 | Rosenlaui | CH00056 | 1880 | 1990 | E | −X | −X | −X | −X | −X |
| 170 | Rossboden | CH00105 | 1891 | 1990 | C | 2.0 | 10.0 | 2.0 | 3.0 | −9.0 |
| 171 | Rotfirn Nord | CH00069 | 1956 | 1990 | C | −5.0 | −12.0 | −X | −9.0 | −11.0 |
| 172 | Saleina | CH00042 | 1888 | 1990 | C | −24.0 | −10.0 | −6.0 | −26.0 | −18.0 |
| 172 | Sankt Anna | CH00067 | 1926 | 1989 | C | −12.0 | −5.0 | | −7.0 | −1.0 |
| 174 | Sardona | CH00091 | 1895 | 1990 | C | −23.0 | −8.0 | | −16.0 | 27.0 |
| 175 | Schwarz | CH00062 | 1924 | 1990 | C | −8.0 | −3.0 | −11.0 | −43.0 | −1.0 |
| 176 | Schwarzberg | CH00010 | 1915 | 1990 | A | 6.0 | −5.0 | −X | −X | −10.0 |
| 177 | Sesvenna | CH00097 | 1956 | 1990 | C | −7.0 | −5.0 | −6.0 | −9.0 | −2.0 |
| 178 | Sex Rouge | CH00047 | 1898 | 1990 | C | −22.0 | −X | −X | ST | ST |
| 179 | Silvretta | CH00090 | 1956 | 1990 | A | −9.0 | −13.0 | −14.0 | −6.0 | −15.0 |
| 180 | Stein | CH00053 | 1894 | 1990 | C | −5.0 | −7.0 | −6.0 | −15.0 | −12.0 |
| 181 | Steinlimmi | CH00054 | 1961 | 1990 | C | −12.0 | −11.0 | −10.0 | −18.0 | −3.0 |
| 182 | Sulz | CH00079 | 1912 | 1989 | C | −10.0 | −5.0 | | | −22.0 |
| 183 | Suretta | CH00087 | 1921 | 1990 | C | 48.0 | −43.0 | −38.0 | 70.0 | −14.0 |
| 184 | Taelliboden | CH00008 | 1922 | 1990 | D | −8.0 | −2.0 | | | +X |
| 185 | Tiatscha | CH00096 | 1926 | 1990 | C | −10.0 | −13.0 | −2.0 | −1.0 | ST |
| 186 | Tiefen | CH00066 | 1925 | 1990 | C | −14.0 | −7.0 | | −20.0 | 3.0 |
| 187 | Trient | CH00043 | 1878 | 1990 | C | −19.0 | −15.0 | −X | −58.0 | −40.0 |
| 188 | Trift (Gadmen) | CH00055 | 1921 | 1990 | E | −X | −X | | −X | −X |
| 189 | Tsanfleuron | CH00033 | 1892 | 1990 | C | −15.0 | | −6.0 | −2.0 | −18.0 |
| 190 | Tschierva | CH00093 | 1943 | 1990 | C | −9.0 | −19.0 | −21.0 | −45.0 | −24.0 |
| 191 | Tschingel | CH00060 | 1893 | 1990 | C | −9.0 | −4.0 | −2.0 | −5.0 | −0.0 |
| 192 | Tseudet | CH00040 | 1890 | 1990 | C | −12.0 | −22.0 | 16.0 | −10.0 | −27.0 |
| 193 | Tsidjiore Nouve | CH00028 | 1880 | 1990 | C | −4.0 | −8.0 | −6.0 | 14.0 | 6.0 |
| 194 | Turtmann (West) | CH00019 | 1883 | 1990 | C | 7.0 | 3.0 | −12.0 | | 2.0 |
| 195 | UNT.Grindelwald | CH00058 | 1880 | 1990 | E | −X | −X | −X | ST | −X |
| 196 | Unteraar | CH00051 | 1893 | 1990 | A | −17.0 | −30.0 | −37.0 | −43.0 | −26.0 |
| 197 | Val Torta | CH00118 | 1970 | 1990 | C | −9.0 | SN | −2.0 | 9.0 | −5.0 |
| 198 | Valleggia | CH00117 | 1971 | 1990 | C | −X | −10.0 | −6.0 | −2.0 | −7.0 |
| 199 | Valsorey | CH00039 | 1889 | 1990 | C | −9.0 | −19.0 | −9.0 | −25.0 | −43.0 |
| 200 | Verstankla | CH00089 | 1926 | 1990 | C | −6.0 | −10.0 | −X | −30.0 | −3.0 |
| 201 | Vorab | CH00085 | 1893 | 1990 | C | −29.0 | −19.0 | | −22.0 | SN |
| 202 | Wallenbur | CH00071 | 1893 | 1990 | C | −6.0 | | −X | −13.0 | −3.0 |
| 203 | Zinal | CH00022 | 1891 | 1990 | C | −15.0 | −30.0 | −7.0 | −4.0 | −6.0 |
| 204 | Zmutt | CH00015 | 1892 | 1990 | C | 3.0 | −2.0 | 2.0 | 0.0 | |
| | **Austria** | | | | | | | | | |
| 205 | Aeu.Pirchi.Kar | A00229 | 1981 | 1990 | C | 3.5 | 1.8 | −1.5 | −3.0 | −.8 |
| 206 | Alp.Kraeul F | A00321 | 1975 | 1990 | C | −2.6 | −8.6 | −2.8 | −10.6 | |
| 207 | Alpeiner F | A00307 | 1881 | 1990 | C | −8.5 | −14.3 | −10.6 | −7.7 | −24.9 |
| 208 | Bachfallen F | A00304 | 1922 | 1990 | C | −5.5 | −11.3 | −8.4 | −7.7 | −11.2 |
| 209 | Baerenkopf K | A00702 | 1924 | 1990 | C | −3.4 | −27.5 | −3.2 | −5.3 | 4.4 |
| 210 | Berglas F | A00308 | 1891 | 1990 | C | −1.7 | −10.0 | −5.6 | −10.5 | −8.0 |
| 211 | Bieltal F | A0105A | 1924 | 1990 | C | −8.9 | −8.8 | −5.0 | −12.6 | −7.1 |
| 212 | Bockkogel F | A00302 | 1922 | 1990 | E | −X | −X | −X | −X | |
| 213 | Brennkogl K | A00727 | 1987 | 1990 | C | −2.3 | −9.3 | −11.5 | −14.4 | −4.0 |
| 214 | Daunkogel F | A0310A | 1891 | 1990 | C | −2.6 | −10.2 | −4.3 | −6.5 | −4.8 |
| 215 | Diem F | A00220 | 1893 | 1990 | C | −3.7 | −1.6 | −3.8 | −6.7 | −5.1 |
| 216 | Dorfer K | A00509 | 1896 | 1990 | C | −6.3 | −16.6 | −9.8 | −13.6 | −13.2 |
| 217 | E.Gruebl F | A00317 | 1891 | 1990 | C | −1.3 | −13.2 | −6.4 | −7.2 | |
| 218 | Eiskar G | A01301 | 1992 | 1992 | C | | | −2.0 | −.4 | −5.0 |
| 219 | Fernau F | A00312 | 1890 | 1990 | C | −1.5 | −4.0 | −2.9 | −7.2 | −3.0 |
| 220 | Freiger F | A00320 | 1974 | 1990 | C | −2.9 | −7.5 | −6.9 | −4.2 | −10.3 |
| 221 | Freiwand K | A00706 | 1950 | 1990 | C | −7.0 | −4.4 | −1.1 | −10.9 | SN |
| 222 | Frosnitz K | A00507 | 1923 | 1990 | C | −3.0 | −5.5 | −5.5 | −6.7 | −1.6 |
| 223 | Fruschnitz K | A00722 | 1974 | 1986 | E | −X | | | | |
| 224 | Furtschagl K | A00406 | 1978 | 1990 | E | −X | −X | −X | −X | −X |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 225 | Gaiskar F | A00325 | 1983 | 1990 | C | −5.6 | −11.5 | −X | −5.9 | −2.5 |
| 226 | Gaissberg F | A00225 | 1891 | 1990 | C | −6.5 | −2.1 | −17.2 | −5.8 | −7.5 |
| 227 | Gepatsch F | A00202 | 1896 | 1990 | C | −4.4 | −6.2 | −6.0 | −10.8 | −8.4 |
| 228 | Goessnitz K | A01201 | 1982 | 1990 | C | −3.3 | −7.3 | −10.9 | −21.1 | −6.6 |
| 229 | GR Goldberg Kee | A0802B | | 1975 | C | −2.5 | −12.1 | −5.5 | −15.0 | −4.2 |
| 230 | GR.Gosau G | A01101 | 1933 | 1990 | C | −2.2 | −14.4 | −4.0 | −8.2 | −10.5 |
| 231 | Grosselend K | A01001 | 1898 | 1990 | C | 0.9 | −6.7 | −7.8 | −29.2 | −6.7 |
| 232 | Gruenau F | A00315 | 1891 | 1990 | C | 6.0 | −6.0 | −17.2 | −12.7 | −15.3 |
| 233 | Gurgler F | A00222 | 1895 | 1990 | C | −2.5 | −6.3 | −1.2 | −7.3 | −3.4 |
| 234 | Guslar F | A00210 | 1894 | 1990 | C | −11.5 | −12.8 | −12.8 | −13.8 | −10.5 |
| 235 | Habach Kees | A00504 | | 1990 | E | −X | | | | |
| 236 | Hallstaetter G | A01102 | 1843 | 1990 | C | 0.4 | −7.7 | | −8.7 | −4.9 |
| 237 | Hinteraeis F | A00209 | 1891 | 1990 | C | −17.2 | −23.4 | −22.4 | −21.8 | −13.1 |
| 238 | Hochalm K | A01005 | 1898 | 1990 | C | 0.3 | −15.0 | −12.4 | −6.1 | −5.1 |
| 239 | Hochjoch F | A00208 | 1890 | 1990 | C | −25.7 | −25.5 | −32.2 | −27.4 | −31.4 |
| 240 | Hochmoos F | A00309 | 1946 | 1990 | C | −4.0 | −1.7 | −2.0 | −2.0 | |
| 241 | Hofmanns K | A00724 | 1977 | 1987 | E | −X | | | | |
| 242 | Horn K. (Schob.) | A01202 | 1983 | 1990 | C | −2.8 | −5.8 | −2.8 | −4.1 | −4.3 |
| 243 | Horn K. (Ziller) | A00402 | 1881 | 1990 | C | −2.7 | −8.7 | −4.7 | −7.7 | −9.3 |
| 244 | INN.Pirchlkar | A00228 | 1982 | 1990 | C | 1.4 | 0.4 | 0.1 | −11.4 | 1.4 |
| 245 | Jamtal F | A00106 | 1892 | 1990 | C | −14.6 | −9.0 | −9.2 | −11.1 | −7.1 |
| 246 | KA.Tauern K.S | A0602B | 1961 | 1990 | C | −2.1 | −27.1 | | −18.8 | |
| 247 | Kaelberspitz K | A01003 | 1927 | 1990 | C | −4.6 | −14.7 | −7.1 | −7.1 | 1.4 |
| 248 | Karles F | A00207 | 1950 | 1990 | C | −9.2 | −13.0 | −7.9 | −4.5 | −2.0 |
| 249 | Karlinger K | A00701 | 1896 | 1990 | C | −12.0 | −10.0 | −84.0 | −37.0 | −X |
| 250 | Kesselwand F | A00226 | 1965 | 1990 | C | −17.5 | −22.3 | −28.4 | −36.1 | −33.9 |
| 251 | KL.Fleiss K | A00801 | 1896 | 1990 | C | −2.6 | −20.8 | −13.0 | −10.8 | −2.2 |
| 252 | Kleineiser K | A00717 | 1961 | 1990 | C | −.2 | −4.7 | | −8.7 | |
| 253 | Kleinelend K | A01002 | 1898 | 1990 | C | −4.3 | −19.4 | −4.8 | −6.0 | 1.4 |
| 254 | Klostertaler M | A0102B | 1964 | 1990 | C | −9.1 | −7.4 | −2.9 | −11.0 | −4.1 |
| 255 | Klostertaler N | A0102A | 1968 | 1990 | C | −4.1 | −5.1 | −1.0 | −4.2 | −7.6 |
| 256 | Klostertaler S | A0102C | 1924 | 1990 | C | −10.9 | −11.4 | −3.8 | −12.7 | |
| 257 | Krimmler K. East | A0501B | | 1992 | C | | | −7.8 | −10.8 | −6.3 |
| 258 | Krimmler K | A0501A | 1895 | 1990 | C | −2.5 | −7.2 | 2.5 | −4.4 | −16.6 |
| 259 | Kruml K | A00806 | 1985 | 1990 | C | −1.5 | −7.0 | −6.5 | | SN |
| 260 | Laengentaler F | A00305 | 1922 | 1990 | C | −3.2 | −5.3 | −4.2 | −4.9 | SN |
| 261 | Landeck K | A00604 | 1979 | 1990 | C | −.7 | −1.4 | | −12.5 | |
| 262 | Langtaler F | A00223 | 1891 | 1990 | C | −18.0 | −27.5 | −6.0 | −25.0 | −15.8 |
| 263 | Laperwitz K | A00721 | 1974 | 1986 | E | −X | | | | |
| 264 | Larain F | A00107 | 1928 | 1990 | C | −24.5 | −23.7 | | | |
| 265 | Liesenser F | A00306 | 1922 | 1990 | C | −7.7 | −16.6 | −6.4 | −16.1 | −4.9 |
| 266 | Litzner GL | A00101 | 1932 | 1990 | C | 4.5 | −1.7 | −1.7 | 0.9 | −3.3 |
| 267 | Marzell F | A00218 | 1891 | 1990 | C | −4.0 | −6.8 | 1.7 | −6.8 | −3.6 |
| 268 | Maurer K (GLO.) | A00714 | 1961 | 1990 | C | 0.2 | −7.6 | −1.0 | −3.9 | SN |
| 269 | Maurer K (VEN.) | A00510 | 1896 | 1990 | C | | −61.8 | −8.8 | −6.5 | SN |
| 270 | Mittelberg F | A00206 | 1924 | 1990 | C | −12.1 | −6.3 | −X | −6.5 | 0.9 |
| 271 | Mitterkar F | A00214 | 1891 | 1990 | C | −22.5 | −21.8 | −3.0 | −10.6 | SN |
| 272 | Mutmal F | A00227 | 1969 | 1990 | C | −8.1 | −21.4 | −16.1 | −24.2 | −7.4 |
| 273 | Niederjoch F | A00217 | 1891 | 1990 | C | −19.7 | −14.4 | −9.2 | −14.2 | −6.4 |
| 274 | Obersulzbach K | A00502 | 1880 | 1990 | C | −6.1 | −13.6 | −14.8 | −18.5 | −8.2 |
| 275 | Ochsentaler GL | A00103 | 1901 | 1990 | C | −7.2 | −18.7 | −15.2 | −25.1 | −9.2 |
| 276 | Oedenwinkel K | A00712 | 1960 | 1990 | C | −4.7 | −1.4 | 0.3 | −3.2 | 0.3 |
| 277 | Pasterzen K | A00704 | 1879 | 1990 | C | −33.5 | −7.6 | −17.5 | −17.1 | −13.6 |
| 278 | Pfaffen F | A00324 | 1981 | 1990 | C | −6.1 | −11.5 | −2.5 | −15.0 | −6.5 |
| 279 | Pfandlscharten | A00707 | 1931 | 1990 | C | −9.5 | −13.1 | | | |
| 280 | Praegrat K | A00603 | 1961 | 1990 | C | −4.5 | −9.2 | | −14.4 | |
| 281 | Rettenbach F | A00212 | 1952 | 1990 | C | −5.4 | −5.9 | −5.9 | −9.8 | −3.4 |
| 282 | Riffl K.N | A00718 | 1961 | 1990 | C | 2.7 | −8.6 | 1.1 | −4.7 | SN |
| 283 | Rifflkar Kees | A0713A | 1961 | 1990 | E | −X | | | | |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 284 | Rofenkar F | A00215 | 1891 | 1990 | C | −6.0 | −10.6 | −3.8 | −9.8 | −7.3 |
| 285 | Rotmoos F | A00224 | 1891 | 1990 | C | −1.0 | −8.8 | −8.0 | −8.0 | −12.1 |
| 286 | Schalf F | A00219 | 1924 | 1990 | C | −2.9 | −9.6 | −15.5 | | −18.1 |
| 287 | Schattenspitz | A00108 | 1973 | 1990 | C | −2.7 | −15.0 | −5.5 | −5.2 | |
| 288 | Schaufel F | A00311 | 1922 | 1990 | C | −1.9 | −4.1 | −5.6 | −11.1 | −3.3 |
| 289 | Schladminger G | A01103 | 1933 | 1990 | C | −1.4 | −3.0 | | −1.4 | −.1 |
| 290 | Schlappereben K | A00805 | 1983 | 1990 | C | −2.0 | −2.8 | −2.9 | −.5 | −3.5 |
| 291 | Schlaten K | A00506 | 1891 | 1990 | C | −4.6 | −7.9 | −6.8 | −10.5 | −7.9 |
| 292 | Schlegeis K | A00405 | 1978 | 1990 | E | −X | −X | −X | −X | −X |
| 293 | Schmiedinger K | A00726 | 1981 | 1990 | C | −0.1 | −3.6 | −2.3 | −2.8 | |
| 294 | Schneeglocken | A00109 | 1973 | 1990 | C | −5.8 | −8.2 | −4.3 | −7.7 | −5.8 |
| 295 | Schneeloch G | A01104 | 1969 | 1990 | C | −1.3 | −5.2 | | −2.2 | −6.7 |
| 296 | Schwarzenberg F | A00303 | 1905 | 1990 | C | −6.8 | −13.8 | −10.8 | −15.3 | −6.8 |
| 297 | Schwarzenstein | A00403 | 1881 | 1990 | C | 5.5 | −15.0 | −17.0 | −16.0 | −12.0 |
| 298 | Schwarzkarl K | A00716 | 1961 | 1990 | C | −4.4 | −11.1 | −6.0 | −19.7 | −2.3 |
| 299 | Schwarzkoepfl K | A00710 | 1954 | 1990 | C | −7.0 | −11.5 | −6.3 | −17.9 | −14.8 |
| 300 | Sexegerten F | A00204 | 1919 | 1990 | C | −6.0 | −28.5 | −10.7 | −39.0 | −5.3 |
| 301 | Simming F | A00318 | 1922 | 1990 | C | −1.9 | −13.4 | −17.5 | −43.4 | −22.6 |
| 302 | Simony K | A00511 | 1896 | 1990 | C | −4.8 | −9.8 | −8.1 | −11.5 | −15.2 |
| 303 | Sonnblick K | A0601A | 1963 | 1990 | C | −2.1 | −7.9 | 0.4 | −8.7 | 0.7 |
| 304 | Spiegel F | A00221 | 1891 | 1990 | C | −6.8 | −2.2 | −4.4 | −10.4 | −9.8 |
| 305 | Sulzenau F | A0314A | 1891 | 1990 | C | −4.0 | −20.3 | −29.9 | −34.2 | −104.4 |
| 306 | Sulztal F | A00301 | 1922 | 1990 | C | −4.3 | −18.5 | −35.8 | −21.6 | −7.8 |
| 307 | Taschach F | A00205 | 1924 | 1990 | C | −4.9 | −12.8 | −12.9 | −10.5 | −13.5 |
| 308 | Taufkar F | A00216 | 1891 | 1990 | C | −8.9 | −12.4 | −3.4 | −6.2 | −6.2 |
| 309 | Teischnitz K | A00723 | 1975 | 1986 | E | −X | | | | |
| 310 | Totenfeld | A00110 | 1976 | 1990 | C | −2.7 | −2.1 | −3.2 | −5.1 | −.3 |
| 311 | Triebenkarlas F | A00323 | 1978 | 1990 | C | 0.1 | −12.0 | −14.3 | −16.3 | −12.3 |
| 312 | Uebergoss.ALM | A00901 | 1892 | 1990 | C | −5.8 | −3.0 | | | |
| 313 | Umbal K | A00512 | 1896 | 1990 | C | −18.2 | | −24.3 | −24.5 | −68.5 |
| 314 | UNT.Riffel Kees | A0713B | 1960 | 1990 | C | −3.0 | −4.7 | −5.8 | −4.4 | −4.1 |
| 315 | Untersulzbach K | A00503 | 1896 | 1990 | C | −5.0 | −7.5 | −6.1 | −11.2 | 0.7 |
| 316 | VD.Kasten K | A00719 | 1961 | 1980 | E | −X | | | | |
| 317 | Verborgenberg F | A00322 | 1977 | 1990 | C | −2.7 | −11.3 | −2.3 | −7.4 | −7.3 |
| 318 | Vermunt GL | A00104 | 1913 | 1909 | C | −7.4 | −12.0 | −5.3 | −15.2 | −4.3 |
| 319 | Vernagt F | A00211 | 1888 | 1990 | C | −13.7 | −11.0 | −15.9 | −16.5 | −13.3 |
| 320 | Viltragen K | A00505 | 1891 | 1990 | C | −3.9 | −10.7 | −10.4 | −12.0 | −12.0 |
| 321 | W.Tripp K | A01004 | 1925 | 1990 | C | 0.4 | −6.4 | | −5.5 | SN |
| 322 | Wasserfallwinkl | A00705 | 1943 | 1990 | C | −5.4 | −15.6 | −1.7 | −7.7 | 3.6 |
| 323 | Waxegg K | A00401 | 1895 | 1990 | C | −6.2 | −3.0 | −12.0 | −8.0 | −38.0 |
| 324 | Weissee F | A00201 | 1891 | 1990 | C | −8.3 | −10.6 | −25.6 | −4.0 | −2.9 |
| 325 | Wielinger K | A00725 | 1980 | 1990 | C | −47.0 | −49.0 | −X | −X | −X |
| 326 | Wildgerlos | A00404 | 1973 | 1990 | C | 6.1 | −30.8 | −12.2 | −20.0 | −8.4 |
| 327 | Winkl K | A01006 | 1928 | 1990 | C | −0.7 | −26.3 | −1.2 | −2.4 | −5.0 |
| 328 | Wurfer K | A00715 | 1961 | 1990 | C | −5.0 | −16.4 | SN | −16.8 | |
| 329 | Wurten K | A00804 | 1896 | 1990 | C | −10.3 | −12.5 | −5.5 | −14.8 | −2.6 |
| 330 | Zettalunitz K | A00508 | 1896 | 1990 | C | −3.4 | −21.0 | −13.7 | −21.1 | −18.0 |
| | **Italy** | | | | | | | | | |
| 331 | Agnello | I00029 | 1928 | 1990 | C | −2.5 | | | SN | −X |
| 332 | Alta (Vedretta) | I00730 | 1923 | 1990 | C | | −8.5 | −7.0 | −10.0 | −17.0 |
| 333 | Amola | I00644 | 1942 | 1990 | C | −1.0 | −9.0 | | −14.0 | −16.0 |
| 334 | Andollanord | I00336 | 1927 | 1990 | C | −8.0 | −24.0 | 1.5 | | −2.0 |
| 335 | Antelao Inf | I00967 | 1939 | 1990 | C | −2.0 | −7.0 | −2.0 | −3.0 | −3.0 |
| 336 | Antelao Sup | I00966 | 1934 | 1990 | C | −3.5 | −2.5 | 0.0 | −4.5 | −3.0 |
| 337 | Aurona | I00338 | 1956 | 1990 | C | | | | −X | −X |
| 338 | Barbadorso D | I00778 | 1935 | 1990 | C | | −65.0 | −29.0 | | |
| 339 | Basei | I00064 | 1925 | 1990 | C | −3.0 | −1.0 | 0.0 | 0.0 | |
| 340 | Belvedere | I00325 | 1927 | 1990 | C | 4.0 | −3.0 | −4.0 | 2.0 | −2.0 |
| 341 | Bessanese | I00040 | 1928 | 1990 | C | −1.0 | −3.0 | −1.5 | −2.0 | 0.0 |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 342 | Brenva | I00219 | 1929 | 1990 | C | 8.0 | −9.0 | 0.0 | | |
| 343 | Caspoggio | I00435 | 1928 | 1990 | C | −2.0 | −X | −X | −43.0 | −12.0 |
| 344 | Cevedale | I00732 | 1923 | 1990 | C | | −X | −17.0 | −16.0 | −19.0 |
| 345 | Chavannes | I00204 | 1930 | 1989 | C | −15.0 | −5.0 | 1.5 | −1.0 | |
| 346 | Ciardoney | I00081 | | 1990 | C | −2.5 | −2.0 | −3.0 | −2.0 | −.5 |
| 347 | Collalto | I00927 | 1932 | 1990 | C | −2.0 | −7.5 | −8.0 | −4.5 | −5.0 |
| 348 | Cristallo | I00937 | 1949 | 1990 | C | 0.0 | −12.0 | −8.0 | −6.0 | −17.5 |
| 349 | Croda Rossa | I00828 | | 1990 | C | | −4.0 | | −4.0 | |
| 350 | Dosde OR | I00473 | 1932 | 1990 | C | −28.0 | −15.5 | −32.0 | −37.0 | −9.0 |
| 351 | Dosegu | I00512 | 1925 | 1990 | C | | −60.0 | −X | −17.0 | −22.0 |
| 352 | Fellaria OCC | I00439 | 1915 | 1990 | C | −13.0 | −12.0 | −9.5 | −9.5 | −15.0 |
| 353 | Fontana OCC | I00780 | 1925 | 1990 | C | | | −14.5 | | |
| 354 | Forcola | I00731 | 1923 | 1990 | C | | −43.0 | −13.0 | −21.0 | −18.0 |
| 355 | Forni | I00507 | 1880 | 1989 | C | −124.0 | −30.0 | −22.0 | −95.0 | −19.5 |
| 356 | Gigante Centr | I00929 | 1930 | 1990 | C | | −X | −92.0 | | −21.5 |
| 357 | Gigante OCC | I00930 | 1930 | 1990 | C | −2.0 | −7.0 | −5.0 | −1.5 | −2.5 |
| 358 | Goletta | I00148 | 1929 | 1990 | C | | −19.5 | | −6.5 | −4.0 |
| 359 | Gran Pilastro | I00893 | 1932 | 1990 | C | −10.5 | | −26.0 | | |
| 360 | Hosand Sett | I00357 | 1926 | 1990 | C | −5.0 | −7.5 | 0.5 | 0.0 | 6.5 |
| 361 | LA Mare | I00699 | 1899 | 1990 | C | −33.0 | −68.0 | −23.5 | −59.0 | −5.5 |
| 362 | Lana | I00913 | 1930 | 1990 | C | −3.0 | −8.0 | −6.5 | −9.0 | −3.5 |
| 363 | LEX Blanche | I00209 | 1929 | 1990 | C | | −40.0 | −X | −X | |
| 364 | Lunga (Vedretta) | I00733 | 1923 | 1990 | C | | −26.0 | −5.0 | −18.0 | −47.0 |
| 365 | LYS | I00304 | 1927 | 1990 | C | 3.0 | −11.0 | −7.0 | −12.0 | −12.0 |
| 366 | M. Nevoso OCC | I0931X | 1930 | 1990 | C | −2.5 | −6.0 | −14.0 | −1.0 | |
| 367 | Malavalle | I00875 | 1928 | 1990 | C | −9.0 | −8.0 | −2.0 | −8.0 | −7.5 |
| 368 | Mandrone | I00639 | 1896 | 1990 | C | −5.0 | −14.0 | −2.0 | −3.0 | −2.5 |
| 369 | Marmolada | I00941 | 1925 | 1990 | C | −11.5 | −13.5 | | −10.0 | |
| 370 | Moncorve | I00131 | 1924 | 1990 | C | −5.0 | −5.0 | −1.0 | −3.0 | |
| 371 | Nardis OCC | I00640 | 1925 | 1990 | C | −10.0 | −4.5 | 2.0 | | −10.0 |
| 372 | Neves OR. | I00902 | 1932 | 1990 | C | −13.0 | −19.0 | −13.0 | −12.5 | −12.0 |
| 373 | Niscli | I00633 | 1919 | 1990 | C | −5.5 | −3.5 | 0.0 | | −7.5 |
| 374 | Pendente | I00876 | 1933 | 1990 | C | −17.0 | −9.0 | −3.0 | −5.0 | −15.0 |
| 375 | Piode | I00312 | 1924 | 1990 | C | −19.0 | | −34.0 | −51.0 | −5.0 |
| 376 | Pisgana OCC. | I00577 | 1920 | 1990 | C | −X | −59.0 | −X | | −X |
| 377 | Pizzo Scalino | I00443 | 1911 | 1990 | C | −8.5 | −8.0 | −2.0 | −14.0 | −10.0 |
| 378 | Pre De Bar | I00235 | 1929 | 1990 | C | −6.5 | −32.0 | 7.0 | −16.0 | −16.0 |
| 379 | Presanella | I00678 | 1951 | 1990 | C | 0.0 | −4.5 | −12.5 | −10.0 | −8.5 |
| 380 | Quaira Bianca | I00889 | 1931 | 1990 | C | −7.0 | −6.0 | −11.0 | | |
| 381 | Rosim | I00754 | 1926 | 1990 | C | | −6.5 | −7.0 | −7.5 | 0.0 |
| 382 | Rossa (Vedr.) | I00697 | 1923 | 1990 | C | −11.0 | −4.0 | −6.0 | −19.0 | −2.5 |
| 383 | Rosso Destro | I00920 | 1952 | 1990 | C | −9.5 | −8.5 | −17.0 | −10.0 | |
| 384 | Rutor | I00189 | 1927 | 1990 | C | −10.5 | −7.0 | −1.5 | −20.5 | −6.5 |
| 385 | Sassolungo OCC | I00926 | 1930 | 1989 | C | −11.0 | −11.0 | −2.5 | −10.5 | |
| 386 | Serana (Vedr.) | I00728 | 1925 | 1990 | C | | | −8.0 | −X | −16.0 |
| 387 | Sforzellina | I00516 | 1925 | 1990 | C | 4.0 | −4.0 | −X | −4.5 | −5.0 |
| 388 | Solda | I00762 | 1922 | 1990 | C | | 3.0 | −12.0 | −8.0 | −8.0 |
| 389 | Tessa | I00829 | 1926 | 1990 | C | | 0.0 | | −4.0 | |
| 390 | Toules | I00221 | 1929 | 1990 | C | −12.0 | −12.0 | −2.0 | | −86.0 |
| 391 | Travignolo | I00947 | 1925 | 1981 | C | −59.0 | −3.5 | | −3.0 | −3.5 |
| 392 | Tresero | I00511 | 1925 | 1990 | C | | −10.0 | | −X | −6.0 |
| 393 | Tza De Tzan | I00259 | 1927 | 1990 | C | +X | −X | −15.0 | −15.0 | −11.5 |
| 394 | Ultima (Vedr.) | I00729 | 1925 | 1990 | C | | −13.0 | −8.0 | −5.5 | −4.5 |
| 395 | Valle Del Vento | I00919 | 1932 | 1990 | C | −9.0 | −10.0 | −13.0 | −2.5 | |
| 396 | Vallelunga | I00777 | 1922 | 1990 | C | | −15.0 | ST | | |
| 397 | Valtournenche | I00289 | 1927 | 1989 | C | −.5 | −1.5 | −9.0 | −8.0 | |
| 398 | Venerocolo | I00581 | 1919 | 1990 | C | −6.0 | −6.0 | | −14.5 | −19.0 |
| 399 | Venezia (Vedr.) | I00698 | 1925 | 1990 | C | −9.5 | −38.5 | −15.0 | −16.5 | −X |
| 400 | Ventina | I00416 | 1890 | 1990 | C | 1.0 | −11.0 | −15.0 | −10.0 | −14.0 |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 401 | Vitelli | I00483 | 1921 | 1990 | C | | −42.0 | −7.0 | 0.0 | −X |
| 402 | Zai Di Dentro | I00749 | 1924 | 1979 | C | | −61.0 | −2.5 | −5.0 | −4.0 |
| 403 | Zai Di Mezzo | I00750 | 1930 | 1979 | C | | −58.0 | −6.0 | −5.5 | −3.0 |
| | **Kenya** | | | | | | | | | |
| 404 | Cesar | KN00004 | 1899 | 1987 | A | | | −25.0 | | |
| 405 | Darwin | KN00006 | 1919 | 1987 | A | | | −15.0 | | |
| 406 | Diamond | KN00010 | 1899 | 1987 | A | | | 0.0 | | |
| 407 | Forel | KN00011 | 1899 | 1987 | A | | | 0.0 | | |
| 408 | Gregory | KN00009 | 1899 | 1990 | A | | | −30.0 | | |
| 409 | Heim | KN00012 | 1899 | 1987 | A | | | 0.0 | | |
| 410 | Joseph | KN00003 | 1899 | 1987 | A | | | 0.0 | | |
| 411 | Krapf | KN00001 | 1899 | 1987 | A | | | −25.0 | | |
| 412 | Lewis | KN00008 | 1899 | 1990 | A | | | −25.0 | | |
| 413 | Northey | KN00013 | 1899 | 1987 | A | | | 0.0 | | |
| 414 | Tyndall | KN00005 | 1899 | 1987 | A | | | −50.0 | | |
| | **Poland** | | | | | | | | | |
| 415 | Mieguszowieckie | PL00140 | 1958 | 1988 | C | 1.0 | −2.0 | | SN | 2.0 |
| 416 | Pod Bula | PL00111 | 1978 | 1990 | C | 34.0 | −14.1 | 2.4 | −1.0 | 13.1 |
| 417 | POD Cubryna | PL00180 | 1978 | 1988 | C | −1.0 | 1.0 | −2.0 | 2.0 | 1.0 |
| | **C.I.S** | | | | | | | | | |
| 418 | Abramov | SU04101 | 1967 | 1990 | C | −9.1 | −12.9 | −22.4 | −25.3 | ST |
| 419 | Alibekskiy | SU03002 | 1954 | 1990 | C | | | | 9.0 | −8.0 |
| 420 | Bezengi | SU03006 | 1956 | 1990 | C | −7.0 | | | | −14.0 |
| 421 | Bolshoy Azau | SU03004 | 1887 | 1987 | B | | −69.0 | | | |
| 422 | Djankuat | SU03010 | 1965 | 1990 | B | | −6.0 | | | −10.0 |
| 423 | Dzhelo | SU07106 | 1952 | 1990 | C | −19.0 | −18.0 | −3.0 | | −14.3 |
| 424 | Garabashi | SU03031 | 1887 | 1987 | B | | 0.0 | | | |
| 425 | Kara-Batkak | SU05080 | 1957 | 1990 | C | −2.5 | −5.5 | −3.3 | −6.8 | −7.2 |
| 426 | Khakel | SU03003 | 1957 | 1990 | C | | | | −16.0 | 8.0 |
| 427 | Korumdu | SU07103 | 1952 | 1990 | C | −3.0 | −12.0 | 0.0 | −3.5 | −1.0 |
| 428 | Kozelskiy | SU08005 | 1948 | 1990 | C | | | | | ST |
| 429 | Leviy Artru | SU07102 | 1952 | 1990 | D | −16.0 | −11.0 | −1.0 | −22.0 | −3.0 |
| 430 | Levivy Karagemsk | SU07107 | 1952 | 1990 | C | −19.0 | 0.0 | ST | ST | −3.8 |
| 431 | Maliy Aktru | SU07100 | 1952 | 1990 | D | −5.0 | −10.0 | 0.5 | −9.0 | −12.0 |
| 432 | Maliy Azau | SU03032 | 1887 | 1987 | B | | 0.0 | | | |
| 433 | Mizhirgichiran | SU03043 | 1956 | 1990 | C | 15.9 | | | | 61.0 |
| 434 | Muravlev | SU06002 | 1966 | 1990 | C | −3.5 | | | | |
| 435 | NO. 122 (UNIV.) | SU07108 | 1952 | 1990 | C | −14.0 | −8.0 | ST | | −6.6 |
| 436 | NO. 125 (VODOP.) | SU07105 | 1956 | 1990 | D | −1.0 | −4.8 | 0.0 | −1.7 | −1.5 |
| 437 | NO. 462V (KULN.) | SU03005 | 1934 | 1990 | C | −7.5 | | | | |
| 438 | Praviy Karagems | SU07109 | 1952 | 1990 | C | −12.0 | −7.0 | ST | | −5.0 |
| 439 | Shumskiy | SU06001 | 1966 | 1990 | C | −7.2 | | | | |
| 440 | TS.Tuyuksuyskiy | SU05075 | 1956 | 1990 | C | −17.0 | −8.4 | −7.3 | −13.8 | −20.8 |
| 441 | Tseya | SU03007 | 1927 | 1990 | C | −11.8 | −1.7 | −16.3 | | −5.0 |
| 442 | Yugo-Vostochniy | SU03018 | 1957 | 1991 | C | | −11.4 | −1.5 | 4.2 | 17.0 |
| 443 | Yuzhniy | SU03017 | 1957 | 1991 | C | | −4.1 | −2.7 | 3.5 | −3.7 |
| | **China** | | | | | | | | | |
| 444 | Urumqihe S.NO.1 | CN00010 | 1960 | 1990 | C | −6.5 | −3.4 | −3.8 | −6.8 | −6.2 |
| | **Pakistan** | | | | | | | | | |
| 445 | Aling | PK00035 | | 1989 | | | | +X | | |
| 446 | Bualtar | PK00004 | | 1988 | | | 1800.0 | | | −X |
| 447 | Karambar | PK00028 | | 1993 | | | | −X | +X | |
| | **Nepal** | | | | | | | | | |
| 448 | AX010 | NP00005 | 1978 | 1989 | C | −30.0 | | | | 25.0 |
| 449 | DX080 | NP00007 | 1976 | 1989 | C | | | | | −29.6 |
| 450 | Gyajo | NP00011 | 1970 | 1978 | C | | | | | −75.6 |
| 451 | Kongma | NP00010 | 1970 | 1989 | C | | | | | −13.0 |
| 452 | Kongma Tikpe | NP00009 | 1974 | 1989 | C | | | | | −53.7 |
| 453 | Rikha Samba | NP00012 | 1974 | 1974 | C | | | | −205.7 | |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 454 | Yala | NP00004 | 1982 | 1989 | C | | | | −30.9 | |
| | **New Zealand** | | | | | | | | | |
| 455 | Abel | NZ893A3 | | 1989 | A | | | +X | ST | ST |
| 456 | Adams | NZ08974 | | 1987 | A | | −X | −X | | +X |
| 457 | Almer | NZ888B1 | | 1989 | A | | | ST | +X | +X |
| 458 | Andy | NZ863C1 | | 1987 | A | | | ST | −X | +X |
| 459 | Ashburton | NZ688A1 | | 1989 | A | | | +X | | +X |
| 460 | Balfour | NZ882B1 | | 1985 | A | | | | | +X |
| 461 | Barlow | NZ893A2 | | 1989 | A | | −X | −X | | +X |
| 462 | Blair | NZ711D1 | | 1989 | A | | | −X | +X | +X |
| 463 | Bonar | NZ863A1 | | 1987 | A | | | | | +X |
| 464 | Brewster | NZ868C1 | | 1989 | A | | −X | +X | −X | ST |
| 465 | Burton | NZ888A1 | | 1989 | A | | | ST | | ST |
| 466 | Cameron | NZ685B2 | | 1988 | A | | | −X | +X | ST |
| 467 | Classen | NZ711M1 | | 1989 | A | | | | −X | ST |
| 468 | Colin Campbell | NZ693C1 | | 1988 | A | | | | | +X |
| 469 | Crow | NZ664C2 | | 1988 | A | | | | | +X |
| 470 | Dart | NZ752C2 | 1980 | 1989 | A | | −X | +X | | −X |
| 471 | Donne | NZ851B2 | | 1987 | A | | | | | −X |
| 472 | Douglas (KAR.) | NZ880B2 | | 1987 | A | | | ST | | ST |
| 473 | Douglas (RAK.) | NZ685B1 | | 1989 | A | | SN | SN | SN | SN |
| 474 | Evans | NZ08972 | | 1988 | A | | ST | | | ST |
| 475 | Fitzgerald | NZ880B3 | | 1984 | A | | | −X | | +X |
| 476 | Fox | NZ882A1 | | 1989 | A | +X | +X | +X | +X | +X |
| 477 | Franz Josef | NZ888B2 | 1867 | 1989 | A | +X | +X | +X | +X | +X |
| 478 | Glenmary | NZ711F1 | | 1989 | A | | | | +X | ST |
| 479 | Godley | NZ711M3 | | 1989 | A | | | | | −X |
| 480 | Grey and Maud | NZ711M2 | | 1989 | A | | | | −X | ST |
| 482 | Hooker | NZ711H2 | | 1985 | A | | −X | −X | | −X |
| 482 | Horace Walker | NZ880B1 | | 1987 | A | | | | | +X |
| 483 | Ivory | NZ09011 | 1989 | 1989 | A | | −X | −X | −X | ST |
| 484 | Jack | NZ08751 | | 1989 | A | | | +X | +X | SN |
| 485 | Jackson | NZ868B5 | | 1989 | A | | | | ST | |
| 486 | Jalf | NZ08861 | | 1989 | A | | | SN | −X | SN |
| 487 | Kahutea | NZ685E1 | | 1989 | A | | | | | +X |
| 488 | KEA | NZ08971 | | 1989 | A | | | SN | SN | SN |
| 489 | LA Perouse | NZ882B2 | | 1985 | A | | | | | ST |
| 490 | Lambert | NZ08973 | | 1989 | A | | ST | +X | −X | |
| 491 | LE Blanc | NZ868B3 | | 1985 | A | | | | −X | +X |
| 492 | Lindsay | NZ08671 | | 1989 | A | | | SN | SN | SN |
| 493 | Lyell | NZ685C2 | | 1989 | A | | | | | −X |
| 494 | Marchant | NZ880A1 | | 1986 | A | | | | | ST |
| 495 | Marion | NZ863B4 | | 1989 | A | | | −X | ST | +X |
| 496 | Marmaduke Dixon | NZ664C1 | | 1989 | A | | | +X | SN | |
| 497 | MC COY | NZ693C2 | | 1985 | A | | | | | +X |
| 498 | Mueller | NZ711H1 | | 1989 | A | −X | −X | | | −X |
| 499 | Murchison | NZ711J1 | | 1989 | A | | | −X | | ST |
| 500 | Park Pass 1 | NZ752B1 | | 1989 | A | | | | +X | +X |
| 501 | Poet | NZ868B2 | | 1986 | A | | | | | +X |
| 502 | Ramsay | NZ685C3 | | 1983 | A | | | | | −X |
| 503 | Reischek | NZ685C1 | | 1989 | A | | | | | −X |
| 504 | Retreat | NZ906A1 | | 1989 | A | | | SN | SN | SN |
| 505 | Richardson | NZ711E1 | | 1987 | A | | | +X | | +X |
| 506 | Ridge | NZ711L1 | | 1989 | A | | | | ST | SN |
| 507 | Rolleston | NZ911A2 | | 1989 | A | | | SN | SN | SN |
| 508 | Sale | NZ906B1 | | 1993 | A | | | | | +X |
| 509 | Siege | NZ893A1 | | 1989 | A | | −X | SN | ST | SN |
| 510 | Sinclair | NZ693C3 | | 1985 | A | | | | | +X |
| 511 | Snow White | NZ863B2 | | 1987 | A | | | −X | | −X |

*(Continued)*

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**Table 5D.28 (Continued)**

| NR | Glacier Name | PSFG NR | First Survey | Last Survey | Method | Variations (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1991 | 1992 | 1993 | 1994 | 1995 |
| 512 | Snowball | NZ863B3 | | 1987 | A | | | ST | ST | ST |
| 513 | Spencer | NZ888A2 | | 1989 | A | | +X | +X | | +X |
| 514 | Strauchon | NZ880A2 | | 1986 | A | | | | −X | ST |
| 515 | Tasman | NZ71111 | | 1989 | A | −X | −X | −X | −X | −X |
| 516 | Therma | NZ08641 | | 1987 | A | | | | | +X |
| 517 | Thurneyson | NZ711B1 | | 1989 | A | | +X | | +X | |
| 518 | Tornado | NZ863C2 | | 1986 | A | | | | | −X |
| 519 | Unnamed NZ664C | NZ664C1 | | 1989 | A | | | SN | | SN |
| 520 | Unnamed NZ685C | NZ685C4 | | 1989 | A | | SN | SN | SN | +X |
| 521 | Unnamed NZ685F | NZ685F1 | | 1989 | A | | | SN | SN | |
| 522 | Unnamed NZ752E | NZ752E1 | | 1989 | A | | | +X | SN | SN |
| 523 | Unnamed NZ752I | NZ75211 | | 1989 | A | | SN | SN | SN | SN |
| 524 | Unnamed NZ797G | NZ797G1 | | 1989 | A | | | SN | SN | SN |
| 525 | Unnamed NZ846 | NZ08461 | | 1989 | A | | | +X | +X | +X |
| 526 | Unnamed NZ851B | NZ851B1 | | 1989 | A | | | ST | ST | ST |
| 527 | Unnamed NZ863B | NZ863B1 | | 1989 | A | | | SN | SN | SN |
| 528 | Unnsmrf NX868B | NZ868B4 | | 1980 | A | | | | | ST |
| 529 | Unnamed NZ911A | NZ911A1 | | 1989 | A | | | SN | SN | SN |
| 530 | Victoria | NZ882A1 | | 1989 | A | | | | | +X |
| 531 | Whitbourne | NZ752C1 | | 1988 | A | | | | | −X |
| 532 | White | NZ664C1 | | 1989 | A | | | +X | | +X |
| 533 | Whymper | NZ893B1 | | 1980 | A | | | | | −X |
| 534 | Wigley | NZ873B2 | | 1989 | A | | −X | | | −X |
| 535 | Wilkinson | NZ906B2 | | 1989 | A | | | | | ST |
| 536 | Zora | NZ868B1 | | 1986 | A | | | | | +X |
| | **Antarctica** | | | | | | | | | |
| 537 | Bartley | AN00016 | 1983 | 1990 | C | | −1.8 | | | 0.2 |
| 538 | Clark CPI | AN00012 | 1982 | 1990 | C | | | | | 2.6 |
| 539 | Hart | AN00019 | 1985 | 1990 | C | | 0.0 | | | −0.5 |
| 540 | Heimdall | AN00003 | 1970 | 1991 | C | | 3.5 | | | |
| 541 | Meserve MPII | AN00017 | 1983 | 1990 | C | | −3.3 | | | |
| 542 | Victoria Upper | AN00013 | 1984 | 1990 | C | | 1.8 | | | |
| 543 | Wright Lower | AN00018 | 1975 | 1990 | C | | −1.8 | | 1.3 | 0.6 |
| 544 | Wright Upper B | AN00011 | 1984 | 1990 | C | | −1.2 | | | |

*Note:*
- NR: Record number
- Glacier Name: 15 alphabetic or numeric digits
- PSFG Number: 5 digits identifying glacier with alphabetic prefix denoting country
- Method:
  - A = aerial photogrammetry
  - B = terrestrial photogrammetry
  - C = geodetic ground survey (theodolite, tape etc.)
  - D = combination of a, b or c
  - E = other methods or no information
- 1ST Survey: Year when glacier was first surveyed
- Last Survey: Last survey before reported period
- Variation in Meters: Variation in the position of the glacier front in horizontal projection expressed as the change in length between the surveys
- Key to Symbols:
  - +X: Glacier in advance
  - −X: Glacier in retreat
  - ST: Glacier stationary
  - SN: Glacier front covered by snow

*Source*: From World Glacier Monitoring Service by Wilfried Haeberli, Martin Hoelzle, Stephan Suter and Regula Frauenfelder www.wgms.ch.

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**Table 5D.29 Changes in Area, Volume and Thickness**

| NR | Glacier Name | Period From | Period To | Altitude From | Altitude To | Area Mean | Area Change | Volume Change | Thickness Change |
|---|---|---|---|---|---|---|---|---|---|
| | **U.S.A** | | | | | | | | |
| 1.1 | McCall | 1972 | 1993 | 2400 | 2500 | 110 | | −248 | −2257 |
| | US00001 | | | 2300 | 2400 | 720 | | −1383 | −1921 |
| | | | | 2200 | 2300 | 1160 | | −4284 | −3693 |
| | | | | 2100 | 2200 | 1360 | | −6126 | −4504 |
| | | | | 2000 | 2100 | 890 | | −5019 | −5639 |
| | | | | 1900 | 2000 | 810 | | −5110 | −6308 |
| | | | | 1800 | 1900 | 530 | | −4286 | −8086 |
| | | | | 1700 | 1800 | 450 | | −5070 | −11267 |
| | | | | 1600 | 1700 | 600 | | −11774 | −19624 |
| | | | | 1500 | 1600 | 360 | | −9733 | −27037 |
| | | | | 1400 | 1500 | 240 | | −8730 | −36374 |
| | Summary Data | | | 1400 | 2500 | 7230 | | −61762 | −8543 |
| | **Switzerland** | | | | | | | | |
| 2.1 | Gries (Aegina) | 1923 | 1961 | 3300 | 3400 | 16 | −7 | −146 | −9120 |
| | CH00003 | | | 3200 | 3300 | 201 | −68 | −2062 | −10260 |
| | | | | 3100 | 3200 | 772 | −239 | −11148 | −14440 |
| | | | | 3000 | 3100 | 1572 | 2 | −28673 | −18240 |
| | | | | 2900 | 3000 | 1040 | −25 | −19760 | −19000 |
| | | | | 2800 | 2900 | 813 | −61 | −18227 | −22420 |
| | | | | 2700 | 2800 | 699 | −94 | −21250 | −30400 |
| | | | | 2600 | 2700 | 1303 | −221 | −45553 | −34960 |
| | | | | 2500 | 2600 | 613 | −50 | −28419 | −46360 |
| | | | | 2400 | 2500 | 716 | −419 | −56048 | −78280 |
| | | | | 2300 | 2400 | 112 | −15 | −22387 | −199880 |
| | Summary Data | | | 2300 | 3400 | 7857 | −1167 | −247810 | −31540 |
| 2.2 | Gries (Aegina) | 1961 | 1979 | 3300 | 3400 | 9 | 1 | 3 | 360 |
| | CH00003 | | | 3200 | 3300 | 133 | 3 | 72 | 540 |
| | | | | 3100 | 3200 | 533 | 14 | 1055 | 1980 |
| | | | | 3000 | 3100 | 1574 | 23 | 4533 | 2880 |
| | | | | 2900 | 3000 | 1015 | −11 | 4385 | 4320 |
| | | | | 2800 | 2900 | 752 | −26 | 3384 | 4500 |
| | | | | 2700 | 2800 | 605 | −62 | 436 | 720 |
| | | | | 2600 | 2700 | 1082 | −98 | −7596 | −7020 |
| | | | | 2500 | 2600 | 563 | 45 | −5472 | −9720 |
| | | | | 2400 | 2500 | 297 | −112 | −8874 | −29880 |
| | | | | 2300 | 2400 | 127 | −123 | −9304 | −73260 |
| | Summary Data | | | 2300 | 3400 | 6690 | −353 | −12042 | −1800 |
| 2.3 | Gries (Aegina) | 1979 | 1986 | 3300 | 3400 | 10 | 0 | −40 | −3990 |
| | CH00003 | | | 3200 | 3300 | 130 | −40 | −355 | −2730 |
| | | | | 3100 | 3200 | 547 | −117 | −3853 | −7043 |
| | | | | 3000 | 3100 | 1597 | 69 | −1006 | −630 |
| | | | | 2900 | 3000 | 1004 | 57 | −2038 | −2030 |
| | | | | 2800 | 2900 | 726 | 1 | −2185 | −3010 |
| | | | | 2700 | 2800 | 543 | 30 | −1368 | −2520 |
| | | | | 2600 | 2700 | 984 | −134 | −4890 | −4970 |
| | | | | 2500 | 2600 | 608 | 70 | −2724 | −4480 |
| | | | | 2400 | 2500 | 184 | −20 | −1468 | −7980 |
| | | | | 2300 | 2400 | 4 | −4 | | |
| | Summary Data | | | 2300 | 3400 | 6337 | −88 | −16413 | −2590 |
| 2.4 | Gries (Aegina) | 1986 | 1991 | 3300 | 3400 | 10 | 0 | 14 | 1350 |
| | CH00003 | | | 3200 | 3300 | 90 | 116 | −266 | −2950 |
| | | | | 3100 | 3200 | 430 | 262 | −1699 | −3950 |
| | | | | 3000 | 3100 | 1666 | −66 | −8580 | −5150 |
| | | | | 2900 | 3000 | 1061 | −67 | −6154 | −5800 |
| | | | | 2800 | 2900 | 727 | −69 | −4435 | −6100 |
| | | | | 2700 | 2800 | 573 | −116 | −3495 | −6100 |
| | | | | 2600 | 2700 | 850 | −231 | −7098 | −8350 |
| | | | | 2500 | 2600 | 678 | 127 | −7831 | −11550 |

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**Table 5D.29 (Continued)**

| NR | Glacier Name | Period | | Altitude | | Area Mean | Area Change | Volume Change | Thickness Change |
|---|---|---|---|---|---|---|---|---|---|
| | | From | To | From | To | | | | |
| | | | | 2400 | 2500 | 164 | −11 | −1796 | −10950 |
| | Summary Data | | | 2400 | 3400 | 6249 | −55 | −41556 | −6650 |
| | **Austria** | | | | | | | | |
| 3.1 | Hintereis F. | 1979 | 1991 | 3700 | 3800 | 3 | −1 | −2 | −667 |
| | A00209 | | | 3600 | 3700 | 52 | −4 | −82 | −1576 |
| | | | | 3500 | 3600 | 48 | −16 | −58 | −1208 |
| | | | | 3400 | 3500 | 229 | −50 | −944 | −4122 |
| | | | | 3300 | 3400 | 701 | −66 | −2694 | −3843 |
| | | | | 3200 | 3300 | 975 | −110 | −5155 | −5287 |
| | | | | 3100 | 3200 | 1535 | −260 | −9390 | −6117 |
| | | | | 3000 | 3100 | 1469 | −181 | −11802 | −8034 |
| | | | | 2900 | 3000 | 1221 | −112 | −12738 | −10432 |
| | | | | 2800 | 2900 | 909 | −64 | −12846 | −14132 |
| | | | | 2700 | 2800 | 968 | −70 | −11516 | −11897 |
| | | | | 2600 | 2700 | 662 | −19 | −9636 | −14556 |
| | | | | 2500 | 2600 | 280 | 19 | −6046 | −21593 |
| | | | | 2400 | 2500 | 156 | −39 | −2529 | −16212 |
| | | | | 2300 | 2400 | 9 | −18 | −48 | −5333 |
| | Summary Data | | | 2300 | 3800 | 9217 | −991 | −85486 | −9275 |
| | **C.I.S** | | | | | | | | |
| 4.1 | Djankuat | 1984 | 1992 | 3600 | 3990 | 207 | −41 | 303 | 1465 |
| | SU03010 | | | 3500 | 3600 | 532 | 81 | −363 | −683 |
| | | | | 3400 | 3500 | 358 | −30 | −165 | −460 |
| | | | | 3300 | 3400 | 370 | −10 | 404 | 1092 |
| | | | | 3200 | 3300 | 427 | −16 | 439 | 1027 |
| | | | | 3100 | 3200 | 361 | −2 | −466 | −1290 |
| | | | | 3000 | 3100 | 292 | −8 | 109 | 374 |
| | | | | 2900 | 3000 | 286 | −1 | −589 | −2059 |
| | | | | 2800 | 2900 | 183 | −6 | −754 | −4121 |
| | | | | 2698 | 2800 | 97 | 7 | −510 | −5258 |
| | Summary Data | | | 2698 | 3990 | 3113 | −26 | −1592 | −511 |
| 5.1 | Muravlev | 1981 | 1982 | 3610 | 3620 | 27 | | 1 | 40 |
| | SU06002 | | | 3600 | 3610 | 22 | | 4 | 170 |
| | | | | 3590 | 3600 | 11 | | 3 | 290 |
| | | | | 3580 | 3590 | 9 | | 3 | 380 |
| | | | | 3570 | 3580 | 10 | | 4 | 370 |
| | | | | 3560 | 3570 | 15 | | 5 | 320 |
| | | | | 3550 | 3560 | 15 | | 3 | 190 |
| | | | | 3540 | 3550 | 15 | | 1 | 60 |
| | | | | 3530 | 3540 | 17 | | −2 | −120 |
| | | | | 3520 | 3530 | 15 | | −4 | −280 |
| | | | | 3510 | 3520 | 15 | | −6 | −420 |
| | | | | 3500 | 3510 | 14 | | −7 | −520 |
| | | | | 3490 | 3500 | 17 | | −10 | −560 |
| | | | | 3480 | 3490 | 11 | | −6 | −550 |
| | | | | 3470 | 3480 | 11 | | −6 | −550 |
| | | | | 3460 | 3470 | 9 | | −5 | −560 |
| | | | | 3450 | 3460 | 12 | | −7 | −580 |
| | | | | 3440 | 3450 | 14 | | −8 | −550 |
| | | | | 3430 | 3440 | 13 | | −7 | −520 |
| | | | | 3420 | 3430 | 11 | | −6 | −520 |
| | | | | 3410 | 3420 | 8 | | −4 | −530 |
| | | | | 3400 | 3410 | 11 | | −6 | −550 |
| | Summary Data | | | 3400 | 3620 | 302 | | −60 | −150 |
| 5.2 | Muravlev | 1982 | 1983 | 3610 | 3620 | 27 | | −21 | −770 |
| | SU06002 | | | 3600 | 3610 | 22 | | −17 | −770 |
| | | | | 3590 | 3600 | 11 | | −8 | −760 |
| | | | | 3580 | 3590 | 9 | | −7 | −750 |
| | | | | 3570 | 3580 | 10 | | −8 | −750 |

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**Table 5D.29 (Continued)**

| NR | Glacier Name | Period | | Altitude | | Area Mean | Area Change | Volume Change | Thickness Change |
|---|---|---|---|---|---|---|---|---|---|
| | | From | To | From | To | | | | |
| | | | | 3560 | 3570 | 15 | | −11 | −720 |
| | | | | 3550 | 3560 | 15 | | −10 | −690 |
| | | | | 3540 | 3550 | 15 | | −10 | −680 |
| | | | | 3530 | 3540 | 17 | | −11 | −660 |
| | | | | 3520 | 3530 | 15 | | −10 | −650 |
| | | | | 3510 | 3520 | 15 | | −9 | −630 |
| | | | | 3500 | 3510 | 14 | | −9 | −650 |
| | | | | 3490 | 3500 | 17 | | −12 | −710 |
| | | | | 3480 | 3490 | 11 | | −8 | −740 |
| | | | | 3470 | 3480 | 11 | | −8 | −770 |
| | | | | 3460 | 3470 | 9 | | −7 | −800 |
| | | | | 3450 | 3460 | 12 | | −10 | −840 |
| | | | | 3440 | 3450 | 14 | | −12 | −870 |
| | | | | 3430 | 3440 | 13 | | −11 | −880 |
| | | | | 3420 | 3430 | 11 | | −10 | −880 |
| | | | | 3410 | 3420 | 8 | | −7 | −890 |
| | | | | 3400 | 3410 | 10 | −1 | −9 | −880 |
| | Summary Data | | | 3400 | 3620 | 301 | −1 | −225 | −740 |
| 5.3 | Muravlev | 1983 | 1984 | 3610 | 3620 | 27 | | −16 | −580 |
| | SU06002 | | | 3600 | 3610 | 22 | | −14 | −620 |
| | | | | 3590 | 3600 | 11 | | −7 | −650 |
| | | | | 3580 | 3590 | 9 | | −6 | −660 |
| | | | | 3570 | 3580 | 10 | | −6 | −640 |
| | | | | 3560 | 3570 | 15 | | −10 | −660 |
| | | | | 3550 | 3560 | 15 | | −10 | −660 |
| | | | | 3540 | 3550 | 15 | | −10 | −650 |
| | | | | 3530 | 3540 | 17 | | −11 | −630 |
| | | | | 3520 | 3530 | 15 | | −9 | −610 |
| | | | | 3510 | 3520 | 15 | | −9 | −600 |
| | | | | 3500 | 3510 | 14 | | −8 | −580 |
| | | | | 3490 | 3500 | 17 | | −10 | −570 |
| | | | | 3480 | 3490 | 11 | | −6 | −570 |
| | | | | 3470 | 3480 | 11 | | −6 | −590 |
| | | | | 3460 | 3470 | 9 | | −5 | −610 |
| | | | | 3450 | 3460 | 12 | | −8 | −650 |
| | | | | 3440 | 3450 | 14 | | −8 | −600 |
| | | | | 3430 | 3440 | 13 | | −7 | −570 |
| | | | | 3420 | 3430 | 11 | | −6 | −570 |
| | | | | 3410 | 3420 | 8 | | −5 | −590 |
| | | | | 3400 | 3410 | 10 | | −6 | −630 |
| | Summary Data | | | 3400 | 3620 | 301 | | −183 | −620 |
| 5.4 | Muravlev | 1984 | 1985 | 3610 | 3620 | 27 | | −21 | −770 |
| | SU06002 | | | 3600 | 3610 | 22 | | −16 | −720 |
| | | | | 3590 | 3600 | 11 | | −8 | −700 |
| | | | | 3580 | 3590 | 9 | | −6 | −650 |
| | | | | 3570 | 3580 | 10 | | −6 | −630 |
| | | | | 3560 | 3570 | 15 | | −10 | −690 |
| | | | | 3550 | 3560 | 15 | | −11 | −730 |
| | | | | 3540 | 3550 | 15 | | −11 | −740 |
| | | | | 3530 | 3540 | 17 | | −13 | −760 |
| | | | | 3520 | 3530 | 15 | | −12 | −800 |
| | | | | 3510 | 3520 | 15 | | −13 | −840 |
| | | | | 3500 | 3510 | 14 | | −11 | −780 |
| | | | | 3490 | 3500 | 17 | | −14 | −840 |
| | | | | 3480 | 3490 | 11 | | −11 | −970 |
| | | | | 3470 | 3480 | 11 | | −11 | −1040 |
| | | | | 3460 | 3470 | 9 | | −10 | −1070 |
| | | | | 3450 | 3460 | 12 | | −13 | −1090 |
| | | | | 3440 | 3450 | 14 | | −15 | −1060 |

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**Table 5D.29 (Continued)**

| NR | Glacier Name | Period | | Altitude | | Area Mean | Area Change | Volume Change | Thickness Change |
|---|---|---|---|---|---|---|---|---|---|
| | | From | To | From | To | | | | |
| | | | | 3430 | 3440 | 13 | | −14 | −1040 |
| | | | | 3420 | 3430 | 11 | | −11 | −1040 |
| | | | | 3410 | 3420 | 8 | | −8 | −1030 |
| | | | | 3400 | 3410 | 9 | −1 | −9 | −1030 |
| | Summary Data | | | 3400 | 3620 | 300 | −1 | −254 | −830 |
| 5.5 | Muravlev | 1985 | 1986 | 3610 | 3620 | 27 | | −17 | −620 |
| | SU06002 | | | 3600 | 3610 | 22 | | −14 | −640 |
| | | | | 3590 | 3600 | 11 | | −7 | −630 |
| | | | | 3580 | 3590 | 9 | | −5 | −610 |
| | | | | 3570 | 3580 | 10 | | −6 | −600 |
| | | | | 3560 | 3570 | 15 | | −9 | −620 |
| | | | | 3550 | 3560 | 15 | | −9 | −620 |
| | | | | 3540 | 3550 | 15 | | −9 | −620 |
| | | | | 3530 | 3540 | 17 | | −11 | −630 |
| | | | | 3520 | 3530 | 15 | | −9 | −600 |
| | | | | 3510 | 3520 | 15 | | −9 | −600 |
| | | | | 3500 | 3510 | 14 | | −9 | −640 |
| | | | | 3490 | 3500 | 17 | | −12 | −720 |
| | | | | 3480 | 3490 | 11 | | −9 | −820 |
| | | | | 3470 | 3480 | 11 | | −9 | −860 |
| | | | | 3460 | 3470 | 9 | | −9 | −960 |
| | | | | 3450 | 3460 | 12 | | −12 | −1020 |
| | | | | 3440 | 3450 | 14 | | −15 | −1070 |
| | | | | 3430 | 3440 | 13 | | −15 | −1130 |
| | | | | 3420 | 3430 | 11 | | −12 | −1140 |
| | | | | 3410 | 3420 | 8 | | −9 | −1150 |
| | | | | 3400 | 3410 | 8 | −1 | −9 | −1160 |
| | Summary Data | | | 3400 | 3620 | 299 | −1 | −225 | −740 |
| 5.6 | Muravlev | 1986 | 1987 | 3610 | 3620 | 27 | | −18 | −680 |
| | SU06002 | | | 3600 | 3610 | 22 | | −14 | −630 |
| | | | | 3590 | 3600 | 11 | | −7 | −600 |
| | | | | 3580 | 3590 | 9 | | −5 | −560 |
| | | | | 3570 | 3580 | 10 | | −5 | −530 |
| | | | | 3560 | 3570 | 15 | | −9 | −580 |
| | | | | 3550 | 3560 | 15 | | −9 | −620 |
| | | | | 3540 | 3550 | 15 | | −9 | −630 |
| | | | | 3530 | 3540 | 17 | | −11 | −630 |
| | | | | 3520 | 3530 | 15 | | −9 | −600 |
| | | | | 3510 | 3520 | 15 | | −9 | −570 |
| | | | | 3500 | 3510 | 14 | | −8 | −550 |
| | | | | 3490 | 3500 | 17 | | −10 | −610 |
| | | | | 3480 | 3490 | 11 | | −8 | −740 |
| | | | | 3470 | 3480 | 11 | | −10 | −950 |
| | | | | 3460 | 3470 | 9 | | −10 | −1060 |
| | | | | 3450 | 3460 | 12 | | −12 | −1000 |
| | | | | 3440 | 3450 | 14 | | −13 | −930 |
| | | | | 3430 | 3440 | 13 | | −12 | −900 |
| | | | | 3420 | 3430 | 11 | | −10 | −890 |
| | | | | 3410 | 3420 | 8 | | −7 | −890 |
| | | | | 3400 | 3410 | 8 | | −7 | −880 |
| | Summary Data | | | 3400 | 3620 | 299 | | −212 | −690 |
| 5.7 | Muravlev | 1987 | 1988 | 3610 | 3620 | 27 | | 3 | 100 |
| | SU06002 | | | 3600 | 3610 | 22 | | 3 | 120 |
| | | | | 3590 | 3600 | 11 | | 1 | 60 |
| | | | | 3580 | 3590 | 9 | | 1 | 70 |
| | | | | 3570 | 3580 | 10 | | 1 | 140 |
| | | | | 3560 | 3570 | 15 | | 2 | 110 |
| | | | | 3550 | 3560 | 15 | | 2 | 110 |
| | | | | 3540 | 3550 | 15 | | 2 | 130 |

*(Continued)*

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**Table 5D.29 (Continued)**

| NR | Glacier Name | Period From | Period To | Altitude From | Altitude To | Area Mean | Area Change | Volume Change | Thickness Change |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 3530 | 3540 | 17 | | 2 | 150 |
| | | | | 3520 | 3530 | 15 | | 2 | 110 |
| | | | | 3510 | 3520 | 15 | | 1 | 40 |
| | | | | 3500 | 3510 | 14 | | −2 | −150 |
| | | | | 3490 | 3500 | 17 | | −4 | −230 |
| | | | | 3480 | 3490 | 11 | | −3 | −240 |
| | | | | 3470 | 3480 | 11 | | −3 | −310 |
| | | | | 3460 | 3470 | 9 | | −3 | −330 |
| | | | | 3450 | 3460 | 12 | | −5 | −450 |
| | | | | 3440 | 3450 | 14 | | −7 | −510 |
| | | | | 3430 | 3440 | 13 | | −6 | −500 |
| | | | | 3420 | 3430 | 11 | | −5 | −490 |
| | | | | 3410 | 3420 | 8 | | −4 | −490 |
| | | | | 3400 | 3410 | 7 | −1 | −3 | −480 |
| | Summary Data | | | 3400 | 3620 | 298 | −1 | −25 | −80 |
| 5.8 | Muravlev | 1988 | 1989 | 3610 | 3620 | 27 | | −3 | −120 |
| | SU06002 | | | 3600 | 3610 | 22 | | −4 | −190 |
| | | | | 3590 | 3600 | 11 | | −2 | −190 |
| | | | | 3580 | 3590 | 9 | | 0 | −30 |
| | | | | 3570 | 3580 | 10 | | 0 | 20 |
| | | | | 3560 | 3570 | 15 | | −2 | −120 |
| | | | | 3550 | 3560 | 15 | | −3 | −200 |
| | | | | 3540 | 3550 | 15 | | −4 | −240 |
| | | | | 3530 | 3540 | 17 | | −4 | −260 |
| | | | | 3520 | 3530 | 15 | | −5 | −330 |
| | | | | 3510 | 3520 | 15 | | −6 | −370 |
| | | | | 3500 | 3510 | 14 | | −5 | −390 |
| | | | | 3490 | 3500 | 17 | | −7 | −390 |
| | | | | 3480 | 3490 | 11 | | −5 | −450 |
| | | | | 3470 | 3480 | 11 | | −6 | −520 |
| | | | | 3460 | 3470 | 9 | | −5 | −570 |
| | | | | 3450 | 3460 | 12 | | −7 | −600 |
| | | | | 3440 | 3450 | 14 | | −10 | −730 |
| | | | | 3430 | 3440 | 13 | | −10 | −790 |
| | | | | 3420 | 3430 | 11 | | −9 | −820 |
| | | | | 3410 | 3420 | 8 | | −7 | −840 |
| | | | | 3400 | 3410 | 7 | | −6 | −860 |
| | Summary Data | | | 3400 | 3620 | 298 | | −110 | −340 |
| 5.9 | Muravlev | 1989 | 1990 | 3610 | 3620 | 27 | | 0 | −10 |
| | SU06002 | | | 3600 | 3610 | 22 | | 2 | 110 |
| | | | | 3590 | 3600 | 11 | | 1 | 90 |
| | | | | 3580 | 3590 | 9 | | −1 | −90 |
| | | | | 3570 | 3580 | 10 | | −1 | −110 |
| | | | | 3560 | 3570 | 15 | | −6 | −370 |
| | | | | 3550 | 3560 | 15 | | −7 | −510 |
| | | | | 3540 | 3550 | 15 | | −7 | −490 |
| | | | | 3530 | 3540 | 17 | | −9 | −590 |
| | | | | 3520 | 3530 | 15 | | −10 | −690 |
| | | | | 3510 | 3520 | 15 | | −10 | −680 |
| | | | | 3500 | 3510 | 14 | | −11 | −760 |
| | | | | 3490 | 3500 | 17 | | −15 | −880 |
| | | | | 3480 | 3490 | 11 | | −9 | −860 |
| | | | | 3470 | 3480 | 11 | | −9 | −820 |
| | | | | 3460 | 3470 | 9 | | −8 | −840 |
| | | | | 3450 | 3460 | 12 | | −12 | −960 |
| | | | | 3440 | 3450 | 14 | | −14 | −1020 |
| | | | | 3430 | 3440 | 13 | | −12 | −950 |
| | | | | 3420 | 3430 | 11 | | −10 | −930 |
| | | | | 3410 | 3420 | 8 | | −7 | −920 |

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**Table 5D.29 (Continued)**

| NR | Glacier Name | Period | | Altitude | | Area Mean | Area Change | Volume Change | Thickness Change |
|---|---|---|---|---|---|---|---|---|---|
| | | From | To | From | To | | | | |
| | | | | 3400 | 3410 | 6 | −1 | −5 | −910 |
| | Summary Data | | | 3400 | 3620 | 297 | −1 | −165 | −530 |
| 5.1 | Muravlev | 1990 | 1991 | 3610 | 3620 | 27 | | −33 | −1220 |
| | SU06002 | | | 3600 | 3610 | 22 | | −25 | −1160 |
| | | | | 3590 | 3600 | 11 | | −13 | −1180 |
| | | | | 3580 | 3590 | 9 | | −12 | −1300 |
| | | | | 3570 | 3580 | 10 | | −13 | −1350 |
| | | | | 3560 | 3570 | 15 | | −22 | −1430 |
| | | | | 3550 | 3560 | 15 | | −22 | −1430 |
| | | | | 3540 | 3550 | 15 | | −22 | −1430 |
| | | | | 3530 | 3540 | 17 | | −26 | −1500 |
| | | | | 3520 | 3530 | 15 | | −24 | −1600 |
| | | | | 3510 | 3520 | 15 | | −25 | −1650 |
| | | | | 3500 | 3510 | 14 | | −22 | −1540 |
| | | | | 3490 | 3500 | 17 | | −25 | −1490 |
| | | | | 3480 | 3490 | 11 | | −19 | −1690 |
| | | | | 3470 | 3480 | 11 | | −22 | −1990 |
| | | | | 3460 | 3470 | 9 | | −19 | −2140 |
| | | | | 3450 | 3460 | 12 | | −26 | −2180 |
| | | | | 3440 | 3450 | 14 | | −31 | −2200 |
| | | | | 3430 | 3440 | 13 | | −27 | −2080 |
| | | | | 3420 | 3430 | 11 | | −22 | −2030 |
| | | | | 3410 | 3420 | 8 | | −16 | −2020 |
| | | | | 3400 | 3410 | 6 | | −12 | −1990 |
| | Summary Data | | | 3400 | 3620 | 297 | | −478 | −1590 |
| 6.1 | Shumskiy | 1989 | 1990 | 3720 | 3740 | 96 | | −42 | −440 |
| | SU06001 | | | 3700 | 3720 | 114 | | −42 | −370 |
| | | | | 3680 | 3700 | 145 | | −46 | −320 |
| | | | | 3660 | 3680 | 111 | | −32 | −290 |
| | | | | 3640 | 3660 | 77 | | −30 | −390 |
| | | | | 3620 | 3640 | 89 | | −34 | −380 |
| | | | | 3600 | 3620 | 76 | | −29 | −380 |
| | | | | 3580 | 3600 | 76 | | −20 | −260 |
| | | | | 3560 | 3580 | 92 | | −28 | −300 |
| | | | | 3540 | 3560 | 104 | | 6 | 60 |
| | | | | 3520 | 3540 | 113 | | −14 | −120 |
| | | | | 3500 | 3520 | 42 | | −24 | −580 |
| | | | | 3480 | 3500 | 35 | | −26 | −750 |
| | | | | 3460 | 3480 | 43 | | −36 | −840 |
| | | | | 3440 | 3460 | 58 | | −57 | −990 |
| | | | | 3420 | 3440 | 92 | | −87 | −950 |
| | | | | 3400 | 3420 | 52 | | −49 | −940 |
| | | | | 3380 | 3400 | 38 | | −27 | −700 |
| | | | | 3360 | 3380 | 31 | | −18 | −570 |
| | | | | 3340 | 3360 | 34 | | −27 | −800 |
| | | | | 3320 | 3340 | 53 | | −45 | −850 |
| | | | | 3300 | 3320 | 46 | | −45 | −980 |
| | | | | 3280 | 3300 | 26 | | −28 | −1060 |
| | | | | 3260 | 3280 | 20 | | −20 | −1020 |
| | | | | 3240 | 3260 | 23 | | −28 | −1200 |
| | | | | 3220 | 3240 | 26 | | −36 | −1400 |
| | | | | 3200 | 3220 | 27 | | −59 | 2190 |
| | | | | 3180 | 3200 | 23 | | −54 | −2370 |
| | | | | 3160 | 3180 | 13 | −1 | −35 | −2690 |
| | | | | 3140 | 3160 | 4 | −1 | −11 | −2740 |
| | Summary Data | | | 3140 | 3740 | 1779 | −2 | −1023 | −600 |
| 6.2 | Shumskiy | 1990 | 1991 | 3720 | 3740 | 96 | | −76 | −790 |
| | SU06001 | | | 3700 | 3720 | 114 | | −89 | −780 |
| | | | | 3680 | 3700 | 145 | | −115 | −790 |

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**Table 5D.29 (Continued)**

| NR | Glacier Name | Period From | Period To | Altitude From | Altitude To | Area Mean | Area Change | Volume Change | Thickness Change |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 3660 | 3680 | 111 | | −84 | −760 |
| | | | | 3640 | 3660 | 77 | | −59 | −770 |
| | | | | 3620 | 3640 | 89 | | −82 | −920 |
| | | | | 3600 | 3620 | 76 | | −71 | −940 |
| | | | | 3580 | 3600 | 76 | | −65 | −850 |
| | | | | 3560 | 3580 | 92 | | −114 | −1240 |
| | | | | 3540 | 3560 | 104 | | −177 | −1700 |
| | | | | 3520 | 3540 | 113 | | −209 | −1850 |
| | | | | 3500 | 3520 | 42 | | −69 | −1650 |
| | | | | 3480 | 3500 | 35 | | −54 | −1530 |
| | | | | 3460 | 3480 | 43 | | −67 | −1550 |
| | | | | 3440 | 3460 | 58 | | −103 | −1780 |
| | | | | 3420 | 3440 | 92 | | −187 | −2030 |
| | | | | 3400 | 3420 | 52 | | −115 | −2210 |
| | | | | 3380 | 3400 | 38 | | −90 | −2370 |
| | | | | 3360 | 3380 | 31 | | −74 | −2400 |
| | | | | 3340 | 3360 | 34 | | −67 | −1960 |
| | | | | 3320 | 3340 | 53 | | −99 | −1870 |
| | | | | 3300 | 3320 | 46 | | −97 | −2110 |
| | | | | 3280 | 3300 | 26 | | −56 | −2170 |
| | | | | 3260 | 3280 | 20 | | −44 | −2220 |
| | | | | 3240 | 3260 | 23 | | −47 | −2060 |
| | | | | 3220 | 3240 | 26 | | −51 | −1980 |
| | | | | 3200 | 3220 | 27 | | −63 | −2340 |
| | | | | 3180 | 3200 | 22 | −1 | −56 | −2560 |
| | | | | 3160 | 3180 | 12 | −1 | −26 | −2210 |
| | | | | 3140 | 3160 | 3 | −1 | −7 | −2240 |
| | Summary Data | | | 3140 | 3740 | 1776 | −3 | −2513 | −1420 |
| 7.1 | TS.Tuyuksuysk SU05075 | 1990 | 1991 | 3800 | 3820 | 117 | | −117 | −1000 |
| | | | | 3780 | 3800 | 150 | | −159 | −1060 |
| | | | | 3760 | 3780 | 184 | | −206 | −1120 |
| | | | | 3740 | 3760 | 200 | | −234 | −1170 |
| | | | | 3720 | 3740 | 166 | | −184 | −1110 |
| | | | | 3700 | 3720 | 138 | | −135 | −980 |
| | | | | 3680 | 3700 | 73 | | −88 | −1200 |
| | | | | 3660 | 3680 | 51 | | −72 | −1410 |
| | | | | 3640 | 3660 | 54 | | −62 | −1150 |
| | | | | 3620 | 3640 | 48 | | −55 | −1140 |
| | | | | 3600 | 3620 | 70 | | −73 | −1040 |
| | | | | 3580 | 3600 | 55 | | −70 | −1280 |
| | | | | 3560 | 3580 | 99 | | −144 | −1460 |
| | | | | 3540 | 3560 | 56 | | −96 | −1710 |
| | | | | 3520 | 3540 | 54 | | −111 | −2060 |
| | | | | 3500 | 3520 | 53 | | −118 | −2220 |
| | | | | 3480 | 3500 | 50 | | −129 | −2590 |
| | | | | 3460 | 3480 | 37 | | −120 | −3230 |
| | Summary Data | | | 3460 | 3820 | 1655 | | −2173 | −1330 |
| 7.2 | TS.Tuyuksuysk SU05075 | 1991 | 1992 | 3800 | 3820 | 117 | | −35 | −300 |
| | | | | 3780 | 3800 | 150 | | −39 | −260 |
| | | | | 3760 | 3780 | 184 | | −52 | −280 |
| | | | | 3740 | 3760 | 200 | | −74 | −370 |
| | | | | 3720 | 3740 | 166 | | −70 | −420 |
| | | | | 3700 | 3720 | 138 | | −63 | −460 |
| | | | | 3680 | 3700 | 73 | | −48 | −660 |
| | | | | 3660 | 3680 | 51 | | −38 | −740 |
| | | | | 3640 | 3660 | 54 | | −42 | −770 |
| | | | | 3620 | 3640 | 48 | | −37 | −770 |
| | | | | 3600 | 3620 | 70 | | −57 | −820 |
| | | | | 3580 | 3600 | 55 | | −51 | −930 |

*(Continued)*

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**Table 5D.29 (Continued)**

| NR | Glacier Name | Period From | Period To | Altitude From | Altitude To | Area Mean | Area Change | Volume Change | Thickness Change |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 3560 | 3580 | 99 | | −130 | −1310 |
| | | | | 3540 | 3560 | 56 | | −88 | −1570 |
| | | | | 3520 | 3540 | 54 | | −89 | −1650 |
| | | | | 3500 | 3520 | 48 | −5 | −96 | −1990 |
| | | | | 3480 | 3500 | 40 | −10 | −91 | −2270 |
| | | | | 3460 | 3480 | 17 | −20 | −38 | −2230 |
| | Summary Data | | | 3460 | 3820 | 1620 | −35 | −1138 | −790 |
| 7.3 | TS.Tuyuksuysk | 1992 | 1993 | 3800 | 3820 | 117 | | | |
| | SU05075 | | | 3780 | 3800 | 150 | | 134 | 891 |
| | | | | 3760 | 3780 | 184 | | 213 | 1160 |
| | | | | 3740 | 3760 | 200 | | 252 | 1259 |
| | | | | 3720 | 3740 | 166 | | 196 | 1180 |
| | | | | 3700 | 3720 | 138 | | 183 | 1324 |
| | | | | 3680 | 3700 | 73 | | 104 | 1431 |
| | | | | 3660 | 3680 | 51 | | 58 | 1141 |
| | | | | 3640 | 3660 | 54 | | 46 | 846 |
| | | | | 3620 | 3640 | 48 | | 40 | 835 |
| | | | | 3600 | 3620 | 70 | | 61 | 866 |
| | | | | 3580 | 3600 | 55 | | 40 | 734 |
| | | | | 3560 | 3580 | 99 | | 69 | 696 |
| | | | | 3540 | 3560 | 56 | | 32 | 567 |
| | | | | 3520 | 3540 | 54 | | 22 | 400 |
| | | | | 3500 | 3520 | 48 | | −2 | −38 |
| | | | | 3480 | 3500 | 40 | | −27 | −681 |
| | | | | 3460 | 3480 | 15 | −2 | −15 | −973 |
| | Summary Data | | | 3460 | 3820 | 1618 | 2 | 1406 | 936 |
| | **Nepal** | | | | | | | | |
| 8.1 | AX010 | 1978 | 1991 | 5340 | 5360 | 6 | −2 | | |
| | NP00005 | | | 5320 | 5340 | 12 | −2 | | |
| | | | | 5300 | 5320 | 12 | −2 | | |
| | | | | 5280 | 5300 | 29 | −8 | | |
| | | | | 5260 | 5280 | 65 | −23 | −97 | −1500 |
| | | | | 5240 | 5260 | 101 | −9 | −324 | −3200 |
| | | | | 5220 | 5240 | 62 | 7 | −353 | −5700 |
| | | | | 5200 | 5220 | 60 | 4 | −576 | −9600 |
| | | | | 5180 | 5200 | 35 | 3 | −378 | −109000 |
| | | | | 5160 | 5180 | 24 | −3 | −278 | −11400 |
| | | | | 5140 | 5160 | 19 | −3 | −229 | −11800 |
| | | | | 5120 | 5140 | 15 | 3 | −232 | −15900 |
| | | | | 5100 | 5120 | 16 | −6 | −271 | −16700 |
| | | | | 5080 | 5100 | 20 | −7 | −354 | −17900 |
| | | | | 5060 | 5080 | 31 | −16 | −564 | −18500 |
| | | | | 5040 | 5060 | 21 | 7 | −387 | −18800 |
| | | | | 5020 | 5040 | 15 | −2 | −321 | −21000 |
| | | | | 5000 | 5020 | 15 | −4 | −355 | −23200 |
| | | | | 4980 | 5000 | 7 | 2 | −145 | −21700 |
| | | | | 4960 | 4980 | 3 | 1 | −51 | −17500 |
| | | | | 4952 | 4960 | 1 | 0 | −18 | −17500 |
| | Summary Data | | | 4952 | 5360 | 568 | −58 | −4934 | −8689 |

*Note:*
NR — Record number
Glacier Name — 15 alphabetic or numeric digits
Period From To — Period in which the changes take place
Altitude — Altitude interval in meters above sea level
Area Mean — Mean area of altitude interval for period of change (thousand square meters)
Area Change — Change in area of altitude interval for period of change (thousand square meters)
Volume Change — Change in volume of altitude interval for period of change (thousand cubic meters)
Thick Change — Change in thickness of altitude interval for period of change (millimeters)

*Source*: From World Glacier Monitoring Service by Wilfried Haeberli, Martin Hoelzle, Stephan Suter and Regula Frauenfelder www.wgms.ch.

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## SECTION 5E FLOODS

[In thousands of cfs; for a typical 300 $mi^2$ (780 $km^2$) drainage basin; a mean annual flood is one that will be exceeded in about half the years; the probability of a mean annual flood in any given year is about 50%]

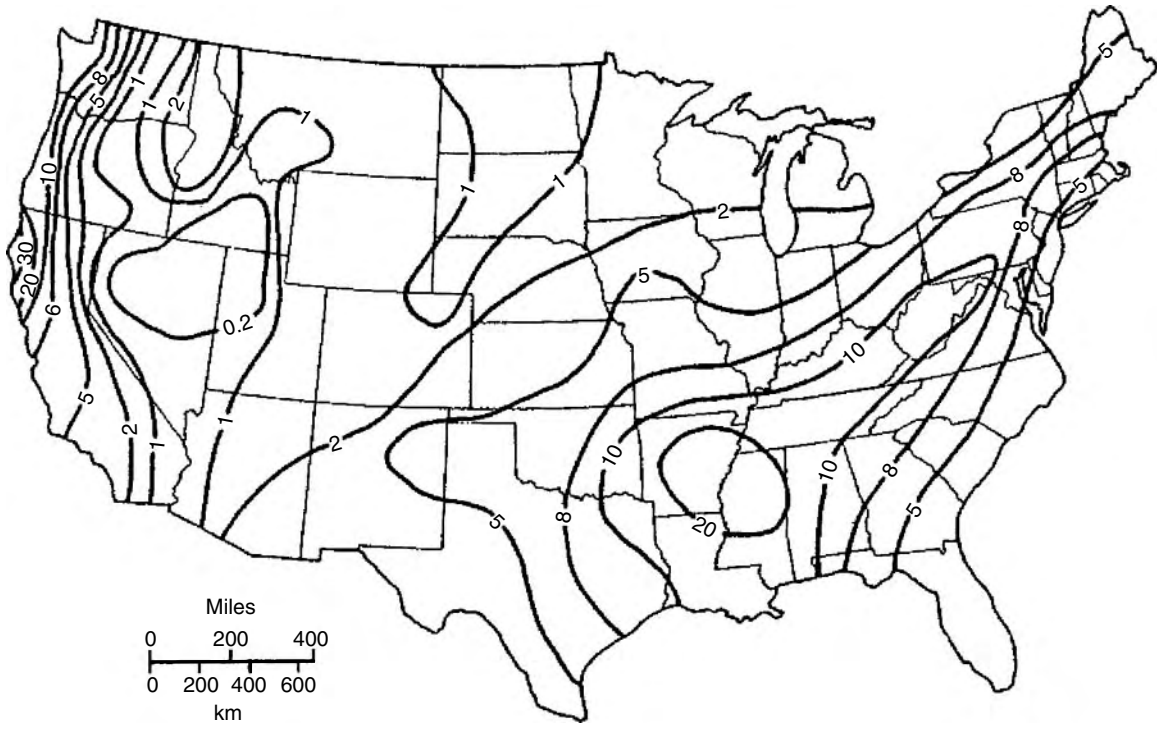


**Figure 5E.15** Mean annual flood potential in the United States. (From U.S. Geological Survey, National Atlas Map 121, 1965.)

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[In thousands of cfs; for a typical 300 $mi^2$ (780 $km^2$) drainage basin; a 10-year flood will be exceeded at irregular intervals that average 10 years; the probability of a 10-year flood in any given year is 10%]

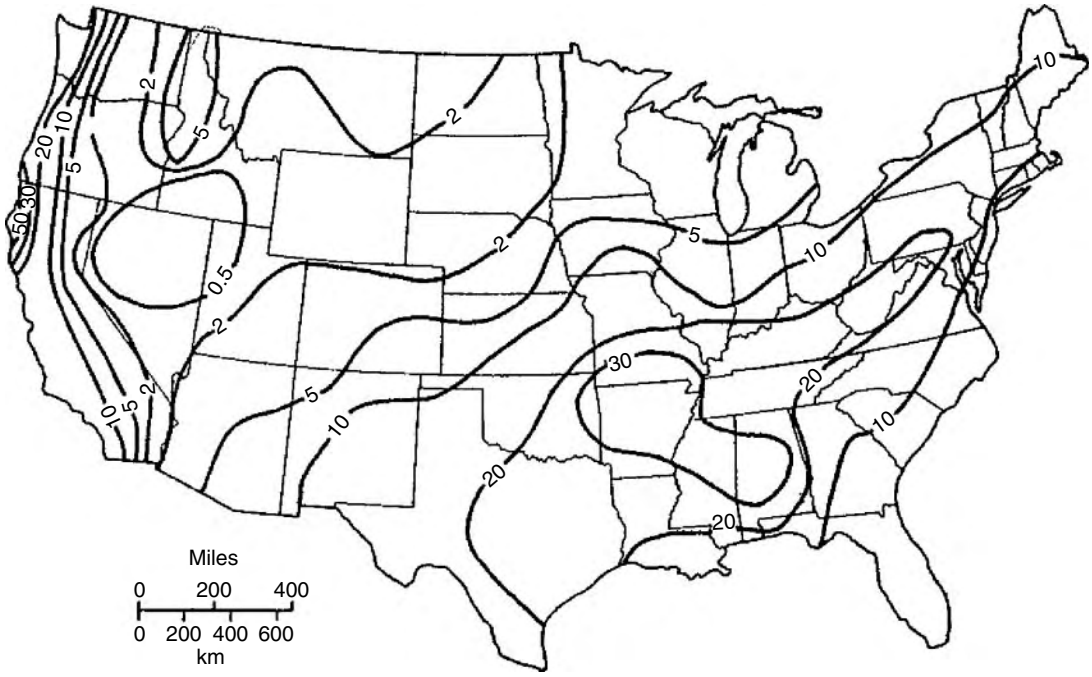


**Figure 5E.16** Ten-year flood potential in the United States. (From U.S. Geological Survey, National Atlas Map 121, 1965.)

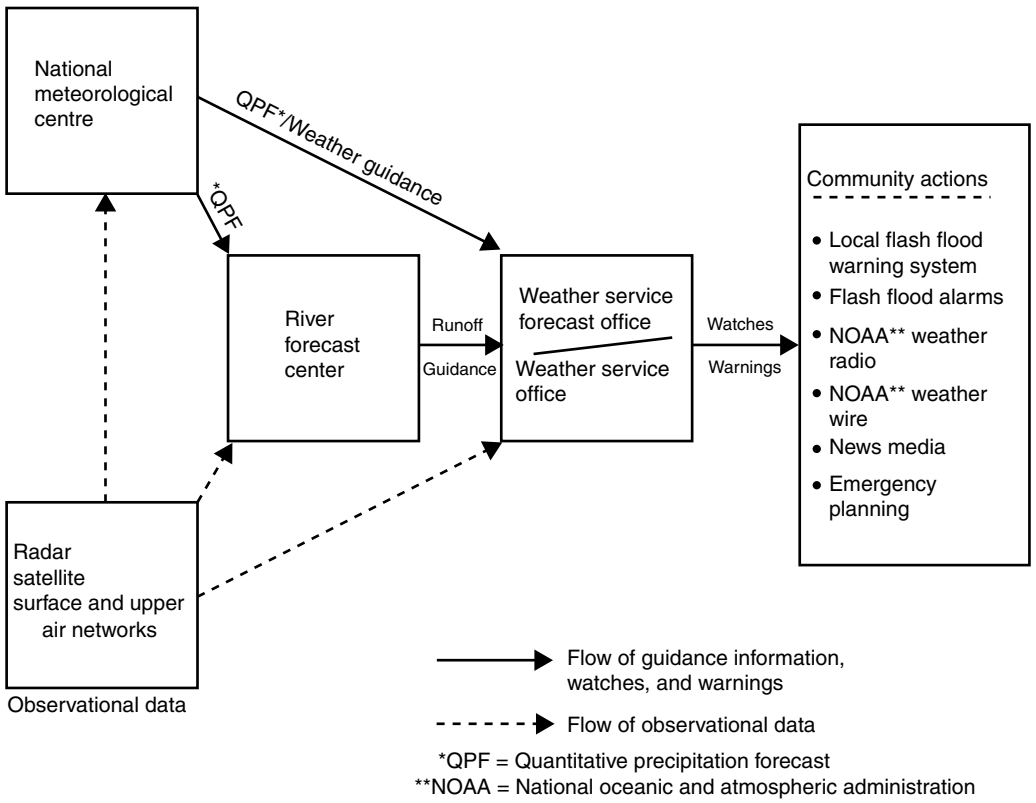


**Figure 5E.17** Flash flood warning system in the United States. (From National weather service, Operations of the national weather service. U.S. Department of Commerce, 1985.)

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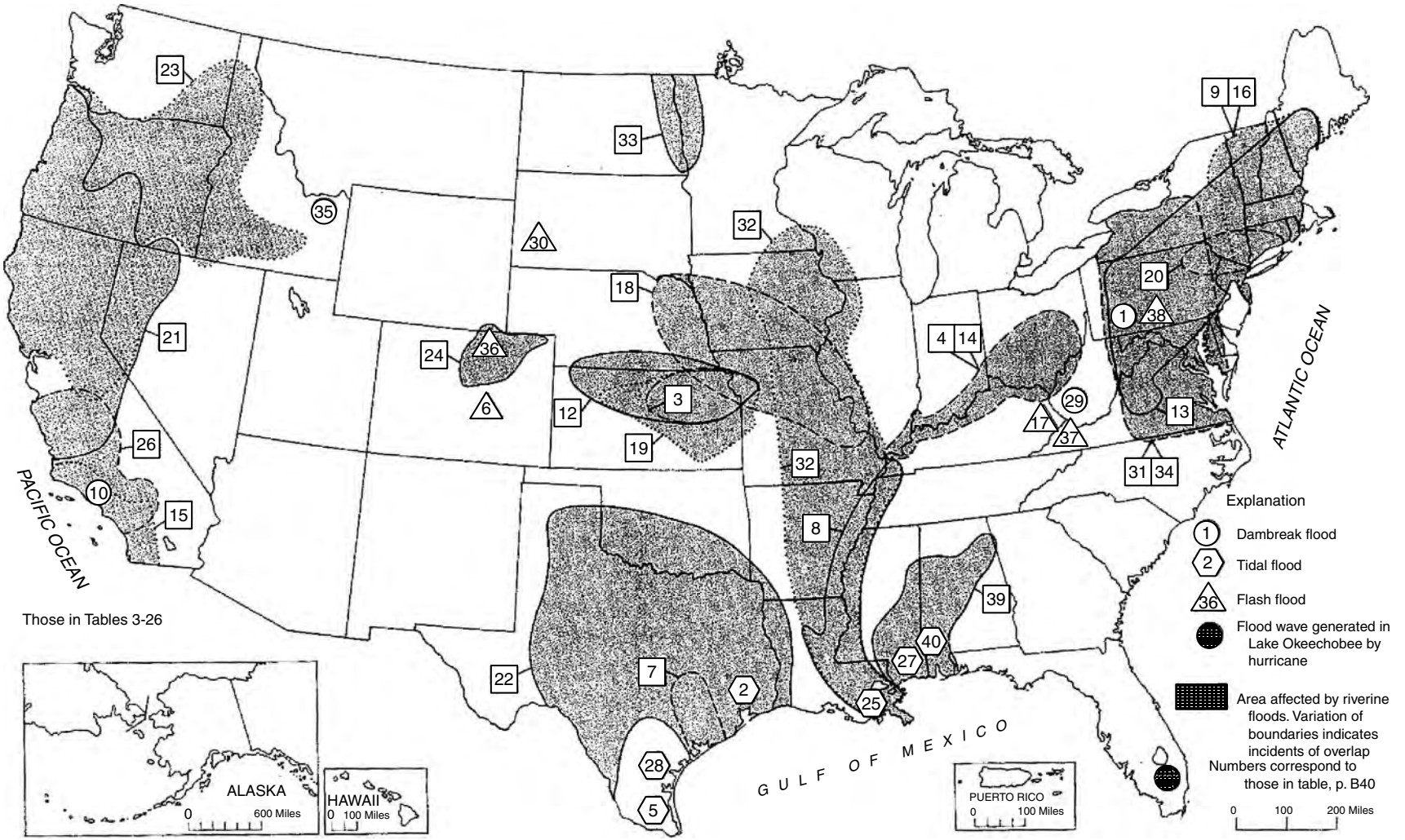


**Figure 5E.18** Distribution of great floods in the conterminous United States since 1889. (From Hays, W.W., Facing geologic and hydrologic hazards, Earth-Science considerations, U.S. geological survey professional paper 1240-B, 1981.)



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**Table 5E.30 Estimated U.S. Flood Damage, by Fiscal Year (Oct–Sep)**

| Fiscal Year | Damage (Millions Current Dollars) | Implicit Price Deflator | Damage (Millions 1995 Dollars) |
|---|---|---|---|
| 1926 | 9.243 | — | — |
| 1927 | 315.187 | — | — |
| 1928 | 88.155 | — | — |
| 1929 | 61.700 | 0.12854 | 480 |
| 1930 | 25.832 | 0.12385 | 209 |
| 1931 | 2.070 | 0.11091 | 19 |
| 1932 | 10.365 | 0.09796 | 106 |
| 1933 | 27.366 | 0.09541 | 287 |
| 1934 | 18.903 | 0.10071 | 188 |
| 1935 | 123.327 | 0.10265 | 1,201 |
| 1936 | 287.137 | 0.10377 | 2,767 |
| 1937 | 433.339 | 0.10815 | 4,007 |
| 1938 | 108.970 | 0.10499 | 1,038 |
| 1939 | 13.861 | 0.10387 | 133 |
| 1940 | 40.067 | 0.10530 | 381 |
| 1941 | 26.092 | 0.11244 | 232 |
| 1942 | 91.548 | 0.12120 | 755 |
| 1943 | 220.553 | 0.12773 | 1,727 |
| 1944 | 99.789 | 0.13058 | 764 |
| 1945 | 159.251 | 0.13425 | 1,186 |
| 1946 | 68.930 | 0.15056 | 458 |
| 1947 | 281.321 | 0.16667 | 1,688 |
| 1948 | 213.716 | 0.17615 | 1,213 |
| 1949 | 108.586 | 0.17594 | 617 |
| 1950 | 129.903 | 0.17788 | 730 |
| 1951 | 1,076.687 | 0.19072 | 5,645 |
| 1952 | 254.190 | 0.19368 | 1,312 |
| 1953 | 121.752 | 0.19623 | 620 |
| 1954 | 74.170 | 0.19817 | 374 |
| 1955 | 784.672 | 0.20163 | 3,892 |
| 1956 | 305.573 | 0.20846 | 1,466 |
| 1957 | 352.145 | 0.21539 | 1,635 |
| 1958 | 224.939 | 0.22059 | 1,020 |
| 1959 | 121.281 | 0.22304 | 544 |
| 1960 | 111.168 | 0.22620 | 491 |
| 1961 | 147.680 | 0.22875 | 646 |
| 1962 | 86.574 | 0.23180 | 373 |
| 1963 | 179.496 | 0.23445 | 766 |
| 1964 | 194.512 | 0.23792 | 818 |
| 1965 | 1,221.903 | 0.24241 | 5,041 |
| 1966 | 116.645 | 0.24934 | 468 |
| 1967 | 291.823 | 0.25698 | 1,136 |
| 1968 | 443.251 | 0.26809 | 1,653 |
| 1969 | 889.135 | 0.28124 | 3,161 |
| 1970 | 173.803 | 0.29623 | 587 |
| 1971 | 323.427 | 0.31111 | 1,040 |
| 1972 | 4,442.992 | 0.32436 | 13,698 |
| 1973 | 1,805.284 | 0.34251 | 5,271 |
| 1974 | 692.832 | 0.37329 | 1,856 |
| 1975 | 1,348.834 | 0.40805 | 3,306 |
| 1976 | 1,054.790 | 0.43119 | 2,446 |
| 1977 | 988.350 | 0.45892 | 2,154 |
| 1978 | 1,028.970 | 0.49164 | 2,093 |
| 1979 | 3,626.030 | 0.53262 | 6,808 |
| 1980 | — | 0.58145 | — |
| 1981 | — | 0.63578 | — |
| 1982 | — | 0.67533 | — |
| 1983 | 3,693.572 | 0.70214 | 5,260 |

*(Continued)*

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**Table 5E.30 (Continued)**

| Fiscal Year | Damage (Millions Current Dollars) | Implicit Price Deflator | Damage (Millions 1995 Dollars) |
|---|---|---|---|
| 1984 | 3,540.770 | 0.72824 | 4,862 |
| 1985 | 379.303 | 0.75117 | 505 |
| 1986 | 5,939.994 | 0.76769 | 7,737 |
| 1987 | 1,442.349 | 0.79083 | 1,824 |
| 1988 | 214.297 | 0.81764 | 262 |
| 1989 | 1,080.814 | 0.84883 | 1,273 |
| 1990 | 1,636.366 | 0.88186 | 1,856 |
| 1991 | 1,698.765 | 0.91397 | 1,859 |
| 1992 | 672.635 | 0.93619 | 718 |
| 1993 | 16,364.710 | 0.95872 | 17,069 |
| 1994 | 1,120.149 | 0.97870 | 1,145 |
| 1995 | 5,110.714 | 1.00000 | 5,111 |
| 1996 | 6,121.753 | 1.01937 | 6,005 |
| 1997 | 8,934.923 | 1.03925 | 8,597 |
| 1998 | 2,465.048 | 1.05199 | 2,343 |
| 1999 | 5,450.375 | 1.06677 | 5,109 |
| 2000 | 1,336.744 | 1.09113 | 1,225 |

*Note:* — Data unavailable.

*Source*: From U.S. Bureau of Economic Analysis, 2001.

**Table 5E.31 Comparison of Damage Estimates by State, 1955–1978 and 1983–1999.**

| State | Region | Median Damage (All Years) | Maximum Damage[a] | Years with No Estimate | Years with 0 < Est 1.0 | Years with Est > 100 |
|---|---|---|---|---|---|---|
| Rhode Island | New England | 0.00 | 143 | 33 | 5 | 1 |
| Delaware | | 0.00 | 7 | 32 | 7 | 0 |
| Massachusetts | New England | 0.00 | 774 | 25 | 5 | 2 |
| New Hampshire | New England | 0.00 | 56 | 23 | 6 | 0 |
| Hawaii | | 0.00 | 44 | 23 | 2 | 0 |
| Connecticut | New England | 0.00 | 1,881 | 21 | 6 | 2 |
| Vermont | New England | 0.00 | 194 | 20 | 9 | 1 |
| Wyoming | Arid West | 0.05 | 53 | 17 | 14 | 0 |
| Maine | New England | 0.06 | 77 | 20 | 3 | 0 |
| New Jersey | | 0.06 | 749 | 18 | 5 | 8 |
| Alaska (29 yr) | | 0.07 | 383 | 14 | 4 | 1 |
| Maryland & DC | | 0.14 | 681 | 15 | 14 | 1 |
| Nevada | Arid West | 0.16 | 616 | 13 | 12 | 1 |
| Michigan | | 0.21 | 528 | 17 | 11 | 3 |
| N. Dakota | N. Central | 0.41 | 3,280 | 14 | 9 | 4 |
| S. Dakota | N. Central | 0.51 | 796 | 10 | 13 | 4 |
| Colorado | Arid West | 0.57 | 1,866 | 11 | 10 | 4 |
| S. Carolina | | 0.66 | 40 | 5 | 18 | 0 |
| New Mexico | Arid West | 0.73 | 34 | 16 | 6 | 0 |
| Utah | Arid West | 0.84 | 712 | 7 | 14 | 2 |
| Montana | Arid West | 1.04 | 229 | 10 | 10 | 1 |
| Idaho | | 1.21 | 1,507 | 9 | 10 | 2 |
| Wisconsin | | 1.61 | 943 | 11 | 8 | 4 |
| Georgia | Southeast | 1.86 | 307 | 5 | 7 | 3 |
| Virginia | | 1.91 | 1,042 | 9 | 9 | 6 |
| Arizona | Arid West | 2.27 | 306 | 7 | 9 | 4 |
| Minnesota | | 2.40 | 1,006 | 4 | 12 | 7 |
| Florida | Southeast | 2.48 | 410 | 6 | 9 | 5 |
| N. Carolina | | 3.99 | 2,919 | 5 | 5 | 3 |
| Oregon | Pacific NW | 4.06 | 3,143 | 2 | 6 | 4 |
| Washington | Pacific NW | 4.32 | 363 | 5 | 7 | 3 |

*(Continued)*

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**Table 5E.31 (Continued)**

| State | Region | Median Damage (All Years) | Maximum Damage[a] | Years with No Estimate | Years with 0 < Est 1.0 | Years with Est > 100 |
|---|---|---|---|---|---|---|
| Louisiana | Lower Miss. | 5.60 | 3,097 | 7 | 7 | 10 |
| Tennessee | Southeast | 6.01 | 193 | 2 | 8 | 1 |
| Alabama | Southeast | 6.10 | 351 | 4 | 4 | 3 |
| Arkansas | Lower Miss. | 6.87 | 712 | 2 | 6 | 4 |
| Mississippi | Lower Miss. | 8.07 | 1,157 | 1 | 3 | 4 |
| W. Virginia | Ohio R. | 8.60 | 782 | 1 | 7 | 5 |
| Kansas | Central | 8.61 | 575 | 3 | 4 | 6 |
| Oklahoma | Central | 8.97 | 1,045 | 4 | 8 | 5 |
| Pennsylvania | | 10.39 | 8,590 | 3 | 7 | 6 |
| Nebraska | Upper Miss. | 13.89 | 307 | 4 | 4 | 4 |
| New York | | 14.60 | 2,305 | 7 | 3 | 6 |
| Illinois | Upper Miss. | 15.31 | 2,754 | 1 | 3 | 8 |
| Iowa | Upper Miss. | 17.18 | 5,987 | 4 | 6 | 9 |
| Kentucky | Ohio R. | 17.67 | 453 | 1 | 7 | 7 |
| Indiana | Ohio R. | 19.29 | 310 | 0 | 3 | 3 |
| Ohio | Ohio R. | 22.06 | 313 | 3 | 5 | 4 |
| Missouri | Upper Miss. | 25.42 | 3,577 | 0 | 7 | 12 |
| California | | 45.64 | 2,007 | 3 | 4 | 13 |
| Texas | | 77.44 | 691 | 1 | 1 | 16 |

[a] Estimates of maximum damage can be misleading. For example, in Idaho the maximum was caused by failure of the Teton Dam in 1976; the worst damage directly from precipitation and streamflow is estimated at $120 million. In Texas, the maximum appears small but much greater damage occurred in a year not covered by this table ($3.76 billion in 1979). States are ordered by increasing median damage. Missing estimates are treated as zero; all estimates are in millions of 1995 dollars.

*Source*: From Pielke, Jr., R.A., M.W. Downton, and J.Z. Barnard Miller, 2002: Flood Damage in the United States, 1926–2000: A Reanalysis of National Weather Service Estimates. Boulder, CO: UCAR, www.flooddamagedata.org.

**Table 5E.32 Damage in Thousands of Current Dollars**

| | Deflator | AL | AK | AZ | AR | CA | CO | CT | DE |
|---|---|---|---|---|---|---|---|---|---|
| 1955 | 0.20163 | 3,379 | | 226 | 61 | 165,767 | 2,567 | 379,360 | 117 |
| 1956 | 0.20846 | 720 | | 0 | 255 | 8,745 | 5,135 | 0 | 0 |
| 1957 | 0.21539 | 2,324 | | 0 | 27,938 | 13 | 2,901 | 0 | 0 |
| 1958 | 0.22059 | 872 | | 0 | 6,202 | 33,063 | 240 | 0 | 0 |
| 1959 | 0.22304 | 0 | | 100 | 3,090 | 4 | 0 | 0 | 0 |
| 1960 | 0.22620 | 670 | | 0 | 580 | 516 | 0 | 750 | 0 |
| 1961 | 0.22875 | 12,625 | | 325 | 3,503 | 95 | 0 | 0 | 0 |
| 1962 | 0.23180 | 3,529 | | 1,000 | 91 | 2,780 | 80 | 0 | 0 |
| 1963 | 0.23445 | 1,280 | | 0 | 2,500 | 11,834 | 50 | 0 | 0 |
| 1964 | 0.23792 | 5,343 | | 55 | 598 | 229,168 | 0 | 0 | 0 |
| 1965 | 0.24241 | 723 | | 11,330 | 143 | 11,321 | 452,293 | 0 | 0 |
| 1966 | 0.24934 | 2,366 | | 3,050 | 5,055 | 24,347 | 707 | 0 | 0 |
| 1967 | 0.25698 | 1,695 | 98,550 | 3,576 | 1,497 | 1,370 | 0 | 0 | 0 |
| 1968 | 0.26809 | 408 | 0 | 188 | 21,099 | 0 | 0 | 100 | 0 |
| 1969 | 0.28124 | 88 | 0 | 0 | 3,411 | 423,296 | 66 | 528 | 0 |
| 1970 | 0.29623 | 10,891 | 0 | 5,000 | 639 | 47,798 | 2,040 | 0 | 0 |
| 1971 | 0.31111 | 2,170 | 8,631 | 3,476 | 2,549 | 3,522 | 0 | 0 | 50 |
| 1972 | 0.32436 | 2,278 | 1,090 | 20,868 | 1,780 | 1,132 | 15 | 15,414 | 0 |
| 1973 | 0.34251 | 5,439 | 1,500 | 0 | 129,579 | 9,480 | 121,383 | 1,950 | 0 |
| 1974 | 0.37329 | 1,731 | 0 | 2,605 | 8,746 | 27,124 | 0 | 0 | 5 |
| 1975 | 0.40805 | 91,815 | 0 | 927 | 21,387 | 1,845 | 0 | 9,360 | 0 |
| 1976 | 0.43119 | 4,710 | 0 | 6,000 | 0 | 120,100 | 35,540 | 7,100 | 0 |
| 1977 | 0.45892 | 4,760 | 200 | 15,590 | 130 | 28,500 | 1,250 | 1,570 | 0 |
| 1978 | 0.49164 | 3,000 | 0 | 131,360 | 23,900 | 124,230 | 70 | 0 | 0 |
| 1979 | 0.53262 | [a] | 0 | 0 | 2,620 | 25,900 | 50 | [a] | 0 |

*(Continued)*

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**Table 5E.32 (Continued)**

| | Deflator | AL | AK | AZ | AR | CA | CO | CT | DE |
|---|---|---|---|---|---|---|---|---|---|
| 1980 | 0.58145 | | | | | | | | |
| 1981 | 0.63578 | | | | | | | | |
| 1982 | 0.67533 | | | | | | | | |
| 1983 | 0.70214 | 29,431 | 0 | 179,938 | 500,000 | 673,000 | 100 | 0 | 0 |
| 1984 | 0.72824 | 23,000 | 7,150 | 223,000 | 5,000 | 0 | 107,050 | 81,700 | 5,000 |
| 1985 | 0.75117 | 1,700 | 50 | 1,350 | 19,823 | 0 | 7,000 | 0 | 50 |
| 1986 | 0.76769 | 0 | 0 | 3,000 | 2,240 | 402,000 | 166 | 0 | 0 |
| 1987 | 0.79083 | 755 | 20,000 | 7 | 15,045 | 1,015 | 0 | 5,000 | 0 |
| 1988 | 0.81764 | 1,721 | 500 | 71 | 12,612 | 52,353 | 0 | 0 | 0 |
| 1989 | 0.84883 | 178 | 6,000 | 33,636 | 2,320 | 38,738 | 481 | 800 | 1,600 |
| 1990 | 0.88186 | 120,000 | 0 | 3,220 | 143,056 | 570 | 130 | 10 | 0 |
| 1991 | 0.91397 | 15,055 | 0 | 258 | 12,006 | 3,376 | 2,820 | 16 | 0 |
| 1992 | 0.93619 | 320 | 7,302 | 5,189 | 909 | 93,152 | 1,602 | 10,366 | 2 |
| 1993 | 0.95872 | 0 | 0 | 228,900 | 2,680 | 165,920 | 100 | 0 | 0 |
| 1994 | 0.97870 | 112,696 | 74,000 | 1,616 | 2,024 | 1,792 | 1,242 | 1,316 | 741 |
| 1995 | 1.00000 | 0 | 10,025 | 6,618 | 0 | 1,495,960 | 18,240 | 0 | 0 |
| 1996 | 1.01937 | 1,649 | 0 | 701 | 205 | 13,205 | 4,058 | 2,092 | 300 |
| 1997 | 1.03925 | 1,354 | 1,271 | 85 | 12,874 | 2,086,125 | 358,890 | 52 | 0 |
| 1998 | 1.05199 | 368,938 | 314 | 66 | 2,045 | 621,588 | 2,550 | 40 | 0 |
| 1999 | 1.06677 | 4,663 | 0 | 12,796 | 1,777 | 14,176 | 50,675 | 1,112 | 0 |
| 2000 | 1.09113 | 3,087 | 110 | 90 | 2,773 | 9,238 | 297 | 6,010 | 0 |
| | **Deflator** | **FL** | **GA** | **HI** | **ID** | **IL** | **IN** | **IA** | **KS** |
| 1955 | 0.20163 | 105 | 1 | 0 | 1,371 | 102 | 1,003 | 35 | 474 |
| 1956 | 0.20846 | 1,891 | 212 | 0 | 6,222 | 1,026 | 4,021 | 51 | 33 |
| 1957 | 0.21539 | 0 | 1,068 | 0 | 20,896 | 1,206 | 66,748 | 1,543 | 9,164 |
| 1958 | 0.22059 | 0 | 323 | 400 | 3 | 17,970 | 52,302 | 7,508 | 4,606 |
| 1959 | 0.22304 | 150 | 0 | 0 | 500 | 1,506 | 12,958 | 128 | 4,061 |
| 1960 | 0.22620 | 12,047 | 392 | 0 | 0 | 7,503 | 2,649 | 7,612 | 1,947 |
| 1961 | 0.22875 | 317 | 5,236 | 0 | 939 | 11,553 | 13,306 | 9,389 | 13,397 |
| 1962 | 0.23180 | 1,481 | 0 | 0 | 8,112 | 891 | 670 | 6,778 | 1,826 |
| 1963 | 0.23445 | 0 | 445 | 2,300 | 2,766 | 513 | 8,266 | 70 | 168 |
| 1964 | 0.23792 | 426 | 3,641 | 0 | 11,704 | 3,044 | 12,327 | 240 | 370 |
| 1965 | 0.24241 | 144 | 397 | 0 | 4,184 | 30,564 | 20 | 32,462 | 29,792 |
| 1966 | 0.24934 | 548 | 1,628 | 0 | 0 | 577 | 3,098 | 904 | 97 |
| 1967 | 0.25698 | 95 | 23 | 1,029 | 792 | 2,629 | 4,618 | 4,416 | 15,093 |
| 1968 | 0.26809 | 46 | 133 | 2,500 | 0 | 2,576 | 22,463 | 1,650 | 2,304 |
| 1969 | 0.28124 | 2,858 | 79 | 0 | 111 | 9,095 | 6,672 | 6,233 | 10,991 |
| 1970 | 0.29623 | 145 | 348 | 0 | 38 | 9,124 | 2,300 | 977 | 4,138 |
| 1971 | 0.31111 | 476 | 243 | 500 | 1,187 | 462 | 1,690 | 684 | 1,644 |
| 1972 | 0.32436 | 41,206 | 328 | 0 | 355 | 5,927 | 4,700 | 13,262 | 1,646 |
| 1973 | 0.34251 | 2,282 | 5,143 | 0 | 0 | 258,704 | 6,326 | 12,724 | 53,772 |
| 1974 | 0.37329 | 23,050 | 405 | 3,869 | 36,118 | 75,068 | 15,805 | 56,367 | 3,700 |
| 1975 | 0.40805 | 15,839 | 3,002 | 0 | 378 | 20,598 | 12,317 | 7,300 | 3,255 |
| 1976 | 0.43119 | 0 | 8,130 | 270 | 650,000 | 3,370 | 3,680 | 160 | 1,330 |
| 1977 | 0.45892 | 140 | 4,160 | 0 | 0 | 7,190 | 8,160 | 0 | 46,350 |
| 1978 | 0.49164 | 3,720 | 0 | 0 | 60 | 50 | 38,960 | 0 | 0 |
| 1979 | 0.53262 | 21,990 | 0 | 11,000 | 0 | 32,250 | 16,000 | 2,000 | 7,000 |
| 1980 | 0.58145 | | | | | | | | |
| 1981 | 0.63578 | | | | | | | | |
| 1982 | 0.67533 | | | | | | | | |
| 1983 | 0.70214 | 0 | 0 | 0 | 2,200 | 202,500 | 20,000 | 0 | 0 |
| 1984 | 0.72824 | 200,000 | 5,050 | 6,055 | 1,000 | 7,992 | 22,194 | 600,550 | 50,050 |
| 1985 | 0.75117 | 30,000 | 0 | 3,100 | 0 | 11,500 | 50,000 | 50 | 5,000 |
| 1986 | 0.76769 | 7,275 | 2,000 | 0 | 2,005 | 104,705 | 2,500 | 45,307 | 181,700 |
| 1987 | 0.79083 | 645 | 1,470 | 2,050 | 17 | 150,000 | 1,906 | 16,755 | 152,000 |
| 1988 | 0.81764 | 50,350 | 230 | 35,647 | 0 | 102 | 89 | 0 | 0 |
| 1989 | 0.84883 | 2,109 | 1,792 | 3,392 | 178 | 1,600 | 716 | 7,286 | 3,394 |
| 1990 | 0.88186 | 500 | 30,658 | 665 | 113 | 71,045 | 105,550 | 351,401 | 2,048 |
| 1991 | 0.91397 | 0 | 106,158 | 23,715 | 2,574 | 19,834 | 89,504 | 195,703 | 16,551 |

*(Continued)*

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**Table 5E.32 (Continued)**

| | Deflator | FL | GA | HI | ID | IL | IN | IA | KS |
|---|---|---|---|---|---|---|---|---|---|
| 1992 | 0.93619 | 41,938 | 1,156 | 9,260 | 224 | 189 | 45,424 | 50,800 | 10,127 |
| 1993 | 0.95872 | 2,080 | 7,340 | 2,910 | 0 | 2,640,140 | 9,550 | 5,740,000 | 551,070 |
| 1994 | 0.97870 | 182,605 | 300,000 | 3,700 | 0 | 32,606 | 2,852 | 9,124 | 10,437 |
| 1995 | 1.00000 | 18,536 | 8,845 | 0 | 2,096 | 27,240 | 6,789 | 3,498 | 8,874 |
| 1996 | 1.01937 | 158,001 | 2,581 | 1,935 | 49,400 | 107,585 | 21,575 | 165,265 | 3,969 |
| 1997 | 1.03925 | 49,707 | 464 | 0 | 125,060 | 4,295 | 68,598 | 3,680 | 102 |
| 1998 | 1.05199 | 431,311 | 166,291 | 0 | 1,005 | 2,380 | 19,611 | 168,101 | 4,888 |
| 1999 | 1.06677 | 60,080 | 8,520 | 0 | 1,297 | 3,666 | 50,124 | 111,221 | 60,030 |
| 2000 | 1.09113 | 499,080 | 2,101 | 400 | 85 | 3,113 | 819 | 14,877 | 250 |
| | **Deflator** | **KY** | **LA** | **ME** | **MD** | **MA** | **MI** | **MN** | **MS** |
| 1955 | 0.20163 | 6,629 | 30 | 0 | 5,450 | 155,982 | 0 | 0 | 3,132 |
| 1956 | 0.20846 | 568 | 0 | 0 | 888 | 0 | 1,278 | 11 | 1,270 |
| 1957 | 0.21539 | 55,233 | 4,147 | 0 | 0 | 0 | 0 | 9,128 | 2,693 |
| 1958 | 0.22059 | 3,817 | 2,842 | 0 | 100 | 0 | 0 | 17 | 13,826 |
| 1959 | 0.22304 | 2,480 | 0 | 61 | 0 | 0 | 0 | 50 | 280 |
| 1960 | 0.22620 | 3 | 112 | 0 | 0 | 6,400 | 1,181 | 212 | 744 |
| 1961 | 0.22875 | 12,969 | 6,074 | 800 | 0 | 0 | 0 | 552 | 15,918 |
| 1962 | 0.23180 | 16,885 | 1,908 | 0 | 0 | 0 | 0 | 1,290 | 1,982 |
| 1963 | 0.23445 | 36,917 | 0 | 0 | 0 | 0 | 0 | 26 | 19 |
| 1964 | 0.23792 | 35,476 | 30 | 0 | 0 | 0 | 0 | 0 | 3,152 |
| 1965 | 0.24241 | 1,044 | 0 | 0 | 53 | 0 | 0 | 97,603 | 1,931 |
| 1966 | 0.24934 | 1,671 | 250 | 528 | 0 | 0 | 0 | 4,300 | 2,706 |
| 1967 | 0.25698 | 17,583 | 0 | 0 | 125 | 0 | 0 | 0 | 1,192 |
| 1968 | 0.26809 | 6,036 | 2,810 | 0 | 0 | 35,000 | 100 | 1,197 | 6,269 |
| 1969 | 0.28124 | 8,075 | 251 | 300 | 200 | 0 | 13 | 67,168 | 1,900 |
| 1970 | 0.29623 | 707 | 1,000 | 0 | 15 | 0 | 0 | 4,350 | 3,586 |
| 1971 | 0.31111 | 6,099 | 0 | 0 | 8,600 | 0 | 0 | 15 | 12,431 |
| 1972 | 0.32436 | 15,841 | 100 | 0 | 220,739 | 10 | 10 | 64,318 | 10,248 |
| 1973 | 0.34251 | 10,491 | 334,904 | 11,200 | 0 | 0 | 530 | 242 | 226,885 |
| 1974 | 0.37329 | 5,218 | 10,343 | 3,000 | 0 | 0 | 240 | 16,939 | 27,827 |
| 1975 | 0.40805 | 26,302 | 90,204 | 0 | 27,200 | 0 | 54,358 | 139,726 | 70,990 |
| 1976 | 0.43119 | 0 | 0 | 3,360 | 4,900 | 1,000 | 790 | 0 | 2,840 |
| 1977 | 0.45892 | 101,000 | 48,040 | 4,190 | 0 | 0 | 0 | 7,870 | 2,780 |
| 1978 | 0.49164 | 100,000 | 145,000 | 0 | 150 | 0 | 0 | 65,000 | 0 |
| 1979 | 0.53262 | 0 | [a] | 0 | 69,000 | [a] | 0 | 13,140 | [a] |
| 1980 | 0.58145 | | | | | | | | |
| 1981 | 0.63578 | | | | | | | | |
| 1982 | 0.67533 | | | | | | | | |
| 1983 | 0.70214 | 100 | 651,000 | 375 | 100 | 0 | 0 | 310 | 812,600 |
| 1984 | 0.72824 | 180,236 | 6,550 | 10,050 | 10,015 | 50,560 | 0 | 5,000 | 6,050 |
| 1985 | 0.75117 | 460 | 8,050 | 45 | 50 | 0 | 80,000 | 500 | 2,000 |
| 1986 | 0.76769 | 25 | 1,515,250 | 5,000 | 0 | 21,500 | 405,000 | 1,501 | 651 |
| 1987 | 0.79083 | 68 | 1,175 | 61,250 | 51 | 47,480 | 15 | 27,800 | 6,380 |
| 1988 | 0.81764 | 250 | 8,708 | 0 | 0 | 0 | 206 | 555 | 39,420 |
| 1989 | 0.84883 | 27,445 | 322,118 | 3,200 | 1,600 | 0 | 180 | 17,600 | 3,635 |
| 1990 | 0.88186 | 5,664 | 115,901 | 0 | 23 | 50 | 627 | 3,032 | 21,805 |
| 1991 | 0.91397 | 9,034 | 221,720 | 16,336 | 48 | 9,716 | 6,133 | 1,280 | 313,359 |
| 1992 | 0.93619 | 46,870 | 4,191 | 2,179 | 339 | 176 | 355 | 1,760 | 1,010 |
| 1993 | 0.95872 | 4,980 | 4,020 | 3,040 | 0 | 160 | 1,600 | 964,050 | 4,480 |
| 1994 | 0.97870 | 2,544 | 675 | 9,323 | 4,524 | 0 | 6,236 | 1,867 | 1,352 |
| 1995 | 1.00000 | 17,673 | 3,097,250 | 0 | 1,620 | 0 | 2,900 | 3,750 | 1,092 |
| 1996 | 1.01937 | 21,323 | 121 | 4,916 | 90,481 | 2,663 | 26,690 | 460 | 200 |
| 1997 | 1.03925 | 470,915 | 4,359 | 26,845 | 198 | 75,024 | 325 | 743,218 | 32,774 |
| 1998 | 1.05199 | 16,639 | 17,845 | 0 | 334 | 13,510 | 18,190 | 2,529 | 3,498 |
| 1999 | 1.06677 | 506 | 5,979 | 1,580 | 9,715 | 250 | 325 | 466 | 1,769 |
| 2000 | 1.09113 | 17,631 | 153 | 2,814 | 2,452 | 206 | 25,430 | 43,112 | 408 |
| | **Deflator** | **MO** | **MT** | **NE** | **NV** | **NH** | **NJ** | **NM** | **NY** |
| 1955 | 0.20163 | 666 | 63 | 1,500 | 7,398 | 0 | 23,102 | 1,066 | 30,072 |
| 1956 | 0.20846 | 167 | 317 | 865 | 237 | 0 | 0 | 0 | 1,089 |

*(Continued)*

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**Table 5E.32 (Continued)**

| | Deflator | MO | MT | NE | NV | NH | NJ | NM | NY |
|---|---|---|---|---|---|---|---|---|---|
| 1957 | 0.21539 | 9,618 | 33 | 5,983 | 0 | 0 | 0 | 0 | 166 |
| 1958 | 0.22059 | 38,718 | 1 | 3,064 | 0 | 0 | 3 | 0 | 42 |
| 1959 | 0.22304 | 6,018 | 82 | 3,753 | 0 | 4,500 | 0 | 0 | 5,667 |
| 1960 | 0.22620 | 13,506 | 57 | 8,884 | 0 | 100 | 0 | 0 | 7,229 |
| 1961 | 0.22875 | 27,375 | 0 | 674 | 891 | 0 | 0 | 0 | 608 |
| 1962 | 0.23180 | 557 | 147 | 2,630 | 762 | 0 | 0 | 0 | 0 |
| 1963 | 0.23445 | 152 | 148 | 13,394 | 2,858 | 0 | 0 | 620 | 33,102 |
| 1964 | 0.23792 | 6,591 | 54,389 | 5,146 | 2,454 | 0 | 0 | 1,235 | 3,275 |
| 1965 | 0.24241 | 33,976 | 253 | 1,368 | 4 | 0 | 0 | 4,833 | 0 |
| 1966 | 0.24934 | 2,781 | 0 | 11,628 | 307 | 0 | 0 | 1,048 | 0 |
| 1967 | 0.25698 | 39,080 | 2,947 | 40,644 | 45 | 0 | 1,438 | 0 | 777 |
| 1968 | 0.26809 | 890 | 0 | 6,029 | 1 | 800 | 166,690 | 0 | 0 |
| 1969 | 0.28124 | 36,601 | 388 | 1,826 | 0 | 400 | 580 | 0 | 3,383 |
| 1970 | 0.29623 | 14,926 | 581 | 0 | 138 | 0 | 0 | 0 | 3,953 |
| 1971 | 0.31111 | 191 | 412 | 5,941 | 0 | 0 | 138,700 | 0 | 1,000 |
| 1972 | 0.32436 | 5,783 | 595 | 73 | 0 | 0 | 15,050 | 6,613 | 747,674 |
| 1973 | 0.34251 | 231,438 | 0 | 10,388 | 0 | 19,100 | 50,868 | 251 | 5,000 |
| 1974 | 0.37329 | 62,594 | 4,217 | 126 | 1,000 | 0 | 0 | 0 | 0 |
| 1975 | 0.40805 | 7,611 | 24,123 | 0 | 6,200 | 0 | 60,687 | 577 | 60,064 |
| 1976 | 0.43119 | 810 | 50 | 0 | 200 | 0 | 0 | 500 | 38,020 |
| 1977 | 0.45892 | 52,500 | 0 | 1,590 | 0 | 610 | 95,880 | 0 | 10,600 |
| 1978 | 0.49164 | 2,000 | 19,060 | 67,000 | 0 | 900 | 14,720 | 14,450 | 0 |
| 1979 | 0.53262 | 0 | 0 | 0 | 0 | 0 | [a] | 3,210 | [a] |
| 1980 | 0.58145 | | | | | | | | |
| 1981 | 0.63578 | | | | | | | | |
| 1982 | 0.67533 | | | | | | | | |
| 1983 | 0.70214 | 50,000 | 0 | 0 | 1,000 | 75 | 0 | 6,000 | 0 |
| 1984 | 0.72824 | 96,293 | 663 | 100,550 | 0 | 6,000 | 334,200 | 23,000 | 217,500 |
| 1985 | 0.75117 | 100 | 0 | 500 | 0 | 50 | 0 | 24,000 | 24,700 |
| 1986 | 0.76769 | 155,000 | 38,674 | 28,482 | 20,650 | 5,962 | 0 | 0 | 30,820 |
| 1987 | 0.79083 | 100,550 | 0 | 25,890 | 13 | 19,100 | 17,050 | 10 | 75,275 |
| 1988 | 0.81764 | 69 | 0 | 61 | 12 | 0 | 50 | 0 | 230 |
| 1989 | 0.84883 | 16,067 | 2,194 | 29,772 | 23 | 0 | 1,600 | 3,378 | 38,271 |
| 1990 | 0.88186 | 1,842 | 1,758 | 36,536 | 51 | 1,200 | 1 | 1,187 | 6,530 |
| 1991 | 0.91397 | 1,960 | 10,743 | 53,615 | 2 | 0 | 16,002 | 1,567 | 19,603 |
| 1992 | 0.93619 | 2,044 | 1,403 | 6,683 | 1,621 | 0 | 500 | 32,264 | 1,862 |
| 1993 | 0.95872 | 3,429,630 | 6,720 | 294,500 | 0 | 0 | 0 | 210 | 55,480 |
| 1994 | 0.97870 | 37,864 | 3,392 | 2,710 | 160 | 0 | 3,520 | 2,000 | 25,707 |
| 1995 | 1.00000 | 25,415 | 510 | 5,129 | 11,970 | 110 | 0 | 954 | 1,485 |
| 1996 | 1.01937 | 871 | 2,243 | 31,233 | 370 | 4,000 | 36,720 | 1,285 | 220,011 |
| 1997 | 1.03925 | 692 | 2,874 | 10,273 | 640,110 | 10,952 | 38,700 | 380 | 55,909 |
| 1998 | 1.05199 | 10,227 | 3,001 | 1,483 | 1,300 | 700 | 750 | 713 | 38,627 |
| 1999 | 1.06677 | 36,862 | 184 | 22,765 | 25,009 | 1,002 | 800,000 | 3,980 | 18,715 |
| 2000 | 1.09113 | 109,760 | 30 | 23,456 | 221 | 515 | 179,100 | 160 | 18,498 |
| | **Deflator** | **NC** | **ND** | **OH** | **OK** | **OR** | **PA** | **RI** | **SC** |
| 1955 | 0.20163 | 625 | 2 | 753 | 977 | 9,515 | 141,381 | 28,830 | 74 |
| 1956 | 0.20846 | 831 | 0 | 1,056 | 0 | 6,376 | 7,199 | 0 | 0 |
| 1957 | 0.21539 | 788 | 100 | 7 | 35,665 | 310 | 1,048 | 0 | 60 |
| 1958 | 0.22059 | 3,201 | 0 | 4,867 | 169 | 363 | 3,582 | 0 | 680 |
| 1959 | 0.22304 | 506 | 28 | 54,840 | 8,907 | 20 | 21,109 | 0 | 122 |
| 1960 | 0.22620 | 100 | 136 | 191 | 2,638 | 360 | 3,072 | 0 | 72 |
| 1961 | 0.22875 | 1,400 | 0 | 1,217 | 2,483 | 757 | 612 | 0 | 369 |
| 1962 | 0.23180 | 0 | 0 | 6,512 | 792 | 1,550 | 15 | 0 | 97 |
| 1963 | 0.23445 | 0 | 0 | 22,359 | 413 | 299 | 5,397 | 0 | 89 |
| 1964 | 0.23792 | 15,816 | 0 | 28,039 | 798 | 187,101 | 16,938 | 0 | 1,809 |
| 1965 | 0.24241 | 88 | 5,192 | 0 | 2,508 | 5,679 | 0 | 0 | 268 |
| 1966 | 0.24934 | 198 | 9,700 | 1,893 | 12 | 2,283 | 705 | 0 | 140 |
| 1967 | 0.25698 | 1,168 | 0 | 6,622 | 3 | 1,044 | 7,251 | 588 | 579 |
| 1968 | 0.26809 | 0 | 0 | 20,074 | 3,021 | 538 | 421 | 9,000 | 0 |

*(Continued)*

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**Table 5E.32 (Continued)**

| | Deflator | NC | ND | OH | OK | OR | PA | RI | SC |
|---|---|---|---|---|---|---|---|---|---|
| 1969 | 0.28124 | 1,338 | 37,436 | 87,916 | 762 | 938 | 3,310 | 0 | 625 |
| 1970 | 0.29623 | 2,326 | 13,832 | 2,478 | 5,212 | 2,518 | 365 | 0 | 52 |
| 1971 | 0.31111 | 965 | 1,266 | 782 | 23,166 | 4,350 | 20,899 | 0 | 295 |
| 1972 | 0.32436 | 10,772 | 537 | 12,929 | 12,006 | 12,977 | 2,786,294 | 0 | 69 |
| 1973 | 0.34251 | 39,004 | 0 | 8,317 | 38,119 | 2,699 | 5,935 | 0 | 7,674 |
| 1974 | 0.37329 | 1,028 | 8,291 | 1,500 | 29,083 | 64,017 | 0 | 0 | 78 |
| 1975 | 0.40805 | 7,932 | 154,715 | 15,513 | 300 | 7,898 | 270,600 | 0 | 1,477 |
| 1976 | 0.43119 | 9,120 | 2,420 | 40 | 52,640 | 1,170 | 440 | 0 | 11,210 |
| 1977 | 0.45892 | 52,500 | 80 | 370 | 12,720 | 10,690 | 330,020 | 0 | 260 |
| 1978 | 0.49164 | 0 | 13,000 | 1,520 | 0 | 0 | 6,630 | 0 | 60 |
| 1979 | 0.53262 | 0 | 20,100 | 60,000 | 0 | 0 | 0 | [a] | 0 |
| 1980 | 0.58145 | | | | | | | | |
| 1981 | 0.63578 | | | | | | | | |
| 1982 | 0.67533 | | | | | | | | |
| 1983 | 0.70214 | 470 | 0 | 0 | 0 | 7,300 | 0 | 0 | 0 |
| 1984 | 0.72824 | 40,000 | 5 | 10,122 | 268,000 | 52,900 | 75,500 | 5 | 1,110 |
| 1985 | 0.75117 | 50 | 0 | 10,000 | 15,030 | 50 | 100 | 0 | 100 |
| 1986 | 0.76769 | 1,990 | 315 | 10,000 | 802,250 | 33,900 | 71,540 | 0 | 3,070 |
| 1987 | 0.79083 | 20,461 | 4,943 | 20,518 | 22,250 | 900 | 28 | 550 | 31,771 |
| 1988 | 0.81764 | 0 | 0 | 2 | 3,437 | 125 | 62 | 0 | 0 |
| 1989 | 0.84883 | 21,072 | 16,000 | 52,240 | 2,121 | 98 | 7,106 | 0 | 370 |
| 1990 | 0.88186 | 1,075 | 0 | 40,846 | 40,650 | 1,070 | 792 | 50 | 677 |
| 1991 | 0.91397 | 2,694 | 32 | 55,165 | 90 | 9,010 | 8,342 | 174 | 11,871 |
| 1992 | 0.93619 | 12,927 | 0 | 20,078 | 10,871 | 32 | 1,805 | 16 | 0 |
| 1993 | 0.95872 | 1,400 | 413,600 | 25,800 | 44,720 | 1,760 | 440 | 0 | 17,920 |
| 1994 | 0.97870 | 2,032 | 58,552 | 39,913 | 166 | 0 | 16,194 | 0 | 6,228 |
| 1995 | 1.00000 | 26,596 | 44,366 | 28,511 | 3,275 | 11,320 | 10,385 | 0 | 28,169 |
| 1996 | 1.01937 | 42,119 | 220 | 22,721 | 0 | 3,203,500 | 494,862 | 0 | 668 |
| 1997 | 1.03925 | 17,994 | 3,408,298 | 66,666 | 155 | 173,200 | 3,136 | 0 | 1,105 |
| 1998 | 1.05199 | 16,135 | 2,583 | 181,409 | 262 | 10 | 1,103 | 0 | 4,044 |
| 1999 | 1.06677 | 3,117,160 | 100,355 | 963 | 9,578 | 2,100 | 27,642 | 0 | 75 |
| 2000 | 1.09113 | 7,605 | 191,177 | 8,839 | 11,691 | 5,734 | 27,476 | 0 | 2,885 |
| | **Deflator** | **SD** | **TN** | **TX** | **UT** | **VT** | **VA** | **WA** | **WV** |
| 1955 | 0.20163 | 11 | 977 | 5,165 | 226 | 0 | 10,695 | 1,165 | 5,187 |
| 1956 | 0.20846 | 10 | 279 | 3,715 | 210 | 0 | 0 | 6,472 | 3,185 |
| 1957 | 0.21539 | 3,969 | 5,118 | 78,881 | 169 | 3 | 139 | 1,664 | 11,052 |
| 1958 | 0.22059 | 0 | 128 | 18,101 | 10 | 0 | 0 | 50 | 1,170 |
| 1959 | 0.22304 | 0 | 0 | 2,886 | 4 | 0 | 28 | 4,914 | 709 |
| 1960 | 0.22620 | 3,417 | 226 | 8,093 | 0 | 0 | 211 | 0 | 370 |
| 1961 | 0.22875 | 1 | 2,263 | 2,846 | 281 | 0 | 231 | 130 | 3,455 |
| 1962 | 0.23180 | 3,030 | 651 | 1,948 | 1,272 | 0 | 0 | 0 | 5,914 |
| 1963 | 0.23445 | 0 | 6,262 | 20 | 64 | 0 | 5,937 | 1,013 | 17,624 |
| 1964 | 0.23792 | 0 | 156 | 5,435 | 70 | 692 | 0 | 11,817 | 4,169 |
| 1965 | 0.24241 | 740 | 2,472 | 39,395 | 1,746 | 0 | 2 | 1,012 | 49 |
| 1966 | 0.24934 | 470 | 1,608 | 28,001 | 1,577 | 0 | 0 | 592 | 1,868 |
| 1967 | 0.25698 | 1,125 | 1,090 | 98,259 | 453 | 0 | 581 | 1,910 | 14,235 |
| 1968 | 0.26809 | 123 | 648 | 24,267 | 1,260 | 100 | 0 | 611 | 47 |
| 1969 | 0.28124 | 31,898 | 1,090 | 12,878 | 237 | 680 | 123,552 | 2,722 | 5,996 |
| 1970 | 0.29623 | 19 | 13,260 | 3,150 | 222 | 0 | 148 | 380 | 297 |
| 1971 | 0.31111 | 0 | 86 | 26,538 | 1,033 | 0 | 1,158 | 3,908 | 1,653 |
| 1972 | 0.32436 | 165,086 | 6,634 | 20,605 | 358 | 40 | 180,770 | 21,029 | 37,974 |
| 1973 | 0.34251 | 0 | 66,273 | 136,758 | 2,270 | 66,466 | 1,615 | 0 | 3,359 |
| 1974 | 0.37329 | 268 | 2,243 | 41,707 | 0 | 0 | 100 | 21,318 | 10,375 |
| 1975 | 0.40805 | 0 | 12,700 | 23,074 | 212 | 200 | 18,340 | 42,289 | 5,913 |
| 1976 | 0.43119 | 5,500 | 200 | 33,390 | 0 | 0 | 0 | 2,500 | 3,260 |
| 1977 | 0.45892 | 0 | 21,000 | 2,450 | 300 | 2,710 | 268,700 | 5,630 | 50,500 |
| 1978 | 0.49164 | 250 | 0 | 132,730 | 0 | 0 | 10,000 | 0 | 2,900 |
| 1979 | 0.53262 | 49,000 | 0 | 2,000,000 | 130 | 0 | 24,800 | 3,100 | 2,000 |
| 1980 | 0.58145 | | | | | | | | |

*(Continued)*

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**Table 5E.32 (Continued)**

| | Deflator | SD | TN | TX | UT | VT | VA | WA | WV |
|---|---|---|---|---|---|---|---|---|---|
| 1981 | 0.63578 | | | | | | | | |
| 1982 | 0.67533 | | | | | | | | |
| 1983 | 0.70214 | 0 | 40,100 | 0 | 500,000 | 0 | 30 | 16,943 | 0 |
| 1984 | 0.72824 | 206,015 | 50,500 | 51,500 | 50,500 | 51,600 | 55,055 | 1,500 | 229,000 |
| 1985 | 0.75117 | 55 | 1,550 | 38,650 | 0 | 0 | 290 | 0 | 1,050 |
| 1986 | 0.76769 | 6,665 | 15,150 | 34,100 | 479,000 | 0 | 800,000 | 20,351 | 600,000 |
| 1987 | 0.79083 | 3 | 95 | 546,515 | 250 | 10,500 | 1,510 | 30,150 | 125 |
| 1988 | 0.81764 | 0 | 5,165 | 2,226 | 0 | 0 | 0 | 11 | 1 |
| 1989 | 0.84883 | 16 | 11,482 | 341,098 | 15,403 | 50 | 39,363 | 320 | 1,010 |
| 1990 | 0.88186 | 3,000 | 18,059 | 386,886 | 56 | 15,657 | 3,472 | 58,770 | 8,930 |
| 1991 | 0.91397 | 2,934 | 13,109 | 188,766 | 6,005 | 19 | 984 | 227,634 | 908 |
| 1992 | 0.93619 | 3,460 | 204 | 199,356 | 24 | 2 | 7,371 | 176 | 5,791 |
| 1993 | 0.95872 | 763,380 | 5,070 | 56,990 | 160 | 7,550 | 0 | 2,080 | 620 |
| 1994 | 0.97870 | 20,399 | 51,039 | 1,721 | 0 | 1,502 | 16,169 | 160 | 5,397 |
| 1995 | 1.00000 | 12,270 | 1,264 | 85,050 | 1,500 | 5,150 | 66,759 | 250 | 8,595 |
| 1996 | 1.01937 | 360 | 2,740 | 407,066 | 312 | 5,123 | 153,516 | 370,060 | 224,172 |
| 1997 | 1.03925 | 100,541 | 23,479 | 136,472 | 10,100 | 170 | 898 | 54,675 | 18,391 |
| 1998 | 1.05199 | 50 | 25,427 | 163,407 | 4,485 | 23,805 | 2,381 | 3,120 | 35,506 |
| 1999 | 1.06677 | 619 | 554 | 612,634 | 1,314 | 1,036 | 255,062 | 2,371 | 363 |
| 2000 | 1.09113 | 0 | 230 | 25,130 | 679 | 1,845 | 1,368 | 488 | 11,003 |

| | Deflator | WI | WY |
|---|---|---|---|
| 1955 | 0.20163 | 50 | 200 |
| 1956 | 0.20846 | 335 | 11 |
| 1957 | 0.21539 | 0 | 526 |
| 1958 | 0.22059 | 0 | 3 |
| 1959 | 0.22304 | 1,791 | 0 |
| 1960 | 0.22620 | 996 | 0 |
| 1961 | 0.22875 | 1,442 | 0 |
| 1962 | 0.23180 | 57 | 0 |
| 1963 | 0.23445 | 142 | 899 |
| 1964 | 0.23792 | 0 | 138 |
| 1965 | 0.24241 | 14,067 | 390 |
| 1966 | 0.24934 | 361 | 0 |
| 1967 | 0.25698 | 0 | 1,096 |
| 1968 | 0.26809 | 0 | 0 |
| 1969 | 0.28124 | 4,763 | 0 |
| 1970 | 0.29623 | 0 | 500 |
| 1971 | 0.31111 | 0 | 503 |
| 1972 | 0.32436 | 0 | 0 |
| 1973 | 0.34251 | 6,121 | 304 |
| 1974 | 0.37329 | 50 | 48 |
| 1975 | 0.40805 | 3,041 | 0 |
| 1976 | 0.43119 | 0 | 100 |
| 1977 | 0.45892 | 0 | 100 |
| 1978 | 0.49164 | 71,000 | 16,320 |
| 1979 | 0.53262 | 0 | 0 |
| 1980 | 0.58145 | | |
| 1981 | 0.63578 | | |
| 1982 | 0.67533 | | |
| 1983 | 0.70214 | 0 | 0 |
| 1984 | 0.72824 | 6,000 | 0 |
| 1985 | 0.75117 | 2,300 | 40,000 |
| 1986 | 0.76769 | 80,000 | 250 |
| 1987 | 0.79083 | 2,992 | 16 |
| 1988 | 0.81764 | 32 | 0 |
| 1989 | 0.84883 | 160 | 1,602 |
| 1990 | 0.88186 | 31,159 | 44 |
| 1991 | 0.91397 | 180 | 2,160 |
| 1992 | 0.93619 | 29,305 | 0 |
| 1993 | 0.95872 | 903,660 | 0 |

*(Continued)*

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**Table 5E.32 (Continued)**

| | Deflator | WI | WY |
|---|---|---|---|
| 1994 | 0.97870 | 62,052 | 0 |
| 1995 | 1.00000 | 675 | 0 |
| 1996 | 1.01937 | 218,025 | 181 |
| 1997 | 1.03925 | 93,346 | 192 |
| 1998 | 1.05199 | 82,825 | 22 |
| 1999 | 1.06677 | 9,305 | 0 |
| 2000 | 1.09113 | 74,298 | 20 |

[a] Damage estimate available for large region, but not for individual state.

*Source*: From Pielke, Jr., R.A., M.W. Downton, and J.Z. Barnard Miller, 2002: Flood damage in the United States, 1926–2000: *A Reanalysis of National Weather Service Estimates*. Boulder, CO: UCAR, www.flooddamagedata.org.

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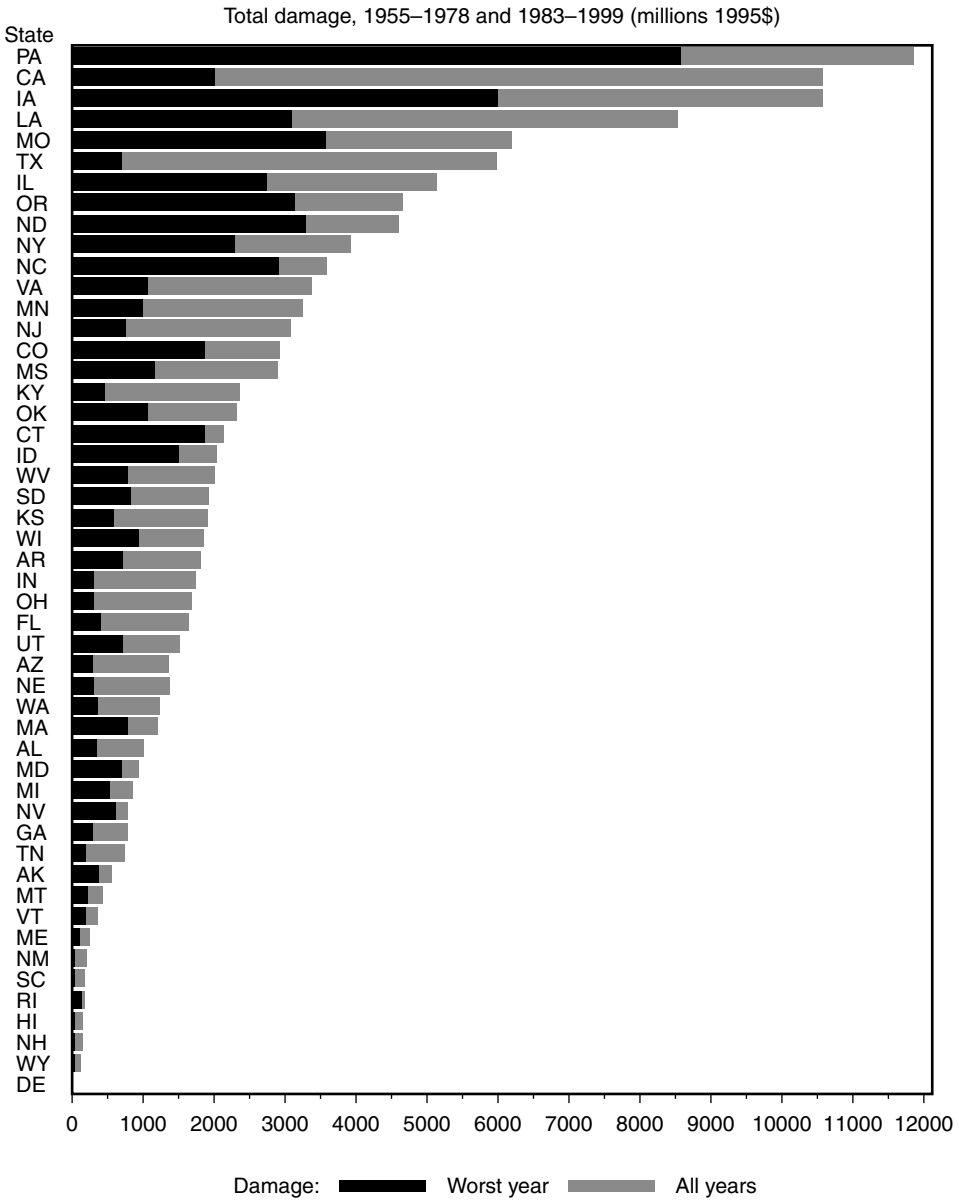


**Figure 5E.19** States ranked by estimated total damage during 1955–1978 and 1983–1999. (From Pielke, Jr., R.A., M.W. Downton, and J.Z. Barnard Miller; Flood damage in the United States, 1926–2000: *A Reanalysis of National Weather Service Estimates*. Boulder, CO:UCAR, 2002, www.flooddamagedata.org.)

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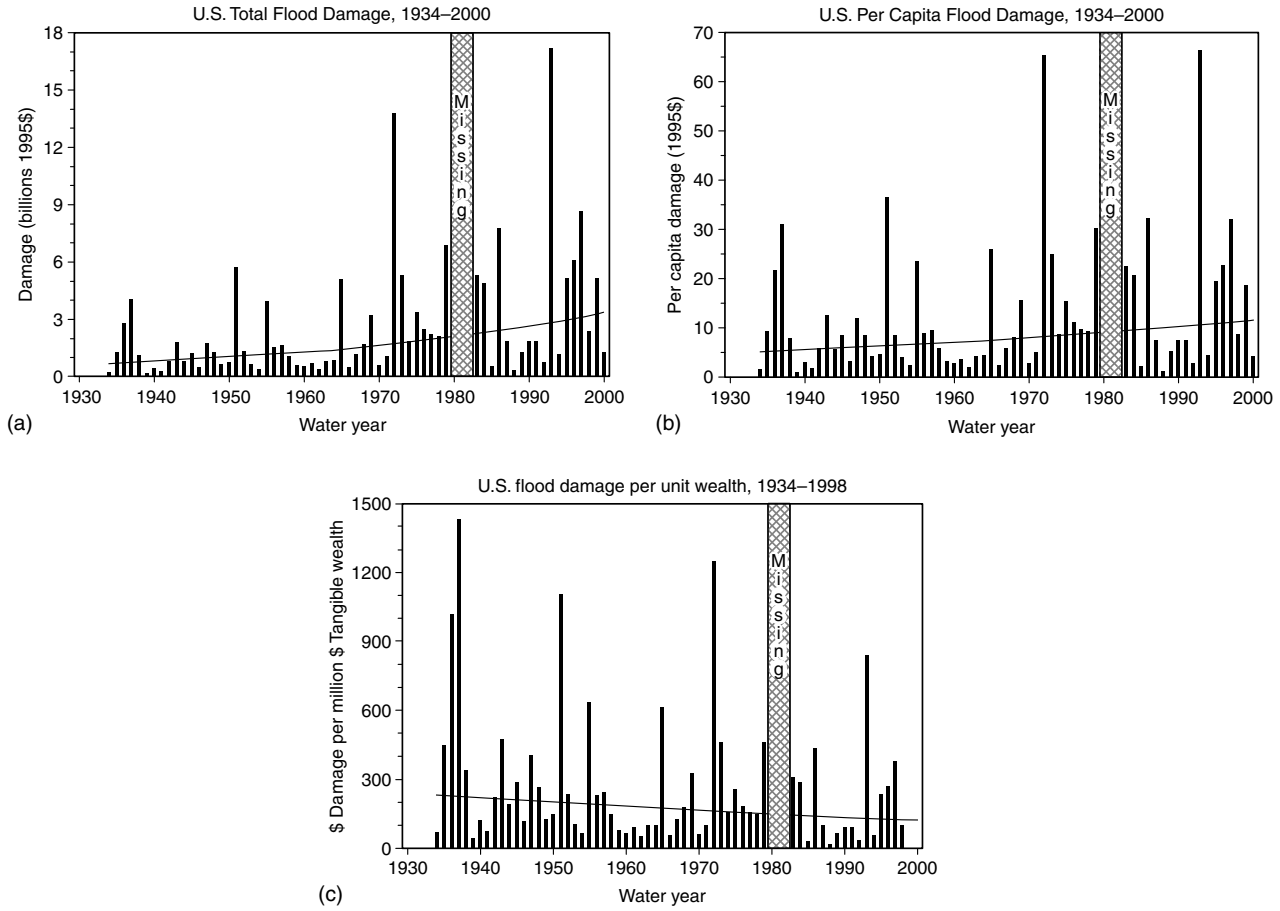


**Figure 5E.20** Estimated annual flood damage in the United States, 1934–1999: (a) Total flood damage, (b) Flood damage per capita, (c) Flood damage per million dollars of tangible wealth. (From Pielke, Jr., R.A., M.W. Downton, and J.Z. Barnard Miller; Flood damage in the United States, 1926–2000: *A Reanalysis of National Weather Service Estimates*. Boulder, CO:UCAR, 2002, www.flooddamagedata.org.)

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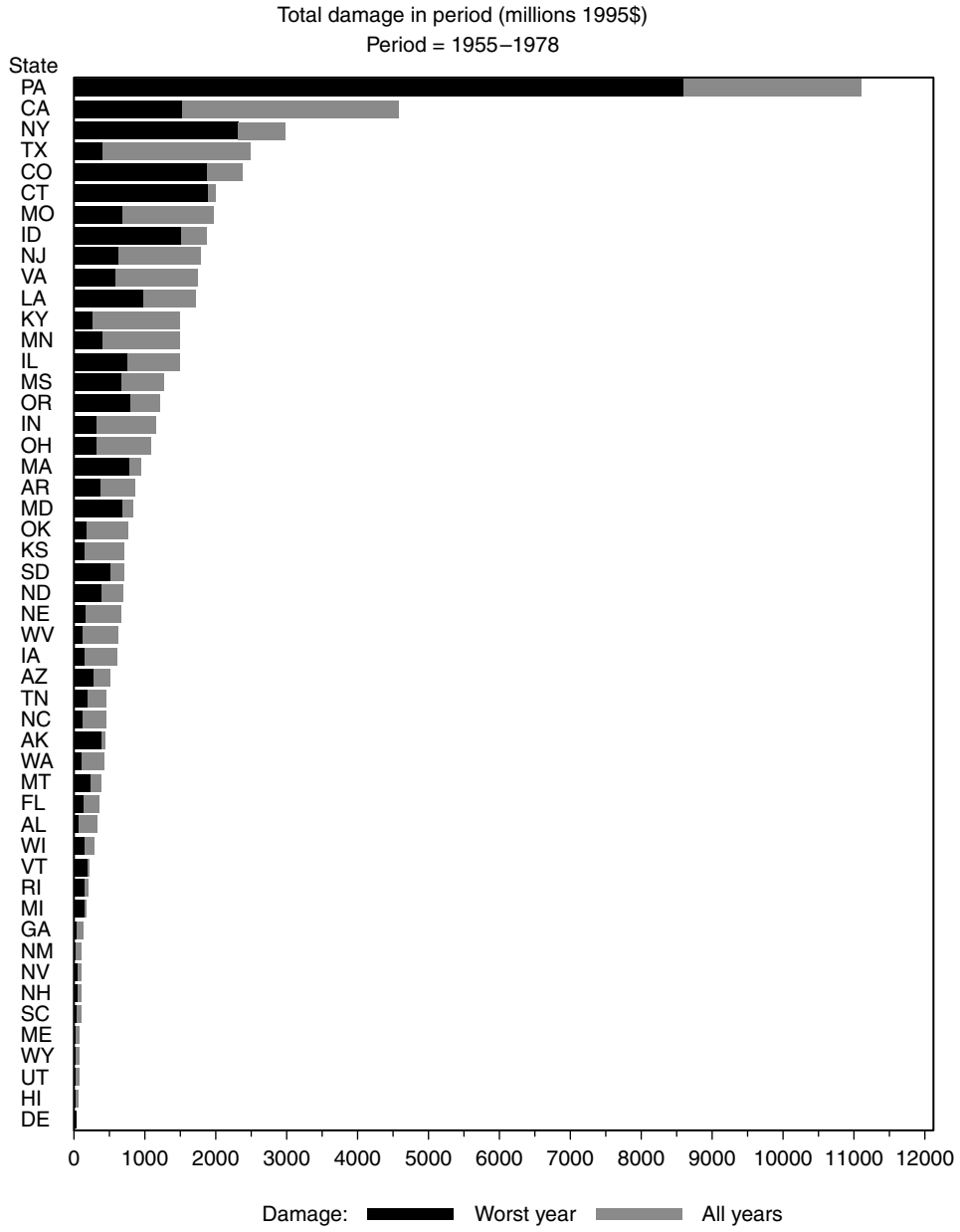


**Figure 5E.21A** States ranked based on total flood damage during 1955–1978. (From Pielke, Jr., R.A., M.W. Downton, and J.Z. Barnard Miller; Flood damage in the United States, 1926–2000: *A Reanalysis of National Weather Service Estimates*. Boulder, CO:UCAR, 2002, www.flooddamagedata.org.)

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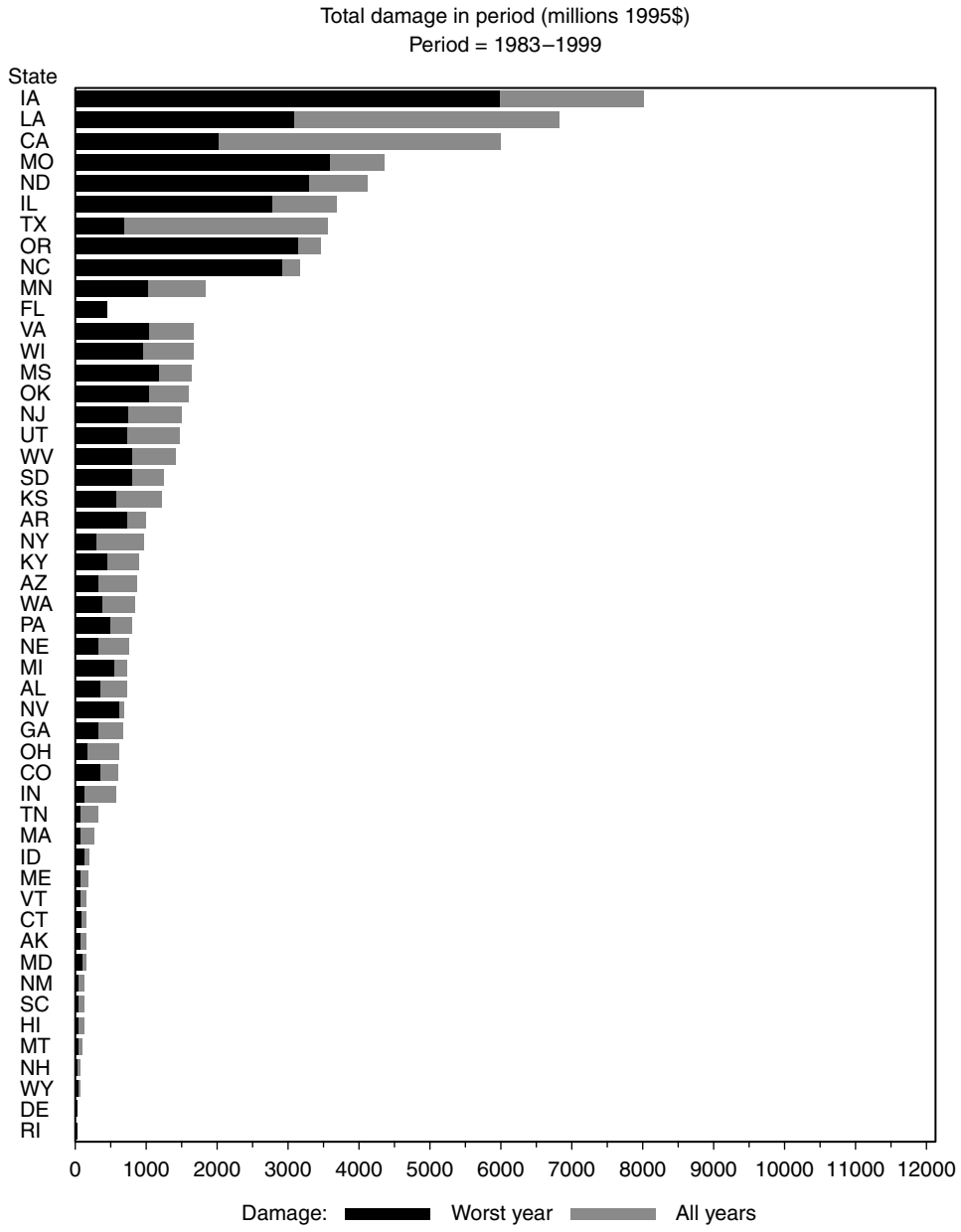


**Figure 5E.21B** States ranked based on total flood damage during 1983–1999.

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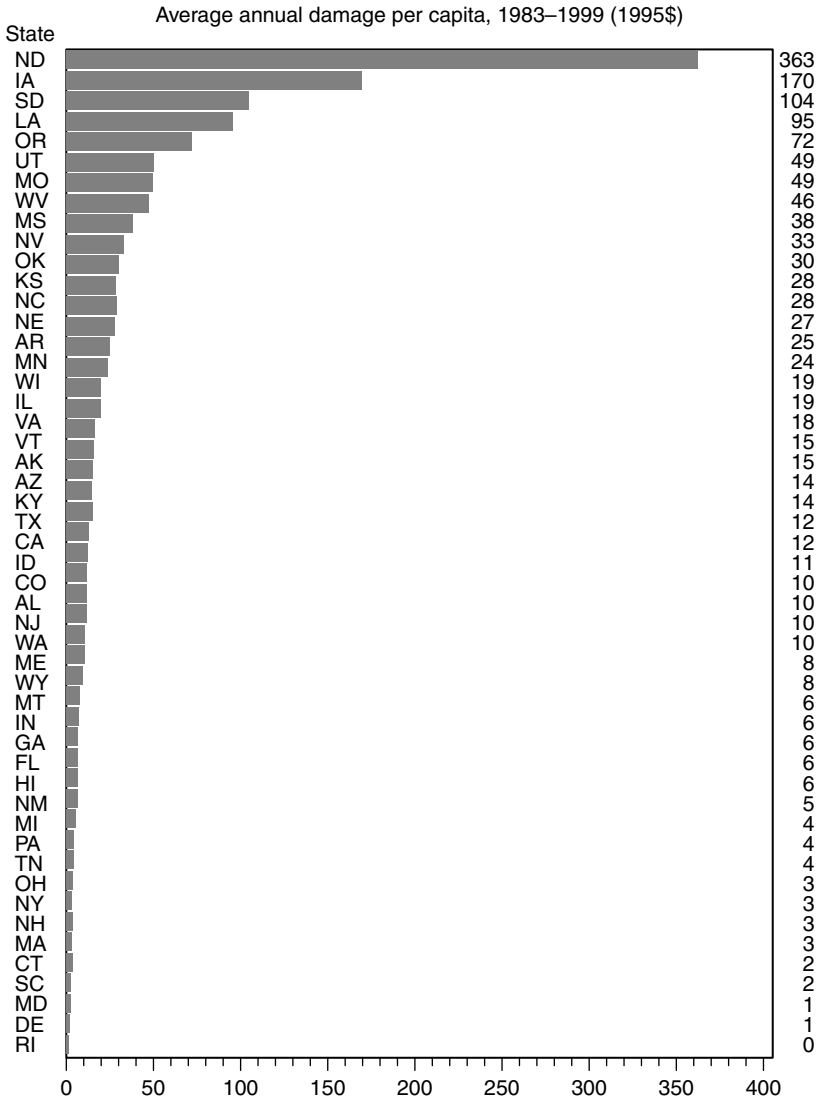


**Figure 5E.22** States ranked based on average annual flood damage per capita, 1983–1999. (From Pielke, Jr., R.A., M.W. Downton, and J.Z. Barnard Miller; Flood damage in the United States, 1926–2000: *A Reanalysis of National Weather Service Estimates*. Boulder, CO:UCAR, 2002, www.flooddamagedata.org.)

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**Table 5E.33 California 1998 El Niño Disaster: Estimated and Actual Public Assistance Costs, in Thousands of Current Dollars**

| County | Actual Cost (By 6/1/01) | IDE | | PDA | |
|---|---|---|---|---|---|
| | | Estimate | Prop. of Actual | Estimate | Prop. of Actual |
| State agencies | 30,091 | 7,129 | 0.24 | 14,497 | 0.48 |
| Alameda | 18,471 | 12,971 | 0.70 | 8,176 | 0.44 |
| Amador | 258 | 235 | 0.91 | 176 | 0.68 |
| Butte | 1,726 | 665 | 0.39 | 706 | 0.41 |
| Calaveras | 131 | — | — | 162 | 1.24 |
| Colusa | 4,652 | 25,000 | 5.37 | 1,829 | 0.39 |
| Contra Costa | 5,631 | 3,885 | 0.69 | 4,760 | 0.85 |
| Del Norte | 271 | — | — | 461 | 1.70 |
| Fresno | 1,701 | 820 | 0.48 | 1,052 | 0.62 |
| Glenn | 3,802 | 21,250 | 5.59 | 9,884 | 2.60 |
| Humboldt | 7,748 | 1,049 | 0.14 | 1,753 | 0.23 |
| Kern | 12,312 | — | — | 10,306 | 0.84 |
| Lake | 1,889 | 1,395 | 0.74 | 3,044 | 1.61 |
| Los Angeles | 31,229 | 5,660 | 0.18 | 35,516 | 1.14 |
| Marin | 6,449 | 3,319 | 0.51 | 5,447 | 0.84 |
| Mendocino | 2,836 | 4,259 | 1.50 | 3,846 | 1.36 |
| Merced | 2,327 | 490 | 0.21 | 734 | 0.32 |
| Monterey | 26,182 | 20,181 | 0.77 | 11,822 | 0.45 |
| Napa | 468 | 720 | 1.54 | 448 | 0.96 |
| Orange | 12,617 | 3,992 | 0.32 | 16,720 | 1.33 |
| Riverside | 3,130 | — | — | 5,964 | 1.91 |
| Sacramento | 2,366 | — | — | 3,066 | 1.30 |
| San Benito | 6,455 | 26,870 | 4.16 | 10,595 | 1.64 |
| San Bernardino | 7,525 | — | — | 30,429 | 4.04 |
| San Diego | 6,977 | — | — | 9,180 | 1.32 |
| San Francisco | 3,859 | 12,300 | 3.19 | 3,703 | 0.96 |
| San Joaquin | 2,657 | 655 | 0.25 | 3,155 | 1.19 |
| San Luis Obispo | 4,006 | 772 | 0.19 | 4,915 | 1.23 |
| San Mateo | 21,951 | 16,110 | 0.73 | 26,328 | 1.20 |
| Santa Barbara | 15,816 | 75 | 0.00 | 12,954 | 0.82 |
| Santa Clara | 13,638 | 9,846 | 0.72 | 13,310 | 0.98 |
| Santa Cruz | 12,459 | 13,673 | 1.10 | 6,320 | 0.51 |
| Solano | 3,346 | 3,628 | 1.08 | 8,564 | 2.56 |
| Sonoma | 11,779 | 11,180 | 0.95 | 4,127 | 0.35 |
| Stanislaus | 2,122 | — | — | 909 | 0.43 |
| Sutter | 1,039 | 1,582 | 1.52 | 758 | 0.73 |
| Tehama | 881 | 20,000 | 22.70 | 616 | 0.70 |
| Trinity | 1,091 | 1,970 | 1.81 | 975 | 0.89 |
| Tulare | 2,149 | — | — | 919 | 0.43 |
| Ventura | 20,391 | 3,302 | 0.16 | 14,350 | 0.70 |
| Yolo | 909 | 4,321 | 4.75 | 4,484 | 4.93 |
| Yuba | 592 | 196 | 0.33 | 249 | 0.42 |
| Total | 315,929 | 239,500 | 0.86[a] | 297,204 | 0.94 |

[a] Proportion of actual cost ($279 million) of cases with an IDE.

*Source*: From Pielke, Jr., R.A., M.W. Downton, and J.Z. Barnard Miller, 2002: Flood Damage in the United States, 1926–2000: *A Reanalysis of National Weather Service Estimates*. Boulder, CO: UCAR, www.flooddamagedata.org.

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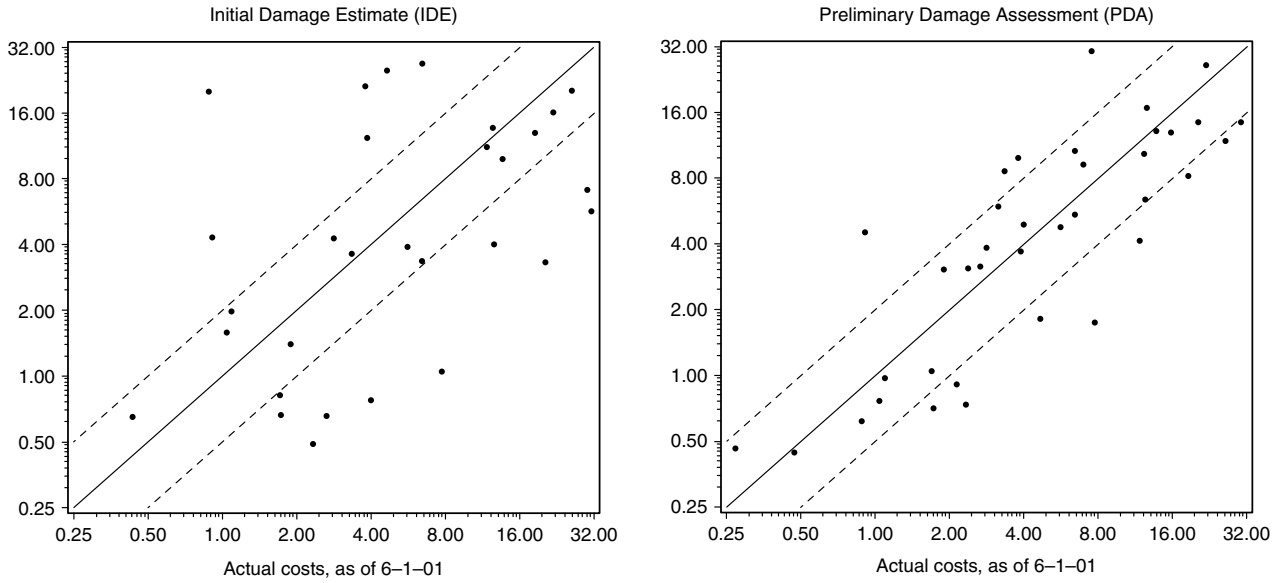


**Figure 5E.23** Flood damage estimates in California 1998 El Nino disaster (millions of dollars) estimated flood damage in California counties in the 1998 El Nino disaster, compared with actual cost as of June 1, 2001: (A) Initial damage estimate, (B) Preliminary damage assessment. (From Pielke, Jr., R.A., M.W. Downton, and J.Z. Barnard Miller; Flood damage in the United States, 1926–2000: *A Reanalysis of National Weather Service Estimates*. Boulder, CO:UCAR, 2002, www.flooddamagedata.org.)

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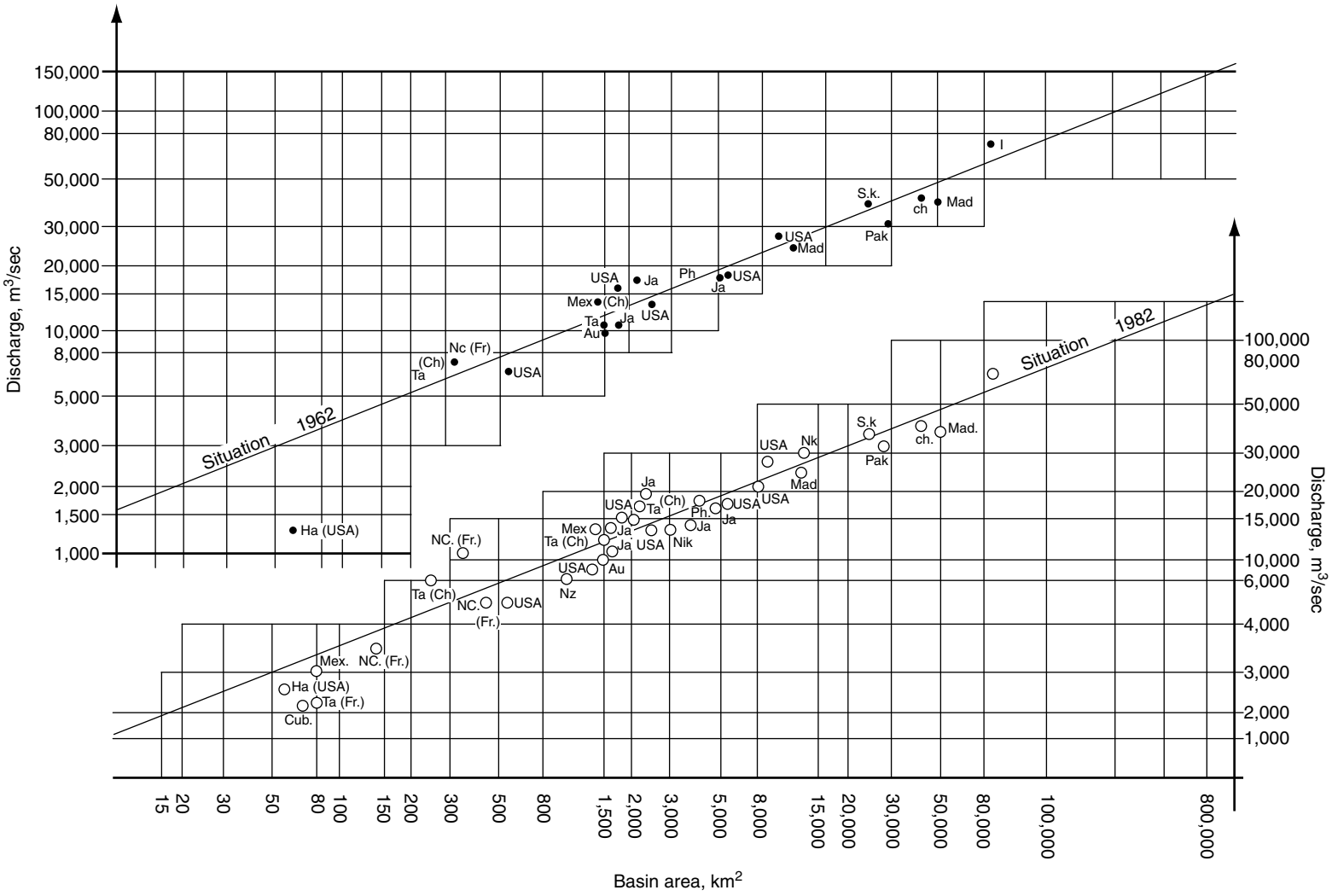


**Figure 5E.24** Relationship between maximum flood flows in the world and size of drainage basin. (From Rodier, J.A., and Roche, M. World Catalogue of Maximum Observed Floods, International Assoc. Hydrological Sciences Publ. No. 143, 1984.)

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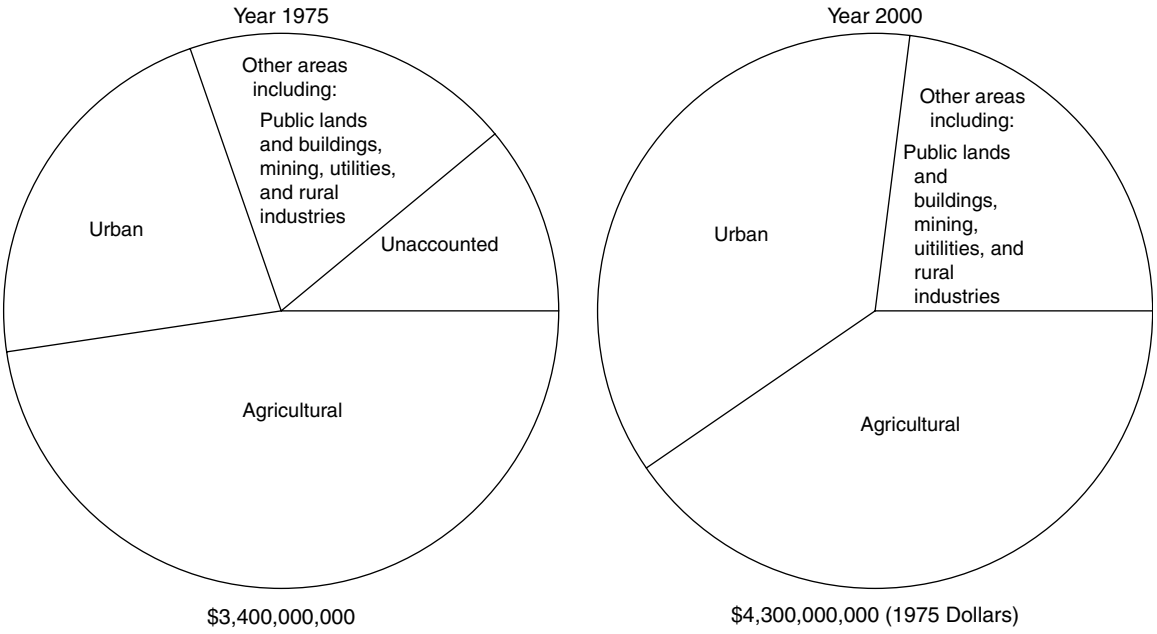


**Figure 5E.25** Trends in distribution of annual flood losses in the United States, 1975–2000. (From Hays, W.W., Facing Geologic and Hydrologic Hazards, Earth-Science Considerations, U.S. Geological Survey Professional Paper 1240-B, 1981.)

**Table 5E.34 Great Floods in the United States Since 1889**

| Number[a] | Type of Flood | Date | Location | Lives Lost | Estimated Damages (Millions of Dollars) |
|---|---|---|---|---|---|
| 1 | [b] | May 1889 | Johnstown, Pennsylvania, Dam failure | 3,000 | — |
| 2 | [c] | September 8, 1900 | Hurricane–Galveston, Texas | 6,000 | 30 |
| 3 | [d] | May–June 1903 | Kansas, Lower Missouri, and Upper Mississippi River | 100 | 40 |
| 4 | [d] | March 1913 | Ohio River and Tributaries | 467 | 147 |
| 5 | [c] | September 14, 1919 | Hurricane–South of Corpus Christi, Texas | 600–900 | 22 |
| 6 | [b,e] | June 1921 | Arkansas River, Colorado | 120 | 25 |
| 7 | [d] | September 1921 | Texas Rivers | 215 | 19 |
| 8 | [d] | Spring 1927 | Mississippi River Valley | 313 | 284 |
| 9 | [d] | November 1927 | New England Rivers | 88 | 46 |
| 10 | [b] | March 12–13, 1928 | St. Francis Dam failure, Southern California | 450 | 14 |
| 11 | [f] | September 13, 1928 | Lake Okeechobee, Florida | 1,836 | 26 |
| 12 | [d] | May–June 1935 | Republican and Kansas Rivers | 110 | 18 |
| 13 | [d] | March–April 1936 | Rivers in Eastern United States | 107 | 270 |
| 14 | [d] | January–February 1937 | Ohio and Lower Mississippi River Basins | 137 | 418 |
| 15 | [d] | March 1938 | Streams in Southern California | 79 | 25 |
| 16 | [d] | September 21, 1938 | New England | 600 | 306 |
| 17 | [e] | July 1939 | Licking and Kentucky Rivers | 78 | 2 |
| 18 | [d] | May–July 1947 | Lower Missouri and Middle Mississippi River Basins | 29 | 235 |
| 19 | [d] | June–July 1951 | Kansas and Missouri | 28 | 923 |
| 20 | [d] | August 1955 | Hurricane Diane floods–Northeastern United States | 187 | 714 |
| 21 | [d] | December 1955 | West coast rivers | 61 | 155 |
| 22 | [d] | June 27–30, 1957 | Hurricane Audrey–Texas and Louisiana | 390 | 150 |
| 23 | [d] | December 1964 | California and Oregon | 40 | 416 |
| 24 | [d] | June 1965 | South Platte River Basin, Colorado | 16 | 415 |
| 25 | [c] | September 10, 1965 | Hurricane Betsy–Florida and Louisiana | 75 | 1,420 |
| 26 | [d] | January–February 1969 | Floods in California | 60 | 399 |

*(Continued)*

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**Table 5E.34 (Continued)**

| Number[a] | Type of Flood | Date | Location | Lives Lost | Estimated Damages (Millions of Dollars) |
|---|---|---|---|---|---|
| 27 | c,d | August 17–18, 1969 | Hurricane Camille–Mississippi, Louisiana, and Alabama | 256 | 1,421 |
| 28 | c | July 30–August 5, 1970 | Hurricane Celia–Texas | 11 | 453 |
| 29 | b | February 1972 | Buffalo Creek, West Virginia | 125 | 10 |
| 30 | e | June 1972 | Black Hills, South Dakota | 237 | 165 |
| 31 | c,d | June 1972 | Hurricane Agnes floods–Eastern United States | 105 | 4,020 |
| 32 | d | Spring 1973 | Mississippi River Basin | 33 | 1,155 |
| 33 | d | June–July 1975 | Red River of the North Basin | <10 | 273 |
| 34 | c,d | September 1975 | Hurricane Eloise floods-Puerto Rico and Northeastern United States | 50 | 470 |
| 35 | b | June 1976 | Teton Dam failure, Southeast Idaho | 11 | 1,000 |
| 36 | e | July 1976 | Big Thompson River, Colorado | 139 | 30 |
| 37 | e | April 1977 | Southern Appalachian Mountains area | 22 | 424 |
| 38 | b,e | July 1977 | Johnstown–Western Pennsylvania | 78 | 330 |
| 39 | d | April 1979 | Mississippi and Alabama | <10 | 500 |
| 40 | c | September 12–13, 1979 | Hurricane Frederic floods–Mississippi, Alabama, and Florida | 13 | 2,000 |

[a] Number corresponds to those shown on Figure 3.12.
[b] Dam break flood.
[c] Tidal flood.
[d] Riverine flood.
[e] Flash flood.
[f] Flood wave generated in Lake Okeechobee by hurricane.

*Source*: From Hays, W.W., 1981, Facing Geologic and Hydrologic Hazards, Earth–Science Considerations, U.S. Geological Survey Professional Paper 1240-B.

**Table 5E.35 Sources of Flood Damage Estimates**

| Source | Timespan | Spatial Scale | Scope |
|---|---|---|---|
| National weather service flood damage data sets | 1925–present | Nation State Basin | Estimates of direct physical damage from significant flooding events that result from rainfall or snowmelt |
| Insurance records (National flood insurance program, private insurers) | 1969–present | Nation Community | Personal property claims made by individuals holding flood insurance |
| Disaster assistance records (Federal emergency management agency) | 1992–present | Nation State | Federal and state outlays for public assistance, individual assistance, and temporary housing in presidentially declared disasters |
| State and local government records | Varies | State | Varies |
| Newspaper archives | Varies | Community | Varies |

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**Table 5E.36 Major Flood Disasters of the World**

| Date | Location | Deaths | Date | Location | Deaths |
|---|---|---|---|---|---|
| 1228 | Holland | 100,000 | 1969 Mar 17 | Mundau Valley, Alagoas, | |
| 1642 | China | 300,000 | | Brazil | 218 |
| 1887 | Huang He River, China | 900,000 | 1969 Aug 20–22 | Western Virginia | 189 |
| 1889 May 31 | Johnstown, PA | 2,200 | 1969 Sep 15 | South Korea | 250 |
| 1900 Sep 8 | Galveston, TX | 5,000 | 1969 Oct 1–8 | Tunisia | 500 |
| 1903 June 15 | Heppner, OR | 325 | 1970 May 20 | Central Romania | 160 |
| 1911 | Chang Jiang River, China | 100,000 | 1970 July 22 | Himalayas, India | 500 |
| 1913 Mar 25–27 | Ohio, IN | 732 | 1971 Feb 26 | Rio de Janeiro, Brazil | 130 |
| 1915 Aug 17 | Galveston, TX | 275 | 1972 Feb 26 | Buffalo Creek, WV | 118 |
| 1928 Mar 13 | Collapse of St. Francis | | 1972 June 9 | Rapid City, SD | 236 |
| | Dam, Santa Paula, CA | 450 | 1972 Aug 7 | Luzon Is., Philippines | 454 |
| 1928 Sep 13 | Lake Okeechobee, FL | 2,000 | 1973 Aug 19–31 | Pakistan | 1,500 |
| 1931 Aug | Huang He River, China | 3,700,000 | 1974 Mar 29 | Tubaro, Brazil | 1,000 |
| 1937 Jan 22 | Ohio, Miss. Valleys | 250 | 1974 Aug 12 | Monty-Long, Bangladesh | 2,500 |
| 1939 | Northern China | 200,000 | 1976 June 5 | Teton Dam collapse, ID | 11 |
| 1946 Apr 1 | Hawaii, Alaska | 159 | 1976 July 31 | Big Thompson Canyon, CO | 139 |
| 1947 | Honshu Island, Japan | 1,900 | 1976 Nov 17 | East Java, Indonesia | 136 |
| 1951 Aug | Manchuria | 1,800 | 1977 July 19–20 | Johnstown, PA | 68 |
| 1953 Jan 31 | Western Europe | 2,000 | 1978 June–Sep | Northern India | 1,200 |
| 1954 Aug 17 | Farahzad, Iran | 2,000 | 1979 Jan–Feb | Brazil | 204 |
| 1955 Oct 7–12 | India, Pakistan | 1,700 | 1979 July 17 | Lomblem Is., Indonesia | 539 |
| 1959 Nov 1 | Western Mexico | 2,000 | 1979 Aug 11 | Morvi, India | 5,000–15,000 |
| 1959 Dec 2 | Frejus, France | 412 | 1980 Feb 13–22 | So. CA., AR | 26 |
| 1960 Oct 10 | Bangladesh | 6,000 | 1981 Apr | Northern China | 550 |
| 1960 Oct 31 | Bangladesh | 4,000 | 1981 July | Sichuan, Hubei Prov., China | 1,300 |
| 1962 Feb 17 | German North Sea coast | 343 | 1982 Jan 23 | Nr. Lima, Perui | 600 |
| 1962 Sep 27 | Barcelona, Spain | 445 | 1982 May 12 | Guangdong, China | 430 |
| 1963 Oct 9 | Dam collapse, Vaiont, Italy | 1,800 | 1982June 6 | So. Conn | 12 |
| 1966 Nov 3–4 | Florence, Venice, Italy | 113 | 1982 Sep 17–21 | El Salvador, Guatemala | 1,300+ |
| 1967 Jan 18–24 | Eastern Brazil | 894 | 1982 Dec 2–9 | IL., MO., AR | 22 |
| 1967 Mar 19 | Rio de Janeiro, Brazil | 436 | 1983 Feb–Mar | CA coast | 13 |
| 1967 Nov 26 | Lisbon, Portugal | 464 | 1983 Apr 6–12 | AL., LA, MS., TN | 15 |
| 1968 Aug 7–14 | Gujarat State, India | 1,000 | 1984 May 27 | Tulsa, OK | 13 |
| 1968 Oct 7 | Northeastern India | 780 | 1984 Aug–Sep | S. Korea | 200+ |
| 1969 Jan 18–26 | So. CA | 100 | 1985 July 19 | Northern Italy, dam burst | 361 |

*Source*: From The World Almanac and Book of Facts 1988. *Copyright Pharos Books*, A Scripps Howard Co., New York. Reproduced with permission.

**Table 5E.37 Maximum Flood Flows in the World**

| Country | Station | Basin Area ($km^2$) | Maximum Discharge ($m^3$/sec) | K[a]Value | Year |
|---|---|---|---|---|---|
| U.S.A. (California) | San Rafael San Rafael | 3.2 | 250 | 5.194 | 1973 |
| U.S.A. (California) | L. San Gorgonio Beaumont | 4.5 | 311 | 5.226 | 1969 |
| U.S.A. (Hawaii) | Halawa | 12 | 762 | 5.494 | 1965 |
| U.S.A. (Hawaii) | Waäilua Lihue | 58 | 2,470 | 5.819 | 1963 |
| Cuba | Buey San Miguel | 73 | 2,060 | 5.623 | 1963 |
| Tahiti | Papenoo | 78 | 2,200 | 5.650 | 1983 |
| Mexico | San Bartolo | 81 | 3,000 | 5.859 | 1976 |
| New Caledonia | Ouinne Embouchure | 143 | 4,000 | 5.845 | 1975 |
| Taiwan | Cho Shui | 259 | 7,780 | 6.225 | 1979 |
| New Caledonia | Ouaälème derniers rapides | 330 | 10,400 | 6.389 | 1981 |

*(Continued)*

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**Table 5E.37 (Continued)**

| Country | Station | Basin Area ($km^2$) | Maximum Discharge ($m^3$/sec) | K[a]Value | Year |
|---|---|---|---|---|---|
| New Caledonia | Yaté | 435 | 5,700 | 5.810 | 1981 |
| U.S.A. (New York) | Little Nemaha Syracuse | 549 | 6,370 | 5.826 | 1950 |
| New Zealand | Haast Roaring Billy | 1,020 | 7,690 | 5.765 | 1979 |
| U.S.A. (California) | M.F. American | 1,360 | 8,780 | 5.770 | 1964 |
| Mexico | Cithuatian Paso del Mojo | 1,370 | 13,500 | 6.156 | 1959 |
| Australia | Pioneer Pleystowe | 1,490 | 9,840 | 5.840 | 1918 |
| Taiwan | Hualien Hualien Bridge | 1,500 | 11,900 | 6.011 | 1973 |
| Japan | Nyodo Ino | 1,560 | 13,510 | 6.111 | 1963 |
| Japan | Kiso Imujama | 1,680 | 11,150 | 5.910 | 1961 |
| U.S.A. (Texas) | W. Nueces Bracketville | 1,800 | 15,600 | 6.156 | 1959 |
| India | Macchu | 1,900 | 14,000 | 6.060 | 1979 |
| Taiwan | Tam Shui Taipei Bridge | 2,110 | 16,700 | 6.199 | 1963 |
| Japan | Shingu Oga | 2,350 | 19,025 | 6.290 | 1959 |
| U.S.A. (Texas) | Pedernales Johnson City | 2,450 | 12,500 | 5.873 | 1952 |
| North Korea | Daeryong Gang | 3,020 | 13,500 | 5.830 | 1975 |
| Japan | Yoshino Iwazu | 3,750 | 14,470 | 5.844 | 1974 |
| Philippines | Cagayan Echague Isabella | 4,244 | 17,550 | 5.980 | 1959 |
| Japan | Tone Yattajima | 5,110 | 16,900 | 5.871 | 1947 |
| U.S.A. (Texas) | Nueces Uvalde | 5,504 | 17,400 | 5.870 | 1935 |
| U.S.A. (California) | Eel Scotia | 8,060 | 21,300 | 5.917 | 1964 |
| U.S.A. (Texas) | Pecos Comstock | (9,100) | 26,800 | 6.110 | 1954 |
| Madagascar | Betsiboka Ambodiroka | 11,800 | 22,000 | 5.780 | 1927 |
| North Korea | Toedong Gang Mirim | 12,175 | 29,000 | 6.060 | 1967 |
| South Korea | Han Koan | 23,880 | 37,000 | 6.047 | 1925 |
| Pakistan | Jhelum Mangla | 29,000 | 31,100 | 5.739 | 1929 |
| China | Hanjiang Hankang | 41,400 | 40,000 | 5.868 | 1583 |
| Madagascar | Mangoky Banyan | 50,000 | 38,000 | 5.698 | 1933 |
| India | Narmada Garudeshwar | 88,000 | 69,400 | 6.210 | 1970 |
| China | Chang Jiang Yitchang | 1,010,000 | 110,000 | 5.197 | 1870 |
| U.S.S.R. | Lena Kusur | 2,430,000 | 189,000 | 5.520 | 1967 |
| Brazil | Amazonas Obidos | 4,640,000 | 370,000 | 6.760 | 1953 |

*Note:* Arranged by size of drainage basin.

[a] Flood coefficient $K = 10\ [(1-(\log(Q)-6)/(\log(A)-8)]$ where Q is the largest flood in $m^3$/sec; A is the basin area in $km^2$.

*Source*: From Rodier, J.A., and Roche, M., 1984, World Catalogue of Maximum Observed Floods, International Assoc. Hydrological Sciences Publ. No. 143. Reproduced with permission.

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**Table 5E.38 Tornadoes, Floods, and Tropical Cyclones in the United States, 1931–1984**

| Item | 1931–1935 | 1936–1945 | 1946–1955 | 1956–1965 | 1966–1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tornadoes, number[a] | 830 | 1,514 | 2,969 | 6,572 | 8,030 | 835 | 852 | 788 | 852 | 866 | 783 | 1,046 | 931 | 907 |
| Lives lost, total | 909 | 1,896 | 1,751 | 924 | 1,172 | 44 | 43 | 53 | 84 | 28 | 24 | 64 | 34 | 122 |
| Most in a single tornado | 37 | 216 | 169 | 44 | 58 | 5 | 22 | 16 | 42 | 5 | 5 | 10 | 3 | 16 |
| Property loss of $500,000 and over | 15 | 56 | 130 | 191 | 428 | 46 | 46 | 59 | 73 | 92 | 55 | 92 | 95 | 125 |
| Floods: Lives lost | 368 | 953 | 808 | 557 | 1,528 | 187 | 212 | 125 | 103 | 97 | 90 | 155 | 200 | 126 |
| Property loss (mil. dot.) | 187 | 1,484 | 3,350 | 2,721 | 10,225 | 1,000 | 1,393 | 1,000 | 4,000 | 1,500 | 1,000 | 3,500 | 4,100 | 4,000 |
| North Atlantic tropical cyclones and hurricanes:[b] | | | | | | | | | | | | | | |
| Number reaching U.S. coast | 21 | 41 | 40 | 33 | 25 | 2 | 1 | 2 | 5 | 2 | 2 | 1 | 2 | 2 |
| Hurricanes only | 12 | 19 | 21 | 14 | 13 | 1 | 1 | — | 3 | 1 | — | — | 1 | 1 |
| Lives lost in U.S. | 494 | 768 | 495 | 692 | 504 | 9 | — | 35 | 11 | 2 | — | — | 22 | 4 |

*Note:* — Represents zero.

[a] A violent, rotating column of air descending from a cumulonimbus cloud in the form of a tubular- or funnel-shaped cloud, usually characterized by movements along a narrow path and wind speeds from 100 to over 300 miles per hour. Also known as a "twister" or "waterspout."

[b] Tropical cyclones have maximum winds of 39–73 miles per hour; hurricanes have maximum winds of 74 miles per hour or higher.

*Source*: From Bureau of the Census, Statistical Abstract of the United States 1987 and data from the U.S. National Oceanic and Atmospheric Administration.



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**Table 5E.39 Tornadoes: Floods, Tropical Storms, and Lightning: 1993–2003**

| Weather type | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003, prel. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tornadoes[a] | | | | | | | | | | | |
| Lives lost | 33 | 69 | 30 | 26 | 67 | 130 | 94 | 41 | 40 | 55 | 54 |
| Injuries | (NA) | (NA) | 650 | 705 | 1,033 | 1,868 | 1,842 | 882 | 743 | 968 | 1,087 |
| Property loss (mil. dol.) | (NA) | (NA) | 410.8 | 719.6 | 730.7 | 1,714.2 | 1,989.9 | 423.6 | 630.1 | 801.3 | 1,263.2 |
| Floods and flash floods: | | | | | | | | | | | |
| Lives lost | 103 | 91 | 80 | 131 | 118 | 136 | 68 | 38 | 48 | 49 | 85 |
| Injuries | (NA) | (NA) | 57 | 95 | 525 | 6,440 | 301 | 47 | 277 | 88 | 65 |
| Property loss (mil. dol.) | (NA) | (NA) | 1,250.5 | 2,120.7 | 6,910.6 | 2,324.8 | 1,420.7 | 1,255.1 | 1,220.3 | 655.0 | 2,540.9 |
| North Atlantic tropical storms and hurricanes[b] | 8 | 7 | 19 | 13 | 7 | 14 | 12 | 15 | 15 | 12 | (NA) |
| Number of hurricanes reaching U.S. mainland | 1 | — | 2 | 2 | 1 | 3 | 3 | — | — | 1 | (NA) |
| Direct deaths on U.S. mainland | 2 | 9 | 17 | 37 | 1 | 9 | 19 | — | 24 | 51 | 14 |
| Property loss in U.S. (mil. dol.) | 57.0 | 973.0 | 5,932.3 | 1,436.1 | 667.6 | 3,546.6 | 4,190.1 | 8.1 | 5,187.8 | 1,104.4 | 1,879.5 |
| Lightning: | | | | | | | | | | | |
| Deaths | 43 | 69 | 85 | 52 | 42 | 44 | 46 | 51 | 44 | 51 | 44 |
| Injuries | 295 | 577 | 433 | 309 | 306 | 283 | 243 | 364 | 371 | 256 | 237 |

*Note:* — Represents zero. NA Not available.

[a] U.S. National Weather Service, Internet site <www.spc.noaa.gov/climo/torn/monthlytomstats.html> (accessed 14 April 2004). A violent, rotating column of air descending from a cumulonimbus cloud in the form of a tubular- or funnel-shaped cloud, usually characterized by movements along a narrow path and wind speeds from 100 to over 300 miles per hour. Also known as a "twister" or "waterspout."

[b] National Hurricane Center (NHC), Coral Gables, FL, unpublished data. For data on individual hurricanes, see the NHC web site at www.nhc.noaa.gov/. Tropical storms have winds of 39–73 miles per hour, hurricanes have winds of 74 miles per hour or higher.

*Source*: From, except as noted, U.S. National Oceanic and Atmospheric Administration (NOAA), *Storm Data*, monthly. See also NOAA website at www.nws.noaa.gov/om/hazstats.shtml and www.nws.noaa.gov/om/severeweather/sum03.pdf (released 03 March 2004).

**Table 5E.40 Deaths, Injuries, and Damage Caused by Floods in the United States, 1965–1985**

| Fiscal Year | No. of Events | Persons Killed | Persons Injured | Dwellings Destroyed | Dwellings Damaged | Dwellings Destroyed & Damaged |
|---|---|---|---|---|---|---|
| 1965–66 | 67 | 22 | 102 | 91 | 9,131 | 9,222 |
| 1966–67 | NA | 16 | 161 | 108 | 22,353 | 22,461 |
| 1967–68 | NA | 38 | 824 | 84 | 14,224 | 14,308 |
| 1968–69 | NA | 24 | 284 | 71 | 17,674 | 17,745 |
| 1969–70 | NA | 51 | 783 | 83 | 33,769 | 33,852 |
| 1970–71 | 49 | 22 | 58 | 105 | 6,993 | 7,098 |
| 1971–72 | 77 | 519 | 16,587 | 7,346 | 133,805 | 141,151 |
| 1972–73 | 78 | 105 | 1,559 | 3,229 | 81,467 | 84,696 |
| 1973–74 | 83 | 71 | 366 | 1,417 | 31,309 | 32,726 |
| 1974–75 | 90 | 48 | 500 | 803 | 25,008 | 25,811 |
| 1975–76 | 70 | 55 | 2,071 | 1,377 | 26,179 | 27,556 |
| 1976–77 | 68 | 165 | 1,469 | 3,581 | 35,942 | 39,523 |
| 1977–78 | 106 | 196 | 3,712 | 1,489 | 48,508 | 49,997 |
| 1978–79 | 148 | 143 | 3,842 | 2,659 | 56,646 | 59,305 |
| 1979–80 | 122 | 79 | 1,121 | 887 | 37,439 | 38,326 |
| 1980–81 | 115 | NA | NA | NA | NA | 19,578 |
| 1981–82 | 133 | 70 | 2,561 | NA | NA | 46,256 |
| 1982–83 | 149 | 69 | 1,988 | NA | NA | 48,874 |
| 1983–84 | 121 | 65 | 1,478 | NA | NA | 41,578 |
| 1984–85 | 48 | 9 | 29 | NA | NA | 2,308 |
| Totals | — | — | — | — | — | 762,371 |

*Note:* Based on American National Red Cross data which are by fiscal year (July 1–June 30).

*Source*: From Rubin, C.B., Yezer, A. M., Hussain, Q, and Webb, A., 1986, Summary of Major Natural Disaster Incidents in the U.S. 1965–85, Natural Hazards Research and Applications Information Center, George Washington University Spec. Publ. 17.

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**Table 5E.41 Deaths Caused by Floods in the United States in 1987**

| State | Boat | Open | Other | Outside | Perm. Home | Playing | Auto | All |
|---|---|---|---|---|---|---|---|---|
| AL | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| AR | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| GA | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| HI | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 3 |
| IL | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| IN | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 |
| KY | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 |
| MA | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| MI | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| MN | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| NY | 0 | 0 | 0 | 1 | 0 | 0 | 10 | 11 |
| OK | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 3 |
| OR | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| PA | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| PR | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 7 |
| SC | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| TN | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| TX | 0 | 1 | 1 | 1 | 0 | 0 | 14 | 17 |
| VA | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 3 |
| VT | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Total | 1 | 3 | 1 | 10 | 1 | 2 | 52 | 70 |
| Percent | 1% | 4% | 1% | 14% | 1% | 3% | 74% | 99%[a] |

*Note:* By location; flash floods and floods.

[a] Rounding to the nearest percent causes the column to sum to less than 100 percent.

*Source*: From Peters, B.E., 1988, *National Weather Service*, Fort Worth, TX.

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**Table 5E.42 Flood Fatalities**

| Flood Fatalities | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Annual Total | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 2004 | 79/51 | 3/3 | 2/0 | 3/3 | 9/9 | 13/13 | 2/2 | 5/4 | 9/8 | 25/5 | 2/1 | 3/2 | 311 |
| 2003 | 99/47 | 0/0 | 7/5 | 0/0 | 8/2 | 14/9 | 14/12 | 9/3 | 14/9 | 1/1 | 3/3 | 12/3 | 17/0 |
| 2002 | 50/31 | 7/4 | 0/0 | 4/2 | 2/1 | 15/8 | 0/0 | 10/6 | 2/1 | 1/1 | 3/3 | 1/0 | 5/5 |
| 2001 | 66/31 | 0/0 | 5/4 | 3/1 | 1/1 | 6/2 | 21/8 | 12/5 | 7/2 | 0/0 | 0/0 | 9/7 | 2/1 |
| 2000 | 41/20 | 0/0 | 5/2 | 2/2 | 0/0 | 0/0 | 6/5 | 3/0 | 6/3 | 4/2 | 9/1 | 4/4 | 2/1 |
| 1999 | 77/40 | 12/11 | 0/0 | 0/0 | 7/2 | 2/1 | 7/4 | 6/2 | 2/0 | 38/17 | 3/3 | 0/0 | 0/0 |
| 1998 | 136/86 | 18/14 | 10/6 | 16/13 | 6/4 | 3/0 | 16/9 | 8/4 | 16/4 | 3/0 | 38/31 | 2/1 | 0/0 |
| 1997 | 98 | | | | | | | | | | 3/0 | 4/0 | 2/2 |

| Flood Fatalities | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Year Annual | Year | Annual Total | Year | Annual Total | Year | Annual Total | Year | Annual Total |
| 1996 | 131 | 1979 | 121 | 1959 | 25 | 1939 | 83 | 1919 | 2 |
| 1995 | 103 | 1978 | 143 | 1958 | 47 | 1938 | 180 | 1918 | 0 |
| 1994 | 70 | 1977 | 210 | 1957 | 82 | 1937 | 142 | 1917 | 80 |
| 1993 | 109 | 1976 | 193 | 1956 | 42 | 1936 | 142 | 1916 | 118 |
| 1992 | 87 | 1975 | 107 | 1955 | 302 | 1935 | 236 | 1915 | 49 |
| 1991 | 58 | 1974 | 121 | 1954 | 55 | 1934 | 88 | 1914 | 180 |
| 1990 | 125 | 1973 | 148 | 1953 | 40 | 1933 | 33 | 1913 | 527 |
| 1989 | 74 | 1972 | 554 | 1952 | 54 | 1932 | 11 | 1912 | 2 |
| 1988 | 37 | 1971 | 74 | 1951 | 51 | 1931 | 0 | 1911 | 0 |
| 1987 | 88 | 1970 | 135 | 1950 | 93 | 1930 | 14 | 1910 | 0 |
| 1986 | 208 | 1969 | 297 | 1949 | 48 | 1929 | 89 | 1909 | 5 |
| 1985 | 70 | 1968 | 31 | 1948 | 82 | 1928 | 15 | 1908 | 11 |
| 1984 | 125 | 1967 | 34 | 1947 | 55 | 1927 | 423 | 1907 | 7 |
| 1983 | 200 | 1966 | 31 | 1946 | 28 | 1926 | 16 | 1906 | 1 |
| 1982 | 155 | 1965 | 119 | 1945 | 91 | 1925 | 36 | 1905 | 2 |
| 1981 | 84 | 1964 | 100 | 1944 | 33 | 1924 | 27 | 1904 | 0 |
| 1980 | 82 | 1963 | 39 | 1943 | 107 | 1923 | 42 | 1903 | 178 |
| | | 1962 | 19 | 1942 | 68 | 1922 | 215 | | |
| | | 1961 | 52 | 1941 | 47 | 1921 | 143 | | |
| | | 1960 | 32 | 1940 | 60 | 1920 | 42 | | |

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**Table 5E.43 Major Natural Disasters in the United States, 1965–1985**

| Type of Disaster | Number | Federal Outlay (thousands of current dollars) | Federal Outlay (thousands of 1982 dollars) |
|---|---|---|---|
| Ice and snow events | 19 | 151,427 | 205,511 |
| Hurricanes/tropical storms | 39 | 1,173,141 | 1,947,939 |
| Earthquakes | 7 | 203,881 | 405,706 |
| Dam and levee failures | 7 | 55,764 | 80,806 |
| Rains, storms & flooding[a] | 337 | 1,684,702 | 2,439,852 |
| High winds & waves | 2 | 125,313 | 120,536 |
| Coastal storms & flooding | 7 | 158,261 | 205,357 |
| Tornadoes | 109 | 441,685 | 648,352 |
| Drought/water shortage | 4 | 1,134 | 5,344 |
| Totals | 531 | 3,995,308 | 6,059,403 |

*Note:* Federally-declared disasters, by type.

[a] Includes land, mud, and debris flows and slides.

*Source*: From Rubin, C.B., Yezer, A.M., Hussain, Q, and Webb, A., 1986, Summary of Major Natural Disaster Incidents in the U.S. 1965–85, Natural Hazards Research and Applications Information Center, George Washington University Spec. Publ. 17.

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**Table 5E.44 No. 375. Major U.S. Weather Disasters: 1990–2003**

| Event | Description | Estimated cost | | |
|---|---|---|---|---|
| | | Time period | (bill. dot.) | Deaths |
| Southern California wildfires | Dry weather, high winds, and resulting wildfires in southern CA burned 743,000 acres & destroyed 3,700 homes | Oct–early Nov 2003 | 2.5 | 22 |
| Hurricane Isabel | Category 2 hurricane makes landfall in eastern NC, causing damage along coasts of NC, VA, and MD with wind damage and flooding in NC, VA, MD, DE, WV, NJ, NY and PA | September 2003 | over 4 | 47 |
| Midwest severe storms and tornadoes | Numerous tornadoes over the Midwest, MS River valley, and OH/TN River valleys with record 400 tornadoes in one week | Early May 2003 | over 3.1 | 41 |
| Storms and hail | Sever storms and large hail over southern plains, lower MS River valley, and TX | Early April 2003 | over 1.6 | — |
| Widespread drought | Moderate to extreme drought over large portions of 30 states | Spring to fall 2002 | over 10 | — |
| Western fire season | Major fires over 11 western states from Rockies to west coast | Spring to fall 2002 | over 2 | 21 |
| Tropical Storm Allison | Tropical storm produced rainfall and severe flooding in coastal portions of TX & LA & damage in MS, FL, VA. and PA | June 2001 | 5.0 | 43 |
| Midwest and Ohio Valley hail and tornadoes | Storms, tornadoes, and hail in TX, OK, KS, NE, IA, MO, IL, IN, WI, MI, OH, KY, and PA | April 2001 | 1.7 | 3 |
| Southern drought/heat wave | Severe drought and heat over south-central and southeast states cause significant losses in agriculture and related industries | Springer-summer 2000 | over 4.0 | 140 |
| Western fire season | Severe fire season in western states | Spring-summer 2000 | over 2.0 | — |
| Hurricane Floyd | Category 2 hurricane in NC, causing severe flooding in NC and some flooding in SC, VA, MD, PA, NY, NJ, DE, RI, CT, MA, and VT | September 1999 | 6.0 | 75 |
| Drought/heat wave | Drought/heatwave over eastern U.S. | Summer 1999 | 1.0 | 256 |
| Oklahoma-Kansas tornadoes | Category F4–F5 tornadoes hit OK, KS, TX, and TN | May 1999 | 1.0 | 55 |
| Arkansas-Tennessee tornadoes | Two outbreaks of tornadoes in 6-day period | January 1999 | 1.3 | 31 |
| Texas flooding | Severe flooding in southeast Texas from 2 heavy rain events with 10–20 in. totals | Oct–Nov 1998 | 1.0 | 31 |
| Hurricane Georges | Category 2 hurricane in Puerto Rico, Florida Keys, and Gulf coasts fo LA, MS, AL, and FL | September 1998 | 3–4 | 16 |
| Hurricane Bonnie | Category 3 hurricane in eastern NC and VA | August 1998 | 1.0 | 2 |
| Southern drought/heat wave | Severe drought and heat wave from TX/OK to the Carolinas | Summer 1998 | 6.0 | 200 |
| Minnesota severe storms/hail | Very damaging severe thunderstorms with large hail over wide areas of Minnesota | May 1998 | 1.5 | 1 |
| Southeast severe weather | Tornadoes and flooding related to strong El Nino in the southeast | Winter/Spring 1998 | 1.0 | Over 130 |
| Northeast ice storm | Intense ice storm hits ME, NH, VT, and NY | January 1998 | 1.4 | 16 |
| Northern plains flooding | Severe flooding in Dakotas and Minnesota due to heavy spring snowmelt | April–May 1997 | 2.0 | 11 |
| MS and OH valleys flooding and tornadoes | Tornadoes and severe flooding hit the slates of AR, MO, MS, TN, IL, IN, KY, OH, and WV | March 1997 | 1.0 | 67 |
| West Coast flooding | Flooding from rains and snowmelt in CA, WA, OR, ID, NV, & MT | Dec 1996–Jan 1997 | 2–3 | 36 |
| Hurricane Fran | Category 3 hurricane in NC and VA | Sep 1996 | 5.0 | 37 |
| Southern Plains severe drought | Drought in agricultural areas of TX & OK | Fall 1995-summer 1996 | Over 4 | (NA) |
| Pacific Northwest severe flooding | Flooding from heavy rain & snowmelt in OR, WA, ID, and MT. | Feb 1996 | 1.0 | 9 |
| Blizzard of ’96 followed by flooding | Heavy snowstorm followed by severe flooding in Appalachians, Mid-Atlantic, and Northeast | Jan 1996 | 3.0 | 187 |
| Hurricane Opal | Category 3 hurricane in FL, AL, parts of GA, TN, & Carolinas. | Oct 1995 | Over 3 | 27 |
| Hurricane Marilyn | Category 2 hurricane in Virgin Islands | Sep 1995 | 2.1 | 13 |
| TX/OK/LA/MS severe weather and flooding | Flooding, hail, & tornadoes across TX, OK, parts of LA, MS, Dallas & New Orleans hardest hit | May 1995 | 5–6 | 32 |

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| | | | | |
|---|---|---|---|---|
| California flooding | Flooding from frequent winter storms across much of CA | Jan–Mar 1995 | 3.0 | 27 |
| Western Fire Season | Severe fire season in western states due to dry weather | Summer-Fall 1994 | 1.0 | (NA) |
| Texas flooding | Flooding from torrential rain & thunderstorms across southeast TX | Oct 1994 | 1.0 | 19 |
| Tropical Storm Alberto | Flooding due to 10–25 inch rain across GA, AL, part of FL intense ice storm in pts of TX, OK, AR, LA, MS, AL, TN, GA, | July 1994 | 1.0 | 32 |
| Southeast ice storm | SC, NC, & VA | Feb 1994 | 3.0 | 9 |
| California wildfires | Out-of-control wildfires over southern CA | Fall 1993 | 1.0 | 4 |
| Midwest flooding | Extreme flooding across central U.S. | Summer 1993 | 15–20 | 48 |
| Drought/heat wave | Extreme drought/heatwave across southeastern U.S. | Summer 1993 | 1.0 | (NA) |
| Storm/blizzard | "Storm of the Century" hits entire eastern seaboard | Mar 1993 | 3–6 | 270 |
| Nor'easter of 1992 | Slow-moving storm batters northeast U.S. coast, New England. | Dec 1992 | 1–2 | 19 |
| Hurricane Iniki | Category 4 hurricane hit Hawaiian Island of Kauai | Sep 1992 | 1.8 | 7 |
| Hurricane Andrew | Category 4 hurricane hit FL & LA | Aug 1992 | 27.0 | 58 |
| Oakland Firestorm | Oakland, CA firestorm due to low humidity & high winds | Oct 1991 | 1.5 | 25 |
| Hurricane Bob | Category 2 hurricane-mainly coastal NC, Long Island, & New England | Aug 1991 | 1.5 | 18 |
| TX/OK/LA/AR Flooding | Torrential rains cause flooding along Trinity, Red, and Arkansas rivers | May 1990 | 1.0 | 13 |

*Note:* 5.0 represents $5,000,000,000. Covers only weather related disasters costing $1 billion or more. — Represents zero. NA not available or not reported. $del.

*Source*: From U.S. National Oceanic and Atmospheric Administration. National Climatic Data Center, "Billion Dollar U.S. Weather Disasters, 1980–2003" (release date: March 2, 2004). See also <www.ncdc.noaa.gov/oa/reports/billionz.html#TOP> (released 02 March 2004).



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**Table 5E.45 Deaths, Injuries, and Damage Caused by Hurricanes in the United States, 1965–1985**

| Fiscal Year | No. of Events | Persons Killed | Persons Injured | Dwellings Destroyed | Dwellings Damaged | Dwellings Destroyed & Damaged |
|---|---|---|---|---|---|---|
| 1965–66 | 5 | 72 | 25,202 | 2,059 | 148,607 | 150,666 |
| 1966–67 | NA | 0 | 13 | 6 | 316 | 322 |
| 1967–68 | NA | 19 | 11,396 | 388 | 29,405 | 29,793 |
| 1968–69 | NA | 2 | 45 | 1 | 705 | 706 |
| 1969–70 | NA | 272 | 9,062 | 6,046 | 48,734 | 54,780 |
| 1970–71 | 5 | 9 | 4,498 | 1,887 | 34,442 | 36,329 |
| 1971–72 | 4 | 2 | 235 | 36 | 24,258 | 24,294 |
| 1972–73 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1973–74 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1974–75 | 2 | 3 | 8 | 45 | 2,514 | 2,559 |
| 1975–76 | 3 | 32 | 4,409 | 4,642 | 31,670 | 36,312 |
| 1976–77 | 1 | 2 | 23 | 15 | 498 | 513 |
| 1977–78 | 3 | 0 | 8 | 6 | 142 | 148 |
| 1978–79 | 1 | 0 | 0 | 1 | 3 | 4 |
| 1979–80 | 6 | 20 | 6,765 | 6,897 | 65,033 | 71,930 |
| 1980–81 | 2 | NA | NA | NA | NA | 14,865 |
| 1981–82 | 1 | 0 | 0 | NA | NA | 3 |
| 1982–83 | 2 | 2 | 961 | NA | NA | 7,454 |
| 1983–84 | 4 | 16 | 3,094 | NA | NA | 18,663 |
| 1984–85 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | — | — | — | — | — | 449,341 |

*Note:* Based on American National Red Cross data which are by fiscal year (July 1–June 30).

*Source*: From Rubin, C.B., Yezer, A.M., Hussain, Q, and Webb, A., 1986, Summary of Major Natural Disaster Incidents in the U.S. 1965–85, Natural Hazards Research and Applications Information Center, George Washington University Spec. Publ. 17.

**Table 5E.46 Public and Private Outlays for Hurricane Damage in the United States, 1965–1985**

| State | Year | Federal Outlay (in Thousands of Dollars) | Insurance Payment (in Thousands of Dollars) | States Affected |
|---|---|---|---|---|
| LA | 1965 | 38,543 | 500,000 | LA,FL,MS |
| FL | 1965 | 1,706 | | |
| MS | 1965 | 1,783 | | |
| | | 42,032 | | |
| TX | 1967 | 9,925 | 34,800 | TX |
| FL | 1968 | 640 | 2,580 | FL |
| MS | 1969 | 74,524 | 165,300 | MS,LA,AL,FL |
| LA | 1969 | 15,167 | | |
| AL | 1969 | 918 | | |
| | | 90,609 | | |
| TX | 1970 | 35,808 | 309,950 | TX |
| LA | 1971 | 1,160 | 4,730 | LA,MS |
| FL | 1972 | 3,361 | 97,853 | FL,NY,VA,PA MD,WV,OH,GA SC,NC,MI,DE DC,NJ,CT,RI MA,VT,ME |
| NY | 1972 | 98,098 | | |
| VA | 1972 | 16,815 | | |
| PA | 1972 | 351,531 | | |
| MD | 1972 | 23,309 | | |
| WV | 1972 | 1,294 | | |
| OH | 1972 | 1,453 | | |
| | | 495,861 | | |
| LA | 1974 | 4,565 | 14,721 | LA |

*(Continued)*

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**Table 5E.46 (Continued)**

| State | Year | Federal Outlay (in Thousands of Dollars) | Insurance Payment (in Thousands of Dollars) | States Affected |
|---|---|---|---|---|
| NY | 1976 | 6,773 | 22,697 | NY,NJ,CT,MA |
| CA | 1976 | 8,507 | NA | — |
| AL | 1979 | 189,893 | 752,510 | AL,MS,FL,GA SC,NC,VA,MD DC,DE,PA,NJ NY,CT,MA |
| MS | 1979 | 33,684 | | |
| FL | 1979 | 3,691 | | |
| | | 227,268 | | |
| TX | 1980 | 31,817 | 57,911 | TX |
| TX | 1980 | 386 | NA | — |
| HI | 1982 | 11,920 | 137,000 | HI |
| TX | 1983 | 40,038 | 675,520 | TX |
| NC | 1984 | 3,460 | 36,000 | NC,SC |
| MS | 1985 | 18,929 | 543,304 | MS,AL,FL,LA |
| AL | 1985 | 4,647 | | |
| FL | 1985 | 13,933 | | |
| | | 37,509 | | |
| PA | 1985 | 9,233 | 418,750 | PA,CT,RI,NJ NY,MA,NC,VA MD,DE,NH,VT ME |
| CT | 1985 | 21,359 | | |
| RI | 1985 | 5,846 | | |
| NJ | 1985 | 4,613 | | |
| NY | 1985 | 38,750 | | |
| MA | 1985 | 13,862 | | |
| | | 93,663 | | |
| LA | 1985 | 23,962 | 44,000 | LA,MS,AL,FL |
| FL | 1985 | 7,238 | 77,600 | FL,GA |
| TOTAL NO = 39 | | 1,173,141 | 3,895,226 | |

*Source*: From Rubin, C.B., Yezer, A.M., Hussain, Q, and Webb, A., 1986, Summary of Major Natural Disaster Incidents in the U.S. 1965–85, Natural Hazards Research and Applications Information Center, George Washington University Spec. Publ. 17.

**Table 5E.47 U.S. Hurricane Strikes by Decade Number of Hurricanes by Saffir-Simpson Category to Strike the Mainland U.S. Each Decade.**

| | Saffir-Simpson Category[a] | | | | | | |
|---|---|---|---|---|---|---|---|
| Decade | 1 | 2 | 3 | 4 | 5 | All 1–5 | Major 3–5 |
| 1900–1909 | 5 | 5 | 4 | 2 | 0 | 16 | 6 |
| 1910–1919 | 8 | 3 | 5 | 3 | 0 | 19 | 8 |
| 1920–1929 | 6 | 4 | 3 | 2 | 0 | 15 | 5 |
| 1930–1939 | 4 | 5 | 6 | 1 | 1 | 17 | 8 |
| 1940–1949 | 7 | 8 | 7 | 1 | 0 | 23 | 8 |
| 1950–1959 | 8 | 1 | 7 | 2 | 0 | 18 | 9 |
| 1960–1969 | 4 | 5 | 3 | 2 | 1 | 15 | 6 |
| 1970–1979 | 6 | 2 | 4 | 0 | 0 | 12 | 4 |
| 1980–1989 | 9 | 1 | 5 | 1 | 0 | 16 | 6 |
| 1990–1999 | 3 | 6 | 4 | 0 | 1[b] | 14 | 5 |
| 2000–2009 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1900–1999 | 61 | 39 | 48 | 14 | 3 | 165 | 65 |

[a] Only the highest Saffir-Simpson Category to affect the U.S. has been used.
[b] This reflects the Hurricane Andrew reanalysis and upgrade from Category 4 to Category 5

*Source*: From www.nhc.noaa.gov.

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## SECTION 5F FLOOD PREVENTION

**Table 5F.48 Strategies and Tools for Achieving Flood Hazard Reduction**

**Nonstructural**

A. Modify susceptibility to flood damage and disruption
- 1. Floodplain regulations
  - a. State regulations for flood hazard areas
  - b. Local regulations for flood hazard areas
    - (1) Zoning
    - (2) Subdivision regulations
    - (3) Building codes
    - (4) Housing codes
    - (5) Sanitary and well codes
    - (6) Other regulatory tools
- 2. Development and redevelopment policies
  - a. Design and location of services and utilities
  - b. Land-right acquisition and open-space use
  - c. Redevelopment and renewal
  - d. Permanent evacuation
- 3. Disaster preparedness and response planning
- 4. Floodproofing
- 5. Flood forecasting and warning systems and emergency plans

B. Modify the impact of flooding on individuals and the community
- 1. Information and education
- 2. Flood insurance
- 3. Tax adjustments
- 4. Flood emergency measures
- 5. Postflood recovery

**Structural**

C. Modify flooding
- 1. Dams and reservoirs
- 2. Dikes, levees, and floodwalls
- 3. Channel alterations
- 4. High-flow diversions and spillways
- 5. Land treatment measures
- 6. On-site detention measures

*Source*: From U.S. Water Resources Council, 1981.

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**Table 5F.49 Structural Adjustments as Floodproofing Measures**

| Measure | Material Protected | Class of Measure | Prerequisites | |
|---|---|---|---|---|
| | | | Structural | Hydrologic |
| Seepage control | St–Co | P–C | Well constructed | None |
| Sewer adjustment | St–Co | P–C | None | H–W |
| Permanent closure | St–Co | P | Impervious walls | H–S |
| Openings protected | St–Co | C–E | Impervious walls | H–S–W |
| Interiors protected | St | P–C | None | S–W |
| Protective coverings | St–Co | P–C–E | None | H–W–F |
| Fire protection | St–Co | P | None | None |
| Appliance protection | Co | E | None | W |
| Utilities service | Co | P–C–E | None | S–W–V |
| Roadbed protection | St | P–E | Sound structure | H–W–V–D |
| Elevation | St–Co | P–C–E | Sound structure | S–W–V–F |
| Temporary removal | Co | E | None | W–F |
| Rescheduling | Co | E | Alternatives | W |
| Proper salvage | Co | — | None | None |
| Watertight caps | Co | P–C | None | W |
| Proper anchorage | St–Co | P–C | Sound structure | S–W–V–D |
| Underpinning | St | P | Sound structure | V |
| Timber treatment | St | P | None | None |
| Deliberate flooding | St–Co | E | None | None |
| Structural design | St–Co | P | Design | H–S |
| Reorganized use | Co | P | Alternatives | None |

St = structure; P = permanent; H = hydrostatic pressure; F = flood-to-peak interval; Co = content; C = contingent; S = stage of flood; V = velocity of flow; E = emergency; W = warning; D = duration of flood.

*Source*: From Schaeffer, Univ. Chicago, Dept. Geography Research Paper, 1960.

**Table 5F.50 Flood Safety Rules**

**Before the Flood**

1. Keep on hand materials like sandbags, plywood, plastic sheeting, and lumber
2. Install check valves in building sewer traps, to prevent flood water from backing up in sewer drains
3. Arrange for auxiliary electrical supplies for hospitals and other operations which are critically affected by power failure
4. Keep first aid supplies at hand
5. Keep your automobile fueled; if electric power is cut off, filling stations may not be able to operate pumps for several days
6. Keep a stock of food which requires little cooking and no refrigeration; electric power may be interrupted
7. Keep a portable radio, emergency cooking equipment, lights and flashlights in working order

**When You Receive a Flood Warning**

8. Store drinking water in clean bathtubs, and in various containers. Water service may be interrupted
9. If forced to leave your home and time permits, move essential items to safe ground; fill tanks to keep them from floating away; grease immovable machinery
10. Move to a safe area before access is cut off by flood water

**During the Flood**

11. Avoid areas subject to sudden flooding
12. Do not attempt to cross a flowing stream where water is above your knees
13. Do not attempt to drive over a flooded road—you can be stranded, and trapped

**After the Flood**

14. Do not use fresh food that has come in contact with flood waters
15. Test drinking water for potability; wells should be pumped out and the water tested before drinking
16. Seek necessary medical care at nearest hospital. Food, clothing, shelter, and first aid are available at Red Cross shelters
17. Do not visit disaster area; your presence might hamper rescue and other emergency operations
18. Do not handle live electrical equipment in wet areas; electrical equipment should be checked and dried before returning to service
19. Use flashlights, not lanterns or torches, to examine buildings; flammables may be inside
20. Report broken utility lines to appropriate authorities

During any flood emergency, stay tuned to your radio or television station. Information from NOAA and civil emergency forces may save your life.

*Source*: From Environmental Science Services Administration, 1966.

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**Table 5F.51 Methods of Flood Control and Organization**

Solutions for the flood problem fall into two distinct classes. The first includes those aimed at preventing the overflow of valley lands. The second embraces measures for human adjustment to the flood hazard

The overflow of the valley lands may be prevented, or reduced in frequency and extent, by

1. Providing an additional or an alternative channel to carry flood flows;
2. Increasing the capacity of the existing channel, so that the same flood may be passed downstream at lesser heights, thus reducing flood damages—a solution commonly known as channel improvement;
3. Reducing flood heights and damages by holding back a part of the floodwaters by means of reservoirs;
4. Constructing levees and flood walls to prevent the spread of floodwaters, or
5. Any combination of the above.

Measures of the second class, aimed at adjustment to the hazard include

1. Zoning of the flood plain to inhibit the development of high damageable values in hazardous areas;
2. Abandonment of efforts to use parts of the flood plain;
3. Use of flood forecasting so that damage may be minimized by removal of people and movable property;
4. Use of flood insurance, not to reduce flood damages, but to spread out the cost of floods over a period of years and thus minimize economic shock;
5. Flood relief in the event of disasters.

*Source*: From Task Force on Water Resources and Power, 1955.

## SECTION 5G FLOOD CONTROLS WORKS

**Table 5G.52 Upstream Flood Control Works in the United States**

| Region | Projects | Watershed Area | Flood Prevention Cost | | | |
|---|---|---|---|---|---|---|
| | | | Land Treatment | Reservoirs | Channel Improvement | Total |
| | *No.* | *1,000 acres* | *Mil. dol.* | *Mil. dol.* | *Mil. dol* | *Mil. dol.* |
| North Atlantic | 120 | 4,906 | 27.0 | 108.8 | 52.5 | 181.3 |
| South Atlantic-Gulf | 163 | 8,897 | 93.9 | 88.6 | 75.5 | 258.0 |
| Great Lakes | 21 | 879 | 11.3 | 6.4 | 7.8 | 25.5 |
| Ohio | 89 | 4,442 | 45.5 | 78.8 | 30.7 | 155.0 |
| Tennessee | 21 | 1,440 | 11.8 | 18.8 | 10.1 | 40.7 |
| Upper Mississippi | 49 | 2,052 | 10.9 | 23.8 | 8.4 | 43.1 |
| Lower Mississippi | 104 | 6,895 | 80.6 | 65.9 | 65.9 | 212.4 |
| Souris-Red-Rainy | 21 | 2,882 | 3.8 | 4.0 | 15.8 | 23.6 |
| Missouri | 184 | 4,938 | 118.9 | 176.4 | 31.1 | 326.4 |
| Arkansas-White-Red | 153 | 12,438 | 94.4 | 274.1 | 27.5 | 369.0 |
| Texas-Gulf | 83 | 14,616 | 65.2 | 113.6 | 24.9 | 203.7 |
| Rio Grande | 29 | 1,512 | 4.7 | 14.3 | 2.0 | 21.0 |
| Upper Colorado | 6 | 517 | 3.2 | 9.7 | 4.3 | 17.2 |
| Lower Colorado | 10 | 884 | 5.6 | 17.0 | 7.7 | 30.3 |
| Great Basin | 13 | 871 | 5.6 | 8.8 | 1.2 | 15.6 |
| Columbia-North Pacific | 24 | 768 | 5.7 | 15.0 | 6.8 | 27.5 |
| California | 31 | 1,402 | 11.2 | 25.7 | 77.2 | 114.1 |
| Alaska | 0 | 0 | 0 | 0 | 0 | 0 |
| Hawaii | 5 | 278 | 0.5 | 0.9 | 10.3 | 11.7 |
| Puerto Rico-Virgin Islands | 3 | 252 | 2.7 | 3.2 | 7.6 | 13.5 |
| Total | 1,129 | 70,869 | 602.5 | 1,046.8 | 467.3 | 2,089.6 |

*Note:* Data covers the existing and approved program of the Soil Conservation Service only. In addition, there have been many projects in upstream areas constructed by the Corps of Engineers, the Bureau of Reclamation, and the Bureau of Land Management. Neither the totals nor regional data are available, but this construction amounted to over 1,000 projects, with an estimated cost of about $1 billion.

*Source*: From U.S. Water Resources Council, 1968.

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**Table 5G.53 Downstream Flood Control Works in the United States**

| Region | Reservoirs | | | Levees and Floodwalls | | | Channel Improvement | | |
|---|---|---|---|---|---|---|---|---|---|
| | Projects | Storage | Cost[a] | Projects | Structures | Cost | Projects | Improvement | Cost |
| | *No.* | *1,000 af* | *Mil. dol.* | *No.* | *Miles* | *Mil. dol.* | *No.* | *Miles* | *Mil. dol.* |
| North Atlantic | 5 | 492 | 36.0 | 36 | 132 | 144.4 | 25 | 54 | 27.3 |
| South Atlantic-Gulf | 7 | 3,090 | 49.8 | [b] | 876 | 154.4 | 23 | 185 | 5.1 |
| Great Lakes | 1 | 377 | 23.4 | 6 | 7 | 1.3 | 9 | 28 | 7.1 |
| Ohio | 36 | 12,500 | 600.0 | 65 | 252 | 202.0 | [b] | 138 | [b] |
| Tennessee | 17 | 11,590 | 180.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Upper Mississippi | 14 | 3,020 | 54.0 | 65 | 861 | 242.0 | 19 | 70 | 8.7 |
| Lower Mississippi | 5 | 4,400 | 76.7 | [b] | 1,621 | 841.0 | [b] | 3,348 | 980.0 |
| Souris-Red-Rainy | 5 | 1,030 | 1.8 | 2 | 2 | 2.7 | 7 | 224 | 2.9 |
| Missouri | 56 | 20,700 | 656.0 | 50 | 1,130 | 193.6 | 7 | 75 | 22.2 |
| Arkansas-White-Red | 43 | 24,800 | 635.5 | 56 | 1,023 | 52.4 | 39 | 563 | 54.0 |
| Texas-Gulf | 20 | 8,600 | 234.2 | 5 | 128 | 121.4 | 8 | 106 | 94.4 |
| Rio Grande[c] | 4 | 795 | 31.1 | 5 | 205 | 7.6 | 7 | 114 | 10.5 |
| Upper Colorado | 3 | 1,500 | 5.5 | 8 | 5 | 0.2 | 1 | 1 | 20.0 |
| Lower Colorado | 6 | 12,100 | 59.6 | 2 | 7 | 3.2 | 1 | 4 | 0.5 |
| Great Basin | 6 | 386 | 7.4 | 4 | 33 | 1.6 | 3 | 23 | 1.4 |
| Columbia-North Pacific | 24 | 15,210 | 320.7 | 103 | 546 | 28.1 | 27 | 55 | 27.7 |
| California | 11 | 3,720 | 186.5 | 13 | 1,515 | 260.6 | 12 | 84 | 91.4 |
| Alaska | 0 | 0 | 0 | 2 | 3 | 0.6 | 1 | 1 | 0.1 |
| Hawaii | 0 | 0 | 0 | 4 | 6 | 0.2 | 4 | 3 | 0.2 |
| Puerto Rico-Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total[d] | 263 | 124,310 | 3,158 | 426+ | 8,352 | 2,257 | 193+ | 5,076 | 1,354+ |

[a] Does not include cost of flood control storage in Bureau of Reclamation projects.
[b] Not reported.
[c] Does not include some facilities constructed by the International Boundary and Water Commission.
[d] Rounded.

*Source*: From U.S. Water Resources Council, 1968.

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## SECTION 5H WATER AREAS — UNITED STATES

**Table 5H.54 Coastline of the United States (by State)**

| | General Coastline[a] | | Tidal Shoreline[b] | |
|---|---|---|---|---|
| **State** | **Statute Miles** | **Kilometers** | **Statute Miles** | **Kilometers** |
| **U.S.** | 12,383 | 19,924 | 88,633 | 142,610 |
| **Atlantic coast** | 2,069 | 3,329 | 28,673 | 46,135 |
| Connecticut | — | — | 618 | 994 |
| Delaware | 28 | 45 | 381 | 613 |
| Florida | 580 | 933 | 3,331 | 5,360 |
| Georgia | 100 | 161 | 2,344 | 3,771 |
| Maine | 228 | 367 | 3,487 | 5,596 |
| Maryland | 31 | 50 | 3,190 | 5,133 |
| Massachusetts | 192 | 309 | 1,519 | 2,444 |
| New Hampshire | 13 | 21 | 131 | 211 |
| New Jersey | 130 | 209 | 1,792 | 2,883 |
| New York | 127 | 204 | 1,850 | 2,977 |
| North Carolina | 301 | 484 | 3,375 | 5,430 |
| Pennsylvania | — | — | 89 | 143 |
| Rhode Island | 40 | 64 | 384 | 618 |
| South Carolina | 187 | 301 | 2,876 | 4,627 |
| Virginia | 112 | 180 | 3,315 | 5,334 |
| **Gulf coast** | 1,631 | 2,624 | 17,141 | 27,580 |
| Alabama | 53 | 85 | 607 | 977 |
| Florida | 770 | 1,239 | 5,095 | 8,198 |
| Louisiana | 397 | 639 | 7,721 | 12,423 |
| Mississippi | 44 | 71 | 359 | 578 |
| Texas | 367 | 591 | 3,359 | 5,405 |
| **Pacific coast** | 7,623 | 12,265 | 40,298 | 64,839 |
| Alaska | 5,580 | 8,978 | 31,383 | 50,495 |
| California | 840 | 1,352 | 3,427 | 5,514 |
| Hawali | 750 | 1,207 | 1,052 | 1,693 |
| Oregon | 296 | 476 | 1,410 | 2,269 |
| Washington | 157 | 253 | 3,026 | 4,869 |
| **Arctic coast** | | | | |
| Alaska | 1,060 | 1,706 | 2,521 | 4,056 |

*Note:* — Represents zero.

[a] Figures are lengths of general outline of seacoast. Measurements were made with a unit measure of 30 min of latitude on charts as near the scale of 1:1,200,000 as possible. Coastline of sounds and bays is included to a point where they narrow to width of unit measure, and includes the distance across at such point.

[b] Figures obtained in 1939–1940 with a recording instrument on the largest-scale charts and maps then available. Shoreline of outer coast, offshore islands, sounds, bays, rivers, and creeks is included to the head of tidewater or to a point where tidal waters narrow to a width of 100 ft.

*Source*: From Statistical Abstract of the United States, 1987.

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**Table 5H.55 Land and Water Area of States and Other Entities: 2000**

| State and Other Area | Total Area | | Land Area | | Water Area | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total | | | | | |
| | Sq. mi. | Sq. km. | Sq. mi. | Sq. km. | Sq. mi. | Sq. km. | Inland (sq. mi.) | Coastal (sq. mi.) | Great Lakes (sq. mi.) | Territorial (sq. mi.) |
| **Total** | **3,800,286** | **9,842,696** | **3,540,999** | **9,171,146** | **259,287** | **671,550** | **79,018** | **42,241** | **60,251** | **77,777** |
| **United States** | **3,794,083** | **9,826,630** | **3,537,439** | **9,161,923** | **256,645** | **664,707** | **78,797** | **42,225** | **60,251** | **75,372** |
| Alabama | 52,419 | 135,765 | 50,744 | 131,426 | 1,675 | 4,338 | 956 | 519 | — | 200 |
| Alaska | 663,267 | 1,717,854 | 571,951 | 1,481,347 | 91,316 | 236,507 | 17,243 | 27,049 | — | 47,024 |
| Arizona | 113,998 | 295,254 | 113,635 | 294,312 | 364 | 942 | 364 | — | — | — |
| Arkansas | 53,179 | 137,732 | 52,068 | 134,856 | 1,110 | 2,876 | 1,110 | — | — | — |
| California | 163,696 | 423,970 | 155,959 | 403,933 | 7,736 | 20,037 | 2,674 | 222 | — | 4,841 |
| Colorado | 104,094 | 269,601 | 103,718 | 268,627 | 376 | 974 | 376 | — | — | — |
| Connecticut | 5,543 | 14,357 | 4,845 | 12,548 | 699 | 1,809 | 161 | 538 | — | — |
| Delaware | 2,489 | 6,447 | 1,954 | 5,060 | 536 | 1,388 | 72 | 371 | — | 93 |
| District of Columbia | 68 | 177 | 61 | 159 | 7 | 18 | 7 | — | — | — |
| Florida | 65,755 | 170,304 | 53,927 | 139,670 | 11,828 | 30,634 | 4,672 | 1,311 | — | 5,845 |
| Georgia | 59,425 | 153,909 | 57,906 | 149,976 | 1,519 | 3,933 | 1,016 | 48 | — | 455 |
| Hawaii | 10,931 | 28,311 | 6,423 | 16,635 | 4,508 | 11,677 | 38 | — | — | 4,470 |
| Idaho | 83,570 | 216,446 | 82,747 | 214,314 | 823 | 2,131 | 823 | — | — | — |
| Illinois | 57,914 | 149,998 | 55,584 | 143,961 | 2,331 | 6,037 | 756 | — | 1,575 | — |
| Indiana | 36,418 | 94,321 | 35,867 | 92,895 | 551 | 1,427 | 316 | — | 235 | — |
| Iowa | 56,272 | 145,743 | 55,869 | 144,701 | 402 | 1,042 | 402 | — | — | — |
| Kansas | 82,277 | 213,096 | 81,815 | 211,900 | 462 | 1,197 | 462 | — | — | — |
| Kentucky | 40,409 | 104,659 | 39,728 | 102,896 | 681 | 1,763 | 681 | — | — | — |
| Louisiana | 51,840 | 134,264 | 43,562 | 112,825 | 8,278 | 21,440 | 4,154 | 1,935 | — | 2,189 |
| Maine | 35,385 | 91,646 | 30,862 | 79,931 | 4,523 | 11,715 | 2,264 | 613 | — | 1,647 |
| Maryland | 12,407 | 32,133 | 9,774 | 25,314 | 2,633 | 6,819 | 680 | 1,843 | — | 110 |
| Massachusetts | 10,555 | 27,336 | 7,840 | 20,306 | 2,715 | 7,031 | 423 | 977 | — | 1,314 |
| Michigan | 96,716 | 250,494 | 56,804 | 147,121 | 39,912 | 103,372 | 1,611 | — | 38,301 | — |
| Minnesota | 86,939 | 225,171 | 79,610 | 206,189 | 7,329 | 18,982 | 4,783 | — | 2,546 | — |
| Mississippi | 48,430 | 125,434 | 46,907 | 121,489 | 1,523 | 3,945 | 785 | 590 | — | 148 |
| Missouri | 69,704 | 180,533 | 68,886 | 178,414 | 818 | 2,120 | 818 | — | — | — |
| Montana | 147,042 | 380,838 | 145,552 | 376,979 | 1,490 | 3,859 | 1,490 | — | — | — |
| Nebraska | 77,354 | 200,345 | 76,872 | 199,099 | 481 | 1,247 | 481 | — | — | — |
| Nevada | 110,561 | 286,351 | 109,826 | 284,448 | 735 | 1,903 | 735 | — | — | — |
| New Hampshire | 9,350 | 24,216 | 8,968 | 23,227 | 382 | 989 | 314 | — | — | 68 |
| New Jersey | 8,721 | 22,588 | 7,417 | 19,211 | 1,304 | 3,377 | 396 | 401 | — | 507 |
| New Mexico | 121,590 | 314,915 | 121,356 | 314,309 | 234 | 606 | 234 | — | — | — |
| New York | 54,556 | 141,299 | 47,214 | 122,283 | 7,342 | 19,016 | 1,895 | 981 | 3,988 | 479 |
| North Carolina | 53,819 | 139,389 | 48,711 | 126,161 | 5,108 | 13,229 | 3,960 | — | — | 1,148 |
| North Dakota | 70,700 | 183,112 | 68,976 | 178,647 | 1,724 | 4,465 | 1,724 | — | — | — |
| Ohio | 44,825 | 116,096 | 40,948 | 106,056 | 3,877 | 10,040 | 378 | — | 3,499 | — |
| Oklahoma | 69,898 | 181,036 | 68,667 | 177,847 | 1,231 | 3,189 | 1,231 | — | — | — |
| Oregon | 98,381 | 254,805 | 95,997 | 248,631 | 2,384 | 6,174 | 1,050 | 80 | — | 1,254 |
| Pennsylvania | 46,055 | 119,283 | 44,817 | 116,075 | 1,239 | 3,208 | 490 | — | 749 | — |
| Rhode Island | 1,545 | 4,002 | 1,045 | 2,706 | 500 | 1,295 | 178 | 9 | — | 314 |
| South Carolina | 32,020 | 82,932 | 30,110 | 77,983 | 1,911 | 4,949 | 1,008 | 72 | — | 831 |
| South Dakota | 77,117 | 199,731 | 75,885 | 196,540 | 1,232 | 3,191 | 1,232 | — | — | — |
| Tennessee | 42,143 | 109,151 | 41,217 | 106,752 | 926 | 2,399 | 926 | — | — | — |
| Texas | 268,581 | 695,621 | 261,797 | 678,051 | 6,784 | 17,570 | 5,056 | 404 | — | 1,324 |
| Utah | 84,899 | 219,887 | 82,144 | 212,751 | 2,755 | 7,136 | 2,755 | — | — | — |
| Vermont | 9,614 | 24,901 | 9,250 | 23,956 | 365 | 945 | 365 | — | — | — |
| Virginia | 42,774 | 110,785 | 39,594 | 102,548 | 3,180 | 8,237 | 1,006 | 1,728 | — | 446 |
| Washington | 71,300 | 184,665 | 66,544 | 172,348 | 4,756 | 12,317 | 1,553 | 2,537 | — | 666 |
| West Virginia | 24,230 | 62,755 | 24,078 | 62,361 | 152 | 394 | 152 | — | — | — |
| Wisconsin | 65,498 | 169,639 | 54,310 | 140,663 | 11,188 | 28,976 | 1,830 | — | 9,358 | — |
| Wyoming | 97,814 | 253,336 | 97,100 | 251,489 | 713 | 1,847 | 713 | — | — | — |
| Other areas | | | | | | | | | | |
| Puerto Rico | 5,325 | 13,790 | 3,425 | 8,870 | 1,900 | 4,921 | 67 | 16 | — | 1,817 |
| U.S. Minor Outlying Islands | 141 | 365 | 3 | 7 | 138 | 359 | 138 | — | — | — |
| Virgin Islands of the U.S. | 737 | 1,910 | 134 | 346 | 604 | 1,564 | 16 | — | — | 588 |

*Note:* One square mile = 2.59 sq. km. Area is calculated from the specific boundary recorded for each entity in the U.S. Census Bureau's geographic TIGER database; —, Represents or rounds to zero.

*Source*: From U.S. Census Bureau, 2000 Census of Population and Housing, Summary Population and Housing Characteristics, Series PHC-1; and unpublished data from the Census TIGER™ data base.

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**Table 5H.56 U.S. Wetland Resources and Deepwater Habitats by Type: 1986 and 1997**

| Wetland or Deepwater Category | 1986 | 1997 | Change, 1986 to 1997 |
|---|---|---|---|
| **All wetlands and deepwater habitats, total** | **144,673.3** | **144,136.8** | **−536.5** |
| All deepwater habitats, total | 38,537.6 | 38,645.1 | 107.5 |
| Lacustrine[a] | 14,608.9 | 14,725.3 | 116.4 |
| Riverine[b] | 6,291.1 | 6,255.9 | −35.2 |
| Estuarine Subtidal[c] | 17,637.6 | 17,663.9 | 26.3 |
| All wetlands, total | 106,135.7 | 105,491.7 | −644 |
| Intertidal wetlands[d] | 5,336.6 | 5,326.2 | −10.4 |
| Marine intertidal | 133.1 | 130.9 | −2.2 |
| Estuarine intertidal non-vegetated | 580.4 | 580.1 | −0.3 |
| Estuarine intertidal vegetated | 4,623.1 | 4,615.2 | −7.9 |
| Freshwater wetlands | 100,799.1 | 100,165.5 | −633.6 |
| Freshwater non-vegetated | 5,251.0 | 5,914.3 | 663.3 |
| Freshwater vegetated | 95,548.1 | 94,251.2 | −1,296.9 |
| Freshwater emergent[e] | 26,383.3 | 25,157.1 | −1,226.2 |
| Freshwater forested[f] | 51,929.6 | 50,728.5 | −1,201.1 |
| Freshwater shrub[g] | 17,235.2 | 18,365.6 | 1,130.4 |

*Note:* In thousands of acres (144,673.3 represents 144,677,300). Wetlands and deepwater habitats are defined separately because the term wetland does not included permanent water bodies. Deepwater habitats are permanently flooded land lying below the deepwater boundary of wetlands. Deepwater habitats include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium within which the dominant organisms live, whether or not they are attached to the substrate. As in wetlands, the dominant plants are hydrophytes; however, the substrates are considered nonsoil because the water is too deep to support emergent vegetation. In general terms, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. The single feature that most wetlands share is soil or substrate that is at least periodically saturated with or covered by water. Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.

[a] The lacustrine system includes deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel: (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30 percent coverage; (3) total area exceeds 20 acres.

[b] The riverine system includes deepwater habitats contained within a channel, with the exception of habitats with water containing ocean derived salts in excess of 0.5 parts per thousand.

[c] The estuarine system consists of deepwater tidal habitats and adjacent tidal wetland that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. Subtidal is where the substrate is continuously submerged by marine or estuarine waters.

[d] Intertidal is where the substrate is exposed and flooded by tides. Intertidal includes the splash zone of coastal waters.

[e] Emergent wetlands are characterized by erect, rooted herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.

[f] Forested wetlands are characterized by woody vegetation that is 20 ft tall or taller.

[g] Shrub wetlands include areas dominated by woody vegetation less than 20 ft tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions.

*Source*: From U.S. Fish and Wildlife Service, Status and Trends of Wetlands In the Conterminous United States, 1986 to 1997, January 2001.

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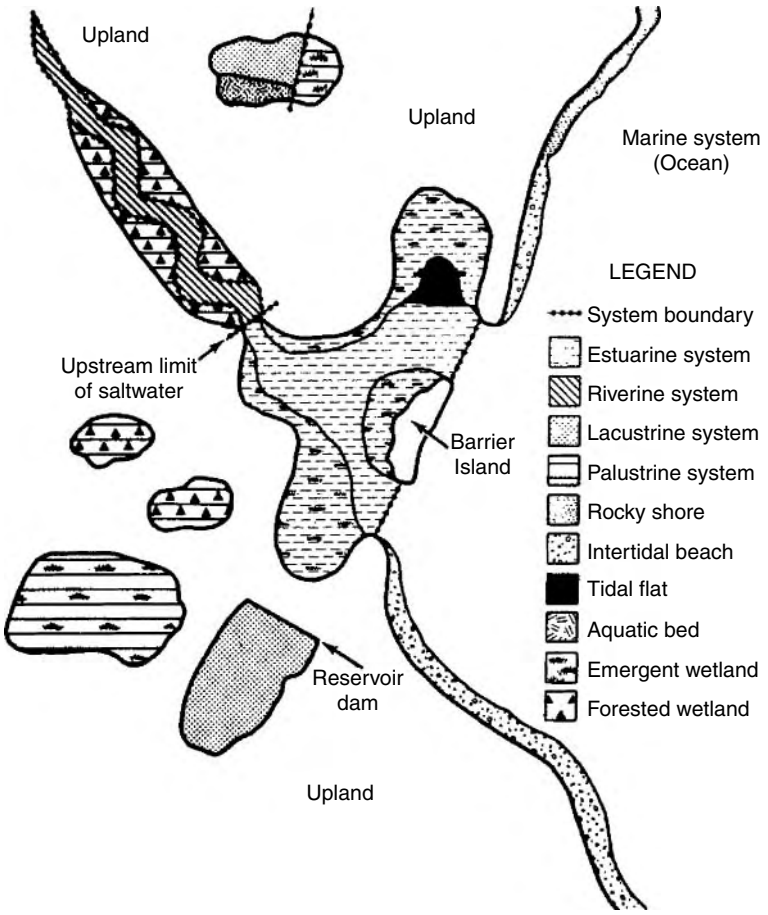


Wetlands occur in every state of the country and due to regional differences in climate, vegetation, soil and hydrologic conditions, they exist in a variety of sizes, shapes and types. Although more abundant in other areas, wetlands even exist in deserts.

Wetlands and deepwater habitats are divided into five ecological systems: (1) Marine, (2) Estuarine, (3) Riverine, (4) Lacustrine, and (5) Palustrine. The Marine System generally consists of the open ocean and its associated coastline. It is mostly a deepwater habitat system, with marine wetlands limited to intertidal areas like beaches, rocky shores and some coral reefs. The Estuarine System includes coastal wetlands like salt and brackish tidal marshes, mangrove swamps, and intertidal flats, as well as deepwater bays, sounds and coastal rivers. The Riverine System is limited to freshwater river and stream channels and is mainly a deepwater habitat system. The Lacustrine System is also a deep water dominated system, but includes standing waterbodies like lakes, reservoirs and deep ponds. The Palustrine System encompasses the vast majority of the country's inland marshes, bogs and swamps and does not include any deepwater habitat.

**Figure 5H.26** Major wetland types in the United States. (From Tiner, R.W., Jr., Wetlands of the United States: Current Status and Recent Trends, U.S. Department of the Interior, Fish and Wildlife Service, 1984.)

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**Table 5H.57 Water Areas for Selected Major Bodies of Water: 2000**

| Body of Water and State | Area | |
|---|---|---|
| | Sq. mi. | Sq. km. |
| Atlantic Coast water bodies | | |
| Chesapeake Bay (MD-VA) | 2747 | 7115 |
| Pamlico Sound (NC) | 1622 | 4200 |
| Long Island Sound (CT-NY) | 914 | 2368 |
| Delaware Bay (DE-NJ) | 614 | 1591 |
| Cape Cod Bay (MA) | 598 | 1548 |
| Albemarle Sound (NC) | 492 | 1274 |
| Biscayne Bay (FL) | 218 | 565 |
| Buzzards Bay (MA) | 215 | 558 |
| Tangier Sound (MD-VA) | 172 | 445 |
| Currituck Sound (NC) | 116 | 301 |
| Pocomoke Sound (MD-VA) | 111 | 286 |
| Chincoteague Bay (MD-VA) | 105 | 272 |
| Gulf Coast water bodies | | |
| Mississippi Sound (AL-LA-MS) | 813 | 2105 |
| Laguna Madre (TX) | 733 | 1897 |
| Lake Pontchartrain (LA) | 631 | 1635 |
| Florida Bay (FL) | 616 | 1596 |
| Breton Sound (LA) | 511 | 1323 |
| Mobile Bay (AL) | 310 | 802 |
| Lake Borgne (LA-MS) | 271 | 702 |
| Matagorda Bay (TX) | 253 | 656 |
| Atchafalaya Bay (LA) | 245 | 635 |
| Galveston Bay (TX) | 236 | 611 |
| Tampa Bay (FL) | 212 | 549 |
| Pacific Coast water bodies | | |
| Puget Sound (WA) | 808 | 2092 |
| San Francisco Bay (CA) | 264 | 684 |
| Willapa Bay (WA) | 125 | 325 |
| Hood Canal (WA) | 117 | 303 |
| Interior water bodies | | |
| Lake Michigan (IL-IN-MI-WI) | 22,342 | 57,866 |
| Lake Superior (MI-MN-WI)[a] | 20,557 | 53,243 |
| Lake Huron (MI)[a] | 8,800 | 22,792 |
| Lake Erie (MI-NY-OH-PA)[a] | 5,033 | 13,036 |
| Lake Ontario (NH)[a] | 3,446 | 8,926 |
| Great Salt Lake (UT) | 1,836 | 4,756 |
| Green Bay (MI-WI) | 1,396 | 3,617 |
| Lake Okeechobee (FL) | 663 | 1,717 |
| Lake Sakakawea (ND) | 563 | 1,459 |
| Lake Oahe (ND-SD) | 538 | 1,394 |
| Lake of the Woods (MN)[a] | 462 | 1,196 |
| Lake Champlain (NY-VT)[a] | 414 | 1,072 |
| Alaska water bodies | | |
| Chatham Strait | 1,559 | 4,039 |
| Prince William Sound | 1,382 | 3,579 |
| Clarence Strait | 1,199 | 3,107 |
| Iliamna Lake | 1,022 | 2,646 |
| Frederick Sound | 792 | 2,051 |
| Sumner Strait | 791 | 2,048 |
| Stephens Passage | 702 | 1,819 |
| Kvichak Bay | 640 | 1,659 |
| Montague Strait | 463 | 1,198 |
| Becharof Lake | 447 | 1,158 |
| Icy Strait | 436 | 1,130 |

*Note:* Includes only that portion of body of water under the jurisdiction of the United States, excluding Hawaii. One square mile = 2.59 sq. km.

[a] Area measurements for Lake Champlain, Lake Erie, Lake Huron, Lake Ontario, Lake St. Clair, Lake Superior, and Lake of the Woods include only those portions under the jurisdiction of the United States.

*Source*: From U.S. Census Bureau, unpublished data from the Census TIGER™ data base.

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**Table 5H.58 Wetlands Lost in the United States**

| State or Region | Original Wetlands (acres) | Wetlands in 1984 (acres) | Percentage of Wetlands Lost |
|---|---|---|---|
| Iowa's natural marshes | 2,333,000 | 26,470 | 99 |
| California | 5,000,000 | 450,000 | 91 |
| Nebraska's rainwater basin | 94,000 | 8,460 | 91 |
| Mississippi alluvial plain | 24,000,000 | 5,200,000 | 78 |
| Michigan | 11,200,000 | 3,200,000 | 71 |
| North Dakota | 5,000,000 | 2,000,000 | 60 |
| Minnesota | 18,400,000 | 8,700,000 | 53 |
| Louisiana's forested wetlands | 11,300,000 | 5,635,000 | 50 |
| Connecticut's coastal marshes | 30,000 | 15,000 | 50 |
| North Carolina's pocosins | 2,500,000 | 1,503,000[a] | 40 |
| South Dakota | 2,000,000 | 1,300,000 | 35 |
| Wisconsin | 10,000,000 | 6,750,000 | 32 |

[a] Only 695,000 acres of pocosins remain undisturbed; the rest are partially drained, developed or planned for development.

*Source*: From Tiner, R.W., Jr., 1984, Wetlands of the United States: Current Status and Recent Trends, U.S. Department of the Interior, Fish and Wildlife Service.

**Table 5H.59 Change in Wetland Area for Selected Wetland and Deepwater Categories, 1986 to 1997**

| | Area in Thousands of Acres | | | |
|---|---|---|---|---|
| Wetland/Deepwater Category | Estimated Area, 1986 | Estimated Area, 1997 | Change, 1986–97 | Change (in Percent) |
| Marine intertidal | 133.1 (19.6) | 130.9 (19.9) | −2.2 (88.5) | −1.7 |
| Estuarine intertidal non-vegetated[a] | 580.4 (10.7) | 580.1 (10.6) | −0.3 (*) | −0.1 |
| Estuarine intertidal vegetated[b] | 4,623.1 (4.0) | 4,615.2 (4.0) | −7.9 (75.1) | −0.2 |
| All intertidal wetlands | 5,336.6 (3.8) | 5,326.2 (3.8) | −10.4 (73.0) | −0.2 |
| Freshwater non-vegetated[c] | 5,251.0 (4.1) | 5,914.3 (3.9) | 663.3 (13.4) | 12.6 |
| Freshwater vegetated[d] | 95,548.1 (3.0) | 94,251.2 (3.0) | −1,296.9 (17.1) | −1.4 |
| Freshwater emergent | 26,383.3 (8.1) | 25,157.1 (8.4) | −1,226.2 (18.2) | −4.6 |
| Freshwater forested | 51,929.6 (2.8) | 50,728.5 (2.8) | 1,201.1 (23.8) | −2.3 |
| Freshwater shrub | 17,235.2 (4.2) | 18,365.6 (4.1) | 1,130.4 (25.7) | 6.6 |
| All freshwater wetlands | 100,799.1 (2.9) | 100,165.5 (2.9) | 633.6 (36.5) | −0.6 |
| All wetlands | 106,135.7 (2.8) | 105,491.7 (2.8) | −644.0 (36.0) | 0.6 |
| Deepwater habitats | | | | |
| Lacustrine[e] | 14,608.9 (10.6) | 14,725.3 (10.5) | 116.4 (*) | 0.8 |
| Riverine | 6,291.1 (9.6) | 6,225.9 (9.4) | −35.2 (*) | −0.6 |
| Estuarine subtidal | 17,637.6 (2.2) | 17,663.9 (2.2) | 26.3 (95.6) | 0.1 |
| All deepwater habitats | 38,537.6 (4.4) | 38,645.1 (4.4) | 107.5 (*) | 0.3 |
| All wetlands and deepwater habitats[a,b] | 144,673.3 (2.4) | 144,136.8 (2.4) | −536.5 (30.7) | −0.4 |

*Note:* The coefficient of variation (CV) for each entry (expressed as a percentage) is given in parentheses.
*Statistically unreliable.

[a] Includes the categories: estuarine intertidal aquatic bed and estuarine intertidal unconsolidated shore.
[b] Includes the categories: estuarine intertidal emergent and estuarine intertidal shrub.
[c] Includes the categories: palustrine aquatic bed, palustrine unconsolidated bottom and palustrine unconsolidated shore.
[d] Includes the categories: palustrine emergent, palustrine forested and palustrine shrub.
[e] Does not include the great lakes.

*Source*: From Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, 82pp. http://training.fws.gov.

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**Table 5H.60 Estuarine and Marine Intertidal Wetland Area and Change, 1986 to 1997**

| | Area in Thousands of Acres | | | |
|---|---|---|---|---|
| **Wetland Category** | **Estimated Area, 1986** | **Estimated Area, 1997** | **Gain or Loss, 1986–1997** | **Area (as Percent) of All Intertidal Wetland, 1997** |
| Marine Intertidal | 133.1 (19.6) | 130.9 (19.9) | −2.2 (88.5) | 2.5 |
| Estuarine Unconsolidated shore | 551.3 (10.9) | 550.8 (10.8) | −0.5 (*) | 10.3 |
| Estuarine aquatic bed | 29.1 (27.1) | 29.3 (26.9) | 0.2 (*) | 0.6 |
| Marine and estuarine intertidal Non-vegetated[a] | 580.4 (10.7) | 580.1 (10.6) | −0.3 (*) | 13.4 |
| Estuarine emergent | 3,956.9 (4.1) | 3,942.4 (4.1) | −14.5 (49.2) | 74.0 |
| Estuarine shrub | 666.2 (12.6) | 672.8 (12.6) | 6.6 (76.5) | 12.6 |
| Estuarine intertidal Vegetated[b] | 4,623.1 (4.0) | 4,615.2 (4.0) | −7.9 (75.1) | 86.6 |
| | Changes in coastal deepwater area, 1986–1997 | | | |
| Estuarine Subtidal | 17,637.6 (2.2) | 17,663.9 (2.2) | 26.3 (95.6) | — |

*Note:* The coefficient of variation (CV) for each entry (expressed as a percentage) is given in parentheses.
*Statistically unreliable.

[a] Includes the categories: estuarine unconsolidated shore and estuarine aquatic bed.
[b] Includes the categories: estuarine emergent and estuarine shrub.

*Source*: From Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, 82pp. http://training.fws.gov.

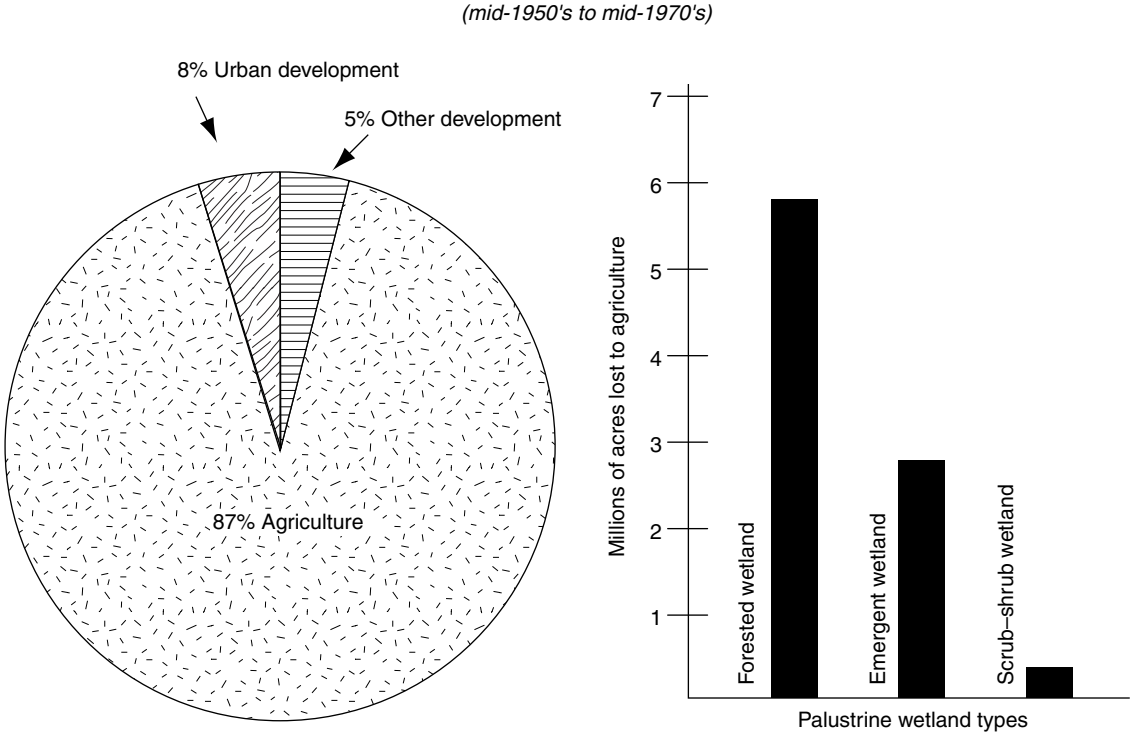


**Figure 5H.27** Causes of recent wetland losses in the conterminous United States. (From Tiner, R.W., Jr., Wetlands of the United States: Current Status and Recent Trends, U.S. Department of the Interior, Fish and Wildlife Service, 1984.)

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**Table 5H.61 Major Causes of Wetland Loss and Degradation**

| |
|---|
| **Human Threats** |
| Direct |
| 1. Drainage for crop production, timber production and mosquito control |
| 2. Dredging and stream channelization for navigation channels, flood protection, coastal housing developments, and reservoir maintenance |
| 3. Filling for dredged spoil and other solid waste disposal, roads and highways, and commercial, residential and industrial development |
| 4. Construction of dikes, dams, levees and seawalls for flood control, water supply, irrigation and storm protection |
| 5. Discharges of materials (e.g., pesticides, herbicides, other pollutants, nutrient loading from domestic sewage and agricultural runoff, and sediments from dredging and filling, agricultural and other land development) into waters and wetlands |
| 6. Mining of wetland soils for peat, coal, sand, gravel, phosphate and other materials |
| Indirect |
| 1. Sediment diversion by dams, deep channels and other structures |
| 2. Hydrologic alterations by canals, spoil banks, roads and other structures |
| 3. Subsidence due to extraction of groundwater, oil, gas, sulphur, and other minerals |
| **Natural Threats** |
| 1. Subsidence (including natural rise of sea level) |
| 2. Droughts |
| 3. Hurricanes and other storms |
| 4. Erosion |
| 5. Biotic effects, e.g., muskrat, nutria and goose “eat-outs” |

*Source*: From Tiner, R.W. Jr., 1984, Wetlands of the United States: Current Status and Trends, U.S. Fish and Wildlife Service.

**Table 5H.62 Major Wetland Values**

| |
|---|
| **Fish and Wildlife Values** |
| Fish and shellfish habitat |
| Waterfowl and other bird habitat |
| Furbearer and other wildlife habitat |
| **Environmental Quality Values** |
| Water quality maintenance |
| Pollution filter |
| Sediment removal |
| Oxygen production |
| Nutrient recycling |
| Chemical and nutrient absorption |
| Aquatic productivity |
| Microclimate regulator |
| World climate (ozone layer) |
| **Socio-economic Values** |
| Flood control |
| Wave damage protection |
| Erosion control |
| Groundwater recharge and water supply |
| Timber and other natural products |
| Energy source (peat) |
| Livestock grazing |
| Fishing and shellfishing |
| Hunting and trapping |
| Recreation |
| Aesthetics |
| Education and scientific research |

*Source*: From Tiner, R.W., Jr., 1984, Wetlands of the United States: Current Status and Trends, U.S. Fish and Wildlife Service.

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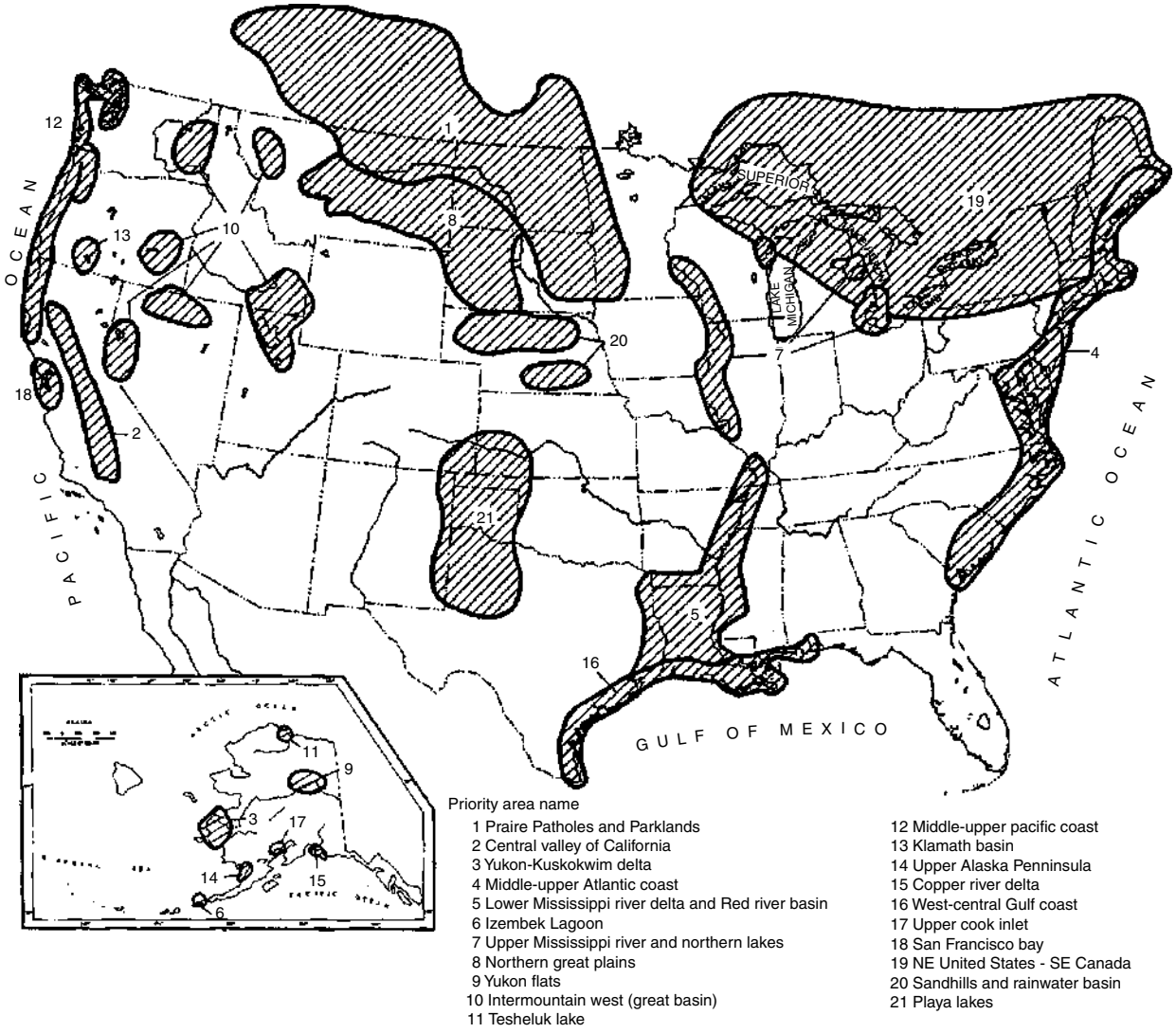


**Figure 5H.28** Principal waterfowl habitat areas in the United States. (From Tiner, R.W. Jr., Wetlands of the United States: Current Status and Recent Trends, U.S. Department of the Interior, Fish and Wildlife Service, 1984.)

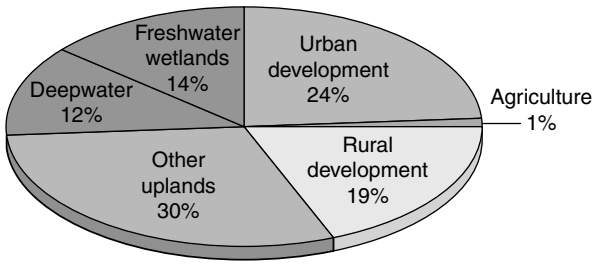


**Figure 5H.29** Percent of estuarine and marine wetlands lost to freshwater wetlands, deepwater, or upland categories between 1986 and 1997. (From Dahl, T.E. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, 82pp, 2000.) (http://training.fws.gov.)

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**Figure 5H.30** Areas along the Gulf and Atlantic coasts where estuarine wetlands were lost to urban or rural development (shown in orange) between 1986 and 1997. (From Dahl, T.E. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, 82pp, 2000.) (http://training.fws.gov.)

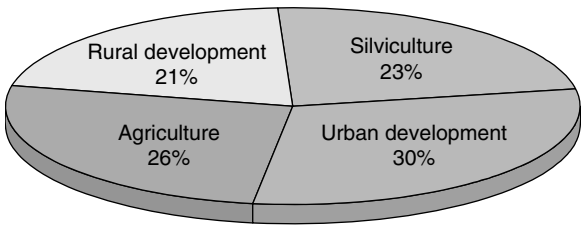


**Figure 5H.31** Change in wetlands converted to various land uses between 1986 and 1997. (From Dahl, T.E. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, 82pp, 2000.) (http://training.fws.gov.)

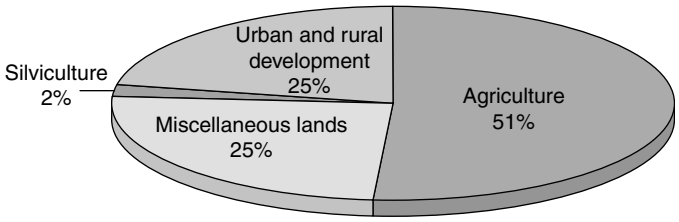


**Figure 5H.32** Current upland classification of areas where emergent wetlands were lost between 1986 and 1997. (From Dahl, T.E. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, 82pp, 2000.) (http://training.fws.gov.)

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**Table 5H.63 Effect of Wetlands on Flood Peak Reduction in Wisconsin**

| Wetland Present in a Basin (percent) | Storm Recurrence Interval (years) | | | |
|---|---|---|---|---|
| | 2 | 25 | 50 | 100 |
| | Percentage of Flood Peak Reduction | | | |
| 1 | 19 | 22 | 26 | 27 |
| 2 | 28 | 33 | 38 | 39 |
| 3 | 34 | 39 | 45 | 46 |
| 5 | 42 | 48 | 54 | 55 |
| 10 | 51 | 58 | 63 | 64 |
| 15 | 56 | 63 | 70 | 71 |
| 30 | 64 | 71 | 77 | 79 |

*Source*: From Conger, D.H., 1971, Estimating Magnitude and Frequency of Floods in Wisconsin, U.S. Geological Survey Open-File Rept.

**Table 5H.64 Terms Descriptive of Water Landscapes**

| | | |
|---|---|---|
| **Fluvial Types** | Fluvial lakes | Rill |
| Bayou | Freshet | River |
| Braided stream | Inlet | Slough |
| Brook | Influent | Spring |
| Canal | Intermittent stream | Stream |
| Connecting stream | Interrupted stream | Torrent |
| Creek | Misfit river | Vigorously meandering stream |
| Disappearing stream | Outlet | Watercourse |
| Feeder stream | Raft | Waterway |
| **Lacustrine Types** | Fluvial lake | Pit lake |
| Aestival ponds | Fluviatile lake | Playa |
| Alkali lakes | Fosse lake | Pond |
| Alluvial dam lakes | Glacial lake | Pool |
| Alpine lakes | Grass lake | Pothole |
| Bar lake | Headwaters lake | Puddle |
| Barrier lake | Holding pond | Quarry pond |
| Bayou | Holm lake | Raft lake |
| Blind lake | Hot springs | Reflection basin |
| Blowout pond | Impoundment | Rejuvenated lake |
| Bog lake | Intermittent lake | Reservoir |
| Borrow pit pond | Kettle lake | Ria lakes |
| Caldera lake | Lagoon | Rift lakes |
| Chain of lakes | Lake | Riverine lakes |
| Charco | Lakelet | Rock lakes |
| Cirque lake | Landslide lake | Sag pond |
| Clear lake | Laguna | Salt lakes |
| Closed lake | Lateral lake | Satellite lakes |
| Crater lake | Marl lake | Scour lakes |
| Dead lake | Marsh lake | Seepage lakes |
| Deflation lake | Meadow lake | Senescent lake |
| Delta lake | Mesotrophic lake | Sink lakes |
| Doline lake | Mill pond | Slough |
| Drainage lake | Mirror lake | Snag lake |
| Dry lake | Moat lake | Strath lake |
| Dugout pond | Morainal lake | Swarm of lakes |
| Dune lake | Nova lake | Tailing pond |
| Dystrophic lake | Oligotrophic lake | Tanks |
| Effluent lake | Open lake | Tarn |
| Evanescent lake | Oriented lake | Thaw lakes |
| Extinct lake | Oxbow | Tundra lakes |
| Farm pond | Palodolac | Vernal & autumnal ponds |
| Finger lake | Perched lake | Walled lakes |
| Fission lake | Perennial lake | |

*Source*: From Litton, R.B., Tetlow, R.J., Sorensen, J., and Beatty, R.A., 1974, Water and Landscape, Water Information Center, Inc.

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**Table 5H.65 Aesthetic Evaluation of Rivers**

| **Aesthetic factors** |
|---|
| Landscape |
| Views and vistas |
| Diversity of flora and geologic features |
| Color |
| Form and contrasts |
| Sensual stimuli |
| Temperature regime |
| Winds and other aerial features |
| Sounds |
| Odors |
| Visual patterns |
| Intellectual interests |
| Opportunities for interpretive programs |
| Ecology |
| Geology |
| Wildlife |
| Range and diversity of subjects available for study |
| Emotional interest |
| Physical stimuli |
| Intellectual potentials |
| Possibility for adventure |
| Interaction of flora, fauna, and people |
| Access |
| Climatic factors |
| Obstacles or discomforts |
| Troublesome flora and fauna |
| Access |
| Climatic factors |
| Culture |
| Quality of land use management construction |
| Scenic pollution |
| Historic artifacts |
| Subjective analysis of most important factors in viewing river — most significant in deriving-pleasurable feelings |
| Vista |
| Color |
| Vegetation (amount and variety) |
| Spaciousness |
| Serenity |
| Naturalness |
| Riffles in water |
| Turbidity |
| Lack of pollution |

*Source*: From Morisawa, M., and Murie, M., 1969, *Evaluation of Natural Rivers*. Antioch College, Water Resources Research, Yellow Springs, OH, in Litton, R.B. and others, 1974, Water and Landscape, Water Information Center, Inc. Reprinted with permission.

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## SECTION 5I OCEANS AND SEAS

**Table 5I.66 Dimensions of the Oceans**

| Ocean | Area ($10^9 m^2$) | Mean Depth (meters) | Volume ($10^{15} m^3$) |
|---|---|---|---|
| Arctic | 14,090 | 1205 | 17.0 |
| North Pacific | 83,462 | 3858 | 322.0 |
| South Pacific | 65,521 | 3891 | 254.9 |
| North Atlantic | 46,772 | 3285 | 153.6 |
| South Atlantic | 37,364 | 4091 | 152.8 |
| Indian | 81,602 | 4284 | 349.6 |
| Antarctic | 32,249 | 3730 | 120.3 |

*Source*: From U.S. Naval oceanographic office, 1966.

**Table 5I.67 Maximum Depths of the Oceans**

| Name of Area | Location | | Depth | | |
|---|---|---|---|---|---|
| | | | m | Fathoms | ft |
| **Pacific Ocean** | | | | | |
| Mariana trench | 11°20′N | 142°12′E | 10,924 | 5973 | 35,840 |
| Tonga trench | 23°16′S | 174°44′W | 10,800 | 5906 | 35,433 |
| Philippine trench | 10°38′N | 126°36′E | 10,057 | 5499 | 32,995 |
| Kermadec trench | 31°53′S | 177°21′W | 10,047 | 5494 | 32,963 |
| Bonin trench | 24°30′N | 143°24′E | 9,994 | 5464 | 32,788 |
| Kuril trench | 44°15′N | 150°34′E | 9,750 | 5331 | 31,988 |
| Izu trench | 31°05′N | 142°10′E | 9,695 | 5301 | 31,808 |
| New Britain trench | 06°19′S | 153°45′E | 8,940 | 4888 | 29,331 |
| Yap trench | 08°33′N | 138°02′E | 8,527 | 4663 | 27,976 |
| Japan trench | 36°08′N | 142°43′E | 8,412 | 4600 | 27,599 |
| Peru-Chile trench | 23°18′S | 71°14′W | 8,064 | 4409 | 26,457 |
| Palau trench | 07°52′N | 134°56′E | 8,054 | 4404 | 26,424 |
| Aleutian trench | 50°51′N | 177°11′E | 7,679 | 4199 | 25,194 |
| New Hebrides trench | 20°36′S | 168°37′E | 7,570 | 4139 | 24,836 |
| North Ryukyu trench | 24°00′N | 126°48′E | 7,181 | 3927 | 23,560 |
| Mid America trench | 14°02′N | 93°39′W | 6,662 | 3643 | 21,857 |
| **Atlantic Ocean** | | | | | |
| Puerto Rico trench | 19°55′N | 65°27′N | 8,605 | 4705 | 28,232 |
| So. Sandwich trench | 55°42′S | 25°56′E | 8,325 | 4552 | 27,313 |
| Romanche gap | 0°13′S | 18°26′W | 7,728 | 4226 | 25,354 |
| Cayman trench | 19°12′N | 80°00′W | 7,535 | 4120 | 24,721 |
| Brazil basin | 09°10′S | 23°02′W | 6,119 | 3346 | 20,076 |
| **Indian Ocean** | | | | | |
| Java trench | 10°19′S | 109°58′E | 7,125 | 3896 | 23,376 |
| Ob trench | 09°45′S | 67°18′E | 6,874 | 3759 | 22,553 |
| Diamantina trench | 35°50′S | 105°14′E | 6,602 | 3610 | 21,660 |
| Vema trench | 09°08′S | 67°15′E | 6,402 | 3501 | 21,004 |
| Agulhas basin | 45°20′S | 26°50′E | 6,195 | 3387 | 20,325 |
| **Arctic Ocean** | | | | | |
| Eurasia basin | 82°23′N | 19°31′E | 5,450 | 2980 | 17,881 |
| **Mediterranean Sea** | | | | | |
| Ionian basin | 36°32′N | 21°06′E | 5,150 | 2816 | 16,896 |

*Source*: From The World Almanac and Book of Facts 1987. Copyright Pharos Books, a Scripps Howard Co., New York.

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**Table 5I.68 Water Residence Times of the Oceans**

| | | North Polar | Atlantic | Pacific | Indian | Total |
|---|---|---|---|---|---|---|
| A. | Ocean volume ($km^3 \times 10^4$) | 8.85 | 350 | 695 | 295 | 1,349 |
| B. | Surface ocean volume (200 m) ($km^3 \times 10^6$) | 1.7 | 19.6 | 35.4 | 15.5 | 72.2 |
| C. | Ocean flow compensation ($km^3$/yr) | 3,000 | −17,100 | +28,000 | −13,900 | 0 |
| D. | Total compensation time: A/C (yr) | 2,950 | 20,500 | 25,000 | 21,200 | |
| E. | Surface-only compensation time: B/C (yr) | 570 | 1,150 | 1,250 | 1,100 | |
| F. | Stream runoff to oceans ($km^3$/yr) | 2,600 | 19,400 | 21,100 | 5,600 | 39,700 |
| G. | Runoff residence time: A/F (yr) | 3,400 | 18,000 | 57,500 | 52,700 | 34,000 |
| H. | Surface runoff residence time: B/F (yr) | 650 | 1,000 | 2,900 | 2,800 | 1,800 |
| I. | Atmospheric cycling (precipitation minus evaporation) ($km^3$/yr) | 400 | −36,500 | 15,900 | −19,500 | −39,700 |
| J. | Whole-ocean atmospheric-cycling residence time: A/I (yr) | 22,125 | 9,600 | 43,700 | 15,100 | 34,000 |
| K. | Atmospheric-cycling surface ocean residence time: B/I (yr) | 4,250 | 500 | 2,200 | 1,000 | 1,800 |

*Source*: From Speidel, D.H., and Agnew, A.F., 1979, The Natural Geochemistry of our Environment, in An Overview of Research in Biogeochemistry and Environmental Health, Committee Print 825, Committee on Science and Technology. U.S. House of 77–239.

**Table 5I.69 Water Balance of the Oceans**

| Ocean | Area | Precipitation | | Evaporation | | Inflow of Water from Continents | | Water Balance | |
|---|---|---|---|---|---|---|---|---|---|
| | 1000 $km^3$ | mm | 1000 $km^3$ | mm | 1000 $km^3$ | mm | 1000 $km^3$ | mm | 1000 $km^3$ |
| Pacific | 178,700 | 1460 | 260 | 1510 | 269.7 | 83 | 14.8 | 30 | 5.1 |
| Southern sector | 25,300 | 1140 | 28.9 | 684 | 17.3 | 72 | 1.8 | 530 | 13.4 |
| Without southern sector | 153,400 | 1510 | 231.1 | 1640 | 252.4 | 85 | 13.0 | −50 | −8.4 |
| Atlantic | 91,700 | 1010 | 92.7 | 1360 | 124.4 | 226 | 20.8 | −120 | −10.9 |
| Southern sector | 15,500 | 1190 | 18.4 | 466 | 7.2 | 37 | 0.6. | 760 | 11.8 |
| Without southern sector | 76,200 | 975 | 74.3 | 1540 | 117.2 | 265 | 20.6 | −300 | −22.7 |
| Indian | 76,200 | 1320 | 100.4 | 1420 | 108.0 | 81 | 6.1 | −20 | −1.5 |
| Southern sector | 28,500 | 1240 | 35.4 | 688 | 19.6 | 30 | 0.8 | 580 | 16.6 |
| Without southern sector | 47,700 | 1360 | 65.0 | 1850 | 88.4 | 111 | 5.3 | −380 | −18.1 |
| Arctic | 14,700 | 361 | 5.3 | 220 | 8.2 | 355 | 5.2 | 500 | 7.3 |
| World | 361,300 | 1270 | 458.0 | 1400 | 505.0 | 130 | 47.0 | 0 | 0 |

*Source*: From UNESCO, 1977, Atlas of World Water Balance. Reproduced with permission.

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**Table 5I.70 Dimensions of Individual Seas**

| Sea | Area ($10^9 m^2$) | Mean Depth (m) | Volume ($10^{12} m^3$) |
|---|---|---|---|
| **Tributary to Arctic Ocean** | | | |
| Norwegian Sea | 1383 | 1742 | 2408 |
| Greenland Sea | 1205 | 1444 | 1740 |
| Barents Sea | 1405 | 229 | 322 |
| White Sea | 90 | 89 | 8 |
| Kara Sea | 883 | 118 | 104 |
| Laptev Sea | 650 | 519 | 338 |
| East Siberian Sea | 901 | 58 | 53 |
| Chukchi Sea | 582 | 88 | 51 |
| Beaufort Sea | 476 | 1004 | 478 |
| Baffin Bay | 689 | 861 | 593 |
| **Tributary to North Atlantic** | | | |
| North Sea | 600 | 91 | 55 |
| Baltic Sea | 386 | 86 | 33 |
| Mediterranean Sea | 2516 | 1494 | 3758 |
| Black Sea | 461 | 1166 | 537 |
| Marmara | 11 | 357 | 4 |
| Azov | 40 | 9 | 0.4 |
| Caribbean Sea | 2754 | 2491 | 6860 |
| Gulf of Mexico | 1543 | 1512 | 2332 |
| Gulf of St. Lawrence | 238 | 127 | 30 |
| Hudson Bay | 1232 | 128 | 158 |
| **Tributary to South Atlantic** | | | |
| Gulf of Guinea | 1533 | 2996 | 4592 |
| **Tributary to Indian Ocean** | | | |
| Red Sea | 450 | 558 | 251 |
| Persian Gulf | 241 | 40 | 10 |
| Arabian Sea | 3863 | 2734 | 10561 |
| Bay of Bengal | 2172 | 2586 | 5616 |
| Andaman Sea | 602 | 1096 | 660 |
| Great Australian Bight | 484 | 950 | 459 |
| **Tributary to North Pacific** | | | |
| Gulf of California | 177 | 818 | 145 |
| Gulf of Alaska | 1327 | 2431 | 3226 |
| Bearing Sea | 2304 | 1598 | 3683 |
| Okhotsk Sea | 1590 | 859 | 1365 |
| Japan Sea | 978 | 1752 | 1713 |
| Yellow Sea | 417 | 40 | 17 |
| East China Sea | 752 | 349 | 263 |
| Sulu Sea | 420 | 1139 | 478 |
| Celebes Sea | 472 | 3291 | 1553 |
| **In both North and South Pacific** | | | |
| South China Sea | 3685 | 1060 | 3907 |
| Makassar Strait | 194 | 967 | 188 |
| Molukka Sea | 307 | 1880 | 578 |
| Ceram Sea | 187 | 1209 | 227 |
| **Tributary to South Pacific** | | | |
| Java Sea | 433 | 46 | 20 |
| Bali Sea | 119 | 411 | 49 |
| Flores Sea | 121 | 1829 | 222 |
| Savu Sea | 105 | 1701 | 178 |
| Banda Sea | 695 | 3064 | 2129 |
| Ceram Sea | 187 | 1209 | 227 |
| Timor Sea | 615 | 406 | 250 |
| Arafura Sea | 1037 | 197 | 204 |
| Coral Sea | 4791 | 2394 | 11470 |

*Source*: From U.S. Naval Oceanographic Office, 1966; amended.

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**Table 5I.71 Average Rise and Fall of Tides in the United States and Canada**

| Location | Feet |
|---|---|
| **East Coast** | |
| Quebec | 13.7 |
| Halifax, NS | 4.4 |
| St. John, NB | 20.8 |
| Eastport, ME | 18.4 |
| Portland, ME | 9.1 |
| Boston, MA | 9.5 |
| Newport, RI | 3.5 |
| New London, CT | 2.6 |
| Bridgeport, CT | 6.7 |
| New York (The Battery) | 4.5 |
| Port Jefferson, NY | 6.6 |
| Albany, NY | 4.6 |
| Newark, NJ | 5.1 |
| Sandy Hook, NJ | 4.7 |
| Philadelphia, PA | 6.2 |
| Cape May, NJ | 4.6 |
| Washington, DC | 2.8 |
| Cape Hatteras, NC | 3.6 |
| Wilmington, NC | 4.2 |
| Charlotte, SC | 5.2 |
| Savannah, GA | 7.9 |
| Miami, FL | 2.4 |
| Key West, FL | 1.3 |
| Mobile, AL | 1.5[a] |
| Galveston, TX | 1.0 |
| San Juan, PR | 1.1 |
| **West Coast** | |
| Vancouver, BC | 10.6[a] |
| Seattle, WA | 7.7 |
| San Francisco, CA | 4.1 |
| Los Angeles, CA | 3.8 |
| San Diego, CA | 4.0 |

[a] Diurnal range.

*Source*: From National Oceanic and Atmospheric Administration, National Ocean Survey Tide Tables.

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**Table 5I.72 Temperatures and Salinities of the Oceans**

| | Temperature | Salinity |
|---|---|---|
| **North Atlantic** | | |
| 1. North Polar water | −1 to +2 | 34.9 |
| 2. Subarctic water | +3 to +5 | 34.7 to 34.9 |
| 3. North Atlantic central water | +4 to +17 | 35.1 to 36.2 |
| 4. North Atlantic water | +3 to +4 | 34.9 to 35.0 |
| 5. North Atlantic bottom water | +1 to +3 | 34.8 to 34.9 |
| 6. Mediterranean water | +6 to +10 | 35.3 to 36.4 |
| **South Atlantic** | | |
| 1. South Atlantic central water | +5 to +16 | 34.3 to 35.6 |
| 2. Antarctic intermediate water | +3 to +5 | 34.1 to 34.6 |
| 3. Subantarctic water | +3 to +9 | 33.8 to 34.5 |
| 4. Antarctic circumpolar water | +0.5 to +2.5 | 34.7 to 34.8 |
| 5. South Atlantic deep and bottom water | 0 to +2 | 34.5 to 34.9 |
| 6. Antarctic bottom water | −0.4 | 34 to 36 |
| **Indian Ocean** | | |
| 1. Equatorial water | 4 to 16 | 34.8 to 35.2 |
| 2. Indian central water | 6 to 15 | 34.5 to 35.4 |
| 3. Antarctic intermediate water | 2 to 6 | 34.4 to 34.7 |
| 4. Subantarctic water | 2 to 8 | 34.1 to 34.6 |
| 5. Indian Ocean deep and Antarctic circumpolar water | 0.5 to 2 | 34.7 to 34.75 |
| 6. Red Sea water | 9 | 35.5 |
| **South Pacific** | | |
| 1. Eastern South Pacific water | 9 to 16 | 34.3 to 35.1 |
| 2. Western South Pacific water | 7 to 16 | 34.5 to 35.5 |
| 3. Antarctic intermediate water | 4 to 7 | 34.3 to 34.5 |
| 4. Subantarctic water | 3 to 7 | 34.1 to 34.6 |
| 5. Pacific deep water and Antarctic circumpolar water | (−1) to 3 | 34.6 to 34.7 |
| **North Pacific** | | |
| 1. Subarctic water | 2 to 10 | 33.5 to 34.4 |
| 2. Pacific equatorial water | 6 to 16 | 34.5 to 35.2 |
| 3. Eastern North Pacific water | 10 to 16 | 34.0 to 34.6 |
| 4. Western North Pacific water | 7 to 16 | 34.1 to 34.6 |
| 5. Arctic intermediate water | 6 to 10 | 34.0 to 34.1 |
| 6. Pacific deep water and Arctic circumpolar water | (−1) to 3 | 34.6 to 34.7 |

*Source*: From U.S. Oceanographic Office, 1966.

**Table 5I.73 Composition of Sea Water**

| Constituent | Concentration (ppm) |
|---|---|
| Chloride | 18,980 |
| Sodium | 10,560 |
| Sulfate | 2,560 |
| Magnesium | 1,272 |
| Calcium | 400 |
| Potassium | 380 |
| Bicarbonate | 142 |
| Bromide | 65 |
| Strontium | 13 |
| Boron | 4.6 |
| Fluoride | 1.4 |
| Rubidium | 0.2 |
| Aluminum | 0.16–1.9 |
| Lithium | 0.1 |
| Barium | 0.05 |
| Iodide | 0.05 |
| Silicate | 0.04–8.6 |
| Nitrogen | 0.03–0.9 |

*(Continued)*

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**Table 5I.73 (Continued)**

| Constituent | Concentration (ppm) |
|---|---|
| Zinc | 0.005–0.014 |
| Lead | 0.004–0.005 |
| Selenium | 0.004 |
| Arsenic | 0.003–0.024 |
| Copper | 0.001–0.09 |
| Tin | 0.003 |
| Iron | 0.002–0.02 |
| Cesium | $\sim$0.002 |
| Manganese | 0.001–0.01 |
| Phosphorous | 0.001–0.10 |
| Thorium | $\leq$0.0005 |
| Mercury | 0.0003 |
| Uranium | 0.00015–0.0016 |
| Cobalt | 0.0001 |
| Nickel | 0.0001–0.0005 |
| Radium | $8\times10^{-11}$ |
| Beryllium | — |
| Cadmium | — |
| Chromium | — |
| Titanium | Trace |

*Source*: From U.S. Geological survey.

**Table 5I.74 Approximate Mineral Content of One Cubic Mile of Sea Water**

| Mineral | Weight (in tons) | Mineral | Weight (in tons) |
|---|---|---|---|
| Sodium chloride | 120,000,000 | Fluorine | 6,400 |
| Magnesium chloride | 18,000,000 | Barium | 900 |
| Magnesium sulfate | 8,000,000 | Iodine | 100 to 12,000 |
| Calcium sulfate | 6,000,000 | Arsenic | 50 to 350 |
| Potassium sulfate | 4,000,000 | Rubidium | 200 |
| Calcium carbonate | 550,000 | Silver | up to 45 |
| Magnesium bromide | 350,000 | Copper, Manganese, Zinc, Lead | 10 to 30 |
| Bromine | 300,000 | Gold | up to 25 |
| Strontium | 60,000 | Radium | about 1/6 (ounce) |
| Boron | 21,000 | Uranium | 7 |

*Source*: From Smith, The Sun, the Sea, and Tomorrow; Potential Sources of Food, Energy and Minerals from the Sea, Charles Scribners, 1954. With permission.

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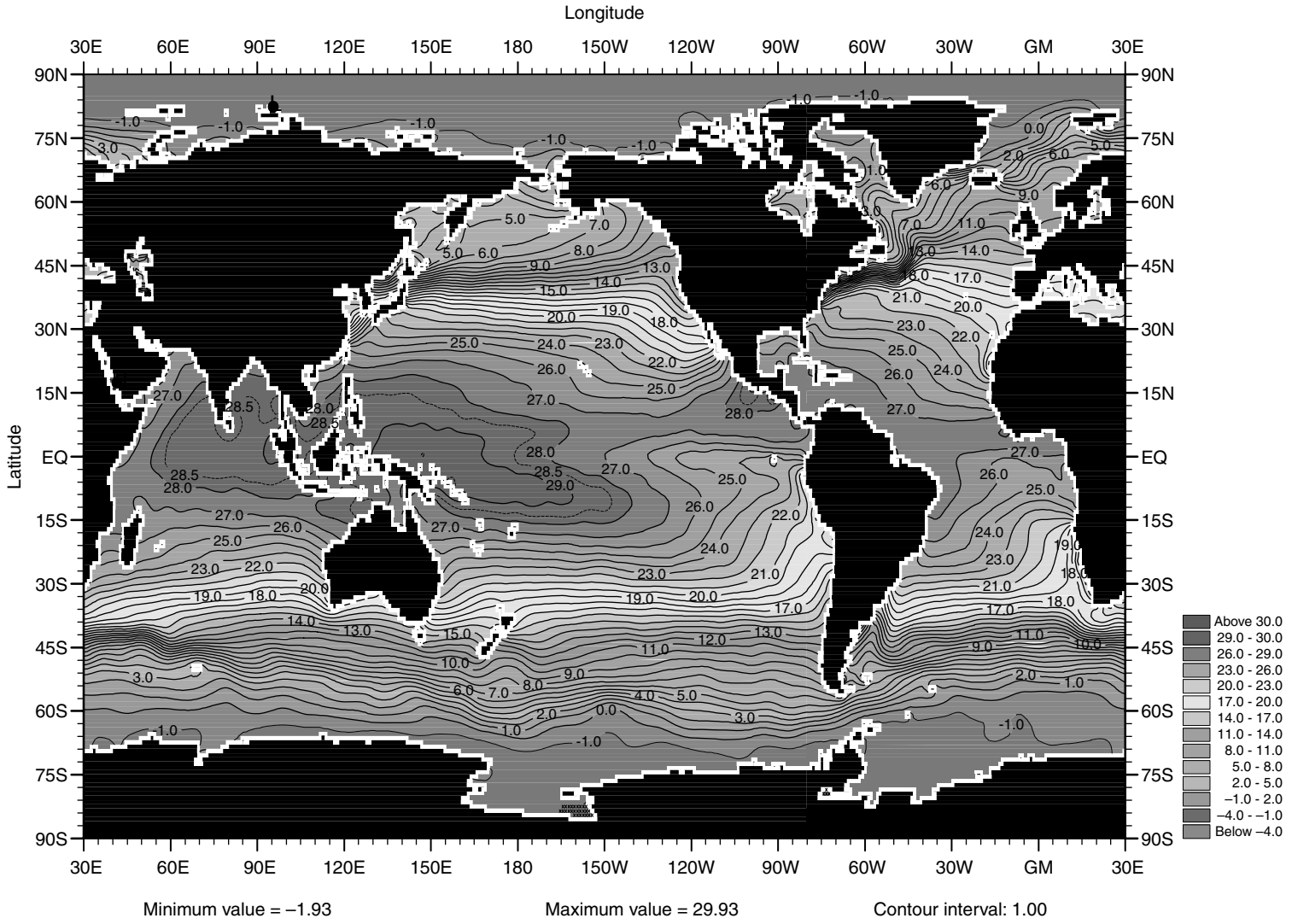


**Figure 5I.33** Annual mean temperature (°C) at the surface. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)

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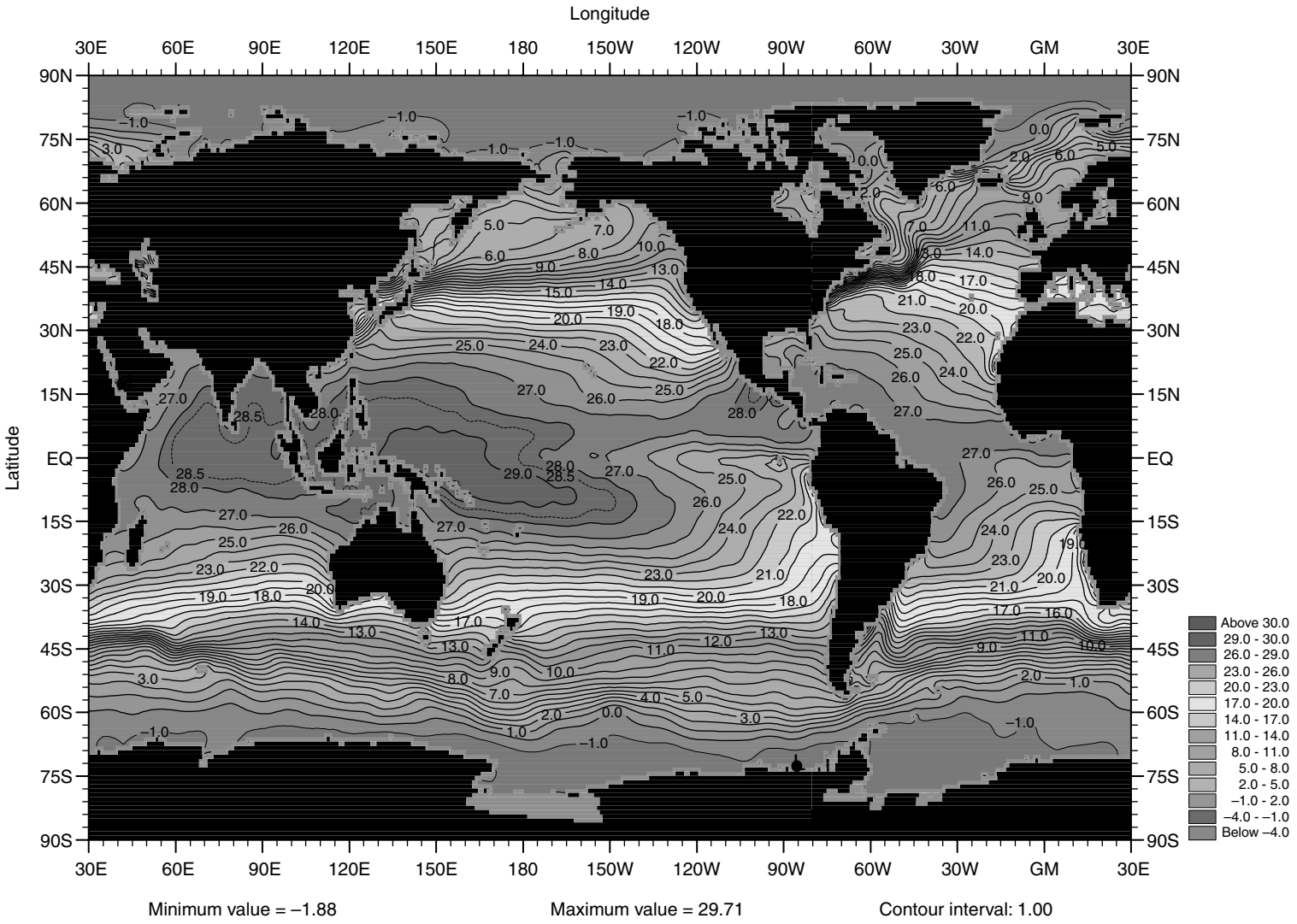


**Figure 5I.34** Annual mean temperature (°C) at 10 m depth. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)



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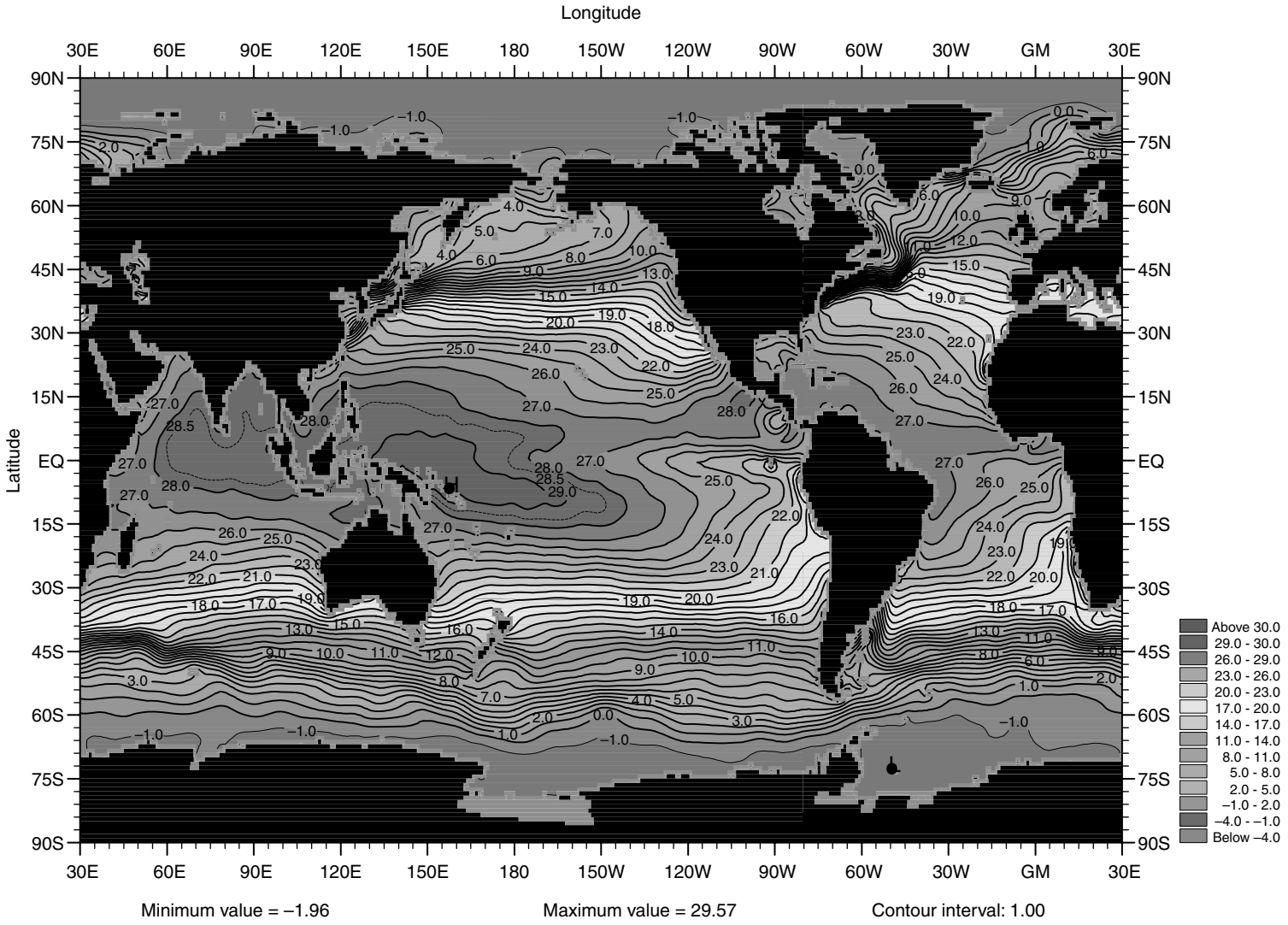


**Figure 5I.35** Annual mean temperature (°C) at 20 m depth. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)

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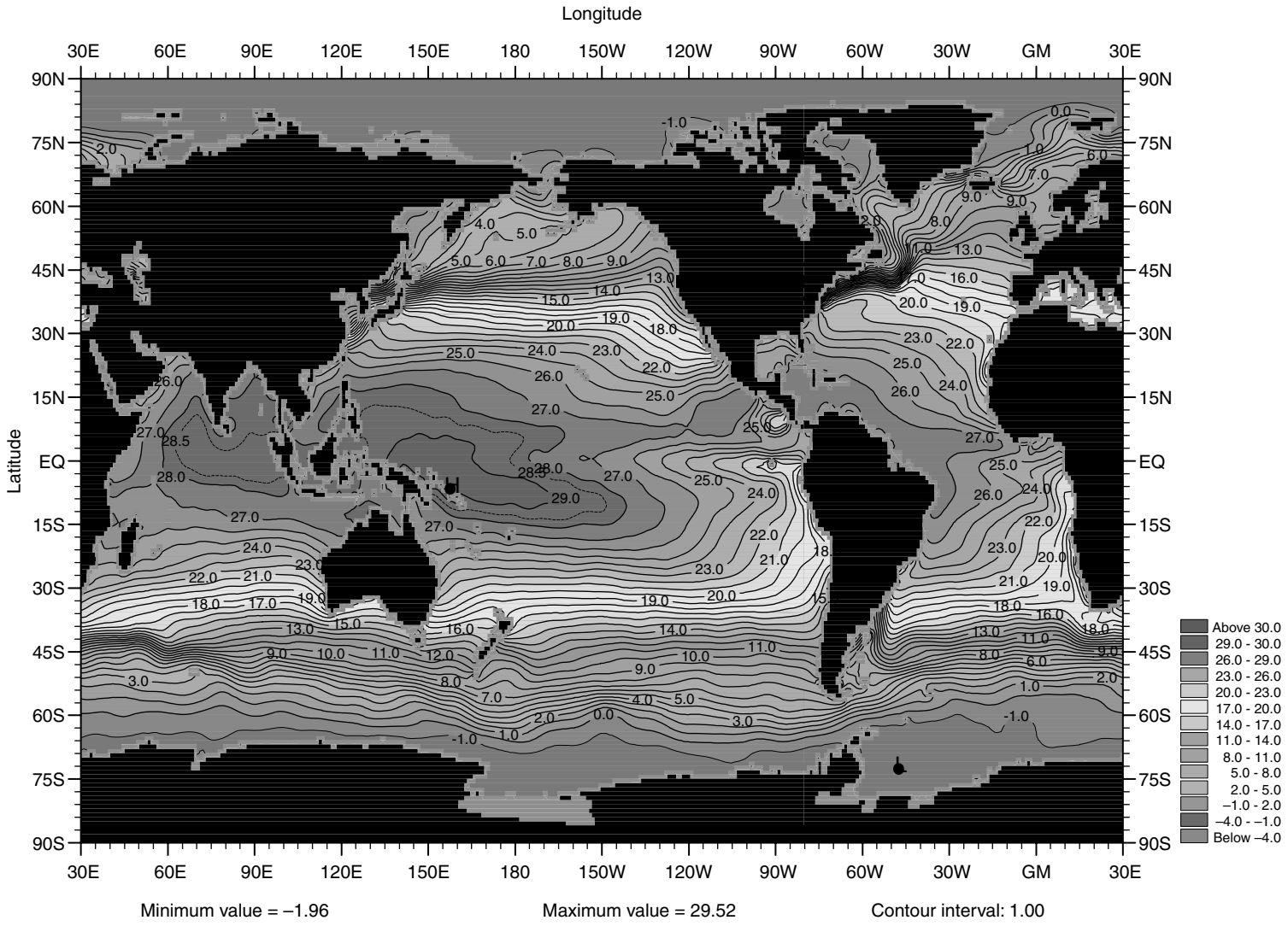


**Figure 5I.36** Annual mean temperature (°C) at 30 m depth. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)



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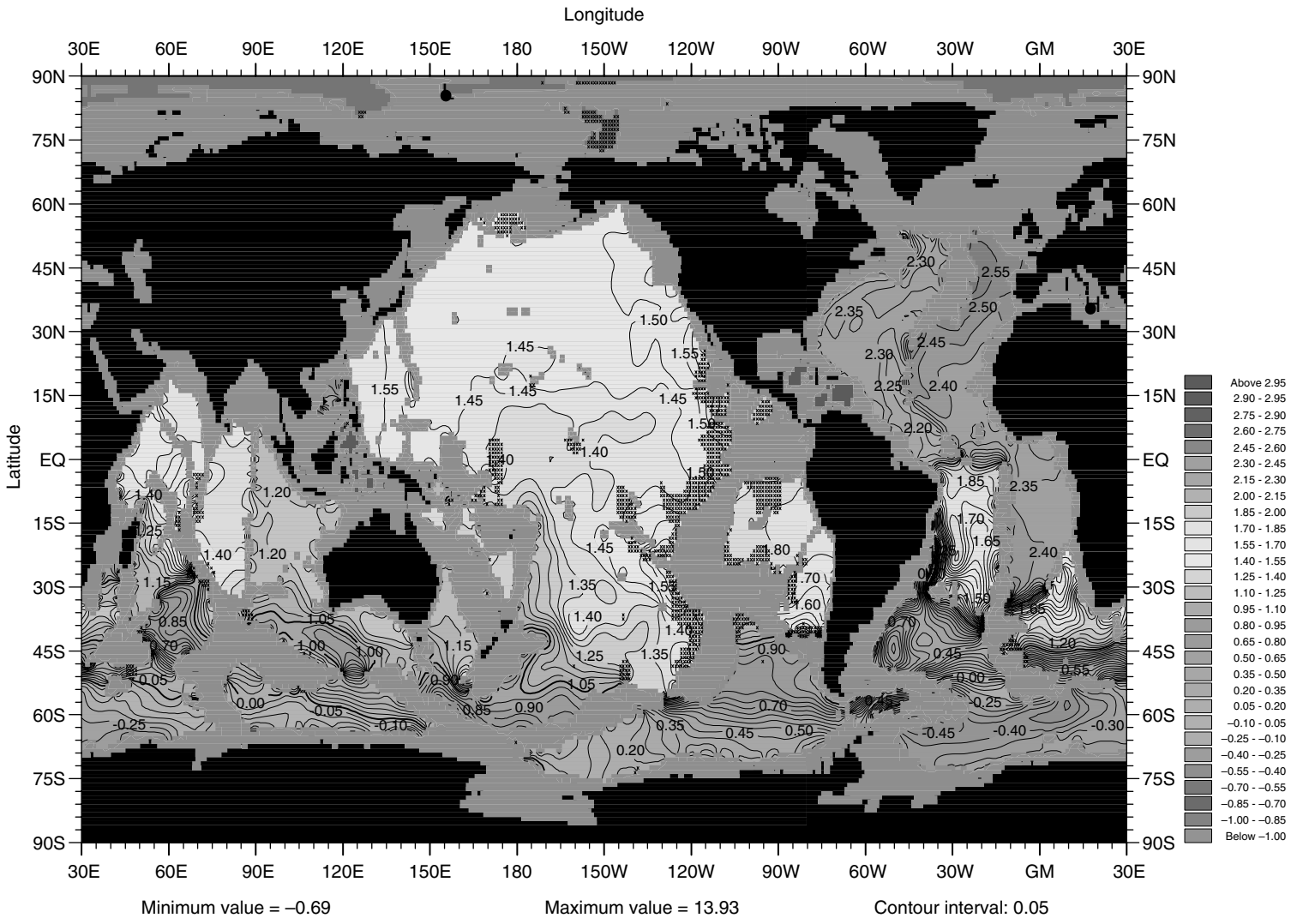


**Figure 5I.37** Annual mean temperature (°C) at 4000 m depth. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)

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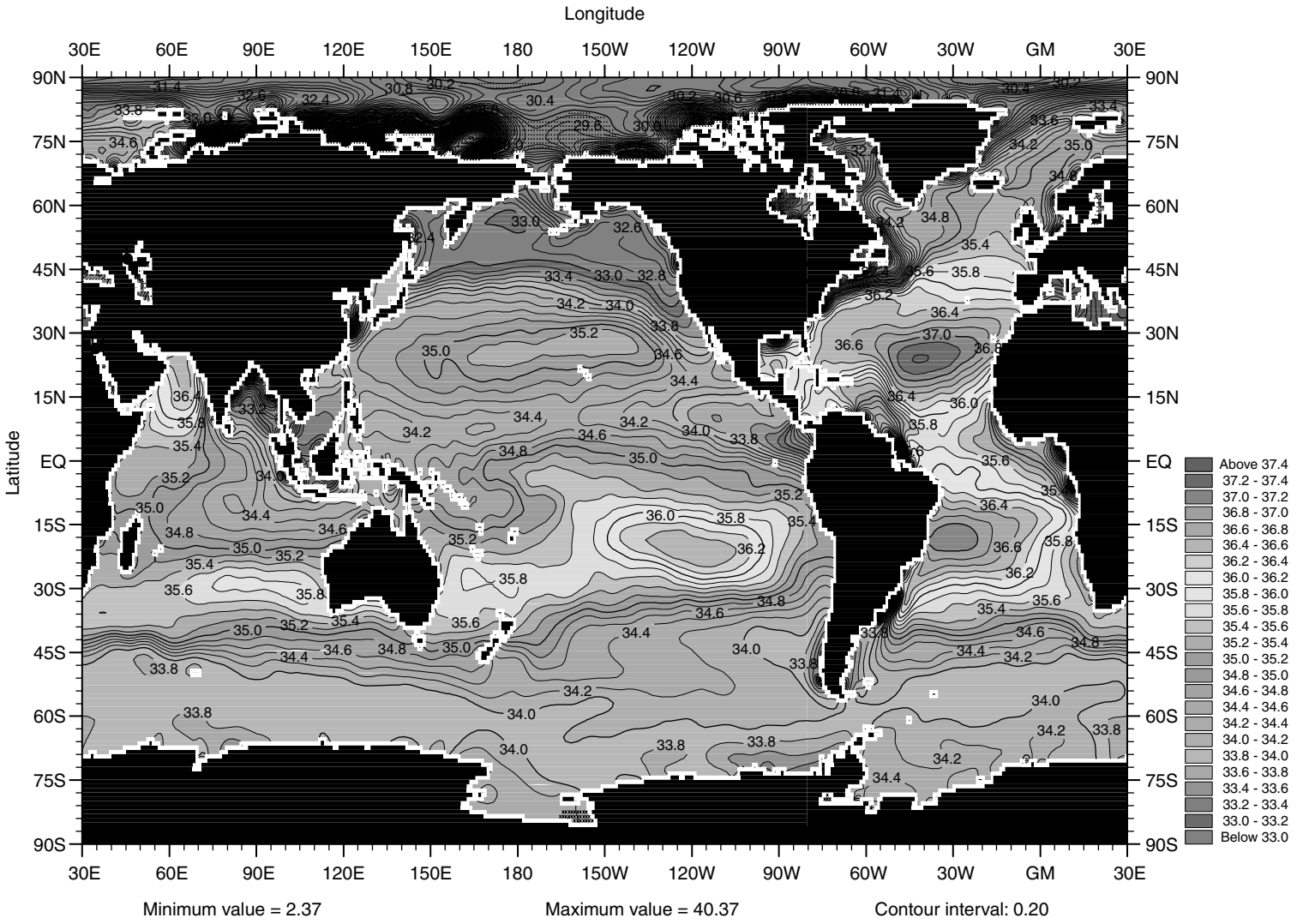


**Figure 5I.38** Annual mean salinity (PSS) at the surface. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)



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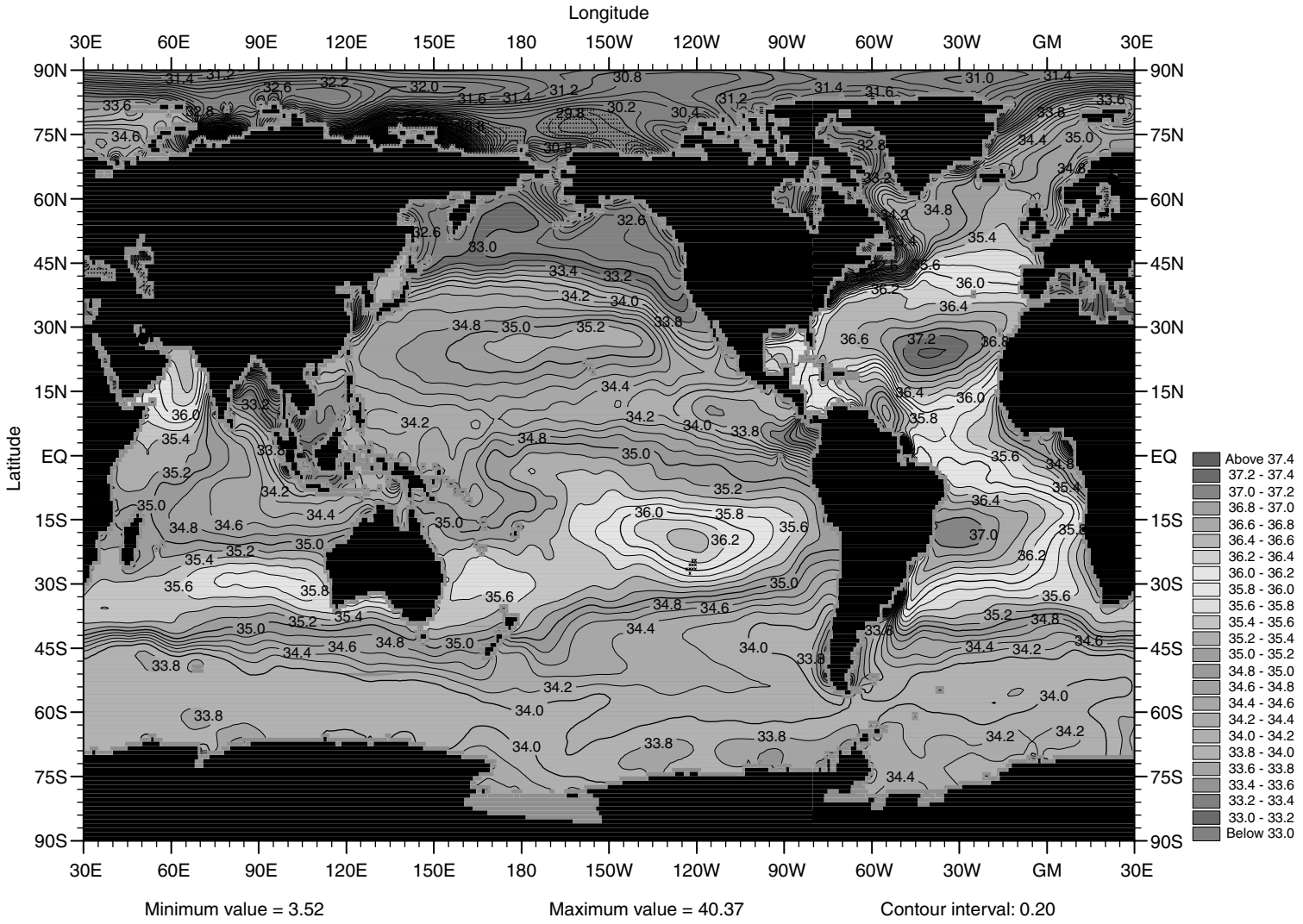


**Figure 5I.39** Annual mean salinity (PSS) at 10 m surface. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)

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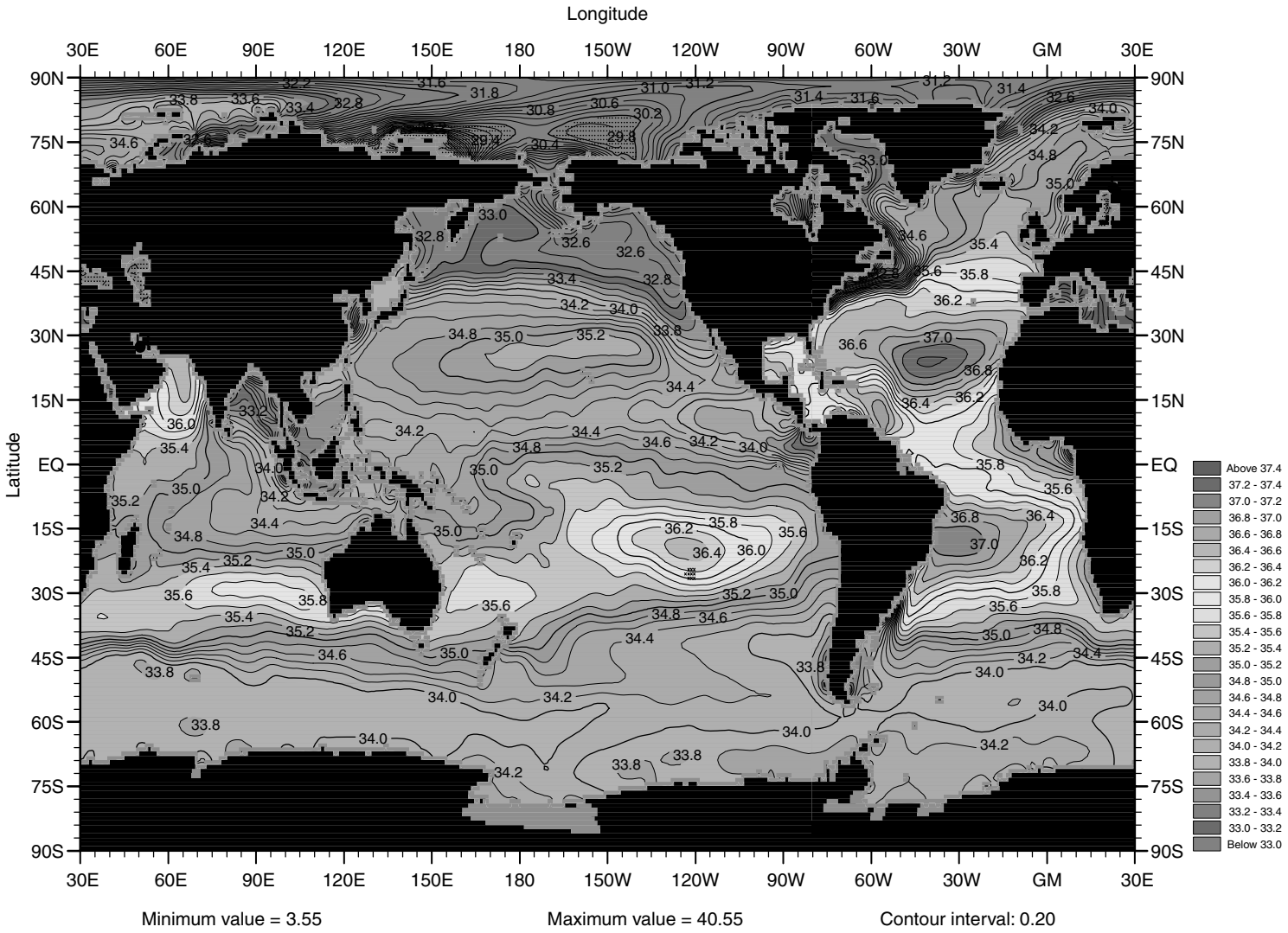


**Figure 5I.40** Annual mean salinity (PSS) at 20 m surface. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)



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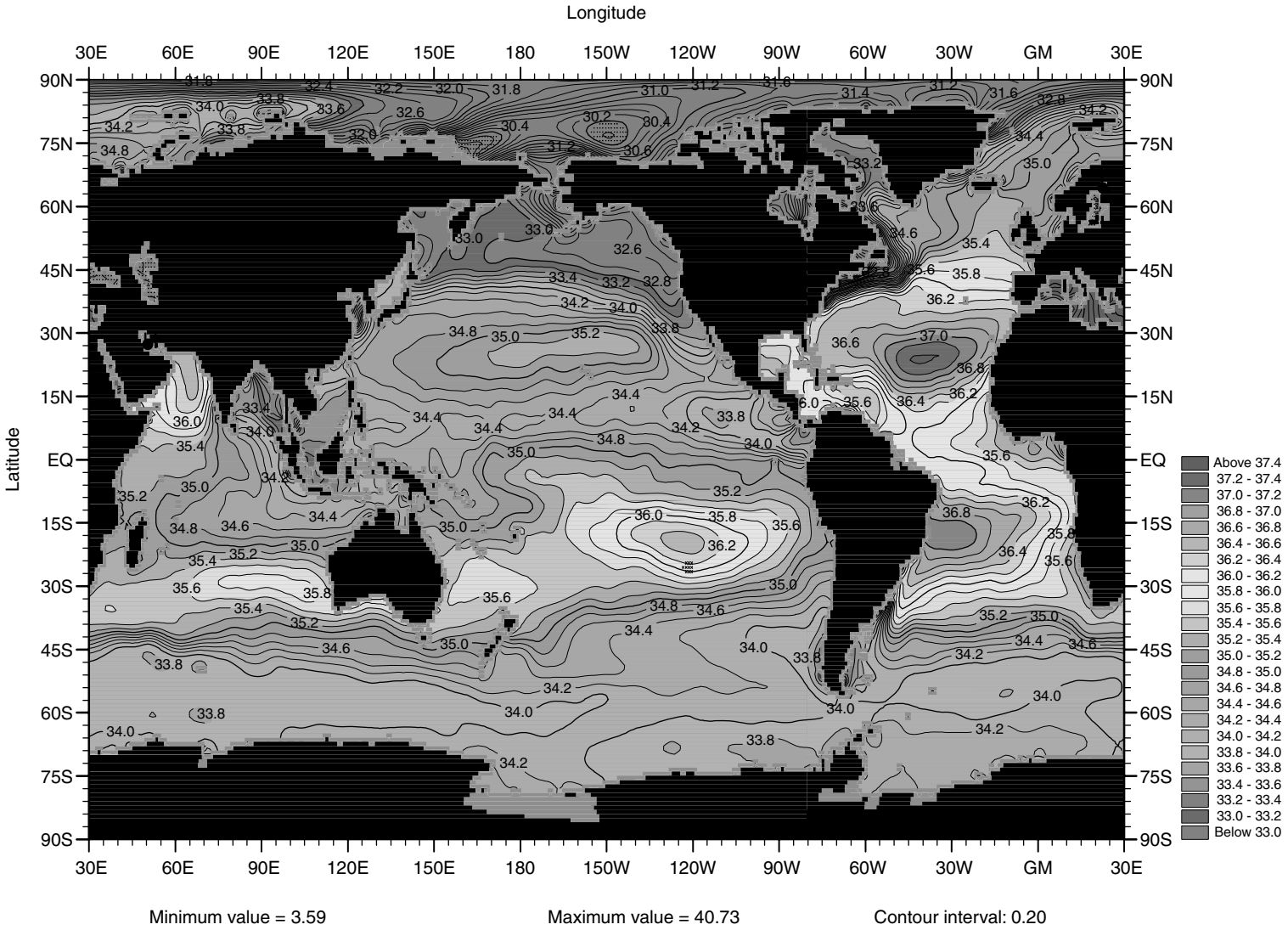


**Figure 5I.41** Annual mean salinity (PSS) at 30 m surface. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)

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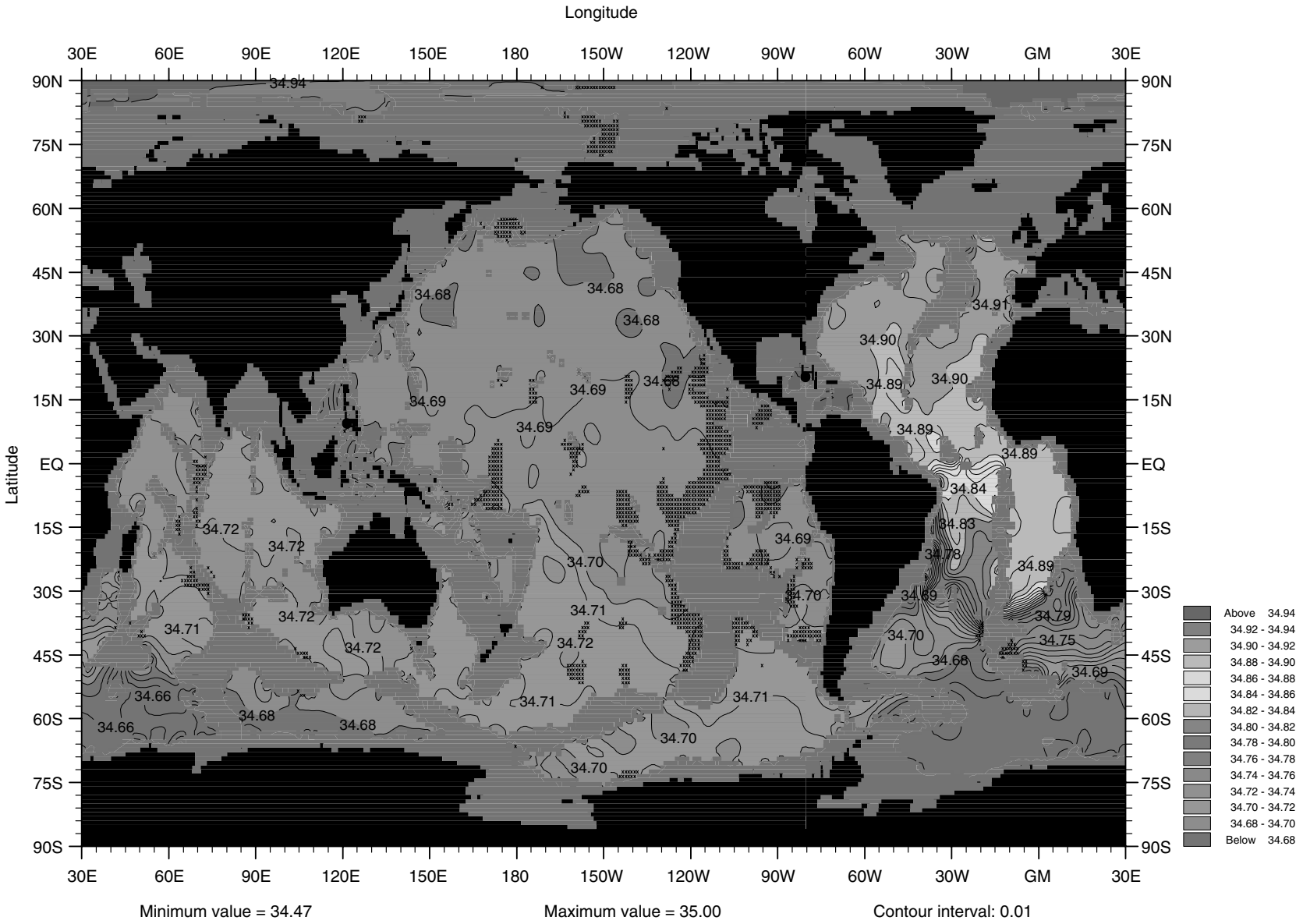


**Figure 5I.42** Annual mean salinity (PSS) at 4000 m surface. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)



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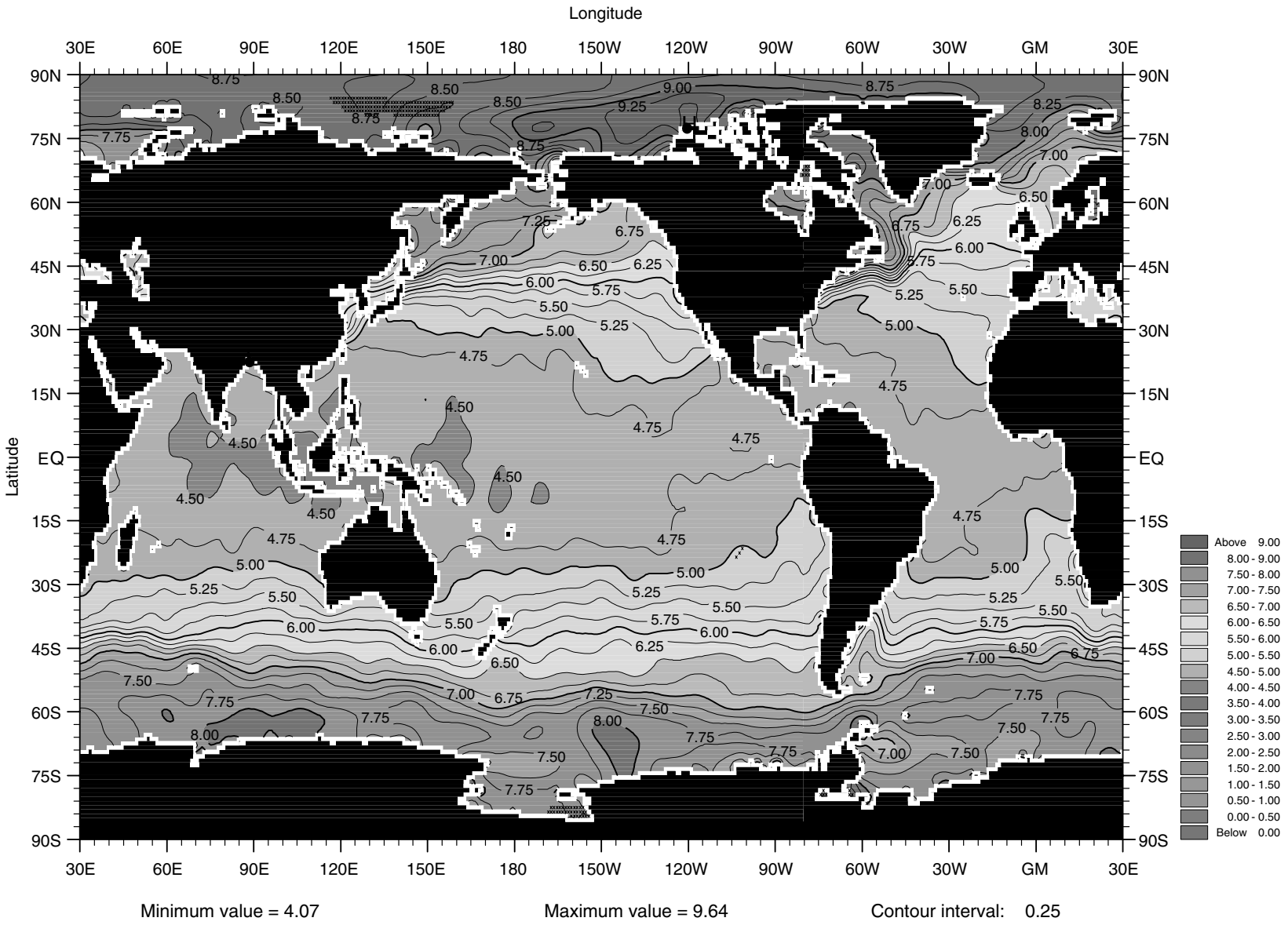


**Figure 5I.43** Annual mean oxygen (mL/l) at the surface. (From World Ocean Atlas 2001, Ocean Climate Laboratory/NODC, www.nodc.noaa.gov.)

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CHAPTER 6

# Groundwater

**Melvin Rivera**

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## SECTION 6A GROUNDWATER — UNITED STATES

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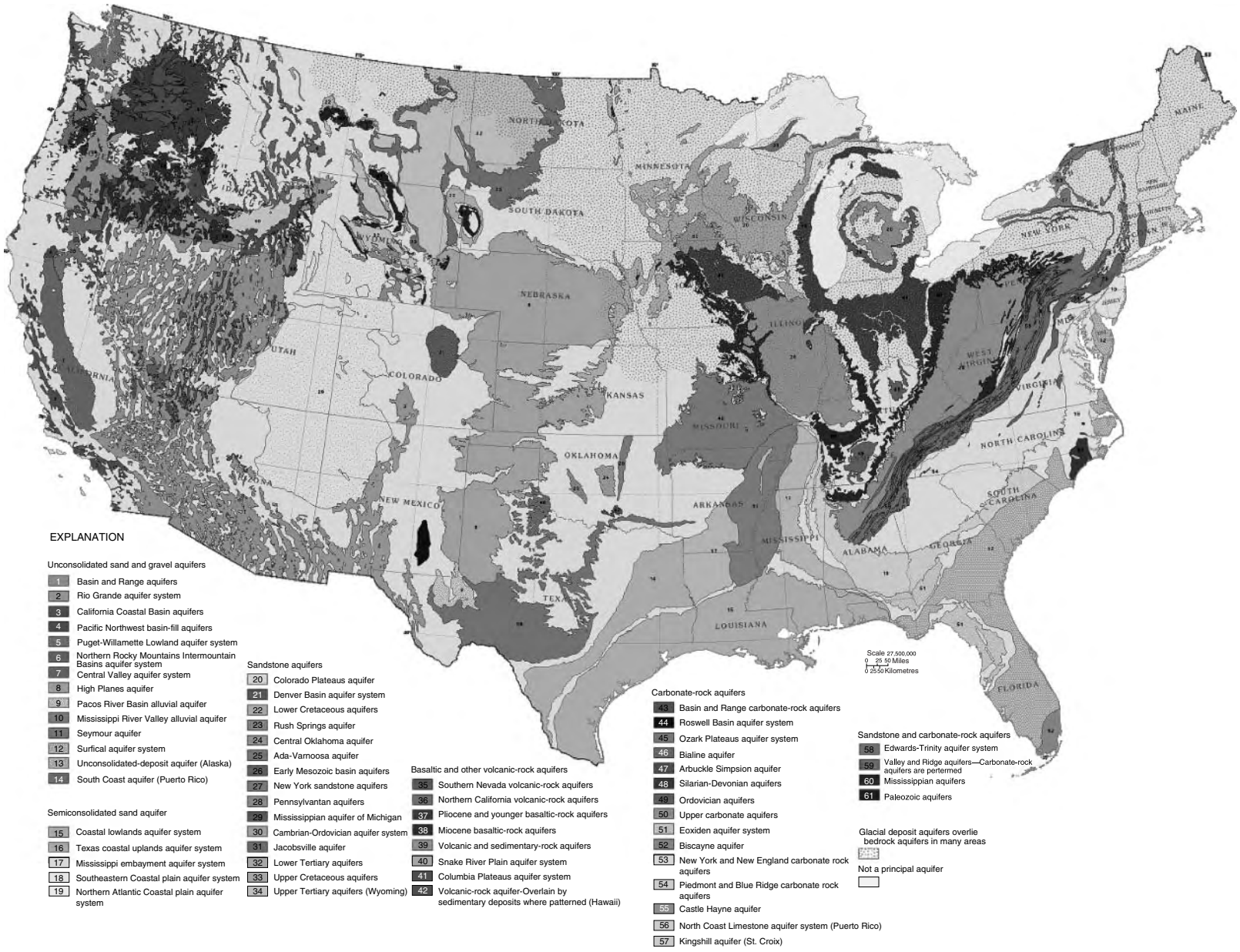


**Figure 6A.1** Principal aquifers of the United States. (From http://capp.water.usgs.gov.)



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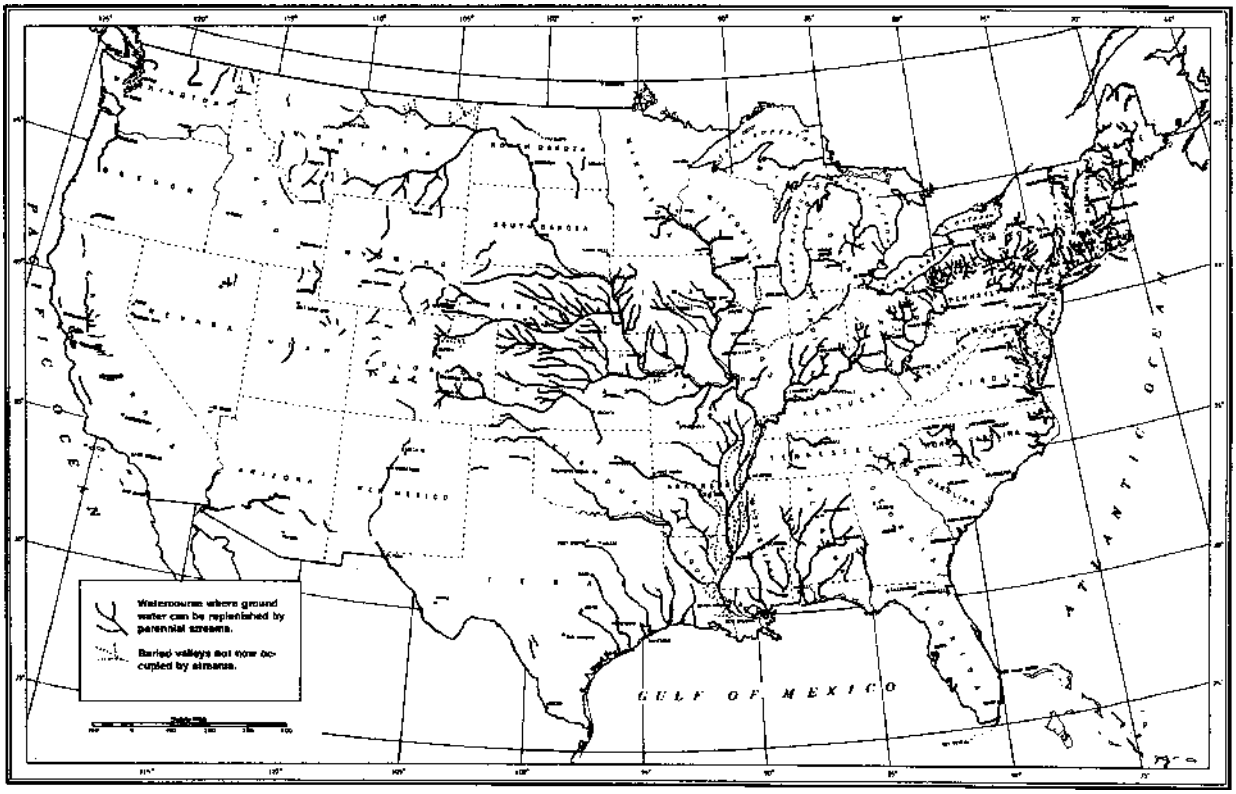


**Figure 6A.2** River valley aquifers in the United States. (From Water Information Center, 1973, Water Atlas of the United States. H.E. Thomas, *The Conservation of Ground Water*, McGraw-Hill, 1951. With permission.)

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**Table 6A.1 Occurrence of Aquifers in the United States**

| (1) Geologic Age and Rock Type | (2) Western Mountain Ranges | (3) Arid Basin | (4) Columbi Lava Plateau | (5) Colorado Plateau | (6) High Plains | (7) Unglaciated Central Region | (8) Glaciated Central Region | (9) Unglaciated Appalachian Region | (10) Glaciated Appalachian Region | (11) Atlantic and Gulf Coastal Plain | (12) Special Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cenozoic | | | | | | | | | | | |
| Quaternary | | | | | | | | | | | |
| Aluvium and related deposits (primarily. Recent and Pleistocene sediments and may include some of Pliocene age) | S and G deposits in valleys and along stream courses. Highly productive but not greatly developed — P to M | S and G deposits in valleys and along stream courses. Highly developed with local depletion. Storage large but perennial recharge limited-P | S and G deposits along streams, interbedded with basalt — I to M | U | S and G along water courses. Sand dune deposits — P (in part) | S and G along water courses and in terrace deposits — I (limited) | S and G along water courses — M | S and G along water courses and in terrace deposits. Not developed | | S and G along water courses and in terrace and littoral deposits, especially in the Mississippi and tributary valleys. Not highly developed in East and South. Some depletion in Gulf Coast — I | The most widespread and important aquifers in the United States. Well over one-half of all groundwater pumped in the United States is withdrawn from these aquifers. Many are easily available for artificial recharge and induced infiltration. Subject to saltwater contamination in coastal areas |
| Glacial drift, especially outwash (Pleisto-cene) | S and G deposits in northern part of region — I | S and G deposits especially in northern part of region and in some valleys — I | S and G outwash, especially in Spokane area — I | U | S and G outwash, much of it reworked (see above) — I | S and G outwash especially along northern boundary of region — I | S and G outwash, terrace deposits and lenses in till throughout region — P (in part) | S and G outwash in northern part. Not highly developed — M | S and G outwash, terrace deposits and lenses in till. Locally highly deve-loped — I | S and G outwash in Mississippi Valley (see above) — I | |
| Other Pleisto-cene sediments | Alluvial Fm and other basin deposits in the southern part — M to P (see Alluvium above) | | U | U | Alluviated plains and valley fills — M to I | | U | U | U | Coquina, limestone, sand, and marl Fms in Florida — M | |

*(Continued)*



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**Table 6A.1 (Continued)**

| (1) Geologic Age and Rock Type | (2) Western Mountain Ranges | (3) Arid Basin | (4) Columbi Lava Plateau | (5) Colorado Plateau | (6) High Plains | (7) Unglaciated Central Region | (8) Glaciated Central Region | (9) Unglaciated Appalachian Region | (10) Glaciated Appalachian Region | (11) Atlantic and Gulf Coastal Plain | (12) Special Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tertiary Sedi-ments, Pliocene | S and G in valley fill and terrace deposits. Not highly developed — M | Some S and G in valley fill — M | U | U | Ogalalla Fm in High Plains. Extensive S and G with huge storage but little recharge locally. Much depletion — P (in part) | U | U | Absent | Absent | Dewitt Ss in Texas. Citronelle and LaFayette Fms in Gulf States — I | |
| Miocene | Ellensburg Fm in Washi-ngton — I; elsewhere — U | U | Ellensburg Fm in Washington — I; elsewhere — U | U | Arikaree Fm — M | Arikaree Fm — M | Flaxville and other terrace deposits, S and G in north western part — M | Absent | Absent | New Jersey, Maryland, Delaware, Virginia — Cohansey and Calvert Fms — I<br>Delaware to North Carolina — St. Marys and Calvert Fms — I<br>Georgia and Florida — Tampa Ls, Alluvium Bluff Gp, and Tamiami Fm — I<br>Eastern Texas — Oakville and Catahoula Ss — I | Aquifers in coastal areas subject to saltwater encroachment and contamination |
| Oligocene | U | U | U | U | Brule, clay, locally — I; else where — U | U | U | Absent | Absent | Suwannee Fm, Byram Ls, and Vicksburg Gp — I | |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Eocene | Knight and Almy Fm in southwest Wyoming — M | U | U | Kngiht and Almy Fm in southwest Wyoming, Chuska Ss, and Tohatchi Sh in northwest Arizona and northeast New Mexico — M | U | Claibourne and Wilcox Gp in southern Illinois (?), Kentucky, and Missouri — M; elsewhere — U | Absent | Absent | Absent | New Jersey, Maryland, Delaware, Virginia — Pamunkey Gp — I. North Carolina to Florida — Ocala Ls and Castle Hayne Marl — P (in part)<br>Florida — Avon Park Ls, South Carolina to Mexican border, Claibourne Gp, Wilcox Gp — I | Includes the principal formations (Ocala Ls, especially) of the great Floridan aquifer. Subject to saltwater contamination in coastal areas but source of largest groundwater supply in southeastern United States |
| Paleocene | U | U | U | U | Feet Union Gp — M | Feet Union Gp — M | Feet Union Gp — M | Absent | Absent | Clayton Fm in Georgia — I | |
| Volcanic rocks, primarily basalt | U | Local flows — M | Many interbeded basalt flows from Eocene to Pliocene — P | Local flows — M | Absent | Absent | Absent | Absent | Absent | Absent | |
| Mesozoic upper cretaceous | U | Ss lenses in southern California — M; elsewhere — U | U | Dakota Ss and other not clearly distinguishable Ss a notable source of water from Minnesota and Iowa to the Rocky Mountains and south into New Mexico; also in Utah and Arizona — I<br>In northwestern part of region Fox Hills and related Ss (Lennep, Colgate, etc.) locally valuable as water sources — M<br>Ss of Montana Gp — M<br>Ss members of Mesaverde Gp in Wyoming, Colorado, Utah, New Mexico, and Arizona — M<br>In Texas aquifers listed under col. 11 — I | | | | U | U | New Jersey, Maryland, Delaware — Magothy and Raritan Fm — I<br>North and South Carolina — Peedee and Black Creek Fms — I<br>Alabama and Georgia — Ripley and Eutah Fms — I | In coastal areas subject to saltwater encroachment and contamination. Ss aquifers of the central regions and the west primarily valuable when water from other sources is unavailable |

*(Continued)*



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**Table 6A.1 (Continued)**

| (1) Geologic Age and Rock Type | (2) Western Mountain Ranges | (3) Arid Basin | (4) Columbi Lava Plateau | (5) Colorado Plateau | (6) High Plains | (7) Unglaciated Central Region | (8) Glaciated Central Region | (9) Unglaciated Appalachian Region | (10) Glaciated Appalachian Region | (11) Atlantic and Gulf Coastal Plain | (12) Special Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Tennessee, Kentucky, Illinois — McNairy Ss — I<br>Arkansas to Texas — Navarro Gp and Taylor Fm — I | |
| Lower creta-ceous | U | U | U | In northern part of these regions Lakota, Cloverly, and Kootenai Ss — M<br>In southern part Purgatoire and Dakota Ss—M. Texas aquifers listed in col. 11—I | | | U | U | U | Texas — Woodbine Ss — I. New Jersey, Maryland, Delaware — Patapsco and Patuxent Fms — I<br>West of Mississippi River, especially in Texas — Edwards Ls and Ss in Trinity Gp — I | |
| Jurassic | Locally — Ss Fm — M | Locally — Ss Fm — M | U | Ss Fms. Some may not be develo-ped — I | U | U | Absent | Absent | Absent | U | |
| Triassic | Locally — Ss and C Fms — M | | U | Ss and C Fms used locally. Shinarump C and corre-latives give rise to springs — I | U | U | Absent | Ss, C, jointed shale, and basalt beds of Newark Gp in Massachusetts, Connecticut, New Jersey, Pennsylvania, Maryland, Virginia, and North Carolina — M | | | Water from Ss, C, and Ls Fms west of Mississippi river, especially valuable when water from other sources is unavailable |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Paleozoic<br>Permian | U | U | U | DeChelly Ss — I<br>Kaibab Ls — M | U | San Andres Ls in Roswell Basin — P<br>Quarter-master Gp gives rise to many springs — M<br>Other Ss and Ls in Kansas, Oklahoma, and Texas — M | U | U | Absent | U | |
| Pennsyl-vanian | Tensleep Ss in Wyoming and other Ss else-where — M | U | U | U | U | Ss and C beds from the Appalachians to Iowa and eastern Kansas — M to I | | | Jointed and weath-ered Sh, Ss, and C in Rhode Island and Massach-usetts — M | U | |
| Mississippian | Ls locally but little deve-loped; springs arise from Ls in Rocky Mountains — M | A few springs arise from Ls locally — U | U | Some springs arise from Ls locally — U | U | In Illinois, Iowa, Missouri, and Kentucky the Burlington, Keokuk, and St. Louis Ls — I<br>Some Ss (primarily Chester) — M<br>In Alabama and Tennessee — the Feet Payne chert, Gaspar Fm, and St. Genevieve and Tuscumbia Ls — I<br>In Kentucky many springs arise in Ls | | | U | U | Do |
| Devonian | U | U | U | U | U | U, except locally in Michigan (Traverse Fm), Illinois, Missouri, Ohio (Columbia Ls), and Kentucky — M | Jointed Ls, Ss, and Sh, some highly metamorphosed M locally and little used | | | U | |
| Silurian | U | U | U | U | U | Ls and dolomite Fms in New York, Kentucky, Tennessee, Ohio, Illinois, and Iowa<br>Better-known aquifers include Monroe dolomite and related carbonate Fms in Ohio — I; "Niagaran" dolomite in Illinois — P (in part) | U | | U | U | |

*(Continued)*



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**Table 6A.1 (Continued)**

| (1) Geologic Age and Rock Type | (2) Western Mountain Ranges | (3) Arid Basin | (4) Columbi Lava Plateau | (5) Colorado Plateau | (6) High Plains | (7) Unglaciated Central Region | (8) Glaciated Central Region | (9) Unglaciated Appalachian Region | (10) Glaciated Appalachian Region | (11) Atlantic and Gulf Coastal Plain | (12) Special Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordovician | U | U | U | U | U | In Arkansas, Missouri, Iowa, Illinois, eastern Indiana, southern Wisconsin, southeastern Minnesota, the St. Peter Ss — I<br>Overlying and subjacent Ls and Ss where present in above states and in Kansas, Oklahoma, and New York — M to I<br>In Kentucky and Tennessee — Ls Fm — M to I | | Locally Ls and Ss Fms; not highly developed — M | | U | |
| Cambrian | U | U | U | U | U | Ss beds in Wisconsin, Minnesota, Iowa, and Illinois include Jordan Ss, "Dresbach Fm" (Galesville Ss, Eau Claire Fm, Mt. Simon Ss) — P (in part)<br>Ls and Ss Fms in Missouri and Arkansas give rise to many large springs and yield water to many wells — P | | Ls Fms give rise to large springs in southern Appalachians. Otherwise — U | Eastern New York and New England Ss Fms — M; otherwise — U | U | |
| Precambrian (including crystalline rocks which may be younger) | Weathered and jointed rocks locally — M | | U | U | U | U | Weathered and jointed rocks locally in Minnesota, Wisconsin, northern Michigan, Piedmont Plateau, New England — M to I. Some Ss in North Central States | | | U | Do |

*Note:* Abbreviations: (1) Aquifers: P, principal aquifer in region; I, important aquifer in region; M, minor aquifer in region; U, unimportant as an aquifer in region. (2) Rock terms; S, sand, Ss, sandstone; G, gravel; C, conglomerate; Sh, shale; Ls, limestone; Fm, formation; Gp, group.

*Source*: From Maxey, In Chow, *Handbook of Applied Hydrology*, McGraw-Hill, Copyright 1964. With permission.

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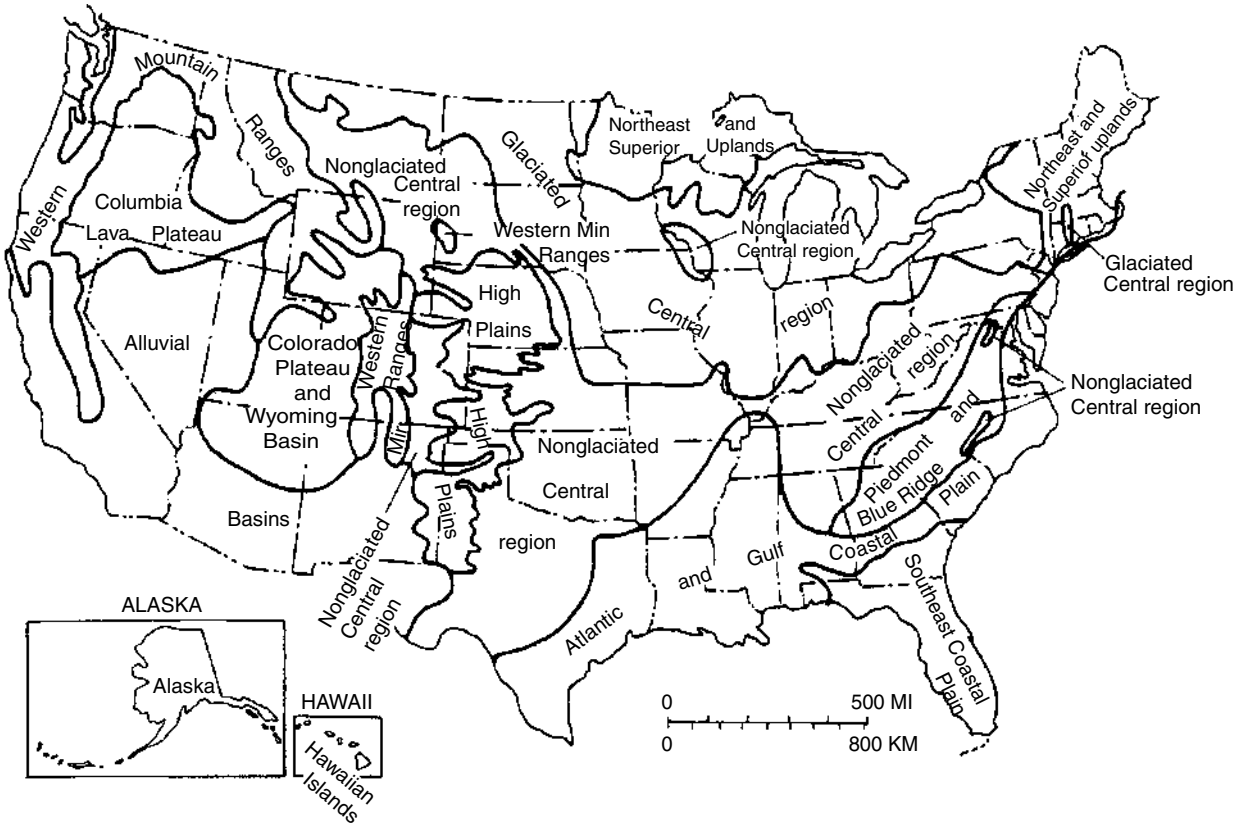


**Figure 6A.3** Groundwater regions of the United States. (From Heath, R.C., Classification of ground-water regions of the United States, *Groundwater*, 20, 4, 1982.)

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**Table 6A.2 Principal Physical and Hydrologic Characteristics of Groundwater Regions in the United States**

| | Components of the System | | | | | | | | | | | | | | | Characteristics of the Dominant Aquifers | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | Water-Bearing Openings | | | | | Compo-sition | | | Storage and Transmission Properties | | | | | | | Recharge and Discharge Conditions | | | | | |
| | Unconfined Aquifer | | | Confining Beds | | | | Confined Aquifers | | | | Presence and Arrangement | | | | Primary | | | Secon-dary | | Degree of Solubility | | | Porosity | | | Trans-missivity | | | | Recharge | | | Discharge | | |
| Name | Hydrologically Insignificant | Minor Aquifer | Dominant Aquifer | Hydrologically Insignificant | Thin, Discontinuous, or v. Leaky | Thick, Impermeable | Interlayered with Aquifers | Hydrologically Insignificant | Not Highly Productive | Multiple Aquifers | A Single, Dominant Aquifer | Single Dominant Unconfined Aquifer | Two Interconnected Aquifers | Unconfined Aquifer, Confining Bed, Confined Aquifer | Complex Interbedded Sequence | Pores in Unconsolidated Deposits | Pores in Semiconsolidated Rocks | Tubes and Cooling Cracks in Lava | Fractures and Faults | Solution Enlarged Openings | Insoluble | Mixed Soluble and Insoluble | Soluble | Large ( >0.2) | Moderate (0.01–0.2) | Small ( <0.01) | Large ( >2500 $m^2$ $day^{-1}$) | Moderate (250 – 2500 $m^2$ $day^{-1}$) | Small (25 – 250 $m^2$ $day^{-1}$) | Very Small ( <25 $m^2$ $day^{-1}$) | Uplands between Streams | Losing Streams | Leakage through Confining Beds | Springs and Surface Seepage | Evaporation and Basin Sinks | Into Other Aquifers |
| Western Mountain Ranges | | X | | X | | | | | X | | | | X | | | X | | | X | | X | | | | X | | | | X | | | X | | | X | |
| Alluvial Basins | | X | | | | | X | | | X | | | | | X | X | | | | | X | | | X | | | X | | | | | X | | | X | X |
| Columbia Lava Plateau | | X | | | | | X | | | X | | | | | X | X | | X | | | X | | | | | X | X | | | | | X | | | X | |
| Colorado Plateau and Wyoming Basin | X | | | | | | X | | | X | | | | | X | | X | | X | | X | | | | | X | | | X | | X | | X | X | | |
| High Plains | | | X | X | | | | X | | | | X | | | | X | | | | | X | | | X | | | X | | | | | X | | | X | | |
| Nonglaciated Central Region | | X | | | | | X | | | X | | | | | X | | X | | X | X | | X | | | X | | X | | | X | | X | | X | X | | X |
| Glaciated Central Region | | X | | | X | | | | | X | | | | | X | X | X | | X | X | | X | | | | X | | | | | | X | | | X | | X |
| Piedmont and Blue Ridge | | X | | X | | | | | X | | | | X | | | X | | | X | | X | | | | | X | | | | X | X | | | X | | |
| Northeast and Superior Uplands | | X | | | X | | | | X | | | | X | | | X | | | X | | X | | | | | X | | | X | | X | | | X | | |
| Atlantic and Gulf Coastal Plain | | X | | | | | X | | | X | | | | | X | X | | | | X | | X | | | X | | | X | | | X | | X | X | | X |
| Southeast Coastal Plain | | X | | | | X | | | | | X | | | X | | X | | | | X | | | X | X | | | X | | | | X | | X | X | | |
| Alluvial Valleys | | | X | | X | | | X | | | | X | | | | X | | | | | X | | | X | | | X | | | | X | | | X | | |
| Hawaii | | | X | | X | | | X | | | | X | | | | | | X | | | X | | | X | | | X | | | | X | X | | X | | |
| Alaska | | | X | | X | | | | X | | | | | | X | X | | | X | | | X | | | X | | | X | | | | X | | | X | | |

*Note:* For map of regions, see Figure 6A.3.

*Source*: From Heath, R.C., Classification of ground-water regions of the United States, *Groundwater*, 20, 4, 1982.

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**Table 6A.3 Basic Data Required for Groundwater Studies**

**A. Maps, Cross Sections, and Fence Diagrams**

1. Planimetric
2. Topographic
3. Geologic
   a. Structure
   b. Stratigraphy
   c. Lithology
4. Hydrologic
   a. Location of wells, observation wells, and springs
   b. Groundwater table and potentiometric contours
   c. Depth to water
   d. Quality of water
   e. Recharge, discharge, and contributing areas
5. Vegetative cover, location of wetlands
6. Soils
7. Aerial photographs

**B. Data on Wells and Springs**

1. Location, depth, diameter, types of well, and logs
2. Static and pumping water level, hydrographs, yield, specific capacity, quality of water
3. Present and projected groundwater development and use
4. Corrosion, incrustation, well interference, and similar operation and maintenance problems
5. Location, type, geologic setting, and hydrographs of springs
6. Observation well networks
7. Water sampling sites

**C. Aquifer Data**

1. Type, such as unconfined, artesian, or perched
2. Thickness, depths, and formational designation
3. Boundaries
4. Transmissivity, storativity, and permeability
5. Specific retention
6. Discharge and recharge
7. Ground and surface water relationships
8. Aquifer models

**D. Climatic Data**

1. Precipitation
2. Temperature
3. Evapotranspiration

**E. Surface Water**

1. Use
2. Quality
3. Runoff distribution, reservoir capacities, inflow and outflow data
4. Return flows, section gain or loss
5. Recording stations
6. Low flow data

**F. Environment**

1. Location of hazardous waste sites or other potential sources of pollution
2. Use of herbicides, pesticides, fertilizers, and road salt
3. Site history

**G. Local Drilling Facilities and Practices**

1. Size and types of drilling rigs locally available
2. Logging services locally available
3. Locally used materials, well designs, and drilling practices
4. State or local rules and regulations

*Source*: From U.S. Bureau of Reclamation, *Groundwater Manual*; Amended, 1977.

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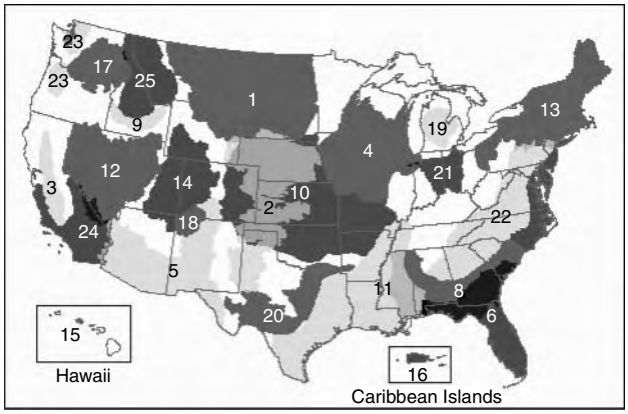


1 Northern Great Plains
2 High Plains
3 Central Valley, California
4 Northern Midwest
5 Southwest Alluvial Basins
6 Floridan
7 Northern Atlantic Coastal Plain
8 Southeastern Coastal Plain
9 Snake River Plain
10 Central Midwest
11 Gulf Coastal Plains
12 Great Basin
13 Northeast Glacial Aquifers
14 Upper Colorado River basin
15 Oahu, Hawaii
16 Caribbean Islands
17 Columbia Plateau
18 San Juan Basin
19 Michigan Basin
20 Edwards-Trinity
21 Midwestern Basins and Arches
22 Appalachian Valleys and Piedmont
23 Puget-Willamette Lowland
24 Southern California Alluvial Basins
25 Northern Rocky Mountain Intermontane

The U.S. Geological Survey initiated the Regional Aquifer-System Analysis (RASA) Program in 1978 in response to Federal and State needs for information to improve management of the Nation's groundwater resources. The objective of the RASA Program is to define the regional geohydrology and establish a framework of background information—geologic, hydrologic, and geochemical—that can be used for regional assessment of groundwater resources and in support of detailed local studies. The program was completed in 1995.

A total of 25 aquifer systems were studied under the RASA Program.

**Figure 6A.4** Regional aquifer study areas. (From http://water.usgs.gov.)

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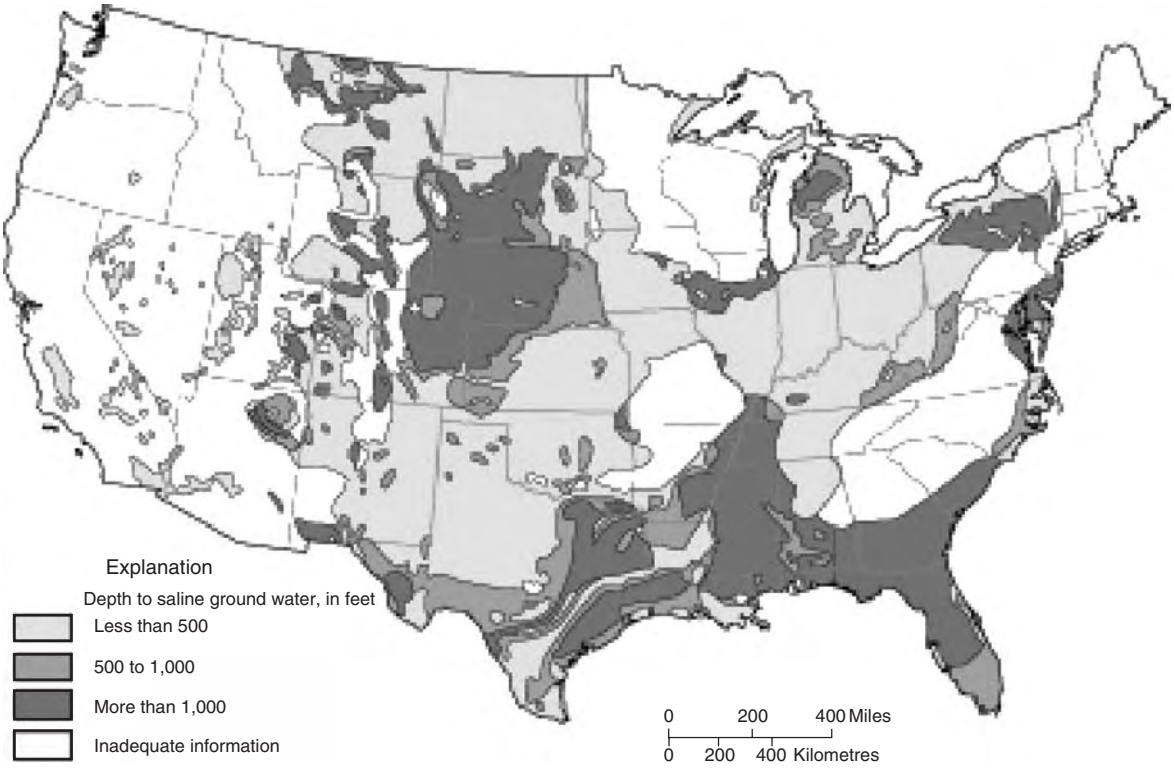


**Figure 6A.5** Depth to saline groundwater in the United States (generalized from Feth and others, 1965). (From USGS fact sheet 075-03, October 2003.)

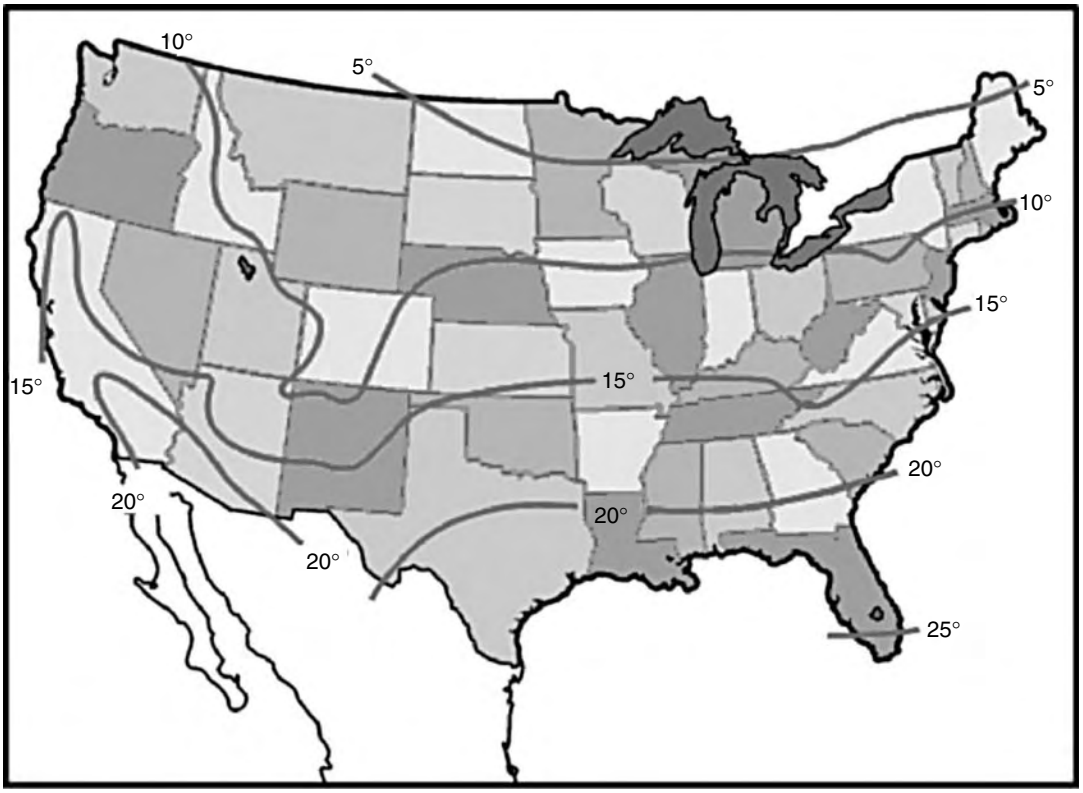


**Figure 6A.6** Average shallow groundwater temperatures in the United States developed by Collins. (From www.epa.gov.)

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**Table 6A.4 Estimated Groundwater in Storage, by Continent**

| Continent | 0–100 m | 100–200 m | 200–2000 m | Total |
|---|---|---|---|---|
| Europe | 0.2 | 0.3 | 1.1 | 1.6 |
| Asia | 1.3 | 2.1 | 4.4 | 7.8 |
| Africa | 1 | 1.5 | 3.0 | 5.5 |
| North America | 0.7 | 1.2 | 2.4 | 4.3 |
| South America | 0.3 | 0.9 | 1.8 | 3 |
| Australia | 0.1 | 0.2 | 0.9 | 1.2 |
| Total | 3.6 | 6.2 | 13.6 | 23.4 |

*Note:* In millions of $km^3$; based on publications by soviet hydrologists.

*Source*: From Castany, G., Hydrogeology of deep aquifers, *Episodes*, 1981, 3, 1981.

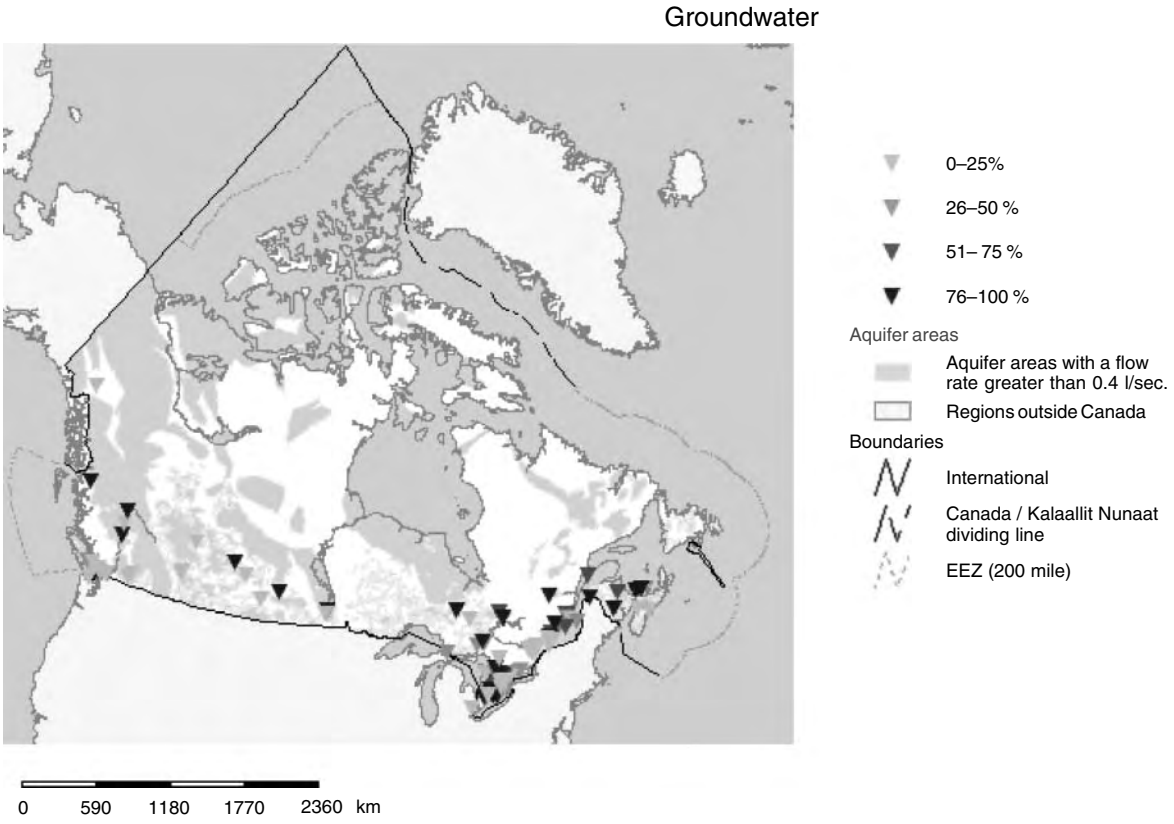


**Figure 6A.7** Groundwater potential in Canada and a percentage of people using groundwater resources in Canadian municipalities over 10,000 people. (From www.atlas.gc.ca.)

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## SECTION 6B WATER WELLS — UNITED STATES

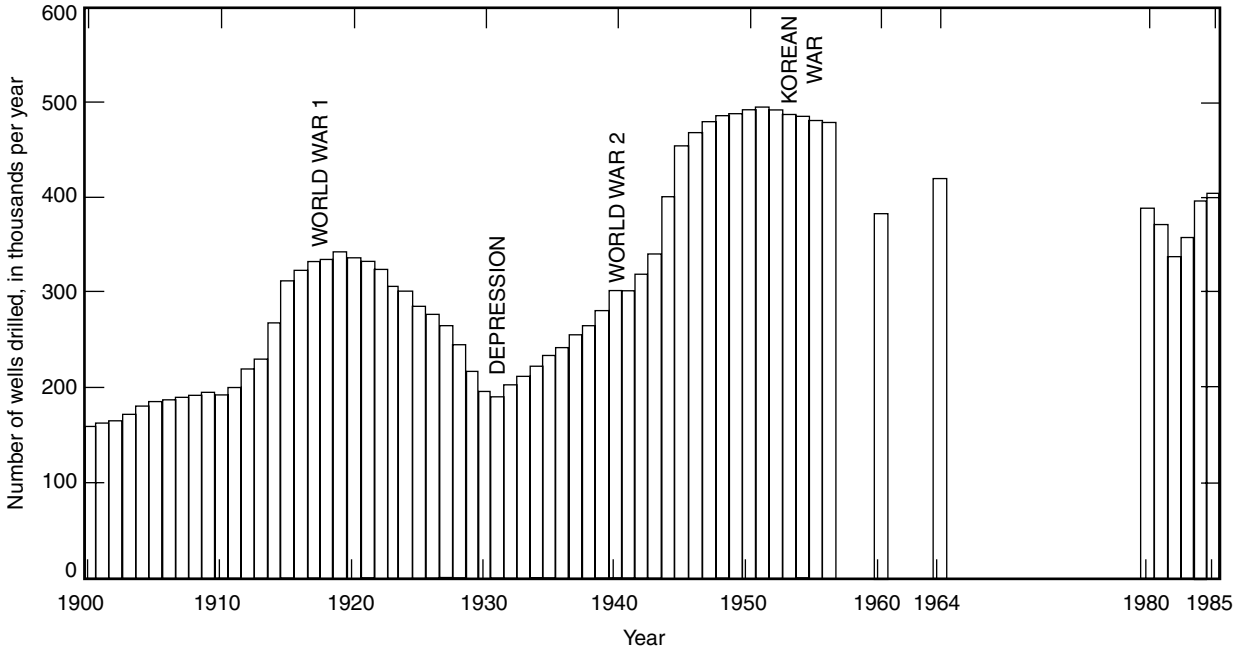
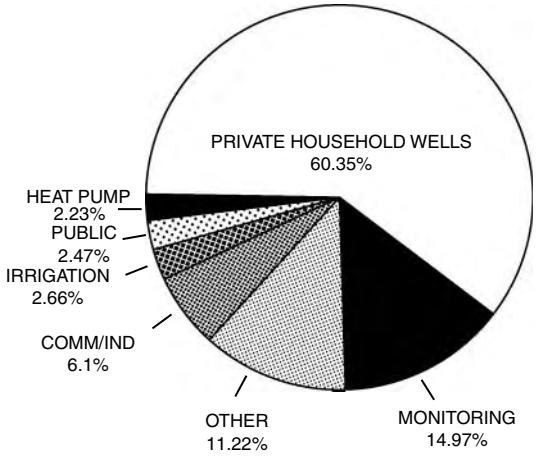



**Figure 6B.8** Number of water wells drilled in the United States and relation to major events in the United Stated history. (From Hindall, S.M., Eberle, Michael,1987, National and regional trends in water-well drilling in the United States 1964–1984, *U.S. Geological Survey, Open File Report 87–247*; 1985 data from National Water Well Association.)

**Table 6B.5 Number and Type of Water Wells and Boreholes Constructed in the United States in 1985**

| Application/type | 1985 |
|---|---|
| Commercial/industrial | 49,379 |
| Heat pump supply/return | 18,029 |
| Agricultural irrigation | 21,583 |
| Private household | 488,918 |
| Public supply | 20,010 |
| Monitoring | 121,294 |
| Livestock watering[a] | 29,343 |
| Lawn/turf irrigation[a] | 27,036 |
| Other | 34,482 |
| **Total** | **810,074** |




*Note:* Based on Water Well Journal Survey of 8,043 firms.

[a] Included in "Other" category on pie chart.

*Source*: From McCray, Kevin. Copyright Water Well Journal September 1986. Reprinted with permission.

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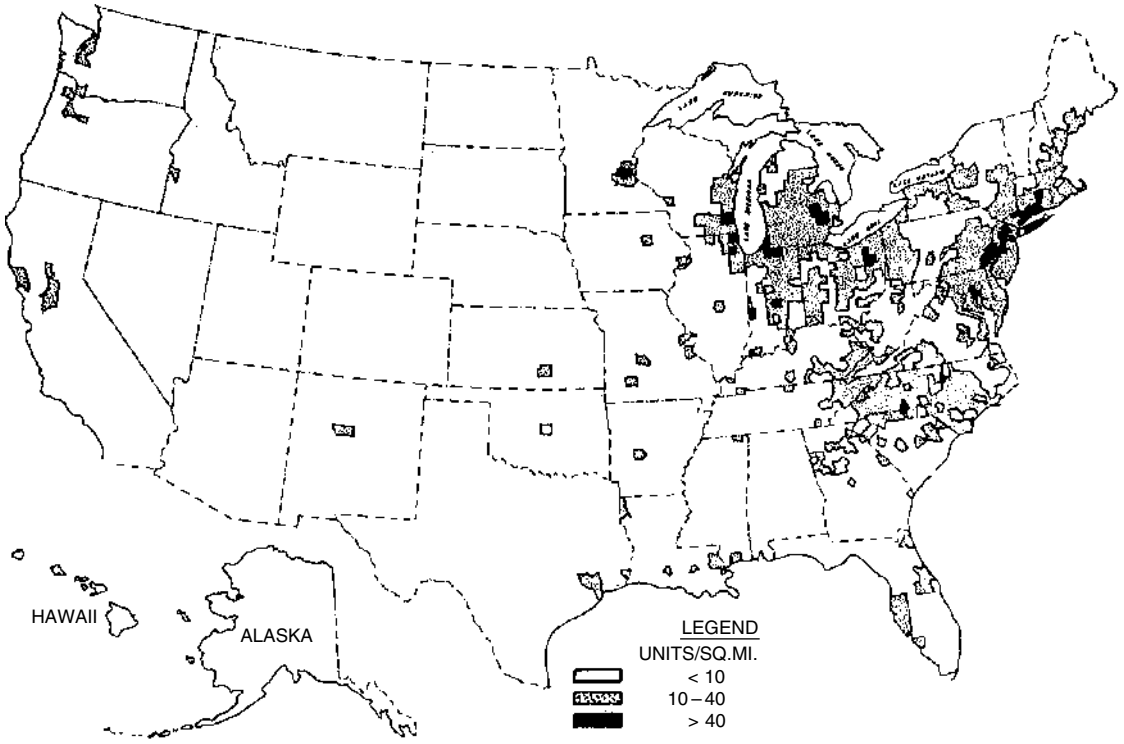


**Figure 6B.9** Density of housing units using on site domestic water supply systems in the United States [By county]. (From U.S. Environmental Protection Agency, Office of Water Supply, Office of Solid Waste Management Programs, 1977, *The Report to Congress: Waste Disposal Practices and Their Effects on Groundwater*.)

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**Table 6B.6 Number and Type of Water Wells in the United States, 1988**

| State | Irrigation | Public Supply[a] | Community Supply | Household |
|---|---|---|---|---|
| Alabama | N/A | 1,706 | 1,013 | 267,202 |
| Alaska | 10 | 1,283 | 454 | 32,391 |
| Arizona | 6,125 | 2,533 | 1,650 | 43,226 |
| Arkansas | 21,078 | 3,220 | 1,073 | 213,672 |
| California | 67,770 | 8,143 | 3,320 | 359,584 |
| Colorado | 17,809 | 3,116 | 1,465 | 84,459 |
| Connecticut | N/A | 5,373 | 1,073 | 241,130 |
| Delaware | 559 | 1,141 | 497 | 52,701 |
| Florida | 29,017 | 11,337 | 4,650 | 573,059 |
| Georgia | 4,492 | 4,139 | 2,460 | 405,078 |
| Hawaii | N/A | 219 | 218 | 536 |
| Idaho | 7,371 | 3,114 | 1,312 | 88,853 |
| Illinois | 1,107 | 10,018 | 1,492 | 443,681 |
| Indiana | N/A | 16,100 | 1,805 | 546,381 |
| Iowa | 2,210 | 5,052 | 3,674 | 236,709 |
| Kansas | 18,658 | 2,456 | 2,405 | 116,567 |
| Kentucky | N/A | 1,144 | 386 | 247,506 |
| Louisiana | 4,558 | 3,162 | 1,996 | 200,446 |
| Maine | N/A | 3,433 | 595 | 149,331 |
| Maryland | N/A | 4,955 | 953 | 252,142 |
| Massachussets | N/A | 2,894 | 1,384 | 132,119 |
| Michigan | N/A | 12,188 | 1,138 | 934,184 |
| Minnesota | 4,250 | 13,163 | 2,467 | 382,572 |
| Missisippi | N/A | 3,109 | 2,257 | 150,816 |
| Missouri | 3,700 | 3,996 | 1,633 | 305,853 |
| Montana | 997 | 2,504 | 999 | 80,817 |
| Nebraska | 61,361 | 1,558 | 1,501 | 112,740 |
| Nevada | 2,332 | 1,156 | 697 | 24,142 |
| New Hampshire | N/A | 2,009 | 733 | 110,712 |
| New Jersey | N/A | 7,765 | 2,256 | 227,326 |
| New Mexico | 8,031 | 2,478 | 1,545 | 70,157 |
| New York | 651 | 18,068 | 5,381 | 659,973 |
| North Carolina | 530 | 15,972 | 5,094 | 821,995 |
| North Dakota | 808 | 1,261 | 718 | 54,008 |
| Ohio | N/A | 13,306 | 3,508 | 692,062 |
| Oklahoma | 4,351 | 3,265 | 2,181 | 164,506 |
| Oregon | 9,241 | 3,330 | 1,267 | 178,407 |
| Pennsylvania | N/A | 17,477 | 5,578 | 800,292 |
| Rhode Island | N/A | 916 | 169 | 33,987 |
| South Carolina | 185 | 3,376 | 2,174 | 297,435 |
| South Dakota | 1,266 | 1,244 | 872 | 56,512 |
| Tennessee | 320 | 3,125 | 1,006 | 258,997 |
| Texas | 59,636 | 13,297 | 9,207 | 490,453 |
| Utah | 2,295 | 1,961 | 1,164 | 14,511 |
| Vermont | N/A | 1,739 | 653 | 58,380 |
| Virginia | N/A | 6,771 | 2,869 | 455,556 |
| Washington | 5,853 | 6,130 | 3,810 | 195,132 |
| West Virginia | N/A | 2,771 | 834 | 181,069 |
| Wisconsin | N/A | 22,982 | 2,239 | 521,579 |
| Wyoming | 1,409 | 1,373 | 647 | 30,900 |
| **Totals** | **348,116** | **282,827** | **98,472** | **13,101,846** |
| **Grand total** | | | | **13,732,680** |

*Note:* N/A, Not available.

[a] Includes community supply (systems with at least 15 service connections used by year-round residents or regularly serving at least 25 year-round residents).

*Source*: From National Water Well Association, 1988.

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**Table 6B.7 Number of Water Wells Drilled in the United States, 1960–1984**

| State | Estimated Number of Wells Drilled[a] | | | | | | | Percent of Total Drilled in 1984 | Percentage Change between Annual Totals[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1960 | 1964 | 1980 | 1981 | 1982 | 1983 | 1984 | | 1960 and 1964 | 1964 and 1984 | 1980 and 1984 |
| Alabama | 4,000 | 4,500 | 5,960 | 6,420 | 5,920 | 5,570 | 6,260 | 1.6 | +13 | +39 | +5 |
| Alaska | 726 | 1,000 | 2,440 | 2,400 | 2,400 | 2,800 | 2,700 | 0.68 | +38 | +170 | +11 |
| Arizona | 1,400 | 1,520 | 2,190 | 2,220 | 2,380 | 2,710 | 2,760 | 0.7 | +8.6 | +82 | +26 |
| Arkansas | 5,000 | 5,000 | 4,010 | 5,910 | 2,750 | 3,320 | 4,200 | 1.1 | NC | −16 | +5 |
| California | 9,100 | 10,000 | 17,100 | 15,900 | 11,300 | 11,000 | 14,300 | 3.6 | +10 | +43 | −16 |
| Colorado | 3,100 | 5,910 | 4,910 | 4,570 | 4,390 | 4,360 | 4,060 | 1.0 | +91 | −31 | −17 |
| Connecticut | 6,500 | 6,500 | 5,470 | 5,410 | 4,500 | 5,140 | 5,780 | 1.5 | NC | −11 | +6 |
| Delaware | 3,800 | 3,440 | 2,000 | 2,680 | 2,290 | 2,700 | 3,100 | 0.78 | −9.5 | −10 | +55 |
| District of Columbia | 12 | 12 | ND | 0 | 0 | 0 | ND | ND | NC | ND | ND |
| Florida | 33,900 | 55,000 | 40,200 | 40,500 | 38,900 | 43,200 | 45,600 | 11 | +62 | −17 | +13 |
| Georgia | 10,500 | 10,000 | 11,000 | 13,400 | 10,100 | 10,800 | 12,200 | 3.1 | −4.8 | +22 | +11 |
| Hawaii | 17 | 21 | 11 | 11 | 7 | 7 | 2 | <0.1 | +24 | −90 | −82 |
| Idaho | 1,400 | 1,400 | 2,880 | 1,470 | 2,400 | 1,590 | 1,630 | 0.35 | NC | +16 | −43 |
| Illinois | 21,000 | 19,500 | 14,000 | 12,200 | 13,400 | 13,600 | 15,300 | 3.9 | −7.1 | −22 | +9.3 |
| Indiana | 17,700 | 15,000 | 9,670 | 8,180 | 9,700 | 9,180 | 10,300 | 2.6 | −15 | −31 | +6.5 |
| Iowa | 9,000 | 15,000 | 5,890 | 6,850 | 4,120 | 3,780 | 3,140 | 0.79 | +67 | −79 | −47 |
| Kansas | 4,700 | 5,500 | 4,530 | 5,050 | 3,380 | 3,420 | 3,910 | 1.0 | +17 | −29 | −14 |
| Kentucky | 9,880 | 9,620 | 5,060 | 5,100 | 4,800 | 5,440 | 5,740 | 1.4 | −2.6 | −40 | +13 |
| Louisiana | 974 | 2,620 | 6,050 | 6,830 | 6,580 | 5,180 | 5,560 | 1.4 | +170 | +110 | −8.1 |
| Maine | 1,500 | 1,700 | 2,860 | 2,570 | 2,440 | 3,470 | 3,900 | 1.0 | +13 | +130 | +36 |
| Maryland | 4,020 | 6,900 | 7,200 | 8,000 | 6,700 | 8,800 | 8,300 | 2.1 | +72 | +20 | +15 |
| Massachusetts | 8,000 | 9,000 | 6,330 | 6,270 | 5,370 | 6,820 | 7,670 | 1.9 | +12 | −15 | +21 |
| Michigan | 25,000 | 25,000 | 24,000 | 20,000 | 16,000 | 17,000 | 18,500 | 4.7 | NC | −26 | −23 |
| Minnesota | 13,000 | 9,000 | 14,400 | 10,500 | 10,800 | 11,100 | 12,500 | 3.1 | −31 | +39 | −13 |
| Mississippi | 5,300 | 5,900 | 2,670 | 3,550 | 2,540 | 2,400 | 2,640 | 0.66 | +11 | −55 | −1 |
| Missouri | 6,380 | 9,990 | 10,900 | 8,530 | 7,830 | 10,200 | 11,500 | 2.9 | +57 | +15 | +5.5 |
| Montana | 1,900 | 2,000 | 3,580 | 6,410 | 6,260 | 2,360 | 2,560 | 0.64 | +5.3 | +28 | −28 |
| Nebraska | 5,510 | 6,000 | 4,500 | 5,940 | 3,470 | 3,260 | 3,660 | 0.92 | +8.9 | −39 | −19 |
| Nevada | 824 | 825 | 775 | 765 | 503 | 639 | 718 | 0.18 | NC | −13 | −7.4 |
| New Hampshire | 3,600 | 4,400 | 3,050 | 4,190 | 2,630 | 5,210 | 5,860 | 1.5 | +22 | +33 | +92 |
| New Jersey | 3,800 | 3,440 | 8,620 | 8,540 | 8,580 | 10,900 | 13,100 | 3.3 | −9.5 | +280 | −52 |
| New Mexico | 2,290 | 3,150 | 2,750 | 2,880 | 3,370 | 3,430 | 3,110 | 0.78 | +38 | −1.3 | +13 |
| New York | 25,000 | 25,000 | 16,800 | 17,000 | 15,600 | 17,800 | 20,000 | 5.0 | NC | −20 | +19 |
| North Carolina | 20,000 | 25,000 | 10,500 | 12,000 | 13,500 | 15,900 | 17,100 | 4.3 | +25 | −32 | +63 |
| North Dakota | 4,200 | 3,760 | 1,710 | 2,190 | 1,450 | 1,480 | 1,450 | 0.36 | −10 | −61 | −15 |
| Ohio | 17,100 | 18,600 | 16,700 | 14,300 | 14,200 | 14,000 | 15,700 | 4.0 | +8.8 | −160 | −6.0 |
| Oklahoma | 4,400 | 5,000 | 7,980 | 7,630 | 6,500 | 5,870 | 6,590 | 1.8 | +14 | +32 | −17 |
| Oregon | 3,500 | 4,500 | 7,500 | 6,620 | 3,800 | 3,550 | 3,530 | 0.89 | +29 | −22 | −53 |
| Pennsylvania | 13,500 | 16,200 | 15,600 | 12,400 | 9,620 | 8,140 | 10,800 | 2.7 | +20 | −33 | −31 |
| Rhode Island | 200 | 250 | 319 | 240 | 206 | 387 | 548 | 0.14 | +25 | +120 | +72 |
| South Carolina | 5,300 | 5,400 | 11,400 | 5,340 | 4,640 | 7,780 | 8,740 | 2.2 | +1.9 | +62 | −23 |
| South Dakota | 6,080 | 5,430 | 2,210 | 1,820 | 1,590 | 1,330 | 1,500 | 0.38 | −11 | −72 | −32 |
| Tennessee | 10,000 | 8,000 | 7,080 | 7,130 | 6,710 | 7,600 | 8,020 | 2.0 | −20 | NC | +13 |
| Texas | 19,000 | 25,000 | 16,200 | 17,700 | 21,700 | 17,700 | 21,200 | 5.3 | +32 | −15 | +31 |
| Utah | 630 | 650 | 630 | 547 | 507 | 488 | 548 | 0.14 | +3.2 | −16 | −13 |
| Vermont | 1,240 | 1,460 | 3,100 | 2,280 | 1,900 | 2,330 | 3,050 | 0.77 | +18 | +110 | −1.6 |
| Virginia | 8,500 | 10,000 | 10,900 | 8,830 | 9,060 | 15,300 | 16,900 | 4.3 | +18 | +69 | +55 |
| Washington | 1,400 | 1,700 | 5,040 | 4,290 | 3,550 | 4,320 | 4,030 | 1.0 | +21 | +137 | −20 |
| West Virginia | 5,500 | 5,900 | 3,280 | 3,510 | 2,730 | 2,580 | 2,900 | 0.73 | +7.3 | −51 | −12 |
| Wisconsin | 11,000 | 12,000 | 11,600 | 9,900 | 9,590 | 10,400 | 11,700 | 2.9 | +9.1 | −2.5 | +0.86 |

*(Continued)*

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**Table 6B.7 (Continued)**

| State | Estimated Number of Wells Drilled[a] 1960 | 1964 | 1980 | 1981 | 1982 | 1983 | 1984 | Percent of Total Drilled in 1984 | Percentage Change between Annual Totals[b] 1960 and 1964 | 1964 and 1984 | 1980 and 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wyoming | 1,000 | 1,000 | 3,010 | 3,680 | 2,970 | 2,500 | 2,520 | 0.6 | NC | +152 | −16 |
| **Totals** | **381,000** | **434,000** | **387,000** | **371,000** | **336,000** | **359,000** | **397,000** | **100** | **+14** | **+8.5** | **+2.6** |

[a] Numbers rounded to three significant figures.
[b] Numbers rounded to two significant figures.

*Source*: From Hindall, S.M., Eberle, Michael, national and regional trends in water-well drilling in the United States 1964–1984, *U.S. Geological Survey, Open File Report*, 87–247, 1987.

**Table 6B.8 Regional Trends in Water-Well Construction in the United States, 1960–1984**

| Region | Number of Wells Drilled 1960 | 1964 | 1980 | 1981 | 1982 | 1983 | 1984 | Average Annual Total 1980 Through 1984 |
|---|---|---|---|---|---|---|---|---|
| Northeast (includes DC) | 63,300 | 68,000 | 62,100 | 60,600 | 50,800 | 60,200 | 70,800 | 60,900 |
| Southeast | 95,300 | 126,000 | 102,000 | 106,000 | 93,600 | 112,000 | 121,000 | 107,000 |
| Great Lakes and Central Appalachians | 130,000 | 123,000 | 106,000 | 95,300 | 87,900 | 90,900 | 101,000 | 96,200 |
| South-Central | 54,800 | 77,200 | 63,200 | 62,100 | 60,600 | 57,300 | 63,300 | 61,300 |
| Northern Rockies and Northern Great Plains | 20,100 | 19,600 | 17,900 | 16,700 | 18,100 | 12,500 | 13,300 | 15,700 |
| Southwest (includes Hawaii) | 12,000 | 13,000 | 20,700 | 17,700 | 15,100 | 14,800 | 18,300 | 17,300 |
| Pacific Northwest (includes Alaska) | 5,620 | 7,200 | 15,000 | 11,400 | 9,750 | 8,670 | 10,300 | 11,000 |
| **Totals** | **381,000** | **434,000** | **387,000** | **370,000** | **336,000** | **359,000** | **397,000** | **370,000** |

| | Percentage of Total Wells Drilled 1964 | 1984 | Percentage Change between Annual Totals 1960 and 1964 | 1964 and 1984 | 1980 and 1984 |
|---|---|---|---|---|---|
| Northeast (includes DC) | 16 | 18 | +7.4 | +4.1 | +14 |
| Southeast | 29 | 30 | +32 | −3.9 | +19 |
| Great Lakes and Central Appalachians | 28 | 25 | −5.4 | −18 | −4.7 |
| South-Central | 18 | 16 | +41 | −18 | NC |
| Northern Rockies and Northern Great Plains | 4.5 | 3.3 | −2.5 | −32 | −26 |
| Southwest (includes Hawaii) | 3.0 | 4.6 | +8.3 | +41 | −12 |
| Pacific Northwest (includes Alaska) | 1.7 | 2.6 | +28 | +43 | −31 |
| **Totals** | **100** | **100** | **+14** | **−8.5** | **+2.6** |

*Source*: From Hindall, S.M., Eberle, Michael, national and regional trends in water-well drilling in the United States 1964–1984, *U.S. Geological Survey, Open File Report*, 87–247, 1987.

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## SECTION 6C WATER WELLS

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**Table 6C.9 Water Well Construction Methods and Applications**

| Method | Materials for Which Best Suited | Water Table Depth for Which Best Suited (m) | Usual Maximum Depth (m) | Usual Diameter Range (cm) | Usual Casing Material | Customary Use | Yield $m^3/day$[a] | Remarks |
|---|---|---|---|---|---|---|---|---|
| **Augering** Hand auger | Clay, silt sand, gravel less than 2 cm | 2–9 | 10 | 5–20 | Sheet metal | Domestic, drainage | 15–250 | Most effective for penetrating and removing clay. Limited by gravel over 2 cm. Casing required if material is loose |
| Power auger | Clay, silt sand, gravel less than 5 cm | 2–15 | 25 | 15–90 | Concrete, steel or wrought-iron pipe | Domestic, irrigation, drainage | 15–500 | Limited by gravel over 5 cm, otherwise same as for hand auger |
| **Driven Wells** Hand, air hammer | Silt, sand, gravel less than 5 cm | 2–5 | 15 | 3–10 | Standard weight pipe | Domestic, drainage | 15–200 | Limited to shallow water table, no large gravel |
| **Jetted Wells** Light, portable rig | Silt, sand, gravel less than 2 cm | 2–5 | 15 | 4–8 | Standard weight pipe | Domestic, drainage | 15–150 | Limited to shallow water table, no large gravel |
| **Drilled Wells** Cable tool | Unconsolidated and consolidated medium hard and hard rock | Any depth | 450[b] | 8–60 | Steel or wrought-iron pipe | All uses | 15–15,000 | Effective for water exploration. Requires casing in loose materials. Mudscow and hollow rod bits developed for drilling unconsolidated fine to medium sediments |
| Rotary | Silt, sand, gravel less than 2 cm; soft to hard consolidated rock | Any depth | 450[b] | 8–45 | Steel or wrought-iron pipe | All uses | 15–15,000 | Fastest method for all except hardest rock. Casing usually not required during drilling. Effective for gravel envelope wells |
| Reserve-circulation rotary | Silt, sand, gravel, cobble | 2–30 | 60 | 40–120 | Steel or wrought-iron pipe | Irrigation, industrial, municipal | 2500–20,000 | Effective for large-diameter holes in unconsolidated and partially consolidated deposits. Requires large volume of water for drilling. Effective for gravel envelope wells |
| Rotary-percussion | Silt, sand, gravel less than 5 cm; soft to hard consolidated rock | Any depth | 600[b] | 30–50 | Steel or wrought–iron pipe | Irrigation, industrial, municipal | 2500–15,000 | Now used in oil exploration. Very fast drilling. Combines rotary and percussion methods (air drilling) cuttings removed by air. Would be economical for deep water wells |

[a] Yield influenced primarily by geology and availability of groundwater.
[b] Greater depths reached with heavier equipment.

*Source*: From U.S. Soil Conservation Service, *Engineering Field Manual for Conservation Practices*, 1969.



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**Table 6C.10 Relative Performance of Different Drilling Methods in Various Types of Geologic Formations**

| Type of Formation | Cable Tool | Direct Rotary (with Fuids) | Direct Rotary (with Air) | Direct Rotary (Down-the-Hole Air Hammer) | Direct Rotary (Drill-Through Casing Hammer) | Reverse Rotary (with fluids) | Reverse Rotary (Dual Wall) | Hydr-aulic Percu-ssion | Jetting | Driven | Auger |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dune sand | 2 | 5 | Not recommended | Not recommended | 6 | 5[a] | 6 | 5 | 5 | 3 | 1 |
| Loose sand and gravel | 2 | 5 | | | 6 | 5[a] | 6 | 5 | 5 | 3 | 1 |
| Quicksand | 2 | 5 | | | 6 | 5[a] | 6 | 5 | 5 | Not recommended | 1 |
| Loose boulders in alluvial fans or glacial drift | 3–2 | 2–1 | | | 5 | 2–1 | 4 | 1 | 1 | | 1 |
| Clay and slit | 3 | 5 | | | 5 | 5 | 5 | 3 | 3 | | 3 |
| Firm shale | 5 | 5 | | | 5 | 5 | 5 | 3 | Not recommended | | 2 |
| Sticky shale | 3 | 5 | | | 5 | 3 | 5 | 3 | | | 2 |
| Brittle shale | 5 | 5 | | | 5 | 5 | 5 | 3 | | | |
| Sandstone — poorly cemented | 3 | 4 | | | Not applicable | 4 | 5 | 4 | | | Not applicable |
| Sandstone — well cemented | 3 | 3 | 5 | | | 3 | 5 | 3 | | | |
| Chert nodules | 5 | 3 | 3 | | | 3 | 3 | 5 | | | |
| Limestone | 5 | 5 | 5 | 6 | | 5 | 5 | 5 | | | |
| Limestone with chert nodules | 5 | 3 | 5 | 6 | | 3 | 3 | 5 | | | |
| Limestone with small cracks or fractures | 5 | 3 | 5 | 6 | | 2 | 5 | 5 | | | |
| Limestone, cavernous | 5 | 3–1 | 2 | 5 | | 1 | 5 | 1 | | | |
| Dolomite | 5 | 5 | 5 | 6 | | 5 | 5 | 5 | | | |
| Basalts, thin layers in sedimentary rocks | 5 | 3 | 5 | 6 | | 3 | 5 | 5 | | | |
| Basalts — thick layers | 3 | 3 | 4 | 5 | | 3 | 4 | 3 | | | |
| Basalts — highly fractured (lost circulation zones) | 3 | 1 | 3 | 3 | | 1 | 4 | 1 | | | |
| Metamorphic rocks | 3 | 3 | 4 | 5 | | 3 | 4 | 3 | | | |
| Granite | 3 | 3 | 5 | 5 | | 3 | 4 | 3 | | | |

*Note:* Rate of Penetration: 1, Impossible; 2, Difficult; 3, Slow; 4, Medium; 5, Rapid; 6, Very rapid.

[a] Assuming sufficient hydrostatic pressure is available to contain active sand (under high confining pressures).

*Source*: From Driscoll, F.G., 1986, *Groundwater and Wells*. Copyright Johnson Division.

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**Table 6C.11 Description of Drilling Methods**

**Methods Without Drilling Fluids**

**Displacement Boring**

Pros:
- Does not require heavy equipment (by hand or lightweight equipment)
- Clean method for shallow well installation

Cons:
- Method limited to shallow depths
- Method limited to soft soils and boulder, cobble-free zones
- Not efficient if necessary to install several wells
- Practical limitation up to $\sim 2''$ diameter sampler

Similar to the above method is "Direct Push Technology" or DPT. A common trade name is GeoProbe. DPT does not require heavy equipment, most units are pickup mounted or ATV mounted for easy accessibility

**Driven Wells**

Pros:
- Cost effective
- Easy access in most conditions

Cons:
- Limited to shallow depths ($< 50$ ft)
- Limited to unconsolidated, soft formations relatively free of cobbles or boulders
- May require pre-drilling a hole of slightly greater diameter that the well point

**Solid-Stem Auger**

Pros:
- Rapid and low-cost drilling in clayey formations
- Clean method, does not require circulation fluids
- No casing necessary where the formation is stable
- Allows collection of representative sample in semi-consolidated formations

Cons:
- Practical limitation to $24''$ diameter
- Inefficient in loose, sandy material (depends on the depth)
- Inefficient below the water table (depends on the depth)

**Hollow-Stem Auger (HSA)**

Pros:
- Allows collection of uncontaminated sample in unconsolidated formation
- Can be used as temporary casing to prevent caving
- Relatively rapid, especially in clayey formations

Cons:
- Ineffective through boulders
- Limited drilling in loose, granular soils, particularly below the water table where sample recovery can be compromised
- Difficult to retrieve a sample in loose, granular soil because cuttings do not always want to come to the surface. Samples must be collected with a split spoon or a continuous corer, either of which can provide excellent samples if done correctly
- Limited to rather shallow depths

**Sonic Drilling**

Pros:
- Drilling can proceed with or without the use of drilling fluids
- Method can be utilized in unconsolidated and some consolidated formations
- Minimal disturbance to soil samples
- Good recovery of quasi-continuous samples
- Conventional air rotary or down-hole hammer methods can be employed through the outer drive casing
- The rig can also be operated as a fluid rotary machine

Cons:
- A relatively new method that is not available everywhere
- Relatively expensive compared to other drilling methods

*(Continued)*

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**Table 6C.11 (Continued)**

- Dry casing advancement generates heat that can affect the sample integrity
- Maximum nominal diameter of less than 12 in.
- Practical depth limitation of less than 500 ft

**Methods that Use Drilling Fluids**

**Rotary (Direct) Drilling**

Pros:

- High penetration rate
- Drilling operation requires a minimum amount of casing
- Rapid mobilization and demobilization

Cons:

- Use of a drilling fluid, both in terms of sample contamination and water management (in the case of water-based fluids and air injected by gasoline compressors)
- Circulation of drilling fluid may be lost in loose/coarse formations, hence making difficult to transport drill cuttings
- Difficult to collect accurate samples, i.e. a sample from a discrete zone since the cuttings accumulate at surface around the rim of the borehole

**Reverse Circulation Rotary Drilling (RC)**

Pros:

- Applicable to a wide variety of formations
- Possible to drill large-diameter holes, both quickly and economically
- Minimal disturbance to the formation due to the pressure being applied inside and outside the pipe string
- Easier recovery of cuttings since the up-hole velocity is controlled by the size of the drill pipe and less subject to lost-circulation
- No casing required during drilling and advantageous when high risks of caving inches. If there is a risk of caving, mud should be used as a stabilizer. In the case of air drilling, it presents the same risk than regular air rotary, since the flow is down the annular space

Cons:

- High water requirements (not for air drilling)
- Collection of a representative sample is difficult due to potential material mixing
- Rig size can render access difficult
- Need for drilling mud management (not for air drilling)

**Dual-Wall Reverse Circulation Drilling**

Pros:

- Good sample recovery due to controlled up-hole fluid velocity
- Fast penetration in coarse alluvial or broken, fissured rock
- Possible to obtain continuous representative samples of the formation and groundwater
- Easy estimate of aquifer yield at many depths in the formation
- Reduction of lost-circulation problems

Cons:

- Practical borehole diameter limited to 10 in.
- Maximum depth of ~1,400 ft, although greater depths can be achieved in hard rock
- Possible to dry out or to not detect a thin of low-yield aquifer
- Possible sample contamination due to the oil used in the air-compressor unless quality air filters are used (this is true for all air methods, unless the contractor uses filters)

**Cable-Tool Percussion**

Pros:

- In situations where the aquifer is thin and yield is low, the method permits identification of zones that might be overlooked by other drilling methods
- Recovery of representative soil samples at every depth, although samples are disturbed due to the impact of the blow which can affect material several feet below the bottom of the hole
- Allows well construction with low chance of contamination
- Borehole can be bailed at any time to determine approximate yield of the formation at a given depth
- Easy access to rough terrain

Cons:

- Slow penetration rate
- Due to the constant mixing of water, it is not possible to obtain groundwater samples during drilling

*(Continued)*

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**Table 6C.11 (Continued)**

- Expensive casing for larger diameters
- Difficult to pull back casing in some geologic conditions

**Air Percussion Down-the-Hole Hammer**

Pros:

- Rapid removal of cuttings
- No use of drilling mud
- High penetration rate, especially in resistant rock formation (e.g. basalt)
- Easy soil and groundwater sampling during drilling
- Possible to measure yield estimate at selected depth in the formation

Cons:

- Restricted to semi-consolidated to consolidated formations

**Air Percussion Casing Hammer**

Pros:

- Wells can be drilled in unconsolidated materials that could be difficult to drill with cable-tool or direct rotary method
- No water-based fluid (drilling mud) is required in unconsolidated materials
- Representative formation and groundwater samples can be collected
- Borehole is fully stabilized during drilling operations through the use of casing
- Rapid penetration rates even in difficult drilling conditions
- Lost circulation problem is rarely a concern, except in very loose materials (e.g. mine waste rock)
- Operates well in cold weather

Cons:

- Method does not permit yield measurements during drilling
- When groundwater static levels are low, the high air pressure in the hole can prevent water from entering the borehole; a “rest” period is necessary to assess the true static level
- Relatively expensive method (increased cost of driving casing in)
- Very noisy (driving of casing)
- Borehole diameter limited to 12 in.

**ODEX Percussion Down-the-Hole Hammer (Odex, Stratex, and Tubex are Trade Names)**

Pros:

- Rapid removal of cuttings
- No use of drilling mud
- High penetration rate, especially in resistant rock formation (e.g. basalt)
- Easy soil and groundwater sampling during drilling
- Possible to measure yield estimate at selected depth in the formation
- Advantageous in unconsolidated formations with a high risk of caving (this is the probably the most important feature)

Cons:

- Practically restricted to unconsolidated formations
- Relatively a more expensive method

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**Table 6C.12 Data on Standard and Line Pipe Commonly Used for Water Well Casing**

| Nominal Size (in.) | Outside Diameter (in.) | Outside Diameter Couplings (in.) | Schedule or Class[a] | Wall Thickness (in.) | Weight per Foot-Plain End (Pounds) | Inside Diameter (in.) | Suggested Maximum Setting (ft)[b] |
|---|---|---|---|---|---|---|---|
| 4 | 4.500 | 5.200 | — | 0.219 | 10.10 | 4.062 | 1,190 |
| | | | 40 | 0.237 | 10.79 | 4.026 | 1,060 |
| 6 | 6.625 | 7.390 | — | 0.250 | 17.02 | 6.125 | 705 |
| | | | 40(S) | 0.280 | 18.97 | 6.065 | 850 |
| 8 | 8.625 | 9.625 | 20 | 0.250 | 22.36 | 8.125 | 420 |
| | | | 30 | 0.277 | 24.70 | 8.071 | 525 |
| | | | 40(S) | 0.322 | 28.55 | 7.981 | 695 |
| 10 | 10.750 | 11.750 | 20 | 0.250 | 28.04 | 10.250 | 235 |
| | | | 30 | 0.307 | 34.24 | 10.136 | 410 |
| | | | 40(S) | 0.365 | 40.48 | 10.020 | 580 |
| 12 | 12.750 | 14.000 | 20 | 0.250 | 33.38 | 12.250 | 140 |
| | | | 30 | 0.330 | 43.77 | 12.090 | 320 |
| | | | S | 0.375 | 49.56 | 12.000 | 435 |
| | | | 40[c] | 0.406 | 53.56 | 11.938 | 515 |
| 14 | 14.000 | 15.000 | 10 | 0.250 | 36.71 | 13.500 | 105 |
| | | | 20 | 0.312 | 45.68 | 13.376 | 195 |
| | | | 30(S) | 0.375 | 54.57 | 13.250 | 350 |
| | | | 40 | 0.438 | 63.37 | 13.124 | 495 |
| 16 | 16.000 | 17.000 | 10 | 0.250 | 42.05 | 15.500 | 70 |
| | | | 20 | 0.312 | 52.36 | 15.376 | 140 |
| | | | 30(S) | 0.375 | 62.58 | 15.250 | 240 |
| | | | 40 | 0.500 | 82.77 | 15.000 | 495 |
| 18 | 18.000 | 19.000 | 10 | 0.250 | 47.39 | 17.500 | 50 |
| | | | 20 | 0.312 | 59.03 | 17.376 | 100 |
| | | | S | 0.375 | 70.59 | 17.250 | 170 |
| | | | 30 | 0.438 | 82.06 | 17.124 | 270 |
| | | | 40 | 0.562 | 104.76 | 16.876 | 495 |
| 20 | 20.000 | 21.000 | 10 | 0.250 | 52.73 | 19.500 | 35 |
| | | | 20(S) | 0.375 | 78.60 | 19.250 | 125 |
| | | | 30 | 0.500 | 104.13 | 19.000 | 295 |
| | | | 40[c] | 0.594 | 123.06 | 18.802 | 445 |
| 22 | 22.000 | — | 10 | 0.250 | 58.07 | 21.500 | 30 |
| | | | 20(S) | 0.375 | 86.61 | 21.250 | 95 |
| | | | 30 | 0.500 | 114.81 | 21.000 | 220 |
| 24 | 24.000 | — | 10 | 0.250 | 63.41 | 23.500 | 20 |
| | | | 20(S) | 0.375 | 94.62 | 23.250 | 70 |
| | | | 30 | 0.562 | 140.80 | 22.876 | 240 |
| | | | 40 | 0.688 | 171.17 | 22.624 | 410 |
| 26 | 26.000 | — | 10 | 0.312 | 85.73 | 25.376 | 30 |
| | | | S | 0.375 | 102.63 | 25.250 | 55 |
| | | | 20 | 0.500 | 136.17 | 25.000 | 135 |
| 28 | 28.000 | — | 10[c] | 0.312 | 92.41 | 27.376 | 25 |
| | | | (S) | 0.375 | 110.41 | 27.250 | 45 |
| | | | 20 | 0.500 | 146.85 | 27.000 | 105 |
| | | | 30 | 0.625 | 182.73 | 26.750 | 210 |
| 30 | 30.000 | — | 10[c] | 0.312 | 99.08 | 29.376 | 20 |
| | | | (S) | 0.375 | 118.65 | 29.250 | 35 |
| | | | 20 | 0.500 | 157.53 | 29.000 | 85 |
| | | | 30 | 0.625 | 196.08 | 28.750 | 170 |

*(Continued)*

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**Table 6C.12 (Continued)**

| Nominal Size (in.) | Outside Diameter (in.) | Outside Diameter Couplings (in.) | Schedule or Class[a] | Wall Thickness (in.) | Weight per Foot-Plain End (Pounds) | Inside Diameter (in.) | Suggested Maximum Setting (ft)[b] |
|---|---|---|---|---|---|---|---|
| 32 | 32.000 | — | 10[c] | 0.312 | 105.76 | 31.376 | 20 |
| | | | (S) | 0.375 | 126.66 | 31.250 | 30 |
| | | | 20 | 0.500 | 168.21 | 33.000 | 70 |
| | | | 30 | 0.625 | 209.43 | 32.750 | 140 |
| 34 | 34.000 | — | 10[c] | 0.312 | 112.43 | 33.376 | 15 |
| | | | S | 0.375 | 134.67 | 33.250 | 25 |
| | | | 20 | 0.500 | 178.89 | 33.000 | 60 |
| | | | 30 | 0.625 | 222.78 | 32.750 | 115 |
| 36 | 36.000 | — | 10[c] | 0.312 | 119.11 | 35.376 | 10 |
| | | | (S) | 0.375 | 142.68 | 35.250 | 20 |
| | | | 20 | 0.500 | 189.57 | 35.000 | 50 |
| | | | 30 | 0.625 | 236.13 | 34.750 | 100 |

[a] ASA Standard B36.10 schedule numbers (S) indicates standard weight pipe.
[b] Maximum settings were estimated for the worst possible conditions in unconsolidated formation. A design factor of approximately 1.5 was used for steel with yield strength less than 40,000 lb/in$^2$. A 50-percent increase in depth of setting beyond those given is considered safe under favorable conditions.
[c] Indicates a non-API standard.

*Source*: From Bureau of Reclamation, *Groundwater Manual*, 1977.

**Table 6C.13 Recommended Casing Diameters for Water Wells**

| Yield, Gallons per Minute | Recommended Casing Size (in.) | |
|---|---|---|
| Less than 100 | 6 | I.D.[a] |
| 75–175 | 8 | I.D. |
| 150–400 | 10 | I.D. |
| 350–600 | 12 | I.D. |
| 600–1,300 | 16 | O.D.[b] |
| 1,300–1,800 | 20 | O.D. |
| 1,800–3,000 | 24 | O.D. |
| 3,000–4,500 | 30 | O.D. |
| Over 4,500 | 30 | O.D. |

*Note:* For line shaft vertical turbine pumps 1800 rpm.

[a] I.D., Inside Diameter.
[b] O.D., Outside Diameter.

*Source*: From U.S. Environmental Protection Agency, *Manual of Water Well Construction Practices*, EPA-570/ 9–75–001.

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**Table 6C.14 Recommended Casing Sizes for Domestic Water Wells**

| Yield at 50″ Drawdown | Recommended Casing Diameter (in.) | Pump Type | | |
|---|---|---|---|---|
| | | Jet | Double Jet | Submersible |
| Less than 8 gpm | 2 | X | X | |
| | 3 | X | X | X |
| | 4 | X | X | X |
| | 5 | | X | X |
| | 6 | | | X |
| 8–16.5 gpm | 2 | X | X | |
| | 3 | X | X | X |
| | 4 | X | X | X |
| | 5 | | X | X |
| | 6 | | | X |
| Greater than 16.5 gpm | 3 | X | | |
| | 4 | X | X | X |
| | 5 | | X | X |
| | 6 | | | X |

*Source*: From U.S. Environmental Protection Agency, *Manual of Water Well Construction Practices*, EPA-570/9–75–001.

**Table 6C.15 Recommended Maximum Depth of Setting for California Stovepipe Casing**

| Diameter (in.) | Gauge[a] | | | | | | Thickness (in.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 12 | | 10 | | 8 | 6 | | | | |
| | D | S | D | S | D | D | 3/16 | 1/4 | 5/16 | 3/8 |
| 8 | 340 | 125 | 750 | 260 | X | X | X | X | X | X |
| 10 | 150 | 60 | 390 | 135 | X | X | 320 | 750 | X | X |
| 12 | 100 | 35 | 225 | 75 | 390 | X | 180 | 435 | 875 | X |
| 14 | 60 | 20 | 140 | 45 | 250 | X | 115 | 270 | 530 | X |
| 16 | 40 | 15 | 90 | 30 | 165 | 275 | 75 | 180 | 360 | 630 |
| 18 | 30 | | 65 | 20 | 115 | 190 | 55 | 125 | 260 | 445 |
| 20 | 20 | | 45 | | 85 | 140 | 35 | 90 | 180 | 320 |
| 22 | | | 35 | | 60 | 105 | X | X | X | X |
| 24 | | | 25 | | 45 | 80 | 20 | 50 | 100 | 185 |
| 26 | | | 20 | | 35 | 60 | X | X | X | X |
| 30 | | | 10 | | 25 | 40 | 10 | 25 | 50 | 95 |

*Note:* D, Telescoping; S, Single thickness; X, Not commonly made in these sizes. Includes similar sheet steel and steel-plate fabricated casing; in feet.

[a] U.S. Standard Gauge.

*Source*: From Bureau of Reclamation, *Groundwater Manual*, 1977.

**Table 6C.16 Recommended Diameter and Thickness of PVC Casing for Water Wells**

| Nominal Size | Outside Diameter | Inside Diameter | Minimum Wall Thickness |
|---|---|---|---|
| **Well Diameters 1.5 in. Through 4 in.-ASTMD 2241-73[a] SDR 21 (Type 1120–1220)** | | | |
| 1.5 | 1.900 | 1.720 | 0.090 |
| 2 | 2.375 | 2.149 | 0.113 |
| 2.5 | 2.875 | 2.601 | 0.137 |
| 3 | 3.500 | 3.166 | 0.177 |
| 4 | 4.500 | 4.072 | 0.214 |
| **Well Diameters 5 in. Through 12 in.-ASTMD 1785-73[a] Schedule 40 (Type 1120–1220)** | | | |
| 5 | 5.563 | 5.047 | 0.258 |
| 6 | 6.625 | 6.065 | 0.280 |
| 8 | 8.625 | 7.981 | 0.322 |
| 10 | 10.750 | 10.020 | 0.365 |
| 12 | 12.750 | 11.938 | 0.406 |

[a] New ASTM Standards are currently under view.

*Source*: From U.S. Environmental Protection Agency, *Manual of Water Well Construction Practices*, EPA-570/9–75–001.

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**Table 6C.17 Well Screen Selection Chart for Small-Capacity Wells**

| Gradation of Sand | Average Slot Size Thousandths of an inch | Minimum Suggested Length for Corresponding Screen Diameter[a] and Desired Well Yield | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1¼″ Screen | 2″ Screen | 3″ Screen | 4″ Screen | 5″ Screen | 6″ Screen |
| **Very Fine Sand** | | | | | | | |
| 6–7–8 Slot | | | | | | | |
| About the finest material that can be utilized for a water supply. A line composed of 12 grains would measure about 1/16″ | 7 | 300 gph– 5 ft<br>450 gph– 8 ft<br>600 gph–12 ft | 450 gph– 6 ft<br>600 gph– 9 ft<br>900 gph–13 ft | 600 gph– 8 ft<br>900 gph–11 ft<br>1200 gph–14 ft | 600 gph– 6 ft<br>1200 gph–10 ft<br>1800 gph–14 ft | 900 gph– 6 ft<br>1200 gph– 9 ft<br>1800 gph–11 ft | 1200 gph– 8 ft<br>2000 gph– 2 ft<br>2400 gph–15 ft |
| **Fine Sand** | | | | | | | |
| 9–10–12 Slot | | | | | | | |
| Often called “sugar sand.” Line of 6 or 7 average grains measures 1/16″ | 10 | 300 gph–4 ft<br>450 gph–6 ft<br>600 gph–9 ft | 450 gph–4 ft<br>600 gph–6 ft<br>900 gph–9 ft | 600 gph–6 ft<br>900 gph–8 ft<br>1200 gph–10 ft | 600 gph–4 ft<br>1200 gph–7 ft<br>1800 gph–10 ft | 900 gph–5 ft<br>1200 gph–7 ft<br>1800 gph–8 ft | 1200 gph–6 ft<br>1200 gph–9 ft<br>2400 gph–11 ft |
| **Medium Sand** | | | | | | | |
| 16–18–20 Slot | | | | | | | |
| Average grain size is about 4 grains 1/16″ | 18 | 300 gph–4 ft<br>450 gph–5 ft<br>600 gph–7 ft | 600 gph–5 ft<br>900 gph–7 ft<br>1200 gph–9 ft | 600 gph–4 ft<br>1200 gph–9 ft<br>1800 gph–13 ft | 600 gph–3 ft<br>1200 gph–6 ft<br>1800 gph–9 ft | 900 gph–4 ft<br>1200 gph–6 ft<br>1800 gph–7 ft | 1200 gph–5 ft<br>2000 gph–8 ft<br>2400 gph–10 ft |
| **Medium and Coarse Sand Mixed** | | | | | | | |
| Average grain size a little less than 1/32″, or between 2 and 3 grains to 1/16″ | 25 | 300 gph–3 ft<br>450 gph–5 ft<br>600 gph–6 ft | 600 gph–5 ft<br>900 gph–6 ft<br>1200 gph–8 ft | 600 gph–4 ft<br>1200 gph–7 ft<br>1800 gph–11 ft | 600 gph–3 ft<br>1200 gph–5 ft<br>1800 gph–8 ft | 900 gph–4 ft<br>1200 gph–5 ft<br>1800 gph–6 ft | 1200 gph–5 ft<br>2000 gph–7 ft<br>2400 gph–91 ft |
| **Coarse Sand** | | | | | | | |
| Average grain size a little over 1/30 (2 grains to 1/16″) | 35 | 450 gph–4 ft<br>600 gph–5 ft<br>900 gph–7 ft | 600 gph–4 ft<br>900 gph–5 ft<br>1200 gph–7 ft | 900 gph–4 ft<br>1200 gph–6 ft<br>1800 gph–10 ft | 900 gph–3 ft<br>1200 gph–4 ft<br>1800 gph–7 ft | 1200 gph–4 ft<br>1800 gph–6 ft<br>2000 gph–8 ft | 1200 gph–4 ft<br>2000 gph–7 ft<br>2400 gph–8 ft |
| **Coarse Sand and Fine Gravel Mixed** | | | | | | | |
| Average grain size about 1/16″. In coarser gravels, No. 80 and No. 100 slot are often used | 50 | 450 gph–4 ft<br>600 gph–5 ft<br>900 gph–7 ft | 600 gph–4 ft<br>900 gph–5 ft<br>1200 gph–6 ft | 900 gph–4 ft<br>1200 gph–6 ft<br>1800 gph–10 ft | 900 gph–3 ft<br>1200 gph–4 ft<br>1800 gph–7 ft | 1200 gph–4 ft<br>1800 gph–6 ft<br>2000 gph–7 ft | 1200 gph–4 ft<br>2000 gph–6 ft<br>2400 gph–8 ft |

[a] Nominal size of screen.

*Source*: From Edward E. Johnson, Inc. With permission.



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**Table 6C.18 Recommended Minimum Screen Assembly Diameters**

| Discharge (gal/min) | Minimum Nominal Screen Assembly Diameter (in.) |
|---|---|
| Up to 50 | 2 |
| 50 to 125 | 4 |
| 125 to 350 | 6 |
| 350 to 800 | 8 |
| 800 to 1,400 | 10 |
| 1,400 to 2,500 | 12 |
| 2,500 to 3,500 | 14 |
| 3,500 to 5,000 | 16 |
| 5,000 to 7,000 | 18 |
| 7,000 to 9,000 | 20 |

*Source*: From U.S. Bureau of Reclamation, *Groundwater Manual*, 1977.

**Table 6C.19 Cost of Water Well Screens**

**304SS Drive Points**

| 1–1/4″ PS 1.71″OD×1″ ID | | | | | 2″PS 2.38″OD × 1.75″ID | | | | | 3″PS All Drive 3.7″OD × 3″ID | | | 4″ PS All Drive 4.69″OD × 4″ID | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Price | | | | | Price | | | | | | | |
| Model Number | Screen Length | Ship Wt/pc | W60 | W90 | Model Number | Screen Length | Ship Wt/pc | W60 | W90 | Screen Length | Ship Wt/pc | Price W60 | Screen Length | Ship Wt/pc | Price W60 |
| 824 | 24″ | 5 | $106 | $96 | 924 | 24″ | 8 | $129 | $117 | 24″ | 10 | $176 | 24″ | 13 | $217 |
| 836 | 36″ | 7 | $133 | $120 | 936 | 36″ | 11 | $159 | $144 | 36″ | 14 | $224 | 36″ | 17 | $279 |
| 848 | 48″ | 9 | $160 | $144 | 948 | 48″ | 14 | $190 | $172 | 48″ | 17 | $272 | 48″ | 21 | $340 |
| 860 | 60″ | 11 | $186 | $169 | 960 | 60″ | 16 | $220 | $200 | 60″ | 22 | $320 | 60″ | 25 | $404 |

Fittings are 304 SS MIP X Carbon Steel Point w/guardian plate or 304 SS MIP X MIP for open end extensions. For other screen lengths add $30/ft for 1 ¼″, $34/ft for 2″, $38/ft for 3″, and $49/ft for 4″. All Drive screens are MIPXFIP only, if cast iron point is required add; 3″PS-$80.00, 4″PS-$85.00 to the list price above.

**304 SS Small Diameter Waterwell Screens**

| | Dimensions[a] | | | Screen Price per foot | | Direct Attached Standard Fittings Per End | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OD Dim[a] | | | | | | | | | Flush Threads | | Misc Attach | | | Type-Max Depth Based on Collapse Strength[a] |
| Nom Dia Wt/ft | W60 | W90 | ID | 60 | 90 | Weld Ring[c] | NPT Thd | Fig K Pkr w/WR | Plate Btm w/WR | Sch40 | Sch80 | Clean and Bag | Ball Loop[d] | SS Point[e] | |
| 2P/3T 3.0# | 2.60 | 2.50 | 2.02 | $34 | $31 | $41 | $39 | n/a | $61 | $37 | $39 | $13 | $41 | $79 | W60–1000 W90–500 |
| 3P/4T 4.0# | 3.74 | 3.64 | 3.16 | $38 | $34 | $43 | $41 | n/a | $64 | $39 | $41 | $21 | $48 | $92 | W60–900 W90–300 |
| 4P/5T 5.0# | 4.74 | 4.64 | 4.16 | $49 | $45 | $49 | $49 | n/a | $72 | $47 | $49 | $21 | $50 | $151 | W60–500 W90–200 |
| 5P/6T 6.0# | 5.63 | 5.53 | 5.05 | $57 | $52 | $51 | $60 | $161 | $86 | $58 | $60 | $32 | $61 | n/a | W60–300 W90–100[b] |

**304 SS Small Diameter Environmental Screens**

| | Dimensions[a] | | | Screen Price per foot | | Direct Attached Standard Fittings Per End | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OD Dim[a] | | | | | | | | | Flush Threads | | Misc Attach | | | Type-Max Depth Based on Collapse Strength[a] |
| Nom Dia Wt/ft | W60 | W90 | ID | 60 | 90 | Weld Ring[c] | NPT Thd | Fig K Pkr w/WR | Plate Btm w/WR | Sch40 | Sch80 | Clean and Bag | Ball Loop[d] | SS Point[e] | |
| 1/2″ PS[b] 1.0# | 0.89 | 0.83 | 0.53 | $30 | $27 | $20 | $19 | n/a | $30 | $73 | $80 | $13 | n/a | n/a | W60-2000 W90-1500 |
| 3/4″ PS[b] 1.5# | 1.09 | 1.06 | 0.73 | $31 | $28 | $21 | $21 | n/a | $32 | $73 | $80 | $13 | n/a | n/a | W60-2000 W90-1000 |

*(Continued)*

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**Table 6C.19 (Continued)**

**304 SS Small Diameter Environmental Screens**

| | Dimensions[a] | | | Screen Price per foot | | Direct Attached Standard Fittings Per End | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OD Dim[a] | | | | | | | | | Flush Threads | | Misc Attach | | | |
| Nom Dia Wt/ft | W60 | W90 | ID | 60 | 90 | Weld Ring[c] | NPT Thd | Fig K Pkr w/WR | Plate Btm w/WR | Sch40 | Sch80 | Clean and Bag | Ball Loop[d] | SS Point[e] | Type-Max Depth Based on Collapse Strength[a] |
| 1″ PS[b] 2.0# | 1.33 | 1.27 | 0.88 | $31 | $28 | $22 | $28 | n/a | $35 | $66 | $72 | $13 | n/a | $53 | W60-2000<br>W90-1000 |
| 1-1/4″PS 1.5# | 1.67 | 1.60 | 1.19 | $30 | $29 | $24 | $36 | n/a | $36 | $33 | $36 | $13 | $38 | $58 | W60-1000<br>W90-600 |
| 1-1/2″ PS 3.0# | 2.01 | 1.95 | 1.54 | $33 | $31 | $25 | $38 | n/a | $37 | $36 | $38 | $13 | $38 | $62 | W60-1000<br>W90-600 |
| 2″ PS 3.0# | 2.47 | 2.41 | 1.99 | $34 | $31 | $41 | $39 | n/a | $61 | $37 | $39 | $13 | $41 | $79 | E60-1000<br>E90-600 |
| 2-1/2″ PS 4.0# | 3.03 | 2.93 | 2.45 | $39 | $35 | $41 | $39 | n/a | $61 | $37 | $39 | $21 | $44 | $81 | W60-1000<br>W90-600 |
| 3″ PS 4.0# | 3.56 | 3.46 | 2.98 | $38 | $34 | $43 | $41 | n/a | $64 | $39 | $41 | $21 | $48 | $92 | E60-1000<br>E90-300 |
| 4″ PS 5.0# | 4.56 | 4.46 | 3.98 | $49 | $45 | $49 | $49 | n/a | $72 | $47 | $49 | $21 | $50 | $151 | E60-500<br>E90-200 |
| 6″ PS 7.0# | 6.64 | 6.54 | 6.02 | $81 | $80 | $79 | $106 | n/a | $126 | $104 | $106 | $32 | $66 | n/a | E60-250<br>E90-50 |

Minimum billing length is 3 ft for all diameters. For Tightwind or Super Construction Screen: Add 25% to Screen Price/Feet. Please specify water well or environmental when ordering. Must add "Clean & Bag" charge for environmental screen. Environmental screens supplied in "Shoulder to Shoulder" lengths. For loose plate bottom deduct (1) weld righ from plate bottom assembly.

[a] Dimensions, weights and collapse strength are approximate (based on an average slot and depth).

[b] Minimum order requirement for ½″ through 1″PS is $300 (net).

[c] Standard weld ring length 2PS″ through 6PS″ is 1-1/2″.

[d] Bail Loop prices Do Not include plate.

[e] SS point is weld on. For threaded point add appropriate thread price.

**Large Diameter "Free Flow" 304 Stainless Steel**

| | Standard Dimensions[f] | | Screen Price Per Foot Max Depth Based on Collapse Strength[f] | | | | Direct Attached Standard Fittings Per End | | | | | | | | | Misc Attachments | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Weld Rings | | | Threads | | | | Fig "K" Pkr w/WR | Plate Btm w/WR | | | |
| Nom Diam | OD | ID | 100 ft | 250 ft | 600 ft | 1000 ft | Std | 4″ | 6″ | Npt | Jws | Flush Sch40 | Flush Sch80 | | | Bail Loop[g] | Lift Lugs[h] | 4″WR W/4″ Collar |
| 6″PS | 6.70<br>Wt/Foot 6# | 6.00 | $81 | $83 | $85 | $93 | $79 | $107 | $131 | $106 | n/a | $104 | $106 | n/a | $126 | $66 | $84 | $279 |
| 8″Tel | 7.50<br>Wt/Foot 10# | 6.75 | $88 | $88 | $96 | $96 | $108 | $141 | $173 | n/a | $154 | n/a | n/a | $435 | $173 | $70 | $93 | |
| 8″PS | 8.63<br>Wt/Foot 12# | 7.88 | $95 | $95 | $99 | $99 | $126 | $148 | $183 | $196 | n/a | $193 | $290 | n/a | $202 | $70 | $93 | $338 |
| 10″Tel | 9.50<br>Wt/Foot 13# | 8.68 | $119 | $119 | $129 | $129 | $144 | $187 | $230 | n/a | $300 | n/a | n/a | $460 | $245 | $70 | $105 | |
| 10″PS | 10.75<br>Wt/Foot 14# | 9.88 | $135 | $135 | $135 | $162 | $149 | $194 | $238 | $254 | n/a | $292 | $440 | n/a | $253 | $70 | $105 | $410 |
| 12″Tel | 11.25<br>Wt/Foot 18# | 10.40 | $143 | $143 | $143 | $170 | $169 | $223 | $276 | n/a | n/a | n/a | N/a | $605 | $287 | $70 | $116 | |
| 12″PS | 12.75<br>Wt/Foot 23# | 11.80 | $146 | $146 | $169 | $192 | $196 | $249 | $304 | $387 | n/a | $623 | $924 | n/a | $333 | $70 | $116 | $512 |
| 14″Tel | 12.50<br>Wt/Foot 25# | 11.60 | $145 | $145 | $164 | $189 | $215 | $280 | $344 | n/a | n/a | n/a | N/a | $809 | $366 | $76 | $121 | |

*(Continued)*

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**Table 6C.19 (Continued)**

**Large Diameter "Free Flow" 304 Stainless Steel**

| | Standard Dimensions[f] | | Screen Price Per Foot Max Depth Based on Collapse Strength[f] | | | | Direct Attached Standard Fittings Per End: Weld Rings | | | Threads | | | | Fig "K" Pkr w/WR | Plate Btm w/WR | Misc Attachments | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nom Diam | OD | ID | 100 ft | 250 ft | 600 ft | 1000 ft | Std | 4″ | 6″ | Npt | Jws | Flush Sch40 | Flush Sch80 | | | Bail Loop[g] | Lift Lugs[h] | 4″WR W/4″ Collar |
| 14P/16T | 14.00 | 13.00 Wt/Foot 30# | $175 | $175 | $192 | $209 | $252 | $329 | $404 | n/a | n/a | na | na | $923 | $441 | $76 | $121 | $601 |
| 16P/18T | 16.00 | 15.00 Wt/Foot 35# | $185 | $202 | $215 | $235 | $302 | $377 | $464 | n/a | n/a | n/a | N/a | $1,014 | $529 | $76 | $128 | $670 |
| 18P/20T | 18.00 | 16.70 Wt/Foot 40# | $214 | $224 | $255 | $304 | $360 | $468 | $576 | n/a | n/a | n/a | N/a | $1,045 | $630 | $76 | $128 | $755 |
| 20″ PS | 20.00 | 18.80 Wt/Foot 42# | $252 | $272 | $295 | $320 | $382 | $497 | $611 | n/a | n/a | n/a | N/a | n/a | $669 | $76 | $139 | $845 |
| 24″ Tel | 22.00 | 20.70 Wt/Foot 46# | $342 | $348 | $391 | $407 | $404 | $525 | $646 | n/a | na | n/a | N/a | n/a | $707 | $87 | $139 | |
| 24P/26T | 24.00 | 22.75 Wt/Foot 58# | $369 | $415 | $493 | $493 | $462 | $601 | $739 | n/a | n/a | n/a | N/a | n/a | $809 | $87 | $151 | $998 |
| 26″ PS | 26.00 | 24.40 Wt/Foot 62# | $436 | $436 | $527 | $627 | $539 | $674 | $830 | n/a | n/a | n/a | n/a | n/a | $943 | $87 | $151 | $1,102 |
| 30″ Tel | 27.25 | 25.75 Wt/Foot 65# | $450 | $490 | $570 | Call | $595 | $774 | $952 | n/a | n/a | n/a | n/a | n/a | $1,041 | $105 | $169 | |
| 30P/36T | 30.00 | 28.30 Wt/Foot 74# | $530 | $593 | $633 | Call | $671 | $872 | $1,074 | n/a | n/a | n/a | n/a | n/a | $1,174 | $105 | $169 | |
| 36″ PS | 36.00 | 34.30 Wt/Foot 90# | $610 | $696 | $696 | Call | $773 | $1,005 | $1,237 | n/a | n/a | n/a | n/a | n/a | $1,353 | $105 | $169 | |

Call for pricing on screens deeper than 1000 feet. Standard weld ring lengths: 6″PS-16P/18T are 1-1/2″ long; 18P/20T and larger are 2″ long. To price Weld Rings longer than 6″, combine prices shown above. For Tightwind: Add 25% to Screen Price/Ft (Min TW slot $<=$0.010 Inch). Minimum billing length for LG Diam SS is 3 feet. Furnished in Full Screen Lengths, unless specified otherwise at the time of order.

[f] Dimensions, weights and collapse strength are approximate (based on an average slot and depth).

[g] Standard weld ring length 2PS″ through 6PS″ is 1-1/2″.

[h] Bail Loop prices Do Not include plate.

**Large Diameter 304 Stainless Steel High Flow (HIQ) and Remediation[i]**

| | Standard Dimensions[i] | | Screen Price Per Foot Max Depth Based on Collapse Strength[i] | | | | Direct Attached Standard Fittings Per End: Weld Rings | | | Threads | | | | Fig "K" Pkr w/WR | Plate Btm w/WR | Misc Attachments | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nom Diam | OD | ID | 100 ft | 250 ft | 600 ft | 1000 ft | STD | 4″ | 6″ | NPT | JWS | Flush Sch40 | Flush Sch80 | | | Bail Loop[j] | Lift Lugs[k] | 4″WR W/4″ Collar |
| 6″PS | 6.70 | 6.00 Wt/Foot 6# | $81 | $89 | $96 | $96 | $79 | $107 | $131 | $106 | n/a | $104 | $106 | n/a | $126 | $66 | $84 | $279 |
| 8″Tel | 7.50 | 6.75 Wt/Foot 10# | $96 | $105 | $105 | $110 | $108 | $141 | $173 | n/a | $153 | n/a | n/a | $435 | $173 | $70 | $93 | |
| 8″PS | 8.63 | 7.88 Wt/Foot 12# | $116 | $116 | $125 | $125 | $126 | $148 | $183 | $196 | n/a | $193 | $290 | n/a | $202 | $70 | $93 | $338 |
| 10″Tel | 9.50 | 8.68 Wt/Foot 13# | $131 | $131 | $141 | $141 | $144 | $187 | $230 | n/a | $301 | n/a | n/a | $460 | $245 | $70 | $105 | |
| 10″PS | 10.75 | 9.88 Wt/Foot 14# | $155 | $155 | $186 | $186 | $149 | $194 | $238 | $255 | n/a | $292 | $440 | n/a | $253 | $70 | $105 | $410 |
| 12″Tel | *11.25* | *10.40* Wt/Foot 18# | $163 | $163 | $194 | $194 | $179 | $233 | $276 | n/a | n/a | n/a | n/a | $605 | $304 | $70 | $116 | |

*(Continued)*

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**Table 6C.19 (Continued)**

**Large Diameter 304 Stainless Steel High Flow (HIQ) and Remediation[i]**

| Nom Diam | Standard Dimensions[i] OD | ID | Screen Price Per Foot Max Depth Based on Collapse Strength[i] 100 ft | 250 ft | 600 ft | 1000 ft | Direct Attached Standard Fittings Per End: Weld Rings STD | 4″ | 6″ | Threads NPT | JWS | Flush Sch40 | Flush Sch80 | Fig "K" Pkr w/WR | Plate Btm w/WR | Misc Attachments: Bail Loop[j] | Lift Lugs[k] | 4″WR W/4″ Collar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12″PS | 12.75 | 11.80 | $178 | $178 | $217 | $217 | $196 | $249 | $304 | $388 | n/a | $623 | $924 | n/a | $333 | $80 | $116 | $512 |
| | Wt/Foot 23# | | | | | | | | | | | | | | | | | |
| 14″Tel | 12.50 | 11.60 | $176 | $176 | $215 | $215 | $215 | $280 | $344 | n/a | n/a | n/a | n/a | $809 | $366 | $76 | $121 | |
| | Wt/Foot 25# | | | | | | | | | | | | | | | | | |
| 14P/16T | 14.00 | 13.00 | $206 | $206 | $226 | $226 | $252 | $329 | $404 | n/a | n/a | na | na | $923 | $441 | $76 | $121 | $601 |
| | Wt/Foot 30# | | | | | | | | | | | | | | | | | |
| **Large Diameter 304 Stainless Steel High Flow (HIQ)[k]** | | | | | | | | | | | | | | | | | | |
| 16P/18T | 16.00 | 15.00 | $210 | $230 | $230 | $235 | $302 | $377 | $464 | n/a | n/a | n/a | n/a | $1,014 | $529 | $76 | $128 | $670 |
| | Wt/Foot 35# | | | | | | | | | | | | | | | | | |
| 18P/20T | 18.00 | 16.70 | $285 | $285 | $285 | $330 | $360 | $468 | $576 | n/a | n/a | n/a | n/a | $1,045 | $630 | $76 | $128 | $755 |
| | Wt/Foot 40# | | | | | | | | | | | | | | | | | |
| 20″ PS | 20.00 | 18.80 | $340 | $340 | $355 | $400 | $382 | $497 | $611 | n/a | n/a | n/a | n/a | n/a | $669 | $76 | $139 | $845 |
| | Wt/Foot 42# | | | | | | | | | | | | | | | | | |
| 24″ Tel | 22.00 | 20.70 | $380 | $380 | $421 | $446 | $404 | $525 | $646 | n/a | n/a | n/a | n/a | n/a | $707 | $87 | $139 | |
| | Wt/Foot 46# | | | | | | | | | | | | | | | | | |
| 24P/26T | 24.00 | 22.75 | $420 | $420 | $488 | $488 | $462 | $601 | $739 | n/a | n/a | n/a | n/a | n/a | $809 | $87 | $151 | $998 |
| | Wt/Foot 58# | | | | | | | | | | | | | | | | | |
| 26″ PS | 26.00 | 24.40 | $436 | $436 | $516 | $527 | $539 | $674 | $830 | n/a | n/a | n/a | n/a | n/a | $943 | $87 | $151 | $1,102 |
| | Wt/Foot 62# | | | | | | | | | | | | | | | | | |
| 30″ Tel | *27.25* | *25.75* | $525 | $525 | $570 | Call | $595 | $774 | $952 | n/a | n/a | n/a | n/a | n/a | $1,041 | $105 | $169 | |
| | Wt/Foot 65# | | | | | | | | | | | | | | | | | |
| 30P/36T | 30.00 | 28.30 | $575 | $580 | $610 | Call | $671 | $872 | $1,074 | n/a | n/a | n/a | n/a | n/a | $1,174 | $105 | $169 | |
| | Wt/Foot 74 | | | | | | | | | | | | | | | | | |
| 36″ PS | 36.00 | 34.30 | $610 | $680 | $696 | Call | $773 | $1,005 | $1,237 | n/a | n/a | n/a | n/a | n/a | $1,353 | $105 | $169 | |
| | Wt/Foot 90# | | | | | | | | | | | | | | | | | |

Call for pricing on screens deeper than 1000 feet. Standard weld ring lengths: 6″PS-16P/18T are 1-1/2″ long; 18P/20T and larger are 2″ long. To price Weld Rings longer than 6″, combine prices shown above. For Tightwind: Add 25% to Screen Price/Ft (Min TW slot $<=$0.010 Inch). Minimum billing length for LG Diam SS is 3 feet. Furnished in Full Screen Lengths, unless specified otherwise at the time of order.

[i] Dimensions, weights and collapse strength are approximate (based on an average slot and depth).
[j] Standard weld ring length 2PS″ through 6PS″ is 1–1/2″.
[k] Bail Loop prices do not include plate.

**304 Stainless Steel Casing[l]**

| Nom Diam | Dimensions: Sch | OD | ID | Wt Per ft | List Price per Foot | Direct Attached Std Fittings Per End: Flush Threads Sch 40 | Sch 80 | Npt Thread | Weld Ring | Plate Bottom | Loose Fittings: Threaded Point | Cap/Plug | Locking Cap | Add/Joint Cln and Bag |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1″PS | 5 | 1.315 | 1.185 | 0.88 | $12 | $66 | $72 | $28 | $22 | $28 | $96 | $94 | $31 | $13 |
| | 10 | | 1.097 | 1.42 | $15 | | | | | | | | | |
| | 40 | | 1.049 | 1.70 | $16 | | | | | | | | | |
| 1-1/4″PS | 5 | 1.660 | 1.530 | 1.12 | $15 | $33 | $36 | $36 | $24 | $29 | $56 | $49 | $34 | $13 |
| | 10 | | 1.442 | 1.82 | $16 | | | | | | | | | |
| | 40 | | 1.380 | 2.29 | $18 | | | | | | | | | |
| 1-1/2″PS | 5 | 1.90 | 1.770 | 1.29 | $14 | $36 | $38 | $38 | $25 | $30 | $60 | $52 | $35 | $13 |
| | 10 | | 1.682 | 2.10 | $16 | | | | | | | | | |
| | 40 | | 1.610 | 2.74 | $19 | | | | | | | | | |

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**Table 6C.19 (Continued)**

| 304 Stainless Steel Casing[l] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Direct Attached Std Fittings Per End | | | | | Loose Fittings | | | |
| | Dimensions | | | | List | Flush Threads | | Npt | Weld | Plate | Threaded | | Locking | Add/Joint |
| Nom Diam | Sch | OD | ID | Wt Per ft | Price per Foot | Sch 40 | Sch 80 | Thread | Ring | Bottom | Point | Cap/Plug | Cap | Cln and Bag |
| 2″PS | 5 | 2.375 | 2.245 | 1.62 | $16 | $37 | $39 | $39 | $41 | $34 | $67 | $52 | $36 | $13 |
| | 10 | | 2.157 | 2.66 | $21 | | | | | | | | | |
| | 40 | | 2.067 | 3.69 | $25 | | | | | | | | | |
| 3″PS | 5 | 3.50 | 3.334 | 3.06 | $29 | $39 | $41 | $41 | $43 | $44 | $90 | $64 | $43 | $21 |
| | 10 | | 3.260 | 4.37 | $34 | | | | | | | | | |
| | 40 | | 3.068 | 7.65 | $40 | | | | | | | | | |
| 4″PS | 5 | 4.50 | 4.334 | 3.95 | $31 | $47 | $49 | $49 | $49 | $48 | $108 | $65 | $56 | $21 |
| | 10 | | 4.260 | 5.67 | $38 | | | | | | | | | |
| | 40 | | 4.026 | 10.90 | $60 | | | | | | | | | |
| 5″PS | 5 | 5.563 | 5.345 | 6.41 | $49 | $58 | $60 | $60 | $54 | $70 | n/a | $92 | $73 | $32 |
| | 10 | | 2.295 | 7.84 | $59 | | | | | | | | | |
| | 40 | | 5.047 | 14.75 | $92 | | | | | | | | | |
| 6″PS | 5 | 6.625 | 6.407 | 7.66 | $56 | $104 | $106 | $106 | $79 | $82 | n/a | $101 | $90 | $32 |
| | 10 | | 6.357 | 9.38 | $65 | | | | | | | | | |
| | 40 | | 6.065 | 19.15 | $109 | | | | | | | | | |
| 8″PS | 10 | 8.625 | 8.329 | 13.53 | $104 | $193 | $290 | $196 | $126 | $88 | n/a | $188 | $186 | n/a |
| | 40 | | 7.981 | 28.82 | $190 | | | | | | | | | |
| 10″PS | 10 | 10.75 | 10.420 | 18.83 | $130 | $292 | $440 | $254 | $149 | $148 | n/a | $316 | $281 | n/a |
| | 40 | | 10.020 | 40.86 | $255 | | | | | | | | | |
| 12″PS | 10 | 12.75 | 12.390 | 24.39 | $172 | $623 | $924 | $387 | $196 | $218 | n/a | $448 | $372 | n/a |
| | 40 | | 12.000 | 50.03 | $340 | | | | | | | | | |

Minimum billing length is 3 ft. Sumps: Add Weld Ring and Plate Bottom price to the sump length needed (minimum billing is 3 ft). Sch40 & Sch80 Threads: 1″ = 8 TPI; 1.25 & 1.5 = 4 TPI; 2″ > 2 TPI. Locking Cap Lugs are $7.00 and shipped loose. (Part Number 248242). 1 For Slip Cap deduct $7.00 from Locking Cap Price. * Price per foot includes beveling

[l] Must add "Clean & Bag" charge for environmental casing.

**Table 6C.20 Intake Areas of Well Screens**

**Wire-Wound Telescopic Screens**
**Intake Areas (sq. in. per ft of Screen)**

| | Slot Opening Size | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nom Diam (in.) | 10-Slot | 20-Slot | 40-Slot | 60-Slot | 80-Slot | 100-Slot | 150-Slot | 250-Slot |
| 3 | 15 | 26 | 41 | 52 | 59 | 65 | 73 | 82 |
| 4 | 20 | 35 | 57 | 71 | 81 | 88 | 101 | 115 |
| 5 | 26 | 45 | 72 | 90 | 102 | 112 | 112 | 132 |
| 6 | 30 | 53 | 85 | 106 | 100 | 112 | 132 | 156 |
| 8 | 28 | 51 | 87 | 113 | 133 | 149 | 160 | 194 |
| 10 | 36 | 65 | 108 | 141 | 166 | 186 | 200 | 243 |
| 12 | 42 | 77 | 130 | 143 | 171 | 195 | 237 | 265 |
| 14 | 37 | 68 | 97 | 132 | 161 | 185 | 232 | 292 |
| 16 | 42 | 60 | 108 | 148 | 180 | 208 | 261 | 327 |
| 18 | 36 | 69 | 124 | 169 | 206 | 237 | 298 | 375 |
| 20 | 41 | 77 | 139 | 189 | 229 | 264 | 280 | 366 |
| 24 | 61 | 113 | 131 | 182 | 226 | 265 | 343 | 449 |
| 26 | 63 | 118 | 138 | 191 | 237 | 278 | 360 | 471 |

*(Continued)*

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**Table 6C.20 (Continued)**

**Wire-Wound Telescopic Screens**
**Intake Areas (sq. in. per ft of Screen)**

| | Slot Opening Size | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Nom Diam (in.)** | **10-Slot** | **20-Slot** | **40-Slot** | **60-Slot** | **80-Slot** | **100-Slot** | **150-Slot** | **250-Slot** |
| 30 | 75 | 138 | 161 | 224 | 278 | 325 | 422 | 552 |
| 36 | 84 | 157 | 184 | 255 | 317 | 371 | 481 | 629 |

**PVC Plastic Screens**
**Intake areas (sq. in. per ft of screen)**

| | Slot Opening Size | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Size (in.)** | **6-Slot** | **8-Slot** | **10-Slot** | **12-Slot** | **15-Slot** | **20-Slot** | **25-Slot** | **30-Slot** | **35-Slot** | **40-Slot** |
| 1¼ | 3.0 | 3.4 | 4.8 | 3.0 | 7.0 | 8.9 | 10.8 | 12.5 | 14.1 | 15.6 |
| 1½ | 3.4 | 4.5 | 5.5 | 6.5 | 8.1 | 10.2 | 12.3 | 14.2 | 16.2 | 17.9 |
| 2 | 4.3 | 5.5 | 6.8 | 8.1 | 10.0 | 12.8 | 15.4 | 17.9 | 20.3 | 22.4 |
| 3 | 5.4 | 7.1 | 8.8 | 10.4 | 12.8 | 16.5 | 20.0 | 23.2 | 26.5 | 29.3 |
| 4 | 7.0 | 9.0 | 11.3 | 13.5 | 16.5 | 21.2 | 25.8 | 30.0 | 3.9 | 37.7 |
| 5 | 8.1 | 10.6 | 13.1 | 15.5 | 19.1 | 24.7 | 30.0 | 34.9 | 39.7 | 44.2 |
| 6 | 8.1 | 10.6 | 13.2 | 15.6 | 19.2 | 25.0 | 30.5 | 35.8 | 40.7 | 45.4 |
| 8 | 13.4 | 17.6 | 21.7 | 25.7 | 31.5 | 40.6 | 49.3 | 57.4 | 65.0 | 72.3 |

*Note:* The maximum transmitting capacity of the screen can be derived from these figures. To determine GPM per feet of screen, multiply the intake area in square inches by 0.31. It must be remembered that this is the maximum capacity of the screen under ideal conditions with an entrance velocity of 0.1 ft/sec.

*Source*: From Johnson Division of Signal Environmental Systems, Inc., St. Paul, MN.

**Table 6C.21 Optimum Well Screen Entrance Velocities**

| Coefficient of Permeability (gallons per day per square foot) | Optimum Screen Entrance Velocities (ft/min) |
|---|---|
| >6000 | 12 |
| 6000 | 11 |
| 5000 | 10 |
| 4000 | 9 |
| 3000 | 8 |
| 2500 | 7 |
| 2000 | 6 |
| 1500 | 5 |
| 1000 | 4 |
| 500 | 3 |
| <500 | 2 |

*Source*: From Illinois State Water Survey, 1962.

**Table 6C.22 Chlorinated Lime Required to Disinfect a Well or Spring**

| Capacity of Well or Spring in Gallons | Chlorinated Lime Required (25% Available Chlorine) | | Approximate Volume of Water, in Gallons to be Used in Preparing Chlorine Solution |
|---|---|---|---|
| | *Pounds and Ounces* | | |
| 50 | — | 1.5 | 5 |
| 100 | — | 3.0 | 5 |
| 200 | — | 6.0 | 5 |
| 300 | — | 9.0 | 5 |
| 400 | — | 12.0 | 5 |
| 500 | — | 15.0 | 5 |
| 1,000 | 1 | 14.0 | 10 |
| 2,000 | 3 | 12.0 | 15 |
| 3,000 | 5 | 10.0 | 20 |

*Note:* Values provide a dosage of approximately 50 parts per million of available chlorine.

*Source*: From U.S. Public Health Service.

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**Table 6C.23 Volume of Water in Well Per Foot of Depth**

| Nominal Casing Size (in.) | Schedule No. | Volume (Gallons per Foot of Depth) |
|---|---|---|
| 4 | 40 | 0.66 |
| 5 | 40 | 1.04 |
| 6 | 40 | 1.50 |
| 8 | 30 | 2.66 |
| 10 | 30 | 4.19 |
| 12 | 30 | 5.80 |
| 14 | 30 | 7.16 |
| 16 | 30 | 9.49 |
| 18 | 30 | 11.96 |
| 20 | 30 | 14.73 |
| 22 | 30 | 17.99 |
| 24 | 30 | 21.58 |

*Source*: From U.S. Bureau of Reclamation, *Groundwater Manual* 1977.

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## SECTION 6D INJECTION WELLS

**Table 6D.24 Statistical Analysis of Injection Well Data**

| Distribution of Injection Wells by Industry Type | |
|---|---|
| **Type of Industry** | **Percentage of Existing Wells (%)** |
| Refineries and natural gas plants | 20 |
| Chemical, petrochemical, and pharmaceutical companies | 55 |
| Metal products companies | 7 |
| Other | 18 |

| Total Depth of Injection Wells | |
|---|---|
| **Total Well Depth** | **Percentage of Wells (%)** |
| 0–1,000 ft | 5 |
| 1,001–2,000 ft | 32 |
| 2,001–4,000 ft | 27 |
| 4,001–6,000 ft | 28 |
| 6,001–12,000 ft | 6 |
| over 12,000 ft | 2 |

| Type of Rock Used for Injection | |
|---|---|
| **Rock Type** | **Percentage of Wells (%)** |
| Sand | 33 |
| Sandstone | 41 |
| Limestone and dolomite | 22 |
| Other | 4 |

| Rate of Injection | |
|---|---|
| **Injection Rate** | **Percentage of Wells (%)** |
| 0–50 gpm | 23 |
| 51–100 gpm | 11 |
| 101–200 gpm | 25 |
| 201–400 gpm | 19 |
| 401–800 gpm | 3 |
| over 800 gpm | 1 |
| Unknown | 18 |

| Pressure at Which Waste Is Injected | |
|---|---|
| **Injection Pressure** | **Percentage of Wells (%)** |
| Gravity flow | 11 |
| Gravity–150 psi | 19 |
| 151–300 psi | 15 |
| 301–600 psi | 6 |
| 601–1,500 psi | 13 |
| over 1,500 psi | 2 |
| Unknown | 34 |

*Source*: From Water Well Journal, 1968.

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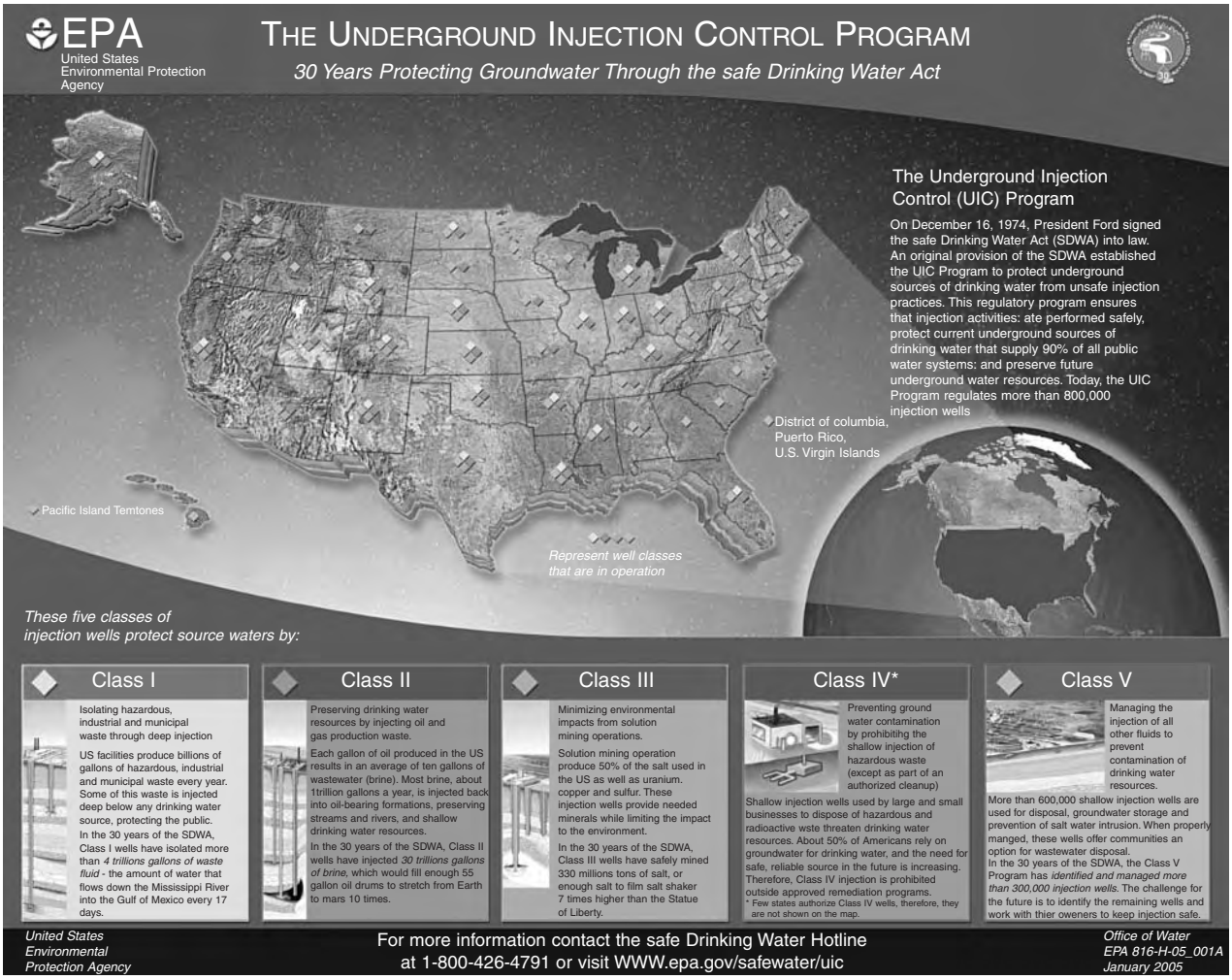


**Figure 6D.10** The underground injection control program. (From www.epa.gov.)

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**Table 6D.25 Classes of Injection Wells**

***Regulatory Definitions of Injection Wells (§144.6)***

The UIC Program provides standards, technical assistance and grants to State governments to regulate injection wells in order to prevent them from contaminating drinking water resources. EPA defines the five classes of wells according to the type of fluid they inject and where the fluid is injected. EPA has published regulations related to the sitting, drilling, construction and operation of many types of injection wells

***Class I wells*** are technologically sophisticated and inject hazardous and non-hazardous wastes below the lowermost underground source of drinking water (*USDW*). Injection occurs into deep, isolated rock formations that are separated from the lowermost USDW by layers of impermeable clay and rock

***Class I wells*** are oil and gas production brine disposal and other related wells. Operators of these wells inject fluids associated with oil and natural gas production. Most of the injected fluid is brine that is produced when oil and gas are extracted from the earth (about 10 barrels of brine for every barrel of oil)

***Class III wells*** are wells that inject superheated steam, water, or other fluids into formations in order to extract minerals. The injected fluids are then pumped to the surface and the minerals in solution are extracted. Generally, the fluid is treated and re-injected into the same formation. More than 50 percent of the salt and 80 percent of the uranium extraction in the U.S. is produced this way

***Class IV wells*** inject hazardous or radioactive wastes into or above underground sources of drinking water. These wells are banned under the UIC program because they directly threaten public health

***Class V wells*** are injection wells that are not included in the other classes. Some Class V wells are technologically advanced wastewater disposal systems used by industry, but most are "low-tech" wells, such as septic systems and cesspools. Generally, they are shallow and depend upon gravity to drain or "inject" liquid waste into the ground above or into underground sources of drinking water. Their simple construction provides little or no protection against possible groundwater contamination, so it is important to control what goes into them

In general, owners and operators of most new Classes I, II and III injection wells are required to:

- Site the wells in a location that is free of faults and other adverse geological features
- Drill to a depth athat allows the injection into formations that do not contain water that can potentially be used as a source of drinking water. These injection zones are confined from any formation that may contain water that may potentially be used as a source of drinking water
- Build to inject through an internal pipe (tubing) that is located inside another pipe (casing). This outer pipe has cement on the outside to fill any voids occurring between the outside pipe and the hole that was bored for the well (borehole). This allows for multiple layers of containment of the potentially contaminating injection fluids
- Test for integrity at the time of completion and every five years thereafter (more frequently for hazardous waste wells, §146.68(d))
- Monitor continuously to assure the integrity of the well

Operators of Class I wells injecting hazardous waste are required to demonstrate that the waste will never return to the surface or impact an underground source of drinking water (for 10,000 years). These wells inject at 4,000 ft below the surface or more. Over 9 billion gallons of hazardous waste is injected into wells each year in the US

The largest number of injection wells are shallow wells that inject non-hazardous fluids into very shallow aquifers that are or can be used as sources of drinking water. Some of the wells in this category are:

- Drainage wells in industrial setting that can receive surface runoff contaminated with a variety of pollutants;
- Septic tank systems and dry-wells used in automotive shops that receive fluids from repair and maintenance bays;
- Cesspools that receive sewage from a community;
- Agricultural drainage wells that may receive water contaminated with pesticides and fertilizers

*Source*: From www.epa.gov.

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**Table 6D.26 Underground Injection Control Program — Inventory of Wells**

| | Class I Hazardous Waste Wells | Class I non-Hazardous Waste Wells | Class II Wells | Class III Facilities (Which May Contain Multiple Wells) | Class III Wells | Class IV Facilities (Which May Contain Multiple Wells) |
|---|---|---|---|---|---|---|
| AK | | 6 | 925 | | | |
| AL | | | 347 | 1 | 3 | |
| AR | 6 | 10 | 1,078 | | | |
| AZ | | | | 3 | 15 | |
| CA | | 6 | 24,955 | 1 | 73 | |
| CO | | 5 | 787 | 2 | 35 | |
| FL | 1 | 136 | 64 | | | |
| IA | | | 1 | | | |
| IL | 3 | 1 | 8,949 | | | |
| IN | 4 | 7 | 1,340 | | | |
| KS | 6 | 44 | 16,371 | 5 | 157 | |
| KY | | 1 | 3,429 | | | |
| LA | 17 | 28 | 3,824 | 15 | 67 | |
| MI | 9 | 15 | 1,459 | 3 | 22 | |
| MO | | | 211 | | | |
| MS | 6 | 1 | 881 | | | |
| MT | | | 897 | | | |
| ND | | 2 | 377 | | | |
| NE | | 1 | 704 | 1 | 1,879 | |
| NM | | 5 | 5,577 | 19 | 104 | |
| NV | | | 12 | | | |
| NY | | 1 | 503 | 6 | 126 | |
| OH | 10 | 2 | 2,890 | 3 | 47 | 1 |
| OK | | 11 | 11,448 | 1 | 1 | |
| OR | | | 2 | | | |
| PA | | 10 | 1,897 | 1 | 10 | |
| SD | | | 63 | | | |
| TN | | | 14 | | | |
| TX | 60 | 46 | 51,998 | 86 | 5,789 | |
| UT | | | 256 | 1 | 4 | 2 |
| VA | | 3 | 252 | 1 | 3 | 1 |
| WA | | | 1 | | | |
| WV | | | 700 | 3 | 31 | |
| WY | | 23 | 4,666 | 12 | 8,211 | 1 |
| EPA R2 tribal | | | 12 | | | |
| EPA R6 tribal | 1 | | 2,674 | | | |
| EPA R8 tribal | | | 723 | | | |
| EPA R9 tribal | | | 542 | | | |
| | 122 | 364 | 146,878 | 164 | 16,577 | 5 |

*Note:* Types of wells: Class I, Deep industrial waste disposal; Class II, For oil and natural gas production; Class III, Related to mineral recovery; Class IV, Banned, inject hazardous or radioactive waste above USDWs; Class V, Generally shallow disposal wells. There are an estimated 650,000 Class V wells nationally. Class I through IV data from annual reporting by states and EPA Regions. The Class V estimate is based on state estimates and modeling of storm water and large capacity septics.

*Source*: From www.epa.gov.

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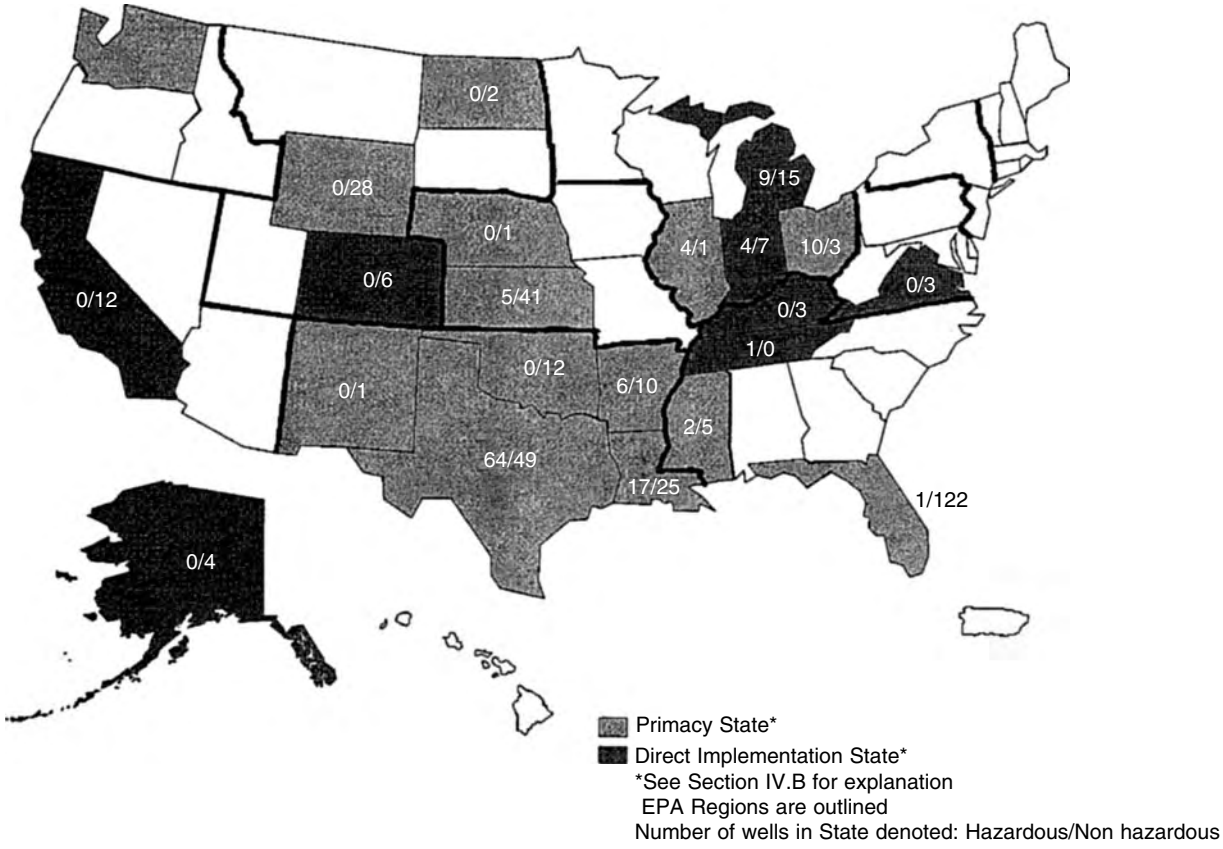


**Figure 6D.11** Number of class I wells by state. (From www.epa.gov EPA's class I well inventory, 1999.)

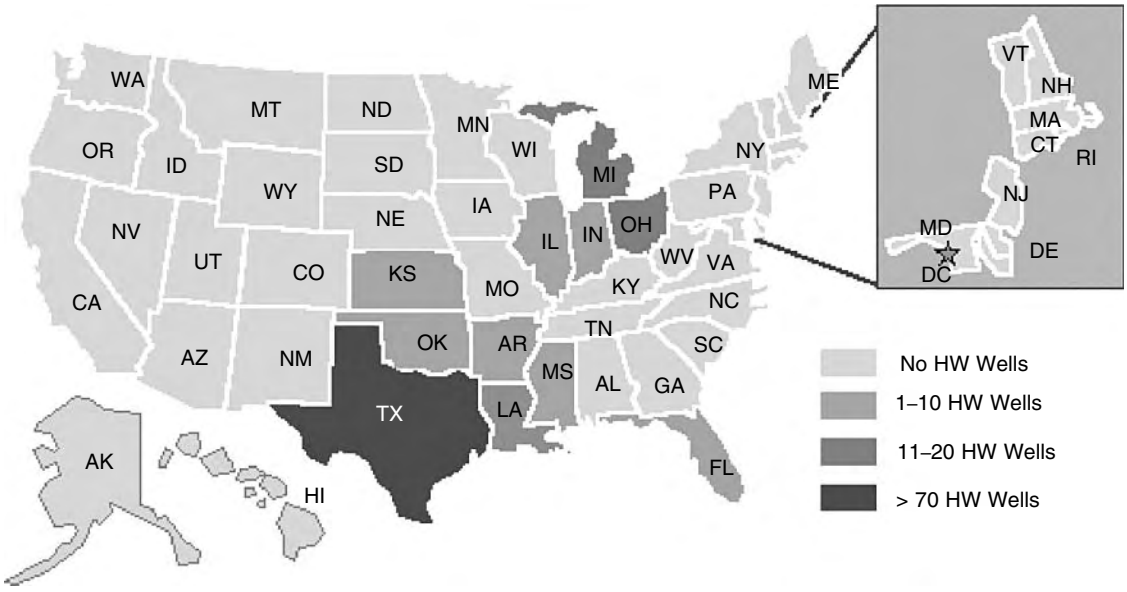


**Figure 6D.12** UIC class I deep/high technology hazardous waste wells. (From www.epa.gov.)

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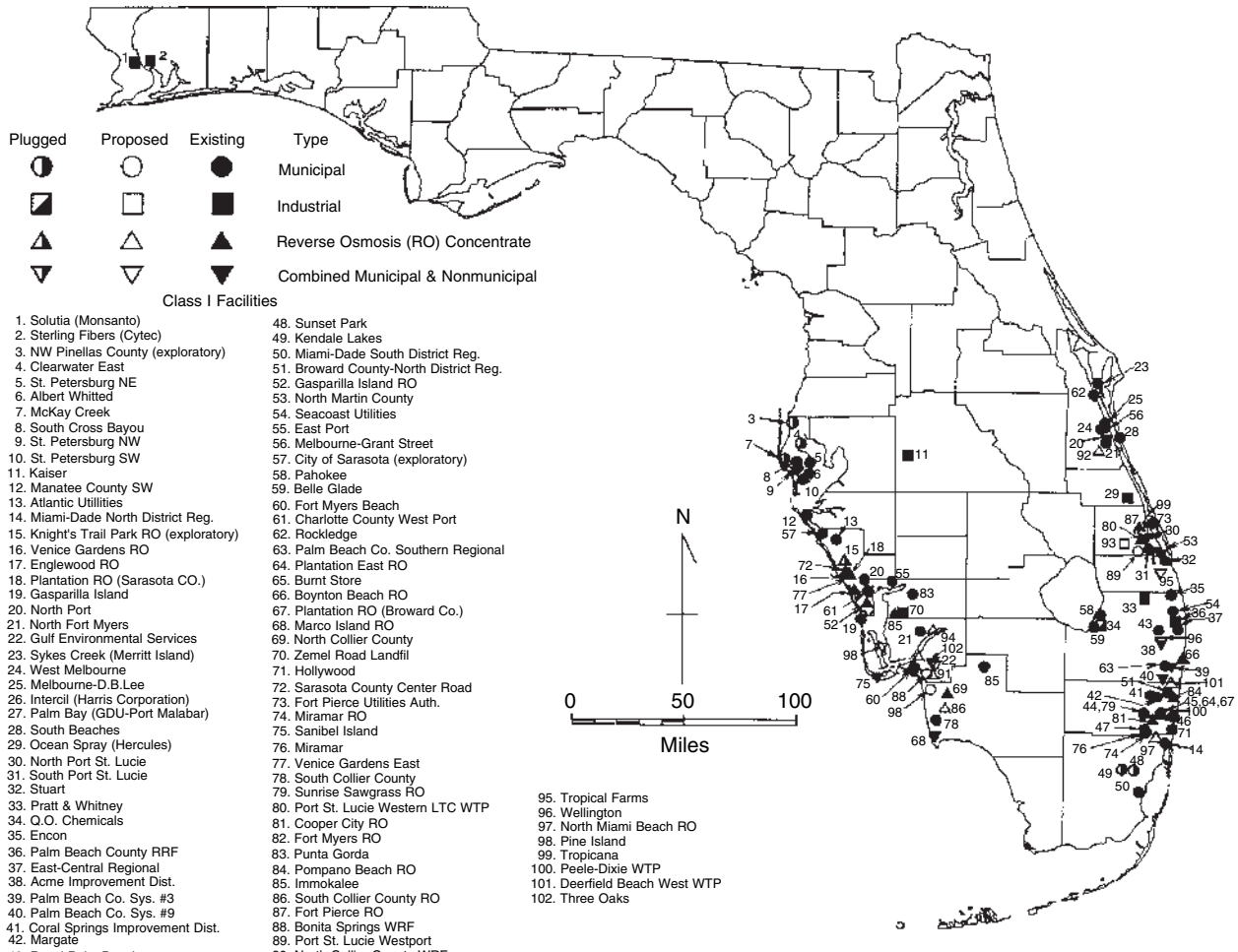


**Figure 6D.13** Class I injection facilities. (From www.dep.state.fl.us.)

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**Table 6D.27 Class I Injection Well Status**

| Map | Facility | Status — November 2003 | | | Total Wells |
|---|---|---|---|---|---|
| | | Proposed | Active | Other | |
| 1 | Solutia (Monsanto) (I) | 0 | 3 | 0 | 3 |
| 2 | Sterling Fibers (Cytec) (I) | 0 | 1 | 1SB | 2 |
| 3 | NW Pinellas County (EX) | 0 | 0 | 3PA | 3 |
| 4 | Clearwater East | 0 | 0 | 1PA | 1 |
| 5 | St. Petersburg NE | 0 | 3 | 0 | 3 |
| 6 | Albert Whitted | 0 | 2 | 0 | 2 |
| 7 | McKay Creek | 0 | 0 | 2PA | 2 |
| 8 | South Cross Bayou | 0 | 3 | 1PA | 4 |
| 9 | St. Petersburg NW | 0 | 2 | 0 | 2 |
| 10 | St. Petersburg SW | 0 | 3 | 0 | 3 |
| 11 | K.C. Industries (Kaiser) (HW) | 0 | 1 | 0 | 1 |
| 12 | Manatee County SW Subregional | 0 | 1 | 1EXM | 2 |
| 13 | Atlantic Utilities | 0 | 1 | 1EXM | 2 |
| 14 | MDW&SA North District Regional | 0 | 2 | 2IA | 4 |
| 15 | Knight's Trail (EX) | 0 | 0 | 1EXM | 1 |
| 16 | Venice Gardens (RO) | 0 | 1 | 0 | 1 |
| 17 | Englewood (RO) | 0 | 1 | 1UC | 2 |
| 18 | Plantation RO (Sarasota Co.) | 0 | 0 | 1IA | 1 |
| 19 | Gasparilla Island | 0 | 1 | 0 | 1 |
| 20 | North Port | 0 | 1 | 0 | 1 |
| 21 | North Fort Myers Utilities | 0 | 1 | 1EXM | 2 |
| 22 | Gulf Environmental Services (MN) | 1 | 0 | 0 | 1 |
| 23 | Sykes Creek (Merritt Island) | 0 | 2 | 1EXM | 3 |
| 24 | West Melbourne | 0 | 1 | 0 | 1 |
| 25 | Melbourne-D.B. Lee | 0 | 0 | 1TA | 1 |
| 26 | Intercil (Harris Corporation) (I) | 0 | 2 | 0 | 2 |
| 27 | Palm Bay (GDU-Port Malabar) | 0 | 1 | 0 | 1 |
| 28 | South Beaches | 0 | 1 | 0 | 1 |
| 29 | Ocean Spray (Hercules) (I) | 0 | 1 | 0 | 1 |
| 30 | North Port St. Lucie (MN) | 0 | 1 | 0 | 1 |
| 31 | South Port St. Lucie | 0 | 1 | 0 | 1 |
| 32 | Stuart | 0 | 2 | 0 | 2 |
| 33 | Pratt and Whitney (I) | 0 | 1 | 0 | 1 |
| 34 | QO Chemicals (I) | 0 | 0 | 4PA | 4 |
| 35 | Encon | 0 | 1 | 0 | 1 |
| 36 | Palm Beach County RRF (I) | 0 | 2 | 0 | 2 |
| 37 | East-Central Regional | 0 | 6 | 1UC | 7 |
| 38 | Acme Improvement District (MN) | 0 | 1 | 0 | 1 |
| 39 | Palm Beach County System #3 (MN) | 0 | 1 | 0 | 1 |
| 40 | Palm Beach County System #9 (MN) | 0 | 1 | 0 | 1 |
| 41 | Coral Springs Improvement District | 0 | 2 | 0 | 2 |
| 42 | Margate | 0 | 2 | 0 | 2 |
| 43 | Royal Palm Beach | 0 | 1 | 0 | 1 |
| 44 | Sunrise | 0 | 3 | 0 | 3 |
| 45 | Plantation Regional (Broward Co.) | 0 | 2 | 0 | 2 |
| 46 | G. T. Lohmeyer | 0 | 5 | 0 | 5 |
| 47 | Pembroke Pines | 0 | 2 | 0 | 2 |
| 48 | Sunset Park | 0 | 0 | 1PA | 1 |
| 49 | Kendale Lakes | 0 | 0 | 1PA | 1 |
| 50 | MDW&SA South District Regional | 0 | 13 | 4IA | 17 |
| 51 | Broward County-North District Regional | 2 | 6 | 0 | 8 |
| 52 | Gasparilla Island RO | 0 | 1 | 0 | 1 |
| 53 | North Martin County (MN) | 0 | 2 | 0 | 2 |
| 54 | Seacoast Utilities | 0 | 1 | 0 | 1 |
| 55 | East Port (Charlotte) | 0 | 2 | 0 | 2 |
| 56 | Melbourne-Grant St. | 0 | 1 | 0 | 1 |
| 57 | City of Sarasota (EX) | 0 | 0 | 1EXM | 1 |
| 58 | Pahokee | 0 | 1 | 0 | 1 |
| 59 | Belle Glade | 0 | 1 | 0 | 1 |

*(Continued)*

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**Table 6D.27 (Continued)**

| Map | Facility | Status — November 2003 | | | Total Wells |
|---|---|---|---|---|---|
| | | Proposed | Active | Other | |
| 60 | Fort Myers Beach | 0 | 1 | 0 | 1 |
| 61 | West Port (Charlotte) | 0 | 1 | 0 | 1 |
| 62 | Rockledge | 0 | 1 | 0 | 1 |
| 63 | Palm Beach County Southern Regional | 0 | 2 | 0 | 2 |
| 64 | Plantation East RO (Broward County) | 0 | 1 | 0 | 1 |
| 65 | Burnt Store (RO) | 0 | 1 | 0 | 1 |
| 66 | Boynton Beach (RO) | 0 | 1 | 0 | 1 |
| 67 | Plantation RO (Broward Co.) | 0 | 1 | 0 | 1 |
| 68 | Marco Island (MN) | 0 | 1 | 0 | 1 |
| 69 | North Collier County (RO) | 0 | 2 | 0 | 2 |
| 70 | Zemel Road Landfill (I) | 0 | 1 | 0 | 1 |
| 71 | Hollywood | 0 | 0 | 2UC | 2 |
| 72 | Sarasota County Center Road | 0 | 1 | 0 | 1 |
| 73 | Fort Pierce Utility Authority | 0 | 1 | 0 | 1 |
| 74 | Miramar RO | 0 | 2 | 0 | 2 |
| 75 | Sanibel Island (MN) | 0 | 1 | 0 | 1 |
| 76 | Miramar | 0 | 2 | 0 | 2 |
| 77 | Venice Gardens East RO | 0 | 1 | 0 | 1 |
| 78 | South Collier County | 1 | 1 | 0 | 2 |
| 79 | Sunrise Sawgrass RO | 0 | 1 | 0 | 1 |
| 80 | Port St. Lucie Western LTC WTP | 0 | 1 | 0 | 1 |
| 81 | Cooper City RO | 0 | 1 | 0 | 1 |
| 82 | Fort Myers RO | 0 | 1 | 0 | 1 |
| 83 | Punta Gorda | 0 | 1 | 1 EXM | 2 |
| 84 | Pompano Beach RO | 0 | 1 | 0 | 1 |
| 85 | Immokalee | 0 | 1 | 0 | 1 |
| 86 | South Collier County RO | 0 | 0 | 2 UC | 2 |
| 87 | Fort Pierce RO | 0 | 1 | 0 | 1 |
| 88 | Bonita Springs RO | 0 | 0 | 1UC | 1 |
| 89 | Port St. Lucie Westport | 0 | 0 | 1UC | 1 |
| 90 | North Collier County WRF | 0 | 0 | 2UC | 2 |
| 91 | Bonita Springs WRF | 0 | 0 | 1UC | 1 |
| 92 | Palm Bay RO | 1 | 0 | 1 EX | 2 |
| 93 | CPV Cana Power Plant | 1 | 0 | 0 | 1 |
| 94 | North Lee County WTP | 0 | 0 | 1UC | 1 |
| 95 | Tropical Farms | 0 | 0 | 2UC | 2 |
| 96 | Wellington (MN) | 1 | 0 | 0 | 1 |
| 97 | North Miami Beach RO | 1 | 0 | 0 | 1 |
| 98 | Pine Island (MN) | 1 | 0 | 0 | 1 |
| 99 | Tropicana | 1 | 0 | 0 | 1 |
| 100 | Peele-Dixie WTP | 1 | 0 | 0 | 1 |
| 101 | Deerfield Beach West WTP | 1 | 0 | 0 | 1 |
| 102 | Three Oaks | 1 | 0 | 0 | 1 |
| | **TOTAL** | **13** | **126** | **45** | **184** |

**Key to Abbreviations**

**Facility**
EX — Exploratory well only
HW — Hazardous waste
I — Industrial (non-hazardous)
RO — Reverse osmosis concentrate
RRF — Resource recovery facility.

**Status**
TA — Temporarily abandoned well
PA — Permanently abandoned well
IA — Inactive well
SB — Standby well
UC — Under Construction/testing

EX — Exploratory well
EXI — Inactive exploratory well
EXW — Exploratory well converted to an injection well
EXM — Exploratory well converted to a monitor well
EXP — Exploratory well plugged and abandoned.

*Source*: From www.dep.state.fl.us.

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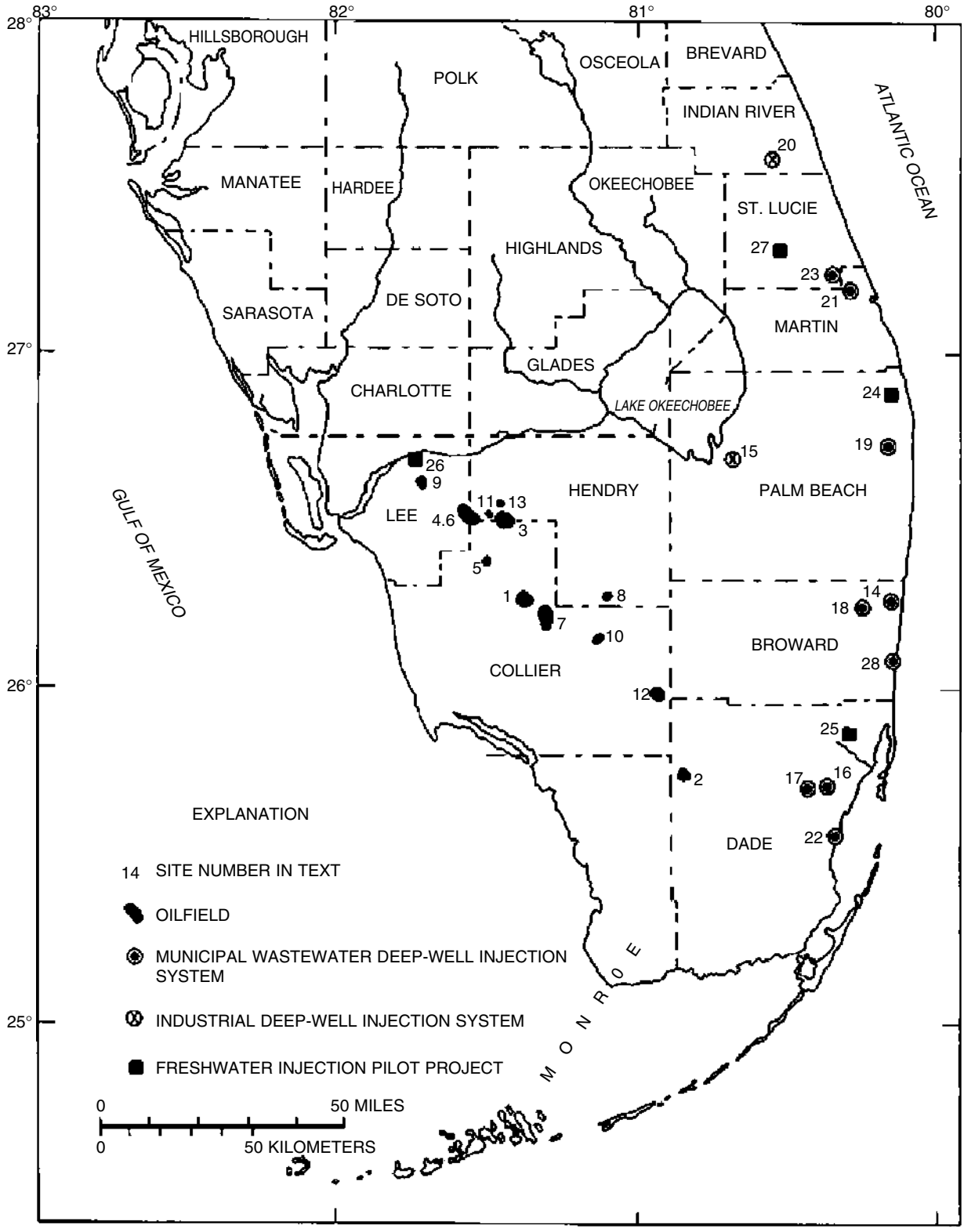


**Figure 6D.14** Deep well injection systems. (From www.sofia.usgs.gov.)

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**Table 6D.28 Summary of Deep-Well Injection Systems in Florida**

| | | | | | | Injection Wells | | | Well Casings | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Injected Effluent | | First Year | Design Capacity | | Number | Depth | | Number | Depth | |
| Location | Type | Pretreatment | of Operation | ML/d | mgd | of Wells | m | ft[a] | of Casings | m | ft[a] |
| Belle Glade, Palm Beach County | Industrial | Cooling | 1966 | 5.6 | 1.5 | 2 | 975 | 3200 | 4 | 883 | 2900 |
| Sunset Park, South Miami | Municipal | Secondary | 1971 | 22.7 | 6.0 | 1 | 914 | 3000 | 3 | 563 | 1850 |
| Mulberry, Polk County | Industrial | None | 1971 | 1.3 | 0.35 | 1 | 1371 | 4500 | 3 | 1219 | 4000 |
| Kendale Lakes, South Miami | Municipal | Secondary | 1973 | 22.7 | 6.0 | 1 | 975 | 3200 | 3 | 670 | 2200 |
| Margate, Broward County | Municipal | Secondary | 1975 | 56.7 | 15.0 | 1 | 975 | 3200 | 3 | 731 | 2400 |
| St. Petersburg, Southwest plant | Municipal | Tertiary | 1976 | 75.7 | 20.0 | 3 | 304 | 1000 | 3 | 274 | 900 |
| Gainesville, Kanapaha plant | Municipal | Advanced wastewater treatment | 1976 | 28.3 | 7.5 | 3 | 304 | 1000 | 3 | 152 | 500 |
| West Palm Beach | Municipal | Secondary | 1978 | 302.8 | 80.0 | 5 | 1097 | 3600 | 4 | 914 | 3000 |
| Vero Beach, Indian River County | Industrial | Neutralization | 1979 | 1.1 | 0.3 | 1 | 914 | 3000 | 4 | 731 | 2400 |
| Miami-Dade Water and Sewer Authority | Municipal | Secondary | 1983 | 423.9 | 112.0 | 9 | 944 | 3100 | 4 | 792 | 2600 |

[a] Rounded to nearest 100 ft.

*Source*: From Garcia-Bengochea, J.I., Protecting water supply aquifers in areas using deep-well wastewater disposal, *J. Am. Water Works Assoc.*, 75, 6, 1983. Copyright AWWA. Reprinted with permission.

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## SECTION 6E PUMPING OF WATER

**Table 6E.29 Useful Factors in Preliminary Planning of Small Pumping Plants**

| Pump or Pipe Size (in.) | Gallons/min | Acre-Inches per 24 hr | Pipe Velocity (ft/sec) | Velocity Head ($V^2/2g$ ft) | Friction in Feet Per 100 Feet of Pipe | Horsepower Required for 10 ft Total Head. Pump and Transmission Efficiency = 70 Percent |
|---|---|---|---|---|---|---|
| 6 | 400 | 21.2 | 4.54 | 0.32 | 2.21 | 1.4 |
| 6 | 600 | 31.8 | 6.72 | 0.70 | 4.7 | 2.2 |
| 6 | 800 | 42.4 | 9.08 | 1.28 | 8.0 | 2.9 |
| 6 | 1,000 | 53.0 | 11.32 | 1.99 | 12.0 | 3.6 |
| 8 | 900 | 47.7 | 5.75 | 0.52 | 2.46 | 3.2 |
| 8 | 1,100 | 58.3 | 7.03 | 0.77 | 3.51 | 4.0 |
| 8 | 1,300 | 68.9 | 8.32 | 1.07 | 4.72 | 4.7 |
| 8 | 1,500 | 79.5 | 9.60 | 1.43 | 6.27 | 5.4 |
| 10 | 1,200 | 63.6 | 4.91 | 0.38 | 1.46 | 4.3 |
| 10 | 1,600 | 84.8 | 6.56 | 0.67 | 2.35 | 5.8 |
| 10 | 2,000 | 108.1 | 8.10 | 1.02 | 3.65 | 7.2 |
| 10 | 2,400 | 127.3 | 9.73 | 1.47 | 5.04 | 8.7 |
| 12 | 2,000 | 106.1 | 5.60 | 0.48 | 1.43 | 7.2 |
| 12 | 2,500 | 132.6 | 7.00 | 0.77 | 2.28 | 9.0 |
| 12 | 3,000 | 159.1 | 8.40 | 1.10 | 3.15 | 10.8 |
| 12 | 3,500 | 185.6 | 9.80 | 1.49 | 4.10 | 12.6 |
| 14 | 2,000 | 106.1 | 4.20 | 0.27 | 0.66 | 7.2 |
| 14 | 3,000 | 159.1 | 6.30 | 0.61 | 1.47 | 10.8 |
| 14 | 4,000 | 212.1 | 8.40 | 1.09 | 2.47 | 14.4 |
| 14 | 5,000 | 265.2 | 10.50 | 1.71 | 3.92 | 18.0 |
| 16 | 3,600 | 190.9 | 5.74 | 0.51 | 1.10 | 13.0 |
| 16 | 4,400 | 233.3 | 7.01 | 0.76 | 1.58 | 15.9 |
| 16 | 5,200 | 275.8 | 8.29 | 1.06 | 2.16 | 18.8 |
| 16 | 6,000 | 318.2 | 9.56 | 1.42 | 2.60 | 21.6 |
| 18 | 4,500 | 238.6 | 5.70 | 0.50 | 0.93 | 16.2 |
| 18 | 5,500 | 291.7 | 6.96 | 0.75 | 1.32 | 19.8 |
| 18 | 6,500 | 344.7 | 8.22 | 1.05 | 1.82 | 23.4 |
| 18 | 8,000 | 424.2 | 10.02 | 1.56 | 2.65 | 28.9 |
| 20 | 5,000 | 265.2 | 5.13 | 0.41 | 0.68 | 18.0 |
| 20 | 6,500 | 344.7 | 6.66 | 0.69 | 1.06 | 23.4 |
| 20 | 8,000 | 424.2 | 8.17 | 1.03 | 1.63 | 28.9 |
| 20 | 10,000 | 530.3 | 10.40 | 1.68 | 2.53 | 36.1 |
| 24 | 8,000 | 424.2 | 5.68 | 0.50 | 0.66 | 28.9 |
| 24 | 10,000 | 630.3 | 7.07 | 0.78 | 0.98 | 36.1 |
| 24 | 12,000 | 636.4 | 8.50 | 1.12 | 1.40 | 43.3 |
| 24 | 14,000 | 742.4 | 9.95 | 1.54 | 1.87 | 50.5 |
| 30 | 12,000 | 636.4 | 5.44 | 0.46 | 0.47 | 43.3 |
| 30 | 16,000 | 848.5 | 7.36 | 0.84 | 0.83 | 57.7 |
| 30 | 20,000 | 1061.0 | 9.09 | 1.29 | 1.22 | 72.2 |
| 30 | 24,000 | 1273.0 | 10.90 | 1.86 | 1.71 | 86.6 |

*Source*: From U.S. Department of Agriculture.

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**Table 6E.30 Characteristics of Pumps Frequently Employed in Wells**

| Type of Pump | Practical Suction Lift[a] | Usual Well-Pumping Depth | Usual Pressure Heads | Advantages | Disadvantages |
|---|---|---|---|---|---|
| Reciprocating | | | | | |
| Shallow well | 6–7 m | 6–7 m | 30–60 m | Positive action; discharge against variable heads; pumps water containing sand and silt; especially adapted to low capacity and high lifts | Pulsating discharge; subject to vibration and noise; maintenance cost may be high; may cause destructive pressure if operated against closed valve |
| Deep well | 6–7 m | Up to 180 m | Up to 180 m above cylinder | | |
| Centrifugal | | | | | |
| Shallow well straight centrifugal (single stage) | 6 m max | 3–6 m | 30–45 m | Smooth, even flow; pumps water containing sand and silt; pressure on system is even and free from shock; low-starting torque; usually reliable and good service life | Loses prime easily; efficiency depends on operating under design heads and speed |
| Regenerative vane turbine type (single impeller) | 8 m max | 8 m | 30–60 m | Same as straight centrifugal except not suitable for pumping water containing sand or silt; self-priming | Same as straight centrifugal except maintains priming easily |
| Deep well | | | | | |
| Vertical line shaft turbine (multistage) | Impellers submerged | 15–90 m | 30–250 m | Same as shallow well turbine | Efficiency depends on operating under design head and speed; requires straight well large enough for turbine bowls and housing; lubrication and alignment of shaft critical; abrasion from sand |
| Submersible turbine (multistage) | Pump and motor submerged | 15–120 m | 15–120 m | Same as shallow well turbine; easy to frostproof installation; short pump shaft to motor | Repair to motor or pump requires pulling from well; sealing of electrical equipment from water vapor critical; abrasion from sand |
| Jet | | | | | |
| Shallow well | 4–6 m below ejector | Up to 4–6 m below ejector | 25–45 m | High capacity at low heads; simple in operation; does not have to be installed over well; no moving parts in well | Capacity reduces as lift increases; air in suction or return line will stop pumping |
| Deep well | 4–6 m below ejector | 7–35 m 60 m max. | 25–45 m | Same as shallow well jet | Same as shallow well jet |
| Rotary | | | | | |
| Shallow well (gear type) | 7 m | 7 m | 15–75 m | Positive action; discharge constant under variable heads; efficient operation | Subject to rapid wear if water contains sand or silt; wear of gears reduces efficiency |
| Deep well (helical rotary type) | Usually submerged | 15–150 m | 30–150 m | Same as shallow well/rotary; only one moving pump device in well | Same as shallow well rotary except no gear wear |

[a] Practical suction lift at sea level. Reduce lift 0.3 m for each 300 m above sea level.

*Source*: From U.S. Public Health Service, *Manual of Individual Water-Supply Systems*, Publication. 24, 1962.

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**Table 6E.31 Selection of Pump Size and Diameter of Wells**

| Anticipated Well Yield | | | Nominal Size of Pump Bowls (in.) | Optimum Well Diameter (in.) |
|---|---|---|---|---|
| In gal $min^{-1}$ | In $ft^3$ $min^{-1}$ | In $m^3$ $min^{-1}$ | | |
| Less than 100 | Less than 13 | Less than 0.38 | 4 | 6 ID |
| 75–175 | 10–23 | 0.28–0.66 | 5 | 8 ID |
| 150–400 | 20–53 | 0.57–1.52 | 6 | 10 ID |
| 350–650 | 47–87 | 1.33–2.46 | 8 | 12 ID |
| 600–900 | 80–120 | 2.27–3.41 | 10 | 14 OD |
| 850–1,300 | 113–173 | 3.22–4.93 | 12 | 16 OD |
| 1,200–1,800 | 160–240 | 4.55–6.82 | 14 | 20 OD |
| 1,600–3,000 | 213–400 | 6.06–11.37 | 16 | 24 OD |

*Note:* ID, inside diameter; OD, outside diameter.

*Source*: From Health, R.C., *Basic Ground-Water Hydrology*, U.S. Geological Survey Water-Supply Paper 2220, 1983.

**Table 6E.32 Pumping Plant Performance Standards**

| Type of Power Unit | Standard Consumption of Fuel or Energy per Water Horsepower[a] |
|---|---|
| Diesel engine | 0.091 gal $hr^{-1}$ |
| Gasoline engine | 0.116 gal $hr^{-1}$ |
| Propane engine | 0.145 gal $hr^{-1}$ |
| Natural gas | 160 $ft^3$ $hr^{-1}$ |
| Electric motor | 0.885 kw-hr $hr^{-1}$ |

[a] Based on pump efficiency of 75 percent.

*Source*: From College of Agriculture, University of Nebraska.

**Table 6E.33 Standard Fuel Requirements for Good Pumping Plants**

| Pumping Rate (in gpm) | Head (in ft) | Water Horsepower | Fuel or Energy Required | | | | |
|---|---|---|---|---|---|---|---|
| | | | Diesel (gal $hr^{-1}$) | Gasoline (gal $hr^{-1}$) | Propane (gal $hr^{-1}$) | Natural Gas (ft $hr^{-1}$) | Electricity (kwh $hr^{-1}$) |
| 500 | 100 | 13 | 1¼ | 1½ | 2 | 190 | 14 |
| | 150 | 19 | 1¾ | 2¼ | 2¾ | 280 | 21 |
| | 200 | 25 | 2¼ | 3 | 3¾ | 380 | 29 |
| 700 | 100 | 18 | 1¾ | 2 | 2¾ | 270 | 20 |
| | 150 | 27 | 2½ | 3¼ | 4 | 400 | 30 |
| | 200 | 35 | 3¼ | 4¼ | 5¼ | 530 | 40 |
| 800 | 100 | 20 | 1¾ | 2½ | 3 | 300 | 23 |
| | 150 | 30 | 2¾ | 3½ | 4½ | 450 | 34 |
| | 200 | 40 | 3¾ | 4¾ | 6 | 610 | 46 |
| 1000 | 100 | 25 | 2¼ | 3 | 3¾ | 380 | 29 |
| | 150 | 38 | 3½ | 4½ | 5¾ | 570 | 43 |
| | 200 | 50 | 4½ | 6 | 7½ | 760 | 57 |

*Note:* Based on performance standards in Table 6E.32.

*Source*: From College of Agriculture, University of Nebraska.

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**Table 6E.34 Pumping Costs in the Texas High Plains (THP) and in South/Central Texas (SCT) Per Acre-inch of Water at 100 ft Total Head from Irrigation Pumping Plant Efficiency Tests Conducted by the Texas Agricultural Extension Service**

| | | Cost ($) Per Acre-Inches per 100 ft Head | | |
|---|---|---|---|---|
| Type and Price[a] | Region[b] | Lowest | Highest | Average |
| Natural Gas | THP | 0.40 | 3.93 | 0.81 |
| @ $3.00 MCF | SCT | 0.31 | 1.96 | 0.76 |
| Electricity | THP | 0.49 | 3.10 | 1.35 |
| @ $0.07/KWH | SCT | 0.29 | 20.20 | 1.49 |
| Diesel | THP | 0.57 | 1.91 | 0.77 |
| @ $0.65/gal | SCT | 0.36 | 3.43 | 0.83 |

[a] Assumed price — actual prices varied in each region.
[b] THP (Texas High Plains) results are from more than 240 efficiency tests. SCT (South/Central Texas) results are from 240 efficiency tests.

*Source*: From Texas Agricultural Extension Service, the Texas A&M University.

**Table 6E.35 Irrigation Pumping Equipment Efficiency**

| Equipment | Attainable Efficiency (Percent) |
|---|---|
| Pumps (centrifugal, turbine) | 75–82 |
| Right-angle pump drives (gear head) | 95 |
| Automotive-type engines | 20–26 |
| Industrial engines | |
| Diesel | 25–37 |
| Natural gas | 24–27 |
| Electric motors | |
| Small | 75–85 |
| Large | 85–92 |

*Source*: From New L.L. Pumping plant efficiency and irrigation cost L-2218, Texas Agricultural Extension Service.

**Table 6E.36 Typical Values of Overall Efficiency for Representative Pumping Plants, Expressed as Percent**

| Power Source | Recommended as Acceptable | Average Values from Field Tests[a] |
|---|---|---|
| Electric | 72–77 | 45–55 |
| Diesel | 20–25 | 13–15 |
| Natural gas | 18–24 | 9–13 |
| Butane, propane | 18–24 | 9–13 |
| Gasoline | 18–23 | 9–12 |

Ranges are given because of the variation in efficiencies of both pumps and power units. The difference in efficiency for high and low compression engines used for natural gas, propane and gasoline must be considered especially. The higher value of efficiency can be used for higher compression engines.

[a] Typical average observed values reported by pump efficiency test teams.

*Source*: From New L.L. Pumping plant efficiency and irrigation cost L-2218, Texas Agricultural Extension Service.

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**Table 6E.37 Nebraska Performance Criteria for Pumping Plants. Fuel Use by New or Reconditioned Plants Should Equal or Exceed These Rates**

| Energy Source | Water Horsepower-hours[a] Per Unit of Energy | Energy Units |
|---|---|---|
| Diesel | 12.5 | gal |
| Gasoline[b] | 8.7 | gal |
| Natural gas | 66.7[c] | 1000 ft[c] |
| Electricity | 0.885[d] | Kwh |

[a] Based on 75 percent efficiency.
[b] Includes drive losses and assumes no cooling fan.
[c] Assumes natural gas content of 1000 btu $ft^{-3}$
[d] Direct connection-no drive.

*Source*: From College of Agriculture, University of Nebraska.

**Table 6E.38 Approximate Maximum Flow Rate in Different Pipe Sizes to Keep Velocity $\leq$ 5 ft $sec^{-1}$**

| Pipe Diameter | Flow Rate (gpm) |
|---|---|
| ½ | 6 |
| ¾ | 10 |
| 1 | 15 |
| 1¼ | 25 |
| 1½ | 35 |
| 2 | 50 |
| 3 | 110 |
| 4 | 200 |
| 5 | 310 |
| 6 | 440 |
| 8 | 780 |
| 10 | 1225 |
| 12 | 1760 |
| 16 | 3140 |

*Source*: From Texas Agricultural Extension Service, the Texas A&M University.

**Table 6E.39 Friction Losses in Feet of Head Per 100 ft of Pipe (for Pipes with Internal Diameters Shown)**

| Pipe Size | 4-inch | | | 6-inch | | | 8-inch | | | 10-inch | | | 12-inch | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow rate (gpm) | Steel | Alum. | PVC | Steel | Alum. | PVC | Steel | Alum. | PVC | Steel | Alum. | PVC | Steel | Alum. | PVC |
| 100 | 1.2 | 0.9 | 0.6 | — | — | — | — | — | — | — | — | | | | |
| 150 | 2.5 | 1.8 | 1.2 | 0.3 | 0.2 | 0.2 | — | — | — | — | — | — | | | |
| 200 | 4.3 | 3.0 | 2.1 | 0.6 | 0.4 | 0.3 | 0.1 | 0.1 | 0.1 | — | — | — | | | |
| 250 | 6.7 | 4.8 | 3.2 | 0.9 | 0.6 | 0.4 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | — | — | — | |
| 300 | 9.5 | 6.2 | 4.3 | 1.3 | 0.8 | 0.6 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | — | — | — | — |
| 400 | 16.0 | 10.6 | 7.2 | 2.2 | 1.5 | 1.0 | 0.5 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | — | — |
| 500 | 24.1 | 17.1 | 11.4 | 3.4 | 2.4 | 1.6 | 0.8 | 0.6 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| 750 | 51.1 | 36.3 | 24.1 | 7.1 | 5.0 | 3.4 | 1.8 | 1.3 | 0.8 | 0.6 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 |
| 1000 | 87.0 | 61.8 | 41.1 | 12.1 | 8.6 | 5.7 | 3.0 | 2.1 | 1.4 | 1.0 | 0.7 | 0.5 | 0.4 | 0.3 | 0.2 |
| 1250 | 131.4 | 93.3 | 62.1 | 18.3 | 13.0 | 8.6 | 4.5 | 3.2 | 2.1 | 1.5 | 1.1 | 0.7 | 0.6 | 0.4 | 0.3 |
| 1500 | 184.1 | 130.7 | 87.0 | 25.6 | 18.2 | 12.1 | 6.3 | 4.5 | 3.0 | 2.1 | 1.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| 1750 | 244.9 | 173.9 | 115.7 | 34.1 | 24.2 | 16.1 | 8.4 | 6.0 | 4.0 | 2.8 | 2.0 | 1.3 | 1.2 | 0.9 | 0.6 |
| 2000 | 313.4 | 222.5 | 148.1 | 43.6 | 31.0 | 20.6 | 10.8 | 7.7 | 5.1 | 3.6 | 2.6 | 1.7 | 1.5 | 1.1 | 0.7 |

*Note:* Flow rates below horizontal line for each pipe size exceed the recommended 5-feet-per-second velocity.

*Source*: From Texas Agricultural Extension Service, the Texas A&M University.

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**Table 6E.40 Friction Loss in Fittings. Friction Loss in Terms of Equivalent Length of Pipe (ft) of Same Diameter**

| | Inside Pipe Diameter (in.) | | | | | |
|---|---|---|---|---|---|---|
| **Type of Fitting** | **4** | **5** | **6** | **8** | **10** | **12** |
| 45-degree elbow | 5 | 6 | 7 | 10 | 12.5 | 15 |
| Long-sweep elbow | 7 | 9 | 11 | 14 | 17 | 20 |
| Standard elbow | 11 | 13 | 16 | 20 | 25 | 32 |
| Close return bend | 24 | 30 | 36 | 50 | 61 | 72 |
| Gate value (open) | 2 | 3 | 3.5 | 4.5 | 5.5 | 7 |
| Gate value (1/2 open) | 65 | 81 | 100 | 130 | 160 | 195 |
| Check valve | 100 | 110 | 30 | 40 | 45 | 35 |

*Source*: From Texas Agricultural Extension Service, the Texas A&M University.

**Table 6E.41 Pumping Capacities of Aermotor Windmills Shown in the Table Below are Approximate, Based on the Mill Set on the Long Stroke, Operating in a 15 to 20 Mile Per Hour Wind**

| | | | | Elevation in Feet to Which Water Can Be Raised | | | | |
|---|---|---|---|---|---|---|---|---|
| | [a]Capacity Per Hour Gallons | | | Size of Aermotor Windmill | | | | |
| **Size of Cylinder (in.)** | **6 ft** | **8–16 ft** | **6 ft** | **8 ft** | **10 ft** | **12 ft** | **14 ft** | **16 ft** |
| 1–7/8 | 125 | 180 | 120 | 175 | 260 | 390 | 560 | 920 |
| 2 | 130 | 190 | 95 | 140 | 215 | 320 | 460 | 750 |
| 2–1/4 | 180 | 260 | 77 | 112 | 170 | 250 | 360 | 590 |
| 2–1/2 | 225 | 325 | 65 | 94 | 140 | 210 | 300 | 490 |
| 2–3/4 | 265 | 385 | 56 | 80 | 120 | 180 | 260 | 425 |
| 3 | 320 | 470 | 47 | 68 | 100 | 155 | 220 | 360 |
| 3–1/2 | 440 | 640 | 35 | 50 | 76 | 115 | 160 | 265 |
| 3–3/4 | | 730 | | | 65 | 98 | 143 | 230 |
| 4 | 570 | 830 | 27 | 37 | 58 | 86 | 125 | 200 |
| 5 | 900 | 1300 | 17 | 25 | 37 | 55 | 80 | 130 |
| 6 | | 1875 | | 17 | 25 | 38 | 55 | 85 |

The short stroke increases elevation by one-third, and reduces pumping capacities by one-fourth.

[a] Approximate Capacity.

*Source*: From Aermotor company. With permission.

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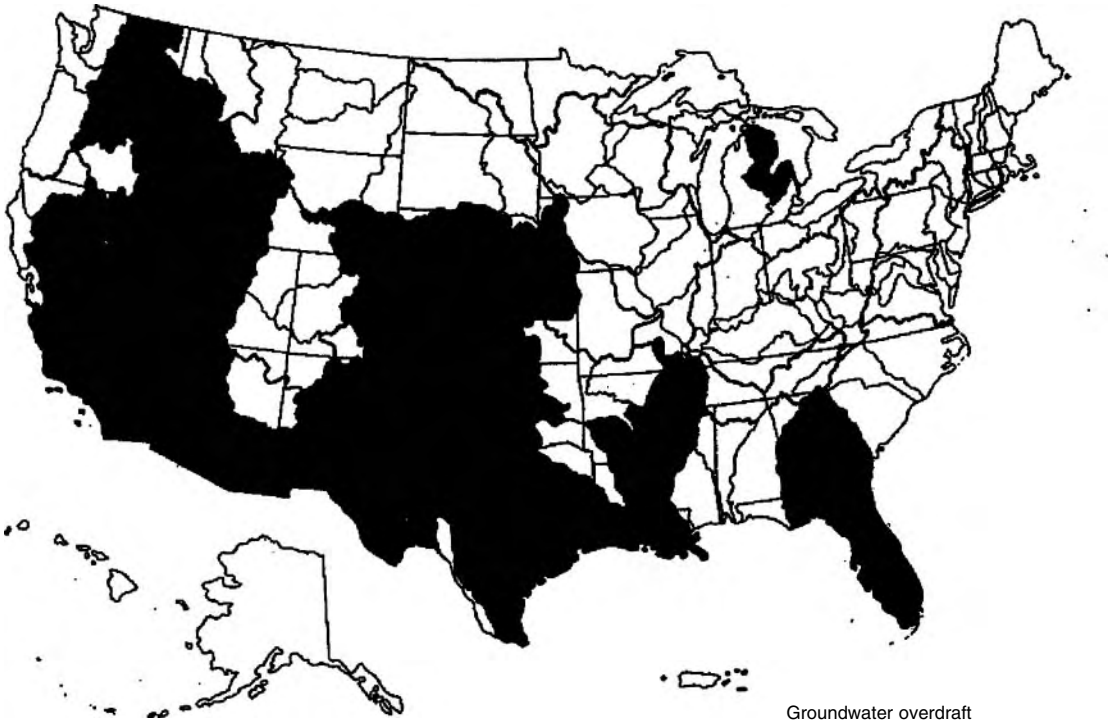


Overdraft of groundwater occurs when water is withdrawn from sources that cannot be renewed or is withdrawn more quickly than they can be recharged.
Of the 106 Water Resources Council subregions, the overdraft in 8 is considered critical–that is, more than, 500 million gallons of water are withdrawn per day; and in 30, groundwater overdraft is moderate–21 to 500 million gallons per day. Groundwater overdraft is a serious problem in the High Plains from Nebraska to Texas and in parts of Arizona and California.

**Figure 6E.15** Groundwater overdraft in the United States [Data as of 1975; by water resource subregion]. (From council on environmental quality, 1981, *Environmental trends*.)

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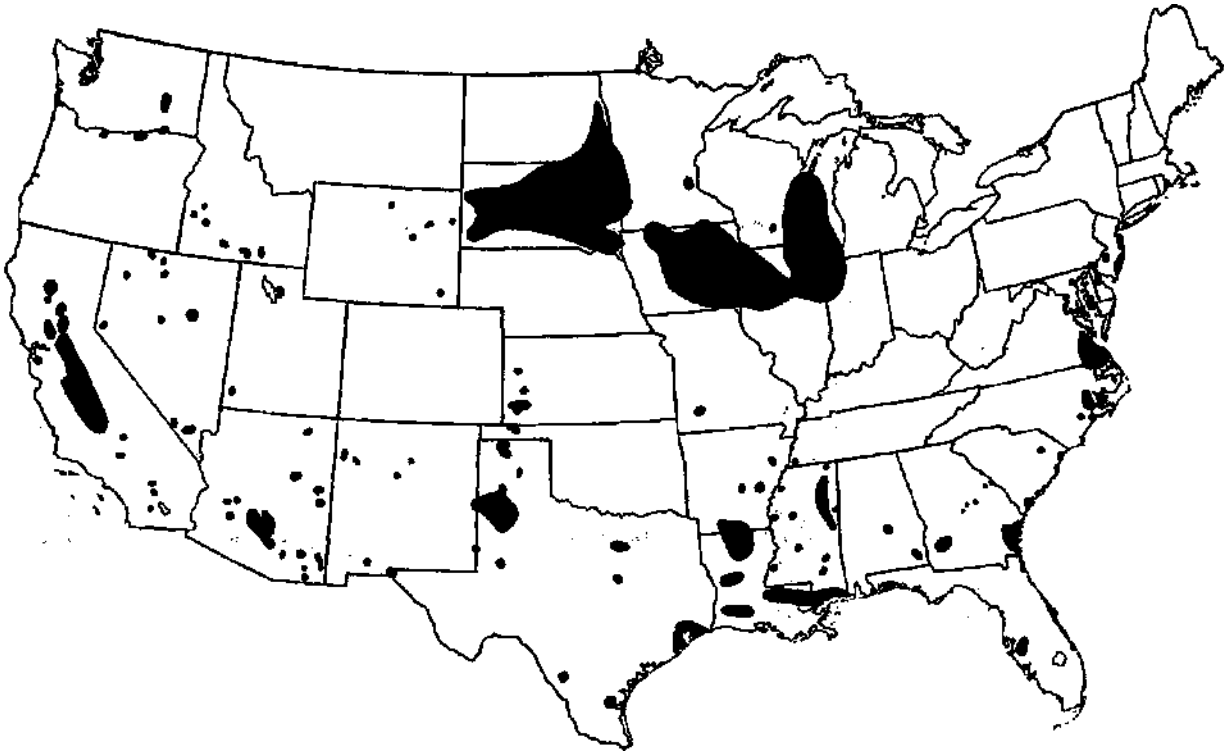

**Figure 6E.16** Areas of water-table or Artesian water-level decline in excess of 40 ft in the United States [Decline in at least one aquifer since predevelopment]. (From U.S. Geological Survey, 1984, *National Water Summary 1983—Hydrologic Events and Issues*, Water-Supply Paper 2250.)

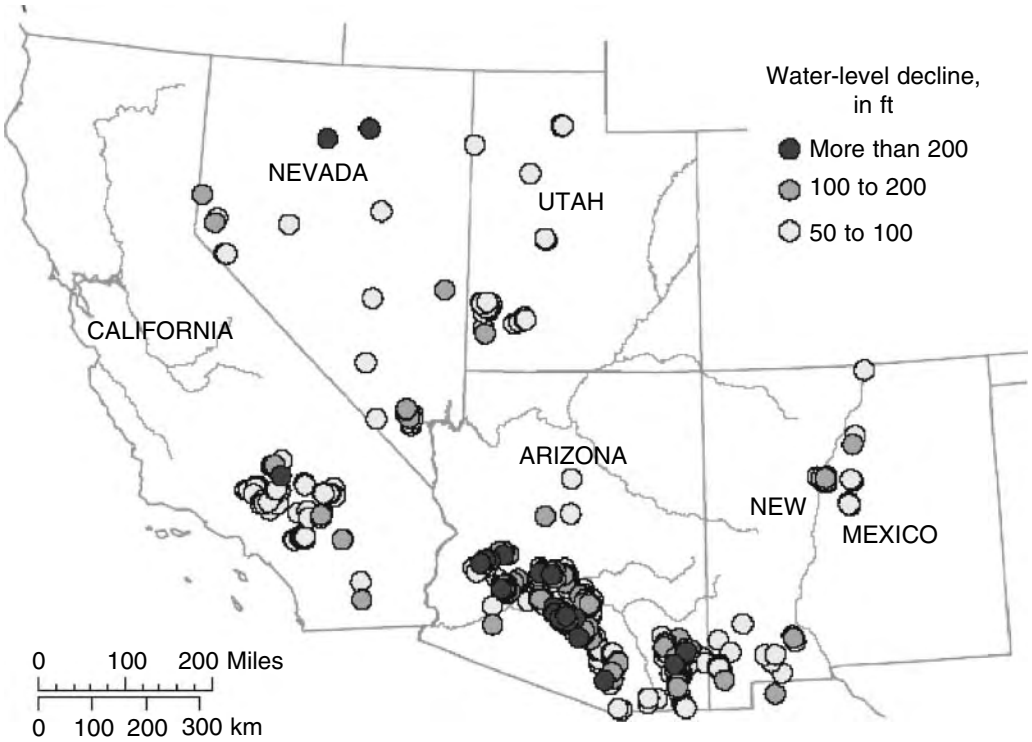


**Figure 6E.17** Locations in the basins of Southern California, Nevada, Utah, Arizona, and New Mexico where substantial groundwater level declines have been measured. (From http://water.usgs.gov.)

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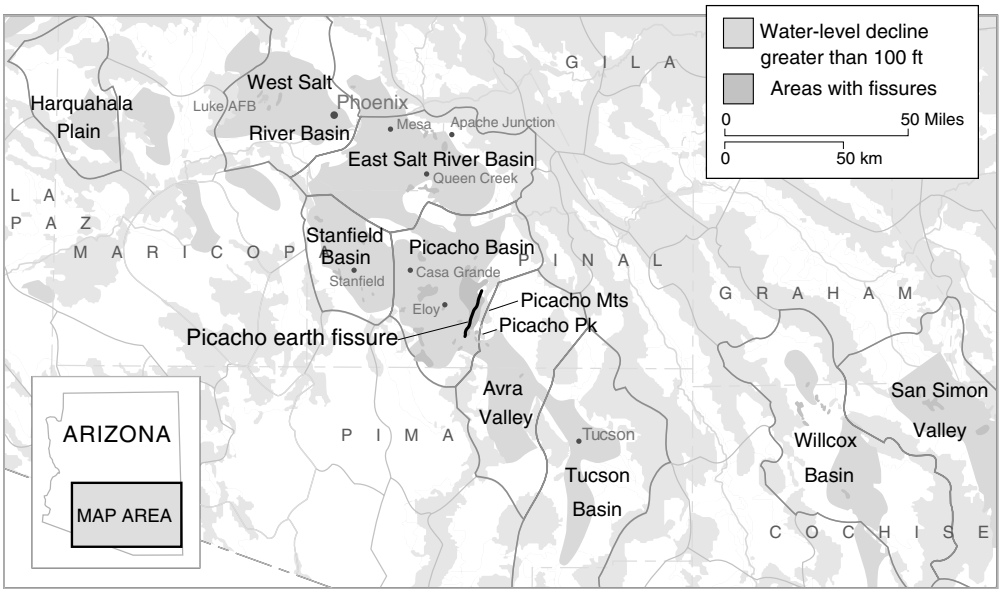


**Figure 6E.18** Water-level decline greater than 100 ft and areas with fissures in Picacho, Arizona. (From http://water.usgs.gov.)

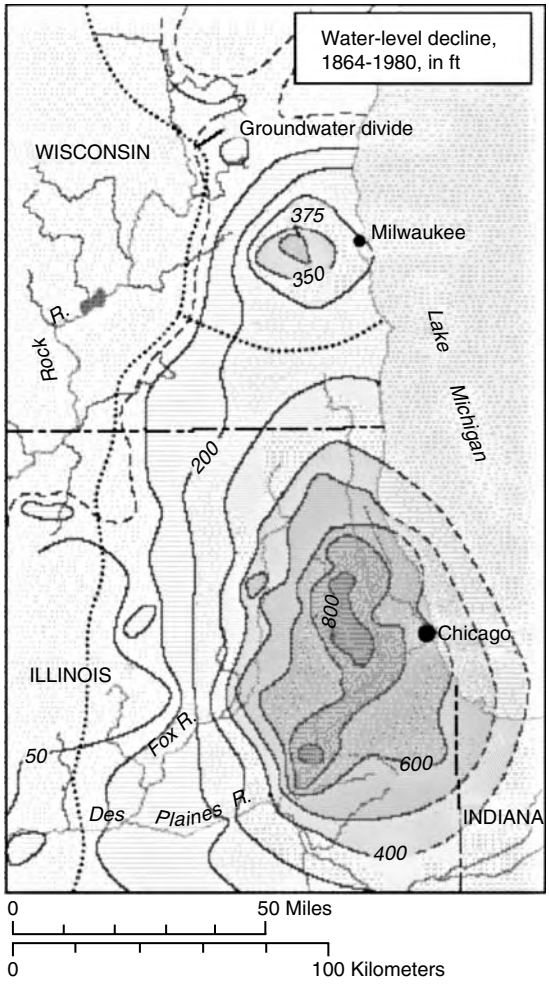


**Figure 6E.19** Chicago, Illinois water-level decline, 1864–1980, in ft. (From http://water.usgs.gov.)

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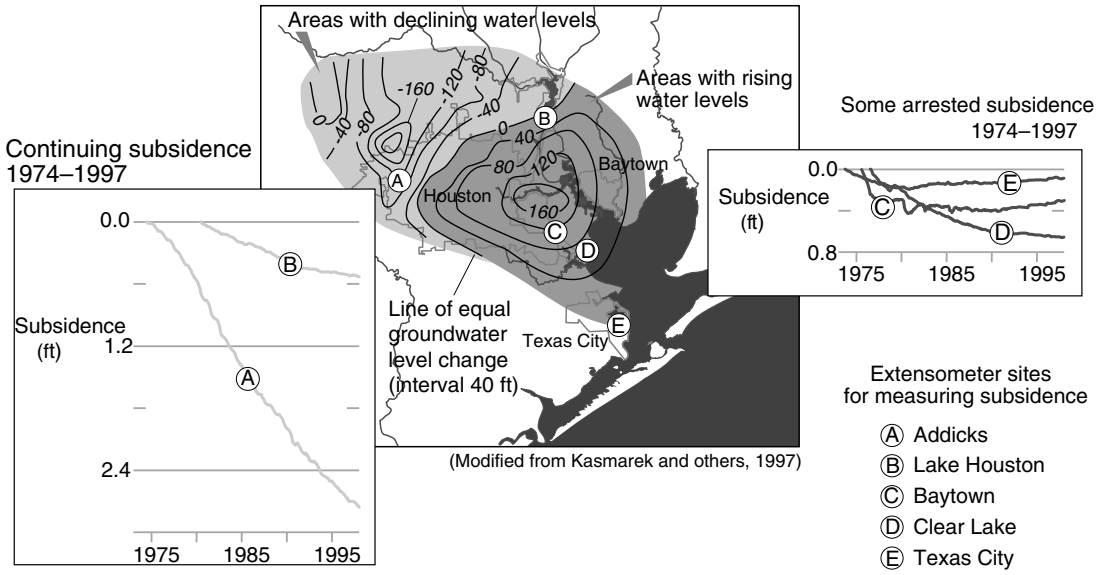


**Figure 6E.20** Change in groundwater levels in wells in the Evangeline aquifer, 1977–1997. (From http://water.usgs.gov.)

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## SECTION 6F SUBSIDENCE

**Figure 6F.21** Areas where subsidence has been attributed to the compaction of aquifer system due to groundwater pumpage (modified from Clawges and Price, 1999). (From http://water.usgs.gov.)

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**Table 6F.42 Areas of Major Land Subsidence Due to Groundwater Overdraft**

| Location | Depositional Environment and Age | Depth Range of Compacting Beds (m) | Maximum Subsidence (m) | Areas of Subsidence (sq km) | Time of Principal Occurrence |
|---|---|---|---|---|---|
| Japan | | | | | |
| Osaka | Alluvial and shallow marine; Quaternary | 10–400 | 3 | 190 | 1928–1968 |
| Tokyo | As above | 10–400 | 4 | 190 | 1920–1970+ |
| Mexico | | | | | |
| Mexico City | Alluvial and lacustrine; late Cenozoic | 10–50 | 9 | 130 | 1938–1970+ |
| Taiwan | | | | | |
| Taipei basin | Alluvial and lacustrine; Quaternary | 10–240 | 1.3 | 130 | 1961–1969+ |
| United States | | | | | |
| Arizona, central | Alluvial and lacustrine; late Cenozoic | 100–550 | 2.3 | 650 | 1948–1967 |
| California | | | | | |
| Santa Clara Valley | Alluvial and shallow marine; late Cenozoic | 55–300 | 4 | 650 | 1920–1970 |
| San Joaquin Valley (three subareas) | Alluvial and lacustrine; late Cenozoic | 60–1000 | 2.9–9 | 11,000 (>0.3 ml) | 1935–1970+ |
| Lancaster area | Alluvial and lacustrine; late Cenozoic | 60–300(?) | 1 | 400 | 1955–1967+ |
| Nevada | | | | | |
| Las Vegas | Alluvial; late Cenozoic | 60–300 | 1 | 500 | 1935–1963 |
| Texas | | | | | |
| Houston-Galveston area | Fluvial and shallow marine; late Cenozoic | 60–600(?) | 1–1.5 | 6,860 (>0.15 m) | 1943–1964+ |
| Louisiana | | | | | |
| Baton Rouge | Fluvial and shallow marine; Miocene to Holocene | 50–600(?) | 0.3 | 650 | 1934–1965+ |

*Source*: From Poland, J.F., Subsidence and its control, in underground waste management and environmental implications, *Amer Assoc. Petr. Geologists*, Memoir 18, 1972.

**Table 6F.43 Amounts of Subsidence in Selected Areas in the Southwest**

| Arizona | | Nevada | | California | | Texas | |
|---|---|---|---|---|---|---|---|
| Eloy | 15 ft | Las Vegas | 6 ft | Lancaster | 6 ft | El Paso | 1 ft |
| West of Phoenix | 18 ft | **New Mexico** | | South west of Mendota | 29 ft | Houston | 9 ft |
| Tucson | <1 ft | Albuquerque | "<" 1 ft | Davis | 4 ft | | |
| | | Mimbres Basin | 2 ft | Santa Clara Valley | 12 ft | | |
| | | | | Ventura | 2 ft | | |

*Source*: From http://geochange.er.usgs.gov.

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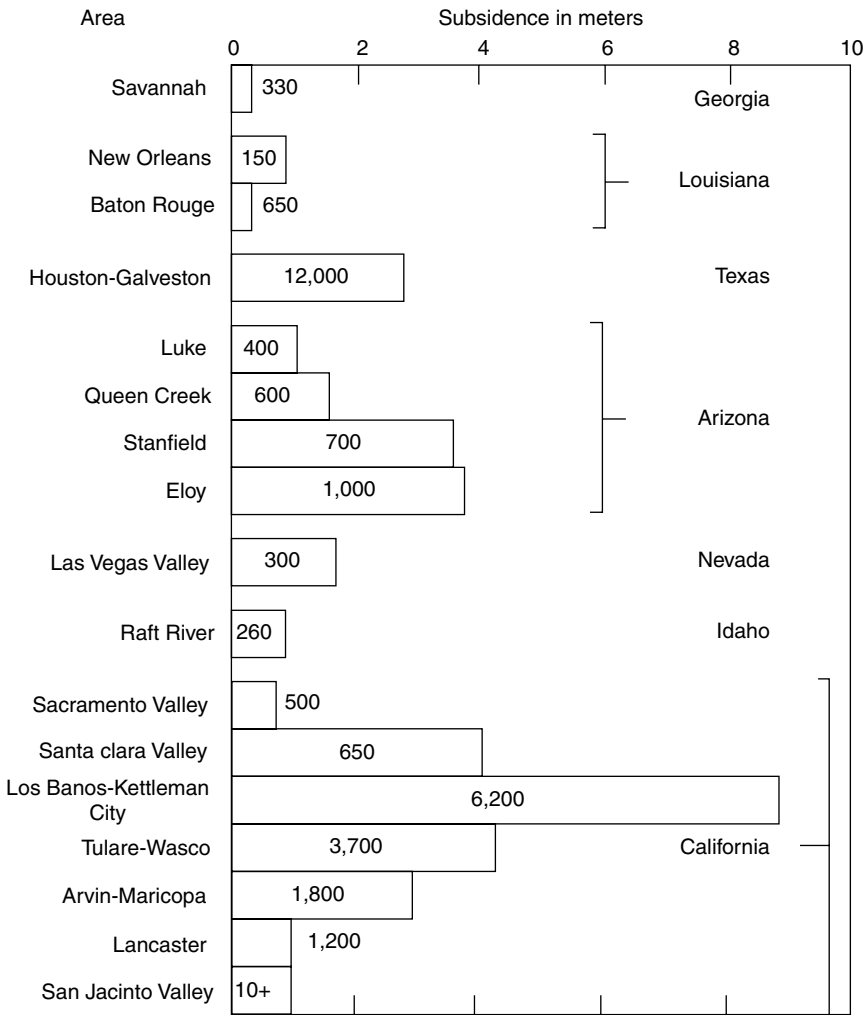


**Figure 6F.22** Magnitude of land subsidence from groundwater withdrawal in the United States [numbers in columns represent area in square kilometers]. (From Poland, J.F., *Irrigation and Drainage division ASCE*, 107,1981, IR2. Copyright American Society of Civil Engineers. Reprinted with permission.)

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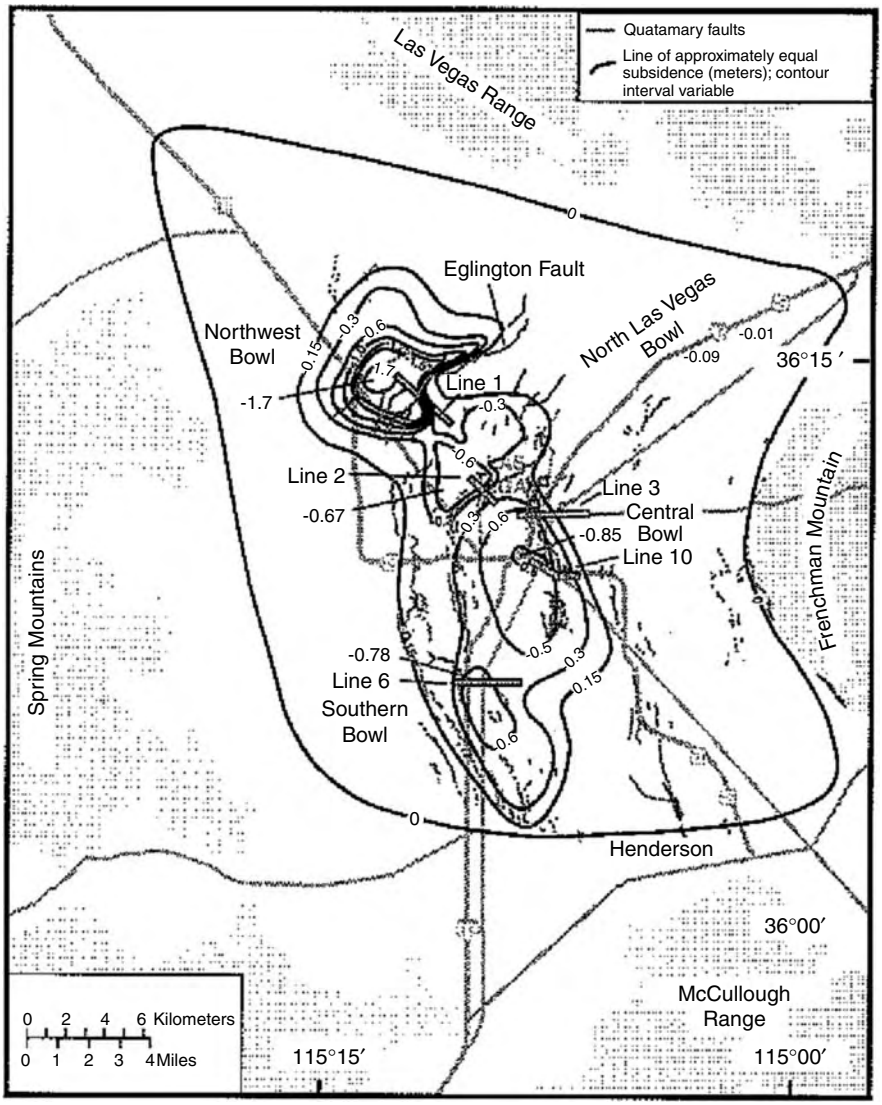


**Figure 6F.23** Revised subsidence contour map for Las Vegas Valley, 1963–2000, showing maximum subsidence measured in four localized bowls and location of level lines. (From http://water.usgs.gov.)

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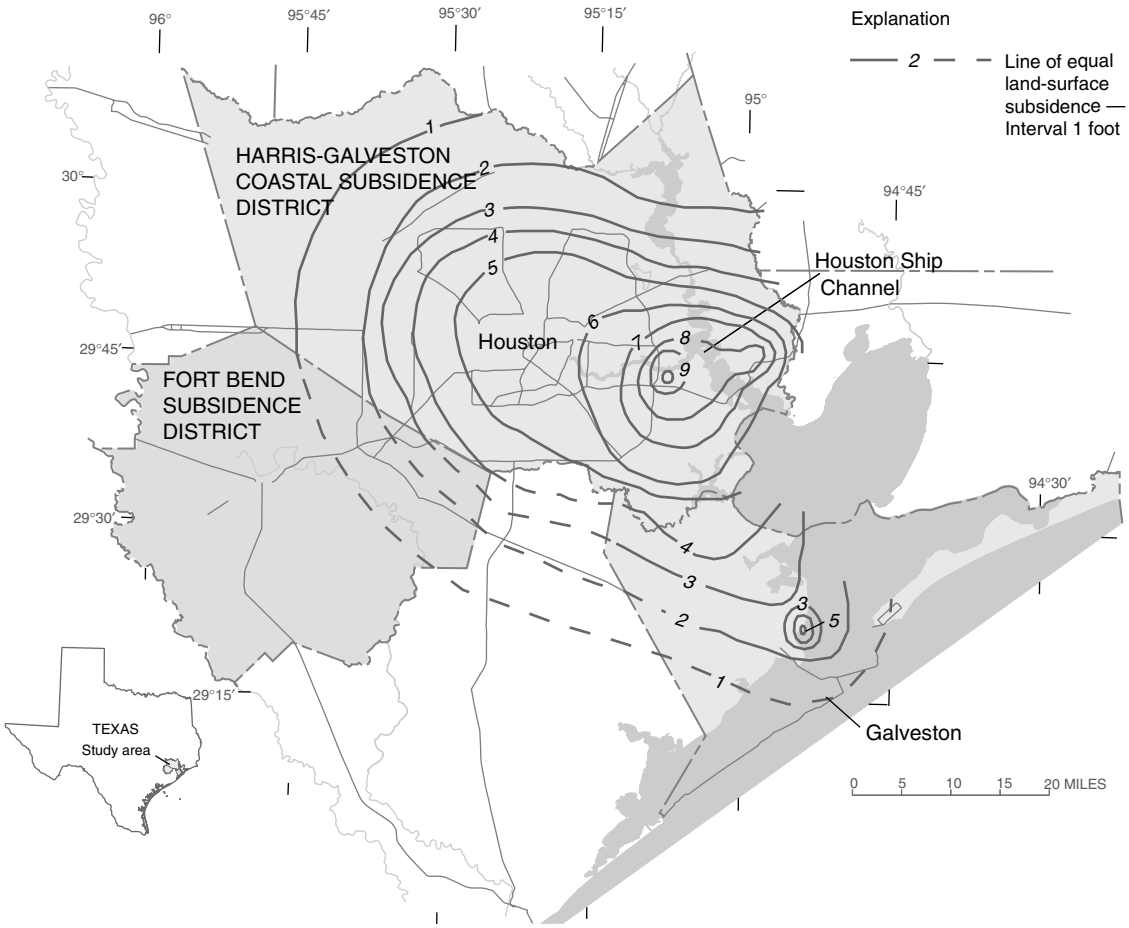


**Figure 6F.24** Subsidence occurring between 1906 and 1987 in the Houston-Galveston region, Texas. (From http://water.usgs.gov.)

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## SECTION 6G AQUIFER CHARACTERISTICS

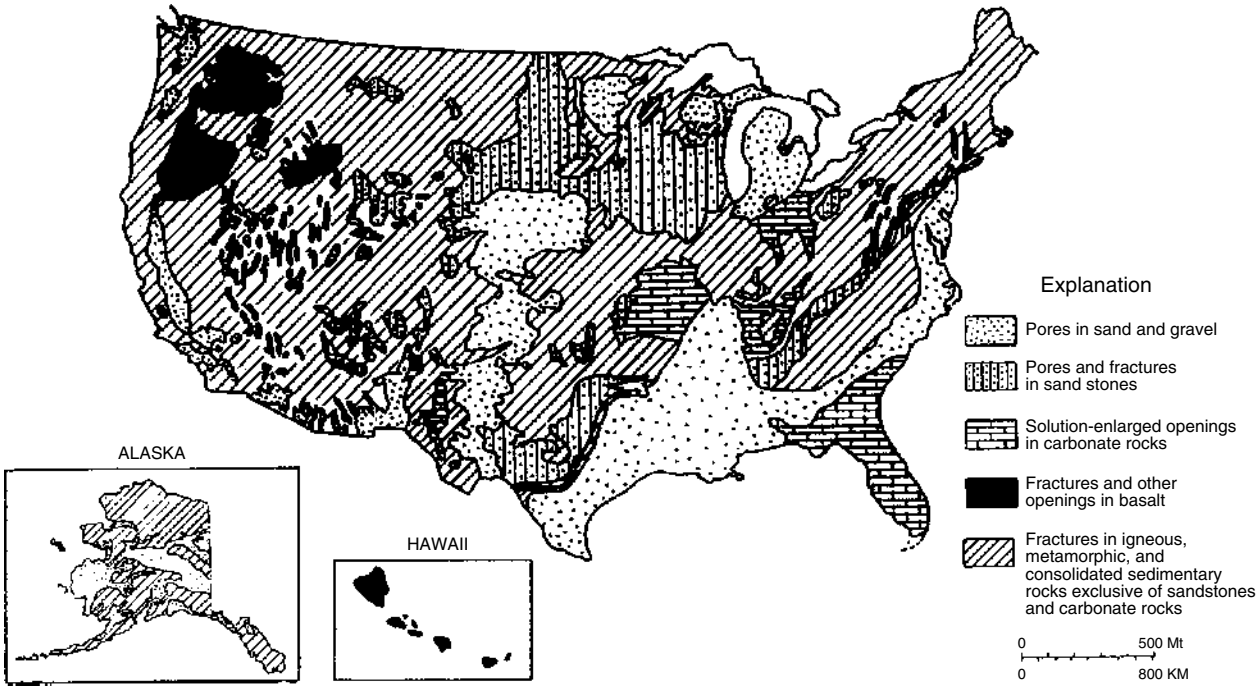


**Figure 6G.25** Types of water-bearing openings in dominant aquifers of the United States. (From Heath, R.C., Classification of groundwater regions of the United States, *Groundwater*, 20, 4, 1982, Reprinted with permission.)

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**Table 6G.44 Features of Groundwater Systems Useful in the Classification of Groundwater Regions**

| Feature | Aspect | Range in Conditions | Significance of Feature |
|---|---|---|---|
| Component of the system | Unconfined aquifer | Thin, discontinuous, hydrologically insignificant<br>Minor aquifer, serves primarily as a storage reservoir and recharge conduit for underlying aquifer<br>The dominant aquifer | Affects response of the system to pumpage and other stresses. Affects recharge and discharge conditions for the system. Determines susceptibility of the system to pollution |
| | Confining beds | Not present, or hydrologically insignificant<br>Thin, markedly discontinuous, or very leaky<br>Thick, extensive, and impermeable<br>Complexly interbedded with aquifers or productive zones | |
| | Confined aquifers | Not present, or hydrologically insignificant<br>Thin or not highly productive<br>Multiple thin aquifers interbedded with non productive zones<br>The dominant aquifer — thick and productive | |
| | Presence and arrangement of components | A single, hydrologically-dominant, unconfined aquifer<br>Two interconnected aquifers of essentially equal hydrologic importance<br>A three-unit system consisting of an unconfined aquifer, a confining bed, and a confined aquifer<br>A complexly interbedded sequence of aquifers and confining beds | |
| Water-bearing openings of dominant aquifer | Primary openings | Pores in unconsolidated deposits<br>Pores in semiconsolidated rocks<br>Pores, tubes, and cooling fractures in volcanic (extrusive-igneous) rocks | Controls water-storage and transmission characteristics. Affects dispersion and dilution of wastes |
| | Secondary openings | Fractures and faults in crystalline and consolidated sedimentary rocks<br>Solution-enlarged openings in limestones and other soluble rocks | |
| Composition of rock matrix of dominant aquifer | Insoluble | Essentially insoluble<br>Both relatively insoluble and soluble constituents | Affects water-storage and transmission characteristics. Has major influence on water quality |
| | Soluble | Relatively soluble | |
| Storage and transmission characteristics of dominant aquifer | Porosity | Large, as in well-sorted, unconsolidated deposits<br>Moderate, as in poorly-sorted unconsolidated deposits and semiconsolidated rocks<br>Small, as in fractures crystalline and consolidated sedimentary rocks | Controls response to pumpage and other stresses. Determines yield of wells. Affects long-term yield of system. Affects rate at which pollutants move |

*(Continued)*

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**Table 6G.44 (Continued)**

| Feature | Aspect | Range in Conditions | Significance of Feature |
|---|---|---|---|
| | Transmissivity | Large, as in cavernous limestones, lava flows with flow tubes, and clean gravels<br>Moderate, as in well-sorted, coarse-grained sands, and semiconsolidated limestones<br>Small, as in poorly-sorted, fine-grained deposits and fractures rocks<br>Very small, as in confining beds, which are commonly clay-rich | |
| Recharge and discharge conditions of dominant aquifer | Recharge | In upland areas between streams<br>Through channels of losing streams<br>Largely or entirely by leakage across confining beds from adjacent aquifers | Affects (a) response to stress and (b) long-term yields. Determines susceptibility to pollution. Affects water quality |
| | Discharge | Through springs or by seepage to stream channels, lakes, estuaries, or the ocean<br>By evaporation on flood plains and in basin "sinks"<br>By seepage across confining beds into adjacent aquifers | |

*Source*: From Heath, R.C., Classification of ground-water systems of the United States, *Ground-Water*, 20, 4, 1982.

**Table 6G.45 Geologic Origin of Aquifers Based on Type of Porosity and Rock Type**

| | Sedimentary | | | | Volcanic | |
|---|---|---|---|---|---|---|
| **Type of Porosity** | **Consolidated** | **Unconsolidated** | **Igneous and Metamorphic** | | **Consolidated** | **Unconsolidated** |
| Intergranular | | Gravelly sand<br>Clayey sand<br>Sandy clay | Weathered zone of granite-gneiss | | Weathered zone of basalt | Volcanic ejecta, blocks, and fragments<br>Ash |
| Intergranular and fracture | Breccia<br>Conglomerate<br>Sandstone<br>Slate | | Zoogenic limestone<br>Oolitic limestone<br>Calcareous grit | | Volcanic tuff<br>Cinder<br>Volcanic breccia<br>Pumice | |
| Fracture | | | Limestone<br>Dolomite<br>Dolomitic limestone | Granite<br>Gneiss<br>Gabbro<br>Quartzite<br>Diorite<br>Schist<br>Mica schist | Basalt<br>Andesite<br>Rhyolite | |

*Source*: From United Nations Department of Economic and Social Affairs, 1975, Ground-water storage and artificial recharge, Natural Resources, *Water Series No.2*.

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**Table 6G.46 Rocks of Greatest Importance in Groundwater Hydrology**

| Sedimentary Rocks | | | Igneous Rocks | |
|---|---|---|---|---|
| **Unconsolidated (Pores)** | **Consolidated (Pores, Fractures, and Solution Openings)** | **Metamorphic Rocks (Fractures)** | **Intrusive (Fractures)** | **Extrusive (Pores, Tubes, Rubble Zones, and Fractures)** |
| GRAVEL[a] | Conglomerate[b] | Gneiss | Granite and other coarse-grained igneous rocks | BASALT and other fine-grained igneous rocks |
| SAND | SANDSTONE | Quartzite-schist | | |
| Silt | Siltstone | Schist | | |
| *Clay*[c] | *Shale* | Slate-schist | | |
| Till | Tillite (rare) | | | |
| *Marl* | LIMESTONE-DOLOMITE | Marble | | |
| Coquina | | | | |

[a] Capitalized names indicate rocks that are major sources of large groundwater supplies.
[b] Lowercase names indicate rocks of relatively wide extent that are sources of small to moderate groundwater supplies.
[c] Italic names indicate rocks that function primarily as confining beds.

*Source*: From Heath, R.C., Ground-water, in *Perspectives on Water, Uses and Abuses*, D. Speidel, editor, Copyright Oxford University Press, 1988. Reprinted With permission.

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**Table 6G.47 Common Ranges in Hydraulic Characteristics of Groundwater Regions in the United States**

| | | | Common Ranges in Hydraulic Characteristics of the Dominant Aquifers | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Transmissivity | | Hydraulic Conductivity | | Recharge Rate | | Well Yield | |
| Region No | Region | Geologic Situation | $m^2\ day^{-1}$ | $ft^2\ day^{-1}$ | $m\ day^{-1}$ | $ft\ day^{-1}$ | $mm\ yr^{-1}$ | $in\ yr^{-1}$ | $m^3\ min^{-1}$ | $gal\ min^{-1}$ |
| 1 | Western mountain ranges | Mountains with thin soils over fractured rocks, alternating with narrow alluvial and, in part, glaciated valleys | 0.5–100 | 5–1,000 | 0.0003–15 | 0.001–50 | 3–50 | 0.1–2 | 0.04–0.4 | 10–100 |
| 2 | Alluvial basins | Thick[a] alluvial (locally glacial) deposits in basins and valleys bordered by mountains | 20–20,000 | 2,000–200,000 | 30–600 | 100–2,000 | 0.03–30 | 0.001–1 | 0.4–20 | 100–5,000 |
| 3 | Columbia lava plateau | Thick lava sequence interbedded with unconsolidated deposits and overlain by thin soils | 2,000–500,000 | 20,000–5,000,000 | 200–3000 | 500–10,000 | 5–300 | 0.2–10 | 0.4–80 | 100–20,000 |
| 4 | Colorado plateau and Wyoming basin | Thin[a] soils over fractured sedimentary rocks | 0.5–100 | 5–1,000 | 0.003–2 | 0.01–5 | 0.3–50 | 0.01–2 | 0.04–2 | 10–1,000 |
| 5 | High plains | Thick alluvial deposits over fractured sedimentary rocks | 1,000–10,000 | 10,000–100,000 | 30–300 | 100–1,000 | 5–80 | 0.2–3 | 0.4–10 | 100–3,000 |
| 6 | Nonglaciated central region | Thin regolith over fractured sedimentary rocks | 300–10,000 | 3,000–100,000 | 3–300 | 10–1,000 | 5–500 | 0.2–20 | 0.4–20 | 100–5,000 |
| 7 | Glaciated central region | Thick glacial deposits over fractured sedimentary rocks | 100–2,000 | 1,000–20,000 | 2–300 | 5–1,000 | 5–300 | 0.2–10 | 0.2–2 | 50–500 |
| 8 | Piedmont and Blue Ridge | Thick regolith over fractured crystalline and metamorphosed | 9–200 | 100–2,000 | 0.001–1 | 0.003–3 | 30–300 | 1–10 | 0.2–2 | 50–500 |
| 9 | Northeast and superior uplands | Thick glacial deposits over fractured crystalline rocks | 50–500 | 500–5,000 | 2–30 | 5–100 | 30–300 | 1–10 | 0.1–1 | 20–200 |
| 10 | Atlantic and gulf coastal plain | Complexly interbedded sands, silts and clays | 500–10,000 | 5,000–100,000 | 3–100 | 10–400 | 50–500 | 2–20 | 0.4–20 | 100–5,000 |
| 11 | Southeast coastal plain | Thick layers of sand and clay over semi-consolidated carbonate rocks | 1,000–100,000 | 10,000–1,000,000 | 30–3000 | 100–10,000 | 30–500 | 1–20 | 4–80 | 1,000–20,000 |
| 12 | Alluvial valleys | Thick and gravel deposits beneath flood-plains and terraces of streams | 200–50,000 | 2,000–50,000 | 30–2000 | 100–5,000 | 50–500 | 2–20 | 0.4–20 | 100–5,000 |
| 13 | Hawaiian islands | Lava flows segmented by dikes, interbedded with ash deposits, and partly overlain by alluvium | 10,000–100,000 | 100,000–1,000,000 | 200–3000 | 500–10,000 | 30–1,000 | 1–40 | 0.4–20 | 100–5,000 |
| 14 | Alaska | Galcial and alluvial deposits in part perennially frozen and overlying crystalline, metamorphic, and sedimentary rocks | 100–10,000 | 1,000–100,000 | 30–600 | 100–2,000 | 3–300 | 0.1–10 | 0.04–4 | 10–1,000 |

*Note:* All values rounded to one significant figure; for map of regions, see Figure 6A.3.

[a] An average thickness of about 5 m was used as the break point between thick and thin.

*Source*: From Heath, R.C., Classification of groundwater regions of the United States, *Groundwater*, 20, 4, 1982.

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**Table 6G.48 Representative Values of Porosity**

| Material | Porosity, Percent |
|---|---|
| Gravel, coarse | 28[a] |
| Gravel, medium | 32[a] |
| Gravel, fine | 34[a] |
| Sand, coarse | 39 |
| Sand, medium | 39 |
| Sand, fine | 43 |
| Silt | 46 |
| Clay | 42 |
| Sandstone, fine-grained | 33 |
| Sandstone, medium-grained | 37 |
| Limestone | 30 |
| Dolomite | 26 |
| Dune sand | 45 |
| Loess | 49 |
| Peat | 92 |
| Schist | 38 |
| Siltstone | 35 |
| Claystone | 43 |
| Shale | 6 |
| Till, predominantly silt | 34 |
| Till, predominantly sand | 31 |
| Tuff | 41 |
| Basalt | 17 |
| Gabbro, weathered | 43 |
| Granite, weathered | 45 |

[a] These values are for repacked samples; all others are undisturbed.

*Source*: From Johnson, A. I., *Specific Yield-Compilation of Specific Yields for Various Materials*, U.S. Geological Survey Water-Supply Paper 1662-D, 1967.

**Table 6G.49 Representative Values of Specific Yield**

| Material | Specific Yield, Percent |
|---|---|
| Gravel, coarse | 23 |
| Gravel, medium | 24 |
| Gravel, fine | 25 |
| Sand, coarse | 27 |
| Sand, medium | 28 |
| Sand, fine | 23 |
| Silt | 8 |
| Clay | 3 |
| Sandstone, fine-grained | 21 |
| Sandstone, medium-grained | 27 |
| Limestone | 14 |
| Dune sand | 38 |
| Loess | 18 |
| Peat | 44 |
| Schist | 26 |
| Siltstone | 12 |
| Till, predominantly silt | 6 |
| Till, predominantly sand | 16 |
| Till, predominantly gravel | 16 |
| Tuff | 21 |

*Source*: From Johnson, A.I., *Specific Yield-Compilation of Specific Yields for Various Materials*, U.S. Geological Survey Water-Supply Paper 1662-D, 1967.

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**Table 6G.50 Drillers' Terms Used in Estimating Specific Yield**

| | |
|---|---|
| **Crystalline Bedrock (fresh)** Specific yield zero | |
| Granite | Hard rock |
| Hard boulders | Graphite and rocks |
| Hard granite | Rock (if in area of known crystalline rocks) |
| **Clay and Related Materials** Specific yield 3 percent | |
| Adobe | Lava |
| Brittle clay | Loose shale |
| Caving clay | Muck |
| Cement | Mud |
| Cement ledge | Packed clay |
| Choppy clay | Poor clay |
| Clay | Shale |
| Clay, occasional rock | Shell |
| Crumbly clay | Slush |
| Cube clay | Soapstone |
| Decomposed granite | Soapstone float |
| Dirt | Soft clay |
| Good clay | Squeeze clay |
| Gumbo clay | Sticky |
| Hard clay | Sticky clay |
| Hardpan (H.P.) | Tiger clay |
| Hardpan shale | Tule mud |
| Hard shell | Variable clay |
| Joint clay | Volcanic rock |
| **Clay and Gravel, Sandy Clay, and Similar Materials** Specific yield 5 percent | |
| Cemented gravel (cobbles) | Clay and sandy clay |
| Cemented gravel and clay | Cay and silt |
| Cemented gravel, hard | Clay, cemented sand |
| Cement and rocks (cobbles) | Clay, compact loam and sand |
| Clay and gravel (rock) | Clay to coarse sand |
| Clay and boulders (cobbles) | Clay, streaks of hard packed |
| Clay, pack sand, and gravel | Sand |
| Cobbles in clay | Clay, streaks of sandy clay |
| Conglomerate | Clay, water |
| Dry gravel (below water table) | Clay with sandy pocket |
| Gravel and clay | Clay with small streaks of sand |
| Gravel (cement) | Clay with some sand |
| Gravel and sandy clay | Clay with streaks of fine sand |
| Gravel and tough shale | Clay with thin streaks of sand |
| Gravelly clay | Porphyry clay |
| Rocks in clay | Quicksandy clay |
| Rotten cement | Sand — clay |
| Rotten concrete mixture | Sand shell |
| Sandstone and float rock | Shale and sand |
| Silt and gravel | Solid clay with strata of cemented sand |
| Soil and boulders | Sticky sand clay |
| | Tight muddy sand |
| | Very fine tight muddy sand |
| Cemented sand | |
| Cemented sand and clay | Dry sandy silt |
| Clay sand | Fine sandy loam |
| Dry hard packed sand | Fine sandy silt |
| Dry and (below water table) | Ground surface |
| | Loam |
| Dry sand and dirt | Loam and clay |
| Fine muddy sand | Sandy clay loam |

*(Continued)*

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**Table 6G.50 (Continued)**

**Clay and Gravel, Sandy Clay, and Similar Materials**
Specific yield 5 percent

| | |
|---|---|
| Fine sand, streaks of clay | Sediment |
| Fine tight muddy sand | Silt |
| Hard packed sand, streaks of clay | Silty and clay |
| | Silty clay loam |
| Hard sand and clay | Silty loam |
| Hard set sand and clay | Soft loam |
| Muddy sand and clay | Soil |
| Packed sand and clay | Soil and clay |
| Packed sand and shale | Soil and mud |
| Sand and clay mix | Soil and sandy shale |
| Sand and tough shale | Surface formation |
| Sand rock | Top hardpan soil |
| Sandstone | Topsoil |
| Sandstone and lava | Topsoil and sandy silt |
| Set sand and clay | Topsoil — silt |
| Set sand, streaks of clay | |
| Cemented sandy clay | |
| Hard sandy clay (tight) | Decomposed hardpan |
| Sandy clay | Hardpan and sandstone |
| Sandy clay with small sand streaks, very fine | Hardpan and sandy clay |
| | Hardpan and sandy shale |
| Sandy shale | Hardpan and sandy stratas |
| Set sandy clay | Hard rock (alluvial) |
| Silty clay | Sandy hardpan |
| Soft sandy clay | Semi-hardpan |
| Clay and fine sand | Washboard |
| Clay and pumice streaks | |
| Ash | Hard pumice |
| Caliche | Porphyry |
| Chalk | Seepage soft clay |
| Hard lava formation | Volcanic ash |

**Fine Sand, Tight Sand, Tight Gravel, and Similar Materials**
Specific yield 10 percent

| | |
|---|---|
| Sand and clay | Sandy loam |
| Sand and clay strata (traces) | Sandy loam, sand, and clay |
| Sand and dirt | Sandy silt |
| Sand and hardpan | Sandy soil |
| Sand and hard sand | Surface and fine sand |
| Sand and lava | |
| Sand and pack sand | Cloggy sand |
| Sand and sandy clay | Coarse pack sand |
| Sand and soapstone | Compacted sand and silt |
| Sand and soil | Dead sand |
| Sand and some clay | Dirty sand |
| Sand, clay, and water | Fine pack sand |
| Sand crust | Fine quicksand with alkali streak |
| Sand-little water | Fine sand |
| Sand, mud, and water | Fine sand, loose |
| Sand (some water) | Hard pack sand |
| Sand streaks, balance clay | Hard sand |
| Sand, streaks of clay | Hard sand and streaks of sandy clay |
| Sand with cemented streaks | |
| Sand with thin streaks of clay | Hard sand rock and some water sand |
| | Hard sand, soft streaks |
| Coarse, and sandy | Loamy fine sand |
| Loose sandy clay | Medium muddy sand |
| Medium sandy | Milk sand |

*(Continued)*

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**Table 6G.50 (Continued)**

**Fine Sand, Tight Sand, Tight Gravel, and Similar Materials**
Specific yield 10 percent

Sandy
Sandy and sandy clay
Sandy clay, sand, and clay
Sandy clay — water bearing
Sandy clay with streaks of sand
Sandy formation
Sandy muck
Sandy sediment
Very sandy clay

Boulders, cemented sand
Cement, gravel, sand, and rocks
Clay and gravel, water bearing
Clay & rock, some loose rock
Clay, sand and gravel
Clay, silt, sand, and gravel
Conglomerate, gravel, and boulders
Conglomerate, sticky clay, sand and gravel
Dirty gravel
Fine gravel, hard
Gravel and hardpan strata
Gravel, cemented sand
Gravel with streaks of clay
Hard gravel
Hard sand and gravel
Packed gravel
Packed sand and gravel
Quicksand and cobbles
Rock sand and clay
Sand and gravel, cemented Streaks
Sand and silt, many gravel
Sand, clay, streaks of gravel
Sandy clay and gravel
Set gravel
Silty sand and gravel (cobbles)
Tight gravel

More of less sand
Muddy sand
Pack sand
Poor water sand
Powder sand
Pumice sand
Quicksand
Sand, mucky or dirty
Set sand
Silty sand
Sloppy sand
Sticky sand
Streaks fine and coarse sand
Surface sand and clay
Tight sand

Brittle clay and sand
Clay and sand
Clay, sand, and water
Clay with sand
Clay with sand streaks
More or less clay, hard sand and boulders
Mud and sand
Mud, sand, and water
Sand and mud with chunks of clay
Silt and fine sand
Silt and sand
Soil, sand, and clay
Topsoil and light sand
Water sand sprinkled with clay

Float rock (stone)
Laminated
Pumice
Seep water
Soft sandstone
Strong seepage

**Gravel, Sand, Sand and Gravel, and Similar Materials**
Specific yield 25 percent

Boulders
Coarse gravel
Coarse sand
Cobbles
Cobbles stones
Dry gravel (if above water table
Float rocks
Free sand
Gravel
Loose gravel
Loose sand
Rocks

Gravel and sand
Gravel sand sandrock
Medium sand
Rock and gravel
Running sand
Sand
Sand, water
Sand and boulders
Sand and cobbles
Sand and fine gravel
Sand and gravel
Sand gravel
Water gravel

*Source*: From U.S. Geological Survey.

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**Table 6G.51 Representative Values of Hydraulic Conductivity**

| Material | Hydraulic Conductivity | | Type of Measurement[a] |
|---|---|---|---|
| | ft day$^{-1}$ | m day$^{-1}$ | |
| Gravel, coarse | 490 | 150 | R |
| Gravel, medium | 890 | 270 | R |
| Gravel, fine | 1,500 | 450 | R |
| Sand, coarse | 150 | 45 | R |
| Sand, medium | 40 | 12 | R |
| Sand, fine | 8.2 | 2.5 | R |
| Silt | 0.62 | 0.08 | H |
| Clay | 0.00068 | 0.0002 | H |
| Sandstone, fine-grained | 0.66 | 0.2 | V |
| Sandstone, medium-grained | 10 | 3.1 | V |
| Limestone | 3 | 0.94 | V |
| Dolomite | 0.0033 | 0.001 | V |
| Dune sand | 66 | 20 | V |
| Loess | 0.26 | 0.08 | V |
| Peat | 19 | 5.7 | V |
| Schist | 0.66 | 0.2 | V |
| Slate | 0.00026 | 0.0008 | V |
| Till, predominantly sand | 1.6 | 0.49 | R |
| Till, predominantly gravel | 100 | 30 | R |
| Tuff | 0.66 | 0.2 | V |
| Basalt | 0.033 | 0.01 | V |
| Gabbro, weathered | 0.66 | 0.2 | V |
| Granite, weathered | 4.6 | 1.4 | V |

[a] H is horizontal hydraulic conductivity, R is repacked sample, and V is vertical hydraulic conductivity.

*Source*: From Morris, D.A. and Johnson, A.I., *U.S. Geological Survey Water-Supply Paper 1839-D*, 1967.

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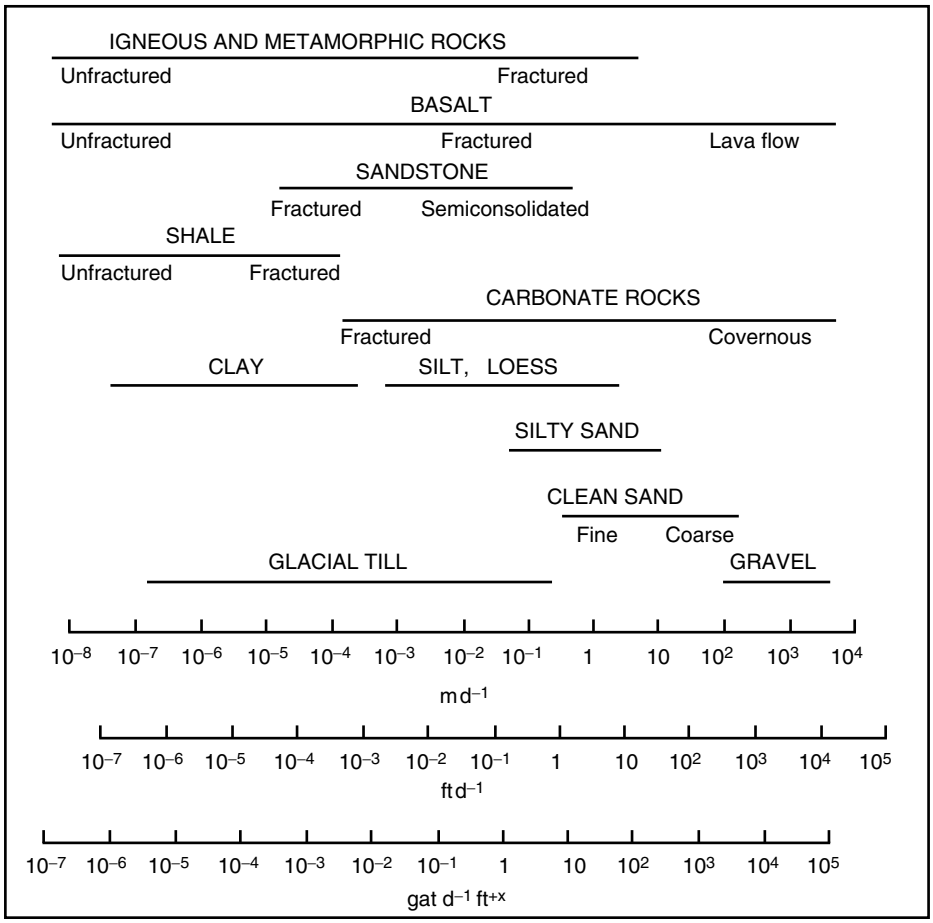


**Figure 6G.26** Hydraulic conductivity of selected consolidated and unconsolidated aquifers. (From Heath, R.C., *Basic Ground-Water Hydrology*, U.S. Geological Survey Water-Supply Paper 2220, 1983.)

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**Table 6G.52 Representative Permeability Ranges for Sedimentary Materials**

| Material | Permeability, gal day$^{-1}$ ft$^{-2}$ | Material | Permeability, gal day$^{-1}$ ft$^{-2}$ |
|---|---|---|---|
| Clay | $10^{-5}$–$10^{-3}$ | Very fine sand | 1–$10^{2}$ |
| Silty clay | $10^{-5}$–$10^{-3}$ | Fine sand | $10^{1}$–$10^{3}$ |
| Sandy clay | $10^{-4}$–$10^{-2}$ | Medium sand | $10^{2}$–$10^{3}$ |
| Silty clay loam | $10^{-3}$–$10^{-1}$ | Coarse sand | $10^{2}$–$10^{4}$ |
| Sandy clay loam | $10^{-2}$–1 | Gravel and sand | $10^{2}$–$10^{4}$ |
| Silt | $10^{-2}$–1 | Gravel | $10^{2}$–$10^{4}$ |
| Silt loam | $10^{-2}$–1 | Sandstone | $10^{1}$–$10^{3}$ |
| Loam | $10^{-2}$–1 | Limestone[a] | 1–$10^{2}$ |
| Sandy loam | $10^{-1}$–$10^{1}$ | Shale | 1–$10^{2}$ |

[a] Excluding cavernous limestone.

**Table 6G.53 Temperature Correction for Permeability**

| °F | $T_C$ | °F | $T_C$ | °F | $T_C$ | °F | $T_C$ |
|---|---|---|---|---|---|---|---|
| 40 | 1.37 | 53 | 1.11 | 66 | 0.92 | 79 | 0.78 |
| 41 | 1.35 | 54 | 1.09 | 67 | 0.91 | 80 | 0.77 |
| 42 | 1.33 | 55 | 1.08 | 68 | 0.89 | 81 | 0.76 |
| 43 | 1.31 | 56 | 1.06 | 69 | 0.88 | 82 | 0.75 |
| 44 | 1.28 | 57 | 1.04 | 70 | 0.87 | 83 | 0.74 |
| 45 | 1.26 | 58 | 1.03 | 71 | 0.86 | 84 | 0.73 |
| 46 | 1.24 | 59 | 1.01 | 72 | 0.85 | 85 | 0.72 |
| 47 | 1.22 | 60 | 1.00 | 73 | 0.84 | 86 | 0.71 |
| 48 | 1.20 | 61 | 0.99 | 74 | 0.83 | 87 | 0.70 |
| 49 | 1.18 | 62 | 0.97 | 75 | 0.82 | 88 | 0.69 |
| 50 | 1.16 | 63 | 0.96 | 76 | 0.81 | 89 | 0.68 |
| 51 | 1.15 | 64 | 0.95 | 77 | 0.80 | 90 | 0.67 |
| 52 | 1.13 | 65 | 0.93 | 78 | 0.79 | | |

*Note:* To convert coefficient of permeability computed at water temperature shown in table to coefficient of permeability at 60°F, multiply by appropriate factor Tc.

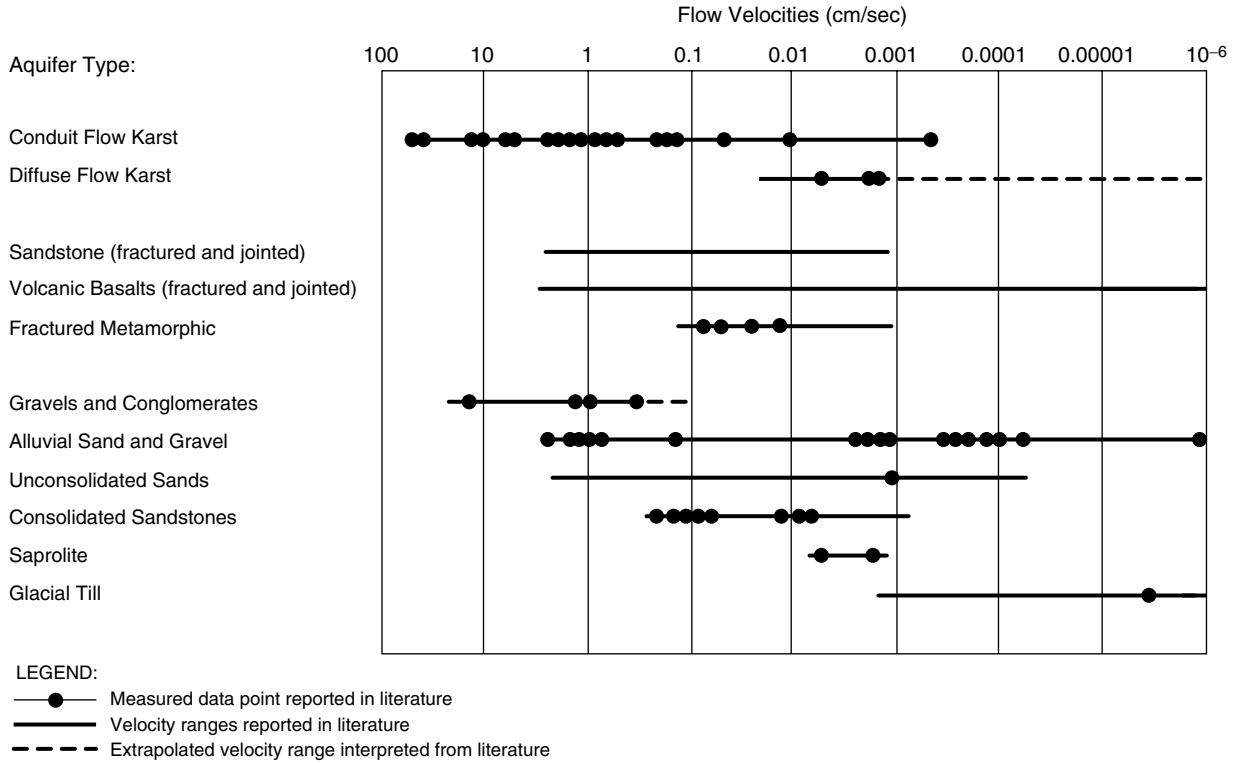


**Figure 6G.27** Groundwater flow velocity ranges. (From U.S. Environmental Protection Agency, 1987, *Guidelines for Delineation of Wellhead Protection Areas*, PB88-111430. Original Everett, A.G., 1987.)

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## SECTION 6H SOIL MOISTURE

**Table 6H.54 Guide for Judging How Much of the Available Moisture Has Been Removed from Soil**

| | Feel or Appearance of Soil and Moisture Deficiency in Inches of Water Per Feet of Soil | | | |
|---|---|---|---|---|
| **Soil Moisture Deficiency** | **Coarse Texture** | **Moderately Coarse Texture** | **Medium Texture** | **Fine and Very Fine Texture** |
| 0% (Field capacity) | Upon squeezing, no free water appears on soil but wet outline of ball is left on hand<br>0.0 | Upon squeezing, no free water appears on soil but wet outline of ball is left on hand<br>0.0 | Upon squeezing, no free water appears on soil but wet outline of ball is left on hand<br>0.0 | Upon squeezing, no free water appears on soil but wet outline of ball is left on hand<br>0.0 |
| 0–25% | Tend to stick together slightly, sometimes forms a very weak ball under pressure<br>0.0–0.2 | Forms weak ball, breaks easily, will not slick<br>0.0–0.4 | Forms a ball, is very pliable, slicks readily if relatively high in clay<br>0.0–0.5 | Easily ribbons out between fingers, has slick feeling<br>0.0–0.6 |
| 25–50% | Appears to be dry, will not form a ball with pressure<br>0.2–0.5 | Tends to ball under pressure but seldom holds together<br>0.4–0.8 | Forms a ball somewhat plastic, will sometimes slick slightly with pressure.<br>0.5–1.0 | Forms a ball, ribbons, out between thumb and forefinger<br>0.6–1.2 |
| 50–75% | Appears to be dry, will not form a ball with pressure[a]<br>0.5–0.8 | Appears to be dry, will not form a ball[a]<br>0.8–1.2 | Somewhat crumbly but holds together from pressure<br>1.0–1.5 | Somewhat pliable, will ball under pressure[a]<br>1.2–1.9 |
| 75–100% (100% is permanent wilting) | Dry, loose, single-grained, flows through fingers<br>0.8–1.0 | Dry, loose, flows through fingers<br>1.2–1.5 | Powdery, dry, sometimes slightly crusted but easily broken down into powdery condition<br>1.6–2.0 | Hard, baked, cracked, sometimes has loose crumbs on surface<br>1.9–2.5 |

[a] Ball is formed by squeezing a handful of soil very firmly.

*Source*: From Israelson and Hansen, *Irrigation Principles and Practices*, John Wiley & Sons, Copyright 1962. With permission.

**Table 6H.55 Approximate Limits of Moisture Conditions in Most Irrigation Soils**

| | | Approximate Limits, percent by Weight | |
|---|---|---|---|
| **Item** | **Soil-Moisture Condition** | **Lower** | **Upper** |
| 1 | Hygroscopic moisture content | 1– | 15 |
| 2 | Hygroscopic coefficient | 1– | 15 |
| 3 | Saturation capacity | 15 | 60 |
| 4 | Field capacity | 7 | 40 |
| 5 | Moisture equivalent | 5 | 50 |
| 6 | Permanent wilting point | | 30 |
| 7 | Ultimate wilting point | 1 | 25 |
| 8 | Moisture in wilting range | 1– | 5 |
| 9 | Available moisture capacity | 5 | 20 |
| 10 | Maximum available storage | 1[a] | 3 |
| 11 | Gravity water in saturated soils | 8 | 40 |

[a] Inches per feet of soil depth.

*Source*: From Houk, *Irrigation Engineering,* 1, John Wiley & Sons, Copyright 1951.

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**Table 6H.56 Water-Holding Characteristics of Various Soils**

| | Approximate Depth of Water Per Feet Depth of Soil in Plant Root Zone (in.) | | |
|---|---|---|---|
| **Soil Type** | **Field Capacity** | **Irrigation Desirable** | **Wilting Point** |
| Sand | 1.2 | 0.6 | 0.3 |
| Fine sand | 1.5 | 0.7 | 0.4 |
| Sandy loam | 1.9 | 1.0 | 0.6 |
| Fine sandy loam | 2.5 | 1.3 | 0.8 |
| Loam | 3.2 | 1.7 | 1.2 |
| Silt loam | 3.5 | 2.0 | 1.4 |
| Light clay loam | 3.7 | 2.2 | 1.6 |
| Clay loam | 3.8 | 2.4 | 1.8 |
| Heavy clay loam | 3.8 | 2.6 | 2.1 |
| Clay | 3.9 | 2.8 | 2.4 |

*Source*: From U.S. department of agriculture.

**Table 6H.57 Representative Physical Properties of Soils**

| | | | | | | Total Available Moisture[b] | | |
|---|---|---|---|---|---|---|---|---|
| **Soil Texture** | **Infiltration[a] and Permeability (in./hr)** | **Total Pore Space (%)** | **Apparent Specific Gravity** | **Field Capacity (%)** | **Permanent Wilting (%)** | **Dry Weight Basis (%)** | **Volume Basis (%)** | **Inches Per Foot** |
| Sandy | 2<br>(1–10) | 38<br>(32–42) | 1.65<br>(1.55–1.80) | 9<br>(6–12) | 4<br>(2–6) | 5<br>(4–6) | 8<br>(6–10) | 1.0<br>(0.8–1.2) |
| Sandy loam | 1<br>(0.5–3) | 43<br>(40–47) | 1.50<br>(1.40–1.60) | 14<br>(10–18) | 6<br>(4–8) | 8<br>(6–10) | 12<br>(9–15) | 1.4<br>(1.1–1.8) |
| Loam | 0.5<br>(0.3–0.8) | 47<br>(43–49) | 1.40<br>(1.35–1.50) | 22<br>(18–26) | 10<br>(8–12) | 12<br>(10–14) | 17<br>(14–20) | 2.0<br>(1.7–2.3) |
| Clay loam | 0.3<br>(0.1–0.6) | 49<br>(47–51) | 1.35<br>(1.30–1.40) | 27<br>(23–31) | 13<br>(11–15) | 14<br>(12–16) | 19<br>(16–22) | 2.3<br>(2.0–2.6) |
| Silty clay | 0.1<br>(0.01–0.2) | 51<br>(49–53) | 1.30<br>(1.25–1.35) | 31<br>(27–35) | 15<br>(13–17) | 16<br>(14–18) | 21<br>(18–23) | 2.5<br>(2.2–2.8) |
| Clay | 0.2<br>(0.05–0.4) | 53<br>(51–55) | 1.25<br>(1.20–1.30) | 35<br>(31–39) | 17<br>(15–19) | 18<br>(16–20) | 23<br>(20–25) | 2.7<br>(2.4–3.0) |

*Note:* Normal ranges are shown in parentheses.

[a] Intake rates vary greatly with soil structure and structural stability, even beyond the normal ranges shown above.
[b] Readily available moisture is approximately 75% of the total available moisture.

*Source*: From Israelson and Hansen, *Irrigation Principles and Practices*, John Wiley & Sons, Copyright 1962. With permission.

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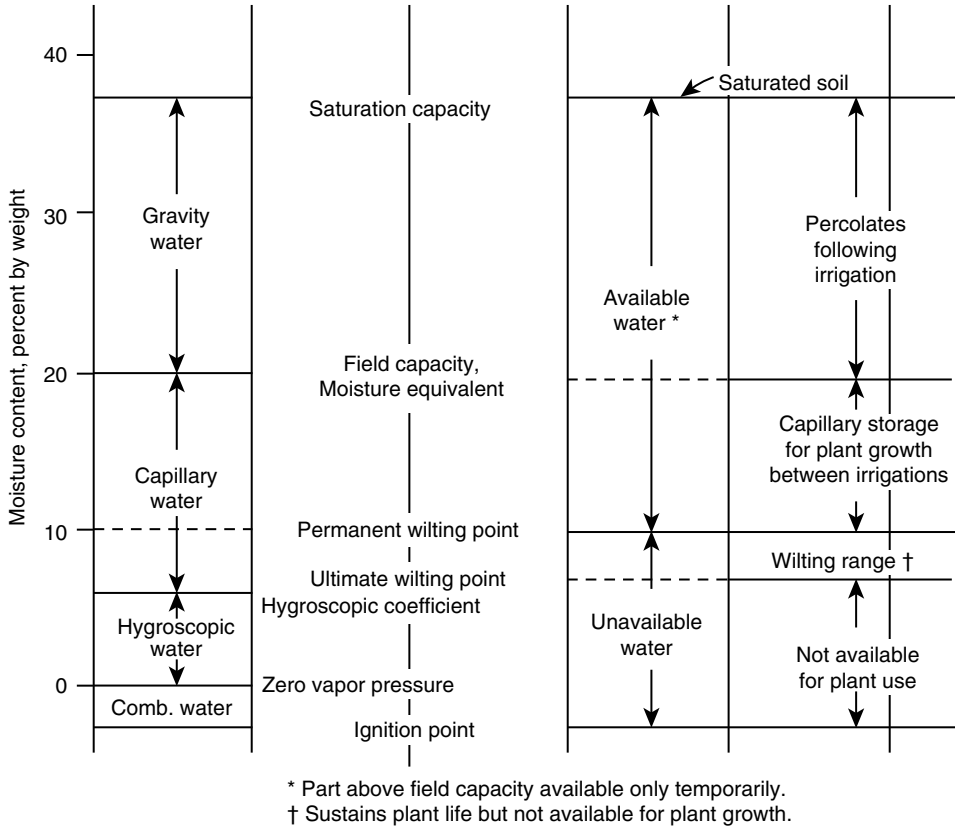


**Figure 6H.28** Soil-moisture forms and properties for an assumed fine sandy loam soil. (From Houk, *Irrigation Engineering*, 1, John Wiley & Sons, Copyright 1951. With permission.)

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# SECTION 6I SPRINGS

**Table 6I.58 Classification of Springs According to Magnitude of Discharge**

| Magnitude | Old System English Units | New System Metric Units |
|---|---|---|
| First | Greater than 100 $ft^3$ sec | $>10$ $m^3$/sec |
| Second | 10 to 100 $ft^3$ sec | 1–10 $m^3$/sec |
| Third | 1 to 10 $ft^3$ sec | 0.1–1 $m^3$/sec |
| Fourth | 100 gal/min to 1 $ft^3$/sec | 10–100 L/sec |
| Fifth | 10 to 100 gal/min | 1–10 L/sec |
| Sixth | 1 to 10 gal/min | 0.1–1 L/sec |
| Seventh | 1 pt/min to 1 gal/min | 10–100 mL/sec |
| Eighth | Less than 1 pt/min | $<10$ mL/sec |

*Source*: From U.S. Geological Survey.

**Table 6I.59 Number of First Magnitude Springs in the United States, by State**

| State | Number | Rock type | References[a] |
|---|---|---|---|
| Florida | 27 | Limestone | — |
| Idaho | 14 | Limestone and basalt | 3, 5 |
| Oregon | 15 | Balsalt | 3 |
| Missouri | 8 | Limestone | 3, 8 |
| California | 4 | Basalt | 3 |
| Hawaii | 3 | do. | 2, 6, 7 |
| Montana | 3 | Sandstone | 3, 4 |
| Texas | 2 | Limestone | 1, 3 |
| Arkansas | 1 | Basalt | 3 |

[a] References are listed at back of book. 1, Brune (1975); 2, Hirashima (1967); 3, Meinzer (1927); 4, Moore, L. Grady, U.S. Geological Survey, written commun., January 1977; 5, Ray, Herman A., U.S. Geological Survey, written commun., January 1977; 6, Stearns (1966); 7, Stearns and Macdonald (1946); 8, Vineyard and Feder (1974).

*Source*: From www.flmnh.ufl.edu.

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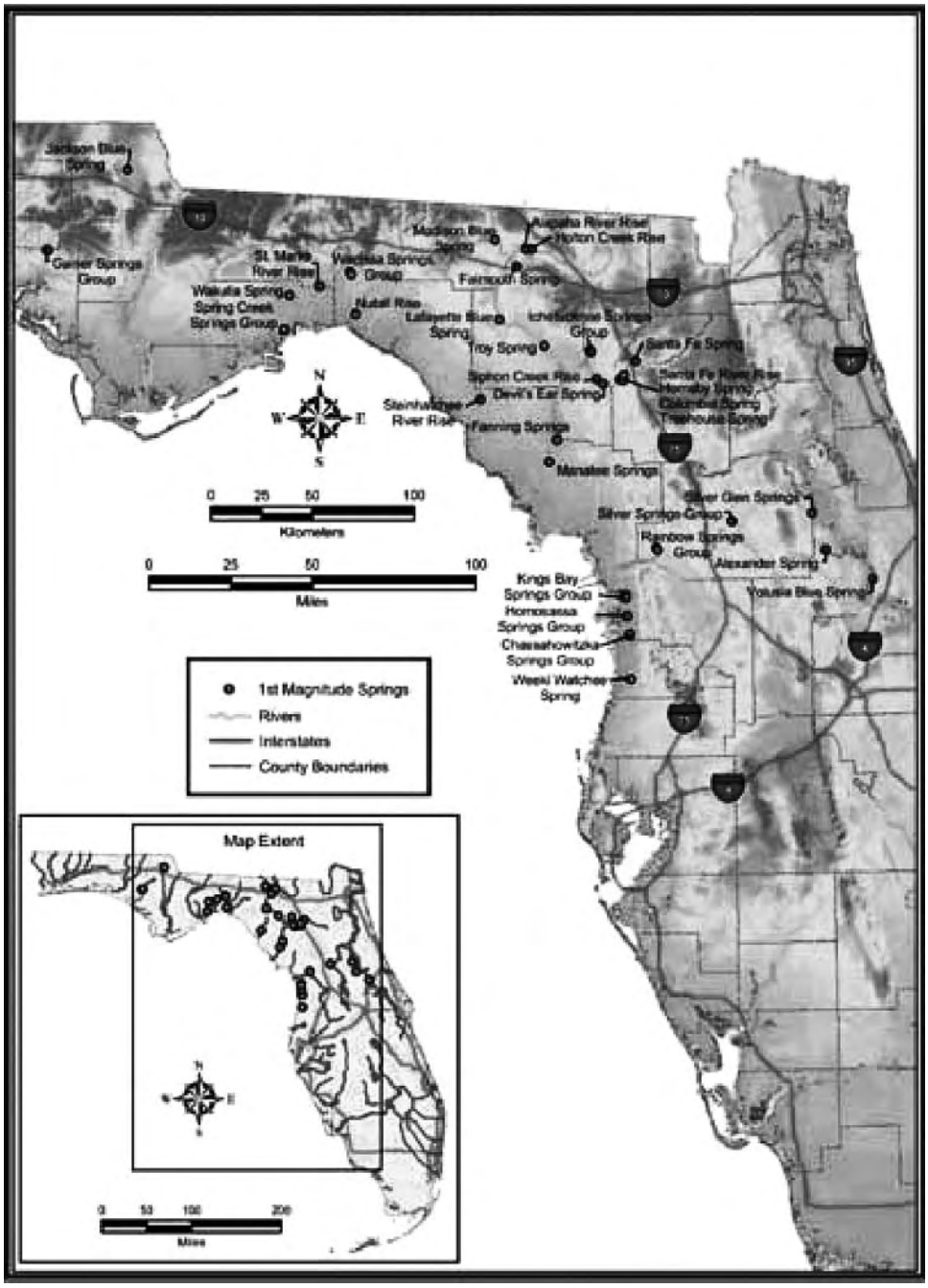


**Figure 6I.29** First magnitude springs of Florida. (From www.dep.state.fl.us.)

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**Table 6I.60 The 27 First-Magnitude Springs and Spring Groups of Florida — with Period of Record, Discharge and Representative Temperatures and Dissolved Solids — Known through December 1976**

| Spring and Number by County (Refer to Figures 11–15 and Figure 17) | Period of Record | Average ($ft^3$/sec) | Discharge Range ($ft^3$/sec) | Number of Measurements | Average Water Temperature C | Average Water Temperature F | Average Dissolved Solids (mg/L) |
|---|---|---|---|---|---|---|---|
| **Alachua County** | | | | | | | |
| 9. Hornsby Spring | 1972–1975 | 163 | 76–250 | 2 | 22.5 | 73 | 230 |
| **Bay County** | | | | | | | |
| 1. Gainer Springs | 1941–1972 | 159 | 131–185 | 7 | 22.0 | 72 | 60 |
| **Citrus County** | | | | | | | |
| 2. Chassahowitzka Springs | 1930–1972 | 139 | 32–197 | 81 | 23.5 | 74 | 740 |
| 4. Crystal River Springs | 1964–1975 | 916 | [a] | [b] | 25.0 | 75 | 144 |
| 5. Homosassa Springs | 1932–1974 | 175 | 125–257 | 90 | 23.0 | 73 | 1800 |
| **Columbia County** | | | | | | | |
| 4. Ichetucknee Springs | 1917–1974 | 361 | 241–578 | 375 | 22.5 | 73 | 170 |
| **Hamilton County** | | | | | | | |
| 3. Alapaha Rise | 1975–1976 | 608 | 508–699 | 4 | 19.0 | 66 | 130 |
| 4. Holton Spring | 1976 | 288 | 69–482 | 3 | — | — | — |
| **Hernando County** | | | | | | | |
| 19. Weeki Wachee Springs | 1917–1974 | 176 | 101–275 | 364 | 23.5 | 74 | 150 |
| **Jackson County** | | | | | | | |
| 3. Blue Springs | 1929–1973 | 190 | 56–287 | 10 | 21.0 | 70 | 116 |
| **Jefferson County** | | | | | | | |
| 1. Wacissa Springs Group | 1971–1974 | 389 | 280–605 | 20 | 20.5 | 69 | 150 |
| **Lafayette County** | | | | | | | |
| 11. Troy Spring | 1942–1973 | 156 | 148–205 | 4 | 22.0 | 72 | 171 |
| **Lake County** | | | | | | | |
| 1. Alexander Springs | 1931–1972 | 120 | 74–162 | 13 | 23.5 | 74 | 512 |
| **Leon County** | | | | | | | |
| 2. Natural Bridge Spring | 1942–1973 | 106 | 79–132 | 5 | 20.0 | 68 | 138 |
| 4. St. Marks Spring | 1956–1973 | 519 | 310–950 | 130 | 20.5 | 69 | 154 |
| **Levy County** | | | | | | | |
| 3. Fannin Springs | 1930–1973 | 103 | 64–139 | 8 | 22.0 | 72 | 194 |
| 5. Manatee Spring | 1932–1973 | 181 | 110–238 | 9 | 22.0 | 72 | 215 |
| **Madison County** | | | | | | | |
| 1. Blue Spring | 1932–1973 | 115 | 75–145 | 6 | 21.0 | 70 | 146 |
| **Marion County** | | | | | | | |
| 5. Rainbow Springs | 1898–1974 | 763 | 487–1,230 | 402 | 23.0 | 73 | 93 |
| 7. Silver Glen Springs | 1931–1972 | 112 | 90–129 | 11 | 23.0 | 73 | 1,200 |
| 8. Silver Springs | 1906–1974 | 820 | 539–1,290 | 155 | 23.0 | 73 | 245 |
| **Suwannee County** | | | | | | | |
| 8. Falmouth Spring | 1908–1973 | 158 | 60–220[c] | 8 | 21.0 | 70 | 190 |
| **Volusia County** | | | | | | | |
| 1. Blue Spring | 1932–1974 | 162 | 63–214 | 360 | 23.0 | 73 | 826 |
| **Wakulla County** | | | | | | | |
| 2. Kini Spring | 1972 | 176 | — | 1 | 20.0 | 68 | 110 |
| 5. River Sink Spring | 1942–1973 | 164 | 102–215 | 6 | 20.0 | 68 | 110 |
| 6. Wakulla Springs | 1907–1974 | 390 | 25–1,920 | 276 | 21.0 | 70 | 153 |
| 13. Spring Creek Springs[a,d] | 1972–1974 | 2,003 | [a] | 1 | 19.5 | 67 | 2,400 |

[a] Tidal affected.
[b] Continuous record, vane gage.
[c] Reverse flow of 365 $ft^3$/sec measured on 02-10-33.
[d] See Figure 11.17.

*Source*: From www.flmnh.ufl.edu.

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Twenty-three states in the United States have Thermal Springs that are included in the database. This table shows the number of Thermal Springs in each state. The first column shows the state abbreviation, the second shows the number of thermal spring in the state, and the third shows a graph of those counts. Nevada has 312 thermal springs, the largest number in any state.

| State | Number of Springs | Graph |
|---|---|---|
| AK | 108 | |
| AR | 6 | |
| AZ | 60 | |
| CA | 304 | |
| CO | 47 | |
| FL | 2 | |
| GA | 7 | |
| HI | 11 | |
| ID | 232 | |
| MA | 1 | |
| MT | 61 | |
| NC | 1 | |
| NM | 77 | |
| NV | 312 | |
| NY | 1 | |
| OR | 126 | |
| SD | 2 | |
| TX | 9 | |
| UT | 116 | |
| VA | 11 | |
| WA | 30 | |
| WV | 5 | |
| WY | 132 | |

**Figure 6I.30** Thermal springs in the United States. (From www.ngdc.noaa.gov.)

**Table 6I.61 Major Springs Reported in Other Countries**

| Spring | Country | Average Discharge ($ft^3/sec$) | Rock Type | Reference[a] |
|---|---|---|---|---|
| Ras-El-Ain | Syria | 1,370 | Limestone | 1,2 |
| Stella Spring | Italy | 1,290 | do. | 6 |
| Rio Maule Spring | Chile | 1,000 | Basalt | 2 |
| Fontaine de Vaucluse | France | 800 | Limestone | 3, 6 |
| Timaso Spring | Italy | 800 | do. | 5 |
| Komishimigawa | Japan | 700 | Basalt | 5 |
| Ain Zarka | Syria | 490 | Limestone | 5 |
| Sinn River | Syria | 430 | do. | 5 |
| El Gato | Mexico | 185 | Basalt | 4, 7 |
| Lanza | Bolivia | 135 | do. | 5 |

[a] References are listed at back of book. 1, Burdon and Safadi (1963); 2, Davis and DeWiest (1966, p. 63, 367–369); 3, Meinzer (1927, p. 91–92, 94); 4, Thomas (1975); 5, Thomas, H. E. (written commun., October 1974); 6, Vineyard and Feder (1974, p. 14); 7, Waring (1965, p. 61);

*Source*: From www.flmnh.ufl.edu.

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**Table 6I.62 Natural Heat Flows of Some Hot Spring Areas of the World**

| Area | Approximate Size[a] ($km^2$) | Maximum Recorded Temperature[b] (°C) | Total Heat Flow[c] ($10^6$ cal/sec) |
|---|---|---|---|
| **British West Indies** | | | |
| Qualibou, St. Lucia | ~0.1 | (S) 185 | 8.6 |
| St. Vincent | ~1 | (S) > 27 | 18 |
| Dominica | ~1 | (S) 90 | 17 |
| Montserrat | ~0.1 | (S) 97 | 1.6 |
| **El Salvador** | | | |
| Total of country | — | — | 200 |
| Northern belt, total | — | — | 50 |
| Southern belt, total | — | — | > 150 |
| Ahuachapán group | 80 | (D) 174 | 80 |
| El Playón de Ahuachapán | ~0.25 | (S) boiling | 0.46 |
| Agua Shuca | ~0.25 | (S) boiling | 0.32 |
| **Fiji Islands** | | | |
| Savusavu | ~1 | (S) 100 | 2 |
| **Iceland** | | | |
| Steam fields, total heat flow | — | — | 630 |
| Hengill, total | 50 | (D) 230 | 55–80 |
| Do | — | — | 25–125 |
| Hengill, southern part only | — | (D) 230 | 28 |
| Torfajökull | 100 | (S) boiling | 500 |
| Reykjanes | 1 | ? | 5–25 |
| Trölladyngja | 5 | ? | 5–25 |
| Krysuvik | 10 | (D) 230 | 5–25 |
| Kerlingafjöll | 5 | (S) boiling | 25–125 |
| Vonarskard | ? | ? | 5–125 |
| Grimsvötn | 12 | ? | 125–750 |
| Kverkfjöll | 10 | ? | 25–125 |
| Askja | 25 | ? | 5–25 |
| Námafjall | 2.5 | ? | 25–125 |
| Krafla | 0.5 | (S) boiling | 5–25 |
| Theistareykir | 2.5 | (S) boiling | 5–25 |
| Low temperature areas; about 250 areas | — | (D) 146 | 100 |
| Six lines of thermal springs, each | — | (S) 100 | 5–25 |
| Reykjavik | ~5 | (D) 146 | 1.7 |
| Reykir | ~5 | (D) 98 | 11 |
| Deilartunga line, total | — | (S) 100 | 25–125 |
| Deliartunga spring | — | (S) 100 | 24 |
| **Italy** | | | |
| (Larderello) | (~50) | ((D) 240) | (5) |
| Ischia and Flegreian Fields | ~10 | (D) 296 | ? |
| (Monta Amiata) | (~3) | ((D) 165) | (?) |
| Vulcano | ~1 | (D) 194 | ? |
| **Japan** | | | |
| Otaki, Kyushu | — | (D) 185 | ? |
| Atami, Shizuoka-ken | 5 | (D) 180 | 16 |
| Do | — | — | 22 |
| Ito, Shizuoka-ken | — | — | 44 |
| Obama, Nagasaki-ken | 1.5 | (D) 180 | 57 |
| Beppu, Oita-ken | ~10 | (D) 150 | 19 |
| Kawayu, Hokkaido | 0.7 | (S) 65 | 8 |
| Yunokawa, Hokkaido | ~1 | (S) 66 | 4.0 |
| Yachigashira, Hokkaido | ? | (S) 69 | 0.5 |
| Shikabe, Hokkaido | ~0.5 | (D) 113 | 1.2 |
| Toyako, Hokkaido | ~3 | (S) 55 | 2.2 |
| Noboribetsu, Hokkaido: | | | |
| Hot Lake area, total | ~0.2 | (D) 112 | 14 |
| Jigokudani Valley (variable) | ~0.3 | (D) 160 | ~6–11.2 |
| Matsukawa, N. Honshu | — | (D) 189 | ? |

*(Continued)*

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**Table 6I.62 (Continued)**

| Area | Approximate Size[a] ($km^2$) | Maximum Recorded Temperature[b] (°C) | Total Heat Flow[c] ($10^6$ cal/sec) |
|---|---|---|---|
| Onikobe, N. Honshu | ~80 | (D) 185 | ? |
| Narugo, N. Honshu | — | (D) 175 | ? |
| **Mexico** | | | |
| Pathé, Hidalgo | ~2 | (D) 155 | ? |
| Ixtlan, Michoacan | — | (D) 150 | ? |
| **New Zealand** | | | |
| Wairakei, 1951, 1952 | 7 | (D) 266 | 133 |
| 1954 | 7 | (D) 266 | 82 |
| 1956? | 7 | (D) 266 | 143 |
| 1958, 1959 | 7 | (D) 266 | 163 |
| 1958 | 7 | (D) 266 | 101 |
| Waiotapu | ~15 | (D) 295 | 272 |
| Orakei Korako | ~5 | (S) boiling | 130 |
| Tikitere | 5 | (S) boiling | 40 |
| Tokopia | — | — | 30 |
| Waikiti | — | (S) 91 | 20 |
| Ngatamariki | ~1 | (S) hot | 12.6 |
| Rotokaua | ~5 | (S) boiling | 52 |
| Ohaki | ~1 | (S) boiling | 12.8 |
| Taupo Spa | ~3 | (S) boiling? | 36 |
| Kawerau (Onepu) 1959? | ? | (D) 277 | 25 |
| 1962 | ? | (D) 285 | 18 |
| Rotorua | ? | (D) > 160 | — |
| **Union of South Africa** | | | |
| Seven scalding springs | ? | (S) 64 | 1.7 |
| **United States** | | | |
| California | | | |
| The Geysers | ~1 | (D) 208 | 0.4 |
| Sulphur Bank | ~2 | (D) 136 | 0.2 |
| Wilbur Springs area | ~5 | (S) 69 | 0.4 |
| Casa Diablo — Hot Creek | >25(?) | (D) 180 | 70 |
| Alkali Lakes area | — | — | — |
| (Salton Sea) | (~50) | (D) > 270 | (4) |
| Nevada | | | |
| Steamboat Springs | 5 | (D) 187 | 7 |
| Bradys Springs | ~2 | (D) 168 | ? |
| Beowawe | ~3 | (D) 207 | ? |
| Wyoming | | | |
| Yellowstone Park, Wyoming | 9,000 | — | — |
| Total, discharging water | ~70 | (S) 138 | 207 |
| Total, calculated | ~70 | (D) 205 | 500 |
| Norris Geyser Basin | ~3 | (D) 205 | 8 |
| Upper Geyser Basin | ~10 | (D) 180 | 90 |
| Mammoth-Hot River | ~8 | (S) 73 | 34 |
| **U.S.S.R.** | | | |
| Pauzhetsk, Kamchatka | ~1 | (D) 195 | 18 |
| Total | | | ~2700 |

[a] The limits of a hydrothermal area are very difficult to define and meaningful criteria are difficult to apply. Depending upon the definition, the "limits" of an area can vary by at least an order of magnitude. The definition used here is: "The rather broad boundaries containing specific areas with some surface evidence for abnormally high temperatures at depth. The evidence can consist of one or more of the following: hot springs, fumaroles, active hydrothermal alteration, and abnormally high near-surface geothermal gradient. Closely spaced 'hot spots' not separated by areas of approximately 'normal' gradient for the region are included in a single thermal area".

[b] (S) indicates temperatures measured at the surface; (D) temperatures from drill holes.

[c] Most heat flows are relative to mean annual surface temperatures but a few are relative to 0° or 4°C; such differences are small compared to the uncertainties and have not been modified. $1 \times 10^6$ cal/$cm^2$/sec approximates the "normal" heat flow from 60 to 70 $km^2$.

*Source*: From U.S. Geological Survey, 1965.

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## SECTION 6J ARTIFICIAL RECHARGE

**Table 6J.63 Artificial Recharge Projects in the United States and Other Countries**

| | | | |
|---|---|---|---|
| **United States** | | | |
| Alabama | 2 | Mississippi | 1 |
| Arizona | 3 | Missouri | 1 |
| Arkansas | 2 | Montana | 2 |
| California | 42 | Nebraska | 4 |
| Colorado | 3 | Nevada | 1 |
| Connecticut | 1 | New Jersey | 3 |
| Florida | 1 | New Mexico | 1 |
| Georgia | 2 | New York | 1 |
| Hawaii | 1 | North Carolina | 3 |
| Illinois | 1 | Ohio | 3 |
| Indiana | 2 | Oklahoma | 4 |
| Iowa | 1 | Pennsylvania | 3 |
| Kansas | 2 | South Carolina | 2 |
| Kentucky | 1 | Tennessee | 1 |
| Louisiana | 3 | Texas | 9 |
| Maine | 1 | Utah | 1 |
| Maryland | 5 | Virginia | 4 |
| Massachusetts | 3 | Washington | 4 |
| Michigan | 3 | Wisconsin | 1 |
| Minnesota | 2 | | |
| **Other Countries** | | | |
| Denmark | 1 | Morocco | 1 |
| Fed. Rep. of Germany | 10 | Namibia | 1 |
| Finland | 1 | Netherlands | 20 |
| Greece | 4 | New Zealand | 2 |
| India | 3 | Oman | 1 |
| Israel | 2 | Qatar | 1 |
| Italy | 5 | Switzerland | 1 |
| Jamaica | 1 | Thailand | 2 |
| Japan | 3 | | |

*Note:* Number of projects reported based on return of American Society of Civil Engineers' questionnaires, 1988.

*Source*: From Johnson, A.I., Personal communication, October 30, 1988.

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**Table 6J.64 Operation and Maintenance Problems of Artificial Recharge Projects**

| Problem | Manifestation | Corrective Actions to be Considered |
|---|---|---|
| Silt | Lodging of particles within interstices of soil near the surface area, reducing the infiltration rate | (1) Desilt in retention reservoir and/or in uppermost series of basins. Flocculating agent such as "Separan" has been used with success.<br>(2) Bypass water until concentration of silt will not be detrimental, with concentration depending upon soil condition. Ditches and furrows generally can accept waters containing higher concentrations of silt if sufficient velocity is maintained through the project to carry silt back to the main canal.<br>(3) Scrape, harrow, and/or disc after proper drying. Period of drying usually ranges from one to seven days depending upon soil and weather conditions.<br>(4) Remove silt after drying. Silt may be used to build up levees of basins or bridges of ditches or furrows.<br>(5) Sustain vegetative growth.<br>(6) Sluice the silt out of ditches and furrows, and from channels, with due regard to erosion problems.<br>(7) Pump injection well to loosen silt from interstices and remove silt from the well. |
| Weeds | Increases percolation rate and shortens drying period required for working an area or removing silt from the basin. There is a disadvantage in that vegetative growth may be a fire hazard | (1) Control by chemical means and/or remove when weeds become a fire hazard, especially around structures. Consider use of hand labor instead of mechanical means in order to maintain infiltration rates. However, if possible, leave vegetation undisturbed in wetted area.<br>(2) Prolonged deep submergence will kill vegetation.<br>(3) The control of weeds is generally not considered a problem in the operation of pits and shafts, or injection wells. |
| Rodents | Leaks and failures of dikes and levees. Public nuisance near urban area | (1) Set out poison about twice a year.<br>(2) Use of traps. |
| Public health and safety | Rodents and mosquito problem and possible injury to individuals. Potential problems of injury is greatest when depth of water is large in basins and pits | (1) Enclose area with fence and gates with locks.<br>(2) Patrol area with particular attention to children and structural failures, before and during oper-ation, especially near inhabited area.<br>(3) Vector control by use of mosquito fish, chemicals, and/or drying.<br>(4) Rodent control by poisoning or traps.<br>(5) Proper posting of signs when using chemical which is poisonous. |

*(Continued)*

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**Table 6J.64 (Continued)**

| Problem | Manifestation | Corrective Actions to be Considered |
|---|---|---|
| Maintaining of percolation rates | Reduction of percolation rates will decrease efficiency of system, increasing the unit cost of the amount of water actually recharged | (1) Proper treatment of water. Desilt water to concentration desired. Use chlorine or copper sulfate for control of bacterial slime and algae. Use of chemicals to reduce the possibility of chemical incrustation, which is usually deposition of calcium carbonate.<br>(2) Schedule intermittent drying periods to prevent problems due to swelling of soil particles. Permit growth of vegetation to decrease the drying period by removing the water in the root zone and loosening the soil. Studies have shown that bermuda grass has been successfully used to maintain rates, even under prolonged periods of deep submergence.<br>(3) Prevent aeration of water, especially when operating recharge wells, pits, and shafts.<br>(4) Increase head of water generally by increasing depth of water.<br>(5) Use hand labor whenever possible to decrease the possibility of using heavy equipment which will cause surface compaction especially when soil is wet.<br>(6) Scrape, harrow, and/or disc after proper drying.<br>(7) Remove silt, chemical incrustation, and/or any material decreasing infiltration rates after proper drying period.<br>(8) Maintain the design velocity to reduce silting to a minimum in use of ditches and furrows.<br>(9) Recondition injection wells by use of dry ice, hydrochloric acid, and/or sulfuric acid.<br>(10) Prevent freezing of water during winter by continuous spreading.<br>(11) Check the possibility of base exchange reactions.<br>(12) Soil can be reconditioned by using organic material such as cotton gin trash, or chemical agents, such as krilium. |
| Maintenance to diversion structures | Breakdown of spreading operations | (1) Systematic and routine maintenance check as well as patrolling when in operation. Attention should be given to wooden structures since they deteriorate faster due to frequent wetting and drying cycles. Also attention should be given to settlement of structures thus changing flow condition.<br>(2) Attention should be given to undercutting of structure particularly on the downstream end with preventive maintenance primarily in the form of riprapping.<br>(3) Sluicing of channel to remove silt and debris which have accumulated near and at diversion structure. |

*Source*: From Richter and Chun, *Proc. Am. Soc. Civil Eng.*, 1959. With permission.

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## SECTION 6K GEOPHYSICAL LOGGING

**Table 6K.65 Borehole Geophysical Logging Methods and Their Uses in Hydrologic Studies**

| Method | Uses | Recommended Conditions |
|---|---|---|
| Electric logging: Single-electrode resistance | Determining depth and thickness of thin beds. Identification of rocks, provided general lithologic information is available, and correlation of formations. Determining casing depths | Fluid-filled hole. Fresh mud required. Hole diameter less than 8 to 10 in. Log only in uncased holes |
| Short normal (electrodes spacing of 16 in.) | Picking tops of resistive beds. Determining resistivity of the invaded zone. Estimating porosity of formations (deeply invaded and thick interval). Correlation and identification, provided general lithologic information is available | Fluid-filled hole. Fresh mud. Ratio of mud resistivity to formation-water resistivity should be 0.2 to 4. Log only in uncased part of hole |
| Long normal (electrode spacing of 64 in.) | Determining true resistivity in thick beds where mud invasion is not too deep. Obtaining data for calculation of formation-water resistivity | Fluid-filled hole. Ratio of mud resistivity to formation-water resistivity should be 0.2 to 4. Log only in uncased part of hole |
| Deep lateral (electrode spacing approximately 19 ft) | Determining true resistivity where mud invasion is relatively deep. Locating thin beds | Fluid-filled uncased hole. Fresh mud. Formations should be of thickness different from electrode spacing and should be free of thin limestone beds |
| Limestone sonde (electrode spacing of 32 in.) | Detecting permeable zones and determining porosity in hard rock. Determining formation factor *in situ* | Fluid-filled uncased hole. May be salty mud. Uniform hole size. Beds thicker than 5 ft |
| Laterolog | Investigating true resistivity of thin beds. Used in hard formations drilled with very salty muds. Correlation of formations, especially in hard-rock regions | Fluid-filled uncased hole. Salty mud satisfactory. Mud invasion not too deep |
| Microlog | Determining permeable beds in hard or well-consolidated formations. Detailing beds in moderately consolidated formations. Correlation in hard-rock country. Determining formation factor in situ in soft or moderately consolidated formations. Detailing very thin beds | Fluid required in hole. Log only in uncased part of hole. Bit-size hole (caved sections may be logged, provided hole enlargements are not too great) |
| Microlaterolog | Determining detailed resistivity of flushed formation at wall of hole when mudcake thickness is less than three-eighths inch in all formations. Determining formation factor and porosity. Correlation of very thin beds | Fluid-filled uncased hole. Thin mud cake. Salty mud permitted |
| Spontaneous potential | Helps delineate boundaries of many formations and the nature of these formations. Indicating approximate chemical quality of water. Indicate zones of water entry in borehole. Locating cased interval. Detecting and correlating permeable beds | Fluid-filled uncased hole. Fresh mud |

*(Continued)*

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**Table 6K.65 (Continued)**

| Method | Uses | Recommended Conditions |
|---|---|---|
| Radiation logging: Gamma Ray | Differentiating shale, clay, and marl from other formations. Correlations of formations. Measurement of inherent radioactivity in formations. Checking formation depths and thicknesses with reference to casing collars before perforating casing. For shale differentiation when holes contain very salty mud. Radioactive tracer studies. Logging dry or cased holes. Locating cemented and cased intervals. Logging in oil-base muds. Locating radioactive ores. In combination with electric logs for locating coal or lignite beds | Fluid-filled or dry cased or uncased hole. Should have appreciable contrast in radioactivity between adjacent formations |
| Neutron | Delineating formations and correlation in dry or cased holes. Qualitative determination of shales, tight formations, and porous sections in cased wells. Determining porosity and water content of formations, especially those of low porosity. Distinguishing between water- or oil-filled and gas-filled reservoirs. Combining with gamma-ray log for better identification of lithology and correlation of formations. Indicating cased intervals. Logging in oil-base muds | Fluid-filled or dry cased or uncased hole. Formations relatively free from shaly material. Diameter less than 6 inches for dry holes. Hole diameter similar throughout |
| Induction logging | Determining true resistivity, particularly for thin beds (down to about 2 feet thick) in wells drilled with comparatively fresh mud. Determining resistivity of formations in dry holes. Logging in oil-base muds. Defining lithology and bed boundaries in hard formations. Detection of water-bearing beds | Fluid-filled or dry uncased hole. Fluid should not be too salty |
| Sonic logging | Logging acoustic velocity for seismic interpretation. Correlation and identification of lithology. Reliable indication of porosity in moderate to hard formations; in soft formations of high porosity it is more responsive to the nature rather than quantity of fluid contained in pores | Not affected materially by type of fluid, hole size, or mud invasion |
| Temperature logging | Locating approximate position of cement behind casing. Determining thermal gradient. Locating depth of lost circulation. Locating active gas flow. Used in checking depths and thickness of aquifers. Locating fissures and solution openings in open holes and leaks or perforated sections in cased holes. Reciprocal-gradient temperature log may be more useful in correlation work | Cased or uncased hole. Can be used in empty hole if logged at very slow speed, but fluid preferred in hole. Fluid should be undisturbed (no circulation) for 6 to 12 hr minimum before logging; possibly several days may be required to reach thermal equilibrium |
| Fluid-conductivity logging | Locating point of entry of different quality water through leaks or perforations in casing or opening in rock hole. (Usually resistivity is determined and must be converted to conductivity.) Determining quality of fluid in hole for improved interpretation of electric logs. Determining fresh-water-salt-water interface | Fluid required in cased or uncased hole. Temperature log required for quantitative information |

*(Continued)*

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**Table 6K.65 (Continued)**

| Method | Uses | Recommended Conditions |
|---|---|---|
| Fluid-velocity logging | Locating zones of water entry into hole. Determining relative quantities of water flow into or out of these zones. Determine direction of flow up or down in sections of hole. Locating leaks in casing. Determine approximate permeability of lithologic sections penetrated by hole, or perforated section of casing | Fluid-filled cased or uncased hole. Injection pumping, flowing, or static (at surface) conditions. Flange or packer units required in large diameter holes. Caliper (section gage) logs required for quantitative interpretation |
| Casing-collar locator | Locating position of casing collars and shoes for depth control during perforating. Determining accurate depth references for use with other types of logs | Cased hole |
| Caliper (section gage) survey | Determining hole or casing diameter. Indicates lithologic character of formations and coherency of rocks penetrated. Locating fractures, solution opening, and other cavities. Correlation of formations. Selection of zone to set a packer. Useful in quantitative interpretation of electric, temperature, and radiation logs. Used with fluid-velocity logs to determine quantities of flow. Determining diameter of underreamed section before placement of gravel pack. Determining diameter of hole for use in computing volume of cement to seal annular space. Evaluating the efficiency of explosive development of rock wells. Determining construction information on abandoned wells | Fluid-filled or dry cased or uncased hole. (In cased holes does not give information on beds behind casing.) |
| Dipmeter survey | Determining dip angle and dip direction (from magnetic north) in relation to well axis in the study of geologic structure. Correlation of formations | Fluid-filled uncased hole. Carefully picked zones needing survey, because of expense and time required. Directional survey required for determination of true dip and strike (generally obtained simultaneously with dipmeter curves) |
| Directional (inclinometer) survey | Locating points in a hole to determine deviation from the vertical. Determining true depth. Determining possible mechanical difficulty for casing installation or pump operation. Determining true dip and strike from dipmeter survey | Fluid-filled or dry uncased hole |
| Magnetic logging | Determining magnetic field intensity in borehole and magnetic susceptibility of rocks surrounding hole. Studying lithology and correlation, especially in igneous rocks | Fluid-filled or dry uncased hole |

*Source*: From U.S. Geological Survey, 1968.

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**Table 6K.66 Geophysical Logging Quick Reference Guide**

**Most Digital Logging Tools from Wherever Include a Gamma Ray Detector for Correlation between Logging Runs**

| Tool Size | Min/Max Hole Size | TYPE OF LOG | Digital | Analog | PROPERTIES MEASURED |
|---|---|---|---|---|---|
| (D = Digital) (A = Analog) (O = Open Hole) (C = Cased Hole) (S = Steel) (P = Plastic) Diameter (in.) | | RESISTIVITY / CONDUCTIVITY | | | |
| D1.7<br>A2.25 | D 2.0/240 (D)<br>A 3.0/36.0 (D) | **ELECTRIC LOG** | X | X | Determination of water quality<br>Bed boundary positions<br>Lithology information<br>Indication of permeable zones are porosity |
| D1.5<br>A3.0 | D 2.0/36.0 (O)<br>A 5.0/36.0 (O) | **GUARD LOG** | X | X | Lithology correlation between boreholes<br>Determination of formation water quality<br>Indications of fractures and permeable zones<br>Bed boundary and thickness measurements<br>Thin bed resolution |
| D1.7 | D 2.0/24 (O) (C, P) | **DUAL INDUCTION LOG**<br>*Includes New Features* | X | | Conductivity measurements<br>Indications of permeable zones and porosity<br>Determination of formation water quality<br>Long term well monitoring<br>Lithology measurements in 2 in. diameter PVC boreholes<br>Magnetic susceptibility (qualitative only) |
| D2.28 | D 2.0/28.7 (O) | **MICRO-RESISTIVITY LOG**<br>*New Logging Tool* | X | | High precision bed boundary and thickness determination<br>Invasion profile information<br>Extreme thin bed resolution in environmental wells<br>Porosity values when combined with deep resistivity readings<br>Flushed zone resistivity |
| D1.7 | D 3.0/24 (O) | **INDUCED POLARIZATION LOG**<br>*New Logging Tool* | X | | Indicator of mineralization<br>Qualitative permeability studies<br>Lithology information |
| | | **RADIOACTIVITY** | | | |
| Various | Various All | **NATURAL GAMMA RAY** | X | X | Correlation between boreholes<br>Lithology information<br>Bed thickness<br>Clay/Shale content |
| D2.36 | D 3.0/11.8 All | **SPECTRAL GAMMA RAY** | X | | Lithology determination<br>Mineral detection<br>Sedimentology<br>Improved clay content computation<br>Correlation |
| A1.7 | A 2.0/24 All | **NEUTRON** | | X | Lithology identification<br>Porosity/Hydrogen index indicator |
| Various | A 1.5/24 All | **DENSITY (GAMMA/GAMMA)** | | X | Bulk density calculation<br>Lithology identification<br>Correlation |
| | | **HOLE SIZE** | | | |
| D1.5<br>D2.36<br>A1.25<br>A2.125 | D 20/50.0 All<br>D 25/50.0 All<br>A 1.5/50 All<br>A 2.5/50 All | **3 ARM CALIPER LOG** | X | X | Average borehole diameter<br>Borehole volume<br>Identification of hard and soft formations<br>Correction of other logs affected by borehole diameter |
| D2.4 | D 3.0/27.5 All | **BOREHOLE GEOMETRY LOG**<br>*New Logging Tool* | X | | Borehole diameter in two orthogonal directions<br>Borehole break out for stress analysis<br>More accurate borehole volume calculation<br>Borehole verticality (from magnetic deviation section) |

*Source*: From www.welenco.com.

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CHAPTER 7

# Water Use

**Katherine L. Thalman**

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## SECTION 7A WATER USE — UNITED STATES

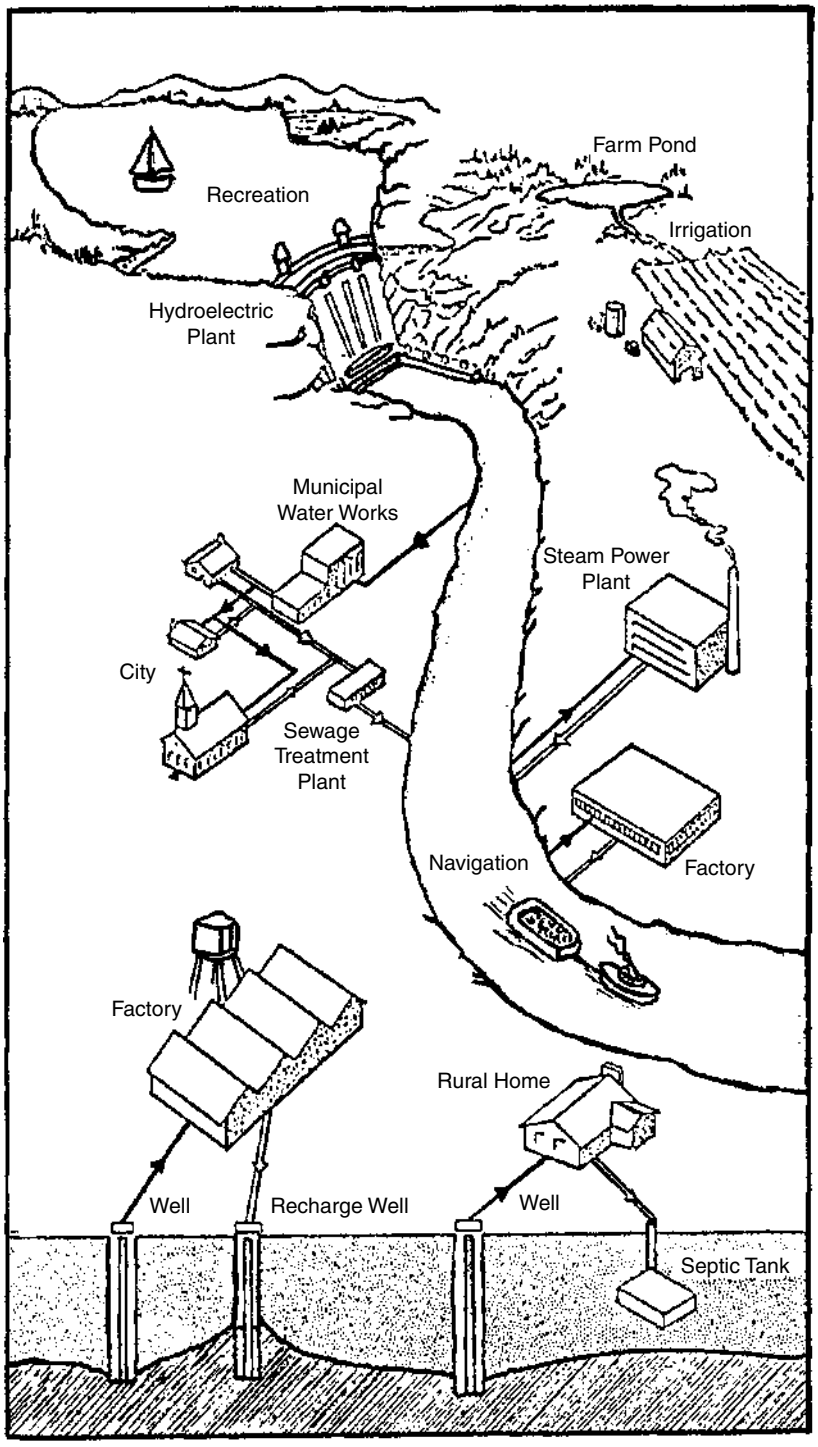


**Figure 7A.1** The many uses of water. (From Laas and Beicos, *The Water in Your Life*, Popular Library In 2nd Edition, 1967.)

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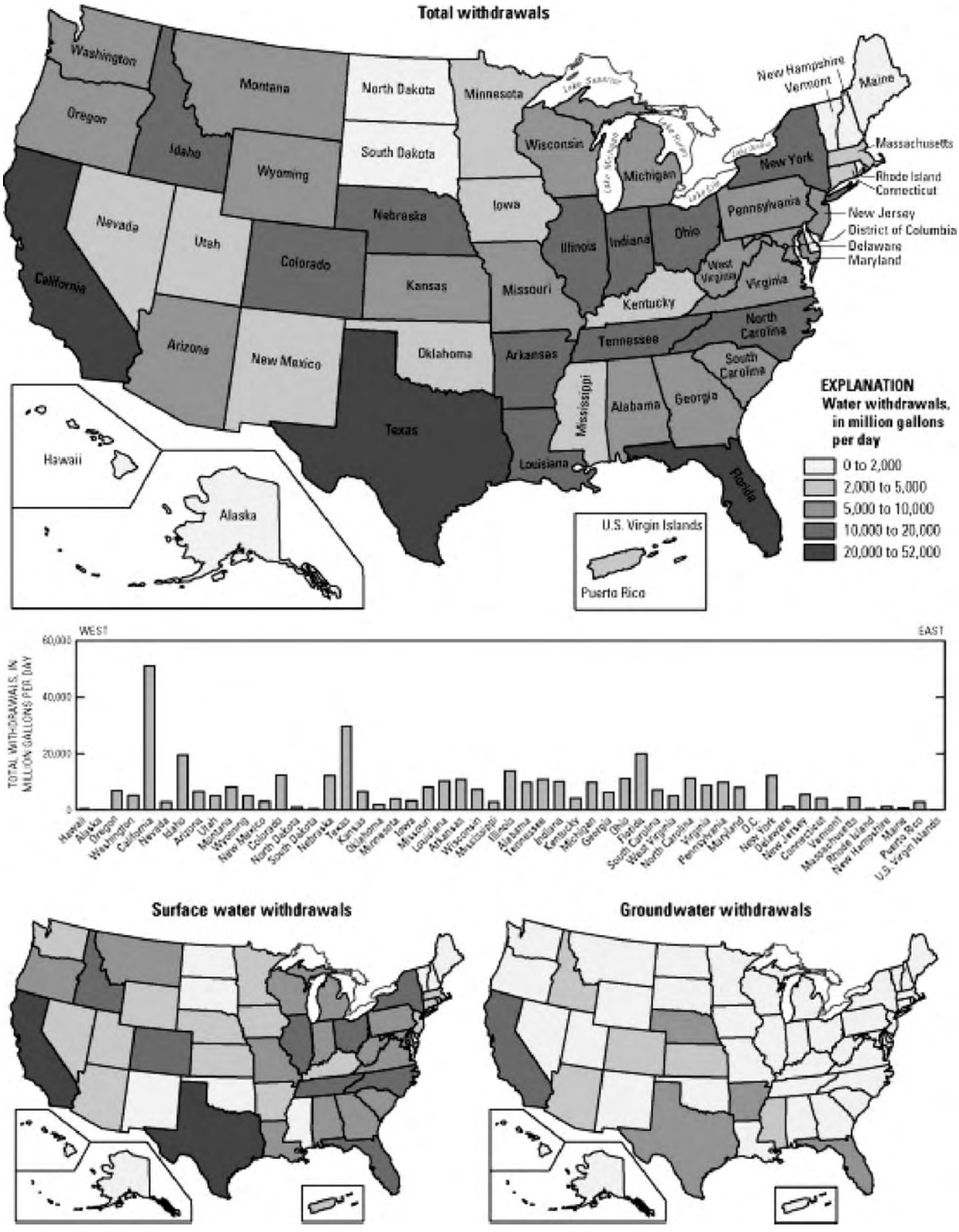


**Figure 7A.2** Total water withdrawals for all off-stream water-use categories in the United States, 2000. (From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov/pubs/circ/2004/circ1268.)

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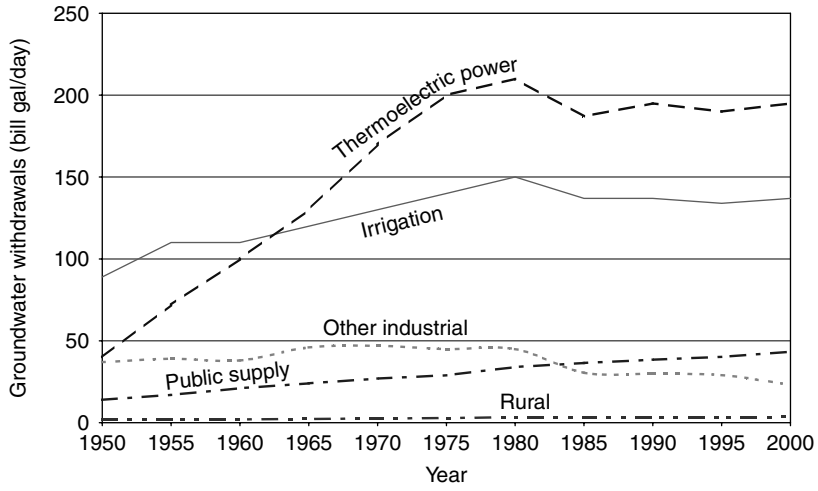


*Note:* The 2000 data for rural domestic and livestock and other industrial are partial totals.

**Figure 7A.3** Total water withdrawal for public supply, rural, irrigation, thermoelectric power, and other industries in the United States, 1950–2000. (Based on data from Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.)

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**Table 7A.1 Trends in Estimated Water Use in the United States, 1950–2000**

| | Year | | | | | | | | | | | Percentage Change |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1950[a] | 1955[b] | 1960[c] | 1965[d] | 1970[d] | 1975[c] | 1980[c] | 1985[c] | 1990[c] | 1995[c] | 2000[c] | 1995–2000 |
| **Population (million)** | 150.7 | 164 | 179.3 | 193.8 | 205.9 | 216.4 | 229.6 | 242.4 | 252.3 | 267.1 | 285.3 | 7 |
| **Offstream use** | | | | | | | | | | | | |
| Total withdrawals | 180 | 240 | 270 | 310 | 370 | 420 | 440 | 399 | 408 | 402 | 408 | 2 |
| Public supply | 14 | 17 | 21 | 24 | 27 | 29 | 34 | 36.5 | 38.5 | 40.2 | 43.3 | 8 |
| Rural domestic and livestock | | | | | | | | | | | | |
| Self-supplied domestic | 2.1 | 2.1 | 2 | 2.3 | 2.6 | 2.8 | 3.4 | 3.32 | 3.39 | 3.39 | 3.59 | 6 |
| Livestock and aquaculture | 1.5 | 1.5 | 1.6 | 1.7 | 1.9 | 2.1 | 2.2 | 4.47[e] | 4.5 | 5.49 | [f] | — |
| Irrigation | 89 | 110 | 110 | 120 | 130 | 140 | 150 | 137 | 137 | 134 | 137 | 2 |
| Industrial | | | | | | | | | | | | |
| Thermoelectric power use | 40 | 72 | 100 | 130 | 170 | 200 | 210 | 187 | 195 | 190 | 195 | 3 |
| Other industrial use | 37 | 39 | 38 | 46 | 47 | 45 | 45 | 30.5 | 29.9 | 29.1 | [g] | — |
| **Source of water** | | | | | | | | | | | | |
| Ground | | | | | | | | | | | | |
| Fresh | 34 | 47 | 50 | 60 | 68 | 82 | 83 | 73.2 | 79.4 | 76.4 | 83.3 | 9 |
| Saline | [h] | 0.6 | 0.4 | 0.5 | 1 | 1 | 0.9 | 0.65 | 1.22 | 1.11 | 1.26 | 14 |
| Surface | | | | | | | | | | | | |
| Fresh | 140 | 180 | 190 | 210 | 250 | 260 | 290 | 265 | 259 | 264 | 262 | −1 |
| Saline | 10 | 18 | 31 | 43 | 53 | 69 | 71 | 59.6 | 68.2 | 59.7 | 61 | 2 |

*Note:* Data for 1995 and earlier from Solley and others (1998). The water-use data are in billion gallons per day (thousand million gallons per day) and are rounded to two significant figures for 1950–80, and to three significant figures for 1985–2000; percentage change is calculated from unrounded numbers. —, not available.

[a] 48 States and district of Columbia, and Hawaii.
[b] 48 States and district of Columbia.
[c] 50 States and district of Columbia, Puerto Rico, and U.S. Virgin Islands.
[d] 50 States and district of Columbia, and Puerto Rico.
[e] From 1985 to present this category includes water use for fish farms.
[f] Data not available for all States; partial total was 5.46.
[g] Commercial use not available; industrial and mining use totaled 23.2.
[h] Data not available.

*Source*: From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, http://water.usgs.gov.



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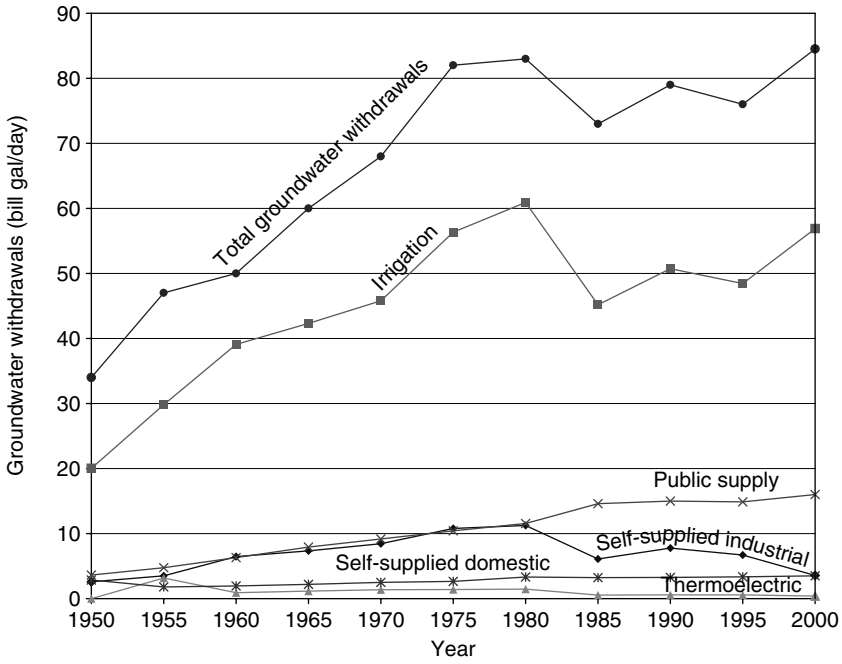


**Figure 7A.4** Trends in groundwater use in the United States, 1950–2000. (Based on information from Dziegielewski, B. et al., 2002, Analysis of Water Use Trends in the United States: 1950–1995 University of Illinois at Urbana-Champaign, Illinois Water Resources Center, Special Report 28, February 2002, environ.uivc.edu/iwrc and Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.)

**Table 7A.2 Changes in Sectoral Withdrawals in the United States, 1950–1995**

| | Withdrawals (bgd) | | | Change (bgd) | | Percent Change | |
|---|---|---|---|---|---|---|---|
| **Sector** | **1950** | **1980** | **1995** | **1980–1995** | **1980–1995** | **1950–1980** | **1980–1995** |
| Domestic | 17.6 | 39.6 | 49.1 | 22.0 | 9.5 | +125.0 | +24.0 |
| Irrigation | 89.0 | 150.0 | 134.0 | 61.0 | −16.0 | +68.5 | −10.7 |
| Thermoelectric | 40.0 | 210.0 | 190.0 | 170.0 | −20.0 | +425.0 | −9.5 |
| Industrial | 37.0 | 45.0 | 29.1 | 8.0 | −15.9 | +21.6 | −35.3 |
| Total | 183.6 | 444.6 | 402.2 | 261.0 | −42.4 | +142.2 | −9.5 |

*Note:* This sectoral breakdown of the 1980–1995 change in total withdrawals shows a consistent decline in off-stream withdrawals for all sectors, with the exception of public supply and domestic use.

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*. Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002. Reprinted with permission, http://info.geography.siu.edu/geography_info/research/.

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**Table 7A.3 Percent of United States Population Relying on Groundwater as a Source of Drinking Water, 1995**

| | |
|---|---|
| Alabama | 40 |
| Alaska | 42 |
| Arizona | 57 |
| Arkansas | 42 |
| California | 43 |
| Colorado | 14 |
| Connecticut | 41 |
| Delaware | 57 |
| Florida | 92 |
| Georgia | 28 |
| Hawaii | 96 |
| Idaho | 94 |
| Illinois | 24 |
| Indiana | 51 |
| Iowa | 71 |
| Kansas | 45 |
| Kentucky | 14 |
| Louisiana | 56 |
| Maine | 31 |
| Maryland | 16 |
| Massachusetts | 41 |
| Michigan | 25 |
| Minnesota | 72 |
| Mississippi | 91 |
| Missouri | 43 |
| Montana | 37 |
| Nebraska | 84 |
| Nevada | 26 |
| New Hampshire | 37 |
| New Jersey | 46 |
| New Mexico | 88 |
| New York | 27 |
| North Carolina | 24 |
| North Dakota | 44 |
| Ohio | 35 |
| Oklahoma | 26 |
| Oregon | 17 |
| Pennsylvania | 22 |
| Rhode Island | 17 |
| South Carolina | 26 |
| South Dakota | 63 |
| Tennessee | 37 |
| Texas | 42 |
| Utah | 55 |
| Vermont | 35 |
| Virginia | 12 |
| Washington | 52 |
| West Virginia | 21 |
| Wisconsin | 57 |
| Wyoming | 42 |
| Total United States Including P.R. and V.I. | 41 |

*Source*: Abstracted from Solley, W.B. et al., 1998, Estimated use of water in the United States in 1995, *U.S. Geological Survey Circular 1200*.

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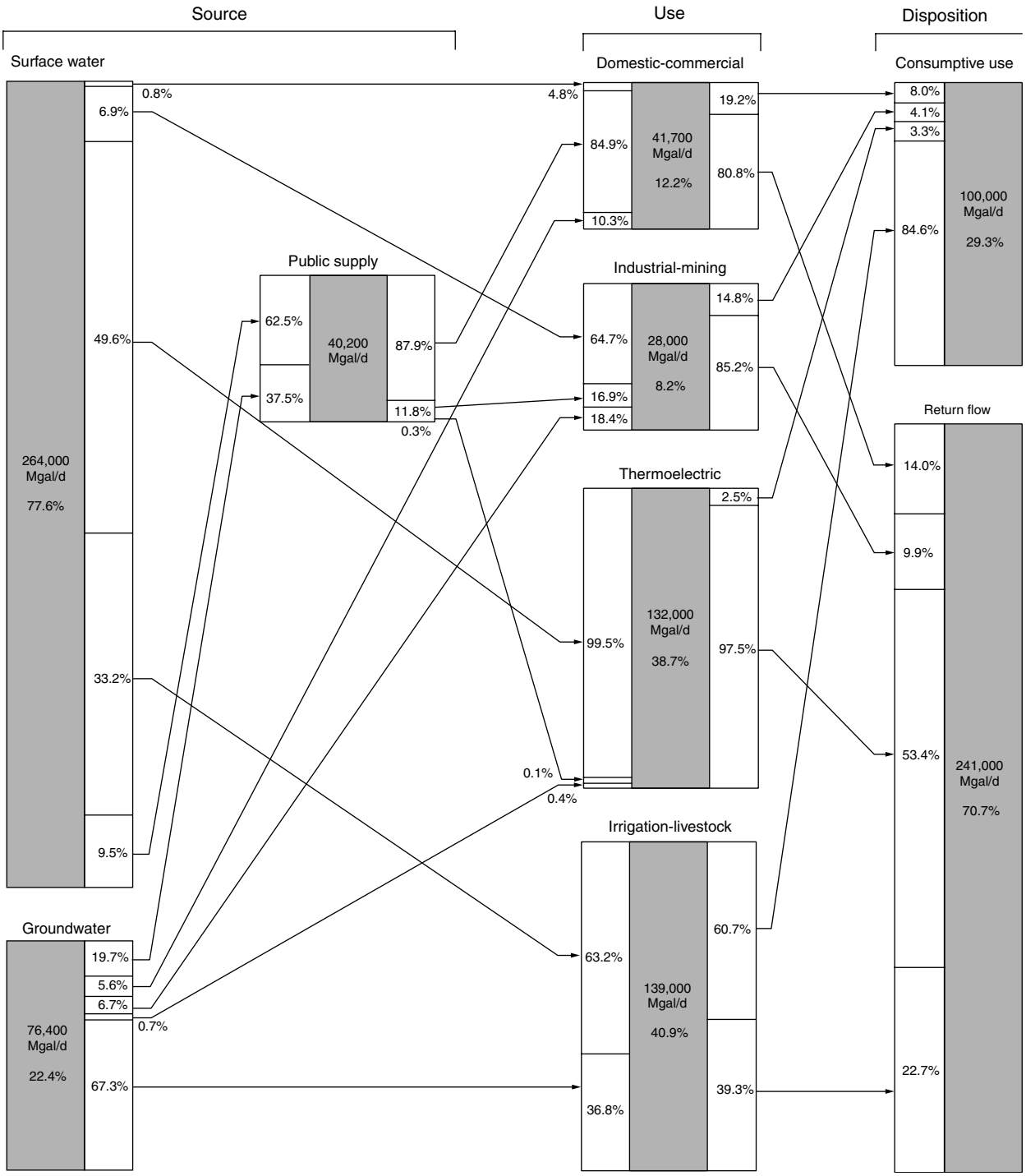


**Figure 7A.5** Source, use, and disposition of freshwater in the United States, 1995. For each water-use category, this diagram shows the relative proportion of water source and disposition and the general distribtion of water from source to disposition. The lines and arrows indicate the distribution of water from source to disposition for each category; for example, surface water was 77.6 percent of total freshwater withdrawn, and going from "Source" to "Use" columns, the line from the surface-water block to the domestic and commercial block indicates that 0.8 percent of all surface water withdrawn was the source for 4.8 percent of total water (self-supplied withdrawals, public-supply deliveries) for domestic and commercial purposes. In addition, going from the "Use" to "Disposition" columns, the line from the domestic and commercial block to the consumptive use block indicates that 19.2 percent of the water for domestic and commercial purposes was consumptive use; this represents 8.0 percent of total consumptive use by all water-use categories. (From Solley, W.B. et al., 1998, Estimated use of water in the United States in 1995, *U.S. Geological Survey Circular 1200*, www.usgs.gov.)

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**Table 7A.4 Surface Water Withdrawals by Water-Use Category, 2000**

| State | Public Supply Fresh | Domestic Fresh | Irrigation Fresh | Livestock Fresh | Aquaculture Fresh | Industrial | | Mining | | Thermoelectric Power | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fresh | Saline | Fresh | Saline | Fresh | Saline | Fresh | Saline | Total |
| Alabama | 553 | 0 | 28.7 | — | 1.44 | 777 | 0 | — | — | 8,190 | 0 | 9,550 | 0 | 9,550 |
| Alaska | 50.7 | 0.25 | 0.02 | — | — | 3.8 | 3.86 | 27.4 | 49.5 | 28.9 | 0 | 111 | 53.4 | 164 |
| Arizona | 613 | 0 | 2,660 | — | — | 0 | 0 | 4.43 | 0 | 26.2 | 0 | 3,300 | 0 | 3,300 |
| Arkansas | 289 | 0 | 1,410 | — | 10.4 | 66.8 | 0 | 2.57 | 0 | 2,170 | 0 | 3,950 | 0 | 3,950 |
| California | 3,320 | 28.6 | 18,900 | 227 | 380 | 5.65 | 13.6 | 2.71 | 0.46 | 349 | 12,600 | 23,200 | 12,600 | 35,800 |
| Colorado | 846 | 0 | 9,260 | — | — | 96.4 | 0 | — | — | 122 | 0 | 10,300 | 0 | 10,300 |
| Connecticut | 358 | 0 | 13.4 | — | — | 6.61 | 0 | — | — | 186 | 3,440 | 565 | 3,440 | 4,010 |
| Delaware | 49.8 | 0 | 7.89 | 0.22 | 0 | 42.5 | 3.25 | — | — | 366 | 738 | 466 | 741 | 1,210 |
| District of Columbia | 0 | 0 | 0.18 | — | — | 0 | 0 | — | — | 9.69 | 0 | 9.87 | 0 | 9.87 |
| Florida | 237 | 0 | 2,110 | 1.51 | 0.21 | 74.7 | 1.18 | 57.8 | 0 | 629 | 12,000 | 3,110 | 12,000 | 15,100 |
| Georgia | 968 | 0 | 392 | 17.7 | 7.72 | 333 | 30 | 2.05 | 0 | 3,240 | 61.7 | 4,960 | 91.7 | 5,060 |
| Hawaii | 7.6 | 7.22 | 193 | — | — | 0 | 0 | — | — | 0 | 0 | 208 | 0 | 208 |
| Idaho | 25.3 | 0 | 13,300 | 7.2 | 1,920 | 19.7 | 0 | — | — | 0 | 0 | 15,300 | 0 | 15,300 |
| Illinois | 1,410 | 0 | 4.25 | 0 | — | 259 | 0 | — | — | 11,300 | 0 | 12,900 | 0 | 12,900 |
| Indiana | 326 | 0 | 45.4 | 14.6 | — | 2,300 | 0 | 78.3 | 0 | 6,700 | 0 | 9,460 | 0 | 9,460 |
| Iowa | 79.8 | 0 | 1.08 | 27.1 | — | 11.7 | 0 | 30.3 | 0 | 2,530 | 0 | 2,680 | 0 | 2,680 |
| Kansas | 244 | 0 | 288 | 23.5 | 2.27 | 6.74 | 0 | 17.4 | 0 | 2,240 | 0 | 2,820 | 0 | 2,820 |
| Kentucky | 455 | 8 | 28.2 | — | — | 222 | 0 | — | — | 3,250 | 0 | 3,970 | 0 | 3,970 |
| Louisiana | 404 | 0 | 232 | 3.31 | 115 | 2,400 | 0 | — | — | 5,580 | 0 | 8,730 | 0 | 8,730 |
| Maine | 72.5 | 0 | 5.23 | — | — | 237 | 0 | — | — | 108 | 295 | 423 | 295 | 718 |
| Maryland | 740 | 0 | 12.6 | 3.18 | 14.8 | 49.9 | 227 | 4.1 | 0.02 | 377 | 6,260 | 1,200 | 6,490 | 7,690 |
| Massachusetts | 542 | 0 | 106 | — | — | 26.2 | 0 | — | — | 108 | 3,610 | 783 | 3,610 | 4,390 |
| Michigan | 896 | 0 | 73.2 | 1.15 | — | 589 | 0 | — | — | 7,710 | 0 | 9,260 | 0 | 9,260 |
| Minnesota | 171 | 0 | 36.6 | 0 | — | 97.8 | 0 | 581 | 0 | 2,260 | 0 | 3,150 | 0 | 3,150 |
| Mississippi | 40.4 | 0 | 99.1 | — | 49.8 | 124 | 0 | — | — | 318 | 148 | 632 | 148 | 781 |
| Missouri | 594 | 0 | 48.1 | 54.1 | 81.3 | 33.5 | 0 | 12.8 | 0 | 5,620 | 0 | 6,450 | 0 | 6,450 |
| Montana | 92.4 | 1.29 | 7,870 | — | — | 29.3 | 0 | — | — | 110 | 0 | 8,100 | 0 | 8,100 |
| Nebraska | 63.8 | 0 | 1,370 | 17.4 | — | 2.6 | 0 | 122 | 0 | 2,810 | 0 | 4,390 | 0 | 4,390 |
| Nevada | 478 | 0 | 1,540 | — | — | 5 | 0 | — | — | 24.7 | 0 | 2,050 | 0 | 2,050 |
| New Hampshire | 64.1 | 0.16 | 4.25 | — | 13.1 | 37.9 | 0 | 6.72 | 0 | 235 | 761 | 362 | 761 | 1,120 |
| New Jersey | 650 | 0 | 117 | 0 | 0 | 66.2 | 0 | 104 | 0 | 648 | 3,390 | 1,590 | 3,390 | 4,980 |
| New Mexico | 33.8 | 0 | 1,630 | — | — | 1.67 | 0 | — | — | 45 | 0 | 1,710 | 0 | 1,710 |
| New York | 1,980 | 0 | 12.1 | — | — | 152 | 0 | — | — | 4,040 | 5,010 | 6,190 | 5,010 | 11,200 |
| North Carolina | 779 | 0 | 221 | 32.3 | 0 | 267 | 0 | — | 0 | 7,850 | 1,620 | 9,150 | 1,620 | 10,800 |
| North Dakota | 31.2 | 0 | 73.2 | — | — | 10.7 | 0 | — | — | 902 | 0 | 1,020 | 0 | 1,020 |
| Ohio | 966 | 2.71 | 17.8 | 17.1 | 0 | 645 | 0 | 35.5 | 0 | 8,590 | 0 | 10,300 | 0 | 10,300 |
| Oklahoma | 562 | 0 | 151 | 97.2 | 16.1 | 19.1 | 0 | 0.23 | 0 | 143 | 0 | 990 | 0 | 990 |
| Oregon | 447 | 7.97 | 5,290 | — | — | 183 | 0 | — | — | 12.8 | 0 | 5,940 | 0 | 5,940 |
| Pennsylvania | 1,250 | 0 | 12.5 | — | — | 1,030 | 0 | 20.9 | 0 | 6,970 | 0 | 9,290 | 0 | 9,290 |

*(Continued)*



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**Table 7A.4 (Continued)**

| State | Public Supply Fresh | Domestic Fresh | Irrigation Fresh | Livestock Fresh | Aquaculture Fresh | Industrial | | Mining | | Thermoelectric Power | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fresh | Saline | Fresh | Saline | Fresh | Saline | Fresh | Saline | Total |
| Rhode Island | 102 | 0 | 2.99 | — | — | 2.09 | 0 | — | — | 2.4 | 290 | 110 | 290 | 400 |
| South Carolina | 462 | 0 | 162 | | — | 514 | 0 | — | — | 5,700 | 0 | 6,840 | 0 | 6,840 |
| South Dakota | 39.1 | 0.01 | 236 | 25.2 | — | 1.96 | 0 | — | — | 4.01 | 0 | 306 | 0 | 306 |
| Tennessee | 569 | 0 | 15.1 | | — | 785 | 0 | — | — | 9,040 | 0 | 10,400 | 0 | 10,400 |
| Texas | 2,970 | 0 | 2,130 | 172 | | 1,200 | 906 | 91.5 | 0 | 9,760 | 3,440 | 16,300 | 4,350 | 20,700 |
| Utah | 274 | 0 | 3,390 | — | 0 | 8.38 | 0 | 17.7 | 177 | 49.2 | 0 | 3,740 | 177 | 3,920 |
| Vermont | 40.6 | 0.25 | 3.45 | — | — | 4.86 | 0 | — | — | 355 | 0 | 404 | 0 | 404 |
| Virginia | 650 | 0 | 22.8 | — | — | 365 | 53.3 | — | — | 3,850 | 3,580 | 4,880 | 3,640 | 8,520 |
| Washington | 552 | 0.02 | 2,290 | — | — | 439 | 39.9 | — | — | 518 | 0 | 3,800 | 39.9 | 3,840 |
| West Virginia | 149 | 0.81 | 0.02 | — | — | 958 | 0 | — | — | 3,950 | 0 | 5,060 | 0 | 5,060 |
| Wisconsin | 293 | 0 | 1.57 | 6.02 | 30.4 | 364 | 0 | — | — | 6,090 | 0 | 6,780 | 0 | 6,780 |
| Wyoming | 49.4 | 0 | 4,090 | — | — | 1.47 | 0 | 20.7 | 0 | 242 | 0 | 4,400 | 0 | 4,400 |
| Puerto Rico | 425 | 0 | 57.5 | — | — | 0 | 0 | — | — | 0 | 2,190 | 483 | 2,190 | 2,670 |
| U.S. Virgin Islands | 5.57 | 1.69 | 0.21 | — | — | 3.12 | 0 | — | — | 0 | 136 | 10.6 | 136 | 147 |
| Total | 27,300 | 58.9 | 80,000 | 747 | 2,640 | 14,900 | 1,280 | 1,240 | 227 | 135,000 | 59,500 | 262,000 | 61,000 | 323,000 |

*Note:* Figures may not sum of totals because of independent rounding. All values are in million gallons per day. —, data not collected.

*Source*: From Hutson, S.S. et al., Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, 2004, http://water.usgs.gov/pubs/circ/2004/circ1268/.

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**Table 7A.5 Groundwater Withdrawals for Off-Stream Water-Use Categories in the United States, 2000**

| State | Public Supply Fresh | Domestic Fresh | Irrigation Fresh | Livestock Fresh | Aquaculture Fresh | Industrial | | Mining | | Thermo-Electric Power Fresh | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fresh | Saline | Fresh | Saline | | Fresh | Saline | Total |
| Alabama | 281 | 78.9 | 14.5 | — | 8.93 | 56 | 0 | — | — | 0 | 440 | 0 | 440 |
| Alaska | 29.3 | 10.9 | 0.99 | — | — | 4.32 | 0 | 0.01 | 90.4 | 4.65 | 50.2 | 90.4 | 141 |
| Arizona | 469 | 28.9 | 2,750 | — | — | 19.8 | 0 | 81.2 | 8.17 | 74.3 | 3,420 | 8.17 | 3,430 |
| Arkansas | 132 | 28.5 | 6,510 | — | 187 | 67 | 0.08 | 0.21 | 0 | 2.92 | 6,920 | 0.08 | 6,920 |
| California | 2,800 | 257 | 11,600 | 182 | 158 | 183 | 0 | 21 | 152 | 3.23 | 15,200 | 152 | 15,400 |
| Colorado | 53.7 | 66.8 | 2,160 | — | — | 23.6 | 0 | — | — | 16.1 | 2,320 | 0 | 2,320 |
| Connecticut | 66 | 56.2 | 17 | — | — | 4.13 | 0 | — | — | 0.08 | 143 | 0 | 143 |
| Delaware | 45 | 13.3 | 35.6 | 3.7 | 0.07 | 17 | 0 | — | — | 0.47 | 115 | 0 | 115 |
| District of Columbia | 0 | 0 | 0 | — | — | 0 | 0 | — | — | 0 | 0 | 0 | 0 |
| Florida | 2,200 | 199 | 2,180 | 31 | 7.81 | 216 | 0 | 160 | 0 | 29.5 | 5,020 | 0 | 5,020 |
| Georgia | 278 | 110 | 750 | 1.66 | 7.7 | 290 | 0 | 7.75 | 0 | 1.03 | 1,450 | 0 | 1,450 |
| Hawaii | 243 | 4.82 | 171 | — | — | 14.5 | 0.85 | — | — | 0 | 433 | 0.85 | 434 |
| Idaho | 219 | 85.2 | 3,720 | 27.7 | 51.5 | 35.8 | 0 | — | — | 0 | 4,140 | 0 | 4,140 |
| Illinois | 353 | 135 | 150 | 37.6 | — | 132 | 0 | — | — | 5.75 | 813 | 0 | 813 |
| Indiana | 345 | 122 | 55.5 | 27.3 | — | 99.7 | 0 | 4.2 | 0 | 2.58 | 656 | 0 | 656 |
| Iowa | 303 | 33.2 | 20.4 | 81.8 | — | 226 | 0 | 2.49 | 0 | 11.9 | 679 | 0 | 679 |
| Kansas | 172 | 21.6 | 3,430 | 87.2 | 3.33 | 46.6 | 0 | 14 | 0 | 14.9 | 3,790 | 0 | 3,790 |
| Kentucky | 71 | 19.5 | 1.14 | — | — | 95.2 | 0 | — | — | 2.71 | 189 | 0 | 189 |
| Louisiana | 349 | 41.2 | 791 | 4.03 | 128 | 285 | 0 | — | — | 28.4 | 1,630 | 0 | 1,630 |
| Maine | 29.6 | 35.7 | 0.61 | — | — | 9.9 | 0 | — | — | 4.92 | 80.8 | 0 | 80.8 |
| Maryland | 84.6 | 77.1 | 29.8 | 7.18 | 4.81 | 15.9 | 0 | 4.21 | 0 | 1.8 | 225 | 0 | 225 |
| Massachusetts | 197 | 42.2 | 19.7 | — | — | 10.7 | 0 | — | — | 0 | 269 | 0 | 269 |
| Michigan | 247 | 239 | 128 | 10.2 | — | 110 | 0 | — | — | 0 | 734 | 0 | 734 |
| Minnesota | 329 | 80.8 | 190 | 52.8 | — | 56.3 | 0 | 6.9 | 0 | 4.17 | 720 | 0 | 720 |
| Mississippi | 319 | 69.3 | 1,310 | — | 321 | 118 | 0 | — | — | 43.5 | 2,180 | 0 | 2,180 |
| Missouri | 278 | 53.6 | 1,380 | 18.3 | 2.01 | 29.2 | 0 | 4.1 | 0 | 12.2 | 1,780 | 0 | 1,780 |
| Montana | 56.1 | 17.3 | 83 | — | — | 31.9 | 0 | — | — | 0 | 188 | 0 | 188 |
| Nebraska | 266 | 48.4 | 7,420 | 76 | — | 35.5 | 0 | 5.64 | 4.55 | 6.87 | 7,860 | 4.55 | 7,860 |
| Nevada | 151 | 22.4 | 567 | — | — | 5.29 | 0 | — | — | 12 | 757 | 0 | 757 |
| New Hampshire | 33 | 40.9 | 0.5 | — | 3.12 | 6.95 | 0 | 0.08 | 0 | 0.71 | 85.2 | 0 | 85.2 |
| New Jersey | 400 | 79.7 | 22.8 | 1.68 | 6.46 | 65.3 | 0 | 6.12 | 0 | 2.24 | 584 | 0 | 584 |
| New Mexico | 262 | 31.4 | 1,230 | — | — | 8.8 | 0 | — | — | 11.4 | 1,540 | 0 | 1,540 |
| New York | 583 | 142 | 23.3 | — | — | 145 | 0 | — | — | 0 | 893 | 0 | 893 |
| North Carolina | 166 | 189 | 65.8 | 89.1 | 7.88 | 25.6 | 0 | 36.4 | 0 | 0.09 | 580 | 0 | 580 |
| North Dakota | 32.4 | 11.9 | 72.2 | — | — | 6.88 | 0 | — | — | 0 | 123 | 0 | 123 |
| Ohio | 500 | 132 | 13.9 | 8.2 | 1.36 | 162 | 0 | 53.1 | 0 | 7.57 | 878 | 0 | 878 |
| Oklahoma | 113 | 25.5 | 566 | 53.6 | 0.29 | 6.83 | 0 | 2.25 | 256 | 3.27 | 771 | 256 | 1,030 |
| Oregon | 118 | 68.3 | 792 | — | — | 12.1 | 0 | — | — | 2.47 | 993 | 0 | 993 |
| Pennsylvania | 212 | 132 | 1.38 | — | — | 155 | 0 | 162 | 0 | 3.98 | 666 | 0 | 666 |

*(Continued)*



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**Table 7A.5 (Continued)**

| State | Public Supply Fresh | Domestic Fresh | Irrigation Fresh | Livestock Fresh | Aquaculture Fresh | Industrial | | Mining | | Thermo-Electric Power Fresh | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fresh | Saline | Fresh | Saline | | Fresh | Saline | Total |
| Rhode Island | 16.9 | 8.99 | 0.46 | — | — | 2.19 | 0 | — | — | 0 | 28.6 | 0 | 28.6 |
| South Carolina | 105 | 63.5 | 106 | — | — | 50.9 | 0 | — | — | 5.83 | 330 | 0 | 330 |
| South Dakota | 54.2 | 9.52 | 137 | 16.9 | — | 3.16 | 0 | — | — | 1.23 | 222 | 0 | 222 |
| Tennessee | 321 | 32.6 | 7.33 | — | — | 56.3 | 0 | — | — | 0 | 417 | 0 | 417 |
| Texas | 1,260 | 131 | 6,500 | 137 | — | 244 | 0.5 | 129 | 504 | 60.2 | 8,470 | 504 | 8,970 |
| Utah | 364 | 16.1 | 469 | — | 116 | 34.3 | 5.08 | 8.6 | 21.5 | 13.1 | 1,020 | 26.5 | 1,050 |
| Vermont | 19.5 | 20.7 | 0.33 | — | — | 2.05 | 0 | — | — | 0.66 | 43.2 | 0 | 43.2 |
| Virginia | 70.7 | 133 | 3.57 | — | — | 104 | 0 | — | — | 1.5 | 314 | 0 | 314 |
| Washington | 464 | 125 | 747 | — | — | 138 | 0 | — | — | 0.92 | 1,470 | 0 | 1,470 |
| West Virginia | 41.6 | 39.6 | 0.02 | — | — | 9.7 | 0 | — | — | 0 | 90.9 | 0 | 90.9 |
| Wisconsin | 330 | 96.3 | 195 | 60.3 | 39.8 | 83 | 0 | — | — | 8.99 | 813 | 0 | 813 |
| Wyoming | 57.2 | 6.57 | 413 | — | — | 4.31 | 0 | 58.8 | 222 | 1.13 | 541 | 222 | 763 |
| Puerto Rico | 88.5 | 0.88 | 36.9 | — | — | 11.2 | 0 | — | — | 0 | 137 | 0 | 137 |
| U.S. Virgin Islands | 0.52 | 0 | 0.29 | — | — | 0.22 | 0 | — | — | 0 | 1.03 | 0 | 1.03 |
| Total | 16,000 | 3,530 | 56,900 | 1,010 | 1,060 | 3,570 | 6.51 | 767 | 1,260 | 409 | 83,300 | 1,260 | 84,500 |

*Note:* Figures may not sum to totals because of independent rounding. All values are in million gallons per day. —, data not collected.

*Source*: From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.

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**Table 7A.6 Total Off-Stream Water Withdrawals by Source and State in the United States, 2000**

| State | Population (thousands) | Withdrawals (mil gal/day) | | | | | | | | | Withdrawals (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | By Source and Type | | | | | | | | | | | |
| | | Groundwater | | | Surface Water | | | Total | | | Total | | |
| | | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total |
| Alabama | 4,450 | 440 | 0 | 440 | 9,550 | 0 | 9,550 | 9,990 | 0 | 9,990 | 11,200 | 0 | 11,200 |
| Alaska | 627 | 50.2 | 90.4 | 141 | 111 | 53.4 | 164 | 161 | 144 | 305 | 181 | 161 | 342 |
| Arizona | 5,130 | 3,420 | 8.17 | 3,430 | 3,300 | 0 | 3,300 | 6,720 | 8.17 | 6,730 | 7,530 | 9.16 | 7,540 |
| Arkansas | 2,670 | 6,920 | 0.08 | 6,920 | 3,950 | 0 | 3,950 | 10,900 | 0.08 | 10,900 | 12,200 | 0.09 | 12,200 |
| California | 33,900 | 15,200 | 152 | 15,400 | 23,200 | 12,600 | 35,800 | 38,400 | 12,800 | 51,200 | 43,100 | 14,300 | 57,400 |
| Colorado | 4,300 | 2,320 | 0 | 2,320 | 10,300 | 0 | 10,300 | 12,600 | 0 | 12,600 | 14,200 | 0 | 14,200 |
| Connecticut | 3,410 | 143 | 0 | 143 | 565 | 3,440 | 4,010 | 708 | 3,440 | 4,150 | 794 | 3,860 | 4,650 |
| Delaware | 784 | 115 | 0 | 115 | 466 | 741 | 1,210 | 582 | 741 | 1,320 | 652 | 831 | 1,480 |
| District of Columbia | 572 | 0 | 0 | 0 | 9.87 | 0 | 9.87 | 9.87 | 0 | 9.87 | 11.1 | 0 | 11.1 |
| Florida | 16,000 | 5,020 | 0 | 5,020 | 3,110 | 12,000 | 15,100 | 8,140 | 12,000 | 20,100 | 9,120 | 13,400 | 22,500 |
| Georgia | 8,190 | 1,450 | 0 | 1,450 | 4,960 | 91.7 | 5,060 | 6,410 | 91.7 | 6,500 | 7,190 | 103 | 7,290 |
| Hawaii | 1,210 | 433 | 0.85 | 434 | 208 | 0 | 208 | 640 | 0.85 | 641 | 718 | 0.95 | 719 |
| Idaho | 1,290 | 4,140 | 0 | 4,140 | 15,300 | 0 | 15,300 | 19,500 | 0 | 19,500 | 21,800 | 0 | 21,800 |
| Illinois | 12,400 | 813 | 0 | 813 | 12,900 | 0 | 12,900 | 13,700 | 0 | 13,700 | 15,400 | 0 | 15,400 |
| Indiana | 6,080 | 656 | 0 | 656 | 9,460 | 0 | 9,460 | 10,100 | 0 | 10,100 | 11,300 | 0 | 11,300 |
| Iowa | 2,930 | 679 | 0 | 679 | 2,680 | 0 | 2,680 | 3,360 | 0 | 3,360 | 3,770 | 0 | 3,770 |
| Kansas | 2,690 | 3,790 | 0 | 3,790 | 2,820 | 0 | 2,820 | 6,610 | 0 | 6,610 | 7,410 | 0 | 7,410 |
| Kentucky | 4,040 | 189 | 0 | 189 | 3,970 | 0 | 3,970 | 4,160 | 0 | 4,160 | 4,660 | 0 | 4,660 |
| Louisiana | 4,470 | 1,630 | 0 | 1,630 | 8,730 | 0 | 8,730 | 10,400 | 0 | 10,400 | 11,600 | 0 | 11,600 |
| Maine | 1,270 | 80.8 | 0 | 80.8 | 423 | 295 | 718 | 504 | 295 | 799 | 565 | 330 | 895 |
| Maryland | 5,300 | 225 | 0 | 225 | 1,200 | 6,490 | 7,690 | 1,430 | 6,490 | 7,910 | 1,600 | 7,270 | 8,870 |
| Massachusetts | 6,350 | 269 | 0 | 269 | 783 | 3,610 | 4,390 | 1,050 | 3,610 | 4,660 | 1,180 | 4,050 | 5,220 |
| Michigan | 9,940 | 734 | 0 | 734 | 9,260 | 0 | 9,260 | 10,000 | 0 | 10,000 | 11,200 | 0 | 11,200 |
| Minnesota | 4,920 | 720 | 0 | 720 | 3,150 | 0 | 3,150 | 3,870 | 0 | 3,870 | 4,340 | 0 | 4,340 |
| Mississippi | 2,840 | 2,180 | 0 | 2,180 | 632 | 148 | 781 | 2,810 | 148 | 2,960 | 3,150 | 166 | 3,320 |
| Missouri | 5,600 | 1,780 | 0 | 1,780 | 6,450 | 0 | 6,450 | 8,230 | 0 | 8,230 | 9,220 | 0 | 9,220 |
| Montana | 902 | 188 | 0 | 188 | 8,100 | 0 | 8,100 | 8,290 | 0 | 8,290 | 9,300 | 0 | 9,300 |
| Nebraska | 1,710 | 7,860 | 4.55 | 7,860 | 4,390 | 0 | 4,390 | 12,200 | 4.55 | 12,300 | 13,700 | 5.1 | 13,700 |
| Nevada | 2,000 | 757 | 0 | 757 | 2,050 | 0 | 2,050 | 2,810 | 0 | 2,810 | 3,140 | 0 | 3,140 |
| New Hampshire | 1,240 | 85.2 | 0 | 85.2 | 362 | 761 | 1,120 | 447 | 761 | 1,210 | 501 | 854 | 1,350 |
| New Jersey | 8,410 | 584 | 0 | 584 | 1,590 | 3,390 | 4,980 | 2,170 | 3,390 | 5,560 | 2,430 | 3,800 | 6,230 |
| New Mexico | 1,820 | 1,540 | 0 | 1,540 | 1,710 | 0 | 1,710 | 3,260 | 0 | 3,260 | 3,650 | 0 | 3,650 |
| New York | 19,000 | 893 | 0 | 893 | 6,190 | 5,010 | 11,200 | 7,080 | 5,010 | 12,100 | 7,940 | 5,610 | 13,600 |
| North Carolina | 8,050 | 580 | 0 | 580 | 9,150 | 1,620 | 10,800 | 9,730 | 1,620 | 11,400 | 10,900 | 1,810 | 12,700 |
| North Dakota | 642 | 123 | 0 | 123 | 1,020 | 0 | 1,020 | 1,140 | 0 | 1,140 | 1,280 | 0 | 1,280 |
| Ohio | 11,400 | 878 | 0 | 878 | 10,300 | 0 | 10,300 | 11,100 | 0 | 11,100 | 12,500 | 0 | 12,500 |

*(Continued)*



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**Table 7A.6 (Continued)**

| State | Population (thousands) | Withdrawals (mil gal/day) | | | | | | | | | Withdrawals (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | By Source and Type | | | | | | | | | | | |
| | | Groundwater | | | Surface Water | | | Total | | | Total | | |
| | | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total |
| Oklahoma | 3,450 | 771 | 256 | 1,030 | 990 | 0 | 990 | 1,760 | 256 | 2,020 | 1,970 | 287 | 2,260 |
| Oregon | 3,420 | 993 | 0 | 993 | 5,940 | 0 | 5,940 | 6,930 | 0 | 6,930 | 7,770 | 0 | 7,770 |
| Pennsylvania | 12,300 | 666 | 0 | 666 | 9,290 | 0 | 9,290 | 9,950 | 0 | 9,950 | 11,200 | 0 | 11,200 |
| Rhode Island | 1,050 | 28.6 | 0 | 28.6 | 110 | 290 | 400 | 138 | 290 | 429 | 155 | 326 | 481 |
| South Carolina | 4,010 | 330 | 0 | 330 | 6,840 | 0 | 6,840 | 7,170 | 0 | 7,170 | 8,040 | 0 | 8,040 |
| South Dakota | 755 | 222 | 0 | 222 | 306 | 0 | 306 | 528 | 0 | 528 | 592 | 0 | 592 |
| Tennessee | 5,690 | 417 | 0 | 417 | 10,400 | 0 | 10,400 | 10,800 | 0 | 10,800 | 12,100 | 0 | 12,100 |
| Texas | 20,900 | 8,470 | 504 | 8,970 | 16,300 | 4,350 | 20,700 | 24,800 | 4,850 | 29,600 | 27,800 | 5,440 | 33,200 |
| Utah | 2,230 | 1,020 | 26.5 | 1,050 | 3,740 | 177 | 3,920 | 4,760 | 203 | 4,970 | 5,340 | 228 | 5,570 |
| Vermont | 609 | 43.2 | 0 | 43.2 | 404 | 0 | 404 | 447 | 0 | 447 | 501 | 0 | 501 |
| Virginia | 7,080 | 314 | 0 | 314 | 4,880 | 3,640 | 8,520 | 5,200 | 3,640 | 8,830 | 5,830 | 4,080 | 9,900 |
| Washington | 5,890 | 1,470 | 0 | 1,470 | 3,800 | 39.9 | 3,840 | 5,270 | 39.9 | 5,310 | 5,910 | 44.7 | 5,960 |
| West Virginia | 1,810 | 90.9 | 0 | 90.9 | 5,060 | 0 | 5,060 | 5,150 | 0 | 5,150 | 5,770 | 0 | 5,770 |
| Wisconsin | 5,360 | 813 | 0 | 813 | 6,780 | 0 | 6,780 | 7,590 | 0 | 7,590 | 8,510 | 0 | 8,510 |
| Wyoming | 494 | 541 | 222 | 763 | 4,400 | 0 | 4,400 | 4,940 | 222 | 5,170 | 5,540 | 248 | 5,790 |
| Puerto Rico | 3,810 | 137 | 0 | 137 | 483 | 2,190 | 2,670 | 620 | 2,190 | 2,810 | 695 | 2,460 | 3,150 |
| U.S. Virgin Islands | 109 | 1.03 | 0 | 1.03 | 10.6 | 136 | 147 | 11.6 | 136 | 148 | 13 | 153 | 166 |
| Total | 285,000 | 83,300 | 1,260 | 84,500 | 262,000 | 61,000 | 323,000 | 345,000 | 62,300 | 408,000 | 387,000 | 69,800 | 457,000 |

*Note:* Figures may not sum to totals because of independent rounding.

*Source*: From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, usgs.gov/pubs/circ/2004/circ1268.

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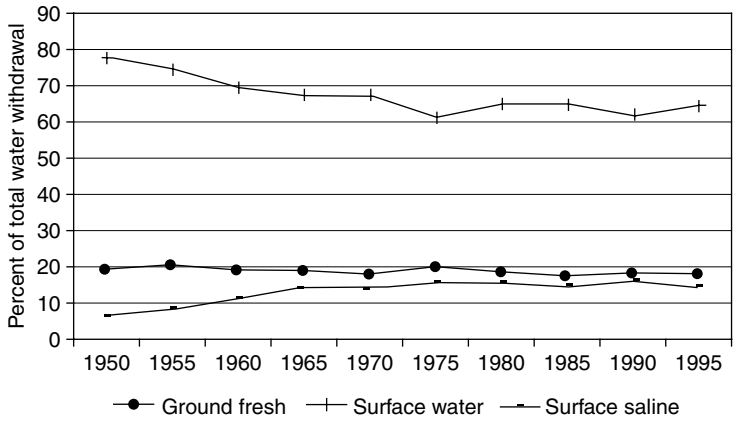


**Figure 7A.6** Total off-stream withdrawals by source in the United States, 1950–1995. (From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.)

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**Table 7A.7 Total and Percent of Withdrawals by Source in the United States, 1950–1995**

| Year | Total With-drawals (bgd) | Groundwater Fresh (bgd) | Surface Water Fresh (bgd) | Surface Water Saline (bgd) | Groundwater Fresh (%) | Surface Water Fresh (%) | Surface Water Saline (%) |
|---|---|---|---|---|---|---|---|
| 1950 | 180 | 34 | 140 | 10 | 19 | 78 | 6 |
| 1955 | 240 | 47 | 180 | 18 | 20 | 75 | 8 |
| 1960 | 270 | 50 | 190 | 31 | 19 | 70 | 11 |
| 1965 | 310 | 60 | 210 | 43 | 19 | 68 | 14 |
| 1970 | 370 | 68 | 250 | 53 | 18 | 68 | 14 |
| 1975 | 420 | 82 | 260 | 69 | 20 | 62 | 16 |
| 1980 | 440 | 83 | 290 | 71 | 19 | 66 | 16 |
| 1985 | 399 | 73 | 265 | 60 | 18 | 66 | 15 |
| 1990 | 408 | 79 | 259 | 68 | 19 | 63 | 17 |
| 1995 | 402 | 76 | 264 | 60 | 19 | 66 | 15 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002. Reprinted with Permission. http://info.geography.siu.edu/geography_info/research/.

**Table 7A.8 Common Uses of Water in Relation to Consumptive and Nonconsumptive Uses**

| Common Uses of Water | Consumptive | Nonconsumptive |
|---|---|---|
| Steam generation (locomotive or stationary) | Steam released to atmosphere | [a] |
| Air conditioning | | |
| Evaporative | Cooling achieved by evaporation | [a] |
| Recirculating | Some water evaporated with each use | [a] |
| Other cooling (recirculating) | Some water evaporated with each use | [a] |
| Storage in surface reservoirs | Evaporation from water surface | Seepage underground |
| Irrigation by sprinkling | Evaporation and transpiration | Little seepage |
| Irrigation by flooding | Evaporation from ponds, transpiration | Seepage varies |
| Cooking | Steam to atmosphere | Contributes to sewage |
| Processing foods, beverages, plastics | Some water goes into manufactured products | Carries organic compounds |
| Processing | | |
| Petroleum products | Proportion of consumptive use is increased by reuse of the nonconsumptive water | Carries chemicals |
| Paper and pulp | Proportion of consumptive use is increased by reuse of the nonconsumptive water | Carries pulp and chemicals |
| Chemicals | Proportion of consumptive use is increased by reuse of the nonconsumptive water | Carries toxic or other chemicals |
| Metal products | Proportion of consumptive use is increased by reuse of the nonconsumptive water | Carries sludge and soluble chemicals |
| Atomic fission | Evaporation from tanks | Carries radioactive materials |
| Stock watering | Evaporation from tanks and ponds | Organic wastes into ground |
| Drinking | Perspiration | Organic wastes into sewage |
| Irrigation by furrow | Evapotranspiration | Dissolves chemicals from soil |
| Washing | Evaporation in drying | Carries sediment and soluble matter |
| Mining (metals, coal, oil) | | Carries natural brines and acids, sediments |
| Cooling (once-through) | [b] | Water temperature increased by use |
| Air conditioning (once-through) | [b] | Water temperature increased by use |
| Fish culture | [c] | |
| Steam heating | [d] | Steam condenses and is reused |
| Year-round heat exchange | [d] | Requires storage of water and heat from one season to another |
| Sanitation (bath, toilet, dishwasher) | [d] | Sewage carries chiefly organic wastes |
| Hydroelectric power | [e] | Takes water toward oceans |
| Navigation | [e] | Inland waterways require maintenance of flow |

[a] With efficient operation, nonconsumptive use is limited to that required for cooling and/or cleaning equipment.
[b] Increase in water temperature may cause increased evaporation.
[c] Consumptive use by evaporation from water surfaces; may be increased by aerators.
[d] Consumptive use is limited to losses through leaking pipes, valves, etc.
[e] Consumptive use is limited to evaporation from lakes, reservoirs, etc. that are required for continuous operation.

*Source*: From House of Representatives, U.S. Congress.

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**Table 7A.9 United States Water Withdrawals and Consumptive Use Per Day by End Use, 1940–1995**

| Year | Total (bil gal) | Per Capita[b] (gal) | Irrigation (bil gal) | Public supply[a] Total (bil gal) | Public supply[a] Per Capita[c] (gal) | Rural[d] (bil gal) | Industrial and Misc[e] (bil gal) | Steam Electric Utilities (bil gal) |
|---|---|---|---|---|---|---|---|---|
| Withdrawals | | | | | | | | |
| 1940 | 140 | 1,027 | 71 | 10 | 75 | 3.1 | 29 | 23 |
| 1950 | 180 | 1,185 | 89 | 14 | 145 | 3.6 | 37 | 40 |
| 1955 | 240 | 1,454 | 110 | 17 | 148 | 3.6 | 39 | 72 |
| 1960 | 270 | 1,500 | 110 | 21 | 151 | 3.6 | 38 | 100 |
| 1965 | 310 | 1,602 | 120 | 24 | 155 | 4.0 | 46 | 130 |
| 1970 | 370 | 1,815 | 130 | 27 | 166 | 4.5 | 47 | 170 |
| 1975 | 420 | 1,972 | 140 | 29 | 168 | 4.9 | 45 | 200 |
| 1980 | 440 | 1,953 | 150 | 34 | 183 | 5.6 | 45 | 210 |
| 1985 | 399 | 1,650 | 137 | 38 | 189 | 7.8 | 31 | 187 |
| 1990 | 408 | 1,620 | 137 | 41 | 195 | 7.9 | 30 | 195 |
| 1995 | 402 | 1,500 | 134 | 43 | 192 | 8.9 | 26 | 190 |
| Consumptive Use | | | | | | | | |
| 1960 | 61 | 339 | 52 | 3.5 | 25 | 2.8 | 3.0 | 0.2 |
| 1965 | 77 | 403 | 66 | 5.2 | 34 | 3.2 | 3.4 | 0.4 |
| 1970 | 87 | 427 | 73 | 5.9 | 36 | 3.4 | 4.1 | 0.8 |
| 1975 | 96 | 451 | 80 | 6.7 | 38 | 3.4 | 4.2 | 1.9 |
| 1980 | 100 | 440 | 83 | 7.1 | 38 | 3.9 | 5.0 | 3.2 |
| 1985 | 92 | 380 | 74 | [f] | [f] | 9.2 | 6.1 | 6.2 |
| 1990 | 94 | 370 | 76 | [f] | [f] | 8.9 | 6.7 | 4.0 |
| 1995 | 100 | 374 | 81 | [f] | [f] | 9.9 | 4.8 | 3.7 |

[a] Includes commercial water withdrawals.
[b] Based on U.S. Census Bureau resident population as of July 1.
[c] Based on population served.
[d] Rural farm and nonfarm household and garden use, and water for farm stock and dairies.
[e] For 1940 to 1960, includes manufacturing and mineral industries, rural commercial industries, air-conditioning, resorts, hotels, motels, military and other state and Federal agencies, and miscellaneous; thereafter, includes manufacturing, mining and mineral processing, ordnance, construction, and miscellaneous.
[f] Public supply consumptive use included in end-use categories.

*Source*: From U.S. Census Bureau, Statistical Abstracts of the United States: 2000, www.census.gov.

*Original Source*: From 1940–1960, U.S. Bureau of Domestic Business Development, based principally on committee prints, Water Resources Activities in the United States, for the Senate Committee on National Water Resources, U.S. Senate, thereafter, U.S. Geological Survey, Estimated Use of Water in the United States in 1995, circular 1200, and previous quinquennial issues.

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## SECTION 7B WATER USE — WORLD

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**Table 7B.10 Major Withdrawal Uses of Water in Canada, 1981, 1986, 1991, and 1996**

| Sector/industry | Year | Total Intake[a] Quantity (mill $m^3$) | Total Intake[a] Change from Previous Period (Percent) | Recirculation[b] Quantity (mill $m^3$) | Recirculation[b] Change from Previous Period (Percent) | Gross Water Use[c] Quantity (mill $m^3$) | Gross Water Use[c] Change from Previous Period (Percent) | Total Discharge[d] Quantity (mill $m^3$) | Total Discharge[d] Change from Previous Period (Percent) | Consumption[e] Quantity (mill $m^3$) | Consumption[e] Change from Previous Period (Percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Business sector** | | | | | | | | | | | |
| Primary resource industries | | | | | | | | | | | |
| Agriculture | 1981 | 3,125 | — | 0 | — | 3,125 | — | 713 | — | 2,412 | — |
| | 1986 | 3,559 | 13.9 | 0 | — | 3,559 | 13.9 | 807 | 13.2 | 2,752 | 14.1 |
| | 1991 | 3,991 | 12.1 | 0 | — | 3,991 | 12.1 | 902 | 11.8 | 3,089 | 12.2 |
| | 1996 | 4,098 | 2.7 | 0 | — | 4,098 | 2.7 | 1,062 | 17.7 | 3,036 | −1.7 |
| Mining | 1981 | 624 | — | 1,742 | — | 2,366 | — | 621 | — | 3 | — |
| | 1986 | 544 | −12.8 | 1,159 | −33.5 | 1,703 | −28.0 | 542 | −12.7 | 2 | −33.3 |
| | 1991 | 489 | −10.1 | 1,221 | 5.3 | 1,710 | 0.4 | 489 | −9.8 | 1 | −50.0 |
| | 1996 | 681 | 39.3 | 1,196 | −2.0 | 1,878 | 9.8 | 672 | 37.4 | 9 | 800.0 |
| Other primary resource industries | 1981 | 251 | — | 1,050 | — | 1,302 | — | 188 | — | 63 | — |
| | 1986 | 180 | −28.3 | 873 | −16.9 | 1,054 | −19.0 | 118 | −37.2 | 62 | −1.6 |
| | 1991 | 183 | 1.7 | 735 | −15.8 | 918 | −12.9 | 111 | −5.9 | 71 | 14.5 |
| | 1996 | 231 | 26.2 | 1,013 | 37.8 | 1,244 | 35.5 | 138 | 24.3 | 92 | 29.6 |
| Manufacturing industries | | | | | | | | | | | |
| Paper and allied products | 1981 | 3,170 | — | 4,612 | — | 7,782 | — | 2,989 | — | 181 | — |
| | 1986 | 3,082 | −2.8 | 3,121 | −32.3 | 6,203 | −20.3 | 2,876 | −3.8 | 206 | 13.8 |
| | 1991 | 2,943 | −4.5 | 2,206 | −29.3 | 5,149 | −17.0 | 2,758 | −4.1 | 185 | −10.2 |
| | 1996 | 2,505 | −14.9 | 3,141 | 42.4 | 5,646 | 9.7 | 2,277 | −17.4 | 228 | 23.2 |
| Primary metal | 1981 | 2,074 | — | 1,325 | — | 3,399 | — | 2,003 | — | 71 | — |
| | 1986 | 2,057 | −0.8 | 1,945 | 46.8 | 4,002 | 17.7 | 2,014 | 0.5 | 43 | −39.4 |
| | 1991 | 1,610 | −21.7 | 1,689 | −13.2 | 3,298 | −17.6 | 1,518 | −24.6 | 92 | 114.0 |
| | 1996 | 1,428 | −11.3 | 1,416 | −16.2 | 2,845 | −13.7 | 1,308 | −13.8 | 120 | 30.4 |
| Chemical and chemical products | 1981 | 3,188 | — | 1,285 | — | 4,473 | — | 2,963 | — | 225 | — |
| | 1986 | 1,694 | −46.9 | 1,494 | 16.3 | 3,189 | −28.7 | 1,630 | −45.0 | 64 | −71.6 |
| | 1991 | 1,326 | −21.7 | 979 | −34.5 | 2,305 | −27.7 | 1,231 | −24.5 | 95 | 48.4 |
| | 1996 | 1,182 | −10.9 | 1,357 | 38.6 | 2,539 | 10.2 | 1,083 | −12.0 | 99 | 4.2 |
| Other manufacturing industries | 1981 | 1,721 | — | 2,286 | — | 4,007 | — | 1,588 | — | 133 | — |
| | 1986 | 1,548 | −10.1 | 1,880 | −17.8 | 3,427 | −14.5 | 1,422 | −10.5 | 126 | −5.3 |
| | 1991 | 1,532 | −1.0 | 1,808 | −3.8 | 3, 340 | −2.5 | 1,357 | −4.6 | 175 | 38.9 |
| | 1996 | 1,282 | −16.3 | 1,067 | −41.0 | 2,349 | −29.7 | 1,131 | −16.7 | 151 | −13.7 |
| Electric power and other utilities | 1981 | 18,166 | — | 1,868 | — | 20,034 | — | 18,084 | — | 82 | — |
| | 1986 | 24,963 | 37.4 | 3,776 | 102.1 | 28,740 | 43.5 | 24,702 | 36.6 | 261 | 218.3 |
| | 1991 | 28,288 | 13.3 | 3,374 | −10.6 | 31,662 | 10.2 | 28,183 | 14.1 | 105 | −59.8 |
| | 1996 | 28,664 | 1.3 | 11,617 | 244.3 | 40,281 | 27.2 | 28,183 | 0.0 | 481 | 358.1 |

*(Continued)*



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**Table 7B.10 (Continued)**

| Sector/industry | Year | Total Intake[a] Quantity (mill $m^3$) | Total Intake[a] Change from Previous Period (Percent) | Recirculation[b] Quantity (mill $m^3$) | Recirculation[b] Change from Previous Period (Percent) | Gross Water Use[c] Quantity (mill $m^3$) | Gross Water Use[c] Change from Previous Period (Percent) | Total Discharge[d] Quantity (mill $m^3$) | Total Discharge[d] Change from Previous Period (Percent) | Consumption[e] Quantity (mill $m^3$) | Consumption[e] Change from Previous Period (Percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Other industries | 1981 | 638 | — | 0 | — | 638 | — | 575 | — | 63 | — |
| | 1986 | 736 | 15.4 | 0 | — | 736 | 15.4 | 660 | 14.8 | 76 | 20.6 |
| | 1991 | 816 | 10.9 | 0 | — | 816 | 10.9 | 737 | 11.7 | 79 | 3.9 |
| | 1996 | 880 | 7.8 | 0 | — | 880 | 7.8 | 796 | 8.0 | 84 | 6.3 |
| Subtotal, business sector | 1981 | 32,957 | — | 14,168 | — | 47,126 | — | 29,724 | — | 3,233 | — |
| | 1986 | 38,363 | 16.4 | 14,248 | 0.6 | 52,613 | 11.6 | 34,771 | 17.0 | 3,592 | 11.1 |
| | 1991 | 41,178 | 7.3 | 12,012 | −15.7 | 53,189 | 1.1 | 37,286 | 7.2 | 3,892 | 8.4 |
| | 1996 | 40,951 | −0.6 | 20,807 | 73.2 | 61,760 | 16.1 | 36,650 | −1.7 | 4,300 | 10.5 |
| Personal and government sectors | 1981 | 3,760 | — | 0 | — | 3,760 | — | 3,363 | — | 397 | — |
| | 1986 | 3,719 | −1.1 | 0 | — | 3,719 | −1.1 | 3,338 | −0.7 | 381 | −4.0 |
| | 1991 | 3,802 | 2.2 | 0 | — | 3,802 | 2.2 | 3,374 | 1.1 | 428 | 12.4 |
| | 1996 | 3,922 | 3.2 | 0 | — | 3,922 | 3.2 | 3,482 | 3.2 | 440 | 2.8 |
| Total, whole economy | 1981 | 36,717 | — | 14,169 | — | 50,886 | — | 33,087 | — | 3,630 | — |
| | 1986 | 42,083 | 14.6 | 14,248 | 0.6 | 56,330 | 10.7 | 38,109 | 15.2 | 3,973 | 9.4 |
| | 1991 | 44,979 | 6.9 | 12,012 | −15.7 | 56,991 | 1.2 | 40,659 | 6.7 | 4,320 | 8.7 |
| | 1996 | 44,873 | −0.2 | 20,807 | 73.2 | 65,682 | 15.2 | 40,132 | −1.3 | 4,740 | 9.7 |

*Note:* Figures may not add up to totals due to rounding.

[a] The quantity of water withdrawn from a water source.
[b] The amount of water used more than once in an industrial application.
[c] Gross water use equals total water intake plus recirculation.
[d] The quantity of water returned to the water source.
[e] Consumption is that part of water intake that is evaporated, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the local hydrologic environment.

*Source*: From Statistics Canada, "Human Activity and the Environment", Annual Statistics 2003, Catalogue 16-201-XPE released December 3, 2003, page 12. Statistics Canada information is used with the permission of Statistics Canada. Users are forbidden to copy this material and/or redisseminate the data, in an original or modified form, for commercial purposes, without the expressed permission of Statistics Canada. Information on the availability of the wide range of data from Statistics Canada can be obtained from Statistics Canada's Regional Offices, its World Wide Web site at www.statcan.ca, and its toll-free access number 1-800-263-1136. With permission.

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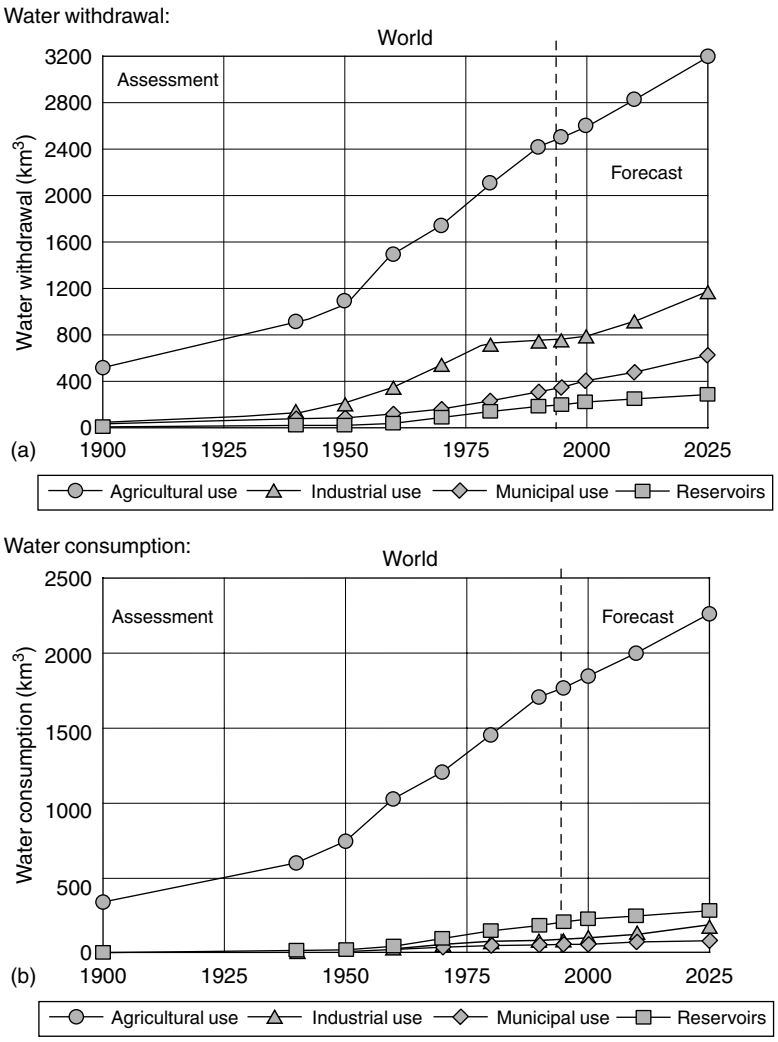


**Figure 7B.7** Dynamics of water use in the world by kind of economic activity. (From Shiklomanov, I.A., 1999, Summary of the Monograph "World Water Resources at the Beginning of the 21st Century" Prepared in the Framework of IHP UNESCO, International Hydrological Programme, UNESCO's Intergovernmental Scientific Programme in Water Resources, World Water Resources and Their Use a Joint State Hydrological Institute (SHI)/UNESCO Product, http://webworld.unesco.org/water/ihp/db/shiklomanov/. Copyright © UNESCO 1999. Reproduced by permission of UNESCO.)

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## Table 7B.11 World Wide Freshwater Resources Availability and Use

| | Renewable Water Resources (annual)[a] | | | | | | Water Withdrawals (annual) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Internal Renewable Water Resources (IRWR) | | | | Natural Renewable Water Resources[b] | | | | | | Sectoral Share (Percent)[c] | | | |
| | Groundwater Recharge ($km^3$)[d] | Surface Water ($km^3$)[d] | Overlap ($km^3$) | Total[e] ($km^3$) | Total ($km^3$) | Per Capita ($m^2$ person)[f] | Year | Total (mill $m^3$) | Per Capita ($m^3$ person) | as a % of Renewable Water Resources | Agriculture | Domestic | Industry | Desalinated Water Production (mill $m^3$)[g] |
| **World** | **11,358** | **40,594** | **10,067** | **43,219** | **—** | **—** | **1990** | **3,414,000** | **650** | **—** | **71** | **9** | **20** | **—** |
| **Asia (Excl. Middle East)** | **2,472** | **10,985** | **2,136** | **11,321** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** |
| Armenia | 4.2 | 6.3 | 1.4 | 9.1 | 11 | 2,778 | 1994 | 2,925 | 784 | 28 | 66 | 30 | 4 | 0 |
| Azerbaijan | 6.5 | 6.0 | 4.4 | 8.1 | 30 | 3,716 | 1995 | 16,533 | 2,151 | 58 | 70 | 5 | 25 | 0 |
| Bangladesh | 21 | 84 | 0 | 105 | 1,211 | 8,444 | 1990 | 14,636 | 133 | 2 | 86 | 12 | 2 | 0 |
| Bhutan | — | 95 | — | 95 | 95 | 43,214 | 1987 | 20 | 13 | 0 | 54 | 36 | 10 | 0 |
| Cambodia | 18 | 116 | 13 | 121 | 476 | 34,561 | 1987 | 520 | 60 | 0 | 94 | 5 | 1 | 0 |
| China | 829 | 2,712 | 728 | 2,812 | 2,830 | 2,186 | 1993 | 525,489 | 439 | 20 | 78 | 5 | 18 | 0 |
| Georgia | 17 | 57 | 16 | 58 | 63 | 12,149 | 1990 | 3,468 | 635 | 5 | 59 | 21 | 20 | 0 |
| India | 419 | 1,222 | 380 | 1,261 | 1,897[h] | 1,822[h] | 1990 | 500,000 | 592 | 32 | 92 | 5 | 3 | 0 |
| Indonesia | 455 | 2,793 | 410 | 2,838 | 2,838 | 13,046 | 1990 | 74,346 | 407 | 3 | 93 | 6 | 1 | 0 |
| Japan | 27 | 420 | 17 | 430 | 430 | 3,372 | 1992 | 91,400 | 735 | 22 | 64 | 19 | 17 | 0 |
| Kazakhstan | 6.1 | 69 | 0 | 75 | 110 | 6,839 | 1993 | 33,674 | 2,010 | 29 | 81 | 2 | 17 | 1,328 |
| Korea, Dem People's Rep | 13 | 66 | 12 | 67 | 77 | 3,415 | 1987 | 14,160 | 742 | 22 | 73 | 11 | 16 | 0 |
| Korea, Rep | 13 | 62 | 11 | 65 | 70 | 1,471 | 1994 | 23,668 | 531 | 36 | 63 | 26 | 11 | 0 |
| Kyrgyzstan | 14 | 44 | 11 | 46 | 21[h] | 4,078[h] | 1994 | 10,086 | 2,231 | 55 | 94 | 3 | 3 | 0 |
| Lao People's Dem Rep | 38 | 190 | 38 | 190 | 334 | 60,318 | 1987 | 990 | 259 | 0 | 82 | 8 | 10 | 0 |
| Malaysia | 64 | 566 | 50 | 580 | 580 | 25,178 | 1995 | 12,733 | 636 | 3 | 77 | 11 | 13 | 0 |
| Mongolia | 6.1 | 33 | 4.0 | 35 | 35 | 13,451 | 1993 | 428 | 182 | 1 | 53 | 20 | 27 | 0 |
| Myanmar | 156 | 875 | 150 | 881 | 1,046 | 21,358 | 1987 | 3,960 | 103 | 0 | 90 | 7 | 3 | 0 |
| Nepal | 20 | 198 | 20 | 198 | 210 | 8,703 | 1994 | 28,953 | 1,451 | 17 | 99 | 1 | 0 | 0 |
| Pakistan | 55 | 47 | 50 | 52 | 223[h] | 2,812[h] | 1991 | 155,600 | 1,382 | 100 | 97 | 2 | 2 | 0 |
| Philippines | 180 | 444 | 145 | 479 | 479 | 6,093 | 1995 | 55,422 | 811 | 13 | 88 | 8 | 4 | 0 |
| Singapore | — | — | — | — | — | — | 1975 | — | — | — | 4 | 45 | 51 | — |
| Sri Lanka | 7.8 | 49 | 7.0 | 50 | 50 | 2,592 | 1990 | 9,770 | 574 | 22 | 96 | 2 | 2 | 0 |
| Tajikistan | 6.0 | 63 | 3.0 | 66 | 16[h] | 2,587[h] | 1994 | 11,874 | 2,096 | 81 | 92 | 3 | 4 | 0 |
| Thailand | 42 | 199 | 31 | 210 | 410 | 6,371 | 1990 | 33,132 | 605 | 10 | 91 | 5 | 4 | 0 |
| Turkmenistan | 0.4 | 1.0 | 0 | 1.4 | 25[h] | 5,015[h] | 1994 | 23,779 | 5,801 | 116 | 98 | 1 | 1 | 0 |
| Uzbekistan | 8.8 | 9.5 | 2 | 16 | 50[h] | 1,968[h] | 1994 | 58, 051 | 2,598 | 132 | 94 | 4 | 2 | 0 |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vietnam | 48 | 354 | 35 | 367 | 891 | 11,109 | 1990 | 54,330 | 822 | 7 | 87 | 4 | 10 | 0 |
| **Europe** | **1,318** | **6,223** | **986** | **6,590** | — | — | — | — | — | — | — | — | — | — |
| Albania | 6.2 | 23 | 2.4 | 27 | 42 | 13,178 | 1995 | 1,400 | 440 | 3 | 71 | 29 | 0 | — |
| Austria | 6.0 | 55 | 6.0 | 55 | 78 | 9,629 | 1991 | 2,360 | 303 | 3 | 9 | 33 | 58 | — |
| Belarus | 18 | 37 | 18 | 37 | 58 | 5,739 | 1990 | 2,734 | 266 | 5 | 35 | 22 | 43 | 0 |
| Belgium | 0.9 | 12 | 0.9 | 12 | 18 | 1,781 | — | — | — | — | — | — | — | — |
| Bosnia and Herzegovina | — | — | — | 36 | 38 | 9,088 | 1995 | 1,000 | 292 | 3 | 60 | 30 | 10 | — |
| Bulgaria | 6.4 | 20 | 5.5 | 21 | 21 | 2,734 | 1988 | 13,900 | 1,573 | 58 | 22 | 3 | 75 | — |
| Croatia | 11 | 27 | 0.5 | 38 | 105 | 22,654 | 1996 | 764 | 164 | 1 | 0 | 50 | 50 | — |
| Czech Rep | 1.4 | 13 | 1.4 | 13 | 13 | 1,283 | 1991 | 2,740 | 266 | 21 | 2 | 41 | 57 | — |
| Denmark | 4.3 | 3.7 | 2.0 | 6.0 | 6 | 1,123.0 | 1990 | 1,200 | 233 | 21 | 43 | 30 | 27 | — |
| Estonia | 4.0 | 12 | 3.0 | 13 | 13 | 9,413 | 1995 | 158 | 106 | 1 | 5 | 56 | 39 | 0 |
| Finland | 2.2 | 107 | 2.0 | 107 | 110 | 21,223 | 1991 | 2,200 | 439 | 2 | 3 | 12 | 85 | — |
| France | 100 | 177 | 98 | 179 | 204 | 3,414 | 1999 | 32,300 | 547 | 16 | 10 | 18 | 72 | — |
| Germany | 46 | 106 | 45 | 107 | 154 | 1,878 | 1991 | 46,270 | 579 | 31 | 20 | 11 | 69 | — |
| Greece | 10 | 56 | 7.8 | 58 | 74 | 6,984 | 1997 | 8,700 | 826 | 12 | 87 | 10 | 3 | — |
| Hungary | 6.0 | 6.0 | 6.0 | 6.0 | 104 | 10,541 | 1991 | 6,810 | 659 | 6 | 36 | 9 | 55 | — |
| Iceland | 24 | 166 | 20 | 170 | 170 | 599,944 | 1991 | 160 | 622 | 0 | 6 | 31 | 63 | — |
| Ireland | 11 | 48 | 10 | 49 | 52 | 13,408 | 1980 | 790 | 232 | 2 | 10 | 16 | 74 | — |
| Italy | 43 | 171 | 31 | 183 | 191 | 3,330 | 1998 | 42,000 | 730 | 22 | 48 | 19 | 34 | — |
| Latvia | 2.2 | 17 | 2.0 | 17 | 35 | 14,820 | 1994 | 285 | 112 | 1 | 13 | 55 | 32 | 0 |
| Lithuania | 1.2 | 15 | 1.0 | 16 | 25 | 6,763 | 1995 | 254 | 68 | 1 | 3 | 81 | 16 | 0 |
| Macedonia, FYR | — | 5.4 | — | 5.4 | 6 | 3,120.6 | 1996 | 1,850 | 936 | 30 | 74 | 12 | 15 | — |
| Moldova, Rep | 0.4 | 1.0 | 0.4 | 1.0 | 12 | 2,726 | 1992 | 2,963 | 678 | 25 | 26 | 9 | 65 | 0 |
| Netherlands | 4.5 | 11 | 4.5 | 11 | 91 | 5,691 | 1991 | 7,810 | 519 | 9 | 34 | 5 | 61 | — |
| Norway | 96 | 376 | 90 | 382 | 382 | 84,787 | 1985 | 2,030 | 489 | 1 | 8 | 20 | 72 | — |
| Poland | 13 | 53 | 12 | 54 | 62 | 1,598 | 1991 | 12,280 | 321 | 20 | 11 | 13 | 76 | — |
| Portugal | 4.0 | 38 | 4.0 | 38 | 69[h] | 6,837[h] | 1990 | 7,290 | 736 | 11 | 48 | 15 | 37 | — |
| Romania | 8.3 | 42 | 8.0 | 42 | 212 | 9,486 | 1994 | 26,000 | 1,141 | 12 | 59 | 8 | 33 | — |
| Russian Federation | 788 | 4,037[i] | 512 | 4,313[i] | 4,507[i] | 31,354[i] | 1994 | 77,100 | 519 | 2 | 20 | 19 | 62 | 0 |
| Serbia and Montenegro | 3.0 | 42 | 1.4 | 44 | 209 | 19,815 | 1995 | 13,000 | 1,233 | 6 | 8 | 6 | 86 | — |
| Slovakia | 1.7 | 13 | 1.7 | 13 | 50 | 9,265 | 1991 | 1,780 | 337 | 4 | — | — | — | — |
| Slovenia | 14 | 19 | 13 | 19 | 32 | 16,070 | 1996 | 1,280 | 642 | 4 | 1 | 20 | 80 | — |
| Spain | 30 | 110 | 28 | 111 | 112 | 2,793 | 1997 | 35,210 | 884 | 32 | 68 | 13 | 19 | — |
| Sweden | 20 | 170 | 19 | 171 | 174 | 19,721 | 1991 | 2,930 | 340 | 2 | 9 | 36 | 55 | — |

*(Continued)*



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**Table 7B.11 (Continued)**

| | Renewable Water Resources (annual)[a] | | | | | | Water Withdrawals (annual) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Internal Renewable Water Resources (IRWR) | | | | Natural Renewable Water Resources[b] | | | | | | Sectoral Share (Percent)[c] | | | |
| | Groundwater Recharge ($km^3$)[d] | Surface Water ($km^3$)[d] | Overlap ($km^3$) | Total[e] ($km^3$) | Total ($km^3$) | Per Capita ($m^2$ person)[f] | Year | Total (mill $m^3$) | Per Capita ($m^3$ person) | as a % of Renewable Water Resources | Agriculture | Domestic | Industry | Desalinated Water Production (mill $m^3$)[g] |
| Switzerland | 2.5 | 40 | 2.5 | 40 | 54 | 7,464 | 1991 | 1,190 | 172 | 2 | 4 | 23 | 73 | — |
| Ukraine | 20 | 50 | 17 | 53 | 140 | 2,868 | 1992 | 25,991 | 500 | 17 | 30 | 18 | 52 | 0 |
| United Kingdom | 9.8 | 144 | 9.0 | 145 | 147 | 2,464 | 1991 | 11,790 | 204 | 8 | 3 | 20 | 77 | — |
| **Middle East & N. Africa** | **149** | **374** | **60** | **518** | — | — | — | — | — | — | — | — | — | — |
| Afghanistan | — | — | — | 55 | 65 | 2,790 | 1987 | 26,110 | 2,007 | 72 | 99 | 1 | 0 | 0 |
| Algeria | 1.7 | 13 | 1.0 | 14 | 14 | 460 | 1995 | 5,000 | 181 | 39 | 52 | 34 | 14 | 64 |
| Egypt | 1.3 | 0.5 | 0 | 1.8 | 58[h] | 830[h] | 1996 | 66,000 | 1,055 | 127 | 82 | 7 | 11 | 25 |
| Iran, Islamic Rep | 49 | 97 | 18 | 129 | 138 | 1,900 | 1993 | 70,034 | 1,122 | 59 | 92 | 6 | 2 | 2.9 |
| Iraq | 1.2 | 34 | 0 | 35 | 75[h] | 3,111[h] | 1990 | 42,800 | 2,478 | 80 | 92 | 3 | 5 | 0 |
| Israel | 0.5 | 0.3 | 0 | 0.8 | 2 | 265.0 | 1997 | 1,620 | 287 | 108 | 54 | 39 | 7 | — |
| Jordan | 0.5 | 0.4 | 0.2 | 0.7 | 1 | 169.4 | 1993 | 984 | 255 | 151 | 75 | 22 | 3 | 2.0 |
| Kuwait | 0 | 0 | 0 | 0 | 0.02 | 9.9 | 1994 | 538 | 306 | 3,097 | 60 | 37 | 2 | 231 |
| Lebanon | 3.2 | 4.1 | 2.5 | 4.8 | 4[h] | 1,219.5[h] | 1996 | 1,300 | 400 | 33 | 68 | 27 | 6 | 0 |
| Libyan Arab Jamahiriya | 0.5 | 0.2 | 0.1 | 0.6 | 1 | 108.5 | 1999 | 4,500 | 870 | 801 | 84 | 13 | 3 | 70 |
| Moroco | 10 | 22 | 3.0 | 29 | 29 | 936 | 1998 | 11,480 | 399 | 43 | 89 | 10 | 2 | 3.4 |
| Oman | 1.0 | 0.9 | 0.9 | 1.0 | 1 | 363.6 | 1991 | 1,223 | 658 | 181 | 94 | 5 | 2 | 34 |
| Saudi Arabia | 2.2 | 2.2 | 2.0 | 2.4 | 2 | 110.6 | 1992 | 17,018 | 1,056 | 955 | 90 | 9 | 1 | 714 |
| Syrian Arab Rep | 4.2 | 4.8 | 2.0 | 7.0 | 26[h] | 1,541[h] | 1995 | 12,000 | 844 | 55 | 90 | 8 | 2 | 0 |
| Tunisia | 1.5 | 3.1 | 0.4 | 4.2 | 5 | 576.5 | 1996 | 2,830 | 312 | 54 | 86 | 13 | 1 | 8.3 |
| Turkey | 69 | 186 | 28 | 227 | 229[h] | 3,344[h] | 1997 | 35,500 | 558 | 17 | 73 | 16 | 12 | 0.5 |
| United Arab Emirates | 0.1 | 0.2 | 0.1 | 0.2 | 0 | 55.5 | 1995 | 2,108 | 896 | 1,614 | 67 | 24 | 9 | 385 |
| Yemen | 1.5 | 4.0 | 1.4 | 4.1 | 4 | 205.9 | 1990 | 2,932 | 253 | 123 | 92 | 7 | 1 | 10 |
| **Sub-Saharab Africa** | **1,549** | **3,812** | **1,468** | **3,901** | — | — | — | — | — | — | — | — | — | — |
| Angola | 72 | 182 | 70 | 184 | 184 | 1,3203 | 1987 | 480 | 54 | 0 | 76 | 14 | 10 | 0 |
| Benin | 1.8 | 10 | 1.5 | 10 | 25 | 3,741 | 1994 | 145 | 27 | 1 | 67 | 23 | 10 | 0 |
| Botswana | 1.7 | 1.7 | 0.5 | 2.9 | 14 | 9,209 | 1992 | 113 | 86 | 1 | 48 | 32 | 20 | 0 |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Burkina Faso | 9.5 | 8.0 | 5.0 | 13 | 13 | 1,024 | 1992 | 376 | 40 | 4 | 81 | 19 | 0 | 0 |
| Burundi | 2.1 | 3.5 | 2.0 | 3.6 | 4 | 538.3 | 1987 | 100 | 19 | 4 | 64 | 36 | 0 | 0 |
| Cameroon | 100 | 268 | 95 | 273 | 286 | 18,378 | 1987 | 400 | 38 | 0 | 35 | 46 | 19 | 0 |
| Central African Rep | 56 | 141 | 56 | 141 | 144 | 37,565 | 1987 | 70 | 25 | 0 | 74 | 21 | 5 | 0 |
| Chad | 12 | 14 | 10 | 15 | 43 | 5,125 | 1987 | 180 | 34 | 1 | 82 | 16 | 2 | 0 |
| Congo | 198 | 222 | 198 | 222 | 832 | 259,547 | 1987 | 40 | 20 | 0 | 11 | 62 | 27 | 0 |
| Congo, Dem Rep | 421 | 899 | 420 | 900 | 1,283 | 23,639 | 1990 | 357 | 10 | 0 | 23 | 61 | 16 | 0 |
| Côte d'Ivoire | 38 | 74 | 35 | 77 | 81 | 4,853 | 1987 | 709 | 62 | 1 | 67 | 22 | 11 | 0 |
| Equatorial Guinea | 10 | 25 | 9.0 | 26 | 26 | 53,841 | 1987 | 10 | 30 | 0 | 6 | 81 | 13 | 0 |
| Eritrea | — | — | — | 2.8 | 6 | 1,577.7 | — | — | — | — | — | — | — | 0 |
| Ethiopia | 40 | 110 | 40 | 110 | 110 | 1,666 | 1987 | 2,200 | 51 | 3 | 86 | 11 | 3 | 0 |
| Gabon | 62 | 162 | 60 | 164 | 164 | 126,789 | 1987 | 60 | 70 | 0 | 6 | 72 | 22 | 0 |
| Gambia | 0.5 | 3.0 | 0.5 | 3.0 | 8 | 5,836.0 | 1982 | 20 | 29 | 1 | 91 | 7 | 2 | 0 |
| Ghana | 26 | 29 | 25 | 30 | 53 | 2,637 | 1970 | 300 | 35 | 1 | 52 | 35 | 13 | 0 |
| Guinea | 38 | 226 | 38 | 226 | 226 | 26,964 | 1987 | 740 | 132 | 0 | 87 | 10 | 3 | 0 |
| Guinea-Bissau | 14 | 12 | 10 | 16 | 31 | 24,670 | 1991 | 17 | 17 | 0 | 36 | 60 | 4 | 0 |
| Kenya | 3.0 | 17 | 0 | 20 | 30 | 947 | 1990 | 2,050 | 87 | 9 | 76 | 20 | 4 | 0 |
| Lesotho | 0.5 | 5.2 | 0.5 | 5.2 | 3[h] | 1,455.6[h] | 1987 | 50 | 32 | 2 | 56 | 22 | 22 | 0 |
| Liberia | 60 | 200 | 60 | 200 | 232 | 70,348 | 1987 | 130 | 59 | 0 | 60 | 27 | 13 | 0 |
| Madagascar | 55 | 332 | 50 | 337 | 337 | 19,925 | 1984 | 16,300 | 1,611 | 8 | 99 | 1 | — | 0 |
| Malawi | 1.4 | 16 | 1.4 | 16 | 17 | 1,461 | 1994 | 936 | 95 | 6 | 86 | 10 | 3 | 0 |
| Mali | 20 | 50 | 10 | 60 | 100 | 8,320 | 1987 | 1,360 | 167 | 2 | 97 | 2 | 1 | 0 |
| Mauritania | 0.3 | 0.1 | 0 | 0.4 | 11 | 4,029 | 1985 | 1,630 | 923 | 23 | 92 | 6 | 2 | 1.7 |
| Mozambique | 17 | 97 | 15 | 99 | 216 | 11,382 | 1992 | 605 | 42 | 0 | 89 | 9 | 2 | 0 |
| Namibia | 2.1 | 4.1 | 0.04 | 6.2 | 18[h] | 9,865[h] | 1991 | 249 | 175 | 2 | 68 | 29 | 3 | 0 |
| Niger | 2.5 | 1.0 | 0 | 3.5 | 34 | 2,891 | 1988 | 500 | 69 | 2 | 82 | 16 | 2 | 0 |
| Nigeria | 87 | 214 | 80 | 221 | 286 | 2,384 | 1987 | 3,630 | 46 | 2 | 54 | 31 | 15 | 0 |
| Rwanda | 3.6 | 5.2 | 3.6 | 5.2 | 5 | 638.2 | 1993 | 768 | 141 | 22 | 94 | 5 | 2 | 0 |
| Senegal | 7.6 | 24 | 5.0 | 26 | 39 | 3,977 | 1987 | 1,360 | 202 | 5 | 92 | 5 | 3 | 0 |
| Sierra Leone | 50 | 150 | 40 | 160 | 160 | 33,237 | 1987 | 370 | 98 | 0 | 89 | 7 | 4 | 0 |
| Somalia | 3.3 | 5.7 | 3.0 | 6.0 | 14 | 1,413 | 1987 | 810 | 119 | 8 | 97 | 3 | 0 | 0.1 |
| South Africa | 4.8 | 43 | 3.0 | 45 | 50 | 1,131 | 1990 | 13,309 | 366 | 32 | 72 | 17 | 11 | 0 |
| Sudan | 7.0 | 28 | 5.0 | 30 | 65[h] | 1,981[h] | 1995 | 17,800 | 637 | 32 | 94 | 4 | 1 | 0.4 |
| Tanzania, United Rep | 30 | 80 | 28 | 82 | 91 | 2,472 | 1994 | 1,165 | 39 | 2 | 89 | 9 | 2 | 0 |
| Togo | 5.7 | 11 | 5.0 | 12 | 15 | 3,076 | 1987 | 91 | 29 | 1 | 25 | 62 | 13 | 0 |
| Uganda | 29 | 39 | 29 | 39 | 66 | 2,663 | 1970 | 200 | 21 | 1 | 60 | 32 | 8 | 0 |

*(Continued)*



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**Table 7B.11 (Continued)**

| | Renewable Water Resources (annual)[a] | | | | | | Water Withdrawals (annual) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Internal Renewable Water Resources (IRWR) | | | | Natural Renewable Water Resources[b] | | | | | | Sectoral Share (Percent)[c] | | | |
| | Groundwater Recharge ($km^3$)[d] | Surface Water ($km^3$)[d] | Overlap ($km^3$) | Total[e] ($km^3$) | Total ($km^3$) | Per Capita ($m^2$ person)[f] | Year | Total (mill $m^3$) | Per Capita ($m^3$ person) | as a % of Renewable Water Resources | Agriculture | Domestic | Industry | Desalinated Water Production (mill $m^3$)[g] |
| Zambia | 47 | 80 | 47 | 80 | 105 | 9,676 | 1994 | 1,706 | 190 | 2 | 77 | 16 | 7 | 0 |
| Zimbabwe | 5.0 | 13 | 4.0 | 14 | 20 | 1,530 | 1987 | 1,220 | 131 | 9 | 79 | 14 | 7 | 0 |
| **North America** | **1,670** | **4,702** | **1,522** | **4,850** | — | — | — | — | — | — | — | — | — | — |
| Canada | 370 | 2,840 | 360 | 2,850 | 2,902 | 92,810 | 1991 | 45,100 | 1,607 | 2 | 12 | 18 | 70 | — |
| United States | 1,300[j] | 1,862[j] | 1,162[j] | 2,800 | 3,051 | 10,574 | 1990 | 467,340 | 1,834 | 26 | 42 | 13 | 45 | — |
| **C. America & Caribean** | **359** | **1,050** | **231** | **1,186** | — | — | — | — | — | — | — | — | — | — |
| Belize | — | — | — | 16 | 19 | 78,763 | 1993 | 95 | 485 | 1 | 0 | 12 | 88 | 0 |
| Costa Rica | 37 | 75 | 0 | 112 | 112 | 26,764 | 1997 | 5,772 | 1,540 | 6 | 80 | 13 | 7 | 0 |
| Cuba | 6.5 | 32 | 0 | 38 | 38 | 3,382 | 1995 | 5,211 | 475 | 14 | 51 | 49 | 0 | 0 |
| Dominican Rep | 12 | 21 | 12 | 21 | 21 | 2,430 | 1994 | 8,339 | 1,102 | 45 | 89 | 11 | 0 | 0 |
| El Salvador | 6.2 | 18 | 6 | 18 | 25 | 3,872 | 1992 | 729 | 137 | 4 | 46 | 34 | 20 | 0 |
| Guatemala | 34 | 101 | 25 | 109 | 111 | 9,277 | 1992 | 1,158 | 126 | 1 | 74 | 9 | 17 | 0 |
| Haiti | 2.2 | 11 | — | 13 | 14 | 1,670 | 1991 | 980 | 139 | 8 | 94 | 5 | 1 | 0 |
| Honduras | 39 | 87 | 30 | 96 | 96 | 14,250 | 1992 | 1,520 | 294 | 2 | 91 | 4 | 5 | 0 |
| Jamaica | 3.9 | 5.5 | 0 | 9.4 | 9 | 3,587.5 | 1993 | 900 | 371 | 10 | 77 | 15 | 7 | 0 |
| Mexico | 139 | 361 | 91 | 409 | 457 | 4,490 | 1998 | 77,812 | 812 | 18 | 78 | 17 | 5 | 0 |
| Nicaragua | 59 | 186 | 55 | 190 | 197 | 36,784 | 1998 | 1,285 | 267 | 1 | 84 | 14 | 2 | 0 |
| Panama | 21 | 144 | 18 | 147 | 148 | 50,299 | 1990 | 1,643 | 685 | 1 | 70 | 28 | 2 | 0 |
| Trinidad and Tobago | — | — | — | 3.8 | 4 | 2,940.4 | 1997 | 297 | 233 | 8 | 6 | 68 | 26 | 0 |
| **South America** | **3,693** | **12,198** | **3,645** | **12,246** | — | — | — | — | — | — | — | — | — | — |
| Argentina | 128 | 276 | 128 | 276 | 814 | 21,453 | 1995 | 28,583 | 822 | 4 | 75 | 16 | 9 | 0 |
| Bolivia | 130 | 277 | 104 | 304 | 623 | 71,511 | 1987 | 1,210 | 197 | 0 | 87 | 10 | 3 | 0 |
| Brazil | 1,874 | 5,418 | 1,874 | 5,418 | 8,233 | 47,125 | 1992 | 54,870 | 359 | 1 | 61 | 21 | 18 | 0 |
| Chile | 140 | 884 | 140 | 884 | 922 | 59,143 | 1987 | 20,289 | 1,629 | 3 | 84 | 5 | 11 | 0 |
| Colombia | 510 | 2,112 | 510 | 2,112 | 2,132 | 49,017 | 1996 | 8,938 | 228 | 0 | 37 | 59 | 4 | 0 |
| Ecuador | 134 | 432 | 134 | 432 | 432 | 32,948 | 1997 | 16,985 | 1,423 | 4 | 82 | 12 | 6 | 0 |
| Guyana | 103 | 241 | 103 | 241 | 241 | 314,963 | 1992 | 1,460 | 1,993 | 1 | 99 | 1 | 1 | 0 |
| Paraguay | 41 | 94 | 41 | 94 | 336 | 58,148 | 1987 | 430 | 112 | 0 | 78 | 15 | 7 | 0 |
| Peru | 303 | 1,616 | 303 | 1,616 | 1,913 | 72,127 | 1992 | 18,973 | 849 | 1 | 86 | 7 | 7 | 0 |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Suriname | 80 | 88 | 80 | 88 | 122 | 289,848 | 1987 | 460 | 1,171 | 0 | 89 | 6 | 5 | 0 |
| Uruguay | 23 | 59 | 23 | 59 | 139 | 41,065 | 1965 | 650 | — | — | 91 | 6 | 3 | 0 |
| Venezuela | 227 | 700 | 205 | 722 | 1,233 | 49,144 | 1970 | 4,100 | 382 | 1 | 46 | 44 | 10 | 0 |
| **Oceania** | **—** | **1,241** | **20** | **1,693** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** |
| Australia | 72 | 440 | 20 | 492 | 492 | 25,185 | 1985 | 14,600 | 933 | 4 | 33 | 65 | 2 | — |
| Fiji | — | — | — | 29 | 29 | 34,330 | 1987 | 30 | 42 | 0 | 60 | 20 | 20 | — |
| New Zealand | — | — | — | 327 | 327 | 85,221 | 1991 | 2,000 | 588 | 1 | 44 | 46 | 10 | — |
| Papua New Guinea | — | 801 | — | 801 | 801 | 159,171 | 1987 | 100 | 29 | 0 | 49 | 29 | 22 | 0 |
| Solomon Islands | — | — | — | 45 | 45 | 93,405 | 1987 | — | — | — | 40 | 40 | 20 | — |
| **Developed** | **3,153** | **12,084** | **2,584** | **13,016** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** |
| **Developing** | **8,128** | **28,500** | **7,483** | **29,289** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** | **—** |

Variable Definitions and Methodology: *Internal Renewable Water Resources* (IRWR) include the average annual flow of rivers and the recharge of groundwater (aquifers) generated from endogenous precipitation — precipitation occurring within a country's borders. IRWR are measured in cubic kilometers per year ($km^3$/year).

*Groundwater recharge* is the total volume of water entering aquifers within a country's borders from endogenous precipitation and surface water flow. Groundwater resources are estimated by measuring rainfall in arid areas where rainfall is assumed to infiltrate into aquifers. Where data are available, groundwater resources in humid areas have been considered as equivalent to the base flow of rivers.

*Surface water* produced internally includes the average annual flow of rivers generated from endogenous precipitation and base flow generated by aquifers. Surface water resources are usually computed by measuring or assessing total river flow occurring in a country on a yearly basis.

*Overlap* is the volume of water resources common to both surface and groundwater. It is subtracted when calculating IRWR to avoid double counting. Two types of exchanges create overlap: contribution of aquifers to surface flow, and recharge of aquifers by surface run-off. In humid temperate or tropical regions, the entire volume of groundwater recharge typically contributes to surface water flow. In karstic domains (regions with porous limestone rock formations), a portion of groundwater resources are assumed to contribute to surface water flow. In arid and semi-arid countries, surface water flows recharge groundwater by infiltrating through the soil during floods. This recharge is either directly measured or inferred by characteristics of the aquifers and piezometric levels.

Total internal renewable water resources is the sum of surface and groundwater resources minus overlap; in other words, IRWR = Surface Water Resources + Groundwater Recharge — Overlap.

*Natural Renewable Water Resources*, measured in cubic kilometers per year ($km^3$/year), is the sum of internal renewable water resources and natural flow originating outside of the country. Natural Renewable Water Resources are computed by adding together both internal renewable water resources (IRWR — see above) and natural flows (flow to and from other countries). Natural incoming flow is the average amount of water which would flow into the country without human influence. In some arid and semi-arid countries, actual water resources are presented instead of natural renewable water resources. These actual totals, labeled with a footnote in the freshwater data table, include the quantity of flows reserved to upstream and downstream countries through formal and informal agreements or treaties. The actual flows are often much lower than natural flow due to water scarcity in arid and semi-arid regions.

*Per Capita Natural Renewable Water Resources* are measured in cubic meters per person per year ($m^3$/person/year). Per capita values were calculated by using national population data for 2002.

*Water Withdrawals (annual)*, measured in million cubic meters, refers to total water removed for human uses in a single year, not counting evaporative losses from storage basins. Water withdrawals also include water from nonrenewable groundwater sources, river flows from other countries, and desalination plants.

*Per Capita Annual Withdrawals* were calculated using national population data for the year the withdrawal data were collected.

*Water Withdrawals as a Percent of Renewable Water Resources* is the proportion of renewable water resources withdrawn on a per capita basis, expressed in cubic meters per person per year ($m^3$/person/year). The value is calculated by dividing water withdrawals per capita by actual renewable water resources per capita.

*Sector Share of water withdrawals*, expressed as a percentage, refers to the proportion of water used for one of three purposes: agriculture, industry, and domestic uses. All water withdrawals are allocated to one of these three categories.

Agricultural uses of water primarily include irrigation and, to a lesser extent, livestock maintenance.

Domestic uses include drinking water plus water withdrawn for homes, municipalities, commercial establishments, and public services (e.g. hospitals).

Industrial uses include cooling machinery and equipment, producing energy, cleaning and washing goods produced as ingredients in manufactured items, and as a solvent.

*(Continued)*



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**Table 7B.11 (Continued)**

Desalinated Water Production, expressed in million cubic meters, refers to the amount of water produced by the removal of salt from saline waters — usually seawater — using a variety of techniques including reverse osmosis. Most desalinated water is used for domestic purposes.

Most Freshwater resources data were provided by AQUASTAT, a global database of water statistics maintained by the Food and Agriculture Organization of the United Nations. AQUASTAT collects its information from a number of sources — national water resources and irrigation master plans; national yearbooks, statistics and reports; FAO reports and project documents; international surveys; and, results from surveys done by national or international research centers. In most cases, a critical analysis of the information was necessary to ensure consistency among the different data collected for a given country.

When possible, cross-checking of information among countries was used to improve assessment in countries where information was limited. When several sources gave different or contradictory figures, preference was always given to information collected at the national or sub-national level. This preference is based on the assumption by FAO that no regional information can be more accurate than studies carried out at the country level. Unless proven to be wrong, official rather than unofficial sources were used. In the case of shared water resources, a comparison among countries was made to ensure consistency at river-basin level.

For more information on the methodology used to collect these data, please refer to the original source or: Food and Agriculture Organization of the United Nations (FAO): Water Resources, Development and Management Service. October, 2001. Statistics on Water Resources by Country in FAO's AQUASTAT Programme (available on-line at fao.org/ag/agl/aglw/aquastat/water_res/index.stm). Rome: FAO.

*Frequency of Update by Data Providers*: AQUASTAT was developed by the Food and Agriculture Organization of the United Nations in 1993; data have been available on-line since 2001. Most freshwater data are not available in a time series, and the global data set contains data collected over a time span of up to 30 years. AQUASTAT updates their website as new data become available, or when FAO conducts special regional studies. Studies were conducted in Africa in 1994, the Near East in 1995–96, the former Soviet republics in 1997, selected Asian countries in 1998–99, and Latin America & the Caribbean in 2000. Data from the Blue Plan on Mediterranean water withdrawals were last updated in 2002. Most data updates include revisions of past data.

*Data Reliability and Cautionary Notes*: While AQUASTAT represents the most complete and careful compilation of country-level water resources statistics to date, freshwater data are generally of poor quality. Information sources are various but rarely complete. Some governments will keep internal water resources information confidential because they are competing for water resources with bordering countries. Many instances of water scarcity are highly localized and are not reflected in national statistics. In addition, the accuracy and reliability of information vary greatly among regions, countries, and categories of information, as does the year in which the information was gathered. As a result, no consistency can be ensured among countries on the duration and dates of the period of reference. All data should be considered order-of-magnitude estimates.

*Groundwater Recharge* tends to be overestimated in arid areas and underestimated in humid areas.

*Natural Renewable Water Resources* vary with time. Exchanges between countries are complicated when a river crosses the same border several times. Part of the incoming water flow may thus originate from the same country in which it enters, making it necessary to calculate a "net" inflow to avoid double counting of resources. In addition, the water that is actually accessible to humans for consumption is often much smaller than the total renewable water resources indicated in the data table.

*Renewable Water Resources Per Capita* contains water resources data from a different set of years than the population data used in the calculation. While the water resources data are usually long-term averages, inconsistencies may arise when combining it with 2002 population data.

*Water Withdrawals as a Percentage of Actual Water Resources* are also calculated using per capita data from two different years. While this ratio can indicate that some countries are depleting their water resources, it does not accurately reflect localized over-extraction from aquifers and streams. In addition, the calculation does not distinguish ground and surface water.

*Sectoral Withdrawal Data* may not add to 100 because of rounding. Evaporative losses from storage basins are not considered; users should keep in mind, however, that in some parts of the world up to 25 percent of water that is withdrawn and placed in reservoirs evaporates before it is used by an sector.

*Desalinated Water Production* may exist in some countries where the volume of production is indicated to be zero, since AQUASTAT assumes that production is zero if no value has been given for those countries where information on water use is available.

[a] Although data were obtained from FAC in 2002, they are long-term averages originating from multiple sources and years. For more information, please consult the original source at fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/water_res/index.stm.
[b] Natural renewable water resources include internal renewable water resources plus or minus the flows of surface and groundwater entering or leaving the country.
[c] Sectoral withdrawal data may not add up to 100 because of rounding.
[d] Groundwater and surface water cannot be added together to calculate total available water resources because of overlap — water that is counted in both the groundwater and surface water totals.
[e] At the country level, total internal renewable water resources = surface water + groundwater — overlap. Regional and global totals represent a sum of available country-level data.
[f] Calculation is based on withdrawals from various years, and population data from 2002.
[g] Data on desalinated water originate from FAO country surveys conducted in various regions between 1992 and 2000.
[h] Data account for the portion of flow secured through treaties or agreements to other countries.
[i] River discharges in Siberia are not well documented and highly uncertain.
[j] Data are for the continental United States.

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*Source*: From World Resources Institute, Earth trends environmental information, *Water Resources and Freshwater Ecosystems*, Data Tables, Freshwater Resources, www.earthtrends.wri.org. With permission.

*Original Source*: Renewable Water Resources: Food and Agriculture Organization of the United Nations (FAO): Water Resources, Development and Management Service. 2002. AQUASTAT Information System on Water in Agriculture: Review of Water Resource Statistics by Country. Rome: FAO. Available on-line at fao.org/waicent/faoinfo/agl/aglw/aquastat/water_res/index.htm.
Water Withdrawals: Food and Agriculture Organisation of the United Nations (FAO): Water Resources, Development and Management Service.2002. AQUASTAT Information System on Water in Agriculture. Rome: FAO. Avaliable on-line at www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/dbase/index.htm. Data for Mediterranean countries were provided directly to WRI from: J. Margat, 2002. Present Water Withdrawals in Mediterranean Countries. Paris: Blue Plan.
Population Data (for per capita calculations): Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. 2002.World Population prospects: The 2000 Revision. New York: United Nations. Data set on CD-ROM.



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**Table 7B.12 Worldwide Freshwater Withdrawal, by Country and Sector**

| Region and Country | Year | Total Freshwater Withdrawal ($km^3$/yr) | Per-Capita Withdrawal ($m^3$/p/yr) | USE | | | | | | Source | 2000 Population (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Domestic (%) | Industrial (%) | Agricultural (%) | Domestic ($m^3$/p/yr) | Industrial ($m^3$/p/yr) | Agricultural ($m^3$/p/yr) | | |
| **Africa** | | | | | | | | | | | |
| Algeria | 2000 | 6.07 | 192 | 22 | 13 | 65 | 42 | 25 | 125 | a | 31.60 |
| Angola | 2000 | 0.34 | 27 | 22 | 16 | 61 | 6 | 4 | 16 | a | 12.80 |
| Benin | 2000 | 0.25 | 40 | 15 | 11 | 74 | 6 | 4 | 30 | a | 6.20 |
| Botswana | 2000 | 0.14 | 86 | 38 | 19 | 43 | 33 | 16 | 37 | a | 1.62 |
| Burkina Faso | 2000 | 0.78 | 65 | 11 | 0 | 88 | 7 | 0 | 57 | a | 12.06 |
| Burundi | 2000 | 0.23 | 33 | 17 | 1 | 82 | 6 | 0 | 27 | a | 6.97 |
| Cameroon | 2000 | 0.73 | 48 | 18 | 8 | 74 | 9 | 4 | 36 | a | 15.13 |
| Cape Verde | 2000 | 0.03 | 68 | 15 | 3 | 83 | 10 | 2 | 56 | a | 0.44 |
| Central African Republic | 2000 | 0.02 | 5 | 77 | 19 | 4 | 4 | 1 | 0 | a | 3.64 |
| Chad | 2000 | 0.23 | 32 | 19 | 1 | 80 | 6 | 0 | 25 | a | 7.27 |
| Comoros | 1987 | 0.01 | 14 | 48 | 5 | 47 | 7 | 1 | 7 | b | 0.71 |
| Congo, Democratic Republic (formerly Zaire) | 2000 | 0.36 | 7 | 52 | 16 | 31 | 4 | 1 | 2 | a | 2.98 |
| Congo, Republic of | 2000 | 0.04 | 13 | 59 | 30 | 10 | 8 | 4 | 1 | a | 51.75 |
| Côte d'Ivoire | 2000 | 0.93 | 61 | 23 | 12 | 65 | 14 | 7 | 40 | a | 15.14 |
| Djibouti | 2000 | 0.01 | 15 | 11 | 0 | 89 | 2 | 0 | 13 | a | 0.69 |
| Egypt | 2000 | 68.65 | 1,008 | 8 | 14 | 78 | 77 | 140 | 791 | a | 68.12 |
| Equatorial Guinea | 2000 | 0.11 | 243 | 83 | 16 | 1 | 202 | 39 | 2 | a | 0.45 |
| Eritrea | 2000 | 0.30 | | 4 | 1 | 95 | | | | a | |
| Ethiopia | 2000 | 2.65 | 38 | 1 | 6 | 93 | 0 | 2 | 35 | a | 69.99 |
| Gabon | 2000 | 0.13 | 105 | 48 | 11 | 40 | 51 | 12 | 43 | a | 1.24 |
| Gambia | 2000 | 0.03 | 24 | 22 | 11 | 67 | 5 | 3 | 16 | a | 1.24 |
| Ghana | 2000 | 0.52 | 26 | 37 | 15 | 48 | 10 | 4 | 13 | a | 19.93 |
| Guinea | 2000 | 1.52 | 193 | 8 | 2 | 90 | 15 | 4 | 174 | a | 7.86 |
| Guinea-Bissau | 2000 | 0.11 | 93 | 9 | 1 | 91 | 8 | 1 | 84 | a | 1.18 |
| Kenya | 2000 | 1.58 | 52 | 30 | 6 | 64 | 16 | 3 | 33 | a | 30.34 |
| Lesotho | 2000 | 0.05 | 22 | 40 | 41 | 19 | 9 | 9 | 4 | a | 2.29 |
| Liberia | 2000 | 0.11 | 34 | 28 | 15 | 56 | 10 | 5 | 19 | a | 3.26 |
| Libya | 2000 | 4.81 | 753 | 8 | 3 | 89 | 62 | 23 | 668 | a | 6.39 |
| Madagascar | 2000 | 14.97 | 861 | 3 | 2 | 96 | 24 | 13 | 823 | a | 17.40 |
| Malawi | 2000 | 1.01 | 92 | 15 | 5 | 81 | 14 | 4 | 74 | a | 10.98 |
| Mali | 2000 | 6.93 | 552 | 1 | 0 | 99 | 4 | 1 | 547 | a | 12.56 |
| Mauritania | 2000 | 1.70 | 659 | 9 | 3 | 88 | 58 | 19 | 582 | a | 2.58 |
| Mauritius | 2000 | 0.61 | 517 | 25 | 14 | 60 | 132 | 74 | 312 | a | 1.18 |
| Morocco | 2000 | 12.76 | 440 | 8 | 2 | 90 | 37 | 7 | 396 | a | 28.98 |
| Mozambique | 2000 | 0.64 | 33 | 11 | 2 | 87 | 4 | 1 | 28 | a | 19.56 |
| Namibia | 2000 | 0.27 | 156 | 33 | 5 | 63 | 51 | 7 | 98 | a | 1.733 |
| Niger | 2000 | 2.19 | 203 | 4 | 1 | 95 | 9 | 1 | 193 | a | 10.81 |
| Nigeria | 2000 | 8.00 | 62 | 21 | 10 | 69 | 13 | 6 | 43 | a | 128.79 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rwanda | 2000 | 0.08 | 10 | 48 | 14 | 39 | 5 | 1 | 4 | a | 7.67 |
| Senegal | 2000 | 1.59 | 167 | 6 | 4 | 90 | 10 | 6 | 151 | a | 9.50 |
| Sierra Leone | 2000 | 0.38 | 78 | 5 | 2 | 93 | 4 | 1 | 73 | a | 4.87 |
| Somalia | 2000 | 3.30 | 286 | 0 | 0 | 100 | 1 | 0 | 285 | a | 11.53 |
| South Africa | 2000 | 15.31 | 331 | 17 | 10 | 73 | 56 | 35 | 241 | a | 46.26 |
| Sudan | 2000 | 37.31 | 1,251 | 3 | 1 | 97 | 33 | 9 | 1,209 | a | 29.82 |
| Swaziland | 2000 | 0.83 | 843 | 3 | 6 | 92 | 23 | 48 | 773 | a | 0.98 |
| Tanzania | 2000 | 2.00 | 59 | 6 | 1 | 93 | 4 | 1 | 55 | a | 33.69 |
| Togo | 2000 | 0.17 | 36 | 45 | 8 | 47 | 16 | 3 | 17 | a | 4.68 |
| Tunisia | 2000 | 2.73 | 278 | 16 | 2 | 82 | 44 | 7 | 227 | a | 9.84 |
| Uganda | 2000 | 0.30 | 13 | 45 | 15 | 39 | 6 | 2 | 5 | a | 22.46 |
| Zambia | 2000 | 1.74 | 191 | 16 | 8 | 76 | 31 | 14 | 145 | a | 9.13 |
| Zimbabwe | 2000 | 2.61 | 210 | 10 | 5 | 86 | 20 | 10 | 180 | a | 12.42 |
| **North and Central America** | | | | | | | | | | | |
| Antigua and Barbuda | 1990 | 0.005 | 75 | 60 | 20 | 20 | 45 | 15 | 15 | g | 0.07 |
| Barbados | 2000 | 0.08 | 308 | 33 | 44 | 23 | 103 | 136 | 69 | a | 0.26 |
| Belize | 2000 | 0.12 | 500 | 11 | 89 | 0 | 56 | 443 | 1 | a | 0.24 |
| Canada | 1990 | 43.89 | 1,431 | 20 | 69 | 12 | 280 | 982 | 168 | d | 30.68 |
| Costa Rica | 2000 | 2.68 | 706 | 29 | 17 | 53 | 208 | 120 | 377 | a | 3.80 |
| Cuba | 2000 | 8.20 | 732 | 19 | 12 | 69 | 139 | 89 | 504 | a | 11.20 |
| Dominica | 1996 | 0.02 | 239 | — | — | — | | | | h | 0.07 |
| Dominican Republic | 2000 | 3.39 | 399 | 32 | 2 | 66 | 128 | 7 | 264 | a | 8.50 |
| El Salvador | 2000 | 1.27 | 201 | 25 | 16 | 59 | 50 | 32 | 119 | a | 6.32 |
| Guatemala | 2000 | 2.00 | 164 | 6 | 13 | 80 | 11 | 22 | 131 | a | 12.22 |
| Haiti | 2000 | 0.98 | 125 | 5 | 1 | 94 | 6 | 1 | 118 | a | 7.82 |
| Honduras | 2000 | 0.86 | 133 | 8 | 11 | 81 | 11 | 15 | 107 | a | 6.49 |
| Jamaica | 2000 | 0.41 | 158 | 34 | 17 | 49 | 54 | 27 | 77 | a | 2.59 |
| Mexico | 2000 | 78.22 | 791 | 17 | 5 | 77 | 137 | 43 | 610 | a | 98.88 |
| Nicaragua | 2000 | 1.30 | 277 | 14 | 3 | 83 | 40 | 7 | 230 | a | 4.69 |
| Panama | 2000 | 0.82 | 287 | 66 | 5 | 28 | 191 | 15 | 81 | a | 2.86 |
| St. Lucia | 1997 | 0.01 | 89 | — | — | — | | | | g | 0.15 |
| St. Vincent and the Grenadines | 1995 | 0.01 | 88 | — | — | — | | | | g | 0.11 |
| Trinidad and Tobago | 2000 | 0.30 | 221 | 67 | 27 | 6 | 149 | 60 | 12 | a | 1.34 |
| United States of America | 2000 | 563.00 | 2,026 | 13 | 46 | 41 | 257 | 933 | 836 | m | 277.83 |
| **South America** | | | | | | | | | | | |
| Argentina | 2000 | 29.07 | 785 | 16 | 9 | 74 | 129 | 74 | 581 | a | 37.03 |
| Bolivia | 2000 | 1.39 | 167 | 13 | 3 | 83 | 22 | 6 | 139 | a | 8.33 |
| Brazil | 2000 | 59.30 | 350 | 20 | 18 | 62 | 71 | 63 | 216 | a | 169.20 |
| Chile | 2000 | 12.54 | 824 | 11 | 25 | 64 | 93 | 208 | 524 | a | 15.21 |
| Colombia | 2000 | 10.71 | 275 | 50 | 4 | 46 | 138 | 10 | 126 | a | 38.91 |
| Ecuador | 2000 | 16.98 | 1,343 | 12 | 5 | 82 | 167 | 71 | 1,104 | a | 12.65 |
| Guyana | 2000 | 1.64 | 1,876 | 2 | 1 | 97 | 32 | 17 | 1,828 | a | 0.87 |
| Paraguay | 2000 | 0.49 | 89 | 20 | 9 | 72 | 18 | 8 | 64 | a | 5.50 |

*(Continued)*



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**Table 7B.12 (Continued)**

| Region and Country | Year | Total Freshwater Withdrawal ($km^3$/yr) | Per-Capita Withdrawal ($m^3$/p/yr) | USE | | | | | | Source | 2000 Population (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Domestic (%) | Industrial (%) | Agricultural (%) | Domestic ($m^3$/p/yr) | Industrial ($m^3$/p/yr) | Agricultural ($m^3$/p/yr) | | |
| Peru | 2000 | 20.13 | 784 | 8 | 10 | 82 | 66 | 79 | 640 | a | 25.66 |
| Suriname | 2000 | 0.67 | 1,482 | 4 | 3 | 93 | 67 | 43 | 1,373 | a | 0.45 |
| Uruguay | 2000 | 3.15 | 962 | 2 | 1 | 96 | 23 | 11 | 928 | a | 3.27 |
| Venezuela | 2000 | 8.37 | 346 | 45 | 7 | 47 | 158 | 24 | 164 | a | 24.17 |
| **Asia** | | | | | | | | | | | |
| Afghanistan | 2000 | 23.26 | 909 | 2 | 0 | 98 | 16 | 0 | 893 | a | 25.59 |
| Armenia | 2000 | 2.95 | 806 | 30 | 4 | 66 | 241 | 35 | 529 | a | 3.66 |
| Azerbaijan | 2000 | 17.25 | 2,204 | 5 | 28 | 68 | 106 | 609 | 1,488 | a | 7.83 |
| Bahrain | 2000 | 0.30 | 485 | 40 | 4 | 57 | 192 | 17 | 276 | a | 0.62 |
| Bangladesh | 2000 | 76.39 | 595 | 3 | 1 | 96 | 19 | 4 | 572 | a | 128.31 |
| Bhutan | 2000 | 0.42 | 207 | 4 | 1 | 95 | 8 | 2 | 197 | a | 2.03 |
| Brunei | 1994 | 0.92 | 2,788 | nd | nd | nd | | | | e | 0.33 |
| Cambodia | 2000 | 4.09 | 365 | 2 | 1 | 98 | 6 | 2 | 357 | a | 11.21 |
| China | 2000 | 549.76 | 431 | 7 | 26 | 68 | 28 | 111 | 292 | k | 1,276.30 |
| Cyprus | 2000 | 0.18 | 228 | 27 | 1 | 71 | 62 | 3 | 163 | p | 0.79 |
| Georgia | 2000 | 3.61 | 666 | 20 | 21 | 59 | 133 | 140 | 393 | a | 5.42 |
| India | 2000 | 645.84 | 641 | 8 | 5 | 86 | 52 | 35 | 555 | a | 1,006.77 |
| Indonesia | 2000 | 82.77 | 389 | 8 | 1 | 91 | 31 | 3 | 356 | a | 212.57 |
| Iran | 2000 | 72.88 | 954 | 7 | 2 | 91 | 65 | 22 | 867 | a | 76.43 |
| Iraq | 2000 | 42.70 | 1,848 | 3 | 5 | 92 | 58 | 85 | 1,704 | a | 23.11 |
| Israel | 2000 | 2.04 | 336 | 31 | 7 | 63 | 103 | 23 | 210 | a | 6.08 |
| Japan | 2000 | 88.43 | 699 | 20 | 18 | 62 | 138 | 125 | 437 | a | 126.43 |
| Jordan | 2000 | 1.02 | 161 | 21 | 4 | 75 | 33 | 7 | 121 | a | 6.33 |
| Kazakhstan | 2000 | 35.01 | 2,068 | 2 | 17 | 82 | 35 | 342 | 1,691 | a | 16.93 |
| Korea Democratic People's Republic | 2000 | 9.02 | 377 | 20 | 25 | 55 | 75 | 95 | 207 | a | 23.91 |
| Korea Rep | 2000 | 18.59 | 397 | 36 | 16 | 48 | 141 | 65 | 190 | a | 46.88 |
| Kuwait | 2000 | 0.45 | 229 | 45 | 3 | 52 | 102 | 7 | 120 | a | 1.97 |
| Kyrgyz Republic | 2000 | 10.08 | 2,219 | 3 | 3 | 94 | 70 | 69 | 2,081 | a | 4.54 |
| Lao People's Dem Rep | 2000 | 2.99 | 525 | 4 | 6 | 90 | 22 | 30 | 473 | a | 5.69 |
| Lebanon | 2000 | 1.37 | 417 | 33 | 1 | 67 | 136 | 2 | 278 | a | 3.29 |
| Malaysia | 2000 | 9.02 | 405 | 17 | 21 | 62 | 68 | 85 | 251 | a | 22.30 |
| Maldives | 1987 | 0.003 | 10 | 98 | 2 | 0 | 10 | 0 | 0 | e | 0.29 |
| Mongolia | 2000 | 0.44 | 161 | 20 | 28 | 52 | 33 | 45 | 83 | a | 2.74 |
| Myanmar | 2000 | 33.22 | 673 | 1 | 1 | 98 | 8 | 4 | 661 | a | 49.34 |
| Nepal | 2000 | 10.18 | 418 | 3 | 1 | 96 | 12 | 3 | 403 | a | 24.35 |
| Oman | 2000 | 1.35 | 497 | 7 | 2 | 91 | 35 | 10 | 452 | a | 2.72 |
| Pakistan | 2000 | 169.38 | 1,086 | 2 | 2 | 96 | 21 | 22 | 1,043 | a | 156.01 |
| Philippines | 2000 | 28.52 | 380 | 17 | 9 | 74 | 63 | 36 | 281 | a | 75.04 |
| Qatar | 2000 | 0.29 | 484 | 25 | 3 | 72 | 122 | 14 | 348 | a | 0.60 |
| Saudi Arabia | 2000 | 17.32 | 800 | 10 | 1 | 89 | 78 | 9 | 712 | a | 21.66 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Singapore | 1975 | 0.19 | 53 | 45 | 51 | 4 | 24 | 27 | 2 | c | 3.59 |
| Sri Lanka | 2000 | 12.60 | 669 | 2 | 2 | 95 | 16 | 16 | 637 | a | 18.82 |
| Syria | 2000 | 19.95 | 1,237 | 3 | 2 | 95 | 41 | 23 | 1,174 | a | 16.13 |
| Tajikistan | 2000 | 11.96 | 1,869 | 4 | 5 | 92 | 69 | 87 | 1,713 | a | 6.40 |
| Thailand | 2000 | 87.07 | 1,439 | 2 | 2 | 95 | 36 | 35 | 1,368 | a | 60.50 |
| Turkey | 2001 | 39.78 | 605 | 15 | 11 | 74 | 90 | 66 | 449 | p | 65.73 |
| Turkmenistan | 2000 | 24.64 | 5,501 | 2 | 1 | 98 | 93 | 42 | 5,366 | a | 4.48 |
| United Arab Emirates | 2000 | 2.31 | 945 | 23 | 9 | 68 | 218 | 82 | 645 | a | 2.44 |
| Uzbekistan | 2000 | 58.33 | 2,332 | 5 | 2 | 93 | 111 | 48 | 2,173 | a | 25.02 |
| Vietnam | 2000 | 71.39 | 886 | 8 | 24 | 68 | 69 | 214 | 604 | a | 80.55 |
| Yemen | 2000 | 6.63 | 366 | 4 | 1 | 95 | 15 | 2 | 349 | a | 18.12 |
| **Europe** | | | | | | | | | | | |
| Albania | 2000 | 1.70 | 487 | 27 | 11 | 62 | 130 | 54 | 302 | a | 3.49 |
| Austria | 1997 | 3.56 | 429 | 35 | 64 | 1 | 151 | 274 | 4 | p | 8.29 |
| Belarus | 2000 | 2.79 | 271 | 23 | 46 | 30 | 64 | 126 | 82 | a | 10.28 |
| Belgium | 1998 | 7.44 | 725 | 13 | 85 | 1 | 96 | 620 | 9 | p | 10.26 |
| Bulgaria | 2002 | 6.59 | 793 | 3 | 78 | 19 | 24 | 621 | 149 | p | 8.31 |
| Czech Republic | 2002 | 1.91 | 187 | 41 | 57 | 2 | 76 | 107 | 4 | p | 10.20 |
| Denmark | 2002 | 0.67 | 127 | 32 | 26 | 42 | 41 | 32 | 54 | p | 5.27 |
| Estonia | 2002 | 1.41 | 994 | 56 | 39 | 5 | 554 | 392 | 49 | p | 1.42 |
| Finland | 1999 | 2.33 | 450 | 14 | 84 | 3 | 61 | 377 | 12 | p | 5.18 |
| France | 2000 | 30.90 | 523 | 16 | 74 | 10 | 82 | 390 | 51 | p | 59.06 |
| Germany | 2001 | 38.00 | 460 | 12 | 68 | 20 | 57 | 312 | 91 | p | 82.69 |
| Greece | 1997 | 8.70 | 821 | 16 | 3 | 81 | 134 | 26 | 661 | p | 10.60 |
| Hungary | 2001 | 4.55 | 464 | 9 | 59 | 32 | 43 | 272 | 149 | p | 9.81 |
| Iceland | 2002 | 0.16 | 567 | 34 | 66 | 0 | 193 | 374 | 1 | p | 0.28 |
| Ireland | 1980 | 1.07 | 299 | 23 | 77 | 0 | 68 | 232 | 0 | p | 3.57 |
| Italy | 1998 | 42.00 | 734 | 18 | 37 | 45 | 134 | 270 | 331 | p | 57.19 |
| Latvia | 2001 | 0.26 | 108 | 55 | 33 | 12 | 60 | 36 | 13 | p | 2.40 |
| Lithuania | 2002 | 3.13 | 848 | 78 | 15 | 7 | 662 | 131 | 56 | p | 3.69 |
| Luxembourg | 1999 | 0.06 | 133 | 42 | 45 | 13 | 56 | 60 | 17 | p | 0.43 |
| Malta | 2000 | 0.02 | 53 | 74 | 1 | 25 | 39 | 0 | 13 | p | 0.38 |
| Moldova | 2000 | 2.31 | 518 | 9 | 58 | 33 | 49 | 298 | 171 | a | 4.46 |
| Netherlands | 2001 | 8.80 | 554 | 6 | 60 | 34 | 34 | 333 | 188 | p | 15.87 |
| Norway | 1996 | 2.40 | 545 | 23 | 67 | 10 | 123 | 364 | 57 | p | 4.41 |
| Poland | 2002 | 11.73 | 303 | 13 | 79 | 8 | 39 | 238 | 25 | p | 38.73 |
| Portugal | 1990 | 7.29 | 745 | 10 | 12 | 78 | 72 | 90 | 583 | p | 9.79 |
| Romania | 2002 | 7.24 | 322 | 9 | 34 | 57 | 28 | 111 | 183 | p | 22.51 |
| Russian Federation | 2000 | 76.69 | 525 | 19 | 63 | 18 | 98 | 333 | 93 | a | 146.20 |
| Slovak Republic | 2002 | 1.09 | 203 | | | | | | | p | 5.37 |
| Slovenia | 2001 | 0.30 | | | | | | | | p | |
| Spain | 2001 | 38.60 | 670 | 13 | 19 | 68 | 130 | 180 | 660 | p | 39.80 |
| Sweden | 2002 | 2.69 | 302 | 37 | 54 | 9 | 111 | 164 | 27 | p | 8.90 |
| Switzerland | 2001 | 2.54 | 343 | 24 | 74 | 2 | 83 | 253 | 7 | p | 7.41 |
| Ukraine | 2000 | 37.52 | 739 | 12 | 35 | 52 | 90 | 261 | 388 | a | 50.80 |
| United Kingdom | 1994 | 11.75 | 201 | 22 | 75 | 3 | 44 | 152 | 6 | d | 58.34 |
| Yugoslavia,[q] former | 1980 | 8.77 | 368 | 16 | 72 | 12 | 59 | 265 | 44 | c | 23.81 |

*(Continued)*



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**Table 7B.12 (Continued)**

| Region and Country | Year | Total Freshwater Withdrawal ($km^3$/yr) | Per-Capita Withdrawal ($m^3$/p/yr) | USE | | | | | | Source | 2000 Population (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Domestic (%) | Industrial (%) | Agricultural (%) | Domestic ($m^3$/p/yr) | Industrial ($m^3$/p/yr) | Agricultural ($m^3$/p/yr) | | |
| **Oceania** | | | | | | | | | | | |
| Australia | 1995 | 17.80 | 945 | 15 | 10 | 75 | 139 | 95 | 711 | [f] | 18.84 |
| Fiji | 2000 | 0.07 | 83 | 11 | 11 | 78 | 9 | 9 | 65 | [a] | 0.85 |
| New Zealand | 2000 | 2.11 | 561 | 49 | 9 | 42 | 272 | 53 | 236 | [a] | 3.76 |
| Papua New Guinea | 1987 | 0.10 | 21 | 56 | 43 | 1 | 12 | 9 | 0 | [c] | 4.81 |
| Solomon Islands | 1987 | | | 40 | 20 | 40 | 0 | 0 | 0 | [c] | 0.44 |

*Note:* Figures may not add to totals due to independent rounding. 2000 Population numbers: medium United Nations variant.

Limitations: Extreme care should be used when applying these data — they are often the least reliable and most inconsistent of all water resources information. They come from a wide variety of sources and are collected using different approaches with few formal standards. Consistent data collection is needed in this area, using standard methods and assumptions. As a result, this table includes data that are actually measured, estimated, modeled using different assumptions, or derived from other data. The data also come from different years, making direct comparisons difficult, though the effort of FAO to standardize water-use data for 2000 has somewhat reduced this problem. Industrial withdrawals for Panama, St. Lucia, St. Vincent, and the Grenadines are included in the domestic category. Another major limitation of these data is that they do not include the use of rainfall in agriculture. Many countries use a significant fraction of the rain falling on their territory for agricultural production, but this water use is neither accurately measured nor reported.

[a] New FAO Aquastat estimates from www.fao.org. March 2004.
[b] World Resources Institute, 1990, *World resources* 1990–1991, New York: Oxford University Press.
[c] World Resources Institute, 1994, *World resources* 1994–1995, in collaboration with the United Nations Environment Programme and the United Nations Development Programme, New York: Oxford University Press.
[d] Eurostat Yearbook, 1997. *Statistics of the European Union*, EC/C/6/Ser.26GT, Luxembourg.
[e] UNFAO 1999. Irrigation in Asia in figures. Food and Agriculture Organization, United Nations, Rome.
[f] Nix, H. 1995. Water/Land/Life, Water Research Foundation of Australia, Canberra.
[g] UNFAO. 2000. *Irrigation in Latin America and the Caribbean*. Food and Agricultural Organization, United Nations, Rome.
[h] AQUASTAT web site January 2002. www.fao.org.
[k] Ministry of Water Resources, China. 2001. *Water resources bulletin of China, 2000*. People's Republic of China, Beijing, September.
[m] Hutson, S. S., Barber, N. L., Kenny, J. E., Linsey, K. S., Lumia, D. S., and Maupin, M. A. 2004. *Estimated use of water in the United States in 2000*. United States Geological Survey, Circular 1268. Reston, Virginia.
[p] See Wieland, U. 2003. *Water use and waste water treatment in the European Union and in candidate countries*. Eurostat Statistics in Focus, Theme 8. European Communities. And Eurostat. 2004. Statistics in Focus. europa.eu.int/comm/eurostat europa.eu.int/comm/eurostat/newcronos/queen/display.do?screen=detail&language=en&product=THEME8&root=THEME8_ copy_151979619462/yearlies_copy_1067300085946/dd_copy_251110364103/dda_copy_649289610368/dda10512_copy_729379227605.
[q] Includes Bosnia and Herzegovina, Macedonia, Croatia.

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**Table 7B.13 Freshwater Abstractions by Major Use in Selected Countries, 1980–1999**

| | Public Water Supply (b) | | | | Irrigation (b) | | | | Manufacturing Industry No Cooling (b) | | | | Electrical Cooling (b) Percent | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1985 | 1990 | 1999 (c) | 1980 | 1985 | 1990 | 1999 (c) | 1980 | 1985 | 1990 | 1999 (c) | 1980 | 1985 | 1990 | 1999 (c) |
| Canada | 11.3 | 11.1 | 11.3 | — | 7.4 | 7.0 | 7.1 | — | 8.6 | 8.9 | 7.9 | — | 39.9 | 56.9 | 59.7 | — |
| Mexico | 7.5 | — | — | 12.6 | 82.1 | — | — | 82.7 | 10.4 | — | — | 4.5 | 0.1 | — | — | 0.2 |
| U.S.A. | 9.1 | 10.8 | 11.4 | — | 38.7 | 40.5 | 40.2 | — | 10.4 | 6.6 | 5.7 | — | 40.4 | 38.7 | 38.6 | — |
| Japan | 14.9 | 16.5 | 17.7 | 18.5 | 67.4 | 67.1 | 65.9 | 66.1 | 17.6 | 16.6 | 16.3 | 15.4 | — | — | — | — |
| Korea | 10.9 | 14.8 | 21.8 | 27.0 | 80.5 | 76.4 | 68.4 | 60.1 | 8.6 | 8.8 | 9.7 | 12.9 | — | — | — | — |
| Australia | — | 12.3 | — | — | 74.3 | 69.9 | — | 74.6 | — | 5.5 | — | — | — | — | — | — |
| New Zealand | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Austria | 16.7 | 17.8 | 16.4 | 17.0 | 1.5 | 1.6 | 1.3 | 1.5 | 46.7 | 45.7 | 39.0 | 36.1 | 33.9 | 33.7 | 41.9 | 44.1 |
| Belgium | — | — | — | 9.8 | — | — | — | 0.1 | — | — | — | 5.1 | — | — | — | 57.0 |
| Czech Rep. | 28.0 | 32.1 | 35.0 | 42.0 | 1.1 | 1.4 | 2.7 | 0.4 | 28.4 | 26.7 | 24.5 | 21.7 | 33.6 | 31.3 | 29.3 | 27.6 |
| Denmark | 58.1 | — | 45.3 | 58.4 | 7.5 | — | 15.4 | 18.6 | 3.7 | — | 17.8 | 8.4 | — | — | — | — |
| Finland | 10.5 | 10.2 | 18.1 | 17.4 | — | 0.5 | 0.9 | 1.7 | — | — | 69.0 | 67.4 | — | — | 10.6 | 11.0 |
| France | 17.5 | 16.9 | 16.2 | 19.4 | 14.1 | 12.8 | 13.0 | 11.0 | 17.9 | 14.7 | 11.8 | 12.8 | 50.4 | 55.5 | 59.1 | 56.7 |
| Germany | 12.0 | 12.4 | 13.6 | 13.7 | — | — | 3.3 | 0.4 | 6.8 | 5.8 | 15.8 | 14.3 | 60.4 | 62.0 | 60.1 | 65.0 |
| Greece | 12.2 | 11.9 | — | 9.9 | 82.5 | 83.7 | — | 87.4 | 2.7 | 2.4 | — | 1.3 | 1.8 | 2.0 | — | 1.4 |
| Hungary | 16.7 | 14.8 | 16.0 | 12.7 | 7.0 | 4.6 | 8.5 | 1.2 | 2.2 | 1.4 | 1.4 | 0.2 | 49.7 | 60.0 | 62.2 | 75.4 |
| Iceland | 85.2 | 85.7 | 50.9 | 47.4 | — | — | — | — | 9.3 | 8.9 | 6.0 | 6.4 | — | — | — | 0.0 |
| Ireland | 34.0 | — | — | — | 12.1 | — | — | — | 23.4 | — | — | — | 25.9 | — | — | — |
| Italy | 14.2 | — | 14.1 | 18.0 | 57.3 | — | — | 46.0 | 14.2 | — | — | 17.0 | 12.5 | — | — | 19.0 |
| Luxembourg | — | — | 95.0 | 62.6 | — | — | 0.3 | 0.3 | — | — | 4.7 | 23.2 | — | — | — | — |
| The Netherlands | 11.2 | 11.9 | 16.4 | 28.6 | — | — | — | — | 2.1 | 2.0 | 2.5 | 4.3 | 65.4 | 70.4 | 65.9 | 54.5 |
| Norway | — | 30.1 | — | — | — | 3.4 | — | — | — | 64.6 | — | — | — | — | — | — |
| Poland | 19.2 | 18.9 | 21.1 | 21.2 | 2.0 | 3.4 | 3.3 | 0.8 | 12.9 | 10.6 | 9.7 | 4.7 | 50.7 | 53.1 | 51.3 | 60.1 |
| Portugal | — | — | 4.7 | 6.8 | — | — | 59.3 | 79.1 | — | — | 12.8 | 3.4 | — | — | 23.3 | 11.2 |
| Slovak Rep. | — | 28.3 | 30.4 | 37.5 | — | 5.9 | 12.6 | 0.8 | — | 63.7 | 53.5 | 58.4 | — | — | — | — |
| Spain | 11.8 | 11.6 | 11.9 | 13.2 | 65.7 | 65.7 | 64.2 | 68.2 | — | — | 5.1 | 4.7 | 22.5 | 22.7 | 12.2 | 13.9 |
| Sweden | 23.3 | 32.8 | 32.9 | 35.1 | 1.6 | 3.2 | 3.2 | 3.7 | 43.3 | 37.4 | 37.5 | 28.3 | — | 0.9 | 0.9 | 1.0 |
| Switzerland | 42.6 | 43.2 | 43.6 | 41.4 | — | — | — | — | — | — | — | — | 57.4 | 56.8 | 56.4 | 58.6 |
| Turkey | — | 14.4 | 14.2 | 14.7 | — | 73.7 | 53.9 | 75.1 | — | 11.9 | 7.6 | 10.3 | — | — | — | 0.1 |
| UK | 43.7 | 52.8 | 55.5 | 53.1 | 0.6 | 0.7 | 1.5 | 1.1 | 13.8 | 9.1 | 7.4 | 5.4 | 28.1 | 21.6 | 20.0 | 11.3 |
| Russian Fed. | 9.7 | — | 12.0 | 18.7 | — | — | — | — | — | — | 12.9 | 12.0 | — | — | 24.5 | 27.9 |

*Note*: a) In general, the data for the four sectors will not sum to 100%, since "agricultural uses other than irrigation", "agricultural uses other than irrigation", "industrial cooling", and "other uses" are not covered here. Exceptions occur when the % are based on partial totals or the categories presented include other uses.
b) "Public water supply" refers to water supply by waterworks, and may include other uses besides the domestic sector. "Irrigation", "Industry no cooling" and "Electrical cooling" refer to self supply (abstraction for own final use).
c) Data refer to 1999 or latest available year. Data prior to 1995 have not been considered.

*Note:* CAN, 1980, 1985 and 1990: 1981, 1986 and 1991 data; MEX, 1980: % based on totals excluding agricultural uses other than irrigation. Industry no cooling: includes cooling. Electrical cooling 1980: data include Secretariat estimates; U.S.A., Industry no cooling: includes cooling; JPN, Industry no cooling: includes industrial and electrical cooling; KOR, % based on partial totals: electrical cooling excluded. Public supply: data refer to domestic sector. Irrigation: includes other agric, uses. Industry no cooling includes cooling, 1999: 1997 data; AUS, 1980: 1977 data adjusted for average climatic year. 1985: data refer to fiscal year 1983/84 and to both waterworks and self-supply; public supply: data refer to domestic sector; industry no cooling: may include industrial and electrical cooling, 1999: 1996/97 data; NZL, % based on partial totals; AUT, % based on partial totals. Irrigation and industry no cooling: groundwater only. Electrical cooling (includes all industrial cooling): surface water only. 1990:1992 data; irrigation includes other agricultural abstractions. 1999: 1997 data; BEL, 1999: 1998 data including Secretariat estimates; CZE, Industry no cooling: includes cooling; DNK, 1980: 1977 data. 1990; % based on totals referring to groundwater abstractions only, which represent the majority of total freshwater abstractions (e.g. 95–99% for 1995). Industry no cooling: includes some industrial and electrical cooling (self-supply). 1999: 1998 data, Irrigation: 1995 data; FIN, % based on partial total: 1985 and 1990 exclude agricultural uses besides irrigation (1985 data); industry no cooling: includes cooling. Irrigation: 1999 data is country estimate; FRA, 1980 and 1999: 1981 and 1997 data. Irrigation: includes other agricultural uses, but irrigation is the main use. Industry no cooling: includes cooling. 1997: break in time series; DEU, % based on totals excluding agricultural uses other than irrigation. Industry no cooling: includes cooling. 1980 and 1985: 1979 and 1983 data, for western Germany only. 1990 and 1999: 1991 and 1998 data for total Germany; GRC, % based on partial totals excluding agricultural uses other than irrigation, 1999: 1997 data. Public water supply: supply by 42 out of 75 great water distribution enterprises; HUN, 1999: 1998 data; ISL, Public supply: includes the domestic use of geothermal water. Industry no cooling: includes cooling. After 1985, fish farming is a major user of abstracted water, explaining the change in the relative contribution of other sectors. 1990: 1992 data; IRL, Industry no cooling: includes cooling. Irrigation: includes other agricultural uses (e.g. rural domestic use). % based on totals including 1980 data for electrical cooling; ITA, % based on totals excluding agricultural uses besides irrigation. 1990 and 1999: 1989 and 1998 data; LUX, Industry no cooling: includes cooling. 1990: 1989 data, except for industry and electrical cooling (1983 data); irrigation; estimated data; NLD, % based on partial totals excluding all agricultural uses. 1980, 1985, 1990 and 1999: 1981, 1986, 1991 and 1996 data; NOR, Data include 1978 data for industry. 1985: 1983 data. Industry no cooling: includes industrial cooling; POL, % based on totals including abstractions for agriculture, which include aquaculture (areas over 10 ha) and irrigation (Arabic land and forest areas greater than 20 ha); animal production and domestic needs of rural inhabitants are not covered (selfsupply); PRT, % based on totals excluding agricultural uses besides irrigation. 1990 and 1999: 1991 and 1998 data; SLO, Irrigation: Secretariat estimates. Industry no cooling: includes cooling; ESP, % based on totals excluding agricultural uses other than irrigation. Industry no cooling: surface water only; includes industrial cooling. Electrical cooling: until 1990 data include total industrial use. 1990 and 1999: 1991 and 1997 data; SWE, Irrigation: 1980 and refer to 1976; since 1985 data are estimates for dry year. Industry no cooling: 1980 data refer to 1974 and include mining and quarrying and electrical cooling: 1985 and 1990 data refer to 1983. Electrical cooling: 1985 and 1990 data refer to 1983. 1999: 1995 data; CHE, % based on partial totals excluding all agricultural uses. Public supply: includes industry (total industry—ISIC 10–45 rev. 3), which totals 215 million $m^3$ (1994), and other activities (101 million $m^3$ (1994)). 1999: 1998 data; TUR, % based on totals excluding agricultural uses other than irrigation. 1985: % based on partial totals excluding electrical cooling. Industry no cooling: includes cooling. 1990: 1991 data. Electrical cooling 1999: estimation (1995 data); UKD, England and Wales only. Data include miscellaneous uses for power generation, but exclude hydroelectric power water use; RUS, 1990 and 1999: 1991 and 1996 data.

*Source*: From Table 3.1C, OECD Environmental Data Compendium 2002, © OCED 2002, www.oecd.org.

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**Table 7B.14 Worldwide Fresh Water Utilization by Purpose, 2000**

| World/ Continent | Total Volume of Fresh Water Utilization ($km^3$/yr) | Fresh Water Utilization by Purpose | | | | | | Utilization [a] as % of Resources |
|---|---|---|---|---|---|---|---|---|
| | | Domestic Use | | Industrial Use | | Agricultural Use | | |
| | | ($km^3$/yr) | % | ($km^3$/yr) | % | ($km^3$/yr) | % | |
| **World** | 3820.3 | 377.4 | 9.9 | 790.7 | 20.7 | 2 652.2 | 69.4 | 8.9 |
| **Developed countries** | 1239.2 | 165.2 | 13.3 | 509.1 | 41.1 | 564.9 | 45.6 | 9.0 |
| Industrialized countries | 893.5 | 131.3 | 14.7 | 395.6 | 44.3 | 366.6 | 41.0 | 10.2 |
| Transition economies | 345.7 | 33.9 | 9.8 | 113.5 | 32.8 | 198.3 | 57.4 | 7.1 |
| **Developing countries** | 2581.1 | 212.2 | 8.2 | 281.6 | 10.9 | 2 087.3 | 80.9 | 8.9 |
| Latin America and the Caribbean | 265.1 | 50.4 | 19.0 | 27.4 | 10.3 | 187.3 | 70.7 | 2.0 |
| Near East and North Africa | 322.6 | 25.1 | 7.8 | 19.5 | 6.0 | 278.0 | 86.2 | 62.5 |
| Sub-Saharan Africa | 98.1 | 6.9 | 7.0 | 2.8 | 2.9 | 88.3 | 90.1 | 2.5 |
| East and Southeast Asia | 977.4 | 71.2 | 7.3 | 192.3 | 19.7 | 714.0 | 73.0 | 11.2 |
| South Asia | 917.8 | 58.7 | 6.4 | 39.6 | 4.3 | 819.6 | 89.3 | 52.1 |
| Oceania developing | 0.1 | 0.0 | 34.2 | 0.0 | 27.6 | 0.1 | 38.2 | 0.0 |
| North America developing | — | — | — | — | — | — | — | — |
| **Continental groupings** | | | | | | | | |
| Africa | 208.4 | 17.9 | 8.6 | 15.2 | 7.3 | 175.2 | 84.1 | 5.3 |
| Asia | 2377.1 | 171.5 | 7.2 | 270.2 | 11.4 | 1 935.5 | 81.4 | 20.4 |
| Latin America | 251.7 | 47.3 | 18.8 | 26.1 | 10.4 | 178.3 | 70.8 | 1.9 |
| Caribbean | 13.4 | 3.1 | 22.9 | 1.3 | 9.4 | 9.1 | 67.7 | 15.7 |
| North America | 525.3 | 69.8 | 13.3 | 252.3 | 48.0 | 203.2 | 38.7 | 9.3 |
| Oceania | 26.2 | 4.6 | 17.6 | 2.6 | 10.1 | 19.0 | 72.4 | 1.6 |
| Europe | 418.2 | 63.2 | 15.1 | 223.0 | 53.3 | 132.0 | 31.6 | 6.5 |

*Source*: From FAO, 2003, *Summary of Food and Agricultural Statistics*, www.fao.org. With permission.

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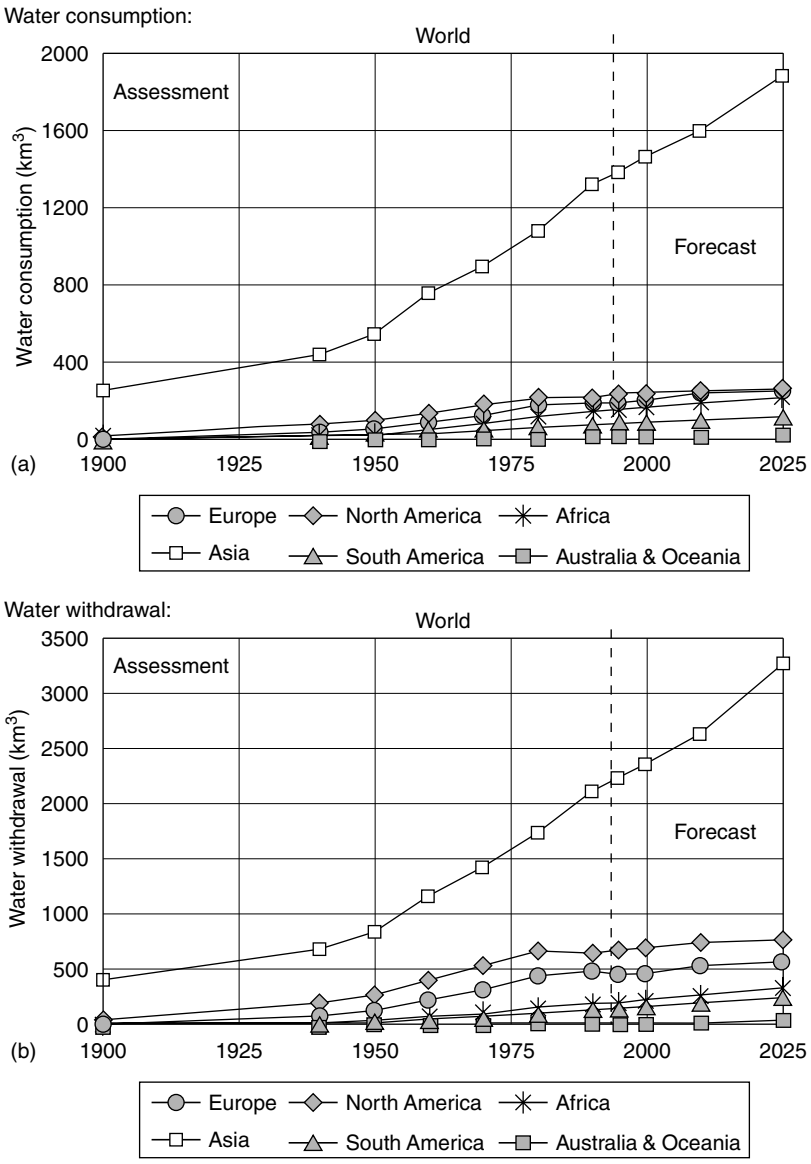


**Figure 7B.8** Dynamics of water use in the world by continents. (From Shiklomanov, I.A., 1999, Summary of the Monograph "World Water Resources at the Beginning of the 21st Century" Prepared in the Framework of IHP UNESCO, International Hydrological Programme, UNESCO'S, Intergovernmental Scientific Programme in Water Resources, World Water Resources and Their Use a Joint State Hydrological Institute (SHI)/UNESCO Product, http://webworld.unesco.org/water/ihp/db/shiklomanov/. Copyright © UNESCO 1999. Reproduced by permission of UNESCO.)

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**Table 7B.15 Freshwater Abstractions by Source, in Selected Countries 1980–1999**

| | Per Capita/ ($m^3$/Capita) (b) | As % of Resources/ (a) (b) | Total Abstractions (mill $m^3$) | | | | Surface Water (mill $m^3$) | | | | Groundwater (mill $m^3$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1980 | 1985 | 1990 | 1999 (c) | 1980 | 1985 | 1990 | 1999 (c) | 1980 | 1985 | 1990 | 1999 (c) |
| Canada | 1610 | 1.7 | 37594 | 42383 | 45096 | 47250 | 36733 | 41486 | 44059 | — | 861 | 897 | 1037 | — |
| Mexico | 800 | 16.2 | 56003 | — | — | 78402 | 39374 | — | — | 53017 | 16629 | 23500 | 24453 | 25385 |
| U.S.A. | 1870 | 19.9 | 517720 | 467335 | 468620 | 492260 | 402750 | 366095 | 358790 | — | 114970 | 101420 | 109830 | — |
| Japan | 710 | 21.2 | 86000 | 87200 | 88900 | 89100 | 74100 | 75300 | 76600 | 77300 | 11900 | 11900 | 12200 | 11900 |
| Korea | 540 | 34.3 | 17510 | 18580 | 20600 | 24800 | — | — | — | 22200 | — | — | — | 2600 |
| Australia | 1300 | 6.8 | 10900 | 14600 | — | 24071 | — | 12360 | — | 19109 | — | 2240 | — | 4962 |
| N. Zealand | 570 | 0.6 | 1200 | 1900 | — | 2000 | — | — | — | 1200 | — | — | — | 800 |
| Austria | 440 | 4.2 | 3342 | 3363 | 3734 | 3561 | 2207 | 2195 | 2561 | 2496 | — | 1168 | 1135 | 1065 |
| Belgium | 730 | 45.1 | — | — | — | 7442 | — | — | — | 6802 | — | — | — | 641 |
| Czech Rep. | 190 | 12.4 | 3622 | 3679 | 3623 | 1976 | 2820 | 2873 | 2787 | 1419 | 802 | 806 | 836 | 557 |
| Denmark | 140 | 12.3 | 1205 | — | 1261 | 754 | 45 | — | — | 20 | 1160 | — | 1261 | 734 |
| Finland | 450 | 2.1 | 3700 | 4000 | 2347 | 2328 | 3510 | 3680 | 2107 | 2043 | 190 | 320 | 240 | 285 |
| France | 520 | 15.9 | 30972 | 34887 | 37687 | 30341 | 25268 | 28714 | 31486 | 24240 | 5704 | 6173 | 6201 | 6101 |
| Germany | 490 | 22.3 | 42206 | 41216 | 47873 | 40591 | 35344 | 34225 | — | 33880 | 6862 | 6991 | — | 6710 |
| Greece | 830 | 12.1 | 5040 | 5496 | — | 8695 | 3470 | — | — | 5023 | 1570 | — | — | 3563 |
| Hungary | 560 | 4.7 | 4805 | 6267 | 6293 | 5653 | 3551 | 4880 | 5266 | 4822 | 1254 | 1386 | 1026 | 831 |
| Iceland | 560 | 0.1 | 108 | 112 | 167 | 156 | 5 | 8 | 7 | 4 | 103 | 104 | 160 | 152 |
| Italy | 980 | 32.1 | 56200 | 52000 | 56200 | 56200 | — | 4000 | — | — | — | 12000 | — | — |
| Luxembourg | 140 | 3.7 | — | 67 | 59 | 60 | — | 22 | 32 | 29 | — | 45 | 27 | 32 |
| The Netherlands | 290 | 4.9 | 9198 | 9302 | 7806 | 4425 | 8190 | 8231 | 6757 | 3427 | 1008 | 1071 | 1049 | 998 |
| Norway | 600 | 0.7 | — | 2025 | — | 2588 | — | 1620 | — | — | — | 405 | — | — |
| Poland | 290 | 17.9 | 14184 | 15453 | 14248 | 11275 | 11899 | 13076 | 11928 | 9339 | 2285 | 2377 | 2320 | 1936 |
| Portugal | 1110 | 15.2 | — | — | 8600 | 11090 | — | — | — | 4800 | — | — | — | 6290 |
| Slovak Rep. | 210 | 1.4 | 2232 | 2061 | 2116 | 1149 | 1575 | 1390 | 1388 | 684 | 657 | 671 | 728 | 465 |
| Spain | 1040 | 36.8 | 39920 | 46250 | 36900 | 40855 | 34800 | 40840 | 31400 | 35323 | 5120 | 5410 | 5500 | 5532 |
| Sweden | 300 | 1.5 | 4106 | 2970 | 2968 | 2668 | 3511 | 2348 | 2360 | 2026 | 595 | 622 | 608 | 642 |
| Switzerland | 360 | 4.8 | 2589 | 2646 | 2665 | 2566 | 1667 | 1693 | 1724 | 1689 | 922 | 953 | 941 | 877 |
| Turkey | 590 | 16.6 | 16200 | 19400 | 32200 | 38900 | 11800 | 14100 | 25600 | 29552 | 4400 | 5300 | 6600 | 6000 |
| UK | 210 | 17.4 | 13514 | 11533 | 12052 | 11162 | 11024 | 9012 | 9344 | 8658 | 2490 | 2521 | 2709 | 2504 |
| Russian Fed. | 560 | 1.9 | 113178 | 117273 | 126083 | 82064 | 101799 | 103407 | 111297 | 72420 | 11379 | 13866 | 14786 | 11624 |
| N. America | 1600 | 11.0 | 611300 | 572000 | 581700 | 617900 | — | — | — | — | — | — | — | — |
| OECD/Europe | 560 | 13.9 | 271400 | 282700 | 299100 | 285600 | — | — | — | — | — | — | — | — |
| EU-15 | 600 | 19.4 | 225600 | 231000 | 235400 | 221300 | — | — | — | — | — | — | — | — |
| OECD | 950 | 11.8 | 998300 | 977000 | 1006800 | 1043500 | — | — | — | — | — | — | — | — |

*Source*: From Table 3.1C, OECD Environmental Data Compendium 2002, © OECD 2002, www.oecd.org.

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*Note:* CAN, 1980, 1985, and 1990: 1981, 1986, and 1991 data. 1999: WWF estimate for 1995; MEX, 1980: excluding agricultural uses besides irrigation. Data include Secretariat estimates for electrical cooling based on electricity generated in power stations in 1980. 1999: Total gross abstraction excluding 143 $km^3$ used in hydroelectric energy generation; U.S.A., 1999: WWF estimate for 1995; JPN, 1999: 1997 data; KOR, Partial totals excluding electrical cooling. 1999: 1997 data; AUS, 1980: 1977 data adjusted for an average climatic year. 1985: fiscal year 1983/84. 1999: 1996/97 data; NZL, Partial totals excluding industrial and electrical cooling. 1980: composite total based on data for various years. 1999: 1993 estimates; AUT, Partial totals. Surface water: excluding agriculture, irrigation and industry except cooling. Groundwater: excluding industry and electrical cooling. 1999: 1997 data; BEL, 1999: 1998 data; data include Secretariat estimates; DNK, 1980 and 1999: 1977 and 1998 data. 1990 refer only to groundwater abstractions, which represent the majority of total freshwater abstractions (e.g. 95–99% for 1995); FIN, Partial totals. 1985 and 1990: exclude agricultural uses besides irrigations. 1999: includes country estimate for agriculture; FRA, 1980 and 1999: 1981 and 1997 data. 1997: Break in time series; DEU, Excluding agricultural uses besides irrigation. 1980 and 1985: 1979 and 1983 data for western Germany only. 1990 and 1999: 1991 and 1998 data for total Germany. Data include electrical cooling; GRC, Partial totals excluding agricultural uses besides irrigation. 1999: 1997 data including, for public water supply, data from 42 out of 75 great water distribution enterprises; HUN, 1999: 1998 data; ISL, Totals include the domestic use of geothermal water. 1990: 1992 data; IRL, 1999: 1994 data; totals include 1980 data for electrical cooling; ITA, Excluding agricultural uses besides irrigation. 1980: including 1973 estimates for industrial cooling. 1990 and 1999: 1989 and 1998 data; LUX, 1990: 1989 data, including 1983 data; NLD, Partial totals excluding all agricultural uses. 1980, 1985, 1990 and 1999: 1981, 1986, 1991 and 1996 data; NOR, Data include 1978 data for industry. 1985: 1983 data. 1999: data are estimates for 1994; POL, Totals include abstractions for agriculture, which refer to aquaculture (areas over 10 ha) and irrigation (arable land and forest areas greater than 20 ha); animal production and domestic needs of rural inhabitants are not covered (selfsupply); PRT, Excluding agricultural uses besides irrigation. 1990: 1991 data. 1999: 1998 data; ESP, Excluding agricultural uses besides irrigation. Groundwater: excluding industry. 1990 and 1999: 1991 and 1997 data; SWE, 1980, 1985 and 1990: include data from different years. 1999: 1995 data; CHE, Partial totals excluding all agricultural uses. 1999: 1998 data; TUR, Partial totals. Excluding agricultural uses besides irrigation. 1980 and 1985: excluding electrical cooling. 1990: 1991 data. 1999: total: country estimates; surface and groundwater: 1997 data; UKD, Partial totals. England Wales only. Data include miscellaneous uses for power generation, but exclude hydroelectric power water use; RUS, 1990: 1991 data; Totals, Rounded figures, including Secretarial estimates. OECD and EU until 1985: western Germany only. % of renewable resources: calculated using the estimated totals for internal resources (not total resources as for countries), and considering England and Wales only.

[a] Data refer to total abstraction divided by total renewable resources, except for regional totals, where the internal resource estimates were used to avoid double counting. Total renewable resources represent the maximum quantity of water available on average.
[b] Data refer to 1999 or latest available year. Data prior to 1994 have not been considered.
[c] Data refer to 1999 or latest available year.

*Source*: From Table 3.1B, OECD Environmental Data Compendium 2002, © OCED 2002, www.oecd.org.



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**Table 7B.16 Worldwide Annual Groundwater Withdrawals and Desalinization**

| | Average Annual Groundwater Recharge | | Annual Groundwater Withdrawals | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Sectoral Share (percent) [a] | | | |
| | Total ($km^3$) Years Vary | Per Capita ($m^3$) Year 2000 | Year | Total ($km^3$) | Percentage of Annual Recharge | Per Capita ($m^3$) | Domestics | Industry | Agriculture | Desalinated Water Production (mill $m^3$) 1990 |
| **World** | **X** | **X** | **1995** | **600–700** | **X** | **106–124** | **65** | **15** | **20** | **X** |
| **Asia (Excl Middle East** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Armenia | 4.2 | 1,193 | X | X | X | X | X | X | X | X |
| Azerbaijan | 6.5 | 842 | X | X | X | X | X | X | X | X |
| Bangladesh | 21.0 | 163 | 1990 | 10.7 | 50.9 | 97.6 | 13 | 1 | 88[l] | X |
| Bhutan | X | X | X | X | X | X | X | X | X | X |
| Cambodia | 17.6 | 1,576 | X | X | X | X | X | X | X | X |
| China | 828.8 | 649 | 1988 | 52.9 | 6.4 | 47.1 | X | X | 54 | X |
| Georgia | 17.2 | 3,469 | 1990 | 3.0 | 17.4 | 549.5 | X | X | X | X |
| India | 418.5 | 413 | 1990 | 190.0 | 45.4 | 223.3 | 9 | 2 | 89[m] | X |
| Indonesia | 455.0 | 2,145 | X | X | X | X | X | X | X | X |
| Japan | 27.0[n] | 213 | 1995[h] | 13.6 | 50.3 | 108.2 | 29 | 41 | 30[o] | 40.0[p] |
| Kazakhstan | 35.9 | 2,211 | 1993[q] | 2.4 | 6.7 | 143.9 | 21 | 71 | 8[q] | 1,328.0[r] |
| Korea, Dem People's Rep | 21.0[b] | 874 | X | X | X | X | X | X | X | X |
| Korea, Rep | 13.3[b] | 284 | 1995[h] | 2.5 | 18.6 | 55.1 | X | X | 17[s] | X |
| Kyrgyzstan | 13.6 | 2,894 | 1994[t] | 0.6 | 4.4 | 132.0 | 50 | 25 | 25[t] | X |
| Lao People's Dem Rep | 38.0 | 6,994 | X | X | X | X | X | X | X | X |
| Malaysia | 64.0 | 2,877 | 1995 | 0.4 | 0.6 | 19.0 | 62 | 33 | 5 | X |
| Mongolia | 6.1 | 2,291 | 1993 | 0.4 | 5.8 | 149.1 | X | X | X | X |
| Maynmar | 156.0[b] | 3,420 | X | X | X | X | X | X | X | X |
| Nepal | X | X | X | X | X | X | X | X | X | X |
| Pakistan | 55.0 | 351 | 1991 | 60.0 | 109.1 | 489.5 | X | X | 90[u] | X |
| Philippines | 180.0[b] | 2,369 | 1980 | 4.0 | 2.2 | 82.8 | 50 | 50 | X | X |
| Singapore | X | X | X | X | X | X | X | X | X | X |
| Sri Lanka | 7.8 | 414 | X | X | X | X | X | X | X | X |
| Tajikistan | 6.0 | 970 | 1994 | 2.3 | 37.7 | 398.7 | X | X | X | X |
| Thailand | 41.9[b] | 682 | 1980 | 0.7 | 1.7 | 15.0 | 60 | 26 | 14 | X |
| Turkmenistan | 3.4 | 753 | 1994 | 0.4 | 11.9 | 100.3 | 53 | 9 | 38 | X |
| Uzbekistan | 19.7 | 809 | 1994 | 7.4 | 37.6 | 334.3 | 33 | 11 | 57[v] | X |
| Vietnam | 48.0 | 601 | 1990 | 0.8 | 1.7 | 11.9 | X | X | X | X |
| **Europe** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Albania | 7.0 | 2,248 | 1989 | 0.6 | 9.0 | 193.6 | 48 | X | 52 | X |
| Austria | 22.3[b] | 2,716 | 1995[h] | 1.4 | 6.2 | 172.5 | 52 | 43 | 5[w] | X |
| Belarus | 18.0 | 1,758 | 1989 | 1.2 | 6.6 | 115.7 | 52 | 13 | 28[x] | X |
| Belgium | 0.9[c] | 89 | 1980 | 0.8 | 86.4 | 79.0 | 55 | 22 | 4 | X |
| Bosnia and Herzegovina | X | X | X | X | X | X | X | X | X | X |
| Bulgaria | 13.4[y] | 1,629 | 1988 | 5.0 | 37.3 | 566.1 | X | X | X | X |
| Croatia | 11.0 | 2,459 | X | X | X | X | X | X | X | X |
| Czech Rep | X | X | 1995[h] | 0.5 | X | 48.0 | X | X | X | X |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Denmark | 30.0[z] | 5,668 | 1995[h] | 0.9 | 3.0 | 169.8 | 40 | 22 | 38[aa] | X |
| Estonia | 4.0 | 2,865 | X | X | X | X | X | X | X | X |
| Finland | 1.9[bb] | 367 | 1995[h] | 0.2 | 12.8 | 47.8 | 65 | 11 | 24[cc] | X |
| France | 100.0[dd] | 1,693 | 1994 | 6.0 | 6.0 | 103.8 | 56 | 27 | 17 | X |
| Germany | 45.7[b] | 556 | 1990 | 7.1 | 15.5 | 89.4 | 48 | 47 | 4[ee] | X |
| Greece | 10.3 | 968 | 1990 | 2.0 | 19.4 | 195.7 | 37 | 5 | 58 | X |
| Hungry | 6.8[c] | 678 | 1995[h] | 1.0 | 14.5 | 96.5 | 35 | 48 | 18[ff] | X |
| Iceland | 24.0[b] | 85,419 | 1995[h] | 0.2 | 0.6 | 558.9 | X | X | X | X |
| Ireland | 3.5[c] | 928 | 1995 | 0.2 | 6.5 | 62.3 | 35 | 38 | 29[gg] | X |
| Italy | 43.0 | 750 | 1992 | 13.9 | 32.3 | 243.2 | 39 | 4 | 58 | X |
| Latvia | 2.2 | 934 | X | X | X | X | X | X | X | X |
| Lithuania | 1.2 | 327 | 1995 | 0.2 | 17.1 | 55.1 | X | X | X | X |
| Macedonia, FYR | X | X | X | X | X | X | X | X | X | X |
| Moldova, Rep | 0.4 | 91 | X | X | X | X | X | X | X | X |
| Netherlands | 4.5[hh] | 285 | 1990 | 1.0 | 23.3 | 70.2 | 32 | 45 | 23[ii] | X |
| Norway | 96.0[b] | 21,502 | 1985 | 0.4 | 0.4 | 97.5 | 27 | 73 | X[ij] | X |
| Poland | 36.0 | 929 | 1995[h] | 2.0 | 5.5 | 51.5 | 70 | 30 | X[kk] | X |
| Portugal | 5.1[c] | 516 | 1995 | 3.1 | 60.1 | 311.0 | 39 | 23 | 39[ll] | X |
| Romania | 8.3[hh] | 372 | 1993 | 3.6 | 43.7 | 158.0 | 61 | 38 | 1[mm] | X |
| Russian Federation | 788.0 | 5,363 | 1988 | 12.6 | 1.6 | 85.5 | X | X | X | X |
| Slovakia | X | X | 1995[h] | 0.6 | X | 113.0 | X | X | X | X |
| Slovenia | X | X | 1994 | 0.2 | X | 88.9 | X | X | X | X |
| Spain | 28.9 | 729 | 1995[h] | 5.4 | 18.8 | 137.2 | 18 | 2 | 80 | X |
| Sweden | 20.0[c] | 2,245 | 1995[h] | 0.6 | 3.2 | 72.8 | 92 | 8 | X[nn] | X |
| Switzerland | 2.7 | 366 | 1995[h] | 0.9 | 33.4 | 126.3 | 72 | 40 | X[oo] | X |
| Ukraine | 20.0 | 396 | 1989 | 4.0 | 20.1 | 77.5 | 30 | 18 | 52[pp] | X |
| United Kingdom | 9.8 | 167 | 1995[h] | 2.5 | 25.2 | 42.4 | 51 | 47 | 2[qq] | X |
| Yugoslavia | 3.0 | 282 | X | X | X | X | X | X | X | X |
| **Middle East & N. Africa** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Afghanistan | 29.0[b] | 1,276 | X | X | X | X | X | X | X | X |
| Algeria | 1.7[c] | 54 | 1989 | 2.9 | 167.6 | 117.1 | 46 | 5 | 49 | 64.0 |
| Egypt | 1.3[c] | 19 | 1995 | 5.3 | 407.7 | 85.1 | 58 | 0 | 42[rr] | 25.0 |
| Iran, Islamic Rep | 42.0[c] | 620 | 1980 | 29.0 | 69.0 | 738.8 | X | X | X | 2.9[ss] |
| Iraq | 13.0[c] | 562 | 1985 | 0.2 | 1.5 | 13.1 | 50 | 40 | X | X |
| Israel | 0.5 | 80 | 1996 | 1.2 | 234.0 | 204.5 | 18 | 2 | 80[tt] | 20.0[uu] |
| Jordan | 0.6[c] | 87 | 1993 | 0.5 | 91.4 | 100.7 | 30 | 4 | 66[vv] | 2.0[r] |
| Kuwait | X | X | 1994 | 0.3 | X | 142.7 | 0 | 0 | 100[ww] | 231.0[r] |
| Lebanon | 4.8 | 1,463 | 1991 | 0.4 | 8.3 | 153.2 | 13 | 9 | 78 | X |
| Libyan Arab Jamahiriya | 0.7 | 116 | 1995 | 3.7 | 561.5 | 734.9 | 9 | 4 | 87[yy] | 70.0[xx] |
| Morocco | 9.0 | 317 | 1998 | 2.7 | 29.8 | 97.9 | 16 | X | 84[zz] | 3.4[aaa] |
| Oman | 1.0 | 376 | 1985 | 0.4 | 41.9 | 280.7 | X | X | X | 34.0[bbb] |
| Saudi Arabia | 1.0[c] | 44 | 1990 | 14.4 | 1518.9 | 899.3 | 10 | X | 90 | 714.0[bbb] |
| Syrian Arab Rep | 6.6 | 409 | 1993 | 1.8 | 27.3 | 133.5 | 13 | 4 | 83[ddd] | X |
| Tunisia | 4.2 | 433 | 1995 | 1.6 | 39.2 | 181.8 | 10 | 4 | 86 | 8.3 |
| Turkey | 20.0 | 300 | 1995[h] | 7.6 | 38.0 | 124.0 | 31 | 9 | 60[ddd] | 0.5 |
| United Arab Emirates | 0.1 | 49 | 1995 | 1.6 | 1333.3 | 724.1 | X | 19[j] | 81[ccc] | 385.0[bbb] |

*(Continued)*



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**Table 7B.16 (Continued)**

| | Average Annual Groundwater Recharge | | Annual Groundwater Withdrawals | | | | | | | Desalinated Water Production (mill $m^3$) 1990 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Sectoral Share (percent) [a] | | | |
| | Total ($km^3$) Years Vary | Per Capita ($m^3$) Year 2000 | Year | Total ($km^3$) | Percentage of Annual Recharge | Per Capita ($m^3$) | Domestics | Industry | Agriculture | |
| Yemen | 1.5 | 84 | 1985[eee] | 1.4 | 88.5 | 139.2 | X | X | X | 10.0[fff] |
| **Sub-Saharan Africa** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Angola | 72.0[b] | 5,591 | X | X | X | X | X | X | X | X |
| Benin | 1.8[c] | 295 | X | X | X | X | X | X | X | X |
| Botswana | 1.7[c] | 1,048 | X | X | X | X | X | X | X | X |
| Burkina Faso | 9.5[c] | 796 | X | X | X | X | X | X | X | X |
| Burundi | 2.1[b] | 314 | X | X | X | X | X | X | X | X |
| Cameron | 100.0[b] | 6,629 | X | X | X | X | X | X | X | X |
| Central African Rep | 56.0[b] | 15,490 | X | X | X | X | X | X | X | X |
| Chad | 11.5[b] | 1,503 | 1990 | 0.1 | 0.8 | 15.7 | 29 | X | 71 | X |
| Congo | 198.0[b] | 67,268 | X | X | X | X | X | X | X | 0.2 |
| Congo, Dem Rep | 421.0[b] | 8,150 | X | X | X | X | X | X | X | X |
| Côte d'Ivoire | 37.7[c] | 2,550 | X | X | X | X | X | X | X | X |
| Equatorial Guinea | 10.0[b] | 22,097 | X | X | X | X | X | X | X | X |
| Eritrea | X | X | X | X | X | X | X | X | X | X |
| Ethiopia | 44.0[b] | 703 | X | X | X | X | X | X | X | X |
| Gabon | 62.0[b] | 50,566 | 1989 | 0.0 | 0.0 | 0.6 | 100 | 0 | 0 | X |
| Gambia | 0.5[b] | 383 | X | X | X | X | X | X | X | X |
| Ghana | 26.3[c] | 1,301 | X | X | X | X | X | X | X | X |
| Guinea | 38.0[b] | 5,114 | X | X | X | X | X | X | X | X |
| Guinea-Bissau | 14.0[b] | 11,541 | X | X | X | X | X | X | X | X |
| Kenya | 3.0[c] | 100 | X | X | X | X | X | X | X | X |
| Lesotho | 0.5[b] | 232 | X | X | X | X | X | X | X | X |
| Liberia | 60.0[b] | 19,023 | X | X | X | X | X | X | X | X |
| Madagascar | 55.0[b] | 3,450 | 1984 | 4.8 | 8.7 | 482.9 | 0 | X | X[d] | X |
| Malawi | 1.4[b] | 128 | X | X | X | X | X | X | X | X |
| Mali | 20.0[c] | 1,780 | 1989 | 0.1 | 0.5 | 11.6 | X | X | X | X |
| Mauritania | 0.3[c] | 112 | 1985 | 0.9 | 293.3 | 498.3 | X | X | X | 1.7 |
| Mozambique | 17.0[b] | 864 | X | X | X | X | X | X | X | 0.1 |
| Namibia | 2.1[b] | 1,217 | X | X | X | X | X | X | X | 3.0 |
| Niger | 2.5[c] | 233 | 1988 | 0.1 | 5.2 | 17.9 | 58 | 4 | 39 | X |
| Nigeria | 87.0[b] | 780 | X | X | X | X | X | X | X | 3.0 |
| Rwanda | 3.6[b] | 466 | X | X | X | X | X | X | X | X |
| Senegal | 7.6[b] | 802 | 1985 | 0.3 | 3.3 | 39.2 | 24 | X | 72 | 0.1 |
| Sierra Leone | 50.0[b] | 10,300 | X | X | X | X | X | X | X | X |
| Somalia | 3.3[b] | 327 | 1985 | 0.3 | 9.1 | 45.8 | X | X | X | 0.1 |
| South Africa | 4.8 | 119 | 1980 | 1.8 | 37.3 | 64.9 | 11 | 6 | 84 | 17.5 |
| Sudan | 7.0 | 237 | 1985 | 0.3 | 4.0 | 13.0 | X | X | X | 0.4 |
| Tanzania, United Rep | 30.0[b] | 895 | X | X | X | X | X | X | X | X |
| Togo | 5.7[c] | 1,231 | X | X | X | X | X | X | X | X |
| Uganda | 29.0[b] | 1,332 | X | X | X | X | X | X | X | X |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Zambia | 47.1 | 5,137 | X | X | X | X | X | X | X | X |
| Zimbabwe | 5.0[b] | 428 | X | X | X | X | X | X | X | X |
| **North America** | **XX** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Canada | 370.0[b] | 11,878 | 1889 | 1.0 | 0.3 | 37.3 | 34 | 11 | 34[e] | X |
| United States | 1,514.0[f] | 5,439 | 1990 | 109.8 | 7.3 | 432.3 | 20 | 5 | 62[g] | X |
| **C. America & Caribbean** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Belize | X | X | X | X | X | X | X | X | X | X |
| Costa Rica | 21.0[b] | 5,219 | X | X | X | X | X | X | X | X |
| Cuba | 8.0[b] | 714 | 1975 | 3.8 | 47.5 | 408.3 | X | X | X | X |
| Dominican Rep | 3.0[b] | 353 | X | X | X | X | X | X | X | X |
| El Salvador | X | X | X | X | X | X | X | X | X | X |
| Guatemala | 31.0[b] | 2.723 | X | X | X | X | X | X | X | X |
| Haiti | 2.5[b] | 304 | X | X | X | X | X | X | X | X |
| Honduras | 39.0[b] | 6,013 | X | X | X | X | X | X | X | X |
| Jamaica | X | X | X | X | X | X | X | X | X | X |
| Mexico | 139.0[b] | 1,406 | 1995[h] | 25.1 | 18.1 | 275.4 | 13 | 23 | 64[l] | X |
| Nicaragua | 59.0[b] | 11,627 | X | X | X | X | X | X | X | X |
| Panama | 42.0[b] | 14,708 | X | X | X | X | X | X | X | X |
| Trinidad and Tobago | X | X | X | X | X | X | X | X | X | X |
| **South America** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Argentina | 128.0[b] | 3,456 | 1975 | 4.7 | 3.7 | 180.4 | 11 | 19 | 70 | X |
| Bolivia | 130.0[b] | 15,609 | X | X | X | X | X | X | X | X |
| Brazil | 1,874.0[b] | 11,016 | 1987 | 8.0 | 0.4 | 57.0 | 38 | 25 | 38 | X |
| Chile | 140.0[b] | 9,204 | X | X | X | X | X | X | X | X |
| Colombia | 510.0[b] | 12,051 | X | X | X | X | X | X | X | X |
| Ecuador | 134.0[b] | 10,596 | X | X | X | X | X | X | X | X |
| Guyana | 103.0[b] | 119,582 | X | X | X | X | X | X | X | X |
| Paraguay | 41.0[b] | 7,459 | X | X | X | X | X | X | X | X |
| Peru | 303.0[b] | 11,807 | 1973 | 2.0 | 0.7 | 139.4 | 25 | 15 | 60 | X |
| Suriname | 80.0[b] | 191,787 | X | X | X | X | X | X | X | X |
| Uruguay | 23.0[b] | 6,892 | X | X | X | X | X | X | X | X |
| Venezuela | 227.0[b] | 9,392 | X | X | X | X | X | X | X | X |
| **Oceania** | X | X | X | X | X | X | X | X | X | X |
| Australia | 72.0[c] | 3,812 | 1985 | 2.2 | 3.1 | 143.2 | X | 20[j] | 57[k] | X |
| Fiji | X | X | X | X | X | X | X | X | X | X |
| New Zealand | 198.0[b] | 51,270 | X | X | X | X | X | X | X | X |
| Papua New Guinea | X | X | X | X | X | X | X | X | X | X |
| Solomon Islands | X | X | X | X | X | X | X | X | X | X |

[a] Estimates are typically approximate and therefore the sum of the sectoral data may not add to 100 percent.
[b] Sum of all groundwater flows, including base flow (as a constituent of surface water flows).
[c] Sum of all aquifer recharge flows.
[d] Sectoral data for Madagascar equal 0.32 percent for domestic for 1984 as reported by Margat 1990.
[e] Sectoral data for Canada are calculated using a groundwater withdrawal value of 1.6 $km^3$ from 1985 as reported by Margat 1990.
[f] Data for the United States are from Economic Commission for Europe (1992) without a specific date. Data reported by Margat (1990) are 660 $km^3$ from a source dated 1974 and refer to the U.S. Including the 50 states and Puerto Rico.
[g] Sectoral data for the U.S. are calculated using a groundwater withdrawal value of 101.3 $km^3$ from 1985 as reported by Margat 1990.
[h] Data refer to 1995 or latest available year (generally from 1991, 1992, 1993, or 1994).

*(Continued)*



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**Table 7B.16 (Continued)**

[i] Sectoral data are calculated using a groundwater withdrawal value of 23.5 $km^3$ from around 1985 as reported by Margat 1990.
[j] Domestic and industrial withdrawals have been combined.
[k] Sectoral data for Australia are calculated using a groundwater withdrawal value of 2.46 $km^3$ from 1983 as reported by Margat 1990.
[l] Sectoral data for Bangladesh are calculated using a groundwater withdrawal value of 3.4 $km^3$ from 1979 as reported by Margat 1990.
[m] Sectoral data are from around 1990 as provided by Shiklomonov; total withdrawal data also are from 1990 but are from FAO, Irrigation in Asia in Figures, p. 95.
[n] Data are from FAO, Irrigation in Asia in Figures (1999) which states "The renewable potential of groundwater resources is estimated at about 27 $km^3$/yr—." A value of 185 $km^3$/yr is provided by Margat (1990) cited from L'vovich 1974.
[o] Sectoral data for Japan are from 1987 as provided by Shiklomonov 1997 based on groundwater withdrawal of 12.88 $km^3$.
[p] Data are from 1996.
[q] Both withdrawal and sectoral data are estimated from a bar graph from FAO Report: Irrigation in the Former Soviet Union Countries in Figures, p. 116.
[r] Data are from 1993.
[s] Sectoral data for the Republic of Korea are calculated using a groundwater withdrawal value of 1.2 $km^3$ from around 1985 as provided by Margat 1990.
[t] Kyrgystan data: FAO Irrigation in the Former Soviet Union Countries in Figures, p. 129, "In 1994, more than 0.6 $km^3$ of water was withdrawn from groundwater." We have entered a value of 0.6 but the figure may be higher; we have calculated the sectoral data from the figure in this report on page 129, using the 0.6 figure for total withdrawal.
[u] Sectoral data for Pakistan are from Shiklomonov who reports "approximately 90 percent" for agriculture share; total withdrawal also is approximately 60 $km^3$/yr for around 990 (table p. 57).
[v] Sectoral data for Uzbekistan are from 1994 FAO Irrigation in the Former Sovet Union Countries in Figures estimated from a bar graph, p. 217.
[w] Sectoral data for Austria are calculated using a groundwater withdrawal value of 1.17 $km^3$ from 1980 as reported by Margat 1990.
[x] Sectoral data Belarus are calculated using a groundwater withdrawal value of 1.06 $km^3$ from 1985 as reported by Margot 1990.
[y] Data for Bulgaria are from ECE (1992) and refer to the year 1988; Margat (1990) reports data from a 1989 source (Anonyme 1989) as 3.1 $km^3$.
[z] Data for Denmark are from ECE (1992) and refer to the year 1985; Margat (1990) reports data from a 1981 source (Anonyme 1981) as 4.3 $km^3$.
[aa] Sectoral data are calculated using a groundwater withdrawal value of 1.32 $km^3$ from 1977 as reported by Margat 1990.
[bb] Data for Finland are from ECE (1992) without a year specified; Margat (1990) reports data from a 1989 source (Anonyme 1989) as 2.2 $km^3$.
[cc] Sectoral data are calculated using a groundwater withdrawal value of 0.37 $km^3$ from 1980 as reported by Margat 1990.
[dd] Data are from Margat (1990) and refer to a source dated 1989 (Margat 1989); data reported from ECE (1992) is 26.0 $km^3$ for 1981.
[ee] Sectoral data are from Margat (1990) and combine his data for both Germanys. Margat's total withdrawal data are from different dates for the two Germanys. Germany—RFA is 7.77 $km^3$ from 1981 and Germany—ex DDR is from 1975; the combined total is 9.55 which is used to calculate the sectoral percentage. The sectoral data also are from 1981 (Germany RFA) and 1975 (Germany—ex DDR).
[ff] Sectoral data are calculated using a groundwater withdrawal value of 1.6 $km^3$ from 1972 as reported by Margat 1990.
[gg] Sectoral data for Ireland are calculated using a groundwater withdrawal value of 0.17 $km^3$ from 1980 as reported by Margat 1990.
[hh] Sum of the total groundwater flow that is exploitable.
[ii] Sectoral data are calculated using a groundwater withdrawal value of 1.28 $km^3$ from 1981 as reported by Margat 1990.
[jj] Sectoral data for Norway are calculated using a groundwater withdrawal value of 0.11 $km^3$ from 1985 as reported by Margat 1990.
[kk] Sectoral data are calculated using a groundwater withdrawal value of 2.0 $km^3$ from 1980–81 as reported by Margat 1990.
[ll] Sectoral data are calculated using a groundwater withdrawal value of 2.0 $km^3$ from 1980 as reported by Margat 1990.
[mm] Sectoral data are calculated using a groundwater withdrawal value of 1.18 $km^3$ from 1975 as reported by Margat 1990.
[nn] Sectoral data for Sweden are calculated using a groundwater withdrawal value of 0.48 $km^3$ from 1985 as reported by Margat 1990.
[oo] Sectoral data for Switzerland are calculated using a groundwater withdrawal value of 1.0 $km^3$ from 1983 as reported by Margat 1990.
[pp] Sectoral data are calculated using a groundwater withdrawal value of 4.22 $km^3$ from 1985 at reported by Margat 1990.
[qq] Sectoral data are calculated using a groundwater withdrawal value of 2.38 $km^3$ from 1975 as reported by Margat 1990.
[rr] Sectoral data are from 1992, Margat Blue Plan.
[ss] Data are from 1991.
[tt] Sectoral data are from 1994, Margat Blue Plan.
[uu] Data are from Margat, personal communication February 2000.
[vv] Groundwater withdrawal and sectoral data are estimated from a bar graph for 1993 from FAD water Report: Irrigation in the Near East Region in Figures, Rome, 1997, p. 115.
[ww] Groundwater withdrawal and sectoral data are estimated from a bar graph for 1994 from FAD Water Report: Irrigation in the Near East Region in Figures, Rome, 1997, p. 124.
[xx] Data are from 1994; from FAD irrigation in the Near East Region in Figures, p. 29.
[yy] Sectoral percentages are calculated using groundwater withdrawal of 3.81 $km^3$ which is an estimate provided with sectoral data for 1995 in Margat Blue Plan.
[zz] Sectoral data are from 1991, Margat Blue Plan.
[aaa] Data are from 1992.
[bbb] Data are from 1995.
[ccc] Sectoral percentage for UAE are a combination of data from text and a bar graph for 1995 from FAO Water Report: Irrigation in the Near East Region in Figures, Rome 1997, p. 266.

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[ddd] Sectoral data are from 1990, Margat Blue Plan.
[eee] Groundwater withdrawal data are from Margat 1990, presented as two separate values, one for Yemen du Nord for around 1985 equal to 1 bill $m^3$/yr; the other for Yemen du Sud for 1975 equal to 0.35 billion m3 per year. These two figures have been added.
[fff] Data are from 1989.
[ggg] Sectoral data are from Margat Blue Plan for 1989.
[hhh] Sectoral data refer only to Mauritius Island only.

**Technical Notes**

*Source*: From World Resources Institute, Earth Trends Environmental Information, Water Resources and Freshwater Ecosystems, Data Tables, Table FW.2 Groundwater and Desalinization, www.earthtrends.wri.org.

*Original Source*: From Groundwater resources and withdrawal data: J. Margat, Les eau — souterraines sand le monde (Bureau de recherches géologiques et minières [BRGM], Département eau, Oriéans, France, December 1990); J. Margat and D. Vallée, Water Resources and Uses in the Mediterranean Countries (Blue Plan, Sophia Antipolis, 1999); I.A. Shiklomanov, Comprehensive Assessment of the Freshwater Resources of the World (Stockholm Environment Institute, Stockholm, 1997); Organisation for Economic Co-Operation and Development (OECD), OECD Environmental Data Compendium 1997 (OECD, Paris, 1997); and Economic Commission for Europe, The Environment in Europe and North America (United Nations, New York, 1992).

Groundwater resources and desalinization activities: J. Margat, Le — Eau — Souterraines Dans Le Bassin Mediterraneen. Resources et Utilisations Plan Bleu, Doc. BRGM 282 (Ed. BRGM, Orléans, France, 1998); Food and Agriculture Organization of the United Nations (FAO), Irrigation in Africa in Figures, Water Reports No. 7 (FAO, Rome, 1995); FAO, Irrigation in the Near East Region in Figures, Water Reports No. 9 (FAO, Rome, 1997); FAO, Irrigation in the Former Soviet Union in Figures, Water Report No. 15 (FAO, Rome, 1997); FAO, Irrigation in Asia in Figures, Water Reports No. 18 (FAO, Rome, 1999); and FAO, Irrigation in Latin America in Figures, Water Reports (FAO, Rome, in preparation). Population data: United Nations (U.N.) Population Division, World Population Prospects, 1950–2050 (The 1998 Revision), on diskette (U.N., New York, 1999).

Average annual groundwater recharge is the amount of water that is estimated to annually infiltrate soils, including water from rivers and streams that lose it to underlying strata. In general, this figure would represent the maximum amount of water that could be withdrawn annually without ultimately depleting the groundwater resource. These data are estimated in a variety of ways and caution should be used in comparing values for different countries.

Per capita recharge is the amount of water that annually infiltrates soils on a per person basis, using 2000 population estimates from the U.N. Population Division.

Annual total groundwater withdrawals refers to abstractions from all groundwater sources — even nonrenewable sources. The percentage of annual recharge refers to total groundwater withdrawals. Per capita annual withdrawals were calculated using national population data for the year of data shown.

Sectoral share of withdrawals of groundwater is classified as domestic (drinking water, homes, commercial establishments, public services, and municipal use), industry including water withdrawn to cool thermoelectric plants), and agriculture (irrigation and livestock).

Desalinated water production refers to the removal of salt from saline waters — usually seawater — using a variety of techniques including reverse osmosis. Most desalinated water is used for domestic purposes.

Totals may not add due to rounding.



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## SECTION 7C PUBLIC WATER SUPPLY — UNITED STATES

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**Table 7C.17 Public Water Supply Supreme in the United States, 2003**

| | | System Size by Population Served | | | | | Water Source Type | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Very Small 500 or Less** | **Small 501–3,300** | **Medium 3,301–10,000** | **Large 10,001–100,000** | **Very Large >100,000** | **Groundwater** | **Surface Water** | **Total** |
| CWS | # systems | 30,417 | 14,394 | 4,686 | 3,505 | 361 | 41,499 | 11,864 | 53,363 |
| | Pop. served | 5,010,834 | 20,261,508 | 27,201,137 | 98,706,485 | 122,149,436 | 86,348,074 | 186,981,326 | 273,329,400 |
| | % of systems | 57% | 27% | 9% | 7% | 1% | 78% | 22% | 100% |
| | % of pop | 2% | 7% | 10% | 36% | 45% | 32% | 68% | 100% |
| NTNCWS | # systems | 16,785 | 2,786 | 97 | 16 | 2 | 18,908 | 778 | 19,686 |
| | Pop. served | 2,327,575 | 2,772,334 | 506,124 | 412,463 | 279,846 | 5,568,192 | 730,150 | 6,298,342 |
| | % of systems | 85% | 14% | 0% | 0% | 0% | 96% | 4% | 100% |
| | % of pop | 37% | 44% | 8% | 7% | 4% | 88% | 12% | 100% |
| TNCWS | # systems | 85,366 | 2,657 | 96 | 29 | 4 | 86,061 | 2,091 | 88,152 |
| | Pop. served | 7,315,647 | 2,602,706 | 528,624 | 619,248 | 12,269,000 | 10,527,089 | 12,808,136 | 23,335,225 |
| | % of systems | 97% | 3% | 0% | 0% | 0% | 98% | 2% | 100% |
| | % of pop | 31% | 11% | 2% | 3% | 53% | 45% | 55% | 100% |
| | **Total # systems** | **132,568** | **19,837** | **4,879** | **3,550** | **367** | **146,468** | **14,733** | **161,201** |
| | **Total Population Served** | | | | | | **102,443,355** | **200,519,612** | |

*Note:* Active, current systems, from Safe Drinking Water Information System/Federal version (SDWIS/FED) 03Q4 frozen inventory table. CWS, Community Water System: A public water system that supplies water to the same population year-round; NTNCWS, Non-Transient Non-Community Water System: A public water system that regularly supplies water to at least 25 of the same people at least six months per year, but not year-round. Some examples are schools, factories, office buildings, and hospitals which have their own water systems; TNCWS, Transient Non-Community Water System: A public water system that provides water in a place such as a gas station or compground where people do not remain for long periods of time. Groundwater systems, groundwater (GW), purchased groundwater (GWP); Surface water systems, surface water (SW), purchased surface water (SWP), groundwater under the direct influence of surface water (GU), purchased groundwater under the direct influence of surface water (GUP).

*Source*: From USEPA, *FACTOIDS: Drinking Water and Groundwater Statistics for 2003*, www.epa.gov.



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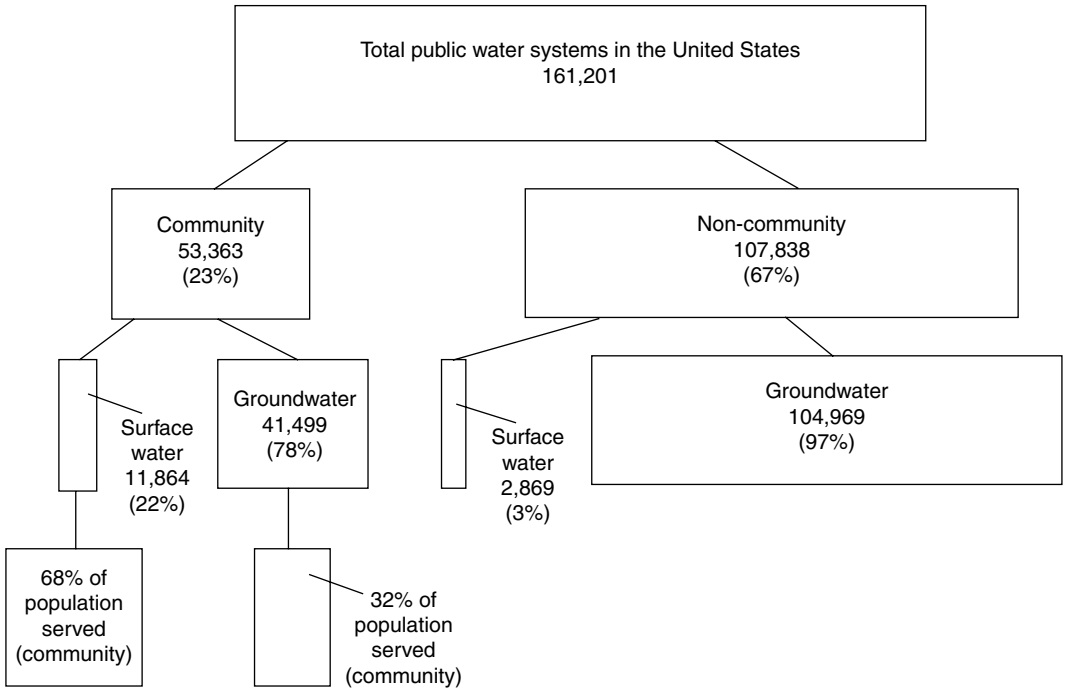


**Figure 7C.9** Number and type of public water systems in the United States in 2003. (From American Water Works Association, 1988, *New Dimensions in Safe Drinking Water*, Copyright AWWA modified with data from USEPA, FY2003, Drinking Water Factors, www.epa.gov.)

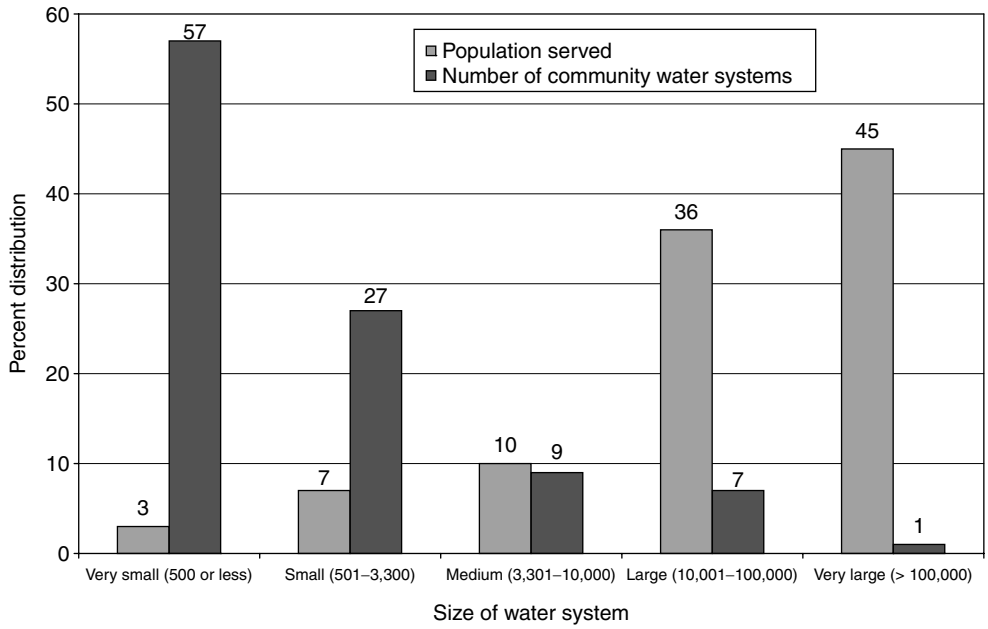


**Figure 7C.10** Size distribution of community water systems in the United States in 2003. (From American Water Works Association, 1988, *New Dimensions in Safe Drinking Water*, modified with data from USEPA, *FACTOIDS: Drinking Water and Groundwater Statistics for 2003*, www.epa.gov.)

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**Table 7C.18 Average Daily Production (MGD) by Primary Water Source in Public Supply Systems in the United States in 2000 (Based on a Survey of 1246 Systems)**

| | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Primary Source of Water** | **100 or Less** | **101–500** | **501–3,300** | **3,301–10,000** | **10,001–50,000** | **50,001–100,000** | **100,001–500,000** | **Over 500,000** | **All Sizes** |
| **Primarily Groundwater Systems** | | | | | | | | | |
| 100% Groundwater | | | | | | | | | |
| Average Daily Production | 0.011 | 0.034 | 0.158 | 1.058 | 2.628 | 11.892 | 17.631 | 125.642 | 0.313 |
| *Confidence Interval* | ±0.009 | ±0.009 | ±0.034 | ±0.193 | ±0.382 | ±1.643 | ±13.186 | ±23.115 | ±0.052 |
| Mostly Groundwater | | | | | | | | | |
| Average Daily Production | 0.003 | 0.019 | 0.524 | 0.872 | 3.718 | 11.225 | 29.778 | 144.963 | 3.587 |
| *Confidence Interval* | ±0.004 | ±0.000 | ±0.552 | ±0.365 | ±1.154 | ±1.490 | ±4.390 | ±32.023 | ±1.236 |
| % Groundwater | 66.7 | 83.3 | 58.1 | 78.0 | 84.5 | 74.1 | 73.0 | 83.5 | 78.6 |
| *Confidence Interval* | ±0.0 | ±0.0 | ±4.9 | ±11.1 | ±9.3 | ±3.6 | ±5.5 | ±14.8 | ±5.9 |
| % Surface Water | 0.0 | 0.0 | 41.9 | 7.4 | 2.1 | 12.4 | 6.1 | 0.0 | 6.0 |
| *Confidence Interval* | ±0.0 | ±0.0 | ±4.9 | ±7.3 | ±3.9 | ±6.1 | ±3.1 | ±0.0 | ±3.9 |
| % Purchased Water | 33.3 | 16.7 | 0.0 | 14.7 | 13.4 | 13.5 | 20.9 | 16.5 | 15.4 |
| *Confidence Interval* | ±0.0 | ±0.0 | ±0.0 | ±9.6 | ±8.8 | ±6.4 | ±5.8 | ±14.8 | ±5.3 |
| Observations | 86 | 88 | 88 | 53 | 35 | 20 | 20 | 5 | 395 |
| **Primarily Surface Water Systems** | | | | | | | | | |
| 100% Surface Water | | | | | | | | | |
| Average Daily Production | 0.010 | 0.071 | 0.279 | 0.935 | 4.766 | 11.041 | 31.875 | 271.287 | 4.280 |
| *Confidence Interval* | ±0.007 | ±0.031 | ±0.059 | ±0.153 | ±1.430 | ±2.681 | ±2.733 | ±79.561 | ±0.995 |
| Mostly Surface Water | | | | | | | | | |
| Average Daily Production | 0.014 | 0.013 | 0.269 | 0.779 | 4.253 | 11.537 | 42.431 | 219.892 | 8.636 |
| *Confidence Interval* | ±0.012 | ±0.010 | ±0.141 | ±0.318 | ±1.325 | ±1.682 | ±5.065 | ±96.067 | ±4.026 |
| % Groundwater | 35.2 | 24.0 | 13.5 | 18.9 | 14.3 | 10.4 | 14.0 | 8.9 | 15.6 |
| *Confidence Interval* | ±19.6 | ±6.5 | ±10.3 | ±10.6 | ±6.5 | ±4.7 | ±2.9 | ±4.1 | ±4.1 |
| % Surface Water | 64.8 | 76.0 | 69.4 | 76.7 | 81.5 | 85.4 | 82.8 | 86.4 | 77.7 |
| *Confidence Interval* | ±19.6 | ±6.5 | ±8.0 | ±8.5 | ±5.8 | ±5.0 | ±3.0 | ±4.1 | ±3.6 |
| % Purchased Water | 0.0 | 0.0 | 17.0 | 4.4 | 4.1 | 4.3 | 3.3 | 4.7 | 6.6 |
| *Confidence Interval* | ±0.0 | ±0.0 | ±13.0 | ±4.4 | ±4.3 | ±3.4 | ±1.6 | ±2.3 | ±3.7 |
| Observations | 41 | 49 | 56 | 63 | 64 | 35 | 70 | 26 | 404 |
| **Primarily Purchased Water Systems** | | | | | | | | | |
| 100% Purchased Water | | | | | | | | | |
| Average Daily Production | 0.008 | 0.017 | 0.150 | 0.886 | 2.302 | 9.595 | 23.975 | 129.602 | 0.866 |
| *Confidence Interval* | ±0.008 | ±0.004 | ±0.046 | ±0.445 | ±0.918 | ±1.417 | ±3.277 | ±69.896 | ±0.309 |
| Mostly Purchased Water | | | | | | | | | |

*(Continued)*



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**Table 7C.18 (Continued)**

| Primary Source of Water | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 or Less | 101–500 | 501–3,300 | 3,301–10,000 | 10,001–50,000 | 50,001–100,000 | 100,001–500,000 | Over 500,000 | All Sizes |
| Average Daily Production | * | 0.016 | 0.103 | 1.407 | 5.595 | 16.498 | 32.220 | 280.185 | 5.538 |
| *Confidence Interval* | * | ±0.000 | ±0.093 | ±0.490 | ±1.969 | ±8.407 | ±4.606 | ±68.668 | ±3.383 |
| % Groundwater | * | 33.3 | 42.8 | 28.4 | 12.8 | 22.4 | 19.5 | 11.2 | 31.0 |
| *Confidence Interval* | * | ±0.0 | ±4.6 | ±10.9 | ±7.3 | ±10.8 | ±4.4 | ±5.8 | ±7.3 |
| % Surface Water | * | 0.0 | 0.0 | 3.9 | 6.9 | 8.1 | 8.3 | 13.1 | 2.8 |
| *Confidence Interval* | * | ±0.0 | ±0.0 | ±6.1 | ±8.0 | ±9.2 | ±3.6 | ±6.0 | ±2.5 |
| % Purchased Water | * | 66.7 | 57.2 | 67.7 | 80.3 | 69.5 | 72.2 | 75.7 | 66.2 |
| *Confidence Interval* | * | ±0.0 | ±4.6 | ±9.7 | ±10.3 | ±7.2 | ±4.7 | ±8.2 | ±6.1 |
| Observations | 6 | 22 | 47 | 19 | 17 | 22 | 23 | 7 | 163 |
| **All Systems** | | | | | | | | | |
| Average Daily Production | 0.011 | 0.033 | 0.166 | 0.995 | 3.589 | 11.305 | 28.811 | 222.672 | 1.103 |
| *Confidence Interval* | ±0.008 | ±0.007 | ±0.024 | ±0.131 | ±0.518 | ±1.093 | ±5.427 | ±41.741 | ±0.124 |
| Observations | 138 | 166 | 208 | 170 | 159 | 116 | 201 | 58 | 1,216 |

*Note:* *No purchased water systems of this size in sample. Definitions: Production is the amount of water drawn from each source. It includes water delivered to customers and system losses.

The tabulations presented in the Community Water System Survery 2000 are based on data collected from a sample of U.S. Water Systems, not from a census of every water system in the United States. A confidence interval is one way to gauge how precisely a given tabulation of survey data can be generalized to the entirety of U.S. Systems represented by the surveyed systems. Any result presented in the table must be viewed as the center of a range that would encompass the precise number that would be found if every U.S. water system could have been included in the tabulation, and not only those who were sampled and responded to the 2000 Community Water System Survey. The confidence interval expresses the range as a "plus/minus," that is, an amount to be added to and subtracted from the calculated data point actually presented in the table. The confidence interval is designed to include the true value in the stated rage 95 perecent of the time.

*Source*: From USEPA, 2002, *Community Water System Survery 2000*, EPA 815-R-02-005A, www.epa.gov.

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**Table 7C.19 Number and Percentage of Systems by Primary Source of Water in Public Supply Systems in the United States in 2000 (Based on a Survey of 1246 September)**

| | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Primary Source of Water** | **100 or Less** | **101–500** | **501–3,300** | **3,301–10,000** | **10,001–50,000** | **50,001–100,000** | **100,001–500,000** | **Over 500,000** | **All Sizes** |
| **Primary Groundwater Systems** | | | | | | | | | |
| 100% Groundwater | | | | | | | | | |
| Number | 10,358 | 12,521 | 8,687 | 2,576 | 971 | 80 | 108 | 7 | 35,308 |
| Percent | 82 | 76 | 62 | 51 | 32 | 17 | 25 | 8 | 68 |
| Mostly Groundwater | | | | | | | | | |
| Number | 1,398 | 624 | 283 | 495 | 368 | 56 | 53 | 3 | 3,280 |
| Percent | 11 | 4 | 2 | 10 | 12 | 12 | 12 | 4 | 6 |
| **Primarily Surface Water Systems** | | | | | | | | | |
| 100% Surface Water | | | | | | | | | |
| Number | 790 | 897 | 1,015 | 835 | 769 | 140 | 113 | 36 | 4,595 |
| Percent | 6 | 5 | 7 | 17 | 26 | 30 | 26 | 43 | 9 |
| Mostly Surface Water | | | | | | | | | |
| Number | 43 | 239 | 197 | 173 | 220 | 70 | 65 | 17 | 1,024 |
| Percent | 0 | 1 | 1 | 3 | 7 | 15 | 15 | 20 | 2 |
| **Primarily Purchased Water Systems** | | | | | | | | | |
| 100% Purchased Water | | | | | | | | | |
| Number | 69 | 2,050 | 3,412 | 773 | 476 | 94 | 46 | 13 | 6,933 |
| Percent | 1 | 12 | 24 | 15 | 16 | 20 | 11 | 15 | 13 |
| **Mostly Purchased Water** | | | | | | | | | |
| Number | [a] | 130 | 423 | 200 | 209 | 31 | 45 | 8 | 1,046 |
| Percent | [a] | 1 | 3 | 4 | 7 | 7 | 10 | 10 | 2 |
| **All** | | | | | | | | | |
| Number | 12,658 | 16,461 | 14,017 | 5,052 | 3,013 | 471 | 430 | 84 | 52,186 |
| Percent | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

*Note:* The tabulations presented in the Community Water System Survey 2000 are based on data collected from a sample of U.S. Water Systems, not from a census of every water system in the United States.

[a] No purchased water systems of this size in sample.

*Source*: From USEPA, 2002, *Community Water Systems Survey 2000*, EPA 815-R-02-005A, www.epa.gov.

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**Table 7C.20 Public Water Supply Systems in United States by State, 2003**

| | Water System Type | | | | Water Source Type | |
|---|---|---|---|---|---|---|
| | CWS | NTNCWS | TNCWS | Total | Groundwater | Surface Water |
| AK | 434 | 213 | 936 | 1,583 | 1,337 | 246 |
| | 461,264 | 43,412 | 91,513 | 596,189 | 294,193 | 301,996 |
| AL | 607 | 32 | 72 | 711 | 417 | 294 |
| | 5,167,519 | 19,448 | 7,399 | 5,194,366 | 1,476,656 | 3,717,710 |
| AR | 730 | 61 | 329 | 1,120 | 705 | 415 |
| | 2,482,867 | 12,622 | 17,365 | 2,512,854 | 920,088 | 1,592,766 |
| AZ | 799 | 210 | 644 | 1,653 | 1,442 | 211 |
| | 4,766,531 | 132,626 | 132,193 | 5,031,350 | 1,440,327 | 3,591,023 |
| CA | 3,140 | 1,413 | 3,017 | 7,570 | 6,488 | 1,082 |
| | 36,207,653 | 495,441 | 11,031,005 | 47,734,099 | 10,688,260 | 37,045,839 |
| CO | 836 | 170 | 1,004 | 2,010 | 1,569 | 441 |
| | 4,923,405 | 91,311 | 264,435 | 5,279,151 | 782,198 | 4,496,953 |
| CT | 573 | 667 | 1,754 | 2,994 | 2,924 | 70 |
| | 2,660,903 | 129,913 | 60,447 | 2,851,263 | 501,499 | 2,349,764 |
| DC | 2 | | | 2 | | 2 |
| | 595,000 | | | 595,000 | | 595,000 |
| DE | 226 | 102 | 176 | 504 | 501 | 3 |
| | 790,178 | 25,247 | 57,545 | 872,970 | 596,840 | 276,130 |
| FL | 1,925 | 1,045 | 3,433 | 6,403 | 6,328 | 75 |
| | 16,281,037 | 263,623 | 298,672 | 16,843,332 | 14,222,761 | 2,620,571 |
| GA | 1,678 | 251 | 559 | 2,488 | 2,268 | 220 |
| | 7,119,376 | 72,646 | 88,806 | 7,280,828 | 1,599,694 | 5,681,134 |
| HI | 116 | 9 | 4 | 129 | 113 | 16 |
| | 1,285,174 | 6,385 | 500 | 1,292,059 | 1,169,290 | 122,769 |
| IA | 1,140 | 146 | 688 | 1,974 | 1,814 | 160 |
| | 2,526,314 | 45,068 | 88,128 | 2,659,510 | 1,473,634 | 1,185,876 |
| ID | 748 | 245 | 1,048 | 2,041 | 1,969 | 72 |
| | 924,721 | 52,667 | 114,320 | 1,091,708 | 839,838 | 251,870 |
| IL | 1,797 | 416 | 3,370 | 5,583 | 4,860 | 723 |
| | 11,300,507 | 150,302 | 374,357 | 11,825,166 | 3,297,942 | 8,527,224 |
| IN | 853 | 715 | 2,928 | 4,496 | 4,364 | 132 |
| | 4,499,532 | 210,497 | 417,480 | 5,127,509 | 2,822,028 | 2,305,481 |
| KS | 912 | 58 | 102 | 1,072 | 745 | 327 |
| | 2,581,726 | 23,945 | 4,054 | 2,609,725 | 830,695 | 1,779,030 |
| KY | 424 | 57 | 138 | 619 | 260 | 359 |
| | 4,588,463 | 21,968 | 11,453 | 4,621,884 | 364,993 | 4,256,891 |
| LA | 1,131 | 185 | 323 | 1,639 | 1,556 | 83 |
| | 4,878,378 | 72,684 | 74,731 | 5,025,793 | 3,022,291 | 2,003,502 |
| MA | 517 | 250 | 920 | 1,687 | 1,504 | 183 |
| | 8,955,179 | 71,673 | 142,832 | 9,169,684 | 2,157,850 | 7,011,834 |
| MD | 501 | 569 | 2,687 | 3,757 | 3,661 | 96 |
| | 4,502,328 | 162,742 | 167,496 | 4,832,566 | 874,747 | 3,957,819 |
| ME | 395 | 373 | 1,211 | 1,979 | 1,900 | 79 |
| | 615,264 | 72,052 | 197,391 | 884,707 | 454,721 | 429,986 |
| MI | 1,447 | 1,689 | 8,986 | 12,122 | 11,815 | 307 |
| | 7,197,342 | 471,246 | 1,063,724 | 8,732,312 | 3,203,122 | 5,529,190 |
| MN | 963 | 565 | 6,257 | 7,785 | 7,675 | 110 |
| | 4,040,822 | 84,158 | 490,353 | 4,615,333 | 3,184,810 | 1,430,523 |
| MO | 1,456 | 254 | 1,001 | 2,711 | 2,475 | 236 |
| | 4,864,516 | 79,159 | 133,877 | 5,077,552 | 1,785,200 | 3,292,352 |
| MS | 1,168 | 94 | 116 | 1,378 | 1,374 | 4 |
| | 3,007,045 | 81,400 | 24,648 | 3,113,093 | 2,789,142 | 323,951 |
| MT | 667 | 225 | 1,129 | 2,021 | 1,803 | 218 |
| | 659,667 | 59,886 | 176,587 | 896,140 | 502,724 | 393,416 |
| NC | 2,430 | 576 | 4,492 | 77,498 | 6,830 | 668 |
| | 6,431,967 | 159,401 | 377,666 | 6,969,034 | 1,963,876 | 5,005,158 |
| ND | 321 | 28 | 179 | 528 | 444 | 84 |
| | 551,709 | 4,102 | 15,523 | 571,334 | 264,665 | 306,669 |
| NE | 610 | 181 | 586 | 1,377 | 1,302 | 75 |

*(Continued)*

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**Table 7C.20 (Continued)**

| | Water System Type | | | | Water Source Type | |
|---|---|---|---|---|---|---|
| | CWS | NTNCWS | TNCWS | Total | Groundwater | Surface Water |
| | 1,424,246 | 42,530 | 113,001 | 1,579,777 | 803,980 | 775,797 |
| NH | 688 | 441 | 1,054 | 2,183 | 2,127 | 56 |
| | 794,419 | 91,054 | 220,026 | 1,105,499 | 582,034 | 523,465 |
| NJ | 607 | 870 | 2,644 | 4,121 | 4,019 | 102 |
| | 7,891,239 | 217,056 | 381,246 | 8,489,541 | 3,128,541 | 5,361,000 |
| NM | 657 | 152 | 509 | 1,318 | 1,242 | 76 |
| | 1,602,714 | 40,246 | 187,878 | 1,830,838 | 1,595,947 | 234,891 |
| NV | 256 | 107 | 260 | 623 | 590 | 33 |
| | 1,941,253 | 34,981 | 28,731 | 2,004,965 | 303,722 | 1,701,243 |
| NY | 2,849 | 759 | 6,564 | 10,172 | 8,983 | 1,189 |
| | 17,784,525 | 337,668 | 2,917,223 | 21,039,416 | 5,566,889 | 15,472,527 |
| OH | 1,334 | 1,018 | 3,221 | 5,573 | 5,148 | 425 |
| | 10,025,325 | 249,361 | 490,709 | 10,765,395 | 3,430,287 | 7,335,108 |
| OK | 1,151 | 110 | 376 | 1,637 | 912 | 725 |
| | 3,429,060 | 18,197 | 28,498 | 3,475,755 | 675,542 | 2,800,213 |
| OR | 883 | 332 | 1,454 | 2,669 | 2,365 | 304 |
| | 2,867,570 | 76,404 | 222,081 | 3,166,055 | 828,976 | 2,337,079 |
| PA | 2,162 | 1,224 | 6,627 | 10,013 | 9,433 | 580 |
| | 10,399,770 | 522,640 | 843,251 | 11,765,661 | 2,825,638 | 8,940,023 |
| RI | 83 | 74 | 322 | 479 | 454 | 25 |
| | 1,273,301 | 26,827 | 56,259 | 1,356,387 | 212,598 | 1,143,789 |
| SC | 655 | 185 | 575 | 1,415 | 1,202 | 213 |
| | 3,343,194 | 61,982 | 35,559 | 3,440,735 | 600,670 | 2,840,065 |
| SD | 468 | 30 | 195 | 693 | 560 | 133 |
| | 653,374 | 12,166 | 26,706 | 692,246 | 295,907 | 396,339 |
| TN | 675 | 50 | 435 | 1,160 | 602 | 558 |
| | 5,308,927 | 30,945 | 59,727 | 5,399,599 | 1,450,421 | 3,949,178 |
| TX | 4,516 | 788 | 1,245 | 6,549 | 5,379 | 1,170 |
| | 22,148,772 | 322,457 | 248,086 | 22,719,315 | 6,728,199 | 15,991,116 |
| UT | 454 | 61 | 438 | 953 | 828 | 125 |
| | 3,688,604 | 42,442 | 74,740 | 3,805,786 | 774,271 | 3,031,515 |
| VA | 1,309 | 618 | 1,309 | 3,236 | 2,846 | 390 |
| | 5,946,179 | 274,867 | 218,251 | 6,439,297 | 847,878 | 5,591,419 |
| VT | 438 | 227 | 695 | 1,360 | 1,223 | 137 |
| | 497,717 | 41,013 | 132,407 | 671,137 | 310,621 | 360,516 |
| WA | 2,282 | 309 | 1,559 | 4,150 | 3,884 | 266 |
| | 5,389,076 | 253,867 | 261,297 | 5,904,240 | 2,876,867 | 3,027,373 |
| WI | 1,096 | 937 | 9,389 | 11,422 | 11,373 | 49 |
| | 3,824,455 | 196,102 | 694,934 | 4,715,491 | 2,969,519 | 1,745,972 |
| WV | 547 | 169 | 560 | 1,276 | 897 | 379 |
| | 1,425,835 | 55,375 | 35,435 | 1,516,645 | 310,377 | 1,206,268 |
| WY | 279 | 87 | 381 | 747 | 634 | 113 |
| | 437,627 | 19,379 | 75,824 | 532,830 | 189,996 | 342,834 |
| | 51,935 | 19,347 | 87,901 | 159,183 | 145,144 | 14,039 |
| Total | 266,963,569 | 6,083,183 | 23,276,369 | | 100,832,964 | 195,490,157 |

*Note:* First row is number of systems; Second row is population served.
CWS, Community Water System; NTNCWS, Non-Transient Non-Community Water System; TNCWS, Transient Non-Community Water System.

*Source*: From USEPA, *FACTOIDS: Drinking Water and Groundwater Statistics for 2003*, www.epa.gov.

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**Table 7C.21 Public Supply Freshwater Use in the United States, 2000 (Figures May Not Sum to Totals Because of Independent Rounding)**

| | Population (thousands) | | | Withdrawals (mill gall/day) | | | Withdrawals (thousand Acre-Feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Served by Public Supply | | By Source | | | By Source | | |
| State | Total | Population | Population (Percent) | Groundwater | Surface Water | Total | Groundwater | Surface Water | Total |
| Alabama | 4,450 | 3,580 | 80 | 281 | 553 | 834 | 315 | 620 | 935 |
| Alaska | 627 | 421 | 67 | 29.3 | 50.7 | 80 | 32.9 | 56.9 | 89.7 |
| Arizona | 5,130 | 4,870 | 95 | 469 | 613 | 1,080 | 526 | 688 | 1,210 |
| Arkansas | 2,670 | 2,320 | 87 | 132 | 289 | 421 | 148 | 324 | 472 |
| California | 33,900 | 30,100 | 89 | 2,800 | 3,320 | 6,120 | 3,140 | 3,730 | 6,860 |
| Colorado | 4,300 | 3,750 | 87 | 53.7 | 846 | 899 | 60.2 | 948 | 1,010 |
| Connecticut | 3,410 | 2,660 | 78 | 66 | 358 | 424 | 74 | 402 | 476 |
| Delaware | 784 | 617 | 79 | 45 | 49.8 | 94.9 | 50.5 | 55.9 | 106 |
| District of Columbia | 572 | 572 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 16,000 | 14,000 | 88 | 2,200 | 237 | 2,440 | 2,470 | 266 | 2,730 |
| Georgia | 8,190 | 6,730 | 82 | 278 | 968 | 1,250 | 311 | 1,090 | 1,400 |
| Hawaii | 1,210 | 1,140 | 94 | 243 | 7.6 | 250 | 272 | 8.52 | 281 |
| Idaho | 1,290 | 928 | 72 | 219 | 25.3 | 244 | 245 | 28.3 | 274 |
| Illinois | 12,400 | 10,900 | 88 | 353 | 1,410 | 1,760 | 396 | 1,580 | 1,970 |
| Indiana | 6,080 | 4,480 | 74 | 345 | 326 | 670 | 386 | 365 | 751 |
| Iowa | 2,930 | 2,410 | 83 | 303 | 79.8 | 383 | 340 | 89.5 | 429 |
| Kansas | 2,690 | 2,500 | 93 | 172 | 244 | 416 | 193 | 273 | 466 |
| Kentucky | 4,040 | 3,490 | 86 | 71 | 455 | 525 | 79.5 | 510 | 589 |
| Louisiana | 4,470 | 3,950 | 88 | 349 | 404 | 753 | 392 | 453 | 844 |
| Maine | 1,270 | 726 | 57 | 29.6 | 72.5 | 102 | 33.2 | 81.3 | 115 |
| Maryland | 5,300 | 4,360 | 82 | 84.6 | 740 | 824 | 94.8 | 829 | 924 |
| Massachusetts | 6,350 | 5,880 | 93 | 197 | 542 | 739 | 220 | 608 | 828 |
| Michigan | 9,940 | 7,170 | 72 | 247 | 896 | 1,140 | 277 | 1,000 | 1,280 |
| Minnesota | 4,920 | 3,770 | 77 | 329 | 171 | 500 | 369 | 192 | 561 |
| Mississippi | 2,840 | 2,190 | 77 | 319 | 40.4 | 359 | 357 | 45.3 | 402 |
| Missouri | 5,600 | 4,770 | 85 | 278 | 594 | 872 | 311 | 666 | 978 |
| Montana | 902 | 664 | 74 | 56.1 | 92.4 | 149 | 62.9 | 104 | 167 |
| Nebraska | 1,710 | 1,390 | 81 | 266 | 63.8 | 330 | 299 | 71.6 | 370 |
| Nevada | 2,000 | 1,870 | 94 | 151 | 478 | 629 | 169 | 536 | 705 |
| New Hampshire | 1,240 | 756 | 61 | 33 | 64.1 | 97.1 | 37 | 71.9 | 109 |
| New Jersey | 8,410 | 7,460 | 89 | 400 | 650 | 1,050 | 449 | 729 | 1,180 |
| New Mexico | 1,820 | 1,460 | 80 | 262 | 33.8 | 296 | 294 | 37.9 | 332 |
| New York | 19,000 | 17,100 | 90 | 583 | 1,980 | 2,570 | 653 | 2,220 | 2,880 |
| North Carolina | 8,050 | 5,350 | 66 | 166 | 779 | 945 | 186 | 873 | 1,060 |
| North Dakota | 642 | 493 | 77 | 32.4 | 31.2 | 63.6 | 36.3 | 35 | 71.3 |
| Ohio | 11,400 | 9,570 | 84 | 500 | 966 | 1,470 | 560 | 1,080 | 1,640 |
| Oklahoma | 3,450 | 3,150 | 91 | 113 | 562 | 675 | 127 | 631 | 757 |
| Oregon | 3,420 | 2,730 | 80 | 118 | 447 | 566 | 133 | 501 | 634 |
| Pennsylvania | 12,300 | 10,100 | 82 | 212 | 1,250 | 1,460 | 237 | 1,400 | 1,640 |
| Rhode Island | 1,050 | 922 | 88 | 16.9 | 102 | 119 | 19 | 115 | 134 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| South Carolina | 4,010 | 3,160 | 79 | 105 | 462 | 566 | 117 | 517 | 635 |
| South Dakota | 755 | 625 | 83 | 54.2 | 39.1 | 93.3 | 60.7 | 43.9 | 105 |
| Tennessee | 5,690 | 5,240 | 92 | 321 | 569 | 890 | 360 | 638 | 997 |
| Texas | 20,900 | 19,700 | 94 | 1,260 | 2,970 | 4,230 | 1,420 | 3,330 | 4,740 |
| Utah | 2,230 | 2,180 | 97 | 364 | 274 | 638 | 408 | 307 | 715 |
| Vermont | 609 | 362 | 59 | 19.5 | 40.6 | 60.1 | 21.8 | 45.6 | 67.4 |
| Virginia | 7,080 | 5,310 | 75 | 70.7 | 650 | 720 | 79.3 | 728 | 808 |
| Washington | 5,890 | 4,900 | 83 | 464 | 552 | 1,020 | 520 | 619 | 1,140 |
| West Virginia | 1,810 | 1,300 | 72 | 41.6 | 149 | 190 | 46.6 | 167 | 213 |
| Wisconsin | 5,360 | 3,620 | 67 | 330 | 293 | 623 | 370 | 329 | 699 |
| Wyoming | 494 | 406 | 82 | 57.2 | 49.4 | 107 | 64.1 | 55.3 | 119 |
| Puerto Rico | 3,810 | 3,800 | 100 | 88.5 | 425 | 513 | 99.2 | 476 | 576 |
| U.S. Virgin Islands | 109 | 53.4 | 49 | 0.52 | 5.57 | 6.09 | 0.58 | 6.24 | 6.83 |
| Total | 285,000 | 242,000 | 85 | 16,000 | 27,300 | 43,300 | 17,900 | 30,600 | 48,500 |

*Source*: From Hutson, S.S. et al., 2004, *Estimated Use of Water in the United States in 2000*, U.S. Geological Survey Circular 1268, www.usgs.gov.



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**Table 7C.22 Water Produced by Selected Public Systems in the United States**

| City/County[a] | Utility | AWWA Study Group[c] | Service Pop.[b](000) | Total Number of Accounts | System Ownership | Daily Gallons Sold | Daily Capacity (MGD) | Max-Day Prod. (MGD) |
|---|---|---|---|---|---|---|---|---|
| **Alaska** | | | | | | | | |
| Anchorage, AK | Anchorage Water and Wastewater Utility | B | 217 | 53,432 | City | 21.75 | 79 | 49 |
| Juneau, AK | City & Borough of Juneau Water Utility | C | 30 | 8,430 | City | 3.29 | 10 | 6 |
| Fairbanks, AK | Golden Heart Utilities | C | 48 | 6,146 | Private | 3.04 | 8 | 6 |
| **Alabama** | | | | | | | | |
| Birmingham, AL | Birmingham Water Works Board | A | 700 | 195,321 | Dist./Auth. | 77.53 | 188 | 140 |
| Mobile Area, AL | Mobile Area Water and Sewer System | B | 259 | 89,168 | Dist/Auth. | 60.78 | 70 | 57 |
| Decatur, AL | Decatur Utilities | B | 103 | 23,871 | City | 27.78 | 48 | 37 |
| Huntsville, AL | Huntsville Utilities | B | 280 | 73,707 | City | 27.58 | 90 | 60 |
| Madison County, AL | Madison County Water Department | C | 67 | 22,481 | County | 5.16 | 12 | 10 |
| Sheffield, AL | Sheffield Utilities | C | 14 | 4,792 | City | 1.78 | 3 | 3 |
| **Arkansas** | | | | | | | | |
| Little Rock, AR | Central Arkansas Water | B | 366 | 132,267 | Other | 53.91 | 174 | 106 |
| North Little Rock, AR | Central Arkansas Water, North Little Rock | C | N/R | N/R | N/R | N/R | N/R | N/R |
| Jonesboro, AR | City Water and Light | C | 56 | 24,958 | Other | 10.88 | 31 | 22 |
| Russellville, AR | City Corporation | C | 25 | 11,036 | City | 6.13 | 20 | 11 |
| **Arizona** | | | | | | | | |
| Phoenix, AZ | City of Phoenix —Water Services Department | A | 1,591 | 355,202 | City | 284.00 | 670 | 421 |
| Tucson, AZ | Tucson Water | A | 680 | 211,337 | City | 98.40 | N/R | 160 |
| Scottsdale, AZ | City of Scottsdale Water Resources | B | 219 | 81,598 | City | 61.25 | 137 | 92 |
| Tempe, AZ | City of Tempe—Water Utilities Department | B | 164 | 41,681 | City | 49.31 | 120 | 74 |
| Peoria, AZ | City of Peoria | B | 106 | 37,300 | City | 20.27 | 54 | 28 |
| Tuscon Area, AZ | Metropolitan Domestic Water Improvement District | C | 45 | 16,974 | Dist./Auth. | 8.59 | 20 | 14 |
| Flagstaff, AZ | City Of Flagstaff | C | 60 | 16,948 | City | 7.50 | 22 | 12 |
| **California** | | | | | | | | |
| Los Angeles, CA | Los Angeles Dept. of Water and Power | A | 3,890 | 673,542 | City | 539.38 | 600 | 417 |
| San Francisco, CA | San Francisco Public Utilities Commission | A | 2,390 | 170,653 | City | 246.99 | 400 | 381 |
| Oakland, CA | East Bay Municipal Utility District | A | 1,300 | 377,094 | Dist./Auth. | 208.99 | 211 | 312 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| San Diego, CA | City of San Diego Water Department | A | 1,357 | 261,348 | City | 207.36 | 294 | 274 |
| Contra Costa, CA | Contra Costa Water District | A | 430 | 60,019 | Dist./Auth. | 170.14 | 75 | 64 |
| Sacramento, CA | City of Sacramento, Department of Utilities | A | 435 | 125,780 | City | 123.42 | 275 | 185 |
| Santa Clara, CA | Santa Clara Valley Water District | A | 1,700 | 8 | Dist./Auth. | 118.63 | 220 | N/A |
| Riverside County, CA | Eastern Municipal Water District | A | 501 | 89,576 | Dist./Auth. | 96.48 | 43 | 43 |
| Long Beach, CA | Long Beach Water Department | B | 461 | 89,139 | City | 62.23 | N/R | N/R |
| Riverside, CA | Riverside Public Utilities | B | 319 | 59,178 | City | 60.29 | 72 | 102 |
| Alameda County, CA | Alameda County Water District | B | 323 | 78,274 | Dist/Auth. | 45.29 | 91 | 75 |
| San Bernardino,CA | San Bernardino Municipal Water Department | B | 160 | 41,218 | City | 42.27 | 70 | 70 |
| Santa Ana, CA | City of Santa Ana, Public Works Agency | B | 344 | 47,468 | City | 40.38 | 132 | 57 |
| Palm Springs, CA | Desert Water Agency | B | 65 | 19,805 | Dist/Auth. | 37.02 | N/R | N/R |
| Glendale, CA | Glendale Water and Power | B | 200 | 32,478 | City | 27.61 | 9 | 38 |
| Oceanside, CA | City of Oceanside | B | 167 | 40,257 | City | 27.15 | 28 | 28 |
| Escondido, CA | City of Escondido | B | 130 | 24,285 | City | 27.08 | 67 | 67 |
| Covina Area, CA | Suburban Water Systems | B | 170 | 34,297 | Private | 23.65 | 7 | N/A |
| Covina, CA | Suburban Water Systems | B | 128 | 32,601 | Private | 21.49 | 17 | 33 |
| Chula Vista, CA | Sweetwater Authority | B | 176 | 33,785 | Dist./Auth. | 21.04 | 36 | 31 |
| Azusa, CA | Azusa Light & Water | C | 110 | N/R | N/R | 19.44 | 8 | N/R |
| Burbank, CA | Burbank Water and Power | C | 106 | 26,240 | City | 19.02 | 9 | 38 |
| Mesa, CA | Mesa Consolidated Water District | C | 111 | 23,530 | Dist./Auth. | 18.48 | 25 | 25 |
| Manteca, CA | City of Manteca | C | 55 | 14,723 | City | 11.33 | 34 | 26 |
| Mllpitas, CA | City of Milpitas | C | 64 | 15,164 | City | 10.42 | N/R | 20 |
| Santa Cruz, CA | City of Santa Cruz Water Department | C | 90 | 23,590 | City | 9.91 | 26 | 15 |
| Marin County, CA | North Marin Water District | C | 58 | 18,500 | Dist./Auth. | 9.66 | 25 | 19 |
| **Colorado** | | | | | | | | |
| Denver, CO | Denver Water | A | 1,081 | 217,607 | City | 197.86 | 645 | 419 |
| Colorado Springs, CO | Colorado Springs Utilities | B | 400 | 115,000 | City | 64.98 | 232 | 182 |
| Arvada, CO | City of Arvada | C | 105 | 31,855 | City | 15.70 | 52 | 38 |

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**Table 7C.22 (Continued)**

| City/County[a] | Utility | AWWA Study Group[c] | Service Pop.[b](000) | Total Number of Accounts | System Ownership | Daily Gallons Sold | Daily Capacity (MGD) | Max-Day Prod. (MGD) |
|---|---|---|---|---|---|---|---|---|
| Longmont, CO | City of Longmont Water/Wastewater Utilities | C | 79 | 23,717 | City | 12.22 | 30 | 32 |
| Grand Junction, CO | City of Grand Junction Water | C | 26 | 9,193 | City | 5.25 | 16 | 12 |
| **Connecticut** | | | | | | | | |
| Bridgeport, CT | Aquarion Water Company of CT | A | 575 | 172,000 | Private | 96.27 | 99 | 151 |
| New Haven, CT | South Central Connecticut Regional Water Authority | B | 391 | 106,467 | Dist/Auth. | 45.41 | 119 | 84 |
| Waterbury, CT | City of Waterbury Bureau of Water | C | 120 | 26,873 | City | 11.86 | 19 | 19 |
| Hartford, CT | The Metropolitan District | C | 359 | 93,520 | Dist./Auth. | 4.98 | 105 | 88 |
| Manchester, CT | Manchester Water Department | C | 56 | 15,301 | City | 4.77 | 12 | 9 |
| **District of Columbia** | | | | | | | | |
| Greater Washington, DC | Washington Aqueduct | A | 1,000 | 3 | Federal Gov. | 178.42 | 350 | 229 |
| **Delaware** | | | | | | | | |
| New Castle County, DE | United Water Delaware | C | 106 | 35,185 | Private | 18.10 | 36 | 27 |
| **Florida** | | | | | | | | |
| Miami, FL | Miami-Dade Water and Sewer Department | A | 2,343 | 408,187 | County | 271.89 | 434 | 363 |
| Orlando, FL | Orlando Utilities Commission | A | 395 | 123,464 | City | 78.13 | 183 | 107 |
| Pinellas County, FL | Pinellas County Utilities | B | 636 | 109,602 | County | 67.50 | 86 | 80 |
| Orange County, FL | Orange County Utilities | B | 596 | 98,001 | County | 46.69 | 110 | 80 |
| Jacksonville, FL | JEA | B | 860 | 240,469 | City | 42.99 | 60 | 46 |
| Fort Lauderdale, FL | City of Fort Lauderdale | B | 168 | 55,553 | City | 41.15 | 90 | 64 |
| Palm Beach County, FL | Palm Beach County Water Utilities Department | B | 440 | 140,188 | County | 39.40 | 73 | 61 |
| Manatee County, FL | Manatee County Utility Operations | B | 340 | 79,840 | County | 36.76 | 51 | 61 |
| Escambia County, FL | Escambia County Utilities Authority | B | 216 | 91,298 | Dist./Auth. | 34.22 | 75 | 58 |
| Pompano Beach, FL | Office of Environmental Services | B | 207 | 51,359 | Dist/Auth. | 27.17 | 46 | 32 |
| Tallahassee, FL | City of Tallahassee, Water Utility | B | 252 | 70,688 | City | 26.87 | 59 | 49 |
| Hollywood, FL | City of Hollywood | B | N/R | 38,400 | City | 23.38 | 41 | 28 |
| Cocoa, FL | City of Cocoa Utilities | B | 195 | 70,264 | City | 23.37 | 60 | 34 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Gainesville, FL | Gainesville Regional Utilities | B | 168 | 60,348 | City | 22.77 | 54 | ’ 37 |
| City of Lakeland, FL | City of Lakeland, Department of Water Utilities | B | 156 | 50,116 | City | 22.67 | 51 | 34 |
| Osceola County, FL | Tohopekaliga Water Authority | C | 151 | 40,931 | Dist./Auth. | 16.71 | 44 | 27 |
| Jupiter, FL | Town of Jupiter Utilities | C | 62 | 23,397 | City | 15.96 | 27 | 20 |
| Cape Coral, FL | City of Cape Coral | C | 100 | 40,000 | City | 6.96 | 15 | 11 |
| Martin County, FL | Martin County Utilities | C | 67 | 20,626 | County | 6.45 | 14 | 8 |
| Winter Springs, FL | City of Winter Springs | C | 30 | 14,500 | City | 4.30 | 12 | 6 |
| **Georgia** | | | | | | | | |
| Gwinnett County, GA | Gwinnett County DPU | B | 700 | 202,198 | County | 71.45 | 150 | 123 |
| DeKalb County, GA | DeKalb County Water & Sewer | B | 659 | 180,673 | County | 70.03 | 128 | 111 |
| Augusta, GA | Augusta Utilities Department | B | 201 | 66,820 | City | 40.50 | 84 | 58 |
| Columbus, GA | Columbus Water Works | B | 187 | 63,665 | City | N/R | 90 | 49 |
| Macon, GA | Macon Water Authority | B | 130 | 54,262 | Dist./Auth. | 26.08 | 76 | 43 |
| Savannah, GA | City of Savannah, Georgia | B | 248 | 81,062 | City | 22.18 | 113 | 87 |
| Douglas County, GA | Douglasville-Douglas County Water and Sewer Authority | C | 76 | 31,277 | Dist./Auth. | 8.48 | 16 | 14 |
| **Hawaii** | | | | | | | | |
| Honolulu, HI | Honolulu Board of Water Supply | A | 878 | 158,141 | City | 143.57 | 30 | N/R |
| Maui, HI | County of Maui—Department of Water Supply | B | 128 | 31,021 | County | 33.73 | 27 | 20 |
| Hawaii County, HI | Department of Water Supply | B | 111 | 37,000 | County | 24.45 | 25 | 37 |
| **Iowa** | | | | | | | | |
| Council Bluffs, IA | Council Bluffs Water Works | C | 61 | 20,035 | City | 9.37 | 20 | 18 |
| Cedar Rapids, IA | Cedar Rapids Water Department | B | 126 | 44,266 | City | 33.02 | 65 | 50 |
| Des Moines, IA | Des Moines Water Works | B | 390 | 72,428 | City | 40.96 | 125 | 82 |
| Waterloo, IA | Waterloo Water Works | C | 100 | 24,497 | City | 12.02 | 50 | 29 |
| Ames, IA | City of Ames Water and Pollution Control | C | 51 | 14,035 | City | 5.33 | 11 | 8 |
| **Idaho** | | | | | | | | |
| Boise, ID | United Water Idaho | B | 190 | 73,862 | Private | 41.14 | 100 | 91 |

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**Table 7C.22 (Continued)**

| City/County[a] | Utility | AWWA Study Group[c] | Service Pop.[b](000) | Total Number of Accounts | System Ownership | Daily Gallons Sold | Daily Capacity (MGD) | Max-Day Prod. (MGD) |
|---|---|---|---|---|---|---|---|---|
| Idaho Falls, ID | City of Idaho Falls | B | 52 | 23,500 | City | 22.93 | 82 | 57 |
| Twin Falls, ID | City of Twin Falls Water Department | C | 36 | 13,097 | City | 12.51 | 40 | 24 |
| **Illinois** | | | | | | | | |
| Chicago, IL | Chicago Department of Water | A | 5,306 | 490,689 | N/R | N/R | N/R | 1,346 |
| Evanston, IL | City of Evanston | B | 357 | 14,327 | City | N/R | N/R | N/R |
| Rockford, IL | City of Rockford Water Division | B | 155 | 52,100 | City | 21.01 | 65 | 46 |
| Decatur, IL | City of Decatur | C | 90 | 31,515 | City | 19.39 | 36 | 31 |
| Lake Bluff Village, IL | Central Lake County Joint Action Water Agency | C | 180 | 9 | Dist./Auth. | 19.17 | 38 | 32 |
| Naperville, IL | City of Naperville | C | 139 | 39,906 | City | 15.48 | 33 | N/A |
| **Indiana** | | | | | | | | |
| Evansville, IN | Evansville Water & Sewer Utility | B | 155 | 58,068 | City | 22.58 | 50 | 38 |
| South Bend, IN | South Bend Water Works | B | 103 | 43,441 | City | 21.53 | 64 | 47 |
| Columbus, IN | Columbus City Utilities | C | 36 | 15,455 | City | N/R | 28 | 19 |
| **Kansas** | | | | | | | | |
| Wichita, KS | Wichita Water & Sewer Utility | B | 414 | 135,552 | City | 55.53 | 160 | 115 |
| Johnson County, KS | Water District No. 1 of Johnson County, KS | B | 369 | 123,386 | Dist./Auth. | 53.41 | 165 | 130 |
| Kansas City, KS | Kansas City Board of Public Utilities | B | 157 | 51,793 | City | 22.54 | 45 | 42 |
| Leavenworth, KS | Leavenworth Water Department | C | 44 | 10,000 | City | 4.81 | 12 | 7 |
| Olathe, KS | City of Olathe | C | 108 | 31,412 | City | 11.44 | 21 | 25 |
| **Kentucky** | | | | | | | | |
| Campbell County, KY | Northern Kentucky Water District | B | N/R | 70,966 | N/R | N/R | N/R | N/R |
| Owensboro, KY | Owensboro Municipal Utilities | C | 92 | 23,861 | City | 11.51 | 30 | 17 |
| Paducah, KY | Paducah Waterworks | C | 70 | 22,180 | City | 7.07 | 12 | 11 |
| Winchester, KY | Winchester Municipal Utilities | C | 33 | 10,974 | City | 2.77 | 6 | 5 |
| Campbellsville, KY | Campbellsville Water Co. | C | 9 | 8,600 | City | 2.23 | 9 | 4 |
| **Louisiana** | | | | | | | | |
| Jefferson Parish, LA | Jefferson Parish Water Department | B | 427 | 142,172 | N/R | 54.95 | 148 | 95 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lafayette, LA | Lafayette Utilities System | C | 191 | 44,448 | City | 19.18 | 47 | 27 |
| Terrebonne Parish, LA | Consolidated Waterworks District No. 1, Terrebonne Parish | C | 104 | 39,138 | Dist./Auth. | 10.94 | 24 | 20 |
| Lafourche Parish, LA | Lafourche Parish Water District No. 1 | C | 78 | 28,087 | County | 9.11 | 18 | 12 |
| Baton Rouge Area, LA | Louisiana Water Company | C | 88 | 31,794 | Private | 8.71 | 18 | 13 |
| **Massachusetts** | | | | | | | | |
| Greater Boston Area, MA | Massachusetts Water Resources Authority | A | 2,200 | 47 | Dist/Auth. | 231.40 | 405 | 310 |
| Boston, MA | Boston Water and Sewer Commission | B | 589 | 87,160 | City | N/R | N/R | N/R |
| Cambridge, MA | Cambridge Water Department | C | 101 | 15,057 | City | 14.50 | 24 | 24 |
| **Maryland** | | | | | | | | |
| Laurel, MD | Washington Suburban Sanitary Commission | A | 1,557 | 433,555 | Dist./Auth. | 138.73 | 315 | 253 |
| Anne Arundel County, MD | Anne Arundel County | B | 324 | 98,469 | County | 34.27 | 42 | N/R |
| Frederick, MD | City of Frederick | C | 55 | 16,582 | City | 4.92 | 10 | 8 |
| Ocean City, MD | Ocean City, MD Water Department | C | 30 | 7,030 | City | 3.99 | 18 | 12 |
| **Maine** | | | | | | | | |
| Portland, ME | Portland Water District | C | 200 | 48,421 | Dist./Auth. | 19.81 | 52 | 43 |
| Kennebec ME | Kennebec Water District | C | 25 | 8,853 | Dist./Auth. | 2.63 | 12 | 5 |
| **Michigan** | | | | | | | | |
| Lansing, MI | Lansing Board of Water S Light | B | 235 | 56,088 | City | 22.12 | 50 | 39 |
| Kalamazoo, MI | City of Kalamazoo Dept. of Public Utilities | C | 120 | 36,601 | City | 18.51 | 67 | 41 |
| Ann Arbor, MI | City of Ann Arbor Water Utilities | C | 150 | 27,502 | City | 17.05 | 50 | 26 |
| Port Huron, MI | City of Port Huron | C | 57 | 12,774 | City | 7.67 | 20 | 15 |
| Grand Rapids, MI | City of Grand Rapids Water System | B | 280 | 76,540 | City | 34.74 | 135 | 80 |
| Waterford, MI | Waterford Township Water and Sewer Dept. | C | 75 | 23,430 | City | N/R | 9 | 21 |
| **Minnesota** | | | | | | | | |
| Saint Paul, MN | Saint Paul Regional Water Services | B | 417 | 92,959 | City | 40.95 | 150 | 80 |
| Dututh, MN | City of Duluth | C | 99 | 27,555 | N/R | 14.74 | 32 | 28 |
| Rochester, MN | Rochester Public Utilities | C | 90 | 32,400 | City | 11.70 | 31 | 28 |

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**Table 7C.22 (Continued)**

| City/County[a] | Utility | AWWA Study Group[c] | Service Pop.[b](000) | Total Number of Accounts | System Ownership | Daily Gallons Sold | Daily Capacity (MGD) | Max-Day Prod. (MGD) |
|---|---|---|---|---|---|---|---|---|
| **Missouri** | | | | | | | | |
| Louisville, MO | Louisville Water Company | A | 820 | 258,548 | City | 110.15 | 240 | 191 |
| Kansas City, MO | City of Kansas City, Missouri, Water Services Department | A | 600 | 167,035 | City | 86.30 | 240 | 200 |
| Springfield, MO | City Utilities of Springfield, MO | B | 195 | 74,946 | City | 26.02 | 61 | 50 |
| Columbia, MO | City of Columbia Water Department | C | 90 | 37,702 | City | 10.87 | 24 | 19 |
| Cape Girardeau, MO | City of Cape Girardeau | C | 35 | 15,000 | City | N/R | 8 | 7 |
| **Montana** | | | | | | | | |
| Great Falls, MT | City of Great Falls Utilities | C | 57 | 19,413 | City | 9.99 | 66 | 32 |
| Missoula, MT | Mountain Water Company | C | 60 | 20,935 | Private | 7.79 | 60 | 38 |
| Kalispell, MT | City of Kafispell | C | 22 | 6,427 | City | 1.89 | 9 | 8 |
| **North Carolina** | | | | | | | | |
| Charlotte, NC | Charlotte-Mecklenburg Utilities | A | 700 | 212,503 | City | 93.97 | 242 | 156 |
| Greensboro, NC | City of Greensboro Water Resources Department | B | 250 | 93,215 | City | 26.11 | 54 | 41 |
| Durham, NC | City of Durham, Env. Res. Dept. | B | 181 | 69,794 | City | 25.52 | 61 | 38 |
| Fayetteville, NC | Public Works Commission | B | 138 | 73,783 | City | 20.01 | 50 | 40 |
| Asheville, NC | City of Asheville—Water Resources Dept. | C | 126 | 46,666 | Dist./Auth. | 14.50 | 36 | 26 |
| Wilmington, NC | City of Wilmington | C | 103 | 40,400 | City | 11.99 | 29 | 21 |
| Cary, NC | Town of Cary | C | 114 | 33,900 | City | 11.75 | 40 | 26 |
| Rocky Mount, NC | City of Rocky Mount | C | 68 | 24,006 | City | 10.45 | 26 | 20 |
| Greenville, NC | Greenville Utilities Commission | C | 68 | 28,381 | City | 8.98 | 24 | 15 |
| Chapel Hill, NC | Orange Water and Sewer Authority | C | 70 | 18,844 | Dist./Auth. | 7.27 | 20 | 14 |
| Dare County, NC | Dare County Water Department | C | 32 | 13,706 | County | 4.62 | 13 | 12 |
| **North Dakota** | | | | | | | | |
| Bismarck, ND | City of Bismarck | C | 61 | 16,251 | City | 9.60 | 30 | 29 |
| Fargo, ND | Fargo Water Treatment Plant | C | 96 | 24,208 | City | 9.33 | 30 | 24 |
| Grand Forks, ND | Grand Forks Water | C | 50 | 12,754 | City | 6.80 | 17 | 11 |

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|---|---|---|---|---|---|---|---|---|
| **Nebraska** | | | | | | | | |
| Omaha, NE | Metropolitan Utilities District of Omaha | A | 550 | 180,540 | Dist./Auth. | 91.62 | 234 | 205 |
| Lincoln, NE | Lincoln Water System | B | 236 | 72,260 | City | 35.08 | 110 | 79 |
| **New Hampshire** | | | | | | | | |
| Concord, NH | City of Concord | B | 41 | 11,000 | City | 23.46 | 10 | 8 |
| Manchester, NH | Manchester Water Works | C | 150 | 27,114 | City | 15.82 | 40 | 31 |
| **New Jersey** | | | | | | | | |
| Morris County, NJ | Southeast Morris County Municipal Utilities Authority | C | 63 | 17,333 | Dist./Auth. | 6.90 | 21 | 21 |
| **New Mexico** | | | | | | | | |
| Albuquerque, NM | City of Albuquerque Public Works Department | A | 509 | 155,213 | City | 87.81 | 294 | 160 |
| **Nevada** | | | | | | | | |
| Reno, NV | Truckee Meadows Water Authority | B | 290 | 82,904 | Dist./Auth. | 35.56 | 159 | 150 |
| Washoe County, NV | Washoe County Department of Water Resources | C | 44 | 16,323 | County | 7.60 | N/R | 15 |
| **New York** | | | | | | | | |
| New York, NY | New York City Water Board | A | 9,000 | 827,072 | Dist./Auth. | 1,236.16 | 1,661 | 1,650 |
| Suffolk County, NY | Suffolk County Water Authority | A | 1,200 | 357,614 | Dist./Auth. | 185.21 | 700 | 470 |
| New Rochelle, NY | United Water New Rochelle | A | 137 | 30,941 | Private | 150.79 | 50 | 31 |
| Rockland County, NY | United Water New York | B | 260 | 68,638 | Private | N/R | N/R | N/R |
| Onondaga County, NY | Onondaga County Water Authority | B | 340 | 80,957 | Dist/Auth. | 38.94 | 70 | 59 |
| Niagara Falls, NY | Niagara Falls Water Board | C | 55 | 19,503 | Dist./Auth. | 17.57 | 35 | 21 |
| Nassau County, NY | New York Water Service Corporation | C | 170 | 45,800 | Private | 15.62 | 50 | 33 |
| Mohawk Valley, NY | Mohawk Valley Water Authority | C | 120 | 37,800 | Dist/Auth. | 11.45 | 32 | 20 |
| Elmira, NY | Elmira Water Board | C | 65 | 17,575 | City | 4.88 | 17 | 9 |
| Canton, NY | Village of Canton | C | 8 | 1,400 | City | 0.90 | 1 | 1 |
| **Ohio** | | | | | | | | |
| Cleveland, OH | Cleveland Division of Water | A | 1,500 | 414,012 | City | 167.50 | 545 | 395 |
| Columbus, OH | City of Columbus, Division of Water | A | 1,070 | 257,697 | City | 122.12 | 265 | 216 |

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**Table 7C.22 (Continued)**

| City/County[a] | Utility | AWWA Study Group[c] | Service Pop.[b](000) | Total Number of Accounts | System Ownership | Daily Gallons Sold | Daily Capacity (MGD) | Max-Day Prod. (MGD) |
|---|---|---|---|---|---|---|---|---|
| Cincinnati, OH | Greater Cincinnati Water Works | A | 1,100 | 236,017 | City | 112.26 | 260 | 220 |
| Akron, OH | City of Akron, Public Utilities Bureau | B | 281 | 82,939 | City | 29.90 | 67 | 54 |
| Canton, OH | City of Canton Water Department | B | 140 | N/R | City | 22.23 | 41 | 28 |
| Dayton, OH | City of Dayton, Department of Water | C | 420 | 57,420 | City | 7.04 | 196 | 114 |
| Newark, OH | City of Newark, OH Division of Water and Wastewater | C | 47 | 18,600 | City | 5.88 | 15 | 12 |
| **Oklahoma** | | | | | | | | |
| Tulsa, OK | Tulsa Metropolitan Utility Authority | A | 655 | 142,753 | City | 94.03 | 220 | 176 |
| Oklahoma City, OK | Oklahoma City Water Utility | A | 1,200 | 177,016 | City | 76.71 | 190 | 185 |
| Broken Arrow, OK | Broken Arrow | C | 88 | 30,286 | City | 10.98 | 6 | 0 |
| Midwest City, OK | City of Midwest City | C | 55 | 18,060 | City | 5.81 | 13 | 12 |
| **Oregon** | | | | | | | | |
| Portland, OR | Portland Bureau of Water Works | A | 787 | 163,819 | City | 105.21 | 325 | 187 |
| Eugene, OR | Eugene Water & Electric Board | B | 140 | 55,629 | City | 27.32 | 72 | 63 |
| Salem, OR | Salem Public Works | B | 170 | 40,760 | City | 25.70 | 85 | 55 |
| Medford, OR | Medford Water Commission | B | 114 | 25,385 | City | 24.58 | 66 | 54 |
| Washington County, OR | Tualatin Valley Water District | B | 222 | 51,963 | Dist./Auth. | 23.13 | N/A | N/A |
| Corvallis, OR | City of Corvallis | C | 52 | 15,217 | City | 5.59 | 25 | 14 |
| **Pennsylvania** | | | | | | | | |
| Philadelphia, PA | Philadelphia Water Department | A | 1,665 | 476,931 | City | 177.60 | 540 | 334 |
| Delaware County, PA | Aqua Pennsylvania, Inc. | A | 1,200 | 340,013 | Private | 95.79 | 176 | 150 |
| Westmoreland County, PA | Municipal Authority of Westmoreland County | B | 400 | 114,219 | N/R | N/R | 84 | 58 |
| Chester, PA | Chester Water Authority | B | 200 | 38,617 | Dist./Auth. | 29.45 | 60 | 41 |
| Lancaster, PA | City of Lancaster, Bureau of Water | C | 115 | 42,886 | City | 15.63 | 34 | 26 |
| Bucks County, PA | Bucks County Water and Sewer Authority | C | 194 | 15,671 | County | 15.40 | 35 | 21 |
| Allentown, PA | City of Allentown | C | 123 | 32,670 | City | 12.28 | 39 | 26 |

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|---|---|---|---|---|---|---|---|---|
| Harrisburg, PA | City of Harrisburg, Bureau of Water | C | 66 | 19,997 | Dist./Auth. | 8.92 | 20 | 11 |
| North Wales, PA | North Wales Water Authority | C | 90 | 26,923 | Dist./Auth. | 7.94 | 17 | 14 |
| Williamsport, PA | Williamsport Municipal Water Authority | C | 54 | 18,726 | Dist./Auth. | 6.91 | 13 | 8 |
| Lebanon, PA | City of Lebanon Authority | C | 57 | 17,152 | City | 4.79 | 8 | 9 |
| State College, PA | State College Water Authority | C | 65 | 12,341 | Dist/Auth. | 4.44 | 9 | 7 |
| Carlisle, PA | Borough of Carlisle Municipal Authority | C | 20 | 6,205 | Dist./Auth. | 1.75 | 7 | 5 |
| **Rhode Island** | | | | | | | | |
| Providence, RI | Providence Water | B | 600 | 73,493 | City | 57.91 | 144 | 120 |
| **South Carolina** | | | | | | | | |
| Greenville, SC | Greenville Water System | B | 400 | 144,015 | City | 50.71 | 142 | 106 |
| Charleston, SC | Commissioners of Public Works, Charleston, SC | B | 409 | 90,121 | Dist/Auth. | 43.86 | 118 | 67 |
| Spartanburg, SC | Spartan burg Water System | B | 125 | 45,780 | Dist/Auth. | 23.55 | N/R | N/R |
| Horry County, SC | Grand Strand Water & Sewer Authority | C | 160 | 41,552 | Dist./Auth. | 19.81 | 45 | 34 |
| Mount Pleasant, SC | Mount Pleasant Waterworks | C | 66 | 26,395 | Dist./Auth. | 5.90 | 7 | 11 |
| Georgetown County, SC | Georgetown County Water & Sewer District | C | 46 | 14,455 | Dist./Auth. | 3.87 | 8 | 7 |
| **South Dakota** | | | | | | | | |
| Sioux—Falls, SD | City of Sioux —Falls | C | 139 | 38,853 | City | 19.53 | 55 | 52 |
| **Tennessee** | | | | | | | | |
| Nashville, TN | Metro Water Services | A | 458 | 155,712 | City | 613.70 | 180 | 104 |
| Erwin, TN | Erwin Utilities | C | 13 | 4,858 | City | 1.83 | 3 | 3 |
| Seliner, TN | Setmer Utility Division | C | 26 | 6,884 | City | 1.55 | 5 | 2 |
| **Texas** | | | | | | | | |
| Dallas, TX | Dallas Water Utilities | A | 1,979 | 314,722 | City | 348.39 | 815 | 641 |
| Houston, TX | City of Houston, Public Works and Engineering | A | 1,954 | 412,000 | City | 309.96 | 884 | 440 |
| San Antonio, TX | San Antonio Water System | A | 1,145 | 304,340 | City | 142.06 | 964 | 230 |
| Fort Worth, TX | Fort Worth Water Department | A | 838 | 171,828 | City | 133.39 | 380 | 274 |
| Austin, TX | Austin Water Utility | A | 770 | 184,608 | City | 120.56 | 260 | 214 |

*(Continued)*



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**Table 7C.22 (Continued)**

| City/County[a] | Utility | AWWA Study Group[c] | Service Pop.[b](000) | Total Number of Accounts | System Ownership | Daily Gallons Sold | Daily Capacity (MGD) | Max-Day Prod. (MGD) |
|---|---|---|---|---|---|---|---|---|
| El Paso, TX | El Paso Water Utilities | A | 696 | 173,653 | City | 96.91 | 235 | 174 |
| Arlington, TX | City of Arlington Water Utilities | B | 346 | 92,755 | City | 52.17 | 174 | 113 |
| Plano, TX | City of Plano—Utility Operations | B | 250 | 75,100 | City | 51.97 | N/A | 109 |
| Amarillo, TX | City of Amarillo TX | B | 175 | 63,360 | City | 45.60 | N/R | N/R |
| Irving, TX | City of Irving Water Utilities | B | 198 | 43,584 | City | 35.66 | 73 | 69 |
| Garland, TX | City of Garland | B | 221 | 62,068 | City | 28.60 | 44 | N/A |
| Laredo, TX | City of Laredo | B | 178 | 56,203 | City | 27.07 | 65 | 58 |
| Midland, TX | City of Midland | B | 96 | 32,494 | City | 23.65 | 57 | 37 |
| Waco, TX | City of Waco Water Utilities | B | 150 | 37,206 | City | 23.64 | 66 | 53 |
| Tyler, TX | City of Tyler Water Utilities | C | 175 | 27,726 | City | 17.61 | 40 | 37 |
| Denton, TX | Denton Municipal Utilities | C | 92 | 24,053 | City | 12.99 | 50 | 26 |
| Sugar Land, TX | City of Sugar Land | C | 65 | 20,940 | City | 11.52 | 43 | 23 |
| College Station, TX | College Station Utilities | C | 79 | 29,360 | City | 8.51 | 23 | 21 |
| Bell County, TX | Central Texas WSC | C | 50 | 15 | N/R | 5.43 | 14 | 12 |
| **Utah** | | | | | | | | |
| Salt Lake City, UT | Salt Lake City Public Utilities | A | 325 | 91,283 | City | 82.54 | 282 | 206 |
| Salt Lake City, UT | Jordan Valley Water Conservancy District | B | 845 | 8,541 | Dist./Auth. | 62.64 | 200 | 159 |
| Provo, UT | Provo City Water Resources | B | 112 | 17,372 | City | 21.64 | 73 | 53 |
| **Virginia** | | | | | | | | |
| Richmond, VA | City of Richmond | A | 502 | 59,747 | City | 83.70 | 132 | 127 |
| Virginia Beach, VA | City of Virginia Beach Public Utilities | B | 421 | 127,314 | City | 31.90 | 60 | 31 |
| Chesterfield County, VA | Chesterfield County Department of Utilities | B | 250 | 88,001 | County | 29.24 | 12 | 11 |
| Chesapeake, VA | City of Chesapeake Public Utilities | C | 167 | 57,613 | City | 16.02 | 10 | 12 |
| Charlottesville, VA | City of Charlottesville | C | 40 | 13,153 | City | 5.48 | N/A | N/A |
| **Vermont** | | | | | | | | |
| Burlington, VT | Burlington Public Works | C | 44 | 9,800 | City | 4.59 | 12 | 7 |
| South Burlington, VT | South Burlington Water Department | C | 15 | 5,300 | City | N/R | N/R | N/R |
| **Washington** | | | | | | | | |
| Seattle, WA | Seattle Public Utilities | A | 1,330 | 176,359 | City | 126.69 | 405 | 223 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tacoma, WA | Tacoma Public Utilities, Water Division | B | 300 | 91,376 | City | 52.66 | 134 | 93 |
| Lakehaven, WA | Lakehaven Utility District | C | 112 | 27 | Dist./Auth. | 11.13 | 34 | 21 |
| Olympia, WA | City of Olympia | C | 51 | 17,064 | City | 9.00 | 25 | 13 |
| Kennewick, WA | City of Kennewick | C | 62 | 18,881 | City | 8.86 | 22 | 18 |
| Renton, WA | City of Renton | C | 54 | 15,042 | City | 6.40 | 22 | 14 |
| Kent, WA | Highline Water District | C | 66 | 18,078 | Dist./Auth. | 6.33 | 2 | 2 |
| Snohomish County, WA | Snohomish County PUD #1 | C | 53 | 15,162 | Dist./Auth. | 3.95 | 20 | 8 |
| **Wisconsin** | | | | | | | | |
| Green Bay, WI | Green Bay Water Utility | C | 103 | 35,466 | City | 15.95 | 28 | 31 |
| Oak Creek, WI | Oak Creek Water and Sewer Utility | C | 60 | 9,503 | City | 6.61 | 20 | 15 |
| Milwaukee, WI | Milwaukee Water Works | A | 831 | 160,976 | City | 109.35 | 380 | 170 |
| Kenosha, WI | Kenosha Water Utility | C | 118 | 28,319 | City | 11.67 | 42 | 25 |
| Janesville, WI | Janesville Water Utility | C | 61 | 22,299 | City | 11.10 | 29 | 22 |
| River Falls, WI | River Falls Municipal Utility | C | 13 | 3,755 | City | 0.95 | 7 | 3 |
| **West Virginia** | | | | | | | | |
| Lubeck, WV | Lubeck Public Service District | C | 11 | 3,794 | Dist./Auth. | 0.73 | 3 | 1 |
| **Wyoming** | | | | | | | | |
| Cheyenne, WY | Cheyenne Board of Public Utilities | C | 53 | 19,998 | City | 13.71 | 32 | N/R |
| Casper, WY | City of Casper Public Utilities | C | 54 | 18,785 | City | 9.21 | 52 | 28 |

*Note:* Group A >75 mgd sold; Group B 20–75 mgd sold; Group C <20 mgd sold.

[a] The primary city, county, or area served by the responding utility is listed.
[b] Includes retail and wholesale population.

*Source*: Adapted from *2004 Water and Wastewater Rate Survey* by permission. Copyright © 2004, American Water Works Association. (Updated information available electronically from AWWA at 800-926-7337), www.awwa.org.



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**Table 7C.23 Summary of 2004 Residential and Industrial Water Charges by Public Water Systems (Based on a Survey of 266 Systems)**

| | | Monthly Water Charges | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 5/8-inch Meter | | | | | | 2-inch Meter | 4-inch Meter | 8-inch Meter |
| Summary Statistics[a] (11,220,000 gal) | Effective Date | Residential 0 cf (0 gal) | Residential 500 cf (3,740 gal) | Residential 1,000 cf (7,480 gal) | Residential 1,500 cf (11,220 gal) | Residential 3,000 cf (22,440 gal) | Nonmanuf./ Commercial 3,000 cf (22,440 gal) | Commercial/ Light Industrial 50,000 cf (374,000 gal) | Industrial 1,000,000 cf (7,480,000 gal) | Industrial 1,500,000 cf |
| ***All Systems (excluding Canadian systems)*** | | | | | | | | | | |
| Average | 11/26/01 | $6.37 | $12.29 | $19.85 | $28.12 | $53.35 | $52.81 | $759.42 | $13.734.00 | $20,611.53 |
| Median | 1/1/03 | $5.55 | $11.67 | $19.08 | $27.15 | $51.37 | $49.85 | $732.40 | $12,954.04 | $19,265.80 |
| Number of Systems | 263 | 257 | 255 | 256 | 255 | 255 | 254 | 253 | 251 | 240 |
| ***Group A Systems (75-MGD Sold)*** | | | | | | | | | | |
| Average | 8/16/02 | $5.76 | $12.00 | $19.31 | $27.63 | $54.77 | $52.57 | $772.28 | $13,943.78 | $20,993,93 |
| Median | 3/3/03 | $4.75 | $10.72 | $18.66 | $26.21 | $49.45 | $49.86 | $755.55 | $13,516,66 | $20,503.95 |
| Number of Systems | 47 | 43 | 42 | 43 | 42 | 42 | 42 | 42 | 42 | 42 |
| ***Group B Systems (20–75 MGD Sold)*** | | | | | | | | | | |
| Average | 11/24/01 | $6.21 | $11.47 | $18.11 | $25.66 | $48.42 | $45.84 | $689.73 | $12,681.52 | $18,248.64 |
| Median | 1/1/03 | $5.60 | $10.76 | $16.37 | $25.07 | $46.17 | $42.95 | $672.88 | $11,747.97 | $17,137.98 |
| Number of Systems | 93 | 93 | 93 | 93 | 93 | 93 | 92 | 92 | 91 | 89 |
| ***Group C Systems (20 MGD Sold)*** | | | | | | | | | | |
| Average | 8/18/01 | $6.71 | $13.03 | $21.40 | $30.19 | $56.68 | $58.24 | $808.76 | $14,470.99 | $22,393.52 |
| Median | 1/1/03 | $5.85 | $12.60 | $21.21 | $29.85 | $54.53 | $54.69 | $758.86 | $13,069.17 | $20,134.83 |
| Number of Systems | 123 | 121 | 120 | 120 | 120 | 120 | 120 | 119 | 118 | 109 |
| ***Canadian Systems***[b] | | | | | | | | | | |
| Average | 12/28/02 | $7.76 | $15.10 | $23.74 | $62.05 | $104.96 | $104,96 | $623.62 | $13,995.92 | $22,312.50 |
| Median | 1/1/03 | $6.71 | $15.60 | $24.00 | $69.64 | $119.89 | $119.89 | $736.26 | $15,062,03 | $24,033.88 |
| Number of Systems | 11 | 8 | 10 | 10 | 10 | 9 | 9 | 10 | 10 | 10 |

[a] Seasonal and zonal water charges are not included in average and median charge calculations. The number of systems indicates the size of sample for which data was provided.
[b] Water charges for Canadian systems are presented in Canadian dollars. The exchange rate on July 21, 2004, was 1.3242 Canadian dollars to 1 US dollar.

*Source*: Adapted from *2004 Water and Wastewater Rate Survey* by permission. Copyright © 2004, American Water Works Association. (Updated information available electronically from AWWA at 800-926-7337), www.awwa.org.

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**Table 7C.24 Unaccounted for Water by Ownership in Public Supply Systems in the United States in 2000 (Based on a Survey of 1246 Systems)**

| Ownership Type | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 or Less | 101–500 | 501–3,300 | 3,301–10,000 | 10,001–50,000 | 50,001–100,000 | 100,001–500,000 | Over 500,000 | All Sizes |
| **Public Systems** | | | | | | | | | |
| Average Unaccounted for Water | 0.003 | 0.001 | 0.017 | 0.113 | 0.296 | 1.166 | 2.152 | 18.272 | 0.188 |
| Confidence Interval | ±0.006 | ±0.000 | ±0.006 | ±0.032 | ±0.074 | ±0.268 | ±0.567 | ±4.405 | ±0.032 |
| % of Total Water Produced | 1.140 | 5.990 | 9.935 | 11.562 | 8.528 | 9.693 | 6.306 | 7.959 | 8.949 |
| Confidents Interval | ±1.419 | ±7.067 | ±3.763 | ±3.161 | ±1.861 | ±2.044 | ±1.556 | ±1.027 | ±2.211 |
| **Private Systems** | | | | | | | | | |
| Average Unaccounted for Water | 0.000 | 0.001 | 0.012 | 0.100 | 0.287 | 1.055 | 3.050 | 7.347 | 0.019 |
| Confidence Interval | ±0.000 | ±0.000 | ±0.009 | ±0.061 | ±0.110 | ±0.395 | ±0.835 | ±2.972 | ±0.006 |
| % of Total Water Produced | 0.187 | 2.188 | 6.237 | 10.686 | 12.330 | 11.093 | 10.636 | 7.744 | 2.323 |
| Confidence Interval | ±0.269 | ±2,660 | ±3.940 | ±4.252 | ±4.511 | ±4.317 | ±2.582 | ±4.017 | ±1.237 |
| **All Systems** | | | | | | | | | |
| Average Unaccounted for Water | 0.000 | 0.001 | 0.016 | 0.111 | 0.294 | 1.152 | 2.227 | 17.258 | 0.098 |
| Confidence Interval | ±0.000 | ±0.000 | ±0.006 | ±0.028 | ±0.064 | ±0.238 | ±0.536 | ±4.031 | ±0.012 |
| % of Total Water Produced | 0.258 | 3.355 | 9.136 | 11.435 | 9.135 | 9.867 | 6.670 | 7.939 | 5.561 |
| Confidence interval | ±0.269 | ±2.859 | ±3.218 | ±2.724 | ±1.747 | ±1.864 | ±1.508 | ±1.001 | ±1.305 |

*Note:* Unaccounted for water includes system losses, water for fire suppression, and water used in the treatment process.
The tabulations presented in the Community Water System Survery 2000 are based on data collected from a sample of U.S. Water Systems, not from a census of every water system in the United States. A confidence interval is one way to gauge how precisely a given tabulation of survey data can be generalized to the entirety of U.S. Systems represented by the surveyed systems. Any result presented in the table must be viewed as the center of a range that would encompass the precise number that would be found if every U.S. water system could have been included in the tabulation, and not only those who were sampled and responded to the 2000 Community Water System Survey. The confidence interval expresses the range as a "plus/minus," that is, an amount to be added to and subtracted from the calculated data point actually presented in the table. The confidence interval is designed to include the true value in the stated range 95 percent of the time.

*Source*: From USEPA, 2002, Community Water System Survery 2000, EPA 815-R-02-005A, www.epa.gov.

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## SECTION 7D PUBLIC WATER SUPPLY—WORLD

**Table 7D.25 Groundwater Use in Canada, 1996**

| Province/Territory | Population Reliant on Groundwater[a] | | Municipal Water Systems Reliant on Groundwater[b] | |
|---|---|---|---|---|
| | Number | Percent | Number | Percent |
| Newfoundland and Labrador | 189,921 | 33.9 | 19 | 23.5 |
| Prince Edward Island | 136,188 | 100.0 | 5 | 100.0 |
| Nova Scotia | 426,433 | 45.8 | 15 | 41.7 |
| New Brunswick | 501,075 | 66.5 | 40 | 72.7 |
| Quebec | 2,013,340 | 27.7 | 142 | 36.7 |
| Ontario | 3,166,662 | 28.5 | 132 | 42.7 |
| Manitoba | 342,601 | 30.2 | 22 | 50.0 |
| Saskatchewan | 435,941 | 42.8 | 44 | 65.7 |
| Alberta | 641,350 | 23.1 | 36 | 29.0 |
| British Columbia | 1,105,803 | 28.5 | 63 | 45.3 |
| Yukon Territory | 15,294 | 47.9 | 4 | 100.0 |
| Northwest Territories[c] | 18,971 | 28.1 | 0 | 0.0 |
| Canada | 8,993,579 | 30.3 | 522 | 41.2 |

[a] It is assumed that the population not covered by the Municipal Water Use Database is rural and that 90% of this population is groundwater reliant (except in Prince Edward Island, where 100% of the population is known to be groundwater reliant).
[b] Includes population and municipal water systems that are reliant on groundwater only, as well as those that are reliant on groundwater and surface water.
[c] Includes Nunavut.

*Source*: Statistics Canada, Human Activity and the Environment Annual Statistics 2003, Catalogue 16-201-XPE, released December 3, 2003, page 25. Statistics Canada information is used with the permission of Statistics Canada. Users are forbidden to copy this material and/or redisseminate the data, in an original or modified form, for commercial purposes, without the expressed permission of Statistics Canada. Information on the availability of the wide range of data from Statistics Canada can be obtained from Statistics Canada's Regional Offices, its World Wide Web site at www.statcan.ca, and its toll-free access number 1-800-263-1136.

*Original Source*: From Statistics Canada, Environment Accounts and Statistics Division, special compilation using data from Environment Canada, Municipal Water Use Database; Statistics Canada, 1996, *Quarterly Estimates of the Population of Canada, the Provinces and the Territories*, 11:3, Catalogue no. 91–001, Ottawa.

**Table 7D.26 Water Flows and Metering Rates in Canada, by Province/Territory and Municipal Population**

| Province/Territory | Percentage of Flow from Surface Water | Total Average Daily Flow (Litres Per Capita) | Average Daily Residential Flow (Litres Per Capita) | Percentage of Residential Clients That Are Metered | Percentage of Business Clients That Are Metered |
|---|---|---|---|---|---|
| Newfoundland | 95.1 | 971 | 664 | 0.0 | 47.4 |
| P.E.I. | 0.0 | 529 | 218 | 13.4 | 100.0 |
| Nova Scotia | 91.4 | 667 | 351 | 89.1 | 99.4 |
| New Brunswick | 79.7 | 1,314 | 416 | 49.6 | 89.5 |
| Quebec | 93.4 | 777 | 395 | 16.2 | 32.8 |
| Ontario | 88.4 | 533 | 285 | 89.9 | 98.4 |
| Manitoba | 81.6 | 410 | 223 | 96.6 | 98.6 |
| Saskatchewan | 87.5 | 517 | 236 | 98.5 | 99.6 |
| Alberta | 93.9 | 519 | 282 | 82.3 | 98.9 |
| British Columbia | 84.6 | 651 | 425 | 26.5 | 93.9 |
| Yukon | 69.0 | 803 | 556 | 52.8 | 100.0 |
| N.W.T. | 100.0 | 424 | 204 | 97.3 | n/a |
| Nunavut | 100.0 | 105 | 88 | 76.7 | 20.0 |

*(Continued)*

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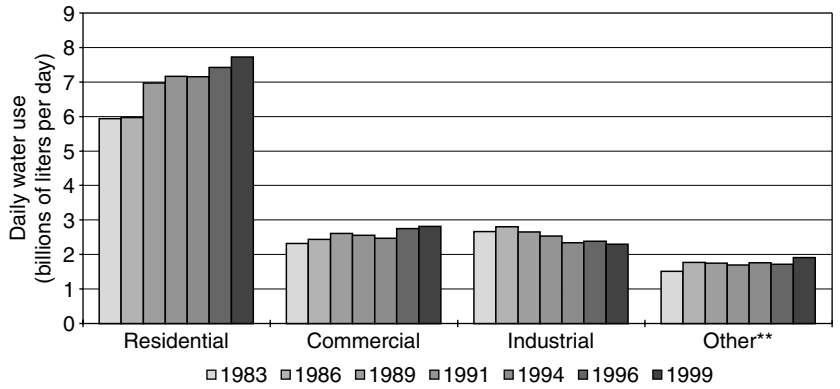
**Table 7D.26 (Continued)**

| Province/Territory | Percentage of Flow from Surface Water | Total Average Daily Flow (Litres Per Capita) | Average Daily Residential Flow (Litres Per Capita) | Percentage of Residential Clients That Are Metered | Percentage of Business Clients That Are Metered |
|---|---|---|---|---|---|
| **Municipal Population** | | | | | |
| Under 2,000 | 61.2 | 715 | 446 | 42.4 | 53.2 |
| 2,000–5,000 | 57.3 | 732 | 466 | 35.4 | 55.5 |
| 5,000–50,000 | 78.9 | 665 | 397 | 47.5 | 75.0 |
| 50,000–500,000 | 88.9 | 596 | 326 | 61.7 | 91.3 |
| More than 500,000 | 99.6 | 614 | 300 | 69.0 | 81.8 |
| Total | 89.2 | 622 | 335 | 60.6 | 83.1 |
| Responding Population | 21,634,144 | 23,822,869 | 23,822,869 | 24,235,565 | 16,075,854 |

*Note:* n/a = not applicable.

*Source*: From *Environment Canada, 2005, 2004 Municipal Water Use Report, Municipal Water Use 2001 Statistics*, www.ec.gc.ca/water/en/manage/use/e_data.htm, Environment Canada, 2005. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

*Original Source*: From values derived from the *2001 Municipal Water Use Database, Sustainable Water Use Branch*, Environment Canada.




*Note:* *Water use values are based on (1) municipalities that responded in a given year, and (2) a national level estimate for all municipalities that did not respond, or in earlier years, were not surveyed.
**The "Other" category includes: water lost through leakage; unaccounted water uses, such as water used in firefighting or to flush out pipes; and water that a municipality was unable to one of the other three sectoral categories.

**Figure 7D.11** Canada—total daily municipal water use* by sector, 1983–1999. (From www.ec.gc.ca. Environment Canada, 2001, Urban Waler Indicators: Municipal Water Use and Wastewater Treatment, SOE Bulletin No. 2001-1, Environment Canada, 2001. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.)

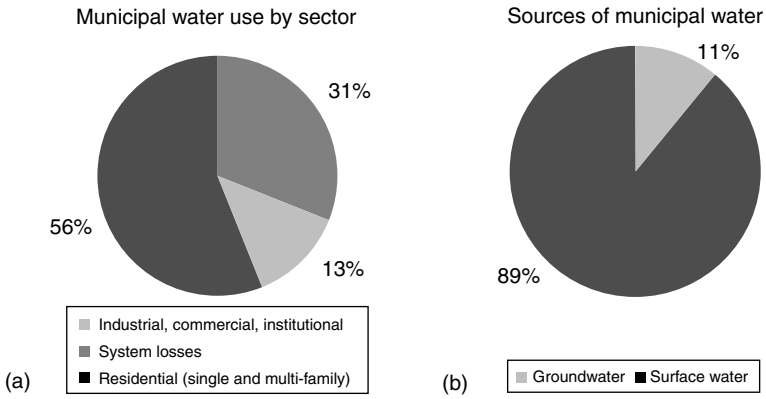



**Figure 7D.12** Canada—municipal water use by sector and sources of municipal water, 2001. (From Environment Canada, 2005, 2004, *Municipal Water Use Report, Municipal Water Use 2001 Statistics*, www.ec.gc.ca/water/en/manage/use/e_data.htm, Environment Canada, 2005. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.)

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**Table 7D.27 Water Use (as a Percentage of Water Served) in Canada, by Province/Territory, by Sector, and Responding Population**

| Province/Territory | Residential (%) | Commercial/Industrial (%) | System Losses (%) | Responding Population |
|---|---|---|---|---|
| Newfoundland | 73 | 21 | 6 | 279,376 |
| P.E.I. | 42 | 41 | 17 | 43,037 |
| Nova Scotia | 59 | 25 | 16 | 462,020 |
| New Brunswick | 50 | 41 | 9 | 309,203 |
| Quebec | 56 | 25 | 19 | 5,892,601 |
| Ontario | 53 | 35 | 12 | 8,157,365 |
| Manitoba | 55 | 36 | 9 | 775,398 |
| Saskatchewan | 46 | 44 | 10 | 613,659 |
| Alberta | 56 | 35 | 9 | 2,327,245 |
| British Columbia | 65 | 28 | 6 | 2,986,953 |
| Yukon | 68 | 32 | n/a | 17,635 |
| N.W.T. | 45 | 30 | 25 | 23,135 |
| Nunavut | 78 | 16 | 6 | 6,204 |
| **Municipal Population** | | | | |
| Under 2,000 | 70 | 24 | 5 | 243,218 |
| 2,000–5,000 | 68 | 27 | 6 | 662,738 |
| 5,000–50,000 | 61 | 31 | 9 | 4,035,190 |
| 50,000–500,000 | 57 | 33 | 10 | 8,344,616 |
| More than 500,000 | 51 | 31 | 18 | 8,608,069 |
| Total, 2001 | 56 | 31 | 13 | 21,893,832 |
| Total, 1999 | 52 | 35 | 13 | |

*Note:* n/a = not applicable.

*Source*: From *Environment Canada 2005, 2004 Municipal Water Use Report, Municipal Water Use 2001 Statistics*, www.ec.gc.ca/water/en/manage/use/e_data.htm, Environment Canada, 2005. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

*Original Source*: From values derived from the *2001 Municipal Water Use Database, Sustainable Water Use Branch*, Environment Canada.

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**Table 7D.28 Public Water System Characteristics of Selected Water Systems in Canada**

| City/County (a) | Utility | Service Pop. (b) (000) | Total Number of Accounts | System Ownership | Daily Gallons Sold | Daily Capacity (MGD) | Max-Day Prod. (MGD) |
|---|---|---|---|---|---|---|---|
| **Canadian Water Systems (d)** | | | | | | | |
| Montreal, PQ | Service de la gestion des infrastructures et de l'environnement | 1,845 | 335,255 | City | 314.84 | 766 | 608 |
| Vancouver, BC | Greater Vancouver Water District | 2,021 | 17 | Dist/Auth. | 306.34 | N/R | 406 |
| Edmonton, AB | EPCOR Water Services Inc | 872 | 198,707 | Private | 91.63 | 114 | 133 |
| Winnipeg, MB | City of Winnipeg—Water and Waste Department | 631 | 183,803 | City | 51.86 | N/R | 166 |
| Regina, SK | City of Regina | 190 | 59,045 | City | 17.37 | 53 | 39 |
| Barrie, ON | City of Barrie Water Section | 135 | 36,000 | City | 9.26 | 26 | 26 |
| Coquitlam, BC | City of Coquitlam | 114 | 33,647 | City | 15.19 | N/R | N/R |
| Victoria, BC | City of Victoria | 90 | 18,843 | City | 12.93 | N/R | N/R |
| Sault Ste Marie, ON | City of Sault Ste Marie Public Utilities Commission | 75 | 25,366 | City | 7.73 | 21 | 17 |
| Strathcona County, AB | Strathcona County | 76 | 18,077 | City | 7.87 | N/R | N/R |
| Prince Albert, SK | City of Prince Albert | 40 | 10,500 | City | N/R | 12 | 10 |

*Note:* N/R, Not Reported

(a) The primary city, county, or area served by the responding utility is listed.

(b) Includes retail and wholesale population.

(d) Daily gallons sold, daily capacity, and max-day production for the Canadian systems have been converted to U.S. gallons (1 U.S. gallon = 0.8327 imperial gallons s 0.003785 $m^3$).

N/R = Not Reported.

*Source*: Adapted from *2004 Water and Wastewater Rate Survey* by permission. Copyright © 2004, American Water Works Association. (Updated information available electronically from AWWA at 800-926-7337), www.awwa.org.

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**Table 7D.29 International Public Water System Characteristics, 2004**

| City/Service Area | Utility | Service Pop.[a](000) | System Ownership | Gallons Sold (MGD)[b] | Active Water Accounts | Water Source[c](%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Groundwater | Surface | Purchased |
| Osaka City, Japan | Osaka Municipal Waterworks Bureau | 2,619,494 | City | 53,814.94 | 887,735 | N/R | 100 | N/R |
| Taichung, Chinese Taiwan | Taiwan Water Supply Corporation | 16,548,877 | Dist/Auth. | 1,421.59 | 5,424,515 | 19 | 79 | 2 |
| Sao Paulo, Brazil | Companhia de Saneamento Basico do Estado de Sao Pauto—SABESP | 24,972,000 | State Owned | 1,281.07 | 5,305,883 | 6 | 94 | 2 |
| Rijswijk, Netherlands | VEWIN, The Netherlands Waterworks Association | 16,109,000 | Dist/Auth. | 831.31 | 7,231,025 | 61 | 39 | 0 |
| Seoul, South Korea | Office of Waterworks Seoul Metropolitan Government | 10,280,183 | Dist./Auth. | 794.48 | 1,939,847 | 0 | 89 | 11 |
| Wan Chai, Hong Kong | Water Supplies Department | 6,809,000 | Dist./Auth. | N/R | 2,545,717 | 0 | 25 | 75 |
| Sydney, Australia | Sydney Water | 4,198,000 | Dist./Auth. | 376.57 | 1,638,000 | 0 | 0 | 100 |
| Bangkok, Thailand | Provincial Waterworks Authority (PWA) | 10,000,000 | Dist./Auth. | 372.74 | 1,897,758 | 14 | 60 | 26 |
| Alexandria, Egypt | Alexandria Water General Authority (AWGA) | 4,500,000 | Dist./Auth. | 364.63 | 1,119,023 | 0 | 0 | 100 |
| Yokohama, Japan | Yokohama Waterworks Bureau | 3,506,966 | City | 317.25 | 1,200,908 | 0 | 44 | 57 |
| Curitiba, Brazil | SANEPAR—Companhia de Saneamento do Parana' | 7,761,171 | Dist/Auth. | 300.51 | 2,020,030 | 17 | 83 | 0 |
| Denmark | DANVA—Danish Water and Waste Water Association | 5,370,000 | Private | 280.91 | 1,287,000 | 98 | 2 | 0 |
| Busan, South Korea | Busan Metropolitan Waterworks Headquarters | 3,701,000 | Dist/Auth. | 254.33 | 331,350 | 0 | 100 | 0 |
| Nagoya, Japan | Nagoya Waterworks & Sewerage Bureau | 2,283,381 | City | 203.1 | 1,129,695 | 0 | 100 | 0 |
| Leederville, Australia | Water Corporation of Western Australia | 1,790,953 | Dist/Auth. | 180.11 | 754,810 | 62 | 38 | 0 |
| Leederville, Australia | Water Corporation | 1,817,750 | Private | 171.43 | 805,988 | 61 | 39 | 0 |
| Adelaide, Australia | South Australia Water Corporation | 1,492,000 | Dist./Auth. | 169.84 | 645,431 | 17 | 83 | 0 |
| Lisbon, Portugal | EPAL—Empressa Portuguesa das Aguas Livres | 2,203,386 | Dist./Auth. | 158.76 | 334,544 | 13 | 87 | 0 |
| Barcelona, Spain | Aguas de Barcelona | 2,848,869 | City | 138.17 | 208,021 | 38 | 11 | 51 |
| Sapporo, Japan | Sapporo Waterworks Bureau | 1,836,629 | City | 129.9 | 809,456 | 0 | 100 | 0 |
| Turin, Italy | Societa Metropolitana Acque Torino Spa | 1,437,536 | City | 121.26 | 144,627 | 81 | 19 | 1 |
| Concepcion, Chile | Empresas de servicios sanrtarios del Bio–Bio | 1,962,726 | Private | 84.36 | 545,202 | 53 | 47 | 0 |
| Dublin, Ireland | Dublin City Council | 1,033,000 | City | 65.78 | 221,005 | 0 | 21 | 79 |
| Bristol, United Kingdom | Bristol Water pic | 1,110,000 | Private | 56.25 | 473,001 | 20 | 80 | 0 |
| Helsinki, Finland | Helsinki Water | 882,000 | City | 52.26 | 25,809 | 0 | 100 | 0 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Oslo, Norway | Oslo Water and Sewage Works | 521,000 | City | 39.28 | 51,300 | 0 | 100 | 0 |
| Addis Ababa, Ethiopia | Addis Ababa Water and Sewerage Authority | 2,600,000 | Dist./Auth. | 36.92 | 210,000 | 11 | 89 | 0 |
| Angered, Sweden | Gothenburg Water and Sewage Works | 471,500 | City | 34.31 | 39,500 | 0 | 100 | 0 |
| Cluj, Romania | R.A.J.A.C. Cluj | 410,000 | County | 28.51 | 26,058 | 0 | 0 | 100 |
| Yucatan, Mexico | Junta de Agua Potable y Alcantarillado de Yucatan | 652,000 | State Owned | 26.20 | 215,679 | 100 | 0 | 0 |
| Cebu City, Philippines | Metropolitan Cebu Water District | 785,760 | Dist./Auth. | 24.81 | 88,271 | 93 | 4 | 3 |
| Uijeongbu, South Korea | Uijeongbu City | 364,530 | Dist./Auth. | 23.11 | 36,672 | 0 | 5 | 95 |
| Iasi, Romania | Regia Aittonoma Judeteana Apa Canal | 348,951 | County | 21.75 | 18,660 | 0 | 0 | 100 |
| Manukau City, New Zealand | Manukau Water | 305,000 | City | 21.12 | 91,594 | 0 | 0 | 100 |
| Timisoara, Romania | Reg1a Autonoma Apa Si Canal Aquatim Timisoara | 320,000 | City | 18.82 | 21,643 | 31 | 69 | 0 |
| Davao, Philippines | Davao City Water District | 1,271,436 | Dist./Auth. | 18.79 | 133,537 | 98 | 2 | 0 |
| Wellington, New Zealand | Wellington City Council | 177,348 | City | 18.00 | 66,010 | 0 | 0 | 100 |
| Ljubljana, Slovenia | Javno podjetje Vodovod-Kanalizacija | 322,800 | City | 17.08 | 44,417 | 99 | 1 | 0 |
| Zamboanga, Philippines | Zamboanga City Water District | 350,000 | Dist./Auth. | 12.33 | 39,288 | 16 | 84 | 0 |
| Nicosia, Cyprus | Water Board of Nicosia — | 200,000 | State Owned | 7.98 | 80,760 | 0 | 100 | 0 |
| Lemesos, Cyprus | Water Board of Lemesos | 150,000 | Dist./Auth. | 7.06 | 57,742 | 30 | 0 | 70 |
| Bistrita, Romania | Raja Aquabis | 89,132 | County | 5.97 | 10,911 | 2 | 98 | 0 |
| Larnaca, Cyprus | Water Board of Larnaca | 55,000 | Dist./Auth. | 2.60 | 27,970 | 25 | 0 | 75 |
| Kiev, Ukraine | Ukrainian Water Association | N/R | Dist./Auth. | N/R | N/R | N/R | N/R | N/R |

*Note:* N/R, not reported.

[a] Includes retail and wholesale population.
[b] Gallons sold has been converted to U.S. gallons.
[c] Due to rounding, water source percentages may not total 100.

*Source*: Adapted from 2004 Water and Wastewater Rate Survey by permission. Copyright © 2004, American Water Works Association. (Updated information available electronically from AWWA at 800-926-7337), www.awwa.org.



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**Table 7D.30 International Public Water System Charges, 2004**

| City/Service Area | Effective Date | Rate Structure | Monthly Water Charges (U.S. Dollars[a]) 0 $m^3$ (0 gal) | 15 $m^3$ (3,960 gal) | 30 $m^3$ (7,920 gal) | 85 $m^3$ (22,400 gal) | 150 $m^3$ (39,600 gal) | 1,000 $m^3$ (264,000 gal) | 25,000 $m^3$ (6,600,000 gal) | 40,000 $m^3$ (10,570,000 gal) |
|---|---|---|---|---|---|---|---|---|---|---|
| Osaka City, Japan | 6/1/97 | IB-7 | $8.98 | $13.57 | $29.89 | $137.82 | $309.04 | $3,035.73 | $86,581.68 | $138,797.89 |
| Taichung, Chinese Taiwan | 7/1/94 | IB-4 | 0.50 | 1.00 | 1.85 | 5.50 | 10.00 | 53.52 | 295.09 | 817.74 |
| Sao Paulo, Brazil | 8/28/03 | IB-4 | 3.24 | 5.77 | 20.94 | 87.99 | 345.75 | 2,500.48 | 40,873.08 | 60,812.41 |
| Rijswijk, Netherlands | 1/1/03 | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R |
| Seoul, South Korea | 5/20/02 | Uniform | N/R | 4.90 | 15.25 | 60.29 | 149.17 | 1,280.83 | 26,562.50 | 42,387.50 |
| Wan Chai, Hong Kong | 2/1/95 | IB-4 | N/R | 7.71 | 25.02 | 88.83 | 88.08 | 587.18 | 14,679.49 | 23,487.18 |
| Sydney, Australia | 7/1/03 | Uniform | 5.05 | 16.69 | 28.33 | 71.01 | 121.44 | 783.82 | 19,682.38 | 31,321.33 |
| Bangkok, Thailand | 6/9/98 | IB-11 | N/R | 3.74 | N/R | N/R | N/R | N/R | 25,794.07 | N/R |
| Alexandria, Egypt | 1/1/03 | IB-2 | 0.18 | 0.21 | 0.30 | 0.73 | 2.60 | 15.87 | 416.55 | 666.23 |
| Yokohama, Japan | 4/1/01 | IB-7 | 7.31 | 15.43 | 43.67 | 188.44 | 377.28 | 3,213.39 | 94,102.28 | 150,907.83 |
| Curitiba, Brazil | 12/13/03 | IB-3 | 5.06 | 8.86 | 20.26 | 91.39 | 152.83 | 1,025.50 | 25,665.50 | 41,065.50 |
| Danva, Denmark | N/R | Uniform | 127.01 | N/R | N/R | N/R | N/R | N/R | N/R | N/R |
| Busan, South Korea | 7/1/01 | Uniform | N/R | 7.75 | 18.08 | 54.54 | 135.83 | 1,295.83 | 30,326.67 | 48,494.17 |
| Nagoya, Japan | 4/1/97 | Flat | 6.65 | 17.92 | 49.62 | 241.93 | 459.43 | 3,115.09 | 7,864.15 | 123,770.75 |
| Leederville, Australia | 7/1/01 | IB-9 | 8.43 | 13.11 | 20.10 | 58.59 | 232.33 | 679.76 | 13,781.67 | 21,677.54 |
| Leederville, Australia | 7/1/03 | IB-7 | 29.91 | N/R | N/R | N/R | N/R | N/R | N/R | N/R |
| Adelaide, Australia | 7/1/03 | IB-2 | 8.65 | 15.54 | 27.08 | 69.38 | 110.73 | 764.58 | 19,240.31 | 30,778.77 |
| Lisbon, Portugal | 12/31/02 | IB-4 | 0.87 | 5.02 | 17.15 | N/R | N/R | N/R | N/R | N/R |
| Barcelona, Spain | 12/31/03 | IB-3 | 9.25 | 20.60 | 44.90 | 120.54 | 182.39 | 1,214.10 | 30,292.45 | 48,371.20 |
| Sapporo, Japan | 4/1/97 | IB-7 | 12.13 | 21.31 | 63.75 | 185.51 | N/R | N/R | N/R | N/R |
| Turin, Italy | 1/1/03 | IB-5 | N/R | 53.28 | 170.81 | 270.64 | 824.18 | 5,472.69 | 129,604.52 | 207,354.88 |
| Concepcion, Chile | 11/14/03 | Flat | 1.02 | 6.49 | 11.97 | 32.05 | 55.78 | 366.11 | 9,128.35 | 14,604.76 |
| Dublin, Ireland | 12/31/03 | Flat | N/R | N/R | N/R | N/R | 183.06 | 1,175.08 | 28,914.13 | 46,290.60 |
| Bristol, United Kingdom | 4/1/03 | Uniform | 2.43 | 18.29 | 34.14 | 92.71 | 161.71 | 1,064.00 | 20,404.29 | 29,607.14 |
| Helsinki, Finland | 12/12/03 | DB-3 | 2.50 | 29.03 | 58.00 | 163.76 | 287.83 | 1,817.02 | 43,428.81 | 69,486.09 |
| Oslo, Norway | 1/1/03 | Uniform | 6.40 | 16.85 | 27.30 | 65.60 | 112.23 | 708.29 | 17,438.15 | 27,897.72 |
| Addis Ababa, Ethiopia | 7/7/03 | IB-3 | 0.15 | 0.24 | 0.34 | N/R | 0.34 | 0.34 | 0.34 | N/R |
| Angered, Sweden | 11/21/03 | Uniform | 7.68 | 45.37 | 78.44 | 140.29 | 330.34 | 934.64 | 15,068.47 | 24,171.01 |
| Cluj, Romania | 7/1/03 | Uniform | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R |
| Yucatan, Mexico | 9/19/99 | IB-11 | 1.79 | 1.79 | 6.43 | 23.85 | 71.17 | N/R | N/R | N/R |
| Cebu City, Philippines | 7/1/01 | IB-4 | 1.94 | 3.01 | 6.59 | 44.51 | 90.53 | 712.45 | 17,360.93 | 27,772.94 |
| Uijeongbu, South Korea | 1/1/02 | Uniform | N/R | 6.75 | 18.00 | 96.33 | 162.50 | 1,666.67 | 41,666.67 | 66,666.67 |
| Iasi, Romania | 8/1/03 | Uniform | N/R | 6.91 | 13.82 | 39.14 | 69.08 | 460.50 | 11,512.50 | 18,420.00 |
| Manukau City, New Zealand | N/R | Uniform | 0.74 | N/R | N/R | N/R | N/R | N/R | N/R | N/R |
| Timisoara, Romania | 11/1/03 | Uniform | N/R | 4.50 | 8.99 | 25.48 | 44.96 | 299.74 | 7,493.38 | 11,989.41 |
| Davao, Philippines | 6/1/00 | IB-5 | 1.42 | 2.17 | 4.85 | 24.22 | 48.50 | 366.00 | 9,330.78 | 14,933.77 |
| Wellington, New Zealand | 6/30/03 | Uniform | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ljubljana, Slovenia | 12/31/02 | Uniform | $6.01 | $8.32 | $23.33 | $34.87 | $8.61 | $35.16 | $92.87 | $346.81 |
| Zambonga, Philippines | 11/1/02 | IB-6 | 1.81 | 2.78 | 5.34 | 13.02 | 3.63 | 10.66 | 64.48 | 115.73 |
| Nicosia, Cyprus | 1/1/02 | IB-7 | 2.75 | 14.84 | 30.22 | 162.09 | 208.79 | 1,483.52 | 50,054.95 | 81,373.63 |
| Lemesos, Cyprus | 1/1/02 | IB-4 | 6.00 | 13.00 | 28.88 | 131.04 | 106.60 | 1,644.60 | 32,853.92 | 492,780.28 |
| Bistrita, Romania | 11/1/03 | Uniform | N/R | 5.28 | 10.57 | 29.94 | 52.84 | 352.24 | 8,805.88 | 14,089.41 |
| Larnaca, Cyprus | 1/1/02 | IB-5 | 2.16 | 7.80 | 21.99 | 107.68 | 105.73 | 964.08 | 23,580.61 | N/R |
| Kiev, Ukraine | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R |

*Note:* N/R, not reported.

[a] All charges have been converted to U.S. dollars based on conversion data provided by the utility.

*Source*: Adapted from 2004 Water and Wastewater Rate Survey by permission. Copyright © 2004, American Water Works Association. (Updated information available electronically from AWWA at 800-926-7337), www.awwa.org.



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**Table 7D.31 Water Prices in Capitals or Major International Cities[a], 1996, 1998**

| | | Current Exchange Rates (USD/m$^3$) | | Current PPPs (USD/m$^3$) | | | | Current Exchange Rates (USD/m$^3$) | | Current PPPs (USD/m$^3$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1996 | 1998 | 1996 | 1998 | | | 1996 | 1998 | 1996 | 1998 |
| Canada | Ottawa | 1.70 | 0.34 | 1.95 | 0.43 | Germany | (national average) | 1.70 | — | 1.47 | — |
| | Toronto | 0.63 | 0.31 | 0.73 | 0.39 | | Berlin | — | 1.94 | — | 1.70 |
| | Winnipeg | 0.75 | 0.73 | 0.87 | 0.92 | | Dosseldorf | — | 1.92 | — | 1.68 |
| | Vancouver | — | 0.35 | — | 0.45 | | Gelsenkirchen | — | 1.47 | — | 1.29 |
| | London | 1.02 | 0.72 | 1.18 | 0.92 | | Hamburg | — | 1.74 | — | 1.53 |
| | Edmonton | 0.93 | 0.90 | 1.07 | 1.14 | | Monchen | — | 1.35 | — | 1.19 |
| U.S.A. | Washington | 0.80 | — | 0.80 | — | | Stuttgart | — | 1.46 | — | 1.28 |
| | New York | 0.88 | 0.43 | 0.88 | 0.43 | Greece | Athens | 0.77 | 0.86 | 0.87 | 1.05 |
| | Los Angeles | 0.60 | 0.58 | 0.60 | 0.58 | | Thessaloniki | 0.82 | 0.55 | 0.94 | 0.68 |
| | Orlando | 0.29 | — | 0.29 | — | | Chanea | — | 1.02 | — | 1.25 |
| | Miami | — | 0.36 | — | 0.36 | | Patras | — | 0.77 | — | 0.94 |
| | Indianapolis | — | 0.88 | — | 0.88 | Hungary | Budapest | 0.28 | 0.32 | 0.58 | 0.71 |
| | Detroit | — | 0.35 | — | 0.35 | | Debrecen | 0.55 | 0.37 | 1.16 | 0.83 |
| Japan | Tokyo | 1.16 | 0.92 | 0.76 | 0.74 | | Pecs | 0.69 | 0.61 | 1.45 | 1.35 |
| | Osaka | 0.70 | 0.68 | 0.46 | 0.54 | | Miskolc | 0.55 | 0.44 | 1.16 | 0.98 |
| | Sapporo | 1.29 | 1.13 | 0.85 | 0.90 | Iceland | Reykjavik | 0.61 | — | 0.53 | — |
| | Yokohama | 0.95 | 0.74 | 0.63 | 0.59 | | Hafnarflorour | 0.51 | — | 0.44 | — |
| | Nagoya | 1.13 | 0.72 | 0.74 | 0.58 | Italy | Rome | 0.33 | 0.28 | 0.32 | 0.29 |
| Korea | (national average) | 0.36 | — | 0.46 | — | | Bologna | 0.65 | 0.61 | 0.63 | 0.64 |
| | Seoul | — | 0.18 | — | 0.38 | | Milan | 0.13 | 0.13 | 0.13 | 0.13 |
| | Daegu | — | 0.19 | — | 0.41 | | Naples | 0.65 | 0.57 | 0.64 | 0.59 |
| | Daeieon | — | 0.18 | — | 0.37 | | Turin | 0.28 | 0.28 | 0.27 | 0.29 |
| | Inchon | — | 0.14 | — | 0.29 | Luxembourg | Luxembourg | 1.64 | 1.60 | 1.28 | 1.40 |
| | Pusan | — | 0.22 | — | 0.46 | Netherlands | Amsterdam | 1.20 | 1.02 | 0.99 | 0.99 |
| Australia | Sydney | 0.93 | 0.73 | 0.91 | 0.89 | | The Hague | 1.92 | 1.91 | 1.59 | 1.85 |
| | Brisbane | 0.80 | 0.68 | 0.79 | 0.82 | | Utrecht | 0.94 | 0.94 | 0.78 | 0.92 |
| | Melbourne | 0.80 | 0.59 | 0.79 | 0.72 | Norway | Oslo | 0.32 | 0.47 | 0.22 | 0.39 |
| | Canberra | — | 0.63 | — | 0.76 | | Bergen | 1.14 | 1.30 | 0.81 | 1.07 |
| | Perth | 0.76 | 0.64 | 0.75 | 0.78 | | Trondheim | 1.05 | 0.80 | 0.74 | 0.65 |
| N.Zealand | Wellington | 0.98 | 0.63 | 1.01 | 0.80 | Ponugal | Lisbon | 0.99 | 0.97 | 1.24 | 1.39 |
| | Auckland | — | 0.46 | — | 0.58 | | Coimbra | 1.02 | 0.72 | 1.28 | 1.04 |
| | North Shore City | — | 0.59 | — | 0.75 | | Porto | 0.98 | 1.02 | 1.23 | 1.46 |
| Austria | Vienna | 1.75 | 1.48 | 1.36 | 1.35 | Spain | Madrid | 0.85 | 0.81 | 0.87 | 0.94 |
| | Salzburg | 1.59 | 1.43 | 1.24 | 1.30 | | Barcelona | 0.81 | 0.78 | 0.83 | 0.91 |
| | Linz | 1.11 | 1.12 | 0.87 | 1.01 | | Bilbao | 0.48 | 0.41 | 0.49 | 0.48 |
| Belgium | Brussels | 1.80 | 1.51 | 1.51 | 1.45 | | Seville | 0.69 | 0.57 | 0.70 | 0.67 |
| | Antwerp | 0.97 | 0.88 | 0.82 | 0.84 | Sweden | Stockholm | 0.86 | 0.76 | 0.60 | 0.62 |
| | Liège | 1.50 | 1.48 | 1.26 | 1.42 | | Goteborg | 0.58 | 0.59 | 0.40 | 0.48 |
| Czech R. | Praha | 0.37 | 0.45 | 0.86 | 1.06 | | Malmo | 0.99 | 0.54 | 0.69 | 0.44 |
| | Brno | 0.29 | 0.37 | 0.67 | 0.88 | Switzerland | Beme | 1.22 | 1.33 | 0.74 | 0.97 |
| | Ostrava | 0.38 | 0.44 | 0.88 | 1.05 | | Geneva | 2.25 | 2.14 | 1.35 | 1.56 |
| Denmark | Copenhagen | 1.34 | 1.68 | 0.93 | 1.32 | | Zurich | 2.26 | 1.88 | 1.36 | 1.37 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aarhus | 0.89 | 1.26 | 0.62 | 0.98 | Turkey | Ankara | 0.18 | — | 0.37 | — |
| | Odense | 0.98 | 1.32 | 0.68 | 1.03 | | Canakkale | 0.20 | — | 0.41 | — |
| Finland | Helsinki | 0.85 | 0.76 | 0.66 | 0.66 | | Eskisehir | 0.19 | — | 0.40 | — |
| | Tampere | 0.90 | 0.86 | 0.70 | 0.75 | UK | London | 0.78 | 0.62 | 0.78 | 0.57 |
| | Vaasa | 1.32 | — | 1.03 | — | | Bristol | 0.78 | 0.57 | 0.78 | 0.52 |
| | Turku | 1.36 | 1.19 | 1.06 | 1.04 | | Manchester | 0.93 | 0.55 | 0.93 | 0.51 |
| | Espoo | — | 1.35 | — | 1.17 | | Newcastle | 0.74 | 0.76 | 0.74 | 0.69 |
| France | Paris | 0.93 | 0.87 | 0.73 | 0.76 | | Cardiff | 1.08 | 0.56 | 1.08 | 0.52 |
| | Banlieue Paris | 1.73 | 1.46 | 1.35 | 1.28 | | | | | | |
| | Bordeaux | 1.39 | 1.16 | 1.08 | 1.02 | | | | | | |
| | Lille | 1.33 | 1.06 | 1.03 | 0.93 | | | | | | |
| | Lyon | 1.78 | 1.45 | 1.38 | 1.27 | | | | | | |

*Note:* [a]Prices calculated on the basis of a family of four (two adults and two children) living in a house with garden rather than an apartment. Where there are water meters, the price is based on annual consumption of 200 $m^3$. Where supply is normally unmeasured the average price has been used (Norway and UK). VAT is not included.
KOR, 1996: national data.
NZL, 1996: Secretariat estimates based on country data for water meter charges for the 1997/98 fiscal year, and considering an annual consumption of 200 $m^3$.
DEU, 1996: country data which refer to 1997 and are provisional.
GRC, 1996 data refer to 1995; source: Ministry of Development.
NOR, Unmeasured data: refer to the average price.
TUR, 1996 data refer to 1995.
UKD, Unmeasured data: refer to the average price.

*Source*: Table 3.2, *OECD Environmental Data Compendium 2002*, © OCED 2002, www.oecd.org.



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**Table 7D.32 Worldwide Unccounted for Water**

| Location | | Percent | Source |
|---|---|---|---|
| Africa (large city average) | 1990 | 39 | e |
| Algiers, Algeria | 1990 | 51 | a |
| Amman, Jordan | 1990 | 52 | a |
| Asia (large city average) | 1990 | 35–42 | e, f |
| Bahrain | 1993 | 36 | o |
| Bahrain | 2000 | 24 | o |
| Barbados | 1996 | 43 | j |
| Buenos Aires, Argentina | 1993 | 43 | n |
| Buenos Aires, Argentina | 1996 | 31 | n |
| Canada (average) | 1990 | 15 | b |
| Casablanca, Morocco | 1990 | 34 | a, b |
| Damascus, Syria | 1995 | 64 | a |
| Dubai, United Arab Emirates | 1990 | 15 | a |
| Gaza | 1995 | 47 | a |
| Gaza | 1999 | 31 | a |
| Haiphong, Vietnam | 1998 | 70 | m |
| Hanoi, Vietnam | 1995 | 63 | f |
| Hebron | 1990 | 48 | a |
| Johor Bahru, Malaysia | 1995 | 21 | f |
| Kansas, United States (average) | 1997 | 15 | h |
| Kansas, United States (range) | 1997 | 3–65 | h |
| Lae, Papua New Guinea | 1995 | 61 | f |
| Latin America and Caribbean (large city average) | | 42 | e |
| Lebanon (average) | | 40 | a |
| Male, Maldives | 1995 | 10 | f |
| Mandalay, Myanmar | 1995 | 60 | f |
| Mexico City, Mexico | 1997 | 37 | l |
| Mexico City, Mexico | 1999 | 32 | l |
| Nairobi, Kenya | 2000 | 50 | g |
| Nicosia, Cyprus | 1990 | 16 | b |
| North America (large city average) | 1990 | 15 | e |
| Oran, Algeria | 1990 | 42 | a |
| Penang, Malaysia | 1995 | 20 | f |
| Phnom Penh, Vietnam | 1995 | 61 | f |
| Poland (medium utility range) | 1990 | 19–51 | d |
| Rabat, Morocco | 1990 | 18 | b |
| Ramallah | 1990 | 25 | a |
| Rarotonga, Cook Islands | 1995 | 70 | f |
| Sana'a, Yemen | 1990 | 50 | a |
| Seoul, South Korea | 1996 | 35 | p |
| Singapore | 1990 | 11 | b |
| Singapore | 1995 | 6 | f |
| Sydney, Australia | 1990 | 13.4 | c |
| Tamir, Yemen | 1990 | 28 | b |
| Teheran, Iran | 1990 | 35 | a |
| Tunisia (large utility range) | 1990 | 8–21 | a, d |
| United Kingdom (small utility range) | 1990 | 14–30 | d |

*(Continued)*

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**Table 7D.32 (Continued)**

| Location | | Percent | Source |
|---|---|---|---|
| United States (average) | 1990s | 12 | [b] |
| Vietnam (average) | 1998 | 50 | [m] |
| Washington, DC, area suppliers | 1999 | 10–28 | [k] |

[a] Saghir, J., Sehiffler, M., and Woldu, M., 1999, *World Bank Urban Water and Sanitation in the Middle East and North Africa Region: The Way Forward*, the World Bank, Middle East and North Africa Region Infrastructure Development Group, December, available at worldbank.org/wbi/mdf/mdf3/papers/fnance/Saghir.pdf.
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**Table 7D.33 Population Supplied with Safe Drinking Water, by Country 1970–2000**

| Region and Country | Fraction of Population with Access to Drinking Water | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | | | | | | | Rural | | | | | | | Total | | | | | | |
| | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 |
| Data Source | a,b | a,b | a,b | a,b | c | d | e | a,b | a,b | a,b | a,b | c | d | e | a,b | a,b | a,b | a,b | c | d | e |
| **Africa** | 66 | 68 | 69 | 77 | | | | | | | | | | | | | | | | | |
| Algeria | 84 | 100 | | 85 | | | 88 | | 61 | | 55 | | | 94 | | 77 | | 68 | | | 94 |
| Angola | | | 85 | 87 | 73 | 69 | 34 | | | 10 | 15 | 20 | 15 | 40 | | | 26 | 33 | 35 | 32 | 38 |
| Benin | 83 | 100 | 26 | 80 | 73 | 41 | 74 | 20 | 20 | 15 | 34 | 43 | 53 | 55 | 29 | 34 | 18 | 50 | 54 | 50 | 63 |
| Botswana | 71 | 95 | | 84 | 100 | | 100 | 26 | 39 | | 46 | 88 | | | 29 | 45 | | 53 | 91 | | |
| Burkina Faso | 35 | 50 | 27 | 43 | | | 84 | 10 | 26 | 31 | 69 | 70 | | | 12 | 25 | 31 | 67 | | 78 | |
| Burundi | 77 | | 90 | 98 | 92 | 92 | 96 | | | 20 | 21 | 43 | 49 | | | | 23 | 25 | 45 | 52 | |
| Cameroon | 77 | | | 43 | 42 | | 82 | 21 | | | 24 | 45 | | 42 | 32 | | | 32 | 44 | | 62 |
| Cape Verde | | | 100 | 83 | | 70 | 64 | | | 21 | 50 | | 34 | 89 | | | 25 | 52 | | 51 | 74 |
| Central African Republic | | | | 13 | 19 | 18 | 80 | | | | | 26 | 18 | 43 | | | | | 23 | 18 | 60 |
| Chad | 47 | 43 | | | | 48 | 31 | 24 | 23 | | | | 17 | 26 | 27 | 26 | | | | 24 | 27 |
| Comoros | | | | | | | 98 | | | | | | | 95 | | | | | | | 96 |
| Congo | 63 | 81 | 42 | | | | 71 | 6 | 9 | 7 | | | | 17 | 27 | 38 | 20 | | | | 51 |
| Congo, Democratic Rep. | 33 | 38 | | 52 | 68 | 37 | 89 | 4 | 12 | | 21 | 24 | 23 | 26 | 11 | 19 | | 32 | 36 | 27 | 45 |
| Côte d'Ivoire | 98 | | | | 57 | 59 | 90 | 29 | | | | 80 | 81 | 65 | 44 | | | | 71 | 72 | 77 |
| Djibouti | | | 50 | 50 | | 77 | 100 | | | 20 | 20 | | 100 | 100 | | | 43 | 45 | | 90 | 100 |
| Egypt | 94 | | 88 | | 95 | 82 | 96 | 93 | | 64 | | 86 | 50 | 94 | 93 | | 84 | | 90 | 64 | 95 |
| Equatorial Guinea | | | 47 | | 65 | 88 | 45 | | | | | 18 | 100 | 42 | | | | | 32 | 95 | 43 |
| Eritrea | | | | | | | 63 | | | | | | | 42 | | | | | | | 46 |
| Ethiopia | 61 | 58 | | 69 | | | 77 | | 1 | | 9 | | | 13 | 6 | 8 | | 16 | | | 24 |
| Gabon | | | | | | | 73 | | | | | | | 55 | | | | | | | 70 |
| Gambia | 97 | | 85 | 97 | 100 | | 80 | 3 | | | 50 | 48 | | 53 | 12 | | | 59 | 60 | 76 | 62 |
| Ghana | 86 | 86 | 72 | 93 | 63 | 70 | 87 | | 14 | 33 | 39 | | 49 | 49 | 35 | 35 | 45 | 56 | 21 | 56 | 64 |
| Guinea | 68 | 69 | 69 | 41 | 100 | 61 | 72 | | | 2 | 12 | 37 | 62 | 36 | | 14 | 15 | 18 | 53 | 62 | 48 |
| Guinea-Bissau | | | 18 | 17 | | 38 | 29 | | | 8 | 22 | | 57 | 55 | | | 10 | 21 | | 53 | 49 |
| Kenya | 100 | 100 | 85 | | | 67 | 87 | 2 | 4 | 15 | | | 49 | 31 | 15 | 17 | 26 | | | 53 | 49 |
| Lesotho | 100 | 65 | 37 | 65 | | 14 | 98 | 1 | 14 | 11 | 30 | | 64 | 88 | 3 | 17 | 15 | 36 | | 52 | 91 |
| Liberia | 100 | | | 100 | | 58 | | 6 | | | 23 | | 8 | | 15 | | | 53 | | 30 | |
| Libya | 100 | 100 | 100 | | | | 72 | 42 | 82 | 90 | | | | 68 | 58 | 87 | 96 | | | | 72 |
| Madagascar | 67 | 76 | 80 | 81 | | 83 | 85 | 1 | 14 | 7 | 17 | | 10 | 31 | 11 | 25 | 21 | 31 | | 29 | 47 |
| Malawi | | | 77 | 97 | | 52 | 95 | | | 37 | 50 | | 44 | 44 | | | 41 | 56 | | 45 | 57 |
| Mali | 29 | | 37 | 46 | 41 | 36 | 74 | | | | 10 | 4 | 38 | 61 | | | | 16 | 13 | 37 | 65 |
| Mauritania | 98 | | 80 | 73 | | 84 | 34 | 10 | | 85 | | | 69 | 40 | 17 | | 84 | | | 76 | 37 |
| Mauritius | 100 | 100 | 100 | 100 | 100 | 95 | 100 | 29 | 22 | 98 | 100 | 100 | 100 | 100 | 61 | 60 | 99 | 100 | 100 | 98 | 100 |
| Morocco | 92 | | 100 | 100 | 100 | 98 | 100 | 28 | | | 25 | 18 | 14 | 58 | 51 | | | 59 | 56 | 52 | 82 |
| Mozambique | | | | 38 | | 17 | 86 | | | | 9 | | 40 | 43 | | | | 15 | | 32 | 60 |

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| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Namibia | | | | | 90 | 87 | 100 | | | | | 37 | 42 | 67 | | | | | 52 | 57 | 77 |
| Niger | 37 | 36 | 41 | 35 | 98 | 46 | 70 | 19 | 26 | 32 | 49 | 45 | 55 | 56 | 20 | 27 | 33 | 47 | 56 | 53 | 59 |
| Nigeria | | | | 100 | 100 | 63 | 81 | | | | 20 | 22 | 26 | 39 | | | | 38 | 49 | 39 | 57 |
| Reunion | | | | | | | | | | | | | | | | | | | | | |
| Rwanda | 81 | 84 | 48 | 79 | 84 | | 60 | 66 | 68 | 55 | 48 | 67 | | 40 | 67 | 68 | 55 | 50 | 68 | | 41 |
| Sao Tome and Principe | | | | | | | | | | | 45 | | | | | | | 45 | | | |
| Senegal | 87 | 56 | 77 | 79 | 65 | 82 | 92 | | | 25 | 38 | 26 | 28 | 65 | | | 43 | 53 | 42 | 50 | 78 |
| Seychelles | | | | | | | | | | | 95 | | | | | | | 95 | | | |
| Sierra Leone | 75 | | 50 | 68 | 80 | 58 | 23 | 1 | | 2 | 7 | 20 | 21 | 31 | 12 | | 14 | 24 | 39 | 34 | 28 |
| Somalia | 17 | 77 | | 58 | | | | 14 | 22 | | 22 | | | | 15 | 38 | | 34 | | | |
| South Africa | | | | | | | 92 | | | | | | | 80 | | | | | | 70 | 86 |
| Sudan | 61 | 96 | 100 | | | 66 | 86 | 13 | 43 | 31 | | | 45 | 69 | 19 | 50 | 51 | | | 50 | 75 |
| Swaziland | | 83 | | 100 | | 41 | | | 29 | | 7 | | 44 | | | 37 | | 31 | | 43 | |
| Tanzania | 61 | 88 | | 90 | | | 80 | 9 | 36 | | 42 | | | 42 | 13 | 39 | | 53 | | | 54 |
| Togo | 100 | 49 | 70 | 100 | | 74 | 85 | 5 | 10 | 31 | 41 | | 58 | 38 | 17 | 16 | 38 | 54 | | 63 | 54 |
| Tunisia | 92 | 93 | 100 | 100 | | 100 | | 17 | | 17 | 31 | | 89 | | 49 | | 60 | 70 | | 99 | |
| Uganda | 88 | 100 | | 37 | 60 | 47 | 72 | 17 | 29 | | 18 | 30 | 32 | 46 | 22 | 35 | | 20 | 33 | 34 | 50 |
| Zambia | 70 | 86 | | 76 | | 64 | 88 | 22 | 16 | | 41 | | 27 | 48 | 37 | 42 | | 58 | | 43 | 64 |
| Zimbabwe | | | | | 95 | | 100 | | | | 32 | 80 | | 77 | | | | | 84 | | 85 |
| **North & Central America & Caribbean** | | | | | | | | | | | | | | | | | | | | | |
| Anguilla | | | | | | | | | | | | | | | | | | | | | |
| Antigua and Barbuda | | | | | | | | | | | | | | | | | | | | | |
| Aruba | | | | | | | | | | | | | | | | | | | | | |
| Bahamas | 100 | 100 | 100 | 100 | 98 | | 99 | 12 | 13 | | | 75 | | 86 | 65 | 65 | 100 | 100 | 90 | | 96 |
| Barbados | 95 | 100 | 99 | 100 | 100 | | 100 | 100 | 100 | 98 | 99 | 100 | | 100 | 98 | 100 | 99 | 99 | 100 | | 100 |
| Belize | | | 99 | 100 | 95 | 96 | 83 | | | 36 | 26 | 53 | 82 | 69 | | | 68 | 64 | 74 | 89 | 76 |
| British Virgin Islands | | | | | 100 | | | | | | | 100 | | | | | | | | | |
| Canada | | | | | | | 100 | | | | | | | 99 | | | | | | | 100 |
| Cayman Islands | | | 100 | 98 | | | | | | | | | | | | | | | | | |
| Costa Rica | 98 | 100 | 100 | 100 | | 85 | 98 | 59 | 56 | 82 | 83 | | 99 | 98 | 74 | 72 | 90 | 91 | | 92 | 98 |
| Cuba | 82 | 96 | | | 100 | 96 | 99 | 15 | | | | 91 | 85 | 82 | 56 | | | | 98 | 93 | 95 |
| Dominican Republic | 72 | 88 | 85 | 85 | 82 | 74 | 83 | 14 | 27 | 34 | 33 | 45 | 67 | 70 | 37 | 55 | 60 | 62 | 67 | 71 | 79 |
| Dominica | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| El Salvador | 71 | 89 | 67 | 68 | 87 | 78 | 88 | 20 | 28 | 40 | 40 | 15 | 37 | 61 | 40 | 53 | 50 | 51 | 47 | 55 | 74 |
| Grenada | 100 | 100 | | | | | 97 | 47 | 77 | | | | | 93 | | | | | | | 94 |
| Guadeloupe | | | | | | | 94 | | | | | | | 94 | | | | | | | 94 |
| Guatemala | 88 | 85 | 90 | 72 | 92 | | 97 | 12 | 14 | 18 | 14 | 43 | | 88 | 38 | 39 | 46 | 37 | 62 | | 92 |
| Haiti | | 46 | 51 | 59 | 56 | 37 | 46 | | 3 | 8 | 30 | 35 | 23 | 45 | | 12 | 19 | 38 | 41 | 28 | 46 |
| Honduras | 99 | 99 | 93 | 56 | 85 | 81 | 97 | 10 | 13 | 40 | 45 | 48 | 53 | 82 | 34 | 41 | 59 | 49 | 64 | 65 | 90 |
| Jamaica | 100 | 100 | 55 | 99 | | | 81 | 48 | 79 | 46 | 93 | | | 59 | 62 | 86 | 51 | 96 | | | 71 |
| Martinique | | | | | | | | | | | | | | | | | | | | | |
| Mexico | 71 | 70 | 90 | 99 | 94 | 91 | 94 | 29 | 49 | 40 | 47 | | 62 | 63 | 54 | 62 | 73 | 83 | 69 | 83 | 86 |

*(Continued)*



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**Table 7D.33 (Continued)**

| Region and Country | Fraction of Population with Access to Drinking Water | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | | | | | | | Rural | | | | | | | Total | | | | | |
| | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 |
| Montserrat | | | | | | | | | | | | | | | | | | | | | |
| The Netherlands Antilles | | | | | | | | | | | | | | | | | | | | | |
| Nicaragua | 58 | 100 | 67 | 76 | | 81 | 95 | 16 | 14 | 6 | 11 | | 27 | 59 | 35 | 56 | 39 | 48 | | 61 | 79 |
| Panama | 100 | 100 | 100 | 100 | | | 88 | 41 | 54 | 62 | 64 | | | 86 | 69 | 77 | 81 | 82 | | 83 | 87 |
| Puerto Rico | | | | | | | | | | | | | | | | | | | | | |
| St. Kitts | | | | | | | | | | | | | | | | | | | | | |
| St. Lucia | | | | | | | | | | | | | | | | | | | | | |
| St. Vincent | | | | | | | | | | | | | | | | | | | | | |
| Trinidad/ Tobago | 100 | 79 | 100 | 100 | 100 | | | 95 | 100 | 93 | 95 | 88 | | | 96 | 93 | 97 | 98 | 96 | | 86 |
| Turks/Caicos Islands | | | | 87 | | | | | | | 68 | | | | | | | 77 | | | |
| United States of America | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| United States Virgin Islands | | | | | | | | | | | | | | | | | | | | | |
| **South America** | | | | | | | | | | | | | | | | | | | | | |
| Argentina | 69 | 76 | 61 | 63 | | | 85 | 12 | 26 | 17 | 17 | | | 30 | 56 | 66 | 54 | 56 | | | 79 |
| Bolivia | 92 | 81 | 69 | 75 | 76 | 78 | 93 | 2 | 6 | 10 | 13 | 30 | 22 | 55 | 33 | 34 | 36 | 43 | 53 | 55 | 79 |
| Brazil | 78 | 87 | 83 | 85 | 95 | 85 | 95 | 28 | | 51 | 56 | 61 | 31 | 54 | 55 | | 72 | 77 | 87 | 72 | 87 |
| Chile | 67 | 78 | 100 | 98 | | 94 | 99 | 13 | 28 | 17 | 29 | | 37 | 66 | 56 | 70 | 84 | 87 | | 85 | 94 |
| Colombia | 88 | 86 | 93 | 100 | 87 | 88 | 98 | 28 | 33 | 73 | 76 | 82 | 48 | 73 | 63 | 64 | 86 | | 86 | 76 | 91 |
| Ecuador | 76 | 67 | 79 | 81 | 63 | 82 | 81 | 7 | 8 | 20 | 31 | 44 | 55 | 51 | 34 | 36 | 50 | 57 | 55 | 70 | 71 |
| Falkland Islands (Malvinas) | | | | | | | | | | | | | | | | | | | | | |
| French Guiana | | | | | | | 88 | | | | | | | 71 | | | | | | | 84 |
| Guyana | 100 | 100 | 100 | 100 | 100 | 90 | 98 | 63 | 75 | 60 | 65 | 71 | 45 | 91 | 75 | 84 | 72 | 76 | 81 | 61 | 94 |
| Paraguay | 22 | 25 | 39 | 53 | 61 | | 95 | 5 | 5 | 9 | 8 | 9 | | 58 | 11 | 13 | 21 | 28 | 34 | | 79 |
| Peru | 58 | 72 | 68 | 73 | 68 | 74 | 87 | 8 | 15 | 18 | 17 | 24 | 24 | 51 | 35 | 47 | 50 | 55 | 55 | 60 | 77 |
| Suriname | | | 100 | 71 | | | 94 | | | 79 | 94 | | | 96 | | | 88 | 83 | | | 95 |
| Uruguay | 100 | 100 | 96 | 95 | 100 | | 98 | 59 | 87 | 2 | 27 | | | 93 | 92 | 98 | 81 | 85 | 89 | | 98 |
| Venezuela | 92 | | 93 | 93 | | 80 | 88 | 38 | | 53 | 65 | 36 | 75 | 58 | 75 | | 86 | 89 | | 79 | 84 |
| **Asia** | | | | | | | | | | | | | | | | | | | | | |
| Afghanistan | 18 | 40 | 28 | 38 | 40 | 39 | 19 | 1 | 5 | 8 | 17 | 19 | 5 | 11 | 3 | 9 | 8 | 17 | 23 | 12 | 13 |
| Armenia | | | | | | | | | | | | | | | | | | | | | |
| Azerbaijan | | | | | | | | | | | | | | | | | | | | | |
| Bahrain | 100 | 100 | | 100 | 100 | | | 94 | 100 | | 100 | 0 | | | 99 | 100 | | 100 | | | |

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| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bangladesh | 13 | 22 | 26 | 24 | 39 | 100 | 99 | 47 | 61 | 40 | 49 | 89 | 97 | 97 | 45 | 56 | 39 | 46 | 81 | 97 | 97 |
| Bhutan | | | 50 | | 60 | 75 | 86 | | | 5 | 19 | 30 | 54 | 60 | | | 7 | | 32 | 64 | 62 |
| Brunei Darus | | | 100 | | | | | | | 95 | | | | | | | | | | | |
| Cambodia | | | | | | | 53 | | | | | | | 25 | | | | | | | 30 |
| China | | | | | 87 | 93 | 94 | | | | | 68 | 89 | 66 | | | | | 73 | 90 | 75 |
| Cyprus | 100 | 94 | | 100 | 100 | | 100 | 92 | 96 | | 100 | 100 | | 100 | 95 | 95 | | 100 | 100 | | 100 |
| East Timor | | | | | | | | | | | | | | | | | | | | | |
| Gaza Strip | | | | | | | | | | | | | | | | | | | | | |
| Georgia | | | | | | | | | | | | | | | | | | | | | |
| Hong Kong | | | 100 | | 100 | | | | | 95 | | 96 | | | | | | | 100 | | |
| India | 60 | 80 | 77 | 76 | 86 | 85 | 92 | 6 | 18 | 31 | 50 | 69 | 79 | 86 | 17 | 31 | 42 | 56 | 73 | 81 | 88 |
| Indonesia | 10 | 41 | 35 | 43 | 35 | 78 | 91 | 1 | 4 | 19 | 36 | 33 | 54 | 65 | 3 | 11 | 23 | 38 | 34 | 62 | 76 |
| Iran | 68 | 76 | 82 | | 100 | 89 | 99 | 11 | 30 | 50 | | 75 | 77 | 89 | 35 | 51 | 66 | | 89 | 83 | 95 |
| Iraq | 83 | 100 | | 100 | 93 | | 96 | 7 | 11 | 54 | 54 | 41 | | 48 | 51 | 66 | | 86 | 78 | 44 | 85 |
| Israel | | | | | | | | | | | | | | | | | | | | | |
| Japan | | | | | | | | | | | | | | | | | | | | | |
| Jordan | 98 | | 100 | 100 | 100 | | 100 | 59 | | 65 | 88 | 97 | | 84 | 77 | | 86 | 96 | 99 | 89 | 96 |
| Kazakhstan | | | | | | | 98 | | | | | | | 82 | | | | | | | 91 |
| Korea DPR | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| Korea Rep | 84 | 95 | 86 | 90 | 100 | | 97 | 38 | 33 | 61 | 48 | 76 | | 71 | 58 | 66 | 75 | 75 | 93 | | 92 |
| Kuwait | 60 | 100 | 86 | 97 | | | | | | 100 | | | | | 51 | 89 | 87 | | | | |
| Kyrgyzstan | | | | | | | 98 | | | | | | | 66 | | | | | | | 77 |
| Laos | 97 | 100 | 28 | | 47 | 40 | 59 | 39 | 32 | 20 | | 25 | 39 | 100 | 48 | 41 | 21 | | 29 | 39 | 90 |
| Lebanon | | | | | | 100 | 100 | | | | | | 100 | 100 | | | | | | 100 | 100 |
| Macau | | | | | | | | | | | | | | | | | | | | | |
| Malaysia | 100 | 100 | 90 | 96 | 96 | | | 1 | 6 | 49 | 76 | 66 | | 94 | 29 | 34 | 63 | 84 | 79 | | |
| Maldives | | | 11 | 58 | 77 | 98 | 100 | | | 3 | 12 | 68 | 86 | 100 | | | 2 | 21 | | 89 | 100 |
| Mongolia | | | | | 100 | | 77 | | | | | 58 | | 30 | | | | | 82 | | 60 |
| Myanmar (Burma) | 35 | 31 | 38 | 36 | 79 | 36 | 88 | 13 | 14 | 15 | 24 | 72 | 39 | 60 | 18 | 17 | 21 | 27 | 74 | 38 | 68 |
| Nepal | 53 | 85 | 83 | 70 | 66 | 66 | 85 | | 5 | 7 | 25 | 34 | 41 | 80 | 2 | 8 | 11 | 28 | 38 | 44 | 81 |
| Oman | | 100 | | 90 | | | 41 | | 48 | | 49 | | | 30 | | 52 | | 53 | | 63 | 39 |
| Pakistan | 77 | 75 | 72 | 83 | 82 | 77 | 96 | 4 | 5 | 20 | 27 | 42 | 52 | 84 | 21 | 25 | 35 | 44 | 55 | 60 | 88 |
| Philippines | 67 | 82 | 49 | 49 | 93 | 93 | 92 | 20 | 31 | 43 | 54 | 72 | 77 | 80 | 36 | 50 | 45 | 52 | 81 | 85 | 87 |
| Qatar | 100 | 100 | 76 | | 100 | | | 75 | 83 | 43 | | | | | 95 | 97 | 71 | | | | |
| Saudi Arabia | 100 | 97 | 92 | 100 | | | 100 | 37 | 56 | 87 | 88 | | | 64 | 49 | 64 | 90 | 94 | | | 95 |
| Singapore | | | 100 | 100 | 100 | | 100 | | | | | | | | | | 100 | 100 | 100 | | 100 |
| Sri Lanka | 46 | 36 | 65 | 82 | 80 | 43 | 91 | 14 | 13 | 18 | 29 | 55 | 47 | 80 | 21 | 19 | 28 | 40 | 60 | 46 | 83 |
| Syria | 98 | | 98 | | | 92 | 94 | 50 | | 54 | | | 78 | 64 | 71 | | 74 | | | 85 | 80 |
| Tajikistan | | | | | | | | | | | | | | | | | | | | | |
| Thailand | 60 | 69 | 65 | 56 | | | 89 | 10 | 16 | 63 | 66 | 85 | | 77 | 17 | 25 | 63 | 64 | | | 80 |
| Turkey | | | 95 | | | | 82 | | | 62 | | | | 84 | | | 76 | | | | 83 |

*(Continued)*



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**Table 7D.33 (Continued)**

| Region and Country | Fraction of Population with Access to Drinking Water | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | | | | | | | Rural | | | | | | | Total | | | | | | |
| | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 |
| Turkmenistan | | | | | | | | | | | | | | | | | | | | | |
| United Arab Emirates | | | 95 | | | | | | | 81 | | | | | | | 92 | | | | |
| Uzbekistan | | | | | | | 96 | | | | | | | 78 | | | | | | | 85 |
| Vietnam | | | | 70 | 47 | 53 | 81 | | | 32 | 39 | 33 | 32 | 50 | | | | 45 | 36 | 36 | 56 |
| Yemen A R | 45 | | 100 | 100 | | | 85 | 2 | | 18 | 25 | | | 64 | 4 | | 31 | 40 | | | 69 |
| Yemen Dem | 88 | | 85 | | | | 85 | 43 | | 25 | | | | 64 | 57 | | 52 | | | | 69 |
| **Oceania** | | | | | | | | | | | | | | | | | | | | | |
| American Samoa | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| Australia | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| Cook Islands | | | 100 | 99 | 100 | | 100 | | | | 88 | 100 | | 100 | | | | 92 | | | 100 |
| Fiji | 78 | 89 | 94 | | 96 | 100 | 43 | 15 | 56 | 66 | | 69 | 100 | 51 | 37 | 69 | 77 | | 80 | 100 | 47 |
| French Polyneisa | | | | | 100 | | 100 | | | | | 18 | | 100 | | | | | | | 100 |
| Guam | | | | | | | | | | | | | | | | | | | | | |
| Kiribati | | | 93 | | 91 | | 82 | | | 25 | | 63 | | 25 | | | | | | | 47 |
| Marshall Islands | | | | | 100 | | | | | | | 45 | | | | | | | | | |
| Micronesia | | | | | | 100 | | | | | | 38 | 100 | | | | | | | 100 | |
| Nauru | | | | | | | | | | | | | | | | | | | | | |
| New Caledonia | | | | | | | | | | | | | | | | | | | | | |
| New Zealand | | | | | | | 100 | | | | | | | | | | | | | | |
| Niue | | | | | 0 | 100 | 100 | | | | 100 | 100 | 100 | 100 | | | | | | 100 | 100 |
| Northern Mariana Islands | | | | | 100 | | | | | | | 0 | | | | | | | | | |
| Palau | | | | | 100 | | 100 | | | | | 97 | | 20 | | | | | | | 79 |
| Papua New Guinea | 44 | 30 | 55 | 95 | 94 | 84 | 88 | 72 | 19 | 10 | 15 | 20 | 17 | 32 | 70 | 20 | 16 | 26 | 32 | 28 | 42 |
| Pitcairn | | | | | | | | | | | | | | | | | | | | | |
| Samoa | 86 | 100 | 97 | | 100 | | 95 | | 23 | 94 | | 77 | | 100 | 17 | 43 | | | | | 99 |
| Solomon Islands | | | 96 | | 82 | | 94 | | | 45 | | 58 | | 65 | | | | | 62 | | 71 |
| Tokelau | | | | | | 100 | | | | | 100 | | 100 | | | | | | | 100 | |
| Tonga | 100 | 100 | 86 | 99 | 92 | 100 | 100 | 53 | 71 | 70 | 99 | 98 | 100 | 100 | 63 | 83 | 17 | 99 | 96 | 100 | 100 |
| Tuvalu | | | | 100 | | 100 | 100 | | | | 100 | | 95 | 100 | | | | | | 98 | 100 |
| Vanuatu | | | 65 | 95 | | | 63 | | | 53 | 54 | | | 94 | | | | 64 | | | 88 |

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| | | | | | |
|---|---|---|---|---|---|
| Wallis and Futuna Islands | | | | | |
| Western Samoa | 97 | 75 | 94 | 67 | 69 |

[a] United Nations Environment Programme, 1989, *Environmental Data Report*, GEMS Monitoring and Assessment Research Centre, Basil Blackwell, Oxford.
[b] WRI 1988, World Health Organization data, cited by the *World Resources Institute, 1988, World Resources 1988–89*, World Resources Institute and the International Institute for Environment and Development in collaboration with the United Nations Environment Programme, Basic Books, New York.
[c] United Nations Environment Programme, 1993–94, *Environmental Data Report*, GEMS Monitoring and Assessment Research Centre in cooperation with the World Resources Institute and the UK Department of the Environment, Basil Blackwell, Oxford.
[d] WHO 1996, *Water Supply and Sanitation Sector Monitoring Report: 1996* (Sector Status as of 1994), in collaboration with the Water Supply and Sanitation Collaborative Council and the United Nations Children's Fund, UNICEF, New York.
[e] WHO 2000, *Global Water Supply and Sanitation Assessment 2000 Report*, available in full at who.int/water_sanitation_health/Globassessment/GlobalTOC.htm.

*Source*: From *World's Water 2002–2003*, by Peter H. Gleick. Copyright © 2002 Island Press. Reproduced by permission of Island Press, Washington, DC.



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**Table 7D.34 Population Supplied with Access to Sanitation, by Country, 1970–2000**

| Region and Country | Fraction of Population with Access to Sanitation | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | | | | | | | Rural | | | | | | | Total | | | | | | |
| | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 |
| Data Source | a,b | a,b | a,b | a,b | c | d | e | a,b | a,b | a,b | a,b | c | d | e | a,b | a,b | a,b | a,b | c | d | e |
| **Africa** | 47 | 75 | 57 | 75 | | | | | | | | | | | | | | | | | |
| Algeria | 13 | 100 | 80 | | | 90 | 6 | 50 | | 40 | | | 47 | 9 | 67 | | 57 | | | 73 | |
| Angola | | | 40 | 29 | 25 | 34 | 70 | | | 15 | 16 | 20 | 8 | 30 | | | 20 | 19 | 21 | 16 | 44 |
| Benin | 83 | | 48 | 58 | 60 | 54 | 46 | 1 | | 4 | 20 | 35 | 6 | 6 | 14 | | 16 | 33 | 45 | 20 | 23 |
| Botswana | | | | 93 | 100 | | | | | | 28 | 85 | | | | | | 40 | 89 | | |
| Burkina Faso | 49 | 47 | 38 | 44 | | 42 | 88 | | | 5 | 6 | | 11 | 16 | 4 | 4 | 7 | 9 | | 18 | 29 |
| Burundi | 96 | | 40 | 84 | 64 | 60 | 79 | | | 35 | 56 | 16 | 50 | | | | 35 | 58 | 18 | 51 | |
| Cameroon | | | | 100 | | | 99 | | | | 1 | | | 85 | | | | 43 | | | 92 |
| Cape Verde | | | 34 | 32 | | 40 | 95 | | | 10 | 9 | | 10 | 32 | | | 11 | 10 | | 24 | 71 |
| Central African Republic | 64 | 100 | | | 45 | | 43 | 96 | 100 | | | 46 | | 23 | 72 | 100 | | | 46 | 46 | 31 |
| Chad | 7 | 9 | | | | 73 | 81 | | 1 | | | | 7 | 13 | 1 | 1 | | | | 21 | 29 |
| Comoros | | | | | | | 98 | | | | | | | 98 | | | | | | | 98 |
| Congo | 8 | 10 | | | | | 14 | 6 | 9 | | | | | | 6 | 9 | | | | | |
| Congo, Democratic Republic | 5 | 65 | | | 46 | 23 | 53 | 5 | 6 | | 9 | 11 | 4 | 6 | 5 | 22 | | | 21 | 9 | 20 |
| Cote D'Ivoire | 23 | | | | 81 | 59 | | | | | | 100 | 51 | | 5 | | | | 92 | 54 | |
| Djibouti | | | 43 | 78 | | 77 | 99 | | | 20 | 17 | | 100 | 50 | | | 39 | 64 | | 90 | 91 |
| Egypt | | | | | 80 | 20 | 98 | | | 10 | | 26 | 5 | 91 | | | | | 50 | 11 | 94 |
| Equatorial Guinea | | | | | 54 | 61 | 60 | | | | | 24 | 48 | 46 | | | | | 33 | 54 | 53 |
| Eritrea | | | | | | | 66 | | | | | | | 1 | | | | | | | 13 |
| Ethiopia | 67 | 56 | | 96 | | | 58 | 8 | 8 | | 96 | | | 6 | 14 | 14 | | | | | 15 |
| Gabon | | | | | | | 25 | | | | | | | 4 | | | | | | | 21 |
| Gambia | | | | | 100 | 83 | 41 | | | | | 27 | 23 | 35 | | | | | 44 | 37 | 37 |
| Ghana | 92 | 95 | 47 | 51 | 63 | 53 | 62 | 40 | 40 | 17 | 16 | 60 | 36 | 64 | 55 | 56 | 26 | 30 | 61 | 42 | 63 |
| Guinea | 70 | | 54 | | | | 94 | 2 | | 1 | | 0 | | 41 | 13 | | 11 | | | 70 | 58 |
| Guinea-Bissau | | | 21 | 29 | | 32 | 88 | | | 13 | 18 | | 17 | 34 | | | 15 | 21 | | 20 | 47 |
| Kenya | 85 | 98 | 89 | | | 69 | 96 | 45 | 48 | 19 | | | 81 | 81 | 50 | 55 | 30 | | | 77 | 86 |
| Lesotho | 44 | 51 | 13 | 22 | | 1 | 93 | 10 | 12 | 14 | 14 | | 7 | 96 | 11 | 13 | 14 | 15 | | 6 | 92 |
| Liberia | 100 | | | 6 | | 38 | | 9 | | | 2 | | 2 | | 19 | | | | | 18 | |
| Libya | 100 | 100 | 100 | | | | 97 | 54 | 69 | 72 | | | | 30 | 67 | 79 | 88 | | | | 97 |
| Madagascar | 88 | | 9 | 55 | | 50 | 70 | | 9 | | | | 3 | 70 | | | | | | 15 | 42 |
| Malawi | | | 100 | | | 70 | 96 | | | 81 | | | 51 | 98 | | | 83 | | | 53 | 77 |
| Mali | 63 | | 79 | 90 | 81 | 58 | 93 | | | | 3 | 10 | 21 | 100 | 8 | | | 19 | 27 | 31 | 69 |
| Mauritania | 100 | | 5 | 8 | | | 44 | | | | | | | 19 | 7 | | | | | | 33 |
| Mauritius | 51 | 63 | 100 | 100 | 100 | 100 | 100 | 99 | 100 | 90 | 86 | 100 | 100 | 99 | 77 | 82 | 94 | 92 | 100 | 100 | 99 |
| Morocco | 75 | | | 62 | 100 | 69 | 100 | 4 | | | 16 | | 18 | 42 | 29 | | | | | 40 | 75 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mozambique | | | | 53 | | 70 | 69 | | | | 12 | | 70 | 26 | | | | 20 | | | 43 |
| Namibia | | | | | 24 | | 96 | | | | | 11 | | 17 | | | | | 15 | | 41 |
| Niger | 10 | 30 | 36 | | 71 | 71 | 79 | | 1 | 3 | | 4 | 4 | 5 | 1 | 3 | 7 | | 17 | 15 | 20 |
| Nigeria | | | | | 80 | 61 | 85 | | | | 5 | 11 | 21 | 45 | | | | | 35 | 36 | 63 |
| Reunion | | | | | | | | | | | | | | | | | | | | | |
| Rwanda | 83 | 87 | 60 | 77 | 88 | | 12 | 52 | 56 | 50 | 55 | 17 | | 8 | 53 | 57 | 51 | 56 | 21 | | 8 |
| Sao Tome and Principe | | | | | | | | | | | 15 | | | | | | | 15 | | | |
| Senegal | | | 100 | 87 | 57 | 83 | 94 | | | 2 | | 38 | 40 | 48 | | | 36 | | 46 | 58 | 70 |
| Seychelles | | | | | | | | | | | | | | | | | | | | | |
| Sierra Leone | | | 31 | 60 | 55 | 17 | 23 | | | 6 | 10 | 31 | 8 | 31 | | | 12 | 24 | 39 | 11 | 28 |
| Somalia | | 77 | | 44 | | | | | 35 | | 5 | | | | | 47 | | 18 | | | |
| South Africa | | | | | | 79 | 99 | | | | | | 12 | 73 | | | | | | 46 | 86 |
| Sudan | 100 | 100 | 73 | 73 | | 79 | 87 | 4 | 10 | | | | 4 | 48 | 16 | 22 | | | | 22 | 62 |
| Swaziland | | 99 | | 100 | | 36 | | | 25 | | 25 | | 37 | | | 36 | | 45 | | 36 | |
| Tanzania | | 88 | | 93 | | | 98 | | 14 | | 58 | | | 86 | | 17 | 66 | | | | 90 |
| Togo | 4 | 36 | 24 | 31 | | 57 | 69 | | 12 | 10 | 9 | | 13 | 17 | 1 | 15 | 13 | 14 | | 26 | 34 |
| Tunisia | 100 | | 100 | 84 | | 100 | | 34 | | | 16 | | 85 | | 62 | | | 55 | | 96 | |
| Uganda | 84 | 82 | | 32 | 32 | 75 | 96 | 76 | 95 | | 30 | 60 | 55 | 72 | 76 | 94 | | 30 | 57 | 57 | 75 |
| Zambia | 12 | 87 | | 76 | | 40 | 99 | 18 | 46 | | 34 | | 10 | 64 | 16 | 42 | | 55 | | 23 | 78 |
| Zimbabwe | | | | | 95 | | 99 | | | | 15 | 22 | | 51 | | | | | 43 | | 68 |
| **North & Central America & Caribbean** | | | | | | | | | | | | | | | | | | | | | |
| Anguilla | | | | | | | | | | | | | | | | | | | | | |
| Antigua and Barbuda | | | | | | | | | | | | | | | | | | | | | |
| Aruba | | | | | | | | | | | | | | | | | | | | | |
| Bahamas | 100 | 100 | 88 | 100 | 98 | | 93 | 13 | 13 | | | 2 | | 94 | 66 | 65 | 88 | 100 | 63 | | 93 |
| Barbados | 100 | 100 | | 100 | 100 | | 100 | 100 | 100 | | | 100 | | 100 | 100 | 100 | | | 100 | | 100 |
| Belize | | | 62 | 87 | 76 | 23 | 59 | | | 75 | 45 | 22 | 87 | 21 | | | 69 | 66 | 50 | 57 | 42 |
| British Virgin Islands | | | | | 100 | | | | | | | 100 | | | | | | | | | |
| Canada | | | | | | | 100 | | | | | | | 99 | | | | | | | 100 |
| Cayman Islands | | | 94 | 96 | | | | | | | 94 | | | | 96 | | | | | | |
| Costa Rica | 66 | 94 | 99 | 99 | | 85 | 98 | 43 | 93 | 84 | 89 | | 99 | 95 | 52 | 93 | 91 | 95 | | 92 | 96 |
| Cuba | 57 | 100 | | | 100 | 71 | 96 | | | | | 68 | 51 | 91 | | | | | 92 | 66 | 95 |
| Dominican Republic | 63 | 74 | 25 | 41 | 95 | 76 | 75 | 54 | 16 | 4 | 10 | 75 | 83 | 64 | 58 | 42 | 15 | 23 | 87 | 78 | 71 |
| Dominica | | | | | | | | | | | | | | | | | | | | | |
| El Salvador | 66 | 71 | 48 | 82 | 85 | 78 | 88 | 18 | 17 | 26 | 43 | 38 | 59 | 78 | 37 | 39 | 35 | 58 | 59 | 68 | 83 |
| Grenada | | | | | | | 96 | | | | | | | 97 | | | | | | | 97 |
| Guadeloupe | | | | | | | 61 | | | | | | | 61 | | | | | | | 61 |
| Guatemala | | | 45 | 41 | 72 | | 98 | 11 | 16 | 20 | 12 | 52 | | 76 | | | 30 | 24 | 60 | | 85 |
| Haiti | | | 42 | 42 | 44 | 42 | 50 | 43 | 1 | 10 | 13 | 17 | 16 | 16 | | | 19 | 21 | 25 | 24 | 28 |

*(Continued)*



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**Table 7D.34 (Continued)**

| Region and Country | Fraction of Population with Access to Sanitation | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | | | | | | | Rural | | | | | | | Total | | | | | | |
| | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 |
| Honduras | 64 | 53 | 49 | 24 | 89 | 81 | 94 | 9 | 13 | 26 | 34 | 42 | 53 | 57 | 24 | 26 | 35 | 30 | 63 | 65 | 77 |
| Jamaica | 100 | 100 | 12 | 92 | | | 98 | 92 | 91 | 2 | 90 | | | 66 | 94 | 94 | 7 | 91 | | | 84 |
| Martinique | | | | | | | | | | | | | | | | | | | | | |
| Mexico | | | 77 | 77 | 85 | 81 | 87 | 13 | 14 | 12 | 13 | | 26 | 32 | | | 55 | 58 | | 66 | 73 |
| Montserrat | | | | | | | | | | | | | | | | | | | | | |
| The Netherlands Antilles | | | | | | | | | | | | | | | | | | | | | |
| Nicaragua | | | 34 | 35 | | 34 | 96 | 8 | 24 | | 16 | | 27 | 68 | | | | 27 | | 31 | 84 |
| Panama | 87 | 78 | 83 | 99 | | | 87 | 69 | 76 | 59 | 61 | | | 94 | 78 | 77 | 71 | 81 | | 86 | 99 |
| Puerto Rico | | | | | | | | | | | | | | | | | | | | | |
| St. Kitts | | | | | | | | | | | | | | | | | | | | | |
| St. Lucia | | | | | | | | | | | | | | | | | | | | | |
| St. Vincent | | | | | | | | | | | | | | | | | | | | | |
| Trinidad/ Tobago | | | | | 100 | | | | | | | 92 | | | | | | | 97 | | 88 |
| Turks/Caicos Islands | 51 | 83 | 96 | 100 | | | | 96 | 97 | 88 | 95 | | | | 81 | 92 | 93 | 98 | | | |
| United States of America | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| United States Virgin Islands | | | | | | | | | | | | | | | | | | | | | |
| **South America** | | | | | | | | | | | | | | | | | | | | | |
| Argentina | 87 | 100 | 80 | 75 | | | 89 | 79 | 83 | 35 | 35 | | | 48 | 85 | 97 | | 69 | | | 85 |
| Bolivia | 25 | | 37 | 33 | 38 | 58 | 82 | 4 | 9 | 4 | 10 | 14 | 16 | 38 | 12 | | 18 | 21 | 26 | 41 | 66 |
| Brazil | 85 | | | 86 | 84 | 55 | 85 | 24 | | 1 | 1 | 32 | 3 | 40 | 58 | | | 63 | 71 | 44 | 77 |
| Chile | 33 | 36 | 100 | 100 | | 82 | 98 | 10 | 11 | 10 | 4 | | | 93 | 29 | 32 | 83 | 84 | | | 97 |
| Colombia | 75 | 73 | 93 | 96 | 84 | 76 | 97 | 8 | 13 | 4 | 13 | 18 | 33 | 51 | 47 | 48 | 61 | | 64 | 63 | 85 |
| Ecuador | | | 73 | 98 | 56 | 87 | 70 | | 7 | 17 | 29 | 38 | 34 | 37 | | | 43 | 65 | 48 | 64 | 59 |
| Falkland Islands (Malvinas) | | | | | | | | | | | | | | | | | | | | | |
| French Guiana | | | | | | | 85 | | | | | | | 57 | | | | | | | 79 |
| Guyana | 95 | 99 | 73 | 100 | 97 | | 97 | 92 | 94 | 80 | 79 | 81 | | 81 | 93 | 96 | 78 | 86 | 86 | | 87 |
| Paraguay | 16 | 28 | 95 | 89 | 31 | | 95 | | | 80 | 83 | 60 | | 95 | 6 | 10 | 86 | 85 | 46 | | 95 |
| Peru | 52 | | 57 | 67 | 76 | 62 | 90 | 16 | | 0 | 12 | 20 | 10 | 40 | 36 | | 36 | 49 | 59 | 44 | 76 |
| Suriname | | | 100 | 78 | | | 100 | | | 79 | 48 | | | 34 | | | 88 | 62 | | | 83 |
| Uruguay | 97 | 97 | 59 | 59 | | | 96 | 13 | 17 | 6 | 59 | | | 89 | 82 | 83 | 51 | 59 | | | 95 |
| Venezuela | | | 60 | 57 | | 64 | 86 | 45 | | 12 | 5 | 72 | 30 | 69 | | | 52 | 50 | | 58 | 74 |
| **Asia** | | | | | | | | | | | | | | | | | | | | | |
| Afghanistan | 69 | 63 | | 5 | 13 | 38 | 25 | 16 | 15 | | | | 1 | 8 | 21 | 21 | | | | 8 | 12 |

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| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Armenia | | | | | | | | | | | | | | | | | | | | | |
| Azerbaijan | | | | | | | | | | | | | | | | | | | | | |
| Bahrain | | | | 100 | 100 | | | | | | 100 | 0 | | | | | | 100 | | | |
| Bangladesh | 87 | 40 | 21 | 24 | 40 | 77 | 82 | | | 1 | 3 | 4 | 30 | 44 | 6 | 5 | 3 | 5 | 10 | 35 | 53 |
| Bhutan | | | | | 80 | 66 | 65 | | | | | 3 | 18 | 70 | | | | | 7 | 41 | 69 |
| Brunei Darus | | | | | | | | | | | | | | | | | | | | | |
| Cambodia | | | 100 | | | | 58 | | | 76 | | | | 10 | | | | | | | 18 |
| China | | | | | 100 | 58 | 68 | | | | | 81 | 7 | 24 | | | | | 86 | 21 | 38 |
| Cyprus | 100 | 94 | | 100 | 96 | | 100 | 92 | 95 | | 100 | 100 | | 100 | 95 | 95 | | 100 | 98 | | 100 |
| East Timor | | | | | | | | | | | | | | | | | | | | | |
| Gaza Strip | | | | | | | | | | | | | | | | | | | | | |
| Georgia | | | | | | | | | | | | | | | | | | | | | |
| Hong Kong | | | | | 90 | | | | | | | 50 | | | | | | | 88 | | |
| India | 85 | 87 | 27 | 31 | 44 | 70 | 73 | 1 | 2 | 1 | 2 | 3 | 14 | 14 | 18 | 20 | 7 | 9 | 14 | 29 | 31 |
| Indonesia | 50 | 60 | 29 | 33 | 79 | 73 | 87 | 4 | 5 | 21 | 38 | 30 | 40 | 52 | 12 | 15 | 23 | 37 | 44 | 51 | 66 |
| Iran | 100 | 100 | 96 | | 100 | 89 | 86 | 48 | 59 | 43 | | 35 | 37 | 74 | 70 | 78 | 69 | | 72 | 67 | 81 |
| Iraq | 82 | 75 | | 100 | 96 | | 93 | | 1 | | 11 | | | 31 | 47 | 47 | | 74 | | 36 | 79 |
| Israel | | | | | | | | | | | | | | | | | | | | | |
| Japan | | | | | | | | | | | | | | | | | | | | | |
| Jordan | | | 94 | 92 | 100 | | 100 | | | 34 | | 100 | | 98 | | | 70 | | 100 | 95 | 99 |
| Kazakhstan | | | | | | | 100 | | | | | | | 98 | | | | | | | 99 |
| Korea DPR | | | | | | | 99 | | | | | | | 100 | | | | | | | 99 |
| Korea Rep | 59 | 80 | 100 | 100 | 67 | | 76 | | 50 | 100 | 100 | 12 | | 4 | 25 | 64 | 100 | 100 | 52 | | 63 |
| Kuwait | | | 100 | 100 | | | | | | 100 | | | | | | | 100 | | | | |
| Kyrgyzstan | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| Lao People's Dem Rep | | 10 | 13 | | 30 | 70 | 84 | | 2 | 4 | | 8 | 13 | 34 | | 3 | 5 | | 12 | 24 | 46 |
| Lebanon | | | | | | 100 | 100 | | | | | | 100 | 92 | | | | | | 100 | 99 |
| Macau | | | | | | | | | | | | | | | | | | | | | |
| Malaysia | 100 | 100 | 100 | 100 | 94 | | | 43 | 43 | 55 | 60 | 94 | | 41 | 59 | 60 | 70 | 75 | 94 | | |
| Maldives | | 21 | 60 | 100 | 95 | 95 | 100 | | | 1 | 2 | 4 | 26 | 58 | | 3 | 13 | 22 | | 44 | 56 |
| Mongolia | | | | | 100 | | 46 | | | | | 47 | | 2 | | | | | 78 | | 30 |
| Myanmar (Burma) | 45 | 38 | 38 | 33 | 50 | 42 | 65 | | | | | 13 | 40 | 39 | 35 | 33 | 20 | 24 | 22 | 41 | 46 |
| Nepal | 14 | 14 | 16 | 17 | 34 | 51 | 75 | | | 1 | 1 | 3 | 16 | 20 | 1 | 1 | 1 | | 6 | 20 | 27 |
| Oman | 100 | 100 | | 88 | | | 98 | | 5 | | 25 | | | 61 | | 12 | | 31 | | 76 | 92 |
| Pakistan | 12 | 21 | 42 | 51 | 53 | 53 | 94 | | | 2 | 6 | 12 | 19 | 42 | 3 | 6 | 13 | 19 | 25 | 30 | 61 |
| Philippines | 90 | 76 | 81 | 83 | 79 | | 92 | 40 | 44 | 67 | 56 | 63 | | 71 | 57 | 56 | 75 | 67 | 70 | | 83 |
| Qatar | 100 | 100 | | | 100 | | | 16 | 100 | | | 85 | | | 83 | 100 | | | | | |
| Saudi Arabia | 67 | 91 | 81 | 100 | | | 100 | 11 | 35 | 50 | 33 | | | 100 | 21 | 47 | 70 | 82 | | | 100 |
| Singapore | | | 80 | 99 | 99 | | 100 | | | | | | | | | | 80 | 99 | | | 100 |
| Sri Lanka | 76 | 68 | 80 | 65 | 68 | 33 | 91 | 61 | 55 | 63 | 39 | 45 | 58 | 80 | 64 | 59 | 67 | 44 | 50 | 52 | 83 |
| Syria | | | 74 | | | 77 | 98 | | | 28 | | | 35 | 81 | | | 50 | | | 56 | 90 |
| Tajikistan | | | | | | | | | | | | | | | | | | | | | |
| Thailand | 65 | 58 | 64 | 78 | | | 97 | 8 | 36 | 41 | 46 | 86 | | 96 | 17 | 40 | 45 | 52 | | | 96 |
| Turkey | | | 56 | | | | 98 | | | | | | | 70 | | | | | | | 91 |

*(Continued)*



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**Table 7D.34 (Continued)**

| Region and Country | Fraction of Population with Access to Sanitation | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | | | | | | | Rural | | | | | | | Total | | | | | | |
| | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 |
| Turkmenistan | | | | | | | | | | | | | | | | | | | | | |
| United Arab Emirates | | | 93 | | | | | | | 22 | | | | | | | 80 | | | | |
| Uzbekistan | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| Vietnam | 100 | | | | 23 | 43 | 87 | | 2 | 55 | | 10 | 15 | 70 | 26 | | | | 13 | 21 | 73 |
| Yemen A R | | | 60 | 83 | | | 99 | | | | | | | 31 | | | | | | | 45 |
| Yemen Dem | | | 70 | | | | 99 | | | 15 | | | | 31 | | | 35 | | | | 45 |
| **Oceania** | | | | | | | | | | | | | | | | | | | | | |
| American Samoa | | | | | | | | | | | | | | | | | | | | | |
| Australia | | | | | | | 100 | | | | | | | 100 | | | | | | | 100 |
| Cook Islands | | | 100 | 100 | 100 | | 100 | | | 76 | 99 | 100 | | 100 | | | | 99 | | | 100 |
| Fiji | 100 | 100 | 85 | | 91 | 100 | 75 | 87 | 93 | 60 | | 65 | 85 | 12 | 91 | 96 | 70 | | 75 | 92 | 43 |
| French Polyneisa | | | | | 98 | | 99 | | | | | 95 | | 97 | | | | | | | 98 |
| Guam | | | | | | | | | | | | | | | | | | | | | |
| Kiribati | | | | | 91 | 100 | 54 | | | | | 49 | 100 | 44 | | | | | | 100 | 48 |
| Marshall Islands | | | | | 100 | | | | | | | 45 | | | | | | | | | |
| Micronesia | | | | | 99 | 100 | | | | | | 46 | 100 | | | | | | | 100 | |
| Nauru | | | | | | | | | | | | | | | | | | | | | |
| New Caledonia | | | | | | | | | | | | | | | | | | | | | |
| New Zealand | | | | | | | | | | | | | | | | | | | | | |
| Niue | | | | | 0 | 100 | 100 | | | | 100 | 100 | 100 | 100 | | | | | | 100 | 100 |
| Northern Mariana Islands | | | | | 100 | | | | | | | 71 | | 92 | | | | | | | |
| Palau | | | | | 95 | | 100 | | | | | 100 | | 100 | | | | | | | 100 |
| Papua New Guinea | 100 | 100 | 96 | 99 | 57 | 82 | 92 | 5 | 5 | 3 | 35 | | 11 | 80 | 14 | 18 | 15 | 44 | | 22 | 82 |
| Pitcairn | | | | | | | | | | | | | | | | | | | | | |
| Samoa | 100 | 100 | 86 | | 100 | | 95 | 80 | 99 | 83 | | 92 | 17 | 100 | 84 | 99 | | | | | 99 |
| Solomon Islands | | | 80 | | 73 | | 98 | | | 21 | | 2 | | 18 | | | | | 13 | | 34 |
| Tokelau | | | | | | 100 | | | | 41 | | | 100 | | | | | | | 100 | |
| Tonga | 100 | 100 | 97 | 99 | 88 | 100 | | 100 | 100 | 94 | 40 | 78 | 100 | | 100 | 100 | 19 | 52 | 82 | 100 | |
| Tuvalu | | | 100 | 81 | | 90 | 100 | | | 80 | 73 | | 85 | 100 | | | | | | 87 | 100 |
| Vanuatu | | | 95 | 86 | | | 100 | | | 68 | 25 | | | 100 | | | | 40 | | | 100 |

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| | | | | | |
|---|---|---|---|---|---|
| Wallis and Futuna Islands | | | | | |
| Western Samoa | 86 | 88 | 83 | 83 | 84 |

[a] United Nations Environment Programme, 1989, *Environmental Data Report*, GEMS Monitoring and Assessment Research Center, Basil Blackwell, Oxford.
[b] WRI 1988, World Health Organization data, cited by the World Resources Institute, 1988, *World Resources 1988–89*, World Resources Institute and the International Institute for Environment and Development in collaboration with the United Nations Environment Programme, Basic Books, New York.
[c] United Nations Environment Programme, 1993–94, *Environmental Data Report*, GEMS Monitoring and Assessment Research Centre in cooperation with the World Resources Institute and the UK Department of the Environment, Basil Blackwell, Oxford.
[d] WHO 1996, World Health Organization, 1996, *Water Supply and Sanitation Sector Monitoring Report: 1996* (Sector Status as of 1994), in collaboration with the Water Supply and Sanitation Collaborative Council and the United Nations Children's Fund, UNICEF, New York.
[e] WHO 2000, World Health Organization, 2000, *Global Water Supply and Sanitation Assessment 2000 Report*, available in full at www.who.int/water_sanitation_health/Globassessment/GlobalTOC.htm.

*Source*: From *World's Water 2002–2003*, by Peter H. Gleick. Copyright © 2002 Island Press. Reproduced by permission of Island Press, Washington, DC.



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**Table 7D.35 Water Supply and Sanitation Coverage by Region, 1990 and 2000**

| Region | 1990 Population (millions) | | | | 2000 Population (millions) | | | |
|---|---|---|---|---|---|---|---|---|
| | Total Population | Population Served | Population Unserved | % Served[a] | Total Population | Population Served | Population Unserved | % Served[a] |
| **Global** | (76% of regional population represented) | | | | (89% of regional population represented) | | | |
| Urban water supply | 2,292 | 2,179 | 113 | 95 | 2,845 | 2,672 | 173 | 94 |
| Rural water supply | 2,974 | 1,961 | 1,013 | 66 | 3,210 | 2,284 | 926 | 71 |
| Total water supply | 5,266 | 4,140 | 1,126 | 79 | 6,055 | 4,956 | 1,099 | 82 |
| Urban sanitation | 2,292 | 1,877 | 415 | 82 | 2,845 | 2,442 | 403 | 86 |
| Rural sanitation | 2,974 | 1,028 | 1,946 | 35 | 3,210 | 1,210 | 2,000 | 38 |
| Total sanitation | 5,266 | 2,905 | 2,361 | 55 | 6,055 | 3,652 | 2,403 | 60 |
| **Africa** | (72% of regional population represented) | | | | (96% of regional population represented) | | | |
| Urban water supply | 197 | 166 | 31 | 84 | 297 | 253 | 44 | 85 |
| Rural water supply | 418 | 183 | 235 | 44 | 487 | 231 | 256 | 47 |
| Total water supply | 615 | 349 | 266 | 57 | 784 | 484 | 300 | 62 |
| Urban sanitation | 197 | 167 | 30 | 85 | 297 | 251 | 46 | 84 |
| Rural sanitation | 418 | 206 | 212 | 49 | 487 | 220 | 267 | 45 |
| Total sanitation | 615 | 373 | 242 | 61 | 784 | 471 | 313 | 60 |
| **Asia** | (88% of regional population represented) | | | | (94% of regional population represented) | | | |
| Urban water supply | 1,029 | 972 | 57 | 94 | 1,352 | 1,254 | 98 | 93 |
| Rural water supply | 2,151 | 1,433 | 718 | 67 | 2,331 | 1,736 | 595 | 75 |
| Total water supply | 3,180 | 2,405 | 775 | 76 | 3,683 | 2,990 | 693 | 81 |
| Urban sanitation | 1,029 | 690 | 339 | 67 | 1,352 | 1,055 | 297 | 78 |
| Rural sanitation | 2,151 | 496 | 1,655 | 23 | 2,331 | 712 | 1,619 | 31 |
| Total sanitation | 3,180 | 1,186 | 1,994 | 37 | 3,683 | 1,767 | 1,916 | 48 |
| **Latin American and the Caribbean** | (77% of regional population represented) | | | | (99% of regional population represented) | | | |
| Urban water supply | 313 | 287 | 26 | 92 | 391 | 362 | 29 | 93 |
| Rural water supply | 128 | 72 | 56 | 56 | 128 | 79 | 49 | 62 |
| Total water supply | 441 | 359 | 82 | 82 | 519 | 441 | 78 | 85 |
| Urban sanitation | 313 | 267 | 46 | 85 | 391 | 340 | 51 | 87 |
| Rural sanitation | 128 | 50 | 78 | 39 | 128 | 62 | 66 | 49 |
| Total sanitation | 441 | 317 | 124 | 72 | 519 | 402 | 117 | 78 |
| **Oceania** | (64% of regional population represented) | | | | (85% of regional population represented) | | | |
| Urban water supply | 18 | 18 | 0 | 100 | 21 | 21 | 0 | 98 |
| Rural water supply | 8 | 5 | 3 | 62 | 9 | 6 | 3 | 63 |
| Total water supply | 26 | 23 | 3 | 88 | 30 | 27 | 3 | 88 |
| Urban sanitation | 18 | 18 | 0 | 99 | 21 | 21 | 0 | 99 |
| Rural sanitation | 8 | 7 | 1 | 89 | 9 | 7 | 2 | 81 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total sanitation | 26 | 25 | 1 | 96 | 30 | 28 | 2 | 93 |
| **Europe** | (15% of regional population represented) | | | | (44% of regional population represented) | | | |
| Urban water supply | 522 | 522 | 0 | 100 | 545 | 542 | 3 | 100 |
| Rural water supply | 200 | 199 | 1 | 100 | 184 | 161 | 23 | 87 |
| Total water supply | 722 | 721 | 1 | 100 | 729 | 703 | 26 | 96 |
| Urban sanitation | 522 | 522 | 0 | 100 | 545 | 537 | 8 | 99 |
| Rural sanitation | 200 | 199 | 1 | 100 | 184 | 137 | 47 | 74 |
| Total sanitation | 722 | 721 | 1 | 100 | 729 | 674 | 55 | 92 |
| **Northern America** | (99.9% of regional population represented) | | | | (99.9% of regional population represented) | | | |
| Urban water supply | 213 | 213 | 0 | 100 | 239 | 239 | 0 | 100 |
| Rural water supply | 69 | 69 | 0 | 100 | 71 | 71 | 0 | 100 |
| Total water supply | 282 | 282 | 0 | 100 | 310 | 310 | 0 | 100 |
| Urban sanitation | 213 | 213 | 0 | 100 | 239 | 239 | 0 | 100 |
| Rural sanitation | 69 | 69 | 0 | 100 | 71 | 71 | 0 | 100 |
| Total sanitation | 282 | 282 | 0 | 100 | 310 | 310 | 0 | 100 |

[a] Due to rounding, coverage figures might not total 100% even if the population unserved is shown as 0.

*Source*: From *World Health Organization and United Nations Children's Fund Global Water Supply and Sanitation Assesment Report 2000*, Copyright © 2000 World' Health Organization and United Nations Children's Fund, www.wssinfo.org.



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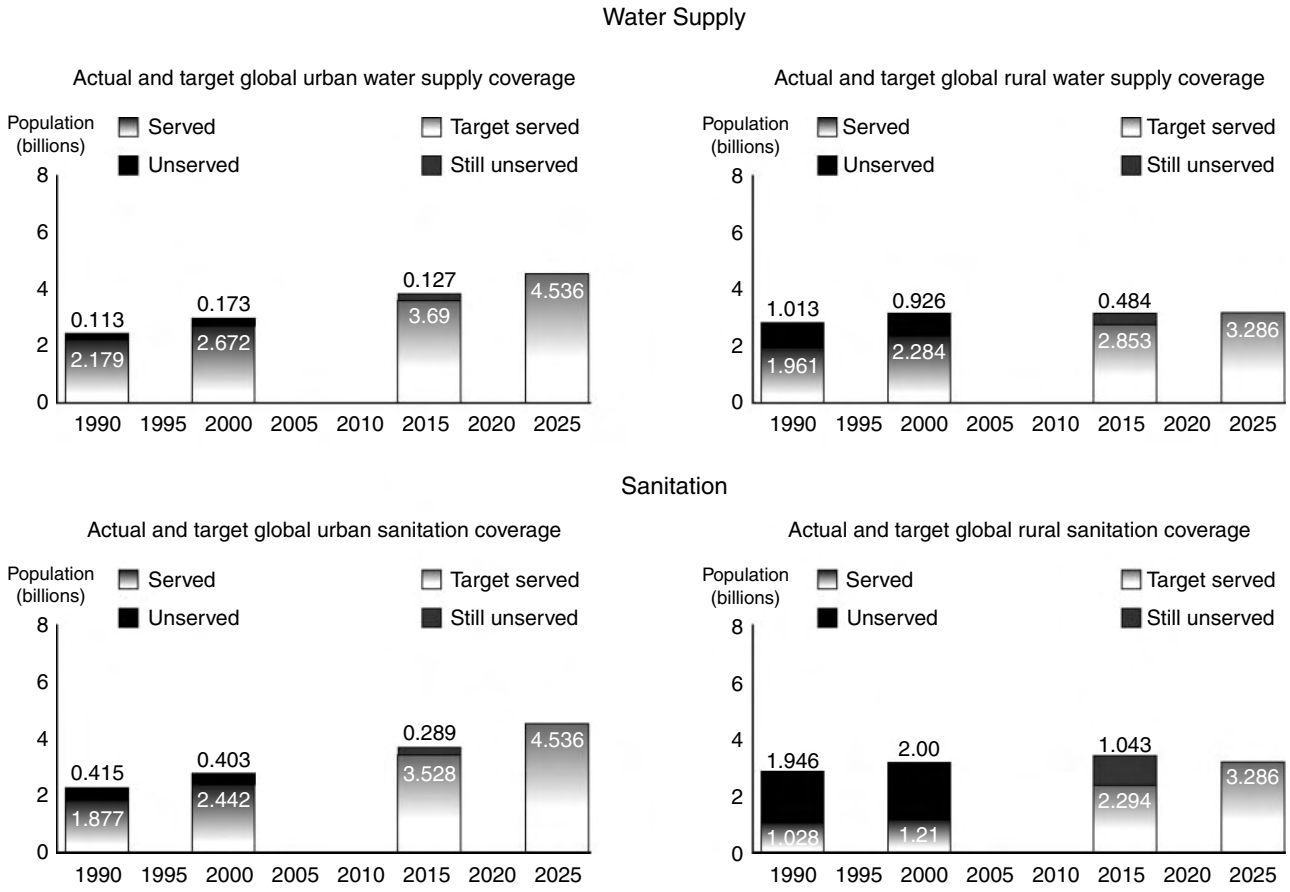


**Figure 7D.13** Actual and target global urban and rural water supply and sanitation coverage. (From World Health Organization and UNICEF, 2000, *Global Water Supply and Sanitation Assessment Report 2000*, Copyright © 2000 World' Health Organization and United Nations Children's Fund, www.wssinfo.org/en/welcome.html. With permission.)

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**Table 7D.36 Constraints in Improving Water Supply and Sanitation Services in Developing Countries**

| Constraints | Number of Countries Indicting Constraint | | | Ranking Index[a] |
|---|---|---|---|---|
| | Very Severe | Severe | Moderate | |
| Insufficiency of trained personnel (professional) | 16 | 40 | 27 | 155 |
| Funding limitations | 21 | 31 | 30 | 155 |
| Insufficiency of trained personnel (sub-professional) | 16 | 38 | 29 | 153 |
| Operation and maintenance[b] | 16 | 36 | 23 | 143 |
| Logistics[b] | 11 | 35 | 23 | 126 |
| Inadequate cost-recovery framework | 11 | 34 | 22 | 123 |
| Inappropriate institutional framework | 6 | 30 | 35 | 113 |
| Insufficient health education efforts | 7 | 24 | 43 | 112 |
| Intermittent water service | 10 | 19 | 32 | 100 |
| Lack of planning and design criteria | 6 | 17 | 41 | 93 |
| Noninvolvement of communities | 6 | 15 | 44 | 92 |
| Inadequate or outmoded legal framework | 10 | 14 | 34 | 92 |
| Inappropriate technology | 5 | 18 | 33 | 84 |
| Insufficient knowledge of water resources | 1 | 20 | 39 | 82 |
| Inadequate water resources | 5 | 11 | 40 | 77 |
| Lack of definite government policy for sector | 4 | 10 | 44 | 76 |
| Import restrictions | 5 | 12 | 21 | 60 |

*Note:* Ranking and frequency of constraints as reported by 87 countries.

[a] Ranking index = (No. very severe × 3) + (No. severe × 2) + (No. moderate × 1).
[b] "Logistics" is ranked ahead of "Operation and maintenance" in the group of Least Developed Countries.

*Source*: World Health Organization, 1984. *The International Drinking Water Supply and Sanitation Decade*, WHO Publ. 85. Reprinted with permission.

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## SECTION 7E DOMESTIC WATER CONSUMPTION

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**Table 7E.37 Domestic Freshwater Use in the United States, 2000**

| State | Population (thousands) | | | | Withdrawals (mil gal/day) | | | Withdrawals (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Served by Public Supply | Self-Supplied Domestic | | By Source | | | By Source | | |
| | Total | Total | Population | Population (Percent) | Groundwater | Surface Water | Total | Groundwater | Surface Water | Total |
| Alabama | 4,450 | 3,580 | 868 | 20 | 78.9 | 0 | 78.9 | 88.4 | 0 | 88.4 |
| Alaska | 627 | 421 | 206 | 33 | 10.9 | 0.25 | 11.2 | 12.2 | 0.28 | 12.5 |
| Arizona | 5,130 | 4,870 | 265 | 5 | 28.9 | 0 | 28.9 | 32.4 | 0 | 32.4 |
| Arkansas | 2,670 | 2,320 | 351 | 13 | 28.5 | 0 | 28.5 | 31.9 | 0 | 31.9 |
| California | 33,900 | 30,100 | 3,810 | 11 | 257 | 28.6 | 286 | 288 | 32 | 320 |
| Colorado | 4,300 | 3,750 | 555 | 13 | 66.8 | 0 | 66.8 | 74.9 | 0 | 74.9 |
| Connecticut | 3,410 | 2,660 | 749 | 22 | 56.2 | 0 | 56.2 | 63 | 0 | 63 |
| Delaware | 784 | 617 | 166 | 21 | 13.3 | 0 | 13.3 | 14.9 | 0 | 14.9 |
| District of Columbia | 572 | 572 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 16,000 | 14,000 | 1,950 | 12 | 199 | 0 | 199 | 223 | 0 | 223 |
| Georgia | 8,190 | 6,730 | 1,450 | 18 | 110 | 0 | 110 | 123 | 0 | 123 |
| Hawaii | 1,210 | 1,140 | 72.9 | 6 | 4.82 | 7.22 | 12 | 5.4 | 8.09 | 13.5 |
| Idaho | 1,290 | 928 | 366 | 28 | 85.2 | 0 | 85.2 | 95.6 | 0 | 95.6 |
| Illinois | 12,400 | 10,900 | 1,500 | 12 | 135 | 0 | 135 | 152 | 0 | 152 |
| Indiana | 6,080 | 4,480 | 1,600 | 26 | 122 | 0 | 122 | 137 | 0 | 137 |
| Iowa | 2,930 | 2,410 | 511 | 17 | 33.2 | 0 | 33.2 | 37.2 | 0 | 37.2 |
| Kansas | 2,690 | 2,500 | 193 | 7 | 21.6 | 0 | 21.6 | 24.2 | 0 | 24.2 |
| Kentucky | 4,040 | 3,490 | 552 | 14 | 19.5 | 8 | 27.5 | 21.9 | 8.97 | 30.8 |
| Louisiana | 4,470 | 3,950 | 523 | 12 | 41.2 | 0 | 41.2 | 46.2 | 0 | 46.2 |
| Maine | 1,270 | 726 | 549 | 43 | 35.7 | 0 | 35.7 | 40 | 0 | 40 |
| Maryland | 5,300 | 4,360 | 932 | 18 | 77.1 | 0 | 77.1 | 86.4 | 0 | 86.4 |
| Massachusetts | 6,350 | 5,880 | 473 | 7 | 42.2 | 0 | 42.2 | 47.2 | 0 | 47.2 |
| Michigan | 9,940 | 7,170 | 2,770 | 28 | 239 | 0 | 239 | 268 | 0 | 268 |
| Minnesota | 4,920 | 3,770 | 1,150 | 23 | 80.8 | 0 | 80.8 | 90.6 | 0 | 90.6 |
| Mississippi | 2,840 | 2,190 | 654 | 23 | 69.3 | 0 | 69.3 | 77.7 | 0 | 77.7 |
| Missouri | 5,600 | 4,770 | 824 | 15 | 53.6 | 0 | 53.6 | 60.1 | 0 | 60.1 |
| Montana | 902 | 664 | 238 | 26 | 17.3 | 1.29 | 18.6 | 19.4 | 1.45 | 20.8 |
| Nebraska | 1,710 | 1,390 | 324 | 19 | 48.4 | 0 | 48.4 | 54.3 | 0 | 54.3 |
| Nevada | 2,000 | 1,870 | 124 | 6 | 22.4 | 0 | 22.4 | 25.2 | 0 | 25.2 |
| New Hampshire | 1,240 | 756 | 479 | 39 | 40.9 | 0.16 | 41 | 45.8 | 0.18 | 46 |
| New Jersey | 8,410 | 7,460 | 952 | 11 | 79.7 | 0 | 79.7 | 89.3 | 0 | 89.3 |
| New Mexico | 1,820 | 1,460 | 360 | 20 | 31.4 | 0 | 31.4 | 35.2 | 0 | 35.2 |
| New York | 19,000 | 17,100 | 1,890 | 10 | 142 | 0 | 142 | 159 | 0 | 159 |
| North Carolina | 8,050 | 5,350 | 2,700 | 34 | 189 | 0 | 189 | 212 | 0 | 212 |
| North Dakota | 642 | 493 | 149 | 23 | 11.9 | 0 | 11.9 | 13.3 | 0 | 13.3 |
| Ohio | 11,400 | 9,570 | 1,790 | 16 | 132 | 2.71 | 134 | 148 | 3.04 | 151 |
| Oklahoma | 3,450 | 3,150 | 299 | 9 | 25.5 | 0 | 25.5 | 28.5 | 0 | 28.5 |
| Oregon | 3,420 | 2,730 | 692 | 20 | 68.3 | 7.97 | 76.2 | 76.5 | 8.93 | 85.5 |
| Pennsylvania | 12,300 | 10,100 | 2,190 | 18 | 132 | 0 | 132 | 148 | 0 | 148 |

*(Continued)*



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**Table 7E.37 (Continued)**

| State | Population (thousands) | | | | Withdrawals (mil gal/day) | | | Withdrawals (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Self-Supplied Domestic | | By Source | | | By Source | | |
| | Total | Served by Public Supply Total | Population | Population (Percent) | Groundwater | Surface Water | Total | Groundwater | Surface Water | Total |
| Rhode Island | 1,050 | 922 | 127 | 12 | 8.99 | 0 | 8.99 | 10.1 | 0 | 10.1 |
| South Carolina | 4,010 | 3,160 | 847 | 21 | 63.5 | 0 | 63.5 | 71.2 | 0 | 71.2 |
| South Dakota | 755 | 625 | 129 | 17 | 9.52 | 0.01 | 9.53 | 10.7 | 0.01 | 10.7 |
| Tennessee | 5,690 | 5,240 | 453 | 8 | 32.6 | 0 | 32.6 | 36.6 | 0 | 36.6 |
| Texas | 20,900 | 19,700 | 1,190 | 6 | 131 | 0 | 131 | 147 | 0 | 147 |
| Utah | 2,230 | 2,180 | 56.2 | 3 | 16.1 | 0 | 16.1 | 18 | 0 | 18 |
| Vermont | 609 | 362 | 247 | 41 | 20.7 | 0.25 | 21 | 23.2 | 0.28 | 23.5 |
| Virginia | 7,080 | 5,310 | 1,770 | 25 | 133 | 0 | 133 | 150 | 0 | 150 |
| Washington | 5,890 | 4,900 | 993 | 17 | 125 | 0.02 | 125 | 140 | 0.02 | 140 |
| West Virginia | 1,810 | 1,300 | 505 | 28 | 39.6 | 0.81 | 40.4 | 44.4 | 0.91 | 45.3 |
| Wisconsin | 5,360 | 3,620 | 1,750 | 33 | 96.3 | 0 | 96.3 | 108 | 0 | 108 |
| Wyoming | 494 | 406 | 87.5 | 18 | 6.57 | 0 | 6.57 | 7.36 | 0 | 7.36 |
| Puerto Rico | 3,810 | 3,800 | 12.8 | 0 | 0.88 | 0 | 0.88 | 0.99 | 0 | 0.99 |
| U.S. Virgin Islands | 109 | 53.4 | 55.2 | 51 | 0 | 1.69 | 1.69 | 0 | 1.89 | 1.89 |
| **Total** | **285,000** | **242,000** | **43,500** | **15** | **3,530** | **58.9** | **3,590** | **3,960** | **66.1** | **4,030** |

*Note:* Figures may not sum to totals because of independent rounding.

*Source*: From Hutson, S.S. et al., 2004, Estimated Use of Water in the United States in 2000, U.S. Geological Survey Circular 1268, www.usgs.gov.

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**Table 7E.38 Groundwater and Surface Water Withdrawals in Public Supply and Rural Domestic Sectors, 1950–1995**

| | Public Supply | | | Self-Supplied Domestic | | |
|---|---|---|---|---|---|---|
| Year | Total Withdrawals (bgd) | Groundwater (%) | Surface Water (%) | Total Withdrawals (bgd) | Groundwater (%) | Surface Water (%) |
| 1950 | 14.0 | 26 | 74 | 3.6 | 80 | 20 |
| 1955 | 17.0 | 28 | 72 | 2.5 | 72 | 28 |
| 1960 | 21.0 | 30 | 70 | 2.1 | 93 | 7 |
| 1965 | 24.0 | 33 | 67 | 2.3 | 95 | 5 |
| 1970 | 27.0 | 34 | 66 | 2.6 | 96 | 4 |
| 1975 | 29.0 | 36 | 64 | 2.8 | 95 | 5 |
| 1980 | 34.0 | 34 | 66 | 3.5 | 95 | 5 |
| 1985 | 36.5 | 40 | 60 | 3.3 | 98 | 2 |
| 1990 | 38.5 | 39 | 61 | 3.4 | 96 | 4 |
| 1995 | 40.2 | 37 | 63 | 3.4 | 99 | 1 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*. Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.

**Table 7E.39 Population and Domestic Withdrawals, 1950–1995**

| Year | Domestic Withdrawals (bgd) | Population (millions) | Per Capita Withdrawals (gpcd) |
|---|---|---|---|
| 1950 | 17.6 | 150.7 | 116.8 |
| 1955 | 20.6 | 164.0 | 125.6 |
| 1960 | 24.6 | 179.3 | 137.2 |
| 1965 | 28.0 | 193.8 | 144.5 |
| 1970 | 31.5 | 205.9 | 153.0 |
| 1975 | 33.9 | 216.4 | 156.7 |
| 1980 | 39.6 | 229.6 | 172.5 |
| 1985 | 44.3 | 242.4 | 182.7 |
| 1990 | 46.4 | 252.3 | 183.9 |
| 1995 | 49.1 | 267.1 | 183.8 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*. Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.

**Table 7E.40 Typical Urban Water Use by a Family of Four**

| | Daily Use | | |
|---|---|---|---|
| | Per Family | | |
| | Gal/day | % | Per Capita gal/day |
| Drinking and water used in kitchen | 8 | 2 | 2.00 |
| Dishwasher (3 loads per day) | 15 | 4 | 3.75 |
| Toilet (16 flushes per day) | 96 | 28 | 24.00 |
| Bathing (4 baths or showers per day) | 80 | 23 | 20.00 |
| Laundering (6 loads per week) | 34 | 10 | 8.50 |
| Automobile washing (2 car washes per month) | 10 | 3 | 2.50 |
| Lawn watering and swimming pools (180 hr/yr) | 100 | 29 | 25.00 |
| Garbage disposal unit (1 percent of all other uses) | 3 | 1 | 0.75 |
| Total | 346 | 100 | 86.50 |

*Note:* Assuming no water delivery losses.

*Source*: From U.S. Water Resources Council, Second National Water Assessment, The Nation's Water Resources 1975–2000; percentage added.

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**Table 7E.41 Flow Rates for Certain Plumbing, Household, and Farm Fixtures**

| Location | Flow Pressure[a] (psi) | Flow Rate (gpm) |
|---|---|---|
| Ordinary basin faucet | 8 | 2.0 |
| Self-closing basin faucet | 8 | 2.5 |
| Sink faucet, 3/8 in. | 8 | 4.5 |
| Sink faucet, 1/2 in. | 8 | 4.5 |
| Bathtub faucet | 8 | 6.0 |
| Laundry tub faucet, 1/2 in. | 8 | 5.0 |
| Shower | 8 | 5.0 |
| Ball-cock for closet | 8 | 3.0 |
| Flush valve for closet (toilet) | 15 | 15–40[b] |
| Flushometer valve for closet (toilet) | 15 | 15.0 |
| Garden hose (50 ft, 3/4 in. sill cock) | 30 | 5.0 |
| Garden hose (50 ft, 5/8 in. outlet) | 15 | 3.33 |
| Drinking fountains | 15 | 0.75 |
| Fire hose 1 1/2 in., 1/2 in. nozzle | 30 | 40.0 |

[a] Flow pressure is the pressure in the supply near the faucet or water outlet while the faucet or water outlet is wide open and flowing.
[b] Wide Range due to variation in design and type of closet (toilet) flush valves.

*Source*: From U.S. Public Health Service, 1962, *Manual of Individual Water Supply Systems*.

**Table 7E.42 Summary of California and Federal Plumbing Fixture Requirements**

| Plumbing Device | California (Covers Sale and Installation) | Effective Date | Energy Policy Act of 1992 (Covers Only Manufacture) |
|---|---|---|---|
| Showerheads | 2.5 gpm | CA 3/20/92 | |
| | | US 1/1/94 | 2.5 gpm[c] |
| Lavatory Faucets[a] | 2.75 gpm | CA 12/22/78 | |
| | 2.2 gpm | CA 3/20/92 | |
| | | US 1/1/94 | 2.5 gpm[c] |
| Sink Faucets[a] | 2.2 gpm | CA 3/20/92 | |
| | | US 1/1/94 | 2.5 gpm[c] |
| Metering (self-closing) Faucets[b] (public restrooms) | Hot water maximum flow rates range from 0.25 to 0.75 gal/cycle and/or from 0.5 gpm to 2.5 gpm, depending on controls and hot water system | CA 7/1/92<br>US 1/1/94 | 0.25 gal/cycle (maximum water delivery per cycle)[c] |
| Tub Spout Diverter[a] | 0.1 (new), to 0.3 gpm (after 15,000 cycles of diverting) | CA 3/20/92 | (does not appear to be included in EPA) |
| Toilets (residential) | 1.6 gpf | CA 1/1/92 (new construction) | |
| | | CA 1/1/94 (all toilets for sale or installation) | |
| | | US 1/1/94 (non-commercial) | 1.6 gpf |
| Flushometer valves[a] | 1.6 gpf | CA 1/1/92 (new construction) | |
| | | CA 1/1/94 (all toilets) | |
| | | US 1/1/94 (commercial) | 3.5 gpf |
| | | US 1/1/97 (commercial) | 1.6 gpf |
| Toilets (Commercial)[a] | 1.6 gpf | CA 1/1/94 (all toilets for sale or installation) | |
| | | US 1/1/97 | 1.6 gpf |
| Urinals | 1.0 gpf | CA 1/1/92 (new) | |
| | | CA 1/1/94 (all) | |
| | | US 1/1/94 | 1.0 gpf |

[a] California requirements are pre-existing and more stringent than federal law; therefore California requirements prevail in California.
[b] Federal law is more stringent than California requirements.
[c] Measured at a flowing water pressure of 80 pounds/sq.in.

*Source*: From California Department of Water Resources, 1998, "Urban, Agricultural and Environmental Water Use," Californaia Water Plan Update Bulletin-160-98, California Dept. of Water Resources, Sacremento, CA, November 1998, www.water.ca.gov.

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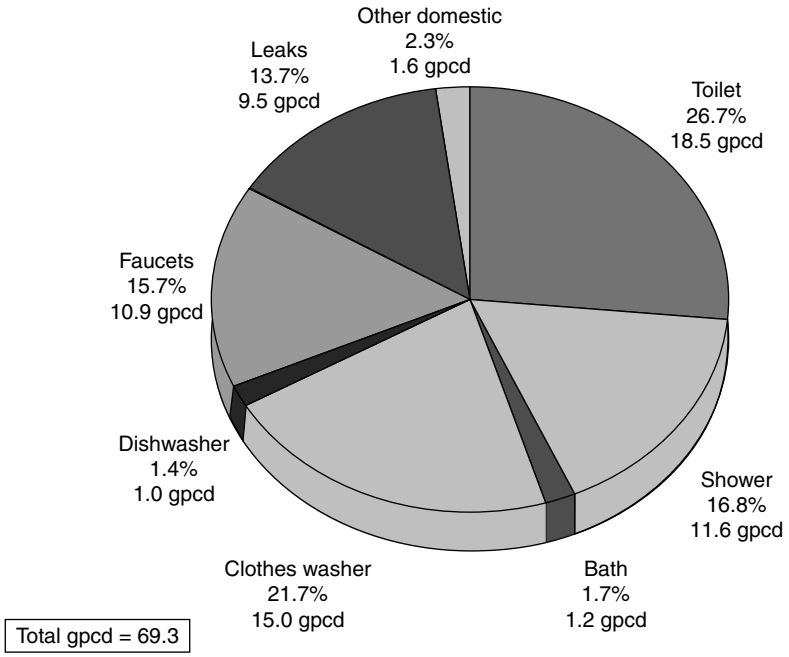


**Figure 7E.14** From United States Environmental Protection Agency, 2002. Onsite Wastewater Treatment Systems Manual, EPA/625-R-00/008, February 2002. Original Soure: Mayer, P.W., DeOreo, W.B. et al., 1999. *Residential End Uses of Water*, American Water Works Association Research Foundation, Denver, Colorado.

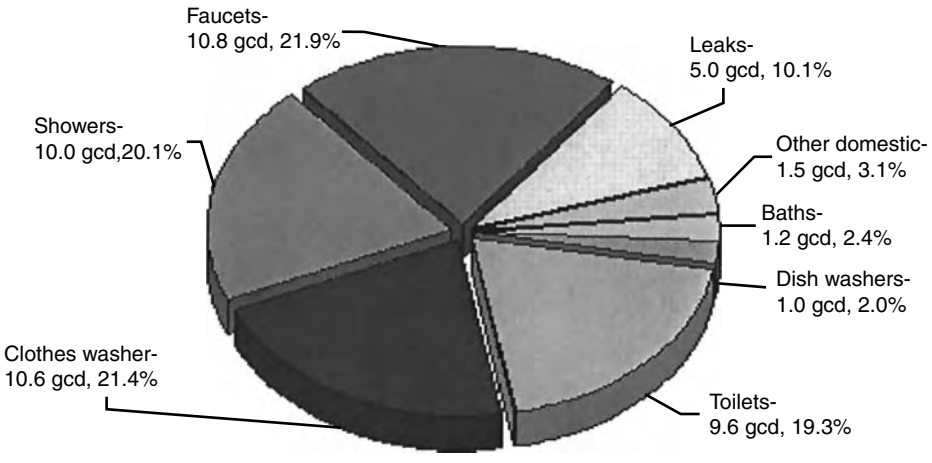


**Figure 7E.15** Typical single family home water use—with conservation. (Reprinted from Waterwiser www.waterwiser.org, by permission. Copyright © 1999, American Water Works Association.)

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**Table 7E.43 Indoor Residential Water Use by Fixture or Appliance**

| Fixture/Use | Gal/Use: Average Range | Uses/Person/Day: Average Range | Gal/Person/Day: Average Range[a] | % Total: Average Range |
|---|---|---|---|---|
| Toilet | 3.5 | 5.05 | 18.5 | 26.7 |
| | 2.9–3.9 | 4.5–5.6 | 15.7–22.9 | 22.6–30.6 |
| Shower | 17.2[b] | 0.75[b] | 11.6 | 16.8 |
| | 14.9–18.6 | 0.6–0.9 | 8.3–15.1 | 11.8–20.2 |
| Bath | See shower | See shower | 1.2 | 1.7 |
| | | | 0.5–1.9 | 0.9–2.7 |
| Clothes washer | 40.5 | 0.37 | 15.0 | 21.7 |
| | — | 0.30–0.42 | 12.0–17.1 | 17.8–28.0 |
| Dishwasher | 10.0 | 0.10 | 1.0 | 1.4 |
| | 9.3–10.6 | 0.06–0.13 | 0.6–1.4 | 0.9–2.2 |
| Faucets | 1.4[c] | 8.1[d] | 10.9 | 15.7 |
| | — | 6.7–9.4 | 8.7–12.3 | 12.4–18.5 |
| Leaks | NA | NA | 9.5 | 13.7 |
| | | | 3.4–17.6 | 5.3–21.6 |
| Other domestic | NA | NA | 1.6 | 2.3 |
| | | | 0.0–6.0 | 0.0–8.5 |
| Total | NA | NA | 69.3 | 100 |
| | | | 57.1–83.5 | |

*Note:* Results from AWWARF REUWS at 1,188 homes in 12 metropolitan areas. Homes surveyed were served by public water supplies, which operate at higher pressure than private water sources. Leakage rates might be lower for homes on private water supplies. Results are averages over range. Range is the lowest to highest average for 12 metropolitan areas.

[a] Gal/person/day might not equal gal/use multiplied by uses/person/day because of differences in the number of data points used to calculate means.
[b] Includes shower and bath.
[c] Gallons per minute.
[d] Minutes of use per person per day.

*Source*: United States Environmental Protection Agency, 2002, Onsite Wastewater Treatment Systems Manual, EPA/625-R-00/008, February 2002.

*Original Source*: Adapted from Residential End Uses of Water, by permission. Copyright © 1999 American Water Works Association and AWWA Research Foundation, www.awwa.org.

**Table 7E.44 Household End Use of Water with and without Conservation**

| | Without Conservation | | With Conservation | | |
|---|---|---|---|---|---|
| Type of Use | Amount (gpcd) | Percent of Total (%) | Amount (gpcd) | Percent of Total (%) | Savings (%) |
| Toilets | 18.3 | 28.4 | 10.4 | 23.2 | 44 |
| Clothes washers | 14.9 | 23.1 | 10.5 | 23.4 | 30 |
| Showers | 12.2 | 18.8 | 10.0 | 22.4 | 18 |
| Faucets | 10.3 | 16.0 | 10.0 | 22.5 | 2 |
| Leaks | 6.6 | 10.2 | 1.5 | 3.4 | 77 |
| Baths | 1.2 | 1.9 | 1.2 | 2.7 | 0 |
| Dish washers | 1.1 | 1.6 | 1.1 | 2.4 | 0 |
| Total indoor water use | 64.6 | 100 | 44.7 | 100 | 31 |

*Note:* These data are provided for illustrative purposes only and may not be applicable to a given situation. To the extent practical, planners use system-specific assumptions and estimates. gpcd, gallons per capita per day.

*Source*: From USEPA, 1998 Water Conservation Plan Guidelines, August 6, 1998.

*Original Source*: From AWWA Waterwiser, "Household End Use of Water without and with Conservation," 1997 Residential Water Use Summary — Typical Single Family Home. With permission (waterwiser.org/wateruse/tables.htm.)

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**Table 7E.45 Potential Water Savings from Efficient Fixtures**

| Fixture[a] | Fixture Capacity[b] | Water Use (gpd) | | Water Savings (gpd) | |
|---|---|---|---|---|---|
| | | Per Capita | 2.7-Person Household | Per Capita | 2.7-Person Household |
| **Toilets[c]** | | | | | |
| Efficient | 1.5 gallons/flush | 6.0 | 16.2 | na | na |
| Low-flow | 3.5 gallons/flush | 14.0 | 37.8 | 8.0 | 21.6 |
| Conventional | 5.5 gallons/flush | 22.0 | 59.4 | 16.0 | 43.2 |
| Conventional | 7.0 gallons/flush | 28.0 | 75.6 | 22.0 | 59.4 |
| **Showerheads[d]** | | | | | |
| Efficient | 2.5 [1.71 gal/min | 8.2 | 22.1 | na | na |
| Low-flow | 3.0 to 5.0 f2.61 gal/min | 12.5 | 33.8 | 4.3 | 11.7 |
| Conventional | 5.0 to 8.0 [3.4] gal/min | 16.3 | 44.0 | 8.1 | 22.0 |
| **Faucets[e]** | | | | | |
| Efficient | 2.5 [1.7] gal/min | 6.8 | 18.4 | na | na |
| Low-flow | 3.0 [2.0] gal/min | 8.0 | 21.6 | 1.2 | 3.2 |
| Conventional | 3.0 to 7.0 [3.3] gal/min | 13.2 | 36.6 | 6.4 | 17.2 |
| **Toilets, Showerheads, and Faucets Combined** | | | | | |
| Efficient | na | 21.0 | 56.7 | na | na |
| Low-flow | na | 34.5 | 93.2 | 13.4 | 36.4 |
| Conventional | na | 54.5 | 147.2 | 33.5 | 90.4 |

*Note:* na = not applicable

[a] Efficient = post-1994
Low-flow = post-1980
Conventional = pre-1980

[b] For showerheads and faucets: maximum rated fixture capacity (measured fixture capacity). Measured fixture capacity equals about two-thirds the maximum.

[c] Assumes four flushes per person per day; does not include losses through leakage.

[d] Assumes 4.8 shower-use-minutes per person per day.

[e] Assumes 4.0 faucet-use-minutes per person per day.

*Source*: From United States Environmental Protection Agency, 1998, Water Conservation Plan Guidelines, August 6, 1998, www.epa.gov.

*Original Source*: From Amy Vickers, "Water Use Efficienty Standards for Plumbing Fixtures: Benefits of National Legislation," *American Water Works Association Journal*. Vol. 82 (May 1990): 53.

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**Table 7E.46 Various Water Requirements in Developing Countries**

| Category | Typical Water Use |
|---|---|
| Schools | |
| Day schools | 15–30 L/day per pupil |
| Boarding schools | 90–140 L/day per pupil |
| Hospitals (with laundry facilities) | 220–300 L/day per bed |
| Hostels | 80–120 L/day per resident |
| Restaurants | 65–90 L/day per seat |
| Cinema houses, concert halls | 10–15 L/day per seat |
| Offices | 25–40 L/day per person |
| Railway and bus stations | 15–20 L/day per user |
| Livestock | |
| Cattle | 25–35 L/day per head |
| Horses and mules | 20–25 L/day per head |
| Sheep | 15–25 L/day per head |
| Pigs | 10–15 L/day per head |
| Poultry | |
| Chicken | 15–25 L/day per 100 |

*Source*: From Vigneswaran, S., 1995, *Water Treatment Processes: Simple Options*, CRC Press, Inc., Boca Raton.

*Original Source*: IRC, 1981.

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**Table 7E.47 Water Requirements for Various Types of Establishments in the United States**

| Types of Establishments | Gal/day |
|---|---|
| Airports (per passenger) | 3–5 |
| Apartments, multiple family (per resident) | 60 |
| Bath houses (per bather) | 10 |
| Camps: Construction, semipermanant (per worker) | 50 |
| Day with no meals served (per camper) | 15 |
| Luxury (per camper) | 100–150 |
| Resorts, day and night, with limited plumbing (per camper) | 50 |
| Tourist with central bath and toilet facilities (per person) | 35 |
| Cottages with seasonal occupancy (per resident) | 50 |
| Courts, tourist with individual bath units (per person) | 50 |
| Clubs: Country (per resident member) | 100 |
| Country (per nonresident member) | 25 |
| Dwelling: Boardinghouse (per boarder) | 50 |
| Luxury (per person) | 100–150 |
| Multiple-family apartments (per resident) | 40 |
| Rooming houses (per resident) | 60 |
| Single family (per resident) | 50–75 |
| Estates (per resident) | 100–150 |
| Factories (gallons per shift) | 15–30 |
| Highway rest area (per person) | 5 |
| Hotels with private baths (2 persons per room) | 60 |
| Hotels without private baths (per person) | 50 |
| Institutions other than hospitals (per person) | 75–125 |
| Hospitals (per bed) | 250–400 |
| Laundaries, self-serviced (gallons per washing, i.e., per customer) | 50 |
| Motels with bath, toilet, and kitchen facilities (per bed space) | 50 |
| With bed and toilet (per bed space) | 40 |
| Parks: Overnight with flush toilets (per camper) | 25 |
| Trailers with individual bath units, no sewer connections (per trailer) | 25 |
| Trailers with individual baths, connected to sewer (per person) | 50 |
| Picnic: With bathhouses, showers, and flush toilets (per picnicker) | 20 |
| With toilet facilities only (gallons per picnicker) | 10 |
| Resturants with toilets facilities (per patron) | 7–10 |
| Without toilet facilities (per patron) | 21/2–3 |
| With bars and cocktail lounge (additional quantity per patron) | 2 |
| Schools: Boarding (per pupil) | 75–100 |
| Day with cafeteria, gymnasiums, and showers (per pupil) | 25 |
| Day with cafeteria but no gymnasium or showers (per pupil) | 20 |
| Day without cafeteria, gymnasiums, or showers (per pupil) | 15 |
| Service stations (per vehicle) | 10 |
| Stores (per toilet room) | 400 |
| Swimming pools (per swimmer) | 10 |
| Theaters (per seat) | 5 |
| Workers: Construction (per person per shift) | 50 |
| Day (school or offices per person per shift) | 15 |

*Source*: From USEPA, 1991, Manual of Individual and Non-Public Water Supply-Systems (EPA 570991004).

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## SECTION 7F BOTTLED WATER

**Table 7F.48 Consumption of Bottled Water in the United States Ranked by Leading States, 1994–1999**

| | | Millions of Gallons | | | | | |
|---|---|---|---|---|---|---|---|
| **State** | **1999 Rank** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** |
| California | 1 | 882.2 | 928.1 | 1,003.70 | 1,038.30 | 1,048.90 | 1,130.70 |
| Texas | 2 | 290.2 | 326.3 | 362.2 | 400.2 | 451.9 | 519.2 |
| Florida | 3 | 179.9 | 202.7 | 231.1 | 256.8 | 298.5 | 339.4 |
| New York | 4 | 179.9 | 193.2 | 210.4 | 237.9 | 269.5 | 303.2 |
| Arizona | 5 | 107.4 | 117.2 | 131.1 | 143.5 | 153.4 | 176.1 |
| Massachusetts | 6 | 95.8 | 104.5 | 110.4 | 124.6 | 141 | 158.9 |
| Illinois | 7 | 110.3 | 117.2 | 124.2 | 128.4 | 136.8 | 156.8 |
| Pennsylvania | 8 | 87.1 | 95 | 103.5 | 113.3 | 124.8 | 141 |
| Louisiana | 9 | 84.2 | 95 | 103.5 | 113.3 | 120.2 | 136.5 |
| Maryland/DC | 10 | 81.3 | 91.9 | 96.6 | 101.9 | 111.9 | 125.4 |
| **Total Top 10** | | **2,098.10** | **2,271.10** | **2,476.60** | **2,658.20** | **2,857.00** | **3,187.20** |
| New Jersey | 11 | 66.7 | 72.9 | 79.3 | 86.8 | 99.5 | 111.1 |
| Ohio | 12 | 58 | 63.4 | 69 | 71.7 | 78.8 | 88.9 |
| Connecticut | 13 | 40.6 | 44.3 | 48.3 | 52.9 | 62.2 | 70.5 |
| Michigan | 14 | 34.8 | 38 | 41.4 | 45.3 | 49.8 | 57.1 |
| Colorado | 15 | 20.3 | 25.3 | 24.1 | 26.4 | 33.2 | 40.1 |
| **Total Top 15** | | **2,318.60** | **2,515.00** | **2,738.70** | **2,941.30** | **3,180.40** | **3,554.90** |
| All Others | | 583.3 | 652.5 | 710.6 | 834.5 | 965.6 | 1,091.20 |
| **Total U.S.** | | **2,901.90** | **3,167.50** | **3,449.30** | **3,775.80** | **4,146.00** | **4,646.10** |

*Note:* (r) Revised.

*Source*: From International Bottled Water Association, www.bottledwater.org.

*Original Source*: From Beverage Marketing Corp., www.beveragemarketing.com. Reprinted with permission.

**Table 7F.49 Per Capita Consumption of Bottled Water in the United States by Region, 1994–1999**

| | Gallons Per Person | | | | | |
|---|---|---|---|---|---|---|
| **Region** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** |
| Pacific | 23.5 | 23.5 | 25.3 | 25.9 | 27.4 | 29.2 |
| Southwest | 17.1 | 18.9 | 20.9 | 22.8 | 24.7 | 27.7 |
| Northeast | 12.4 | 13.3 | 14.1 | 16.1 | 18.4 | 20.6 |
| South | 6.7 | 7.6 | 8.5 | 9.4 | 10.5 | 11.8 |
| West | 5.9 | 6.8 | 7.7 | 8 | 8 | 9.6 |
| West Central | 4.8 | 5.2 | 5.8 | 6.1 | 6.7 | 7.7 |
| East Central | 5 | 5.3 | 5.6 | 5.8 | 6.5 | 7.4 |
| **Total** | **11.3** | **12** | **13** | **14** | **15.3** | **17** |

*Note:* (r) Revised.

*Source*: From International Bottled Water Association, www.bottledwater.org. copyright 1999–2004 IBWA.

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**Table 7F.50 Bottled Water Market Volume, Growth, and Consumption in the United States, 1976–1999**

| Year | Millions of Gallons | Volume Change (%) | Gallons Per Capita | Annual Change (%) |
|---|---|---|---|---|
| 1976 | 354.3 | — | 1.6 | — |
| 1977 | 388.6 | 9.70 | 1.8 | — |
| 1978 | 468.1 | 20.50 | 2.1 | — |
| 1979 | 547.2 | 16.90 | 2.4 | — |
| 1980 | 605 | 10.60 | 2.7 | — |
| 1981 | 691.1 | 14.20 | 3 | — |
| 1982 | 782.6 | 13.20 | 3.4 | — |
| 1983 | 910.1 | 16.30 | 3.9 | — |
| 1984 | 1,058.50 | 16.30 | 4.5 | — |
| 1985 | 1,214.20 | 14.70 | 5.1 | — |
| 1986 | 1,365.70 | 12.50 | 5.7 | — |
| 1987 | 1,554.00 | 13.80 | 6.4 | — |
| 1988 | 1,777.20 | 14.40 | 7.2 | — |
| 1989 | 2,029.40 | 14.20 | 8.2 | — |
| 1990 | 2,237.60 | 10.30 | 9 | 9.30 |
| 1991 | 2,286.50 | 2.20 | 9.1 | 1.30 |
| 1992 | 2,422.00 | 5.90 | 9.5 | 5.10 |
| 1993 | 2,623.90 | 8.30 | 10.3 | 7.50 |
| 1994 | 2,901.90 | 10.60 | 11.3 | 9.70 |
| 1995 | 3,167.50 | 9.20 | 12 | 6.80 |
| 1996 | 3,449.30 | 8.90 | 13 | 8.00 |
| 1997 | 3,775.80 | 9.50 | 14 | 8.30 |
| 1998 | 4,146.00 | 9.80 | 15.3 | 9.20 |
| 1999 | 4,646.10 | 12.10 | 17 | 11.10 |

*Note:* (r) Revised.

*Source*: From International Bottled Water Association, www.bottledwater.org. Copyright 2002 International Bottled Water Association.

*Original Source*: From Beverage Marketing Corp., U.S. Bureau of Census, www.beveragemarketing.com. Reprinted with permission.

**Table 7F.51 Consumption of Bottled Water in the United States by Type of Water, 1993–2003(P)**

| | Nonsparkling | | Sparkling | | Imports | | Total | |
|---|---|---|---|---|---|---|---|---|
| Year | Volume[a] | Change (%) | Volume[a] | Change (%) | Volume[a] | Change (%) | Volume[a] | Change (%) |
| 1993 | 2,422.20 | 8.70 | 174.7 | 1.40 | 92.5 | 7.20 | 2,689.40 | 8.20 |
| 1994 | 2,687.60 | 11.00 | 174.8 | 0.10 | 104 | 12.40 | 2,966.40 | 10.30 |
| 1995 | 2,965.60 | 10.30 | 164.2 | −6.10 | 97.1 | −6.60 | 3,226.90 | 8.80 |
| 1996 | 3,224.30 | 8.70 | 159 | −3.20 | 111.8 | 15.10 | 3,495.10 | 8.30 |
| 1997 | 3,491.40 | 8.30 | 153.8 | −3.30 | 149.1 | 33.40 | 3,794.30 | 8.60 |
| 1998 | 3,823.80 | 9.50 | 146.1 | −5.00 | 160.8 | 7.80 | 4,130.70 | 8.90 |
| 1999 | 4,286.30 | 12.10 | 146 | −0.10 | 151.1 | −6.00 | 4,583.40 | 11.00 |
| 2000 | 4,622.40 | 7.80 | 144.2 | −1.20 | 137.8 | −8.80 | 4,904.40 | 7.00 |
| 2001 | 5,104.20 | 10.40 | 144 | −0.10 | 123.9 | −10.10 | 5,372.10 | 9.50 |
| 2002 | 5,677.50 | 11.20 | 149.5 | 3.80 | 123.7 | −0.20 | 5,950.70 | 10.80 |
| 2003(P) | 6,115.80 | 7.70 | 149.5 | 0.00 | 129.7 | 4.90 | 6,395.00 | 7.50 |

*Note:* (P) Preliminary.

[a] Millions of gallons.

*Source*: From International Bottled Water Association, www.bottledwater.org.

*Original Source*: From Beverage Marketing Corp., www.beveragemarketing.com. Reprinted with permission.

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**Table 7F.52 Bottled Water Volume Producer Revenues and Per Capita Consumption in the United States, 1993–2003(P)**

| Year | Millions of Gallons | Annual Change (%) | Millions of Dollars | Annual Change (%) | Gallons Per Capita | Annual Change (%) |
|---|---|---|---|---|---|---|
| 1993 | 2,689.40 | 8.20 | $2,876.70 | 8.20 | 10.5 | — |
| 1994 | 2,966.40 | 10.30 | $3,164.30 | 10.00 | 11.5 | 9.40 |
| 1995 | 3,226.90 | 8.80 | $3,521.90 | 11.30 | 12.2 | 6.40 |
| 1996 | 3,495.10 | 8.30 | $3,835.40 | 8.90 | 13.1 | 7.40 |
| 1997 | 3,794.30 | 8.60 | $4,222.70 | 10.10 | 14.1 | 7.40 |
| 1998 | 4,130.70 | 8.90 | $4,666.10 | 10.50 | 15.3 | 8.30 |
| 1999 | 4,583.40 | 11.00 | $5,314.70 | 13.90 | 16.8 | 10.00 |
| 2000 | 4,904.40 | 7.00 | $5,809.00 | 9.30 | 17.8 | 6.00 |
| 2001 | 5,372.10 | 9.50 | $6,880.00 | 18.40 | 19.3 | 8.50 |
| 2002 | 5,950.70 | 10.80 | $7,725.00 | 12.30 | 21.2 | 9.80 |
| 2003(P) | 6,395.00 | 7.50 | $8,277.20 | 7.10 | 22.6 | 6.30 |

*Note:* (P) Preliminary.

*Source*: From International Bottled Water Association, www.bottledwater.org.

*Original Source*: From Beverage Marketing Corp., www.beveragemarketing.com. Reprinted with permission.

**Table 7F.53 Global Bottled Water Market, Leading Countries' Consumption and Compound Annual Growth Rates 1998–2003(P)**

| 2003 Rank | Countries | Millions of Gallons | | CAGR 1998/03(P) (%) |
|---|---|---|---|---|
| | | 1998 | 2003(P) | |
| 1 | United States | 4,130.70 | 6,395.00 | 9.10 |
| 2 | Mexico | 2,873.00 | 4,354.70 | 8.70 |
| 3 | Brazil | 1,251.80 | 2,840.10 | 17.80 |
| 4 | China | 934.6 | 2,805.80 | 24.60 |
| 5 | Italy | 2,038.70 | 2,791.00 | 6.50 |
| 6 | Germany | 2,169.10 | 2,727.20 | 4.70 |
| 7 | France | 1,733.20 | 2,351.40 | 6.30 |
| 8 | Indonesia | 722.2 | 1,963.30 | 22.10 |
| 9 | Thailand | 1,014.40 | 1,302.50 | 5.10 |
| 10 | Spain | 981.1 | 1,213.90 | 4.40 |
| | **Top 10 Subtotal** | **17,848.80** | **28,744.90** | **10.00** |
| | **All Others** | **5,340.70** | **9,278.40** | **11.70** |
| | **World Total** | **23,189.50** | **38,023.30** | **10.40** |

*Note:* (P) Preliminary. CAGR, Compound annual growth rate.

*Source*: From International Bottled Water Association, www.bottledwater.org.

*Original Source*: From Beverage Marketing Corp., www.beveragemarketing.com. Reprinted with permission.

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**Table 7F.54 Global Bottled Water Market, Per Capita Consumption by Leading Countries 1998–2003(P)**

| 2003 Rank | Countries | Gallons Per Capita | |
|---|---|---|---|
| | | 1998 | 2003(P) |
| 1 | Italy | 35.9 | 48.1 |
| 2 | Mexico | 29.2 | 41.5 |
| 3 | France | 29.5 | 39.1 |
| 4 | United Arab Emirates | 28.1 | 38.1 |
| 5 | Belgium-Luxembourg | 30.7 | 35.1 |
| 6 | Germany | 26.4 | 33.1 |
| 7 | Spain | 25.1 | 30.2 |
| 8 | Switzerland | 23.8 | 25.4 |
| 9 | Lebanon | 16.2 | 25.3 |
| 10 | Saudi Arabia | 18.9 | 23.3 |
| 11 | Cyprus | 17.2 | 22.8 |
| 12 | Austria | 19.8 | 22.7 |
| 13 | United States | 15.3 | 22.6 |
| 14 | Czech Republic | 15.4 | 22.2 |
| 15 | Portugal | 17.2 | 20.6 |
| | **Global Average** | **3.9** | **6** |

*Note:* (P) Preliminary.

*Source*: From International Bottled Water Association, www.bottledwater.org.

*Original Source*: From Beverage Marketing Corp., www.beveragemarketing.com. Reprinted with permission.

**Table 7F.55 Bottled Water Consumption by Country in North America and South America, 1997–2002**

| Region | Country | Year (1000 $m^3$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1997 | 1998 | 1999 | 2000 | 2001 | 2002(P) |
| North America | United States | 14,361.6 | 15,634.8 | 17,348.2 | 18,563.2 | 20,534.8 | 22,893.4 |
| North America | Mexico | 10,484.1 | 10,882.5 | 11,579.0 | 12,424.3 | 13,244.3 | 14,767.4 |
| South America | Brazil | 3,931.7 | 4,741.7 | 5,658.3 | 6,816.6 | 8,166.3 | 9,628.1 |
| North America | Canada | 541.2 | 650.5 | 754.6 | 847.9 | 938.6 | 1,027.3 |
| South America | Argentina | 568.9 | 575.2 | 594.2 | 598.9 | 600.1 | 603.1 |
| South America | Colombia | 562.8 | 579.0 | 560.0 | 549.0 | 548.4 | 556.7 |
| South America | Venezuela, Republic of Bolivia | 201.6 | 220.9 | 230.3 | 247.9 | 263.3 | 289.6 |
| South America | Peru | 75.6 | 80.9 | 89.1 | 103.5 | 118.0 | 132.1 |
| South America | Chile | 66.8 | 80.6 | 88.6 | 95.8 | 103.8 | 113.0 |
| South America | Paraguay | 46.2 | 50.2 | 53.5 | 56.9 | 60.6 | 64.5 |
| South America | Uruguay | 17.3 | 18.7 | 20.5 | 21.9 | 23.2 | 24.5 |
| South America | Nicaragua | 13.2 | 14.5 | 15.7 | 17.2 | 19.0 | 20.4 |
| North America | Cuba | 10.7 | 12.0 | 13.2 | 14.9 | 16.8 | 18.7 |

*Note:* (P) Preliminary. Not all of the water put into a water system reaches customers or is paid for by water users. This water is typically called "unaccounted-for water," but it is measured and define in a variety of ways. Many in the water industry consider all water that is not metered and billed to customer accounts to be unaccounted-for water. High rates of unaccounted-for water result in financial losses and poor performance of the water agency.

*Source*: From *World's Water 2004–2005*, by Peter H. Gleick. Copyright © 2004 Island Press. Reproduced by permission of Island Press, Washington, DC.

*Original Source*: Data were provided by the Beverage Marketing Corporation (BMC) to the author in 2003 and were used with permission, www.worldwater.org.

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**Table 7F.56 Bottled Water Consumption by Country in Europe, 1997–2002**

| | | Year (1000 $m^3$) | | | | | |
|---|---|---|---|---|---|---|---|
| **Region** | **Country** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002(P)** |
| Europe | Italy | 7,558.5 | 7,722.5 | 8,924.6 | 9,221.5 | 9,479.9 | 9,690.1 |
| Europe | Germany | 8,207.2 | 8,216.2 | 8,602.9 | 8,693.7 | 8,850.2 | 8,983.0 |
| Europe | France | 6,053.1 | 6,565.2 | 6,947.3 | 7,462.2 | 7,820.4 | 8,430.4 |
| Europe | Spain | 3,542.6 | 3,716.1 | 3,879.7 | 4,003.8 | 4,133.9 | 4,294.3 |
| Europe | Turkey | 931.7 | 1,185.4 | 1,368.8 | 1,667.2 | 1,870.6 | 2,007.2 |
| Europe | Poland | 828.6 | 943.7 | 1,106.3 | 1,279.0 | 1,460.6 | 1,722.7 |
| Europe | Russian Federation | 524.5 | 610.6 | 790.7 | 967.8 | 1,162.4 | 1,406.4 |
| Europe | United Kingdom | 724.1 | 812.8 | 967.5 | 1,071.6 | 1,195.9 | 1,339.4 |
| Europe | Belgium-Luxembourg[a] | 1,213.0 | 1,233.6 | 1,299.0 | 1,262.4 | 1,264.9 | 1,329.7 |
| Europe | Czech Republic | 555.1 | 598.1 | 639.0 | 701.5 | 763.2 | 820.5 |
| Europe | Portugal | 647.1 | 645.8 | 705.9 | 719.3 | 735.8 | 761.1 |
| Europe | Romania | 406.2 | 447.6 | 504.4 | 553.9 | 620.9 | 698.5 |
| Europe | Switzerland | 622.7 | 653.4 | 651.8 | 653.6 | 656.9 | 668.1 |
| Europe | Austria | 569.3 | 610.0 | 605.1 | 609.8 | 631.5 | 645.4 |
| Europe | Hungary | 202.1 | 245.0 | 300.4 | 397.6 | 467.2 | 514.8 |
| Europe | Greece | 392.8 | 410.1 | 436.3 | 450.3 | 463.3 | 483.3 |
| Europe | Ukraine | 241.8 | 274.2 | 315.6 | 362.0 | 420.6 | 479.1 |
| Europe | Netherlands | 248.8 | 240.7 | 273.3 | 286.1 | 296.1 | 316.8 |
| Europe | Croatia | 135.8 | 157.7 | 176.9 | 199.9 | 223.7 | 247.2 |
| Europe | Slovakia | 158.9 | 161.8 | 168.8 | 170.2 | 173.5 | 178.2 |
| Europe | Bulgaria | 53.9 | 67.2 | 88.1 | 112.2 | 142.1 | 177.8 |
| Europe | Sweden | 126.8 | 127.1 | 143.7 | 150.8 | 158.1 | 164.2 |
| Europe | Slovenia | 67.9 | 80.9 | 93.2 | 108.5 | 124.3 | 137.9 |
| Europe | Ireland | 50.5 | 61.5 | 75.1 | 83.5 | 92.4 | 99.4 |
| Europe | Norway | 67.3 | 76.3 | 76.9 | 77.2 | 80.5 | 82.8 |
| Europe | Denmark | 71.6 | 72.0 | 71.8 | 72.0 | 72.3 | 74.1 |
| Europe | Finland | 45.2 | 51.0 | 58.3 | 62.0 | 65.6 | 68.4 |
| Europe | Cyprus | 48.4 | 48.7 | 50.8 | 54.9 | 58.3 | 62.3 |
| Europe | Lithuania | 15.0 | 17.6 | 20.4 | 23.8 | 28.6 | 34.6 |
| Europe | Estonia | 15.2 | 18.5 | 20.9 | 23.9 | 26.8 | 30.2 |
| Europe | Latvia | 2.4 | 3.0 | 3.7 | 4.6 | 5.6 | 6.9 |

*Note:* (P) Preliminary. Not all of the water put into a water system reaches customers or is paid for by water users. This water is typically called "unaccounted-for water," but it is measured and define in a variety of ways. Many in the water industry consider all water that is not metered and billed to customer accounts to be unaccounted-for water. High rates of unaccounted-for water result in financial losses and poor performance of the water agency.

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**Table 7F.57 Bottled Water Consumption by Country in Asia, 1997–2002**

| Region | Country | Year (1000 $m^3$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1997 | 1998 | 1999 | 2000 | 2001 | 2002(P) |
| Asia | China | 2,750.0 | 3,540.1 | 4,610.0 | 5,993.0 | 7,605.1 | 9,886.7 |
| Asia | Indonesia | 2,261.5 | 2,735.7 | 3,435.9 | 4,300.3 | 5,121.6 | 6,145.9 |
| Asia | Thailand | 3,567.1 | 3,842.4 | 4,063.7 | 4,286.2 | 4,539.0 | 4,837.0 |
| Asia | India | 1,047.0 | 1,364.2 | 1,681.8 | 2,149.7 | 2,667.8 | 3,361.4 |
| Asia | Japan | 646.6 | 789.5 | 922.7 | 1,149.0 | 1,230.6 | 1,461.3 |
| Asia | Korea, Republic of | 892.5 | 1,008.8 | 1,110.3 | 1,191.5 | 1,273.7 | 1,359.0 |
| Asia | Philippines | 727.8 | 837.2 | 999.1 | 1,119.0 | 1,213.0 | 1,291.8 |
| Asia | Pakistan | 69.3 | 108.2 | 157.6 | 242.3 | 360.3 | 547.7 |
| Asia | China, Hong Kong SAR | 191.0 | 222.1 | 245.4 | 271.1 | 298.2 | 331.1 |
| Asia | Malaysia | 137.5 | 157.9 | 179.6 | 199.1 | 217.9 | 236.8 |
| Asia | Viet Nam | 114.9 | 139.5 | 159.3 | 179.6 | 199.9 | 219.4 |
| Asia | Singapore | 57.2 | 63.5 | 69.7 | 75.6 | 81.8 | 88.2 |
| Asia | Brunei Darussalam | 9.9 | 11.1 | 12.2 | 13.6 | 14.9 | 16.3 |
| Asia | Bangladesh[a] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Asia | Fiji Islands[b] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*Note:* (P) Preliminary. Not all of the water put into a water system reaches customers or is paid for by water users. This water is typically called "unaccounted-for water," but it is measured and define in a variety of ways. Many in the water industry consider all water that is not metered and billed to customer accounts to be unaccounted-for water. High rates of unaccounted-for water result in financial losses and poor performance of the water agency.

[a] Commercial bottled water essentially does not exist in Bangladesh.
[b] Consumption in Fiji is virtually nil, immeasurable in terms of thousands of cubic meters.

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*Original Source*: Data were provided by the Beverage Marketing Corporation (BMC) to the author in 2003 and were used with permission, www.worldwater.org.

**Table 7F.58 Bottled Water Consumption by Country in Africa/Mideast/Oceania, 1997–2002**

| Region | Country | Year (1000 $m^3$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1997 | 1998 | 1999 | 2000 | 2001 | 2002(P) |
| Mideast | Saudi Arabia | 1,297.7 | 1,490.1 | 1,610.0 | 1,769.9 | 1,938.0 | 2,116.3 |
| Oceania | Australia | 304.2 | 354.9 | 389.6 | 443.3 | 488.0 | 566.5 |
| Mideast | Lebanon | 180.7 | 214.8 | 239.8 | 275.3 | 309.7 | 346.2 |
| Mideast | United Arab Emirates | 229.9 | 245.3 | 256.1 | 269.9 | 285.2 | 326.4 |
| Mideast | Israel | 100.2 | 111.7 | 132.6 | 170.3 | 224.9 | 283.4 |
| Mideast | Egypt | 133.7 | 145.7 | 167.7 | 188.4 | 208.6 | 234.6 |
| Mideast | Kuwait | 68.2 | 77.5 | 95.6 | 112.5 | 128.4 | 144.0 |
| Africa | South Africa | 30.9 | 41.1 | 57.9 | 68.8 | 81.2 | 96.3 |
| Mideast | Qatar | 33.0 | 38.1 | 42.8 | 47.2 | 51.6 | 56.2 |
| Mideast | Jordan | 27.9 | 31.1 | 35.7 | 40.3 | 44.4 | 48.5 |
| Mideast | Bahrain | 26.7 | 28.4 | 31.4 | 34.1 | 36.7 | 39.5 |
| Mideast | Oman | 16.1 | 18.2 | 20.3 | 23.2 | 26.2 | 29.5 |
| Oceania | Pacific Islands[a] | 10.2 | 10.9 | 12.0 | 12.9 | 14.0 | 15.1 |
| All Others | | 507.9 | 595.3 | 737.1 | 891.0 | 1,032.7 | 1,233.6 |

*Note:* (P) Preliminary. Not all of the water put into a water system reaches customers or is paid for by water users. This water is typically called "unaccounted-for water," but it is measured and define in a variety of ways. Many in the water industry consider all water that is not metered and billed to customer accounts to be unaccounted-for water. High rates of unaccounted-for water result in financial losses and poor performance of the water agency.

[a] Includes the Caroline Islands (Micronesia excluding Palau), the Marshall Islands, and the Northern Marianas (excluding Guam).

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**Table 7F.59 Global Bottled Water Production Volume and Value and Per Capita Consumption, 2000–2003**

| Region | Production Volume (mil L) | | | | Production Value (mil USD) | | | | Per Capita Consumption (L) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2002 | 2001 | 2000 | 2003 | 2002 | 2001 | 2000 | 2003 | 2002 | 2001 | 2000 |
| Africa & Middle East | 12,400 | 11,220 | 9,200 | 8,720 | 2,110 | 1,825 | 1,450 | 1,250 | 11 | 10 | 9 | 9 |
| Asia | 33,465 | 30,100 | 24,030 | 19,990 | 7,395 | 6,490 | 4,500 | 3,650 | 10 | 9 | 7 | 6 |
| Australia | 695 | 650 | 850 | 740 | 440 | 340 | 400 | 350 | 35 | 33 | 37 | 33 |
| Canada | 1,490 | 1,310 | 920 | 820 | 650 | 525 | 350 | 310 | 47 | 41 | 29 | 26 |
| East Europe | 9,500 | 8,330 | 6,770 | 6,010 | 2,630 | 2,250 | 1,500 | 1,400 | 24 | 21 | 17 | 15 |
| Latin America | 27,050 | 26,060 | 26,950 | 25,150 | 3,970 | 3,800 | 5,050 | 5,809 | 51 | 50 | 53 | 50 |
| U.S.A.[a] | 24,463 | 23,803 | 24,414 | 22,020 | 8,277 | 7,724 | 14,500 | 13,600 | 90 | 85 | 74 | 67 |
| West Europe | 44,020 | 39,970 | 38,210 | 36,350 | 20,300 | 15,200 | 14,500 | 14,600 | 112 | 102 | 97 | 93 |
| **Total** | **153,083** | **141,443** | **131,344** | **119,800** | **45,772** | **38,154** | **34,227** | **30,819** | | | | |

[a] Beverage Marketing Corporation.

*Source*: From International Council of Bottled Water Associations, Bottled Water Statistics.

*Original Source*: From Zenith International and Beverage Marketing Corporation, www.icbwa.org. Reprinted with permission.

**Table 7F.60 Global Projected Bottled Water Sales**

| Country/Region | 1996 Sales (mil L) | Projected 2006 Sales (mil L) | Annual Percentage of Growth (%) |
|---|---|---|---|
| Australia | 500 | 1,000 | 11 |
| Africa | 500 | 800 | 4 |
| CIS | 600 | 1,500 | 13 |
| Asia | 1,000 | 5,000 | 12 |
| East Europe | 1,200 | 8,500 | 14 |
| Middle East | 1,500 | 3,000 | 3 |
| South America | 1,700 | 4,000 | 7 |
| Pacific Rim | 4,000 | 37,000 | 18 |
| Central America | 6,000 | 25,000 | 11 |
| North America | 13,000 | 25,000 | 4.5 |
| West Europe | 27,000 | 33,000 | 2.5 |
| **Total** | **57,000** | **143,800** | |

*Source*: From *World's Water 2002–2003*, by Peter H. Gleick. Copyright © 2002 Island Press. Reproduced by permission of Island Press, Washington, DC.

*Original Source*: Modified from soc.duke.edu/-s142tm16/World%20Markets.htm.

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## SECTION 7G INDUSTRIAL AND COMMERCIAL WATER USE — UNITED STATES

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**Table 7G.61 Industrial Self-Supplied Water Withdrawals in the United States, 2000**

| | Withdrawals (mill gal/day) | | | | | | | | | Withdrawals (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | By Source and Type | | | | | | Total | | | By Type | | |
| | Groundwater | | | Surface Water | | | | | | | | |
| State | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total |
| Alabama | 56 | 0 | 56 | 777 | 0 | 777 | 833 | 0 | 833 | 934 | 0 | 934 |
| Alaska | 4.32 | 0 | 4.32 | 3.8 | 3.86 | 7.66 | 8.12 | 3.86 | 12 | 9.1 | 4.33 | 13.4 |
| Arizona | 19.8 | 0 | 19.8 | 0 | 0 | 0 | 19.8 | 0 | 19.8 | 22.2 | 0 | 22.2 |
| Arkansas | 67 | 0.08 | 67.1 | 66.8 | 0 | 66.8 | 134 | 0.08 | 134 | 150 | 0.09 | 150 |
| California | 183 | 0 | 183 | 5.65 | 13.6 | 19.3 | 188 | 13.6 | 202 | 211 | 15.3 | 226 |
| Colorado | 23.6 | 0 | 23.6 | 96.4 | 0 | 96.4 | 120 | 0 | 120 | 135 | 0 | 135 |
| Connecticut | 4.13 | 0 | 4.13 | 6.61 | 0 | 6.61 | 10.7 | 0 | 10.7 | 12 | 0 | 12 |
| Delaware | 17 | 0 | 17 | 42.5 | 3.25 | 45.7 | 59.4 | 3.25 | 62.7 | 66.6 | 3.64 | 70.3 |
| District of Columbia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 216 | 0 | 216 | 74.7 | 1.18 | 75.9 | 291 | 1.18 | 292 | 326 | 1.32 | 328 |
| Georgia | 290 | 0 | 290 | 333 | 30 | 363 | 622 | 30 | 652 | 698 | 33.6 | 731 |
| Hawaii | 14.5 | 0.85 | 15.4 | 0 | 0 | 0 | 14.5 | 0.85 | 15.4 | 16.2 | 0.95 | 17.2 |
| Idaho | 35.8 | 0 | 35.8 | 19.7 | 0 | 19.7 | 55.5 | 0 | 55.5 | 62.2 | 0 | 62.2 |
| Illinois | 132 | 0 | 132 | 259 | 0 | 259 | 391 | 0 | 391 | 438 | 0 | 438 |
| Indiana | 99.7 | 0 | 99.7 | 2,300 | 0 | 2,300 | 2,400 | 0 | 2,400 | 2,690 | 0 | 2,690 |
| Iowa | 226 | 0 | 226 | 11.7 | 0 | 11.7 | 237 | 0 | 237 | 266 | 0 | 266 |
| Kansas | 46.6 | 0 | 46.6 | 6.74 | 0 | 6.74 | 53.3 | 0 | 53.3 | 59.8 | 0 | 59.8 |
| Kentucky | 95.2 | 0 | 95.2 | 222 | 0 | 222 | 317 | 0 | 317 | 356 | 0 | 356 |
| Louisiana | 285 | 0 | 285 | 2,400 | 0 | 2,400 | 2,680 | 0 | 2,680 | 3,010 | 0 | 3,010 |
| Maine | 9.9 | 0 | 9.9 | 237 | 0 | 237 | 247 | 0 | 247 | 277 | 0 | 277 |
| Maryland | 15.9 | 0 | 15.9 | 49.9 | 227 | 277 | 65.8 | 227 | 292 | 73.8 | 254 | 328 |
| Massachusetts | 10.7 | 0 | 10.7 | 26.2 | 0 | 26.2 | 36.8 | 0 | 36.8 | 41.3 | 0 | 41.3 |
| Michigan | 110 | 0 | 110 | 589 | 0 | 589 | 698 | 0 | 698 | 782 | 0 | 782 |
| Minnesota | 56.3 | 0 | 56.3 | 97.8 | 0 | 97.8 | 154 | 0 | 154 | 173 | 0 | 173 |
| Mississippi | 118 | 0 | 118 | 124 | 0 | 124 | 242 | 0 | 242 | 271 | 0 | 271 |
| Missouri | 29.2 | 0 | 29.2 | 33.5 | 0 | 33.5 | 62.7 | 0 | 62.7 | 70.3 | 0 | 70.3 |
| Montana | 31.9 | 0 | 31.9 | 29.3 | 0 | 29.3 | 61.3 | 0 | 61.3 | 68.7 | 0 | 68.7 |
| Nebraska | 35.5 | 0 | 35.5 | 2.6 | 0 | 2.6 | 38.1 | 0 | 38.1 | 42.7 | 0 | 42.7 |
| Nevada | 5.29 | 0 | 5.29 | 5 | 0 | 5 | 10.3 | 0 | 10.3 | 11.5 | 0 | 11.5 |
| New Hampshire | 6.95 | 0 | 6.95 | 37.9 | 0 | 37.9 | 44.9 | 0 | 44.9 | 50.3 | 0 | 50.3 |
| New Jersey | 65.3 | 0 | 65.3 | 66.2 | 0 | 66.2 | 132 | 0 | 132 | 147 | 0 | 147 |
| New Mexico | 8.8 | 0 | 8.8 | 1.67 | 0 | 1.67 | 10.5 | 0 | 10.5 | 11.7 | 0 | 11.7 |
| New York | 145 | 0 | 145 | 152 | 0 | 152 | 297 | 0 | 297 | 333 | 0 | 333 |
| North Carolina | 25.6 | 0 | 25.6 | 267 | 0 | 267 | 293 | 0 | 293 | 329 | 0 | 329 |
| North Dakota | 6.88 | 0 | 6.88 | 10.7 | 0 | 10.7 | 17.6 | 0 | 17.6 | 19.7 | 0 | 19.7 |
| Ohio | 162 | 0 | 162 | 645 | 0 | 645 | 807 | 0 | 807 | 905 | 0 | 905 |
| Oklahoma | 6.83 | 0 | 6.83 | 19.1 | 0 | 19.1 | 25.9 | 0 | 25.9 | 29.1 | 0 | 29.1 |
| Oregon | 12.1 | 0 | 12.1 | 183 | 0 | 183 | 195 | 0 | 195 | 218 | 0 | 218 |
| Pennsylvania | 155 | 0 | 155 | 1,030 | 0 | 1,030 | 1,190 | 0 | 1,190 | 1,330 | 0 | 1,330 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rhode Island | 2.19 | 0 | 2.19 | 2.09 | 0 | 2.09 | 4.28 | 0 | 4.28 | 4.8 | 0 | 4.8 |
| South Carolina | 50.9 | 0 | 50.9 | 514 | 0 | 514 | 565 | 0 | 565 | 633 | 0 | 633 |
| South Dakota | 3.16 | 0 | 3.16 | 1.96 | 0 | 1.96 | 5.12 | 0 | 5.12 | 5.74 | 0 | 5.74 |
| Tennessee | 56.3 | 0 | 56.3 | 785 | 0 | 785 | 842 | 0 | 842 | 944 | 0 | 944 |
| Texas | 244 | 0.5 | 244 | 1,200 | 906 | 2,110 | 1,450 | 907 | 2,350 | 1,620 | 1,020 | 2,640 |
| Utah | 34.3 | 5.08 | 39.4 | 8.38 | 0 | 8.38 | 42.7 | 5.08 | 47.8 | 47.8 | 5.69 | 53.5 |
| Vermont | 2.05 | 0 | 2.05 | 4.86 | 0 | 4.86 | 6.91 | 0 | 6.91 | 7.75 | 0 | 7.75 |
| Virginia | 104 | 0 | 104 | 365 | 53.3 | 419 | 470 | 53.3 | 523 | 526 | 59.7 | 586 |
| Washington | 138 | 0 | 138 | 439 | 39.9 | 479 | 577 | 39.9 | 617 | 647 | 44.7 | 692 |
| West Virginia | 9.7 | 0 | 9.7 | 958 | 0 | 958 | 968 | 0 | 968 | 1,090 | 0 | 1,090 |
| Wisconsin | 83 | 0 | 83 | 364 | 0 | 364 | 447 | 0 | 447 | 501 | 0 | 501 |
| Wyoming | 4.31 | 0 | 4.31 | 1.47 | 0 | 1.47 | 5.78 | 0 | 5.78 | 6.48 | 0 | 6.48 |
| Puerto Rico | 11.2 | 0 | 11.2 | 0 | 0 | 0 | 11.2 | 0 | 11.2 | 12.5 | 0 | 12.5 |
| U.S. Virgin Islands | 0.22 | 0 | 0.22 | 3.12 | 0 | 3.12 | 3.34 | 0 | 3.34 | 3.74 | 0 | 3.74 |
| Total | 3,570 | 6.51 | 3,580 | 14,900 | 1,280 | 16,200 | 18,500 | 1,280 | 19,700 | 20,700 | 1,440 | 22,100 |

*Note:* Figures may not sum to totals because of independent rounding.

*Source*: From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.



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**Table 7G.62 Self-Supplied Industrial Withdrawals by Source, 1950–1995**

| Year | Groundwater Fresh (%) | Groundwater Saline (%) | Groundwater Total (%) | Surface Water Fresh (%) | Surface Water Saline (%) | Surface Water Total (%) | Reclaimed Sewage (%) |
|---|---|---|---|---|---|---|---|
| 1950 | — | — | 7 | — | — | 93 | — |
| 1955 | 93 | 7 | 9 | 82 | 18 | 91 | 0.1 |
| 1960 | 94 | 6 | 17 | 85 | 15 | 83 | 0.2 |
| 1965 | 93 | 7 | 16 | 78 | 22 | 84 | 0.3 |
| 1970 | 88 | 12 | 18 | 83 | 17 | 82 | 0.3 |
| 1975 | 91 | 9 | 24 | 84 | 16 | 76 | 0.4 |
| 1980 | 92 | 8 | 25 | 87 | 13 | 75 | 0.4 |
| 1985 | 89 | 11 | 20 | 84 | 16 | 80 | 0.5 |
| 1990 | 83 | 17 | 26 | 83 | 17 | 74 | 0.3 |
| 1995 | 84 | 16 | 23 | 91 | 9 | 77 | 0.5 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.

**Table 7G.63 Self-Supplied Industrial Withdrawals and Manufacturing Employment, 1950–1995**

| Year | Self-Supplied Industrial Withdrawals (bgd) | Industrial Withdrawals Per Capita (gpcd) | Total Manufacturing Employment (1,000s) | Per-Employee Withdrawals (gped) | Employment in Primary Metal Industries (1,000s) |
|---|---|---|---|---|---|
| 1950 | 37.0 | 246 | 15,241 | 2,428 | 1,276 |
| 1955 | 39.0 | 238 | 16,882 | 2,310 | 1,321 |
| 1960 | 38.0 | 212 | 16,796 | 2,262 | 1,073 |
| 1965 | 46.0 | 237 | 18,062 | 2,547 | 1,243 |
| 1970 | 47.0 | 228 | 19,367 | 2,427 | 1,206 |
| 1975 | 45.0 | 208 | 18,323 | 2,456 | 1,115 |
| 1980 | 45.0 | 196 | 20,285 | 2,218 | 1,140 |
| 1985 | 30.5 | 126 | 19,248 | 1,585 | 788 |
| 1990 | 29.9 | 119 | 19,076 | 1,567 | 746 |
| 1995 | 29.1 | 109 | 18,469 | 1,576 | 713 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.

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**Table 7G.64 Commercial Freshwater Use in the United States, 1995**

| State | Self-Supplied Withdrawals | | | Public-Supply Deliveries | Total Use | |
|---|---|---|---|---|---|---|
| | Source | | Total | | Withdrawals and Deliveries | Consumptive Use |
| | Groundwater | Surface Water | | | | |
| Alabama | 4.9 | 0 | 4.9 | 122 | 127 | 28 |
| Alaska | 11 | 0.1 | 11 | 23 | 34 | 5.1 |
| Arizona | 21 | 0 | 21 | 135 | 155 | 78 |
| Arkansas | 0.4 | 100 | 100 | 58 | 158 | 12 |
| California | 77 | 309 | 385 | 994 | 1,380 | 259 |
| Colorado | 7.7 | 0.9 | 8.6 | 101 | 109 | 16 |
| Connecticut | 25 | 1.5 | 27 | 89 | 116 | 12 |
| Delaware | 2.8 | 0 | 2.8 | 20 | 22 | 2.2 |
| DC | 0 | 0 | 0 | 50 | 50 | 5.0 |
| Florida | 50 | 0.2 | 50 | 386 | 436 | 54 |
| Georgia | 33 | 13 | 46 | 168 | 215 | 39 |
| Hawaii | 45 | 0.4 | 46 | 47 | 92 | 43 |
| Idaho | 9.8 | 297 | 306 | 18 | 324 | 1.4 |
| Illinois | 16 | 88 | 104 | 440 | 544 | 44 |
| Indiana | 45 | 48 | 93 | 119 | 212 | 32 |
| Iowa | 18 | 25 | 43 | 65 | 108 | 14 |
| Kansas | 4.9 | 0.3 | 5.2 | 67 | 72 | 38 |
| Kentucky | 8.0 | 14 | 22 | 23 | 45 | 1.6 |
| Louisiana | 10 | 0.7 | 11 | 55 | 66 | 8.8 |
| Maine | 9.8 | 1.7 | 11 | 25 | 37 | 3.7 |
| Maryland | 19 | 14 | 33 | 85 | 118 | 11 |
| Massachusetts | 12 | 0 | 12 | 188 | 200 | 25 |
| Michigan | 16 | 25 | 41 | 253 | 294 | 31 |
| Minnesota | 46 | 20 | 66 | 103 | 169 | 18 |
| Mississippi | 18 | 0 | 18 | 33 | 51 | 8.6 |
| Missouri | 13 | 0.5 | 14 | 59 | 73 | 5.3 |
| Montana | 0 | 0 | 0 | 26 | 26 | 9.6 |
| Nebraska | 0.3 | 0 | 3 | 79 | 79 | 30 |
| Nevada | 7.1 | 14 | 21 | 116 | 137 | 24 |
| New Hampshire | 12 | 18 | 30 | 21 | 51 | 3.5 |
| New Jersey | 17 | 1.2 | 18 | 179 | 197 | 7.5 |
| New Mexico | 18 | 1.6 | 20 | 78 | 97 | 56 |
| New York | 136 | 65 | 200 | 409 | 609 | 61 |
| North Carolina | 7.3 | 0.3 | 7.6 | 138 | 146 | 7.2 |
| North Dakota | 0.1 | 0.2 | 0.2 | 15 | 15 | 2.3 |
| Ohio | 28 | 41 | 68 | 355 | 424 | 66 |
| Oklahoma | 6.6 | 16 | 23 | 170 | 193 | 18 |
| Oregon | 4.4 | 752 | 756 | 79 | 835 | 0.7 |
| Pennsylvania | 16 | 14 | 30 | 218 | 247 | 11 |
| Rhode Island | 1.5 | 0 | 1.5 | 20 | 21 | 2.1 |
| South Carolina | 1.7 | 0 | 1.7 | 50 | 52 | 7.8 |
| South Dakota | 6.1 | 4.1 | 10 | 21 | 31 | 3.1 |
| Tennessee | 2.0 | 18 | 20 | 214 | 234 | 21 |
| Texas | 33 | 11 | 44 | 130 | 174 | 35 |
| Utah | 3.8 | 0 | 3.8 | 115 | 119 | 35 |
| Vermont | 9.6 | 16 | 26 | 7.7 | 33 | 2.4 |
| Virginia | 28 | 13 | 41 | 152 | 193 | 23 |
| Washington | 24 | 0.4 | 24 | 161 | 185 | 37 |
| West Virginia | 36 | 9.2 | 46 | 23 | 68 | 10 |
| Wisconsin | 17 | 0 | 17 | 111 | 128 | 26 |
| Wyoming | 0.9 | 0.6 | 1.6 | 16 | 18 | 2.7 |
| Puerto Rico | 1.2 | 1.5 | 2.7 | 61 | 64 | 19 |
| Virgin Islands | 0.1 | 0.6 | 0.8 | 3.3 | 4.1 | 0.6 |
| **Total** | **939** | **1,950** | **2,890** | **6,690** | **9,590** | **1,310** |

*Note:* Figures may not add to totals because of independent rounding. All values in million gallons per day.

*Source*: From Salley, W.B. et al., 1998, Estimated use of water in the United States in 1995, *U.S. Geological Survey Circular 1200*, www.usgs.gov.

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**Table 7G.65 Average Rates of Nonresidential Water Use from Establishment Level Data**

| Category | SIC Code | Use Rate (gal/employee day) | Sample Size |
|---|---|---|---|
| Construction | — | 31 | 246 |
| General building contractors | 15 | 118 | 66 |
| Heavy construction | 16 | 20 | 30 |
| Special trade contractors | 17 | 25 | 150 |
| Manufacturing | — | 164 | 2790 |
| Food and kindred products | 20 | 469 | 252 |
| Textile mill products | 22 | 784 | 20 |
| Apparel and other textile products | 23 | 26 | 91 |
| Lumber and wood products | 24 | 49 | 62 |
| Furniture and fixtures | 25 | 36 | 83 |
| Paper and allied products | 26 | 2614 | 93 |
| Printing and publishing | 27 | 37 | 174 |
| Chemicals and allied products | 28 | 267 | 211 |
| Petroleum and coal products | 29 | 1045 | 23 |
| Rubber and miscellaneous plastics products | 30 | 119 | 116 |
| Leather and leather products | 31 | 148 | 10 |
| Stone, clay, and glass products | 32 | 202 | 83 |
| Primary metal industries | 33 | 178 | 80 |
| Fabricated metal products | 34 | 194 | 395 |
| Industrial machinery and equipment | 35 | 68 | 304 |
| Electronic and other electrical equipment | 36 | 95 | 409 |
| Transportation equipment | 37 | 84 | 182 |
| Instruments and related products | 38 | 66 | 147 |
| Miscellaneous manufacturing industries | 39 | 36 | 55 |
| Transportation and public utilities | — | 50 | 226 |
| Railroad transportation | 40 | 68 | 3 |
| Local and interurban passenger transit | 41 | 26 | 32 |
| Trucking and warehousing | 42 | 85 | 100 |
| U.S. postal service | 43 | 5 | 1 |
| Water transportation | 44 | 353 | 10 |
| Transportation by air | 45 | 171 | 17 |
| Transportation services | 47 | 40 | 13 |
| Communications | 48 | 55 | 31 |
| Electric, gas, and sanitary services | 49 | 51 | 19 |
| Wholesale trade | — | 53 | 751 |
| Wholesale trade—durable goods | 50 | 46 | 518 |
| Wholesale trade—nondurable goods | 51 | 87 | 233 |
| Retail trade | — | 93 | 1044 |
| Building materials and garden supplies | 52 | 35 | 56 |
| General merchandise stores | 53 | 45 | 50 |
| Food stores | 54 | 100 | 90 |
| Automotive dealers and service stations | 55 | 49 | 198 |
| Apparel and accessory stores | 56 | 68 | 48 |
| Furniture and homefurnishings stores | 57 | 42 | 100 |
| Eating and drinking places | 58 | 156 | 341 |
| Miscellaneous retail | 59 | 132 | 161 |
| Finance, insurance, and real estate | — | 192 | 238 |
| Depository institutions | 60 | 62 | 77 |
| Nondepository institutions | 61 | 361 | 36 |
| Security and commodity brokers | 62 | 1240 | 2 |
| Insurance carriers | 63 | 136 | 9 |
| Insurance agents, brokers, and service | 64 | 89 | 24 |
| Real Estate | 65 | 609 | 84 |
| Holding and other investment offices | 67 | 290 | 5 |
| Services | — | 137 | 1878 |
| Hotels and other lodging places | 70 | 230 | 197 |
| Personal services | 72 | 462 | 300 |
| Business services | 73 | 73 | 243 |

*(Continued)*

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**Table 7G.65 (Continued)**

| Category | SIC Code | Use Rate (gal/employee day) | Sample Size |
|---|---|---|---|
| Auto repair, services, and parking | 75 | 217 | 108 |
| Miscellaneous repair services | 76 | 69 | 42 |
| Motion pictures | 78 | 110 | 40 |
| Amusement and recreation services | 79 | 429 | 105 |
| Health services | 80 | 91 | 353 |
| Legal services | 81 | 821 | 15 |
| Educational services | 82 | 117 | 300 |
| Social services | 83 | 106 | 55 |
| Museums, botanical, zoological gardens | 84 | 208 | 9 |
| Membership organizations | 86 | 212 | 45 |
| Engineering and management services | 87 | 58 | 5 |
| Services, NEC | 89 | 73 | 60 |
| Public administration | — | 106 | 25 |
| Executive, legislative, and general | 91 | 155 | 2 |
| Justice, public order, and safety | 92 | 18 | 4 |
| Administration of human resources | 94 | 87 | 6 |
| Environmental quality and housing | 95 | 101 | 6 |
| Administration of economic programs | 96 | 274 | 5 |
| National security and international affairs | 97 | 112 | 2 |

*Source*: From Mays, L.W. ed., 1996, *Water Resources Handbook*, Copyright © The McGraw-Hill, Companies, Inc., NY. Reprinted with permission.

*Original Source*: From Planning and Management Consultants, Ltd. (1994; unpublished data).

**Table 7G.66 Selected Commercial and Institutional Unit Use Coefficients**

| CI Category | Unit | Gal/Unit/Day |
|---|---|---|
| Barber shops | Chairs | 54.60 |
| Beauty shops | Station | 269.00 |
| Bus/rail depots | Square foot | 3.33 |
| Car washes | Inside square foot | 4.78 |
| Churches | Member | 0.14 |
| Golf/swim clubs | Member | 22.20 |
| Bowling alleys | Alley | 133.00 |
| Residential colleges | Student | 106.00 |
| Hospitals | Bed | 346.00 |
| Hotels | Square foot | 0.26 |
| Laundromats | Square foot | 2.17 |
| Laundry | Square foot | 0.25 |
| Medical offices | Square foot | 0.62 |
| Motels | Square foot | 0.22 |
| Drive-in movies | Car stall | 5.33 |
| Nursing homes | Bed | 133.00 |
| New office buildings | Square foot | 0.19 |
| Old office buildings | Square foot | 0.14 |
| Jails and prisons | Person | 133.00 |
| Restaurants | Seat | 24.20 |
| Drive-in restaurants | Car stall | 109.00 |
| Night clubs | Person served | 1.33 |
| Retail space | Sale square foot | 0.11 |
| Elementary schools | Student | 3.83 |
| High schools | Student | 8.02 |
| YMCA/YWCA | Person | 33.30 |
| Service stations | Inside square foot | 0.25 |
| Theaters | Seat | 3.33 |

*Source*: From Dziegielewski, B. et al., 2000, Commercial and Institutional End Uses of Water, AWWA.

*Original Source*: From Crews, J.E. and Miller, M.A., 1983. Forecasting Municipal and Industrial Water Use. IWR Research Report 83R-3. U.S. Army Corps of Engineers, Fort Belvoir, Virginia, www.awwa.org.

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**Table 7G.67 Distribution of Commercial Water Use by Category in Selected Cities (Percent of CI Sector Use)**

| Commercial Users Reporting Year | Austin TX 1992 | Buffalo NY 1995 | Burbank CA 1995 | EB- MUD CA 1994 | Glendale CA 1995 | Miami FL 1995 | Orlando FL 1995 | Portland OR 1995 | San Diego CA 1995 | Santa Monica CA 1995 | St. Paul MN 1994–95 | Santa Rosa CA 1994 | Weighted Average 1992–1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hospitality[a] | 13.26 | 20.94 | 11.75 | 7.94 | 13.45 | 17.53 | 34.86 | 5.45 | 34.28 | 38.55 | 15.96 | 28.12 | 14.80 |
| Warehousing | 1.79 | 10.83 | | 30.77 | 0.45 | 6.73 | 30.94 | 2.78 | 0.03 | | 16.87 | 0.25 | 12.40 |
| Offices[b] | 13.97 | 15.81 | 11.37 | 7.09 | 12.78 | 12.29 | 9.7 | 5.69 | 7.59 | | 13.03 | 15.4 | 9.20 |
| Irrigation[c] | 2.18 | 5.13 | | 21.94 | 5.12 | | 0.8 | 1.57 | 4.25 | 10.32 | 3.12 | 0.3 | 6.15 |
| Miscellaneous commercial[d] | | | | | | 31.05 | 0.45 | | 0.06 | | 0.46 | | 5.72 |
| Sales[e] | 6.82 | 18.15 | 9.36 | 3.91 | 3.54 | 8.29 | 2.32 | 2.99 | 7.23 | 6.59 | 11.97 | 7.54 | 5.48 |
| Services[f] | 5.64 | 0.22 | 0.59 | 2.61 | 4.97 | | 0.45 | 0.75 | 13.07 | | 0.21 | 0.43 | 2.36 |
| Laundries | | 3.41 | 3.52 | 2.53 | | 2.89 | 2.13 | 1.10 | | 3.91 | | 5.88 | 1.73 |
| Vehicle dealers and services | 0.90 | 3.39 | 0.24 | 0.59 | 4.17 | 0.95 | 2.11 | 0.50 | 2.63 | 0.57 | 3.37 | 4.83 | 1.15 |
| Meeting and recreation[g] | 0.96 | | 2.48 | 2.13 | 9.59 | 0.26 | 0.53 | 0.01 | 2.17 | 3.14 | 4.98 | 0.44 | 1.11 |
| Communication and research | 0.11 | 0.06 | 27.84 | 0.15 | 7.77 | | 1.04 | | 2.97 | 1.43 | 0 | 0.26 | 0.72 |
| Landscape[h] | 0.05 | 2.26 | 1.01 | 0.42 | | | 0.15 | 1.63 | | | | 0.3 | 0.58 |
| Transportation and fuels | | 1.15 | | 1.40 | 0.58 | | 0.74 | 0 | | | 0.61 | 1.12 | 0.43 |
| Car wash | | 2.15 | 1.17 | 0.38 | 0.40 | | 0.20 | | 0.77 | 2.54 | 1.24 | 1.23 | 0.28 |
| Passenger terminals | 0.45 | 1.17 | 2.31 | | 0.05 | | 0.01 | 0.30 | 0.22 | 0.33 | 0.16 | | 0.20 |
| Share of Reported CI Use | 46.13 | 84.67 | 76.64 | 81.86 | 62.87 | 79.99 | 86.43 | 22.77 | 75.27 | 67.38 | 71.98 | 66.9 | 62.28 |

*Note:* Tabular Valves are in percentages.

[a] Hospitality includes restaurant/bar, overnight accommodations, and other group shelter.
[b] Office includes finance, insurance, real estate, and government.
[c] Irrigation includes parks, gardens, botanical, zoological, cemeteries, and open land.
[d] Miscellaneous commercial includes warehousing, warehouse-cold storage, and boat dock.
[e] Sales include grocery stores, convenience stores, and dry goods.
[f] Services include miscellaneous repair services, crematories, funeral homes, laboratories, and printing.
[g] Meeting and recreation include convention center, recreation and theaters, and amusement parks.
[h] Landscape includes landscape horticultural service, agriculture, soil preparation, crop services, veterinary, equestrian, livestock, poultry, and game propagation.

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.

*Original Source*: Derived from U.S. Environmental Protection Agency (1997). Table 2.

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**Table 7G.68 Characteristics of Significant Commercial and Institutional Categories in Five Participating Agencies**

| Customer Category Description | Average Annual Daily Use (gpdc)[a] | Coefficient of Variation in Daily Use (gpdc)[b] | Percent of Total CI Use (%) | Percent of CI Customers (%)[c] | Percent Seasonal Use (%)[d] | Scaled Average Daily Use (gpdc)[e] |
|---|---|---|---|---|---|---|
| Urban irrigation | 2,596 | 8.73 | 28.48 | 30.22 | 86.90 | 739.0 |
| Schools and colleges | 2,117 | 12.13 | 8.84 | 4.79 | 57.99 | 187.0 |
| Hotels and motels | 7,113 | 5.41 | 5.82 | 1.92 | 23.07 | 414.0 |
| Laundries and laundromats | 3,290 | 8.85 | 3.95 | 1.38 | 13.35 | 130.0 |
| Office buildings | 1,204 | 6.29 | 10.19 | 11.67 | 29.04 | 123.0 |
| Hospitals and medical offices | 1,236 | 78.50 | 3.90 | 4.19 | 23.16 | 48.0 |
| Restaurant | 906 | 7.69 | 8.83 | 11.18 | 16.13 | 80.0 |
| Food stores | 729 | 16.29 | 2.86 | 5.20 | 19.37 | 21.0 |
| Auto shops | 687 | 7.96 | 1.97 | 6.74 | 27.16 | 14.0 |
| Membership organizations | 629 | 6.42 | 1.95 | 5.60 | 46.18 | 12.0 |
| Car washes | 3,031 | 3.12 | 0.82 | 0.36 | 14.22 | 25.0 |

[a] gpdc: gallons per day per customer.
[b] Coefficient of variation in daily use: The ratio of standard deviation of daily use to average of daily use.
[c] Percent of CI customers pertains to CI customers in agencies that have respective category only.
[d] Percent seasonal use = [(total annual use —12 × minimum month use]/total annual use.
[e] Scaled average daily use = average annual daily use in category × percent of total CI use attributed to the category.

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.



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**Table 7G.69 Water Use in Mining and Manufacturing in the United States, 1968–1983, and by Industry Group, 1983**

| Industry | Establishments Reporting[a] | Gross Water Used: Total Quantity (bil gal) | Gross Water Used: Total Average per Establishment (mil gal) | Gross Water Used: Water Intake (bil gal) | Gross Water Used: Water Recycled[b] (bil gal) | Water Discharged: Quantity (bil gal) | Water Discharged: Percent Untreated | Water Pollutants Abatement: Capital Expenditures (mil dol) | Water Pollutants Abatement: Operating Cost (mil dol) |
|---|---|---|---|---|---|---|---|---|---|
| **Mining** | | | | | | | | | |
| 1968 | 1,801 | 3,694 | 2,051 | 1,408 | (NA) | 1,365 | 78.8 | (NA) | (NA) |
| 1973 | 1,687 | 3,965 | 2,350 | 1,665 | 2,300 | 1,605 | 54.3 | 38 | 124 |
| 1978 | 1,056 | 3,554 | 3,366 | 1,473 | 2,430 | 1,592 | 67.3 | 244 | 201 |
| **1983, total** | 1,534 | 3,328 | 2,169 | 1,197 | 2,131 | 1,037 | 31.9 | 189 | 499 |
| Metal mining | 135 | 735 | 5,444 | 170 | 564 | 133 | 39.8 | 22 | 65 |
| Anthracite mining | 16 | 5 | 313 | 2 | 3 | 8 | 12.5 | (Z) | 1 |
| Bituminous coal, lignite mining | 275 | 119 | 433 | 45 | 73 | 116 | 26.7 | 14 | 69 |
| Oil and gas extraction | 555 | 1,452 | 2,616 | 602 | 850 | 476 | 31.1 | 131 | 318 |
| Nonmetallic minerals, exc. fuels | 553 | 1,018 | 1,841 | 378 | 640 | 304 | 32.6 | 22 | 46 |
| **Manufacturing** | | | | | | | | | |
| 1968 | 9,402 | 35,701 | 3,797 | 15,467 | (NA) | 14,276 | 69.5 | (NA) | (NA) |
| 1973 | 10,668 | 43,413 | 4,069 | 15,024 | [c] | 14,144 | 56.5 | 511 | 866 |
| 1978 | 9,605 | 44,494 | 4,632 | 12,992 | 34,199 | 11,682 | 59.7 | 1,249 | 2,119 |
| **1983, total** | 10,262 | 33,835 | 3,297 | 10,039 | 23,796 | 8,914 | 54.9 | 819 | 3,259 |
| Food and kindred products | 2,656 | 1,406 | 529 | 648 | 759 | 552 | 64.5 | 105 | 187 |
| Tobacco products | 20 | 34 | 1,700 | 5 | 29 | 4 | (D) | (D) | 5 |
| Textile mill products | 761 | 333 | 438 | 133 | 200 | 116 | 52.6 | (D) | 25 |
| Lumber and wood products | 223 | 218 | 978 | 86 | 132 | 71 | 63.4 | 4 | 23 |
| Furniture and fixtures | 66 | 7 | 106 | 3 | 3 | 3 | 100.0 | 2 | 4 |
| Paper and allied products | 600 | 7,436 | 12,393 | 1,899 | 5,537 | 1,768 | 27.1 | 66 | 438 |
| Chemicals and allied products | 1,315 | 9,630 | 7,323 | 3,401 | 6,229 | 2,980 | 67.0 | 187 | 1,013 |
| Petroleum and coal products | 260 | 6,177 | 23,758 | 818 | 5,359 | 699 | 46.2 | 165 | 543 |
| Rubber, misc. plastic products | 375 | 328 | 875 | 76 | 252 | 63 | 63.5 | 4 | 37 |
| Leather and leather products | 69 | 7 | 101 | 6 | 1 | 6 | (D) | (S) | 6 |
| Stone, clay, and glass products | 602 | 337 | 560 | 155 | 182 | 133 | 75.2 | 10 | 38 |
| Primary metal products | 776 | 5,885 | 7,584 | 2,363 | 3,523 | 2,112 | 58.1 | 100 | 421 |
| Fabricated metal products | 724 | 258 | 356 | 65 | 193 | 61 | 49.2 | 33 | 100 |
| Machinery, exc. electrical | 523 | 307 | 587 | 120 | 186 | 105 | 67.6 | 19 | 76 |
| Electric and electronic equipment | 678 | 335 | 494 | 74 | 261 | 70 | 61.4 | 45 | 108 |
| Transportation equipment | 380 | 1,011 | 2,661 | 153 | 859 | 139 | 67.6 | 55 | 171 |
| Instruments and related products | 154 | 112 | 727 | 30 | 82 | 28 | 50.0 | 10 | 45 |
| Miscellaneous manufacturing | 80 | 15 | 188 | 4 | 11 | 4 | (D) | 2 | 7 |

*Note:* Based on establishments reporting water intake of 20 mil gal. This represented 95 percent and 96 percent of the total water use estimated for mining and manufacturing industries. Water intake refers to that which is used/consumed in the production and processing operations and for sanitary services. D, Withheld to avoid disclosing individual company data; NA, Not available; S, Figure does not meet publication standards; Z, Less than $500,000.

[a] Establishments reporting water intake of 20 million gallons or more. These counts do not apply to water pollutants abatement columns for manufacturing in 1983.
[b] Refers to water recirculated and water reused.
[c] Data estimated; not strictly comparable to other years.

*Source*: From U.S. Department of Commerce, Statistical Abstract of the United States, 1987.

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**Table 7G.70 Mining Water Use in the United States, 2000**

| State | Withdrawals (mil gal/day) | | | | | | | | | Withdrawals, (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | By Source and Type | | | | | | | | | By Type | | |
| | Groundwater | | | Surface Water | | | Total | | | | | |
| | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total |
| Alabama | — | — | — | — | — | — | — | — | — | — | — | — |
| Alaska | 0.01 | 90.4 | 90.4 | 27.4 | 49.5 | 76.9 | 27.4 | 140 | 167 | 30.7 | 157 | 188 |
| Arizona | 81.2 | 8.17 | 89.4 | 4.43 | 0 | 4.43 | 85.7 | 8.17 | 93.8 | 96 | 9.16 | 105 |
| Arkansas | 0.21 | 0 | 0.21 | 2.57 | 0 | 2.57 | 2.78 | 0 | 2.78 | 3.12 | 0 | 3.12 |
| California | 21 | 152 | 173 | 2.71 | 0.46 | 3.17 | 23.7 | 153 | 177 | 26.6 | 171 | 198 |
| Colorado | — | — | — | — | — | — | — | — | — | — | — | — |
| Connecticut | — | — | — | — | — | — | — | — | — | — | — | — |
| Delaware | — | — | — | — | — | — | — | — | — | — | — | — |
| District of Columbia | — | — | — | — | — | — | — | — | — | — | — | — |
| Florida | 160 | 0 | 160 | 57.8 | 0 | 57.8 | 217 | 0 | 217 | 244 | 0 | 244 |
| Georgia | 7.75 | 0 | 7.75 | 2.05 | 0 | 2.05 | 9.8 | 0 | 9.8 | 11 | 0 | 11 |
| Hawaii | — | — | — | — | — | — | — | — | — | — | — | — |
| Idaho | — | — | — | — | — | — | — | — | — | — | — | — |
| Illinois | — | — | — | — | — | — | — | — | — | — | — | — |
| Indiana | 4.2 | 0 | 4.2 | 78.3 | 0 | 78.3 | 82.5 | 0 | 82.5 | 92.5 | 0 | 92.5 |
| Iowa | 2.49 | 0 | 2.49 | 30.3 | 0 | 30.3 | 32.8 | 0 | 32.8 | 36.8 | 0 | 36.8 |
| Kansas | 14 | 0 | 14 | 17.4 | 0 | 17.4 | 31.4 | 0 | 31.4 | 35.2 | 0 | 35.2 |
| Kentucky | — | — | — | — | — | — | — | — | — | — | — | — |
| Louisiana | — | — | — | — | — | — | — | — | — | — | — | — |
| Maine | — | — | — | — | — | — | — | — | — | — | — | — |
| Maryland | 4.21 | 0 | 4.21 | 4.1 | 0.02 | 4.12 | 8.31 | 0.02 | 8.33 | 9.32 | 0.02 | 9.34 |
| Massachusetts | — | — | — | — | — | — | — | — | — | — | — | — |
| Michigan | — | — | — | — | — | — | — | — | — | — | — | — |
| Minnesota | 6.9 | 0 | 6.9 | 581 | 0 | 581 | 588 | 0 | 588 | 659 | 0 | 659 |
| Mississippi | — | — | — | — | — | — | — | — | — | — | — | — |
| Missouri | 4.1 | 0 | 4.1 | 12.8 | 0 | 12.8 | 16.9 | 0 | 16.9 | 19 | 0 | 19 |
| Montana | — | — | — | — | — | — | — | — | — | — | — | — |
| Nebraska | 5.64 | 4.55 | 10.2 | 122 | 0 | 122 | 128 | 4.55 | 132 | 143 | 5.1 | 148 |
| Nevada | — | — | — | — | — | — | — | — | — | — | — | — |
| New Hampshire | 0.08 | 0 | 0.08 | 6.72 | 0 | 6.72 | 6.8 | 0 | 6.8 | 7.62 | 0 | 7.62 |
| New Jersey | 6.12 | 0 | 6.12 | 104 | 0 | 104 | 110 | 0 | 110 | 124 | 0 | 124 |
| New Mexico | — | — | — | — | — | — | — | — | — | — | — | — |
| New York | — | — | — | — | — | — | — | — | — | — | — | — |
| North Carolina | 36.4 | 0 | 36.4 | 0 | 0 | 0 | 36.4 | 0 | 36.4 | 40.8 | 0 | 40.8 |
| North Dakota | — | — | — | — | — | — | — | — | — | — | — | — |
| Ohio | 53.1 | 0 | 53.1 | 35.5 | 0 | 35.5 | 88.5 | 0 | 88.5 | 99.2 | 0 | 99.2 |

*(Continued)*



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**Table 7G.70 (Continued)**

| State | Withdrawals (mil gal/day) | | | | | | | | | Withdrawals, (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | By Source and Type | | | | | | | | | By Type | | |
| | Groundwater | | | Surface Water | | | Total | | | | | |
| | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total |
| Oklahoma | 2.25 | 256 | 258 | 0.23 | 0 | 0.23 | 2.48 | 256 | 258 | 2.78 | 287 | 290 |
| Oregon | — | — | — | — | — | — | — | — | — | — | — | — |
| Pennsylvania | 162 | 0 | 162 | 20.9 | 0 | 20.9 | 182 | 0 | 182 | 205 | 0 | 205 |
| Rhode Island | — | — | — | — | — | — | — | — | — | — | — | — |
| South Carolina | — | — | — | — | — | — | — | — | — | — | — | — |
| South Dakota | — | — | — | — | — | — | — | — | — | — | — | — |
| Tennessee | — | — | — | — | — | — | — | — | — | — | — | — |
| Texas | 129 | 504 | 633 | 91.5 | 0 | 91.5 | 220 | 504 | 724 | 247 | 565 | 812 |
| Utah | 8.6 | 21.5 | 30.1 | 17.7 | 177 | 194 | 26.3 | 198 | 225 | 29.4 | 222 | 252 |
| Vermont | — | — | — | — | — | — | — | — | — | — | — | — |
| Virginia | — | — | — | — | — | — | — | — | — | — | — | — |
| Washington | — | — | — | — | — | — | — | — | — | — | — | — |
| West Virginia | — | — | — | — | — | — | — | — | — | — | — | — |
| Wisconsin | — | — | — | — | — | — | — | — | — | — | — | — |
| Wyoming | 58.8 | 222 | 280 | 20.7 | 0 | 20.7 | 79.5 | 222 | 301 | 89.1 | 248 | 338 |
| Puerto Rico | — | — | — | — | — | — | — | — | — | — | — | — |
| U.S. Virgin Islands | — | — | — | — | — | — | — | — | — | — | — | — |
| Total | 767 | 1,260 | 2,030 | 1,240 | 227 | 1,470 | 2,010 | 1,490 | 3,490 | 2,250 | 1,660 | 3,920 |

*Note:* Figures may not sum to totals because of independent rounding; —, data not collected.

*Source*: From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.

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**Table 7G.71 Changes in Manufacturing and Mining Employment and Industrial Withdrawals (Selected States), 1980–1995**

| State | Change in Industrial Withdrawals (mgd) | Change in Manufacturing Employment (employees) |
|---|---|---|
| **Decreasing Withdrawals/Decreasing Employment** | | |
| New York | −711 | −578,907 |
| Pennsylvania | −1,687 | −465,730 |
| Illinois | −1,217 | −305,198 |
| New Jersey | −1,247 | −262,443 |
| California | −88 | −265,131 |
| Massachusetts | −277 | −239,587 |
| Ohio | −1,252 | −248,244 |
| Connecticut | −240 | −177,407 |
| Michigan | −128 | −112,866 |
| **Increasing Withdrawals/Decreasing Employment** | | |
| Virginia | 112 | −24,057 |
| South Carolina | 218 | −26,298 |
| West Virginia | 543 | −68,941 |
| Oregon | 635 | 9,667 |
| Texas | 1,131 | −111,709 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.

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**Table 7G.72 Water Use by Mineral Industries in the United States, 1983**

| Industry Group and Industry | Establishments Reporting Water Intake of 20 bil gal or More During 1982 (Number) | Gross Water Used[a] | | | | | Water Discharged[b] | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total | | Water Intake | | | | | |
| | | Quantity (bil gal) | Percent of All Mineral Industries | Quantity (bil gal) | Percent of All Mineral Industries | Water Re-Circulated and Reused (bil gal) | Total (bil gal) | Untreated (bil gal) | Treated (bil gal) |
| **All mineral industries** | 1,534 | 3,328.3 | 100 | 1,197.1 | 100 | 2,131.1 | 1,036.7 | 331.2 | 705.5 |
| **Metal mining** | 135 | 734.5 | 22 | 170.2 | 14 | 564.3 | 133.0 | 52.8 | 80.2 |
| Iron ores | 15 | 421.6 | 13 | 45.7 | 4 | 375.9 | 51.2 | 40.3 | 11.0 |
| Copper ores | 29 | 223.4 | 7 | 89.7 | 7 | 133.7 | 17.7 | (D) | (D) |
| Lead and zinc ores | 14 | (D) | (D) | (D) | (D) | (D) | 26.6 | 0.7 | 25.9 |
| Gold and silver ores | 28 | 12.4 | (Z) | 7.3 | 1 | 5.0 | 5.5 | 1.2 | 4.3 |
| Gold ores | 20 | (D) | (D) | 5.8 | (Z) | (D) | 4.0 | (D) | (D) |
| Silver ores | 8 | (D) | (D) | 1.6 | (Z) | (D) | 1.5 | (D) | (D) |
| Miscellaneous metal ores | 42 | 46.0 | 1 | 14.4 | 1 | 31.6 | 16.2 | 6.6 | 9.7 |
| Uranium-radium-vanadium ores | 34 | 15.5 | (Z) | 10.5 | 1 | 5.0 | 11.3 | 6.5 | 4.8 |
| Metallic ores, n.e.c. | 8 | 30.5 | 1 | 3.9 | (Z) | 26.6 | 4.9 | (Z) | 4.9 |
| **Anthracite mining** | 16 | 5.4 | (Z) | 2.2 | (Z) | 3.2 | 7.5 | 0.9 | 6.5 |
| Anthracite | 16 | 5.4 | (Z) | 2.2 | (Z) | 3.2 | 7.5 | 0.9 | 6.5 |
| **Bituminous coal and lignite mining** | 275 | 118.6 | 4 | 45.3 | 4 | 73.3 | 116.2 | 30.5 | 85.7 |
| Bituminous coal and lignite mining | 275 | 118.6 | 4 | 45.3 | 4 | 73.3 | 116.2 | 30.5 | 85.7 |
| Bituminous coal and lignite | 275 | 118.6 | 4 | 45.3 | 4 | 73.3 | 116.2 | 30.5 | 85.7 |
| **Oil and gas extraction** | 555 | 1,451.8 | 44 | 601.6 | 50 | 850.1 | 475.6 | 147.5 | 328.1 |
| Crude petroleum and natural gas | 312 | 672.8 | 20 | 436.6 | 36 | 236.2 | 318.8 | 84.7 | 234.1 |
| Natural gas liquids | 161 | 750.7 | 23 | 146.7 | 12 | 604.1 | (D) | (D) | (D) |
| Oil and gas field services | 82 | 28.2 | 1 | 18.4 | 2 | 9.8 | (D) | (D) | (D) |
| Drilling oil and gas wells | 67 | 27.3 | 1 | 17.5 | 1 | 9.7 | 16.7 | 8.1 | 8.5 |
| Oil and gas field services, n.e.c. | 14 | 0.9 | (Z) | 0.8 | (Z) | 0.1 | (D) | (D) | (D) |
| **Nonmetallic minerals, except fuels** | 553 | 1,018.1 | 31 | 377.8 | 32 | 640.2 | 304.3 | 99.3 | 205.0 |
| Dimension stone | 3 | (D) | (D) | 1.3 | (Z) | (D) | 1.0 | (D) | (D) |
| Crushed and broken stone, including riprap | 178 | 63.1 | 2 | 46.5 | 4 | 16.6 | 45.6 | 19.2 | 26.4 |
| Crushed and broken limestone | 97 | 52.9 | 2 | 39.0 | 3 | 13.9 | 39.7 | 15.7 | 24.1 |
| Crushed and broken granite | 46 | 5.1 | (Z) | 3.3 | (Z) | 1.8 | 2.6 | (D) | (D) |
| Crushed and broken stone, n.e.c. | 35 | 5.1 | (Z) | 4.2 | (Z) | 0.9 | 3.3 | (D) | (D) |
| Sand and gravel | 248 | 201.4 | 6 | 123.1 | 10 | 78.3 | 67.0 | 25.6 | 41.4 |
| Construction sand and gravel | 215 | 123.5 | 4 | 85.1 | 7 | 38.4 | 57.3 | 23.3 | 34.1 |
| Industrial sand | 33 | 77.8 | 2 | 38.0 | 3 | 39.8 | 9.7 | 2.3 | 7.4 |
| Clay, ceramic, and refractory minerals | 35 | (D) | (D) | (D) | (D) | (D) | (D) | (D) | (D) |
| Kaolin and ball clay | 11 | 16.2 | (Z) | 15.0 | 1 | 1.2 | 13.4 | (D) | (D) |
| Clay, ceramic, and refractory minerals, n.e.c. | 16 | 11.4 | (Z) | 4.4 | (Z) | 7.0 | 2.6 | (D) | (D) |
| Chemical and fertilizer mineral mining | 71 | 684.8 | 21 | 149.6 | 12 | 535.1 | 141.3 | (D) | (D) |
| Barite | 10 | 2.7 | (Z) | (D) | (D) | (D) | (D) | (D) | (D) |
| Potash, soda, and borate minerals | 20 | 125.5 | 4 | 26.9 | 2 | 98.6 | 12.4 | (D) | (D) |
| Phosphate rock | 19 | 489.5 | 15 | 60.2 | 5 | 429.3 | 63.4 | 0.3 | 63.1 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Miscellaneous nonmetallic minerals | 17 | (D) | (D) | (D) | (D) | 1.4 | (D) | (D) | 0.7 |
| Talc, soapstone, and pyrophyllite | 5 | (D) | (D) | 0.4 | (Z) | (D) | 0.3 | (D) | (D) |
| Miscellaneous nonmetallic minerals, n.e.c. | 12 | (D) | (D) | (D) | (D) | (D) | (D) | (D) | (D) |

*Note:* D, Withheld to avoid disclosing data for individual companies; Z, Less than half the unit shown; n.e.c., not elsewhere classified.

[a] Total gross water used is equal to sum of water intake plus water reciruclated and reused without regard to evaporation.
[b] Volume of water discharged may be greater than water intake due to mine water that is drained and discharged.

*Source*: From 1982 Census of Mineral Industries, U.S. Dept. of Commerce Bureau of the Census, 1985.



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**Table 7G.73 Water Use by Manufacturing Industries in the United States, 1983 (Bil Gal)**

| Industry Group and Industry | Establishments Reporting Water Intake of 20 Mil Gal or More During 1982 | Gross Water Used[a] | | | | Water Discharged | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water Intake | | | | | |
| | | Total | Total | From Public Water System | Water Re-Circulated and Reused | Total | Untreated | Treated |
| **All manufacturing industries[b]** | 10,262 | 33,835.2 | 10,038.9 | 1,310.7 | 23,796.3 | 8,913.7 | 4,889.8 | 4,023.9 |
| **Food and kindred productions** | 2,656 | 1,406.2 | 647.7 | 219.0 | 758.6 | 552.0 | 355.8 | 196.1 |
| Meat products | 552 | 119.5 | 92.7 | 49.5 | 26.8 | 85.5 | 28.7 | 56.8 |
| Meat packing plants | 205 | 56.5 | 44.7 | 16.9 | 11.8 | 41.9 | 14.7 | 27.2 |
| Sausages and other prepared meats | 104 | 13.9 | 11.3 | 7.8 | 2.6 | 9.8 | 4.1 | 5.6 |
| Poultry dressing plants | 217 | 47.3 | 35.2 | 24.0 | 12.1 | 32.4 | 9.0 | 23.4 |
| Poultry and egg processing | 26 | 1.8 | 1.5 | 0.8 | 0.3 | 1.4 | 0.9 | 0.6 |
| Dairy products | 498 | 69.8 | 38.8 | 17.9 | 30.9 | 35.9 | 29.4 | 6.4 |
| Creamery butter | 17 | 1.3 | 1.0 | 0.3 | 0.2 | 0.9 | 0.8 | 0.1 |
| Cheese, natural and processed | 111 | 15.2 | 10.2 | 3.9 | 5.1 | 9.3 | 6.6 | 2.7 |
| Condensed and evaporated milk | 67 | 14.2 | 9.5 | 2.4 | 4.8 | 8.6 | 7.1 | 1.5 |
| Ice cream and frozen desserts | 40 | 2.0 | 1.4 | 1.1 | 0.6 | 1.1 | 1.1 | 0.1 |
| Fluid milk | 263 | 37.0 | 16.7 | 10.3 | 20.3 | 16.0 | 13.9 | 2.1 |
| Preserved fruits and vegetables | 489 | 201.4 | 100.1 | 38.6 | 101.3 | 88.6 | 46.7 | 41.9 |
| Canned specialties | 52 | 21.5 | 17.4 | 10.3 | 4.1 | 13.4 | 7.0 | 6.5 |
| Canned fruits and vegetables | 224 | 81.3 | 30.6 | 13.9 | 50.7 | 26.3 | 13.8 | 12.5 |
| Dehydrated fruits, vegetables, and soups | 26 | (D) | 5.6 | 1.8 | (D) | 4.9 | 1.8 | 3.0 |
| Pickles, sauces, and salad dressings | 36 | 7.2 | 2.4 | 2.1 | 4.9 | 1.9 | 0.8 | 1.1 |
| Frozen fruits and vegetables | 117 | 70.4 | 40.0 | 8.1 | 30.4 | 38.8 | 21.5 | 17.3 |
| Frozen specialties | 34 | (D) | 4.1 | 2.5 | (D) | 3.4 | 1.8 | 1.6 |
| Grain mill products | 119 | 147.0 | 79.3 | 19.7 | 67.6 | 74.3 | 65.7 | 8.6 |
| Flour and other grain mill products | 19 | 0.9 | 0.8 | 0.5 | 0.1 | 0.5 | (D) | (D) |
| Cereal breakfast foods | 19 | 12.7 | 5.9 | 3.6 | 6.9 | 3.8 | (D) | (D) |
| Rice milling | 10 | (D) | 0.6 | 0.6 | (D) | 0.4 | (D) | (D) |
| Blended and prepared flour | 4 | (D) | 0.1 | 0.1 | (D) | 0.1 | 0.1 | – |
| Wet corn milling | 21 | 126.9 | 68.3 | 12.9 | 58.6 | 66.6 | 59.7 | 7.0 |
| Dog, cat, and other pet food | 32 | (D) | 2.9 | 1.9 | (D) | 2.1 | 1.1 | 1.1 |
| Prepared feeds, n.e.c. | 14 | 1.1 | 0.8 | 0.3 | 0.3 | 0.7 | 0.6 | 0.2 |
| Bakery products | 76 | 7.6 | 3.0 | 2.3 | 4.6 | 2.0 | 1.7 | 0.3 |
| Bread, cake, and related products | 61 | 2.8 | 1.9 | (D) | 0.9 | 1.1 | 1.0 | 0.1 |
| Cookies and crackers | 15 | 4.8 | 1.1 | (D) | 3.7 | 0.9 | 0.8 | 0.1 |
| Sugar and confectionery products | 151 | 377.2 | 178.7 | 12.7 | 198.5 | 142.0 | 93.8 | 48.3 |
| Raw cane sugar | 35 | 198.9 | 83.1 | (D) | 115.8 | 63.0 | 40.1 | 23.0 |
| Cane sugar refining | 20 | 76.0 | 62.8 | (D) | 13.3 | 54.9 | 39.1 | 15.9 |
| Beet sugar | 37 | 65.3 | 14.6 | 0.9 | 50.7 | 9.6 | (D) | (D) |
| Confectionery products | 44 | (D) | (D) | 2.1 | 15.2 | (D) | (D) | (D) |
| Chocolate and cocoa products | 10 | (D) | (D) | 1.0 | 3.4 | (D) | (D) | 0.3 |
| Fats and oils | 154 | 103.3 | 34.1 | 10.4 | 69.2 | 28.9 | 18.4 | 10.6 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cottonseed oil mills | 18 | 2.8 | 1.2 | (D) | 1.5 | (D) | (D) | (D) |
| Soybean oil mills | 60 | 70.4 | 20.1 | (D) | 50.4 | 18.2 | 13.5 | 4.7 |
| Vegetable oil mills, n.e.c. | 5 | 0.8 | 0.5 | (D) | 0.3 | (D) | (D) | (D) |
| Animal and marine fats and oils | 31 | 6.3 | 2.8 | 0.5 | 3.6 | 1.5 | 0.8 | 8 |
| Shortening and cooking oils | 40 | 23.0 | 9.5 | 3.0 | 13.5 | 7.8 | 3.3 | 4.5 |
| Beverages | 406 | 308.7 | 88.5 | 46.9 | 220.3 | 68.2 | 50.9 | 17.3 |
| Malt beverages | 56 | (D) | 53.3 | 32.1 | (D) | 41.4 | 30.8 | 10.7 |
| Malt | 20 | 19.5 | 7.3 | 0.8 | 12.1 | 6.5 | 4.7 | 1.8 |
| Wines, brandy, and brandy spirits | 27 | 2.7 | 2.6 | 0.3 | 0.1 | 2.3 | 0.8 | 1.5 |
| Distilled liquor, except brandy | 28 | 17.2 | 10.3 | 1.5 | 6.9 | 9.0 | (D) | (D) |
| Bottled and canned soft drinks | 247 | 14.3 | 12.3 | 10.9 | 2.0 | 6.8 | 5.1 | 1.7 |
| Flavoring extracts and syrups, n.e.c. | 28 | (D) | 2.7 | 1.4 | (D) | 2.3 | (D) | (D) |
| Miscellaneous foods and kindred products | 211 | 71.9 | 32.6 | 20.9 | 39.3 | 26.5 | 20.6 | 5.9 |
| Canned and cured seafoods | 10 | (D) | 3.0 | (D) | (D) | (D) | (D) | (D) |
| Fresh or frozen packaged fish | 43 | 4.5 | 4.4 | (D) | 0.1 | 4.3 | 3.0 | 1.3 |
| Roasted coffee | 9 | (D) | (D) | — | 30.4 | (D) | (D) | (D) |
| Manufactured ice | 24 | (D) | 1.2 | 0.4 | (D) | 0.9 | 0.8 | 0.1 |
| Macaroni and spaghetti | 7 | (D) | 0.1 | 01 | (D) | (D) | (D) | — |
| Food preparations, n.e.c. | 118 | (D) | (D) | 8.7 | 8.5 | 11.3 | 7.4 | 3.8 |
| Tobacco products | 20 | 33.9 | 5.3 | (D) | 28.6 | 4.0 | (D) | (D) |
| Cigarettes | 11 | (D) | (D) | (D) | (D) | 3.1 | (D) | (D) |
| Textile mill products | 761 | 332.9 | 132.6 | 70.2 | 200.3 | 115.6 | 61.2 | 54.4 |
| Weaving mills, cotton | 69 | 70.9 | 20.7 | (D) | 50.2 | 17.9 | 13.2 | 4.7 |
| Weaving mills, manmade fiber and silk | 135 | 67.7 | 18.1 | 11.0 | 49.6 | 14.5 | 9.4 | 5.1 |
| Weaving and finishing mills, wool | 23 | 2.9 | 2.7 | 0.7 | 0.2 | 2.6 | (D) | (D) |
| Narrow fabric mills | 12 | 0.5 | 0.5 | (D) | 0.1 | 0.4 | (D) | (D) |
| Knitting mills | 191 | 48.2 | 27.2 | 20.6 | 21.0 | 25.3 | 15.9 | 9.3 |
| Women's hosiery, except socks | 11 | (D) | 0.7 | (D) | (D) | 0.7 | 0.7 | (Z) |
| Hosiery, n.e.c. | 20 | 2.8 | 0.9 | 08 | 1.9 | 0.8 | (D) | (D) |
| Knit outerwear mills | 23 | 2.6 | 2.2 | (D) | 0.4 | 2.1 | 1.5 | 0.7 |
| Knit underwear mills | 12 | (D) | 0.6 | (D) | (D) | 0.5 | (D) | (D) |
| Circular knit fabric mills | 89 | 26.2 | 17.2 | 13.0 | 9.0 | 16.2 | 9.9 | 6.3 |
| Warp knit fabric mills | 36 | (D) | 5.6 | 4.1 | (D) | 4.9 | 2.8 | 2.1 |
| Textile finishing, except wool | 125 | 62.3 | 39.0 | 15.4 | 23.3 | 33.6 | 11.5 | 22.1 |
| Finishing plants, cotton | 27 | 8.9 | 6.8 | 1.9 | 2.1 | 6.2 | 1.0 | 5.2 |
| Finishing plants, manmade | 69 | 45.4 | 26.9 | 9.2 | 18.5 | 22.5 | 7.6 | 14.9 |
| Finishing plants, n.e.c. | 29 | 8.1 | 5.4 | 4.2 | 2.7 | 4.8 | 2.8 | 2.0 |
| Floor covering mills | 65 | 14.1 | 11.3 | 8.8 | 2.8 | 9.8 | 4.7 | 5.1 |
| Tufted carpets and rugs | 61 | (D) | 10.4 | (D) | (D) | (D) | (D) | (D) |
| Carpets are rugs, n.e.c. | 4 | (D) | 1.0 | (D) | (D) | (D) | (D) | (D) |
| Yarn and thread mills | 77 | 40.5 | 8.1 | 5.7 | 32.4 | 7.4 | 4.0 | 3.3 |
| Yarn mills, except wool | 49 | 30.2 | 4.6 | 3.2 | 25.6 | 4.2 | 2.8 | 1.4 |
| Throwing and winding mills | 15 | (D) | 1.8 | 1.4 | (D) | 1.6 | 0.9 | 0.7 |
| Thread mills | 11 | (D) | (D) | 1.1 | (D) | 1.5 | 0.4 | 1.1 |
| Miscellaneous textile goods | 64 | 25.7 | 5.0 | 2.3 | 20.7 | 4.3 | 1.6 | 2.7 |
| Felt goods, except woven felts and hats | 10 | (D) | 1.4 | 0.2 | (D) | 1.4 | 0.1 | 1.2 |
| Processed textile waste | 4 | 0.2 | 0.2 | 0.2 | — | (D) | (D) | — |

*(Continued)*



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**Table 7G.73 (Continued)**

| Industry Group and Industry | Establishments Reporting Water Intake of 20 Mil Gal or More During 1982 | Gross Water Used[a] | | | | Water Discharged | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water Intake | | | | | |
| | | Total | Total | From Public Water System | Water Re-Circulated and Reused | Total | Untreated | Treated |
| Coated fabrics, not rubberized | 9 | (D) | 0.6 | 0.3 | (D) | 0.6 | (D) | (D) |
| Tire cord and fabric | 8 | (D) | 0.3 | (D) | (D) | 0.2 | (D) | (D) |
| Nonwoven fabrics | 22 | (D) | 1.5 | 1.1 | (D) | 1.0 | 0.6 | 0.5 |
| Textile goods, n.e.c. | 7 | (D) | (D) | 0.1 | (D) | (D) | (Z) | (D) |
| Lumber and wood products | 223 | 218.2 | 86.0 | (D) | 132.2 | 71.0 | 44.9 | 26.1 |
| Logging camps and logging contractors | 9 | (D) | 0.2 | 0.1 | (D) | 0.3 | (D) | (D) |
| Sawmills and planning mills | 89 | 168.5 | 68.4 | (D) | 100.1 | 58.9 | 39.4 | 19.5 |
| Sawmills and planning mills, general | 89 | 168.5 | 68.4 | (D) | 100.1 | 58.9 | 39.4 | 19.5 |
| Millwork, plywood, and structural members | 78 | 25.9 | 7.6 | 1.9 | 18.3 | 4.4 | (D) | (D) |
| Millwork | 3 | (D) | 0.4 | (Z) | (D) | 0.4 | (Z) | 0.3 |
| Hardwood veneer and plywood | 10 | 0.4 | 0.3 | 0.1 | 0.1 | 0.1 | (D) | (D) |
| Softwood veneer and plywood | 64 | (D) | 6.9 | 1.7 | (D) | 3.9 | (D) | (D) |
| Miscellaneous wood products | 42 | (D) | 9.6 | (D) | (D) | 7.3 | (D) | (D) |
| Wood preserving | 7 | 0.4 | (D) | — | (D) | (D) | (D) | (D) |
| Particleboard | 8 | (D) | (D) | (D) | (D) | (D) | (D) | (D) |
| Wood products, n.e.c. | 27 | 21.2 | 8.5 | 1.3 | 12.7 | 6.6 | (D) | (D) |
| **Furniture and fixtures** | 66 | 6.8 | 3.4 | 2.2 | 3.4 | 3.3 | 2.9 | 0.4 |
| Household furniture | 26 | 3.6 | 1.9 | (D) | 1.7 | 1.8 | (D) | (D) |
| Wood household furniture | 15 | 1.7 | 1.5 | (D) | 0.2 | 1.5 | (D) | (D) |
| Metal household furniture | 6 | (D) | 0.2 | 0.2 | (D) | 0.2 | (D) | (D) |
| Office furniture | 11 | (D) | 0.6 | (D) | (D) | 0.6 | 0.4 | 0.2 |
| Metal office furniture | 10 | (D) | 0.6 | (D) | (D) | 0.6 | 0.4 | 0.2 |
| Partitions and fixtures | 17 | (D) | 0.5 | 0.5 | (D) | 0.5 | (D) | (D) |
| Metal partitions and fixtures | 13 | (D) | (D) | (D) | (D) | (D) | (D) | (D) |
| Miscellaneous furniture and fixtures | 8 | (D) | (D) | (D) | (Z) | (D) | (D) | (D) |
| Drapery hardware and blinds and shades | 7 | (D) | (D) | (D) | (Z) | (D) | (D) | (D) |
| **Paper and allied products** | 600 | 7,435.8 | 1,899.3 | 257.3 | 5,536.5 | 1,768.1 | 479.0 | 1,289.1 |
| Pulp mills | 36 | 1,020.0 | 283.2 | 49.1 | 736.8 | 282.7 | 45.7 | 237.0 |
| Paper mills, except building paper | 234 | 3,908.6 | 1,009.5 | 92.1 | 2,899.0 | 958.2 | 304.3 | 653.9 |
| Paperboard mills | 151 | 2,353.9 | 538.7 | 107.2 | 1,815.2 | 462.3 | 85.4 | 377.0 |
| Miscellaneous converted paper products | 104 | 125.2 | 56.5 | (D) | 68.7 | 55.0 | 36.9 | 18.1 |
| Paper coating and glazing | 41 | 16.0 | 6.5 | (D) | 9.4 | 6.2 | 3.7 | 2.4 |
| Bags, except textile bags | 16 | 26.2 | 5.6 | (D) | 20.6 | 5.5 | (D) | (D) |
| Pressed and molded pulp goods | 11 | (D) | 32.1 | (D) | (D) | (D) | (D) | (D) |
| Sanitary paper products | 20 | (D) | 8.9 | (D) | (D) | 9.4 | (D) | (D) |
| Converted paper products, n.e.c. | 12 | (D) | 3.3 | (D) | (D) | 3.2 | (D) | (D) |
| Paperboard containers and boxes | 57 | 16.8 | 6.6 | (D) | 10.3 | 5.9 | 4.5 | 1.4 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Folding paperboard boxes | 17 | 6.2 | 4.1 | 04 | 2.1 | (D) | (D) | (D) |
| Corrugated and solid fiber boxes | 21 | 0.9 | 0.4 | 0.4 | 0.5 | 0.4 | 0.3 | 0.1 |
| Sanitary food containers | 14 | (D) | 0.9 | 0.4 | (D) | 0.9 | 0.8 | (Z) |
| Fiber cans, drums, and similar products | 5 | (D) | 1.1 | (D) | (D) | (D) | (D) | (D) |
| Building paper and board mills | 18 | 11.3 | 4.8 | (D) | 6.5 | 3.9 | 2.2 | 1.7 |
| **Chemicals and allied products** | 1,315 | 9,630.1 | 3,400.7 | 210.5 | 6,229.4 | 2,979.8 | 1,996.3 | 983.6 |
| Industrial inorganic chemicals | 301 | 2,164.0 | 885.0 | 57.0 | 1,279.6 | 758.4 | 556.3 | 202.1 |
| Alkalies and chlorine | 32 | 287.0 | 157.4 | (D) | 129.6 | 142.9 | 40.8 | 102.1 |
| Industrial gases | 76 | 492.4 | 18.6 | 8.9 | 473.8 | 11.9 | 7.3 | 4.6 |
| Inorganic pigments | 22 | 96.0 | 48.9 | (D) | 47.1 | 49.5 | 26.0 | 23.5 |
| Industrial inorganic chemicals, n.e.c. | 171 | 1,289.1 | 660.1 | 28.6 | 629.0 | 554.0 | 482.2 | 71.9 |
| Plastics materials and synthetics | 206 | 1,435.7 | 427.1 | 23.4 | 1,008.6 | 391.7 | 277.0 | 114.6 |
| Plastics materials and resins | 143 | 580.5 | 132.7 | 16.0 | 447.9 | 108.0 | 62.3 | 45.8 |
| Synthetic rubber | 22 | 236.6 | 62.9 | (D) | 173.7 | 58.5 | (D) | (D) |
| Cellulosic manmade fibers | 7 | 133.4 | 71.7 | (D) | 61.7 | 67.6 | (D) | (D) |
| Organic fibers, noncellulosic | 34 | 485.2 | 159.9 | 4.1 | 325.3 | 157.5 | 123.1 | 34.3 |
| Drugs | 112 | 240.1 | 90.5 | 19.9 | 149.6 | 87.1 | 55.8 | 31.3 |
| Biological products | 17 | 3.3 | 0.8 | 0.8 | 2.5 | 0.5 | 0.3 | 0.2 |
| Medicinals and botanicals | 23 | 122.9 | 55.3 | 5.3 | 67.7 | 54.9 | (D) | (D) |
| Pharmaceutical preparations | 72 | 113.8 | 34.4 | 13.9 | 79.4 | 31.6 | (D) | (D) |
| Soaps, cleaners, and toilet goods | 108 | 103.6 | 64.8 | 8.5 | 38.8 | 61.2 | 53.7 | 7.5 |
| Soap and other detergents | 32 | 42.0 | 16.6 | 4.3 | 25.4 | 14.3 | (D) | (D) |
| Polishes and sanitation goods | 22 | (D) | (D) | (D) | (D) | 3.8 | (D) | (D) |
| Surface active agents | 25 | (D) | (D) | 1.3 | 8.0 | (D) | (D) | (D) |
| Toilet preparations | 29 | (D) | 2.3 | (D) | (D) | (D) | (D) | (D) |
| Paints and allied products | 41 | 3.5 | 2.1 | 1.5 | 1.4 | 2.1 | 1.7 | 0.3 |
| Industrial organic chemicals | 296 | 4,122.3 | 1,515.9 | 78.6 | 2,606.4 | 1,381.0 | 815.2 | 565.8 |
| Gum and wood chemicals | 10 | (D) | (D) | (D) | 21.3 | 6.5 | (D) | (D) |
| Cyclic crudes and intermediates | 75 | (D) | (D) | 7.0 | 287.2 | 30.9 | (D) | (D) |
| Industrial organic chemicals, n.e.c. | 211 | 3,765.5 | 1,467.6 | (D) | 2,297.9 | 1,343.5 | 798.5 | 545.0 |
| Agricultural chemicals | 116 | 1,381.4 | 305.0 | 14.5 | 1,076.4 | 202.7 | 154.6 | 48.1 |
| Nitrogenous fertilizers | 59 | 757.4 | 70.5 | 12.1 | 686.9 | 45.2 | (D) | (D) |
| Phosphatic fertilizers | 34 | 559.0 | 216.1 | (D) | 342.9 | 142.2 | (D) | (D) |
| Agricultural chemicals, n.e.c. | 18 | 64.9 | 18.4 | (D) | 46.5 | 15.3 | (D) | (D) |
| Miscellaneous chemical products | 135 | 178.9 | 110.3 | 7.1 | 68.6 | 95.7 | 82.0 | 13.7 |
| Adhesives and sealants | 31 | (D) | (D) | 0.6 | (D) | (D) | (D) | 0.9 |
| Explosives | 13 | 53.4 | (D) | — | (D) | (D) | (D) | (D) |
| Carbon black | 14 | (D) | 1.6 | (D) | (D) | 0.3 | (D) | (D) |
| Chemical preparations, n.e.c. | 73 | 93.6 | 63.3 | 5.8 | 30.3 | 52.4 | (D) | (D) |
| **Petroleum and coal products** | 260 | 6,177.3 | 818.4 | 137.7 | 5,358.9 | 699.3 | 323.4 | 375.9 |
| Petroleum refining | 202 | 6,170.3 | 814.4 | 135.9 | 5,355.9 | 695.1 | 321.0 | 374.1 |
| Paving and roofing materials | 39 | 4.9 | 2.6 | 1.0 | 2.3 | 3.3 | (D) | (D) |
| Paving mixtures and blocks | 15 | 1.8 | 0.8 | (D) | 1.0 | 1.9 | (D) | (D) |
| Asphalt felts and coatings | 24 | 3.0 | 1.8 | (D) | 1.3 | 1.4 | (D) | (D) |
| Miscellaneous petroleum and coal products | 19 | 2.2 | 1.4 | 0.8 | 0.7 | 0.9 | (D) | (D) |
| Lubricating oils and greases | 7 | (D) | 0.2 | 0.2 | (D) | 0.1 | (D) | (D) |
| Petroleum and coal products, n.e.c. | 12 | (D) | 1.3 | 0.6 | (D) | 07 | (D) | (D) |

*(Continued)*



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**Table 7G.73 (Continued)**

| Industry Group and Industry | Establishments Reporting Water Intake of 20 Mil Gal or More During 1982 | Gross Water Used[a] | | | | Water Discharged | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water Intake | | | | | |
| | | Total | Total | From Public Water System | Water Re-Circulated and Reused | Total | Untreated | Treated |
| **Rubber and miscellaneous plastics products** | 375 | 327.8 | 76.0 | 27.4 | 251.8 | 62.6 | 39.8 | 22.8 |
| Tires and inner tubes | 47 | 121.5 | (D) | 4.2 | (D) | 16.5 | 8.2 | 8.3 |
| Rubber and plastics footwear | 3 | 0.1 | 0.1 | (Z) | (Z) | 0.1 | 0.1 | (Z) |
| Rubber and plastics hose and belting | 24 | 58.0 | (D) | 3.0 | (D) | 5.0 | (D) | (D) |
| Fabricated rubber products, n.e.c. | 82 | 26.8 | 8.3 | 4.6 | 18.4 | 7.4 | (D) | (D) |
| Miscellaneous plastics products | 219 | 121.4 | 41.9 | 15.6 | 79.5 | 33.6 | 22.9 | 10.8 |
| **Leather and leather products** | 69 | 6.5 | 6.1 | 2.7 | 0.4 | 5.7 | (D) | (D) |
| Leather tanning and finishing | 65 | (D) | (D) | (D) | 0.4 | (D) | (D) | (D) |
| **Stone, clay, and glass products** | 602 | 336.7 | 154.7 | 24.0 | 181.9 | 132.8 | 99.5 | 33.3 |
| Flat glass | 16 | 20.9 | 4.8 | (D) | 16.0 | 4.7 | (D) | (D) |
| Glass and glassware, pressed or blown | 120 | 92.2 | 13.3 | 8.7 | 78.9 | 11.4 | 7.1 | 4.3 |
| Glass containers | 75 | 38.3 | 7.1 | 4.0 | 31.2 | 5.9 | 3.8 | 2.1 |
| Pressed and blown glass, n.e.c. | 45 | 53.9 | 6.2 | 4.7 | 47.7 | 5.5 | 3.3 | 2.2 |
| Products of purchased glass | 26 | (D) | 7.2 | (D) | (D) | 7.1 | (D) | (D) |
| Cement, hydraulic | 100 | 115.2 | 80.0 | 2.4 | 35.2 | 68.7 | 58.6 | 10.1 |
| Structural clay products | 10 | (D) | 1.4 | 0.8 | (D) | 0.7 | 0.5 | 0.2 |
| Ceramic wall and floor tile | 4 | (D) | (D) | — | (D) | (D) | (D) | (D) |
| Clay refractories | 5 | (D) | (D) | — | (D) | (D) | (D) | (D)/ |
| Pottery and related products | 30 | 2.1 | 1.5 | 1.1 | 0.6 | 1.1 | 0.5 | 0.6 |
| Vitreous plumbing fixtures | 9 | (D) | 0.5 | 0.3 | (D) | 0.4 | 0.1 | 0.3 |
| Vitreous china food utensils | 5 | 0.4 | 0.3 | 0.3 | 0.1 | 0.3 | 0.1 | 0.2 |
| Porcelain electrical supplies | 11 | 0.9 | 0.6 | 0.4 | 0.3 | 0.4 | 0.3 | 0.2 |
| Concrete, gypsum, and plaster products | 160 | 16.7 | 10.8 | 2.7 | 5.8 | 6.5 | 3.9 | 2.7 |
| Concrete products, n.e.c. | 20 | (D) | (D) | 0.1 | (D) | 0.3 | (D) | (D) |
| Ready-mixed concrete | 65 | 4.5 | 2.1 | 0.7 | 2.4 | 1.5 | 1.0 | 0.4 |
| Lime | 23 | 7.0 | 4.3 | (D) | 2.8 | 3.2 | (D) | (D) |
| Gypsum products | 51 | 4.3 | 3.7 | (D) | 0.6 | 1.5 | 1.0 | 0.5 |
| Cut stone and stone products | 15 | (D) | 1.1 | 0.5 | (D) | 1.1 | (D) | (D) |
| Miscellaneous nonmetallic mineral products | 125 | 70.4 | 34.5 | (D) | 35.9 | 31.5 | 22.7 | 8.7 |
| Abrasive products | 17 | (D) | 3.5 | 1.0 | (D) | 3.5 | 2.6 | 0.9 |
| Asbestos products | 13 | 8.2 | 1.8 | 0.8 | 6.3 | 1.4 | 1.0 | 0.3 |
| Gaskets, packing, and sealing devices | 12 | 3.6 | 1.8 | 0.5 | 1.7 | 0.9 | 0.6 | 0.2 |
| Minerals, ground or treated | 22 | 22.2 | 18.7 | 0.8 | 3.5 | 18.8 | (D) | (D) |
| Mineral wool | 42 | 27.4 | 6.2 | (D) | 21.2 | 4.4 | 2.7 | 1.7 |
| Nonclay refractories | 12 | 2.4 | 2.0 | 0.3 | 0.3 | 2.0 | (D) | (D) |
| Nonmetallic mineral products, n.e.c. | 7 | (D) | 0.5 | (D) | (D) | 0.5 | (D) | (D) |
| **Primary metal industries** | 776 | 5,885.2 | 2,362.5 | 108.7 | 3,522.8 | 2,112.0 | 1,227.9 | 884.1 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Blast furnace and basic steel products | 259 | 4,990.5 | 2,077.6 | 62.2 | 2,912.9 | 1,868.1 | 1,113.7 | 754.3 |
| Blast furnaces and steel mills | 137 | 4,908.4 | 2,038.9 | 53.9 | 2,869.5 | 1,.829.8 | 1,090.9 | 739.0 |
| Electrometallurgical products | 13 | 11.3 | 1.2 | 0.4 | 10.1 | 1.5 | (D) | (D) |
| Steel wire and related products | 34 | 4.5 | 2.1 | 1.4 | 2.5 | 2.1 | (D) | (D) |
| Cold finishing of steel shapes | 32 | 18.0 | 11.3 | 1.4 | 6.7 | 11.0 | 5.8 | 5.2 |
| Steel pipe and tubes | 43 | 48.3 | 24.1 | 5.2 | 24.1 | 23.7 | (D) | (D) |
| Iron and steel foundries | 154 | 218.1 | 69.1 | 22.6 | 149.0 | 51.5 | 24.2 | 27.3 |
| Gray iron foundries | 93 | 200.8 | 63.0 | 18.8 | 137.8 | 45.7 | 18.7 | 27.0 |
| Malleable iron foundries | 7 | (D) | (D) | 1.4 | (D) | 1.4 | 1.4 | — |
| Steel investment foundries | 10 | (D) | (D) | 0.4 | (D) | 0.5 | (D) | (D) |
| Steel foundries, n.e.c. | 44 | 7.4 | 4.2 | 2.0 | 3.2 | 3.9 | (D) | (D) |
| Primary nonferrous metals | 71 | 417.1 | 125.6 | 3.6 | 291.4 | 111.6 | 51.6 | 60.0 |
| Primary copper | 20 | 77.0 | (D) | (D) | (D) | 10.6 | 8.0 | 2.5 |
| Primary lead | 5 | 5.1 | 0.7 | (D) | 4.4 | 0.3 | (D) | (D) |
| Primary zinc | 5 | 18.7 | 7.2 | 0.5 | 11.5 | (D) | (D) | (D) |
| Primary aluminum | 24 | (D) | 67.8 | 1.1 | (D) | 62.9 | (D) | (D) |
| Primary nonferrous metals, n.e.c. | 17 | (D) | (D) | 0.5 | 0.8 | (D) | (D) | (D) |
| Secondary nonferrous metals | 34 | 13.5 | 3.7 | 1.3 | 9.8 | 3.1 | 2.2 | 0.9 |
| Nonferrous rolling and drawing | 170 | 213.2 | 79.9 | 15.7 | 133.3 | 71.4 | 32.9 | 38.6 |
| Copper rolling and drawing | 29 | 43.8 | 18.6 | 5.2 | 25.2 | 14.8 | 8.0 | 6.8 |
| Aluminum sheet, plate, and foil | 23 | 93.5 | 37.0 | 2.1 | 56.4 | 34.6 | 12.4 | 22.2 |
| Aluminum extruded products | 40 | 9.1 | 3.9 | 2.6 | 5.3 | 3.7 | 2.1 | 1.6 |
| Aluminum rolling and drawing, n.e.c. | 6 | 12.0 | 7.1 | 0.5 | 4.9 | 6.9 | 3.6 | 3.3 |
| Nonferrous rolling and drawing, n.e.c. | 26 | 30.6 | 6.6 | 3.0 | 24.0 | 4.9 | 1.5 | 3.4 |
| Nonferrous wire drawing and insulating | 46 | 24.3 | 6.8 | 2.5 | 17.5 | 6.5 | 5.3 | 1.2 |
| Nonferrous foundries | 46 | 15.5 | 2.4 | 1.6 | 13.1 | 2.2 | 1.1 | 1.1 |
| Aluminum foundries | 29 | 14.2 | 1.7 | 1.2 | 12.5 | (D) | (D) | (D) |
| Brass, bronze, and copper foundries | 6 | (D) | 0.2 | (D) | (D) | (D) | (D) | (D) |
| Nonferrous foundries, n.e.c. | 11 | (D) | 0.5 | (D) | (D) | 0.5 | 0.1 | 0.4 |
| Miscellaneous primary metal products | 42 | 17.3 | 4.1 | 1.8 | 13.2 | 4.0 | 2.1 | 1.9 |
| Metal heat treating | 28 | 1.9 | 1.5 | 1.3 | 0.4 | 1.5 | 0.5 | 1.0 |
| Primary metal products, n.e.c. | 14 | 15.4 | 2.6 | 0.4 | 12.8 | 2.6 | 1.6 | 1.0 |
| **Fabricated metal products** | 724 | 257.9 | 65.4 | 38.1 | 192.5 | 61.4 | 29.7 | 31.7 |
| Metal cans and shipping containers | 89 | 62.1 | 6.6 | 5.6 | 55.5 | 6.0 | 1.5 | 4.4 |
| Metal cans | 80 | (D) | 6.2 | 5.2 | (D) | 5.6 | (D) | (D) |
| Metal barrels, drums, and pails | 9 | (D) | 0.4 | 0.4 | (D) | 0.4 | (D) | (D) |
| Cutlery, hand tools, and hardware | 72 | 30.8 | 14.9 | 4.0 | 15.8 | 14.5 | (D) | (D) |
| Cutlery | 4 | (D) | (D) | 0.2 | (D) | (D) | (D) | (D) |
| Hand and edge tools, n.e.c. | 28 | (D) | 1.0 | 0.8 | (D) | 0.9 | (D) | (D) |
| Hand saws and saw blades | 4 | (D) | 0.4 | (D) | (D) | (D) | (D) | (D) |
| Hardware, n.e.c. | 36 | (D) | (D) | (D) | (D) | 2.9 | 1.2 | 1.7 |
| Plumbing and heating, except electric | 25 | 3.7 | 3.0 | 2.5 | 0.7 | 3.0 | (D) | (D) |
| Metal sanitary ware | 6 | (D) | 0.6 | (D) | (D) | 0.7 | (D) | (D) |
| Plumbing fittings and brass goods | 12 | (D) | 2.1 | (D) | (D) | 2.1 | (D) | (D) |
| Heating equipment, except electric | 7 | (D) | 0.3 | 0.3 | (D) | 0.2 | 0.2 | — |
| Fabricated structural metal product | 76 | 28.3 | 7.0 | 4.4 | 21.4 | 6.0 | 3.8 | 2.2 |
| Fabricated structural metal | 11 | (D) | 1.2 | (D) | (D) | 1.1 | (D) | (D) |

*(Continued)*



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**Table 7G.73 (Continued)**

| Industry Group and Industry | Establishments Reporting Water Intake of 20 Mil Gal or More During 1982 | Gross Water Used[a] | | | | Water Discharged | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water Intake | | | | | |
| | | Total | Total | From Public Water System | Water Re-Circulated and Reused | Total | Untreated | Treated |
| Metal doors, sash, and trim | 10 | (D) | 0.6 | 0.6 | (D) | 0.6 | 0.2 | 0.3 |
| Fabricated plate work (boiler shops) | 30 | 22.2 | 4.0 | 2.6 | 18.2 | 3.3 | 1.7 | 1.6 |
| Sheet metal work | 11 | 0.7 | 0.3 | 0.2 | 0.4 | 0.3 | 0.2 | 0.1 |
| Prefabricated metal buildings | 5 | (D) | (D) | (D) | — | (D) | (D) | (D) |
| Miscellaneous metal work | 8 | 1.6 | 0.6 | — | 1.0 | 0.6 | (D) | (D) |
| Screw machine products, bolts, etc. | 49 | 8.4 | 2.8 | 1.8 | 5.6 | 2.7 | 1.6 | 1.1 |
| Screw machine products | 5 | (D) | 0.1 | 0.1 | (D) | 0.1 | (D) | (D) |
| Bolts, nuts, rivets, and washers | 44 | (D) | 2.7 | 1.7 | (D) | 2.6 | (D) | (D) |
| Metal forgings and stampings | 122 | 81.5 | 10.1 | 8.0 | 71.5 | 9.7 | 7.7 | 2.1 |
| Iron and steel forgings | 36 | 12.0 | 2.8 | 2.3 | 9.2 | 2.8 | 1.9 | 0.9 |
| Nonferrous forgings | 6 | 3.7 | 1.4 | 1.4 | 2.3 | 1.4 | 1.1 | 0.3 |
| Automotive stampings | 42 | 62.4 | 3.3 | 2.8 | 59.2 | 3.0 | (D) | (D) |
| Crowns and closures | 4 | 0.3 | 0.3 | (D) | — | 0.3 | (D) | (D) |
| Metal stampings, n.e.c. | 34 | 3.1 | 2.3 | (D) | 0.8 | 2.2 | 1.7 | 0.5 |
| Metal services, n.e.c. | 138 | 7.8 | 6.9 | 4.8 | 1.0 | 6.7 | 2.9 | 3.8 |
| Plating and polishing | 126 | (D) | 6.0 | (D) | (D) | 5.8 | 2.6 | 3.2 |
| Metal coating and allied services | 12 | (D) | 0.9 | (D) | (D) | 0.9 | 0.3 | 0.5 |
| Ordnance and accessories, n.e.c. | 35 | 9.5 | 6.7 | 2.7 | 2.8 | 6.0 | 3.5 | 2.6 |
| Small arms ammunition | 7 | (D) | 1.4 | (D) | (D) | 1.2 | (D) | (D) |
| Ammunition, except for small arms, n.e.c. | 14 | (D) | 2.2 | (D) | (D) | 2.0 | 0.7 | 1.3 |
| Small arms | 6 | (D) | 0.8 | (D) | (D) | 0.8 | (D) | (D) |
| Ordnance and accessories, n.e.c. | 8 | (D) | 2.3 | 1.7 | (D) | 2.0 | 1.6 | 0.4 |
| Miscellaneous fabricated metal products | 118 | 25.8 | 7.5 | 4.3 | 18.3 | 6.8 | (D) | (D) |
| Steel springs, except wire | 4 | (D) | 0.2 | 0.2 | (D) | (D) | (D) | (D) |
| Valves and pipe fittings | 54 | 10.4 | 2.9 | 2.0 | 7.4 | 2.8 | 2.1 | 0.7 |
| Wire springs | 4 | 0.9 | 0.1 | 0.1 | 0.8 | 0.1 | (D) | (D) |
| Miscellaneous fabricated wire products | 8 | (D) | 0.2 | 0.2 | (D) | 0.2 | (D) | (D) |
| Metal foil and leaf | 11 | (D) | 1.7 | (D) | (D) | 1.4 | 1.0 | 0.4 |
| Fabricated pipe and fittings | 9 | 0.2 | 0.2 | 0.1 | (Z) | (D) | (D) | (D) |
| Fabricated metal products, n.e.c. | 28 | (D) | 2.2 | (D) | (D) | 2.1 | (D) | (D) |
| **Machinery, except electrical** | 523 | 306.5 | 120.0 | 52.5 | 186.4 | 104.9 | 71.2 | 33.8 |
| Engines and turbines | 47 | 66.2 | 32.0 | (D) | 34.1 | 20.7 | 12.8 | 7.9 |
| Internal combustion engines, n.e.c. | 35 | (D) | (D) | 3.8 | (D) | (D) | (D) | (D) |
| Farm and garden machinery | 41 | 40.1 | 32.8 | (D) | 7.3 | 32.0 | (D) | (D) |
| Farm machinery and equipment | 28 | 39.2 | 32.1 | (D) | 7.1 | 31.3 | (D) | (D) |
| Lawn and garden equipment | 13 | 0.9 | 0.7 | (D) | 0.2 | 0.7 | (D) | (D) |
| Construction and related machinery | 69 | 51.2 | 11.4 | 3.5 | 39.8 | 11.8 | 6.8 | 5.1 |
| Construction machinery | 31 | 42.6 | 10.3 | (D) | 32.3 | 10.8 | 6.2 | 4.6 |
| Mining machinery | 8 | 0.3 | (D) | (D) | (D) | 0.1 | 0.1 | (Z) |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Oil field machinery | 21 | (D) | 0.8 | (D) | (D) | (D) | (D) | (D) |
| Metalworking machinery | 57 | (D) | 4.0 | 1.8 | (D) | 3.7 | 3.6 | 0.2 |
| Machine tools, metal cutting types | 22 | 3.2 | 3.0 | (D) | 0.2 | 2.7 | (D) | (D) |
| Machine tools, metal forming types | 3 | (D) | (D) | — | — | (D) | (D) | — |
| Special dies, tools, jigs, and fixtures | 6 | (D) | 0.2 | 0.2 | (D) | (D) | (D) | — |
| Machine tool accessories | 14 | (D) | (D) | — | (D) | 0.4 | (D) | (D) |
| Power driven hand tools | 10 | (D) | 0.3 | 0.2 | (D) | 0.3 | 0.2 | 0.1 |
| Special industry machinery | 36 | (D) | 6.4 | (D) | (D) | 6.2 | (D) | (D) |
| Food products machinery | 9 | (D) | (D) | — | (Z) | 0.3 | 0.2 | (Z) |
| Paper industries machinery | 5 | (D) | (D) | (D) | 0.2 | 0.1 | 0.1 | (Z) |
| Printing trades machinery | 4 | (D) | (D) | — | (D) | 0.1 | (D) | (D) |
| Special industry machinery, n.e.c. | 13 | (D) | (D) | 0.3 | (D) | (D) | (D) | (D) |
| General industrial machinery | 101 | 38.5 | 7.1 | 4.1 | 31.4 | 6.1 | 4.7 | 1.4 |
| Pumps and pumping equipment | 26 | (D) | 1.6 | 0.8 | (D) | 1.5 | 1.2 | 0.3 |
| Ball and roller bearings | 22 | 26.5 | 2.6 | 1.4 | 23.9 | 2.4 | 1.7 | 0.7 |
| Air and gas compressors | 15 | (D) | 1.4 | 1.0 | (D) | 0.7 | (D) | (D) |
| Blowers and fans | 9 | (D) | (D) | — | 0.1 | (D) | (D) | (Z) |
| Speed changers, drives, and gears | 5 | (D) | 0.4 | (D) | (D) | 0.4 | (D) | (D) |
| Power transmission equipment, n.e.c. | 15 | 1.1 | 0.7 | 0.3 | 0.4 | 0.7 | (D) | (D) |
| General industrial machinery, n.e.c. | 7 | (D) | 0.2 | 0.2 | (D) | 0.2 | (D) | (D) |
| Office and computing machines | 71 | 39.7 | 15.0 | 6.0 | 24.7 | 13.3 | 12.0 | 1.3 |
| Electronic computing equipment | 57 | (D) | (D) | — | (D) | 12.3 | (D) | (D) |
| Office machines, n.e.c. and typewriters | 12 | (D) | (D) | — | (D) | (D) | (D) | (D) |
| Refrigeration and service machinery | 70 | 32.5 | 9.6 | 8.7 | 23.0 | 9.6 | (D) | (D) |
| Refrigeration and heating equipment | 61 | (D) | 9.2 | 8.4 | (D) | 9.3 | (D) | (D) |
| Measuring and dispensing pumps | 4 | (D) | 0.2 | 0.2 | (D) | 0.2 | 0.2 | — |
| Service industry machinery, n.e.c. | 3 | (D) | (D) | — | — | 0.1 | 0.1 | — |
| Miscellaneous machinery, except electrical | 31 | 18.3 | 1.7 | (D) | 16.5 | 1.5 | 0.8 | 0.7 |
| Carburetors, pistons, rings, valves | 18 | 17.8 | 1.5 | (D) | 16.3 | 1.3 | 0.6 | 0.7 |
| Machinery, except electrical, n.e.c. | 13 | 0.5 | 0.2 | (D) | 0.2 | 0.2 | 0.2 | (Z) |
| **Electric and electronic equipment** | 678 | 334.8 | 74.1 | 55.1 | 260.7 | 70.3 | 42.5 | 27.8 |
| Electric distributing equipment | 43 | (D) | 3.4 | 3.2 | (D) | 4.7 | (D) | (D) |
| Transformers | 14 | (D) | 1.6 | (D) | (D) | 2.9 | (D) | (D) |
| Switchgear and switchboard apparatus | 29 | 3.3 | 1.9 | (D) | 1.4 | 1.8 | (D) | (D) |
| Electrical industrial apparatus | 76 | 18.5 | 9.5 | 6.6 | 9.1 | 9.4 | 7.4 | 1.9 |
| Motors and generators | 30 | 6.7 | 4.8 | (D) | 2.0 | 5.0 | 4.5 | 0.5 |
| Industrial controls | 18 | (D) | (D) | — | (D) | 0.6 | 0.5 | 0.1 |
| Welding apparatus, electric | 6 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | (Z) |
| Carbon and graphite products | 19 | 9.8 | 3.8 | 3.6 | 6.1 | 3.5 | 2.2 | 1.3 |
| Electrical industrial apparatus, n.e.c. | 3 | (D) | (D) | (D) | (D) | 0.1 | 0.1 | — |
| Household appliances | 75 | 24.1 | 9.4 | 8.8 | 14.7 | 9.1 | 5.7 | 3.4 |
| Household cooking equipment | 15 | 2.8 | 1.8 | 1.5 | 1.0 | 1.7 | (D) | (D) |
| Household refrigerators and freezers | 11 | (D) | 2.6 | (D) | (D) | 2.5 | (D) | (D) |
| Household laundry equipment | 10 | 4.5 | 2.1 | 2.1 | 2.3 | 2.2 | 1.4 | 0.9 |
| Electric housewares and fans | 17 | 1.6 | 1.0 | (D) | 0.6 | 0.9 | 0.8 | 0.2 |
| Household vacuum cleaners | 4 | (D) | (D) | — | (D) | 0.2 | 0.1 | 0.1 |
| Household appliances, n.e.c. | 15 | (D) | 1.5 | 1.5 | (D) | 1.5 | 1.1 | 0.4 |

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**Table 7G.73 (Continued)**

| Industry Group and Industry | Establishments Reporting Water Intake of 20 Mil Gal or More During 1982 | Gross Water Used[a] | | | | Water Discharged | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water Intake | | | | | |
| | | Total | Total | From Public Water System | Water Re-Circulated and Reused | Total | Untreated | Treated |
| **Electric lighting and wiring equipment** | 75 | 17.8 | 6.9 | 4.2 | 10.9 | 6.0 | 4.3 | 1.7 |
| Electric lamps | 15 | 1.2 | (D) | — | (D) | 0.8 | 0.6 | 0.1 |
| Current-carrying wiring devices | 15 | 2.7 | 2.1 | 1.4 | 0.5 | 2.1 | 1.7 | 0.4 |
| Noncurrent-carrying wiring devices | 20 | 2.8 | 1.7 | 1.2 | 1.1 | 1.6 | 1.0 | 0.6 |
| Residential lighting fixtures | 10 | 0.4 | 0.3 | 0.3 | 0.1 | 0.3 | 0.2 | 0.1 |
| Commercial lighting fixtures | 5 | (D) | 0.1 | 0.1 | (D) | 0.1 | (D) | (D) |
| Lighting equipment, n.e.c. | 4 | (D) | 0.2 | 0.2 | (D) | (D) | (Z) | (D) |
| Radio and TV receiving equipment | 22 | (D) | 2.3 | (D) | (D) | 2.4 | (D) | (D) |
| Radio and TV receiving sets | 12 | 2.6 | 1.7 | (D) | 0.8 | 1.8 | (D) | (D) |
| Phonograph records and prerecorded tape | 10 | (D) | 0.6 | (D) | (D) | 0.5 | (D) | (D) |
| Communication equipment | 122 | 61.4 | 13.3 | 9.1 | 48.1 | 11.7 | 8.3 | 3.5 |
| Telephone and telegraph apparatus | 26 | 9.2 | 3.5 | 2.3 | 5.7 | 3.2 | 2.0 | 1.3 |
| Radio and TV communication equipment | 96 | 52.2 | 9.8 | 6.8 | 42.4 | 8.5 | 6.3 | 2.2 |
| Electronic components and accessories | 193 | 166.0 | 23.6 | 17.6 | 142.4 | 21.9 | 10.3 | 11.6 |
| Electron tubes, all types | 19 | (D) | 2.8 | (D) | (D) | 2.6 | 1.8 | 0.8 |
| Semiconductors and related devices | 65 | 78.0 | 11.6 | 9.6 | 66.4 | 10.7 | 3.3 | 7.3 |
| Electronic capacitors | 12 | (D) | 3.0 | 0.5 | (D) | 2.9 | 2.4 | 0.6 |
| Electronic resistors | 8 | (D) | 0.4 | (D) | (D) | 0.4 | (D) | (D) |
| Electronic connectors | 21 | 1.5 | 1.4 | 0.7 | 0.2 | 1.2 | (D) | (D) |
| Electronic components, n.e.c. | 68 | 63.3 | 4.6 | 4.1 | 58.7 | 4.2 | 1.8 | 2.4 |
| Miscellaneous electrical equipment and supplies | 72 | 26.7 | 5.6 | (D) | 21.0 | 5.1 | (D) | (D) |
| Storage batteries | 36 | (D) | 1.9 | (D) | (D) | 1.5 | 0.7 | 0.8 |
| X-ray electromedical, and electrotherapeutic apparatus | 8 | 0.6 | 0.4 | 0.4 | 0.3 | (D) | (D) | (D) |
| Engine electrical equipment | 13 | 17.0 | 2.7 | (D) | 14.2 | 2.7 | (D) | (D) |
| Electrical equipment and supplies, n.e.c. | 7 | (D) | (D) | — | (D) | 0.2 | 0.2 | (Z) |
| **Transportation equipment** | 380 | 1,011.3 | 152.8 | 82.3 | 858.6 | 139.2 | 94.0 | 45.2 |
| Motor vehicles and equipment | 194 | (D) | 66.4 | 42.8 | (D) | 59.6 | 30.7 | 28.9 |
| Motor vehicles and car bodies | 55 | (D) | 22.6 | (D) | (D) | 21.0 | (D) | (D) |
| Truck and bus bodies | 6 | (D) | (D) | — | (D) | 0.2 | (D) | (D) |
| Motor vehicle parts and accessories | 130 | 229.7 | 43.5 | 22.0 | 186.2 | 38.4 | 19.2 | 19.2 |
| Aircraft and parts | 93 | (D) | 58.4 | (D) | (D) | 54.1 | 43.6 | 10.5 |
| Aircraft | 26 | 54.2 | 18.0 | (D) | 36.2 | (D) | (D) | 2.8 |
| Aircraft engines and engine parts | 34 | (D) | (D) | 6.9 | (D) | (D) | (D) | (D) |
| Aircraft equipment, n.e.c. | 33 | (D) | (D) | 4.2 | 21.5 | 4.5 | (D) | (D) |
| Ship and boat building and repairing | 30 | 27.6 | 16.3 | (D) | 11.3 | 15.8 | 12.6 | 3.2 |
| Ship building and repairing | 30 | 27.6 | 16.3 | (D) | 11.3 | 15.8 | 12.6 | 3.2 |
| Railroad equipment | 16 | 8.1 | 3.1 | 2.4 | 5.0 | 2.8 | 1.8 | 1.0 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Motorcycles, bicycles, and parts | 3 | 5.0 | 1.0 | 0.9 | 4.0 | 0.9 | 0.6 | 0.3 |
| Guided missiles and space vehicles, parts | 34 | 30.2 | 6.5 | 6.0 | 23.8 | 4.9 | 4.0 | 0.9 |
| Guided missiles and space vehicles | 17 | 19.7 | 2.8 | (D) | 16.9 | 2.2 | 1.8 | 0.4 |
| Space propulsion units and parts | 12 | 5.2 | 3.3 | (D) | 1.9 | 2.3 | 1.9 | 0.5 |
| Space vehicle equipment, n.e.c. | 5 | 5.4 | 0.4 | 0.4 | 4.9 | 0.4 | 0.3 | (Z) |
| Miscellaneous transportation equipment | 10 | 5.3 | 1.2 | 0.9 | 4.1 | 1.1 | 0.7 | 0.3 |
| Tanks and tank components | 5 | 5.2 | 1.1 | 0.8 | 4.1 | 1.0 | 0.7 | 0.3 |
| Transportation equipment, n.e.c. | 4 | (D) | (D) | — | — | (Z) | (Z) | (Z) |
| Instruments and related products | 154 | 112.0 | 29.8 | 9.8 | 82.3 | 27.6 | 13.6 | 13.9 |
| Engineering and scientific instruments | 5 | (D) | 0.2 | (D) | (D) | 0.2 | (D) | (D) |
| Measuring and controlling devices | 57 | 21.6 | 4.2 | 3.2 | 17.4 | 3.8 | 2.6 | 1.2 |
| Environmental controls | 10 | (D) | 1.0 | (D) | (D) | 1.0 | (D) | (D) |
| Process control instruments | 12 | (D) | 0.8 | (D) | (D) | 0.7 | (D) | (D) |
| Fluid meters and counting devices | 11 | (D) | 0.4 | 0.3 | (D) | 0.3 | 0.3 | (Z) |
| Instruments to measure electricity | 14 | (D) | 1.7 | 1.3 | (D) | 1.5 | 0.7 | 0.9 |
| Measuring and controlling devices, n.e.c. | 10 | (D) | 0.3 | (D) | (D) | 0.3 | 0.2 | 0.1 |
| Optical instruments and lenses | 15 | 2.1 | (D) | — | (D) | 0.4 | (D) | (D) |
| Medical instruments and supplies | 40 | 4.2 | 2.2 | (D) | 2.0 | 2.1 | 1.5 | 0.5 |
| Surgical and medical instruments | 16 | (D) | (D) | — | (D) | 0.8 | (D) | (D) |
| Surgical appliances and supplies | 23 | (D) | 1.4 | 1.4 | (D) | 1.3 | (D) | (D) |
| Photographic equipment and supplies | 25 | 77.7 | 17.3 | (D) | 60.4 | 15.7 | (D) | (D) |
| Watches, clocks, and watchcases | 5 | (D) | (D) | — | (D) | (D) | (D) | (D) |
| Miscellaneous manufacturing industries | 80 | 15.4 | 4.3 | 3.4 | 11.1 | 4.0 | (D) | (D) |
| Toys and sporting goods | 28 | (D) | 1.5 | 1.3 | (D) | 1.4 | 1.2 | 0.2 |
| Games, toys, and children's vehicles | 13 | (D) | (D) | — | (D) | 0.4 | (D) | (D) |
| Sporting and athletic goods, n.e.c. | 14 | (D) | 1.0 | 1.0 | (D) | 0.9 | (D) | (D) |
| Pens, pencils, and office and art supplies | 8 | (D) | 0.6 | 0.3 | (D) | 0.6 | 0.6 | (Z) |
| Pens and mechanical pencils | 3 | (D) | (D) | — | (D) | (D) | (D) | (D) |
| Costume jewelry and notions | 22 | (D) | 0.8 | (D) | (D) | 0.8 | (D) | (D) |
| Costume jewelry | 8 | (D) | (D) | — | — | (D) | (D) | (D) |
| Needles, pins, and fasteners | 13 | (D) | 0.6 | (D) | (D) | (D) | (D) | (D) |
| Miscellaneous manufactures | 15 | (D) | 1.2 | (D) | (D) | 1.1 | (D) | (D) |
| Manufacturing industries, n.e.c. | 7 | (D) | 0.6 | (D) | (D) | (D) | (D) | (D) |

*Note:* Billion gallons. D., Withheld to avoid disclosing data for individual companies; Z, Less than half the unit shown; n.e.c., not elsewhere classified.

[a] Total gross water used is equal to sum of water intake plus water recirculated and reused without regard to evaporation.

[b] Excludes data for establishments classified as Apparel and Other Textile Products; Printing and Publishing; and Publishing; and administrative and auxiliary establishments for all major groups.

*Source*: From 1982 Census of Manufacturers, U.S. Dept. of Commerce Bureau of the Census, 1986. National Aluminate Corp. With permission.



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**Table 7G.74 Make-Up Water Required in Industrial Cooling Systems**

| | Temperature Drop | | | | |
|---|---|---|---|---|---|
| **Cycles of Concentration** | **15°F (gal)** | **20°F (gal)** | **25°F (gal)** | **30°F (gal)** | **35°F (gal)** |
| 1.5 | 45 | 60 | 75 | 90 | 105 |
| 2.0 | 30 | 40 | 50 | 60 | 70 |
| 2.5 | 25 | 33 | 42 | 50 | 58.5 |
| 3.0 | 22.5 | 30 | 37.5 | 45 | 52.5 |
| 3.5 | 21 | 28 | 35 | 42 | 49.1 |
| 4.0 | 20 | 26.7 | 33.2 | 40 | 46.9 |
| 4.5 | 19.2 | 25.7 | 32.0 | 38.7 | 45.1 |
| 5.0 | 18.7 | 25.0 | 31.8 | 37.5 | 44 |
| 5.5 | 18.3 | 24.5 | 30.7 | 36.8 | 43 |
| 6.0 | 18 | 24 | 30 | 36.1 | 42.1 |
| 6.5 | 17.7 | 23.7 | 29.5 | 35.5 | 41.5 |
| 7.0 | 17.5 | 23.3 | 29.1 | 35 | 40.9 |

*Note:* Estimated amounts in gallons per 1,000 gal/min recirculation.

*Source*: From National Aluminate Corp.

**Table 7G.75 Geographic Distribution of Water-Intensive Manufacturing Industries in the United States**

| | Paper | | Chemicals | | Petroleum Refining | | Primary Metals | |
|---|---|---|---|---|---|---|---|---|
| **Water Resource Region** | **ML/day[a]** | **mgd** | **ML/day** | **mgd** | **ML/day** | **mgd** | **ML/day** | **mgd** |
| New England | 9,401 | 2,541 | 1,598 | 432 | | | 643 | 174 |
| Mid-Atlantic | 7,104 | 1,920 | 15,736 | 4,253 | 10,704 | 2,893 | 10,341 | 2,795 |
| South Atlantic Gulf | 31,627 | 8,548 | 13,590 | 3,673 | 1,417 | 383 | 4,329 | 1,170 |
| Great Lakes | 8,156 | 2,196 | 10,859 | 2,935 | 6,389 | 1,727 | 38,298 | 10,351 |
| Ohio | 2,471 | 668 | 21,108 | 5,705 | 3,193 | 863 | 33,562 | 9,071 |
| Tennessee | 4,151 | 1,122 | 1,342 | 2,525 | 973 | 263 | 395 | 107 |
| Upper Mississippi | 2,101 | 568 | 2,882 | 779 | 2,638 | 713 | 2,752 | 744 |
| Lower Mississippi | 6,471 | 1,749 | 19,920 | 5,384 | 10,744 | 2,904 | 2,186 | 591 |
| Souris-Red-Rainy | 510 | 138 | | | | | | |
| Missouri | 99 | 27 | 2,527 | 683 | 1,986 | 537 | 381 | 103 |
| Arkansas-White-Red | 1,809 | 489 | 3,455 | 934 | 7,425 | 2,007 | 1,653 | 447 |
| Texas Gulf | 3,814 | 1,031 | 41,425 | 11,196 | 32,996 | 8,918 | 4,495 | 1,215 |
| Rio Grande | | | 1,010 | 273 | | | 103 | 28 |
| Upper Colorado | | | | | 44 | 12 | | |
| Lower Colorado | 432 | 117 | 399 | 108 | 40 | 11 | 136 | 37 |
| Great Basin | | | 48 | 13 | 614 | 166 | 1,949 | 527 |
| Columbia-North Pacific | 13,819 | 3,735 | 1,798 | 486 | 1,017 | 275 | 1,646 | 445 |
| California | 4,310 | 1,165 | 2,682 | 725 | 8,029 | 2,170 | 795 | 215 |
| Alaska | 1,306 | 353 | 162 | 44 | 51 | 14 | | |
| Hawaii | | | | | 310 | 84 | | |
| **Total** | **96,658** | **26,124** | **148,543** | **40,147** | **87,601** | **23,676** | **104,251** | **28,176** |

*Note:* 1975 Data.

[a] Million liters per day.

*Source*: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

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**Table 7G.76 Percentage of Gross Industrial Water Use by Purpose in the United States**

| Industry | Parameters of Water Use | Gross Water Use by Unit of Production | Percentage Noncontact Cooling | Percentage Process and Related | Percentage Sanitary and Miscellaneous |
|---|---|---|---|---|---|
| Meatpacking | gal/lb carcass weight | 3.6 gal/lb | 42 | 46 | 12 |
| Poultry dressing | gal/bird poultry slaughter | 11.6 gal/bird | 12 | 77 | 12 |
| Dairy products | gal/lb milk processed | 0.85 gal/lb | 53 | 27 | 19 |
| Canned fruits and vegetables | gal/case 24–303 cans eq | 225 gal/case | 19 | 67 | 13 |
| Frozen fruits and vegetables | gal/lb frozen product | 11.2 /gal/lb | 19 | 72 | 8 |
| Wet corn milling | gal/lb corn grind | 416 gal/bu | 36 | 63 | 1 |
| Cane sugar | gal/ton cane sugar | 28,100 gal/ton | 30 | 69 | 1 |
| Beet sugar | gal/ton beet sugar | 33,100 gal/ton | 31 | 67 | 2 |
| Malt beverages | gal/barrel malt beverage | 1,500 gal/bbl | 72 | 13 | 15 |
| Textile mills | gal/lb fiber consumption | 34 gal/lb | 57 | 37 | 6 |
| Sawmills | gal/bd ft lumber | 5.4 gal/bd ft | 58 | 36 | 6 |
| Pulp and paper mills | gal/ton pulp and paper | 130,000 gal/ton | 18 | 80 | 1 |
| Paper converting | gal/ton paper converted | 6,600 gal/ton | 18 | 77 | 5 |
| Alkalis and chlorine | gal/ton chlorine | 29,800 gal/ton | 85 | 14 | 1 |
| Industrial gases | gal/1,000 cu ft industrial gases | 636 gal/mcf | 86 | 13 | 1 |
| Inorganic pigments | gal/ton inorganic pigments | 97,800 gal/ton | 41 | 58 | 1 |
| Industrial inorganic chemicals | gal/ton chemicals 100 percent basic | 14,500 gal/ton | 83 | 16 | 1 |
| Plastic materials and resins | gal/lb plastic | 24 gal/lb | 93 | 7 | |
| Synthetic rubber | gal/lb synthetic rubber | 55 gal/lb | 83 | 17 | Z |
| Cellulosic man-made fibers | gal/lb fibers | 231 gal/lb | 69 | 30 | 1 |
| Organic fibers, noncellulosic | gal/lb fibers | 101 gal/lb | 94 | 6 | 1 |
| Paints and pigments | gal/gal paint | 13 gal/gal | 79 | 17 | 4 |
| Industrial organic chemicals | gal/ton chemical building blocks | 125,000 gal/ton | 91 | 9 | 1 |
| Nitrogenous fertilizers | gal/ton fertilizer | 28,506 gal/ton | 92 | 8 | Z |
| Phosphatic fertilizers | gal/ton fertilizer | 35,602 gal/ton | 71 | 28 | 1 |
| Carbon black | gal/lb carbon black | 4.6 gal/lb | 57 | 38 | 6 |
| Petroleum refining | gal/barrel crude oil input | 1,851 gal/bbl | 95 | 5 | Z |
| Tires and inner tubes | gal/tire car and truck tires | 518 gal/tire | 81 | 16 | 3 |
| Hydraulic cement | gal/ton cement | 1,360 gal/ton | 82 | 17 | 1 |
| Steel | gal/ton steel net production | 62,600 gal/ton | 56 | 43 | 1 |
| Iron and steel foundries | gal/ton ferrous castings | 12,400 gal/ton | 34 | 58 | 8 |
| Primary copper | gal/lb copper | 53 gal/lb | 52 | 46 | 2 |
| Primary aluminum | gal/lb aluminum | 49 gal/lb | 72 | 26 | 2 |
| Automobiles | gal/car domestic automobiles | 36,500 gal/car | 28 | 69 | 3 |

*Note:* Z = less than 0.5 percent of gross water use; percentages may not add evenly due to rounding.

*Source*: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

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**Table 7G.77 Industrial Water Use Per Employee in the United States**

| | Gross Water Use Per Employee | | Intake Per Employee | |
|---|---|---|---|---|
| **Industry Group** | **L/day** | **gal/d** | **L/day** | **gal/d** |
| Food and kindred products | 15,540 | 4,200 | 10,360 | 2,800 |
| Tobacco manufacturers | 22,570 | 6,100 | 1,480 | 400 |
| Textile mill products | 6,660 | 1,800 | 2,960 | 800 |
| Apparel and related products | 370 | 100 | 370 | 100 |
| Lumber and wood products | 5,920 | 1,600 | 3,700 | 1,000 |
| Furniture and fixtures | 440 | 120 | 370 | 100 |
| Paper and allied products | 43,930 | 38,900 | 42,920 | 11,600 |
| Printing and publishing | 370 | 100 | 370 | 100 |
| Chemicals and allied products | 149,110 | 40,300 | 56,240 | 15,200 |
| Petroleum and coal products | 603,100 | 163,000 | 94,350 | 25,500 |
| Rubber and plastic products | 10,730 | 2,900 | 3,700 | 1,000 |
| Leather and leather products | 740 | 200 | 703 | 190 |
| Stone, clay, and glass products | 11,470 | 3,100 | 5,550 | 1,500 |
| Primary metal industries | 78,440 | 21,200 | 44,030 | 11,900 |
| Fabricated metal products | 2,960 | 800 | 1,110 | 300 |
| Machinery, except electrical | 3,700 | 1,000 | 1,480 | 400 |
| Electrical machinery | 9,250 | 2,500 | 1,110 | 300 |
| Transportation equipment | 17,020 | 4,600 | 2,220 | 600 |
| Instruments and related products | 4,440 | 1,200 | 1,110 | 300 |
| Miscellaneous manufacturing | 1,110 | 300 | 2,960 | 200 |

*Source*: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

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**Table 7G.78 Water Use Versus Industrial Units of Production in the United States**

| Industry | Parameters of Water Use | Gross Water Used by Unit of Production | Intake by Unit of Production | Consumption by Unit of Production | Discharge by Unit of Production |
|---|---|---|---|---|---|
| Meatpacking | gal/lb carcass weight | 3.6 gal/lb | 2.2 gal/lb | 0.1 gal/lb | 2.1 gal/lb |
| Poultry dressing | gal/bird poultry slaughter | 11.6 gal/bird | 10.3 gal/bird | 0.5 gal/bird | 9.8 gal/bird |
| Dairy products | gal/lb milk processed | 0.85 gal/lb | 0.52 gal/lb | 0.03 gal/lb | 0.48 gal/lb |
| Canned fruits and vegetables | gal/case 24–303 cans eq | 225 gal/case | 107 gal/case | 10 gal/case | 98 cal/case |
| Frozen fruits and vegetables | gal/lb frozen product | 11.2 gal/lb | 7.1 gal/lb | 0.2 gal/lb | 6.9/gal/lb |
| Wet corn milling | gal/lb corn grind | 416 gal/bu | 223 gal/bu | 18 gal/bu | 205 gal/bu |
| Cane sugar | gal/ton cane sugar | 28,100 gal/ton | 18,250 gal/ton | 950 gal/ton | 17,300 gal/ton |
| Beet sugar | gal/ton beet sugar | 33,100 gal/ton | 11,100 gal/ton | 390 gal/ton | 10,700 gal/ton |
| Malt beverages | gal/barrel malt beverage | 1,500 gal/bbl | 420 gal/bbl | 90 gal/bbl | 330 gal/bbl |
| Textile mills | gal/lb fiber consumption | 34 gal/lb | 14 gal/lb | 1.4 gal/lb | 12.8 gal/lb |
| Sawmills | gal/bd ft lumber | 5.4 gal/bd ft | 3.3 gal/bd ft | 0.6 gal/bd ft | 2.7 gal/bd ft |
| Pulp and paper mills | gal/ton pulp and paper | 130,000 gal/ton | 38,000 gal/ton | 1,800 gal/ton | 36,200 gal/ton |
| Paper converting | gal/ton paper converted | 6,600 gal/ton | 3,900 gal/ton | 270 gal/ton | 3,600 gal/ton |
| Alkalis and chlorine | gal/ton chlorine | 29,800 gal/ton | 22,200 gal/ton | 700 gal/ton | 21,600 gal/ton |
| Industrial gases | gal/1,000 cu ft industrial gases | 636 gal/mcf | 226 gal/mcf | 31 gal/mcf | 193 gal/mcf |
| Inorganic pigments | gal/ton inorganic pigments | 97,800 gal/ton | 49,400 gal/ton | 1,600 gal/ton | 47,800 gal/ton |
| Industrial inorganic chemicals | gal/ton chemicals 100 percent basic | 14,500 gal/ton | 4,750 gal/ton | 470 gal/ton | 4,300 gal/ton |
| Plastic materials and resins | gal/lb plastic | 24 gal/lb | 6.7 gal/lb | 0.6 gal/lb | 6.1 gal/lb |
| Synthetic rubber | gal/lb synthetic rubber | 55 gal/lb | 6.5 gal/lb | 1.4 gal/lb | 5.1 gal/lb |
| Cellulosic man-made fibers | gal/lb fibers | 231 gal/lb | 68 gal/lb | 4.6 gal/lb | 63 gal/lb |
| Organic fibers, noncellulosic | gal/lb fibers | 101 gal/lb | 38 gal/lb | 1.1 gal/lb | 37 gal/lb |
| Paints and pigments | gal/gal paint | 13 gal/gal | 7.8 gal/gal | 0.4 gal/gal | 7.4 gal/gal |
| Industrial organic chemicals | gal/ton chemical building blocks | 125,000 gal/ton | 54,500 gal/ton | 2,800 gal/ton | 51,700 gal/ton |
| Nitrogenous fertilizers | gal/ton fertilizer | 28,506 gal/ton | 4,001 gal/ton | 701 gal/ton | 3,299 gal/ton |
| Phosphatic fertilizers | gal/ton fertilizer | 35,602 gal/ton | 8,461 gal/ton | 1,277 gal/ton | 7,184 gal/ton |
| Carbon black | gal/lb carbon black | 4.6 gal/lb | 3.9 gal/lb | 0.9 gal/lb | 3.1 gal/lb |
| Petroleum refining | gal/barrel crude oil input | 1,851 gal/bbl | 289 gal/bbl | 28 gal/bbl | 261 gal/bbl |
| Tires and inner tubes | gal/tire car and truck tires | 518 gal/tire | 153 gal/tire | 14 gal/tire | 139 gal/tire |
| Hydraulic cement | gal/ton cement | 1,360 gal/ton | 830 gal/ton | 150 gal/ton | 680 gal/ton |
| Steel | gal/ton steel net production | 62,600 gal/ton | 38,200 gal/ton | 1,400 gal/ton | 36,800 gal/ton |
| Iron and steel foundries | gal/ton ferrous castings | 12,400 gal/ton | 3,030 gal/ton | 260 gal/ton | 2,760 gal/ton |
| Primary copper | gal/lb copper | 53 gal/lb | 17 gal/lb | 4.1 gal/lb | 13 gal/lb |
| Primary aluminum | gal/lb aluminum | 49 gal/lb | 12 gal/lb | 0.2 gal/lb | 11.8 gal/lb |
| Automobiles | gal/car domestic automobiles | 36,500 gal/car | 11,464 gal/car | 649 gal/car | 10,814 gal/car |

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**Table 7G.79 Water Use Versus Standardized Units of Production in the United States**

| Industry | Parameters of Water Use | Gross Water Used by Unit of Production | Intake by Unit of Production | Consumption by Unit of Production | Discharge by Unit of Production |
|---|---|---|---|---|---|
| Meatpacking | gal/lb carcass weight | 7,194 gal/ton | 4,331 gal/ton | 78 gal/ton | 4,253 gal/ton |
| Poultry dressing | gal/ton ready-to-cook weight | 7,389 gal/ton | 6,542 gal/ton | 296 gal/ton | 6,246 gal/ton |
| Dairy products | gal/lb milk processed | 1,692 gal/ton | 1,035 gal/ton | 63 gal/ton | 964 gal/ton |
| Canned fruits and vegetables | gal/ton vegetables canned | 19,700 gal/ton | 9,400 gal/ton | 850 gal/ton | 8,550 gal/ton |
| Frozen fruits and vegetables | gal/ton vegetables frozen | 22,500 gal/ton | 14,100 gal/ton | 300 gal/ton | 13,800 gal/ton |
| Wet corn milling | gal/lb corn grind | 14,869 gal/ton | 7,988 gal/ton | 643 gal/ton | 7,345 gal/ton |
| Cane sugar | gal/ton cane sugar | 28,102 gal/ton | 18,256 gal/ton | 944 gal/ton | 17,312 gal/ton |
| Beet sugar | gal/ton beet sugar | 33,145 gal/ton | 11,118 gal/ton | 386 gal/ton | 10,731 gal/ton |
| Malt beverages | gal/beer and malt liquor | 49 gal/gal | 14 gal/gal | 3 gal/gal | 11 gal/gal |
| Textile mills | gal/ton textile fiber input | 69,808 gal/ton | 30,016 gal/ton | 3,008 gal/ton | 27,008 gal/ton |
| Sawmills | gal/bd ft lumber | 5.4 gal/bd ft | 3.3 gal/bd ft | 0.63 gal/bd ft | 2.7 gal/bd ft |
| Pulp and paper mills | gal/ton paper | 130,047 gal/ton | 37,971 gal/ton | 1,178 gal/ton | 36,193 gal/ton |
| Paper converting | gal/ton paper converted | 6,584 gal/ton | 3,861 gal/ton | 273 gal/ton | 3,588 gal/ton |
| Alkalis and chlorine | gal/ton chlorine | 29,840 gal/ton | 22,302 gal/ton | 676 gal/ton | 21,626 gal/ton |
| Industrial gases | gal/ton weight of gas | 16,080 gal/ton | 5,700 gal/ton | 780 gal/ton | 4,900 gal/ton |
| Inorganic pigments | gal/ton pigments | 97,800 gal/ton | 49,400 gal/ton | 1,600 gal/ton | 47,800 gal/ton |
| Industrial inorganic chemicals | gal/ton chemical products | 14,500 gal/ton | 4,700 gal/ton | 470 gal/ton | 4,300 gal/ton |
| Plastic materials and resins | gal/ton plastics | 47,061 gal/ton | 13,338 gal/ton | 1,078 gal/ton | 12,278 gal/ton |
| Synthetic rubber | gal/ton synthetic rubber | 110,600 gal/ton | 13,200 gal/ton | 2,800 gal/ton | 10,373 gal/ton |
| Cellulosic man-made fibers | gal/ton fibers | 462,230 gal/ton | 135,100 gal/ton | 9,200 gal/ton | 125,846 gal/ton |
| Organic fibers, noncellulosic | gal/ton fibers | 202,123 gal/ton | 76,523 gal/ton | 2,153 gal/ton | 74,369 gal/ton |
| Paints and pigments | gal/gal paint | 13.2 gal/gal | 7.8 gal/gal | 0.4 gal/gal | 7.4 gal/gal |
| Industrial organic chemicals | gal/ton chemical building blocks | 124,700 gal/ton | 54,500 gal/ton | 2,800 gal/ton | 51,700 gal/ton |
| Nitrogenous fertilizers | gal/ton fertilizer | 28,506 gal/ton | 4,001 gal/ton | 701 gal/ton | 3,299 gal/ton |
| Phosphatic fertilizers | gal/ton fertilizer | 35,602 gal/ton | 8,461 gal/ton | 1,277 gal/ton | 7,184 gal/ton |
| Carbon black | gal/ton carbon black | 9,200 gal/ton | 7,885 gal/ton | 1,771 gal/ton | 6,114 gal/ton |
| Petroleum refining | gal/gal crude petroleum input | 44 gal/gal | 6.9 gal/gal | 0.7 gal/gal | 6.2 gal/gal |
| Tires and inner tubes | gal/tire car and truck tires | 518 gal/tire | 153 gal/tire | 14 gal/tire | 139 gal/tire |
| Hydraulic cement | gal/ton cement | 1,355 gal/ton | 831 gal/ton | 146 gal/ton | 685 gal/ton |
| Steel | gal/ton steel net tons | 62,601 gal/ton | 38,200 gal/ton | 1,400 gal/ton | 36,800 gal/ton |
| Iron and steel foundries | gal/ton ferrous castings | 12,407 gal/ton | 3,024 gal/ton | 260 gal/ton | 2,764 gal/ton |
| Primary copper | gal/ton copper | 106,000 gal/ton | 34,000 gal/ton | 8,200 gal/ton | 26,000 gal/ton |
| Primary aluminum | gal/ton aluminum | 96,300 gal/ton | 23,900 gal/ton | 381 gal/ton | 23,500 gal/ton |
| Automobiles | gal/car automobiles | 36,500 gal/car | 11,464 gal/car | 649 gal/car | 10,814 gal/car |

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**Table 7G.80 Typical Water Uses in Paper Mills**

| | Gross Water Use | | Intake Requirement (Low Reuse) | | Intake Requirement (High Reuse) | |
|---|---|---|---|---|---|---|
| **Purpose** | **ML/day** | **mgd** | **ML/day** | **mgd** | **ML/day** | **mgd** |
| Kraft pulping (process use) | 118 | 32 | 51 | 14 | 22 | 6 |
| Kraft pulping (cooling system) | 44 | 12 | 44 | 12 | 1.5 | 0.4 |
| Bleaching | 140 | 38 | 70 | 19 | 18 | 5 |
| Paper forming (process system) | 129 | 35 | 44 | 12 | 22 | 6 |
| Paper forming (cooling system) | 14 | 4 | 14 | 4 | 0.7 | 0.2 |
| Electric power cooling[a] | 51 | 14 | 51 | 14 | 1.8 | 0.5 |
| Net totals[b] | 499 | 135 | 225 | 61 | 44 | 12.1 |

*Note:* 1,000 ton per day integrated bleached kraft paper mill.

[a] Condenser cooling requirements for a steam electric plant producing half of the total electric power needs.
[b] Intake net totals are less than the sum of the individual components because much of the wastewater from high quality uses is cascaded to lower quality uses.

*Source*: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

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**Table 7G.81 Water Intake Requirements in the United States — Average Plants Versus High Recycling Plants**

| | | Intake | | Recycling Rate[a] | |
|---|---|---|---|---|---|
| Industry | Parameters of Water Use | 1973 Industry Average | BAT[b] with Maximum Feasible Recycling | 1973 Industry Average | BAT[b] with Maximum Feasible Recycling |
| Meatpacking | gal/lb carcass weight | 2.2 gal/lb | 0.5 gal/lb | 1.66 | 6.67 |
| Poultry dressing | gal/bird poultry slaughter | 10.3 gal/bird | 1.7 gal/bird | 1.13 | 6.71 |
| Dairy products | gal/lb milk processed | 0.52 gal/lb | 0.13 gal/lb | 1.64 | 6.67 |
| Canned fruits and vegetables | gal/case 24–303 cans eq | 107 gal/case | 29 gal/case | 2.10 | 7.75 |
| Frozen fruits and vegetables | gal/lb frozen product | 7.1 gal/lb | 1.6 gal/lb | 1.60 | 7.25 |
| Wet corn milling | gal/bu corn grind | 223 gal/bu | 46 gal/bu | 1.86 | 9.09 |
| Cane sugar | gal/ton cane sugar | 18,250 gal/ton | 5,300 gal/ton | 1.54 | 5.26 |
| Beet sugar | gal/ton beet sugar | 11,100 gal/ton | 6,200 gal/ton | 2.98 | 5.38 |
| Malt beverages | gal/barrel malt beverage | 420 gal/bbl | 105 gal/bbl | 3.50 | 14.3 |
| Textile mills | gal/lb fiber consumption | 14 gal/lb | 1.8 gal/lb | 2.23 | 18.2 |
| Sawmills | gal/bd ft lumber | 3.3 gal/ft | 0.8 gal/ft | 1.64 | 6.85 |
| Pulp and paper mills | gal/ton pulp and paper | 38,000 gal/ton | 10,700 gal/ton | 3.42 | 12.2 |
| Paper converting | gal/ton paper converted | 3,900 gal/ton | 750 gal/ton | 1.70 | 8.93 |
| Alkalis and chlorine | gal/ton chlorine | 22,200 gal/ton | 860 gal/ton | 1.34 | 34.5 |
| Industrial gases | gal/1,000 cu ft industrial gases | 226 gal/mcf | 18 gal/mcf | 2.82 | 34.5 |
| Inorganic pigments | gal/ton inorganic pigments | 49,400 gal/ton | 6,100 gal/ton | 1.98 | 16.1 |
| Industrial inorganic chemicals | gal/ton chemicals 100 percent basis | 4,750 gal/ton | 470 gal/ton | 3.08 | 31.2 |
| Plastic materials and resins | gal/lb plastic | 6.7 gal/lb | 0.7 gal/lb | 3.53 | 33.3 |
| Synthetic rubber | gal/lb synthetic rubber | 6.5 gal/lb | 1.6 gal/lb | 8.38 | 33.3 |
| Cellulosic man-made fibers | gal/lb fibers | 68 gal/lb | 8.4 gal/lb | 3.42 | 27.8 |
| Organic fibers, noncellulosic | gal/lb fibers | 38 gal/lb | 5.0 gal/lb | 2.64 | 20.0 |
| Paints and pigments | gal/gal paint | 7.8 gal/gal | 0.8 gal/gal | 1.69 | 16.1 |
| Industrial organic chemicals | gal/ton chemical building blocks | 54,500 gal/ton | 4,000 gal/ton | 2.29 | 31.2 |
| Nitrogenous fertilizers | gal/ton fertilizer | 4,000 gal/ton | 900 gal/ton | 7.12 | 31.2 |
| Phosphatic fertilizers | gal/ton fertilizer | 8,500 gal/ton | 2,400 gal/ton | 4.21 | 14.7 |
| Carbon black | gal/lb carbon black | 3.9 gal/lb | 0.3 gal/lb | 1.17 | 16.1 |
| Petroleum refining | gal/barrel crude oil input | 289 gal/bbl | 55 gal/bbl | 6.38 | 33.3 |
| Tires and inner tubes | gal/tire car and truck tires | 153 gal/tire | 18 gal/tire | 3.39 | 29.4 |
| Hydraulic cement | gal/ton cement | 830 gal/ton | 180 gal/ton | 1.63 | 7.41 |
| Steel | gal/ton steel net production | 38,200 gal/ton | 5,300 gal/ton | 1.64 | 11.9 |
| Iron and steel foundries | gal/ton ferrous castings | 3,030 gal/ton | 1,080 gal/ton | 4.10 | 11.5 |
| Primary copper | gal/lb copper | 17 gal/lb | 4.5 gal/lb | 3.12 | 11.9 |
| Primary aluminum | gal/lb aluminum | 12 gal/lb | 2.9 gal/lb | 4.11 | 16.9 |
| Automobiles | gal/car domestic automobiles | 11,500 gal/car | 2,200 gal/car | 3.18 | 16.3 |

[a] The recycling rate is obtained by dividing gross water use by intake.
[b] Best available technology economically achievable as defined by Water Pollution Control Act amendments of 1972.

*Source*: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

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**Table 7G.82 Water Recycling in the 20 Plants with the Highest Rates in 34 Major Water-Using Industries in the United States, 1970**

| Industry | Gross Water Use[a] | Intake[a] | Mean Recycling Rate[b] | Highest Recycling Rate[b] | Tenth Highest Recycling Rate[b] | Twentieth Highest Recycling Rate[b] |
|---|---|---|---|---|---|---|
| Meat packing plants | 49.732 | 20.335 | 2.45 | 7.05 | 2.41 | 1.85 |
| Poultry dressing | 3.473 | 1.990 | 1.75 | 4.28 | 1.30 | 1.14 |
| Fluid milk | 8.118 | 0.859 | 9.45 | 71.71 | 7.92 | 3.96 |
| Canned fruit and vegetables | 10.673 | 3.419 | 3.12 | 18.24 | 2.50 | 1.76 |
| Frozen fruit and vegetables | 17.353 | 9.259 | 1.87 | 7.13 | 1.97 | 1.39 |
| Wet corn milling | 53.986 | 32.109 | 1.68 | 11.91 | 2.31 | 1.11 |
| Beet sugar | 58.949 | 16.829 | 3.50 | 22.24 | 2.97 | 1.84 |
| Malt liquors | 64.350 | 12.675 | 5.08 | 10.00 | 2.85 | 1.11 |
| Shortening and cooking oils | 48.106 | 5.425 | 8.87 | 113.53 | 8.23 | 1.30 |
| Cigarettes | 60.765 | 2.292 | 26.51 | 33.39 | 15.31 | 1.11 |
| Weaving mills, cotton | 74.289 | 1.186 | 62.64 | 285.31 | 64.25 | 27.99 |
| Weaving mills, synthetics | 88.114 | 0.717 | 122.89 | 558.25 | 111.27 | 48.53 |
| Weaving and finishing, wool | 19.163 | 2.637 | 7.27 | 93.44 | 24.19 | 1.18 |
| Pulp mills | 713.440 | 208.179 | 3.43 | 7.57 | 3.84 | 1.41 |
| Papermills, except building paper | 723.008 | 71.057 | 10.18 | 76.54 | 8.96 | 6.06 |
| Paperboard mills | 272.670 | 14.515 | 18.79 | 50.00 | 14.68 | 8.22 |
| Alkalis and chlorine | 198.798 | 87.167 | 2.28 | 25.11 | 1.79 | 1.12 |
| Industrial gases | 141.450 | 1.490 | 94.93 | 157.80 | 84.83 | 46.23 |
| Cyclic intermediate and crudes | 327.354 | 55.446 | 5.90 | 160.00 | 13.45 | 2.24 |
| Inorganic pigments | 120.387 | 50.222 | 2.40 | 15.22 | 1.53 | 1.11 |
| Industrial organic chemicals | 962.830 | 35.142 | 27.40 | 48.18 | 23.20 | 15.80 |
| Industrial inorganic chemicals | 505.919 | 16.670 | 30.35 | 70.95 | 30.10 | 23.81 |
| Plastic materials and resins | 704.229 | 5.131 | 137.25 | 613.60 | 27.37 | 13.81 |
| Cellulosic man-made fibers | 209.801 | 48.088 | 4.36 | 20.83 | 4.30 | 1.37 |
| Organic fibers, noncellulosic | 392.335 | 151.969 | 2.58 | 28.06 | 2.82 | 1.16 |
| Pharmaceutical preparations | 70.621 | 15.385 | 4.59 | 104.73 | 7.36 | 1.11 |
| Fertilizers | 282.251 | 23.373 | 12.08 | 90.60 | 9.72 | 2.45 |
| Petroleum refining | 2,026.521 | 30.221 | 67.06 | 251.05 | 44.08 | 34.36 |
| Cement, hydraulic | 20.868 | 4.320 | 4.83 | 97.35 | 2.58 | 1.77 |
| Blast furnaces and steel mills | 394.549 | 29.050 | 13.58 | 95.13 | 18.66 | 6.76 |
| Electrometallurgical products | 22.732 | 1.827 | 12.44 | 65.81 | 25.64 | 5.07 |
| Gray iron foundaries | 35.396 | 10.254 | 3.45 | 15.23 | 2.86 | 1.82 |
| Primary copper | 78.473 | 33.218 | 2.36 | 9.85 | 2.23 | 1.18 |
| Primary aluminum | 65.519 | 15.723 | 4.17 | 10.10 | 3.50 | 1.66 |

[a] Billions of gallons per year: 1 bil gal = 3.7 GL.
[b] The recycling rate is obtained by dividing gross water use by intake.

*Source*: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

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**Table 7G.83 Typical Unit Water Requirements for Energy Production in the United States**

| Fuel and Process | Standard Unit | Gallons per Standard Unit | Gallons per Million Btu | Major Use |
|---|---|---|---|---|
| *Coal* | | | | |
| Western coal mining | ton | 6.0–14.7 | 0.25–0.61 | Dust control and washing |
| Eastern coal mining | Ton | 15.8–18.0 | 0.66–0.75 | Dust control and washing |
| Coal gasification | MSCF[a] | 72.0–158 | 72–158 | Process and cooling |
| Coal liquefaction | Barrel | 1,134.0–1,750 | 31–200 | Process and cooling |
| *Petroleum* | | | | |
| Oil and gas production | Barrel | 1.7–3.0 | 3.05 | Well drilling and recovery |
| Oil refining | Barrel | 43.0 | 7.58 | Process and cooling |
| Oil shale production | Barrel | 145.4 | 30.1 | Mining, cooling, processing, and waste disposal |
| Gas processing | MSCF[a] | 1.67 | 1.67 | Cooling |
| *Nuclear fuels* | — | — | 14.3 | Mining and processing |
| *Power generation* | | | | |
| Fossil fuels | kWh | 0.41 | 120.16 | Cooling |
| Nuclear fuels | kWh | 0.80 | 234.46 | Cooling |
| Geothermal | — | — | 527 | Cooling and extraction |

[a] Million standard cubic feet.

*Source*: From United States Federal Energy Administration, 1974, "Project Independence," Project Independence Report, p. 304: U.S. Government Printing Office, Washington, DC, 20402.

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**Table 7G.84 Thermoelectric Power Water Use by Energy Source and State, 1995**

| State | Fossil Fuel | | | | | | Nuclear | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Withdrawals, by Source and Type | | | | Consumptive Use | | Withdrawals, by Source and Type | | | | Consumptive Use | |
| | Groundwater Fresh | Surface Water | | | | | Groundwater Fresh | Surface Water | | | | |
| | | Fresh | Saline | Total | Fresh | Saline | | Fresh | Saline | Total | Fresh | Saline |
| Alabama | 6.0 | 4,330 | 0 | 4,330 | 30 | 0 | 0 | 862 | 0 | 862 | 1.7 | 0 |
| Alaska | 4.2 | 26 | 0 | 26 | 3.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Arizona | 42 | 20 | 0 | 20 | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Arkansas | 5.2 | 798 | 0 | 798 | 27 | 0 | 0 | 967 | 0 | 967 | 1.2 | 0 |
| California | 3.5 | 190 | 4,730 | 4,920 | 9.4 | 2.8 | 0.1 | 12 | 4,690 | 4,710 | 0.3 | 1.3 |
| Colorado | 22 | 93 | 0 | 93 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Connecticut | 0.1 | 276 | 882 | 1,160 | 5.9 | 74 | 0.1 | 484 | 2,300 | 2,780 | 0 | 0 |
| Delaware | 0.2 | 534 | 740 | 1,270 | 0.2 | 2.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| District of Columbia | 0 | 9.7 | 0 | 9.7 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 21 | 615 | 9,140 | 9,760 | 54 | 0 | 0.3 | 0 | 1,810 | 1,810 | 1.2 | 0 |
| Georgia | 3.9 | 2,910 | 33 | 2,950 | 52 | 0 | 1.0 | 122 | 0 | 122 | 93 | 0 |
| Hawaii | 67 | 0 | 903 | 903 | 0.7 | 9.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Idaho | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Illinois | 9.5 | 9,570 | 0 | 9,570 | 144 | 0 | 1.3 | 7,520 | 0 | 7,520 | 263 | 0 |
| Indiana | 11 | 5,680 | 0 | 5,680 | 114 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iowa | 13 | 2,100 | 0 | 2,100 | 7.8 | 0 | 2.0 | 8.1 | 0 | 8.1 | 2.6 | 0 |
| Kansas | 14 | 1,230 | 0 | 1,230 | 45 | 0 | 0 | 22 | 0 | 22 | 13 | 0 |
| Kentucky | 38 | 3,410 | 0 | 3,410 | 203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Louisiana | 31 | 4,430 | 0 | 4,430 | 212 | 0 | 0.1 | 1,020 | 0 | 1,020 | 10 | 0 |
| Maine | 0.7 | 30 | 105 | 135 | 3.5 | 1.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maryland | 1.6 | 358 | 2,780 | 3,140 | 3.7 | 32 | 0.2 | 0 | 3,220 | 3,220 | 0 | 16 |
| Massachusetts | 46 | 150 | 3,910 | 4,060 | 0 | 0 | 0 | 0 | 454 | 454 | 0 | 6.0 |
| Michigan | 3.0 | 6,030 | 0 | 6,030 | 50 | 0 | 0.1 | 2,340 | 0 | 2,340 | 76 | 0 |
| Minnesota | 1.8 | 1,210 | 0 | 1,210 | 28 | 0 | 0.1 | 886 | 0 | 886 | 20 | 0 |
| Mississippi | 10 | 220 | 112 | 333 | 8.0 | 3.6 | 32 | 0 | 0 | 0 | 19 | 0 |
| Missouri | 9.1 | 5,520 | 0 | 5,520 | 40 | 0 | 0.4 | 21 | 0 | 21 | 11 | 0 |
| Montana | 0 | 22 | 0 | 22 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebraska | 4.4 | 1,290 | 0 | 1,290 | 12 | 0 | 0 | 1,060 | 0 | 1,060 | 0 | 0 |
| Nevada | 6.2 | 21 | 0 | 21 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| New Hampshire | 0.8 | 228 | 292 | 521 | 4.3 | 0 | 0 | 0 | 585 | 585 | 0 | 0 |
| New Jersey | 1.2 | 578 | 980 | 1,560 | 3.7 | 9.9 | 0.7 | 0 | 2,800 | 2,800 | 0.7 | 22 |
| New Mexico | 9.3 | 46 | 0 | 46 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| New York | 0 | 5,140 | 5,470 | 10,600 | 103 | 109 | 0 | 1,420 | 1,010 | 2,440 | 68 | 20 |
| North Carolina | 0.1 | 3,210 | 0 | 3,210 | 56 | 0 | 0 | 2,660 | 1,550 | 4,210 | 1.5 | 17 |
| North Dakota | 0 | 879 | 0 | 879 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ohio | 19 | 8,040 | 0 | 8,040 | 309 | 0 | 0 | 137 | 0 | 137 | 27 | 0 |
| Oklahoma | 3.5 | 121 | 0 | 121 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*(Continued)*



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**Table 7G.84 (Continued)**

| | Fossil Fuel | | | | | | Nuclear | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Withdrawals, by Source and Type | | | | Consumptive Use | | Withdrawals, by Source and Type | | | | Consumptive Use | |
| State | Groundwater Fresh | Surface Water Fresh | Surface Water Saline | Surface Water Total | Fresh | Saline | Groundwater Fresh | Surface Water Fresh | Surface Water Saline | Surface Water Total | Fresh | Saline |
| Oregon | 0 | 9.0 | 0 | 9.0 | 7.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pennsylvania | 6.2 | 3,870 | 0 | 3,870 | 120 | 0 | 0 | 2,050 | 0 | 2,050 | 119 | 0 |
| Rhode Island | 0 | 0 | 275 | 275 | 0 | 5.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| South Carolina | 0.4 | 1,290 | 0 | 1,290 | 23 | 0 | 39 | 3,470 | 0 | 3,470 | 28 | 0 |
| South Dakota | 2.6 | 1.9 | 0 | 1.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tennessee | 0 | 6,830 | 0 | 6,830 | 0.5 | 0 | 0 | 1,470 | 0 | 1,470 | 0 | 0 |
| Texas | 58 | 6,710 | 3,870 | 10,600 | 271 | 12 | 0.8 | 2,820 | 0 | 2,820 | 26 | 0 |
| Utah | 0 | 48 | 0 | 48 | 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vermont | 0.4 | 0.5 | 0 | 0.5 | 0.7 | 0 | 0 | 452 | 0 | 452 | 3.2 | 0 |
| Virginia | 0.1 | 1,820 | 973 | 2,790 | 8.8 | 0 | 0.3 | 2,080 | 1,760 | 3,830 | 0 | 0 |
| Washington | 0.4 | 17 | 0 | 17 | 0.4 | 0 | 0.1 | 358 | 0 | 358 | 9.8 | 0 |
| West Virginia | 0.5 | 3,010 | 0 | 3,010 | 122 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 5.6 | 3,860 | 0 | 3,860 | 39 | 0 | 0.1 | 1,970 | 0 | 1.970 | 20 | 0 |
| Wyoming | 1.0 | 219 | 0 | 219 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Puerto Rico | 2.2 | 0 | 2,260 | 2,260 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Virgin Islands | 0 | 0 | 173 | 173 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **486** | **97,000** | **37,600** | **135,000** | **2,500** | **263** | **78** | **34,300** | **20,200** | **54,500** | **815** | **82** |

*Note:* Figures may not add to totals because of independent rounding. All values in million gallons per day.

*Source*: From Solley, W.B. et al., 1998. Esimated Use of Water in the United States in 1995, *U.S. Geological Survey Circular 1200*, www.usgs.gov.

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**Table 7G.85 Thermoelectric Generation from Different Sources, 1960–1995**

| Year | Generation by Coal (%) | Generation by Petroleum (%) | Generation by Gas (%) | Generation by Nuclear (%) | Generation by Conventional Steam (%) | Generation by Internal Combustion (%) |
|---|---|---|---|---|---|---|
| 1960 | 65.88 | 7.37 | 26.49 | 0.26 | 99.31 | 0.72 |
| 1965 | 66.50 | 7.25 | 25.82 | 0.43 | 99.04 | 0.58 |
| 1970 | 55.25 | 13.84 | 29.20 | 1.71 | 97.90 | 0.46 |
| 1975 | 51.20 | 16.94 | 17.93 | 10.33 | 85.96 | 0.32 |
| 1980 | 58.23 | 11.93 | 17.26 | 12.59 | 87.53 | 0.15 |
| 1985 | 64.67 | 4.29 | 13.34 | 17.70 | 82.74 | 0.05 |
| 1990 | 62.21 | 4.33 | 10.43 | 23.03 | 77.40 | 0.04 |
| 1995 | 61.56 | 2.01 | 11.35 | 25.08 | 75.12 | 0.03 |

*Source*: From Dziegielewski, B. et al., 2002. *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL February 28, 2002. Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.

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**Table 7G.86 Thermoelectric Power Water Withdrawals by Cooling Type in the United States, 2000**

| | Withdrawals for Once-Through Cooling | | | | Withdrawals for Closed-Loop Cooling by Source and Type | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Surface Water | | | Groundwater | Surface Water | | | Total | | |
| State | Fresh | Saline | Total | Fresh | Fresh | Saline | Total | Fresh | Saline | Total |
| Alabama | 8,020 | 0 | 8,020 | 0 | 167 | 0 | 167 | 167 | 0 | 167 |
| Alaska | 28.9 | 0 | 28.9 | 4.65 | 0 | 0 | 0 | 4.65 | 0 | 4.65 |
| Arizona | 0 | 0 | 0 | 74.3 | 26.2 | 0 | 26.2 | 100 | 0 | 100 |
| Arkansas | 1,690 | 0 | 1,690 | 2.92 | 478 | 0 | 478 | 481 | 0 | 481 |
| California | 344 | 12,600 | 12,900 | 3.23 | 5.41 | 0 | 5.41 | 8.64 | 0 | 8.64 |
| Colorado | 90.2 | 0 | 90.2 | 16.1 | 31.8 | 0 | 31.8 | 48 | 0 | 48 |
| Connecticut | 115 | 3,440 | 3,560 | 0.08 | 71.7 | 0 | 71.7 | 71.8 | 0 | 71.8 |
| Delaware | 0 | 0 | 0 | 0.47 | 366 | 738 | 1,100 | 366 | 738 | 1,100 |
| District of Columbia | 0 | 0 | 0 | 0 | 9.69 | 0 | 9.69 | 9.69 | 0 | 9.69 |
| Florida | 559 | 11,800 | 12,400 | 29.5 | 69.8 | 150 | 219 | 99.3 | 150 | 249 |
| Georgia | 2,800 | 61.7 | 2,860 | 1.03 | 444 | 0 | 444 | 445 | 0 | 445 |
| Hawaii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Idaho | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Illinois | 11,000 | 0 | 11,000 | 5.75 | 239 | 0 | 239 | 245 | 0 | 245 |
| Indiana | 6,450 | 0 | 6,450 | 2.58 | 252 | 0 | 252 | 254 | 0 | 254 |
| Iowa | 2,510 | 0 | 2,510 | 11.9 | 15.6 | 0 | 15.6 | 27.6 | 0 | 27.6 |
| Kansas | 2,210 | 0 | 2,210 | 14.9 | 29.1 | 0 | 29.1 | 44 | 0 | 44 |
| Kentucky | 824 | 0 | 824 | 2.71 | 2,430 | 0 | 2,430 | 2,430 | 0 | 2,430 |
| Louisiana | 4,500 | 0 | 4,500 | 28.4 | 1,080 | 0 | 1,080 | 1,110 | 0 | 1,110 |
| Maine | 90.8 | 295 | 385 | 4.92 | 17.2 | 0 | 17.2 | 22.2 | 0 | 22.2 |
| Maryland | 377 | 5,670 | 6,050 | 1.8 | 0 | 589 | 589 | 1.8 | 589 | 591 |
| Massachusetts | 108 | 3,610 | 3,720 | 0 | 0.45 | 0 | 0.45 | 0.45 | 0 | 0.45 |
| Michigan | 7,710 | 0 | 7,710 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Minnesota | 1,330 | 0 | 1,330 | 4.17 | 935 | 0 | 935 | 939 | 0 | 939 |
| Mississippi | 307 | 148 | 456 | 43.5 | 11.2 | 0 | 11.2 | 54.7 | 0 | 54.7 |
| Missouri | 5,200 | 0 | 5,200 | 12.2 | 422 | 0 | 422 | 434 | 0 | 434 |
| Montana | 84.4 | 0 | 84.4 | 0 | 25.6 | 0 | 25.6 | 25.6 | 0 | 25.6 |
| Nebraska | 2,390 | 0 | 2,390 | 6.87 | 418 | 0 | 418 | 424 | 0 | 424 |
| Nevada | 0 | 0 | 0 | 12 | 24.7 | 0 | 24.7 | 36.7 | 0 | 36.7 |
| New Hampshire | 234 | 761 | 995 | 0.71 | 1.37 | 0 | 1.37 | 2.08 | 0 | 2.08 |
| New Jersey | 648 | 3,330 | 3,980 | 2.24 | 0 | 57.6 | 57.6 | 2.24 | 57.6 | 59.9 |
| New Mexico | 0 | 0 | 0 | 11.4 | 45 | 0 | 45 | 56.4 | 0 | 56.4 |
| New York | 4,040 | 5,010 | 9,050 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| North Carolina | 7,850 | 1,620 | 9,470 | 0.09 | 0 | 0 | 0 | 0.09 | 0 | 0.09 |
| North Dakota | 887 | 0 | 887 | 0 | 14.5 | 0 | 14.5 | 14.5 | 0 | 14.5 |
| Ohio | 7,790 | 0 | 7,790 | 7.57 | 799 | 0 | 799 | 806 | 0 | 806 |
| Oklahoma | 37.9 | 0 | 37.9 | 3.27 | 105 | 0 | 105 | 109 | 0 | 109 |
| Oregon | 0 | 0 | 0 | 2.47 | 12.8 | 0 | 12.8 | 15.3 | 0 | 15.3 |
| Pennsylvania | 4,330 | 0 | 4,330 | 3.98 | 2,650 | 0 | 2,650 | 2,650 | 0 | 2,650 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rhode Island | 0 | 290 | 290 | 0 | 2.4 | 0 | 2.4 | 2.4 | 0 | 2.4 |
| South Carolina | 3,860 | 0 | 3,860 | 5.83 | 1,850 | 0 | 1,850 | 1,850 | 0 | 1,850 |
| South Dakota | 0 | 0 | 0 | 1.23 | 4.01 | 0 | 4.01 | 5.24 | 0 | 5.24 |
| Tennessee | 8,860 | 0 | 8,860 | 0 | 174 | 0 | 174 | 174 | 0 | 174 |
| Texas | 6,990 | 3,440 | 10,400 | 60.2 | 2,770 | 0 | 2,770 | 2,830 | 0 | 2,830 |
| Utah | 0 | 0 | 0 | 13.1 | 49.2 | 0 | 49.2 | 62.2 | 0 | 62.2 |
| Vermont | 354 | 0 | 354 | 0.66 | 0.55 | 0 | 0.55 | 1.21 | 0 | 1.21 |
| Virginia | 3,850 | 3,580 | 7,430 | 1.5 | 0 | 0 | 0 | 1.5 | 0 | 1.5 |
| Washington | 444 | 0 | 444 | 0.92 | 74.2 | 0 | 74.2 | 75.1 | 0 | 75.1 |
| West Virginia | 3,790 | 0 | 3,790 | 0 | 163 | 0 | 163 | 163 | 0 | 163 |
| Wisconsin | 6,090 | 0 | 6,090 | 8.99 | 0 | 0 | 0 | 8.99 | 0 | 8.99 |
| Wyoming | 179 | 0 | 179 | 1.13 | 63.4 | 0 | 63.4 | 64.6 | 0 | 64.6 |
| Puerto Rico | 0 | 2,190 | 2,190 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| U.S. Virgin Islands | 0 | 136 | 136 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **119,000** | **58,000** | **177,000** | **409** | **16,300** | **1,530** | **17,900** | **16,800** | **1,530** | **18,300** |

*Note:* Figures may not sum to totals because of independent rounding. All values are in million gallons per day.

*Source*: From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.



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**Table 7G.87 Thermoelectric Power Water Use in the United States, 2000**

| | Withdrawals (mil gal/day) | | | | | | | Withdrawals (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | By Source and Type | | | | | | | By Type | | |
| | Groundwater | Surface Water | | | Total | | | | | |
| State | Fresh | Fresh | Saline | Total | Fresh | Saline | Total | Fresh | Saline | Total |
| Alabama | 0 | 8,190 | 0 | 8,190 | 8,190 | 0 | 8,190 | 9,180 | 0 | 9,180 |
| Alaska | 4.65 | 28.9 | 0 | 28.9 | 33.6 | 0 | 33.6 | 37.6 | 0 | 37.6 |
| Arizona | 74.3 | 26.2 | 0 | 26.2 | 100 | 0 | 100 | 113 | 0 | 113 |
| Arkansas | 2.92 | 2,170 | 0 | 2,170 | 2,180 | 0 | 2,180 | 2,440 | 0 | 2,440 |
| California | 3.23 | 349 | 12,600 | 12,900 | 352 | 12,600 | 12,900 | 395 | 14,100 | 14,500 |
| Colorado | 16.1 | 122 | 0 | 122 | 138 | 0 | 138 | 155 | 0 | 155 |
| Connecticut | 0.08 | 186 | 3,440 | 3,630 | 187 | 3,440 | 3,630 | 209 | 3,860 | 4,070 |
| Delaware | 0.47 | 366 | 738 | 1,100 | 366 | 738 | 1,100 | 411 | 827 | 1,240 |
| District of Columbia | 0 | 9.69 | 0 | 9.69 | 9.69 | 0 | 9.69 | 10.9 | 0 | 10.9 |
| Florida | 29.5 | 629 | 12,000 | 12,600 | 658 | 12,000 | 12,600 | 738 | 13,400 | 14,100 |
| Georgia | 1.03 | 3,240 | 61.7 | 3,310 | 3,250 | 61.7 | 3,310 | 3,640 | 69.2 | 3,710 |
| Hawaii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Idaho | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Illinois | 5.75 | 11,300 | 0 | 11,300 | 11,300 | 0 | 11,300 | 12,600 | 0 | 12,600 |
| Indiana | 2.58 | 6,700 | 0 | 6,700 | 6,700 | 0 | 6,700 | 7,510 | 0 | 7,510 |
| Iowa | 11.9 | 2,530 | 0 | 2,530 | 2,540 | 0 | 2,540 | 2,850 | 0 | 2,850 |
| Kansas | 14.9 | 2,240 | 0 | 2,240 | 2,260 | 0 | 2,260 | 2,530 | 0 | 2,530 |
| Kentucky | 2.71 | 3,250 | 0 | 3,250 | 3,260 | 0 | 3,260 | 3,650 | 0 | 3,650 |
| Louisiana | 28.4 | 5,580 | 0 | 5,580 | 5,610 | 0 | 5,610 | 6,290 | 0 | 6,290 |
| Maine | 4.92 | 108 | 295 | 403 | 113 | 295 | 408 | 127 | 330 | 457 |
| Maryland | 1.8 | 377 | 6,260 | 6,640 | 379 | 6,260 | 6,640 | 425 | 7,020 | 7,440 |
| Massachusetts | 0 | 108 | 3,610 | 3,720 | 108 | 3,610 | 3,720 | 121 | 4,050 | 4,170 |
| Michigan | 0 | 7,710 | 0 | 7,710 | 7,710 | 0 | 7,710 | 8,640 | 0 | 8,640 |
| Minnesota | 4.17 | 2,260 | 0 | 2,260 | 2,270 | 0 | 2,270 | 2,540 | 0 | 2,540 |
| Mississippi | 43.5 | 318 | 148 | 467 | 362 | 148 | 510 | 406 | 166 | 572 |
| Missouri | 12.2 | 5,620 | 0 | 5,620 | 5,640 | 0 | 5,640 | 6,320 | 0 | 6,320 |
| Montana | 0 | 110 | 0 | 110 | 110 | 0 | 110 | 123 | 0 | 123 |
| Nebraska | 6.87 | 2,810 | 0 | 2,810 | 2,820 | 0 | 2,820 | 3,160 | 0 | 3,160 |
| Nevada | 12 | 24.7 | 0 | 24.7 | 36.7 | 0 | 36.7 | 41.1 | 0 | 41.1 |
| New Hampshire | 0.71 | 235 | 761 | 997 | 236 | 761 | 997 | 265 | 854 | 1,120 |
| New Jersey | 2.24 | 648 | 3,390 | 4,040 | 650 | 3,390 | 4,040 | 729 | 3,800 | 4,530 |
| New Mexico | 11.4 | 45 | 0 | 45 | 56.4 | 0 | 56.4 | 63.2 | 0 | 63.2 |
| New York | 0 | 4,040 | 5,010 | 9,050 | 4,040 | 5,010 | 9,050 | 4,530 | 5,610 | 10,100 |
| North Carolina | 0.09 | 7,850 | 1,620 | 9,470 | 7,850 | 1,620 | 9,470 | 8,800 | 1,810 | 10,600 |
| North Dakota | 0 | 902 | 0 | 902 | 902 | 0 | 902 | 1,010 | 0 | 1,010 |
| Ohio | 7.57 | 8,590 | 0 | 8,590 | 8,590 | 0 | 8,590 | 9,630 | 0 | 9,630 |
| Oklahoma | 3.27 | 143 | 0 | 143 | 146 | 0 | 146 | 164 | 0 | 164 |
| Oregon | 2.47 | 12.8 | 0 | 12.8 | 15.3 | 0 | 15.3 | 17.2 | 0 | 17.2 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pennsylvania | 3.98 | 6,970 | 0 | 6,970 | 6,980 | 0 | 6,980 | 7,820 | 0 | 7,820 |
| Rhode Island | 0 | 2.4 | 290 | 293 | 2.4 | 290 | 293 | 2.69 | 326 | 328 |
| South Carolina | 5.83 | 5,700 | 0 | 5,700 | 5,710 | 0 | 5,710 | 6,400 | 0 | 6,400 |
| South Dakota | 1.23 | 4.01 | 0 | 4.01 | 5.24 | 0 | 5.24 | 5.87 | 0 | 5.87 |
| Tennessee | 0 | 9,040 | 0 | 9,040 | 9,040 | 0 | 9,040 | 10,100 | 0 | 10,100 |
| Texas | 60.2 | 9,760 | 3,440 | 13,200 | 9,820 | 3,440 | 13,300 | 11,000 | 3,860 | 14,900 |
| Utah | 13.1 | 49.2 | 0 | 49.2 | 62.2 | 0 | 62.2 | 69.8 | 0 | 69.8 |
| Vermont | 0.66 | 355 | 0 | 355 | 355 | 0 | 355 | 398 | 0 | 398 |
| Virginia | 1.5 | 3,850 | 3,580 | 7,430 | 3,850 | 3,580 | 7,430 | 4,310 | 4,020 | 8,330 |
| Washington | 0.92 | 518 | 0 | 518 | 519 | 0 | 519 | 582 | 0 | 582 |
| West Virginia | 0 | 3,950 | 0 | 3,950 | 3,950 | 0 | 3,950 | 4,430 | 0 | 4,430 |
| Wisconsin | 8.99 | 6,090 | 0 | 6,090 | 6,090 | 0 | 6,090 | 6,830 | 0 | 6,830 |
| Wyoming | 1.13 | 242 | 0 | 242 | 243 | 0 | 243 | 273 | 0 | 273 |
| Puerto Rico | 0 | 0 | 2,190 | 2,190 | 0 | 2,190 | 2,190 | 0 | 2,460 | 2,460 |
| U.S. Virgin Islands | 0 | 0 | 136 | 136 | 0 | 136 | 136 | 0 | 153 | 153 |
| Total | 409 | 135,000 | 59,500 | 195,000 | 136,000 | 59,500 | 195,000 | 152,000 | 66,700 | 219,000 |

*Note:* Figures may not sum to totals because of independent rounding.

*Source*: From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.



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**Table 7G.88 Self-Supplied Thermoelectric Withdrawals and Production, 1950–1995**

| Year | Self-supplied Thermoelectric Withdrawals (bgd) | Withdrawals Per Capita (gpcd) | Thermoelectric Production (bil kWh) | Annual Growth Rate in Production (%) | Energy Production Per Capita (kWh/Capita/d) | Withdrawals Per Unit Production (gal/kWh) |
|---|---|---|---|---|---|---|
| 1950 | 40 | 264.5 | 232.8 | — | 4.2 | 62.7 |
| 1955 | 72 | 438.2 | 433.8 | 13.26 | 7.2 | 60.6 |
| 1960 | 100 | 560.4 | 609.6 | 7.04 | 9.4 | 59.9 |
| 1965 | 130 | 674.3 | 861.0 | 7.15 | 12.2 | 55.1 |
| 1970 | 170 | 841.1 | 1,283.3 | 8.31 | 17.4 | 48.4 |
| 1975 | 200 | 938.8 | 1,614.2 | 4.69 | 20.8 | 45.2 |
| 1980 | 210 | 934.5 | 2,004.9 | 4.43 | 24.4 | 38.2 |
| 1985 | 187 | 788.8 | 2,177.9 | 1.67 | 25.2 | 31.3 |
| 1990 | 195 | 789.3 | 2,517.6 | 2.94 | 27.9 | 28.3 |
| 1995 | 190 | 726.8 | 2,694.4 | 1.37 | 28.2 | 25.7 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL February 28, 2002, Reprinted with permission. http://info.geography.siu.edu/geography_info/research/.

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## SECTION 7H INDUSTRIAL WATER USE — WORLD

**Table 7H.89 Water Intake in Manufacturing (MCM/yr) by Purpose of Initial Use and Industry in Canada, 1996**

| Industry Group | Number of Plants | Processing | Cooling, Condensing, and Steam | Sanitary Services | Other | Total Intake | % |
|---|---|---|---|---|---|---|---|
| Food | 1,264 | 128.6 | 107.3 | 27.8 | 5.9 | 269.5 | 4.5 |
| Beverages | 121 | 38.4 | 29.0 | 4.6 | 1.1 | 73.1 | 1.2 |
| Rubber products | 96 | 3.6 | 7.7 | 0.9 | 0.1 | 12.3 | 0.2 |
| Plastic products | 486 | 5.9 | 5.9 | 1.3 | 0.2 | 13.3 | 0.2 |
| Primary textiles | 87 | 15.5 | 64.6 | 6.5 | 0.0 | 86.7 | 1.4 |
| Textile products | 47 | 12.8 | 1.8 | 0.4 | 0.1 | 15.0 | 0.2 |
| Wood products | 454 | 9.7 | 24.4 | 2.2 | 8.8 | 45.1 | 0.7 |
| Paper + allied products | 292 | 1,847.5 | 508.3 | 49.1 | 16.4 | 2,421.3 | 40.1 |
| Primary metals | 217 | 557.6 | 830.1 | 21.5 | 13.8 | 1,423.0 | 23.6 |
| Fabricated metals | 543 | 11.3 | 6.4 | 1.6 | 0.1 | 19.4 | 0.3 |
| Transportation equipment | 547 | 28.5 | 25.0 | 11.1 | 0.4 | 65.0 | 1.1 |
| Nonmetallic mineral products | 726 | 21.6 | 44.9 | 3.5 | 32.1 | 102.1 | 1.7 |
| Petroleum + coal products | 27 | 34.4 | 324.6 | 4.9 | 6.6 | 370.5 | 6.1 |
| Chemicals + chemical products | 599 | 220.9 | 879.8 | 10.9 | 9.7 | 1,121.3 | 18.6 |
| Total | 5,506 | 2,936.3 | 2,859.6 | 146.3 | 95.3 | 6,037.5 | 100.0 |
| **%** | | **48.6** | **47.4** | **2.4** | **1.6** | **100.0** | |

*Source*: From Scharf, D., Burke, D., Villeneuve, and Leigh, L., 1996. Industrial Water Use 1996, Scharf, D., Burke, D.W., Villeneuve, M., and Leigh, L., Environmental Economics Branch, Environment Canada, 2002. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

**Table 7H.90 Water Intake in Manufacturing (MCM/yr) by Source and Industry Group in Canada, 1996**

| | | Fresh Water | | | | Brackish Water | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Self-Supplied | | | Self-Supplied | | | |
| Industry Group | Number of Plants | Public Supplied Municipal | Surface | Ground | Other | Ground | Tidewater | Other | Total Intake |
| Food | 1,254 | 118.7 | 61.8 | 44.6 | 3.4 | 1.9 | 38.7 | 0.2 | 269.3 |
| Beverages | 121 | 49.0 | 16.1 | 8.1 | 0.0 | 0.0 | 0.0 | 0.0 | 73.1 |
| Rubber products | 96 | 8.2 | 1.3 | 2.4 | 0.5 | 0.0 | 0.0 | 0.0 | 12.3 |
| Plastic products | 482 | 7.0 | 4.8 | 1.2 | 0.1 | 0.1 | 0.0 | 0.0 | 13.2 |
| Primary textiles | 87 | 34.6 | 51.4 | 0.1 | 0.0 | 0.1 | 0.0 | 0.5 | 86.7 |
| Textile products | 47 | 13.1 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.0 |
| Wood products | 454 | 18.8 | 16.4 | 9.5 | 0.2 | 0.1 | 0.1 | 0.0 | 45.1 |
| Paper + allied products | 292 | 70.4 | 2,240.0 | 65.8 | 45.3 | 0.0 | 0.0 | 0.0 | 2,421.3 |
| Primary metals | 217 | 61.2 | 1,314.0 | 22.9 | 12.8 | 0.0 | 12.1 | 0.0 | 1,423.0 |
| Fabricated metals | 543 | 12.1 | 6.8 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 19.4 |
| Transportation equipment | 547 | 59.5 | 4.7 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 65.0 |
| Non-metallic mineral products | 725 | 19.5 | 36.3 | 9.9 | 36.0 | 0.0 | 0.4 | 0.0 | 102.1 |
| Petroleum + coal products | 27 | 11.4 | 249.0 | 2.5 | 1.3 | 0.0 | 102.1 | 4.2 | 370.5 |
| Chemicals + chemical products | 599 | 66.1 | 940.1 | 7.2 | 67.2 | 0.1 | 40.5 | 0.1 | 1,121.3 |
| Total | 5,491 | 549.6 | 4,942.5 | 177.3 | 166.8 | 2.3 | 193.9 | 5.0 | 6,037.4 |
| **%** | | **9.1** | **81.9** | **2.9** | **2.8** | **0.0** | **3.2** | **0.1** | **100.0** |

*Source*: From Scharf, D., Burke, D., Villeneuve, and Leigh, L., 1996. Industrial Water Use 1996, Scharf, D., Burke, D.W., Villeneuve, M., and Leigh, L., Environmental Economics Branch, Environment Canada, 2002. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

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**Table 7H.91 Competing Water Uses for Main Income Groups of Countries**

| | Agricultural Use (%) | Industrial Use (%) | Domestic Use (%) |
|---|---|---|---|
| **World** | 70 | 22 | 8 |
| Low income | 87 | 8 | 5 |
| Middle income | 74 | 13 | 12 |
| Lower middle income | 75 | 15 | 10 |
| Upper middle income | 73 | 10 | 17 |
| **Low and middle income** | 82 | 10 | 8 |
| East Asia and Pacific | 80 | 14 | 6 |
| Europe and central Asia | 63 | 26 | 11 |
| Latin America and Caribbean | 74 | 9 | 18 |
| Middle East and North Africa | 89 | 4 | 6 |
| South Asia | 93 | 2 | 4 |
| Sub-Saharan Africa | 87 | 4 | 9 |
| **High income** | 30 | 59 | 11 |
| Europe Economic and Monetary Union (EMU) | 21 | 63 | 16 |

*Source*: From *Water for People Water for Life*, The United Nations World Water Development Report. Copyright © United Nations Educational, Scientific, and Cultural Organization - World Water Assessment Programme (UNESCO-WWAP), 2003. Reproduced by permission of UNESCO. www.unesco.org.

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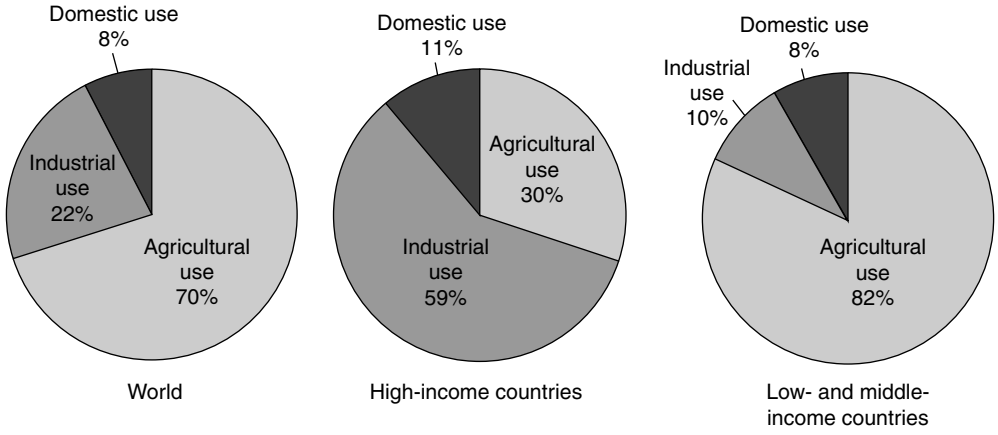


**Figure 7H.16** Industrial use of water increases with country income. (From *Water for People Water for Life*, The United Nations World Water Development Report. Copyright © United Nations Educational, Scientific, and Cultural Organization - World Water Assessment Programme (UNESCO-WWAP), 2003. Reproduced by permission of UNESCO. www.unesco.org. Original Source: World Bank, 2001, World Development Indicators (WDI), Washington, DC, Available on CD-ROM, Copyright © International Bank for Reconstruction and development/The World Bank, www.worldbank.org. Reprinted with permission.

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**Table 7H.92 World-Industrial Water Efficiency**

| Country | Total Annual Freshwater Withdrawal (bill m)[3a] | % for Industry[b] | Industrial Value Added (IVA) (mi US$)[c] | Population (mi)[d] | IVA/Industrial Annual Withdrawal (US$/m$^3$/Capita)[e] |
|---|---|---|---|---|---|
| Algeria | 4.5 | 15 | 22,618 | 30 | 1.11 |
| Angola | 0.5 | 10 | 4,182 | 12 | 7.26 |
| Argentina | 28.6 | 9 | 77,171 | 37 | 0.84 |
| Armenia | 2.9 | 4 | 1,029 | 4 | 2.14 |
| Austria | 2.2 | 60 | 76,386 | 8 | 7.14 |
| Azerbaijan | 16.5 | 25 | 1,213 | 8 | 0.04 |
| Bangladesh | 14.6 | 2 | 11,507 | 128 | 0.31 |
| Belarus | 2.7 | 43 | 9,543 | 10 | 0.81 |
| Benin | 0.2 | 10 | 333 | 6 | 3.59 |
| Bolivia | 1.4 | 20 | 1,529 | 8 | 0.68 |
| Botswana | 0.1 | 20 | 2,593 | 2 | 58.94 |
| Brazil | 54.9 | 18 | 231,442 | 168 | 0.14 |
| Cameroon | 0.4 | 19 | 2,360 | 15 | 2.07 |
| Central African Republic | 0.1 | 6 | 211 | 4 | 13.46 |
| Chad | 0.2 | 2 | 233 | 7 | 8.75 |
| Chile | 21.4 | 11 | 24,385 | 15 | 0.70 |
| China | 525.5 | 18 | 498,292 | 1,254 | 0.00 |
| Colombia | 8.9 | 4 | 23,120 | 42 | 1.40 |
| Congo Dem Rep. | 0.0 | 27 | 852 | 3 | 26.29 |
| Costa Rica | 5.8 | 7 | 4,456 | 4 | 2.88 |
| Côte d'Ivoire | 0.7 | 11 | 3,039 | 16 | 2.47 |
| Croatia | 0.1 | 50 | 4,995 | 4 | 31.22 |
| Czech Republic | 2.5 | 57 | 20,512 | 10 | 1.42 |
| Denmark | 0.9 | 9 | 40,142 | 5 | 100.23 |
| Dominican Republic | 8.3 | 1 | 5,530 | 8 | 16.58 |
| Ecuador | 17.0 | 6 | 6,535 | 12 | 0.57 |
| Egypt, Arab Rep. | 55.1 | 8 | 22,221 | 63 | 0.08 |
| El Salvador | 0.7 | 20 | 3,158 | 6 | 3.57 |
| Estonia | 0.2 | 39 | 1,494 | 1 | 23.88 |
| Ethiopia | 2.2 | 3 | 726 | 63 | 0.17 |
| Finland | 2.4 | 82 | 48,807 | 5 | 4.89 |
| Gabon | 0.1 | 22 | 2,752 | 1 | 208.45 |
| Gambia | 0.0 | 2 | 50 | 1 | 83.74 |
| Georgia | 3.5 | 20 | 378 | 5 | 0.11 |
| Germany | 46.3 | 86 | 760,536 | 82 | 0.23 |
| Ghana | 0.3 | 13 | 1,927 | 19 | 2.60 |
| Guatemala | 1.2 | 17 | 3,468 | 11 | 1.60 |
| Guinea | 0.7 | 3 | 1,431 | 7 | 9.21 |
| Guinea Bissau | 0.0 | 4 | 46 | 1 | 63.33 |
| Haiti | 1.0 | 1 | 641 | 8 | 13.62 |
| Honduras | 1.5 | 5 | 1,234 | 6 | 2.71 |
| India | 500.0 | 3 | 113,041 | 998 | 0.01 |
| Indonesia | 74.3 | 1 | 85,633 | 207 | 0.56 |
| Iran, Islamic Rep. | 70.0 | 2 | 34,204 | 63 | 0.37 |
| Italy | 57.5 | 37 | 323,494 | 58 | 0.27 |
| Jamaica | 0.9 | 7 | 1,619 | 3 | 8.33 |
| Jordan | 1.0 | 3 | 1,738 | 5 | 10.43 |
| Kenya | 2.0 | 4 | 1,325 | 29 | 0.57 |
| Korea, Rep. | 23.7 | 11 | 249,268 | 23 | 4.16 |
| Kyrgyztan | 10.1 | 3 | 699 | 6 | 0.46 |
| Latvia | 0.3 | 32 | 1,627 | 2 | 8.71 |
| Lithuania | 0.3 | 16 | 2,156 | 4 | 13.56 |
| Malawi | 0.9 | 3 | 288 | 11 | 0.82 |
| Malaysia | 12.7 | 13 | 43,503 | 23 | 1.14 |
| Mali | 1.4 | 1 | 580 | 11 | 3.88 |
| Mauritania | 16.3 | 2 | 284 | 3 | 0.32 |
| Mauritius | 0.4 | 7 | 1,419 | 1 | 57.13 |
| Mexico | 77.8 | 5 | 96,949 | 97 | 0.25 |

*(Continued)*

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**Table 7H.92 (Continued)**

| Country | Total Annual Freshwater Withdrawal (bill m)[3a] | % for Industry[b] | Industrial Value Added (IVA) (mi US$)[c] | Population (mi)[d] | IVA/Industrial Annual Withdrawal (US$/m$^3$/Capita)[e] |
|---|---|---|---|---|---|
| Moldova | 3.0 | 65 | 508 | 4 | 0.07 |
| Mongolia | 0.4 | 27 | 362 | 2 | 1.56 |
| Morocco | 11.1 | 3 | 12,558 | 28 | 1.40 |
| Mozambique | 0.6 | 2 | 1,020 | 17 | 4.92 |
| Namibia | 0.3 | 3 | 971 | 2 | 57.12 |
| The Netherlands | 7.8 | 68 | 116,700 | 16 | 1.37 |
| New Zealand | 2.0 | 13 | 15,683 | 4 | 15.08 |
| Nicaragua | 1.3 | 2 | 538 | 5 | 3.97 |
| Niger | 0.5 | 2 | 376 | 10 | 3.76 |
| Nigeria | 4.0 | 15 | 14,918 | 124 | 0.20 |
| Norway | 2.0 | 68 | 47,599 | 4 | 8.61 |
| Pakistan | 155.6 | 2 | 14,685 | 135 | 0.04 |
| Panama | 1.6 | 2 | 1,561 | 3 | 19.84 |
| Papua New Guinea | 0.1 | 22 | 1,779 | 5 | 16.17 |
| Paraguay | 0.4 | 7 | 2,334 | 5 | 15.51 |
| Peru | 19.0 | 7 | 20,714 | 25 | 0.61 |
| Philippines | 55.4 | 4 | 26,364 | 74 | 0.16 |
| Poland | 12.1 | 67 | 47,846 | 39 | 0.15 |
| Russian Federation | 77.1 | 62 | 97,800 | 146 | 0.01 |
| Rwanda | 0.8 | 1 | 356 | 8 | 4.13 |
| Senegal | 1.5 | 3 | 1,235 | 9 | 3.05 |
| Sierra Leone | 0.4 | 4 | 170 | 5 | 2.30 |
| Slovak Republic | 1.4 | 50 | 7,036 | 5 | 2.01 |
| Slovenia | 0.5 | 50 | 7,337 | 2 | 14.67 |
| South Africa | 13.3 | 11 | 49,363 | 42 | 0.81 |
| Sri Lanka | 9.8 | 2 | 3,862 | 19 | 1.04 |
| Sweden | 2.7 | 30 | 74,703 | 9 | 10.07 |
| Tanzania, United Republic of | 1.2 | 2 | 928 | 33 | 1.15 |
| Thailand | 33.1 | 4 | 64,800 | 60 | 0.81 |
| Togo | 0.1 | 13 | 309 | 5 | 5.21 |
| Tunisia | 2.8 | 2 | 6,297 | 9 | 13.01 |
| Turkey | 35.5 | 11 | 51,575 | 64 | 0.20 |
| Turkmenistan | 23.8 | 1 | 2,957 | 5 | 2.49 |
| Uganda | 0.2 | 8 | 1,191 | 21 | 3.55 |
| Ukraine | 26.0 | 52 | 17,854 | 50 | 0.03 |
| United Kingdom | 9.3 | 8 | 330,097 | 60 | 7.10 |
| Uruguay | 4.2 | 3 | 5,703 | 3 | 15.61 |
| Uzbekistan | 58.0 | 2 | 4,340 | 24 | 0.16 |
| Venezuela | 4.1 | 10 | 30,083 | 24 | 3.12 |
| Vietnam | 54.3 | 10 | 9,052 | 78 | 0.02 |
| Yemen | 2.9 | 1 | 1,683 | 17 | 3.07 |
| Zambia | 1.7 | 7 | 996 | 10 | 0.84 |
| Zimbabwe | 1.2 | 7 | 2,005 | 12 | 1.96 |

*Note:* The industrial water productivity shows the economic value (US$) obtained annually by industry per cubic meter of water used. Very high differences can be noted, between high-income countries such as the United Kingdom, showing a per capita industrial water efficiency of US$ 7.10/m$^3$, and many low-income countries, such as Moldova, with only US$ 0.07/m$^3$. Observe, however, that countries having small populations or highly specialized industries (high-value gems tourism)—such as Gabon, Namibia, or Mauritius—have also achieved high productivity.

[a] Data refer to any year from 1980 to 1999.
[b] Withdrawal shares are mostly estimated for 1987.
[c] US constant dollar 1995, data for 1999.
[d] Data estimated for 1999.
[e] Population is expressed in millions, U.S. constant dollar 1995.

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**Table 7H.93 Water Requirements for Selected Industries in the World**

| Industry, Product, and Country | Unit of Product (Ton, Except as Specified) | Water Required per Unit (L) |
|---|---|---|
| **Food Products** | | |
| Bread or pastry, Belgium | | 1,100 |
| Bread, United States | | 2,100–4,200 |
| Bread, Cyprus[a] | | 600 |
| **Canned food** | | |
| *Belgium* | | |
| Fish, canned | | 400 |
| Fish, preserved | | 1,500 |
| Fruit | | 15,000 |
| Vegetables | | 8,000–80,000 |
| *Canada* | | |
| Fruits and vegetables[a] | | 10,000–50,000 |
| *Cyprus* | | |
| Citrus/tomato juice[a] | | 2,800 |
| Grapefruit sections[a] | | 16,000 |
| Peaches/pears[a] | | 10,000–15,000 |
| Grapes[a] | | 30,000 |
| Tomatoes, whole[a] | | 2,000 |
| Tomato paste[a] | | 21,000 |
| Peas[a] | | 10,000 |
| Carrots[a] | | 16,000 |
| Spinach[a] | | 30,000 |
| *Israel* | | |
| Citrus fruits[a] | Ton of raw citrus | 4,000 |
| Vegetables[a] | | 10,000–15,000 |
| *United States* | | |
| Apricots | | 21,200 |
| Asparagus | | 20,500 |
| Beans, green | | 9,300 |
| Beans, lima | | 69,800 |
| Beets, corn and peas | | 7,000 |
| Grapefruit juice | | 2,800 |
| Grapefruit sections | | 15,600 |
| Peaches and pears | | 18,100 |
| Pork and beans | | 9,300 |
| Pumpkin and squash | | 7,000 |
| Sauerkraut | | 950 |
| Spinach | | 49,400 |
| Succotash | | 34,800 |
| Tomato products | | 20,500 |
| Tomatoes, whole | | 2,200 |
| Industry average, fruits, vegetables, and juices (1965)[a] | | 24,000 |
| **Meat** | | |
| Meat freezing, Cyprus[a] | Ton of carcass | 500 |
| Meat freezing, New Zealand | | 3,000–8,600 |
| Meat packing, United States[a] | Ton of prepared meat | 23,000 |
| Meat packing, Canada[a] | Ton of carcass | 8,800–34,000 |
| Meat products, Belgium | Ton of prepared meat | 200 |
| Sausage factory, Finland | | 20,000–35,000 |
| Sausage factory, Cyprus[a] | | 25,000 |
| Slaughtering, Finland | Ton, live weight | 4,000–9,000 |
| Slaughtering, Cyprus[a] | Ton of carcass | 10,000 |
| Meat preserving, Israel[a] | Ton of prepared meat | 10,000 |
| **Fish** | | |
| Fresh and frozen fish, Canada[a] | | 30,000–300,000 |
| Canned fish, Canada[a] | | 58,000 |
| Canning and preserving fish, Israel[a] | Ton of raw fish | 16,000–20,000 |
| **Poultry** | | |
| Poultry, Canada[a] | Ton | 6,000–43,000 |
| Chickens, Israel[a] | Ton of dressed chicken | 33,000 |
| Chickens, United States[a] | Per bird | 25 |
| Turkeys, United States[a] | Per bird | 75 |
| **Milk and Milk Products** | | |
| *Butter* | | |
| New Zealand[a] | | 20,000 |

*(Continued)*

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**Table 7H.93 (Continued)**

| Industry, Product, and Country | Unit of Product (Ton, Except as Specified) | Water Required per Unit (L) |
|---|---|---|
| *Cheese* | | |
| Cyprus[a] | | 10,000 |
| New Zealand[a] | | 2,000 |
| United States[a] | | 27,500 |
| *Milk* | | |
| Belgium | 1,000 L | 7,000 |
| Finland | | 2,000–5,000 |
| Israel[a] | | 2,700 |
| Sweden | | 2,000–4,000 |
| United States[a] | | 3,000 |
| *Milk powder* | | |
| New Zealand[a] | | 45,000 |
| South Africa | | 200,000 |
| Whey, United States[a] | | 10,000 |
| Dairy products, general, Canada[a] | | 12,200 |
| Ice cream, United States[a] | | 10,000 |
| Yogurt, Cyprus[a] | | 20,000 |
| **Sugar** | | |
| Denmark[a] | Ton of sugar beets | 4,800–15,800 |
| Finland | Ton of sugar beets | 10,000–20,000 |
| France[a] | Ton of sugar beets | 10,900 |
| Germany, Federal[a] | Ton of sugar beets | 10,400–14,000 |
| Great Britain[a] | Ton of sugar beets | 14,900 |
| Israel[a] | Ton of sugar beets | 1,800 |
| Italy[a] | Ton of sugar beets | 10,500–12,500 |
| Republic of China[a] | Ton of sugar cane | 15,000 |
| United States[a] | Ton of sugar beets (range) | 3,200–8,300 |
| United States[a] | Ton of sugar beets (average) | 6,000 |
| **Beverages** | | |
| *Beer* | | |
| Belgium | Kiloliter | 7,000–20,000 |
| Canada[a] | Kiloliter | 10,000–20,000 |
| Cyprus[a] | Kiloliter (incl. cleaning bottles) | 22,000–30,000 |
| Finland | Kiloliter | 10,000–20,000 |
| France[a] | Kiloliter | 14,500 |
| Israel[a] | Kiloliter | 13,500 |
| United Kingdom[a] | Kiloliter | 6,000–10,000 |
| United States | Kiloliter | 15,200 |
| Whiskey, United States[a] | Kiloliter of proof spirit | 2,600–76,000 |
| Distilled spirits, Israel[a] | Kiloliter | 30,000 |
| Wine, France[a] | Kiloliter | 2,900 |
| Wine, Israel[a] | Kiloliter | 500 |
| **Miscellaneous Food Products** | | |
| Chocolate confectionery, Belgium | | 15,000–17,000 |
| Gelatin (edible), United States | | 55,100–83,500 |
| Maize (wet milling), United States | Liter of maize | 15.0–25.5 |
| Maize syrup, United States | Liter of maize | 3.8–4.3 |
| Wheat milling, Cyprus[a] | | 2,000 |
| Wheat milling, Israel[a] | | 700–1,300 |
| Potato flour, Finland | Ton of potatoes | 10,000–20,000 |
| Potato starch, Canada[a] | Ton of starch | 80,000–150,000 |
| Macaroni, Cyprus[a] | | 1,200 |
| Molasses, Belgium | Hectoliter of raw material | 1,000–12,000 |
| Molasses, United States | Hectoliter of 100 proof | 840 |
| **Pulp and Paper** | | |
| *Groundwood pulp* | | |
| Finland | Ton of wood-pulp | 30,000–40,000 |
| *Sulphate pulp* | | |
| China, Republic of[a] | Ton of bleached pulp | 340,000 |
| China, Republic of[a] | Ton of unbleached pulp | 230,000 |
| Finland | Ton of pulp | 250,000–350,000 |
| Sweden[a] | Ton of unbleached pulp | 75,000–300,000 |
| Sweden[a] | Ton of bleached pulp | 170,000–500,000 |
| *Sulphite pulp* | | |

*(Continued)*

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**Table 7H.93 (Continued)**

| Industry, Product, and Country | Unit of Product (Ton, Except as Specified) | Water Required per Unit (L) |
|---|---|---|
| Finland | Ton of bleached pulp | 450,000–500,000 |
| Finland | Ton of unbleached pulp | 250,000–300,000 |
| Sweden[a] | Ton of bleached pulp | 300,000–700,000 |
| Sweden[a] | Ton of unbleached pulp | 140,000–500,000 |
| *Wood pulp* | | |
| Sweden[a] | Ton of dry pulp | 50,000–100,000 |
| South Africa | | 150,000 |
| Blotting paper, Sweden | | 350,000–400,000 |
| Craft, printing and fine paper, Finland | | 375,000 |
| Printing paper, Republic of China[a] | | 340,000 |
| Newsprint, Republic of China[a] | | 190,000 |
| Newsprint, Canada[a] | | 165,000–200,000 |
| Fine paper, Republic of China[a] | | 800,000 |
| Fine paper, Sweden | | 900,000–1,000,000 |
| Newsprint paper, Sweden | | 200,000 |
| Packing and cartridge paper, Sweden | | 125,000 |
| Press paper, Finland | | 200,000 |
| Printing paper, Sweden | | 500,000 |
| Cardboard, Finland | | 125,000 |
| Paperboard, United States | | 62,000–376,000 |
| Paper and cardboard, Belgium | | 180,000 |
| Strawboard, United States | | 109,000 |
| Wallboard, Finland | | 125,000 |
| Wallboard, Sweden[a] | | 50,000 |
| Industry average, United States[a] | Ton of pulp and paper | 236,000 |
| Industry average, United Kingdom[a] | Ton of paper and board | 90,000[b] |
| Industry average, France[a] | Ton of pulp and paper | 150,000 |
| **Petroleum and Synthetic Fuels** | | |
| Aviation gasoline, United States | Kiloliter | 25,000 |
| Aviation gasoline, Republic of China[a] | Kiloliter | 25,000 |
| Gasoline, United States | Kiloliter | 7,000–10,000 |
| Gasoline, Republic of China[a] | Kiloliter | 8,000 |
| Gasoline, polymerization, United States | Kiloliter | 34,000 |
| Kerosene, Belgium | Ton | 40,000 |
| Synthetic gasoline, United States | Kiloliter | 377,000 |
| Oilfields, United States | Kiloliter of crude petroleum | 4,000 |
| *Oil refineries* | | |
| Belgium[a] | | |
| China, Republic of[a] | Ton of crude petroleum | 30,500 |
| Sweden | Ton of crude petroleum | 10,000 |
| United States[a] | | |
| *Synthetic fuel* | | |
| From coal | | |
| South Africa | | 50,100 |
| United States | Kiloliter | 265,500 |
| From natural gas, United States | Kiloliter | 88,900 |
| From shale, United States | Kiloliter | 20,800 |
| **Chemicals** | | |
| Acetic acid, United States | | 417,000–1,000,000 |
| Alcohol, 100 proof, United States | Liter | 138 |
| Alcohol, 190 proof, United States | Liter | 52–100 |
| Alumina (Bayer process), United States | | 26,300 |
| Ammonia, synthetic, United States | Ton of liquid $NH_3$ | 129,000 |
| Ammonia (Naphtha, reforming), Japan[a] | | 255,000 |
| Ammonium nitrate, Belgium | | 52,000 |
| Ammonium sulphate, United States | | 835,000 |
| Calcium carbide, United States | | 125,000 |
| Calcium metaphosphate, United States | | 16,700 |
| Carbon dioxide, United States | | 83,500 |
| Caustic soda and chlorine, Canada[a] | | 125,000 |
| Caustic soda (Solvay process), United States[a] | | 60,500 |
| Caustic soda (Dual process), Federal Republic of Germany[a] | | 160,000 |
| Caustic soda (Dual process), Republic of China[a] | | 200,000 |

*(Continued)*

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**Table 7H.93 (Continued)**

| Industry, Product, and Country | Unit of Product (Ton, Except as Specified) | Water Required per Unit (L) |
|---|---|---|
| Caustic soda (Solvay process), Republic of China[a] | | 150,000 |
| Cellulose nitrate, United States | | 41,700 |
| Charcoal and wood chemicals, United States | Ton of crude $CaAc_2$ | 271,000 |
| Chlorine, Federal Republic of Germany[a] | | 12,600 |
| Ethylene, Israel[a] | | 16,000 |
| Gases, compressed and liquified, Canada[a] | Cubic meter | 60–70 |
| Glycerine, United States | | 4,600 |
| Gunpowder, United States | | 401,000–835,000 |
| Hydrochloric acid (salt process), United States | Ton of 20 Be HCl | 12,100 |
| Hydrochloric acid (synthetic process), United States | Ton of 20 Be HCl | 2,000–4,200 |
| Hydrogen, United States | | 2,750,000 |
| Lactose, United States | | 835,000–918,000 |
| Magnesium carbonate, basic | Ton of basic $MgCO_3$ | 18,000 |
| United States | Ton of $MgCO_3$ | 163,000 |
| Oxygen, United States | Cubic meter of $O_2$ | 243 |
| Polyethylene, Federal Republic of Germany[a] | | 231,000 (incl. 225,000 cooling water) |
| Polyethylene, Israel[a] | | 8,400 |
| Potassium chloride (sylvinite), United States | | 167,000–209,000 |
| Smokeless powder, United States | | 209,000 |
| Soap, Belgium | | 37,000 |
| Soap, Cyprus[a] | | 4,500 |
| Soap (laundry), United States | | 960–2,100 |
| Soda ash (ammonia soda process), 58 percent, United States | | 62,600–75,100 |
| Sodium chlorate, United States | | 250,000 |
| Sodium silicate, United States | Ton of 40 Be water-glass | 670 |
| Stearine, soap and washing agents, Sweden | Ton of fat | 70,000–200,000 |
| Sulfuric acid, Belgium | | 20,000–25,000 |
| Sulfuric acid (chamber process), United States | Ton of 100 percent $H_2SO_4$ | 10,400 |
| Sulfuric acid (contact process), United States | Ton of 100 percent $H_2SO_4$ | 2,700–20,300 |
| Sulfuric acid, Federal Republic of Germany[a] | Ton of $SO_3$ | 83,500 |
| **Textiles** | | |
| *Steeping, dressing, scouring and bleaching* | | |
| Steeping flax, Belgium | | 30,000–40,000 |
| Dressing flax, Sweden | | 30,000–40,000 |
| Scouring wool, Belgium | | 240,000–250,000 |
| Washing wool, Sweden | | 10,000 |
| Bleaching textiles, Belgium | | 180,000 |
| *Dyeing* | | |
| Textiles, Belgium | | 200,000 |
| Textiles, France (range)[a] | | 52,000–560,000 |
| Textiles, France (average)[b] | | 180,000 |
| *Finishing* | | |
| Wet finishing of textiles, Belgium | | 100,000–150,000 |
| *Dyeing and finishing* | | |
| Cotton yarn, Israel[a] | | 60,000–180,000 |
| Synthetic yarn, Israel[a] | | 90,000–180,000 |
| Wool yarn, Israel | | 70,000–140,000 |
| Fabrics, Israel[a] | | 60,000–100,000 |
| *Mills* | | |
| Cotton | | |
| Finland | | 50,000–150,000 |
| Sweden | | 10,000–250,000 |
| Canada[a] | Square yard | 1.0 |
| *Wool* | | |
| Finland | Ton of cloth or yarn | 150,000–350,000 |
| Sweden | Ton of wool | 400,000 |
| *Synthetic fibers* | | |
| Artificial silk, Sweden | | 2,000,000 |
| *Rayon* | | |
| Belgium | | 2,000,000 |
| Finland | | 1,000,000–2,000,000 |
| Rayon staple, Belgium | | 550,000 |

*(Continued)*

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**Table 7H.93 (Continued)**

| Industry, Product, and Country | Unit of Product (Ton, Except as Specified) | Water Required per Unit (L) |
|---|---|---|
| Industrial duck products, Canada[a] | | 22,000 |
| Carpets, Canada[a] | Square yard | 20 |
| **Mining and Quarrying** | | |
| Gold, South Africa | Ton of ore | 1,000 |
| Iron ore (brown), United States | | 4,200 |
| Bauxite, United States[a] | Ton of ore | 300 |
| Sulfur, United States | | 12,500 |
| Copper, Finland | | 3,750 |
| Copper, Israel[a] | | 3,100 |
| Gravel, Israel[a] | | 400 |
| Limestone and by-products, Belgium | | 200–6,500 |
| **Iron and Steel Products** | | |
| *Belgium* | | |
| Blast furnace, no recycling | | 58,000–73,000 |
| Blast furnace, with recycling | | 50,000 |
| Finished and semi-finished steel, no recycling[a] | | 61,000 |
| Finished and semi-finished steel, with recycling | | 27,000 |
| *Canada* | | |
| Pig iron[b] | | 130,000 |
| Open hearth steel[a] | | 22,000 |
| *France* | | |
| Smelting[a] | | 46,000 |
| Martin process (Open hearth)[a] | | 15,000 |
| Thomas process (Bessemer converter)[a] | | 10,000 |
| Electric furnace steel[a] | | 40,000 |
| Rolling mills[a] | | 30,000 |
| *Germany, Federal Republic* | | |
| Steel works[a] | | 8,000–12,000 |
| *South Africa* | | |
| Steel | | 12,500 |
| *Sweden* | | |
| Iron and steel works | | 10,000–30,000 |
| *United States (average)* | | |
| Fully integrated mills[a] | | 86,000 |
| Rolling and drawing mills[a] | | 14,700 |
| Blast furnace smelting[a] | | 103,000 |
| Electrometallurgical ferroalloys[a] | | 72,000 |
| Industry, consumptive use (est.)[a] | | 3,800 |
| **Miscellaneous Products** | | |
| Automobiles, United States[a] | Vehicle | 38,000 |
| Boilers, steam, United States | Horsepower-hour | 15 |
| Casein, New Zealand[a] | | 55,000 |
| *Cement, Portland* | | |
| Belgium[a] | | 1,900 |
| Cyprus (dry process)[a] | | 550 |
| Finland | | 2,500 |
| United States (wet process)[a] | | 900 |
| Ceramics and tiles, Belgium | | 1,800–2,000 |
| *Coal*:[c] | | |
| Ruhr (Fed. Rep. Of Germany)[a] | | 1,000 (min.)–1,750 (avg.) |
| Great Britain[a] | | <3,000 |
| Netherlands[a] | | 2,650 |
| Coal, Belgium | | 5,000–6,000 |
| Coal, coke and by-product coke, United States | | 6,300–15,000 |
| Coal washing, United States | | 840 |
| Condensers, surface, United States | Pound of condensed steam | 9.1–27.3 |
| *Distilling, grain* | | |
| Belgium | Hectoliter of grain treated | 6,000–7,000 |
| United States | Hectoliter of grain treated | 6,450 |
| Distilling, Sweden | Kiloliter of 100 percent alcohol | 15,000–100,000 |
| *Electric power (conventional thermal)* | | |
| Sweden | Ton of coal | 200,000–400,000 |
| South Africa | Kilowatt-hour (consumptive use) | 5 |
| United States[a] | Kilowatt-hour | 200 |

*(Continued)*

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**Table 7H.93 (Continued)**

| Industry, Product, and Country | Unit of Product (Ton, Except as Specified) | Water Required per Unit (L) |
|---|---|---|
| Republic of China[a] | Kilowatt-hour | 230 |
| *Explosives* | | |
| Sweden | | 800,000 |
| United States | | 835,000 |
| Fertilizer plant, Finland | Ton of saltpeter (25 percent nitrogen) | 270,000 |
| Glass, Belgium | | 68,000 |
| *Laundry* | | |
| Cyprus[a] | Ton of washed goods | 45,000 |
| Finland | Ton of washed goods | 20,000 |
| Sweden | Ton of washed goods | 30,000–50,000 |
| Leather, South Africa | | 50,100 |
| Leather factory, Finland | Ton of hides | 50,000–125,000 |
| Leather tanning, United States[a] | Sq. meter of hide | 20–2,550 (range) |
| Leather tanning, United States[a] | Sq. meter of hide | 440 (average) |
| Leather tanning, Cyprus[a] | Sq. meter of small animal skins | 110 |
| Non-ferrous metals, raw and semi-finished, Belgium | | 80,000 |
| Rock wool, United States | | 16,700–20,900 |
| *Rubber, synthetic, United States* | | |
| Butadiene | | 83,500–2,750,000 |
| Buna S | | 125,000–2,630,000 |
| Grade GR-S | | 117,000–2,800,000 |
| *Starch* | | |
| Belgium | Ton of maize | 13,000–18,000 |
| Sweden | Ton of potatoes | 10,000 |

*Note:* Water requirements for unit of product produced. Other figures based on older data (pre-1950).

[a] Figures based on newer data (post-1960).
[b] Does not include cooling water for power generating plants.
[c] Includes generation of electricity. If this is not included, the quantities above are reduced by about one-half.

*Source*: From Dept. of Economic and Social Affairs, United Nations, 1969.

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## SECTION 7I IRRIGATION — UNITED STATES

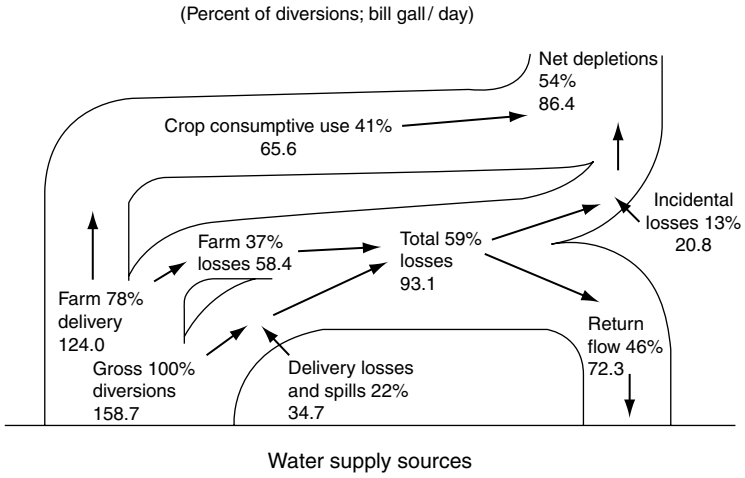


**Figure 7I.17** Irrigation water budget of the United States. (From Soil Conservation Service, *America's Soil and Water: Condition and Trends*, 1981.)

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**Table 7I.94 Acreage Irrigated with On-Farm and Off-Farm Pumped Water in the United States, 1994, 1998, and 2003**

| | Groundwater | | | On-Farm Surface Water | | | Off-Farm Surface Water | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1994 | 1998 | 2003 | 1994 | 1998 | 2003 | 1994 | 1998 | 2003 | 1994 | 1998 | 2003 |
| **Northeast** | | | | | | | | | | | | |
| Connecticut | — | 172 | 290 | — | 1,699 | 1,523 | — | 55 | 409 | — | 1,913 | 2,213 |
| Delaware | — | 67,262 | 64,840 | — | 11,207 | 4,803 | — | (D) | 375 | — | 77,382 | 69,088 |
| Maine | — | 700 | 1,480 | — | 17,331 | 15,278 | — | (D) | 1 | — | 18,324 | 18,163 |
| Maryland | — | 33,427 | 40,131 | — | 22,006 | 13,124 | — | 401 | 891 | — | 55,150 | 53,734 |
| Massachusetts | — | 779 | 1,289 | — | 15,696 | 13,972 | — | 251 | 954 | — | 16,367 | 16,151 |
| New Hampshire | — | 117 | 162 | — | 542 | 592 | — | 62 | 64 | — | 718 | 818 |
| New Jersey | — | 37,406 | 26,487 | — | 26,853 | 21,219 | — | 996 | 289 | — | 63,508 | 46,679 |
| New York | — | 9,762 | 12,289 | — | 19,024 | 33,598 | — | 2,355 | 2,712 | — | 29,176 | 48,545 |
| Pennsylvania | — | 3,469 | 5,230 | — | 14,418 | 13,103 | — | 199 | 1,594 | — | 17,916 | 19,633 |
| Rhode Island | — | 33 | 52 | — | 317 | 567 | — | 58 | 29 | — | 408 | 648 |
| Vermont | — | 42 | 208 | — | 537 | 509 | — | — | 108 | — | 579 | 825 |
| **Lake States** | | | | | | | | | | | | |
| Michigan | 184,943 | 228,137 | 286,450 | 116,109 | 134,858 | 140,338 | 7,827 | 5,598 | 6,533 | 305,481 | 367,992 | 432,665 |
| Minnesota | 292,643 | 301,550 | 400,925 | 24,929 | 16,382 | 23,335 | 9,729 | 5,448 | 10,240 | 326,781 | 322,346 | 434,500 |
| Wisconsin | 270,362 | 315,241 | 345,408 | 35,196 | 37,668 | 45,436 | 1,928 | 1,834 | 1,279 | 306,096 | 351,023 | 391,763 |
| **Corn Belt** | | | | | | | | | | | | |
| Illinois | 251,551 | 280,060 | 360,740 | 18,428 | 12,347 | 12,905 | 1,760 | 289 | 1,274 | 271,725 | 290,825 | 374,919 |
| Indiana | — | 176,427 | 227,750 | — | 42,329 | 48,533 | — | 960 | 129 | — | 217,197 | 276,294 |
| Iowa | — | 62,718 | 127,128 | — | 4,109 | 4,909 | — | 1,138 | 2,147 | — | 67,852 | 134,164 |
| Missouri | 650,580 | 783,174 | 961,231 | 56,363 | 49,155 | 55,341 | 1,744 | 2,702 | 4,156 | 702,183 | 832,591 | 1,020,728 |
| Ohio | — | 4,718 | 6,995 | — | 5,428 | 5,126 | — | 2,037 | 2,355 | — | 12,037 | 14,476 |
| **Northern Plains** | | | | | | | | | | | | |
| Kansas | 2,446,630 | 2,577,611 | 2,430,557 | 18,945 | 46,457 | 75,062 | 59,251 | 34,520 | 60,901 | 2,501,925 | 2,650,486 | 2,543,950 |
| Nebraska | 5,408,543 | 5,069,036 | 6,974,942 | 133,254 | 183,012 | 121,860 | 544,246 | 534,208 | 443,354 | 5,979,661 | 5,692,215 | 7,516,171 |
| North Dakota | 93,983 | 103,714 | 152,714 | 27,321 | 14,846 | 25,381 | 37,272 | 46,355 | 30,400 | 157,426 | 164,741 | 207,772 |
| South Dakota | 178,827 | 137,788 | 233,600 | 54,117 | 52,406 | 39,400 | 72,576 | 110,822 | 117,406 | 304,454 | 297,205 | 390,406 |
| **Appalachia** | | | | | | | | | | | | |
| Kentucky | — | 11,005 | 10,264 | — | 14,032 | 10,386 | — | 526 | 280 | — | 25,454 | 20,685 |
| North Carolina | — | 13,209 | 14,559 | — | 120,610 | 85,237 | — | 1,713 | 3,109 | — | 134,468 | 101,055 |
| Tennessee | — | 16,387 | 25,636 | — | 6,256 | 9,119 | — | 98 | 574 | — | 22,741 | 34,429 |
| Virginia | — | 6,411 | 6,619 | — | 60,221 | 28,077 | — | 692 | 496 | — | 65,734 | 33,635 |
| West Virginia | — | 207 | 247 | — | 939 | 532 | — | 65 | 22 | — | 1,211 | 801 |
| **Southeast** | | | | | | | | | | | | |
| Alabama | — | 14,079 | 24,451 | — | 33,087 | 26,994 | — | 465 | 1,333 | — | 46,811 | 52,722 |
| Florida | 746,071 | 1,032,746 | 772,907 | 246,527 | 274,388 | 418,190 | 447,724 | 340,507 | 319,598 | 1,416,019 | 1,613,719 | 1,497,653 |
| Georgia | 450,029 | 435,770 | 518,239 | 169,433 | 218,532 | 194,926 | 1,000 | 1,871 | 56 | 619,536 | 647,749 | 711 |
| South Carolina | — | 28,515 | 31,157 | — | 32,306 | 22,017 | — | 584 | 232 | — | 61,015 | 52,046 |
| **Delta States** | | | | | | | | | | | | |
| Arkansas | 2,581,693 | 3,722,635 | 3,421,365 | 271,512 | 349,574 | 509,914 | 13,196 | 23,485 | 26,793 | 2,853,929 | 4,043,382 | 3,944,867 |
| Louisiana | 557,431 | 709,207 | 633,455 | 240,593 | 219,653 | 186,544 | 34,880 | 9,810 | 23,596 | 820,816 | 920,823 | 838,717 |
| Mississippi | 624,182 | 1,078,511 | 1,115,676 | 25,361 | 39,012 | 46,834 | 378 | 1,245 | 9,213 | 646,761 | 1,109,079 | 1,169,793 |



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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Southern Plains** | | | | | | | | | | | | |
| Oklahoma | 392,063 | 355,414 | 413,067 | 34,105 | 33,189 | 62,572 | 48,579 | 66,743 | 36,513 | 474,201 | 451,788 | 508,842 |
| Texas | 4,319,337 | 4,576,456 | 4,174,840 | 203,619 | 246,693 | 184,173 | 606,841 | 488,571 | 588,932 | 5,100,979 | 5,237,584 | 4,947,745 |
| **Mountain** | | | | | | | | | | | | |
| Arizona | 340,306 | 243,313 | 291,025 | 26,012 | 6,412 | 72,213 | 492,398 | 683,637 | 516,422 | 752,019 | 873,589 | 836,587 |
| Colorado | 1,357,765 | 1,331,615 | 1,095,601 | 517,976 | 559,887 | 694,262 | 1,383,255 | 1,211,561 | 810,713 | 2,998,888 | 2,942,230 | 2,562,329 |
| Idaho | 1,307,688 | 1,226,924 | 1,202,870 | 352,423 | 388,335 | 352,666 | 1,643,919 | 1,656,908 | 1,609,148 | 3,183,733 | 3,188,406 | 3,126,857 |
| Montana | 136,969 | 46,606 | 96,469 | 691,982 | 695,480 | 724,542 | 1,134,537 | 1,015,467 | 1,313,763 | 1,936,292 | 1,740,873 | 2,131,955 |
| Nevada | 202,566 | 223,747 | 259,721 | 184,808 | 296,811 | 241,713 | 155,591 | 191,692 | 145,684 | 519,507 | 694,930 | 639,310 |
| New Mexico | 381,244 | 425,530 | 502,021 | 56,803 | 49,881 | 89,790 | 275,091 | 281,300 | 206,658 | 685,695 | 720,319 | 769,787 |
| Utah | 196,191 | 139,693 | 191,842 | 162,912 | 170,750 | 104,527 | 741,809 | 791,945 | 790,434 | 1,085,083 | 1,076,346 | 1,082,213 |
| Wyoming | 78,842 | 90,730 | 114,676 | 556,782 | 700,511 | 512,153 | 774,364 | 771,299 | 794,498 | 1,374,447 | 1,533,468 | 1,415,037 |
| **Pacific** | | | | | | | | | | | | |
| California | 3,876,870 | 3,071,740 | 3,823,115 | 628,817 | 745,056 | 1,045,025 | 3,910,823 | 5,120,793 | 4.166,854 | 7,245,487 | 8,139,834 | 8,471,936 |
| Oregon | 501,297 | 304,579 | 421,642 | 564,577 | 622,453 | 629,850 | 682,894 | 650,475 | 720,621 | 1,587,152 | 1,534,961 | 1,731,660 |
| Washington | 501,662 | 445,927 | 484,392 | 163,723 | 190,423 | 292 | 827,817 | 963,804 | 1,041,882 | 1,434,800 | 1,554,813 | 1,806,782 |
| Alaska | — | 2,424 | 2,128 | — | 191 | 113 | — | 3 | 11 | — | 2,618 | 2,252 |
| Hawaii | — | 43,996 | 33,938 | — | 34,850 | 17,036 | — | 46,893 | 50,999 | — | 96,543 | 78,538 |
| **Total** | **28,816,442** | **32,222,665** | **32,342,820** | **5,926,902** | **7,402,653** | **7,277,527** | **13,919,132** | **16,408,547** | **13,867,438** | **46,418,380** | **54,249,965** | **52,583,431** |

*Source*: Abstracted from: USDA, 2004, Farm and Ranch Irrigation Survey (2003), vol. 3, Special Studies, Part 1,—2002; Census of Agriculture; USDA, 1999, 1998 Farm and Ranch Irrigation Survey, Vol. 3, Special Studies, Part 1—1997 Census of Agriculture and USDA, 1994 Farm and Ranch Irrigation Survey—1992, Census of Agriculture; (D) Withheld to avoid disclosing data for individual farms, www.nass.usda.gov.



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**Table 7I.95 Growth of Irrigated Farmland in the United States, 1889–2002**

| Year | Land in Farms[a] (mil acres) | Irrigated Land in Farms (mil acres) | Share of Farmland Irrigated (percent) | Acreage Irrigated per Farm Irrigated (acres) | Change In Irrigated Acreage (mil acres) | Average Annual Growth in Irrigated Acreage (percent) |
|---|---|---|---|---|---|---|
| 1889 | 623 | 3.6 | 0.6 | 67 | NA | NA |
| 1900 | 839 | 7.5 | 0.9 | 70 | 3.9 | 6.9 |
| 1910 | 879 | 14.4 | 1.6 | 89 | 6.9 | 6.7 |
| 1920 | 956 | 19.2 | 2.0 | 83 | 4.8 | 2.9 |
| 1930 | 987 | 19.5 | 2 | 74 | 0.3 | 0.2 |
| 1939 | 1,065 | 18 | 1.7 | 60 | −1.5 | −0.9 |
| 1949 | 1,161 | 25.8 | 2.2 | 84 | 7.8 | 3.7 |
| 1959 | 1,123 | 33 | 3 | 108 | 7.2 | 2.5 |
| 1969 | 1,063 | 39.1 | 3.7 | 152 | 6.0 | 1.7 |
| 1974 | 1017 | 41.2 | 4.1 | 174 | 2.1 | 1.1 |
| 1978 | 1,015 | 50.3 | 5 | 179 | 9.1 | 2.8 |
| 1982 | 987 | 49 | 4.9 | 176 | −1.3 | −0.7 |
| 1987 | 964 | 46.4 | 4.8 | 159 | −2.6 | −1.1 |
| 1992 | 946 | 49.4 | 5.2 | 177 | 3.0 | 1.3 |
| 1997 | 932 | 55.1 | 5.9 | 197 | 5.7 | 2.2 |
| Adjusted for coverage[b] | | | | | | |
| 1997 | 955 | 56.3 | 5.9 | 182 | NA | NA |
| 2002 | 938 | 55.3 | 5.9 | 184 | −1.0 | −0.4 |

*Note:* NA, Not applicable.

[a] Land in Farms includes agricultural land used for crops, pasture, or grazing. It also includes woodland and wasteland not actually under cultivation or used for pasture or grazing, provided it is part of the farm operator's total operation.

[b] The 2002 Census of Agriculture estimates include an area-frame adjustment for incompleteness of the list frame. Similar estimates were calculated for 1997 for the purpose of comparison with the 2002 Census estimates.

*Source*: From U.S. Dept. of Commerce and U.S. Dept of Agriculture, Census of Agriculture, www.usda.gov.

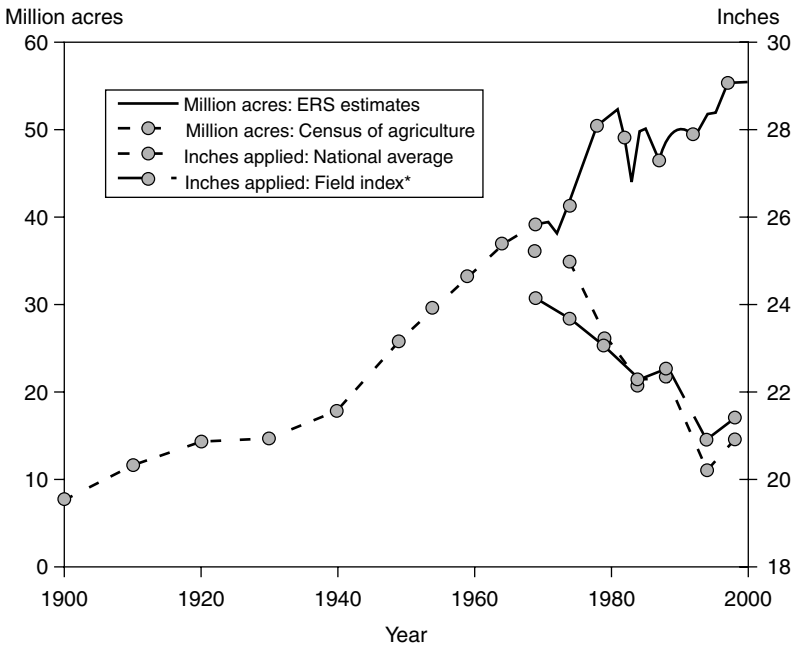


**Figure 7I.18** Irrigation trends-in the United States, 1900–2000. (From Heimlich, R., 2003, *Agricultural Resources and Environmental Indicators 2003*, Agriculture Handbook No. (AH722), February 2003.) www.ers.usda.gov.

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**Table 7I.96 Irrigated Land in Farms, by Region and Crop, 1900–2000**

| Region | 1900[a] | 1949[a] | 1969[a] | 1978[a] | 1982[a] | 1987[a] | 1992[a] | 1997[a] | 1998[b] | 1999[b] | 2000[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **USDA Production Region** | | | | | | | 1,000 acres | | | | |
| Atlantic Regions[c] | — | 500 | 1,800 | 2,900 | 2,700 | 3,000 | 3,200 | 3,600 | 3,600 | 3,500 | 3,500 |
| North Central[d] | — | — | 500 | 1,400 | 1,700 | 2,000 | 2,500 | 2,800 | 2,800 | 2,900 | 3,000 |
| Northern Plains | 200 | 1,100 | 4,600 | 8,800 | 9,300 | 8,700 | 9,600 | 10,200 | 10,100 | 10,200 | 10,500 |
| Delta States | 200 | 1,000 | 1,900 | 2,700 | 3,100 | 3,700 | 4,500 | 5,700 | 6,300 | 6,000 | 5,900 |
| Southern Plains | 100 | 3,200 | 7,400 | 7,500 | 6,100 | 4,700 | 5,400 | 6,000 | 5,900 | 5,900 | 5,800 |
| Mountain States | 5,300 | 11,600 | 12,800 | 14,800 | 14,100 | 13,300 | 13,300 | 14,400 | 14,300 | 14,400 | 14,200 |
| Pacific Coast | 2,000 | 8,300 | 10,000 | 12,000 | 11,900 | 10,800 | 10,800 | 12,400 | 12,200 | 12,300 | 12,400 |
| United States[e] | 7,800 | 25,800 | 39,100 | 50,300 | 49,000 | 46,400 | 49,400 | 55,100 | 55,200 | 55,300 | 55,300 |
| **Irrigated Crop** | | | | | | | | | | | |
| Corn for Grain | | | 3,200 | 8,700 | 8,500 | 8,000 | 9,700 | 10,600 | 10,700 | 9,900 | 10,200 |
| Sorghum for grain | | | 3,500 | 2,000 | 2,200 | 1,300 | 1,600 | 900 | 600 | 800 | 600 |
| Barley | | | 1,600 | 2,000 | 1,900 | 1,300 | 1,100 | 1,100 | 1,000 | 1,000 | 1,000 |
| Wheat | | | 1,900 | 3,000 | 4,600 | 3,700 | 4,100 | 4,000 | 3,700 | 3,400 | 3,300 |
| Rice | | | 2,200 | 3,000 | 3,200 | 2,400 | 3,100 | 3,100 | 3,400 | 3,500 | 3,100 |
| Soybeans | | | 700 | 1,300 | 2,300 | 2,600 | 2,500 | 4,200 | 4,400 | 4,800 | 5,200 |
| Cotton | | | 3,100 | 4,700 | 3,400 | 3,500 | 3,700 | 4,900 | 4,600 | 4,800 | 5,300 |
| Alfalfa hay | | | 5,000 | 5,900 | 5,500 | 5,500 | 5,700 | 6,000 | 6,300 | 6,400 | 6,300 |
| Other hay | | | 2,900 | 3,000 | 3,000 | 3,100 | 2,900 | 3,600 | 3,400 | 3,500 | 3,300 |
| Vegetables | | | 1,500 | 1,900 | 1,900 | 2,000 | 2,200 | 2,400 | 2,500 | 2,600 | 2,700 |
| Land in orchards | | | 2,400 | 3,000 | 3,300 | 3,400 | 3,600 | 4,100 | 4,100 | 4,200 | 4,300 |
| Other irrigated land in farms | | | 11,100 | 11,800 | 9,200 | 9,500 | 9,100 | 10,300 | 10,500 | 10,400 | 10,300 |

*Note:* Indicates none or fewer than 5,000 acres.

[a] Census of Agriculture.
[b] Estimates constructed from the Census of Agriculture and other USDA sources.
[c] Northeast, Appalachian, and Southeast farm production regions.
[d] Lake States and Corn Belt production regions.
[e] Includes Alaska and Hawaii.

*Source*: From Heimlich, R., 2003, *Agricultural Resources and Environmental Indicators 2003*, Agriculture Handbook No. (AH722), February 2003, www.ers.usda.gov.

*Original Source*: USDA, ERS, based on Census of Agriculture, various years (USDA, 1999a; USDC, 1994; and previous versions); and USDA, ERS data.

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**Table 7I.97 Acreage and Value of Irrigated Cropland in the United States, 1982**

| | Acreage | | | Value | | | | |
|---|---|---|---|---|---|---|---|---|
| | Irrigated (1,000 acres) | Share of Crop Irrigated (percent) | Share of Total Cropland[a] (percent) | Irrigated (million dollars) | Irrigated Share of Crop Value (percent) | Irrigated Share of Total Crop Value[b] (percent) | Irrigated Value per Acre (dollars) | Rainfed Value per Acre (dollars) |
| Corn | 9,604 | 12.3 | 2.8 | 3,440 | 17.2 | 4.5 | 358 | 235 |
| Sorghum | 2,295 | 17.0 | 0.7 | 901 | 53.2 | 1.2 | 393 | 66 |
| Wheat | 4,650 | 6.6 | 1.4 | 1,144 | 16.7 | 1.4 | 246 | 84 |
| Barley and oats | 2,098 | 11.8 | 0.6 | 375 | 20.0 | 0.5 | 179 | 93 |
| Rice | 3,233 | 100.0 | 1.0 | 1,226 | 100.0 | 1.7 | 379 | NA |
| Cotton | 3,424 | 35.0 | 1.0 | 1,883 | 58.4 | 2.5 | 549 | 200 |
| Soybeans | 2,321 | 3.6 | 0.7 | 491 | 4.4 | 0.6 | 211 | 17 |
| Irish potatoes | 812 | 64.0 | 0.2 | 1,261 | 81.7 | 1.7 | 1,553 | 546 |
| Hay | 8,507 | 15.0 | 2.5 | 2,275 | 27.7 | 3.0 | 267 | 120 |
| Vegetables and melons | 2,029 | 60.7 | 0.6 | 3,375 | 79.7 | 4.5 | 1,663 | 591 |
| Orchard crops | 3,343 | 70.4 | 1.0 | 4,732 | 85.1 | 6.2 | 1,415 | 502 |
| Sugar beets | 550 | 53.2 | 0.2 | 491 | 77.7 | 0.6 | 893 | 262 |
| Other crops[c] | 2,428 | 17.9 | 0.7 | 2,424 | 25.4 | 3.1 | 998 | 638 |
| Total[d] | 45,289 | NA | 13.4 | 24,047 | NA | 31.8 | 531[e] | 176[e] |

*Note:* NA, Not applicable. By crop; contiguous United States.

[a] This is the share each irrigated crop represents of the total acreage of crops produced in the 48 States in 1982.
[b] This is the share each irrigated crop represents of the total value of crops produced in the 48 States in 1982.
[c] Includes peanuts, tobacco, dry edible beans, and the minor acreage crops rye, flax, sugarcane, and dry edible pears.
[d] Includes about 932,000 acres of double-cropped land. Figures might not add to totals due to rounding.
[e] Average weighted by acreage.

*Source*: From Day, J.C. and Horner, G.L., 1987, U.S. Irrigation, extent and economic importance, *U.S. Department of Agriculture Information Bulletin 523*.

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**Table 7I.98 Irrigation Water Use in the United States, 2000**

| State | Irrigated Land (1000 acres) | | | | Withdrawals (1000 mil gal/day) | | | Withdrawals (1000 acre-feet/yr) | | | Application Rate (acre-feet/acre) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | By Type of Irrigation | | | | By Source | | | By Source | | | |
| | Sprinkler | Micro-Irrigation | Surface | Total | Ground-water | Surface Water | Total | Ground-water | Surface Water | Total | |
| Alabama | 68.7 | 1.3 | 0 | 70 | 14.5 | 28.7 | 43.1 | 16.2 | 32.2 | 48.4 | 0.69 |
| Alaska | 2.43 | 0 | 0.07 | 2.5 | 0.99 | 0.02 | 1.01 | 1.11 | 0.02 | 1.13 | 0.45 |
| Arizona | 183 | 14 | 779 | 976 | 2,750 | 2,660 | 5,400 | 3,080 | 2,980 | 6,060 | 6.21 |
| Arkansas | 631 | 0 | 3,880 | 4,510 | 6,510 | 1,410 | 7,910 | 7,290 | 1,580 | 8,870 | 1.97 |
| California | 1,660 | 3,010 | 5,470 | 10,100 | 11,600 | 18,900 | 30,500 | 13,100 | 21,100 | 34,200 | 3.37 |
| Colorado | 1,190 | 1.16 | 2,220 | 3,400 | 2,160 | 9,260 | 11,400 | 2,420 | 10,400 | 12,800 | 3.76 |
| Connecticut | 20.6 | 0.39 | 0 | 21 | 17 | 13.4 | 30.4 | 19 | 15 | 34 | 1.62 |
| Delaware | 81.1 | 0.71 | 0 | 81.8 | 35.6 | 7.89 | 43.5 | 39.9 | 8.84 | 48.7 | 0.6 |
| District of Columbia | 0.32 | 0 | 0 | 0.32 | 0 | 0.18 | 0.18 | 0 | 0.2 | 0.2 | 0.63 |
| Florida | 515 | 704 | 839 | 2,060 | 2,180 | 2,110 | 4,290 | 2,450 | 2,370 | 4,810 | 2.34 |
| Georgia | 1,470 | 73.8 | 0 | 1,540 | 750 | 392 | 1,140 | 841 | 439 | 1,280 | 0.83 |
| Hawaii | 16.7 | 105 | 0 | 122 | 171 | 193 | 364 | 191 | 216 | 407 | 3.35 |
| Idaho | 2,440 | 4.7 | 1,300 | 3,750 | 3,720 | 13,300 | 17,100 | 4,170 | 15,000 | 19,100 | 5.1 |
| Illinois | 365 | 0 | 0 | 365 | 150 | 4.25 | 154 | 168 | 4.76 | 173 | 0.47 |
| Indiana | 250 | 0 | 0 | 250 | 55.5 | 45.4 | 101 | 62.2 | 51 | 113 | 0.45 |
| Iowa | 84.5 | 0 | 0 | 84.5 | 20.4 | 1.08 | 21.5 | 22.9 | 1.21 | 24.1 | 0.28 |
| Kansas | 2,660 | 2.14 | 647 | 3,310 | 3,430 | 288 | 3,710 | 3,840 | 323 | 4,160 | 1.26 |
| Kentucky | 66.6 | 0 | 0 | 66.6 | 1.14 | 28.2 | 29.3 | 1.28 | 31.6 | 32.9 | 0.49 |
| Louisiana | 110 | 0 | 830 | 940 | 791 | 232 | 1,020 | 887 | 261 | 1,150 | 1.22 |
| Maine | 35 | 0.95 | 0.03 | 36 | 0.61 | 5.23 | 5.84 | 0.68 | 5.86 | 6.55 | 0.18 |
| Maryland | 57.3 | 3.32 | 0 | 60.6 | 29.8 | 12.6 | 42.4 | 33.4 | 14.1 | 47.6 | 0.78 |
| Massachusetts | 26.6 | 2.35 | 0 | 29 | 19.7 | 106 | 126 | 22.1 | 119 | 141 | 4.88 |
| Michigan | 401 | 8.67 | 4.87 | 415 | 128 | 73.2 | 201 | 144 | 82 | 226 | 0.54 |
| Minnesota | 546 | 0 | 26.9 | 573 | 190 | 36.6 | 227 | 213 | 41.1 | 254 | 0.44 |
| Mississippi | 455 | 0 | 966 | 1,420 | 1,310 | 99.1 | 1,410 | 1,470 | 111 | 1,580 | 1.11 |
| Missouri | 532 | 1.43 | 792 | 1,330 | 1,380 | 48.1 | 1,430 | 1,550 | 53.9 | 1,600 | 1.21 |
| Montana | 506 | 0 | 1,220 | 1,720 | 83 | 7,870 | 7,950 | 93 | 8,820 | 8,920 | 5.18 |
| Nebraska | 4,110 | 0 | 3,710 | 7,820 | 7,420 | 1,370 | 8,790 | 8,320 | 1,540 | 9,860 | 1.26 |
| Nevada | 192 | 0 | 456 | 647 | 567 | 1,540 | 2,110 | 635 | 1,730 | 2,360 | 3.65 |
| New Hampshire | 6.08 | 0 | 0 | 6.08 | 0.5 | 4.25 | 4.75 | 0.56 | 4.76 | 5.32 | 0.88 |
| New Jersey | 109 | 15.7 | 3.7 | 128 | 22.8 | 117 | 140 | 25.5 | 131 | 156 | 1.22 |
| New Mexico | 461 | 7.17 | 530 | 998 | 1,230 | 1,630 | 2,860 | 1,380 | 1,830 | 3,210 | 3.22 |
| New York | 70 | 8.73 | 1.84 | 80.6 | 23.3 | 12.1 | 35.5 | 26.1 | 13.6 | 39.8 | 0.49 |
| North Carolina | 193 | 3.7 | 0 | 196 | 65.8 | 221 | 287 | 73.8 | 248 | 322 | 1.64 |
| North Dakota | 200 | 0 | 26.7 | 227 | 72.2 | 73.2 | 145 | 80.9 | 82.1 | 163 | 0.72 |
| Ohio | 61 | 0 | 0 | 61 | 13.9 | 17.8 | 31.7 | 15.6 | 19.9 | 35.5 | 0.58 |
| Oklahoma | 392 | 1.5 | 113 | 507 | 566 | 151 | 718 | 635 | 170 | 804 | 1.59 |
| Oregon | 1,160 | 4.02 | 1,000 | 2,170 | 792 | 5,290 | 6,080 | 887 | 5,920 | 6,810 | 3.14 |

*(Continued)*



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**Table 7I.98 (Continued)**

| State | Irrigated Land (1000 acres) | | | | Withdrawals (1000 mil gal/day) | | | Withdrawals (1000 acre-feet/yr) | | | Application Rate (acre-feet/acre) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | By Type of Irrigation | | | | By Source | | | By Source | | | |
| | Sprinkler | Micro-Irrigation | Surface | Total | Ground-water | Surface Water | Total | Ground-water | Surface Water | Total | |
| Pennsylvania | 28.9 | 7.17 | 0 | 36 | 1.38 | 12.5 | 13.9 | 1.55 | 14 | 15.6 | 0.43 |
| Rhode Island | 4.48 | 0.29 | 0.05 | 4.82 | 0.46 | 2.99 | 3.45 | 0.52 | 3.35 | 3.87 | 0.8 |
| South Carolina | 166 | 3.66 | 17.5 | 187 | 106 | 162 | 267 | 118 | 181 | 300 | 1.6 |
| South Dakota | 276 | 0 | 78.3 | 354 | 137 | 236 | 373 | 153 | 264 | 418 | 1.18 |
| Tennessee | 51.2 | 5.35 | 3.96 | 60.5 | 7.33 | 15.1 | 22.4 | 8.22 | 16.9 | 25.1 | 0.41 |
| Texas | 4,010 | 89.4 | 2,390 | 6,490 | 6,500 | 2,130 | 8,630 | 7,290 | 2,390 | 9,680 | 1.49 |
| Utah | 526 | 1.68 | 880 | 1,410 | 469 | 3,390 | 3,860 | 526 | 3,800 | 4,330 | 3.08 |
| Vermont | 4.95 | 0 | 0 | 4.95 | 0.33 | 3.45 | 3.78 | 0.37 | 3.87 | 4.24 | 0.86 |
| Virginia | 64.3 | 13.9 | 0 | 78.2 | 3.57 | 22.8 | 26.4 | 4 | 25.6 | 29.6 | 0.38 |
| Washington | 1,270 | 49.9 | 252 | 1,570 | 747 | 2,290 | 3,040 | 837 | 2,570 | 3,400 | 2.16 |
| West Virginia | 2.21 | 0 | 0.98 | 3.19 | 0.02 | 0.02 | 0.04 | 0.02 | 0.02 | 0.04 | 0.01 |
| Wisconsin | 355 | 0 | 0 | 355 | 195 | 1.57 | 196 | 218 | 1.76 | 220 | 0.62 |
| Wyoming | 190 | 4.73 | 964 | 1,160 | 413 | 4,090 | 4,500 | 463 | 4,580 | 5,050 | 4.36 |
| Puerto Rico | 15.5 | 33 | 5.35 | 53.8 | 36.9 | 57.5 | 94.5 | 41.4 | 64.5 | 106 | 1.97 |
| U.S. Virgin Islands | 0.2 | 0 | 0 | 0.2 | 0.29 | 0.21 | 0.5 | 0.33 | 0.24 | 0.56 | 2.8 |
| **Total** | **28,300** | **4,180** | **29,400** | 61,900 | **56,900** | **80,000** | **137,000** | **63,800** | **89,700** | **153,000** | **2.48** |

*Note:* Figures may not sum to totals because of independent rounding.

*Source*: From Hutson, S.S. et al., 2004, Estimated use of water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.



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**Table 7I.99 Irrigation Withdrawals by Source in the United States, 1950–1995**

| Year | Irrigation Withdrawals (bgd) | Percent from Surface Water Sources (%) | Percent of Total from Reclaimed (%) |
|---|---|---|---|
| 1950 | 89 | 77.5 | — |
| 1955 | 110 | 72.8 | 0.10 |
| 1960 | 110 | 63.8 | 0.68 |
| 1965 | 120 | 64.3 | 0.44 |
| 1970 | 130 | 64.5 | 0.28 |
| 1975 | 140 | 59.5 | 0.26 |
| 1980 | 150 | 59.2 | 0.19 |
| 1985 | 137 | 66.7 | 0.32 |
| 1990 | 137 | 62.6 | 0.38 |
| 1995 | 134 | 63.3 | 0.54 |

*Note*: bgd, billion gallons per day.

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002, http://info.geography.siu.edu/geography_info/research/. Reprinted with permission.

**Table 7I.100 Total Irrigation Withdrawals and Irrigated Acres in the United States, 1950–1995**

| Year | Total Irrigation Withdrawals (bgd) | USGS Estimated Total Irrigated Acres (thousands) | Average Depth of Water applied (ft/yr) (USGS Acreage Estimate) | Interpolated US Census Bureau Estimated Total Irrigated Acres (thousands) | Average Depth of Water Applied (ft/yr) (USCB Acreage Estimate) |
|---|---|---|---|---|---|
| 1950 | 89 | 25,000 | 3.20 | 26,634 | 3.00 |
| 1955 | 110 | 34,000 | 2.68 | 30,274 | 3.01 |
| 1960 | 110 | 39,000 | 2.41 | 33,942 | 2.77 |
| 1965 | 120 | 44,000 | 2.95 | 37,470 | 3.47 |
| 1970 | 130 | 50,000 | 2.80 | 39,546 | 3.54 |
| 1975 | 140 | 54,000 | 2.96 | 43,519 | 3.68 |
| 1980 | 150 | 58,000 | 2.93 | 49,676 | 3.42 |
| 1985 | 137 | 57,275 | 2.68 | 47,432 | 3.24 |
| 1990 | 137 | 57,400 | 2.67 | 48,196 | 3.17 |
| 1995 | 134 | 57,900 | 2.59 | 52,796 | 2.84 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002, http://info.geography.siu.edu/geography_info/research/. Reprinted with permission.

**Table 7I.101 Changes in Irrigation Withdrawals in Selected States, 1960–1995 and 1980–1995**

| State | 1960–1995 Change (mgd) | 1980–1995 Change (mgd) |
|---|---|---|
| California | 10,894 | −8,106 |
| Nebraska | 5,350 | −1,750 |
| Arkansas | 5,016 | 836 |
| Colorado | 3,735 | −1,265 |
| Wyoming | 3,495 | 1,695 |
| Montana | 3,446 | −2,454 |
| Florida | 2,809 | 469 |
| Washington | 2,769 | 69 |
| Idaho | 2,048 | −2,952 |
| Kansas | 1,583 | −2,217 |
| Oregon | 1,368 | 268 |
| Mississippi | 1,232 | 762 |
| New Mexico | 1,193 | −607 |
| Arizona | 972 | −1,428 |
| **Lower 48 States** | **49,960** | **−17,589** |

*Note*: mgd, million gallons per day.

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002, http://info.geography.siu.edu/geography_info/research/. Reprinted with permission.

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**Table 7I.102 Number of Farms Supplied with Off-Farm Water from the Bureau of Reclamation and Other Federal Agencies, 2003**

| Geographic Area | Farms Using Any Off-Farm Water | | | | | | Farms Using Only Off-Farm Water | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Supplier of Off-Farm Water[a] (Number of Farms) | | | | | | Supplier of Off-Farm Water[a] (Number of Farms) | | |
| | Farms | Acres Irrigated with Off-Farm Water | Quantity of Off-Farm Water (acre-ft) | Bureau of Reclamation | Other Federal Agencies | All Other Suppliers | Farms | Acres Irrigated with Off-Farm Water | Quantity of Off-Farm Water (acre-ft) | Bureau of Reclamation | Other Federal Agencies | All Other Suppliers |
| **Corn Belt** | | | | | | | | | | | | |
| Ohio | 203 | 2,355 | 1,234 | 16 | 1 | 36 | 198 | 637 | 258 | 16 | — | 33 |
| **Northern Plains** | | | | | | | | | | | | |
| Kansas | 315 | 60,901 | 56,658 | 114 | 16 | 43 | 204 | 30,554 | 26,836 | 62 | | |
| Nebraska | 1,736 | 443,354 | 488,295 | 1,268 | 19 | 451 | 493 | 197,822 | 193,616 | 277 | — | 173 |
| North Dakota | 90 | 30,400 | 46,896 | 46 | 22 | 16 | 79 | 26,632 | 43,352 | 36 | 20 | 14 |
| South Dakota | 491 | 117,406 | 740,110 | 302 | 40 | 90 | 465 | 109,780 | 732,712 | 282 | 38 | 84 |
| **Southern Plains** | | | | | | | | | | | | |
| Oklahoma | 64 | 36,513 | 40,668 | 46 | 2 | 9 | 55 | 27,481 | 29,431 | 44 | | 5 |
| Texas | 4,208 | 588,932 | 916,727 | 1,474 | 33 | 1,342 | 3,911 | 501,965 | 711,220 | 1,423 | 33 | 1,190 |
| **Mountain** | | | | | | | | | | | | |
| Arizona | 1,726 | 516,422 | 2,332,795 | 619 | 91 | 568 | 1,601 | 397,087 | 1,835,249 | 551 | 66 | 532 |
| Colorado | 6,476 | 810,713 | 1,365,054 | 1,684 | 99 | 3,004 | 6,034 | 676,181 | 1,172,001 | 1,567 | 61 | 2,752 |
| Idaho | 11,059 | 1,609,148 | 3,360,210 | 4,884 | 520 | 3,193 | 10,123 | 1,159,032 | 2,510,827 | 4,425 | 394 | 2,924 |
| Montana | 4,861 | 1,313,763 | 1,855,914 | 1,886 | 419 | 821 | 4,637 | 1,211,250 | 1,696,914 | 1,772 | 406 | 762 |
| Nevada | 623 | 145,684 | 366,463 | 249 | — | 168 | 576 | 97,238 | 256,905 | 233 | — | 146 |
| New Mexico | 2,944 | 206,658 | 492,319 | 1,692 | 4 | 776 | 2,670 | 178,546 | 433,484 | 1,490 | 4 | 707 |
| Utah | 8,429 | 790,434 | 1,604,167 | 1,381 | 549 | 4,596 | 7,856 | 704,474 | 1,410,309 | 1,339 | 393 | 4,379 |
| Wyoming | 2,999 | 794,498 | 1,329,559 | 1,075 | 121 | 1,031 | 2,876 | 743,246 | 1,248,919 | 1,041 | 117 | 971 |
| **Pacific** | | | | | | | | | | | | |
| California | 22,558 | 4,166,854 | 12,189,829 | 6,737 | 1,541 | 10,491 | 17,810 | 2,383,051 | 7,563,592 | 4,802 | 1,215 | 8,625 |
| Oregon | 5,615 | 720,621 | 1,450,562 | 2,552 | 173 | 1,602 | 5,306 | 548,155 | 1,074,139 | 2,350 | 151 | 1,510 |
| Washington | 8,271 | 1,041,882 | 2,464,111 | 5,185 | 139 | 1,692 | 7,517 | 842,209 | 2,024,760 | 4,584 | 69 | 1,601 |
| **Other States** | 3,737 | 470,900 | 536,895 | — | 43 | 1,326 | 3,365 | 335,129 | 318,623 | — | 31 | 2,371 |
| **U.S. Total (all states)** | 86,405 | 13,867,438 | 31,638,466 | 31,210 | 3,832 | 31,255 | 75,776 | 10,170,469 | 23,283,147 | 26,294 | 2,998 | 27,589 |

[a] Counts only include those reporting some or all of their water from a given source. Those reporting an unknown water supplier are excluded.

*Source*: Abstracted from USDA, 2004, *Farm and Ranch Irrigation Survey (2003)*, vol. 3, Special Studies, Part 1, 2002; Census of Agriculture, www.nass.usda.gov.



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**Table 7I.103 Irrigation in Areas of the United States with Declining Groundwater Supplies**

| State | Total Groundwater Irrigation | | Irrigated Area with Declining Water[a] | | Percent of Irrigated Land Experiencing Declining Water Levels in 1983 |
|---|---|---|---|---|---|
| | 1977 | 1983 | 1977 | 1983 | |
| | 1,000 acres | | | | |
| Arizona | 940 | 938 | —[b] | 606 | 65 |
| Arkansas | 1,400 | 2,337 | —[b] | 425 | 18 |
| California | 4,388 | 4,265 | —[b] | 2,068 | 48 |
| Colorado | 1,650 | 1,660 | 570 | 590 | 36 |
| Florida | 1,076 | 1,610 | —[b] | 250 | 16 |
| Idaho | 1,149 | 1,450 | —[b] | 223 | 15 |
| Kansas | 3,083 | 3,504 | 1,950 | 2,180 | 62 |
| Nebraska | 5,855 | 7,025 | 1,842 | 2,029[c] | 29 |
| New Mexico | 760 | 805 | 560 | 560 | 70 |
| Oklahoma | 730 | 645 | 507 | 523 | 81 |
| Texas | 7,846 | 6,685 | 6,425 | 4,565[c] | 73 |
| **Total** | **28,877** | **30,924** | **—[a]** | **14,029** | **45** |

*Note:* In 11 states with major groundwater irrigation. Total groundwater area irrigated was estimated for 1977 and 1983. Decline area irrigated was estimated from data for the latest year available.

[a] Only areas experiencing at least a six-inch average annual decline are included in these estimates.
[b] Data insufficient to make time comparisons.
[c] Data for 1984.

*Source*: From Ogg, C.W., Hostetter, J.E., and Lee, D.J., 1988, Expanding the conservation reserve to achieve multiple environmental goals, *J. of Soil and Water Conservation*. Copyright 1988. Soil and Water Conservation Society. Reprinted with permission.

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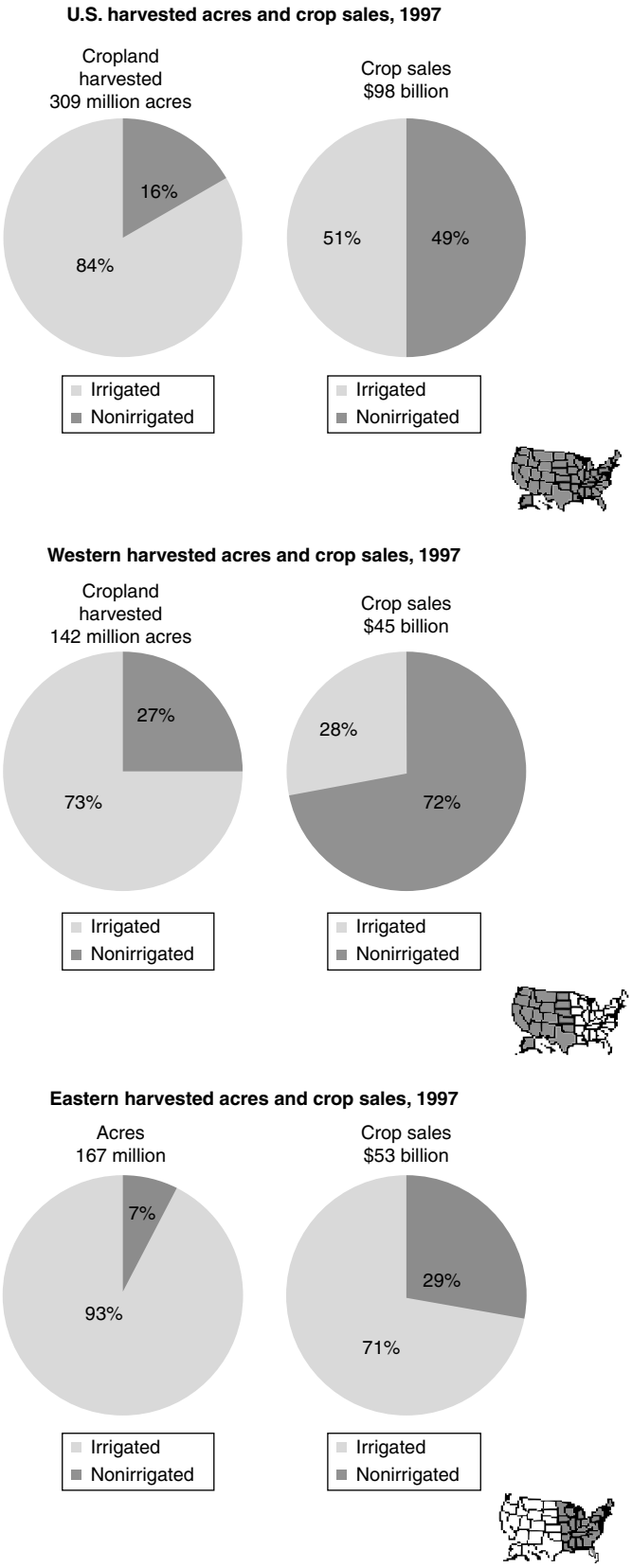


**Figure 7I.19** Percent of United States harvested acres and crop sales irrigated, 1997. (From United States Department of Agriculture, Economic Research Service, www.ers.usda.gov, from 1997 census of Agriculture Data.)

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**Table 7I.104 Top 10 States in Irrigated Agriculture in the United States**

| Item | Unit | Ranking by State 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of farms in 2002 | | | | | | | | | | | |
| All farms | 1000 | TX | MO | IA | TN | KY | OK | CA | MN | OH | WI |
| | | 230 | 107 | 92.5 | 90 | 89 | 87 | 84 | 79 | 78 | 77 |
| Irrigated farms 2003 | do | CA | NE | TX | ID | OR | WA | CO | UT | MT | FL |
| | | 46.8 | 16.3 | 15.4 | 14.3 | 14.2 | 12.9 | 11.6 | 10.1 | 8.6 | 8.3 |
| Percentage of farms with irrigated land in 2003 | Percent | UT | ID | NV | CA | WY | NM | CO | AZ | OR | WA |
| | | 67.1 | 59.6 | 57.4 | 55.8 | 52.4 | 44.9 | 38.6 | 38.0 | 34.6 | 33.0 |
| Irrigated land in 2003 | Mil acre | CA | NE | TX | AR | ID | CO | KS | MT | WA | OR |
| | | 8.5 | 7.5 | 4.9 | 3.9 | 3.1 | 2.6 | 2.5 | 2.1 | 1.8 | 1.7 |
| Percentage of harvested cropland irrigated in 2003 | Percent | AZ | NV | CA | NM | FL | ID | WY | WA | UT | HI |
| | | 100 | 96.8 | 96.6 | 94.3 | 93.1 | 92.1 | 90.3 | 88.8 | 88.0 | 85.3 |
| Market value of crops sold in 2002 | | | | | | | | | | | |
| All farms | $bil | CA | IA | IL | FL | MN | TX | WA | NE | IN | ND |
| | | 19.2 | 6.1 | 5.9 | 5.0 | 4.6 | 3.7 | 3.6 | 3.4 | 3.0 | 2.5 |
| Major irrigated crops in 2003 | | | | | | | | | | | |
| Corn (all) | 1000 acres | NE | KS | TX | CA | CO | MO | IL | MI | AR | MN |
| | | 4684 | 1298 | 831 | 665 | 633 | 307 | 223 | 200 | 195 | 187 |
| Wheat | do | TX | ID | KS | CA | WA | CO | OR | OK | AZ | MT |
| | | 657 | 501 | 415 | 407 | 278 | 156 | 143 | 132 | 122 | 119 |
| Hay (all) | do | CA | CO | MT | ID | WY | OR | UT | WA | NE | NV |
| | | 1353 | 1102 | 1098 | 862 | 833 | 741 | 623 | 510 | 483 | 455 |
| Energy expense for on-farm pumping of irrigation water in 2003 | | | | | | | | | | | |
| Total | $mil | CA | TX | NE | KS | ID | WA | AR | CO | NM | OR |
| | | 378.0 | 246.8 | 219.2 | 105.4 | 102.8 | 70.7 | 68.7 | 58.8 | 34.8 | 32.8 |
| Electricity | do | CA | TX | ID | NE | WA | CO | OR | NM | AR | AZ |
| | | 304.4 | 105.0 | 100.3 | 83.1 | 69.9 | 52.4 | 31.6 | 29.0 | 24.6 | 22.7 |
| Natural gas | do | TX | KS | NE | CA | OK | AZ | NM | CO | AR | LA |
| | | 123.5 | 70.0 | 47.8 | 15.3 | 8.2 | 5.3 | 3.8 | 3.7 | 2.1 | 0.4 |
| Acres irrigated by source of water in 2003 | | | | | | | | | | | |
| Wells | Thous. acre | NE | TX | CA | AR | KS | ID | MS | CO | MO | FL |
| | | 6975 | 4175 | 3823 | 3421 | 2431 | 1203 | 1116 | 1096 | 961 | 773 |
| On-farm surface | do | CA | MT | CO | OR | WY | AR | FL | ID | WA | NV |
| | | 1045 | 725 | 694 | 630 | 512 | 510 | 418 | 353 | 292 | 242 |
| Off-farm suppliers | do | CA | ID | MT | WA | CO | WY | UT | OR | TX | AZ |
| | | 4167 | 1609 | 1314 | 1042 | 811 | 794 | 790 | 721 | 589 | 516 |
| Water applied in irrigation by source in 2003 | | | | | | | | | | | |
| Total | Mil acre-feet | CA | NE | ID | TX | AR | CO | WA | AZ | OR | KS |
| | | 24.8 | 8.5 | 6.1 | 6.0 | 4.3 | 4.0 | 3.9 | 3.8 | 3.3 | 3.1 |

*(Continued)*



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**Table 7I.104 (Continued)**

| Item | Unit | Ranking by State | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Wells | do | CA | NE | TX | AR | KS | ID | CO | NM | AZ | MS |
| | | 9.7 | 7.9 | 4.8 | 3.5 | 3.0 | 2.1 | 1.5 | 1.2 | 1.2 | 0.9 |
| On-farm sources | do | CA | OR | CO | MT | AR | WY | FL | ID | WA | NV |
| | | 3.0 | 1.1 | 1.1 | 0.8 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.5 |
| Off-farm suppliers | do | CA | ID | WA | AZ | MT | UT | OR | CO | WY | TX |
| | | 12.2 | 3.4 | 2.5 | 2.3 | 1.9 | 1.6 | 1.5 | 1.4 | 1.3 | 0.9 |
| Irrigation water applied per acre in 2003 | Acre-feet | MA | AZ | HI | CA | NV | SD | NM | WA | UT | ID & OR |
| | | 5.6 | 4.5 | 4.0 | 2.9 | 2.5 | 2.5 | 2.4 | 2.2 | 2.1 | 1.9 |
| Average land value per acre in 2003 | | | | | | | | | | | |
| Irrigated land | $ per acre | CA | AZ | FL | UT | WA | NM | OR | ID | MO | CO |
| | | 6300 | 6000 | 4180 | 3500 | 3200 | 2650 | 2250 | 2200 | 2150 | 2000 |
| Nonirrigated cropland | do | FL | GA | CA | MO | LA | OR | MS | AR | NE | WA |
| | | 2670 | 2200 | 2000 | 1540 | 1280 | 1200 | 1140 | 1100 | 980 | 950 |

*Note:* In selected categories.

*Source*: Abstracted from: USDA, 2004, *Farm and Ranch Irrigation Survey (2003)*, vol. 3, Special Studies, Part 1, 2002; Census of Agriculture; USDA, Farms and Land in Farms, February 2003; USDA, Census of Agriculture State Data, State Summary Highlights 2002, USDA-NASS, Agricultural Statistics, 2003, www.nass.usda.gov.



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**Table 7I.105 Standards for Classification of Lands as Irrigable**

| Land Characteristics | Minimum Requirements |
|---|---|
| **Soils** | |
| Texture | Loamy sand to permeably clay |
| Depth | |
| To sand, gravel, or cobble | 18 in. of good free-working soil of the fine sandy loam or heavier, or from 24–30 in. of lighter textured soil |
| To bedrock | At least 18 inches over shattered bedrock or tilted shale bedrock; or 24 in. over massive bedrock or hardpan |
| **Topography** | |
| Slopes | Smooth slopes up to no more than 30 percent in general gradient in reasonably large-sized bodies sloping in the same plane; or undulating slopes which are less than 20 percent in general gradient |
| Rock cover | No more than enough loose rock and rock outcroppings to moderately reduce productivity and interfere with cultural practices. Varies with soil depth and topographic conditions |
| Erosion | No more than moderate erosion, with very few gullies which are not crossable by tillage implements |
| **Drainage** | |
| Soil and topography | Such that moderate farm drainage may be required, but without excessive cost |
| Salinity | Total salts in the soil solution do not exceed 0.5 percent, except in readily drained soils where reclamation appears feasible |
| Alkalinity | The pH value is 9.0 or less, unless the soil is calcareous in which case higher values may be allowed. If there is evidence of black alkali a lower pH value may be limiting |

*Source*: From California State Water Resources Board, 1955.

**Table 7I.106 Summary of Losses and Waste of Irrigation Water**

| | |
|---|---|
| **During Delivery** | |
| Average field evaporation before topsoil dries | 0.5 in. per irrigation |
| Surface waste, allowance for large projects | 10 per cent of diversions |
| Seasonal percolation losses, except on porous soils | 0–1.5 acre-ft per acre |
| Losses of flow in farm ditches | 5–50 per cent per mile |
| Deliveries to farms | 1–7 acre-ft per acre |
| Consumptive use, diversified crops | 1–3.5 acre-ft per acre |
| Irrigation efficiencies, common farm crops | 20–50 per cent |
| Irrigation efficiencies, fruit, and special crops | 35–70 per cent |
| Average irrigation efficiencies on large projects | 30–50 per cent |
| **During Conveyance** | |
| Evaporation from canal surfaces | Negligible |
| Evapotranspiration at canal banks | Negligible |
| Canal seepage, large projects, mostly unlined canals | 15–45 per cent of diversions |
| Seepage losses, most canals lined | 5–15 per cent of diversions |
| Waste on large projects, ample water supplies | 5–30 per cent of diversions |
| Waste on large projects, limited water supplies | 1–10 per cent of diversions |
| Over-all efficiencies, large projects | 20–35 per cent |
| Diversions for large projects | 2–10 acre-ft per acre |

*Source*: From Houk, *Irrigation Engineering*, vol.1, John Wiley & Sons, Copyright 1951.

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**Table 7I.107 Typical Water-Application Losses and Irrigation Efficiencies for Different Soil Conditions**

| | General Soil Type | | |
|---|---|---|---|
| **Item** | **Open, Porous (%)** | **Medium Loam (%)** | **Heavy Clay (%)** |
| Farm-lateral loss[a] | 15 | 10 | 5 |
| Surface runoff loss | 5 | 10 | 25 |
| Deep percolation loss | 35 | 15 | 10 |
| Field-irrigation efficiency[b] | 60 | 75 | 65 |
| Farm-irrigation efficiency[c] | 45 | 65 | 60 |

[a] Unlined ditches (loss in new-lined ditches and pipelines is usually about one percent).
[b] For water measured at the field.
[c] For water measured at the farm headgate.

*Source*: From U.S. Department of Agriculture.

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**Table 7I.108 Adaptations and Limitations of Common Irrigation Methods**

| | Suitabilities and Conditions of Use | | | | |
|---|---|---|---|---|---|
| **Irrigation Method** | **Crops** | **Topography** | **Water Supply** | **Soils** | **Remarks** |
| Small rectangular basins | Grain, field crops, orchards, rice | Relatively flat land; area within each basin should be levelled | Can be adapted to streams of various sizes | Suitable for soils of high or low intake rates; should not be used on soils that tend to puddle | High installation costs. Considerable labor required for irrigating. When used for close-spaced crops, a high percentage of land is used for levees and distribution ditches. High efficiencies of water use possible |
| Large rectangular basins | Grain, field crops, rice | Flat land; must be graded to uniform plane | Large flows of water | Soils of fine texture with low intake rates | Lower installation costs and less labor required for irrigation than with small basins. Substantial levees needed |
| Contour checks | Orchards, grain, rice, forage crops | Irregular land; slopes less than 2 percent | Flows greater than 30 L (1 cubic foot) per second | Soils of medium to heavy texture which do not crack on drying | Little land grading required. Checks can be continuously flooded as for rice, water ponded as for orchards, or intermittently flooded as for pastures |
| Narrow borders up to 5 m (16 ft) wide | Pasture, grain, lucerne, vineyards, orchards | Uniform slopes less than 7 percent | Moderately large flows | Soils of medium to heavy texture | Borders should be in direction of maximum slope. Accurate cross-levelling required between guide levees |
| Wide borders up to 30 m (100 ft) wide | Grain, lucerne, orchards | Land graded to uniform plane with maximum slope less than 0.5 percent | Large flows, up to 600 L (20 cubic feet) per second | Deep soils of medium to fine texture | Very careful land grading necessary. Minimum of labor required for irrigation. Little interference with use of farm machinery |
| Wild flooding | Pasture, grain | Irregular surfaces with slopes up to 20 percent | Can utilize small continuous flows on steeper land or large flows or large flows on flatter land | Soils of medium to fine texture with stable aggregate which do not crack on drying | Little land grading required. Low initial cost for system. Best adapted to shallow soils since percolation losses may be high on deep permeable soils |
| Benched terraces | Grain, field crops, forage crops, orchards, vineyards | Slopes up to 20 percent | Streams of small to medium size | Soils must be sufficiently deep that grading operations will not impair crop growth | Care must be taken in constructing benches and providing adequate drainage channels for excess water. Irrigation water must be properly managed. Misuse of water can result in serious soil erosion |

*(Continued)*



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**Table 7I.108 (Continued)**

| Irrigation Method | Suitabilities and Conditions of Use | | | | Remarks |
|---|---|---|---|---|---|
| | Crops | Topography | Water Supply | Soils | |
| Straight furrows | Vegetables, row crops, orchards, vineyards | Uniform slopes not exceeding 2 percent for cultivated crops | Flows up to 350 L (12 cubic ft) per second | Can be used on all soils if length of furrows is adjusted to type of soil | Best suited for crops which cannot be flooded. High irrigation efficiency possible. Well adapted to mechanized farming |
| Graded contour furrows | Vegetables, field crops, orchards, vineyards | Undulating land with slopes up to 8 percent | Flows up to 100 L (3 cubic ft) per second | Soils of medium to fine texture which do not crack on drying | Rodent control is essential. Erosion hazard from heavy rains or water breaking out of furrows. High labor requirement for irrigation |
| Corrugations | Close-spaced crops such as grain, pasture, lucerne | Uniform slopes of up to 10 percent | Flows up to 30 L (1 cubic foot) per second | Best on soils of medium to fine texture | High water losses possible from deep percolation or surface run-off. Care must be used in limiting size of flow in corrugations to reduce soil erosion. Little land grading required |
| Basin furrows | Vegetables, cotton, maize and other row crops | Relatively flat land | Flows up to 150 L (5 cubic ft) per second | Can be used with most soil types | Similar to small rectangular basins, except crops are planted on ridges |
| Zigzag furrows | Vineyards, bush berries, orchards | Land graded to uniform slopes of less than 1 percent | Flows required are usually less than for straight furrows | Used on soils with low intake rates | This method is used to slow the flow of water in furrows to increase water penetration into soil |

*Source*: From Bouher, L.J., 1974, Surface irrigation, *FAO Agricultural Development Paper 95*. Reprinted With permission.



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**Table 7I.109 Water Application Efficiencies of Irrigation Systems**

| Type of System | Attainable Efficiencies (%) |
|---|---|
| **Surface Irrigation** | |
| Basin | 80–90 |
| Border | 70–85 |
| Furrow | 60–75 |
| **Sprinkler Irrigation** | |
| Hand move or portable | 65–75 |
| Traveling gun | 60–70 |
| Center pivot & linear move | 75–90 |
| Solid set or permanent | 70–80 |
| **Trickle Irrigation** | |
| With point source emitters | 75–90 |
| With line source products | 70–85 |

*Source*: From Solomon, K.H., 1998, *Irrigation Systems and Water Application Efficiencies, Center of Irrigation Technology*, Irrigation Notes, California State University, January 1998, www.wateright.org. Reprinted with permission.

**Table 7I.110 Irrigation Efficiencies**

**A. Field Efficiencies by Method of Irrigation**

| Method of Irrigation | Range of Efficiency (percent) |
|---|---|
| Graded borders | 60–75 |
| Basins and level borders | 60–80 |
| Contour ditch | 50–55 |
| Furrows | 55–70 |
| Corrugations | 50–70 |
| Subsurface | Up to 80 |

**B. Average Efficiencies for Selected Crops in California**

| Crop | Average Efficiency (percent) |
|---|---|
| Alfalfa and irrigated pasture | 85 |
| Citrus | 80 |
| Deciduous | 85 |
| Truck | 70 |
| Vineyard | 80 |
| Walnuts | 85 |

**C. Sprinkler Efficiencies**

| Climate | Efficiency (percent) |
|---|---|
| Hot dry | 60 |
| Moderate | 70 |
| Humid or cool | 80 |

*Source*: From U.S. Soil Conservation Service and California State Water Rights Board.

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**Table 7I.111 Crop Irrigation Depths**

| Crop | Humid Areas | Semiarid to Arid Areas[a] |
|---|---|---|
| Alfalfa | 36–42 | 60–120 |
| Beans | — | 36–48 |
| Beets (sugar) | — | 48–72 |
| Broccoli | — | 24 |
| Cabbage | — | 24 |
| Clover (ladino) | — | 24 |
| Corn (maize) | 24–36 | 48–60 |
| Cotton | 24–36 | 48–72 |
| Grapes | 24–30 | 48–72 |
| Orchards | | |
| Citrus | — | 48–72 |
| Deciduous | 36–60 | 72–96 |
| Pasture | 18–36 | 36–48 |
| Peas | — | 36–48 |
| Potatoes (white) | 12–24 | 26–48 |
| Small grain | 18–30 | 48 |
| Sorghum | 20–30 | — |
| Soybeans | 18–36 | — |
| Tobacco | 15–24 | — |
| Tomatoes | — | 72–120 |
| Truck crops | | |
| Shallow-rooted | 9–12 | — |
| Medium-rooted | 12–24 | — |
| Deep-rooted | 24–30 | — |

*Note:* Soil depth in inches.

[a] Larger figure applies to arid areas.

*Source*: From U.S. Soil Conservation Service.

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**Table 7I.112 Water Requirements for Various Irrigation and Soil Types**

| | | Coarse Sandy Soils | | Light Sandy Loam | | Medium Silt Loam | | Clay Loam Soils | | Very Heavy Clay Soils | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation Type | Slope Land Percent | Q per Unit | Length of Run | Q per Unit | Length of Run | Q per Unit | Length of Run | Q per Unit | Length of Run | Q per Unit | Length or Run |
| Basins[a] | 0–2 | 20 cfs per acre | | 7.5 cfs per acre | | 5 cfs per acre | | 3 cfs per acre | | 2 cfs per acre | |
| Border[a] or checks | 0–2 | 1.5 cfs per 10′ width | 220′ | 0.75 cfs per 10′ width | 440′ | 0.5 cfs per 10′ width | 550′–880′ | 0.33 cfs per 10′ width | 660′–880′ | 3 cfs per 10′ width | 1,000′ |
| Furrows | 0–2 | 0.2 cfs per each | 220′ | 0.01 cfs per each | 330′ | 0.01 cfs per each | 440′–660′ | 0.008 cfs each | 660′ | 0.005 cfs per each | 880′ |
| | 2–5 | — | | 0.005 each | 220′ | 0.005 per each | 220′–440′ | 0.003 per each | 440′ | 0.003 per each | 550′ |
| | 5–8 | — | | — | | 0.002 per each | 110′–220′ | 0.001 per each | 330′ | 0.001 per each | 330′ |
| Sprinkling | 0–2 | 2″ per hour | | 0.75″ per hour | | 0.5″ per hour | | 0.2″ per hour | | | |
| | 2–5 | 2″ per hour | | 0.75″ per hour | | 0.5″ per hour | | 0.2″ per hour | | | |
| | 5–8 | 1.5″ per hour | | 0.5″ per hour | | 0.4″ per hour | | 0.15″ per hour | | | |
| | 8–12 | 1.0″ per hour | | 0.4″ per hour | | 0.3″ per hour | | | | | |

[a] The range in slope 0–2 per cent is in itself a very rough picture of field practices where the actual slopes, particularly with borders, tend to be closer to 0.2 or 0.3 per cent rather than this higher limit 2 per cent.

*Source*: From Calif. Agric. Exp. Station.



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**Table 7I.113 Border Irrigation Relationships for Various Soils, Slopes, and Depths of Application**

| Soil Texture | Slope of Land (percent) | Depth of Application (in.) | Suggested Borderstrip Size | | Size of Irrigation Stream ($ft^3/s$) |
|---|---|---|---|---|---|
| | | | Width (ft) | Length (ft) | |
| Coarse | 0.25 | 2 | 50 | 500 | 8.0 |
| | | 4 | 50 | 800 | 7.0 |
| | | 6 | 50 | 1,320 | 6.0 |
| | 1.00 | 2 | 40 | 300 | 2.75 |
| | | 4 | 40 | 500 | 2.50 |
| | | 6 | 40 | 900 | 2.50 |
| | 2.00 | 2 | 30 | 200 | 1.25 |
| | | 4 | 30 | 300 | 1.00 |
| | | 6 | 30 | 600 | 1.00 |
| Medium | 0.25 | 2 | 50 | 800 | 7.0 |
| | | 4 | 50 | 1,320 | 6.0 |
| | | 6 | 50 | 1,320 | 3.5 |
| | 1.00 | 2 | 40 | 500 | 2.5 |
| | | 4 | 40 | 1,000 | 2.5 |
| | | 6 | 40 | 1,320 | 2.5 |
| | 2.00 | 2 | 30 | 300 | 1.0 |
| | | 4 | 30 | 600 | 1.0 |
| | | 6 | 30 | 1,000 | 1.0 |
| Fine | 0.25 | 2 | 50 | 1,320 | 4.0 |
| | | 4 | 50 | 1,320 | 2.5 |
| | | 6 | 50 | 1,320 | 1.5 |
| | 1.00 | 2 | 40 | 1,320 | 2.5 |
| | | 4 | 40 | 1,320 | 1.25 |
| | | 6 | 40 | 1,320 | 0.75 |
| | 2.00 | 2 | 30 | 660 | 1.0 |
| | | 4 | 30 | 1,320 | 1.0 |
| | | 6 | 30 | 1,320 | 0.67 |

*Source*: From U.S. Dept. of Agriculture.

**Table 7I.114 Irrigation Frequency in Relation to Soil Texture and Depth of Root Zone Wetted**

| Soil Depth Irrigated (in.) | Soil Type | | |
|---|---|---|---|
| | Sands | Loams | Clays |
| 6 | 3 | 5 | 8 |
| 12 | 5 | 10 | 17 |
| 18 | 8 | 16 | 25 |
| 24 | 10 | 21 | 35 |
| 30 | 13 | 26 | — |
| 36 | 15 | 31 | — |
| 42 | 18 | 36 | — |
| 48 | 20 | — | — |

*Note:* Approximate number of days between irrigations assuming water use to be 1 in./wk.

*Source*: From U.S. Dept. of Agriculture.

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**Table 7I.115 Furrow Irrigation Relationships for Various Soils, Slopes, and Depths of Application**

| Soil Texture | | Coarse | | | | Medium | | | | Fine | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Furrow Slope (percent) | Maximum Allowable Nonerosive Furrow Stream (gal/min) | Depth or Irrigation Application (in.) | | | | | | | | | | | |
| | | 2 | 4 | 6 | 8 | 2 | 4 | 6 | 8 | 2 | 4 | 6 | 8 |
| | | Maximum Allowable Length of Run (ft) | | | | | | | | | | | |
| 0.25 | 40 | 500 | 720 | 875 | 1,000 | 820 | 1,150 | 1,450 | 1,650 | 1,050 | 1,500 | 1,750 | 2,140 |
| 0.50 | 20 | 345 | 480 | 600 | 680 | 560 | 800 | 975 | 1,120 | 730 | 1,020 | 1,250 | 1,460 |
| 0.75 | 13 | 270 | 380 | 480 | 550 | 450 | 630 | 775 | 900 | 580 | 820 | 1,000 | 1,150 |
| 1.00 | 10 | 235 | 330 | 400 | 470 | 380 | 540 | 650 | 760 | 500 | 750 | 850 | 990 |
| 1.50 | 7 | 190 | 265 | 330 | 375 | 310 | 430 | 530 | 620 | 400 | 570 | 700 | 800 |
| 2.00 | 5 | 160 | 225 | 275 | 320 | 260 | 370 | 450 | 530 | 345 | 480 | 600 | 675 |
| 3.00 | 3 | 125 | 180 | 220 | 250 | 210 | 295 | 360 | 420 | 270 | 385 | 470 | 550 |
| 5.00 | 2 | 95 | 135 | 165 | 190 | 160 | 225 | 270 | 320 | 210 | 290 | 350 | 410 |

*Source*: From U.S. Dept. of Agriculture.



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**Table 7I.116 Types of Microirrigation Systems**

| Type | Description | Discharge Rate |
|---|---|---|
| Point-source emitters (drip/trickle/bubbler) | Water is applied to the soil surface as discrete or continuous drops, tiny streams, or low volume fountain through small openings | Discharge is in units of gallons per hour (gph) or gallons per minute (gpm) over a specified pressure range. Discharge rates typically range from 0.5 gph to nearly 0.5 gpm for individual drip emitters. Discharge rates are adjusted by varying the length of the tubing. The longer the tube, the greater the friction loss, which decreases the discharge rate. Flows for bubblers are generally less than 1 gal/min |
| | Microtubes (spaghetti tubing) are classed as point-source emitters even though they are actually tubes rather than emitters. Microtubes consist of various lengths of flexible tubing that is small in diameter (0.020–0.040 in.). Typically, no other water control device is used. Because discharge orifices are small, complete filtration of water is required | |
| Surface or subsurface line-source emitter systems | This type of irrigation uses surface or buried flexible tubing with uniformly spaced emitter points (or porous tubing). The tubing comes as layflat tubing, flexible tubing or as a semirigid tubing that retains its shape. Because discharge orifices are small, complete filtration of water is required | Surface or subsurface line-source emitter systems have a uniform discharge units of gallons per hour per foot (gph/ft) or gallons per minute per 100 feet (gpm/100 ft) over a specified pressure range |
| Basin bubblers | The basin bubbler microirrigation system applies water to the soil surface in small fountain type streams. The discharge rate normally exceeds the infiltration rate of the soil, so small basins are used to contain the water until infiltration occurs. Discharge is generally from a small diameter (3/8–1/2 in.) flexible tube that is attached to a buried or surface lateral and located at each plant vine or tree. The typical emitter device is not used, and discharge pressures are very low ($<5$ lb/in$^2$) | The streams have a point discharge rate greater than that for a typical drip or line source system, but generally less than 1 gal/min |
| | The discharge orifice is larger than that of the other systems, so little or no water filtration is required. Generally, screening of coarse debris and small creatures is sufficient. Drains must be provided to allow discharge of any collected sediment. | |
| | Bubbler basins apply water to a larger soil volume than do drip emitters; therefore, only one outlet device is needed per plant or tree | |
| Spray or mini sprinkler | With spray or mini sprinkler micro irrigation systems, water is applied to the soil surface as spray droplets from small, low-pressure heads. The typical wetted diameter is 2–7 ft. The wetted pattern is larger than that of typical drip emitter devices, and generally fewer application devices are needed per plant. Spray and mini sprinklers also have less plugging problems and less filtration required than point-source emitters (drippers). Many spray heads only require the replacement of the orifice to change discharge rate. If an orifice becomes plugged, it is easily removed and cleaned or replaced. Spray or mini sprinkler head application patterns can be full, half circle, or partial circle (both sides) | Discharge rates are generally less than 30 gallons per hour (0.5 gph) |

*Source*: From USDA, National Resources Conservation Service (NRCS) Irrigation—Handbooks and Manuals—*National Engineering Handbook Part 652—Irrigation Guide*, www.info.usda.gov.



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**Table 7I.117 Advantages and Disadvantages of Microirrigation**

| Advantages | Disadvantages |
|---|---|
| Little if any run-off and little evaporation occur, and deep percolation can be controlled with good water management. Water is applied at the point of use (plant transpiration) | Microirrigation is considered expensive to install and maintain. In general, the cost of micro systems is greater than that for sprinkle or surface systems |
| Systems are easily automated with soil moisture sensors and computer controlled for low labor requirements | Frequent maintenance is essential, and a high level of management is required to obtain optimum application efficiencies |
| Soil moisture levels can be maintained at predetermined levels for start-stop operation | Clogging is a major problem in all micro systems. Emitter outlets are very small, and can be easily clogged with chemical precipitates, soil particles, or organic materials. Clogging can reduce or stop water emission. Chemical treatment of the water is often necessary, and filters are almost always required. Filtration and treatment can be costly, especially where water is taken from surface sources containing sediment and debris. During installation, care should be taken to clean all construction debris from the inside of pipelines as this material can cause plugging |
| Fertilizer can be efficiently added to irrigation water. With proper water management, there is minimum waste caused by deep percolation, and less opportunity for groundwater pollution | Animals, especially rodents, can damage surface (and shallow subsurface) installed plastic pipe less than 4 in. in diameter |
| Much of the soil surface remains dry, reducing weed growth and soil surface evaporation | With low operating pressures, poor distribution uniformity can result because of elevation differences on undulating ground. Pressure regulators or pressure compensated emitters are then necessary. However, they require about 2 pounds per square inch for operation |
| The soil surface remains firm for use by farm workers and equipment | On steep terrain, automatic gravity draining of laterals to a low point within the field can cause low distribution uniformity, especially in low pressure, high volume systems. This problem is aggravated by frequent on-off cycles, but can be overcome by installing air-vacuum valves in a raised pipe arch (i.e., dog leg) at one or more locations in the lateral. Drains are installed just upstream of each pipe arch. This increases the number of sites affected by lateral pipe drainage, thus decreasing effects on distribution uniformity because each drain discharges less water |
| Frequent irrigations can be used to keep salts in the soil water more diluted and moved away from plant roots. Irrigation with water of higher salinity is possible (requires a high level of management). Where salts are present, soil-water movement must always be toward the edges of the wetted bulb (away from roots). A common mistake is to shut the system down when precipitation occurs, often creating soil-water movement into the plant root zone | When soil water is reduced in the plant root zone, light rains can move salts in surrounding soil into the plant root zone, which can constitute a potential hazard. Salts also concentrate below the soil surface at the perimeter of the soil volume wetted by each emitter. If the soil dries between irrigations, reverse movement of soil water can carry salts from the perimeter back into the root zone. To avoid salt damage to roots, water movement must always be away from the emitter and from the plant root zone. In high soil salinity areas or when using high saline or sodic water for irrigation, one may need to irrigate when it rains |
| Microirrigation can be used on all terrain and most agricultural crops and soils and is often used on steep, rocky ground that is unsuitable for other forms of irrigation | A smaller volume of soil is wetted at each plant. Plants can be quickly stressed if the system fails (i.e., pump failure, water source cutoff, pipeline or valve failure). Daily checking of the system is necessary even when all or part is automated. Storing a 3-day plant-water supply in the soil is recommended along with daily replacement of water used |
| Low tension water availability to plants enhances growth and improves crop yield and quality | Multiple emitters at each plant are recommended to decrease effects of manufacturer variability, to increase area of root development, and to reduce risk of plant damage should an emitter become plugged |

*Source*: From USDA, National Resources Conservation Service (NRCS) Irrigation—Handbooks and Manuals—*National Engineering Handbook Part 652—Irrigation Guide*, www.info.usda.gov.

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**Table 7I.118 Percentage of Water Obtained by Plants from Various Depths in the Soil**

| Item | Crop | Soil | Water Obtained from | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | First Foot (Percent) | Second Foot (Percent) | Third Foot (Percent) | Fourth Foot (Percent) | Fifth Foot (Percent) | Sixth Foot (Percent) |
| 1 | Cotton | Heavy clay | 66.0 | 15.9 | 6.1 | 5.2 | 5.7 | 1.1 |
| 2 | …do | Sandy loam | 34.6 | 27.2 | 20.7 | 12.5 | 4.9 | — |
| 3 | …do | Clay loam | 33.2 | 25.6 | 17.3 | 12.6 | 6.7 | 4.5 |
| 4 | Alfalfa | Fine sandy loam | 47.0 | 15.0 | 15.0 | 12.0 | 8.0 | 3.0 |
| 5 | Orange trees, mature | Sandy loam | 37.0 | 30.0 | 15.0 | 11.0 | 4.0 | 3.0 |

*Source*: From Univ. of California Agric. Extension and U.S. Dept. of Agriculture.

**Table 7I.119 Irrigation Frequency and Amount of Water to Be Applied by Sprinkling Irrigation When Varying Amounts of Available Water Remain on the Soil**

| Time Since Planting in Days | Consumptive Use of Water (in./day) | Average Depth of Rooting (in.) | Maximum Depth of Available Root Zone (in.) | Interval in Days between Irrigations and Depth in Inches to Be Applied When Different Amounts of Available Water Remain in the Soil | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 75% | | 50% | | 25% | | 0% | |
| | | | | Days | Depth Inches | Days | Depth Inches | Days | Depth Inches | Days | Depth Inches |
| 0–9 | 0.05 | 2 | 0.2 | 1 | 0.3 | 2 | 0.4 | 3 | 0.5 | 4 | 0.6 |
| 9–18 | 0.07 | 6 | 0.6 | 2 | 0.5 | 5 | 0.7 | 8 | 1.0 | 10 | 1.3 |
| 18–27 | 0.08 | 11 | 1.1 | 3 | 0.6 | 7 | 1.1 | 10 | 1.5 | 13 | 1.9 |
| 27–36 | 0.09 | 16 | 1.6 | 4 | 0.8 | 8 | 1.4 | 13 | 2.0 | 17 | 2.5 |
| 36–45 | 0.10 | 21 | 2.1 | 5 | 1.0 | 10 | 1.7 | 15 | 2.5 | 20 | 3.1 |
| 45–54 | 0.11 | 26 | 2.6 | 6 | 1.1 | 12 | 2.1 | 17 | 2.9 | 24 | 3.7 |
| 54–63 | 0.11 | 31 | 3.1 | 7 | 1.3 | 14 | 2.4 | 21 | 3.3 | 28 | 4.2 |
| 63–72 | 0.10 | 35 | 3.5 | 8 | 1.5 | 17 | 2.7 | 25 | 3.7 | 34 | 4.7 |
| 72–81 | 0.09 | 38 | 3.8 | 11 | 1.6 | 21 | 2.9 | 33 | 4.0 | 44 | 5.1 |
| 81–90 | 0.05 | 41 | 4.2 | 20 | 1.7 | 41 | 3.1 | 61 | 4.2 | 82 | 5.5 |

*Note:* Length of growing period is 3 months; soil texture is coarse.

*Source*: From Israelson and Hansen, *Irrigation Principles and Practices*, John Wiley & Sons, Copyright 1962. With permission.

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**Table 7I.120 Acres Irrigated by Method of Irrigation and Irrigation Water Used by Source in the United States, 1998 and 2003**

| | 1998 | 2003 | Percent Change |
|---|---|---|---|
| **Irrigation Method (acres irrigated)** | | | |
| **Sprinklers** | 24,865,142 | 26,937,835 | +8.3 |
| Center pivot—low pressure | 9,292,022 | 9,696,930 | +4.4 |
| Center pivot—medium pressure | 7,419,409 | 9,657,353 | 30.2 |
| Center pivot—high pressure | 1,983,869 | 1,938,808 | −2.3 |
| Linear move towers | 284,756 | 344,162 | 20.9 |
| Solid set and permanent | 1,222,683 | 1,177,953 | −3.7 |
| Side roll | 2,033,825 | 1,825,901 | −10.3 |
| Big gun or traveler | 765,794 | 633,188 | −17.3 |
| Hand move | 1,862,784 | 1,663,540 | −10.7 |
| Gravity flow | 27,273,419 | 23,124,131 | −15.2 |
| **Down rows or furrows** | 14,025,125 | 11,723,084 | −16.4 |
| Controlled flooding | 8,472,646 | 8,847,392 | +4.4 |
| Uncontrolled flooding | 3,273,796 | 2,297,956 | −29.8 |
| Other gravity | 1,501,852 | 255,699 | −83 |
| Drip, trickle, or low-flow | 2,259,176 | 2,988,101 | +32.3 |
| **Subirrigation** | 549,655 | 279,522 | −49.2 |
| **Irrigation Water Used by Source** | | | |
| Total: Acre-feet (million) | 97.3 | 86.9 | |
| Wells: Acre-feet (million) | 43.8 | 43.5 | |
| Percent | 45 | 50 | |
| On-farm: Acre-feet (million) | 11.9 | 11.8 | |
| Percent | 12 | 14 | |
| Off-farm: Acre-feet (million) | 41.5 | 31.6 | |
| Percent | 43 | 36 | |
| **Average Acre-Feet of Water Applied** | 1.79 | 1.65 | |

*Source*: From USDA, 2004, *Farm and Ranch Irrigation Survey (2003)* Vol. 3, Special Studies, Part 1, 2002; Census of Agriculture, www.nass.usda.gov.

**Table 7I.121 Sprinkler Irrigation in the United States, 1998 and 2003**

| Region and State | 1998 (Acres) | 2003 (Acres) | Share of Total in 2003 (Percent) | Acreage Change, 1998–2003 (Percent) |
|---|---|---|---|---|
| **Eastern states** | | | | |
| Arkansas | 579,218 | 550,123 | 2.0 | −5.0 |
| Florida | 301,735 | 176,384 | 0.7 | −41.5 |
| Georgia | 613,379 | 596,133 | 2.2 | −2.8 |
| Illinois | 288,513 | 372,212 | 1.4 | 29.0 |
| Indiana | 212,606 | 271,231 | 1.0 | 27.6 |
| Iowa | 65,879 | 128,824 | 0.5 | 95.5 |
| Louisiana | 105,525 | 99,285 | 0.4 | −5.9 |
| Michigan | 354,350 | 418,778 | 1.6 | 18.2 |
| Minnesota | 311,627 | 416,901 | 1.5 | 33.8 |
| Mississippi | 350,358 | 377,268 | 1.4 | 7.7 |
| Missouri | 342,009 | 412,214 | 1.5 | 20.5 |
| Wisconsin | 352,699 | 389,434 | 1.4 | 10.4 |
| All other states | 602,638 | 500,499 | 1.9 | −16.9 |
| Subtotal | 4,480,536 | 4,709,286 | 17.5 | 5.1 |
| **Western states** | | | | |
| Arizona | 81,385 | 152,754 | 0.6 | 87.7 |
| California | 1,528,038 | 1,723,040 | 6.4 | 12.8 |
| Colorado | 1,290,045 | 1,246,601 | 4.6 | −3.4 |
| Idaho | 2,186,806 | 2,202,917 | 8.2 | 0.7 |
| Kansas | 2,054,238 | 2,283,103 | 8.5 | 11.1 |
| Montana | 570,550 | 773,008 | 2.9 | 35.5 |
| Nebraska | 3,686,495 | 5,605,283 | 20.8 | 52.0 |
| Nevada | 179,859 | 211,890 | 0.8 | 17.8 |
| New Mexico | 346,535 | 389,774 | 1.4 | 12.5 |
| North Dakota | 121,389 | 171,673 | 0.6 | 41.4 |

*(Continued)*

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**Table 7I.121 (Continued)**

| Region and State | 1998 (Acres) | 2003 (Acres) | Share of Total in 2003 (Percent) | Acreage Change, 1998–2003 (Percent) |
|---|---|---|---|---|
| Oklahoma | 335,014 | 433,099 | 1.6 | 29.3 |
| Oregon | 769,310 | 1,048,211 | 3.9 | 36.3 |
| South Dakota | 199,855 | 287,014 | 1.1 | 43.6 |
| Texas | 3,195,982 | 3,506,636 | 13.0 | 9.7 |
| Utah | 427,319 | 472,180 | 1.8 | 10.5 |
| Washington | 1,263,572 | 1,450,274 | 5.4 | 14.8 |
| Wyoming | 234,847 | 262,994 | 1.0 | 12.0 |
| Subtotal | 18,471,239 | 22,220,451 | 82.5 | 20.3 |
| **U.S. Total (excluding Hawaii and Alaska)** | 22,951,775 | 26,929,737 | 100.0 | 17.3 |

*Source*: From USDA, 1999, 1998 Farm and Ranch Irrigation Survey, vol. 3, Special Studies, Part 1 1997 Census of Agriculture, USDA, 2004, *Farm and Ranch Irrigation Survey (2003)*, vol. 3, Special Studies, Part 1, 2002 Census of Agriculture, www.nass.usda.gov.

**Table 7I.122 Water Applications for Selected Crops in the United States, 2003**

| Crop | Average Application Rate AF/Acre | Irrigated Acreage Harvested 1000 Acres | Estimated Water Use Million AF | Share of Total Water Used Percent (%) |
|---|---|---|---|---|
| Corn for grain or seed | 1.2 | 9,750 | 11.7 | 15 |
| Corn for silage or greenchop | 2.2 | 1,313 | 2.9 | 4 |
| Sorghum for grain or seed | 1.0 | 1,108 | 1.1 | 1 |
| Wheat for grain or seed | 1.5 | 3,269 | 4.9 | 6 |
| Barley for grain or seed | 1.5 | 991 | 1.5 | 2 |
| Rice | 2.3 | 2,995 | 6.9 | 9 |
| Cotton | 1.4 | 4,080 | 5.7 | 7 |
| Soybeans for beans | 0.8 | 5,347 | 4.3 | 6 |
| Beans, dry edible | 1.6 | 458 | 0.7 | 1 |
| Alfalfa and alfalfa mixtures (dry hay, haylage and greenchop) | 2.3 | 6,222 | 14.3 | 19 |
| All other hay (dry hay, haylage, grass silage, and greenchop) | 1.7 | 3,254 | 5.5 | 7 |
| Sugarbeets for sugar | 2.7 | 562 | 1.5 | 2 |
| Potatoes | 1.8 | 1,033 | 1.9 | 2 |
| Vegetables | 2.1 | 2,081 | 4.4 | 6 |
| Orchards | 2.2 | 4,105 | 9.0 | 12 |
| **Total** | | **46,567** | **76** | **100** |

*Source*: Abstracted from *Farm and Ranch Irrigation Survey (2003)*, vol. 3, Special Studies, Part 1, 2002; Census of Agriculture issued November 2004, www.nass.usda.gov.

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**Table 7I.123 Depth of Irrigation Water Applied, by Region and Crop, 1969–1998**

| | 1969[a] | 1974[a] | 1979[b] | 1984[b] | 1988[b] | 1994[b] | 1998[b] |
|---|---|---|---|---|---|---|---|
| | | | | Inches[c] | | | |
| **Region** | | | | | | | |
| Atlantic[d] | 8.0 | 11.0 | 13.0 | 14.0 | 12.5 | 10.5 | 13.0 |
| North Central[e] | 7.5 | 8.0 | 8.5 | 9.0 | 10.0 | 7.5 | 8.0 |
| Northern Plains | 16.0 | 17.5 | 15.0 | 13.5 | 14.5 | 12.0 | 12.0 |
| Delta States | 15.5 | 17.0 | 17.5 | 17.5 | 18.0 | 13.0 | 16.5 |
| Southern Plains | 18.0 | 18.5 | 17.5 | 16.5 | 17.0 | 17.0 | 17.0 |
| Mountain States | 30.5 | 28.5 | 26.5 | 24.5 | 24.5 | 24.0 | 24.5 |
| Pacific Coast | 32.5 | 33.5 | 33.5 | 33.5 | 34.5 | 32.5 | 33.0 |
| United States[e] | 25.2 | 25.0 | 23.2 | 22.1 | 22.3 | 20.2 | 20.9 |
| **Crop** | | | | | | | |
| Corn for grain | 18.5 | 19.5 | 16.5 | 16.0 | 16.0 | 13.5 | 14.5 |
| Sorghum for grain | 19.0 | 19.0 | 16.5 | 14.5 | 14.5 | 13.5 | 12.5 |
| Barley | 30.0 | 26.5 | 23.0 | 18.5 | 18.0 | 19.0 | 19.5 |
| Wheat | 23.5 | 24.0 | 21.0 | 16.5 | 16.0 | 17.0 | 17.0 |
| Rice | 28.0 | 28.5 | 30.0 | 33.5 | 32.5 | 27.0 | 28.5 |
| Soybeans | 12.0 | 11.0 | 10.5 | 9.5 | 10.0 | 8.5 | 10.0 |
| Cotton | 23.0 | 25.5 | 26.0 | 24.5 | 24.0 | 20.0 | 19.0 |
| Alfalfa | 32.5 | 30.5 | 28.0 | 28.0 | 29.0 | 26.5 | 29.0 |
| Other hays | 22.0 | 21.0 | 20.0 | 21.0 | 19.5 | 20.5 | 24.5 |
| Vegetables | 25.0 | 25.5 | 25.5 | 27.0 | 26.5 | 24.0 | 24.0 |
| Land in orchards | 29.0 | 30.0 | 30.0 | 31.0 | 31.5 | 27.0 | 28.0 |

[a] Census of Agriculture.
[b] Estimates constructed by State/crop from the Farm and Ranch Irrigation Survey and ERS estimates of irrigated area.
[c] Includes Alaska and Hawaii.
[d] Northeast, Appalachian, and Southeast production regions.
[e] Lake States and Corn Belt farm production regions.

*Source*: From Heimlict. R., 2003, *Agricultural Resources and Environmental Indicators 2003*, Agriculture Handbook No. (AH722), February 2003, www.ers.usda.gov.

*Original Source*: USDA, ERS, based on USDC Census of Agriculture, various years; Farm and Ranch Irrigation Surveys (USDA, 1999b; USDC, 1996; USDC, 1990, and previous versions).

**Table 7I.124 Irrigation System versus Crops Grown**

| | Crop Category | | | |
|---|---|---|---|---|
| **Irrigation System** | **1[a]** | **2[b]** | **3[c]** | **4[d]** |
| **Surface** | | | | |
| Basins, borders | | X | X | X |
| Furrows, corrugations | X | X | | X |
| Contour levee-rice | | X | X | |
| **Sprinkler** | | | | |
| Side (wheel) roll lateral | X | X | | |
| Hand move lateral | X | X | | X |
| Fixed (solid) set | | X | | X |
| Center pivot, linear move | X | X | | |
| Big guns-traveling, stationary | X | X | | |
| **Micro** | | | | |
| Point source | | | | X |
| Line source | X | | | X |
| Basin bubbler | | | | X |
| Mini sprinklers & spray heads | | | | X |
| **Subirrigation** | X | X | X | X |

[a] Row or bedded crops: sugar beets, sugarcane, potatoes, pineapple, cotton, soybeans, corn, sorghum, milo, vegetables, vegetable and flower seed, melons, tomatoes, and strawberries.
[b] Close-growing crops (sown, drilled, or sodded): small grain, alfalfa, pasture, and turf.
[c] Water flooded crops: rice and taro.
[d] Permanent crops: orchards of fruit and nuts, citrus groves, grapes, cane berries, blueberries, cranberries, bananas and papaya plantations, hops, and trees and shrubs for windbreaks, wildlife, landscape, and ornamentals.

*Source*: From USDA, National Resources Conservation Service (NRCS) Irrigation-Handbook and Manuals – *National Engineering Handbook Part 652-Irrigation Guide*, www.info.usda.gov.

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**Table 7I.125 Typical Life and Annual Maintenance Cost Percentage for Irrigation System Components**

| System and Components | Life (yr) | Annual Maint. (% of Cost) | System and Components | Life (yr) | Annual Maint. (% of Cost) |
|---|---|---|---|---|---|
| **Sprinkler systems** | 10–15 | 2–6 | **Surface & subsurface systems** | 15 | 5 |
| Handmove | 15+ | 2 | | | |
| Side or wheel roll | 15+ | 2 | **Related components** | | |
| End tow | 10+ | 3 | Pipelines | | |
| Side move w/drag lines | 15+ | 4 | buried thermoplastic | 25+ | 1 |
| Stationary gun type | 15+ | 2 | buried steel | 25 | 1 |
| Center pivot—standard | 15+ | 5 | surface aluminum | 20+ | 2 |
| Linear move | 15+ | 6 | surface thermoplastic | 5+ | 4 |
| Cable tow | 10+ | 6 | buried nonreinforced concrete | 25+ | 1 |
| Hose pull | 15+ | 6 | buried galv. steel | 25+ | 1 |
| Traveling gun type | 10+ | 6 | buried corrugated metal | 25+ | 1 |
| Fixed or solid set | | | buried reinforced PMP | 25+ | 1 |
| Permanent | 20+ | 1 | gated pipe, rigid, surface | 10+ | 2 |
| Portable | 15+ | 2 | surge valves | 10+ | 6 |
| Sprinkler gear driven, impact & spray heads | 5–10 | 6 | Pumps | | |
| Valves | 10–25 | 3 | pump only | 15+ | 3 |
| | | | w/electric motors | 10+ | 3 |
| **Micro system**[a] | 1–20 | 2–10 | w/internal combustion engine | 10+ | 6 |
| Drip | 5–10 | 3 | | | |
| Spray | 5–10 | 3 | Wells | 25+ | 1 |
| Bubbler | 15+ | 2 | Linings | | |
| Semi-rigid, buried | 10–20 | 2 | nonreinforced concrete | 15+ | 5 |
| Semi-rigid, surface | 10 | 2 | flexible membrane | 10 | 5 |
| Flexible, thin wall, buried | 10 | 2 | reinforced concrete | 20+ | 1 |
| Flexible, thin wall, surface | 1–5 | 10 | | | |
| Emitters & heads | 5–10 | 6 | Land grading, leveling | [b] | |
| Filters, injectors, valves | 10+ | 7 | Reservoirs | [c] | |

[a] With no disturbance from tillage and harvest equipment.
[b] Indefinite with adequate maintenance.
[c] Indefinite with adequate maintenance of structures, watershed.

*Source*: From USDA, National Resources Conservation Service (NRCS) *Irrigation-Handbook and Manuals – National Engineering Handbook Part 652-Irrigation Guide*, wcc.nrcs.usda.

**Table 7I.126 Energy Requirement and Energy Costs for Various Irrigation Systems in the United States**

| | Total Lift (Feet) | Field Efficiency (Percent) | Potential Efficiency | Water Per Acre (Inches) | Fuel Per Acre (Gallons) | Cost of Energy (Dollars) 1973 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|
| Traveling big guns | 389 | 70 | 75 | 17 | 91.1 | $13.67 | $74.70 | $113.88 |
| Center-Pivot | | | | | | | | |
| (High) 75 | 273 | 80 | 85 | 15 | 56.4 | 8.46 | 46.25 | 70.50 |
| (Low) 50 | 215 | 80 | 85 | 15 | 44.4 | 6.66 | 36.41 | 55.50 |
| Skid-Tow | 215 | 75 | 80 | 16 | 47.4 | 7.11 | 38.87 | 59.25 |
| Gated pipe without reuse | 120 | 60 | 70 | 20 | 33.1 | 4.97 | 27.14 | 41.38 |
| Gated pipe with reuse | 120 | 70 | 85 | 17 | 28.1 | 4.22 | 23.04 | 35.13 |
| Auto-surface | 120 | 85 | 92 | 14 | 23.1 | 3.47 | 18.94 | 28.88 |
| Drip trickle | 150 | 85 | 92 | 14 | 28.9 | 4.34 | 23.70 | 36.13 |

*Note:* Diesel fuel only. Based on 100 foot of lift from groundwater reservoir; 12 in. net of water; pumping plant operating at 75% of Nebraska performance standard of 10.94 water horsepower hours per gallon of diesel fuel or 14.6 brake horsepower hours per gallon of diesel fuel.
Fuel cost per gallon: $0.15–1973, $0.82–1979; $1.25–1980.

*Source*: From Fischbach, P.E., 1980, *Energy Requirements of Auto-Surface Irrigation*, Copyright, The Irrigation Assoc., 1980 Technical Conference Proceedings. Reprinted with permission.

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**Table 7l.127 On-Farm Energy Expense in the United States, 1998 and 2003**

| | 1998 | | 2003 | | |
|---|---|---|---|---|---|
| | | | | Expenses Per Acre Irrigated (Dollars) | |
| On-Farm Energy Pumping Expenses | Expenses ($1,000) | Expenses Per Acre Irrigated (Dollars) Wells and Surface Water | Expenses ($1,000) | Water from Wells | Surface Water |
| Total energy expenses for pump | 1,223,106 | 31.92 | 1,551,847 | 39.50 | 26.39 |
| Electricity | 801,184 | 39.75 | 953,247 | 42.64 | 29.84 |
| Natural gas | 206,900 | 33.99 | 281,029 | 57.25 | 33.67 |
| LP gas, propane, and butane | 27,716 | 16.99 | 34,053 | 27.21 | 22.68 |
| Diesel fuel | 182,832 | 17.78 | 281,490 | 25.09 | 16.27 |
| Gasoline and gasohol | 4475 | 28.14 | 2,027 | 11 60 | 18.05 |

*Source*: Abstracted from USDA, 1999, 1998 *Farm and Ranch Irrigation Survey*, vol. 3, Special Studies, Part 1, 1997 Census of Agriculture. USDA, 2004, Farm and Ranch Irrigation Survey (2003), vol. 3, Special Studies, Part 1, 2002; Census of Agriculture, nass.usda.gov.

**Table 7l.128 Supply Sources and Variables Costs of Irrigation Water, 1998[a]**

| Water Source | Acre Irrigated (Million) | Share of Acres Irrigated[b] (Percent) | Average cost[b] ($/Acre) | Cost Range[b] ($/Acre) | Comments |
|---|---|---|---|---|---|
| **Groundwater** | | | 32[c] | 7–69[d] | Pumping cost varies with energy prices, depth to water, and efficiency of pumping system |
| Only source[e] | 23.5 | 47 | | | |
| Combined sources | 6.3 | 13 | | | |
| **Onfarm surface water** | | | n/a | 0–15[f] | Costs are very low in most cases. Some water is pumped from surface sources at higher costs, since energy is required |
| Only source | 4.2 | 8 | | | |
| Combined sources | 2.7 | 5 | | | |
| **Off-farm surface water[g]** | | | 41[h] | 10–85[i] | Most actress relying on off-farm sources are located in West |
| Only source | 10.3 | 21 | | | |
| Combined sources | 4.8 | 10 | | | |
| **Total** | | | n/a | n/a | The sum of acres is greater than the irrigated total in the Farm and Ranch Irrigation Survey due to double counting of combined water sources |
| Only source | 37.9 | 76 | | | |
| Combined sources | 13.8 | 27 | | | |

*Note:* n/a indicates data not available.

[a] These values include only energy costs for pumping or purchased water costs. Management and labor costs associated with irrigation decisions, system maintenance, and water distribution are not included.
[b] Available data are from the 1998 Farm and Ranch Irrigation Survey.
[c] Reported national average energy expense for the on-farm pumping of irrigation water.
[d] Range in State energy expenses for the onfarm pumping of irrigation water.
[e] Only source means that farms used no other irrigation water source.
[f] Cost estimates based on engineering formulas with an efficient electric system.
[g] Included a minor amount of groundwater supplied from off-farm suppliers.
[h] Reported average cost for off-farm supplies.
[i] Range in reported State average cost of water from off-farm suppliers for State irrigating 50,000 or more acres from off-farm sources. If all States are included, the range expands to $2–$175 per acre.

*Source*: From Helmich, R., 2003, *Agricultural Resource and Environmental Indicators 2003*, Agricultural Handbook No (AH 777) February 2003, ers.200usda.gov.

*Original Source*: USDA, ERS based on USDA (1999), 1998 Farm and Ranch Irrigation Survey.

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**Table 7I.129 Distribution of Irrigation Withdrawals, Acres, Annual Application and Estimated Pumping Costs: 1995**

| State | Irrigation Withdrawals (mgd) | Irrigated Acres (1,000) | Irrigation Depth (ft/yr) | Surface Irrigation (% area) | Estimated Pumping Cost ($1995/ac/yr) |
|---|---|---|---|---|---|
| California | 28,894 | 9,484 | 3.42 | 47.4 | 76.38 |
| Idaho | 13,048 | 3,011 | 4.86 | 33.2 | 39.02 |
| Colorado | 12,735 | 3,307 | 4.32 | 75.9 | 34.74 |
| Texas | 9,451 | 6,313 | 1.68 | 55.7 | 40.48 |
| Montana | 8,546 | 1,810 | 5.29 | 71.0 | 16.24 |
| Nebraska | 7,550 | 7,449 | 1.14 | 47.1 | 18.99 |
| Wyoming | 6,595 | 1,991 | 3.71 | 85.3 | 20.83 |
| Washington | 6,469 | 2,120 | 3.42 | 24.1 | 41.83 |
| Oregon | 6,168 | 1,844 | 3.75 | 41.6 | 30.83 |
| Arkansas | 5,936 | 3,511 | 1.90 | 85.0 | 20.10 |
| Arizona | 5,672 | 1,088 | 5.84 | 73.5 | 71.62 |
| Utah | 3,533 | 1,143 | 3.47 | 63.2 | 28.91 |
| Florida | 3,469 | 2,134 | 1.82 | 48.9 | 19.81 |
| Kansas | 3,383 | 3,086 | 1.23 | 32.0 | 24.55 |
| New Mexico | 2,993 | 959 | 3.50 | 56.7 | 53.55 |
| Mississippi | 1,742 | 1,374 | 1.42 | 71.7 | 17.43 |
| Nevada | 1,644 | 560 | 3.29 | 75.7 | 49.96 |
| **48-State Total/Average** | 132,969 | 58,066 | 2.57 | 54.9 | 34.63 |

*Source*: From Dziegielewski, B. et al., 2002, *Analysis of Water Use Trends in the United States: 1950–1995*, Southern Illinois University at Carbondale, Carbondale, IL, February 28, 2002, http://info.geography.siu.edu/geography_info/research/. Reprinted with permission.

**Table 7I.130 Fuel Energy Requirements for Pumping One Acre-Foot of Water at One Pound Per Square Inch**

| Energy | Horsepower Hours[a] | Percentage of Water Pump Efficiency (Unit Fuel Per Acre-Foot Per psi) | | |
|---|---|---|---|---|
| | | 65 | 60 | 55 |
| Electricity | 1.206 per kWh | 4.0503 | 4.3876 | 4.7866 |
| Diesel | 12.35 per gal | 0.4000 | 0.4330 | 0.4659 |
| Gasoline | 9.875 per gal | 0.5004 | 0.5417 | 0.5830 |
| Natural gas | 79 per MCF[b] | 0.0625 | 0.0677 | 0.0729 |
| LPG | 7.9 per gal | 0.6254 | 0.6771 | 0.7287 |

[a] This column refers to the assumed number of horsepower hours produced per unit of fuel.
[b] MCF equals 1,000 $ft^3$.

*Source*: From Sloggett, G., 1985, *Energy and U.S. Agriculture: Irrigation Pumping, 1974–83*, U.S. Dept. of Agriculture Economic Report 545.

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**Table 7I.131 Natural Gas, Electricity, and Petroleum Prices by Sector in the United States, 1995–2003**

| | Natural Gas (cents/ft$^3$) | | | | Electricity (cents/kwh) | | | | Petroleum (dollars/gal) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Industrial[a] Prices | | | | Industrial[b] Prices | | | | | | | |
| Year | Nominal | | Real[c] | | Nominal | | Real[c] | | All Grades Nominal | Real[c] | | On-Highway Diesel Fuel[d] |
| 1995 | 0.271 | | 0.294 | [R] | 4.66 | | 5.06 | [R] | 1.21 | 1.31 | [R] | 1.11 |
| 1996 | 0.342 | | 0.364 | [R] | 4.60 | | 4.90 | [R] | 1.29 | 1.37 | [R] | 1.24 |
| 1997 | 0.359 | | 0.376 | [R] | 4.53 | | 4.75 | [R] | 1.29 | 1.35 | [R] | 1.20 |
| 1998 | 0.314 | | 0.325 | [R] | 4.48 | | 4.64 | [R] | 1.12 | 1.16 | [R] | 1.04 |
| 1999 | 0.312 | | 0.319 | [R] | 4.43 | | 4.53 | [R] | 1.22 | 1.25 | [R] | 1.12 |
| 2000 | 0.445 | | 0.445 | [R] | 4.64 | | 4.64 | [R] | 1.56 | 1.56 | [R] | 1.49 |
| 2001 | 0.524 | [R] | 0.512 | [R] | 5.04 | | 4.92 | [R] | 1.53 | 1.50 | [R] | 1.40 |
| 2002 | 0.402 | [R] | 0.387 | [R] | 4.88 | [R] | 4.69 | [R] | 1.44 | 1.39 | [R] | 1.32 |
| 2003 | 0.578 | [P] | 0.547 | [P] | 4.95 | | 4.68 | | 1.64 | 1.55 | | 1.51 |

*Note:* R = Revised, P = Preliminary.

[a] Residential, commercial, and industrial prices do not include the price of natural gas delivered to consumers on behalf of third parties.

[b] Retail customers are classified as "Commercial" or "Industrial" based on NAICS (North American Industry Classification System) codes or usage falling within specified limits by rate schedule.

[c] In chained (2000) dollars, calculated by using gross domestic product implicit price deflators. Corrected for inflation.

[d] Nominal dollars.

*Source*: DOE, *Annual Energy Review 2003*, www.eia.doe.gov.



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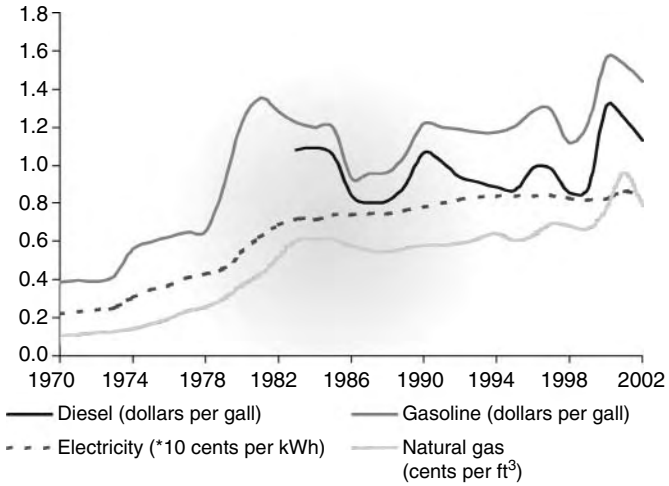


**Figure 7I.20** Nominal prices of major fuel sources: 1970–2002. (From Miranowski, J.A., *Energy Demand and Capacity to Adjust in Agricultural Production*, U.S. Department of Agriculture, Agricultural Outlook Forum 2005 on Feb. 24 and 25, 2005.) www.usda.gov.

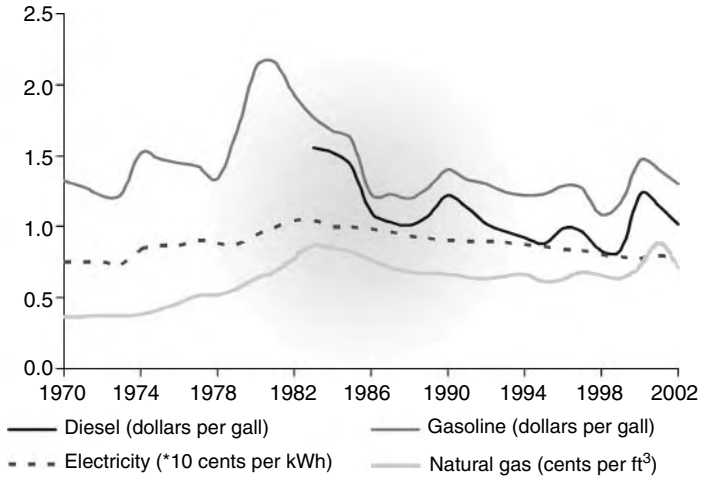


**Figure 7I.21** Real prices of major fuel sources: 1970–2002 (1996 dollars). (From Miranowski, J.A., *Energy Demand and Capacity to Adjust in Agricultural Production*, U.S. Department of Agriculture, Agricultural Outlook Forum 2005 on Feb. 24 and 25, 2005.) www.usda.gov.

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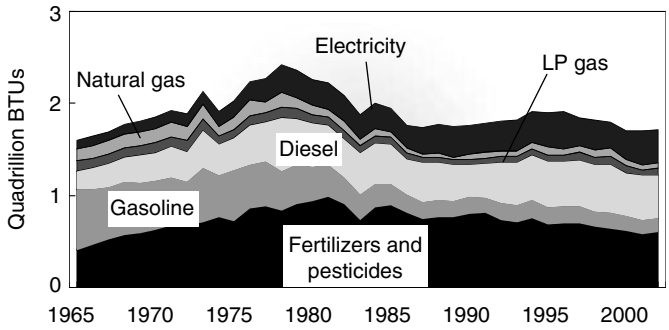


**Figure 7I.22** Total energy used on farms, 1965–2002. (From Miranowski, J.A., *Energy Demand and Capacity to Adjust in Agricultural Production*, U.S. Department of Agriculture, Agricultural Outlook Forum 2005 on Feb. 24 and 25, 2005.) www.usda.gov.

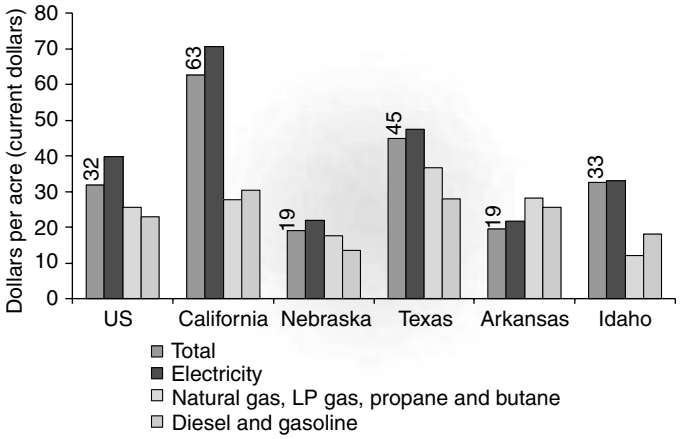


**Figure 7I.23** Average irrigation costs per acre—by energy source. (From Miranowski, J.A., *Energy Demand and Capacity to Adjust in Agricultural Production*, U.S. Department of Agriculture, Agricultural Outlook Forum 2005 on Feb. 24 and 25, 2005.) usda.gov/oce/forum/Archives/pastyears.htm.

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**Table 7I.132 Irrigation Technology and Water Management: Conventional Methods and Improved Practices**

| System and Aspect | Conventional Technology or Management Practice | Improved Technology or Management Practice |
|---|---|---|
| **Onfarm conveyance** | Open earthen ditches | Concrete or other ditch linings; aboveground pipe; belowground pipe |
| **Gravity application systems** | | |
| Release of water | Dirt or canvas checks with siphon tubes | Ditch portals or gates; gated pipe; gated pipe with surge flow or cablegation |
| Length of irrigation run | Length of field, often one-half mile or more | Shorter runs, one-quarter mile or less |
| Field gradient | Natural field slope, often substantial; uneven field surface | Land leveled to reduce and smooth field surface gradient |
| Field runoff | Water allowed to move off field | Applications controlled to avoid runoff; tailwater return systems |
| Furrow management | Full furrow wetting; furrow bottoms uneven | Alternate furrow wetting; furrow bottoms smooth and consistent |
| **Pressurized application systems** | | |
| Pressure requirements | High pressure, typically above 60 pounds per square inche (psi) | Reduced pressure requirements, often 10–30 psi |
| Water distribution | Large water dispersal pattern | More narrow water dispersal through sprinkler droptubes, improved emitter spacing, and low-flow systems |
| Automation | Handmove systems; manually operated systems | Self-propelled systems; computer control of water applications |
| Versatility | Limited to specific crops; used only to apply irrigation | Multiple crops; various uses—irrigation, chemigation, manure applications, frost protection, crop cooling |
| **Water management** | | |
| Assessing crop needs | Judgment estimates | Soil moisture monitoring; plant tissue monitoring; weather-based computations |
| Timing of applied water | Fixed calendar schedule | Water applied at needed by crop; managed for profit (not yield); managed for improved effectiveness of rainfall |
| Measurement of water | Not metered | Measured using canal flumes, weirs, and meters; external and in-pipe flow meters |
| **Drainage** | Runoff to surface-water system or Evaporation ponds; percolation to aquifers | Applications managed to limit drainage; reuse through tailwater pumpback; dual-use systems with subirrigation |

*Source*: From USDA, ERS.

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**Table 7I.133 Efficient Water Management Practices for Agricultural Water Suppliers in California**

| |
|---|
| **List A-Generally Applicable EWMPs** |
| Prepare and adopt and water management plan |
| Designate a water conservation coordinator |
| Support the availability of water management services to water users |
| Improve communication and among water suppliers, water users, and other agencies |
| Evaluate the need, if any for change in institutional policies to which the water supplier is subject |
| Evaluate and improve efficiencies of the water supplier's pumps |
| **List B-Conditionally Applicable EWMPs** |
| Facilitate alternative land use |
| Facilitate using available recycled water that otherwise would not be used beneficially, meets all health and safety criteria and does not cause harm to crops or soil |
| Facilitate financing capital improvements for on-farm irrigation systems |
| Facilitate voluntary water transfers that do not unreasonably affect the water user, water supplier, the environment, or third parties |
| Line or pipe ditches and canals |
| Increase flexibility in water ordering by, and delivery to, water users within operational limits |
| Construct and operate water supplier spill and tailwater recovery systems |
| Optimize conjunctive use of surface and groundwater |
| Automate canal structures |
| **List C-Other EWMPs** |
| Water measurement and water use reporting |
| Pricing or other incentives |

*Source*: From California Department of Water Resources 1998, "Urban, Agricultural and Environmental Water Use," California Water Plan Update Bulletin-160-98, California Dept. of Water Resources, Sacremento, Calif., November 1998, water.ca.gov.

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## SECTION 7J IRRIGATION — WORLD

**Table 7J.134 Water Use in the Agriculture Industry by Province, in Canada, 1996**

| Province | Livestock Watering (1000 $m^3$) | Irrigation (1000 $m^3$) | Total (1000 $m^3$) |
|---|---|---|---|
| Newfoundland and Labrador | 483 | 144 | 627 |
| Prince Edward Island | 1,904 | 1,715 | 3,618 |
| Nova Scotia | 3,199 | 2,272 | 5,471 |
| New Brunswick | 2,369 | 1,443 | 3,812 |
| Quebec | 45,001 | 58,394 | 103,395 |
| Ontario | 59,233 | 114,000 | 173,233 |
| Manitoba | 23,843 | 24,670 | 48,513 |
| Saskatchewan | 39,890 | 271,370 | 311,260 |
| Alberta | 61,468 | 2,609,000 | 2,670,468 |
| British Columbia | 14,682 | 763,110 | 777,791 |
| Canada | 252,071 | 3,846,117 | 4,098,188 |

*Note:* There is no significant agricultural activity in the Territories.

*Source*: From Statistics Canada "Human Activity and the Environment," Annual Statistics 2003, page 14.Statistics Canada information is used with the permission of Statistics Canada. Users are forbidden to copy this material and/or redisseminate the data, in an original or modified form, for commercial purposes, without the expressed permissionof Statistics Canada. Information on the availability of the wide range of data from Statictics Canada can be obtained from Statistics Canada's Regional Offices, its World Wide Web site at statcan.ca, and its toll-free access number 1-800-263-1136.

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**Table 7J.135 Land Areas under Irrigation in Various Countries of the World, 1961–1997**

| Country and Region | 1961 | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 1997 |
|---|---|---|---|---|---|---|---|---|---|
| **Africa** | | | | | | | | | |
| Algeria | 229 | 233 | 238 | 244 | 253 | 338 | 384 | 555 | 560 |
| Angola | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 |
| Benin | 0 | 2 | 2 | 4 | 5 | 6 | 6 | 10 | 20 |
| Botswana | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 1 |
| Burkina Faso | 2 | 2 | 4 | 8 | 10 | 12 | 20 | 25 | 25 |
| Burundi | 3 | 5 | 5 | 5 | 10 | 14 | 14 | 14 | 14 |
| Cameroon | 2 | 4 | 7 | 10 | 14 | 21 | 21 | 21 | 21 |
| Cape Verde | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
| Chad | 5 | 5 | 5 | 6 | 6 | 10 | 14 | 17 | 20 |
| Congo | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| Congo, Dem. Rep. (formerly Zaire) | | | | 0 | 7 | 9 | 10 | 11 | 11 |
| Côte d'Ivoire | 4 | 6 | 20 | 34 | 44 | 54 | 66 | 73 | 73 |
| Djibouti | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Egypt | 2,568 | 2,672 | 2,843 | 2,825 | 2,445 | 2,497 | 2,648 | 3,283 | 3,300 |
| Eritrea | | | | | | | | 28 | 28 |
| Ethiopia | 150 | 150 | 155 | 158 | 160 | 162 | 162 | 190 | 190 |
| Gabon | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 7 | 7 |
| Gambia | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| Ghana | 0 | 0 | 7 | 7 | 7 | 7 | 6 | 11 | 11 |
| Guinea | 20 | 20 | 50 | 50 | 90 | 90 | 90 | 93 | 95 |
| Guinea Bissau | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| Kenya | 14 | 14 | 29 | 40 | 40 | 42 | 54 | 67 | 67 |
| Lesotho | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Liberia | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Libya | 121 | 130 | 175 | 200 | 225 | 300 | 470 | 470 | 470 |
| Madagascar | 300 | 330 | 330 | 465 | 645 | 826 | 1,000 | 1,087 | 1,090 |
| Malawi | 1 | 1 | 4 | 13 | 18 | 18 | 20 | 28 | 28 |
| Mali | 60 | 60 | 61 | 60 | 60 | 60 | 78 | 85 | 86 |
| Mauritania | 20 | 20 | 30 | 30 | 49 | 49 | 49 | 49 | 49 |
| Mauritius | 8 | 12 | 15 | 15 | 16 | 17 | 17 | 18 | 18 |
| Morocco | 875 | 895 | 920 | 1,060 | 1,217 | 1,245 | 1,258 | 1,258 | 1,251 |
| Mozambique | 8 | 16 | 26 | 40 | 65 | 93 | 105 | 107 | 107 |
| Namibia | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 7 | 7 |
| Niger | 16 | 16 | 18 | 18 | 23 | 30 | 66 | 66 | 66 |
| Nigeria | 200 | 200 | 200 | 200 | 200 | 200 | 230 | 235 | 233 |
| Reunion | 3 | 5 | 5 | 5 | 5 | 8 | 11 | 12 | 12 |
| Rwanda | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Sao Tome and Principe | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Senegal | 70 | 85 | 78 | 78 | 62 | 90 | 94 | 71 | 71 |
| Sierra Leone | 1 | 2 | 6 | 13 | 20 | 28 | 28 | 29 | 29 |
| Somalia | 90 | 90 | 95 | 100 | 125 | 180 | 180 | 200 | 200 |
| South Africa | 808 | 890 | 1,000 | 1,017 | 1,128 | 1,128 | 1,290 | 1,270 | 1,270 |
| Sudan | 1,480 | 1,550 | 1,625 | 1,700 | 1,800 | 1,946 | 1,946 | 1,946 | 1,950 |
| Swaziland | 36 | 40 | 47 | 56 | 58 | 62 | 67 | 69 | 69 |
| Tanzania | 20 | 28 | 38 | 52 | 120 | 127 | 144 | 150 | 155 |
| Togo | 2 | 2 | 4 | 6 | 6 | 7 | 7 | 7 | 7 |
| Tunisia | 100 | 100 | 200 | 200 | 243 | 300 | 300 | 361 | 380 |
| Uganda | 2 | 3 | 4 | 4 | 6 | 9 | 9 | 9 | 9 |
| Zambia | 2 | 2 | 9 | 18 | 19 | 28 | 30 | 46 | 46 |
| Zimbabwe | 22 | 34 | 46 | 70 | 80 | 90 | 100 | 150 | 150 |
| **North and Central America** | | | | | | | | | |
| Barbados | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Belize | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 3 |
| Canada | 350 | 380 | 421 | 500 | 596 | 748 | 718 | 720 | 720 |
| Costa Rica | 26 | 26 | 26 | 36 | 61 | 110 | 118 | 126 | 126 |
| Cuba | 230 | 330 | 450 | 580 | 762 | 861 | 900 | 910 | 910 |

*(Continued)*

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**Table 7J.135 (Continued)**

| Country and Region | 1961 | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 1997 |
|---|---|---|---|---|---|---|---|---|---|
| Dominican Republic | 110 | 115 | 125 | 140 | 165 | 198 | 225 | 259 | 259 |
| El Salvador | 18 | 20 | 20 | 33 | 110 | 110 | 120 | 120 | 120 |
| Guadeloupe | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| Guatemala | 32 | 43 | 56 | 72 | 87 | 102 | 117 | 125 | 125 |
| Haiti | 35 | 40 | 60 | 70 | 70 | 70 | 75 | 90 | 90 |
| Honduras | 50 | 66 | 66 | 70 | 72 | 72 | 74 | 74 | 74 |
| Jamaica | 22 | 24 | 24 | 32 | 33 | 33 | 33 | 33 | 33 |
| Martinique | 1 | 1 | 1 | 2 | 5 | 4 | 4 | 3 | 3 |
| Mexico | 3,000 | 3,200 | 3,583 | 4,479 | 4,980 | 5,285 | 5,600 | 6,100 | 6,500 |
| Nicaragua | 18 | 18 | 40 | 67 | 80 | 83 | 85 | 88 | 88 |
| Panama | 14 | 18 | 20 | 23 | 28 | 30 | 31 | 32 | 32 |
| Puerto Rico | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 40 | 40 |
| Saint Lucia | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 |
| St. Vincent | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Trindad and Tobago | 11 | 11 | 15 | 18 | 21 | 22 | 22 | 22 | 22 |
| United States | 14,000 | 15,200 | 16,000 | 16,690 | 20,582 | 19,831 | 20,900 | 21,400 | 21,400 |
| **South America** | | | | | | | | | |
| Argentina | 980 | 1,110 | 1,280 | 1,440 | 1,580 | 1,620 | 1,680 | 1,700 | 1,700 |
| Bolivia | 72 | 75 | 80 | 120 | 140 | 125 | 110 | 78 | 88 |
| Brazil | 490 | 610 | 796 | 1,100 | 1,600 | 2,100 | 2,700 | 3,169 | 3,169 |
| Chile | 1,075 | 1,100 | 1,180 | 1,242 | 1,255 | 1,257 | 1,265 | 1,265 | 1,270 |
| Colombia | 226 | 235 | 250 | 300 | 400 | 465 | 680 | 1,037 | 1,061 |
| Ecuador | 440 | 450 | 470 | 506 | 500 | 300 | 290 | 240 | 250 |
| French Guiana | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| Guyana | 90 | 109 | 115 | 120 | 125 | 127 | 130 | 130 | 130 |
| Paraguay | 30 | 30 | 40 | 55 | 60 | 65 | 67 | 67 | 67 |
| Peru | 1,016 | 1,060 | 1,106 | 1,130 | 1,160 | 1,210 | 1,450 | 1,753 | 1,760 |
| Suriname | 14 | 15 | 28 | 33 | 42 | 55 | 59 | 60 | 60 |
| Uruguay | 27 | 35 | 52 | 57 | 79 | 97 | 120 | 140 | 140 |
| Venezuela | 60 | 62 | 70 | 90 | 137 | 171 | 180 | 200 | 205 |
| **Asia** | | | | | | | | | |
| Afghanistan | 2,160 | 2,260 | 2,340 | 2,430 | 2,505 | 2,586 | 3,000 | 2,800 | 2,800 |
| Armenia | Formerly included in Soviet Union | | | | | | | 290 | 290 |
| Azerbaijan | Formerly included in Soviet Union | | | | | | | 1,453 | 1,455 |
| Bahrain | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 4 | 5 |
| Banglaesh | 426 | 572 | 1,058 | 1,441 | 1,569 | 2,073 | 2,936 | 3,429 | 3,693 |
| Bhutan | 8 | 10 | 18 | 22 | 26 | 30 | 39 | 39 | 40 |
| Brunei Darsm | | | | 0 | 1 | 1 | 1 | 1 | 1 |
| Cambodia | 62 | 100 | 89 | 89 | 100 | 130 | 160 | 270 | 270 |
| China | 30,402 | 33,579 | 38,113 | 42,776 | 45,467 | 44,581 | 47,965 | 49,857 | 51,819 |
| Cyprus | 30 | 30 | 30 | 30 | 30 | 30 | 36 | 40 | 40 |
| Gaza Strip | 8 | 8 | 9 | 10 | 10 | 11 | 11 | 12 | 12 |
| Georgia | Formerly included in Soviet Union | | | | | | | 469 | 470 |
| Hong Kong | 9 | 8 | 8 | 6 | 3 | 3 | 2 | 2 | 2 |
| India | 24,685 | 26,510 | 30,440 | 33,730 | 38,478 | 41,779 | 45,144 | 53,000 | 57,000 |
| Indonesia | 3,900 | 3,900 | 3,900 | 3,900 | 4,301 | 4,300 | 4,410 | 4,687 | 4,815 |
| Iran | 4,700 | 4,900 | 5,200 | 5,900 | 4,948 | 6,800 | 7,000 | 7,264 | 7,265 |
| Iraq | 1,250 | 1,350 | 1,480 | 1,567 | 1,750 | 1,750 | 3,525 | 3,525 | 3,525 |
| Israel | 136 | 151 | 172 | 180 | 203 | 233 | 206 | 199 | 199 |
| Japan | 2,940 | 2,943 | 3,415 | 3,171 | 3,055 | 2,952 | 2,846 | 2,745 | 2,701 |
| Jordan | 31 | 32 | 34 | 36 | 37 | 48 | 63 | 75 | 75 |
| Kazakstan | Formerly included in Soviet Union | | | | | | | 2,380 | 2,149 |
| Korea, DPR | 500 | 500 | 500 | 900 | 1,120 | 1,270 | 1,420 | 1,460 | 1,460 |
| Korea, Rep. | 1,150 | 1,199 | 1,184 | 1,277 | 1,307 | 1,325 | 1,345 | 1,206 | 1,163 |
| Kuwait | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 5 |
| Kyrgyzstan | Formerly included in Soviet Union | | | | | | | 1,077 | 1,074 |
| Laos | 12 | 13 | 17 | 40 | 115 | 119 | 130 | 155 | 164 |

*(Continued)*

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**Table 7J.135 (Continued)**

| Country and Region | 1961 | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 1997 |
|---|---|---|---|---|---|---|---|---|---|
| Lebanon | 41 | 61 | 68 | 86 | 86 | 86 | 86 | 105 | 117 |
| Malaysia | 228 | 236 | 262 | 308 | 320 | 334 | 335 | 340 | 340 |
| Mongolia | 5 | 5 | 10 | 23 | 35 | 60 | 77 | 84 | 84 |
| Myanmar (Burma) | 536 | 753 | 839 | 976 | 999 | 1,085 | 1,005 | 1,555 | 1,556 |
| Nepal | 70 | 86 | 117 | 230 | 520 | 760 | 900 | 1,134 | 1,135 |
| Oman | 20 | 23 | 29 | 34 | 38 | 41 | 58 | 62 | 62 |
| Pakistan | 10,751 | 11,472 | 12,950 | 13,630 | 14,680 | 15,760 | 16,940 | 17,200 | 17,580 |
| Philippines | 690 | 730 | 826 | 1,040 | 1,219 | 1,440 | 1,560 | 1,550 | 1,550 |
| Qatar | 1 | 1 | 1 | 1 | 3 | 5 | 6 | 13 | 13 |
| Saudi Arabia | 343 | 353 | 365 | 375 | 600 | 800 | 900 | 1,620 | 1,620 |
| Sri Lanka | 335 | 341 | 465 | 480 | 525 | 583 | 520 | 570 | 600 |
| Syria | 558 | 522 | 451 | 516 | 539 | 652 | 693 | 1,089 | 1,168 |
| Tajikistan | Formerly included in Soviet Union | | | | | | | 719 | 720 |
| Thailand | 1,621 | 1,768 | 1,960 | 2,419 | 3,015 | 3,822 | 4,238 | 4,642 | 5,010 |
| Turkey | 1,310 | 1,400 | 1,800 | 2,200 | 2,700 | 3,200 | 3,800 | 4,186 | 4,200 |
| Turkmenistan | Formerly included in Soviet Union | | | | | | | 1,750 | 1,800 |
| United Arab Emirates | 30 | 35 | 45 | 50 | 53 | 58 | 63 | 68 | 72 |
| Uzbekistan | Formerly included in Soviet Union | | | | | | | 4,281 | 4,281 |
| Vietnam | 1,000 | 980 | 980 | 1,000 | 1,542 | 1,770 | 1,840 | 2,000 | 2,300 |
| West Bank | 10 | 10 | 9 | 8 | 9 | 10 | 10 | 9 | 9 |
| Yemen | 207 | 231 | 260 | 282 | 289 | 302 | 348 | 485 | 485 |
| **Europe** | | | | | | | | | |
| Albania | 156 | 205 | 284 | 331 | 371 | 399 | 423 | 340 | 340 |
| Austria | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Bel-Lux | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 24 | 35 |
| Belarus | Formerly included in Soviet Union | | | | | | | 115 | 115 |
| Bulgaria | 720 | 945 | 1,001 | 1,128 | 1,197 | 1,229 | 1,263 | 800 | 800 |
| Bosnia Herzegovina | Formerly included in Yugoslavia | | | | | | | 2 | 2 |
| Croatia | Formerly included in Yugoslavia | | | | | | | 3 | 3 |
| Czechoslovakia | 108 | 116 | 126 | 136 | 123 | 187 | 282 | | |
| Czech Republic | Formerly included in Czechoslovakia | | | | | | | 24 | 24 |
| Denmark | 40 | 65 | 90 | 180 | 391 | 410 | 430 | 481 | 476 |
| Estonia | Formerly included in Soviet Union | | | | | | | 4 | 4 |
| Finland | 2 | 7 | 16 | 40 | 60 | 62 | 64 | 64 | 64 |
| France | 360 | 440 | 539 | 680 | 870 | 1,050 | 1,300 | 1,630 | 1,670 |
| Germany | 321 | 390 | 419 | 448 | 460 | 470 | 482 | 475 | 475 |
| Greece | 430 | 576 | 730 | 875 | 961 | 1,099 | 1,195 | 1,325 | 1,385 |
| Hungary | 133 | 100 | 109 | 156 | 134 | 138 | 204 | 210 | 210 |
| Italy | 2,400 | 2,400 | 2,400 | 2,400 | 2,400 | 2,425 | 2,711 | 2,698 | 2,698 |
| Latvia | Formerly included in Soviet Union | | | | | | | 20 | 20 |
| Lithuania | Formerly included in Soviet Union | | | | | | | 9 | 9 |
| Macedonia | Formerly included in Yugoslavia | | | | | | | 61 | 55 |
| Malta | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Moldova Rep. | Formerly included in Soviet Union | | | | | | | 309 | 309 |
| Netherlands | 290 | 330 | 380 | 430 | 480 | 530 | 555 | 565 | 565 |
| Norway | 18 | 25 | 30 | 40 | 74 | 90 | 97 | 127 | 127 |
| Poland | 295 | 275 | 213 | 231 | 100 | 100 | 100 | 100 | 100 |
| Portugal | 620 | 621 | 622 | 625 | 630 | 630 | 630 | 632 | 632 |
| Romania | 206 | 230 | 731 | 1,474 | 2,301 | 2,956 | 3,109 | 3,110 | 3,089 |
| Russia | Formerly included in Soviet Union | | | | | | | 5,362 | 4,990 |
| Slovakia | Formerly included in Czechoslovakia | | | | | | | 217 | 190 |
| Slovenia | Formerly included in Yugoslavia | | | | | | | 2 | 2 |
| Spain | 1,950 | 2,226 | 2,379 | 2,818 | 3,029 | 3,217 | 3,402 | 3,527 | 3,603 |
| Sweden | 20 | 22 | 33 | 45 | 70 | 99 | 114 | 115 | 115 |
| Switzerland | 20 | 23 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Ukraine | Formerly included in Soviet Union | | | | | | | 2,585 | 2,466 |
| United Kingdom | 108 | 105 | 88 | 86 | 140 | 152 | 164 | 108 | 108 |

*(Continued)*

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**Table 7J.135 (Continued)**

| Country and Region | 1961 | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 1997 |
|---|---|---|---|---|---|---|---|---|---|
| Yugoslavia | 121 | 118 | 130 | 133 | 145 | 164 | 170 | | |
| Yugoslav SFR | Formerly included in Yugoslavia | | | | | | | 65 | 65 |
| Former Soviet Union | 9,400 | 9,900 | 11,100 | 14,500 | 17,200 | 19,689 | 20,800 | | |
| **Oceania** | | | | | | | | | |
| Australia | 1,001 | 1,274 | 1,476 | 1,469 | 1,500 | 1,700 | 1,832 | 2,500 | 2,700 |
| Fiji | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 |
| New Zealand | 77 | 93 | 111 | 150 | 183 | 256 | 280 | 285 | 285 |
| **Total Irrigated Area (000 ha)** | **138,813** | **149,740** | **167,331** | **187,559** | **209,233** | **223,304** | **242,185** | **260,083** | **267,727** |
| Rate of Change over Period | | 0.08 | 0.12 | 0.12 | 0.12 | 0.07 | 0.08 | 0.07 | 0.03 |
| Average Annual Change (%) | | 1.97 | 2.35 | 2.42 | 2.31 | 1.35 | 1.69 | 1.48 | 1.47 |

*Note:* Data for the former Soviet Union after 1990 are split among the separate independent states, now included in Asia and Europe. Data from Yugoslavia and Czechoslovakia after 1990 are now split among several independent states. Original Source Food and Agriculture Organization, 1999. Web site at www.fao.org.

*Source*: From *World's Water 2000–2001*, by Peter H. Gleick. Copyright © 2000 Island Press. Reproduced by permission of Island Press, Washington, DC.

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**Table 7J.136 Irrigated Areas for Selected Countries of the World, 1980–2000**

| | 1980 | 1985 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | 5,960 | 7,480 | 7,180 | 7,200 | 7,200 | 7,200 | 7,200 | 7,200 | 7,200 | 7,200 | 7,200 | 7,200 | 7,200 |
| Mexico | 49,800 | 52,850 | 56,000 | 58,000 | 61,000 | 62,000 | 63,000 | 64,000 | 65,000 | 65,000 | 65,000 | 65,000 | 65,000 |
| U.S.A. | 205,820 | 198,310 | 209,000 | 209,000 | 214,000 | 215,000 | 217,000 | 218,000 | 220,000 | 222,820 | 223,000 | 224,000 | 224,000 |
| Japan | 30,550 | 29,520 | 28,460 | 28,250 | 28,020 | 27,820 | 27,640 | 27,450 | 27,240 | 27,010 | 26,790 | 26,590 | 26,410 |
| Korea | 13,070 | 13,250 | 13,450 | 13,350 | 13,000 | 12,700 | 12,350 | 12,060 | 11,760 | 11,630 | 11,590 | 11,530 | 11,490 |
| Australia | 15,000 | 17,000 | 18,320 | 20,120 | 20,690 | 21,070 | 24,080 | 24,000 | 23,900 | 23,800 | 23,650 | 22,510 | 23,850 |
| N.Zealand | 1,830 | 2,560 | 2,800 | 2,830 | 2,850 | 2,850 | 2,850 | 2,850 | 2,850 | 2,850 | 2,850 | 2,850 | 2,850 |
| Austria | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Belgium | 130 | 170 | 180 | 180 | 180 | 180 | 180 | 240 | 300 | 350 | 350 | 350 | 350 |
| Czech R. | — | — | — | — | — | 240 | 240 | 240 | 240 | 240 | 240 | 240 | 240 |
| Denmark | 3,910 | 4,100 | 4,300 | 4,350 | 4,350 | 4,550 | 4,650 | 4810 | 4,810 | 4,760 | 4,600 | 4,470 | 4470 |
| Finland | 600 | 620 | 640 | 640 | 640 | 640 | 6,40 | 640 | 640 | 640 | 640 | 640 | 640 |
| France | 8,700 | 10,500 | 13,000 | 13,500 | 14,000 | 14,770 | 15,000 | 16,300 | 17,500 | 1,9070 | 20,000 | 21,000 | 22,000 |
| Germany | 4,600 | 4,700 | 4,820 | 4,820 | 4,820 | 4,850 | 4,850 | 4,850 | 4,850 | 4,850 | 4,850 | 4,850 | 4,850 |
| Greece | 9,610 | 11,240 | 11,950 | 12,020 | 12,890 | 13,300 | 13,520 | 13,830 | 14,140 | 1,4820 | 14,220 | 14,410 | 14,510 |
| Hungary | 1,340 | 1,380 | 2,040 | 2,100 | 2,240 | 2,060 | 2,100 | 2,100 | 2,100 | 2,100 | 2,100 | 2,100 | 2,100 |
| Iceland | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Ireland | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Italy | 24,000 | 24,250 | 27,110 | 27,100 | 27,000 | 27,000 | 27,000 | 26,980 | 26,980 | 26,980 | 26,980 | 26,980 | 27,000 |
| The Netherl. | 4,800 | 5,300 | 5,550 | 5,570 | 5,600 | 5,600 | 5,650 | 5,650 | 5,650 | 5,650 | 5,650 | 5,650 | 5,650 |
| Norway | 740 | 900 | 970 | 970 | 970 | 1,000 | 1,100 | 1,270 | 1,270 | 1,270 | 1,270 | 1,270 | 1,270 |
| Poland | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Portugal | 6,300 | 6,300 | 6,310 | 6,310 | 6,310 | 6,310 | 6,310 | 6,320 | 6,500 | 6,500 | 6,500 | 6,500 | 6,500 |
| Slov.R. | — | — | — | — | — | 2,990 | 2,350 | 2,170 | 1,940 | 1,710 | 1,740 | 1,780 | 1,830 |
| Spain | 30,290 | 32,170 | 34,020 | 33,880 | 34,030 | 34,530 | 36,570 | 35,270 | 36,030 | 36,340 | 36,520 | 36,550 | 36,550 |
| Sweden | 700 | 990 | 1,140 | 1,160 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 |
| Switzerland | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |
| Turkey | 27,000 | 32,000 | 38,000 | 40,000 | 40,000 | 40,000 | 41,860 | 41,860 | 42,000 | 42,000 | 43,800 | 45,000 | 45,000 |
| UK | 1,400 | 1,520 | 1,640 | 1,360 | 1,080 | 1,080 | 1,080 | 1,080 | 1,080 | 1,080 | 1,080 | 1,080 | 1,080 |
| Russ.F. | 49,940 | 58,050 | 61,220 | 60,540 | 55,530 | 52,980 | 51,580 | 53,620 | 51,080 | 49,900 | 46,630 | 46,000 | 46,000 |
| N.America | 261,580 | 258,640 | 272,180 | 274,200 | 282,200 | 284,200 | 287,200 | 289,200 | 292,200 | 295,020 | 295,200 | 296,200 | 296,200 |
| Australia | 16,830 | 19,560 | 21,120 | 22,950 | 23,540 | 23,920 | 26,930 | 26,850 | 26,750 | 26,650 | 26,500 | 25,360 | 26,700 |
| OECD | 126,640 | 139,300 | 155,780 | 156,950 | 157,900 | 161,540 | 165,540 | 166,050 | 168,470 | 170,800 | 172,980 | 175,310 | 176,480 |
| EU | 95,080 | 101,900 | 110,700 | 110,930 | 112,090 | 114,000 | 116,640 | 117,160 | 119,670 | 122,230 | 122,580 | 123,670 | 124,790 |
| OECD | 448,670 | 460,270 | 490,990 | 495,700 | 504,660 | 510,180 | 519,660 | 521,610 | 526,420 | 531,110 | 533,060 | 534,990 | 537,280 |
| World | 2,097,160 | 2,251,380 | 2,443,060 | 2,479,660 | 2,514,540 | 2,555,470 | 2,579,820 | 2,614,280 | 2,638,870 | 2,673,220 | 2,686,880 | 2,699,340 | 2,716,890 |

*Note:* Units are given in $km^2$.

a. Areas equipped to provide water to the crops. These include areas equipped for full and partial control irrigation, spate irrigation areas, and equipped wetland or inland valley bottoms. All figures are rounded to the nearest 10 $km^2$.
- JPN, Rice irrigation only;
- KOR, Rice irrigation only;
- BEL, Data for Belgium include Luxembourg.

*Source*: Table 10.2, *OECD Environment Data Compendium 2002*, © OECD 2002, www.oecd.org.



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**Table 7J.137 Irrigation Water Use Per Country in the Year 2000**

| | Total Renewable Water Resources ($km^3$) | Irrigation Water Requirements ($km^3$) | Water Requirement Ratio in Percentages (%) | Water Withdrawal for Agriculture ($km^3$) | Water Withdrawal as Percentage of Renewable Water Resources (%) |
|---|---|---|---|---|---|
| Afghanistan | 65 | 8.78 | 38 | 22.84 | 35 |
| Algeria | 14.32 | 1.45 | 37 | 3.94 | 27 |
| Angola | 184 | 0.04 | 20 | 0.21 | 0 |
| Argentina | 814 | 3.43 | 16 | 21.52 | 3 |
| Bangladesh | 1210.644 | 19.09 | 25 | 76.35 | 6 |
| Benin | 24.8 | 0.06 | 30 | 0.19 | 1 |
| Bolivia | 622.531 | 0.26 | 23 | 1.16 | 0 |
| Botswana | 14.4 | 0.02 | 30 | 0.06 | 0 |
| Brazil | 8233 | 6.21 | 17 | 36.63 | 0 |
| Burkina Faso | 12.5 | 0.21 | 30 | 0.69 | 5 |
| Burundi | 3.6 | 0.06 | 30 | 0.19 | 5 |
| Cambodia | 476.11 | 1.2 | 30 | 4 | 1 |
| Cameroon | 285.5 | 0.22 | 30 | 0.73 | 0 |
| Chad | 43 | 0.07 | 35 | 0.19 | 0 |
| Chile | 922 | 1.59 | 20 | 7.97 | 1 |
| China | 2829.569 | 153.9 | 36 | 426.85 | 15 |
| Colombia | 2132 | 1.23 | 25 | 4.92 | 0 |
| Congo, Republic of | 832 | 0 | 30 | 0 | 0 |
| Congo, Dem Republic of | 1283 | 0.03 | 30 | 0.11 | 0 |
| Costa Rica | 112.4 | 0.36 | 25 | 1.43 | 1 |
| Côte d'Ivoire | 81 | 0.17 | 28 | 0.6 | 1 |
| Cuba | 38.12 | 1.41 | 25 | 5.64 | 15 |
| Dominican Republic | 20.995 | 0.56 | 25 | 2.24 | 11 |
| Ecuador | 432 | 2.67 | 19 | 13.96 | 3 |
| Egypt | 58.3 | 28.43 | 53 | 53.85 | 92 |
| El Salvador | 25.23 | 0.19 | 25 | 0.76 | 3 |
| Eritrea | 6.3 | 0.09 | 32 | 0.29 | 5 |
| Ethiopia | 110 | 0.56 | 22 | 2.47 | 2 |
| Gabon | 164 | 0.02 | 30 | 0.05 | 0 |
| Gambia | 8 | 0.01 | 30 | 0.02 | 0 |
| Ghana | 53.2 | 0.06 | 26 | 0.25 | 0 |
| Guatemala | 111.27 | 0.4 | 25 | 1.61 | 1 |
| Guinea | 226 | 0.41 | 30 | 1.36 | 1 |
| Guyana | 241 | 0.45 | 28 | 1.6 | 1 |
| Haiti | 14.025 | 0.18 | 20 | 0.93 | 7 |
| Honduras | 95.929 | 0.17 | 25 | 0.69 | 1 |
| India | 1896.66 | 303.24 | 54 | 558.39 | 29 |
| Indonesia | 2838 | 21.49 | 28 | 75.6 | 3 |
| Iran, Islamic Rep of | 137.51 | 21.06 | 32 | 66.23 | 48 |
| Iraq | 75.42 | 11.2 | 28 | 39.38 | 52 |
| Jamaica | 9.404 | 0.01 | 25 | 0.02 | 0 |
| Jordan | 0.88 | 0.29 | 39 | 0.76 | 86 |
| Kenya | 30.2 | 0.3 | 30 | 1.01 | 3 |
| Korea, Dem People's Rep | 77.135 | 1.49 | 30 | 4.96 | 6 |
| Korea, Republic of | 69.7 | 2.67 | 30 | 8.92 | 13 |
| Laos | 333.55 | 0.81 | 30 | 2.7 | 1 |
| Lebanon | 4.407 | 0.37 | 40 | 0.92 | 21 |
| Libyan Arab Jamahiriya | 0.6 | 2.56 | 60 | 4.27 | 712 |
| Madagascar | 337 | 3.58 | 25 | 14.31 | 4 |
| Malawi | 17.28 | 0.2 | 25 | 0.81 | 5 |
| Malaysia | 580 | 1.68 | 30 | 5.6 | 1 |
| Mali | 100 | 2.06 | 30 | 6.87 | 7 |
| Mauritania | 11.4 | 0.44 | 29 | 1.5 | 13 |
| Mexico | 457.222 | 18.53 | 31 | 60.34 | 13 |
| Morocco | 29 | 4.28 | 37 | 11.48 | 40 |
| Mozambique | 216.11 | 0.22 | 39 | 0.55 | 0 |
| Myanmar | 1045.601 | 9.79 | 30 | 32.64 | 3 |
| Namibia | 17.94 | 0.07 | 40 | 0.17 | 1 |

*(Continued)*

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**Table 7J.137 (Continued)**

| | Total Renewable Water Resources ($km^3$) | Irrigation Water Requirements ($km^3$) | Water Requirement Ratio in Percentages (%) | Water Withdrawal for Agriculture ($km^3$) | Water Withdrawal as Percentage of Renewable Water Resources (%) |
|---|---|---|---|---|---|
| Nepal | 210.2 | 2.45 | 25 | 9.82 | 5 |
| Nicaragua | 196.69 | 0.3 | 27 | 1.08 | 1 |
| Niger | 33.65 | 0.62 | 30 | 2.08 | 6 |
| Nigeria | 286.2 | 1.65 | 30 | 5.51 | 2 |
| Pakistan | 222.67 | 72.14 | 44 | 162.65 | 73 |
| Panama | 147.98 | 0.05 | 20 | 0.23 | 0 |
| Paraguay | 336 | 0.08 | 23 | 0.35 | 0 |
| Peru | 1913 | 5.07 | 31 | 16.42 | 1 |
| Philippines | 479 | 6.33 | 30 | 21.1 | 4 |
| Rwanda | 5.2 | 0.01 | 30 | 0.03 | 1 |
| Saudi Arabia | 2.4 | 6.68 | 43 | 15.42 | 643 |
| Senegal | 39.4 | 0.43 | 30 | 1.43 | 4 |
| Sierra Leone | 160 | 0.12 | 33 | 0.35 | 0 |
| Somalia | 13.5 | 0.98 | 30 | 3.28 | 24 |
| South Africa | 50 | 2.34 | 21 | 11.12 | 22 |
| Sri Lanka | 50 | 2.92 | 24 | 12 | 24 |
| Sudan | 64.5 | 14.43 | 40 | 36.07 | 56 |
| Suriname | 122 | 0.18 | 30 | 0.62 | 1 |
| Swaziland | 4.51 | 0.12 | 16 | 0.76 | 17 |
| Syrian Arab Republic | 26.26 | 8.52 | 45 | 18.93 | 72 |
| Tanzania, United Rep of | 91 | 0.56 | 30 | 1.85 | 2 |
| Thailand | 409.944 | 24.83 | 30 | 82.75 | 20 |
| Togo | 14.7 | 0.02 | 30 | 0.08 | 1 |
| Tunisia | 4.56 | 1.21 | 54 | 2.23 | 49 |
| Turkey | 229.3 | 11.27 | 40 | 27.86 | 12 |
| Uganda | 66 | 0.03 | 30 | 0.12 | 0 |
| Uruguay | 139 | 0.66 | 22 | 3.03 | 2 |
| Venezuela, Boliv Rep of | 1233.17 | 1.24 | 31 | 3.97 | 0 |
| Vietnam | 891.21 | 15.18 | 31 | 48.62 | 5 |
| Yemen | 4.1 | 2.53 | 40 | 6.32 | 154 |
| Zambia | 105.2 | 0.26 | 19 | 1.32 | 1 |
| Zimbabwe | 20 | 0.67 | 30 | 2.24 | 11 |

*Source:* From Food and Agriculture Organization of the United Nations (FAO). AQUASTAT - FAO's Information System on Water and Agriculture, www.fao.org. Reprinted with permission.

**Table 7J.138 Summary Results of Agricultural Water Use and Comparison with Water Resources, 2000**

| | Total Renewable Water Resources ($km^3$) | Irrigation Water Requirements ($km^3$) | Water Requirement Ratio (%) | Water Withdrawal for Agriculture ($km^3$) | Water Withdrawal as Percentage of Renewable Water Resources (%) |
|---|---|---|---|---|---|
| Latin America | 13,409 | 45 | 24 | 187 | 1 |
| Near East and North Africa | 541 | 109 | 40 | 274 | 51 |
| Sub-Saharan Africa | 3,518 | 31 | 32 | 97 | 3 |
| East Asia | 8,609 | 232 | 34 | 693 | 8 |
| South Asia | 2,469 | 397 | 44 | 895 | 36 |
| 90 developing countries | 28,545 | 814 | 38 | 2146 | 8 |

*Source*: From Food and Agriculture Organization of the United Nations (FAO), AQUASTAT - FAO's Information System on Water and Agriculture, www.fao.org. Reprinted with permission.

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**Table 7J.139 Irrigated Area, by World Region, 1961–2001**

| | Thousand Hectares | | | | |
|---|---|---|---|---|---|
| **Region** | **1961** | **1965** | **1970** | **1975** | **1980** |
| Africa | 7,410 | 7,795 | 8,483 | 9,010 | 9,491 |
| Asia | 90,166 | 97,093 | 109,666 | 121,565 | 132,377 |
| Europe | 8,468 | 9,401 | 10,583 | 12,704 | 14,479 |
| North & Central America | 17,950 | 19,526 | 20,939 | 22,833 | 27,597 |
| Oceania | 1,079 | 1,368 | 1,588 | 1,620 | 1,684 |
| South America | 4,661 | 5,070 | 5,673 | 6,403 | 7,392 |
| U.S.S.R. | 9,400 | 9,900 | 11,100 | 14,500 | 17,200 |
| World | 139,134 | 150,153 | 168,032 | 188,635 | 210,220 |
| **Region** | **1985** | **1990** | **1995** | **2000** | **2001** |
| Africa | 10,331 | 11,235 | 12,383 | 12,700 | 12,813 |
| Asia | 141,922 | 155,009 | 180,508 | 190,014 | 190,385 |
| Europe | 16,018 | 17,414 | 26,104 | 25,382 | 25,347 |
| North & Central America | 27,471 | 28,913 | 30,473 | 31,223 | 31,344 |
| Oceania | 1,957 | 2,114 | 2,689 | 2,674 | 2,674 |
| South America | 8,296 | 9,499 | 10,086 | 10,489 | 10,489 |
| U.S.S.R. | 19,689 | 20,800 | | | |
| World | 225,684 | 244,984 | 262,243 | 272,482 | 273,052 |

*Note:* After 1990, all irrigated area in the former U.S.S.R. is split among Europe and Asia.

*Source*: From *World's Water 2004–2005*, by Peter H. Gleick. Copyright © 2004 Island Press. Reproduced by permission of Island Press, Washington, DC.

**Table 7J.140 Agricultural Land Use for Developing Countries**

| | Arable Land (mi ha) | | | Harvested Land (mi ha) | | | Cropping Intensity (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Total** | **Rainfed** | **Irrigated** | **Total** | **Rainfed** | **Irrigated** | **Total** | **Rainfed** | **Irrigated** |
| **Developing countries** | | | | | | | | | |
| 1997–99 | 956 | 754 | 202 | 885 | 628 | 257 | 93 | 83 | 127 |
| 2015 | 1,017 | 796 | 221 | 977 | 671 | 306 | 96 | 84 | 138 |
| 2030 | 1,076 | 834 | 242 | 1,063 | 722 | 341 | 99 | 87 | 141 |
| **Sub-Saharan Africa** | | | | | | | | | |
| 1997–99 | 228 | 223 | 5.3 | 154 | 150 | 4.5 | 68 | 67 | 86 |
| 2015 | 262 | 256 | 6 | 185 | 179 | 5.7 | 71 | 70 | 95 |
| 2030 | 288 | 281 | 6.8 | 217 | 210 | 7 | 76 | 75 | 102 |
| **Near East and North Africa** | | | | | | | | | |
| 1997–99 | 86 | 60 | 26 | 70 | 43 | 27 | 81 | 72 | 102 |
| 2015 | 89 | 60 | 29 | 77 | 45 | 32 | 86 | 75 | 110 |
| 2030 | 93 | 60 | 33 | 84 | 46 | 37 | 90 | 78 | 112 |
| **Latin America and Caribbean** | | | | | | | | | |
| 1997–99 | 203 | 185 | 18 | 127 | 112 | 16 | 63 | 60 | 86 |
| 2015 | 223 | 203 | 20 | 150 | 131 | 19 | 67 | 64 | 95 |
| 2030 | 244 | 222 | 22 | 172 | 150 | 22 | 71 | 68 | 100 |
| **South Asia** | | | | | | | | | |
| 1997–99 | 207 | 126 | 81 | 230 | 131 | 100 | 111 | 103 | 124 |
| 2015 | 210 | 123 | 87 | 248 | 131 | 117 | 118 | 106 | 134 |
| 2030 | 216 | 121 | 95 | 262 | 131 | 131 | 121 | 109 | 137 |
| **East Asia** | | | | | | | | | |
| 1997–99 | 232 | 161 | 71 | 303 | 193 | 110 | 130 | 120 | 154 |
| 2015 | 233 | 155 | 78 | 317 | 186 | 131 | 136 | 120 | 168 |
| 2030 | 237 | 151 | 85 | 328 | 184 | 144 | 139 | 122 | 169 |

*Source*: Food and Agriculture Organization of the United Nations (FAO), *World Agricultrure: towards 2015/2030 Summary Report*, www.fao.org. Reprinted with permission.

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**Table 7J.141 Irrigated Land and Percentage of Arable Land That Is Irrigated**

| | Irrigated Land | | | | | |
|---|---|---|---|---|---|---|
| | Area (1000 ha) | | | As % of Arable Land | | |
| World/Continent | 1980 | 1990 | 2001 | 1980 | 1990 | 2001 |
| World | 210,220 | 244,984 | 273,052 | 15.7 | 17.6 | 19.5 |
| Developed countries | 58,926 | 66,286 | 67,988 | 9.0 | 10.2 | 11.1 |
| Industralized countries | 37,355 | 39,935 | 43,226 | 9.9 | 10.5 | 11.8 |
| Transition economies | 21,571 | 26,351 | 24,762 | 7.9 | 9.8 | 10.0 |
| Developing countries | 151,294 | 178,698 | 205,064 | 21.9 | 24.1 | 26.0 |
| Latin America and the Caribbean | 13,811 | 16,794 | 18,613 | 10.8 | 12.5 | 12.5 |
| Near East and North Africa | 17,982 | 24,864 | 27,808 | 21.8 | 28.8 | 32.3 |
| Sub-Saharan Africa | 3,980 | 4,885 | 5,221 | 3.2 | 3.7 | 3.6 |
| East and Southeast Asia | 59,722 | 65,624 | 74,605 | 37.0 | 33.9 | 35.0 |
| South Asia | 55,798 | 66,529 | 78,813 | 28.6 | 33.9 | 40.3 |
| Oceania developing | 1 | 2 | 4 | 0.2 | 0.4 | 0.7 |
| North America developing | — | — | — | — | — | — |
| Continental groupings | | | | | | |
| Africa | 9,491 | 11,235 | 12,813 | 6.0 | 6.7 | 7.0 |
| Asia | 132,377 | 155,009 | 190,385 | 31.3 | 33.8 | 37.4 |
| Caribbean | 1,074 | 1,269 | 1,308 | 22.0 | 23.3 | 22.2 |
| Latin America | 12,737 | 15,525 | 17,305 | 10.4 | 12.0 | 12.1 |
| North America | 21,178 | 21,618 | 23,220 | 9.0 | 9.3 | 10.5 |
| Oceania | 1,684 | 2,114 | 2,674 | 3.6 | 4.2 | 5.1 |
| Europe | 14,479 | 17,414 | 25,347 | 11.5 | 14.0 | 8.8 |

*Source*: From Food and Agriculture Organization of the United Nations (FAO), 2003, *Summary of Food and Agricultural Statistics*, www.fao.org. Reprinted with permission.

**Table 7J.142 Irrigated (Arable) Land: Past and Projected**

| | Irrigated Land in Use (mi ha) | | | | | Annual Growth (% p.a.) | | Land in Use as % of Potential (%) | | Balance (mi ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1961/63 (1) | 1979/81 (2) | 1997/99 (3) | 2015 (5) | 2030 (6) | 1961–1999 (7) | 1997/99–2030 (8) | 1997/99 (9) | 2030 (10) | 1997/99 (11) | 2030 (12) |
| Sub-Saharan Africa | 3 | 4 | 5 | 6 | 7 | 2.0 | 0.9 | 14 | 19 | 32 | 30 |
| Near East/North Africa | 15 | 18 | 26 | 29 | 33 | 2.3 | 0.6 | 62 | 75 | 17 | 11 |
| Latin America and the Caribbean | 8 | 14 | 18 | 20 | 22 | 1.9 | 0.5 | 27 | 32 | 50 | 46 |
| South Asia | 37 | 56 | 81 | 87 | 95 | 2.2 | 0.5 | 57 | 67 | 61 | 47 |
| excl. India | 12 | 17 | 23 | 24 | 25 | 1.9 | 0.2 | 84 | 89 | 4 | 3 |
| East Asia | 40 | 59 | 71 | 78 | 85 | 1.5 | 0.6 | 64 | 76 | 41 | 27 |
| excl. China | 10 | 14 | 19 | 22 | 25 | 2.1 | 0.9 | 40 | 53 | 29 | 23 |
| All above | 103 | 151 | 202 | 221 | 242 | 1.9 | 0.6 | 50 | 60 | 200 | 161 |
| excl. China | 73 | 106 | 150 | 165 | 182 | 2.1 | 0.6 | 44 | 54 | 188 | 157 |
| excl. China/India | 48 | 67 | 93 | 102 | 112 | 2.0 | 0.6 | 41 | 50 | 132 | 114 |
| Industrial countries | 27 | 37 | 42 | | | 1.3 | | | | | |
| Transition countries | 11 | 22 | 25 | | | 2.6 | | | | | |
| World | 142 | 210 | 271 | | | 1.8 | | | | | |

*Source*: From Food and Agriculture Organization, of the United Nations (FAO), World Agriculture Towards 2015/2030, www.fao.org. Reprinted with permission.

*Original Source*: From Columns (1)–(3): FAOSTAT, November 2001.

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**Table 7J.143 Irrigation Lending by Continent and Decade**

| | Irrigation Lending (% of global amount) | | | | Projects (% of global number) | | | | Average Irrigation Lending Amount (1991 US$M) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Decade | Asia | America | Africa | Europe | Asia | America | Africa | Europe | Asia | America | Africa | Europe | World |
| 1950 | 75 | 25 | | | 67 | 33 | | | 70 | 47 | | | 62 |
| 1960 | 75 | 12 | 13 | | 71 | 20 | 10 | | 89 | 51 | 112 | | 84 |
| 1970 | 66 | 12 | 13 | 9 | 47 | 14 | 31 | 7 | 61 | 37 | 18 | 55 | 44 |
| 1980 | 73 | 12 | 11 | 4 | 47 | 13 | 34 | 5 | 76 | 44 | 16 | 39 | 49 |
| 1990–91 | 61 | 23 | 16 | | 60 | 17 | 23 | | 69 | 93 | 47 | | 68 |
| Total | 69 | 13 | 12 | 5 | 50 | 14 | 30 | 5 | 71 | 47 | 21 | 48 | 51 |

*Source*: From Jones, W.I., 1995, *The World Bank and Irrigation, The World Bank*, Washington, DC, Copyright © International Bank for Reconstruction and Development/The World Bank, www.worldbank.org. Reprinted with permission.

**Table 7J.144 Average Unit Costs for World Bank Irrigation Projects**

| | Unit Cost ($/ha) | Number | Adjusted Unit Cost ($/ha) | Number | Adjusted/ Unadjusted Ratio |
|---|---|---|---|---|---|
| All | 4,837 | 191 | 7,950 | 184 | 1.64 |
| Satisfactory | 2,643 | 128 | 2,906 | 125 | 1.10 |
| Unsatisfactory | 9,294 | 63 | 18,637 | 59 | 2.01 |
| Gravity | 5,584 | 113 | 10,355 | 112 | 1.85 |
| Pump (mostly from groundwater) | 3,766 | 52 | 4,415 | 46 | 1.17 |
| Mixed | 3,727 | 26 | 3,846 | 26 | 1.03 |
| New construction | 7,740 | 86 | 12,915 | 81 | 1.67 |
| Rehabilitation | 1,633 | 34 | 5,258 | 34 | 3.22 |
| Rehabilitation and extension | 3,171 | 55 | 3,834 | 54 | 1.21 |
| Paddy | 6,374 | 73 | 11,063 | 72 | 1.74 |
| Nonpaddy | 3,886 | 118 | 5,950 | 112 | 1.53 |
| *Selected areas* | | | | | |
| East and South Asia | 2,831 | 112 | 4,694 | 107 | 1.66 |
| East Asia | 4,291 | 56 | 7,379 | 56 | 1.72 |
| South Asia | 1,370 | 56 | 1,746 | 51 | 1.27 |
| India | 1,421 | 30 | 1,596 | 27 | 1.12 |
| Europe | 4,743 | 17 | 4,759 | 17 | 1.00 |
| Middle East | 5,062 | 9 | 4,663 | 7 | 0.92 |
| Africa | 12,925 | 30 | 20,833 | 30 | 1.61 |
| North Africa | 4,911 | 12 | 5,226 | 12 | 1.06 |
| Sub-Saharan Africa | 18,269 | 18 | 31,238 | 18 | 1.71 |
| Latin America and Caribbean | 3,923 | 20 | 10,283 | 20 | 2.62 |

*Note:* Two measures of unit cost are used. "Unit cost" is defined as the actual project cost ($US) measured at evaluation divided by the completion command area (hectares) measured at evaluation. "Adjusted unit cost" is "unit cost" with the denominator adjusted by the completion achievement of construction target (%) measured at evaluation. Two projects, Lake Chad Polders (Chad) and Black Bush Irrigation (Guyana), had completion command areas measured at evaluation equal to zero. This resulted in infinite measures of unit cost, and thus they were not included in the calculation of averages.

*Source*: From Jones, W.I., 1995, *The World Bank and Irrigation, The World Bank*, Washington, DC, Copyright © International Bank for Reconstruction and Development/The World Bank, www.worldbank.org. Reprinted with permission.

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## SECTION 7K LIVESTOCK

**Table 7K.145 Water Requirements for Farm Animals and Poultry**

| | |
|---|---|
| Horse, work | 12 |
| Mule | 12 |
| Cattle | |
| Holstein calves (liquid milk or dried milk and water supplied) | |
| 4 weeks of age | 1.2–1.4 |
| 8 weeks of age | 1.6 |
| 12 weeks of age | 2.2–2.4 |
| 16 weeks of age | 3.0–3.4 |
| 20 weeks of age | 3.8–4.3 |
| 26 weeks of age | 4.0–5.8 |
| Dairy heifers—Pregnant | 7.2–8.4 |
| Steers | |
| Maintenance ration | 4.2 |
| Fattening ration | 8.4 |
| Range cattle | 4.2–8.4 |
| Jersey cows[a] | |
| Milk production 5–30 lbs/day | 7.2–12 |
| Holstein cows[a] | |
| Milk production 20–50 lbs/day | 7.8–22 |
| Milk production 80 lbs/day | 23 |
| Dry | 11 |
| Pigs | |
| Body weight—30 lbs | 0.6–1.2 |
| Body weight—60–80 lbs | 0.8 |
| Body weight—75–125 lbs | 1.9 |
| Body weight—200–380 lbs | 1.4–3.6 |
| Pregnant sows | 3.6–4.6 |
| Lactating sows | 4.8–6.0 |
| Sheep | |
| On range of dry pasture | 0.6–1.6 |
| On range (salty feeds) | 2.0 |
| On rations of hay and grain or hay, roots and grain | 0–0.7 |
| On good pasture | Little, if any |
| Chickens (100 birds) | |
| 1–3 weeks of age | 0.4–2.0 |
| 3–6 weeks of age | 1.4–3.0 |
| 6–10 weeks of age | 3.0–4.0 |
| 9–13 weeks of age | 4.0–5.0 |
| Pullets | 3.0–4.0 |
| Nonlaying hens | 5.0 |
| Laying hens (moderate temperatures) | 5.0–7.5 |
| Laying hens (temperature 90 °F) | 9.0 |
| Turkeys (100 birds) | |
| 1–3 weeks of age | 1.1–2.6 |
| 7–4 weeks of age | 3.7–8.4 |
| 9–13 weeks of age | 9–14 |
| 15–19 weeks of age | 17 |
| 21–26 weeks of age | 14–15 |

*Note:* Gallons per day.

[a] Allow 15–20 additional gallons per day for each cow for flushing stables and washing dairy utensils.

*Source*: From U.S. Dept. of Agriculture.

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**Table 7K.146 Livestock Freshwater Use in the United States, 2000**

| | Withdrawals (mi/gal/day) | | | Withdrawals (thousand acre-feet/yr) | | |
|---|---|---|---|---|---|---|
| | By Source | | | By Source | | |
| | Groundwater | Surface Water | Total | Groundwater | Surface Water | Total |
| Alabama | — | — | — | — | — | — |
| Alaska | — | — | — | — | — | — |
| Arizona | — | — | — | — | — | — |
| Arkansas | — | — | — | — | — | — |
| California | 182 | 227 | 409 | 204 | 255 | 458 |
| Colorado | — | — | — | — | — | — |
| Connecticut | — | — | — | — | — | — |
| Delaware | 3.7 | 0.22 | 3.92 | 4.15 | 0.25 | 4.39 |
| District of Columbia | — | — | — | — | — | — |
| Florida | 31 | 1.51 | 32.5 | 34.7 | 1.69 | 36.4 |
| Georgia | 1.66 | 17.7 | 19.4 | 1.86 | 19.9 | 21.7 |
| Hawaii | — | — | — | — | — | — |
| Idaho | 27.7 | 7.2 | 34.9 | 31 | 8.07 | 39.1 |
| Illinois | 37.6 | 0 | 37.6 | 42.1 | 0 | 42.1 |
| Indiana | 27.3 | 14.6 | 41.9 | 30.6 | 16.4 | 47 |
| Iowa | 81.8 | 27.1 | 109 | 91.8 | 30.4 | 122 |
| Kansas | 87.2 | 23.5 | 111 | 97.7 | 26.3 | 124 |
| Kentucky | — | — | — | — | — | — |
| Louisiana | 4.03 | 3.31 | 7.34 | 4.52 | 3.71 | 8.23 |
| Maine | — | — | — | — | — | — |
| Maryland | 7.18 | 3.18 | 10.4 | 8.05 | 3.56 | 11.6 |
| Massachusetts | — | — | — | — | — | — |
| Michigan | 10.2 | 1.15 | 11.3 | 11.4 | 1.29 | 12.7 |
| Minnesota | 52.8 | 0 | 52.8 | 59.2 | 0 | 59.2 |
| Mississippi | — | — | — | — | — | — |
| Missouri | 18.3 | 54.1 | 72.4 | 20.5 | 60.6 | 81.1 |
| Montana | — | — | — | — | — | — |
| Nebraska | 76 | 17.4 | 93.4 | 85.2 | 19.5 | 105 |
| Nevada | — | — | — | — | — | — |
| New Hampshire | — | — | — | — | — | — |
| New Jersey | 1.68 | 0 | 1.68 | 1.88 | 0 | 1.88 |
| New Mexico | — | — | — | — | — | — |
| New York | — | — | — | — | — | — |
| North Carolina | 89.1 | 32.3 | 121 | 99.9 | 36.2 | 136 |
| North Dakota | — | — | — | — | — | — |
| Ohio | 8.2 | 17.1 | 25.3 | 9.19 | 19.2 | 28.4 |
| Oklahoma | 53.6 | 97.2 | 151 | 60 | 109 | 169 |
| Oregon | — | — | — | — | — | — |
| Pennsylvania | — | — | — | — | — | — |
| Rhode Island | — | — | — | — | — | — |
| South Carolina | — | — | — | — | — | — |
| South Dakota | 16.9 | 25.2 | 42 | 18.9 | 28.2 | 47.1 |
| Tennessee | — | — | — | — | — | — |
| Texas | 137 | 172 | 308 | 153 | 192 | 346 |
| Utah | — | — | — | — | — | — |
| Vermont | — | — | — | — | — | — |
| Virginia | — | — | — | — | — | — |
| Washington | — | — | — | — | — | — |
| West Virginia | — | — | — | — | — | — |
| Wisconsin | 60.3 | 6.02 | 66.3 | 67.6 | 6.75 | 74.4 |
| Wyoming | — | — | — | — | — | — |
| Puerto Rico | — | — | — | — | — | — |
| U.S. Virgin Islands | — | — | — | — | — | — |
| **Total** | **1,010** | **747** | **1,760** | **1,140** | **838** | **1,980** |

*Note:* Figures may not sum to totals because of independent rounding. —, data not collected.

*Source*: From Hutson, S.S. et al., 2004, Estimated Use of Water in the United States in 2000, *U.S. Geological Survey Circular 1268*, www.usgs.gov.

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## SECTION 7L NAVIGATION AND WATERWAYS

**Table 7L.147 Projected Flows Required for Efficient Navigation on Inland Waterways of the United States**

| Waterway | Critical Flow[a] ($ft^3/s$) 1,959 | 1,980 | 2,000 | Comments |
|---|---|---|---|---|
| New England, existing waterways: all | 0 | 0 | 0 | All waterways are in tidal reaches |
| Middle Atlantic, existing waterways | | | | |
| Great Lakes to Hudson River and Champlain Canals | 2,000 | 2,000 | 2,000 | Available flow 13,000 c.f.s. |
| Delaware | [b] | [b] | [b] | If depth increased to 45 ft minimum flow will have to be increased by 2,900, c.f.s. to repel salinity |
| South Atlantic | | | | |
| Existing waterways | | | | |
| Cape Fear River above Wilmington, NC | 50 | 100 | [c] | |
| Savannah River below Augusta, GA | 5,000 | 5,800 | [c] | |
| Altamaha River below junction of Ocmulgee and Oconee Rivers | 1,000 | 5,000 | [c] | |
| Okeechobee Waterway | 50 | 50 | [c] | |
| Apalachicola below Jim Woodruff lock and dam | 9,300 | 9,300 | [c] | |
| Alabama River below Selma, AL | 3,000 | 3,000 | [c] | |
| Warrior system | 540 | 540 | [c] | |
| Possible future waterways | | | | |
| Santee-Congaree | — | 5,200 | [c] | Project might be found feasible if river developed for power |
| Ocmulgee River below Macon, GA | — | 300 | [c] | |
| Cross-Florida Barge Canal | — | 700 | [c] | Authorized project |
| Chattahoochee River below Atlanta, GA | — | 300 | [c] | |
| Flint River below Albany, GA | — | 200 | [c] | |
| Coosa River | — | 300 | [c] | Do |
| Tennessee-Tombigbee | — | 1,246 | [c] | Completed project. (1,246 c.f.s. to be diverted from the Tennessee River.) |
| Arkansas-White-Red | | | | |
| Existing waterways | | | | |
| White River (to mile 168.7) | 6,500 | 10,000 | 10,000 | |
| Ouachita-Black | 100 | 100 | 100 | |
| Waterways under construction | | | | |
| Verdigris River (at Catoosa, OK) | — | 115 | 115 | Provision of 9-ft waterway as part of multiple-purpose development of the Arkansas River |
| Arkansas (at Webber Falls) | — | 300 | 300 | Do |
| Arkansas (at Short Mountain) | — | 530 | 530 | Do |
| Arkansas (at Dardanelle) | — | 505 | 505 | Do |
| Arkansas (Dardenelle to mouth) | — | 1,000 | 1,000 | Do |
| Possible future waterways: Overton-Red Waterway | — | 300 | | Authorized project |
| Gulf-Southwest | | | | |
| Waterways under construction: Guadalupe to Victoria | — | 0–1,800 | 0–1,800 | For periodic flushing |

*(Continued)*

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**Table 7L.147 (Continued)**

| Waterway | Critical Flow[a] ($ft^3/s$) 1,959 | 1,980 | 2,000 | Comments |
|---|---|---|---|---|
| Possible future waterways | | | | |
| Trinity River (below Dallas) | — | 400 | 800 | Authorized project |
| Trinity River (above Dallas) | — | 150 | 325 | Do |
| Missouri River Basin, existing waterways | | | | |
| Missouri at Sioux City[d] | — | 30,000 | 30,000 | Could be reduced to 25,000 by dredging |
| Missouri at Omaha[d] | 28,000 | 28,000 | 28,000 | |
| Missouri at Nebraska City | 31,000 | 31,000 | 31,000 | |
| Missouri at Kansas City[d] | 35,000 | 32,500 | 32,500 | Could be reduced to 27,500 by dredging |
| Missouri at mouth[d] | — | 35,000 | 35,000 | |
| Upper Mississippi Basin | | | | |
| Existing waterways | | | | |
| Main stem, pools 1–10 | 375 | 750 | 940 | Not required in winter |
| Main stem, pools 11–22 | 2,000 | 2,000 | 2,000 | Do |
| Main stem, pools 24–26 | 70,000 | 25,000 | 25,000 | Required all year |
| Main stem, Missouri to Ohio | 54,000 | 75,000 | 75,000 | Do |
| Minnesota | 0 | 0 | 0 | Mississippi backwater |
| St. Croix | 0 | 0 | 0 | Do |
| Illinois Waterway | 720[e] | 1,826[e,f] | 1,826[e,f] | |
| Fox River | 300 | 300 | 300 | Not required in winter |
| Possible future waterways | | | | |
| Kaskaskia River | 0 | 200 | 300 | |
| Big Muddy River | 0 | 200 | 400 | |
| Tittabawassee River | 0 | 200 | 200 | |
| Ohio River Basin | | | | |
| Existing waterways | | | | |
| Ohio River (main stem) | [c] | [c] | [c] | River canalized |
| Allegheny River | 100 | 140 | 150 | |
| Monongahela River | 340 | 440 | 670 | |
| Kanawha River | 300 | 400 | 400 | |
| Kentucky River | 100 | 150 | 200 | |
| Green River | 150 | 250 | 400 | |
| Cumberland River | 100 | 150 | 250 | |
| Possible future waterways | | | | |
| Big Sandy River (main stem) | 0 | 329 | 329 | |
| Big Sandy River (Levisa Fork) | 0 | 176 | 176 | |
| Lake Erie-Ohio River Canal | 0 | 430 | 430 | |
| Lower Mississippi River | | | | |
| Existing waterways | | | | |
| Main stem at Cairo | 100,000 | 120,000 | 120,000 | |
| Main stem below Arkansas | 140,000 | 150,000 | 150,000 | |
| Ouachita-Black | 100 | 150 | 150 | |
| Possible future waterways | | | | |
| Yazoo below Greenwood | — | 100 | 100 | |
| Columbia River Basin | | | | |
| Existing waterways | | | | |
| Main stem at Bonneville | 40,000 | 40,000 | 40,000 | |
| Main stem at The Dallas | 700 | 1,500 | 2,500 | |
| Willamette, mouth to Salem | 6,000 | 6,000 | 6,000 | |
| Willamette, Salem to Corvallis | 5,000 | 5,000 | 5,000 | |
| Snake, mouth to Ice Harbor | 300 | 1,000 | 2,000 | |
| Waterways under construction | | | | |
| Main stem John Day to McNary | 110,000 | 1,500 | 2,500 | |
| Snake, Ice Harbor to Lewiston | — | 1,000 | 2,000 | |
| Possible future waterways | | | | |
| Main stem head McNary Pool to Rock Island | — | 36,000 | — | Under study |
| Snake, Lewiston to mile 174 | — | 500 | 1,000 | Do |

*(Continued)*

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**Table 7L.147 (Continued)**

| Waterway | Critical Flow[a] ($ft^3/s$) 1,959 | 1,980 | 2,000 | Comments |
|---|---|---|---|---|
| Snake, mile 174 to mile 188 | — | 500 | 1,000 | |
| Snake, mile 188 to mile 232 | — | 350 | 700 | |
| North Pacific Coast, Possible future waterways | — | 10,000 | 10,000 | |
| Skagit, mouth to Concrete | | | | |
| Central Valley, existing waterways | | | | |
| Sacramento | 5,000 | 5,000 | 5,000 | Shallow draft |
| San Joaquin above Mossdale | 100 | 100 | 100 | Do |

[a] Rate below which streamflow cannot drop without reducing the efficiency of navigation.
[b] Anticipated flows will meet the needs of navigation.
[c] Estimates not available.
[d] Flows required from April through November, assuming continuation of open river navigation. Canalization now being studied. If Missouri canalized these flows would be greatly reduced.
[e] Average annual flow required at Lockport, III. Includes 250 c.f.s. to prevent reversal of flow into Lake Michigan when storm runoff occurs. Excludes 120 c.f.s. of present industrial usage which bypasses Lockport lock.
[f] Requirements for recommended duplicate lock system.

*Source*: From Select Committee on National Water Resources, U.S. Senate, 1960; amended.

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## Table 7L.148 Navigation Locks and Dams in the United States (Operable as of May 2005)

| | | | | | Locks | | | | | | Dam | | | | Authorized Channel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Depth of Miter Sill | | | | | | | | |
| Project | River Mile | Type of Structure[a] | Status[b] | Community in Vicinity | Width of Chamber | Chamber Useable Length | Lift at Normal Pool Level | Upper | Lower | Type | Length (ft) | Year Opened | Length (miles) | Depth (ft) | Width (above) (ft) | Width (below) (ft) |
| **Alabama-Coosa Rivers** | | | | | | | | | | | | | | | | |
| Claiborne Lock & Dam | 117.5 | L | 1 | Claiborne, AL | 84 | 600 | 30 | 16 | 13 | Moveable | 1,603.0 | 1973 | 61 | 9 | 200 | 200 |
| Millers Ferry Lock & Dam | 178 | L | 1 | Camden, AL | 84 | 600 | 45 | 16 | 13 | Moveable | 9,900.0 | 1969 | 103 | 9 | 200 | 200 |
| Jones Bluff Lock & Dam | 281.2 | L | 1 | Benton, AL | 84 | 600 | 45 | 16 | 13 | Moveable | 1,496.0 | 1974 | 88 | 9 | 200 | 200 |
| **Allegheny River, PA and NY** | | | | | | | | | | | | | | | | |
| Lock & Dam 2 | 6.7 | L | 1 | Aspinwall, PA | 56 | 360 | 11 | 11 | 12 | Miter | 1,393.0 | 1934 | 8 | 9 | 200 | 200 |
| Lock & Dam 3 | 14.5 | L | 1 | Cheswick, PA | 56 | 360 | 14 | 12 | 11 | Miter | 1,436.0 | 1934 | 10 | 9 | 200 | 200 |
| Lock & Dam 4 | 24.2 | L | 1 | Natrona, PA | 56 | 360 | 11 | 9 | 10 | Miter | 876.0 | 1927 | 6 | 9 | 200 | 200 |
| Lock & Dam 5 | 30.4 | L | 2 | Freeport, PA | 56 | 360 | 12 | 10 | 11 | Miter | 780.0 | 1927 | 6 | 9 | 200 | 200 |
| Lock & Dam 6 | 36.3 | L | 2 | Clinton, PA | 56 | 360 | 12 | 11 | 11 | Miter | 1,140.0 | 1928 | 9 | 9 | 200 | 200 |
| Lock & Dam 7 | 45.7 | L | 2 | Kittanning, PA | 56 | 360 | 13 | 11 | 10 | Miter | 916.0 | 1930 | 7 | 9 | 200 | 200 |
| Lock & Dam 8 | 52.6 | L | 2 | Templeton, PA | 56 | 360 | 18 | 14 | 10 | Miter | 984.0 | 1931 | 10 | 9 | 200 | 200 |
| Lock & Dam 9 | 62.2 | L | 3 | Rimer, PA | 56 | 360 | 22 | 11 | 11 | Miter | 950.0 | 1938 | 10 | 9 | 200 | 200 |
| **Apalachicola, Chattahoochee, & Flint Rivers, GA, AL and FL** | | | | | | | | | | | | | | | | |
| Jim Woodruff Lock & Dam | 106.3 | L | 1 | Chattahoochee, FL | 82 | 450 | 33 | 14 | 14 | Moveable | 6,359.0 | 1957 | 47 | 6 | 100 | 100 |
| Gordon, GA (no name given) | 46.7 | L | 1 | Gordon, GA | 82 | 450 | 25 | 19 | 13 | Moveable | 750.0 | 1963 | 29 | 9 | 100 | 100 |
| Walter F George Lock & Dam | 75.1 | L | 1 | Fort Gaines, GA | 82 | 450 | 88 | 18 | 13 | Moveable | 1,325.0 | 1963 | 85 | 9 | 100 | 100 |
| **Atlantic Intracoastal Waterway between Norfolk, VA & St. Johns River, FL** | | | | | | | | | | | | | | | | |
| Great Bridge Guard Lock | 12.2 | L | 1 | Chesapeake, VA | 72 | 530 | 3 | 16 | 16 | Miter | NA | 1932 | 6 | 12 | 200 | 200 |
| Deep Creek Lock | 10.6 | L | 1 | Chesapeake, VA | 52 | 300 | 12 | 12 | 12 | Miter | NA | 1940 | 22 | 50 | 50 | 50 |
| South Mills Lock | 33.2 | L | 1 | South Mills, NC | 52 | 300 | 12 | 12 | 12 | Miter | NA | 1941 | 22 | 6 | 50 | 50 |
| **Bayou Teche, LA** | | | | | | | | | | | | | | | | |
| Bayou Teche, LA (FCMR&T) | 4 | F | 2 | Berwick, LA | 45 | 90 | 0 | 0 | 0 | Sector | NA | | 80 | 8 | 80 | 80 |
| Keystone Lock | 72 | L | 1 | New Iberia, LA | 36 | 160 | 8 | 9 | 8 | Miter | 175.0 | 1913 | 35 | 6 | 80 | 80 |
| Bayou Teche, LA (FCMR&T)–Grand Lake | 35.7 | F | 2 | Charenton, LA | 45 | 0 | 0 | 0 | 0 | Sector | NA | | 80 | 8 | 80 | 80 |
| Berwick Lock | 1.5 | L | 1 | Berwick, LA | 45 | 300 | 14 | 9 | 9 | Sector | NA | 1950 | 125 | 8 | 80 | 80 |
| **Black Rock Channel & Tonawanda Harbor, NY** | | | | | | | | | | | | | | | | |
| Black Rock Lock | 4 | L | 1 | Buffalo, NY | 70 | 625 | 5 | 22 | 22 | Fixed | NA | 1914 | 6 | 21 | 200 | 200 |
| **Black Warrior & Tombigbee Rivers, AL** | | | | | | | | | | | | | | | | |
| Coffeeville Lock | 116.6 | L | 1 | Coffeeville, AL | 110 | 600 | 34 | 13 | 13 | Moveable | 1,185.0 | 1965 | 97 | 9 | 200 | 200 |
| Demopolis Lock & Dam | 213.2 | L | 1 | Demopolis, AL | 110 | 600 | 40 | 13 | 13 | Moveable | 1,485.0 | 1962 | 48 | 9 | 200 | 200 |
| Warrior Lock & Dam | 262 | L | 1 | Eutaw, AL | 110 | 600 | 22 | 13 | 13 | Moveable | 1,832.0 | 1962 | 77 | 9 | 200 | 200 |
| William Bacon Oliver Lock & Dam | 337.6 | L | 1 | Tuscaloosa, AL | 110 | 600 | 28 | 18 | 18 | Moveable | 800.0 | 1991 | 43 | 9 | 200 | 200 |
| Holt Lock and Dam | 347 | L | 1 | Holt, AL | 110 | 600 | 64 | 19 | 13 | Moveable | 1,138.0 | 1969 | 18 | 9 | 200 | 200 |
| John Hollis Bankhead Lock & Dam | 366 | L | 1 | Adger, AL | 110 | 600 | 68 | 13 | 13 | Moveable | 1,170.0 | 1975 | 43 | 9 | 200 | 200 |
| **Calcasieu River And Pass, LA** | | | | | | | | | | | | | | | | |
| Calcasieu Salt Wtr Barrier | 38.9 | B | 1 | West Lake, LA | 56 | 575 | 0 | 0 | 0 | Sector | 450.0 | 1968 | 15 | 13 | 56 | 56 |
| **Canaveral Harbor, FL** | | | | | | | | | | | | | | | | |
| Canaveral Lock | 3 | L | 1 | Cape Canaveral, FL | 90 | 600 | 3 | 13 | 13 | Sector | NA | 1965 | 6 | 12 | 100 | 100 |
| **Cape Fear River, NC** | | | | | | | | | | | | | | | | |
| Lock & Dam 1 | 39 | L | 1 | Kings Bluff, NC | 40 | 200 | 11 | 9 | 9 | Miter | 275.0 | 1915 | 32 | 8 | 100 | 100 |
| Lock & Dam 2 | 71 | L | 1 | Browns Landing, NC | 40 | 200 | 9 | 12 | 12 | Miter | 229.0 | 1917 | 24 | 8 | 100 | 100 |
| William O. Huske Lock & Dam | 95 | L | 1 | Tolars Landing, NC | 40 | 300 | 9 | 9 | 9 | Miter | 220.0 | 1935 | 20 | 8 | 100 | 100 |
| **Chicago Harbor** | | | | | | | | | | | | | | | | |
| Chicago Lock | 327.2 | L | 1 | Chicago, IL | 80 | 600 | 4 | 27 | 23 | Sector | NA | 1939 | 1 | 21 | 470 | 190 |
| **Colorado River, TX** | | | | | | | | | | | | | | | | |
| Colorado River East Lock | 441.1 | L | 1 | Matagorda, TX | 75 | 1,180 | 12 | 15 | 15 | Sector | 520.0 | 1944 | 3,700 | 12 | 125 | 125 |
| Colorado River West Lock | 441.8 | L | 1 | Matagorda, TX | 75 | 1,180 | 12 | 15 | 15 | Fixed | 520.0 | 1944 | 3,700 | 12 | 125 | 125 |
| **Columbia River, OR and WA** | | | | | | | | | | | | | | | | |
| Bonneville Lock & Dam | 145.3 | L | 1 | Cascade Locks, OR | 86 | 650 | 65 | 19 | 24 | Miter | 2,680.0 | 1938 | 1,080 | 14 | 300 | 300 |
| The Dalles Dam | 191.7 | L | 1 | The Dalles, WA | 86 | 650 | 88 | 15 | 15 | Vertical | 8,735.0 | 1957 | 1,000 | 14 | 250 | 250 |
| John Day Lock & Dam | 216.5 | L | 1 | Rufus, WA | 86 | 650 | 110 | 15 | 15 | Vertical | 5,900.0 | 1968 | 1,600 | 14 | 250 | 250 |
| McNary Lock & Dam | 292 | L | 1 | Plymouth, WA | 86 | 650 | 103 | 15 | 21 | Miter | 7,365.0 | 1953 | 64 | 14 | 250 | 250 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cross Florida Barge Canal** | | | | | | | | | | | | | | | |
| Henry Holland Buckman Lock | 20 | L | 1 | Palatka, FL | 84 | 600 | 20 | 14 | 15 | Miter | | 1968 | 21 | 12 | 0 | 0 |
| Inglis Lock Dam And and Spillway | 92 | L | 3 | Inglis, FL | 84 | 600 | 28 | 18 | 15 | Miter | 5,100.0 | 1968 | 11 | 12 | 0 | 0 |
| **Cumberland River, TN & KY** | | | | | | | | | | | | | | | | |
| Barkley Lock & Dam | 30.6 | L | 1 | Grand Rivers, KY | 110 | 800 | 57 | 24 | 13 | Miter | 9,959.0 | 1964 | 118 | 9 | 300 | 300 |
| Cheatham Lock & Dam | 148.7 | L | 1 | Ashland City, TN | 110 | 798 | 26 | 14 | 12 | Miter | 801.0 | 1956 | 68 | 9 | 200 | 200 |
| Cordull Hull Lock & Dam | 313.5 | L | 1 | Carthage, TN | 84 | 400 | 59 | 14 | 13 | Miter | 1,138.0 | 1973 | 72 | 9 | 150 | 150 |
| Old Hickory Lock & Dam | 216.2 | L | 1 | Old Hickory, TN | 84 | 397 | 60 | 14 | 13 | Miter | 3,605.0 | 1957 | 97 | 9 | 150 | 150 |
| **Four Rivers Basins** | | | | | | | | | | | | | | | | |
| Oklawaha River [no name] | 66.9 | L | 1 | Ocklawaha, FL | 30 | 125 | 22 | 8 | 8 | Moveable | 50.0 | 1969 | 0 | 8 | 0 | 0 |
| **Freshwater Bayou, LA** | | | | | | | | | | | | | | | | |
| Freshwater Bayou Lock | 1.2 | L | 1 | Intracoastal City, LA | 84 | 590 | 4 | 16 | 16 | Sector | 401.0 | 1968 | 250 | 12 | 120 | 120 |
| **Gulf Intracoastal Waterway between Apalachee Bay, FL & Mexican Border** | | | | | | | | | | | | | | | | |
| Algiers Lock | 0 | L | 1 | Algiers, LA | 75 | 797 | 18 | 13 | 13 | Sector | NA | 1956 | 384 | 16 | 150 | 150 |
| Harvey Lock | 0 | L | 1 | Harvey, LA | 75 | 415 | 20 | 12 | 12 | Miter | NA | 1935 | 384 | 12 | 120 | 120 |
| Inner Harbor Nav Canal Lock | 7 | L | 1 | New Orleans, LA | 75 | 626 | 17 | 31 | 31 | Miter | NA | 1923 | 384 | 12 | 150 | 150 |
| Bayou Sorrel Lock | 37.5 | L | 1 | Plaquemine, LA | 56 | 790 | 21 | 14 | 14 | Sector | NA | 1952 | 64 | 12 | 120 | 120 |
| Port Allen Lock | 64.1 | L | 1 | Port Allen, LA | 84 | 1,188 | 45 | 13 | 14 | Miter | NA | 1961 | 64 | 12 | 120 | 120 |
| Bayou Boeuf Lock | 93.3 | L | 1 | Morgan City, LA | 75 | 1,148 | 11 | 13 | 13 | Sector | NA | 1956 | 384 | 16 | 150 | 150 |
| Leland Bowman Lock | 162.7 | L | 1 | Abbeville, LA | 110 | 1,190 | 5 | 11 | 11 | Sector | NA | 1934 | 384 | 16 | 200 | 200 |
| Calcasieu Lock | 238.5 | L | 1 | Lake Charles, LA | 75 | 1,194 | 4 | 13 | 13 | Sector | NA | 1950 | 384 | 16 | 200 | 200 |
| Brazos East Gate | 400.8 | F | 1 | Freeport, TX | 75 | 750 | 0 | 15 | 15 | Sector | 520.0 | 1943 | 3,700 | 12 | 125 | 125 |
| Brazos West Gate | 401.1 | F | 1 | Freeport, TX | 75 | 750 | 0 | 15 | 15 | Sector | 520.0 | 1944 | 3,700 | 12 | 125 | 125 |
| **Green & Barren Rivers, KY** | | | | | | | | | | | | | | | | |
| Green River Lock & Dam 1 | 9.1 | L | 1 | Spottsville, KY | 84 | 600 | 8 | 12 | 15 | Miter | 760.0 | 1956 | 54 | 9 | 150 | 150 |
| Green River lock Lock & Dam 2 | 63.1 | L | 1 | Calhoun, KY | 84 | 600 | 14 | 12 | 12 | Miter | 512.0 | 1956 | 45 | 9 | 150 | 150 |
| **Hudson River, NY** | | | | | | | | | | | | | | | | |
| Troy Lock & Dam | 153.8 | L | 1 | Troy, NY | 45 | 493 | 17 | 16 | 13 | Fixed | 1,495.0 | 1916 | 2 | 14 | 200 | 200 |
| **Illinois Waterway, IL** | | | | | | | | | | | | | | | | |
| Lagrange Lock & Dam | 80.2 | L | 1 | Beardstown, IL | 110 | 600 | 10 | 16 | 13 | Miter | 1,066.0 | 1939 | 78 | 9 | 300 | 300 |
| Peoria Lock & Dam | 157.7 | L | 1 | Creve Coeur, IL | 110 | 600 | 11 | 15 | 12 | Miter | 3,446.0 | 1938 | 73 | 9 | 300 | 300 |
| Starved Rock Lock & Dam | 231 | L | 1 | Utica, IL | 110 | 600 | 19 | 17 | 14 | Miter | 1,280.0 | 1933 | 14 | 9 | 300 | 300 |
| Marseilles Lock & Dam | 244.6 | L | 1 | Marseilles, IL | 110 | 600 | 24 | 19 | 14 | Miter | 778.5 | 1933 | 27 | 9 | 300 | 300 |
| Dresden Island Lock & Dam | 271.5 | L | 1 | Morris, IL | 110 | 600 | 22 | 17 | 12 | Miter | 1,615.5 | 1933 | 15 | 9 | 300 | 300 |
| Lockport Lock | 291.1 | L | 1 | Lockport, IL | 110 | 600 | 39 | 20 | 15 | Miter | 500.0 | 1933 | 35 | 9 | 300 | 300 |
| **Thomas J. O'Brien Lock & Dam–Calumet River** | | | | | | | | | | | | | | | | |
| Thomas J. O'Brien Lock & Dam | 326.5 | L | 1 | Chicago, IL | 110 | 1,000 | 4 | 18 | 18 | Sector | 256.75 | 1960 | 7 | 9 | 300 | 300 |
| **Brandon Road Lock &Dam–Illinois River** | | | | | | | | | | | | | | | | |
| Brandon Road Lock & Dam | 286 | L | 1 | Joliet, IL | 110 | 600 | 34 | 18 | 14 | Miter | 2,373.0 | 1933 | 5 | 9 | 160 | 160 |
| **Kanawha Lock & Dam, WV** | | | | | | | | | | | | | | | | |
| Winfield Locks & Dam Main 800 | 31.1 | L | 1 | Winfield, WV | 110 | 800 | 28 | 18 | 18 | Miter | 700.0 | 1936 | 37 | 9 | 300 | 300 |
| Winfield Locks & Dam Main 1 | 31.1 | L | 1 | Winfield, WV | 56 | 360 | 28 | 18 | 12 | Miter | 700.0 | 1,935 | 37 | 9 | 300 | 300 |
| Winfield Locks & Dam Main 2 | 31.1 | L | 1 | Winfield, WV | 56 | 360 | 28 | 18 | 12 | Miter | 700.0 | 1935 | 37 | 9 | 300 | 300 |
| Marmet Locks & Dam Main 1 | 67.7 | L | 1 | Marmet, WV | 56 | 360 | 24 | 18 | 12 | Miter | 557.0 | 1934 | 16 | 9 | 150 | 150 |
| Marmet Locks & Dam Main 2 | 67.7 | L | 1 | Marmet, WV | 56 | 360 | 24 | 18 | 12 | Miter | 557.0 | 1934 | 16 | 9 | 150 | 150 |
| London Locks & Dam Main 1 | 82.8 | L | 1 | London, WV | 56 | 360 | 24 | 18 | 12 | Miter | 557.0 | 1934 | 8 | 9 | 150 | 150 |
| London Locks & Dam Main 2 | 82.8 | L | 1 | London, WV | 56 | 360 | 24 | 18 | 12 | Miter | 557.0 | 1934 | 8 | 9 | 150 | 150 |
| **Kaskaskia River, IL** | | | | | | | | | | | | | | | | |
| Kaskaskia River Navigation Lock | 0.8 | L | 1 | Modoc, IL | 84 | 600 | 29 | 19 | 11 | Miter | 120.0 | 1973 | 35 | 9 | 225 | 225 |
| **Kentucky River, KY** | | | | | | | | | | | | | | | | |
| Lock & Dam 1 | 4 | L | 1 | Carrollton, KY | 38 | 145 | 8 | 8 | 15 | Miter | 424.0 | 1839 | 27 | 6 | 150 | 150 |
| Lock & Dam 2 | 31 | L | 1 | Lockport, KY | 38 | 145 | 14 | 8 | 6 | Fixed | 400.0 | 1839 | 11 | 6 | 150 | 150 |
| Lock & Dam 3 | 42 | L | 1 | Gest, KY | 38 | 145 | 13 | 9 | 6 | Miter | 465.0 | 1844 | 23 | 6 | 150 | 150 |
| Lock & Dam 4 | 65 | L | 1 | Frankfort, KY | 38 | 145 | 13 | 6 | 7 | Fixed | 534.0 | 1844 | 17 | 6 | 150 | 150 |
| Lock & Dam 5 | 82.2 | L | 2 | Tyrone, KY | 38 | 145 | 15 | 10 | 6 | Fixed | 556.0 | 1844 | 14 | 6 | 100 | 100 |
| Lock & Dam 6 | 96.2 | L | 2 | High Bridge, KY | 52 | 147 | 14 | 9 | 6 | Fixed | 413.0 | 1891 | 21 | 6 | 100 | 100 |
| Lock & Dam 7 | 117 | L | 2 | High Bridge, KY | 52 | 147 | 15 | 9 | 7 | Fixed | 350.0 | 1897 | 23 | 6 | 100 | 100 |
| Lock & Dam 8 | 139.9 | L | 2 | Camp Nelson, KY | 52 | 146 | 19 | 11 | 6 | Fixed | 257.0 | 1900 | 18 | 6 | 100 | 100 |
| Lock & Dam 9 | 157.5 | L | 2 | Valley View, KY | 52 | 148 | 17 | 11 | 7 | Fixed | 362.0 | 1907 | 19 | 6 | 100 | 100 |
| Lock & Dam 10 | 176.4 | L | 2 | Ford, KY | 52 | 148 | 17 | 9 | 6 | Fixed | 472.0 | 1907 | 25 | 6 | 100 | 100 |
| Lock & Dam 11 | 201 | L | 2 | Irvine, KY | 52 | 148 | 18 | 10 | 6 | Fixed | 208.0 | 1906 | 20 | 6 | 100 | 100 |

*(Continued)*



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**Table 7L.148 (Continued)**

| Project | River Mile | Type of Structure[a] | Status[b] | Community in Vicinity | Locks | | | | | | Dam | | | | Authorized Channel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Width of Chamber | Chamber Useable Length | Lift at Normal Pool Level | Depth of Miter Sill | | Type | Length (ft) | Year Opened | Length (miles) | Depth (ft) | Width (above) (ft) | Width (below) (ft) |
| | | | | | | | | Upper | Lower | | | | | | | |
| Lock & Dam 12 | 220.9 | L | 2 | Ravenna, KY | 52 | 148 | 17 | 10 | 6 | Fixed | 240.0 | 1910 | 19 | 6 | 100 | 100 |
| Lock & Dam 13 | 239.9 | L | 2 | Willow, KY | 52 | 148 | 18 | 10 | 6 | Fixed | 248.0 | 1915 | 9 | 6 | 100 | 100 |
| Lock & Dam 14 | 249 | L | 2 | Heidelberg, KY | 52 | 148 | 17 | 9 | 6 | Fixed | 248.0 | 1917 | 26 | 6 | 100 | 100 |
| **Lake Washington Ship Canal** | | | | | | | | | | | | | | | | |
| Hiram M. Chittenden Lock AUX —1 [Ballard Locks] | 0 | L | 1 | Seattle, WA | 28 | 123 | 26 | 16 | 16 | Miter | 235.0 | 1916 | 0 | 30 | 0 | 0 |
| Hiram M. Chittenden Lock [Ballard Locks] | 0 | L | 1 | Seattle, WA | 80 | 760 | 26 | 36 | 29 | Miter | 235.0 | 1916 | 8 | 30 | 100 | 150 |
| **McClellan-Kerr Arkansas River Navigation System, AR and OK** | | | | | | | | | | | | | | | | |
| Norrell Lock & Dam [Lock & Dam 1] | 10.3 | L | 1 | Arkansas Post, AR | 110 | 600 | 30 | 16 | 15 | Fixed | 277.0 | 1967 | 3 | 9 | 300 | 300 |
| Lock & Dam 2 | 13.3 | L | 1 | Arkansas Post, AR | 110 | 600 | 20 | 18 | 14 | Tainter | 1,120.0 | 1967 | 37 | 9 | 300 | 300 |
| Joe Hardin L & D [Lock & Dam 3] | 50.2 | L | 1 | Grady, AR | 110 | 600 | 20 | 18 | 14 | Tainter | 1,260.0 | 1968 | 16 | 9 | 250 | 250 |
| Emmett Sanders Lock & Dam [Lock & Dam 4] | 66 | L | 1 | Pine Bluff, AR | 110 | 600 | 14 | 18 | 14 | Tainter | 1,190.0 | 1968 | 20 | 9 | 250 | 250 |
| Lock & Dam 5 | 86.3 | L | 1 | Redfield, AR | 110 | 600 | 17 | 18 | 14 | Tainter | 1,050.0 | 1968 | 22 | 9 | 250 | 250 |
| David D. Terry Lock & Dam [Lock & Dam 6] | 108.1 | L | 1 | Little Rock, AR | 110 | 600 | 18 | 18 | 14 | Tainter | 1,190.0 | 1968 | 17 | 9 | 250 | 250 |
| Murray Lock & Dam [Lock & Dam 7] | 125.4 | L | 1 | Little Rock, AR | 110 | 600 | 18 | 18 | 14 | Tainter | 980.0 | 1969 | 31 | 9 | 250 | 250 |
| Toad Suck Ferry Lock & Dam [Lock & Dam 8] | 155.9 | L | 1 | Conway, AR | 110 | 600 | 16 | 18 | 14 | Tainter | 1,200.0 | 1969 | 21 | 9 | 250 | 250 |
| Arthur V. Ormond L & D [Lock & Dam 9] | 176.9 | L | 1 | Morrilton, AR | 110 | 600 | 19 | 18 | 14 | Tainter | 1,797.0 | 1969 | 29 | 9 | 250 | 250 |
| Dardanelle Lock & Dam [Lock & Dam 10] | 205.5 | L | 1 | Russellville, AR | 110 | 600 | 55 | 18 | 14 | Tainter | 1,210.0 | 1969 | 51 | 9 | 250 | 250 |
| Ozark Lock & Dam [Lock & Dam 12] | 256.8 | L | 1 | Ozark, AR | 110 | 600 | 34 | 18 | 15 | Tainter | 900.0 | 1969 | 36 | 9 | 250 | 250 |
| James W. Trimble Lock & Dam [Lock & Dam 13] | 292.8 | L | 1 | Fort Smith, AR | 110 | 600 | 20 | 18 | 14 | Tainter | 1,050.0 | 1969 | 27 | 9 | 250 | 250 |
| W.D. Mayo Lock & Dam [Lock & Dam 14] | 319.6 | L | 1 | Spiro, OK | 110 | 600 | 21 | 14 | 14 | Moveable | 840.0 | 1970 | 17 | 9 | 250 | 250 |
| Robert S. Kerr Lock & Dam & Res [Lock & Dam 15] | 336.2 | L | 1 | Salisaw, OK | 110 | 600 | 48 | 16 | 14 | Moveable | 1,090.0 | 1970 | 30 | 9 | 250 | 250 |
| Webbers Falls Lock & Dam [Lock & Dam 16] | 366.6 | L | 1 | Webber Falls, OK | 110 | 600 | 30 | 16 | 14 | Moveable | 720.0 | 1970 | 35 | 9 | 250 | 250 |
| Chouteau Lock & Dam [Lock & Dam 17] | 5 | L | 1 | Muskogee, OK | 110 | 600 | 21 | 15 | 14 | Moveable | 210.0 | 1970 | 20 | 9 | 150 | 150 |
| Newt Graham Lock & Dam [Lock & Dam 18] | 26 | L | 1 | Inola, OK | 110 | 600 | 21 | 15 | 14 | Moveable | 210.0 | 1970 | 23 | 9 | 150 | 150 |
| Montgomery Point Lock & Dam | 0.5 | L | 1 | Tichnor, AR | 110 | 600 | 20 | 18 | 15 | Miter | 300 | 2004 | 10 | 9 | 300 | 300 |
| **Mermentau River, LA** | | | | | | | | | | | | | | | | |
| Schooner Bayou Control Structure | 3.4 | C | 1 | Abbeville, LA | 75 | 525 | 0 | 0 | 0 | Sector | NA | | 11 | 6 | 60 | 60 |
| Catfish Point Control Structure | 25 | C | 1 | Creole, LA | 56 | 500 | 0 | 0 | 0 | Sector | NA | | 5 | 15 | 200 | 200 |
| **Mississippi River between Missouri River & Minneapolis, MN** | | | | | | | | | | | | | | | | |
| Chains Of of Rocks L/D 27 | 185.5 | L | 1 | Granite City, IL | 110 | 1,200 | 21 | 15 | 15 | Vertical | 3,000.0 | 1962 | 15 | 9 | 350 | 350 |
| Chains Of of Rocks L/D 27 AUX —1 | 185.5 | L | 1 | Granite City, IL | 110 | 600 | 21 | 15 | 15 | Miter | 3,000.0 | 1962 | 15 | 9 | 350 | 350 |
| Mel Price Lock & Dam [Locks No 26 Main) | 200.8 | L | 1 | East Alton, IL | 110 | 1,200 | 24 | 23 | 18 | Vertical | 990.0 | 1989 | 40 | 9 | 300 | 300 |
| Mel Price Lock & Dam [Locks No 26 AUX) | 200.8 | L | 1 | East Alton, IL | 110 | 600 | 24 | 42 | 18 | Miter | 990.0 | 1989 | 40 | 9 | 300 | 300 |
| Lock & Dam 25 | 241.4 | L | 1 | Winfield, MO | 110 | 600 | 15 | 19 | 12 | Miter | 1,140.0 | 1939 | 32 | 9 | 300 | 300 |
| Lock & Dam 24 | 273.4 | L | 1 | Clarksville, MO | 110 | 600 | 15 | 19 | 12 | Miter | 1,200.0 | 1940 | 27 | 9 | 300 | 300 |
| Lock & Dam 22 | 301.2 | L | 1 | Saverton, MO | 110 | 600 | 10 | 18 | 14 | Miter | 3,084.0 | 1938 | 24 | 9 | 300 | 300 |
| Lock & Dam 21 | 324.9 | L | 1 | Quincy, IL | 110 | 600 | 10 | 17 | 12 | Miter | 2,955.0 | 1938 | 18 | 9 | 300 | 300 |
| Lock & Dam 20 | 343.2 | L | 1 | Canton, MO | 110 | 600 | 10 | 15 | 12 | Miter | 2,144.0 | 1936 | 21 | 9 | 300 | 300 |
| Lock & Dam 19 | 364.3 | L | 1 | Keokuk, IA | 110 | 1,200 | 38 | 15 | 13 | Vertical | 8,809.0 | 1913 | 46 | 9 | 300 | 300 |
| Lock & Dam 18 | 410.5 | L | 1 | Gladstone, IL | 110 | 600 | 10 | 17 | 14 | Miter | 6,960.0 | 1937 | 27 | 9 | 300 | 300 |
| Lock & Dam 17 | 437.1 | L | 1 | New Boston, IL | 110 | 600 | 8 | 16 | 13 | Miter | 3,196.0 | 1939 | 20 | 9 | 300 | 300 |
| Lock & Dam 16 | 457.2 | L | 1 | Muscatine, IL | 110 | 600 | 9 | 17 | 12 | Miter | 3,555.0 | 1937 | 26 | 9 | 300 | 300 |
| Lock & Dam 15 | 482.9 | L | 1 | Rock Island, IL | 110 | 600 | 16 | 27 | 11 | Miter | 1,203.0 | 1934 | 10 | 9 | 300 | 300 |
| Lock & Dam 15 AUX —1 | 482.9 | L | 1 | Rock Island, IL | 110 | 360 | 16 | 27 | 11 | Miter | 1,203.0 | 1934 | 0 | 9 | 300 | 300 |
| Lock & Dam 14 | 493 | L | 1 | LeClaire, IA | 110 | 600 | 11 | 20 | 13 | Miter | 2,703.0 | 1922 | 29 | 9 | 300 | 300 |
| Lock & Dam 14 AUX —1 | 493 | L | 2 | LeClaire, IA | 80 | 320 | 11 | 21 | 14 | Miter | 2,703.0 | 1939 | 29 | 9 | 300 | 300 |
| Lock & Dam 13 | 522.5 | L | 1 | Clinton, IL | 110 | 600 | 11 | 19 | 13 | Miter | 1,407.0 | 1939 | 34 | 9 | 300 | 300 |
| Lock &Dam 12 | 556.7 | L | 1 | Bellevue, IA | 110 | 600 | 9 | 17 | 13 | Miter | 8,369.0 | 1938 | 26 | 9 | 300 | 300 |
| Lock & Dam 11 | 583 | L | 1 | Dubuque, IA | 110 | 600 | 12 | 19 | 13 | Miter | 4,784.0 | 1937 | 32 | 9 | 300 | 300 |
| Lock & Dam 10 | 615.1 | L | 2 | Guttenburg, IA | 110 | 600 | 8 | 15 | 12 | Miter | 763.0 | 1937 | 33 | 9 | 300 | 300 |
| Lock & Dam 9 | 647.9 | L | 2 | Lynxville, WI | 110 | 600 | 9 | 16 | 13 | Miter | 811.0 | 1937 | 31 | 9 | 300 | 300 |
| Lock & Dam 8 | 679.2 | L | 2 | Genoa, WI | 110 | 600 | 11 | 22 | 14 | Miter | 935.0 | 1937 | 23 | 9 | 300 | 300 |
| Lock & Dam 7 | 702.5 | L | 2 | Dresbach, MN | 110 | 600 | 8 | 18 | 12 | Miter | 940.0 | 1937 | 12 | 9 | 300 | 300 |

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| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lock & Dam 6 | 714.3 | L | 2 | Trempealeau, WI | 110 | 600 | 6 | 17 | 13 | Miter | 893.0 | 1936 | 14 | 9 | 300 | 300 |
| Lock & Dam 5A | 728.5 | L | 2 | Winona,MN, MN | 110 | 600 | 5 | 18 | 13 | Miter | 682.0 | 1936 | 10 | 9 | 300 | 300 |
| Lock & Dam 5 | 738.1 | L | 2 | Minneiska, MN | 110 | 600 | 9 | 18 | 12 | Miter | 1,619.0 | 1935 | 15 | 9 | 300 | 300 |
| Lock & Dam 4 | 752.8 | L | 2 | Alma, WI | 110 | 600 | 7 | 17 | 13 | Miter | 1,367.0 | 1935 | 44 | 9 | 300 | 300 |
| Lock & Dam 3 | 796.9 | L | 2 | Red Wing, MN | 110 | 600 | 8 | 17 | 14 | Miter | 365.0 | 1938 | 18 | 9 | 300 | 300 |
| Lock & Dam 2 | 815.2 | L | 2 | Hastings, MN | 110 | 500 | 12 | 22 | 13 | Miter | 822.0 | 1948 | 32 | 9 | 300 | 300 |
| Lock & Dam 1 Main Chamber 1 | 847.6 | L | 2 | Minn. St. Paul, MN | 56 | 400 | 38 | 13 | 8 | Miter | 574.0 | 1932 | 6 | 9 | 300 | 300 |
| | 847.6 | L | 2 | Minn. St. Paul, MN | 56 | 400 | 38 | 13 | 10 | Miter | 579.0 | 1917 | 6 | 9 | 300 | 300 |
| St. Anthony Falls Lower Lock & Dam | 853.3 | L | 2 | Minneapolis, MN | 56 | 400 | 25 | 14 | 10 | Miter | 188.0 | 1956 | 1 | 9 | 200 | 200 |
| St. Anthony Falls Upper Lock & Dam | 853.9 | L | 2 | Minneapolis, MN | 56 | 400 | 49 | 16 | 14 | Miter | NA | 1963 | 4 | 9 | 100 | 100 |
| **Monongahela River, PA and WV** | | | | | | | | | | | | | | | | |
| Lock & Dam 2 | 11.2 | L | 1 | Braddock, PA | 110 | 720 | 9 | 15 | 16 | Miter | 748.0 | 1951 | 13 | 9 | 300 | 300 |
| Lock & Dam 2 AUX | 11.2 | L | 1 | Braddock, PA | 56 | 360 | 9 | 15 | 16 | Miter | 748.0 | 1951 | 13 | 9 | 300 | 300 |
| Lock & Dam 3 | 23.8 | L | 1 | Elizabeth, PA | 56 | 720 | 8 | 11 | 11 | Miter | 670.0 | 1907 | 18 | 9 | 300 | 300 |
| Lock & Dam 3 AUX | 23.8 | L | 1 | Elizabeth, PA | 56 | 360 | 8 | 11 | 11 | Miter | 670.0 | 1907 | 18 | 9 | 300 | 300 |
| Lock & Dam 4 | 41.5 | L | 1 | Monessen, PA | 56 | 720 | 17 | 20 | 10 | Miter | 535.0 | 1932 | 20 | 9 | 300 | 300 |
| Lock & Dam 4 AUX | 41.5 | L | 1 | Monessen, PA | 56 | 360 | 17 | 20 | 10 | Miter | 535.0 | 1932 | 20 | 9 | 300 | 300 |
| Maxwell Lock & dam | 61.2 | L | 1 | Maxwell, PA | 84 | 720 | 20 | 20 | 14 | Miter | 460.0 | 1964 | 24 | 9 | 300 | 300 |
| Maxwell Lock & dam AUX | 61.2 | L | 1 | Maxwell, PA | 84 | 720 | 20 | 20 | 14 | Miter | 460.0 | 1964 | 24 | 9 | 300 | 300 |
| Grays Landing Lock & Dam | 82 | L | 1 | Grays Landing, PA | 84 | 720 | 15 | 27 | 18 | Miter | 576.0 | 1995 | 21 | 9 | 300 | 300 |
| L & D 8 | 90.8 | L | 1 | Point Marion, PA | 84 | 720 | 19 | 16 | 35 | Miter | 682.0 | 1925 | 11 | 9 | 300 | 300 |
| Morgantown Lock & Dam | 102 | L | 1 | Morgantown, WV | 84 | 600 | 17 | 17 | 14 | Miter | 410.0 | 1950 | 6 | 9 | 300 | 300 |
| Hildebrand Lock & Dam | 108 | L | 1 | Morgantown, WV | 84 | 600 | 21 | 14 | 15 | Miter | 530.0 | 1959 | 7 | 9 | 300 | 300 |
| Opekiska Lock & Dam | 115.4 | L | 1 | Opekiska, WV | 84 | 600 | 22 | 18 | 14 | Miter | 366.0 | 1964 | 7 | 9 | 300 | 300 |
| **Ohio River** | | | | | | | | | | | | | | | | |
| Emsworth Lock & Dam | 6.2 | L | 1 | Emsworth, PA | 110 | 600 | 18 | 17 | 13 | Miter | 1,717.0 | 1921 | 6 | 9 | 300 | 300 |
| Emsworth Lock & Dam AUX | 6.2 | L | 1 | Emsworth, PA | 56 | 360 | 18 | 16 | 13 | Miter | 1,717.0 | 1921 | 6 | 9 | 300 | 300 |
| Dashields Lock & Dam | 13.3 | L | 1 | Glenwillard, PA | 110 | 600 | 10 | 13 | 18 | Miter | 1,585.0 | 1929 | 7 | 9 | 300 | 300 |
| Dashields Lock & Dam AUX | 13.3 | L | 1 | Glenwillard, PA | 56 | 360 | 10 | 13 | 18 | Miter | 1,585.0 | 1929 | 7 | 9 | 300 | 300 |
| Montgomery Lock & Dam | 31.7 | L | 1 | Monaca, PA | 110 | 600 | 18 | 16 | 15 | Miter | 1,379.0 | 1936 | 18 | 9 | 300 | 300 |
| Montgomery Lock & Dam AUX | 31.7 | L | 1 | Monaca, PA | 56 | 360 | 18 | 16 | 15 | Miter | 1,379.0 | 1936 | 18 | 9 | 300 | 300 |
| New Cumberland Lock & Dam | 54.4 | L | 1 | Stratton, OH | 110 | 1200 | 21 | 17 | 15 | Miter | 1,315.0 | 1961 | 23 | 9 | 300 | 300 |
| New Cumberland Lock & Dam AUX | 54.4 | L | 1 | Stratton, OH | 110 | 600 | 21 | 17 | 15 | Miter | 1,315.0 | 1961 | 23 | 9 | 300 | 300 |
| Pike Island Lock & Dam | 84.2 | L | 1 | Warwood, WV | 110 | 1200 | 18 | 17 | 18 | Miter | 1,315.0 | 1965 | 30 | 9 | 300 | 300 |
| Pike Island Lock & Dam | 84.2 | L | 1 | Warwood, WV | 110 | 600 | 18 | 17 | 18 | Miter | 1,315.0 | 1965 | 30 | 9 | 300 | 300 |
| Hannibal Locks & Dam | 126.4 | L | 1 | Hannibal, OH | 110 | 1200 | 21 | 38 | 17 | Miter | 1,098.0 | 1972 | 36 | 9 | 300 | 300 |
| Hannibal Locks & Dam AUX | 126.4 | L | 1 | Hannibal, OH | 110 | 600 | 21 | 38 | 17 | Miter | 1,098.0 | 1972 | 36 | 9 | 300 | 300 |
| Willow Island Locks & Dam | 161.7 | L | 1 | Newport, OH | 110 | 1200 | 20 | 35 | 15 | Miter | 1,128.0 | 1973 | 35 | 9 | 300 | 300 |
| Willow Island Locks & Dam AUX | 161.7 | L | 1 | Newport, OH | 110 | 600 | 20 | 35 | 15 | Miter | 1,128.0 | 1973 | 35 | 9 | 300 | 300 |
| Belleville Locks & Dam | 203.9 | L | 1 | Reedsville, OH | 110 | 1200 | 22 | 37 | 15 | Miter | 1,206.0 | 1969 | 36 | 9 | 300 | 300 |
| Belleville Locks & Dam AUX | 203.9 | L | 1 | Reedsville, OH | 110 | 600 | 22 | 37 | 15 | Miter | 1,206.0 | 1969 | 36 | 9 | 300 | 300 |
| Racine Locks & Dam | 237.5 | L | 1 | Letart, WV | 110 | 1200 | 22 | 37 | 15 | Miter | 1,173.0 | 1970 | 34 | 9 | 300 | 300 |
| Racine Locks & Dam AUX | 237.5 | L | 1 | Letart, WV | 110 | 600 | 22 | 37 | 15 | Miter | 1,173.0 | 1970 | 34 | 9 | 300 | 300 |
| Robert C. Byrd | 279.2 | L | 1 | Hogsett, WV | 110 | 1200 | 23 | 41 | 18 | Miter | 1,132.0 | 1937 | 42 | 9 | 300 | 300 |
| Robert C. Byrd AUX | 279.2 | L | 1 | Hogsett, WV | 110 | 600 | 23 | 41 | 18 | Miter | 1,132.0 | 1937 | 42 | 9 | 300 | 300 |
| Greenup Locks & Dam | 341 | L | 1 | Greenup, KY | 110 | 1200 | 30 | 45 | 15 | Miter | 1,287.0 | 1962 | 62 | 9 | 300 | 300 |
| Greenup Locks & Dam AUX | 341 | L | 1 | Greenup, KY | 110 | 600 | 30 | 45 | 15 | Miter | 1,287.0 | 1962 | 62 | 9 | 300 | 300 |
| Capt Anthony Meldahl Lock & Dam | 436.2 | L | 1 | Chilo, OH | 110 | 1200 | 30 | 45 | 15 | Miter | 1,756.0 | 1962 | 95 | 9 | 300 | 300 |
| Capt Anthony Meldahl Lock & Dam AUX | 436.2 | L | 1 | Chilo, OH | 110 | 600 | 30 | 45 | 15 | Miter | 1,756.0 | 1962 | 95 | 9 | 300 | 300 |
| Markland Locks & Dam | 531.5 | L | 1 | Warsaw, KY | 110 | 1200 | 35 | 50 | 15 | Miter | 1,395.0 | 1963 | 95 | 9 | 300 | 300 |
| Markland Locks & Dam AUX | 531.5 | L | 1 | Markland, KY | 110 | 600 | 35 | 50 | 15 | Miter | 1,395.0 | 1963 | 75 | 9 | 300 | 300 |
| Mcalpine Locks & Dam | 606.8 | L | 1 | Louisville, KY | 110 | 1200 | 37 | 49 | 12 | Miter | 8,725.0 | 1963 | 75 | 9 | 300 | 300 |
| Mcalpine Locks & Dam AUX | 606.8 | L | 1 | Louisville, KY | 110 | 600 | 37 | 19 | 11 | Miter | 8,725.0 | 1963 | 75 | 9 | 300 | 300 |
| Cannelton Lock & Dam | 720.7 | L | 1 | Cannelton, IN | 110 | 1200 | 25 | 40 | 15 | Miter | 2,054.0 | 1971 | 114 | 9 | 300 | 300 |
| Cannelton Lock & Dam AUX | 720.7 | L | 1 | Cannelton, IN | 110 | 600 | 25 | 40 | 15 | Miter | 2,054.0 | 1971 | 114 | 9 | 300 | 300 |
| Newburgh Lock & Dam | 776.1 | L | 1 | Newburgh, IN | 110 | 1200 | 16 | 31 | 15 | Miter | 2,275.6 | 1975 | 55 | 9 | 300 | 300 |
| Newburgh Lock & Dam AUX | 776.1 | L | 1 | Newburgh, IN | 110 | 600 | 16 | 31 | 15 | Miter | 2,275.6 | 1975 | 55 | 9 | 300 | 300 |
| John T. Myers Lock & Dam | 846 | L | 1 | Mount Vernon, IN | 110 | 1200 | 18 | 34 | 16 | Miter | 3,504.0 | 1975 | 70 | 9 | 300 | 300 |
| John T. Myers Lock & Dam AUX | 846 | L | 1 | Mount Vernon, IN | 110 | 600 | 18 | 34 | 16 | Miter | 3,504.0 | 1975 | 70 | 9 | 300 | 300 |
| Smithland Lock & Dam | 918.5 | L | 1 | Hamletsburg, IL | 110 | 1200 | 22 | 34 | 12 | Miter | 2,962.0 | 1980 | 73 | 9 | 300 | 300 |
| Smithland Lock & Dam AUX | 918.5 | L | 1 | Hamletsburg, IL | 110 | 1200 | 22 | 34 | 12 | Miter | 2,962.0 | 1980 | 73 | 9 | 300 | 300 |

*(Continued)*



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**Table 7L.148 (Continued)**

| Project | River Mile | Type of Structure[a] | Status[b] | Community in Vicinity | Locks | | | | | | Dam | | | | Authorized Channel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Width of Chamber | Chamber Useable Length | Lift at Normal Pool Level | Depth of Miter Sill | | Type | Length (ft) | Year Opened | Length (miles) | Depth (ft) | Width (above) (ft) | Width (below) (ft) |
| | | | | | | | | Upper | Lower | | | | | | | |
| Lock & Dam 52 | 938.9 | L | 1 | Brookport, IL | 110 | 1200 | 12 | 15 | 11 | Miter | 2,998.0 | 1928 | 20 | 9 | 300 | 300 |
| Lock & Dam 52 AUX | 938.9 | L | 1 | Brookport, IL | 110 | 600 | 12 | 15 | 11 | Miter | 2,978.0 | 1928 | 20 | 9 | 300 | 300 |
| Lock & Dam 53 | 962.6 | L | 1 | Mound City, IL | 110 | 1200 | 12 | 15 | 10 | Miter | 3,560.0 | 1929 | 24 | 9 | 300 | 300 |
| Lock &Dam 53 AUX | 962.6 | L | 1 | Mound City, IL | 110 | 600 | 12 | 15 | 10 | Miter | 3,560.0 | 1929 | 24 | 9 | 300 | 300 |
| **Okeechobee Waterway, FL** | | | | | | | | | | | | | | | | |
| S-78 Waterway (Ortona Lock & Dam) | 93.6 | L | 1 | LaBelle, FL | 50 | 225 | 11 | 12 | 15 | Sector | 104.0 | 1937 | 16 | 8 | 90 | 90 |
| W.P.Franklin Lock/Cntl Strct [Olga Lock] | 122 | L | 1 | Fort Myers, FL | 56 | 400 | 3 | 13 | 13 | Sector | 1,150.0 | 1965 | 8 | 8 | 90 | 90 |
| S-308-B | 38.5 | L | 1 | Port Mayaca, FL | 56 | 400 | 2 | 17 | 17 | Sector | 116.0 | 1977 | 5 | 8 | 100 | 100 |
| **St. Lucie Lock & Dam** | | | | | | | | | | | | | | | | |
| St. Lucie Lock & Dam | 15.3 | L | 1 | Stuart, FL | 50 | 225 | 13 | 15 | 13 | Sector | 170.0 | 1944 | 15 | 8 | 80 | 80 |
| **Moore Haven Lock** | | | | | | | | | | | | | | | | |
| Moore Haven Lock | 78 | L | 1 | Moore Haven, FL | 50 | 250 | 2 | 10 | 11 | Sector | 89.8 | 1953 | 16 | 8 | 90 | 90 |
| **Old River, LA (MR&T)** | | | | | | | | | | | | | | | | |
| Old River Lock | 1 | L | 1 | Simmesport, LA | 75 | 1190 | 35 | 11 | 11 | Miter | 1,100.0 | 1963 | 7 | 12 | 120 | 120 |
| **Ouachita & Black Rivers Below Camden, AR & LA** | | | | | | | | | | | | | | | | |
| Columbia Lock & Dam | 117.2 | L | 1 | Columbia, LA | 84 | 600 | 18 | 18 | 18 | Miter | 400.0 | 1972 | 109 | 9 | 100 | 100 |
| Felsenthal Lock & Dam [Lock & Dam No 3] | 226.8 | L | 1 | Felsenthal, AR | 84 | 600 | 18 | 18 | 13 | Miter | 350.0 | 1984 | 55 | 9 | 100 | 100 |
| H. K. Thatcher Lock & Dam [Lock & Dam No 4] | 281.7 | L | 1 | Calion, AR | 84 | 600 | 12 | 18 | 13 | Miter | 350.0 | 1984 | 50 | 7 | 100 | 100 |
| Jonesville Lock & Dam | 25 | L | 1 | Jonesville, LA | 84 | 600 | 30 | 18 | 15 | Miter | 450.0 | 1972 | 92 | 9 | 100 | 100 |
| **Pearl River Lateral Canal** | | | | | | | | | | | | | | | | |
| Lock 1 | 29.7 | L | 1 | Pearl River, LA | 65 | 274 | 27 | 10 | 10 | Miter | NA | 1951 | 11 | 7 | 80 | 80 |
| Lock 2 | 40.8 | L | 1 | Bush, LA | 65 | 274 | 15 | 10 | 10 | Miter | NA | 1951 | 3 | 7 | 80 | 80 |
| Lock 3 | 43.9 | L | 1 | Sun, LA | 65 | 274 | 11 | 10 | 10 | Miter | NA | 1951 | 5 | 7 | 80 | 80 |
| **Red River WW-Mississippi R to Shreveport, LA** | | | | | | | | | | | | | | | | |
| Lindy Claiborne Boggs [Red River Lock & Dam No. 1] | 44 | L | 1 | Larto, LA | 84 | 685 | 36 | 22 | 13 | Miter | 630.0 | 1984 | 30 | 9 | 200 | 200 |
| John H.Overton [Red River Lock & Dam No. 2] | 74 | L | 1 | Ruby, LA | 84 | 685 | 24 | 23 | 23 | Miter | 348.0 | 1986 | 42 | 9 | 200 | 200 |
| Red River Lock & Dam No. 3 | 116.4 | L | 1 | Colfax, LA | 84 | 685 | 31 | 25 | 18 | Miter | 432.0 | 1992 | 40 | 9 | 100 | 100 |
| Red River Lock & Dam No. 4 | 169 | L | 1 | Coushatta, LA | 84 | 685 | 25 | 25 | 18 | Miter | 690.0 | 1994 | 31 | 9 | 200 | 200 |
| Joe D. Waggonner Lock & Dam [5] | 200 | L | 1 | Caspiana, LA | 84 | 685 | 25 | 22 | 23 | Miter | 663.0 | 1994 | 28 | 9 | 200 | 200 |
| **Savannah River, GA** | | | | | | | | | | | | | | | | |
| New Savannah Bluff Lock & Dam | 187.2 | L | 1 | Augusta, GA | 56 | 360 | 15 | 14 | 12 | Miter | 360.0 | 1937 | 16 | 9 | 90 | 90 |
| **Snake River, WA** | | | | | | | | | | | | | | | | |
| Ice Harbor Lock & Dam | 9.7 | L | 1 | Pasco, WA | 86 | 650 | 103 | 15 | 14 | Vertical | 2,790.0 | 1962 | 32 | 14 | 250 | 250 |
| Lower Monumental Lock & Dam | 41.6 | L | 1 | Kahlotus, WA | 86 | 650 | 103 | 15 | 15 | Vertical | 3,800.0 | 1969 | 29 | 14 | 250 | 250 |
| Little Goose Lock & Dam | 70.3 | L | 1 | Starbuck, WA | 86 | 650 | 101 | 15 | 15 | Miter | 2,655.0 | 1970 | 37 | 14 | 250 | 250 |
| Lower Granite Lock & Dam | 107.5 | L | 1 | Pomeroy, WA | 86 | 650 | 105 | 15 | 15 | Miter | 3,200.0 | 1975 | 38 | 14 | 250 | 250 |
| **St. Marys River, MI** | | | | | | | | | | | | | | | | |
| Macarthur Lock | 47 | L | 1 | Sault Ste. Marie, MI | 80 | 780 | 22 | 31 | 31 | Leaf | 1,300.0 | 1914 | 0 | 27 | 300 | 300 |
| Davis Lock | 47 | L | 2 | Sault Ste. Marie, MI | 80 | 1320 | 22 | 24 | 23 | Leaf | 1,300.0 | 1914 | 0 | 0 | 300 | 300 |
| New Poe Lock | 47 | L | 1 | Sault Ste. Marie, MI | 110 | 1200 | 22 | 32 | 32 | Leaf | 1,300.0 | 1914 | 0 | 0 | 300 | 300 |
| **Tennessee River, TN, AL, & KY** | | | | | | | | | | | | | | | | |
| Kentucky Lock | 22.4 | L | 1 | Grand Rivers, KY | 110 | 600 | 57 | 24 | 13 | Miter | 7,976.0 | 1944 | 184 | 9 | 300 | 300 |
| Pickwick Landing Lock | 206.7 | L | 1 | Pickwick Dam, TN | 110 | 1000 | 55 | 19 | 17 | Miter | 7,385.0 | 1984 | 53 | 9 | 300 | 300 |
| Pickwick Landing Lock AUX | 206.7 | L | 1 | Pickwick Dam, TN | 110 | 600 | 55 | 16 | 17 | Miter | 7,385.0 | 1937 | 53 | 9 | 300 | 300 |
| Wilson Lock | 259.4 | L | 1 | Florence, AL | 110 | 600 | 94 | 11 | 11 | Miter | 3,728.0 | 1959 | 16 | 9 | 300 | 300 |
| Wilson Lock | 259.4 | L | 1 | Florence, AL | 60 | 300 | 49 | 13 | 13 | Miter | 3,728.0 | 1927 | 16 | 9 | 300 | 300 |
| | 259.4 | L | 1 | Florence, AL | 60 | 300 | 45 | 11 | 11 | Miter | 3,728.0 | 1927 | 16 | 9 | 300 | 300 |
| Gen Jos Wheeler Lock | 274.9 | L | 1 | Rogersville, AL | 110 | 600 | 48 | 15 | 13 | Miter | 5,738.0 | 1933 | 74 | 9 | 300 | 300 |
| Gen Jos Wheeler Lock AUX | 274.9 | L | 1 | Rogersville, AL | 60 | 400 | 48 | 15 | 13 | Miter | 5,738.0 | 1933 | 74 | 9 | 300 | 300 |
| Guntersville Lock [Lock 5, CH 1, Main Channel] | 349 | L | 1 | Guntersville, AL | 110 | 600 | 39 | 17 | 18 | Miter | 3,837.0 | 1939 | 76 | 9 | 300 | 300 |
| Guntersville Lock [Lock 5, CH 1, AUX] | 349 | L | 1 | Guntersville, AL | 60 | 360 | 39 | 17 | 18 | Miter | 3,837.0 | 1939 | 76 | 9 | 300 | 300 |
| Nickajac Lock | 424.7 | L | 1 | Jasper, TN | 110 | 600 | 39 | 13 | 11 | Miter | 3,763.0 | 1967 | 46 | 9 | 300 | 300 |
| Chickamauga Lock | 471 | L | 1 | Chattanooga, TN | 60 | 360 | 49 | 10 | 14 | Miter | 5,654.0 | 1940 | 59 | 9 | 300 | 300 |
| Watts Bar Lock | 529.9 | L | 1 | Breendenton, TN | 60 | 360 | 58 | 12 | 12 | Miter | 2,646.0 | 1942 | 72 | 9 | 300 | 300 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fort Loudon Lock | 602.3 | L | 1 | Lenoir City, TN | 60 | 360 | 72 | 12 | 12 | Miter | 3,687.0 | 1943 | 50 | 9 | 300 | 300 |
| Melton Hill Lock & Dam (Clinch River) | 23.1 | L | 1 | Kingston, TN | 75 | 400 | 58 | 13 | 13 | Miter | 1,072.0 | 1963 | 38 | 9 | 300 | 300 |
| **Tennessee-Tombigbee Waterway AL, MS** | | | | | | | | | | | | | | | | |
| Howell Heflin Lock & Dam [Gainesville Lock & Dam] | 266.1 | L | 1 | Gainesville, AL | 110 | 600 | 36 | 15 | 15 | Moveable | 817.0 | 1978 | 49 | 9 | 300 | 300 |
| Tom Bevill Lock & Dam [Aliceville Lock & Dam] | 306.8 | L | 1 | Aliceville, AL | 110 | 600 | 27 | 15 | 15 | Moveable | 647.0 | 1979 | 41 | 9 | 300 | 300 |
| John C. Stennis Lock & Dam [Columbus Lock & Dam] | 334.7 | L | 1 | Columbus, MS | 110 | 600 | 27 | 15 | 15 | Moveable | 573.0 | 1981 | 28 | 9 | 300 | 300 |
| Aberdeen Lock & Dam | 357.5 | L | 1 | Aberdeen, MS | 110 | 600 | 27 | 15 | 15 | Moveable | 641.0 | 1984 | 23 | 9 | 300 | 300 |
| Amory Lock [Lock A] | 371.1 | L | 1 | Amory, MS | 110 | 600 | 30 | 15 | 15 | Moveable | 284.0 | 1985 | 14 | 9 | 300 | 300 |
| Glover Wilkins Lock [Lock B] | 376.3 | L | 1 | Smithville, AL | 110 | 600 | 25 | 18 | 18 | Moveable | 779.0 | 1985 | 15 | 9 | 300 | 300 |
| Fulton Lock [Lock C] | 391 | L | 1 | Fulton, MS | 110 | 600 | 25 | 18 | 18 | Moveable | 396.0 | 1985 | 7 | 9 | 300 | 300 |
| John Rankin Lock [Lock D] | 398.4 | L | 1 | Fulton, MS | 110 | 600 | 30 | 18 | 18 | Moveable | 282.0 | 1985 | 8 | 9 | 300 | 300 |
| G.V. “Sonny” Montgomery Lock [Lock E] | 406.7 | L | 1 | Belmont, MS | 110 | 600 | 30 | 18 | 18 | Moveable | 449.0 | 1985 | 5 | 9 | 300 | 300 |
| Jamie Whitten Lock & Dam [Bay Springs Lock & Dam] | 411.9 | L | 1 | Tupelo, MS | 110 | 600 | 84 | 18 | 18 | Moveable | 2,750.0 | 1985 | 65 | 9 | 300 | 300 |
| **Willamette River at Willamette Falls** | | | | | | | | | | | | | | | | |
| 2 | 26 | L | 1 | West Linn, OR | 40 | 198 | 10 | 6 | 8 | Leaf | NA | 1872 | 0 | 6 | 150 | 150 |
| 3 | 26 | L | 1 | West Linn, OR | 40 | 198 | 10 | 6 | 8 | Leaf | NA | 1872 | 0 | 6 | 150 | 150 |
| 4 | 26 | L | 1 | West Linn, OR | 40 | 198 | 10 | 6 | 8 | Leaf | NA | 1872 | 0 | 6 | 150 | 150 |
| Willamette River At at Willamette Falls | 26 | L | 1 | West Linn, OR | 40 | 198 | 20 | 6 | 8 | Leaf | NA | 1872 | 0 | 6 | 150 | 150 |
| Willamette Falls Guard Lock | 26 | L | 1 | West Linn, OR | 40 | 198 | 10 | 6 | 8 | Leaf | NA | 1872 | 24 | 6 | 150 | 150 |

[a] L, Lock & Dam; F-Flood Gate; B-Barrier; C-Control Structure.
[b] 1, Operational; 2, Seasonal; 3, Operational Weekend/Summer.

*Source*: From USACE, Navigation Data Center, U.S. Waterway Data Lock Characteristics, www.iwr.usace.army.mil.



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**Table 7L.149 Lock Characteristics Operational Statistics—1999**

| River/ Lock | Chamber | River Mile | Year Open | Average Processing Time[a] | Total Tonnage | Average Tow Size | | Percent Chamber Available | Lock Closures | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Barges/ Tow | Tons/ Tow | | Total Number | Avg Time[b] |
| **Alabama** | | | | | | | | | | |
| Claiborne | Main | 117.5 | 1969 | 23 | 236,895 | 4 | 2,096 | 100.00 | 0 | 0.00 |
| **Albemarle & Chesapeake Canal** | | | | | | | | | | |
| Great Bridge | Main | 11.5 | 1932 | 18 | 545,630 | 1 | 610 | 99.72 | 8 | 3.05 |
| **Allegheny** | | | | | | | | | | |
| 2 | Main | 6.7 | 1934 | 30 | 2,611,580 | 3 | 1,687 | 93.47 | 9 | 63.53 |
| 3 | Main | 14.5 | 1934 | 32 | 2,567,580 | 3 | 1,691 | 97.63 | 2 | 103.93 |
| 4 | Main | 24.2 | 1927 | 28 | 1,612,797 | 2 | 1,122 | 99.76 | 9 | 2.35 |
| 5 | Main | 30.4 | 1927 | 24 | 766,237 | 4 | 1,593 | 94.25 | 4 | 125.85 |
| 6 | Main | 36.3 | 1928 | 20 | 161,199 | 2 | 844 | 87.77 | 3 | 357.13 |
| 7 | Main | 45.7 | 1930 | 19 | 133,662 | 2 | 941 | 70.99 | 6 | 423.52 |
| 8 | Main | 52.6 | 1931 | 22 | 673,120 | 1 | 784 | 68.80 | 5 | 546.67 |
| 9 | Main | 62.2 | 1938 | 15 | 0 | 0 | 0 | 48.22 | 7 | 647.97 |
| **Apalachicola** | | | | | | | | | | |
| Jim Woodruff | Main | 106.3 | 1954 | 29 | 337,305 | 2 | 799 | 100.00 | 0 | 0.00 |
| **Arkansas** | | | | | | | | | | |
| Norrell | Main | 10.3 | 1967 | 37 | 8,797,103 | 6 | 5,215 | 99.63 | 13 | 2.47 |
| 2 | Main | 13.3 | 1967 | 44 | 8,826,997 | 6 | 5,239 | 98.59 | 188 | 0.67 |
| Joe Hardin | Main | 50.2 | 1968 | 45 | 8,048,954 | 7 | 6,211 | 99.95 | 1 | 4.33 |
| Emmett Sanders | Main | 66.0 | 1968 | 43 | 8,043,052 | 7 | 6,274 | 100.00 | 0 | 0.00 |
| 5 | Main | 86.3 | 1968 | 40 | 7,431,516 | 7 | 6,219 | 100.00 | 0 | 0.00 |
| David D. Terry | Main | 108.1 | 1968 | 39 | 7,387,876 | 7 | 6,224 | 99.99 | 1 | 0.58 |
| Murray | Main | 125.4 | 1969 | 41 | 6,490,453 | 7 | 6,193 | 99.75 | 14 | 1.53 |
| Toad Suck Ferry | Main | 155.9 | 1969 | 51 | 6,364,044 | 7 | 6,137 | 100.00 | 0 | 0.00 |
| Arthur V. Ormond | Main | 176.9 | 1969 | 53 | 5,973,962 | 7 | 6,322 | 99.70 | 9 | 2.93 |
| Dardanelle | Main | 205.5 | 1969 | 50 | 5,993,626 | 7 | 6,336 | 99.94 | 2 | 2.72 |
| Ozark—Jeta Taylor | Main | 256.8 | 1969 | 46 | 4,361,324 | 6 | 6,500 | 99.95 | 1 | 4.00 |
| James W. Trimble | Main | 292.8 | 1969 | 38 | 4,608,165 | 3 | 3,278 | 99.94 | 4 | 1.22 |
| W.D. Mayo | Main | 319.6 | 1970 | 57 | 4,132,431 | 5 | 6,477 | 100.00 | 0 | 0.00 |
| Robert S. Kerr | Main | 336.2 | 1970 | 53 | 4,155,658 | 5 | 6,544 | 100.00 | 0 | 0.00 |
| Webbers Falls | Main | 366.6 | 1970 | 54 | 4,007,128 | 5 | 6,232 | 100.00 | 0 | 0.00 |
| **Atchafalaya** | | | | | | | | | | |
| Berwick | Main | 1.5 | 1950 | 10 | 169,881 | 1 | 504 | 99.96 | 1 | 3.65 |
| **Black** | | | | | | | | | | |
| Jonesville | Main | 25.0 | 1972 | 30 | 1,573,714 | 2 | 2,377 | 100.00 | 0 | 0.00 |
| **Black Rock Channel** | | | | | | | | | | |
| Black Rock | Main | 4.0 | 1914 | 14 | 285,595 | 1 | 4,327 | 39.50 | 251 | 21.12 |
| **Black Warrior** | | | | | | | | | | |
| Armistead I. Seldon | Main | 262.0 | 1957 | 51 | 9,458,220 | 5 | 5,753 | 100.00 | 0 | 0.00 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Calcasieu River** | | | | | | | | | | |
| Calcasieu Barrier | Cntrl | 38.9 | 1968 | 3 | 627,857 | 2 | 1,618 | 100.00 | 0 | 0.00 |
| **Caloosahatchee** | | | | | | | | | | |
| Moore Haven | Main | 78.0 | 1953 | 15 | 21,326 | 1 | 117 | 64.70 | 384 | 8.05 |
| W. P. Franklin | Main | 122.0 | 1965 | 15 | 14,285 | 1 | 121 | 65.71 | 367 | 8.18 |
| **Canaveral Barge Canal** | | | | | | | | | | |
| Canaveral | Main | 3.0 | 1965 | 14 | 873,290 | 1 | 1,078 | 66.99 | 391 | 7.40 |
| **Cape Fear** | | | | | | | | | | |
| 1 | Main | 39.0 | 1915 | 20 | 0 | 0 | 0 | 100.00 | 0 | 0.00 |
| 2 | Main | 71.0 | 1917 | 19 | 0 | 0 | 0 | 85.96 | 2 | 614.98 |
| William O. Huske | Main | 95.0 | 1935 | 20 | 0 | 0 | 0 | 85.48 | 3 | 423.98 |
| **Chicago Harbor Channel** | | | | | | | | | | |
| Chicago | Main | 327.2 | 1939 | 17 | 315,530 | 1 | 1,005 | 75.31 | 19 | 113.85 |
| **Columbia** | | | | | | | | | | |
| Bonneville | Main | 145.3 | 1993 | 37 | 9,678,824 | 3 | 4,228 | 97.77 | 8 | 24.38 |
| The Dalles | Main | 191.7 | 1957 | 31 | 9,271,751 | 3 | 4,259 | 97.93 | 3 | 60.52 |
| John Day | Main | 216.5 | 1968 | 39 | 8,600,616 | 3 | 4,379 | 97.85 | 3 | 62.67 |
| Mcnary | Main | 292.0 | 1953 | 26 | 7,604,466 | 3 | 4,282 | 96.95 | 4 | 66.70 |
| **Cumberland** | | | | | | | | | | |
| Barkley | Main | 30.6 | 1964 | 56 | 9,072,278 | 8 | 5,305 | 99.07 | 33 | 2.47 |
| Cheatham | Main | 148.7 | 1952 | 61 | 9,542,172 | 8 | 6,101 | 95.94 | 112 | 3.17 |
| Old Hickory | Main | 216.2 | 1954 | 55 | 3,933,051 | 5 | 4,733 | 94.45 | 27 | 18.00 |
| **Dismal Swamp Canal** | | | | | | | | | | |
| Deep Creek | Main | 10.6 | 1940 | 20 | 300 | 0 | 300 | 78.31 | 5 | 379.95 |
| South Mills | Main | 33.2 | 1941 | 23 | 0 | 0 | 0 | 80.60 | 6 | 283.18 |
| **Freshwater Bayou** | | | | | | | | | | |
| Freshwater Bayou | Main | 1.2 | 1968 | 26 | 4,482,515 | 38 | 8,379 | 100.00 | 0 | 0.00 |
| **GIWW** | | | | | | | | | | |
| Harvey | Main | 0.0 | 1935 | 35 | 4,215,364 | 2 | 880 | 98.98 | 32 | 2.78 |
| Inner Harbor Nvg Chnl | Main | 5.6 | 1923 | 46 | 19,416,663 | 3 | 2,143 | 90.23 | 479 | 1.78 |
| Bayou Boeuf | Main | 93.3 | 1954 | 38 | 22,193,235 | 2 | 1,689 | 98.53 | 23 | 5.62 |
| Leland Bowman | Main | 162.7 | 1985 | 30 | 40,563,247 | 3 | 2,895 | 95.65 | 40 | 9.53 |
| Calcasieu | Main | 238.5 | 1950 | 36 | 39,525,354 | 3 | 2,948 | 96.07 | 59 | 5.83 |
| **Giww Algiers Canal** | | | | | | | | | | |
| Algiers | Main | 0.0 | 1956 | 48 | 19,222,359 | 3 | 2,878 | 86.51 | 132 | 8.95 |
| **Giww Port Allen–Morgan Cty Alt. Rte** | | | | | | | | | | |
| Bayou Sorrel | Main | 37.5 | 1952 | 55 | 23,157,835 | 3 | 3,742 | 95.03 | 68 | 6.40 |
| Port Allen | Main | 64.1 | 1961 | 81 | 24,167,141 | 3 | 3,436 | 98.02 | 59 | 2.93 |
| **Giww Texas** | | | | | | | | | | |
| Brazos East | Main | 400.4 | 1943 | 0 | 21,131,151 | 2 | 1,938 | 99.98 | 1 | 1.50 |
| Brazos West | Main | 400.9 | 1943 | 0 | 21,184,202 | 2 | 1,981 | 100.00 | 0 | 0.00 |
| Colorado River East | Main | 441.1 | 1944 | 13 | 21,110,876 | 2 | 2,097 | 97.84 | 21 | 9.02 |
| Colorado River West | Main | 441.8 | 1944 | 3 | 20,783,851 | 2 | 2,168 | 97.32 | 26 | 9.03 |
| **Green** | | | | | | | | | | |
| 1 | Main | 9.1 | 1956 | 18 | 4,353,350 | 3 | 3,049 | 96.00 | 4 | 87.67 |
| 2 | Main | 63.1 | 1956 | 22 | 1,491,500 | 3 | 2,302 | 100.00 | 0 | 0.00 |

*(Continued)*



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**Table 7L.149 (Continued)**

| River/ Lock | Chamber | River Mile | Year Open | Average Processing Time[a] | Total Tonnage | Average Tow Size | | Percent Chamber Available | Lock Closures | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Barges/ Tow | Tons/ Tow | | Total Number | Avg Time[b] |
| **Hudson** | | | | | | | | | | |
| Troy | Main | 153.8 | 1916 | 23 | 13,819 | 1 | 494 | 58.56 | 6 | 604.97 |
| **Illinois** | | | | | | | | | | |
| Lagrange | Main | 80.2 | 1939 | 64 | 35,597,851 | 10 | 11,435 | 97.73 | 47 | 4.23 |
| Peoria | Main | 157.7 | 1938 | 73 | 31,128,998 | 9 | 9,427 | 98.70 | 43 | 2.65 |
| Lockport | Main | 291.1 | 1933 | 82 | 16,039,564 | 6 | 5,443 | 98.36 | 32 | 4.48 |
| Thomas J. O'Brien | Main | 326.5 | 1960 | 22 | 7,371,509 | 3 | 2,913 | 99.65 | 17 | 1.82 |
| **Kanawha** | | | | | | | | | | |
| Winfield | Main8 | 31.1 | 1997 | 56 | 19,521,262 | 9 | 6,711 | 99.01 | 50 | 1.73 |
| Winfield | Main2 | 31.1 | 1937 | 0 | 0 | 0 | 0 | 100.00 | 0 | 0.00 |
| Winfield | Main1 | 31.1 | 1937 | 0 | 0 | 0 | 0 | 100.00 | 0 | 0.00 |
| Marmet | Main2 | 67.7 | 1934 | 161 | 7,801,139 | 6 | 3,807 | 98.19 | 60 | 2.65 |
| Marmet | Main1 | 67.7 | 1934 | 172 | 6,928,584 | 6 | 3,739 | 95.06 | 47 | 9.20 |
| London | Main2 | 82.8 | 1934 | 85 | 2,315,757 | 4 | 1,722 | 96.99 | 211 | 1.25 |
| London | Main1 | 82.8 | 1933 | 119 | 4,184,898 | 5 | 3,864 | 97.44 | 216 | 1.03 |
| Kaskaskia | | | | | | | | | | |
| Kaskaskia | Main | 0.8 | 1973 | 14 | 583,183 | 2 | 1,122 | 99.46 | 4 | 11.80 |
| **Lake Washington Ship Canal** | | | | | | | | | | |
| Hiram M. Chittenden | Main | 1.3 | 1916 | 28 | 1,816,245 | 2 | 1,408 | 96.19 | 3 | 111.38 |
| Hiram M. Chittenden | Aux 1 | 1.3 | 1916 | 13 | 1,931 | 2 | 149 | 96.88 | 1 | 273.00 |
| **Mermentau** | | | | | | | | | | |
| Catfish Point | Cntrl | 25.0 | 1951 | 7 | 84,226 | 1 | 354 | 99.93 | 2 | 3.27 |
| **Mississippi** | | | | | | | | | | |
| 27 | Main | 185.5 | 1953 | 40 | 79,858,929 | 11 | 11,810 | 96.89 | 29 | 9.40 |
| 27 | Aux 1 | 185.5 | 1953 | 30 | 3,519,785 | 4 | 3,520 | 91.82 | 31 | 23.10 |
| Melvin Price | Main | 200.8 | 1990 | 44 | 69,623,228 | 13 | 13,236 | 91.06 | 49 | 15.98 |
| Melvin Price | Aux | 200.8 | 1994 | 30 | 7,957,608 | 6 | 6,140 | 85.47 | 10 | 127.28 |
| 25 | Main | 241.4 | 1939 | 79 | 39,536,830 | 13 | 12,870 | 81.55 | 61 | 26.50 |
| 24 | Main | 273.4 | 1940 | 85 | 39,296,994 | 13 | 12,846 | 82.07 | 60 | 26.17 |
| 22 | Main | 301.2 | 1938 | 92 | 38,074,304 | 13 | 12,500 | 98.78 | 49 | 2.18 |
| 21 | Main | 324.9 | 1938 | 80 | 37,863,139 | 12 | 12,047 | 97.69 | 25 | 8.08 |
| 20 | Main | 343.2 | 1936 | 80 | 36,512,515 | 12 | 12,058 | 82.57 | 58 | 26.32 |
| 19 | Main | 364.2 | 1957 | 55 | 35,803,139 | 12 | 12,088 | 83.02 | 33 | 45.08 |
| 18 | Main | 410.5 | 1937 | 71 | 35,707,505 | 12 | 11,883 | 99.21 | 34 | 2.02 |
| 17 | Main | 437.1 | 1939 | 89 | 34,170,210 | 12 | 11,591 | 98.67 | 39 | 3.00 |
| 16 | Main | 457.2 | 1937 | 68 | 33,139,184 | 11 | 10,534 | 98.87 | 52 | 1.90 |
| 15 | Main | 482.9 | 1934 | 98 | 30,582,032 | 11 | 10,645 | 98.55 | 150 | 0.85 |
| 15 | Aux 1 | 482.9 | 1934 | 20 | 627,728 | 1 | 890 | 99.91 | 19 | 0.43 |
| 14 | Main | 493.0 | 1939 | 78 | 30,839,734 | 11 | 9,803 | 97.78 | 85 | 2.30 |
| 14 | Aux 1 | 493.0 | 1922 | 17 | 0 | 0 | 0 | 100.00 | 0 | 0.00 |
| 13 | Main | 523.0 | 1938 | 58 | 24,803,042 | 12 | 11,552 | 99.65 | 13 | 2.35 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 12 | Main | 556.0 | 1938 | 56 | 24,426,919 | 12 | 11,555 | 86.96 | 22 | 51.95 |
| 11 | Main | 583.0 | 1937 | 52 | 22,495,873 | 11 | 10,621 | 87.19 | 18 | 62.35 |
| 10 | Main | 615.0 | 1936 | 48 | 22,005,796 | 11 | 11,182 | 77.79 | 4 | 486.32 |
| 9 | Main | 647.0 | 1938 | 47 | 18,820,219 | 11 | 11,800 | 78.06 | 14 | 137.28 |
| 8 | Main | 679.0 | 1937 | 47 | 16,826,021 | 11 | 11,195 | 78.01 | 7 | 275.15 |
| 7 | Main | 702.0 | 1937 | 38 | 15,856,894 | 11 | 10,592 | 78.53 | 7 | 268.70 |
| 6 | Main | 714.0 | 1936 | 42 | 15,793,578 | 11 | 10,593 | 78.02 | 6 | 320.88 |
| 5A | Main | 728.5 | 1936 | 33 | 12,760,903 | 10 | 10,266 | 77.56 | 6 | 327.68 |
| 5 | Main | 738.1 | 1935 | 39 | 12,770,886 | 10 | 10,274 | 74.76 | 4 | 552.83 |
| 4 | Main | 752.8 | 1935 | 35 | 12,340,409 | 10 | 10,033 | 73.85 | 5 | 458.12 |
| 3 | Main | 796.9 | 1938 | 30 | 11,549,156 | 10 | 9,616 | 74.13 | 5 | 453.30 |
| 2 | Main | 815.0 | 1930 | 36 | 11,539,256 | 9 | 9,490 | 73.86 | 6 | 381.63 |
| 1 | Main | 847.6 | 1930 | 20 | 2,071,780 | 2 | 1,734 | 69.07 | 5 | 541.97 |
| Lower Saint Anthony Falls | Main | 853.3 | 1959 | 24 | 2,066,980 | 2 | 1,733 | 69.05 | 5 | 542.27 |
| Upper Saint Anthony Falls | Main | 853.9 | 1963 | 20 | 2,064,130 | 2 | 1,727 | 69.04 | 5 | 542.40 |
| **Monongahela** | | | | | | | | | | |
| 2 | Main | 11.2 | 1905 | 57 | 20,725,032 | 7 | 6,032 | 99.92 | 1 | 6.73 |
| 2 | Aux 1 | 11.2 | 1905 | 18 | 399,555 | 1 | 249 | 98.59 | 2 | 61.63 |
| 3 | Main | 23.8 | 1907 | 37 | 15,810,950 | 4 | 2,800 | 91.13 | 7 | 111.02 |
| 3 | Aux 1 | 23.8 | 1907 | 25 | 2,180,600 | 2 | 1,458 | 98.93 | 35 | 2.68 |
| 4 | Main | 41.5 | 1932 | 45 | 12,824,375 | 5 | 2,933 | 99.15 | 6 | 12.42 |
| 4 | Aux 1 | 41.5 | 1932 | 25 | 387,050 | 2 | 732 | 99.96 | 3 | 1.20 |
| Maxwell | Main | 61.2 | 1963 | 33 | 4,114,250 | 5 | 2,033 | 95.76 | 1 | 371.33 |
| Maxwell | Aux 1 | 61.2 | 1963 | 37 | 9,265,800 | 5 | 4,520 | 99.86 | 3 | 4.12 |
| Grays Landing | Main | 82.0 | 1993 | 30 | 5,772,720 | 5 | 3,090 | 99.97 | 5 | 0.50 |
| Pt. Marion | Main | 90.8 | 1994 | 30 | 5,211,735 | 5 | 3,192 | 99.86 | 3 | 4.13 |
| Morgantown | Main | 102.0 | 1950 | 26 | 383,435 | 4 | 2,062 | 100.00 | 0 | 0.00 |
| Hildebrand | Main | 108.0 | 1959 | 24 | 26,235 | 3 | 1,093 | 100.00 | 0 | 0.00 |
| Opekiska | Main | 115.4 | 1964 | 23 | 27,910 | 2 | 1,469 | 100.00 | 0 | 0.00 |
| **Ohio** | | | | | | | | | | |
| Emsworth | Main | 6.2 | 1921 | 70 | 22,529,859 | 7 | 5,726 | 98.02 | 13 | 13.33 |
| Emsworth | Aux 1 | 6.2 | 1921 | 24 | 1,021,740 | 1 | 866 | 99.48 | 2 | 22.93 |
| Dashields | Main | 13.3 | 1929 | 68 | 24,019,078 | 8 | 6,157 | 99.72 | 21 | 1.18 |
| Dashields | Aux 1 | 13.3 | 1929 | 23 | 494,215 | 1 | 619 | 97.29 | 3 | 79.27 |
| Montgomery | Main | 31.7 | 1936 | 73 | 25,975,596 | 8 | 6,550 | 97.82 | 68 | 2.82 |
| Montgomery | Aux 1 | 31.7 | 1936 | 26 | 568,956 | 2 | 791 | 84.04 | 11 | 127.13 |
| New Cumberland | Main | 54.4 | 1959 | 61 | 31,846,533 | 11 | 9,796 | 99.46 | 18 | 2.62 |
| New Cumberland | Aux 1 | 54.4 | 1959 | 36 | 2,051,242 | 3 | 1,784 | 99.49 | 15 | 2.95 |
| Pike Island | Main | 84.2 | 1965 | 56 | 39,404,927 | 11 | 10,381 | 99.56 | 21 | 1.83 |
| Pike Island | Aux 1 | 84.2 | 1965 | 36 | 1,866,363 | 2 | 1,637 | 99.78 | 5 | 3.82 |
| Hannibal | Main | 126.4 | 1973 | 52 | 46,249,423 | 12 | 12,104 | 99.96 | 2 | 1.75 |
| Hannibal | Aux 1 | 126.4 | 1973 | 38 | 1,001,031 | 3 | 1,738 | 97.02 | 7 | 37.33 |
| Willow Island | Main | 161.7 | 1972 | 57 | 38,901,384 | 12 | 12,452 | 89.87 | 4 | 221.90 |
| Willow Island | Aux | 161.7 | 1972 | 54 | 5,413,991 | 6 | 6,166 | 99.70 | 7 | 3.77 |
| Belleville | Main | 203.9 | 1969 | 57 | 47,457,409 | 12 | 12,525 | 99.83 | 8 | 1.90 |
| Belleville | Aux 1 | 203.9 | 1969 | 36 | 521,700 | 3 | 1,793 | 100.00 | 0 | 0.00 |

*(Continued)*



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**Table 7L.149 (Continued)**

| River/ Lock | Chamber | River Mile | Year Open | Average Processing Time[a] | Total Tonnage | Average Tow Size | | Percent Chamber Available | Lock Closures | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Barges/ Tow | Tons/ Tow | | Total Number | Avg Time[b] |
| Racine | Main | 237.5 | 1969 | 58 | 47,763,667 | 12 | 12,599 | 99.98 | 1 | 2.00 |
| Racine | Aux 1 | 237.5 | 1969 | 34 | 878,229 | 3 | 1,807 | 100.00 | 0 | 0.00 |
| Robert C. Byrd | Main | 279.2 | 1993 | 58 | 55,188,585 | 12 | 12,302 | 99.25 | 33 | 1.98 |
| Robert C. Byrd | Aux | 279.2 | 1993 | 37 | 784,300 | 2 | 1,491 | 99.98 | 1 | 1.58 |
| Greenup | Main | 341.0 | 1959 | 51 | 63,998,888 | 12 | 11,420 | 89.24 | 153 | 6.17 |
| Greenup | Aux 1 | 341.0 | 1959 | 49 | 6,040,145 | 6 | 5,541 | 93.62 | 80 | 6.98 |
| Captain Anthony Meldahl | Main | 436.2 | 1962 | 58 | 62,006,780 | 12 | 12,033 | 98.92 | 25 | 3.80 |
| Captain Anthony Meldahl | Aux 1 | 436.2 | 1962 | 27 | 772,018 | 3 | 2,347 | 98.31 | 6 | 24.60 |
| Markland | Main | 531.5 | 1959 | 57 | 52,796,082 | 11 | 11,972 | 96.53 | 23 | 13.22 |
| Markland | Aux 1 | 531.5 | 1959 | 35 | 2,053,048 | 4 | 3,733 | 99.90 | 4 | 2.20 |
| Mcalpine | Main | 606.8 | 1961 | 58 | 52,983,711 | 10 | 11,451 | 94.58 | 56 | 8.48 |
| Mcalpine | Aux 1 | 606.8 | 1961 | 145 | 1,846,382 | 10 | 12,734 | 99.96 | 3 | 1.18 |
| Cannelton | Main | 720.7 | 1971 | 59 | 55,135,133 | 11 | 12,588 | 96.20 | 74 | 4.50 |
| Cannelton | Aux | 720.7 | 1971 | 45 | 1,516,795 | 6 | 5,767 | 66.04 | 12 | 247.88 |
| Newburgh | Main | 776.1 | 1975 | 53 | 63,546,772 | 12 | 12,303 | 99.89 | 6 | 1.58 |
| Newburgh | Aux 1 | 776.1 | 1975 | 30 | 963,038 | 2 | 1,351 | 100.00 | 0 | 0.00 |
| John T. Myers | Main | 846.0 | 1975 | 52 | 70,689,316 | 12 | 12,790 | 99.48 | 60 | 0.77 |
| John T. Myers | Aux 1 | 846.0 | 1975 | 21 | 704,872 | 2 | 1,500 | 99.87 | 16 | 0.70 |
| Smithland | Main | 918.5 | 1980 | 43 | 36,106,180 | 10 | 10,387 | 99.00 | 130 | 0.67 |
| Smithland | Aux 1 | 918.5 | 1980 | 43 | 46,005,193 | 11 | 11,912 | 99.56 | 16 | 2.40 |
| 52 | Main | 938.9 | 1969 | 35 | 87,088,317 | 11 | 11,533 | 98.62 | 48 | 2.52 |
| 52 | Aux 1 | 938.9 | 1928 | 56 | 8,034,188 | 4 | 3,881 | 98.19 | 22 | 7.20 |
| 53[c] | Main | 962.6 | 1980 | 19 | 84,347,119 | 11 | 11,705 | 99.29 | 34 | 1.83 |
| 53[c] | Aux | 962.6 | 1929 | 46 | 3,421,135 | 3 | 3,719 | 99.84 | 10 | 1.37 |
| **Okeechobee** | | | | | | | | | | |
| St. Lucie | Main | 15.3 | 1941 | 22 | 54,561 | 1 | 134 | 64.39 | 368 | 8.48 |
| Port Mayaca | Main | 38.5 | 1977 | 11 | 20,922 | 1 | 176 | 77.36 | 240 | 8.27 |
| Ortona | Main | 93.6 | 1937 | 21 | 19,920 | 1 | 150 | 64.31 | 384 | 8.15 |
| **Old River** | | | | | | | | | | |
| Old River | Main | 304.0 | 1963 | 35 | 8,348,430 | 3 | 2,882 | 99.92 | 2 | 3.62 |
| **Ouachita** | | | | | | | | | | |
| Columbia | Main | 117.2 | 1972 | 20 | 1,064,862 | 2 | 2,223 | 100.00 | 0 | 0.00 |
| Felsenthal | Main | 226.8 | 1984 | 11 | 225,329 | 1 | 1,587 | 100.00 | 0 | 0.00 |
| H. K. Thatcher | Main | 281.7 | 1984 | 11 | 214,300 | 1 | 1,520 | 100.00 | 0 | 0.00 |
| **Red** | | | | | | | | | | |
| Lindy Claiborne Boggs | Main | 44.0 | 1984 | 23 | 2,119,661 | 4 | 2,423 | 100.00 | 0 | 0.00 |
| John H. Overton | Main | 74.0 | 1987 | 31 | 2,005,959 | 4 | 2,452 | 99.98 | 2 | 0.95 |
| 3 | Main | 116.4 | 1992 | 22 | 1,168,038 | 3 | 2,364 | 100.00 | 0 | 0.00 |
| 4 | Main | 169.0 | 1994 | 27 | 753,684 | 3 | 2,054 | 100.00 | 0 | 0.00 |
| Joe D. Waggonner | Main | 200.0 | 1994 | 17 | 643,066 | 3 | 1,991 | 100.00 | 0 | 0.00 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Schooner Bayou** | | | | | | | | | | |
| Schooner Bayou | Cntrl | 3.4 | 1950 | 4 | 51,265 | 4 | 276 | 86.24 | 6 | 200.85 |
| **Snake** | | | | | | | | | | |
| Ice Harbor | Main | 9.7 | 1962 | 33 | 4,067,370 | 2 | 3,345 | 95.75 | 20 | 18.62 |
| Lower Monumental | Main | 41.6 | 1969 | 37 | 3,495,982 | 3 | 3,800 | 96.13 | 10 | 33.88 |
| Little Goose | Main | 70.3 | 1970 | 25 | 3,127,538 | 3 | 3,612 | 95.39 | 3 | 134.60 |
| Lower Granite | Main | 107.5 | 1975 | 28 | 1,987,253 | 2 | 2,843 | 93.94 | 2 | 265.48 |
| **St. Marys** | | | | | | | | | | |
| Davis | Main | 47.0 | 1914 | 41 | 0 | 1 | 0 | 54.16 | 7 | 573.68 |
| Macarthur | Main | 47.0 | 1943 | 40 | 16,043,560 | 5 | 42,783 | 68.64 | 15 | 183.17 |
| New Poe | Main | 47.0 | 1963 | 54 | 66,372,865 | 11 | 214,106 | 81.13 | 18 | 91.82 |
| **Tennessee** | | | | | | | | | | |
| Ft. Loudon | Main | 602.3 | 1943 | 63 | 636,791 | 3 | 2,367 | 95.58 | 34 | 11.38 |
| **Tenn–Tombigbee** | | | | | | | | | | |
| Howell Heflin | Main | 266.1 | 1978 | 39 | 8,274,930 | 5 | 3,927 | 99.86 | 4 | 2.98 |
| Jamie Whitten | Main | 411.9 | 1985 | 41 | 5,775,215 | 6 | 4,170 | 99.87 | 8 | 1.42 |
| **Tombigbee** | | | | | | | | | | |
| Demopolis | Main | 213.2 | 1954 | 46 | 15,472,123 | 5 | 4,670 | 100.00 | 0 | 0.00 |
| **Verdigris** | | | | | | | | | | |
| Chouteau | Main | 401.4 | 1970 | 42 | 3,508,854 | 5 | 5,316 | 100.00 | 0 | 0.00 |
| Newt Graham Lock | Main | 421.6 | 1970 | 44 | 3,350,217 | 4 | 4,956 | 100.00 | 0 | 0.00 |
| **West Pearl** | | | | | | | | | | |
| 1 | Main | 29.7 | 1949 | 0 | 0 | 0 | 0 | 100.00 | 0 | 0.00 |
| 2 | Main | 40.8 | 1950 | 0 | 0 | 0 | 0 | 100.00 | 0 | 0.00 |
| 3 | Main | 43.9 | 1950 | 0 | 0 | 0 | 0 | 100.00 | 0 | 0.00 |

[a] Average time from start of lockage to end of lockage; expressed in minutes.
[b] Average time lock is closed (unavailable) expressed in hours.
[c] LPMS data not collected at this site.

*Source*: From www.iwr.usace.army.mil.



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**Table 7L.150 Important Ship Canals of the World**

| Canal | Location | Length | | Minimum Width | | Minimum Depth | | Number of Locks | Year Opened |
|---|---|---|---|---|---|---|---|---|---|
| | | mi | km | ft | m | ft | m | | |
| Albert | Belgium | 80.8 | 130 | 335 | 102 | 15 | 4.5 | 6 | 1939 |
| Amsterdam-Rhine | The Netherlands | 45 | 72.4 | 246 | 75 | 7.2 | 2.2 | 4 | 1952 |
| Cape Cod | Massachusetts | 17.5 | 28.2 | 500 | 152 | 32 | 10 | 0 | 1914 |
| Chesapeake and Delaware | Delaware, Maryland | 46 | 74 | 450 | 137 | 35 | 10.7 | 0 | 1829 |
| Chicago Sanitary and Ship | Illinois | 30.6 | 49.2 | 175 | 53.3 | 9 | 2.7 | 1 | 1900 |
| Corinth | Greece | 3.9 | 6.3 | 81 | 24.6 | 26 | 8 | 0 | 1893 |
| Erie Canal | New York | 363 | 584 | 120 | 36.6 | 12 | 3.7 | 57 | 1825 |
| Grand Canal | China | 1000 | 1609 | 100 | 30.5 | 2 | 0.6 | 24 | 610 |
| Kiel (Nord-Ostsee) | Germany | 61.3 | 98.6 | 336.3 | 102.5 | 36 | 11 | 8 | 1895 |
| Manchester Ship | England | 36 | 58 | 120 | 36.6 | 22 | 6.7 | 5 | 1894 |
| McClellan-Kerr Arkansas River System | Arkansas, Oklahoma | 445 | 716 | 150 | 45.7 | 9 | 2.7 | 17 | 1970 |
| Moscow | Russia | 80 | 128 | 98 | 30 | 18 | 5.5 | 7 | 1937 |
| North Sea | Netherlands | 15.3 | 24.7 | 525 | 160 | 49.5 | 15.1 | 4 | 1876 |
| Panama | Panama | 50.7 | 81.6 | 550 | 168 | 45 | 13.7 | 12 | 1914 |
| Sabine-Neches Waterway | Texas | 93.7 | 150.8 | 200 | 61 | 30 | 9.1 | 0 | 1916 |
| Saint Lawrence Seaway[a] | Canada, New York | 182 | 293 | 200 | 61 | 27 | 8.2 | 7 | 1959 |
| Soo (Sault Sainte Marie) | Canada | 1.4 | 2.2 | 61 | 18.6 | 19 | 5.8 | 1 | 1895 |
| Soo (St. Marys Falls Canal and Locks) | Michigan | 1.8 | 2.9 | 300 | 91.4 | 25.5 | 7.8 | 4 | 1855 |
| Suez[b] | Egypt | 117.9 | 189.7 | 741 | 226 | 64 | 19.5 | 0 | 1869 |
| Tennessee-Tombigbee Waterway | Alabama, Mississippi | 234 | 377 | 300 | 91.4 | 9 | 2.7 | 10 | 1985 |
| Volga-Baltic | Russia | 528 | 850 | 70 | 21.4 | 11 | 3.5 | 7 | 1964 |
| Welland Ship | Canada | 26 | 42 | 200 | 61 | 27 | 8.2 | 8 | 1932 |
| White Sea-Baltic | Russia | 138 | 222 | 46 | 14 | 10 | 3.2 | 19 | 1933 |

[a] Excludes passage through Lake Ontario and Welland Ship Canal.
[b] Includes entrance channels at both ends.

*Source*: From The World Book Encyclopedia © 2006 World Book, Inc. By permission of the publisher, www.worldbook.com.

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## SECTION 7M WATERBORNE COMMERCE

**Table 7M.151 Waterborne Commerce of the United States, 1984–2003**

| Year | Grand Total | Foreign | | | Domestic | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total | Great Lakes | Coastal | Total | Coastwise | Lakewise | Internal | Intraport |
| Tons. (millions) | | | | | | | | | |
| 1984 | 1,832.6 | 803.3 | 58.8 | 744.6 | 1,029.3 | 307.7 | 98.0 | 542.5 | 81.1 |
| 1985 | 1,785.0 | 774.3 | 51.3 | 723.0 | 1,010.7 | 309.8 | 92.0 | 534.7 | 74.3 |
| 1986 | 1,870.5 | 837.2 | 45.8 | 791.4 | 1,033.2 | 308.0 | 87.4 | 560.5 | 77.4 |
| 1987 | 1,962.8 | 891.0 | 45.9 | 845.1 | 1,071.8 | 323.5 | 96.5 | 569.8 | 82.0 |
| 1988 | 2,082.9 | 976.2 | 52.5 | 923.7 | 1,106.6 | 325.2 | 109.7 | 588.1 | 83.7 |
| 1989 | 2,135.2 | 1,037.9 | 54.8 | 983.1 | 1,097.3 | 302.0 | 109.1 | 606.0 | 80.2 |
| 1990 | 2,159.3 | 1,041.6 | 50.5 | 991.1 | 1,117.8 | 298.6 | 110.2 | 622.5 | 86.4 |
| 1991 | 2,087.6 | 1,013.6 | 41.8 | 971.8 | 1,074.0 | 294.5 | 103.4 | 600.4 | 75.6 |
| 1992 | 2,127.9 | 1,037.5 | 45.5 | 992.0 | 1,090.4 | 285.1 | 107.4 | 621.0 | 76.8 |
| 1993 | 2,123.3 | 1,060.0 | 43.6 | 1,016.4 | 1,063.2 | 271.7 | 109.8 | 607.3 | 74.4 |
| 1994 | 2,208.8 | 1,115.7 | 50.1 | 1,065.6 | 1,093.1 | 277.0 | 114.8 | 618.4 | 82.9 |
| 1995 | 2,233.5 | 1,147.4 | 51.9 | 1,095.5 | 1,086.2 | 266.6 | 116.1 | 620.3 | 83.1 |
| 1996 | 2,276.7 | 1,183.4 | 56.4 | 1,127.0 | 1,093.4 | 267.4 | 114.9 | 622.1[a] | 89.0[a] |
| 1997 | 2,326.9 | 1,220.6 | 57.7 | 1,162.9 | 1,106.3 | 263.1 | 122.7 | 630.6 | 89.8 |
| 1998 | 2,332.3 | 1,245.4 | 62.4 | 1,183.0 | 1,086.9 | 249.6 | 122.2 | 625.0 | 90.1 |
| 1999 | 2,316.7 | 1,260.8 | 62.4 | 1,198.3 | 1,055.9 | 228.8 | 113.9 | 624.6 | 88.60 |
| 2000 | 2,419.1 | 1,354.8 | 64.0 | 1,290.7 | 1,064.3 | 226.9 | 114.4 | 628.4 | 94.6 |
| 2001 | 2,387.4 | 1,350.8 | 62.5 | 1,288.3 | 1,036.6 | 223.6 | 100.0 | 619.8 | 93.2 |
| 2002 | 2,335.2 | 1,319.3 | 59.6 | 1,259.7 | 1,015.9 | 216.4 | 101.5 | 608.0 | 90.0 |
| 2003 | 2,387.9 | 1,378.1 | 56.3 | 1,321.8 | 1,009.7 | 223.5 | 89.8 | 609.6 | 86.9 |

[a] Beginning in 1996, fish was excluded.

*Source*: From U.S. Army Corps of Engineers, *2003 Waterborne Commerce of the United States (WCUS) Waterways and Harbors on the: Part V National Summaries of Domestic and Foreign Waterborne Commerce*, www.iwr.usace.army.mil.

**Table 7M.152 Freight Carried on Inland Waterways of the United States, 2001–2003**

| Waterway | Length (miles) | Tons | | Tons | | Tons | |
|---|---|---|---|---|---|---|---|
| | | 2001 | %[a] | 2002 | %[b] | 2003 | %[c] |
| **Atlantic Coast** | | | | | | | |
| Atlantic Intracoastal Waterway, VA-FL | 793 | 2.5 | −20.1 | 1.9 | −26.1 | 1.9 | 3.5 |
| Intracoastal Wtwy, Jacksonville to Miami, FL | 349 | 1.0 | 18.5 | 0.5 | −43.2 | 0.9 | 69.5 |
| **Gulf Coast** | | | | | | | |
| Bayou Teche, LA | 107 | 1.7 | 10.4 | 1.6 | −9.3 | 1.4 | −10.0 |
| Black Warrior and Tombigbee Rivers, AL | 449 | 18.9 | −19.4 | 19 | −0.5 | 21.0 | 10.3 |
| Chocolate Bayou, TX | 13 | 3.4 | −11.4 | 2.9 | −14.0 | 3.3 | 13.8 |
| Gulf Intracoastal Waterway, TX-FL | 1,109 | 112.2 | −1.4 | 107.7 | −4.0 | 117.8 | 9.5 |
| GIWW: Morgan City-Port Allen Route, LA | 64 | 23.3 | 1.0 | 20.8 | −10.6 | 24.3 | 16.6 |
| Petit Anse, Tigre, Carlin Bayous, LA | 16 | 3.1 | 19.7 | 2.2 | −27.8 | 2.5 | 13.1 |
| Tennessee-Tombigbee Waterway, AL and MS | 234 | 6.8 | −3.6 | 6.2 | −8.1 | 6.2 | −0.2 |
| **Mississippi River System** | | | | | | | |
| Allegheny River, PA | 72 | 3.0 | −21.9 | 2.8 | −4.6 | 3.3 | 17.7 |
| Atchafalaya River, LA | 121 | 11.6 | −14.0 | 10.7 | −7.3 | 9.8 | −8.8 |
| Big Sandy River, KY and WV | 27 | 24.2 | 3.0 | 25.1 | 3.7 | 22.6 | −9.9 |
| Cumberland River, KY and TN | 381 | 23.2 | 2.2 | 22.6 | −2.5 | 20.6 | −8.7 |
| Green and Barren Rivers, KY | 109 | 7.8 | 88.7 | 10.4 | 33.9 | 7.9 | −24.2 |
| Illinois Waterway, IL | 357 | 43.5 | −1.7 | 43.0 | −1.0 | 45.0 | 4.6 |
| Kanawha River, WV | 91 | 22.2 | −1.4 | 19.2 | −13.2 | 19.4 | 0.8 |
| McClellan-Kerr Arkansas R. Nav. Sys., AR/OK | 462 | 11.2 | 4.4 | 11.9 | 6.2 | 13.0 | 9.1 |
| Mississippi River Mpls, MN to Mouth of Passes | 1,814 | 316.5 | −3.3 | 316.2 | −0.1 | 308.2 | −2.5 |
| Minneapolis, MN to Mouth of Missouri River | 663 | 78.8 | −5.4 | 84.1 | 6.7 | 77.8 | −7.4 |

*(Continued)*

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**Table 7M.152 (Continued)**

| Waterway | Length (miles) | Tons 2001 | %[a] | Tons 2002 | %[b] | Tons 2003 | %[c] |
|---|---|---|---|---|---|---|---|
| Mouth of Missouri R. to Mouth of Ohio R. | 195 | 119.1 | −2.1 | 121.5 | 2.0 | 111.5 | −8.2 |
| Mouth of Ohio River up to Baton Rouge, LA | 720 | 200.7 | −1.8 | 198.3 | −1.2 | 185.5 | −6.5 |
| Baton Rouge up to New Orleans, LA[d] | 130 | 220.0 | −2.7 | 222.4 | 1.1 | 212.9 | −4.3 |
| New Orleans, LA to Mouth of Passes[d] | 106 | 116.7 | −3.8 | 114.8 | −1.6 | 115.8 | −0.8 |
| Missouri R. (MO, KS, NE & IA) to Sioux City, IA | 732 | 9.7 | 11.4 | 8.3 | −15.1 | 8.1 | −2.6 |
| Monongahela River, PA and WV | 129 | 38.1 | 2.1 | 38.2 | 0.4 | 27.6 | −27.8 |
| Ohio River, PA, WV, OH, KY, IN, and IL | 981 | 242.5 | 2.6 | 248.2 | 0.3 | 228.3 | −5.9 |
| Ouachita and Black Rivers, AR and LA | 332 | 1.6 | 6.7 | 1.4 | −11.5 | 2.2 | 57.7 |
| Red River, LA | 212 | 3.7 | −2.1 | 3.7 | 0.6 | 4.2 | 12.6 |
| Tennessee River, TN, KY, MS and AL | 652 | 47.9 | −3.3 | 43.9 | −8.3 | 49.8 | 13.4 |
| **Pacific Coast** | | | | | | | |
| Columbia River System, OR, WA, and ID | 596 | 20.2 | −12.2 | 16.5 | 18.5 | 16.5 | 0.5 |
| Columbia River and Willamette River below Vancouver, WA and Portland, OR[d] | 113 | 19.8 | −11.6 | 15.9 | −19.4 | 16.2 | 1.5 |
| Vancouver, WA to The Dalles, OR | 85 | 9.8 | −8.2 | 8.0 | −18.4 | 9.4 | 18.0 |
| The Dalles Dam to McNary Lock and Dam | 100 | 8.9 | −9.2 | 7.3 | −18.2 | 8.5 | 17.5 |
| Above McNary L & D to Kennewick, WA | 39 | 6.7 | −14.6 | 5.1 | −24.5 | 6.5 | 27.0 |
| Snake River (WA and ID) to Lewiston, ID | 141 | 5.6 | −15.9 | 4.3 | −24.0 | 5.3 | 24.6 |
| Willamette River above Portland, OR | 118 | 1.6 | 83.7 | 1.6 | 1.4 | 1.3 | −22.3 |

[a] Percent change from 2000
[b] Percent change from 2001
[c] Percent change from 2002
[d] Includes deep draft waterways (2001, 2002). Includes coastwise entrance channel miles.

*Source*: From U.S., Army Corps of Engineers, *2003 Waterborne Commerce of United States (WCUS) Waterways and Harbors on the: Part V - Natinal summaries of Domestic and Foreign Waterbome Commerce:* U.S. Army Corps of Engineers, *2002 Waterborne Commerce of the United States (WCUS) Waterways and Harbors on the: Part V - National Summaries of Domestic and Foreign Waterborne Commerce:* U.S. Army Corps of Engineers, *2001 Waterborne Commerce of the United States (WCUS) Waterways and Harbors on the: Part V - national Summaries of Domestic and Foreign Waterborne commer commerce*, www.iwr.usace.army.mil.

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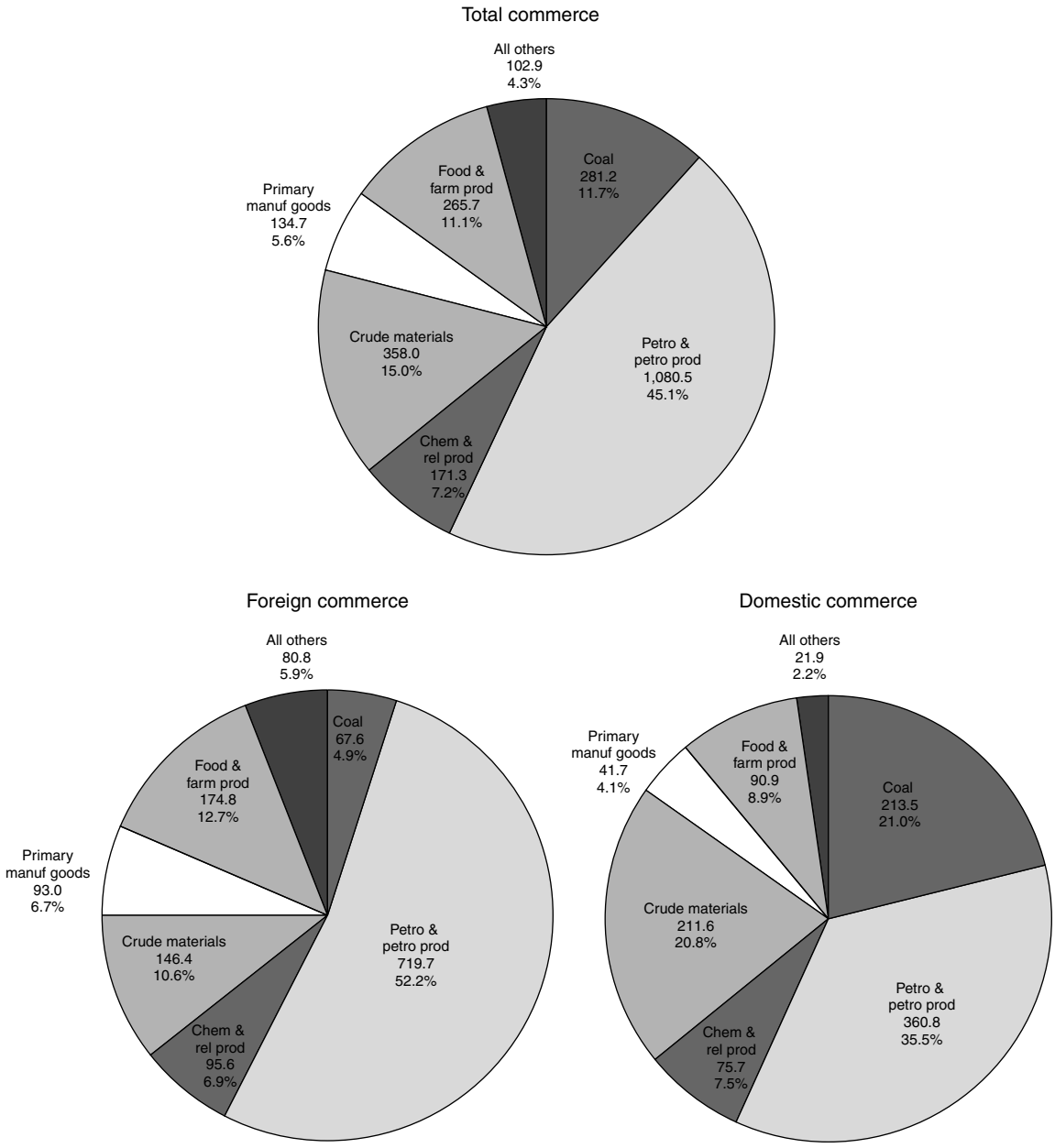


*Note:* Million short tons and percentage of short tons.

**Figure 7M.24** Principal commodities carried on waterways of the United States in 2003. (From U.S. Army Corps of Engineers, *2003 Waterborne Commerce of the United States (WCUS) Waterways and Harbors on the: Part V National Summaries of Domestic and Foreign Waterborne Commerce*, www.iwr.usace.army.mil.)

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**Table 7M.153 Domestic and Foreign Waterborne Commerce by Type of Commodity in the United States, 2000–2003**

| | 2000 | | | 2001 | | | 2002 | | | 2003 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Foreign | | | Foreign | | | Foreign | | | Foreign | |
| **Commodity** | **Domestic** | **Imports** | **Exports** | **Domestic** | **Imports** | **Exports** | **Domestic** | **Imports** | **Exports** | **Domestic** | **Imports** | **Exports** |
| Total, all commodoties | 1,069,798 | 976,784 | 415,042 | 1,042,472 | 945,075 | 399,011 | 1,021,001 | 934,941 | 384,350 | 1,016,136 | 1,004,791 | 373,324 |
| Coal and lignite | 220,679 | 15,462 | 60,879 | 227,718 | 19,857 | 55,764 | 227,011 | 16,671 | 43,252 | 213,517 | 25,015 | 42,624 |
| Petroleum and petroleum products[a] | 370,603 | 651,650 | 58,696 | 369,745 | 620,556 | 58,292 | 348,671 | 609,289 | 59,929 | 360,809 | 661,540 | 58,199 |
| Crude Petroleum | 83,806 | 521,619 | 3,064 | 85,971 | 486,249 | 1,344 | 85,506 | 479,318 | 1,208 | 87,491 | 515,747 | 1,248 |
| Gasoline | 94,658 | 24,157 | 6,434 | 93,098 | 27,732 | 6,906 | 86,602 | 29,282 | 6,726 | 87,524 | 32,294 | 6,630 |
| Distillate fuel oil | 65,695 | 21,111 | 4,953 | 65,591 | 20,589 | 4,982 | 62,651 | 19,936 | 5,861 | 65,569 | 29,115 | 7,046 |
| Residual fuel oil | 78,534 | 40,361 | 12,693 | 78,742 | 40,891 | 14,032 | 69,420 | 35,411 | 12,129 | 75,958 | 31,330 | 9,420 |
| Chemicals and Related Products | 75,996 | 38,479 | 57,888 | 71,080 | 43,830 | 54,741 | 73,063 | 39,572 | 54,962 | 75,718 | 42,007 | 53,575 |
| Crude Materials, inedible except fuels[a,b] | 234,210 | 97,350 | 48,753 | 213,673 | 95,041 | 45,283 | 214,745 | 92,225 | 44,983 | 211,563 | 102,215 | 44,235 |
| Forest products, wood and chips | 13,475 | 5,505 | 14,131 | 10,222 | 6,119 | 10,725 | 9,243 | 7,024 | 8,853 | 8,090 | 7,415 | 8,090 |
| Soil, sand, gravel, rock and stone[b] | 132,275 | 29,061 | 3,635 | 129,267 | 29,793 | 3,534 | 128,777 | 33,691 | 3,657 | 130,829 | 37,453 | 2,539 |
| Limestone | 54,185 | 10,703 | 2,476 | 56,034 | 10,439 | 2,422 | 54,418 | 11,706 | 2,709 | 50,340 | 12,483 | 1,838 |
| Phosphate rock | 3,418 | — | 7 | 1,736 | — | — | 3,497 | 2,670 | 1 | 3,141 | 2,547 | 6 |
| Sand and gravel | 71,447 | 6,611 | 850 | 68,510 | 8,144 | 864 | 67,474 | 7,929 | 639 | 73,651 | 11,103 | 519 |
| Iron ore and scrap | 69,215 | 19,412 | 9,281 | 54,006 | 13,431 | 9,319 | 58,471 | 15,513 | 11,818 | 52,918 | 16,886 | 11,107 |
| Nonferrous ores and scrap | 6,730 | 19,370 | 3,135 | 6,159 | 17,117 | 2,430 | 6,594 | 15,505 | 2,243 | 6,869 | 16,870 | 2,443 |
| Primary manufactured goods | 45,788 | 91,959 | 15,256 | 40,336 | 82,854 | 13,892 | 42,426 | 83,922 | 14,502 | 41,695 | 76,428 | 16,537 |
| Food and farm products[a,c] | 96,940 | 30,026 | 156,333 | 96,514 | 30,766 | 154,577 | 97,556 | 32,150 | 150,323 | 90,923 | 32,793 | 142,003 |
| Wheat | 12,885 | 147 | 30,378 | 12,074 | 155 | 28,039 | 9,677 | 248 | 26,066 | 10,758 | 230 | 26,358 |
| Corn | 37,960 | 163 | 50,048 | 38,999 | 99 | 48,772 | 41,720 | 95 | 47,936 | 36,673 | 83 | 41,447 |
| Soybeans | 20,242 | 30 | 27,013 | 20,034 | 31 | 29,352 | 21,538 | 39 | 28,175 | 20,378 | 33 | 29,270 |
| Other agricultural products[d] | 7,489 | 15,920 | 22,724 | 7,302 | 22,905 | 15,887 | 7,322 | 24,213 | 15,697 | 7,073 | 24,985 | 15,454 |
| All manufactured equipment, machinery and products | 21,245 | 48,598 | 13,762 | 19,870 | 47,726 | 12,753 | 14,576 | 54,865 | 12,419 | 18,714 | 58,502 | 12,809 |
| Waste and scrap nec | 4,267 | — | — | 3,469 | — | — | 2,745 | — | — | 3,108 | — | — |
| Unknown or not elsewhere classified | 71 | 3,259 | 3,474 | 67 | 4,445 | 3,708 | 208 | 6,247 | 3,981 | 89 | 6,293 | 3,342 |

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*Note:* Thousand of short tons.

[a] Includes commodities not shown seperately.
[b] Dose not include waterways improvement material, 2000-5.3 million short tons, 2001-6.5 million short tons, 2002-6.4 million short tons, 2003-4.4 million short tons.
[c] Does not include fish landings.
[d] Food, alcoholic beverages, tobacco products, cotton, etc.

*Source*: From U.S. Army Corps of Engineers, *2003 Waterborns Commerce of the United Sates (WCUS) Waterways and Harbors on the: Part V-National Summaries of Domestic and Foreign Waterborne Commerce*; U.S. Army Corps of Engineers, *2002 Waterborne Commerce of the United States Domestic and Foreign Waterborne Commerce*; U.S. Army Corps of Engineers, *2001 Waterborne Commerce of the United States (WCUS) Waterways and Harborne Commerce*; U.S. Army Corps of Engineers, *2000 Waterborne Commerce of the United States (WCUS) Waterways and Harbors on the: Part V-National Summaries of Domestic and Foreign Waterborne Commerce*, www.iwr.usace.army.mil.



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**Table 7M.154 Freight Carried on the Mississippi River System by Type of Traffic, 1984–2003**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total** | 543.5 | 527.8 | 556.4 | 583.4 | 601.6 | 626.4 | 659.1 | 646.6 | 673.1 | 660.4 | 693.3 | 707.2 | 701.8 | 707.1 | 707.4 | 716.9 | 715.5 | 714.8 | 712.8 | 676.8 |
| Foreign | | | | | | | | | | | | | | | | | | | | |
| Inbound | 34.1 | 27.0 | 35.1 | 38.1 | 45.3 | 59.9 | 63.1 | 60.1 | 63.0 | 76.9 | 89.8 | 81.5 | 77.3 | 83.5 | 85.2 | 83.5 | 87.7 | 87.8 | 86.3 | 78.4 |
| Outbound | 85.9 | 81.0 | 81.1 | 93.7 | 97.5 | 104.0 | 106.0 | 109.9 | 112.3 | 100.0 | 92.4 | 115.8 | 108.7 | 98.5 | 94.7 | 99.2 | 100.5 | 99.8 | 99.2 | 91.3 |
| Domestic | | | | | | | | | | | | | | | | | | | | |
| Coastwise | 36.7 | 40.9 | 37.4 | 37.4 | 35.8 | 31.1 | 32.6 | 31.3 | 32.3 | 31.8 | 32.4 | 30.6 | 33.0 | 36.3 | 36.7 | 34.6 | 34.1 | 30.9 | 33.0 | 31.8 |
| Internal | 386.6 | 378.9 | 402.8 | 414.2 | 423.0 | 431.5 | 457.5 | 445.1 | 465.4 | 451.7 | 478.7 | 479.4 | 482.8 | 488.9 | 490.7 | 499.6 | 493.1 | 496.3 | 494.3 | 475.2 |

*Note:* Million short tons. Foreign Inbound includes Upbound Thru Traffic. Foreign Outbound includes Downbound Thru Traffic.

*Source*: From U.S. Army Corps of Engineers, 2003 *Waterborne Commerce of the United States (WCUS) Waterways and Harbors on the: Part V National Summaries of Domestic and Foreign Waterborne Commerce*, www.iwr.usace.army.mil.



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**Table 7M.155 U.S. Freight Carried on the Great Lakes by Type of Traffic, 1984–2003**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total** | **162.8** | **148.1** | **137.9** | **148.1** | **168.8** | **168.9** | **167.1** | **151.1** | **159.9** | **159.6** | **175.3** | **177.8** | **181.8** | **188.6** | **192.2** | **182.9** | **187.5** | **171.4** | **167.2** | **156.5** |
| Foreign | | | | | | | | | | | | | | | | | | | | |
| Inbound | 17.8 | 17.1 | 13.8 | 13.9 | 15.9 | 17.8 | 17.6 | 14.2 | 15.4 | 18.1 | 23.1 | 18.9 | 24.5 | 24.5 | 25.6 | 22.2 | 23.9 | 22.0 | 21.5 | 23.3 |
| Outbound | 40.9 | 34.2 | 32.0 | 32.1 | 36.6 | 37.1 | 32.9 | 27.5 | 30.4 | 25.8 | 27.8 | 33.5 | 32.8 | 33.7 | 37.9 | 40.8 | 42.9 | 43.6 | 38.4 | 33.1 |
| Domestic | | | | | | | | | | | | | | | | | | | | |
| Coastwise | 0.0 | 0.0 | — | 0.0 | — | 0.0 | 0.0 | — | 0.0 | 0.0 | 0.0 | — | — | — | — | — | 0.0 | — | — | 0.0 |
| Lakewise | 98.0 | 92.0 | 87.4 | 96.5 | 109.7 | 109.1 | 110.2 | 103.4 | 107.4 | 109.9 | 114.8 | 116.2 | 115.0 | 122.8 | 122.2 | 113.4 | 114.4 | 100.1 | 101.6 | 89.8 |
| Internal | 1.8 | 2.2 | 1.7 | 1.4 | 1.6 | 1.7 | 3.1 | 3.2 | 3.4 | 3.1 | 4.6 | 3.6 | 3.3 | 2.3 | 2.3 | 1.5 | 2.1 | 1.7 | 2.5 | 2.8 |
| Intraport | 4.2 | 2.7 | 3.0 | 4.3 | 5.0 | 3.3 | 3.4 | 2.7 | 3.3 | 2.8 | 5.0 | 5.5 | 6.2 | 5.2 | 4.3 | 4.4 | 4.2 | 4.0 | 3.2 | 7.4 |

*Note:* Million Short Tons. Foreign Outbound includes Great Lakes Thru Foreign Traffic.

*Source*: From U.S. Army Corps of Engineers, 2003 *Waterborne Commerce of the United States (WCUS) Waterways and Harbors on the: Part V. National Summaries of Domestic and Foreign Waterborne Commerce*, www.iwr.usace.army.mil.



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## SECTION 7N WATER–BASED RECREATION

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**Table 7N.156 Recreational Boats in Use by Boat Type 1997–2003 and Estimates of Retail Expenditures on Recreational Boats**

| Estimates of Retail Expenditures on Recreational Boating 1997–2003 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|
| New Boats | 610,100 | 575,300 | 584,900 | 576,900 | 882,300[a] | 846,000 | 840,800[b] |
| Total New Boat Retail dollars | $6,636,856,000 | $6,308,685,000 | $7,711,369,000 | $9,515,192,800 | $10,223,862,700 | $10,898,635,200 | $10,603,725,600 |
| Average New Boat Retail Price | $10,878 | $10,966 | $12,176 | $16,494 | $11,588 | $12,883 | $12,611 |
| Used Boats | 1,038,819 | 979,565 | 995,911 | 982,289 | 1,502,295 | 1,440,486 | 1,431,632 |
| Total Used Boat Retail Dollars | $4,067,750,452 | $3,866,613,387 | $4,365,102,290 | $5,831,892,361 | $6,266,238,429 | $6,679,808,671 | $6,499,057,626 |
| Average Used Boat Retail Price | $3,916 | $3,947 | $4,383 | $5,937 | $4,171 | $4,637 | $4,540 |
| New Outboard Motors | 302,000 | 314,000 | 331,900 | 348,700 | 299,100 | 302,100 | 305,400 |
| Total New Outboard Motor Retail Dollars | $2,006,186,000 | $2,155,610,000 | $2,602,096,000 | $2,901,861,400 | $2,411,045,100 | $2,479,938,900 | $2,554,533,570 |
| Average New Outboard Motor Retail Price | $6,643 | $6,865 | $7,840 | $8,322 | $8,061 | $8,209 | $8,365 |
| Used Outboard Motors | 514,216 | 534,649 | 565,127 | 393,732 | 509,278 | 514,386 | 520,005 |
| Total Used Outboard Motor Retail Dollars | $1,229,597.871 | $1,321,180,323 | $1,594,833,032 | $1,778,572,471 | $1,477,737,319 | $1,519,962,552 | $1,565,681,865 |
| Average Used Outboard Motor Retail Price | $2,391 | $2,471 | $2,822 | $2,996 | $2,902 | $2,955 | $3,011 |
| New Boat Trailers | 181,000 | 174,000 | 168,000 | 158,500 | 135,900 | 141,200 | 130,600 |
| Total New Boat Retail Dollars | $190,050,000 | $189,660,000 | $190,008,000 | $184,494,000 | $181,698,300 | $200,645,200 | $202,012,080 |
| Average New Boat Trailer Retail Price | $1,050 | $1,090 | $1,131 | $1,164 | $1,337 | $1,421 | $1,547 |
| Estimated Boat/Motor/Trailer Dollars | $14,130,440,323 | $13,841,748,710 | $16,463,408,323 | $20,212.033,032 | $20,560,581,848 | $21,778,990,523 | $21,425,010,741 |
| Estimated Accessory Aftermarket Sales | 1,214,057,000 | 1,650,000,000 | 1,848,000,000 | 2,032,800,000 | 1,937,268,400 | 2,028,309,545 | 2,123,640,093 |
| Sub Total | $15,344,497,323 | $15,491,748,710 | $17,722,048,323 | $22,244,833,032 | $22,497,840,248 | $23,807,300,067 | $23,548,650,835 |
| Estimated Other (fuel, finance, insurance, docking, maintenance etc) | $3,573,140,718 | $3,500,139,754 | $4,014,043.945 | $5,625,013,577 | $6,058,281,452 | $6,554,969,366 | $6,448,429,689 |
| Total Expenditures | $18,917,638,040 | $18,991,888,464 | $21,736,092,268 | $27,869,846,610 | $28,556,121,701 | $30,362,269,433 | $29,997,080,523 |
| Percent Change | | 0.39% | 14.45% | 28.22% | 2.46% | 6.32% | –1.20% |
| New Boat/Motor Expenditures | $8,643,042,000 | $8,464,295,000 | $10,313,465,000 | $12,417,074,200 | $12,634,907,800 | $13,378,574,100 | $13,158,259,170 |
| Percent Change | | –2.07% | 21.85% | 20.40% | 1.75% | 5.89% | –1.65% |
| Recreational Boats in Use by Boat Type 1997–2003 | | | | | | | |
| Outboard boats (millions) | 8.13 | 8.19 | 8.21 | 8.29 | 8.34 | 8.38 | 8.42 |
| Inboard boats (millions) | 1.59 | 1.61 | 1.63 | 1.66 | 1.69 | 1.71 | 1.74 |
| Sterndrive boats (millions) | 1.58 | 1.62 | 1.67 | 1.71 | 1.74 | 1.77 | 1.79 |
| Personal Watercraft (millions) | 1.00 | 1.10 | 1.18 | 1.24 | 1.29 | 1.35 | 1.42 |
| Sailboats (millions) | 1.65 | 1.67 | 1.65 | 1.64 | 1.63 | 1.61 | 1.60 |
| Others (millions) | 2.29 | 2.45 | 2.49 | 2.50 | 2.51 | 2.53 | 2.53 |
| Total (millions) | 16.23 | 16.65 | 16.82 | 17.03 | 17.20 | 17.36 | 17.49 |

[a] Includes 357,100 kayaks not previously reported.
[b] Includes 30,580 inflatables not previously reported.

*Source*: From National Marine Manufactures Association, 2003 Recreational Statistical Abstract, www.nmma.org. Reprinted with permission.

*Original Source*: From Recreational Boats in Use by Type 1997 to 2003 data USCG/NMMA.



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**Table 7N.157 The Retail Boating Market 1997–2003 Total Units Sold, Total Retail Value, and Average Retail Unit Cost**

| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|
| **Outboard Boats** | | | | | | | |
| Total units sold | 20,000 | 213,700 | 230,200 | 241,200 | 217,800 | 212,000 | 207,100 |
| Retail value | $1,421,400,000 | $1,547,188,000 | $1,988,928,000 | $2,306,577,000 | $2,195,859,600 | $2,280,908,000 | $2,742,825,960 |
| Average unit cost | $7,107 | $7,240 | $8,640 | $9,563 | $10,082 | $10,759 | $13,244 |
| **Outboard Motors** | | | | | | | |
| Total units sold | 302,000 | 314,000 | 331,900 | 348,700 | 299,100 | 302,100 | 305,400 |
| Retail value | $2,006,186,000 | $2,155,610,000 | $2,602,096,000 | $2,901,881,400 | $2,411,045,100 | $2,478,838,900 | $2,554,533,570 |
| Average unit cost | $6,643 | $6,865 | $7,840 | $8,322 | $8,061 | $8,205 | $8,365 |
| **Boat Traillers** | | | | | | | |
| Total units sold | 181,000 | 174,000 | 168,000 | 158,500 | 135,900 | 141,200 | 130,600 |
| Retail value | $190,050,000 | $189,660,000 | $190,008,000 | $184,494,000 | $181,698,300 | $200,645,200 | $202,012,080 |
| Average unit cost | $1,050 | $1,090 | $1,131 | $1,164 | $1,337 | $1,421 | $1,547 |
| **Inboard Boats-Ski/Wakeboard Boats** | | | | | | | |
| Total units sold | 6,100 | 10,900 | 12,100 | 13,600 | 11,100 | 10,500 | 11,100 |
| Retail value | $136,408,200 | 253,348,700 | $308,429,000 | $366,438,400 | $352,569,300 | $398,811,000 | $403,289,640 |
| Average unit cost | $22,362 | 23,243 | $25,490 | $26,944 | $31,763 | $37,982 | $36,332 |
| **Inboard Boats-Cruisers** | | | | | | | |
| Total units sold | 6,300 | 6,700 | 7,000 | 10,300 | 10,800 | 11,800 | 9,300 |
| Retail value | $1,669,103,100 | $1,704,245,500 | $1,799,420,000 | $2,925,756,200 | $3,758,475,600 | $4,336,559,000 | $3,467,322,720 |
| Average unit cost | $264,937 | $254,365 | $257,060 | $284,054 | $348,007 | $367,505 | $372,830 |
| **Stemdrive Boats** | | | | | | | |
| Total units sold | 92,000 | 77,700 | 79,600 | 78,400 | 72,000 | 69,300 | 69,200 |
| Retail value | $2,068,528,000 | $1,746,696,000 | $2,054,476,000 | $2,253,843,200 | $2,216,448,000 | $2,192,929,200 | $2,221,116,840 |
| Average unit cost | $22,484 | $22,480 | $25,810 | $28,748 | $30,784 | $31,644 | $32,097 |
| **Canoes** | | | | | | | |
| Total units sold | 103,600 | 107,800 | 121,000 | 111,800 | 105,800 | 100,000 | 86,700 |
| Retail value | $61,124,000 | $64,033,200 | $67,034,000 | $64,508,600 | $57,449,400 | $56,900,000 | $49,644,420 |
| Average unit cost | $590 | $594 | $554 | $577 | $543 | $569 | $573 |
| **Kayaks** | | | | | | | |
| Total units sold | N/A | N/A | N/A | N/A | 357,100 | 340,300 | 324,000 |
| Retail value | N/A | N/A | N/A | N/A | $176,764,500 | $157,558,900 | $151,048,800 |
| Average unit cost | N/A | N/A | N/A | N/A | $495 | $463 | $465 |
| **Inflatables** | | | | | | | |
| Total units sold | N/A | N/A | N/A | N/A | N/A | N/A | 30,500 |
| Retail value | N/A | N/A | N/A | N/A | N/A | N/A | $67,417,200 |
| Average unit cost | N/A | N/A | N/A | N/A | N/A | N/A | $2,210 |
| **Personal Water Craft** | | | | | | | |
| Total units sold | 176,000 | 130,000 | 106,000 | 92,000 | 80,900 | 79,300 | 80,600 |
| Retail value | $1,135,904,000 | $868,530,000 | $771,044,000 | $720,176,000 | $641,456,100 | $697,681,400 | $716,501,760 |
| Average unit cost | $6,454 | $6,681 | $7,274 | $7,828 | $7,929 | $8,798 | $8,890 |
| **Jet Boats** | | | | | | | |
| Total units sold | 11,700 | 10,100 | 7,800 | 7,000 | 6,200 | 5,100 | 5,600 |
| Retail value | $144,389,700 | $167,033,800 | $132,678,000 | $123,641,000 | $118,692,800 | $107,997,600 | $115,268,160 |
| Average unit cost | $12,341 | $16,538 | $17,010 | $17,663 | $19,144 | $21,176 | $20,584 |
| **Sailboats**[a] | | | | | | | |
| Total units sold | 14,400 | 18,400 | 21,600 | 22,600 | 20,600 | 17,700 | 16,700 |
| Retail value | N/A | N/A | N/A | $754,252,400 | $706,139,303 | $669,290,100 | $669,290,100 |
| Average unit cost | N/A | N/A | N/A | $33,374 | $34,279 | $37,813 | $40,077 |

*Note*: [a]The Sailing Company's Annual Sailing Business Review.

*Source*: From National Marine Manufactures Association, 2003 Recreational Statistical Abstract, www.nmma.org. Reprinted with permission.

*Original Source*: From The Sailing Company's Annual Sailing Business Review.

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**Table 7N.158 Boat Registration Data by State, 2003**

| | Boat Registration Data by State[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Powered | | | | | Nonpowered | | | Other | Total |
| | Inboard | Outboard | Sterndrive | Auxiliary Sail | PWC | Rowboat | Canoe or Kayak | Sail Only | Other Boats | Total |
| **Totals** | **1,457,376** | **8,003,686** | **1,601,156** | **139,885** | **744,473** | **118,295** | **282,612** | **146,084** | **301,049** | **12,794,616** |
| Alabama | 17,582 | 205,393 | 20,256 | 994 | 14,141 | 534 | 375 | 2,631 | 343 | 262,249 |
| Alaska | 4,195 | 31,284 | 4,337 | 607 | 1,673 | 8,767 | 0 | 193 | 360 | 51,416 |
| Arizona | 45,865 | 65,061 | 0 | 1,572 | 28,081 | 0 | 0 | 0 | 6,634 | 147,213 |
| Arkansas | 29,704 | 148,573 | 0 | 0 | 0 | 0 | 0 | 472 | 17,466 | 196,215 |
| California | 115,697 | 356,955 | 209,788 | 20,414 | 184,105 | 8,691 | 6,863 | 35,853 | 25,013 | 963,379 |
| Colorado | 21,496 | 49,595 | 7,715 | 0 | 17,136 | 0 | 0 | 3,937 | 696 | 100,575 |
| Connecticut | 7,746 | 68,915 | 16,998 | 4,997 | 8,433 | 302 | 56 | 207 | 253 | 107,907 |
| Delaware | 6,193 | 32,037 | 11,190 | 0 | 0 | 0 | 0 | 0 | 515 | 49,935 |
| District of Columbia | 543 | 614 | 337 | 150 | 39 | 262 | 13 | 150 | 44 | 2,152 |
| Florida | 66,694 | 624,342 | 92,408 | 9,932 | 106,783 | 4,224 | 3,511 | 7,657 | 24,417 | 939,968 |
| Georgia | 17,839 | 218,634 | 36,247 | 0 | 37,673 | 0 | 0 | 4,414 | 11,911 | 326,718 |
| Hawaii | 7,860 | 3,267 | 2,217 | 1,246 | 0 | 0 | 0 | 690 | 320 | 15,600 |
| Idaho | 17,579 | 40,559 | 16,160 | 838 | 4,634 | 0 | 0 | 800 | 2,106 | 82,676 |
| Illinois | 30,268 | 225,527 | 50,920 | 3,032 | 13,995 | 16,012 | 0 | 8,078 | 12,420 | 360,252 |
| Indiana | 25,293 | 129,966 | 35,494 | 713 | 0 | 0 | 0 | 1,308 | 23,371 | 216,145 |
| Iowa | 19,569 | 131,236 | 23,592 | 471 | 0 | 956 | 23,379 | 4,324 | 7,309 | 210,836 |
| Kansas | 7,177 | 65,842 | 9,816 | 406 | 12,731 | 1,305 | 272 | 2,618 | 296 | 100,463 |
| Kentucky | 15,750 | 119,450 | 17,224 | 342 | 8,298 | 0 | 0 | 0 | 12,354 | 173,418 |
| Louisiana | 21,225 | 262,311 | 10,583 | 0 | 12,932 | 0 | 0 | 0 | 0 | 307,051 |
| Maine | 7,021 | 73,542 | 9,570 | 0 | 0 | 0 | 0 | 0 | 471 | 90,604 |
| Maryland | 15,493 | 110,726 | 36,046 | 10,318 | 16,753 | 0 | 0 | 483 | 8,576 | 198,395 |
| Massachusetts | 8,361 | 98,952 | 27,392 | 6,565 | 8,503 | 0 | 0 | 0 | 6,348 | 156,121 |
| Michigan | 268,629 | 577,579 | 41,288 | 13,569 | 0 | 26,408 | 0 | 26,081 | 0 | 953,554 |
| Minnesota | 23,735 | 510,654 | 56,709 | 2,864 | 40,394 | 12,791 | 169,933 | 15,622 | 12,677 | 845,379 |
| Mississippi | 17,109 | 168,113 | 12,305 | 3,930 | 0 | 0 | 0 | 0 | 0 | 201,457 |
| Missouri | 9,326 | 227,118 | 43,244 | 155 | 0 | 500 | 502 | 1,948 | 43,360 | 326,153 |
| Montana | 19,125 | 33,596 | 0 | 152 | 0 | 147 | 18 | 346 | 0 | 53,384 |
| Nebraska | 5,939 | 47,034 | 9,968 | 24 | 8,819 | 75 | 191 | 155 | 3,558 | 75,763 |
| Nevada | 3,574 | 21,223 | 18,681 | 483 | 13,524 | 233 | 0 | 165 | 697 | 58,580 |
| New Hampshire | 15,887 | 53,193 | 16,282 | 2,324 | 0 | 0 | 0 | 4,183 | 8,966 | 100,835 |
| New Jersey | 18,623 | 112,269 | 38,683 | 7,174 | 22,589 | 6,011 | 0 | 1,793 | 446 | 207,588 |
| New Mexico | 3,284 | 21,246 | 7,035 | 182 | 6,821 | 0 | 0 | 1,291 | 435 | 40,294 |
| New York | 99,062 | 280,721 | 132,021 | 6,687 | 0 | 0 | 0 | 0 | 9,603 | 528,094 |
| North Carolina | 16,929 | 245,772 | 44,575 | 3,583 | 39,759 | 0 | 0 | 1,788 | 7,451 | 359,857 |
| North Dakota | 2,909 | 36,549 | 4,295 | 130 | 4,457 | 0 | 513 | 67 | 329 | 49,249 |
| Ohio | 31,626 | 189,359 | 66,634 | 1,923 | 42,849 | 11,721 | 52,339 | 9,418 | 7,179 | 413,048 |
| Oklahoma | 40,787 | 164,219 | 22,950 | 1,822 | 0 | 0 | 0 | 0 | 0 | 229,778 |

*(Continued)*



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**Table 7N.158 (Continued)**

| | Boat Registration Data by State[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Powered | | | | | Nonpowered | | | Other | Total |
| | Inboard | Outboard | Sterndrive | Auxiliary Sail | PWC | Rowboat | Canoe or Kayak | Sail Only | Other Boats | Total |
| Oregon | 64,352 | 125,047 | 0 | 4,971 | 0 | 0 | 0 | 0 | 3,221 | 197,591 |
| Pennsylvania | 30,445 | 237,196 | 47,972 | 344 | 0 | 2,082 | 24,337 | 1,801 | 11,058 | 355,235 |
| Rhode Island | 4,824 | 22,502 | 9,983 | 3,372 | 2,326 | 0 | 0 | 0 | 0 | 43,007 |
| South Carolina | 13,464 | 278,142 | 36,498 | 5,345 | 25,421 | 17,226 | 180 | 1,782 | 2,256 | 380,314 |
| South Dakota | 1,877 | 36,069 | 10,739 | 244 | 0 | 0 | 0 | 0 | 4,540 | 53,469 |
| Tennessee | 41,701 | 188,816 | 28,864 | 525 | 0 | 0 | 0 | 1,730 | 0 | 261,636 |
| Texas | 117,514 | 404,827 | 87,257 | 0 | 0 | 0 | 0 | 2,398 | 7,092 | 619,088 |
| Utah | 11,527 | 29,363 | 19,329 | 0 | 14,645 | 0 | 0 | 1,314 | 0 | 76,178 |
| Vermont | 8,517 | 24,743 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33,260 |
| Virginia | 6,261 | 156,813 | 43,019 | 4,602 | 25,968 | 0 | 0 | 234 | 5,096 | 241,993 |
| Washington | 0 | 156,447 | 98,586 | 10,740 | 0 | 0 | 0 | 0 | 0 | 265,773 |
| West Virginia | 4,419 | 39,239 | 5,566 | 0 | 2,405 | 0 | 0 | 0 | 7,088 | 58,717 |
| Wisconsin | 42,696 | 514,895 | 52,881 | 0 | 0 | 0 | 0 | 0 | 328 | 610,800 |
| Wyoming | 14,977 | 1,962 | 5,599 | 0 | 2,555 | 0 | 89 | 100 | 443 | 25,725 |
| Guam[b] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,000 | 4,000 |
| Puerto Rico | 8,195 | 33,993 | 1,804 | 967 | 15,949 | 0 | 0 | 0 | 3 | 60,911 |
| Virgin Islands | 809 | 1,834 | 96 | 1,168 | 14 | 46 | 41 | 53 | 0 | 4,061 |
| Amer Samoa | 19 | 75 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 102 |
| No. Marianas | 85 | 297 | 3 | 0 | 68 | 2 | 0 | 0 | 0 | 455 |

[a] The figures in this table are derived from reports from the State and jurisdictions. There are a total of 12,794,616 registered recreational vessels. This table classifies registered motorboats and registered nonpowered boats for each State and jurisdiction. Please note that the scope of the boat registration system for each State and jurisdiction is not the same. This explains why some States report the number of non-powered vessels such as rowboats, canoes, and non-powered sailboats and others do not. Also notice that some State and jurisdictions report Personal Watercraft (PWC) as a separate vessel category and others report PWC as an inboard motorboat. An accurate figure on the number of PWC will be provided when all States and jurisdictions classify and report PWC as a separate as a separate vessel category.

[b] Estimate.

*Source*: From U.S. Department of Homeland Security, United States Coast Guard, 2004, Boating Statistics 2003, COMDTPUB P16754017, www.uscgboating.org.

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**Table 7N.159 Fatality Rate in Recreational Boating in the United States, 1991–2003**

| Year | Fatalities | Number of Registered Boats | Fatalities Per 100,000 Registered Boats |
|---|---|---|---|
| 1991 | 924 | 11,068,440 | 8.3 |
| 1992 | 816 | 11,132,386 | 7.3 |
| 1993 | 800 | 11,282,736 | 7.1 |
| 1994 | 784 | 11,429,585 | 6.9 |
| 1995 | 829 | 11,734,710 | 7.1 |
| 1996 | 709 | 11,877,938 | 5.9 |
| 1997 | 821 | 12,312,982 | 6.7 |
| 1998 | 815 | 12,565,930 | 6.5 |
| 1999 | 734 | 12,738,271 | 5.8 |
| 2000 | 701 | 12,782,143 | 5.5 |
| 2001 | 681 | 12,876,346 | 5.3 |
| 2002 | 750 | 12,854,054 | 5.8 |
| 2003 | 703 | 12,794,616 | 5.5 |

*Source*: From U.S. Department of Homeland Security, United States Coast Guard, 2004, Boating Statistics 2003, COMDTPUB P16754.17, www.uscgboating.org.

**Table 7N.160 Types of Boating Accidents in the United States, 2003**

| | Types of Boating Accidents | | | | |
|---|---|---|---|---|---|
| | Accidents | Vessels Involved | Drowning Deaths | Other Deaths | Total Fatalities |
| **Total** | **5,438** | **7,363** | **481** | **22** | **703** |
| Capsizing | 514 | 576 | 170 | 36 | 206 |
| Collision with fixed object | 558 | 629 | 19 | 31 | 50 |
| Collision with floating object | 152 | 215 | 1 | 2 | 3 |
| Collision with another vessel | 1,469 | 2,972 | 9 | 61 | 70 |
| Falls within boat | 233 | 249 | 3 | 3 | 6 |
| Falls overboard | 509 | 530 | 169 | 32 | 201 |
| Fire/explosion (fuel) | 142 | 163 | 4 | 3 | 7 |
| Fire/explosion (other than fuel) | 68 | 79 | 0 | 2 | 2 |
| Flooding/swamping | 274 | 293 | 36 | 5 | 41 |
| Grounding | 291 | 297 | 2 | 6 | 8 |
| Sinking | 128 | 135 | 6 | 2 | 8 |
| Skier mishap | 451 | 477 | 1 | 5 | 6 |
| Struck by boat | 89 | 128 | 1 | 8 | 9 |
| Struck by motor or propeller | 107 | 120 | 1 | 5 | 6 |
| Struck submerged object | 128 | 129 | 2 | 2 | 4 |
| Other (not specified) | 80 | 88 | 1 | 3 | 4 |
| Carbon monoxide poisoning | 20 | 20 | 0 | 7 | 7 |
| Departed vessel (swimming) | 34 | 34 | 28 | 1 | 29 |
| Departed vessel (other) | 11 | 11 | 10 | 0 | 10 |
| Ejected from vessel | 7 | 7 | 3 | 2 | 5 |
| Falls on PWC | 15 | 18 | 0 | 1 | 1 |
| Not reported | 158 | 193 | 15 | 5 | 20 |

*Source*: From U.S. Department of Homeland Security, United States Coast Guard, 2004, Boating Statistics 2003, COMDTPUB P16754.17, www.uscgboating.org.

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**Table 7N.161 Boating Accidents in the United States, 2003**

| | Time Period | Accidents | Fatalities |
|---|---|---|---|
| Time of Day | Midnight to 2:30 am | 174 | 44 |
| | 2:31 am to 4:30 am | 54 | 9 |
| | 4:31 am to 6:30 am | 65 | 11 |
| | 6:31 am to 8:30 am | 131 | 22 |
| | 8:31 am to 10:30 am | 305 | 33 |
| | 10:31 am to 12:30 pm | 579 | 65 |
| | 12:31 pm to 2:30 pm | 878 | 90 |
| | 2:31 pm to 4:30 pm | 1,163 | 124 |
| | 4:31 pm to 6:30 pm | 973 | 104 |
| | 6:31 pm to 8:30 pm | 575 | 85 |
| | 8:31 pm to 10:30 pm | 297 | 61 |
| | 10:31 pm to midnight | 132 | 21 |
| | Unknown | 112 | 34 |
| Month of Year | January | 70 | 24 |
| | February | 98 | 18 |
| | March | 180 | 34 |
| | April | 225 | 47 |
| | May | 638 | 87 |
| | June | 849 | 95 |
| | July | 1,480 | 112 |
| | August | 1,075 | 109 |
| | September | 383 | 67 |
| | October | 235 | 50 |
| | November | 127 | 35 |
| | December | 78 | 25 |
| Day of Week | Monday | 485 | 76 |
| | Tuesday | 393 | 62 |
| | Wednesday | 395 | 66 |
| | Thursday | 397 | 62 |
| | Friday | 768 | 113 |
| | Saturday | 1,560 | 159 |
| | Sunday | 1,440 | 165 |
| **Totals** | | **5,438** | **703** |

*Source*: U.S. Department of Homeland Security, United States Coast Guard, 2004, Boating Statistics 2003, COMDTPUB P16754.17, www.uscgboating.org.

**Table 7N.162 Life Expectancy in Water**

| | Water Temperature | | | | |
|---|---|---|---|---|---|
| **Duration, Hours** | **30°F** | **40°F** | **50°F** | **60°F** | **70°F** |
| 1 | M | M | M | S | S |
| 2 | L | L | M | M | S |
| 3 | L | L | M | M | S |
| 4 | L | L | L | M | S |

*Note:* Exposure by immersion in low temperature water can have serious consequences. Life expectancies for various durations of exposure are indicated by: L — Lethal, 100 percent expectancy of death; M — Marginal, 50 percent expectancy of unconsciousness which will probably result in drowning; S — Safe. It should also be noted that sudden immersion in ice cold water can cause temporary paralysis with resulting helplessness and loss of buoyancy, causing the victim to sink to the bottom.

*Source*: Pan American Airways and Calif. Dept. of Harbors and Watercraft. With permission.

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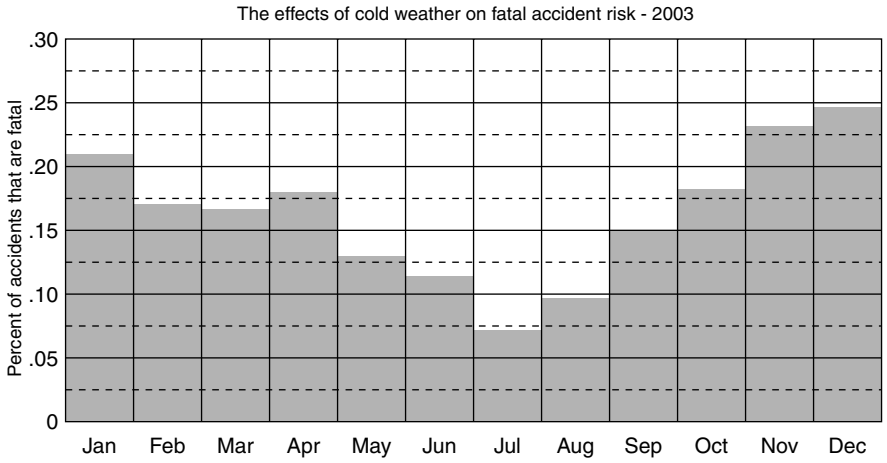


Boaters are more likely to perish if they are involved in a reported accident during the fall & winter months

| Month | Fatal accidents | Non-fatal accidents | Total accidents | Fatal accident risk | Total fatalities |
|---|---|---|---|---|---|
| January | 15 | 55 | 70 | 21% | 24 |
| February | 17 | 81 | 98 | 17% | 18 |
| March | 29 | 151 | 180 | 16% | 34 |
| April | 41 | 184 | 225 | 18% | 47 |
| May | 81 | 557 | 638 | 13% | 87 |
| June | 90 | 759 | 849 | 11% | 95 |
| July | 106 | 1,374 | 1,480 | 7% | 112 |
| August | 96 | 979 | 1,075 | 9% | 109 |
| September | 56 | 327 | 383 | 15% | 67 |
| October | 42 | 193 | 235 | 18% | 50 |
| November | 29 | 98 | 127 | 23% | 35 |
| December | 19 | 59 | 78 | 24% | 25 |
| Total | 621 | 4,817 | 5,438 | | 703 |

**Figure 7N.25** The effects of cold water on fatal accidents, 2002. U.S. Department of Homeland Security, United States Coast Guard, 2004, Boating Statistics 2003, COMDTPUB P16754.17, uscgboating.org/statistics/Boating_Statistics_2003.pdf. http://library.fws.gov/nat_survey2001_trends.pdf.

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**Table 7N.163 Number of Fishing Participants, Days, and Expenditures of Sport Fishermen in the United States, 1991, 1996, and 2001**

| | 1991 | | 1996 | | 2001 | | 1991–2001 | 1996–2001 |
|---|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | %change | %change |
| **Participants** | | | | | | | | |
| **Anglers, Total** | **35,578** | **100** | **35,246** | **100** | **34,067** | **100** | **−4** | **−3** |
| All freshwater | 31,041 | 87 | 29,734 | 84 | 28,439 | 83 | −8 | −4 |
| Freshwater, except Great Lakes | 30,186 | 85 | 28,921 | 82 | 27,913 | 82 | −8 | −3[a] |
| Great Lakes | 2,552 | 7 | 2,039 | 6 | 1,847 | 5 | −28 | −9[a] |
| Saltwater | 8,885 | 25 | 9,438 | 27 | 9,051 | 26 | 2[a] | −4[a] |
| **Days** | | | | | | | | |
| **Total** | **511,329** | **100** | **625,893** | **100** | **557,394** | **100** | **9** | **−11** |
| All freshwater | 439,536 | 86 | 515,115 | 82 | 466,984 | 84 | 6 | −9 |
| Freshwater, except Great Lakes | 430,922 | 84 | 485,474 | 78 | 443,247 | 80 | 3[a] | −9 |
| Great Lakes | 25,335 | 5 | 20,095 | 3 | 23,138 | 4 | −9[a] | 15[a] |
| Saltwater | 74,696 | 15 | 103,034 | 17 | 90.838 | 16 | 22 | −12[a] |
| **Expenditures (in 2001 dollars)** | | | | | | | | |
| **Fishing, Total** | **$31,175,168** | **100** | **$42,710,679** | **100** | **$35,632,132** | **100** | **14** | **−17** |
| Trips | 15,396,151 | 49 | 17,380,775 | 41 | 14,656,001 | 41 | −5[a] | −16 |
| Equipment | 12,170,062 | 39 | 21,666,341 | 51 | 16,963,398 | 48 | 39 | −22 |
| Fishing equipment | 4,860,266 | 16 | 5,998,802 | 14 | 4,617,488 | 13 | −5[a] | −23 |
| Auxiliary equipment | 804,953 | 3 | 1,171,540 | 3 | 721,048 | 2 | −10[a] | −38 |
| Special equipment | 6,504,844 | 21 | 14,495,999 | 34 | 11,624,862 | 33 | 79 | −20[a] |
| Other | 3,608,953 | 12 | 3,663,563 | 9 | 4,012,733 | 11 | 11 | 10[a] |

*Note:* U.S. Population 16 Years Old and Older, Numbers in Thousands.

[a] Not different from zero at the 5 percent level.

*Source*: From U.S. Department of Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau, 2002,2001 National Survey of Fishing, Hunting and Wildlife-Associated Recreation, cenovs.gov.

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**Table 7N.164 Number and Cost of Sport Fishing Licenses in the United States, 1991, 1996, and 2001**

| | 1991 | | 1996 | | 2001 | |
|---|---|---|---|---|---|---|
| **Anglers** | **Number (Thousands)** | **Percent** | **Number (Thousands)** | **Percent** | **Number (Thousands)** | **Percent** |
| Total anglers | 35,578 | 100 | 35,246 | 100 | 34,071 | 100 |
| Total license purchasers[a] | 23,302 | 65 | 23,203 | 66 | 21,396 | 63 |
| Anglers purchasing licenses: In state of residence | 21,445 | 60 | 21,437 | 61 | 20,004 | 59 |
| In other states | 3,653 | 10 | 4,356 | 12 | 3,781 | 11 |
| Total exempt from purchasing licenses | 3,037 | 9 | 3,281 | 9 | 4,284 | 13 |
| Anglers exempt from license purchase: In state of residence | 2,596 | 7 | 2,365 | 7 | 3,959 | 12 |
| In other states | 375 | 1 | 427 | 1 | 608 | 2 |
| Other[b] | 6,586 | 19 | 9,143 | 26 | 10,268 | 30 |
| Not reported | 3,329 | 9 | 558 | 2 | 448 | 1 |
| **Expenditures** | **1991 Thousands of Dollars** | | **1996 Thousands of Dollars** | | **2001 Thousands of Dollars** | |
| Total, all licenses, stamps, tags and permits | 486,700 | | 579,753 | | 639876 | |
| Licenses | 443,287 | | 519,061 | | 597,210 | |
| Stamps, tags, permits | 43,414 | | 60,692 | | 42,666 | |

*Note:* Detail does not add to total because of multiple responses and nonresponse. Respondents could have been licensed in one state and exempt in another.

[a] Includes persons who had license bought for them. Does not include persons who purchase license and did not fish in 1991, 1996, and 2001.

[b] Includes persons engaged in activities requiring to license or exemptions and those who failed to buy a license for activities requiring a license.

*Source*: From U.S. Department of Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau, 2002, 2001 National Survey of Fishing, Hunting and Wildlife-Associated Recreation; U.S. Department of Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau, 1998, 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation; U.S. Department of Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau, 1993, 1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, www.census.gov.

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**Table 7N.165 Fish Trips and Fish Harvested: Estimated Number of Fishing Trips Taken by Marine Recreational Fisherman by Subregion and Year, Atlantic and Pacific Coasts, 1998–2001**

| | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| **Subregion** | **Fish Trips** | **Fish Harvested** | **Fish Trips** | **Fish Harvested** | **Fish Trips** | **Fish Harvested** | **Fish Trips** | **Fish Harvested** |
| North Atlantic | 6,796 | 6783 | 6,478 | 8841 | 8,765 | 17185 | 9,035 | 12153 |
| Mid-Atlantic | 14,453 | 29447 | 14,105 | 24756 | 19,451 | 50,652 | 21,206 | 34704 |
| South Atlantic[b] | 16,837 | 24704 | 14,435 | 33914 | 20,075 | 40,414 | 21,596 | 43824 |
| Gulf[b] | 16,703 | 60561 | 15,894 | 55525 | 21,018 | 67385 | 22,890 | 76571 |
| **Total** | 54,789 | 121495 | 50,912 | 123036 | 69,309 | 175,616 | 74,727 | 167252 |
| Pacific:[c] | | | | | | | | |
| Southern California | 2,973 | 5827 | 2,437 | 5098 | 3,787 | 7494 | 4,052 | 7726 |
| Northern California | 1,932 | 6123 | 1,713 | 3909 | 2,158 | 3787 | 2,208 | 4799 |
| Oregon | 649 | 1712 | 554 | 1153 | 930 | 1848 | 1,170 | 21283 |
| Washington | 1,463 | 5220 | 1,256 | 2486 | 1,643 | 3288 | 2,191 | 4796 |
| Total | 7,017 | 18882 | 5,960 | 12646 | 8,518 | 16,367 | 9,621 | 19,446 |

*Note:* "Harvested" includes dead discards and fish used for bait but does not include fish released alive. Numbers in thousands.

[a] 1998–2000 were revised. Data do not include recreational catch in Texas.
[b] Does not include catch from headboats (party boats) in the South Atlantic and Gulf of Mexico.
[c] Data do not include recreational catch in Hawaii or Alaska. Pacific state estimates do not include salmon data collected by recreational surveys.

*Source*: From USDA–NASS, Agricultural Statistics 2003, Miscellaneous, Agricultural Statistics, www.usda.gov.

*Original Source*: U.S. Department of Commerce, NOAA, NMFS, Fisheries Statistics and Economics Division, www.nass.usda.gov.

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# SECTION 7O FISHERIES

**Table 7O.166 United States Fisheries—Quantity and Value of Catch, by Region and by State, 1999–2003**

| Regions and States | 1999 | | 2000 | | 2001 | | 2002 | | 2003 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Thousand Pounds | Thousand Dollars | Thousand Pounds | Thousand Dollars | Thousand Pounds | Thousand Dollars | Thousand Pounds | Thousand Dollars | Thousand Pounds | Thousand Dollars |
| **New England** | 583,863 | 655,377 | 570,728 | 681,092 | 635,162 | 646,447 | 583,915 | 685,428 | 666,179 | 683,395 |
| Maine | 229,633 | 265,236 | 226,849 | 275,107 | 239,868 | 251,441 | 197,057 | 279,396 | 232,284 | 283,802 |
| New Hampshire | 11,258 | 12,542 | 17,160 | 13,951 | 18,584 | 17,865 | 23,201 | 16,691 | 27,410 | 15,125 |
| Massachusetts | 198,336 | 260,239 | 187,861 | 288,263 | 242,066 | 281,059 | 243,824 | 297,312 | 294,477 | 291,596 |
| Rhode Island | 126,206 | 79,270 | 119,295 | 72,544 | 115,957 | 65,457 | 103,656 | 64,250 | 95,727 | 63,054 |
| Connecticut | 18,430 | 38,090 | 19,563 | 31,227 | 18,687 | 30,625 | 16,177 | 27,779 | 16,281 | 29,818 |
| **Middle Atlantic** | 225,278 | 180,673 | 219,661 | 173,296 | 217,975 | 172,503 | 206,697 | 170,134 | 214,454 | 177,404 |
| New York | 48,175 | 76,049 | 41,181 | 59,426 | 42,422 | 55,038 | 38,665 | 51,334 | 39,409 | 51,628 |
| New Jersey | 168,676 | 97,731 | 171,804 | 107,163 | 168,430 | 109,820 | 162,175 | 112,733 | 170,017 | 120,556 |
| Delaware | 8,427 | 6,893 | 6,676 | 6,707 | 7,123 | 7,645 | 5,857 | 6,067 | 5,018 | 5,204 |
| **Chesapeake** | 527,407 | 172,012 | 492,110 | 172,210 | 617,244 | 174,968 | 495,675 | 172,320 | 10 | 16 |
| Maryland | 67,118 | 63,759 | 48,913 | 53,874 | 55,536 | 55,586 | 53,185 | 49,013 | 496,178 | 179,701 |
| Virginia | 460,289 | 108,253 | 443,197 | 118,336 | 561,708 | 119,382 | 442,490 | 123,307 | 49,350 | 49,038 |
| **South Atlantic** | 230,971 | 198,347 | 221,350 | 204,480 | 199,554 | 176,488 | 214,799 | 173,429 | 446,828 | 130,663 |
| North Carolina | 154,869 | 97,304 | 155,214 | 95,305 | 139,277 | 90,202 | 159,557 | 98,723 | 203,566 | 161,445 |
| South Carolina | 17,773 | 29,265 | 15,835 | 30,344 | 14,111 | 23,398 | 13,458 | 20,760 | 139,215 | 82,960 |
| Georgia | 11,234 | 21,100 | 9,694 | 21,331 | 9,036 | 14,752 | 9,563 | 15,068 | 22,043 | 29,075 |
| Florida, East Coast | 47,095 | 50,678 | 40,607 | 57,500 | 37,130 | 48,136 | 32,221 | 38,878 | 7,453 | 13,510 |
| **Gulf** | 1,945,063 | 757,857 | 1,759,993 | 910,685 | 1,605,564 | 798,319 | 1,716,140 | 692,717 | 34,855 | 35,900 |
| Florida, West Coast | 83,792 | 146,976 | 79,415 | 155,200 | 78,105 | 143,810 | 78,975 | 138,968 | 1,600,481 | 683,276 |
| Alabama | 27,399 | 50,415 | 29,931 | 63,275 | 24,740 | 43,170 | 23,380 | 35,102 | 76,448 | 135,912 |
| Mississippi | 267,546 | 48,526 | 217,744 | 58,715 | 213,889 | 50,561 | 217,053 | 46,093 | 25,344 | 39,521 |
| Louisiana | 1,480,045 | 302,735 | 1,344,913 | 401,095 | 1,191,460 | 342,748 | 1,308,531 | 305,534 | 213,116 | 45,508 |
| Texas | 86,281 | 209,205 | 87,990 | 232,400 | 97,370 | 218,030 | 88,201 | 167,020 | 1,189,448 | 294,011 |
| **Pacific Coast** | 5,765,700 | 1,422,258 | 5,750,364 | 1,320,763 | 6,173,671 | 1,187,106 | 6,138,249 | 1,130,633 | 96,125 | 168,324 |
| Alaska | 4,492,649 | 1,105,946 | 4,465,987 | 956,990 | 5,036,338 | 869,885 | 5,066,263 | 811,545 | 6,277,566 | 1,375,763 |
| Washington | 392,555 | 98,471 | 380,223 | 145,311 | 337,231 | 134,454 | 362,049 | 142,521 | 5,305,960 | 989,781 |
| Oregon | 233,177 | 67,590 | 262,917 | 79,351 | 234,097 | 72,516 | 211,183 | 68,431 | 379,732 | 170,158 |
| California | 647,319 | 150,251 | 641,237 | 139,111 | 526,005 | 110,251 | 498,754 | 108,136 | 225,528 | 85,549 |
| **Great Lakes** | 23,843 | 16,009 | 22,245 | 18,508 | 18,818 | 17,844 | 17,848 | 15,544 | 366,346 | 130,275 |
| Illinois | 86 | 50 | 49 | 35 | 16 | 14 | – | – | 17,471 | 13,174 |
| Indiana | — | — | — | — | — | — | — | — | — | — |
| Michigan | 13,546 | 9,339 | 12,704 | 8,963 | 10,322 | 9,235 | 9,459 | 7,362 | 8,690 | 5,702 |
| Minnesota | 443 | 197 | 377 | 172 | 501 | 202 | 449 | 180 | 435 | 228 |
| New York | 1 | 2 | 49 | 75 | 71 | 113 | 47 | 81 | 43 | 50 |
| Ohio | 3,932 | 2,186 | 3,497 | 2,442 | 3,535 | 3,287 | 3,427 | 3,093 | 3,994 | 3,037 |
| Pennsylvania | 32 | 43 | 20 | 29 | 25 | 44 | 15 | 37 | 11 | 23 |
| Wisconsin | 5,803 | 4,192 | 5,549 | 6,792 | 4,348 | 4,949 | 4,451 | 4,791 | 4,298 | 4,134 |
| **Hawaii** | 36,907 | 64,557 | 32,531 | 68,447 | 23,870 | 54,561 | 23,841 | 52,113 | 23,556 | 52,433 |
| **Utah** | — | — | — | — | — | — | — | — | 5,997 | 15,593 |
| **Total, United States** | 9,339,032 | 3,467,090 | 9,068,982 | 3,549,481 | 9,491,858 | 3,228,236 | 9,397,164 | 3,092,318 | 9,505,448 | 3,342,184 |

*Note:* Landings are reported in round (live) weight for all items except univalve and bivalve mollusks such as clams, oysters, scallops, which are reported in weight of meats (excluding the shell). Landings for Mississippi River drainage area States are not available. Data are preliminary. Landings of Alaska pollock, Pacific whiting, and other Pacific groundfish that are caught in waters off Washington, Oregon, and Alaska and are processed at-sea aboard U.S. vessels are credited to the State nearest to the area of capture. Totals may not add due to roundings. Data do not include landings by U.S.-flag vessels at Puerto Rico and other ports outside the 50 States. Data do not include aquaculture products, except oysters and clams.

*Source*: From U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2004, Fisheries of the United States 2003; U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2003, Fisheries of the United States 2002; U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2002, Fisheries of the United States 2001; U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2001, Fisheries of the United States 2000, www.st.nmfs.gov.

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**Table 7O.167 Major U.S. Domestic Species Landed in 2003 Ranked by Quantity and Value**

| Rank | Species | Pounds | Rank | Species | Dollars |
|---|---|---|---|---|---|
| 1 | Pollock | 3,372,338 | 1 | Crabs | 483,586 |
| 2 | Menhaden | 1,599,444 | 2 | Shrimp | 424,027 |
| 3 | Salmon | 674,096 | 3 | Lobsters | 308,005 |
| 4 | Cod | 591,130 | 4 | Flatfish | 266,618 |
| 5 | Flatfish | 444,075 | 5 | Scallops | 229,240 |
| 6 | Hakes | 339,944 | 6 | Pollock | 208,581 |
| 7 | Crabs | 338,854 | 7 | Salmon | 200,838 |
| 8 | Shrimp | 313,624 | 8 | Cod | 187,113 |
| 9 | Herring (sea) | 286,050 | 9 | Clams | 162,838 |
| 10 | Sardines | 159,493 | 10 | Oysters | 103,045 |

*Note:* Numbers in thousands.

*Source*: From U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2004, Fisheries of the United States 2003, www.st.nmfs.gov.

**Table 7O.168 United States Domestic Fish and Shellfish Catch and Value by Major Species Caught, 1990–2002**

| | Quantity (1,000 lb) | | | | Value ($1,000) | | | |
|---|---|---|---|---|---|---|---|---|
| **Species** | **1990** | **2000** | **2001** | **2002** | **1990** | **2000** | **2001** | **2002** |
| Cod: Atlantic | 95,881 | 25,060 | 33,211 | 29,841 | 61,329 | 26,384 | 32,086 | 30,715 |
| Pacific | 526,396 | 530,505 | 471,711 | 512,827 | 91,384 | 142,330 | 118,071 | 96,206 |
| Flounder | 254,519 | 412,723 | 352,363 | 372,697 | 112,921 | 109,910 | 105,240 | 102,370 |
| Halibut | 70,454 | 75,190 | 77,978 | 82,044 | 96,700 | 143,826 | 115,169 | 135,603 |
| Herring, sea; Atlantic | 113,095 | 160,269 | 209,191 | 135,871 | 5,746 | 9,972 | 12,717 | 9,106 |
| Herring, sea; Pacific | 108,120 | 74,835 | 91,297 | 78,408 | 32,178 | 12,043 | 13,213 | 11,534 |
| Menhaden | 1,962,160 | 1,760,498 | 1,741,430 | 1,750,609 | 93,896 | 112,403 | 102,690 | 105,102 |
| Pollock, Alaska | 3,108,031 | 2,606,802 | 3,179,407 | 3,341,105 | 268,344 | 160,525 | 230,723 | 203,696 |
| Salmon | 733,146 | 628,638 | 722,832 | 567,179 | 612,367 | 270,213 | 208,926 | 155,010 |
| Tuna | 62,393 | 50,779 | 51,854 | 49,358 | 105,040 | 95,176 | 93,497 | 84,116 |
| Whiting (Atlantic, silver) | 44,500 | 26,855 | 28,479 | 17,622 | 11,281 | 11,370 | 13,232 | 7,454 |
| Whiting (Pacific, hake) | 21,232 | 452,718 | 379,304 | 285,714 | 1,229 | 18,809 | 16,147 | 13,584 |
| Shellfish, total[a] | 1,312,503 | 1,379,324 | 1,138,512 | 1,178,590 | 1,621,898 | 1,954,666 | 1,711,391 | 1,706,426 |
| Clams | 139,198 | 118,482 | 122,764 | 130,076 | 130,194 | 153,973 | 161,992 | 167,215 |
| Crabs | 499,416 | 299,006 | 272,246 | 307,601 | 483,837 | 405,006 | 381,667 | 397,695 |
| Lobsters: American | 61,017 | 83,180 | 73,637 | 82,252 | 154,677 | 301,300 | 254,334 | 293,329 |
| Oysters | 29,193 | 41,146 | 32,673 | 34,397 | 93,718 | 90,667 | 80,946 | 89,071 |
| Scallops, sea | 39,917 | 32,747 | 46,958 | 53,056 | 153,696 | 164,609 | 175,349 | 203,707 |
| Shrimp | 346,494 | 332,486 | 324,481 | 316,727 | 491,433 | 690,453 | 568,547 | 460,878 |
| Squid, Pacific | 36,082 | 259,508 | 191,532 | 160,677 | 2,636 | 27,077 | 17,834 | 18,262 |
| Total | 9,403,571 | 9,068,985 | 9,491,836 | 9,397,164 | 3,521,995 | 3,549,481 | 3,228,285 | 3,092,318 |
| Fish, total[a] | 8,091,068 | 7,689,661 | 8,242,490 | 8,089,987 | 1,900,097 | 1,594,815 | 1,479,988 | 1,359,392 |

[a] Includes other types of fish and shellfish, not shown separately.

*Source*: From U.S. Census Bureau, *Statistical Abstract of the United States*. 2004–2005, www.census.gov.

*Original Source*: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Fisheries of the United States, annual.

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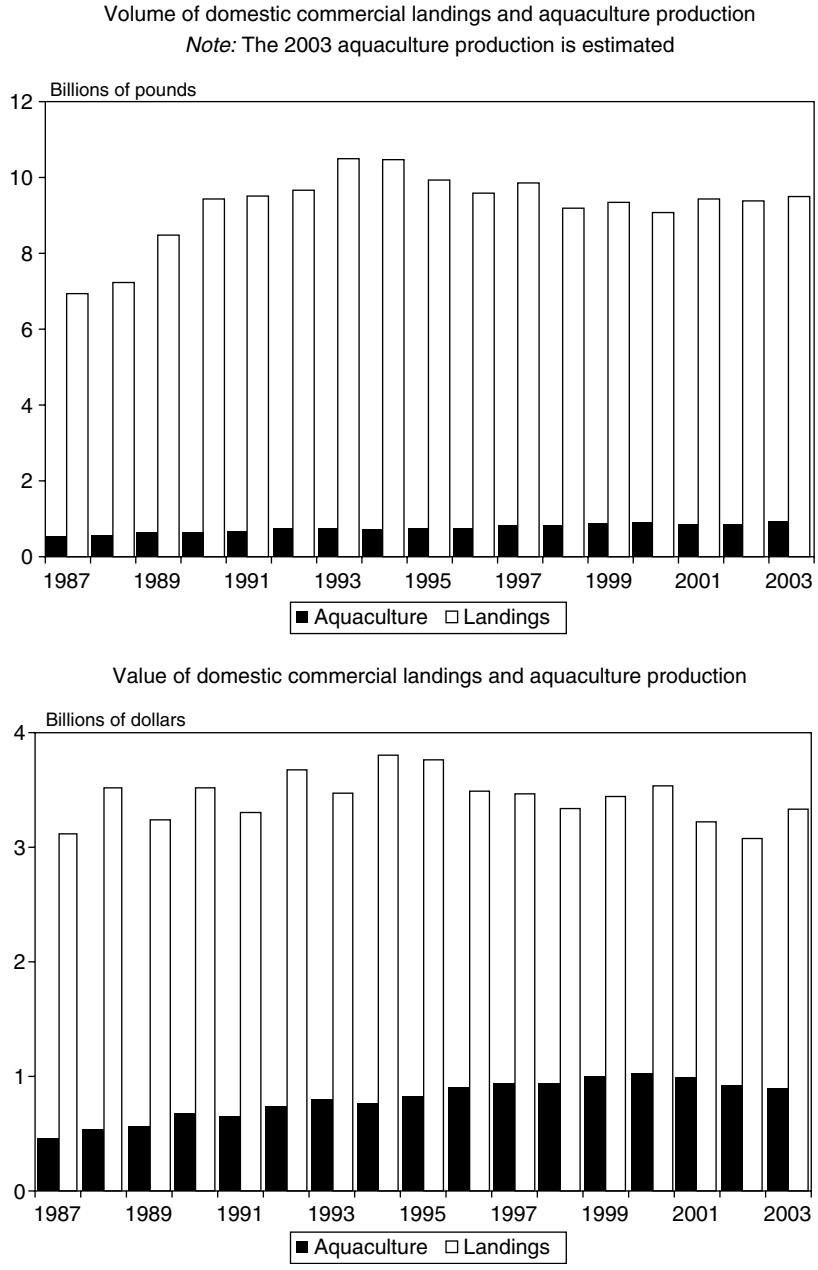


**Figure 7O.26** Quantity and volume of domestic commercial landings and aquaculture production in the United States, 2003. (From U.S. Department of Commerce, NOAA, and National Marine Fisheries Service, 2004, Fisheries of the United States 2003, www.st.nmfs.gov.)

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**Table 7O.169 United States Fisheries Estimated Number of Commercial Fishing Vessels and Fishing Boats by Region and State, 1998–2002**

| | 1998 | | | 1999 | | | 2000 | | | 2001 | | | 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area and State** | **Vessels** | **Boats** | **Total** | **Vessels** | **Boats** | **Total** | **Vessels** | **Boats** | **Total** | **Vessels** | **Boats** | **Total** | **Vessels** | **Boats** | **Total** |
| **Northeast** | | | | | | | | | | | | | | | |
| Connecticut | 245 | 318 | 563 | 232 | 281 | 513 | 182 | 243 | 425 | 182 | 243 | 425 | NA | NA | NA |
| Delaware | 175 | NA | 175 | 178 | NA | NA | 184 | NA | NA | 184 | NA | NA | NA | NA | NA |
| Maine | 1,642 | 5,799 | 7,441 | 1,653 | 5,821 | 7,474 | 1,656 | 5,836 | 7,492 | 1,656 | 5,836 | 7,492 | NA | NA | NA |
| Maryland[a] | 33 | NA | 33 | 34 | NA | NA | 32 | NA | NA | 32 | NA | NA | NA | NA | NA |
| Massachusetts | 715 | 4,500 | 5,215 | 700 | 4,520 | 5,220 | 695 | 4,540 | 5,235 | 695 | 4,540 | 5,235 | NA | NA | NA |
| New Hampshire | 115 | 461 | 576 | 121 | 468 | 589 | 109 | 471 | 580 | 109 | 471 | 580 | NA | NA | NA |
| New Jersey | 387 | 1,147 | 1,534 | 421 | NA | NA | 397 | NA | NA | 397 | NA | NA | NA | NA | NA |
| New York[b] | 689 | 2,931 | 3,620 | 678 | 2,825 | 3,503 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Rhode Island | 312 | 2,401 | 2,713 | 330 | 2,239 | 2,569 | 344 | 2,920 | 3,264 | 344 | 2,920 | 3,264 | NA | NA | NA |
| Virginia[a] | 122 | NA | 122 | 241 | NA | NA | 261 | NA | NA | 261 | NA | NA | NA | NA | NA |
| **South Atlantic and Gulf** | | | | | | | | | | | | | | | |
| North Carolina | 891 | NA | 891 | 667 | NA | NA | 773 | NA | NA | 773 | NA | NA | 763 | NA | NA |
| South Carolina | 569 | NA | 569 | 577 | NA | NA | 520 | NA | NA | 520 | NA | NA | 556 | NA | NA |
| Georgia | 350 | NA | 350 | 350 | NA | NA | 265 | NA | NA | 265 | NA | NA | 226 | NA | NA |
| Florida | 2,384 | 6,157 | 8,541 | 2,214 | 5,602 | 7,816 | 2,136 | 5,502 | 7,638 | 2,136 | 5,502 | 7,638 | 1,934 | 4,438 | 6,372 |
| Alabama | 398 | 1,338 | 1,736 | 454 | 1,231 | 1,685 | 443 | 1,328 | 1,771 | 443 | 1,328 | 1,771 | 425 | 1,350 | 1,775 |
| Mississippi | 454 | 688 | 1,142 | 502 | 707 | 1,209 | 504 | 743 | 1,247 | 504 | 743 | 1,247 | 522 | 843 | 1,365 |
| Louisiana | 2,535 | 11,637 | 14,172 | 2,450 | 11,414 | 13,864 | 2,393 | 11,830 | 14,223 | 2,393 | 11,830 | 14,223 | 2,084 | 8,874 | 10,958 |
| Texas | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **West Coast** | | | | | | | | | | | | | | | |
| Alaska | 6,384 | 9,445 | 15,829 | 6,232 | 9,374 | 15,606 | 6,169 | 9,461 | 15,630 | 6,126 | 9,062 | 15,188 | 5,494 | 8,541 | 14,035 |
| Washington | 904 | 428 | 1,332 | 783 | 343 | 1,126 | 726 | 355 | 1,081 | 726 | 355 | 1,081 | 695 | 329 | 1,024 |
| Oregon | 668 | 296 | 964 | 643 | 308 | 951 | 721 | 376 | 1,097 | 721 | 376 | 1,097 | 639 | 359 | 998 |
| California | 1,392 | 1,191 | 2,583 | 1,438 | 1,142 | 2,580 | 1,307 | 1,132 | 2,439 | 1,307 | 1,132 | 2,439 | 1,201 | 997 | 2,198 |
| Hawaii | 2,855 | NA | 2,855 | NA | NA | NA | 347 | 2,467 | 2,901 | 347 | 2,467 | 2,814 | NA | NA | NA |
| **Great Lakes[c]** | | | | | | | | | | | | | | | |
| Illinois | 5 | NA | 5 | 5 | NA | NA | 5 | NA | NA | 5 | NA | NA | NA | NA | NA |
| Indiana | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Michigan | 61 | 74 | 135 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Minnesota | 1 | 22 | 23 | 1 | 24 | 25 | 1 | 24 | 25 | 1 | 24 | 25 | NA | NA | NA |
| New York | 2 | NA | 2 | 2 | NA | NA | 1 | NA | NA | 1 | NA | NA | NA | NA | NA |
| Ohio | 40 | 19 | 59 | 34 | 21 | 55 | 31 | 19 | 50 | 31 | 19 | 50 | NA | NA | NA |
| Pennsylvania | 2 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 3 | NA | NA | NA |
| Wisconsin | 89 | 16 | 105 | 68 | 18 | 86 | 78 | 18 | 96 | 78 | 18 | 96 | NA | NA | NA |

*Note:* NA, Data not available or provided seperately. Vessels are documented craft greater than 5 net registered tons. Boats are craft less than 5 net registered ton.

[a] Only federally collected data are available. Inshore data are not available.
[b] Excludes vessels and boats in the Great Lakes.
[c] Commercial fishing fleet size of the Great Lakes states represent only the number of licenses issued by the State; therefore, may not be an accurate total. Tribal data are not included in this table.

*Source*: From U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2004, Fisheries of the United States 2003; U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2003, Fisheries of the United States 2002; U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2002, Fisheries of the United States 2001; U.S. Department of Commerce, NOAA, and National Marine Fisheries Services, 2001, Fisheries of the United States 2000, www.st.nmfs.gov.

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**Table 7O.170 Aquaculture Water Withdrawals in the United States, 2000**

| | Withdrawals (mil gal/day) | | | Withdrawals (thousand acre-feet yr) | | |
|---|---|---|---|---|---|---|
| | By Source | | | By Source | | |
| State | Groundwater | Surface Water | Total | Groundwater | Surface Water | Total |
| Alabama | 8.93 | 1.44 | 10.4 | 10 | 1.61 | 11.6 |
| Alaska | — | — | — | — | — | — |
| Arizona | — | — | — | — | — | — |
| Arkansas | 187 | 10.4 | 198 | 210 | 11.6 | 222 |
| California | 158 | 380 | 537 | 177 | 426 | 603 |
| Colorado | — | — | — | — | — | — |
| Connecticut | — | — | — | — | — | — |
| Delaware | 0.07 | 0 | 0.07 | 0.08 | 0 | 0.08 |
| District of Columbia | — | — | — | — | — | — |
| Florida | 7.81 | 0.21 | 8.02 | 8.76 | 0.24 | 8.99 |
| Georgia | 7.7 | 7.72 | 15.4 | 8.63 | 8.65 | 17.3 |
| Hawaii | — | — | — | — | — | — |
| Idaho | 51.5 | 1,920 | 1,970 | 57.7 | 2,150 | 2,210 |
| Illinois | — | — | — | — | — | — |
| Indiana | — | — | — | — | — | — |
| Iowa | — | — | — | — | — | — |
| Kansas | 3.33 | 2.27 | 5.6 | 3.73 | 2.54 | 6.28 |
| Kentucky | — | — | — | — | — | — |
| Louisiana | 128 | 115 | 243 | 144 | 129 | 273 |
| Maine | — | — | — | — | — | — |
| Maryland | 4.81 | 14.8 | 19.6 | 5.39 | 16.6 | 22 |
| Massachusetts | — | — | — | — | — | — |
| Michigan | — | — | — | — | — | — |
| Minnesota | — | — | — | — | — | — |
| Mississippi | 321 | 49.8 | 371 | 360 | 55.9 | 416 |
| Missouri | 2.01 | 81.3 | 83.3 | 2.25 | 91.2 | 93.4 |
| Montana | — | — | — | — | — | — |
| Nebraska | — | — | — | — | — | — |
| Nevada | — | — | — | — | — | — |
| New Hampshire | 3.12 | 13.1 | 16.3 | 3.5 | 14.7 | 18.2 |
| New Jersey | 6.46 | 0 | 6.46 | 7.24 | 0 | 7.24 |
| New Mexico | — | — | — | — | — | — |
| New York | — | — | — | — | — | — |
| North Carolina | 7.88 | 0 | 7.88 | 8.83 | 0 | 8.83 |
| North Dakota | — | — | — | — | — | — |
| Ohio | 1.36 | 0 | 1.36 | 1.52 | 0 | 1.52 |
| Oklahoma | 0.29 | 16.1 | 16.4 | 0.33 | 18.1 | 18.4 |
| Oregon | — | — | — | — | — | — |
| Pennsylvania | — | — | — | — | — | — |
| Rhode Island | — | — | — | — | — | — |
| South Carolina | — | — | — | — | — | — |
| South Dakota | — | — | — | — | — | — |
| Tennessee | — | — | — | — | — | — |
| Texas | — | — | — | — | — | — |
| Utah | 116 | 0 | 116 | 130 | 0 | 130 |
| Vermont | — | — | — | — | — | — |
| Virginia | — | — | — | — | — | — |
| Washington | — | — | — | — | — | — |
| West Virginia | — | — | — | — | — | — |
| Wisconsin | 39.8 | 30.4 | 70.2 | 44.6 | 34.1 | 78.7 |
| Wyoming | — | — | — | — | — | — |
| Puerto Rico | — | — | — | — | — | — |
| U.S. Virgin Islands | — | — | — | — | — | — |
| **Total** | **1,060** | **2,640** | **3,700** | **1,180** | **2,960** | **4,150** |

*Note:* Figures may not sum to totals because of independent rounding; —, data not collected.

*Source*: From Hutson, S.S. and others, 2004, Estimated Use of Water in the United States in 2003. *U.S. Geological Survey Circular 1268*, www.usgs.gov.

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**Table 7O.171 U.S. Private Aquaculture — Trout and Catfish Production and Value: 1990–2002**

| Item | Unit | 1990 | 1995 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| **Trout Foodsize** | | | | | | | | | |
| Number sold | Millions | 67.8 | 60.2 | 59.3 | 57.6 | 61.0 | 58.5 | 54.5 | 50.2 |
| Total weight | Mil lb | 56.8 | 55.6 | 56.9 | 57.9 | 60.2 | 59.2 | 56.9 | 54.5 |
| Total value of sales | Mil dol | 64.6 | 60.8 | 60.7 | 60.3 | 64.7 | 63.7 | 64.4 | 58.3 |
| Average price received | Dol lb | 1.14 | 1.09 | 1.07 | 1.04 | 1.07 | 1.08 | 1.13 | 1.07 |
| Percent sold to processors | Percent | 58 | 68 | 63 | 62 | 68 | 70 | 68 | 69 |
| **Catfish Foodsize** | | | | | | | | | |
| Number sold | Millions | 272.9 | 321.8 | 391.8 | 409.8 | 424.5 | 420.1 | 406.9 | 405.8 |
| Total weight | Mil lb | 392.4 | 481.5 | 569.6 | 601.4 | 635.2 | 633.8 | 647.5 | 673.7 |
| Total value of sales | Mil dol | 305.1 | 378.1 | 406.8 | 445.4 | 464.7 | 468.8 | 410.7 | 378.5 |
| Average price received | Dol /lb | 0.78 | 0.79 | 0.71 | 0.74 | 0.73 | 0.74 | 0.63 | 0.56 |
| Fish sold to processors | Mil lb | 360.4 | 446.9 | 524.9 | 564.4 | 596.6 | 593.6 | 597.1 | 630.6 |
| Avg. price paid by processors | Cents/lb | 75.8 | 78.6 | 71.2 | 74.3 | 73.7 | 75.1 | 64.7 | 56.8 |
| Processor sales | Mil lb | 183.1 | 227.0 | 261.8 | 281.4 | 292.7 | 297.2 | 296.4 | 317.6 |
| Avg. price received by processors | Cents/lb | 224.1 | 240.3 | 226.0 | 229.0 | 234.0 | 236.0 | 226.0 | 207.0 |
| Inventory (Jan 1) | Mil lb | 9.4 | 10.9 | 11.9 | 10.8 | 12.6 | 13.6 | 15.0 | 12.3 |

*Note:* 67.8 represents 67,800,000. Periods are from Sept 1 of the previous year to Aug 31 of stated year. Data are for foodsize fish, those over 12 in. long.

*Source*: From U.S. Census Bureau, Statistical Abstract of the United States. 2004–2005, www.census.gov.

*Original Source*: From U.S. Dept. of Agriculture, National Agricultural Statistics Service, *Trout Production* released February; *Catfish Production* released February; and *Catfish Processing* released February. Also in annual.

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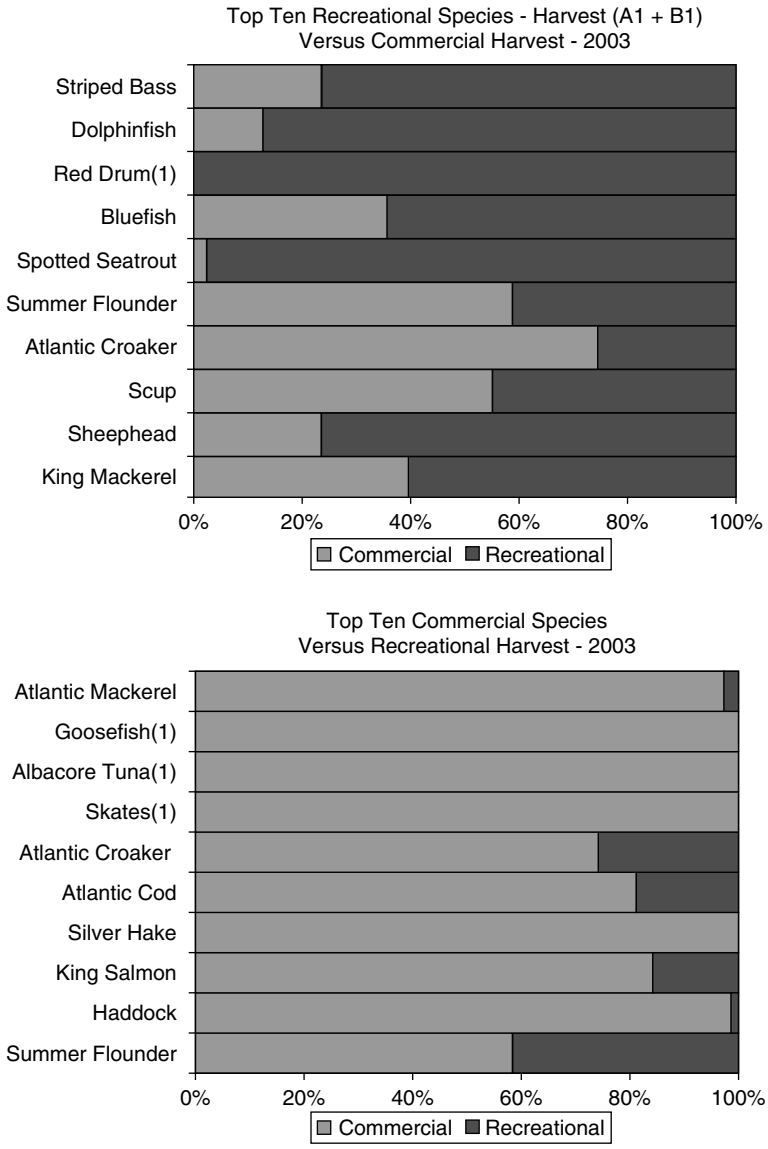


**Figure 7O.27** Top ten recreational species versus commercial harvest/top ten commercial species versus recreational harvest, 2003. (From U.S. Department of Commerce, NOAA, and (1) less than 1 percent National Marine Fisheries Service, 2004, Fisheries of the United States 2003, www.st.nmfs.gov.)

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**Table 7O.172 World Aquaculture and Commercial Catches by Area of Fish, Crustaceans, and Mollusks, 2001–2002**

| | 2001 | | | 2002 | | |
|---|---|---|---|---|---|---|
| **Country** | **Aquaculture** | **Catch** | **Total** | **Aquaculture** | **Catch** | **Total** |
| **Marine Areas** | Metric tons Live-Weight | | | Metric tons Live-Weight | | |
| **Atlantic Ocean** | | | | | | |
| Northeast | 1,315,707 | 11,143,204 | 12,458,911 | 1,307,923 | 11,048,962 | 12,356,885 |
| Northwest | 108,149 | 2,240,365 | 2,348,514 | 104,761 | 2,245,008 | 2,349,769 |
| Eastern central | 251 | 3,929,630 | 3,929,881 | 342 | 3,373,623 | 3,373,965 |
| Western central | 85,094 | 1,686,404 | 1,771,498 | 99,919 | 1,764,352 | 1,864,271 |
| Southeast | 2,680 | 1,648,084 | 1,650,764 | 2,675 | 1,701,440 | 1,704,115 |
| Southwest | 52,877 | 2,287,502 | 2,340,379 | 71,793 | 2,089,660 | 2,161,453 |
| **Mediterranean and Black Sea** | 367,777 | 1,570,335 | 1,938,112 | 339,264 | 1,550,099 | 1,889,363 |
| **Indian Ocean** | | | | | | |
| Eastern | 432,253 | 4,877,380 | 5,309,633 | 432,048 | 5,100,261 | 5,532,309 |
| Western | 30,563 | 3,981,292 | 4,011,855 | 44,074 | 4,243,330 | 4,287,404 |
| **Pacific Ocean** | | | | | | |
| Northeast | 134,724 | 2,759,090 | 2,893,814 | 141,812 | 2,702,885 | 2,844,697 |
| Northwest | 11,286,336 | 22,550,874 | 33,837,210 | 12,063,628 | 21,436,229 | 33,499,857 |
| Eastern central | 60,875 | 1,860,373 | 1,921,248 | 63,540 | 2,037,267 | 2,100,807 |
| Western central | 640,227 | 10,103,215 | 10,743,442 | 538,639 | 10,510,202 | 11,048,841 |
| Southeast | 633,595 | 12,653,427 | 13,287,022 | 611,092 | 13,765,143 | 14,376,235 |
| Southwest | 93,343 | 752,661 | 846,004 | 106,053 | 739,868 | 845,921 |
| **Antarctic** | — | 120,159 | 120,159 | — | 144,158 | 144,158 |
| **Inland Areas** | | | | | | |
| Africa | 366,787 | 2,051,183 | 2,417,970 | 405,320 | 2,092,924 | 2,498,244 |
| Asia | 21,053,159 | 5,734,686 | 26,787,845 | 22,295,148 | 5,722,141 | 28,017,289 |
| Europe | 479,242 | 347,242 | 826,484 | 467,769 | 354,270 | 822,039 |
| North America | 414,512 | 174,959 | 589,471 | 448,661 | 170,614 | 619,275 |
| South America | 227,141 | 368,803 | 595,944 | 250,864 | 377,313 | 628,177 |
| Oceania | 3,803 | 21,219 | 25,022 | 3,246 | 20,905 | 24,151 |
| **Total** | **37,789,095** | **92,862,087** | **130,651,182** | **39,798,571** | **93,190,654** | **132,989,225** |

*Note:* Data for marine mammals and aquatic plants are excluded.

*Source*: From U.S. Census Bureau, *Statistical Abstract of the United States. 2004–2005*, www.census.gov.

*Original Source*: From Food and Agrculture Organizaiton of the United Nations (FAO).

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**Table 7O.173 Capture and Aquaculture Production Totals for Marine and Inland Fisheries**

| | Total Capture and Aquaculture Production for All Species (thousand metric tons) | | | Marine Aquaculture Production (thousand metric tons) | | | Inland Aquaculture Production (thousand metric tons) | | | Marine Capture Production (thousand metric tons) | | | Inland Capture Production (thousand metric tons) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 |
| **World** | **72,900** | **99,449** | **129,429** | **2,136** | **5,020** | **14,240** | **2,632** | **8,025** | **21,372** | **63,018** | **80,101** | **85,153** | **5,114** | **6,303** | **8,665** |
| **Asia (Excl. Middle East)** | **29,517** | **44,556** | 74,156 | **1,404** | **3,700** | **11,481** | **1,973** | **6,774** | **19,663** | **23,602** | **30,786** | **37,521** | **2,539** | **3,296** | **5,491** |
| Armenia | — | 7 | 2 | — | — | — | — | 4 | 1 | — | — | — | — | 2 | 1 |
| Azerbaijan | — | 45 | 17 | — | — | — | — | 2 | 0.1 | — | — | — | — | 44 | 17 |
| Bangladesh | 648 | 862 | 1,643 | 6 | 19 | 66 | 86 | 177 | 588 | 116 | 255 | 325 | 441 | 412 | 663 |
| Bhutan | 0.3 | 0.3 | 0.3 | — | — | — | — | 0.03 | 0.03 | — | — | — | 0.3 | 0.3 | 0.3 |
| Cambodia | 34 | 104 | 332 | — | 0 | 1 | 0.1 | 6 | 14 | 3 | 34 | 38 | 30 | 63 | 279 |
| China | 4,437 | 13,200 | 41,392 | 422 | 2,051 | 9,361 | 910 | 4,418 | 15,113 | 2,743 | 5,833 | 14,696 | 362 | 898 | 2,223 |
| Georgia | — | 105 | 2 | — | — | — | — | 1 | 0.1 | — | 103 | 2 | — | 0.1 | 0.02 |
| India | 2,412 | 3,830 | 5,752 | 4 | 34 | 94 | 363 | 1,048 | 1,999 | 1,493 | 2,258 | 2,784 | 552 | 490 | 875 |
| Indonesia | 1,812 | 3,072 | 4,889 | 25 | 115 | 147 | 164 | 373 | 654 | 1,366 | 2,291 | 3,775 | 256 | 292 | 313 |
| Japan | 10,377 | 10,279 | 5,738 | 461 | 700 | 714 | 94 | 97 | 60 | 9,691 | 9,374 | 4,896 | 131 | 107 | 68 |
| Kazakhstan | — | 86 | 35 | — | — | — | — | 11 | 1 | — | — | — | — | 76 | 34 |
| Korea, Dem People's Rep | 1,410 | 1,394 | 270 | 6 | 48 | 63 | 3 | 6 | 4 | 1,332 | 1,290 | 184 | 69 | 50 | 20 |
| Korea, Rep | 2,207 | 2,733 | 2,274 | 299 | 361 | 285 | 1 | 14 | 12 | 1,868 | 2,334 | 1,970 | 39 | 24 | 6 |
| Kyrgyzstan | — | 1 | 0.1 | — | — | — | — | 1 | 0.1 | — | — | — | — | 0.3 | 0.1 |
| Lao People's Dem Rep | 24 | 28 | 71 | — | — | — | 1 | 10 | 41 | — | — | — | 23 | 19 | 30 |
| Malaysia | 750 | 977 | 1,418 | 85 | 47 | 109 | 4 | 10 | 46 | 655 | 919 | 1,259 | 6 | 1 | 3 |
| Mongolia | 0.4 | 0.2 | 0.4 | — | — | — | — | — | — | — | — | — | 0.4 | 0.2 | 0.4 |
| Myanmar | 580 | 738 | 1,156 | — | 0 | 5 | 3 | 8 | 99 | 429 | 593 | 857 | 148 | 137 | 195 |
| Nepal | 4 | 14 | 30 | — | — | — | 1 | 9 | 15 | — | — | — | 2 | 5 | 15 |
| Pakistan | 299 | 480 | 643 | 0 | 0.04 | 0.1 | 5 | 11 | 17 | 251 | 369 | 446 | 43 | 101 | 179 |
| Philippines | 1,586 | 2,209 | 2,300 | 13 | 81 | 82 | 195 | 302 | 312 | 1,153 | 1,595 | 1,761 | 224 | 231 | 145 |
| Singapore | 16 | 13 | 10 | 0.2 | 2 | 4 | 0 | 0 | 1 | 16 | 11 | 5 | 1 | 0.1 | 0 |
| Sri Lanka | 186 | 191 | 294 | 0.01 | 1 | 5 | 1 | 5 | 4 | 164 | 158 | 252 | 21 | 27 | 33 |
| Tajikistan | — | 4 | 0.2 | — | — | — | — | 4 | 0.1 | — | — | — | — | 0.3 | 0.1 |
| Thailand | 1,194 | 2,822 | 3,631 | 74 | 198 | 445 | 44 | 104 | 271 | 1,691 | 2,389 | 2,709 | 105 | 131 | 206 |
| Turkmenistan | — | 47 | 11 | — | — | — | — | 2 | 0.1 | — | — | — | — | 45 | 11 |
| Uzbekistan | — | 27 | 8 | — | — | — | — | 22 | 5 | — | — | — | — | 4 | 3 |

*(Continued)*

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**Table 7O.173 (Continued)**

| | Total Capture and Aquaculture Production for All Species (thousand metric tons) | | | Marine Aquaculture Production (thousand metric tons) | | | Inland Aquaculture Production (thousand metric tons) | | | Marine Capture Production (thousand metric tons) | | | Inland Capture Production (thousand metric tons) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 |
| Vietnam | 585 | 963 | 1,941 | 7 | 39 | 97 | 91 | 124 | 402 | 403 | 665 | 1,273 | 84 | 135 | 170 |
| **Europe** | **12,622** | **21,829** | **18,138** | **546** | **871** | **1,608** | **198** | **601** | **459** | **11,713** | **19,798** | **15,661** | **165** | **559** | **410** |
| Albania | 9 | 10 | 3 | 0.1 | 2 | 0.2 | 0.2 | 0.5 | 0.1 | 6 | 6 | 2 | 3 | 2 | 1 |
| Austria | 4 | 4 | 3 | — | — | — | 3 | 4 | 3 | — | — | — | 1 | 1 | 0.4 |
| Belarus | — | 19 | 6 | — | — | — | — | 16 | 6 | — | — | — | — | 2 | 1 |
| Belgium | 47 | 41 | 32 | — | — | — | 0.1 | 1 | 2 | 47 | 40 | 29 | 0.00 | 1 | 1 |
| Bosnia and Herzegovina | — | — | 3 | — | — | — | — | — | — | — | — | 0 | — | — | 3 |
| Bulgaria | 108 | 73 | 12 | 0 | 0 | 0.04 | 11 | 9 | 4 | 95 | 62 | 6 | 1 | 2 | 2 |
| Croatia | — | — | 29 | — | — | 4 | — | — | 4 | — | — | 21 | — | — | 0.02 |
| Czech Rep | — | — | 24 | — | — | — | — | — | 19 | — | — | — | — | — | 4 |
| Denmark | 1,878 | 1,747 | 1,526 | 0.4 | 6 | 7 | 19 | 33 | 36 | 1,858 | 1,707 | 1,483 | 0.2 | 0.4 | 0.2 |
| Estonia | — | 377 | 110 | — | 0.1 | 0 | — | 1 | 0.3 | — | 372 | 107 | — | 4 | 3 |
| Finland | 157 | 159 | 171 | 2 | 14 | 13 | 3 | 5 | 3 | 99 | 91 | 120 | 53 | 49 | 35 |
| France | 787 | 854 | 867 | 174 | 197 | 207 | 24 | 45 | 54 | 586 | 608 | 603 | 2 | 4 | 2 |
| Germany | 579 | 371 | 285 | 9 | 23 | 25 | 25 | 45 | 42 | 526 | 293 | 196 | 21 | 9 | 23 |
| Greece | 105 | 143 | 197 | 0.02 | 7 | 89 | 2 | 2 | 3 | 94 | 131 | 101 | 9 | 3 | 3 |
| Hungary | 35 | 31 | 20 | — | — | — | 24 | 18 | 13 | — | — | — | 12 | 13 | 7 |
| Iceland | 1,534 | 1,354 | 1,904 | 0.03 | 2 | 3 | 0.02 | 0.2 | 1 | 1,533 | 1,350 | 1,900 | 0.5 | 1 | 0.2 |
| Ireland | 145 | 237 | 358 | 5 | 24 | 51 | 0.5 | 1 | 1 | 140 | 208 | 305 | 0.1 | 4 | 1 |
| Italy | 498 | 548 | 512 | 52 | 109 | 164 | 24 | 42 | 49 | 413 | 385 | 293 | 8 | 13 | 5 |
| Latvia | — | 479 | 129 | — | — | — | — | 4 | 0 | — | 474 | 128 | — | 0.3 | 1 |
| Lithuania | — | 416 | 103 | — | — | — | — | 5 | 2 | — | 407 | 99 | — | 4 | 2 |
| Macedonia, FYR | — | — | 2 | — | — | — | — | — | 1 | — | — | — | — | — | 0.2 |
| Moldova, Rep | — | 8 | 1 | — | — | — | — | 6 | 1 | — | — | — | — | 1 | 0.3 |
| Netherlands | 381 | 499 | 588 | 95 | 86 | 73 | 0.1 | 1 | 6 | 285 | 408 | 507 | 2 | 3 | 2 |
| Norway | 2,540 | 1,945 | 3,166 | 9 | 142 | 493 | — | — | — | 2,530 | 1,803 | 2,672 | 0.4 | 1 | 1 |
| Poland | 625 | 498 | 261 | — | — | — | 11 | 27 | 35 | 603 | 456 | 210 | 10 | 15 | 16 |
| Portugal | 260 | 327 | 203 | 0.1 | 5 | 6 | 0.5 | 2 | 1 | 259 | 321 | 196 | 0 | 0 | 0 |
| Romania | 182 | 159 | 17 | — | — | — | 36 | 37 | 10 | 129 | 107 | 2 | 16 | 15 | 5 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Russian Federation | — | 7,733 | 3,992 | — | 0.3 | 1 | — | 179 | 77 | — | 7,196 | 3,646 | — | 358 | 269 |
| Serbia and Montenegro | — | — | 4 | — | — | 0.01 | — | — | 3 | — | — | 0.4 | — | — | 1 |
| Slovakia | — | — | 2 | — | — | — | — | — | 1 | — | — | — | — | — | 1 |
| Slovenia | — | — | 3 | — | — | 0.1 | — | — | 1 | — | — | 2 | — | — | 0.2 |
| Spain | 1,371 | 1,378 | 1,415 | 198 | 196 | 282 | 11 | 21 | 33 | 1,144 | 1,151 | 1,091 | 18 | 10 | 9 |
| Sweden | 230 | 254 | 340 | 0.2 | 5 | 3 | 1 | 4 | 3 | 226 | 244 | 332 | 2 | 2 | 1 |
| Switzerland | 4 | 5 | 3 | — | — | — | 0.2 | 1 | 1 | — | — | — | 4 | 3 | 2 |
| Ukraine | 0 | 1,016 | 146 | 0 | 0.5 | 0.04 | 0 | 77 | 32 | — | 901 | 379 | — | 38 | 5 |
| United Kingdom | 867 | 856 | 936 | 1 | 38 | 146 | 2 | 15 | 13 | 862 | 800 | 773 | 1 | 3 | 4 |
| **Middle East & N. Africa** | **1,407** | **2,148** | **3,432** | **0.1** | **4** | **76** | **45** | **111** | **385** | **1,220** | **1,765** | **2,535** | **141** | **268** | **437** |
| Afghanistan | 1 | 1 | 1 | — | — | — | — | — | — | — | — | — | 1 | 1 | 1 |
| Algeria | 48 | 90 | 101 | | 0.03 | 0.04 | — | 0.3 | 0.2 | 48 | 90 | 101 | 0 | 0 | 0 |
| Egypt | 140 | 302 | 701 | 0 | 0.5 | 30 | 19 | 61 | 273 | 34 | 79 | 140 | 86 | 162 | 258 |
| Iran, Islamic Rep | 60 | 268 | 414 | — | — | 4 | 9 | 24 | 40 | 47 | 201 | 256 | 4 | 42 | 114 |
| Iraq | 45 | 21 | 23 | — | — | — | 4 | 2 | 2 | 27 | 2 | 13 | 14 | 17 | 9 |
| Israel | 29 | 24 | 25 | — | 0.1 | 3 | 12 | 15 | 17 | 13 | 7 | 4 | 4 | 2 | 2 |
| Jordan | 0.04 | 0.4 | 1 | — | — | — | — | 0.05 | 1 | 0.04 | 0.01 | 0.2 | 0 | 0.4 | 0.4 |
| Kuwait | 3 | 5 | 6 | — | 0 | 0.2 | — | 0 | 0.04 | 3 | 5 | 6 | 0 | 0 | 0 |
| Lebanon | 2 | 2 | 4 | — | — | — | 0.05 | 0.1 | 0.3 | 2 | 2 | 4 | 0 | 0.01 | 0.02 |
| Libyan Arab Jamahiriya | 10 | 24 | 33 | — | — | — | — | 0.1 | 0.1 | 10 | 24 | 33 | 0 | 0 | 0 |
| Morocco | 335 | 562 | 910 | 0.1 | 0.4 | 1 | 0.01 | 0.05 | 1 | 335 | 560 | 907 | 1 | 2 | 2 |
| Oman | 80 | 118 | 121 | — | 0 | 2 | — | — | — | 80 | 118 | 119 | 0 | 0 | 0 |
| Saudi Arabia | 26 | 44 | 55 | 0 | 0.1 | 3 | — | 2 | 4 | 26 | 43 | 48 | 0 | 0 | 0 |
| Syrian Arab Rep | 4 | 6 | 14 | — | — | — | 1 | 3 | 6 | 1 | 2 | 3 | 2 | 2 | 5 |
| Tunisia | 60 | 90 | 97 | 0.1 | 1 | 1 | 0 | 0.1 | 1 | 60 | 89 | 95 | 0 | 0 | 1 |
| Turkey | 417 | 401 | 605 | 0 | 2 | 30 | 1 | 4 | 40 | 387 | 356 | 490 | 29 | 40 | 45 |
| United Arab Emirates | 66 | 93 | 113 | 0 | 0 | 0 | — | 0 | 0 | 66 | 93 | 113 | 0 | 0 | 0 |
| Yemen | 73 | 77 | 127 | — | — | — | — | — | — | 73 | 77 | 127 | 0 | 0 | 0 |
| **Sub-Saharan Africa** | **3,173** | **3,929** | **5,122** | **0.4** | **3** | **8** | **7** | **23** | **44** | **1,999** | **2,309** | **3,296** | **1,166** | **1,594** | **1,775** |
| Angola | 110 | 129 | 222 | — | — | — | — | — | — | 102 | 122 | 216 | 7 | 8 | 6 |
| Benin | 37 | 38 | 37 | — | — | — | — | — | — | 4 | 8 | 8 | 33 | 30 | 29 |
| Botswana | 1 | 1 | 0.1 | — | — | — | — | — | — | — | — | — | 1 | 1 | 0.1 |
| Burkina Faso | 7 | 7 | 8 | — | — | — | 0 | 0.01 | 0.01 | — | — | — | 7 | 7 | 8 |

*(Continued)*



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**Table 7O.173 (Continued)**

| | Total Capture and Aquaculture Production for All Species (thousand metric tons) | | | Marine Aquaculture Production (thousand metric tons) | | | Inland Aquaculture Production (thousand metric tons) | | | Marine Capture Production (thousand metric tons) | | | Inland Capture Production (thousand metric tons) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 |
| Burundi | 13 | 16 | 12 | — | — | — | — | 0.04 | 0.1 | — | — | — | 13 | 16 | 12 |
| Cameroon | 81 | 70 | 111 | — | — | — | 0.04 | 0.1 | 0.1 | 61 | 48 | 59 | 20 | 22 | 53 |
| Central African Rep | 13 | 13 | 15 | — | — | — | 0.1 | 0.1 | 0.1 | — | — | — | 13 | 13 | 15 |
| Chad | 62 | 65 | 84 | — | — | — | — | — | — | — | — | — | 62 | 65 | 84 |
| Congo | 30 | 47 | 43 | — | — | — | 0 | 0.2 | 0.2 | 19 | 21 | 18 | 11 | 26 | 25 |
| Congo, Dem Rep | 107 | 165 | 209 | — | — | — | — | 1 | 0.4 | 1 | 3 | 4 | 106 | 162 | 205 |
| Côte d'Ivoire | 88 | 92 | 76 | — | — | — | — | 0.2 | 1 | 71 | 68 | 64 | 18 | 24 | 11 |
| Equatorial Guinea | 3 | 4 | 5 | — | — | — | — | — | — | 3 | 3 | 4 | 0 | 0.4 | 1 |
| Eritrea | — | — | 10 | — | — | — | — | — | — | — | — | 10 | — | — | 0 |
| Ethiopia | 3 | 5 | 16 | — | — | — | — | 0.04 | 0 | 0.2 | 1 | 0 | 3 | 4 | 16 |
| Gabon | 20 | 21 | 47 | — | — | — | 0 | 0 | 0.4 | 19 | 19 | 36 | 2 | 2 | 10 |
| Gambia | 13 | 22 | 31 | — | 0.1 | — | — | 0 | 0 | 10 | 19 | 29 | 3 | 3 | 3 |
| Ghana | 237 | 374 | 468 | — | — | — | 0.3 | 0.4 | 5 | 197 | 316 | 389 | 40 | 58 | 75 |
| Guinea | 20 | 45 | 90 | — | — | — | — | 0 | 0 | 19 | 42 | 86 | 1 | 3 | 4 |
| Guinea-Bissau | 4 | 5 | 5 | — | — | — | — | — | — | 4 | 5 | 5 | 0.01 | 0.2 | 0.2 |
| Kenya | 53 | 183 | 196 | 0.0 | 0.1 | 0 | 0.2 | 1 | 1 | 5 | 9 | 7 | 47 | 173 | 189 |
| Lesotho | 0.02 | 0.03 | 0.04 | — | — | — | 0.02 | 0.02 | 0.01 | — | — | — | 0 | 0.01 | 0.03 |
| Liberia | 13 | 10 | 13 | — | — | — | 0 | 0 | 0.02 | 9 | 6 | 9 | 4 | 4 | 4 |
| Madagascar | 56 | 100 | 139 | — | 0.02 | 5 | 0.1 | 0.2 | 2 | 17 | 71 | 102 | 39 | 29 | 30 |
| Malawi | 59 | 70 | 44 | — | — | — | 0.1 | 0.2 | 1 | — | — | — | 59 | 69 | 43 |
| Mali | 82 | 70 | 103 | — | — | — | — | 0.02 | 0.05 | — | — | — | 82 | 70 | 103 |
| Mauritania | 35 | 70 | 80 | — | — | — | — | — | — | 29 | 64 | 75 | 6 | 6 | 5 |
| Mozambique | 34 | 32 | 35 | — | — | — | — | 0.02 | 0 | 31 | 29 | 25 | 4 | 4 | 10 |
| Namibia | 10 | 163 | 573 | — | 0.02 | 0.04 | — | — | 0.01 | 10 | 162 | 571 | 0.1 | 1 | 2 |
| Niger | 9 | 4 | 16 | — | — | — | — | 0.03 | 0.02 | — | — | — | 9 | 4 | 16 |
| Nigeria | 263 | 295 | 474 | 0.2 | 1 | — | 6 | 15 | 24 | 149 | 192 | 308 | 108 | 86 | 142 |
| Rwanda | 1 | 3 | 7 | — | — | — | 0.02 | 0.1 | 0.3 | — | — | — | 1 | 2 | 7 |
| Senegal | 228 | 307 | 407 | 0.1 | — | — | 0 | 0.01 | 0.2 | 213 | 290 | 381 | 15 | 18 | 25 |
| Sierra Leone | 52 | 58 | 70 | — | — | — | 0 | 0.02 | 0.03 | 38 | 43 | 56 | 14 | 15 | 14 |
| Somalia | 12 | 23 | 20 | — | — | — | — | — | — | 12 | 22 | 20 | 0.1 | 0.4 | 0.2 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South Africa | 905 | 639 | 666 | 0.01 | 2 | 3 | — | 2 | 2 | 904 | 635 | 661 | 1 | 1 | 1 |
| Sudan | 28 | 32 | 55 | — | — | — | — | 0.2 | 1 | 1 | 1 | 5 | 27 | 30 | 48 |
| Tanzania, United Rep | 213 | 373 | 327 | — | — | — | — | 0.4 | 0.2 | 37 | 54 | 52 | 176 | 319 | 274 |
| Togo | 9 | 15 | 23 | — | — | — | — | 0.02 | 0.1 | 6 | 10 | 18 | 4 | 5 | 5 |
| Uganda | 171 | 224 | 223 | — | — | — | — | 0.1 | 1 | — | — | — | 171 | 224 | 222 |
| Zambia | 47 | 68 | 71 | — | — | — | 0.03 | 2 | 4 | — | — | — | 47 | 66 | 66 |
| Zimbabwe | 13 | 24 | 13 | — | — | — | 0.1 | 0.2 | 0.2 | — | — | — | 13 | 24 | 13 |
| **North America** | **5,225** | **7,485** | **6,596** | **100** | **142** | **242** | **83** | **248** | **345** | **4,926** | **7,005** | **5,939** | **116** | **91** | **69** |
| Canada | 1,395 | 1,608 | 1,160 | 3 | 35 | 118 | 1 | 5 | 13 | 1,340 | 1,519 | 990 | 51 | 48 | 39 |
| United States | 3,718 | 5,713 | 5,270 | 97 | 107 | 123 | 82 | 242 | 333 | 3,474 | 5,321 | 4,784 | 65 | 42 | 30 |
| **C. America & Caribbean** | **1,742** | **1,912** | **1,972** | **1** | **16** | **63** | **10** | **28** | **92** | **1,676** | **1,721** | **1,703** | **54** | **147** | **115** |
| Belize | 2 | 2 | 44 | — | 0.3 | 4 | — | 0 | — | 2 | 2 | 40 | 0.03 | 0 | 0 |
| Costa Rica | 18 | 18 | 43 | — | 0.3 | 2 | 0.03 | 1 | 8 | 17 | 17 | 32 | 0.3 | 0.4 | 1 |
| Cuba | 168 | 184 | 114 | 1 | 2 | 1 | 1 | 6 | 53 | 160 | 161 | 55 | 6 | 14 | 5 |
| Dominican Rep | 10 | 20 | 13 | — | 0.1 | 0.3 | 0 | 0.3 | 2 | 8 | 18 | 10 | 2 | 1 | 1 |
| El Salvador | 16 | 10 | 15 | — | 0.5 | 0.2 | — | 0.01 | 0.1 | 14 | 6 | 12 | 2 | 4 | 2 |
| Guatemala | 4 | 6 | 27 | — | 1 | 2 | 0.01 | 0.2 | 3 | 4 | 4 | 16 | 0.5 | 2 | 7 |
| Haiti | 5 | 5 | 5 | — | — | — | — | — | — | 5 | 5 | 5 | 0.3 | 0.4 | 0.5 |
| Honduras | 7 | 19 | 19 | 0.1 | 3 | 8 | 0.01 | 0.2 | 1 | 6 | 16 | 11 | 0.1 | 0.04 | 0.1 |
| Jamaica | 9 | 45 | 44 | — | 0 | 0 | 0.03 | 3 | 4 | 9 | 8 | 6 | 0.2 | 0.4 | 0.5 |
| Mexico | 1,280 | 1,416 | 1,367 | 0 | 6 | 39 | 9 | 16 | 21 | 1,228 | 1,269 | 1,210 | 43 | 125 | 97 |
| Nicaragua | 7 | 5 | 30 | 0 | 0.1 | 5 | 0 | 0 | 0.01 | 7 | 4 | 24 | 0.1 | 0.2 | 1 |
| Panama | 175 | 162 | 196 | 0.2 | 3 | 2 | 0 | 0.3 | 1 | 175 | 158 | 193 | 0 | 0.02 | 0.02 |
| Trinidad and Tobago | 4 | 9 | 10 | — | — | — | — | 0 | 0.01 | 4 | 9 | 10 | 0 | 0 | 0 |
| **South America** | **8,237** | **15,274** | **17,226** | **10** | **123** | **549** | **5** | **32** | **208** | **7,960** | **14,810** | **16,124** | **262** | **309** | **345** |
| Argentina | 438 | 561 | 973 | — | 0 | 0.02 | 0.1 | 0.3 | 1 | 427 | 550 | 944 | 11 | 10 | 27 |
| Bolivia | 5 | 6 | 6 | — | — | — | — | 0.4 | 0.4 | — | — | — | 5 | 6 | 6 |
| Brazil | 801 | 814 | 923 | 0.2 | 2 | 37 | 4 | 19 | 139 | 630 | 601 | 552 | 167 | 193 | 195 |
| Chile | 2,948 | 5,885 | 4,793 | 1 | 28 | 409 | 0.1 | 4 | 2 | 2,947 | 5,853 | 4,383 | 0 | 0.02 | 0.00 |
| Colombia | 78 | 113 | 184 | 0.03 | 5 | 11 | 0.2 | 4 | 49 | 30 | 74 | 98 | 48 | 30 | 26 |
| Ecuador | 595 | 496 | 645 | 9 | 84 | 79 | 0.4 | 1 | 7 | 585 | 410 | 559 | 0.2 | 1 | 0.4 |
| Guyana | 33 | 38 | 53 | — | 0.02 | 0.2 | 0 | 0.03 | 0.4 | 32 | 37 | 51 | 1 | 1 | 1 |
| Paraguay | 3 | 12 | 25 | — | — | — | — | 0.1 | 0.1 | — | — | — | 3 | 12 | 25 |
| Peru | 3,027 | 6,878 | 9,033 | 1 | 4 | 4 | 0.5 | 2 | 4 | 3,011 | 6,837 | 8,990 | 15 | 35 | 35 |

*(Continued)*



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**Table 7O.173 (Continued)**

| | Total Capture and Aquaculture Production for All Species (thousand metric tons) | | | Marine Aquaculture Production (thousand metric tons) | | | Inland Aquaculture Production (thousand metric tons) | | | Marine Capture Production (thousand metric tons) | | | Inland Capture Production (thousand metric tons) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 | 1979–1981 | 1989–1991 | 1999–2001 |
| Suriname | 3 | 7 | 18 | — | — | 0.2 | — | 0 | 0.1 | 3 | 6 | 17 | 0.1 | 0.4 | 0.2 |
| Uruguay | 125 | 119 | 108 | — | — | 0 | — | 0 | 0.04 | 125 | 118 | 106 | 0.4 | 0.3 | 2 |
| Venezuela | 179 | 335 | 405 | 0 | 0.3 | 8 | 0.3 | 0.5 | 5 | 167 | 313 | 364 | 12 | 21 | 28 |
| **Oceania** | **419** | **788** | **1,246** | **11** | **47** | **124** | **1** | **2** | **4** | **396** | **718** | **1,095** | **11** | **22** | **22** |
| Australia | 136 | 215 | 240 | 8 | 12 | 37 | 1 | 1 | 3 | 126 | 199 | 199 | 1 | 2 | 2 |
| Fiji | 21 | 30 | 43 | — | 0.01 | 1 | 0 | 0.02 | 0.3 | 21 | 26 | 35 | 1 | 4 | 6 |
| New Zealand | 149 | 379 | 654 | 3 | 35 | 84 | — | 0.2 | 0.5 | 146 | 344 | 568 | 1 | 1 | 1 |
| Papua New Guinea | 42 | 26 | 95 | — | 0 | 0 | — | 0.01 | 0.01 | 34 | 12 | 81 | 8 | 14 | 14 |
| Solomon Islands | 35 | 51 | 38 | — | 0 | 0.01 | — | 0 | 0 | 35 | 51 | 38 | 0 | 0 | 0 |
| **Developed** | **29,330** | **41,007** | **31,968** | **1,118** | **1,762** | **2,689** | **387** | **1,011** | **894** | **27,407** | **37,300** | **27,765** | **418** | **935** | **620** |
| **Developing** | **33,012** | **56,915** | **95,919** | **954** | **3,145** | **11,459** | **1,935** | **6,808** | **20,306** | **26,087** | **41,612** | **56,110** | **4,035** | **5,350** | **8,044** |

*Note:* All figures are three year averages for the range of years specified. Numbers in this table are reported with varying precision: values greater than 0.5 thousand metric tons are rounded to the nearest whole number, values between 0.05 and 0.5 thousand metric tons are rounded to the nearest tenth (one decimal place), value between 0.005 and 0.05 are rounded to the nearest hundredth (two decimal places), and "0" represents a value of less than 0.005 thousand metric tons.

**Variable Definitions and Methodology.**

***Total Capture and Aquaculture Production for All Species*** includes both capture and aquaculture production of fish, crustaceans, molluscs, aquatic mammals, and other aquatic animals, taken for commercial, industrial, recreational and subsistence purposes from inland, brackish and marine waters. For each country, the four sub-categories of production (Marine Aquaculture, Inland Aquaculture, Marine Capture, and Inland Capture) listed in this table should sum to *Total Capture and Aquaculture Production for All Species.*

***Marine Aquaculture Production*** data include fish, crustaceans, molluscs, aquatic mammals, and other aquatic animals, taken for commercial, industrial, recreational and subsistence purposes from marine and brackish environments. The harvest from inland waters is not included. Aquaculture production is defined by FAO as "the farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. [It] also implies ownership of the stock being cultivated." Aquatic organisms that are exploitable by the public as a common property resource are not included in the aquaculture production.

***Inland Aquaculture production*** data include fish, molluscs, crustaceans, aquatic mammals, and other aquatic animals, taken for commercial, industrial, recreational and subsistence purposes from inland waters, such as lakes and rivers. The harvest from marine areas is not included. Some inland lakes are saltwater, thus the data include not only freshwater species but also saltwater species. Aquaculture production is defined by FAO as "the farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. [It] also implies ownership of the stock being cultivated." Aquatic organisms that are exploitable by the public as a common property resource are not included in the aquaculture production.

***Marine Capture Production*** data include fish, crustaceans, molluscs, aquatic mammals, and other aquatic animals, taken for commercial, industrial, recreational and subsistence purposes from marine and brackish environments. The harvest from inland waters is not included. Capture production data refer to the nominal catch of fish, crustaceans, molluscs, aquatic mammals, and other aquatic animals, taken for commercial, industrial, recreational and subsistence purposes from marine, brackish, and inland waters. The harvest from aquaculture and other kind of farming are excluded.

***Inland Capture Production*** data include fish, molluscs, crustaceans, aquatic mammals, and other aquatic animals, taken for commercial, industrial, recreational and subsistence purposes from inland waters, such as lakes and rivers. The harvest from marine areas is not included. Some inland lakes are saltwater, thus the data include not only freshwater species but also saltwater species. Capture production data refer to the nominal catch of fish, crustaceans, molluscs, aquatic mammals, and other aquatic animals, taken for commercial, industrial, recreational and subsistence purposes from marine, brackish, and inland waters. The harvest from aquaculture and other kind of farming are excluded.

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Statistics for aquatic plants are excluded from country totals. For a more detailed listing of species groups represented in the table, please refer to the original source at fao.org/waicent/faostat/agricult/fishitems-e-e.html.

Data include all quantities caught for both food and feed purposes but exclude discards. The harvest of fish, crustaceans and molluscs are expressed in live weight, that is the nominal weight of the aquatic organisms at the time of capture.

Aquatic organisms included in the FAO FISHSTAT capture production database have been classified according to approximately 1290 commercial species items, further arranged within the 50 groups of species constituting the nine divisions of the FAO International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP). Most fisheries statistics are collected by FAO from official national reports. When these data are missing or considered unreliable, FAO estimates fishery production based on regional fishery organizations, project documents, industry magazines, or statistical interpolations. Fishery production statistics were revised completely by FAO in the 1990s. At this time, FAO estimated missing data points, updated taxonomical classifications, and discriminated more clearly between aquaculture and capture fisheries production.

Fisheries production statistics typically refer to the calendar years (January 1–December 31) with exception of data from Antarctic waters, which use a split year (July 1–June 30).

***Frequency of Update by Data Providers***. FAO publishes updated data sets annually for FishStat. This table represents data through the year 2001; data were acquired by WRI in May, 2003.

***Data Reliability and Cautionary Notes***. While the FAO data set provides the most extensive, global time series of fishery statistics since 1970, there are some problems associated with the data. Funding for the development and maintenance of fisheries statistics at the national level has been decreasing in real terms since 1992, while the demand is growing for a variety of global statistics on discards, fish inventories, aquaculture, and illegal activites. Country-level data are often submitted with a 1–2 year delay, and countries are declaring an increasing percentage of their catch as "unidentified fish." As a result, species-item totals frequently underestimate the real catch of individual species. Stock assessment working groups can more accurately estimate the composition of a catch; however, due to financial constraints, these groups are rare, especially in developing countries. Statistics from smaller artisanal and subsistence fisheries are particularly sparse.

FAO states that "general trends are probably reliably reflected by the available statistics…but the annual figures and the assessments involve a certain degree of uncertainty and small changes from year to year are probably not statistically significant." These statistics provide a good overview of regional fisheries trends. However, when reviewing the state of fisheries stocks, evaluating food security, etc., these data should be used with caution and supplemented with estimates from regional organizations, academic literature, expert consultations, and trade data.

For more information, please consult Fishery Statistics: Reliability and Policy Implications, published by the FAO Fisheries Department and available on-line at fao.org/fi/statist/naturechina/30jan02.asp.

*Source*: From World Resources Institute, Earth Trends Environmental Information, Coastal and Marine Ecosystems, www.earthtrends.wri.org.

*Original Source*: Fishery Information, Data and Statistics Unit, Food and Agriculture Organization of the United Nations (FAO). 2003. *FISHSTAT Plus: Universal software for fishery statistical time series*, Version 2.3 (available on-line at fao.org/fi/statist/FISOFT/FISHPLUS.asp); Total production dataset. Rome: FAO.



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## Table 7O.174 World-Fisheries and Aquaculture

| State | Marine Catch[a] (annual average) Metric Tons (000) 1998–2000 | Marine Catch[a] (annual average) Percent Change since 1988–1990 | Freshwater Catch[b] (annual average) Metric Tons (000) 1998–2000 | Freshwater Catch[b] (annual average) Percent Change since 1988–1990 | Total Aquaculture Production (annual average) Metric Tons (000) 1998–00 | Total Aquaculture Production (annual average) Percent Change since 1988–1990 | Trade in Fish and Fish Products[c] (annual average mil US$) Exports 1998–2000 | Trade in Fish and Fish Products[c] (annual average mil US$) Imports 1998–2000 | Food Supply from Fish and Fish Products (kg/person/yr)[d] 1997–1999 | Fish Protein as a Percent of All Animal Protein 1997–1999 | Number of Fishers 2000 | Number of Decked Fishery Vessels 1995[e] | Population within 100 km of the Coast (Percent) 1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **World** | **81,601.9** | **2** | **9,550.7** | **31** | **33,179.7** | **63** | **52,548.9** | **57,624.7** | **16.0** | **16** | **34,501,411** | **1,256,841** | **39** |
| **Asia (Excl. Middle East)** | **36,527.8** | **20** | **5,751.2** | **61** | **26,625.3** | **62** | **15,235.0** | **20,418.1** | **18.0** | **28** | **28,890,352** | **1,057,966** | **38** |
| Armenia | — | — | 1.0 | (63) | 0.7 | — | 0.3 | 1.0 | 0.5 | 1 | 244[f] | 6 | 0 |
| Azerbaijan | 0.0 | (67) | 14.8 | (70) | 0.2 | — | 1.7 | 1.3 | 0.9 | 1 | 1,500[f] | — | 56 |
| Bangladesh | 179.6 | 27 | 754.6 | 47 | 597.4 | 69 | 313.6 | 2.5 | 10.2 | 47 | 1,320,480 | 61 | 55 |
| Bhutan | — | — | 0.3 | — | 0.0 | 67 | — | — | — | — | 450[f] | — | 0 |
| Cambodia | 36.4 | 25 | 184.1 | 212 | 14.5 | 62 | 35.3 | 3.1 | 12.0 | 35 | 73,425[g] | — | 24 |
| China | 14,395.9 | 170 | 2,367.1 | 188 | 22,722.0 | 73 | 3,081.3 | 1,315.0 | 24.5 | 21 | 12,233,128[h] | 432,674 | 24 |
| Georgia | 2.2 | (99) | 0.2 | (60) | 0.1 | — | 0.3 | 1.6 | 1.3 | 2 | 1,900[f] | 82 | 39 |
| India | 2,726.5 | 33 | 753.5 | 48 | 2,039.2 | 52 | 1,221.4 | 24.0 | 4.7 | 14 | 5,958,744[f] | 56,600 | 26 |
| Indonesia | 3,624.7 | 69 | 375.3 | 18 | 722.5 | 37 | 1,582.2 | 69.7 | 19.0 | 56 | 5,118,571 | 67,325 | 96 |
| Japan | 4,836.3 | (52) | 285.1 | (3) | 763.0 | (5) | 756.2 | 14,406.3 | 65.4 | 45 | 260,200 | 360,747 | 96 |
| Kazakhstan | 0.0 | (83) | 23.3 | (70) | 1.2 | — | 13.2 | 13.3 | 1.9 | 2 | 16,000[f] | 1,970 | 4 |
| Korea, Dem People's Rep | 190.2 | (87) | 20.0 | (66) | 67.9 | 23 | 69.6 | 5.6 | 9.4 | 36 | 129,000[f] | 2,900 | 93 |
| Korea, Rep | 1,968.3 | (16) | 16.4 | (59) | 317.9 | (30) | 1,346.6 | 1,037.6 | 47.3 | 39 | 176,928[j] | 76,801 | 100 |
| Kyrgyzstan | — | — | 0.1 | (79) | 0.1 | — | — | 2.0 | 0.7 | 1 | 154[f] | — | 0 |
| Lao People's Dem Rep | — | — | 26.3 | 34 | 31.2 | 73 | 0.0 | 1.4 | 10.0 | 31 | 15,000[f] | — | 6 |
| Malaysia | 1,201.8 | 42 | 20.4 | 74 | 146.8 | 65 | 189.6 | 262.6 | 57.0 | 35 | 100,666[f] | 17,965 | 98 |
| Mongolia | — | — | 0.4 | 91 | — | — | 0.2 | 0.0 | 0.1 | 0 | 0 | — | 0 |
| Myanmar | 772.7 | 33 | 166.2 | 21 | 90.7 | 93 | 162.0 | 1.0 | 16.0 | 45 | 610,000[f] | 140 | 49 |
| Nepal | — | — | 13.8 | 131 | 13.6 | 48 | 0.2 | 0.3 | 1.1 | 3 | 50,000[f] | — | 0 |
| Pakistan | 448.3 | 28 | 173.9 | 78 | 17.6 | 50 | 141.9 | 0.4 | 2.5 | 3 | 272,273 | 5,064 | 9 |
| Philippines | 1,719.0 | 14 | 146.4 | (37) | 342.7 | (5) | 408.7 | 109.2 | 29.6 | 42 | 990,872[f] | 3,220 | 100 |
| Singapore | 6.5 | (44) | 0.04 | (68) | 4.3 | 55 | 413.6 | 483.9 | — | — | 364 | 110 | 100 |
| Sri Lanka | 255.3 | 67 | 32.7 | 4 | 10.2 | 45 | 103.5 | 66.5 | 21.2 | 54 | 146,188 | 2,990 | 100 |
| Tajikistan | — | — | 0.1 | (81) | 0.1 | — | — | 0.2 | 0.1 | 0 | 200[f] | — | 0 |
| Thailand | 2,654.6 | 14 | 206.5 | 77 | 664.5 | 61 | 4,180.5 | 841.3 | 28.2 | 37 | 354,495 | 17,600 | 39 |
| Turkmenistan | 0.0 | (93) | 9.4 | (79) | 0.6 | (338) | 0.4 | 0.1 | 1.7 | 2 | 611[i] | 45 | 8 |
| Uzbekistan | — | — | 3.0 | (40) | 5.9 | (257) | 0.0 | 2.0 | 0.5 | 1 | 4,800 | — | 3 |
| Vietnam | 1,217.6 | 92 | 156.3 | 19 | 463.6 | 66 | 1,080.4 | 12.1 | 18.1 | 37 | 1,000,000 | 140 | 83 |
| **Europe** | **15,710.1** | **(24)** | **674.7** | **(18)** | **1,726.0** | **13** | **19,063.8** | **22,875.8** | **20.6** | **10** | **855,333** | **105,324** | **40** |
| Albania | 2.1 | (73) | 0.8 | (64) | 0.2 | — | 6.5 | 4.5 | 2.4 | 1 | 1,590[j] | 2 | 97 |
| Austria | — | — | 0.6 | 4 | 2.9 | (37) | 9.0 | 189.7 | 14.3 | 4 | 2,300 | — | 2 |
| Belarus | — | — | 0.5 | (84) | 5.6 | (203) | 16.4 | 72.8 | 8.5 | 4 | 5,000[f] | — | 0 |
| Belgium | 29.7 | (27) | 0.5 | 4 | 1.4 | 49 | 471.9 | 1,059.0 | — | — | 544[j] | 156 | 83 |
| Bosnia and Herzegovina | 0.0 | — | 2.5 | — | — | — | — | 8.3 | 1.9 | 2 | 3,500[f] | — | 47 |
| Bulgaria | 10.2 | (87) | 1.9 | 37 | 5.2 | (102) | 7.2 | 15.5 | 4.2 | 3 | 1,483[f] | 30 | 29 |
| Croatia | 20.6 | — | 0.4 | — | 6.3 | — | 40.9 | 38.1 | 5.2 | 5 | 65,151[i] | 305 | 38 |
| Czech Rep | — | — | 4.3 | — | 18.5 | — | 27.7 | 79.4 | 12.7 | 5 | 2,243 | — | 0 |
| Denmark | 1,497.3 | (15) | 1.5 | (71) | 42.9 | 19 | 2,856.3 | 1,804.9 | 26.0 | 10 | 6,711[j] | 4,285 | 100 |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Estonia | 110.2 | (72) | 4.4 | (36) | 0.2 | (286) | 86.6 | 37.6 | 19.7 | 12 | 13,346 | 186 | 86 |
| Finland | 108.7 | 28 | 56.4 | (16) | 15.6 | (14) | 19.1 | 127.5 | 33.6 | 14 | 5,879 | 3,838 | 73 |
| France | 573.2 | (10) | 3.3 | (40) | 266.8 | 11 | 1,104.7 | 3,275.8 | 31.3 | 9 | 26,113[g] | 6,586 | 40 |
| Germany | 212.6 | (33) | 24.5 | 96 | 66.8 | (1) | 1,044.5 | 2,403.1 | 14.9 | 7 | 4,358 | 2,406 | 15 |
| Greece | 104.4 | (16) | 4.4 | 15 | 73.1 | 92 | 248.5 | 301.0 | 26.0 | 11 | 19,847 | 18,375 | 99 |
| Hungary | — | — | 7.3 | (58) | 11.7 | (60) | 8.1 | 45.7 | 4.3 | 2 | 4,900 | — | 0 |
| Iceland | 1,799.9 | 13 | 0.3 | (57) | 3.8 | 50 | 1,352.0 | 80.3 | 93.1 [n] | 30 | 6,100 | 826 | 100 |
| Ireland | 290.2 | 38 | 2.6 | (52) | 45.8 | 52 | 356.4 | 113.5 | 16.0 | 6 | 8,478[i] | 1,353 | 100 |
| Italy | 298.7 | (24) | 5.2 | (61) | 208.8 | 34 | 370.5 | 2,705.7 | 24.2 | 11 | 48,770 | 16,000 | 79 |
| Latvia | 120.2 | (77) | 1.2 | (43) | 0.4 | (853) | 54.4 | 35.9 | 15.4 | 11 | 6,571 | 351 | 75 |
| Lithuania | 57.8 | (85) | 1.9 | (63) | 1.7 | (152) | 40.0 | 56.1 | 22.0 | 15 | 4,700 | 131 | 23 |
| Macedonia, FYR | — | — | 0.2 | — | 1.5 | — | 0.6 | 8.8 | 5.1 | 5 | 8,472 | — | 14 |
| Moldova, Rep | — | — | 0.3 | (86) | 1.1 | (537) | 2.0 | 4.6 | 3.3 | 4 | 40[f] | — | 9 |
| Netherlands | 513.6 | 27 | 2.1 | (47) | 101.4 | 5 | 1,490.2 | 1,237.0 | 19.7 | 9 | 3,743 | 1,008 | 93 |
| Norway | 2,726.8 | 59 | 1.4 | (56) | 458.2 | 74 | 3,668.3 | 635.4 | 52.2 | 26 | 23,552 | 8,664 | 95 |
| Poland | 211.1 | (60) | 19.5 | 23 | 33.1 | 21 | 266.8 | 293.7 | 12.8 | 11 | 8,640[i] | 445 | 14 |
| Portugal | 206.6 | (37) | 0.04 | (23) | 7.1 | (12) | 276.6 | 936.1 | 65.7 | 23 | 25,021 | 9,265 | 93 |
| Romania | 3.0 | (98) | 5.1 | (75) | 9.4 | (369) | 5.4 | 38.8 | 2.5 | 2 | 8,519 | 33 | 6 |
| Russian Federation | 3,700.0 | (50) | 488.3 | (10) | 68.6 | (179) | 1,269.1 | 230.6 | 21.7 | 15 | 316,300 | 3,584 | 15 |
| Serbia and Montenegro | 0.4 | — | 1.2 | — | 4.3 | — | 0.8 | 44.0 | 2.9 | 1 | 1,429[f] | 5 | 8 |
| Slovakia | — | — | 1.7 | — | 0.8 | — | 2.2 | 36.3 | 8.3 | 5 | 215 | — | 0 |
| Slovenia | 1.8 | — | 0.2 | — | 1.1 | — | 6.4 | 28.5 | 6.9 | 3 | 231 | 11 | 61 |
| Spain | 1,133.8 | (8) | 8.9 | (6) | 316.3 | 26 | 1,582.1 | 3,399.6 | 44.4 | 18 | 75,434[f] | 15,243 | 68 |
| Sweden | 363.2 | 51 | 3.6 | (46) | 5.5 | (55) | 472.0 | 688.9 | 30.4 | 14 | 2,783 | 1,240 | 88 |
| Switzerland | — | — | 1.8 | (49) | 1.1 | 26 | 3.1 | 374.1 | 18.3 | 7 | 522 | — | 0 |
| Ukraine | 409.3 | (57) | 11.6 | (81) | 31.0 | (193) | 56.4 | 109.6 | 11.4 | 10 | 120,000[f] | 444 | 21 |
| United Kingdom | 830.6 | (1) | 4.2 | 81 | 148.2 | 69 | 1,421.8 | 2,294.9 | 21.8 | 10 | 17,847 | 9,562 | 99 |
| **Middle East & N. Africa** | **2,348.0** | **24** | **411.0** | **74** | **355.9** | **62** | **—** | **756.3** | **7.2** | **9** | **746,955** | **21,990** | **47** |
| Afghanistan | — | — | 1.1 | 10 | — | — | — | — | — | — | 1,500[f] | — | 0 |
| Algeria | 98.2 | (1) | 0.0 | — | 0.3 | (35) | 2.7 | 11.2 | 3.5 | 6 | 26,151[i] | 2,184 | 69 |
| Egypt | 156.0 | 81 | 219.8 | 44 | 235.3 | 75 | 1.6 | 157.3 | 11.2 | 19 | 250,000 | — | 53 |
| Iran, Islamic Rep | 248.3 | 23 | 140.3 | 424 | 35.2 | 25 | 48.2 | 56.1 | 4.4 | 7 | 138,965 | 900 | 24 |
| Iraq | 12.5 | 204 | 10.1 | (43) | 3.8 | 16 | — | 0.6 | 1.5 | 8 | 12,000[f] | 8 | 6 |
| Israel | 4.2 | (57) | 1.8 | 8 | 19.1 | 23 | 8.2 | 133.2 | 23.4 | 9 | 1,535[f] | 384 | 97 |
| Jordan | 0.1 | — | 0.4 | 10 | 0.5 | 87 | — | 23.4 | 5.1 | 5 | 721 | — | 29 |
| Kuwait | 5.8 | (19) | 1.0 | 127 | 0.3 | — | 5.3 | 16.4 | 12.1 | 5 | 670[j] | 917 | 100 |
| Lebanon | 3.6 | 122 | 0.0 | — | 0.4 | 75 | — | 24.2 | 8.0 | 7 | 9,825 | 5 | 100 |
| Libyan Arab Jamahiriya | 33.0 | 45 | 0.0 | — | 0.1 | 50 | 35.0 | 11.3 | 6.1 | 7 | 9,500[f] | 93 | 79 |
| Morocco | 782.3 | 43 | 1.8 | 16 | 2.2 | 89 | 815.3 | 11.3 | 8.4 | 17 | 106,096[f] | 3052 | 65 |
| Oman | 110.1 | (18) | 0.0 | — | 5.1 | 22 | 46.6 | 5.3 | — | — | 28,003[j] | 390 | 88 |
| Saudi Arabia | 49.1 | 10 | 0.1 | — | 5.4 | 78 | 8.6 | 108.5 | 7.6 | 6 | 25,360 | 23 | 30 |
| Syrian Arab Rep | 2.6 | 81 | 4.6 | 282 | 6.7 | 58 | — | 48.9 | 1.8 | 2 | 11,292 | 5 | 34 |
| Tunisia | 90.9 | (4) | 1.0 | 291 | 1.5 | 37 | 94.7 | 13.1 | 9.4 | 12 | 50,815 | 17 | 84 |
| Turkey | 491.3 | 5 | 28.9 | (12) | 66.2 | 93 | 96.4 | 62.7 | 8.0 | 10 | 33,614[f] | 9,710 | 58 |
| United Arab Emirates | 112.5 | 22 | 0.1 | 82 | 0.0 | — | 36.8 | 27.5 | 25.9 | 12 | 15,543 | 4,050 | 85 |
| Yemen | 122.3 | 64 | 0.0 | — | — | — | 26.1 | 4.8 | 6.8 | 22 | 12,200 | 71 | 63 |
| **Sub-Saharan Africa** | **2806.5** | **15** | **1808.0** | **13** | **37.2** | **25** | **1,691.4** | **845.5** | **7.6** | **25** | **1,995,694[l]** | **71** | **21** |
| Angola | 186.4 | 50 | 6.0 | (25) | — | — | 10.8 | 14.3 | 10.4 | 28 | 30,364[f] | 580 | 29 |

*(Continued)*



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**Table 7O.174 (Continued)**

| State | Marine Catch[a] (annual average) Metric Tons (000) 1998–2000 | Marine Catch[a] (annual average) Percent Change since 1988–1990 | Freshwater Catch[b] (annual average) Metric Tons (000) 1998–2000 | Freshwater Catch[b] (annual average) Percent Change since 1988–1990 | Total Aquaculture Production (annual average) Metric Tons (000) 1998–00 | Total Aquaculture Production (annual average) Percent Change since 1988–1990 | Trade in Fish and Fish Products[c] (annual average mil US$) Exports 1998–2000 | Trade in Fish and Fish Products[c] (annual average mil US$) Imports 1998–2000 | Food Supply from Fish and Fish Products (kg/person/yr)[d] 1997–1999 | Fish Protein as a Percent of All Animal Protein 1997–1999 | Number of Fishers 2000 | Number of Decked Fishery Vessels 1995[e] | Population within 100 km of the Coast (Percent) 1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benin | 13.8 | 6 | 24.5 | (6) | 0.0 | — | 2.2 | 4.7 | 8.7 | 26 | 61,793 | 5 | 62 |
| Botswana | — | — | 0.2 | (89) | — | — | 0.1 | 5.3 | 6.1 | 5 | 2,620[f] | — | 0 |
| Burkina Faso | — | — | 8.1 | 7 | 0.0 | — | 0.0 | 1.4 | 1.9 | 6 | 8,300 | — | 0 |
| Burundi | — | — | 10.9 | (18) | 0.1 | 60 | 0.2 | 0.1 | 2.3 | 23 | 7,030[j] | — | 0 |
| Cameroon | 59.6 | 21 | 50.0 | 138 | 0.1 | (117) | 2.7 | 30.2 | 12.3 | 31 | 24,500 | 25 | 22 |
| Central African Rep | — | — | 14.8 | 14 | 0.1 | 20 | — | 0.4 | 4.2 | 9 | 5,410 | — | 0 |
| Chad | — | — | 84.0 | 31 | — | — | — | — | 6.9 | 14 | 300,000[g] | — | 0 |
| Congo | 20.6 | (6) | 25.5 | 10 | 0.2 | (29) | 2.4 | 19.7 | 21.4 | 46 | 10,500 | 26 | 25 |
| Congo, Dem Rep | 3.9 | 97 | 194.4 | 21 | 0.4 | (66) | 0.5 | 42.5 | 6.7 | 34 | 108,400 | 23 | 3 |
| Côte d'Ivoire | 65.5 | (2) | 11.5 | (59) | 1.0 | 86 | 171.0 | 171.7 | 14.2 | 42 | 19,707[f] | 63 | 40 |
| Equatorial Guinea | 4.5 | 34 | 1.0 | 162 | — | — | 2.8 | 2.1 | — | — | 9,218 | 5 | 72 |
| Eritrea | 7.0 | — | 0.0 | — | — | — | 1.0 | 0.1 | 0.9 | 3 | 14,500[f] | — | 73 |
| Ethiopia[k] | — | — | 15.2 | 365 | 0.0 | — | — | — | 0.2 | 1 | 6,272 | — | 1 |
| Gabon | 40.4 | 114 | 10.1 | 421 | 0.4 | — | 14.0 | 7.1 | 49.6 | 37 | 8,259[g] | 39 | 63 |
| Gambia | 26.5 | 69 | 2.5 | (7) | 0.0 | — | 4.9 | 1.3 | 24.1 | 64 | 2,000[f] | — | 91 |
| Ghana | 384.6 | 24 | 77.9 | 24 | 0.5 | 18 | 81.1 | 97.3 | 28.1 | 66 | 230,000[f] | 500 | 42 |
| Guinea | 78.9 | 108 | 4.0 | 33 | 0.0 | — | 23.1 | 14.3 | 11.2 | 51 | 10,707[f] | 15 | 41 |
| Guinea-Bissau | 5.1 | 3 | — | — | — | — | 3.1 | 0.4 | 4.4 | 14 | 2,500[f] | 8 | 95 |
| Kenya | 6.0 | (29) | 191.7 | 25 | 0.3 | (188) | 36.8 | 6.3 | 5.4 | 10 | 59,565 | 32 | 8 |
| Lesotho | — | — | 0.0 | 494 | 0.00 | — | — | — | 0.0 | 0 | 60[f] | — | 0 |
| Liberia | 8.5 | 3 | 4.1 | (1) | 0.0 | — | 0.0 | 1.9 | 5.9 | 26 | 5,143 | 14 | 58 |
| Madagascar | 98.9 | 47 | 30.0 | (10) | 5.9 | 96 | 77.0 | 6.4 | 7.5 | 16 | 83,310[j] | 65 | 55 |
| Malawi | — | — | 43.8 | (41) | 0.4 | 55 | 0.2 | 0.3 | 4.5 | 34 | 42,922[j] | 57 | 0 |
| Mali | — | — | 102.1 | 55 | 0.1 | 80 | 0.4 | 2.2 | 8.8 | 15 | 70,000[j] | — | 0 |
| Mauritania | 32.9 | (51) | 5.0 | (17) | — | — | 70.1 | 0.5 | 10.6 | 11 | 7,944[g] | 126 | 40 |
| Mozambique | 25.8 | (16) | 10.8 | 215 | 0.0 | — | 84.0 | 8.8 | 2.7 | 21 | 20,000[f] | 291 | 59 |
| Namibia | 305.0 | 191 | 1.5 | 49 | 0.0 | 50 | 266.1 | — | 11.6 | 20 | 2,700[f] | 218 | 5 |
| Niger | — | — | 11.4 | 226 | 0.0 | (100) | 0.7 | 0.6 | 0.9 | 3 | 7,983[f] | — | 0 |
| Nigeria | 316.4 | 66 | 136.9 | 46 | 22.6 | 35 | 4.8 | 231.6 | 8.8 | 32 | 481,264[g] | 318 | 26 |
| Rwanda | — | — | 6.6 | 287 | 0.2 | 65 | — | 0.1 | 1.0 | 7 | 5,690 | — | 0 |
| Senegal | 378.8 | 42 | 27.3 | 47 | 0.1 | 82 | 287.6 | 7.0 | 32.1 | 45 | 55,547[j] | 180 | 83 |
| Sierra Leone | 49.5 | 32 | 16.3 | (0) | 0.03 | 33 | 14.6 | 3.3 | 13.6 | 61 | 17,990[f] | 27 | 55 |
| Somalia | 20.7 | (2) | 0.2 | (50) | — | — | 3.7 | — | 2.9 | 2 | 18,900[f] | 12 | 55 |
| South Africa | 596.4 | (34) | 0.9 | 10 | 4.4 | 47 | 259.0 | 64.1 | 6.9 | 8 | 10,500[f] | 600 | 39 |
| Sudan | 5.7 | 336 | 44.0 | 52 | 1.0 | 88 | 0.4 | 0.4 | 1.7 | 2 | 27,700[j] | — | 3 |
| Tanzania, United Rep | 49.6 | (4) | 280.0 | (18) | 0.2 | (30) | 66.8 | 0.4 | 8.9 | 32 | 92,529 | 30 | 21 |
| Togo | 15.4 | 34 | 5.2 | 20 | 0.1 | 89 | 1.8 | 14.2 | 13.4 | 51 | 14,120 | 3 | 45 |
| Uganda | — | — | 267.5 | 19 | 0.2 | 80 | 33.8 | 0.1 | 8.9 | 28 | 57,862[j] | — | 0 |
| Zambia | — | — | 68.0 | 6 | 4.2 | 70 | 0.4 | 0.9 | 7.4 | 25 | 23,833[f] | 235 | 0 |
| Zimbabwe | — | — | 14.0 | (41) | 0.2 | 11 | 2.2 | 9.3 | 2.7 | 10 | 1,804[l] | — | 0 |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **North America** | **5457.1** | **(19)** | **419.4** | **(19)** | **559.8** | **32** | **5,682.6** | **10,840.9** | **21.5** | **12** | **303,784** | **45,480** | **41** |
| Canada | 933.5 | (37) | 68.9 | (56) | 109.1 | 70 | 2,575.9 | 1,318.9 | 23.8 | 10 | 8,696 | 18,280 | 24 |
| United States | 4365.8 | (15) | 350.5 | (3) | 450.7 | 23 | 2,847.5 | 9,511.3 | 21.3 | 7 | 290,000[f] | 27,200 | 43 |
| **C. America & Caribbean** | **1582.5** | **(7)** | **117.0** | **(25)** | **132.8** | **(697)** | **1,529.2** | **423.0** | **8.8** | **14** | **446,390** | **7,161** | **55** |
| Belize | 37.8 | — | 0.0 | (50) | 2.5 | 92 | 27.7 | 2.4 | 13.0 | 13 | 1,872 | 12 | 100 |
| Costa Rica | 23.2 | 40 | 1.0 | 233 | 9.0 | 95 | 177.4 | 27.4 | 5.9 | 5 | 6,510[j] | 1,003 | 100 |
| Cuba | 58.4 | (68) | 5.0 | (61) | 51.5 | 86 | 90.1 | 26.9 | 13.1 | 16 | 11,865[f] | 1,250 | 100 |
| Dominican Rep | 9.2 | (44) | 0.6 | (57) | 1.2 | 80 | 0.9 | 52.4 | 12.6 | 10 | 9,286 | — | 100 |
| El Salvador | 7.5 | 2 | 2.6 | (5) | 0.3 | (119) | 31.9 | 6.9 | 2.9 | 4 | 24,534 | 80 | 99 |
| Guatemala | 13.7 | 324 | 6.9 | 477 | 4.0 | 79 | 29.9 | 7.6 | 1.6 | 3 | 17,275 | 85 | 61 |
| Haiti | 4.6 | (9) | 0.5 | 58 | — | — | 3.4 | 7.4 | 3.1 | 11 | 4,700[f] | 1 | 100 |
| Honduras | 10.8 | (25) | 0.1 | 115 | 8.3 | 62 | 40.2 | 14.8 | 2.9 | 3 | 21,000[i] | 280 | 65 |
| Jamaica | 6.5 | (18) | 0.5 | 1 | 4.0 | 23 | 13.0 | 56.0 | 25.5 | 20 | 23,465 | 5 | 100 |
| Mexico | 1130.8 | (9) | 98.5 | (27) | 47.7 | 60 | 694.0 | 125.2 | 9.6 | 8 | 262,401 | 3,100 | 29 |
| Nicaragua | 21.7 | 444 | 1.2 | 813 | 4.8 | 99 | 87.1 | 6.5 | 3.3 | 7 | 14,502 | 280 | 72 |
| Panama | 182.2 | 27 | 0.0 | 21 | 5.3 | 28 | 232.8 | 15.4 | 11.0 | 8 | 13,062 | 695 | 100 |
| Trinidad and Tobago | 9.1 | 12 | 0.0 | — | 0.02 | — | 11.8 | 7.7 | 14.2 | 14 | 7,297 | 19 | 100 |
| **South America** | **14649.6** | **1** | **345.7** | **6** | **318.2** | **61** | **4,980.1** | **687.7** | **8.9** | **12** | **784,051** | **13,106** | **49** |
| Argentina | 1006.7 | 101 | 24.7 | 133 | 1.3 | 77 | 824.7 | 86.5 | 8.5 | 4 | 12,320 | 800 | 45 |
| Bolivia | 0.9 | (64) | 5.2 | 59 | 0.4 | 21 | 0.1 | 5.6 | 1.7 | 2 | 7,754[f] | — | 0 |
| Brazil | 520.5 | (16) | 180.9 | (6) | 132.7 | 86 | 168.7 | 357.0 | 6.5 | 4 | 290,000[f] | 1,450 | 49 |
| Chile | 4150.8 | (26) | 0.0 | (97) | 319.6 | 94 | 1,694.4 | 54.1 | 17.6 | 10 | 50,873 | 563 | 82 |
| Colombia | 101.7 | 71 | 25.1 | (37) | 53.6 | 88 | 195.1 | 86.5 | 4.5 | 5 | 129,410[i] | 167 | 30 |
| Ecuador | 466.4 | (18) | 0.4 | (32) | 112.0 | 33 | 915.7 | 16.1 | 7.0 | 9 | 162,870[g] | 515 | 61 |
| Guyana | 51.2 | 44 | 0.7 | (16) | 0.5 | 92 | 38.6 | 0.7 | 59.9 | 47 | 6,571 | 55 | 77 |
| Paraguay | — | — | 25.0 | 124 | 0.1 | 44 | 0.1 | 2.3 | 5.5 | 4 | 4,469[g] | — | 0 |
| Peru | 7773.0 | 15 | 34.6 | 2 | 7.6 | 34 | 852.2 | 15.4 | 20.3 | 21 | 66,361 | 7,710 | 57 |
| Suriname | 16.0 | 209 | 0.2 | (27) | 0.2 | — | 6.9 | 4.1 | 24.6 | 24 | 3,628[f] | 22 | 87 |
| Uruguay | 117.9 | 11 | 2.2 | 878 | 0.0 | — | 115.0 | 13.4 | 8.6 | 4 | 4,023 | 958 | 78 |
| Venezuela | 389.9 | 37 | 46.7 | 41 | 11.1 | 94 | 126.9 | 45.5 | 18.3 | 19 | 44,302[i] | 866 | 73 |
| **Oceania** | **1110.1** | **75** | **23.0** | **(1)** | **127.6** | **62** | **1,681.7** | **629.9** | **22.7** | **25** | **85,324** | **1,917** | **87** |
| Australia | 214.6 | 13 | 4.1 | 9 | 33.9 | 62 | 885.7 | 518.8 | 21.3 | 7 | 13,800[i] | 246 | 90 |
| Fiji | 27.9 | 17 | 5.5 | 18 | 1.3 | 99 | 28.5 | 16.8 | 32.1 | 21 | 8,985[j] | — | 100 |
| New Zealand | 594.9 | 97 | 1.6 | (20) | 90.4 | 69 | 682.2 | 55.9 | 30.3 | 13 | 1,928 | 1,375 | 100 |
| Papua New Guinea | 47.1 | 271 | 11.7 | (7) | 0.0 | — | 31.7 | 11.5 | 15.1 | 31 | 16,000[f] | 35 | 61 |
| Solomon Islands | 46.8 | (0) | 0.0 | — | 0.0 | — | 10.2 | 0.2 | 52.5 | 82 | 11,000[m] | 130 | 100 |
| **Developed** | **27258.0** | **(30)** | **1439.3** | **(21)** | **3180.4** | **12** | **27,094.4** | **48,905.7** | **23.7** | **10** | **1,467,401** | **516,259** | **45** |
| **Developing** | **53010.2** | **32** | **8110.6** | **49** | **26702.3** | **60** | **24,010.7** | **8,571.6** | **13.8** | **20** | **32,640,482** | **740,322** | |

*Note:* Negative values are shown in parentheses.

### Variable Definitions and Methodology

**Marine and Freshwater Catch** data refer to marine and freshwater fish caught or trapped for commercial, industrial, and subsistence use (catches from recreational activities are included where available); they include fish caught by a country's fleet anywhere in the world. Statistics for mariculture, aquaculture, and other kinds of fish or shellfish farming are not included in the country totals. Marine fish includes demersal fish (flounders, halibuts, soles, etc; cods, hakes, haddocks, etc; redfishes, basses, congers, etc; and sharks, rays, chimeras, etc.), pelagic fish (jacks, mullets, sauries, etc; herrings, sardines, anchovies, etc; tunas, bonitos, billfishes, etc; and mackerels, snooks, cutlassfishes, etc.), and diadromous fish caught in marine areas (i.e. sturgeons, paddlefishes, river eels, salmons, trouts, smelt, shads, and miscellaneous diadromous fishes), marine molluscs (squids, cuttlefishes, octopuses, etc; abalones, winkles, conchs, etc; oysters; mussels; scallops, pectens, etc; clams, cockles, arkshells, etc; and miscellaneous marine molluscs) and marine crustaceans (sea-spiders, crabs, etc; lobsters, spiny-rock lobsters, etc; squat lobsters; shrimps, prawns, etc; krill, planktonic crustaceans, etc; and miscellaneous marine crustaceans).



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Freshwater fish includes fish caught in inland waters (i.e. carps, barbels, and other cyprinids; tilapias and other cichlids; and miscellaneous and freshwater fishes), and diadromous fish caught in inland waters, as well as freshwater molluscs and crustaceans. Catch figures are the national totals averaged over a 3-year period. Data are represented as nominal catches, which are the landings converted to a live-weight basis, that is, the weight when caught. Fish catch does not include discards. Landings for some countries are identical to catches. Catch data are provided annually to the FAO Fisheries Department by national fishery offices and regional fishery commissions. Some recent data are provisional. If no data are submitted, FAO uses the previous year's figures or makes estimates based on other information.

**Aquaculture** is defined by FAO as "the farming of aquatic organisms, including fish, molluscs, and crustaceans. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, and protection from predators, etc. [It] also implies ownership of the stock being cultivated¥" Aquatic organisms that are exploitable by the public as a common property resource are included in the harvest of fisheries.
FAO's global collection of aquaculture statistics from questionnaires to national fishery offices was begun in 1984. FAO's aquaculture database has 337 "species items" that are grouped into six categories. **Total Aquaculture Production** includes marine, freshwater, and diadromous fishes, molluscs and crustaceans cultivated in marine, inland, or brackish environments. For a detailed listing of species, please refer to the original source. Aquaculture production is expressed as an annual average over a 3-year period.

**Trade in Fish and Fish Products** expresses the value associated with imports and exports of fish that are live, fresh, chilled, frozen, dried, salted, smoked, or canned, and other derived products and preparations. Trade includes freshwater and marine fish, aquaculture, molluscs and crustaceans, meals, and solubles. Aquatic plants are not included. Figures are the national totals averaged over a 3-year period in millions of U.S. dollars. Exports are generally on a free-on-board basis (i.e. not including insurance or freight costs). Imports are usually on a cost, insurance, and freight basis (i.e. insurance and freight costs added in). Regional totals are calculated by adding up imports or exports of each country included in that region.
Therefore, the regional totals should not be taken as a net trade for that region, since there may also be trade occurring within a region. To collate national data, FAO uses its International Standard Statistical Classification of Fishery Commodities. Commodities produced by aquaculture and other kinds of fish farming are also included.

**Food Supply from Fish and Fish Products** is defined as the quantity of both freshwater and marine fish, seafood and derived products available for human consumption. Data were calculated by taking a country's fish production plus imports of fish and fishery products, minus exports, minus the amount of fishery production destined to non-food uses (i.e. reduction to meal, etc.), and plus or minus variations in stocks. The quantity of fish and fish products consumed include the bones and all parts of the fish.

**Fish Protein as a Percent of Animal Protein Supply** is defined as the quantity of protein from both freshwater and marine fish, seafood and derived products available for human consumption as a percentage of all available animal protein. FAO calculates food supply for all products, including fish, in its food balance sheets. FAOSTAT maintains statistics on apparent consumption of fish and fishery products, in live weight, for 220 countries in a collection of Supply/Utilization Accounts (SUAs). For each product, the SUA traces supplies from production, imports, and stocks to its utilization in different forms–addition to stocks; exports; animal feed; seed; processing for food and non-food purposes; waste (or losses); and lastly; as food available for human consumption, where appropriate. For more detailed information, please refer to the following article: "Supply Utilization Accounts and Food Balance Sheets in the Context of a National Statistical System", maintained on-line by FAO at fao.org/es/ESS/Suafbs.htm.

**Number of Fishers** includes the number of people employed in commercial and subsistence fishing (both personnel on fishing vessels and on shore), operating in freshwater, brackish and marine areas, and in aquaculture production activities. Data on people employed in fishing and aquaculture are collected by the FAO through annual questionnaires submitted to the national reporting offices of the member countries. When possible, other national and/or regional published sources are also used to estimate figures. Please refer to the original source for further information on collection methodologies (available online at fao.org/fi/statist/fisoft/fishers.asp) or to the following publication: *Numbers of Fishers 1970–1997, FAO Fisheries Circular N.929 Revision 2, Fishery Information, Data and Statistics Unit (FAO, Rome, 1999).*

**Decked Fishery Vessels** include trawlers, purse seiners, gill netters, long liners, trap setters, other seiners and liners, multipurpose vessels, dredgers, and other fishing vessels. Data on undecked vessels are being collected by FAO, but are not yet available. Fleet data are collected by the FAO through questionnaires submitted to the national reporting offices of the member countries. Other national or regional published sources, such as the registry of fishing vessels, are also used to estimate fleet size. The flag of the vessel is used to assign its nationality. However, in many cases vessels are flagged in one country, while the ownership, landings, and trade resides with another nation. This approach is referred to as a "flag of convenience," and fishers or corporations use this method to facilitate registration of a vessel (i.e. some countries have fewer registration restrictions), to gain access to fish in different Exclusive Economic Zones, or to avoid having to follow set fishing quotas in their own nation, among other reasons.

**Population within 100 km of the Coast** refers to estimates of the percentage of the population living within the coastal area based on 1995 population figures. These estimates were calculated using a data set that provides information on the spatial distribution of the world's human population on a 2.5-minute grid. Populations are distributed according to administrative districts, which vary in scale, level, and size from country to country. A 100-km coastal buffer was used to calculate the number of people in the coastal zone for each country. The percentage of the population in the coastal zone was calculated from 1995 United Nations Population Division totals for each country.

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**Frequency of Update by Data Providers**

The Food and Agriculture Organization updates the FishStat database annually. Updates can be found on the FishStat website at fao.org/fi/statist/FISOFT/FISHPLUS.asp. The FAO updates the data on Food Supply variables annually; the most recent updates incorporated in these tables are from July 2002. Data on the number of fishers and decked fishery vessels are updated by the Fishery Information, Data and Statistics Unit (FIDI) of FAO.

**Data Reliability and Cautionary Notes**

**Marine Catch, Freshwater Catch, Total Aquaculture Production, and Trade in Fish and Fishery Products.** While the FAO data set provides the most extensive, global time series of fishery statistics since 1 970, there are some problems associated with the data. Funding for the development and maintenance of fisheries statistics at the national level has been decreasing in real terms since 1992, while the demand is growing for a variety of global statistics on discards, fish inventories, aquaculture, and illegal activities. Country-level data are often submitted with a 1–2 year delay, and countries are declaring an increasing percentage of their catch as "unidentified fish." Stock assessment working groups can more accurately estimate the composition of a catch; however, due to financial constraints, these groups are rare, especially in developing countries. Statistics from smaller artisanal and subsistence fisheries are particularly sparse. In addition, fishers sometimes underreport their catches because they have not kept within harvest limits established to manage the fishery. In some cases, catch statistics are inflated to increase the importance of the fishing industry to the national economy. FAO states that "general trends are probably reliably reflected by the available statistics¥ but the annual figures and the assessments involve a certain degree of uncertainty and small changes from year to year are probably not statistically significant." The quality of the aquaculture production estimates varies because many countries lack the resources to adequately monitor landings within their borders.

These statistics provide a good overview of regional fisheries trends. However, when reviewing the state of fisheries stocks, evaluating food security, etc., these data should be used with caution and supplemented with estimates from regional organizations, academic literature, expert consultations, and trade data. For more information, please consult Fishery Statistics: Reliability and Policy Implications, published by the FAO Fisheries Department and available on-line at fao.org/fi/statist/nature-china/30janO2.asp.

**Food Supply from Fish and Fishery Products and Fish Protein as a Percent of Total Protein:** Food supply is different from actual consumption. Figures do not account for discards (including bones) and losses during storage and preparation. Supply data should only be used to assess food security if it is combined with an analysis of food availability and accessibility. Per capita supply averages can also mask disparate food availability within a particular country. Nonetheless, the data are subject to "vigorous consistency checks." According to FAO, the food supply statistics, "while often far from satisfactory in the proper statistical sense, do provide an approximate picture of the overall food situation in a country and can be useful for economic and nutritional studies, for preparing development plans and for formulating related projects." For more information see Food Balance Sheets: A Handbook, maintained on-line by FAO at fao.org/DOCREP/003/X9892E/X9892E00.htm.

**Number of Fishers:** Numbers presented in this table are gross estimates. Many countries do not submit data on fishers, or submit incomplete information; therefore the quality of these data is poor. Apart from the gaps and the heavy presence of estimates due to non-reporting, the information provided by national statistical offices may not be strictly comparable since different definitions and methods are used in assessing the number of people engaged in fishing and aquaculture.

FAO recognizes that these statistics are incomplete and may not accurately reflect the current level of employment in the fishing sector. Specifically, it is aware that some countries failed to report for several years, that those which reported regularly have occasionally omitted fish farmers from the total or included subsistence and sport fishers as well as family members living on fishing.

**Decked Fishery Vessels:** As with the number of fishers, FAO recognizes that these fleet statistics are incomplete and may not accurately reflect current world fishing capacity. These data may include vessels that are no longer in operation. The quality of the estimates varies because many countries lack the resources to adequately monitor and report on fleet size. For further information, please refer to the original source or to *"Fishery Fleet Statistics, 1970 1975, 1980 1985, 1989–95"* Bulletin of Fishery Statistics No. 35 (FAO, Rome, 1998).

[a] Includes marine fish and diadromous fish caught in marine areas, as well as molluscs and crustaceans.
[b] Includes freshwater fish and diadromous fish caught in inland waters or low-salinity marine areas, as well as molluscs and crustaceans.
[c] Includes trade of all marine and freshwater catch, and total aquaculture production, excluding aquatic plants.
[d] Per capita values are expressed on a live-weight equivalent basis, which means that all parts of the fish, including bones, are taken into account when estimating consumption of fish and fishery products.
[e] Includes fishing vessels such as trawlers, long liners, etc., and nonfishing vessels such as motherships, fish carriers, etc.
[f] Data were collected between 1991 and 1996.
[g] Data are for 1997.
[h] Does not include Taiwan or Hong Kong.
[i] Data are for 1998.
[j] Data are for 1999.
[k] Data for Ethiopia before 1993 include Eritrea.
[l] Since independence, data include a substantial but unquantifiable number of sport fishers.
[m] Data are for 1980.
[n] Per capita fish consumption in Iceland includes quantities of fish and fish products destined for the export market.

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*Source:* From World Resources Institute, Earth Trends Environmental Information, *Coastal and Marine Ecosystems*, www.earthtrends.wri.org.

*Original Source:* **Catch, Aquaculture Production, and Trade in Fish and Fishery Products** data produced by the Fishery Information, Data and Statistics Unit, Food and Agriculture Organization of the United Nations (FAO). 2002. FISHSTAT Plus: *Universal software for fishery statistical time series, Version 2.3* Rome: FAO. Available on-line at: fao.org/fi/statist/FISOFT/FISH PLUS. asp **Food Supply Variables** are from the Food and Agriculture Organization of the United Nations (FAO), *FAOSTAT on-line statistical service.* 2002. Rome: FAO. Available on-line at: http://apps.fao.org. **Data on the Number of Fishers** are from the Food and Agriculture Organization of the United Nations (FAO), Fishery Information, Data and Statistics Unit (FIDI) December, 1999. **Number of People within 100 km of the Coast** is derived from the Center for International Earth Science Information Network (CIESIN), World Resources Institute, and International Food Policy Research Institute. 2000. *Gridded Population of the World, Version 2 alpha* Columbia University, Palisades, NY. Available online at: sedac.ciesin.org/plue/gwp. **Population** (used to calculate per capita values): Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. 2002. World Population Prospects: The 2000 Revision. Data set on CD-ROM New York: United Nations.

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**Table 7O.175 World Aquaculture**

| World/Region | Production (thousand MT) | | | Average Annual Rate of Growth (%) | |
|---|---|---|---|---|---|
| | 1980 | 1990 | 2001 | 1980–1990 | 1990–2001 |
| **World** | **4,707** | **13,080** | **37,851** | **10.8** | **10.1** |
| **Developed countries** | **1,685** | **2,867** | **3,652** | **5.5** | **2.2** |
| Industrialized countries | 1,419 | 2,327 | 3,419 | 5.1 | 3.6 |
| Transition economies | 266 | 540 | 233 | 7.3 | −7.3 |
| **Developing countries** | **3,022** | **10,212** | **34,199** | **12.9** | **11.6** |
| Latin America and the Caribbean | 27 | 193 | 1,112 | 21.7 | 17.3 |
| Near East and North Africa | 34 | 104 | 498 | 11.8 | 15.4 |
| Sub-Saharan Africa | 7 | 13 | 50 | 6.6 | 12.8 |
| East and Southeast Asia | 2,490 | 8,668 | 29,603 | 13.3 | 11.8 |
| South Asia | 464 | 1,235 | 2,931 | 10.3 | 8.2 |
| Oceania developing | 0 | 1 | 4 | 0.0 | 13.8 |
| North America developing | 0 | 0 | 0 | 0.0 | 0.0 |
| **Continental groupings** | | | | | |
| Africa | 26 | 81 | 402 | 12.0 | 15.7 |
| Asia | 3,553 | 10,806 | 33,514 | 11.8 | 10.8 |
| Latin America | 25 | 179 | 1,051 | 22.0 | 17.4 |
| Caribbean | 2 | 13 | 62 | 18.9 | 15.1 |
| North America | 172 | 357 | 613 | 7.6 | 5.1 |
| Oceania | 12 | 42 | 124 | 13.1 | 10.3 |
| Europe | 916 | 1,602 | 2,086 | 5.7 | 2.4 |

*Note:* Aquaculture excludes aquatic plants.

*Source*: From Food and Agriculture Organization of the United Nations (FAO), 2003, *Summary of Food and Agricultural Statistics*, www.fao.org. Reprinted with permission.

**Table 7O.176 World Capture Fisheries**

| World/Region | Production (thousand MT) | | | Average Annual Rate of Growth (%) | |
|---|---|---|---|---|---|
| | 1980 | 1990 | 2001 | 1980–1990 | 1990–2001 |
| **World** | **67,706** | **85,507** | **92,356** | **2.4** | **0.7** |
| **Developed countries** | **37,476** | **38,138** | **28,428** | **0.2** | **−2.6** |
| Industralized countries | 26,873 | 27,414 | 23,546 | 0.2 | −1.4 |
| Transition economies | 10,603 | 10,725 | 4,881 | 0.1 | −6.9 |
| **Developing countries** | **30,229** | **47,368** | **63,928** | **4.6** | **2.8** |
| Latin America and the Caribbean | 9,530 | 16,082 | 16,800 | 5.4 | 0.4 |
| Near East and North Africa | 1,360 | 2,027 | 3,174 | 4.1 | 4.2 |
| Sub-Saharan Africa | 2,233 | 3,517 | 4,391 | 4.6 | 2.0 |
| East and Southeast Asia | 13,720 | 21,235 | 33,254 | 4.5 | 4.2 |
| South Asia | 3,136 | 4,157 | 5,792 | 2.9 | 3.1 |
| Oceania developing | 133 | 184 | 355 | 3 | 6.1 |
| North America developing | 116 | 167 | 163 | 4 | −0.2 |
| **Continental groupings** | | | | | |
| Africa | 3,663 | 5,075 | 6,890 | 3.3 | 2.8 |
| Asia | 27,519 | 36,226 | 45,262 | 2.8 | 2.0 |
| Latin America | 9,279 | 15,818 | 16,620 | 5.5 | 0.5 |
| Caribbean | 251 | 264 | 180 | 0.5 | −3.4 |
| North America | 5,001 | 7,359 | 6,157 | 3.9 | −1.6 |
| Oceania | 411 | 741 | 1,108 | 6.1 | 3.7 |
| Europe | 21,284 | 19,947 | 15,963 | −0.6 | −2.0 |

*Source*: From Food and Agriculture Organization of the United Nations (FAO), 2003, *Summary of Food and Agricultural Statistics*, www.fao.org. Reprinted with permission.

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**Table 7O.177 Capture Fisheries and Aquaculture — Leading Species in 2001**

| Species | Production (thousand MT) | % of World Production |
|---|---|---|
| **Capture Fisheries** | | |
| Anchoveta (Peruvian anchovy) | 7,213 | 7.8 |
| Alaska pollock (Walleye poll.) | 3,136 | 3.4 |
| Chilean jack mackerel | 2,509 | 2.7 |
| Atlantic herring | 1,953 | 2.1 |
| Japanese anchovy | 1,837 | 2.0 |
| Skipjack tuna | 1,836 | 2.0 |
| Blue whiting (Poutassou) | 1,823 | 2.0 |
| Chub mackerel | 1,799 | 1.9 |
| Capelin | 1,671 | 1.8 |
| Largehead hairtail | 1,472 | 1.6 |
| Other species | 67,107 | 72.7 |
| **Aquaculture** | | |
| Pacific cupped oyster | 4,110 | 10.9 |
| Grass carp (White amur) | 3,636 | 9.6 |
| Silver carp | 3,546 | 9.4 |
| Common carp | 2,849 | 7.5 |
| Japanese carpet shell | 2,091 | 5.5 |
| Bighead carp | 1,663 | 4.4 |
| Crucian carp | 1,527 | 4.0 |
| Yesso scallop | 1,196 | 3.2 |
| Nile tilapia | 1,109 | 2.9 |
| Atlantic salmon | 1,025 | 2.7 |
| Other species | 15,097 | 39.9 |

*Source*: From Food and Agriculture Organization of the United Nations (FAO), 2003, *Summary of Food and Agricultural Statistics*, www.fao.org. With permission.

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## SECTION 7P WATER IN FOODS

**Table 7P.178 Water Content in Various Foods**

| | |
|---|---|
| Tortilla chips | 1 |
| Potato chips | 2 |
| Peanut butter | 2 |
| Popcorn | 4 |
| Margarine | 14 |
| Butter | 16 |
| Croissant | 23 |
| Jam | 29 |
| Bagel | 29 |
| Parmesan cheese | 30 |
| Angel food cake | 32 |
| Maple syrup | 33 |
| Swiss cheese | 38 |
| Whole wheat bread | 38 |
| English muffin | 42 |
| Cheese cake | 46 |
| Pizza | 48 |
| Brie | 49 |
| Apple pie | 51 |
| Frankfurter | 54 |
| Cream cheese | 54 |
| Hamburger | 55 |
| Whipping cream | 58 |
| Flounder, baked | 58 |
| Veal, chuck | 59 |
| Chicken, roasted | 60 |
| Ice cream | 61 |
| Turkey, roasted | 62 |
| Tuna, in water | 62 |
| Salmon, broiled | 63 |
| Ham, smoked, cooked | 66 |
| Halibut, broiled | 67 |
| Liver, beef, raw | 70 |
| Sour cream | 71 |
| Lima beans, cooked | 71 |
| Avocado | 73 |
| Corn, cooked | 74 |
| Ricotta cheese | 74 |
| Banana | 74 |
| Egg, boiled | 75 |
| Cottage cheese | 79 |
| Potato, raw | 80 |
| Clams | 81 |
| Grapes | 81 |
| Pear | 84 |
| Oysters | 85 |
| Orange | 87 |
| Beets, raw | 87 |
| Apple juice | 88 |
| Milk, whole | 88 |
| Yoghurt, whole milk | 88 |
| Carrots, raw | 88 |
| Broccoli, raw | 89 |
| Mushroom, raw | 90 |
| Cantaloupe | 90 |
| Milk, skim | 91 |
| Beer | 92 |
| Asparagus, cooked | 94 |
| Tomato, raw | 94 |
| Squash, boiled | 96 |
| Lettuce, raw | 96 |

*Note:* Percentage by Weight.

*Source*: From Calculated from weight and water content values given in *Bowes and Church's Food Values of Portions Commonly Used*, 14th ed., Harper & Row.

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CHAPTER 8

# Water Quality

**Katherine L. Thalman and James M. Bedessem**

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# SECTION 8A WATER QUALITY

**Table 8A.1 Summary of Quality Inputs to Surface and Groundwaters**

| Contributing Factor | Principal Quality Input to Surface Waters |
|---|---|
| Meteorological water | Dissolved gases native to atmosphere<br>Soluble gases from man's industrial activities<br>Particulate matter from industrial stacks, dust, and radioactive particles<br>Material washed from surface of earth, e.g.,<br>Organic matter such as leaves, grass, and other vegetation in all stages of biodegradation<br>Bacteria associated with surface debris (including intestinal organisms)<br>Clay, silt, and other mineral particles<br>Organic extractives from decaying vegetation<br>Insecticide and herbicide residues |
| Domestic use (exclusive of industrial) | Undecomposed organic matter, such as garbage ground to sewer, grease, etc.<br>Partially degraded organic matter such as raw wastes from human bodies<br>Combination of above two after biodegradation to various degrees of sewage treatment<br>Bacteria (including pathogens), viruses, worm eggs<br>Grit from soil washings, eggshells, ground bone, etc.<br>Miscellaneous organic solids, e.g., paper, rags, plastics, and synthetic materials<br>Detergents |
| Industrial use | Biodegradable organic matter having a wide range of oxygen demand<br>Inorganic solids, mineral residues<br>Chemical residues ranging from simple acids and alkalis to those of highly complex molecular structure<br>Metal ions |
| Agricultural use | Increased concentration of salts and ions<br>Fertilizer residues<br>Insecticide and herbicide residues<br>Silt and soil particles<br>Organic debris, e.g., crop residue |
| Consumptive use (all sources) | Increased concentration of suspended and dissolved solids by loss of water to atmosphere |
| **Contributing Factor** | **Principal Quality Input to Groundwater** |
| Meteorological water | Gases, including $O_2$ and $CO_2$, $N_2$, $H_2S$, and H<br>Dissolved minerals, e.g.:<br>Bicarbonates and sulfates of Ca and Mg dissolved from earth minerals<br>Nitrates and chlorides of Ca, Mg, Na and K dissolved from soil and organic decay residues<br>Soluble iron, Mn, and F salts |
| Domestic use (principally via septic tank systems and seepage from polluted surface waters) | Detergents<br>Nitrates, sulfates, and other residues of organic decay<br>Salts and ions dissolved in the public water supply<br>Soluble organic compounds |
| Industrial use (not much direct disposal to soil) | Soluble salts from seepage of surface waters containing industrial wastes |
| Agriculture use | Concentrated salts normal to water applied to land<br>Other materials as per meteorological waters |
| Land disposal of solid wastes (not properly installed) | Hardness-producing leaching from ashes<br>Soluble chemical and gaseous products or organic decay |

*Note:* This list includes the types of things that may come from any contributing factor. Not all are present in each specific instance.

*Source*: From McGauhey, *Engineering Management of Water Quality*, McGraw-Hill, Copyright 1968.

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**Table 8A.2 Conditions That May Cause Variations in Water Quality**

| | |
|---|---|
| Climatic conditions | Runoff from snowmelt—muddy, soft, high bacterial count<br>Runoff during drought—high mineral content, hard, groundwater characteristics<br>Runoff during floods—less bacteria than snowmelt, may be muddy (depending upon other factors listed below) |
| Geographic conditions | Steep headwater runoff differs from lower valley areas in ground cover, gradients, transporting power, etc. |
| Geologic conditions | Clay soils produce mud<br>Organic soils or swamps produce color<br>Cultivated land yields silt, fertilizers, herbicides, and insecticides<br>Fractured or fissured rocks may permit silt, bacteria, etc., to move with groundwater<br>Mineral content dependent upon geologic formations |
| Season of year | Fall runoff carries dead vegetation—color, taste, organic extractives, bacteria<br>Dry season yields dissolved salts<br>Irrigation return water, in growing season only<br>Cannery wastes seasonal<br>Aquatic organisms seasonal<br>Overturn of lakes and reservoirs seasonal<br>Floods generally seasonal<br>Dry period, low flows, seasonal |
| Resource management practices | Agricultural soils and other denuded soils are productive of sediments, etc. (See third item under Geologic conditions.)<br>Forested land and swampland yield organic debris<br>Overgrazed or denuded land subject to erosion<br>Continuous or batch discharge of industrial wastes alters shock loads<br>Inplant management of waste streams governs nature of waste |
| Diurnal variation | Production of oxygen by planktonic algae varies from day to night<br>Dissolved oxygen in water varies in some fashion<br>Raw sewage flow variable within 24-hr period; treated sewage variation less pronounced<br>Industrial wastes variable—process wastes during productive shift; different material during washdown and cleanup |

*Source*: From McGauhey, *Engineering Management of Water Quality*, McGraw-Hill, Copyright 1968.

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**Table 8A.3 Principal Chemical Constituents in Water — Their Sources, Concentrations, and Effects upon Usability**

| Constituent | Major Sources | Concentration in Natural Water | Effect upon Usability of Water |
|---|---|---|---|
| Silica ($SiO_2$) | Feldspars, ferromagnesium and clay minerals, amorphous silicachert, opal | Ranges generally from 1.0 to 30 mg/L, although as much as 100 mg/L is fairly common; as much as 4,000 mg/L is found in brines | In the presence of calcium and magnesium, silica forms a scale in boilers and on steam turbines that retards heat; the scale is difficult to remove. Silica may be added to soft water to inhibit corrosion of iron pipes |
| Iron (Fe) | 1. Natural sources<br>*Igneous rocks:*<br>Amphiboles, ferromagnesian micas, ferrous sulfide (FeS), ferric sulfide or iron pyrite ($FeS_2$), magnetite ($Fe_3O_4$)<br>*Sandstone rocks:*<br>Oxides, carbonates, and sulfides or iron clay minerals<br>2. Man-made sources:<br>Well casing, piping, pump parts, storage tanks, and other objects of cast iron and steel which may be in contact with the water<br>Industrial wastes | Generally less than 0.50 mg/L in fully aerated water. Groundwater having a pH less than 8.0 may contain 10 mg/L; rarely as much as 50 mg/L may occur. Acid water from thermal springs, mine wastes and industrial may contain more than 6,000 mg/L | More than 0.1 mg/L precipitates after exposure to air; causes turbidity, stains plumbing fixtures, laundry and cooking utensils, and imparts objectionable tastes and colors to foods and drinks. More than 0.2 mg/L is objectionable for most industrial uses |
| Manganese (Mn) | Manganese in natural water probably comes most often from soils and sediments. Metamorphic and sedimentary rocks and mica biotite and amphibole hornblende minerals contain large amounts of manganese | Generally 0.20 mg/L or less. Groundwater and acid mine water may contain more than 10 mg/L. Reservoir water that has "turned over" may contain more than 150 mg/L | More than 0.2 mg/L precipitates upon oxidation; causes undesirable tastes, deposits on foods during cooking, stains plumbing fixtures and laundry and fosters growths in reservoirs, filters, and distribution systems. Most industrial users object to water containing more than 0.2 mg/L |
| Calcium (Ca) | Amphiboles, feldspars, gypsum, pyroxenes, aragonite, calcite, dolomite, clay minerals | As much as 600 mg/L in some western streams; brines may contain as much as 75,000 mg/L | Calcium and magnesium combine with bicarbonate, carbonate, sulfate, and silica to form heat-retarding, pipe-clogging scale in boilers and in other heat-exchange equipment. Calcium and magnesium combine with ions of fatty acid in soaps to form soap suds; the more calcium and magnesium, the more soap required to form suds. A high concentration of magnesium has a laxative effect, especially on new users of the supply |
| Magnesium (Mg) | Amphiboles, olivine, pyroxenes, dolomite, magnesite, clay minerals | As much as several hundred mg/L in some western streams; ocean water contains more than 1,000 mg/L and brines may contain as much as 57,000 mg/L | |
| Sodium (Na) | Feldspars (albite), clay minerals, evaporates, such as halite (NaCl) and mirabilite ($Na_2SO_410H_2O$), industrial wastes | As much as 1,000 mg/L in some western streams; about 10,000 mg/L in sea water; about 25,000 mg/L in brines | More than 50 mg/L sodium and potassium in the presence of suspended matter causes foaming, which accelerates scale formation |

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| | | | |
|---|---|---|---|
| Potassium (K) | Feldspars (orthoclase and microcline), feldspathoids, some micas, clay minerals | Generally less than about 10 mg/L; as much as 100 mg/L in hot springs; as much as 25,000 mg/L in brines | and corrosion in boilers. Sodium and potassium carbonate in recirculating cooling water can cause deterioration of wood in cooling towers. More than 65 mg/L of sodium can cause problems in ice manufacture |
| Carbonate ($CO_3$) | | Commonly 0 mg/L in surface water; commonly less than 10 mg/L in groundwater. Water high in sodium may contain as much as 50 mg/L of carbonate | Upon heating, bicarbonate is changed into steam, carbon dioxide, and carbonate. The carbonate combines with alkaline earths—principally calcium and magnesium—to form a crustlike scale of calcium carbonate that retards flow of heat through pipe walls and restricts flow of fluids in pipes. Water containing large amounts of biocarbonate and alkalinity are undesirable in many industries |
| Bicarbonate ($HCO_3$) | Limestone, dolomite | Commonly less than 500 mg/L; may exceed 1,000 mg/L in water highly charged with carbon dioxide | |
| Sulfate ($SO_4$) | Oxidation of sulfide ores; gypsum; anhydrite; industrial wastes | Commonly less than 1,000 mg/L except in streams and wells influenced by acid mine drainage. As much as 200,000 mg/L in some brines | Sulfate combines with calcium to form an adherent, heat-retarding scale. More than 250 mg/L is objectionable in water in some industries. Water containing about 500 mg/L of sulfate tastes bitter; water containing about 1,000 mg/L may be cathartic |
| Chloride (Cl) | Chief source is sedimentary rock (evaporates); minor sources are igneous rocks. Ocean tides force salty water upstream in tidal estuaries | Commonly less than 10 mg/L in humid regions; tidal streams contain increasing amounts of chloride (as much as 19,000 mg/L) as the bay or ocean is approached. About 19,300 mg/L in seawater, and as much as 200,000 mg/L in brines | Chloride in excess of 100 mg/L imparts a salty taste. Concentrations greatly in excess of 100 mg/L may cause physiological damage. Food processing industries usually require less than 250 mg/L. Some industries—textile processing, paper manufacturing, and synthetic rubber manufacturing—desire less than 100 mg/L |
| Fluoride (F) | Amphiboles (hornblende), apatite, fluorite, mica | Concentrations generally do not exceed 10 mg/L in groundwater or 1.0 mg/L in surface water. Concentrations may be as much as 1,600 mg/L in brines | Fluoride concentration between 0.6 and 1.7 mg/L in drinking water has a beneficial effect on the structure and resistance to decay of children's teeth. Fluoride in excess of 1.5 mg/L in some areas causes "mottled enamel" in children's teeth. Fluoride in excess of 6.0 mg/L causes pronounced mottling and disfiguration of teeth |

*(Continued)*



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**Table 8A.3 (Continued)**

| Constituent | Major Sources | Concentration in Natural Water | Effect upon Usability of Water |
|---|---|---|---|
| Nitrate ($NO_3$) | Atmosphere; legumes, plant debris, animal excrement, nitrogenous fertilizer in soil and sewage | In surface water not subjected to pollution, concentration of nitrate may be as much as 5.0 mg/L but is commonly less than 1.0 mg/L. In groundwater the concentration of nitrate may be as much as 1,000 mg/L | Water containing large amount of nitrate (more than 100 mg/L) is bitter tasting and may cause physiological distress. Water from shallow wells containing more than 45 mg/L has been reported to cause methemoglobinemia in infants. Small amounts of nitrate help reduce cracking of high-pressure boiler steel |
| Dissolved solids | The mineral constituents dissolved in water constitute the dissolved solids | Surface water commonly contains less than 3,000 mg/L; streams draining salt beds in arid regions may contain in excess of 15,000 mg/L. Groundwater commonly contains less than 5,000 mg/L; some brines contain as much as 300,000 mg/L | More than 500 mg/L is undesirable for drinking and many industrial uses. Less than 300 mg/L is desirable for dyeing of textiles and the manufacture of plastics, pulp paper, rayon. Dissolved solids cause foaming in steam boilers; the maximum permissible content decreases with increases in operating pressure |

*Source*: From U.S. Geological Survey, 1962; amended.



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**Table 8A.4 Relative Abundance of Dissolved Solids in Potable Water**

| Major Constituents (1.0 to 1000 mg/L) | Secondary Constituents (0.01 to 10.0 mg/L) | Minor Constituents (0.0001 to 0.1 mg/L) | Trace Constituents (generally less than 0.001 mg/L) |
|---|---|---|---|
| Sodium | Iron | Antimony[a] | Beryllium |
| Calcium | Strontium | Aluminum | Bismuth |
| Magnesium | Potassium | Arsenic | Cerium[a] |
| Bicarbonate | Carbonate | Barium | Cesium |
| Sulfate | Nitrate | Bromide | Gallium |
| Chloride | Fluoride | Cadmium[a] | Gold |
| Silica | Boron | Chromium[a] | Indium |
| | | Cobalt | Lanthanum |
| | | Copper | Niobium[a] |
| | | Germanium[a] | Platinum |
| | | Iodide | Radium |
| | | Lead | Ruthenium[a] |
| | | Lithium | Scandium[a] |
| | | Manganese | Silver |
| | | Molybdenum | Thallium[a] |
| | | Nickel | Thorium[a] |
| | | Phosphate | Tin |
| | | Rubidium[a] | Tungsten[a] |
| | | Selenium | Ytterbium |
| | | Titanium[a] | Yttrium[a] |
| | | Uranium | Zirconium |
| | | Vanadium | |
| | | Zinc | |

[a] These elements occupy an uncertain position in the list.

*Source*: From Davis and DeWiest, *Hydrogeology*, John Wiley & Sons, Copyright 1966.

**Table 8A.5 Characteristics of Water That Affect Water Quality**

| Characteristic | Principal Cause | Significance | Remarks |
|---|---|---|---|
| Hardness | Calcium and magnesium dissolved in the water | Calcium and magnesium combine with soap to form an insoluble precipitate (curd) and thus hamper the formation of a lather. Hardness also affects the suitability of water for use in the textile and paper industries and certain others and in steam boilers and water heating | USGS classification of hardness (mg/L as $CaCO_3$)<br>0–60: Soft<br>61–120: Moderately hard<br>121–180: Hard<br>More than 180: Very hard |
| pH (or hydrogen-ion activity) | Dissociation of water molecules and of acids and bases dissolved in water | The pH of water is a measure of its reactive characteristics. Low values of pH, particularly below pH 4, indicate a corrosive water that will tend to dissolve metals and other substances that it contacts. High values of pH, particularly above pH 8.5, indicate an alkaline water that, on heating, will tend to form scale. The pH significantly affects the treatment and use of water | pH values: less than 7, water is acidic; value of 7, water is neutral; more than 7, water is basic |

*(Continued)*

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**Table 8A.5 (Continued)**

| Characteristic | Principal Cause | Significance | Remarks |
|---|---|---|---|
| Specific electrical conductance | Substances that form ions when dissolved in water | Most substances dissolved in water dissociate into ions that can conduct an electrical current. Consequently, specific electrical conductance is a valuable indicator of the amount of material dissolved in water. The larger the conductance, the more mineralized the water | Conductance values indicate the electrical conductivity, in micromhos, of 1 $cm^3$ of water at a temperature of 25°C |
| Total dissolved solids | Mineral substances dissolved in water | Total dissolved solids is a measure of the total amount of minerals dissolved in water and is, therefore, a very useful parameter in the evaluation of water quality. Water containing less than 500 mg/L is preferred for domestic use and for many industrial processes | USGS classification of water based on dissolved solids (mg/L)<br>Less than 1,000: Fresh<br>1,000–3,000: Slightly saline<br>3,000–10,000: Moderately saline<br>10,000–35,000: Very saline<br>More than 35,000: Briny |

*Source*: From Heath, R.C., 1984, Basic groundwater hydrology, *U.S. Geological Survey Water-Supply Paper 2220*.

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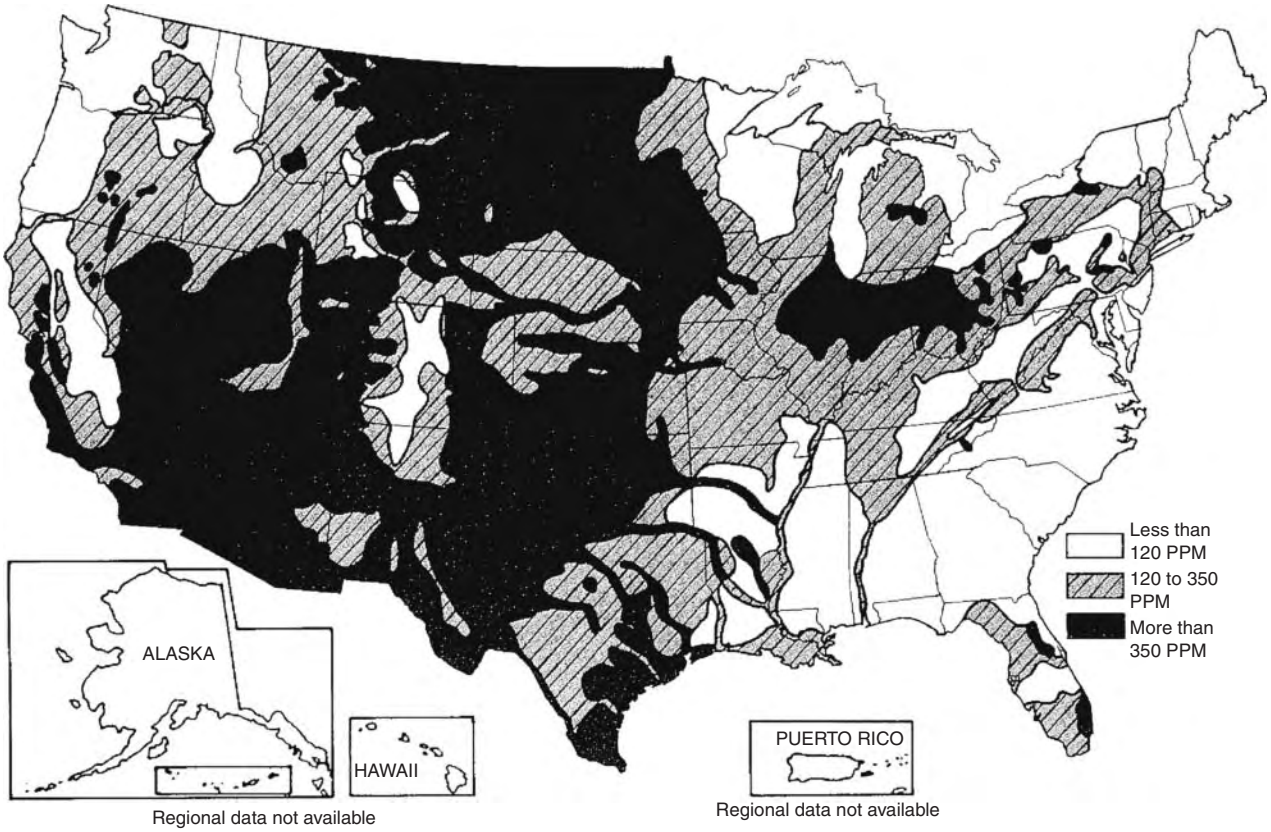


**Figure 8A.1** Dissolved solids in surface water. (From U.S. Water Resources Council, 1968.)

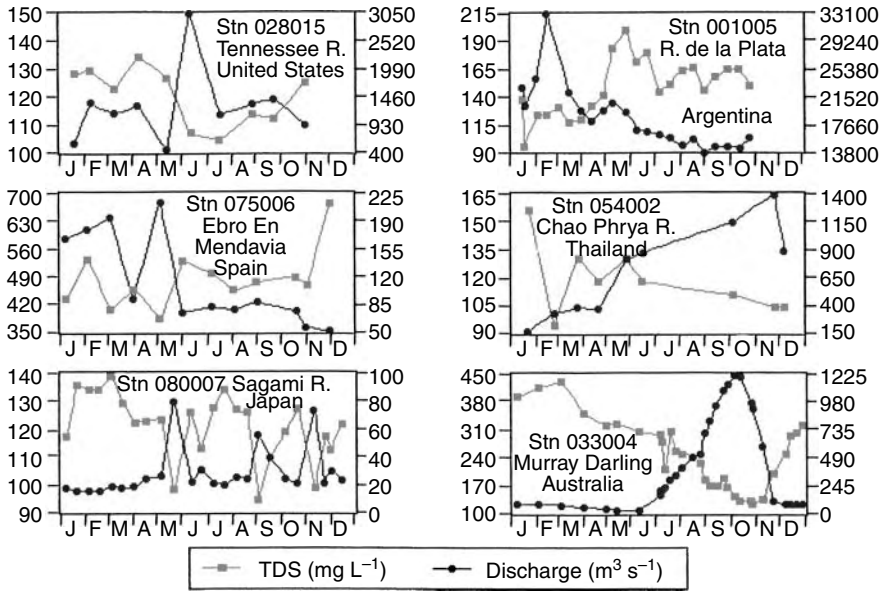


**Figure 8A.2** Seasonal variation of total dissolved solids (TDS) and water discharge at selected world river stations for selected years. (From United Nations Environment Programme, Global Environment Monitoring System Water Programme (GEMS/WATER), The annotated digital atlas of global water quality, www.gemswater.org. Reprinted with permission.)

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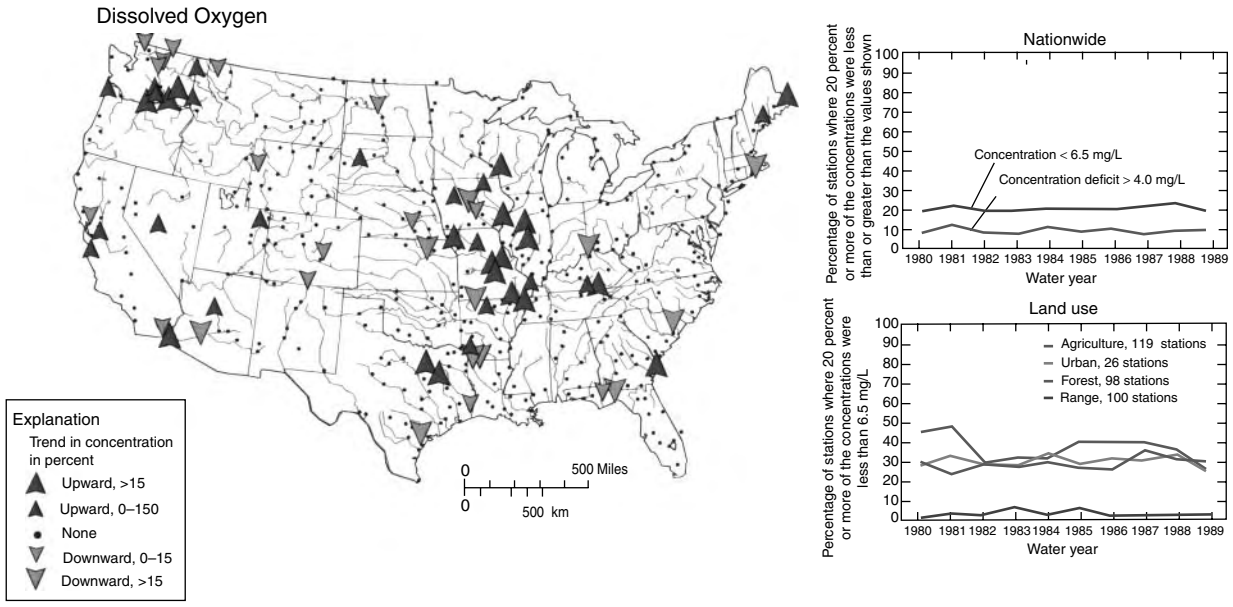
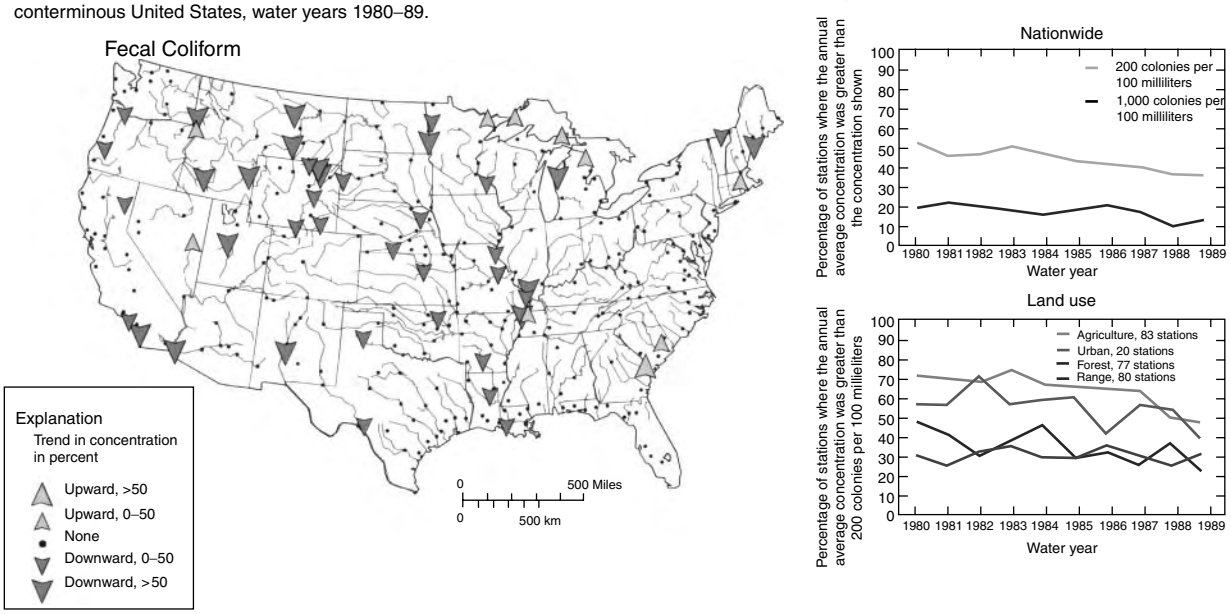



Concentration and trends in dissolved oxygen in stream water at 424 selected water-quality monitoring stations in the conterminous United States, water years 1980–89.




Concentration and trends in fecal coliform bacteria in stream water at 313 selected water-quality monitoring stations in the conterminous United States, water years 1980–89.

**Figure 8A.3** Concentration trends in dissolved oxygen and fecal coliform bacteria in United States rivers, 1980–1989. (From USDA, Natural Resources Conservation Services, 1997, Water Quality and Agriculture, Status, Conditions, and Trends, www.nrcs.usda.gov. *Original Source*: Smith, R.A., Alexander, R.B., and Lanfear, K.J., 1993, Stream water quality in the conterminous United States – status and trends of selected indicators during the 1980's in National Water Summary 1990–91 – Stream water quality, *U.S. Geological Survey Water-Supply Paper 2400*, www.usgs.gov.)

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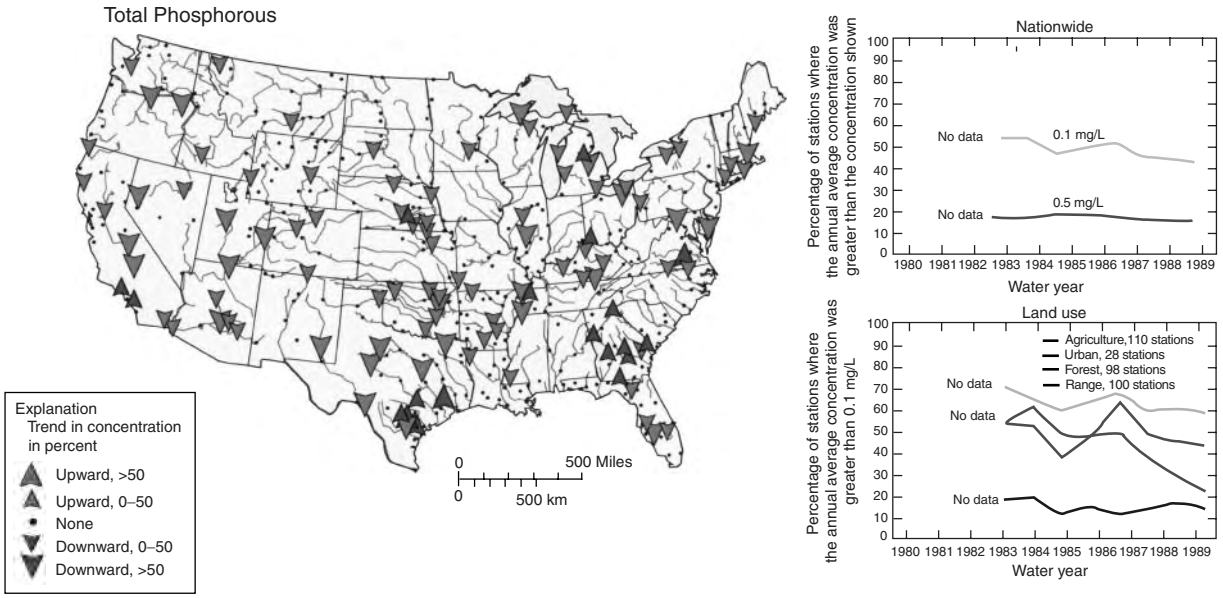
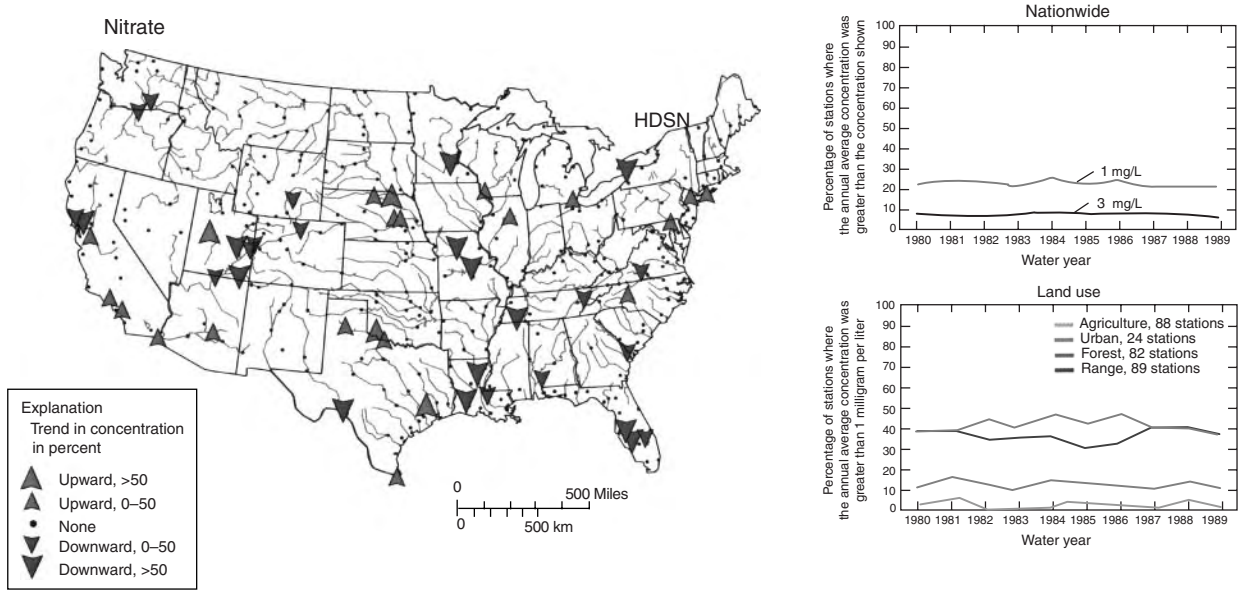



Concentration and trends total phosphorus in stream water at 410 selected water-quality monitoring stations in the conterminous United States, water years 1982–1989.




Concentration and trends in nitrate in stream water at 344 selected water-quality monitoring stations in the conterminous United States, water years 1980–1989.

**Figure 8A.4** Concentration trends in phosphorous, nitrate, and suspended solids in United States rivers, 1980 to 1989. (From USDA, Natural Resources Conservation Services, 1997, Water quality and agriculture, status, conditions, and trends, www.nrcs.usda.gov. *Original Source*: Smith, R.A., Alexander, R.B., and Lanfear, K.J., 1993, Stream water quality in the conterminous United States – status and trends of selected indicators during the 1980's in National Water Summary 1990–91–Stream water quality, *U.S. Geological Survey Water-Supply Paper 2400*, www.usgs.gov.)

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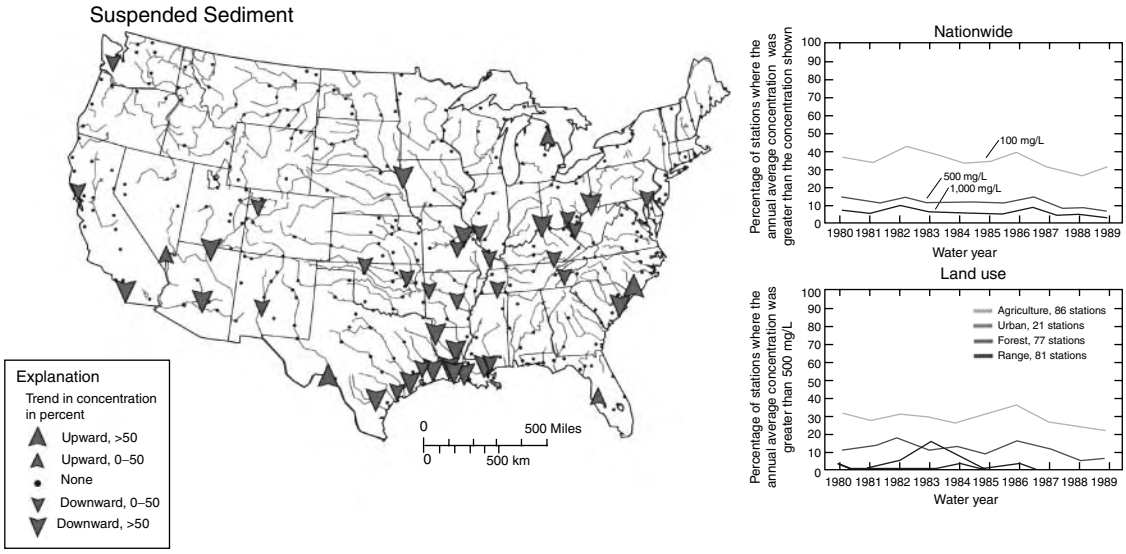


Concentration and trends in suspended sediment in stream water at 324 selected water-quality monitoring stations in the conterminous United States, water years 1980–1989.

**Figure 8A.4** (*Continued*)

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**Table 8A.6 Trends of Surface-Water Quality in the United States, 1974–1981**

| Constituents and Properties | Number of Stations with— Increasing Trends | No Change | Decreasing Trends | Total Stations |
|---|---|---|---|---|
| Temperature | 39 | 218 | 46 | 303 |
| pH | 74 | 174 | 56 | 304 |
| Alkalinity | 18 | 207 | 79 | 304 |
| Sulfate | 82 | 182 | 40 | 304 |
| Nitrate-nitrite | 76 | 203 | 25 | 304 |
| Ammonia | 31 | 221 | 30 | 282 |
| Total organic carbon | 36 | 230 | 13 | 279 |
| Phosphorus | 39 | 232 | 30 | 301 |
| Calcium | 23 | 198 | 83 | 304 |
| Magnesium | 50 | 208 | 46 | 304 |
| Sodium | 103 | 173 | 28 | 304 |
| Potassium | 69 | 193 | 42 | 304 |
| Chloride | 104 | 164 | 36 | 304 |
| Silica | 48 | 213 | 41 | 302 |
| Dissolved solids | 68 | 183 | 51 | 302 |
| Suspended sediment | 44 | 204 | 41 | 289 |
| Conductivity | 69 | 193 | 43 | 305 |
| Turbidity | 42 | 199 | 18 | 259 |
| Fecal coliform bacteria | 19 | 216 | 34 | 269 |
| Fecal streptococcus bacteria | 2 | 190 | 78 | 270 |
| Phytoplankton | 22 | 234 | 44 | 300 |
| Dissolved trace metals | | | | |
| Arsenic | 68 | 228 | 11 | 307 |
| Barium | 4 | 81 | 1 | 86 |
| Boron | 2 | 15 | 3 | 20 |
| Cadmium | 32 | 264 | 7 | 303 |
| Chromium | 12 | 152 | 2 | 166 |
| Copper | 6 | 83 | 6 | 95 |
| Iron | 28 | 258 | 21 | 307 |
| Lead | 5 | 232 | 76 | 313 |
| Manganese | 30 | 250 | 19 | 299 |
| Mercury | 8 | 194 | 2 | 204 |
| Selenium | 2 | 201 | 21 | 224 |
| Silver | 1 | 32 | 0 | 33 |
| Zinc | 19 | 251 | 32 | 302 |

*Note:* Selected water-quality constituents and properties at NASQAN stations.

*Source*: From *U.S. Geological Survey Water-Supply Paper 2250*.

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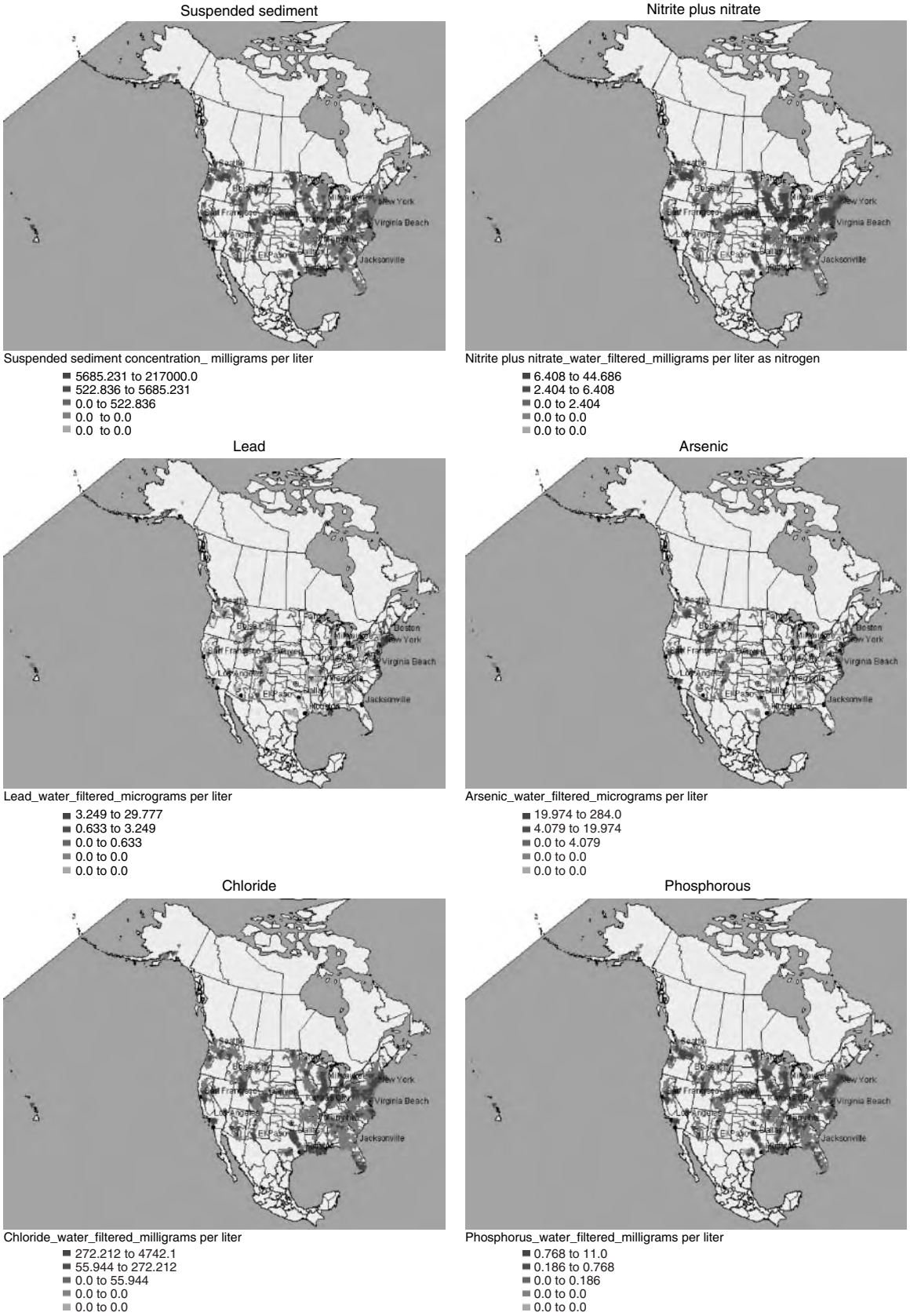


**Figure 8A.5** United States Geological Survey NAWQA water quality thematic maps showing maximum concentrations of suspended sediment, nitrite plus nitrate, lead, arsenic, chloride, and phosphorous detected in rivers of the United States. (From United States Geological Survey, NAWQA Date Warehouse Mapper, www.maptrek.er.usgs.gov/NAWQAMapTheme/index.jsp, Maps generated in May 2005.)

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**Table 8A.7 Estimates of National Background Nutrient Concentrations in the United States**

| Nutrient | Background Concentration (mg/L) |
|---|---|
| Total nitrogen in streams<br>(Data from 28 watersheds in first 20 study units) | 1.0 |
| Nitrate in streams[26] | 0.6 |
| Ammonia in streams[26] | 0.1 |
| Nitrate in shallow groundwater[27] | 2.0 |
| Total phosphorus in streams[26] | 0.1 |
| Orthophosphate in shallow groundwater<br>(Data from 47 wells in first 20 study units) | 0.02 |

*Source*: From U.S. Geological Survey, 1999, The quality of our nation's waters, nutrients and pesticides, *U.S. Geological Survey Circular 1225*, http://usgs.gov.

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**Table 8A.8 Water Quality of Great Salt Lake, Utah, 1850–1998**

| | Silica ($SiO_2$) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Lithium (Li) | Bicarbonate ($AsCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Boron (B) | Bromlum (Br) | Total Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Precauseway | | | | | | |
| 1850 | — | | 0.27 | 38.29 | — | — | — | 5.57 | 55.87 | — | — | — | 100 |
| 1869 | — | 0.17 | 2.52 | 33.15 | 1.60 | — | — | 6.57 | 55.99 | — | — | — | 100 |
| August 1892 | — | 1.05 | 1.23 | 33.22 | 1.71 | — | — | 6.57 | 56.22 | — | — | — | 100 |
| October 1913 | — | 0.16 | 2.76 | 33.17 | 1.66 | — | 0.09 | 6.68 | 55.48 | — | — | — | 100 |
| March 1930 | — | 0.17 | 2.75 | 32.90 | 1.61 | — | 0.05 | 5.47 | 57.05 | — | — | — | 100 |
| | | | | | | | South of causeway | | | | | | |
| April 1960 | 0.00 | 0.12 | 2.91 | 32.71 | 1.71 | — | 0.06 | 6.60 | 55.88 | | 0.01 | — | 100 |
| December 1963 | 0.00 | 0.09 | 3.29 | 31.02 | 1.86 | — | 0.07 | 9.02 | 54.64 | — | 0.01 | — | 100 |
| May 1966 | 0.00 | 0.09 | 3.80 | 30.56 | 2.22 | 0.02 | 0.10 | 7.99 | 65.21 | 0.00 | 0.01 | — | 100 |
| June 1976 | — | 0.17 | 3.47 | 31.29 | 2.66 | 0.02 | — | 7.22 | 55.11 | — | 0.01 | 0.04 | 100 |
| July 1998 | — | 0.23 | 3.52 | 31.67 | 2.16 | — | — | 6.36 | 56.07 | — | — | — | 100 |
| | | | | | | | North of causeway | | | | | | |
| December 1963 | 0.00 | 0.09 | 4.66 | 29.08 | 2.75 | — | 0.09 | 7.28 | 56.04 | — | 0.01 | — | 100 |
| May 1966 | — | 0.05 | 4.38 | 29.67 | 2.61 | 0.02 | 0.09 | 8.58 | 54.59 | 0.00 | 0.01 | — | 100 |
| June 1976 | — | 0.13 | 3.17 | 32.04 | 2.58 | 0.02 | — | 6.62 | 55.39 | — | 0.01 | 0.04 | 100 |
| July 1998 | — | 0.11 | 3.09 | 32.59 | 1.53 | — | — | 6.40 | 56.29 | — | — | — | 100 |

*Note:* Composition, in percentage by weight, of dissolved ions in brine.

*Source*: From Modified from Arnow, Ted, 1984, Water-level and water-quality changes in Great Salt Lake, Utah, 1847–1983, *U.S. Geological Survey Circ. 913*; 1998 Data Utah Geological Survey met.utah.edu/jhorel/homepages/jhorel/saltlake/chemistry.html.

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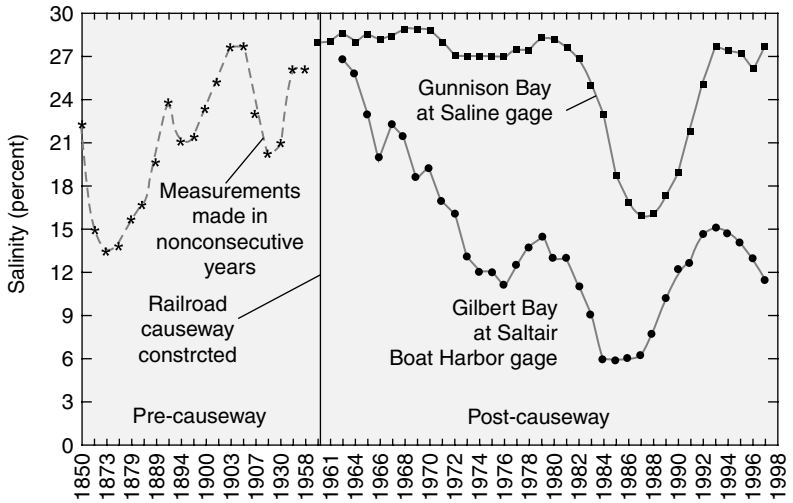


**Figure 8A.6** Salinity in the Great Salt Lake, Utah 1950–1998. The Salinity of Great Salt Lake is determined by the amount of inflow (and its salt content) and the amount of evaporation. When there is a lot of inflow, the lake elevation increases and the salinity of the water decreases. When there is less inflow or the evaporation rate is high, the lake elevation declines and the water becomes saltier. In 1959, a solid-fill railroad causeway was constructed across the middle of the lake. The causeway divides the lake into two parts: the north part (Gunnison Bay), which receives little freshwater inflow, and the south part (Gilbert Bay), which receives almost all the inflow. For any given lake elevation, the salinity of Gunnison Bay is always greater than the salinity of Gilbert Bay. The USGS measures salinity periodically at Saltair Boat Harbor and at Promontory (Gilbert Bay) and at Saline (Gunnison Bay). (From U.S. Geological Survey, http://ut.water.usgs.gov/salinity/index.html.)

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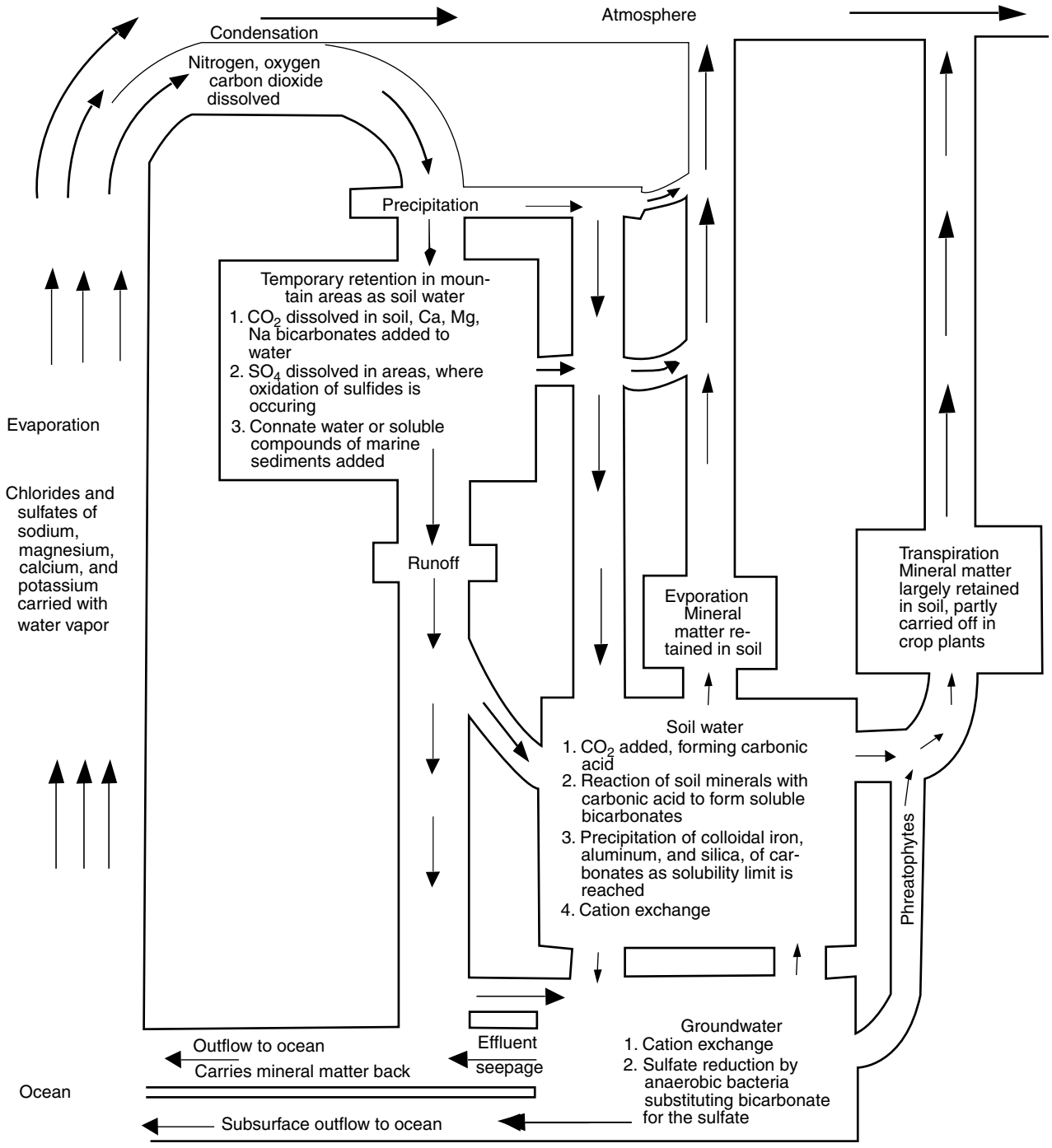


**Figure 8A.7** Geochemical cycle of surface and groundwater. (From U.S Geological Survey.)

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**Table 8A.9 Natural Inorganic Constituents Commonly Dissolved in Groundwater That Are Most Likely to Affect Use of the Water**

| Substance | Major Natural Sources | Effect on Water Use | Concentrations of Significance (mg/L)[a] |
|---|---|---|---|
| Bicarbonate ($HCO_3$) and carbonate ($CO_3$) | Products of the solution of carbonate rocks, mainly limestone ($CaCO_3$) and dolomite ($CaMgCO_3$), by water containing carbon dioxide | Control the capacity of water to neutralize strong acids. Bicarbonates of calcium and magnesium decompose in steam boilers and water heaters to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness | 150–200 |
| Calcium (Ca) and magnesium (Mg) | Soils and rocks containing limestone, dolomite, and gypsum ($CaSO_4$). Small amounts from igneous and metamorphic rocks | Principal cause of hardness and of boiler scale and deposits in hot-water heaters | 25–50 |
| Chloride (Cl) | In inland areas, primarily from seawater trapped in sediments at time of deposition; in coastal areas, from seawater in contact with freshwater in productive aquifers | In large amounts, increase corrosiveness of water and, in combination with sodium, gives water a salty taste | 250 |
| Fluoride (F) | Both sedimentary and igneous rocks. Not widespread in occurrence | In certain concentrations, reduces tooth decay; at higher concentrations, causes mottling of tooth enamel | 0.7–1.2[b] |
| Iron (Fe) and manganese (Mn) | Iron present in most soils and rocks; manganese less widely distributed | Stain laundry and are objectionable in food processing, dyeing, bleaching, ice manufacturing, brewing, and certain other industrial processes | Fe > 0.3, Mn > 0.05 |
| Sodium (Na) | Same as for chloride. In some sedimentary rocks, a few hundred milligrams per liter may occur in freshwater as a result of exchange of dissolved calcium and magnesium for sodium in the aquifer materials | See chloride. In large concentrations, may affect persons with cardiac difficulties, hypertension, and certain other medical conditions. Depending on the concentrations of calcium and magnesium also present in the water, sodium may be detrimental to certain irrigated crops | 69 (irrigation), 20–170 (health)[c] |
| Sulfate ($SO_4$) | Gypsum, pyrite (FeS), and other rocks containing sulfur (S) compounds | In certain concentrations, gives water a bitter taste and, at higher concentrations, has a laxative effect. In combination with calcium, forms a hard calcium carbonate scale in steam boilers | 300–400 (taste), 600–1,000 (laxative) |

[a] A range in concentration is intended to indicate the general level at which the effect on water use might become significant.
[b] Optimum range determined by the U.S. Public Health Service, depending on water intake.
[c] Lower concentration applies to drinking water for persons on a strict diet; higher concentration is for those on a moderate diet.

*Source*: From Heath, R.C., 1982, Basic groundwater hydrology, *U.S. Geological Survey Water-Supply Paper 2220*.

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**Table 8A.10 Inorganic Substances Found in Groundwater**

| | Concentration (mg/L) |
|---|---|
| Aluminum | 0.1–1,200 |
| Ammonia | 1.0–900 |
| Antimony | — |
| Arsenic | 0.01–2,100 |
| Barium | 2.8–3.8 |
| Beryllium | less than 0.01 |
| Boron | — |
| Cadmium | 0.01–180 |
| Calcium | 0.5–225 |
| Chlorides | 1.0–49,500 |
| Chromium | 0.06–2,740 |
| Cobalt | 0.01–0.18 |
| Copper | 0.01–2.8 |
| Cyanides | 1.05–14 |
| Fluorides | 0.1–250 |
| Iron | 0.04–6,200 |
| Lead | 0.01–5.6 |
| Lithium | — |
| Magnesium | 0.2–70 |
| Manganese | 0.1–110 |
| Mercury | 0.003–0.01 |
| Molybdenum | 0.4–40 |
| Nickel | 0.05–0.5 |
| Nitrates | 1.4–433 |
| Nitrites | — |
| Palladium | — |
| Potassium | 0.5–2.4 |
| Phosphates | 0.4–33 |
| Selenium | 0.6–20 |
| Silver | 9.0–330 |
| Sodium | 3.1–211 |
| Sulfates | 0.2–32,318 |
| Sulfites | — |
| Thallium | — |
| Titanium | — |
| Vanadium | 243.0 |
| Zinc | 0.1–240 |

*Source*: From Office of Technology Assessment 1984, Protecting the nation's groundwater from contamination, U.S. Congress, Washington DC.

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**Table 8A.11 Summary of Inorganic Elements Found in Rural Water Supplies**

| Element | Level Exceeded (mg/L) | In % of Rural Households | | | | |
|---|---|---|---|---|---|---|
| | | Nationwide | West | North-Central | Northeast | South |
| Mercury | 0.002 | 24.1 | 10.4 | 31.8 | 22.0 | 25.0 |
| Iron | 0.3 | 18.7 | 7.0 | 28.2 | 16.0 | 17.0 |
| Cadmium | 0.01 | 16.8 | 27.1 | 20.7 | 1.6 | 17.3 |
| Lead | 0.05 | 16.6 | 16.9[a] | 10.8[a] | 9.6[a] | 23.1[a] |
| Manganese | 0.05 | 14.2 | 4.7 | 19.9 | 16.9 | 12.3 |
| Sodium | 100 | 14.2 | 15.0 | 19.2 | 6.0 | 14.1 |
| Selenium | 0.01 | 13.7 | 41.3 | 25.7 | 0.0 | 2.1 |
| Silver | 0.05 | 4.7 | 2.1 | 3.7 | 4.8 | 4.8 |
| Sulfates | 250.0 | 4.0 | 11.7 | 7.4 | 0.5 | 0.7 |
| Nitrate-N | 10.0 | 2.7 | 4.0 | 5.8 | 0.3 | 1.3 |
| Fluoride | 1.4 | 2.5 | 6.2 | 1.8 | 0.0 | 2.7 |
| Arsenic | 0.05 | 0.8 | 2.1 | 1.8 | 0.0 | 0.0 |
| Barium | 1.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.7 |
| Magnesium | 125.0 | 0.1 | 0.5 | 0.1 | 0.0 | 0.0 |
| Chromium | 0.05 | [b] | 0.0 | 0.0 | 0.0 | 0.0 |
| Boron | [c] | | | | | |

*Note:* According to survey conducted by United States Environmental Protection Agency.

[a] May be distorted upwards.
[b] Not detected.
[c] Not tested.

*Source*: From U.S Environmental Protection Agency, 1984, *National Statistical Assessment of Rural Conditions, Executive Summary*. Office of Drinking Water.

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**Table 8A.12 Water Quality in Selected Rivers in the World, 1996–1999**

| | Dissolved Oxygen (DO) (mg/L) | | | | | Biological Oxygen Demand (BOD) (mg/L) | | | | | Nitrates (c) (mg/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) |
| Canada | | | | | | | | | | | | | | | |
| Mackenzie | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Saskatchewan | 8.8 | 9.2 | — | — | 9.1 | X | X | X | X | X | 0.14 | 0.15 | — | — | 0.14 |
| Columbia | X | X | X | X | X | X | X | X | X | X | 0.11 | 0.10 | 0.08 | — | 0.10 |
| Saint John | X | X | X | X | X | X | X | X | X | X | — | — | — | — | — |
| Mexico | | | | | | | | | | | | | | | |
| Bravo | 7.5 | 8.0 | 7.7 | — | 7.7 | 3.1 | 2.0 | 2.4 | — | 2.5 | 0.15 | 0.18 | 0.16 | — | 0.16 |
| Lerma | 5.8 | 3.5 | 0.7 | — | 3.3 | 17.0 | 12.0 | 92.3 | — | 40.4 | 0.78 | 0.30 | 0.82 | — | 0.63 |
| Pánuco | 6.6 | 7.6 | 6.5 | — | 6.9 | 1.7 | 1.6 | 1.1 | — | 1.4 | 0.13 | 1.06 | 0.19 | — | 0.46 |
| Grijalva | 5.1 | 6.4 | 6.2 | — | 5.9 | 4.4 | 4.3 | 5.4 | — | 4.7 | — | 0.10 | 0.14 | — | 0.10 |
| U.S.A | | | | | | | | | | | | | | | |
| Delaware | 10.6 | 11.8 | 11.9 | 11.1 | 11.6 | 1.6 | 1.9 | 1.3 | 2.6 | 1.9 | — | — | — | — | — |
| Mississippi | 8.4 | 8.5 | 8.2 | 8.8 | 8.5 | 0.9 | 1.1 | 1.2 | 1.4 | 1.2 | — | — | — | — | — |
| Japan | | | | | | | | | | | | | | | |
| Ishikari | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 1.2 | 1.2 | 1.2 | 0.9 | 1.1 | X | X | X | X | X |
| Yodo | 9.6 | 9.4 | 9.4 | 9.3 | 9.4 | 2.0 | 1.6 | 1.7 | 1.6 | 1.6 | X | X | X | X | X |
| Tone {Sakae-hashi} | 9.5 | 9.4 | 9.4 | 9.5 | 9.4 | 2.3 | 1.5 | 1.5 | 2.0 | 1.7 | X | X | X | X | X |
| Chikugo | 9.9 | 9.8 | 9.8 | 10.0 | 9.9 | 1.4 | 1.2 | 1.3 | 1.4 | 1.3 | X | X | X | X | X |
| Korea | | | | | | | | | | | | | | | |
| Keum | 8.7 | 8.9 | 9.8 | 10.0 | 9.6 | 3.9 | 2.7 | 2.6 | 3.0 | 2.8 | 2.15 | 2.09 | 2.05 | 2.36 | 2.17 |
| NakDong | 9.3 | 9.7 | 9.8 | 10.5 | 10.0 | 3.6 | 3.4 | 2.2 | 2.9 | 2.8 | 3.01 | 2.88 | 2.78 | 2.91 | 2.86 |
| YoungSan | 9.4 | 9.7 | 9.8 | 9.5 | 9.7 | 2.1 | 2.1 | 2.2 | 2.0 | 2.1 | 1.89 | 2.87 | 3.23 | 2.89 | 3.00 |
| Han | 8.7 | 9.1 | 10.0 | 8.3 | 9.1 | 3.9 | 4.1 | 3.6 | 3.3 | 3.7 | 1.39 | 2.05 | 2.36 | 2.44 | 2.29 |
| Austria | | | | | | | | | | | | | | | |
| Donau | 11.0 | 11.5 | 10.8 | — | 11.1 | 3.7 | 2.5 | 2.8 | — | 3.0 | 2.29 | 2.21 | 0.85 | — | 1.78 |
| Inn | 11.5 | 11.3 | 11.0 | — | 11.3 | 2.4 | 2.2 | 2.4 | — | 2.3 | 1.48 | 1.29 | 1.26 | — | 1.35 |
| Grossache | 11.7 | 11.2 | — | — | 11.3 | 1.2 | 1.1 | — | — | 1.4 | 0.73 | 0.68 | — | — | 0.72 |
| Belgium | | | | | | | | | | | | | | | |
| Meuse | 11.0 | — | — | — | — | 2.5 | — | — | — | — | 2.00 | — | — | — | — |
| Escaut | 7.4 | — | — | — | — | 5.7 | — | — | — | — | 4.67 | — | — | — | — |
| Czech R. | | | | | | | | | | | | | | | |
| Labe | 10.3 | 10.3 | 9.9 | 10.3 | 10.1 | 3.5 | 3.9 | 3.7 | 3.7 | 3.8 | 4.57 | 4.31 | 3.89 | 4.02 | 4.07 |
| Odra | 9.7 | 9.5 | 9.9 | 10.2 | 9.9 | 4.9 | 4.2 | 3.9 | 4.8 | 4.3 | 3.77 | 2.35 | 3.24 | 3.03 | 2.87 |
| Morava | 11.2 | 11.0 | 11.0 | 10.9 | 11.0 | 5.0 | 5.4 | 4.4 | 5.5 | 5.1 | 3.98 | 3.27 | 3.29 | 3.46 | 3.34 |
| Dyje | 10.3 | 10.4 | 10.5 | 11.2 | 10.7 | 4.5 | 5.1 | 6.4 | 4.5 | 5.4 | 5.43 | 4.44 | 3.63 | 3.55 | 3.87 |
| Denmark | | | | | | | | | | | | | | | |
| Gudená | X | X | X | X | X | 2.4 | 3.0 | 2.3 | — | 2.6 | 0.98 | 1.36 | 1.50 | — | 1.28 |
| Skjerná | 10.5 | 9.7 | 8.7 | — | 9.6 | 1.3 | 1.6 | 1.3 | — | 1.4 | 2.29 | 2.33 | 2.90 | — | 2.50 |
| Susá | X | X | X | X | X | 1.9 | 2.7 | — | — | 2.1 | 1.01 | 1.18 | — | — | 1.83 |
| Odense | X | X | X | X | X | 2.0 | 1.9 | — | — | 1.9 | 4.22 | 3.69 | 5.98 | — | 4.63 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finland | | | | | | | | | | | | | | | |
| Torniojoki | 11.8 | 11.7 | — | — | 11.6 | X | X | X | X | X | 0.07 | 0.06 | — | — | 0.06 |
| Kymijoki | 8.6 | 12.1 | — | — | 10.6 | X | X | X | X | X | 0.32 | 0.19 | — | — | 0.25 |
| Kokemäenjoki | 10.8 | 10.6 | — | — | 10.7 | X | X | X | X | X | 0.53 | 0.71 | — | — | 0.58 |
| France | | | | | | | | | | | | | | | |
| Loire | 10.1 | 10.3 | 10.7 | 9.9 | 10.3 | 5.8 | 5.9 | 5.9 | 4.6 | 5.4 | 2.32 | 2.53 | 2.65 | 3.03 | 2.74 |
| Seine | 4.2 | 4.6 | 5.9 | 7.1 | 5.8 | 4.7 | 5.3 | 4.4 | 3.4 | 4.4 | 6.62 | 6.27 | 5.90 | 5.77 | 5.98 |
| Garonne | 9.5 | 9.6 | 9.3 | 8.5 | 9.1 | 1.1 | 1.4 | 1.4 | 1.7 | 1.5 | 1.92 | 2.14 | 1.85 | 2.22 | 2.07 |
| Rhöne | 9.1 | 9.9 | 9.7 | 10.5 | 10.0 | 2.1 | 1.3 | 1.3 | 1.5 | 1.4 | 1.44 | 1.50 | 1.59 | 1.41 | 1.50 |
| German | | | | | | | | | | | | | | | |
| Rhein | 10.0 | 9.9 | 9.7 | 10.3 | 10.0 | X | X | X | X | X | 3.49 | 3.15 | 3.15 | 2.59 | 2.96 |
| Elbe | 11.6 | 11.2 | 11.3 | 11.6 | 11.4 | X | X | X | X | X | 4.29 | 3.92 | 3.57 | 3.41 | 3.63 |
| Weser | 9.7 | 10.8 | 10.1 | 9.9 | 10.3 | 3.8 | 2.9 | 2.1 | 2.4 | 2.5 | 4.52 | 4.52 | 4.20 | 4.43 | 4.38 |
| Donau | 11.1 | 11.1 | 10.9 | 11.1 | 11.0 | 2.2 | 2.4 | 2.2 | 2.1 | 2.2 | 2.34 | 2.22 | 2.07 | 2.10 | 2.13 |
| Donar | 11.1 | 11.1 | 10.9 | 11.1 | 11.9 | X | X | X | X | X | X | X | X | X | X |
| Greece | | | | | | | | | | | | | | | |
| Strimonas | — | — | 9.8 | 11.1 | 10.8 | X | X | X | X | X | 0.87 | 2.29 | 1.04 | 1.52 | 1.62 |
| Axios | — | — | 8.3 | 8.5 | 9.6 | X | X | X | X | X | 1.13 | 2.31 | 0.66 | 1.24 | 1.40 |
| Akeloos | — | — | — | — | — | X | X | X | X | X | X | X | X | X | X |
| Nestos | — | — | — | — | — | X | X | X | X | X | X | X | X | X | X |
| Hungary | | | | | | | | | | | | | | | |
| Maros | 9.9 | 9.7 | 9.9 | 10.1 | 9.9 | 4.3 | 2.9 | 3.3 | 3.7 | 3.3 | 1.95 | 2.06 | 2.16 | 2.34 | 2.19 |
| Duna | 9.7 | 10.8 | 9.5 | 10.1 | 10.1 | 2.6 | 2.7 | 2.6 | 2.1 | 2.5 | 2.59 | 2.59 | 1.90 | 2.12 | 2.20 |
| Dráva | 10.6 | 10.1 | 9.8 | 9.8 | 9.9 | 3.1 | 3.3 | 3.0 | 2.9 | 3.1 | 1.64 | 1.37 | 1.63 | 1.47 | 1.49 |
| Tisza | 11.1 | 12.6 | 12.1 | 12.7 | 12.5 | 1.5 | 2.0 | 2.6 | 3.6 | 2.7 | 0.77 | 0.66 | 0.77 | 0.64 | 0.69 |
| Ireland | | | | | | | | | | | | | | | |
| Boyne | 10.9 | 10.9 | 11.0 | 10.7 | 10.9 | 2.0 | 1.5 | 1.9 | 1.6 | 1.7 | 3.69 | 3.25 | 3.14 | 2.48 | 2.96 |
| Clare | 11.6 | 10.9 | 10.3 | 10.7 | 10.6 | 1.6 | 1.1 | 1.5 | 2.5 | 1.7 | 1.82 | 1.97 | 1.80 | 1.40 | 1.72 |
| Barrow | 11.4 | 10.8 | 10.9 | 11.0 | 10.9 | 2.4 | 1.6 | 1.8 | 1.5 | 1.6 | 5.22 | 4.58 | 4.95 | 4.14 | 4.55 |
| Blackwater | 10.7 | 10.2 | 10.8 | 10.5 | 10.5 | 1.9 | 2.0 | 2.1 | 2.7 | 2.2 | 2.89 | 2.76 | 2.74 | 2.20 | 2.57 |
| Italy | | | | | | | | | | | | | | | |
| Po | X | X | X | X | X | X | X | X | X | X | 2.89 | 2.21 | 2.05 | 2.10 | 2.12 |
| Adige | 10.4 | — | 10.7 | 8.3 | 9.8 | X | X | X | X | X | 1.26 | 1.37 | 1.22 | 1.15 | 1.25 |
| Arno | 9.2 | 13.0 | 7.2 | 8.1 | 9.4 | X | X | X | X | X | X | X | X | X | X |
| Metauro | 9.9 | 10.2 | 9.9 | 10.0 | 10.0 | X | X | X | X | X | — | — | — | 1.53 | — |
| Luxembourg | | | | | | | | | | | | | | | |
| Moselle | 9.4 | 9.1 | 9.1 | 9.2 | 9.1 | 2.6 | 2.6 | 2.2 | 2.6 | 2.5 | 3.07 | 2.88 | 2.92 | 2.62 | 2.81 |
| Süre | 10.0 | 10.2 | 10.4 | 10.6 | 10.4 | 3.1 | 2.9 | 2.7 | 3.1 | 2.9 | 5.0 | 5.45 | 5.74 | 4.90 | 5.36 |
| The Netherlands | | | | | | | | | | | | | | | |
| Maas-Keizersveer | 9.8 | 9.2 | 9.2 | — | 9.4 | X | X | X | X | X | X | X | X | X | X |
| Maas-Eysden | X | X | X | X | X | 3.0 | 2.0 | 3.6 | — | 2.9 | X | X | X | X | X |
| Rijn/Maas Delta | 11.9 | 11.4 | 10.5 | — | 11.3 | X | X | X | X | X | 3.64 | 3.03 | 3.55 | 2.55 | 3.04 |
| Rijn-Lobith | 10.2 | 10.0 | 10.3 | — | 10.2 | 3.0 | 5.0 | — | — | 3.3 | 3.64 | 3.55 | 3.55 | 2.53 | 3.14 |
| Ijssel-Kampen | 10.0 | 9.6 | 9.5 | — | 9.7 | X | X | X | X | X | 4.02 | 3.55 | 3.95 | 2.64 | 3.38 |
| Norway | | | | | | | | | | | | | | | |
| Skienselva | X | X | X | X | X | X | X | X | X | X | 0.21 | 0.20 | 0.21 | 0.20 | 0.20 |
| Glomma | X | X | X | X | X | X | X | X | X | X | 0.40 | 0.39 | 0.38 | 0.36 | 0.38 |
| Drammenselva | X | X | X | X | X | X | X | X | X | X | 0.28 | 0.29 | 0.27 | 0.26 | 0.27 |

*(Continued)*



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**Table 8A.12 (Continued)**

| | Dissolved Oxygen (DO) (mg/L) | | | | | Biological Oxygen Demand (BOD) (mg/L) | | | | | Nitrates (c) (mg/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) |
| Otra | X | X | X | X | X | X | X | X | X | X | 0.16 | 0.14 | 0.14 | 0.14 | 0.14 |
| Poland | | | | | | | | | | | | | | | |
| Wisia | 10.2 | 10.6 | 10.8 | 10.5 | 10.6 | 3.9 | 4.6 | 3.4 | 3.4 | 3.8 | 1.62 | 1.37 | 1.84 | 1.42 | 1.54 |
| Odra | 9.8 | 9.6 | 11.6 | 10.9 | 10.7 | 3.7 | 5.1 | 5.5 | 4.0 | 4.9 | 2.20 | 1.89 | 2.63 | 2.51 | 2.34 |
| Slovak R. | | | | | | | | | | | | | | | |
| Maly Dunaj | 9.1 | 10.5 | 9.5 | 9.6 | 9.8 | 2.6 | 3.7 | 2.9 | 3.1 | 3.2 | 2.55 | 2.27 | 2.31 | 2.48 | 2.35 |
| Vah | 10.1 | 9.7 | 9.9 | 9.3 | 9.6 | 4.5 | 3.9 | 2.6 | 2.1 | 2.9 | 2.41 | 2.12 | 1.71 | 2.06 | 1.97 |
| Hron | 10.4 | 10.9 | 10.5 | — | 10.6 | 3.9 | 3.3 | 3.2 | — | 3.5 | 1.86 | 1.96 | 1.89 | — | 1.90 |
| Hornad | 9.6 | 9.9 | 9.5 | 9.6 | 9.7 | 6.8 | 5.4 | 3.1 | 2.7 | 3.7 | 2.85 | 3.06 | 2.64 | 2.62 | 2.77 |
| Spain | | | | | | | | | | | | | | | |
| Guadalquivir | 7.0 | 5.0 | 6.0 | 4.0 | 5.0 | 14.5 | 2.6 | 3.4 | 6.6 | 4.2 | 3.67 | 6.55 | 6.08 | 5.65 | 6.09 |
| Duero | 7.0 | 7.0 | 9.0 | 10.0 | 8.7 | 3.8 | 2.5 | 2.1 | 3.7 | 2.8 | 1.79 | 1.81 | 2.37 | 1.31 | 1.83 |
| Ebro | 9.6 | 9.5 | 10.0 | 10.0 | 9.8 | 5.2 | 5.5 | 4.3 | — | 5.0 | 2.26 | 2.75 | 2.42 | — | 2.48 |
| Guadiana | 9.9 | 9.3 | 8.0 | — | 9.1 | 2.9 | 1.8 | 2.9 | — | 2.6 | 2.10 | 1.97 | 1.82 | — | 1.96 |
| Sweden | | | | | | | | | | | | | | | |
| Delàlven | X | X | X | X | X | X | X | X | X | X | 0.12 | 0.10 | 0.12 | 0.12 | 0.11 |
| Ràne alv | X | X | X | X | X | X | X | X | X | X | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| Mònumsán | X | X | X | X | X | X | X | X | X | X | 0.16 | 0.12 | 0.16 | 0.19 | 0.16 |
| Rònneàn | X | X | X | X | X | X | X | X | X | X | 1.35 | 1.74 | 1.59 | 1.30 | 1.54 |
| Switzerland | | | | | | | | | | | | | | | |
| Rhin | 10.6 | 10.4 | 10.4 | 11.1 | 10.6 | X | X | X | X | X | 1.56 | 1.40 | 1.37 | 1.34 | 1.37 |
| Aare | 10.1 | 10.5 | 10.6 | 10.4 | 10.5 | X | X | X | X | X | 1.99 | 1.77 | 1.78 | 1.49 | 1.68 |
| Rhöne | 11.2 | 11.5 | 11.5 | 11.6 | 11.5 | X | X | X | X | X | X | X | X | X | X |
| Turkey | | | | | | | | | | | | | | | |
| Porsuk | 9.2 | 9.5 | 8.7 | 8.2 | 8.8 | 1.3 | 1.1 | 1.3 | 1.3 | 1.2 | 1.45 | 1.20 | 1.15 | 1.21 | 1.19 |
| Sakarya | 8.8 | 9.1 | 9.3 | 8.6 | 9.0 | 3.7 | 3.2 | 3.5 | 3.4 | 3.4 | 1.37 | 1.42 | 1.43 | 1.50 | 1.45 |
| Yesilirmak | 10.2 | 9.6 | 9.6 | 8.8 | 9.3 | 2.0 | 2.7 | 2.4 | 2.2 | 2.4 | 2.90 | 1.70 | 7.53 | 5.05 | 4.76 |
| Gediz | 3.9 | 4.9 | 6.3 | 5.5 | 5.6 | 2.2 | 2.0 | 5.5 | 3.3 | 3.6 | 1.15 | 0.57 | 0.29 | 0.06 | 0.31 |
| UK | | | | | | | | | | | | | | | |
| Thames | 10.2 | 11.0 | 10.8 | 10.5 | 10.8 | 3.0 | 2.7 | 1.7 | 1.7 | 2.0 | 8.13 | 7.85 | 7.68 | 6.79 | 7.44 |
| Severn | 10.7 | 10.8 | 10.3 | — | 10.6 | 2.8 | 2.0 | 1.9 | 7.9 | 3.9 | 6.95 | 6.64 | 6.70 | 6.20 | 6.51 |
| Clyde | 8.5 | 8.0 | 9.6 | 8.7 | 8.8 | 3.9 | 2.1 | 2.5 | 2.3 | 2.3 | 1.95 | 1.88 | 2.06 | 1.70 | 1.88 |
| Mersey | 8.1 | 7.7 | 8.2 | 8.2 | 8.0 | 3.9 | 3.6 | 3.1 | 2.8 | 3.2 | 4.83 | 4.43 | 4.73 | 5.64 | 4.94 |
| Lower Bann (N. Ireland) | 9.8 | 9.1 | — | — | 9.2 | 3.8 | 2.8 | — | — | 3.4 | 0.80 | 1.09 | — | — | 1.01 |

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| | Total Phosphorus (c) (mg/L) | | | | | Ammonium (c) (mg/L) | | | | | Lead (c) (mg/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last2 3 yrs (b) |
| Canada | | | | | | | | | | | | | | | |
| Mackenzie | 0.07 | — | — | — | — | X | X | X | X | X | 1.63 | — | — | — | — |
| Saskatchewan | 0.04 | 0.05 | — | — | 0.044 | 0.041 | 0.041 | — | — | 0.039 | 0.87 | 2.57 | — | — | 1.39 |
| Columbia | 0.01 | 0.01 | 0.01 | 0.01 | 0.009 | X | X | X | X | X | 0.96 | 0.76 | 0.42 | 0.34 | 0.51 |
| Saint John | — | — | — | — | — | X | X | X | X | X | — | — | — | — | — |
| Mexico | | | | | | | | | | | | | | | |
| Bravo | 0.11 | 0.13 | 0.10 | — | 0.113 | 0.030 | 0.030 | 0.030 | — | 0.030 | X | X | X | X | X |
| Lerma | — | 2.60 | 5.63 | — | — | — | 1.350 | 18.450 | — | — | X | X | X | X | X |
| Panuco | — | — | 0.03 | — | — | 0.020 | 0.060 | 0.030 | — | 0.037 | X | X | X | X | X |
| Grijalya | 0.19 | 0.03 | 0.04 | — | 0.085 | — | 0.080 | 0.120 | — | 0.067 | X | X | X | X | X |
| USA | | | | | | | | | | | | | | | |
| Delaware | 0.05 | 0.06 | 0.05 | 0.09 | 0.067 | 0.030 | 0.040 | 0.030 | 0.040 | 0.037 | — | — | — | — | — |
| Mississippi | 0.19 | 0.15 | 0.18 | 0.24 | 0.190 | 0.020 | 0.020 | 0.060 | 0.020 | 0.033 | — | — | — | — | — |
| Japan | | | | | | | | | | | | | | | |
| Ishikari | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Yodo | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Tone {Sakae-hashi} | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Chikugo | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Korea | | | | | | | | | | | | | | | |
| Keum | 0.13 | 0.10 | 0.05 | 0.04 | 0.064 | 0.838 | 0.922 | 0.530 | 0.411 | 0.621 | — | — | — | — | 0 |
| NakDong | 0.07 | 0.14 | 0.08 | 0.04 | 0.086 | 0.901 | 0.516 | 0.283 | 0.124 | 0.308 | — | — | — | — | 0 |
| YoungSan | 0.15 | 0.07 | 0.14 | 0.10 | 0.105 | 0.510 | 0.230 | 0.236 | 0.317 | 0.261 | — | — | — | — | 0 |
| Han | 0.28 | 0.37 | 0.21 | 0.21 | 0.264 | 2.368 | 2.416 | 1.624 | 1.540 | 1.860 | — | — | — | — | 0 |
| Austria | | | | | | | | | | | | | | | |
| Donau | 0.04 | 0.11 | 0.16 | — | 0.104 | 0.160 | 0.124 | 0.150 | — | 0.145 | 0.64 | 0.54 | 5.00 | — | 2.06 |
| Inn | 0.04 | 0.18 | 0.14 | — | 0.117 | 0.098 | 0.101 | 0.080 | — | 0.093 | 0.58 | 1.34 | 1.60 | — | 1.17 |
| Grossache | 0.08 | 0.07 | — | — | 0.070 | 0.015 | 0.030 | — | — | 0.025 | 3.20 | 4.00 | — | — | 2.40 |
| Belgium | | | | | | | | | | | | | | | |
| Meuse | 0.15 | — | — | — | — | 0.050 | — | — | — | — | 3.90 | — | — | — | — |
| Escaut | 0.80 | — | — | — | — | 4.450 | — | — | — | — | 8.50 | — | — | — | — |
| Czech R. | | | | | | | | | | | | | | | |
| Labe | — | 0.23 | 0.23 | 0.21 | 0.223 | 0.505 | 0.429 | 0.300 | 0.250 | 0.326 | 2.00 | 1.20 | 0.85 | 1.10 | 1.05 |
| Odra | 0.44 | 0.45 | 0.39 | 0.33 | 0.389 | 1.912 | 1.336 | 0.590 | 0.500 | 0.809 | 17.50 | 6.38 | 1.90 | 1.30 | 3.19 |
| Morava | 0.31 | 0.25 | 0.20 | 0.28 | 0.243 | 0.688 | 0.660 | 0.390 | 0.440 | 0.497 | 2.67 | 2.42 | 1.18 | 2.20 | 1.93 |
| Dyje | 0.32 | 0.38 | 0.51 | 0.37 | 0.420 | 0.462 | 0.475 | 0.340 | 0.390 | 0.402 | X | X | X | X | X |
| Denmark | | | | | | | | | | | | | | | |
| Gudená | 0.10 | 0.11 | 0.10 | — | 0.101 | 0.089 | 0.095 | 0.047 | — | 0.077 | X | X | X | X | X |
| Skjerná | 0.05 | 0.05 | 0.06 | — | 0.053 | 0.119 | 0.106 | 0.094 | — | 0.106 | X | X | X | X | X |
| Susá | 0.32 | 0.36 | — | — | 0.278 | 0.096 | 0.103 | — | — | 0.097 | X | X | X | X | X |
| Odense | 0.14 | 0.14 | 0.16 | — | 0.145 | 0.154 | 0.076 | 0.076 | — | 0.102 | X | X | X | X | X |
| Finland | | | | | | | | | | | | | | | |
| Torniojoki | 0.01 | 0.02 | — | — | 0.017 | 0.017 | — | — | — | 0.017 | 0.12 | 0.23 | — | — | 0.15 |

*(Continued)*



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**Table 8A.12 (Continued)**

| | Total Phosphorus (c) (mg/L) | | | | | Ammonium (c) (mg/L) | | | | | Lead (c) (mg/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last2 3 yrs (b) |
| Kymijoki | 0.03 | 0.01 | — | — | 0.019 | 0.035 | 0.004 | — | — | 0.022 | 0.19 | 0.15 | — | — | 0.20 |
| Kokemäenjoki | 0.04 | 0.05 | — | — | 0.048 | 0.079 | 0.075 | — | — | 0.074 | 1.00 | 0.95 | — | — | 1.00 |
| France | | | | | | | | | | | | | | | |
| Loire | 0.25 | 0.27 | 0.17 | 0.22 | 0.220 | 0.060 | 0.160 | 0.043 | 0.062 | 0.088 | X | X | X | X | X |
| Seine | 1.23 | 1.22 | 1.06 | 0.82 | 1.031 | 0.278 | 0.484 | 0.275 | 0.164 | 0.308 | X | X | X | X | X |
| Garonne | 0.11 | 0.15 | 0.13 | 0.34 | 0.208 | 0.130 | 0.152 | 0.071 | 0.080 | 0.101 | 1.08 | 0.11 | — | — | 1.03 |
| Rhône | 0.13 | 0.11 | 0.08 | 0.06 | 0.084 | 0.102 | 0.126 | 0.122 | 0.095 | 0.114 | X | X | X | X | X |
| German | | | | | | | | | | | | | | | |
| Rhein | 0.16 | 0.16 | 0.16 | 0.14 | 0.153 | 0.160 | 0.130 | 0.110 | 0.079 | 0.106 | 3.00 | 3.70 | 3.90 | 4.70 | 4.10 |
| Elbe | 0.23 | 0.22 | 0.21 | 0.19 | 0.207 | 0.300 | 0.210 | 0.140 | 0.130 | 0.160 | — | — | 3.50 | 2.63 | 2.38 |
| Weser | 0.24 | 0.21 | 0.24 | 0.16 | 0.203 | 0.400 | 0.240 | 0.100 | 0.100 | 0.147 | 4.10 | 4.60 | 6.10 | 3.86 | 4.85 |
| Donau | 0.09 | 0.08 | 0.08 | 0.08 | 0.079 | 0.080 | 0.067 | 0.069 | 0.078 | 0.071 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Greece | | | | | | | | | | | | | | | |
| Strimonas | — | — | 0.06 | 0.06 | 0.078 | — | — | 0.141 | 0.093 | 0.091 | X | X | X | X | X |
| Axios | — | — | 0.90 | 0.52 | 0.700 | — | — | 0.404 | 0.179 | 0.229 | X | X | X | X | X |
| Akeloos | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Nestos | X | X | X | X | X | — | — | 0.233 | 0.095 | 0.118 | X | X | X | X | X |
| Hungary | | | | | | | | | | | | | | | |
| Maros | 0.26 | 0.30 | 0.23 | 0.26 | 0.263 | 0.240 | 0.130 | 0.080 | 0.140 | 0.117 | 0.50 | 0.90 | 0.70 | 0.50 | 0.70 |
| Duna | 0.09 | 0.11 | 0.10 | 0.12 | 0.108 | 0.086 | 0.078 | 0.074 | 0.072 | 0.075 | 3.20 | 2.50 | 2.80 | 1.30 | 2.20 |
| Drava | 0.16 | 0.14 | 0.12 | 0.14 | 0.133 | 0.053 | 0.067 | 0.055 | 0.047 | 0.056 | 1.30 | 1.30 | 1.70 | 1.10 | 1.37 |
| Tisza | X | X | X | X | X | 0.032 | 0.080 | 0.060 | 0.068 | 0.069 | X | X | X | X | X |
| Ireland | | | | | | | | | | | | | | | |
| Boyne | 0.09 | — | 0.08 | 0.06 | 0.046 | 0.053 | 0.043 | 0.068 | 0.047 | 0.053 | X | X | X | X | X |
| Clare | 0.07 | 0.06 | 0.05 | 0.14 | 0.084 | 0.042 | 0.022 | 0.039 | 0.078 | 0.046 | X | X | X | X | X |
| Barrow | 0.11 | 0.08 | 0.10 | 0.08 | 0.087 | 0.057 | 0.039 | 0.031 | 0.031 | 0.034 | X | X | X | X | X |
| Blackwater | 0.17 | 0.10 | 0.09 | 0.09 | 0.092 | 0.039 | 0.048 | 0.086 | 0.109 | 0.081 | X | X | X | X | X |
| Italy | | | | | | | | | | | | | | | |
| Po | 0.18 | 0.14 | 0.15 | 0.18 | 0.157 | 0.140 | 0.086 | 0.163 | 0.130 | 0.126 | X | X | X | X | X |
| Adige | — | 0.05 | 0.05 | — | 0.048 | 0.062 | 0.062 | 0.054 | 0.110 | 0.076 | X | X | X | X | X |
| Amo | — | 0.16 | 0.16 | 0.23 | 0.183 | X | X | X | X | X | X | X | X | X | X |
| Metauro | 0.13 | 0.22 | 0.11 | 0.18 | 0.170 | — | — | — | — | — | X | X | X | X | X |
| Luxembourg | | | | | | | | | | | | | | | |
| Moselle | 0.61 | 0.55 | 0.57 | 0.17 | 0.429 | 0.184 | 0.165 | 0.284 | 0.174 | 0.208 | 3.90 | 2.00 | 2.10 | 2.20 | 2.10 |
| Süre | 0.52 | 0.45 | 0.56 | 0.18 | 0.394 | 0.224 | 0.220 | 0.211 | 0.162 | 0.198 | 4.10 | 2.00 | 2.00 | 2.30 | 2.10 |
| The Netherlands | | | | | | | | | | | | | | | |
| Maas-Kezersveer | 0.28 | 0.39 | 0.24 | 0.22 | 0.283 | X | X | X | X | X | 4.90 | 2.30 | 4.11 | 3.83 | 3.41 |
| Maas-Eysden | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Rijn/Maas Delta | 0.14 | 0.16 | 0.14 | 0.19 | 0.163 | X | X | X | X | X | 1.10 | 1.50 | 1.90 | 2.20 | 1.87 |
| Rijn-Lobith | 0.22 | 0.21 | 0.22 | 0.18 | 0.203 | 0.220 | 0.100 | 0.110 | — | 0.143 | 4.50 | 3.90 | 4.60 | 3.60 | 4.03 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ijssel-Kampen | 0.20 | 0.20 | 0.19 | 0.17 | 0.187 | X | X | X | X | X | 3.10 | 3.80 | 2.60 | 3.30 | 3.23 |
| Norway | | | | | | | | | | | | | | | |
| Skienselva | 0.00 | 0.01 | 0.00 | 0.01 | 0.005 | 0.017 | 0.015 | 0.014 | 0.015 | 0.015 | 0.11 | 0.07 | 0.19 | 0.07 | 0.11 |
| Glomma | 0.02 | 0.02 | 0.01 | 0.03 | 0.021 | 0.045 | 0.033 | 0.032 | 0.035 | 0.033 | 0.50 | 0.55 | 3.70 | 0.40 | 1.55 |
| Drammenselva | 0.01 | 0.01 | 0.00 | 0.01 | 0.007 | 0.015 | 0.017 | 0.016 | 0.019 | 0.017 | 0.17 | 0.12 | 0.13 | 0.15 | 0.13 |
| Otra | 0.00 | 0.00 | 0.00 | 0.01 | 0.003 | 0.016 | 0.015 | 0.013 | 0.018 | 0.015 | 0.34 | 0.27 | 0.30 | 0.30 | 0.29 |
| Poland | | | | | | | | | | | | | | | |
| Wisia | 0.14 | 0.21 | 0.20 | 0.23 | 0.212 | 0.449 | 0.225 | 0.210 | 0.368 | 0.268 | 0.45 | 0.60 | 1.00 | 0.40 | 0.67 |
| Odra | 0.34 | 0.31 | 0.30 | 0.26 | 0.291 | 0.605 | 0.330 | 0.120 | 0.091 | 0.180 | 1.37 | 0.50 | 0.20 | 0.10 | 0.27 |
| Slovak R. | | | | | | | | | | | | | | | |
| Maly Dunaj | 0.28 | 0.29 | 0.27 | 0.24 | 0.265 | 0.423 | 0.274 | 0.246 | 0.109 | 0.210 | 1.40 | — | 2.29 | 0.81 | 1.50 |
| Vah | 0.24 | 0.15 | 0.12 | 0.15 | 0.140 | 0.626 | 0.539 | 0.371 | 0.378 | 0.429 | 0.58 | 1.15 | 1.10 | 0.85 | 1.03 |
| Hron | 0.23 | 0.21 | 0.18 | — | 0.205 | 0.456 | 0.303 | 0.313 | — | 0.357 | X | X | X | X | X |
| Hornad | 0.26 | 0.18 | 0.18 | 0.14 | 0.170 | 0.840 | 0.528 | 0.637 | 0.534 | 0.566 | 8.42 | 13.62 | 4.45 | 3.40 | 7.16 |
| Spain | | | | | | | | | | | | | | | |
| Guadalquivir | 0.67 | — | — | — | — | 0.414 | 0.143 | — | — | 0.285 | 3.00 | — | — | — | 0.00 |
| Duero | 0.19 | 0.20 | 0.15 | 0.15 | 0.165 | 0.288 | 0.266 | 0.266 | — | 0.273 | — | 1.00 | 1.00 | — | 0.67 |
| Ebro | 0.28 | 0.19 | 0.12 | — | 0.199 | 0.167 | 0.023 | 0.041 | — | 0.077 | — | 1.67 | — | — | 0.56 |
| Guadiana | 0.25 | 0.19 | — | — | 0.316 | 0.151 | 0.100 | 0.106 | — | 0.119 | — | — | — | — | 0.00 |
| Sweden | | | | | | | | | | | | | | | |
| Dalàlven | 0.02 | 0.02 | 0.01 | 0.01 | 0.015 | 0.020 | 0.017 | 0.018 | 0.020 | 0.018 | 0.39 | 0.42 | 0.49 | 0.44 | 0.45 |
| Ràne alv | 0.01 | 0.02 | 0.01 | 0.01 | 0.015 | 0.013 | 0.016 | 0.012 | 0.012 | 0.013 | 0.12 | 0.26 | 0.15 | 0.09 | 0.17 |
| Mònumsán | 0.02 | 0.02 | 0.02 | 0.02 | 0.022 | 0.026 | 0.019 | 0.017 | 0.027 | 0.021 | 0.35 | 0.28 | 0.38 | 0.47 | 0.38 |
| Rònneàn | 0.04 | 0.04 | 0.45 | 0.71 | 0.402 | 0.060 | 0.076 | 0.061 | 0.050 | 0.062 | 0.23 | 0.37 | 0.44 | 0.57 | 0.46 |
| Switzerland | | | | | | | | | | | | | | | |
| Rhin | 0.05 | 0.05 | 0.05 | 0.04 | 0.047 | X | X | X | X | X | 0.60 | 0.60 | 0.80 | 0.70 | 0.70 |
| Aare | 0.07 | 0.07 | 0.06 | 0.04 | 0.055 | X | X | X | X | X | X | X | X | X | X |
| Rhöne | 0.12 | 0.14 | 0.14 | 0.14 | 0.138 | X | X | X | X | X | 3.00 | 4.50 | 4.60 | 4.10 | 4.40 |
| Turkey | | | | | | | | | | | | | | | |
| Porsuk | — | — | 0.04 | 0.09 | 0.061 | 0.045 | 0.068 | 0.100 | 0.170 | 0.113 | 5.00 | — | 8.00 | 5.00 | 4.33 |
| Sakarya | 0.50 | 0.49 | 0.16 | 0.27 | 0.307 | 0.340 | 0.340 | 0.260 | 0.300 | 0.300 | 13.00 | — | 12.00 | 6.00 | 6.00 |
| Yesilinmak | 0.27 | 0.42 | 0.10 | 0.07 | 0.197 | 0.190 | 0.750 | 0.290 | 0.210 | 0.417 | X | X | X | X | X |
| Gediz | 0.32 | 0.42 | 0.05 | 0.02 | 0.163 | 0.013 | — | — | — | 0.004 | — | — | — | — | — |
| UK | | | | | | | | | | | | | | | |
| Thames | 1.69 | 1.88 | 1.03 | 1.16 | 1.357 | 0.313 | 0.198 | 0.176 | 0.187 | 0.187 | 3.50 | 2.70 | 3.10 | 4.10 | 3.30 |
| Severn | 0.86 | 1.08 | 0.72 | 0.47 | 0.753 | 0.198 | 0.174 | 0.127 | 0.114 | 0.138 | 6.80 | 4.30 | 4.10 | 4.50 | 4.30 |
| Clyde | 0.59 | 0.56 | 0.40 | 0.41 | 0.458 | 1.404 | 0.867 | 0.657 | 0.727 | 0.750 | 7.20 | 3.00 | 2.40 | 3.50 | 2.97 |
| Mersey | 1.54 | 1.16 | 1.02 | 1.09 | 1.089 | 4.342 | 3.705 | 2.073 | 1.445 | 2.408 | 4.80 | 5.00 | 6.60 | 5.60 | 5.73 |
| Lower Bann (N. Ireland) | 0.16 | 0.16 | — | — | 0.161 | 0.105 | 0.077 | — | — | 0.108 | 0.40 | 0.41 | — | — | 0.41 |

*(Continued)*



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**Table 8A.12 (Continued)**

| | Cadmium (c) (mg/L) | | | | | Chromium (c) (mg/L) | | | | | Copper (c) (mg/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) |
| Canada | | | | | | | | | | | | | | | |
| Mackenzie | 0.250 | — | — | — | — | 1.58 | — | — | — | — | 3.52 | — | — | — | — |
| Saskatchewan | 0.325 | 0.730 | — | — | 0.412 | 1.38 | 1.86 | — | — | 1.49 | 3.05 | 2.61 | — | — | 2.69 |
| Columbia | 0.075 | 0.079 | 0.102 | 0.100 | 0.094 | 0.36 | 0.22 | 0.21 | 0.21 | 0.21 | 1.21 | 1.03 | 0.86 | 0.86 | 0.92 |
| Saint John | — | — | — | — | — | X | X | X | X | X | — | — | — | — | — |
| Mexico | | | | | | | | | | | | | | | |
| Bravo | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Lerma | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Pánuco | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Grijalva | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| USA | | | | | | | | | | | | | | | |
| Delaware | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Mississippi | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | — | — | — | — | — | — | — | — | — | — |
| Japan | | | | | | | | | | | | | | | |
| Ishikari | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Yodo | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Tone {Sakae-hashi} | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Chikugo | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Korea | | | | | | | | | | | | | | | |
| Keum | — | — | — | — | 0.000 | — | — | — | — | 0.00 | X | X | X | X | X |
| NakDong | — | — | — | — | 0.000 | — | — | — | — | 0.00 | X | X | X | X | X |
| YoungSan | — | — | — | — | 0.000 | — | — | — | — | 0.00 | X | X | X | X | X |
| Han | — | — | — | — | 0.000 | — | — | — | — | 0.00 | X | X | X | X | X |
| Austria | | | | | | | | | | | | | | | |
| Donau | — | — | <0.20 | — | 0.000 | 0.27 | — | 1.00 | — | 0.42 | 2.00 | 2.35 | 2.40 | — | 2.25 |
| Inn | — | — | 0.100 | — | 0.033 | 0.25 | 0.91 | 0.80 | — | 0.65 | 2.33 | 3.10 | 2.80 | — | 2.74 |
| Grossache | 0.200 | 0.200 | — | — | 0.133 | 2.00 | 4.00 | — | — | 2.00 | 3.80 | 5.00 | — | — | 2.93 |
| Belgium | | | | | | | | | | | | | | | |
| Meuse | 0.100 | — | — | — | — | 1.00 | — | — | — | — | 1.80 | — | — | — | — |
| Escaut | 0.300 | — | — | — | — | 2.80 | — | — | — | — | 16.20 | — | — | — | — |
| Czech R | | | | | | | | | | | | | | | |
| Labe | 0.312 | 0.154 | 0.230 | 0.160 | 0.181 | 1.80 | 2.42 | 2.27 | 2.19 | 2.29 | 9.79 | 9.23 | 12.77 | 12.15 | 11.38 |
| Odra | 2.583 | 0.090 | 0.080 | 0.060 | 0.077 | — | 1.92 | 2.25 | 1.79 | 1.99 | 8.83 | 3.58 | 5.42 | 6.75 | 5.25 |
| Morava | 0.150 | 0.108 | 0.130 | 0.120 | 0.119 | 1.92 | 2.82 | 1.10 | 0.50 | 1.47 | 3.79 | 2.80 | 2.32 | 3.30 | 2.81 |
| Dyje | X | X | X | X | X | — | 0.94 | 0.80 | 0.30 | 0.68 | X | X | X | X | X |
| Denmark | | | | | | | | | | | | | | | |
| Gudená | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Skjerná | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Susá | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Odense | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Finland | | | | | | | | | | | | | | | |
| Torniojoki | 0.030 | 0.030 | — | — | 0.033 | 0.34 | 0.55 | — | — | 0.45 | 0.84 | 0.71 | — | — | 0.79 |
| Kymijoki | 0.034 | 0.030 | — | — | 0.032 | 0.61 | 0.53 | — | — | 0.53 | 1.34 | 1.13 | — | — | 1.18 |
| Kokemäenjoki | 0.074 | 0.138 | — | — | 0.096 | 1.78 | 1.61 | — | — | 1.82 | 15.53 | 20.60 | — | — | 28.38 |
| France | | | | | | | | | | | | | | | |
| Loire | — | — | — | — | — | X | X | X | X | X | X | X | X | X | X |
| Seine | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Garonne | 0.389 | 0.000 | — | — | 0.184 | 3.21 | 1.17 | — | — | 2.33 | 5.62 | 3.56 | — | — | 4.71 |
| Rhöne | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| German | | | | | | | | | | | | | | | |
| Rhein | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 2.70 | 3.10 | 3.30 | 3.87 | 3.42 | 6.30 | 10.40 | 12.00 | 8.55 | 10.32 |
| Elbe | — | — | 0.320 | 0.243 | 0.248 | — | — | 2.10 | 1.93 | 1.68 | — | — | 6.40 | 6.44 | 4.98 |
| Weser | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 2.00 | 2.00 | 2.10 | 2.00 | 2.03 | 4.60 | 4.80 | 5.10 | 4.33 | 4.74 |
| Donau | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.30 | 2.70 | 3.00 | 3.07 | 2.92 |
| Greece | | | | | | | | | | | | | | | |
| Strimonas | 0.140 | 0.140 | 0.040 | 1.600 | 0.593 | X | X | X | X | X | X | X | X | X | X |
| Axios | 0.110 | 0.270 | 1.200 | 0.400 | 0.623 | X | X | X | X | X | X | X | X | X | X |
| Akeloos | 0.200 | — | — | — | — | X | X | X | X | X | X | X | X | X | X |
| Nestos | 0.200 | 0.200 | 1.800 | 0.470 | 0.823 | X | X | X | X | X | X | X | X | X | X |
| Hungary | | | | | | | | | | | | | | | |
| Maros | 0.140 | 0.170 | 0.150 | 0.100 | 0.140 | 15.00 | 15.60 | 16.90 | 26.80 | 19.77 | 5.30 | 7.30 | 10.10 | 4.80 | 7.40 |
| Duna | 0.630 | 0.700 | 0.980 | 0.580 | 0.753 | 1.60 | 4.00 | 2.10 | 1.20 | 2.43 | 13.40 | 8.40 | 9.40 | 10.10 | 9.30 |
| Drava | 0.090 | 0.060 | 0.070 | 0.070 | 0.067 | 0.50 | 0.50 | 0.60 | 0.70 | 0.60 | 1.50 | 1.80 | 2.40 | 2.80 | 2.33 |
| Tisza | X | X | X | X | X | 1.40 | 1.20 | 0.70 | 1.00 | 0.97 | X | X | X | X | X |
| Ireland | | | | | | | | | | | | | | | |
| Boyne | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | X | X | X | X | X | X | X | X | X | X |
| Clare | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | X | X | X | X | X | X | X | X | X | X |
| Barrow | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | X | X | X | X | X | X | X | X | X | X |
| Blackwater | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | X | X | X | X | X | X | X | X | X | X |
| Italy | | | | | | | | | | | | | | | |
| Po | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Adige | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Arno | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Metauro | <0.0002 | <0.0002 | <0.0002 | — | 0.000 | X | X | X | X | X | X | X | X | X | X |
| Luxembourg | | | | | | | | | | | | | | | |
| Moselle | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 1.50 | 1.10 | 1.10 | 1.10 | 1.10 | 4.30 | 3.40 | 4.00 | 3.70 | 3.70 |
| Süre | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 1.50 | 1.00 | 1.00 | 1.00 | 1.00 | 2.70 | 2.40 | 2.60 | 2.50 | 2.50 |
| The Netherlands | | | | | | | | | | | | | | | |
| Maas-Keizersveer | 0.290 | 0.140 | 0.300 | 0.200 | 0.213 | 2.98 | 2.06 | 2.16 | 1.95 | 2.06 | 4.15 | 3.35 | 4.72 | 4.67 | 4.25 |
| Maas-Eysden | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Rijn/Maas Delta | 0.500 | 0.040 | 0.060 | 0.140 | 0.080 | — | 1.30 | 1.81 | 1.40 | 1.50 | 3.30 | 3.10 | 3.60 | 2.80 | 3.17 |
| Rijn-Lobith | 0.070 | 0.060 | 0.080 | 0.080 | 0.073 | 2.90 | 3.57 | 3.76 | 2.40 | 3.24 | 5.20 | 5.00 | 5.30 | 4.70 | 5.00 |
| Ijssel-Kampen | 0.080 | 0.100 | 0.050 | 0.090 | 0.080 | — | 3.26 | 2.42 | 2.00 | 2.56 | 5.30 | 5.50 | 4.20 | 11.10 | 6.93 |
| Norway | | | | | | | | | | | | | | | |
| Skienselva | 0.060 | 0.020 | 0.020 | 0.010 | 0.017 | 0.50 | 0.50 | 0.50 | 0.13 | 0.38 | 1.79 | 0.90 | 0.70 | 0.54 | 0.71 |
| Glomma | 0.080 | 0.030 | 0.160 | 0.020 | 0.070 | 0.50 | 0.50 | 0.50 | 0.62 | 0.54 | 2.20 | 2.10 | 3.20 | 2.01 | 2.44 |

*(Continued)*



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**Table 8A.12 (Continued)**

| | Cadmium (c) (mg/L) | | | | | Chromium (c) (mg/L) | | | | | Copper (c) (mg/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs (b) |
| Drammenselva | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.50 | 0.50 | 0.50 | 0.46 | 0.49 | 0.91 | 1.00 | 0.80 | 1.03 | 0.94 |
| Otra | 0.030 | 0.030 | 0.030 | 0.030 | 0.030 | 0.50 | 0.50 | 0.50 | 0.19 | 0.40 | 0.50 | 0.50 | 0.50 | 0.62 | 0.54 |
| Poland | | | | | | | | | | | | | | | |
| Wisla | 0.070 | 0.100 | 0.100 | 0.100 | 0.100 | 0.22 | 0.00 | 1.00 | 0.10 | 0.37 | 1.47 | 1.30 | 2.00 | 2.00 | 1.77 |
| Odra | 0.096 | 0.040 | 0.020 | 0.000 | 0.020 | 0.30 | 0.00 | 0.10 | 0.00 | 0.03 | 2.77 | 2.30 | 2.00 | 3.00 | 2.43 |
| Slovak | | | | | | | | | | | | | | | |
| Maly Dunaj | 0.032 | 0.024 | 0.080 | 0.070 | 0.058 | 0.52 | — | 0.26 | 0.17 | 0.32 | 17.45 | 3.32 | 3.37 | 3.51 | 3.40 |
| Vah | 0.055 | 0.092 | 0.040 | 0.060 | 0.064 | 0.65 | 1.02 | 1.65 | 1.53 | 1.40 | 2.02 | 1.73 | 2.33 | 2.68 | 2.25 |
| Hron | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Hornad | 1.267 | 1.333 | 0.820 | 0.670 | 0.941 | 0.14 | 4.79 | 2.34 | 2.19 | 3.11 | X | X | X | X | X |
| Spain | | | | | | | | | | | | | | | |
| Guadalquivir | 1.500 | — | — | — | 0.000 | — | — | — | — | 0.00 | 5.61 | — | — | — | 0.00 |
| Duero | 0.680 | 0.240 | 0.010 | 0.030 | 0.093 | — | 0.10 | 0.50 | 2.00 | 0.87 | — | 0.70 | 6.00 | — | 2.23 |
| Ebro | 0.030 | 0.040 | — | — | 0.023 | — | 1.67 | 0.25 | — | 0.64 | 0.83 | 0.83 | 1.00 | 3.00 | 1.61 |
| Guadiana | — | — | — | — | 0.000 | — | — | — | — | 0.00 | — | — | — | — | 0.00 |
| Sweden | | | | | | | | | | | | | | | |
| Dalàlven | 0.016 | 0.018 | 0.017 | 0.016 | 0.017 | 0.30 | 0.29 | 0.35 | 0.38 | 0.34 | 1.30 | 1.20 | 1.40 | 1.40 | 1.33 |
| Ràne alv | 0.008 | 0.012 | 0.024 | 0.006 | 0.014 | 0.11 | 0.13 | 0.19 | 0.17 | 0.16 | 0.80 | 1.70 | 0.80 | 0.40 | 0.97 |
| Mòrrumsán | 0.011 | 0.013 | 0.009 | 0.012 | 0.011 | 0.35 | 0.41 | 0.36 | 0.45 | 0.41 | 1.10 | 1.40 | 1.30 | 1.60 | 1.43 |
| Ròmneàn | 0.022 | 0.027 | 0.040 | 0.032 | 0.033 | 0.55 | 0.62 | 0.59 | 0.61 | 0.61 | 1.20 | 1.40 | 1.70 | 1.70 | 1.60 |
| Switzerland | | | | | | | | | | | | | | | |
| Guadiana | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Rhin | X | X | X | X | X | X | X | X | X | X | 1.60 | 1.50 | 1.70 | 1.70 | 1.63 |
| Aare | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Rhöne | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Turkey | | | | | | | | | | | | | | | |
| Porsuk | 0.000 | 5.000 | 5.000 | 5.000 | 5.000 | 0.00 | 9.00 | 5.00 | 5.00 | 6.33 | 3.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Sakarya | — | — | 5.000 | — | 1.667 | — | — | 6.00 | — | 2.00 | 14.00 | — | 8.00 | 15.00 | 7.67 |
| Yesilirmak | — | — | — | — | — | X | X | X | X | X | — | — | — | — | — |
| Gediz | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| UK | | | | | | | | | | | | | | | |
| Thames | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 1.30 | 1.20 | 1.30 | 1.30 | 1.27 | 6.30 | 7.10 | 6.30 | 6.50 | 6.63 |
| Severn | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 2.80 | 1.90 | 1.80 | 2.30 | 2.00 | 5.50 | 5.10 | 4.90 | 5.50 | 5.17 |
| Clyde | 0.000 | 0.000 | 0.100 | 0.000 | 0.033 | 17.00 | 13.00 | 14.70 | 12.30 | 13.33 | 4.90 | 4.30 | 3.60 | 3.70 | 3.87 |
| Mersey | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 5.70 | 4.90 | 5.30 | 4.40 | 4.87 | 7.60 | 6.90 | 7.50 | 7.40 | 7.27 |
| Lower Bann (N. Ireland) | 0.100 | 0.100 | — | — | 0.100 | 1.00 | 1.00 | — | — | 1.00 | 3.53 | 3.37 | — | — | 3.28 |

*Note:* a) Measured at the mouth or downstream frontier of river; b) Average over the last 3 years available: data prior to 1993 have not been taken into account; c) Data refer to total concentrations unless otherwise specified. DO: Concentrations are annual mean conventration; x=Data not available; JPN) Data refer to fiscal year (April to March); KOR) Han: samples were taken at 26 km upstream from the mouth of the river due to the tidal influence; AUT) 1985: 1984 data; FRA) Data refer to hydrological year (September-August). Seine: station under marine influence. Rhöne since 1987 data refer to another station; DEU) Elbe: Measuring station—Elbel/Geestacht; 1988 Elbe/Brunsbuttel; since 1989 Elbel/Zollenspieker; GRC) 1980: 1982 data; ESP) Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and farther away from Sevilla influence; TUR) 1980: 1982 data.

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BOD: MEX) 1985: 1984 data. 1998: the data's variations can be explained by fluctuations of meteorological conditions and the CNA's actions on control of residual water discharges; JPN) Data refer to fiscal year (April to March); KOR) Han: samples were taken at 26 km upstream from the mouth of the river due to the tidal influence; FRA) Data refer to hydrological year (September–August). Seine: station under marine influence. Rhöne since 1987 data refer to another station; DEU) Weser: 1990–1997—BOD7 (20°); NLD) Mass-Eijsden 1990 and 1993–1994; Rijn-Lobith 1993–1996: average include limit of detection values; ESP) Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and further away from Sevilla influence; TUR) 1980: 1982 data; UKD) When the parameter is unmeasurable (quantity is too small), the limit of detection values are used when calculating annual averages. Actual averages may therefore to lower. Clyde 1980: 1982 data.

Nitrates: CAN) Saskatchewan: N02 + N03; U.S.A.) Delaware 1985: 1984 data; KOR) Han: samples were taken at 26 km upstream from the mouth of the rivers due to the tidal influence; AUT) 1985: 1984 data; DNK) Data refer to N02 + N03; FRA) Data refer to hydrological year (September–August). Loire and Seine: dissolved concentrations. Seine: station under marine influence. Rhöne: since 1987 data refer to another station; DEU) Dissolved concentrations; ITA) Po: until 1986 data refer to Ponte Polesella (76 km far from the mouth); since 1989 data refer to Pontelagoscuro (91 km far from the mouth). Metaure 1985: 1984 data; NLD) Rijn-Lobith: dissolved concentrations; NOR) Skienselva and Drammenselva: until 1990 data refer to stations which may have marine influence; from 1990 onwards, data refer to new stations further away from the outlet Skienselva and Glomma 1985: 1983 data. Drammenselva 1985: 1984 data; SPAIN) Dissolved concentrations. Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and farther away from Sevilla influence. Ebro 1980: 1981 data; UKD) When the parameter is unreasonable (quantity too small) the limit of detection values are used when calculating annual averages. Actual averages may therefore be lower.

Phosphorus: CAN) Columbia 1980: 1981 data; MEX) Orthophosphate concentrations; U.S.A.) Mississippi 1985 and 1990 and Delaware 1998 and 1999: annual averages include estimated values; KOR) Han samples were taken at 26 km upstream from the mouth of the river due to the tidal influence; AUT) 1985: 1984 data; FRA) Data refer to hydrological year (September–August). Loire—1980: 1982 data: since 1982 data refer to another station. Seine: station under marine influence. Rhöne: sicne 1987 data refer to another station; GRC) Strimonas: 1998 and 1999 data refer to ortho-phosphate; IRL) Boyne: Data refers to ortho-phosphate; ITA) Po: Data until 1988 refer to Ponte Polesella (76 km from the mouth); since 1989 data refer to Pontelagoscuro (91 km from the mouth); Metauro 1985: 1984 data; NOR) Skienselva and Drammenselva: until 1990 data refer to stations which may have marine influence; from 1990 onwards, data refer to new stations further away from the outlet; Skienselva and Glomma 1985: 1983 data; SLO) Maly Dunaj: orthophosphate concentrations; 1980: 1981 data; SPAIN) Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and farther away from Sevilla influence; TUR) Orthophosphate concentrations; Yesilirmak 1980 and Gediz 1980: 1982 and 1981 data; UKD) Orthophosphate concentrations. When a parameter is unmeasurable (quantity too small), limit of detection values are used when calculating annual averages. Actual averages may therefore be lower.

Ammorium: CAN) Dissolved concentrations. 1980: 1981 data; U.S.A.) Delaware and Mississippi: dissolved concentrations; Mississippi: 1980, 1985 and 1999 data include limit of detection values; Delaware: 1982, 1983, 1985, 1988, 1992–1999 include limit of detection values; KOR) Han: samples were taken at 26 km upstream from the mouth of the river due to the tidal influence; AUT) 1985: 1984 data; FRA) Data refer to hydrological year (September–August). Loire and Seine: data refer to dissolved concentrations. Seine: station under marine influence. Rhöne: since 1987 data refer to another station; DEU) Dissolved concentrations; GRC) 1980: 1982 data; ITA) Po: until 1988 data refer to Ponte Polesella (76 km from the mouth): since 1989 data refer to Pontelagoscuro (91 km from the mouth). Adige 1988 and Metauro 1995: averages represent upper limits. Adige 1985: 1984 data; LUX) Moselle 91, 96 to 99: upper limits; Süre-Wasserbillig: 1985, 1990–1992, 1994–1999: upper detection limits; NLD) Rhine-Lobith: dissolved concentrations; NOR) Skienselva: until 1990 data refer to a station which may have marine influence; from 1990 onwards, data refer to a different station further away from the outlet; ESP) Dissolved concentrations. Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and farther away from Sevilla influence; TUR) Excepted for 1990–1991 data refer to NH3. Yesihrmak 1980: 1982 data; UKD) When the parameter is unmeasurable (quantity too small) the limit of detection values are used when calculating annual averages. Actual averages may therefore be lower.

Lead: U.S.A.) Delaware: 1988 data represent upper limits: dissolved concentrations. Mississippi: dissolved concentrations; KOR) Han: samples were taken at 26 km upstream from the mouth of the river due to the tidal influence; AUT) 1985: 1984 data. Donau 1980, 82, 86, Inn 1982, 84 and Grossache 1980, 86: limit of detection values; CZE) Labe: from 1988 to 1993 data are upper limit values. Morava: 1995 data is an upper limit value; FIN) Tornionjoki and Kymijoki: include limit of detection values; Kokemäenjoki 1980: 1981 data; FRA) Data refer to hydrological year (September–August); DEU) Elbe: dissolved concentrations: 1988–1989, 1991–1993 and 1995: include limit of detection values. Rhein 1994, 95, Weser 1988–1991 and Donau 1996, 97: include limit of detection values; HUN) Until 1994: total concentrations: 1994–1999: dissolved concentrations; LUX) Moselle and Süre all years: include limit of detection values; Both analysis methods and limit of detection have changed over the years; NLD) Rijn-Maas Delta 1992 and 1996, and Rijn-Lobith 1995: include limit of detection values; NOR) Glomma 1985: 1983 data. Drammenselva: until 1990 data refer to a station which may have marine influence; from 1990 onwards, data refer to a new station further away from the outlet. All rivers: from 1991 heavy metal concentrations have been determined by a different analysing method; SPAIN) Dissolved concentration. Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and farther away from Sevilla influence; SWE) Dissolved concentrations based on analysis of unfiltered samples; TUR) Porsuk 1999: upper limit; UKD) When the parameter is unmeasurable (quantity too small), the limit of detection values are used when calculating annual averages; actual averages may therefore be lower.

*(Continued)*



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**Table 8A.12 (Continued)**

Cadmium: U.S.A.) Delaware and Mississippi dissolved concentrations. Delaware 1982–1989, 1992–1993, and Mississippi 1980, 1989–1999; include limit of detection values; KOR) Han: samples were taken at 26 km upstream from the mouth of the river due to the tidal influence; AUT) Donau 1980: figure is approximate: Donau 1982, 86–87, 91 and 93, Inn 1984, 86, 88–90, 94 and Grossache 1980, 82 and 84: upper limits. 1985: 1984 data; BEL) Meuse (Agimont): 1994–1996 are upper limits; CZE Labe:from 1990 to 1993 data are upper limit values. Morava: 1993 figure is an upper limit value; FIN) Tornionjoki and Kymijoki: upper limits; 1985: 1984 data; FRA) Data refer to hydrological year (September–August). Loire: since 1988 data refer to another station; 1980 and 1985; 1982 and 1984 data; DEU) Rhein 1984–1989 and 95–97: upper limits: Elbe: data refer to dissolved concentrations; 1990–1991: upper limits. Weser 1988–1997, and Donau: upper limits; GRC) Strimonas 1986–1987, 92–94, Axios 1986–1987, Axeloos 1990, 92–96 and Nestos 1986, 92–97: include limit of detection values. Akeloos and Nestlos 1980: 1982 data; HUN) Until 1994. total concentrations; 1994–1999: dissolved concentrations; Duna: until 1996 total concentrations, 1996–1999 dissolved concentrations; IRL) Data represent upper limits; ITA) Metauro 1996: upper limits; LUX) Moselle and Süre 90 to 99 and Süre 1980, 1985, 1989: upper limits; NLD) Rijn/Maas, Delta 1993–1996, Rijn-Lobith 1993–1996 and Ijssel-Kampen 1993, 95–96: upper limits; NOR) Skienselva and Drammenselva: until 1990 data refer to stations which may have marine influence; from 1990 onwards, data refer to new stations further away from the outlet. Drammenselva 1980 (1981 data): refers to median values, and represents an upper limit; 1986 figure is a time-weighted average. All rivers: from 1991 heavy metal concentrations have been determined by a different analysing method; SPAIN) Dissolved concentrations. Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and farther away from Sevilla influence; Guadiana 1980: 1981 data; SWE) Dalàven and Morrumsàn: dissolved concentrations based on analysis of unifiltered samples; TUR) Porsak 1991–1993, 1995, 1997–1999. Sakarya 1989, 1991–1992, 1995, 1998 and Gediz 1995: upper limits; UKD) When the parameter is unmeasurable (quantity is too small), limit of detection values are used when calculating annual averages. Actual averages may therefore be lower.

Chromium: U.S.A.) Dissolved concentrations. Delaware 1980–1982, 1986–1988 and Mississippi 1985, 1988–1989: included limit of detection values; KOR) Han: samples were taken at 26 km upstream from the mouth of the river due to the tidal influence; AUT) Donau 1982, Inn 1994 and Grossache 1980, 82: include limit of detection values. 1985: 1984 data; BEL) Meuse (Agimont): 1994–1995 are upper limits; CZE) Labe 1988–1993: upper limits. Odra 1991–1992, 94–95: upper limits. Morava 1991–1992 and 1995: upper limits; FIN) Tornionjoki: include limit of detection values. Kymijoki 1985: 1984 data; FRA) Data refer to hydrological year (September–August); DEU) Elbe: dissolved concentrations. Elbe 1988, 90, 92, Weser 1987–1997, and Donau 1989–1997: include limit of detection values; HUN) Until 1994: total concentrations; 1994–1999; dissolved concentrations; Duna: until 1996 total concentrations, 1996–1999 dissolved concentrations; LUX) Moselle 91, 92, 95 to 99 and Süre 1991, 93, 95 to 99: include limit of detection values; NOR) Glomma 1985: 1983 data Drammenselva—1980: 1982 data; until 1990 data refer to a station which may have marine influence; from 1990 onwards, data refer to new station further away from the outlet. All rivers: since 1991 heavy metal concentrations have been determined by a different analysing method. Average of last 3 years represent or include the detection limit value (including 1998: the detection limit for Cr was 0.5); SPAIN) Dissolved concentrations. Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and farther away from Sevilla influence; Guadiana 1985: 1983 data; TUR) Porsuk 1998–1999: upper limits; UKD) When the parameter is unmeasarable (quantity is too small), limit of detection values are used when calculating annual averages. Actual averages may therefore be lower. Lower Bann: dissolved concentrations.

Copper: U.S.A.) Delaware and Mississippi dissolved concentrations; AUT) 1985: 1984 data. Grossache 1980: includes limit of detection values; CZE) Morava 1995: upper limit; FRA) Data refer to hydrological year (September–August); DEU) Elbe: dissolved concentrations; HUN) Until 1994: total concentrations; 1994–1999: dissolved concentrations; Duna: until 1996 total concentrations, 1995–1999 dissolved concentrations; LUX) Moselle 91 to 94, 96 to 98 and Süre 1990–1991, 93, 95, 99: upper limits; NOR) Skienselva and Drammenselva: until 1990 data refer to stations which may have marine influence: from 1990 onwards, data refer to new stations further away from the outlets. Glomma 1985: 1983 data. Drammenselva 1980 (1981data): include limits of detection values and represent a median value. All rivers: from 1991 heavy metal concentrations have been determined by a different analysing method; SPAIN) Dissolved concentrations. Guadalquivir: from 1990 onwards data refer to another station closer to the mouth and farther away from Sevilla influence; SWE) Data refer to dissolved concentrations based on analysis of unfiltered samples; TUR) Porsuk 1988–1998: upper limits; UKD) When the parameter is unreasonable (quantity is too small), limit of detection values are used when calculating annual averages. Actual averages may therefore be lower.

*Source*: From Tables 3.4A through 3.4I (data from 1996, 1997, 1998, 1999, and average last 3 years), *OECD Environmental Data Compendium 2002*, © OECD 2002, www.oecd.org.

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## SECTION 8B DRINKING WATER QUALITY STANDARDS UNITED STATES

The U.S. Environmental Protection Agency's National Primary Drinking-Water Regulations and National Secondary Drinking-Water Regulations are summarized in the following tables. The primary regulations specify maximum contaminant levels (MCLs), and health advisories. The MCLs, which are the maximum permissible level of a contaminant in water at the tap, are health related and are legally enforceable. If these concentrations are exceeded or if required monitoring is not performed the public must be notified. The secondary drinking-water regulations specify the secondary maximum contaminant levels (SMCL). The SMCLs are for contaminants in drinking water that primarily affect the esthetic qualities related to public acceptance of drinking water; they are intended to be guidelines for the States and are not federally enforceable. Health advisories are guidance contaminant levels that would not result in adverse health effects over specified short-time periods for most people.

As provided by the Safe Drinking Water Act of 1974, the U.S. Environmental Protection Agency has the primary responsibility for establishing and enforcing regulations. However, States may assume primacy if they adopt regulations that are at least as stringent as the Federal regulations in levels specified for protection of public health and in provision of surveillance and enforcement. The States may adopt more stringent regulations and may establish regulations for other constituents.

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**Table 8B.13 Contaminants Regulated under the Safe Drinking Water Act**

| Contaminants Regulated under the Safe Drinking Water Act | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1976 | 1979 | 1986 | 1987 | 1989 | | 1991 | | | 1992 | |
| **Final Regulations** | NPD WRs 12/75; 7/76 | TTHMs 11/79 | Fluoride 4/86 | Phase 1 (VOCs) 7/87 | TCR 6/89 | SWTR 6/89 | Phase II 1/91; 7/91 | | LCR 6/91 | Phase V 7/92 | |
| **Summary of Final Actions** | New regs | New reg | *Revision* | New regs | *Revision* | 1 *Revision* 4 New regs | 38 SOCs & IOCs; 11 *Revisions* 27 New regs | | 1 *Revision* 1 New reg | 23 SOCs & IOCs; 1 *Revision* 22 New regs | |
| **# in Regulation** | 22 | 1 | 1 | 8 | 1 | 5 | 39 | | 2 | 23 | |
| **Cumulative # of regulated contaminants** | 22 | 23 | 23 | 31 | 31 | 35 | 61 | | 62 | 84 | |
| **Contaminants regulated** | 2,4-D<br>2,4,5-TP (Silvex)<br>arsenic<br>barium<br>cadmium<br>chromium<br>coliform bacterial<br>cadrin<br>fluoride<br>gross alpha<br>gross beta<br>lead<br>lindane<br>mercury<br>methoxychlor<br>nitrate<br>radium-226[1]<br>radium-228[1]<br>selenium<br>silver<br>toxaphene<br>turbidity | total THMs[2] | *fluoride* | benzone<br>carbon tetrachloride<br>1,2-dichloroethane<br>p-dichlorobenzene<br>1,1-dichloroethylene<br>1,1,1-trichloroethlane<br>trichloroethylene<br>vinyl chloride[3] | *total coliforms*[2] | Giardia[4]<br>*turbidity*[4]<br>HPC bacteria[4]<br>Legionella[4]<br>viruses[4] | 2-4-D<br>2,4,5-*TP*<br>acrylamide[4]<br>alachlor<br>aldicarb[5]<br>aldicarb sulfone[5]<br>aldicarb sulfoxide[5]<br>asbestos<br>atrazinc<br>*barium*<br>*cadmium*<br>carbofuran<br>chlordane | (mono) chlorobenzene<br>*chromium*<br>dibromochloropropane<br>o-dichlorobenzene<br>cis-1,2-dichloroethylene<br>trans-1,2-dichloroethylene<br>1,2-dichloropropane<br>epichlorohydrin[4]<br>ethylbenzene<br>ethylene dibromide<br>heptachlor<br>heptachlor epoxide<br>*lindane*<br>*mercury (inorganic)* | *methoxychlor*<br>*nitrate* nitrite total nitrate/nitrite<br>PCBs<br>pentachlorophenol<br>*selenium* styrene<br>tetrachlorethylene<br>toluene *toxophene*<br>xylenes | copper[4]<br>*lead*[4] | Adupate di(2-ethylhexyl)<br>antimony<br>beryilium<br>eyanide<br>dalapon<br>dichloromethane[4]<br>dinoseb<br>dioxin 2,3,7,8-TCDD)<br>diqual<br>endothall *endrin*<br>glyphosate | hexachlorobenzene<br>hexachlorocyclopentadiene<br>nickel<br>oxamyl (vydate)<br>PAHs (benzo(a) pyrene)<br>phthalate, di(2-ethylhexyl)<br>picloram<br>simazine<br>thalium<br>1,2,4-trichlorobenzene<br>1,1,2-trichloroethane |

| | 1995 | 1998 | | 2000 | 2001 |
|---|---|---|---|---|---|
| **Final Regulations** | | Stage 1 DBPR 12/98 | Interim ERSWTR 12/98 | Radionuclides 12/00 | Arsenic 1/01 |
| **Summary of Final Actions** | *Remand* | 1 *Revision* 6 New regs | 2 *Revisions* 1 New reg | *4 Revisions* 1 new reg | *1 Revision* |
| **# in Regulation** | 1 | 1 | 3 | 5 | 1 |
| **Cumulative # of regulated contaminants** | 83 | 89 | 90 | 91 | 91 |
| **Contaminants regulated** | *nickel* | bromate<br>chloramine<br>chlorine<br>chlorine dioxide<br>chlorine<br>haloacetic acids (HAAS)[2]<br>*TTHMs* | Cryptosporidium<br>*Glardia*<br>*turbidity* | grass alpha<br>gross-beta<br>radium-226[1]<br>radium-228[1]<br>uranium | arsenic |

**Notes:**

1. Radium-226 and radium-228 arecontrol as two contaminants althoughtheir standard is combined.
2. Total THMs, haloacetic acids, and total coliforms are counted as one contaminant although both are combined standards: THMs (chloroform, bromodichloromethane, dibromochloromethane, bromoform), TC (total coliform bacteria including fecal coliform and E coli); HAAS (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, bromoacetic acid, and dibromoacetic acid).
3. Vinyl chloride is also known aschloroethylene & monochloroethylene.
4. These nine contaminants have a treatment technique instead of aMCL.
5. Aldicarb, aldicarb sulfone, and aldicarb sulfoxide are considered regulated contaminants although their MCLs are strayed.
6. Dichloromethane is also known as methylene chloride.

**Updated 13 February 2001**
www.epa.gov/safowater/mcl.html.

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**Table 8B.14 National Primary Drinking Water Standards**

| | MCLG[1] (mg/L)[2] | MCL or TT[1] 3(mg/L)[2] |
|---|---|---|
| **Microorganisms** | | |
| Cryptosporidium | zero | TT[3] |
| *Giardia lamblia* | zero | TT[3] |
| Heterotrophic plate count | n/a | TT[3] |
| *Legionella* | zero | TT[3] |
| Total Coliforms (including fecal coliform and *E. Coli*) | zero | 5.0%[4] |
| Turbidity | n/a | TT[3] |
| Viruses (enteric) | zero | TT[3] |

**Disinfection Byproducts**

| Constituent | MCLG[1] (mg/L)[2] | MCL or TT[1] (mg/L)[2] |
|---|---|---|
| Bromate | zero | 0.01 |
| Chlorite | 0.8 | 1 |
| Haloacetic acids (HAA5) | n/a[6] | 0.06 |
| Total Trihalomethanes (TTHMs) | none[7] | 0.1 |
| | — | — |
| | n/a[6] | 0.08 |

**Disinfectants**

| Constituent | MCLG[1] (mg/L)[2] | MCL or TT[1] (mg/L)[2] |
|---|---|---|
| Chloramines (as $Cl_2$) | MRDLG = 41 | MRDL = 4.01 |
| Chlorine (as $Cl_2$) | MRDLG = 41 | MRDL = 4.01 |
| Chlorine dioxide (as $ClO_2$) | MRDLG = 0.81 | MRDL = 0.81 |

**Inorganic Chemicals**

| Constituent | MCLG[1] (mg/L)[2] | MCL or TT[1] (mg/L)[2] |
|---|---|---|
| Antimony | 0.006 | 0.006 |
| Arsenic | 7 | 0.01 as of 01/23/06 |
| Asbestos (fiber $>10$ μm) | 7 million fibers/L | 7 MFL |
| Barium | 2 | 2 |
| Beryllium | 0.004 | 0.004 |
| Cadmium | 0.005 | 0.005 |
| Chromium (total) | 0.1 | 0.1 |
| Copper | 1.3 | TT[8]; Action Level = 1.3 |
| Cyanide (as free cyanide) | 0.2 | 0.2 |
| Fluoride | 4 | 4 |
| Lead | zero | TT[8]; Action Level = 0.015 |
| Mercury (inorganic) | 0.002 | 0.002 |
| Nitrate (measured as Nitrogen) | 10 | 10 |
| Nitrite (measured as Nitrogen) | 1 | 1 |
| Selenium | 0.05 | 0.05 |
| Thallium | 0.0005 | 0.002 |

*(Continued)*

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**Table 8B.14 (Continued)**

| Constituent | MCLG[1] (mg/L)[2] | MCL or TT[1] (mg/L)[2] |
|---|---|---|
| **Organic Chemicals** | | |
| Acrylamide | zero | TT[9] |
| Alachlor | zero | 0.002 |
| Atrazine | 0.003 | 0.003 |
| Benzene | zero | 0.005 |
| Benzo(a)pyrene (PAHs) | zero | 0.0002 |
| Carbofuran | 0.04 | 0.04 |
| Carbon tetrachloride | zero | 0.005 |
| Chlordane | zero | 0.002 |
| Chlorobenzene | 0.1 | 0.1 |
| 2,4-D | 0.07 | 0.07 |
| Dalapon | 0.2 | 0.2 |
| 1,2-Dibromo-3-chloropropane (DBCP) | zero | 0.0002 |
| o-Dichlorobenzene | 0.6 | 0.6 |
| p-Dichlorobenzene | 0.075 | 0.075 |
| 1,2-Dichloroethane | zero | 0.005 |
| 1,1-Dichloroethylene | 0.007 | 0.007 |
| cis-1,2-Dichloroethylene | 0.07 | 0.07 |
| trans-1,2-Dichloroethylene | 0.1 | 0.1 |
| Dichloromethane | zero | 0.005 |
| 1,2-Dichloropropane | zero | 0.005 |
| Di(2-ethylhexyl) adipate | 0.4 | 0.4 |
| Di(2-ethylhexyl) phthalate | zero | 0.006 |
| Dinoseb | 0.007 | 0.007 |
| Dioxin (2,3,7,8-TCDD) | zero | 0.00000003 |
| Diquat | 0.02 | 0.02 |
| Endothall | 0.1 | 0.1 |
| Endrin | 0.002 | 0.002 |
| Epichlorohydrin | zero | TT[9] |
| Ethylbenzene | 0.7 | 0.7 |
| Ethylene dibromide | zero | 0.00005 |
| Glyphosate | 0.7 | 0.7 |
| Heptachlor | zero | 0.0004 |
| Heptachlor epoxide | zero | 0.0002 |
| Hexachlorobenzene | zero | 0.001 |
| Hexachlorocyclopentadiene | 0.05 | 0.05 |
| Lindane | 0.0002 | 0.0002 |
| Methoxychlor | 0.04 | 0.04 |
| Oxamyl (Vydate) | 0.2 | 0.2 |
| Polychlorinated biphenyls (PCBs) | zero | 0.0005 |
| Pentachlorophenol | zero | 0.001 |
| Picloram | 0.5 | 0.5 |
| Simazine | 0.004 | 0.004 |
| Styrene | 0.1 | 0.1 |
| Tetrachloroethylene | zero | 0.005 |
| Toluene | 1 | 1 |
| Toxaphene | zero | 0.003 |
| 2,4,5-TP (Silvex) | 0.05 | 0.05 |
| 1,2,4-Trichlorobenzene | 0.07 | 0.07 |
| 1,1,1-Trichloroethane | 0.2 | 0.2 |
| 1,1,2-Trichloroethane | 0.003 | 0.005 |
| Trichloroethylene | zero | 0.005 |
| Vinyl chloride | zero | 0.002 |
| Xylenes (total) | 10 | 10 |

*(Continued)*

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**Table 8B.14 (Continued)**

| Constituent | MCLG[1] (mg/L)[2] | MCL or TT[1] (mg/L)[2] |
|---|---|---|
| **Radionuclides** | | |
| Alpha particles | none[7] | 15 picocuries per Liter (pCi/L) |
| | — | |
| | zero | |
| Beta particles and photon emitters | none[7] | 4 millirems/yr |
| | — | |
| | zero | |
| Radium 226 and Radium 228 (combined) | none[7] | 5 pCi/L |
| | — | |
| | zero | |
| Uranium | zero | 30 ug/L as of 12/08/03 |

*Note:*

[1]Definitions:
**Maximum Contaminant Level (MCL)**—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

**Maximum Contaminant Level Goal (MCLG)**—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

**Maximum Residual Disinfectant Level (MRDL)**—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

**Maximum Residual Disinfectant Level Goal (MRDLG)**—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

**Treatment Technique**—A required process intended to reduce the level of a contaminant in drinking water.

[2]Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

[3]EPA's surface water treatment rules require systems using surface water or groundwater under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

*Cryptosporidium*: (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal;
*Giardia lamblia*: 99.9% removal/inactivation;

*Viruses*: 99.99% removal/inactivation;

*Legionella*: No limit, but EPA believes that if *Giardia* and viruses are
*Turbidity*: At no time can turbidity (cloudiness of water) go above 5 nephelolometric
*HPC*: No more than 500 bacterial colonies per milliliter.

Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).

Filter Backwash Recycling; The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

[4]More than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E.coli* fecal coliforms, system has an acute MCL violation.

*(Continued)*

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**Table 8A.14 (Continued)**

[5]Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

[6]Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

*Trihalomethanes*: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L). Chloroform is regulated with this group but has no MCLG.

*Haloacetic acids*: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L). Monochloroacetic acid, bromoacetic acid, and dibromoacetic acid are regulated with this group but have no MCLGs.

[7]MCLGs were not established before the 1986 Amendments to the Safe Drinking Water Act. Therefore, there is no MCLG for this contaminant.

[8]Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

[9]Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

Acrylamide = 0.05% dosed at 1 mg/L (or equivalent);
Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

*Source*: From United States Environmental Protection Agency, www.epa.gov.

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**Table 8B.15 National Secondary Drinking Water Standards**

| Constituent | SMCL Level |
|---|---|
| Aluminum | 0.05 to 0.2 mg/L |
| Chloride | 250 mg/L |
| Color | 15 (color units) |
| Copper | 1.0 mg/L |
| Corrosivity | Noncorrosive |
| Fluoride | 2.0 mg/L |
| Foaming Agents | 0.5 mg/L |
| Iron | 0.3 mg/L |
| Manganese | 0.05 mg/L |
| Odor | 3 threshold odor number |
| pH | 6.5–8.5 |
| Silver | 0.10 mg/L |
| Sulfate | 250 mg/L |
| Total Dissolved Solids | 500 mg/L |
| Zinc | 5 mg/L |

*Note:* National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are nonenforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

*Source*: From United States Environmental Protection Agency, www.epa.gov.

**Table 8B.16 National Proposed MRDLGs, MRDLs, MCLGs, MCLs, AND AMCLs for Radon, Disinfectanct Residuals, and Disinfection Byproducts**

| Radon | MCLG | MCL | AMCL |
|---|---|---|---|
| Radon | zero | 300 pCi/L | 4000 pCi/L |
| **Stage 1 Disinfectants and Disinfection Byproducts Rule** | | | |
| **Disinfectant Residual** | **MRDLG (mg/L)** | **MRDL (mg/L)** | **Compliance Based on** |
| Chlorine | 4 (as $Cl_2$) | 4.0 (as $Cl_2$) | Annual Average |
| Chloramine | 4 (as $Cl_2$) | 4.0 (as $Cl_2$) | Annual Average |
| Chlorine Dioxide | 0.8 (as $ClO_2$) | 0.8 (as $ClO_2$) | Daily Samples |
| **Disinfection Byproducts** | **MCLG (mg/L)** | **MCL (mg/L)** | **Compliance Based on** |
| Total trihalomethanes (TTHM)[a] | N/A | 0.080 | Annual Average |
| Chloroform | *** | | |
| Bromodichloromethane | 0 | | |
| Dibromochloromethane | 0.06 | | |
| Bromoform | 0 | | |
| Haloacetic acids (five) (HAA5)[b] | N/A | 0.060 | Annual Average |
| Dichloroacetic acid | 0 | | |
| Trichloroacetic acid | 0.3 | | |
| Chlorite | 0.8 | 1.0 | Monthly Average |
| Bromate | 0 | 0.010 | Annual Average |

*Notes:* N/A-Not applicable because there are individual MCLGs for TTHMs or HAAs; MRDLGs, Maximum residual disinfectant level goals; MRDLs, Maximum residual disinfectant level; MCLGs, Maximum contaminant level goal; MCLs, Maximum contaminant level; AMCL, Alternate Maximum Contaminant Level; pCi/L, picoCuries per liter; mg/L, milligrams per liter.

[a] Total trihalomethanes is the sum of the concentrations of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.
[b] Haloacetic acids (five) is the sum of the concentrations of mono-, di-, and trichloroacetic acids and mono—and dibromoacetic acids.

*Source*: From United States Environmental Protection Agency, www.epa.gov.

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**Table 8B.17 Summary of State Drinking Water Quality Standards That Differ from USEPA Standards**

| Compound (mg/L) | Alabama | California | Connecticut | Delaware | Florida | Hawaii | Iillinois | Massachusetts | New Hampshire | New Jersey | New York | North Carolina | Pennsylvania | Utah | Wisconsin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| aldicarb | 0.003 | — | — | — | — | — | 0.002 | — | — | — | 0.003 | 0.002 | — | — | — |
| aldicarb sulfone | 0.002 | — | — | — | — | — | 0.002 | — | — | — | 0.002 | 0.003 | — | — | — |
| aldicarb sulfoxide | 0.004 | — | — | — | — | — | 0.004 | — | — | — | 0.004 | 0.004 | — | — | — |
| aldrin | — | — | — | — | — | — | 0.001 | — | — | — | — | — | — | — | — |
| aluminum | — | 1 | — | — | — | — | | — | — | — | — | — | — | — | — |
| atrazine | — | 0.003 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| barium | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| bentazon | — | 0.018 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| benzene | — | 0.001 | — | — | 0.001 | — | — | — | — | 0.001 | — | — | — | — | — |
| bis(2-ethylhexyl)phthalate | — | 0.004 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| carbofuran | — | 0.018 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| carbon tetrachloride | — | 0.0005 | — | — | 0.003 | — | — | — | — | 0.002 | — | — | — | — | — |
| chlordane | — | 0.0001 | — | — | — | — | — | — | — | 0.0005 | — | — | — | — | — |
| chlorobenzene | — | 0.07 | — | — | — | — | — | — | — | 0.05 | — | — | — | — | — |
| chromium | — | 0.05 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| cis-1, 2-dichloroethylene | — | 0.006 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 2,4-D | — | — | — | — | — | — | 0.01 | — | — | — | 0.05 | — | — | — | — |
| DDT | — | — | — | — | — | — | 0.05 | — | — | — | — | — | — | — | — |
| 1, 2-dibromo-3-chloropropane | — | 0.0002 | — | — | — | 0.00004 | — | — | — | — | — | — | — | — | — |
| 1,2-dichlorobenzene | — | — | — | — | — | — | — | — | — | 0.6 | — | — | — | — | — |
| 1,3-dichlorobenzene | — | — | — | — | — | — | — | — | — | 0.6 | — | — | — | — | — |
| 1,4-dichlorobenzene | — | 0.005 | — | — | — | — | — | 0.005 | — | — | — | — | — | — | — |
| 1,1-dichloroethane | — | 0.005 | — | — | — | — | — | — | — | 0.05 | — | — | — | — | — |
| 1,2-dichloroethane | — | 0.0005 | — | — | 0.003 | — | — | — | — | 0.002 | — | — | — | — | — |
| 1,1-dichloroethylene | — | 0.006 | — | — | — | — | — | — | — | 0.002 | — | — | — | — | — |
| dichloromethane | — | — | — | — | — | — | — | — | — | 0.002 | — | — | — | — | — |
| 1,2-dichloropropane | — | 0.005 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 1,3-dichloropropene | — | 0.0005 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| dieldrin | — | — | — | — | — | — | 0.001 | — | — | — | — | — | — | — | — |
| endrin | — | — | — | — | — | — | — | — | — | — | 0.0002 | — | — | — | — |
| ethion | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| ethylene dibromide | — | — | — | — | 0.00002 | 0.00004 | — | 0.00002 | — | — | — | — | — | — | — |
| fluoride | — | 2 | — | 1.8 | — | 1.4–2.4 | — | — | — | — | — | 4 | 2 | — | — |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| formaldehyde | — | 0.03 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| heptachlor | — | 0.00001 | — | — | — | — | 0.0001 | — | — | — | — | — | — | — | — |
| heptachlor epoxide | — | 0.00001 | — | — | — | — | 0.0001 | — | — | — | — | — | — | — | — |
| iron | — | — | — | — | — | — | 1 | — | — | — | — | 0.3 | — | — | — |
| isopropanol | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| manganese | — | — | — | — | — | — | 0.15 | — | — | — | 0.3 | 0.05 | — | — | — |
| methyl t-butyl ether | — | 0.005 | — | — | — | — | — | — | — | 0.07 | — | — | — | — | — |
| molinate | — | 0.02 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| naphthalene | — | — | — | — | — | — | — | — | — | 0.3 | — | — | — | — | — |
| polychlorinated biphenyls | — | — | — | — | — | — | — | — | — | 0.0005 | — | — | — | — | — |
| silver | — | — | 0.05 | — | — | — | — | — | — | — | — | — | — | — | — |
| sodium | — | — | — | — | 0.16 | — | — | — | — | — | — | — | — | — | — |
| strontium 90 | 0.008 | 0.008 | 0.008 | — | — | — | 0.008 | — | 0.008 | — | — | — | — | — | 0.008 |
| sulfate | 500 | — | — | — | — | — | — | — | — | — | — | — | — | 1,000 | — |
| tetrachloroethylene | — | — | — | — | 0.003 | — | — | — | — | 0.001 | — | — | — | — | — |
| 1,1,2,2-tetrachloroethane | — | 0.001 | — | — | — | — | — | — | — | 0.001 | — | — | — | — | — |
| thiobencarb | — | 0.07 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 2,4,5-TP | — | — | — | — | — | — | — | — | — | — | 0.01 | | | | |
| toluene | — | 0.15 | — | — | — | — | — | — | — | — | — | — | — | — | 1 |
| 1,2,4-trichloro-benzene | — | — | — | — | — | — | — | — | — | 0.009 | — | — | — | — | — |
| 1,1,1-trichloroethane | — | — | — | — | — | — | — | — | — | 0.03 | — | — | — | — | — |
| 1,1,2-trichloroethane | — | — | — | — | — | — | — | — | — | 0.003 | — | — | — | — | — |
| trans-1,2-dichloroethylene | — | 0.01 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| trichloroethylene | — | — | — | — | 0.003 | — | — | — | — | 0.001 | — | — | — | — | — |
| trichlorofluoro-methane | — | 0.15 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 1,2,3-trichloropropane | — | — | — | — | — | 0.0008 | — | — | — | — | — | — | — | — | — |
| 1,1,2-trichloro-1, 2,2~trifluoro-ethane | — | 1.2 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| tritium | 20 | 20 | 20 | — | — | — | 20 | — | 20 | — | — | — | — | — | 20 |
| uranium | — | 0.02 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| vinyl chloride | — | 0.0005 | — | — | 0.001 | — | — | — | — | 0.002 | — | — | — | — | 0.0002 |

*(Continued)*



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**Table 8B.17 (Continued)**

| Compound (mg/L) | Alabama | California | Connecticut | Delaware | Florida | Hawaii | Iillinois | Massachusetts | New Hampshire | New Jersey | New York | North Carolina | Pennsylvania | Utah | Wisconsin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-xylene | — | 1.75 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 3-xylene | — | 1.75 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 4-xylene | — | 1.75 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| xylene | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | 10 |
| zinc, elemental | — | — | — | — | — | — | 5 | — | — | — | — | — | — | — | — |

*Note:* Concentrations are in milligram per liter (mg/L).

*Source*: From Data Bank Update Committee, Federal-State Toxicology and Risk Analysis Committee (FSTRAC), *Summary of State and Federal Drinking Water Standards and Guidelines 1998–1999*, www.sis.nlm.nih.gov.



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**Table 8B.18 Public Water Supply Standard**

| IOCs, SOCs, VOCs | | Second Cycle | | | | | | | | | Third Cycle | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st Period | | | 2nd Period | | | 3rd Period | | | 1st Period | | | 2nd Period | | | 3rd Period | | |
| | | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Inorganic Contaminants (IOCs)[1] | **Groundwater (Below MCL)** | | | | | | | | | | | | | | | | | | |
| | Waiver[2] | | | | | * | | | | | | | | | * | | | | |
| | No Waiver | | * | | | * | | | * | | | * | | | * | | | * | |
| | **Surface Water (Below MCL)** | | | | | | | | | | | | | | | | | | |
| | Waiver[2] | | | | | * | | | | | | | | | * | | | | |
| | No Waiver | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | **Groundwater and Surface Water (Above MCL)[3]** | | | | | | | | | | | | | | | | | | |
| | Reliably and Consistently ≤ MCL for Groundwater Systems | | * | | | * | | | * | | | * | | | * | | | * | |
| | Reliably and Consistently ≤ MCL for Surface Water Systems | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | > MCL or Not Reliably and Consistently ≤ MCL | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** |
| Synthetic Organic Contaminants (SOCs) | **Population >3,300 (Below Detection Limit)** | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | Waiver | | × | | | × | | | × | | | × | | | × | | | × | |
| | < Detect and No Waiver | | ** | | | ** | | | ** | | | ** | | | ** | | | ** | |
| | **Population 3,300 (Below Detection Limit)** | | | | | | | | | | | | | | | | | | |
| | Waiver | | × | | | × | | | × | | | × | | | × | | | × | |
| | < Detect and No Waiver | | * | | | * | | | * | | | * | | | * | | | * | |
| | **Above Detection Limit** | | | | | | | | | | | | | | | | | | |
| | Reliably and Consistently ≤ MCL[4] | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | ≥ Detect or Not Reliably and Consistently ≤ MCL | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** |
| | | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Volatile Organic Contaminants (VOCs) | **Groundwater (Below Detection Limit)** | | | | | | | | | | | | | | | | | | |
| | < Detect, Vulnerability Assessment, and Waiver[5] | | | * | | | | | | * | | | | | | * | | | |
| | No Waiver[6] | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | **Surface Water (Below Detection Limit)** | | | | | | | | | | | | | | | | | | |
| | < Detect, Vulnerability Assessment, and Waiver[7] | | × | | | × | | | × | | | × | | | × | | | × | |
| | No Waiver[8] | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | **Above Detection Limit** | | | | | | | | | | | | | | | | | | |
| | Reliably and Consistently < MCL[4] | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | ≥ Detect or Not Reliably and Consistently ≤ MCL | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** |



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**Table 8B.18 (Continued)**

| | EXCEPTIONS | Second Cycle | | | | | | | | | Third Cycle | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st Period | | | 2nd Period | | | 3rd Period | | | 1st Period | | | 2nd Period | | | 3rd Period | | |
| Nitrate | | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| | **CWSs & NTNCWSs** | | | | | | | | | | | | | | | | | | |
| | Surface Water with 4 Quarters of Results < 1/2 MCL[9] | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | Groundwater Reliably and Consistently < MCL[9] | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | ≥ 1/2 MCL | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** |
| | **TNCWSs** | | | | | | | | | | | | | | | | | | |
| | Standard Monitoring | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Nitrite | | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | < 1/2 MCL | # | | | | | | | | | # | | | | | | | | |
| | Reliably and Consistently < MCL[9] | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | ≥ 1/2 MCL or Not Reliably and Consistently < MCL | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** |
| Radio nuclides | | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | < Detection Limit | ! | | **** | | | | * | | | * | | | | | | * | | |
| | ≥ Detection Limit but ≤ 1/2 MCL | | | **** | | | | * | | | * | | | * | | | | | |
| | > 1/2 MCL but ≤ MCL | | | **** | | | | * | | | * | | | * | | | * | | |
| | > MCL | | | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | *** * | **** | **** |
| Asbestos | | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | Waiver | | × | | | × | | | × | | | × | | | × | | | × | |
| | No Waiver, Reliably and Consistently ≤ MCL, or Vulnerable to Asbestos Contamination[10] | * | | | | | | | | | * | | | | | | | | |
| | > MCL | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** | **** |

**Legend**

* = 1 sample at each entry point to distribution system (EPTDS).

** = 2 quarterly samples at each EPTDS. Samples must be taken during 1 calendar year during each 3-year compliance period.

**** = 4 quarterly samples at each EPTDS within time frame designated by the primacy agency.

× = No sampling required unless required by the primacy agency.

# = Systems must monitor at a frequency specified by the primacy agency.

! = When allowed by the primacy agency, data collected between June 2000 and December 8, 2003 may be grandfathered to satisfy the initial monitoring requirements due in 2004 for gross alpha, radium 226/228, and uranium.

[1]Until January 22, 2006 the maximum contaminant level (MCL) for arsenic is 50 μg/L; on January 23, 2006 the MCL for arsenic becomes 10 μg/L.

[2]Based on 3 rounds of monitoring at each EPTDS with all analytical results below the MCL. Waivers are not permitted under the current arsenic requirements, however systems are eligible for arsenic waivers after January 23, 2006.

[3]A system with a sampling point result above the MCL must collect quarterly samples, at that sampling point, until the system is determined by the primacy agency to be reliably and consistently below the MCL.

[4]Samples must be taken during the quarter which previously resulted in the highest analytical result. Systems can apply for a waiver after 3 consecutive annual sampling results are below the detection limit.

[5]Groundwater systems must update their vulnerability assessments during the time the waiver is effective. Primacy agencies must re-confirm that the system is nonvulnerable within 3 years of the initial determination or the system must return to annual sampling.

[6]If all monitoring results during initial quarterly monitoring are less than the detection limit, the system can take annual samples. If after a minimum of 3 years of annual sampling with all analytical results less than the detection limit, the primacy agency can allow a system to take 1 sample during each compliance period. Systems are also eligible for a waiver.

[7]Primacy agencies must determine that a surface water system is nonvulnerable based on a vulnerability assessment during each compliance period or the system must return to annual sampling.

[8]If all monitoring results during initial quarterly monitoring are less than the detection limit, the system can take annual samples. Systems are also eligible for a waiver.

[9]Samples must be taken during the quarter which previously resulted in the highest analytical result.

[10]Systems are required to monitor for asbestos during the first 3-year compliance period of each 9-year compliance cycle. A system vulnerable to asbestos contamination due solely to corrosion of asbestos-cement pipe must take 1 sample at a tap served by that pipe. A system vulnerable to asbestos contamination at the source must sample at each EPTDS.

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*Note:* The Standardized Monitoring Framework (SMF), was promulgated in the Phase II Rule on January 30, 1991 (56 FR 3526). The purpose of the SMF is to standardize, simplify, and consolidate monitoring requirements across contaminant groups. The SMF increases public health protection by simplifying monitoring plans and synchronizing monitoring schedules leading to increased compliance with monitoring requirements. The SMF reduces the variability within monitoring requirements for chemical and radiological contaminants across system sizes and types. The SMF summarizes existing systems' ongoing federal monitoring requirements only. Primacy agencies have the flexibility to issue waivers, with EPA approval, which take into account regional and state specific characteristics and concerns. To determine exact monitoring requirements, the SMF must be used in conjunction with any EPA approved waiver and additional requirements as determined by the primacy agency. New water systems may have different and additional requirements as determined by the primacy agency.

**Regulated Contaminants:**
Inorganic Contaminants (IOCs) — Fifteen (15) (Nitrate, Nitrite, total Nitrate/Nitrite, and Asbestos are exceptions to SMF)
Synthetic Organic Contaminants (SOCs) & Volatile Organic Contaminants (VOCs) — Fifty-One (51)
Radionuclides — Four (4)

**Utilities Covered:**
All PWS must monitor for Nitrate and Nitrite
CWSs must monitor for IOCs, SOCs, VOCs, and Radionuclides
NTNCWSs must monitor for IOCs SOCs, and VOCs.

*Source*: From United States Environmental Protection Agency, www.epa.gov.



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**Table 8B.19 Drinking Water Priority Rulemaking: Microbial and Disinfection Byproduct Rules Summary**

**Existing M–DBP Regulations**

- Microbial Contaminants: The Surface Water Treatment Rule (SWTR), promulgated in 1989, applies to all public water systems using surface water sources or groundwater sources under the direct influence of surface water. It establishes maximum contaminant level goals (MCLGs) for viruses, bacteria and *Giardia lamblia*. It also includes treatment technique requirements for filtered and unfiltered systems that are specifically designed to protect against the adverse health effects of exposure to these microbial pathogens. The Total Coliform Rule, revised in 1989, applies to all PWSs and establishes a maximum contaminant level (MCL) for total coliforms
- Disinfection Byproducts: In 1979, EPA set an interim MCL for total trihalomethanes of 0.10 mg/L as an annual average. This applies to any community water system serving at least 10,000 people that adds a disinfectant to the drinking water during any part of the treatment process

**Information Collection Rule (ICR)**: To support the M–DBP rulemaking process, the ICR required large public water systems serving at least 100,000 people to monitor and collect data on microbial contaminants, disinfectants and disinfection byproducts for 18 months. The data provide EPA with information about disinfection byproducts, disease-causing microorganisms, including *Cryptosporidium*, and engineering data to control these contaminants

**Interim Enhanced Surface Water Treatment Rule (IESWTR):**

The IESWTR applies to systems using surface water, or groundwater under the direct influence of surface water, that serve 10,000 or more persons. The rule also includes provisions for states to conduct sanitary surveys for surface water systems regardless of system size. The rule builds upon the treatment technique requirements of the SWTR with the following key additions and modifications

- Maximum contaminant level goal (MCLG) of zero for *Cryptosporidium*
- 2-log *Cryptosporidium* removal requirements for systems that filter
- Strengthened combined filter effluent turbidity performance standards
- Individual filter turbidity monitoring provisions
- Disinfection profiling and benchmarking provisions
- Systems using groundwater under the direct influence of surface water now subject to the new rules dealing with *Crypdosporidium*
- Inclusion of *Cryptosporidium* in the watershed control requirements for unfiltered public water systems
- Requirements for covers on new finished water reservoirs
- Sanitary surveys, conducted by states, for all surface water systems regardless of size

The IESWTR, with tightened turbidity performance criteria and required individual filter monitoring, is designed to optimize treatment reliability and to enhance physical removal efficiencies to minimize the *Cryptosporidium* levels in finished water. In addition, the rule includes disinfection benchmark provisions to assure continued levels of microbial protection while facilities take the necessary steps to comply with new DBP standards

**Stage 1 Disinfectants and Disinfection Byproducts Rule (DBPR):**

The final Stage 1 DBPR applies to community water systems and nontransient noncommunity systems, including those serving fewer than 10,000 people, that add a disinfectant to the drinking water during any part of the treatment process

The final Stage 1 DBPR includes the following key provisions

- Maximum residual disinfectant level goals (MRDLGs) for chlorine (4 mg/L), chloramines (4 mg/L), and chlorine dioxide (0.8 mg/L)
- Maximum contaminant level goals (MCLGs) for four trihalomethanes (chloroform (zero), bromodichloromethane (zero), dibromochloromethane (0.06 mg/L), and bromoform (zero)), two haloacetic acids (dichloroacetic acid (zero) and trichloroacetic acid (0.3 mg/L)), bromate (zero), and chlorite (0.8 mg/L); EPA subsequently removed the zero MCLG for chloroform from its National Primary Drinking Water Regulations, effective May 30, 2000, in accordance with an order of the U.S. Court of Appeals for the District of Columbia Circuit
- MRDLs for three disinfectants (chlorine (4.0 mg/L), chloramines (4.0 mg/L), and chlorine dioxide (0.8 mg/L))
- MCLs for total trihalomethanes—a sum of the four listed above (0.080 mg/L), haloacetic acids (HAA5) (0.060 mg/L)—a sum of the two listed above plus monochloroacetic acid and mono—and dibromoacetic acids), and two inorganic disinfection byproducts (chlorite (1.0 mg/L)) and bromate (0.010 mg/L)); and
- A treatment technique for removal of DBP precursor material

The terms MRDLG and MRDL, which are not included in the SDWA, were created during the negotiations to distinguish disinfectants (because of their beneficial use) from contaminants. The final rule includes monitoring, reporting, and public notification requirements for these compounds. This final rule also describes the best available technology (BAT) upon which the MRDLs and MCLs are based

*(Continued)*

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**Table 8B.19 (Continued)**

**Filter Backwash Recycling Rule (FBRR)**

The FBRR requires public water systems (PWSs) to review their backwash water recycling practices to ensure that they do not compromise microbial control. Under the FBRR, recycled filter backwash water, sludge thickener supernatant, and liquids from dewatering processes must be returned to a location such that all processes of a system's conventional or direct filtration including coagulation, flocculation, sedimentation (conventional filtration only) and filtration, are employed. Systems may apply to the State for approval to recycle at an alternate location. The Filter Backwash Rule applies to all public water systems, regardless of size

**Long-Term 1 Enhanced Surface Water Treatment Rule (Long-Term 1 ESWTR)**

While the Stage 1 DBPR applies to systems of all sizes, the IESWTR only applies to systems serving 10,000 or more people. The Long Term 1 ESWTR, promulgated in January 2002, will strengthen microbial controls for small systems i.e. those systems serving fewer than 10,000 people. The rule will also prevent significant increase in microbial risk where small systems take steps to implement the Stage 1 DBPR

EPA believes that the rule will generally track the approaches in the IESWTR for improved turbidity control, including individual filter monitoring and reporting. The rule will also address disinfection profiling and benchmarking. The Agency is considering what modifications of some large system requirements may be appropriate for small systems

**Future M–DBP Rules**

**Groundwater Rule**

EPA has proposed a Groundwater Rule that specifies the appropriate use of disinfection while addressing other components of groundwater systems to ensure public health protection. There are more than 158,000 public groundwater systems. Almost 89 million people are served by community groundwater systems, and 20 million people are served by noncommunity groundwater systems. Ninety-nine percent (157,000) of groundwater systems serve fewer than 10,000 people. However, systems serving more than 10,000 people serve 55% (more than 60 million) of all people who get their drinking water from public groundwater systems. The Groundwater Rule will be promulgated summer 2001

**Long-Term 2 Enhanced Surface Water Treatment Rule (Long-Term 2 ESWTR)**

EPA is proposing the Long-Term 2 ESWTR to reduce disease incidence associated with Cryptosporidium and other pathogenic microorganisms in drinking water. The Long-Term 2 ESWTR will supplement existing regulations by targeting additional Cryptosporidium treatment requirements to higher risk systems. This proposed regulation also contains provisions to mitigate risks from uncovered finished water storage facilities and to ensure that systems maintain microbial protection as they take steps to reduce the formation of disinfection byproducts. The Long-Term 2 ESWTR will apply to all systems that use surface water or groundwater under the direct influence of surface water

**Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR)**

The Stage 2 DBPR is one part of the Stage 2 Microbial and Disinfection Byproducts Rules (M–DBP), which are a set of interrelated regulations that address risks from microbial pathogens and disinfectants/disinfection byproducts (D/DBPs). The Stage 2 M–DBP Rules are the final phase in the M–DBP rulemaking strategy, affirmed by Congress as part of the 1996 Amendments to the SDWA. The Stage 2 DBPR focuses on public health protection by limiting exposure to DBPs, specifically total trihalomethanes (TTHM) and five haloacetic acids (HAA5), which can form in water through disinfectants used to control microbial pathogens. This rule will apply to all community water systems (CWSs) and nontransient noncommunity water systems (NTNCWSs) that add a primary or residual disinfectant other than ultraviolet (UV) light or deliver water that has been disinfected by a primary or residual disinfectant other than UV

*Source*: From United States Environmental Protection Agency, www.epa.gov.

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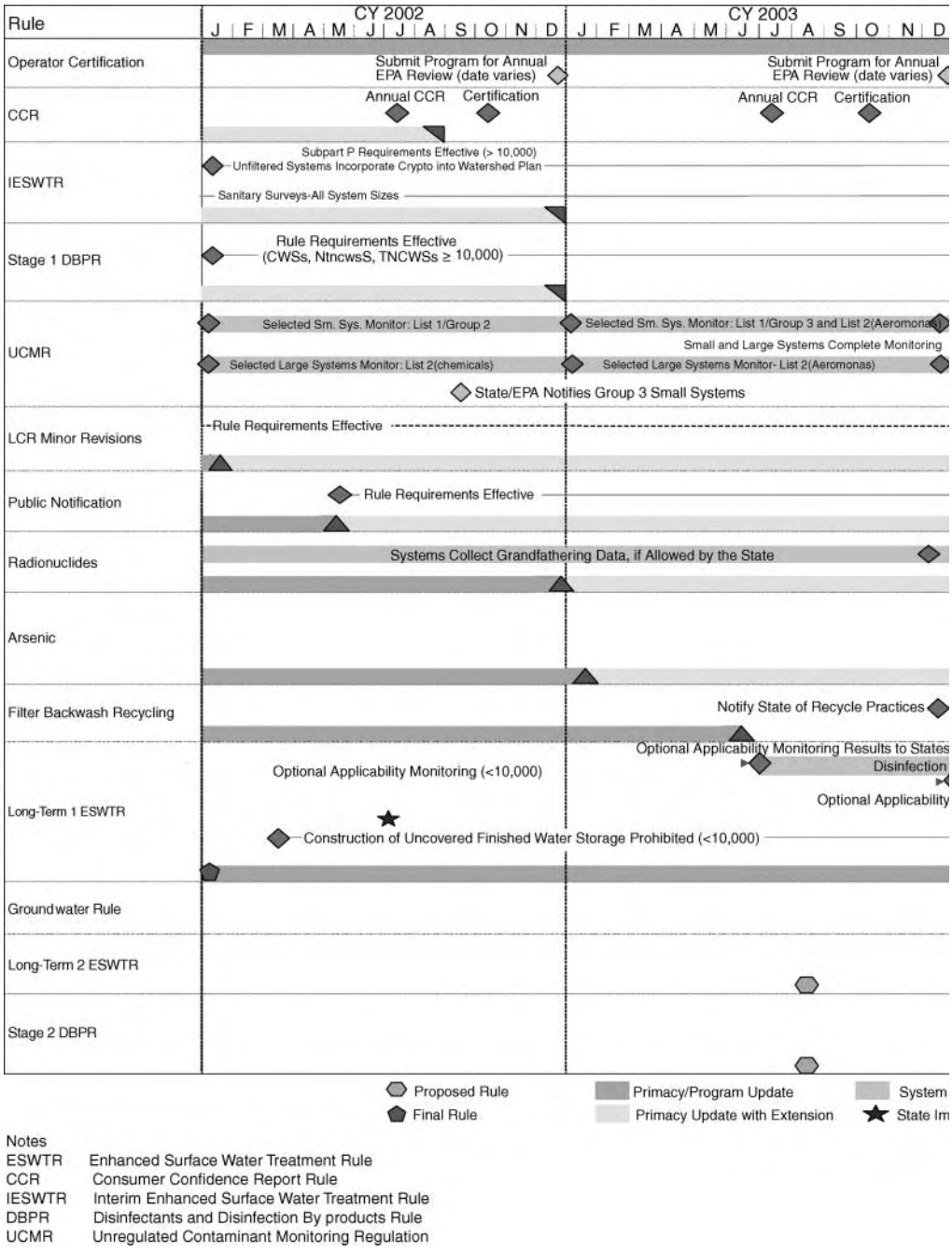


Notes
ESWTR Enhanced Surface Water Treatment Rule
CCR Consumer Confidence Report Rule
IESWTR Interim Enhanced Surface Water Treatment Rule
DBPR Disinfectants and Disinfection By products Rule
UCMR Unregulated Contaminant Monitoring Regulation

**Figure 8B.8** Public water supply rule implementation and milestone timeline. (From United States Environmental Protection Agency, www.epa.gov.)

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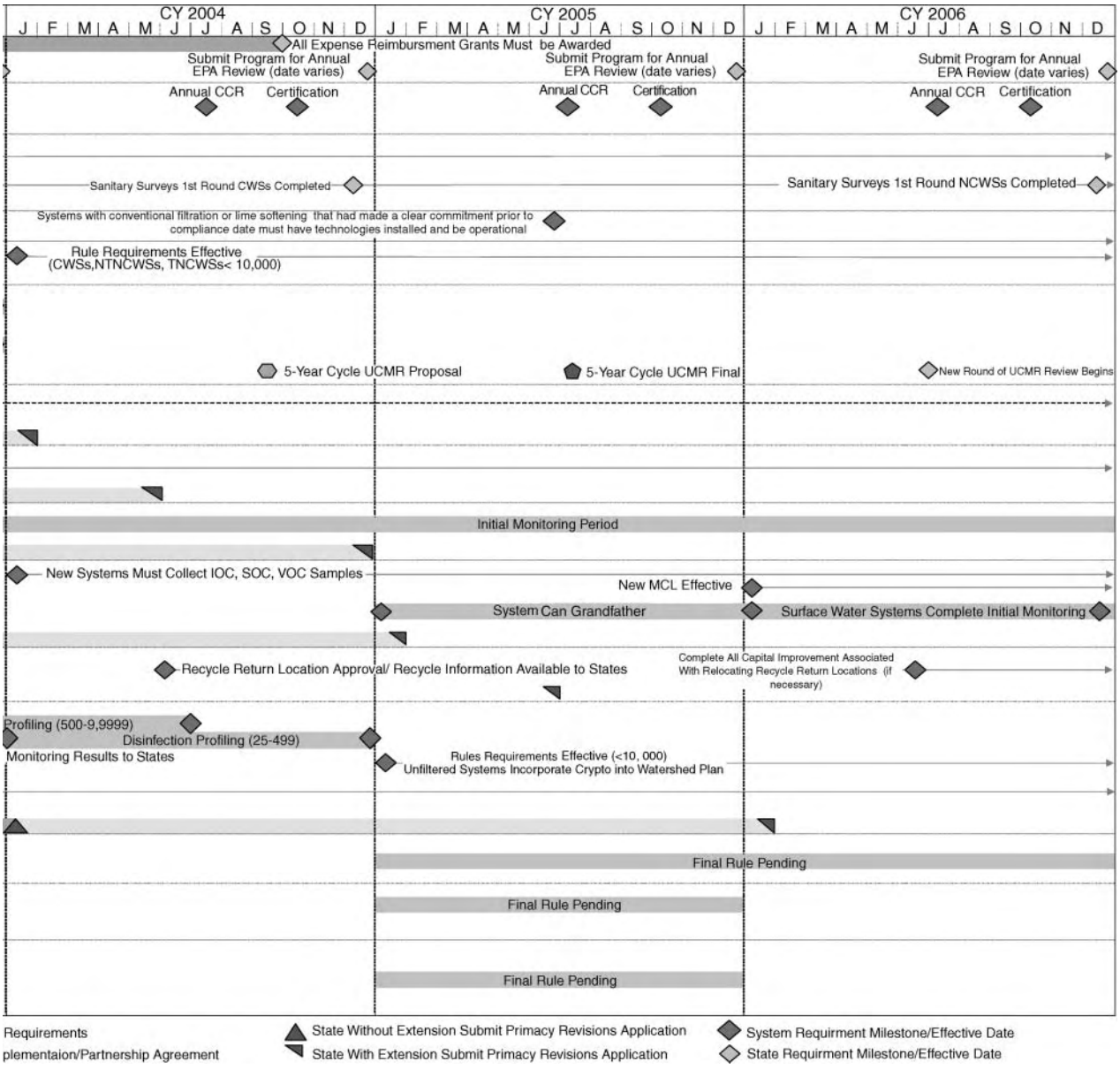


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**Table 8B.20 Unregulated Chemical Contanminents (1999 List) to Be Monitored in Public Supply Systems in the United States**

| | | |
|---|---|---|
| **List 1 Contaminants—Assessment Monitoring** | | |
| 2,4-dinitrotoluene | DCPA mono-acid degradate | MTBE |
| 2,6-dinitrotoluene | DDE | Nitrobenzene |
| Acetochlor | EPTC | Perchlorate |
| DCPA di-acid degradate | Molinate | Terbacil |
| **List 2 Contaminants—Screening Surveys** | | |
| 1,2-diphenylhydrazine | Diazinon | Prometon |
| 2-methyl-phenol | Disulfoton | RDX |
| 2,4-dichlorophenol | Diuron | Terbufos |
| 2,4-dinitrophenol | Fonofos | *Aeromonas* |
| 2,4,6-trichlorophenol | Linuron | |
| Alachlor ESA | Nitrobenzene (low-level)[a] | |
| **List 3 Contaminants—Pre-Screen Testing** | | |
| Lead-210 | Cyanobacteria (blue–green algae), other fresh water algae, and their toxins | Echoviruses |
| Polonium-210 | Caliciviruses | *Helicobacter pylori* |
| Adenoviruses | Coxsackieviruses | Microsporidia |

[a] Nitrobenzene has been added to List 2 from the original UCMR (1999) List to track its occurrence at a concentration lower than the List 1 nitrobenzene minimum reporting level.

*Source*: From USEPA, 2001, *Unregulated Contaminant Monitoring Regulation Reporting Guidance*, (EPA 815-R-01-029, November 2001), www.epa.gov.

**Table 8B.21 Monitoring Requirements for Unregulated Contaminant Program**

| Contaminant Type | Water Source Type | Timeframe | Frequency |
|---|---|---|---|
| Chemical | Surface water | Twelve (12) months | Four (4) quarterly samples taken as follows: Select either the first, second, or third month of a quarter and sample in that same month of each of four (4) consecutive quarters[a] to ensure that one of those sampling events occurs during the vulnerable time[b] |
| | Groundwater | Twelve (12) months | Two (2) times in a year taken as follows: Sample during one (1) month of the vulnerable time[b] and during one (1) month five (5) to seven (7) months earlier or later[c] |
| Microbiological | Surface and groundwater | Twelve (12) months | Six (6) times in a year taken as follows: Select either the first, second, or third month of a quarter and sample in that same month of each of four (4) quarters, and sample an additional two (2) months during the warmest (vulnerable) quarter of the year[d] |

[a] "Select either the first, second, or third month of a quarter and sample in that same month of each of four consecutive quarters" means that the system must monitor during each of the 4 months of either: January, April, July, October; or February, May, August, November; or March, June, September, December.

[b] "Vulnerable time" means May 1 through July 31, unless the State or EPA informs the system that it has selected a different time period for sampling as its vulnerable time.

[c] "Sample during one month of the vulnerable time and during one month five to seven months earlier or later" means, for example, that if the system selects May as its "vulnerable time" month to sample, then one month five to seven months earlier would be either October, November, or December of the preceding year, and one month five to seven months later would be either, October, November, or December of the same year.

[d] This means that the system must monitor during each of the six months of either: January, April, July, August, September, October, or February, May, July, August, September, November, or March, June, July, August, September, December; unless the State or EPA informs the system that a different vulnerable quarter has been selected for it.

*Source*: From USEPA, 2001, *Reference Guide for the Unregulated Contaminant Monitoring Program*, (EPA 815-R-01-023, October 2001), www.epa.gov.

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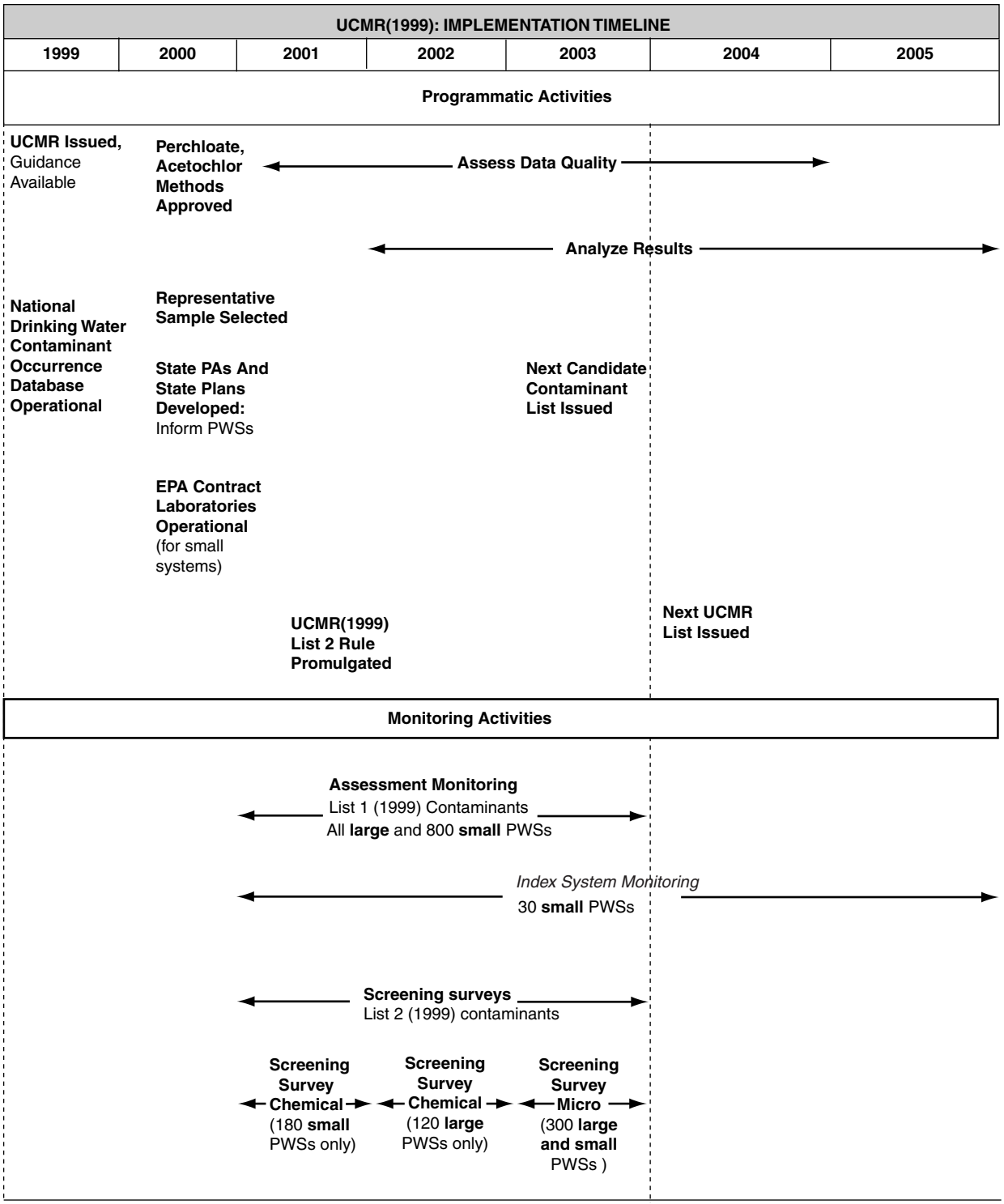


**Figure 8B.9** Unregulated chemical contaminant monitoring regulation (1999) timeline and related activities. (From USEPA, 2001, *Reference Guide for the Unregulated Contaminant Monitoring Program*, (EPA 815-R-01-023, October 2001), www.epa.gov.

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**Table 8B.22 Drinking Water Contaminant Candidate List 2**

| **Microbial Contaminant Candidates** |
|---|
| Adenoviruses |
| Aeromonas hydrophila |
| Caliciviruses |
| Coxsackieviruses |
| Cyanobacteria (blue–green algae), other freshwater algae, and their toxins |
| Echoviruses |
| Helicobacter pylori |
| Microsporidia (Enterocytozoon & Septata) |
| Mycobacterium avium intracellulare (MAC) |
| **Chemical Contaminant Candidates** |
| 1,1,2,2-tetrachloroethane |
| 1,2,4-trimethylbenzene |
| 1,1-dichloroethane |
| 1,1-dichloropropene |
| 1,2-diphenylhydrazine |
| 1,3-dichloropropane |
| 1,3-dichloropropene |
| 2,4,6-trichlorophenol |
| 2,2-dichloropropane |
| 2,4-dichlorophenol |
| 2,4-dinitrophenol |
| 2,4-dinitrotoluene |
| 2,6-dinitrotoluene |
| 2-methyl-Phenol (o-cresol) |
| Acetochlor |
| Alachlor ESA & other acetanilide pesticide degradation products |
| Aluminum |
| Boron |
| Bromobenzene |
| DCPA mono-acid degradate |
| DCPA di-acid degradate |
| DDE |
| Diazinon |
| Disulfoton |
| Diuron |
| EPTC (s-ethyl-dipropylthiocarbamate) |
| Fonofos |
| p-Isopropyltoluene (p-cymene) |
| Linuron |
| Methyl bromide |
| Methyl-t-butyl ether (MTBE) |
| Metolachlor |
| Molinate |
| Nitrobenzene |
| Organotins |
| Perchlorate |
| Prometon |
| RDX |
| Terbacil |
| Terbufos |
| Triazines & degradation products of triazines including, but not limited to Cyanazine and atrazine-desethyl |
| Vanadium |

*Source*: From United States Environmental Protection Agency, Office of Water (4607m), EPA 815-F-05-001, February 2005, www.epa.gov.

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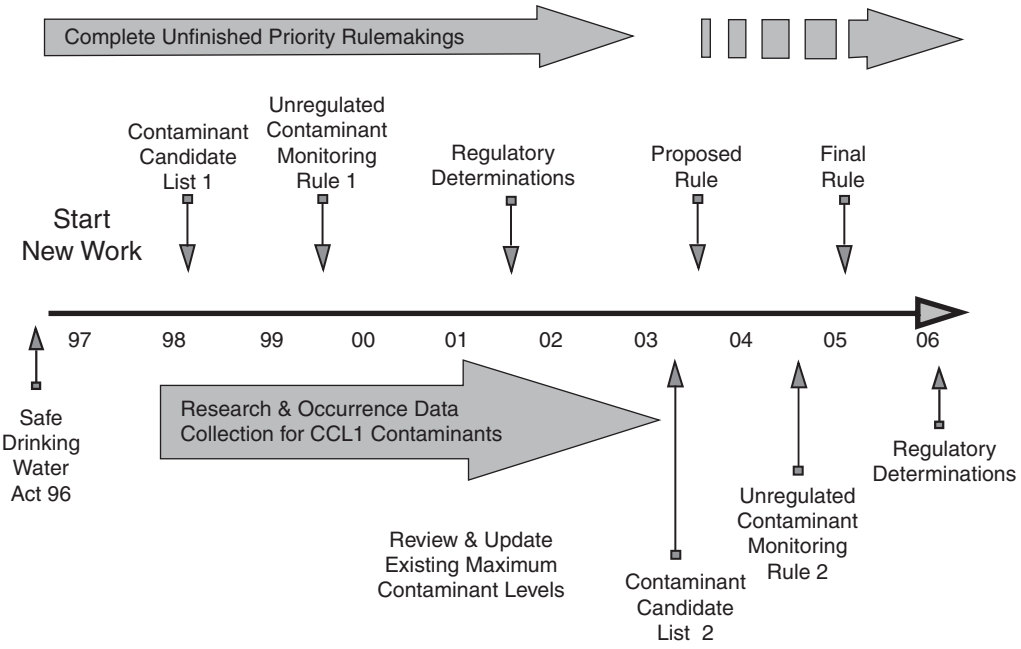


**Figure 8B.10** Contaminant candidate identification and selection cycle. (From United States Environmental Protection Agency), www.epa.gov.)

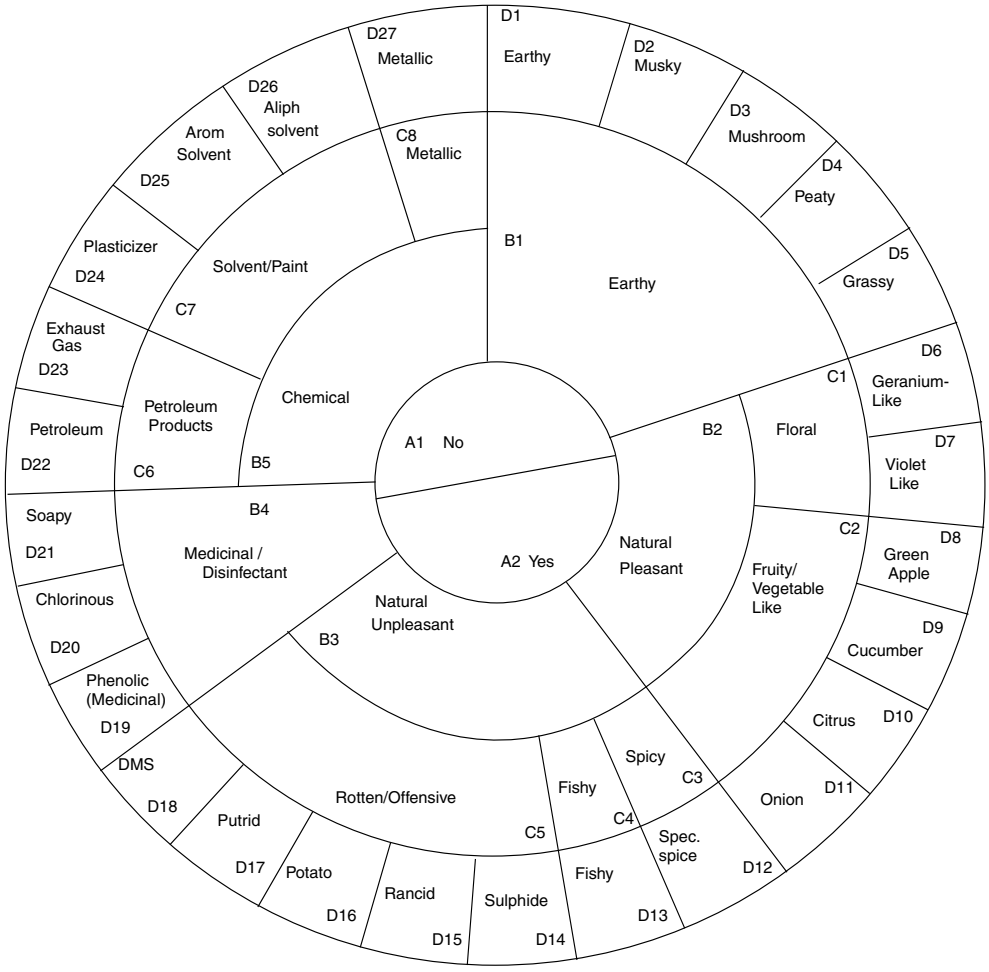


**Figure 8B.11** Flavor wheel for drinking water. (From International Association of Water Pollution Research and Control; *Water Quality Bulletin*, Vol. 13, no. 2–3, April–July 1998.)

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## SECTION 8C DRINKING WATER STANDARDS — WORLD

**Table 8C.23 World Health Organization Drinking Water Guideline Values for Chemicals That Are of Health Significance**

| Chemical | Guideline Value[a] (mg/L) | Remarks |
|---|---|---|
| Acrylamide | 0.0005[b] | |
| Alachlor | 0.02[b] | |
| Aldicarb | 0.01 | Applies to aldicarb sulfoxide and aldicarb sulfone |
| Aldrin and dieldrin | 0.00003 | For combined aldrin plus dieldrin |
| Antimony | 0.02 | |
| Arsenic | 0.01 (P) | |
| Atrazine | 0.002 | |
| Barium | 0.7 | |
| Benzene | 0.01[b] | |
| Benzo[a]pyrene | 0.0007[b] | |
| Boron | 0.5 (T) | |
| Bromate | 0.01[b] (A, T) | |
| Bromodichloromethane | 0.06[b] | |
| Bromoform | 0.1 | |
| Cadmium | 0.003 | |
| Carbofuran | 0.007 | |
| Carbon tetrachloride | 0.004 | |
| Chloral hydrate (trichloroacetaldehyde) | 0.01 (P) | |
| Chlorate | 0.7 (D) | |
| Chlordane | 0.0002 | |
| Chlorine | 5 (C) | For effective disinfection, there should be a residual concentration of free chlorine of $\geq$0.5 mg /L after at least 30 min contact time at pH $<$8.0 |
| Chlorite | 0.7 (D) | |
| Chloroform | 0.2 | |
| Chlorotoluron | 0.03 | |
| Chlorpyrifos | 0.03 | |
| Chromium | 0.05 (P) | For total chromium |
| Copper | 2 | Staining of laundry and sanitary ware may occur below guideline value |
| Cyanazine | 0.0006 | |
| Cyanide | 0.07 | |
| Cyanogen chloride | 0.07 | For cyanide as total cyanogenic compounds |
| 2,4-D (2,4-dichlorophenoxyacetic acid) | 0.03 | Applies to free acid |
| 2,4-DB | 0.09 | |
| DDT and metabolites | 0.001 | |
| Di(2-ethylhexyl)phthalate | 0.008 | |
| Dibromoacetonitrile | 0.07 | |
| Dibromochloromethane | 0.1 | |
| 1,2-Dibromo-3-chloropropane | 0.001[b] | |
| 1,2-Dibromoethane | 0.0004[b] (P) | |
| Dichloroacetate | 0.05 (T, D) | |
| Dichloroacetonitrile | 0.02 (P) | |
| Dichlorobenzene, 1,2− | 1 (C) | |
| Dichlorobenzene, 1,4− | 0.3 (C) | |
| Dichloroethane, 1,2− | 0.03[b] | |
| Dichloroethene, 1,1− | 0.03 | |
| Dichloroethene, 1,2− | 0.05 | |
| Dichloromethane | 0.02 | |
| 1,2-Dichloropropane (1,2-DCP) | 0.04 (P) | |
| 1,3-Dichloropropene | 0.02[b] | |
| Dichlorprop | 0.1 | |
| Dimethoate | 0.006 | |
| Edetic acid (EDTA) | 0.6 | Applies to the free acid |
| Endrin | 0.0006 | |

*(Continued)*

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**Table 8C.23 (Continued)**

| Chemical | Guideline Value[a] (mg/L) | Remarks |
|---|---|---|
| Epichlorohydrin | 0.0004 (P) | |
| Ethylbenzene | 0.3 (C) | |
| Fenoprop | 0.009 | |
| Fluoride | 1.5 | Volume of water consumed and intake from other sources should be considered when setting national standards |
| Formaldehyde | 0.9 | |
| Hexachlorobutadiene | 0.0006 | |
| Isoproturon | 0.009 | |
| Lead | 0.01 | |
| Lindane | 0.002 | |
| Manganese | 0.4 (C) | |
| MCPA | 0.002 | |
| Mecoprop | 0.01 | |
| Mercury | 0.001 | For total mercury (inorganic plus organic) |
| Methoxychlor | 0.02 | |
| Metolachlor | 0.01 | |
| Microcystin-LR | 0.001 (P) | For total microcystin-LR (free plus cell-bound) |
| Molinate | 0.006 | |
| Molybdenum | 0.07 | |
| Monochloramine | 3 | |
| Monochloroacetate | 0.02 | |
| Nickel | 0.02 (P) | |
| Nitrate (as $NO_3^-$) | 50 | Short-term exposure |
| Nitrilotriacetic acid (NTA) | 0.2 | |
| Nitrite (as $NO_2^-$) | 3 | Short-term exposure |
| | 0.2 (P) | Long-term exposure |
| Pendimethalin | 0.02 | |
| Pentachlorophenol | 0.009[b] (P) | |
| Pyriproxyfen | 0.3 | |
| Selenium | 0.01 | |
| Simazine | 0.002 | |
| Styrene | 0.02 (C) | |
| 2,4,5-T | 0.009 | |
| Terbuthylazine | 0.007 | |
| Tetrachloroethene | 0.04 | |
| Toluene | 0.7 (C) | |
| Trichloroacetate | 0.2 | |
| Trichloroethene | 0.07 (P) | |
| Trichlorophenol, 2,4,6− | 0.2[b] (C) | |
| Trifluralin | 0.02 | |
| Trihalomethanes | | The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1 |
| Uranium | 0.015 (P, T) | Only chemical aspects of uranium addressed |
| Vinyl chloride | 0.0003[b] | |
| Xylenes | 0.5 (C) | |

[a] P, provisional guideline value, as there is evidence of a hazard, but the available information on health effects is limited; T, provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection, etc.; A, provisional guideline value because calculated guideline value is below the achievable quantification level; D, provisional guideline value because disinfection is likely to result in the guideline value being exceeded; C, concentrations of the substance at or below the health-based guideline value may affect the appearance, taste or odour of the water, leading to consumer complaints.

[b] For substances that are considered to be carcinogenic, the guideline value is the concentration in drinking water associated with an upper-bound excess lifetime cancer risk of $10^{-5}$ (one additional cancer per 100000 of the population ingesting drinking-water containing the substance at the guideline value for 70 years). Concentrations associated with upper-bound estimated excess lifetime cancer risks of $10^{-4}$ and $10^{-6}$ can be calculated by multiplying and dividing, respectively, the guideline value by 10.

*Source*: From World Health Organization, 2004, *Guidelines for Drinking-Water Quality*, Third Edition, Volume 1, Recommendations. Copyright © World Health Organization 2004, www.who.int.

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**Table 8C.24 World Health Organization Drinking Water Guideline Levels for Radionuclides**

| Radionuclides | Guidance Level (Bq/L)[a] | Radionuclides | Guidance Level (Bq/L)[a] | Radionuclides | Guidance Level (Bq/L)[a] |
|---|---|---|---|---|---|
| $^{3}H$ | 10000 | $^{93}Mo$ | 100 | $^{140}La$ | 100 |
| $^{7}Be$ | 10000 | $^{99}Mo$ | 100 | $^{139}Ce$ | 1000 |
| $^{14}C$ | 100 | $^{96}Tc$ | 100 | $^{141}Ce$ | 100 |
| $^{22}Na$ | 100 | $^{97}Tc$ | 1000 | $^{143}Ce$ | 100 |
| $^{32}P$ | 100 | $^{97m}Tc$ | 100 | $^{144}Ce$ | 10 |
| $^{33}P$ | 1000 | $^{99}Tc$ | 100 | $^{143}Pr$ | 100 |
| $^{35}S$ | 100 | $^{97}Ru$ | 1000 | $^{147}Nd$ | 100 |
| $^{36}Cl$ | 100 | $^{103}Ru$ | 100 | $^{147}Pm$ | 1000 |
| $^{45}Ca$ | 100 | $^{106}Ru$ | 10 | $^{149}Pm$ | 100 |
| $^{47}Ca$ | 100 | $^{105}Rh$ | 1000 | $^{151}Sm$ | 1000 |
| $^{46}Sc$ | 100 | $^{103}Pd$ | 1000 | $^{153}Sm$ | 100 |
| $^{47}Sc$ | 100 | $^{105}Ag$ | 100 | $^{152}Eu$ | 100 |
| $^{48}Sc$ | 100 | $^{110m}Ag$ | 100 | $^{154}Eu$ | 100 |
| $^{48}V$ | 100 | $^{111}Ag$ | 100 | $^{155}Eu$ | 1000 |
| $^{51}Cr$ | 10000 | $^{109}Cd$ | 100 | $^{153}Gd$ | 1000 |
| $^{52}Mn$ | 100 | $^{115}Cd$ | 100 | $^{160}Tb$ | 100 |
| $^{53}Mn$ | 10000 | $^{115m}Cd$ | 100 | $^{169}Er$ | 1000 |
| $^{54}Mn$ | 100 | $^{111}In$ | 1000 | $^{171}Tm$ | 1000 |
| $^{55}Fe$ | 1000 | $^{114m}In$ | 100 | $^{175}Yb$ | 1000 |
| $^{59}Fe$ | 100 | $^{113}Sn$ | 100 | $^{182}Ta$ | 100 |
| $^{56}Co$ | 100 | $^{125}Sn$ | 100 | $^{181}W$ | 1000 |
| $^{57}Co$ | 1000 | $^{122}Sb$ | 100 | $^{185}W$ | 1000 |
| $^{58}Co$ | 100 | $^{124}Sb$ | 100 | $^{186}Re$ | 100 |
| $^{60}Co$ | 100 | $^{125}Sb$ | 100 | $^{185}Os$ | 100 |
| $^{59}Ni$ | 1000 | $^{123m}Te$ | 100 | $^{191}Os$ | 100 |
| $^{63}Ni$ | 1000 | $^{127}Te$ | 1000 | $^{193}Os$ | 100 |
| $^{65}Zn$ | 100 | $^{127m}Te$ | 100 | $^{190}Ir$ | 100 |
| $^{71}Ge$ | 10000 | $^{129}Te$ | 1000 | $^{192}Ir$ | 100 |
| $^{73}As$ | 1000 | $^{129m}Te$ | 100 | $^{191}Pt$ | 1000 |
| $^{74}As$ | 100 | $^{131}Te$ | 1000 | $^{193}M$ | 1000 |
| $^{76}As$ | 100 | $^{131m}Te$ | 100 | $^{198}Au$ | 100 |
| $^{77}As$ | 1000 | $^{132}Te$ | 100 | $^{199}Au$ | 1000 |
| $^{75}Se$ | 100 | $^{125}I$ | 10 | $^{197}Hg$ | 1000 |
| $^{82}Br$ | 100 | $^{126}I$ | 10 | $^{203}Hg$ | 100 |
| $^{86}Rb$ | 100 | $^{129}I$ | 1000 | $^{200}Tl$ | 1000 |
| $^{85}Sr$ | 100 | $^{131}I$ | 10 | $^{201}Tl$ | 1000 |
| $^{89}Sr$ | 100 | $^{129}Cs$ | 1000 | $^{202}Tl$ | 1000 |
| $^{90}Sr$ | 10 | $^{131}Cs$ | 1000 | $^{204}Tl$ | 100 |
| $^{90}Y$ | 100 | $^{132}Cs$ | 100 | $^{203}Pb$ | 1000 |
| $^{91}Y$ | 100 | $^{134}Cs$ | 10 | $^{206}Bi$ | 100 |
| $^{93}Zr$ | 100 | $^{135}Cs$ | 100 | $^{207}Bi$ | 100 |
| $^{95}Zr$ | 100 | $^{136}Cs$ | 100 | $^{210}Bi^{b}$ | 100 |
| $^{93m}Nb$ | 1000 | $^{137}Cs$ | 10 | $^{210}Pb^{b}$ | 0.1 |
| $^{94}Nb$ | 100 | $^{131}Ba$ | 1000 | $^{210}Po^{b}$ | 0.1 |
| $^{95}Nb$ | 100 | $^{140}Ba$ | 100 | $^{223}Ra^{b}$ | 1 |
| $^{224}Ra^{b}$ | 1 | $^{235}U^{b}$ | 1 | $^{242}Cm$ | 10 |
| $^{225}Ra$ | 1 | $^{236}U^{b}$ | 1 | $^{243}Cm$ | 1 |
| $^{226}Ra^{b}$ | 1 | $^{237}U$ | 100 | $^{244}Cm$ | 1 |
| $^{228}Ra^{b}$ | 0.1 | $^{238}U^{b,c}$ | 10 | $^{245}Cm$ | 1 |
| $^{227}Th^{b}$ | 10 | $^{237}Np$ | 1 | $^{246}Cm$ | 1 |
| $^{228}Th^{b}$ | 1 | $^{239}Np$ | 100 | $^{247}Cm$ | 1 |
| $^{229}Th$ | 0.1 | $^{236}Pu$ | 1 | $^{248}Cm$ | 0.1 |
| $^{230}Th^{b}$ | 1 | $^{237}Pu$ | 1000 | $^{249}Bk$ | 100 |
| $^{231}Th^{b}$ | 1000 | $^{238}Pu$ | 1 | $^{246}Cf$ | 100 |
| $^{232}Th^{b}$ | 1 | $^{239}Pu$ | 1 | $^{248}Cf$ | 10 |
| $^{234}Th^{b}$ | 100 | $^{240}Pu$ | 1 | $^{249}Cf$ | 1 |
| $^{230}Pa$ | 100 | $^{241}Pu$ | 10 | $^{250}Cf$ | 1 |
| $^{231}Pa^{b}$ | 0.1 | $^{242}Pu$ | 1 | $^{251}Cf$ | 1 |
| $^{233}Pa$ | 100 | $^{244}Pu$ | 1 | $^{252}Cf$ | 1 |
| $^{230}U$ | 1 | $^{241}Am$ | 1 | $^{253}Cf$ | 100 |

*(Continued)*

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**Table 8C.24 (Continued)**

| Radionuclides | Guidance Level (Bq/L)[a] | Radionuclides | Guidance Level (Bq/L)[a] | Radionuclides | Guidance Level (Bq/L)[a] |
|---|---|---|---|---|---|
| $^{231}U$ | 1000 | $^{242}Am$ | 1000 | $^{254}Cf$ | 1 |
| $^{232}U$ | 1 | $^{242m}Am$ | 1 | $^{253}Es$ | 10 |
| $^{233}U$ | 1 | $^{243}Am$ | 1 | $^{254}Es$ | 10 |
| $^{234}U$[b] | 10 | | | $^{254m}Es$ | 100 |

[a] Guidance levels are rounded according to averaging the log scale values (to $10^n$ if the calculated value was below $3\times10^n$ and above $3\times10^{n-1}$).
[b] Natural radionuclides.
[c] The provisional guideline value for uranium in drinking-water is 15 μg/litre based on its chemical toxicity for the kidney (www.ec.gc.ca).

*Source*: From World Health Organization, 2004, *Guidelines for Drinking-Water Quality*, Third Edition, Volume 1, Recommendations. Copyright © World Health Organization 2004, www.who.int.

**Table 8C.25 Canadian Guidelines for Drinking Water Quality — Chemical and Physical Parameters**

| Parameter | Maximum Acceptable Concentration (mg/L) | Aesthetic Objectives (mg/L) |
|---|---|---|
| Aldicarb | 0.009 | |
| Aldrin + dieldrin | 0.0007 | |
| Aluminum[a] | | |
| Antimony | 0.006[b] | |
| Arsenic | 0.025 | |
| Atrazine + metabolites | 0.005 | |
| Azinphos-methyl | 0.02 | |
| Barium | 1.0 | |
| Bendiocarb | 0.04 | |
| Benzene | 0.005 | |
| Benzo[a]pyrene | 0.00001 | |
| Boron | 5 | |
| Bromate | 0.01 | |
| Bromoxynil | 0.005 | |
| Cadmium | 0.005 | |
| Carbaryl | 0.09 | |
| Carbofuran | 0.09 | |
| Carbon tetrachloride | 0.005 | |
| Chloramines (total) | 3.0 | |
| Chloride | | ≤250 |
| Chlorpyrifos | 0.09 | |
| Chromium | 0.05 | |
| Colour | | ≤15 TCU[d] |
| Copper[b] | | ≤1.0 |
| Cyanazine | 0.01 | |
| Cyanide | 0.2 | |
| Cyanobacterial toxins (as microcystin-LR)[c] | 0.0015 | |
| Diazinon | 0.02 | |
| Dicamba | 0.12 | |
| Dichlorobenzene, 1,2−[e] | 0.20 | ≤0.003 |
| Dichlorobenzene, 1,4−[e] | 0.005 | ≤0.001 |
| Dichloroethane, 1,2− | 0.005 | |
| Dichloroethylene, 1,1− | 0.014 | |
| Dichloromethane | 0.05 | |
| Dichlorophenol, 2,4− | 0.9 | ≤0.0003 |
| Dichlorophenoxyacetic acid, 2,4− (2,4−D) | 0.1 | |
| Diclofop-methyl | 0.009 | |
| Dimethoate | 0.02 | |
| Dinoseb | 0.01 | |
| Diquat | 0.07 | |
| Diuron | 0.15 | |
| Ethylbenzene | | ≤0.0024 |
| Fluoride[f] | 1.5 | |
| Glyphosate | 0.28 | |
| Iron | | ≤0.3 |
| Lead[b] | 0.010 | |
| Malathion | 0.19 | |

*(Continued)*

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**Table 8C.25 (Continued)**

| Parameter | Maximum Acceptable Concentration (mg/L) | Aesthetic Objectives (mg/L) |
|---|---|---|
| Manganese | | ≤0.05 |
| Mercury | 0.001 | |
| Methoxychlor | 0.9 | |
| Metolachlor | 0.05 | |
| Metribuzin | 0.08 | |
| Monochlorobenzene | 0.08 | ≤0.03 |
| Nitrate[g] | 45 | |
| Nitrilotriacetic acid (NTA) | 0.4 | |
| Odour | | Inoffensive |
| Paraquat (as dichloride) | 0.01[h] | |
| Parathion | 0.05 | |
| Pentachlorophenol | 0.06 | ≤0.030 |
| pH | | 6.5–8.5[i] |
| Phorate | 0.002 | |
| Picloram | 0.19 | |
| Selenium | 0.01 | |
| Simazine | 0.01 | |
| Sodium[j] | | ≤200 |
| Sulphate[k] | | ≤500 |
| Sulphide (as $H_2S$) | | ≤0.05 |
| Taste | | Inoffensive |
| Temperature | | ≤15°C |
| Terbufos | 0.001 | |
| Tetrachloroethylene | 0.03 | |
| Tetrachlorophenol, 2,3,4,6− | 0.1 | ≤0.001 |
| Toluene | | ≤0.024 |
| Total dissolved solids (TDS) | | ≤500 |
| Trichloroethylene | 0.05 | |
| Trichlorophenol, 2,4,6− | 0.005 | ≤0.002 |
| Trifluralin | 0.045 | |
| Trihalomethanes (total)[l] | 0.1 | |
| Turbidity | 1 NTU[m] | ≤5 NTU[m,n] |
| Uranium | 0.02 | |
| Vinyl chloride | 0.002 | |
| Xylenes (total) | | ≤0.3 |
| Zinc[b] | | ≤5.0 |

[a] A health-based guideline for aluminum in drinking water has not been established. However, water treatment plants using aluminum-based coagulants should optimize their operations to reduce residual aluminum levels in treated water to the lowest extent possible as a precautionary measure. *Operational guidance values* of less than 100 μg/L total aluminum for conventional treatment plants and less than 200 μg/L total aluminum for other types of treatment systems are recommended. Any attempt to minimize aluminum residuals must not compromise the effectiveness of disinfection processes or interfere with the removal of disinfection by-product precursors.

[b] Because first-drawn water may contain higher concentrations of metals than are found in running water after flushing, faucets should be thoroughly flushed before water is taken for consumption or analysis.

[c] The guideline is considered protective of human health against exposure to other microcystins (total microcystins) that may also be present.

[d] TCU = true colour unit.

[e] In cases where total dichlorobenzenes are measured and concentrations exceed the most stringent value (0.005 mg/L), the concentrations of the individual isomers should be established.

[f] It is recommended, however, that the concentration of fluoride be adjusted to 0.8–1.0 mg/L, which is the optimum range for the control of dental caries.

[g] Equivalent to 10 mg/L as nitrate-nitrogen. Where nitrate and nitrite are determined separately, levels of nitrite should not exceed 3.2 mg/L.

[h] Equivalent to 0.007 mg/L for paraquation.

[i] No units.

[j] It is recommended that sodium be included in routine monitoring programmes, as levels may be of interest to authorities who wish to prescribe sodium-restricted diets for their patients.

[k] There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.

[l] The IMAC for trihalomethanes is expressed as a running annual average. It is based on the risk associated with chloroform, the trihalomethane most often present and in greatest concentration in drinking water. The guideline is designated as interim until such time as the risks from other disinfection by-products are ascertained. The preferred method of controlling disinfection byproducts is precursor removal; however, any method of control employed must not compromise the effectiveness of water disinfection.

[m] NTU = Nephelometric turbidity unit.

[n] At the point of consumption.

*Source*: From Health Canada, 2004, *Summary of Guidelines for Canadian Drinking Water Quality*, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment, April 2004, ec.gc.ga.

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**Table 8C.26 Canadian Guidelines for Drinking Water Quality—Radionuclides**

| Radionuclide | | Half-life $t_{1/2}$ | DCF (Sv/Bq) | MAC (Bq/L) |
|---|---|---|---|---|
| **Primary List of Radionuclides—Maximum Acceptable Concentrations (MACs)** | | | | |
| *Natural Radionuclides* | | | | |
| Lead-210 | $^{210}$Pb | 22.3 yrs | $1.3\times10^{-6}$ | 0.1 |
| Radium-224 | $^{224}$Ra | 3.66 d | $8.0\times10^{-8}$ | 2 |
| Radium-226 | $^{226}$Ra | 1600 yrs | $2.2\times10^{-7}$ | 0.6 |
| Radium-228 | $^{228}$Ra | 5.76 yrs | $2.7\times10^{-7}$ | 0.5 |
| Thorium-228 | $^{228}$Th | 1.91 yrs | $6.7\times10^{-8}$ | 2 |
| Thorium-230 | $^{230}$Th | $7.54\times10^{4}$ yrs | $3.5\times10^{-7}$ | 0.4 |
| Thorium-232 | $^{232}$Th | $1.40\times10^{10}$ yrs | $1.8\times10^{-6}$ | 0.1 |
| Thorium-234 | $^{234}$Th | 24.1 d | $5.7\times10^{-9}$ | 20 |
| Uranium-234 | $^{234}$U | $2.45\times10^{5}$ yrs | $3.9\times10^{-8}$ | 4[a] |
| Uranium-235 | $^{235}$U | $7.04\times10^{8}$ yrs | $3.8\times10^{-8}$ | 4[a] |
| Uranium-238 | $^{238}$U | $4.47\times10^{9}$ yrs | $3.6\times10^{-8}$ | 4[a] |
| *Artificial Radionuclides* | | | | |
| Cesium-134 | $^{134}$Cs | 2.07 yrs | $1.9\times10^{-8}$ | 7 |
| Cesium-137 | $^{137}$Cs | 30.2 yrs | $1.3\times10^{-8}$ | 10 |
| Iodine-125 | $^{125}$I | 59.9 d | $1.5\times10^{-8}$ | 10 |
| Iodine-131 | $^{131}$I | 8.04 d | $2.2\times10^{-8}$ | 6 |
| Molybdenum-99 | $^{99}$Mo | 65.9 hr | $1.9\times10^{-9}$ | 70 |
| Strontium-90 | $^{90}$Sr | 29 yrs | $2.8\times10^{-8}$ | 5 |
| Tritium[b] | $^{3}$H | 12.3 yrs | $1.8\times10^{-11}$ | 7000 |
| **Secondary List of Radionuclides—Maximum Acceptable Concentrations (MACs)** | | | | |
| *Natural Radionuclides*[c] | | | | |
| Beryllium-7 | $^{7}$Be | 53.3 d | $3.3\times10^{-11}$ | 4000 |
| Bismurh-210 | $^{210}$Bi | 5.01 d | $2.1\times10^{-9}$ | 70 |
| Polonium-210 | $^{210}$Po | 138.4 d | $6.2\times10^{-7}$ | 0.2 |
| *Artificial Radionuclides* | | | | |
| Americium-241 | $^{241}$Am | 432 yrs | $5.7\times10^{-7}$ | 0.2 |
| Antimony-122 | $^{122}$Sb | 2.71 d | $2.8\times10^{-9}$ | 50 |
| Antimony-124 | $^{124}$Sb | 60.2 d | $3.6\times10^{-9}$ | 40 |
| Antimony-125 | $^{125}$Sb | 2.76 yrs | $9.8\times10^{-10}$ | 100 |
| Barium-140 | $^{140}$Ba | 12.8 d | $3.7\times10^{-9}$ | 40 |
| Bromine-82 | $^{82}$Br | 35.3 hr | $4.8\times10^{-10}$ | 300 |
| Calcium-45 | $^{45}$Ca | 165 d | $8.9\times10^{-10}$ | 200 |
| Calcium-47 | $^{47}$Ca | 4.54 d | $2.2\times10^{-9}$ | 60 |
| Carbon-14[b] | $^{14}$C | 5730 yrs | $5.6\times10^{-10}$ | 200[b] |
| Cerium-141 | $^{141}$Ce | 32.5 d | $1.2\times10^{-9}$ | 100 |
| Cerium-144 | $^{144}$Ce | 284.4 d | $8.8\times10^{-9}$ | 20 |
| Cesium-131 | $^{131}$Cs | 9.69 d | $6.6\times10^{-11}$ | 2000 |
| Cesium-136 | $^{136}$Cs | 13.1 d | $3.0\times10^{-9}$ | 50 |
| Chromium-51 | $^{51}$Cr | 27.7 d | $5.3\times10^{-11}$ | 3000 |
| Cobalt-57 | $^{57}$Co | 271.8 d | $3.5\times10^{-9}$ | 40 |
| Cobalt-58 | $^{58}$Co | 70.9 d | $6.8\times10^{-9}$ | 20 |
| Cobalt-60 | $^{60}$Co | 5.27 yrs | $9.2\times10^{-8}$ | 2 |
| Gallium-67 | $^{67}$Ga | 78.3 hr | $2.6\times10^{-10}$ | 500 |
| Gold-198 | $^{198}$Au | 2.69 d | $1.6\times10^{-9}$ | 90 |
| Indium-111 | $^{111}$In | 2.81 d | $3.9\times10^{-10}$ | 400 |
| Iodine-129 | $^{129}$I | $1.60\times10^{7}$ yrs | $1.1\times10^{-7}$ | 1 |
| Iron-55 | $^{55}$Fe | 2.68 yrs | $4.0\times10^{-10}$ | 300 |
| Iron-59 | $^{59}$Fe | 44.5 d | $3.1\times10^{-9}$ | 40 |
| Manganese-54 | $^{54}$Mn | 312.2 d | $7.3\times10^{-10}$ | 200 |
| Mercury-197 | $^{197}$Hg | 64.1 hr | $3.3\times10^{-10}$ | 400 |
| Mercury-203 | $^{203}$Hg | 46.6 d | $1.8\times10^{-9}$ | 80 |
| Neptunium-239 | $^{239}$Np | 2.35 d | $1.2\times10^{-9}$ | 100 |
| Niobium-95 | $^{95}$Nb | 35.0 d | $7.7\times10^{-10}$ | 200 |
| Phosphorus-32 | $^{32}$P | 14.3 d | $2.6\times10^{-9}$ | 50 |
| Plutonium-238 | $^{238}$Pu | 87.7 yrs | $5.1\times10^{-7}$ | 0.3 |
| Plutonium-239 | $^{239}$Pu | $2.41\times10^{4}$ yrs | $5.6\times10^{-7}$ | 0.2 |
| Plutonium-240 | $^{240}$Pu | 6560 yrs | $5.6\times10^{-7}$ | 0.2 |
| Plutonium-241 | $^{241}$Pu | 14.4 yrs | $1.1\times10^{-8}$ | 10 |

*(Continued)*

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**Table 8C.26 (Continued)**

| Radionuclide | | Half-life $t_{1/2}$ | DCF (Sv/Bq) | MAC (Bq/L) |
|---|---|---|---|---|
| Rhodium-105 | $^{105}Rh$ | 35.4 hr | $5.4\times10^{-10}$ | 300 |
| Rubidium-81 | $^{81}Rb$ | 4.58 hr | $5.3\times10^{-11}$ | 3000 |
| Rubidium-86 | $^{86}Rb$ | 18.6 d | $2.5\times10^{-9}$ | 50 |
| Ruthenium-103 | $^{103}Ru$ | 39.2 d | $1.1\times10^{-9}$ | 100 |
| Ruthenium-106 | $^{106}Ru$ | 372.6 d | $1.1\times10^{-8}$ | 10 |
| Selenium-75 | $^{75}Se$ | 119.8 d | $2.1\times10^{-9}$ | 70 |
| Silver-108m | $^{108m}Ag$ | 127 yrs | $2.1\times10^{-9}$ | 70 |
| Silver-110m | $^{110m}Ag$ | 249.8 d | $3.0\times10^{-9}$ | 50 |
| Silver-111 | $^{111}Ag$ | 7.47 d | $2.0\times10^{-9}$ | 70 |
| Sodium-22 | $^{22}Na$ | 2.61 yrs | $3.0\times10^{-9}$ | 50 |
| Strontium-85 | $^{85}Sr$ | 64.8 d | $5.3\times10^{-10}$ | 300 |
| Strontium-89 | $^{89}Sr$ | 50.5 d | $3.8\times10^{-9}$ | 40 |
| Sulphur-35 | $^{35}S$ | 87.2 d | $3.0\times10^{-10}$ | 500 |
| Technetium-99 | $^{99}Tc$ | $2.13\times10^{5}$ yrs | $6.7\times10^{-10}$ | 200 |
| Technetium-99m | $^{99m}Tc$ | 6.01 hr | $2.1\times10^{-11}$ | 7000 |
| Tellurium-129m | $^{129m}Te$ | 33.4 d | $3.9\times10^{-9}$ | 40 |
| Tellurium-131m | $^{131m}Te$ | 32.4 hr | $3.4\times10^{-9}$ | 40 |
| Tellurium-132 | $^{132}Te$ | 78.2 hr | $3.5\times10^{-9}$ | 40 |
| Thallium-201 | $^{201}Tl$ | 3.04 d | $7.4\times10^{-11}$ | 2000 |
| Ytterbium-169 | $^{169}Yb$ | 32.0 d | $1.1\times10^{-9}$ | 100 |
| Yttrium-90 | $^{90}Y$ | 64 hr | $4.2\times10^{-9}$ | 30 |
| Yttrium-91 | $^{91}Y$ | 58.5 d | $4.0\times10^{-9}$ | 30 |
| Zinc-65 | $^{65}Zn$ | 243.8 d | $3.8\times10^{-9}$ | 40 |
| Zirconium-95 | $^{95}Zr$ | 64.0 d | $1.3\times10^{-9}$ | 100 |

[a] The activity concentrations of natural corresponding to the guideline of 0.02 mg/L is about 0.5 Bq/L.
[b] Tritium is also produced naturally in the atmosphere in significant quanties.
[c] The activity concentration of natural uranium corresponding to the chemical guideline of 0.1 mg/L (see separate criteria summary on uranium in the Supporting Documentation) is about 2.6 Bq/L.
[d] Tritium and $^{14}C$ are also produced naturally in the atmosphere in significant quantities.

*Source*: From Health Canada, 2004, *Summary of Guidelines for Canadian Drinking Water Quality*, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment, April 2004, ec.gc.ga.

**Table 8C.27 Australian Drinking Water Guideline Values for Physical and Chemical Characteristics**

| | Guideline Values[a] | |
|---|---|---|
| Characteristic | Health | Aesthetic[b] |
| Acrylamide | 0.0002 | |
| Aluminum (acid-soluble) | [c] | 0.2 |
| Ammonia (as $NH_3$) | [c] | 0.5 |
| Antimony | 0.003 | |
| Arsenic | 0.007 | |
| Asbestos | [c] | |
| Barium | 0.7 | |
| Benzene | 0.001 | |
| Beryllium | [c] | |
| Boron | 4 | |
| Bromate | 0.02 | |
| Cadmium | 0.002 | |
| Carbon tetrachloride | 0.003 | |
| Chloramine—see monochloramine | | |
| Chlorate | [c] | |
| Chloride | [e] | 250 |
| Chlorinated furanones (MX) | [c] | |
| Chlorine | 5 | 0.6 |
| Chlorine dioxide | 1 | 0.4 |
| Chlorite | 0.3 | |
| Chloroacetic acids | | |
| Chloroacetic acid | 0.15 | |
| Dichloroacetic acid | 0.1 | |

*(Continued)*

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**Table 8C.27 (Continued)**

| Characteristic | Guideline Values[a] Health | Aesthetic[b] |
|---|---|---|
| Trichloroacetic acid | 0.1 | |
| Chlorobenzene | 0.3 | 0.01 |
| Chloroketones | | |
| 1,1-Dichloropropanone | [c] | |
| 1,3-Dichloropropanone | [c] | |
| 1,1,1-Trichloropropanone | [c] | |
| 1,1,3-Trichloropropanone | [c] | |
| Chlorophenols | | |
| 2-Chlorophenol | 0.3 | 0.0001 |
| 2,4-Dichlorophenol | 0.2 | 0.0003 |
| 2,4,6-Trichlorophenol | 0.02 | 0.002 |
| Chloropicrin | [c] | |
| Chromium (as Cr(VI)) | 0.05 | |
| Copper | 2 | 1 |
| Cyanide | 0.08 | |
| Cyanogen chloride (as cyanide) | 0.08 | |
| Dichlorobenzenes | | |
| 1,2-Dichlorobenzene | 1.5 | 0.001 |
| 1,3-Dichlorobenzene | [c] | 0.02 |
| 1,4-Dichlorobenzene | 0.04 | 0.003 |
| Dichloroethanes | | |
| 1,1-Dichloroethane | [c] | |
| 1,2-Dichloroethane | 0.003 | |
| Dichloroethenes | | |
| 1,1-Dichloroethene | 0.03 | |
| 1,2-Dichloroethene | 0.06 | |
| Dichloromethane (methylene chloride) | 0.004 | |
| Dissolved oxygen | Not necessary | > 85% |
| Epichlorohydrin | 0.0005[d] | |
| Ethylbenzene | 0.3 | 0.003 |
| Ethylenediamine tetraacetic acid (EDTA) | 0.25 | |
| Fluoride | 1.5 | |
| Formaldehyde | 0.5 | |
| Haloacetonitriles | | |
| Dichloroacetonitrile | [c] | |
| Trichloroacetonitrile | [c] | |
| Dibromoacetonitrile | [c] | |
| Bromochloroacetonitrile | [c] | |
| Hardness (as $CaCO_3$) | Not necessary | 200 |
| Hexachlorobutadiene | 0.0007 | |
| Hydrogen sulfide | [c] | 0.05 |
| Iodine | [c] | |
| Iodide | 0.1 | |
| Iron | [c] | 0.3 |
| Lead | 0.01 | |
| Manganese | 0.5 | 0.1 |
| Mercury | 0.001 | |
| Molybdenum | 0.05 | |
| Monochloramine | 3 | 0.5 |
| Nickel | 0.02 | |
| Nitrate (as nitrate) | 50 | |
| Nitrite (as nitrite) | 3 | |
| Nitrilotriacetic acid | 0.2 | |
| Organotins | | |
| Dialkyltins | [c] | |
| Tributyltin oxide | 0.001 | |
| Ozone | | |
| pH | [c] | pH 6.5–8.5 |
| Plasticisers | | |
| Di(2-ethylhexyl) phthalate | 0.01 | |
| Di(2-ethylhexyl) adipate | [c] | |
| Polycyclic aromatic hydrocarbons (PAHs) | | |
| Benzo-(a)-pyrene | 0.00001 (10 ng/L) | |
| Selenium | 0.01 | |
| Silver | 0.1 | |

*(Continued)*

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**Table 8C.27 (Continued)**

| Characteristic | Guideline Values[a] Health | Aesthetic[b] |
|---|---|---|
| Sodium | [e] | 180 |
| Styene (vinylbenzene) | 0.03 | 0.004 |
| Sulfate | 500 | 250 |
| Taste and odor | Not necessary | Acceptable to most people |
| Temperature | Not necessary | No value set |
| Tetrachloroethene | 0.05 | |
| Tin | [e] | |
| Toluene | 0.8 | 0.025 |
| Total dissolved solids | Not necessary | 500 |
| Trichloroacetaldehyde (chloral hydrate) | 0.02 | |
| Trichlorobenzenes (total) | 0.03 | 0.005 |
| 1,1,1-Trichloroethane | [c] | |
| Trichloroethylene | [c] | |
| Trihalomethanes (THMs) (Total) | 0.25 | |
| True Color | Not necessary | 15 HU |
| Turbidity | [c] | 5 NTU |
| Uranium | 0.02 | |
| Vinyl chloride | 0.0003 | |
| Xylene | 0.6 | 0.02 |
| Zinc | [c] | 3 |

*Note:* All values are as "total" unless otherwise stated; Routine monitoring for these compounds is not required unless there is potential for contamination of water supplies (e.g. accidental spillage); The concentration of all chlorination byproducts can be minimized by removing naturally occurring organic matter from the source water, reducing the amount of chlorine added, or using an alternative disinfectant (which may produce other byproducts). Action to reduce trihalomethanes and other byproducts is encouraged, but must not compromise disinfection.
HU, Hazen units; NTU, Nephelometric turbidity units; THMs, trihalomethanes.

[a] All values mg/L unless otherwise stated.
[b] Aesthetic values are not listed if the compound does not cause aesthetic problems, or if the value determined from health considerations is the same or lower.
[c] Insufficient data to set a guideline value based on health considerations.
[d] The guideline value is below the limit of determination. Improved analytical procedures are required for this compound.
[e] No health-based guideline value is considered necessary.

*Source*: From Australian Government, National Health and Medical Research Council and Natural Resource Management Ministerial Council, National Water Quality Management Strategy, *Australian Drinking Water Guidelines, 2004*, www.waterquality.crc.org.au. With permission.

**Table 8C.28 Australian Drinking Water Guideline Values for Pesticides**

| Pesticide | Guideline Value[a] (mg/L) | Health Value[b] (mg/L) |
|---|---|---|
| Acephate | | 0.01 |
| Aldicarb | 0.001 | 0.001 |
| Aldrin[c] (and dieldrin) | 0.00001 | 0.0003 |
| Ametryn | 0.005 | 0.05 |
| Amitrole[c] | 0.001 | 0.01 |
| Asulam | | 0.05 |
| Atrazine[c] | 0.0001 | 0.04 |
| Azinphos-methyl | 0.002 | 0.003 |
| Benomyl | | 0.1 |
| Bentazone | | 0.03 |
| Bioresmethrin | | 0.1 |
| Bromacil | 0.01 | 0.3 |
| Bromophos-ethyl | | 0.01 |
| Bromoxynil | | 0.03 |
| Carbaryl | 0.005 | 0.03 |
| Carbendazim | | 0.1 |
| Carbofuran | 0.005 | 0.01 |
| Carbophenothion | | 0.0005 |
| Carboxin | 0.002 | 0.3 |
| Chlordane[c] | 0.00001 | 0.001 |
| Chlorfenvinphos | | 0.005 |

*(Continued)*

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**Table 8C.28 (Continued)**

| Pesticide | Guideline Value[a] (mg/L) | Health Value[b] (mg/L) |
|---|---|---|
| Chlorothalonil | 0.0001 | 0.03 |
| Chloroxuron | | 0.01 |
| Chlorpyrifos[c] | | 0.01 |
| Chlorsulfuron | | 0.1 |
| Clopyralid[c] | 1 | 1 |
| 2,4-D[c] | 0.0001 | 0.03 |
| DDT[c] | 0.00006 | 0.02 |
| Diazinon | 0.001 | 0.003 |
| Dicamba | | 0.1 |
| Dichlobenil | | 0.01 |
| Dichlorvos | 0.001 | 0.001 |
| Diclofop-methyl | | 0.005 |
| Dicofol | | 0.003 |
| Dieldrin[c](see aldrin) | 0.00001 | 0.0003 |
| Difenzoquat | | 0.1 |
| Dimethoate | | 0.05 |
| Diphenamid | 0.002 | 0.3 |
| Diquat[c] | 0.0005 | 0.005 |
| Disulfoton | 0.001 | 0.003 |
| Diuron[c] | | 0.03 |
| DPA (2,2-DPA) | | 0.5 |
| EDB | 0.001 | 0.001 |
| Endosulfan[c] | 0.00005 | 0.03 |
| Endothal | 0.01 | 0.1 |
| EPTC | 0.001 | 0.03 |
| Ethion | | 0.003 |
| Ethoprophos | 0.001 | 0.001 |
| Etridiazole | 0.0001 | 0.1 |
| Fenamiphos | | 0.0003 |
| Fenarimol | 0.001 | 0.03 |
| Fenchlorphos | | 0.03 |
| Fenitrothion | | 0.01 |
| Fenoprop | | 0.01 |
| Fensulfothion | 0.01 | 0.01 |
| Fenvalerate | | 0.05 |
| Flamprop-methyl | | 0.003 |
| Fluometuron | | 0.05 |
| Formothion | | 0.05 |
| Fosamine[c] | | 0.03 |
| Glyphosate | 0.01 | 1 |
| Heptachlor[c](including its epoxide) | 0.00005 | 0.0003 |
| Hexaflurate | | 0.03 |
| Hexazinone[c] | 0.002 | 0.3 |
| Lindane[c] | 0.00005 | 0.02 |
| Maldison | | 0.05 |
| Methidathion | | 0.03 |
| Methiocarb | 0.005 | 0.005 |
| Methomyl | 0.005 | 0.03 |
| Methoxychlor | 0.0002 | 0.3 |
| Metolachlor | 0.002 | 0.3 |
| Metribuzin | 0.001 | 0.05 |
| Metsulfuron-methyl | | 0.03 |
| Mevinphos | 0.005 | 0.005 |
| Molinate[c] | 0.0005 | 0.005 |
| Monocrotophos | | 0.001 |
| Napropamide | 0.001 | 1 |
| Nitralin | | 0.5 |
| Norflurazon | 0.002 | 0.05 |
| Oryzalin | | 0.3 |
| Oxamyl | 0.005 | 0.1 |
| Paraquat[c] | 0.001 | 0.03 |
| Parathion | | 0.01 |
| Parathion methyl | 0.0003 | 0.1 |
| Pebulate | 0.0005 | 0.03 |
| Pendimethalin | | 0.3 |
| Pentachlorophenol | 0.00001 | 0.01 |
| Permethrin | 0.001 | 0.1 |
| Picloram[c] | | 0.3 |

*(Continued)*

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**Table 8C.28 (Continued)**

| Pesticide | Guideline Value[a] (mg/L) | Health Value[b] (mg/L) |
|---|---|---|
| Piperonyl butoxide | | 0.1 |
| Pirimicarb | | 0.005 |
| Pirimiphos-ethyl | | 0.0005 |
| Pirimiphos-methyl | | 0.05 |
| Profenofos | | 0.0003 |
| Promecarb | | 0.03 |
| Propachlor | 0.001 | 0.05 |
| Propanil | 0.0001 | 0.5 |
| Propargite | | 0.05 |
| Propazine | 0.0005 | 0.05 |
| Propiconazole[c] | 0.0001 | 0.1 |
| Propyzamide | 0.002 | 0.3 |
| Pyrazophos | | 0.03 |
| Quintozene | | 0.03 |
| Simazine | 0.0005 | 0.02 |
| Sulprofos | | 0.01 |
| Silvex (see Fenoprop) | | |
| 2,4,5-T | 0.00005 | 0.1 |
| Temephos[c] | 0.3 | 0.3 |
| Terbacil | 0.01 | 0.03 |
| Terbufos | 0.0005 | 0.0005 |
| Terbutryn | 0.001 | 0.3 |
| Tetrachlovinphos | 0.002 | 0.1 |
| Thiobencarb | | 0.03 |
| Thiometon | | 0.003 |
| Thiophanate | | 0.005 |
| Thiram | | 0.003 |
| Triadimefon | 0.1 | 0.002 |
| Trichlorfon | | 0.005 |
| Triclopyr[c] | | 0.01 |
| Trifluralin | 0.0001 | 0.05 |
| Vernolate | 0.0005 | 0.03 |

*Note:* Routine monitoring for pesticides is not required unless potential exists for contamination of water supplies.

[a] These are generally based on the analytical limit of determination (the level at which the pesticide can be reliably detected using practicable, readily available and validated analytical methods). If a pesticide is detected at or above this value the source should be identified and action taken to prevent further contamination.

[b] Based on 10% of acceptable daily intake (ADI).

[c] These pesticides have either been detected on occasions in Australian drinking water or their likely use would indicate that they may occasionally be detected.

*Source*: From Australian Government, National Health and Medical Research Council and Natural Resource Management Ministerial Council, National Water Quality Management Strategy, Australian Drinking Water Guidelines, 2004, www.waterquality.crc.org.au. With permission.

**Table 8C.29 Australian Drinking Water Guideline Values for Radiological Quality**

| Guideline value |
|---|
| The total estimated dose per year from all radionuclides in drinking water, excluding the dose from potassium-40, should not exceed 1.0 mSv |
| If this guideline value of exceeded, the water provider, in conjunction with the relevant health authority, should evaluate possible remedial actions on a cost-benefit basis of assess what action can be justified to reduce the annual exposure |
| **Screening of water supplies** |
| Compliance with the guideline for radiological quality of drinking water should be assessed, initially, by screening for gross alpha and gross beta activity concentration. The recommended screening level for gross alpha activity is 0.5 Bq/L. The recommended screening level for gross beta activity is 0.5 Bq/L after subtraction of the contribution form potassium-40 |
| If either of these activity concentrations is exceeded, specific radionuclides should be identified and their activity concentrations determined. The concentration of both radium-226 and radium-228 should always be determined, as these are the most significant naturally occurring radionuclides in Australian water supplies. Other radionuclides should be identified in necessary of ensure all gross alpha and beta activity is accounted for, after taking into account the counting and other analytical uncertainties involved in the determination |

*Source*: From Australian Government, National Health and Medical Research Council and Natural Resource Management Ministerial Council, National Water Quality Management Strategy, Australian Drinking Water Guidelines, 2004, www.waterquality.crc.org.au. With permission.

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**Table 8C.30 Comparison of Inorganic Drinking Water Guidelines Recommended by WHO and Standards for Several Developed and Developing Countries**

| Inorganics (mg/L) | WHO (2004) | U.S.A. (2005) | EEC (1998) | Canada (2004) | Australia (2000) | Thailand (1978) | Vietnam (2002) | Korea (2000) | Indonesia (1995) | Japan (2004) | China (1985) | South Africa (1996) | Chile (1984) | Brazil (2004) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Antimony | 0.02 | 0.006 | 0.005 | 0.006 | 0.003 | | 0.005 | | | 0.002 | | | | 0.005 |
| Arsenic | 0.01(P) | 7; 0.01 as of 01/23/06 | 0.01 | 0.025 | 0.007 | 0.05 | 0.01 | 0.05 | 0.05 | 0.01 | 0.05 | 0.01 | 0.05 | 0.01 |
| Barium | 0.7 | 2 | | 1 | 0.7 | 1 | 0.7 | | 1 | | | | | 0.7 |
| Boron | 0.5 (T) | | 1 | 5 | 4 | | 0.3 | 0.3 | | 1 | | | | |
| Cadmium | 0.003 | 0.005 | 0.005 | 0.005 | 0.002 | 0.01 | 0.003 | 0.01 | 0.005 | 0.01 | 0.01 | 5 | 0.01 | 0.005 |
| Chromium | 0.05 (P) | 0.1 | 0.05 | 0.05 | 0.05 (VI) | 0.05 (VI) | 0.05 | 0.05 (VI) | 0.05 (VI) | 0.05 (VI) | 0.05 (VI) | 0.05 (VI) | 0.05 (VI) | 0.05 |
| Copper | 2 | TT, Action Level = 1.3 | 2.0 | | 2 | | 2 | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2 |
| Cyanide | 0.07 | 0.2 | 0.05 | 0.2 | 0.08 | 0.2 | 0.07 | 0.01 | 0.1 | 0.01 | 0.05 | | 0.2 | 0.07 |
| Fluoride | 1.5 | 4 | 1.5 | 1.5 | 1.5 | 0.7 | 0.7–1.5 | 1.5 | 0.5 | 0.8 | 1.0 | 1.0 | 1.5 | 1.5 |
| Lead | 0.01 | TT, Action Level = 0.015 | 0.025, 0.01[a] | 0.01 | 0.01 | 0.05 | 0.01 | 0.05 | 0.05 | 0.01 | 0.05 | 0.01 | 0.05 | 0.01 |
| Manganese | 0.4 (C) | | | | 0.5 | | | | | 0.05 | | | 0.1 | |
| Mercury (total) | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.0005 | 0.001 | 0.001 | 0.001 | 0.001 |
| Molybdenum | 0.07 | | | | 0.05 | | 0.07 | | | | | | | |
| Nickel | 0.02 (P) | | 0.02 | | 0.02 | | 0.02 | | | 0.01 | | | | |
| Nitrate | 50 (acute) as $NO_3$ | 10 as N | 50 as $NO_3$ | 10 as N | 50 as $NO_3$ | 45 as $NO_3$ | 50 as $NO_3$ | 10 as N | 10 as N | 10 as N | 20 as N | 6 as N | 10 as N | 10 as N |
| Nitrite | 3 (acute), 0.2 (P) (chronic) as $NO_2$ | 1 as N | 0.5 as $NO_2$ (tap) | 3.2 as N | 3 as $NO_2$ | | 3 as $NO_2$ | | 1 as N | 10 as N | | 6 as N | 1 as N | 1 as N |
| Selenium | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 |
| Uranium | 0.015 (P,T) | | | 0.02 | 0.02 | | | | | 0.002 | | | | |

*Note:* P, provisional guideline value, as there is evidence of a hazard, but the available information on health effects is limited; T, provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection, etc; A, provisional guideline value because calculated guideline value is below the achievable quantification level; D, provisional guideline value because disinfection is likely to result in the guideline value being exceeded; C, concentrations of the substance at or below the health-based guideline value may affect the appearance, taste or odour of the water, leading to consumer complaints; TT, Treatment Technique—A required process intended to reduce the level of a contaminant in drinking water.

[a] 0.025 (12/25/03–12/25/13), 0.01 (2/25/13+).

*Source*: Modified from Vigneswaran, Saravanamuthu, 1995, *Water Treatment Processes: Simple Options*, CRC Press, Inc., Boca Raton. **WHO**, World Health Organization, 2004, *Guidelines for Drinking-Water Quality, Third Edition*, Volume 1, Recommendations. www.who.int/water_sanitation_health/dwq/gdwq3/en/index.html. **U.S.A.**, United States Environmental Protection Agency, www.epa.gov/OGWDW/mcl.html. **Australia**, Australian Government, National Health and Medical Research Council and Natural Resource Management Ministerial Council, National Water Quality Management Strategy, Austrlian Drinking Water Guidelines, 2004. www.waterquality.crc.org.au. EEC, Lenntech Drinking Water Standards, www.lenntech.com. **Canada**, Health Canada, 2004, Summary of Guidelines for Canadian Drinking Water Quality, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment, April 2004. ec.gc.ga. **Thailand**, Notification of the Ministry of Industry, No. 322, B.E. 2521 (1978), issued under the Industrial Products Standards Act B.E. 2511 (1968), published in the Royal Gazette, Vol. 95, Part 68, dated July 4, B.E. 2521 (1978). pcdv1.pcd.go.th/Information/Regulations/WaterQuality/WaterQualityStandards.cfm. **Vietnam**, Hue, N.D. and Viet, P.H., 2003, Environmental Quality Standards in Vietnam, in United Nations University, Capacity Development Training for Monitoring of POPs in the East Asia Hydrosphere, 1–2 September 2003, Tokyo. **Korea**, Oh, J.R, 2003, Environmental Standards of Korea in United Nations University, Capacity Development Training for Monitoring of POPs in the East Asia Hydrosphere, 1–2 September 2003, Tokyo. **Indonesia**, Vigneswaran, Saravanamuthu, 1995, *Water Treatment Processes: Simple Options*, CRC Press, Inc., Boca Raton (Criteria of Water Quality, Category A). **Japan**, Japan Ministry of Health, Labour and Welfare jwwa.or.jp/water-e07.html. **China**, Chinese Drinking Water Standards (GB 5749–85). **South Africa**, Republic of South Africa, Department of Water Affairs and Forestry, 1996, South African Water Quality Guidelines, Volume 8, Field Guide, First Edition 1996, dwaf.pwv.gov.za/IWQS/wq_guide/field.pdf#search = 'Recreation%20Water%20Quality%20Guidelines'. **Chile**, Normas oficiales para la calidad del agua Chile, NORMA CHILENA OFICIAL 409/1.Of.84, Agua Potable Parte 1: Requisitos cepis.ops-oms.org/bvsacg/e/normas2/Norma-Chi.pdf#search = "NORMA%20CHILENA%20OFICIAL%20409/1.Of.84". **Brazil**, Ministerio da Saude, Portaria N.o 518, DE 25 De Marco De 2004 www.saneago.com.br/novasan/leis/port518.pdf#search = "Ministerio%20da%20Saude%2C%20Portaria%20N.%20518".



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**Table 8C.31 Comparison of Organic Compound Drinking Water Guidelines Recommended by WHO and Standards for Several Developed and Developing Countries**

| | WHO (2004) | U.S.A. (2005) | EEC (1998) | Canada (2004) | Australia (2000) | Thailand (1978) | Vietnam (2002) | Korea (2000) | Indonesia (1995) | Japan (2004) | China (1985) | South Africa (1996) | Chile (1984) | Brazil (2004) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Organic Compounds (mg/L)** | | | | | | | | | | | | | | |
| Acrylamide | 0.0005 | TT9 | 0.0001 | | 0.0002 | | 0.0005 | | | | | | | 0.0005 |
| Benzene | 0.01 | 0.005 | 0.001 | 0.005 | 0.001 | | 0.01 | 0.01 | 0.01 | 0.01 | | | | 0.005 |
| Benzo[a]pyrene | 0.0007 | 0.0002 | 0.00001 | 0.00001 | 0.00001 | | 0.0007 | | 0.00001 | | 0.00001 | | | 0.0007 |
| Carbon tetrachloride | 0.004 | 0.005 | | 0.005 | 0.003 | | 0.002 | 0.002 | | 0.002 | 0.003 | | | 0.002 |
| 1,2-Dichlorobenzene | 1(C) | 0.6 | | 0.2 | 1.5 | | 1 | | | | | | | |
| 1,4-Dichlorobenzene | 0.3(C) | 0.075 | | 0.005 | 0.04 | | 0.3 | | | | | | | |
| 1,2-Dichloroethane | 0.03 | 0.005 | 0.003 | 0.005 | 0.003 | | 0.03 | | 0.01 | | | | | 0.01 |
| 1,1-Dichloroethene | 0.03 | 0.007 | | 0.014 | 0.03 | | 0.03 | 0.03 | | 0.02 | | | | 0.03 |
| 1,2-Dichloroethene | 0.05 | 0.07 (cis), 0.1 (trans) | | | 0.06 | | 0.05 | | | 0.04 (cis) | | | | |
| Dichloromethane | 0.02 | 0.005 | | 0.05 | 0.004 | | 0.02 | 0.02 | | 0.02 | | | | 0.02 |
| Di(2-ethylhexyl)phthalate | 0.008 | 0.006 | | | 0.01 | | 0.008 | 0.08 | | | | | | |
| Edetic acid (EDTA) | 0.6 | | | | 0.25 | | 0.2 | | | | | | | |
| Epichlorohydrin | 0.0004 (P) | TT9 | 0.0001 | | 0.0005 | | 0.0004 | | | | | | | |
| Ethylbenzene | 0.3 | 0.7 | | | 0.3 | | 0.3 | 0.3 | | | | | | |
| Hexachlorobutadiene | 0.0006 | | | | 0.0007 | | 0.0006 | | | | | | | |
| Microcystin-LR | 0.001 (P) | | | 0.0015 | | | | | | | | | | 0.001 |
| Monochlorobenzene | | 0.1 | | 0.08 | 0.3 | | 0.3 | | | | | | | |
| Nitrilotriacetic acid | 0.2 | | | 0.4 | 0.2 | | 0.2 | | | | | | | |
| Styrene | 0.02 | 0.1 | | | 0.03 | | 0.02 | | | | | | | 0.02 |
| Tetrachloroethene | 0.04 | 0.005 | 0.01[a] | 0.03 | 0.05 | | 0.04 | 0.01 | | 0.01 | | | | 0.04 |
| Toluene | 0.7 | 1 | | | 0.8 | | 0.7 | 0.7 | | | | | | |
| Trichloroethene | 0.07 (P) | 0.005 | 0.01[a] | 0.05 | | | 0.07 | 0.03 | | 0.03 | | | | 0.07 |
| Vinyl chloride | 0.0003 | 0.002 | 0.0005 | 0.002 | 0.0003 | | 0.005 | | | | | | | 0.005 |
| Xylenes | 0.5 | 10 | | | 0.6 | | 0.5 | 0.5 | | | | | | |
| **Pesticides (mg/L)** | | | | | | | | | | | | | | |
| Alachlor | 0.02 | 0.002 | | | | | 0.02 | | | | | | | 0.02 |
| Aldicarb | 0.01 | | | 0.009 | 0.001 | | 0.01 | | | | | | | |
| Aldrin/dieldrin | 0.00003 | | 0.0003 | 0.0007 | 0.0003 | | 0.0003 | | 0.0007 | | | | 0.00003 | 0.00003 |
| Atrazine | 0.002 | 0.003 | | 0.005 | 0.04 | | 0.002 | | | | | 0.002 | | 0.002 |
| Carbofuran | 0.007 | 0.04 | | 0.09 | 0.01 | | 0.005 | | | | | | | |
| Chlordane | 0.0002 | 0.002 | | | 0.001 | | 0.0002 | | 0.0003 | | | | 0.0003 | 0.0002 |
| Chlorpyrifos | 0.03 | | | 0.09 | 0.01 | | | | | | | | | |
| Chlorotoluron | 0.03 | | | | | | 0.03 | | | | | | | |
| Cyanazine | 0.0006 | | | 0.01 | | | | | | | | | | |
| DDT and metabolites | 0.001 | | | | 0.02 | | 0.002 | | 0.03 | | 0.001 | | 0.001 | 0.002 |
| 1,2-Dibromo-3-chloropropane | 0.001 | 0.0002 | | | | | 0.001 | | | | | | | |
| 1,2-Dibromoethane | 0.0004 (P) | | | | | | | | | | | | | |
| 2,4-Dichlorophenoxyacetic acid (2,4-D) | 0.03 | 0.07 | | 0.1 | 0.03 | | 0.03 | | 0.1 | | | | 0.1 | 0.03 |
| 1,2-Dichloropropane (1,2-DCP) | 0.04 (P) | 0.005 | | | | | 0.02 | | | | | | | |
| 1,3-Dichloropropane | 0.04 | | | | | | | | | | | | | |
| 1,3-Dichloropropene | 0.02 | | | | | | | | | | | | | |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Isoproturon | 0.009 | | | | | 0.009 | | | | | | | |
| Lindane | 0.002 | 0.0002 | | | 0.02 | 0.002 | | 0.004 | | | | 0.003 | 0.002 |
| MCPA | 0.002 | | | | | 0.002 | | | | | | | |
| Methoxychlor | 0.02 | 0.04 | | 0.9 | 0.3 | 0.02 | | 0.03 | | | | 0.03 | 0.02 |
| Metolachlor | 0.01 | | | 0.05 | 0.3 | 0.01 | | | | | | | 0.01 |
| Molinate | 0.006 | | | | 0.0005 | 0.006 | | | | | | | 0.006 |
| Pendimethalin | 0.02 | | | | 0.3 | 0.02 | | | | | | | 0.02 |
| Pentachlorophenol | 0.009 (P) | 0.001 | | 0.06 | 0.01 | 0.009 | | 0.01 | | | | | 0.009 |
| Phenol | | | | | | 0.001 | 0.005 | | 0.005 | 0.002 | 1 | 0.002 | |
| Pyriproxyfen | 0.3 | | | | | | | | | | | | |
| Simazine | 0.002 | 0.004 | | 0.01 | 0.02 | 0.02 | | | | | | | 0.002 |
| Terbuthylazine (TBA) | 0.007 | | | | | | | | | | | | |
| Trifluralin | 0.02 | | | 0.045 | 0.05 | 0.02 | | | | | | | 0.02 |
| **Chlorophenoxy herbicides other than 2,4-D and CPA (mg/L)** | | | | | | | | | | | | | |
| 2,4-DB | 0.09 | | | | | 0.09 | | | | | | | |
| Dichlorprop | 0.1 | | | | | 0.1 | | | | | | | |
| Dimethoate | 0.006 | | | 0.02 | 0.05 | | | | | | | | |
| Endrin | 0.0006 | 0.002 | | | | | | | | | | 0.0002 | 0.0006 |
| Fenoprop | 0.009 | | | | 0.01 | 0.009 | | | | | | 0.01 | |
| Mecoprop | 0.01 | | | | | 0.01 | | | | | | | |
| 2,4,5-T | 0.009 | | | | 0.1 | 0.009 | | | | | | | |
| **Disinfectants and disinfectant by-products (mg/L)** | | | | | | | | | | | | | |
| Monochloramine | 3 | 4.01 | | 3 (total) | 3 | 3 | | | | | | | 3 |
| Chlorine | 5 (C) | 4.01 | | | 5 | 0.003–0.005 (active) | | | | | | 0.2 (free) | 5 |
| **Disinfectant by-products** | | | | | | | | | | | | | |
| Bromate | 0.01 (A,T) | 0.01 | 0.01 | 0.01 | 0.02 | 0.025 | | | 0.01 | | | | 0.025 |
| Chlorate | 0.7 (D) | | | | | | | | | | | | 0.2 |
| Chlorite | 0.7 (D) | 1 | | | 0.3 | 0.2 | | | | | | | |
| 2,4,6-Trichlorophenol | 0.2 (C) | | | 0.005 | 0.02 | 0.2 | | 0.01 | | | | | 0.2 |
| Formaldehyde | 0.9 | | | | 0.5 | 0.9 | | | 0.08 | | | | |
| Trihalomethanes | 0.001 | 0.1 | 0.1 | 0.1 | | | 0.1 | | 0.01 | | | | 0.1 |
| Bromoform | 0.1 | | | | 0.25 | 0.1 | | | 0.09 | | | | |
| Dibromochloromethane | 0.1 | | | | | 0.1 | | | 0.1 | | | | |
| Bromodichloromethane | 0.06 | | | | | 0.06 | | | 0.03 | | | | |
| Chloroform | 0.2 | | | | | 0.2 | 0.08 | 0.03 | 0.06 | 0.06 | | | |
| **Chlorinated acetic acids** | | | | | | | | | | | | | |
| Monochloroacetic acid | 0.02 | | | | 0.15 | | | | 0.02 | | | | |
| Dichloroacetic acid | 0.05 (T,D) | 0.06 | | | 0.1 | 0.05 | | | 0.04 | | | | |
| Trichloroacetic acid | 0.2 | 0.06 | | | 0.1 | 0.1 | | | 0.02 | | | | |
| Chloral hydrate (trichloroacetaldehyde) | 0.01 (P) | | | | 0.02 | 0.01 | | | | | | | |

*(Continued)*



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**Table 8C.31 (Continued)**

| | WHO (2004) | U.S.A. (2005) | EEC (1998) | Canada (2004) | Australia (2000) | Thailand (1978) | Vietnam (2002) | Korea (2000) | Indonesia (1995) | Japan (2004) | China (1985) | South Africa (1996) | Chile (1984) | Brazil (2004) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Halogenated acetonitriles** | | | | | | | | | | | | | | |
| Dichloroacetonitrile | 20 | | | | | | 0.09 | | | | | | | |
| Dibromoacetonitrile | 0.07 | | | | | | 0.1 | | | | | | | |
| Cyanogen chloride (as CN) | 0.07 | | | | 0.08 | | 0.01 | 0.01 | | | | | | |

*Note:* P = provisional guideline value, as there is evidence of a hazard, but the available information on health effects is limited; T = provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection, etc; A = provisional guideline value because calculated guideline value is below the achievable quantification level; D = provisional guideline value because disinfection is likely to result in the guideline value being exceeded; C = concentrations of the substance at or below the health-based guideline value may affect the appearance, taste or odour of the water, leading to consumer complaints; TT = Treatment Technique—A required process intended to reduce the level of a contaminant in drinking water.

[a] Sum of trichloroethene and tretrachloroethene.

*Source*: From **WHO**, World Health Organization, 2004, *Guidelines for Drinking-Water Quality, Third Edition*, Volume 1, Recommendations. who.int/water_sanitation_health/dwq/gdwq3/en/index.html. **U.S.A.**, United States Environmental Protection Agency, www.epa.gov/OGWDW/mcl.html. **Australia**, Australian Government, National Health and Medical Research Council and Natural Resource Management Ministerial Council, National Water Quality Management Strategy, Australian Drinking Water Guidelines, 2004, www.waterquality.crc.org.au. **EEC**, Lenntech Drinking Water Standards, www.lenntech.com. **Canada**, Health Canada, 2004, *Summary of Guidelines for Canadian Drinking Water Quality*, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial committee on Health and the Environment, April 2004, ec.gc.ga. **Thailand**, Notification of the Ministry of Industry, No. 322, B.E. 2521 (1978), issued under the Industrial Products Standards Act B.E. 2511 (1968), published in the Royal Gazette, Vol. 95, Part 68, dated July 4, B.E. 2521 (1978). pcdv1.pcd.go.th/Information/Regulations/WaterQuality/WaterQualityStandards.cfm. **Vietnam**, Hue, N.D. and Viet, P.H., 2003, Environmental Quality Standards in Vietnam, in United Nations University, Capacity Development Training for Monitoring of POPs in the East Asia Hydrosphere, 1–2 September 2003, Tokyo. **Korea**, Oh, J.R, 2003, Environmental Standards of Korea in United Nations University, Capacity Development Training for Monitoring of POPs in the East Asia Hydrosphere, 1–2 September 2003, Tokyo. **Indonesia**, Vigneswaran, Saravanamuthu, 1995, Water Treatment Processes: Simple Options, CRC Press, Inc., Boca Raton (Criteria of Water Quality, Category A). **Japan**, Japan Ministry of Health, Labour and Welfare jwwa.or.jp/water-e07.html. **China**, Chinese Drinking Water Standards (GB 5749–85). **South Africa**, Republic of South Africa, Department of Water Affairs and Foresty, 1996, South African Water Quality Guidelines, Volume 8, Field Guide, First Edition 1996, dwaf.pwv.gov.za/IWQS/wq_guide/field.pdf#search = 'Recreation%20Water%20Quality%20Guidelines'. **Chile**, Normas oficiales para la calidad del agua Chile, NORMA CHILENA OFICIAL 409/1.Of.84;, Agua Potable Parte 1: Requisitos cepis.ops-oms.org/bvsacg/e/normas2/Norma-Chi.pdf#search = "NORMA%20CHILENA%20OFICIAL%20409/1.Of.84". **Brazil**, Ministerio da Saude, Portaria N.o 518, DE 25 De Marco De 2004 saneago.com.br/novasan/leis/port518.pdf#search = "Ministerio%20da%20Saude%2C%20Portaria%20N.%20518".

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**Table 8C.32 Comparison of Aesthetic Drinking Water Guidelines Recommended by WHO and Standards for Several Developed and Developing Countries**

| | WHO (2004) | U.S.A. (2005) | EEC (1998) | Canada (2004) | Australia (2000) | Thailand (1978) | Vietnam (2002) | Korea (2000) | Indonesia (1995) | Japan (2004) | China (1985) | South Africa (1996) | Chile (1984) | Brazil (2004) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Physical parameters** | | | | | | | | | | | | | | |
| Color | 15 TCU | 15 (color units) | Acceptable to consumers and no abnormal change | 15 TCU | 15 HU | 5 Pt–Co | 15 TCU | 5 | 15 TCU | 5 Degrees | <15 ° | | 20 Pt–Co | 15 |
| Taste and odor | Should be acceptable | 3 threshold odor number | Acceptable to consumers and no abnormal change | Inoffensive | Acceptable to most people | Non objectionable | Nil | Not abnormal | Odorless, tasteless | Not Abnormal | | 1 (odour) | Tasteless, odorless | Not objectionable |
| Turbidity | 5 NTU | 5 NTU | Acceptable to consumers and no abnormal change | 1 NTU (MAC) 5 NTU (AO) | 5 NTU | 5 SSU | 2 NTU | 1 NTU, 0.5 NTU for Tap Water | 5 NTU | 2 Degrees | Less than 3 ° not to exceed 5 | 1 NTU | 5 | 5 |
| pH (standard units) | <8.0 | 6.5–8.5 | 6.5–9.5 | 6.5–8.5 | 6.5–8.5 | 6.5–8.5 | 6.5–8.5 | 5.8–8.5 | 6.5–8.5 | 5.8–8.6 | 6.5–8.5 | 6–9 | | |
| **Inorganic constituents (mg/L)** | | | | | | | | | | | | | | |
| Aluminum | 0.1–0.2 | 0.05 to 0.2 | 0.2 | 0.1 | 0.2 | | 0.2 | 0.2 | 0.2 | 0.2 | | 0.15 | | 0.2 |
| Ammonia | 1.5 (odor), 35 (taste) | | 0.5 | | 0.5 | | 1.5 | 0.5 | | | | 1 | 0.25 | 1.5 |
| Chloride | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 200 | 250 | 100 | 250 | 250 |
| Copper | 1 | 1 | 2 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | | | |
| Hydrogen sulphide | 0.05 | | | 0.3 | 0.05 | | 0.05 | | 0.05 | | | | | 0.05 |
| Iron | 0.3 | 0.3 | 0.2 | 0.005 | 0.3 | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.1 | 0.3 | 0.3 |
| Manganese | 0.1 | 0.05 | 0.05 | 0.05 | 0.1 | 0.3 | 0.5 | 0.3 | 0.1 | 0.05 | 0.1 | 0.05 | 0.1 | 0.1 |
| Dissolved oxygen | Narrative | | | | >85% | | | | | | | | | |
| Sodium | 200 | | 200 | 200 | 180 | | 200 | | 200 | 200 | | 100 | | 200 |
| Sulfate | 250 | 250 | 250 | 500 | 250 | 200 | 250 | 200 | 400 | 200 | 250 | 200 | 250 | 250 |
| Total dissolved solids | 1000 | 500 | | 500 | 500 | 500 | 1000 | 500 | 1000 | 500 | 1000 | 450 | 1000 | 1000 |
| Zinc | 3 | 5 | | 5 | 3 | 5 | 3 | 1 | 5 | 1 | 1 | 3 | 5 | 5 |
| **Organic constituents (mg/L)[a]** | | | | | | | | | | | | | | |
| Toluene | 0.024–0.17 | | | 0.024 | 0.025 | | | | | | | | | 0.17 |
| Xylene | 0.020–1.80 | | | 0.3 | 0.02 | | | | | | | | | 0.3 |
| Ethylbenzene | 0.002–0.20 | | | 0.0024 | 0.003 | | | | | | | | | 0.2 |
| Styrene | 0.004–2.6 | | | | 0.004 | | | | | | | | | |
| Monochlorobenzene | 0.010–0.120 | | | 0.3 | 0.01 | | | | | | | | | 0.12 |
| 1,2-dichlorobenzene | 0.001–0.01 | | | 0.003 | 0.001 | | | | | | | | | |
| 1,4-dichlorobenzene | 0.0003–0.03 | | | 0.001 | 0.003 | | | | | | | | | |
| Trichlorobenzenes (total) | 0.005–0.05 | | | | 0.005 | | 0.020 | | | | | | | 0.02 |
| **Synthetic detergents** | no foam or taste problems | | | | | | | | | | | | | |
| **Disinfectants and disinfectant by-products (mg/L)** | | | | | | | | | | | | | | |
| Chlorine | 0.6–1.0 | | | | 0.6 | | | | | | | | | 0.2 |
| Chlorophenols | | | | | | | | | | | | | | 5 |
| 2-chlorophenol | 0.0001–0.010 | | | | 0.0001 | | | | | | | | | |
| 2,4-dichlorophenol | 0.0003–0.040 | | | 0.0003 | 0.0003 | | | | | | | | | |
| Monochloramine | 0.3 | | | | 0.0002 | | | | | | | | | 3 |
| 2,4,6-trichlorophenol | 0.002–0.3 | | | 0.002 | 0.002 | | | | | | | | | 0.2 |

*(Continued)*



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**Table 8C.32 (Continued)**

[a] The levels indicated are not precise numbers. Problems may occur at lower or higher values according to local circumstances. A range of taste and odour threshold concentrations is given for organic constituents.

*Source*: From **WHO**, World Health Organization, 2004, *Guidelines for Drinking-Water Quality, Third Edition*, Volume 1, Recommendations. www.who.int/water_sanitation_health/dwq/gdwq3/en/index.html. **U.S.A.**, United States Environmental Protection Agency, www.epa.gov/OGWDW/mcl.html. **Australia**, Australian Government, National Health and Medical Research Council and Natural Resource Management Ministerial Council, National Water Quality Management Strategy, Austrailian Drinking Water Guidelines, 2004. www.waterquality.crc.org.au. **EEC**, Lenntech Drinking Water Standards, www.lenntech.com. **Canada**, Health Canada, 2004, Summary of Guidelines for Canadian Drinking Water Quality, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment, April 2004, ec.gc.ga. **Thailand**, Notification of the Ministry of Industry, No. 322, B.E. 2521 (1978), issued under the Industrial Products Standards Act B.E. 2511 (1968), published in the Royal Gazette, Vol. 95, Part 68, dated July 4, B.E. 2521 (1978). pcdv1.pcd.go.th/Information/Regulations/WaterQuality/WaterQualityStandards.cfm. **Vietnam**, Hue, N.D. and Viet, P.H., 2003, Environmental Quality Standards in Vietnam, in United Nations University, Capacity Development Training for Monitoring of POPs in the East Asia Hydrosphere, 1–2 September 2003, Tokyo. **Korea**, Oh, J.R, 2003, Environmental Standards of Korea in United Nations University, Capacity Development Training for Monitoring of POPs in the East Asia Hydrosphere, 1–2 September 2003, Tokyo. **Indonesia**, Vigneswaran, Saravanamuthu, 1995, Water Treatment Processes: Simple Options, CRC Press, Inc., Boca Raton (Criteria of Water Quality, Category A). **Japan**, Japan Ministry of Health, Labour and Welfare jwwa.or.jp/water-e07.html. **China**, Chinese Drinking Water Standards (GB 5749–85). **South Africa**, Republic of South Africa, Department of Water Affairs and Foresty, 1996, South African Water Quality Guidelines, Volume 8, Field Guide, First Edition 1996, dwaf.pwv.gov.za/IWQS/wq_guide/field.pdf#search=“Recreation%20Water%20Quality%20Guidelines”. **Chile**, Normas oficiales para la calidad del agua Chile, NORMA CHILENA OFICIAL 409/1.Of.84, Agua Potable Parte 1: Requisitos cepis.ops-oms.org/bvsacg/e/normas2/Norma-Chi.pdf#search=“NORMA%20CHILENA%20OFICIAL%20409/1.Of.84”. **Brazil**, Ministerio da Saude, Portaria N.o 518, DE 25 De Marco De 2004 saneago.com.br/novasan/leis/port518.pdf#search=“Ministerio%20da%20Saude%2C%20Portaria%20N.%20518”.



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## SECTION 8D MUNICIPAL WATER QUALITY

**Table 8D.33 Range in Quality of Finished Water in Public Water Supplies of the 100 Largest Cities in the United States**

| Constituent or Property | Maximum | Median | Minimum |
|---|---|---|---|
| **Chemical Analyses (parts per million)** | | | |
| Silica ($SiO_2$) | 72 | 7.1 | 0.0 |
| Iron (Fe) | 1.30 | 0.02 | 0.00 |
| Manganese (Mn) | 2.50 | 0.00 | 0.00 |
| Calcium (Ca) | 145 | 26 | 0.0 |
| Magnesium (Mg) | 120 | 6.25 | 0.0 |
| Sodium (Na) | 198 | 12 | 1.1 |
| Potassium (K) | 30 | 1.6 | 0.0 |
| Bicarbonate ($HCO_3$) | 380 | 46 | 0 |
| Carbonate ($CO_3$) | 26 | 0 | 0 |
| Sulfate ($SO_4$) | 572 | 26 | 0.0 |
| Chloride (Cl) | 540 | 13 | 0.0 |
| Fluoride (F) | 7.0 | 0.4 | 0.0 |
| Nitrate ($NO_3$) | 23 | 0.7 | 0.0 |
| Dissolved solids | 1,580 | 186 | 22 |
| Hardness as $CaCO_3$ | 738 | 90 | 0 |
| Noncarbonate hardness as $CaCO_3$ | 446 | 34 | 0 |
| Specific conductance micromhos at 25°C | 1,660 | 308 | 18 |
| pH, pH units | 10.5 | 7.5 | 5.0 |
| Color, color units | 24 | 2 | 0 |
| Turbidity | 13 | 0 | 0 |
| **Spectrographic Analyses (μg/L)** | | | |
| Silver (Ag) | 7.0 | 0.23 | ND |
| Aluminum (Al) | 1,500 | 54 | 3.3 |
| Boron (B) | 590 | 31 | 2.5 |
| Barium (Ba) | 380 | 43 | 1.7 |
| Chromium (Cr) | 35 | 0.43 | ND |
| Copper (Cu) | 250 | 8.3 | <0.61 |
| Iron (Fe) | 1,700 | 43 | 1.9 |
| Lithium (Li) | 170 | 2.0 | ND |
| Manganese (Mn) | 1,100 | 5.0 | ND |
| Molybdenum (Mo) | 68 | 1.4 | ND |
| Nickel (Ni) | 34 | <2.7 | ND |
| Lead (Pb) | 62 | 3.7 | ND |
| Rubidium (Rb) | 67 | 1.05 | ND |
| Strontium (Sr) | 1,200 | 110 | 2.2 |
| Titanium (Tl) | 49 | <1.5 | ND |
| Vanadium (V) | 70 | <4.3 | ND |
| **Radiochemical Analyses** | | | |
| Beta activity picocuries per liter | 130 | 7.2 | <1.1 |
| Radium (Ra) picocuries per liter | 2.5 | <0.1 | <0.1 |
| Uranium (U) micrograms per liter | 250 | 0.15 | <0.1 |

*Note:* Maximum, median, and minimum values of as of 1962; ND means not detected.

*Source*: From U.S. Geological Survey.

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**Table 8D.34 Quality Limits of Finished Water in Public Water Supplies of the 100 Largest Cities in the United States**

| | Water Supplies Having Less Than Stated Concentration | |
|---|---|---|
| **Constituent or Property** | **Concentration** | **Percent of Water Supplies** |
| **Chemical Analyses (parts per million)** | | |
| Silica ($SiO_2$) | 30 | 94 |
| Iron (Fe) | 0.25 | 98 |
| Manganese (Mn) | 0.10 | 95 |
| Calcium (Ca) | 50 | 93 |
| Magnesium (Mg) | 20 | 96 |
| Sodium (Na) | 50 | 93 |
| Potassium (K) | 5.0 | 93 |
| Bicarbonate ($HCO_3$) | 150 | 91 |
| Carbonate ($CO_3$) | 1.0 | 86 |
| Sulfate ($SO_4$) | 100 | 93 |
| Chloride (Cl) | 50 | 93 |
| Fluoride (F) | 1.0 | 92 |
| Nitrate ($NO_3$) | 5.0 | 93 |
| Dissolved solids | 500 | 97 |
| | 250 | 86 |
| Hardness as $CaCO_3$ | 200 | 94 |
| Noncarbonate hardness as $CaCO_3$ | 75 | 94 |
| Specific conductance (micro mhos at 25°C) | 500 | 93 |
| pH, pH units | 9.0 | 90 |
| Color, color units | 10 | 96 |
| Turbidity | 3 | 94 |
| **Spectrographic Analyses (μg/L)** | | |
| Silver (Ag) | 0.50 | 95 |
| Aluminum (Al) | 500 | 87 |
| Boron (B) | 100 | 94 |
| Barium (Ba) | 100 | 94 |
| Chromium (Cr) | 5.0 | 95 |
| Copper (Cu) | 100 | 94 |
| Iron (Fe) | 150 | 94 |
| Lithium (Li) | 50 | 96 |
| Manganese (Mn) | 100 | 97 |
| Molybdenum (Mo) | 10 | 96 |
| Nickel (Ni) | 10 | 95 |
| Phosphorus (P) | ND | 92 |
| Lead (Pb) | 10 | 95 |
| Rubidium (Rb) | 5.0 | 91 |
| Strontium (Sr) | 500 | 96 |
| Titanium (Ti) | 5.0 | 96 |
| Vanadium | 10 | 91 |
| **Radiochemical Analyses** | | |
| Beta activity picocuries per liter | 20 | 92 |
| Radium (Ra) picocuries per liter | 0.2 | 91 |
| Uranium (U) micrograms per liter | 2.0 | 93 |

*Note:* Data as of 1962; ND means not detected.

*Source*: From U.S. Geological Survey.

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**Table 8D.35 Quality of Raw and Treated Water in Public Water Supplies of the 100 Largest Cities in the United States**

| | Raw-Water Supplies[a] | | Treated-Water Supplies | |
|---|---|---|---|---|
| | Population Served (millions) | Number of Cities | Population Served (millions) | Number of Cities |
| Hardness (ppm) | | | | |
| Less than 61 | 21 | 29 | 23 | 30 |
| 61–120 | 15 | 16 | 22 | 41 |
| 21–180 | 16 | 22 | 11 | 16 |
| More than 180 | 8 | 27 | 3.7 | 13 |
| Dissolved solids (ppm) | | | | |
| Less than 100 | 21 | 27 | 21 | 27 |
| 101–250 | 23 | 38 | 28 | 48 |
| 251–500 | 11 | 29 | 8 | 22 |
| More than 500 | 1.5 | 6 | 1 | 3 |
| pH | | | | |
| Less than 7.0 | 16 | 18 | 14 | 9 |
| 7.0–9.0 | 42 | 80 | 38 | 74 |
| More than 9.0 | | | 7 | 17 |

*Note:* Data as of 1962.

[a] A few cities are not included because data are lacking.

*Source*: From U.S. Geological Survey.

**Table 8D.36 Standards for Raw Water Used as Sources of Domestic Water Supply**

| Constituents | | Excellent Source of Water Supply, Requiring Disinfection Only, as Treatment | Good Source of Water Supply Requiring Usual Treatment Such as Filtration and Disinfection | Poor Source of Water Supply, Requiring Special or Auxiliary Treatment and Disinfection |
|---|---|---|---|---|
| B.O.D. (5-day) ppm | Monthly Average | 0.75 | 1.5–2.5 | 2.0–5.5 |
| | Maximum Day, or sample | 1.0 | 3.0–3.5 | 4.0–7.5 |
| Coliform MPN per 100 mL | Monthly Average | 50–100 | 240–5,000 | 10,000–20,000 |
| | Maximum Day, or sample | — | <20%>5,000 <5%>20,000 | |
| Dissolved oxygen | ppm. average | 4.0–7.5 | 2.5–7.0 | 2.5–6.5 |
| | % saturation | 50–75 | 25–75 | — |
| pH | Average | 6.0–8.5 | 5.0–9.0 | 3.8–10.5 |
| Chlorides, max | ppm. | 50 | 250 | 500 |
| Iron and manganese together | Max. ppm. | 0.3 | 1.0 | 15 |
| Fluorides | ppm. | 1.0 | 1.0 | 1.0 |
| Phenolic compounds | Max. ppm | none | 0.005 | 0.025 |
| Color | ppm. | 0–20 | 20–70 | 150 |
| Turbidity | ppm. | 0–10 | 40–250 | — |

*Source*: From Calif. State Water Pollution Control Board, 1952.

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**Table 8D.37 Summer Temperatures of Selected Municipal Water Supplies in the United States**

| Location | Temperature at Main Outlet, °F | | | |
|---|---|---|---|---|
| | June | July | August | September |
| **Surface Water Sources** | | | | |
| Atlanta, GA | 78.1 | 83.5 | 79.5 | 77.8 |
| Baltimore, MD | 61.0 | 66.0 | 70.0 | 64.0 |
| Birmingham, AL | 78.0 | 82.0 | 81.0 | 79.0 |
| Boston, MA | 68.3 | 74.3 | 73.4 | 69.4 |
| Buffalo, NY | 62.0 | 71.0 | 73.0 | 66.0 |
| Chicago, IL | 55.4 | 68.0 | 69.4 | 62.5 |
| Cincinnati, OH | 76.0 | 82.0 | 81.0 | 77.0 |
| Cleveland, OH | 58.0 | 68.0 | 73.5 | 71.0 |
| Detroit, MI | 64.0 | 75.0 | 74.0 | 68.0 |
| Kansas City, MO | 84.0 | 93.0 | 91.0 | 85.0 |
| Louisville, KY | 77.0 | 82.0 | 82.0 | 77.0 |
| Nashville, TN | 84.0 | 88.0 | 88.0 | 84.0 |
| New Orleans, LA | 86.0 | 89.0 | 90.0 | 90.0 |
| Oakland, CA | 59.0 | 62.0 | 64.0 | 64.0 |
| Philadelphia, PA | 71.0 | 79.0 | 77.0 | 72.0 |
| Pittsburgh, PA | 75.2 | 80.6 | 80.6 | 75.2 |
| Sacramento, CA | 70.7 | 70.7 | 80.6 | 77.0 |
| St. Louis, MO | 77.0 | 85.0 | 83.0 | 75.0 |
| Washington, DC | 43.0 | 67.0 | 73.0 | 75.0 |
| **Groundwater Sources** | | | | |
| Albuquerque, NM | 72.0 | 72.0 | 72.0 | 72.0 |
| Aurora, CO | 60.0 | 60.0 | 60.0 | 60.0 |
| Camden, NJ | 58.0 | 58.0 | 58.0 | 58.0 |
| El Paso, TX | 84.0 | 85.0 | 85.0 | 84.0 |
| Fresno, CA | 72.0 | 72.0 | 72.0 | 72.0 |
| Houston, TX | 84.0 | 84.0 | 84.0 | 84.0 |
| Jacksonville, FL | 84.8 | 86.3 | 86.7 | 82.4 |
| Kalamazoo, MI | 52.0 | 52.0 | 52.0 | 52.0 |
| Lafayette, LA | 53.0 | 53.0 | 53.0 | 53.0 |
| Lansing, MI | 57.5 | 58.0 | 59.0 | 59.0 |
| Lincoln, NE | 58.0 | 59.0 | 59.0 | 59.0 |
| Lowell, MA | 50.0 | 50.0 | 50.0 | 50.0 |
| Madison, WI | 53.0 | 52.0 | 52.0 | 53.0 |
| Marion, FL | 54.0 | 54.0 | 55.0 | 55.0 |
| Montgomery, AL | 70.0 | 70.0 | 71.0 | 71.0 |
| Pensacola, FL | 70.0 | 70.0 | 70.0 | 70.0 |
| Peoria, IL | 56.0 | 56.0 | 56.0 | 54.0 |
| Pontiac, MI | 55.0 | 55.0 | 55.0 | 55.0 |
| San Antonio, TX | 76.0 | 76.0 | 76.0 | 76.0 |
| Sioux Falls, SD | 55.0 | 55.0 | 55.0 | 55.0 |

*Source*: From U.S. Dept. of Commerce.

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**Table 8D.38 Quality of Water Supplied by Municipal Water Systems in the United States–1984**

| State and Water Utility | Avg Temp Raw (°F) | Hardness ($CaCO_3$) Raw (mg/L) | Hardness ($CaCO_3$) Finished (mg/L) | Alkalinity ($CaCO_3$) Raw (mg/L) | Alkalinity ($CaCO_3$) Finished (mg/L) | pH Raw | pH Finished |
|---|---|---|---|---|---|---|---|
| **Alabama** | | | | | | | |
| Birmingham | 60.8 | 75 | 104 | 73 | 77 | 7.9 | 8.2 |
| Montgomery | 54.0 | 18 | 30 | 15 | 32 | 6.7 | 8.6 |
| **Alaska** | | | | | | | |
| Anchorage | 37.4 | 63 | 61 | 52 | 42 | 7.6 | 7.2 |
| **Arizona** | | | | | | | |
| Phoenix/Phoenix Wtr & Swr Dept | 60.1 | 190 | 190 | 125 | 105 | 8.2 | 7.6 |
| Tucson | 75.2 | 141 | 141 | 150 | 150 | 7.5 | 7.5 |
| **Arkansas** | | | | | | | |
| Fort Smith | 56.5 | 39 | 18 | 14 | 28 | 6.6 | 9.0 |
| Little Rock | 64.2 | 9 | 19 | 7 | 11 | 6.7 | 7.7 |
| **California** | | | | | | | |
| Anaheim | 64.0 | 331 | 345 | 123 | 186 | 8.3 | 7.7 |
| Burbank | 60.0 | 165 | | 159 | | 7.6 | |
| Concord/Contra Costa Water Dept | 63.0 | 80 | 68 | 64 | 59 | 8.0 | 8.5 |
| Corte Madera/Marin Munic Wtr Dist | 58.1 | 57 | 67 | 58 | 71 | 7.4 | 8.7 |
| Fremont/Alameda Cnty Wtr Dist | 62.1 | 97 | 97 | 65 | 65 | 7.6 | 8.7 |
| Fresno | 70.0 | 119 | 119 | 123 | 123 | 7.8 | 7.8 |
| Glendale | 69.8 | 190 | 296 | 156 | 108 | 7.9 | 8.0 |
| La Mesa/Helix Wtr District | 71.6 | 300 | 300 | 115 | 115 | 7.7 | 8.0 |
| La Puente/Southwest Suburban Wtr | 68.0 | 220 | 220 | 180 | 180 | 7.4 | 7.4 |
| Los Angeles/Los Angeles Wtr & Power | 58.1 | 69 | 69 | 89 | 89 | 7.9 | 7.9 |
| Oakland/East Bay Munic Util Dist | 60.4 | 26 | 27 | 22 | 22 | 8.9 | 8.9 |
| Palm Springs/Desert Wtr Agency | 64.9 | 150 | 150 | 120 | 120 | 7.0 | 7.0 |
| San Diego | 66.2 | 224 | 235 | 131 | 135 | 8.0 | 8.2 |
| San Jose/California Wtr Serv Co | 68.0 | | 181 | | 134 | | 7.9 |
| Santa Barbara/Santa Barbara Pub | 66.2 | 550 | 550 | 210 | 200 | 8.1 | 7.9 |
| Santa Monica | 68.0 | 400 | 180 | 220 | 220 | 7.8 | 8.1 |
| Sunnyvale | 60.1 | 300 | 140 | 200 | | 8.0 | 7.3 |
| **Colorado** | | | | | | | |
| Boulder | 54.5 | 13 | 23 | | | 7.0 | 7.2 |
| Colorado Spgs | 42.3 | 34 | 36 | 22 | 29 | 7.5 | 7.7 |
| Denver | 50.0 | 102 | 99 | 72 | 63 | 8.0 | 7.5 |
| Greeley | 50.5 | 34 | 36 | 42 | 41 | 7.4 | 7.1 |
| **Connecticut** | | | | | | | |
| Bridgeport | 55.8 | 28 | 45 | 14 | 19 | 6.7 | 7.1 |
| Hartford | 55.4 | | 20 | | 8 | 6.5 | 7.1 |
| New Britain | 50.0 | 50 | 35 | 12 | 14 | 6.5 | 8.3 |
| New Haven/Regional Wtr Authority | 53.6 | 50 | 69 | 46 | 53 | 7.1 | 6.9 |
| **Delaware** | | | | | | | |
| Newark/Artesian Wtr Co | 55.4 | 77 | 77 | 40 | 45 | 5.8 | 7.4 |
| **District of Columbia** | | | | | | | |
| Washington/Washington Aqueduct | 62.6 | 127 | 137 | 77 | 70 | 8.0 | 7.7 |
| **Florida** | | | | | | | |
| Clearwater/Pinellas Cnty Wtr Sys | 75.2 | 215 | 215 | 200 | 210 | 7.2 | 7.8 |
| Fort Lauderdale | 78.8 | 259 | 90 | 231 | 59 | 7.6 | 9.6 |
| Jacksonville | 79.0 | 248 | 248 | 139 | 138 | 7.5 | 7.5 |
| Miami | 77.0 | 250 | 66 | 224 | 37 | 7.3 | 9.0 |
| Orlando | 75.2 | 125 | 125 | 120 | 120 | 7.8 | 7.4 |
| Pompano Beach | 68.0 | 240 | 63 | 198 | 30 | 7.1 | 8.8 |
| Tallahassee | 68.0 | | 143 | | | | 7.8 |
| Tampa | 72.5 | 107 | 151 | 90 | 85 | 7.5 | 7.7 |
| W. Palm Beach/City of West Palm | 68.2 | 71 | 102 | 58 | 58 | 8.1 | 8.4 |
| Winter Haven | 74.5 | 140 | 140 | 125 | 125 | 8.1 | 7.8 |
| **Georgia** | | | | | | | |
| Acworth/Wyckoff Treatment Div | 61.3 | 17 | 30 | 15 | 22 | 6.7 | 7.5 |
| Marietta/Quarles Treatment Div | 53.6 | 15 | 25 | 10 | 18 | 6.8 | 8.7 |
| Stone Mountain/Dekalb Cnty Wtr | 64.4 | 14 | 28 | 11 | 17 | 6.8 | 8.9 |
| **Hawaii** | | | | | | | |
| Honolulu | | | 60 | | 60 | | 8.0 |
| Pearl Harbor | 72.0 | 121 | | 69 | | 6.9 | |
| **Idaho** | | | | | | | |
| Boise | | | 117 | | 223 | | 7.6 |

*(Continued)*

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**Table 8D.38 (Continued)**

| State and Water Utility | Avg Temp Raw (°F) | Hardness ($CaCO_3$) Raw (mg/L) | Hardness ($CaCO_3$) Finished (mg/L) | Alkalinity ($CaCO_3$) Raw (mg/L) | Alkalinity ($CaCO_3$) Finished (mg/L) | pH Raw | pH Finished |
|---|---|---|---|---|---|---|---|
| **Illinois** | | | | | | | |
| Champaign/Northern Illinois Wtr | 53.6 | 258 | 80 | 336 | 110 | 7.7 | 9.0 |
| East St. Louis/Interurban Dist | 60.8 | 228 | 228 | 159 | 144 | 7.7 | 7.2 |
| Peoria/Peoria Dist/IL-Amer Wtr | 53.6 | 250 | 250 | 170 | 161 | 8.0 | 7.6 |
| Springfield | 60.8 | 195 | 105 | 140 | 25 | 8.2 | 9.8 |
| **Indiana** | | | | | | | |
| Bloomington | 59.0 | 64 | 80 | 28 | 34 | 7.3 | 8.0 |
| Fort Wayne | 55.4 | 272 | 97 | 200 | 25 | 7.9 | 9.7 |
| Indianapolis | 57.2 | | 252 | 170 | 159 | 8.1 | 7.6 |
| South Bend | 51.8 | 340 | 340 | 260 | 260 | 8.5 | 7.8 |
| **Iowa** | | | | | | | |
| Cedar Rapids | 53.6 | 276 | 129 | 217 | 67 | 7.7 | 9.5 |
| Davenport/Davenport Water Co | 55.9 | 200 | 200 | 155 | 129 | 8.2 | 7.1 |
| Des Moines | 51.1 | 304 | 145 | 239 | 63 | 8.3 | 9.3 |
| Sioux City | 54.0 | 445 | 445 | 267 | 267 | 7.2 | 7.5 |
| **Kansas** | | | | | | | |
| Kansas City | 62.6 | 294 | 272 | 205 | 215 | 8.1 | 8.0 |
| Mission/Johnson Cnty Wtr Dist 1 | 59.0 | 245 | 121 | 191 | 54 | 7.8 | 9.1 |
| Topeka | 57.2 | 250 | 114 | 195 | 79 | 8.2 | 9.4 |
| **Kentucky** | | | | | | | |
| Lexington/Kentucky–American Wtr | 59.9 | 165 | 148 | 66 | 72 | 7.7 | 8.1 |
| Louisville | 57.2 | 138 | 148 | 66 | 65 | 7.5 | 8.5 |
| **Louisiana** | | | | | | | |
| Baton Rouge/Baton Rouge Wtr Wks | | 5 | 5 | | 175 | 8.7 | 8.5 |
| Jefferson | 64.4 | 154 | 152 | 104 | 99 | 7.5 | 7.4 |
| Lake Charles | 69.8 | 110 | 110 | 160 | 175 | 7.1 | 8.0 |
| New Orleans | 64.0 | 161 | 117 | 106 | 61 | 8.0 | 10.1 |
| **Maine** | | | | | | | |
| Portland | 50.0 | 9 | 9 | 4 | | 6.9 | 6.7 |
| **Maryland** | | | | | | | |
| Annapolis/City of Annapolis Wtr | 64.4 | 25 | 70 | 20 | 50 | 6.0 | 8.7 |
| Baltimore | | 47 | 70 | 40 | 46 | 7.3 | 8.0 |
| Glen Burnie/Anne Arundel Cnty | 53.6 | 41 | 56 | | | 5.1 | 8.5 |
| **Massachusetts** | | | | | | | |
| Fall River | 46.0 | 2 | 3 | 1 | 5 | 5.7 | 8.5 |
| Springfield | 45.7 | 11 | 11 | 8 | 11 | 6.4 | 6.9 |
| Weymouth | 55.0 | 21 | 47 | 7 | 11 | 6.5 | 8.4 |
| **Michigan** | | | | | | | |
| Ann Arbor | 55.8 | 269 | 142 | 210 | 60 | 8.0 | 9.3 |
| Grand Rapids | 45.9 | 140 | 141 | 115 | 106 | 8.4 | 7.6 |
| Lansing | 51.8 | 412 | 88 | 318 | 39 | 7.0 | 9.4 |
| Saginaw | | 96 | 106 | 82 | 84 | 8.0 | 8.2 |
| **Minnesota** | | | | | | | |
| Bloomington | 50.0 | 310 | 90 | 315 | 92 | 7.6 | 8.3 |
| Duluth | 39.6 | 45 | 45 | 43 | 36 | 7.9 | 7.1 |
| St. Paul | 51.8 | 175 | 92 | 166 | 62 | 8.1 | 8.4 |
| **Mississippi** | | | | | | | |
| Jackson | 65.7 | 19 | 52 | 15 | 17 | 6.5 | 8.8 |
| **Missouri** | | | | | | | |
| Independence/Missouri Wtr Co | 59.5 | 297 | 119 | 227 | 48 | 7.3 | 9.6 |
| Kansas City/Kansas City, Mo Wtr | 55.0 | 261 | 173 | 182 | 85 | 8.2 | 9.5 |
| Springfield | 61.5 | 150 | 152 | 132 | 123 | 7.6 | 7.3 |
| St. Louis/St. Louis Cnty Wtr Co | 57.2 | 221 | 124 | 155 | 48 | 8.3 | 9.5 |
| Lincoln | 54.0 | 240 | 240 | 180 | 180 | 7.8 | 7.8 |
| Omaha | 53.2 | 286 | 185 | 177 | 68 | 8.2 | 9.0 |
| **Nevada** | | | | | | | |
| Las Vegas | 59.4 | 288 | 287 | 128 | 130 | 8.0 | 7.9 |
| Reno/Sierra Pacific Power Co | 53.6 | 40 | 40 | 40 | 27 | 7.7 | 6.9 |
| **New Hampshire** | | | | | | | |
| Manchester | 59.0 | 11 | 11 | 3 | 4 | 6.3 | 7.2 |
| Nashua/Pennichuck Wtr Wks | 59.0 | 30 | 50 | 9 | 16 | 6.4 | 7.3 |
| **New Jersey** | | | | | | | |
| Clifton/Passaic Valley Wtr Comm | 54.0 | 86 | 85 | 58 | 55 | 7.2 | 7.1 |
| East Orange | 50.0 | 280 | 280 | 158 | 158 | 7.7 | 7.7 |

*(Continued)*

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**Table 8D.38 (Continued)**

| State and Water Utility | Avg Temp Raw (°F) | Hardness ($CaCO_3$) Raw (mg/L) | Hardness ($CaCO_3$) Finished (mg/L) | Alkalinity ($CaCO_3$) Raw (mg/L) | Alkalinity ($CaCO_3$) Finished (mg/L) | pH Raw | pH Finished |
|---|---|---|---|---|---|---|---|
| Elizabeth/Elizabethtown Wtr Co | 51.8 | 73 | 86 | 47 | 40 | 7.5 | 7.2 |
| Harrington Park/Hackensack Wtr | 55.4 | 120 | 120 | 85 | 80 | 7.4 | 7.9 |
| Parsippany | 52.0 | 177 | 177 | 139 | 139 | 7.1 | 7.1 |
| Short Hills/Commonwealth Wtr Co | 55.0 | 72 | 135 | 42 | 77 | 7.8 | 7.4 |
| Toms River | 65.3 | 12 | 60 | 38 | 70 | 6.2 | 7.4 |
| Wanaque/North NJ Dist Wtr Supply | 50.0 | 28 | 36 | 16 | 20 | 6.7 | 7.4 |
| **New Mexico** | | | | | | | |
| Albuquerque | 69.8 | 120 | 120 | 138 | 138 | 7.3 | 7.3 |
| Santa Fe/Sangre De Cristo Wtr Co | 59.0 | 150 | 150 | 200 | 200 | 7.8 | 7.8 |
| **New York** | | | | | | | |
| Albany | 48.4 | 43 | 54 | 38 | 48 | 7.3 | 8.9 |
| Buffalo/Tonawanda Wtr Dept | 55.4 | 140 | 135 | 95 | 90 | 8.2 | 7.8 |
| East Meadow/Hempstead Wtr Dept | | 30 | 30 | 5 | 30 | 5.6 | 8.6 |
| Lake Success/Jamaica Water Co. | | 50 | 50 | 30 | 50 | 6.3 | 7.2 |
| Massapequa | 62.1 | 8 | 13 | 6 | 30 | 5.8 | 7.2 |
| New York/New Bur Wtr Supply | | | 65 | 37 | | 7.3 | |
| Rochester/Monroe Cnty Wtr Auth | 55.9 | 130 | 130 | 95 | 90 | 7.8 | 7.4 |
| Syracuse | 52.0 | 120 | 120 | 100 | 100 | 8.2 | 8.1 |
| Yonkers | 59.0 | 110 | 100 | 80 | 65 | 7.1 | 6.5 |
| **North Carolina** | | | | | | | |
| Charlotte | 64.9 | 13 | 28 | 12 | 19 | 7.2 | 9.2 |
| Greensboro | 64.4 | 27 | 44 | 24 | 26 | 7.0 | 7.7 |
| Raleigh | 68.0 | 20 | 40 | 29 | 30 | 6.8 | 7.4 |
| Winston-Salem/Cnty Util Com | 60.8 | 16 | 30 | 16 | 20 | 7.0 | 7.4 |
| **North Dakota** | | | | | | | |
| Fargo | 44.6 | 289 | 123 | 203 | 84 | 8.1 | 9.1 |
| **Ohio** | | | | | | | |
| Akron | 54.3 | 112 | 112 | 78 | 74 | 7.6 | 7.3 |
| Cincinnati | 60.1 | 112 | 130 | 44 | 54 | 7.6 | 8.5 |
| Cleveland | 50.9 | 125 | 125 | 92 | 84 | 8.0 | 7.5 |
| Dayton | | 362 | 149 | 278 | 62 | 7.5 | 8.6 |
| Toledo | | 127 | 74 | 93 | 38 | 8.1 | 9.2 |
| **Oklahoma** | | | | | | | |
| Oklahoma City | 63.9 | 154 | 101 | 97 | 40 | 8.2 | 10.3 |
| Tulsa | 66.2 | 140 | 136 | 97 | 102 | 8.0 | 8.2 |
| Oregon | | | | | | | |
| Eugene | 55.4 | 24 | 22 | 23 | 22 | 7.5 | 7.3 |
| Medford | 44.6 | 33 | 33 | 35 | 35 | 6.8 | 6.8 |
| Portland | 50.0 | 12 | 12 | 12 | 10 | 7.1 | 6.8 |
| **Pennsylvania** | | | | | | | |
| Allentown | 55.9 | 176 | 199 | 128 | 144 | 7.7 | 7.6 |
| Bryn Mawr/Philadelphia Suburban | 58.3 | 109 | 208 | 35 | 38 | 7.0 | 7.4 |
| Hershey/Riverton Consol Wtr Co | 58.6 | 145 | 145 | 121 | 110 | 8.0 | 7.4 |
| Lancaster | 57.2 | 195 | 208 | 135 | 126 | 7.8 | 7.6 |
| Philadelphia | 55.4 | 148 | 132 | 64 | 53 | 7.6 | 7.0 |
| Pittsburgh/Western Pennsylvania | 56.8 | 111 | 122 | 21 | 31 | 7.3 | 7.3 |
| **Rhode Island** | | | | | | | |
| Newport | 60.8 | 60 | 70 | 22 | 26 | 6.5 | 7.5 |
| West Warwick/Kent Cnty Wtr Auth | | 32 | 32 | 13 | 13 | 5.8 | 6.8 |
| **South Carolina** | | | | | | | |
| Anderson | 66.0 | 6 | 6 | 9 | 10 | 7.0 | 7.1 |
| Charleston | 68.0 | 29 | 29 | 24 | 30 | 6.8 | 8.2 |
| Spartanburg | 62.6 | 11 | 20 | 11 | 11 | 6.9 | 7.1 |
| **South Dakota** | | | | | | | |
| Rapid City | 55.0 | 283 | 283 | 180 | 180 | 7.7 | 7.5 |
| **Tennessee** | | | | | | | |
| Chattanooga/Tennessee-American | 64.9 | 68 | 77 | 53 | 50 | 7.1 | 7.2 |
| Knoxville/Knoxville Utils Brd | 60.8 | 81 | 83 | 78 | 70 | 7.6 | 7.5 |
| Memphis | 63.3 | 47 | 47 | 55 | 55 | 6.4 | 7.2 |
| Nashville/Metro Dept Wtr & Swr | 60.8 | 90 | 90 | 65 | 65 | 7.6 | 8.0 |
| **Texas** | | | | | | | |
| Arlington | 69.8 | 109 | 110 | 90 | 90 | 8.0 | 8.2 |
| Dallas | 64.4 | 130 | 86 | 110 | 50 | 8.0 | 8.9 |
| El Paso | 68.0 | 250 | 150 | 192 | 80 | 8.2 | 8.7 |

*(Continued)*

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**Table 8D.38 (Continued)**

| State and Water Utility | Avg Temp Raw (°F) | Hardness ($CaCO_3$) Raw (mg/L) | Hardness ($CaCO_3$) Finished (mg/L) | Alkalinity ($CaCO_3$) Raw (mg/L) | Alkalinity ($CaCO_3$) Finished (mg/L) | pH Raw | pH Finished |
|---|---|---|---|---|---|---|---|
| Fort Worth | 66.2 | 105 | 107 | 87 | 93 | 8.0 | 8.5 |
| Lubbock | 60.1 | 223 | 222 | 177 | 166 | 8.3 | 7.8 |
| San Antonio | 75.7 | 250 | | 215 | | 7.2 | |
| Wichita Falls | 69.8 | 125 | 70 | 125 | 50 | 8.1 | 9.4 |
| **Utah** | | | | | | | |
| Ogden | 53.6 | 170 | 125 | 131 | 118 | 7.4 | 7.1 |
| Salt Lake City/Salt Lake Cnty Co | 46.0 | 159 | 156 | 137 | 132 | 7.4 | 7.3 |
| **Vermont** | | | | | | | |
| Burlington | 50.0 | 69 | 59 | 47 | 47 | 7.6 | 8.0 |
| **Virginia** | | | | | | | |
| Merrifield/Fairfax Cnty Wtr Auth | 59.0 | 60 | 90 | 33 | 44 | 7.3 | 7.5 |
| Newport News | 60.8 | 80 | 80 | 55 | 50 | 7.4 | 7.1 |
| Norfolk | 64.9 | 45 | 69 | 40 | 37 | 6.8 | 7.0 |
| Richmond/City of Richmond | 57.2 | 70 | 70 | 45 | 35 | 7.6 | 7.5 |
| **Washington** | | | | | | | |
| Everett | 51.1 | 12 | 12 | 11 | 20 | 6.5 | 7.2 |
| Seattle/Seattle Wtr Dept | 47.3 | 15 | 17 | 11 | 16 | 7.2 | 7.7 |
| Tacoma | 50.0 | 15 | 15 | 20 | 20 | 6.9 | 6.9 |
| Vancouver | 53.0 | 98 | 98 | | | 6.7 | 6.7 |
| **West Virginia** | | | | | | | |
| Charleston/W VA Wtr Co - Kanawha | 57.9 | 47 | 62 | 19 | 26 | 6.8 | 8.7 |
| Huntington | 69.0 | 109 | 121 | 39 | 38 | 7.4 | 7.3 |
| Wheeling | 56.5 | 109 | 129 | 32 | 40 | 7.4 | 8.9 |
| **Wisconsin** | | | | | | | |
| Green Bay | 46.4 | | 130 | 132 | 118 | 8.2 | 7.6 |
| Madison | 50.0 | 350 | 350 | 300 | 300 | 7.4 | 7.4 |
| Milwaukee | | 93 | 93 | 112 | 104 | 8.2 | 7.5 |
| Racine | 44.3 | 140 | 140 | 112 | 107 | 8.3 | 7.7 |
| **Wyoming** | | | | | | | |
| Casper | 48.9 | 175 | 208 | | 124 | 8.1 | 7.4 |
| Cheyenne | 61.9 | 110 | 110 | 63 | 65 | 7.2 | 7.1 |

*Note:* Average temperature, hardness, alkalinity, and pH; selected systems only. The quality of water supplied by municipal water systems in 1996 is available from the American Water Works Association, American Water Works Association WaterStats2ev2, Water:\STATS 1996 Survey, Water Quality, www.awwa.org.

*Source*: From American water works association 1984 Water Utility Operating Data. Copyright AWWA.

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**Table 8D.39 Radium-226, Radium-228, Radon-222, and Uranium in Public Drinking Water Supplies in the United States (Population-Weighted Average Activates)**

| State | Radium-226 (pCi/L) | Radium-228 (pCi/L) | Radon-222 (pCi/L) | Uranium (μg/L) |
|---|---|---|---|---|
| Alabama | 0.202 | 1.00 | 420.1 | 0.30 |
| Alaska | 0.180 | 1.00 | 128.5 | 0.16 |
| Arizona | 0.180 | 1.03 | 1435.1 | 3.65 |
| Arkansas | 0.285 | 1.01 | 100.0 | 0.15 |
| California | 0.332 | 1.02 | 228.4 | 1.54 |
| Colorado | 0.199 | 1.00 | 329.9 | 6.81 |
| Connecticut | 0.206 | 1.00 | 1208.9 | 1.24 |
| Delaware | 0.180 | 1.62 | 123.3 | 0.10 |
| Florida | 0.341 | 1.01 | 127.3 | 0.22 |
| Georgia | 1.274 | 1.01 | 563.4 | 1.31 |
| Hawaii | — | — | — | — |
| Idaho | 0.181 | 1.00 | 437.4 | 2.60 |
| Illinois | 5.290 | 4.24 | 193.2 | 0.36 |
| Indiana | 0.347 | 1.22 | 187.4 | 1.05 |
| Iowa | 0.390 | 1.02 | 136.4 | 0.96 |
| Kansas | 0.195 | 1.00 | 396.1 | 3.39 |
| Kentucky | 0.184 | 1.00 | 205.5 | 0.38 |
| Louisiana | 0.218 | 1.00 | 108.2 | 0.12 |
| Maine | 0.180 | 1.00 | 1228.4 | 0.42 |
| Maryland | 0.486 | 1.00 | 266.1 | 0.08 |
| Massachusetts | 0.180 | 1.00 | 587.8 | 0.48 |
| Michigan | 0.357 | 1.10 | 185.2 | 0.23 |
| Minnesota | 1.899 | 1.82 | 388.7 | 0.87 |
| Mississippi | 0.390 | 1.10 | 104.3 | 0.10 |
| Missouri | 1.283 | 1.13 | 143.7 | 1.27 |
| Montana | 0.244 | 1.00 | 344.6 | 1.95 |
| Nebraska | 0.281 | 1.04 | 351.6 | 3.56 |
| Nevada | 0.180 | 1.00 | 743.2 | 2.85 |
| New Hampshire | 0.255 | 1.00 | 2673.5 | 1.70 |
| New Jersey | 0.181 | 1.00 | 137.1 | 0.09 |
| New Mexico | 0.396 | 1.15 | 309.1 | 7.99 |
| New York | 0.185 | 1.01 | 223.7 | 0.24 |
| North Carolina | 0.389 | 1.14 | 2277.7 | 1.13 |
| North Dakota | 0.194 | 1.02 | 114.0 | 0.90 |
| Ohio | 0.373 | 1.02 | 175.2 | 0.91 |
| Oklahoma | 0.383 | 1.00 | 158.0 | 4.02 |
| Oregon | 0.180 | 1.00 | 118.2 | 0.14 |
| Pennsylvania | 0.227 | 1.00 | 507.8 | 0.83 |
| Rhode Island | 0.180 | 1.00 | 1170.0 | 0.10 |
| South Carolina | 0.250 | 1.06 | 557.7 | 0.52 |
| South Dakota | 0.185 | 1.00 | 281.6 | 3.84 |
| Tennessee | 0.228 | 1.01 | 113.7 | 0.16 |
| Texas | 0.327 | 1.03 | 150.5 | 0.86 |
| Utah | 0.252 | 1.00 | 226.8 | 2.94 |
| Vermont | 0.189 | 1.00 | 997.1 | 0.42 |
| Virginia | 0.215 | 1.00 | 485.4 | 0.61 |
| Washington | 0.180 | 1.00 | 432.5 | 1.52 |
| West Virginia | 0.189 | 1.00 | 263.6 | 0.22 |
| Wisconsin | 2.688 | 3.32 | 367.2 | 0.95 |
| Wyoming | 0.770 | 1.41 | 558.0 | 1.32 |
| United States | 0.905 | 1.41 | 249.0 | 0.82 |

*Note:* Minimum Reporting Limit (MRL) was used in the average for those cases in which the activity or concentration was les than the MRL. The international unit of activity is the Becquerel (Bq), which is approximately equal to 27 pCi.

*Source*: From Longtin, J., 1990, Chapter 8, Occurrence of radionuclides in drinking water, a national study In Cothern, R. and Rebers, P (Editors), 1990, *Radon, Radium, and Uranium in Drinking Water*, Lewis Publishers, Inc, Chelsea, Michigan.

*Original Source*: From Longtin, J., 1988.

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**Table 8D.40 Occurrence of Selected Radionuclides in Groundwater Used for Drinking Water in the United States**

| | Concentration (Picocuries/L) | | | | |
|---|---|---|---|---|---|
| **Radionuclide** | **Mean** | **Median** | **Standard Deviation** | **Maximum** | **Number of Samples** |
| Ra-224 | 3.2 | 0.3 | 10.1 | 73.6 | 99 |
| Ra-226 | 1.6 | 0.4 | 2.8 | 16.9 | 99 |
| Ra-228 | 2.1 | 0.5 | 7.9 | 72.3 | 99 |
| Pb-210 | 0.6 | 0.5 | 0.5 | 4.1 | 96 |
| Po-210 | 0.1 | 0.01 | 0.5 | 4.9 | 96 |

*Source*: From Focazio, M.J., et al., 2001, *Occurrence of Selected Radionuclides in Groundwater Used for Drinking Water in the United States: A Reconnaissance Survey*, 1998, USGS Water-Resources Investigations Report 00-4273, www.usgs.gov.

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**Table 8D.41 Concentrations of Uranium and Thorium Series Radionuclides in Drinking Water in the United States, Asia, and Europe**

| | Concentration (mBq $kg^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Region/country** | **$^{238}U$** | **$^{230}Th$** | **$^{226}Ra$** | **$^{210}Pb$** | **$^{210}Po$** | **$^{232}Th$** | **$^{228}Ra$** | **$^{228}Th$** | **$^{235}U$** |
| North America | 0.3–77 | 0.1 | 0.4–1.8 | 0.1–1.5 | | 0.05 | 0–0.5 | | 0.04 |
| United States | | | | | | | | | |
| Asia | | | | | | | | | |
| China | 0.1–700 | | 0.2–120 | | | 0.04–12 | | | |
| India | 0.09–1.5 | | | | | | | | |
| Europe | | | | | | | | | |
| Finland | 0.5–150,000 | | 10–49,000 | 0.2–21,000 | 0.2–7,600 | | 18–570 | | |
| France | 4.4–930 | | 7–700 | | | 0–4.2 | | | |
| Germany | 0.4–600 | | 1–1,800 | 0.2–200 | 0.1–200 | | | | |
| Italy | 0.5–130 | | 0.2–1,200 | | | | | | |
| Poland | 7.3 | 1.4 | 1.7–4.5 | 1.6 | 0.5 | 0.06 | | | |
| Romania | 0.4–37 | | 0.7–21 | 7–44 | 7–44 | 0.04–9.3 | | | |
| Switzerland | 0–1,000 | | 0–1,500 | | | | 0–200 | | 0–50 |
| Spain | 3.7–4.4 | | $<$20–4,000 | | | | | | |
| UK | | | 0–180 | 40–200 | | | | | |
| Reference value | 1 | 0.1 | 0.5 | 10 | 5 | 0.05 | 0.5 | 0.05 | 0.04 |

*Source*: From The United Nations is the author of the original material. United Nations Scientific Committee on the Effects of Atomic Radiation, 2000, *UNSCEAR 2000 Report Vol. I, Sources and Effects of Ionizing Radiation*.



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**Table 8D.42 Radon in Public Drinking Water Supplies in the United States (Population-Weighted Average Activities (pCi/L))**

| | Sites with ≤1000 People | | Sites with >1000 People | |
|---|---|---|---|---|
| **State** | **Cothern** | **NIRS** | **Cothern** | **NIRS** |
| Alabama | 160 (40) | 2,025 (5) | 160 (35) | 171 (26) |
| Alaska | 100 (47) | 129 (44) | 100 (47) | — |
| Arizona | 120 (44) | 1,302 (7) | 320 (17) | 1,610 (1) |
| Arkansas | 75 (51) | — | 75 (50) | 100 (42) |
| California | 500 (18) | 538 (18) | 500 (10) | 161 (28) |
| Colorado | 380 (23) | 336 (29) | 380 (14) | 317 (12) |
| Connecticut | 1,500 (3) | 3,328 (1) | 770 (4) | 646 (2) |
| Delaware | 100 (48) | 116 (48) | 126 (42) | 126 (33) |
| Florida | 1,000 (9) | 393 (25) | 148 (40) | 118 (35) |
| Georgia | 1,100 (6) | 419 (24) | 150 (37) | 583 (4) |
| Hawaii | 50 (52) | — | 50 (51) | — |
| Idaho | 256 (30) | 431 (22) | 256 (25) | 438 (9) |
| Illinois | 100 (49) | 136 (40) | 167 (34) | 198 (20) |
| Indiana | 105 (45) | 136 (41) | 105 (45) | 195 (22) |
| Iowa | 250 (31) | 166 (35) | 200 (29) | 130 (32) |
| Kansas | 250 (32) | 365 (27) | 106 (44) | 370 (11) |
| Kentucky | 250 (33) | 148 (39) | 110 (43) | 220 (19) |
| Louisiana | 180 (39) | 116 (49) | 180 (31) | 107 (41) |
| Maine | 10,000 (1) | 1,228 (9) | 2,000 (1) | — |
| Maryland | 700 (15) | 2,161 (4) | 450 (11) | 112 (36) |
| Massachusetts | 1,500 (4) | 253 (33) | 770 (5) | 596 (3) |
| Michigan | 105 (46) | 370 (26) | 105 (46) | 164 (27) |
| Minnesota | 210 (36) | 342 (28) | 210 (28) | 397 (10) |
| Mississippi | 150 (41) | 133 (42) | 82 (49) | 100 (43) |
| Missouri | 300 (24) | 125 (46) | 100 (48) | 148 (33) |
| Montana | 500 (19) | 535 (19) | 328 (16) | 112 (37) |
| Nebraska | 300 (25) | 291 (31) | 290 (19) | 444 (8) |
| Nevada | 550 (17) | 743 (12) | 550 (9) | — |
| New Hampshire | 1,400 (5) | 2,674 (3) | 1,183 (2) | — |
| New Jersey | 150 (42) | 737 (13) | 300 (18) | 125 (34) |
| New Mexico | 200 (37) | 423 (23) | 180 (32) | 250 (16) |
| New York | 500 (20) | 647 (14) | 132 (41) | 173 (25) |
| North Carolina | 1,100 (7) | 2,876 (2) | 278 (21) | 100 (44) |
| North Dakota | 300 (26) | 125 (47) | 150 (38) | 109 (40) |
| Ohio | 200 (38) | 164 (36) | 169 (33) | 177 (24) |
| Oklahoma | 250 (34) | 164 (37) | 160 (36) | 158 (29) |
| Oregon | 300 (27) | 130 (43) | 264 (23) | 112 (38) |
| Pennsylvania | 1,000 (10) | 467 (20) | 720 (6) | 535 (5) |
| Rhode Island | 3,400 (2) | 1,170 (10) | 1,151 (3) | — |
| South Carolina | 1,100 (8) | 1,260 (8) | 276 (22) | 196 (21) |
| South Dakota | 300 (28) | 334 (30) | 290 (20) | 273 (15) |
| Tennessee | 100 (50) | 128 (45) | 24 (52) | 112 (39) |
| Texas | 150 (43) | 264 (32) | 150 (39) | 138 (31) |
| Utah | 500 (21) | 157 (38) | 360 (15) | 238 (18) |
| Vermont | 250 (35) | 1,533 (6) | 656 (8) | 497 (7) |
| Virginia | 700 (16) | 952 (11) | 450 (12) | 313 (13) |
| Washington | 300 (29) | 238 (34) | 264 (24) | 520 (6) |
| West Virginia | 1,000 (11) | 459 (21) | 720 (7) | 240 (17) |
| Wisconsin | 750 (14) | 540 (17) | 234 (27) | 300 (14) |
| Wyoming | 880 (12) | 558 (16) | 415 (13) | — |
| Puerto Rico | 500 (22) | — | 200 (30) | — |
| United States | 780 (13) | 602 (15) | 240 (26) | 194 (23) |

*Note:* Numbers in parentheses are relative rankings; The international unit of activity is the Becquerel (Bq), which is approximately equal to 27 pCi.

*Source*: From Longtin, J., 1990, Chapter 8, Occurrence of radionuclides in drinking water, a national study In Cothern, R. and Rebers, P (Editors), 1990, *Radon, Radium, and Uranium in Drinking Water*, Lewis Publishers, Inc, Chelsea, Michigan.

*Original Source*: Longtin, J., 1988.

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**Table 8D.43 Number of Public Drinking Water Supplies in the United States Exceeding Various Levels of Radon**

| Lifetime Risk Level | Radon Concentration (pCi/L) | Estimated Numbers That Exceed the Concentration in Column 2 | |
|---|---|---|---|
| | | Public Drinking Water Supplies | Population thousands |
| $10^{-3}$ | 10,000 | 500–4000 | 20–300 |
| $10^{-4}$ | 1,000 | 1000–10,000 | 200–4000 |
| $10^{-5}$ | 100 | 5000–30,000 | 10,000–100,000 |
| $10^{-6}$ | 10 | 10,000–40,000 | 50,000–100,000 |

*Note:* Rounded off to one significant figure.

*Source*: From Cothern, C.R., 1987, Estimating the health risk of radon in drinking water, *J. Am. Water Works Assoc.*, vol. 79, no. 4. Copyright AWWA. Reprinted with permission.

**Table 8D.44 Occurrence of Radon in Well Water in the United States**

| State | Number of Wells Sampled | Range of Detected Radon Levels (pCi/L) | Mean Radon Concentration (pCi/L) | Associated Error ± pCi/L |
|---|---|---|---|---|
| Arizona | 5 | 434–681 | 582 | 105 |
| California | 44 | <100–2,003 | 589 | 91 |
| Connecticut | 3 | 757–984 | 841 | 98 |
| Iowa | 6 | All<100 | 12 | 75 |
| Illinois | 16 | 182–714 | 449 | 115 |
| Indiana | 28 | <100–624 | 324 | 106 |
| Massachusetts | 28 | <100–3,288 | 1,145 | 101 |
| New Hampshire | 12 | 880–4,609 | 1,716 | 134 |
| New Jersey | 113 | <100–3,805 | 394 | 79 |
| New Mexico | 36 | <100–678 | 253 | 266 |
| Ohio | 10 | <100–343 | 148 | 116 |
| Pennsylvania | 64 | <100–4,622 | 1,570 | 89 |
| Rhode Island | 3 | 640–787 | 702 | 61 |
| Virginia | 2 | 465–468 | 467 | 53 |
| West Virginia | 7 | <100–281 | 93 | 42 |
| Cumulative | 377 | <100–4,622 | 686 | 104 |

*Note:* Range of detected radon concentrations and corresponding mean radon levels.

*Source*: From Dixon, K.L., and Lee, R.G., 1988, Occurrence of radon in well supplies, *J. Am. Water Works Assoc.*, vol. 80, no. 7. Copyright AWWA. Reprinted with permission.

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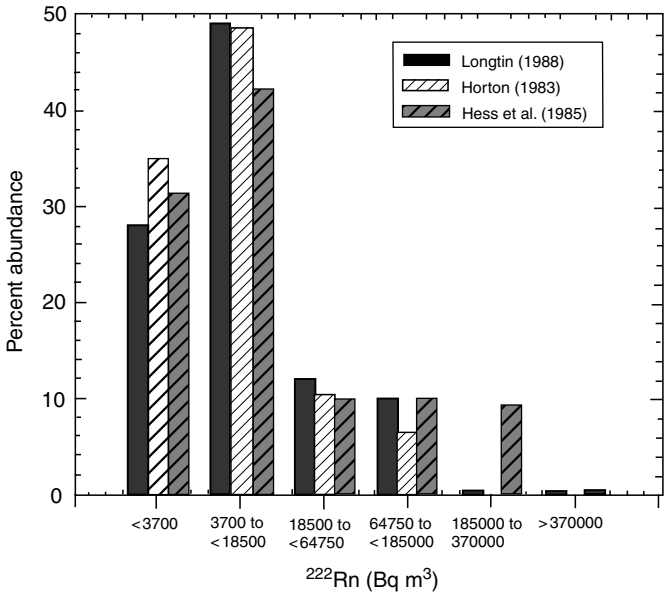


**Figure 8D.12** Distributions of radon in drinking water in several studies in the United States. (Reprinted with permission from (*Risk Assessment of Radon in Drinking Water*) © (1999) by the National Academy of Sciences, Courtesy of the National Academies Press, Washington, DC)

**Table 8D.45 Aluminum in Public Drinking Water Supplies in the United States**

| Category | Samples | Samples With Concentrations >0.05 mg/L percent | Samples with Concentrations >0.014 mg/L | | | Overall Median (mg/L) |
|---|---|---|---|---|---|---|
| | | | Percent | Median (mg/L) | Maximum (mg/L) | |
| Region | | | | | | |
| I | 46 | 13 | 33 | 0.043 | 0.179 | <0.014 |
| II | 71 | 25 | 44 | 0.066 | 0.249 | <0.014 |
| III | 123 | 37 | 54 | 0.070 | 2.670 | 0.022 |
| IV | 80 | 54 | 68 | 0.161 | 0.449 | 0.060 |
| V | 100 | 51 | 64 | 0.082 | 2.160 | 0.051 |
| VI | 35 | 29 | 60 | 0.040 | 0.889 | 0.029 |
| VII | 53 | 2 | 13 | 0.026 | 0.051 | <0.014 |
| VIII | 105 | 30 | 47 | 0.083 | 2.580 | <0.014 |
| IX | 89 | 29 | 52 | 0.053 | 1.167 | 0.020 |
| X | 14 | 0 | 7 | | | <0.014 |
| Population served | | | | | | |
| 25–9999 | 286 | 15 | 28 | 0.051 | 1.167 | <0.014 |
| 10,000–99,999 | 92 | 39 | 61 | 0.087 | 2.580 | 0.023 |
| 100,000–999,999 | 222 | 48 | 66 | 0.094 | 2.670 | 0.045 |
| ≥1,000,000 | 116 | 38 | 62 | 0.058 | 0.402 | 0.033 |

*Note:* Finished water; by USEPA region and population category.

*Source*: From Miller, R.G. and others, 1984. The occurrence of aluminum in drinking water, *J. Am. Water Works Assoc.*, vol. 76, no. 1. Copyright Am. Water Works Assoc. Reprinted with permission.

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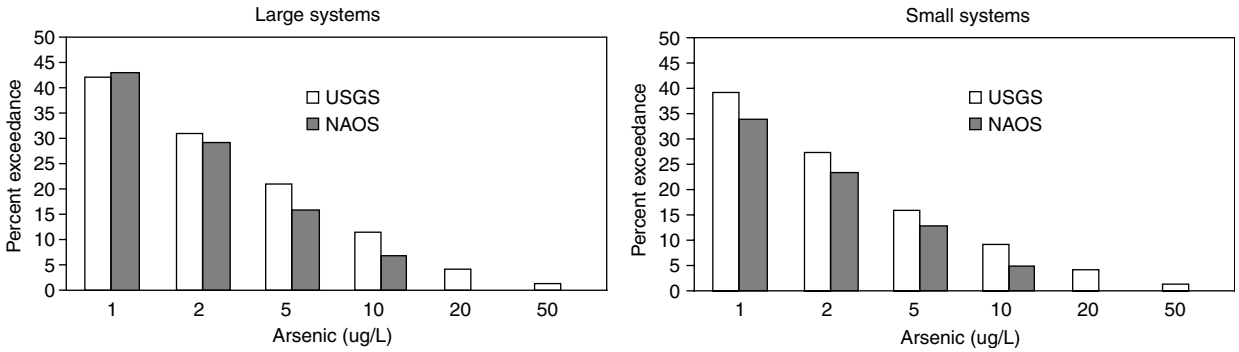


**Figure 8D.13** Exceedance frequency of arsenic concentrations in small and large regulated water supply systems in the United States. (From Welch, A.H., et al. 1999, Arsenic in groundwater supplies of the United States, In: *Arsenic Exposure and Health Effects*, W.R. Chappell, C.O. Abernathy and R.L. Calderon, Eds., Elsevier Science, New York, pp. 9–17, http://water.usgs.gov.)

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**Table 8D.46 Statistical Results of Differences in Arsenic Concentrations in Water Collected from Public Water-Supply Wells and Other Types of Wells, by Physiographic Provinces in the United States**

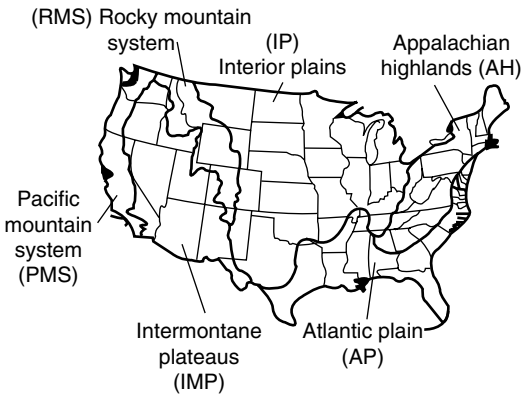
| Physiographic Province | Number of Samples Public Water-Supply Wells / All Other Wells | Mean (μg/L) Public Water-Supply wells / All Other Wells | Median (μg/L) Public Water-Supply Wells / All Other Wells | 95th Percentile (μg/L) Public Water-Supply Wells / All Other Wells | 99th Percentile (μg/L) Public Water-Wupply Wells / All Other Wells | Wilcoxon Test Statistic[a] (p>/z/) |
|---|---|---|---|---|---|---|
| 1. Appalachian Highlands | 376<br>2,212 | 1<br>3 | ≤1<br>≤1 | 5<br>8 | 10<br>25 | 0.6552 |
| 2. Atlantic Coast Plain | 646<br>2,047 | 1<br>2 | ≤1<br>≤1 | 2<br>6 | 7<br>21 | 0.0067 |
| 3. Interior Highlands, Interior Plains, and Laurentian Upland | 342<br>3,947 | 5<br>5 | ≤1<br>≤1 | 19<br>16 | 75<br>48 | 0.3289 |
| 4. Intermontane Plateaus | 458<br>4,640 | 9<br>15 | 3<br>3 | 39<br>44 | 100<br>200 | 0.1389 |
| 5. Pacific Mountain System | 303<br>2,401 | 6<br>9 | 2<br>2 | 21<br>27 | 92<br>82 | 0.7159 |
| 6. Rocky Mountain System | 74<br>1,028 | 2<br>7 | ≤1<br>≤1 | 6<br>20 | 30<br>100 | 0.6444 |

*Note:* μg/L, micrograms per liter; ≥, greater than or equal to; <, less than.

[a] A value <0.05 indicates the two data sets are different.

*Source*: From Focazio, M.J., et al., 2000, A Retrospective Analysis on the Occurrence of Arsenic in Groundwater Resources of the United States and Limitations in Drinking-Water-Supply Characterizations, *USGS, Water Resources Investigations Report 99-4279*, www.usgs.gov. With permission.

Locations of major physiographic provinces of the United States

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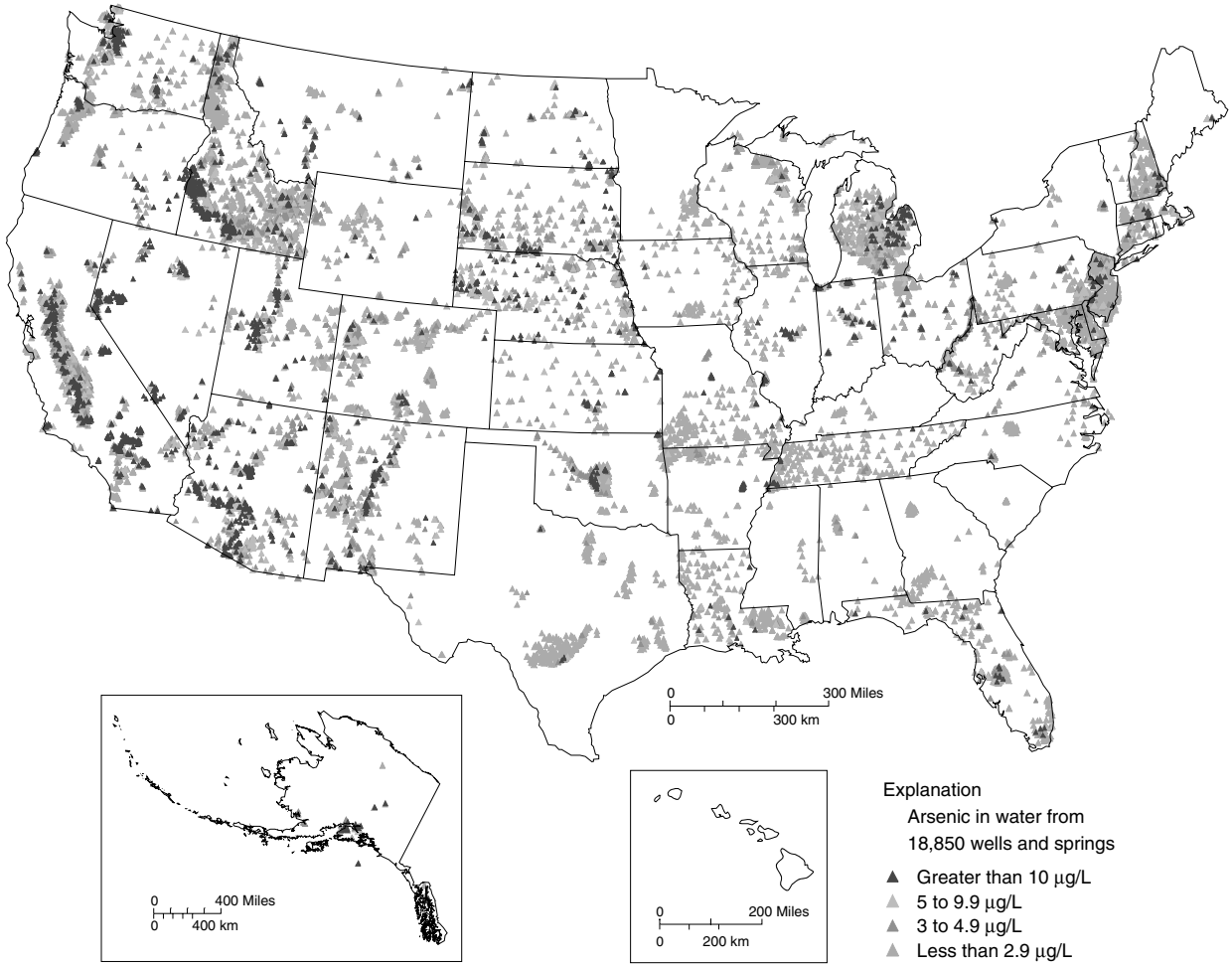


**Figure 8D.14** Locations and concentration ranges of samples in the USGS arsenic point data base. (From Focazio, M.J., et al. A Retrospective Analysis on the Occurrence of Arsenic in Groundwater Resources of the United States and Limitations in Drinking-Water-Supply Characterizations, USGS, *Water Resources Investigations Report 99–4279*, 2000, http://water.usgs.gov.)

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**Table 8D.47 Estimated Arsenic Occurrence in United States Groundwater Community Water Systems**

| System Size (Population Served) | Total Number of Systems[a] | Number of Systems with Arsenic Concentrations (μg/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | >2 | >3 | >5 | >10 | >15 | >20 | >25 | >30 | >40 | >50 |
| <25 | 178 | 49 | 35 | 22 | 9 | 5 | 4 | 3 | 2 | 1 | 1 |
| 25–100 | 14,025 | 3,833 | 2,788 | 1,696 | 743 | 429 | 281 | 199 | 147 | 90 | 60 |
| 101–500 | 14,991 | 4,097 | 2,980 | 1,812 | 795 | 459 | 300 | 213 | 157 | 96 | 64 |
| 501–1,000 | 4,671 | 1,277 | 929 | 565 | 248 | 143 | 93 | 66 | 49 | 30 | 20 |
| 1,001–3,300 | 5,710 | 1,561 | 1,135 | 690 | 303 | 175 | 114 | 81 | 60 | 37 | 25 |
| 3,301–10,000 | 2,459 | 672 | 489 | 297 | 130 | 75 | 49 | 35 | 26 | 16 | 11 |
| 10,001–50,000 | 1,215 | 332 | 242 | 147 | 64 | 37 | 24 | 17 | 13 | 8 | 5 |
| 50,001–100,000 | 131 | 36 | 26 | 16 | 7 | 4 | 3 | 2 | 1 | 1 | 1 |
| 100,001–1,000,000 | 61 | 17 | 12 | 7 | 3 | 2 | 1 | 1 | 1 | 0 | 0 |
| > 1,000,000 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Systems[b] | 434,43 | 11,873 | 8,636 | 5,252 | 2,302 | 1,329 | 869 | 617 | 456 | 278 | 187 |
| Lower 95% CI | | 11,543 | 8,363 | 5,100 | 2,250 | 1,269 | 821 | 573 | 421 | 252 | 165 |
| Upper 95% CI | | 13,007 | 9,501 | 5,665 | 2,567 | 1,499 | 995 | 712 | 534 | 335 | 226 |

*Note:* CI, confidence interval.

[a] Based on 1998 Baseline SDWIS data for purchased and non-purchased systems. Systems characterized as GW under the influence of SW are considered to be surface water systems.
[b] Totals may not add up due to rounding of the number of systems to the nearest whole number.

*Source*: From USEPA, 2000, *Arsenic Occurrence in Public Drinking Water Supplies*, EPA-815-R-00-023, December 2000, www.epa.gov.

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**Table 8D.48 Estimated Arsenic Occurrence in United States Surface Water Community Water Systems**

| System Size (Population Served) | Total Number of Systems[a] | Number of Systems with Arsenic Concentrations (μg/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | >2 | >3 | >5 | >10 | >15 | >20 | >25 | >30 | >40 | >50 |
| <25 | 74 | 7 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25–100 | 1,001 | 98 | 56 | 30 | 8 | 5 | 3 | 2 | 2 | 1 | 1 |
| 101–500 | 1,983 | 195 | 110 | 60 | 16 | 9 | 6 | 5 | 4 | 3 | 2 |
| 501–1,000 | 1,219 | 120 | 68 | 37 | 10 | 6 | 4 | 3 | 2 | 2 | 1 |
| 1,001–3,300 | 2,420 | 238 | 135 | 73 | 19 | 11 | 8 | 6 | 5 | 3 | 2 |
| 3,301–10,000 | 1,844 | 181 | 103 | 56 | 15 | 9 | 6 | 4 | 3 | 2 | 2 |
| 10,001–50,000 | 1,606 | 158 | 89 | 49 | 13 | 7 | 5 | 4 | 3 | 2 | 2 |
| 50,001–100,000 | 300 | 29 | 17 | 9 | 2 | 1 | 1 | 1 | 1 | 0 | 0 |
| 100,001–1,000,000 | 261 | 26 | 15 | 8 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| > 1,000,000 | 13 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Systems | 10,721 | 1,052 | 597 | 325 | 86 | 50 | 34 | 26 | 20 | 14 | 10 |
| Lower 95% CI | | 973 | 514 | 193 | 56 | 25 | 14 | 9 | 6 | 3 | 2 |
| Upper 95% CI[b] | | 2,730 | 2,212 | 1,036 | 167 | 107 | 88 | 77 | 71 | 65 | 63 |

*Note:* CI, confidence interval.

[a] Based on 1998 Baseline SDWIS data for purchased and non-purchased systems. Systems characterized as GW under the influence of SW are considered to be surface water systems.
[b] Totals may not add up due to rounding of the number of systems to the nearest whole number.

*Source*: From USEPA, 2000, *Arsenic Occurence in Public Drinking Water Supplies*, EPA-815-R-00-023, December 2000, www.epa.gov.



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**Table 8D.49 Summary of Documented Cases of Naturally-Occurring Arsenic Problems in World Groundwaters**

| Country/Region | Area ($km^2$) | Population Exposed[a] | Concentration Ranges ($\mu g\ L$) | Aquifer Type | Groundwater Conditions | Reference |
|---|---|---|---|---|---|---|
| Bangladesh | 150,000 | ca. $3\times10^7$ | <0.5–2,500 | Holocene alluvial/deltaic sediments. Abundance of solid organic matter | Strongly reducing, neutral pH, high alkalinity, slow groundwater flow rates | DPHE/BGS/MML (1999) |
| West Bengal | 23,000 | $6\times10^6$ | <10–3,200 | As Bangladesh | As Bangladesh | CGWB (1999); POA (1999) |
| China | | $5.6\times10^6$ | | | | Sun et al. (2000) |
| Taiwan | 4000 | $10^5$ (formerly) | 10–1820 | Sediments, including black shale | Strongly reducing, artesian conditions, some groundwaters contain humic acid | Kuo (1968), Tseng et al. (1968) |
| Inner Mongolia (Huhhot Basin (HB), Bayingao, Hexi, Ba Meng, Tumet Plain) | 4300 (HB) 30,000 total | ca. $10^5$ in HB | <1–2400 | Holocene alluvial and lacustrine sediments | Strongly reducing conditions, neutral pH, high alkalinity. Deep groundwaters often artesian, some have high concentrations of humic acid | Luo et al. (1997), Zhai et al. (1998), Ma et al. (1999), Sun et al. (1999), Smedley et al. (2000b, 2001b) |
| Xinjiang (Tianshan Plain) | 38,000 | (500 diagnosed) | 40–750 | Holocene alluvial plain | Reducing, deep wells (up to 660 m) are artesian | Wang and Huang (1994) |
| Shanxi | | | | Alluvial plain | Reducing | Sun et al. (1999) |
| Hungary, Romania (Danube Basin) | 110,000 | 29,000 | <2–176 | Quaternary alluvial plain | Reducing groundwater, some artesian. Some high in humic acid | Varsányi et al. (1991); Gurzau (2000) |
| Argentina (Chaco-Pampean Plain | $10^6$ | $2\times10^6$ | <1–5300 (7800 in some porewaters) | Holocene and earlier loess with rhyolitic volcanic ash | Oxidizing, neutral to high pH, high alkalinity. Groundwaters often saline. As(V), accompanied by high B, V, Mo, U. Also high As concentrations in some river waters | Nicolli et al., 1989; Nicolli and Merino (2001); Smedley et al. (2001a); Sancha and Castro (2000) |
| Northern Chile (Antofagasta) | 125,000 | 500,000 | 100–1000 | Quaternary volcanogenic sediment | Generally oxidizing. Arid conditions, high salinity, high B. Also high-As river waters | Cáceres et al. (1992), Karcher et al. (1999); Sancha and Castro (2000) |
| Southwest U.S.A. | | $3.5\times10^5$ (tot) | | | | Smith et al. (1992) |
| Basin & Range, Arizona | 200,000 | | up to 1300 | Alluvial basins, some evaporites | Oxidizing, high pH. As (mainly As (V)) correlates positively with Mo, Se, V, F | Robertson (1989) |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Tulare Basin, San Joaquin Valley, California | 5000 | | <1–2600 | Holocene and older basin-fill sediments | Internally-drained basin. Mixed redox conditions. Proportion of As(III) increases with well depth. High salinity in some shallow groundwaters. High Se, U, B, Mo | Fujii and Swain (1995) |
| Southern Carson Desert, Nevada | 1300 | | up to 2600 | Holocene mixed aeolian, alluvial, lacustrine sediments, some thin volcanic ash bands | Largely reducing, some high pH. Some with high salinity due to evaporation. Associated high, U, P, Mn, DOC (Fe to a lesser extent) | Welch and Lico (1998) |
| Salton Sea Basin | | | | | Some saline groundwaters, with high U | Welch and Lico (1998) |
| Mexico (Lagunera) | 32,000 | $4\times10^5$ | 8–620 | Volcanic sediments | Oxidising, neutral to high pH, As mainly as As(V) | Del Razo et al. (1990) |
| **Some problem areas related to mining activity and mineralized areas** | | | | | | |
| Thailand (Ron Phibun) | 100 | 15,000 | 1–5000 | Dredged quatemary alluvium (some problems in limestone), tailings | Oxidation of disseminated arsenopyrite due to former tin mining, subsequent groundwater rebound | Williams et al. (1996), Williams (1997) |
| Greece (Lavrion) | | | | Mine tailings | Mining | |
| Fairbanks, Alaska, U.S.A. | | | up to 10,000 | Schist, alluvium, mine tailings | Gold mining, arsenopyite, possibly scorodite | Wilson and Hawkins (1978); Welch et al. (1988) |
| Moira Lake, Ontario, Canda | 100 | | 50–3000 | Mine tailings | Ore mining (gold, hematite, magnetite, lead, cobalt) | Azcue and Nriagu (1995) |
| Coeur d'Alene, Idaho, U.S.A. | | | up to 1400 | Valley-fill deposits | River water and groundwater affected by lead-zinc-silver mining | Welch et al. (1988). Mok and Wai (1990) |
| Lake Oahe, South Datoka, U.S.A. | | | up to 2000 | Lake sediments | As in sediment porewaters from gold mining in the Black Hills | Ficklin and Callender (1989) |
| Bowen Island, British Colombia | 50 | | 0.5–580 | Sulphide mineral veins in volcanic country rocks | Neutral to high-pH groundwaters (up to 8.9), As correlated with B, F | Boyle et al. (1998) |

[a] Exposed refers to population drinking water with As $>50\ \mu g\ L^{-1}$ (drinking-water standard of most countries).

*Source*: From Smedley, P.L. and Kinniburgh, D.G., Chapter 1, Source and Behavior of Arsenic in Natural Waters in WHO, 2001, *United Nations Synthesis Report on Arsenic in Drinking Water Developed on Behalf of the United Nations Administrative Committee on Cooperation Sub-Committee on Water Resources*, with active participation of UNICEF, UNIDO, IAEA and the World Bank, April 20, 2001, www.who.int.



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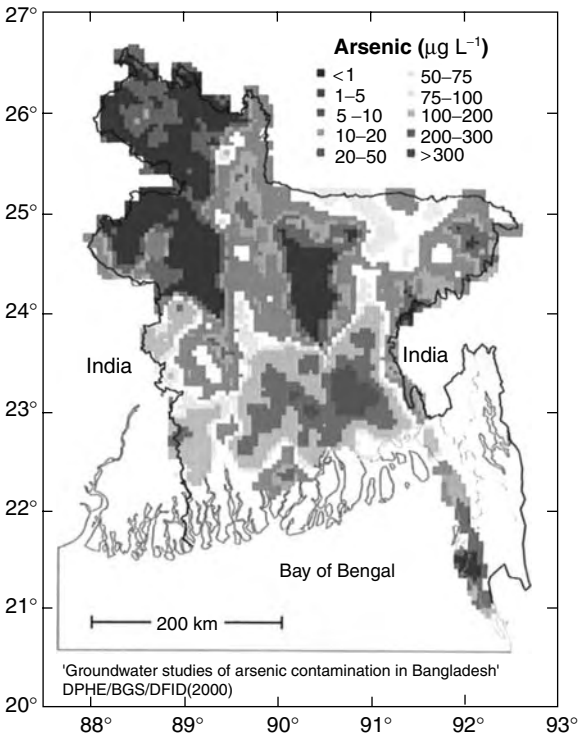


**Figure 8D.15** Smoothed map showing the regional trends in groundwater arsenic concentrations in shallow wells in Bangladesh. (From British Geological Survey (BGS) and Government of the People's Republic of Bangladesh, Ministry of Local Government, Rural Development Co-operatives, Department of Public Health Engineering, 2001, *Arsenic Contamination of Groundwater in Bengladesh*, Kinniburgh, D.G. and Smedley, P.L. (eds), vol. 1: Summary, British Geological Survey (BGS) technical Report WC/00/19, British Geological Survey, Keyworth, www.bgs.ac.uk.)

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[Total number of arsenic affected districts 9 and blocks 85]

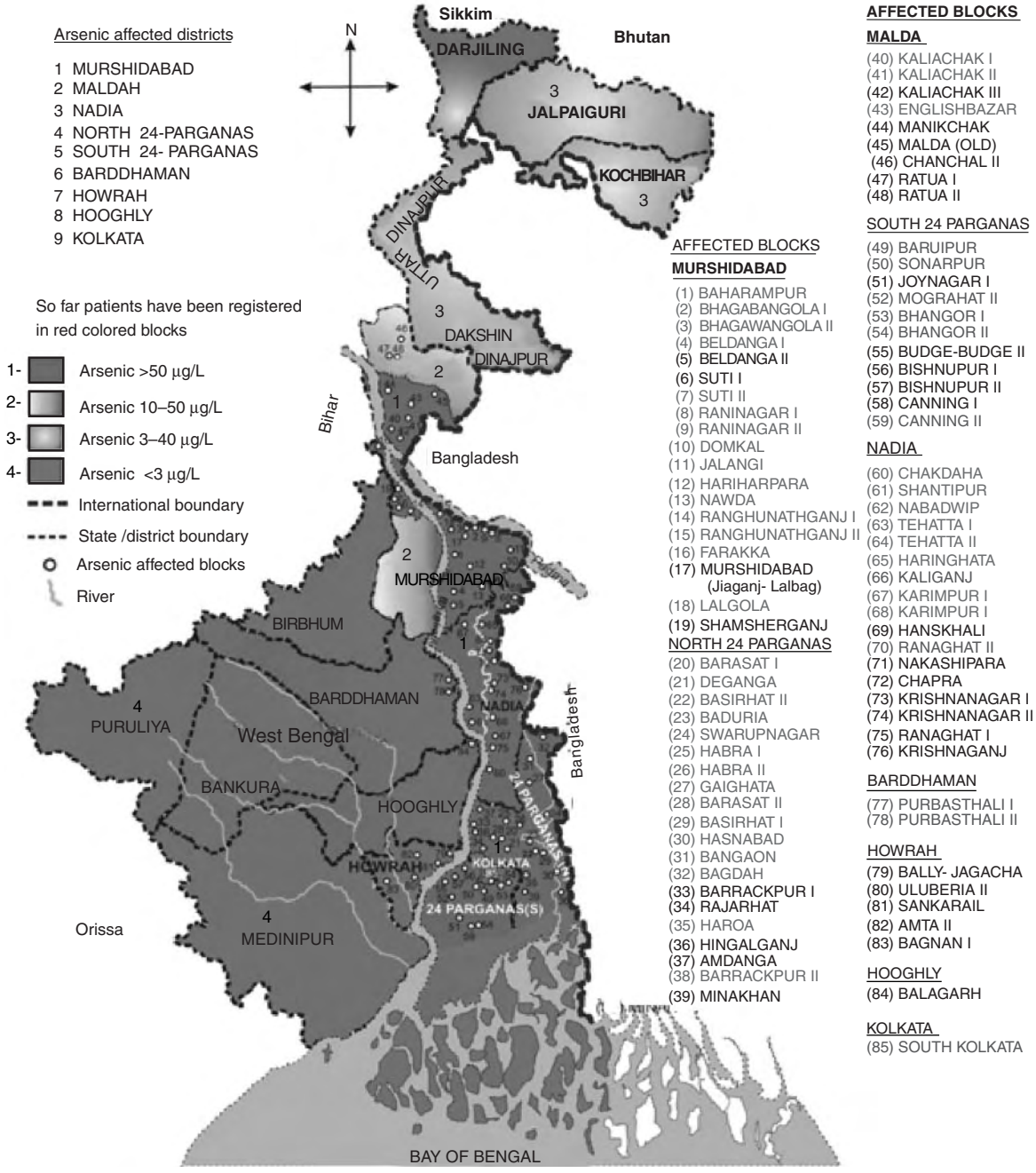


**Figure 8D.16** Groundwater arsenic contamination status in West Bengal-India. (From School of Environment Studies, Jadavpur University, Kolkata 700 032, India, Groundwater and Arsenic Contamination Stutus in West Bengal-India, www.soesju.org.)

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**Table 8D.50 The Effects of Too Little — and Too Much — Fluoride**

| Level in Water | Effects |
|---|---|
| 0.8–1.2 mg/L | Prevention of tooth decay, strengthening of skeleton |
| Above 1.5 mg/L | Fluorosis: pitting of tooth enamel and deposits in bones |
| Above about 10 mg/L | Crippling skeletal fluorosis |

*Note:* Fluoride is a desirable substance: it can prevent or reduce dental decay and strengthen bones, thus preventing bone fractures in older people. Where the fluoride level is naturally low, studies have shown higher levels of both dental caries (tooth decay) and fractures. Because of its positive effect, fluoride is added to water during treatment in some areas with low levels. But you can have too much of a good thing; and in the case of fluoride, water levels above 1.5 mg/L may have long-term undesirable effects. Much depends on whether other sources, such as vegetables, also have high levels. The risk of toxic effect rises with the concentration. It only becomes obvious at much higher levels than 1.5 mg/L.

*Source*: From World Health Organization, Water Sanitation and Health (WSH), *Naturally Occuring Hazards—Fluoride*, www.who.int/water_sanitation_health/naturalhazards/en/index2.html. Downloaded July 17, 2005. Copyright © World Health Organization.

**Table 8D.51 National Surveys of Fluoride in Drinking Water**

| Location | Fluoride Concentration (mg/L) | Comment | References |
|---|---|---|---|
| Canada | 0.05–0.21 | Range of mean concentration in nonfluoridated[a] samples collected between 1984 and 1989 from 67 communities in 5 provinces | Health Canada (1993) |
| | 0.73–1.25 | Range of mean concentrations in fluoridated[b] samples collected between 1986 and 1989 from 320 communities in 8 provinces | Health Canada (1993) |
| Czech Republic | 0.05–3.0 | Range of concentrations in more than 4000 samples of drinking water collected between 1994 and 1996 from 36 districts within the Czech Republic | NIPH (1996) |
| Finland | <0.1–3.0 | Range of concentrations in 5900 groundwater samples | Lahermo et al. (1990) |
| | <0.1–5.8 | Range of concentrations in 1421 well-water samples | Korkka-Niemi et al. (1993) |
| | <0.1–6.0 | Range of concentrations in groundwater database of Geological Survey of Finland, 7229 shallow wells | Lahermo & Backman (2000) |
| | <0.1–9.3 | Range of concentrations in groundwater database of Geological Survey of Finland, 571 drilled wells | Lahermo & Backman (2000) |
| Germany | 0.02–0.17 | Range of concentrations of drinking water collected from various facilities in Germany between 1975 and 1986 | Bergmann (1995) |
| The Netherlands | 0.04–0.23 | Public drinking water samples collected in 1985 from water treatment plants in 12 provinces | Sloof et al. (1989) |
| Poland | 0.02–3.0 | Range of mean concentrations in samples of drinking water collected from 94 localities in central and northern Poland between 1993 and 1995 | Czarnowski et al. (1996) |
| U.S.A. | <0.1–1.0 | Fluoride levels in drinking water of approximately 62% of the U.S. population served by public supplies range from <0.1 to 1.2 mg/L; levels of fluoride in drinking water of approximately 14% of the US population served by public supplies range from 1 to 2 mg/L | US EPA (1985); US DHHS (1991) |

[a] Drinking water in which inorganic fluoride was not intentionally added for the prevention of dental caries.
[b] Drinking water in which inorganic fluoride was intentionally added for the prevention.

*Source*: From WHO, 2002, *Fluorides, Environmental Health Criteria 227*, Copyright © World Health Organization 2002, www.who.int.

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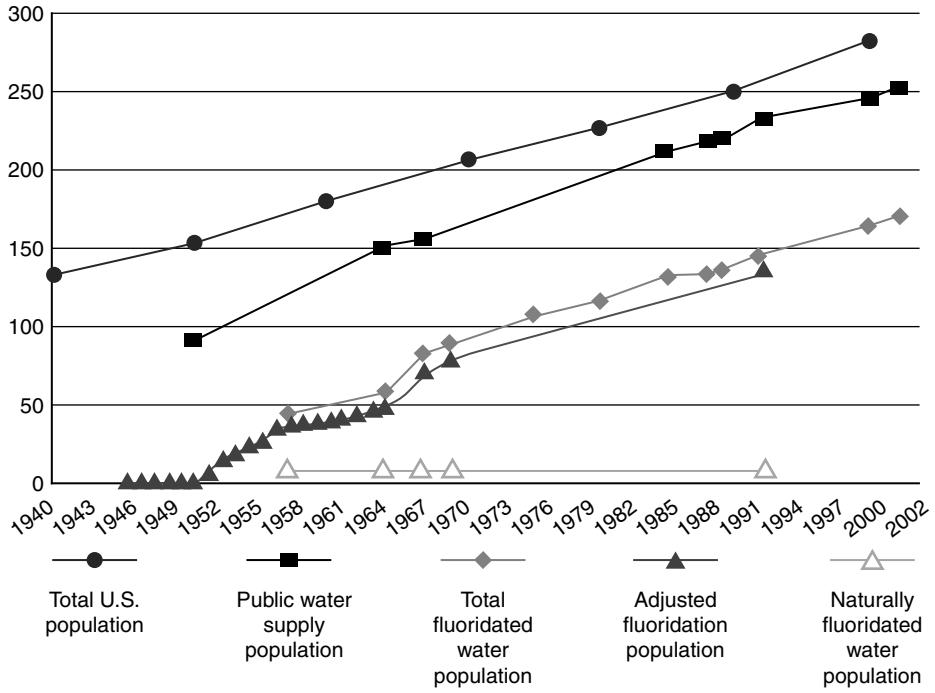


**Figure 8D.17** Fluroidation growth, by population, in the United States 1940–2002. (From Center of Disease Control, www.cdc.gov.)

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**Table 8D.52 Number of Persons and Percentage of the Population Receiving Optimally Fluoridated Water through Public Water Systems (PWS), by State in the United States, 1992 and 2000**

| State | 2000 Fluoridated Population | 2000 Total PWS Population | 2000 Percentage Fluoridated (%) | 1992 Percentage Fluoridated (%) | Change in Percentage 1992–2000 |
|---|---|---|---|---|---|
| Alabama[a] | 3,967,059 | 4,447,100 | 89.2 | 82.6 | 6.6 |
| Alaska | 270,099 | 489,371 | 55.2 | 61.2 | −6.0 |
| Arizona | 2,700,354 | 4,869,065 | 55.5 | 49.9 | 5.6 |
| Arkansas[b] | 1,455,767 | 2,431,477 | 59.9 | 58.7 | 1.2 |
| California | 9,551,961 | 33,238,057 | 28.7 | 15.7 | 13.0 |
| Colorado[b] | 2,852,386 | 3,708,061 | 76.9 | 81.7 | −4.8 |
| Connecticut | 2,398,227 | 2,701,178 | 88.8 | 85.9 | 2.9 |
| Delaware | 505,747 | 624,923 | 80.9 | 67.4 | 13.5 |
| District of Columbia | 595,000 | 595,000 | 100.0 | 100.0 | 0.0 |
| Florida | 9,407,494 | 15,033,574 | 62.6 | 58.3 | 4.3 |
| Georgia | 6,161,139 | 6,634,635 | 92.9 | 92.1 | 0.8 |
| Hawaii[a] | 109,147 | 1,211,537 | 9.0 | 13.0 | −4.0 |
| Idaho | 383,720 | 845,780 | 45.4 | 48.3 | −2.9 |
| Illinois | 10,453,837 | 11,192,286 | 93.4 | 95.2 | −1.8 |
| Indiana | 4,232,907 | 4,441,502 | 95.3 | 98.6 | −3.3 |
| Iowa | 2,181,649 | 2,390,661 | 91.3 | 91.4 | −0.1 |
| Kansas | 1,513,306 | 2,421,274 | 62.5 | 58.4 | 4.1 |
| Kentucky | 3,235,053 | 3,367,812 | 96.1 | 100.0 | −3.9 |
| Louisiana[a] | 2,375,702 | 4,468,976 | 53.2 | 55.7 | −2.5 |
| Maine | 466,208 | 618,033 | 75.4 | 55.8 | 19.6 |
| Maryland[b] | 4,124,953 | 4,547,908 | 90.7 | 85.8 | 4.9 |
| Massachusetts[a,b] | 3,546,099 | 6,349,097 | 55.8 | 57.0 | −1.2 |
| Michigan | 6,568,151 | 7,242,531 | 90.7 | 88.5 | 2.2 |
| Minnesota | 3,714,465 | 3,780,942 | 98.2 | 93.4 | 4.8 |
| Mississippi | 1,227,268 | 2,665,075 | 46.0 | 48.4 | −2.4 |
| Missouri[a] | 4,502,722 | 5,595,211 | 80.5 | 71.4 | 9.1 |
| Montana | 143,092 | 645,452 | 22.2 | 25.9 | −3.7 |
| Nebraska[b] | 966,262 | 1,243,713 | 77.7 | 62.1 | 15.6 |
| Nevada[b] | 1,078,479 | 1,637,105 | 65.9 | 2.1 | 63.8 |
| New Hampshire | 347,007 | 807,438 | 43.0 | 24.0 | 19.0 |
| Naw Jersey | 1,120,410 | 7,208,514 | 15.5 | 16.2 | −0.7 |
| New Mexico | 1,187,404 | 1,548,084 | 76.7 | 66.2 | 10.5 |
| New York[b] | 12,000,000 | 17,690,198 | 67.8 | 69.7 | −1.9 |
| North Carolina | 4,862,220 | 5,837,936 | 83.3 | 78.5 | 4.8 |
| North Dakota | 531,738 | 557,595 | 95.4 | 96.4 | −1.0 |
| Ohio | 8,355,002 | 9,535,188 | 87.6 | 87.9 | −0.3 |
| Oklahoma[b] | 2,164,330 | 2,900,000 | 74.6 | 58.0 | 16.6 |
| Oregon[b] | 612,485 | 2,700,000 | 22.7 | 24.8 | −2.1 |
| Pennsylvania | 5,825,328 | 10,750,095 | 54.2 | 50.9 | 3.3 |
| Rhode Island | 842,797 | 989,786 | 85.1 | 100.0 | −14.0 |
| South Carolina | 3,086,974 | 3,383,434 | 91.2 | 90.0 | 1.2 |
| South Dakota[b] | 553,503 | 626,221 | 88.4 | 100.0 | −11.6 |
| Tennessee | 4,749,493 | 5,025,998 | 94.5 | 92.0 | 2.5 |
| Texas | 11,868,046 | 18,072,680 | 65.7 | 64.0 | 1.7 |
| Utah[a,b] | 43,816 | 2,233,169 | 2.0 | 3.1 | −1.1 |
| Vermont | 240,579 | 443,901 | 54.2 | 57.4 | −3.2 |
| Virginia | 5,677,551 | 6,085,436 | 93.3 | 72.1 | 21.2 |
| Washington[b] | 2,844,893 | 4,925,540 | 57.8 | 53.2 | 4.6 |
| West Virginia[a] | 1,207,000 | 1,387,000 | 87.0 | 82.1 | 4.9 |
| Wisconsin | 3,108,738 | 3,481,285 | 89.3 | 93.0 | −3.7 |
| Wyoming[a] | 149,774 | 493,782 | 30.3 | 35.7 | −5.4 |
| Total | 162,067,341 | 246,120,616 | 65.8 | 62.1 | 3.7 |

[a] Reported PWS population exceeded total state population; PWS population was set to the 2000 U.S. census of state populations.
[b] Complete data were not available from Water Flouridation Reporting System: additional information was obtained from states.

*Source*: From CDC, 2002, *Populations Receiving Optimally Fluoridated Public Drinking Water - United States, 2000*, MMWR Weekly, February 22, 2002/51(07); 144-7, 2002, www.cdc.gov.

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**Table 8D.53 Percentage of United States Population on Public Water Supply Systems Receiving Fluoridated Water, in 2002**

| Location | 2002[a] |
|---|---|
| United States | 67.3 |
| Alabama | 82.0[b] |
| Alaska | 57.3 |
| Arizona | 55.4 |
| Arkansas | 62.1 |
| California | 27.7 |
| Colorado | 75.4 |
| Connecticut | 87.5[b] |
| Delaware | 80.9 |
| District of Columbia | 100.0[c,d] |
| Florida | 68.6[c] |
| Georgia | 93.0 |
| Hawaii | 8.8[c] |
| Idaho | 47.5 |
| Illinois | 99.1 |
| Indiana | 95.5 |
| Iowa | 91.3 |
| Kansas | 62.1 |
| Kentucky | 99.7 |
| Louisiana | 46.1[c] |
| Maine | 74.4 |
| Maryland | 93.7 |
| Massachusetts | 60.7[b] |
| Michigan | 86.2 |
| Minnesota | 98.4 |
| Mississippi | 48.4[c] |
| Missouri | 82.0[c] |
| Montana | 23.8 |
| Nebraska | 69.5 |
| Nevada | 69.4 |
| New Hampshire | 42.7 |
| New Jersey | 20.8 |
| New Mexico | 76.5 |
| New York | 72.9 |
| North Carolina | 84.6 |
| North Dakota | 95.6 |
| Ohio | 90.6[b] |
| Oklahoma | 74.6[b] |
| Oregon | 19.4 |
| Pennsylvania | 54.0 |
| Rhode Island | 89.2[b] |
| South Carolina | 91.4[b] |
| South Dakota | 78.0[b] |
| Tennessee | 96.0[b] |
| Texas | 68.6[b] |
| Utah | 2.3[c] |
| Vermont | 55.7[b] |
| Virginia | 93.8 |
| Washington | 58.9[b] |
| West Virginia | 91.5 |
| Wisconsin | 89.4 |
| Wyoming | 36.7 |

[a] Data Source: CDC Water Fluoridation Reporting System (WFRS).
[b] Complete data not available from WFRS, additional information obtained from States.
[c] Reported PWS population exceeded U.S. Census 2000 state population, thus PWS population set to U.S. Census 2000 state population.
[d] Reported fluoridated population exceeded U.S. Census 2000 state population, thus fluoridated population was set to U.S. Census 2000 state population.

*Source*: From Center of Disease Control, cdc.gov/nohss/FluoridationMapV.asp?Year=2000.

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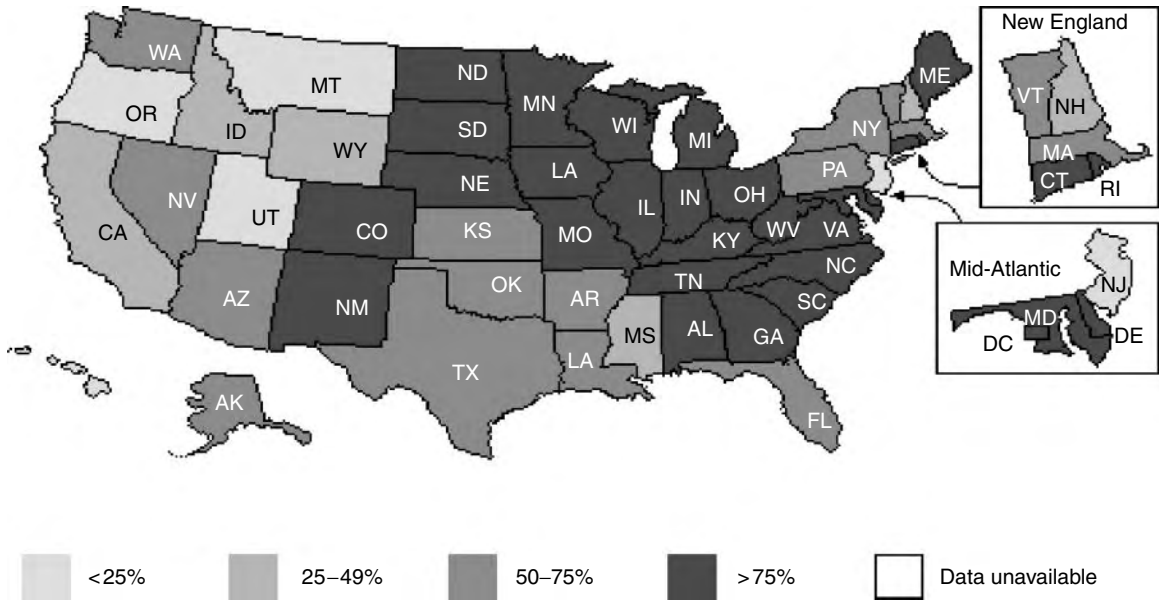


**Figure 8D.18** Percent of United States population on fluoridated water, 2002. (From Center of Disease Control, cdc.gov/nohss/FluoridationMapV.asp?Year=2002.)

Geographical belts of high fluoride concentrations in groundwater extend from Syria through Jordan, Egypt, Libya, Algeria, Morocco and the Rift Valley of Western Africa through the Sudan and Kenya. Another belt stretches from Turkey through Iraq, Iran and Afghanistan to India, Northern Thailand and China. The highest natural fluoride concentration ever found in water (2,800 mg/L) was recorded in Lake Nakuru in the Rift Valley in Kenya. High groundwater fluoride concentrations are associated with igneous and metamorphic rocks such as granites and gneisses, volcanic rocks, and salt deposits of marine origin.

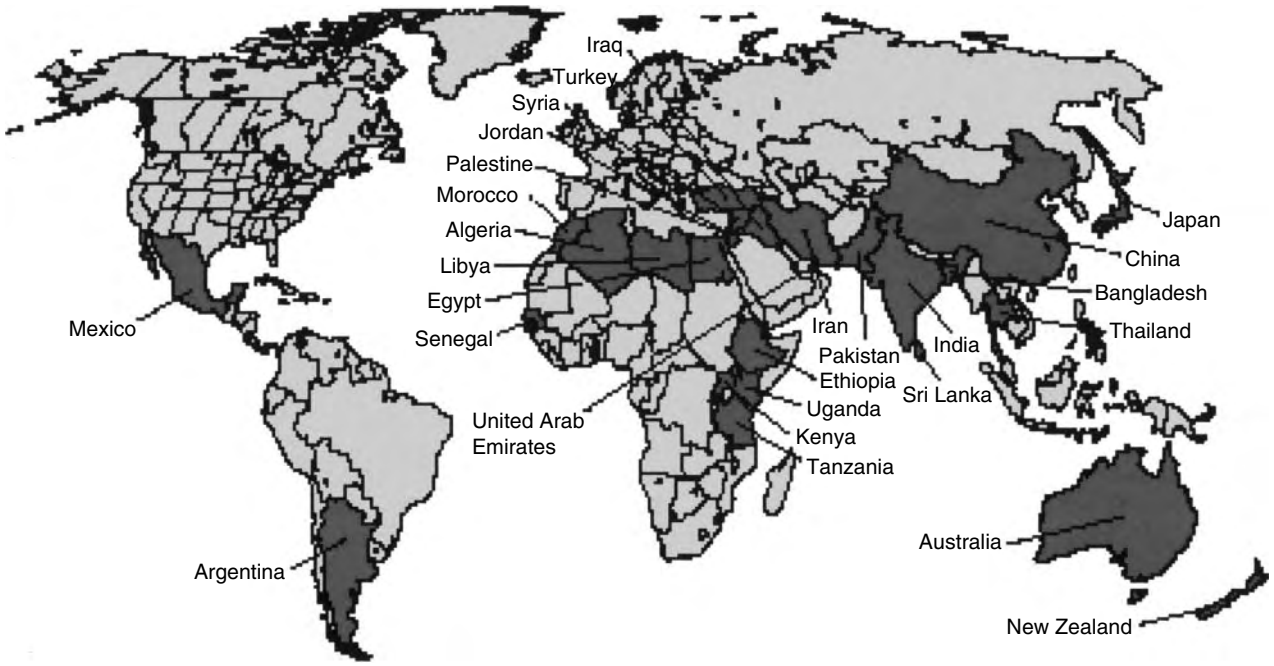


**Figure 8D.19** Countries with endemic fluorosis due to excess fluoride in drinking water. (From UNICEF, *Fluoride and Fluoridation*, UNICEF Questions Benefits and Safety, rvi.net/~Flouride/000133.htm.)

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**Table 8D.54 Summary of Concentrations of Naturally-Occurring Fluoride Detected in Selected Countries with Endemic Fluorosis**

| Country | Fluoride Concentrations in Groundwater | Population Affected | Reference |
|---|---|---|---|
| **Africa** | | | |
| Ghana | up to 3.8 mg/L | | BGS, 2000 |
| Ethiopia | 0.8–24.5 mg/L | | Alem, 1998 |
| Ethiopia (Lake Ziway) | 0.1–23.3 mg/L | | Haile, 1999 |
| Kenya | up to 11 mg/L | | Nyanchaga and Bailey, 2003 |
| Tanzania | 30% of drinking water >1.5 mg/L, up to 8.0 mg/L | | WHO 2004a, EHC 227 |
| South Africa (Port Elizabeth) | 0.05–14.00 mg/L | | Maclear et al., 2003 |
| **Australia** | 50% groundwater boreholes >1.5 mg/L with several in range of 3 to 9 mg/L | | WHO, 2004a |
| **China** | | Over 26 million-dental fluorosis<br>1 million-skeletal fluorosis | WHO, 2004b<br>WHO, 2004b |
| Inner Mongolia | 0.4–6.9 mg/L | | Xu et al., 1997 |
| **India** | | 66 million consume drinking water with elevated Fluoride-15 of India's 32 States | UNICEF |
| Rajasthan | 0.2–5.1 mg/L | | Choubisa, 2001 |
| Punjab | 0.5–16.2 mg/L | | Jolly, 1968 |
| Karnataka State | 0.97–7.40 mg/L | | Latha et al., 1998 |
| **Mexico** | | 5 million (about 6% of population) affected by fluoride in groundwater | UNICEF, WHO, 2004b |
| Los Altos de Jalisco | 0.14–12.97 mg/L | | Hurtado et al., 2000 |
| Durango | 1–5.67 mg/L | | Oritz et al., 1998 |
| **Argentina** | | | |
| La Pampa | 0.3–29 mg/L | | Smedley et al., 2000 |

*Source*: From Alem, Getachew, 1998, Groundwater for rural water supply in the Rift Valley, 24th WEDC Conference, *Sanitation and Water for All. British Geological Survey, 2000*, Water Aid Country Information Sheet: Ghana.
Choubisa, SL., 2001, *Endemic Fluorosis in Southern Rajasthan*, India, Fluoride 34: 61–70.
Haile, G., 1999, Hydrogeochemistry of the Waters in the Lake Ziway Area, 25th WEDC Conference, Integrated Development for Water Supply and Sanitation.
Hurtado, R., Gardea-Torresdey, J, and Tiemann, K.J., 2000, *Fluoride Occurrence in Tap Water at "Los Altos de Jalisco" in the Central Mexico Region*, Proceedings of the 2000 Conference on Hazardous Waste Research.
Jolly SS, 1968, Fluoride 1: 65–75.
Latha, S.S, Ambika, S.R., and Prasad, S.J, 1998, *Fluoride Contamination Status of Groundwater in Karnataka* iisc. ernet.in/currsci/mar25/articles13.htm.
Nyanchaga, E.N. and Bailey, T., 2003, Flouride contamination in drinking water in the Rift Valley, Kenya and evaluation of the efficiency of locally manufactured defluoridation filter, *Journal of Civil Engineering*, JKUAT Vol 8, pp. 79–88.
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Ortiz, D., Castro, L., Turrubiartes, F., Milan, J., Diaz-Barriga, F., 1998, Assessment of the exposure to fluoride from drinking water in durango, Mexico, using a geographic information system, *Fluoride* 31 (4), pp 183–187.
Smedley, P, Nicolli, H, and MacDonald, D., 2000, Hydrogeochemisty of arsenic and other problem constituents in groundwaters from La Pampa, Argentina, *Journal of Conference Abstracts*, Volume 5(2), 936, Cambridge Publications.
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WHO, 2004b, *WHO Issues Revised Drinking Water Guidelines to Help Prevent Water-Related Outbreaks and Disease, Press Release WHO/67*, September 21, 2004.
WHO, 2002, Fluorides, *Environmental Health Criteria*, 227.
Xu RQ, Wu DQ, Xu RY, 1997, Water Fluoride and Skeletal Fluorosis-Inner Mongolia, *Fluoride* 30: 26–28.

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**Table 8D.55 Detections of Giardia Cysts in Source Waters of Public Drinking Water Supplies in the United States**

| Classification | Samples | No. of Sites | No. of Positive Samples | No. of Positive Sites | Percent | |
|---|---|---|---|---|---|---|
| | | | | | Positive of Samples | Positive of Sites |
| Creeks | 444 | 75 | 181 | 38 | 41 | 51 |
| Rivers | 449 | 74 | 163 | 38 | 36 | 51 |
| Lakes | 829 | 49 | 138 | 19 | 17 | 39 |
| Springs[a] | 84 | 6 | 16 | 2 | 19 | 33 |
| Wells[a] | 63 | 40 | 2 | 2 | 3 | 5 |

[a] Samples represent finished water. Most water from springs and wells is unfiltered and may or may not be disinfected before consumption.

*Source*: From U.S. Environmental Protection Agency, 1987; Hibler, 1987.

**Table 8D.56 Detections of Giardia Cysts in Finished Drinking Waters Supplies of the United States**

| Classification | Samples | No. of Sites | No. of Positive Samples | No. of Positive Sites | Percent | |
|---|---|---|---|---|---|---|
| | | | | | Positive of Samples | Positive of Sites |
| Unfiltered, chlorinated | 1,214 | 94 | 80 | 16 | 6.6 | 17 |
| Direct filtration[a] | 615 | 92 | 148 | 17 | 24.0 | 18.5 |
| Conventional treatment | 357 | 86 | 12 | 5 | 3.4 | 5.8 |
| Slow sand and diatomaceous earth filtration | 18 | 3 | 0 | 0 | 0 | 0 |
| Commercial filters and/or pressure filters | 33 | 12 | 4 | 2 | 12.1 | 16.7 |
| Cartridge filters | 51 | 13 | 11 | 7 | 21.6 | 53.8 |
| Infiltration galleries | 37 | 16 | 7 | 5 | 18.9 | 31.3 |
| Filter type unknown | 83 | 24 | 15 | 6 | 18.0 | 25.0 |

[a] May or may not include coagulation or disinfection. Number of systems applying coagulant and/or polymer, or whether disinfection was interrupted, could not be determined.

*Source*: From U.S. Environmental Protection Agency, 1987; Based on data collected from 1979–1986, Hibler, 1987.

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**Table 8D.57 United States National Source Water (Untreated) Levels of Giardia, January to December 1998**

| Level of Total Giardia (#cysts/100 mL) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Water Treatment Plants | | | | | | | | | | | |
| 0 | 220 | 232 | 248 | 268 | 262 | 281 | 276 | 280 | 290 | 265 | 264 | 233 |
| 0.1–0.9 | | 1 | 1 | 1 | | 1 | 1 | 2 | | 1 | | 1 |
| 1–9 | 18 | 18 | 10 | 13 | 14 | 9 | 14 | 6 | 6 | 7 | 8 | 11 |
| 10–99 | 45 | 35 | 39 | 25 | 20 | 25 | 24 | 20 | 19 | 33 | 32 | 26 |
| 100–999 | 37 | 38 | 28 | 23 | 24 | 15 | 10 | 21 | 13 | 21 | 16 | 28 |
| 1,000–9,999 | | 2 | 3 | | 2 | 1 | | 1 | | 1 | 3 | |

*Note:* Data Purpose, The Information Collection Rule (ICR) data were collected as part of a national research project to support development of national drinking water standards. They should NOT be used to determine local water systems compliance with drinking water standards, nor should they be used to make personal judgements about health risks.
Results of Zero: A measurement of zero means that no *Giardia* was found in the sample volume that was analyzed. Zero results do not indicate the absence of Giardia in the source water because the method recovery is low and the amount of sample analyzed is small. In other words, Giardia may be present in source water even if no oocysts are counted for the sample volume analyzed. The presence of Giardia may also be mistakenly identified as other organic material such as algae. The current ICR method for detecting *Giardia* and *Cryptosporidium* has significant technical limitations: Better detection methods are currently being developed to detect and count protozoa. It is difficult to accurately estimate the numbers of protozoan cysts without testing large quantities of water, and this is not always feasible. The actual levels of these pathogens in source water may be much higher than those found by the tests. However, the current ICR detection method does not distinguish between species of *Giardia* and *Cryptosporidium* that may cause illness and those that do not. The method may also misidentify algae as a Cryptosporidium. With the ICR detection method, both false positive (microbe is counted when it is not actually present) and false negative (microbe is not counted when it is present) results are possible. The ICR detection method cannot determine whether the microbes are alive or whether they are able to cause illness.

*Source*: From United States Environmental Protection Agency, www.epa.gov.

**Table 8D.58 Occurrence of *Cryptosporidium* in Surface and Groundwaters**

| Water Type | Samples (*n*) | % Positive | Range of Oocyst Concentration (oocysts/L) | Mean Concentration (oocysts/L) | Reference |
|---|---|---|---|---|---|
| Stream/river[a] N Amer | 6 | 100 | 0.8–5,800 | 1920 | Madore et al., 1987[c] |
| River[a] (2 sites) UK | 375 | 4.5 | 0.07–4 | 0.95(g) | The National Cryptosporidium Survey Group, 1992[c] |
| River[a] (4 sites) UK | 691 | 55.2 | 0.04–3.0 | 0.38(g) | The National Cryptosporidium Survey Group, 1992[c] |
| River[a] (4 sites) UK | 430 | 4.4 | 0.007–2.75 | 0.5(g) | The National Cryptosporidium Survey Group, 1992[c] |
| 6 Rivers[a] N Amer | 11 | 100 | 2–112 | 25(adj) | Ongerth and Stibbs, 1987[c] |
| Stream N Amer | 19 | 73.7 | 0–240 | 1.09(g) | Rose et al., 1988[c] |
| Stream/river N Amer | 58 | 77.6 | 0.04–18 | 0.94(g) | Rose, 1988[c] |
| Stream/river N Amer | 38 | 73.7 | <0.001–44 | 0.66(g) | Rose et al., 1991[c] |
| River/lake N Amer | 85 | 87.1 | 0.07–484 | 2.7(g) | LeChevallier et al., 1991a[c] |
| River/lake N Amer | 262 | 51.5 | 0.065–65.1 | 2.4(g) | LeChevallier and Norton, 1995 |
| River N Amer | 22 | 31.8 | 0.01–75.7 | 0.58(g) | Stetzenbach et al., 1988[c] |
| 3 Rivers[a] Ottawa, Canada | 41 | 78.8 | <0.02–2.25 | 0.26 | Chauret et al., 1995[b] |
| Surface waters Canada | 1173 | 4.5 | NR | NR | Wallis et al., 1996 |
| Surface waters South Africa | NR | 18(?) | 0–25/L | 0.6 | Kfir et al., 1995 |
| River/lake N Amer | 18 | NR | 7.1–28.5 | 17.8 | Rose et al., 1988[c] |
| Stream/lake (impact if any, NR) UK | 84 | 40.5 | 0.006–2.3 | NR | Smith et al., 1991[c] |
| Lake N Amer | 20 | 70.7 | 0–22 | 0.58(g) | Rose et al., 1988[c] |
| Lake/reservoir N Amer | 32 | 75 | 1.1–8.9 | 0.91(g) | Rose, 1988[c] |
| Lake N Amer | 24 | 58.3 | <0.001–3.8 | 1.03(g) | Rose et al., 1991[c] |
| Lake N Amer | 44 | 27.3 | 0.11–251.7 | 4.74 | Stetzenbach et al., 1988[c] |

*(Continued)*

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**Table 8D.58 (Continued)**

| Water Type | Samples (*n*) | % Positive | Range of Oocyst Concentration (oocysts/L) | Mean Concentration (oocysts/L) | Reference |
|---|---|---|---|---|---|
| Pristine river N Amer | 3 | NR | NR | 0.08(g) | Rose et al., 1988[c] |
| Pristine river N Amer | 59 | 32.2 | NR | 0.29 | Rose et al., 1991[c] |
| Pristine lake N Amer | 34 | 52.9 | NR | 0.093(g) | Rose et al., 1991[c] |
| Pristine spring N Amer | 7 | 28.6 | <0.003–0.13 | 0.04(g) | Rose et al., 1991[c] |
| Pristine lake Yukon, Canada | 11 | 9.1 | 0–0.003 | 0.003 | Roach et al., 1993[c] |
| Groundwater well N Amer | 18 | 5.6 | NR | 0.003 (single value) | Rose et al., 1991[c] |
| Deep pristine groundwater well UK | 120 | 0 | — | — | The National Cryptosporidium Survey Group, 1992[c] |
| Groundwater well[b] UK | 138 | 5.8 | 0.004–0.922 | 0.23(g) | The National Cryptosporidium Survey Group, 1992[c] |

*Note:* Pristine = little or no human activity in the watershed or water, restricted access, no agricultural activity within the watershed and no sewage treatment facility discharges impacting the water upstream from the sampling site (Lisle and Rose, 1995); NR = not recorded; (g) = geometric mean; (adj) = data adjusted for recovery efficiencies; (?) legend is missing from the relevant figure in Kfir et al.

[a] Affected by domestic or agricultural waste.
[b] History of coliform contamination.
[c] As cited by Lisle and Rose (1995).

*Source*: From Butler, B.J. and Mayfield, C.I., 1996, *Cryptospordium* spp. A review of the organism. *Disease and Implications of Managing Water Resources*, Prepared for Waterloo Centre of Groundwater Research, Waterloo, Ontario, Canada, www.inweh.unu.edu. Reprinted with permission.

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**Table 8D.59 United States National Source Water (Untreated) Levels of Cryptosporidium, January to December 1998**

| Level of Total Cryptosporidium (oocysts/100 L) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Water Treatment Plants | | | | | | | | | | | |
| 0 | 293 | 292 | 304 | 312 | 305 | 307 | 310 | 309 | 301 | 306 | 302 | 283 |
| 0.01–0.9 | 1 | | | | | | | | | | | 1 |
| 1–9 | 4 | 6 | 4 | 6 | 3 | 2 | 1 | 1 | 2 | 7 | 2 | 4 |
| 10–99 | 17 | 21 | 16 | 6 | 10 | 17 | 12 | 12 | 15 | 11 | 17 | 9 |
| 100–999 | 5 | 7 | 5 | 6 | 4 | 6 | 2 | 8 | 10 | 4 | 2 | 2 |
| 1,000–9,999 | | | | | | | | | | | | |

*Note:* Data Purpose, The Information Collectin Rule (ICR) data were collected as part of a national research project to support development of national drinking water standards. They should NOT be be used to determine local water systems compliance with drinking water standards, nor should they be used to make personal judgements about health risks. Results of Zero: A measurement of zero means that no Cryptosporidium was found in the sample volume that was analyzed. Zero results do not indicate the absence of Cryptosporidium in the source water because the method recovery is low and the amount of sample analyzed is small. In other words, Cryptosporidium may be present in source water even if no oocysts are counted for the sample volume analyzed. The presence of Cryptosporidium may also be mistakenly identified as other organic material such as algae. The current ICR method for detecting *Giardia* and *Cryptosporidium* has significant technical limitations:
It is difficult to accurately estimate the numbers of protozoan cysts without testing large quantities of water, and this is not always feasible. The actual levels of these pathogens in source water may be much higher than those found by the tests
However, the current ICR detection method does not distinguish between species of *Giardia* and *Cryptosporidium* that may cause illness and those that do not. The method may also misidentify algae as a Cryptosporidium. With the ICR detection method, both false positive (microbe is counted when it is not actually present) and false negative (microbe is not counted when it is present) results are possible. The ICR detection method cannot determine whether the microbes are alive or whether they are able to cause illness. Better detection methods are currently being developed to detect and count protozoa.

*Source*: From United States Environmental Protection Agency, www.epa.gov.

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**Table 8D.60 Occurrence of Cryptosporidium in Treated Drinking Water**

| Study Site | Filtration | Samples (*n*) | % Positive | Range of Oocyst Concentration (oocysts/L) | Mean Concentration (oocysts/L) | Reference |
|---|---|---|---|---|---|---|
| U.S.A. | yes | 28 | 14.3 | 0.005–0.007 | 0.001(g) | Rose et al., 1991[a] |
| U.S.A. | yes | 82 | 26.8 | 0.001–0.48 | 0.015(g) | LeChevallier et al., 1991b[a] |
| U.S.A. | no | 6 | 33.3 | 0.001–0.017 | 0.002(g) | Rose et al., 1991[a] |
| Yukon, Canada | no | 42 | 3.8 | 0.002–0.005 | NR | Roach et al., 1993[a] |
| Scotland | NR | 142 | 40.1 | 0.007–0.72 | NR | Smith et al., 1991[a] |
| South Africa | NR | NR | 1.1 | 0–1 | 0 | Kfir et al., 1995 |

*Note:* NR = not recorded; (g) = geometric mean.

[a] As cited by Lisle and Rose, 1995.

*Source*: From Butler, B.J. and Mayfield, C.I., 1996, *Cryptospordium* spp. A review of the organism. *Disease and Implications of Managing Water Resources*, Waterloo Centre of Groundwater Research, Waterloo, Ontario, Canada, www.inweh.unu.edu. Reprinted with permission.

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# SECTION 8E INDUSTRIAL WATER QUALITY

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## Table 8E.61 Water Quality Tolerance for Certain Industrial Applications

| Industry | Turbidity | Color | Color + $O_2$ Consumed | D.O.[a] (mL/L) | Odor | Hardness | Alkalinity | pH | Total Solids | Fe | Mn | Fe + Mn | $Al_2O_3$ | $SiO_2$ | Cl | F | $CO_3$ | $HCO_3$ | OH | $Na_2SO_4$ to $Na_2SO_3$ (ratio) | General[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Conditioning[c] | — | — | — | — | — | — | — | — | — | 0.5 | 0.5 | 0.5 | — | — | — | — | — | — | — | — | A,B |
| Baking | 10 | 10 | — | — | Low | —[d] | — | — | — | 0.2 | 0.2 | 0.2 | — | — | — | — | — | — | — | — | C |
| Boiler Feed (pounds per sq. in.) | | | | | | | | | | | | | | | | | | | | | |
| 0–150 | 20 | 80 | 100 | 2 | — | 80 | — | 8.0+ | 3000–1000 | — | — | — | 5 | 40 | — | — | 200 | 50 | 50 | 1–1 | — |
| 150–250 | 10 | 40 | 50 | 0.2 | — | 40 | — | 8.5+ | 2500–500 | — | — | — | 0.5 | 20 | — | — | 100 | 30 | 40 | 2–1 | — |
| 250–400 | 5 | 5 | 10 | 0.0 | — | 10 | — | 9.0+ | 1500–100 | — | — | — | 0.05 | 5 | — | — | 40 | 5 | 30 | 3–1 | — |
| 400–over | 1 | 2 | | 0.0 | — | 2 | — | 9.6+ | 50 | — | — | — | 0.01 | 1 | — | — | 20 | 0 | 15 | 3–1 | — |
| Brewing[e] | | | | | | | | | | | | | | | | | | | | | |
| Light | 10 | 10 | — | — | Low | — | 75 | 6.5–7.0 | 500 | 0.1 | 0.1 | 0.1 | — | 50 | 100 | 1.0 | 50 | — | — | — | C,D,G |
| Dark | 10 | 10 | — | — | Low | — | 150 | 7.0+ | 1000 | 0.1 | 0.1 | 0.1 | — | 50 | 100 | 1.0 | 50 | — | — | — | C.D,H |
| Canning | | | | | | | | | | | | | | | | | | | | | |
| Legumes | 10 | — | — | — | Low | 25–75 | — | 7.5+ | 850 | 0.2 | 0.2 | 0.3 | — | — | — | 1.0 | — | — | — | — | C |
| General | 10 | — | — | — | Low | 50–400 | — | 7.5+ | 850 | 0.2 | 0.2 | 0.3 | — | — | — | 1.0 | — | — | — | — | C |
| Carbonated Beverages[f] | 2 | 10 | 10 | — | Low | 250 | 125 | — | 850 | 0.2 | 0.2 | 0.3 | — | — | 250 | 0.2–1.0 | — | — | — | — | C |
| Confectionery | — | — | — | — | Low | — | — | —[g] | 100 | 0.2 | 0.2 | 0.2 | — | — | — | — | — | — | — | — | — |
| Cooling[h] | 50 | — | — | — | — | 50 | — | — | — | 0.5 | 0.5 | 0.5 | — | — | — | — | — | — | — | — | A,B |
| Food general | 10 | 5–10 | — | — | Low | 10–250 | 30–250 | — | 850 | 0.2 | 0.2 | 0.2 | — | — | — | 1.0 | — | — | — | — | C |
| Ice (raw water)[i] | 1–5 | 5 | — | — | — | — | 30–50 | — | 300 | 0.2 | 0.2 | 0.2 | — | 10 | — | — | — | — | — | — | C |
| Laundering | — | — | — | — | — | 50 | 60 | 6.0–6.8 | — | 0.2 | 0.2 | 0.2 | — | — | — | — | — | — | — | — | — |
| Plastics, clear uncolored | 2 | 2 | — | — | — | — | — | — | 200 | 0.02 | 0.02 | 0.02 | — | — | — | — | — | — | — | — | — |
| Paper and Pulp[j] | | | | | | | | | | | | | | | | | | | | | |
| Groundwood | 50 | 30 | — | — | — | 200 | 150 | — | 500 | 0.3 | 0.1 | 0.3 | — | 50 | 75 | — | — | — | — | — | E |
| Kraft, paper, bleached | 40 | 25 | — | — | — | 100 | 75 | — | 300 | 0.2 | 0.1 | 0.2 | — | 50 | 200 | — | — | — | — | — | E |
| Soda and sulfite pulps | 25 | 5 | — | — | — | 100 | 75 | — | 250 | .01 | 0.05 | 0.1 | — | 20 | 75 | — | — | — | — | — | E |
| Fine paper | 10 | 5 | — | — | — | 100 | 75 | — | 200 | .01 | 0.05 | 0.1 | — | 20 | — | — | — | — | — | — | E |
| Rayon (viscose) | | | | | | | | | | | | | | | | | | | | | |
| Pulp: Production | 5 | 5 | — | — | — | 8 | 50 | — | 100 | 0.05 | 0.03 | 0.05 | 8.0 | 25 | 5 | — | — | — | — | — | F |
| Manufacture | 0.3 | — | — | — | — | 55 | — | 7.8–8.3 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Tanning[k] | 20 | 10–100 | — | — | — | 50–135 | 135 | 6.0–8.0 | — | 0.2 | 0.2 | 0.2 | — | — | — | — | — | — | — | — | — |
| Textiles | | | | | | | | | | | | | | | | | | | | | |
| General | 5 | 20 | — | — | — | 20 | — | — | — | 0.25 | 0.25 | — | — | — | 100 | — | — | — | — | — | — |
| Dyeing[l] | 5 | 5–20 | — | — | — | 20 | — | — | — | 0.25 | 0.25 | 0.25 | — | — | — | — | — | — | — | — | — |

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| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wool scouring[m] | | 70 | — | — | — | 20 | — | — | | 1.0 | 1.0 | 1.0 | — | — | — | — | — | — | — | — | — |
| Cotton bandage[m] | 5 | 5 | — | — | Low | 20 | — | — | — | 0.2 | 0.2 | 0.2 | — | — | — | — | — | — | — | — | — |

*Note:* Milligrams per liter, except as indicated.

[a] Abbreviations as follows: D.O., dissolved oxygen; ppm, parts per million; pH, hydrogen-ion concentration.
[b] A—no corrosiveness; B—no slime formation; C—conformity with federal drinking water standards necessary; D—NaCl, 275 ppm; E—free $CO_2$ less than 10 mg/L; F—copper less than 5 mg/L; G—calcium 100–200 mg/L; H—calcium 200–500 mg/L
[c] Water with algae, or hydrogen sulphide odors, is most unsuitable for air conditioning.
[d] Some hardness desirable.
[e] Water for distilling must meet the same general requirements as for brewing (gin and spirits mashing water of light-beer quality, whiskey mashing water of dark-beer quality).
[f] Clear, odorless, sterile water for syrup and carbonization. Water consistent in character. Most high quality filtered municipal water not satisfactory for beverages.
[g] Hard candy requires pH of 7.0 or greater, as low value favors inversion of sucrose, causing sticky products.
[h] Control of corrosiveness is necessary, as is also control of organisms, such as sulphur and iron bacteria, which tend to form slimes.
[i] Ca $(HCO_3)_2$ particularly troublesome. $Mg(HCO_3)_2$ tends to greenish color. $CO_2$ assists in preventing cracking. Sulphates and chlorides of Ca, Mg, Na should each be less than 300 ppm (white butts).
[j] Uniformity of composition and temperature desirable. Iron objectionable since cellulose absorbs iron from dilute solutions. Manganese very objectionable, clogs pipelines and is oxidized to permanganates by chlorine, causing reddish color.
[k] Excessive iron, manganese, or turbidity creates spots and discoloration in tanning of hides and leather goods.
[l] Constant composition; residual alumina $<0.5$ ppm.
[m] Calcium, magnesium, iron, manganese, suspended matter, and soluble organic matter may be objectionable.

*Source*: From American Water Works Association, *Water Quality and Treatment, second edition (New York, 1950). Water Quality Criteria*, California State Water Quality Control Board, second edition (Sacramento, 1963.)



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**Table 8E.62 Water Quality Guidelines for the Pulp and Paper Industry**

| | Concentration (mg/L) | | | | | |
|---|---|---|---|---|---|---|
| | | | Kraft | | Chem. Pulp & Paper | |
| Parameter | Fine Paper | Ground Wood | Bleached | Unbleached | Bleached | Unbleached |
| pH | — | 6–8 | — | — | 6–8 | 6–8 |
| Color (HU) | <40 | <100 | <25 | <100 | <50 | <100 |
| Turbidity (NTU) | <10 | <20 | <40 | <100 | <10 | <20 |
| Calcium | <20 | <20 | — | — | <20 | <20 |
| Magnesium | <12 | <12 | — | — | <12 | <12 |
| Iron | <0.1 | <0.1 | <0.2 | <1.0 | <0.1 | <1.0 |
| Manganese | <0.3 | <0.1 | <0.1 | <0.5 | <0.5 | <0.5 |
| Chloride | — | 25–75 | <200 | <200 | <200 | <200 |
| Silica | <20 | <100 | <50 | <100 | <50 | <50 |
| Hardness | <100 | <100 | <100 | <100 | <100 | <100 |
| Alkalinity | 40–75 | <150 | <75 | <150 | — | — |
| Dissolved solids | <200 | <250 | <300 | <500 | <200 | <250 |
| Suspended solids | <10 | — | — | — | <10 | <10 |
| Temperature (°C) | — | — | — | — | <36 | — |
| $CO_2$ | <10 | <10 | <10 | <10 | — | — |
| Corrosion tendency | NIL | NIL | NIL | NIL | NIL | NIL |
| Residual chloride | <2.0 | — | — | — | — | — |

*Source*: From Canadian Council of Resource and Environment Ministers, *Canadian Water Quality Guidelines*, March 1987.

**Table 8E.63 Water Quality Guidelines for the Iron and Steel Industry**

| | Concentration (mg/L) | | | | |
|---|---|---|---|---|---|
| | | | Rinse Water | | |
| Parameter | Hot-Rolling, Quenching, Gas Cleaning | Cold-Rolling | Softened | Demineralized | Steel Manufacturing |
| pH | 5.0–9.0 | 5.0–9.0 | 6.0–9.0 | — | 6.8–7.0 |
| Suspended solids | <25 | <10 | ND[a] | ND | — |
| Dissolved solids | <1000 | <1000 | ND | ND | — |
| Settleable solids | <100 | <5.0 | ND | ND | — |
| Dissolved oxygen | minimum for aerobic conditions | | | | |
| Temperature (°C) | <38 | <38 | <38 | <38 | <38 |
| Hardness | NS[b,c] | NS[b] | <100 | <0.1 | <50 |
| Alkalinity | NS[c] | NS[c] | NS[c] | <0.5 | — |
| Sulfate | <200 | <200 | <200 | — | <175 |
| Chloride | <150 | <150 | <150 | ND | <150 |
| Oil | NS | ND | ND | ND | ND |
| Floating material | NS | ND | ND | ND | ND |

[a] ND = not detected.
[b] Controlled by other treatments.
[c] NS = not specified; the parameter has never been a problem at concentrations encountered.

*Source*: From Canadian Council of Resource and Environment Ministers, *Canadian Water Quality Guidelines*, March 1987; U.S. Environmental Protection Agency, 1973.

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**Table 8E.64 Water Quality Guidelines for the Petroleum Industry**

| Parameter | Concentration (mg/L)[a] |
|---|---|
| pH units | 6.0–9.0 |
| Color | NS[b] |
| Calcium | <75 |
| Magnesium | <25 |
| Iron | <1 |
| Bicarbonate | NS |
| Sulphate | NS |
| Chloride | <200 |
| Nitrate | NS |
| Fluoride | NS |
| Silica | NS |
| Hardness (as $CaCO_3$) | <350 |
| Dissolved solids | <750 |
| Suspended solids | <10 |

[a] Unless otherwise indicated.
[b] NS = not specified. The parameter has never been a problem at concentrations encountered.

*Source*: From *Canadian Water Quality Guidelines* 1987; Federal Water Pollution Control Administration 1968; Ontario Ministry of the Environment 1974.

**Table 8E.65 Water Quality Guidelines for Power Generation Stations**

| | Concentration (mg/L) | | | |
|---|---|---|---|---|
| | Cooling Once-Through | | | |
| Parameter | Fresh | Brackish[a] | Boiler Feedwater (10.35–34.48 MPa) | Miscellaneous Uses |
| Silica | <50 | <25 | <0.01 | — |
| Aluminum | NS[b] | NS | <0.01 | — |
| Iron | NS | NS | <0.01 | <1.0 |
| Manganese | NS | NS | <0.01 | — |
| Calcium | <200 | <420 | <0.01 | — |
| Magnesium | NS | NS | <0.01 | — |
| Ammonia | NS | NS | <0.07 | — |
| Bicarbonate | <600 | <140 | <0.5 | — |
| Sulphate | <680 | <2,700 | NS[c] | — |
| Chloride | <600 | <19,000 | NS[c] | — |
| Dissolved solids | <1000 | <35,000 | <0.5 | <1000 |
| Copper | NS | NS | <0.01 | — |
| Hardness | <850 | <6250 | <0.07 | — |
| Zinc | NS | NS | <0.01 | — |
| Alkalinity (as $CaCO_3$) | <500 | <115 | <1 | — |
| pH units | 5.0–8.3 | 6.0–8.3 | 8.8–9.4 | 5.0–9.0 |
| Organic material | | | | |
| Methylene blue active substances | NS | NS | <0.1 | <10 |
| Carbon tetrachloride extract | NS[d] | NS[d] | NS | <10 |
| Chemical oxygen demand (COD) | <75 | <75 | <1.0 | — |
| Dissolved oxygen | — | — | <0.007 | — |
| Suspended solids | <5000 | <2500 | <0.05 | <5 |

[a] Brackish water—dissolved solids more than 1000 mg/L.
[b] NS = not specified; the parameter has never been a problem at concentrations encountered.
[c] Controlled by treatment for other constituents.
[d] No floating oil.

*Source*: From Canadian Council of Resource and Environment Ministers, *Canadian Water Quality Guidelines*, March 1987; Krisher, A.S., 1978, Raw water treatment in the CPI. *Chem. Eng.* (N.Y.), vol. 85, pp. 78–98. *Chemical Engineering*, Aug. 28, 1978. © McGraw-Hill, Inc.

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**Table 8E.66 Water Quality Guidelines for the Food and Beverage Industry**

| | Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Baking** | **Brewing** | **Carbonate Beverages** | **Confectionary** | **Dairy** | **Food Canning, Freezing, Dried, Frozen Fruits, Vegetables** | **Food Process (General)** | **Sugar Manufacturing** |
| pH | — | 6.5–7.0 | <6.9 | >7.0 | — | 6.5–8.5 | — | — |
| Color (HU) | <10 | <5 | <10 | — | ND | <5 | 5–10 | — |
| Turbidity (NTU) | <10 | <10 | 1–2 | — | — | <5 | 1–10 | — |
| Taste, odor (units) | low | low | ND[a] | low | ND | ND | low | — |
| Suspended solids | — | — | — | 50–100 | <500 | <10 | — | ND |
| Dissolved solids | — | <800 | <850 | 50–100 | <500 | <500 | <850 | — |
| Calcium | NS[b,c] | <100 | — | — | — | <100 | — | <20 |
| Magnesium | — | <30 | — | — | — | — | — | <10 |
| Iron | <0.2 | 0.1–1.0 | <0.1 | <0.2 | 0.1–0.3 | <0.2 | <0.2 | <1 |
| Manganese | <0.2[d] | <0.1[d] | <0.05 | <0.2[d] | 0.03–0.1 | <0.2[d] | <0.2 | <0.1 |
| Copper | — | — | — | — | ND | — | — | — |
| Ammonium | — | — | — | — | Trace | <0.5 | — | — |
| Bicarbonate | — | ND | — | — | — | — | — | <100 |
| Carbonate | — | <50 | <5 | — | — | — | — | — |
| Sulphate | — | <100 | <200 | — | <60 | <250 | — | <20 |
| Chloride | — | 20–60 | <250 | <250 | <30 | <250 | — | <20 |
| Nitrate | — | <10 | — | — | <20 | <10 | — | — |
| Fluoride | — | <1 | 0.2–1.0 | — | — | <1 | <1 | — |
| Silica | — | <50 | ND | — | — | <50 | — | — |
| Hardness | NS[b] | <70 | 200–250 | — | <180 | <250 | 10–250 | <100 |
| Alkalinity | — | <85 | 50–128 | — | — | 30–250 | 30–250 | — |
| Hydrogen sulphide | <0.2 | <0.2 | <0.2 | <0.2 | — | — | — | — |
| Oxygen consumed | — | — | <15 | — | — | <1 | — | — |
| Carbon tetrachloride extract | — | — | Slight | — | <10 | <0.2 | — | — |
| Chloroform extract | — | — | <0.2 | — | — | — | — | — |
| Acidity | — | — | — | — | — | ND | — | — |
| Phenol | — | ND | ND | — | — | ND | — | ND |
| Nitrite | — | — | — | — | — | ND | — | — |
| Organic matter | — | trace | trace | — | — | — | — | trace |

[a] ND = not detected.
[b] Some required for yeast action; excess retards fermentation.
[c] NS = not specified.
[d] Total Fe and Mn.

*Source*: From Canadian Council of Resource and Environment Ministers, *Canadian Water Quality Guidelines*, March, 1987.

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**Table 8E.67 International Council of Bottled Water Associations Standard of Quality**

| Monitoring Parameter Group | Standard |
|---|---|
| **Inorganic Chemicals (IOCs)** | Standard |
| Antimony | 0.005 |
| Arsenic | 0.01 |
| Barium | 0.7 |
| Boron | 0.3 |
| Bromate | 0.010 |
| Cadmium | 0.003 |
| Chlorine | 5.0 |
| Chloramine | 3.0 |
| Chlorite | 0.2 |
| Chromium | 0.05 |
| Cyanide | 0.07 |
| Fluoride | 1.5 |
| Lead | 0.01 |
| Mercury | 0.001 |
| Molybdenum | 0.07 |
| Nickel | 0.02 |
| Nitrate-N | 50 |
| Nitrite-N | 3 |
| Selenium | 0.01 |
| **Secondary Inorganic Parameters** | |
| Copper | 2 |
| Manganese | 0.05 |
| **Volatile Organic Chemicals (VOCs)** | |
| 1,1,1-Trichloroethane | 2 |
| 1,1-Dichloroethylene | 0.03 |
| 1,2,4-Trichlorobenzene | 0.02 |
| 1,2-Dichloroethane | 0.03 |
| 1,2-Dichloropropane | 0.02 |
| 1,3-Dichloropropene | 0.02 |
| Benzene | 0.01 |
| Carbon tetrachloride | 0.002 |
| 1,2-Dichloroethylene | 0.05 |
| Ethylbenzene | 0.3 |
| Methylene chloride (Dichloromethane) | 0.02 |
| Monochlorobenzene | 0.3 |
| o-Dichlorobenzene | 1 |
| p-Dichlorobenzene | 0.3 |
| Styrene | 0.02 |
| Tetrachloroethylene | 0.04 |
| Toluene | 0.7 |
| Trichloroethylene | 0.07 |
| Vinyl chloride | 0.005 |
| Xylenes (total) | 0.5 |
| Bromodichloromethane | 0.06 |
| Chlorodibromomethane | 0.1 |
| Chloroform | 0.2 |
| Bromoform | 0.1 |
| **Semivolatile Organic Chemicals (SVOCs)** | |
| Benzo(a)pyrene | 0.0007 |
| Di(2-ethyhexyl)adipate | 0.08 |
| Di(2-ethyhexyl)phthalate | 0.008 |
| Hexachlorobenzene | 0.001 |
| **Synthetic Organic Chemical (SOCs)** | |
| Alachlor | 0.02 |
| Aldicarb | 0.01 |
| Aldrin/Dieldrin | 0.00003 |
| Atrazine | 0.002 |
| Bentazone | 0.03 |
| Carbofuran | 0.005 |

*(Continued)*

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**Table 8E.67 (Continued)**

| Monitoring Parameter Group | Standard |
|---|---|
| Chlordane | 0.0002 |
| Chlorotoluron | 0.03 |
| DDT | 0.002 |
| Dibromochloropropane (DBCP) | 0.001 |
| 2,4-D | 0.03 |
| 2,4-DB | 0.09 |
| Dichlorprop | 0.1 |
| Fenoprop | 0.009 |
| Heptachlor | 0.03 |
| Heptachlor epoxide | 0.03 |
| Isoproturon | 0.009 |
| Lindane | 0.002 |
| Methoxychlor | 0.02 |
| MCPA | 0.002 |
| Mecoprop | 0.01 |
| Metolachlor | 0.01 |
| Molinate | 0.006 |
| Pendimethalin | 0.02 |
| Pentachlorophenol | 0.009 |
| Permethrin | 0.02 |
| Propanil | 0.02 |
| Pyridate | 0.1 |
| Simazine | 0.002 |
| 2,4,5-T | 0.009 |
| Trifluralin | 0.02 |
| **Additional Regulated Conlaminants** | |
| Acrylamide | 0.0005 |
| Cyanogen chloride | 0.07 |
| Epichlorohydrin | 0.0004 |
| Hexachlorobutadiene | 0.0006 |
| Edetic acid (EDTA) | 0.2 |
| Nitrilotriacetic acid | 0.2 |
| 2,4,6-Trichlorophenol (DBP) | 0.2 |
| Dichloroacetic acid | 0.05 |
| Trichloroacetic acid | 0.1 |
| Formaldehyde (DBP) | 0.9 |
| Chloral hydrate (Trichloroacetaldehyde) | 0.01 |
| Dichloroacetonitrile | 0.09 |
| Dibromoacetonitrile | 0.1 |
| Trichloroacetonitrile | 0.07 |
| Tributyltin oxide | 0.002 |
| **Microbiological Contaminants** | |
| Total coliform / *E. coli* | 0 |
| **Radiological Contaminants** | Standard |
| Gross alpha | 0.1 Bq/l |
| Gross beta | 1.0 Bq/l |
| **Water Properties** | Standard |
| Color | 15 TCU |
| Turbidity | 5 NTU |
| PH | 6.5–8.0 |
| Odor | Not Offensive |

*Note:* All Standards are in mg/L (ppm) except as noted.

*Source*: From International Council of Bottled Water Associations, ICBWA Model Code, September 27, 2004, www.icbwa.org. With permission.

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**Table 8E.68 United States Bottled Water Standards**

| Physical | Maximum |
|---|---|
| Color (units) | 15 |
| Odor | Threshold Odor No.3 |
| Turbidity (units) | 5 |
| Total Dissolved Solids | 500[a] |
| **Inorganic Substances** | **Maximum (mg/L)** |
| Aluminum | 0.2 |
| Antimony | 0.006 |
| Arsenic | 0.05 |
| Barium | 2 |
| Beryllium | 0.004 |
| Cadmium | 0.005 |
| Chloride | 250[a] |
| Chromium | 0.1 |
| Copper | 1 |
| Cyanide | 0.2 |
| Fluoride | [b] |
| Iron | 0.3[a] |
| Lead | 0.005 |
| Manganese | 0.05[a] |
| Mercury | 0.002 |
| Nickel | 0.1 |
| Nitrate (as nitrogen) | 10 |
| Nitrite (as nitrogen) | 1 |
| Total Nitrate & Nitrite (sum as nitrogen) | 10 |
| Phenols | 0.001 |
| Selenium | 0.05 |
| Silver | 0.1 |
| Sulfate | 250[a] |
| Thallium | 0.002 |
| Zinc | 5[a] |
| **Volatile Organic Chemicals or VOCs** | **Maximum (mg/L)** |
| Benzene | 0.005 |
| Carbon Tetrachloride | 0.005 |
| o-Dichlorobenzene | 0.6 |
| p-Dichlorobenzene | 0.075 |
| 1,2-Dichloroethane | 0.005 |
| 1,1-Dichloroethylene | 0.007 |
| cis-1,2-Dichloroethylene | 0.07 |
| trans-1,2-Dichloroethylene | 0.1 |
| Dichloromethane | 0.005 |
| 1,2-Dichloropropane | 0.005 |
| Ethylbenzene | 0.7 |
| Monochlorobenzene | 0.1 |
| Styrene | 0.1 |
| Tetrachloroethylene | 0.005 |
| Toluene | 1 |
| 1,2,4-Trichlorobenzene | 0.07 |
| 1,1,1-Trichloroethane | 0.2 |
| 1,1,2-Trichloroethane | 0.005 |
| Trichloroethylene | 0.005 |
| Vinyl chloride | 0.002 |
| Xylenes | 10 |
| **Pesticides and Other Synthetice Organic Chemicals** | **Maximum (mg/L)** |
| Alachlor | 0.002 |
| Atrazine | 0.003 |
| Benzo(a)pyrene | 0.0002 |
| Carbofuran | 0.04 |
| Chlordane | 0.002 |
| Dalapon | 0.2 |
| 1,2-Dibromochloropropane (DBCP) | 0.0002 |
| 2, 4-D | 0.07 |
| Di(2-ethylhexyl)adipate | 0.4 |
| Dinoseb | 0.007 |
| Diquat | 0.02 |

*(Continued)*

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**Table 8E.68 (Continued)**

| Pesticides and Other Synthetice Organic Chemicals | Maximum (mg/L) |
|---|---|
| Endothall | 0.1 |
| Endrin | 0.002 |
| Ethyiene Dibromide (EDB) | 0.00005 |
| Glyphosate | 0.7 |
| Heptachlor | 0.0004 |
| Heptachlor Epoxide | 0.0002 |
| Hexachlorobenzene | 0.001 |
| Hexachlorocyclopentadiene | 0.05 |
| Lindane | 0.0002 |
| Methoxychlor | 0.04 |
| Oxamyl | 0.2 |
| Pentachlorophenol | 0.001 |
| PCB's (as decachiorobiphenyls) | 0.0005 |
| Picloram | 0.5 |
| Simazine | 0.004 |
| 2,3,7,8-TCDD (Dioxin) | $3\times10^{-8}$ |
| Toxaphene | 0.003 |
| 2,4,5-TP(Si!vex) | 0.05 |
| **Radioactivity** | **Maximum** |
| Combined Radium-226 and Radium-228 | 5 pCi/L |
| Gross alpha particle activity (including Radium-226 but excluding Radon and Uranium) | 15 pCi/L |
| Gross beta particle activity | 50 pCi/L |
| Uranium | 30 ug/L |
| **Bacteriological** | **Maximum** |
| Coliforms: Multiple Tube Fermentation Method | 2.2MPN/100mL |
| Membrane Filter Method | 1c/100mL |
| **Disinfection Byproducts (DBp's)** | **Maximum (mg/L)** |
| Bromate | 0.01 |
| Chlorite | 1 |
| Haloacetic acids (five)(HAA5) | 0.06 |
| Total Trihalomethanes (THMs)[b] | 0.08 |
| **Residual Disinfectants** | **Maximum (mg/L)** |
| Chloramine (as $Cl_2$) | 4 |
| Chlorine (as $Cl_2$) | 4 |
| Chlorine dioxide (as $ClO_2$) | 0.8 |

| | Fluoride Maximum (mg/L) | |
|---|---|---|
| **Annual Average of Maximum Daily Air Temperatures (°F) at the Location Where the Bottled Water Is Sold at Retail** | **No Fluoride Added** | **Fluoride Added** |
| 53.7 and below | 2.4 | 1.7 |
| 53.8–58.3 | 2.2 | 1.5 |
| 58.4–63.8 | 2 | 1.3 |
| 63.9–70.6 | 1.8 | 1 |
| 70.7–79.2 | 1.6 | 1 |
| 79.3–90.5 | 1.4 | 0.8 |

Imported bottled water with no fluoride added: 1.4 mg/L Fluoride

[a] Mineral water is exempt from allowable level. The exemptions are aesthetically based allowable levels and do not relate to a health concern.

[b] Fluoride standards: Bottled water packaged in the United States.

[c] Total Trihalomethanes (TTHM): Sum of chloroform, bromodichloromethane, chiorodibromomethane, and bromoform. 10 ppb Pursuant to H&SC 111080(b).

*Source*: From United States Food and Drug Administration 21 CFR 165 Beverages: Title 21—Food and Drugs, Chapter 1, Food and Drug Adminstration Department of Health and Human Services, Subchapter B, Food for Human Consuption, Subpart B, Requirements for Specifics Standardized Beverages, Section 165.110 Bottled Water, www.accessdata.fda.gov.

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## SECTION 8F IRRIGATION WATER QUALITY

**Table 8F.69 Relative Tolerance of Crop Plants to Salt**

| | | |
|---|---|---|
| **Field Crops** | | |
| $EC \times 10^3 = 16$ | $EC \times 10^3 = 10$ | $EC \times 10^3 = 4$ |
| Barley (grain) | Rye (grain) | Field beans |
| Sugar beet | Wheat (grain) | |
| Rape | Oats (grain) | |
| Cotton | Rice | |
| | Sorghum (grain) | |
| | Corn (field) | |
| | Flax | |
| | Sunflower | |
| | Castorbeans | |
| $EC \times 10^3 = 10$ | $EC \times 10^3 = 6$ | |
| **Vegetable Crops** | | |
| $EC \times 10^3 = 12$ | $EC \times 10^3 = 10$ | $EC \times 10^3 = 4$ |
| Garden beets | Tomato | Radish |
| Kale | Broccoli | Celery |
| Asparagus | Cabbage | Green beans |
| Spinach | Bell pepper | |
| | Cauliflower | |
| | Lettuce | |
| | Sweet corn | |
| | Potatoes (white rose) | |
| | Carrot | |
| | Onion | |
| | Peas | |
| | Squash | |
| | Cucumber | |
| $EC \times 10^3 = 10$ | $EC \times 10^3 = 4$ | $EC \times 10^3 = 3$ |
| **Fruit and Nut Crops** | | |
| **High Salt Tolerance** | **Medium Salt Tolerance** | **Low Salt Tolerance** |
| Date palm | Cantaloupe | Almond |
| | Fig | Apple |
| | Grape | Apricot |
| | Jujube | Avocado |
| | Olive | Blackberry |
| | Papaya | Boysenberry |
| | Pineapple | Cherimoya |
| | Pomegranate | Cherry, sweet |
| | | Cherry, sand |
| | | Currant |
| | | Gooseberry |
| | | Grapefruit |
| | | Lemon |
| | | Lime |
| | | Loquat |
| | | Mango |
| | | Orange |
| | | Passion fruit |
| | | Peach |
| | | Pear |
| | | Persimmon |
| | | Plum: prune |

*(Continued)*

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**Table 8F.69 (Continued)**

| High Salt Tolerance | Medium Salt Tolerance | Low Salt Tolerance |
|---|---|---|
| | | Pummelo |
| | | Raspberry |
| | | Rose, apple |
| | | Sapote, white |
| | | Strawberry |
| | | Tangerine |
| | **Forage Crops** | |
| $EC \times 10^3 = 18$ | $EC \times 10^3 = 12$ | $EC \times 10^3 = 4$ |
| Alkali sacaton | White sweetclover | White Dutch clover |
| Saltgrass | Yellow sweetclover | Meadow foxtail |
| Nuttall alkaligrass | Perennial ryegrass | Alsike clover |
| Bermuda grass | Mountain brome | Red clover |
| Rhodes grass | Strawberry clover | Ladino clover |
| Fescue grass | Dallis grass | Burnet |
| Canada wild rye | Sudan grass | |
| Western wheat-grass | Hubam clover | |
| | Alfalfa (California common) | |
| Barley (hay) | Tall fescue | |
| Bridsfoot trefoil | Rye (hay) | |
| | Wheat (hay) | |
| | Oats (hay) | |
| | Orchardgrass | |
| | Blue grama | |
| | Meadow fescue | |
| | Reed canary | |
| | Big trefoil | |
| | Smooth brome | |
| | Tall meadow oat-grass | |
| | Cicer milkvetch | |
| | Sourclover | |
| | Sickle milkvetch | |
| $EC \times 10^3 = 12$ | $EC \times 10^3 = 4$ | $EC \times 10^3 = 2$ |

*Note:* The numbers following $EC \times 10^3$ are the electrical conductivity values of the saturation extract in millimhos per centimeter at 25°C associated with a 50-percent decrease in yields. The saturation extract is the solution extracted from a soil at its saturation percentage.

*Source*: From U.S. Department of Agriculture, 1954; Kandiah, A., FAO, 1987.

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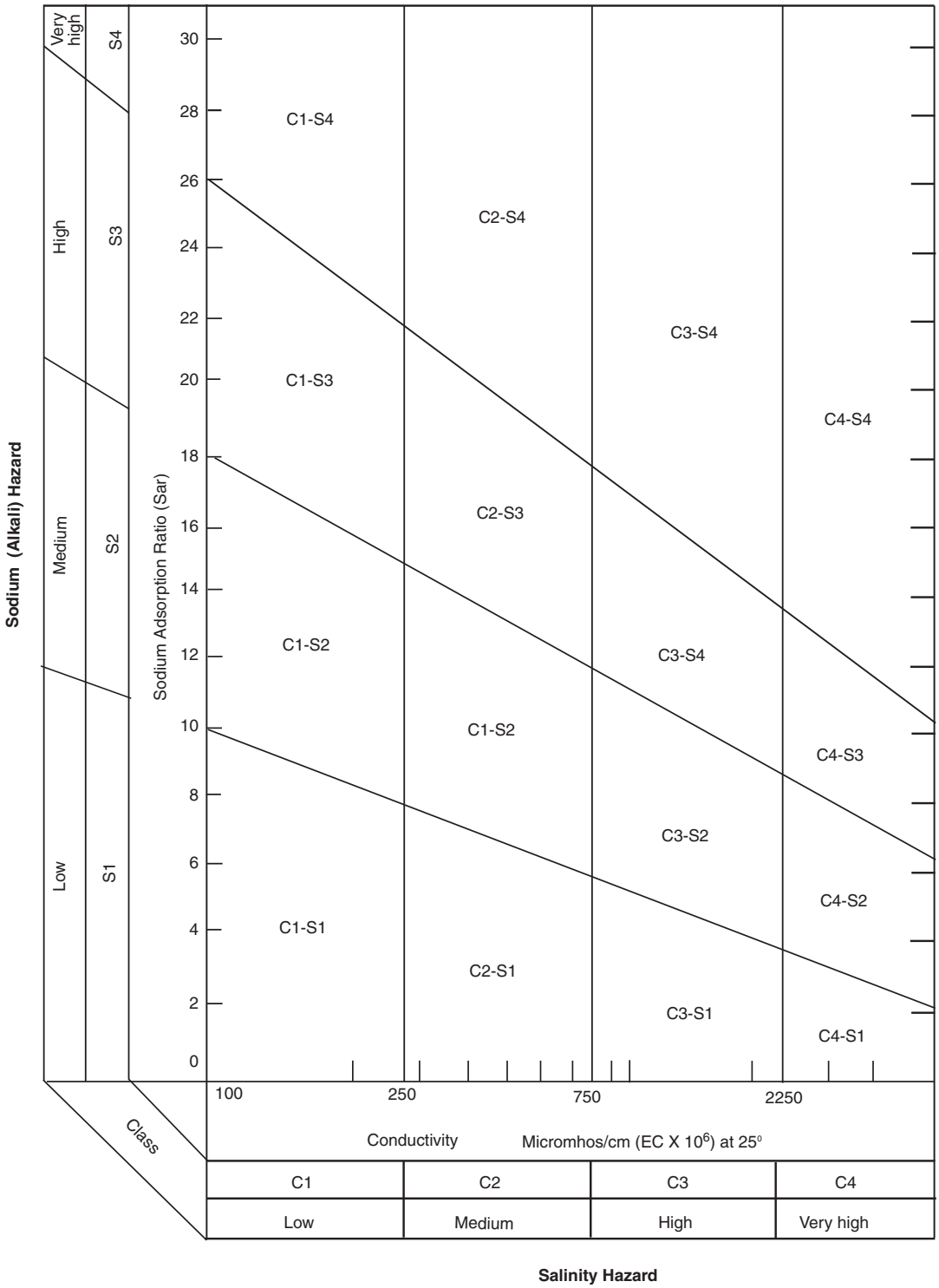


**Figure 8F.20** Quality criteria for irrigation water. Note: Sodium Adsorption Ratio SAR = Na/(Ca + Mg)/2 where concentrations are expressed in millequivalents per liter.

*Conductivity*

Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very high-salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special

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circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

*Sodium*

Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management-good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

Another criterion for the evaluation of irrigation water is:

Residual Sodium Carbonate (RSC) = (CO3 + HCO3) − (Ca + Mg) where concentrations are expressed in meq/liter.

When RSC > 2.5 Probably not suitable for irrigation

1.25-2.5 Marginal

< 1.25 Probably safe for irrigation. (From U.S. Department of Agriculture.)

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**Table 8F.70 Guides for Evaluating the Quality of Water Used for Irrigation**

| Quality Factor | Threshold Concentration[a] | Limiting Concentration[b] |
|---|---|---|
| Coliform organisms, MPN per 100 mL | 1000[c] | —[d] |
| Total dissolved solids (TDS), mg/L | 500[c] | 1500[c] |
| Electrical conductivity, μmhos/cm | 750[c] | 2250[c] |
| Range of pH | 7.0–8.5 | 6.0–9.0 |
| Sodium adsorption ratio (SAR) | 6.0[c] | 15 |
| Residual sodium carbonate (RSC), meq | 1.25[c] | 2.5 |
| Arsenic, mg/L | 1.0 | 5.0 |
| Boron, mg/L | 0.5[c] | 2.0 |
| Chloride, mg/L | 100[c] | 350 |
| Sulfate, mg/L | 200[c] | 1000 |
| Copper, mg/L | 0.1[c] | 1.0 |

*Note:* MPN is most probable number. Sodium absorption ratio is defined by the formula SAR = Na/ (Ca + Mg)/2 where the concentrations are expressed in milliequivalents per liter. Residual sodium carbonate is the sum of the equivalents of normal carbonate and bicarbonate minus the sum of the equivalents of calcium and magnesium.

[a] Threshold values at which irrigator might become concerned about water quality and might consider using additional water for leaching. Below these values, water should be satisfactory for almost all crops and almost any arable soil.

[b] Limiting values at which the yield of high-value crops might be reduced drastically, or at which an irrigator might be forced to less valuable crops.

[c] Values not to be exceeded more than 20 percent of any 20 consecutive samples, nor in any 3 consecutive samples. The frequency of sampling should be specified.

[d] Aside from fruits and vegetables which are likely to be eaten raw, no limits can be specified. For such crops, the threshold concentration would be limiting.

*Source*: From Calif. State Water Quality Control Board, 1963.

**Table 8F.71 FAO Guidelines for Evaluating the Quality of Water for Irrigation**

| | | Degree of Restriction on Use | | |
|---|---|---|---|---|
| **Potential Irrigation Problem** | **Units** | **None** | **Slight to Moderate** | **Severe** |
| Salinity (affects crop water availability)[a] | | | | |
| $EC_W$ | dS/m | <0.7 | 0.7–3.0 | >3.0 |
| or TDS | mg/L | <450 | 450–2000 | >2000 |
| Infiltration (affects infiltration rate of water into the soil. Evaluate using $EC_W$ and SAR together)[b] | | | | |
| SAR = 0–3 and $EC_W$ = | | >0.7 | 0.7–0.2 | <0.2 |
| =3–6 = | | >1.2 | 1.2–0.3 | <0.3 |
| =6–12= | | >1.9 | 1.9–0.5 | <0.5 |
| =12–20= | | >2.9 | 2.9–1.3 | <1.3 |
| =20–40= | | >5.0 | 5.0–2.9 | <2.9 |
| Specific Ion Toxicity (affects sensitive crops) | | | | |
| Sodium (Na) | | | | |
| Surface irrigation | SAR | <3 | 3–9 | >9 |
| Sprinkler irrigation | me/L | <3 | >3 | |
| Chloride (Cl) | | | | |
| Surface irrigation | me/L | <4 | 4–10 | >10 |
| Sprinkler irrigation | me/L | <3 | <3 | |
| Boron (B) | mg/L | <0.7 | 0.7–3.0 | >3.0 |
| Trace elements (see Table 8F–77) | | | | |
| Miscellaneous Effects (affects susceptible crops) | | | | |
| Nitrogen ($NO_3$-N) | mg/L | <5 | 5–30 | >30 |
| Bicarbonate ($HCO_3$)(overhead sprinkling only) | me/L | <1.5 | 1.5–8.5 | >8.5 |
| pH | | | Normal range 6.5–8.4 | |

[a] $EC_W$ means electrical conductivity, a measure of the water salinity, reported in deciSiemens per meter at 25°C (dS/m) or in units millimhos per centimeter (mmho/cm). Both are equivalent. TDS means total dissolved solids, reported in milligrams per liter (mg/L).

[b] SAR means sodium absorption ratio.

*Source*: From Food and Agriculture Organization of the United Nations, 1985, Water quality for agriculture, irrigation, and drainage paper no. 29. Kandiah, A., *Water Quality in Food Production, Water Quality Bulletin*, vol. 12, no. 1, Jan. 1987.

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**Table 8F.72 Chloride Concentrations (mg/L) Causing Foliar Injury in Crops of Varying Sensitivity**

| Sensitivity <175 | Moderately Sensitive 175–350 | Moderately Tolerant 350–700 | Tolerant >700 |
|---|---|---|---|
| Almond | Pepper | Barley | Cauliflower |
| Apricot | Potato | Maize | Cotton |
| Citrus | Tomato | Cucumber | Sugar beet |
| Plum | | Luceme | Sunflower |
| Grape | | Safflower | |
| | | Sorghum | |

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: From Mass (1990).

**Table 8F.73 Risks of Increasing Cadmium Concentrations in Crops Due to Chloride in Irrigation Waters**

| Irrigation Water Chloride Concentration (mg/L) | Risk of Increasing Crop Cadmium Concentrations |
|---|---|
| 0–350 | Low |
| 350–750 | Medium |
| >750 | High |

*Note:* If high chloride concentrations are present in irrigation water, it is recommended that produce is tested for cadmium concentration in the edible portions (e.g., tubers for potatoes, leaves for leafy vegeatables, grain for cereals, etc).

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

*Orginal Source*: From McLaughlin et al. (1999).

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**Table 8F.74 Sodium Concentration (mg/L) Causing Foliar Injury in Crops of Varying Sensitivity**

| Sensitivity <115 | Moderately Sensitive 115–230 | Moderately Tolerant 230–460 | Tolerant >460 |
|---|---|---|---|
| Almond | Pepper | Barley | Cauliflower |
| Apricot | Potato | Maize | Cotton |
| Citrus | Tomato | Cucumber | Sugar beet |
| Plum | | Lucerne | Sunflower |
| Grape | | Safflower | |
| | | Sesame | |
| | | Sorghum | |

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: From Mass (1990).

**Table 8F.75 Effect of Sodium Expressed as Sodium Adsorption Ratio (SAR) on Crop Yield and Quality under Nonsaline Conditions**

| Tolerance to SAR and Range at Which Affected | Crop | Growth Response under Field Conditions |
|---|---|---|
| Extremely sensitive SAR = 2–8 | Avocado<br>Deciduous fruits<br>Nuts<br>Citrus | Leaf tip burn, leaf scorch |
| Sensitive SAR = 8–18 | Beans | Stunted growth |
| Medium SAR = 18–46 | Clover<br>Oats<br>Tall fescue<br>Rice<br>Dallis grass | Stunted growth, possible sodium toxicity, possible calcium or magnesium deficiency |
| High SAR = 46–102 | Wheat<br>Cotton<br>Lucerne<br>Barley<br>Beets<br>Rhodes grass | Stunted growth |

*Note:* SAR = Sodium Adsorption Ratio.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: From Pearson (1960).

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**Table 8F.76 Limits of Boron in Irrigation Water**

**A. Permissible Limits (Boron in parts per million)**

| | Crop Group | | |
|---|---|---|---|
| **Class of Water** | **Sensitive** | **Semitolerant** | **Tolerant** |
| | | | Excellent |
| <0.33 | <0.67 | <1.00 | Good |
| 0.33–0.67 | 0.67–1.33 | 1.00–2.00 | Permissible |
| 0.67–1.00 | 1.33–2.00 | 2.00–3.00 | Doubtful |
| 1.00–1.25 | 2.00–2.50 | 3.00–3.75 | Unsuitable |
| >1.25 | >2.50 | >3.75 | |

**B. Crop Groups of Boron Tolerance (In each group, the plants first named are considered as being more tolerant; the last named, more sensitive.)**

| **Sensitive** | **Semitolerant** | **Tolerant** |
|---|---|---|
| Pecan | Sunflower (native) | Athel (*Tamarix aphylla*) |
| Walnut (Black; and Persian, or English) | Potato | Asparagus |
| | Cotton (Acala and Pima) | Palm (*Phoenix canariensis*) |
| Jerusalem-artichoke | Tomato | Date palm (*P. dactylifera*) |
| Navy bean | Sweetpea | Sugar beet |
| American elm | Radish | Mangel |
| Plum | Field pea | Garden beet |
| Pear | Ragged robin rose | Alfalfa |
| Apple | Olive | Gladiolus |
| Grape (Sultanina and Malaga) | Barley | Broadbean |
| Kadota fig | Wheat | Onion |
| Persimmon | Corn | Turnip |
| Cherry | Milo | Cabbage |
| Peach | Oat | Lettuce |
| Apricot | Zinnia | Carrot |
| Thornless blackberry | Pumpkin | |
| Orange | Bell pepper | |
| Avocado | Sweet potato | |
| Grapefruit | Lima bean | |
| Lemon | | |

*Source*: From U.S. Dept. of Agriculture.

**Table 8F.77 FAO Recommended Maximum Concentrations of Trace Elements in Irrigation Water**

| **Element** | **Recommended Maximum Concentration[a] (mg/L)** | **Remarks** |
|---|---|---|
| Al | 5.0 | Can cause nonproductivity in acid soils (pH <5.5), but more alkaline soils at >pH 7.0 will precipitate the Ion and eliminate any toxicity |
| As | 0.10 | Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice |
| Be | 0.10 | Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans |
| Cd | 0.01 | Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/L in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans |
| Co | 0.05 | Toxic to tomato plants at 0.1 mg/L in nutrient solution. Tends to be inactivated by neutral and alkaline soils |
| Cr | 0.10 | Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants |
| Cu | 0.20 | Toxic to a number of plants at 0.1 to 1.0 mg/L in nutrient solutions |
| F | 1.0 | Inactivated by neutral and alkaline soils |

*(Continued)*

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**Table 8F.77 (Continued)**

| Element | Recommended Maximum Concentration[a] (mg/L) | Remarks |
|---|---|---|
| Fe | 5.0 | Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings |
| Li | 2.5 | Tolerated by most crops up to mg/L; mobile in soil. Toxic to citrus at low concentrations (0.075 mg/L). Acts similarly to boron |
| Mn | 0.20 | Toxic to a number of crops at a few-tenths to a few mg/L, but usually only in acid soils |
| Mo | 0.01 | Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum |
| Ni | 0.20 | Toxic to a number of plants at 0.5 mg/L to 1.0 mg/L; reduced toxicity at neutral or alkaline pH |
| Pd | 5.0 | Can inhibit plant cell growth at very high concentrations |
| Se | 0.02 | Toxic to plants at concentrations as low as 0.025 mg/L and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations |
| Sn | | |
| Ti | | Effectively excluded by plants; specific tolerance unknown |
| W | | |
| V | 0.10 | Toxic to many plants at relatively low concentrations |
| Zn | 2.0 | Toxic to many plants at widely varying concentrations; reduced toxicity at pH $>$ 6.0 and in fine textured or organic soils |

[a] The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10000 $m^3$/ha/yr). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10000 $m^3$/ha/yr. The values given are for water used on a continuous basis at one site.

*Source*: From Food and Agriculture Organization of the United Nations, 1985, Water quality for agriculture, irrigation, and drainage paper no. 29. Kandiah, A., *Water Quality in Food Production, Water Quality Bulletin*, vol. 12, no. 1, Jan. 1987.

**Table 8F.78 Australian Agricultural Irrigation Water Long-Term Trigger Value (LTV), Short-Term Trigger Value (STV), and Soil Cumulative Contaminant Loading Limit (CCL) Triggers for Heavy Metals and Metalloids**

| Element | Suggested Soil CCL[a] (kg/ha) | LTV in Irrigation Water (Long-Term Use—Up to 100 yrs) (mg/L) | STV in Irrigation Water (Short-Term Use—Up to 20 yrs) (mg/L) |
|---|---|---|---|
| Aluminum | ND | 5 | 20 |
| Arsenic | 20 | 0.1 | 2.0 |
| Beryllium | ND | 0.1 | 0.5 |
| Boron | ND | 0.5 | Refer to table 9.2.18 (Volume 3) |
| Cadmium | 2 | 0.01 | 0.05 |
| Chromium | ND | 0.1 | 1 |
| Cobalt | ND | 0.05 | 0.1 |
| Copper | 140 | 0.2 | 5 |
| Fluoride | ND | 1 | 2 |
| Iron | ND | 0.2 | 10 |
| Lead | 260 | 2 | 5 |
| Lithium | ND | 2.5 (0.075 Citrus crops) | 2.5 (0.075 Citrus crops) |
| Manganese | ND | 0.2 | 10 |
| Mercury | 2 | 0.002 | 0.002 |
| Molybdenum | ND | 0.01 | 0.05 |
| Nickel | 85 | 0.2 | 2 |

*(Continued)*

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**Table 8F.78 (Continued)**

| Element | Suggested Soil CCL[a] (kg/ha) | LTV in Irrigation Water (Long-Term Use—Up to 100 yrs) (mg/L) | STV in Irrigation Water (Short-Term Use—Up to 20 yrs) (mg/L) |
|---|---|---|---|
| Selenium | 10 | 0.02 | 0.05 |
| Uranium | ND | 0.01 | 0.1 |
| Vanadium | ND | 0.1 | 0.5 |
| Zinc | 300 | 2 | 5 |

*Note:* Trigger values should only be used in conjunction with information on each individual element and the potential for off-site transport of contaminants.

[a] ND = Not determined; in sufficient background data to calculate CCL.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8F.79 Canadian Water Quality Guidelines for the Protection of Agricultural Uses—Irrigation**

| Parameter[a] | Irrigation Water Quality Guideline (μg/L) | Date [b] |
|---|---|---|
| Aldicarb | 54.9[c] | 1993 |
| Aluminum[d] | 5000 | 1987 |
| Arsenic[e] | 100[f] | 1997 |
| Atrazine | 10[f] | 1989 |
| Beryllium[d] | 100 | 1987 |
| Boron[d] | 500–6000[h] | 1987 |
| Bromacil | 0.2[f] | 1997 |
| Bromoxynil | 0.33[i] | 1993 |
| Cadmium | 5.1[i,f] | 1996 |
| Chloride[d] | 100,000–700,000[k] | 1987 |
| Chlorothalonil | 5.8[f] (other crops) | 1984 |
| Chromium | | 1997 |
| Trivalent chromium (Cr(III)) | 4.9[f,n] | 1997 |
| Hexavalent chromium (Cr(VI)) | 8[n] | 1987 |
| Cobalt[d] | 50 | 1987 |
| Coliforms, fecal [d] | 100 per 100 mL | 1987 |
| Coliforms, total[d] | 1000 per 100 mL | 1987 |
| Copper[d] | 200–1000[o] | 1987 |
| Cyanazine | 0.5[f] | 1990 |
| Dicamba | 0.006 | 1993 |
| Diclofop-methyl | 0.18 | 1993 |
| Diisopropanolinine | 2000[f] | 2005 |
| Dinoseb | 16[j] | 1982 |
| Fluoride[d] | 1000 | 1987 |
| Iron[d] | 5000 | 1987 |
| Lead[d] | 200 | 1987 |
| Linuron | 0.071[f] | 1995 |
| Lithium[d] | 2500 | 1987 |
| Manganese[d] | 200 | 1987 |
| MCPA (4-chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid) | 0.0025 | 1995 |
| Metolachlor | 28[f] | 1991 |
| Metribuzin | 0.5[f] | 1990 |
| Molybdenum[d] | 10–50[r] | 1987 |
| Selenium[d] | 20–50[s] | 1987 |
| Simazine | 0.5[f] | 1891 |
| Nickel[d] | 200 | 1987 |

*(Continued)*

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**Table 8F.79 (Continued)**

| Parameter[a] | Irrigation Water Quality Guideline (μg/L) | Date [b] |
|---|---|---|
| Sulfolane | 500[f] | 2005 |
| Tebuthiuron | 0.27 [f] (cereals) | 1995 |
| Total dissolved solids (salinity)[d] | 500,000– 3,500,000[t] | 1887 |
| Uranium[d] | 10[f] | 1987 |
| Vanadium[d] | 100 | 1987 |
| Zinc[d] | 1,000–5,000[u] | 1987 |

*Note:* ug/L—Micrograms per liter.

[a] Unless otherwise indicated, supporting documents are available from the guidelines and Standards Division, Environment Canada.

[b] The guidelines dated 1987 have been carried over from *Canadian Water Quality Guidelines* (CCREM 1987) and no fact sheet was prepared. The guidelines dated 1989 to 1997 were developed and initially published in CCREM 1987 as appendixes on the date indicated. They are published as fact sheets in this document. Other guidelines dated 1997 and those dated 1999 are published for the first time in this document.

[c] Concentration of total aldicarb residues.

[d] No fact sheet created.

[e] The technical document for the guideline is available from the Ontario Ministry of the Environment.

[f] Interim guideline.

[h] Boron guideline
=500 $\mu g\ L^{-1}$ for blackberries
=500–1000 $\mu g\ L^{-1}$ for peaches, cherries, plums, grapes, cowpeas, onions, garlic, sweet potatoes, wheat, barley, sunflowers, mungbeans, sesame, lupins, strawberries, Jerusalem artichokes, kidney beans, and lima beans
=1000–2000 $\mu g\ L^{-1}$ for red peppers, peas, carrots, radishes, potatoes, and cucumbers
=2000–4000 $\mu g\ L^{-1}$ for lettuce, cabbage, celery, turnips, Kentucky bluegrass, oats, corn, artichokes, tobacco, mustard, clover, squash, and muskmelons
=4000–6000 $\mu g\ L^{-1}$ for sorghum, tomatoes, alfalfa, purple vetch, parsley, red beets, and sugar beets
=6000 $\mu g\ L^{-1}$ for asparagus.

[i] Guideline value slightly modified from CCREM 1987 + Appendixes due to re-evaluation of the significant figures.

[j] Guideline is crop-specific (see fact sheet).

[k] Chloride guideline
Foliar damage
=100–178 mg $L^{-1}$ for almond, apricots, and plums
=178–355 mg $L^{-1}$ for grapes, peppers, potatoes, and tomatoes
=355–710 mg $L^{-1}$ for alfalfa, barley, corn, and cucumbers
$>$710 mg $L^{-1}$ for cauliflower, cotton, safflower, sesame, sorghum, sugar beets, and sunflowers
Rootstocks
=180–600 mg $L^{-1}$ for stone fruit (peaches, plums, etc)
=710–900 mg $L^{-1}$ for grapes
Cultivars
=110–180 mg $L^{-1}$ for strawberries
=230–460 mg $L^{-1}$ for grapes
=250 mg $L^{-1}$ for boysenberries, blackberries, and raspberries.

[n] Substance has been re-evaluated since CCREM 1987 + Appendixes. Either a new guideline has been derived or insufficient data existed to derive a new guideline.

[o] Copper guideline
= 200 $\mu g\ L^{-1}$ for cereals
= 1000 $\mu g\ L^{-1}$ for tolerant crops

[r] Molybdenum guideline = 50 $\mu g\ L^{-1}$ for short-terms use on acidic soils

[s] Selenium guideline = 20 $\mu g\ L^{-1}$ for continuous use
=50 $\mu g\ L^{-1}$ for intermittent use

[t] Total dissolved solids guideline =500 mg $L^{-1}$ for strawberries, raspberries, beans, and carrots
=500–800 mg $L^{-1}$ for boysenberries, currants, blackberries, gooseberries, plums, grapes, apricots, peaches, pears, cherries, apples, onions, parsnips, radishes, peas, pumpkins, lettuce, peppers, muskmelons, sweet potatoes, sweet corn, potatoes, celery, cabbage, kohlrabi, cauliflower, cowpeas, broadbeans, flax, sunflowers, and corn
=800–1500 mg $L^{-1}$ for spinach, cantaloupe, cucumbers, tomatoes, squash, brussels sprouts, broccoli, turnips, smooth brome, alfalfa, big trefoil, beardless wild rye, vetch, timothy, and crested wheat grass
=1500–2500 mg $L^{-1}$ for beets, zucchini, rape, sorghum, oat hay, wheat hay, mountain brome, tall fescue, sweet clover, reed canary grass, birdsfoot trefoil, perennial ryegrass
=3500 mg $L^{-1}$ for asparagus, soybeans, safflower, oats, rye, wheat, sugar beets, barley, barley hay, and tall wheat grass

[u] Zinc guideline =1000 mg $L^{-1}$ when soil pH $<$ 6.5
=5000 mg $L^{-1}$ when soil pH $>$ 6.5

*Source*: From Canadian Council of Ministers of the Environment, 2005, Canadian water quality guidelines for the protection of agricultural water uses: summary table, Updated October 2005. In: *Canadian Environmental Quality Guidelines, 1999*, Canadian Council of Ministers of the Environment, Winnipeg.

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**Table 8F.80 Australian Trigger Values for Thermotolerant Coliforms in Irrigation Water Used for Food and Nonfood Crops**

| Intended use | Level of thermotolerant coliforms[a] (mL) |
|---|---|
| Raw human food crops in direct contact with irrigation water (e.g. via sprays, irrigation of salad vegetables) | <10 cfu[b] / 100 |
| Raw human food crops not in direct contact with irrigation water (edible product separated from contact with water, e.g. by peel, use of trickle irrigation); or crops sold to consumer cooked or processed | <1000 cfu / 100 |
| Pasture and fodder for dairy animals (without withholding period) | <100 cfu / 100 |
| Pasture and fodder for dairy animals (with withholding period of 5 days) | <1000 cfu / 100 |
| Pasture and fodder (for grazing animals except pigs and dairy animals, i.e. cattle, sheep, and goats) | <1000 cfu / 100 |
| Silviculture, turf, cotton, etc (restricted public access) | <10 000 cfu / 100 |

[a] Median values.
[b] cfu = colony forming units.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: Adapted from ARMCANZ, ANZECC & NHMRC (1999).

**Table 8F.81 Australian Agricultural Irrigation Water Long-Term Trigger Value (LTV) and Short-Term Trigger Value (STV) Guidelines for Nitrogen and Phosphorus**

| Element | LTV in Irrigation Water (Long-Term—up to 100 yrs) (mg/L) | STV in Irrigation Water (Short-Term—up to 20 yrs) (mg/L) |
|---|---|---|
| Nitrogen | 5 | 25–125[a] |
| Phosphorus | 0.05 (To minimise bioclogging of irrigation equipment only) | 0.8–12[a] |

[a] Requires site-specific assessment.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8F.82 Interim Trigger Value Concentrations for a Range of Herbicides Registered in Australia for Use in or Near Waters**

| Herbicide | Residue Limits in Irrigation Water (mg/L)[a] | Hazard to Crops from Residue in Water[b] | Crop Injury Threshold in Irrigation Water (mg/L) |
|---|---|---|---|
| Acrolein | 0.1 | + | Flood or furrow: beans 60, corn 60, cotton 80, soybeans 20, sugar-beets 60 |
| AF 100 | | + | Sprinkler: corn 60, soybeans 15, sugar-beets 15, beets (rutabaga) 3.5, corn 3.5, |
| Amitrol | 0.002 | ++ | lucerne 1600, beans 1200, carrots 1600, corn 3000, cotton 1600, grains sorghum 800, |
| Aromatic solvents (Xylene) | | + | oats 2400, potatoes 1300, wheat 1200 |
| Asulam | | ++ | |
| Atrazine | | ++ | |
| Bromazil | | +++ | |
| Chlorthiamid | | ++ | |
| Copper sulfate | | + | Apparently above concentrations used for weed control |
| 2,4-D | | ++ | Field beans 3.5–10, grapes 0.7–1.5, sugar-beets 1.0–10 |
| Dicamba | | ++ | Cotton 0.18 |

*(Continued)*

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**Table 8F.82 (Continued)**

| Herbicide | Residue Limits in Irrigation Water (mg/L)[a] | Hazard to Crops from Residue in Water[b] | Crop Injury Threshold in Irrigation Water (mg/L) |
|---|---|---|---|
| Dichlobenil | | ++ | Lucerne 10, corn 10, soybeans 1.0, sugar-beets 1.0–10, corn 125, beans 5 |
| Diquat | | + | |
| Diuron | 0.002 | +++ | |
| 2,2-DPA (Dalapon) | 0.004 | ++ | Beets 7.0, corn 0.35 |
| Fosamine | | +++ | |
| Fluometuron | | ++ | Sugar-beets, alfalfa, tomatoes, squash 2.2 |
| Glyphosate | | + | |
| Hexazinone | | +++ | |
| Karbutilate | | +++ | |
| Molinate | | ++ | |
| Paraquat | | + | Corn 10, field beans 0.1, sugar-beets 1.0 |
| Picloram | | +++ | |
| Propanil | | ++ | Alfalfa 0.15, brome grass (eradicated) 0.15 |
| Simazine | | ++ | |
| 2,4,5-T | | ++ | Potatoes, alfalfa, garden peas, corn sugar-beets, wheat, peaches, grapes, apples, tomatoes 0.5 |
| TCA (Trichloroacetic acid) | | +++ | |
| Terbutryne | | ++ | |
| Triclopyr | | ++ | |

*Note*: These should be regarded as interim trigger values only.

[a] Guidelines have not been set for all herbicides where specific residue limits are not provided, except for a general limit of 0.01 mg/L for herbicides in NSW.

[b] Hazard from residue at maximum concentration likely to be found in irrigation water: +, low; ++, moderate; +++, high.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: From ANZECC (1992).

**Table 8F.83 Australian Trigger Values for Radioactive Contaminants for Irrigation Water**

| Radionuclide | Trigger Concentration (Bq/L) |
|---|---|
| Radium 226 | 5 |
| Radium 228 | 2 |
| Uranium 238 | 0.2 |
| Gross alpha | 0.5 |
| Gross beta (excluding K-40) | 0.5 |

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8F.84 Corrosion Potential of Waters on Metal Surface and Fouling Potential as Indicated by pH, Hardness, Langelier Index, Ryznar Index, and the Log of Chloride Carbonate Ratio**

| Parameter[a] | Value | Comments |
|---|---|---|
| **Corrision Potential** | | |
| pH | <5 | High corrosion potential |
| | 5–6 | Likelihood of corrosion |
| | >6 | Limited corrosion potential |
| Hardness | <60 mg/L CaCO3 | Increased corrosion potential |
| Langelier index | < −0.5 | Increased corrosion potential |
| | −0.5–0.5 | Limited corrosion potential |
| Ryznar index | <6 | Limited corrosion potential |
| | >7 | Increased corrosion potential |
| Log of chloride to carbonate ratio | >2 | Increased corrosion potential |
| **Fouling potential** | | |
| pH | <7 | Limited fouling potential |
| | 7–8.5 | Moderate fouling potential (groundwater)[b] |
| | >8.5 | Increased fouling potential (groundwater)[c] |
| Hardness | <350 mg/L $CaCO_3$ | Increased fouling potential |
| Langelier index | >0.5 | Increased fouling potential |
| | −0.5–0.5 | Limited fouling potential |
| Ryznar index | <6 | Increased fouling potential |
| | >7 | Limited fouling potential |
| Log of chloride to carbonate ratio | <2 | Increased fouling potential |

[a] For further information on these parameters refer to Volume 3, Section 9.2.9.1.
[b] For surface waters, pH range 7 to 9.
[c] For surface waters, pH >9.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8F.85 Influence of Water Quality on the Potential for Clogging Problems in Localized (Drip) Irrigation Systems**

| | | Degree of Restriction on Use | | |
|---|---|---|---|---|
| **Potential Problem** | **Units** | **None** | **Slight to Moderate** | **Severe** |
| **Physical** | | | | |
| Suspended solids | mg/L | <50 | 50–100 | >100 |
| **Chemical** | | | | |
| pH | | <7.0 | 7.0–8.0 | >8.0 |
| Dissolved solids | mg/L | <500 | 500–2000 | >2000 |
| Manganese[a] | mg/L | <0.1 | 0.1–1.5 | >1.5 |
| Iron[b] | mg/L | <0.1 | 0.1–1.5 | >1.5 |
| Hydrogen sulphide | mg/L | <0.5 | 0.5–2.0 | >2.0 |
| **Biological** | | | | |
| Bacterial populations | Maximum number/ML | <10000 | 10000–50000 | >50000 |

[a] While restrictions in use of localized (drip) irrigation systems may not occur at these manganese concentrations, plant toxicities may occur at lower concentrations.
[b] Iron concentrations >5.0 mg/L may cause nutritional imbalances in certain crops. www.fao.org/icatalog/inter-e.htm

*Source*: From Food and Agriculture Organization of the United Nations, 1994, Water Quality for Agriculture, Irrigation, and Drainage Paper No 29, Rev. 1, www.fao.org. Reprinted with permission.

*Original Source*: Adapted from Nakayama (1982).

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# SECTION 8G WATER QUALITY FOR AQUATIC LIFE

## United States National Recommended Water Quality Criteria for Priority Toxic Pollutants

Section 304(a)(1) of the Clean Water Act requires the United States Environmental Protection Agency (EPA) to develop criteria for water quality that accurately reflects the latest scientific knowledge. These criteria are based solely on data and scientific judgments on pollutant concentrations and environmental or human health effects. Section 304(a) also provides guidance to states and tribes in adopting water-quality standards. Criteria are developed for the protection of aquatic life as well as for human health.

The Criteria Maximum Concentration (CMC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. The CMC and CCC are just two of the six parts of an aquatic life criterion; the other four parts are the acute averaging period, chronic averaging period, acute frequency of allowed exceedence, and chronic frequency of allowed exceedence. Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States.

The tables below lists all priority toxic pollutants and some non priority toxic pollutants, and both human health effect and organoleptic effect criteria issued pursuant to CWA §304(a). Blank spaces indicate that EPA has no CWA §304(a) criteria recommendations. For a number of nonpriority toxic pollutants not listed, CWA §304(a) "water + organism" human health criteria are not available, but EPA has published MCLs under the SDWA that may be used in establishing water-quality standards to protect water supply designated uses.

The human health criteria for the priority and nonpriority pollutants are based on carcinogenicity of $10^{-6}$ risk. Alternate risk levels may be obtained by moving the decimal point (e.g., for a risk level of $10^{-5}$, move the decimal point in the recommended criterion one place to the right).

The compilation contains 304(a) criteria for pollutants with toxicity-based criteria as well as nontoxicity based criteria. The basis for the nontoxicity based criteria are organoleptic effects (e.g., taste and odor) which would make water and edible aquatic life unpalatable but not toxic to humans. The table includes criteria for organoleptic effects for 23 pollutants. Pollutants with organoleptic effect criteria more stringent than the criteria based on toxicity (e.g., included in both the priority and nonpriority pollutant tables) are footnoted as such.

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**Table 8G.86 United States National Recommended Water Quality Criteria for Priority Toxic Pollutants**

| | | | Freshwater | | Saltwater | | Human Health for the Consumption of | | |
|---|---|---|---|---|---|---|---|---|---|
| | Priority Pollutant | CAS Number | CMC (acute) (μg/L) | CCC (chronic) (μg/L) | CMC (acute) (μg/L) | CCC (chronic) (μg/L) | Water + Organism (μg/L) | Organism Only (μg/L) | FR Cite/Source |
| 1 | Antimony | 7440360 | | | | | 5.6[A] | 640[A] | 65FR66443 |
| 2 | Arsenic | 7440382 | 340[B,C,D] | 150[B,C,D] | 69[B,C,D,E] | 36[B,C,D,E] | | | 65FR31682 |
| | | | | | | | 0.018[F,G,H] | 0.14[F,G,H] | 57FR60848 |
| 3 | Beryllium | 7440417 | | | | | [i] | | 65FR31682 |
| 4 | Cadmium | 7440439 | 2.0[C,D,E,J] | 0.25[C,D,E,J] | 40[C,E] | 8.8[C,E] | [i] | | EPA-822-R-01–001 |
| | | | | | | | | | 65FR31682 |
| 5a | Chromium (III) | 16065831 | 570[C,J,D] | 74[C,J,D] | | | Total[i] | | EPA820/B-96–001 |
| | | | | | | | | | 65FR31682 |
| 5b | Chromium (VI) | 18540299 | 16[C,D] | 11[C,D] | 1,100[C,E] | 50[C,E] | Total[i] | | 65FR31682 |
| 6 | Copper | 7440508 | 13[C,D,J,K] | 9.0[C,D,J,K] | 4.8[C,K,L] | 3.1[C,K,L] | 1,300[M] | | 65FR31682 |
| 7 | Lead | 7439921 | 65[C,E,J,N] | 2.5[C,E,J,N] | 210[C,E] | 8.1[C,E] | | | 65FR31682 |
| 8a | Mercury | 7439976 | 1.4[C,D,O] | 0.77[C,D,O] | 1.8[C,O,P] | 0.94[C,O,P] | | | 62FR42160 |
| 8b | Methylmercury | 22967926 | | | | | | 0.3 mg/kg[Q] | EPA823-R-01–001 |
| 9 | Nickel | 7440020 | 470[C,J,D] | 52[C,J,D] | 74[C,E] | 8.2[C,E] | 610[A] | 4,600[A] | 65FR31682 |
| 10 | Selenium | 7782492 | —[R,S,T] | | | | | | 62FR42160 |
| | | | | 5.0[T] | 290[C,E,U] | 71[C,E,U] | | | 65FR31682 |
| | | | | | | | 170[i] | 4200 | 65FR66443 |
| 11 | Silver | 7440224 | 3.2[C,J,V] | | 1.9[C,V] | | | | 65FR31682 |
| 12 | Thallium | 7440280 | | | | | 0.24 | 0.47 | 68FR75510 |
| 13 | Zinc | 7440666 | 120[C,J,D] | 120[C,J,D] | 90[C,E] | 81[C,E] | | | 65FR31682 |
| | | | | | | | 7,400[M] | 26,000[M] | 65FR66443 |
| 14 | Cyanide | 57125 | 22[D,W] | 5.2[D,W] | | | | | EPA820/B-96–001 |
| | | | | | 1[E,W] | 1[E,W] | | | 57FR60848 |
| | | | | | | | 140[X] | 140[X] | 68FR75510 |
| 15 | Asbestos | 1332214 | | | | | 7 million fibers/L[YX] | | 57FR60848 |
| 16 | 2,3,7,8-TCDD (Dioxin) | 1746016 | | | | | 5.0E−9[F] | 5.1E−9[F] | 65FR66443 |
| 17 | Acrolein | 107028 | | | | | 190 | 290 | 65FR66443 |
| 18 | Acrylonitrile | 107131 | | | | | 0.051[A,F] | 0.25[A,F] | 65FR66443 |
| 19 | Benzene | 71432 | | | | | 2.2[A,F] | 51[A,F] | IRIS 01/19/00 &65FR66443 |
| 20 | Bromoform | 75252 | | | | | 4.3[A,F] | 140[A,F] | 65FR66443 |
| 21 | Carbon Tetrachloride | 56235 | | | | | 0.23[A,F] | 1.6[A,F] | 65FR66443 |
| 22 | Chlorobenzene | 108907 | | | | | 130[I,M] | 1,600[M] | 68FR75510 |
| 23 | Chlorodibromo-methane | 124481 | | | | | 0.40[A,F] | 13[A,F] | 65FR66443 |
| 24 | Chloroethane | 75003 | | | | | | | |
| 25 | 2-Chloroethylvinyl Ether | 110758 | | | | | | | |
| 26 | Chloroform | 67663 | | | | | 5.7[F,Z] | 470[F,Z] | 62FR42160 |
| 27 | Dichlorobro-momethane | 75274 | | | | | 0.55[A,F] | 17[A,F] | 65FR66443 |
| 28 | 1,1-Dichloroethane | 75343 | | | | | | | |
| 29 | 1,2-Dichloroethane | 107062 | | | | | 0.38[A,F] | 37[A,F] | 65FR66443 |
| 30 | 1,1-Dichloroethylene | 75354 | | | | | 330 | 7,100 | 68FR75510 |
| 31 | 1,2-Dichloropropane | 78875 | | | | | 0.50[A,F] | 15[A,F] | 65FR66443 |
| 32 | 1,3-Dichloropropene | 542756 | | | | | 0.34[F] | 21[F] | 68FR75510 |
| 33 | Ethylbenzene | 100414 | | | | | 530 | 2,100 | 68FR75510 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 34 | Methyl Bromide | 74839 | | | | | 47[A] | 1,500[A] | 65FR66443 |
| 35 | Methyl Chloride | 74873 | | | | | | | 65FR31682 |
| 36 | Methylene Chloride | 75092 | | | | | 4.6[A,F] | 590[A,F] | 65FR66443 |
| 37 | 1,1,2,2-Tetrachloroethane | 79345 | | | | | 0.17[A,F] | 4.0[A,F] | 65FR66443 |
| 38 | Tetrachloroethylene | 127184 | | | | | 0.69[F] | 3.3[F] | 65FR66443 |
| 39 | Toluene | 108883 | | | | | 1,300[I] | 15,000 | 68FR75510 |
| 40 | 1,2-Trans-Dichloroethylene | 156605 | | | | | 140[I] | 10,000 | 68FR75510 |
| 41 | 1,1,1-Trichloroethane | 71556 | | | | | —[I] | | 65FR31682 |
| 42 | 1,1,2-Trichloroethane | 79005 | | | | | 0.59[A,F] | 16[A,F] | 65FR66443 |
| 43 | Trichloroethylene | 79016 | | | | | 2.5[F] | 30[F] | 65FR66443 |
| 44 | Vinyl Chloride | 75014 | | | | | 0.025[F,aa] | 2.4[F,aa] | 68FR75510 |
| 45 | 2-Chlorophenol | 95578 | | | | | 81[A,M] | 150[A,M] | 65FR66443 |
| 46 | 2,4-Dichlorophenol | 120832 | | | | | 77[A,M] | 290[A,M] | 65FR66443 |
| 47 | 2,4-Dimethylphenol | 105679 | | | | | 380[A] | 850[A,M] | 65FR66443 |
| 48 | 2-Methyl-4,6-Dinitrophenol | 534521 | | | | | 13 | 280 | 65FR66443 |
| 49 | 2,4-Dinitrophenol | 51285 | | | | | 69[A] | 5,300[A] | 65FR66443 |
| 50 | 2-Nitrophenol | 88755 | | | | | | | |
| 51 | 4-Nitrophenol | 100027 | | | | | | | |
| 52 | 3-Methyl-4-Chlorophenol | 59507 | | | | | —[M] | —[M] | |
| 53 | Pentachlorophenol | 87865 | 19[D,bb] | 15[D,bb] | 13[E] | 7.9[E] | | | 65FR31682 |
| | | | | | | | 0.27[A,F] | 3.0[A,F,cc] | 65FR66443 |
| 54 | Phenol | 108952 | | | | | 21,000[A,M] | 1,700,000[A,M] | 65FR66443 |
| 55 | 2,4,6-Trichlorophenol | 88062 | | | | | 1.4[A,F] | 2.4[A,F,M] | 65FR66443 |
| 56 | Acenaphthene | 83329 | | | | | 670[A,M] | 990[A,M] | 65FR66443 |
| 57 | Acenaphthylene | 208968 | | | | | | | |
| 58 | Anthracene | 120127 | | | | | 8,300[A] | 40,000[A] | 65FR66443 |
| 59 | Benzidine | 92875 | | | | | 0.000086[A,F] | 0.00020[A,F] | 65FR66443 |
| 60 | Benzo(a) Anthracene | 56553 | | | | | 0.0038[A,F] | 0.018[A,F] | 65FR66443 |
| 61 | Benzo(a) Pyrene | 50328 | | | | | 0.0038[A,F] | 0.018[A,F] | 65FR66443 |
| 62 | Benzo(b) Fluoranthene | 205992 | | | | | 0.0038[A,F] | 0.018[A,F] | 65FR66443 |
| 63 | Benzo(ghi) Perylene | 191242 | | | | | | | |
| 64 | Benzo(k) Fluoranthene | 207089 | | | | | 0.0038[A,F] | 0.018[A,F] | 65FR66443 |
| 65 | Bis(2-Chloroethoxy) Methane | 111911 | | | | | | | |
| 66 | Bis(2-Chloroethyl) Ether | 111444 | | | | | 0.030[A,F] | 0.53[A,F] | 65FR66443 |
| 67 | Bis(2-Chloroisopropyl) Ether | 108601 | | | | | 1,400[A] | 65,000[A] | 65FR66443 |
| 68 | Bis(2-Ethylhexyl) Phthalate[dd] | 117817 | | | | | 1.2[A,F] | 2.2[A,F] | 65FR66443 |
| 69 | 4-Bromophenyl Phenyl Ether | 101553 | | | | | | | |
| 70 | Butylbenzyl Phthalate[ee] | 85687 | | | | | 1,500[A] | 1,900[A] | 65FR66443 |
| 71 | 2-Chloronaphthalene | 91587 | | | | | 1,000[A] | 1,600[A] | 65FR66443 |
| 72 | 4-Chlorophenyl Phenyl Ether | 7005723 | | | | | | | |
| 73 | Chrysene | 218019 | | | | | 0.0038[A,F] | 0.018[A,F] | 65FR66443 |
| 74 | Dibenzo(a,h) Anthracene | 53703 | | | | | 0.0038[A,F] | 0.018[A,F] | 65FR66443 |
| 75 | 1,2-Dichlorobenzene | 95501 | | | | | 420 | 1,300 | 68FR75510 |

*(Continued)*



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**Table 8G.86 (Continued)**

| | Priority Pollutant | CAS Number | Freshwater | | Saltwater | | Human Health for the Consumption of | | FR Cite/Source |
|---|---|---|---|---|---|---|---|---|---|
| | | | CMC (acute) (μg/L) | CCC (chronic) (μg/L) | CMC (acute) (μg/L) | CCC (chronic) (μg/L) | Water + Organism (μg/L) | Organism Only (μg/L) | |
| 76 | 1,3-Dichlorobenzene | 541731 | | | | | 320 | 960 | 65FR66443 |
| 77 | 1,4-Dichlorobenzene | 106467 | | | | | 63 | 190 | 68FR75510 |
| 78 | 3,3′-Dichlorobenzidine | 91941 | | | | | 0.021[A,F] | 0.028[A,F] | 65FR66443 |
| 79 | Diethyl Phthalate[ee] | 84662 | | | | | 17,000[A] | 44,000[A] | 65FR66443 |
| 80 | Dimethyl Phthalate[ee] | 131113 | | | | | 270,000 | 1,100,000 | 65FR66443 |
| 81 | Di-n-Butyl Phthalate[ee] | 84742 | | | | | 2,000[A] | 4,500[A] | 65FR66443 |
| 82 | 2,4-Dinitrotoluene | 121142 | | | | | 0.11[F] | 3.4[F] | 65FR66443 |
| 83 | 2,6-Dinitrotoluene | 606202 | | | | | | | |
| 84 | Di-n-Octyl Phthalate | 117840 | | | | | | | |
| 85 | 1,2-Diphenyl-hydrazine | 122667 | | | | | 0.036[A,F] | 0.20[A,F] | 65FR66443 |
| 86 | Fluoranthene | 206440 | | | | | 130[A] | 140[A] | 65FR66443 |
| 87 | Fluorene | 86737 | | | | | 1,100[A] | 5,300[A] | 65FR66443 |
| 88 | Hexachlorobenzene | 118741 | | | | | 0.00028[A,F] | 0.00029[A,F] | 65FR66443 |
| 89 | Hexachloro-butadiene | 87683 | | | | | 0.44[A,F] | 18[A,F] | 65FR66443 |
| 90 | Hexachloro-cyclopentadiene | 77474 | | | | | 40[M] | 1,100[M] | 68FR75510 |
| 91 | Hexachloroethane | 67721 | | | | | 1.4[A,F] | 3.3[A,F] | 65FR66443 |
| 92 | Ideno(1,2,3-cd)Pyrene | 193395 | | | | | 0.0038[A,F] | 0.018[A,F] | 65FR66443 |
| 93 | Isophorone | 78591 | | | | | 35[A,F] | 960[A,F] | 65FR66443 |
| 94 | Naphthalene | 91203 | | | | | | | |
| 95 | Nitrobenzene | 98953 | | | | | 17[A] | 690[A,cc,M] | 65FR66443 |
| 96 | N-Nitroso-dimethylamine | 62759 | | | | | 0.00069[A,F] | 3.0[A,F] | 65FR66443 |
| 97 | N-Nitroso-di-n-Propylamine | 621647 | | | | | 0.0050[A,F] | 0.51[A,F] | 65FR66443 |
| 98 | N-Nitroso-diphenylamine | 86306 | | | | | 3.3[A,F] | 6.0[A,F] | 65FR66443 |
| 99 | Phenanthrene | 85018 | | | | | | | |
| 100 | Pyrene | 129000 | | | | | 830[A] | 4,000[A] | 65FR66443 |
| 101 | 1,2,4-Trichlorobenzene | 120821 | | | | | 35 | 70 | 68FR75510 |
| 102 | Aldrin | 309002 | 3.0[V] | | 1.3[V] | | | | 65FR31682 |
| | | | | | | | 0.000049[A,F] | 0.000050[A,F] | 65FR66443 |
| 103 | alpha-BHC | 319846 | | | | | 0.0026[A,F] | 0.0049[A,F] | 65FR66443 |
| 104 | beta-BHC | 319857 | | | | | 0.0091[A,F] | 0.017[A,F] | 65FR66443 |
| 105 | gamma-BHC (Lindane) | 58899 | 0.95[D] | | 0.16[V] | | | | 65FR31682 |
| | | | | | | | 0.98 | 1.8 | 68FR75510 |
| 106 | delta-BHC | 319868 | | | | | | | |
| 107 | Chlordane | 57749 | 2.4[V] | 0.0043[V,ff] | 0.09[V] | 0.004[V,ff] | | | 65FR31682 |
| | | | | | | | 0.00080[A,F] | 0.00081[A,F] | 65FR66443 |
| 108 | 4,4′-DDT | 50293 | 1.1[V,gg] | 0.001[V,ff,gg] | 0.13[V,gg] | 0.001[V,ff,gg] | | | 65FR31682 |
| | | | | | | | 0.00022[A,F] | 0.00022[A,F] | 65FR66443 |
| 109 | 4,4′-DDE | 72559 | | | | | 0.00022[A,F] | 0.00022[A,F] | 65FR66443 |
| 110 | 4,4′-DDD | 72548 | | | | | 0.00031[A,F] | 0.00031[A,F] | 65FR66443 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 111 | Dieldrin | 60571 | 0.24[D] | 0.056[D,hh] | 0.71[V] | 0.0019[V,ff] | | | 65FR31682 |
| | | | | | | | 0.000052[A,F] | 0.000054[A,F] | 65FR66443 |
| 112 | Alpha-Endosulfan | 959988 | 0.22[V,ii] | 0.056[V,ii] | 0.034[V,ii] | 0.0087[V,ii] | | | 65FR31682 |
| | | | | | | | 62[A] | 89[A] | 65FR66443 |
| 113 | Beta-Endosulfan | 33213659 | 0.22[V,gg] | 0.056[V,ii] | 0.034[V,ii] | 0.0087[V,ii] | | | 65FR31682 |
| | | | | | | | 62[A] | 89[A] | 65FR66443 |
| 114 | Endosulfan Sulfate | 1031078 | | | | | 62[A] | 89[A] | 65FR66443 |
| 115 | Endrin | 72208 | 0.086[D] | 0.036[D,hh] | 0.037[V] | 0.0023[V,ff] | | | 65FR31682 |
| | | | | | | | 0.059 | 0.060 | 68FR75510 |
| 116 | Endrin Aldehyde | 7421934 | | | | | 0.29[A] | 0.30[A,cc] | 65FR66443 |
| 117 | Heptachlor | 76448 | 0.52[V] | 0.0038[V,ff] | 0.053[V] | 0.0036[V,ff] | | | 65FR31682 |
| | | | | | | | 0.000079[A,F] | 0.000079[A,F] | 65FR66443 |
| 118 | Heptachlor Epoxide | 1024573 | 0.52[V,jj] | 0.0038[V,ff,jj] | 0.053[V,jj] | 0.0036[V,ff,jj] | | | 65FR31682 |
| | | | | | | | 0.000039[A,F] | 0.000039[A,F] | 65FR66443 |
| 119 | Polychlorinated Biphenyls PCBs | | | 0.014[ff] | | 0.03[ff,kk] | | | 65FR31682 |
| | | | | | | | 0.000064[A,F,ii] | 0.000064[A,F,ii] | 65FR66443 |
| 120 | Toxaphene | 8001352 | 0.73 | 0.0002 | 0.21[ff] | 0.0002[ff] | | | 65FR31682 |
| | | | | | | | 0.00028[A,F] | 0.00028[A,F] | 65FR66443 |

[A] This criterion has been revised to reflect The Environmental Protection Agency's q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of May 17, 2002. The fish tissue bioconcentration factor (BCF) from the 1980 Ambient Water Quality Criteria document was retained in each case.

[B] This recommended water quality criterion was derived from data for arsenic (III), but is applied here to total arsenic, which might imply that arsenic (III) and arsenic (V) are equally toxic to aquatic life and that their toxicities are additive. In the *arsenic criteria document* (EPA 440/5–84–033, January 1985), Species Mean Acute Values are given for both arsenic (III) and arsenic (V) for five species and the ratios of the SMAVs for each species range from 0.6 to 1.7. Chronic values are available for both arsenic (III) and arsenic (V) for one species; for the fathead minnow, the chronic value for arsenic (V) is 0.29 times the chronic value for arsenic (III). No data are known to be available concerning whether the toxicities of the forms of arsenic to aquatic organisms are additive.

[C] Freshwater and saltwater criteria for metals are expressed in terms of the dissolved metal in the water column. The recommended water quality criteria value was calculated by using the previous 304(a) aquatic life criteria expressed in terms of total recoverable metal, and multiplying it by a conversion factor (CF). The term "Conversion Factor" (CF) represents the recommended conversion factor for converting a metal criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column. (Conversion Factors for saltwater CCCs are not currently available. Conversion factors derived for saltwater CMCs have been used for both saltwater CMCs and CCCs). See "*Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria*," October 1, 1993, by Martha G. Prothro, Acting Assistant Administrator for Water, available from the *Water Resource Center* and 40CFR§131.36(b)(1). Conversion Factors applied in the table can be found in Appendix A to the Preamble-Conversion Factors for Dissolved Metals.

[D] This recommended criterion is based on a 304(a) aquatic life criterion that was issued in the 1995 *Updates*: *Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water*, (EPA-820-B-96-001, September 1996). This value was derived using the GLI Guidelines (60FR15393–15399, March 23, 1995; 40CFR132 Appendix A); the difference between the 1985 Guidelines and the GLI Guidelines are explained on page iv of the 1995 Updates. None of the decisions concerning the derivation of this criterion were affected by any considerations that are specific to the Great Lakes.

[E] This water quality criterion is based on a 304(a) aquatic life criterion that was derived using the *1985 Guidelines* (*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, PB85–227049, January 1985) and was issued in one of the following criteria documents: *Arsenic* (EPA 440/5-84-033), *Cadmium* (EPA-822-R-01-001), *Chromium* (EPA 440/5-84-029), *Copper* (EPA 440/5-84-031), *Cyanide* (EPA 440/5- 84-028), Lead (EPA 440/5-84-027), Nickel (EPA 440/5-86-004), Pentachlorophenol (EPA 440/5-86-009), Toxaphene, (EPA 440/5-86-006), Zinc (EPA 440/5-87- 003).

[F] This criterion is based on carcinogenicity of $10^{-6}$ risk. Alternate risk levels may be obtained by moving the decimal point (e.g., for a risk level of $10^{-5}$, move the decimal point in the recommended criterion one place to the right).

[G] EPA is currently reassessing the criteria for arsenic.

[H] This recommended water quality criterion for arsenic refers to the inorganic form only.

[I] A more stringent MCL has been issued by EPA. Refer to drinking water regulations (40 CFR 141) or Safe Drinking Water Hotline (1-800-426-4791) for values.

*(Continued)*



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**Table 8G.86 (Continued)**

J The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a hardness of 100 mg/L. Criteria values for other hardness may be calculated from the following: CMC (dissolved) $= \exp\{m_A [\ln(\text{hardness})] + b_A\}$ (CF), or CCC (dissolved) $= \exp\{m_C [\ln (\text{hardness})] + b_C\}$ (CF) and the parameters specified in Appendix B- Parameters for Calculating Freshwater Dissolved Metals Criteria That Are Hardness-Dependent.

K When the concentration of dissolved organic carbon is elevated, copper is substantially less toxic and use of Water-Effect Ratios might be appropriate.

L This recommended water quality criterion was derived in *Ambient Water Quality Criteria Saltwater Copper Addendum* (Draft, April 14, 1995) and was promulgated in the Interim final National Toxics Rule (*60FR22228–222237*, May 4, 1995).

M The organoleptic effect criterion is more stringent than the value for priority toxic pollutants.

N EPA is actively working on this criterion and so this recommended water quality criterion may change substantially in the near future.

O This recommended water quality criterion was derived from data for inorganic mercury (II), but is applied here to total mercury. If a substantial portion of the mercury in the water column is methylmercury, this criterion will probably be under protective. In addition, even though inorganic mercury is converted to methylmercury and methylmercury bioaccumulates to a great extent, this criterion does not account for uptake via the food chain because sufficient data were not available when the criterion was derived.

P This recommended water quality criterion was derived on page 43 of the *mercury criteria document* (EPA 440/5-84-026, January 1985). The saltwater CCC of 0.025 ug/L given on page 23 of the criteria document is based on the Final Residue Value procedure in the 1985 Guidelines. Since the publication of the Great Lakes Aquatic Life Criteria Guidelines in 1995 (60FR15393–15399, March 23, 1995), the Agency no longer uses the Final Residue Value procedure for deriving CCCs for new or revised 304(a) aquatic life criteria.

Q This fish tissue residue criterion for methylmercury is based on a total fish consumption rate of 0.0175 kg/day.

R The CMC $= 1/[(f1/CMC1) + (f2/CMC2)]$ where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 g/L and 12.82 g/L, respectively.

S This value for selenium was announced (*61FR58444–58449*, November 14, 1996) as a proposed GLI 303(c) aquatic life criterion. EPA is *currently working on this criterion* and so this value might change substantially in the near future.

T This recommended water quality criterion for selenium is expressed in terms of total recoverable metal in the water column. It is scientifically acceptable to use the conversion factor (0.996- CMC or 0.922- CCC) that was used in the GLI to convert this to a value that is expressed in terms of dissolved metal.

U The selenium criteria document (EPA 440/5-87-006, September 1987) provides that if selenium is as toxic to saltwater fishes in the field as it is to freshwater fishes in the field, the status of the fish community should be monitored whenever the concentration of selenium exceeds 5.0 g/L in salt water because the saltwater CCC does not take into account uptake via the food chain.

V This Criterion is based on 304(a) aquatic life criterion issued in 1980, and was issued in one of the following documents: *Aldrin/Dieldrin* (EPA 440/5-80-019), *Chlordane* (EPA 440/5-80-027), *DDT* (EPA 440/5-80-038), *Endosulfan* (EPA 440/5-80-046), *Endrin* (EPA 440/5-80-047), *Heptachlor* (EPA 440/5-80-052), *Hexachlorocyclohexane* (EPA 440/5-80-054), Silver (EPA 440/5-80-071). The Minimum Data Requirements and derivation procedures were different in the 1980 Guidelines than in the *1985 Guidelines*. For example, a "CMC" derived using the 1980 Guidelines was derived to be used as an instantaneous maximum. If assessment is to be done using an averaging period, the values given should be divided by 2 to obtain a value that is more comparable to a CMC derived using the *1985 Guidelines*.

W This recommended water quality criterion is expressed as g free cyanide (as CN)/L.

X This recommended water quality criterion is expressed as total cyanide, even though the IRIS RFD we used to derive the criterion is based on free cyanide. The multiple forms of cyanide that are present in ambient water have significant differences in toxicity due to their differing abilities to liberate the CN-moiety. Some complex cyanides require even more extreme conditions than refluxing with sulfuric acid to liberate the CN-moiety. Thus, these complex cyanides are expected to have little or no 'bioavailability' to humans. If a substantial fraction of the cyanide present in a water body is present in a complexed form (e.g. $Fe_4[Fe(CN)_6]_3$), this criterion may be over conservative.

Y This criterion for asbestos is the Maximum Contaminant Level (MCL) developed under the Safe Drinking Water Act (SDWA).

Z Although a new RfD is available in IRIS, the surface water criteria will not be revised until the National Primary Drinking Water Regulations: Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) is completed, since public comment on the relative source contribution (RSC) for chloroform is anticipated.

aa This recommended water quality criterion was derived using the cancer slope factor of 1.4 (LMS exposure from birth).

bb Freshwater aquatic life values for pentachlorophenol are expressed as a function of pH, and are calculated as follows: $\text{CMC} = \exp(1.005(\text{pH}) - 4.869)$; $\text{CCC} = \exp(1.005(\text{pH}) - 5.134)$. Values displayed in table correspond to a pH of 7.8.

cc No criterion for protection of human health from consumption of aquatic organisms excluding water was presented in the 1980 criteria document or in the 1986 *Quality Criteria for Water*. Nevertheless, sufficient information was presented in the 1980 document to allow the calculation of a criterion, even though the results of such a calculation were not shown in the document.

dd There is a full set of aquatic life toxicity data that show that DEHP is not toxic to aquatic organisms at or below its solubility limit.

ee Although EPA has not published a completed criteria document for butylbenzyl phthalate it is EPA's understanding that sufficient data exist to allow calculation of aquatic criteria. It is anticipated that industry intends to publish in the peer reviewed literature draft aquatic life criteria generated in accordance with EPA Guidelines. EPA will review such criteria for possible issuance as national WQC.

ff This criterion is based on a 304(a) aquatic life criterion issued in 1980 or 1986, and was issued in one of the following documents: *Aldrin/Dieldrin* (EPA 440/5-80-019), *Chlordane* (EPA 440/5-80-027), *DDT* (EPA 440/5-80-038), *Endrin* (EPA 440/5-80-047), *Heptachlor* (EPA 440/5-80-052), Polychlorinated biphenyls (EPA 440/5-80-068), Toxaphene (EPA 440/5-86-006). This CCC is currently based on the Final Residue Value (FRV) procedure. Since the publication of the Great Lakes Aquatic Life Criteria Guidelines in 1995 (60FR15393–15399, March 23, 1995), the Agency no longer uses the Final Residue Value procedure for deriving CCCs for new or revised 304(a) aquatic life criteria. Therefore, the Agency anticipates that future revisions of this CCC will not be based on the FRV procedure.

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[gg] This criterion applies to DDT and its metabolites (i.e. the total concentration of DDT and its metabolites should not exceed this value).
[hh] The derivation of the CCC for this pollutant (Endrin) did not consider exposure through the diet, which is probably important for aquatic life occupying upper trophic levels.
[ii] This value was derived from data for endosulfan and is most appropriately applied to the sum of alpha-endosulfan and beta-endosulfan.
[jj] This value was derived from data for heptachlor and the criteria document provides insufficient data to estimate relative toxicities of heptachlor and heptachlor epoxide.
[kk] This criterion applies to total pcbs, (e.g. the sum of all congener or all isomer or homolog or Aroclor analyses.)

*Source*: From United States Environmental Protection Agency, 2005, *National Recommended Water Quality Criteria*, www.epa.gov.



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**Table 8G.87 United States National Recommented Water Quality Criteria for Nonpriority Pollutants**

| | | | Freshwater | | Saltwater | | Human Health for the Consumption of | | |
|---|---|---|---|---|---|---|---|---|---|
| | Nonpriority Pollutant | CAS Number | CMC (acute) (μg/L) | CCC (chronic) (μg/L) | CMC (acute) (μg/L) | CCC (chronic) (μg/L) | Water + Organism (μg/L) | Organism Only (μg/L) | FR Cite/Source |
| 1 | Alkalinity | — | | 20000[a] | | | | | Gold Book |
| 2 | Aluminum pH 6.5–9.0 | 7429905 | 750[b,c] | 87[b,c,d] | | | | | 53FR33178 |
| 3 | Ammonia | 7664417 | Freshwater criteria are pH, temperature and life-stage dependent—see document[e] Saltwater criteria are pH and temperature dependent | | | | | | EPA822-R-99–014 EPA440/5-88-004 |
| 4 | Aesthetic Qualities | — | Narrative statement—see document (See table notes) | | | | | | Gold Book |
| 5 | Bacteria | — | For primary recreation and shellfish uses—see document | | | | | | Gold Book |
| 6 | Barium | 7440393 | | | | | 1,000[f] | | Gold Book |
| 7 | Boron | — | Narrative statement—see document | | | | | | Gold Book |
| 8 | Chloride | 16887006 | 860000[b] | 230000[b] | | | | | 53FR19028 |
| 9 | Chlorine | 7782505 | 19 | 11 | 13 | q | —[g] | | Gold Book |
| 10 | Chlorophenoxy Herbicide (2,4,5,-TP) | 93721 | | | | | 10[f] | | Gold Book |
| 11 | Chlorophenoxy Herbicide (2,4-D) | 94757 | | | | | 100[f,g] | | Gold Book |
| 12 | Chloropyrifos | 2921882 | 0.083[b] | 0.041[b] | 0.011[b] | 0.0056[b] | | | Gold Book |
| 13 | Color | — | Narrative statement—see document (See table notes)[a] | | | | | | Gold Book |
| 14 | Demeton | 8065483 | | 0.1[a] | | 0.1[a] | | | Gold Book |
| 15 | Ether, Bis (Chloromethyl) | 542881 | | | | | 0.00010[h,i] | 0.00029[h,i] | 65FR66443 |
| 16 | Gases, Total Dissolved | — | Narrative statement—see document[a] (See table notes) | | | | | | Gold Book |
| 17 | Guthion | 86500 | | 0.01[a] | | 0.01[a] | | | Gold Book |
| 18 | Hardness | — | Narrative statement—see document | | | | | | Gold Book |
| 19 | Hexachlorocyclo-hexane-Technical | 319868 | | | | | 0.0123 | 0.0414 | Gold Book |
| 20 | Iron | 7439896 | | 1000[a] | | | 300[f] | | Gold Book |
| 21 | Malathion | 121755 | | 0.1[a] | | 0.1[a] | | | Gold Book |
| 22 | Manganese | 7439965 | | | | | 50[f,j] | 100[f] | Gold Book |
| 23 | Methoxychlor | 72435 | | 0.03[a] | | 0.03[a] | 100[f,g] | | Gold Book |
| 24 | Mirex | 2385855 | | 0.001[a] | | 0.001[a] | | | Gold Book |
| 25 | Nitrates | 14797558 | | | | | 10,000[f] | | Gold Book |
| 26 | Nitrosamines | — | | | | | 0.0008 | 1.24 | Gold Book |
| 27 | Dinitrophenols | 25550587 | | | | | 69 | 5300 | 65FR66443 |
| 28 | Nitrosodi-butylamine,[k] | 924163 | | | | | 0.0063[f,i] | 0.22[f,i] | 65FR66443 |
| 29 | Nitrosodi-ethylamine,[k] | 55185 | | | | | 0.0008[f,l] | 1.24[f,i] | Gold Book |
| 30 | Nitrosopy-rrolidine,[k] | 930552 | | | | | 0.016[i] | 34[l] | 65FR66443 |
| 31 | Oil and Grease | — | Narrative statement—see document[a] (See table notes) | | | | | | Gold Book |
| 32 | Oxygen, Dissolved Freshwater | 7782447 | Warmwater and coldwater matrix—see document[k] | | | | | | Gold Book |
| | Oxygen, Dissolved Saltwater | | Saltwater—see document | | | | | | EPA-822R-00–012 |
| 33 | Parathion | 56382 | 0.065[l] | 0.013[l] | | | | | Gold Book |
| 34 | Pentachlo-robenzene | 608935 | | | | | 1.4[h] | 1.5[h] | 65FR66443 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 35 | pH | — | 6.5–9[a] | | | 6.5–8.5[a,m] | 5–9 | | Gold Book |
| 36 | Phosphorus Elemental | 7723140 | | | | 0.1[a,m] | | | Gold Book |
| 37 | Nutrients | — | See EPA's *Ecoregional criteria* for Total Phosphorus, Total Nitrogen, Chlorophyll *a* and Water Clarity (Secchi depth for lakes; turbidity for streams and rivers) (& Level III Ecoregional criteria) | | | | | | [n] |
| 38 | Solids Dissolved and Salinity | — | | | | | 250,000[f] | | Gold Book |
| 39 | Solids Suspended and Turbidity | — | Narrative statement—see document[a] (See table notes) | | | | | | Gold Book |
| 40 | Sulfide-Hydrogen Sulfide | 7783064 | 2.0[a] | | | 2.0[a] | | | Gold Book |
| 41 | Tainting Substances | — | Narrative statement—see document (See table notes) | | | | | | Gold Book |
| 42 | Temperature | — | Species dependent criteria—see document[o] | | | | | | Gold Book |
| 43 | Tetrachloro-benzene,-1,2,4,5- | 95943 | | | | | 0.97[h] | 1.1[h] | 65FR66443 |
| 44 | Tributyltin (TBT) | — | 0.46[p] | 0.072[p] | 0.42[p] | 0.0074[p] | | | 69FR342 |
| 45 | Trichloro-phenol,2,4,5- | 95954 | | | | | 1,800[h,q] | 3,600[h,q] | 65FR66443 |

Appendix C — Calculation of Freshwater Ammonia Criterion

1. The one-hour average concentration of total ammonia nitrogen (in mg N/L) does not exceed, more than once every 3 years on the average, the CMC (acute criterion) calculated using the following equations

Where salmonid fish are present:

$$\text{CMC} = \frac{0.275}{1 + 10^{7.204-\text{pH}}} + \frac{39.0}{1 + 10^{\text{pH}-7.204}}$$

Or where salmonid fish are not present:

$$\text{CMC} = \frac{0.411}{1 + 10^{7.204-\text{pH}}} + \frac{58.4}{1 + 10^{\text{pH}-7.204}}$$

2A. The 30 average concentration of total ammonia nitrogen (in mg N/L) does not exceed, more than once every 3 years on the average, the CCC (chronic criterion) calculated using the following equations

When fish early life stages are present:

$$\text{CCC} = \frac{0.0577}{1 + 10^{7.688-\text{pH}}} + \frac{2.487}{1 + 10^{\text{pH}-7.688}} \times \text{MIN}\left(2.85, 1.45 \times 10^{0.028(25-T)}\right)$$

When fish early life stages are absent:

$$\text{CCC} = \frac{0.0577}{1 + 10^{7.688-\text{pH}}} + \frac{2.487}{1 + 10^{\text{pH}-7.688}} \times 1.45 \times 10^{0.028(25-\text{MAX}(T,7))}$$

2B. In addition, the highest 4-day average within the 30-day period should not exceed 2.5 times the CCC.

*Notes:*

**Narrative Statements: National Recommended Water Quality Criteria for Nonpriority Pollutants**

*Aesthetic Qualities*

All waters free from substances attributable to wastewater or other discharges that

(1) settle to form objectionable deposits
(2) float as debris, scum, oil, or other matter to form nuisances
(3) produce objectionable color, odor, taste, or turbidity
(4) injure or are toxic or produce adverse physiological responses in humans, animals, or plants, and

*(Continued)*



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**Table 8G.87 (Continued)**

(5) produce undesirable or nuisance aquatic life

*Color*

Waters shall be virtually free from substances producing objectionable color for aesthetic purposes

the source of supply should not exceed 75 color units on the platinum-cobalt scale for domestic water supplies; and

Increased color (in combination with turbidity) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life

*Gases, Total Dissolved*

To protect freshwater and marine aquatic life, the total dissolved gas concentrations in water should not exceed 110 percent of the saturation value for gases at the existing atmospheric and hydrostatic pressures

*Oil and Grease*

For aquatic life

(1) 0.01 of the lowest continuous flow 96-hour LC50 to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals

(2) Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed

(3) Surface waters shall be virtually free from floating nonpetroleum oils of vegetable or animal origin, as well as petroleum-derived oils

*Solids (Suspended, Settleable) and Turbidity*

*Freshwater* fish and other aquatic life

Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life

*Tainting Substances*

Materials should not be present in concentrations that individually or in combination produce undesirable flavors which are detectable by organoleptic tests performed on the edible portions of aquatic organisms

[a] The derivation of this value is presented in the *Red Book* (EPA 440/9-76-023, July, 1976).

[b] This value is based on a 304(a) aquatic life criterion that was derived using the 1985 Guidelines (*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, PB85-227049, January 1985) and was issued in one of the following criteria documents: Aluminum (EPA 440/5-86-008); Chloride (EPA 440/5-88-001); Chloropyrifos (EPA 440/5-86-005).

[c] This value for aluminum is expressed in terms of total recoverable metal in the water column.

[d] There are three major reasons why the use of Water-Effect Ratios might be appropriate. (1) The value of 87 ug/L is based on a toxicity test with the striped bass in water with pH = 6.5–6.6 and hardness $<10$ mg/L. Data in "Aluminum Water-Effect Ratio for the 3M Plant Effluent Discharge, Middleway, West Virginia" (May 1994) indicate that aluminum is substantially less toxic at higher pH and hardness, but the effects of pH and hardness are not well quantified at this time. (2) In tests with the brook trout at low pH and hardness, effects increased with increasing concentrations of total aluminum even though the concentration of dissolved aluminum was constant, indicating that total recoverable is a more appropriate measurement than dissolved, at least when particulate aluminum is primarily aluminum hydroxide particles. In surface waters, however, the total recoverable procedure might measure aluminum associated with clay particles, which might be less toxic than aluminum associated with aluminum hydroxide. (3) EPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 μg aluminum/L, when either total recoverable or dissolved is measured.

[e] According to the procedures described in the *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, except possibly where a very sensitive species is important at a site, freshwater aquatic life should be protected if both conditions specified in Appendix C to the Preamble- Calculation of Freshwater Ammonia Criterion are satisfied.

[f] This human health criterion is the same as originally published in the Red Book(EPA 440/9-76-023, July, 1976) which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value is now published in the *Gold Book*(Quality Criteria for Water: 1986. EPA 440/5-86-001).

[g] A more stringent Maximum Contaminant Level (MCL) has been issued by EPA under the Safe Drinking Water Act. Refer to drinking water regulations 40CFR141 or Safe Drinking Water Hotline (1-800-426-4791) for values.

[h] This criterion has been revised to reflect EPA's q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of May 17, 2002. The fish tissue bioconcentration factor (BCF) used to derive the original criterion was retained in each case.

[i] This criterion is based on carcinogenicity of $10^{-6}$ risk. Alternate risk levels may be obtained by moving the decimal point (e.g., for a risk level of $10^{-5}$, move the decimal point in the recommended criterion one place to the right).

[j] This criterion for manganese is not based on toxic effects, but rather is intended to minimize objectionable qualities such as laundry stains and objectionable tastes in beverages. U.S. EPA. 1973. Water Quality Criteria 1972. EPA-R3-73-033. National Technical Information Service, Springfield, VA.; U.S. EPA. 1977. Temperature Criteria for Freshwater Fish: Protocol and Procedures. EPA-600/3-77-061. National Technical Information Service, Springfield, VA.

[K] U.S. EPA. 1986. *Ambient Water Quality Criteria for Dissolved Oxygen*. EPA 440/5-86-003. National Technical Information Service, Springfield, VA.

[l] This value is based on a 304(a) aquatic life criterion that was issued in the 1995 *Updates*: *Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water* (EPA-820-B-96-001). This value was derived using the GLI Guidelines (60FR15393–15399, March 23, 1995; 40CFR132 Appendix A); the differences between the 1985 Guidelines and the GLI Guidelines are explained on page iv of the 1995 Updates. No decision concerning this criterion was affected by any considerations that are specific to the Great Lakes.

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[m] According to page 181 of the *Red Book*: For open ocean waters where the depth is substantially greater than the euphotic zone, the pH should not be changed more than 0.2 units from the naturally occurring variation or any case outside the range of 6.5 to 8.5. For shallow, highly productive coastal and estuarine areas where naturally occurring pH variations approach the lethal limits of some species, changes in pH should be avoided but in any case should not exceed the limits established for fresh water, i.e. 6.5–9.0.

[n] *Lakes and Reservoirs in Nutrient Ecoregion*: II EPA 822-B-00-007, III EPA 822-B-01-008, IV EPA 822-B-01-009, V EPA 822-B-01-010, VI EPA 822-B-00-008, VII EPA 822-B-00-009, VIII EPA 822-B-01-015, IX EPA 822-B-00-011, XI EPA 822-B-00-012, XII EPA 822-B-00-013, XIII EPA 822-B-00-014, XIV EPA 822-B-01-011; *Rivers and Streams in Nutrient Ecoregion*: I EPA 822-B-01-012, II EPA 822-B-00-015, III EPA 822-B-00-016, IV EPA 822-B-01-013, V EPA 822-B-01-014, VI EPA 822-B-00-017, VII EPA 822-B-00-018, VIII EPA 822-B-01-015, IX EPA 822-B-00-019, X EPA 822-B-01-016, XI EPA 822-B-00-020, XII EPA 822-B-00-021, XIV EPA 822-B-00-022; and *Wetlands in Nutrient Ecoregion* XIII EPA 822-B-00-023.

[p] EPA announced the availability of a draft updated tributyltin (TBT) document on August 7, 1997 (62FR42554). The Agency *has reevaluated this document* and anticipates releasing an updated document for public comment in the near future.

[q] The organoleptic effect criterion is more stringent than the value presented in the nonpriority pollutants table.

*Source*: From United States Environmental Protection Agency, 2005, *National Recommended Water Quality Criteria*, www.epa.gov.

*Original Source*: From United States Environmental Protection Agency Gold Book, *Quality Criteria for Water: 1986*, EPA 44015-86-001.



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**Table 8G.88 United States National Recommended Water Quality Criteria for Organoleptic Effects**

| | Pollutant | CAS Number | Organoleptic Effect Criteria (μg/L) | FR Cite/Source |
|---|---|---|---|---|
| 1 | Acenaphthene | 83329 | 20 | Gold Book[a] |
| 2 | Monochlorobenzene | 108907 | 20 | Gold Book |
| 3 | 3-Chlorophenol | — | 0.1 | Gold Book |
| 4 | 4-Chlorophenol | 106489 | 0.1 | Gold Book |
| 5 | 2,3-Dichlorophenol | — | 0.04 | Gold Book |
| 6 | 2,5-Dichlorophenol | — | 0.5 | Gold Book |
| 7 | 2,6-Dichlorophenol | — | 0.2 | Gold Book |
| 8 | 3,4-Dichlorophenol | — | 0.3 | Gold Book |
| 9 | 2,4,5-Trichlorophenol | 95954 | 1 | Gold Book |
| 10 | 2,4,6-Trichloropehnol | 88062 | 2 | Gold Book |
| 11 | 2,3,4,6-Tetrachlorophenol | — | 1 | Gold Book |
| 12 | 2-Methyl-4-Chlorophenol | — | 1800 | Gold Book |
| 13 | 3-Methyl-4-Chlorophenol | 59507 | 3000 | Gold Book |
| 14 | 3-Methyl-6-Chlorophenol | — | 20 | Gold Book |
| 15 | 2-Chlorophenol | 95578 | 0.1 | Gold Book |
| 16 | Copper | 7440508 | 1000 | Gold Book |
| 17 | 2,4-Dichlorophenol | 120832 | 0.3 | Gold Book |
| 18 | 2,4-Dimethylpehnol | 105679 | 400 | Gold Book |
| 19 | Hexachlorocyclopentadiene | 77474 | 1 | Gold Book |
| 20 | Nitrobenzene | 98953 | 30 | Gold Book |
| 21 | Pentachlorophenol | 87865 | 30 | Gold Book |
| 22 | Phenol | 108952 | 300 | Gold Book |
| 23 | Zinc | 7440666 | 5000 | 45 FR 79341 |

*Note:* These criteria are based on organoleptic (taste and odor) effects. Because of variations in chemical nomenclature systems, this listing of pollutants does not duplicate the listing in Appendix A of 40 CFR Part 423. Also listed are the Chemical Abstracts Service (CAS) registry numbers, which provide a unique identification for each chemical.

[a] The Gold book is Quality Crieteria for Water: 1986. EPA 440/5-86-001.

*Source*: From United States Environmental Protection Agency, 2005, *Nutrient Recommended Water Quality Criteria*, www.epa.gov.

These tables present the recommended EPA criteria for each of the aggregate nutrient ecoregions for the following parameters: Total Phosphorus (TP), Total Nitrogen (TN), Chlorophyll *a*, and Turbidity or Secchi. Criteria are presented for both Lakes & Reservoirs and Rivers & Streams.

**Table 8G.89 United States Recommended Criteria for Each of the Aggregate Nutrients Ecoregions Lakes and Reservoirs**

| Parameter | Agg Ecor II | Agg Ecor III | Agg Ecor IV | Agg Ecor V | Agg Ecor VI | Agg Ecor VII | Agg Ecor VIII | Agg Ecor IX | Agg Ecor XI | Agg Ecor XII | Agg Ecor XIII | Agg Ecor XIV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TP μg/L | 8.75 | 17.00 | 20.00 | 33.00 | 37.5 | 14.75 | 8.00 | 20.00 | 8.00 | 10.00 | 17.50 | 8.00 |
| TN μg/L | 0.10 | 0.40 | 0.44 | 0.56 | 0.78 | 0.66 | 0.24 | 0.36 | 0.46 | 0.52 | 1.27 | 0.32 |
| Chl a μg/L | 1.90 | 3.40 | 2.00 S | 2.30 S | 8.59 S | 2.63 | 2.43 | 4.93 | 2.79 S | 2.60 | 12.35 T | 2.90 |
| Secchi (m) | 4.50 | 2.70 | 2.00 | 1.30 | 1.36 | 3.33 | 4.93 | 1.53 | 2.86 | 2.10 | 0.79 | 4.50 |

*Note:* Chl *a*, Chlorophyll *a* measured by Fluorometric method, unless specified; S is for Spectrophotometric and T is for Trichromatic method.

*Source*: From United States Environmental Protection Agency, *Nutrient Water Quality Criteria, Ecoregional Criteria*, www.epa.gov/waterscience/criteria/nutrient/ecoregions.

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**Table 8G.90 United States Recommended Criteria for Each of the Aggregate Nutrient Ecoregions Rivers and Streams**

| Parameter | Agg Ecor I | Agg Ecor II | Agg Ecor III | Agg Ecor IV | Agg Ecor V | Agg Ecor VI | Agg Ecor VII | Agg Ecor VIII | Agg Ecor IX | Agg Ecor X | Agg Ecor XI | Agg Ecor XII | Agg Ecor XIV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TP μg/L | 47.00 | 10.00 | 21.88 | 23.00 | 67.00 | 76.25 | 33.00 | 10.00 | 36.56 | 128[a] | 10.00 | 40.00 | 31.25 |
| TN μg/L | 0.31 | 0.12 | 0.38 | 0.56 | 0.88 | 2.18 | 0.54 | 0.38 | 0.69 | 0.76 | 0.31 | 0.90 | 0.71 |
| Chl a μg/L | 1.80 | 1.08 | 1.78 | 2.40 | 3.00 | 2.70 | 1.50 | 0.63 | 0.93 S | 2.10 S | 1.61 S | 0.40 S | 3.75 S |
| Turb FTU/NTU | 4.25 | 1.30 N | 2.34 | 4.21 | 7.83 | 6.36 | 1.70 N | 1.30 | 5.70 | 17.50 | 2.30 N | 1.90 N | 3.04 |

*Note:* Turb, Turbidity; Chl *a*, Chlorophyll *a* measured by Fluorometric method, unless specified; S is for Spectrophotometric and T is for Trichromatic method; N for NTU. Unit of measurement for Turbidity.

[a] This value appears inordinately high and may either be a statistical anomaly or reflects a unique condition. In any case, further regional investigation is indicated to determine the sources, i.e. measurement error, notational error, statistical anomaly, natural enriched conditions, or cultural impacts. From United States Environmental Protection Agency, Nutrient Water Quality Criteria, Ecoregional Criteria, www.epa.gov/waterscience/criteria/nutrient/ecoregions/.

*Source*: From United States Environmental Protection Agency, *Nutrient Water Quality Criteria, Ecoregional Criteria*, www.epa.gov/waterscience/criteria/nutrient/ecoregions/.

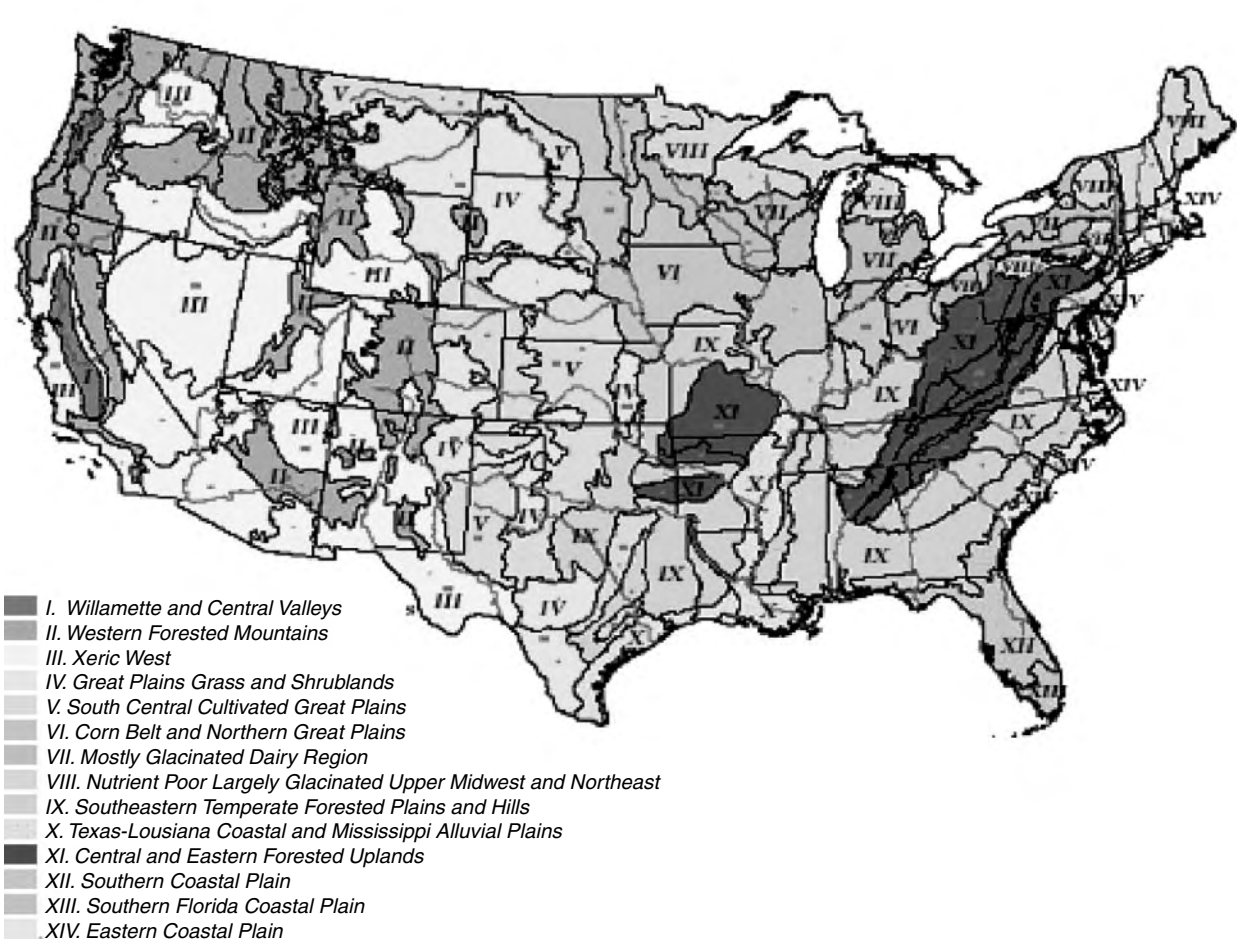


**Figure 8G.21** United States draft aggregations of level III ecoregions for the national nutrient strategy. (From United States Environmental Protection Agency, *Nutrient Water Quality Criteria, Where-You-Live*, epa.gov/waterscience/criteria/nutrient/where-you-live.htm).

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**Table 8G.91 Aquatic Life Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras**

| Endpoint | Persistent Exposure (24 hr or Greater Continuous Low DO Conditions) | Episodic and Cyclic Exposure (Less Than 24 hr Duration of Low DO Conditions) |
|---|---|---|
| Juvenile and adult survival (minimum allowable conditions) | (1) *a limit for continuous exposure*<br><br>DO = 2.3 mg/L<br>(criterion minimum concentration, CMC) | (4) *a limit based on the hourly duration of exposure*<br><br>DO = 3.70 n($t$) + 1.095<br>where:<br>DO, allowable concentration (mg/L); $t$, exposure duration (hrs) |
| Growth effects (maximum conditions required) | (2) *a limit for continuous exposure*<br><br>DO = 4.8 mg/L<br><br>(criterion continuous concentration, CCC) | (5) *a limit based on the intensity and hourly duration of exposure*<br>Cumulative cyclic adjusted percent daily reduction in growth must not exceed 25%<br>$\sum_{1}^{n} \frac{t_i \times 1.56 \times \text{Gredi}}{24} < 25\%$ and Gredi $= -23.1 \times \text{DO}_i + 138.1$<br>where:<br>$\text{Gred}_i$, growth reduction (%); $\text{DO}_i$, allowable concentration (mg/L); $t_i$, exposure interval duration (hrs); $i$, exposure interval |
| Larval recruitment effects[a] (specific allowable conditions) | (3) *a limit based on the number of days a continuous exposure can occur*<br><br>Cumulative fraction of allowable days above a given daily mean DO must not exceed 1.0<br><br>$\sum \frac{t_i(\text{actual})}{t_i(\text{allowed})} < 1.0$ and $\text{DO}_i = \frac{13.0}{(2.80 + 1.84e^{-0.10t_i})}$<br><br>where:<br>$\text{DO}_i$, allowable concentration (mg/L); $t_i$, exposure interval duration (d); $i$, exposure interval | (6) *a limit based on the number of days an intensity and hourly duration pattern of exposure can occur*<br><br>Maximum daily cohort mortality for any hourly duration interval of a DO minimum must not exceed a corresponding allowable days of occurrence<br><br>where:<br><br>Allowable number of days is a function of maximum daily cohort mortality (%)<br><br>Maximum daily cohort mortality (%) is a function of DO minimum for any exposure interval (mg/L) and the duration of the interval (hrs) |

[a] Model integrating survival effects to maintain minimally impaired larval populations.

*Source*: From USEPA, 2000, *Aquatic Life Criteria Document for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, EPA-822-R-00-012, November 2000, www.epa.gov.

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**Table 8G.92 United States Sediment Quality Guidelines for Metals in Freshwater Ecosystems That Reflect Threshold Effect Concentrations (TECs) (i.e., Below Which Harmful Effects are Unlikely to Be Observed)**

| | Threshold Effect Concentrations | | | | | | |
|---|---|---|---|---|---|---|---|
| **Substance** | **TEL** | **LEL** | **MET** | **ERL** | **TEL-HA28** | **SQAL** | **Consensus-Based TEC** |
| Metals (mg/kg DW) | | | | | | | |
| Arsenic | 5.9 | 6 | 7 | 33 | 11 | NG | 9.79 |
| Cadmium | 0.596 | 0.6 | 0.9 | 5 | 0.58 | NG | 0.99 |
| Chromium | 37.3 | 26 | 55 | 80 | 36 | NG | 43.4 |
| Copper | 35.7 | 16 | 28 | 70 | 28 | NG | 31.6 |
| Lead | 35 | 31 | 42 | 35 | 37 | NG | 35.8 |
| Mercury | 0.174 | 0.2 | 0.2 | 0.15 | NG | NG | 0.18 |
| Nickel | 18 | 16 | 35 | 30 | 20 | NG | 22.7 |
| Zinc | 123 | 120 | 150 | 120 | 98 | NG | 121 |
| Polycyclic aromatic hydrocarbons (μg/kg DW) | | | | | | | |
| Anthracene | NG | 220 | NG | 85 | 10 | NG | 57.2 |
| Fluorene | NG | 190 | NG | 35 | 10 | 540 | 77.4 |
| Naphthalene | NG | NG | 400 | 340 | 15 | 470 | 176 |
| Phenanthrene | 41.9 | 560 | 400 | 225 | 19 | 1,800 | 204 |
| Benz[a]anthracene | 31.7 | 320 | 400 | 230 | 16 | NG | 108 |
| Benzo(a)pyrene | 31.9 | 370 | 500 | 400 | 32 | NG | 150 |
| Chrysene | 57.1 | 340 | 600 | 400 | 27 | NG | 166 |
| Dibenz[a,h]anthracene | NG | 60 | NG | 60 | 10 | NG | 33.0 |
| Fluoranthene | 111 | 750 | 600 | 600 | 31 | 6,200 | 423 |
| Pyrene | 53 | 490 | 700 | 350 | 44 | NG | 195 |
| Total PAHs | NG | 4,000 | NG | 4,000 | 260 | NG | 1,610 |
| Polychlorinated biphenyls (μg/kg DW) | | | | | | | |
| Total PCBs | 34.1 | 70 | 200 | 50 | 32 | NG | 59.8 |
| Organochlorine pesticides (μg/kg DW) | | | | | | | |
| Chlordane | 4.5 | 7 | 7 | 0.5 | NG | NG | 3.24 |
| Dieldrin | 2.85 | 2 | 2 | 0.02 | NG | 110 | 1.90 |
| Sum DDD | 3.54 | 8 | 10 | 2 | NG | NG | 4.88 |
| Sum DDE | 1.42 | 5 | 7 | 2 | NG | NG | 3.16 |
| Sum DDT | NG | 8 | 9 | 1 | NG | NG | 4.16 |
| Total DDTs | 7 | 7 | NG | 3 | NG | NG | 5.28 |
| Endrin | 2.67 | 3 | 8 | 0.02 | NG | 42 | 2.22 |
| Heptachlor epoxide | 0.6 | 5 | 5 | NG | NG | NG | 2.47 |
| Lindane (gamma-BHC) | 0.94 | 3 | 3 | NG | NG | 3.7 | 2.37 |

*Note:* TEL, threshold effect level; dry weight (Smith et al., 1996); LEL, lowest effect level, dry weight (Persaud et al., 1993); MET, minimal effect threshold; dry weight (EC and MENVIQ, 1992); ERL, effect range low; dry weight (Long and Morgan, 1991); TEL-HA28, threshold effect level for *Hyalella azteca*; 28 day test; dry weight (US EPA 1996a); SQAL, sediment quality advisory levels; dry weight at 1% OC (US EPA 1997a); NG, no guideline.

*Source*: From MacDonald, D.D, Ingersoll, C.G., and Berger, T.A., 2000, Development and evaluation of consensus-based sediment quality guidelines for freshwater ecostystems, *Archives of Environmental Contamination Toxicology* 39, 20–31, Table 2, © 2000 Springer-Verlag New York, Inc. With kind permission of Springer Science and Business Media.

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**Table 8G.93 United States Sediment Quality Guidelines for Metals in Freshwater Ecosystems That Reflect Probable Effect Concentrations (PECs) (i.e., Above Which Harmful Effects are Unlikely to Be Observed)**

| | Probable Effect Concentrations | | | | | |
|---|---|---|---|---|---|---|
| **Substance** | **PEL** | **SEL** | **TET** | **ERM** | **PEL-HA28** | **Consensus-Based TEC** |
| Metals (mg/kg DW) | | | | | | |
| Arsenic | 17 | 33 | 17 | 85 | 48 | 33.0 |
| Cadmium | 3.53 | 10 | 3 | 9 | 3.2 | 4.98 |
| Chromium | 90 | 110 | 100 | 145 | 120 | 111 |
| Copper | 197 | 110 | 86 | 390 | 100 | 149 |
| Lead | 91.3 | 250 | 170 | 110 | 82 | 128 |
| Mercury | 0.486 | 2 | 1 | 1.3 | NG | 1.06 |
| Nickel | 36 | 75 | 61 | 50 | 33 | 48.6 |
| Zinc | 315 | 820 | 540 | 270 | 540 | 459 |
| Polycyclic aromatic hydrocarbons (μg/kg DW) | | | | | | |
| Anthracene | NG | 3,700 | NG | 960 | 170 | 845 |
| Fluorene | NG | 1,600 | NG | 640 | 150 | 536 |
| Naphthalene | NG | NG | 600 | 2,100 | 140 | 561 |
| Phenanthrene | 515 | 9,500 | 800 | 1,380 | 410 | 1,170 |
| Benz[a]anthracene | 385 | 14,800 | 500 | 1,600 | 280 | 1,050 |
| Benzo(a)pyrene | 782 | 14,400 | 700 | 2,500 | 320 | 1,450 |
| Chrysene | 862 | 4,600 | 800 | 2,800 | 410 | 1,290 |
| Fluoranthene | 2,355 | 10,200 | 2,000 | 3,600 | 320 | 2,230 |
| Pyrene | 875 | 8,500 | 1,000 | 2,200 | 490 | 1,520 |
| Total PAHs | NG | 100,000 | NG | 35,000 | 3,400 | 22,800 |
| Polychlorinated biphenyls (μg/kg DW) | | | | | | |
| Total PCBs | 277 | 5,300 | 1,000 | 400 | 240 | 676 |
| Organochlorine pesticides (μg/kg DW) | | | | | | |
| Chlordane | 8.9 | 60 | 30 | 6 | NG | 17.6 |
| Dieldrin | 6.67 | 910 | 300 | 8 | NG | 61.8 |
| Sum DDD | 8.51 | 60 | 60 | 20 | NG | 28.0 |
| Sum DDE | 6.75 | 190 | 50 | 15 | NG | 31.3 |
| Sum DDT | NG | 710 | 50 | 7 | NG | 62.9 |
| Total DDTs | 4,450 | 120 | NG | 350 | NG | 572 |
| Endrin | 62.4 | 1,300 | 500 | 45 | NG | 207 |
| Heptachlor epoxide | 2.74 | 50 | 30 | NG | NG | 16.0 |
| Lindane (gamma-BHC) | 1.38 | 10 | 9 | NG | NG | 4.99 |

*Source*: From MacDonald, D.D, Ingersoll, C.G., and Berger, T.A., 2000, Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems, *Archives of Environmental Contamination Toxicology* 39, 20–31, Table 3, © 2000 Springer-Verlag New York, Inc. With kind permission of Springer Science and Business Media.

**Table 8G.94 United States Sediment Quality Guidelines for Marine Sediment**

| **Chemical** | **CAS No.** | **Threshold Effects Level (TEL)** | **Effects Range-Low (ERL)** | **Effects Range-Median (ERM)** | **Probable Effects Level (PEL)** | **Apparent[a] Effects Threshold (AET)** |
|---|---|---|---|---|---|---|
| Aluminum (Al) (%) | | | | | | 1.8% N |
| Antimony (Sb) | | | | | | 9,300 E |
| Arsenic (As) | | 7,240 | 8,200 | 70,000 | 41,600 | 35,000 B |
| Barium (Ba) | | | | | | 48,000 A |
| Cadmium (Cd) | | 676 | 1,200 | 9,600 | 4,210 | 3,000 N |
| Chromium (Cr) | | 52,300 | 81,000 | 370,000 | 160,400 | 62,000 N |
| Cobalt (Co) | | | | | | 10,000 N |
| Copper (Cu) | | 18,700 | 34,000 | 270,000 | 108,200 | 390,000 MO |
| Iron (Fe) (%) | | | | | | 22% N |
| Lead (Pb) | | 30,240 | 46,700 | 218,000 | 112,180 | 400,000 B |

*(Continued)*

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**Table 8G.94 (Continued)**

| Chemical | CAS No. | Threshold Effects Level (TEL) | Effects Range-Low (ERL) | Effects Range-Median (ERM) | Probable Effects Level (PEL) | Apparent[a] Effects Threshold (AET) |
|---|---|---|---|---|---|---|
| Manganese (Mn) | | | | | | 260,000 N |
| Mercury (Hg) | | 130 | 150 | 710 | 696 | 410 M |
| Nickel (Ni) | | 15,900 | 20,000 | 51,600 | 42,800 | 110,000 EL |
| Selenium (Se) | | | | | | 1,000 A |
| Silver (Ag) | | 730 | 1,000 | 3,700 | 1,770 | 3,100 B |
| Tin (Sn) | | | | | | >3,400 N as TBT |
| Vanadium (V) | | | | | | 57,000 N |
| Zinc (Zn) | | 124,000 | 150,000 | 410,000 | 271,000 | 410,000 I |
| Sulfides | | | | | | 4,500 MO |
| **Chlorinated dioxins and PCBs** | | | | | | |
| TCDD 2,3,7,8- | 1746016 | | | | | 0.0036 N |
| Polychlorinated biphenyls | 1336363 | 21.55 | 22.7 | 180 | 188.79 | 130 M |
| **Semivolatiles** | | | | | | |
| Benzoic acid | 65850 | | | | | 65 O |
| Benzyl alcohol | 100516 | | | | | 52 B |
| Dibenzofuran | 132649 | 5100 H | | | | 110 E |
| **Semivolatile, nitroaromatics** | | | | | | |
| Nitrobenzene | 98953 | | | | | 21 N |
| N-nitrosodiphenylamine | 86306 | | | | | 28 I |
| **Semivolatile, organochlorines** | | | | | | |
| Aldrin | 309002 | | | | | 9.5 AE |
| Chlordane | 57749 | 2.26 | 0.5 | 6 | 4.79 | 2.8 A |
| p,p-DDD (TDE) | 72548 | 1.22 | 2 | 20 | 7.81 | 16 I |
| p,p-DDE | 72559 | 2.07 | 2.2 | 27 | 374.17 | 9 I |
| p,p-DDT | 50293 | 1.19 | 1 | 7 | 4.77 | 12 E |
| DDT, total | | 3.89 | 1.58 | 46.1 | 51.7 | 11 B |
| Dieldrin[b] | 60571 | 0.715 | 0.02 | 8 | 4.3 | 1.9 E |
| Heptachlor | 76448 | | | | | 0.3 B |
| Hexachlorobenzene | 118741 | | | | | 6 B |
| Hexachlorobutadiene | 87683 | | | | | 1.3 E |
| Hexachlorocyclohexane (BHC) | 608731 | | | | | |
| Hexachloroethane | 67721 | | | | | 73 BL |
| Lindane | 58899 | 0.32 | | | 0.99 | >4.8 N |
| **Semivolatile, PAHs** | | | | | | |
| Acenaphthene | 83329 | 6.71 | 16 | 500 | 88.9 | 130 E |
| Acenaphthylene | 208968 | 5.87 | 44 | 640 | 127.87 | 71 E |
| Anthracene | 120127 | 46.85 | 85.3 | 1100 | 245 | 280 E |
| Benzo(k)fluoranthene | 207089 | | | | | 1800 EI |
| Benzo(a)pyrene | 50328 | 88.81 | 430 | 1600 | 763.22 | 1100 E |
| Benzo(b)fluoranthene | 205992 | | | | | 1800 EI |
| Benzo(ghi)perylene | 191242 | | | | | 670 M |
| Benz(a)anthracene | 56553 | 74.83 | 261 | 1600 | 692.53 | 960 E |
| Chrysene | 218019 | 107.77 | 384 | 2800 | 845.98 | 950 E |
| Dibenz(a,h)anthracene | 53703 | 6.22 | 63.4 | 260 | 134.61 | 230 OM |
| Fluoranthene | 206440 | 112.82 | 600 | 5100 | 1493.54 | 1300 E |
| Fluorene | 86737 | 21.17 | 19 | 540 | 144.35 | 120 E |
| Indeno(1,2,3-cd)pyrene | 193395 | | | | | 600 M |
| Methylnaphthalene, 2- | 91576 | 20.21 | 70 | 670 | 201.28 | 64 E |
| Naphthalene | 91203 | 34.57 | 160 | 2100 | 390.64 | 230 E |
| Phenanthrene | 85018 | 86.68 | 240 | 1500 | 543.53 | 660 E |
| Pyrene | 129000 | 152.66 | 665 | 2600 | 1397.6 | 2400 E |
| LMW PAHs | | 311.7 | 552 | 3160 | 1442.00 | 1200 E |
| HMW PAHs | | 655.34 | 1700 | 9600 | 6676.14 | 7900 E |
| Total PAHs | | 1684.06 | 4022 | 44792 | 16770.4 | |
| **Volatile, aromatic and halogenated** | | | | | | |
| Dichlorobenzene 1,2- | 95501 | | | | | 13 N |
| Dichlorobenzene 1,4- | 106467 | | | | | 110 IM |

*(Continued)*

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**Table 8G.94 (Continued)**

| Chemical | CAS No. | Threshold Effects Level (TEL) | Effects Range-Low (ERL) | Effects Range-Median (ERM) | Probable Effects Level (PEL) | Apparent[a] Effects Threshold (AET) |
|---|---|---|---|---|---|---|
| **Semivolatile, phenolics** | | | | | | |
| Chlorophenol 2- | 95578 | | | | | 8 A |
| Dichlorophenol 2,4- | 120832 | | | | | 5 A |
| Dimethylphenol 2,4- | 105679 | | | | | 18 N |
| Methyl phenol 2- [O-cresol] | 95487 | | | | | 8 B |
| Methyl phenol 4- [P-cresol] | 106445 | | | | | 100 B |
| Pentachlorophenol [at pH 7.8][c] | 87865 | | | | | 17 B |
| Phenol | 108952 | | | | | 130 E |
| Trichlorophenol 2,4,5- | 95954 | | | | | 3 I |
| Trichlorophenol 2,4,6- | 88062 | | | | | 6 I |
| **Semivolatile, phthalates** | | | | | | |
| Butyl benzyl phthalate | 85687 | | | | | 63 M |
| Di[2-ethylhexyl] phthalate | 117817 | 182.16 | | | 2646.51 | 1300 I |
| Diethyl phthalate | 84662 | | | | | 6 BL |
| Dimethyl phthalate | 131113 | | | | | 6 B |
| Di-*N*-octyl phthalate | 117840 | | | | | 61 BL |
| Di-N-butyl phthalate | 84742 | | | | | 58 BL |
| Dichloropropene | 542756 | | | | | 4 EL |
| Tetrachloroethylene | 127184 | | | | | 57 I |
| Trichlorbenzene 1,2,4- | 120821 | | | | | >4.8 E |
| Trichloroethylene | 79016 | | | | | 41 N |
| Xylene | 1330207 | | | | | 4 BL |

*Note:* The Effects Range-Low (ERLs) and Effects Range-Median (ERMs) plus the marine Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) are based upon a similar data compilations, but use different calculations. The ERL is calculated as the lower 10th percentile concentration of the available sediment toxicity data which has been screened for only those samples which were identified as toxic by original investigators. It is *not* an $LC_{10}$. Since the ERL is at the low end of a range of levels at which effects were observed in the studies compiled, it represents the value at which toxicity may begin to be observed in sensitive species. The ERM is simply the median concentration of the compilation of just toxic samples. It is *not* an $LC_{50}$. The TEL is calculated as the geometric mean of the 15th percentile concentration of the toxic effects data set and the median of the no-effect data set; as such, it represents the concentration below which adverse effects are expected to occur only rarely. The PEL, as the geometric mean of the 50% of impacted, toxic samples and the 85% of the non-impacted samples, is the level above which adverse effects are frequently expected.

From Apparent Effect Thresholds (AETs) relate chemical concentrations in sediments to synoptic biological indicators of injury (i.e., sediment bioassays or diminished benthic infaunal abundance). Individual AETs are essentially equivalent to the concentration observed in the highest nontoxic sample. As such, they represent the concentration above which adverse biological impacts would *always* be expected by that biological indicator due to exposure to that contaminant alone. Conversely, adverse impacts are known to occur at levels below the AET. Only the lowest of the potential AETs is listed. AET values were developed for use in Puget Sound (Washington) and are not easily compared directly to other benchmarks based on single-chemical models and broader data sources. SquiRT cards have been updated with interim AET values which are subject to change. (All sediment and soil values in ppb dry weight, except as noted.)

[a] Entry is lowest value among AET tests. I, infaunal community impacts; A, amphipod; B, bivalve; M, microtox; O, Oyster larvae; E, Echinoderm larvae; L, $larval_{max}$; or, N-Neanthes bioassays.

[b] EPA proposed criteria, based on equilibrium partitioning, for Dieldrin are 11,000 and 20,000, and for Endrin are 4,200 and 760 μg/kg O.C. in freshwater and marine sediment, respectively.

[c] For PCP, freshwater $CMC = e^{1.005pH-4.869}$ and $CCC = e^{1.005pH-5.134}$.

*Source*: From NOAA, 1999, Screening Quick Reference Tables (SQuiRTs), www.response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html.

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**Table 8G.95 United States Equilibrium Partitioning Sediment Benchmarks ($ESB_{WQC}$s) for Dieldrin and Endrin Using the Water Quality Criteria (WQC) FCVs as the Effect Concentration**

| Type of Water Body | $Log_{10}K_{OW}$ (L/kg) | $Log_{10}K_{OC}$ (L/kg) | FCV (μg/L) | $ESG_{OC}$ (μg/$g_{OC}$) |
|---|---|---|---|---|
| **Dieldrin** | | | | |
| Freshwater | 5.37 | 5.28 | 0.06589 | 12[a] |
| Saltwater | 5.37 | 5.28 | 0.1469 | 28[b] |
| **Endrin** | | | | |
| Freshwater | 5.06 | 4.97 | 0.05805 | 5.4[a] |
| Saltwater | 5.06 | 4.97 | 0.01057 | 0.99[b] |

[a] $ESB_{WQCOC} = (10^{5.28}\ L/kg_{OC}) \times (10^{-3}\ kg_{OC}/g_{OC}) \times (0.6589\ \mu g\ dieldrin/L) = 12\ \mu g\ dieldrin/g_{OC}$.
[b] $ESB_{WQCOC} = (10^{5.28}\ L/kg_{OC}) \times (10^{-3}\ kg_{OC}/g_{OC}) \times (0.1469\ \mu g\ dieldrin/L) = 28\ \mu g\ dieldrin/g_{OC}$.
[c] $ESB_{WQCOC} = (10^{4.97}\ L/kg_{OC}) \times (10^{-3}\ kg_{OC}/g_{OC}) \times (0.05805\ \mu g\ endrin/L) = 5.4\ \mu g\ endrin/g_{OC}$.
[d] $ESB_{WQCOC} = (10^{4.97}\ L/kg_{OC}) \times (10^{-3}\ kg_{OC}/g_{OC}) \times (0.01057\ \mu g\ endrin/L) = 0.99\ \mu g\ endrin/g_{OC}$.

*Source*: From USEPA, 2003, *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Dieldrin*, EPA-600-R-02-010, August 2003; USEPA, 2003, *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Endrin*, EPA-600-R-02-009, August 2003, www.epa.gov.

**Table 8G.96 Canadian Water Quality Guidelines for the Protection of Aquatic Life**

| | Freshwater | | Marine | |
|---|---|---|---|---|
| **Parameter**[a] | **Concentration (μg/L)** | **Date**[b] | **Concentration (μg/L)** | **Date**[b] |
| **Acenaphthene [see Polycyclic aromatic hydrocarbons (PAHs)]** | | | | |
| **Acridine [see Polycyclic aromatic hydrocarbons (PAHs)]** | | | | |
| Aldicarb | 1[c] | 1993 | 0.15[c] | 1993 |
| Aldrin + Dieldrin[d] | ~~0.004~~[e,f] | 1987 | | |
| Aluminum[d] | 5–100[g] | 1987 | | |
| Ammonia (total)[h] | See factsheet | 2001 | | |
| Ammonia (unionized) | 19 | 2001 | | |
| Aniline | 2.2[i] | 1993 | Insufficient data | 1993 |
| Anthracene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Arsenic[j] | 5.0[k] | 1997 | 12.5[c] | 1997 |
| Atrazine | 1.8[i] | 1989 | | |
| Benz*(a)*anthracene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Benzene[j] | 370[c,k] | 1999 | 110[c] | 1999 |
| Benzo*(a)*pyrene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| 2,2-Bis(*p*-chlorophenyl)-1,1,-trichloroethane [see DDT (total)] | | | | |
| Bromacil | 5.0[c,i] | 1997 | Insufficient data | 1997 |
| Bromoform [see Halogenated methanes, tribromomethane] | | | | |
| Bromoxynil | 5.0[i] | 1993 | Insufficient data | 1993 |
| Cadmium | 0.017[c,l] | 1996 | 0.12[i] | 1996 |
| Captan | 1.3[c] | 1991 | | |
| Carbaryl | 0.20[i] | 1997 | 0.32[c,i] | 1997 |
| Carbofuran | 1.8[i] | 1989 | | |
| Carbon tetrachloride [see Halogenated methanes, tetrachloromethanes] | | | | |
| Chlordane[d] | ~~0.006~~[e,f] | 1987 | | |
| Chlorinated benzenes | | | | |
| Monochlorobenzene | 1.3[c,k] | 1997 | 25[c,k] | 1997 |
| 1,2-Dichlorobenzene | 0.70[c,k] | 1997 | 42[c,k] | 1997 |
| 1,3-Dichlorobenzene | 150[c,k] | 1997 | Insufficient data[k] | 1997 |
| 1,4-Dichlorobenzene | 26[c,k] | 1997 | Insufficient data[k] | 1997 |
| 1,2,3-Trichlorobenzene | 8.0[c,k] | 1997 | Insufficient data[k] | 1997 |
| 1,2,4-Trichlorobenzene | 24[c,k] | 1997 | 5.4[c,k] | 1997 |

*(Continued)*

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**Table 8G.96 (Continued)**

| Parameter[a] | Freshwater Concentration (μg/L) | Freshwater Date[b] | Marine Concentration (μg/L) | Marine Date[b] |
|---|---|---|---|---|
| 1,3,5-Trichlorobenzene[d] | Insufficient data[k] | 1997 | Insufficient data[k] | 1997 |
| 1,2,3,4-Tetrachlorobenzene | 1.8[c,k] | 1997 | Insufficient data[k] | 1997 |
| 1,2,3,5-Tetrachlorobenzene[d] | Insufficient data[k] | 1997 | Insufficient data | 1997 |
| 1,2,4,5-Tetrachlorobenzene | Insufficient data[k] | 1997 | Insufficient data[k] | 1987 |
| Pentachlorobenzene | 6.0[c,k] | 1997 | Insufficient data | 1997 |
| Hexachlorobenzene[d] | Insufficient data[e,f,k] | | Insufficient data | 1997 |
| Chlorinated ethanes | | | | |
| 1,2-Dichloroethane | 100[c,i] | 1991 | Insufficient data | 1991 |
| 1,1,1-Trichloroethane | Insufficient data | 1991 | Insufficient data | 1991 |
| 1,1,2,2-Tetrachloroethane | Insufficient data | 1991 | Insufficient data | 1991 |
| Chlorinated ethenes | | | | |
| 1,1,2-Trichloroethene (Tichloroethylene; TCE) | 21[c,i] | 1991 | Insufficient data | 1991 |
| 1,1,2,2-Tetrachloroethene (Tetrachloroethylene; PCE) | 111[c,i] | 1993 | Insufficient data | 1993 |
| Chlorinated methanes [see Halogenated methanes] | | | | |
| Chlorinated phenols[d] | | | | |
| Monochlorophenols | 7 | 1987 | | |
| Dichlorophenols | 0.2 | 1987 | | |
| Trichlorophenols | 18 | 1987 | | |
| Tetrachlorophenols | 1 | 1987 | | |
| Pentachlorophenol (PCP) | 0.5 | 1987 | | |
| Chlorine, reactive [see Reactive chlorine species] | | | | |
| Chloroform [see Halogenated methanes, trichloromethane] | | | | |
| 4-Chloro-2-methyl phenoxy acetic acid [See MCPA] | | | | |
| Chlorothalonil | 0.18[c] | 1994 | 0.36[c] | 1994 |
| Chlorpyrifos | 0.0035 | 1997 | 0.002[c] | 1997 |
| Chromium | | | | |
| Trivalent chromium (Cr(III)) | 8.9[c,k] | 1997 | 56[c,k] | 1997 |
| Hexavalent chromium (Cr(VI)) | 1.0[k] | 1997 | 1.5[k] | 1997 |
| Chrysene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Color | Narrative | 1999 | Narrative | 1999 |
| Copper[d] | 2–4[m] | 1987 | | |
| Cyanazine | 2.0[c,i] | 1990 | | |
| Cyanide[d] | 5 (as free CN) | 1987 | | |
| DDAC (Didecyl dimethyl ammonium chloride) | 1.5 | 1999 | | |
| DDT (total)[d] (2,2-Bis(*p*-chlorophenyl)-1,1,1-trichloroethane; dichloro diphenyl trichloroethane) | ~~0.001~~[e,f] | 1987 | | |
| Debris (litter/settleable matter) | | | Narrative[c] | 1996 |
| Deltamethrin | 0.0004 | 1997 | Insufficient data | 1997 |
| Deposited bedload sediment [see Total particulate matter] | | | | |
| Dibromochloromethane [see Halogenated methanes] | | | | |
| Dicamba | 10[c,i] | 1993 | | |
| Dichlorobenzene [see Chlorinated benzenes] | | | | |
| Dichlorobromomethane [see Halogenated methanes] | | | | |
| Dichloro diphenyl trichloroethane [see DDT (total)] | | | | |
| Dichloroethane [see Chlorinated ethanes] | | | | |
| Dichloroethylene [see Chlorinated ethanes, 1,2-dichloroethane] | | | | |
| Dichloromethane [see Halogenated methanes] | | | | |
| Dichlorophenols [see Chlorinated phenols] | | | | |
| 2,4-Dichlorophenoxyacetic acid [see Phenoxy herbicides] | | | | |
| Diclofop-methyl | 6.1 | 1993 | | |
| Didecyl dimethyl ammonium chloride [see DDAC] | | | | |
| Diethylene glycol [see Glycols] | | | | |
| Di(2-ethylhexyl) phthalate [see Phthalate esters] | | | | |
| Diisopropanolamine | 1600[c] | 2005 | Insufficient data | 2005 |
| Dimethoate | 6.2[c] | 1993 | Insufficient data | 1993 |
| Di-*n*-butyl phthalate [see Phthalate esters] | | | | |

*(Continued)*

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**Table 8G.96 (Continued)**

| Parameter[a] | Freshwater Concentration (μg/L) | Freshwater Date[b] | Marine Concentration (μg/L) | Marine Date[b] |
|---|---|---|---|---|
| Di-*n*-octyl phthalate [see Phthalate esters] | | | | |
| Dinoseb | 0.05 | 1992 | | |
| Dissolved gas supersaturation | Narrative | 1999 | Narrative | 1999 |
| Dissolved oxygen | 5500–9500[k,n] | 1999 | >8000 and narrative[c,k] | 1996 |
| Endosulfan[d] | 0.02 | 1987 | | |
| Endrin[d] | ~~0.0023~~[e,f] | 1987 | | |
| Ethylbenzene[j] | 90[c,k] | 1996 | 25[c,k] | 1996 |
| Ethylene glycol [see Glycols] | | | | |
| Fluoranthene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Fluorene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Glycols | | | | |
| Ethylene glycol | 192,000[k] | 1997 | Insufficient data | 1997 |
| Diethylene glycol | Insufficient data[k] | 1997 | Insufficient data | 1997 |
| Propylene glycol | 500,000[k] | 1997 | Insufficient data | 1997 |
| Glyphosate | 65[c] | 1989 | | |
| Halogenated methanes | | | | |
| Monochloromethane (Methyl chloride)[d] | Insufficient data | 1992 | Insufficient data | 1992 |
| Dichloromethane (Methylene chloride) | 98.1[c,i] | 1992 | Insufficient data | 1992 |
| Trichloromethane (Chloroform) | 1.8[c,i] | 1992 | Insufficient data | 1992 |
| Tetrachloromethane (Carbon tetrachloride) | 13.3[c,i] | 1992 | Insufficient data | 1992 |
| Monobromomethane (Methyl bromide)[d] | Insufficient data | 1992 | Insufficient data | 1992 |
| Tribromomethane (Bromoform)[d] | Insufficient data | 1992 | Insufficient data | 1992 |
| Dibromochloromethane[d] | Insufficient data | 1992 | Insufficient data | 1992 |
| Dichlorobromomethane[d] | Insufficient data | 1992 | Insufficient data | 1992 |
| HCBD [see Hexachlorobutadiene (HCBD)] | | | | |
| Heptachlor (Heptochlor epoxide)[d] | 0.01[e,f] | 1987 | | |
| Hexachlorobenzene [see Chlorinated benzenes] | | | | |
| Hexachlorobutadiene (HCBD) | 1.3[c,k] | 1999 | | |
| Hexachlorocyclohexane (Lindane)[d] | 0.01 | 1987 | | |
| Hypochlorous acid [see Reactive chlorine species] | | | | |
| Inorganic fluorides | 0.12[c] | 2002 | NRG[o] | 2002 |
| 3-Iodo-2-propynyl butyl carbamate [see IPBC] | | | | |
| IPBC (3-Iodo-2-propynyl butyl carbamate) | 1.9 | 1999 | | |
| Iron[d] | 300 | 1987 | | |
| Lead[d] | 1–7[p] | 1987 | | |
| Lindane [see Hexachlorocyclohexane] | | | | |
| Linuron | 7.0[c] | 1995 | Insufficient data | 1995 |
| MCPA (4-Chloro-2-methyl phenoxy acetic acid (2-methyl-4-chloro phenoxy acetic acid) | 2.6[c] | 1995 | 4.2[c] | 1995 |
| Mercury[w] | | | | |
| Inorganic mercury[w] | 0.026 | 2003 | 0.016[c,x] | 2003 |
| Methyl mercury[w] | 0.004[c,x] | NRG | | |
| Methyl bromide [see Halogenated methanes, Monobromomethane] | | | | |
| Methyl chloride [see Halogenated methanes, Monochloromethane] | | | | |
| 2-Methyl-4-chloro phenoxy acetic acid [see MCPA] | | | | |
| Methylene chloride [see Halogenated methanes, Dichloromethane] | | | | |
| Metolachlor | 7.8[c] | 1991 | | |
| Metribuzin | 1.0[c] | 1990 | | |
| Molybdenum[j] | 73[c] | 1999 | | |
| Monobromomethane [see Halogenated methanes] | | | | |
| Monochloramine [see Reactive chlorine species] | | | | |
| Monochlorobenzene [see Chlorinated benzenes] | | | | |
| Monochloromethane [see Halogenated methanes] | | | | |

*(Continued)*

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**Table 8G.96 (Continued)**

| Parameter[a] | Freshwater Concentration (μg/L) | Freshwater Date[b] | Marine Concentration (μg/L) | Marine Date[b] |
|---|---|---|---|---|
| Monochlorophenols [see Chlorinated phenols] | | | | |
| MTBE (methyl *tertiary* butyl ether) | 10,000 | 2003 | 5,000[c] | 2003 |
| Naphthalene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Nickel[d] | 25–150[q] | 1987 | | |
| Nitrate[d] | 13,000[c,v] | 2003 | 16,000[c,v] | 2003 |
| Nitrite[d] | 60 | 1987 | | |
| Nonylphenol and its ethoxylates | 1.0[r] | 2002 | 0.7[c,r] | 2002 |
| Organotins | | | | |
| Tributyltin | 0.008[c] | 1992 | 0.001 | 1992 |
| Tricyclohexyltin | Insufficient data | 1992 | Insufficient data | 1992 |
| Triphenyltin | 0.022[c,l] | 1992 | Insufficient data | 1992 |
| Oxygen, dissolved [see Dissolved oxygen] | | | | |
| PAHs [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| PCBs [see Polychlorinated biphenyls (PCBs)(total)] | | | | |
| PCE [see Chlorinated ethenes, 1,1,2,2-Tetrachloroethene] | | | | |
| PCP [see Chlorinated phenols, Pentachlorophenol] | | | | |
| Pentachlorobenzene [see Chlorinated benzenes] | | | | |
| Pentachlorophenol [see Chlorinated phenols] | | | | |
| pH | 6.5–9[d] | 1987 | 7.0–8.7 and narrative | 1996 |
| Phenanthrene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Phenols (mono- & dihydric) | 4.0[k] | 1999 | | |
| Phenoxy herbicides[d,s] | 4.0 | 1987 | | |
| Phophorous | narrative[v] | | | |
| Phthalate esters | | | | |
| Di-*n*-butyl phthalate | 19[c] | 1993 | Insufficient data | 1993 |
| Di(2-ethylhexyl) phthalate | 16[c] | 1993 | Insufficient data | 1993 |
| Di-*n*-octyl phthalate | Insufficient data | 1993 | Insufficient data | 1993 |
| Picloram | 29[c] | 1990 | | |
| Polychlorinated biphenyls (PCBs) (total)[d] | ~~0.001~~[e,f] | 1987 | ~~0.01~~[e,f] | 1991 |
| Polycyclic aromatic hydrocarbons (PAHs) | | | | |
| Acenaphthene | 5.8[c] | 1999 | Insufficient data | 1999 |
| Acridine | 4.4[c] | 1999 | Insufficient data | 1999 |
| Anthracene | 0.012[c] | 1999 | Insufficient data | 1999 |
| Benz*(a)*anthracene | 0.018[c] | 1999 | Insufficient data | 1999 |
| Benzo*(a)*pyrene | 0.015[c] | 1999 | Insufficient data | 1999 |
| Chrysene | Insufficient data | 1999 | Insufficient data | 1999 |
| Fluoranthene | 0.04[c] | 1999 | Insufficient data | 1999 |
| Fluorene | 3.0[c] | 1999 | Insufficient data | 1999 |
| Naphthalene | 1.1[c] | 1999 | 1.4[c] | 1999 |
| Phenanthrene | 0.4[c] | 1999 | Insufficient data | 1999 |
| Pyrene | 0.025[c] | 1999 | Insufficient data | 1999 |
| Quinoline | 3.4[c] | 1999 | Insufficient data | 1999 |
| Propylene glycol [see Glycols] | | | | |
| Pyrene [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Quinoline [see Polycyclic aromatic hydrocarbons (PAHs)] | | | | |
| Reactive chlorine species (hypochlorous acid and monochloramine) | 0.5 | 1999 | 0.5 | 1999 |
| Salinity | | | <10% fluctuation[c] | 1996 |
| Selenium[d] | 1.0 | 1987 | | |
| Silver[d] | 0.1 | 1987 | | |
| Simazine | 10 | 1991 | | |
| Streambed substrate [see Total particulate matter] | | | | |
| Styrene | 72[c] | 1999 | | |
| Sulfolane | 50,000[c] | 2005 | Insufficient data | 2005 |

*(Continued)*

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**Table 8G.96 (Continued)**

| Parameter[a] | Freshwater | | Marine | |
|---|---|---|---|---|
| | Concentration (μg/L) | Date[b] | Concentration (μg/L) | Date[b] |
| Suspended sediments [see Total particulate matter] | | | | |
| TCE [see Chlorinated ethenes, 1,1,2-Trichloroethene] | | | | |
| Tebuthiuron | 1.6[c] | 1995 | Insufficient data | 1995 |
| Temperature | Narrative[t] | 1987 | Not to exceed ± 1°C[c] | 1996 |
| Tetrachlorobenzene [see Chlorinated benzenes] | | | | |
| Tetrachloroethane [see Chlorinated ethanes] | | | | |
| Tetrachloroethene [see Chlorinated ethenes] | | | | |
| Tetrachloroethylene [see Chlorinated ethenes, 1,1,2,2-Tetrachloroethene] | | | | |
| Tetrachloromethane [see Halogenated methanes] | | | | |
| Tetrachlorophenols [see Chlorinated phenols] | | | | |
| Thallium[j] | 0.8 | 1999 | | |
| Toluene | 2.0[c,j,k] | 1996 | 215[c,k] | 1996 |
| Total particulate matter[u] | | | | |
| Deposited bedload sediment | Insufficient data | 1999 | Insufficient data | 1999 |
| Streambed substrate | Narrative | 1999 | Narrative | 1999 |
| Suspended sediments | Narrative | 1999 | Narrative | 1999 |
| Turbidity | Narrative | 1999 | Narrative | 1999 |
| Toxaphene[d] | ~~0.008~~[e,f] | 1987 | | |
| Triallate | 0.24[c] | 1992 | | |
| Tribromomethane [see Halogenated methanes] | | | | |
| Tributyltin [see Organotins] | | | | |
| Trichlorobenzene [see Chlorinated benzenes] | | | | |
| Trichloroethane [see Chlorinated ethanes] | | | | |
| Trichloroethene [see Chlorinated ethenes] | | | | |
| Trichloroethylene [see Chlorinated ethenes, 1,1,2-Trichloroethene] | | | | |
| Trichloromethane [see Halogenated methanes] | | | | |
| Trichlorophenols [see Chlorinated phenols] | | | | |
| Tricyclohexyltin [see Organotins] | | | | |
| Trifluralin | 0.20[i] | 1993 | | |
| Triphenyltin [see Organotins] | | | | |
| Turbidity [see Total particulate matter] | | | | |
| Zinc[d] | 30 | 1987 | | |

[a] Unless otherwise indicated, supporting documents are available from the Guidelines and standards division, environment Canada.
[b] The guidelines dated 1987 have been carried over from *Canadian Water Quality Guidelines* (CCREM 1987) and no fact sheet was prepared. The guidelines dated 1989 to 1997 were developed and initially published in CCREM 1987 as appendixes on the date indicated. They are published as fact sheets in this document. Other guidelines dated 1997 and those dated 1999 are published for the first time in this document.
[c] Interim guideline.
[d] No fact sheet created. For more information on this guideline, please refer to *Canadian Water Quality Guidelines* (CCREM 1987).
[e] This guideline (originally published in *Canadian Water Quality Guidelines* [CCREM 1987 + Appendixes] in 1987 or 1991 [PCBs in marine water]) is no longer recommended and the value is withdrawn. A water quality guideline is not recommended. Environmental exposure is predominantly via sediment, soil, and/or tissue, therefore, the reader is referred to the respective guidelines for these media.
[f] This substance meets the criteria for Track 1 substances under the national CCME Policy for the Management of Toxic Substances (PMTS) (i.e., persistent, bioaccumulative, primarily the result of human activity, and CEPA-toxic or equivalent), and should be subject to virtual elimination strategies. Guidelines can serve as action levels or interim management objectives toward virtual elimination.
[g] Aluminium guideline = 5 μg/L at pH < 6.5; $[Ca^{2+}] < 4$ mg/L; DOC < 2 mg/L = 100 μg/L at pH ≥ 6.5; $[Ca^{2+}] \geq 4$ mg/L; DOC ≥ 2 mg/L.
[h] Ammonia guideline: Guideline for total ammonia is temperature and pH dependent, please consult factsheet for more information.
[i] Guideline value slightly modified from CCREM 1987 + Appendixes due to re-evaluation of the significant figures.
[j] The technical document for the guideline is available from the Ontario Ministry of the Environment.
[k] Substance has been re-evaluated since CCREM 1987 + Appendixes. Either a new guideline has been derived or insufficient data existed to derive a new guideline.
[l] Cadmium guideline = $10^{\{0.86[\log(\text{hardness})]-3.2\}}$.
[m] Copper guideline = 2 μg/L at $[CaCO_3]$ = 0–120 mg/L; = 3 μg/L at $[CaCO_3]$ = 120–180 mg/L; = 4 μg/L at $[CaCO_3] > 180$ mg/L.
[n] Dissolved oxygen for warm-water biota: early life stages = 6,000 μg/L; other life stages = 5,500 μg/L; for cold-water biota: early life stages = 9,500 μg/L; other life stages = 6,500 μg/L
[o] No recommended guideline.

*(Continued)*

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**Table 8G.96 (Continued)**

[p] Lead guideline = 1 g/L at $[CaCO_3]$ = 0–60 mg/L; = 2 μg/L at $[CaCO_3]$ = 60–120 mg/L; = 4 μg/L at $[CaCO_3]$ = 120–180 mg/L; = 7 μg/L at $[CaCO_3]$ = > 180 mg/L.
[q] Nickel guideline = 25 μg/L at $[CaCO_3]$ = 0–60 mg/L; = 65 μg/L at $[CaCO_3]$ = 60–120 mg/L; = 110 μg/L at $[CaCO_3]$ = 120–180 mg/L; = 150 μg/L at $[CaCO_3]$ = > 180 mg/L.
[r] Expressed on a TEQ basis using NP TEFs, see Table 2 in factsheet.
[s] The guideline of 4.0 μg/L for phenoxy herbicides is based on data for ester formulations of 2,4-dichlorophenoxyacetic acid.
[t] Temperature: (for more information, see CCREM 1987).
*Thermal Stratification*: Thermal additions to receiving waters should be such that thermal stratification and subsequent turnover dates are not altered from those existing prior to the addition of heat from artificial origins.
*Maximum Weekly Average Temperature*: Thermal additions to receiving waters should be such that the maximum weekly average temperature is not exceeded.
*Short-term Exposure to Extreme Temperature*: Thermal additions to receiving waters should be such that the short-term exposures to maximum temperatures are not exceeded. Exposures should not be so lengthy or frequent as to adversely affect the important species.
[u] The technical document for the guideline is available from British Columbia Ministry of Environment, Lands and Parks.
[v] For protection from direct toxic effects; the guidelines do not consider indirect effects due to eutrophication.
[w] May not prevent accumulation of methylmercury in aquatic life, therefore, may not protect wildlife that consume aquatic life; see factsheet for details. Consult also the appropriate Canadian Tissue Residue Guideline for the Protection of Wildlife consumers of Aquatic Biota
[x] May not protect fully higher trophic level fish; see factsheet for details.
[y] Canadian Trigger Ranges (for further narrative see factsheet). Total Phosphorus ($ugL^{-1}$):
ultra-oligotrophic < 4
oligotrophic 4–10
mesotrophic 10–20
eutrophic 35–100
hyper-eutrophic > 100

*Source*: From Canadian Council of Ministers of the Environment, 2005. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Summary Table, Updated October 2005. In: *Canadian Environmental Quality Guidelines*, 1999, Canadian Council of Ministers of the Environment, Winnipeg, www.ec.gc.ca/CEQG-RCQE.

**Table 8G.97 Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota**

| Parameter[a] | Guideline (μg/kg diet ww)[b] | Date |
|---|---|---|
| DDT (total) | 14.0 | 1997 |
| Methylmercury | 33.0 | 2001 |
| Polychlorinated biphenyls (PCBs) | Mammalian: 0.79 ng TEQ/kg diet ww[c] | 1998 |
| | Avian: 2.4 ng TEQ/kg diet ww[d] | 1998 |
| Polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans | Mammalian: 0.71 ng TEQ/kg diet ww[c] | 2001 |
| | Avian: 4.75 ng TEQ/kg diet ww[d] | 2001 |
| Toxaphene | 6.3 | 1997 |

[a] Supporting documents are available from the Guidelines and Standards Division, Environment Canada.
[b] Guideline refers to the total concentration of the contaminant found in an aquatic organism on a wet weight (ww) basis that is not expected to result in adverse effects in predaceous wildlife.
[c] TEQ refers to dioxin toxic equivalents using toxic equivalency factors (TEFs) for PCBs for mammals developed by the World Health Organization in 1998. See fact sheet or supporting document for more details.
[d] TEQ refers to dioxin toxic equivalents using toxic equivalency factors (TEFs) for PCBs for birds developed by the World Health Organization in 1998. See fact sheet or supporting document for more details.

*Source*: From Canadian Council of Ministers of the Environment, 2001, Canadian Tissue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota: Summary Table. Updated. In: *Canadian Environmental Quality Guidelines*, 1999, Canadian Council of Ministers of the Environment, www.ec.gc.ca.

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**Table 8G.98 Summary of Water Quality Guidelines for Turbidity, Suspended and Benthic Sediments, British Columbia, Canada**

| Water Use | Maximum Induced Turbidity—NTU or % of Background | Maximum Induced Suspended Sediments—mg/L or % of Background | Streambed Substrate Composition |
|---|---|---|---|
| Drinking Water—raw untreated | 1 NTU when background is less than or equal to 5 | No Guideline | No Guideline |
| Drinking Water—raw treated | 5 NTU when background is less than or equal to 50<br>10% when background is greater than 50 | No Guideline | No Guideline |
| Recreation and Aesthetics | Maximum 50 NTU<br>secchi disc visible at 1.2 m | No Guideline | No Guideline |
| Aquatic Life<br>Fresh<br>Marine<br>Estuarine | 8 NTU in 24 hrs when background is less than or equal to 8<br>Mean of 2 NTU in 30 days when background is less than or equal to 8 | 25 mg/L in 24 hrs when background is less than or equal to 25<br>Mean of 5 mg/L in 30 days when background is less than or equal to 25 | Fines not to exceed<br>−10% as less than 2 mm<br>−19% as less than 3 mm<br>−25% as less than 6.35 mm at salmonid spawning sites |
| Aquatic Life<br>Fresh<br>Marine<br>Estuarine | 8 NTU when background is between 8 and 80<br>10% when background is greater than or equal to 80 | 25 mg/L when background is between 25 and 250<br>10% when background is greater than or equal to 250 | Geometric mean diameter not less than 12 mm<br>Fredle number not less than 5 mm |
| Terrestrial Life<br>Wildlife<br>Livestock water<br>Irrigation<br>Industrial | 10 NTU when background is less than or equal to 50<br>20% when background is greater than or equal to 50 | 20 mg/L when background is less than or equal to 100<br>20% when background is greater than or equal to 100 | No guideline |

*Source*: From British Columbia Approved Water Quality Guidelines (Criteria) 2006 Edition, Updated: August 2006, www.env.gov.bc.ca. Reprinted with Permission.

**Table 8G.99 Canadian Sediment Quality Guidelines for the Protection of Aquatic Life**

| | Freshwater | | Marine | |
|---|---|---|---|---|
| **Parameter** | **ISQG[a](ug/kg)** | **PEL[b] (ug/kg)** | **ISQG[a] (ug/kg)** | **PEL[b] (ug/kg)** |
| Arsenic | 5,900 | 17,000 | 7,240 | 41,600 |
| Cadmium | 600 | 3,500 | 700 | 4,200 |
| Chlordane | 4.50 | 8.87 | 2.26 | 4.79 |
| Chromium | 37,300 | 90,000 | 52,300 | 160,000 |
| Copper | 35,700 | 197,000 | 18,700 | 108,000 |
| DDD (2,2-Bis (*p*-chlorophenyl)-1,1-dichloroethane; Dichloro diphenyl dichloroethane)[c] | 3.54 | 8.51 | 1.22 | 7.81 |
| DDE(1,1-Dichloro-2,2-bis(*p*-chlorophenyl)-ethene, Diphenyl dichloro ethylene[c] | 1.42 | 6.75 | 2.07 | 374 |
| DDT(2,2-Bis(*p*-chlorophenyl)-1,1,1-trichloroethane; Dichloro diphenyl trichloroethane)[c] | 1.19[d] | 4.77[e] | 1.19 | 4.77 |
| Dieldrin | 2.85 | 6.67 | 0.71 | 4.3 |
| Endrin | 2.67 | 62.4 | 2.67[d] | 62.4[e] |
| Heptachlor (Heptachlor epoxide} | 0.60 | 2.74 | 0.60[d] | 2.74[e] |
| Lead | 35,000 | 91,300 | 30,200 | 112,000 |
| Lindane (Hexachlorocyclohexane) | 0.94 | 1.38 | 0.32 | 0.99 |
| Mercury | 170 | 486 | 130 | 700 |
| Nonylphenol and its ethoxylates | 1.4 mg/kg dw[f,g] | | 1.0 mg/kg dw[f,h] | |
| Polychlorinated biphenyls (PCBs) | | | | |
| Aroclor 1254 | 0.60 | 340[j] | 63.3 | 709 |
| Total PCBs | 34.1 | 277 | 21.5 | 189 |

*(Continued)*

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**Table 8G.99 (Continued)**

| Parameter | Freshwater | | Marine | |
|---|---|---|---|---|
| | ISQG[a](ug/kg) | PEL[b] (ug/kg) | ISQG[a] (ug/kg) | PEL[b] (ug/kg) |
| Polychlorinated dibenzo-*p*-dioxins/dibenzo furans (PCDD/Fs) | 0.85 ng TEQ/kg dw[k] | 21.5 ng TEQ/kg dw[k] | 0.85 ng TEQ/kg dw[k] | 21.5 ng TEQ/kg dw[k] |
| Polycyclic aromatic hydrocarbons (PAHs) | | | | |
| Acenapthene | 6.71[d] | 88.9[e] | 6.71 | 88.9 |
| Acenaphthylene | 5.87[d] | 128[e] | 5.87[d] | 128[e] |
| Anthracene | 46.9[d] | 245[e] | 46.9 | 245 |
| Benzo(a)anthracene | 31.7 | 385 | 74.8 | 693 |
| Benzo(a)pyrene | 31.9 | 782 | 88.8 | 763 |
| Chrysene | 57.1 | 862 | 108 | 846 |
| Dibenz(a,h)anthracene | 6.22[d] | 135[e] | 6.22 | 135 |
| Fluoranthene | 111 | 2,355 | 113 | 1,494 |
| Fluorene | 21.2[d] | 144[e] | 21.2 | 144 |
| 2-MethyInaphthalene | 20.2[d] | 201[e] | 20.2 | 201 |
| Naphthalene | 34.6[d] | 391[e] | 34.6 | 391 |
| Phenanthrene | 41.9 | 515 | 86.7 | 544 |
| Pyrene | 53.0 | 875 | 153 | 1,398 |
| Toxaphene | 0.1[l] | —[m] | 0.1[l] | —[m] |
| Zinc | 123,000 | 315,000 | 124,000 | 271,000 |

[a] ISQG: Interim sediment quality guideline Canadian Environmental Quality Guidelines Summary Table December 2003.
[b] PEL: Probable effect level.
[c] Sum of *p,p'* and *o,p'* isomers.
[d] Provisional: adoption of marine ISQG.
[e] Provisional: adoption of marine PEL.
[f] Provisional; use of equilibrium partitioning approach.
[g] Note that the incidence of adverse biological effects below the TEL, between the TEL and PEL, and above the PEL were 22%, 24%, and 65%, respectively, prior to the application of a safety factor.
[h] Expressed in a toxic equivalency (TEQ) basis using NP TEFs; assumes 1% TOC.
[i] Provisional: adoption of lowest effect level from Ontario (Persaud et al. 1993).
[j] Provisional: 1% TOC: adoption of severe effect level of 34μg.g-*1*TOC from Ontario (Persaud et al. 1993).
[k] Values are expressed as toxic equivalency (TEQ) units, based on WHO 1998 TEF values for fish.
[l] Provisional; 1% TOC: adoption of the chronic sediment quality criterion of 0.01 ug/gl TOC of the New York State Department of Environmental Conservation (NYSDEC 1994).
[m] No PEL derived.

*Source*: From Canadian Council of Ministers of the Environment, 2002, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Summary Table, Updated 2002. In: *Canadian Environmental Quality Guidelines*, 1999, Canadian Council of Ministers of the Environment, Winnipeg, www.ec.gc.ca/CEQG-RCQE.

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**Table 8G.100 ECE Standard Statistical Classification of Surface Freshwater Quality for the Maintenance of Aquatic Life**

| Variables | Class I | Class II | Class III | Class IV | Class V |
|---|---|---|---|---|---|
| ***Oxygen regime*** | | | | | |
| DO (%) | | | | | |
| Epilimnion (stratified waters) | 90–110 | 70–90 or 110–120 | 50–70 or 120–130 | 30–50 or 130–150 | <30 or >150 |
| Hypolimnion (stratified waters) | 90–70 | 70–50 | 50–30 | 30–10 | <10 |
| Unstratified waters | 90–70 | 70–50 or 110–120 | 50–30 or 120–130 | 30–10 or 130–150 | <10 or >150 |
| DO(mg/L) | >7 | 7-6 | 6-4 | 4-3 | <3 |
| COD-Mn (mg $O_2$ /L) | <3 | 3-10 | 10-20 | 20-30 | >30 |
| COD-Cr (mg $O_2$/L) | — | — | — | — | — |
| ***Eutrophication*** | | | | | |
| Total P (μg/L)[a] | <10 (<15) | 10–25 (15–40) | 25–50 (40–75) | 50–125 (75–190) | >125 (>190) |
| Total N (μg/L)[a] | <300 | 300–750 | 750–1,500 | 1,500–2,500 | >2,500 |
| Chlorophyll a (μg/L)[a] | <2.5 (<4) | 2.5–10 (4–15) | 10–30 (15–45) | 30–110 (45–165) | >110 (>165) |
| ***Acidification*** | | | | | |
| pH[b] | 9.0–6.5 | 6.5–6.3 | 6.3–6.0 | 6.0–5.3 | <5.3 |
| Alkalinity (mg $CaCO_3$/l) | >200 | 200–100 | 100–20 | 20–10 | <10 |
| ***Metals*** | | | | | |
| Aluminium (μg/l; pH 6.5) | <1.6 | 1.6–3.2 | 3.2–5 | May-75 | >75 |
| Arsenic (μg/L)[c] | <10 | 10–100 | 100–190 | 190–360 | >360 |
| Cadmium (μg/L)[d] | <0.07 | 0.07–0.53 | 0.53–1.1 | 1.1–3.9 | >3.9 |
| Chromium (μg/L)[c] | <1 | 1-6 | 6-11 | 11-16 | >16 |
| Copper (μg/L)[d] | <2 | 2-7 | 7-12 | 12-18 | >18 |
| Leader (μg/L)[d] | <0.1 | 0.1–1.6 | 1.6–3.2 | 3.2–82 | >82 |
| Mercury (μg/L)[d] | <0.003 | 0.003–0.007 | 0.007–0.012 | 0.012–2.4 | >2.4 |
| Nickel (μg/L)[d] | <15 | 15–87 | 87–160 | 160–1,400 | >1,400 |
| Zinc (μg/L)[d] | <45 | 45–77 | 77–110 | 110–120 | >120 |
| ***Chlorinated micropollutants and other hazardous substances*** | | | | | |
| Dieldrin (μg/L) | na | na | <0.0019 | 0.0019–2.5 | >2.5 |
| DDT and metabolites (μg/L) | na | na | <0.001 | 0.001–1.1 | >1.1 |
| Endrin (μg/L) | na | na | <0.0023 | 0.0023–0.18 | >0.18 |
| Heptachlor (μg/L) | na | na | <0.0038 | 0.0038–0.52 | >0.52 |
| Lindane (μg/L) | na | na | <0.08 | 0.08–2.0 | >2.0 |
| Pentachlorophenol (μg/L) | na | na | <13 | 13–20 | >20 |
| PCBs (μg/L) | na | na | <0.014 | 0.014–2.0 | >2.0 |
| Free ammonia ($NH_3$) | na | na | — | — | — |
| ***Radioactivity*** | | | | | |
| Gross-alpha activity (mBq/L) | <50 | 50–100 | 100–500 | 500–2,500 | >2,500 |
| Gross-beta activity (mBq/L) | <200 | 200–500 | 500–1,000 | 1,000–2,500 | >2,500 |

*Note:* Measures falling on the boundary between two classes are to be classified in the lower class; na, Not applicable; —, No value set at present.

[a] Data in brackets refer to flowing waters.
[b] Values >9.0 are disregarded in the classification of acidification.
[c] Applicable for hardness from about 0.5 to 8 meq/L. Arsenic V and chromium III to be converted to arsenic III and chromium VI, respectively.
[d] Applicable for hardness from about 0.5 to 8 meq/L.

*Source*: From Ute S. Enderlein, Rainer E. Enderlein and W. Peter Williams, 1997, Chapter 2—Water Quality Requirements, In: World Health Organization, *Water Pollution Control—A Guide to the Use of Water Quality Management Principles*, Copyright © 1997 WHO/UNEP.

*Original Source*: From The United Nations is the author of the original material. United Nations Economic Commission for Europe, 1994, Standard Statistical Classification of Surface Freshwater Quality for the Maintenance of Aquatic Life. In: *Readings in International Environment Statistics*, United Nations Economic Commission of Europe, United Nations, New York, and Geneva.

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**Table 8G.101 Water-Quality Objectives for the River Rhine Related to Organic Substances**

| Water-Quality Variable | Water-Quality Objective (μg/L) | Basis for Elaboration[a] |
|---|---|---|
| Tetrachloromethane | 1.0 | Drw + aqL |
| Trichloromethane | 0.6 | aqL |
| Aldrin, Dieldrin, Endrin, Isodrin | 0.0001 (per substance) | aq + terrL |
| Endosulfan | 0.003 | aqL |
| Hexachlorobenzene | 0.0005 | aqL |
| Hexachlorobutadien | 0.001 | aqL |
| PCB 28, 52, 101,180, 138, 153 | 0.001 (per substance) | aqL |
| 1-Chloro-4-nitro-Benzen | 1.0 | Drw |
| 1-Chloro-2-nitro-Benzen | 1.0 | Drw + aqL |
| Trichlorobenzene | 0.1 | aqL |
| Pentachlorophenol | 0.001 | aq + terrL |
| Trichloroethen | 1.0 | Drw |
| Tetrachloroethen | 1.0 | Drw |
| 3,4-Dichloroanilin | 0.1 | aqL |
| 2-Chloroanilin | 0.1 | Drw + aqL |
| 3-Chloroanilin | 0.1 | Drw |
| 4-Chloroanilin | 0.01 | aqL |
| Parathion(-ethyl) | 0.0002 | aqL |
| Parathion(-methyl) | 0.01 | aqL |
| Benzene | 0.1 | aqL |
| 1,1,1-Trichloroethane | 1.0 | Drw |
| 1,2-Dichloroethane | 1.0 | aqL |
| Azinphos-methyl | 0.001 | aqL |
| Bentazon | 0.1 | Drw |
| Simazine | 0.1 | Drw + aqL |
| Atrazine | 0.1 | Drw + aqL |
| Dichlorvos | 0.001 | aqL |
| 2-Chlorotoluol | 1.0 | Drw |
| 4-Chlorotoluol | 1.0 | Drw |
| Tributyl tin-substances | 0.001 | aqL |
| Triphenyl tin-substances | 0.001 | aqL |
| Trifluralin | 0.1 | aqL |
| Fenthion | 0.01 | aqL |

[a] Water-quality objectives have been set on the basis of water-quality criteria for drinking-water supply (Drw), drinking-water supply and aquatic life (Drw + aqL) and/or aquatic life (aqL), as well as on the basis of toxicity testing on selected species of aquatic and terrestrial life (aq + terrL).

*Source*: From Ute S. Enderlein, Rainer E. Enderlein and W. Peter Williams, 1997, Chapter 2 — Water Quality Requirements, In: *Water Pollution Control — A Guide to the Use of Water Quality Management Principles.* Copyright © 1997 WHO/UNEP.

*Original Source*: From ICPR, *Konzept zur Ausfüllung des Punktes A.2 des APR über Zielvorgaben,* 1991. Lenzburg, den 2. Juli (Methodology to implement item A.2 of the Rhine Action Programme related to water quality objectives, prepared at Lenzbourg on 2 July 1991). PLEN 3/91, *International Commission for the Protection of the Rhine against Pollution*, Koblenz, Germany, 1991, www.who.int.

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**Table 8G.102 Maximum Permissible Concentrations and Negligible Concentrations for Metals, The Netherlands**

| | Surface Water (ug/L) | | | | | | | | SED (mg/kg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metal** | **MPA (fresh)** | **NA (fresh)** | **C*b* (fresh)** | **MPC (fresh)** | **NC (fresh)** | **C*b* (marine)** | **MPC (marine)** | **NC (marine)** | **MPA (sed) (d)** | **NA (sed)** | **C*b* (sed)** | **MPC (sed)** | **Nc (sed)** |
| Antimony(Sb) | 6.2[a] | 0.062 | 0.29 | 6.5 | 0.35 | | | | 16 | 0.16 | 3.0 | 19 | 3.2 |
| Arsenic (As) | 24[b] | 0.24 | 0.77 | 25 | 1.0 | | | | 160 | 1.6 | 29 | 190 | 31 |
| Barium (Ba) | 150[a] | 1.5 | 73 | 220 | 75 | | | | 150 | 1.5 | 155 | 300 | 157 |
| Beryllium (Be) | 0.16[b] | 0.0016 | 0.02 | 0.18 | 0.022 | | | | 0.096 | 0.00096 | 1.1 | 1.2 | 1.1 |
| Cadmium (Cd) | 0.34[b] | 0.0034 | 0.08 | 0.42 | 0.083 | 0.025 | 0.37 | 0.028 | 29 | 0.29 | 0.8 | 30 | 1.1 |
| Chromium (Cr) | 8.5[b] | 0.085 | 0.17 | 8.7 | 0.26 | | | | 1,620 | 16 | 100 | 1,720 | 116 |
| Cobalt (Co) | 2.6[b] | 0.026 | 0.20 | 2.8 | 0.23 | | | | 10 | 0.10 | 9.0 | 19 | 9.1 |
| Copper (Cu) | 1.1[b] | 0.011 | 0.44 | 1.5 | 0.45 | 0.25 | 1.4 | 0.26 | 37 | 0.37 | 36 | 73 | 36 |
| Lead (Pb) | 11[b] | 0.11 | 0.15 | 11 | 0.26 | 0.02 | 11 | 0.13 | 4,700 | 47 | 85 | 4,800 | 132 |
| Mercury (Hg) | 0.23[b] | 0.0023 | 0.01 | 0.24 | 0.012 | 0.0025 | 0.23 | 0.0048 | 26 | 0.26 | 0.3 | 26 | 0.56 |
| Methyl-mercury | 0.01[b] | 0.0001 | 0.01 | 0.02 | 0.01 | 0.0025 | 0.013 | 0.0026 | 1.1 | 0.011 | 0.3 | 1.4 | 0.31 |
| Molybdenum (Mo) | 290[a] | 2.9 | 1.4 | 290 | 4.3 | | | | 250 | 2.5 | 0.5 | 250 | 3.0 |
| Nickel (Ni) | 1.8[b] | 0.018 | 3.3 | 5.1 | 3.3 | | | | 9.4 | 0.094 | 35 | 44 | 35 |
| Selenium (Se) | 5.3[b] | 0.053 | 0.04 | 5.3 | 0.093 | | | | 2.2 | 0.022 | 0.7 | 2.9 | 0.72 |
| Thallium (Tl) | 1.6[a] | 0.016 | 0.04 | 1.6 | 0.056 | | | | 1.6 | 0.016 | 1.0 | 2.6 | 1.0 |
| Tia (Sn) | 18[a] | 0.18 | 0.0002 | 18 | 0.18 | | | | 22,000 | 220 | 19 | 22,000 | 239 |
| Vanadium (V) | 3.5[a] | 0.035 | 0.82 | 4.3 | 0.86 | | | | 14 | 0.14 | 42 | 56 | 42 |
| Zinc (Zn) | 6.6[b] | 0.066 | 2.8 | 9.4 | 2.9 | 0.35 | 7.0 | 0.42 | 480 | 4.8 | 140 | 620 | 145 |

*Note:* MPA, maximum permissible addition; NA, Negligible Addition, Cb, background concentration; MPC, maximum permissible concentration; NC, negligible concentration for metals; fresh, freshwater; marine, saltwater.

[a] MPA based on modified EPA-method
[b] MPA based on statistical extrapolation
[c] Values are given as concentrations in mg/kg standard soil/sediment (soil/sediment containing 10% organic matter and 25% clay)
[d] MPA based on equilibrium partitioning.

*Source*: From Crommentuijn, T., M. Polder, and E. van de Plassche. 1997. Maximum permissible concentrations and negligible concentrations for metals, taking background concentrations into account. *Nat. Inst. Public Health and the Environ.*, Bilthoven, The Netherlands. RIVM Report 601501001, tivm.nl.



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**Australia and New Zealand**
**Physico-Chemical Stressor Low-Risk Guideline Trigger Values for Ecosystems**

The default approach to deriving trigger values has used the statistical distribution of reference data collected within five geographical regions across Australia and New Zealand. Here, depending on the stressor, a *measureable perturbation* in slightly to moderately disturbed ecosystems has been defined using the 80th and/or 20th percentile of the reference data.

First, New Zealand and Australian state and territory representatives used percentile distributions of available data and professional judgement to derive trigger values for each ecosystem type in their regions.Trigger values were then collated, discussed and agreed for southeast Australia (VIC, NSW, ACT, south-east QLD, and TAS,) southwest Australia (southern WA), tropical Australia (northern WA, NT, northern QLD), south central Australia —— low rainfall area (SA) and New Zealand.

The default trigger values in the present guidelines were derived from ecosystem data for unmodified or slightly-modified ecosystems supplied by state agenicies. However, the choice of these reference systems was not based on any objective biological criteria. This lack of specificity may have resulted in inclusion of reference systems of varying quality, and further emphasises that the default trigger values should only be used until site- or ecosystem-specific values can be generated.

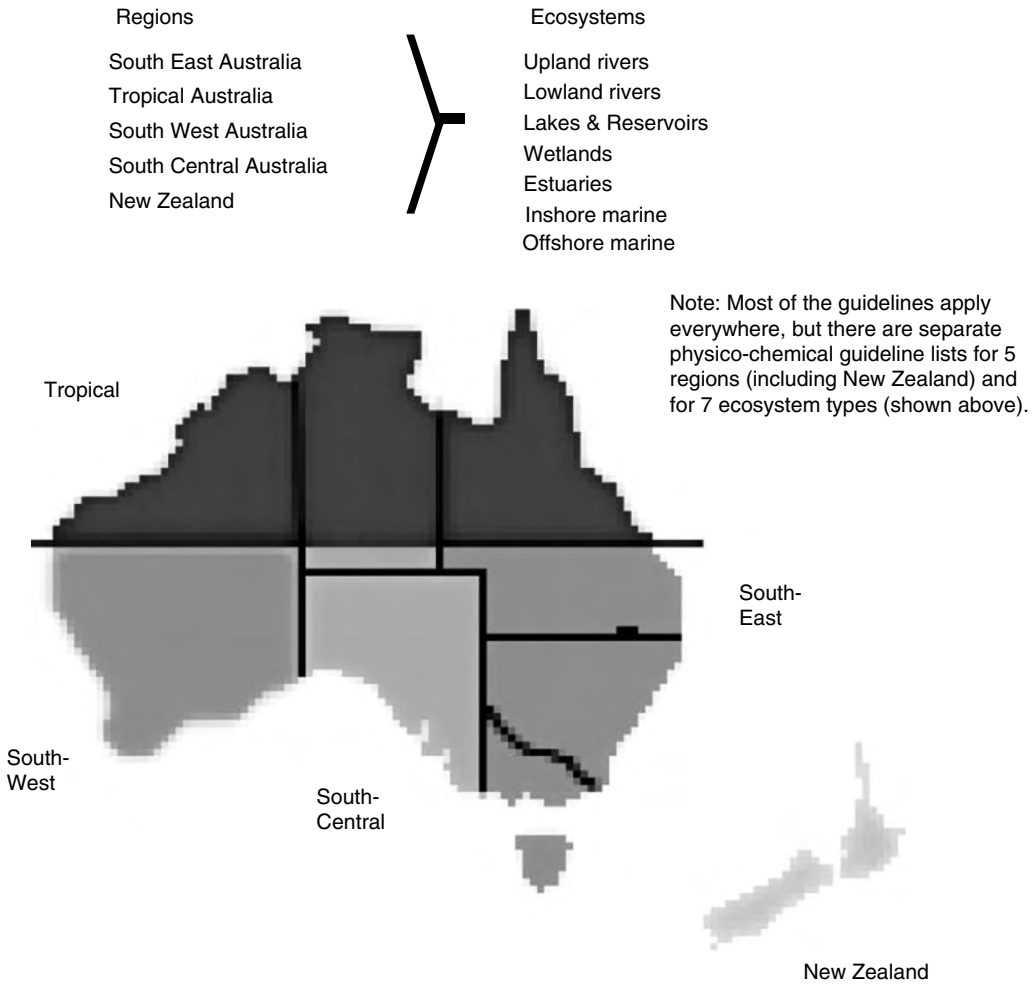


**Figure 8G.22** Geographic regions of Australia and New Zealand. (From Australia Water Quality — Introduction, *The Guideline Value Lists*; www.ozh2o.com/ozh3a.html.)

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**Table 8G.103 Default Trigger Values for Physical and Chemical Stressors for Southeast Australia for Slightly Disturbed Ecosystems**

| Ecosystem Type | Chl *a* (μg/L) | TP (μg P/L) | FRP (μg P/L) | TN (μg N/L) | $NO_x$ (μg N/L) | $NH_4^+$ (μg N/L) | DO (% saturation)[a] Lower Limit | DO (% saturation)[a] Upper Limit | pH Lower Limit | pH Upper Limit |
|---|---|---|---|---|---|---|---|---|---|---|
| Upland river | na[b] | 20[c] | 15[d] | 250[e] | 15[f] | 13[k] | 90 | 110 | 6.5 | 7.5[g] |
| Lowland river[h] | 5 | 50 | 20 | 500 | 40[i] | 20 | 85 | 110 | 6.5 | 8.0 |
| Freshwater lakes & Reservoirs | 5[j] | 10[k] | 5 | 350 | 10 | 10 | 90 | 110 | 6.5 | 8.0[g] |
| Wetlands | no data | no data | no data | no data | no data | no data | no data | no data | no data | no data |
| Estuaries[l] | 4[m] | 30 | 5[n] | 300 | 15 | 15 | 80 | 110 | 7.0 | 8.5 |
| Marine[l] | 1[o] | 25[o] | 10 | 120 | 5[p] | 15[p] | 90 | 110 | 8.0 | 8.4 |

*Note:* Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Data derived from trigger values supplied by Australian states and territories. Chl *a*, chlorophyll *a*; TP, total phosphorus; FRP, filterable reactive phosphate; TN, total nitrogen; $NO_x$, oxides of nitrogen; $NH_4^+$, ammonium; DO, dissolved oxygen; na, not applicable.

[a] Dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may very diurnally and with depth. Monitoring programs should assess this potential variability.
[b] Monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers — values for periphyton biomass (mg Chl a $m^{-2}$) to be developed.
[c] Values are 30 μg/L for Qld rivers, 10 μg/L for Vic. Alpine streams and 13 μg/L for Tas. Rivers.
[d] Values is 5 μg/L for Vic. alpine streams and Tas. rivers;
[e] Values are 100 μg/L for Vic. alpine streams and 480 μg/L for Tas. rivers.
[f] Value is 190 μg/L for Tas. rivers.
[g] Values for NSW upland rivers are 6.5–8.0, for NSW lowland rivers 6.5–8.5, for humic rich Tas. lakes and rivers 4.0–6.5.
[h] Values are 3 μg/L for Chl *a*, 25 μg/L for TP and 350 μg/L for TN for NSW & Vic. east flowing coastal rivers.
[i] value is 60 μg/L for Qld rivers.
[j] Values are 3 μg/L for Tas. lakes.
[k] Values is 10 μg/L for Qld. rivers.
[l] No data available for Tasmanian estuarine and marine waters. A precautionary approach should be adopted when applying default trigger values to these systems.
[m] Values is 5 μg/L for Qld estuaries.
[n] Value is 15 μg/L for Qld. estuaries.
[o] values are 20 μg/L for TP for offshore waters and 1.5 μg/L for Chl a for Old inshore waters.
[p] Values of 25 μg/L for $NO_x$ and 20 μg/L for $NH_4^+$ for NSW are elevated due to frequent upwelling events.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8G.104 Ranges of Default Trigger Values for Conductivity (EC, salinity), Turbidity and Suspended Particulate Matter (SPM) Indicative of Slightly Disturbed Ecosystems in Southeast Australia**

| Ecosystem type | Salinity (μS/cm) | Turbidity (NTU) |
|---|---|---|
| Upland rivers | 30–350 | 2–25 |
| Lawland rivers | 125–2,200 | 6–50 |
| Lakes & reservoirs | 20–30 | 1–20 |
| Estuarine & marine | | 0.5–10 |

*Note:* Ranges for turbidity and SPM are similar and only turbidity is reported here. Values reflect high site-specific and regional variability. Explanatory notes provide detail on specific variability issues for ecosystem type, can be found in the guidance document.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Volume I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8G.105 Default Trigger Values for Physical and Chemical Stressors for Tropical Australia for Slightly Disturbed Ecosystems**

| Ecosystem type | | Chl *a* (μg/L) | TP (μg P/L) | FRP (μg P/L) | TN (μg N/L) | $NO_x$ (μg N/L) | $NH_4^+$ (μg N/L) | DO (% saturation)[a] Lower limit | DO (% saturation)[a] Upper limit | pH Lower limit | pH Upper limit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Upland river[b] | | na[c] | 10 | 5 | 150 | 30 | 6 | 90 | 120 | 6.0 | 7.5 |
| Lowland river[b] | | 5 | 10 | 4 | 200–300[d] | 10[e] | 10 | 85 | 120 | 6.0 | 8.0 |
| Freshwater lakes & Reservoirs | | 3 | 10 | 5 | 350[f] | 10[e] | 10 | 90 | 120 | 6.0 | 8.0 |
| Wetlands | | 10 | 10–50[g] | 5–25[g] | 350–1,200[g] | 10 | 10 | 90[e] | 120[e] | 6.0 | 8.0 |
| Estuaries[b] | | 2 | 20 | 5 | 250 | 30 | 15 | 80 | 120 | 7.0 | 8.5 |
| Marine | Inshore | 0.7–1.4[h] | 15 | 5 | 100 | 2–8[h] | 1–10[h] | 90 | no data | 8.0 | 8.4 |
| | Offshore | 0.5–0.9[h] | 10 | 2–5[h] | 100 | 1–4[h] | 1–6[h] | 90 | no data | 8.2 | 8.2 |

*Note:* Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Data derived from trigger values supplied by Australian states and territories for the Northern Territory and regions north of Carnarvon in the west and Rockhampton in the east. Chl *a*, chlorophyll *a*; TP, total phosphorus; FRP, filterable reactive phosphate; TN, total nitrogen; $NO_x$, oxides of nitrogen; $NH_4^+$, ammonium; DO, dissolved oxygen; na, not applicable.

[a] Dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability.
[b] No data available for tropical WA estuaries or rivers. A precautionary approach should be adopted when applying default trigger values to these systems.
[c] Monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers — values for periphyton biomass (mg Chl a $m^{-2}$) to be developed.
[d] Lower values from rivers draining rainforest catchments.
[e] Northern Territory values for 5 μg/L for $No_x$, and $<80$ (lower limit) and $>110$% saturation (upper limit) for DO.
[f] This value represents turbid lakes only. Clear lakes have much lower values.
[g] Higher values are indicative of tropical WA river pools.
[h] The lower values are typical of clear coral dominated waters (e.g. Great Barrier Reef), while higher values typical of turbid macrotidal systems (e.g. Northwest Shelf of WA).

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8G.106 Ranges of Default Trigger Values for Conductivity (EC, salinity), Turbidity and Suspended Particulate Matter (SPM) Indicative of Slightly Disturbed Ecosystems in Tropical Australia**

| Ecosystem Type | Salinity (μS/cm) | Turbidity (NTU) |
|---|---|---|
| Upland & lowland rivers | 20–250 | 2–15 |
| Lakes, reservoirs & wetlands | 90–900 | 2–200 |
| Estuarine & marine | — | 1–20 |

*Note:* Ranges for turbidity and SPM are similar and only turbidity is reported here. Values reflect high site-specific and regional variability. Explanatory notes provide detail on specific variability issues for groupings of ecosystem type can be found in the guidance document.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Volume I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8G.107 Default Trigger Values for Physical and Chemical Stressors for South-West Australia for Slightly Disturbed Ecosystems**

| | | | | | | | | DO (% saturation)[a] | | pH | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ecosystem type | | Chl *a* (μg/L) | TP (μg P/L) | FRP (μg P/L) | TN (μg N/L) | $NO_x$ (μg N/L) | $NH_4^+$ (μg N/L) | Lower Limit | Upper Limit | Lower Limit | Upper Limit |
| Upland river[b] | | na[c] | 20 | 10 | 450 | 200 | 60 | 90 | na | 6.5 | 8.0 |
| Lowland river[b] | | 3–5 | 65 | 40 | 1,200 | 150 | 80 | 80 | 120 | 6.5 | 8.0 |
| Freshwater lakes & reservoirs | | 3–5 | 10 | 5 | 350 | 10 | 10 | 90 | no data | 6.5 | 8.0 |
| Wetlands[d] | | 30 | 60 | 30 | 1,500 | 100 | 40 | 90 | 120 | 7.0[e] | 8.5[e] |
| Estuaries | | 3 | 30 | 5 | 750 | 45 | 40 | 90 | 110 | 7.5 | 8.5 |
| Marine[f,g] | Inshore[h] | 0.7 | 20[i] | 5[i] | 230 | 5 | 5 | 90 | na | 8.0 | 8.4 |
| | Offshore | 0.3[i] | 20[i] | 5 | 230 | 5 | 5 | 90 | na | 8.2 | 8.2 |

*Note:* Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Data derived from trigger values supplied by Western Australia. Chl *a*, chlorophyll *a*; TP, total phosphorus; FRP, filterable reactive phosphate; TN, total nitrogen; $NO_x$, oxides of nitrogen; $NH_4^+$, ammonium; DO, dissolved oxygen; na, not applicable.

[a] Dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diumally and with depth. Monitoring programs should assess this potential variability.
[b] All values derived during base river flow conditions not storm events.
[c] Monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers—values for periphyton biomass (mg Chl a $m^{-2}$) to be developed.
[d] Elevated nutrient concentrations in highly coloured wetlands (given $>52$ $g_{440}$/m) do not appear to stimulate algal growth.
[e] In highly coloured wetlands (given $>52$ $g_{440}$/m) pH typically ranges 4.5–6.5.
[f] Nutrient concentrations alone are poor indicators of marine trophic status.
[g] These trigger values are generic and therefore do not necessarily apply in all circumstances, e.g. for some unprotected coastlines, such as Albany and Geographe Bay, it may be more appropriate to use offshore values for inshore waters.
[h] Inshore waters defined as coastal lagoons (excluding estuaries) and embayments and waters less than 20 m depth.
[i] Summer (low rainfall) values, values higher in winter for Chi a (1.0 μg/L), TP (40 μg P/L), FRP (10 μg P/L).

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8G.108 Ranges of Default Trigger Values for Conductivity (EC, salinity), Turbidity and Suspended Particulate Matter (SPM) Indicative of Slightly Disturbed Ecosystems in Southwest Australia**

| Ecosystem type | Salinity (μS/cm) | Turbidity (NTU) |
|---|---|---|
| Upland & lowland rivers | 120–300 | 10–20 |
| Lakes, reservoirs & wetlands | 300–1,500 | 10–100 |
| Estuarine & marine | — | 1–2 |

*Note:* Ranges for turbidity and SPM are similar and only turbidity is reported here. Values reflect high site-specific and regional variability. Explanatory notes that provide detail on specific variability issues for ecosystem types can be found in the guidance document.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8G.109 Default Trigger Values for Physical and Chemical Stressors for South-Central Australia for Slightly Disturbed Ecosystems**

| | | | | | | | DO (% Saturation) | | pH | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ecosystem Type | Chl *a* (μg/L) | TP (μg P/L) | FRP (μg P/L) | TN (μg N/L) | $NO_x$ (μg N/L) | $NH_4^+$ (μg N/L) | Lower Limit | Upper Limit | Lower Limit | Upper Limit |
| Upland river | No data | No data | No data | No data | No data | No data | No data | No data | No data | No data |
| Lowland river | No data | 100 | 40 | 1,000 | 100 | 100 | 90 | No data | 6.5 | 9.0 |
| Freshwater lakes & reservoirs | No data | 25 | 10 | 1,000 | 100 | 25 | 90 | No data | 6.5 | 9.0 |
| Wetlands | No data | No data | No data | No data | No data | No data | No data | No data | No data | No data |
| Estuaries | 5 | 100 | 10 | 1,000 | 100 | 50 | 90 | No data | 6.5 | 9.0 |
| Marine | 1 | 100 | 10 | 1,000 | 50 | 50 | No data | No data | 8.0 | 8.5 |

*Note:* Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Data derived from trigger values supplied by South Australia. Chl *a*, chlorophyll *a*; TP, total phosphorus; FRP, filterable reactive phosphate; TN, total nitrogen; $NO_x$, oxides of nitrogen; $NH_4^+$, ammonium; DO, dissolved oxygen.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8G.110 Ranges of Default Trigger Values for Conductivity (EC, salinity), Turbidity, and Suspended Particulate Matter (SPM) Indicative of Slightly Disturbed Ecosystems in South-Central Australia**

| Ecosystem Types | Salinity (μS/cm) | Turbidity (NTU) |
|---|---|---|
| Lowland rivers | 100–5,000 | |
| Upland & lowland rivers | | 1–50 |
| Lakes, reservoirs & wetlands | 300–1,000 | 1–100 |
| Estuarine & marine | | 0.5–10 |

*Note:* Ranges for turbidity and SPM are similar and only turbidity is reported here. Values reflect high site-specific and regional variability. Explanatory notes provide detail on specific variability issues for groupings of ecosystem types can be found in the guidance document.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8G.111 Default Trigger Values for Physical and Chemical Stressors in New Zealand for Slightly Disturbed Ecosystems**

| Ecosystem Type | Chl *a* (μg/L) | TP (μg P/L) | FRP (μg P/L) | TN (μg N/L) | $NO_x$ (μg N/L) | $NH_4^+$ (μg N/L) | DO[a] (% Saturation) Lower Limit | DO[a] (% Saturation) Upper Limit | pH[a] Lower Limit | pH[a] Upper Limit |
|---|---|---|---|---|---|---|---|---|---|---|
| Upland river | na[b] | 26[c] | 9[c] | 295[c] | 167[c] | 10[c] | 99 | 103 | 7.3 | 8.0 |
| Lowland river | no data | 33[d] | 10[d] | 614[d] | 444[d] | 21[d] | 98 | 105 | 7.2 | 7.8 |

*Note:* Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Chl *a*, chlorophyll *a*; TP, total phosphorus; FRP, filterable reactive phosphate; TN[e], total nitrogen; $NO_x$, oxides of nitrogen; $NH_4^+$, ammonium nitrogen; DO, dissolved oxygen, na, not applicable.

[a] DO and pH percentiles may not be very useful as trigger values because of diurnal and seasonal variation—values listed are for daytime sampling.

[b] Monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers—values for periphyton biomass (mg Chl a $m^{-2}$) to be developed. New Zealand is currently making routine observations of periphyton cover.

[c] Values for glacial and lake-fed sites in upland rivers are lower;

[d] Values are lower for Haast River which receives waters from alpine regions;

[e] Commonly referred to dissolved reactive phosphorus in New Zealand.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Volume I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8G.112 Default Trigger Values for Water Clarity (Lower Limit) and Turbidity (Upper Limit) Indicative of Unmodified or Slightly Disturbed Ecosystems in New Zealand**

| Ecosystem types | Upland rivers[a,b] Clarity (1/m)[c,d] | Upland rivers[a,b] Turbidity (NTU)[c,d] | Lowland rivers Clarity (1/m) | Lowland rivers Turbidity (NTU) |
|---|---|---|---|---|
| | 0.6 | 4.1 | 0.8 | 5.6 |

[a] Light availability is generally less of an issue in NZ rivers and streams than is visual clarity because, in contrast to many of Australia's rivers, most NZ rivers are comparatively clear and/or shallow. Davies-Colley et al. (1992) recommend that visual clarity, light penetration and water colour are important optical properties of an ecosystem which need to be protected. Neither turbidity nor visual clarity provide a useful estimate of light penetration—light penetration should be considered separately to turbidity or visual clarity. Clarity relates to the transmission of light through water and is measured by the visual range of a black disk (see NZ Ministry for the Environment (1994)) or a Secchi disk.

[b] Recent work has shown that at least some NZ indigenous fish are sensitive to low levels of turbidity; however, it may also be desirable to protect the naturally high turbidities of alpine glacial lakes to prevent possible ecological impacts, such as change in predator-prey relationships.

[c] Note that turbidity and visual water clarity are closely and inversely related, and the 80th percentile for turbidity is consistent with the 20th percentile for visibility and vice versa.

[d] Clarity and turbidity values for glacial sites in upland rivers are lower and higher, respectively.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8G.113 General Framework for Applying Australian Levels of Protection for Toxicants to Different Ecosystem Conditions**

| Ecosystem Condition | Level of Protection |
|---|---|
| 1 High conservation/ecological value | For anthropogenic toxicants, detection at any concentration could be grounds for source investigation and management intervention; for natural toxicants background concentrations should not be exceeded[a]<br>*Where local biological or chemical data have not yet been gathered,* apply the 99% protection levels (Table 8.114) as default values<br>Any relaxation of these objectives should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered<br>In the case of effluent discharges, Direct Toxicity Assessment (DTA) should also be required on the effluent<br>Precautionary approach taken to assessment of post-baseline data through trend analysis or feedback triggers |
| 2 Slightly to moderately disturbed ecosystems | Always preferable to use local biological effects data (including DTA) to derive guidelines<br>*If local biological effects data unavailable*, apply 95% protection levels (Table 8.114) as default, low-risk trigger values.[b] 99% values are recommended for certain chemicals as noted in Table 8.114[c]<br>Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers<br>In the case of effluent discharges DTA may be required |
| 3 High disturbed ecosystems | Apply the same guidelines as for slightly-moderately disturbed systems. However, the lower protection levels provided in the Guidelines may be accepted by stakeholders<br>DTA could be used as an alternative approach for deriving site-specific guidelines |

[a] This means that indicator values at background and test sites should be statistically indistinguishable. It is acknowledged that it may not be strictly possible to meet this criterion in every situation.

[b] For slightly disturbed ecosystems where the management goal is no change in biodiversity, users may prefer to apply a higher protection level.

[c] 99% values recommended for chemicals that bioaccumulate or for which 95% provides inadequate protection for key test species. Jurisdictions may choose 99% values for some ecosystems that are more towards the slightly disturbed end of the continuum.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8G.114 Australian Trigger Values for Toxicants at Alternative Levels of Protection**

| | Trigger Values for Freshwater (μg/L) Level of Protection (% species) | | | | Trigger Values for Marine Water (μg/L) Level of Protection (% Species) | | | |
|---|---|---|---|---|---|---|---|---|
| **Chemical** | **99%** | **95%** | **90%** | **80%** | **99%** | **95%** | **90%** | **80%** |
| **Metals & metalloids** | | | | | | | | |
| Aluminum pH > 6.5 | 27 | **55** | 80 | 150 | ID | ID | ID | ID |
| Aluminum pH < 6.5 | ID | ID | ID | ID | ID | ID | ID | ID |
| Antimony | ID | ID | ID | ID | ID | ID | ID | ID |
| Arsenic (As III) | 1 | **24** | 94[a] | 360[a] | ID | ID | ID | ID |
| Arsenic (AsV) | 0.8 | **13** | 42 | 140[a] | ID | ID | ID | ID |
| Beryllium | ID | ID | ID | ID | ID | ID | ID | ID |
| Bismuth | ID | ID | ID | ID | ID | ID | ID | ID |
| Boron | 90 | **370[a]** | 680[a] | 1,300[a] | ID | ID | ID | ID |
| Cadmium[b] | 0.06 | **0.2** | 0.4 | 0.8[a] | **0.7[c]** | 5.5[a,c] | 14[a,c] | 36[c,d] |
| Chromium (Cr III)[b] | ID | ID | ID | ID | 7.7 | **27.4** | 48.6 | 90.6 |
| Chromium (CrVI) | 0.01 | **1.0[a]** | 6[d] | 40[d] | 0.14 | **4.4** | 20[a] | 85[a] |
| Cobalt | ID | ID | ID | ID | 0.005 | **1** | 14 | 150[a] |
| Copper[b] | 1.0 | **1.4** | 1.8[a] | 2.5[a] | 0.3 | **1.3** | 3[a] | 8[d] |
| Gallium | ID | ID | ID | ID | ID | ID | ID | ID |
| Iron | ID | ID | ID | ID | ID | ID | ID | ID |
| Lanthanum | ID | ID | ID | ID | ID | ID | ID | ID |
| Lead[b] | 1.0 | **3.4** | 5.6 | 9.4[a] | 2.2 | **4.4** | 6.6[a] | 12[a] |
| Manganese | 1,200 | **1,900[a]** | 2,500[a] | 3,600[a] | ID | ID | ID | ID |
| Mercury (inorganic)[c] | **0.06** | 0.6 | 1.9[a] | 5.4[d] | **0.1** | 0.4[a] | 0.7[a] | 1.4[a] |
| Mercury (methyl) | ID | ID | ID | ID | ID | ID | ID | ID |
| Molybdenum | ID | ID | ID | ID | ID | ID | ID | ID |
| Nickel[b] | 8 | **11** | 13 | 17[a] | **7** | 70[a] | 200[d] | 560[d] |
| Selenium (Total)[c] | **5** | 11 | 18 | 34 | ID | ID | ID | ID |
| Selenium (SeIV)[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Silver | 0.2 | **0.05** | 0.1 | 0.2[a] | 0.8 | **1.4** | 1.8 | 2.6[a] |
| Thallium | ID | ID | ID | ID | ID | ID | ID | ID |
| Tin (inorganic, SnIV) | ID | ID | ID | ID | ID | ID | ID | ID |
| Tributyltin (as μg/L Sn) | ID | ID | ID | ID | 0.0004 | **0.006[a]** | 0.02[a] | 0.05[a] |
| Uranium | ID | ID | ID | ID | ID | ID | ID | ID |
| Vanadium | ID | ID | ID | ID | 50 | **100** | 160 | 280 |
| Zinc[b] | 2.4 | **8.0[a]** | 15[a] | 31[a] | 7 | **15[a]** | 23[a] | 43[a] |
| **Nonmetallic Inorganics** | | | | | | | | |
| Ammonia[e] | 320 | **900[a]** | 1,430[a] | 2,300[d] | 500 | **910** | 1,200 | 1,700 |
| Chlorine[f] | 0.4 | **3** | 6[d] | 13[d] | ID | ID | ID | ID |
| Cyanide[g] | 4 | **7** | 11 | 18 | 2 | **4** | 7 | 14 |
| Nitrate[h] | 17 | **700** | 3,400[a] | 17,000[d] | ID | ID | ID | ID |
| Hydrogen sulfide[i] | 0.5 | **1.0** | 1.5 | 2.8 | ID | ID | ID | ID |
| **Organic Alcohols** | | | | | | | | |
| Ethanol | 400 | **1,400** | 2,400[a] | 4,000[a] | ID | ID | ID | ID |
| Ethylene glycol | ID | ID | ID | ID | ID | ID | ID | ID |
| Isopropyl alcohol | ID | ID | ID | ID | ID | ID | ID | ID |
| **Chlorinated Alkanes** | | | | | | | | |
| *Chloromethanes* | | | | | | | | |
| Dichloromethane | ID | ID | ID | ID | ID | ID | ID | ID |
| Chloroform | ID | ID | ID | ID | ID | ID | ID | ID |
| Carbon tetrachloride | ID | ID | ID | ID | ID | ID | ID | ID |
| *Chloroethanes* | | | | | | | | |
| 1,2-dichloroethane | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1,1-trichloroethane | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1,2-trichloroethane | 5,400 | **6,500** | 7,300 | 8,400 | 140 | **1,900** | 5,800[a] | 18,000[a] |
| 1,1,2,2-tetrachloroethane | ID | ID | ID | ID | ID | ID | ID | ID |
| Pentachloroethane | ID | ID | ID | ID | ID | ID | ID | ID |
| Hexachloroethane[c] | **290** | 360 | 420 | 500 | ID | ID | ID | ID |
| *Chloropropanes* | | | | | | | | |
| 1,1-dichloropropane | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-dichloropropane | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3-dichloropropane | ID | ID | ID | ID | ID | ID | ID | ID |

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**Table 8G.114 (Continued)**

| | Trigger Values for Freshwater (μg/L) Level of Protection (% species) | | | | Trigger Values for Marine Water (μg/L) Level of Protection (% Species) | | | |
|---|---|---|---|---|---|---|---|---|
| **Chemical** | **99%** | **95%** | **90%** | **80%** | **99%** | **95%** | **90%** | **80%** |
| **Chlorinated Alkenes** | | | | | | | | |
| Chloroethylene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1-dichloroethylene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1,2-trichloroethylene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,1,2,2-tetrachloroethylene | ID | ID | ID | ID | ID | ID | ID | ID |
| 3-chloropropene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3-dichloropropene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Anilines** | | | | | | | | |
| Aniline | **8** | 250[d] | 1,100[d] | 4,800[d] | ID | ID | ID | ID |
| 2,4-dichloroaniline | 0.6 | **7** | 20 | 60[a] | ID | ID | ID | ID |
| 2,5-dichloroaniline | ID | ID | ID | ID | ID | ID | ID | ID |
| 3,4-dichloroaniline | 1.3 | **3** | 6[a] | 13[a] | 85 | **150** | 190 | 260 |
| 3,5-dichloroaniline | ID | ID | ID | ID | ID | ID | ID | ID |
| Benzidine | ID | ID | ID | ID | ID | ID | ID | ID |
| Dichlorobenzidine | ID | ID | ID | ID | ID | ID | ID | ID |
| **Aromatic Hydrocarbons** | | | | | | | | |
| Benzene | 600 | **950** | 1,300 | 2,000 | **500[a]** | 700[a] | 900[a] | 1,300[a] |
| Toluene | ID | ID | ID | ID | ID | ID | ID | ID |
| Ethylbenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| o-xylene | 200 | **350** | 470 | 670 | ID | ID | ID | ID |
| *m*-xylene | ID | ID | ID | ID | ID | ID | ID | ID |
| *p*-xylene | 140 | **200** | 250 | 340 | ID | ID | ID | ID |
| *m*+*p*-xylene | ID | ID | ID | ID | ID | ID | ID | ID |
| Cumene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Polycyclic Aromatic Hydrocarbons** | | | | | | | | |
| Naphthalene | 2.5 | **16** | 37 | 85 | **50[a]** | 70[a] | 90[a] | 120[a] |
| Anthracene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Phenanthrene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Fluoranthene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Benzo(a)pyrene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| **Nitrobenzenes** | | | | | | | | |
| Nitrobenzene | 230 | **550** | 820 | 1,300 | ID | ID | ID | ID |
| 1,2-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,4-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3,5-trinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-methoxy-2-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-methoxy-4-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloro-2-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloro-3-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloro-4-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloro-2,4-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-dichloro-3-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3-dichloro-5-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,4-dichloro-2-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-dichloro-2-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2,4,5-tetrachloro-3-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,5-dichloro-2,4-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,3,5-trichloro-2,4-dinitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-fluoro-4-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Nitrotoluenes** | | | | | | | | |
| 2-nitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| 3-nitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| 4-nitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3-dinitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |

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**Table 8G.114 (Continued)**

| Chemical | Trigger Values for Freshwater (μg/L) Level of Protection (% species) | | | | Trigger Values for Marine Water (μg/L) Level of Protection (% Species) | | | |
|---|---|---|---|---|---|---|---|---|
| | 99% | 95% | 90% | 80% | 99% | 95% | 90% | 80% |
| 2,4-dinitrotoluene | **16** | 65[a] | 130[a] | 250[a] | ID | ID | ID | ID |
| 2,4,6-trinitrotoluene | 100 | **140** | 160 | 210 | ID | ID | ID | ID |
| 1,2-dimethyl-3-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-dimethyl-4-nitrobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 4-chloro-3-nitrotoluene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Chlorobenzenes and Chloronaphthalenes** | | | | | | | | |
| Monochlorobenzene | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-dichlorobenzene | 120 | **160** | 200 | 270 | ID | ID | ID | ID |
| 1,3-dichlorobenzene | 160 | **260** | 350 | 520[a] | ID | ID | ID | ID |
| 1,4-dichlorobenzene | 40 | **60** | 75 | 100 | ID | ID | ID | ID |
| 1,2,3-trichlorobenzene[c] | **3** | 10 | 16 | 30[a] | ID | ID | ID | ID |
| 1,2,4-trichlorobenzene[c] | **85** | 170[a] | 220[a] | 300[a] | **20** | 80 | 140 | 240 |
| 1,3,5-trichlorobenzene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2,3,4-tetrachlorobenzene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2,3,5-tetrachlorobenzene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2,4,5-tetrachlorobenzene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Pentachlorobenzene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Hexachlorobenzene[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| 1-chloronaphthalene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Polychlorinated Biphenyls (PCBs) & Dioxins** | | | | | | | | |
| Capacitor 21[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1016[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1221[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1232[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1242[c] | **0.3** | 0.6 | 1.0 | 1.7 | ID | ID | ID | ID |
| Aroclor 1248[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1254[c] | **0.01** | 0.03 | 0.7 | 0.2 | ID | ID | ID | ID |
| Aroclor 1260[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1262[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Aroclor 1268[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,4′-trichlorobipheny[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| 4,4′-dichlorobiphenyl | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,2′,4,5,5′-pentachloro-1,1′-biphenyl[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4,6,2′4,6′-hexachlorobiphenyl[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Total PCBs[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,7,8-TCDD[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| **Phenols and Xylenols** | | | | | | | | |
| Phenol | 85 | **320** | 600 | 1,200[a] | 270 | **400** | 520 | 720 |
| 2,4-dimethylphenol | ID | ID | ID | ID | ID | ID | ID | ID |
| Nonylphenol | ID | ID | ID | ID | ID | ID | ID | ID |
| 2-chlorphenol[j] | **340[a]** | 490[a] | 630[a] | 870[a] | ID | ID | ID | ID |
| 3-chlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 4-chlorophenol[j] | 160 | **220** | 280[a] | 360[a] | ID | ID | ID | ID |
| 2,3-dichlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-dichlorophenol[j] | **120** | 160[a] | 200[a] | 270[a] | ID | ID | ID | ID |
| 2,5-dichlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,6-dichlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 3,4-dichlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 3,5-dichlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,4-trichlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,5-trichlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,6-trichlorophenol[j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4,6-trichlorophenol[c,j] | **3** | 20 | 40 | 95 | ID | ID | ID | ID |
| 2,3,4,5-tetrachlorophenol[c,j] | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,3,4,6-tetrachlorophenol[c,j] | **10** | 20 | 25 | 30 | ID | ID | ID | ID |
| 2,3,5,6-tetrachlorophenol[c,j] | ID | ID | ID | ID | ID | ID | ID | ID |

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**Table 8G.114 (Continued)**

| | Trigger Values for Freshwater (μg/L) Level of Protection (% species) | | | | Trigger Values for Marine Water (μg/L) Level of Protection (% Species) | | | |
|---|---|---|---|---|---|---|---|---|
| **Chemical** | **99%** | **95%** | **90%** | **80%** | **99%** | **95%** | **90%** | **80%** |
| Pentachlorophenol[c,j] | **3.6** | 10 | 17 | 27[d] | **11** | 22 | 33 | 55[d] |
| **Nitrophenols** | | | | | | | | |
| 2-nitrophenol | ID | ID | ID | ID | ID | ID | ID | ID |
| 3-nitrophenol | ID | ID | ID | ID | ID | ID | ID | ID |
| 4-nitrophenol | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-dinitrophenol | 13 | **45** | 80 | 140 | ID | ID | ID | ID |
| 2,4,6-trinitrophenol | ID | ID | ID | ID | ID | ID | ID | ID |
| **Organic Sulfur Compounds** | | | | | | | | |
| Carbon disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Isopropyl | ID | ID | ID | ID | ID | ID | ID | ID |
| n-propyl sulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Propyl disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Tert-butyl sulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Phenyl disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Bis(dimethylthiocarbamyl) sulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| Bis(diethylthiocarbamyl) disulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| 2-methoxy-4H-1,3,2-benzodioxaphosphorium-2sulfide | ID | ID | ID | ID | ID | ID | ID | ID |
| **Xanthates** | | | | | | | | |
| Potassium amyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Potassium ethyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Potassium hexyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Potassium isopropyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Sodium ethyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Sodium isobutyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Sodium isopropyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| Sodium sec-butyl xanthate | ID | ID | ID | ID | ID | ID | ID | ID |
| **Phthalates** | | | | | | | | |
| Dimethylphthalate | 3,000 | **3,700** | 4,300 | 5,100 | ID | ID | ID | ID |
| Diethylphthaiate | 900 | **1,000** | 1,100 | 1,300 | ID | ID | ID | ID |
| Dibutylphthalate[c] | **9.9** | 26 | 40.2 | 64.6 | ID | ID | ID | ID |
| Di(2-ethylhexyl)phthalate[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| **Miscellaneous Industrial Chemicals** | | | | | | | | |
| Acetonitrile | ID | ID | ID | ID | ID | ID | ID | ID |
| Acrylonitrile | ID | ID | ID | ID | ID | ID | ID | ID |
| Poly(acrylonitrile-co-butadiene-co-styrene) | 200 | **530** | 800[a] | 1,200[a] | 200 | **250** | 280 | 340 |
| Dimethylformamide | ID | ID | ID | ID | ID | ID | ID | ID |
| 1,2-diphenylhydrazine | ID | ID | ID | ID | ID | ID | ID | ID |
| Diphenylnitrosamine | ID | ID | ID | ID | ID | ID | ID | ID |
| Hexachlorobutadiene | ID | ID | ID | ID | ID | ID | ID | ID |
| Hexachlorocyclopentadiene | ID | ID | ID | ID | ID | ID | ID | ID |
| Isophorone | ID | ID | ID | ID | ID | ID | ID | ID |
| **Organochlorine Pesticides** | | | | | | | | |
| Aldrin[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Chlordane[c] | **0.03** | 0.08 | 0.14 | 0.27[a] | ID | ID | ID | ID |
| DDE[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| DDT[c] | **0.006** | 0.01 | 0.02 | 0.04 | ID | ID | ID | ID |
| Dicofol[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Dieldrin[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Endosulfan[c] | **0.03** | 0.2[d] | 0.6[d] | 1.8[d] | **0.005** | 0.01 | 0.02 | 0.05[d] |
| Endosulfan alpha[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Endosulfan beta[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Endrin[c] | **0.01** | 0.02 | 0.04[a] | 0.06[d] | **0.004** | 0.008 | 0.01 | 0.02 |
| Heptachlor[c] | **0.01** | 0.09 | 0.25 | 0.7[d] | ID | ID | ID | ID |

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**Table 8G.114 (Continued)**

| Chemical | Trigger Values for Freshwater (μg/L) Level of Protection (% species) | | | | Trigger Values for Marine Water (μg/L) Level of Protection (% Species) | | | |
|---|---|---|---|---|---|---|---|---|
| | 99% | 95% | 90% | 80% | 99% | 95% | 90% | 80% |
| Lindane | 0.07 | **0.2** | 0.4 | 1.0[d] | ID | ID | ID | ID |
| Methoxychlor[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Mirex[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Toxaphene[c] | **0.1** | 0.2 | 0.3 | 0.5 | ID | ID | ID | ID |
| **Organophosphorus Pesticides** | | | | | | | | |
| Azinphos methyl | **0.01** | 0.02 | 0.05 | 0.11[d] | ID | ID | ID | ID |
| Chlorpyrifos[c] | 0.00004 | **0.01** | 0.11[d] | 1.2[d] | 0.0005 | **0.009** | 0.04[d] | 0.3[d] |
| Demeton | ID | ID | ID | ID | ID | ID | ID | ID |
| Demeton-S-methyl | ID | ID | ID | ID | ID | ID | ID | ID |
| Diazinon | 0.00003 | **0.01** | 0.2[d] | 2[d] | ID | ID | ID | ID |
| Dimethoate | 0.1 | **0.15** | 0.2 | 0.3 | ID | ID | ID | ID |
| Fenitrothion | 0.1 | **0.2** | 0.3 | 0.4 | ID | ID | ID | ID |
| Malathion | 0.002 | **0.05** | 0.2 | 1.1[d] | ID | ID | ID | ID |
| Parathion | 0.0007 | **0.004**[a] | 0.01[a] | 0.04[d] | ID | ID | ID | ID |
| Profenofos[c] | ID | ID | ID | ID | ID | ID | ID | ID |
| Temephos[c] | ID | ID | ID | ID | 0.0004 | **0.05** | 0.4 | 3.6[d] |
| **Carbamate & Other Pesticides** | | | | | | | | |
| Carbofuran | **0.06** | 1.2[d] | 4[d] | 15[d] | ID | ID | ID | ID |
| Methomyl | 0.5 | **3.5** | 9.5 | 23 | ID | ID | ID | ID |
| S-methoprene | ID | ID | ID | ID | ID | ID | ID | ID |
| **Pyrethroids** | | | | | | | | |
| Deltamethrin | ID | ID | ID | ID | ID | ID | ID | ID |
| Esfenvalerate | ID | 0.001[k] | ID | ID | ID | ID | ID | ID |
| **Herbicides & Fungicides** | | | | | | | | |
| *Bypyridilium herbicides* | | | | | | | | |
| Diquat | 0.01 | **1.4** | 10 | 80[d] | ID | ID | ID | ID |
| Paraquat | ID | ID | ID | ID | ID | ID | ID | ID |
| *Phenoxyacetic acid herbicides* | | | | | | | | |
| MCPA | ID | ID | ID | ID | ID | ID | ID | ID |
| 2,4-D | 140 | **280** | 450 | 830 | ID | ID | ID | ID |
| 2,4,5-T | 3 | **36** | 100 | 290[d] | ID | ID | ID | ID |
| *Sulfonylurea herbicides* | | | | | | | | |
| Bensulfuron | ID | ID | ID | ID | ID | ID | ID | ID |
| Metsulfuron | ID | ID | ID | ID | ID | ID | ID | ID |
| *Thiocarbamate herbicides* | | | | | | | | |
| Molinate | 0.1 | **3.4** | 14 | 57 | ID | ID | ID | ID |
| Thiobencarb | 1 | **2.8** | 4.6 | 8[a] | ID | ID | ID | ID |
| Thiram | **0.01** | 0.2 | 0.8[a] | 3[d] | ID | ID | ID | ID |
| *Triazine herbicides* | | | | | | | | |
| Amitrole | ID | ID | ID | ID | ID | ID | ID | ID |
| Atrazine | 0.7 | **13** | 45[a] | 150[a] | ID | ID | ID | ID |
| Hexazinone | ID | ID | ID | ID | ID | ID | ID | ID |
| Simazine | 0.2 | **3.2** | 11 | 35 | ID | ID | ID | ID |
| *Urea herbicides* | | | | | | | | |
| Diuron | ID | ID | ID | ID | ID | ID | ID | ID |
| Tebuthiuron | 0.02 | **2.2** | 20 | 160[a] | ID | ID | ID | ID |
| *Miscellaneous herbicides* | | | | | | | | |
| Acrolein | ID | ID | ID | ID | ID | ID | ID | ID |
| Bromacil | ID | ID | ID | ID | ID | ID | ID | ID |
| Glyphosate | **370** | 1,200 | 2,000 | 3,600[d] | ID | ID | ID | ID |
| Imazethapyr | ID | ID | ID | ID | ID | ID | ID | ID |
| Ioxynil | ID | ID | ID | ID | ID | ID | ID | ID |
| Metolachlor | ID | ID | ID | ID | ID | ID | ID | ID |
| Sethoxydim | ID | ID | ID | ID | ID | ID | ID | ID |
| Trifluralin[c] | **2.6** | 4.4 | 6 | 9[d] | ID | ID | ID | ID |

*(Continued)*

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**Table 8G.114 (Continued)**

| Chemical | Trigger Values for Freshwater (μg/L) Level of Protection (% species) 99% | 95% | 90% | 80% | Trigger Values for Marine Water (μg/L) Level of Protection (% Species) 99% | 95% | 90% | 80% |
|---|---|---|---|---|---|---|---|---|
| **Generic Groups of Chemicals** | | | | | | | | |
| **Surfactants** | | | | | | | | |
| Linear alkylbenzene sulfonates (LAS) | 65 | **280** | 520[a] | 1,000[a] | ID | ID | ID | ID |
| Alcohol ethoxyolated sulfate (AES) | 340 | **650** | 850[a] | 1,100[a] | ID | ID | ID | ID |
| Alcohol ethoxylated surfactants (AE) | 50 | **140** | 220 | 360[a] | ID | ID | ID | ID |
| **Oils & Petroleum Hydrocarbons** | ID | ID | ID | ID | ID | ID | ID | ID |
| **Oil Spill Dispersants** | | | | | | | | |
| BP 1100X | ID | ID | ID | ID | ID | ID | ID | ID |
| Corexit 7664 | ID | ID | ID | ID | ID | ID | ID | ID |
| Corexit 8667 | | ID | ID | ID | ID | ID | ID | ID |
| Corexit 9527 | ID | ID | ID | ID | 230 | 1100 | 2,200 | 4,400[d] |
| Corexit 9550 | ID | ID | ID | ID | ID | ID | ID | ID |

*Note:* ID, Insufficient data to derive a reliable trigger value. Users advised to check if a low reliability value or an ECL is available **Section 8.3.7.** Values in grey shading are the trigger values applying to typical *slightly-moderately disturbed systems*; see Table 8-113. And Section 3.4.2.4 of the guidance document for guidance on applying these levels to different ecosystem conditions. Where the final water quality guideline to be applied to a site is below current analytical practical quantitation limits, see Section 3.4.3.3 of guidance document. Most trigger values listed here for metals and metalloids are *High reliability* figures, derived from field or chronic NOEC data. The exceptions are *Moderate reliability* for freshwater aluminium (pH $>6.5$), manganese and marine chromium (III). Most trigger values listed here for non-metallic inorganices and organic chemicals are *Moderate reliability* figures, derived for acute $LC_{50}$ data. The exceptions are *High reliability* for freshwater ammonia, 3,4-DCA, endosulfan chlorpyrifos, esfenvalerate, tebuthiuron, three surfactants and marine for 1, 1,2-TCE and chlorpyrifos.

[a] Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species)—check Section 8.3.7 of guidance document for spread of data and its significance. Where grey shading and 'C' coincide, refer to text in Section 8.3.7. of guidance document.

[b] Chemicals for which algorithms have been provided in Table 3.4.3 of guidance document to account for the effects of hardness. The values have been calculated using a hardness of 30 mg/L $CaCO_3$. These should be adjusted to the site-specific hardness (see Section 3.4.3) of guidance document.

[c] Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered.

[d] Figure may not protect key test species from acute toxicity (and chronic)—check Section 8.3.7 for spread of data and its significance. 'A' indicates that trigger value > acute toxicity figure; note that trigger value should be $<1/3$ of acute figure.

[e] Ammonla as TOTAL ammonia as ($NH_3$-N) at pH 8. For changes in trigger value with ph refer to Section 8.3.7.2 of the guidance document.

[f] Chlorine as total chlorine, as [Cl].

[g] Cyanide as unionised HCN, measured as [CN] of the guidance document.

[h] Figures protect against toxicity and do not relate to eutrophication issues. Refer to Section 3.3 if eutrophication is the issue of concern.

[i] Sulfide as un-lonised $H_2S$, measured as [S] of the guidance document.

[j] Tainting or flavour impairment of fish flesh may possibly occur at concentrations below the trigger value.

[k] *High reliability* figure for esfenvalerate derived form mesocosm NOEC data (no alternative protection levels available).

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Volume I, The Guidelines, October 2000, www.deh.gov.au.

**Table 8G.115 Australian Guidelines for the Protection of Human Consumers of Fish and Other Aquatic Organisms from Bacterial Infection**

| Toxicant | Guideline *in Shellfishing Water* | Standard *in Edible Tissue* |
|---|---|---|
| Faecal (thermotolerant) coliforms | The median faecal coliform bacterial concentration should not exceed 14 MPN/100 mL, with no more than 10% of the samples exceeding 43 MPN/100 mL | Fish destined for human consumption should not exceed a limit of 2.3 MPN *E. coli lg* of flesh with a standard place count of 100,000 organisms/g |

*Note:* MPN: Most probable number, The guideline for faecal (thermotolerant) coliforms should not be used in conjunction with the data from a sanitary survey of the shellfish harvesting areas for the purpose of harvesting area classification.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8G.116 Australian Guidelines of Chemical Compounds in Water Found to Cause Tainting of Fish Flesh and Other Aquatic Organisms**

| Parameter | Estimated Threshold Level in Water (mg/L) |
|---|---|
| Acenaphthene | 0.02 |
| Acetophenone | 0.5 |
| Acrylonitrile | 18.0 |
| Copper | 1.0 |
| *m*-cresol | 0.2 |
| *o*-cresol | 0.4 |
| *p*-cresol | 0.1 |
| Cresylic acids (meta, para) | 0.2 |
| Chlorobenzene | 0.02 |
| *n*-butylmercaptan | 0.06 |
| *o*-sec. butylphenol | 0.3 |
| *p*-tert. butylphenol | 0.03 |
| *o*-chlorophenol | 0.0001–0.015 |
| *p*-chlorophenol | 0.0001 |
| 2,3-dinitrophenol | 0.08 |
| 2,4,6-trinitrophenol | 0.002 |
| 2,4-dichlorophenol | 0.0001–0.014 |
| 2,5-dichlorophenol | 0.02 |
| 2,6-dichlorophenol | 0.03 |
| 3,4-dichlorophenol | 0.0003 |
| 2-methyl-4-chlorophenol | 2.0 |
| 2-methyl-6-chlorophenol | 0.003 |
| 3-methyl-4-chlorophenol | 0.02–3.0 |
| *o*-phenylphenol | 1.0 |
| Pentachlorophenol | 0.03 |
| Phenol | 1.0–10.0 |
| Phenols in polluted rivers | 0.15–0.02 |
| 2,3,4,6-tetrachlorophenol | 0.001 |
| 2,3,5-trichlorophenol | 0.001 |
| 2,4,6-trichlorophenol | 0.002 |
| 2,4-dimethylphenol | 0.4 |
| Dimethylamine | 7.0 |
| Diphenyloxide | 0.05 |
| B,B-dichlorodiethyl ether | 0.09–1 |
| *o*-dichlorobenzene | $<$0.25 |
| Ethylbenzene | 0.25 |
| Ethanethiol | 0.2 |
| Ethylacrylate | 0.6 |
| Formaldehyde | 95.0 |
| Gasoline | 0.005 |
| Guaicol | 0.08 |
| Kerosene | 0.1 |
| Kerosene plus kaolin | 1.0 |
| Hexachlorocyclopentadiene | 0.001 |
| Isopropylbenzene | $<$0.25 |
| Naphtha | 0.1 |
| Naphthalene | 1.0 |
| Naphthol | 0.5 |
| 2-Naphthol | 0.3 |
| Nitrobenzene | 0.03 |
| a-methylstyrene | 0.25 |
| Oil, emulsifiable | $>$15.0 |
| Pyridine | 5–28 |
| Pyrocatechol | 0.8–5 |
| Pyrogallol | 20–30 |
| Quinoline | 0.5–1 |
| *p*-quinone | 0.5 |
| Styrene | 0.25 |

*(Continued)*

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**Table 8G.116 (Continued)**

| Parameter | Estimated Threshold Level in Water (mg/L) |
|---|---|
| Toluene | 0.25 |
| Outboard motor fuel as exhaust | 7.2 |
| Zinc | 5.0 |

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: Reproduced from ANZECC (1992), an adaptation of NAS/NAE (1973).

**Table 8G.117 Australian Recommended Sediment Quality Guidelines**

| Contaminant | ISQG-Low (Trigger Value) | ISQG-High |
|---|---|---|
| **Metals (mg/kg dry wt)** | | |
| Antimony | 2 | 25 |
| Cadmium | 1.5 | 10 |
| Chromium | 80 | 370 |
| Copper | 65 | 270 |
| Lead | 50 | 220 |
| Mercury | 0.15 | 1 |
| Nickel | 21 | 52 |
| Silver | 1 | 3.7 |
| Zinc | 200 | 410 |
| **Metalloids (mg/kg dry wt)** | | |
| Arsenic | 20 | 70 |
| **Organometallics** | | |
| Tributyltin (μg Sn/kg dry wt) | 5 | 70 |
| **Organics (μg/kg dry wt)**[a] | | |
| Acenaphthene | 16 | 500 |
| Acenaphthalene | 44 | 640 |
| Anthracene | 85 | 1,100 |
| Fluorene | 19 | 540 |
| Naphthalene | 160 | 2,100 |
| Phenanthrene | 240 | 1,500 |
| Low Molecular Weight PAHs[b] | 552 | 3,160 |
| Benzo(a)anthracene | 261 | 1,600 |
| Benzo(a)pyrene | 430 | 1,600 |
| Dibenzo(a, h)anthracene | 63 | 260 |
| Chrysene | 384 | 2,800 |
| Fluoranthene | 600 | 5,100 |
| Pyrene | 665 | 2,600 |
| High Molecular Weight PAHs[b] | 1,700 | 9,600 |
| Total PAHs | 4,000 | 45,000 |
| Total DDT | 1.6 | 46 |
| p.p′-DDE | 2.2 | 27 |
| o,p′-+p,p′-DDD | 2 | 20 |
| Chlordane | 0.5 | 6 |
| Dieldrin | 0.02 | 8 |

*(Continued)*

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**Table 8G.117 (Continued)**

| Contaminant | ISQG-Low (Trigger Value) | ISQG-High |
|---|---|---|
| Endrin | 0.02 | 8 |
| Lindane | 0.32 | 1 |
| Total PCBs | 23 | — |

[a] Normalised to 1% organic carbon;
[b] Low molecular weight PAHs are the sum of concentrations of acenaphthene, acenaphthalene, anthracene, fluorene, 2-methylnaphthalene, naphthalene and phenanthrene; high molecular weight PAHs are the sum of concentrations of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthrancene, fluoranthene and pyrene.

*Source:* From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: Primarily adapted from Long et al. (1995).

**Table 8G.118 Maximum Concentrations of Copper Sulfate Safe for Fish**

| | Safe Copper Sulfate Concentration | |
|---|---|---|
| Fish | ppm | lb/mill gal |
| Trout | 0.14 | 1.2 |
| Carp | 0.30 | 2.5 |
| Suckers | 0.30 | 2.5 |
| Catfish | 0.40 | 3.5 |
| Pickerel | 0.40 | 3.5 |
| Goldfish | 0.50 | 4.0 |
| Perch | 0.75 | 6.0 |
| Sunfish | 1.20 | 10.0 |
| Black Bass | 2.10 | 17.0 |

*Source*: From U.S. Public Health Service.

**Table 8G.119 Observed Lethal Concentration of Selected Chemicals in Aquatic Environments**

| Chemical | Organism Tested | Lethal Concentration (mg/L) | Exposure Time (hr) |
|---|---|---|---|
| ABS (100 percent) | Fathead minnow | 3.5–4.5 | 96 |
| ABS (100 percent) | Bluegills | 4.2–4.4 | 96 |
| Household syndets | Fathead minnow | 39–61 | 96 |
| Alkyl sulfate | Fathead minnow | 5.1–5.9 | 96 |
| LAS (C12) | Bluegill fingerlings | 3 | 96 |
| LAS (C14) | Bluegill fingerlings | 0.6 | 96 |
| Acetic acid | Goldfish | 423 | 20 |
| Alum | Goldfish | 100 | 12–96 |
| Ammonia | Goldfish | 2–2.5 $NH_3$ | 24–96 |
| Ammonia | Perch, roach, rainbow trout | 3N | 2–20 |
| Sodium arsenite | Minnow | 17.8 As | 36 |
| Sodium arsenate | Minnow | 234 As | 15 |
| Barium chloride | Goldfish | 5,000 | 12–17 |
| Barium chloride | Salmon | 158 | — |
| Cadmium chloride | Goldfish | 0.017 | 9–18 |
| Cadmium nitrate | Goldfish | 0.3 Cd | 190 |
| $CO_2$ | Various species | 100–200 | — |
| CO | Various species | 1.5 | 1–10 |
| Chloramine | Brown trout fry | 0.06 | — |

*(Continued)*

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**Table 8G.119 (Continued)**

| Chemical | Organism Tested | Lethal Concentration (mg/L) | Exposure Time (hr) |
|---|---|---|---|
| Chlorine | Rainbow trout | 0.03–0.08 | — |
| Chromic acid | Goldfish | 200 | 60–84 |
| Copper sulfate | Stickleback | 0.03 Cu | 160 |
| Copper nitrate | Stickleback | 0.02 Cu | 192 |
| Cyanogen chloride | Goldfish | 1 | 6–48 |
| $H_2S$ | Goldfish | 10 | 96 |
| HCl | Stickleback | pH 4.8 | 240 |
| HCl | Goldfish | pH 4.0 | 4–6 |
| Lead nitrate | Minnow, stickleback, brown trout | 0.33 Pb | — |
| Mercuric chloride | Stickleback | 0.01 Hg | 204 |
| Nickel nitrate | Stickleback | 1 Ni | 156 |
| Nitric acid | Minnow | pH 5.0 | — |
| Oxygen | Rainbow trout | 3 cc/L | — |
| Phenol | Rainbow trout | 6 | 3 |
| Phenol | Perch | 9 | 1 |
| Potassium chromate | Rainbow trout | 75 | 60 |
| Potassium cyanide | Rainbow trout | 0.13 Cn | 2 |
| Sodium cyanide | Stickleback | 1.04 Cn | 2 |
| Silver nitrate | Stickleback | 70 K | 154 |
| Sodium fluoride | Goldfish | 1,000 | 60–102 |
| Sodium sulfide | Brown trout | 15 | — |
| Zinc sulfate | Stickleback | 0.3 Zn | 120 |
| Zinc sulfate | Rainbow trout | 0.5 | 64 |
| **Pesticides** | | | |
| 1. Chlorinated hydrocarbons | | | |
| Aldrin | Goldfish | 0.028 | 96 |
| DDT | Goldfish | 0.027 | 96 |
| DDT | Rainbow trout | 0.5–0.32 | 24–36 |
| DDT | Salmon | 0.08 | 36 |
| DDT | Brook trout | 0.032 | 36 |
| DDT | Minnow, guppy | 0.75 ppb | 29 |
| DDT | Stoneflies (species) | 0.32–1.8 | 96 |
| BHC | Goldfish | 2.3 | 96 |
| BHC | Rainbow trout | 3 | 96 |
| Chlordane | Goldfish | 0.082 | 96 |
| Chlordane | Rainbow trout | 0.5 | 24 |
| Dieldrin | Goldfish | 0.037 | 96 |
| Dieldrin | Bluegill | 0.008 | 96 |
| Dieldrin | Rainbow trout | 0.05 | 24 |
| Endrin | Goldfish | 0.0019 | 96 |
| Endrin | Carp | 0.14 | 48 |
| Endrin | Fathead minnow | 0.001 | 96 |
| Endrin | Various species | 0.03–0.05 ppb | — |
| Endrin | Stoneflies (species) | 0.32–2.4 ppb | 96 |
| Heptachlor | Rainbow trout | 0.25 | 24 |
| Heptachlor | Goldfish | 0.23 | 96 |
| Heptachlor | Bluegill | 0.019 | 96 |
| Heptachlor | Redear sunfish | 0.017 | 96 |
| Methoxychlor | Rainbow trout | 0.05 | 24 |
| Methoxychlor | Goldfish | 0.056 | 96 |
| Toxaphene | Rainbow trout | 0.05 | 24 |
| Toxaphene | Goldfish | 0.0056 | 96 |
| Toxaphene | Carp | 0.1 | — |
| Toxaphene | Goldfish | 0.2 | 24 |
| Toxaphene | Goldfish | 0.04 | 170 |
| Toxaphene | Minnows | 0.2 | 24 |
| 2. Organic phosphates | | | |
| Chlorothion | Fathead minnow | 3.2 | 96 |
| Dipterex | Fathead minnow | 180 | 96 |
| EPN | Fathead minnow | 0.2 | 96 |

*(Continued)*

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**Table 8G.119 (Continued)**

| Chemical | Organism Tested | Lethal Concentration (mg/L) | Exposure Time (hr) |
|---|---|---|---|
| Guthion | Fathead minnow | 0.093 | 96 |
| Guthion | Bluegill | 0.005 | 96 |
| Malathion | Fathead minnow | 12.5 | 96 |
| Parathion | Fathead minnow | 1.4–2.7 | 96 |
| TEPP | Fathead minnow | 1.7 | 96 |
| 3. Herbicides | | | |
| Weedex | Young roach and trench | 40–80 | 1 m |
| Weeda Zol | | 15–30 | 1 m |
| Weeda Zol T.L. | | 20–40 | 1 m |
| Simazine (no plants present) | Minnow | 0.5 | $<$3 d |
| Atrazine (A361) (plants present) | Minnow | 5.0 | 24 |
| Atrazine in Gesaprime | Minnow | 3.75 | 24 |
| 4. Bactericides | | | |
| Algibiol | Minnow | 20 | 24 |
| Soricide tetraminol | Minnow | 8 | 48 |

*Source*: From McGauhey, *Engineering Management of Water Quality*, McGraw-Hill, copyright 1968.

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## SECTION 8H RECREATIONAL WATER QUALITY

**Table 8H.120 Water Quality Characteristics Relevant to Recreational Use**

| Characteristics | Primary Contact (e.g. swimming) | Secondary Contact (e.g. boating) | Visual Use (no contact) |
|---|---|---|---|
| Microbiological guidelines | X | X | |
| Nulsance organisms (e.g., algae) | X | X | X |
| Physical and chemical guidelines: | | | |
| Aesthetics | X | X | X |
| Clarity | X | X | X |
| Color | X | X | X |
| pH | X | | |
| Temperature | X | | |
| Toxic chemicals | X | X | |
| Oil, debris | X | X | X |

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. 1, The Guidelines, October 2000, www.deh.gov.au.

**Table 8H.121 Guides for Evaluating Recreational Waters**

| | Water Contact | | Boating and Aesthetic | |
|---|---|---|---|---|
| Determination | Noticeable Threshold | Limiting Threshold | Noticeable Threshold | Limiting Threshold |
| Coliforms, MPN per 100 mL | 1,000[a] | —[b] | | |
| Visible solids of sewage origin | None | None | None | None |
| ABS (detergent) (mg/L) | 1[a] | 2 | 1[a] | 5 |
| Suspended solids (mg/L) | 20[a] | 100 | 20[a] | 100 |
| Flotable oil and grease, mg/L | 0 | 5 | 0 | 10 |
| Emulsified oil and grease (mg/L) | 10[a] | 20 | 20[a] | 50 |
| Turbidity, silica scale units | 10[a] | 50 | 20[a] | —[c] |
| Color, standard cobalt scale units | 15[a] | 100 | 15[a] | 100 |
| Threshold odor number | 32[a] | 256 | 32[a] | 256 |
| Range of pH | 6.5–9.0 | 6.0–10.0 | 6.5–9.0 | 6.0–10.0 |
| Temperature, maximum °C | 30 | 50 | 30 | 50 |
| Transparency, Secchi disk (ft) | — | — | 20[a] | —[c] |

*Note:* Noticeable threshold represents the level at which people begin to notice and perhaps to complain. Limiting threshold in the level at which recreational use of water is prohibited or seriously impaired.

[a] Value not to be exceeded in more than 20 percent of 20 consecutive samples, nor in any 3 consecutive samples.
[b] No limiting concentration can be specified in the basis of epidemiological evidence, provided no fecal pollution is evident.
[c] No concentration likely to be found in surface waters would impede use.

*Source*: From California State Water Quality Control Board, 1963.

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**Table 8H.122 United States Criteria for Bathing (Full Body Contact) Recreational Waters**

**Freshwater**

Based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period), the geometric mean of the indicated bacterial densities should not exceed one or the other of the following[a]:

| | |
|---|---|
| *E. coli* | 126 per 100 mL; or |
| *Enterococci* | 33 per 100 mL; |

No sample should exceed a one sided confidence limit (C.L.) calculated using the following as guidance:

| | |
|---|---|
| Designated bathing beach | 75% C.L. |
| Moderate use for bathing | 82% C.L. |
| Light use for bathing | 90% C.L. |
| Infrequent use for bathing | 95% C.L. |

based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using 0.4 as the log standard deviation for both indicators

**Marine Water**

Based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period), the geometric mean of the enterococci densities should not exceed 35 per 100 mL;

No sample should exceed a one sided confidence limit using the following as guidance:

| | |
|---|---|
| Designated bathing beach | 75% C.L. |
| Moderate use for bathing | 82% C.L. |
| Light use for bathing | 90% C.L. |
| Infrequent use for bathing | 95% C.L. |

based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using 0.7 as the log standard deviation

[a] Only one indicator should be used. The Regulatory agency should select the appropriate indicator for its conditions.

*Source*: From United States Environmental Protection Agency, 2003, *Bacterial Water Quality Standards for Recreational Waters (Freshwater and Marine Waters) Status Report*, EPA-823-R-03-008, www.epa.gov.

**Table 8H.123 WHO Guidelines for Safe Practice in Managing Recreational Waters**

| Guidance Level or Situation | How Guidance Level Derived | Health Risks | Typical Actions[a] |
|---|---|---|---|
| **Relatively low probability of adverse health effects** | | | |
| 20,000 cyanobacterial cells/mL or 10 μg chlorophyll-a/L with dominance of cyanobacteria | From human bathing epidemiological study | Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness | Post on site risk advisory signs<br>Inform relevant authorities |
| **Moderate probability of adverse health effects** | | | |
| 100,000 cyanobacterial cells/ml or 50 μg chlorophyll-a/L with dominance of cyanobacteria | From provisional drinking-water guideline value for microcystin-LR[b] and data concerning other cyanotoxins | Potential for long-term illness with some cyanobactieral species<br>Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness | Watch for scums or conditions conducive to scums<br>Discourage swimming and further investigate hazard<br>Post on-site risk advisory signs<br>Inform relevant authorities |
| **High probability of adverse health effects** | | | |
| Cyanobacterial scum formation in areas where whole-body contact and/or risk of ingestion/aspiration occur | Inference from oral animal lethal poisonings<br>Actual human illness case histories | Potential for acute poisoning<br>Potential for long-term illness with some cyanobacterial species<br>Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness | Immediate action to control contact with scums; possible prohibition of swimming and other water contact activities<br>Public health follow-up investigation<br>Inform public and relevant authorities |

[a] Actual action taken should be determined in light of extent of use and public health assessment of hazard.
[b] The provisional drinking-water guideline value for microcystin-LR is 1 μg/L (WHO, 1998).

*Source*: From WHO, 2003, *Guidelines for Safe Recreational Water Environments, Volume 1: Coastal and Fresh Waters*, Copyright © World Health Organization 2003. www.who.int.

*Original Source*: Derived from Chorus & Bartram, 1999.

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**Table 8H.124 WHO Guideline Values for Microbial Quality of Recreational Waters**

| 95th Percentile Value of Intestinal Enterococci/100 mL (rounded values) | Basis of Derivation | Estimated Risk Per Exposure |
|---|---|---|
| **≤40**<br>**A** | This range is below the NOAEL in most epidemiological studies | **<1% GI illness risk**<br>**<0.3% AFRI risk**<br>This upper 95th percentile value of 40/100 mL relates to an average probability of less than one case of gastroenteritis in every 100 exposures. The AFRI burden would be negligible |
| **41–200**<br>**B** | The 200/100 ml value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or LOAEL for GI illness and AFRI | **1–5% GI illness risk**<br>**0.3–1.9% AFRI risk**<br>The upper 95th percentile value of 200/100 mL relates to an average probability of one case of gastroenteritis in 20 exposures. The AFRI illness rate at this upper value would be less than 19 per 1,000 exposures, or less than approximately 1 in 50 exposures |
| **201–500**<br>**C** | This range represents a substantial elevation in the probability of all adverse health outcomes for which dose-response data are available | **5–10% GI illness risk**<br>**1.9–3.9% AFRI risk**<br>This range of 95th percentiles represents a probability of 1 in 10 to 1 in 20 of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI in the range of 19–39 per 1,000 exposures, or a range of approximately 1 in 50 to 1 in 25 exposures |
| **>500**<br>**D** | Above this level, there may be a significant risk of high levels of minor illness transmission | **>10% GI illness risk**<br>**>3.9% AFRI risk**<br>There is a greater than 10% chance of gastroenteritis per single exposure. The AFRI illness rate of the 95th percentile point of >500/100 mL would be greater than 39 per 1,000 exposures, or greater than approximately 1 in 25 exposures |

*Note:* 1. Abbreviations used: A–D are the corresponding microbial water quality assessment categories used as part of the classification procedure; AFRI = acute febrile respiratory illness; GI = gastrointestinal; LOAEL = lowest-observed-adverse-effect level; NOAEL = no observed-adverse-effect level.
2. The "exposure" in the key studies was a minimum of 10 min of swimming involving three head immersions. It is envisaged that this is equivalent to many immersion activities of similar duration, but it may underestimate risk for longer periods of water contact or for activities involving higher risks of water ingestion.
3. The "estimated risk" refers to the excess risk of illness (relative to a group of non-bathers) among a group of bathers who have been exposed to faecally contaminated recreational water under conditions similar to those in the key studies.
4. The functional form used in the dose-response curve assumes no further illness outside the range of the data (i.e. at concentrations above 158 intestinal enterococci/100 mL). Thus, the estimates of illness rate reported above this value are likely to be underestimates of the actual disease incidence attributable to recreational water exposure.
5. This estimated risks were derived from sewage-impacted marine waters. Different sources of pollution and more or less aggressive environments may modify the risks.
6. This table is derived from risk to healthy adult bathers to marine waters in temperate north European waters.

*Source*: From WHO, 2003, *Guidelines for Safe Recreational Waters, Volume 1: Coastal and Fresh Waters*. Copyright © World Health Organization 2003, www.who.int.

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**Table 8H.125 Summary of Guidelines for Canadian Recreational Water Quality**

| Parameter | Guideline |
|---|---|
| Microbiological | |
| *Escherichia coli* (fecal coliforms) | The geometric mean of at least five samples, taken during a period not to exceed 30 days, should not exceed 2,000 *E. coli*/L. Resampling should be performed when any sample exceeds 4,000 *E. coli*/L |
| Enterococci | The geometric mean of at least five samples, taken during a period not to exceed 30 days, should not exceed 350 enterococci/L. Resampling should be performed when any sample exceeds 700 enterococci/L |
| Coliphages | Limits on coliphages can not be specified at this time. See Health and Welfare Canada (1992) for additional information |
| Waterborne pathogens | The pathogens most frequently responsible for diseases associated with recreational water use are described in Health and Welfare Canada (1992), i.e. *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Salmonella*, *Shigella*, *Aeromonas*, *Campylobacter jejuni*, *Legionella*, human enteric viruses, *Giardia lamblia*, and *Cryptosporidium* |
| Cyanobacteria (blue–green algae) | Limits have not been specified. Health Canada is in the process of developing a numerical guideline for microcystin, a cyanobacterial toxin. Water with blue-green surface scum should be avoided because of reduced clarity and possible presence of toxins |
| Chemical characteristics | Limits for chemicals have not been specified because of lack of data. Decisions for use should be based on an environmental health assessment and the aesthetic quality. Dermal exposures to environmental contaminants has recently been reviewed by Moody and Chu (1995) |
| Aquatic plants | Bathers should avoid areas with rooted or floating plants; very dense growths could affect other activities such as boating and fishing |
| Aesthetics | All water should be free from<br>• materials that will settle to form objectionable deposits;<br>• floating debris, oil, scum, and other matter;<br>• substances producing objectionable color, odor, taste, or turbidity; and<br>• substances and conditions or combinations thereof in concentrations that produce undesirable aquatic life |
| Nuisance organisms | Bathing areas should be as free as possible from nuisance organisms that<br>• endanger the health and physical comfort of users or<br>• render the area unusable<br>Common examples include biting and nonbiting insects and poisonous organisms, for example jellyfish |
| pH | The pH of the waters used for total body contact recreation should be in the pH range of 6.5 to 8.5. If the water has a very low buffering capacity, pH values from 5.0 to 9.0 should be acceptable |
| Temperature | The thermal characteristics of waters used for bathing and swimming should not cause an appreciable increase or decrease in the deep body temperature of bathers and swimmers |
| Turbidity | 50 Nephelometric Turbidity Units (NTU) |
| Clarity—Light penetration | Water should be sufficiently clear that a Secchi disc is visible at a minimum depth of 1.2 m |
| Color | Color should not be so intense as to impede visibility in areas used for swimming. A maximum limit of 100 platinum-cobalt (Pt-Co) units was proposed by Environment Canada (1972) |
| Oil and grease | Oil or petrochemicals should not be present in concentrations that<br>• Can be detected as a visible film, sheen, or discoloration on the surface<br>• Can be detected by odor<br>• Can form deposits on shorelines and bottom sediments that are detectable by sight or odor (International Joint Commission 1977) |

*Note*: See guidance document for a complete narrative of recreational water quality guidelines.

*Source*: From Health and Welfare Canada, 1992, *Guidelines for Canadian Recreational Water Quality*, www.ccme.ca.

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**Table 8H.126 Summary of Australian Water Quality Guidelines of Recreational Waters**

| Parameter | Guideline |
|---|---|
| ***Microbiological*** | |
| Primary contact[a] | The median bacterial content in fresh and marine waters taken over the bathing season should not exceed 150 fecal coliform organisms/100 mL or 35 enterococci organisms/100 mL. Pathogenic free-living protozoans should be absent from bodies of fresh water[b] |
| Secondary contact[a] | The median value in fresh and marine waters should not exceed 1,000 fecal coliform organisms/100 mL or 230 enterococci organisms/100 mL[b] |
| Nuisance organisms | Macrophytes, phytoplankton scums, filamentous algal mats, sewage fungus, leeches, etc., should not be present in excessive amounts[a]. Direct contact activities should be discouraged if algal levels of 15,000–20,000 cells/mL are present, depending on the algal species. Large numbers of midges and aquatic worms should also be avoided |
| ***Physical and chemical*** | |
| Visual clarity & color | To protect the aesthetic quality of a waterbody:<br>• the natural visual clarity should not be reduced by more than 20%<br>• the natural hue of the water should not be changed by more than 10 points on the Munsell Scale<br>• the natural reflectance of the water should not be changed by more than 50%<br>To protect the visual clarity of waters used for swimming, the horizontal sighting of a 200 mm diameter black disc should exceed 1.6 m |
| pH | The pH of the water should be within the range 5.0–9.0, assuming that the buffering capacity of the water is low near the extremes of the pH limits |
| Temperature | For prolonged exposure, temperatures should be in the range 15–35°C |
| Toxic chemicals | Water containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable of recreation. Toxic substances should not exceed values in Table 8.127 and 8.128 |
| Surface films | Oil and petrochemicals should not be noticeable as a visible film on the water nor should they be detectable by odor |

[a] Refer to Section 3.3 of this revised Australian Guidelines relating to nutrient concentrations necessary to limit excessive aquatic plant growth.

[b] Sampling frequency and maximum values are given in Section 5.2.3.1 of the guidance document.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8H.127 Summary of Australian Water-Quality Guidelines for Recreational Purposes: General Chemicals**

| Parameter | Guideline Values (μg/L, Unless Otherwise Stated) |
|---|---|
| *Inorganic:* | |
| Arsenic | 50 |
| Asbestos | NR |
| Barium | 1,000 |
| Boron | 1,000 |
| Cadmium | 5 |
| Chromium | 50 |
| Cyanide | 100 |
| Lead | 50 |
| Mercury | 1 |
| Nickel | 100 |
| Nitrate-N | 10,000 |
| Nitrite-N | 1,000 |
| Salenium | 10 |
| Silver | 50 |
| *Organic:* | |
| Benzene | 10 |
| Benzo(*a*)pyrene | 0.01 |
| Carbon tetrachloride | 3 |
| 1,1-Dichloroethene | 0.3 |
| 1,2-Dichloroethane | 10 |
| Pentachlorophenol | 10 |
| Polychlorinated biphenyls | 0.1 |
| Tetrachloroethene | 10 |
| 2,3,4,6-Tetrachlorophenol | 1 |
| Trichloroethene | 30 |
| 2,4,5-Trichlorophenol | 1 |
| 2,4,6-Trichlorophenol | 10 |
| *Radiological:* | |
| Gross alpha activity | 0.1 Bq/L |
| Gross beta activity (excluding activity of $^{40}K$) | 0.1 Bq/L |
| *Other chemicals:* | |
| Aluminum | 200 |
| Ammonia (as N) | 10 |
| Chloride | 400,000 |
| Copper | 1,000 |
| Oxygen | >6.5 (>80% saturation) |
| Hardness (as $CaCO^3$) | 500,000 |
| Iron | 300 |
| Manganese | 100 |
| Organics (CCE & CAE) | 200 |
| pH | 6.5–8.5 |
| Phenolics | 2 |
| Sodium | 300,000 |
| Sulfate | 400,000 |
| Sulfide | 50 |
| Surfactant (MBAS) | 200 |
| Total dissolved solids | 1,000,000 |
| Zinc | 5,000 |

*Note:* NR = No guideline recommended at this time; MBAS Methylene blue active substances.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I, The Guidelines, October 2000, www.deh.gov.au.

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**Table 8H.128 Summary of Water-Quality Guidelines for Recreational Purposes: Pesticides**

| Compound | Maximum Concentration (μg/L) | Compound | Maximum Concentration (μg/L) |
|---|---|---|---|
| Acephate | 20 | Fenvalerate | 40 |
| Alachlor | 3 | Flamprop-methyl | 6 |
| Aldrin | 1 | Fluometuron | 100 |
| Amitrol | 1 | Formothion | 100 |
| Asulam | 100 | Fosamine (ammonium salt) | 3,000 |
| Azinphos-methyl | 10 | Glyphosate | 200 |
| Barban | 300 | Heptachlor | 3 |
| Benomyl | 200 | Hexaflurate | 60 |
| Bentazone | 400 | Hexazinone | 600 |
| Bioresmethrin | 60 | Lindane | 10 |
| Bromazil | 600 | Maidison | 100 |
| Bromophos-ethyl | 20 | Methidathion | 60 |
| Bromoxynil | 30 | Methomyl | 60 |
| Carbaryl | 60 | Metolachlor | 800 |
| Carbendazim | 200 | Metribuzin | 5 |
| Carbofuran | 30 | Mevinphos | 6 |
| Carbophenothion | 1 | Molinate | 1 |
| Chlordane | 6 | Monocrotophos | 2 |
| Chlordimeform | 20 | Nabam | 30 |
| Chlorfenvinphos | 10 | Nitralin | 1,000 |
| Chloroxuron | 30 | Omethoate | 0.4 |
| Chlorpyrifos | 2 | Oryzalin | 60 |
| Clopzralid | 1,000 | Paraquat | 40 |
| Cyhexatin | 200 | Parathion | 30 |
| 2,4-D | 100 | Parathion-methyl | 6 |
| DDT | 3 | Pendimethalin | 600 |
| Demeton | 30 | Perfluidone | 20 |
| Diazinon | 10 | Permethrin | 300 |
| Dicamba | 300 | Pioloram | 30 |
| Dichlobenil | 20 | Piperonyl butoxide | 200 |
| 3,6-Dichloropicolinic acid | 1,000 | Pirimicarb | 100 |
| Dichlorvos | 20 | Pirimiphos-ethyl | 1 |
| Diclofop-methyl | 3 | Pirimiphos-methyl | 60 |
| Dicofol | 100 | Profenofos | 0.6 |
| Dieldrin | 1 | Promecarb | 60 |
| Difenzoquat | 200 | Propanil | 1,000 |
| Dimethoate | 100 | Propargite | 1,000 |
| Diquat | 10 | Propoxur | 1,000 |
| Disulfoton | 6 | Pyrazophos | 1,000 |
| Diuron | 40 | Quintozene | 6 |
| DPA | 500 | Sulprofos | 20 |
| Endosulfan | 40 | 2,4,5-T | 2 |
| Endothal | 600 | Temephos | 30 |
| Endrin | 1 | Thiobencarb | 40 |
| EPTC | 60 | Thiometon | 20 |
| Ethion | 6 | Thiophanate | 100 |
| Ethoprophos | 1 | Thiram | 30 |
| Fenchlorphos | 60 | Trichlorofon | 10 |
| Fenitrothion | 20 | Triclopyr | 20 |
| Fenoprop | 20 | Trifuralin | 500 |
| Fensulfothion | 20 | | |

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. 1, The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: From NHMRC & AWRC (1987), NHMRC (1989).

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# SECTION 8I WATER QUALITY FOR LIVESTOCK AND AQUACULTURE

**Table 8I.129 Guides for Evaluating the Quality of Water Used by Livestock**

| Quality Factor (mg/L) | Threshold Concentration[a] | Limiting Concentration[b] |
|---|---|---|
| Total dissolved solids (TDS) | 2500 | 5000 |
| Cadmium | 5 | |
| Calcium | 500 | 1000 |
| Magnesium | 250 | 500[c] |
| Sodium | 1000 | 2000[c] |
| Arsenic | 1 | |
| Bicarbonate | 500 | 500 |
| Chloride | 1500 | 3000 |
| Fluoride | 1 | 6 |
| Nitrate | 200 | 400 |
| Nitrite | None | None |
| Sulfate | 500 | 1000[c] |
| Range of pH | 6.0–8.5 | 5.6–9.0 |

[a] Threshold values represent concentrations at which poultry or sensitive animals might show slight effects from prolonged use of such water. Lower concentrations are of little or no concern.
[b] Limiting concentrations based on interim criteria, South Africa. Animals in lactation or production might show definite adverse reactions.
[c] Total magnesium compounds plus sodium sulfate should not exceed 50 percent of the total dissolved solids.

*Source*: From California State Water Quality Control Board, 1963.

**Table 8I.130 Guide to the Use of Saline Waters for Livestock and Poultry**

| Total Soluble Salts Content of Waters | Uses |
|---|---|
| Less than 1,000 mg/L (EC < 1.5 mmhhos/cm) | Relatively low level of salinity. Excellent for all classes of livestock and poultry |
| 1,000–3,000 mg/L (EC = 1.5–5 mmhos/cm) | Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them; may cause watery droppings in poultry |
| 3,000–5,000 mg/L (EC = 5–8 mmhos/cm) | Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing watery feces, increased mortality, and decreased growth, especially in turkeys |
| 5,000–7,000 mg/L (EC = 8–11 mmhos/cm) | Can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry |
| 7,000–10,000 mg/L (EC = 11–16 mmhos/cm) | Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, poultry, and swine may subsist on them under certain conditions |
| Over 10,000 mg/L (EC > 11–16 mmhos/cm) | Risks with these highly saline waters are so great that they cannot be recommended for use under any condition |

*Source*: From Soltanpour, P. N. and Raley, W. L., Livestock Drinking Water Quality, Colorado State University Cooperative Extension – Agriculture, no. 4.908, www.ext.colostate.edu.

*Original Source*: From Environmental Studies Board, Nat. Acad. of Sci., Nat. Acad. of Eng., *Water Quality Criteria,* 1972. Ayers, R.S. and D.W. Westcot. *Water Quality for Agriculture.* Food and Agriculture Organization of the United Nations, Rome, 1976. P.N. Soltanpour, Colorado State University professor, soil and crop sciences; and W.L. Raley, former Colorado State University Cooperative Extension western district director. 10/93. Reviewed 3/99.

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**Table 8I.131 Canadian Water-Quality Guidelines for the Protection of Agricultural Water Uses–Livestock**

| Parameter[a] | Livestock Water (μg/L) |
|---|---|
| Aldicarb | 11[c] |
| Aluminum[d] | 5,000 |
| Arsenic[e] | 25[f] |
| Atrazine | 5[f,g] |
| Beryllium[d] | 100[f] |
| Blue-green algae(Cyanobacteria)[d] | |
| Boron[d] | 5,000 |
| Bromacil | 1,100[f] |
| Bromoxynil | 11[f] |
| Cadmium | 80 |
| Calcium[d] | 1,000,000 |
| Captan | 13[f,i] |
| Carbaryl | 1,100 |
| Carbofuran | 45 |
| Chlordane | 7[l,m] |
| Hexachlorobenzene | 0.52[f,n] |
| 1,2-Dichloroethane | 5[f] |
| 1.1,2-Trichloroethene (Trichloroethylene, TCE) | 50[f] |
| Chlorothalonil | 170[f] |
| Chlorpyrifos | 24[f] |
| Chromium | |
| Trivalent chromium (Cr(III)) | 50[f,n] |
| Hexavalent chromium (Cr(VI)) | 50[f,n] |
| Cobalt[d] | 1,000 |
| Color | Narrative |
| Copper[d] | 500–5,000[p] |
| Cyanazine | 10[f] |
| Cyanobacteria (Blue-green algae) | Narrative |
| 2,4-D [See 2,4-Dichlorophenoxyacetic acid] | See also Phenoxy herbicides |
| DDT(2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane; Dichloro diphenyl trichloroethane)[d] | 30[l,m] |
| Deltamethrin | 2.5 |
| Dicamba | 122 |
| 2,4-Dichlorophenoxyacetic acid (2,4-D) [See also Phenoxy herbicides] | See also Phenoxy herbicides |
| Diclofop-methyl | 9[f] |
| Dimethoate | 3[f] |
| Dinoseb | 150 |
| Endrin[d] | 0.2[l,m] |
| Ethylbenzene[d,e] | 2.4 |
| Fluoride[d] | 1,000–2,000[n] |
| Glyphosate[d] | 280 |
| Dichloromethane[d] (Methylene chloride) | 50[f] |
| Trichloromethane[d] (Chloroform) | 100[g] |
| Tetrachloromethane[d] (Carbon tetrachloride) | 5[f] |
| Tribromomethane (Bromoform) | 100[g] |
| Dichlorobromomethane | 100[g] |
| Dibromochloromethane | 100[g] |
| Heptachlor (Heptachlor epoxide)[d] | 3[l,m] |
| Lead[d] | 100 |
| Lindane (Hexachlorocyclohexane)[d] | 4 |
| MCPA (4-chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid) | 25[f] |
| Mercury[d] | 3 |
| Metolachlor | 50[f] |
| Metribuzin | 80 |
| Molybdenum[d] | 500 |
| Nickel[d] | 1,000 |
| Nitrate + Nitrite[d] | 100,000 |
| Nitrite[d] | 10,000 |
| Tributyltin | 250 |
| Tricyclohexyltin | 250[f] |
| Triphenyltin | 820[f,i] |

*(Continued)*

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**Table 8I.131 (Continued)**

| Parameter[a] | Livestock Water (μg/L) |
|---|---|
| Phenols[d] | 2 |
| Phenoxy herbicides[d] | 100 |
| Picloram[d] | 190 |
| Selenium[d] | 50 |
| Simazine | 10[f] |
| Sulphate[d] | 1,000,000 |
| Tebuthiuron | 130[f] |
| Toluene[d,e] | 24 |
| Total dissolved solids (salinity)[d] | 3,000,000 |
| Toxaphene[d] | 5[l,m] |
| Triallate[d] | 230[f] |
| Trifluralin | 45[f] |
| Uranium[d] | 200 |
| Vanadium[d] | 100 |
| Zinc[d] | 50,000 |

*Note:* μg/L is microgram per liter.

[a] Unless otherwise indicated, supporting documents are available from the Guidelines and Standards Division, Environment Canada.
[b] The guidelines dated 1987 have been carried over from *Canadian Water Qualify Guidelines* (CCREM 1987) and no fact sheet was prepared. The guidelines dated 1989 to 1997 were developed and initially published in CCREM 1987 as appendixes on the date indicated. They are published as fact sheets in this document. Other guidelines dated 1997 and those dated 1999 are published for the first time in this document.
[c] Concentration of total aldicarb residue.
[d] No fact sheet created.
[e] The technical document for the guideline is available from the Ontario Ministry of the Environment.
[f] Interim guideline.
[g] During the initial development of this guideline, insufficient data were available to derive a livestock watering guideline value. Therefore, the Canadian drinking water quality guideline (Health and Welfare Canada 1987) was adopted. Since then, this value has been revised by Health Canada (1996). This revised drinking water quality guideline in now adopted as the guideline for livestock water.
[h] Guideline value slightly modified from CCREM 1987 + Appendixes due to re-evaluation of the significant figures.
[i] Guideline is crop-specific (see fact sheet).
[j] This guideline (originally published in *Canadian Water Quality Guidelines* [CCREM 1987]) is no longer recommended and the value is withdrawn. A water quality guideline is not recommended. Environmental exposure is predominantly via sediment, soil, and/or tissue, therefore, the reader is referred to the respective guidelines for these media.
[k] This substance meets the criteria for Track substances under (the national CCME Policy for the Management of Toxic Substances (PMTS) (i.e., persistent, bioaccumulative, primarily result of human activity, and CEPA-toxic or equivalent) and should be subject to virtual elimination strategies. Guidelines can serve as action levels or interim management objectives towards virtual elimination.
[l] Substance has been re-evaluated since CCREM 1987+Appendixes. Either a new guideline has been derived or insufficient data existed to derive a new guideline.
[m] Copper guideline =500 $\mu g L^{-1}$ for sheep, 1000 $\mu g\ L^{-1}$ for cattle, 5000 $\mu g\ L^{-1}$ for swine and poultry.
[n] Fluoride guideline = 1000 $\mu g\ L^{-1}$ if feed contains fluoride.
[o] Molybdenum guideline = 50 $\mu g\ L^{-1}$ for short-term use on acidic soils.

*Source*: From Canadian Council of Ministers of the Environment, 2005, Canadian water quality guidelines for the protection of agricultural water uses: summary table, Updated October 2005. In: *Canadian Environmental Quality Guidelines*, 1999, Canadian Council of Ministers of the Environment, Winnipeg, ec.gc.ca/CEQC-RCQE.

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**Table 8I.132 Tolerances of Livestock to Total Dissolved Solids (Salinity) in Drinking Water**

| | Total Dissolved Solids (mg/L) | | |
|---|---|---|---|
| **Livestock** | **No Adverse Effects on Animals Expected** | **Animals May Have Initial Reluctance to Drink or There May Be Some Scouring, but Stock Should Adapt without Loss of Production** | **Loss of Production and a Decline in Animal Condition and Health Would Be Expected. Stock may Tolerate These Levels for Short Periods if Introduced Gradually** |
| Beef cattle | 0–4,000 | 4,000–5,000 | 5,000–10,000 |
| Dairy cattle | 0–2,500 | 2,500–4,000 | 4,000–7,000 |
| Sheep | 0–5,000 | 5,000–10,000 | 10,000–13,000[a] |
| Horses | 0–4,000 | 4,000–6,000 | 6,000–7,000 |
| Pigs | 0–4,000 | 4,000–6,000 | 6,000–8,000 |
| Poultry | 0–2,000 | 2,000–3,000 | 3,000–4,000 |

[a] Sheep on lush green feed may tolerate up to 13,000 mg/L TDS without loss of condition or production.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. 1. The Guidelines, October 2000, www.deh.gov.au.

*Original Source*: From ANZECC (1992), adapted to incorporate more recent information.

**Table 8I.133 Recommended Water Quality Trigger Values (Low Risk) for Heavy Metals and Metalloids in Livestock Drinking Water**

| **Metal or Metalloid** | **Trigger Value (low risk)[a] (mg/L)** |
|---|---|
| Aluminum | 5 |
| Arsenic | 0.5<br>up to 5[c] |
| Beryllium | ND[b] |
| Boron | 5 |
| Cadmium | 0.01 |
| Chromium | 1 |
| Cobalt | 1 |
| Copper | 0.4 (sheep)<br>1 (cattle)<br>5 (pigs)<br>5 (poultry) |
| Fluoride | 2 |
| Iron | Not sufficiently toxic |
| Lead | 0.1 |
| Manganese | Not sufficiently toxic |
| Mercury | 0.002 |
| Molybdenum | 0.15 |
| Nickel | 1 |
| Selenium | 0.02 |
| Uranium | 0.2 |
| Vanadium | ND |
| Zinc | 20 |

[a] Higher concentrations may be tolerated in some situations (details provided in Volume 3, Section 9.3.5).
[b] ND = not determined, insufficient background data to calculate.
[c] May be tolerated if not provided as a food additive and natural levels in the diet are low.

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. I. The Guidelines, October 2000, www.deh.gov.au.

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**Table 8I.134 Australian Trigger Values for Radioactive Contaminants in Livestock Drinking Water**

| Radionuclide | Trigger Value (Bq/L) |
|---|---|
| Radium 226 | 5 |
| Radium 228 | 2 |
| Uranium 238 | 0.2 |
| Gross alpha | 0.5 |
| Gross beta (excluding K-40) | 0.5 |

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. 1. The Guidelines, October 2000, www. deh.gov.au.

**Table 8I.135 Australian Physico-Chemical Stressor Guidelines for the Protection of Aquaculture Species**

| | Recommended Guideline (mg/L) | |
|---|---|---|
| **Measured Parameter** | **Freshwater Production** | **Saltwater Production** |
| Alkalinity | ≥20[e] | >20[c] |
| Biochemical oxygen demand (BODs) | <15[a] | ND |
| Chemical oxygen demand (COD) | <40[a] | ND |
| Carbon dioxide | <10 | <15 |
| Color and appearance of water | 30–40[b] (Pt-Co units) | 30–40[b] (Pt-Co units) |
| Dissolved oxygen | >5[c] | >5[c] |
| Gas supersaturation | <100%[f] | <100%[f] |
| Hardness ($CaCO_3$) | 20–100[e] | NC[f] |
| pH | 5.0–9.0 | 6.0–9.0 |
| Salinity (total dissolved solids) | <3,000[f] | 33,000–37,000[f] (3,000–35,000 Brackish)[f] |
| Suspended solids | <40 | <10 (<75 Brackish) |
| Temperature | <2.0°C change over 1 hr[d] | <2.0°C change over 1 hr[d] |

*Note:* Unless noted, guidelines are based on professional judgements.

[a] Schlotfeldt & Aldeman (1995).
[b] O'Connor pers. comm.
[c] Meade (1989).
[d] ANZECC (1992).
[e] DWAF (1996).
[f] Lawson (1995).

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. 1. The Guidelines, October 2000, www.deh.gov.au.

**Table 8I.136 Australian Toxicant Guidelines for the Protection of Acquaculture Species**

| | Guideline (μg/L) | |
|---|---|---|
| **Measured Parameter** | **Freshwater Production** | **Saltwater Production** |
| **Inorganic Toxicants (Heavy metals and others)** | | |
| Aluminum | <30 (pH>6.5)[a]<br><10 (pH<6.5) | <10[a] |
| Ammonia (unionized) | <20 (pH>8.0) coldwater[b]<br><30 warmwater[b] | <100 |
| Arsenic | <50[a,b] | <30[a,b] |
| Cadmium (varies with hardness) | <0.2–1.8[b] | <0.5–5[a] |
| Chlorine | <3[a] | <3[a] |
| Chromium | <20[b] | <20 |
| Copper (varies with hardness) | <5[b] | <5[c] |
| Cyanide | <5[a] | <5[a] |

*(Continued)*

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**Table 8I.136 (Continued)**

| | Guideline (μg/L) | |
|---|---|---|
| **Measured Parameter** | **Freshwater Production** | **Saltwater Production** |
| Fluorides | <20[d] | ND |
| Hydrogen sulfide | <1[b] | <2 |
| Iron | <10[a] | <10[a] |
| Lead (varies with hardness) | <1–7[d] | <1–7[d] |
| Magnesium | <15,000[a] | ND |
| Manganese | <10[a,e] | <10[a,e] |
| Mercury | <1 | <1 |
| Nickel | <100[a] | <100[a] |
| Nitrate ($NO_3^-$) | <50,000[f] | <100,000[c,g] |
| Nitrite ($NO_2^-$) | <100[a,g] | <100[a,g] |
| Phosphates | <100[b] | <50 |
| Selenium | <10[a] | <10[a] |
| Silver | <3[a] | <3[a] |
| Tributyltin (TBT) | <0.026[a] | <0.01[a] |
| Total available nitrogen (TAN) | <1,000[a] | <1,000[a] |
| Vanadium | <100[a] | <100[a] |
| Zinc | <5[a] | <5[a] |
| **Organic Toxicants (nonpesticides)** | | |
| Detergents and surfactants | <0.1[h] | ND |
| Methane | <65,000[i,j] | <65,000[i,j] |
| Oils and greases (including petrochemicals) | <300[f] | ND |
| Phenols and chlorinated phenols | <0.6–1.7[f] | ND |
| Polychlorinated biphenyls (PCBs) | <2[a] | <2[a] |
| **Pesticides** | | |
| 2,4-dichlorophenol | <4.0[b] | ND |
| Aldrin | <0.01[b,c,h] | ND |
| Azinphos-methyl | <0.01[b] | ND |
| Chlordane | <0.01[k] | 0.004[k] |
| Chlorpyrifos | <0.001[b] | ND |
| DDT (including DDD & DDE) | <0.0015[b] | ND |
| Demton | <0.01[k] | ND |
| Dieldrin | <0.005[b] | ND |
| Endosulfan | <0.003[b,k] | 0.001[k] |
| Endrin | <0.002[b] | ND |
| Gunthion (see also Azinphos-methyl) | <0.01[k] | ND |
| Hexachlorobenzole | <0.00001[f] | ND |
| Heptachlor | <0.005[b] | ND |
| Lindane | <0.01[k] | 0.004[k] |
| Malathion | <0.1[e,k] | ND |
| Methoxychlor | <0.03[k] | ND |
| Mirex | <0.001[b,k] | ND |
| Paraquat | ND | <0.01 |
| Parathion | 0.04[k] | ND |
| Toxaphene | <0.002[b] | ND |

*Note:* ND, Not determined—insufficient information, NC, Not of concern; Unless noted, guidelines are based on professional judgements.

[a] Meade (1989).
[b] DWAF (1996).
[c] Piliay (1990).
[d] Tebbutt (1972).
[e] Zweig et al. (1999).
[f] Schlotfeldt & Alderman (1995).
[g] Coche (1981).
[h] Langdon (1988).
[i] McKee & Wolf (1963).
[j] Boyd (1990).
[k] Lannan et al. (1986).

*Source*: From Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000, *National Water Quality Management Strategy*, Paper No. 4, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, vol. 1. The Guidelines, October 2000, www.deh.gov.au.

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## SECTION 8J WATER TREATMENT PROCESSES

**Table 8J.137 Common Water Quality Problems, Effects, and Treatment**

| Probable Cause | General Effect | Probable Remedy |
|---|---|---|
| Hardness (Calcium and Magnesium) | Scales in pipes and water heaters; causes "soap curd" on fixtures, tiles, dishes and laundry; low sudsing characteristics | Removal by ion exchange softener |
| Iron, Manganese, Copper, Zinc | Causes discolored water; red, brown, orange or black stains on fixtures, appliances and laundry; dark scale in pipes and water heaters | Low level (2 ppm) removal by ion exchange softener when hardness is also present; best removed by oxidizing iron filter, aeration and/or chlorination followed by filtration in some cases |
| Iron, Manganese, Sulfur Bacteria | Same general effects as above plus slimey deposits that form in pumps, pipes, softeners and toilet tanks | Low level removal possible by oxidizing iron filter; best removed by disinfection followed by filtration |
| Hydrogen Sulfide Gas | Foul rotten-egg odor; corrosion to plumbing; tarnishes silver and stains fixtures and laundry; ruins the taste of foods and beverages | Best removed by aeration, scrubbing and filtration; also removed by oxidizing filters or chlorination followed by filtration |
| Turbidity | Suspended matter in water; examples include mud, clay, silt and sand; can ruin seals and moving parts in appliances | Removal by backwashing sediment filters; extra fine treatment utilizing sediment cartridge elements |
| Acid Water (low pH) | Corrosive water attacks piping and other metals; red and/or green staining of fixtures and laundry | Best corrected by neutralizing filters or soda ash feeding |
| Taste, Odor, Color (organic matter) | Makes water unpalatable; can cause staining | Depending on the nature of contaminant, aeration followed by filtration; carbon filtration; oxidation followed by filtration |
| Tannins, Humic Acid | Can impart an "iced-tea" color to water; causes light staining; can affect the taste of foods and beverages | Removal by special ion exchange or oxidizing agents and filtration |
| Coliform Bacteria, Cryptosporidium, Giardia Lamblia, Viruses | Can cause serious disease and intestinal disorders | Disinfection and filtration is most widely practiced |
| Organic Halides (e.g., herbicides and pesticides) | Can cause serious disease and/or poisoning | Most are readily removed by absorption with carbon filters; some can also be removed by hydrolysis and oxidation |
| Nitrates, Chlorides and Sulfates | Can cause health-related problems if quantities are high | Removal by special ion exchange, deionization process or reverse osmosis |
| Sodium Salts | Imparts an alkaline or soda taste to water | Removal by deionization process or reverse osmosis, distillation can be used |
| Arsenic[a] | Can cause health-related problems; Known carcinogen | Removal using conventional coagulation with iron or aluminum salts followed by filtration; may also be removed by adsorption onto activated alumina or by ion exchange |
| Radionuclides[b] | Can cause health-related problems | Best Available Technology (BAT) identified for removal include ion exchange, reverse osmosis, lime softening, and conventional coagulation followed by filtration |
| Synthetic Organic Compounds[a] | Can cause health-related problems | Removal using aeration, air stripping for volatile organic compounds; removal using granular activated carbon adsorption or chemical oxidation for volatile or non-volatile compounds |

[a] J.M. Montgomery Consulting Engineers, Inc., 1985, *Water Treatment Principles and Design*, John Wiley & Sons, Inc.
[b] USEPA, 2005, A Regulator's Guide to the Management of Radioactive Residuals from Drinking Water Treatment Technologies, EPA 816-R-05-004, July 2005

*Source*: From Chandler, J., A comprehensive look at water treatment, *Water Well Journal*, May 1988. Copyright Water Well Publ. Co. Reprinted with permission. Amended.

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**Table 8J.138 Summary of Conventional Processes and Systems for Water Quality Control**

| Type or Process | Common Application | Approximate Limit of Quality Input | Principal Change in Quality Factors (Approximate) |
|---|---|---|---|
| | | **Gravity Separation** | |
| Plain sedimentation | Reduction in suspended solids in raw water to be pumped | No theoretical limit: 3,000–5,000 mg/L typical maximum in flood waters | Removes larger and heavier suspended solids |
| | Primary sewage treatment | Unspecified | 50% reduction in suspended solids<br>35–40% reduction in BOD<br>50% reduction in turbidity |
| | Secondary sewage treatment | Unspecified | Unreported |
| | Concentrating return activated sludge (secondary treatment) | Unspecified | Thickens sludge to 20–25% original volume |
| | Concentrating or reducing suspended solids in industrial wastes, organic and inorganic | Unspecified | Highly dependent upon nature of waste treated |
| | Grit removal-raw sewage | Unspecified | Removes heavy suspended solids not transported at velocity of 1 ft/sec |
| Plain sedimentation plus skimming | Primary sewage treatment | Unspecified | 25–40% reduction in BOD<br>40–70% reduction in suspended solids<br>25–75% reduction in bacteria<br>2% reduction in detergents |
| | Various industrial wastes | Unspecified | Dependent upon nature of waste |
| Trickling filter plus plain sedimentation | Secondary sewage treatment | 0.25-3.0 lb BOD/cu yd/filter | 80–95% reduction in BOD<br>70–92% reduction in suspended solids<br>90–95% reduction in bacteria<br>30–35% reduction in ABS<br>80–90% reduction in LAS |
| | Organic industrial wastes (e.g., milk process) | Dependent upon waste treated | Dependent upon nature of waste |
| Activated sludge plus plain sedimentation | Secondary sewage treatment | Unspecified | 80–95% reduction in BOD<br>85–95% reduction in suspended solids<br>95–98% reduction in bacteria<br>50% reduction in BAS<br>90–99% reduction in LAS |
| Sedimentation after mechanical flocculation | Raw sewage (experimentally) | Unspecified | 64% reduction in turbidity<br>40% reduction in suspended solids<br>60% reduction in BOD |
| | Industrial wastes | Unspecified | Variable, depending upon nature of wastes treated |
| Sedimentation after chemical coagulation | Municipal and industrial water supply water softening | Unspecified | Seldom evaluated separate from filtration |
| | Raw sewage (not common) | Unspecified | 50–85% reduction in BOD<br>70–90% reduction in suspended solids<br>40–80% reduction in bacteria |
| | Industrial wastes | Dependent upon waste | Variable, dependent upon nature of waste |

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| | | | |
|---|---|---|---|
| Chemical coagulation plus sedimentation | Municipal water supply | Unspecified | Coalesces and precipitates dispersed clay colloids<br>Reduces turbidity<br>Reduces color |
| | Phosphate removal from waste waters | Unspecified | Reduces soluble phosphates to trace amounts |
| | Lime-soda softening of water supplies | Applicable to waters containing Ca and Mg sulfates and bicarbonates; Iron and Mg in natural waters (e.g. maximum from 10 mg/L; minimum, 3 mg/L) | Reduces hardness to approximately 75 mg/L; by excess lime to 30–50 mg/L; by hot process to $<10$ mg/L as $CaCO_3$<br>Reduces Fe to 0.1 mg/L ($\pm$)<br>Removes $CO_2$—requiring restabilization<br>80–100% reduction in bacteria by excess lime |
| | | **Filtration** | |
| Slow sand (gravity) | Tertiary treatment of sewage effluent<br>Water reclamation systems | Relatively low turbidity | 90–95% reduction in BOD<br>85–95% reduction in suspended solids<br>95–98% reduction in bacteria<br>90–99% reduction in surfactants |
| | Municipal water supply | Turbidity 40 mg/L | 99% reduction in bacteria<br>95–100% reduction in turbidity<br>30% reduction in color<br>Odors and tastes removed<br>60% reduction in iron |
| | Industrial wastes | Unspecified | Varies with nature of waste |
| Rapid sand (gravity) | Municipal and industrial water supply (little used without coagulation) | Low turbidity, e.g., 50 mg/L, maximum coliform MPN 5,000/100 mL | 95% reduction in bacteria<br>90% reduction in turbidity |
| Rapid sand plus chemical coagulation (gravity) | Municipal and industrial water supply | No limit specified for maximum turbidity<br>Maximum coliform MPN 5,000–20,000/100 mL | 90–99% reduction in bacteria<br>100% ($-$) reduction in turbidity<br>Color reduction to less than 5 mg/L<br>Alkali increased 7.7 mg/L/gr. alum<br>$CO_2$ increased 6.8 mg/L/gr. alum<br>Slight reduction in iron<br>Odor and taste partially removed |
| Rapid sand plus chemical coagulation, chlorination, and activated carbon | Municipal and industrial water supply | No limit specified for maximum turbidity<br>Maximum coliform MPN 5,000–20,000/100 mL | Approximately 100% reduction in bacteria<br>100% reduction in turbidity<br>Color reduced to near zero<br>Iron and Mn reduced<br>Taste and odor removed |
| Rapid sand (pressure) (precoat with chemical floc) | Small municipal supplies<br>Institutional water supply<br>Swimming pools Industrial supply and process Emergency and military use | Generally unspecified<br>Low turbidity desirable | Similar to rapid sand filter but more variable in performance |

*(Continued)*



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**Table 8J.138 (Continued)**

| Type or Process | Common Application | Approximate Limit of Quality Input | Principal Change in Quality Factors (Approximate) |
|---|---|---|---|
| | | **Filtration (Continued)** | |
| Diatomaceous earth (pressure and vacuum) | Small municipal supplies<br>Institutional water supply<br>Swimming pools<br>Industrial supply and process<br>Emergency and military use | None specified, but operation depends upon nature of water | Capable of good clarification of water; efficiency, however, not well documented<br>40–90% reduction in suspended solids<br>50% reduction in color |
| Contact filters | Manganese removal<br>Iron removal | None specified | Reduces to USPHS Standards<br>88% reduction in iron |
| Bag filters | Swimming pools | Unspecified | Strains out hair and coarser suspended solids, reduces bacteria to level controllable by chlorination practice |
| Microstraining | Primary clarification of water prior to filtration<br>Clarification of sewage effluents<br>Treatment of industrial wastes | Size of particles to be removed greater than screen size<br>Material suitable for microstraining | 87–96% reduction in microscopic organisms<br>60–90% reduction in microscopic particulates<br>50–60% reduction in suspended solids trickling filter effluent<br>30–40% reduction on turbidity |
| Fine screening | Raw sewage | None specified | 5–10% reduction in BOD<br>2–20% reduction on suspended solids<br>10–20% reduction in bacteria |
| | Industrial wastes (e.g., cannery, pulp mill, etc.) | None specified | Varies with nature of waste |
| Carbon filters | Special municipal and industrial water applications | Very low turbidity, other not specified | Adsorbs exotic organic chemicals, including surfactants<br>Removes tastes and odors<br>Adsorbs miscellaneous gases |
| | | **Aeration** | |
| Spray or cascade | Municipal and industrial water supply<br>Industrial waste treatment | Unspecified | Releases gases producing taste and odor<br>Reduces $CO_2$ in groundwaters to normal surface water levels<br>Partial removal of $H_2S$<br>Partial removal of gases of decomposition<br>Oxidation and removal of soluble iron in groundwaters; 80–97% reduction observed |
| Pressure aerators | Treatment of sewage and industrial wastes | Limits variable or unspecified | Grit precipitated<br>Grease concentrated at surface<br>Separates various solids by flotation<br>Maintains aerobic conditions in biological systems, e.g., activated sludge, aerated ponds<br>Reduces ABS or LAS 1–2 mg/L<br>Reduces septicity of sewage |

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| | | | |
|---|---|---|---|
| | **Aeration (Continued)** | | |
| Oxidation ponds | Treatment of domestic sewage and organic industrial wastes | No toxic substances | 75–96% reduction in BOD<br>90–99% reduction in suspended solids<br>98–99.9% reduction in bacteria<br>56–93% reduction in LAS |
| | **Deminerlization** | | |
| Ion exchange (natural or synthetic zeolite) | Softening of groundwater supplies for municipal or industrial use | Hardness (Ca and Mg sulfates and bicarbonates) of natural waters $>$850–1,000 mg/L $CaCO_3$<br>Iron $<$1.5–2 mg/L<br>Low in silica $CO_2<15$ mg/L | Increases sodium content by exchange with removed Ca and Mg |
| Ion exchange (greensand or styrene base gels) | Iron or Mn removal from groundwater | Iron less than approximately 2.0 mg/L | 90–100% removal of iron<br>Mn partially removed |
| Ion exchange (organic cation exchangers) | Special water conditioning for industry and commerce | Unspecified | Removes all cations (Na, K, Mg, Fe, Cu, Mn) |
| Ion exchange (anion exchangers) | Special water conditioning for industry and commerce | Unspecified | Removes $SO_4$, Cl, $NO_3$, etc. |
| Ion exchange (fluoride exchangers) | Defluoridation of public water supply | More than 1.5 mg/L F in water supply | Approximately 100% removal possible<br>Normally reduced to $<$1.5 mg/L |
| Electrochemical desalting | Reclaiming water from saline sources, public and industrial supplies<br>Demineralizing municipal waste effluents | Applicable to highly saline or brackish waters | Removes anions and cations |
| Reverse osmosis | Reclamation of water from brackish natural or waste waters (experimental) | Brackish waters, upper limit not specified | Reduces ions depending upon concentration difference across membrane<br>97–98% reduction in TDS, ABS, and COD |
| Distillation | Reclamation of water from saline sources<br>Specialty industrial and commercial supplies | No limit | Produces distilled water (may be contamination with $NH_3$, volatile organics, etc.) |
| Freezing | Reclamation of water from saline sources<br>Specialty industrial and commercial supplies | No limit | (Experimental) |
| | **Disinfection** | | |

*(Continued)*



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**Table 8J.138 (Continued)**

| Type or Process | Common Application | Approximate Limit of Quality Input | Principal Change in Quality Factors (Approximate) |
|---|---|---|---|
| Liquid $Cl_2$ and $Cl_2$ Compounds such as chlorine dioxide and chloramines[a] | Public water supply<br>Industrial water supply | Turbidity low for waters to be sterilized by $Cl_2$<br>Total organic carbon (TOC) concentration $<2$ mg/L to minimize disinfection byproduct (DBP) formation | Reduces bacterial load on filters<br>Oxidizes organic matter<br>Reduces odor<br>Assists in color removal<br>100% (—) reduction in bacteria<br>Controls plankton growth in reservoirs<br>Reduces Mn concentration in breakpoint |
| | | **Disinfection (Continued)** | |
| | Municipal and industrial waste-water treatment and management. | Unspecified | Assists in grease removal<br>Controls filter fly nuisance<br>Cleans air stones in aeration systems<br>Removes $H_2S$<br>Removes $NH_3$ Controls slime formation in sewers and cooling towers<br>Assists in control of digester foaming<br>Disinfects effluent; 98–99% reduction in bacteria |
| Ozone[a] | Public water supply | Bromide concentrations less than 0.1 mg/L to minimize potential for bromate formation | Oxidizes organics<br>Microbial inactivation including coliform, giardia, cryptosporidium, and viruses<br>Reduces odor<br>Removes color |
| Utraviolet Radiation[a] | Small public water supply | Low turbidity | Microbial inactivation including coliform and viruses<br>Some organic oxidation |
| | | **Digestion** | |
| Anaerobic digestion | Stabilization of sewage solids<br>Stabilization of organic industrial wastes | pH above 6.8<br>Acids limited<br>No toxic substances in significant amounts<br>Minimum of grit | Reduces organic sludges to humus and relatively stable chemical compounds<br>Produces offensive supernatant |

[a] USEPA, 1999, Alternative Disinfectants and Oxidants Guidance Manual, EPA 815-R-99-014, April 1999.

*Source*: From McGauhey, Engineeering Management of Water Quality, McGraw-Hill, Copyright 1968. Amended.

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**Table 8J.139 Potential Water Treatment Efficiences**

| | Conventional Processes | | | | | Special Processes | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Activated Carbon Absorption | | | | | | |
| Parameter | Aeration | Chemical Oxidation (Chlorination, etc.) | Coagulation Flocculation | Lime Softening | Filtration | PAC | GAC | Air Stripping | Demineralizing (Reverse Osmosis, etc.) | Ion Exchange | Ozone | Comments |
| Aldrin | P | | P | | | G | VG | | | | VG | |
| Antimony | | | X | | A | | X | | | | | |
| Arsenic | | A | L–G | G–VG | A | P | | | G–VG | VG | | Valencies important |
| Asbestos | | | G–VG | | G | | | | | | | |
| Barium | | | P | G–VG | A | P | P | | VG | VG | | |
| Boron | | | X | | | | G–VG | | X | G–VG | | |
| Cadmium | | | L–G | VG | A | | P–L | | | | | pH important |
| Chlordane | | P | L | L | | VG | VG | | | | | |
| Chloride | | | | | | | | | VG | VG | | |
| Chromium | | | G | G | A | P | P | | X | X | | Valencies important |
| Color | | | VG | | A | | | | | | VG | |
| Copper | A | | F–G | | A | | | | | | | |
| Cyanide | | VG | | | | | | | | | VG | |
| 2,4-D | | P | P | | A | VG | X | | | | | |
| DDT | | P | L–VG | F | | VG | X | | | | P | |
| Diazinon | | | | | | | X(L) | | | | | |
| Dieldrin | | | P–L | | A | | G–VG | L | | | | |
| Endrin | | | L | | | G–VG | VG | | | | | |
| Fluoride | | | | | | | | | G | G–VG | | |
| Heptachlor | | | | | | VG | X(VG) | | | | | |
| Heptachlor Epoxide | | | | | | VG | X | | | | | |
| Iron | A | A | | A | VG | | | | | VG | | |
| Lead | | | G–VG | VG | A | | X | | G–VG | X | | |
| Lindane | | P | P | | P | G | G–VG | | | | | |
| Manganese | | A | L–G | G | A | | | | | VG | | |
| Mercury | | | G | F–G | A | VG | VG | | | | | Form important |
| Methoxychlor | | | G | G–VG | A | VG | VG | | | | | |
| Methyl Parathion | | | | | | X | X | | | | X | |
| Nitrate | | | | | | | | | F | F–VG | | |
| NTA | | P | | | | | | | | | G–VG | |
| Odor | A | VG | | | | VG | VG | | | | VG | |
| Parathion | | P–VG | P | P | A | VG | L–VG | | | | G–VG | |
| Ph | A | | A | A | | | | | | | | |
| Phenol | | G | P | | | G–VG | X | | | | G–VG | |
| Radionuclides | | | | | | | | | | | | |
| $^{226}Ra$ | | | P | G–VG | A | | | | VG | G–VG | | |
| $^{90}Sr$ | | | P | G–VG | A | | | | | G–VG | | |
| $^{137}Cs$ | | | | P | P–F | | | | VG | VG | | |
| $^{131}I$ | | | P | L | | | | | VG | | | |
| Selenium | | | P–G | P–F | A | | | | F–G | X | | Valencies important |
| Silver | | | F–G | G–VG | A | | P | | X | X | | |
| Sulphate | | | | | | | | | G–VG | G–VG | | |
| Sulphide | F–VG | F–VG | | | | | | | | | F–VG | pH important |
| 2,4,5-TP | | P | X(F) | | | X(G) | X(G–VG) | | | | | |

*(Continued)*



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**Table 8J.139 (Continued)**

| | Conventional Processes | | | | | Special Processes | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Activated Carbon Absorption | | | | | | |
| Parameter | Aeration | Chemical Oxidation (Chlorination, etc.) | Coagulation Flocculation | Lime Softening | Filtration | PAC | GAC | Air Stripping | Demineralizing (Reverse Osmosis, etc.) | Ion Exchange | Ozone | Comments |
| T. Dissolved Solids | | | | | | | | | G–VG | G–VG | | |
| Toxaphene | | P | P | | | VG | X(VG) | X | | | | |
| Trihalomethanes | | | | | | | F–G | F–G | | | | Process generated |
| Turbidity | | | G–VG | | A | | | | | | | |
| Uranium | | | L–G | F–G | A | | P | | | VG | | |
| Zinc | | | P | F–G | A | | | | | | | |

*Note:* VG, 90–100% removal; G, 70–90% removal; F, 50–70% removal; L, 25–50% removal; P, 0.25% removal; A, auxiliary process; X, possible candidate process (data lacking); PAC, Powdered activated carbon; GAC, Granular activated carbon. Treatment based on available full-scale, pilot or bench studies and should only be used as potential indicators. Treatabilty studies and/or site experience should be assessed for specific applications.

*Source*: From Canadian Council of Resource and Environment Ministers, March 1987. *Canadian Water Quality Guidelines*. Data provided by McDonald & Associates Consulting Engineers, Regina, Saskatchewan.

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**Table 8J.140 Treatment Technology Removal Effectiveness Reported for Organic Contaminants (Percent)**

| Contaminant | Coagulation/ Filtration | GAC | PCA | PAC | Dilfused Aeration | Oxidation[a] | Reverse Osmosis |
|---|---|---|---|---|---|---|---|
| Acrylamide | 5 | NA | 0–29 | 13 | NA | NA | 0–97 |
| Aidicarb | NA | NA | 0–29 | NA | NA | NA | 94–99 |
| Alactior | 0–49 | 70–100 | 70–100 | 36–100 | NA | 70–100 | 70–100 |
| Benzene | 0–29 | 70–100 | 70–100 | NA | NA | 70–100 | 0–29 |
| Carbofuren | 54–79 | 70–100 | 0–29 | 45–75 | 11–20 | 70–100 | 70–100 |
| Carbon tetrachloride | 0–29 | 70–100 | 70–100 | 0–25 | NA | 0–29 | 70–100 |
| Chlordane | NA | 70–100 | 0–29 | NA | NA | NA | NA |
| Chlorobenzene | 0–29 | 70–100 | 70–100 | NA | NA | 30–69 | 70–100 |
| 2,4-D | 0–29 | 70–100 | 70–100 | 69–100 | NA | W | 0–65 |
| 1,2-Dichloroethane | 0–29 | 70–100 | 70–100 | NA | 42–77 | 0–29 | 15–70 |
| 1,2-Dichloropropane | 0–29 | 70–100 | 70–100 | NA | 12–79 | 0–29 | 10–100 |
| Dibroinochloropropane | 0–29 | 70–100 | 30–69 | NA | NA | 0–29 | NA |
| Dichlorobenzene | NA | 70–100 | NA | NA | NA | NA | NA |
| o-Dichlorobenzene | 0–29 | 70–100 | 70–100 | 38–95 | 14–72 | 30–88 | 30–69 |
| p-Dichlorobenzene | 0–29 | 70–100 | 70–100 | NA | NA | 30–69 | 0–10 |
| 1,1-Dichloroethylene | 0–29 | 70–100 | 70–100 | NA | 97 | 70–100 | NA |
| cis-1,2-Dichloroethylene | 0–29 | 70–100 | 70–100 | NA | 32–85 | 70–100 | 0–30 |
| Trans-1,2-Dichloroelhylene | 0–29 | 70–100 | 70–100 | NA | 37–96 | 70–100 | 0–30 |
| Epichlorohydrin | NA | NA | 0–29 | NA | NA | 0–29 | NA |
| Ethylbenzene | 0–29 | 70–100 | 70–100 | 33–99 | 24–89 | 70–100 | 0–30 |
| Ethylene dibromide | 0–29 | 70–100 | 70–100 | NA | NA | 0–29 | 37–100 |
| Heptachlor | 64 | 70–100 | 70–100 | 53–97 | NA | 70–100 | NA |
| Heptachlor epoxide | NA | NA | NA | NA | NA | 25 | NA |
| High molecular weight | NA | W | NA | NA | NA | NA | NA |
| Hydrocarbons (gasoline, dyes, amines, humics) | | | | | | | |
| Lindane | 0–29 | 70–100 | 0–29 | 82–97 | NA | 0–100 | 50–75 |
| Methoxychlor | NA | 70–100 | NA | NA | NA | NA | >90 |
| Monochlorobenzene | NA | NA | NA | 14–99 | 14–85 | 86–98 | 50–100 |
| Natural organic material | P | P | NA | P | NA | W | P |
| PCBs | NA | 70–100 | 70–100 | NA | NA | NA | 95 |
| Phenol and chlorophenol | NA | W | NA | NA | NA | W | NA |
| Pentachlorophenol | NA | 70–100 | 0 | NA | NA | 70–100 | NA |
| Styrene | 0–29 | NA | NA | NA | NA | 70–100 | NA |
| Tetrachloroethylene | NA | 70–100 | NA | NA | 73–95 | W | 70–90 |
| Trichloroethane | 0–29 | 70–100 | 70–100 | NA | 53–95 | 30–69 | 0–100 |
| Trichlorethane | NA | 70–100 | NA | NA | NA | NA | NA |
| 1,1,1-Trichloroethane | 0–29 | 70–100 | 70–100 | 40–65 | 58–90 | 0–29 | 15–100 |
| Toluene | 0–29 | 70–100 | 70–100 | 0–67 | 22–89 | 70–100 | NA |
| 2,4,5-TP | 63 | 70–100 | NA | 82–99 | NA | 30–69 | NA |
| Toxaphene | 0–29 | 70–100 | 70–100 | 40–99 | NA | NA | NA |
| Vinyl chloride | 0–29 | 70–100 | 70–100 | NA | NA | 70–100 | NA |
| Xylenes | 0–29 | 70–100 | 70–100 | 60–99 | 18–89 | 70–100 | 10–85 |

*Note:* W, well removed; P, poorly removed; NA, not available. Little or no specific performance data were available for: 1. Multiple Tray Aeration; 2. Catenary Aeration; 3. Higee Aeration; 4. Resins; 5. Ultrafiltration; 6. Mechanical Aeration.

[a] The specifics of the oxidation processes effective in removing each contaminant are provided in Chapter 8 of the USEPA report.

*Source*: From United States Environmental Protection Agency, 1990, *Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities*, EPA/625/4-89/023, March 1990, http://nepis.epa.gov.

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**Table 8J.141 Removal Effectiveness for Inorganic Contaminant**

| | Contaminant | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | **Ag** | **As** | **$As^{III}$** | **$AS^{V}$** | **Ba** | **Cd** | **Cr** | **$Cr^{III}$** | **$Cr^{VI}$** | **F** | **Hg** | **Hg(0)** | **$Hg^{III}$** | **$NO_3$** | **Pb** | **Ra** | **Rn** | **Se** | **$Se^{(V)}$** | **$Se^{(II)}$** | **U** |
| Conventional treatment | H | — | M | H | L | H | — | H | H | L | — | M | M | L | H | L | — | — | M | L | M |
| Coagulation-aluminum | H | — | — | H | — | M | — | H | — | — | M | — | — | — | H | — | — | — | — | — | — |
| Coagulation-Iron | M | — | — | H | — | — | — | H | H | — | — | — | — | — | — | — | — | — | — | — | — |
| Lime softening | — | — | M | H | H | H | — | H | L | M | — | L | M | L | H | H | — | — | M | L | H |
| Reverse osmosis and electrodialysis | H | — | M | H | H | H | H | — | — | H | H | — | — | M | H | H | — | H | — | — | H |
| Cation exchange | — | L | — | — | H | H | — | H | L | L | — | — | — | L | H | H | — | L | — | — | H |
| Anion exchange | — | — | — | — | M | M | — | M | H | — | — | — | — | H | M | M | — | H | — | — | H |
| Activated alumina | — | — | H | — | L | L | — | — | — | H | — | — | — | — | — | L | — | H | — | — | — |
| Powdered activated carbon | L | — | — | — | L | M | — | L | — | L | — | M | M | L | — | L | — | — | — | — | — |
| Granular activated carbon | — | — | — | — | L | M | — | L | — | L | — | H | H | L | — | L | H | — | — | — | — |

*Note:* H, High $\geq$ 80% removal; M, Medium 20–80% removal; L, Low $\leq$ 20% removal; "—", indicate no data were provided.

*Source*: From United States Environmental Protection Agency, 1990, *Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities*, EPA/625/4-89/023, March 1990, http://nepis.epa.gov.

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**Table 8J.142 Arsenic Treatment Technologies Summary Comparison**

| Factors | Sorption Processes: Ion Exchange IX | Sorption Processes: Activated Alumina[a] AA | Sorption Processes: Iron Based Sorbents IBS | Membrane Processes: Reverse Osmosis RO |
|---|---|---|---|---|
| USEPA BAT[b] | Yes | Yes | No[c] | Yes |
| USEPA SSCT[b] | Yes | Yes | No[c] | Yes |
| System Size[b,d] | 25–10,000 | 25–10,000 | 25–10,000 | 501–10,000 |
| SSCT for POU[b] | No | Yes | No[c] | Yes |
| POU System Size[b,d] | — | 25–10,000 | 25–10,000 | 25–10,000 |
| Removal Efficiency | 95%[e] | 95%[e] | up to 98%[e] | >95%[e] |
| Total Water Loss | 1–2% | 1–2% | 1–2% | 15–75% |
| Pre-Oxidation Required[f] | Yes | Yes | Yes[g] | Likely[h] |
| Optimal Water Quality Conditions | pH 6.5–9 [e]<br><5 mg/L $NO_3^-$ [i]<br><50 mg/L $SO_4^{2}$ [j]<br><500 mg/L TDS [k]<br><0.3 NTU Turbidity | pH 5.5–6 [i]<br>pH 6–8.3 [l]<br><250 mg/L $Cl^-$ [i]<br><2 mg/L $F^-$ [i]<br><360 mg/L $SO_4^{2-}$ [k]<br><30 mg/L Silica[m]<br><0.5 mg/L $Fe^{+3}$ [j]<br><0.05 mg/L $Mn^{+2}$ [l]<br><1,000 mg/L TDS[k]<br><4 mg/L TOC[k]<br><0.3 NTU Turbidity | pH 6–8.5<br><1 mg/L $PO_4^{-3}$ [n]<br><0.3 NTU Turbidity | No Particulates |
| Operator Skill Required | High | Low[a] | Low | Medium |
| Waste Generated | Spent Resin, Spent Brine, Backwash Water | Spent Media, Backwash Water | Spent Media, Backwash Water | Reject Water |
| Other Considerations | Possible pre & post pH adjustment.<br>Pre-filtration required<br>Potentially hazardous brine waste,<br>Nitrate peaking<br>Carbonate peaking affects pH | Possible pre & post pH adjustment<br>Pre-filtration may be required<br>Modified AA available | Media may be very expensive[o]<br>Pre-filtration may be required | High water loss (15–75% of feed water) |
| Centralized Cost | Medium | Medium | Medium | High |
| POU Cost | — | Medium | Medium | Medium |

| Factors | Precipitative Processes: Enhanced Lime Softening LS | Precipitative Processes: Enhanced (Conventional) Coagulation Filtration CF | Precipitative Processes: Coagulation Assisted Micro-Filtration CMF | Precipitative Processes: Coagulation-Assisted Direct Filtration CADF | Precipitative Processes: Oxidation Filtration OxFilt |
|---|---|---|---|---|---|
| USEPA BAT[b] | Yes | Yes | No | Yes | Yes |
| USEPA SSCT[b] | No | No | Yes | Yes | Yes |
| System Size[b,d] | 25–10,000 | 25–10,000 | 500–10,000 | 500–10,000 | 25–10,000 |
| SSCT for POU[b] | No | No | No | No | No |
| POU System Size[b,d] | — | — | — | — | — |
| Removal Efficiency | 90% [p] | 95% (w/$FeCl_3$)[p]<br><90%(w/Alum)[p] | 90% [p] | 90%[p] | 50–90%[p] |
| Total Water Loss | 0% | 0% | 5% | 1–2% | 1–2% |
| Pre-Oxidation Required[f] | Yes | Yes | Yes | Yes | Yes |
| Optimal Water Quality Conditions | pH 10.5–11 [i]<br>>5 mg/L $Fe^{+3}$ [i] | pH 5.5–8.5 [q] | pH 5.5–8.5 [q] | pH 5.5–8.5 [q] | pH 5.5–8.5<br><0.3 mg/L Fe<br>Fe:As Ratio >20:1 |
| Operator Skill Required | High | High | High | High | Medium |

*(Continued)*

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**Table 8J.142 (Continued)**

| | Precipitative Processes | | | | |
|---|---|---|---|---|---|
| **Factors** | **Enhanced Lime Softening LS** | **Enhanced (Conventional) Coagulation Filtration CF** | **Coagulation Assisted Micro-Filtration CMF** | **Coagulation-Assisted Direct Filtration CADF** | **Oxidation Filtration OxFilt** |
| Waste Generated | Backwash Water, Sludge (high volume) | Backwash Water, Sludge | Backwash Water, Sludge | Backwash Water, Sludge | Backwash Water, Sludge |
| Other Considerations | Treated water requires pH adjustment | Possible pre & post pH adjustment | Possible pre & post pH adjustment | Possible pre & post pH adjustment | None |
| Centralized Cost | Low[r] | Low[r] | High | Medium | Medium |
| POU Cost | N/A | N/A | N/A | N/A | N/A |

[a] Activated alumina is assumed to operate in a nonregenerated mode.
[b] USEPA 2002a.
[c] IBS's track record in U.S. was not established enough to be considered as Best Available Technology (BAT) or Small System Compliance Technology (SSCT) at the time the rule was promulgated.
[d] Affordable for systems with the given number of people served.
[e] USEPA, 2000.
[f] Pre-oxidation only required for As(III).
[g] Some iron based sorbents may catalyze the As(III) to As(V) oxidation and therefore would not require a pre-oxidation step.
[h] RO will remove As(III), but its efficiency is not consistent and pre-oxidation will increase removal efficiency.
[i] AwwaRF, 2002.
[j] Kempic, 2002.
[k] Wang, 2000.
[l] AA can be used economically at higher pHs, but with a significant decrease in the capacity of the media.
[m] Clifford, 2001.
[n] Tumalo, 2002.
[o] With increased domestic use, IBS cost will significantly decrease.
[p] Depends on arsenic and iron concentrations.
[q] Fields, et al., 2002a.
[r] Cost for enhanced LS and enhanced CF are based on modification of an existing technology. Most small systems will not have this technology in place.

*Source*: From United States Environmental Protection Agency, 2003, *Arsenic Treatment Technology Evaluation Handbook for Small Systems*, EPA-816-R-03-014, July 2003, www.epa.gov.

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**Table 8J.143 Treatment Utilized by Major Water Utilites in the United States in 1996**

| Utility Name | Water Source (Percent) | | | Softening | | | Predisinfection/ Oxidation | | | | | | Softening | | Rapid Mix | | | | Flocculation/ Coagulation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Groundwater | Surface Water | Purchased Water | Lime/Soda Ash Softening | Lime/Soda Ash Softening | Aeration (conventional use) | Chlorine | Chlorine Dioxide | Chloramines | Ozone | Potassium Permanganate | UV Radiation | Lime/Soda Ash Softening | Recarbonation with $CO_2$ | In-Line Hydraulic | In-Line Mechanical | In-Line Static | Basin Mechanical | Aluminum Salts | Iron Salts | pH Adjustment | Alkalinity Adjustment | Activated Silica | Clays |
| **ALASKA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Anchorage Water/WW Util | 22 | 78 | 0 | | y | | | | | | | | | | y | | | | y | y | y | y | | |
| **ALABAMA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Mobile Area Water & Sewer Service System | 0 | 100 | 0 | | y | | | y | | | | | | | | y | y | | y | | y | y | | |
| **ARIZONA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Glendale, (City of) | 28 | 72 | 0 | | y | | y | y | | | y | | | | | | y | y | y | | | | | |
| Phoenix, (City of) | 7 | 94 | 0 | | y | | y | | | | | | | | | y | | | y | y | y | | | |
| Scottsdale, (City of) | 40 | 41 | 19 | | y | y | y | | | | y | | | | | y | | y | y | | | | | |
| Tempe, (City of) Water Mngmt Div | 0 | 100 | 0 | | y | | y | | | | | | | | | y | | y | y | | | | | |
| Tucson Water | 100 | 0 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| **CALIFORNIA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Anaheim, (City of) | 75 | 0 | 25 | | y | | y | | | y | | | | | | | | y | y | | | | | |
| Coachella Valley Water Dist | 100 | 0 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| Contra Costa Water Dist | 0 | 100 | 0 | | y | | | | | y | y | | | | y | | | | y | | | | | |
| Corona, (City of) Util Svcs | 42 | 58 | 0 | | | | y | | | | | | | | | y | y | | y | | | | | |
| Corte Madera/Marin Muni Water Dist | 0 | 81 | 19 | | | | y | | | | | | | | y | | | y | y | | | | | |
| Cucamonga County Water Dist | 51 | 18 | 31 | | y | | y | | | | | | | | y | y | y | y | y | | y | | | |
| Downey/Park Water Co | 10 | 0 | 90 | | | | | | | | | | | | | | | | | | | | | |
| El Monte/San Gabriel Valley Water Co | 100 | 0 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| Fremont/Alameda County Water Dist | 26 | 51 | 24 | | | | y | | | y | y | | | | y | | | y | y | y | | | | |
| Fresno, (City of) | 100 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | |
| Fullerton, (City of) | 75 | 25 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| Glendale Public Service Dept | 6 | 0 | 94 | | | | | | | | | | | | | | | | | | | | | |
| Granite Bay/San Juan Suburban Water Dist | 0 | 100 | 0 | | | | y | | | | | | y | | | y | | y | y | | | | | |
| Irvine Ranch Water Dist | 53 | 0 | 47 | | | | y | | | | | | | | | | | | | | | | | |
| La Mesa/Helix Water Dist | 0 | 28 | 72 | | | | y | | | | | | | | | y | | | y | | y | | | |
| Long Beach/Dominguez Services Inc | 100 | 0 | 0 | | | y | y | | y | | | | | | | | | | | | | | | |
| Long Beach Water Dept | 46 | 0 | 54 | | y | y | y | | | | y | | | | | | | y | y | | | | | |
| Los Angeles Water & Power | 17 | 44 | 39 | | y | | | | | y | | | | | | | | y | | y | | | | |
| Los Angeles/Metro Water Dist of So Calif | 0 | 100 | 0 | | | | y | | | | | | | | y | y | | | y | | | | | |
| Modesto Public Works | 49 | 51 | 0 | | | | | | | y | | | | y | | | | y | y | | | | | |
| Monterey Division—CA-American Water Co | 48 | 9 | 43 | | | | y | | | y | y | | | | y | | | | | y | y | y | | |
| Oakland/East Bay Muni Util Dist | 0 | 100 | 0 | | | y | y | | | y | y | | y | | y | | | y | y | | | | | |
| Riverside Water Div | 100 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | |
| Sacramento/Citizens Util Co of California | 100 | 0 | 0 | | y | | y | | | | y | | | | | | | | | | | | | |
| Sacramento, (City of) Util Dept | 20 | 80 | 0 | | | | y | | | | | | | | y | | | | y | | | | | |
| San Bernardino Water Dept | 100 | 0 | 0 | | y | y | y | | | | | | | | | | | | | | | | | |
| San Diego, (City of) | 0 | 100 | 0 | | y | | y | | | | y | | | | | y | | | | y | y | | | |
| San Francisco Water Dept | 0 | 100 | 0 | | | y | y | | | y | | | | | y | | | | y | | | | | |
| San Jacinto/Eastern Muni Water Dist | 18 | 0 | 82 | | | y | | | | | | | | | | | | | | | | | | |
| San Jose Water Co | 45 | 11 | 45 | | | | | | | | | | | | | | | y | y | | | | | |
| San Jose/Santa Clara Valley Water Dist | 0 | 100 | 0 | | y | | y | | y | | | | | | | y | y | y | y | | | | | |
| Santa Barbara, (City of) | 0 | 100 | 0 | | | y | y | | | | | | | | | y | | | y | | | | | |
| Santa Clarita/Castaic Lake Water Agency | 0 | 100 | 0 | | | | y | | | y | | | | | y | | | y | y | y | | | | |
| Stockton East Water Dist | 0 | 100 | 0 | | | | y | | | | y | | | | y | | | | y | | | | | |
| Sunnyvale, (City of) Public Works | 9 | 0 | 91 | y | | | | | | | | | | | | | | | | | | | | |
| Thousand Oaks/Calleguas Muni Water Dist | 0 | 0 | 100 | | y | | y | | | y | | | | | | y | | | y | | | | | |
| Torrance Muni Water Dept | 5 | 0 | 95 | | y | y | y | | | | | | | | | | | | | | | | | |
| Vacaville/Suisun Solano Water Auth | 5 | 95 | 0 | | | | y | | | | | | | | | | | | y | | | | | |
| Vallejo, (City of) | 0 | 100 | 0 | | y | | y | | | y | | | | | y | y | y | y | y | | y | y | | |
| Vista Irrigation Dist | 0 | 61 | 39 | | | | | | | | | | | | | | | | | | | | | |
| **COLORADO** | | | | | | | | | | | | | | | | | | | | | | | | |
| Arvada, (City of) | 0 | 100 | 0 | | y | | y | | | | y | | | y | | y | | y | y | | y | y | | |
| Colorado Springs Util | 1 | 99 | 0 | | y | y | y | | | | | | | | | y | y | y | y | | | | | |
| Denver Water Dept | 0 | 100 | 0 | | y | | y | | y | | | | | | | | | y | y | | y | | | |
| Fort Collins Water Util | 0 | 100 | 0 | | y | | y | | | | y | | | | | | | y | y | | | | | |
| Pueblo Board of Waterworks | 0 | 100 | 0 | | | | y | | y | | y | | | | | | | y | y | | | | | |
| **CONNECTICUT** | | | | | | | | | | | | | | | | | | | | | | | | |
| Bridgeport Hydraulic Co - Main System | 13 | 87 | 0 | | | y | y | | | | | | | | | | | y | y | | y | | | |
| Hartford Metropolitan Dist | 0 | 100 | 0 | | | y | | | | | | | | | | y | | | y | | | | | |
| New Haven/Regional Water Auth | 13 | 88 | 0 | | | | y | | | | y | | | | | | y | y | | y | y | | | |
| **WASHINGTON DC** | | | | | | | | | | | | | | | | | | | | | | | | |
| Washington Aqueduct | 0 | 100 | 0 | | y | | | | | | | | | | y | | | | y | | | | | |

*(Continued)*

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**Table 8J.143 (Continued)**

| Utility Name | Water Source (Percent) | | | Lime/Soda Ash Softening | Lime/Soda Ash Softening | Aeration (conventional use) | Predisinfection/ Oxidation | | | | | | Lime/Soda Ash Softening | Recarbonation with $CO_2$ | Rapid Mix | | | | Flocculation/ Coagulation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Groundwater | Surface Water | Purchased Water | | | | Chlorine | Chlorine Dioxide | Chloramines | Ozone | Potassium Permanganate | UV Radiation | | | In-Line Hydraulic | In-Line Mechanical | In-Line Static | Basin Mechanical | Aluminum Salts | Iron Salts | pH Adjustment | Alkalinity Adjustment | Activated Silica | Clays |
| **DELAWARE** | | | | | | | | | | | | | | | | | | | | | | | | |
| Newark/Artesian Water Company Inc | 72 | 0 | 28 | | | y | y | | | | y | | | | | | y | | | | y | | | |
| Wilmington/United Water Delaware | 0 | 96 | 4 | | y | | y | | | | y | | | | y | | | y | | y | y | | | |
| **FLORIDA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Clearwater Water Div | 26 | 0 | 74 | | | y | y | | | | | | | | | | | | | | | | | |
| Cocoa, (City of) Util Dept | 100 | 0 | 0 | | y | y | y | | y | | | | y | y | | | | | | | | | | |
| Coral Gables/Miami-Dade Water & Sewer Dept | 100 | 0 | 0 | | | | | | | | | | y | y | | | | y | | | y | y | y | |
| Jacksonville, (City of) Water Div | 100 | 0 | 0 | | y | y | | | | | | | | | | | | | | | | | | |
| Jacksonville/United Water Florida | 97 | 0 | 3 | | | y | y | | | | | | | | | | | | | | | | | |
| Kissimmee, (City of) | 100 | 0 | 0 | | y | y | | | | | | | | | | | | | | | | | | |
| Lakeland Electric & Water Util | 100 | 0 | 0 | | | | y | | | | | | y | | | | | | | | | | | |
| Orlando/Orange County Util | 100 | 0 | 0 | | | y | y | | | | | | | | | | | | | | | | | |
| Orlando Util Comm | 100 | 0 | 0 | | | y | y | | | | | | | | | | | | | | | | | |
| Pensacola/Escambia County Util Auth | 100 | 0 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| Pompano Beach/Broward County Enviro Services | 88 | 0 | 12 | | | | y | | y | | | | y | | | y | | | | y | | | | |
| Sarasota County Util | 39 | 0 | 61 | | | y | y | | | | | | | | | | | | | | | | | |
| Tallahassee Water Util | 100 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | |
| Tampa Water Dept | 5 | 95 | 0 | | | | y | | | | y | | y | y | | | | y | | y | y | y | | |
| W Coast Regional Water Supply | 100 | 0 | 0 | | y | y | y | | | | | | | | | | | | | | | | | |
| West Palm Beach/Palm Beach County Water Util | 100 | 0 | 0 | | | y | | | y | y | | | | y | | | | y | | | y | y | | |
| **GEORGIA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Atlanta-Fulton County Water | 0 | 100 | 0 | | y | y | y | | | | y | | | | | y | | | y | | | y | | |
| Cobb County-Marietta Wtr Auth | 0 | 100 | 0 | | | | y | y | | | | | | | | y | | | y | | | | | |
| Columbus Water Works | 0 | 100 | 0 | | | | | y | | | | | | | | y | | | y | | | | | |
| Morrow/Clayton County Water Auth | 0 | 100 | 0 | | y | | y | | | | y | | | | | y | | y | y | | y | y | | |
| Stone Mountain/DeKalb County Public Works | 0 | 100 | 0 | | | | y | | | | y | | | | y | | | y | y | | | | | |
| **HAWAII** | | | | | | | | | | | | | | | | | | | | | | | | |
| Honolulu/Board of Water Supply | 100 | 0 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| Pearl Harbor/Navy Public Wrks Util Dept | 99 | 0 | 1 | | | | | | | | | | | | | | | | | | | | | |
| **IOWA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Cedar Rapids Water Dept | 100 | 0 | 0 | | | y | | | | | | | y | y | | | | y | | | | | | |
| Des Moines Water Works | 59 | 41 | 0 | | y | | | | | | y | | y | y | | | | y | y | y | | | | |
| **ILLINOIS** | | | | | | | | | | | | | | | | | | | | | | | | |
| Champaign Division - Northern Illinois Water Inc | 100 | 0 | 0 | | | | | | | | | | y | y | | | | y | | y | | | | |
| Chicago, (City of) Dept of Water | 0 | 100 | 0 | | | | y | | | | | | | | | y | | y | y | | | | | |
| Decatur, (City of) | 0 | 100 | 0 | | | | | | | | y | | y | y | y | | | | y | | | | | |
| Elmhurst/DuPage Water Comm | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | | | |
| Evanston Water Dept | 0 | 100 | 0 | | | | y | | | | | | | | | y | | | y | | | | | |
| Interurban District - IL-American Water Co. | 0 | 100 | 0 | | | | y | | | | y | | | | | | y | | y | | | | | |
| Lake Bluff/Central Lake Cnty Water Agency | 0 | 100 | 0 | | | | | | | y | y | | | | | | | y | y | | | | | |
| Peoria District - IL-American Water Co. | 69 | 31 | 0 | | | | y | | | | y | | | | | | | | y | | | | | |
| Rockford City Water Div | 100 | 0 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| Springfield/City Water, Light and Power | 0 | 100 | 0 | | | | | | | | | | y | y | y | | | | | y | | | | |
| Wilmette Water Plant | 0 | 100 | 0 | | | | y | | | | | | | | | | | y | y | | | | | |
| **INDIANA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Evansville Water & Sewer Dept | 0 | 100 | 0 | | | | | y | | | | | | | | | y | | y | | | | | |
| Gary/Northwest Indiana Water Co. | 0 | 100 | 0 | | | | y | | | | y | | | | | | | y | y | | | | | |
| Indianapolis Water Co. | 6 | 94 | 0 | | | y | y | | | | | | | | | y | y | | y | | y | y | | |
| **KANSAS** | | | | | | | | | | | | | | | | | | | | | | | | |
| Kansas City Public Util Board | 0 | 100 | 0 | | y | | y | y | | | | | | | y | y | | | y | | y | | y | |
| **KENTUCKY** | | | | | | | | | | | | | | | | | | | | | | | | |
| Covington/Kenton County Water Dist No.1 | 0 | 100 | 0 | | y | | y | | | | y | | | | | | | y | | y | y | | | |
| Lexington/KY-American Water Co. | 0 | 100 | 0 | | | y | y | | | | y | | | | | | | y | y | y | y | y | | |
| Louisville Water Company | 0 | 100 | 0 | | y | | y | | | | | | | | y | y | y | y | | y | | | | |
| **LOUISIANA** | | | | | | | | | | | | | | | | | | | | | | | | |
| The Baton Rouge Water Co. | 100 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | |
| Harahan/Jefferson Parish Water Dept | 0 | 100 | 0 | | | | | | | | | | | | | y | y | | | | | | | |
| Lake Charles, (City of) Water Div | 100 | 0 | 0 | | | y | y | | | | y | | | | | | | | | | | | | |
| New Orleans Water/Sewer Board | 0 | 100 | 0 | | | | | | y | | | | y | | | | | y | | y | y | | | |
| **MASSACHUSETTS** | | | | | | | | | | | | | | | | | | | | | | | | |
| Fall River Water Dept | 0 | 100 | 0 | | | | y | | | | | | | | | | | y | y | | y | | | |
| Lowell Water Dept | 0 | 100 | 0 | | | | y | | | | | | | | | | y | | y | | y | y | | |
| New Bedford, (City of) Water Dept | 0 | 100 | 0 | | | | | | | | | | | | | y | | | y | | | | | |
| Springfield Water Dept | 0 | 100 | 0 | | y | | | | | | | | | | | | | y | | | | | | |

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**Table 8J.143 (Continued)**

| Utility Name | Water Source (Percent) | | | Lime/Soda Ash Softening | Lime/Soda Ash Softening | Aeration (conventional use) | Predisinfection/ Oxidation | | | | | | Rapid Mix | | | | Flocculation/ Coagulation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Groundwater | Surface Water | Purchased Water | | | | Chlorine | Chlorine Dioxide | Chloramines | Ozone | Potassium Permanganate | UV Radiation | Lime/Soda Ash Softening | Recarbonation with $CO_2$ | In-Line Hydraulic | In-Line Mechanical | In-Line Static | Basin Mechanical | Aluminum Salts | Iron Salts | pH Adjustment | Alkalinity Adjustment | Activated Silica | Clays |
| **MARYLAND** | | | | | | | | | | | | | | | | | | | | | | | | |
| Annapolis/Anne Arundel County DPW | 78 | 0 | 22 | | | y | y | | | | | | y | | | | y | y | | | y | | | |
| Laurel/Washington Suburban Sanit Comm | 0 | 100 | 0 | | | | y | | | | y | | | | | | y | | y | y | y | | | |
| **MAINE** | | | | | | | | | | | | | | | | | | | | | | | | |
| Portland Water District | 4 | 96 | 0 | | | | | | | y | | | | | | | | | | | | | | |
| **MICHIGAN** | | | | | | | | | | | | | | | | | | | | | | | | |
| Ann Arbor Util Dept | 0 | 100 | 0 | | y | | | | | | | | y | y | | y | | | | | | | | |
| Grand Rapids, (City of) | 0 | 100 | 0 | | | | y | | | | y | | | | | | | y | y | y | | | | |
| Holland/Wyoming Util Dept | 0 | 100 | 0 | | | | y | | | | y | | | | | y | | | y | | | | | |
| Kalamazoo Dept Public Util | 100 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | |
| **MINNESOTA** | | | | | | | | | | | | | | | | | | | | | | | | |
| St. Paul Water Util | 0 | 100 | 0 | | | | y | | y | | y | | y | y | y | | | | y | y | y | | | |
| **MISSOURI** | | | | | | | | | | | | | | | | | | | | | | | | |
| Independence Water Dept | 100 | 0 | 0 | | | y | y | | | | | | | | | | | | | | y | y | | |
| Kansas City Water Svcs Dept | 10 | 90 | 0 | | y | y | | | | | y | | y | y | y | | | | y | y | y | y | | |
| Springfield City Util | 24 | 76 | 0 | | y | | y | | | | y | | | | | y | | | y | y | | | | |
| St. Louis County Water Co | 0 | 100 | 0 | | y | | y | | y | | | | y | | | y | | | | y | | | | |
| **NORTH CAROLINA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Asheville, (City of) | 0 | 100 | 0 | | | | y | | | | | | | | y | | | | | | | | | |
| Charlotte-Mecklenburg Util | 0 | 100 | 0 | | y | | y | | | | | | | | | | y | | y | | | | | |
| Durham, (City of) Dept Water Res | 0 | 100 | 0 | | y | y | y | | | | y | | | | | | | y | y | | y | y | | |
| Fayetteville Public Works Comm | 0 | 100 | 0 | | | | | | | | | | | | | y | | y | y | | y | y | | |
| Greensboro, (City of) Util Dept | 0 | 100 | 0 | | y | | | | | | y | | | | | | | y | y | | | | | |
| **NEBRASKA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Lincoln Water System | 100 | 0 | 0 | | | y | y | | | y | | | | | | | | | | | | | | |
| Omaha Metro Util Dist | 47 | 53 | 0 | | y | | y | | | | | | y | | | | | y | y | | y | | | |
| **NEW HAMPSHIRE** | | | | | | | | | | | | | | | | | | | | | | | | |
| Manchester Water Works | 0 | 100 | 0 | | | | y | | | | | | | | | y | | | y | | y | | | |
| **NEW JERSEY** | | | | | | | | | | | | | | | | | | | | | | | | |
| Brick Township Muni Util Auth | 35 | 65 | 0 | | | y | | y | | | | | y | | | | | y | y | | y | | | |
| Clifton/Passaic Valley Water Comm | 0 | 54 | 46 | | | | y | y | | | | | | | y | | | | y | | y | | | |
| Haddon System - NJ-American Water Co. | 93 | 0 | 7 | | y | y | y | | | y | | | | | | | y | y | | y | y | y | | |
| Harrington Park/United Water New Jersey | 1 | 97 | 2 | | | | | | | y | | | | | y | | | | y | | | | | |
| Iselin/Middlesex Water Company | 28 | 65 | 6 | | | | y | | | | | | | | | | | | y | | y | | | |
| Little Falls/Newark Div of Water/Sewer Util | 0 | 100 | 0 | | | y | y | | | | | | | | | | | | y | | | | | |
| Short Hills System - NJ-American Water Co. | 15 | 30 | 54 | | y | | y | | | | | | | | | | | | y | | | | | |
| Shrewsbury/NJ-American Water Co.- Monmouth System | 0 | 80 | 20 | | y | y | y | y | | | | | | | y | | | y | y | | | | | |
| Westfield/Elizabethtown Water Co. | 11 | 88 | 0 | | | | y | | | | y | | | | y | y | | | y | | y | y | | |
| **NEW MEXICO** | | | | | | | | | | | | | | | | | | | | | | | | |
| Albuquerque Public Works Dept | 100 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | |
| **NEVADA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Boulder City/Southern Nevada Water System | 0 | 100 | 0 | | | y | y | | | | | | | | | y | | | | y | | | | |
| Las Vegas Valley Wtr Dist | 16 | 84 | 0 | | | | | | | | | | | | | | | | | | | | | |
| North Las Vegas, (City of) | 9 | 0 | 91 | | | | y | | | | | | | | | | | | | | | | | |
| **NEW YORK** | | | | | | | | | | | | | | | | | | | | | | | | |
| Buffalo/Erie County Water Auth | 0 | 100 | 0 | | | | y | | | | y | | | | | y | | y | y | | | | | |
| Lynbrook/Long Island Water Inc | 100 | 0 | 0 | | | y | y | | | | | | | | | | | | | | | | | |
| Oakdale/Suffolk County Water Auth | 100 | 0 | 0 | | | | y | | | | y | | | | | | | | | | | | | |
| Rochester, (City of) Water Bureau | 0 | 86 | 14 | | | | y | | | | y | | | | | | | y | y | y | | | | |
| Syracuse/Onondaga County Water Auth | 0 | 40 | 60 | | | | y | | | | y | | | | | | y | | y | | | | | |
| Syracuse Dept of Water | 0 | 98 | 2 | | | | y | | | | | | | | | | | | | | | | | |
| West Nyack/United Water New York | 77 | 23 | 0 | | | y | | | | | y | | | | y | | | | y | | | | | |
| **OHIO** | | | | | | | | | | | | | | | | | | | | | | | | |
| Akron Public Util Bureau | 0 | 100 | 0 | | | | y | y | | | | | | | | | | y | y | | | | | |
| Cincinnati Water Works | 12 | 88 | 0 | | y | | y | | | | y | | y | | y | | y | y | y | | | | | |
| Cleveland Div of Water | 0 | 100 | 0 | | y | y | y | | | | y | | | | y | y | | y | y | | | | | |
| Columbus Water Div | 16 | 84 | 0 | | | | y | | | | y | | y | y | | y | | | y | | y | y | | |
| Dayton Water Supply/Treatment | 100 | 0 | 0 | | | | | | | | | | y | y | | y | | y | | | y | y | | |
| Fairfield/Hamilton Util | 100 | 0 | 0 | | | y | | y | | | | | y | y | | y | | | | | | | | |
| Toledo, (City of) Water Div | 0 | 100 | 0 | | | | | | | | | | y | y | y | | | | y | | | | | |
| **OKLAHOMA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Lawton Water/Wastewater Plants | 0 | 100 | 0 | | | y | y | | y | | | | | | y | | | | y | | y | y | | y |
| Oklahoma City, (City of) | 0 | 100 | 0 | | y | | y | | y | y | y | | y | y | | y | | y | | y | y | y | | |
| Tulsa Public Works Dept | 0 | 100 | 0 | | y | | y | | | | y | | y | | | y | | | y | | y | | | |
| **OREGON** | | | | | | | | | | | | | | | | | | | | | | | | |
| Eugene Water & Electric Board | 0 | 100 | 0 | | | | y | | | | | | | | | | y | | y | | y | | | |
| Portland Water Bureau | 4 | 96 | 0 | | | | | | | | | | | | | | | | | | | | | |

*(Continued)*

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**Table 8J.143 (Continued)**

| Utility Name | Water Source (Percent) | | | Predisinfection/ Oxidation | | | | | | | | | Rapid Mix | | | | Flocculation/ Coagulation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Groundwater | Surface Water | Purchased Water | Lime/Soda Ash Softening | Lime/Soda Ash Softening | Aeration (conventional use) | Chlorine | Chlorine Dioxide | Chloramines | Ozone | Potassium Permanganate | UV Radiation | Lime/Soda Ash Softening | Recarbonation with $CO_2$ | In-Line Hydraulic | In-Line Mechanical | In-Line Static | Basin Mechanical | Aluminum Salts | Iron Salts | pH Adjustment | Alkalinity Adjustment | Activated Silica | Clays |
| **PENNSYLVANIA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Allentown Muni Water System | 50 | 50 | 0 | | y | | y | | | | | | | | | | | y | y | | | | | |
| Bethlehem, (City of) | 0 | 100 | 0 | | y | | y | | | | | | | | | | y | | y | | y | | | |
| Bryn Mawr/Philadelphia Suburban Water Co. | 14 | 80 | 6 | | | | y | y | | | y | | | | | y | | | y | | y | | | |
| Harrisburg/United Water PA | 11 | 88 | 1 | | | | y | y | | | y | | | | | | | | y | | | | | |
| Lancaster, (City of) Water Bureau | 0 | 100 | 0 | | | | y | | | | y | | y | | | | | y | y | | y | | | |
| Philadelphia Water Dept | 0 | 100 | 0 | | y | | y | y | | | y | | | | | | | | y | y | y | | | |
| Pittsburgh/West View Water Auth | 0 | 100 | 0 | | | | y | | | | y | | | | | y | | | | y | y | y | | |
| Reading Area Water Auth | 0 | 100 | 0 | | | | y | | | | y | | y | | y | | | | y | | | | | |
| The York Water Co. | 0 | 100 | 0 | | y | | y | | | | y | | | | | | | y | y | | | | | |
| **RHODE ISLAND** | | | | | | | | | | | | | | | | | | | | | | | | |
| Pawtucket Water Supply Board | 15 | 85 | 0 | | y | y | y | | | | | | | | | y | | | y | | y | | | |
| **SOUTH CAROLINA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Charleston Comm Public Works | 0 | 100 | 0 | | | | | | y | | | | | | | | | y | y | | y | | | |
| Spartanburg Water System | 0 | 100 | 0 | | | | y | | | | | | | | y | | | | y | | y | | | |
| **SOUTH DAKOTA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Sioux Falls, (City of) | 0 | 100 | 0 | | | | | | | | y | | y | y | | | y | y | | y | | | | |
| **TENNESSEE** | | | | | | | | | | | | | | | | | | | | | | | | |
| Chattanooga/TN-American Water Co | 0 | 100 | 0 | | | | y | | | | | | | | | | y | | y | | | | | |
| Memphis Light Gas & Water | 100 | 0 | 0 | | | y | y | | | | | | | | | | | | y | | | | | |
| Nashville/Metro Water Services | 0 | 100 | 0 | | y | y | y | | | | y | | | | y | | | | y | | y | | | |
| **TEXAS** | | | | | | | | | | | | | | | | | | | | | | | | |
| Abilene, (City of) | 0 | 100 | 0 | | y | y | | y | y | | | | y | | y | y | | y | y | | y | y | | |
| Amarillo Muni Water System | 45 | 55 | 0 | | y | | y | | | | | | | | y | y | | | y | | | | | |
| Arlington/Trinity River Auth | 0 | 100 | 0 | | | | y | y | y | | y | | y | | | y | | | y | y | y | | | |
| Austin, (City of) Water/WW | 0 | 100 | 0 | | | | y | | | | | | y | y | y | | | y | | y | y | | | |
| Dallas Water Util | 0 | 99 | 1 | | y | | y | | y | y | | | y | y | y | | | y | | y | y | y | | |
| El Paso Water Util | 57 | 43 | 0 | | y | | y | y | | y | | | y | | | y | | | | y | | | | |
| Galveston, (City of) Dept Pub Wks | 10 | 90 | 0 | | | | y | | y | | | | | | | | | | | | | | | |
| Houston, (City of) | 41 | 59 | 0 | | y | | y | | y | | | | | | y | y | y | | y | | | | | |
| Killeen/Bell County WCID #1 | 0 | 100 | 0 | | | | y | | y | | y | | | | | y | | | y | | y | | | |
| Lubbock, (City of) Water Util | 15 | 85 | 0 | | | | y | | y | | y | | | | y | | | | y | y | | | | |
| San Antonio Water System | 100 | 0 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| Wichita Falls, (City of) | 0 | 100 | 0 | | y | | | y | y | | | | y | y | y | | | | | y | y | y | | |
| **UTAH** | | | | | | | | | | | | | | | | | | | | | | | | |
| Layton/Weber Basin Water Cons Dist | 22 | 78 | 0 | | y | | y | | | | y | | | | y | | | y | y | | | | | |
| Orem/Central Utah Water Cons Dist | 0 | 100 | 0 | | | | | | | | y | | | | y | | | | y | | | | | |
| Salt Lake City/Metropolitan Water Dist | 0 | 100 | 0 | | | y | y | | | | y | | | | | y | | | y | | y | y | | |
| Salt Lake City Public Util | 14 | 43 | 43 | | | | y | | | | y | | | | y | y | y | | y | y | | y | | |
| West Jordan/Salt Lake Cnty Water Cons Dist | 15 | 79 | 6 | | y | | y | | | | y | y | | | y | | | | y | | y | | | |
| **VIRGINIA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Chesapeake, (City of) | 9 | 46 | 45 | | | | | y | | | | | | | | | | y | y | | y | | | |
| Chesterfield County Util Dept | 0 | 36 | 64 | | | | | | | | y | | | | | y | | | y | | y | | | |
| Merrifield/Fairfax County Water Auth | 0 | 99 | 0 | | | y | | | | | y | | | | | y | | | y | | y | y | | |
| Newport News Waterworks | 0 | 100 | 0 | | | | | | | | y | | | | | y | | | y | | | | | |
| Petersburg/Appomattox River Water Auth | 0 | 100 | 0 | | | | y | | | | y | | | | | | y | | y | | y | y | | |
| Richmond/Henrico Co Public Util | 13 | 0 | 87 | | | | | | | | | | | | | | | | | | | | | |
| Richmond Dept of Public Util | 0 | 100 | 0 | | y | y | y | | | | | | | | | y | | | y | | | | | |
| Woodbridge/Prince William Co. Service Auth | 13 | 0 | 87 | y | | | | | | | | | | | | | | | | | | | | |
| **WASHINGTON** | | | | | | | | | | | | | | | | | | | | | | | | |
| Everett Water Util | 0 | 100 | 0 | | y | | y | | | | | | | | | | y | | y | | | | | |
| Seattle Water Dept | 6 | 94 | 0 | | | | | | | | | | | | | | | | | | | | | |
| Tacoma Public Util | 10 | 90 | 0 | | | | y | | | | | | | | | | | | | | | | | |
| Vancouver, (City of) | 100 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | |
| **WISCONSIN** | | | | | | | | | | | | | | | | | | | | | | | | |
| Green Bay Water Util | 1 | 99 | 0 | | | | y | | | | y | | | | | y | | | y | | | | | |
| Kenosha Water Util | 0 | 100 | 0 | | | | y | | | | y | | | | | y | | | y | | | | | |
| Madison Water Util | 100 | 0 | 0 | | y | | y | | | | | | | | | | | | | | | | | |
| Milwaukee Water Works | 0 | 100 | 0 | | | | y | | | | | | | | | y | | y | y | | | | | |
| Sheboygan Water Util | 0 | 100 | 0 | | | | y | | | | y | | | | | y | | | y | | | | | |
| **WEST VIRGINIA** | | | | | | | | | | | | | | | | | | | | | | | | |
| Charleston/WV-American Water Co.-Kanawha Valley District | 0 | 100 | 0 | | | | y | | | | | | | | | y | | | | | | | | |

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**Table 8J.143 (Continued)**

| Utility Name | Polymers | | | Settling/ Sedimentation | | | | | Filtration | | | | | | | Filter Backwash Practices | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Anionic Polymers | Cationic Polymers | Nonionic Polymers | Conventional Sedimentation/ Clarification | Upflow Clarifiers | Tube Settlers | Lamella Plates | Dissolved Air Flotation | Direct Filtration | Microstrainer | Slow Sand | Rapid Sand | Dual/Multi-Media | Diatomaceous Earth | Pressure Filtration | Air Scouring | Surface Wash | Recycle Filter Backwash | Filter-to-Waste |
| **ALASKA** | | | | | | | | | | | | | | | | | | | |
| Anchorage Water/WW Util | y | | y | y | | | | | y | | | y | y | | | y | y | y | y |
| **ALABAMA** | | | | | | | | | | | | | | | | | | | |
| Mobile Area Water & Sewer Service System | | | | y | | | | | | | | y | y | | | | y | y | y |
| **ARIZONA** | | | | | | | | | | | | | | | | | | | |
| Glendale, (City of) | | y | y | y | | | | | | | | | y | | | y | y | y | |
| Phoenix, (City of) | y | y | | y | | | | | y | | | | y | | | y | y | y | y |
| Scottsdale, (City of) | | y | | y | | | | | | | | | y | | | y | | y | |
| Tempe, (City of) Water Mngmt Div | | y | y | y | | | | | | | | | y | | | | y | | y |
| Tucson Water | | | | | | | | | | | | | | | | | | | |
| **CALIFORNIA** | | | | | | | | | | | | | | | | | | | |
| Anaheim, (City of) | | y | | | | y | | | | | | | | | | y | | y | |
| Coachella Valley Water Dist | | | | | | | | | | | | | | | | | | | |
| Contra Costa Water Dist | | y | y | y | | | | | y | | | | y | | | y | y | y | y |
| Corona, (City of) Util Svcs | y | y | | y | | y | | | y | | | | y | | | y | y | y | |
| Corte Madera/Marin Muni Water Dist | y | y | y | | y | | | | | | | | y | | | | y | y | |
| Cucamonga County Water Dist | y | y | | y | | | | | | | | | y | | | y | y | y | y |
| Downey/Park Water Co. | | | | | | | | | | | | | | | | | | | |
| El Monte/San Gabriel Valley Water Co. | | | | | | | | | | | | | | | | | | | |
| Fremont/Alameda County Water Dist | y | y | y | y | y | | | | | | | | y | | | y | y | y | y |
| Fresno, (City of) | | | | | | | | | | | | | | | | | | | |
| Fullerton, (City of) | | | | | | | | | | | | | | | | | | | |
| Glendale Public Service Dept | | | | | | | | | | | | | | y | | | | | |
| Granite Bay/San Juan Suburban Water Dist | | y | y | y | | y | | | y | | | y | y | | | | y | y | |
| Irvine Ranch Water Dist | | | | | | | | | | | | | | | | | | | |
| La Mesa/Helix Water Dist | y | y | | y | | | | | | | | | y | | | | y | | |
| Long Beach/Dominguez Services Inc | | | | | | | | | | | | | | | | | | | |
| Long Beach Water Dept | | y | | y | | | | | | | | | y | | | | y | y | |
| Los Angeles Water & Power | | y | | | | | | | y | | | | | | | y | | y | |
| Los Angeles/Metro Water Dist of So Calif | y | y | y | y | | | | | y | | | | y | | | | y | y | |
| Modesto Public Works | y | y | | y | | | | | y | | | | | | | y | | | |
| CA-American Water Co.—Monterey Division | | y | | | | | | | | | | y | y | | y | y | y | | y |
| Oakland/East Bay Muni Util Dist | | y | y | y | | | | | y | | | y | y | | | | y | y | y |
| Riverside Water Div | | | | | | | | | | | | | | | | | | | |
| Sacramento/Citizens Util Co of California | | | y | | | | | | y | | | | | | y | | y | y | |
| Sacramento, (City of) Util Dept | | | y | y | | | | | | | | | y | | | | y | y | |
| San Bernardino Water Dept | | | | | | | | | | | | | | | | | | | |
| San Diego, (City of) | | y | | y | | | | | | | | | y | | | | y | | |
| San Francisco Water Dept | | y | y | y | | | | | y | | | | y | | | y | y | y | y |
| San Jacinto/Eastern Muni Water Dist | | | | y | | | | | | | | | | | | | | | |
| San Jose Water Co. | | y | | | | | | | y | | | y | | | | y | | y | |
| San Jose/Santa Clara Valley Water Dist | y | y | y | y | y | y | | | | | | | y | | | y | | y | y |
| Santa Barbara, (City of) | | y | | y | | | | | | | | | y | | | | y | y | |
| Santa Clarita/Castaic Lake Water Agency | y | y | y | y | | y | | | | | | | y | | | y | | y | y |
| Stockton East Water Dist | | y | | y | | | | | | | | | y | | | | y | y | y |
| Sunnyvale, (City of) Public Works | | | | | | | | | | | | | | | | | | | |
| Thousand Oaks/Calleguas Muni Water Dist | y | y | y | | | | | | y | | | | | | | y | | y | |
| Torrance Muni Water Dept | | | | | | | | | | | | | | | | | | | |
| Vacaville/Suisun Solano Water Auth | | y | | | y | | | | | | | | | | y | | y | y | y |
| Vallejo, (City of) | y | y | y | y | | | | | | | | y | y | | | | y | y | y |
| Vista Irrigation Dist | y | y | | y | | | | | | | | | y | | | | y | y | |
| **COLORADO** | | | | | | | | | | | | | | | | | | | |
| Arvada, (City of) | | | y | y | | | | | y | | | | y | | | | y | y | |
| Colorado Springs Util | y | y | y | y | | | y | | | | | y | y | | | y | y | y | y |
| Denver Water Dept | y | y | y | y | | | | | | | | y | y | | | | y | y | |
| Fort Collins Water Util | y | y | y | y | y | y | y | | | | | | y | | | y | y | y | |
| Pueblo Board of Waterworks | | y | | y | | | | | | | | | y | | | | | y | |
| **CONNECTICUT** | | | | | | | | | | | | | | | | | | | |
| Bridgeport Hydraulic Co.- Main System | y | | | | | | y | | | | | | y | | | y | | y | y |
| Hartford Metropolitan Dist | | | | y | | | | | | | y | y | | | | | y | | |
| New Haven/Regional Water Auth | | y | y | y | | | | | y | | | | y | | | | y | y | |
| **WASHINGTON DC** | | | | | | | | | | | | | | | | | | | |
| Washington Aqueduct | | y | y | y | | | | | | | | | y | | | | y | y | y |

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**Table 8J.143 (Continued)**

| Utility Name | Polymers | | | Settling/ Sedimentation | | | | | Filtration | | | | | | | Filter Backwash Practices | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Anionic Polymers | Cationic Polymers | Nonionic Polymers | Conventional Sedimentation/ Clarification | Upflow Clarifiers | Tube Settlers | Lamella Plates | Dissolved Air Flotation | Direct Filtration | Microstrainer | Slow Sand | Rapid Sand | Dual/Multi-Media | Diatomaceous Earth | Pressure Filtration | Air Scouring | Surface Wash | Recycle Filter Backwash | Filter-to-Waste |
| **DELAWARE** | | | | | | | | | | | | | | | | | | | |
| Newark/Artesian Water Company Inc | y | | | | | | | | | | | | | | y | | | y | y |
| Wilmington/United Water Delaware | y | y | | y | y | | y | | | | | | y | | y | | y | y | y |
| **FLORIDA** | | | | | | | | | | | | | | | | | | | |
| Clearwater Water Div | | | | | | | | | | | | | | | | | | | |
| Cocoa, (City of) Util Dept | | | | | y | | | | | | | | y | | | | y | y | |
| Coral Gables/Miami-Dade Water & Sewer Dept | | | | y | y | | | | | | | | y | | | | y | y | |
| Jacksonville, (City of) Water Div | | | | | | | | | | | | | | | | | | | |
| Jacksonville/United Water Florida | | | | | | | | | | | | | | | | | | | |
| Kissimmee, (City of) | | | | | | | | | | | | | | | | | | | |
| Lakeland Electric & Water Util | y | | | | y | | | | | | | | y | | | | y | | |
| Orlando/Orange County Util | | | | | | | | | | | | | | | | | | | |
| Orlando Util Comm | | | | | | | | | | | | | | | | | | | |
| Pensacola/Escambia County Util Auth | | | | | | | | | | | | | | | | | | | |
| Pompano Beach/Broward County Enviro Services | | y | y | | y | | | | | | | | y | | | | y | y | |
| Sarasota County Util | | | | | | | | | | | | | | | y | | | y | |
| Tallahassee Water Util | | | | | | | | | | | | | | | | | | | |
| Tampa Water Dept | | y | y | y | | | | | | | | | y | | | | y | y | |
| W Coast Regional Water Supply | | | | | | | | | | | | | | | | | | | |
| West Palm Beach/Palm Beach County Water Util | y | | y | | y | | | | | | | | y | | | y | y | y | y |
| **GEORGIA** | | | | | | | | | | | | | | | | | | | |
| Atlanta-Fulton County Water | | | | | | | y | | | | | | y | | | y | | y | y |
| Cobb County-Marietta Wtr Auth | y | | | y | | | | | | | | y | y | | | | y | y | y |
| Columbus Water Works | | | | y | | | | | | | | | y | | | | y | y | |
| Morrow/Clayton County Water Auth | | | | y | | | | | | | | | y | | | | y | y | y |
| Stone Mountain/DeKalb County Public Works | | y | | y | | | | | | | | | y | | | | y | y | y |
| **HAWAII** | | | | | | | | | | | | | | | | | | | |
| Honolulu/Board of Water Supply | | | | | | | | | | | | | | | | | | | |
| Pearl Harbor/Navy Public Wrks Util Dept | | | | | | | | | | | | | | | | | | | |
| **IOWA** | | | | | | | | | | | | | | | | | | | |
| Cedar Rapids Water Dept | y | | | | y | | | | | | | y | y | | | y | y | y | y |
| Des Moines Water Works | | | | y | | | | | | | | y | | | | y | | y | |
| **ILLINOIS** | | | | | | | | | | | | | | | | | | | |
| Champaign Division - Northern Illinois Water Inc | | | | | y | | | | | | | | y | | | | y | y | |
| Chicago, (City of) Dept of Water | | y | | y | | | | | | | | y | | | | | y | y | |
| Decatur, (City of) | | y | | | y | | | | | | | | y | | | y | | y | |
| Elmhurst/DuPage Water Comm | | | | | | | | | | | | | | | | | | | |
| Evanston Water Dept | | y | | y | | | | | | | | y | y | | | | y | y | |
| Interurban District - IL-American Water Co. | | y | y | y | | | y | | | | | y | y | | | | y | y | y |
| Lake Bluff/Central Lake Cnty Water Agency | | | | | | | y | | | | | | y | | | y | | y | y |
| Peoria District - IL-American Water Co. | | y | y | y | | | | | | | | y | y | | y | | y | | |
| Rockford City Water Div | | | | | | | | | | | | | | | | | | | |
| Springfield/City Water, Light and Power | | y | | | y | | | | | | | | y | | | | y | | y |
| Wilmette Water Plant | | | | y | | | | | | | | | y | | | | y | y | |
| **INDIANA** | | | | | | | | | | | | | | | | | | | |
| Evansville Water & Sewer Dept | | | | y | | | | | | | | | y | | | | y | | |
| Gary/Northwest Indiana Water Co. | | y | | y | | | | | | | | | y | | | | y | | |
| Indianapolis Water Co. | | y | | y | | | | | | | | y | | | y | | y | y | |
| **KANSAS** | | | | | | | | | | | | | | | | | | | |
| Kansas City Public Util Board | | y | | y | | | | | | | | | y | | | | y | | y |
| **KENTUCKY** | | | | | | | | | | | | | | | | | | | |
| Covington/Kenton County Water Dist No.1 | | | y | y | y | y | | | | | | y | y | | | | y | | |
| Lexington/KY-American Water Co. | | y | | y | y | | | | | | | | y | | | y | y | y | |
| Louisville Water Company | | y | | y | | | | | | | | | y | | | y | y | | |
| **LOUISIANA** | | | | | | | | | | | | | | | | | | | |
| The Baton Rouge Water Co. | | | | | | | | | | | | | | | | | | | |
| Harahan/Jefferson Parish Water Dept | | y | | y | y | | | | | | | y | y | | | | y | | y |
| Lake Charles, (City of) Water Div | | | | y | | | | | | | | y | y | | y | y | y | y | y |
| New Orleans Water/Sewer Board | | y | | y | y | | | | | | | y | y | | | y | y | y | y |
| **MASSACHUSETTS** | | | | | | | | | | | | | | | | | | | |
| Fall River Water Dept | | | | y | | | | | | | | y | | | | | | | y |
| Lowell Water Dept | | | | y | | | | | | | | | y | | | | | | y |
| New Bedford, (City of) Water Dept | | | | y | | | | | | | | | y | | | y | | | |
| Springfield Water Dept | | y | | | | | | | y | | y | y | y | | | y | y | | |

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**Table 8J.143 (Continued)**

| Utility Name | Polymers | | | Settling/ Sedimentation | | | | | Filtration | | | | | | | Filter Backwash Practices | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Anionic Polymers | Cationic Polymers | Nonionic Polymers | Conventional Sedimentation/ Clarification | Upflow Clarifiers | Tube Settlers | Lamella Plates | Dissolved Air Flotation | Direct Filtration | Microstrainer | Slow Sand | Rapid Sand | Dual/Multi-Media | Diatomaceous Earth | Pressure Filtration | Air Scouring | Surface Wash | Recycle Filter Backwash | Filter-to-Waste |
| **MARYLAND** | | | | | | | | | | | | | | | | | | | |
| Annapolis/Anne Arundel County DPW | | | | y | y | y | | | | | y | y | | | y | y | y | y | y |
| Laurel/Washington Suburban Sanit Comm | | y | | y | | y | | | | | | | y | | | | y | y | y |
| **MAINE** | | | | | | | | | | | | | | | | | | | |
| Portland Water District | | | | | | | | | | | | | | | | | | | |
| **MICHIGAN** | | | | | | | | | | | | | | | | | | | |
| Ann Arbor Util Dept | | y | | y | | | | | | | | | y | | | | y | y | |
| Grand Rapids, (City of) | | | | y | y | | | | | | | y | | | | | y | | y |
| Holland/Wyoming Util Dept | y | y | | y | y | | | | | | | y | y | | | | y | y | |
| Kalamazoo Dept Public Util | | | | | | | | | | | | | | | | | | | |
| **MINNESOTA** | | | | | | | | | | | | | | | | | | | |
| St. Paul Water Util | | | | y | | | | | | | | y | y | | | y | | y | |
| **MISSOURI** | | | | | | | | | | | | | | | | | | | |
| Independence Water Dept | | | | y | | | | | | | | y | | | | | y | y | |
| Kansas City Water Svcs Dept | | y | | y | y | | | | | | | y | | | | | y | | y |
| Springfield City Util | | y | | y | | | | | | | | y | y | | | | y | y | y |
| St. Louis County Water Co. | y | y | | y | y | | | | | | | y | y | | | | y | | y |
| **NORTH CAROLINA** | | | | | | | | | | | | | | | | | | | |
| Asheville, (City of) | | y | | | | | | | y | | | | y | | | y | | | y |
| Charlotte-Mecklenburg Util | | | | y | | | | | | | | | y | | | | y | | y |
| Durham, (City of) Dept Water Res | | | y | y | | | | | | | | | y | | | y | y | y | y |
| Fayetteville Public Works Comm | | | | y | | y | | | | | | | y | | | | y | | y |
| Greensboro, (City of) Util Dept | | | | y | | y | | | | | | | y | | | | y | | y |
| **NEBRASKA** | | | | | | | | | | | | | | | | | | | |
| Lincoln Water System | | y | | | | | | | | | | y | y | | | y | y | | |
| Omaha Metro Util Dist | | y | | | y | | | | | | | | y | | | y | | | |
| **NEW HAMPSHIRE** | | | | | | | | | | | | | | | | | | | |
| Manchester Water Works | | | y | y | | | | | | | | y | | | | | | y | |
| **NEW JERSEY** | | | | | | | | | | | | | | | | | | | |
| Brick Township Muni Util Auth | y | | | y | | y | | | | | | y | y | | | y | y | y | y |
| Clifton/Passaic Valley Water Comm | | | y | y | | y | | | | | | | y | | | | | y | |
| Haddon System - NJ-American Water Co. | | y | | | y | | | | | | | | | | y | y | y | y | y |
| Harrington Park/United Water New Jersey | | y | | | | | | | y | | | | y | | | y | | | |
| Iselin/Middlesex Water Company | y | y | y | y | | y | | | | | | | y | | | | y | y | |
| Little Falls/Newark Div of Water/Sewer Util | | y | y | | | | | | y | | | | | | | | y | y | |
| Short Hills System - NJ-American Water Co. | y | y | y | y | y | | | | | | | | y | | | | y | y | |
| Shrewsbury/NJ-American Water Co. - Monmouth System | y | y | | y | | | | | | | | y | y | | | y | y | y | y |
| Westfield/Elizabethtown Water Co. | | y | | y | | y | | | | | | | y | | | | y | y | |
| **NEW MEXICO** | | | | | | | | | | | | | | | | | | | |
| Albuquerque Public Works Dept | | | | | | | | | | | | | | | | | | | |
| **NEVADA** | | | | | | | | | | | | | | | | | | | |
| Boulder City/Southern Nevada Water System | | y | | | | | | | y | | | | y | | | y | | y | |
| Las Vegas Valley Wtr Dist | | | | | | | | | | | | | | | | | | | |
| North Las Vegas, (City of) | | | | | | | | | | | | | | | | | | | |
| **NEW YORK** | | | | | | | | | | | | | | | | | | | |
| Buffalo/Erie County Water Auth | | | | y | | y | | | | | | | y | | | | y | y | |
| Lynbrook/Long Island Water Inc | | | y | | | | | | | | | y | y | | y | y | | | y |
| Oakdale/Suffolk County Water Auth | | | | | | | | | | | | | | | | | | | |
| Rochester, (City of) Water Bureau | | y | | | | | | | y | | | | y | | | y | | y | y |
| Syracuse/Onondaga County Water Auth | | | | | | | | | y | | | | y | | | | y | y | y |
| Syracuse Dept of Water | | | | | | | | | | | | | | | | | | | |
| West Nyack/United Water New York | | y | | y | | | | | | | | | y | | | | y | | |
| **OHIO** | | | | | | | | | | | | | | | | | | | |
| Akron Public Util Bureau | | | | y | | | | | | | | y | y | | | | y | | |
| Cincinnati Water Works | | y | | y | y | | y | | | | | y | y | | | | y | y | |
| Cleveland Div of Water | | y | | y | | | | | | | | y | y | | | | y | y | y |
| Columbus Water Div | | | | y | y | | | | | | | | y | | | | | y | |
| Dayton Water Supply/Treatment | | | | y | y | | | | | | | y | y | | | | y | y | |
| Fairfield/Hamilton Util | | | | y | y | | | | | | | y | y | | | | y | y | |
| Toledo, (City of) Water Div | | | | y | | | | | | | | y | | | | | y | | |
| **OKLAHOMA** | | | | | | | | | | | | | | | | | | | |
| Lawton Water/Wastewater Plants | | y | | | y | | | | | | | y | | | | | y | | y |
| Oklahoma City, (City of) | | y | | y | y | | | | | | | | y | | | y | y | y | y |
| Tulsa Public Works Dept | y | y | y | y | | | | | | | | | y | | | y | y | y | y |
| **OREGON** | | | | | | | | | | | | | | | | | | | |
| Eugene Water & Electric Board | | | | y | | | | | | | | | y | | | | y | | |
| Portland Water Bureau | | | | | | | | | | | | | | | | | | | |

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**Table 8J.143 (Continued)**

| Utility Name | Polymers | | | Settling/ Sedimentation | | | | | Filtration | | | | | | | Filter Backwash Practices | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Anionic Polymers | Cationic Polymers | Nonionic Polymers | Conventional Sedimentation/ Clarification | Upflow Clarifiers | Tube Settlers | Lamella Plates | Dissolved Air Flotation | Direct Filtration | Microstrainer | Slow Sand | Rapid Sand | Dual/Multi-Media | Diatomaceous Earth | Pressure Filtration | Air Scouring | Surface Wash | Recycle Filter Backwash | Filter-to-Waste |
| **PENNSYLVANIA** | | | | | | | | | | | | | | | | | | | |
| Allentown Muni Water System | | | | y | | | | | | | | y | y | | | | y | | y |
| Bethlehem, (City of) | | | | | | | | | y | | | | y | | | y | | y | y |
| Bryn Mawr/Philadelphia Suburban Water Co. | | y | y | y | | | | | y | | | | y | | | y | y | y | y |
| Harrisburg/United Water PA | | y | y | y | | | | | | | | | y | | | | y | | y |
| Lancaster, (City of) Water Bureau | y | | y | y | y | | | | | | | y | | | | | y | y | y |
| Philadelphia Water Dept | | | y | y | | | | | | | | y | y | | | | y | y | |
| Pittsburgh/West View Water Auth | | | | | y | | | | | | | | y | | | | y | y | y |
| Reading Area Water Auth | | | | y | | | | | | | | y | y | | | y | | | y |
| The York Water Co. | | | | y | | | | | | | | | y | | | | y | y | y |
| **RHODE ISLAND** | | | | | | | | | | | | | | | | | | | |
| Pawtucket Water Supply Board | | y | | y | | | | | | | | | | | | | | | |
| **SOUTH CAROLINA** | | | | | | | | | | | | | | | | | | | |
| Charleston Comm Public Works | | y | | y | | | | | | | | y | | | | y | | | |
| Spartanburg Water System | | y | | y | | | | | | | | | y | | | | y | | y |
| **SOUTH DAKOTA** | | | | | | | | | | | | | | | | | | | |
| Sioux Falls, (City of) | y | | | | | | | | | | | y | | | | y | y | y | |
| **TENNESSEE** | | | | | | | | | | | | | | | | | | | |
| Chattanooga/TN-American Water Co. | | | | y | | | | | | | | | y | | | | y | y | |
| Memphis Light Gas & Water | | | | | | | | | | | | y | y | | | | | y | y |
| Nashville/Metro Water Services | | | y | | y | y | | | | | | y | y | | | | y | y | y |
| **TEXAS** | | | | | | | | | | | | | | | | | | | |
| Abilene, (City of) | | y | | | y | | | | | | | | y | | | | y | y | y |
| Amarillo Muni Water System | | | | y | | | | | | | | y | | | | | y | | |
| Arlington/Trinity River Auth | y | y | | y | | | | | | | | | y | | | | y | y | |
| Austin, (City of) Water/WW | | | | y | y | | | | | | | | y | | | | y | y | |
| Dallas Water Util | | y | | y | | | | | | | | | y | | | y | y | y | |
| El Paso Water Util | y | y | | y | | | | | | | | | y | | | y | | y | y |
| Gavelston, (City of) Dept Pub Wks | | | | | | | | | | | | | | | | | | | |
| Houston, (City of) | y | y | y | y | | | | | | | | | y | | | | y | y | |
| Killeen/Bell County WCID #1 | | y | | y | y | | | | | | | y | y | | | | y | y | |
| Lubbock, (City of) Water Util | | | | y | | | | | | | | y | | | | | y | | |
| San Antonio Water System | | | | | | | | | | | | | | | | | | | |
| Wichita Falls, (City of) | | y | | y | y | | | | | | | y | y | | | y | y | y | |
| **UTAH** | | | | | | | | | | | | | | | | | | | |
| Layton/Weber Basin Water Cons Dist | | | | y | | | | | | | | y | y | | | y | y | y | y |
| Orem/Central Utah Water Cons Dist | | y | | | | | | | y | | | | | | | | y | y | |
| Salt Lake City/Metropolitan Water Dist | y | y | | y | | | | | | | | | y | | | | y | y | y |
| Salt Lake City Public Util | y | y | | y | | y | | | | | y | | y | | | y | y | y | y |
| West Jordan/Salt Lake Cnty Water Cons Dist | y | y | y | y | | | | | y | | | | y | | | y | y | y | y |
| **VIRGINIA** | | | | | | | | | | | | | | | | | | | |
| Chesapeake, (City of) | | | y | y | | | | | | | | y | y | | | | | | y |
| Chesterfield County Util Dept | | y | | y | | | | | | | | | y | | | | y | | y |
| Merrifield/Fairfax County Water Auth | y | y | | y | y | y | | | | | | y | y | | | | y | y | y |
| Newport News Waterworks | | y | | y | y | | y | | | | | | y | | | y | y | | y |
| Petersburg/Appomattox River Water Auth | | | y | y | | | | | | | | | y | | | | y | | y |
| Richmond/Henrico Co Public Util | | | | | | | | | | | | | | | | | | | |
| Richmond Dept of Public Util | | | y | y | | y | | | | | | | y | | | y | y | y | |
| Woodbridge/Prince William Co. Service Auth | | | | | | | | | | | | | | | | | | | |
| **WASHINGTON** | | | | | | | | | | | | | | | | | | | |
| Everett Water Util | | y | y | | | | | | y | | | | | | | y | y | y | y |
| Seattle Water Dept | | | | | | | | | | | | | | | | | | | |
| Tacoma Public Util | | | | | | | | | | | | | | | | | | | |
| Vancouver, (City of) | | | | | | | | | | | | | | | | y | | y | y |
| **WISCONSIN** | | | | | | | | | | | | | | | | | | | |
| Green Bay Water Util | | | | y | | | | | | | | y | y | | | | y | y | |
| Kenosha Water Util | | | | y | | | | | | | | y | | | | | y | | |
| Madison Water Util | | | | | | | | | | | | | | | | | | | |
| Milwaukee Water Works | | | | y | | | | | | | | y | y | | | | y | | |
| Sheboygan Water Util | | | | y | | | | | | | | | y | | | | y | y | y |
| **WEST VIRGINIA** | | | | | | | | | | | | | | | | | | | |
| Charleston/WV-American Water Co. - Kanawha Valley District | | y | | | y | | | | | | | | y | | | | y | y | y |

*(Continued)*

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**Table 8J.143 (Continued)**

| Utility Name | Post-Disinfection: Chlorine | Chlorine Dioxide | Chloramines | Ozone | UV Radiation | Fluoridation | Defluoridation | Corrosion Control: pH Adjustment | Alkalinity Adjustment | Corrosion Inhibitors | Membrane Processes: Reverse Osmosis | Nanofiltration | Ultrafiltration | Microfiltration | Electrodialysis | Ion Exchange | Iron/Manganese Removal | Manganese Green Sand | GranularActivated Carbon | Powdered Activated Carbon | Resin Adsorption | Air Stripping | Off Gas Treatment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ALASKA** | | | | | | | | | | | | | | | | | | | | | | | |
| Anchorage Water/WW Util | y | | | | | y | | | | | | | | | | | | | | | | | |
| **ALABAMA** | | | | | | | | | | | | | | | | | | | | | | | |
| Mobile Area Water & Sewer Service System | y | | | | | y | | y | | y | | | | | | | | | | | | | |
| **ARIZONA** | | | | | | | | | | | | | | | | | | | | | | | |
| Glendale, (City of) | y | | | | | y | | y | | | | | | | | | | | | y | | | |
| Phoenix, (City of) | y | | | | | y | | y | | | | | | | | | | | | | | | |
| Scottsdale, (City of) | y | | | | | | | | | | | | | | | | y | | | y | | y | |
| Tempe, (City of) Water Mngmt Div | y | | | | | y | | y | y | | | | | | | | | | | y | | | |
| Tucson Water | | | | | | | | | | | | | | | | | | | | | | | |
| **CALIFORNIA** | | | | | | | | | | | | | | | | | | | | | | | |
| Anaheim, (City of) | y | | | | | | | | | | | | | | | | | | | | | | |
| Coachella Valley Water Dist | y | | | | | | | | | | | | | | | | | | | | | | |
| Contra Costa Water Dist | | | y | y | | y | | y | | | | | | | | | | | y | y | | | |
| Corona, (City of) Util Svcs | y | | | | | | | | | | | | | | | | | | | | | | |
| Corte Madera/Marin Muni Water Dist | | | y | | | y | | y | | y | | | | | | | | | | | | | |
| Cucamonga County Water Dist | y | | | | | | | y | | | | | | | | | | | | | | | |
| Downey/Park Water Co | y | | | | | | | | | | | | | | | | | | | | | | |
| El Monte/San Gabriel Valley Water Co. | | | | | | | | | | | | | | | | | y | | | | | | |
| Fremont/Alameda County Water Dist | y | | y | | | y | | y | | | | | | | | | | | | | | | |
| Fresno, (City of) | y | | | | | y | | | | | | | | | | | | | | | | | |
| Fullerton, (City of) | | | | | | | | | | | | | | | | | | | | | | | |
| Glendale Public Service Dept | y | | | | | | | | | | | | | | | | | | | | | | |
| Granite Bay/San Juan Suburban Water Dist | y | | | | | | | y | y | | | | | | | | | | | | | | |
| Irvine Ranch Water Dist | y | | | | | | | | | | | | | | | | | | | | | | |
| La Mesa/Helix Water Dist | | | y | | | | | y | | | | | | | | | | | | y | | | |
| Long Beach/Dominguez Services Inc | | | | | | | | | | | y | | | | | | | | | | | | |
| Long Beach Water Dept | y | | y | | | y | | y | | y | | | | | | | | | | | | | |
| Los Angeles Water & Power | y | | | | | | | | | y | | | | | | | | | | | | y | y |
| Los Angeles/Metro Water Dist of So Calif | y | | y | | | | | y | | | | | | | | | | | | | | | |
| Modesto Public Works | y | | | | | | | y | y | | | | | | | | | | y | | | | |
| CA-American Water Co—Monterey Division | y | | | | | | | y | | y | | | | | | | y | | y | | | | y |
| Oakland/East Bay Muni Util Dist | y | | | | | y | | y | | | | | | | | | | | y | | | | |
| Riverside Water Div | y | | | | | | | | | | | | | | | | | | | | | | |
| Sacramento/Citizens Util Co of California | y | | | | | y | | | | | | | | | | | y | y | | | | y | |
| Sacramento, (City of) Util Dept | y | | | | | | | y | y | | | | | | | | | | | | | | |
| San Bernardino Water Dept | | | | | | | | | | | | | | | | | | | y | | | y | |
| San Diego, (City of) | | | y | | | | | y | | | | | | | | | | | | | | | |
| San Francisco Water Dept | y | | | | | y | | y | | | | | | | | | y | | | | | | |
| San Jacinto/Eastern Muni Water Dist | y | | | | | | | | | y | | | | | | | | | | | | | |
| San Jose Water Co. | | | | | | | | | | | | | | y | | | | | | | | | |
| San Jose/Santa Clara Valley Water Dist | y | | y | | | | | y | | y | | | | | | | | | | y | | | |
| Santa Barbara, (City of) | y | | | | | | | | | | | | | | | | | | | y | | | |
| Santa Clarita/Castaic Lake Water Agency | y | | | | | | | y | | y | | | | | | | | | | y | | | |
| Stockton East Water Dist | y | | | | | | | y | | | | | | | | | | | y | | | | |
| Sunnyvale, (City of) Public Works | | | | | | | | | | | | | | | | | | | | | | | |
| Thousand Oaks/Calleguas Muni Water Dist | y | | | | | | | | | y | | | | | | | | | | | | | |
| Torrance Muni Water Dept | | | | | | | | | | | | | | | | | | | | | | | |
| Vacaville/Suisun Solano Water Auth | y | | | | | | | | | | | | | | | | | | | | | | |
| Vallejo, (City of) | y | | | | | y | | y | | | | | | | | | | | y | | | | y |
| Vista Irrigation Dist | | | | | | | | | | | | | | | | | | | | | | | |
| **COLORADO** | | | | | | | | | | | | | | | | | | | | | | | |
| Arvada, (City of) | y | | | | | y | | y | | | | | | | | | y | | | y | | | |
| Colorado Springs Util | y | | | | | | | y | | | | | | | | | y | | | | | | |
| Denver Water Dept | y | | y | | | y | | y | | | | | | | | | | | | | | | |
| Fort Collins Water Util | | | | | | y | | y | y | | | | | | | | y | | | y | | | |
| Pueblo Board of Waterworks | y | | y | | | y | | | | | | | | | | | | | | y | | | |
| **CONNECTICUT** | | | | | | | | | | | | | | | | | | | | | | | |
| Bridgeport Hydraulic Co - Main System | y | | | | | y | | y | | y | | | | | | | y | | | | | | |
| Hartford Metropolitan Dist | y | | | | | y | | y | | | | | | | | | | | | y | | | |
| New Haven/Regional Water Auth | y | | | | | y | | y | | y | | | | | | | y | | | | | y | |
| **WASHINGTON DC** | | | | | | | | | | | | | | | | | | | | | | | |
| Washington Aqueduct | y | | | | | y | | y | | | | | | | | | | | | y | | | |

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**Table 8J.143 (Continued)**

| Utility Name | Post-Disinfection: Chlorine | Post-Disinfection: Chlorine Dioxide | Post-Disinfection: Chloramines | Post-Disinfection: Ozone | Post-Disinfection: UV Radiation | Fluoridation | Defluoridation | Corrosion Control: pH Adjustment | Corrosion Control: Alkalinity Adjustment | Corrosion Control: Corrosion Inhibitors | Membrane Processes: Reverse Osmosis | Membrane Processes: Nanofiltration | Membrane Processes: Ultrafiltration | Membrane Processes: Microfiltration | Membrane Processes: Electrodialysis | Ion Exchange | Iron/Manganese Removal | Manganese Green Sand | GranularActivated Carbon | Powdered Activated Carbon | Resin Adsorption | Air Stripping | Off Gas Treatment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DELAWARE** | | | | | | | | | | | | | | | | | | | | | | | |
| Newark/Artesian Water Company Inc | y | | | | | y | | y | | y | | | | | | | y | y | | | | y | |
| Wilmington/United Water Delaware | y | | | | | y | | y | | | | | | | | | | | | y | | | |
| **FLORIDA** | | | | | | | | | | | | | | | | | | | | | | | |
| Clearwater Water Div | y | | | | | | | | | | | | | | | | | | | | | | |
| Cocoa, (City of) Util Dept | | | y | | | y | | y | | | | | | | | | | | | | | y | |
| Coral Gables/Miami-Dade Water & Sewer Dept | | | y | | | y | | y | | y | | | | | | | | | | | | y | |
| Jacksonville, (City of) Water Div | y | | | | | | | | | | | | | | | | | | | | | | |
| Jacksonville/United Water Florida | y | | | | | | | | | y | | | | | | | | | | | | | |
| Kissimmee, (City of) | y | | | | | y | | y | | | | | | | | | | | | | | | |
| Lakeland Electric & Water Util | | | | | | y | | y | | | | | | | | | | | | | | | |
| Orlando/Orange County Util | | | | | | | | y | | | | | | | | | | | | | | y | |
| Orlando Util Comm | y | | | | | y | | y | | | | | | | | | | | | | | | |
| Pensacola/Escambia County Util Auth | | | | | | | | y | | | | | | | | | | | y | | | | |
| Pompano Beach/Broward County Enviro Services | y | | y | | | y | | | | | | | | | | | | | | | | | |
| Sarasota County Util | | | y | | | | | y | | y | | | | | y | | | | | | | | |
| Tallahassee Water Util | y | | | | | | | | | | | | | | | | | | | | | | |
| Tampa Water Dept | y | y | y | | | y | | y | | | | | | | | | | | | y | | | |
| W Coast Regional Water Supply | y | | | | | | | y | | | | | | | | | | | | | | | |
| West Palm Beach/Palm Beach County Water Util | | | y | | | | | | y | y | | | | | | | | | | | | | |
| **GEORGIA** | | | | | | | | | | | | | | | | | | | | | | | |
| Atlanta-Fulton County Water | y | | | | | y | | | | y | | | | | | | y | | | y | | | |
| Cobb County-Marietta Wtr Auth | y | | | | | y | | y | | | | | | | | | | | | | | | |
| Columbus Water Works | y | | | | | y | | y | | | | | | | | | | | | y | | | |
| Morrow/Clayton County Water Auth | y | | | | | y | | | | y | | | | | | | y | | | y | | | |
| Stone Mountain/DeKalb County Public Works | y | | | | | y | | y | | | | | | | | | y | | | | | | |
| **HAWAII** | | | | | | | | | | | | | | | | | | | | | | | |
| Honolulu/Board of Water Supply | y | | | | | | | | | | | | | | | | | | y | | | | |
| Pearl Harbor/Navy Public Wrks Util Dept | y | | | | | y | | | | | | | | | | | | | | | | | |
| **IOWA** | | | | | | | | | | | | | | | | | | | | | | | |
| Cedar Rapids Water Dept | y | | | | | y | | y | | y | | | | | | | | | | | | | |
| Des Moines Water Works | y | | | | | y | | | | y | | | | | | y | | | | y | | | |
| **ILLINOIS** | | | | | | | | | | | | | | | | | | | | | | | |
| Northern Illinois Water Inc - Champaign Division | y | | | | | y | | y | y | | | | | | | | | | | | | | |
| Chicago, (City of) Dept of Water | y | | | | | y | | | | y | | | | | | | | | | y | | | |
| Decatur, (City of) | y | y | | | | y | | y | y | y | | | | | | | | | | y | | | |
| Elmhurst/DuPage Water Comm | y | | | | | | | | | | | | | | | | | | | | | | |
| Evanston Water Dept | y | | | | | y | | | | y | | | | | | | | | | y | | | |
| Interurban District - IL-American Water Co. | y | | y | | | y | | y | | y | | | | | | | | | y | y | | | |
| Lake Bluff/Central Lake Cnty Water Agency | | | | | | y | | | | y | | | | | | | | | y | | | | |
| Peoria District - IL-American Water Co. | y | | | | | y | | y | | y | | | | | | | y | | y | y | | | |
| Rockford City Water Div | | | | | | y | | | | y | | | | | | | | | y | | | | |
| Springfield/City Water, Light and Power | y | | y | | | y | | | | | | | | | | | | | | y | | | |
| Wilmette Water Plant | y | | | | | y | | | | y | | | | | | | | | | y | | | |
| **INDIANA** | | | | | | | | | | | | | | | | | | | | | | | |
| Evansville Water & Sewer Dept | y | | | | | y | | y | | | | | | | | | | | | | | | |
| Gary/Northwest Indiana Water Co. | | | y | | | y | | | | y | | | | | | | | | | y | | | |
| Indianapolis Water Co. | | | y | | | y | | | | | | | | | | | | | | | | | |
| **KANSAS** | | | | | | | | | | | | | | | | | | | | | | | |
| Kansas City Public Util Board | y | | y | | | y | | y | | | | | | | | | | | | y | | | |
| **KENTUCKY** | | | | | | | | | | | | | | | | | | | | | | | |
| Covington/Kenton County Water Dist No.1 | y | | | | | y | | y | | y | | | | | | | | | | y | | | |
| Lexington/KY-American Water Co. | | | y | | | y | | y | y | | | | | | | | | | y | y | | | |
| Louisville Water Company | | | y | | | y | | y | y | | | | | | | | | | | y | | | |
| **LOUISIANA** | | | | | | | | | | | | | | | | | | | | | | | |
| Baton Rouge Water Co. | | | y | | | | | | | | | | | | | | | | | | | | |
| Harahan/Jefferson Parish Water Dept | y | | y | | | y | | | | y | | | | | | | | | | y | | | |
| Lake Charles, (City of) Water Div | | | y | | | y | | y | | y | | | | | | | y | y | | | | | |
| New Orleans Water/Sewer Board | | | | | | y | | y | | | | | | | | | | | | y | | | |
| **MASSACHUSETTS** | | | | | | | | | | | | | | | | | | | | | | | |
| Fall River Water Dept | y | | | | | y | | y | | y | | | | | | | | | y | | | | |
| Lowell Water Dept | y | | | | | y | | | | | | | | | | | | | y | | | | |
| New Bedford, (City of) Water Dept | y | | | | | | | y | | | | | | | | | | | | | | | |
| Springfield Water Dept | y | | | | | | | y | | y | | | | | | | | | | | | | |

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**Table 8J.143 (Continued)**

| Utility Name | Post-Disinfection | | | | | | | Corrosion Control | | | Membrane Processes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chlorine | Chlorine Dioxide | Chloramines | Ozone | UV Radiation | Fluoridation | Defluoridation | pH Adjustment | Alkalinity Adjustment | Corrosion Inhibitors | Reverse Osmosis | Nanofiltration | Ultrafiltration | Microfiltration | Electrodialysis | Ion Exchange | Iron/Manganese Removal | Manganese Green Sand | GranularActivated Carbon | Powdered Activated Carbon | Resin Adsorption | Air Stripping | Off Gas Treatment |
| **MARYLAND** | | | | | | | | | | | | | | | | | | | | | | | |
| Annapolis/Anne Arundel County DPW | y | | | | | y | | y | | | | | | | | | y | | | | | | |
| Laurel/Washington Suburban Sanit Comm | y | | | | | y | | y | | | | | | | | | | | | y | | | |
| **MAINE** | | | | | | | | | | | | | | | | | | | | | | | |
| Portland Water District | y | | y | | | | | y | | y | | | | | | | | | | | | y | |
| **MICHIGAN** | | | | | | | | | | | | | | | | | | | | | | | |
| Ann Arbor Util Dept | | | y | y | | y | | y | | | | | | | | | | | y | | | | |
| Grand Rapids, (City of) | y | | | | | y | | | | y | | | | | | | | | | y | | | |
| Holland/Wyoming Util Dept | y | | | | | y | | | | | | | | | | | | | | y | | | |
| Kalamazoo Dept Public Util | y | | | | | y | | | | y | | | | | | | | | | | | y | |
| **MINNESOTA** | | | | | | | | | | | | | | | | | | | | | | | |
| St. Paul Water Util | y | | | | | y | | y | | | | | | | | | | | | y | | | |
| **MISSOURI** | | | | | | | | | | | | | | | | | | | | | | | |
| Independence Water Dept | | | y | | | | | | | y | | | | | | | | | | | | | |
| Kansas City Water Svcs Dept | y | | y | | | y | | y | y | y | | | | | | | | | | y | | | |
| Springfield City Util | y | | | | | y | | y | y | | | | | | | | | | | y | | | |
| St. Louis County Water Co. | | | y | | | y | | | | | | | | | | | | | | y | | | |
| **NORTH CAROLINA** | | | | | | | | | | | | | | | | | | | | | | | |
| Asheville, (City of) | y | | | | | y | | y | | y | | | | | | | | | | | | | |
| Charlotte-Mecklenburg Util | y | | | | | y | | y | y | | | | | | | | | | | y | | | |
| Durham, (City of) Dept Water Res | | | | | | y | | y | | y | | | | | | | y | | | | | | |
| Fayetteville Public Works Comm | y | | | | | y | | y | | y | | | | | | | | | | y | | | |
| Greensboro, (City of) Util Dept . | | | | | | y | | y | y | y | | | | | | | | | | | | | |
| **NEBRASKA** | | | | | | | | | | | | | | | | | | | | | | | |
| Lincoln Water System | | | y | | | y | | | | | | | | | | | y | | | | | | |
| Omaha Metro Util Dist | y | | | | | y | | y | y | | | | | | | | | | | y | | | |
| **NEW HAMPSHIRE** | | | | | | | | | | | | | | | | | | | | | | | |
| Manchester Water Works | y | | | | | | | y | | y | | | | | | | | | y | | | | |
| **NEW JERSEY** | | | | | | | | | | | | | | | | | | | | | | | |
| Brick Township Muni Util Auth | y | | | | | | | y | | | | | | | | | | | | | | | |
| Clifton/Passaic Valley Water Comm | y | | | | | | | | | | | | | | | | | | | | | | |
| NJ-American Water Co.-Haddon System | y | | | | | | | y | | y | | | | | | | y | | y | | | | y |
| Harrington Park/United Water New Jersey | | | y | | | | | y | | | | | | | | | | | | | | | |
| Iselin/Middlesex Water Company | y | | | | | | | y | | y | | | | | | | | | | y | | y | |
| Little Falls/Newark Div of Water/Sewer Util | y | | | | | | | y | y | | | | | | | | | | | | | | |
| NJ-American Water Co.- Short Hills System | y | | | | | | | y | | y | | | | | | | | | y | y | | y | |
| Shrewsbury/NJ-American Water Co.- Monmouth System | y | | | | | y | y | y | | y | | | | | | | y | | y | y | | y | |
| Westfield/Elizabethtown Water Co. | y | | y | | | y | | y | y | y | | | | | | | y | y | | y | | y | |
| **NEW MEXICO** | | | | | | | | | | | | | | | | | | | | | | | |
| Albuquerque Public Works Dept | y | | | | | y | | | | | | | | | | | | | | | | | |
| **NEVADA** | | | | | | | | | | | | | | | | | | | | | | | |
| Boulder City/Southern Nevada Water System | y | | | | | | | | | y | | | | | | | | | | y | | | |
| Las Vegas Valley Wtr Dist | y | | | | | | | | | | | | | | | | | | | | | | |
| North Las Vegas, (City of) | | | | | | | | | | | | | | | | | | | | | | | |
| **NEW YORK** | | | | | | | | | | | | | | | | | | | | | | | |
| Buffalo/Erie County Water Auth | y | | | | | y | | y | y | | | | | | | | | | | y | | | |
| Lynbrook/Long Island Water Inc | | | | | | | | y | | | | | | | | | y | | | | | y | |
| Oakdale/Suffolk County Water Auth | y | | | | | | | y | | y | | | | | | | y | y | y | | | | |
| Rochester, (City of) Water Bureau | y | | | | | y | | y | | y | | | | | | | | | | | | | |
| Syracuse/Onondaga County Water Auth | y | | | | | y | | | | | | | | | | | | | | y | | | |
| Syracuse Dept of Water | | | | | | y | | | | | | | | | | | | | | | | | |
| West Nyack/United Water New York | | | | | | | | | | y | | | | | | | | | | | | | |
| **OHIO** | | | | | | | | | | | | | | | | | | | | | | | |
| Akron Public Util Bureau | y | | | | | y | | y | | y | | | | | | | | | | y | | | |
| Cincinnati Water Works | y | | | | | y | | y | | | | | | | | | | | y | y | | | |
| Cleveland Div of Water | y | | | | | y | | | | y | | | | | | | | | | y | | | |
| Columbus Water Div | y | | | | | y | | y | y | y | | | | | | | | | | y | | | |
| Dayton Water Supply/Treatment | y | | | | | y | | | | | | | | | | | | | | | | | |
| Fairfield/Hamilton Util | | y | | | | y | | | | | | | | | | | | | | | | | |
| Toledo, (City of) Water Div | y | y | | | | y | | y | y | | | | | | | | | | | y | | | |
| **OKLAHOMA** | | | | | | | | | | | | | | | | | | | | | | | |
| Lawton Water/Wastewater Plants | y | | y | | | y | | y | y | | | | | | | | | | | y | | | |
| Oklahoma City, (City of) | y | | y | | | y | | y | | y | | | | | | | | | y | y | | | |
| Tulsa Public Works Dept | y | | | | | y | | y | y | | | | | | | | | | y | y | | | |
| **OREGON** | | | | | | | | | | | | | | | | | | | | | | | |
| Eugene Water & Electric Board | | | | | | | | y | | | | | | | | | | | | | | | |
| Portland Water Bureau | | | y | | | | | | | | | | | | | | | | | | | | |

*(Continued)*

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**Table 8J.143 (Continued)**

| Utility Name | Post-Disinfection: Chlorine | Chlorine Dioxide | Chloramines | Ozone | UV Radiation | Fluoridation | Defluoridation | Corrosion Control: pH Adjustment | Alkalinity Adjustment | Corrosion Inhibitors | Membrane Processes: Reverse Osmosis | Nanofiltration | Ultrafiltration | Microfiltration | Electrodialysis | Ion Exchange | Iron/Manganese Removal | Manganese Green Sand | GranularActivated Carbon | Powdered Activated Carbon | Resin Adsorption | Air Stripping | Off Gas Treatment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PENNSYLVANIA** | | | | | | | | | | | | | | | | | | | | | | | |
| Allentown Muni Water System | y | | | | | | | | | | | | | | | | | | | y | | | |
| Bethlehem, (City of) | y | | | | | y | | y | y | y | | | | | | | | | | | | | |
| Bryn Mawr/Philadelphia Suburban Water Co. | | | y | | | y | | y | y | y | | | | | | | | | | y | | | |
| Harrisburg/United Water PA | y | | | | | | | y | | y | | | | | | | | | | y | | | |
| Lancaster, (City of) Water Bureau | y | | | | | y | | y | | | | | | | | | | | | y | | | |
| Philadelphia Water Dept | | | y | | | y | | | | y | | | | | | | | | | y | | | |
| Pittsburgh/West View Water Auth | y | | | | | y | | y | y | | | | | | | | | | y | y | | | |
| Reading Area Water Auth | | | y | | | y | | y | | y | | | | | | | | | | y | | | |
| The York Water Co. | | | y | | | | | y | | | | | | | | | y | | | y | | | |
| **RHODE ISLAND** | | | | | | | | | | | | | | | | | | | | | | | |
| Pawtucket Water Supply Board | y | | | | | y | | y | | y | | | | | | | | | | | | | |
| **SOUTH CAROLINA** | | | | | | | | | | | | | | | | | | | | | | | |
| Charleston Comm Public Works | y | y | y | | | y | | y | | y | | | | | | | | | | y | | | |
| Spartanburg Water System | y | | | | | y | | y | | y | | | | | | | y | | | y | | | |
| **SOUTH DAKOTA** | | | | | | | | | | | | | | | | | | | | | | | |
| Sioux Falls, (City of) | y | | | | | y | | y | | | | | | | | | | | | y | | | |
| **TENNESSEE** | | | | | | | | | | | | | | | | | | | | | | | |
| Chattanooga/TN-American Water Co. | y | | | | | y | | y | | y | | | | | | | | | y | y | | | |
| Memphis Light Gas & Water | y | | | | | y | | | | y | | | | | | | | | | | | | |
| Nashville/Metro Water Services | y | | | | | y | | | | y | | | | | | | | | | y | | | |
| **TEXAS** | | | | | | | | | | | | | | | | | | | | | | | |
| Abilene, (City of) | | | y | | | | | y | y | y | | | | | | | | | | | | | |
| Amarillo Muni Water System | y | | | | | | | | | | | | | | | | | | | y | | | |
| Arlington/Trinity River Auth | | | y | | | y | | y | | | | | | | | | | | | | | | |
| Austin, (City of) Water/WW | | | y | | | y | | | | | | | | | | | | | | y | | | |
| Dallas Water Util | | | y | | | y | | y | y | | | | | | | | | | | y | | | |
| El Paso Water Util | y | | | | | | | | | y | | | | | | | | | y | y | | | y |
| Gavelston, (City of) Dept Pub Wks | y | | y | | | | | y | | | | | | | | | | | | | | | |
| Houston, (City of) | y | | y | | | y | | y | | | | | | | | | | | | y | | | |
| Killeen/Bell County WCID #1 | | | y | | | y | | | | | | | | | | | | | | | | | |
| Lubbock, (City of) Water Util | | | | | | | | | | | | | | | | | | | | y | | | |
| San Antonio Water System | | | | | | | | | | | | | | | | | | | | | | | |
| Wichita Falls, (City of) | | | y | | | y | | y | y | | | | | | | | | | | y | | | |
| **UTAH** | | | | | | | | | | | | | | | | | | | | | | | |
| Layton/Weber Basin Water Cons Dist | y | | | | | | | | | | | | | | | | | | y | y | | | |
| Orem/Central Utah Water Cons Dist | y | | | | | | | | | | | | | | | | | | | y | | | |
| Salt Lake City/Metropolitan Water Dist | y | | | | | | | y | y | | | | | | | | | | | | | | |
| Salt Lake City Public Util | y | | | | | | | | y | | | | | | | | | | | | | | |
| West Jordan/Salt Lake Cnty Water Cons Dist | y | | | | | | | y | | | | | | | | | | | | y | | | |
| **VIRGINIA** | | | | | | | | | | | | | | | | | | | | | | | |
| Chesapeake, (City of) | y | | y | | | y | | | | y | | | | | | | | | | y | | y | |
| Chesterfield County Util Dept | y | | | | | y | | | | y | | | | | | | y | | | | | | |
| Merrifield/Fairfax County Water Auth | y | | y | | | y | | y | y | | | | | | | | | | y | | | | |
| Newport News Waterworks | y | | | | | y | | y | y | y | | | | | | | y | | | y | | | |
| Petersburg/Appomattox River Water Auth | y | | | | | y | | y | | y | | | | | | | y | | y | | | | |
| Richmond/Henrico Co Public Util | | | | | | | | | | y | | | | | | | | | | | | | |
| Richmond Dept of Public Util | | | y | | | y | | | | y | | | | | | | | | | y | | | |
| Woodbridge/Prince William Co. Service Auth | | | | | | | | | | | | | | | | | | | | | | | |
| **WASHINGTON** | | | | | | | | | | | | | | | | | | | | | | | |
| Everett Water Util | y | | | | | y | | y | y | | | | | | | | | | | | | | |
| Seattle Water Dept | | | | | | | | | | | | | | | | | | | | | | | |
| Tacoma Public Util | | | | | | y | | y | | | | | | | | | | | | | | y | |
| Vancouver, (City of) | y | | | | | y | | | | | | | | | | | y | y | | | | y | y |
| **WISCONSIN** | | | | | | | | | | | | | | | | | | | | | | | |
| Green Bay Water Util | y | | | | | y | | | | | | | | | | | y | | | y | | | |
| Kenosha Water Util | y | | | | | y | | | | | | | | | | | | | | | | | |
| Madison Water Util | | | | | | y | | | | | | | | | | | | | | | | | |
| Milwaukee Water Works | y | | y | | | y | | | | | | | | | | | | | | y | | | |
| Sheboygan Water Util | y | | | | | y | | | | y | | | | | | | | | | y | | | |
| **WEST VIRGINIA** | | | | | | | | | | | | | | | | | | | | | | | |
| Charleston/WV-American Water Co.-Kanawha Valley District | y | | | | | y | | | | y | | | | | | | | | | y | | | |

*Note:* Selected utilities serving a population of 100,000 or more.

*Source*: Adapted from water:\Stats: 1996 Survey, by permission. Copyright © 2000, American Water Works Associations. (Updated information available electronically from AWWA at 800-926-7337), www.awwa.org.

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**Table 8J.144 Water Treatment Processes Considered for Best Available Technology**

| Conventional Processes | Advanced Processes |
|---|---|
| Coagulation, sedimentation, filtration | Activated alumina |
| Direct filtration | Adsorption |
| Diatomaceous earth filtration | GAC |
| Slow sand filtration | Powdered activated carbon |
| Lime softening | Resins |
| Ion exchange | Aeration |
| Oxidation-disinfection | Packed column |
| Chlorination | Diffused air |
| Chorine dioxide | Spray |
| Chloramines | Slat tray |
| Ozone | Mechanical |
| Bromine | Cartridge filtration |
| Others | Electrodialysis |
| | Reverse osmosis |
| | Ultrafiltration |
| | Ultraviolet light (UV) |
| | UV with other oxidants |

*Source*: From Dyksen, J.E., Hiltebrand, D.J., and Raczko. R.F., 1988, SDWA amendments: effects on the water industry. *J. Am. Water Works Assoc.*, vol. 80, no. 1. Copyright AWWA. Reprinted with permission.

**Table 8J.145 Chemicals Used for Treatment by Public Water-Supply Systems in the United States and Canada**

| Chemical | Total Use Tons |
|---|---|
| Quick lime | 330,988 |
| Aluminum sulfate | 188,986 |
| Chlorine | 79,034 |
| Hydrated lime | 44,679 |
| Caustic soda | 39,030 |
| Carbon dioxide | 18,111 |
| Soda ash | 13,750 |
| Ferrous sulfate | 10,590 |
| Powdered activated carbon | 9,016 |
| Ferric sulfate | 7,956 |
| Sodium silicofluoride | 7,903 |
| Polyelectrolytes | 5,915 |
| Ammonia | 5,232 |
| Phosphate | 3,970 |
| Copper sulfate | 2,825 |
| Granular activated carbon | 2,587 |
| Potassium permanganate | 1,231 |
| Sodium aluminate | 1,129 |
| Hypochlorites | 1,112 |
| Sodium chloride | 828 |
| Clays | 133 |

*Note:* Based on data from 430 of the largest U.S. utilities and 24 of the 75 largest Canadian utilities.

*Source*: From American Water Works Association, 1988. Grigg, N.S., 1984 Water Utility Operating Data, Summary Report. Reprinted with permission.

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**Table 8J.146 Costs of Some Water Treatment Technologies**

| Population Range | Type of Treatment | Cost per Family per Year |
|---|---|---|
| 501–1,000 | conventional coagulation | $125 |
| 50,001–75,000 | filtration and disinfection to | $ 50 |
| >1,000,000 | control microbial contaminants | $ 25 |
| 501–1,000 | corrosion control (stabilization | $ 60 |
| 50,001–75,000 | with lime) to control lead and | $ 15 |
| >1,000,000 | other corrosion products | <$ 10 |
| 501–1,000 | packed tower aeration to | $ 55 |
| 50,000–75,000 | control organic chemicals | $ 28 |
| >1,000,000 | | $ 20 |
| 501–1,000 | granular activated carbon to | $190 |
| 50,001–75,000 | control synthetic organic | $130 |
| >1,000,000 | chemicals | $ 40 |

*Note:* Basic Assumptions: 3.2 persons per household; each person using 180 gallons per day; total cost per household including operation, maintenance and amortization of capital at 10 percent per year for 20 years.

*Source*: From U.S. Environmental Protection Agency; League of Women Voters Education Fund, 1987, Safety on Tap. Reprinted with permission.

**Table 8J.147 Cost of Treating Contaminated Groundwater (Portable Treatment Systems, 1987)**

| Unit type | Cost (dollars/unit[a]) |
|---|---|
| *In situ* biological treatment (suspended growth reactor) | $15–40/cu yd, treated |
| Rotating biodisks | 0.20–1.10 |
| Trickling filter | 0.08–0.15 |
| Activated sludge | 0.10–0.30 |
| Packed towers | 0.02–0.10 |
| Aeration basins | 0.02–0.08 |
| Carbon adsorption | 0.20–0.90 |
| Ultraviolet/hydrogen peroxide | 0.04–0.18 |
| Belt press | 0.01–0.05 |
| Mixing tangs (including chemicals) | 0.03–0.29 |
| Equalization tanks | 0.005–0.01 |
| Clarifiers | 0.008–0.06 |
| Solidification of solids in situ | 0.20–1.00 |

*Note:* Portable treatment systems — 1987.

[a] All costs per 1,000 gal except as noted.

*Source*: From Estimated by Geraghty & Miller Inc Oak Ridge, TN.

**Table 8J.148 Treatment Costs for Removal of Trichloroethylene from Drinking Water [US Dollars; Cost Data as of 1984]**

| | Treatment Technique | | | | | |
|---|---|---|---|---|---|---|
| | GAC absorption[a] | | | Packed-Tower Aeration[b] | | |
| | System Size | | | | | |
| Cost Component[c] | 0.037 mgd | 0.95 mgd | 36.8 mgd | 0.037 mgd | 0.95 mgd | 36.8 mgd |
| Capital[d] (*Thousand$)* | 24 | 240 | 9,000 | 69 | 264 | 4,789 |
| Annual O&M (*Thousand $*) | 4.5 | 86 | 710 | 1.4 | 18 | 617 |
| Total (¢ per 1,000 gal) | 57.0 | 34.0 | 14.0 | 79.0 | 15.5 | 9.4 |

*Note:* Raw water concentration 500 ug/L; assuming 99-percent removal.

[a] Based on 10-min empty bad contact time.
[b] Does not include air pollution controls.
[c] USEPA estimates in August 1983 dollars.
[d] Includes site work, engineering, contractor overhead and profit, and contingencies.

*Source*: From American Water Works Association, 1988, *New Dimensions in Safe Drinking Water*. Copyright AWWA. Reprinted with permission.

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**Table 8J.149 Cost of Removal of Volatile Organic Chemicals in Drinking Water**

| | Capacity[a] | | | Cost (Dollars per Thousand Gallons)[b] | | |
|---|---|---|---|---|---|---|
| Contaminant (1) | Millions of Gallons per Day (2) | μg/L (3) | Percent Removal (4) | Tower (5) | Aeration Basin (6) | Carbon Adsorption (7) |
| Trichloroethylene | 0.5 | 100 | 90 | 0.273 | 0.546 | 0.868 |
| | | 10 | 99 | 0.287 | 0.793 | 0.918 |
| | | 1 | 99.9 | 0.296 | 1.032 | 1.010 |
| | | 0.1 | 99.99 | 0.303 | 1.270 | 1.124 |
| | 1 | 100 | 90 | 0.182 | 0.383 | 0.637 |
| | | 10 | 99 | 0.191 | 0.611 | 0.679 |
| | | 1 | 99.9 | 0.196 | 0.850 | 0.765 |
| | | 0.1 | 99.99 | 0.202 | 1.088 | 0.867 |
| | 10 | 100 | 90 | 0.083 | 0.207 | 0.356 |
| | | 10 | 99 | 0.088 | 0.403 | 0.390 |
| | | 1 | 99.9 | 0.093 | 0.587 | 0.458 |
| | | 0.1 | 99.99 | 0.099 | 0.755 | 0.543 |
| Tetrachloroethylene | 0.5 | 100 | 90 | 0.279 | 0.637 | 0.610 |
| | | 10 | 99 | 0.293 | 0.935 | 0.660 |
| | | 1 | 99.9 | 0.302 | 1.228 | 0.705 |
| | | 0.1 | 99.99 | 0.308 | 1.486 | 0.805 |
| | 1 | 100 | 90 | 0.186 | 0.460 | 0.453 |
| | | 10 | 99 | 0.194 | 1.752 | 0.502 |
| | | 1 | 99.9 | 0.201 | 1.046 | 0.548 |
| | | 0.1 | 99.99 | 0.206 | 1.296 | 0.651 |
| | 10 | 100 | 90 | 0.085 | 0.277 | 0.197 |
| | | 10 | 99 | 0.091 | 0.514 | 0.224 |
| | | 1 | 99.9 | 0.098 | 0.726 | 0.251 |
| | | 0.1 | 99.99 | 0.103 | 0.905 | 0.313 |
| 1.1.1-Trichloroethane | 0.5 | 100 | 90 | 0.270 | 0.502 | 1.445 |
| | | 10 | 99 | 0.289 | 0.825 | 1.651 |
| | | 1 | 99.9 | 0.307 | 1.421 | 1.945 |
| | | 0.1 | 99.99 | 0.332 | 2.572 | 2.605 |
| | 1 | 100 | 90 | 0.180 | 0.348 | 1.396 |
| | | 10 | 99 | 0.192 | 0.644 | 1.500 |
| | | 1 | 99.9 | 0.205 | 1.234 | 1.801 |
| | | 0.1 | 99.99 | 0.230 | 2.313 | 2.402 |
| | 10 | 100 | 90 | 0.082 | 0.176 | 0.802 |
| | | 10 | 99 | 0.089 | 0.430 | 0.973 |
| | | 1 | 99.9 | 0.102 | 0.860 | 1.229 |
| | | 0.1 | 99.99 | 0.122 | 1.821 | 1.818 |
| Carbon tetrachloride | 0.5 | 100 | 90 | 0.264 | 0.428 | 0.942 |
| | | 10 | 99 | 0.287 | 0.531 | 1.021 |
| | | 1 | 99.9 | 0.272 | 0.600 | 1.132 |
| | | 0.1 | 99.99 | 0.280 | 0.648 | 1.340 |
| | 1 | 100 | 90 | 0.176 | 0.292 | 0.703 |
| | | 10 | 99 | 0.181 | 0.371 | 0.775 |
| | | 1 | 99.9 | 0.184 | 0.427 | 0.940 |
| | | 0.1 | 99.99 | 0.186 | 0.470 | 1.063 |
| | 10 | 100 | 90 | 0.081 | 0.133 | 0.408 |
| | | 10 | 99 | 0.683 | 0.196 | 0.467 |
| | | 1 | 99.9 | 0.084 | 0.247 | 0.550 |
| | | 0.1 | 99.99 | 0.085 | 0.286 | 0.719 |
| Cis-1,2-Dichloroethylene | 0.5 | 100 | 90 | 0.284 | 0.727 | 2.513 |
| | | 10 | 99 | 0.296 | 1.010 | 2.791 |
| | | 1 | 99.9 | 0.304 | 1.281 | 3.153 |
| | | 0.1 | 99.99 | 0.310 | 1.572 | 3.511 |
| | 1 | 100 | 90 | 0.189 | 0.547 | 2.156 |
| | | 10 | 99 | 0.196 | 0.828 | 2.417 |
| | | 1 | 99.9 | 0.202 | 1.098 | 2.760 |
| | | 0.1 | 99.99 | 0.206 | 1.379 | 3.099 |

*(Continued)*

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**Table 8J.149 (Continued)**

| Contaminant (1) | Capacity[a] Millions of Gallons per Day (2) | Capacity[a] μg/L (3) | Percent Removal (4) | Cost (Dollars per Thousand Gallons)[b] Tower (5) | Aeration Basin (6) | Carbon Adsorption (7) |
|---|---|---|---|---|---|---|
| | 10 | 100 | 90 | 0.087 | 0.350 | 1.735 |
| | | 10 | 99 | 0.093 | 0.571 | 1.989 |
| | | 1 | 99.9 | 0.099 | 0.763 | 2.327 |
| | | 0.1 | 99.99 | 0.104 | 0.966 | 2.660 |
| 1,2-Dichloroethane | 0.5 | 100 | 90 | 0.276 | 0.587 | 1.286 |
| | | 10 | 99 | 0.285 | 0.749 | 1.465 |
| | | 1 | 99.9 | 0.292 | 0.901 | 1.748 |
| | | 0.1 | 99.99 | 0.297 | 1.054 | 2.322 |
| | 1 | 100 | 90 | 0.184 | 0.415 | 1.015 |
| | | 10 | 99 | 0.190 | 0.568 | 1.177 |
| | | 1 | 99.9 | 0.194 | 0.720 | 1.437 |
| | | 0.1 | 99.99 | 0.197 | 0.871 | 2.980 |
| | 10 | 100 | 90 | 0.084 | 0.237 | 0.675 |
| | | 10 | 99 | 0.087 | 0.368 | 0.820 |
| | | 1 | 99.9 | 0.090 | 0.489 | 1.057 |
| | | 0.1 | 99.99 | 0.094 | 0.603 | 1.566 |
| 1,1-Dichlorethylene | 0.5 | 100 | 90 | 0.262 | 0.406 | 0.880 |
| | | 10 | 99 | 0.265 | 0.448 | 0.963 |
| | | 1 | 99.9 | 0.270 | 0.500 | 1.066 |
| | | 0.1 | 99.99 | 0.272 | 0.531 | 1.243 |
| | 1 | 100 | 90 | 0.174 | 0.274 | 0.647 |
| | | 10 | 99 | 0.177 | 0.307 | 0.721 |
| | | 1 | 99.9 | 0.180 | 0.348 | 0.814 |
| | | 0.1 | 99.99 | 0.181 | 0.371 | 0.977 |
| | 10 | 100 | 90 | 0.080 | 0.121 | 0.364 |
| | | 10 | 99 | 0.081 | 0.144 | 0.423 |
| | | 1 | 99.9 | 0.082 | 0.176 | 0.499 |
| | | 0.1 | 99.99 | 0.083 | 0.196 | 0.640 |

*Note:* US dollars; cost data as of 1984.

[a] To convert from mgd to $m^3$/day, multiply by 3,785.
[b] To convert from dollars/1,000 gal to dollars/$m^3$ multiply by 0.26412.

*Source*: From Clark, R.M., Eilers, R.G., and Goodrich, J.A., 1984, *VOC's in Drinking Water: Cost of Removal*, U.S. Environmental Protection Agency, Cincinnati, OH 45268; PB85-166429.

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**Table 8J.150 Cost of Removal of MTBE from Drinking Water for Various Treatment Systems**

| | | | | Air Stripping | | | AOPs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Flow (gpm)** | **Influent (μg/L)** | **Effluent (μg/L)** | **Removal (%)** | **Packed Tower** | **Low Profile** | **Packed Tower w/OGT** | **$H_2O_2$/ MP-UV** | **$O_3/H_2O_2$** | **GAC** | **Resin Sorption** | **Lowest Unit Cost Amongst the Technologies Evaluated** |
| 60 | 20 | 5 | 75.00 | **$1.66** | NE | NR | $2.18 | $2.63 | NE | $2.50 | Packed Tower |
| | 20 | 0.5 | 97.50 | **$1.75** | $1.86 | NR | $2.50 | $2.68 | $2.30 | $2.81 | Packed Tower |
| | 200 | 20 | 90.00 | **$1.66** | $1.70 | NR | $2.32 | $2.65 | NE | $4.16 | Packed Tower |
| | 200 | 5 | 97.50 | **$1.75** | $1.80 | NR | $2.50 | $2.68 | NE | $4.16 | Packed Tower |
| | 200 | 0.5 | 99.75 | **$1.82** | $1.89 | NR | $2.72 | $2.98 | $3.10 | $4.16 | Packed Tower |
| | 2,000 | 20 | 99.00 | $1.79[a] | $1.90 | **$3.08** | $3.07 | $3.29 | NE | $4.56 | Packed Tower with OGT |
| | 2,000 | 5 | 99.75 | $1.82[a] | $2.02 | **$3.20** | $3.47 | $3.31 | NE | $4.57 | Packed Tower with OGT |
| | 2,000 | 0.5 | 99.98 | NE | NE | NE | $4.11 | **$3.62** | $4.61 | $4.57 | $O_3/H_2O_2$ |
| 600 | 20 | 5 | 75.00 | $0.30 | $0.78 | NR | $0.57 | $0.82 | NE | $1.01 | Packed Tower |
| | 20 | 0.5 | 97.50 | $0.34 | $0.92 | NR | $0.91 | $0.90 | $0.77 | $1.01 | Packed Tower |
| | 200 | 20 | 90.00 | $0.32[a] | $0.85 | **$0.57** | $0.71 | $0.84 | NE | $1.16 | Packed Tower with OGT |
| | 200 | 5 | 97.50 | $0.34[a] | $0.96 | **$0.59** | $0.96 | $0.90 | NE | $1.17 | Packed Tower with OGT |
| | 200 | 0.5 | 99.75 | $0.37[a] | $1.09 | **$0.62** | $1.27 | $0.95 | $1.15 | $1.17 | Packed Tower with OGT |
| | 2,000 | 20 | 99.00 | $0.36[a] | $0.96 | **$0.90** | $1.52 | $1.07 | NE | $1.32 | Packed Tower with OGT |
| | 2,000 | 5 | 99.75 | $0.37[a] | $1.09 | **$0.91** | $1.75 | $1.13 | NE | $1.36 | Packed Tower with OGT |
| | 2,000 | 0.5 | 99.98 | NE | NE | NE | $2.08 | **$1.19** | $2.37 | $1.38 | $O_3/H_2O_2$ |
| 6,000 | 20 | 5 | 75.00 | $0.13[a] | $0.34 | $0.36 | $0.32 | $0.35 | NE | **$0.30** | Resin Sorption |
| | 20 | 0.5 | 97.50 | $0.16[a] | $0.48 | $0.39 | $0.52 | $0.43 | $0.50 | **$0.36** | Resin Sorption |
| | 200 | 20 | 90.00 | $0.15[a] | $0.41 | $0.38 | $0.42 | **$0.37** | NE | $0.39 | $O_3/H_2O_2$ |
| | 200 | 5 | 97.50 | $0.16[a] | $0.48 | **$0.39** | $0.60 | $0.43 | NE | $0.41 | Packed Tower with OGT |
| | 200 | 0.5 | 99.75 | $0.17[a] | $0.64 | **$0.40** | $0.74 | $0.48 | $0.97 | $0.41 | Packed Tower with OGT |
| | 2,000 | 20 | 99.00 | $0.17[a] | NE | NE | $0.65 | $0.56 | NE | **$0.53** | Resin Sorption |
| | 2,000 | 5 | 99.75 | $0.18[a] | NE | NE | $1.24 | $0.59 | NE | **$0.54** | Resin Sorption |
| | 2,000 | 0.5 | 99.98 | NE | NE | NE | $1.59 | $0.68 | $2.22 | **$0.58** | Resin Sorption |

*Note:* Costs are in 1999 dollars, total amortized costs 1,000 gallons; NE, not evaluated due to lack of data; NR, off-gas treatment not required; Bold numbers indicate the lowest unit cost amongst the technologies evaluated; OGT, off-gas treatment; AOP, Treatment Costs for byproduct and residual oxidant removal not included.

[a] Off-gas treatment is expected to be required based on 1 lb/day emission standards.

*Source*: From Stocking, A. et al., 2000, Appendix 24, MTBE Treatability, Executive Summary, Treatment Technologies for Removal of Methyl Tertiary Butyl Ether (MTBE) from *Drinking Water: Air Stripping, Advanced Oxidation Processes, Granular Activated Carbon, Synthetic Resin Sorbents*, Second Edition, February 2000, Written for the California Agencies MTBE Research Partnership, Center for Groundwater Restoration and Protection, National Water Research Institute, NWRI-99-08, www.nwri-usa.org.



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## SECTION 8K WATER TREATMENT FACILITIES

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**Table 8K.151 Data on Selected Large Rapid-Sand Filter Plants in the United States**

| | Chemical Feed and Mix | | | | | Sedimentation | | | | Filtration | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| City | Capacity (mgd) | Type Feed | Alum Used (Grains/gal) | Lime Used (Grains/gal) | Mixing Time (min) | Type of Mix | Time (hr) | Flow V (ft/min) | Basin Depth (ft) | Filter Rate (mgd/acre) | Unit Size (mgd) | Sand Depth (in.) | Sand Size (mm) | Gravel Depth (in.) | Wash Rate (in./min) | Wash Water (percent) |
| Detroit, MI | 320 | Dry | 0.74 | 0 | 3 | Baffles | 2.0 | 4.2 | 16 | 160 | 4 | 30 | 0.45 | 17 | 26–30 | 2.0 |
| Milwaukee, WI | 200 | Dry | 0.5 | 0.11 | 64 | Mechanical | 4.0 | 2.32 | 27 | 125 | 6.25 | 27 | 0.51 | 24 | 24 | 2.2 |
| St. Louis, MO | 160 | Solution | 1.2 | 4.7 | 45 | Baffles | 36.0 | 1.5 | 16–23 | 125 | 4 | 30 | 0.4 | 12 | 24 | 1.67 |
| Louisville, KY | 120 | Dry | 0.65 | 0.31 | — | None | 2.0 | 5.7 | 17.5 | 125 | 6 and 3 | 26–30 | 0.4–0.5 | 14–24 | 22–36 | 2.0 |
| Toledo, OH | 80 | Dry | 1.12 | 0.5 | 40 | Mechanical | 2.8 | 1.5 | 15 | 94 | 2 | 22 | 0.42 | 18 | 20 | 2.43 |
| Denver, CO | 64 | Dry | 0.1–1.0 | 0.05–0.5 | 20 | Baffles | 1.0 | 12.0 | 13.5 | 156 | 4.5 | 48[a] | 0.62 | 15 | 25 | 1.4 |
| Atlanta, GA | 54 | Dry | 0.59 | 0.26 | 23 | Baffles | 9.3 | 0.7 | 14–24 | 125 | 3 and 5 | 24–27 | 0.4–0.5 | 18 | 30 | 1.3 |
| Dallas, TX | 48 | Dry | 1.0 | 5.2 | 12 | Baffles | 8.0 | 1.1 | 18 | 120 | 2 | 30 | 0.4–0.45 | 18 | 20 | 1.5 |
| New Orleans, LA | 40 | Solution | 0.75 | 5.0 | 60 | Baffles | 18.0 | 0.55 | 13.75 | 122 | 4 | 30 | 0.33 | 9 | 24 | 0.3 |
| Albany, NY | 32 | Dry | 1.5 | 0 | 20 | Baffles | 2.25 | 1.5 | 10–18 | 125 | 4 | 30 | 0.33 | 18 | 24 | 2.5 |
| Richmond, VA | 30 | Dry | 2.0 | 0 | 10 | Combined | 10.0 | 6.0 | 10 | 120 | 3 | 26 | 0.43 | 16 | 24 | 1.0 |

[a] Coal.

*Source*: From Cosens, *J. Am. Water Works Assoc*, 1956.



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**Table 8K.152 Community Water System Treatment Schemes (Percentage of Plants Using Each Treatment Scheme)**

| | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Water Source** | **100 or Less** | **101–500** | **501–3,300** | **3,301–10,000** | **10,001–50,000** | **50,001–100,000** | **100,001–500,000** | **Over 500,000** | **All Sizes** |
| **Groundwater Plants** | | | | | | | | | |
| Disinfection with no additional treatment | 68.7 | 55.5 | 52.1 | 37.4 | 43.5 | 54.2 | 60.3 | 84.1 | 54.5 |
| Other chemical addition | 7.7 | 21.7 | 11.4 | 30.5 | 15.8 | 15.0 | 2.7 | 0.6 | 16.1 |
| Ion exchange, activated alumina, aeration | 0.0 | 9.8 | 22.0 | 18.7 | 23.1 | 25.3 | 14.1 | 14.9 | 13.7 |
| Other filtration (not direct or conventional) | 12.3 | 9.5 | 3.9 | 4.6 | 9.0 | 0.6 | 7.0 | 0.2 | 7.6 |
| Direct filtration | 0.1 | 0.0 | 0.1 | 0.2 | 0.3 | 0.6 | 0.2 | 0.0 | 0.1 |
| Conventional filtration | 0.0 | 0.0 | 0.0 | 2.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| Membranes | 1.1 | 0.0 | 0.1 | 0.5 | 0.0 | 0.6 | 0.6 | 0.0 | 0.3 |
| Softening | 10.0 | 3.6 | 6.9 | 5.5 | 6.9 | 1.4 | 3.7 | 0.2 | 6.1 |
| Observations | 83 | 98 | 127 | 125 | 168 | 191 | 394 | 469 | 1,655 |
| **Surface Water Plants** | | | | | | | | | |
| Disinfection with no additional treatment | 50.0 | 14.3 | 3.6 | 1.0 | 0.3 | 0.0 | 2.4 | 2.6 | 10.7 |
| Other chemical addition | 0.0 | 0.0 | 4.3 | 1.0 | 0.0 | 1.0 | 4.2 | 6.0 | 1.5 |
| Ion exchange, activated alumina, aeration | 0.0 | 2.3 | 2.1 | 7.1 | 6.5 | 5.3 | 4.6 | 10.2 | 4.0 |
| Other filtration (not direct or conventional) | 12.8 | 28.4 | 14.5 | 6.0 | 0.0 | 11.1 | 2.3 | 0.0 | 11.8 |
| Direct filtration | 7.2 | 18.8 | 9.2 | 16.9 | 15.5 | 8.9 | 13.5 | 15.4 | 13.5 |
| Conventional filtration | 11.9 | 8.9 | 37.4 | 35.7 | 59.2 | 60.7 | 64.5 | 45.4 | 34.7 |
| Membranes | 6.4 | 5.8 | 1.3 | 1.0 | 0.0 | 0.0 | 0.6 | 0.9 | 2.5 |
| Softening | 11.7 | 20.8 | 27.6 | 30.2 | 16.3 | 12.9 | 6.7 | 12.0 | 20.6 |
| Observations | 50 | 58 | 76 | 82 | 85 | 81 | 169 | 115 | 716 |
| **Mixed Plants** | | | | | | | | | |
| Disinfection with no additional treatment | 0.0 | 89.8 | 100.0 | 46.7 | 14.2 | 0.0 | 3.2 | 0.0 | 51.5 |
| Other chemical addition | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 0.0 | 14.2 | 0.0 | 1.8 |
| Ion exchange, activated alumina, aeration | 0.0 | 0.0 | 0.0 | 14.6 | 0.0 | 28.5 | 16.3 | 0.0 | 5.9 |
| Other filtration (not direct or conventional) | 0.0 | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 3.2 | 0.0 | 1.6 |
| Direct filtration | 0.0 | 6.8 | 0.0 | 7.3 | 9.6 | 0.0 | 3.2 | 0.0 | 6.8 |
| Conventional filtration | 100.0 | 0.0 | 0.0 | 16.8 | 31.5 | 57.1 | 40.5 | 100.0 | 17.9 |
| Membranes | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Softening | 0.0 | 0.0 | 0.0 | 14.6 | 42.0 | 14.4 | 16.3 | 0.0 | 14.2 |
| Observations | 1 | 3 | 1 | 9 | 11 | 4 | 29 | 6 | 64 |
| **All Plants** | | | | | | | | | |
| Disinfection with no additional treatment | 67.0 | 52.9 | 47.5 | 31.8 | 33.5 | 37.3 | 43.9 | 68.5 | 49.4 |
| Other chemical addition | 7.0 | 19.8 | 10.7 | 25.1 | 12.1 | 10.6 | 3.6 | 1.5 | 14.3 |
| Ion exchange, activated alumina, aeration | 0.0 | 9.1 | 20.1 | 16.7 | 19.0 | 19.3 | 11.9 | 13.9 | 12.5 |
| Other filtration (not direct or conventional) | 12.4 | 10.8 | 4.9 | 4.7 | 6.9 | 3.7 | 5.7 | 0.2 | 8.0 |
| Direct filtration | 0.7 | 1.5 | 1.0 | 3.1 | 3.8 | 3.1 | 3.6 | 2.8 | 1.7 |
| Conventional filtration | 1.1 | 0.7 | 3.5 | 8.2 | 13.5 | 18.9 | 17.3 | 9.1 | 4.4 |
| Membranes | 1.6 | 0.4 | 0.2 | 0.6 | 0.0 | 0.4 | 0.6 | 0.2 | 0.5 |
| Softening | 10.2 | 4.8 | 8.9 | 9.6 | 9.7 | 5.0 | 4.9 | 2.3 | 7.8 |
| Observations | 134 | 159 | 204 | 216 | 264 | 276 | 592 | 590 | 2,435 |

*Note:* Excludes plants that treat purchased water. The tabulations presented in the Community Water-System Survey 2000 are based on data collected from a sample of U.S. Water Systems, not from a census of every water system in the United States.

*Source*: From USEPA, 2002, *Community Water System Survey 2000*, EPA 815-R-02-005A.

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**Table 8K.153 Community Water System Surface Water Treatment Practices (Percentage of Plants Performing Each Treatment)**

| | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Surface Water Treatment Practice** | **100 or Less** | **101–500** | **501–3,300** | **3,301–10,000** | **10,001–50,000** | **50,001–100,000** | **100,001–500,000** | **Over 500,000** | **All Sizes** |
| Chlorination only | 49.5 | 32.4 | 7.9 | 6.0 | 0.3 | 1.0 | 6.8 | 10.2 | 16.2 |
| Raw water storage/ presedimentation basin | 12.5 | 20.5 | 11.5 | 16.3 | 20.5 | 29.8 | 19.1 | 26.5 | 17.3 |
| Predisinfection/oxidation prior to sedimentation | | | | | | | | | |
| Chlorine | 18.6 | 2.9 | 37.6 | 50.9 | 51.7 | 45.8 | 52.2 | 45.4 | 34.5 |
| Chlorine dioxide | 0.0 | 0.0 | 0.0 | 3.0 | 3.9 | 11.4 | 7.4 | 4.3 | 2.2 |
| Chloramines | 0.0 | 0.0 | 0.0 | 1.0 | 8.3 | 0.0 | 10.0 | 11.1 | 2.4 |
| Ozone | 0.5 | 0.9 | 0.0 | 1.0 | 0.0 | 5.3 | 3.9 | 6.0 | 1.0 |
| Potassium permanganate | 0.0 | 1.1 | 24.9 | 29.4 | 37.1 | 29.2 | 27.8 | 26.6 | 20.3 |
| Other predisinfection | 0.0 | 0.0 | 4.8 | 1.0 | 0.0 | 0.0 | 1.7 | 0.0 | 1.3 |
| Predisinfection/oxidation prior to filtration | | | | | | | | | |
| Chlorine | 7.4 | 11.9 | 24.2 | 24.3 | 35.4 | 38.3 | 31.5 | 37.7 | 23.0 |
| Chlorine dioxide | 0.0 | 2.0 | 0.0 | 0.0 | 1.1 | 2.0 | 2.8 | 0.0 | 0.8 |
| Chloramines | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | 1.3 | 6.9 | 7.7 | 1.4 |
| Ozone | 0.0 | 15.3 | 0.0 | 0.0 | 1.1 | 2.3 | 4.1 | 6.0 | 3.5 |
| Potassium permanganate | 0.0 | 1.2 | 6.9 | 10.1 | 5.5 | 7.8 | 3.9 | 2.6 | 5.0 |
| Other predisinfection | 0.0 | 0.0 | 4.4 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 1.0 |
| Rapid mix | 7.8 | 13.1 | 43.3 | 67.5 | 90.9 | 75.6 | 77.8 | 62.4 | 48.9 |
| Coagulation/flocculation | 11.0 | 22.6 | 63.1 | 87.9 | 96.4 | 82.0 | 85.2 | 77.0 | 60.8 |
| Polymers | 15.5 | 21.5 | 54.4 | 63.7 | 62.1 | 53.4 | 58.4 | 53.9 | 46.0 |
| Setting/sedimentation | 11.9 | 15.9 | 60.8 | 67.9 | 79.8 | 74.7 | 71.7 | 63.3 | 51.5 |
| Softening | | | | | | | | | |
| Lime/soda ash | 0.0 | 20.8 | 27.6 | 34.2 | 20.7 | 12.9 | 7.2 | 12.0 | 20.5 |
| Recarbonation | 0.0 | 0.0 | 0.0 | 6.1 | 7.7 | 5.0 | 4.4 | 3.4 | 2.9 |
| Ion exchange | 11.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 |
| Filtration | | | | | | | | | |
| Direct filtration | 2.6 | 2.3 | 0.8 | 8.1 | 5.3 | 4.0 | 9.6 | 6.8 | 4.1 |
| Micro strainer | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.9 | 0.1 |
| Slow sand | 4.9 | 10.8 | 4.8 | 3.1 | 0.0 | 0.0 | 1.7 | 0.0 | 4.3 |
| Bag and cartridge | 18.9 | 18.6 | 0.0 | 0.0 | 1.0 | 0.0 | 0.6 | 0.0 | 6.3 |
| Rapid sand | 0.0 | 9.4 | 24.5 | 32.5 | 17.6 | 7.9 | 16.2 | 23.2 | 17.3 |
| Green sand | 0.7 | 0.0 | 3.0 | 1.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.9 |
| Diatomaceous earth | 2.6 | 1.0 | 2.5 | 2.0 | 0.0 | 13.1 | 2.9 | 0.0 | 2.2 |
| Dual/multi media | 13.7 | 14.0 | 51.8 | 46.6 | 73.2 | 68.7 | 59.3 | 52.1 | 43.5 |
| Pressure filtration | 9.5 | 20.7 | 2.2 | 2.6 | 0.0 | 2.0 | 0.0 | 0.0 | 6.2 |
| Other filtration | 0.6 | 0.8 | 4.1 | 0.0 | 3.9 | 2.3 | 3.0 | 2.6 | 2.1 |
| Post-disinfection after filters | | | | | | | | | |
| Chlorine | 27.8 | 58.3 | 77.4 | 85.3 | 83.7 | 75.3 | 74.5 | 53.9 | 68.7 |
| Chlorine dioxide | 0.0 | 0.0 | 0.0 | 1.0 | 5.0 | 1.5 | 0.6 | 0.0 | 1.1 |
| Chloramines | 0.0 | 0.0 | 0.0 | 4.1 | 22.5 | 18.9 | 23.6 | 21.3 | 7.1 |
| Ozone | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 5.3 | 0.0 | 1.7 | 0.4 |
| UV | 11.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 1.6 |
| Other post disinfection | 0.0 | 0.0 | 7.9 | 0.0 | 2.1 | 1.0 | 1.1 | 0.0 | 2.1 |
| Clearwell | 11.0 | 37.4 | 80.0 | 81.0 | 82.7 | 85.4 | 82.0 | 64.1 | 63.2 |
| Membranes | | | | | | | | | |
| Reverse osmosis | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| Micro filtration | 6.4 | 5.8 | 1.3 | 1.0 | 0.0 | 0.0 | 0.6 | 0.9 | 2.5 |
| Ultrafiltration | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Nanofiltration | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Corrosion control | 1.5 | 14.1 | 40.8 | 48.9 | 70.6 | 62.9 | 69.7 | 72.6 | 40.2 |
| Miscellaneous | | | | | | | | | |
| Ion exchange | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| Granular activated carbon | 2.2 | 2.6 | 0.8 | 21.1 | 14.9 | 15.9 | 11.0 | 6.0 | 8.6 |
| Activated alumina | 0.0 | 2.3 | 0.0 | 1.0 | 0.0 | 1.3 | 1.1 | 0.9 | 0.7 |
| Aeration | 0.0 | 0.0 | 2.1 | 6.1 | 7.6 | 5.0 | 5.7 | 10.2 | 3.6 |
| Other | | | | | | | | | |
| Flouride | 0.0 | 2.5 | 37.4 | 57.3 | 69.4 | 60.4 | 64.4 | 71.0 | 38.0 |
| PAC | 0.0 | 1.1 | 5.7 | 6.1 | 18.7 | 12.3 | 18.1 | 20.5 | 7.6 |

*(Continued)*

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**Table 8K.153 (Continued)**

| Surface Water Treatment Practice | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 or Less | 101–500 | 501–3,300 | 3,301–10,000 | 10,001–50,000 | 50,001–100,000 | 100,001–500,000 | Over 500,000 | All Sizes |
| pH adjust | 0.0 | 0.0 | 6.1 | 1.0 | 1.1 | 1.0 | 3.3 | 2.5 | 1.9 |
| Iron/mag. removal/seq. | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| Taste/odor | 0.0 | 0.0 | 0.0 | 1.0 | 0.3 | 0.0 | 1.2 | 0.0 | 0.3 |
| Filter aid | 0.0 | 0.0 | 7.7 | 5.9 | 2.2 | 1.0 | 0.0 | 0.0 | 3.1 |
| Clarify | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Blending | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*Note:* Represents treatment practices for plants treating water that comes entirely or partly from surface sources. Chlorination only is indicated when a plant chlorinated but did not filter. It includes plants that only chlorinated and plants that chlorinated and used other nonfiltration practices. The tabulations presented in the Community Water System Survey 2000 are based on data collected from a sample of U.S. Water Systems, not from a census of every water system in the United States. Percentages may not sum to 100 percent because systems may perform more than one treatment.

*Source*: From USEPA, 2002, *Community Water System Survery 2000*, EPA 815-R-02-005A.

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**Table 8K.154 Community Water System Groundwater Treatment Practices**

| Groundwater Treatment Practice | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 or Less | 101–500 | 501–3,300 | 3,301–10,000 | 10,001–50,000 | 50,001–100,000 | 100,001–500,000 | Over 500,000 | All Sizes |
| Chlorination only | 81.4 | 73.2 | 72.7 | 72.5 | 67.8 | 71.1 | 68.6 | 96.9 | 74.3 |
| Raw water storage/ Presedimentation basin | 1.5 | 0.0 | 0.4 | 1.6 | 1.4 | 1.2 | 5.8 | 0.0 | 0.8 |
| Predisinfection/oxidation prior to sedimentation | | | | | | | | | |
| Chlorine | 0.0 | 7.5 | 9.4 | 10.6 | 11.3 | 5.9 | 9.5 | 0.0 | 7.2 |
| Chlorine dioxide | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 10.5 | 0.4 | 0.0 | 0.2 |
| Chloramines | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 4.5 | 0.0 | 0.1 |
| Ozone | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0.1 |
| Potassium permanganate | 0.0 | 3.7 | 3.2 | 4.4 | 0.7 | 1.2 | 0.4 | 0.0 | 2.6 |
| Other Predisinfection | 1.3 | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 4.9 | 0.0 | 0.4 |
| Predisinfection/oxidation prior to filtration | | | | | | | | | |
| Chlorine | 1.5 | 7.1 | 10.0 | 7.5 | 10.8 | 1.2 | 3.0 | 2.5 | 6.9 |
| Chlorine dioxide | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| Chloramines | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.4 | 0.0 | 0.0 |
| Ozone | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Potassium permanganate | 1.0 | 1.4 | 5.0 | 2.4 | 4.0 | 0.0 | 0.4 | 0.0 | 2.6 |
| Other predisinfection | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| Rapid mix | 0.0 | 0.0 | 2.4 | 5.0 | 0.0 | 3.0 | 2.7 | 0.0 | 1.3 |
| Coagulation/flocculation | 0.0 | 0.0 | 4.3 | 6.0 | 2.6 | 4.7 | 1.7 | 0.0 | 2.1 |
| Polymers | 0.1 | 0.0 | 8.4 | 3.5 | 2.2 | 2.2 | 1.0 | 0.0 | 2.9 |
| Settling/sedimentation | 0.0 | 0.0 | 4.3 | 8.1 | 5.4 | 3.6 | 3.0 | 0.2 | 2.6 |
| Softening | | | | | | | | | |
| Lime/soda ash | 3.4 | 2.5 | 10.3 | 8.2 | 9.1 | 4.7 | 12.7 | 0.4 | 6.1 |
| Recarbonation | 0.0 | 0.0 | 1.0 | 5.1 | 2.2 | 1.8 | 7.1 | 0.2 | 1.2 |
| Ion exchange | 6.6 | 2.2 | 6.0 | 2.3 | 3.6 | 0.6 | 0.0 | 0.0 | 4.1 |
| Filtration | | | | | | | | | |
| Direct filtration | 1.1 | 0.0 | 0.0 | 2.5 | 0.0 | 1.2 | 0.2 | 0.0 | 0.5 |
| Micro strainer | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Slow sand | 0.0 | 0.0 | 1.0 | 3.4 | 0.0 | 0.0 | 0.2 | 0.0 | 0.7 |
| Bag and cartridge | 8.9 | 0.1 | 0.4 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 1.8 |
| Rapid sand | 0.0 | 0.9 | 2.7 | 7.2 | 4.4 | 1.2 | 2.0 | 0.0 | 2.2 |
| Green sand | 1.6 | 7.5 | 4.2 | 4.4 | 2.9 | 0.0 | 0.4 | 0.0 | 4.5 |
| Diatomaceous earth | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| Dual/multi media | 0.1 | 0.0 | 4.6 | 3.4 | 5.7 | 3.2 | 10.5 | 2.5 | 2.4 |
| Pressure filtration | 0.0 | 3.7 | 8.1 | 2.6 | 7.2 | 1.2 | 1.0 | 0.0 | 4.2 |
| Other filtration | 0.8 | 2.1 | 0.0 | 0.3 | 0.3 | 0.8 | 0.0 | 0.0 | 0.8 |
| Post-disinfection after filters | | | | | | | | | |
| Chlorine | 8.5 | 7.8 | 15.3 | 21.0 | 19.9 | 3.3 | 11.5 | 2.7 | 12.3 |
| Chlorine dioxide | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.6 | 0.0 | 0.1 |
| Chloramines | 0.0 | 0.0 | 0.0 | 0.8 | 1.4 | 1.8 | 3.4 | 0.0 | 0.3 |
| Ozone | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| UV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Other post disinfection | 0.0 | 0.0 | 1.4 | 0.0 | 0.0 | 5.8 | 0.0 | 0.0 | 0.5 |
| Clearwell | 11.4 | 15.4 | 24.7 | 23.6 | 16.0 | 6.9 | 13.3 | 0.4 | 17.7 |
| Membranes | | | | | | | | | |
| Reverse osmosis | 1.1 | 0.0 | 0.1 | 0.5 | 0.0 | 0.6 | 0.6 | 0.0 | 0.3 |
| Micro filtration | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Ultrafiltration | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Nanofiltration | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Corrosion control | 8.0 | 17.6 | 17.4 | 28.9 | 21.2 | 19.0 | 7.3 | 0.8 | 16.9 |
| Miscellaneous | | | | | | | | | |
| Ion exchange | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 | 0.1 |
| Granular activated carbon | 0.0 | 0.0 | 0.0 | 0.8 | 1.9 | 0.6 | 8.6 | 0.2 | 0.4 |
| Activated alumina | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 18.1 | 0.0 | 0.0 | 0.3 |
| Aeration | 0.0 | 9.8 | 22.0 | 19.0 | 21.7 | 7.9 | 17.4 | 14.9 | 13.4 |
| Other | | | | | | | | | |
| Flouride | 0.0 | 4.4 | 18.3 | 27.6 | 20.5 | 9.4 | 12.1 | 0.6 | 11.4 |

*(Continued)*

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**Table 8K.154 (Continued)**

| Groundwater Treatment Practice | System Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 or Less | 101–500 | 501–3,300 | 3,301–10,000 | 10,001–50,000 | 50,001–100,000 | 100,001–500,000 | Over 500,000 | All Sizes |
| PAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 |
| pH adjust | 0.0 | 1.2 | 4.7 | 0.0 | 2.2 | 0.0 | 0.0 | 0.0 | 1.8 |
| Iron/mag. removal/seq. | 2.3 | 3.8 | 3.0 | 4.7 | 1.4 | 0.6 | 0.0 | 0.0 | 3.1 |
| Taste/odor | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| Filter aid | 0.0 | 0.0 | 3.5 | 0.0 | 0.0 | 0.0 | 5.8 | 0.0 | 1.0 |
| Clarify | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Blending | 0.0 | 2.0 | 0.0 | 6.0 | 0.7 | 1.2 | 0.2 | 0.0 | 1.4 |

*Note:* Represents treatment practices for plants treating water that comes entirely or partly from ground sources. Percentages may not sum to 100 percent because systems may perform more than one treatment. Chlorination only is indicated when a plant chlorinated but did not filter. It includes plant that only chlorinated and plants that chlorinated and used other nonfiltration practices. The tabulations presented in the Commonly Water System Survery 2000 are based on data collected from a sample of U.S. Water Systems, not from a census of every water system in the United States.

*Source*: From USEPA, 2002, *Community Water System Survery 2000*, EPA 815-R-02-005A.

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CHAPTER 9

# Wastewater

**William H. Lynch**

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## SECTION 9A WASTEWATER CHARACTERISTICS

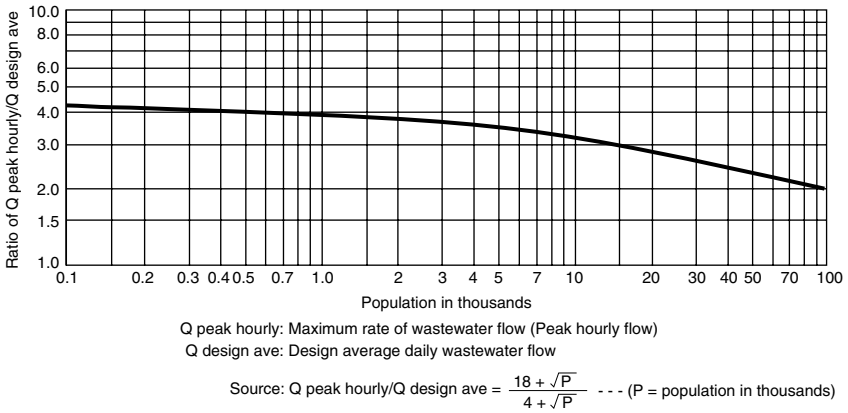


**Figure 9A.1** Ratio of peak hourly flow to design average flow. (From Board of State and Provincial Public Health and Environmental Managers, Health Education Services Division, Recommended Standards for Wastewater Facilities, Figure 1, p. 10.5, 2004 Edition. www.hes.org.)

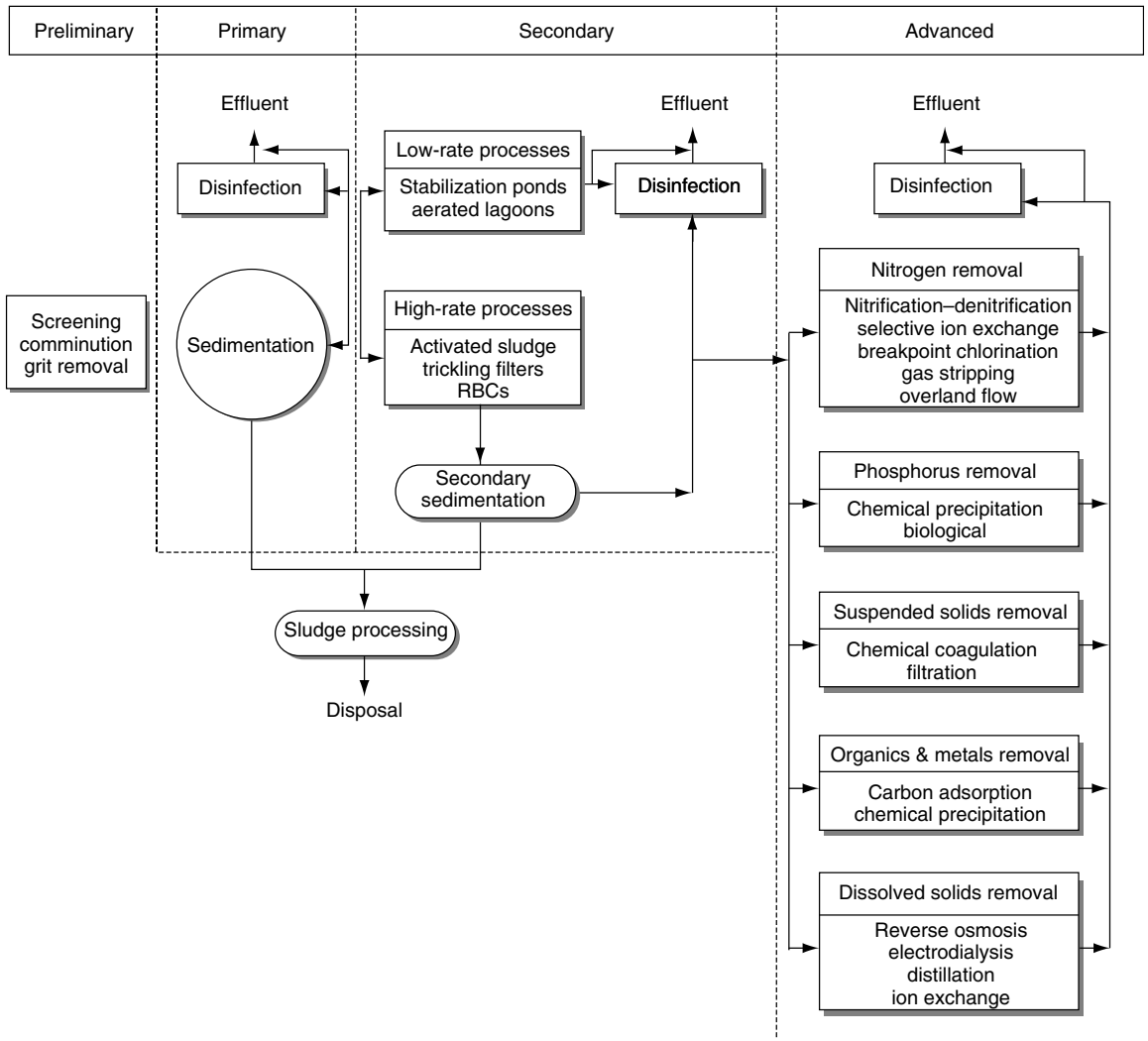


**Figure 9A.2** Generalized flow sheet for wastewater treatment. (From USEPA, *Manual Guidelines Water Reuse*, Office of Water, Figure 12 (EPA/625/R-92/004), September 1992.)

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**Table 9A.1 Typical Wastewater Flowrates from Urban Residential Sources in the United States**

| Household Size, No. of Persons | Flowrate, gal/capita d | | Flowrate, l/capita d | |
|---|---|---|---|---|
| | Range | Typical | Range | Typical |
| 1 | 75–130 | 97 | 285–490 | 365 |
| 2 | 63–81 | 76 | 225–385 | 288 |
| 3 | 54–70 | 66 | 194–335 | 250 |
| 4 | 41–71 | 53 | 155–268 | 200 |
| 5 | 40–68 | 51 | 150–260 | 193 |
| 6 | 39–67 | 50 | 147–253 | 189 |
| 7 | 37–64 | 48 | 140–244 | 182 |
| 8 | 36–62 | 46 | 135–233 | 174 |

*Source*: From Metcalf & Eddy, Inc., McGraw-Hill, *Wastewater Engineering Treatment and Reuse, Fourth Edition*, 2003, Table 3.1, p. 156. With permission. Adapted in part from AWWARF (1999).

**Table 9A.2 Typical Wastewater Flowrates from Recreational Facilities in the United States**

| Facility | Unit | Flowrate, gal/unit d | | Flowrate, l/unit d | |
|---|---|---|---|---|---|
| | | Range | Typical | Range | Typical |
| Apartment, resort | Person | 50–70 | 60 | 190–260 | 230 |
| Cabin, resort | Person | 8–50 | 40 | 30–190 | 150 |
| Cafeteria | Customer | 2–4 | 3 | 8–15 | 10 |
| | Employee | 8–12 | 10 | 30–45 | 40 |
| **Camp** | | | | | |
| With toilets only | Person | 15–30 | 25 | 55–110 | 95 |
| With central toilet and bath facilities | Person | 35–50 | 45 | 130–190 | 170 |
| Day | Person | 15–20 | 15 | 55–76 | 60 |
| Cottages, (seasonal with private bath) | Person | 40–60 | 50 | 150–230 | 190 |
| Country club | Member present | 20–40 | 25 | 75–150 | 100 |
| | Employee | 10–15 | 13 | 38–57 | 50 |
| Dining hall | Meal served | 4–10 | 7 | 15–40 | 25 |
| Dormitory, bunkhouse | Person | 20–50 | 40 | 75–190 | 150 |
| Fairground | Visitor | 1–3 | 2 | 4–12 | 8 |
| Picnic park with flush toilets | Visitor | 5–10 | 5 | 19–38 | 19 |
| **Recreational vehicle park** | | | | | |
| With individual connection | Vehicle | 75–150 | 100 | 280–570 | 380 |
| With comfort station | Vehicle | 40–50 | 45 | 150–190 | 170 |
| Roadside rest areas | Person | 3–5 | 4 | 10–19 | 15 |
| Swimming pool | Customer | 5–12 | 10 | 19–45 | 40 |
| | Employee | 8–12 | 10 | 30–45 | 40 |
| Vacation home | Person | 25–60 | 50 | 90–230 | 190 |
| Visitor center | Visitor | 3–5 | 4 | 10–19 | 15 |

*Source*: From Metcalf & Eddy, Inc., McGraw-Hill, *Wastewater Engineering Treatment and Reuse, Fourth Edition*, 2003, Table 3.4, p. 159. With permission. Adapted from Metcalf & Eddy (1991), Salvato (1992), and Crites and Tchobanoglous (1998).

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**Table 9A.3 Typical Wastewater Flowrates from Commercial Sources in the United States**

| | | Flowrate, gal/unit d | | Flowrate, l/unit d | |
|---|---|---|---|---|---|
| **Source** | **Unit** | **Range** | **Typical** | **Range** | **Typical** |
| Airport | Passenger | 3–5 | 4 | 11–19 | 15 |
| Apartment | Bedroom | 100–150 | 120 | 380–570 | 450 |
| Automobile service station | Vehicle served | 8–15 | 10 | 30–57 | 40 |
| | Employee | 9–15 | 13 | 34–57 | 50 |
| Bar/cocktail lounge | Seat | 12–25 | 20 | 45–95 | 80 |
| | Employee | 10–16 | 13 | 38–60 | 50 |
| Boarding house | Person | 25–65 | 45 | 95–250 | 170 |
| Conference center | Person | 6–10 | 8 | 40–60 | 30 |
| Department store | Toilet room | 350–600 | 400 | 1,300–2,300 | 1,500 |
| | Employee | 8–15 | 10 | 30–57 | 40 |
| Hotel | Guest | 65–75 | 70 | 150–230 | 190 |
| | Employee | 8–15 | 10 | 30–57 | 40 |
| Industrial building (sanitary waste only) | Employee | 15–35 | 20 | 57–130 | 75 |
| Laundry (self-service) | Machine | 400–550 | 450 | 1,500–2,100 | 1,700 |
| | Customer | 45–55 | 50 | 170–210 | 190 |
| Mobile home park | Unit | 125–150 | 140 | 470–570 | 530 |
| Motel (with kitchen) | Guest | 55–90 | 60 | 210–340 | 230 |
| Motel (without kitchen) | Guest | 50–75 | 55 | 190–290 | 210 |
| Office | Employee | 7–16 | 13 | 26–60 | 50 |
| Public lavatory | User | 3–5 | 4 | 11–19 | 15 |
| Restaurant: | | | | | |
| Conventional | Customer | 7–10 | 8 | 26–40 | 35 |
| With bar/ cocktail lounge | Customer | 9–12 | 10 | 34–45 | 40 |
| Shopping center | Employee | 7–13 | 10 | 26–50 | 40 |
| | Parking space | 1–3 | 2 | 4–11 | 8 |
| Theater (Indoor) | Seat | 2–4 | 3 | 8–15 | 10 |

*Source*: From Metcalf & Eddy, Inc., McGraw-Hill, *Wastewater Engineering Treatment and Reuse, Fourth Edition*, 2003, Table 3.2, p. 157. With permission. Adapted from Metcalf & Eddy (1991), Salvato (1992), and Crites and Tchobanoglous (1998).

**Table 9A.4 Typical Wastewater Flowrates from Institutional Sources in the United States**

| | | Flowrate, gal/unit d | | Flowrate, l/unit d | |
|---|---|---|---|---|---|
| **Source** | **Unit** | **Range** | **Typical** | **Range** | **Typical** |
| Assembly hall | Guest | 3–5 | 4 | 11–19 | 15 |
| Hospital | Bed | 175–400 | 250 | 660–1,500 | 1,000 |
| | Employee | 5–15 | 10 | 20–60 | 40 |
| Institutions other than hospitals | Bed | 75–125 | 100 | 280–470 | 380 |
| | Employee | 5–15 | 10 | 20–60 | 40 |
| Prison | Inmate | 80–150 | 120 | 300–570 | 450 |
| | Employee | 5–15 | 10 | 20–60 | 40 |
| **School, day:** | | | | | |
| With cafeteria, gym, and showers | Student | 15–30 | 25 | 60–120 | 100 |
| With cafeteria only | Student | 10–20 | 15 | 40–80 | 60 |
| School, boarding | Student | 75–100 | 85 | 280–380 | 320 |

*Source*: From Metcalf & Eddy, Inc., McGraw-Hill, *Wastewater Engineering Treatment and Reuse, Fourth Edition*, 2003, Table 3.3, p. 158. With permission. Adapted from Metcalf & Eddy (1991), Salvato (1992), and Crites and Tchobanoglous (1998).

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**Table 9A.5 Terminology Used to Quantify Observed Variations in Flowrate and Constituent Concentrations**

| Item | Description |
|---|---|
| Average dry-weather flow (ADWF) | The average of the daily flows sustained during dry-weather periods with limited infiltration |
| Average wet-weather flow (AWWF) | The average of the daily flows sustained during wet-weather periods when infiltration is a factor |
| Average annual daily flow | The average flowrate occurring over a 24-h period based on annual flowrate data |
| Instantaneous peak | Highest record flowrate occurring for a period consistent with the recording equipment. In many situations the recorded peak flow may be considerably below the actual peak flow because of metering and recording equipment limitations |
| Peak hour | The average of the peak flows sustained for a period of 1 h in the record examined (usually based on 10-min increments) |
| Maximum day | The average of the peak flows sustained for a period of 1 day in the record examined (the duration of the peak flows may vary) |
| Maximum month | The average of the maximum daily flows sustained for a period of 1 month in the record examined |
| Minimum hour | The average of the minimum flows sustained for a period of 1 h in the record examined (usually based on 10-min increments) |
| Minimum day | The average of the minimum flows sustained for a period of 1 day in the record examined (usually for the period from 2 a.m. to 6 a.m.) |
| Minimum month | The average of the minimum daily flows sustained for a period of 1 month in the record examined |
| Sustained flow (and load) | The value (flowrate or mass loading) sustained or exceeded for a given period of time (e.g., 1 h, 1 day, or 1 month) |

*Source*: From Metcalf & Eddy, Inc., McGraw-Hill, *Wastewater Engineering Treatment and Reuse, Fourth Edition*, 2003, Table 3.11, p. 179. With permission. Adapted in part from Crites and Tchobanoglous (1998).

**Table 9A.6 Terminology Commonly Used in the Field of Wastewater Engineering**

| Term | Definition |
|---|---|
| Biosolids | Primarily an organic, semisolid wastewater product that remains after solids are stabilized biologically or chemically and are suitable for beneficial use |
| Class A biosolids[a] | Biosolids in which the pathogens (including enteric viruses, pathogenic bacteria, and viable helminth ova) are reduced below current detectable levels |
| Class B biosolids[a] | Biosolids in which the pathogens are reduced to levels that are unlikely to pose a threat to public health and the environment under specific use conditions. Class B biosolids cannot be sold or given away in bags on other containers or applied on lawns or home gardens |
| Characteristics (wastewater) | General classes of wastewater constituents such as physical, chemical, biological, and biochemical |
| Composition | The makeup of wastewater, including the physical, chemical, and biological constituents |
| Constituents[b] | Individual components, elements, or biological entities such as suspended solids or ammonia nitrogen |
| Contaminants | Constituents added to the water supply through use |
| Disinfection | Reduction of disease-causing microorganisms by physical or chemical means |
| Effluent | The liquid discharged from a processing step |
| Impurities | Constituents added to the water supply through use |
| Nonpoint sources | Sources of pollution that originate from multiple sources over a relatively large area |
| Nutrient | An element that is essential for the growth of plants and animals. Nutrients in wastewater, usually nitrogen and phosphorus, may cause unwanted algal and plant growths in lakes and streams |
| Parameter | A measurable factor such as temperature |
| Point sources | Pollutional loads discharged at a specific location from pipes, outfalls, and conveyance methods from either municipal wastewater treatment plants or industrial waste treatment facilities |
| Pollutants | Constituents added to the water supply through use |
| Reclamation | Treatment of wastewater for subsequent reuse application or the act of reusing treated wastewater |

*(Continued)*

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**Table 9A.6 (Continued)**

| Term | Definition |
|---|---|
| Recycling | The reuse of treated wastewater and biosolids for beneficial purposes |
| Repurification | Treatment of wastewater to a level suitable for a variety of applications including indirect or direct potable reuse |
| Reuse | Beneficial use of reclaimed or repurified wastewater or stabilized biosolids |
| Sludge | Solids removed from wastewater during treatment. Solids that are treated further are termed biosolids |
| Solids | Material removed from wastewater by gravity separation (by clarifiers, thickeners, and logoons) and is the solid residue from dewatering operations |

[a] U.S. EPA (1997b).
[b] To avoid confusion, the term "constituents" is used in this text in place of contaminants, impurities, and pollutants.

*Source*: From Metcalf & Eddy, Inc., McGraw-Hill, *Wastewater Engineering Treatment and Reuse, Fourth Edition*, 2003, Table 1.1, p. 4. With permission. Adapted in part from Crites and Tchobanoglous (1998).

**Table 9A.7 Levels of Wastewater Treatment**

| Treatment Level | Description |
|---|---|
| Preliminary | Removal of wastewater constituents such as rags, sticks, floatables, grit, and grease that may cause maintenance or operational problems with the treatment operations, processes, and ancillary systems |
| Primary | Removal of a portion of the suspended solids and organic matter from the wastewater |
| Advanced primary | Enhanced removal of suspended solids and organic matter from the wastewater. Typically accomplished by chemical addition or filtration |
| Secondary | Removal of biodegradable organic matter (in solution or suspension) and suspended solids. Disinfection is also typically included in the definition of conventional secondary treatment |
| Secondary with nutrient removal | Removal of biodegradable organics, suspended solids, and nutrients (nitrogen, phosphorus, or both nitrogen and phosphorus) |
| Tertiary | Removal of residual suspended solids (after secondary treatment), usually by granular medium filtration or microscreens. Disinfection is also typically a part of tertiary treatment. Nutrient removal is often included in this definition |
| Advanced | Removal of dissolved and suspended materials remaining after normal biological treatment when required for various water reuse applications |

*Source*: From Metcalf & Eddy, Inc., McGraw-Hill, *Wastewater Engineering Treatment and Reuse, Fourth Edition*, 2003, Table 1.4, p. 11. Adapted in part from Crites and Tchobanoglous (1998).

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**Table 9A.8 Commonly Used Treatment Processes and Optional Treatment Methods**

| Treatment Objective | Treatment Process | Treatment Methods |
|---|---|---|
| Suspended solids removal | Sedimentation | Septic tank |
| | | Free water surface constructed wetland |
| | | Vegetated submerged bed |
| | Filtration | Septic tank effluent screens |
| | | Packed-bed media filters (incl. dosed systems) |
| | | Granular (sand, gravel, glass, bottom ash) |
| | | Peat, textile |
| | | Mechanical disk filters |
| | | Soil infiltration |
| Soluble carbonaceous BOD and ammonium removal | Aerobic, suspended-growth reactors | Extended aeration |
| | | Fixed-film activated sludge |
| | | Sequencing batch reactors (SBRs) |
| | Fixed-film aerobic bioreactor | Soil infiltration |
| | | Packed-bed media filters (incl. dosed systems) |
| | | Granular (sand, gravel, glass) |
| | | Peat, textile, foam |
| | | Trickling filter |
| | | Fixed-film activated sludge |
| | | Rotating biological contactors |
| | Lagoons | Facultative and aerobic lagoons |
| | | Free water surface constructed wetlands |
| Nitrogen transformation | Biological | Activated sludge (N) |
| | Nitrification (N) | Sequencing batch reactors (N) |
| | Denitrification (D) | Fixed film bio-reactor (N) |
| | | Recirculating media filter (N, D) |
| | | Fixed-film activated sludge (N) |
| | | Anaerobic upflow filter (N) |
| | | Anaerobic submerged media reactor (D) |
| | | Submerged vegetated bed (D) |
| | | Free water surface constructed wetland (N, D) |
| | Ion exchange | Cation exchange (ammonium removal) |
| | | Anion exchange (nitrate removal) |
| Phosphorus removal | Physical/Chemical | Infiltration by soil and other media |
| | | Chemical flocculation and settling |
| | | Iron-rich packed-bed media filter |
| | Biological | Sequencing batch reactors |
| Pathogen removal (bacteria, viruses, parasites) | Filtration/Predation/Inactivation | Soil infiltration |
| | | Packed-bed media filters |
| | | Granular (sand, gravel, glass bottom, ash) |
| | | Peat, textile |
| | Disinfection | Hypochlorite feed |
| | | Ultraviolet light |
| Grease removal | Flotation | Grease trap |
| | | Septic tank |
| | Adsorption | Mechanical skimmer |
| | Aerobic biological treatment (incidental removal will occur; overloading is possible) | Aerobic biological systems |

*Source*: From USEPA, On-Site *Wastewater Treatment Systems Manual*, Office of Water, Office of Research and Development, EPA, (EPA/625/R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008totaldocument.pdf.

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**Table 9A.9 Number of Operational Treatment Facilities and Collection Systems in 2000**

| State | Treatment Facilities | Collection Systems |
|---|---|---|
| Alabama | 272 | 275 |
| Alaska | 45 | 46 |
| Arizona | 118 | 132 |
| Arkansas | 335 | 367 |
| California[a] | 586 | 797 |
| Colorado[a] | 311 | 391 |
| Connecticut | 91 | 137 |
| Delaware | 18 | 42 |
| District of Columbia | 1 | 1 |
| Florida | 277 | 317 |
| Georgia | 352 | 403 |
| Hawaii | 21 | 21 |
| Idaho | 168 | 207 |
| Illinois | 721 | 1,018 |
| Indiana | 404 | 482 |
| Iowa | 726 | 756 |
| Kansas | 634 | 673 |
| Kentucky | 224 | 255 |
| Louisiana | 355 | 382 |
| Maine | 137 | 171 |
| Maryland | 156 | 201 |
| Massachusetts | 126 | 230 |
| Michigan | 396 | 663 |
| Minnesota | 514 | 655 |
| Mississippi | 303 | 352 |
| Missouri | 678 | 751 |
| Montana | 194 | 204 |
| Nebraska | 464 | 469 |
| Nevada[b] | 85 | 117 |
| New Hampshire | 85 | 117 |
| New Jersey | 156 | 575 |
| New Mexico | 55 | 64 |
| New York[a] | 588 | 1,048 |
| North Carolina | 491 | 617 |
| North Dakota | 282 | 284 |
| Ohio | 765 | 1,008 |
| Oklahoma | 489 | 495 |
| Oregon | 207 | 254 |
| Pennsylvania | 779 | 1,553 |
| Rhode Island | 21 | 34 |
| South Carolina | 186 | 206 |
| South Dakota[a] | 271 | 274 |
| Tennessee | 246 | 281 |
| Texas | 1,363 | 1,675 |
| Utah | 97 | 164 |
| Vermont | 81 | 97 |
| Virginia | 227 | 290 |
| Washington | 235 | 331 |
| West Virginia | 212 | 289 |
| Wisconsin | 592 | 823 |
| Wyoming[b] | 96 | 121 |
| American Samoa[b] | 2 | 2 |
| Guam[b] | 7 | 7 |
| N. Mariana Islands[b] | 2 | 2 |
| Puerto Rico[b] | 30 | 30 |
| Virgin Islands[b] | 12 | 12 |
| Total | 16,255 | 21,107 |

[a] California, Colorado, New York, and South Dakota did not have the resources to complete the updating of these data.

[b] Results presented in this table for American Samoa, Guam, Northern Mariana Islands, Nevada, Puerto Rico, Virgin Islands, and Wyoming are from the 1996 survey because these States and Territories did not participate in the CWNS 2000.

*Source*: From 2000 Clean Watersheds Needs Survey Report to Congress, Published 2003, Appendix C, Table C.1, p. C.2. epa.gov/owm/mtb/cwns/2000rtc/cwns2000-appendix-c.pdf, epa.gov/owm/mtb/cwns/2000rtc/toc.htm.

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**Table 9A.10 Number of Operational Treatment Facilities and Collection Systems if All Documented Needs Are Met**

| State | Treatment Facilities | Collection Systems |
|---|---|---|
| Alabama | 279 | 285 |
| Alaska | 50 | 51 |
| Arizona | 232 | 258 |
| Arkansas | 360 | 406 |
| California[a] | 579 | 799 |
| Colorado[a] | 331 | 430 |
| Connecticut | 99 | 159 |
| Delaware | 18 | 49 |
| District of Columbia | 1 | 1 |
| Florida | 302 | 346 |
| Georgia | 345 | 405 |
| Hawaii | 27 | 27 |
| Idaho | 177 | 219 |
| Illinois | 754 | 1,056 |
| Indiana | 424 | 510 |
| Iowa | 744 | 775 |
| Kansas | 665 | 712 |
| Kentucky | 301 | 369 |
| Louisiana | 371 | 405 |
| Maine | 145 | 184 |
| Maryland | 180 | 303 |
| Massachusetts | 141 | 267 |
| Michigan | 403 | 673 |
| Minnesota | 518 | 661 |
| Mississippi | 372 | 475 |
| Missouri | 729 | 848 |
| Montana | 208 | 218 |
| Nebraska | 475 | 483 |
| Nevada[b] | 52 | 56 |
| New Hampshire | 85 | 120 |
| New Jersey | 164 | 600 |
| New Mexico | 58 | 68 |
| New York[a] | 657 | 1,175 |
| North Carolina | 518 | 702 |
| North Dakota | 282 | 286 |
| Ohio | 837 | 1,213 |
| Oklahoma | 487 | 496 |
| Oregon | 219 | 270 |
| Pennsylvania | 1,013 | 1,936 |
| Rhode Island | 20 | 36 |
| South Carolina | 187 | 222 |
| South Dakota[a] | 273 | 276 |
| Tennessee | 251 | 286 |
| Texas | 1,469 | 1,850 |
| Utah | 114 | 188 |
| Vermont | 84 | 100 |
| Virginia | 254 | 383 |
| Washington | 240 | 337 |
| West Virginia | 404 | 626 |
| Wisconsin | 628 | 974 |
| Wyoming[b] | 96 | 121 |
| American Samoa[b] | 2 | 2 |
| Guam[b] | 6 | 7 |
| N. Mariana Islands[b] | 2 | 2 |
| Puerto Rico[b] | 30 | 30 |
| Virgin Islands[b] | 12 | 12 |
| Total | 17,674 | 23,748 |

[a] California, Colorado, New York, and South Dakota did not have the resources to complete the updating of these data.

[b] Results presented in this table for American Samoa, Guam, Northern Mariana Islands, Nevada, Puerto Rico, Virgin Islands, and Wyoming are from the 1996 survey because these States and Territories did not participate in the CWNS 2000.

*Source*: From 2000 Clean Watersheds Needs Survey Report to Congress, Published 2003, Appendix C, Table C.2, p. C.3. www.epa.gov/owm/mtb/cwns/2000rtc/cwns2000-appendix-c.pdf, www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm.

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**Table 9A.11 Number of Treatment Facilities by Flow Range**

| Treatment Facilities in Operation in 2000[a,b] | | |
|---|---|---|
| **Existing Flow Range (mgd)** | **Number of Facilities** | **Total Existing Flow (mgd)** |
| 0.001–0.100 | 6,583 | 290 |
| 0.101–1.000 | 6,462 | 2,339 |
| 1.001–10.000 | 2,665 | 8,328 |
| 10.001–100.000 | 487 | 12,741 |
| 100.001 and greater | 46 | 11,201 |
| Other[c] | 12 | — |
| Total | 16,255 | 34,899 |

| Treatment Facilities in Operation in 2000 if All Documented Needs Are Met[a,b] | | |
|---|---|---|
| **Design Flow Range (mgd)** | **Number of Facilities** | **Total Future Design Flow Capacity (mgd)** |
| 0.001–0.100 | 6,112 | 298 |
| 0.101–1.000 | 7,223 | 2,750 |
| 1.001–10.000 | 3,525 | 12,081 |
| 10.001–100.000 | 748 | 19,873 |
| 100.001 and greater | 64 | 15,040 |
| Other[c] | 2 | — |
| Total | 17,674 | 50,042 |

[a] California, Colorado, New York, and South Dakota did not have the resources to complete the updating of these data.
[b] Results presented in this table for American Samoa, Guam, Nevada, Northern Mariana Islands, Puerto Rico, Virgin Islands, and Wyoming are from the 1996 survey because these States and Territories did not participate in the CWNS 2000.
[c] Flow data for these facilities were unavailable.

*Source*: From 2000 Clean Watersheds Needs Survey Report to Congress, Published 2003, Appendix C, Table C.3, p. C.4. www.epa.gov/owm/mtb/cwns/2000rtc/cwns2000-appendix-c.pdf, www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm.

**Table 9A.12 Improvements in Treatment Level of the Nation's Municipal Wastewater Treatment Facilities**

| Level of Treatment | 1992 Number of Facilities | 1996 Number of Facilities | Change 1992–1996 (%) | 2000 Number of Facilities | Change 1992–2000 (%) | Change 1996–2000 (%) |
|---|---|---|---|---|---|---|
| No discharge[a] | 1,981 | 2,032 | 2.6 | 1,938 | −2.2 | −4.6 |
| Less than secondary[b] | 868 | 176 | −79.7 | 47 | −94.5 | −73.3 |
| Secondary | 9,086 | 9,388 | 3.3 | 9,156 | 0.8 | −2.5 |
| Greater than secondary | 3,678 | 4,428 | 20.4 | 4,892 | 33.0 | 10.5 |
| Total facilities | 15,613 | 16,024 | 2.6 | 16,255[c] | 4.1 | 1.4 |

*Note:* A secondary treatment level is defined as meeting an effluent quality of 30 mg/L for biochemical oxygen demand (BOD) and suspended solids.

[a] *No discharge* refers to facilities that do not discharge effluent to surface waters (e.g., spray irrigation, groundwater recharge).
[b] Includes facilities granted section 301(h) waivers from secondary treatment for discharges to marine waters. As of January 1, 2000, waivers for 34 facilities in the CWNS 2000 database had been granted or were pending.
[c] The number of facilities includes 222 facilities that provide partial treatment and whose flow goes to another facility for further treatment.

*Source*: From 2000 Clean Watersheds Needs Survey Report to Congress, Published 2003, Table 3.2, p. 3–4. www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm, www.epa.gov/owm/mtb/cwns/2000rtc/cwns2000-chapter-3.pdf.

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**Table 9A.13 Comparison of Total Needs for the 1992 Needs Survey, 1996 Clean Water Needs Survey, and CWNS 2000 (January 2000 Dollars in Billions)**

| Needs Category | | 1992[a] | 1996[a] | 2000 |
|---|---|---|---|---|
| **Publicly Owned Wastewater Treatment and Collection Systems and Storm Water Management Programs** | | | | |
| I | Secondary wastewater treatment | 39.3 | 29.4 | 36.8 |
| II | Advanced wastewater treatment | 19.4 | 19.4 | 20.4 |
| III-A | Infiltration/inflow correction | 3.4 | 3.7 | 8.2 |
| III-B | Sewer replacement/rehabilitation | 4.6 | 7.7 | 16.8 |
| IV-A | New collector sewers and appurtenances | 22.5 | 12.0 | 14.3 |
| IV-B | New interceptor sewers and appurtenances | 18.4 | 11.9 | 14.8 |
| V | Combined sewer overflow correction | 51.7[b] | 49.6 | 50.6 |
| VI | Storm water management programs | 0.1[b] | 8.2[b] | 5.5 |
| **Nonpoint Source Pollution Control Projects** | | | | |
| VII-A | Agriculture (cropland) | 4.7[b] | 4.2[b] | 0.5 |
| VII-B | Agriculture (animals) | 3.4[b] | 2.3[b] | 0.7 |
| VII-C | Silviculture | 3.0[b] | 3.9[b] | 0.04 |
| VII-D | Urban | — | 1.1 | 4.4 |
| VII-E | Groundwater protection: unknown source | 1.4 | 1.1 | 0.9 |
| | Estuaries[c] | 0.01 | 0.04 | — |
| | Wetlands[c] | 0.04 | 0.01 | — |
| VII-F | Marinas | — | — | 0.002 |
| VII-G | Resource extraction | — | — | 0.04 |
| VII-H | Brownfields | — | — | 0.4 |
| VII-I | Storage tanks | — | — | 1.0 |
| VII-J | Sanitary landfills | — | — | 1.8 |
| VII-K | Hydromodification | — | — | 4.1 |
| | Total needs | 172.0 | 154.6 | 181.2 |
| | Treatment categories I and II only | 58.7 | 48.8 | 57.2 |
| | Collection and conveyance categories III and IV only | 48.9 | 35.3 | 54.1 |
| | Category I to V subtotal | 159.3 | 133.7 | 161.9 |

[a] The needs from 1992 and 1996 were inflated to January 2000 dollars for comparison with CWNS 2000 data.
[b] Modeled needs.
[c] Documented needs for estuaries and wetlands were provided by States during the 1992 and 1996 surveys, but they are no longer reported as individual categories.

*Source*: From 2000 Clean Watersheds Needs Survey Report to Congress, Published 2003, Table 3.4, p. 3–6. www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm, www.epa.gov/owm/mtb/cwns/2000rtc/cwns2000-chapter-3.pdf.

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**Table 9A.14 Number of Treatment Facilities by Level of Treatment**

**Treatment Facilities in Operation in 2000[a,b]**

| Level of Treatment | Number of Facilities | Present Design Capacity (mgd) | Number of People Served | Percent of U.S. Population |
|---|---|---|---|---|
| Less than secondary[c] | 47 | 1,023 | 6,426,062 | 2.3 |
| Secondary | 9,156 | 19,268 | 88,221,896 | 32.0 |
| Greater than secondary | 4,892 | 22,165 | 100,882,207 | 36.6 |
| No discharge[d] | 1,938 | 2,039 | 12,283,047 | 4.5 |
| Partial treatment[e] | 222 | 563 | — | — |
| Total | 16,255 | 45,058 | 207,813,212[f] | 75.4 |

**Treatment Facilities in Operation in 2000 if All Documented Needs Are Met[a,b]**

| Level of Treatment | Number of Facilities | Future Design Capacity (mgd) | Number of People Served | Percent of U.S. Population |
|---|---|---|---|---|
| Less than secondary[c] | 27 | 481 | 3,851,000 | 1.2 |
| Secondary | 9,463 | 20,008 | 103,716,058 | 31.9 |
| Greater than secondary | 5,739 | 26,239 | 140,251,554 | 43.2 |
| No discharge[d] | 2,221 | 2,579 | 21,224,596 | 6.5 |
| Partial treatment[e] | 224 | 734 | — | — |
| Total | 17,674 | 50,041 | 269,043,208[f] | 82.8 |

[a] California, Colorado, New York, and South Dakota did not have the resources to complete the updating of these data.
[b] Results presented in this table for American Samoa, Guam, Nevada, Northern Mariana Islands, Puerto Rico, Virgin Islands, and Wyoming are from the 1996 survey because these States and Territories did not participate in the CWNS 2000.
[c] Less-than-secondary facilities include facilities granted or pending section 301(h) waivers from secondary treatment for discharges to marine waters.
[d] No-discharge facilities do not discharge treated wastewater to the Nation's waterways. These facilities dispose of wastewater via methods such as industrial reuse, irrigation, or evaporation.
[e] These facilities provide some treatment to wastewater and discharge their effluents to wastewater facilities for further treatment and discharge.
[f] This table does not include the results for approximately 3.3 million people (present) and 3.5 million people (future) that are receiving centralized collection because the data related to flow and effluent levels were not complete for the CWNS 2000.

*Source*: From 2000 Clean Watersheds Needs Survey Report to Congress, Published 2003, Appendix C, Table C.4, p. C.5. www.epa.gov/owm/mtb/cwns/2000rtc/cwns2000-appendix-c.pdf, www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm.

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**Table 9A.15 Clean Watersheds Needs Survey 2000 Total Needs (January 2000 Dollars in Millions)**

| | | Category of Need | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **State** | **Total** | **I** | **II** | **III-A** | **III-B** | **IV-A** | **IV-B** | **V** | **VI** | **VII** | **Total (I–V)** |
| Alabama | 2,720 | 14 | 951 | 135 | 1,168 | 386 | 66 | 0 | 0 | 0 | 2,720 |
| Alaska | 560 | 306 | 7 | 7 | 65 | 163 | 7 | 5 | 0 | 0 | 560 |
| Arizona | 6,199 | 726 | 2,368 | 126 | 240 | 319 | 1,081 | 0 | 1,251 | 88 | 4,860 |
| Arkansas | 500 | 37 | 117 | 22 | 24 | 41 | 71 | 0 | 0 | 188 | 312 |
| California | 14,402 | 3,916 | 3,748 | 111 | 3,114 | 82 | 1,853 | 426 | 352 | 800 | 13,250 |
| Colorado | 1,340 | 183 | 812 | 5 | 179 | 16 | 37 | 9 | 48 | 51 | 1,241 |
| Connecticut | 2,349 | 399 | 923 | 85 | 16 | 170 | 161 | 500 | 0 | 95 | 2,254 |
| Delaware | 288 | 33 | 23 | 0 | 68 | 58 | 4 | 102 | 0 | 0 | 288 |
| District of Columbia | 1,478 | 305 | 37 | 14 | 64 | 0 | 0 | 1,019 | 37 | 2 | 1,439 |
| Florida | 9,966 | 299 | 2,853 | 129 | 562 | 1,191 | 1,012 | 0 | 680 | 3,240 | 6,046 |
| Georgia | 2,336 | 114 | 205 | 1,004 | 25 | 9 | 61 | 918 | 0 | 0 | 2,336 |
| Hawaii | 1,743 | 575 | 19 | 471 | 441 | 88 | 149 | 0 | 0 | 0 | 1,743 |
| Idaho | 207 | 119 | 29 | 3 | 18 | 18 | 20 | 0 | 0 | 0 | 207 |
| Illinois | 11,888 | 795 | 103 | 27 | 1,204 | 95 | 169 | 9,450 | 0 | 45 | 11,843 |
| Indiana | 7,222 | 626 | 171 | 65 | 419 | 291 | 176 | 5,468 | 0 | 6 | 7,216 |
| Iowa | 1,954 | 240 | 22 | 23 | 79 | 36 | 19 | 1,534 | 1 | 0 | 1,953 |
| Kansas | 1,419 | 373 | 100 | 213 | 2 | 65 | 270 | 396 | 0 | 0 | 1,419 |
| Kentucky | 2,797 | 654 | 101 | 193 | 280 | 756 | 592 | 217 | 3 | 1 | 2,793 |
| Louisiana | 2,370 | 410 | 146 | 1,167 | 216 | 240 | 189 | 0 | 0 | 2 | 2,368 |
| Maine | 1,102 | 176 | 7 | 3 | 31 | 88 | 16 | 653 | 0 | 128 | 974 |
| Maryland | 4,779 | 1,239 | 837 | 94 | 739 | 407 | 369 | 396 | 456 | 242 | 4,081 |
| Massachusetts | 4,675 | 874 | 249 | 59 | 92 | 662 | 406 | 2,324 | 0 | 9 | 4,666 |
| Michigan | 4,092 | 837 | 73 | 107 | 307 | 301 | 30 | 2,437 | 0 | 0 | 4,092 |
| Minnesota | 2,319 | 660 | 101 | 42 | 281 | 45 | 104 | 6 | 120 | 960 | 1,239 |
| Mississippi | 856 | 92 | 129 | 156 | 152 | 184 | 143 | 0 | 0 | 0 | 856 |
| Missouri | 4,998 | 725 | 22 | 720 | 297 | 301 | 193 | 1,180 | 0 | 1,560 | 3,438 |
| Montana | 516 | 170 | 70 | 14 | 55 | 100 | 60 | 0 | 0 | 47 | 469 |
| Nebraska | 1,194 | 149 | 56 | 7 | 11 | 11 | 75 | 861 | 24 | 0 | 1,170 |
| Nevada | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| New Hampshire | 906 | 127 | 47 | 7 | 33 | 6 | 135 | 485 | 0 | 66 | 840 |
| New Jersey | 12,827 | 2,818 | 368 | 339 | 610 | 1,007 | 411 | 4,385 | 89 | 2,800 | 9,938 |
| New Mexico | 206 | 94 | 15 | 9 | 42 | 18 | 21 | 0 | 0 | 7 | 199 |
| New York | 20,422 | 9,853 | 776 | 75 | 2,072 | 538 | 173 | 5,497 | 16 | 1,422 | 18,984 |
| North Carolina | 5,927 | 423 | 1,737 | 291 | 205 | 1,725 | 1,535 | 3 | 1 | 7 | 5,919 |
| North Dakota | 52 | 27 | 0[a] | 2 | 17 | 0 | 1 | 0 | 4 | 1 | 47 |
| Ohio | 8,722 | 1,219 | 391 | 1,493 | 112 | 725 | 533 | 3,623 | 0 | 626 | 8,096 |

*(Continued)*



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**Table 9A.15 (Continued)**

| State | Category of Need | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | I | II | III-A | III-B | IV-A | IV-B | V | VI | VII | Total (I–V) |
| Oklahoma | 586 | 85 | 25 | 1 | 207 | 33 | 45 | 0 | 190 | 0 | 396 |
| Oregon | 1,477 | 540 | 155 | 4 | 654 | 16 | 34 | 74 | 0 | 0 | 1,477 |
| Pennsylvania | 8,060 | 845 | 204 | 121 | 119 | 963 | 197 | 5,431 | 17 | 163 | 7,880 |
| Rhode Island | 1,415 | 109 | 113 | 12 | 52 | 345 | 119 | 633 | 0 | 32 | 1,383 |
| South Carolina | 1,309 | 551 | 334 | 1 | 13 | 283 | 125 | 0 | 0 | 2 | 1,307 |
| South Dakota | 142 | 16 | 29 | 0 | 44 | 13 | 6 | 2 | 14 | 18 | 110 |
| Tennessee | 604 | 66 | 45 | 48 | 107 | 58 | 36 | 244 | 0 | 0 | 604 |
| Texas | 9,152 | 2,009 | 813 | 235 | 1,323 | 616 | 1,890 | 0 | 2,225 | 41 | 6,886 |
| Utah | 848 | 347 | 74 | 0[a] | 97 | 98 | 217 | 0 | 5 | 10 | 833 |
| Vermont | 144 | 45 | 32 | 0[a] | 0[a] | 33 | 2 | 31 | 0 | 1 | 143 |
| Virginia | 3,519 | 727 | 777 | 111 | 358 | 516 | 570 | 460 | 0 | 0 | 3,519 |
| Washington | 2,744 | 1,000 | 52 | 226 | 136 | 198 | 521 | 608 | 0 | 3 | 2,741 |
| West Virginia | 2,529 | 298 | 12 | 134 | 47 | 691 | 478 | 869 | 0 | 0 | 2,529 |
| Wisconsin | 3,338 | 588 | 141 | 54 | 365 | 260 | 462 | 342 | 16 | 1,110 | 2,212 |
| Wyoming | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| American Samoa | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Guam | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| N. Mariana Islands | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Puerto Rico | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Virgin Islands | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Total | 181,198 | 36,833 | 20,419 | 8,165 | 16,762 | 14,265 | 14,844 | 50,588 | 5,549 | 13,773 | 161,876 |

**Categories**

I Secondary wastewater treatment
II Advanced wastewater treatment
III-A Infiltration/inflow correction
III-B Sewer replacement/rehabilitation
IV-A New collector sewers and appurtenances
IV-B New interceptor sewers and appurtenances
V Combined sewer overflow correction
VI Storm water management programs
VII NPS pollution control (see Table A.2 for totals by subcategory)

*Note:* NR, not reported. American Samoa, Guam, Nevada, Northern Mariana Islands, Puerto Rico, Virgin Islands, and Wyoming did not participate in the CWNS 2000.

[a] Estimate is less than $0.5 million.

*Source*: From 2000 Clean Watersheds Needs Survey Report to Congress, Published 2003, Appendix A, Table A.1, p. A.2 and A.3. www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm, www.epa.gov/owm/mtb/cwns/2000rtc/cwns2000-appendix-a.pdf.

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**Table 9A.16 Number of Treatment Facilities and Population Served Per State by Level of Treatment for Year 2000**

| State | Number of Facilities Providing Listed Effluent Level | | | | Population Served by Listed Effluent Level | | | |
|---|---|---|---|---|---|---|---|---|
| | Less than Secondary[a] | Secondary | Greater than Secondary | No Discharge[b] | Less than Secondary[a] | Secondary | Greater than Secondary | No Discharge[b] |
| Alabama | 0 | 130 | 129 | 8 | 0 | 732,009 | 1,994,219 | 7,593 |
| Alaska | 5 | 30 | 0 | 9 | 207,994 | 108,879 | 0 | 21,920 |
| Arizona | 0 | 17 | 18 | 81 | 0 | 111,767 | 2,215,703 | 1,378,004 |
| Arkansas | 0 | 118 | 207 | 9 | 0 | 726,471 | 803,753 | 12,155 |
| California[c] | 5 | 182 | 77 | 309 | 4,198,270 | 12,159,009 | 7,919,130 | 3,577,181 |
| Colorado[c] | 0 | 246 | 38 | 22 | 0 | 1,556,854 | 2,142,434 | 7,788 |
| Connecticut | 0 | 49 | 38 | 4 | 0 | 1,266,574 | 813,536 | 1,210 |
| Delaware | 0 | 3 | 11 | 4 | 0 | 10,476 | 728,997 | 13,070 |
| District of Columbia[d] | 0 | 0 | 1 | 0 | 0 | 0 | 1,298,601 | 0 |
| Florida | 0 | 17 | 84 | 175 | 0 | 238,764 | 6,155,714 | 4,931,819 |
| Georgia | 0 | 227 | 80 | 35 | 0 | 1,721,572 | 2,594,389 | 89,249 |
| Hawaii | 2 | 5 | 2 | 12 | 532,378 | 139,609 | 20,286 | 89,512 |
| Idaho | 0 | 107 | 5 | 55 | 0 | 562,008 | 265,812 | 60,303 |
| Illinois | 0 | 415 | 301 | 1 | 0 | 683,543 | 9,811,768 | 572 |
| Indiana | 0 | 125 | 274 | 0 | 0 | 410,940 | 3,416,852 | 0 |
| Iowa | 0 | 707 | 9 | 3 | 0 | 1,925,926 | 181,763 | 1,393 |
| Kansas | 0 | 355 | 79 | 197 | 0 | 694,512 | 1,277,425 | 101,964 |
| Kentucky | 0 | 123 | 94 | 0 | 0 | 1,242,187 | 921,134 | 0 |
| Louisiana | 1 | 184 | 163 | 1 | 3,000 | 2,268,451 | 878,478 | 207 |
| Maine | 12 | 116 | 2 | 7 | 9,303 | 624,604 | 16,038 | 5,956 |
| Maryland | 0 | 75 | 75 | 6 | 0 | 949,367 | 2,045,325 | 3,920 |
| Massachusetts | 1 | 77 | 35 | 7 | 20,074 | 4,235,095 | 822,135 | 17,043 |
| Michigan | 0 | 204 | 120 | 68 | 0 | 1,254,599 | 6,161,491 | 108,121 |
| Minnesota | 1 | 411 | 100 | 0 | 42 | 967,813 | 2,073,977 | 0 |
| Mississippi | 0 | 195 | 75 | 1 | 0 | 1,139,734 | 507,809 | 524 |
| Missouri | 0 | 578 | 77 | 21 | 0 | 3,757,717 | 451,630 | 2,663 |
| Montana | 0 | 107 | 5 | 80 | 0 | 397,988 | 89,635 | 63,564 |
| Nebraska | 0 | 298 | 19 | 146 | 0 | 977,825 | 155,078 | 64,166 |
| Nevada[e] | 0 | 44 | 3 | 4 | 0 | 139,996 | 252,229 | 237,442 |
| New Hampshire | 1 | 70 | 2 | 10 | 25,409 | 555,435 | 17,890 | 7,984 |
| New Jersey | 0 | 94 | 55 | 1 | 0 | 6,762,536 | 1,090,502 | 34,307 |
| New Mexico | 0 | 57 | 1 | 17 | 0 | 898,530 | 7,150 | 135,338 |
| New York[c] | 0 | 360 | 178 | 27 | 0 | 11,273,282 | 3,748,413 | 116,814 |
| North Carolina | 0 | 313 | 134 | 33 | 0 | 1,056,606 | 2,576,092 | 112,989 |
| North Dakota | 0 | 254 | 1 | 27 | 0 | 468,946 | 21,531 | 5,909 |
| Ohio | 0 | 169 | 593 | 2 | 0 | 1,401,922 | 7,404,543 | 956 |
| Oklahoma | 0 | 249 | 39 | 199 | 0 | 1,716,478 | 712,679 | 151,004 |
| Oregon | 1 | 101 | 67 | 37 | 625 | 1,333,432 | 1,219,279 | 33,050 |
| Pennsylvania | 2 | 360 | 397 | 2 | 1,476 | 6,237,683 | 4,157,929 | 2,314 |
| Rhode Island | 0 | 19 | 2 | 0 | 0 | 687,805 | 10,184 | 0 |
| South Carolina | 0 | 123 | 53 | 7 | 0 | 1,769,072 | 549,626 | 30,628 |
| South Dakota[c] | 0 | 234 | 8 | 29 | 0 | 268,874 | 164,144 | 14,467 |
| Tennessee | 0 | 110 | 130 | 5 | 0 | 1,459,559 | 1,700,862 | 4,193 |
| Texas | 2 | 524 | 661 | 160 | 1,070 | 2,538,924 | 14,025,086 | 640,857 |
| Utah | 0 | 49 | 4 | 44 | 0 | 1,636,148 | 190,027 | 134,011 |
| Vermont | 0 | 48 | 31 | 2 | 0 | 90,497 | 193,684 | 722 |
| Virginia | 0 | 157 | 60 | 2 | 0 | 2,166,150 | 2,318,144 | 1,373 |
| Washington | 0 | 201 | 7 | 27 | 0 | 2,847,237 | 894,801 | 31,127 |
| West Virginia | 3 | 142 | 63 | 0 | 2,205 | 581,527 | 374,677 | 0 |
| Wisconsin | 0 | 283 | 279 | 26 | 0 | 573,346 | 3,250,360 | 20,360 |
| Wyoming[e] | 0 | 78 | 3 | 14 | 0 | 244,075 | 87,923 | 3,030 |
| American Samoa[e] | 2 | 0 | 0 | 0 | 5,511 | 0 | 0 | 0 |
| Guam[e] | 2 | 2 | 0 | 2 | 62,639 | 9,236 | 0 | 4,275 |
| N. Mariana Islands[e] | 0 | 2 | 0 | 0 | 0 | 1,118 | 0 | 0 |
| Puerto Rico[e] | 6 | 22 | 2 | 0 | 1,336,535 | 581,405 | 151,290 | 0 |

*(Continued)*

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**Table 9A.16 (Continued)**

| State | Number of Facilities Providing Listed Effluent Level | | | | Population Served by Listed Effluent Level | | | |
|---|---|---|---|---|---|---|---|---|
| | Less than Secondary[a] | Secondary | Greater than Secondary | No Discharge[b] | Less than Secondary[a] | Secondary | Greater than Secondary | No Discharge[b] |
| Virgin Islands[e] | 1 | 10 | 1 | 0 | 19,531 | 58,294 | 50 | 0 |
| Total | 47 | 9,156 | 4,892 | 1,938 | 6,426,062 | 88,221,896 | 100,882,207 | 12,283,047 |

[a] Less-than-secondary facilities include facilities granted or pending section 301(h) waivers from secondary treatment for discharges to marine waters.
[b] No-discharge facilities do not discharge treated wastewater to the Nation's waterways. These facilities dispose of wastewater via methods such as industrial reuse, irrigation, or evaporation.
[c] California, Colorado, New York, and South Dakota did not have the resources to complete updating of these data.
[d] The reported population served for the District of Columbia includes populations from Maryland and Virginia that receive wastewater treatment at the Blue Plains facility in the District of Columbia.
[e] Results presented in this table for American Samoa, Guam, Northern Mariana Islands, Nevada, Puerto Rico, Virgin Islands, and Wyoming are from the 1996 survey because these States and Territories did not participate in the CWNS 2000.

*Source*: From 2000 Clean Watersheds Needs Survey Report to Congress, Published 2003, Appendix C, Table C.7, p. C.10 and C.11. www.epa.gov/owm/mtb/cwns/2000rtc/cwns2000-appendix-c.pdf, www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm.

**Table 9A.17 Typical Wastewater Pollutants of Concern**

| Pollutant | Reason for Concern |
|---|---|
| Total suspended solids (TSS) and turbidity (NTU) | In surface waters, suspended solids can result in the development of sludge deposits that smother benthic macroinvertebrates and fish eggs and can contribute to benthic enrichment, toxicity, and sediment oxygen demand. Excessive turbidity (colloidal solids that interfere with light penetration) can block sunlight, harm aquatic life (e.g., by blocking sunlight needed by plants), and lower the ability of aquatic plants to increase dissolved oxygen in the water column. In drinking water, turbidity is aesthetically displeasing and interferes with disinfection |
| Biodegradable organics (BOD) | Biological stabilization of organics in the water column can deplete dissolved oxygen in surface waters, creating anoxic conditions harmful to aquatic life. Oxygen-reducing conditions can also result in taste and odor problems in drinking water |
| Pathogens | Parasites, bacteria, and viruses can cause communicable diseases through direct/indirect body contact or ingestion of contaminated water or shellfish. A particular threat occurs when partially treated sewage pools on ground surfaces or migrates to recreational waters. Transport distances of some pathogens (e.g., viruses and bacteria) in groundwater or surface waters can be significant |
| Nitrogen | Nitrogen is an aquatic plant nutrient that can contribute to eutrophication and dissolved oxygen loss in surface waters, especially in lakes, estuaries, and coastal embayments. Algae and aquatic weeds can contribute trihalomethane (THM) precursors to the water column that may generate carcinogenic THMs in chlorinated drinking water. Excessive nitrate-nitrogen in drinking water can cause methemoglobinemia in infants and pregnancy complications for women. Livestock can also suffer health impacts from drinking water high in nitrogen |
| Phosphorus | Phosphorus is an aquatic plant nutrient that can contribute to eutrophication of inland and coastal surface waters and reduction of dissolved oxygen |
| Toxic organics | Toxic organic compounds present in household chemicals and cleaning agents can interfere with certain biological processes in alternative OWTSs. They can be persistent in groundwater and contaminate downgradient sources of drinking water. They can also cause damage to surface water ecosystems and human health through ingestion of contaminated aquatic organisms (e.g., fish, shellfish) |
| Heavy metals | Heavy metals like lead and mercury in drinking water can cause human health problems. In the aquatic ecosystem, they can also be toxic to aquatic life and accumulate in fish and shellfish that might be consumed by humans |
| Dissolved inorganics | Chloride and sulfide can cause taste and odor problems in drinking water. Boron, sodium, chlorides, sulfate, and other solutes may limit treated wastewater reuse options (e.g., irrigation). Sodium and to a lesser extent potassium can be deleterious to soil structure and SWIS performance |

*Source*: From USEPA, *On-Site Wastewater Treatment Systems Manual*, Office of Water, Office of Research and Development, EPA, (EPA/625/R-00/0008), Table 3.16, p. 3–23. www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008totaldocument.pdf; Adapted in part from Tchobanoglous and Burton, 1991.

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**Table 9A.18 Wastewater Constituents of Concern and Representative Concentrations in the Effluent of Various Treatment Units**

| | | Tank-Based Treatment Unit Effluent Concentrations | | | | | |
|---|---|---|---|---|---|---|---|
| **Constituents of Concern** | **Example Direct or Indirect Measures (Units)** | **Domestic STE[a]** | **Domestic STE with N-Removal Recycle[b]** | **Aerobic Unit Effluent** | **Sand Filter Effluent** | **Foam or Textile Filter Effluent** | **SWIS Percolate into Groundwater at 3 to 5 ft Depth (% Removal)** |
| Oxygen demand | $BOD_5$ (mg/L) | 140–200 | 80–120 | 5–50 | 2–15 | 5–15 | >90 |
| Particulate solids | TSS (mg/L) | 50–100 | 50–80 | 5–100 | 5–20 | 5–10 | >90 |
| Nitrogen | Total N (mg N/L) | 40–100 | 10–30 | 25–60 | 10–50 | 30–60 | 10–20 |
| Phosphorus | Total P (mg P/L) | 5–15 | 5–15 | 4–10 | $<1$–$10^4$ | 5–$15^4$ | 0–100 |
| Bacteria (e.g., *Clostridium perfringens, Salmonella Shigella*) | Fecal coliform (organisms per 100 mL) | $10^6$–$10^8$ | $10^6$–$10^8$ | $10^3$–$10^4$ | $10^1$–$10^3$ | $10^1$–$10^3$ | >99.99 |
| Virus (e.g., hepatitis, polio, echo, coxsackie, coliphage) | Specific virus (pfu/mL) | 0–$10^5$ (episodically present at high levels) | 0–$10^5$ (episodically present at high levels) | 0–$10^5$ (episodically present at high levels) | 0–$10^5$ (episodically present at high levels) | 0–$10^5$ (episodically present at high levels) | >99.9% |
| Organic chemicals (e.g., solvents, petrochemicals, pesticides) | Specific organics or totals (μg/L) | 0 to trace levels (?) | 0 to trace levels (?) | 0 to trace levels (?) | 0 to trace levels (?) | 0 to trace levels (?) | >99% |
| Heavy metals (e.g., Pb, Cu, Ag, Hg) | Individual metals (μg/L) | 0 to trace levels | 0 to trace levels | 0 to trace levels | 0 to trace levels | 0 to trace levels | >99% |

[a] Septic tank effluent (STE) concentrations given are for domestic wastewater. However, restaurant STE is markedly higher particularly in BOD, COD, and suspended solids while concentrations in graywater STE are noticeably lower in total nitrogen.

[b] N-removal accomplished by recycling STE through a packed bed for nitrification with discharge into the influent end of the septic tank for denitrification.

*Source*: From Van Cuyk, S.M., R.L. Siegrist, and A.L. Logan. 2001. Evaluation of virus and microbiological purification in wastewater soil absorption systems using multicomponent surrogate and tracer additions. *On-Site Wastewater Treatment: Proceedings of the Ninth National Symposium on Individual and Small Community Sewage Systems*. American Society of Agricultural Engineers, St. Joseph, MI; USEPA, *On-Site Wastewater Treatment Systems Manual*, Office of Water, Office of Research and Development, EPA (EPA/625/R-00/0008), Table 3.19, p. 3–29. www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008totaldocument.pdf.



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**Table 9A.19 Proposed On-Site System Treatment Performance Standards in Various Control Zones**

| Standard | BOD (mg/L) | TSS (mg/L) | PO.-P (mg/L) | NH.-N (mg/L) | N03-N (mg/L) | Total N (% Removed)[a] | Fecal Coliforms (CFU/1,000 mL)[b] |
|---|---|---|---|---|---|---|---|
| T81—primary treatment | | | | | | | |
| T81u—unfiltered | 300 | 300 | 15 | 80 | NA | NA | 10,000,000 |
| T811—filtered | 200 | 80 | 15 | 80 | NA | NA | 10,000,000 |
| T82—secondary treatment | 30 | 30 | 15 | 10 | NA | NA | 50,000 |
| T83—tertiary treatment | 10 | 10 | 15 | 10 | NA | NA | 10,000 |
| T84—nutrient reduction | | | | | | | |
| T84n—nitrogen reduction | 10 | 10 | 15 | 5 | NA | 50 | 10,000 |
| T84p—phosphorus reduction | 10 | 10 | 2 | 10 | NA | 25 | 10,000 |
| T84np—N & P reduction | 10 | 10 | 2 | 5 | NA | 50 | 10,000 |
| T85—bodily contact disinfection | 10 | 10 | 15 | 10 | NA | 25 | 200 |
| T86—wastewater reuse | 5 | 5 | 15 | 5 | NA | 50 | 14 |
| T87—near drinking water | 5 | 5 | 1 | 5 | 10 | 75 | <1b |

*Note:* NA, not available.

[a] Minimum percentage reduction of total nitrogen (as nitrate-nitrogen plus ammonium nitrogen) concentration in the raw, untreated wastewater.
[b] Total coliform colony densities <50 per 100 mL of effluent.

*Source*: From Hoover, M.T., A. Arenovski, D. Daly, and D. Lindbo. 1998. A risk-based approach to on-Site system siting, design and management. In *On-Site Wastewater Treatment. Proceedings of the Eighth National Symposium on Individual and Small Community Sewage Systems.* American Society of Agricultural Engineers, St. Joseph, MI; USEPA, *On-Site Wastewater Treatment Systems Manual*, Office of Water, Office of Research and Development, EPA, (EPA/625/R-00/0008), Table 3.27, p. 3–48. www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008totaldocument.pdf.

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**Table 9A.20 Typical Wastewater Constituent Data for Various Countries**

| Country/ Constituent | BOD, g/capita d | TSS, g/capita d | TKN, g/capita d | $NH_3$-N, g/capita d | Total P, g/capita d |
|---|---|---|---|---|---|
| Brazil | 55–68 | 55–68 | 8–14 | ND | 0.6–1 |
| Denmark | 55–68 | 82–96 | 14–19 | ND | 1.5–2 |
| Egypt | 27–41 | 41–68 | 8–14 | ND | 0.4–0.6 |
| Germany | 55–68 | 82–96 | 11–16 | ND | 1.2–1.6 |
| Greece | 55–60 | ND | ND | 8–10 | 1.2–1.5 |
| India | 27–41 | ND | ND | ND | ND |
| Italy | 49–60 | 55–82 | 8–14 | ND | 0.6–1 |
| Japan | 40–45 | ND | 1–3 | ND | 0.15–0.4 |
| Palestine[a] | 32–68 | 52–72 | 4–7 | 3–5 | 0.4–0.7 |
| Sweden | 68–82 | 82–96 | 11–16 | ND | 0.8–1.2 |
| Turkey | 27–50 | 41–68 | 8–14 | 9–11 | 0.4–2 |
| Uganda | 55–68 | 41–55 | 8–14 | ND | 0.4–0.6 |
| United States[b] | 50–120 | 60–150 | 9–22 | 5–12 | 2.7–4.5 |

[a] West Bank and Gaza Strip.
[b] From Table 3.11.

*Source*: From Metcalf & Eddy, Inc., McGraw-Hill, *Wastewater Engineering Treatment and Reuse, Fourth Edition*, 2003, Table 3.14, p. 184. With permission. Adapted from Henze et al. (1997), Ozturk et al. (1992), Andreadakis (1992), and Nashashibi and van Duijl (1995).

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## SECTION 9B CENTRALIZED WASTEWATER TREATMENT

**Table 9B.21 Gravity Sewer Average Design Flows for Development Types**

| Type of Development | Design Flow (GPD) |
|---|---|
| *Residential* | |
| General | 100/person |
| Single family | 370/residence |
| Townhouse unit | 300/unit |
| Apartment unit | 300/unit |
| *Commercial* | |
| General | 2,000/acre |
| Motel | 130/unit |
| Office | 20/employee<br>0.20/net sq.ft |
| *Industrial (varies with type of industry)* | |
| General | 10,000/acre |
| Warehouse | 600/acre |
| **School site (general)** | 16/student |

*Source*: From Darby, 1995; USEPA, *Collection Systems Technology Fact Sheet, Sewers, Conventional Gravity*, Office of Water, Municipal Technology Branch, Table 1, (EPA/823/F-02/007), September 2002. epa.gov/owm/mtb/congrasew.pdf.

**Table 9B.22 Minimum Slope for Gravity Sewers**

| Nominal Sewer Size | Minimum Slope (in ft per 100 ft lm/100 m) |
|---|---|
| 8 in. (200 mm) | 0.40 |
| 10 in. (250 mm) | 0.28 |
| 12 in. (300 mm) | 0.22 |
| 14 in. (350 mm) | 0.17 |
| 15 in. (375 mm) | 0.15 |
| 16 in. (400 mm) | 0.14 |
| 18 in. (450 mm) | 0.12 |
| 21 in. (525 mm) | 0.10 |
| 24 in. (600 mm) | 0.08 |
| 27 in. (675 mm) | 0.067 |
| 30 in. (750 mm) | 0.058 |
| 33 in. (825 mm) | 0.052 |
| 36 in. (900 mm) | 0.046 |
| 39 in. (975 mm) | 0.041 |
| 42 in. (1,050 mm) | 0.037 |

*Source*: From Board of State and Provincial Public Health and Environmental Managers, Health Education Services Division, Recommended Standards for Wastewater Facilities, 2004 Edition. hes.org.

**Table 9B.23 Force Main Capacity**

| | Velocity = 2 fps | | Velocity = 4 fps | | Velocity = 6 fps | |
|---|---|---|---|---|---|---|
| Diameter (in.) | gpm | lps | gpm | lps | gpm | lps |
| 6 | 176 | 11 | 362 | 22 | 528 | 33 |
| 8 | 313 | 20 | 626 | 40 | 626 | 60 |
| 10 | 490 | 31 | 980 | 62 | 1,470 | 93 |
| 18 | 1,585 | 100 | 3,170 | 200 | 4,755 | 300 |
| 24 | 2,819 | 178 | 5,638 | 356 | 8,457 | 534 |
| 36 | 6,342 | 400 | 12,684 | 800 | 19,026 | 1,200 |

*Source*: From Metcalf and Eddy, 1981; USEPA, *Wastewater Technology Fact Sheet Sewers, Force Main,* Office of Water, Municipal Technology Branch, Table 2 (EPA/823/f-00/071), September 2000. epa.gov/own/mtb/force_main_sewers.pdf.

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**Table 9B.24 Common Sewer Cleaning Methods**

| Technology | Uses and Applications |
|---|---|
| **Mechanical** | |
| Rodding | Uses an engine and a drive unit with continuous rods or sectional rods. As blades rotate they break up grease deposits, cut roots, and loosen debris<br>Rodders also help thread the cables used for TV inspections and bucket machines<br>Most effective in lines up to 300 mm (12 in.) in diameter |
| Bucket machine | Cylindrical device, closed on one end with 2 opposing hinged jaws at the other<br>Jaws open and scrape off the material and deposit it in the bucket<br>Partially removes large deposits of silt, sand, gravel, and some types of solid waste |
| **Hydraulic** | |
| Balling | A threaded rubber cleaning ball that spins and scrubs the pipe interior as flow increases in the sewer line<br>Removes deposits of settled inorganic material and grease build-up<br>Most effective in sewers ranging in size from 13 to 60 cm (5–24 in.) |
| Flushing | Introduces a heavy flow of water into the line at a manhole. Removes floatables and some sand and grit<br>Most effective when used in combination with other mechanical operations, such as rodding or bucket machine cleaning |
| Jetting | Directs high velocities of water against pipe walls. Removes debris and grease build-up, clears blockages, and cuts roots within small diameter pipes<br>Efficient for routine cleaning of small diameter, low flow sewers |
| **Technology** | **Applications** |
| Scooter | Round, rubber-rimmed, hinged metal shield that is mounted on a steel framework on small wheels. The shield works as a plug to build a head of water<br>Scours the inner walls of the pipe lines<br>Effective in removing heavy debris and cleaning grease from line |
| Kites, bags, and poly pigs | Similar in function to the ball<br>Rigid rims on bag and kite induce a scouring action<br>Effective in moving accumulations of decayed debris and grease downstream |
| Silt traps | Collect sediments at convenient locations<br>Must be emptied on a regular basis as part of the maintenance program |
| Grease traps and sand/oil interceptors | The ultimate solution to grease build-up is to trap and remove it<br>These devices are required by some uniform building codes and/or sewer-use ordinances. Typically sand/oil interceptors are required for automotive business discharge<br>Need to be thoroughly cleaned to function properly<br>Cleaning frequency varies from twice a month to once every 6 months, depending on the amount of grease in the discharge<br>Need to educate restaurant and automobile businesses about the need to maintain these traps |
| **Chemicals**<br>Before using these chemicals review the material safety data sheets (MSDS) and consult the local authorities on the proper use of chemicals as per local ordinance and the proper disposal of the chemicals used in the operation. If assistance or guidance is needed regarding the application of certain chemicals, contact the U.S. EPA or state water pollution control agency | Used to control roots, grease, odors ($H_2S$ gas), concrete corrosion, rodents and insects<br>Root control — Longer lasting effects than power rodder (approximately 2–5 years)<br>$H_2S$ gas — Some common chemicals used are chlorine ($Cl_2$), hydrogen peroxide ($H_2O_2$), pure oxygen ($O_2$), air, lime ($Ca(OH_2)$), sodium hydroxide (NaOH), and iron salts<br>Grease and soap problems — Some common chemicals used are bioacids, digester, enzymes, bacteria cultures, catalysts, caustics, hydroxides, and neutralizers |

*Source*: From information provided by Arbour and Kerri, 1997 and Sharon, 1989; USEPA, *Collection Systems, O&M Fact Sheet, Sewer Cleaning and Inspection*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/f-99/031), September 1999. www.epa.gov/owm/mtb/sewcl.pdf.

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**Table 9B.25 Frequency of Maintenance Activities for Sewer Lines**

| Activity | Average (% of system/year) |
|---|---|
| Cleaning | 29.9 |
| Root removal | 2.9 |
| Manhole inspection | 19.8 |
| CCTV inspection | 6.8 |
| Smoke testing | 7.8 |

*Source*: From ASCE, 1998; USEPA, *Collection Systems, O&M Fact Sheet, Sewer Cleaning and Inspection*, Office of Water, Municipal Technology Branch, Table 2 (EPA/823/f-99/031), September 1999. www.epa.gov/owm/mtb/sewcl.pdf.

**Table 9B.26 Limitations of Standard Inspection Techniques for Sewer Lines**

| Inspection Technique | Limitations |
|---|---|
| Visual inspection | In smaller sewers, the scope of problems detected is minimal because the only portion of the sewer that can be seen in detail is near the manhole. Therefore, any definitive information on cracks or other structural problems is unlikely. However, this method does provide information needed to make decisions on rehabilitation |
| Camera inspection | When performing a camera inspection in a large diameter sewer, the inspection crew is essentially taking photographs haphazardly, and as a result, the photographs tend to be less comprehensive |
| Closed circuit television (CCTV) | This method requires late night inspection and as a result the TV operators are vulnerable to lapses in concentration. CCTV inspections are also quite expensive and time-consuming |
| Lamping inspection | The video camera does not fit into the pipe and during the inspection it remains only in the maintenance hole. As a result, only the first 10 ft of the pipe can be viewed or inspected using this method |

*Source*: From Water Pollution Control Federation, 1989; USEPA, *Collection Systems, O&M Fact Sheet, Sewer Cleaning and Inspection*, Office of Water, Municipal Technology Branch, Table 3 (EPA/823/F-99/031), September 1999. www.epa.gov/owm/mtb/-sewcl.pdf.

**Table 9B.27 Limitations of Cleaning Methods for Sewer Lines**

| Cleaning Method | Limitations |
|---|---|
| Balling, jetting, scooter | In general, these methods are only successful when necessary water pressure or head is maintained without flooding basements or houses at low elevations. Jetting—The main limitation of this technique is that caution needs to be used in areas with basement fixtures and in steep-grade hill areas. Balling—Balling cannot be used effectively in pipes with bad offset joints or protruding service connections because the ball can become distorted<br>Scooter—When cleaning larger lines, the manholes need to be designed to a larger size in order to receive and retrieve the equipment. Otherwise, the scooter needs to be assembled in the manhole. Caution also needs to be used in areas with basement fixtures and in steep-grade hill areas |
| Bucket, machine | This device has been known to damage sewers. The bucket machine cannot be used when the line is completely plugged because this prevents the cable from being threaded from one manhole to the next. Set-up of this equipment is time-consuming |
| Flushing | This method is not very effective in removing heavy solids. Flushing does not remedy this problem because it only achieves temporary movement of debris from one section to another in the system |
| High velocity cleaner | The efficiency and effectiveness of removing debris by this method decreases as the cross-sectional areas of the pipe increase. Backups into residences have been known to occur when this method has been used by inexperienced operators. Even experienced operators require extra time to clear pipes of roots and grease |
| Kite or bag | When using this method, use caution in locations with basement fixtures and steep-grade hill areas |
| Rodding | Continuous rods are harder to retrieve and repair if broken and they are not useful in lines with a diameter of greater than 300 mm (0.984 ft) because the rods have a tendency to coil and bend. This device also does not effectively remove sand or grit, but may only loosen the material to be flushed out at a later time |

*Source*: From USEPA, 1993; USEPA, *Collection Systems, O&M Fact Sheet, Sewer Cleaning and Inspection*, Office of Water, Municipal Technology Branch, Table 4 (EPA/823/F-99/031), September 1999. www.epa.gov/owm/mtb/sewcl.pdf.

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**Table 9B.28 Comparison of Various Sewer Rehabilitation Techniques**

| Method | | Diameter Range (mm) | Maximum Installation (m) | Liner Material |
|---|---|---|---|---|
| In-line expansion | Pipe bursting | 100–600 (4–24 in.) | 230 (750 ft) | PE, PP, PVC, GRP |
| Sliplining | Segmental | 100–4,000 (4–158 in.) | 300 (1,000 ft) | PE, PP, PVC, GRP (−EP & −UP) |
| | Continuous | 100–1,600 (4–63 in.) | 300 (1,000 ft) | PE, PP, PE/EPDM, PVC |
| | Spiral wound | 150–2,500 (6–100 in.) | 300 (1,000 ft) | PE, PVC, PP, PVDF |
| Cured-in-place Product linings | Inverted-in-place | 100–2,700 (4–108 in.) | 900 (3,000 ft) | Thermoset Resin/fabric composite |
| | Winched-in-place | 100–1,400 (4–54 in.) | 150 (500 ft) | Thermoset resin/fabric composite |
| | Spray-on-linings | 76–4,500 (3–180 in.) | 150 (500 ft) | Epoxy resins/cement mortar |
| Modified cross-sectional methods | Fold and form | 100–400 (4–15 in.) | 210 (700 ft) | PVC |
| | Deformed/reformed | 100–400 (4–15 in.) | 800 (2,500 ft) | (Thermoplastics) HDPE (thermoplastics) |
| | Drawdown | 62–600 (3–24 in.) | 300 (1,000 ft) | HDPE, MDPE |
| | Rolldown | 62–600 (3–24 in.) | 300 (1,000 ft) | HDPE, MDPE |
| | Thin-walled lining | 500–1,100 (20–46 in.) | 960 (3,000 ft) | HDPE |
| Internal point Repair | Robotic repair | 200–760 (8–30 in.) | N/A | Exopy resins Cement mortar |
| | Grouting/sealing & spray-on | N/A | N/A | Chemical grouting |
| | Link seal | 100–600 (4–24 in.) | N/A | Special sleeves |
| | Point CIPP | 100–600 (4–24 in.) | 15 (50 ft) | Fiberglass/polyester, etc |

*Note:* Spiral wound sliplining, robotic repair, and point CIPP can only be used only with gravity pipeline. All other methods can be used with both gravity and pressure pipeline. EPDM, ethylene polypelene diene monomer; GRP, glassfiber reinforced polyester; HDPE, high density polyethylene; MDPE, medium density polyethylene; PE, polyethylene; PP, polypropylene; PVC, poly vinyl chloride; PVDF, poly vinylidene chloride.

*Source*: From Iseley and Najafi (1995); USEPA, *Collection Systems, O&M Fact Sheet, Trenchless Sewer Rehabilitation*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-99/0032), September 1999. www.epa.gov/owm/mtb/rehabl.pdf.

**Table 9B.29 Limitations of Trenchless Sewer Rehabilitation Techniques**

| Method | Limitations |
|---|---|
| Pipe bursting | Bypass or diversion of flow required |
| | Insertion pit required |
| | Percussive action can cause significant ground movement may not be suitable for all materials |
| Sliplining | Insertion pit required |
| | Reduces pipe diameter |
| | Not well suited for small diameter pipes |
| CIPP | Bypass or diversion of flow required |
| | Curing can be difficult for long pipe segments |
| | Must allow adequate curing time |
| | Defective installation may be difficult to rectify |
| | Resin may clump together on bottom of pipe |
| | Reduces pipe diameter |
| Modified cross section | Bypass or diversion of flow required |
| | The cross section may shrink or unfold after expansion |
| | Reduces pipe diameter |
| | Infiltration may occur between liner and host pipe unless sealed |
| | Liner may not provide adequate structural support |

*Source*: From USEPA, *Collection Systems, O&M Fact Sheet, Trenchless Sewer Rehabilitation*, Office of Water, Municipal Technology Branch, Table 2 (EPA/823/F-99/0032), September 1999. www.epa.gov/owm/mtb/rehabl.pdf.

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**Table 9B.30 Characteristics of Common Force Main Pipe Materials**

| Material | Application | Key Advantages | Key Disadvantages |
|---|---|---|---|
| Cast or ductile iron, cement lined | High pressure available sizes of 4–54 in. | Good resistance to pressure surges | More expensive than concrete and fiberglass |
| Steel, cement lined | High pressure all pipe sizes | Excellent resistance to pressure surges | More expensive than concrete and fiberglass |
| Asbestos cement | Moderate pressure for 36-in. + pipe sizes | No corrosion slow grease buildup | Relatively brittle |
| Fiberglass reinforced epoxy pipe | Moderate pressure for up to 36-in. pipe sizes | No corrosion slow grease buildup | 350 psi max pressure |
| Plastic | Low pressure for up to 36-in. pipe sizes | No corrosion slow grease buildup | Suitable for small pipe sizes and low pressure only |

*Source*: From Sanks, 1998; USEPA, *Wastewater Technology Fact Sheet Sewers, Force Main*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-99/040), September 1999. www.epa.gov/owm/mtb/force_main_sewers.pdf.

**Table 9.31 Design Parameters for Static Screens**

| | |
|---|---|
| Hydraulic loading, gal/min/ft of width | 100–180 |
| Incline of screens, degrees from vertical[a] | 35 |
| Slot space, μm | 250–1,600 |
| Automatic controls | None |

*Note:* gal/min/ft × 0.207 = l/m/s.

[a] Bauer Hydrasieves™ have 3-stage slopes on each screen: 25°, 35°, 45°.

*Source*: From USEPA, *Combined Sewer Overflow, Technology Fact Sheet, Screens Office of Water*, Municipal Technology Brach, Table 1 (EPA/823/F/F-99/040), September 1999. www.epa.gov/own/mtb/screens.pdf.

**Table 9B.32 Design Parameters for Drum Screens and Rotary Screen**

| Parameter | Drum/Band Screen | Rotary Screen |
|---|---|---|
| Screen spacing, μm | 100–420 | 74–167<br>105 recommended |
| Screen material | Stainless steel or plastic | Stainless steel or plastic |
| Drum speed, r/min | | |
| Speed range | 2–7 | 30–65 |
| Recommended speed | 5 | 55 |
| Peripheral speed, ft/s | | 14–16 |
| Submergence of drum, % | 60–70 | |
| Flux density, gal/ft$^2$/min of submergence screen | 20–50 | 70–150 |
| Hydraulic efficiency, % of inflow | | 75–90 |
| Headloss, in. | 6–24 | |
| Backwash | | |
| Volume, % of inflow | 0.5–3 | 0.02–2.5 |
| Pressure, lb/in.$^2$ | 30–50 | 50 |

*Note:* gal/ft$^2$/min × 2.44 = m$^3$/h/m$^2$ in. × 2.54 = cm ft × 0.305 = cm; lb/in.$^2$ × 0.0703 = kg/cm$^2$.

*Source*: From USEPA, *Combined Sewer Overflow, Technology Fact Sheet, Screens Office of Water*, Municipal Technology Brach, Table 2 (EPA/823/F/F-99/040), September 1999. www.epa.gov/owm/mtb/screens.pdf.

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**Table 9B.33 Typical Design Parameters for Package Plant**

| | Extended Aeration | SBR | Oxidation Ditch |
|---|---|---|---|
| $BOD_5$ loading (F:M) (lb $BOD_5$/lb MLVSS) | 0.05–0.15 | 0.05–0.30 | 0.05–0.30 |
| Oxygen required avg. at 20 °C (lb/lb $BOD_5$ applied) | 2–3 | 2–3 | 2–3 |
| Oxygen required peak at 20 °C (value × avg. flow) | 1.5–2.0 | 1.25–2.0 | 1.5–2.0 |
| MLSS (mg/L) | 3,000–6,000 | 1,500–5,000 | 3,000–6,000 |
| Detention time (hours) | 18–36 | 16–36 | 18–36 |
| Volumetric Loading (lb $BOD_5$/d/$10^3$ cu ft) | 10–25 | 5–15 | 5–30 |

*Source*: Adapted from Metcalf and Eddy, 1991 and WEF, 1998; USEPA, *Wastewater Technology Fact Sheet, Package Plants*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-00/016) September 2000. www.epa.gov/owm/mtb/package_plant.pdf.

**Table 9B.34 Extended Aeration Performance**

| | Typical Effluent Quality | Aldie WWTP (Monthly Average) |
|---|---|---|
| BOD (mg/L) | <30 or <10 | 5 |
| TSS (mg/L) | <30 or <10 | 17 |
| TP (mg/L) | <2[a] | [b] |
| $NH_3$-N (mg/L) | <2 | [b] |

[a] May require chemicals to achieve.
[b] DEQ does not require monitoring of these parameters.

*Source*: From Sloan, 1999 and Broderick, 1999; USEPA, *Wastewater Technology Fact Sheet, Package Plants*, Office of Water, Municipal Technology Brach, Table 1 (EPA/823/F-00/016) September 2000. www.epa.gov/owm/mtb/package_plant.pdf.

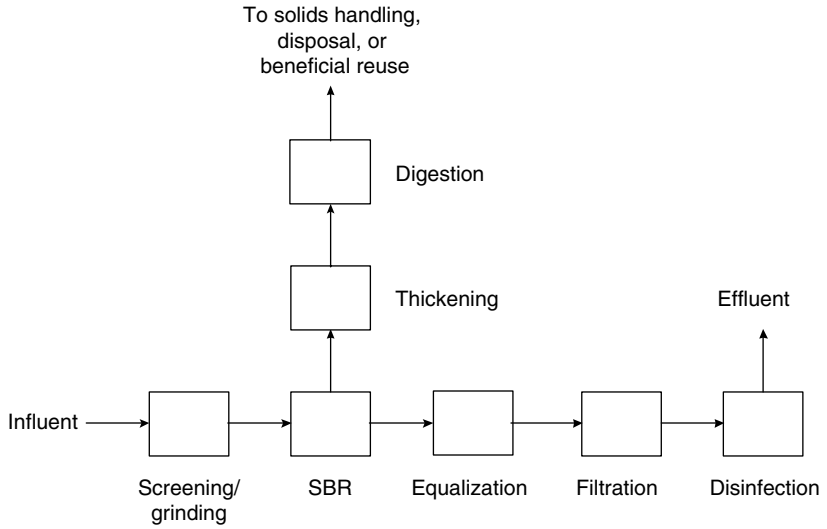


**Figure 9B.3** Sequencing batch reactors key design parameters for a conventional load. (From USEPA, *Wastewater Technology Fact Sheet, Sequencing Batch Reactors*, Office of Water, Municipal Technology Branch, Figure 1 (EPA/823/F-99/073) September 1999. www.epa.gov/owm/mtb/sbr_new.pdf.)

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**Table 9B.35 Sequencing Batch Reactors Key Design Parameters for A Conventional Load**

| | Municipal | Industrial |
|---|---|---|
| Food to mass (F:M) | 0.15–0.4/day | 0.15–0.6/day |
| Treatment cycle duration | 4.0 h | 4.0–24 h |
| Typically low water level mixed liquor suspended solids | 2,000–2,500 mg/L | 2,000–4,000 mg/L |
| Hydraulic retention time | 6–14 h | Varies |

*Source*: From USEPA, *Wastewater Technology Fact Sheet, Sequencing Batch Reactors*, Office of Water, Municipal Technology Brach, Table 1 (EPA/823/F-00/073) September 1999. www.epa.gov/owm/mtb/sbr_new pdf.

**Table 9B.36 Sequencing Batch Reactors Performance**

| | | Harrah WWTP | |
|---|---|---|---|
| | Typical Effluent | % Removal | Effluent |
| BOD (mg/L) | 10 | 98 | 3 |
| TSS (mg/L) | 10 | 98 | 3 |
| $NH_3$ (mg/L) | $<1$ | 97 | 0.6 |

*Source*: From Sloan, 1999 and Reynolds, 1999; USEPA, *Wastewater Technology Fact Sheet, Sequencing Batch Reactors*, Office of Water, Municipal Technology Brach, Table 2 (EPA/823/F-99/073) September 1999. www.epa.gov/owm/mtb/sbr_new pdf.

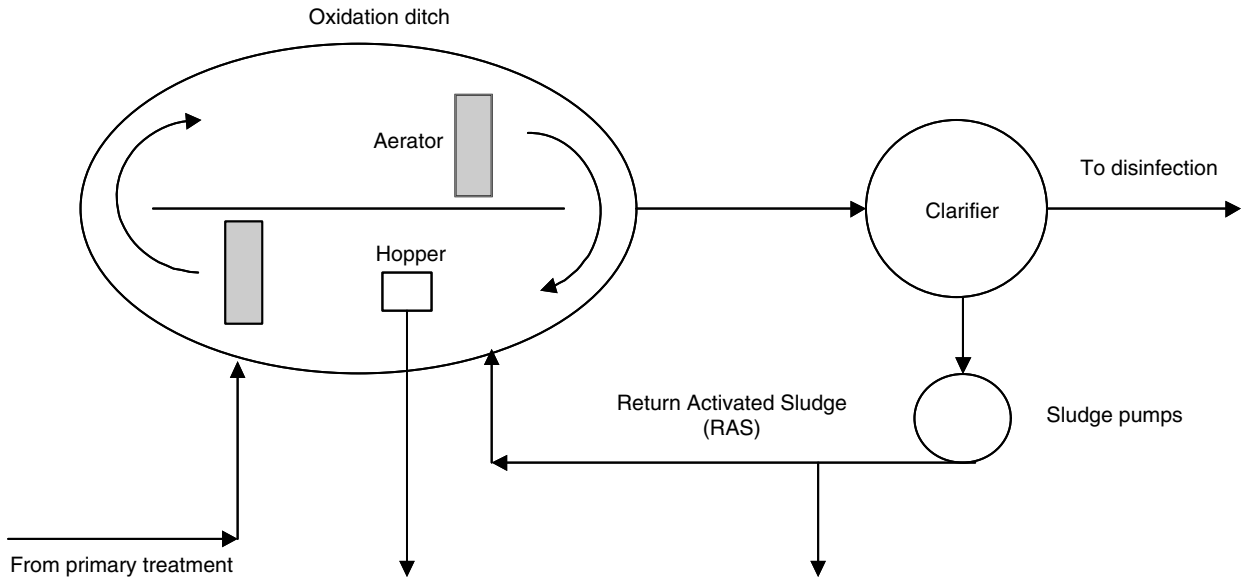


**Figure 9B.4** Typical oxidation ditch activated sludge system. (From USEPA, *Wastewater Technology Fact Sheet, Oxidation Ditches*, Office of Water, Municipal Technology Branch, Figure 1 (EPA /823/F-00/013) September 2000. www.epa.gov/owm/mtb/oxidation_ditch.pdf.)

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**Table 9B.37 Oxidation Ditch Performance**

| | Typical Effluent Quality | | Ocoee WWTP | |
|---|---|---|---|---|
| | With 2° Clarifier | With Filter | % Removal | Effluent |
| CBOD (mg/L) | 10 | 5 | >97 | 4.8 |
| TSS (mg/L) | 10 | 5 | >97 | 0.32 |
| TP (mg/L) | 2 | 1 | NA | NA |
| $N–NO_3$ (mg/L) | NA | NA | >95 | 0.25 |

*Note:* 2°, secondary; NA, not available.

*Source*: From Kruger, 1999 and Holland, 1999; USEPA, *Wastewater Technology Fact Sheet, Package Plants*, Office of Water, Municipal Technology Branch, Table 4 (EPA/823/F-00/016) September 2000. www.epa.gov/owm/mtb/package_plant.pdf.

**Table 9B.38 Trickling Filters Operational Parameters**

| Parameter | Low-Rate | High-Rate |
|---|---|---|
| Hydraulic loading gpd/ft | 25–100 | 200–1000 |
| Organic loading lb $BOD_5$/1000 $ft^3$ | 5–25 | 25–300 |
| Depth, ft | 6–8 | 15–40 |
| Filter media | Rock | Plastic |

*Source*: From USEPA, *Technology Transfer, Summary Report, Small Community Water and Wastewater Treatment*, Table 1, p. 20 (EPA/625/R-92/010) September 1992.

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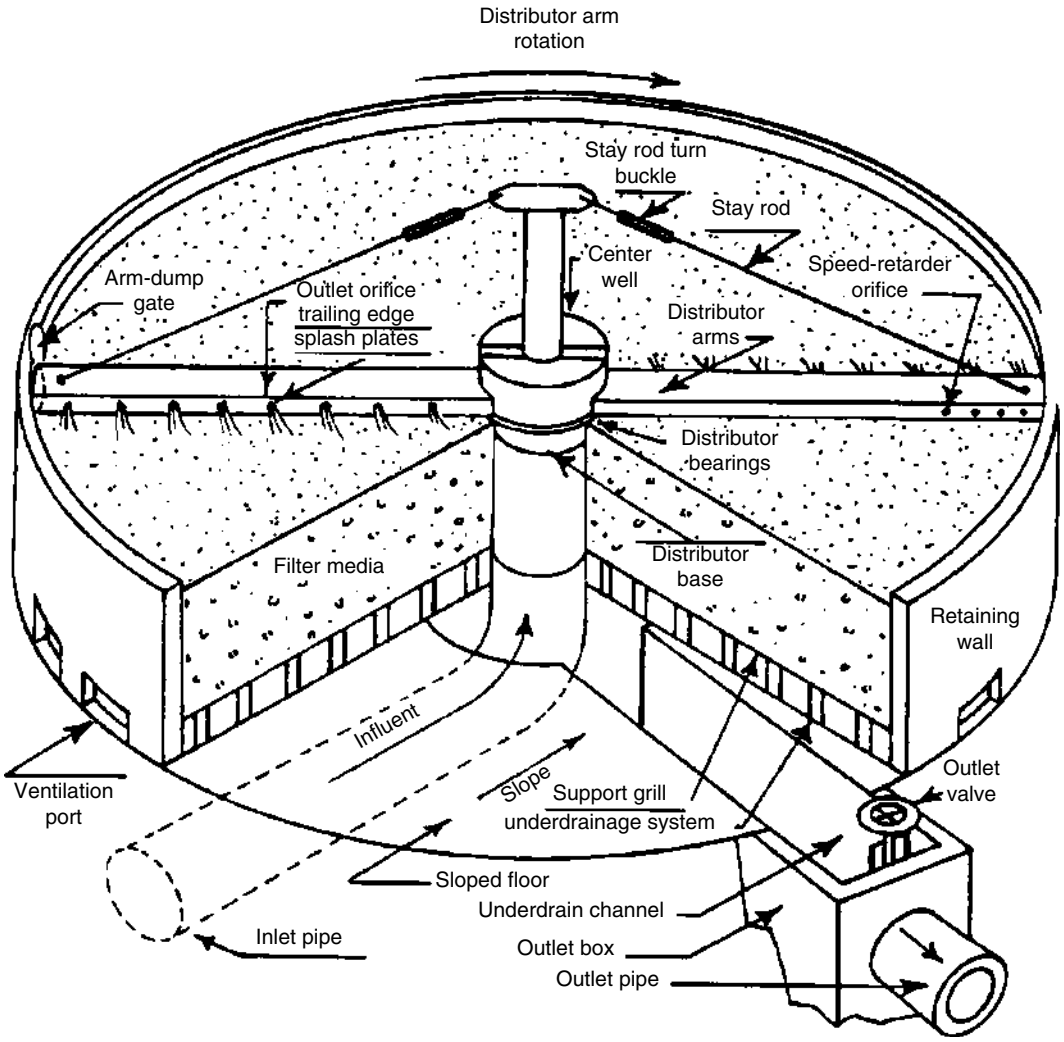


**Figure 9B.5** Typical trickling filter. (From USEPA, *Wastewater Technology Fact Sheet, Trickling Filter*, Office of Water, Municipal Technology Branch, Figure 1 (EPA/823/F-00/014) September 2000. www.epa.gov/owm/mtb/trickling_filter.pdf.)

**Table 9B.39 Typical Loading Rates for Single-Stage Nitrification in Trickling Filters**

| TF Media | % Nitrification | Loading Rate lb BOD/1,000 $ft^3$/d (g BOD/$m^3$/d) |
|---|---|---|
| Rock | 75–85 | 10–6 (160–96) |
| | 85–95 | 6–3 (96–48) |
| Plastic | 75–85 | 181–12 (288–192) |
| Tower TF | 85–95 | 12–6 (192–96) |

*Source*: From Metcalf & Eddy, Inc. with permission from the McGraw-Hill Companies, 1991; USEPA, *Wastewater Technology Fact Sheet, Trickling Filter Nitrification*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-00/015) September 2000. www.epa.gov/owm/mtb/trickling_filt_nitrification.pdf.

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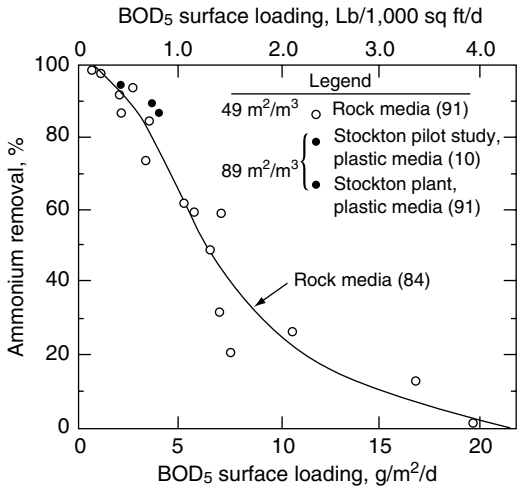


**Figure 9B.6** Effect of $BOD_5$ Surface loading on nitrification efficiency of rock and plastic media trickling filters. (From USEPA, *Wastewater Technology Fact Sheet, Trickling Filter Nitrification*, Office of Water, Municipal Technology Branch, Figure 2 (EPA/823/F-00/015) September 2000. www.epa.gov/owm/mtb/trickling_filt_nitrification.pdf.)

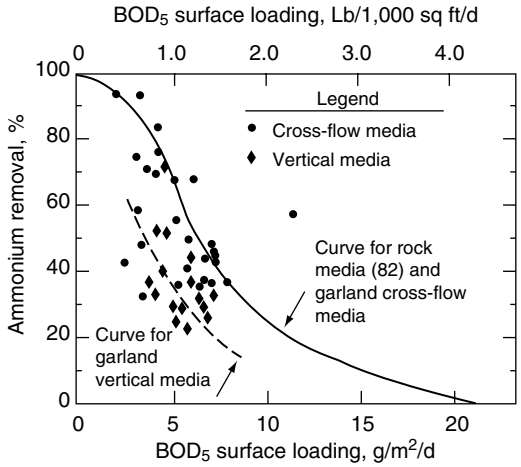


**Figure 9B.7** Performance comparison of various trickling filter media. (From USEPA, *Wastewater Technology Fact Sheet, Trickling Filter Nitrification*, Office of Water, Municipal Technology Branch, Figure 2 (EPA/823/F-00/015) September 2000. www.epa.gov/owm/mtb/trickling_filt_nitrification.pdf.)

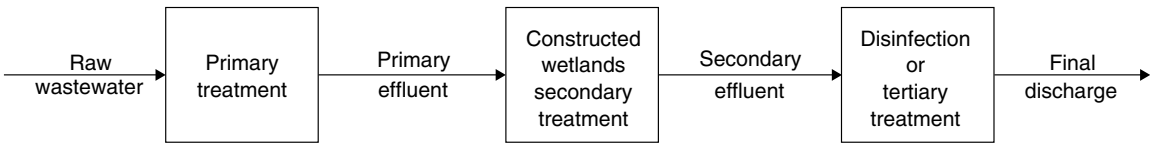


**Figure 9B.8** Constructed wetland in wastewater treatment train. (From USEPA, *Manual, Constructed Wetlands Treatment of Municipal Wastewaters*, Office of Research and Development, Figure 2.1, p. 22 (EPA/625/R-99/010) September 2000. www.epa.gov/owow/wetlands/pdf/Design_Manual2000.pdf.)

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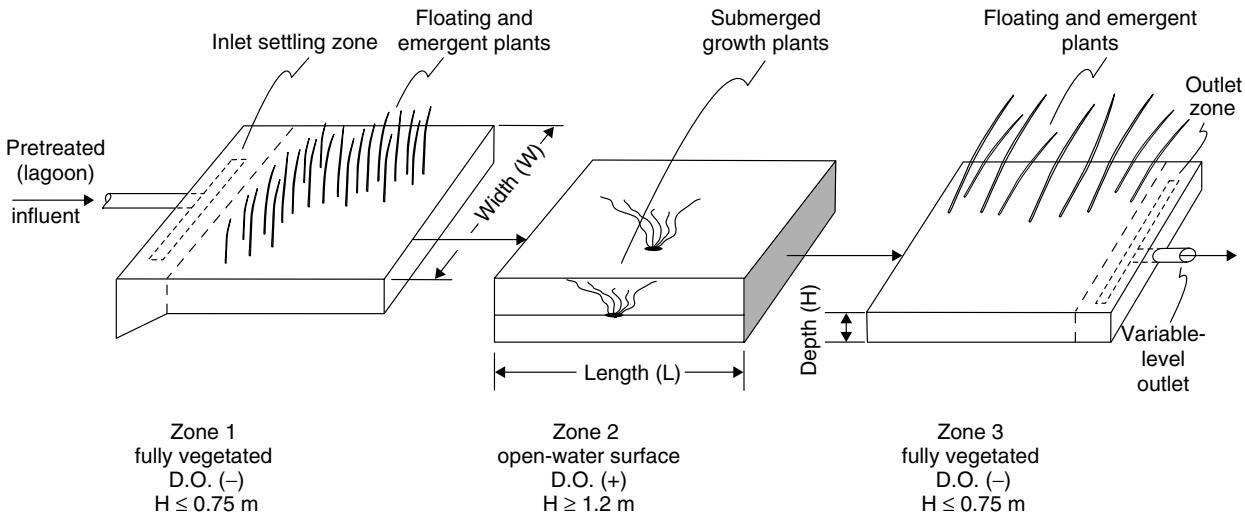


**Figure 9B.9** Elements of a free water surface constructed wetland. (From USEPA, *Manual, Constructed Wetlands Treatment of Municipal Wastewaters*, Office of Research and Development, Figure 2.2, p. 22 (EPA/625/R-99/010) September 2000. www.epa.gov/owow/wetlands/pdf/Design_Manual2000.pdf.)

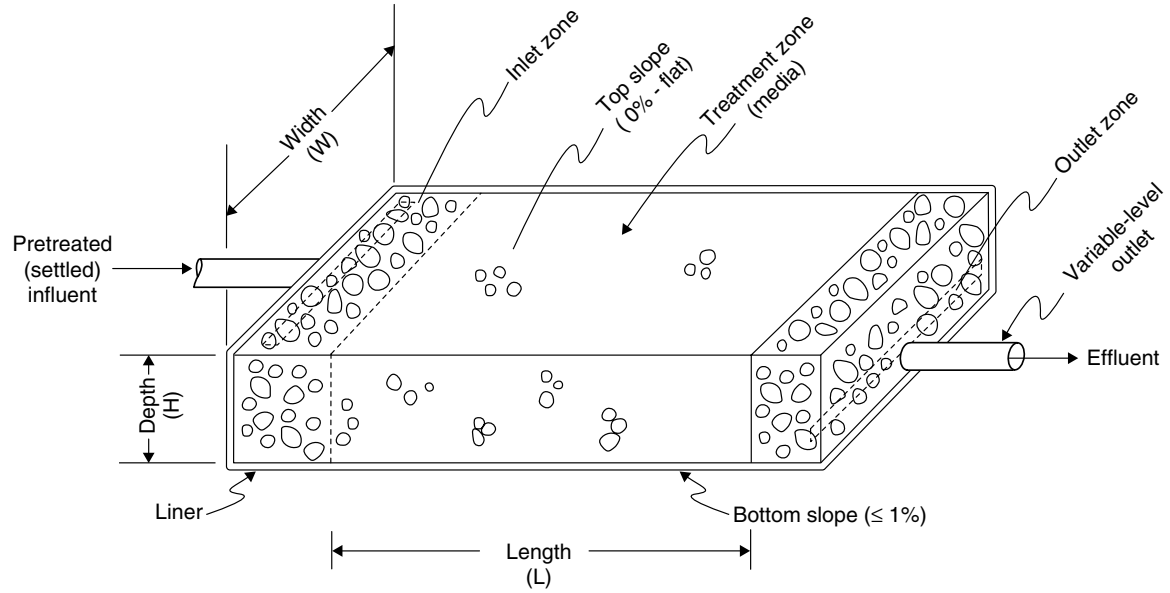


**Figure 9B.10** Elements of a vegetated submerged bed system. (From USEPA, *Manual, Constructed Wetlands Treatment of Municipal Wastewaters*, Office of Research and Development, Figure 2.3, p. 22 (EPA/625/R-99/010) September 2000. www.epa.gov/owow/wetlands/pdf/Design_Manual2000.pdf.)

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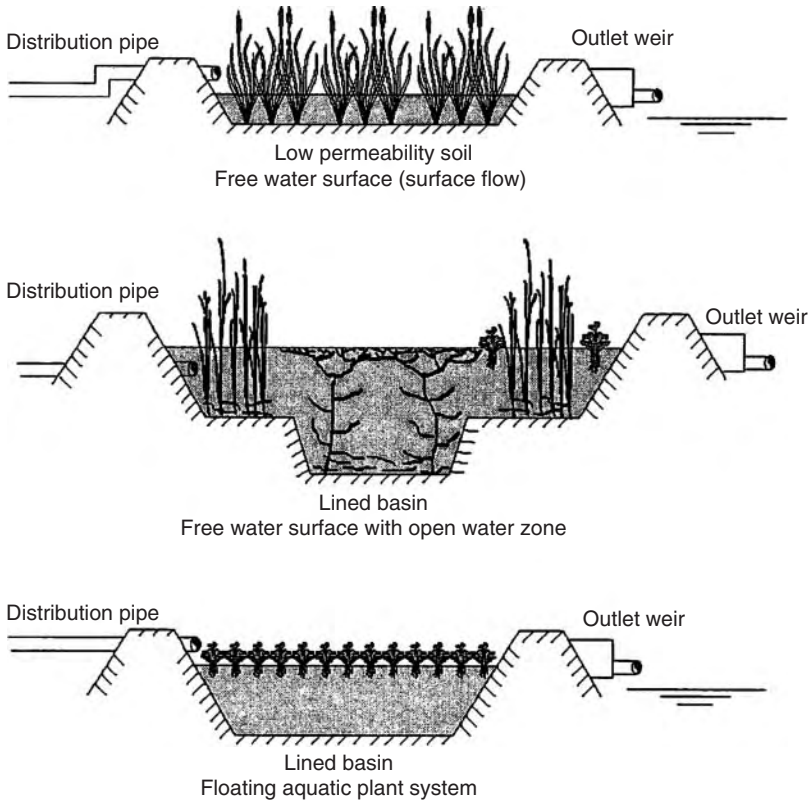


**Figure 9B.11** Floating aquatic plant system. (From USEPA, *Free Water Surface Wetlands for Wastewater Treatment, A Technologic Assessment*, Office of Water, Figure 1.1, p. 1–4, (EPA/832/S-99/002) June 1999. www.epa.gov/owow/wetlands/pdf/FW_Surface_wetlands.pdf.)

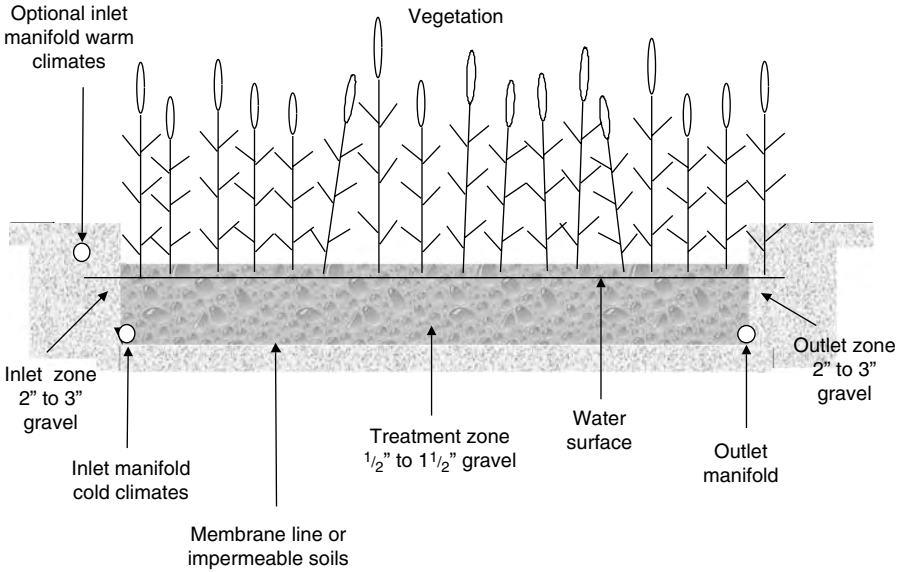


**Figure 9B.12** Subsurface flow constructed wetlands. (From USEPA, *Wastewater Technology Fact Sheet, Wetlands: Subsurface Flow*, Office of Water, Municipal Technology Branch, Figure 1 (EPA/823/F-00/023) September 2000. www.epa.gov/owm/mtb/wetlands-subsurface_flow.pdf.)

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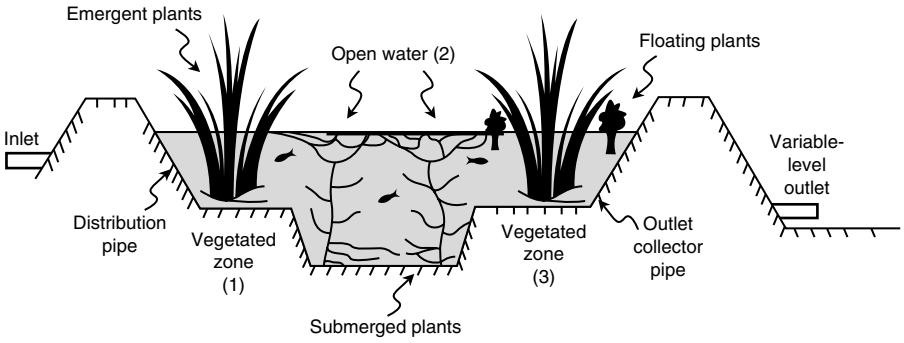


**Figure 9B.13** Profile of a three-zone free water surface constructed wetland cell. (From USEPA, *Manual, Constructed Wetlands Treatment of Municipal Wastewaters*, Office of Research and Development, Figure 2.3, p. 22 (EPA/625/R-99/010) September 2000. www.epa.gov/owow/wetlands/pdf/Design_Manual2000.pdf.)

**Table 9B.40 Typical Constructed Wetland Influents**

| Constituent (mg/L) | Septic Tank Effluent[a] | Primary Effluent[b] | Pond Effluent[c] |
|---|---|---|---|
| BOD | 129–147 | 40–200 | 11–35 |
| Sol. BOD | 100–118 | 35–160 | 7–17 |
| COD | 310–344 | 90–400 | 60–100 |
| TSS | 44–54 | 55–230 | 20–80 |
| VSS | 32–39 | 45–180 | 25–65 |
| TN | 41–49 | 20–85 | 8–22 |
| $NH_3$ | 28–34 | 15–40 | 0.6–16 |
| $NO_3$ | 0–0.9 | 0 | 0.1–0.8 |
| TP | 12–14 | 4–15 | 3–4 |
| OrthoP | 10–12 | 3–10 | 2–3 |
| Fecal coli (log/100 mL) | 5.4–6.0 | 5.0–7.0 | 0.8–5.6 |

[a] EPA (1978), 95% confidence interval. Prior to major detergent reformulations which reduce P species by ~50%.
[b] Adapted from Metcalf and Eddy, (1991) assuming typical removal by primary sedimentation-soluble BOD = 35–45% total.
[c] EPA (1980).

*Source*: From USEPA, *Manual, Constructed Wetlands Treatment of Municipal Wastewaters*, Office of Research and Development, Table 3.1, p. 41 (EPA/625/R-99/010) September 2000. www.epa.gov/owow/wetlands/pdf/Design_Manual2000.pdf.

**Table 9B.41 Loading and Performance Data for Systems Analyzed in This Document (DMDB)**

| | Pollutant Loading Rate (kg/ha-day) | | | Influent (mg/L) | | | Effluent (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|
| Constituent | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max |
| $BOD_5$ | 2.3 | 51 | 183 | 6.2 | 113 | 438 | 5.8 | 22 | 70 |
| TSS | 5 | 41 | 180 | 12.7 | 112 | 587 | 5.3 | 20 | 39 |
| $NH_4$–N | 0.3 | 5.8 | 16 | 3.2 | 13.4 | 30 | 0.7 | 12 | 23 |
| TKN | 1.0 | 9.5 | 20 | 8.7 | 28.3 | 51 | 3.9 | 19 | 32 |
| TP | — | — | — | 0.56 | 1.39 | 2.41 | 0.68 | 2.42 | 3.60 |
| FC | — | — | — | 42000 | 73000 | 250000 | 112 | 403 | 713 |

BOD, Biochemical Oxygen Demand (5 day); TSS, Total Suspended Solids; $NH_4$-N, Ammonia Nitrogen; TKN, Total Kjeldahl Nitrogen; TP, Total Phosphorus; FC, Fecal Coliform, cfu/100 mL.

*Source*: From USEPA, Manual, *Constructed Wetlands Treatment of Municipal Wastewaters*, Office of Research and Development, Table 4.1, p. 67 (EPA/625/R-99/010) September 2000. www.epa.gov/owow/wetlands/pdf/Design_Manual2000.pdf.

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**Table 9B.42 Typical Areal Loading Rates for SF Constructed Wetlands**

| Constituent | Typical Influent Concentration mg/L | Target Effluent Concentration mg/L | Mass Loading Rate lb/ac/d[a] |
|---|---|---|---|
| Hydraulic Load (in./d) | 3–12[b] | | |
| BOD | 30–175 | 10–30 | 60–140 |
| TSS | 30–150 | 10–30 | 40–150 |
| $NH_3/NH_4$ as N | 2–35 | 1–10 | 1–10 |
| $NO_3$ as N | 2–10 | 1–10 | 3–12 |
| TN | 2–40 | 1–10 | 3–11 |
| TP | 1–10 | 0.5–3 | 1–4 |

*Note:* Wetland water temperature >> 20 °C.

*Source*: From USEPA, *Waster Technology Fact Sheet, Wetlands: Subsurface Flow*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-00/023) September 2000. www.epa.gov/owm/mtb/wetlands-subsurface_flow.pdf.

**Table 9B.43 Typical Media Characteristics for Subsurface Wetlands**

| Media Type | Effective Size $D_{10}$ (mm)[a] | Porosity, n (%) | Hydraulic Conductivity $k_s$ ($ft^3/ft^2/d$)[b] |
|---|---|---|---|
| Coarse sand | 2 | 28–32 | 300–3,000 |
| Gravelly sand | 8 | 30–35 | 1,600–16,000 |
| Fine gravel | 16 | 35–38 | 3,000–32,000 |
| Medium gravel | 32 | 36–40 | 32,000–160,000 |
| Coarse rock | 128 | 38–45 | $16\times10^4$–$82\times10^4$ |

[a] mm $\times$ 0.03937 = inches.
[b] $ft^3/ft^2/d \times 0.3047 = m^3/m^2/d$, or $\times$ 7.48 = $gal/ft^2/d$.

*Source*: From Reed, S.C., R.W. Crites, E.J. Middlebrooks (1995) *Natural Systems for Waste Management and Treatment - Second Edition*, McGraw-'Hill Co, New York; USEPA, *Waste Water Technology Fact Sheet, Wetlands: Subsurface Flow, Office of Water*, Municipal Technology Branch, Table 3 (EPA/823/F-00/023) September 2000. www.epa.gov/owm/mtb/wetlands-subsurface_flow.pdf.

**Table 9B.44 Summary of Performance for 14 Subsurface Flow Wetland Systems**

| Constituent | Mean Influent (mg/L) | Mean Effluent (mg/L) |
|---|---|---|
| $BOD_5$ | 28[a] (5–51)[b] | 8[a] (1–15)[b] |
| TSS | 60 (23–118) | 10 (3–23) |
| TKN as N | 15 (5–22) | 9 (2–18) |
| $NH_3/NH_4$ as N | 5 (1–10) | 5 (2–10) |
| $NO_3$ as N | 9 (1–18) | 3 (0.1–13) |
| TN | 20 (9–48) | 9 (7–12) |
| TP | 4 (2–6) | 2 (0.2–3) |
| Fecal coliforms (#/100 ml) | 270,000 (1,200–1,380,000) | 57,000 (10–330,000) |

Mean detention time 3 d (range 1–5 d).

[a] Mean value.
[b] Range of values.

*Source*: From USEPA, 1993; USEPA, *Wastewater Technology Fact Sheet, Wetlands: Subsurface Flow*, Office of Water, Municipal Technology Branch, Table 4 (EPA/823/F-00/023) September 2000. www.epa.gov/owm/mtb/wetlands-subsurface_flow.pdf.

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**Table 9B.45 Typical Areal Loading Rates for Free Water Surface Wetlands**

| Constituent | Typical Influent Conc. (mg/L) | Target Effluent Conc. (mg/L) | Mass Loading Rate (lb/ac/d) |
|---|---|---|---|
| Hydraulic Load (in./d) | 0.4–4 | | |
| BOD | 5–100 | 5–30 | 9–89 |
| TSS | 5–100 | 5–30 | 9–100 |
| $NH_3/NH_4$ as N | 2–20 | 1–10 | 1–4 |
| $NO_3$ as N | 2–10 | 1–10 | 2–9 |
| TN | 2–20 | 1–10 | 2–9 |
| TP | 1–10 | 0.5–3 | 1–4 |

*Source*: From USEPA, *Wastewater Technology Fact Sheet, Free Water Surface Wetlands*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-00/024) September 2000. www.epa.gov/owm/mtb/free_water_surface_wetlands.pdf.

**Table 9B.46 Summary of Performance for 27 Free Water Surface Wetlands**

| Constituent | Mean Influent (mg/L) | Mean Effluent (mg/L) |
|---|---|---|
| $BOD_5$ | 70 | 15 |
| TSS | 69 | 15 |
| TKN as N | 18 | 11 |
| $NH_3/NH_4$ as N | 9 | 7 |
| $NO_3$ as N | 3 | 1 |
| TN | 12 | 4 |
| TP | 4 | 2 |
| Dissolved P | 3 | 2 |
| Fecal coliforms (#/100 mL) | 73,000 | 1,320 |

*Source*: USEPA, 2000; USEPA, *Wastewaster Technology Fact Sheet, Free Water Surface Wetlands*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-00/024) September 2000. www.epa.gov/owm/mtb/free_water_surface_wetlands.pdf.

**Table 9B.47 Wastewater Characteristics Affecting Chlorination Performance**

| Wastewater Characteristic | Effects on Chlorine Disinfection |
|---|---|
| Ammonia | Forms chloramines when combined with chlorine |
| Biochemical oxygen demand (BOD) | The degree of interference depends on their functional groups and chemical structures |
| Hardness, iron, nitrate | Minor effect, if any |
| Nitrite | Reduces effectiveness of chlorine and results in THMs |
| pH | Affects distribution between hypochlorous acid and hypochlorite ions and among the various chloramine species |
| Total suspended solids | Shielding of embedded bacteria and chlorine demand |

*Source*: From Darby et al., with permission from the water environment research foundation, 1995; USEPA, *Wastewater Technology Fact Sheet, Chlorine Disinfection*, Office of Water, Municipal Technology Branch, Table 2 (EPA/823/F-99/063) September 1999. www.epa.gov/owm/mtb/chlo.pdf.

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**Table 9B.48 Wastewater Characteristics Affecting Ultraviolet Disinfection Performance**

| Wastewater Characteristic | Effects on UV Disinfection |
|---|---|
| Ammonia | Minor effect, if any |
| Nitrite | Minor effect, if any |
| Nitrate | Minor effect, if any |
| Biochemical oxygen demand (BOD) | Minor effect, if any. Although, if a large portion of the BOD is humic and/or unsaturated (or conjugated) compounds, then UV transmittance may be diminished |
| Hardness | Affects solubility of metals that can absorb UV light. Can lead to the precipitation of carbonates on quartz tubes |
| Humic materials, iron | High absorbency of UV radiation |
| pH | Affects solubility of metals and carbonates |
| TSS | Absorbs UV radiation and shields embedded bacteria |

*Source*: From USEPA, *Wastewater Technology Fact Sheet, Ultraviolet Disinfection*, Office of Water, Municipal Technology Branch, Table 2 (EPA/823/F-99/064) September 1999. www.epa.gov/owm/mtb/uv.pdf.

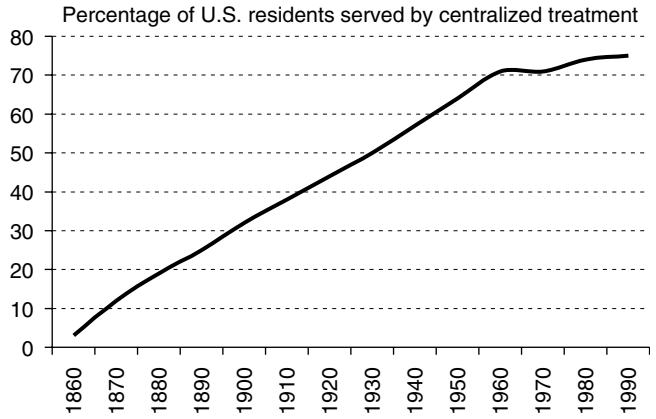


**Figure 9B.14** Percentage of US residents severed by centralized treatment. (From USEPA, *Draft Handbook for Management of On-Site and Clustered (Decentralized) Wastewater Treatment Systems*, Office of Water, Table 1.1, p. 12 (EPA /PA 823/P-03/001), February 2003.)

**Table 9B.49 Comparison of Design and Operating Parameters, Land Treatment Systems**

| Parameters | Irrigation | Overland Flow | Rapid Infiltration |
|---|---|---|---|
| Weekly application rate (in.) | 0.5–4.0 | 2.4–6.0 | 4–96 |
| Annual application rate (ft) | 2–18 | 8–40 | 20–410 |
| Estimated land required for 100,000 gpd (acres) | 20–25 | 5–10 | 1–7 |
| Minimum preapplication treatment requirements | Lagoons | Screening and grit removal | Lagoons |
| Climate restrictions | Storage needed for cold and wet climates | Storage needed for cold and wet climates | Cold weather may reduce hydraulic loading cycles |
| Slopes | $<$20% | Smooth sloes of 2–8% | Not critical |
| Soil permeability | Slow to moderate | Impermeable (clays, silts, soils with impermeable barriers) | Rapid |

*Source*: From USEPA, *Wastewater Technology Transfer, Summary Report*, Small Community Water and Wastewater Treatment, Table 2, p. 34 (EPA/525/R-92/010) September 1992.

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**Table 9B.50 Design Criteria for Rapid Land Infiltration Land Treatment**

| Item | Range |
|---|---|
| Basin infiltration area | 0.3–5.5 ha/$10_3m_3$/d (3–56 acres/MGD) |
| Hydraulic loading rate | 6–90 m/yr (20–300 ft/yr) [6–92 $m_3/m_2$/yr (150–2250 gal/$ft_2$/yr)] |
| BOD loading | 22–112 kg/ha/d (20–100 lb/acre/d) |
| Soil depth | At least 3–4.5 m (10–15 ft) |
| Soil permeability | At least 1.5 cm/h (0.6 in./h) |
| Wastewater application period | 4 h to 2 wks |
| Drying period | 8 h to 4 wks |
| Soil texture | Coarse sands, sandy gravels |
| Individual basin size (at least 2 basins in parallel) | 0.4–4 ha (1–10 acres) |
| Height of dikes | 0.15 m (0.5 ft) above maximum expected water level |
| Application method | flooding or sprinkling |
| Pretreatment required | primary or secondary |

*Source*: From Crites, et al., 2000; USEPA, *Wastewater Technology Fact Sheet, Rapid Land Infiltration Land Treatment*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-03/025) September 2003. www.epa.gov/owm/mtb/final_rapidinfiltration.pdf.

**Table 9B.51 Effluent Quality for Rapid Land Infiltration Land Treatment**

| Parameter | % Removal |
|---|---|
| $BOD_5$ | 95–99 |
| TSS | 95–99 |
| TN | 25–90 |
| TP | 0–90 |
| Fecal coliform | 99.9–99.99 + percent |

*Source*: From USEPA, *Wastewater Technology Fact Sheet, Rapid Land Infiltration Land Treatment*, Office of Water, Municipal Technology Branch, Table 2 (EPA/823/F-03/025) September 2003. www.epa.gov/owm/mtb/final_rapidinfiltration.pdf.

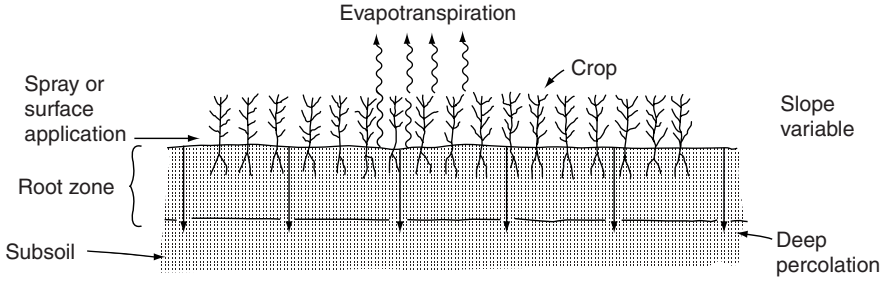


**Figure 9B.15** Schematic of spray irrigation. (From USEPA, *Technology Transfer, Summary Report, Small Community Water and Wastewater Treatment*, Figure 2, p. 33 (EPA/625/R-92/010) September 1992.)

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**Table 9B.52 Design Criteria for Slow Rate Land Treatment**

| Item | Range |
|---|---|
| Field area | 56–560 acres/MGD |
| Application rate | 2–20 ft/yr (0.5–4 in./wk) |
| BOD Loading | 0.2–5 lb/acre/d |
| Soil depth | At least 2–5 ft |
| Soil permeability | 0.06–2.0 in./h |
| Lower temperature limit | 25°F |
| Application method | Sprinkler or surface |
| Pretreatment required | Preliminary & secondary |
| Particle size (for sprinkler applications) | Solids less than 1/3 sprinkler nozzle |

*Source*: From Crites, et al., 2000; USEPA, *Wastewater Technology Fact Sheet, Slow Rate Land Treatment*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-02/012) September 2002. www.epa.gov/owm/mtb/sloratre.pdf.

**Table 9B.53 Maximum Metal Concentrations for Land Application**

| Metal | Ceiling Concentration (mg/kg) | Cumulative Pollutant Loading Rates (kg/hectare) | Pollutant Concentrations (mg/kg) |
|---|---|---|---|
| Arsenic | 75 | 41 | 41 |
| Cadmium | 85 | 39 | 39 |
| Copper | 4,300 | 1,500 | 1,500 |
| Lead | 840 | 300 | 300 |
| Mercury | 57 | 17 | 17 |
| Molybdenum | 75 | NL | NL |
| Nickel | 420 | 420 | 420 |
| Selenium | 100 | 100 | 100 |
| Zinc | 7,500 | 2,800 | 2,800 |

NL, No limit.

*Source*: From USEPA, 1993 and 1994; USEPA, *Wastewater Technology Fact Sheet, Land Application*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-00/064) September 2000. www.epa.gov/owm/mtb/land_application.pdf.

**Table 9B.54 Range of Expected Centrifuge Performance**

| Type of Wastewater Solids | Feed (%TS) | Polymer (lb/DTS) | Cake (%TS) |
|---|---|---|---|
| Primary undigested | 4–8 | 5–30 | 25–40 |
| WAS undigested | 1–4 | 15–30 | 16–25 |
| Primary + WAS undigested | 2–4 | 5–16 | 25–35 |
| Primary + WAS aerobic digested | 1.5–3 | 15–30 | 16–25 |
| Primary + WAS anaerobic digested | 2–4 | 15–30 | 22–32 |
| Primary anaerobic digested | 2–4 | 8–12 | 25–35 |
| WAS aerobic digested | 1–4 | 20 | 18–21 |
| Hi-Temp aerobic | 4–6 | 20–40 | 20–25 |
| Hi-Temp anaerobic | 3–6 | 20–30 | 22–28 |
| Lime stabilized | 4–6 | 15–25 | 20–28 |

*Source*: From various centrifuge manufactures; Ireland and Balchunas, 1998; Henderson and Schultz, 1999; Leber and Garvey, 2000; USEPA, *Biosolids Technology Fact Sheet, Centrifuge Thickening and Dewatering*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-00/053) September 2000. www.epa.gov/owm/mtb/centrifuge_thickening.pdf.

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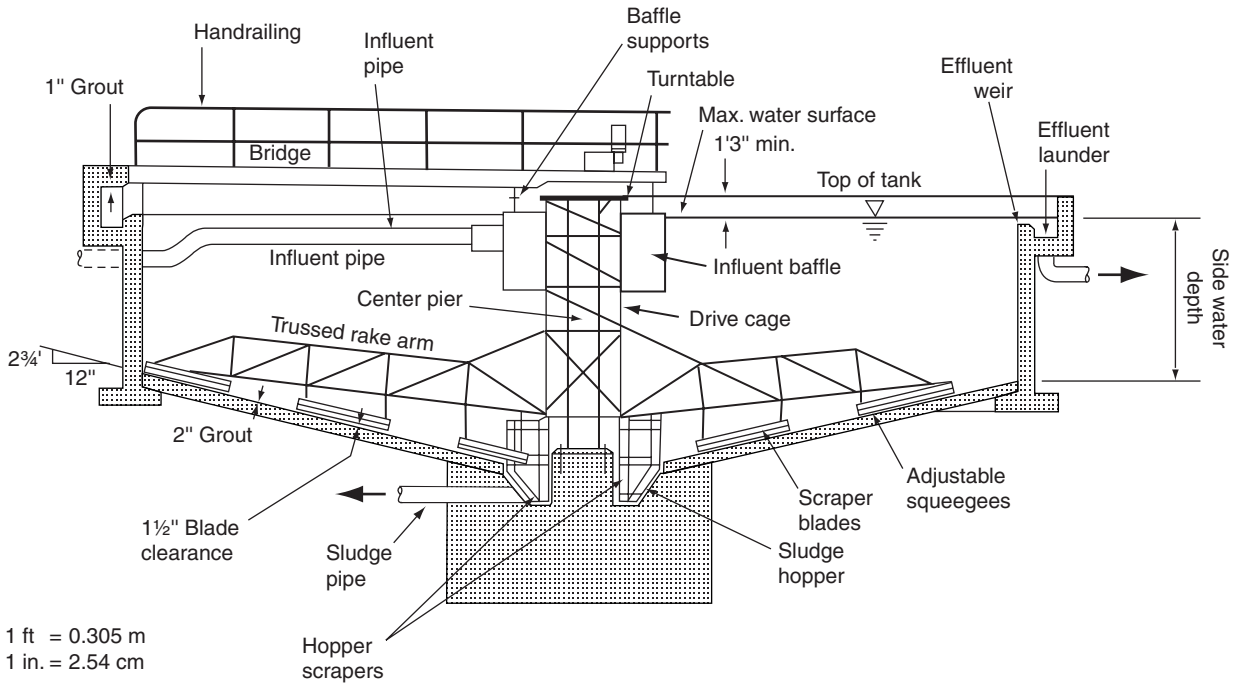


**Figure 9B.16** Gravity thickener. (From USEPA, *Biosolids Technology Fact Sheet, Gravity Thickening and Dewatering*, Office of Water, Municipal Technology Branch, Figure 2 (EPA/823/F-03/022) September 2002. www.epa.gov/owm/mtb/final_gravitythickening.pdf.)

**Table 9B.55 Factors Affecting Gravity Thickening Performance**

| Factor | Effect |
|---|---|
| Nature of the solids feed | Affects the thickening process because some solids thicken more easily than others |
| Freshness of feed solids | High solids age can result in septic conditions |
| High volatile solids concentrations | Hamper gravity settling due to reduced particle specific gravity |
| High hydraulic loading rates | Increase velocity and cause turbulence that will disrupt settling and carry the lighter solids past the weirs |
| Solids loading rate | If rates are high, there will be insufficient detention time for settling. If rates are too low, septic conditions may arise |
| Temperature and variation in temperature of thickener contents | High temperatures will result in septic conditions. Extremely low temperatures will result in lower settling velocities. If temperature varies, settling decreases due to stratification |
| High solids blanket depth | Increases the performance of the settling by causing compaction of the lower layers, but it may result in solids being carried over the weir |
| Solids residence time | An increase may result in septic conditions. A decrease may result in only partial settling |
| Mechanism and rate of solids withdrawal | Must be maintained to produce a smooth and continuous flow. Otherwise, turbulence, septic conditions, altered settling, and other anomalies may occur |
| Chemical treatment | Chemicals—such as potassium permanganate, polymers, or ferric chloride—may improve settling and/or supernatant quality |
| Presence of bacteriostatic agents or oxidizing agents | Allows for longer detention times before anaerobic conditions create gas bubbles and floating solids |
| Cationic polymer addition | Helps thicken waste-activated solids and clarify the supernatant |
| Use of metal salt coagulants | Improves overflow clarity but may have little impact on underflow concentration |

*Source*: From Parsons, 2003; USEPA, *Biosolids Technology Fact Sheet, Gravity Thickening and Dewatering*, Office of Water, Municipal Technology Branch, Table 2 (EPA/823/F-03/022) September 2002. www.epa.gov/owm/mtb/final_gravitythickening.pdf.

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**Table 9B.56 Performance of Conventional Gravity Thickening**

| Type of Solids | Feed (%TS) | Thickened solids (%TS) |
|---|---|---|
| Primary (PRI) | 2–7 | 5–10 |
| Trickling filter (TF) | 1–4 | 3–6 |
| Rotating biological contactor (RBC) | 1–3.5 | 2–5 |
| Waste activated solids (WAS) | 0.2–1 | 2–3 |
| PRI + WAS | 0.5–4 | 4–7 |
| PRI + TF | 2–6 | 5–9 |
| PRI + RBC | 2–6 | 5–8 |
| PRI + Lime | 3–4.5 | 10–15 |
| PRI + (WAS + iron) | 1.5 | 3 |
| PRI + (WAS + aluminum salts) | 0.2–0.4 | 4.5–6.5 |
| Anaerobically digested PRI + WAS | 4 | 8 |

*Source*: From WEF, 1987; USEPA, *Biosolids Technology Fact Sheet, Gravity Thickening and Dewatering*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-03/022) September 2002. www.epa.gov/owm/mtb/final_gravitythickening.pdf.

**Table 9B.57 Typical Data for Various Types of Sludges Dewatered on Belt Filter Presses**

| Type of Wastewater Sludge | Total Feed Solids (%) | Polymer (g/kg) | Total Cake Solids (%) |
|---|---|---|---|
| Raw primary | 3–10 | 1–5 | 28–44 |
| Raw WAS | 0.5–4 | 1–10 | 20–35 |
| Raw primary + WAS | 3–6 | 1–10 | 20–35 |
| Anaerobically digested primary | 3–10 | 1–5 | 25–36 |
| Anaerobically digested WAS | 3–4 | 2–10 | 12–22 |
| Anaerobically digested primary + WAS | 3–9 | 2–8 | 18–44 |
| Aerobically digested primary + WAS | 1–3 | 2–8 | 12–20 |
| Oxygen activated WAS | 1–3 | 4–10 | 15–23 |
| Thermally conditioned primary + WAS | 4–8 | 0 | 25–50 |

*Source*: From USEPA, 1987; USEPA, *Biosolids Technology Fact Sheet, Belt Filter Press*, Office of Water, Municipal Technology Branch, Table 1 (EPA/823/F-03/057) September 2000. www.epa.gov/owm/mtb/belt_filter.pdf.

**Table 9B.58 Typical Biosolids Application Scenarios**

| Type of Site/Vegetation | Schedule | Application Frequency | Application Rate |
|---|---|---|---|
| Agricultural land | | | |
| Corn | April, May, after harvest | Annually | 5–10 dry tons per acre |
| Small grains | March–June, August, fall | Up to 3 times per year | 2–5 dry tons per acre |
| Soybeans | April–June, fall | Annually | 5–20 dry tons per acre |
| Hay | After each cutting | Up to 3 times per year | 2–5 dry tons per acre |
| Forest land | Year round | Once every 2–5 years | 5–100 dry tons per acre |
| Range land | Year round | Once every 1–2 years | 2–60 dry tons per acre |
| Reclamation sites | Year round | Once | 60–100 dry tons per acre |

*Source*: From USEPA, 1994; USEPA, *Wastewater Technology Fact Sheet, Land Application*, Office of Water, Municipal Technology Branch, Table 2 (EPA/823/F-00/064) September 2000. www.epa.gov/owm/mtb/land_application.pdf.

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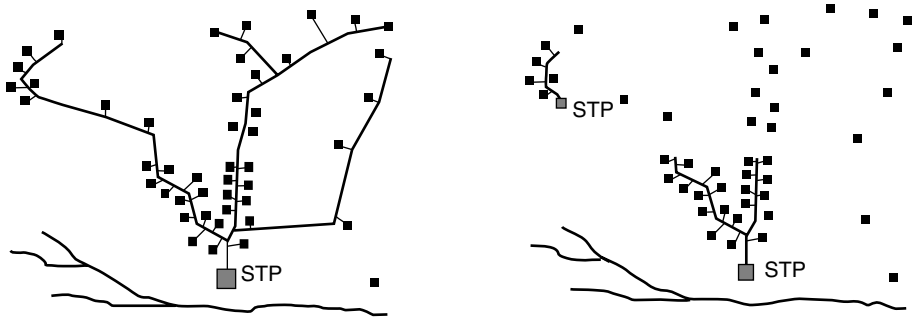
**Table 9B.59 Pipe Paint Color Scheme Recommendations**

| |
|---|
| Raw sludge line—brown with black bands |
| Sludge recirculation suction line—brown with yellow bands Sludge draw off line—brown with orange bands Sludge recirculation discharge line—brown Sludge gas line—orange (or red) |
| Natural gas line—orange (or red) with black bands Nonpotable water line—blue with black bands Potable water line—blue Chlorine line—yellow |
| Sulfur dioxide—yellow with red bands Sewage (wastewater) line—gray Compressed air line—green |
| Water lines for heating digesters or buildings—blue with a 6-inch (150 mm) red band spaced 30 in. (760 mm) apart Fuel oil/diesel—red |
| Plumbing drains and vents—black Polymer-purple |

The contents and direction of flow shall be stenciled on the piping in a contrasting color. The use of paints containing lead or mercury should be avoided. In order to facilitate identification of piping, particularly in the large plants, it is suggested that the different lines be color-coded.

*Source*: From Board of State and Provincial Public Health and Environmental Manager, Health Education Services Division, Recommended Standards for Wastewater Facilities, 2004 edition, p. 50–5. www.hes.org.

## SECTION 9C DECENTRALIZED WASTEWATER TREATMENT




Centralized wastewater treatment Decentralized approach

**Figure 9C.17** Centralized wastewater treatment vs. decentralized approach. (From USEPA, *Draft Handbook for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems*, Office of Water, Figure 1.4 (EPA/PA 823/P-03/001), February 2003. www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008totaldocument.pdf.)

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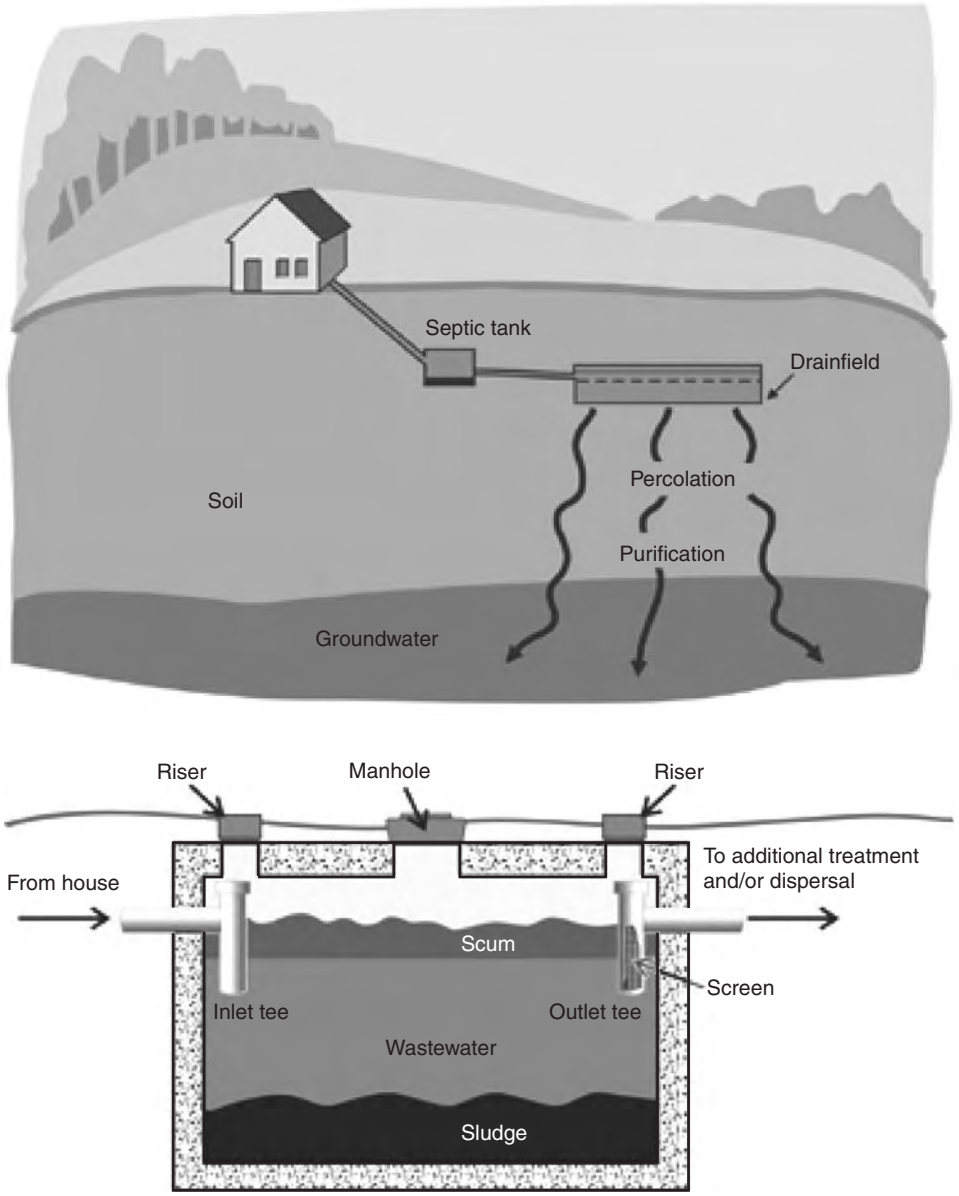


**Figure 9C.18** Conventional system. (From USEPA website. www.epa.gov.)

**Table 9C.60 Types of Decentralized Wastewater Treatment Systems**

| Type of System | Description |
|---|---|
| Individual on-site systems | Systems that serve an individual residence and can range from conventional septic tank/drainfield systems to systems composed of complex mechanical treatment trains |
| Cluster systems | Wastewater collection and treatment systems that serve two or more dwellings or buildings, but less than an entire community, on a suitable site near the served structures |
| Commercial, residential, institutional, and recreational facilities | Systems designed to treat larger and sometimes more complex wastewater sources from commercial buildings (e.g. restaurants), apartments, or institutional or recreational facilities |

*Source*: From USEPA, *Draft Handbook for Management of On-Site and Clustered (Decentralized) Wastewater Treatment Systems*, Office of Water, Table 1.1, p. 12 (EPA/PA 823/P-03/001), February 2003.

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**Table 9C.61 Characteristics of Septage Conventional Parameters**

| Concentration Parameter | Minimum | Maximum |
|---|---|---|
| Total solids | 1,132 | 130,475 |
| Total volatile solids | 353 | 71,402 |
| Total suspended solids | 310 | 93,378 |
| Volatile suspended | 95 | 51,500 |
| Biochemical oxygen demand | 440 | 78,600 |
| Chemical oxygen demand | 1,500 | 703,000 |
| Total kjeldahl nitrogen | 66 | 1,060 |
| Ammonia nitrogen | 3 | 116 |
| Total phosphorus | 20 | 760 |
| Alkalinity | 522 | 4,190 |
| Grease | 208 | 23,368 |
| $P^H$ | 1.5 | 12.6 |
| Total coliform | $10^7$/100 mL | $10^9$/100 mL |
| Fecal coliform | $10^6$/100 mL | $10^8$/100 mL |

*Note:* The measurements above are in mg/L unless otherwise indicted.

*Source*: From USEPA, 1994; USEPA, *Decentralized Systems, Technology Fact Sheet, Septage Treatment/Disposal*, Office of Water, Table 1 (EPA/823/F-99/068), September 1999. www.epa.gov/owm/mtb/septage.pdf.

**Table 9C.62 Sources of Septage**

| Description Rate | Removal Pump-out | Characteristics |
|---|---|---|
| Septic tank | 2–6 years, but can vary with location local ordinances | Concentrated BOD, solids, nutrients, variable toxins (such as metals), inorganics (sand), odor, pathogens, oil, and grease |
| Cesspool | 2–10 years | Concentrated BOD, solids, nutrients, variable toxins, inorganics, sometimes high grit, odor, pathogens, oil, and grease |
| Privies/portable toilets | 1 week to months | Variable BOD, solids, inorganics, odor, pathogens, and some chemicals |
| Aerobic tanks | Months to 1 year | Variable BOD, inorganics, odor, pathogens, and concentrated solids |
| Holding tanks (septic tank with no drain-field, typically a local requirement | Days to weeks | Variable BOD, solids, inorganics, odor, and pathogens, similar to raw wastewater solids |
| Dry pits (associated with septic fields) Miscellaneous may exhibit characteristics of septage | 2–6 years | Variable BOD, solids, inorganics, and odor |
| Private wastewater treatment plants | Variable | Septic tank |
| Boat pump-out station | Variable | Portable toilets |
| Grit traps | Variable | Oil, grease, solids, inorganics, odor, and variable BOD |
| Grease traps | Weeks to months | Oil, grease, BOD, viscous solids, and odor |

*Source*: From Septage Handling Task Force (1997), copyright Water Environment Federation, used with permission. USEPA, *Decentralized Systems, Technology Fact Sheet, Septage Treatment/Disposal*, Office of Water, Table 2 (EPA/823/F-99/068), September 1999. www.epa.gov/owm/mtb/septage.pdf.

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**Table 9C.63 Physical and Chemical Characteristics of Septage, as Found in the Literature, with Suggested Design Values**

| | United States (5) (9–19) | | | | Europe/Canada (4) (20) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Average** | **Minimum** | **Maximum** | **Variance** | **Average** | **Minimum** | **Maximum** | **Variance** | **EPA Mean** | **Suggested Design Value** |
| TS | 34,106 | 1,132 | 130,475 | 115 | 33,800 | 200 | 123,860 | 619 | 38,800 | 40,000 |
| TVS | 23,100 | 353 | 71,402 | 202 | 31,600 | 160 | 67,570 | 422 | 25,260 | 25,000 |
| TSS | 12,862 | 310 | 93,378 | 301 | 45,000 | 5,000 | 70,920 | 14 | 13,000 | 15,000 |
| VSS | 9,027 | 95 | 51,500 | 542 | 29,900 | 4,000 | 52,370 | 13 | 8,720 | 10,000 |
| BODs | 6,480 | 440 | 78,600 | 179 | 8,343 | 700 | 25,000 | 36 | 5,000 | 7,000 |
| COD | 31,900 | 1,500 | 703,000 | 469 | 28,975 | 1,300 | 114,870 | 88 | 42,850 | 15,000 |
| TKN | 588 | 66 | 1,060 | 16 | 1,067 | 150 | 2,570 | 17 | 677 | 700 |
| $NH_3$–N | 97 | 3 | 116 | 39 | — | — | — | — | 157 | 150 |
| Total P | 210 | 20 | 760 | 38 | 155 | 20 | 636 | 32 | 253 | 250 |
| Alkalinity | 970 | 522 | 4,190 | 8 | — | — | — | — | — | 1,000 |
| Grease | 5,600 | 208 | 23,368 | 112 | — | — | — | — | 9,090 | 8,000 |
| pH | — | 1.5 | 12.6 | 8.0 | — | 5.2 | 9.0 | | 6.9 | 6.0 |
| LAS | — | 110 | 200 | 2 | — | — | — | | 157 | 150 |

Values expressed as mg/L, except for pH.

*Source*: From Board of State and Provincial Public Health and Environmental Managers, Health Education Services Division, Recommended Standards for Wastewater Facilities, 2004 Edition, p. A4. www.hes.org.



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**Table 9C.64 Comparison of Septage and Municipal Wastewater[a]**

| Parameter | Septage[b] | Wastewater[c] | Ratio of Septage to Wastewater |
|---|---|---|---|
| TS | 40,000 | 720 | 55:1 |
| TVS | 25,000 | 365 | 68:1 |
| TSS | 15,000 | 220 | 68:1 |
| VSS | 10,000 | 165 | 61:1 |
| BODs | 7,000 | 220 | 32:1 |
| COD | 15,000 | 500 | 30:1 |
| TKN | 700 | 40 | 17:1 |
| $NH_3$–N | 150 | 25 | 6:1 |
| Total P | 250 | 8 | 31:1 |
| Alkalinity | 1,000 | 100 | 10:1 |
| Grease | 8,000 | 100 | 80:1 |
| pH | 6.0 | | |
| LAS | 150 | | |

Table including footnotes is a taken from the USEPA Handbook entitled "Septage Treatment and Disposal," 1984, EPA-625/6-84-009 and is designated in that document as "Table 3.8."

[a] Values expressed as mg/L, except for pH.
[b] Based on suggested design values in Appendix-Table No.1 (USEPA Table 3.4).
[c] From Metcalf and Eddy, 4th Edition, "Medium strength sewage."

*Source*: From Board of State and Provincial Public Health and Environmental Managers, Health Education Services Division, Recommended Standards for Wastewater Facilities, 2004 Edition, p. A5. www.hes.org.

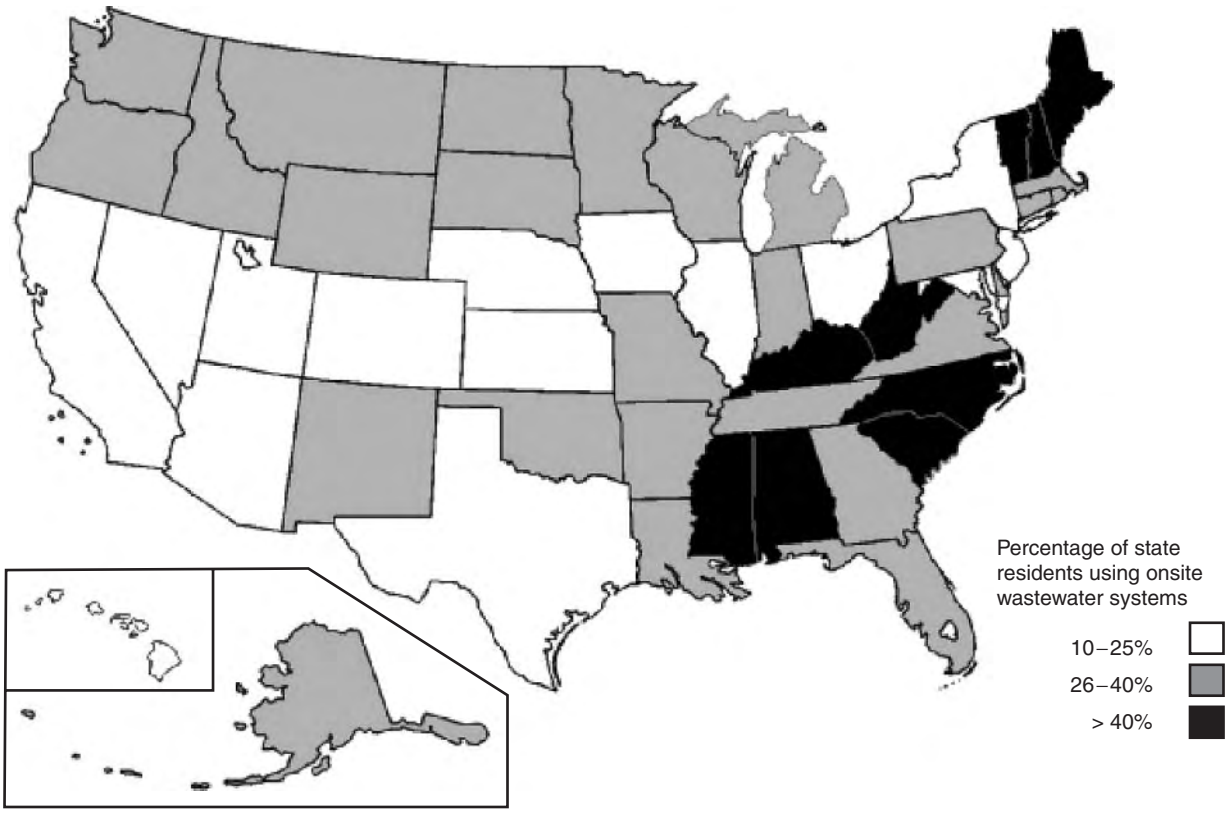


**Figure 9C.19** On-site treatment system distribution in the United States. (From USEPA, *Draft Handbook for Management of On-site and Clustered (Decentralized) Wastewater Treatment Systems*, Office of Water, Figure 1.1 (EPA/PA 823/P-03/001), February 2003. www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008totaldocument.pdf.)

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**Table 9C.65 Septic Tank Capacities for One- and Two-Family Dwellings**

| Number of Bedrooms | Septic Tank Volume (gallons) |
|---|---|
| 1 | 750[a] |
| 2 | 750[a] |
| 3 | 1,000 |
| 4 | 1,200 |
| 5 | 1,425 |
| 6 | 1,650 |
| 7 | 1,875 |
| 8 | 2,100 |

[a] Many States have established 1,000 gallons or more as the minimum size.

*Source*: From USEPA, *Draft Handbook for Management of On-site and Clustered (Decentralized) Wastewater Treatment Systems*, Office of Water, Table 1.1, p. 12 (EPA/PA 823/ 823/P-03/001), February 2003.

**Table 9C.66 Treatment Performance of On-Site Septic Tank and Sand Filter**

| Parameter | Raw Waste | Septic Tank Effluent | Intermittent Sand Filter Effluent |
|---|---|---|---|
| BOD, mg/L | 210–530 | 140–200 | <10 |
| SS, mg/L | 237–600 | 50–90 | <10 |
| Total nitrogen, mg/L | 35–80 | 25–60 | — |
| Ammonia-nitrogen, mg/L | 7–40 | 20–60 | <0.5 |
| Nitrate-nitrogen, mg/L | <1 | <1 | 25 |
| Total phosphorus, mg/L | 10–27 | 10–30 | — |
| Fecal coliforms (#/100 mL) | $10^6$–$10^{10}$ | $10^3$–$10^6$ | $10^2$–$10^4$ |
| Viruses (#/100 mL) | Unknown | $10^5$–$10^7$ | — |

*Source*: Adapted from Tchobanoglous and Burton, 1991; USEPA, *Decentralized Systems, Technology Fact Sheet, Septic Tank Polishing*, Office of Water, Table 1 (EPA/823/F-02/021), September 2002. www.epa.gov/owm/mtb/septn_pol.pdf.

**Table 9C.67 Design Parameters for Continuous-Flow, Suspended Growth Systems Extended Aeration Package Plant**

| Parameter | Extended Aeration |
|---|---|
| Pretreatment (if needed) | Septic tank or equivalent |
| Mixed liquor suspended solids (mg/L)a | 2,000–6,000 |
| F/M Load (lb BOD/d/MLVSS), | 0.05–0.15 |
| Hydraulic retention time (h) | 24–120 |
| Solids retention time (days) | 20–40 |
| Mixing power inpuf | 0.2–3.0 hp/1,000 $ft^3$ |
| Clarifier overflow rate (gpd/$ft^2$) | 200–400 avg., 800 peak |
| Clarifier solids loading (lb/d/$ft^2$) | 30 avg., 50 peak |
| Dissolved oxygen (mg/L) | >2.0 |
| Residuals generated | 0.6–0.9 lb TSS/Lb BOD removed |
| Sludge removal | 3–6 months as needed |

*Source*: From USEPA, *On-site Wastewater Treatment Systems Manual Technology Fact Sheet 1, Table 1.1, Continuous-flow, Suspended growth systems (CFSGAS)*, Office of Water, Office of Research and Development, EPA, (EPA/625/ R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/6250R0008totaldocument.pdf.

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**Table 9C.68 Common Operational Problems of Extended Aeration Package Plants**

| Observation | Cause | Remedy |
|---|---|---|
| Excessive local turbulence | Diffuser plugging | Remove and clean |
| In aeration tank | Pipe breakage | Replace as required |
| | Excessive aeration | Throttle blower |
| White, thick, billowy foam on aeration tank | Insufficient MLSS | Avoid wasting solids |
| Thick, scummy, dark tan foam on aeration tank | High MLSS | Waste solids |
| Dark brown/black foam and mixed liquor in aeration tank | Anaerobic conditions Aerator failure | Check aeration system, aeration tank DO |
| Billowing sludge washout in clarifier | Hydraulic or solids overload | Waste sludge; check flow to unit |
| | Bulking sludge | See EPA, 1977 |
| Clumps of rising sludge in clarifier | Denitrification | Increase sludge return rate to decrease sludge retention time in clarifier |
| | Septic conditions in clarifier | Increase return rate |
| Fine dispersed floc, turbid effluent | Turbulence in aeration tank | Reduce power input |
| | Siudae age too high | Waste sludae |
| Poor TSS and/or BOD removal | Excess flow and strength variations | Install flow smoothing system |
| Poor nitrification | Low temperatures | Insulate, upgrade to high biomass, etc |
| | Excessive biocide use | Reduce biocide loading |

*Source*: From USEPA, *On-site Wastewater Treatment Systems Manual Technology Fact Sheet 1, Table 1.2, Continuous-flow, suspended growth systems (CFGAS)*, Office of Water, Office of Research and Development, EPA, (EPA/625/R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008totaldocument.pdf.

**Table 9C.69 Design Parameters for Fixed Film Systems**

| Parameter | Trickling Filter | RBC |
|---|---|---|
| Pretreatment | Septic tank (primary clarifier) | Septic tank (primary clarifier) |
| Surface hydraulic loading | 10–25 gal/d-ft$^2$ | N/A |
| Organic loading[a] | 5–20 lb BOD/d-ft$^2$ (3–10 Lb BOD/d-ft$^2$ to nitrify) | 2.5 lb SBOD/d-1,000 ff (6.4 lb BOD/d-1,000 ft$^2$) |
| *Clarifier overflow rate* | | |
| Average flow | 600–800 gal/d-ft$^2$ | 600–800 gal/d-ft$^2$ |
| Peak flow | 1,000–1,200 gal/d-ft$^2$ | 1,000–1,200 gal/d-ft' |
| *Clarifier TSS loading rate* | | |
| Average flow | 0.8–1.2 LbTSS/d-ft' | 0.8–1.2 Lb TSS *Id-ft*$^2$ |
| Peak flow | 2.0 Lb TSS *Id-W* | 2.0 Lb TSS *Id-ft'* |
| Recirculation | Optional | Optional |
| Sludge generated[b] | 0.6–1.1 Lb TSS lib BOD removed | 0.6–1.1 Lb TSS lib BOD removed |

[a] Loading rates for RBC are expressed per 1,000 ft$^2$ of total disk surface.
[b] Sludge generated is in addition to solids removed in septic tank.

*Source*: From USEPA, *On-site Wastewater Treatment Systems Manual Technology Fact Sheet 2, Table 1, Fixed Film Processes, Office of Water*, Office of Research and Development, EPA, (EPA/625/R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008total document.pdf.

**Table 9C.70 Design Parameters for IF-Type Sequencing Batch Reactors Systems Treatment Systems**

| Parameter | SBR Systems |
|---|---|
| Pretreatment | Septic tank or equivalent |
| Mixed liquor suspended solids (mg/L) | 2,000–6,500 |
| F/M load (Lb BOD/d/MLVSS) | 0.04–0.20 |
| Hydraulic retention time (h) | 9–30 |
| Total cycle times (h)[a] | 4–12 |
| Solids retention time (days) | 20–40 |
| Decanter overflow ratea (gpm/ff) | $<$100 |
| Sludge wasting | As needed to maintain performance |

[a] Cycle times should be tuned to effluent quality requirements, wastewater flow, and other site constraints.

*Source*: From USEPA, *On-site Wastewater Treatment Systems Manual Technology Fact Sheet 3,Sequencing Batch Reactors Systems*, Office of Water, Office of Research and Development, EPA, (EPA/625/R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008total document.pdf.

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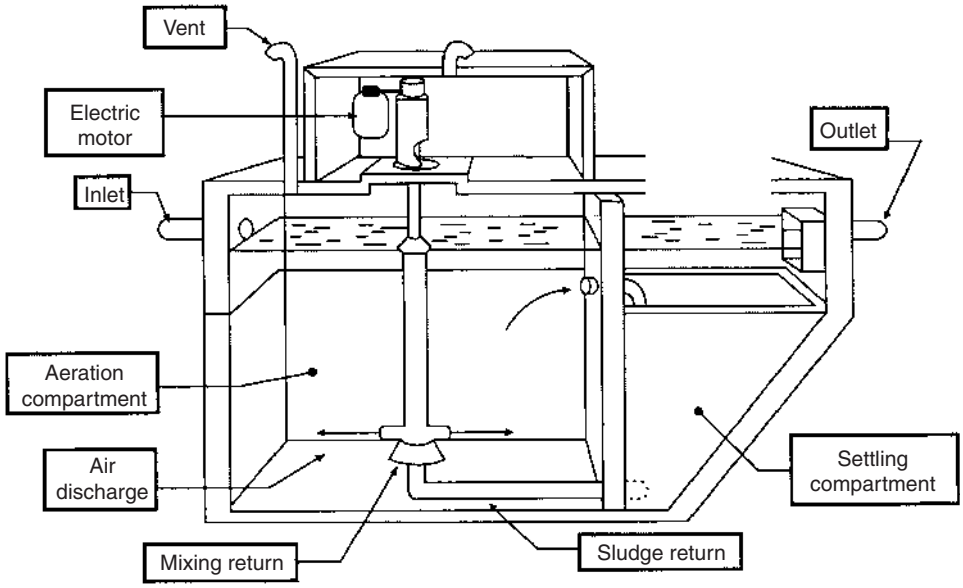


**Figure 9C.20** Components of a typical aerobic treatment system. (From USEPA, *Draft Handbook for Management of On-site and Clustered (Decentralized) Wastewater Treatment Systems*, Office of Water, Figure 3 (EPA/PA 823/P-03/001), February 2003. www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008totaldocument.pdf.)

**Table 9C.71 Chlorine Disinfection Dose (in mg/L) Design Guidelines for On-Site Applications**

| Calcium Hypochlorite | Septic Tank Effluent | Biological Treatment Effluent | Sand Filter Effluent |
|---|---|---|---|
| pH 6 | 35–50 | 15–30 | 2–10 |
| pH 7 | 40–55 | 20–35 | 10–20 |
| pH 8 | 50–65 | 30–45 | 20–35 |

*Note:* Contact time = 1 h at average flow and temperature 20 °C. Increase contact time t 02 h at 10 °C and 8 h at 5 °C for comparable efficiency. Dose = mg/L as CI. Doses assume typical chlorine demand and are conservative estimates based on fecal coliform data.

*Source*: From USEPA, *On-site Wastewater Treatment Systems Manual Technology Fact Sheet 4, Table 1, Effluent Disinfection Processes*, Office of Water, Office of Research and Development, EPA, (EPA/625/R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008total document.pdf.

**Table 9C.72 Typical Design Guidance for Aquatic System**

| Parameter | Facultative Lagoon | Aerated Lagoon | FWS Constructed Wetland |
|---|---|---|---|
| HRT (days) | 30–180 | 3 (max) | 6 (min) |
| Power (hp/1 06gal) | 0 | 30 | 0 |
| Depth (ft) | 3–5 | 10 | 2–5 |
| Minimum no. of celis | 3 | 2 | 3 |
| BOD loading (Lb/acre-day) | 20–60 | 200–600 | 40–53 |
| TSS loading (Lb/acre-day) | N/A | N/A | 27–45 |

*Source*: From USEPA, *On-site Wastewater Treatment Systems Manual Technology Fact Sheet 7, Table 1, Stabilization Ponds, FWS Constructed Wetlands, and Other Aquatic Systems*, Office of Water, Office of Research and Development, EPA, (EPA/625/R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008total document.pdf.

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**Table 9C.73 Typical N-Removal Ranges for Managed Systems**

| Process | Percent TN Removal |
|---|---|
| RSF | 40–50 |
| RSF (with recycle to ST or AUF) | 70–80 |
| ST-FFS (with recycle to ST or AUF)[a] | 65–75 |
| SBR[a] | 50–80 |
| SS and removal | 60–80 |
| (SS-TT R)[a] | 40–60 |
| ISF-AUF | 55–75 |

*Note:* RSF, recirculating sand filters; AUF, anaerobic upflow filter; ST, septic tank; FFS, fixed film system; SBR, sequencing batch reactor; SS, source separation; TT, treatment applied to both systems; R, recombined; ISF, intermittent sand filter.

[a] Commercially available systems.

*Source*: From USEPA, *On-site Wastewater Treatment Systems Manual Technology Fact Sheet 10, Table 1, Enhanced Nutrient Removal-Nitrogen*, Office of Water, Office of Research and Development, EPA, (EPA/625/R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008total document.pdf.

**Table 9C.74 Types of Mass Loadings to Subsurface Wastewater Infiltrations Systems**

| Mass Loading Type | Units | Typical Loading Rates |
|---|---|---|
| *Hydraulic* | | |
| Daily | Volume per day per unit area of boundary surface | *Septic tank effluent*: 0.15–1.0 gpd/ft$^2$ (0.6–4.0 cm/d)<br>*Secondary effluent*: 0.15→2.0 gpd/ft$^2$ (0.6→8.0 cm/d) |
| Instantaneous | Volume per dose per unit area of boundary surface | 1/24–1/8 of the average daily wastewater volume |
| Contour (Linear) | Volume per day per unit length of boundary surface contour (which can be a critical design parameter in areas with high water tables) | Depends on soil $K_{sai}$[a], maximum allowable thickness of saturated zone, and slope of the boundary surface (see section 5.3) |
| *Constituent* | | |
| Organic | Mass of BOD per day unit area of boundary surface | 0.2–5.0 Lb BOD/1,000 ft$^2$ (1.0–29.4.4 kg BOD/1,000 m$^2$) |
| Other pollutants | Mass of specific wastewater pollutant of concern per unit area of boundary surface (e.g., number of fecal coliforms, mass of nitratre nitrogen, etc | Variable with the constituent, its fate and transport and the considered risk it imposes |

[a] $K_{sai}$ is the saturated conductivity of the soil.

*Source*: From Otis, 2001; USEPA, *On-site Wastewater Treatment Systems Manual, Table 5.1, Office of Water*, Office of Research and Development, EPA, (EPA/625/R-00/0008). www.epa.gov/ord/NRMRL/Pubs/625R00008/625R00008total document.pdf.

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## SECTION 9D INDUSTRIAL WASTEWATER TREATMENT

**Table 9D.75 Toxic Chemical Releases by Industry: 2001**

| Industry | 1987 SIC[a] Code | Total Facilities (Number) | Total On and Off-Site Releases | On-Site Release | | | | Off-Site Releases/ Transfers to Disposal |
|---|---|---|---|---|---|---|---|---|
| | | | | Total | Air Emissions | Surface Water Discharges | Other[b] | |
| Metal mining | 10 | 89 | 2,782.6 | 2,782.0 | 2.9 | 0.4 | 2,778.7 | 0.5 |
| Coal mining | 12 | 88 | 16.1 | 16.1 | 0.8 | 0.8 | 14.6 | — |
| Food and kindred products | 20 | 1,688 | 125.1 | 118.9 | 56.1 | 55.2 | 7.6 | 6.2 |
| Tobacco products | 21 | 31 | 3.6 | 3.2 | 2.5 | 0.5 | 0.2 | 0.3 |
| Textile mill products | 22 | 289 | 7.0 | 6.2 | 5.7 | 0.2 | 0.3 | 0.7 |
| Apparel and other textile products | 23 | 16 | 0.4 | 0.3 | 0.3 | — | — | 0.1 |
| Lumber and wood products | 24 | 1,006 | 31.4 | 30.9 | 30.5 | — | 0.4 | 0.5 |
| Furniture and fixtures | 25 | 282 | 8.0 | 7.8 | 7.8 | — | — | 0.2 |
| Paper and allied products | 26 | 507 | 195.7 | 189.9 | 157.2 | 16.5 | 16.2 | 5.8 |
| Printing and publishing | 27 | 231 | 19.7 | 19.3 | 19.3 | — | — | 0.4 |
| Chemical and allied products | 28 | 3,618 | 582.6 | 501.3 | 227.8 | 57.6 | 215.9 | 81.3 |
| Petroleum and coal products | 29 | 542 | 71.4 | 68.1 | 48.2 | 17.1 | 2.8 | 3.3 |
| Rubber and misc. plastic products | 30 | 1,822 | 88.5 | 78.1 | 77.1 | 0.1 | 0.9 | 10.5 |
| Leather and leather products | 31 | 60 | 2.6 | 1.3 | 1.2 | 0.1 | — | 1.3 |
| Stone, clay, glass products | 32 | 1,027 | 40.5 | 35.4 | 31.3 | 0.2 | 4.0 | 5.1 |
| Primary metal industries | 33 | 1,941 | 558.6 | 286.8 | 57.6 | 44.7 | 184.5 | 271.8 |
| Fabricated metals products | 34 | 2,959 | 64.0 | 42.8 | 40.4 | 1.7 | 0.6 | 21.2 |
| Industrial machinery and equipment | 35 | 1,143 | 15.4 | 10.7 | 8.3 | — | 2.5 | 4.6 |
| Electronic, electric equipment | 36 | 1,831 | 23.9 | 16.4 | 12.7 | 2.9 | 0.7 | 7.6 |
| Transportation equipment | 37 | 1,348 | 80.6 | 67.7 | 66.7 | 0.2 | 0.8 | 13.0 |
| Instruments and related products | 38 | 375 | 9.4 | 8.6 | 7.2 | 1.4 | — | 0.8 |
| Miscellaneous | 39 | 312 | 8.4 | 6.8 | 6.8 | — | — | 1.6 |
| Electric utilities | 49 | 732 | 1,062.2 | 989.2 | 717.6 | 3.5 | 268.1 | 73.1 |
| Chemical wholesalers | 5169 | 475 | 1.5 | 1.3 | 1.3 | — | — | 0.2 |
| Petroleum bulk terminals | 5171 | 596 | 21.3 | 21.2 | 21.2 | — | — | 0.2 |
| RCRA/solvent recovery | 4953/7369 | 223 | 219.9 | 168.4 | 1.0 | — | 167.4 | 51.4 |
| Total[c] | (X) | 24,896 | 6,158.0 | 5,580.3 | 1,679.4 | 220.8 | 3,680.1 | 577.7 |

[In millions of pounds (6,158.0 represents 6,158,000,000), except as indicated. "Original industries" include owners and operators covers facilities that are classified within standard classification code groups 20 through 39,10,12,49, 5169, 5171, and 4953/7169 that have 10 or more full-time employees, and that manufacture, process, or otherwise uses any listed toxic chemical in quantities greater than the established threshold in the course of a calendar year are covered and required to report.

— Represents or rounds to zero, X, Not applicable.
[a] Standard industrial classification, see text, section 12.
[b] Includes underground injection for class I and class II to V wells and land releases.
[c] Includes industries with no specific industry identified, not shown separately.

*Source*: From Table 378 and Table 379 U.S. Environmental Protection Agency, *Toxics Release Inventory*, Annual. U.S. Census Bureau, Statistical Abstract of the U.S., 2003. www.census.gov/compendia/statab/.

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**Table 9D.76 Overview of Facility, Impoundment, and Wastewater Quantity Estimates**

| Characteristic | Direct Dischargers | Zero Dischargers | Total Population |
|---|---|---|---|
| Estimated number of facilities | 3,944 | 512 | 4,457 |
| Estimated number of impoundments | 10,987 | 876 | 11,863 |
| Total quantity of wastewaters managed (metric tons)[a] | 627,218,336 | 27,250,309 | 654,468,645 |

[a] The estimate of the wastewater quantity for the total population differs from the estimates shown in Table 2.2 and Table 2.15. This is due to missing data associated with this variable. Refer to Appendix A on missing data and Appendix B for the standard error associated with this variable.

*Source*: From USEPA, *Industrial Surface Impoundments in the United States*, Table 2.1 (530R01005). www.epa.gov/epaoswer/hazwaste/ldr/icr/ldr-impd.htm.

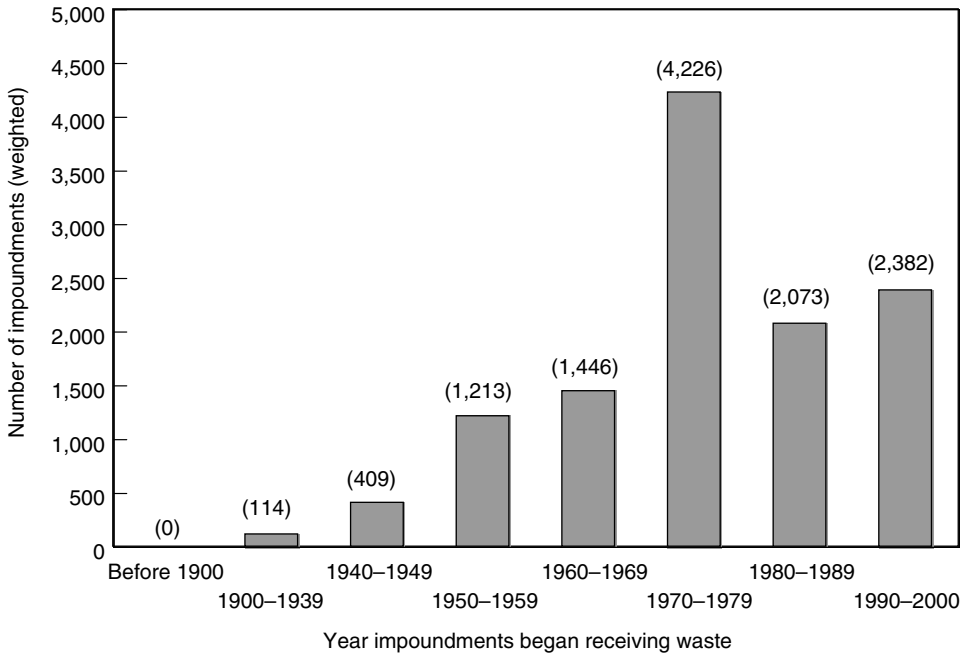


**Figure 9D.21** Distribution of 11,863 impoundments by year unit began receiving waste. (From USEPA, *Industrial Surface Impoundments in the United States*, Figure 2.1, (530R01005). www.epa.gov/epaoswer/hazwaste/ldr/icr/ldr-impd.htm.)

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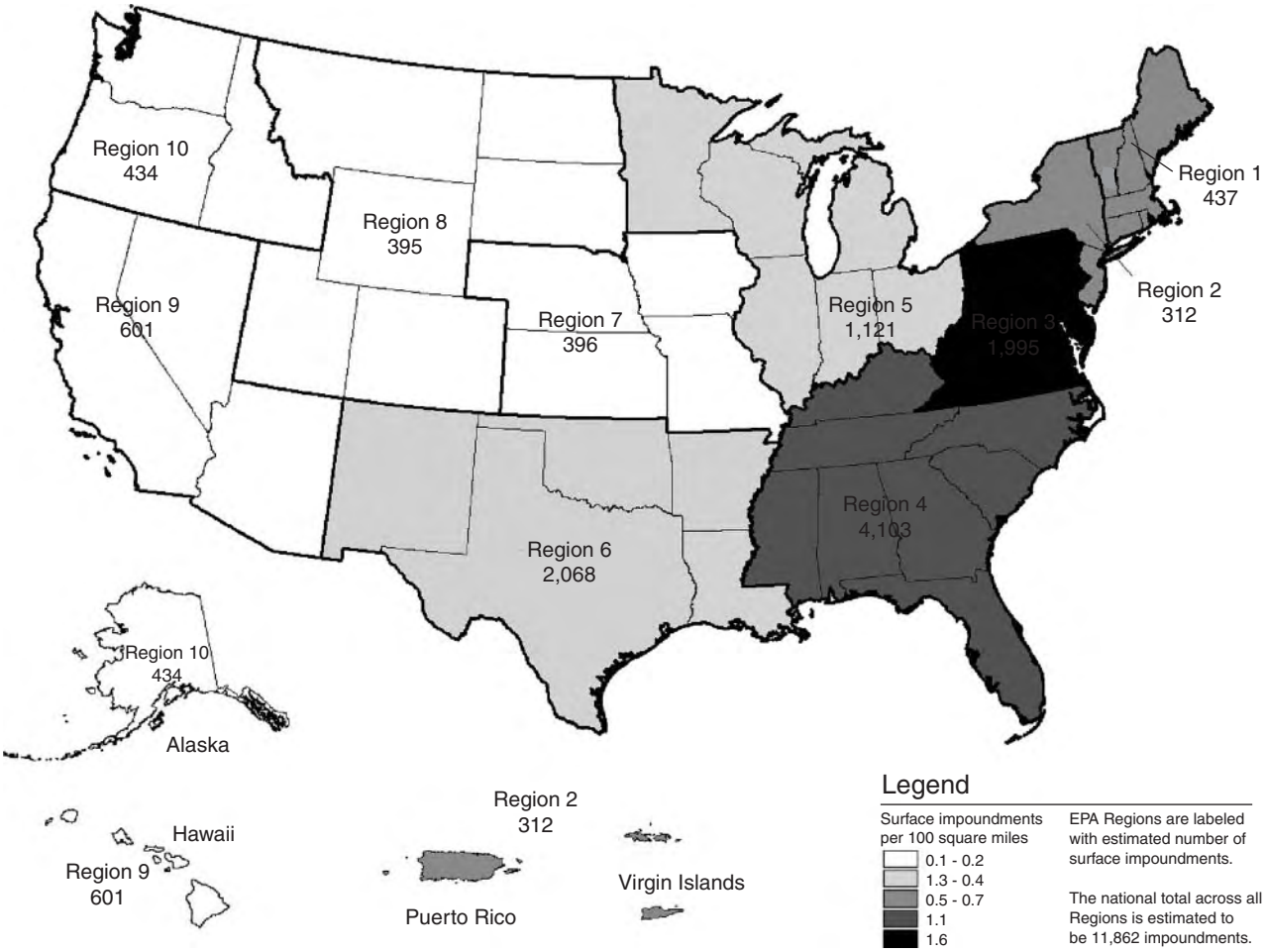


**Figure 9D.22** Regional distribution of surface impoundments. (From USEPA, *Industrial Surface Impoundments in the United States*, Figure 2.2, (530R01005). www.epa.gov/epaoswer/hazwaste/ldr/icr/ldr-impd.htm.)

**Table 9D.77 Breakdown by 2-Digit SIC Code of Surface Impoundments That Manage Chemicals/pH of Concern and of Quantities of Wastewater Managed**

| SIC Code Descriptor | Percent of 4,457 Facilities | Percent of 11,863 Impoundments | Percent of 653,314,426[a] Metric Tons Wastewater |
|---|---|---|---|
| Chemical and allied products (SIC 28) | 19 | 23 | 9 |
| Stone, clay, glass, concrete products (SIC 32) | 15 | 13 | 1 |
| Wholesale trade-nondurable goods (SIC 51) | 12 | 10 | 4 |
| Primary metals industry (SIC 33) | 10 | 8 | 7 |
| Food and kindred products (SIC 20) | 8 | 8 | 5 |
| Petroleum and coal products (SIC 29) | 7 | 11 | 6 |
| Paper and allied products (SIC 26) | 6 | 12 | 66 |
| All other SIC codes | 23 | 15 | 2 |

SIC, standard industrial classification.

[a] The estimate of the wastewater quantity for the total population differs from the estimates shown in Table 2.1 and Table 2.15. This is due to missing data associated with this variable. Refer to Appendix A on missing data and Appendix B for the standard error associated with this variable.

*Source*: From USEPA, *Industrial Surface Impoundments in the United States*, Table 2.2 (530R01005). www.epa.gov/epaoswer/hazwaste/ldr/icr/ldr-impd.htm.

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**Table 9D.78 Breakdown of Chemical Categories for Wastewater and Sludge (at Different Sampling Points) on Impoundment and Volume Basis**

| | Wastewater | | | | | | Sludge | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Influent | | In Impoundment | | Effluent | | Influent | | In Impoundment | | Effluent | |
| Chemical Categories | # Imps | % Vol | # Imps | % Vol | # Imps | % Vol | # Imps | % Vol | # Imps | % Vol | # Imps | % Vol |
| VOCs | 5,866 | 76 | 5,412 | 76 | 4,815 | 72 | 1,690 | 4 | 2,006 | 21 | 1,311 | 14 |
| SVOCs | 3,824 | 75 | 3,786 | 75 | 3,508 | 69 | 863 | 7 | 1,261 | 24 | 605 | 3 |
| Metals | 9,966 | 84 | 9,982 | 83 | 7,762 | 85 | 3,925 | 42 | 5,551 | 98 | 3,078 | 88 |
| Dioxin-like compounds | 291 | 24 | 218 | 21 | 346 | 22 | 247 | 10 | 861 | 35 | 412 | 41 |
| Mercury | 2,483 | 27 | 2,479 | 30 | 2,235 | 31 | 1,061 | 0.9 | 1,745 | 66 | 826 | 6 |
| Any chemicals | 10,745 | 96 | 10,766 | 97 | 8,187 | 92 | 4,101 | 45 | 5,759 | 100 | 3,230 | 89 |

# Imps, number of impoundments; % Vol, percent of total volume; SVOCs , Semivolatile organic compounds; VOCs, Volatile organic compounds.

*Source*: From USEPA, *Industrial Surface Impoundments in the United States*, Table 2.5 (530R01005). www.epa.gov/epaoswer/hazwaste/ldr/icr/ldr-impd.htm.

**Table 9D.79 Number and Percentage of Impoundments by Liner Status**

| Liner Status | Number of Impoundments | Percentage of Impoundments |
|---|---|---|
| Compacted clay | 1,680 | 14 |
| Flexible membrane (FML) | 1,584 | 13 |
| Composite (FML and clay) | 536 | 5 |
| Concrete | 629 | 5 |
| Asphalt | 55 | <1 |
| Other | 363 | 3 |
| Unlined[a] | 7,017 | 59 |
| Total | 11,863 | 100 |

[a] This estimate differs from the estimate of outlined impoundments shown in Table 2.12. This is due to missing data associated with this variable. Refer to Appendix A on missing data and Appendix B for the standard error associated with this variable.

*Source*: From USEPA, *Industrial Surface Impoundments in the United States*, Table 2.10, (530R01005). www.epa.gov/epaoswer/hazwaste/ldr/icr/ldr-impd.htm.

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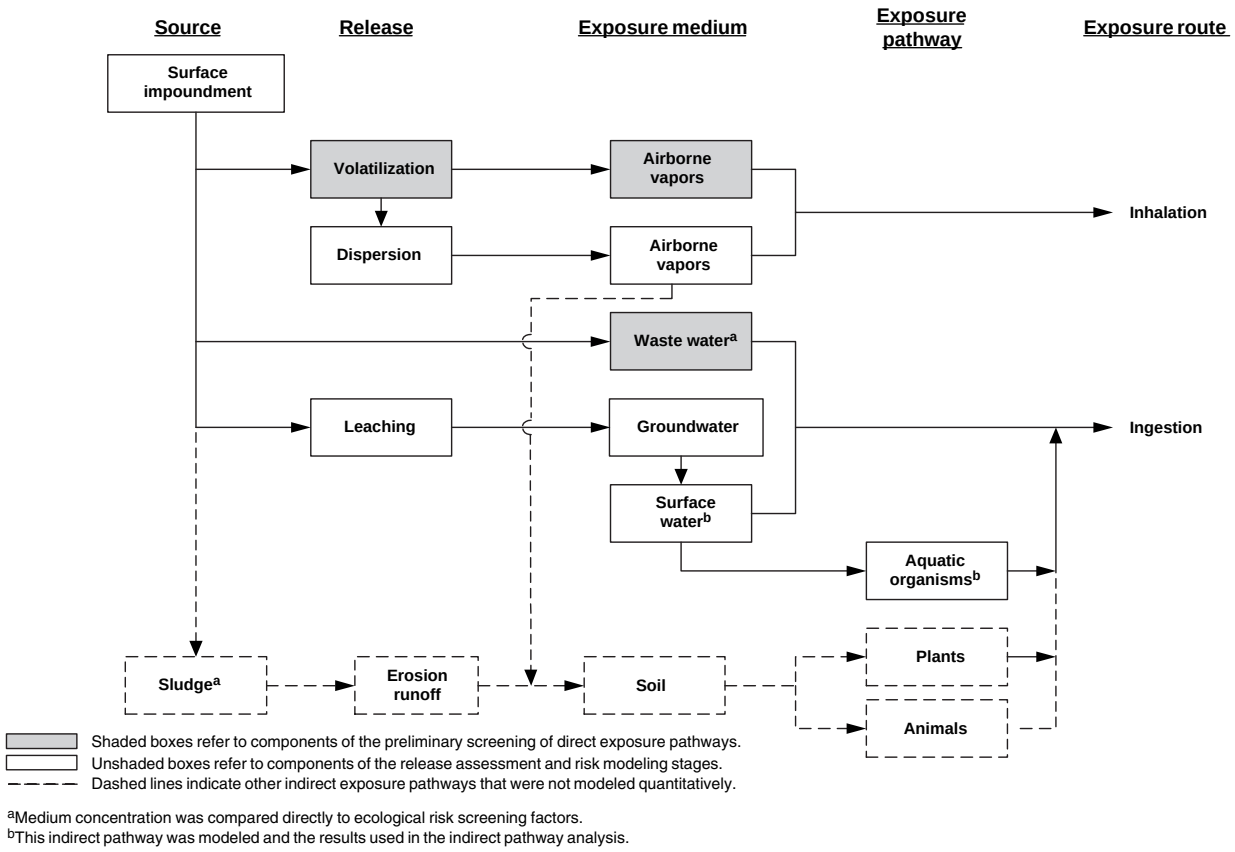


**Figure 9D.23** Exposure pathways for active surface impoundments considered for humans and ecological receptors. (From USEPA, *Industrial Surface Impoundments in the United States*, Figure 3.1, (530R01005). www.epa.gov/epaoswer/hazwaste/ldr/icr/ldr-impd.htm.)

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CHAPTER 10

# Environmental Problems

**Katherine L. Thalman**

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## SECTION 10A POLLUTION SOURCES AND PATHWAYS

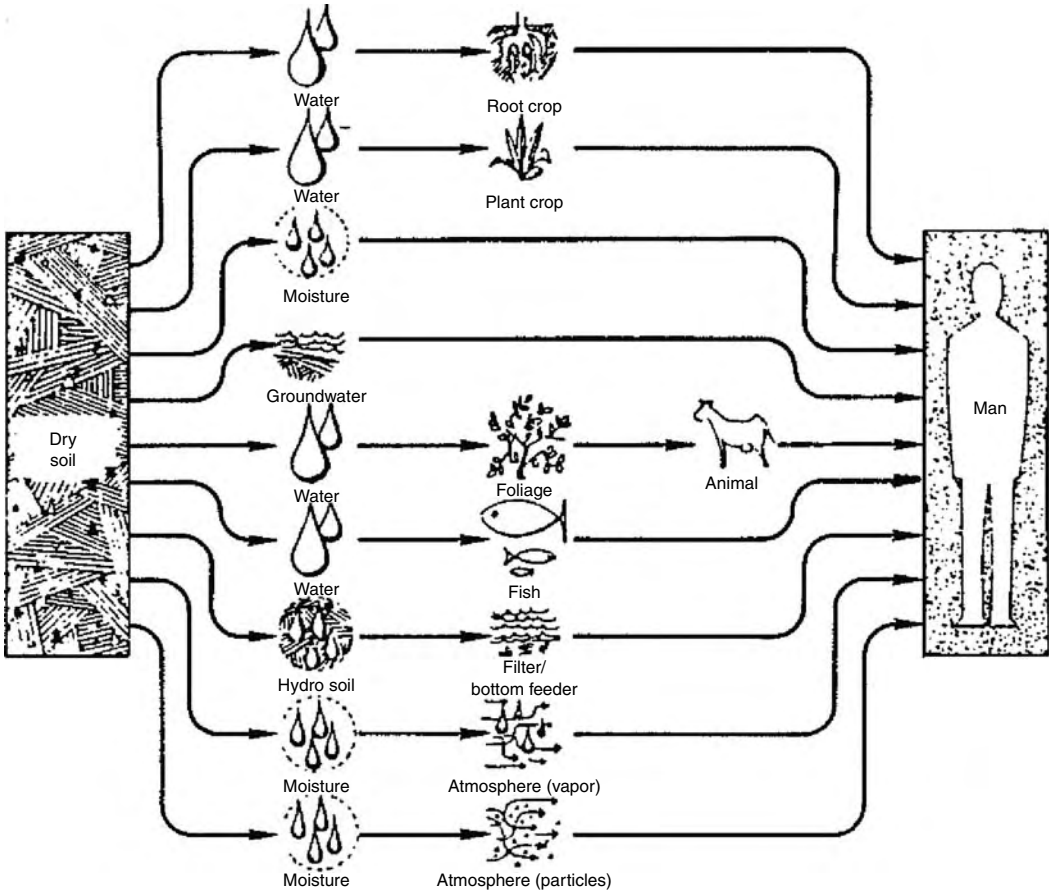


**Figure 10A.1** Pollutant pathways from soil to man. (From Dacre, I.C., Rosenblatt, D.H., and Cogley, D.R., 1980, *Preliminary Pollutant Limit Values for Human Health Effects, Environmental Technology* 14: 778–783, Copyright American Chemical Society, Washington, DC.)

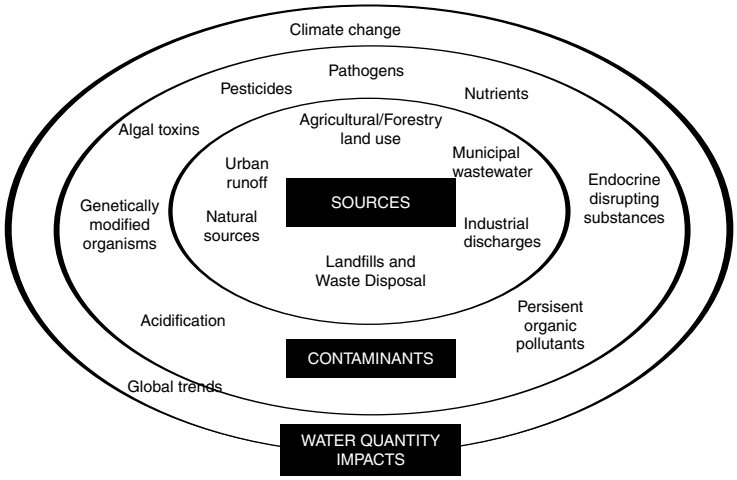


**Figure 10A.2** Threats to water sources. (From Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada, page x, Environment Canada, 2001. Reproduced with permission from the National Water Research Institute, Environment Canada, 2006.)

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**Table 10A.1 Causes of Damage to the Quality of Water Resources**

| Types of Waste | Wastewater Sources | Water-Quality Measures | Effects on Water Quality | Effects on Aquatic Life | Effects on Recreation |
|---|---|---|---|---|---|
| Disease-carrying agents — human feces, warm-blooded animal feces | Municipal discharges, watercraft discharges, urban runoff, agricultural runoff, feedlot wastes, combined sewer overflows, industrial discharges | Fecal coliform, fecal streptococcus, other microbes | Health hazard for human consumption and contact | Inedibility of shellfish for humans | Reduced contact recreation |
| Oxygen-demanding wastes — high concentrations of biodegradable organic matter | Municipal discharges, industrial discharges, combined sewer overflows, watercraft discharges, urban runoff, agricultural runoff, feedlot wastes, natural sources | Biochemical oxygen demand, dissolved oxygen, volatile solids sulfides | Deoxygenation, potential for septic conditions | Fish kills | If severe, eliminated recreation |
| Suspended organic and inorganic material | Mining discharges, municipal discharges, industrial discharges, construction runoff, agricultural runoff, urban runoff, silvicultural runoff, natural sources, combined sewer overflows | Suspended solids, turbidity, biochemical oxygen demand, sulfides | Reduced light penetration, deposition on bottom, benthic deoxygenation | Reduced photosynthesis, changed bottom organism population, reduced fish production, reduced sport fish population, increased nonsport fish population | Reduced game fishing, aesthetic appreciation |
| Inorganic materials, mineral substances — metal, salts, acids, solid matter, other chemicals, oil | Mining discharges, acid mine drainage, industrial discharges, municipal discharges, combined sewer overflows, urban runoff, oil fields, agricultural runoff, irrigation return flow, natural sources, cooling tower blowdown, transportation spills, coal gasification | pH, acidity, alkalinity, dissolved solids, chlorides, sulfates, sodium, specific metals, toxicity bioassay, visual (oil spills) | Acidity, salination, toxicity of heavy metals, floating oils | Reduced biological productivity, reduced flow, fish kills, reduced production, tainted fish | Reduced recreational use, fishing, aesthetic appreciation |
| Synthetic organic chemicals — dissolved organic material, e.g., detergents, household aids, pesticides | Industrial discharges, urban runoff, municipal discharges, combined sewer overflow, agricultural runoff, silvicultural runoff, transportation spills, mining discharges | Cyanides, phenols, toxicity bioassay | Toxicity of natural organics, biodegradable or persistent synthetic organics | Fish kills, tainted fish, reduced reproduction, skeletal development | Reduced fishing, inedible fish for humans |
| Nutrients — nitrogen, phosphorus | Municipal discharges, agricultural runoff, combined sewer overflows, industrial discharges, urban runoff, natural sources | Nitrogen, phosphorus | Increased algal growth, dissolved oxygen reduction | Increased production, reduced sport fish population, increased nonsport fish population | Tainted drinking water, reduced fishing and aesthetic appreciation |
| Radioactive materials | Industrial discharges, mining | Radioactivity | Increased radioactivity | Altered natural rate of genetic mutation | Reduced opportunities |
| Heat | Cooling water discharges, industrial discharges, municipal discharges, cooling tower blowdown | Temperature | Increased temperature, reduced capacity to absorb oxygen | Fish kills, altered species composition | Possible increased sport fishing by extended season for fish, which might otherwise migrate |

*Source*: From Council of Environmental Quality, 1981, *Environmental Trends*.



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**Table 10A.2 Point- and Nonpoint Sources of Water Pollution**

| Sources | Common Pollutant Categories |
|---|---|
| POINT SOURCES | |
| Municipal sewage treatment plants | BOD; bacteria; nutrients; ammonia; toxics |
| Industrial facilities | Toxics; BOD |
| Combined sewer overflows | BOD; bacteria; nutrients; turbidity; total dissolved solids; ammonia; toxics; bacteria |
| NONPOINT SOURCES | |
| Agricultural runoff | Nutrients; turbidity; total dissolved solids; toxics; bacteria |
| Urban runoff | Turbidity; bacteria; nutrients; total dissolved solids; toxics |
| Construction runoff | Turbidity; nutrients; toxics |
| Mining runoff | Turbidity; acids; toxics; total dissolved solids |
| Septic systems | Bacteria; nutrients |
| Landfills/spills | Toxics; miscellaneous substances |
| Silvicultural runoff | Nutrients; turbidity; toxics |

*Source*: From U.S. Environmental Protection Agency, *National Water Quality Inventory*, 1986 Report to Congress.

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**Table 10A.3 Classes of Nonpoint Source Pollution**

| Class | | Description | Common Pollutants |
|---|---|---|---|
| **Agriculture** | | | |
| | Animal feedlots<br>Irrigation Cultivation<br>Pastures Dairy farming<br>Orchards Aquaculture | Runoff from all categories of agriculture leading to surface and groundwater pollution. In northern climates, runoff from frozen ground is a major problem, especially where manure is spread during the winter. Vegetable handling, especially washing in polluted surface waters in many developing countries, leads to contamination of food supply. Growth of aquaculture is becoming a major polluting activity in many countries. Irrigation return flows carry salts, nutrients, and pesticides. Tile drainage rapidly carries leachates such as nitrogen to surface waters | Phosphorus, nitrogen, metals, pathogens, sediment, pesticides, salt, BOD[a], trace elements (e.g., selenium) |
| Forestry | | Increased runoff from disturbed land. Most damaging is forest clearing for urbanization | Sediment, pesticides |
| Liquid waste disposal | | Disposal of liquid wastes from municipal wastewater effluents, sewage sludge, industrial effluents and sludges, wastewater from home septic systems; especially disposal on agricultural land, and legal or illegal dumping in watercourses | Pathogens, metals, organic compounds |
| **Urban Areas** | | | |
| | Residential<br>Commercial Industrial | Urban runoff from roofs, streets, parking lots, etc. leading to overloading of sewage plants from combined sewers, or polluted runoff routed directly to receiving waters; local industries and businesses may discharge wastes to street gutters and storm drains; street cleaning; road salting contributes to surface and groundwater pollution | Fertilizers, greases and oils, fecal matter and pathogens, organic contaminants (e.g., PAHs[b] and PCBs[c]), heavy metals, pesticides, nutrients, sediment, salts, BOD, COD[d], etc. |
| Rural sewage systems | | Overloading and malfunction of septic systems leading to surface runoff and/or direct infiltration to groundwater | Phosphorus, nitrogen, pathogens (fecal matter) |
| Transportation | | Roads, railways, pipelines, hydroelectric corridors, etc. | Nutrients, sediment, metals, organic contaminants, pesticides (especially herbicides) |
| Mineral extraction | | Runoff from mines and mine wastes, quarries, well sites | Sediment, acids, metals, oils, organic contaminants, salts (brine) |
| Recreational land use | | Large variety of recreational land uses, including ski resorts, boating and marinas, campgrounds, parks; waste and "grey" water from recreational boats is a major pollutant, especially in small lakes and rivers. Hunting (lead pollution in waterfowl) | Nutrients, pesticides, sediment, pathogens, heavy metals |
| Solid waste disposal | | Contamination of surface and groundwater by leachates and gases. Hazardous wastes may be disposed of through underground disposal | Nutrients, metals, pathogens, organic contaminants |
| Dredging | | Dispersion of contaminated sediments, leakage from containment areas | Metals, organic contaminants |
| Deep well disposal | | Contamination of groundwater by deep well injection of liquid wastes, especially oilfield brines and liquid industrial wastes | Salts, heavy metals, organic contaminants |
| Atmospheric deposition | | Long-range transport of atmospheric pollutants (LRTAP) and deposition of land and water surfaces. Regarded as a significant source of pesticides (from agriculture, etc.), nutrients, metals, etc. especially in pristine environments | Nutrients, metals, organic contaminants |

[a] BOD, Biological Oxygen Demand.
[b] PAH, Polycyclic Aromatic Hydrocarbons.
[c] PCB, Polycyclic Chlorinated Bi-Phenyls.
[d] COD, Chemical Oxygen Demand.

*Source*: From Ongley, E.D., 1996, Control of water pollution from agriculture-FAO irrigation and drainage paper 55, *Food and Agriculture Organization of the United Nations*, Rome. Reprinted with permission.



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**Table 10A.4 Contamination Sources Reported by Public Water-Supply Systems in the United States**

| | Water-Supply Source | | |
|---|---|---|---|
| **Type of Contamination** | **Groundwater** | **River/Stream** | **Lake/Reservoir** |
| Industrial/commercial discharges | 62 | 97 | 38 |
| Leaking underground tanks | 81 | 33 | 23 |
| Urban runoff | 35 | 91 | 24 |
| Landfills | 67 | 49 | 22 |
| Synthetic or volatile organics | 83 | 56 | 18 |
| Hazardous waste site(s) | 37 | 31 | 8 |
| Land development | 36 | 76 | 32 |
| Underground waste injection | 27 | 5 | 3 |
| Agricultural runoff (pesticides, fertilizers, etc.) | 49 | 126 | 86 |
| Algae/bacteria | 15 | 117 | 124 |
| Overdraft | 40 | 7 | 4 |
| Water rights disputes | 16 | 22 | 12 |
| Natural contamination (radionuclides, salinity, etc.) | 52 | 56 | 35 |

*Note:* Number of utilities reporting in each category.

*Source*: From American Water Works Association, 1984 Water Utility Operating Data; Copyright AWWA.

**Table 10A.5 Anthropogenic Sources of Pollutants in the Aquatic Environment**

| **Source** | **Bacteria** | **Nutrients** | **Trace Elements** | **Pesticides/ Herbicides** | **Industrial Organic Micro Pollutants** | **Oils and Greases** |
|---|---|---|---|---|---|---|
| **Atmosphere** | | x | xxxG | xxxG | xxxG | |
| ***Point sources*** | | | | | | |
| Sewage | xxx | xxx | xxx | x | xxx | |
| Industrial effluents | | x | xxxG | | xxxG | xx |
| ***Diffuse sources*** | | | | | | |
| Agriculture | xx | xxx | x | xxxG | | |
| Dredging | | x | xxx | xx | xxx | x |
| Navigation and harbors | x | x | xx | | x | xxx |
| ***Mixed sources*** | | | | | | |
| Urban runoff and waste disposal | xx | xxx | xxx | xx | xx | xx |
| Industrial waste disposal sites | | x | xxx | x | xxx | x |

*Note:* x, Low local significance; xx, Moderate local/regional significance; xxx, High local/regional significance; G, Globally significant.

*Source*: From Chapman, D. (ed.), 1996, Water quality assessments-A guide to use of biota, *Sediments and Water in Environmental Monitoring—Second Edition*, Copyright © UNESO/WHO/UNEP, 1996, www.who.int. Reprinted with permission.

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## SECTION 10B SURFACE WATER POLLUTION

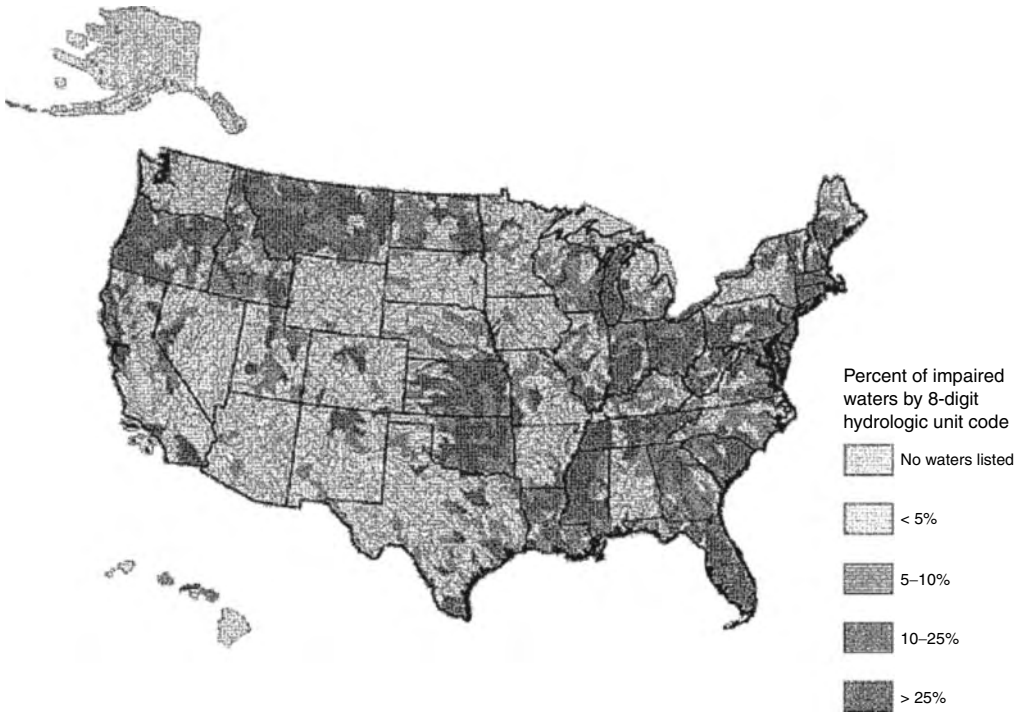


**Figure 10B.3** Percentage of impaired waters in the United States by 8-digit hydrologic unit code. (From United States Environmental Protection Agency, 2000, *Atlas of America's Polluted Waters*, EPA-840-B-00-002, May 2000, www.epa.gov.)

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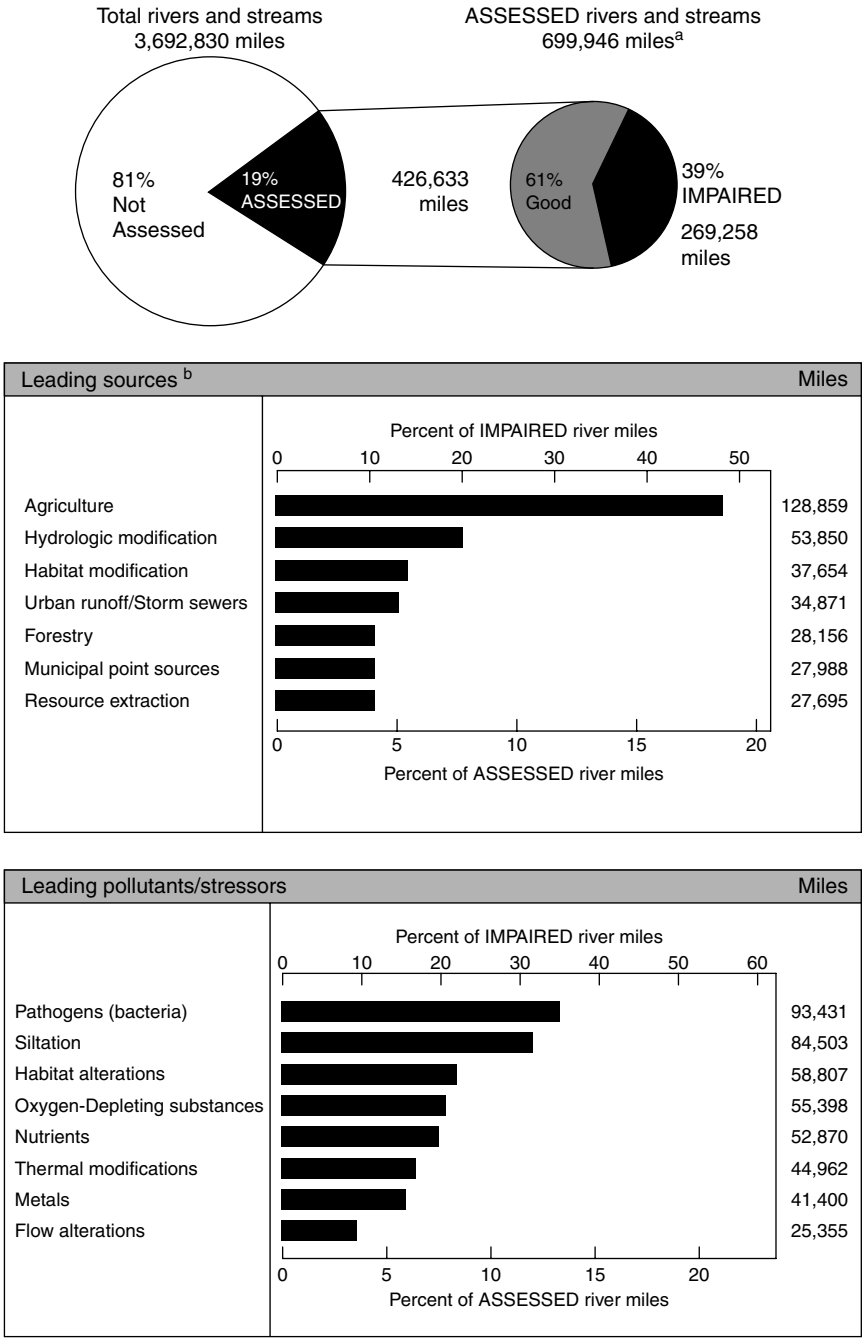


**Figure 10B.4** Leading pollutants and sources of river and stream impairment in the United States.[a] Excluding unknown and natural sources.[b] Includes miles assessed as not attainable. Percentages do not add up to 100% because more than one pollutant or source may impair a river segment. (From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.)

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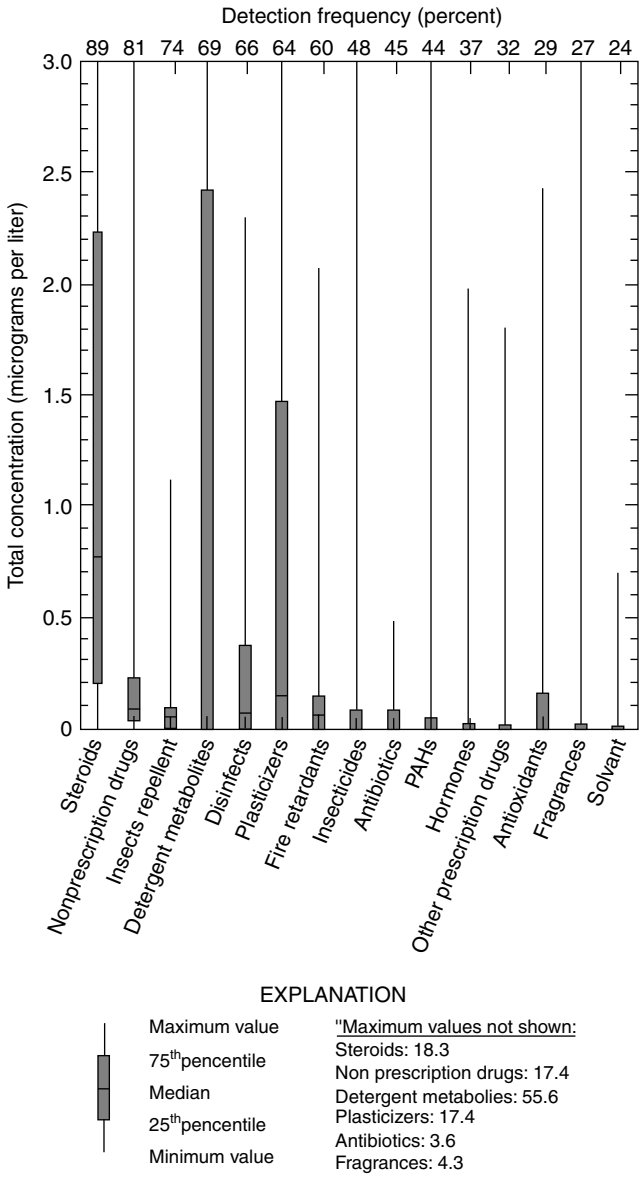


*Steroids, nonprescription drugs, and an insects repellent were the three chemical groups most commonly detected in susceptible streams. Detergent and metabolites, steroids, and plasticizers generally were found at the highest concentrations.*

**Figure 10B.5** Pharmaceuticals, hormones, and other organic wastewater contaminants in United States streams. (From Buxton, H.T. and Kolpin, D.W., 2002, *Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in U.S. Streams*, USGS Fact Sheet FS-027-02, June 2002, www.usgs.gov.)

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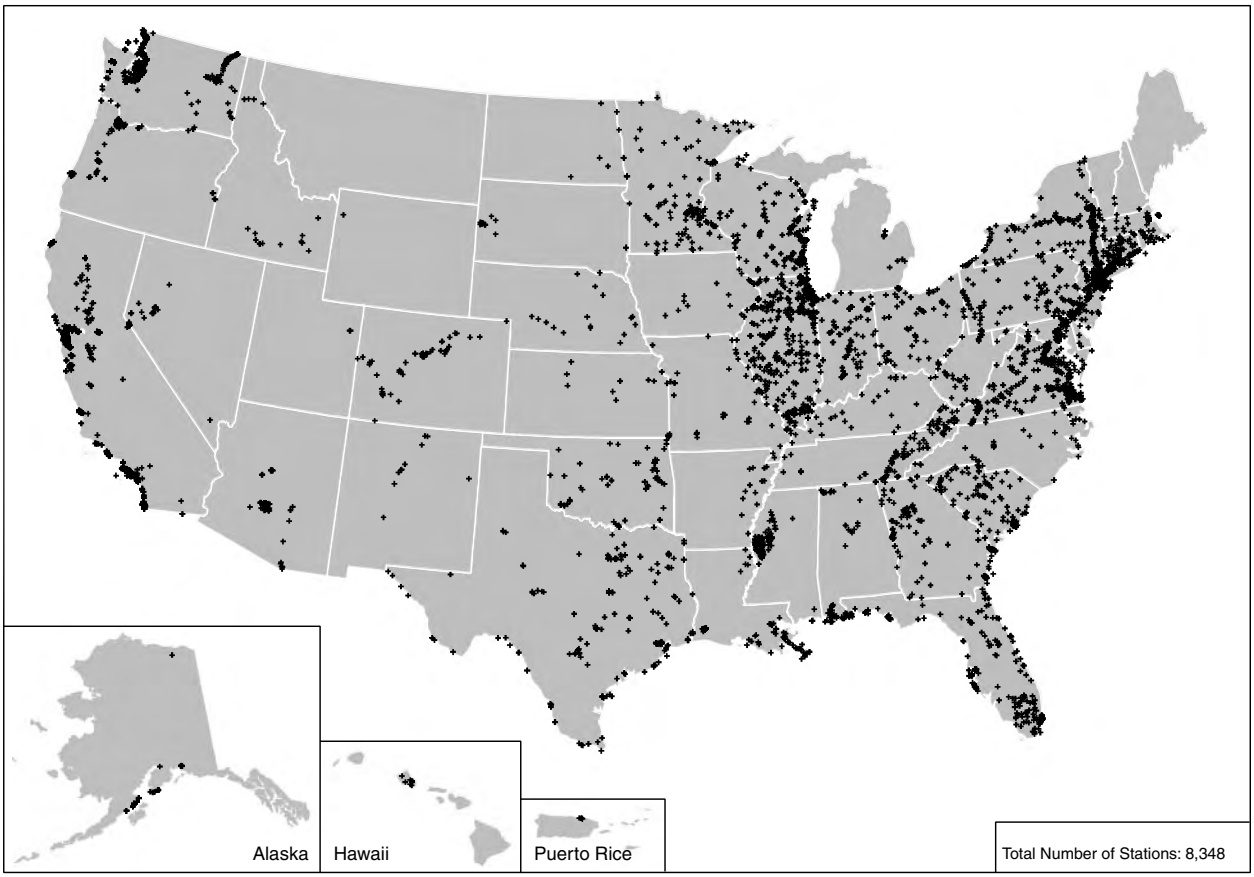


**Figure 10B.6** Sampling stations classified as tier 1 (associated adverse effects are probable). (From USEPA, 2004, The incidence and severity of sediment contamination in surface waters of the United States, *National Sediment Quality Survey: Second Edition*, EPA 823-R-04-007, www.epa.gov.)

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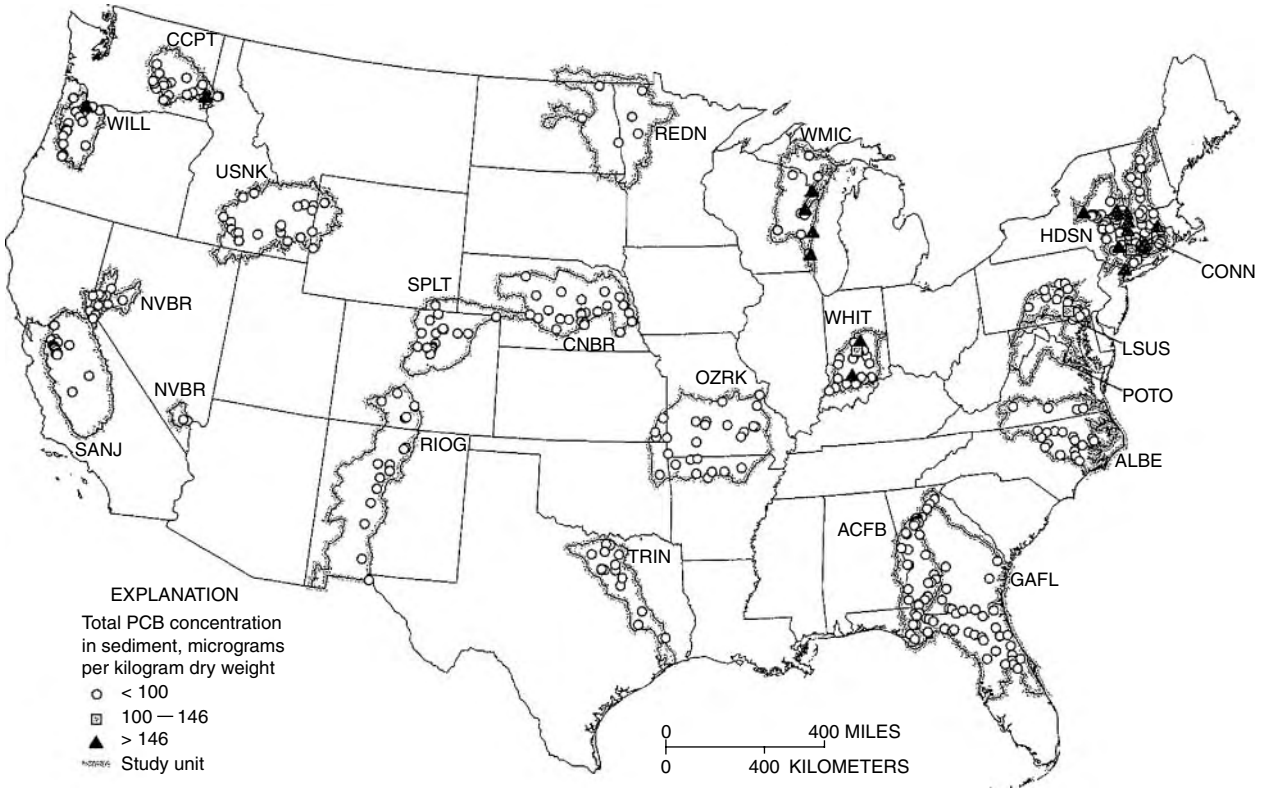


**Figure 10B.7** Geographic distribution of total polychlorinated biphenyls in sediment samples in the United States. (From Wong, C.S., Capel, P.D., and Nowell, L.H., 2000, *Organochlorine Pesticides and PCBs in Stream Sediment and Aquatic Biota—Initial Results from the National Water-Quality Assessment Program, 1992–1995*, Water-Resources Investigations Report 00-4053, www.usgs.gov.)

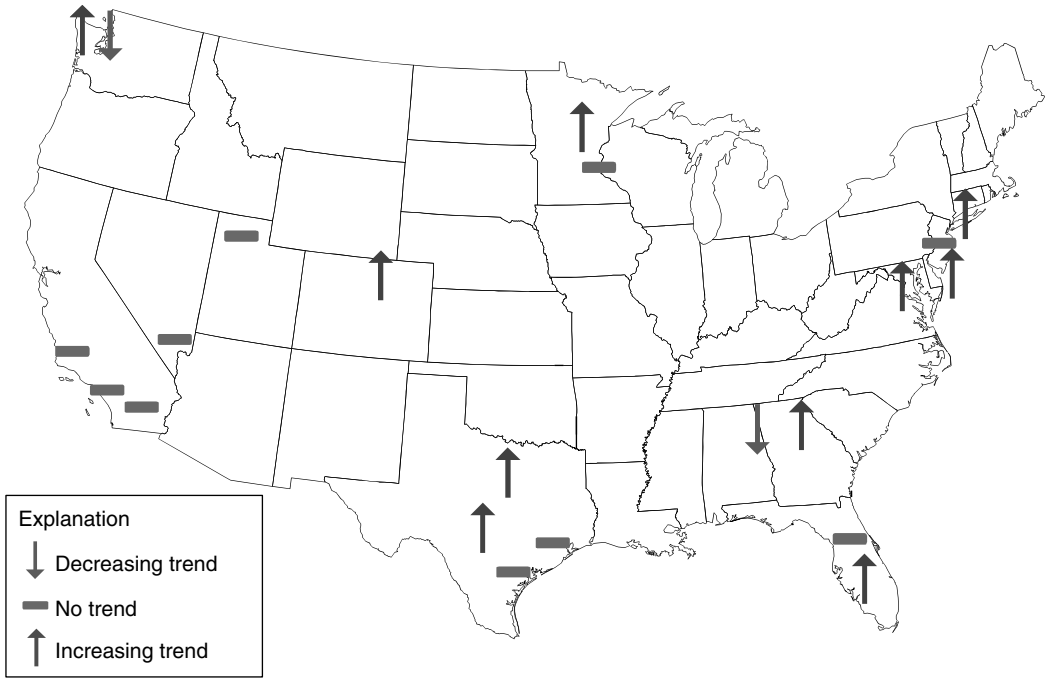


**Figure 10B.8** PAH trends throughout the United States using sediment core data from 1970 to top of core. (From USEPA, 2004, The incidence and severity of sediment contamination in surface waters of the United States, *National Sediment Quality Survey: Second Edition*, EPA 823-R-04-007, www.epa.gov.)

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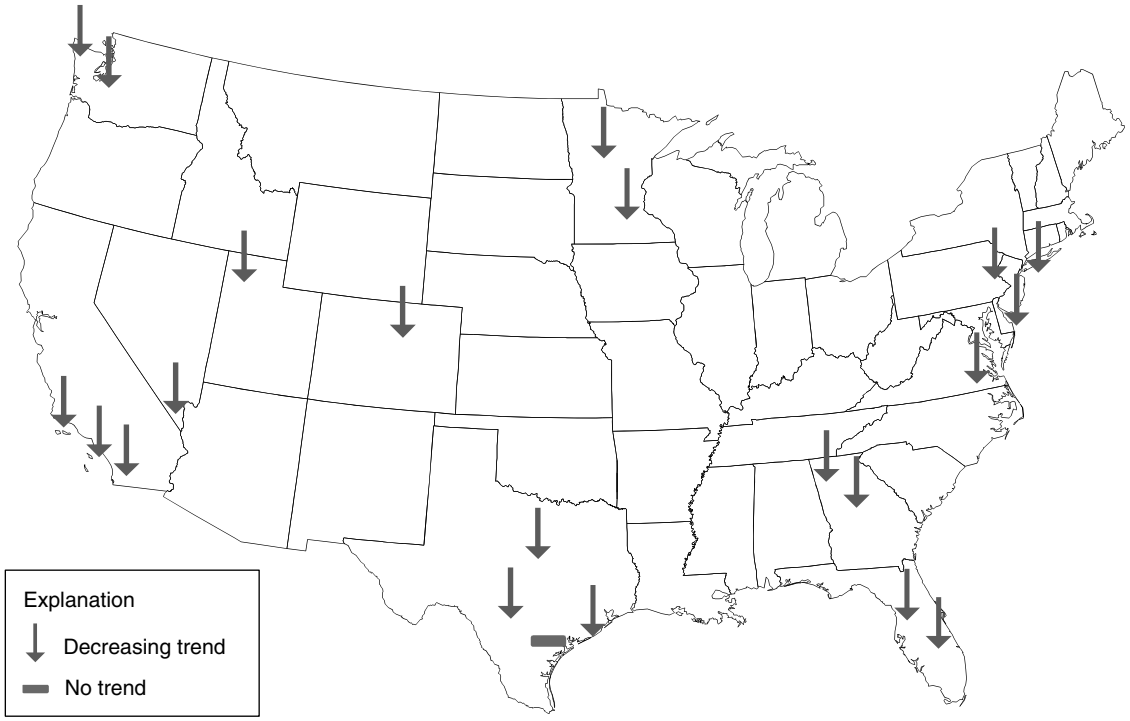


**Figure 10B.9** Lead trends throughout the United States using sediment core data from 1975 to top of core. (From USEPA, 2004, The incidence and severity of sediment contamination in surface waters of the United States, *National Sediment Quality Survey: Second Edition*, EPA 823-R-04-007, www.epa.gov.)

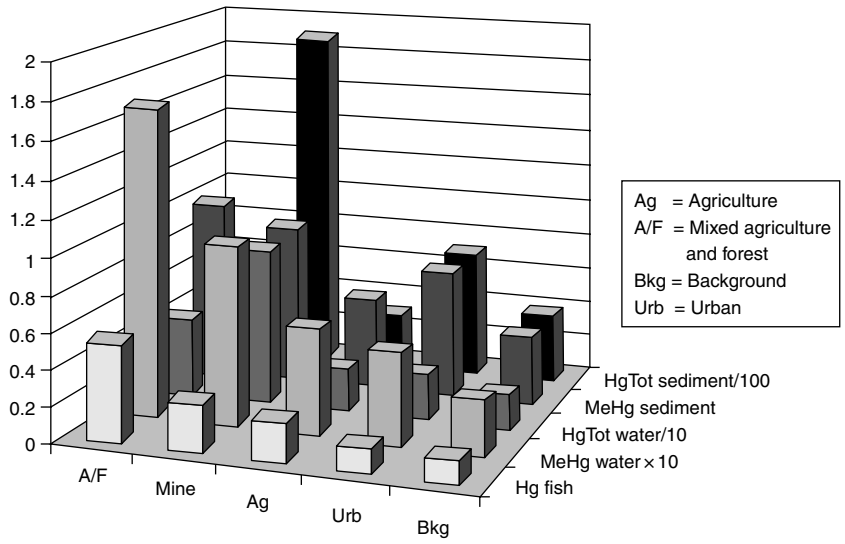


**Figure 10B.10** Geometric mean of mercury and methylmercury in fish (μg/g wet), water (μg/L), and sediment (hg/g dry) for land use categories: mixed agriculture and forest, mine, agriculture, urban or industrial activity, and background. (Number of observation = 13, 42, 23, 15, and 34 for A/F, Mine, Ag, Bkg and Urb, respectively. Excludes South Florida Basin.) (From Brumbaugh, W.G. et al., 2001, A national pilot study mercury contamination of aquatic ecosystems along multiple gradients: Bioaccumulation in Fish, *USGS, Biological Science Report USGS/BRD/BSR-2001-0009*, www.usgs.gov.)

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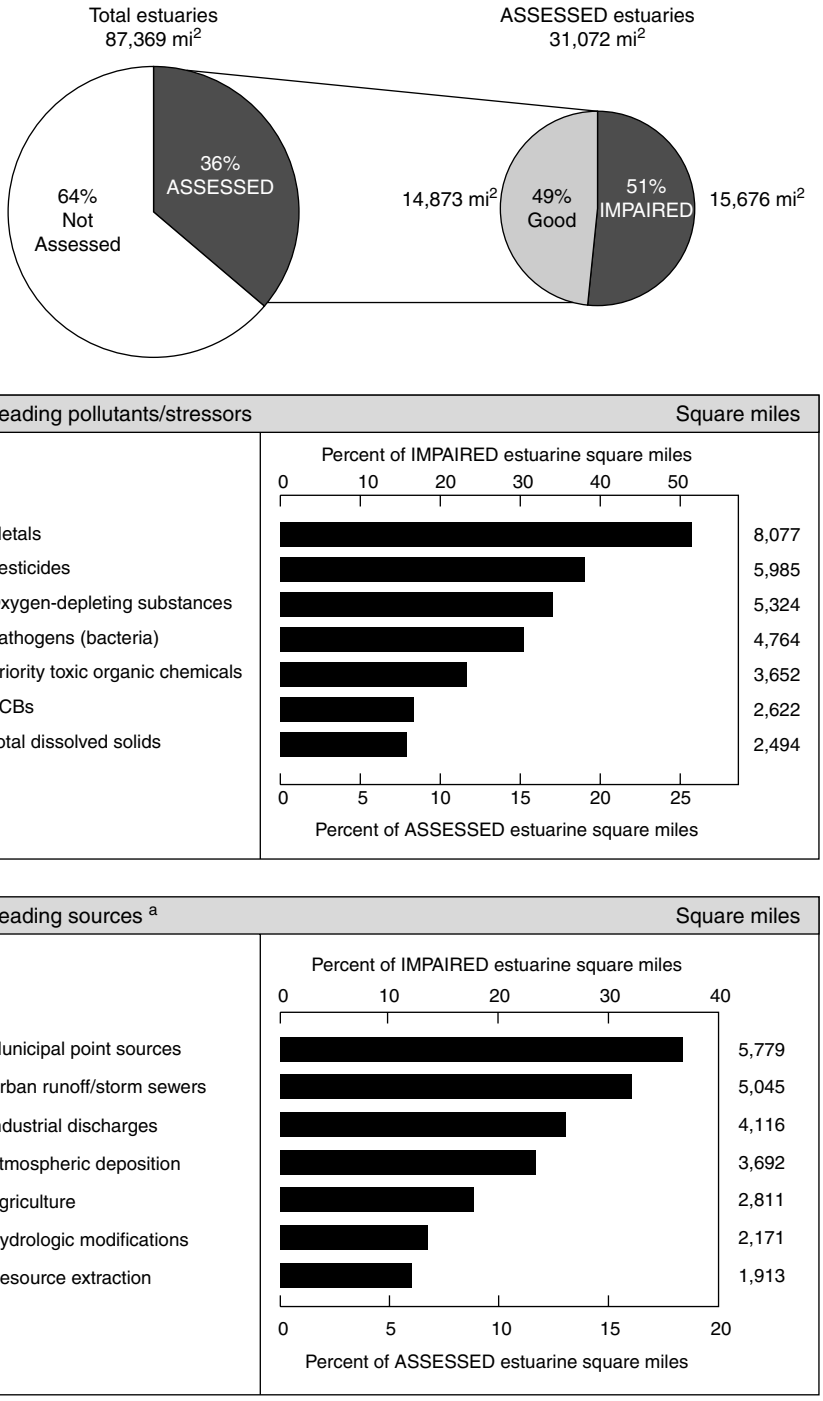


**Figure 10B.11** Leading pollutants and sources of estuary impairment in the United States.[a] Excludes unknown, natural, and "other sources." Percentages do not add up to 100% because more than one pollutant or source may impair an estuary. (From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.)

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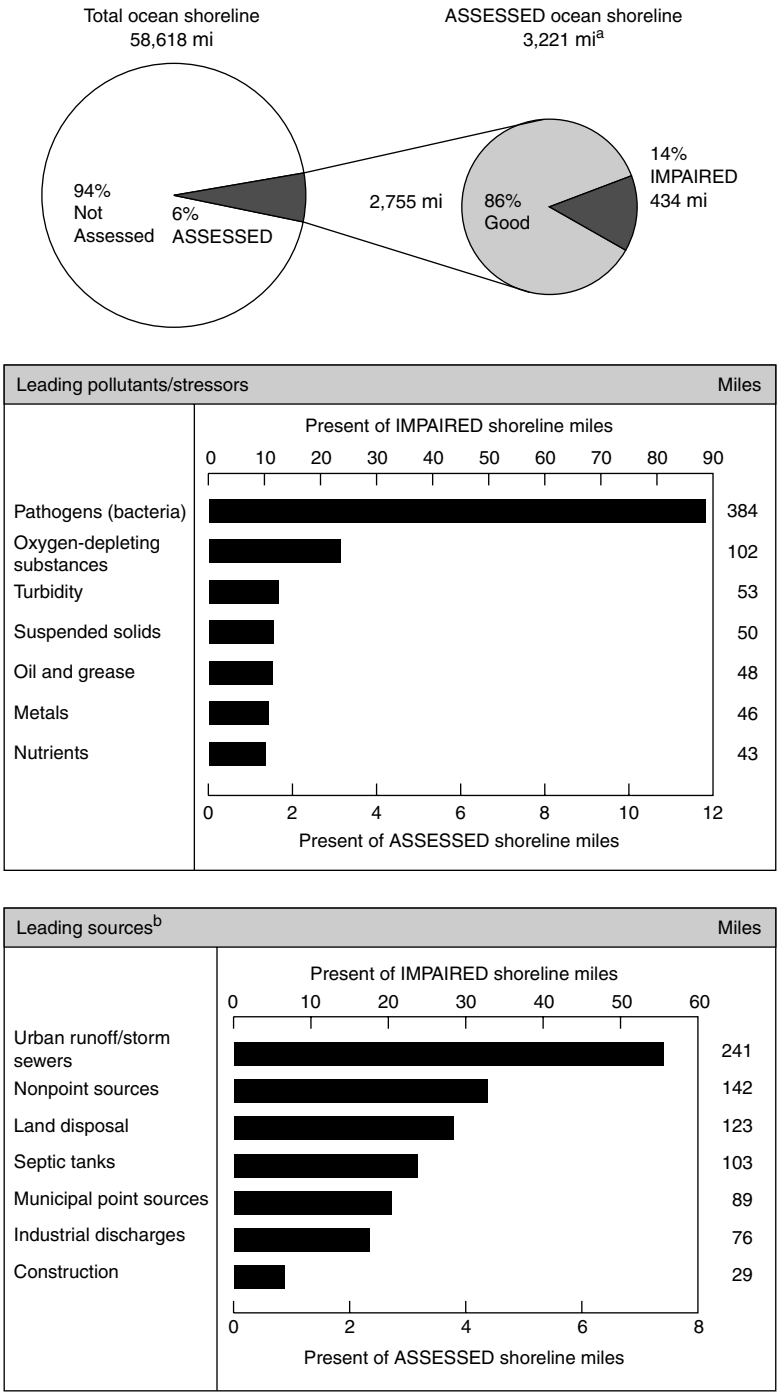


**Figure 10B.12** Leading pollutants and sources of ocean shoreline water impairment in the United States.[a] Includes miles assessed as not attainable.[b] Excludes natural sources. Percentages do not add up to 100% because more than one pollutant or source may impair a segment of ocean shoreline. (From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.)

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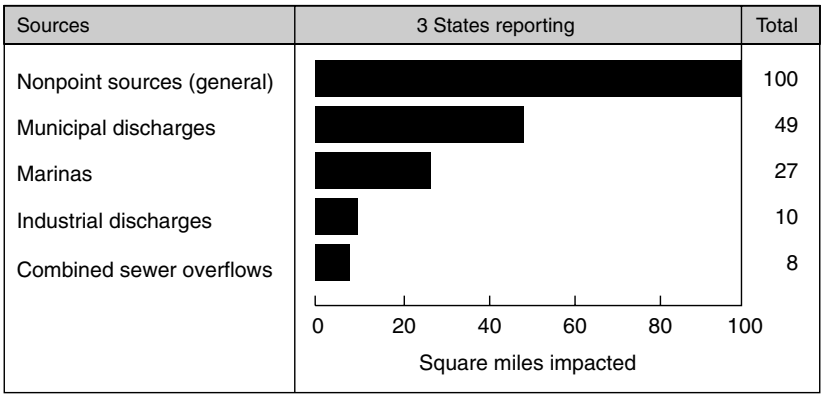


**Figure 10B.13** Sources associated with shellfish harvesting restrictions. (From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.)

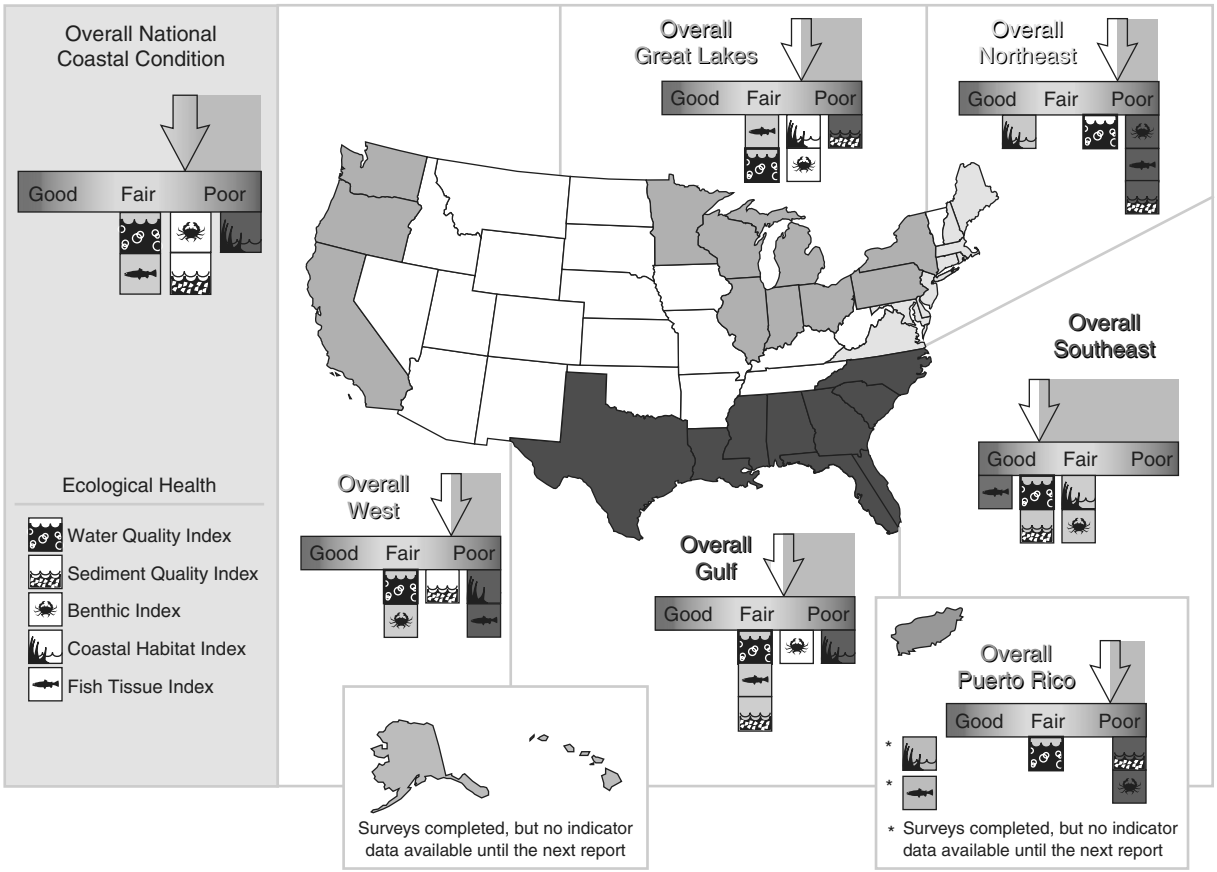


**Figure 10B.14** Overall United States national coastal condition. (From United States Environmental Protection Agency, 2004, *National Coastal Condition Report II*, EPA-620/R-03/002, December 2004, www.epa.gov.)

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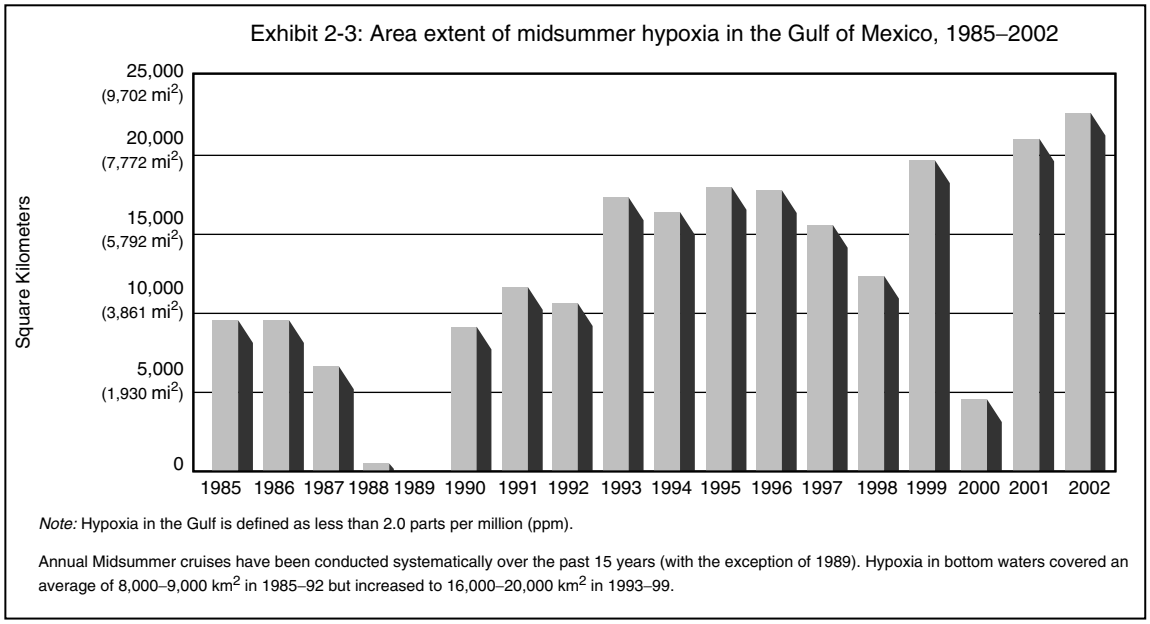
*The area and duration of hypoxia are tracked in the Gulf of Mexico and Long Island Sound as indicators of the natural variability in those waterbodies to determine whether actions to control nutrients are having the desired effect and how local species are affected.*

*The largest of oxygen-depleted coastal waters in the U.S. is in the northern Gulf of Mexico on the Louisiana/Texas continental shelf. Hypoxic waters are most prevalent from late spring through late summer and are more widespread and persistent in some years that in others, depending on river flow, winds, and other environmental variables. Hypoxia occurs mostly in the lower water column, but can encompass as much as the lower half to two-thirds of the entire column.*

*The midsummer bottom area extent of hypoxic water in the Gulf of Mexico increased from 3,500 mi$^2$ (9,000 km$^2$) in 1985 to 8,500 mi$^2$ (22,000 km$^2$) in July 2002 (Exhibit 2-3). The primary cause of the hypoxic conditions is probably the eutrophication of those waters from nutrient enrichment delivered to the Gulf by the Mississippi River and its drainage basin.*[13,14]




*The maximum area of hypoxia in Long Island Sound averaged 201* mi$^2$ *(521* km$^2$*) from 1987 through 2001. The largest area was 395* mi$^2$ *(1,023* km$^2$*) in 1994, and the smallest was 30* mi$^2$ *(78* km$^2$*) in 1997 (Exhibit 2-4). The duration of hypoxia averaged 56 days during the same period, with a low of 34 days in 1996 and a high of 82 days in 1989. Hypoxia is typically more severe in the western portions of the sound, where the nitrogen load is higher and mixing of fresh and salt water is more restricted.*[15]

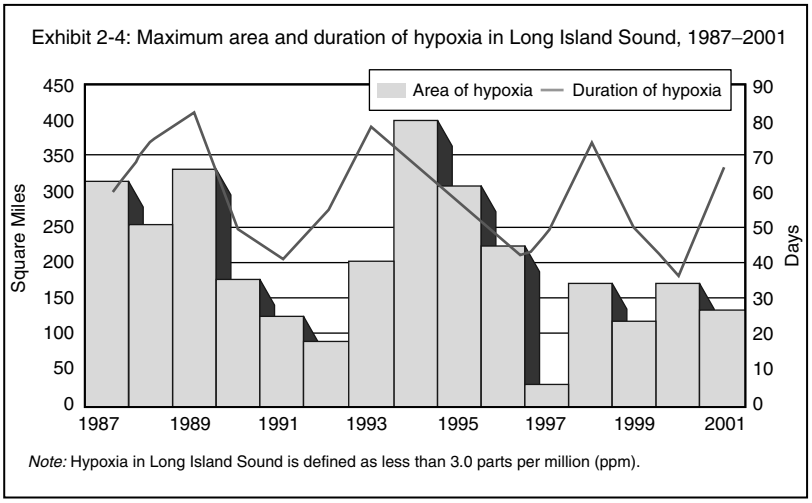



**Figure 10B.15** Hypoxia in the Gulf of Mexico and Long Island Sound. (From United States Environmental Protection Agency, 2003, *EPA's Draft Report on the Environment*, 2003, EPA 600-R-03-050, www.epa.gov.)

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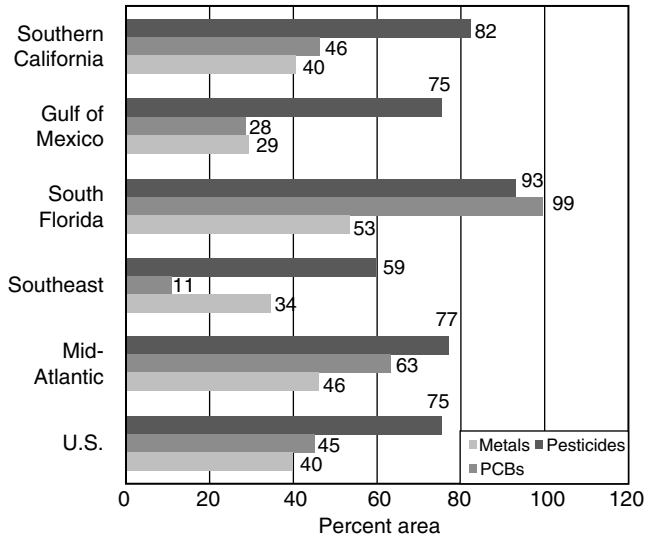
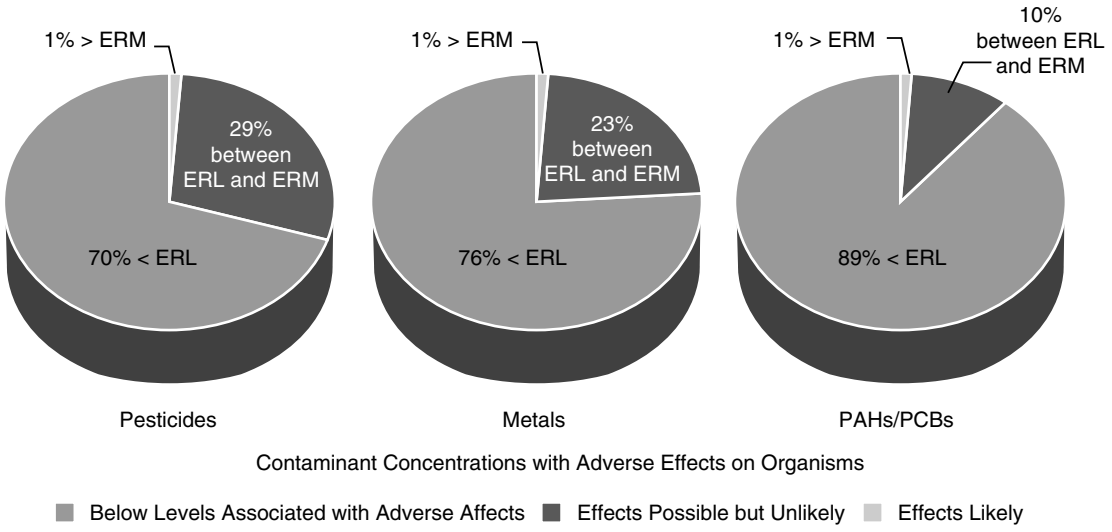



**Figure 10B.16** Regional sediment enrichment (1990–1997) in United States coastal waters due to human sources. (From United States Enviornmental Protection Agency, 2003, *EPA's Draft Report on the Environment, 2003*, EPA 600-R-03-050, www.epa.gov.) Original Source: USEPA, *National Coastal Condition Report*, September 2001.




Coverage: United States east coast (excluding waters north of Cape Cod) and Gulf of Mexico

**Figure 10B.17** Distribution of sediment contaminant concentrations in sampled estuarine sites, 1990–1997. ERL, NOAA Effects Range Low; ERM, NOAA Effects Range median. (From United States Enviornmental Protection Agency, 2003, *EPA's Draft Report on the Environment, 2003*, EPA 600-R-03-050, www.epa.gov.) Original Source: USEPA, *National Coastal Condition Report*, September 2001.

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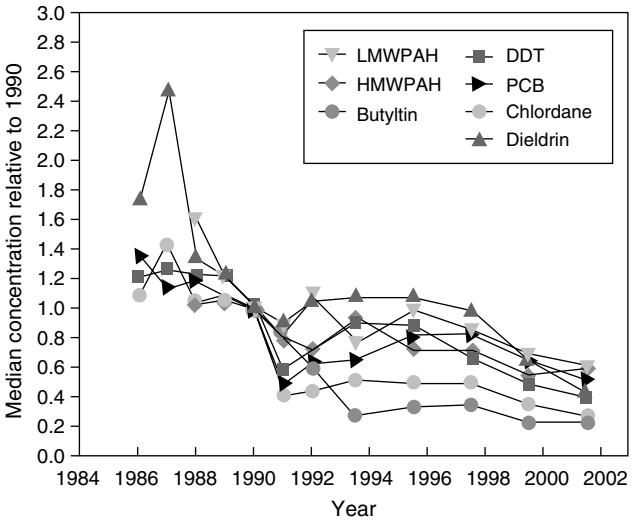


**Figure 10B.18** Trends in contaminant concentrations measured in NOAA's mussel water project since 1986. (From United States Environmental Protection Agency, 2004, *National Coastal Condition Report II*, EPA-620/R-03/002, December 2004, www.epa.gov.)

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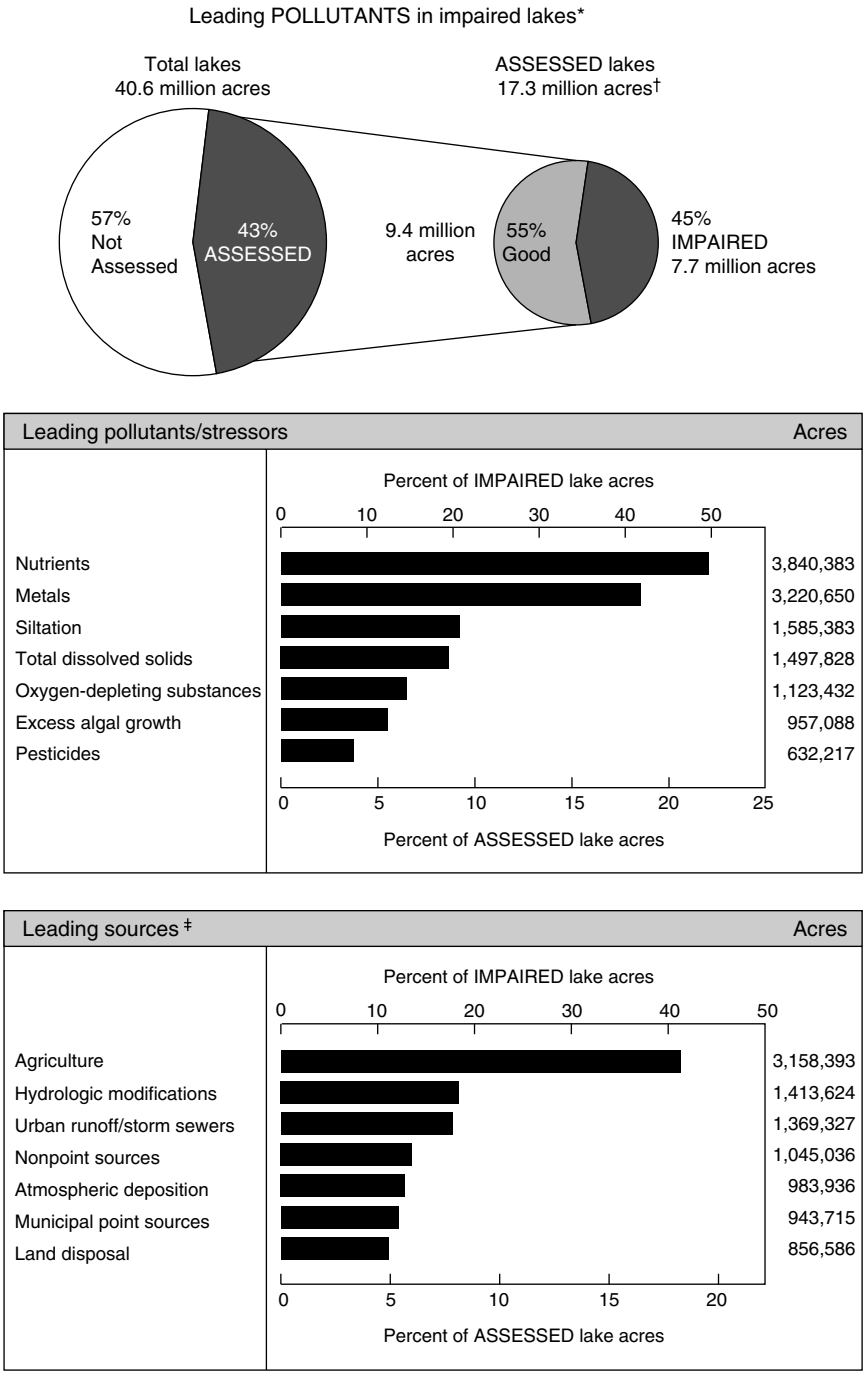


* Eleven states did not include the effects of statewide fish consumption advisories when reporting the pollutants and sources responsible for impairment. Therefore, certain pollutants and sources, such as metals and atmospheric deposition, may be under represented.

‡ Excluding unknown, natural, and "other" sources.

† Includes acres assessed as not attainable.

*Note*: Percentages do not add up to 100% because more than one pollutant or source may impair a lake.

**Figure 10B.19** Leading pollutants and sources in impaired lakes in the United States. (From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.)

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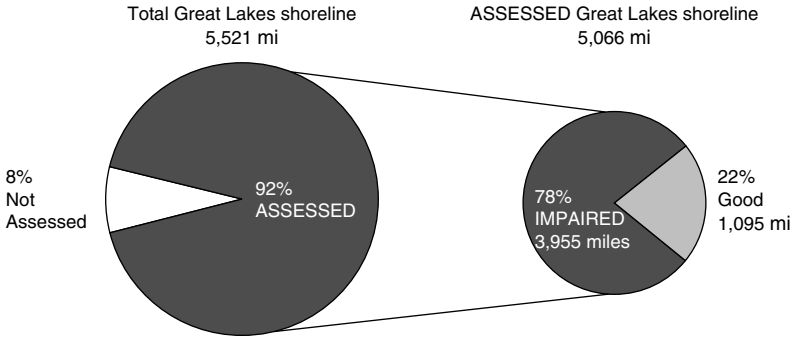


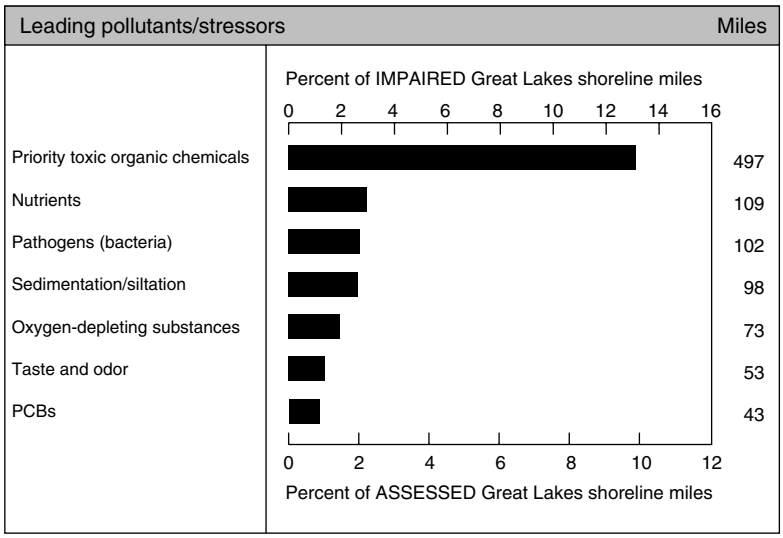


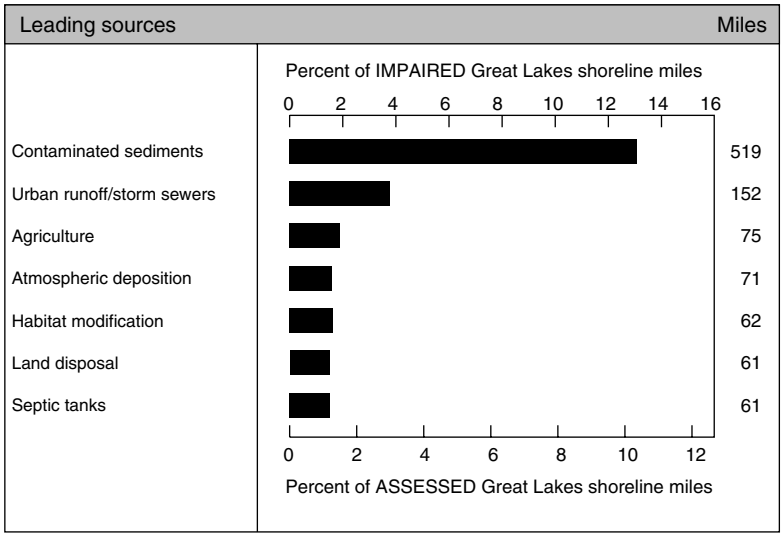


*Note*: Percentages do not add up to 100% because more than one pollutant or source may impair a segment of great lakes shoreline.

**Figure 10B.20** Leading pollutants and sources in impaired Great Lakes shoreline waters in the United States. (From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.)

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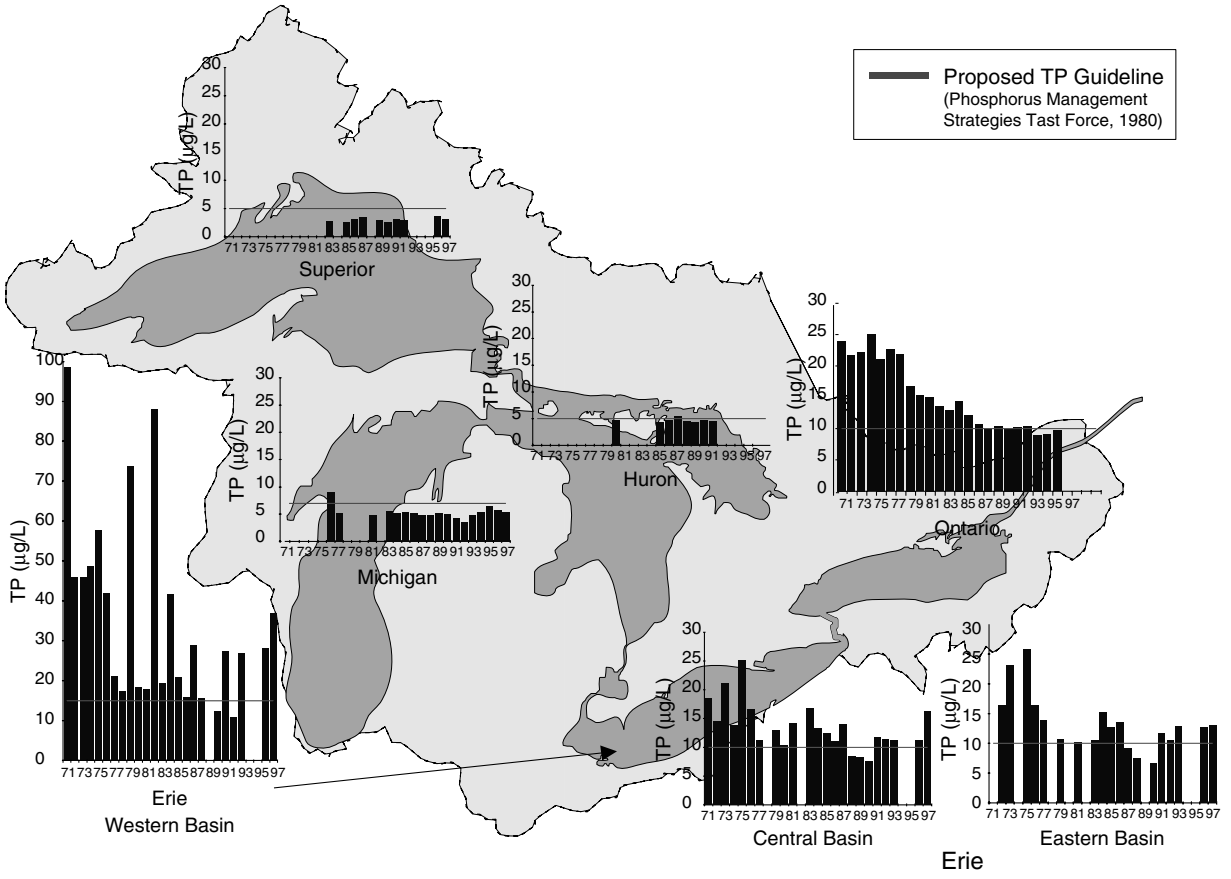


**Figure 10B.21** Total phosphorous trends in the Great Lakes from 1971 to 1997 (spring, open lake surface). (From International Joint Commission, 2004, *12th Biennial Report on Great Lakes Water Quality, September 2004*, www.ijc.org.)

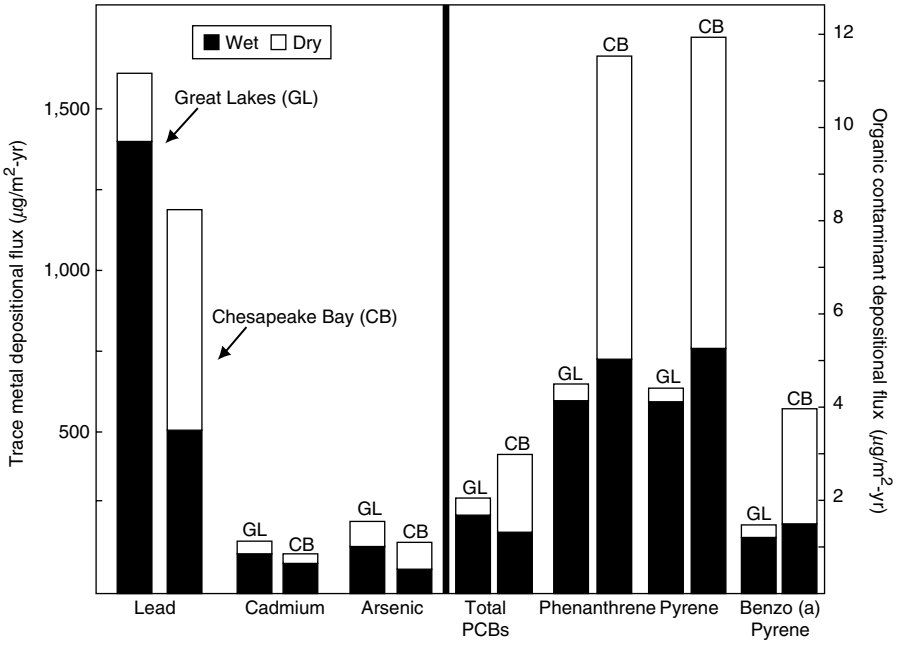


**Figure 10B.22** Comparison of Chesapeake Bay and Great Lakes atmospheric depositional fluxes. (From United States Environmental Protection Agency, 1997, *Deposition of Air Pollutants to the Great Waters Second Report to Congress*, EPA-453/R-97-011, www.epa.gov.) Original Source: Baker et al., 1996 (Chesapeake Bay) and Eisenreich and Strachen 1992 (Great Lakes).

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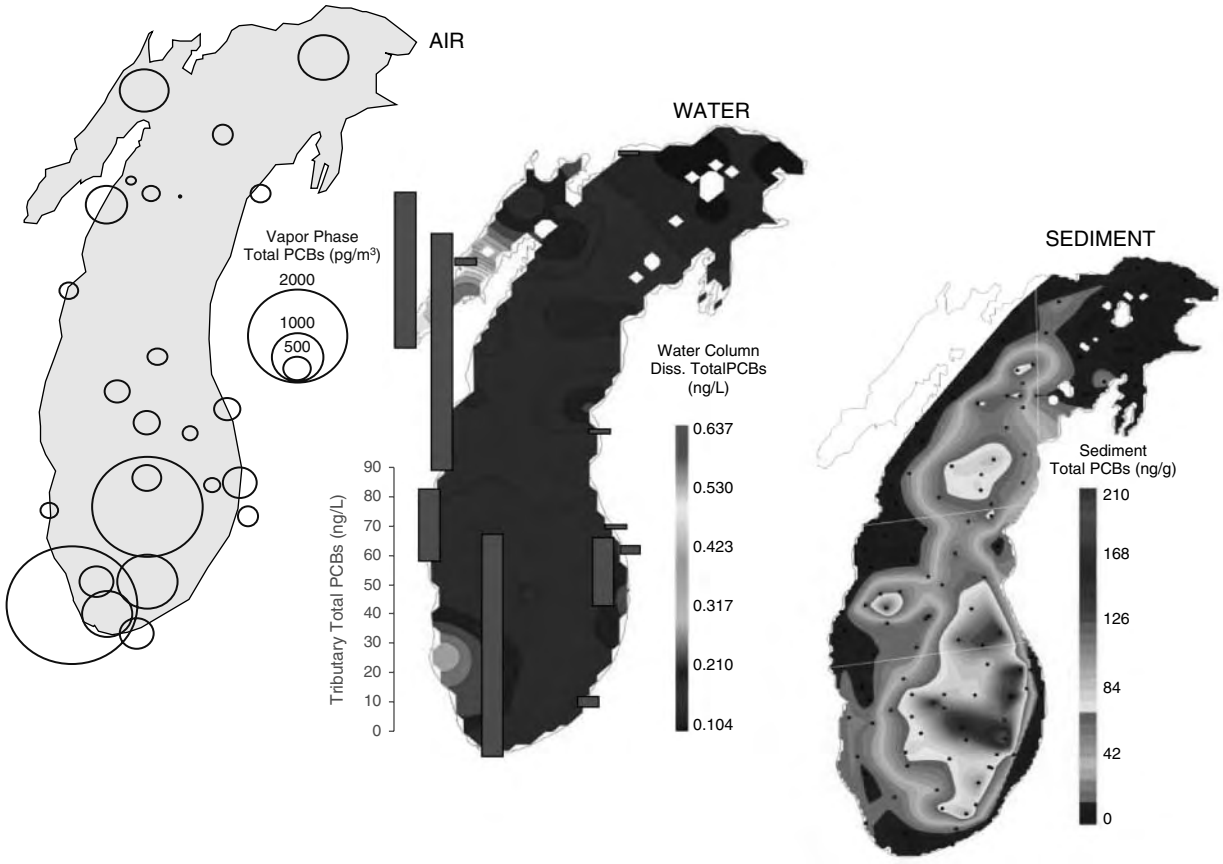


**Figure 10B.23** Concentrations of total PCBs in the atmosphere, tributaries, water column and sediments of Lake Michigan. (From McCarty, H.B. et al., United States Environmental Protection Agency, 2004, *Results of the Lake Michigan Mass Balance Study: Polychlorinated Biphenyls and trans-Nonachlor Data Report*, EPA 905 R-01-011, April 2004, www.epa.gov.)

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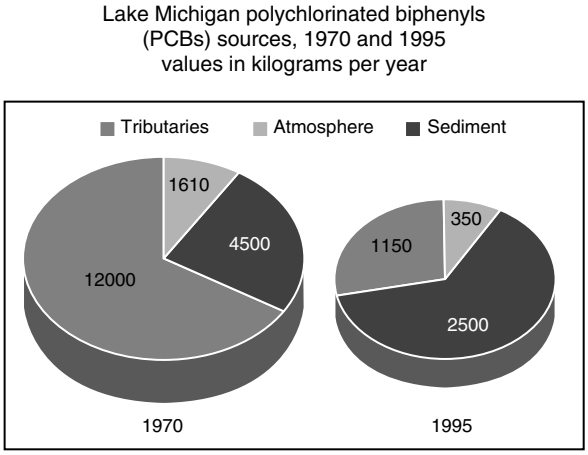
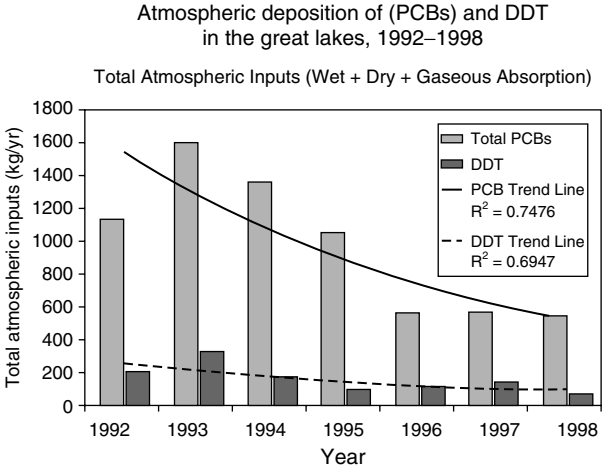



*Note:* This graphic was created for this report by the EPA Great Lakes National Program Office and the EPA, Office of Research and Developments Large Lakes Research Station using MICHTOX a mass balance and bio accumulation model and air, water, and sediment data drawn from the Great Lakes Environmental Monitoring Database (GLENDA). The 1970 model run was based on available data and extrapolations. The 1995 model run was based on data collected during the Lake Michigan Mass Balance Study that collected over 25,000 samples at 200 locations in 1994–1995.




*Note:* $R^2$ is the coefficient of determination. It gives a measure of the strength of the correlation.

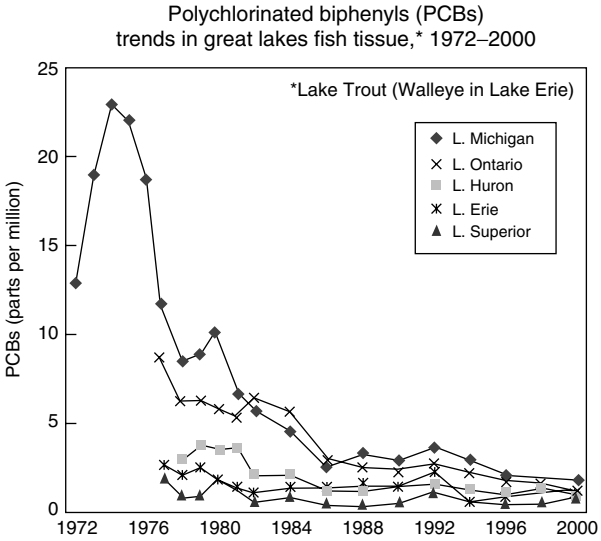



**Figure 10B.24** Bioaccumulation of PCBs and DDT in the Great Lakes. (From United States Environmental Protection Agency, 2003, *EPA's Draft Report on the Environment, 2003*, EPA 600-R-03-050, www.epa.gov.)

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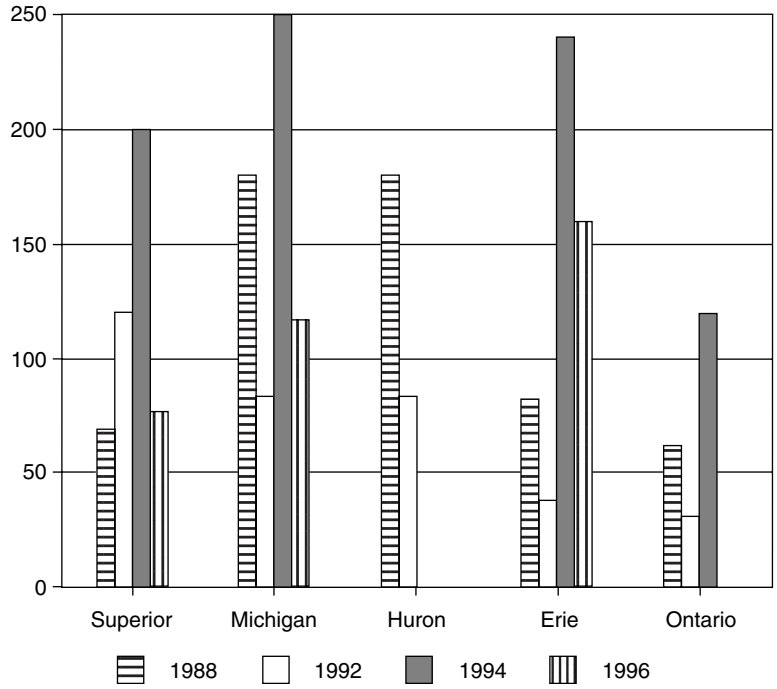


**Figure 10B.25** Loading estimates of benzo(a)pyrene to the Great Lakes (kg/yr). (From United States Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters Third Report to Congress*, EPA-453/R-00-005, www.epa.gov.)

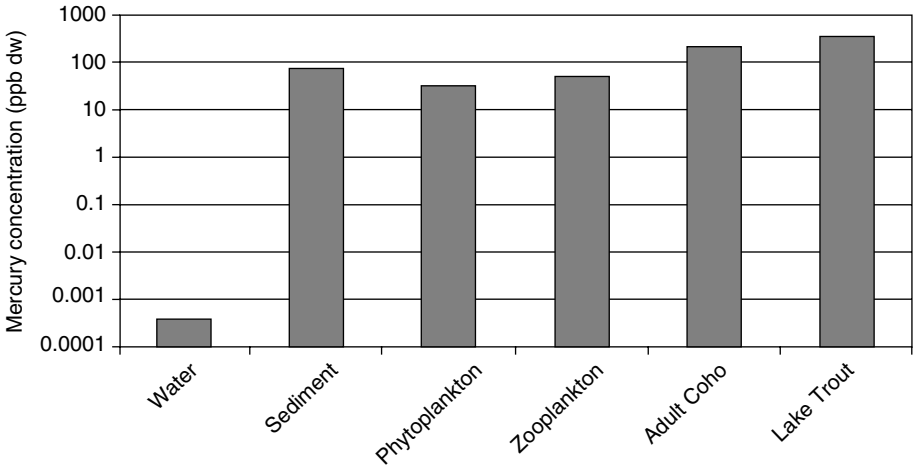


**Figure 10B.26** Mercury concentrations in various components of the Lake Michigan ecosystem. (From McCarty, H.B., Brent, R.N., Schofield, J., and Rossmann, R., 2004, *Results of the Lake Michigan Mass Balance Study: Mercury Data Report*, EPA 905 R-01-012, www.epa.gov.)

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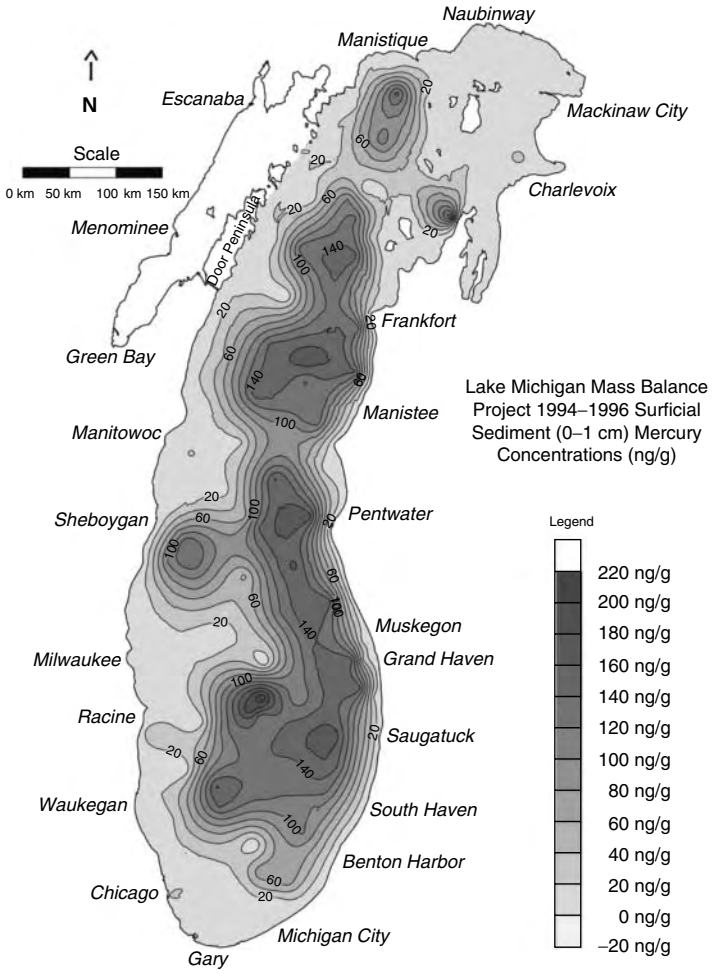


**Figure 10B.27** Mercury concentrations (mg/kg) in Lake Michigan surficial sediments (1994–1996). (From McCarty, H.B. et al., 2004, *Results of the Lake Michigan Mass Balance Study: Mercury Data Report*, EPA 905 R-01-012, www.epa.gov.)

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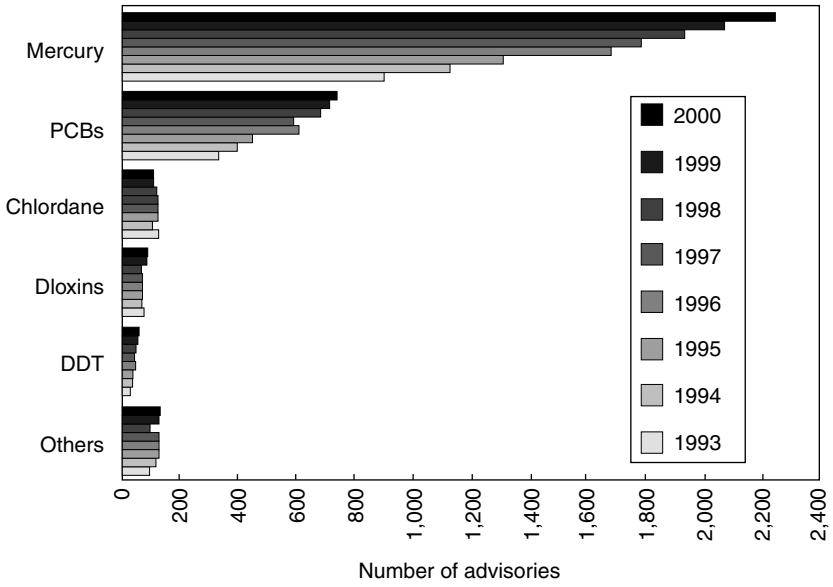


**Figure 10B.28** Trends in the number of fish consumption advisories issued for various pollutants. (From United States Environmental Protection Agency, 2001, *Fact Sheet Update: National Listing of Fish and Wildlife Advisories*, EPA-823-F-01-010, April 2001, www.epa.gov.)

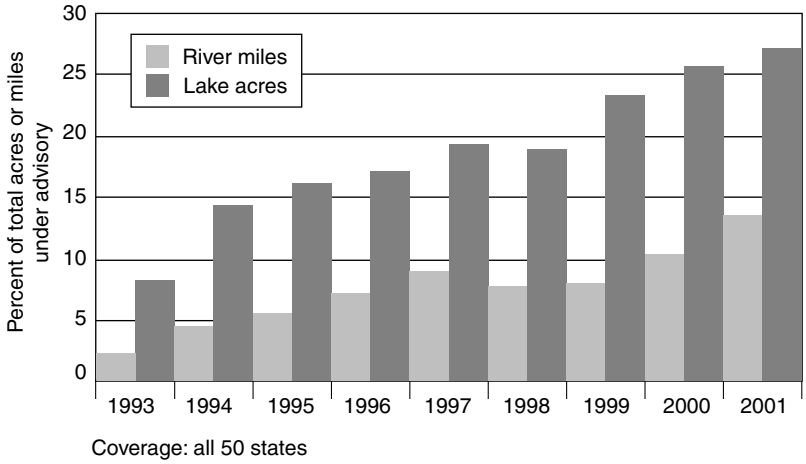


**Figure 10B.29** Trends in percentage of river miles and lake acres under fish consumption advisory, 1993–2001. (From United States Environmental Protection Agency, 2003, *EPA's Draft Report on the Environment, 2003*, EPA 600-R-03-050, www.epa.gov.)

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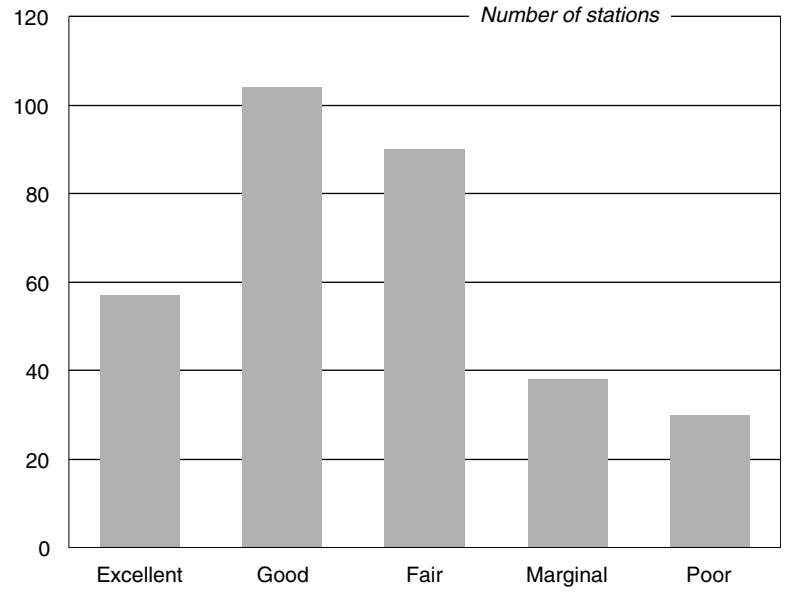


*Note:* Data were taken over the period 1990 to 2002.
These Water Quality Index (WQI) results are preliminary and should not be regarded as a benchmark or starting point for future trends. Rather, this pilot study provides a first approximation for a national picture of ambient fresh water quality in Canada. Improvements in consistency of application and representation will be sought in the near future.
The WQI values have been calculated by each province and territory (except Quebec) using the methodology developed and endorsed by the Canadian Council of Ministers of the Environment (CCME) in September 2001. According to the CCME user's manual,[1] the specific variables, objectives and time periods used in the index are not specified by the methodology and, because of differences in local conditions, monitoring programs and water quality issues, they vary from one jurisdiction to another. In this regard, it is expected that the variables and objectives chosen to calculate the index provide relevant information about a particular site.
In Quebec, water quality was evaluated using an index other than the CCME WQI: *L'indice de la qualité bactériologique et physico-chimique*. The results between the two indexes have a reasonable degree of comparability. The premise is that the evaluation of water quality in one jurisdiction by water quality experts familiar with the local conditions should be comparable with a similar evaluation by experts in another jurisdiction, even though the index tools may have some variation.
The national portrayal of the WQI results includes information from all provinces and territories except Nunavut and the Yukon, for which suitable data were unavailable at this time. The water bodies included in the WQI calculations do not provide uniform coverage across Canada, but rather tend to be concentrated in the more populated areas of the country where the potential threats to water quality are generally greatest. The coverage and the density of sites are also higher in some provinces than in others.
1. Canadian Council of Ministers of the Environment, 2001, Canadian Water Quality Guidelines for the Protection of Aquatic Life; CCME Water Quality Index 1.0, User's Manual.

**Figure 10B.30** Canadian freshwater quality indicator by quality class. Data were taken over the period 1990–2002. (From Produced by Environment Canada based on the Index values or water quality data supplied by the provinces and territories under the auspices of the Water Quality Task Group of the Canadian Council of Ministers of the Environment. Environment Canada, National Round Table on the Environment and the Economy, 2003, *Environment and Sustainable Development Indicators for Canada*, Ottawa.)

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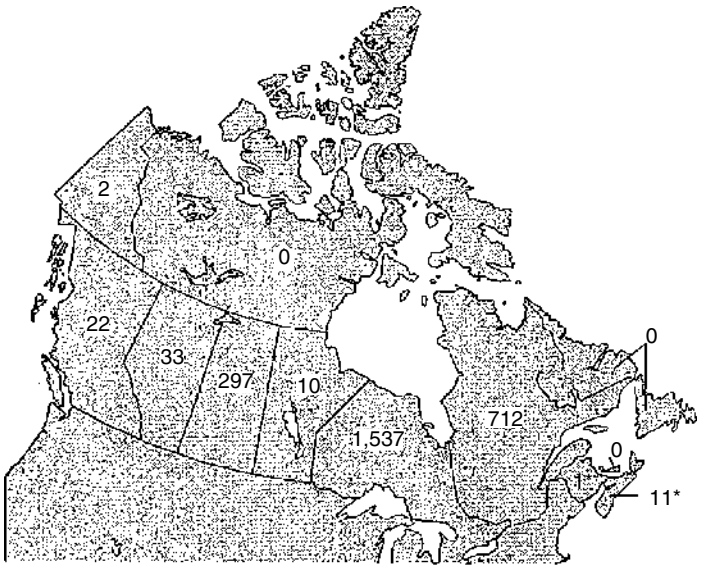


*Provincewide advisories in effect in 1997 for Nova Scotia (all rivers and lakes) and New Brunswick (all lakes).

**Figure 10B.31** Total number of fish advisories in effect in Canada. (From United States Environmental Protection Agency, 2001, *Fact Sheet Update: National Listing of Fish and Wildlife Advisories*, EPA-823-F-01-010, April 2001, www.epa.gov.)

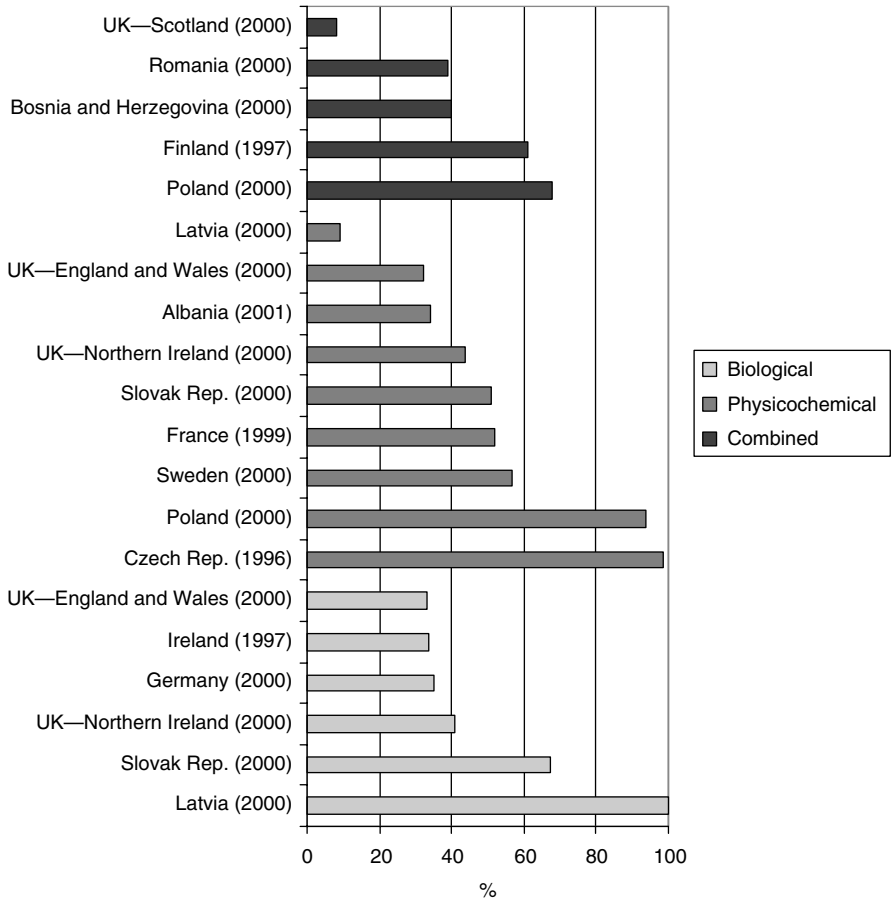


**Figure 10B.32** Percentage of European rivers classified as less than good, by country. (From Trent, Z, European Environment Agency, *Indicator Fact Sheet, National River Classification System (WEC04e), Version 13.10.03*, eeaeuropa.eu. Reprinted with permission © EEA.)

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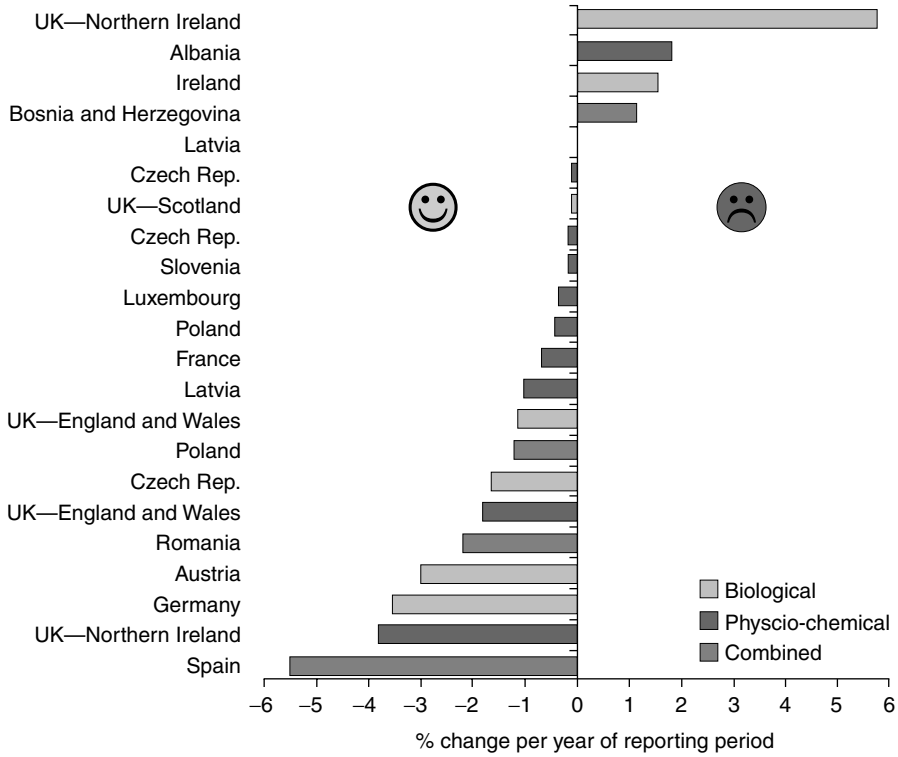


**Figure 10B.33** Rate of change in rivers classified as less than good and good as a percentage of the total river classified. (From European Environment Agency, 2003, *Europe's Water: An Indicator-Based Assessment Summary*, EEA, Copenhagen, www.eea.europa.eu. Reprinted with permission © EEA.)

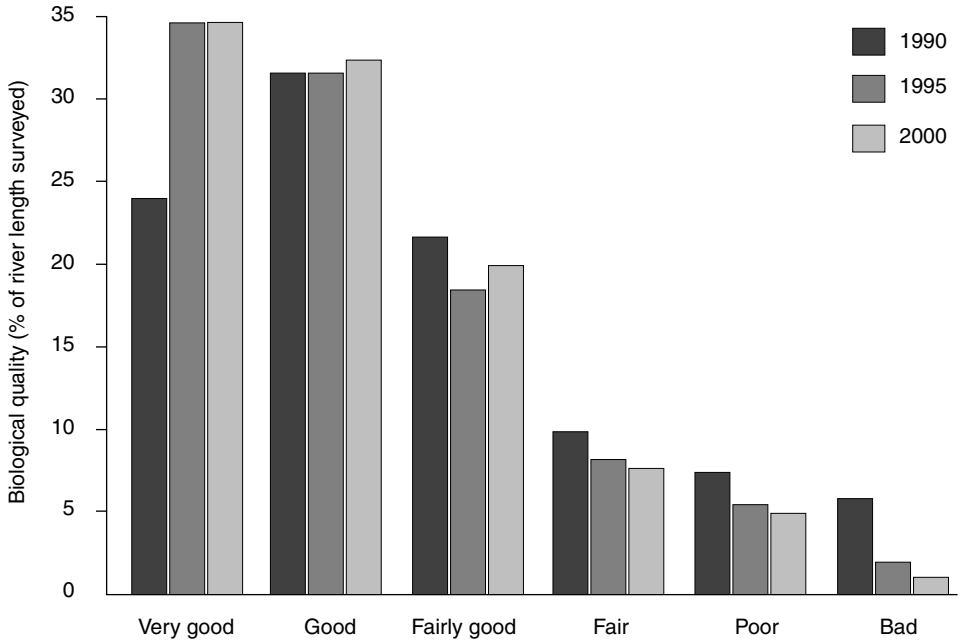


**Figure 10B.34** Biological quality of United Kingdom rivers, 1990–2000. (From United Nations Educational, Scientific and Cultural Organization, 2003, *Water for People Water for Life*, The United Nations World Water Development, United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn Books, www.unesco.org. Reprinted with permission.) Original Source: Adapted from Environmental Agency, UK, 2002.

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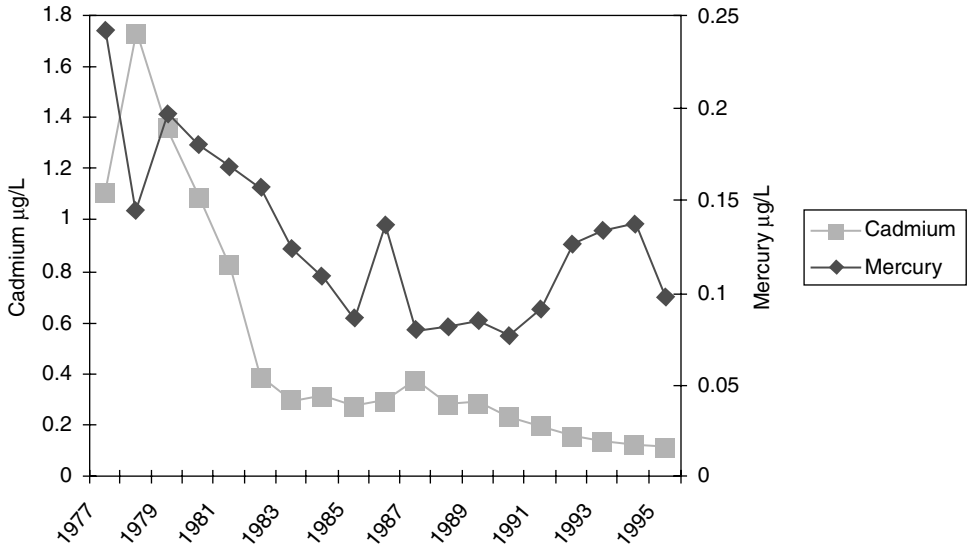


**Figure 10B.35** Trends in concentrations of cadmium and mercury at river stations included in the European Union exchange of information decision. The EU environmental quality standards for cadmium and mercury in inland waters are 5µg/L and 1µg/L as annual averages, respectively. In less polluted areas in e.g. Nordic countries concentrations of cadmium and mercury are only 10% and 1% of these values. Average of country annual average concentrations. Cadmium data from Belgium, Germany, Ireland, Luxembourg, Netherlands, UK. Mercury data from Belgium, France Germany, Ireland, Netherlands, UK. (From EEA, Indicator fact sheet, *Hazardous Substances in River Water (WHS02)*, www.eea.europa.eu. Reprinted with permission © EEA.)

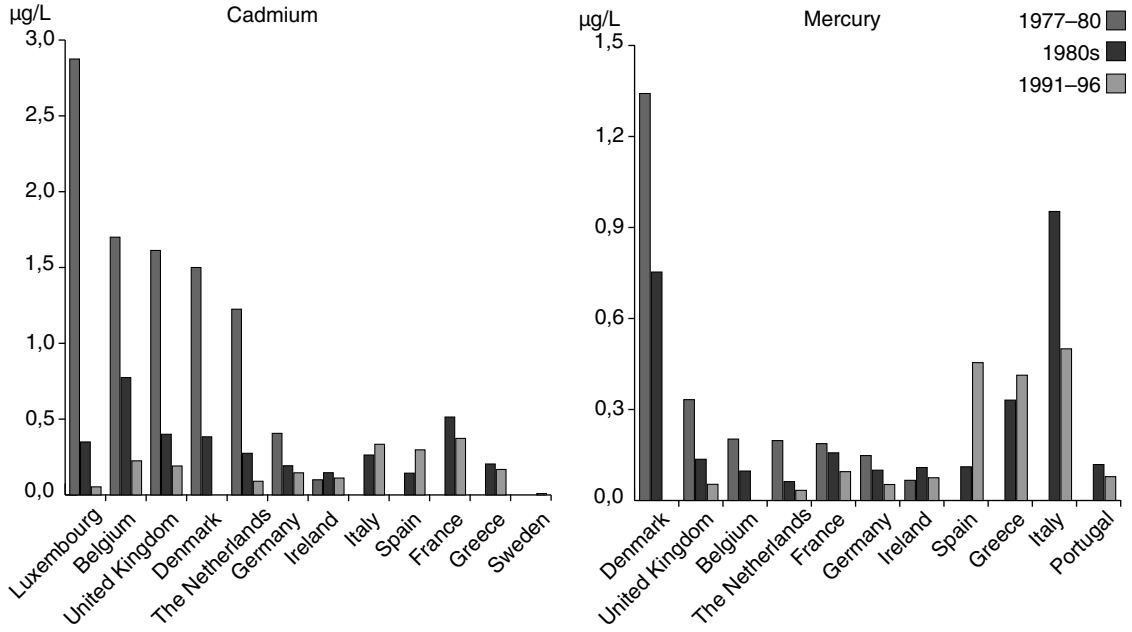


**Figure 10B.36** Annual average concentrations of cadmium and mercury in European Union rivers between late 1970s and 1996. (From EEA, 2003, *Europe's Environment, The Third Assessment, Environmental Assessment Report No. 10*, EE1, Copenhagen, eea. Reprinted with permission © EEA.)

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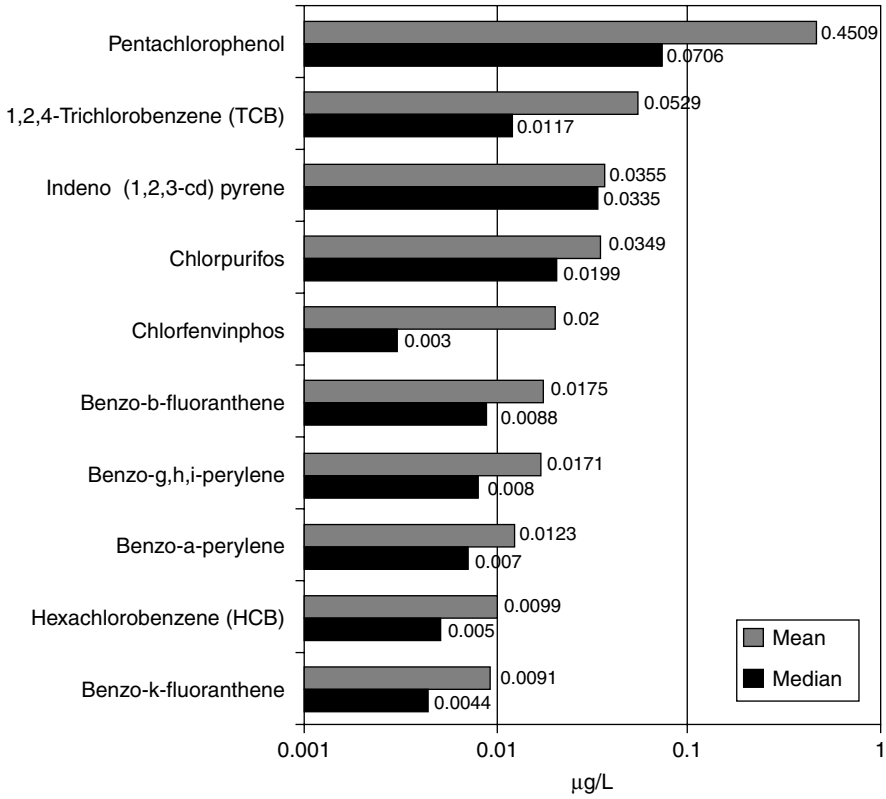
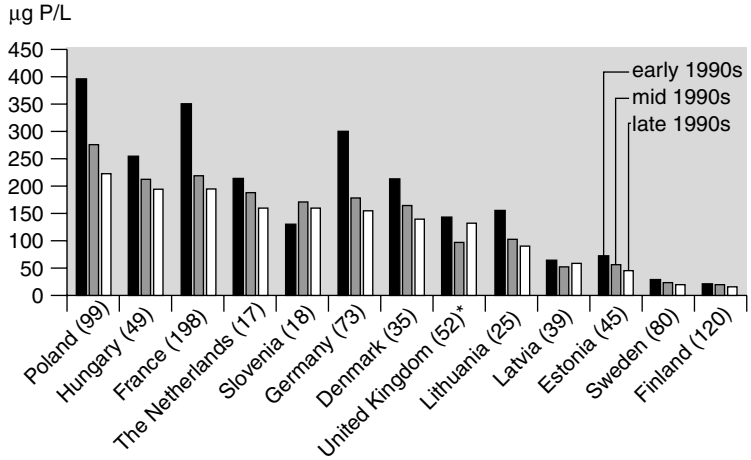



**Figure 10B.37** Median and mean concentrations of the 10 most highly ranked substances in the water framework directive priority list in European rivers. (From EEA, Indicator fact sheet, *Hazardous Substances in River Water (WHS02)*, www.eea.europa.eu. Reprinted with permission © EEA.)




*Note*: Average of annual median concentrations. Number of stations in brackets:
*UK figures for orthophosphate-p.

**Figure 10B.38** Total phosphorus concentrations in rivers, selected European Union and accession countries. (From European Environmental Agency (EEA), 2002, *Environmental Signals 2002—Benchmarking the Millennium, Environmental Assessment Report No. 9*, www.eea.europa.eu. Reprinted with permission © EEA.)

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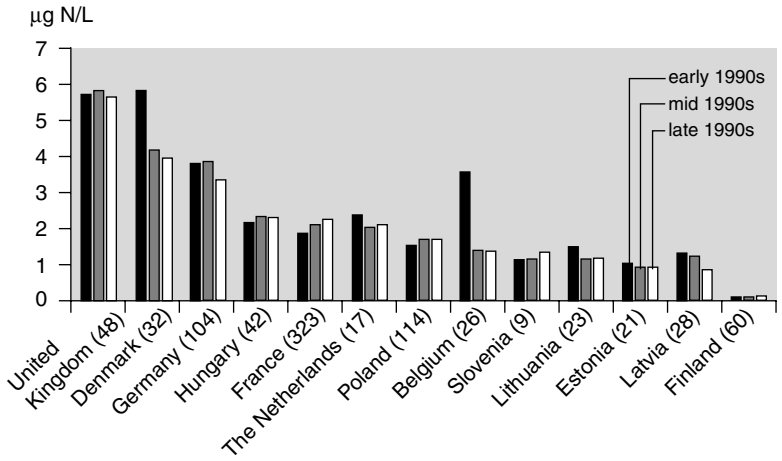


*Note*: Average of annual median concentrations. Number of stations in brackets.

**Figure 10B.39** Nitrate concentrations in rivers, selected European Union and accession countries. (From European Environmental Agency (EEA), 2002, *Environmental Signals 2002—Benchmarking the Millennium, Environmental Assessment Report No. 9*, www.eea.europa.eu. Reprinted with permission © EEA.)

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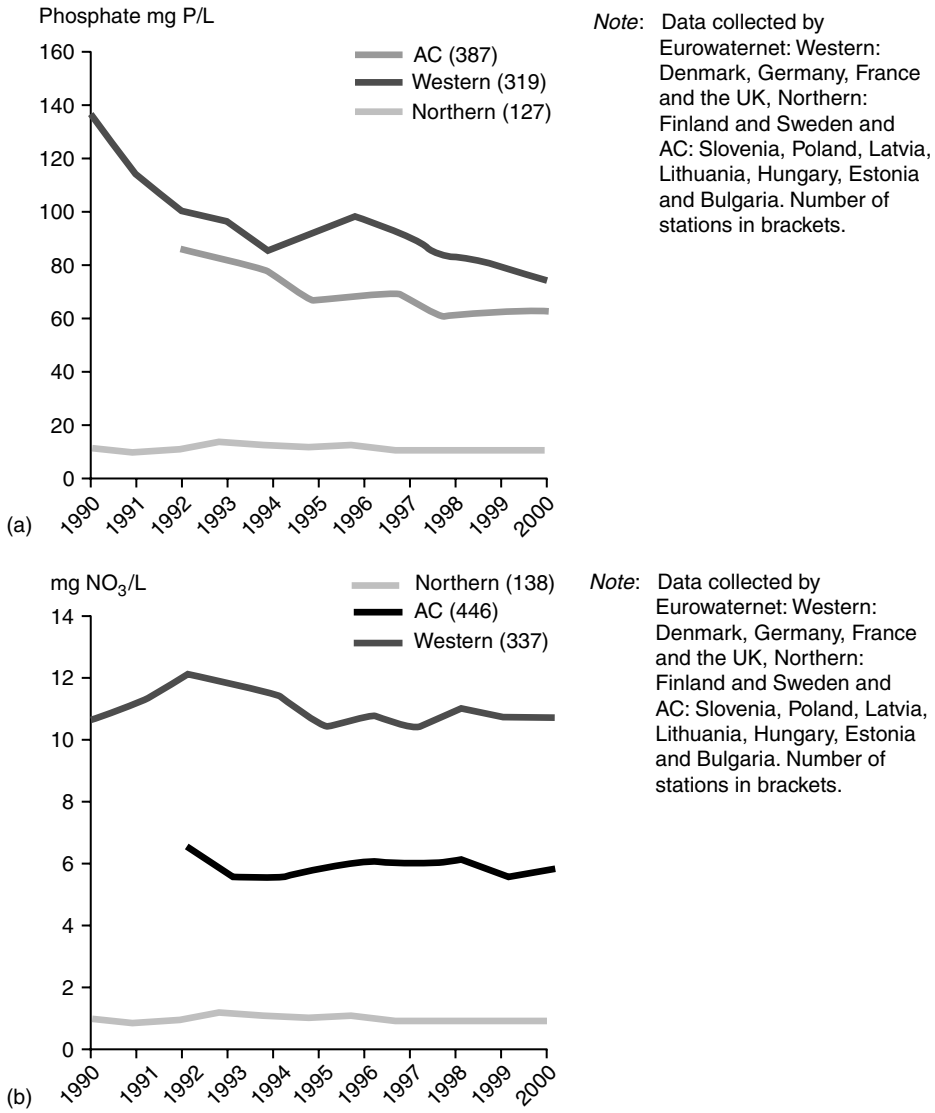


**Figure 10B.40** Phosphate and nitrate in European rivers. (From European Environment Agency, 2003, *Europe's Water: An Indicator-Based Assessment Summary*, EEA. Copenhagen. © EEA, www.eea.europa.eu.)

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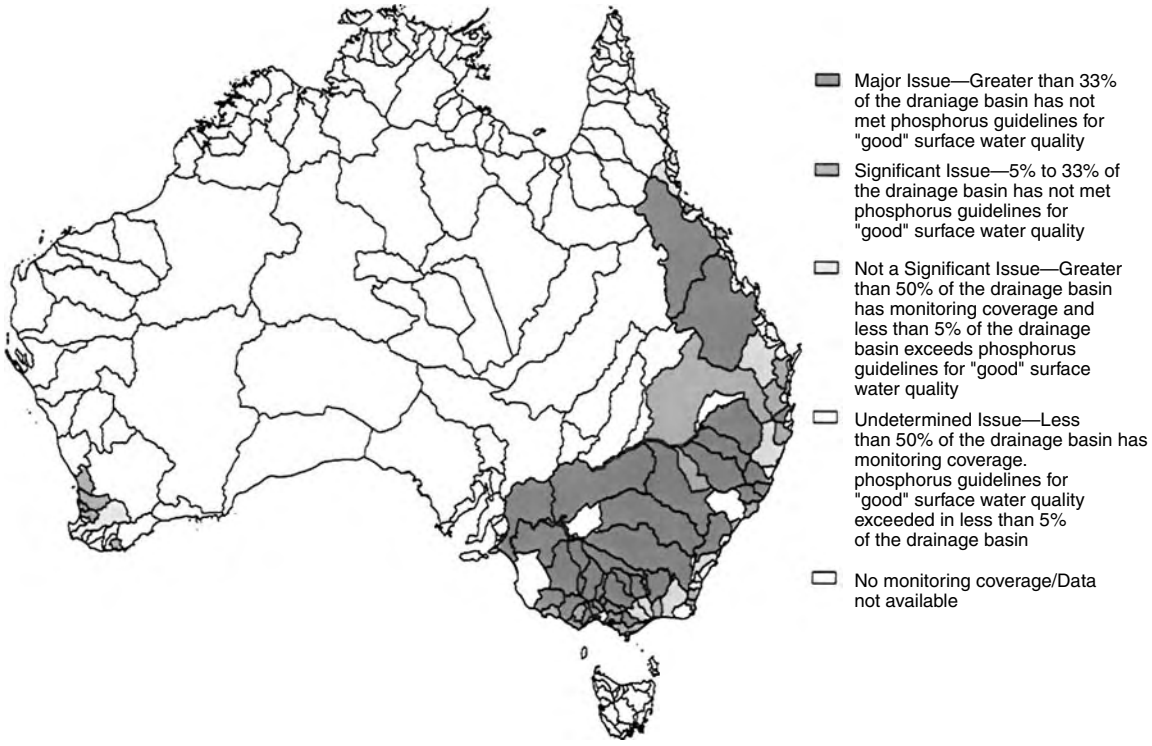
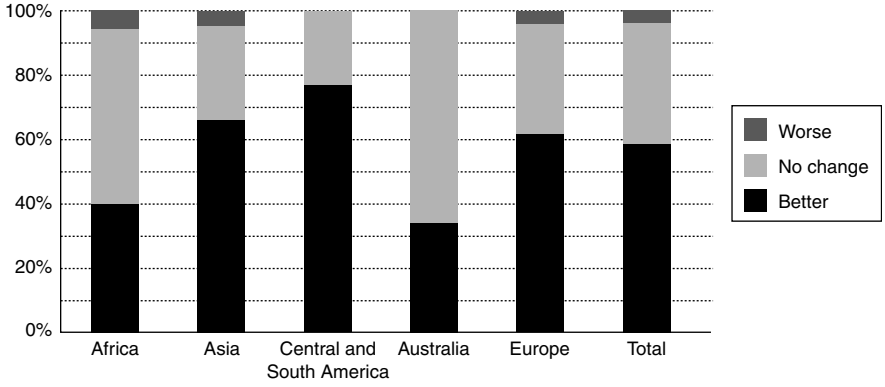



**Figure 10B.41** Australian river systems where phosphorous levels exceed state or territory guidelines for the protection of ecosystems. (From Ball, J. et al., 2001, *Inland Waters, Australia State of Environment Report 2001 (Theme Report)*, CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra, www.deh.gov.au. Reprinted with permission.) Original Source: National Land and Water Resources Audit, 2001a.




*Note*: This figure is based on a sample of 93 lakes. Although there has been improvement of lake water condition in some areas of all regions, the overwhelming trend illustrated here is deterioration in quality, most notably in Central and South America where close to 80 percent of sampled lakes deteriorated in the studied period.

**Figure 10B.42** Changes in world lake conditions, 1960–1990. (From United Nations Educational, Scientific and Cultural Organization, 2003, *Water for People Water for Life*, The United Nations World Water Development, United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn Books, www.unesco.org.) Original Source: Data collated for Loh et al., 1998.

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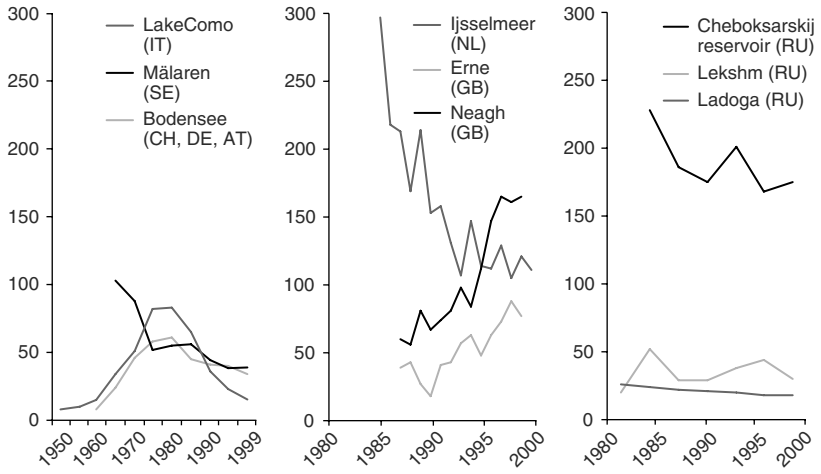


**Figure 10B.43** Trends in total phosphorous concentrations in some large European lakes. (From EEA, 2003, Europe's Environment, *The Third Assessment, Environmental Assessment Report No. 10*, EE1, Copenhagen. Reprinted with permission © EEA, www.eea.europa.eu.)

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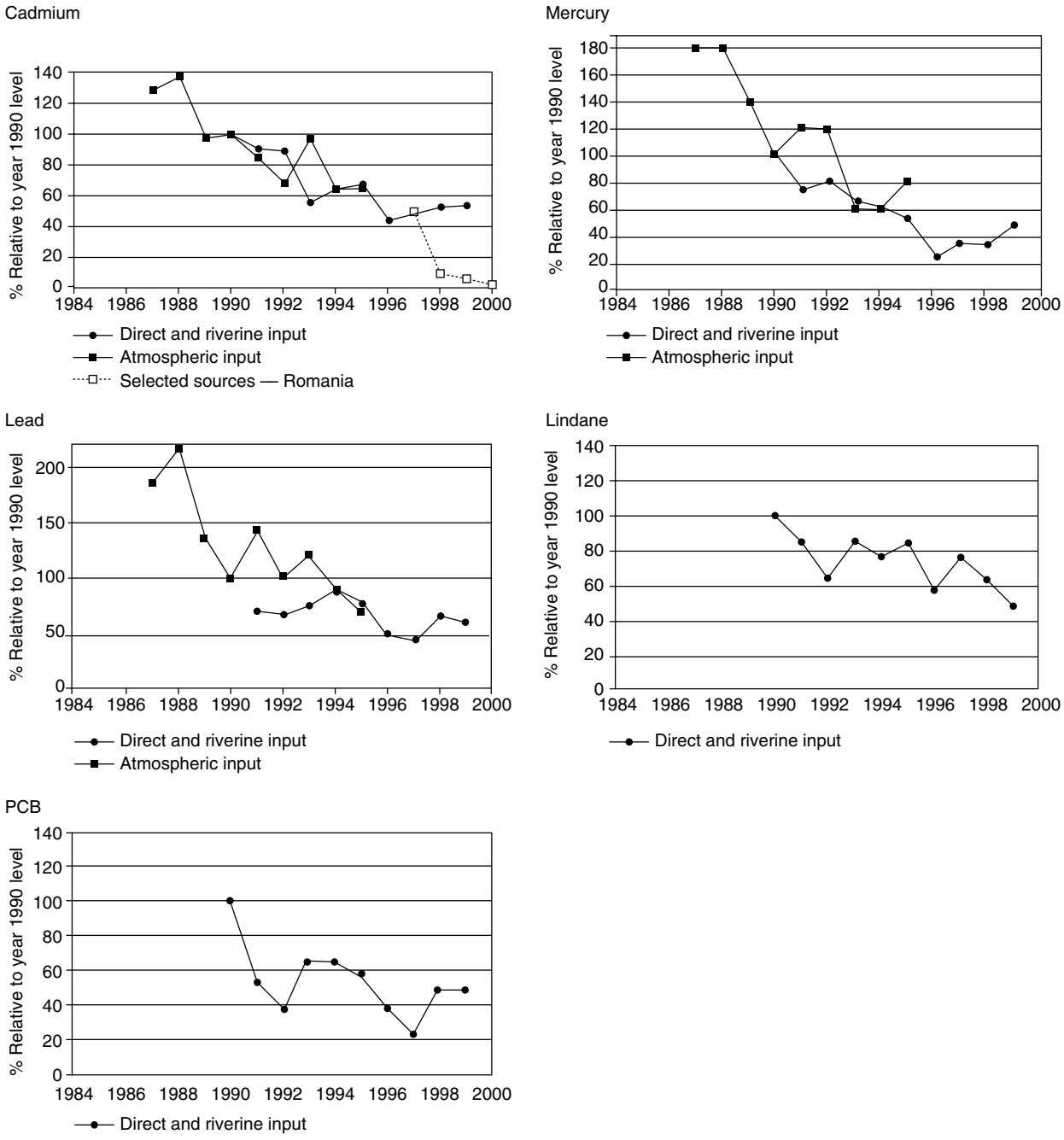


**Figure 10B.44** Change (%) in direct riverine and atmospheric inputs of cadmium, mercury, lead, lindane, and PCB in the Northeast Atlantic. (From Green, N. et al., 2003, *Hazardous Substances in the European Marine Environment: Trends in Metals and Persistent Organic Pollutants, European Environment Agency, Topic Report 2/2003*, www.eea.europa.eu. Reprinted with permission © EEA.)

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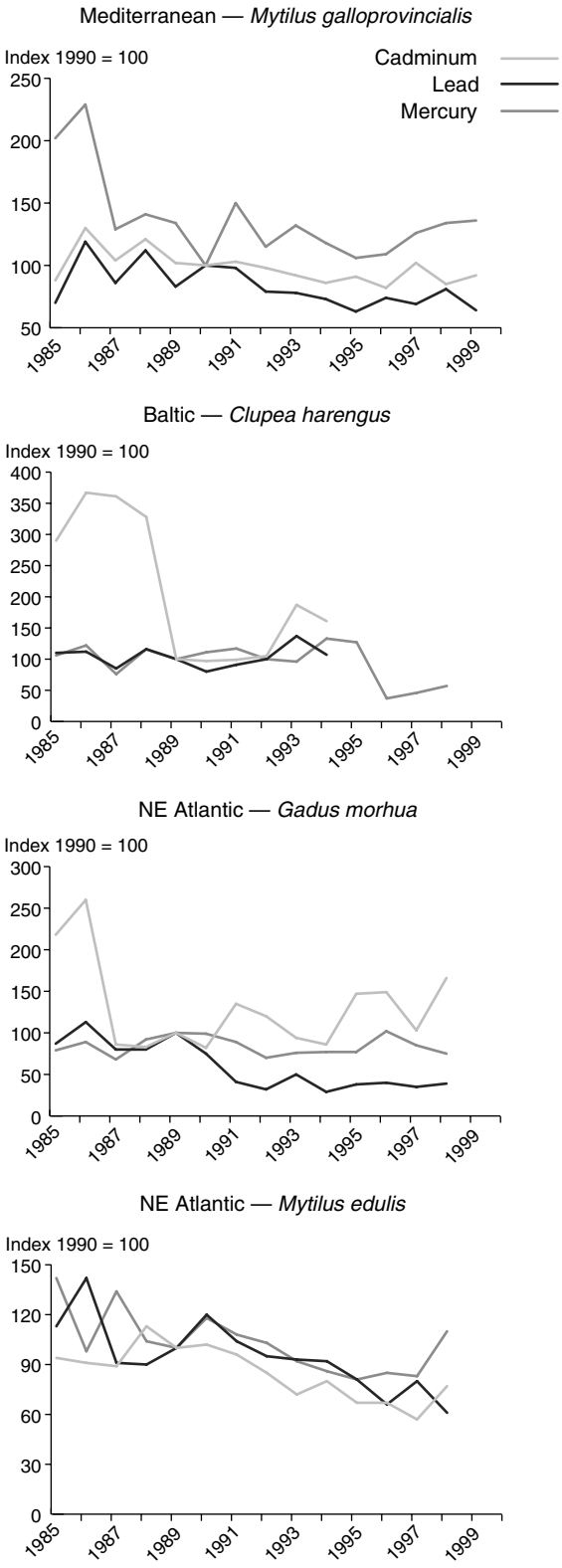


**Figure 10B.45** Concentrations of selected metals and synthetic organic substances in marine organisms in the Mediterranean and Baltic Sea, and in the North East Atlantic Ocean. (From European Environmental Agency (EEA), 2003, *Europe's Environment, The Third Assessment, Environmental Assessment Report No. 10*, EE1, Copenhagen, www.eea.europa.eu. Reprinted with permission © EEA.)

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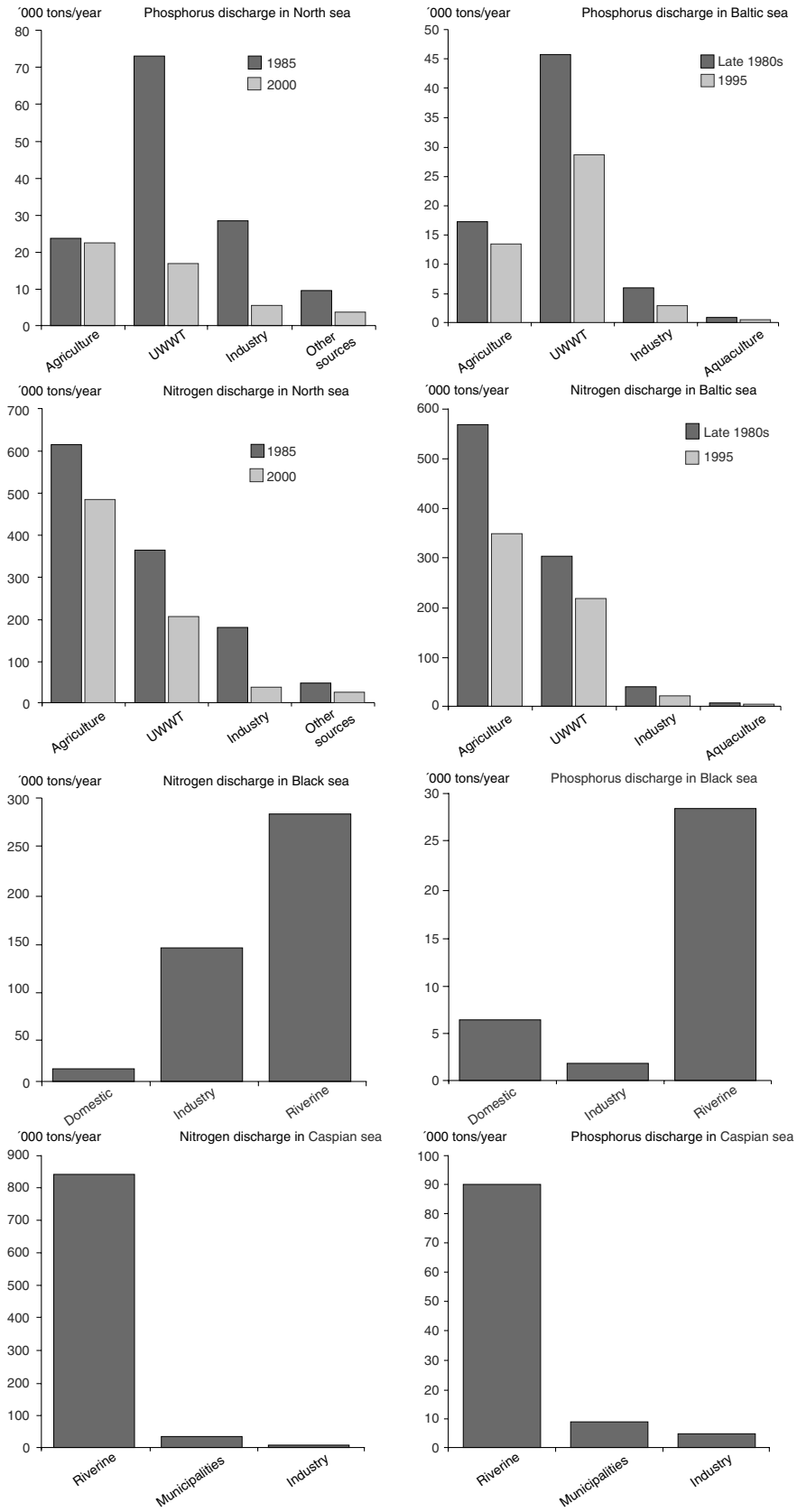


**Figure 10B.46** Source apportionment of nitrogen and phosphorus discharges in Europe's seas and percentage reductions. (From European Environmental Agency (EEA), 2003, *Europe's Environment, The Third Assessment, Environmental Assessment Report No. 10*, EE1, Copenhagen, www.eea.europa.eu. Reprinted with permission.) Original Source: North Sea progress report 2002; Finnish Environmental Insitute. 2002, Black Sea Commission, 2002; Caspian Environmental Program, no date. © EEA.

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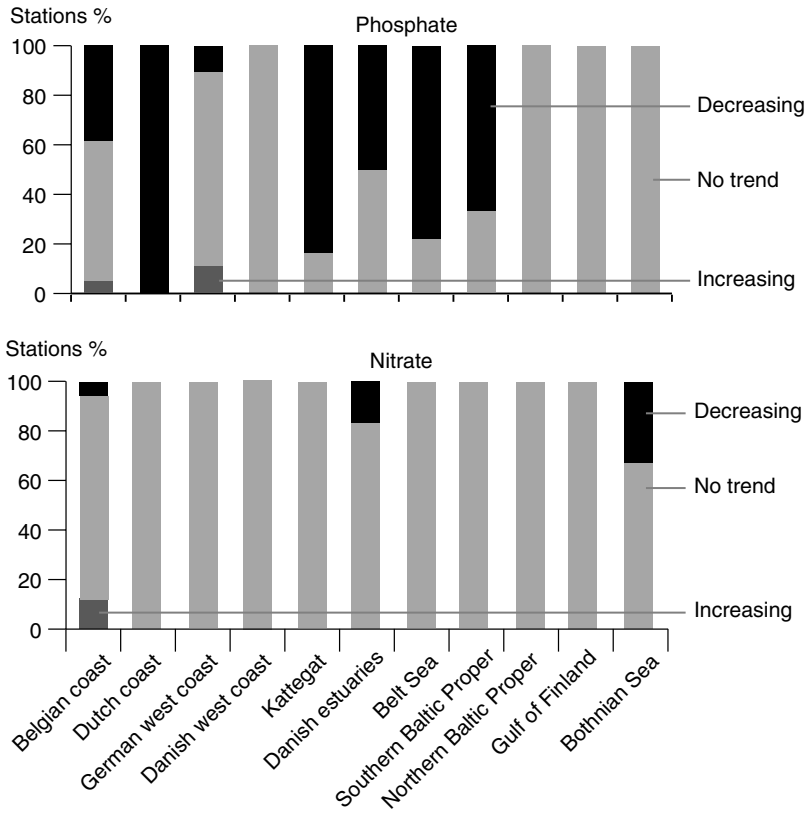


*Note*: For each station or sampling point in the subregions of the Baltic and North Seas, a trend analysis of winter nutrient concentrations in water from 1985 to 1997/2000 was carried out.The bars in the graph show, at how many sampling points (as %) a decrease or an increase in nutrient concentrations at the 5 % significance level is observed.

**Figure 10B.47** Trends in nutrients in the Baltic Sea and coastal North Sea waters, 1985–1997/2000. (From European Environmental Agency (EEA), 2002, *Environmental Signals 2002—Benchmarking the Millenium, Environmental Assessment Report No. 9*, www.eea.europa.eu. Reprinted with permission © EEA.)

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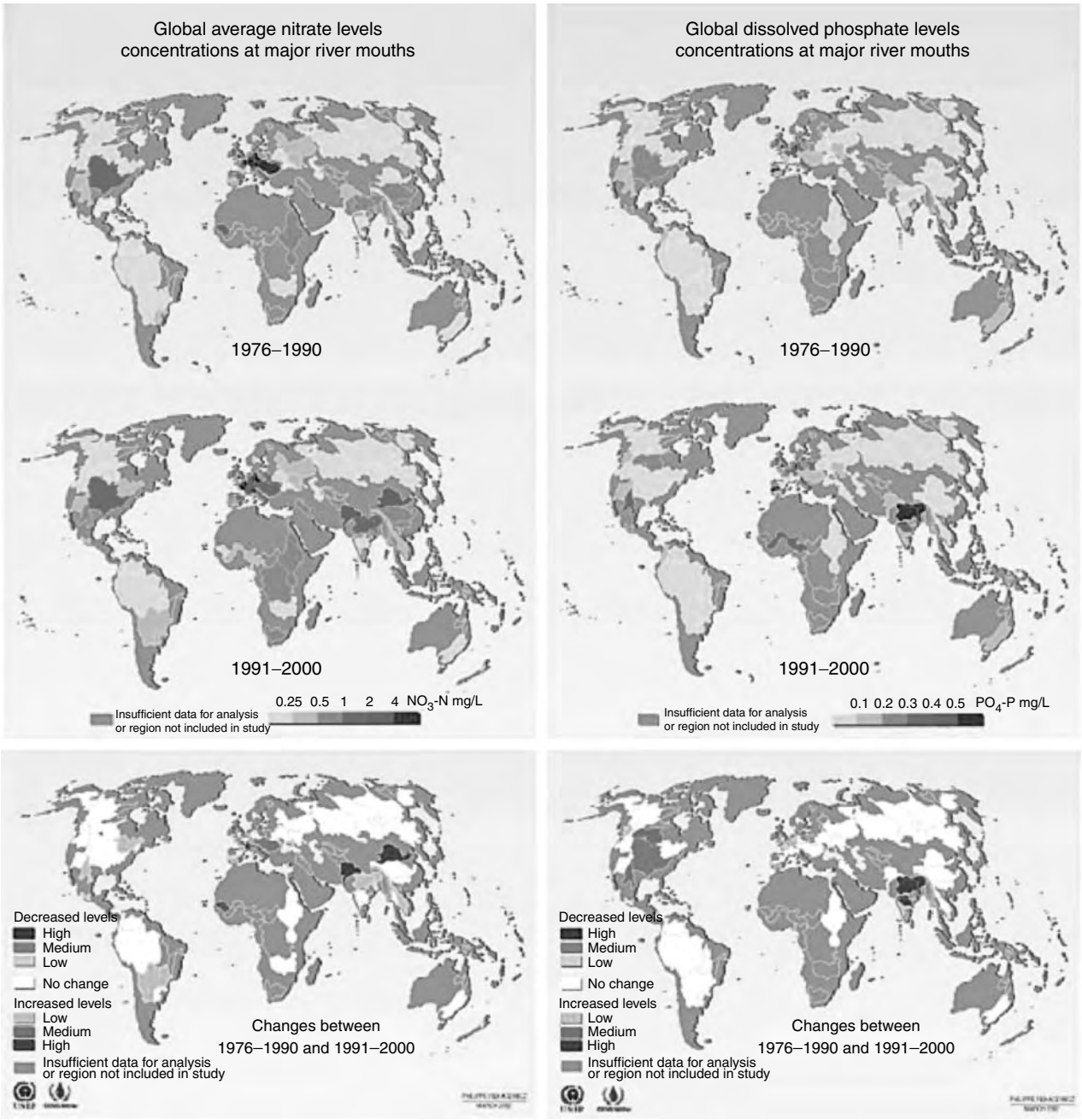


**Figure 10B.48** Global average nitrate and dissolved phosphate levels. (From United Nations Environment Programme (UNEP) *Vital Water Graphics, Global Average Nitrate Levels and Global Dissolved Phosphate Levels*, Downloaded 9/22/05, www.unep.org.)

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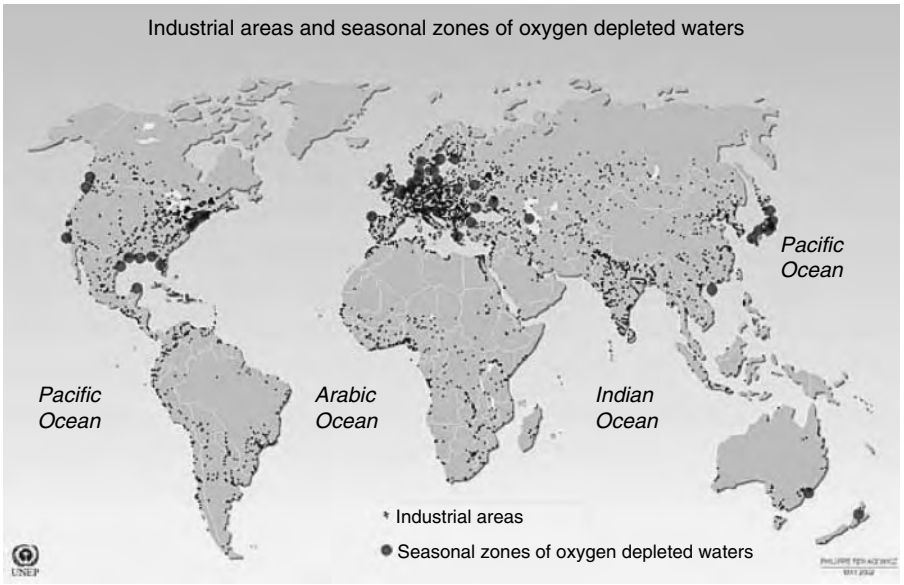


**Figure 10B.49** World industrial areas and seasonal zones of oxygen depleted waters. (From United Nations Environment Programme (UNEP), *Vital Water Graphics, Industrial Areas and Seasonal of Oxygen Depleted Waters*, Downloaded 9/22/05, www.unep.org.) Original Source: Malakoff, D., 1998, after Diaz, R.J., and Rosenberg, R., 1995, ESRI, 1990.

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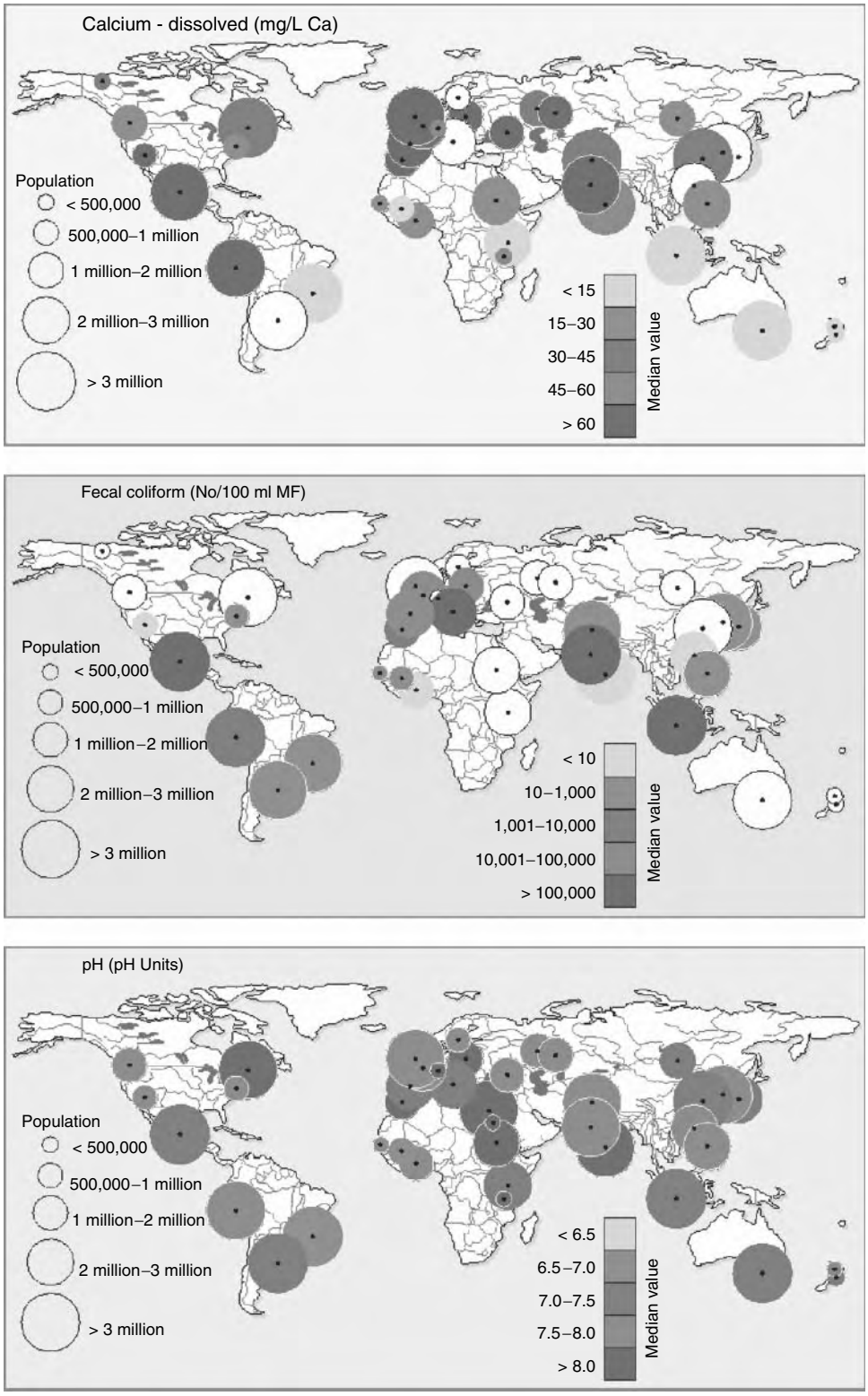


**Figure 10B.50** Fecal coliform concentrations and pH values measured in global environment monitoring system stations. (From United Nations Environment Programe, *Global Environment Monitoring System (GEMS) Water Programs, 2004 State of the UNEP GEMS/Water Global Calcium Network and Annual Report*, www.unep.org.)

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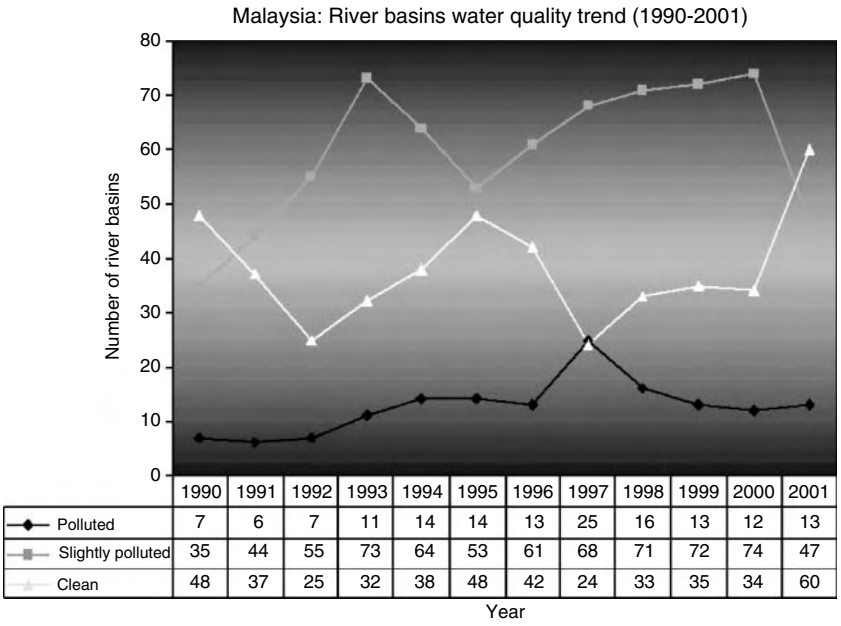


| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Polluted | 7 | 6 | 7 | 11 | 14 | 14 | 13 | 25 | 16 | 13 | 12 | 13 |
| Slightly polluted | 35 | 44 | 55 | 73 | 64 | 53 | 61 | 68 | 71 | 72 | 74 | 47 |
| Clean | 48 | 37 | 25 | 32 | 38 | 48 | 42 | 24 | 33 | 35 | 34 | 60 |

**Figure 10B.51** Malaysia: river basins water quality trend (1990–2001). (From Leong, K.H. and Mustafa, A.M., 2003, National Water Quality Standards and Status in Malaysia in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1–2 September, 2003, UNU Centre, Tokyo, www.unv.org.) Original Source: DOE (1991–2002).

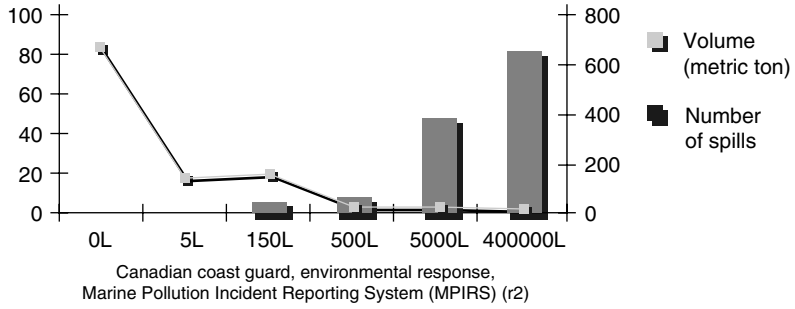


**Figure 10B.52** Canadian petrol and chemical spills distribution by volume (metric tonne) and number of spills, 2003, (From *Marine Programs National Performance Report for 2003–2004*, Environmental Response, Fisheries and Oceans Canada, Canadian Coast Guard, 2003. Reproduced with the permission of Her Majesty the Queen in Right of Canada, 2006.)

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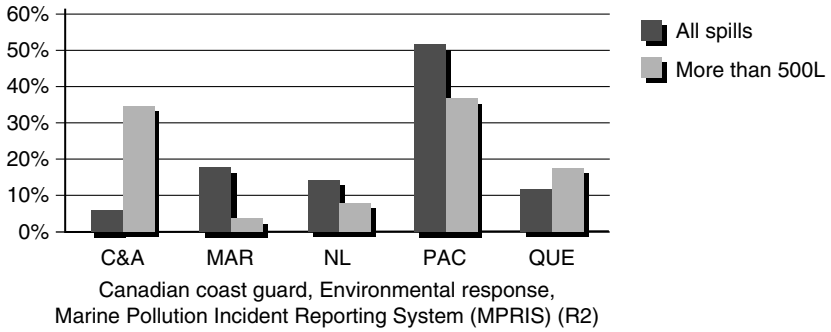


**Figure 10B.53** Regional distribution of Canadian spills in percent. (From *Marine Programs National Performance Report for 2003–2004*, Environmental Response, Fisheries and Oceans Canada, Canadian Coast Guard, 2003. Reproduced with the permission of Her Majesty the Queen in Right of Canada, 2006.)

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**Table 10B.6 Total Assimilative Capacity of Streams of Different Orders**

| Stream Order | Average Discharge (cfs) | Average Depth (ft) | Average Velocity (ft/sec) | Coefficient of Reaeration ($day^{-1}$) | Total Length of Streams (miles) | Total Assimilative Capacity (tons per day per unit deficiency in dissolved oxygen) | U.S. Rivers Representative of Each Order |
|---|---|---|---|---|---|---|---|
| 1 | 0.6 | — | — | — | 1,570,000 | — | — |
| 2 | 2.8 | — | — | — | 810,000 | — | — |
| 3 | 14 | 0.55 | 1.2 | 9.3 | 420,000 | 16,300 | — |
| 4 | 65 | 0.95 | 1.6 | 5.5 | 220,000 | 19,000 | — |
| 5 | 310 | 1.8 | 1.8 | 2.6 | 116,000 | 20,000 | Pecos |
| 6 | 1,500 | 2.7 | 2.0 | 1.8 | 61,000 | 30,000 | Shenandoah, Raritan |
| 7 | 7,000 | 5 | 2.5 | 1.0 | 30,000 | 31,000 | Allegheny, Kansas, Rio Grande |
| 8 | 33,000 | 12 | 3.0 | 0.37 | 14,000 | 21,000 | Tennessee, Wabash |
| 9 | 160,000 | 25 | 4.0 | 0.19 | 6,200 | 18,000 | Columbia, Ohio |
| 10 | 700,000 | 45 | 5.0 | 0.10 | 1,800 | 9,400 | Mississippi |

*Source*: From U.S. Geological Survey, 1967.

**Table 10B.7 Surface Waters Impacted in the United States, 2000 (Assessed Waters Only)**

| Status | Rivers (thousands of miles) | Lakes (thousands of acres) | Estuaries (thousands of square miles) | Ocean (thousands of shoreline miles) |
|---|---|---|---|---|
| Full Supporting | 367.1 | 8,027.0 | 13.8 | 2.5 |
| Threatened | 59.5 | 1,348.9 | 1.0 | 0.2 |
| Impaired | 269.3 | 7,702.4 | 15.7 | 0.4 |
| Not Attainable | 0.3 | 0.7 | 0.0 | 0.0 |
| **Total Assessed** | 696.2 | 17,079.0 | 30.5 | 3.2 |

*Note:* Fully Supporting, Fully supporting of all uses; Threatened, Fully supporting all uses but threatened for one or more uses; Impaired, Partially or not supporting one or more uses; Not Attainable, Not able to support one or more uses.

*Source*: Abstracted from United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

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**Table 10B.8 Status of the United States Surface-Water Quality, 1990–2000**

| | Rivers | | | | | | Lakes[a] | | | | | | Estuaries | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | **1990** | **1992** | **1994** | **1996** | **1998[b]** | **2000[c]** | **1990** | **1992** | **1994** | **1996** | **1998[b]** | **2000[c]** | **1990** | **1992** | **1994** | **1996** | **1998[b]** | **2000[c]** |
| | | | | | | | | | *Percent of total water[d]* | | | | | | | | | |
| Water systems assessed | 36 | 18 | 17 | 19 | 23 | 19 | 47 | 46 | 42 | 40 | 42 | 43 | 75 | 74 | 78 | 72 | 32 | 36 |
| | | | | | | | | | Percent of assessed waters | | | | | | | | | |
| **Meeting designated uses[e]** | | | | | | | | | | | | | | | | | | |
| Supporting | 69 | 62 | 64 | 64 | 55 | 53 | 60 | 56 | 63 | 61 | 46 | 47 | 67 | 68 | 63 | 62 | 47 | 45 |
| Partially supporting[f] | 21 | 25 | 22 | 36 | 10 | 8 | 19 | 35 | 28 | | 9 | 8 | 25 | 23 | 27 | | 10 | <4 |
| Not supporting | 10 | 13 | 14 | | 35 | 39 | 21 | 9 | 9 | 39 | 45 | 45 | 8 | 9 | 9 | 36 | 44 | 51 |
| **Clean Water Act goals: Fishable** | | | | | | | | | | | | | | | | | | |
| Meeting | 80 | 66 | 69 | 68 | 87 | 61 | 70 | 69 | 69 | 69 | 54 | 61 | 77 | 78 | 70 | 69 | 63 | 47 |
| Not meeting | 19 | 34 | 31 | 31 | 13 | 39 | 30 | 31 | 31 | 31 | 46 | 39 | 23 | 22 | 30 | 30 | 37 | 53 |
| Not attainable | 1 | — | — | — | 0 | — | 0 | — | — | — | — | — | — | 0 | 0 | 0 | 0 | — |
| **Clean Water Act goals: Swimmable** | | | | | | | | | | | | | | | | | | |
| Meeting | 75 | 71 | 77 | 79 | 69 | 68 | 82 | 77 | 81 | 75 | 69 | 70 | 88 | 83 | 85 | 84 | 88 | 80 |
| Not meeting | 15 | 20 | 23 | 20 | 27 | 32 | 18 | 22 | 19 | 25 | 31 | 30 | 12 | 17 | 15 | 16 | 12 | 20 |
| Not attainable | 10 | 9 | — | — | 5 | — | — | — | — | — | — | — | — | 0 | — | — | 0 | — |

*Note:* —, less than 1 percent of assessed waters.

[a] Excluding Great Lakes.
[b] United States Environmental Protection Agency, 2000, National Water Quality Inventory: 1998 Report to Congress.
[c] United States Environmental Protection Agency, 2002, National Water Quality Inventory 2000 Report, EPA-841-R-02-001.
[d] Miles of rivers, acres of lakes, square miles of estuaries.
[e] Supporting—water quality meets designated use criteria; partially supporting—water quality fails to meet designated use criteria at times; not supporting—water quality frequently fails to meet designated use criteria.
[f] In 1996, the categories "Partially supporting" and "Not supporting" were combined.

*Source*: From Ribaudo, M.O., Horan, R.D., and Smith, M.E., 1999, *Economics of Water Quality Protection from Nonpoint Sources: Theory and Practice, Resource Economic Division, Economic Research Service*, U.S. Department of Agriculture, Agricultural Economic Report No. 782 amended with 1998 and 2000 data, www.ers.usda.gov.

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**Table 10B.9 Ambient Water Quality in United States Rivers and Streams: Violation Rates, 1975–1997**

| Year | Fecal Coliform Bacteria | Dissolved Oxygen | Total Phosphorus | Total Cadmium, Dissolved | Total Lead, Dissolved |
|---|---|---|---|---|---|
| | Percent of all measurements exceeding national water quality criteria | | | | |
| 1975 | 36 | 5 | 5 | * | * |
| 1976 | 32 | 6 | 5 | * | * |
| 1977 | 34 | 11 | 5 | * | * |
| 1978 | 35 | 5 | 5 | * | * |
| 1979 | 34 | 4 | 3 | 4 | 13 |
| 1980 | 31 | 5 | 4 | 1 | 5 |
| 1981 | 30 | 4 | 4 | 1 | 3 |
| 1982 | 33 | 5 | 3 | 1 | 2 |
| 1983 | 34 | 4 | 3 | 1 | 5 |
| 1984 | 30 | 3 | 4 | <1 | <1 |
| 1985 | 28 | 3 | 3 | <1 | <1 |
| 1986 | 24 | 3 | 3 | <1 | <1 |
| 1987 | 23 | 2 | 3 | <1 | <1 |
| 1988 | 22 | 2 | 4 | <1 | <1 |
| 1989 | 30 | 3 | 2 | <1 | <1 |
| 1990 | 26 | 2 | 3 | <1 | <1 |
| 1991 | 15 | 2 | 2 | <1 | <1 |
| 1992 | 28 | 2 | 2 | <1 | <1 |
| 1993 | 31 | <1 | 2 | na | na |
| 1994 | 28 | 2 | 2 | na | na |
| 1995 | 35 | 1 | 4 | na | na |
| 1996 | na | 1 | 1 | <1 | <1 |
| 1997 | na | 1 | 2 | <1 | <1 |

*Notes:* *Base figure too small to meet statistical standards for reliability of derived figures. na, not available. Violation levels are based on the following U.S. Environmental Protection Agency water quality criteria: fecal coliform bacteria — above 200 cells per 100 ml; dissolved oxygen — below 5 milligrams per liter; total phosphorus — above 1.0 milligrams per liter; cadmium, dissolved — above 10 micrograms per liter; and total lead, dissolved — above 50 micrograms per liter.

*Source*: From The 1997 Annual Report of the Council of Environmental Quality, www.whitehouse.gov/CEQ.

*Original Source*: From U.S. Geological survey, national-level data, unpublished, Reston, VA, 1999.

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**Table 10B.10 Major Pollutants Causing Impairment in 1998 in the United States by State**

| State | Impaired | Sedimentation | Nutrients | Pathogens | Toxics/ Metals/ Inorganics | Toxics/ Organics | Mercury | Pesticides | Other |
|---|---|---|---|---|---|---|---|---|---|
| Alabama | miles | 576 | 385 | 587 | 280 | 281 | 70 | 98 | 1,642 |
| | acres | 4,084 | 70,606 | 3,628 | 529 | 68,083 | 559 | 10,147 | 140,041 |
| Arkansas | miles | 910 | 213 | 218 | 45 | 79 | 555 | 0 | 252 |
| | acres | 3,045 | 4,924 | 35 | 4,413 | 0 | 25,853 | 0 | 1,816 |
| Arizona | miles | 959 | 80 | 194 | 304 | 0 | 0 | 244 | 346 |
| | acres | 3,973 | 241 | 19,336 | 3,026 | 0 | 3,053 | 212 | 5,877 |
| California | miles | 5,768 | 1,086 | 755 | 2,464 | 306 | 303 | 2,773 | 5,717 |
| | acres | 151,677 | 470,153 | 18,027 | 709,129 | 332,963 | 862,749 | 818,002 | 1,450,270 |
| Colorado | miles | 233 | 42 | 90 | 1,355 | 0 | 29 | 0 | 442 |
| | acres | 160 | 0 | 119 | 9,100 | 0 | 1,561 | 144 | 7,928 |
| Connecticut | miles | 101 | 525 | 1,237 | 625 | 615 | 53 | 380 | 2,777 |
| | acres | 772 | 7,577 | 20,554 | 6,723 | 18,532 | 1,019 | 4,921 | 29,010 |
| District of Columbia | miles | 0 | 0 | 83 | 59 | 98 | 0 | 0 | 43 |
| | acres | 0 | 0 | 2,998 | 1,250 | 2,998 | 0 | 0 | 2,125 |
| Delaware | miles | 5 | 775 | 760 | 28 | 76 | 0 | 0 | 1,234 |
| | acres | 0 | 2,334 | 3,190 | 0 | 1,056 | 0 | 0 | 871 |
| Florida | miles | 1,219 | 4,007 | 2,826 | 1,045 | 16 | 1,445 | 0 | 5,616 |
| | acres | 33,248 | 332,502 | 82,704 | 179,598 | 135 | 226,025 | 0 | 333,798 |
| Georgia | miles | 149 | 16 | 2,649 | 1,918 | 1 | 250 | 76 | 5,936 |
| | acres | 132 | 0 | 45,411 | 123,012 | 0 | 161,96 | 225 | 229,830 |
| Hawaii | miles | 212 | 183 | 10 | 10 | 0 | 0 | 0 | 13 |
| | acres | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iowa | miles | 175 | 71 | 565 | 1,447 | 161 | 61 | 94 | 3,204 |
| | acres | 18,535 | 10,858 | 27,113 | 22,228 | 97,042 | 5 | 9,072 | 79,113 |
| Idaho | miles | 6,228 | 2,653 | 1,539 | 503 | 105 | 0 | 134 | 7,554 |
| | acres | 84,145 | 110,854 | 5,184 | 28,942 | 0 | 0 | 4,850 | 229,183 |
| Illinois | miles | 4,001 | 4,061 | 204 | 1,514 | 582 | 62 | 36 | 4,017 |
| | acres | 269,323 | 270,352 | 7,825 | 101,836 | 95,491 | 5 | 12,881 | 375,681 |
| Indiana | miles | 0 | 78 | 1,251 | 673 | 3,194 | 2,431 | 93 | 1,115 |
| | acres | 0 | 23 | 47,604 | 4,695 | 89,953 | 75,516 | 442 | 4,511 |
| Kansas | miles | 317 | 1,165 | 9,994 | 3,635 | 0 | 0 | 435 | 8,944 |
| | acres | 38,291 | 64,255 | 19,739 | 15,589 | 0 | 0 | 6,446 | 39,851 |
| Kentucky | miles | 469 | 521 | 1,289 | 83 | 656 | 6 | 17 | 835 |
| | acres | 1,236 | 6,885 | 20,964 | 536 | 134,087 | 0 | 0 | 3,276 |
| Louisiana | miles | 1,022 | 1,566 | 3,390 | 3,242 | 592 | 4,911 | 697 | 4,862 |
| | acres | 94,235 | 541,140 | 590,269 | 581,092 | 30,201 | 804,207 | 74,589 | 730,729 |
| Maine | miles | 6 | 147 | 682 | 15 | 185 | 0 | 0 | 987 |
| | acres | 0 | 33,690 | 52,291 | 0 | 8,487 | 0 | 0 | 85,533 |
| Maryland | miles | 2,610 | 5,053 | 1,138 | 530 | 7 | 26 | 32 | 467 |
| | acres | 442,854 | 904,112 | 121,256 | 86,927 | 3,333 | 13,134 | 16,916 | 21,958 |
| Massachusetts | miles | 208 | 332 | 945 | 376 | 363 | 0 | 4 | 1,908 |
| | acres | 4,253 | 4,874 | 138 | 897 | 934 | 0 | 150 | 29,454 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Michigan | miles | 17 | 253 | 612 | 39 | 604 | 254 | 195 | 1,818 |
| | acres | 0 | 2,043 | 19,799 | 27 | 333,258 | 362,042 | 314,084 | 792 |
| Minnesota | miles | 603 | 0 | 703 | 135 | 0 | 160 | 0 | 513 |
| | acres | 6,808 | 0 | 4,528 | 2,380 | 0 | 10,589 | 0 | 3,714 |
| Mississippi | miles | 72,256 | 72,241 | 27,189 | 1,595 | 777 | 358 | 67,633 | 1,818 |
| | acres | 452,878 | 447,838 | 80,919 | 3,934 | 4,576 | 9,396 | 436,763 | 792 |
| Missouri | miles | 1,120 | 228 | 90 | 479 | 0 | 0 | 67 | 1,535 |
| | acres | 17 | 2,249 | 0 | 47,396 | 0 | 0 | 32,167 | 336,693 |
| Montana | miles | 15,015 | 6,703 | 895 | 6,798 | 139 | 0 | 0 | 31,731 |
| | acres | 550,491 | 501,586 | 76,292 | 338,591 | 3,342 | 0 | 0 | 1,396,433 |
| Nebraska | miles | 54 | 93 | 1,987 | 1,190 | 0 | 0 | 894 | 263 |
| | acres | 3,266 | 17,979 | 83,978 | 26,612 | 0 | 0 | 29,692 | 1,677 |
| Nevada | miles | 587 | 702 | 0 | 924 | 0 | 384 | 0 | 589 |
| | acres | 15,617 | 51,693 | 0 | 27,527 | 0 | 14,504 | 0 | 14,504 |
| New Hampshire | miles | 0 | 19 | 678 | 795 | 445 | 0 | 0 | 503 |
| | acres | 0 | 750 | 8,421 | 26,189 | 25,166 | 0 | 0 | 5,947 |
| New Jersey | miles | 8 | 518 | 749 | 952 | 106 | 928 | 20 | 7,882 |
| | acres | 4,154 | 7,773 | 4,007 | 10,292 | 1,941 | 37,219 | 74 | 7,550 |
| New Mexico | miles | 638 | 703 | 154 | 628 | 13 | 185 | 12 | 3,675 |
| | acres | 995 | 172 | 1,460 | 53 | 0 | 63,658 | 0 | 5,589 |
| New York | miles | 25 | 99 | 602 | 5 | 920 | 0 | 0 | 733 |
| | acres | 1,147 | 31,369 | 19,291 | 24,332 | 405,342 | 7,337 | 13,747 | 111,143 |
| North Carolina | miles | 1,161 | 64 | 746 | 117 | 126 | 378 | 14 | 1,813 |
| | acres | 5,329 | 19,890 | 7,499 | 8,386 | 25,151 | 16,685 | 0 | 18,035 |
| North Dakota | miles | 2,604 | 2,616 | 2,691 | 356 | 0 | 0 | 0 | 4,327 |
| | acres | 11,904 | 58,964 | 6,595 | 6,277 | 0 | 0 | 0 | 18,714 |
| Ohio | miles | 3,563 | 1,347 | 321 | 2,020 | 885 | 0 | 441 | 11,456 |
| | acres | 44,234 | 50,907 | 3,250 | 21,697 | 14,358 | 0 | 11,154 | 105,140 |
| Oklahoma | miles | 4,791 | 4,066 | 524 | 1,531 | 306 | 0 | 4,295 | 6,614 |
| | acres | 445,672 | 269,714 | 77,059 | 150,373 | 47,244 | 0 | 293,999 | 500,257 |
| Oregon | miles | 1,446 | 598 | 2,565 | 308 | 199 | 602 | 317 | 19,611 |
| | acres | 8,207 | 82,975 | 8,190 | 0 | 0 | 17,453 | 0 | 149,335 |
| Pennsylvania | miles | 2,191 | 920 | 49 | 3,190 | 572 | 0 | 462 | 2,278 |
| | acres | 4,353 | 3,118 | 0 | 38,139 | 48,213 | 1 | 33,403 | 5,677 |
| Puerto Rico | miles | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 210 |
| | acres | 0 | 71 | 0 | 0 | 0 | 0 | 0 | 873 |
| Rhode Island | miles | 14 | 150 | 192 | 153 | 3 | 3 | 0 | 146 |
| | acres | 358 | 1,390 | 1,857 | 1,342 | 46 | 46 | 0 | 1,145 |
| South Carolina | miles | 0 | 10 | 2,674 | 230 | 307 | 28,527 | 10 | 4,908 |
| | acres | 0 | 30,799 | 122,128 | 22,000 | 71,102 | 209,663 | 0 | 88,157 |
| South Dakota | miles | 1,828 | 336 | 1,049 | 521 | 0 | 0 | 0 | 723 |
| | acres | 29,647 | 66,074 | 9,561 | 304 | 0 | 0 | 0 | 43,966 |
| Tennessee | miles | 12,309 | 3,285 | 4,149 | 1,608 | 2,042 | 152 | 845 | 10,072 |
| | acres | 212,709 | 29,289 | 9,317 | 7,437 | 254,155 | 23,505 | 179,553 | 49,513 |
| Texas | miles | 0 | 132 | 5,463 | 952 | 575 | 927 | 433 | 3,648 |

*(Continued)*



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**Table 10B.10 (Continued)**

| State | Impaired | Sedimentation | Nutrients | Pathogens | Toxics/ Metals/ Inorganics | Toxics/ Organics | Mercury | Pesticides | Other |
|---|---|---|---|---|---|---|---|---|---|
| | acres | 0 | 131 | 201,824 | 27,823 | 9,961 | 374,434 | 67,337 | 399,673 |
| Utah | miles | 1,194 | 708 | 402 | 823 | 414 | 17 | 0 | 5,417 |
| | acres | 4,879 | 109,589 | 5,215 | 7,465 | 5,215 | 0 | 0 | 152,529 |
| Vermont | miles | 102 | 133 | 237 | 42 | 36 | 72 | 0 | 314 |
| | acres | 907 | 13,755 | 349 | 228 | 6,120 | 10,689 | 0 | 6,248 |
| Virginia | miles | 0 | 45 | 1,691 | 2,069 | 101 | 147 | 104 | 4,171 |
| | acres | 0 | 18 | 16,125 | 3,086 | 2,434 | 21 | 4,495 | 5,547 |
| Virgin Islands | miles | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 13 |
| | acres | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Washington | miles | 18 | 1 | 393 | 63 | 28 | 14 | 29 | 812 |
| | acres | 0 | 5,632 | 1,004 | 1,357 | 149 | 28 | 6,736 | 148 |
| West Virginia | miles | 0 | 0 | 174 | 5,276 | 384 | 0 | 278 | 2,633 |
| | acres | 2,849 | 1,899 | 0 | 82,124 | 50,907 | 0 | 44,534 | 2,947 |
| Wisconsin | miles | 787 | 231 | 49 | 35 | 585 | 661 | 0 | 2,050 |
| | acres | 41,935 | 4,460 | 0 | 0 | 149,226 | 239,092 | 0 | 53,827 |
| Wyoming | miles | 238 | 47 | 517 | 580 | 27 | 0 | 0 | 250 |
| | acres | 16 | 215 | 3,862 | 5,600 | 0 | 0 | 0 | 12 |

*Note:* Miles include river and shoreline miles, including the Great Lakes and estuarine shorelines. Acres include lake acres, excluding the Great Lakes.

*Source*: From United States Environmental Protection Agency, *Total Maximum Daily Loads, National Overview, Major Pollutants Causing Impairment by State*, Last updated on Wednesday, February 16th, 2005, www.epa.gov/owow/tmdl/status.html.

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**Table 10B.11 Top 100 Impairments of Waters in the United States Reported in 1998 for Section 303(d) of the Clean Water Act**

| General Impairment Name | Impairments Reported | Percent of Reported |
|---|---|---|
| Metals | 11,538 | 19.22 |
| Pathogens | 7,902 | 13.16 |
| Nutrients | 5,586 | 9.31 |
| Sediment/siltation | 5,047 | 8.41 |
| Organic enrichment/low DO | 4,405 | 7.34 |
| Fish consumption advis. | 3,178 | 5.29 |
| pH | 2,906 | 4.84 |
| Other habitat alterations | 2,389 | 3.98 |
| Thermal modifications | 2,200 | 3.67 |
| Biological criteria | 2,116 | 3.53 |
| Flow alteration | 1,576 | 2.63 |
| Pesticides | 1,468 | 2.45 |
| Turbidity | 1,140 | 1.90 |
| Salinity/TDS/chlorides | 994 | 1.66 |
| Suspended solids | 969 | 1.61 |
| Cause unknown | 896 | 1.49 |
| PCBs | 884 | 1.47 |
| Unionized ammonia | 797 | 1.33 |
| Priority organics | 681 | 1.13 |
| Sulfates | 621 | 1.03 |
| Algal growth/chlorophylla | 476 | 0.79 |
| Noxious aquatic plants | 351 | 0.58 |
| Oil and grease | 286 | 0.48 |
| Unknown toxicity | 282 | 0.47 |
| Other cause | 221 | 0.37 |
| General WQS (benthic) | 195 | 0.32 |
| Dioxins | 184 | 0.31 |
| Other inorganics | 144 | 0.24 |
| Chlorine | 98 | 0.16 |
| Nonpriority organics | 97 | 0.16 |
| Taste and odor | 85 | 0.14 |
| Stream bottom deposits | 75 | 0.12 |
| Total toxics | 48 | 0.08 |
| Cyanide | 47 | 0.08 |
| Biodiversity impacts | 47 | 0.08 |
| Exotic species | 42 | 0.07 |
| Radiation | 22 | 0.04 |
| Natural limits (wetlands) | 13 | 0.02 |
| Fish kill(s) | 12 | 0.02 |
| Hydrogen sulfide | 4 | 0.01 |
| Ambient water quality criteria | 2 | 0.00 |
| Low nutrients | 1 | 0.00 |
| RDX—Hexahydro-1,3,5-trinitro-1,3,5-triazine | 1 | 0.00 |
| 1,2-Diphenylhdrazine | 1 | 0.00 |

*Note:* Total impairments reported nationwide: 60,027.

*Source*: From United States Environmental Protection Agency, *National Section 303(d) List Fact Sheet*, Downloaded 8/28/05, www.epa.gov/owow/tmdl/status.html.

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**Table 10B.12 Probable Sources of Water-Quality Problems in the Nation's Streams in 1982**

| Probable Source | Stream Miles | Percentage |
|---|---|---|
| Total nonpoint source contribution | 367,244 | 38.4 |
| Agricultural sources | 281,241 | 29.5 |
| Natural sources | 212,389 | 22.2 |
| Total point source contribution | 117,684 | 12.3 |
| Silviculture/logging | 71,736 | 7.5 |
| Municipal point sources | 63,816 | 6.7 |
| Feed lots | 59,947 | 6.3 |
| Individual sewage disposal | 47,823 | 5.0 |
| Industrial point sources | 47,097 | 4.9 |
| Urban runoff | 40,376 | 4.2 |
| Mining (nonpoint) | 31,847 | 3.3 |
| Combined sewers | 29,246 | 3.1 |
| Construction activity | 29,110 | 3.1 |
| Mining (point) | 28,686 | 3.0 |
| Grazing | 21,970 | 2.3 |
| Other | 19,445 | 2.0 |
| Dam releases | 19,314 | 2.0 |
| Landfill leachate | 5,504 | 0.6 |
| Bedload movement | 5,299 | 0.6 |
| Roads | 3,569 | 0.4 |

*Note:* Expressed in total stream miles and as percentages of total miles.

*Source*: From Judy, R.D., and others, 1984, *1982 National Fisheries Survey*, U.S. Fish and Wildlife Service, FWS/OBS-84/06.

**Table 10B.13 Sources of Water-Quantity Problems Adversely Affecting the Nation's Streams in 1982**

| Source | Stream Miles | Percentage |
|---|---|---|
| Natural conditions | 477,791 | 50.1 |
| Diversions (agricultural) | 130,223 | 13.6 |
| Dam(s) (water storage) | 32,901 | 3.5 |
| Dam(s) (flood control) | 28,002 | 2.9 |
| Dam(s) (power) | 24,821 | 2.6 |
| Other | 18,851 | 2.0 |
| Diversions (municipal) | 10,694 | 1.1 |
| Channelization | 10,629 | 1.1 |
| Floods/low flows | 10,527 | 1.1 |
| Irrigation | 8,897 | 0.9 |
| Logging | 6,271 | 0.7 |
| Ditches | 5,335 | 0.6 |
| Diversions (industrial) | 3,292 | 0.3 |

*Note:* Expressed in total stream miles and as percentages of total miles.

*Source*: From Judy, R.D., and others, 1984. *1982 National Fisheries Survey*, U.S. Fish and Wildlife Service, FWS/OBS-84/06.

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**Table 10B.14 Leading Sources Impairing Assessed Rivers and Streams in the United States in 2000**

| Sources | Stream Miles | Percent of Impaired | Percent of Assessed |
|---|---|---|---|
| Agriculture | 128,859 | 47.9 | 18.4 |
| Hydromodification | 53,850 | 20.0 | 7.7 |
| Crop-related sources | 53,067 | 19.7 | 7.6 |
| Grazing related sources | 43,469 | 16.1 | 6.2 |
| Source unknown | 39,056 | 14.5 | 5.6 |
| Habitat modification (other than hydromodification) | 37,654 | 14.0 | 5.4 |
| Urban runoff/storm sewers | 34,871 | 13.0 | 5.0 |
| Natural sources | 31,033 | 11.5 | 4.4 |
| Silviculture | 28,156 | 10.5 | 4.0 |
| Municipal point sources | 27,988 | 10.4 | 4.0 |
| Resource extraction | 27,695 | 10.3 | 4.0 |
| Nonirrigated crop production | 26,830 | 10.0 | 3.8 |
| Intensive animal feeding operations | 24,616 | 9.1 | 3.5 |
| Channelization | 23,795 | 8.8 | 3.4 |
| Bank or shoreline modification/destabilization | 18,040 | 6.7 | 2.6 |
| Removal of riparian vegetation | 17,912 | 6.7 | 2.6 |
| Land disposal | 17,821 | 6.6 | 2.5 |
| Irrigated crop production | 17,667 | 6.6 | 2.5 |
| Erosion and sedimentation | 16,137 | 6.0 | 2.3 |
| Unspecified nonpoint source | 15,988 | 5.9 | 2.3 |

*Source*: From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001/, www.epa.gov.

**Table 10B.15 Heat Generated and Discharged to the Nation's Fresh and Saline Surface Waters, 1975–2000**

| | 1975 | | 1985 | | 2000 | |
|---|---|---|---|---|---|---|
| | Btus $\times 10^{15}$ | Percent of Total Discharged | Btus $\times 10^{15}$ | Percent of Total Discharged | Btus $\times 10^{15}$ | Percent of Total Discharged |
| Electric power generation | | | | | | |
| Heat generated | 11.0 | — | 24.3 | — | 57.1 | — |
| Heat discharged to water | 5.7 | 66 | 7.8 | 98 | 7.4 | 98 |
| (Fresh) | (3.9) | (45) | (3.9) | (49) | (2.8) | (37) |
| (Saline) | (1.8) | (21) | (3.9) | (49) | (4.6) | (61) |
| Manufacturing | | | | | | |
| Heat discharged to water | 3.0 | 34 | 0.2 | 2 | 0.2 | 2 |
| (Fresh) | (2.2) | (73) | (0.2) | (2) | (0.2) | (2) |
| (Saline) | (0.8) | (27) | (0) | (0) | (0) | (0) |
| Total heat discharged | 8.7 | 100 | 8.0 | 100 | 7.6 | 100 |
| (Fresh) | (6.1) | (70) | (4.1) | (51) | (3.0) | (39) |
| (Saline) | (2.6) | (30) | (3.9) | (49) | (4.6) | (61) |

*Source*: From U.S. Water Resources Council, 1978, *The Nation's Water Resources 1975–2000, Second National Water Assessment*.

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**Table 10B.16 Point Source Loadings to Receiving Waters in the United States, mid 1980s**

| Industry | TSS | BOD | Phosphorus | Metals |
|---|---|---|---|---|
| Minerals & metals | 0.355 | 0.006 | 0.255 | 4.931 |
| Chemical & manufacturing | 0.086 | 0.125 | 0.267 | 2.919 |
| Agriculture & fisheries | 0.277 | 0.404 | 92.800 | 0.000 |
| POTWs | 1.594 | 1.830 | 49.555 | 2.838 |
| Total | 2.312 | 2.365 | 142.877 | 10.688 |

*Note:* Millions of tons per year for TSS, BOD, and phosphorus and millions of pounds per year for metals; mid1980s. Minerals & metals includes aluminum forming, coal mining, copper forming, foundries, iron and steel, metal finishing, nonferrous metals mining, nonferrous metals forming, ore mining and petroleum refining industries. Chemical & manufacturing includes battery manufacturing, coil coating, electrical and electronic components, organic and inorganic chemicals, plastics, synthetic fibers, pesticide manufacturing, pharmaceuticals manufacturing, plastics molding and forming, porcelain enameling, leather tanning, pulp and paper, and textile industries. Agriculture & fisheries includes animal feedlots, fish hatcheries, food and beverages, fruits and vegetables, meat packing, and seafood industries. POTWs, publicly owned treatment works. TSS, total suspended solids, BOD, biochemical oxygen demand. Metals, cadmium, copper, lead, mercury and zinc. Industrial loadings are direct discharges based on long-term average concentrations and total industry flows at Best Available Technology (BAT) presented in U.S. EPA (1983), except as follows: loadings for electrical and electronic components reflect current level of treatment (U.S. EPA, 1983); conventional loadings for agriculture & fisheries industries represent post-BAT treatment levels; and conventional and toxic pollutant loadings for POTWs include indirect industrial and residential/commercial loadings not removed by the POTWs. Phosphorus loadings for POTWs represent effluent levels of 5 mg/L.

*Source*: From U.S. Environmental Protection Agency, *Effluent Technology Division*, unpublished data. 1979. Washington, DC; U.S. Geological Survey, National Water Summary 1986.

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**Table 10B.17 Point Source Discharges to Water in the United States, 1977 (by Sector)**

| Total Suspended Solids | | Total Dissolved Solids | | Biochemical Oxygen Demand | |
|---|---|---|---|---|---|
| **Sector** | **Million Pounds Per Year** | **Sector** | **Million Pounds Per Year** | **Sector** | **Million Pounds Per Year** |
| Municipal sewage plants | 3,850.0 | Organic chemicals | 36,540.4 | Municipal sewage plants | 3,800.0 |
| Powerplants | 1,165.7 | Municipal sewage plants | 30,255.2 | Pulp & paper mills | 530.2 |
| Pulp & paper mills | 781.8 | Powerplants | 18,418.1 | Organic chemicals | 107.6 |
| Feedlots | 422.0 | Pulp & paper mills | 16,825.8 | Feedlots | 95.9 |
| Iron & steel mills | 254.3 | Misc. chemicals | 8,176.4 | Seafoods | 86.9 |
| Organic chemicals | 144.0 | Misc. food & beverages | 7,420.2 | Misc. food & beverages | 54.8 |
| Misc. food & beverages | 91.9 | Oil & gas extraction | 6,077.0 | Cane sugar mills | 50.4 |
| Textiles | 61.7 | Petroleum refining | 2,389.8 | Iron & steel mills | 37.8 |
| Mineral mining | 52.7 | Coal mining | 1,328.7 | Misc. chemicals | 35.2 |
| Seafoods | 50.0 | Iron & steel mills | 1,324.0 | Textiles | 24.8 |
| **Total, top 10 sectors** | **6,874.1** | **Total, top 10 sectors** | **128,755.6** | **Total, top 10 sectors** | **4,823.6** |
| **Total, all sectors** | **13,746.0** | **Total, all sectors** | **170,759.0** | **Total, all sectors** | **6,944.0** |
| **Top 10 sectors as percent of all sectors** | **50%** | **Top 10 sectors as percent of all sectors** | **75%** | **Top 10 sectors as percent of all sectors** | 69% |

| Nitrogen | | Phosphorus | | Dissolved Heavy Metals | |
|---|---|---|---|---|---|
| **Sector** | **Million Pounds Per Year** | **Sector** | **Million Pounds Per Year** | **Sector** | **Million Pounds Per Year** |
| Municipal sewage plants | 813.5 | Municipal sewage plants | 73.9 | Powerplants | 24.4 |
| Pharmaceuticals | 87.6 | Feedlots | 21.8 | Municipal sewage plants | 9.3 |
| Organic chemicals | 41.1 | Misc. food & beverages | 4.7 | Iron & steel mills | 7.6 |
| Feedlots | 39.9 | Meat packing | 3.4 | Petroleum refining | 6.0 |
| Meat packing | 36.0 | Laundries | 3.3 | Organic chemicals | 3.6 |
| Petroleum refining | 15.5 | Fertilizers | 2.6 | Ore mining | 2.5 |
| Misc. food & beverages | 12.3 | Petroleum refining | 1.5 | Electroplating | 0.5 |
| Seafoods | 9.5 | Seafoods | 1.4 | Machinery | 0.5 |
| Pesticides | 8.9 | Organic chemicals | 1.4 | Oil & gas extraction | 0.4 |
| Leather tanning | 7.1 | Poultry | 1.2 | Foundries | 0.1 |
| **Total, top 10 sectors** | **1,071.4** | **Total, top 10 sectors** | **115.2** | **Total, top 10 sectors** | **54.9** |
| **Total, all sectors** | **1,237.0** | **Total, all sectors** | **191.0** | **Total, all sectors** | **59.0** |
| **Top 10 sectors as percent of all sectors** | **87%** | **Top 10 sectors as percent of all sectors** | **60%** | **Top 10 sectors as percent of all sectors** | **93%** |

*Source*: From Council on Environmental Quality, 1981, *Environmental Trends*.

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**Table 10B.18 Nonpoint Source Contributions to Receiving Waters in the United States**

| Source | TSS | BOD | Nitrogen | Phosphorus |
|---|---|---|---|---|
| Cropland | 1,870.00 | 9.00 | 4.30 | 1.56 |
| Pasture and rangeland | 1,220.00 | 5.00 | 2.50 | 1.08 |
| Forest land | 256.00 | 0.80 | 0.39 | 0.09 |
| Construction sites | 197 | NA | NA | NA |
| Mining sites | 59 | NA | NA | NA |
| Urban runoff | 20 | 0.5 | 0.15 | 0.019 |
| Rural roadways | 2 | 0.004 | 0.0005 | 0.001 |
| Small feedlots | 2 | 0.05 | 0.17 | 0.032 |
| Landfills | NA | 0.3 | 0.026 | NA |
| Background | 1,260.00 | 5.00 | 2.50 | 1.10 |
| **Total** | **4,886.00** | **20.35** | **10.04** | **3.88** |

*Note:* By source; millions of tons per year; 1980. TSS, total suspended solids. BOD, biochemical oxygen demand. Excluded from the survey area are 207 million acres in public land (14% of the contiguous United States), mostly in the Rocky Mountains, because of inadequacy of information. Urban runoff includes storm water sewers only.

*Source*: From U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Nonpoint Source Control Section. 1986. Estimated pollutant contributions to source waters from selected nonpoint sources in the contiguous 48 states (1980). Washington, DC; U.S. Geological survey, National Water Summary 1986.

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**Table 10B.19 United States Water Quality Conditions by Type of Waterbody: 2000**

| Item | Rivers and Streams (mi) | Lakes, Reservoirs, and Ponds (acres) | Estuaries ($mi^2$) | Great Lakes Shoreline (mi) | Ocean Shoreline (mi) |
|---|---|---|---|---|---|
| Total size | 3,692,830 | 40,603,893 | 87,369 | 5,521 | 58,618 |
| Amount accessed[a] | 699,946 | 17,339,080 | 31,072 | 5,066 | 3,221 |
| Percent of total size | 19 | 43 | 36 | 92 | 6 |
| Amount accessed as— | | | | | |
| Good[b] | 463,441 | 8,026,988 | 13,850 | — | 2,176 |
| Good but threatened[c] | 85,544 | 1,343,903 | 1,023 | 1,095 | 193 |
| Polluted[d] | 291,264 | 7,702,370 | 15,676 | 3,955 | 434 |
| Percent of accessed as— | | | | | |
| Good[b] | 53 | 47 | 45 | — | 79 |
| Good but threatened[c] | 8 | 8 | 4 | 22 | 7 |
| Polluted[d] | 39 | 45 | 51 | 78 | 14 |
| Amount impaired by leading sources of pollution[e] | | | | | |
| Agriculture | 128,859 | 3,158,393 | 2,811 | 75 | (NA) |
| Atmospheric deposition | (NA) | 983,936 | 3,692 | 71 | (NA) |
| Construction | (NA) | (NA) | (NA) | (NA) | 29 |
| Contaminated sediments | (NA) | (NA) | (NA) | 519 | (NA) |
| Forestry | 28,156 | (NA) | (NA) | (NA) | (NA) |
| Habitat modification | 37,654 | (NA) | (NA) | 62 | (NA) |
| Hydrologic modification | 53,850 | 1,413,624 | 2,171 | (NA) | (NA) |
| Industrial discharges/point sources | (NA) | (NA) | 4,116 | (NA) | 76 |
| Land disposal of wastes | (NA) | 856,586 | (NA) | 61 | 123 |
| Municipal point sources | 27,988 | 943,715 | 5,779 | (NA) | 89 |
| Nonpoint sources | (NA) | 1,045,036 | (NA) | (NA) | 142 |
| Resource extraction | 27,695 | (NA) | 1,913 | (NA) | (NA) |
| Septic tanks | (NA) | (NA) | (NA) | 61 | 103 |
| Urban runoff and storm sewers | 34,871 | 13,699,327 | 5,045 | 152 | 241 |

*Note:* Section 305(b) of the Clean Water Act requires states and other jurisdiction to assess the health of their waters and the extent to which their waters support quality standards. Section 305(b) requires that states submit reports describing water quality conditions to the Environment Protection Agency every two years. Water quality standard have three elements (designated uses, criteria developed to protect each use, and an antidegradation policy). For information on survey methodology and assessment criteria, see report. —, Representation zero. NA, Not available.

[a] Includes waterbodies accessed as not attainable for one or more uses. Most states do not assess all their waterbodies during the 2-year reporting cycle, but use a "rotating basin approach" whereby all waters are monitored over a set period of time.

[b] Based on accessment of available data, water quality supports all designated uses. Water quality meets narrative and/or numberic criteria adopted to protect and support a designated use.

[c] Although all assessed uses are currently met, data show a declining trend in water quality. Projections based on this trend indicate water quality will be impaired in the future, unless action is taken to prevent further degradation.

[d] Impaired or not attainable. The reporting state or jurisdiction has performed a "use-attainability analysis" and demonstrated that support of one or more designated beneficial uses is not attainable due to specific biological, chemical, physical, or economic/social conditions.

[e] Excludes unknown and natural sources.

*Source*: From U.S. Census Bureau, *Statistical Abstract of the United States: 2004–2005*.

*Original Source*: From U.S. Environmental Protection Agency, *National Water Quality Inventory: 2000 Report,* EPA-841-R-02-001, August 2002, www.epa.gov/305b/2000report.

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**Table 10B.20 Summary of Individual Use Support for Rivers, Lakes, Estuaries, Ocean Shoreline Waters and Great Lakes in the United States in 2000**

| | | Good | | Impaired | | |
|---|---|---|---|---|---|---|
| | Area Assessed | Full Support (%) | Threatened (%) | Partial Support (%) | Not Supporting (%) | Not Attainable |
| **Rivers and Streams** | **Miles** | | | | | |
| Aquatic life support | 616,860 | 55.4 | 10.1 | 18.7 | 15.5 | 0.3 |
| Fish consumption | 205,153 | 60.9 | 1.2 | 15.2 | 22.8 | 0.0 |
| Primary contact-swimming | 313,832 | 67.8 | 3.4 | 11.9 | 16.3 | 0.5 |
| Secondary contact | 219,776 | 73.5 | 2.3 | 11.1 | 13.1 | 0.0 |
| Drinking water supply | 153,155 | 83.5 | 2.8 | 7.6 | 6.1 | 0.1 |
| Agriculture | 274,736 | 90.7 | 0.9 | 3.8 | 4.6 | 0.0 |
| **Lakes, Reservoirs and Ponds** | **Acres** | | | | | |
| Aquatic life support | 11,224,279 | 60.9 | 10.3 | 19.0 | 9.8 | 0.0 |
| Fish consumption | 8,566,710 | 60.6 | 4.4 | 21.4 | 13.6 | 0.0 |
| Primary contact-swimming | 12,662,298 | 70.2 | 6.5 | 16.7 | 6.6 | 0.0 |
| Secondary contact | 5,855,176 | 73.5 | 6.9 | 13.9 | 5.6 | 0.0 |
| Drinking water supply | 7,244,575 | 78.5 | 4.9 | 10.4 | 6.2 | 0.0 |
| Agriculture | 4,653,670 | 84.1 | 3.0 | 5.3 | 7.6 | 0.0 |
| **Estuaries** | **Square miles** | | | | | |
| Aquatic life support | 22,047 | 43.7 | 4.7 | 37.1 | 14.5 | 0.0 |
| Fish consumption | 12,940 | 46.6 | 5.0 | 45.3 | 3.1 | 0.0 |
| Shellfishing | 20,967 | 75.7 | 0.6 | 10.5 | 13.2 | 0.0 |
| Primary contact-swimming | 21,169 | 80.0 | 4.7 | 14.3 | 1.0 | 0.0 |
| Secondary contact | 9,524 | 72.8 | 4.2 | 22.2 | 0.9 | 0.0 |
| **Ocean Shoreline Waters** | **Shoreline Miles** | | | | | |
| Aquatic life support | 2,079 | 86.1 | 7.7 | 2.2 | 4.1 | 0.0 |
| Fish consumption | 1,136 | 87.3 | 3.9 | 5.5 | 3.3 | 0.0 |
| Shellfishing | 1,420 | 86.4 | 0.0 | 11.6 | 2.0 | 0.0 |
| Primary contact-swimming | 2,521 | 76.8 | 8.6 | 6.6 | 8.0 | 0.0 |
| Secondary contact | 1,925 | 87.3 | 4.2 | 4.4 | 4.2 | 0.0 |
| **Great Lakes** | **Shoreline Miles** | | | | | |
| Aquatic life support | 1,343 | 3.2 | 78.6 | 16.4 | 1.8 | 0.0 |
| Fish consumption | 4,976 | 0.0 | 0.0 | 33.4 | 66.6 | 0.0 |
| Primary contact-swimming | 3,663 | 89.9 | 7.4 | 2.5 | 0.2 | 0.0 |
| Secondary contact | 3,256 | 99.8 | 0.0 | 0.2 | 0.0 | 0.0 |
| Drinking water supply | 3,313 | 97.6 | 0.0 | 0.0 | 2.4 | 0.0 |
| Agriculture | 3,250 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*Note:* Water-quality conditions: Good, Fully supporting of all of their uses or fully supporting but threatened for one or more uses; Impaired, Partially or not supporting one or more uses; Not Attainable, Not able to support one or more uses. Use Support Levels: Supporting, Fully supporting of all uses; Threatened, Fully supporting all uses but threatened for one or more uses; Partially Supporting, Partially supporting one or more uses; Not Supporting, Not able to support one or more uses.

*Source*: Abstracted from United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

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**Table 10B.21 Leading Sources Impairing Assessed Rivers in the United States in 2000 (Expressed in Stream Miles)**

| | | | | Miles Alloted to Each Source | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | State by EPA Region | Assessed Miles | Miles Impaired | Agriculture | Hydro-modification | Habitat Modification (Other than Hydro-modification) | Urban Runoff/Storm Sewers | Natural Sources | Forestry/ Silviculture | Municipal Point Sources | Resource Extraction | Land Disposal |
| 1 | Connecticut | 1,207 | 389 | 120.5 | 177.45 | 9 | 188.6 | 7.5 | — | 194.3 | 27.3 | 40.6 |
| | Maine | 31,752 | 729 | 174.8 | — | 23.6 | 101.5 | — | 1 | 93.5 | 1 | 35.5 |
| | Massachusetts | 1,496 | 969 | 39.6 | 146.1 | 29.9 | 361.1 | — | — | 221.35 | 1.7 | 83.1 |
| | New Hampshire | 2,677 | 444 | 59 | 11.1 | 11.5 | 13.4 | 8 | 0 | 11.9 | 0 | 7.4 |
| | Rhode Island | 649 | 217 | 35.07 | 27.62 | 7.99 | 151.1 | 29.32 | | 35.99 | 6.53 | 60.28 |
| | Vermont | 5,462 | 1,169 | 688.8 | 418.3 | 771.6 | 367.5 | 373.6 | 45.4 | 202.9 | 67.1 | 335.4 |
| 2 | New Jersey | 330 | 209 | — | — | — | — | — | — | — | — | — |
| | New York | 2,914 | 1,081 | 1,485.6 | 589.1 | 1,340.2 | 944 | — | 100 | 545.9 | 268 | 1,467.3 |
| 3 | Delaware | 2,506 | 1,765 | 984.03 | — | — | 304.07 | 423.51 | — | 118.42 | — | 213.44 |
| | Delaware river basin | 206 | 206 | 206 | — | — | 206 | 2 | — | 206 | — | — |
| | District of Columbia | 38 | 38 | — | 8.8 | 17.6 | 38.4 | 8.3 | — | 0.9 | — | 9.8 |
| | Maryland | 8,617 | 3,212 | 351.82 | 1,136.33 | 1,006.02 | 650.68 | 1,104.17 | — | 181.23 | 56.69 | 9.29 |
| | Pennsylvania | 35,496 | 7,261 | 2,426.95 | 186.17 | 590.22 | 1,526.45 | 43.28 | 3.43 | 258.54 | 2,728.57 | 117.02 |
| | Virginia | 9,190 | 4,466 | 1,105.35 | 18.27 | 44.8 | 766.49 | 1,054.72 | — | 162.85 | 140.95 | 46.35 |
| | West Virginia | 11,550 | 5,313 | 1,760.29 | 346.75 | 392.74 | 1,157.03 | 14.87 | 1,311.83 | 1,016.42 | 2,706.79 | 1,208.95 |
| 4 | Alabama | 2,628 | 1,930 | 111.2 | — | — | 282.6 | 12 | — | 151.3 | — | — |
| | Florida | 10,159 | 3,147 | 1,833.4 | 1,189.6 | — | 1,126.6 | — | 411.1 | 205.8 | 465.7 | 916.3 |
| | Georgia | 9,996 | 5,986 | 0 | 65 | — | 1,925 | 433 | 0 | 203 | 0 | 0 |
| | Kentucky | 9,923 | 3,688 | 1,133.2 | 172.2 | 235.3 | 1,053.7 | 21.3 | 100.9 | 609.9 | 705.7 | 1,308.5 |
| | Mississippi | 14,972 | 10,824 | 10,471.5 | 224.3 | 177.82 | 634.07 | 235.4 | 707.32 | 566.7 | 151.91 | 415.15 |
| | North Carolina | 37,662 | 2,143 | 1,201.71 | 166 | 8.7 | 900.15 | 37 | 126.6 | 398.58 | 11.88 | 38.4 |
| | South Carolina | 15,405 | 4,011 | 1,462.35 | 35.55 | — | 2,862.6 | — | — | 679.09 | 23.49 | 219.4 |
| | Tennessee | 24,326 | 7,538 | 3,886.6 | 2,672.6 | 425 | 1,030.8 | — | 14.9 | 451.9 | 602.7 | 332.5 |
| 5 | Illinois | 15,587 | 7,844 | 4,395.06 | 2,613.12 | 795.31 | 1,020.47 | 137.19 | — | 1,640.98 | 1,047.79 | 37.51 |
| | Indiana | 17,541 | 4,230 | 124.84 | 81.91 | 38.35 | 113.25 | 0.3 | — | 71.34 | — | 71.05 |
| | Michigan | 13,117 | 2,456 | 1,059 | 248 | 108 | 344 | 30 | — | 423 | 24 | 9 |
| | Minnesota | 11,403 | 7,900 | 6,601.2 | 3,889.7 | — | 2,889 | 35.6 | 279.5 | 524.3 | 591.4 | 3,630 |
| | Ohio | 8,232 | 3,743 | 1,820.49 | 2,887.33 | 47.22 | 556.96 | 301.41 | 11.5 | 978.19 | 720.22 | 450.74 |
| | Ohio river valley | 981 | — | 981 | — | — | — | — | — | 981 | — | — |
| | Wisconsin | 23,530 | 10,029 | 3,539.9 | 2,693.25 | 1,483.05 | 989.7 | 1,082.5 | 89.3 | 1,169 | 153.9 | 51.3 |
| 6 | Arkansas | 8,112 | 1,177 | 705.5 | — | — | 13.5 | — | — | 97.9 | 24 | — |
| | Louisiana | 7,359 | 6,575 | 2,021 | 810 | 121 | 839 | 2,364 | 286 | 1,798 | 383 | 1,501 |
| | New Mexico | 4,284 | 2,675 | 2,531.85 | 376.7 | 2,103.35 | 97.1 | 422.7 | 196 | 262.8 | 596.2 | 149.4 |
| | Oklahoma | 14,071 | 7,647 | 4,481.18 | 867.38 | 1,423.18 | 779.58 | 86.26 | 197.5 | 190.49 | 1,157.31 | 847.63 |
| | Texas | 15,101 | 4,548 | 545 | — | — | 796 | 212.1 | — | 1,398.2 | 44 | 33.3 |
| 7 | Iowa | 6,390 | 1,903 | 1,018.04 | 790.99 | 399.29 | 45.05 | 98.63 | — | 105.43 | 17.14 | 24 |
| | Kansas | 18,236 | 14,819 | 13,128.31 | 1,171.84 | 5,911.66 | 1,295.94 | 6,148.69 | — | 4,882.77 | 2,107.05 | 575.59 |

*(Continued)*



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**Table 10B.21 (Continued)**

| | | | | Miles Alloted to Each Source | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | State by EPA Region | Assessed Miles | Miles Impaired | Agriculture | Hydro-modification | Habitat Modification (Other than Hydro-modification) | Urban Runoff/Storm Sewers | Natural Sources | Forestry/ Silviculture | Municipal Point Sources | Resource Extraction | Land Disposal |
| | Missouri | 21,615 | 10,321 | 7,624.4 | 3,758.9 | 21 | 44.5 | 154.5 | — | 92.8 | 179.7 | 0.3 |
| | Nebraska | 6,500 | 3,759 | — | — | — | — | — | — | — | — | — |
| 8 | Colorado | 41,837 | 1,244 | 123.3 | 4.7 | — | 244.16 | 474.05 | 10.52 | 145.1 | 757.46 | — |
| | Montana | 11,443 | 8,576 | 5,833.6 | 3,620.4 | 2,093.7 | 159 | 656.3 | 810.7 | 371.9 | 2,534.3 | 172.7 |
| | North Dakota | 14,965 | 7,224 | 6,982.77 | 2,621.39 | 2,458.94 | 501.38 | 509.75 | — | 556.7 | 489.06 | 97.25 |
| | South Dakota | 3,564 | 1,778 | 1,623.5 | — | 200 | 48.3 | 1,172.1 | 26.2 | — | 2.1 | — |
| | Utah | 10,519 | 2,825 | 2,298.25 | 887.8 | 960.41 | 85.79 | 1,377.24 | — | 125.39 | 205.16 | — |
| | Wyoming | 2,955 | 452 | 101.1 | — | — | 20.88 | 45.18 | — | 11.7 | 17.45 | — |
| 9 | Arizona | 4,052 | 986 | 538.85 | | 30.29 | 120.22 | 804.87 | — | 51.27 | 301 | 54.19 |
| | California | 25,269 | 20,949 | 17,064.33 | 9,217.46 | 11,662.3 | 2,204.68 | 4,906.15 | 14,140.2 | 3,266.88 | 6,838.16 | 667.86 |
| | Hawaii | 3,904 | 2,737 | 1,553.45 | 958.84 | 573.78 | 1,566.25 | 1,820.74 | 29.8 | 18.7 | 20 | 1 |
| | Nevada | 1,564 | 953 | 593.7 | 247.8 | — | 61.75 | 589.33 | — | — | — | — |
| 10 | Alaska | 1,421 | 518 | — | 13 | 21 | 109.8 | — | 16.5 | — | 309.3 | 108.6 |
| | Idaho | 17,333 | 8,230 | — | — | — | — | — | — | — | — | — |
| | Oregon | 53,735 | 13,937 | — | 1,624 | 2,103 | 505 | — | 7,707 | — | — | — |
| | Washington | 70,439 | 37,722 | 11,316.51 | 6,789.906 | — | 2,263.3 | 3,772.17 | 1,508.86 | 2,263.3 | 1,131.65 | 377.217 |
| | Jurisdictions | | | | | | | | | | | |
| | American Samoa | 17 | 16 | — | — | 6.7 | — | — | — | — | — | — |
| | Big Sandy Rancheria | 0 | — | — | — | — | — | — | — | — | — | — |
| | Guam | 167 | 63 | — | — | — | — | — | — | 1.67 | | 6.51 |
| | Hoopa Valley Tribe | 90 | — | — | — | — | — | — | — | — | — | — |
| | La Posta Band | 0 | — | — | — | — | — | — | — | — | — | — |
| | N Mariana Islands | 0 | 0 | — | — | — | — | — | — | — | — | — |
| | Pauma Band | 23 | 0 | 0 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Puerto Rico | 5,394 | 4,653 | 699.6 | 70.1 | 0 | 556.4 | 0.5 | 0 | 43 | 63.5 | 2,079.9 |
| | Round Valley Tribe | 35 | 35 | 15.5 | 14 | — | 8 | 23 | 24 | — | 14.5 | 10 |
| | **Total** | **699,946** | **269,258** | **128,859** | **53,850** | **37,654** | **34,871** | **31,033** | **28,156** | **27,988** | **27,695** | **17,821** |
| | **Percent of impaired** | | | **47.9%** | **20.0%** | **14.0%** | **13.0%** | **11.5%** | **10.5%** | **10.4%** | **10.3%** | **6.6%** |
| | **Percent of assessed** | | | **18.4%** | **7.7%** | **5.4%** | **5.0%** | **4.4%** | **4.0%** | **4.0%** | **4.0%** | **2.5%** |

*Note:* Includes leading sources of River and Stream Impairment Shown on Fig. 10B.4 plus natural sources and land disposal; —, no data.

*Source*: Abstracted from United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov/305b/2000report.

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**Table 10B.22 Relative Impact of Pollution Sources in Rivers and Streams with Impaired Uses in the United States in 1986 (Percent)**

| State | Industrial | Municipal | Combined Sewers | Nonpoint Sources | Natural | Other/ Unknown |
|---|---|---|---|---|---|---|
| Alaska | 85 | 1 | 0 | 12 | 0 | 2 |
| Arizona | 26 | 10 | 0 | 20 | 0 | 44 |
| California | 0 | 16 | 0 | 64 | 0 | 20 |
| Connecticut | 0 | 40 | 20 | 9 | 0 | 31 |
| Delaware | 8 | 6 | 8 | 59 | 19 | 0 |
| Florida | 25 | 29 | 0 | 40 | 2 | 4 |
| Georgia | 1 | 95 | 0 | 4 | 0 | 0 |
| Idaho | 2 | 3 | 0 | 78 | 17 | 0 |
| Indiana | 2 | 56 | 30 | 10 | 0 | 2 |
| Iowa | 0 | 3 | 0 | 97 | 0 | 0 |
| Kansas | 7 | 36 | 0 | 25 | 28 | 4 |
| Kentucky | 26 | 20 | 0 | 54 | 0 | 0 |
| Louisiana | 7 | 26 | 0 | 46 | 17 | 4 |
| Maine | 0 | 100 | 0 | 0 | 0 | 0 |
| Maryland | 5 | 30 | 0 | 50 | 15 | 0 |
| Massachusetts | 6 | 26 | 16 | 26 | 14 | 12 |
| Minnesota | 0 | 42 | 0 | 51 | 0 | 7 |
| Mississippi | 5 | 23 | 0 | 72 | 0 | 0 |
| Missouri | 0 | 1 | 0 | 99 | 0 | 0 |
| Montana | 2 | 3 | 0 | 95 | 0 | 0 |
| Nebraska | 1 | 7 | 0 | 92 | 0 | 0 |
| New Hampshire | 12 | 64 | 6 | 18 | 0 | 0 |
| New Jersey | 25 | 35 | 0 | 35 | 0 | 5 |
| New Mexico | 1 | 5 | 0 | 81 | 2 | 11 |
| New York | 20 | 40 | 13 | 11 | 0 | 16 |
| North Carolina | 12 | 17 | 0 | 71 | 0 | 0 |
| Ohio | 16 | 36 | 11 | 30 | 0 | 7 |
| Oregon | 3 | 10 | 0 | 57 | 30 | 0 |
| Pennsylvania | 7 | 13 | 1 | 71 | 3 | 5 |
| Rhode Island | 42 | 24 | 0 | 19 | 0 | 15 |
| South Carolina | 12 | 60 | 0 | 26 | 0 | 2 |
| South Dakota | 4 | 9 | 0 | 34 | 49 | 4 |
| Tennessee | 5 | 8 | 0 | 76 | 0 | 11 |
| Texas | 4 | 71 | 0 | 14 | 11 | 0 |
| Vermont | 11 | 22 | 0 | 50 | 11 | 6 |
| Virginia | 4 | 34 | 1 | 51 | 10 | 0 |
| West Virginia | 4 | 26 | 0 | 64 | 6 | 0 |
| Wisconsin | 1 | 1 | 0 | 98 | 0 | 0 |
| Wyoming | 10 | 4 | 0 | 43 | 43 | 0 |
| Puerto Rico | 11 | 21 | 0 | 63 | 0 | 5 |
| Guam | 5 | 10 | 15 | 50 | 20 | 0 |
| **Average (weighted)** | 9 | 17 | 1 | 65 | 6 | 2 |

*Source*: From U.S. Environmental Protection Agency, *National Water Quality Inventory*, 1986 Report to Congress.

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**Table 10B.23 River Miles Meeting the Fishable and Swimmable Goals of the Clean Water Act in the United States, by Jurisdiction, in 2000**

| | Fish Consumption | | | Swimming | | |
|---|---|---|---|---|---|---|
| **Jurisdiction** | **Total Assessed** | **Full Support** | **Threatened** | **Total Assessed** | **Full Support** | **Threatened** |
| Alabama | 0 | — | — | 0 | — | — |
| Alaska | 0 | — | — | 0 | — | — |
| American Samoa | — | — | — | 0 | — | — |
| Arizona | 3,798 | 3,632 | — | 3,714 | 3,457 | — |
| Arkansas | 8,112 | 7,739 | — | 7,629 | 7,596 | — |
| Big Sandy Rancheria | 0 | — | — | 0 | — | — |
| California | 11,842 | 1,638 | 715 | 17,896 | 2,151 | 1,343 |
| Colorado | 0 | — | — | 14,600 | 14,572 | 0 |
| Connecticut | 1,285 | 1,175 | 0 | 1,080 | 619 | 192 |
| Delaware | 67 | 54 | 0 | 2,506 | 99 | 0 |
| Delaware River Basin | 206 | 0 | 0 | 206 | 194 | 12 |
| District of Columbia | 24 | 0 | 0 | 38 | 2 | 0 |
| Florida | 3,771 | 1,002 | 0 | 9,524 | 5,998 | 552 |
| Georgia | 0 | — | — | 0 | — | — |
| Guam | — | — | — | 32 | 1 | — |
| Hawaii | 3,887 | 3,874 | 0 | 3,893 | 3,892 | 0 |
| Hoopa Valley Tribe | 90 | — | 90 | 90 | 90 | 0 |
| Idaho | 0 | 0 | 0 | 0 | 0 | 0 |
| Illinois | 3,969 | 2,920 | 0 | 2,944 | 742 | 0 |
| Indiana | 3,030 | 0 | 0 | 7,300 | 4,510 | 0 |
| Iowa | 1,892 | 1,452 | 441 | 836 | 254 | 149 |
| Kansas | 271 | 92 | 0 | 1,697 | — | — |
| Kentucky | 2,361 | 1,574 | 0 | 2,810 | 696 | 71 |
| La Posta Band | 0 | — | — | 0 | — | — |
| Louisiana | 0 | — | — | 7,063 | 4,030 | 74 |
| Maine | 31,752 | 31,325 | — | 31,752 | 31,576 | — |
| Maryland | 8,617 | 8,617 | — | 8,617 | 8,617 | — |
| Massachusetts | 644 | 240 | 0 | 933 | 457 | 9 |
| Michigan | 1,402 | — | — | 555 | — | — |
| Minnesota | 0 | — | — | 6,584 | 1,727 | 1 |
| Mississippi | 1,744 | 1,005 | 322 | 442 | 37 | 16 |
| Missouri | 21,837 | 21,671 | — | 5,405 | 5,355 | — |
| Montana | 9,080 | 1,510 | 8 | 7,066 | 3,620 | 0 |
| N. Mariana Islands | — | — | — | 0 | — | — |
| Nebraska | 2,056 | 2,056 | — | 3,239 | 365 | — |
| Nevada | 5 | 5 | — | 1,393 | 1,388 | — |
| New Hampshire | 279 | 0 | — | 2,769 | 2,657 | — |
| New Jersey | 124 | 0 | 30 | 176 | 30 | 0 |
| New Mexico | 93 | 0 | — | 4,134 | 4,103 | — |
| New York | 427 | 0 | 86 | 157 | 0 | 82 |
| North Carolina | 0 | — | — | 0 | — | — |
| North Dakota | 147 | — | — | 9,707 | 3,484 | 1,938 |
| Ohio | 451 | 0 | — | 1,536 | 805 | — |
| Ohio River Valley | 981 | 0 | — | 376 | 21 | — |
| Oklahoma | 10 | 0 | 0 | 5,096 | 1,112 | 2,016 |
| Oregon | 984 | 84 | 103 | 5,062 | 2,777 | 48 |
| Pauma Band | 23 | 23 | — | 23 | 23 | — |
| Pennsylvania | 0 | — | — | 0 | — | — |
| Puerto Rico | 0 | — | — | 5,394 | 193 | 1,008 |
| Rhode Island | 6 | 0 | 0 | 574 | 434 | 0 |
| Round Valley Tribes | — | — | — | 0 | — | — |
| South Carolina | 0 | — | — | 14,726 | 7,672 | — |
| South Dakota | 170 | 170 | — | 1,043 | 342 | — |
| Tennessee | 0 | — | — | 9,182 | 6,117 | 0 |
| Texas | 3,158 | 2,841 | 0 | 9,598 | 7,084 | 0 |
| Utah | 16 | 0 | 0 | 518 | 508 | 0 |
| Vermont | 5,201 | 4,956 | 13 | 5,310 | 4,115 | 650 |
| Virginia | 9,183 | 8,716 | 124 | 6,510 | 3,456 | 5 |

*(Continued)*

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**Table 10B.23 (Continued)**

| | Fish Consumption | | | Swimming | | |
|---|---|---|---|---|---|---|
| **Jurisdiction** | **Total Assessed** | **Full Support** | **Threatened** | **Total Assessed** | **Full Support** | **Threatened** |
| Washington | 58,990 | 15,294 | — | 70,439 | 58,892 | — |
| West Virginia | 870 | 201 | 0 | 11,408 | 6,790 | 2,615 |
| Wisconsin | 2,300 | 1,077 | 455 | 0 | — | — |
| Wyoming | 0 | — | — | 251 | 0 | 1 |
| **Total** | **205,153** | **124,941** | **2,387** | **313,832** | **212,659** | **10,779** |
| **Percent of assessed for use** | | **60.9%** | **1.2%** | | **67.8%** | **3.4%** |

*Note:* Fully Supporting, Fully supporting of all uses; Threatened, Fully supporting all uses but threatened for one or more uses; —, no data.

*Source*: Abstracted from United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

**Table 10B.24 Water-Quality Factors Affecting the Nation's Fisheries**

| Factor | Stream Miles | Percentage |
|---|---|---|
| Turbidity | 328,261 | 34.4 |
| High water temperature | 250,187 | 26.2 |
| Nutrient surplus | 119,519 | 12.5 |
| Toxic substances | 93,602 | 9.8 |
| Dissolved oxygen problem | 91,022 | 9.5 |
| Nutrient deficiency | 40,603 | 4.3 |
| Low water temperature | 29,877 | 3.1 |
| Other | 26,685 | 2.8 |
| pH too acidic | 24,793 | 2.6 |
| Low flow | 24,364 | 2.6 |
| Salinity | 17,217 | 1.8 |
| Sedimentation | 14,378 | 1.5 |
| Siltation | 9,644 | 1.0 |
| Gas supersaturation | 5,500 | 0.6 |
| Intermittent water | 4,839 | 0.5 |
| Herbicides and pesticides | 4,356 | 0.5 |
| pH too basic | 3,998 | 0.4 |
| Channelization | 2,937 | 0.3 |

*Note:* Expressed in total stream miles and as percentage of total miles.

*Source*: From Judy, R.D., and others, 1984. *1982 National Fisheries Survey*, U.S. Fish and Wildlife Service, FWS/OBS-84/06.

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**Table 10B.25 Limiting Factors Adversely Affecting the Nation's Fish Communities**

| Factor | Stream Miles | Percentage |
|---|---|---|
| Fish kills | 115,432 | 12.1 |
| Contamination | 81,927 | 8.6 |
| Overharvest | 35,566 | 3.7 |
| Poaching | 28,145 | 2.9 |
| Diseases/parasites | 21,873 | 2.3 |
| Fish stocking | 19,350 | 2.0 |
| Other | 18,063 | 1.9 |
| Habitat | 14,213 | 1.5 |
| Underharvest | 12,714 | 1.3 |
| Competition | 10,836 | 1.1 |
| Water quality | 5,879 | 0.6 |
| Tumors/lesions | 5,101 | 0.5 |
| Low flow | 3,194 | 0.3 |
| Small channel capacity | 1,657 | 0.2 |

*Note:* Expressed in total stream miles and as percentage of total miles.

*Source*: From Judy, R.D., and others, 1984. *1982 National Fisheries Survey*, U.S. Fish and Wildlife Service, FWS/OBS-84/06.

**Table 10B.26 Designated Use Support in Rivers and Streams of the United States by Jurisdiction, in 2000**

| Jurisdiction | Total River Miles | River Miles Assessed | Miles Fully Supporting | Miles Threatened | Miles Impaired | Miles Not Attainable |
|---|---|---|---|---|---|---|
| Alabama | 77,242.0 | 2,627.9 | 698.4 | 0 | 1,929.5 | 0 |
| Alaska | 365,000.0 | 1,420.5 | 902.6 | 0 | 517.9 | 0 |
| American Samoa | 169.0 | 16.9 | 0.7 | 0 | 16.2 | 0 |
| Arizona | 127,505.0 | 4,052.0 | 3,066 | 0 | 986.0 | 0 |
| Arkansas | 87,617.4 | 8,113.0 | 6,935.7 | 0 | 1,177.3 | 0 |
| Big Sandy Rancheria | — | 0 | — | — | — | — |
| California | 211,513.0 | 25,274.0 | 2,463 | 1,862.0 | 20,949 | 0 |
| Colorado | 107,403.0 | 41,470.0 | 40,226 | 0 | 1,244.0 | 0 |
| Connecticut | 5,830.0 | 1,207.2 | 479.4 | 334.2 | 389.4 | 4.2 |
| Delaware | 2,506.0 | 2,505.8 | 740.84 | 0 | 1,765.0 | 0 |
| Delaware River Basin | 206.0 | 206.0 | 0 | 0 | 206.0 | 0 |
| District of Columbia | 39.0 | 38.4 | 0 | 0 | 38.4 | 0 |
| Florida | 51,858.0 | 10,159.0 | 6,460 | 552.0 | 3,147.0 | 0 |
| Georgia | 70,150.0 | 9,999.0 | 4,013 | 0 | 5,986.0 | 0 |
| Guam | 228.0 | 167.1 | 23.1 | 81 | 63.0 | 0 |
| Hawaii | 3,904.7 | 3,993.8 | 1,254.71 | 0 | 2,737.1 | 2 |
| Hoopa Valley Tribe | 319.6 | 0.0 | — | — | — | — |
| Idaho | 115,595.0 | 17,332.6 | 8,434 | 669.0 | 8,229.6 | 0 |
| Illinois | 87,110.0 | 15,587.2 | 7,674.06 | 69.2 | 7,843.9 | 0 |
| Indiana | 35,673.0 | 17,541.0 | 13,310 | 0 | 4,230.0 | 1 |
| Iowa | 71,665.0 | 6,389.7 | 1,702.57 | 2,784.0 | 1,903.1 | 0 |
| Kansas | 134,338.0 | 18,236.0 | 3,417 | 0 | 14,819.0 | 0 |
| Kentucky | 49,105.0 | 9,922.7 | 5,954.75 | 280.1 | 3,687.8 | 0 |
| La Posta Band | — | 0.0 | — | — | — | — |
| Louisiana | 66,294.0 | 7,359.0 | 723 | 61 | 6,575.0 | 0 |
| Maine | 31,752.0 | 31,752.0 | 31,023 | 0 | 729.0 | 0 |
| Maryland | 8,789.0 | 8,616.8 | 5,405.3 | 0 | 3,211.5 | 0 |
| Massachusetts | 8,229.0 | 1,496.2 | 479.9 | 47 | 969.3 | 0 |
| Michigan | 51,438.0 | 10,309.0 | 7,829 | 24 | 2,456.0 | 0 |
| Minnesota | 91,944.0 | 11,403.4 | 1,149.6 | 2,181.7 | 7,899.6 | 172.48 |
| Mississippi | 84,003.0 | 14,972.2 | 3,263.2 | 855.5 | 10,824.2 | 29.2 |
| Missouri | 51,977.8 | 21,615.1 | 11,129.5 | 164.2 | 10,321.4 | 0 |

*(Continued)*

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**Table 10B.26 (Continued)**

| Jurisdiction | Total River Miles | River Miles Assessed | Miles Fully Supporting | Miles Threatened | Miles Impaired | Miles Not Attainable |
|---|---|---|---|---|---|---|
| Montana | 176,750.0 | 11,442.7 | 2,858.2 | 8.1 | 8,576.4 | 0 |
| N. Mariana Islands | 59.3 | 0.0 | 0 | 0 | 0 | 0 |
| Nebraska | 83,258.0 | 6,500.0 | 2,741.0 | 0 | 3,759.0 | 0 |
| Nevada | 143,578.0 | 1,564.3 | 611.5 | 0 | 952.8 | 0 |
| New Hampshire | 10,881.2 | 2,677.4 | 2,233.1 | 0 | 444.3 | 0 |
| New Jersey | 8,050.0 | 330.0 | 121.0 | 0 | 209.0 | 0 |
| New Mexico | 110,741.0 | 4,284.0 | 1,608.8 | 0 | 2,675.2 | 0 |
| New York | 52,337.0 | 2,914.0 | 0 | 1,833.0 | 1,081.0 | 0 |
| North Carolina | 37,662.0 | 32,072.0 | 29,929.0 | 0 | 2,143.0 | 0 |
| North Dakota | 54,427.4 | 14,964.5 | 1,656.9 | 6,083.5 | 7,224.2 | 0 |
| Ohio | 29,113.0 | 8,231.6 | 3,857.2 | 631.8 | 3,742.6 | 0 |
| Oklahoma | 78,778.0 | 14,070.8 | 1,558.3 | 4,764.8 | 7,647.4 | 100.3 |
| Oregon | 115,472.0 | 59,735.0 | 22,292.0 | 23,506.0 | 13,937.0 | 0 |
| Pauma Band | 22.9 | *22.9* | 22.9 | 0 | 0 | 0 |
| Pennsylvania | 83,161.0 | 35,496.0 | 28,235.0 | 0 | 7,261.0 | 0 |
| Puerto Rico | 5,394.2 | 5,394.2 | 150.4 | 590.5 | 4,653.3 | 0 |
| Rhode Island | 1,383.0 | 648.8 | 431.6 | 0 | 217.2 | 0 |
| Round Valley Tribes | 384.0 | *34.5* | 0 | 0 | 34.5 | 0 |
| South Carolina | 29,794.0 | 15,404.6 | 11,394.0 | 0 | 4,010.6 | 0 |
| South Dakota | 9,937.0 | 3,564.0 | 1,786.0 | 0 | 1,778.0 | 0 |
| Tennessee | 61,075.0 | 24,326.4 | 16,755.2 | 33.6 | 7,537.6 | 0 |
| Texas | 191,228.0 | 15,101.4 | 10,449.6 | 104.0 | 4,547.8 | 0 |
| Utah | 85,916.0 | 10,518.7 | 7,693.9 | 0 | 2,824.8 | 0 |
| Vermont | 7,099.0 | 5,462.2 | 3,105.3 | 1,188.4 | 1,168.5 | 0 |
| Virginia | 49,460.2 | 9,190.0 | 4,088.0 | 636.0 | 4,466.0 | 0 |
| Washington | 70,439.4 | 70,439.5 | 32,717.8 | 0 | 37,721.7 | 0 |
| West Virginia | 32,278.0 | 11,549.6 | 3,091.8 | 3,145.0 | 5,312.9 | 0 |
| Wisconsin | 55,000.0 | 23,530.3 | 6,858.0 | 6,634.8 | 10,029.3 | 8.2 |
| Wyoming | 108,767.0 | 2,954.8 | 2,124.1 | 379.2 | 451.5 | 0 |
| **Total** | **3,692,830.0** | **696,207.5** | **367,128.7** | **59,503.6** | **269,257.9** | **317.4** |
| **Percent of assessed for summary of use support** | | | **53%** | **9%** | **39%** | **0%** |

*Note:* Supporting, Fully supporting of all uses; Threatened, Fully supporting all uses but threatened for one or more uses; Impaired, Partially or not supporting one or more uses; Not Attainable, Not able to support one or more uses; —, no data.

*Source*: Abstracted from United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

**Table 10B.27 River and Stream Miles Supporting Uses in the United States, 1972–1982**

| Status | 1972 Miles | Percent | 1982 Miles | Percent |
|---|---|---|---|---|
| Supporting uses | 272 | 36 | 488 | 64 |
| Partially supporting uses | 46 | 6 | 167 | 22 |
| Not supporting uses | 30 | 4 | 35 | 5 |
| Unknown or not reported | 410 | 54 | 68 | 9 |

*Note:* Thousand of miles and percentage of waters assessed. Forty-nine (49) states reported on water-quality conditions between 1972 and 1982 for 758,000 river and stream miles. Some proportion of the 1972 data unknown or not reported fell into each of the levels of use support.

*Source*: From The Association of State and Interstate Water Pollution Control Administrators, in cooperation with the U.S. Environmental Protection Agency, 1984, *America's Clean Water: The States' Evaluation of Progress, 1972–1982*. Washington, DC; U.S. Geological Survey, National Water Summary 1986.

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**Table 10B.28 Condition of Perennial Streams Related to Their Ability to Support Fish in the United States, 1977–1982**

| Condition (Worst to Best) | 1977 | 1982 |
|---|---|---|
| 0 | 29.87 | 29.87 |
| 1 | 48.79 | 49.31 |
| 2 | 170.07 | 166.31 |
| 3 | 222.02 | 228.66 |
| 4 | 155.57 | 156.24 |
| 5 | 38.20 | 36.13 |

*Note:* Thousands of miles.

*Source*: From U.S. Department of the Interior, Fish and Wildlife Service. 1984. *1982 National Fisheries Survey*, vol. 1. FWS/OBS-84/06. Washington, DC; U.S. Geological Survey, National Water Summary 1986.

**Table 10B.29 Sources of Drinking Water Use Impairment in the United States**

| Contaminant Group | Specific Contaminant | |
|---|---|---|
| Pesticides | Atrazine | Molinate |
| | Metolachlor | Ethylene dibromide |
| | Triazine | |
| Volatile organic chemicals | Trichloroethylene | Dichloromethane |
| | Tetrachloroethylene | 1,1-Dichloroethane |
| | 1,1,1-Trichloroethane | 1,1-Dichloroethylene |
| | cis-1,2-Dichloroethylene | Toluene |
| | Trihalomethanes | Benzene |
| | Carbon tetrachloride | Dichlorobenzene |
| | Ethylbenzene | Methyl tertiary butyl ether |
| | 1,1,2,2-Tetrachloroethane | Xylene |
| Inorganic chemicals | Arsenic | Fluoride |
| | Nitrates | Manganese |
| | Iron | Lead |
| | Copper | Sodium |
| | Chloride | |
| Microbiological contaminants | Exceedance of total coliform rule | Exceedance of fecal coliform rule |

*Source*: From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

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**Table 10B.30 Frequency of Detection and Concentrations of Volatile Organic Compounds in Surface Water Source Samples Collected from United States Drinking Water Supplies between May 3, 1999 and October 23, 2000**

| | River | | | | | Reservoir | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Compound** | **Number of Samples** | **Number of Detects** | **Detection Frequency** | **Minimum Concentration** | **Maximum Concentration** | **Number of Samples** | **Number of Detects** | **Detection Frequency** | **Minimum Concentration** | **Maximum Concentration** |
| **Gasoline Oxygenates** | | | | | | | | | | |
| *tert*-Amyl methyl ether | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Diisopropyl ether | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Ethyl *tert*-butyl ether | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Methyl *tert*-butyl ether | 165 | 24 | 14 | 0.2 | 1.2 | 198 | 26 | 13 | 0.2 | 20 |
| **Other Gasoline Compounds** | | | | | | | | | | |
| Benzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 1 | 0.49 | 0.22 | 0.22 |
| *n*-Butylbenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| sec-Butylbenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| *tert*-Butylbenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Ethylbenzene | 170 | 0 | 0 | <0.2 | <0.2 | 203 | 2 | 0.98 | 0.26 | 1.0 |
| Naphthalene | 171 | 1 | 0.58 | 1.2 | 1.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Toluene | 169 | 5 | 3 | 0.2 | 0.45 | 200 | 2 | 1.0 | 0.52 | 1.0 |
| 1,3,5-Trimethylbenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| *o*-Xylene | 170 | 0 | 0 | <0.2 | <0.2 | 202 | 2 | 0.99 | 0.45 | 1.4 |
| *m*- *p*-Xylene | 168 | 1 | 0.60 | 0.35 | 0.35 | 202 | 2 | 0.99 | 0.71 | 2.5 |
| **Trihalomethanes** | | | | | | | | | | |
| Bromodichloromethane | 171 | 13 | 7.6 | 0.39 | 26 | 204 | 14 | 6.9 | 0.25 | 24 |
| Bromoform | 171 | 2 | 1.2 | 0.53 | 3.5 | 204 | 3 | 1.5 | 0.23 | 0,62 |
| Chlorodibromomethane | 171 | 8 | 4.7 | 0.25 | 20 | 204 | 9 | 4.4 | 0.22 | 8.9 |
| Chloroform | 168 | 27 | 16 | 0.20 | 34 | 203 | 25 | 12 | 0.21 | 85 |
| **Organic Syntheses** | | | | | | | | | | |
| Acrylonitrile | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Bromobenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Bromochloromethane | 170 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Carbon tetrachloride | 171 | 1 | 0.58 | 0.43 | 0.43 | 204 | 1 | 0.49 | 0.25 | 0.25 |
| Chlorobenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Chloroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 2-Chlorotoluene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 4-Chlorotoluene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Dibromomethane | 163 | 0 | 0 | <0.2 | <0.2 | 195 | 0 | 0 | <0.2 | <0.2 |
| 1,2-Dichlorobenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,3-Dichlorobenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,1-Dichloroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,2-Dichloroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,1-Dichloroethene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| cis-1,2-Dichloroethene | 171 | 1 | 0.58 | 0.93 | 0.93 | 204 | 0 | 0 | <0.2 | <0.2 |
| trans-1,2-Dichloro-ethene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,2-Dichloropropane | 163 | 0 | 0 | <0.2 | <0.2 | 195 | 0 | 0 | <0.2 | <0.2 |
| 1,3-Dichloropropane | 170 | 0 | 0 | <0.2 | <0.2 | 203 | 0 | 0 | <0.2 | <0.2 |
| 2,2-Dichloropropane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,1-Dichloropropene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |

*(Continued)*



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**Table 10B.30 (Continued)**

| Compound | River | | | | | Reservoir | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Samples | Number of Detects | Detection Frequency | Minimum Concentration | Maximum Concentration | Number of Samples | Number of Detects | Detection Frequency | Minimum Concentration | Maximum Concentration |
| Hexachlorobutadiene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Hexachloroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Isopropylbenzene | 170 | 0 | 0 | <0.2 | <0.2 | 204 | 1.0 | 0.49 | 0.37 | 0.37 |
| *p*-Isopropyltoluene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Methylene chloride | 171 | 1 | 0.58 | 2.6 | 2.6 | 204 | 0 | 0 | <0.2 | <0.2 |
| Methyl ethyl ketone | 171 | 1 | 0.98 | 120 | 120 | 204 | 2 | 0.58 | 2.3 | 9.1 |
| *n*-Propylbenzene | 170 | 0 | 0 | <0.2 | <0.2 | 204 | 1.0 | 0.58 | 0.21 | 0.21 |
| Styrene | 169 | 1 | 0.59 | 2.3 | 2.3 | 202 | 2 | 0.99 | 0.41 | 0.97 |
| 1,1,1,2-Tetrachloroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,1,2,2-Tetrachloroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Tetrachloroethene | 171 | 3 | 1.8 | 0.29 | 5.5 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,1,1-Trichloroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,1,2-Trichloroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Trichloroethene | 171 | 3 | 1.8 | 0.31 | 2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,2,3-Trichloropropane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,2,4-Trimethylbenzene | 170 | 2 | 1.2 | 0.43 | 0.77 | 204 | 1 | 0.49 | 0.36 | 0.36 |
| Vinyl bromide | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Vinyl chloride | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,2,3-Trichlorobenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,2,4-Trichlorobenzene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| **Fumigants** | | | | | | | | | | |
| Bromomethane | 171 | 1 | 0.58 | 0.22 | 0.22 | 204 | 0 | 0 | <0.2 | <0.2 |
| 1,4-Dichlorobenzene | 171 | 1 | 0.58 | 0.22 | 0.22 | 203 | 1 | 0.49 | 0.36 | 0.36 |
| cis-1,3-Dichloropropene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| *trans*−1,3-Dichloropropene | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| **Refrigerants** | | | | | | | | | | |
| Chloromethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Dichlorodifluoro-methane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| Trichlorofluoromethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |
| l,l,2-Trichloro-l,2,2-trifluoroethane | 171 | 0 | 0 | <0.2 | <0.2 | 204 | 0 | 0 | <0.2 | <0.2 |

*Note:* Concentrations are in micrograms per liter.

*Source*: From Grady, S., 2003, *A National Survey of Methyl tert-Butyl Ether and Other Volatile Organic Compounds in Drinking Water Sources: Results of a Random Survey*, U.S. Geological Survey Water-Resource Investigations Report 02-4079, www.usgs.gov.

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**Table 10B.31 Summary of Analytical Results of United States Streams Sampled for 95 Pharmaceuticals, Hormones and Other Organic Wastewater Contaminants, 1999–2000**

| Chemical (Method) | CASRN | N | RL (μg/L) | freq (%) | max (μg/L) | med (μg/L) | Use | MCL or HAL (23) (μg/L) | Lowest $LC_{50}$ for the Most Sensitive Indicator Species (μg/L)/ No. of Aquatic Studies Identified (24) |
|---|---|---|---|---|---|---|---|---|---|
| **Veterinary and Human Antibiotics** | | | | | | | | | |
| Carbodox (1) | 6804-07-5 | 104 | 0.10 | 0 | ND | ND | Antibiotic | — | -/1 |
| Chlortetracycline (1) | 57-62-5 | 115 | 0.05 | 0 | ND | ND | Antibiotic | — | 88,000[a]/3 |
| Chlortetracycline (2) | 57-62-5 | 84 | 0.10 | 2.4 | 0.69 | 0.42 | Antibiotic | — | 88,000[a]/3 |
| Ciprofloxacin (1) | 85721-33-1 | 115 | 0.02 | 2.6 | 0.03 | 0.02 | Antibiotic | — | -/0 |
| Doxycycline (1) | 564-25-0 | 115 | 0.1 | 0 | ND | ND | Antibiotic | — | -/0 |
| Enrofloxacin (1) | 93106-60-6 | 115 | 0.02 | 0 | ND | ND | Antibiotic | — | 40[b]/29 |
| Erythromycin-$H_2O$ (1) | 114-07-8 | 104 | 0.05 | 21.5 | 1.7 | 0.1 | Erythromycin metabolite | — | 665,000[b]/35 |
| Lincomycin (1) | 154-21-2 | 104 | 0.05 | 19.2 | 0.73 | 0.06 | Antibiotic | — | -/0 |
| Norfloxacin (1) | 70458-96-7 | 115 | 0.02 | 0.9 | 0.12 | 0.12 | Antibiotic | — | -/6 |
| Oxytetracycline (1) | 79-57-2 | 115 | 0.1 | 0 | ND | ND | Antibiotic | — | 102,000[a]/46 |
| Oxytetracycline (2) | 79-57-2 | 84 | 0.10 | 1.2 | 0.34 | 0.34 | Antibiotic | — | 102,000[a]/46 |
| Roxithromycin (1) | 80214-83-1 | 104 | 0.03 | 4.8 | 0.18 | 0.05 | Antibiotic | — | -/0 |
| Sarafloxacin (1) | 98105-99-8 | 115 | 0.02 | 0 | ND | ND | Antibiotic | — | -/0 |
| Sulfachloropyridazine (2) | 80-32-0 | 84 | 0.05 | 0 | ND | ND | Antibiotic | — | -/0 |
| Sulfadimethoxine (1) | 122-11-2 | 104 | 0.05 | 0 | ND | ND | Antibiotic | — | -/5 |
| Sulfadimethoxine (2) | 122-11-2 | 84 | 0.05 | 1.2 | 0.06 | 0.06 | Antibiotic | — | -/5 |
| Sulfamerazine (1) | 127-79-7 | 104 | 0.05 | 0 | ND | ND | Antibiotic | — | 100,000[c]/17 |
| Sulfamerazine (2) | 127-79-7 | 84 | 0.05 | 0 | ND | ND | Antibiotic | — | 100,000[c]/17 |
| Sulfamethazine (1) | 57-68-1 | 104 | 0.05 | 4.8 | 0.12 | 0.02 | Antibiotic | — | 100,000[c]/17 |
| Sulfamethazine (2) | 57-68-1 | 84 | 0.05 | 1.2 | 0.22 | 0.22 | Antibiotic | — | 100,000[c]/17 |
| Sulfamethizole (1) | 144-82-1 | 104 | 0.05 | 1.0 | 0.13 | 0.13 | Antibiotic | — | -/0 |
| Sulfamethoxazole (1) | 723-46-6 | 104 | 0.05 | 12.5 | 1.9 | 0.15 | Antibiotic | — | -/0 |
| Sulfamethoxazole (3) | 723-46-6 | 84 | 0.023 | 19.0 | 0.52 | 0.066 | Antibiotic | — | -/0 |
| Sulfathiazole (1) | 72-14-0 | 104 | 0.10 | 0 | ND | ND | Antibiotic | — | -/0 |
| Sulfathiazole (2) | 72-14-0 | 84 | 0.05 | 0 | ND | ND | Antibiotic | — | -/0 |
| Tetracycline (1) | 60-54-8 | 115 | 0.05 | 0 | ND | ND | Antibiotic | — | 550,000[b]/3 |
| Tetracycline (2) | 60-54-8 | 84 | 0.10 | 1.2 | 0.11 | 0.11 | Antibiotic | — | 550,000[b]/3 |
| Trimethoprim (1) | 738-70-5 | 104 | 0.03 | 12.5 | 0.71 | 0.15 | Antibiotic | — | 3,000[c]/4 |
| Trimethoprim (3) | 738-70-5 | 84 | 0.014 | 27.4 | 0.30 | 0.013 | Antibiotic | — | 3,000[c]/4 |
| Tylosin (1) | 1401-69-0 | 104 | 0.05 | 13.5 | 0.28 | 0.04 | Antibiotic | — | -/0 |
| Virginiamycin (1) | 21411-53-0 | 104 | 0.10 | 0 | ND | ND | Antibiotic | — | -/0 |
| **Prescription Drugs** | | | | | | | | | |
| Albuterol (salbutamol) (3) | 18559-94-9 | 84 | 0.029 | 0 | ND | ND | Antiasthmatic | — | -/0 |
| Cimetidine (3) | 51481-61-9 | 84 | 0.007 | 9.5 | 0.58[d] | 0.074[d] | Antacid | — | -/0 |
| Codeine (3) | 76-57-3 | 46 | 0.24 | 6.5 | 0.019 | 0.012 | Analgesic | — | -/0 |
| Codeine (4) | 76-57-3 | 85 | 0.1 | 10.6 | 1.0[d] | 0.2[d] | Analgesic | — | -/0 |
| Dehydronifedipine (3) | 67035-22-7 | 84 | 0.01 | 14.3 | 0.03 | 0.012 | Antianginal | — | -/0 |
| Digoxin (3) | 20830-75-5 | 46 | 0.26 | 0 | ND[d] | ND[d] | Cardiac stimulant | — | 10,000,000[a]/24 |
| Digoxigenin (3) | 1672-46-4 | 84 | 0.008 | 0 | ND | ND | Digoxin metabolite | — | -/0 |
| Diltiazem (3) | 42399-41-7 | 84 | 0.012 | 13.1 | 0.049 | 0.021 | Antihypertensive | — | -/0 |

*(Continued)*



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**Table 10B.31 (Continued)**

| Chemical (Method) | CASRN | N | RL (μg/L) | freq (%) | max (μg/L) | med (μg/L) | Use | MCL or HAL (23) (μg/L) | Lowest $LC_{50}$ for the Most Sensitive Indicator Species (μg/L)/ No. of Aquatic Studies Identified (24) |
|---|---|---|---|---|---|---|---|---|---|
| Enalaprilat (3) | 76420-72-9 | 84 | 0.15 | 1.2 | 0.046[d] | 0.046[d] | Enalapril maleate (antihypertensive) metabolite | — | -/0 |
| Fluoxetine[h] (3) | 54910-89-3 | 84 | 0.018 | 1.2 | 0.012[d] | 0.012[d] | Antidepressant | — | -/0 |
| Gemfibrozil (3) | 25812-30-0 | 84 | 0.015 | 3.6 | 0.79 | 0.048 | Antihyperlipidemic | — | -/0 |
| Metformin (3) | 657-24-9 | 84 | 0.003 | 4.8 | 0.15[d] | 0.11[d] | Antidiabetic | — | -/0 |
| Paroxetine metabolite (3) | — | 84 | 0.26 | 0 | ND[d] | ND[d] | Paroxetine (antidepressant) metabolite | — | -/0 |
| Ranitidine (3) | 66357-35-5 | 84 | 0.01 | 1.2 | 0.01[d] | 0.01[d] | Antacid | — | -/0 |
| Warfarin (3) | 81-82-2 | 84 | 0.001 | 0 | ND | ND | Anticoagulant | — | 16,000[c]/33 |
| **Nonprescription Drugs** | | | | | | | | | |
| Acetaminophen (3) | 103-90-2 | 84 | 0.009 | 23.8 | 10 | 0.11 | Antipyretic | — | 6,000[a]/14 |
| Caffeine (3) | 58-08-2 | 84 | 0.014 | 61.9 | 6.0 | 0.081 | Stimulant | — | 40,000[i]/77 |
| Caffeine (4) | 58-08-2 | 85 | 0.08 | 70.6 | 5.7 | 0.1 | Stimulant | — | 40,000[i]/77 |
| Cotinine (3) | 486-56-6 | 84 | 0.023 | 38.1 | 0.90 | 0.024 | Nicotine metabolite | — | -/0 |
| Cotinine (4) | 486-56-6 | 54 | 0.04 | 31.5 | 0.57 | 0.05 | Nicotine metabolite | — | -/0 |
| 1,7-dimethylxanthine (3) | 611-59-6 | 84 | 0.018 | 28.6 | 3.1[d] | 0.11[d] | Caffeine metabolite | — | -/0 |
| Ibuprofen (3) | 15687-27-1 | 84 | 0.018 | 9.5 | 1.0 | 0.20 | Antiinflammatory | — | -/0 |
| **Other Wastewater-Related Compounds** | | | | | | | | | |
| 1,4-dichlorobenzene (4) | 106-46-7 | 85 | 0.03 | 25.9 | 4.3 | 0.09 | Deodorizer | 75 | 1,100[c]/190 |
| 2,6-di-*tert*-butylphenol[h] (4) | 128-39-2 | 85 | 0.08 | 3.5 | 0.11[d] | 0.06[d] | Antioxidant | — | -/2 |
| 2,6-di*tert*-butyl-1,4-benzoquinone[h] (4) | 719-22-2 | 85 | 0.10 | 9.4 | 0.46 | 0.13 | Antioxidant | — | -/0 |
| 5-methyl-1H-benzotriazole (4) | 136-85-6 | 54 | 0.10 | 31.5 | 2.4 | 0.39 | Antiocorrosive | — | -/0 |
| Acetophenone (4) | 98-86-2 | 85 | 0.15 | 9.4 | 0.41 | 0.15 | Fragrance | — | 155,000[i]/21 |
| Anthracene (4) | 120-12-7 | 85 | 0.05 | 4.7 | 0.11 | 0.07 | Pah | — | 5.4[i]/188 |
| Benzo[a]pyrene[h] (4) | 50-32-8 | 85 | 0.05 | 9.4 | 0.24 | 0.04 | Pah | 0.2 | 1.5[a]/428 |
| 3-*tert*-butyl-4-hydroxy anisole[h] (4) | 25013-16-5 | 85 | 0.12 | 2.4 | 0.2[d] | 0.1[d] | Antioxidant | — | 870[c]/14 |
| Butylated hydroxyl toluene (4) | 128-37-0 | 85 | 0.08 | 2.4 | 0.1[d] | 0.1[d] | Antioxidant | — | 1,440[a]/15 |
| Bis(2-ethylhexyl) adipate (4) | 103-23-1 | 85 | 2.0 | 3.5 | 10[g] | 3[g] | Plasticizer | 400 | 480[a]/9 |
| Bis(2-ethylhexyl) phthalate[h] (4) | 117-81-7 | 85 | 2.5 | 10.6 | 20[g] | 7[g] | Plasticizer | 6 | 7,500[a]/309 |
| **Other Wastewater-Related Compounds** | | | | | | | | | |
| Bisphenol A[h] (4) | 80-05-7 | 85 | 0.09 | 41.2 | 12 | 0.14 | Plasticizer | — | 3,600[i]/26 |
| Carbaryl[h] (4) | 63-25-2 | 85 | 0.06 | 16.5 | 0.1[d] | 0.04[d] | Insecticide | 700 | 0.4[a]/1,541 |
| *cis*-Chlordane[h] (4) | 5103-71-9 | 85 | 0.04 | 4.7 | 0.1 | 0.02 | Insecticide | 2 | 7.4[b]/28 |
| Chlorpyrifos[h] (4) | 2921-88-2 | 85 | 0.02 | 15.3 | 0.31 | 0.06 | Insecticide | 20 | 0.1[a]/1,794 |
| Diazinon[h] (4) | 333-41-5 | 85 | 0.03 | 25.9 | 0.35 | 0.07 | Insecticide | 0.6 | 0.56[a]/1,040 |
| Dieldrin[h] (4) | 60-57-1 | 85 | 0.08 | 4.7 | 0.21 | 0.18 | Insecticide | 0.2 | 2.6[c]/1,540 |
| Diethylphthalate[h] (4) | 84-66-2 | 54 | 0.25 | 11.1 | 0.42 | 0.2 | Plasticizer | — | 12,000[c]/129 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ethanol,2-butoxy-phosphate (4) | 78-51-3 | 85 | 0.2 | 45.9 | 6.7 | 0.51 | Plasticizer | — | 10,400[i]/7 |
| Fluoranthene (4) | 206-44-0 | 85 | 0.03 | 29.4 | 1.2 | 0.04 | PAH | — | 74[i]/216 |
| Lindane[h] (4) | 58-89-9 | 85 | 0.05 | 5.9 | 0.11 | 0.02 | Insecticide | 0.2 | 30[c]/1,979 |
| Methyl parathion[h] (4) | 298-00-0 | 85 | 0.06 | 1.2 | 0.01 | 0.01 | Insecticide | 2 | 12[a]/888 |
| 4-Methyl phenol (4) | 106-44-5 | 85 | 0.04 | 24.7 | 0.54 | 0.05 | Disinfectant | — | 1,400[a]/74 |
| Naphthalene (4) | 91-20-3 | 85 | 0.02 | 16.5 | 0.08 | 0.02 | PAH | 20 | 910[c]/519 |
| *N,N*-diethyltoluamide (4) | 134-62-3 | 54 | 0.04 | 74.1 | 1.1 | 0.06 | Insect repellant | — | 71,250[c]/9 |
| 4-Nonylphenol[h] (4) | 251-545-23 | 85 | 0.50 | 50.6 | 40[f] | 0.8[f] | Nonionic detergent metabolite | — | 130[i]/135 |
| 4-Nonylphenol Monoethoxylate[h] (4) | — | 85 | 1.0 | 45.9 | 20[f] | 1[f] | Nonionic detergent metabolite | | 14,450[a]/4 |
| 4-Nonylphenol diethoxylate[h] (4) | — | 85 | 1.1 | 36.5 | 9[f] | 1[f] | Nonionic detergent metabolite | — | 5,500[a]/6 |
| 4-Octylphenol Monoethoxylate[h] (4) | — | 85 | 0.1 | 43.5 | 2[f] | 0.2[f] | Nonionic detergent metabolite | — | -/0 |
| 4-Octylphenol diethoxylate[h] (4) | — | 85 | 0.2 | 23.5 | 1[f] | 0.1[f] | Nonionic detergent metabolite | — | -/0 |
| Phenanthrene (4) | 85-01-8 | 85 | 0.06 | 11.8 | 0.53 | 0.04 | PAH | — | 590[a]/192 |
| Phenol (4) | 108-95-2 | 85 | 0.25 | 8.2 | 1.3[e] | 0.7[e] | Disinfectant | 400 | 4,000[c]/2,085 |
| Phthalic anhydride (4) | 85-44-9 | 85 | 0.25 | 17.6 | 1[e] | 0.7[e] | Plastic manufacturing | — | 40,400[c]/5 |
| Pyrene (4) | 129-00-0 | 85 | 0.03 | 28.2 | 0.84 | 0.05 | PAH | — | 90.9[a]/112 |
| Tetrachloroethylene (4) | 127-18-4 | 85 | 0.03 | 23.5 | 0.70[d] | 0.07[d] | Solvent, degreaser | 5 | 4,680[c]/147 |
| Triclosan[h] (4) | 3380-34-5 | 85 | 0.05 | 57.6 | 2.3 | 0.14 | Antimicrobial disinfectant | — | 180[i]/3 |
| Tri(2-chloroethyl) phosphate (4) | 115-96-8 | 85 | 0.04 | 57.6 | 0.54 | 0.1 | Fire retardant | — | 66,000[b]/8 |
| Tri(dichlorisopropyl) Phosphate (4) | 13674-87-8 | 85 | 0.1 | 12.9 | 0.16 | 0.1 | Fire retardant | — | 3,600[b]/9 |
| Triphenyl phosphate (4) | 115-86-6 | 85 | 0.1 | 14.1 | 0.22 | 0.04 | Plasticizer | — | 280[c]/66 |
| **Steroids and Hormones** | | | | | | | | | |
| *cis*-Androsterone[h] (5) | 53-41-8 | 70 | 0.005 | 14.3 | 0.214 | 0.017 | Urinary steroid | — | -/0 |
| Cholesterol (4) | 57-88-5 | 85 | 1.5 | 55.3 | 10[d] | 1[d] | Plant/animal steroid | — | -/0 |
| Cholesterol (5) | 57-88-5 | 70 | 0.005 | 84.3 | 60[g] | 0.83 | Plant/animal steroid | — | -/0 |
| Coprostanol (4) | 360-68-9 | 85 | 0.6 | 35.3 | 9.8[d] | 0.70[d] | Fecal steroid | — | -/0 |
| Coprostanol (5) | 360-68-9 | 70 | 0.005 | 85.7 | 150[g] | 0.088 | Fecal steroid | — | -/0 |
| Equilenin[h] (5) | 517-09-9 | 70 | 0.005 | 2.8 | 0.278 | 0.14 | Estrogen replacement | — | -/0 |
| Equilin[h] (5) | 474-86-2 | 70 | 0.005 | 1.4 | 0.147 | 0.147 | Estrogen replacement | — | -/0 |
| 17$\alpha$-ethynyl estradiol[h] (5) | 57-63-6 | 70 | 0.005 | 15.7 | 0.831 | 0.073 | Ovulation inhibitor | — | -/22 |
| 17$\alpha$-estradiol[h] (5) | 57-91-0 | 70 | 0.005 | 5.7 | 0.074 | 0.03 | Reproductive hormone | — | -/0 |
| 17$\beta$-estradiol[h] (4) | 50-28-2 | 85 | 0.5 | 10.6 | 0.2[d] | 0.16[d] | Reproductive hormone | — | -/0 |
| 17$\beta$-estradiol[h] (5) | 50-28-2 | 70 | 0.005 | 10.0 | 0.093 | 0.009 | Reproductive hormone | — | -/0 |
| Estriol[h] (5) | 50-27-1 | 70 | 0.005 | 21.4 | 0.051 | 0.019 | Reproductive hormone | — | -/0 |

*(Continued)*



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**Table 10B.31 (Continued)**

| Chemical (Method) | CASRN | N | RL (μg/L) | freq (%) | max (μg/L) | med (μg/L) | Use | MCL or HAL (23) (μg/L) | Lowest $LC_{50}$ for the Most Sensitive Indicator Species (μg/L)/ No. of Aquatic Studies Identified (24) |
|---|---|---|---|---|---|---|---|---|---|
| Estrone[h] (5) | 53-16-7 | 70 | 0.005 | 7.1 | 0.112 | 0.027 | Reproductive hormone | — | -/11 |
| Mestranol[h] (5) | 72-33-3 | 70 | 0.005 | 10.0 | 0.407 | 0.074 | Ovulation inhibitor | — | -/0 |
| 19-Norethisterone[h] (5) | 68-22-4 | 70 | 0.005 | 12.8 | 0.872 | 0.048 | Ovulation inhibitor | — | -/0 |
| Progesterone[h] (5) | 57-83-0 | 70 | 0.005 | 4.3 | 0.199 | 0.11 | Reproductive hormone | — | -/0 |
| Stigmastanol (4) | 19466-47-8 | 54 | 2.0 | 5.6 | 4[d] | 2[d] | Plant steroid | — | -/0 |
| Testosterone[h] (5) | 58-22-0 | 70 | 0.005 | 2.8 | 0.214 | 0.116 | Reproductive hormone | — | -/4 |

*Note:* CASRN, Chemical Abstracts service Registry Number; *N*, number of samples; RL, reporting level; freq, frequency of detection; max, maximum concentration; med, median detectable concentration; MCL, maximum contaminant level; HAL, health advisory level; $LC_{50}$, lethal concentration with 50% mortality; Nd, not detected; —, not available; PAH, polycyclic aromatic hydrocarbon.

[a] Daphnia magna (water flea), 48 h exposure $LC_{50}$.
[b] Other species and variable conditions.
[c] Oncorhynchus mykiss (rainbow trout), 96 h exposure $LC_{50}$.
[d] Concentration estimated, average recovery $<60\%$.
[e] Concentration estimated, compound routinely detected in laboratory blanks.
[f] Concentration estimated, reference standard prepared from a technical mixture.
[g] Concentration estimated, value greater than highest point on calibration curve.
[h] Compounds suspected of being hormonally active.
[i] Pimephales promelas (fathead minnow), 96 h exposure $LC_{50}$.

*Source*: From Kolpin, D.W., Furlong, E.T., Meyer, M.T., Thurman, E. M., Zaugg, S. D., Barber, L.B., and Buxton, H.T., 2002, Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999–2000. *A National Reconnaissance, Environmental Science & Technology*, vol 36, no. 6, Web Release Date: March 15, 2002, 10.1021/es011055j S0013-936X(01)01055-0, www.usgs.gov.

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**Table 10B.32 Regions 1–10: River Reach and Watershed Evaluation Summary, United States National Sediment Quality Survey**

| EPA Region (State) | River Reach Evaluation[a] | | | | | Watershed Evaluation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Number of River Reaches | River Reaches with at Least One Tier 1 Station | River Reaches with at Least One Tier 2 Station and Zero Tier 1 Stations | River Reaches with All Tier 3 Stations | River Reaches with No Data | Total Number of Watersheds | Watersheds Containing APCs | Watersheds with at Least One Tier 1 Station | Watersheds with at Least One Tier 2 Station and Zero Tier 1 Stations | Watersheds with All Tier 3 Stations | Watersheds with No Data |
| Region 1 (CT, ME, MA, NH, RI, VT) | 2,764 | 97 (3.5%) | 23 (0.8%) | 5 (0.2%) | 2,639 (95.5%) | 62 | 9 (14.5%) | 13 (21.0%) | 6 (9.7%) | 0 (0.0%) | 34 (54.8%) |
| Region 2 (NJ, NY, PR) | 1,845 | 217 (11.8%) | 102 (5.5%) | 45 (2.4%) | 1,481 (80.3%) | 71 | 17 (23.9%) | 35 (49.3%) | 3 (4.2%) | 3 (4.2%) | 13 (18.3%) |
| Region 3 (DE, DC, MD, PA, VA, WV) | 3,388 | 385 (11.4%) | 313 (9.2%) | 301 (8.9%) | 2,389 (70.5%) | 126 | 7 (5.6%) | 96 (76.2%) | 11 (8.7%) | 4 (3.2%) | 8 (6.3%) |
| Region 4 (AL, FL, GA, KY, MS, NC, SC, TN) | 10,078 | 444 (4.4%) | 461 (4.6%) | 301 (3.0%) | 8,872 (88.0%) | 307 | 13 (4.2%) | 142 (46.3%) | 57 (18.6%) | 25 (8.1%) | 70 (22.8%) |
| Region 5 (IL, IN, MI, MN, OH, WI) | 6,151 | 532 (8.6%) | 401 (6.5%) | 316 (5.1%) | 4,902 (79.7%) | 278 | 25 (9.0%) | 144 (51.8%) | 31 (11.2%) | 19 (6.8%) | 59 (21.2%) |
| Region 6 (AR, LA, NM, OK, TX) | 7,577 | 226 (3.0%) | 222 (2.9%) | 289 (3.8%) | 6,840 (90.3%) | 402 | 4 (1.0%) | 117 (29.1%) | 69 (17.2%) | 44 (10.9%) | 168 (41.8%) |
| Region 7 (IA, KS, MO, NE) | 4.915 | 94 (1.9%) | 161 (3.3%) | 136 (2.8%) | 4,524 (92.0%) | 238 | 1 (0.4%) | 60 (25.2%) | 72 (30.3%) | 29 (12.2%) | 76 (31.9%) |
| Region 8 (CO, MT, ND, SD, UT, WY) | 13,860 | 59 (0.4%) | 77 (0.6%) | 68 (0.5%) | 13,656 (98.5%) | 385 | 1 (0.3%) | 34 (8.8%) | 41 (10.6%) | 31 (8.1%) | 278 (72.2%) |
| Region 9 (AZ, CA, HI, NV) | 4,686 | 156 (3.3%) | 63 (1.3%) | 40 (0.9%) | 4,427 (94.5%) | 288 | 19 (6.6%) | 41 (14.2%) | 19 (6.6%) | 15 (5.2%) | 194 (67.4%) |
| Region 10 (AK, ID, OR, WA) | 10,462 | 177 (1.7%) | 121 (1.2%) | 49 (0.5%) | 10,115 (96.7%) | 355 | 10 (2.8%) | 48 (13.5%) | 29 (8.2%) | 21 (5.9%) | 247 (69.6%) |
| **Total for United States[b]** | **64,591** | **2,298 (3.6%)** | **1,891 (2.9%)** | **1,506 (2.3%)** | **58,896 (91.2%)** | **2,264** | **96 (4.2%)** | **658 (29.1%)** | **302 (13.3%)** | **168 (7.4%)** | **1,040 (45.9%)** |

Tier 1, Associated adverse effects on aquatic life or human health are probable.
Tier 2, Associated adverse effects on aquatic life or human health are possible.
Tier 3, No indication of adverse effects.

[a] River reaches based on EPA River Reach File (RF1). RF1 does not include data outside the contiguous United States.
[b] Because some reaches and watersheds occur in more than one region, the total number of reaches and watersheds in each category or the country might not equal the sum of reaches or watersheds in the regions.

*Source*: From USEPA, 2004, The incidence and severity of sediment contamination in surface waters of the United States, National sediment contamination in surface waters of the United States, *National Sediment Quality Survey: Sectond Edition*, EPA 823-R-04-007, www.epa.gov.



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**Table 10B.33 Statistical Summary of Semivolatile Organic Compounds in Streambed Sediment That Exceeded Sediment Quality Screening Values in the United States 1992–1995**

| Compound Name | Number of Sites | Percent Detection | Concentration, in μg/kg Dry Weight at the Given Percentile and Maximum Value | | | | Lower Screening Value | | Upper Screening Value | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 75th | 90th | 95th | Maximum | μg/kg | N | μg/kg | N |
| **Polycyclic aromatic hydrocarbons** | | | | | | | | | | |
| Acenaphthene[a] | 530 | 10.0 | <50 | 51 | 94 | 1,500 | 6.71 | 53 | 500 | 3 |
| Acenaphthylene[a] | 535 | 12.9 | <50 | 77 | 170 | 1,500 | 5.87 | 69 | 640 | 4 |
| Anthracene[b] | 533 | 22 | <50 | 150 | 520 | 4,100 | 57.2 | 106 | 845 | 14 |
| Benz[a]anthracene[b] | 518 | 30.7 | 79 | 430 | 1,100 | 12,000 | 108 | 108 | 1,050 | 28 |
| Benzo[b]fluoranthene[a] | 533 | 36.8 | 92 | 460 | 1,400 | 12,000 | 3,600 | 5 | — | — |
| Benzo[k]fluoranthene[a] | 532 | 33.1 | 84 | 400 | 1,100 | 10,000 | 3,600 | 5 | — | — |
| Benzo[a]pyrene[b] | 535 | 32.9 | 80 | 350 | 1,000 | 9,900 | 150 | 101 | 1,450 | 17 |
| Benzo[ghi]perylene[a] | 526 | 23.4 | <50 | 200 | 480 | 6,700 | 720 | 15 | — | — |
| Chrysene[b] | 521 | 35.7 | 120 | 570 | 1,400 | 16,000 | 166 | 111 | 1,290 | 31 |
| Dibenz [*a, h*] anthracene[c] | 524 | 16.8 | <50 | 130 | 280 | 4,400 | 33 | 101 | 260 | 26 |
| Fluoranthene[b] | 498 | 39.8 | 170 | 1,000 | 2,700 | 26,000 | 423 | 78 | 2,230 | 27 |
| Fluorene[b] | 518 | 10.4 | <50 | 53 | 140 | 6,700 | 77.4 | 40 | 536 | 3 |
| Indeno[1,2,3-cd]pyrene[a] | 500 | 27.8 | 63 | 370 | 710 | 8,400 | 690 | 25 | — | — |
| Naphthalene[b] | 496 | 7.7 | <50 | <50 | 78 | 4,900 | 176 | 9 | 561 | 1 |
| Phenanthrene[b] | 506 | 30.8 | 78 | 500 | 1,400 | 15,000 | 204 | 82 | 1,170 | 31 |
| Pyrene[b] | 496 | 37.9 | 140 | 780 | 2,000 | 21,000 | 195 | 104 | 1,520 | 33 |
| Total PAHs[b] | | | | | | | 1,610 | 105 | 22,800 | 14 |
| **Phthalates** | | | | | | | | | | |
| Bis(2-Ethylhexyl) Phthalate[a] | 536 | 30.0 | 98 | 540 | 1,000 | 17,000 | 182 | 101 | 2,650 | 6 |
| Butylbenzylphthalate[a] | 536 | 5.6 | <50 | <50 | 76 | 2,240 | 900 | 1 | 11,000[d] | 0 |
| **Phenols** | | | | | | | | | | |
| *p*-Cresol[a] | 505 | 37.8 | 99 | 430 | 870 | 4,800 | 670 | 31 | — | — |
| **Halo- and Nitroso-Compounds** | | | | | | | | | | |
| 1,2-Dichlorobenzene[a] | 516 | 0.6 | <50 | <50 | <50 | 86 | 50 | 3 | 340[d] | 0 |
| 1,4-Dichlorobenzene[a] | 518 | 1.2 | <50 | <50 | <50 | 140 | 110 | 2 | 350[d] | 0 |
| *N*-Nitrosodiphenylamine[a] | 487 | 0.6 | <50 | <50 | <50 | 79 | 28 | 7 | — | — |
| 1,2,4-Trichlorobenzene[a] | 517 | 0.2 | <50 | <50 | <50 | 68 | 51 | 1 | 9,200[d] | 0 |

*Note:* N, number of sites exceeding screening value; —, does not exist or apply. Data was collected from the United States Geological Survey National Water-Quality Assessment (NAWQA) Program river basins.

[a] Marine sediment quality guidelines.
[b] Freshwater sediment quality guidelines.
[c] Lower screening value is freshwater and upper screening value is marine sediment quality guideline.
[d] Screening value assuming 1% organic carbon.

*Source*: Abstracted from Lopes, T.J. and Furlong, E.T., 2001, Occurrence and potential adverse effects of semivolatile organic compounds in streambed sediment, United States, 1992–1995; *Environmental Toxicology and Chemistry*, vol. 20, no. 4, p. 727–737, www.usgs.gov. Printed with permission.

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**Table 10B.34 Pollutant Discharges into Coastal Waters of the United States, 1980–1985**

| Coastal Region | BOD | TSS | TN | TP |
|---|---|---|---|---|
| Northeast | 0.57 | 5.33 | 0.14 | 0.05 |
| Mid-Atlantic | 0.54 | 5.42 | 0.20 | 0.05 |
| Southeast | 0.25 | 3.18 | 0.14 | 0.04 |
| Gulf of Mexico | 2.03 | 149.00 | 0.88 | 0.22 |
| West Coast | 1.52 | 101.12 | 0.64 | 0.76 |

*Note:* (million tons per year) BOD, biochemical oxygen demand; TSS, total suspended solids; TN, total nitrogen; TP, total phosphorus.

*Source*: From U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Ocean Assessments Division, Strategic Assessment Branch. 1986. Pollutant discharges from East Coast and Gulf of Mexico coastal counties, circa 1980–1985 and unpublished data compiled from the National Coastal Pollutant Discharge Inventory database. Rockville, MD; U.S. Geological Survey, National Water Summary 1986.

**Table 10B.35 Point Sources of Pollutants to Coastal Waters of the United States, 1980–1985**

| Coastal Region | Municipal Wastewater Treatment Facilities | Industrial Wastewater Treatment Facilities |
|---|---|---|
| Northeast | 540 | 1,025 |
| Mid-Atlantic | 666 | 1,518 |
| Southeast | 1,053 | 458 |
| Gulf of Mexico | 1,651 | 830 |
| West Coast | 521 | 920 |

*Note:* Number of wastewater discharge facilities by region.

*Source*: From U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean survey, Ocean Assessments Division, Strategic Assessment Branch. 1986. Pollutant discharges from East Coast and Gulf of Mexico coastal counties, circa 1980–1985 and unpublished data compiled from the National Coastal Pollutant Discharge Inventory database. Rockville, MD; U.S. Geological Survey, National Water Summary 1986.

**Table 10B.36 United States Shellfish Growing Waters, 1966–1995**

| Year | 1966 | 1971 | 1974 | 1980 | 1985 | 1990 | 1995 |
|---|---|---|---|---|---|---|---|
| | | | | 1000 acres | | | |
| Approved for harvest | 8,100 | 10,362 | 10,560 | 10,685 | 11,402 | 12,304 | 14,853 |
| Harvested limited | 2,090 | 3,738 | 4,232 | 3,533 | 5,435 | 6,398 | 6,721 |
| Conditionally approved | 88 | 410 | 387 | 587 | 1,463 | 1,571 | 1,695 |
| Restricted | na | 30 | 34 | 55 | 637 | 463 | 2,106 |
| Conditionally restricted | na | na | na | na | na | 0 | 119 |
| Prohibited | 2,002 | 3,298 | 3,811 | 2,891 | 3,335 | 4,364 | 2,801 |
| Total | 10,190 | 14,100 | 14,792 | 14,218 | 16,837 | 18,702 | 21,574 |

*Note:* Based on National Shellfish Registers published only in years indicated. Data do not include Alaska, Hawaii, or waters designated as unclassified. The total acreage of classified shellfish growing waters varies with each register. There may be several reasons why shellfish harvest is prohibited, including water-quality problems, lack of funding for complete surveying and monitoring, conservation measures, and other management/administrative actions.

*Source*: From The 1996 Annual Report of the Council on Environmental Quality, www.whitehouse.gov/CEQ.

*Orginal Source*: From U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Office of Ocean Resources Conservation and Assessment, Strategic Environmental Assessments Division, *The 1995 National Shellfish Register of Classified Growing Waters (DOC, NOAA, ORCA, Silver Spring, MD, 1997)*, www.nos.noaa.gov.

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**Table 10B.37 Assessed Estuaries and Ocean Shoreline Waters Supporting Shellfishing Use Requirements in the United States in 2000**

| | Estuaries ($mi^2$) | | | Ocean Shoreline Waters (mi) | | |
|---|---|---|---|---|---|---|
| **State** | **Total Assessed** | **Full Support** | **Threatened** | **Total Assessed** | **Full Support** | **Threatened** |
| Alabama | 0 | — | — | 0 | — | — |
| Alaska | 0 | — | — | 0 | — | — |
| California | 758 | 43 | 19 | 760 | 694 | 0 |
| Connecticut | 611 | 273 | 0 | 0 | — | — |
| Delaware | 15 | 1 | 0 | 15 | 1 | 0 |
| Delaware River | 679 | 579 | 0 | — | — | — |
| District of Columbia | 0 | — | — | — | — | — |
| Florida | 1,765 | 1,398 | 111 | 0 | — | — |
| Georgia | 0 | — | — | 0 | — | — |
| Hawaii | 39 | 33 | 0 | 425 | 422 | 0 |
| Louisiana | 1,153 | 1,078 | 0 | 0 | — | — |
| Maine | 2,852 | 2,542 | 0 | 0 | — | — |
| Maryland | 1,839 | 1,672 | — | 32 | 32 | — |
| Massachusetts | 2,526 | 2,254 | — | 0 | — | — |
| Mississippi | 579 | 550 | 2 | 89 | 0 | 0 |
| New Hampshire | 21 | 0 | — | 18 | 0 | — |
| New Jersey | 614 | 456 | 0 | 0 | — | — |
| New York | 163 | — | 0 | 3 | — | 0 |
| North Carolina | 0 | — | — | 0 | — | — |
| Oregon | 72 | 4 | 0 | 0 | — | — |
| Puerto Rico | 0 | 0 | 0 | 0 | 0 | 0 |
| Rhode Island | 128 | 96 | 0 | 79 | 79 | — |
| South Carolina | 891 | 613 | — | 0 | — | — |
| Texas | 1,625 | 1,037 | 0 | 0 | — | — |
| Virgin Islands | 0 | — | — | 0 | — | — |
| Virginia | 1,735 | 1,642 | 2 | 0 | — | — |
| Washington | 2,904 | 1,274 | — | 0 | — | — |
| **Total** | **20,967** | **15,545** | **134** | **1,420** | **1,227** | **0** |
| **Percent of assessed for use** | | **75.7%** | **0.6%** | | **86.4%** | **0.0%** |

*Note:* Supporting, Fully supporting of all uses; Threatened, Fully supporting all uses but threatened for one or more uses; —, no data.

*Source*: From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

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**Table 10B.38 Shellfish Harvesting Restrictions Due to Pathogens as Reported by States, Territories, and Commissions in 2000**

| Jurisdiction | Number of Waterbodies with Restrictions | Approved ($mi^2$) | (Sq. Miles) Conditionally Approved[a] | Restricted[b] | Prohibited[c] | Management Closures[d] | Total Area Affected[e] |
|---|---|---|---|---|---|---|---|
| Alabama | — | — | — | — | — | — | — |
| Alaska | — | — | — | — | — | — | — |
| American Samoa | — | — | — | — | — | — | — |
| California | — | — | — | — | — | — | — |
| Connecticut | — | — | — | — | — | — | — |
| Delaware | — | — | — | — | — | — | — |
| District of Columbia | — | — | — | — | — | — | — |
| Florida | — | — | — | — | — | — | — |
| Georgia | — | — | — | — | — | — | — |
| Guam | — | — | — | — | — | — | — |
| Hawaii | — | — | — | — | — | — | — |
| Louisiana | 26 | — | — | — | — | — | — |
| Maine | — | — | — | — | — | — | — |
| Maryland | 36 | 1,672.19 | 58.26 | 108 | 0 | — | 1,838.45 |
| Massachusetts | — | 2,254.07 | — | 40.85 | 224.2 | 201.1 | 2,720.22 |
| Mississippi | — | — | — | — | — | — | — |
| N. Mariana Islands | — | — | — | — | — | — | — |
| New Hampshire | 11 | 7.18 | 0.61 | 1.57 | 11.26 | 0.81 | 21.43 |
| New Jersey | — | 808 | — | 115 | 130 | — | 1,053 |
| New York | — | 1,562.5 | — | — | 312.5 | — | 1,875 |
| North Carolina | — | — | — | — | — | — | — |
| Oregon | 8 | 15.84 | 16.54 | — | — | — | 32.38 |
| Puerto Rico | — | — | — | — | — | — | — |
| Rhode Island | 19 | 96 | 22 | — | 10 | — | 128 |
| South Carolina | — | 613.06 | 7.517 | 151.28 | 119.233 | — | 891.09 |
| Texas | — | — | — | — | — | 346.1 | 346.1 |
| Virgin Islands | — | — | — | — | — | — | — |
| Virginia | — | — | — | 3 | 148 | — | 151 |
| Washington | — | 341.8 | 46.5 | — | 104 | — | 492.3 |
| **Total** | **100** | **7,370.64** | **151.427** | **419.7** | **1,059.193** | **548.01** | **9,548.97** |

*Note:* —, no data.

[a] Conditionally approved waters do not always meet criteria for harvesting shellfish, but may be harvested when criteria are met.
[b] Restricted water may be harvested if the shellfish are purified with clean water following harvest.
[c] Shellfish may not be harvested in prohibited waters.
[d] Preventative closures due to a lack of data or proximity to point sources or marinas.
[e] Includes water that are classified as conditionally approved, restricted, prohibited, and management closures.

*Source*: From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.



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**Table 10B.39 Summary of Fully Supporting, Threatened, and Impaired Waters Assessed in Estuaries and Ocean Shoreline Waters in the United States in 2000**

| | Estuaries ($mi^2$) | | | | | | Ocean Shoreline Waters (mi) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Jurisdiction** | **Total Sq. Miles** | **Assessed** | **Full Support** | **Threatened** | **Impaired** | **Not Attainable** | **Total Miles** | **Assessed** | **Full Support** | **Threatened** | **Impaired** | **Not Attainable** |
| Alabama | 610 | 541 | 0 | 0 | 541 | 0 | 337 | 0 | 0 | 0 | 0 | 0 |
| Alaska | 33,204 | 28 | 3 | 0 | 25 | 0 | 36,000 | 25 | 16 | 0 | 9 | 0 |
| American Samoa | 184 | 0 | 0 | 0 | 0 | 0 | 116 | 53 | 7 | 30 | 16 | 0 |
| California | 2,139 | 2,033 | 35 | 1 | 1,997 | 0 | 1,609 | 997 | 775 | 0 | 222 | 0 |
| Connecticut | 612 | 611 | 139 | 14 | 458 | 0 | 380 | 0 | 0 | 0 | 0 | 0 |
| Delaware | 449 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 0 | 0 |
| Delaware River | 866 | 866 | 0 | 0 | 866 | 0 | — | — | — | — | — | — |
| District of Columbia | 6 | 6 | 0 | 0 | 6 | 0 | — | — | — | — | — | — |
| Florida | 4,437 | 4,037 | 3,055 | 121 | 861 | 0 | 8,460 | 0 | 0 | 0 | 0 | 0 |
| Georgia | 854 | 858 | 509 | 0 | 349 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| Guam | 1 | 11 | 0 | 0 | 11 | 0 | 117 | 17 | 1 | 6 | 10 | 0 |
| Hawaii | 55 | 54 | 23 | 0 | 31 | 0 | 1,052 | 871 | 834 | 8 | 29 | 0 |
| Louisiana | 7,656 | 4,036 | 318 | 7 | 3,711 | 0 | 397 | 0 | 0 | 0 | 0 | 0 |
| Maine | 2,852 | 2,783 | 2,473 | 0 | 310 | 0 | 5,296 | 0 | 0 | 0 | 0 | 0 |
| Maryland | 2,522 | 2,478 | 918 | 0 | 1,560 | 0 | 32 | 32 | 32 | 0 | 0 | 0 |
| Massachusetts | 223 | 128 | 46 | 0 | 82 | 0 | 1,519 | 0 | 0 | 0 | 0 | 0 |
| Mississippi | 760 | 613 | 0 | 62 | 551 | 0 | 245 | 94 | 53 | 41 | 0 | 0 |
| N. Mariana Islands | 15,989 | 1 | 0 | 0 | 1 | 0 | 52 | 0 | 0 | 0 | 0 | 0 |
| New Hampshire | 21 | 21 | 0 | 0 | 21 | 0 | 18 | 18 | 0 | 0 | 18 | 0 |
| New Jersey | 725 | 614 | 456 | 0 | 158 | 0 | 127 | 127 | 127 | 0 | 0 | 0 |
| New York | 1,530 | 402 | 0 | 11 | 391 | 0 | 120 | 3 | 0 | 0 | 3 | 0 |
| North Carolina | 3,121 | 3,115 | 3,006 | 0 | 109 | 0 | 320 | 0 | 0 | 0 | 0 | 0 |
| Oregon | 206 | 54 | 8 | 11 | 35 | 0 | 362 | 0 | 0 | 0 | 0 | 0 |
| Puerto Rico | | 0 | 0 | 0 | 0 | 0 | 550 | 550 | 302 | 131 | 117 | 0 |
| Rhode Island | 151 | 151 | 103 | 0 | 47 | 0 | 79 | 79 | 79 | 0 | 0 | 0 |
| South Carolina | 401 | 221 | 136 | 0 | 85 | 0 | 190 | 0 | 0 | 0 | 0 | 0 |
| Texas | 2,394 | 1,993 | 1,236 | 0 | 758 | 0 | 624 | 0 | 0 | 0 | 0 | 0 |
| Virgin Islands | 3 | 0 | 0 | 0 | 0 | 0 | 209 | 202 | 173 | 21 | 9 | 0 |
| Virginia | 2,494 | 1,991 | 773 | 796 | 422 | 0 | 120 | 120 | 120 | 0 | 0 | 0 |
| Washington | 2,904 | 2,904 | 611 | 0 | 2,293 | 0 | 163 | — | — | — | — | — |
| **Total** | **87,369** | **30,548** | **13,850** | **1,023** | **15,676** | **0** | **58,618** | **3,189** | **2,518** | **237** | **434** | **0** |
| **Percent of assessed** | | | **45.3%** | **3.3%** | **51.3%** | **0.0%** | | | **79.0%** | **7.4%** | **13.6%** | **0.0%** |

*Note:* Supporting, Fully supporting of all uses; Threatened, Fully supporting all uses but threatened for one or more uses; Impaired, Partially or not supporting one or more uses; Not Attainable, Not able to support one or more uses; —, no data.

*Source*: Abstracted from United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

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**Table 10B.40 United States National Coastal Condition Rating Scores by Indicator and Region**

| Indicator | Northeast Coast | Southeast Coast | Gulf Coast | West Coast | Great Lakes | Puerto Rico | United States[a] |
|---|---|---|---|---|---|---|---|
| Water-quality index | 2 | 4 | 3[b] | 3 | 3 | 3 | 3.0 |
| Sediment quality index | 1 | 4 | 3 | 2 | 1 | 1 | 2.1 |
| Benthic index | 1 | 3 | 2 | 3 | 2 | 1 | 2.0 |
| Coastal habitat index | 4 | 3 | 1 | 1 | 2 | —[c] | 1.7 |
| Fish tissue contaminants index | 1 | 5 | 3 | 1 | 3 | —[c] | 2.7 |
| Overall condition | 1.8 | 3.8 | 2.4 | 2.0 | 2.2 | 1.7 | 2.3 |

*Note:* Rating scores are based on a 5-point system, where 1 is poor and 5 is good.

[a] The U.S. score is based on an aerially weighted mean of regional scores.
[b] This rating score does not include the impact of the hypoxic zone in offshore Gulf Coast waters.
[c] No coastal habitat index loss or fish tissue contaminants index results were available for Puerto Rico.

*Source*: From United States Environmental Protection Agency, 2004, *National Coastal Condition Report II*, EPA-620/R-03/002, December 2004, www.epa.gov.

**Table 10B.41 Percent of United States National Coastal Area in Poor Condition by Indicator (except Coastal Habitat Index) and Region**

| Indicator | Northeast Coast | Southeast Coast | Gulf Coast | West Coast | Great Lakes | Puerto Rico | United States |
|---|---|---|---|---|---|---|---|
| Water-quality index[a] | 19 | 5 | 9[b] | 3 | — | 9 | 11 |
| Sediment quality index[c] | 16 | 8 | 12 | 14 | — | 61 | 13 |
| Benthic index | 22 | 11 | 17 | 13 | — | 35 | 17 |
| Coastal habitat index[d] | 1.00 | 1.06 | 1.30 | 1.90 | — | — | 1.26 |
| Fish tissue contaminants index[e] | 31 | 5 | 14 | 27 | — | — | 22 |
| Overall condition[f] | 40[g] | 23 | 40 | 23 | — | 77 | 35 |

*Note:* The percent area of poor condition is the percentage of total estuarine surface area in the region or the nation (proportional area information is not available for the Great Lakes).

[a] The water-quality index is based on a combination of water quality measurements (dissolved oxygen, chlorophyll *a*, nitrogen, phosphorus, and water clarity).
[b] The area of poor condition does not include the hypoxic zone in offshore Gulf Coast waters.
[c] The sediment quality index is based on a combination of sediment quality measurements (sediment toxicity, sediment contaminants, and sediment TOC).
[d] The coastal habitat index is based on the average of the mean long-term, decadal wetland loss (1780–1990) and the present decadal wetland loss rate (1990–2000).
[e] The fish tissue contaminants index is based on analyses of whole fish (not fillets).
[f] The overall percentage is based on the overlap of the five indicators and includes estuarine area for all of the conterminous 48 states (by region and total) and Puerto Rico.
[g] In Northeast Coast estuaries, at least one of the five indicators is rated poor at sites representing 40% of total estuarine area.

*Source*: From United States Environmental Protection Agency, 2004, *National Coastal Condition Report II*, EPA-620/R-03/002, December 2004, www.epa.gov.

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**Table 10B.42 Average PCB and PAH Concentrations in Sediments from Selected Estuaries in the United States, 1984–1992 (Milligrams per Kilogram Dry Weight)**

| Estuary | Total PCBs | Total PAHs |
|---|---|---|
| Machias Bay, ME-Hog Island | 24.07 | 132.20 |
| Machias Bay, ME-Chance Island | 25.40 | 221.03 |
| Frenchman Bay, ME-Long Porcupine Island | 28.90 | 234.99 |
| Penobscot Bay, ME-Colt Head Island | 59.31 | 834.41 |
| Johns Bay, ME–Pemaquid | 7.46 | 95.90 |
| Casco Bay, ME-Great Chebeague Island | 98.28 | 3,138.86 |
| Casco Bay, ME-Cousins Island | 161.75 | 3,097.25 |
| Cape Elizabeth, ME-Richmond Island | 13.88 | 257.17 |
| Merrimack River, MA-Plum Island | 33.19 | 927.98 |
| Salem Harbor, MA-Folger Point | 295.81 | 8,100.99 |
| Boston Harbor, MA-President Roads | 5961.75 | 16,069.24 |
| Boston Harbor, MA-Deer Island | 2671.75 | 8,267.36 |
| Boston Harbor, MA-Quincy Bay | 599.39 | 15,541.18 |
| Boston Harbor, MA-Hull Bay | 128.67 | 2,941.00 |
| Boston Harbor, MA-Mystic River | 1436.33 | 51,263.33 |
| Massachusetts Bay, MA | 2.63 | 28.97 |
| Buzzards Bay, MA-West Island | 171.64 | 653.93 |
| New Bedford Harbor, MA-Clarks Point | 2915.50 | 2,438.17 |
| Narragansett Bay, RI-Prudence Island | 265.00 | 2,899.00 |
| Narragansett Bay, RI-Conanicut Island | 309.11 | 2,152.35 |
| Niantic Bay, CON-Black Point | 41.72 | 704.85 |
| Long Island Sound, NY-New Haven | 237.33 | 3,885.00 |
| Long Island Sound, NY-Norwalk | 139.70 | 2,693.75 |
| Long Island Sound, NY-Long Island Shoal | 7.92 | 93.02 |
| Long Island Sound, NY-Rock Point | 9.13 | 42.26 |
| Long Island Sound, NY-Lloyd Point | 8.78 | 51.81 |
| Long Island Sound, NY-Oak Neck Point | 177.36 | 5,839.20 |
| Hudson River, NY-Englewood Cliffs | 947.33 | 7,843.33 |
| Raritan Bay, NY-Upper Bay | 162.37 | 5,891.03 |
| Raritan Bay, NY-Gravesand Bay | 337.67 | 7,697.50 |
| Raritan Bay, NY-West Reach | 386.30 | 7,385.70 |
| Raritan Bay, NJ-East Reach | 468.64 | 6,711.00 |
| Raritan Bay, NJ-Lower Bay | 546.87 | 6,607.25 |
| Great Bay, NJ-Wells Island | 146.00 | 1,086.67 |
| Great Bay, NJ-Seven Island | 85.00 | 895.12 |
| Great Bay, NJ-Intercoastal Waterway | 62.87 | 444.97 |
| Delaware Bay, DE-Cherry Island Range | 485.12 | 3,117.17 |
| Delaware Bay, DE-Brandywine Shoal | 99.05 | 491.28 |
| Delaware Bay, DE-The Shears | 61.10 | 339.67 |
| Baltimore Harbor, MD, Fort McHenry Channel | 616.08 | 12,282.12 |
| Baltimore Harbor, MD-Brewerton Channel | 299.23 | 13,528.33 |
| Chesapeake Bay, MD-Gibson Island | 144.45 | 3,691.02 |
| Chesapeake Bay, MD-Chester River | 75.43 | 2,116.03 |
| Chesapeake Bay, MD-Kent Island | 228.75 | 5,296.25 |
| Chesapeake Bay, MD-Patuxent River | 22.40 | 489.00 |
| Chesapeake Bay, MD-Smith Island | 17.36 | 355.51 |
| Chesapeake Bay, VA-James River | 84.10 | 2,215.33 |
| Chesapeake Bay, VA-York River | 37.14 | 258.50 |
| Chesapeake Bay, VA-Elizabeth River | 165.41 | 13,649.91 |
| Pamlico Sound, NC-Jones Bay | 21.89 | 443.59 |
| Cape Fear River, NC-Horseshoe Shoal | 6.63 | 21.00 |
| Charleston Harbor, SC-Coastal | 246.28 | 14,135.00 |
| Charleston Harbor, SC-South Channel | 29.05 | 2,082.26 |
| Savannah River, GA-Elba Island | 5.97 | 274.00 |
| Sapelo Sound, GA-South Newport River | 1.05 | 26.23 |
| Sapelo Sound, GA-High Point | 0.00 | 466.92 |
| St. Johns River, FL-Trout River | — | 23,228.20 |
| St. Johns River, FL-West Mill Cove | 98.35 | 3,368.49 |
| St. Johns River, FL-Ortega River | — | 4,863.00 |

*(Continued)*

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**Table 10B.42 (Continued)**

| Estuary | Total PCBs | Total PAHs |
|---|---|---|
| St. Johns River, FL-Piney Point | — | 7,933.67 |
| St. Johns River, FL-Orange Point | — | 8,094.77 |
| St. Lucie River, FL-Stuart | 46.67 | 711.00 |
| Biscayne Bay, FL-North Bay | 61.20 | 270.00 |
| Biscayne Bay, FL-Chicken Key | 28.33 | 9.45 |
| Charlotte Harbor, FL-Cape Haze | 8.86 | 44.89 |
| Tampa Bay, FL-Northern Tampa Bay | 5.54 | 69.50 |
| Apalachicola Bay, FL-St. George Island | 10.77 | 218.07 |
| St. Andrew Bay, FL-Military Point | 110.33 | 1,266.43 |
| Choctawhatchee Bay, FL | 20.43 | 34.03 |
| Pensacola Bay, FL | 58.19 | 1,828.31 |
| Mobile Bay, AL-North Point | 19.33 | 134.27 |
| Pascagoula River, MS-Escatawpa River | 129.13 | 1,318.33 |
| Pascagoula River, MS | 71.50 | 525.56 |
| Round Island, MS-Round Island | 1.10 | 83.64 |
| Heron Bay, MS-Heron Bay | 11.72 | 129.29 |
| Mississippi River Delta, LA-Southeast Pass | 23.80 | 922.73 |
| Mississippi River Delta, LA-Head of Passes | 581.80 | 103.80 |
| Barataria Bay, LA-Barataria Pass | 3.18 | 169.77 |
| Calcasieu River, LA-Prien Lake | 901.67 | 133.20 |
| Calcasieu River, LA-West Cove | 41.67 | 5.27 |
| Galveston Bay, TX-East Bay | — | 197.00 |
| Galveston Bay, TX-Trinity Bay | — | 624.67 |
| Galveston Bay, TX-Greens Bayou | 785.07 | 4,594.17 |
| Galveston Bay, TX-Goat Islands | 233.60 | 1,698.20 |
| Galveston Bay, TX-Morgans Point | 32.07 | 413.93 |
| Galveston Bay, TX-Eagle Point | 45.03 | 194.12 |
| Galveston Bay, TX-Texas City | — | 281.90 |
| Lavaca Bay, TX | 50.70 | 263.17 |
| San Antonio Bay, TX-Mosquito Point | 3.12 | 9.93 |
| San Antonio Bay, TX-San Antonio Bay | 11.16 | 132.08 |
| Corpus Christi Bay, TX-Long Reef | 5.70 | 354.34 |
| Lower Laguna Madre, TX-Laguna Heights | 5.07 | 83.25 |
| Lower Laguna Madre, TX-Long Island | 6.33 | 1.00 |
| San Diego Harbor, CA-Outside | 10.30 | 107.88 |
| San Diego Bay, CA-National City | 167.84 | 2,156.23 |
| San Diego Bay, CA-28th Street | 393.08 | 5,096.15 |
| San Diego Bay, CA-North | 311.36 | 4,165.71 |
| San Diego Bay, CA-Harbor Island | 103.88 | 1,178.17 |
| San Diego Bay, CA-Shelter Island | 50.70 | 773.32 |
| Mission Bay, CA-Outside | 12.00 | 3.00 |
| Dana Point Harbor, CA-Outside | 8.59 | 10.64 |
| San Pedro Bay, CA-Seal Beach | 60.47 | 329.75 |
| San Pedro Bay, CA-Long Beach | 180.06 | 899.96 |
| San Pedro Bay, CA-Outer Harbor | 279.14 | 2,391.78 |
| San Pedro Bay, CA-Cerritos Channel | 800.20 | 8,724.80 |
| Santa Monica Bay, CA-Southeast | 89.43 | 212.33 |
| Santa Monica Bay, CA-South | 166.00 | 350.50 |
| Santa Monica Bay, CA-Manhattan Beach | 13.58 | 28.08 |
| Santa Monica Bay, CA-West | 118.07 | 354.69 |
| Santa Monica Bay, CA-Deep | 20.08 | 104.00 |
| Santa Monica Bay, CA-North | 75.27 | 34.33 |
| San Luis Obispo, CA-San Luis Obispo | 15.60 | 32.80 |
| Estero Bay, CA-Estero Bay | 1.20 | 3.40 |
| Monterrey Bay, CA-Indian Head Beach | 8.56 | 13.33 |
| San Francisco Bay, CA-Redwood City | 104.50 | 3,021.50 |
| San Francisco Bay, CA-Hunters Point | 92.46 | 8,388.11 |
| San Francisco Bay, CA-Oakland Estuary | 226.50 | 6,543.30 |
| San Francisco Bay, CA-Southampton Shoal | 37.96 | 1,357.39 |
| San Francisco Bay, CA-Oakland Entrance | 61.43 | 1,701.33 |

*(Continued)*

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**Table 10B.42 (Continued)**

| Estuary | Total PCBs | Total PAHs |
|---|---|---|
| San Francisco Bay, CA-Castro Creek | 50.18 | 1,137.05 |
| San Francisco Bay, CA-San Pablo Bay | 24.25 | 470.12 |
| Bodega Bay, CA-North | 10.62 | 59.13 |
| Coos Bay, OR-North Bend | 20.95 | 831.94 |
| Columbia River Mouth, WA-Desdemona Sands | 5.15 | 53.08 |
| Puget Sound, Nisqually Reach, WA | 4.77 | 11.92 |
| Puget Sound, WA-Commencement Bay | 70.07 | 1,334.87 |
| Puget Sound, WA-Elliott Bay | 420.59 | 6,393.67 |
| Boca de Quadra, AK-Bacrian Point | 18.00 | 115.00 |
| Lutak Inlet, AK-Chilkoot River Mouth | 10.33 | 2.17 |
| Skagway, AK-Skagway River | 13.57 | 630.67 |
| Nahku Bay, AK-East Side | 7.02 | 98.33 |
| Prince William Sound, AK-Port Valdez | 13.57 | 630.67 |
| Gulf of Alaska, AK-Kamishak Bay | 16.67 | 16.33 |
| Bering Sea, AK,-Dutch Harbor | 58.83 | 715.00 |
| Bering Sea, AK,-Port Moller | 43.50 | 0.00 |
| Chukchi Sea, AK-Red Dog Mine | 24.80 | 4.80 |
| Beaufort Sea, AK-Olitok Point | 44.28 | 730.33 |
| Beaufort Sea, AK-Prudhoe Bay | 19.18 | 274.42 |

*Note:* PCBs, Polychlorinated biphenyls; PAHs, Polycyclic aromatic hydrocarbons; ND, Not detected.

*Source*: From Marmon, M.R., Gottholm, W., and Robertson, *A., 1998, A Summary of Chemical Contaminant Levels at Benthic Surveillance Project Sites (1984–1992)—NOAA Technical Memorandum NOS ORCA 124*, www.nos.noaa.gov.

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**Table 10B.43 Sewage Indicators In Sediments from Selected Estuaries in the Untied States, 1984**

| Estuary | Clostridium perfringens (cells/g) | Coprostanol (ng/g) |
|---|---|---|
| Casco Bay, ME | 710.00 | 221.27 |
| Merrimack River, MA | 670.06 | 206.47 |
| Salem Harbor, MA | 57,000.00 | 7,040.23 |
| Boston Harbor, MA | 79,000.00 | 9,000.00 |
| Buzzards' Bay, MA | 413.00 | 1,376.60 |
| Narragansett Bay, RI | 220,00 | 647.80 |
| East Long Island Sound, NY | 290.00 | 17.00 |
| West Long Island Sound, NY | 2,090.00 | 957.11 |
| Raritan Bay, NJ | 24,373.52 | 5,402.00 |
| Delaware Bay, DE | 91.00 | 148.00 |
| Lower Chesapeake Bay, VA | 4.00 | 781.56 |
| Pamlico Sound, NC | 120.00 | 1,100.00 |
| Charleston Harbor, SC | 1,600.00 | 1,253.23 |
| Sapelo Sound, GA | 270.00 | 510.00 |
| St. Johns River, FL | 1,400.00 | 790.07 |
| Charlotte Harbor, FL | 33.00 | 692.47 |
| Tampa Bay, FL | 3.00 | 350.92 |
| Apalachicola Bay, FL | 74.00 | 687.56 |
| Mobile Bay, AL | 100.43 | 304.90 |
| Round Island, MS | 75.00 | 256.87 |
| Mississippi River Delta, LA | 1,200.00 | 523.98 |
| Barataria bay, LA | 45.00 | 395.68 |
| Galveston Bay, TX | 34.00 | 278.57 |
| San Antonio Bay, TX | 6.00 | 109.78 |
| Corpus Christi Bay, TX | 1.00 | 248.84 |
| Lower Laguna Madre, TX | 27.00 | 240.00 |
| San Diego Harbor, CA | 2,600.00 | 600.00 |
| San Diego Bay, CA | 121.79 | 33.00 |
| Dana Point, CA | 103.27 | 98.00 |
| Seal Beach, CA | 832.72 | 180.00 |
| San Pedro Canyon, CA | 6,596.78 | 780.00 |
| Santa Monica Bay, CA | 471.53 | 230.00 |
| San Francisco Bay, CA | 5,093.47 | 1,860.00 |
| Bodega Bay, CA | 29.00 | 120.00 |
| Coos Bay, OR | 30.96 | 230.00 |
| Columbia River Mouth, OR/WA | 261.05 | 580.00 |
| Nisqually Reach, WA | 35.49 | 5.33 |
| Commencement Bay, WA | 5,300.00 | 1,900.00 |
| Elliott Bay, WA | 7,725.95 | 370.00 |
| Lutak Inlet, AK | 91.78 | 83.33 |
| Nahku Bay, AK | 212.13 | 310.00 |

*Source*: From U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Ocean Assessments Division. 1987. *National Status and Trends Program for Marine Environmental Quality. Progress Report on Preliminary Assessment of Findings of the Benthic Surveillance Project, 1984*. Rockville, MD; U.S. Geological Survey, National Water Summary 1986.

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**Table 10B.44 Average Trace Metal Concentrations Detected in Sediments from Selected Estuaries in the United States, 1984–1992 (Milligrams per Kilogram Dry Weight)**

| Estuary | Silver | Arsenic | Cadmium | Chromium | Copper | Mercury | Nickel | Lead | Selenium | Tin | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Machias Bay, ME-Hog Island | 0.13 | 5.90 | — | 122.64 | 9.02 | — | 15.23 | 21.37 | 0.25 | 3.03 | 50.67 |
| Machias Bay, ME-Chance Island | 0.06 | 7.89 | 0.08 | 66.71 | 11.13 | 0.05 | 21.26 | 19.27 | 0.14 | 2.08 | 55.52 |
| Frenchman Bay, ME-Long Porcupine Island | 0.09 | 10.34 | 0.18 | 82.97 | 17.13 | 0.05 | 40.23 | 27.90 | 0.42 | 3.75 | 102.45 |
| Penobscot Bay, ME-Job Island | 0.24 | 11.29 | — | 329.93 | 17.70 | 0.07 | 24.80 | 28.43 | 0.86 | 4.40 | 109.53 |
| Penobscot Bay, ME-Colt Head Island | 0.11 | 11.12 | 0.12 | 100.33 | 19.52 | 0.21 | 36.68 | 31.08 | 0.48 | 3.79 | 115.83 |
| Casco Bay, ME-Great Chebeague Island | 0.19 | 11.91 | 0.33 | 92.20 | 22.62 | 0.18 | 30.08 | 37.18 | 0.39 | 4.72 | 102.53 |
| Casco Bay, ME-Cousins Island | 0.25 | 10.20 | 0.20 | 183.94 | 14.79 | 0.09 | 20.70 | 39.26 | 0.63 | 4.01 | 83.17 |
| Merrimac River, MA-Plum Island | 0.03 | 4.25 | 0.11 | 27.70 | 5.02 | 0.06 | 5.02 | 21.46 | 0.04 | 3.94 | 28.53 |
| Salem Harbor, MA-Folger Point | 1.49 | 13.89 | 4.87 | 1,671.81 | 67.29 | 0.98 | 27.41 | 186.32 | 0.73 | 24.34 | 198.87 |
| Boston Harbor, MA-President Roads | 6.12 | 10.23 | 1.86 | 232.02 | 143.81 | 1.00 | 30.28 | 110.25 | 0.64 | 24.86 | 238.86 |
| Boston Harbor, MA-Deer Island | 2.87 | 10.12 | 1.30 | 121.72 | 88.66 | 0.67 | 29.90 | 95.51 | 0.30 | 11.35 | 156.18 |
| Boston Harbor, MA-Quincy Bay | 5.52 | 12.34 | 1.20 | 213.50 | 130.42 | 1.39 | 30.40 | 120.56 | 0.39 | 22.28 | 194.69 |
| Boston Harbor, MA-Hull Bay | 4.02 | 14.25 | 0.66 | 136.13 | 78.63 | 0.65 | 30.35 | 101.87 | 0.40 | 10.75 | 143.60 |
| Boston Harbor, MA-Mystic River | 2.41 | 26.20 | 1.81 | 120.53 | 126.08 | 0.74 | 35.57 | 158.93 | 0.50 | 9.66 | 223.97 |
| Massachusetts Bay, MA-Plymouth Entrance | 0.04 | 0.95 | 0.02 | 2.88 | 0.72 | 0.02 | 1.90 | 5.47 | 0.08 | 0.21 | 7.57 |
| Buzzards Bay, MA-West Island | 0.64 | 9.55 | 0.18 | 67.26 | 20.49 | 0.11 | 20.95 | 31.15 | 0.28 | 2.89 | 84.79 |
| New Bedford Harbor, MA-Clarks Point | 1.79 | 7.46 | 0.97 | 79.80 | 64.68 | 0.24 | 17.52 | 58.00 | 0.38 | 6.01 | 116.74 |
| Narragansett Bay, RI-Prudence Island | 3.24 | 9.65 | 0.85 | 119.72 | 147.99 | 0.60 | 29.86 | 112.69 | 0.51 | 19.64 | 218.37 |
| Narragansett Bay, RI-Conanicut Island | 1.18 | 8.29 | 0.41 | 95.58 | 76.22 | 0.34 | 23.84 | 61.77 | 0.35 | 7.74 | 143.13 |
| Niantic Bay, CON-Black Point | 0.17 | 3.58 | 0.15 | 50.23 | 9.63 | 0.03 | 15.04 | 20.05 | 0.07 | 2.72 | 114.13 |
| Long Island Sound, NY-Long Island Shoal | 0.08 | 3.62 | 0.10 | 42.31 | 7.92 | 0.08 | 10.26 | 18.50 | 0.04 | 2.19 | 56.76 |
| Long Island Sound, NY-Rocky Point | 0.05 | 3.34 | 0.06 | 30.32 | 4.40 | 0.04 | 9.17 | 18.68 | 0.27 | 1.12 | 40.76 |
| Long Island Sound, NY-Lloyd Point | 0.92 | 7.13 | 0.47 | 67.84 | 57.31 | 0.25 | 23.78 | 52.94 | 0.21 | 3.57 | 215.42 |
| Long Island Sound, NY-Oak Neck Point | 1.58 | 8.01 | 0.87 | 123.04 | 114.56 | 0.49 | 32.65 | 77.12 | 0.44 | 9.23 | 232.30 |
| Raritan Bay, NY-Upper Bay | 1.69 | 7.96 | 0.84 | 59.57 | 44.15 | 0.55 | 19.23 | 74.26 | 0.19 | 6.25 | 122.31 |
| Raritan Bay, NY-Gravesend Bay | 3.62 | 14.94 | 1.73 | 120.76 | 100.44 | 1.41 | 34.10 | 124.64 | 0.41 | 13.08 | 305.15 |
| Raritan Bay, NY-West Reach | 3.60 | 21.67 | 1.61 | 138.33 | 111.69 | 1.94 | 36.07 | 160.04 | 0.54 | 15.94 | 308.87 |
| Raritan Bay, NJ-East Reach | 4.68 | 20.25 | 1.51 | 154.68 | 142.86 | 2.43 | 36.86 | 158.84 | 0.68 | 21.10 | 270.45 |
| Raritan Bay, NJ-Lower Bay | 3.85 | 20.07 | 2.63 | 230.89 | 160.92 | 2.12 | 37.61 | 157.68 | 0.98 | 15.86 | 413.19 |
| Great Bay, NJ-Wells Island | 0.25 | 8.68 | 0.38 | 98.42 | 21.93 | 0.09 | 27.87 | 47.03 | 0.78 | 3.36 | 137.00 |
| Great Bay, NJ-Seven Island | 0.69 | 11.69 | 0.53 | 107.65 | 29.62 | 0.40 | 29.53 | 43.93 | 0.46 | 5.12 | 156.00 |
| Great Bay, NJ-Intercoastal Waterway | 0.36 | 6.85 | 0.28 | 45.63 | 12.05 | 0.20 | 14.99 | 26.80 | 0.32 | 3.57 | 75.96 |
| Delaware Bay, DE-Brandywine Shoal | 0.19 | 7.57 | 0.34 | 46.00 | 10.45 | 0.10 | 13.89 | 21.35 | 0.12 | 2.57 | 81.24 |
| Delaware Bay, DE-The Shears | 0.05 | 5.66 | 0.13 | 226.33 | 12.21 | 0.07 | 15.83 | 27.47 | 0.34 | 2.97 | 90.20 |
| Baltimore Harbor, MD, Fort McHenry Channel | 1.94 | 30.43 | 3.11 | 515.67 | 246.33 | 0.73 | 69.80 | 172.00 | 1.59 | 74.17 | 634.33 |
| Baltimore Harbor, MD-Brewerton Channel | 1.12 | 30.23 | 0.68 | 196.78 | 74.92 | 0.33 | 60.07 | 123.78 | 1.02 | 18.39 | 451.02 |
| Chesapeake Bay, MD-Gibson Island | 1.12 | 30.23 | 0.68 | 196.78 | 74.92 | 0.33 | 60.07 | 123.78 | 1.02 | 18.39 | 451.02 |
| Chesapeake Bay, MD-Chester River | 0.40 | 12.68 | 0.46 | 81.42 | 32.06 | 0.13 | 46.49 | 53.41 | 0.63 | 3.24 | 202.27 |
| Chesapeake Bay, MD-Kent Island | 0.18 | 13.59 | 0.77 | 83.87 | 46.13 | 0.19 | 61.67 | 61.63 | 1.60 | 4.38 | 316.33 |
| Chesapeake Bay, MD-Smith Island | 0.08 | 7.80 | 0.24 | 52.25 | 12.32 | 0.06 | 18.34 | 17.19 | 0.39 | 1.65 | 81.17 |
| Chesapeake Bay, MD-Patuxent River | 0.33 | 9.48 | 1.03 | — | 26.59 | 0.30 | — | 38.24 | — | 3.20 | 170.75 |
| Chesapeake Bay, VA-James River | 0.36 | 8.13 | 0.33 | — | 27.95 | 0.32 | — | 44.74 | — | 3.07 | 174.93 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chesapeake Bay, VA-York River | 0.08 | 5.61 | 0.24 | 55.24 | 9.82 | 0.09 | 17.17 | 15.49 | 0.18 | 2.08 | 64.08 |
| Chesapeake Bay, VA-Elizabeth River | 0.51 | 10.58 | 1.20 | 71.97 | 104.60 | 0.64 | 22.87 | 106.23 | 0.29 | 7.37 | 406.67 |
| Pamlico Sound, NC-Jones Bay | 0.08 | 8.22 | 0.28 | 67.70 | 11.01 | 0.11 | 18.77 | 24.96 | 0.73 | 2.82 | 72.04 |
| Charleston Harboar, SC-South Channel | 0.11 | 12.79 | 0.16 | 67.21 | 15.12 | 0.09 | 18.10 | 23.11 | 0.44 | 2.34 | 68.96 |
| Sapelo Sound, GA-South Newport River | 0.02 | 3.66 | 0.05 | 34.47 | 3.36 | — | 4.62 | 9.48 | 0.15 | 1.05 | 26.23 |
| Sapelo Sound, GA-Barbour Island River | 0.03 | 4.39 | 0.07 | 35.89 | 3.44 | — | 6.79 | 9.11 | 0.15 | 1.07 | 27.91 |
| Sapelo Sound, GA-Sapelo Sound Inlet | 0.02 | 3.34 | 0.06 | 27.02 | 3.45 | — | 6.01 | 8.84 | 0.09 | 1.03 | 20.71 |
| Sapelo Sound, GA-High Point | 0.03 | 8.08 | 0.11 | 45.81 | 6.69 | 0.05 | 10.70 | 15.18 | 0.29 | 1.44 | 42.40 |
| Sapelo Sound, GA-Dog Hammock | 0.03 | 4.95 | 0.15 | 38.38 | 3.83 | — | 7.53 | 9.09 | 0.14 | 1.06 | 29.38 |
| St. Johns River, FL-Trout River | 0.22 | 3.41 | 0.33 | 58.96 | 22.13 | — | 14.14 | 40.84 | 0.52 | 2.85 | 96.65 |
| St. Johns River, FL-West Mill Cove | 0.30 | 5.33 | 0.40 | 50.72 | 18.39 | 0.16 | 12.78 | 38.30 | 0.57 | 2.64 | 107.32 |
| St. Johns River, FL-Ortega River | 0.61 | 3.03 | 0.97 | 66.23 | 45.00 | — | 15.65 | 92.30 | 1.28 | 4.81 | 194.38 |
| St. Johns River, FL-Piney Point | 0.25 | 4.03 | 0.33 | 78.63 | 16.77 | — | 18.62 | 35.37 | 1.51 | 2.57 | 86.39 |
| St. Johns River, FL-Orange Point | 0.06 | 1.74 | 0.14 | 49.66 | 6.46 | — | 12.96 | 13.89 | 1.46 | 2.11 | 33.20 |
| Charlotte Harbor, FL-Cape Haze | 0.01 | 1.35 | 0.10 | 19.34 | 1.62 | 0.04 | 2.86 | 4.21 | 0.30 | 0.76 | 7.82 |
| Tampa Bay, FL-Northern Tampa Bay | 0.11 | 1.20 | 0.27 | 21.52 | 4.37 | 0.07 | 4.10 | 7.65 | 0.28 | 0.86 | 15.02 |
| Apalachicola Bay, FL-St. George Island | 0.06 | 18.45 | 0.07 | 78.75 | 18.54 | 0.10 | 25.65 | 29.48 | 0.55 | 3.57 | 95.65 |
| St. Andrew Bay, FL-Military Point | 0.30 | 13.76 | 0.28 | 82.28 | 21.04 | 0.21 | 21.43 | 54.15 | 0.65 | 1.80 | 93.23 |
| Choctawhatchee Bay, FL | 0.11 | 38.31 | 3.22 | 127.75 | 22.02 | 0.27 | 39.90 | 41.48 | 0.70 | 3.95 | 161.09 |
| Choctawhatchee Bay, FL-Destin Harbor | 0.16 | 19.97 | 0.73 | 39.78 | 85.14 | 0.19 | 10.01 | 57.37 | 0.55 | 2.19 | 182.78 |
| Pensacola Bay, FL | 0.17 | 20.38 | 0.21 | 122.26 | 21.63 | 0.17 | 28.55 | 38.75 | 0.81 | 3.21 | 129.54 |
| Mobile Bay, AL-North Point | 0.10 | 17.09 | 0.11 | 101.34 | 19.11 | 0.12 | 34.91 | 32.59 | 0.53 | 3.59 | 153.77 |
| Pascagoula River, MS | 0.14 | 6.72 | 0.21 | 43.43 | 15.05 | 0.11 | 12.97 | 18.22 | 0.28 | 1.78 | 82.48 |
| Round Island, MS-Round Island | 0.07 | 7.71 | 0.08 | 48.97 | 8.22 | 0.08 | 15.48 | 17.01 | 0.26 | 2.01 | 64.14 |
| Herron Bay, MS-Heron Bay | 0.10 | 6.84 | 0.19 | 41.18 | 10.79 | 0.08 | 14.89 | 17.05 | 0.31 | 1.52 | 53.36 |
| Mississippi River Delta, LA-Southeast Pass | 0.16 | 8.35 | 0.42 | 58.66 | 18.57 | 0.07 | 27.24 | 20.02 | 0.33 | 1.98 | 86.90 |
| Barataria Bay, LA-Barataria Pass | 0.09 | 5.96 | 0.17 | 39.89 | 9.12 | 0.05 | 16.32 | 14.83 | 0.21 | 1.44 | 55.21 |
| Lake Pontchartrain, LA-North Shore | 0.12 | 5.70 | 0.20 | — | 13.08 | 0.11 | — | 17.57 | — | 1.55 | 73.13 |
| Lake Pontchartrain, LA-South Shore | 0.22 | 6.53 | 0.37 | — | 20.89 | 0.14 | — | 28.11 | — | 2.38 | 125.84 |
| Galveston Bay, TX-East Bay | 0.09 | 3.23 | 0.06 | 28.63 | 5.83 | — | 11.68 | 11.23 | 0.11 | 0.89 | 38.83 |
| Galveston Bay, TX-Trinity Bay | 0.12 | 5.89 | 0.15 | 53.39 | 11.15 | — | 20.37 | 18.06 | 0.25 | 2.34 | 61.49 |
| Galveston Bay, TX-Cedar Bayou | 0.11 | 38.31 | 3.22 | 127.75 | 22.02 | 0.27 | 39.90 | 41.48 | 0.70 | 3.95 | 161.09 |
| Galveston Bay, TX-Greens Bayou | 0.62 | 7.11 | 0.96 | 71.69 | 41.40 | 0.41 | 23.58 | 63.65 | 0.36 | 3.92 | 183.80 |
| Galveston Bay, TX-Goat Islands | 0.18 | 6.51 | 0.26 | 52.09 | 16.93 | 0.17 | 20.04 | 33.53 | 0.41 | 2.25 | 103.24 |
| Galveston Bay, TX-Morgans Point | 0.16 | 6.36 | 0.19 | 55.31 | 16.04 | 0.07 | 20.22 | 30.82 | 0.29 | 2.19 | 81.70 |
| Galveston Bay, TX-Clear Lake | 0.18 | 4.98 | 0.16 | 35.56 | 23.55 | 0.07 | 15.47 | 23.47 | 0.27 | 2.05 | 72.90 |
| Galveston Bay, TX-Eagle Point | 0.09 | 3.90 | 0.07 | 30.73 | 8.70 | 0.04 | 10.31 | 14.24 | 0.19 | 1.52 | 42.06 |
| Galveston Bay, TX-Texas City | 0.22 | 6.94 | 0.09 | 64.79 | 15.69 | — | 22.21 | 25.43 | 0.15 | 3.79 | 79.68 |
| Lavaca Bay, TX | 0.11 | 6.29 | 0.14 | 36.05 | 11.11 | 0.25 | 14.04 | 21.38 | 0.22 | 1.60 | 58.25 |
| San Antonio Bay, TX-San Antonio Bay | 0.07 | 4.41 | 0.12 | 31.92 | 6.92 | 0.05 | 10.37 | 12.96 | 0.15 | 1.24 | 38.09 |
| Corpus Christi Bay, TX-Long Reef | 0.09 | 6.04 | 0.35 | 47.73 | 12.47 | 0.07 | 15.32 | 20.41 | 0.25 | 2.35 | 104.25 |
| Arroyo Colorado, TX-Arroyo City | 0.09 | 2.98 | 0.15 | — | 7.86 | 0.21 | — | 11.04 | — | 1.06 | 72.12 |
| Lower Laguna Madre, TX-Laguna Heights | 0.07 | 6.90 | 0.08 | 17.37 | 5.35 | 0.04 | 5.48 | 12.35 | 0.12 | 1.63 | 31.35 |
| San Diego Bay, CA-Outside | 0.19 | 6.60 | 0.37 | 43.30 | 8.18 | 0.05 | 6.03 | 11.35 | 0.12 | 1.85 | 54.72 |
| Machias Bay, ME-Hog Island | 0.13 | 5.90 | — | 122.64 | 9.02 | — | 15.23 | 21.37 | 0.25 | 3.03 | 50.67 |

*(Continued)*



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**Table 10B.44 (Continued)**

| Estuary | Silver | Arsenic | Cadmium | Chromium | Copper | Mercury | Nickel | Lead | Selenium | Tin | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| San Diego Bay, CA-National City | 1.43 | 9.44 | 0.36 | 60.13 | 117.15 | 0.43 | 22.87 | 44.35 | 0.13 | 4.81 | 206.52 |
| San Diego Bay, CA-28th Street | 1.09 | 10.16 | 0.65 | 84.98 | 176.49 | 0.71 | 21.38 | 79.14 | 0.18 | 10.19 | 279.33 |
| San Diego Bay, CA-North | 0.78 | 7.96 | 0.53 | 58.71 | 96.83 | 0.60 | 17.00 | 52.93 | 0.26 | 10.92 | 226.33 |
| San Diego Bay, CA-Harbor Island | 0.28 | 5.47 | 0.32 | 55.63 | 37.57 | 0.24 | 10.33 | 24.82 | 0.22 | 6.74 | 116.00 |
| San Diego Bay, CA-Shelter Island | 0.20 | 5.09 | 0.25 | 35.49 | 30.83 | 0.15 | 14.64 | 24.83 | 0.29 | 11.49 | 87.64 |
| Mission Bay, CA-Outside | 0.34 | 2.28 | 0.12 | 40.03 | 1.62 | 0.06 | 16.42 | 7.80 | 0.13 | 2.67 | 42.29 |
| Ocean Side Harbor, CA-Outside | 0.04 | 3.03 | 0.10 | 73.48 | 4.71 | 0.02 | 20.85 | 8.57 | 0.07 | 2.54 | 70.87 |
| Dana Point Harbor, CA-Outside | 0.17 | 5.75 | 0.31 | 35.87 | 6.39 | 0.24 | 14.22 | 14.18 | 0.23 | 2.36 | 48.94 |
| Dana Point Harbor, CA-Inside Harbor | 0.11 | 8.34 | 1.20 | 59.00 | 40.00 | 0.04 | 29.50 | 26.20 | 0.53 | 3.06 | 118.00 |
| San Pedro Bay, CA-Seal Beach | 0.35 | 6.70 | 0.24 | 82.88 | 24.60 | 0.31 | 36.70 | 32.23 | 0.13 | 1.97 | 111.17 |
| San Pedro Bay, CA-Long Beach | 0.30 | 9.36 | 0.72 | 80.13 | 58.22 | 0.24 | 30.24 | 75.74 | 0.45 | 6.12 | 184.61 |
| San Pedro Bay, CA-Mid Harbor | — | 15.87 | 1.31 | 151.67 | 201.00 | 0.22 | 53.37 | 49.83 | 2.21 | — | 205.67 |
| San Pedro Bay, CA-Outer Harbor | 0.49 | 8.31 | 1.00 | 85.70 | 106.27 | 0.32 | 37.54 | 38.05 | 1.39 | 6.57 | 173.93 |
| San Pedro Bay, CA-Cerritos Channel | 0.13 | 16.00 | 0.86 | 77.42 | 125.67 | 0.68 | 45.97 | 129.28 | 0.62 | 18.73 | 307.83 |
| Santa Monica Bay, CA-Southeast | 2.24 | 7.34 | 1.24 | 90.83 | 36.85 | 0.26 | 26.15 | 17.62 | 0.17 | 2.30 | 85.33 |
| Santa Monica Bay, CA-South | 0.91 | 5.75 | 1.19 | 121.17 | 36.45 | 0.29 | 29.92 | 25.17 | 0.30 | 2.97 | 91.73 |
| Santa Monica Bay, CA-Manhattan Beach | 0.36 | 8.95 | 0.29 | 60.23 | 10.05 | — | 12.59 | 25.73 | 0.15 | 1.12 | 35.48 |
| Santa Monica Bay, CA-West | 4.17 | 4.10 | 1.65 | 81.78 | 43.15 | 0.13 | 16.56 | 22.48 | 0.33 | 4.33 | 87.70 |
| San Luis Obispo, CA-San Luis Obispo | 0.60 | 1.48 | 0.39 | 130.00 | 7.49 | 0.08 | 30.40 | 4.90 | — | 0.80 | 43.60 |
| Estero Bay, CA-Estero Bay | 0.50 | 5.01 | 0.08 | 5,770.00 | 5.72 | 0.08 | 49.20 | — | — | — | 38.50 |
| Monterrey Bay, CA-Indian Head Beach | 0.12 | 5.93 | 0.19 | 72.80 | 4.11 | 0.06 | 20.45 | 11.81 | 0.14 | 1.53 | 24.18 |
| Monterrey Bay, CA-Moss Landing | 1.77 | 4.39 | 0.14 | 233.33 | 12.20 | — | 16.10 | 14.77 | 0.15 | 1.81 | 54.67 |
| Farallon Islands, CA | — | 6.39 | 3.33 | 210.00 | 8.00 | 0.09 | 41.90 | 10.30 | 0.29 | 2.27 | 48.00 |
| San Francisco Bay, CA-Redwood City | 0.34 | 9.90 | 0.16 | 167.17 | 55.10 | 0.29 | 92.15 | 30.15 | 0.56 | 6.68 | 165.50 |
| San Francisco Bay, CA-Hunters Point | 0.45 | 12.16 | 0.29 | 229.43 | 54.13 | 0.35 | 76.75 | 29.53 | 0.38 | 3.07 | 137.71 |
| San Francisco Bay, CA-Islais Creek Channel | 0.59 | 9.40 | 0.51 | 145.00 | 73.00 | 0.32 | 108.10 | 47.20 | 0.26 | 2.99 | 174.50 |
| San Francisco Bay, CA-Oakland Sanctuary | 0.42 | 12.88 | 0.73 | 233.84 | 105.06 | 1.13 | 112.38 | 128.98 | 0.90 | 16.32 | 287.50 |
| San Francisco Bay, CA-Oakland Entrance | 0.34 | 13.00 | 0.16 | 196.00 | 71.67 | 0.50 | 104.00 | 43.50 | 0.37 | 1.87 | 171.67 |
| San Francisco Bay, CA-Southampton Shoal | 0.32 | 9.09 | 0.24 | 202.67 | 30.93 | 0.16 | 64.73 | 17.15 | 0.21 | 2.23 | 102.14 |
| San Francisco Bay, CA-Castro Creek | 0.16 | 8.50 | 0.18 | 199.33 | 46.27 | 0.16 | 83.12 | 30.23 | 0.19 | 4.43 | 128.53 |
| Bodega Bay, CA-North | 0.19 | 4.55 | 0.16 | 409.52 | 7.44 | 0.14 | 48.49 | 4.85 | 0.13 | 2.31 | 44.86 |
| Humbolt Bay, CA-Indian Island | 0.08 | 8.54 | 0.23 | 453.67 | 6.95 | 0.06 | 60.07 | — | 0.08 | — | 45.60 |
| Coos Bay, OR-North Bend | 0.13 | 6.67 | 0.35 | 82.82 | 14.14 | 0.15 | 27.93 | 13.48 | 0.30 | 2.45 | 68.16 |
| Columbia River Mouth, OR-Youngs Bay | 0.62 | 3.08 | 0.13 | 50.33 | 35.67 | 0.03 | 17.87 | 17.80 | 0.15 | 2.71 | 132.33 |
| Columbia River Mouth, WA-Desdemona Sands | 0.12 | 3.18 | 0.45 | 35.73 | 16.45 | 0.10 | 23.94 | 7.79 | 0.25 | 2.60 | 90.79 |
| Puget Sound, Nisqually Reach, WA | 0.23 | 1.48 | 0.45 | 95.33 | 16.02 | 0.29 | 35.77 | 13.13 | 0.13 | 2.54 | 104.09 |
| Puget Sound, Commencement Bay, WA | 0.25 | 5.20 | 0.45 | 57.95 | 49.60 | 0.17 | 30.65 | 20.07 | 0.48 | 2.29 | 91.45 |
| Puget Sound, WA-Elliott Bay | 0.23 | 8.08 | 0.54 | 90.13 | 101.63 | 0.61 | 38.24 | 42.78 | 0.34 | 2.35 | 168.03 |
| Boca de Quadra, AK-Bacrian Point | 0.29 | 1.90 | 0.44 | 52.67 | 22.00 | 0.04 | 7.49 | 17.87 | 0.74 | 3.21 | 104.33 |
| Lutak Inlet, AK-Chilkoot River Mouth | 0.27 | 1.54 | 0.64 | 72.13 | 28.83 | 0.14 | 17.12 | 18.27 | 0.43 | 1.62 | 180.17 |
| Skagway, AK-Skagway River | 0.42 | 3.45 | 0.40 | 43.00 | 16.90 | 0.08 | 4.28 | 52.20 | 0.15 | 2.76 | 169.33 |
| Nahku Bay, AK-East Side | 0.30 | 1.51 | 1.09 | 23.27 | 9.80 | 0.23 | 11.57 | 43.30 | 0.87 | 0.21 | 191.33 |
| Prince William Sound, AK-Port Valdez | 0.36 | 9.74 | 0.21 | 148.33 | 59.67 | 0.08 | 16.60 | 23.13 | 0.41 | 2.79 | 150.00 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Machias Bay, ME-Hog Island | 0.13 | 5.90 | — | 122.64 | 9.02 | — | 15.23 | 21.37 | 0.25 | 3.03 | 50.67 |
| Gulf of Alaska, AK-Kamishak Bay | 0.26 | 1.75 | 0.19 | 82.33 | 26.67 | 0.06 | 9.32 | 14.67 | 0.19 | 2.70 | 89.67 |
| Bering Sea, AK-Dutch Harbor | 0.11 | 2.22 | 0.70 | 30.67 | 49.67 | 0.24 | 5.13 | 12.93 | 0.70 | 2.77 | 85.33 |
| Bering Sea, AK-Port Moller | 0.06 | 1.67 | 0.43 | 63.00 | 13.33 | 0.06 | 5.82 | 9.84 | 0.06 | 3.37 | 100.67 |
| Bering Sea, AK-Kvichak Bay | 0.26 | 1.75 | 0.19 | 82.33 | 26.67 | 0.06 | 9.32 | 14.67 | 0.19 | 2.70 | 89.67 |
| Chukchi Sea, AK-Red Dog Mine | 0.04 | 5.69 | — | 213.33 | 10.00 | 0.06 | 32.63 | 8.49 | 0.17 | 2.10 | 51.00 |
| Beaufort Sea, AK-Olitok Point | 0.13 | 2.33 | 0.32 | 70.85 | 18.29 | 0.20 | 23.11 | 14.02 | 0.41 | 1.34 | 80.98 |
| Beaufort Sea, AK-Prudhoe Bay | 0.17 | 1.34 | 0.26 | 58.53 | 11.83 | 0.09 | 17.79 | 7.88 | 0.32 | 2.31 | 72.23 |

*Source*: Abstracted from Marmon, M.R., Gottholm, W., and Robertson, *A., 1998, A Summary of Chemical Contaminant Levels at Benthic Surveillance Project Sites (1984–1992)—NOAA Technical Memorandum NOS ORCA 124*, www.nos.noaa.gov.



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**Table 10B.45 Cadmium and Lead in Sediments of the Chesapeake Bay Mainstem**

| | Concentration | | Aquatic Life Benchmark | | Location of Maximum | |
|---|---|---|---|---|---|---|
| **Contaminant** | **Median (ppm)** | **Maximum (ppm)** | **NOEL[a] (ppm)** | **PEL[b] (ppm)** | **Concentrations** | **Trends** |
| Cadmium | 0.4 | 2.9 | 1.0 | 7.5 | Baltimore region south to the Little Choptank River; mouth of Potomac River | Concentrations are declining |
| Lead | 35 | 86 | 21 | 160 | Baltimore region | Concentrations are declining in some areas |

[a] No Observed Effect Level. Level above which impacts are considered "possible."
[b] Probable Effect Level. Level above which impacts are considered "probable."

*Source*: From United States Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters, Third Report to Congress*, EPA-453/R-00-005.

*Original Source*: From Eskin et al., 1996.

**Table 10B.46 Temporal Trends in Chemical Concentrations Measured Nationally at 206 Mussel Watch Project Sites and at 30 Sites in the NERRS for Which Data Exist for Six Years During 1986–1999**

| | Trend | | | | Trend | | |
|---|---|---|---|---|---|---|---|
| **Organics*** | **I** | **D** | **NT** | **Element** | **I** | **D** | |
| ΣCdane | 1 | 85(8) | 120 | As | 9 | 15(3) | 182 |
| ΣDDTs | 1(1) | 54(5) | 151 | Cd | 7(4) | 20(2) | 179 |
| ΣDiel | 4(2) | 32(4) | 170 | Cu | 9 | 10(1) | 187 |
| ΣPCBs | 5(1) | 30 | 171 | Hg | 13(1) | 14(2) | 179 |
| ΣPAHs | 18(3) | 26(1) | 162 | Ni | 11(2) | 6(1) | 189 |
| ΣBTs | 0 | 100(10) | 106 | Pb | 11(2) | 12(3) | 183 |
| HCB | 16 | 7 | 183 | Se | 14(2) | 4 | 188 |
| Lindane | 3 | 31 | 172 | Zn | 7(1) | 15(4) | 184 |
| Mirex | 17 | 6 | 183 | | | | |

*Note*: I, Increasing; D, Decreasing; NT, No trend. Increasing and decreasing trends for NERRs are given in parentheses. *Individual organic compound concentrations have been aggregated into these groups:

ΣBTs, the sum of the concentrations of tributyltin and its breakdown products dibutyltin and monobutyltin;
ΣCdance, the sum of *cis*-chlordane, *trans*-nonachlor, heptachlor and heptachlorepoxide;
ΣDDTs, the sum of concentrations of DDTs and its metabolities, DDEs and DDDs;
ΣDield, the sum of concentrations of aldrin and dieldrin;
ΣPAHs, the sum of concentrations of the 18 PAH compounds;
ΣPCBs, the sum of the concentrations of homologs, which is approximately twice the sum of the 18 congeners.

*Source*: From Lauenstein, G.G. and Cantillo, A.Y., 2002, Contaminant Trends in US National Estuaries Research Reserves, Nation Status and Trends Program for Marine Environmental Quality, *NOAA NAS Technical Memorandum NCCOS 156*, October 2002, www.noaa.gov.

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**Table 10B.47 Trophic Status of Lakes in the United States in 1998**

| Jurisdiction | Assessed | | Oligotrophic | | Mesotrophic | | Eutrophic | | HyperEutrophic | | Dystrophic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes |
| Alabama | 33 | 276,436 | 3 | 585 | 8 | 54,077 | 21 | 210,539 | 1 | 11,235 | 0 | 0 |
| Alaska | — | — | — | — | — | — | — | — | — | — | — | — |
| Arizona | 11 | — | 0 | — | 3 | — | 8 | — | — | — | — | — |
| Arkansas | — | — | — | — | — | — | — | — | — | — | — | — |
| California | — | — | — | — | — | — | — | — | — | — | — | — |
| Colorado | 38 | 47,530 | 7 | 5,272 | 14 | 15,722 | 13 | 15,957 | 4 | 10,579 | — | — |
| Connecticut | — | — | — | — | — | — | — | — | — | — | — | — |
| *Cortina Rancheria* | — | — | — | — | — | — | — | — | — | — | — | — |
| Delaware | — | — | — | — | — | — | — | — | — | — | — | — |
| District of Columbia | — | — | — | — | — | — | — | — | — | — | — | — |
| Florida | 262 | 1,571 | 191 | 604 | 51 | 802 | 13 | 71 | 7 | 94 | — | — |
| Georgia | — | — | — | — | — | — | — | — | — | — | — | — |
| Hawaii | — | — | — | — | — | — | — | — | — | — | — | — |
| Idaho | — | — | — | — | — | — | — | — | — | — | — | — |
| Illinois | 329 | 157,408 | 6 | 180 | 30 | 3,912 | 159 | 79,398 | 134 | 73,918 | — | — |
| Indiana | 164 | 54,153 | 42 | 4,761 | 62 | 37,389 | 41 | 10,205 | 19 | 1,798 | 0 | 0 |
| Iowa | 115 | 41,190 | — | — | — | — | 115 | 41,190 | — | — | | |
| Kansas | 240 | 123,632 | 3 | 140 | 36 | 22,052 | 129 | 98,521 | 64 | 2,919 | 0 | 0 |
| Kentucky | 105 | 217,480 | 15 | 72,143 | 33 | 42,972 | 54 | 102,237 | 3 | 128 | 0 | 0 |
| Louisiana | — | — | — | — | — | — | — | — | — | — | — | — |
| Maine | — | — | — | — | — | — | — | — | — | — | — | — |
| *Manzanita Band* | — | — | — | — | — | — | — | — | — | — | — | — |
| Maryland | 58 | 21,010 | 0 | 0 | 16 | 15,172 | 42 | 5,838 | 0 | 0 | 0 | 0 |
| Massachusetts | 593 | 64,688 | 8 | 25,790 | 150 | 17,057 | 380 | 18,912 | 54 | 2,892 | 1 | 37 |
| Michigan | 730 | 491,931 | 115 | 172,591 | 375 | 175,307 | 207 | 124,881 | 33 | 19,152 | — | — |
| Minnesota | 1,984 | 2,131,026 | 309 | 210,108 | 723 | 1,099,929 | 667 | 645,241 | 285 | 175,748 | 0 | 0 |
| Mississippi | — | — | — | — | — | — | — | — | — | — | — | — |
| Missouri | 145 | — | 8 | — | 37 | — | 89 | — | 11 | — | — | — |
| Montana | 177 | 797,184 | 49 | 289,569 | 71 | 425,599 | 46 | 81,495 | 1 | 500 | 10 | 22 |
| Nebraska | 81 | 121,610 | 2 | 1,601 | 3 | 3,023 | 29 | 94,393 | 47 | 22,593 | — | — |
| Nevada | 17 | 319,946 | 3 | 133,230 | 12 | 133,116 | 2 | 53,600 | — | — | — | — |
| New Hampshire | 671 | 155,773 | 199 | 115,924 | 315 | 31,672 | 157 | 8,177 | — | — | — | — |
| New Jersey | 116 | 10,462 | — | — | 3 | 111 | 113 | 10,351 | — | — | — | — |
| New Mexico | — | — | — | — | — | — | — | — | — | — | — | — |
| New York | — | — | — | — | — | — | — | — | — | — | — | — |
| North Carolina | 161 | 311,236 | 44 | 103,130 | 29 | 75,898 | 70 | 112,820 | 4 | 404 | 14 | 18,984 |
| North Dakota | 124 | 617,330 | 0 | 0 | 20 | 503,386 | 49 | 19,152 | 55 | 94,792 | — | — |

*(Continued)*



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**Table 10B.47 (Continued)**

| Jurisdiction | Assessed | | Oligotrophic | | Mesotrophic | | Eutrophic | | HyperEutrophic | | Dystrophic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes | Number of Significant Public Lakes | Acreage of Significant Public Lakes |
| Ohio | — | — | — | — | — | — | — | — | — | — | — | — |
| Oklahoma | 199 | 624,343 | 14 | 10,568 | 69 | 105,325 | 77 | 342,706 | 39 | 165,744 | 0 | 0 |
| Oregon | 201 | 491,255 | 58 | 35,280 | 72 | 75,212 | 60 | 191,310 | 11 | 189,453 | 0 | 0 |
| Pennsylvania | 66 | 76,122 | — | — | 13 | 6,268 | 39 | 44,630 | 14 | 25,224 | — | — |
| Puerto Rico | 18 | — | 3 | — | 3 | — | 12 | — | — | — | — | — |
| Rhode Island | 62 | 7,307 | 21 | 1,900 | 28 | 4,089 | 10 | 1,199 | 2 | 99 | 1 | 20 |
| South Carolina | 27 | 452,654 | — | — | 14 | 247,414 | 13 | 205,240 | — | — | — | — |
| South Dakota | 112 | 132,159 | 2 | 1,199 | 10 | 23,205 | 37 | 30,526 | 63 | 77,229 | 0 | 0 |
| Tennessee | 122 | 538,438 | 21 | 100,346 | 38 | 320,408 | 39 | 73,338 | 24 | 44,346 | — | — |
| Texas | — | — | — | — | — | — | — | — | — | — | — | — |
| *Torres—Martinez Desert Band* | — | — | — | — | — | — | — | — | — | — | — | — |
| Utah | 129 | 460,561 | 47 | 285,154 | 57 | 59,191 | 24 | 116,166 | 1 | 50 | — | — |
| Vermont | 202 | 42,299 | 33 | 9,817 | 121 | 25,404 | 30 | 6,205 | 2 | 473 | 16 | 400 |
| Virginia | — | — | — | — | — | — | — | — | — | — | — | — |
| Washington | — | — | — | — | — | — | — | — | — | — | — | — |
| West Virginia | 81 | 21,423 | 17 | 7,724 | 31 | 5,335 | 33 | 8,365 | — | — | — | — |
| Wisconsin | — | — | — | — | — | — | — | — | — | — | — | — |
| Wyoming | — | — | — | — | — | — | — | — | — | — | — | — |
| Total | 7,373 | 8,808,157 | 1,220 | 1,587,615 | 2,447 | 3,529,046 | 2,778 | 2,752,663 | 878 | 919,371 | 42 | 19,463 |

*Note*: Oligotrophic, Clear waters with little organic matter or sediment and minimum biological activity; Mesotrophic, Waters with more nutrients, and therefore, more biological productivity; Eutrophic, Waters extremely rich in nutrients, with high biological productivity. Some species may be choked out; Hypereutrophic, Murky, highly productive waters, closest to the wetland status. Many clearwater species cannot survive; Dystrophic, Low in nutrients, highly colored with dissolved humic organic material. (Not necessarily a part of the natural trophic progression.); —, no data.

*Source*: From United States Environmental Protection Agency, 2000, *National Water Quality Inventory: 1998 Report to Congress*, www.epa.gov.

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**Table 10B.48 Lake Acres Meeting Fishable and Swimmable Goals of the Clean Water Act in the United States, by Jurisdiction, in 2000**

| | Fishing | | | Swimming | | |
|---|---|---|---|---|---|---|
| **Jurisdiction** | **Total Assessed** | **Full Support** | **Threatened** | **Total Assessed** | **Full Support** | **Threatened** |
| Alabama | 464,815 | 391,952 | 12,650 | 418,703 | 318,593 | 82,955 |
| Alaska | 0 | — | — | 0 | — | — |
| American Samoa | 0 | — | — | 0 | — | — |
| Arizona | 135,451 | 134,896 | — | 135,379 | 134,320 | — |
| Arkansas | 355,954 | 339,004 | — | 339,004 | 339,004 | — |
| California | 484,834 | 104,952 | 64,678 | 634,251 | 202,876 | 77,465 |
| Colorado | 5,975 | 0 | 0 | 56,658 | 56,650 | 0 |
| Connecticut | 27,601 | 26,809.30 | 0 | 26,049 | 16,767 | 9,011 |
| Delaware | 0 | — | — | 2,954 | 911 | 0 |
| District of Columbia | 238 | 0 | 0 | 238 | 0 | 0 |
| Florida | 883,840 | 654,720 | 0 | 1,260,800 | 760,960 | 110,080 |
| Georgia | 0 | — | — | 0 | — | — |
| Guam | 0 | — | — | 0 | — | — |
| Hawaii | 0 | — | — | 0 | — | — |
| Idaho | 0 | — | — | 0 | — | — |
| Illinois | 123,702 | 100,646 | 0 | 152,628 | 22,129 | 0 |
| Indiana | 45,540 | 0 | 0 | 0 | 0 | 0 |
| Iowa (flood control reservoirs) | 29,850 | 29,850 | 0 | 40,850 | 40,850 | 0 |
| Iowa (lakes) | 21,067 | 20,844 | 59 | 22,924 | 16,091 | 1,041 |
| Kansas | 13,684 | — | 13,683 | 188,506 | — | 47,903 |
| Kentucky | 205,712 | 197,502 | 0 | 215,646 | 215,427 | 0 |
| Louisiana | 0 | — | — | 492,913 | 453,343 | 0 |
| Maine | 987,283 | 987,283 | 0 | 987,283 | 879,314 | 71,105 |
| Maryland | 21,010 | 20,910 | — | 5,069 | 5,069 | — |
| Massachusetts | 10,674 | 193 | 0 | 21,015 | 2,022 | 4,190 |
| Michigan | 889,600 | 0 | — | 3,770 | — | — |
| Minnesota | 0 | — | — | 2,591,796 | 1,769,686 | 557 |
| Mississippi | 275,720 | 134,638 | 112,579 | 19,821 | 19,821 | 0 |
| Missouri | 293,305 | 292,365 | | 262,372 | 261,757 | — |
| Montana | 283,747 | 215,435 | 7,550 | 508,922 | 205,107 | 0 |
| N. Mariana Islands | 0 | — | — | 0 | — | — |
| Nebraska | 114,734 | 114,734 | — | 4,083 | 4,083 | — |
| Nevada | 0 | — | — | 168,354 | 168,354 | — |
| New Hampshire | 168,002 | 168,002 | 0 | 160,406 | 158,034 | 1,085 |
| New Jersey | 14,245 | 0 | 114 | 16,820 | 11,343 | 0 |
| New Mexico | 109,909 | 410 | — | 0 | — | — |
| New York | 151,557 | — | 0 | 125,387 | — | 32,371 |
| North Carolina | 310,727 | 275,547.00 | — | 209,819 | 204,626 | — |
| North Dakota | 518,175 | — | — | 687,315 | 511,376 | 28,881 |
| Ohio | 103,867 | 28,682 | 62,385 | 78,175 | 641 | 51,921 |
| Oklahoma | 0 | — | — | 530,124 | 61,635 | 271,024 |
| Oregon | 31,489 | 0 | 13,008 | 507,536 | 479,174 | 9,428 |
| Pennsylvania | 0 | — | — | 0 | — | — |
| Puerto Rico | 0 | — | — | 12,146 | 7,741 | 1,878 |
| Rhode Island | 175 | 0 | 0 | 14,493 | 13,792 | 0 |
| South Carolina | 0 | — | — | 313,306.0 | 310,027.9 | — |
| South Dakota | 31,438 | 31,438 | — | 48,468 | 48,468 | — |
| Tennessee | 0 | — | — | 494,479 | 395,923 | 0 |
| Texas | 620,092 | 265,599 | 0 | 480,467 | 480,067 | 0 |
| Utah | 460,642 | 460,642 | 0 | 162,760 | 161,760 | — |
| Vermont | 51,739 | 30,781 | 0 | 52,943 | 34,256 | 10,712 |
| Virginia | 116,565 | 45,487 | 71,078 | 109,574 | 109,469 | 0 |
| Washington | 0 | — | — | 0 | — | — |
| West Virginia | 48 | 48 | 0 | 4,430 | — | 4,430 |
| Wisconsin | 203,704 | 116,474 | 22,504 | 93,663 | 3,623 | 1,367 |
| Wyoming | 0 | — | — | 0 | — | — |
| **Total** | **8,566,710** | **5,189,844** | **380,288** | **12,662,298** | **8,885,090** | **817,405** |
| **Percent of assessed** | | **60.6%** | **4.4%** | | **70.2%** | **6.5%** |

*Note:* Supporting, Fully supporting of all uses; Threatened, Fully supporting all uses but threatened for one or more uses; —, no data

*Source*: From Abstracted from United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

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**Table 10B.49 Summary of Acres of Fully Supporting, Threatened, Imparied Waters in Assessed Lakes in the United States by Jurisdiction, in 2000**

| Jurisdiction | Total Lake Acres | Assessed | Full Support | Threatened | Impaired | Not Attainable |
|---|---|---|---|---|---|---|
| Alabama | 490,472 | 464,811 | 217,431 | 131,587 | 115,793 | 0 |
| Alaska | 12,787,200 | 16,376 | 11,438 | 0 | 4,938 | 0 |
| American Samoa | — | 0 | 0 | 0 | 0 | 0 |
| Arizona | 400,720 | 135,451 | 118,361 | 0 | 17,090 | 0 |
| Arkansas | 514,245 | 355,954 | 339,004 | 0 | 16,950 | 0 |
| California | 1,672,684 | 754,737 | 175,282 | 64,636 | 514,819 | 0 |
| Colorado | 164,029 | 62,920 | 56,669 | 0 | 6,251 | 0 |
| Connecticut | 64,973 | 27,669 | 19,145 | 6,984 | 1,540 | 0 |
| Delaware | 2,954 | 0 | 0 | 0 | 0 | 0 |
| District of Columbia | 238 | 238 | 0 | 0 | 238 | 0 |
| Florida | 2,085,120 | 1,683,000 | 771,840 | 110,080 | 801,080 | 0 |
| Georgia | 425,382 | 402,849 | 65,166 | 0 | 337,683 | 0 |
| Guam | 169 | 0 | 0 | 0 | 0 | 0 |
| Hawaii | 2,168 | 0 | 0 | 0 | 0 | 0 |
| Idaho | 700,000 | 0 | 0 | 0 | 0 | 0 |
| Illinois | 309,340 | 154,795 | 7,855 | 0 | 146,940 | 0 |
| Indiana | 142,871 | 71,120 | 25,580 | 0 | 45,540 | 0 |
| Iowa (flood control reservoirs) | — | 40,850 | 19,000 | 16,950 | 4,900 | 0 |
| Iowa (lakes) | 161,366 | 43,268 | 10,336 | 18,695 | 14,237 | 0 |
| Kansas | 188,506 | 188,506 | 0 | 26,884 | 161,622 | 0 |
| Kentucky | 228,385 | 217,422 | 100,447 | 94,839 | 22,136 | 0 |
| Louisiana | 1,078,031 | 518,176 | 40,259 | 1,926 | 475,991 | 0 |
| Maine | 987,283 | 987,283 | 758,081 | 80,134 | 149,068 | 0 |
| Maryland | 77,965 | 21,010 | 8,922 | 0 | 12,087 | 0 |
| Massachusetts | 151,173 | 67,749 | 26,965 | 652 | 39,425 | 706 |
| Michigan | 889,600 | 891,225 | 0 | 1,625 | 889,600 | 0 |
| Minnesota | 3,290,101 | 2,591,796 | 1,769,686 | 557 | 821,553 | 0 |
| Mississippi | 500,000 | 291,721 | 190,239 | 92,655 | 8,827 | 0 |
| Missouri | 293,305 | 293,305 | 110,189 | 122,241 | 60,875 | 0 |
| Montana | 844,802 | 547,929 | 64,146 | 7,550 | 476,233 | 0 |
| N. Mariana Islands | — | 0 | 0 | 0 | 0 | 0 |
| Nebraska | 280,000 | 127,926 | 116,958 | 0 | 10,968 | 0 |
| Nevada | 533,239 | 168,446 | 168,446 | 0 | 0 | 0 |
| New Hampshire | 168,017 | 160,583 | 153,191 | 1,123 | 6,269 | 0 |
| New Jersey | 72,235 | 18,359 | 5,550 | 12,409 | 400 | 0 |
| New Mexico | 997,467 | 154,550 | 30,410 | 0 | 124,140 | 0 |
| New York | 790,782 | 402,486 | 0 | 90,944 | 311,542 | 0 |
| North Carolina | 311,071 | 310,513 | 305,247 | 0 | 5,266 | 0 |
| North Dakota | 714,910 | 0 | 0 | 0 | 0 | 0 |
| Ohio | 118,461 | 78,175 | 641 | 51,921 | 25,613 | 0 |
| Oklahoma | 1,041,884 | 592,147 | 76,188 | 75,677 | 440,282 | 0 |
| Oregon | 618,934 | 507,536 | 296,173 | 88,786 | 122,577 | 0 |
| Pennsylvania | 161,445 | 42,421 | 16,157 | 0 | 26,264 | 0 |
| Puerto Rico | 12,146 | 12,146 | 6,404 | 1,878 | 3,864 | 0 |
| Rhode Island | 21,796 | 16,554 | 13,742 | 5 | 2,808 | 0 |
| South Carolina | 407,505 | 313,865 | 74,044 | 0 | 239,821 | 0 |
| South Dakota | 750,000 | 138,857 | 22,831 | 0 | 116,026 | 0 |
| Tennessee | 538,060 | 530,619 | 412,538 | 0 | 118,081 | 0 |
| Texas | 1,994,600 | 1,547,955 | 858,967 | 97,522 | 591,466 | 0 |
| Utah | 481,638 | 460,642 | 321,453 | 0 | 139,189 | 0 |
| Vermont | 228,920 | 53,350 | 10,452 | 12,488 | 30,410 | 0 |
| Virginia | 149,982 | 116,399 | 25,265 | 87,254 | 3,880 | 0 |
| Washington | 466,296 | 243,749 | 151,763 | 0 | 91,986 | 0 |
| West Virginia | 22,373 | 21,523 | 2,426 | 6,295 | 12,801 | 0 |
| Wisconsin | 944,000 | 230,006 | 52,100 | 44,606 | 133,300 | 0 |
| Wyoming | 325,048 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **40,603,893** | **17,078,967** | **8,026,988** | **1,348,903** | **7,702,370** | **706** |
| **Percent of assessed** | | | **47.0%** | **7.9%** | **45.1%** | **0.0%** |

*Note:* Supporting, Fully supporting of all uses; Threatened, Fully supporting all uses but threatened for one or more uses; Impaired, Partially or not supporting one or more uses; Not Attainable, Not able to support one or more uses; —, no data.

*Source*: From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

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**Table 10B.50 Estimated Phosphorus Loadings to the Great Lakes, 1976–1991**

| Year | Lake Superior | Lake Michigan | Lake Huron | Lake Erie | Lake Ontario |
|---|---|---|---|---|---|
| | | *Metric Tons* | | | |
| 1976 | 3,550 | 6,656 | 4,802 | 18,480 | 12,695 |
| 1977 | 3,661 | 4,666 | 3,763 | 14,576 | 8,935 |
| 1978 | 5,990 | 6,245 | 5,255 | 19,431 | 9,547 |
| 1979 | 6,619 | 7,659 | 4,881 | 11,941 | 8,988 |
| 1980 | 6,412 | 6,574 | 5,307 | 14,855 | 8,579 |
| 1981 | 3,412 | 4,091 | 3,481 | 10,452 | 7,437 |
| 1982 | 3,160 | 4,084 | 4,689 | 12,349 | 8,891 |
| 1983 | 3,407 | 4,515 | 3,978 | 9,880 | 6,779 |
| 1984 | 3,642 | 3,611 | 3,452 | 12,874 | 7,948 |
| 1985 | 2,864 | 3,956 | 5,758 | 11,216 | 7,083 |
| 1986 | 3,059 | 4,981 | 4,210 | 11,118 | 9,561 |
| 1987 | 1,949 | 3,298 | 2,909 | 8,381 | 7,640 |
| 1988 | 2,067 | 2,907 | 3,165 | 7,841 | 6,521 |
| 1989 | 2,323 | 4,360 | 3,277 | 8,568 | 6,728 |
| 1990 | 1,750 | 3,006 | 2,639 | 12,899 | 8,542 |
| 1991 | 2,709 | 3,478 | 4,460 | 11,113 | 10,475 |

*Note:* The 1978 Great Lakes Water Quality Agreement set target loadings for each lake (in metric tons per year): Lake Superior, 3,400; Lake Michigan, 5,600; Lake Huron, 4,360; Lake Erie, 11,000; and Lake Ontario, 7,000. Data do not include loadings to the St. Lawrence River. Data analysis was discontinued after 1991.

*Source*: From The 1997 Annual Report of the Council of Environmental Quality. Great Lakes Water Quality Board, *Great Lakes Water Quality Surveillance Subcommittee Report to the International Joint Commission,* United States and Canada, (International Joint Commission, Windsor, ON, Canada, Biennial).

*Orignal Source*: From www.whitehouse.gov/CEQ.

**Table 10B.51 Summary of Fully Supporting, Threatened, and Impaired Waters in Assessed Great Lakes Shoreline in the United States in 2000**

| Jurisdiction | Total Miles | Assessed | Full Support | Threatened | Impaired | Not Attainable |
|---|---|---|---|---|---|---|
| Illinois | 63 | 63 | 0 | 63 | 0 | 0 |
| Indiana | 43 | 43 | 0 | 0 | 43 | 0 |
| Michigan | 3,250 | 3,250 | 0 | 0 | 3,250 | 0 |
| Minnesota | 272 | 0 | 0 | 0 | 0 | 0 |
| New York | 577 | 457 | 0 | 40 | 417 | 0 |
| Ohio | 236 | 220 | 0 | 185 | 35 | 0 |
| Pennsylvania | 63 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 1,017 | 1,017 | 0 | 807 | 210 | 0 |
| **Total** | **5,521** | **5,050** | **0** | **1,095** | **3,955** | **0** |
| **Percent of assessed** | | | **0.0%** | **21.7%** | **78.3%** | **0.0%** |

*Note:* Supporting, fully supporting of all uses; Threatened, fully supporting all uses but threatened for one or more uses; Impaired, partially or not supporting one or more uses; Not Attainable, not able to support one or more uses.

*Source*: From Abstracted from United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

**Table 10B.52 Atmospheric Input of Some Organic Contaminants to the Great Lakes**

| Compound | Lakes Superior | Lake Michigan | Lake Huron | Lake Erie | Lake Ontario |
|---|---|---|---|---|---|
| Total PCB | 9.8 | 6.9 | 7.2 | 3.1 | 2.3 |
| Dieldrin | 0.5 | 0.4 | 0.6 | 0.2 | 0.1 |
| Total PAH | 163 | 114 | 118 | 51 | 38 |
| Total DOT | 0.6 | 0.4 | 0.4 | 0.2 | 0.1 |
| p.p′-Methoxychlor | 8.3 | 5.9 | 6.1 | 2.6 | 1.9 |

*Note:* Metric tons per Year.

*Source*: From Great Lakes Water Quality Board, 1985 Report on Great Lakes Water Quality.

*Original Source*: Eisenreich et al., 1981.

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**Table 10B.53 Atmospheric Loading Estimates for Selected Pollutants (kg/yr) in the Great Lakes**

| Pollutant of Concern | Superior | Michigan | Huron | Erie | Ontario |
|---|---|---|---|---|---|
| PCBs[a] (wet and dry) | | | | | |
| 1988 | 550 | 400 | 400 | 180 | 140 |
| 1992 | 160 | 110 | 110 | 53 | 42 |
| 1994 | 85 | 69 | 180 | 37 | 64 |
| 1996 | 50 | 42 | N/A | 34 | N/A |
| PCBs[a] (net gas transfer)[b] | | | | | |
| 1988 | −1900 | −5140 | −2560 | −1100 | −708 |
| 1994 | −1,700 | −2,700 | — | −420 | −440 |
| DDT (wet and dry) | | | | | |
| 1988 | 90 | 64 | 65 | 33 | 26 |
| 1992 | 34 | 25 | 25 | 12 | 10 |
| 1994 | 17 | 32 | 37 | 46 | 16 |
| 1996 | 4 | 12 | N/A | 2 | N/A |
| DDT (net gas transfer) | | | | | |
| 1988 | −681 | −480 | −495 | −213 | −162 |
| 1994 | 30 | 67 | — | 34 | 13 |
| Benzo(a)pyrene (wet and dry) | | | | | |
| 1988 | 69 | 180 | 180 | 81 | 62 |
| 1992[c] | 120 | 84 | 84 | 39 | 31 |
| 1994 | 200 | 250 | — | 240 | 120 |

*Note:* —, Not determined or reported.

[a] Data presented for PCB congeners 18, 44, 52, and 101 (each with 3–5 chlorines in chemical structure).
[b] The convention is to assign a negative number to loss of pollutant from the lake (i.e., volatilization). Thus, the resulting number expresses the mass of a pollutant going into or coming out of the lake per year (i.e., a positive net gas transfer indicates a net input of the pollutant to the lake and a negative net gas transfer indicates a net loss or output from the lake).
[c] Data from 1992 may represent an underestimation in the measurement of benzo(a)pyrene.

*Source*: Modified From United States Environmental Protection Agency, 1997, *Deposition of Air Pollutants to the Great Waters Second Report to Congress*, EPA-453/R-97-011. 1996; data source: United States Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters Third Report to Congress*, EPA-453/R-00-005.

*Original Source*: From Eisenreich and Strachan 1992; Hillery et al., 1996; Hoff et al., 1996; Strachan and Eisenreich 1988.

**Table 10B.54 Sources of PCBs to Lake Superior**

| Source | kg/yr | Percent of Total |
|---|---|---|
| Atmosphere | 6,600–8,300 | 82–86 |
| Tributary | 1,300 | 13–16 |
| Municipal discharges | 66 | 1 |
| Industrial discharges | 2 | 1 |
| Total | 8,000–9,000 | |

*Source*: From Great Lakes Water Quality Board, 1985 Report on Great Lakes Water Quality.

*Original Source*: From Eisenreich et al., 1981.

**Table 10B.55 Concentration of Total PCBs in Lake Superior Water Column**

| Year | Total PCB Concentration (μg/L) | Total Concentration of 25 PCB Congeners (μg/L) |
|---|---|---|
| 1978 | 0.00173±0.00065 | NA |
| 1979 | 0.00404±0.00056 | NA |
| 1980 | 0.00113±0.00011 | 0.00099±0.00010 |
| 1983 | 0.0008±0.00007 | 0.00073±0.00006 |
| 1986 | 0.00056±0.00016 | 0.00055±0.00015 |
| 1988 | 0.00033±0.00004 | 0.00020±0.00001 |
| 1990 | 0.00032±0.00003 | 0.00021±0.00001 |
| 1992 | 0.00018±0.00002 | 0.00009±0.00001 |

*Note:* NA, not applicable.

*Source*: From United States Environmental Protection Agency, 1997, *Deposition of Air Pollutants to the Great Waters*, Second Report to Congress, EPA-453/R-97-01.

*Original Source*: From Jeremiason et al., 1994.

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**Table 10B.56 Comparison of Water-Quality Criteria to Pollutant Concentrations in the Great Lakes (μg/L)**

| Pollutant | National AWQC: Fresh Water Aquatic Life[a] | National AWQC: Human Health[b] | Great Lakes Water-Quality Agreement Objective[c] | Great Lakes Water-Quality Criterion[d] | Total Water Column Concentration[e] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lake Superior | Lake Michigan | Lake Huron | Lake Erie | Lake Ontario |
| DDT/DD[f] | 0.001 | 0.00024 | 0.003 | 0.000011 | <0.00006 | NA | <0.00006 | <0.00006 | <0.00006 |
| Dieldrin | 0.0019 | 0.00071 | 0.001[g] | 0.0000065 | **0.00026** | NA | **0.00032–0.00035** | **0.00038** | **0.00028–0.00032** |
| HCB | — | 0.0072 | — | 0.00045 | <0.00004 | NA | 0.000072 | 0.000047 | 0.000036 |
| α-HCH | — | 0.092 | — | — | 0.0011 | 0.0016 | 0.0015 | 0.0011 | 0.0008–0.0009 |
| Lindane | 0.08 | 0.186 | 0.01 | 0.47 | 0.0004 | 0.00034 | 0.00038 | 0.00049 | 0.00036 |
| Total PCBs | 0.014 | 0.00079 | — | 0.0000039 | **0.00018** | **0.00020–0.00036** | **0.0007–0.0009** | ***0.00122*** | ***0.0012*** |
| POM[h] | — | 0.028 | — | — | <0.00046 | NA | <0.00046 | <0.00046 | <0.00046 |

*Note:* NA, No data available; Bold texts indicate exceedances of GLWQC; bold-italic texts indicate exceedances of AW/QC for human health.

[a] Values are for freshwater chronic criteria (U.S. EPA 1986).
[b] Values are for human chronic exposure through both fish consumption and drinking water (U.S. EPA 1986).
[c] Values are for protection of the most sensitive user of the water among humans, aquatic life and wildlife (IJC 1978).
[d] Values are the most stringent (i.e., lowest) among those for protection of human health, aquatic life, or wildlife (U.S. EPA 1995a).
[e] Concentrations are taken from De Vault et al. (1995) and L'Italian (1993). Concentrations of dieldrin and PCBs that are reported as ranges represent two different concentrations reported in two different studies. For α-HCH, the range of concentrations in Lake Ontario represents the range reported in a single study.
[f] Sampling data are for *p,p'*-DDE.
[g] Value for aldrin and dieldrin combined.
[h] AWQC for human health is for polycyclic aromatic hydrocarbons (PAHs), a subset of POM, sampling data are for benzo(a)pyrene, a PAH.

*Source*: From United States Environmental Protection Agency, 1997, *Deposition of Air Pollutants to the Great Waters, Second Report to Congress*, EPA-453/R-97-011, www.epa.gov.

**Table 10B.57 Modeled Air Deposition, Depositional Flux, and Waterborne Inputs of Dioxins and Furans to the Great Lakes**

| Dioxins and Furans | Superior | Huron | Michigan | Erie | Ontario | Total |
|---|---|---|---|---|---|---|
| Atmospheric deposition (g TEQ/yr) | 5.6 | 8.6 | 13.7 | 7.3 | 6.4 | 42 |
| (range) | (2–17) | (3–25) | (5–43) | (2–21) | (2–18) | (13–124) |
| Depositional flux ($\mu g/km^2/yr$) | 69 | 145 | 238 | 284 | 337 | 172 |
| Waterborne inputs (g TEQ/yr) | 1.4 | 1.4 | 1.9 | 11 | >3.9 | >19.6 |
| Percent contribution from atmospheric sources | 80 | 86 | 88 | 40 | ~62 | ~68 |

*Source*: From United States Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters. Third Report to Congress*, EPA-453/R-00-005, www.epa.gov.

*Orginal Source*: From Cohen et al., 1995.

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**Table 10B.58 Current Rates of Dioxins and Furans Accumulation in Great Lakes Sediments**

| Location | Number of Sediment Cores Analyzed | Accumulation Rates in Sediment ($pg/cm^2/yr$) | | Percent Contribution from Atmospheric Sources | |
|---|---|---|---|---|---|
| | | Dioxins[a] | Furans[a] | Dioxins[a] | Furans[a] |
| Lake Superior | 2 | 7.4–8.0 | 0.8–0.9 | 100 | 100 |
| Northern Lake Michigan | 2 | 44–49 | 22–25 | 33–55 | 5–35 |
| Southern Lake Michigan near Chicago Urban Area | 1 | 17 | 17 | 100 | 5–35 |
| Lake Ontario | 3 | 120–220 | 130–230 | 5–35 | <5 |

[a] Includes the total of all dioxin homologs. Includes the total of all furan homologs.

*Source*: From United States Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters, Third Report to Congress*, EPA-453/R-00-005, www.epa.gov.

*Orginal Source*: From Pearson et al., 1998.

**Table 10B.59 Modeled Air Deposition, Depositional Flux, and Waterborne inputs of Hexachlorobenzene to the Great Lakes**

| HCB | Superior | Michigan | Huron | Erie | Ontario | Total |
|---|---|---|---|---|---|---|
| Total deposition (kg/yr) (range) | 11 (4–49) | 15 (5–73) | 16 (6–74) | 15 (6–65) | 23 (9–101) | 79 (30–362) |
| Depositional flux ($g/km^2/yr$) | 0.13 | 0.26 | 0.27 | 0.58 | 1.19 | 0.32 |
| Waterborne inputs (kg/yr) | 0.1 | 0.8 | 0.6 | <72 | 35 | <108.5 |

*Source*: From United States Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters, Third Report to Congress*, EPA-453/R-00-005, www.epa.gov.

*Orginal Source*: From Cohen et al., 1995.

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**Table 10B.60 Mercury Sources Identified for Lake Michigan, Chesapeake Bay, and Long Island Sound in Mass Balance Studies (by Percent Contribution)**

| Location | Atmospheric Deposition (%) | Urban Area (%) | Riverine | Groundwater | Direct Discharge | Comments |
|---|---|---|---|---|---|---|
| Lake Michigan[a] | ~80 | ~30 (Chicago) | ~17 | <1 | Not reported | Air-water exchange and sediment burial account for the major loss pathways from the lake, but atmospheric deposition dominates inputs |
| Chesapeake Bay[b] | >50 (Wet 47–53) (Dry 9–11) | Baltimore (percent not known) | ~33–49 | Not reported | Not reported | Over 90 percent of the mercury entering the watershed is retained in the terrestrial system and does not reach the aquatic system |
| Long Island Sound[c] | ~10 | New York New Jersey (percent not known) | ~52 | Not reported | ~36 | Tidal exchange, sediment burial, and air-water exchange are major loss pathways, 45 percent of the mercury entering the sound is re-emitted |

*Source*: From United States Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters, Third Report to Congress*, EPA-453/R-00-005, www.epa.gov.
*Original Source*: From [a] Mason and Sullivan (1997); [b] Mason et al., (1997); [c] Fitzgerald (1998).



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**Table 10B.61 Preliminary Estimates of Total Atmospheric Mercury Deposition to Lake Michigan**

| Deposition | Annual Total (kg) | Annual Mean ($\mu g/m^2$) |
|---|---|---|
| Wet | $614 \pm 186$ | $10.6 \pm 3.2$ |
| Aerosol Dry | $69 \pm 38$ | $1.2 \pm 0.7$ |
| Reactive Gaseous Mercury[a] | 506 | 8.8 |
| Dissolved Gaseous Mercury[b] | $-460$ | $-8.0$ |
| Total | 729 | 12.6 |

[a] Reactive gaseous mercury (RGM) deposition values do not include error bars because they reflect a sensitivity analysis performed on a single measurement in place of direct measurements since no measurement method was available for RGM at the time of the study.

[b] Dissolved gaseous mercury (DGM) deposition values do not include error bars because the values reflect a single measurement taken to establish modeling parameters.

*Source*: From United states Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters, Third Report to Congress*, EPA-453/R-00-005, www.epa.gov.

*Orginal Source*: From Landis, 1998.

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**Table 10B.62 Number of Fish Consumption Advisories from the National Listing of Fish and Wildlife Advisories, 2000**

| Jurisdiction | Rivers | Lakes, Reservoirs, Ponds | Great Lakes | Estuaries | Bayous | Coastal | Canal | Wetland | Multi-class Waters | Regional | Statewide | Total Advisories |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alabama | 11 | 2 | — | — | — | 1 | — | — | — | 1 | — | 15 |
| Alaska | — | — | — | — | — | — | — | — | — | — | — | 0 |
| American Samoa | — | — | — | 1 | — | — | — | — | — | — | — | 1 |
| Arizona | 3 | 2 | — | — | — | — | — | — | — | — | — | 5 |
| Arkansas | 8 | 10 | — | — | 3 | — | — | — | 1 | — | — | 22 |
| California | 4 | 12 | — | 2 | — | 11 | — | — | 1 | — | — | 30 |
| Colorado | — | 11 | — | — | — | — | — | — | — | — | — | 11 |
| Connecticut | 5 | 6 | — | 1 | — | — | — | — | — | | 1 | 13 |
| Delaware | 6 | 5 | — | 8 | — | — | 1 | — | — | — | — | 20 |
| District of Columbia | — | — | — | — | — | — | — | — | — | — | 1 | 1 |
| Florida | 27 | 52 | — | — | — | 8 | 1 | — | 10 | — | — | 98 |
| Georgia | 68 | 33 | | 3 | | 1 | | 1 | — | — | — | 106 |
| Hawaii | 2 | — | — | 1 | — | — | — | — | — | — | — | 3 |
| Idaho | — | 1 | | — | — | — | — | — | — | — | — | 1 |
| Illinois | 19 | 11 | 1 | — | — | — | — | — | — | — | — | 31 |
| Indiana | 127 | 69 | 1 | — | — | — | — | — | — | — | 1 | 198 |
| Iowa | — | 1 | — | — | — | — | — | — | — | — | — | 1 |
| Kansas | 10 | 1 | — | — | — | — | — | — | — | — | — | 11 |
| Kentucky | 7 | 1 | — | — | — | — | — | — | 1 | — | 1 | 10 |
| Louisiana | 8 | 12 | — | 1 | 6 | 1 | — | — | 1 | — | — | 29 |
| Maine | 15 | — | — | — | — | 1 | — | — | — | — | 2 | 18 |
| Maryland | 1 | 1 | — | 2 | — | | — | — | — | — | — | 4 |
| Massachusetts | 17 | 83 | — | 4 | — | 1 | — | — | 1 | — | 1 | 107 |
| Michigan[a] | 62 | 64 | 13 | — | — | — | — | 1 | — | — | 1 | 141 |
| Minnesota[a] | 89 | 850 | 1 | — | — | — | — | — | — | — | 1 | 941 |
| Mississippi | 8 | 3 | — | — | — | 1 | — | — | — | 1 | — | 13 |
| Missouri | 5 | — | — | — | — | — | — | — | 1 | 1 | 1 | 8 |
| Montana | 3 | 23 | — | — | — | — | — | — | — | — | — | 26 |
| Nebraska | 15 | 20 | — | — | — | — | 2 | — | — | — | — | 37 |
| Nevada | 1 | 1 | — | — | — | — | — | — | — | — | — | 2 |
| New Hampshire | 1 | 3 | — | — | — | 1 | — | — | — | — | 1 | 6 |
| New Jersey | 14 | 25 | — | 6 | — | 2 | — | — | 1 | — | 1 | 49 |
| New Mexico | 3 | 23 | — | | — | | — | — | — | — | — | 26 |
| New York | 27 | 45 | 8 | 3 | — | 3 | — | — | — | — | 1 | 87 |
| North Carolina | 6 | 7 | — | 1 | — | 1 | — | — | — | 1 | 1 | 17 |
| North Dakota | 2 | 18 | — | — | — | — | 1 | — | — | — | — | 21 |
| Ohio | 53 | 9 | 1 | — | — | — | — | — | — | — | 1 | 64 |
| Oklahoma | 1 | — | — | — | — | — | — | — | — | — | — | 1 |
| Oregon | 6 | 7 | — | — | — | — | — | — | — | — | — | 13 |
| Pennsylvania | 28 | 2 | 2 | 1 | — | — | — | — | — | — | — | 33 |
| Rhode Island | 1 | 1 | — | — | — | 1 | — | — | — | — | — | 3 |
| South Carolina | 39 | 17 | — | — | — | 1 | 2 | — | 1 | — | — | 60 |
| South Dakota | — | 1 | — | — | — | — | — | — | — | — | — | 1 |
| Tennessee | 7 | 9 | — | — | — | — | — | — | 1 | — | — | 17 |

*(Continued)*



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**Table 10B.62 (Continued)**

| Jurisdiction | Rivers | Lakes, Reservoirs, Ponds | Great Lakes | Estuaries | Bayous | Coastal | Canal | Wetland | Multi-class Waters | Regional | Statewide | Total Advisories |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Texas | 4 | 15 | — | 2 | — | 1 | — | — | — | — | — | 22 |
| Utah | 1 | 1 | — | — | — | — | — | — | — | — | — | 2 |
| Vermont | 1 | 9 | — | — | — | — | — | — | — | — | 1 | 11 |
| Virginia | 10 | — | — | — | — | — | — | — | — | — | — | 10 |
| Washington | 1 | 1 | — | 8 | — | 2 | — | — | — | — | — | 12 |
| West Virginia | 10 | — | — | — | — | — | — | — | — | — | — | 10 |
| Wisconsin[a] | 101 | 364 | 4 | — | — | — | — | — | — | — | 1 | 470 |
| **Totals** | **837** | **1,831** | **31** | **44** | **9** | **37** | **7** | **2** | **19** | **—** | **17** | **2,838** |

*Note:* Data from the National Listing of Fish and Wildlife Advisories.

[a] Includes Tribal and joint State/Tribal advisories; Alabama, Connecticut, Florida, Georgia, Louisiana, Maine, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, and Texas the coastal advisory extends statewide.

*Source*: From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.

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**Table 10B.63 Fish Advisories Issued for the Great Lakes**

| Great Lakes | PCBs | Dioxins | Mercury | Chlordane | Mirex | DDT |
|---|---|---|---|---|---|---|
| Lake Superior | • | • | • | • | | |
| Lake Michigan | • | • | • | • | | • |
| Lake-Huron | • | • | • | • | | |
| Lake Erie | • | • | • | | | |
| Lake Ontario | • | • | | | • | |

*Source*: From United States Environmental Protection Agency, 2004, *Fact Sheet Update: National Listing of Fish Advisories*, EPA-823-F-04 016, August 2004, www.epa.gov.

**Table 10B.64 Pollution Discharges in Navigable Waters of the United States in 2001 (by Size)**

| | Petroleum | | | Chemical | | | Other | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Spill Size (Gallons) | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume |
| 1–100 | 7,256 | 96.00 | 33,276 | 86 | 81.90 | 624 | 50 | 90.90 | 259 | 4.70 |
| 101–1,000 | 216 | 2.90 | 86,955 | 10 | 9.50 | 4,680 | 3 | 5.50 | 775 | 14.00 |
| 1,001–3,000 | 45 | 0.60 | 77,447 | 1 | 1.00 | 2,000 | 2 | 3.60 | 4,500 | 81.30 |
| 3,001–5,000 | 16 | 0.20 | 67,241 | 1 | 1.00 | 4,006 | | | | |
| 5,001–10,000 | 11 | 0.10 | 89,224 | 5 | 4.80 | 38,390 | | | | |
| 10,001–50,000 | 14 | 0.20 | 376,057 | 1 | 1.00 | 21,680 | | | | |
| 100,001–1,000,000 | 1 | 0.00 | 124,320 | 1 | 1.00 | 200,049 | | | | |
| **Year-End Statistics** | **7,559** | **100.00** | **854,520** | **105** | **100.00** | **271,429** | **55** | **100.00** | **5,534** | **100.00** |

*Source*: From U.S. Coast Guard, Pollution incidents in and around U.S. waters a spill/release compendium: 1969–2001, *Annual Data and Graphics for Oil Spills (1969–2001)*, www.uscg.mil.

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**Table 10B.65 Pollution Discharges in Navigable Waters of the United States in 2001 (by Type of Source)**

| | Oil | | | | Chemical | | | | Other | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Detailed Source | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume |
| Tankship | 95 | 1.30 | 125,217 | 14.70 | 2 | 1.90 | 11 | 0.00 | 1 | 1.80 | 120 | 2.20 |
| Tankbarge | 246 | 3.30 | 212,298 | 24.80 | 8 | 7.60 | 200,059 | 73.70 | 6 | 10.90 | 11 | 0.20 |
| Commercial vessel | 46 | 0.60 | 474 | 0.10 | | | | | | | | |
| Fishing boat | 562 | 7.40 | 122,454 | 14.30 | | | | | | | | |
| Freight barge | 27 | 0.40 | 86 | 0.00 | | | | | | | | |
| Freight ship | 139 | 1.80 | 22,007 | 2.60 | | | | | | | | |
| Industrial vessel | 42 | 0.60 | 1,284 | 0.20 | 1 | 1.00 | 1 | 0.00 | 1 | 1.80 | 1 | 0.00 |
| Oil recovery | 4 | 0.10 | 6 | 0.00 | | | | | | | | |
| Passenger | 179 | 2.40 | 1,163 | 0.10 | | | | | | | | |
| Public vessel | 197 | 2.60 | 10,192 | 1.20 | | | | | 1 | 1.80 | 3 | 0.10 |
| Unclassified | | | | | | | | | | | | |
| Recreational | 613 | 8.10 | 8,907 | 1.00 | | | | | | | | |
| Research vessel | 36 | 0.50 | 162 | 0.00 | | | | | | | | |
| Towboat/Tugboat | 382 | 5.10 | 12,980 | 1.50 | | | | | 4 | 7.30 | 4 | 0.10 |
| Unclassified vessel | 2,299 | 30.40 | 47,512 | 5.60 | 6 | 5.70 | 6 | 0.00 | 8 | 14.50 | 78 | 1.40 |
| Modu | 38 | 0.50 | 1,775 | 0.20 | 5 | 4.80 | 23 | 0.00 | 1 | 1.80 | 1 | 0.00 |
| OSV | 108 | 1.40 | 3,314 | 0.40 | 4 | 3.80 | 4,016 | 1.50 | 1 | 1.80 | 1 | 0.00 |
| Public tank ship/barge | 4 | 0.10 | 12 | 0.00 | | | | | | | | |
| Public freight | 4 | 0.10 | 13 | 0.00 | | | | | | | | |
| Designated waterfront | 266 | 3.50 | 112,648 | 13.20 | 25 | 23.80 | 36,515 | 13.50 | 3 | 5.50 | 591 | 10.70 |
| facility | | | | | | | | | | | | |
| Land facility nonmarine | 61 | 0.80 | 23,099 | 2.70 | 3 | 2.90 | 2,051 | 0.80 | 1 | 1.80 | 1 | 0.00 |
| Other onshore marine | 3 | 0.00 | 10 | 0.00 | | | | | | | | |
| facility | | | | | | | | | | | | |
| Fixed platform | 620 | 8.20 | 63,470 | 7.40 | 14 | 13.30 | 7,195 | 2.70 | 4 | 7.30 | 118 | 2.10 |
| Mobile facility | 27 | 0.40 | 459 | 0.10 | 2 | 1.90 | 402 | 0.10 | | | | |
| Municipal facility | 18 | 0.20 | 1,339 | 0.20 | 1 | 1.00 | 50 | 0.00 | 1 | 1.80 | 1,500 | 27.10 |
| Offshore pipeline | 13 | 0.20 | 1,241 | 0.10 | | | | | | | | |
| Onshore pipeline | 21 | 0.30 | 12,336 | 1.40 | 1 | 1.00 | 1 | 0.00 | | | | |
| Aircraft | 10 | 0.10 | 861 | 0.10 | | | | | | | | |
| Other land vehicle | 40 | 0.50 | 13,860 | 1.60 | | | | | | | | |
| Other railroad | 1 | 0.00 | 500 | 0.10 | 1 | 1.00 | 250 | 0.10 | 1 | 1.80 | 3,000 | 54.20 |
| equipment | | | | | | | | | | | | |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tank truck | 1 | 0.00 | 5 | 0.00 | | | | | | | | |
| Bridge | 1 | 0.00 | 40 | 0.00 | | | | | | | | |
| Factory | 12 | 0.20 | 95 | 0.00 | | | | | | | | |
| Fleeting area | 2 | 0.00 | 24 | 0.00 | | | | | | | | |
| Industrial facility | 28 | 0.40 | 7,859 | 0.90 | 6 | 5.70 | 1,731 | 0.60 | 1 | 1.80 | 31 | 0.60 |
| Locks | 1 | 0.00 | 5 | 0.00 | | | | | | | | |
| Marina | 50 | 0.70 | 2,207 | 0.30 | | | | | | | | |
| Marpol reception | 6 | 0.10 | 3,042 | 0.40 | | | | | | | | |
| Non-vessel common carrier | 1 | 0.00 | 5 | 0.00 | | | | | | | | |
| Outfall/sewer/drain | 7 | 0.10 | 20 | 0.00 | | | | | | | | |
| Permanently moored | 4 | 0.10 | 115 | 0.00 | | | | | | | | |
| Shipyard/repair facility | 20 | 0.30 | 4,134 | 0.50 | | | | | | | | |
| Shoreline | 252 | 3.30 | 23,149 | 2.70 | 10 | 9.50 | 10.635 | 3.90 | 1 | 1.80 | 50 | 0.90 |
| Unknown or other | 1,073 | 14.20 | 14,141 | 1.70 | 16 | 15.20 | 8,483 | 3.10 | 20 | 36.40 | 24 | 0.40 |
| **Year-end statistics** | **7,559** | **100.00** | **854,520** | **100.00** | **105** | **100.00** | **271,429** | **100.00** | **55** | **100.00** | **5,534** | **100.00** |

*Source*: From U.S. Coast Guard, Pollution incidents in and around U.S. waters a spill/release compendium: 1969–2001, *Annual Data and Graphics for Oil Spills (1969–2001)*, www.uscg.mil.



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**Table 10B.66 Pollution Discharges in Navigable Water in the United States (by Type of Location and Water Body)**

| | Petroleum | | | | Chemical | | | | Other | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume |
| **Waterbody** | | | | | | | | | | | | |
| Atlantic Ocean | 83 | 1.10 | 7,168 | 0.80 | 1 | 1.00 | 5 | 0.00 | | | | |
| Pacific Ocean | 493 | 6.50 | 53,295 | 6.20 | 7 | 6.70 | 16 | 0.00 | | | | |
| Gulf of Mexico | 1,728 | 22.90 | 133,872 | 15.70 | 28 | 26.70 | 19,634 | 7.20 | 17 | 30.90 | 136 | 2.50 |
| Great Lakes | 109 | 1.40 | 1,600 | 0.20 | | | | | | | | |
| Lakes | 35 | 0.50 | 244 | 0.00 | | | | | | | | |
| Rivers & canals | 1,682 | 22.30 | 237,980 | 27.80 | 20 | 19.00 | 20,492 | 7.50 | 13 | 23.60 | 3,075 | 55.60 |
| Bays & sounds | 1,140 | 15.10 | 139,300 | 16.30 | 12 | 11.40 | 1,070 | 0.40 | 2 | 3.60 | 2 | 0.00 |
| Harbors | 693 | 11.80 | 158,667 | 18.60 | 17 | 16.20 | 206,869 | 76.20 | 8 | 14.50 | 213 | 3.80 |
| Other | 1,396 | 18.50 | 122,394 | 14.30 | 20 | 19.00 | 23,343 | 8.60 | 15 | 27.30 | 2,108 | 38.10 |
| Year-end statistics | 7,559 | 100.00 | 854,520 | 100.00 | 105 | 100.00 | 271,429 | 100.00 | 55 | 100.00 | 5,534 | 100.00 |
| **Location** | | | | | | | | | | | | |
| Internal/headlands | 3,677 | 48.60 | 529,482 | 62.00 | 50 | 47.60 | 228,432 | 84.20 | 22 | 40.00 | 3,289 | 59.40 |
| Coastal (0–3 Ml) | 796 | 10.50 | 121,432 | 14.20 | 10 | 9.50 | 7,173 | 2.60 | 6 | 10.90 | 11 | 0.20 |
| Contiguous zone (3–12 Ml) | 118 | 1.60 | 287 | 0.00 | 1 | 1.00 | 5 | 0.00 | 1 | 1.80 | 1 | 0.00 |
| Ocean (12–200 Ml) | 1,005 | 13.30 | 52,784 | 6.20 | 22 | 21.00 | 12,465 | 4.60 | 10 | 18.20 | 124 | 2.20 |
| Ocean general | 503 | 6.70 | 26,891 | 3.10 | 2 | 1.90 | 11 | 0.00 | 1 | 1.80 | 1 | 0.00 |
| Other | 1,460 | 19.30 | 123,664 | 14.50 | 20 | 19.00 | 23,343 | 8.60 | 15 | 27.30 | 2,108 | 38.10 |
| Year-end statistics | 7,559 | 100.00 | 854,520 | 100.00 | 105 | 100.00 | 271,429 | 100.00 | 55 | 100.00 | 5,534 | 100.00 |

*Source*: From U.S. Coast Guard, Pollution incidents in and around U.S. waters a spill/release compendium: 1969–2001, *Annual Data and Graphics for Oil Spills (1969–2001)*, www.uscg.mil.

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**Table 10B.67 Pollution Discharges in Navigable Waters of the United States in 2001 by State**

| State | Oil | | | | Chemical | | | | Other | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume |
| Alaska | 350 | 4.60 | 47,643 | 5.60 | 6 | 5.70 | 15 | 0.00 | | | | |
| Alabama | 152 | 2.00 | 2,450 | 0.30 | 2 | 1.90 | 2 | 0.00 | | | | |
| American Samoa | 65 | 0.90 | 2,423 | 0.30 | | | | | | | | |
| California | 641 | 8.50 | 24,794 | 2.90 | 3 | 2.90 | 403 | 0.10 | 1 | 1.80 | 7 | 0.10 |
| Connecticut | 21 | 0.30 | 2,665 | 0.30 | | | | | | | | |
| District of Columbia | 11 | 0.10 | 5,048 | 0.60 | 1 | 1.00 | 10,000 | 3.70 | | | | |
| Delaware | 36 | 0.50 | 1,621 | 0.20 | 1 | 1.00 | 1,000 | 0.40 | | | | |
| Florida | 554 | 7.30 | 11,508 | 1.30 | 1 | 1.00 | 2 | 0.00 | 1 | 1.80 | 3 | 0.10 |
| Georgia | 20 | 0.30 | 47 | 0.00 | 1 | 1.00 | 500 | 0.20 | | | | |
| Guam | 44 | 0.60 | 694 | 0.10 | | | | | | | | |
| Hawaii | 115 | 1.50 | 5,854 | 0.70 | | | | | | | | |
| Iowa | 2 | 0.00 | 3 | 0.00 | | | | | | | | |
| Illinois | 49 | 0.60 | 2,034 | 0.20 | | | | | | | | |
| Indiana | 10 | 0.10 | 39 | 0.00 | | | | | | | | |
| Iowa | 2 | 0.00 | 65 | 0.00 | | | | | | | | |
| Kentucky | 58 | 0.80 | 125,917 | 14.70 | | | | | | | | |
| Louisiana | 1,487 | 19.70 | 147,740 | 17.30 | 10 | 9.50 | 15,640 | 5.80 | 21 | 38.20 | 565 | 10.20 |
| Massachusetts | 136 | 1.80 | 7,794 | 0.90 | | | | | | | | |
| Maryland | 154 | 2.00 | 4,095 | 0.50 | 3 | 2.90 | 256 | 0.10 | 1 | 1.80 | 3,000 | 54.20 |
| Maine | 53 | 0.70 | 1,607 | 0.20 | 3 | 2.90 | 52 | 0.00 | | | | |
| Michigan | 62 | 0.80 | 353 | 0.00 | 2 | 1.90 | 2,020 | 0.70 | | | | |
| Minnesota | 25 | 0.30 | 309 | 0.00 | 1 | 1.00 | 4 | 0.00 | 1 | 1.80 | 1 | 0.00 |
| Missouri | 8 | 0.10 | 75 | 0.00 | 1 | 1.00 | 7,600 | 2.80 | | | | |
| N. Mariana Islands | 2 | 0.00 | 2 | 0.00 | | | | | | | | |
| Mississippi | 119 | 1.60 | 2,465 | 0.30 | | | | | | | | |
| North Carolina | 126 | 1.70 | 2,399 | 0.30 | 2 | 1.90 | 17 | 0.00 | | | | |
| New Hampshire | 22 | 0.30 | 42 | 0.00 | | | | | | | | |
| New Jersey | 114 | 1.50 | 10,854 | 1.30 | 4 | 3.80 | 109 | 0.00 | 1 | 1.80 | 50 | 0.90 |
| New York | 156 | 2.10 | 32,114 | 3.80 | 5 | 4.80 | 1,554 | 0.60 | 2 | 3.60 | 2 | 0.00 |
| Ohio | 43 | 0.60 | 2,123 | 0.20 | | | | | | | | |
| Oregon | 67 | 0.90 | 18,765 | 2.20 | | | | | | | | |
| Pennsylvania | 42 | 0.60 | 9,003 | 1.10 | 1 | 1.00 | 1 | 0.00 | 1 | 1.80 | 1 | 0.00 |
| Puerto Rico | 52 | 0.70 | 779 | 0.10 | | | | | | | | |
| Rhode Island | 78 | 1.00 | 1,497 | 0.20 | | | | | 1 | 1.80 | 1 | 0.00 |
| South Carolina | 58 | 0.80 | 1,227 | 0.10 | | | | | | | | |
| Tennessee | 9 | 0.10 | 334 | 0.00 | | | | | 1 | 1.80 | 1 | 0.00 |
| Texas | 1,072 | 14.20 | 213,653 | 25.00 | 25 | 23.80 | 206,411 | 76.00 | 11 | 20.00 | 277 | 5.00 |

*(Continued)*



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**Table 10B.67 (Continued)**

| State | Oil | | | | Chemical | | | | Other | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume |
| Virginia | 132 | 1.70 | 21,383 | 2.50 | 3 | 2.90 | 21,687 | 8.00 | 1 | 1.80 | 1 | 0.00 |
| Virgin Islands | 30 | 0.40 | 1,364 | 0.20 | | | | | | | | |
| Washington | 465 | 6.20 | 24,800 | 2.90 | 5 | 4.80 | 73 | 0.00 | 1 | 1.80 | 1 | 0.00 |
| Wisconsin | 21 | 0.30 | 10,186 | 1.20 | 2 | 1.90 | 7 | 0.00 | 1 | 1.80 | 1,500 | 27.10 |
| West Virginia | 14 | 0.20 | 543 | 0.10 | | | | | | | | |
| Unknown or beyond state waters | 882 | 11.70 | 106,209 | 12.40 | 23 | 21.90 | 4,076 | 1.50 | 10 | 18.20 | 124 | 2.20 |
| **Year-end statistics** | **7,559** | **100.00** | **854,520** | **100.00** | 105 | **100.00** | **271,429** | **100.00** | **55** | **100.00** | **5,534** | **100.00** |

*Source*: From U.S. Coast Guard, Pollution incidents in and around U.S. waters a spill/release compendium: 1969–2001, *Annual Data and Graphics for Oil Spills (1969–2001)*, www.uscg.mil.

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**Table 10B.68 Type of Oil Discharged to Navigable Waters of the United States in 2001**

| Oil Type | Number of Spills | % of Spill Incidents | Spill Volume (Gallons) | % of Spill Volume |
|---|---|---|---|---|
| Crude oils | 1,173 | 15.50 | 182,999 | 21.40 |
| Heavy fuel oils | 121 | 1.60 | 82,168 | 9.60 |
| Intermediate fuel oils | 2,181 | 28.90 | 228,320 | 26.70 |
| Gasoline products | 260 | 3.40 | 27,233 | 3.20 |
| Other petroleum oils | 3,788 | 50.10 | 333,643 | 39.00 |
| Nonpetroleum oils | 36 | 0.50 | 157 | 0.00 |
| **Year-end statistics** | **7,559** | **100.00** | **854,520** | **100.00** |

*Source*: From U.S. Coast Guard, Pollution incidents in and around U.S. waters a spill/release compendium: 1969–2001, *Annual Data and Graphics for Oil Spills (1969–2001)*, www.uscg.mil.

**Table 10B.69 Oil Spills in U.S. Water — Number and Volume: 1998–2001**

| | Number of Spills | | | | Spill Volume (Gallons) | | | |
|---|---|---|---|---|---|---|---|---|
| **Spill Characteristics** | **1998** | **1999** | **2000** | **2001** | **1998** | **1999** | **2000** | **2001** |
| Total | 8,315 | 8,539 | 8,354 | 7,539 | 885,303 | 1,172,449 | 1,431,370 | 854,520 |
| **Size of spill (gallons)** | | | | | | | | |
| 1–100 | 7,962 | 8,212 | 8,058 | 7,258 | 38,093 | 38,119 | 39,355 | 33,276 |
| 101–1,000 | 259 | 240 | 219 | 216 | 86,606 | 86,530 | 78,779 | 86,955 |
| 1,001–3,000 | 54 | 42 | 37 | 45 | 96,743 | 74,582 | 67,529 | 77,447 |
| 3,001–5,000 | 15 | 18 | 12 | 16 | 64,609 | 73,798 | 45,512 | 67,241 |
| 5,001–10,000 | 15 | 10 | 16 | 11 | 108,148 | 66,274 | 112,415 | 89,224 |
| 10,001–50,000 | 8 | 12 | 6 | 14 | 216,335 | 301,510 | 108,400 | 376,057 |
| 50,001–100,000 | — | 4 | 4 | — | — | 245,406 | 266,380 | — |
| 100,001–1,00,000 | 2 | 1 | 2 | 1 | 274,769 | 285,230 | 713,000 | 124,320 |
| 1,000,000 and over | — | — | — | — | — | — | — | — |
| **Waterbody** | | | | | | | | |
| Atlantic ocean | 109 | 148 | 150 | 83 | 6,674 | 29,440 | 135,010 | 7,168 |
| Pacific ocean | 644 | 758 | 623 | 493 | 192,775 | 150,694 | 36,301 | 53,295 |
| Gulf of Mexico | 2,190 | 1,756 | 1,838 | 1,728 | 181,372 | 45,786 | 112,069 | 133,872 |
| Great Lakes | 119 | 129 | 95 | 109 | 3,006 | 906 | 4,535 | 1,600 |
| Lakes | 25 | 31 | 32 | 35 | 63 | 624 | 349 | 244 |
| Rivers and canals | 1,944 | 1,924 | 1,816 | 1,682 | 280,651 | 504,254 | 663,404 | 237,980 |
| Bays and sounds | 891 | 1,299 | 1,248 | 1,140 | 24,234 | 136,650 | 49,783 | 139,300 |
| Harbors | 790 | 907 | 801 | 893 | 97,223 | 105,213 | 273,095 | 158,667 |
| Other | 1,603 | 1,587 | 1,750 | 1,396 | 99,305 | 198,872 | 156,824 | 122,394 |
| **Source** | | | | | | | | |
| Tankship | 104 | 82 | 111 | 95 | 56,673 | 8,414 | 608,176 | 125,217 |
| Tankbarge | 220 | 227 | 229 | 246 | 248,089 | 158,977 | 133,540 | 212,298 |
| All other vessels | 4,848 | 5,361 | 5,220 | 4,680 | 316,473 | 409,084 | 291,927 | 232,341 |
| Facilities | 937 | 1,019 | 1,054 | 995 | 166,269 | 367,537 | 311,604 | 201,025 |
| Piperlines | 45 | 25 | 25 | 34 | 47,863 | 36,140 | 17,021 | 13,577 |
| All other non vessels | 571 | 571 | 566 | 436 | 32,584 | 147,704 | 45,136 | 55,921 |
| Unknown | 1,590 | 1,244 | 1,149 | 1,073 | 17,352 | 44,593 | 23,966 | 14,141 |

*Note:* Based on reported discharges into U.S. navigable waters, including territorial waters (extending 3 to 12 mi from the coastline), tributaries, the contiguous zone, onto shoreline, or into other waters that threaten the marine environment. Data found in Marine Safety Management System; — Represents or rounds to zero.

*Source*: From U.S. Census Bureau, *Statistical Abstract of the United States 2004–2005*, www.census.gov.

*Orginal Source*: From U.S. Coast Guard, www.uscg.mil/hq/g-m/nmc/response/stats/Summary.htm and uscg.mil/hq/g-m/nmc/response/stats/chp2001.pdf (released August 2003).

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**Table 10B.70 Number and Volume of Spills by Type of Oil in the United States, 1973 to 2001**

| | Crude Oils | | Heavy Fuel Oils | | Intermediate Fuel Oils | | Gasoline Products | | Other Petroleum Oils | | Nonpetroleum Oils | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Number** | **Volume** | **Number** | **Volume** | **Number** | **Volume** | **Number** | **Volume** | **Number** | **Volume** | **Number** | **Volume** |
| 73 | 4,807 | 7,219,648 | 915 | 2,068,102 | 1,423 | 2,271,442 | 535 | 1,070,803 | 985 | 2,476,361 | 349 | 147,224 |
| 74 | 5,243 | 10,102,280 | 932 | 1,858,340 | 1,712 | 1,189,120 | 684 | 1,763,230 | 1,051 | 664,618 | 377 | 121,145 |
| 75 | 4,643 | 7,138,446 | 826 | 7,342,076 | 1,654 | 1,091,283 | 684 | 2,068,473 | 1,075 | 3,763,013 | 410 | 116,792 |
| 76 | 4,521 | 5,631,995 | 809 | 9,811,141 | 1,867 | 1,033,888 | 735 | 1,127,213 | 1,156 | 571,926 | 334 | 341,786 |
| 77 | 4,347 | 3,331,533 | 863 | 1,151,495 | 1,944 | 1,528,183 | 762 | 993,647 | 1,285 | 1,041,758 | 258 | 142,518 |
| 78 | 4,481 | 3,518,825 | 938 | 925,233 | 2,498 | 1,653,321 | 854 | 3,780,524 | 1,509 | 759,190 | 364 | 227,015 |
| 79 | 4,036 | 15,411,430 | 873 | 950,344 | 2,396 | 1,658,465 | 771 | 996,134 | 1,414 | 1,340,479 | 344 | 536,710 |
| 80 | 3,358 | 7,762,112 | 773 | 275,089 | 2,083 | 1,328,861 | 604 | 1,601,836 | 1,259 | 1,512,769 | 306 | 116,303 |
| 81 | 3,216 | 2,440,608 | 627 | 4,114,826 | 1,850 | 850,052 | 591 | 841,469 | 1,158 | 427,372 | 369 | 246,666 |
| 82 | 3,070 | 4,761,261 | 454 | 2,906,973 | 1,885 | 911,026 | 620 | 815,359 | 1,100 | 434,293 | 355 | 515,884 |
| 83 | 3,188 | 3,763,206 | 448 | 409,906 | 1,873 | 2,136,142 | 603 | 854,318 | 1,355 | 1,109,342 | 449 | 106,934 |
| 84 | 2,919 | 4,281,504 | 400 | 2,159,878 | 1,927 | 7,224,260 | 664 | 891,746 | 1,594 | 3,360,784 | 754 | 87,706 |
| 85 | 2,153 | 2,012,551 | 291 | 964,056 | 1,596 | 1,997,320 | 582 | 721,325 | 1,152 | 2,617,914 | 395 | 123,083 |
| 86 | 875 | 1,720,405 | 379 | 840,040 | 1,772 | 1,025,190 | 439 | 471,692 | 1,469 | 139,051 | 59 | 85,600 |
| 87 | 555 | 1,768,240 | 325 | 489,686 | 1,867 | 858,323 | 452 | 272,265 | 1,585 | 158,184 | 57 | 62,187 |
| 88 | 660 | 1,856,136 | 314 | 448,387 | 1,941 | 3,452,480 | 447 | 597,773 | 1,572 | 203,555 | 64 | 27,672 |
| 89 | 1,183 | 10,997,750 | 371 | 957,043 | 2,578 | 1,173,326 | 429 | 258,328 | 1,998 | 84,992 | 54 | 7,254 |
| 90 | 1,992 | 4,730,679 | 362 | 499,347 | 2,829 | 1,322,094 | 479 | 756,680 | 2,457 | 603,189 | 58 | 3,017 |
| 91 | 1,712 | 896,683 | 316 | 205,063 | 2,622 | 366,201 | 448 | 98,483 | 3,423 | 307,422 | 48 | 2,099 |
| 92 | 1,728 | 803,160 | 350 | 192,638 | 2,659 | 564,314 | 542 | 124,806 | 4,161 | 184,873 | 51 | 5,876 |
| 93 | 1,598 | 319,467 | 234 | 743,447 | 2,595 | 662,415 | 512 | 99,164 | 3,958 | 217,856 | 75 | 25,039 |
| 94 | 1,549 | 626,821 | 206 | 824,254 | 2,710 | 345,726 | 468 | 219,804 | 3,929 | 414,767 | 98 | 57,901 |
| 95 | 1,467 | 195,857 | 223 | 213,949 | 2,963 | 290,186 | 469 | 46,416 | 3,829 | 344,664 | 86 | 707,157 |
| 96 | 1,783 | 222,976 | 175 | 266,034 | 2,706 | 2,206,213 | 422 | 267,992 | 4,177 | 147,849 | 72 | 6,767 |
| 97 | 1,642 | 412,747 | 163 | 19,710 | 2,477 | 193,390 | 419 | 124,976 | 3,849 | 182,535 | 74 | 9,216 |
| 98 | 1,593 | 304,424 | 122 | 63,885 | 2,576 | 299,337 | 423 | 82,499 | 3,531 | 70,145 | 70 | 65,013 |
| 99 | 1,352 | 148,654 | 116 | 108,408 | 2,751 | 305,096 | 381 | 77,992 | 3,852 | 520,088 | 87 | 12,211 |
| 2000 | 1,283 | 704,259 | 94 | 156,135 | 2,479 | 274,545 | 314 | 32,921 | 4,121 | 262,373 | 63 | 1,137 |
| 2001 | 1,173 | 182,999 | 121 | 82,168 | 2,181 | 228,320 | 260 | 27,233 | 3,788 | 333,643 | 36 | 157 |
| **Totals** | **72,127** | **103,266,654** | **13,020** | **41,047,653** | **64,414** | **38,440,519** | **15,593** | **21,085,101** | **67,793** | **25,095,005** | **6,116** | **3,908,069** |

*Source*: From U.S. Coast Guard, Pollution incidents in and around U.S. waters a spill/release compendium: 1969–2001. *Cumulative date for oil spills 1973–2001*, www.uscg.mil.

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**Table 10B.71 Number and Volume of Oil Spills by Source in the United States, 1973–2001**

| | Tankship | | Tankbarge | | All Other Vessels | | Facilities | | Pipelines | | All Other Nonvessels | | Unknown | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Number** | **Gallons** | **Number** | **Gallons** | **Number** | **Gallons** | **Number** | **Gallons** | **Number** | **Gallons** | **Number** | **Gallons** | **Number** | **Gallons** |
| 73 | 694 | 3,153,070 | 603 | 1,251,320 | 1,527 | 1,049,748 | 3,317 | 5,250,092 | 511 | 2,353,744 | 301 | 424,055 | 2,061 | 1,771,550 |
| 74 | 846 | 1,177,851 | 754 | 2,331,302 | 1,566 | 317,939 | 3,844 | 3,834,292 | 582 | 6,833,402 | 376 | 588,091 | 2,031 | 615,854 |
| 75 | 595 | 8,723,153 | 767 | 2,572,118 | 1,499 | 1,415,466 | 3,139 | 4,663,214 | 667 | 2,769,165 | 390 | 1,149,716 | 2,235 | 227,251 |
| 76 | 526 | 9,315,761 | 894 | 1,702,772 | 1,514 | 281,032 | 2,978 | 2,046,062 | 627 | 4,283,495 | 398 | 647,656 | 2,485 | 241,170 |
| 77 | 533 | 202,590 | 993 | 1,566,631 | 1,760 | 275,255 | 2,671 | 2,353,360 | 461 | 2,528,165 | 426 | 593,305 | 2,615 | 669,827 |
| 78 | 678 | 329,699 | 980 | 3,239,284 | 2,057 | 474,151 | 2,534 | 4,391,595 | 406 | 1,220,486 | 530 | 501,074 | 3,459 | 707,819 |
| 79 | 647 | 13,077,598 | 862 | 1,162,569 | 1,833 | 394,951 | 2,358 | 1,824,738 | 583 | 3,351,156 | 506 | 608,740 | 3,045 | 473,806 |
| 80 | 547 | 1,597,088 | 799 | 1,738,003 | 1,698 | 290,976 | 2,011 | 2,926,797 | 552 | 3,067,276 | 377 | 382,505 | 2,399 | 2,594,326 |
| 81 | 419 | 1,074,621 | 718 | 4,294,542 | 1,584 | 341,595 | 2,007 | 1,126,966 | 561 | 1,338,116 | 324 | 313,718 | 2,198 | 431,436 |
| 82 | 279 | 1,219,922 | 547 | 2,146,576 | 1,383 | 412,484 | 2,244 | 1,660,560 | 598 | 4,213,862 | 392 | 368,696 | 2,041 | 322,696 |
| 83 | 258 | 145,822 | 523 | 1,807,897 | 1,444 | 378,537 | 2,443 | 1,385,766 | 582 | 3,036,906 | 444 | 323,750 | 2,222 | 1,301,170 |
| 84 | 238 | 4,663,952 | 499 | 2,484,481 | 1,530 | 1,863,435 | 2,408 | 1,193,770 | 557 | 1,212,702 | 565 | 381,704 | 2,461 | 6,205,834 |
| 85 | 164 | 732,397 | 385 | 3,683,548 | 1,113 | 446,966 | 2,032 | 2,237,558 | 385 | 777,017 | 385 | 235,654 | 1,705 | 323,108 |
| 86 | 196 | 1,164,962 | 516 | 1,510,064 | 900 | 160,890 | 1,382 | 902,917 | 91 | 230,785 | 158 | 28,596 | 1,750 | 283,764 |
| 87 | 158 | 1,547,462 | 413 | 550,108 | 1,208 | 848,200 | 1,160 | 317,437 | 95 | 196,852 | 142 | 36,522 | 1,665 | 112,303 |
| 88 | 222 | 852,287 | 486 | 3,164,017 | 1,300 | 369,985 | 1,038 | 1,368,898 | 120 | 704,719 | 142 | 39,383 | 1,690 | 86,715 |
| 89 | 200 | 11,272,324 | 504 | 746,833 | 1,564 | 674,660 | 1,688 | 448,792 | 110 | 214,920 | 138 | 33,030 | 2,409 | 88,137 |
| 90 | 249 | 4,977,251 | 457 | 992,025 | 1,779 | 417,882 | 2,287 | 1,059,302 | 149 | 316,928 | 148 | 32,242 | 3,108 | 119,377 |
| 91 | 220 | 92,334 | 428 | 241,346 | 1,780 | 362,809 | 2,389 | 445,986 | 105 | 49,382 | 117 | 10,068 | 3,530 | 674,027 |
| 92 | 193 | 118,075 | 322 | 149,212 | 4,795 | 398,145 | 2,045 | 504,600 | 36 | 200,396 | 815 | 235,839 | 1,285 | 269,400 |
| 93 | 172 | 69,541 | 314 | 697,653 | 4,944 | 409,963 | 2,320 | 350,141 | 35 | 362,399 | 826 | 145,796 | 361 | 31,895 |
| 94 | 172 | 69,694 | 393 | 955,582 | 4,681 | 308,343 | 2,258 | 677,016 | 55 | 62,340 | 796 | 348,577 | 605 | 77,721 |
| 95 | 148 | 125,491 | 353 | 1,101,938 | 4,977 | 396,724 | 586 | 868,900 | 30 | 11,894 | 500 | 77,428 | 2,444 | 55,854 |
| 96 | 122 | 219,311 | 313 | 1,163,258 | 5,151 | 298,451 | 509 | 406,384 | 17 | 978,392 | 552 | 23,527 | 2,671 | 28,508 |
| 97 | 124 | 22,429 | 252 | 165,649 | 4,971 | 192,801 | 838 | 204,935 | 32 | 224,122 | 486 | 72,208 | 1,921 | 60,430 |
| 98 | 104 | 56,673 | 220 | 248,089 | 4,848 | 316,473 | 937 | 166,269 | 45 | 47,863 | 571 | 32,584 | 1,590 | 17,352 |
| 99 | 92 | 8,414 | 228 | 210,383 | 5,360 | 357,678 | 1,019 | 367,537 | 25 | 36,140 | 571 | 147,704 | 1,244 | 44,593 |
| 2000 | 111 | 608,176 | 229 | 133,540 | 5,220 | 291,927 | 1,054 | 311,604 | 25 | 17,021 | 566 | 45,136 | 1,149 | 23,966 |
| 2001 | 95 | 125,217 | 246 | 212,298 | 4,680 | 232,341 | 995 | 201,025 | 34 | 13,577 | 436 | 55,921 | 1,073 | 14,141 |
| **Totals** | **9,002** | **66,743,165** | **14,998** | **42,223,038** | **78,666** | **13,979,807** | **56,491** | **43,486,513** | **8,076** | **40,653,222** | **12,378** | **7,883,225** | **59,452** | **17,874,030** |

*Source*: From U.S. Coast Guard, Pollution incidents in and around U.S. waters a spill/release compendium: 1969–2001. *Cumulative data for oil spills 1973–2001*, www.uscg.mil.



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**Table 10B.72 Number and Volume of Oil Spills by Waterbody in the United States, 1973–2001**

| | Atlantic Ocean | | Pacific Ocean | | Gulf of Mexico | | Great Lakes | | Lakes | | Rivers & Canals | | Bays & Sounds | | Harbors | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Number | Gallons | Number | Gallons | Number | Gallons | Number | Gallons | Number | Gallons | Number | Gallons | Number | Gallons | Number | Gallons | Number | Gallons |
| 73 | 117 | 2,459,968 | 455 | 281,546 | 38 | 8,553 | 62 | 72,971 | 0 | 0 | 3,566 | 8,250,726 | 1,116 | 387,285 | 3,503 | 3,224,849 | 157 | 567,682 |
| 74 | 203 | 185,682 | 622 | 218,073 | 218 | 157,926 | 72 | 131,059 | 0 | 0 | 2,383 | 5,613,582 | 1,941 | 454,526 | 4,015 | 4,714,829 | 545 | 4,223,054 |
| 75 | 156 | 6,107,710 | 477 | 253,517 | 727 | 1,418,791 | 72 | 60,463 | 0 | 0 | 2,544 | 6,486,011 | 934 | 3,184,703 | 3,789 | 2,937,545 | 593 | 1,071,342 |
| 76 | 175 | 7,569,064 | 297 | 436,868 | 936 | 850,660 | 194 | 179,912 | 0 | 0 | 2,457 | 3,763,548 | 967 | 512,399 | 3,614 | 2,655,553 | 782 | 2,549,944 |
| 77 | 283 | | 162 | | 731 | | 209 | | 0 | | 3,763 | | 1,125 | | 2,634 | | 552 | |
| 78 | 270 | 119,135 | 614 | 88,314 | 656 | 402,392 | 113 | 40,706 | 0 | 0 | 4,573 | 4,924,452 | 726 | 2,803,394 | 3,079 | 701,866 | 613 | 1,783,850 |
| 79 | 225 | 307,823 | 487 | 556,054 | 867 | 386,281 | 129 | 72,982 | 0 | 0 | 4,223 | 5,804,497 | 479 | 11,060,800 | 2,654 | 563,290 | 770 | 2,141,835 |
| 80 | 173 | 242,993 | 362 | 210,428 | 743 | 437,069 | 80 | 155,358 | 0 | 0 | 3,294 | 7,090,268 | 366 | 692,490 | 2,650 | 1,590,711 | 715 | 2,177,654 |
| 81 | 149 | 350,511 | 351 | 49,965 | 857 | 99,120 | 45 | 29,508 | 0 | 0 | 2,826 | 6,144,670 | 471 | 152,695 | 2,388 | 590,160 | 724 | 1,504,366 |
| 82 | 119 | 31,305 | 276 | 127,377 | 1,061 | 121,889 | 18 | 10,027 | 0 | 0 | 2,593 | 5,388,921 | 512 | 366,107 | 1,896 | 1,417,451 | 1,009 | 2,881,720 |
| 83 | 135 | 57,083 | 332 | 129,264 | 1,290 | 295,736 | 2 | 11 | 0 | 0 | 2,666 | 2,814,518 | 768 | 1,601,887 | 1,784 | 1,212,231 | 939 | 2,269,117 |
| 84 | 157 | 58,201 | 468 | 1,555,741 | 1,583 | 2,897,179 | 37 | 18,612 | 0 | 0 | 2,453 | 3,928,947 | 647 | 192,080 | 1,848 | 7,604,388 | 1,065 | 1,750,729 |
| 85 | 124 | 56,026 | 361 | 493,419 | 951 | 116,969 | 23 | 1,583 | 2 | 9 | 1,808 | 4,169,267 | 581 | 201,348 | 1,143 | 722,800 | 1,176 | 2,674,827 |
| 86 | 59 | 4,401 | 229 | 171,520 | 431 | 97,221 | 130 | 6,854 | 14 | 1,445 | 1,379 | 1,410,325 | 639 | 335,795 | 723 | 1,172,891 | 1,389 | 1,081,527 |
| 87 | 63 | 8,250 | 348 | 1,342,548 | 218 | 91,524 | 176 | 4,951 | 10 | 235 | 1,273 | 391,057 | 817 | 390,047 | 692 | 302,665 | 1,244 | 1,077,607 |
| 88 | 68 | 9,961 | 366 | 2,191,448 | 372 | 1,076,986 | 155 | 32,898 | 6 | 98 | 1,166 | 1,878,896 | 932 | 312,885 | 724 | 126,498 | 1,209 | 956,333 |
| 89 | 45 | 30,955 | 524 | 480,644 | 1,063 | 108,519 | 179 | 4,875 | 10 | 1,752 | 1,373 | 322,326 | 1,145 | 11,062,200 | 881 | 766,281 | 1,393 | 701,139 |
| 90 | 92 | 13,400 | 480 | 624,494 | 1,834 | 4,115,264 | 194 | 129,131 | 11 | 383 | 1,749 | 1,775,142 | 988 | 263,436 | 940 | 455,108 | 1,889 | 538,649 |
| 91 | 109 | 9,009 | 446 | 199,306 | 1,977 | 100,702 | 191 | 5,103 | 14 | 1,256 | 2,010 | 430,905 | 938 | 143,723 | 916 | 687,563 | 1,968 | 298,385 |
| 92 | 129 | | 594 | | 1,974 | | 229 | | 21 | | 1,999 | | 969 | | 1,241 | | 2,335 | |
| 93 | 132 | 14,713 | 649 | 262,292 | 1,763 | 53,265 | 256 | 10,602 | 19 | 2,300 | 1,744 | 942,114 | 1,004 | 418,137 | 1,095 | 51,842 | 2,310 | 312,123 |
| 94 | 206 | 799,549 | 666 | 128,752 | 1,350 | 205,151 | 240 | 15,984 | 16 | 318 | 1,814 | 383,171 | 1,062 | 72,022 | 1,016 | 346,649 | 2,590 | 537,677 |
| 95 | 267 | 48,313 | 648 | 69,053 | 1,485 | 253,040 | 282 | 3,103 | 26 | 92 | 1,849 | 1,156,002 | 1,109 | 41,004 | 1,176 | 148,229 | 2,196 | 919,393 |
| 96 | 119 | 27,980 | 491 | 29,209 | 2,403 | 45,145 | 228 | 3,507 | 19 | 52 | 1,984 | 475,550 | 793 | 1,092,207 | 992 | 288,252 | 2,306 | 1,155,929 |
| 97 | 87 | 40,875 | 505 | 32,841 | 2,341 | 105,462 | 156 | 4,311 | 29 | 210,270 | 1,821 | 182,676 | 811 | 46,450 | 858 | 45,932 | 2,016 | 273,775 |
| 98 | 109 | 6,674 | 644 | 192,775 | 2,190 | 181,372 | 119 | 3,006 | 25 | 63 | 1,944 | 280,651 | 891 | 24,234 | 790 | 97,223 | 1,603 | 99,305 |
| 99 | 148 | 29,440 | 758 | 150,694 | 1,756 | 45,786 | 129 | 906 | 31 | 624 | 1,924 | 504,264 | 1,299 | 136,650 | 907 | 105,213 | 1,587 | 198,872 |
| 2000 | 150 | 135,010 | 623 | 36,301 | 1,838 | 112,069 | 96 | 4,535 | 32 | 349 | 1,816 | 663,404 | 1,248 | 49,783 | 801 | 273,095 | 1,750 | 156,824 |
| 2001 | 83 | 7,168 | 493 | 53,295 | 1,728 | 133,872 | 109 | 1,600 | 35 | 244 | 1,682 | 237,980 | 1,140 | 139,300 | 893 | 158,667 | 1,396 | 122,394 |
| Total | 4,152 | 19,054,638 | 13,728 | 10,653,402 | 35,381 | 15,214,328 | 3,925 | 1,192,525 | 320 | 219,867 | 66,676 | 79,244,143 | 26,418 | 36,765,442 | 49,642 | 34,240,859 | 38,821 | 36,257,796 |

*Source*: From U.S. Coast Guard, Pollution incidents in and around U.S. waters a spill/release compendium: 1969–2001. *Cumulative data for oil spills 1973–2001*, www.uscg.mil.

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**Table 10B.73 The World's Major Water-Quality Issues**

| Issue Scale | Water Bodies Polluted | Sector Affected | Time Lag between Cause and Effect | Effects Extent |
|---|---|---|---|---|
| Organic pollution | Rivers[a]<br>Lakes[a]<br>Groundwater[b] | Aquatic environment | <1 yr | Local to district |
| Pathogens | Rivers[a]<br>Lakes[b]<br>Groundwater[b] | Health[a] | <1 yr | Local |
| Salinization | Groundwater[a]<br>Rivers[b] | Most uses<br>Aquatic environment<br>Health | 1–10 yrs | District to region |
| Nitrate | Rivers[b]<br>Lakes[b]<br>Groundwater[a] | Health | >10 yrs | District to region |
| Heavy metals | All bodies | Health<br>Aquatic environment<br>Ocean fluxes | <1 to >10 yrs | Local to global |
| Organic | All bodies | Health<br>Aquatic environment<br>Ocean fluxes | 1 to 10 yrs | Local to global |
| Acidification | Rivers[a]<br>Lakes[a]<br>Groundwater[b] | Health<br>Aquatic environment | >10 yrs | District to region |
| Eutrophication | Lakes[a]<br>Rivers[b] | Aquatic environment<br>Most uses<br>Ocean fluxes | > 10 yrs | Local |
| Sediment load (increase and decrease) | Rivers[b]<br>Lakes | Aquatic environment<br>Most uses<br>Ocean fluxes | 1–10 years | Regional |
| Diversions, dams | Rivers[a]<br>Lakes[b]<br>Groundwater[a] | Aquatic environment<br>Most uses | 1–10 yrs | District to region |

*Note:* Pollutants of many kinds eventually find their way into water bodies at all levels. Although it may take some years for problems to become evident, poor water quality affects both human health and ecosystem health.

[a] Very serious issue on a global scale.
[b] Series issue on a global scale.

*Source*: From *Water for People Water for Life*, The United Nations World Water Development, Copyright © United Nations Educational, Scientific and Cultural Organization (UNESCO) - World Water Assessment Programme (UNESC0-WWAP), 2003. Reproduced by permission of UNESCO. www.unesco.org.

*Original Source*: From WHO/UNEP (World Health Orgauization/United Nations Environment Programme), 1991. *Water Quality: Progress in the Implementation of the Mar del Plata Action Plan and a Strategy for the 1990s*, Nairobi, Earthwatch Global Monitoring System, World Health Organization, United Nations Environment Programme.

**Table 10B.74 Median Concentrations of Acidic Drugs in Raw and Finished Drinking Water (ug/L) in Ontario, Canada, Separated According to the Source of the Water**

| | Row Water | | | Finished water | | |
|---|---|---|---|---|---|---|
| | Wells | Lakes | Rivers | Wells | Lakes | Rivers |
| Clofibric acid | Nd | 0.3 | 0.5 | Nd | 0.1 | 0.4 |
| Ibuprofen | Nd | 0.6 | 54.7 | Nd | 0.5 | 13 |
| Gemfibrozil | Nd | 1.4 | 8.6 | Nd | Nd | Nd |
| Fenoprofen | Nd | Nd | 0.5 | Nd | Nd | Nd |
| Naproxen | Nd | 1.3 | 69.3 | Nd | Nd | Nd |
| Ketoprofen | Nd | 0.3 | Nd | Nd | Nd | Nd |
| Diclofenac | Nd | Nd | 5.7 | Nd | Nd | Nd |
| Indomethacin | Nd | Nd | 2.5 | Nd | Nd | Nd |

*Note:* Nd, not detected.

*Source*: From Kummerer, K., (eds.), 2004, *Pharmaceuticals in Environment*, Sources, Fate, Effects and Risks, Second Edition, © Springer-Verlag, Berline Heidelberg 2004. Table 6.5. With kind permission of Springer Science and Business Media.

*Original Source*: From Servos M.R. et al., 2004, Presence and removal of acidic drugs in drinking water treatment plants in Ontario, Canada. Water Qual Res J Can (to be published).

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**Table 10B.75 Theoretical Environmental Loads of Selected Pharmaceuticals to Italy and Concentrations Measured in the River Po**

| | Theoretical Environmental Load 1997 (tons $yr^{-1}$) | Theoretical Environmental Load 2001 (tons $yr^{-1}$) | Measured Concentration in 1997 (range; ng $l^{-1}$) | Measured concentration in 2001 (range; ng $l^{-1}$) |
|---|---|---|---|---|
| Pharmaceuticals measured in 1997 and 2001 | | | | |
| Amoxycillin | 59.64 | 125.75 | Nd | Nd |
| Atenolol | 7.54 | 19.86 | 49.5–84.32 | 3.4–39.4 |
| Bezafibrate | — | 3.80 | 15.1–22.4 | 0.8–2.7 |
| Ceftriaxone | 11.42 | 5.93 | Nd | Nd |
| Cyclophosphamide | — | — | Nd | Nd |
| Diazepam | — | — | 0.5–0.7 | Nd-2.1 |
| Erythromycin | 1.00 | 0.39 | 0.7–0.9 | 1.4–15.9 |
| Furosemide | 3.49 | 5.76 | Nd | 1.7–67.2 |
| Ibuprofen | 1.00 | 0.19 | Nd-4.0 | Nd-9.7 |
| Lincomycin | 5.11 | 3.60 | 1.2–4.6 | 3.1–248.9 |
| Ranitidine | 10.46 | 10.67 | Nd | Nd-4.0 |
| Salbutamol | 0.034 | 0.126 | Nd-4.6 | Nd-1.7 |
| Spiramycin | — | 1.02 | Nd | Nd-43.8 |
| Pharmaceuticals measured only in 2001 | | | | |
| Ciprofloxacin | — | 2.96 | — | Nd-26.1 |
| Clarythromycin | — | 8.47 | — | 0.5–20.3 |
| Enalapril | — | 1.47 | — | Nd-0.1 |
| Hydrochlorothiazide | — | 13.93 | — | Nd-24.4 |
| Omeprazole | — | 0.67 | — | Nd |

*Source*: From Kummerer, K., (eds.), 2004, *Pharmaceuticals in Environment*, *Sources, Fate, Effects and Risks, Second Edition*, © Springer-Verlag Berline Heidelberg 2004. Table 4.2. With kind permission of Springer Science and Business Media.

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**Table 10B.76 Concentrations of Total Phosphorus and Total Nitrogen in Selected Lakes of the World**

| | | Total Phosphorus (mgP/L) | | | | | Total Nitrogen (mgN/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1996 | 1997 | 1998 | 1999 | Average Last 3 Yrs[a] | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs[a] |
| Canada | Ontario | — | — | — | — | — | — | — | — | — | — |
| | Huron | — | — | 0.004 | — | — | — | — | 0.11 | — | — |
| | Superior | 0.004 | — | 0.004 | — | — | 0.11 | 0.11 | — | — | 0.11 |
| Mexico | Chapala | 0.430 | 0.380 | 0.380 | — | 0.397 | 0.17 | 0.12 | 0.12 | — | 0.14 |
| | Patzcuaro | — | — | — | — | — | — | — | — | — | — |
| | Catemaco | — | — | — | — | — | 0.02 | 0.01 | — | — | 0.02 |
| | Chairel | 0.050 | 0.020 | — | — | 0.030 | 0.16 | 0.13 | — | — | 0.13 |
| | Cantenano | — | — | — | — | — | 0.24 | 0.16 | — | — | 0.21 |
| U.S.A. | Twin-Portage (Ohio) | — | — | — | — | — | — | — | — | — | — |
| Japan | Biwa (North) | 0.009 | 0.009 | 0.010 | 0.008 | 0.009 | 0.31 | 0.32 | 0.33 | 0.32 | 0.32 |
| | Biwa (South) | 0.018 | 0.021 | 0.018 | 0.020 | 0.020 | 0.40 | 0.42 | 0.40 | 0.40 | 0.41 |
| | Kasumigaura | 0.120 | 0.100 | 0.100 | 0.091 | 0.097 | 0.91 | 0.89 | 1.30 | 0.93 | 1.04 |
| Korea | Chunchonho | 0.015 | 0.025 | 0.016 | 0.014 | 0.018 | 1.51 | 1.52 | 1.44 | 1.60 | 1.52 |
| | Chungjiuho | 0.022 | 0.027 | 0.023 | 0.019 | 0.023 | 1.77 | 3.06 | 3.38 | 2.59 | 3.01 |
| | Paldang lake | 0.032 | 0.141 | 0.040 | 0.036 | 0.039 | 2.14 | 2.39 | 2.24 | 2.24 | 2.29 |
| Austria | Mondsee | 0.009 | 0.008 | — | — | 0.008 | — | — | — | — | — |
| | Ossiachersee | 0.009 | — | 0.011 | — | 0.010 | — | — | — | — | — |
| | Wallersee | 0.014 | 0.018 | — | — | 0.016 | — | — | — | — | — |
| | Zellersee | 0.008 | 0.008 | — | — | 0.008 | — | — | — | — | — |
| Denmark | Dons Norreso | — | — | — | — | — | — | — | — | — | — |
| | Arreso | 0.206 | 0.230 | 0.200 | — | 0.212 | 2.25 | 2.64 | 2.80 | — | 2.56 |
| | Fureso | 0.122 | 0.109 | 0.090 | — | 0.107 | 0.81 | 0.80 | 0.74 | — | 0.78 |
| | Sobygard | 0.543 | 0.341 | 0.270 | — | 0.385 | 2.18 | 1.63 | 1.87 | — | 1.89 |
| Finland | Pääjärvi | 0.012 | 0.013 | — | — | 0.012 | 1.03 | 1.01 | — | — | 1.03 |
| | Päijänne | 0.006 | 0.006 | — | — | 0.006 | 0.51 | 0.48 | — | — | 0.49 |
| | Yli-Kitka | 0.007 | 0.005 | — | — | 0.006 | 0.20 | 0.23 | — | — | 0.22 |
| France | Parentis-Biscarrosse | 0.039 | 0.050 | 0.069 | 0.076 | 0.065 | 1.00 | 0.89 | 1.07 | 0.88 | 0.95 |
| | Cazaux-Sanguinet | — | 0.013 | — | — | — | — | 0.44 | — | — | — |
| | Réservoir Marne | — | — | — | — | — | 0.85 | — | — | — | — |
| | Réservoir-Seine | — | — | — | — | — | 0.55 | — | — | — | — |
| | Lac d'Annecy | — | — | — | — | — | — | — | — | — | — |
| Germany | Bodensee-Fischbach-Uttwil | 0.019 | 0.017 | — | — | 0.019 | 0.97 | 0.98 | — | — | 0.99 |
| Hungary | Ferto | 0.130 | 0.087 | 0.089 | 0.049 | 0.075 | — | — | — | — | — |
| | Balaton | 0.075 | 0.110 | 0.082 | 0.056 | 0.083 | 0.74 | 1.06 | 0.98 | 0.94 | 0.99 |
| | Velencei | 0.071 | 0.069 | 0.059 | 0.053 | 0.060 | 2.53 | 2.35 | 2.46 | 2.12 | 2.31 |
| Ireland | Ennel | 0.017 | 0.017 | — | — | 0.018 | 0.52 | 0.48 | 0.48 | 0.29 | 0.41 |
| | Owel | 0.011 | 0.011 | — | — | 0.011 | 0.09 | 0.05 | 0.08 | 0.05 | 0.06 |
| | Derg | 0.042 | 0.048 | — | 0.032 | 0.041 | 1.24 | 1.23 | — | — | 0.99 |
| | Sheelin | 0.023 | 0.025 | 0.021 | 0.019 | 0.022 | — | — | — | — | — |
| Italy | Maggiore | 0.010 | 0.010 | 0.012 | — | 0.011 | 0.83 | 0.84 | 0.84 | — | 0.84 |
| | Como | 0.042 | 0.046 | 0.038 | — | 0.042 | 0.88 | 0.89 | 0.87 | — | 0.88 |
| | Garda | 0.017 | 0.015 | 0.022 | — | 0.018 | 0.35 | 0.35 | 0.36 | — | 0.35 |
| | Orta | 0.001 | 0.002 | 0.001 | —. | 0.001 | 2.50 | 2.30 | 2.30 | — | 2.37 |
| Luxembourg | EschSure | — | — | — | — | — | 2.73 | 5.15 | 3.31 | 3.42 | 3.96 |

*(Continued)*

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**Table 10B.76 (Continued)**

| | | Total Phosphorus (mgP/L) | | | | | Total Nitrogen (mgN/L) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1996 | 1997 | 1998 | 1999 | Average Last 3 Yrs[a] | 1996 | 1997 | 1998 | 1999 | Average Last 3 yrs[a] |
| | Weiswarnpach | 0.100 | 0.500 | 0.340 | 0.119 | 0.286 | 2.71 | 2.48 | 2.48 | 2.48 | 2.48 |
| Norway | Mjoesa | 0.007 | 0.007 | 0.005 | 0.152 | 0.021 | 0.45 | 0.44 | 0.46 | 0.44 | 0.44 |
| | Randsfjorden | 0.006 | 0.007 | 0.004 | 0.003 | 0.005 | 0.53 | 0.53 | 0.55 | 0.51 | 0.53 |
| | Tyrifjorden | 0.004 | 0.004 | — | — | — | 0.47 | 0.42 | — | — | — |
| Poland | Sriardwy | — | 0.043 | — | — | — | — | 0.90 | — | — | — |
| | Hancza | 0.063 | 0.025 | — | — | — | 0.94 | 0.68 | — | — | — |
| | Niegocin | — | — | — | — | — | — | — | — | — | — |
| | Northern Mamry | — | — | 0.052 | — | — | — | — | — | 1.06 | — |
| Sweden | Mälaren | 0.023 | 0.018 | 0.019 | 0031 | 0.023 | 0.55 | 0.67 | 0.66 | 0.87 | 0.73 |
| | Vänern | 0.006 | 0.006 | 0.006 | 0.008 | 0.007 | 0.80 | 0.88 | 0.85 | 0.83 | 0.85 |
| | Vättern | 0.005 | 0.004 | 0.003 | 0.005 | 0.004 | 0.71 | 0.83 | 0.79 | 0.78 | 0.80 |
| | Hjälmaren | 0.033 | 0.033 | 0.043 | 0.039 | 0.038 | 0.57 | 0.67 | 0.79 | 0.59 | 0.68 |
| Switzerland | Léman | 0.041 | 0.038 | 0.040 | 0.039 | 0.039 | 0.68 | 0.67 | 0.66 | 0.66 | 0.66 |
| | Constance | 0.019 | 0.018 | 0.015 | 0.014 | 0.016 | 1.11 | 1.21 | 1.18 | 1.19 | 1.19 |
| Turkey | Kurtbogazi | — | — | — | — | — | — | — | — | — | — |
| | Sapanca | — | — | — | — | — | — | — | — | — | — |
| | Gala | — | — | — | — | — | 1.10 | 1.29 | 0.65 | 0.93 | 0.96 |
| | Altinapa | — | — | — | — | — | 1.27 | 1.84 | 2.74 | 1.64 | 2.07 |
| UK | Lough Neagh | 0.095 | — | 0.158 | — | 0.124 | 0.83 | — | 0.61 | — | 0.62 |
| | Lomond | — | — | 0.000 | 0.000 | 0.003 | — | — | 0.30 | 0.37 | 0.35 |
| | Bewl Water | 0.077 | 0.105 | 0.065 | 0.032 | 0.067 | 2.12 | 3.08 | 2.60 | 1.29 | 2.32 |

*Total Phosphorus Note:* CAN, Ontario, Haron and Superior: data represent annual mean surface values from several hundred open water samples for each lake (mainly spring and summer); MEX, Orthophosphates; U.S.A., W. Twin(Ohio), samples obtained from the deepest point in each lake, generally weekly from late spring-eady fall and less frequently the rest of the year at 0.1, 2, 4, 7 and 10 m; FIN, data refer to surface measurements; DEU, Bodensee, Lac Constance (Switzerland); IRL, Derg, 1996 and 1997 data refer to mean values recorded in samples taken in Apr, Jul, Sep and Oct each year; LUX, Weiswarnpach, 96 and 98, upper limits; POL, Data refer to spring and summer surveys, and to surface measurements; CHE, Lac Constance, Bodensee (Germany); UKD, Lomond and Bewl Water: annual averages were calculated using the limit of detection values; actual average may therefore be lower. Bowl Water: 1994–1999 data refer to Total inorganic Phosphate.

*Total Nitrogen Note:* CAN, Ontario, Huron and Superior data represent annual mean surface values from several handed open water samples for each lake (mainly spring and summer); MEX, Data refer to nitrates only; U.S.A., W: Twin(Ohio): total inorganic nitrogen ($NH_4+NO_3+NO_2$). Samples obtained from the deepest point in each lake, generally weekly from late-spring early fall, and less frequently the rest of the year at 0.1, 2, 4, 7 and 10 m; AUT, data refer to total inorganic nitrogen ($NH_4+NO_3+NO_2$) measured in the epilimnion; FIN, Data refer to surface measurements; FRA, Réservoirs Marne and Seine, and Lac d'Annecy: Kjeldhai nitrogen. Réservoirs Marme and Seine 1980: 1981 data; DEU, Total inorganic nitrogen ($NH_4+NO_3+NO_2$). Bodensee: Lac Constance (Switzerland); IRL, Nitrates and nitrites only. Ennel and Owel: 1990–99 data refer to nitrate only and to limited surveys (March–October). Derg: 1996 and 1997 data refer to mean values recorded in samples taken in Apr, Jul, Sep and Oct each year; ITA, Maggiore: total inorganic nitrogen ($NH_4+NO_3+NO_2$). Average of monthly samples taken at the deepest point of the lake; LUX, Nitrates only; POL, Data refer to spring and summer surveys; CHE, Lac Constance: Bodensee (Germany); TUR, Total inorganic nitrogen ($NH_4+NO_3+NO_2$); UKD, Neath and Lomond; nitrates ($NO_3$) only. Lomond and Bewel Water: annual averages were calculated using the limit of detection values; actual averages may therefore be lower.

[a] Average over the latest 3 years available: data prior to 1953 have not been taken into account.

*Source*: Table 3.5a and 3.5b (data from 1996, 1997, 1998, 1999, and average last 3 years), *OECD Environmental Data Compendium 2002*, © OECD 2002, www.oecd.org.

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**Table 10B.77 Country Contributions to Sum of Direct and Riverine Inputs in Tonnes Per Year of Cadmium, Mercury, Lead, Lindane and Pcb to the Northeast Atlantic**

| Substance/Year | B | DK | F | D | IRL | NL | NO | P | E | S | UK | SUM | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cadmium** | | | | | | | | | | | | | |
| 1990 | 4.30 | 0.57 | 4.70 | 8.54 | 3.39 | 10.30 | 16.21 | 9.00 | n.a. | 0.67 | 51.30 | 108.97 | 100.00 |
| 1991 | 3.90 | n.a. | 3.30 | 7.24 | 3.39 | 7.00 | 8.31 | 15.00 | n.a. | 0.34 | 49.35 | 97.83 | 89.80 |
| 1992 | 6.70 | n.a. | 4.50 | 10.55 | 2.31 | 5.70 | 7.90 | 24.00 | n.a. | 0.54 | 34.69 | 96.89 | 88.90 |
| 1993 | 3.42 | n.a. | 3.20 | 9.20 | 1.76 | 4.70 | 7.18 | 1.70 | 0.06 | 0.11 | 29.30 | 60.62 | 55.60 |
| 1994 | 3.44 | n.a. | 3.20 | 8.14 | 2.44 | 12.76 | 9.23 | 3.93 | 0.10 | 0.42 | 25.87 | 69.52 | 63.80 |
| 1995 | 3.81 | n.a. | 2.70 | 7.54 | 2.17 | 26.60 | 8.99 | 0.20 | 0.10 | 0.24 | 21.31 | 73.67 | 67.60 |
| 1996 | 2.90 | n.a. | 2.20 | 5.65 | 3.94 | 8.40 | 5.85 | n.a. | n.a. | n.a. | 19.11 | 48.05 | 44.10 |
| 1997 | 2.65 | n.a. | n.a. | 6.35 | 2.55 | 4.05 | 5.20 | 1.35 | 14.50 | 0.47 | 15.35 | 52.47 | 48.10 |
| 1998 | 2.45 | n.a. | n.a. | 6.25 | 3.45 | 9.70 | 7.75 | 0.60 | 6.80 | 0.56 | 19.75 | 57.31 | 52.60 |
| 1999 | 2.30 | n.a. | n.a. | 4.99 | 2.91 | 11.90 | 4.60 | 0.40 | 12.80 | 0.90 | 18.00 | 58.80 | 54.00 |
| **Mercury** | | | | | | | | | | | | | |
| 1990 | 4.05 | 0.13 | 5.70 | 10.54 | 2.45 | 3.18 | 0.85 | 4.90 | n.a. | 0.11 | 8.81 | 40.71 | 100.00 |
| 1991 | 1.15 | n.a. | 2.70 | 10.01 | 2.45 | 3.30 | 0.50 | 1.75 | n.a. | 0.13 | 7.85 | 29.83 | 73.30 |
| 1992 | 0.68 | n.a. | 8.70 | 11.03 | 2.40 | 3.26 | 0.53 | 0.04 | n.a. | 0.13 | 6.00 | 32.78 | 80.50 |
| 1993 | 2.62 | n.a. | 0.80 | 10.05 | 2.40 | 3.46 | 0.49 | 0.26 | n.a. | 0.11 | 6.55 | 26.73 | 65.70 |
| 1994 | 3.10 | n.a. | 1.10 | 5.65 | 2.40 | 6.41 | 0.38 | 0.85 | n.a. | 0.10 | 4.83 | 24.82 | 61.00 |
| 1995 | 0.60 | n.a. | 0.80 | 4.64 | 2.40 | 8.06 | 0.54 | 0.35 | n.a. | 0.15 | 4.13 | 21.67 | 53.20 |
| 1996 | 0.03 | n.a. | 0.50 | 2.94 | n.a. | 3.28 | 0.47 | n.a. | n.a. | n.a. | 3.26 | 10.48 | 25.70 |
| 1997 | 0.25 | n.a. | n.a. | 1.95 | n.a. | 2.70 | 0.40 | 1.15 | 2.60 | 0.09 | 4.41 | 13.54 | 33.30 |
| 1998 | 0.61 | n.a. | n.a. | 2.15 | n.a. | 2.15 | 2.86 | 0.75 | 0.40 | 0.13 | 4.68 | 13.72 | 33.70 |
| 1999 | 0.72 | n.a. | n.a. | 2.39 | n.a. | 2.33 | 1.46 | 0.56 | 8.60 | 0.20 | 3.31 | 19.60 | 48.10 |
| **Lead** | | | | | | | | | | | | | |
| 1990 | 27.5 | 7.2 | 150.0 | 212.8 | 63.4 | 346.5 | 120.9 | 680.0 | n.a. | 8.3 | 591.1 | 2,207.6 | 100.0 |
| 1991 | 36.6 | n.a. | 150.0 | 297.5 | 63.4 | 230.0 | 102.8 | 80.0 | 7.7 | 5.3 | 575.6 | 1,548.8 | 70.2 |
| 1992 | 32.5 | n.a. | 110.0 | 314.9 | 82.1 | 221.8 | 70.5 | 120.0 | 2.6 | 4.3 | 501.6 | 1,460.2 | 66.1 |
| 1993 | 36.6 | n.a. | 100.0 | 378.1 | 55.5 | 393.8 | 58.5 | 7.3 | 0.9 | 3.2 | 631.4 | 1,665.2 | 75.4 |
| 1994 | 48.2 | n.a. | 170.0 | 247.7 | 79.6 | 701.8 | 82.6 | 6.1 | 2.2 | 10.5 | 528.3 | 1,877.1 | 85.0 |
| 1995 | 43.2 | n.a. | 55.0 | 185.5 | 63.3 | 871.8 | 82.5 | 2.8 | 1.3 | 8.2 | 384.8 | 1,698.3 | 76.9 |
| 1996 | 44.5 | n.a. | 66.0 | 126.5 | 115.6 | 382.9 | 62.6 | n.a. | n.a. | n.a. | 311.5 | 1,109.5 | 50.3 |
| 1997 | 40.0 | n.a. | n.a. | 151.5 | 120.5 | 233.0 | 63.7 | 43.0 | 17.0 | 8.7 | 303.3 | 980.7 | 44.4 |
| 1998 | 51.5 | n.a. | n.a. | 181.5 | 143.0 | 257.5 | 150.0 | 4.9 | 54.0 | 14.3 | 601.5 | 1,458.2 | 66.1 |
| 1999 | 56.5 | n.a. | n.a. | 125.4 | 145.0 | 326.0 | 53.6 | 2.1 | 58.0 | 17.3 | 546.0 | 1,330.0 | 60.2 |
| **Lindane** | | | | | | | | | | | | | |
| 1990 | 102.0 | 26.0 | 175.0 | 342.0 | n.a. | 16.7 | 536.0 | n.a. | n.a. | n.a. | 588.4 | 1,786.1 | 100.0 |
| 1991 | 111.0 | 26.0 | 175.0 | 187.8 | n.a. | 7.2 | 261.3 | n.a. | n.a. | n.a. | 759.5 | 1,527.8 | 85.5 |
| 1992 | 82.5 | 26.0 | 175.0 | 208.0 | n.a. | 10.5 | 97.9 | 0.7 | n.a. | n.a. | 543.0 | 1,143.6 | 64.0 |
| 1993 | 80.0 | 26.0 | 175.0 | 191.5 | n.a. | 360.0 | 90.9 | 3.4 | n.a. | n.a. | 601.8 | 1,528.6 | 85.6 |
| 1994 | 74.5 | 26.0 | 175.0 | 261.0 | n.a. | 230.0 | 87.7 | 15.0 | n.a. | n.a. | 501.8 | 1,371.0 | 76.8 |
| 1995 | 55.5 | 26.0 | 175.0 | 291.4 | n.a. | 370.0 | 107.4 | 2.8 | n.a. | n.a. | 484.7 | 1,512.8 | 84.7 |
| 1996 | n.a. | n.a. | 100.0 | 239.0 | n.a. | 300.0 | 75.9 | n.a. | n.a. | n.a. | 312.4 | 1,027.3 | 57.5 |
| 1997 | 66.0 | n.a. | n.a. | 370.0 | n.a. | 300.0 | 78.7 | n.a. | 203.5 | n.a. | 354.5 | 1,372.7 | 76.9 |
| 1998 | 110.5 | n.a. | n.a. | 261.0 | n.a. | 259.5 | 84.8 | n.a. | 15.0 | n.a. | 403.8 | 1,134.6 | 63.5 |

*(Continued)*



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**Table 10B.77 (Continued)**

| Substance/Year | B | DK | F | D | IRL | NL | NO | P | E | S | UK | SUM | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 77.0 | n.a. | n.a. | 68.0 | n.a. | 279.0 | 9.4 | n.a. | 121.0 | n.a. | 324.0 | 877.0 | 49.1 |
| **$PCB_7$** | | | | | | | | | | | | | |
| 1990 | 30.5 | 30.3 | 100.0 | 143.5 | n.a. | 150.0 | 484.5 | n.a. | n.a. | n.a. | 2,158.1 | 3,096.8 | 100.0 |
| 1991 | 24.5 | 30.3 | 160.0 | 89.4 | n.a. | 130.0 | 38.0 | n.a. | n.a. | n.a. | 1,183.5 | 1,655.7 | 53.5 |
| 1992 | 26.5 | 30.3 | 130.0 | 43.6 | n.a. | 100.0 | 40.5 | 4.9 | n.a. | n.a. | 764.7 | 1,140.5 | 36.8 |
| 1993 | 211.0 | 30.3 | 130.0 | 54.1 | n.a. | 130.0 | 21.6 | 25.0 | n.a. | n.a. | 1,417.1 | 2,019.0 | 65.2 |
| 1994 | 223.5 | 30.3 | 160.0 | 95.5 | n.a. | 300.0 | 55.0 | 84.0 | n.a. | n.a. | 1,066.9 | 2,015.2 | 65.1 |
| 1995 | 45.9 | 30.3 | 130.0 | 144.0 | n.a. | 470.0 | 27.8 | 26.0 | n.a. | n.a. | 938.7 | 1,812.6 | 58.5 |
| 1996 | n.a. | n.a. | 100.0 | 127.5 | n.a. | 200.0 | 16.6 | n.a. | n.a. | n.a. | 739.6 | 1,183.6 | 38.2 |
| 1997 | 66.0 | n.a. | n.a. | 109.0 | n.a. | 170.0 | 22.6 | n.a. | n.a. | n.a. | 360.0 | 727.6 | 23.5 |
| 1998 | 135.0 | n.a. | n.a. | 88.0 | n.a. | 181.0 | 22.4 | n.a. | n.a. | n.a. | 1,089.4 | 1,515.8 | 48.9 |
| 1999 | 164.0 | n.a. | n.a. | 123.0 | n.a. | 236.0 | n.a. | n.a. | 158.0 | n.a. | 835.0 | 1,516.0 | 49.0 |

*Note:* Belgium (B), Denmark (DK), France (F), Germany (D), Ireland (IRL), the Netherlands (NL), Norway (NO), Portugal (P), Spain (E), Sweden (S), United Kingdom (UK), n.a. indicates where data was not available. Rounded values from EEA Fact Sheet YIR01HS01, zero or near zero ($<1$ kg) submissions assumed as data not available; %, percent as of 1990.

*Source*: From Green, N. et al., 2003, *Hazardous Substances in the European Marine Environment: Trends in Metals and Persistent Organic Pollutants, European Environment Agency, Topic Report 2/2003*, www.eea.europa.eu. Reprinted with permission © EEA.

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**Table 10B.78 PCBs Concentrations in Freshwater and Seawater in China (ng/L)**

| Water Body | | | Sampling Date | Concentration Range | Mean |
|---|---|---|---|---|---|
| Freshwater | Pearl River, Guangzhou reach | | May 24–26, 2000 | $0.70\times10^{-3}\sim3.96\times10^{-3}$ | $2.3\times10^{-3}$ |
| | Donghu Lake Wuhan | | | $2.7\times10^{-3}$ | |
| | Yangtse River, Nanjing section | | May 16–17, 1998 | $1.74\times10^{-3}\sim2.0\times10^{-3}$ | $1.91\times10^{-3}$ |
| Seawater | Pearl River Delta | Humen | May–June, Oct–Nov, 2000 | $2.08\times10^{-3}\sim3.92\times10^{-3}$ | $2.70\times10^{-3}$ |
| | | Hengmen | | $0.475\times10^{-3}\sim1.54\times10^{-3}$ | $0.999\times10^{-3}$ |
| | | Jiaomen | | $1.73\times10^{-3}\sim3.26\times10^{-3}$ | $2.62\times10^{-3}$ |
| | | Dourmen | | $1.73\times10^{-3}\sim3.26\times10^{-3}$ | $1.16\times10^{-3}$ |
| | Daya Bay | | Aug 4, 1999 | 0.091 ~ 1.355 | 0.314 |
| | Minjing River Estuary | Surface water | Nov, 1999 | 0.204 ~ 2.473 | 0.985 |
| | | Pore water | | 3.19 ~ 10.86 | 6.37 |
| | Xiamen Harbor | | July 20, 1998 | $0.12\times10^{-3}\sim1.69\times10^{-3}$ | $0.74\times10^{-3}$ |
| | Jiulong River Estuary | | Early than 1999 | 0.032 ~ 0.169 | |
| | Pearl River Estuary | | Early than 1999 | 0.033 ~ 1.064 | |

*Source*: From Yeru, H. et al., 2003, Water Quality Standards and POPs Pollution in China in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1–2 September, 2003, UNU Centre, Tokyo.



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**Table 10B.79 Polluting Incidents from Vessels in Canadian Waters, 1974–1983**

| | Transfer Accident | | Collision, Ground, Sinking | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|
| Year | Events | Tons | Events | Tons | Events | Tons | Events | Tons |
| 1974 | 60 | 371 | 21 | 4,277 | 60 | 248 | 141 | 4,896 |
| 1975 | 52 | 116 | 13 | 613 | 28 | 886 | 93 | 1,615 |
| 1976 | 53 | 206 | 13 | 1,613 | 19 | 160 | 85 | 1,979 |
| 1977 | 47 | 249 | 11 | 931 | 38 | 294 | 96 | 1,474 |
| 1978 | 51 | 154 | 16 | 1,343 | 33 | 73 | 99 | 1,570 |
| 1979 | 49 | 108 | 6 | 948 | 33 | 8,186 | 88 | 9,242 |
| 1980 | 68 | 145 | 12 | 121 | 68 | 213 | 148 | 479 |
| 1981 | 75 | 97 | 13 | 2,296 | 33 | 931 | 121 | 3,324 |
| 1982 | 58 | 199 | 16 | 2,106 | 27 | 989 | 101 | 3,294 |
| 1983 | 28 | 73 | 7 | 504 | 22 | 404 | 57 | 981 |
| Total | 541 | 1,718 | 127 | 14,752 | 361 | 12,384 | 1,029 | 28,854 |
| Percent | 53 | 6 | 12 | 51 | 35 | 43 | 100 | 100 |

*Note:* Tankers, bulk carriers and other vessels; metric tons.

*Source*: From Environment Canada, *Summary of Spill Events in Canada*, 1974–1983, EPS 5/SP/1, www.ec.gc.ca.

**Table 10B.80 Top Releases of Chemicals to Water in Canada, 2001**

| Chemical | Release Tons |
|---|---|
| Ammonia (total)[a] | 26,106 |
| Nitrate ion in solution at pH $\geq$6.0 | 22,450 |
| Manganese (and its compounds) | 1,157 |
| Methanol | 697 |
| Zinc (and its compounds) | 308 |

[a] Refers to the total of both ammonia ($NH_3$) and ammonium ion ($NH_4^+$) in solution.

*Source*: From Environment Canada, National Pollutant Release Inventory Database, www.ec.gc.ca/pdb/npri, 2001. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

**Table 10B.81 Water Bodies Receiving over 500 Tons of Pollutants in Canada, 2001**

| Water Body | Total Release (tons) | Dominant Release | Share of Total Release (percent) |
|---|---|---|---|
| Fraser River | 9,168 | Ammonia[a] | 49.2 |
| Lake Ontario | 8,877 | Ammonia[a] | 41.6 |
| Bow River | 8,264 | Nitrate Ion | 90.8 |
| Ottawa River | 3,066 | Ammonia[a] | 76.6 |
| North Saskatchewan River | 2,953 | Nitrate ion | 61.3 |
| Red River | 2,766 | Ammonia[a] | 72.7 |
| Hamilton Harbour | 1,516 | Ammonia[a] | 70.6 |
| South Saskatchewan River | 1,275 | Nitrate Ion | 62.4 |
| St. Lawrence River | 1,088 | Nitrate Ion | 43.6 |
| Saint John River | 984 | Methanol | 28.6 |
| Frank Lake | 818 | Nitrate ion | 70.3 |
| Detroit River | 679 | Ammonia[a] | 83.8 |
| Kelly Lake | 619 | Nickel (and its compounds) | 29.6 |
| Neroutsos Inlet | 526 | Nitrate ion | 64.4 |

*Note:* The information in this table is not intended to be an assessment of environmental impact or water quality. The totals do not include releases to tributaries of the named rivers.

[a] Refers to the total of both ammonia ($NH_3$) and ammonium ion ($NH_4^+$) in solution.

*Source*: From Environment Canada, Pollution Data Branch, National Pollutant Release Inventory Database, www.ec.gc.ca/pdb/npri/npri_dat_rep_e_cfm, 2001. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

*Original Source*: From Environment Canada, Pollution Data Branch, National Pollutant Release inventory Database, www.ec.gc.ca/pdb/nprl/npri_dat_rep_e_cfm (accessed March 25, 2003).

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**Table 10B.82 Accidental Oil Spills in the World from Tankers, 1975–2000 (a)**

| Year[a] | Date | Name of Ship | Flag | Country Affected | Quality Spilled (tons) | Indemnity Million/s USD (estimates) |
|---|---|---|---|---|---|---|
| 1975 | 6.1 | Showa Manu | Japan | Singapore | 3 800 | 10.9 |
| | 10.1 | British Ambassador | UK | Japan (Pacif.) | 45 000 | — |
| | 29.1 | Jakob Maersk | Denmark | Portugal | 84 000 | 2.8 |
| | 31.1 | Corinthos/E.M. Queeny | U.S.A. | U.S.A. (Delaware) | 40 000 | 5.9 |
| | 4.4 | Spartan Lady | Liberia | U.S.A. | 25 000 | — |
| | 4.1 | Shell Barge No 2 | U.S.A. | U.S.A. | — | 5.7 |
| | 17.4 | Mitsu Maru 3 | Japan | Japan | 500 | 5.7 |
| | 13.5 | Epic Colocoltroni | Greece | Dominican Rep. | 57 000 | — |
| 1976 | 6.2 | Saint Peter | Liberia | Colombia | 33 000 | 0.9 |
| | 12.5 | Urquiola | Spain | Spain | 101 000 | 19.7 |
| | 23.6 | Nepco 140 | U.S.A. | Canada—U.S.A. | 1 200 | 11.1 |
| | 12.7 | Crelan Star | Cyprus | Indian Ocean | 28 600 | — |
| | 14.10 | Boehlen | GDR | France | 11 000 | 20.3 |
| | 15.12 | Argo Merchant | Liberia | U.S.A. (Massach.) | 28 000 | 2.5 |
| 1977 | 18.1 | Irenes Challenge | Liberia | Pacific | 34 000 | — |
| | 7.1 | Borag | Liberia | East China | 4 000 | 15.6 |
| | 25.2 | Hawaiian Patriot | Liberia | Honolulu (Pacif.) | 99 000 | — |
| | 27.5 | | Panama | Nicaragua | 30 000 | — |
| | 16.12 | Venoil/Venpet | Liberia | South Africa | 26 000 | 5.4 |
| | 30.12 | Grand Zenith | Panama | U.S.A. (Massach.) | 29 000 | — |
| 1978 | 16.3 | Amoco Cadiz | Liberia | France | 228 000 | — |
| | 6.5 | Eleni V | Greece | UK | 3 000 | 10.6 |
| | 7.7 | Cabo Tamar | Chile | Chile | 60 000 | 4.2 |
| | 12.10 | Christos Bitas | Greece | UK | 5 000 | 13.1 |
| | 30.12 | Esso Bernica | UK | UK (Shetland) | 1 160 | 9.8 |
| | 31.12 | Andrus Patria | Greece | Spaint | 47 000 | 6.4 |
| 1979 | 8.1 | Betelgeuse | France | Ireland | 27 000 | 36.2 |
| | 28.2 | Antonio Gransci | U.S.S.R. | Sweden, Finland, U.S.S.R. | 6 000 | 54.1 |
| | 2.3 | Messlaniki Frontis | Liberia | Greece | 6 000 | 11.5 |
| | 15.3 | Kurdistan | UK | Canada | 7 000 | 5.1 |
| | 28.4 | Gino | Liberia | France | 42 000 | 0.8 |
| | 28.6 | Aviles | Liberia | Arabian Sea | 25 000 | — |
| | 29.7 | Atlantic Express | Greece | Tobago | 276 000 | 1.5 |
| | 16.8 | Ionnis Angelicoussis | Greece | Angola | 30 000 | — |
| | 1.9 | Chevron Hawaii | U.S.A. | U.S.A. | 2 000 | 12.0 |
| | 1.11 | Burmah Agate | Liberia | U.S.A. (Texas) | 40 000 | 11.5 |
| | 15.11 | Independenta | Romania | Turkey | 94 600 | 17.2 |
| 1980 | 28.1 | Princess Anne Marie | Greece | Cuba | 6 000 | 51.7 |
| | 24.2 | Irenes Serenade | Greece | Greece | 102 000 | 12.5 |
| | 7.3 | Tanio | Madagascar | France, UK | 13 500 | 40.0 |
| | 29.12 | Juan A. Lavalleja | Uruguay | Algeria | 40 000 | — |

*(Continued)*



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**Table 10B.82 (Continued)**

| Year[a] | Date | Name of Ship | Flag | Country Affected | Quality Spilled (tons) | Indemnity Million/s USD (estimates) |
|---|---|---|---|---|---|---|
| 1981 | 7.1 | Jose Marti | U.S.S.R. | Sweden | 6 000 | 6.7 |
| | 3.3 | Ondina | Dubai | Germany | 5 000 | 7.0 |
| 1983 | 7.1 | Assimi | Greece | Oman | 51,431 | — |
| | 6.8 | Castillo de Bellver | Spain | South Africa | 255 525 | 1.0 |
| | 27.9 | Sivand | Iran | UK | 6 000 | 5.0 |
| | 25.11 | Feoso Ambassador | China | China | 4 000 | 10.0 |
| | 10.12 | Pericles GC | Greece | Qatar | 46 631 | — |
| 1985 | 14.2 | Neptunia | Liberia | Iran | 60 000 | — |
| | 6.12 | Nova | Liberia | Iran | 71 120 | — |
| 1989 | 24.3 | Exxon Valdez | U.S.A. | U.S.A. (Alaska) | 35 000 | 2000 |
| | 19.12 | Kharg 5 | .. | Morocco | 70 000 | 37 |
| | 29.12 | Aragon | Spain | Madeira | 25 000 | — |
| 1991 | 9/11.4 | Le Haven | Cyprus | Italy | 30 000 | — |
| | | ABT Summer | .. | .. | 260 000 | — |
| 1992 | 21.1 | Maersk Navigator | Singapore | Sumatra | >25 000 | — |
| 1993 | 5.1 | Braer | Liberia | UK | 84 000 | — |
| 1994 | 6.1 | Red Star | .. | Portgual | — | 14.0 |
| | 8.2 | Albinoni | Bahamas | Caribbean | — | 50.0 |
| 1995 | 21.1 | Maersk Navigator | Denmark | Indonesia | — | 33.0 |
| 1996 | 15.2 | Sea Empress | .. | UK | 72 000 | 30.0 |
| 1997 | 2.1 | Nakhodka | Russia | Japan | 37,000 | 1,233 |
| | 15.1 | Orapin Global & Evoikos | Singapore | Thailand & Cypress | 25,000 (Evoikos) | >100 |
| 1999 | 12.12 | Erika | Malta | France | 19 800 | 155 |

*Note*: Over 25,000 tons or over USD 5 million of indemnity, world.

[a] 1986–1988: no major oil spills over 25,000 tons.

*Source*: Table 6.1, *OECD Environmental Data Compendium 2002*, © OECD 2002, www.oecd.org.

*Original Source*: From IMO, IOPC-Fund, ACOPS, IFP, TAC, TOVALOP, SIGMA.

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## SECTION 10C GROUNDWATER CONTAMINATION

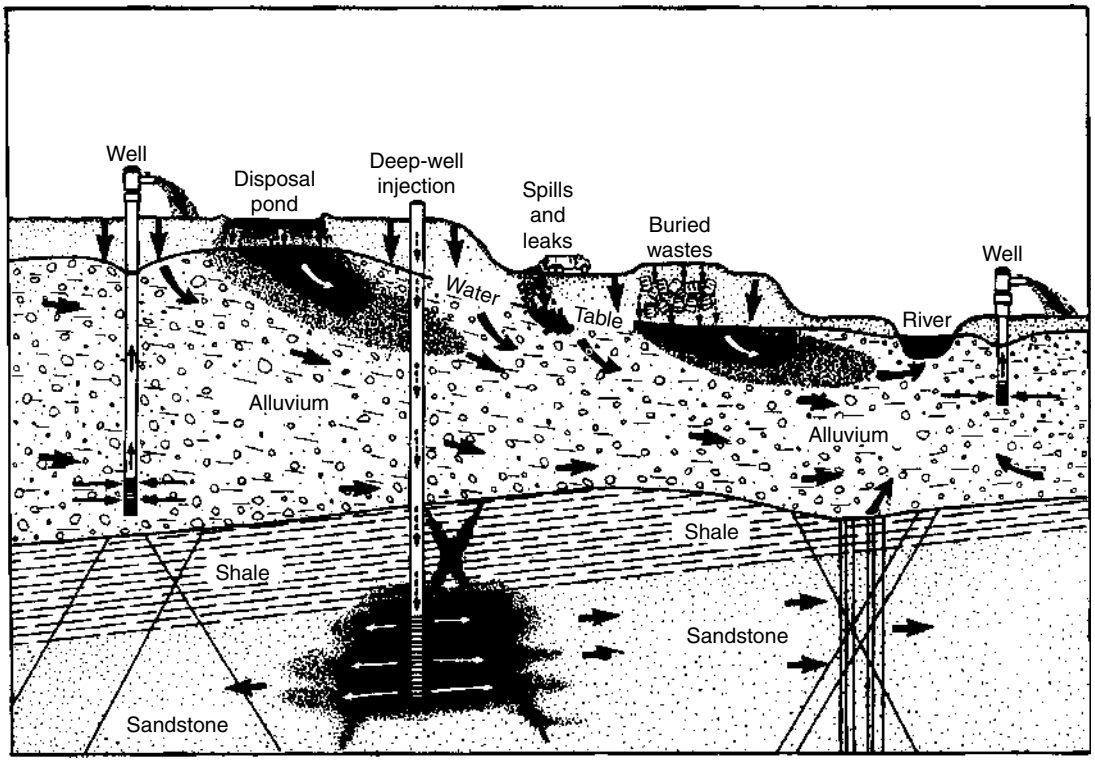


**Figure 10C.54** Waste disposal practices and contamination of groundwater. Movement of contaminants in unsaturated zone, alluvial aquifer, and bedrock shown by dark shading. (From U.S. Geological Survey Water Fact Sheet. *Toxic Waste, Groundwater Contamination*, 1983.)

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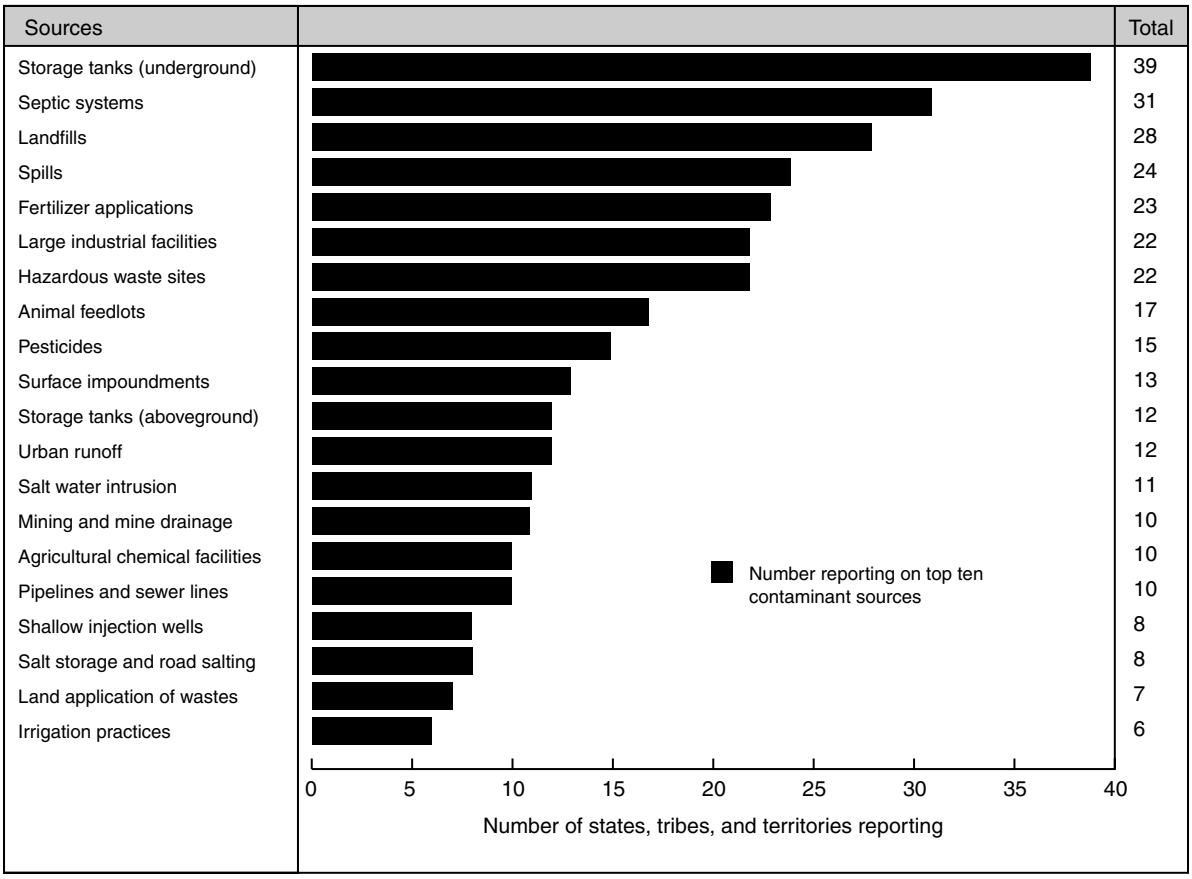


**Figure 10C.55** Major source of groundwater contamination. (From United States Environmental Protection Agency, 2002, *National Water Quality Inventory 2000 Report*, EPA-841-R-02-001, www.epa.gov.)

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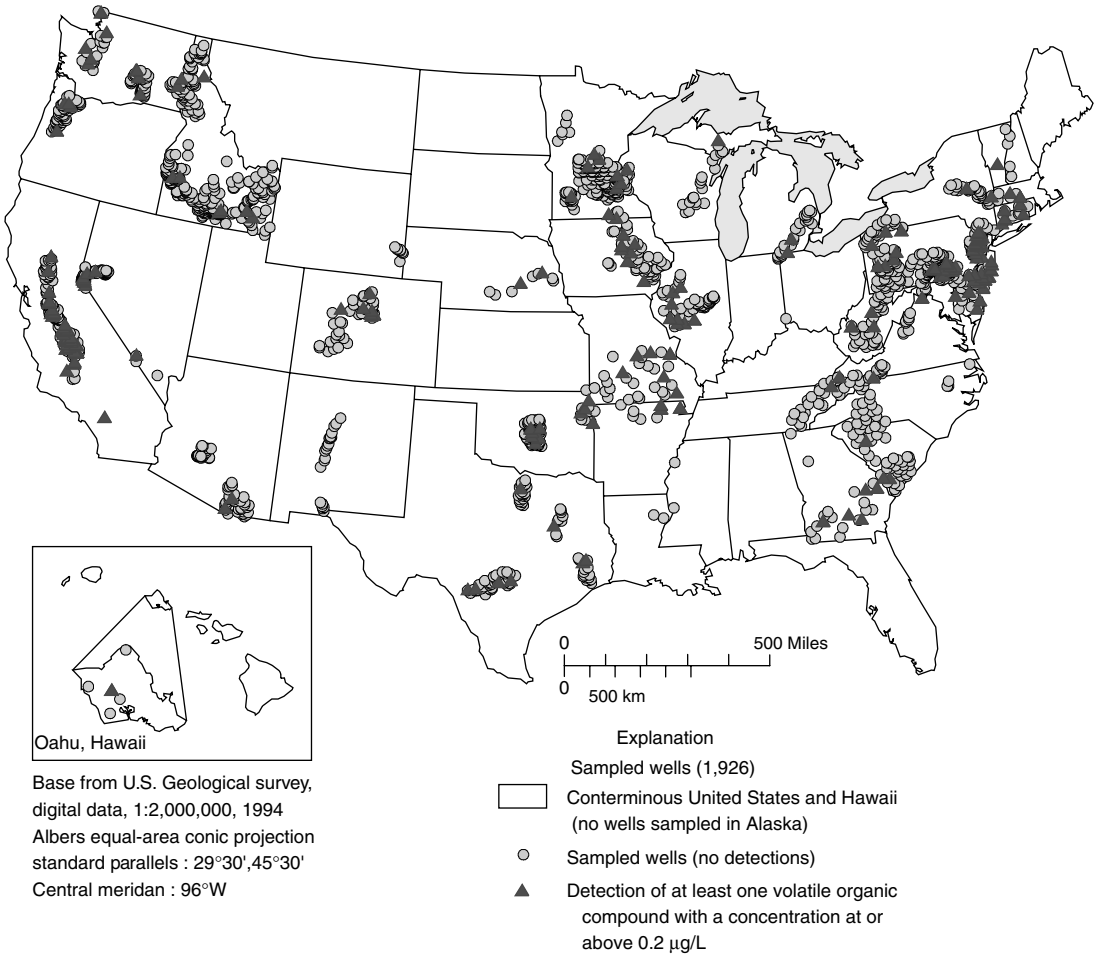


**Figure 10C.56** Location of rural, untreated, self-supplied domestic wells in the United States where at least one volatile organic compound was detected at an assessment level of 0.2 µ/L, 1986–1999. (From Moran, M.J., Lapham, W.W., Rowe, B.L., and Zogorski, J.S., 2002, *Occurrence and Status of Volatile Organic Compounds in Groundwater from Rural, Untreated, Self-Supplied Domestic Wells in the Untied States, 1986–1999*, United States Geological Survey, Water Resources Investigation Report 02-4085, www.usgs.gov.)

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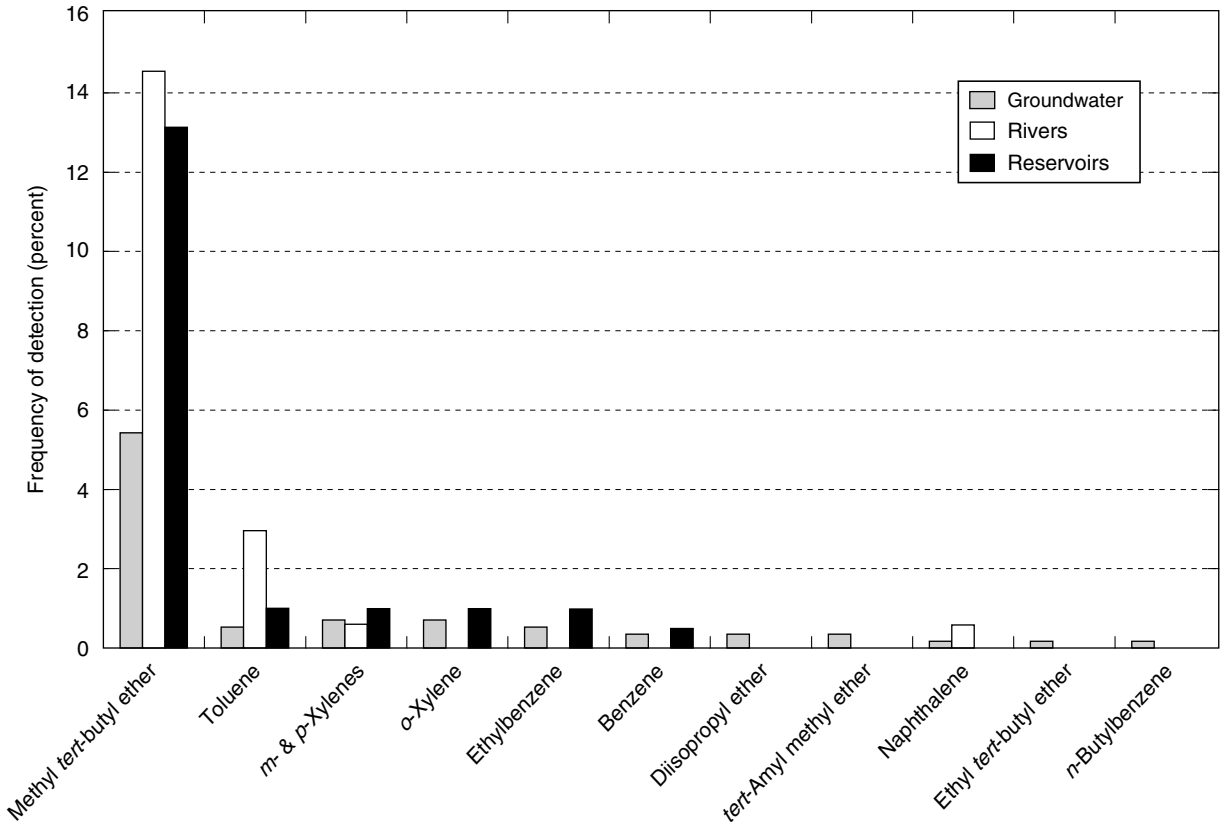


**Figure 10C.57** Frequency of detection of gasoline compounds in source-water samples from groundwater, rivers, and reservoirs in the United States from May 3, 1999 through October 23, 2000. (From Grady, S., 2003, *A National Survey of Methyl tert-Butyl Ether and Other Volatile Organic Compounds in Drinking Water Sources: Results of a Random Survey*, United States Geological Survey, Water-Resource Investigations Report 02-4079, www.usgs.gov.)

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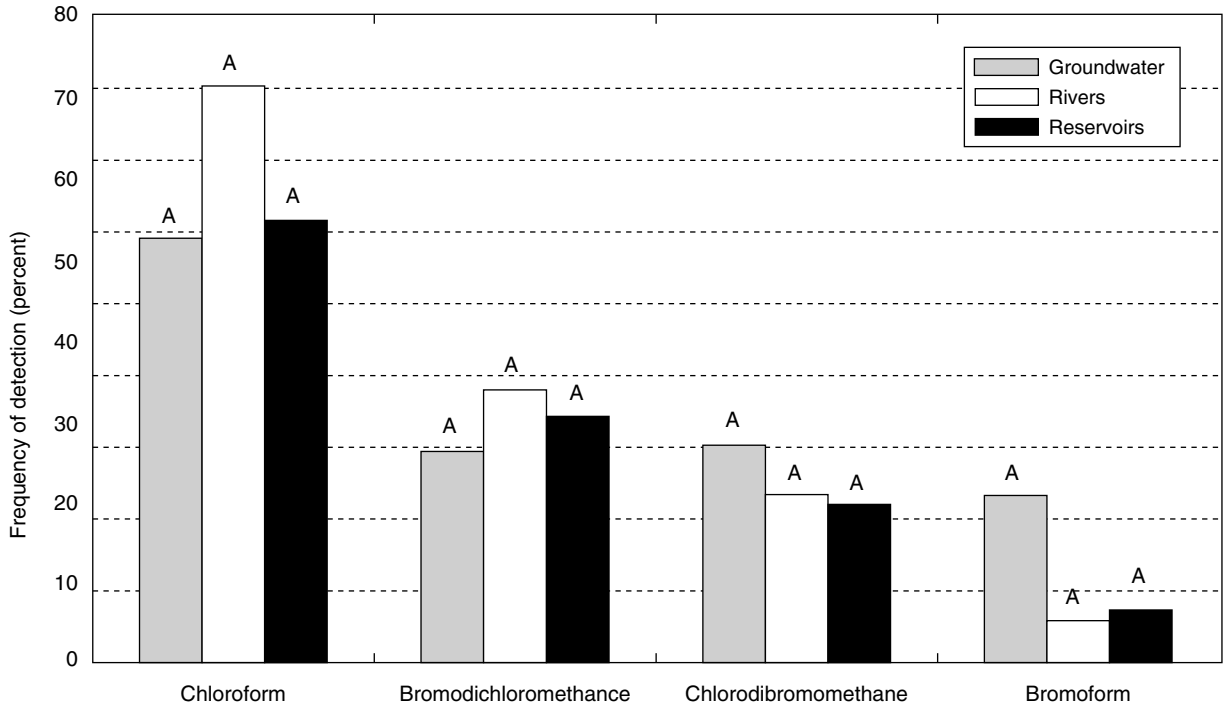


**Figure 10C.58** Frequency of detection of trihalomethanes in source-water samples from groundwater, rivers, and reservoirs in the United States from May 3, 1999 through October 23, 2000 (populations that share the same letter symbol are not significantly different at the 95-perecent confidence). (From Grady, S., 2003, *A National Survey of Methyl tert-Butyl Ether and Other Volatile Organic Compounds in Drinking Water Sources: Results of a Random Survey*, United States Geological Survey, Water-Resource Investigations Report 02-4079, www.usgs.gov.)

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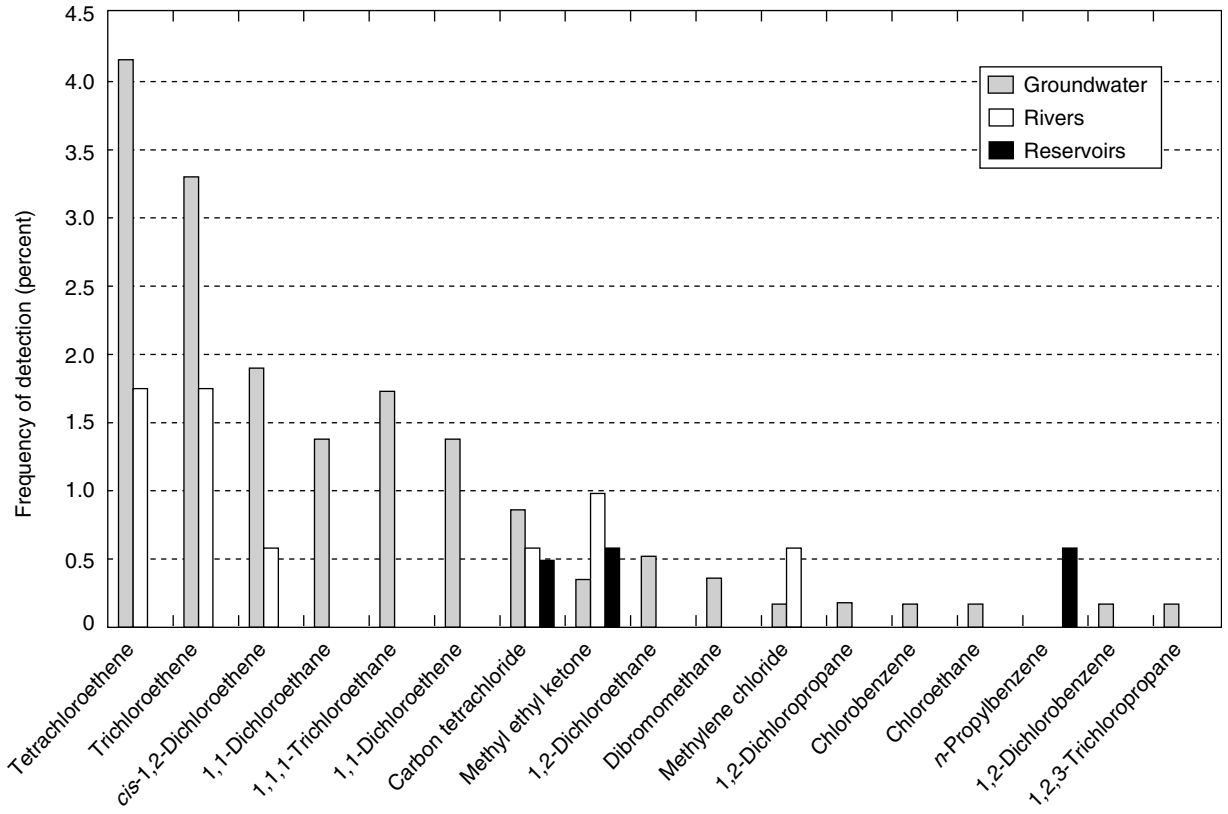


**Figure 10C.59** Frequency of detection of solvents in source-water samples from groundwater, rivers, and reservoirs in the United States from May 3, 1999 through October 23, 2000. (From Grady, S., 2003, *A National Survey of Methyl tert-Butyl Ether and Other Volatile Organic Compounds in Drinking Water Sources: Results of a Random Survey, United States Geological Survey*, Water-Resource Investigations Report 02-4079, www.usgs.gov.)

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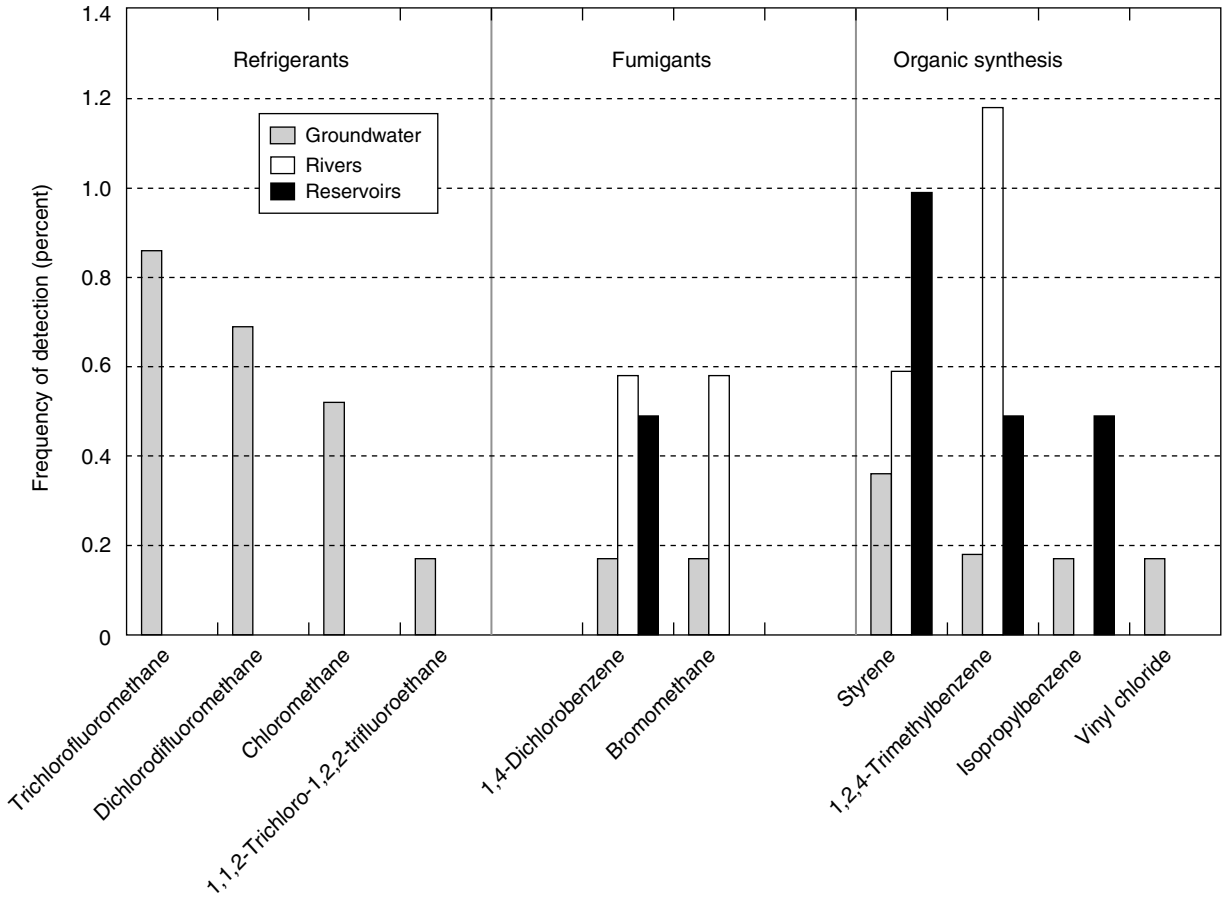


**Figure 10C.60** Frequency of detection of refrigerants, fumigants, and organic synthesis compounds in source-water samples from groundwater, rivers, and reservoirs in the United States from May 3, 1999 through October 23, 2000. (From Grady, S., 2003, *A National Survey of Methyl tert-Butyl Ether and Other Volatile Organic Compounds in Drinking Water Sources: Results of a Random Survey*, United States Geological Survey, Water-Resource Investigations Report 02-4079, www.usgs.gov.)

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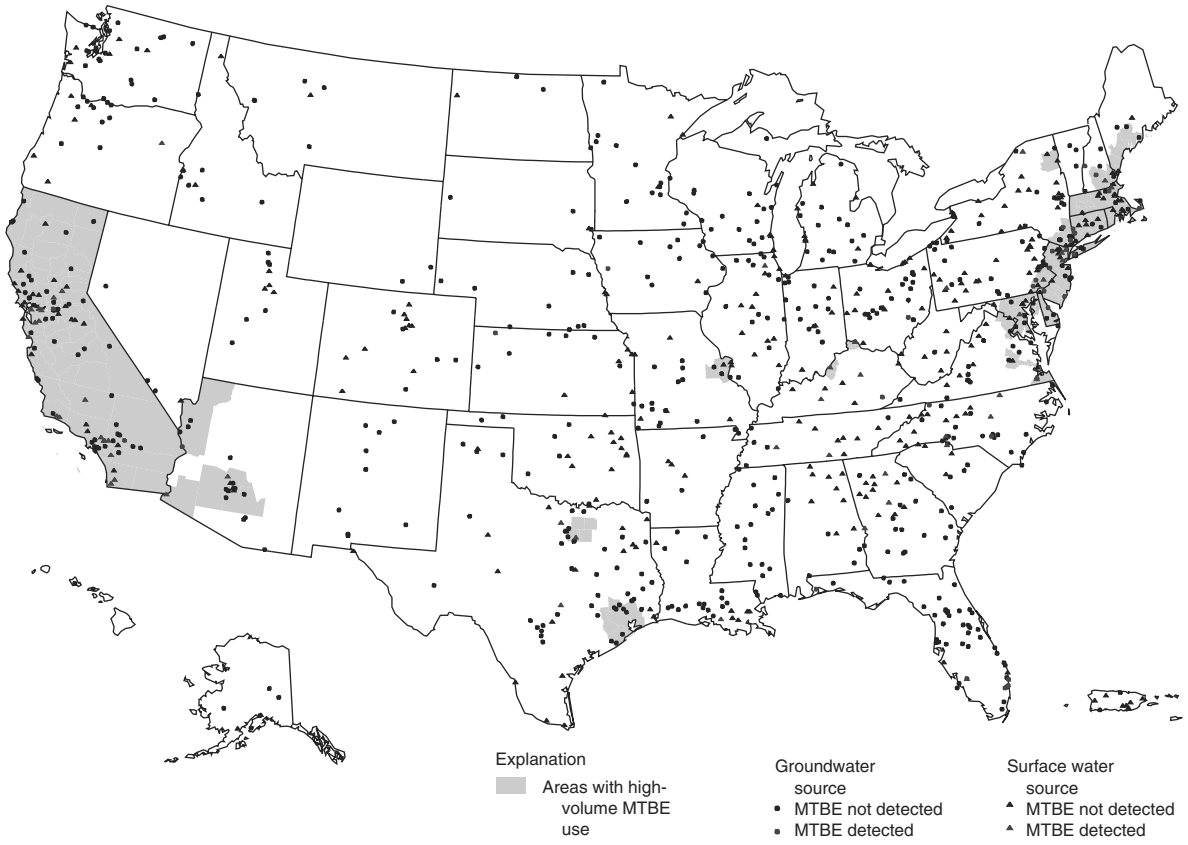


**Figure 10C.61** Distribution of methyl *tert*-butyl ether (MTBE) in ground- and surface-water sources in the United States and Puerto Rico in relation to high MTBE-use areas. (From Grady, S., 2003, *A National Survey of Methyl tert-Butyl Ether and Other Volatile Organic Compounds in Drinking Water Sources: Results of a Random Survey*, United States Geological Survey, Water-Resource Investigations Report 02-4079, www.usgs.gov.)

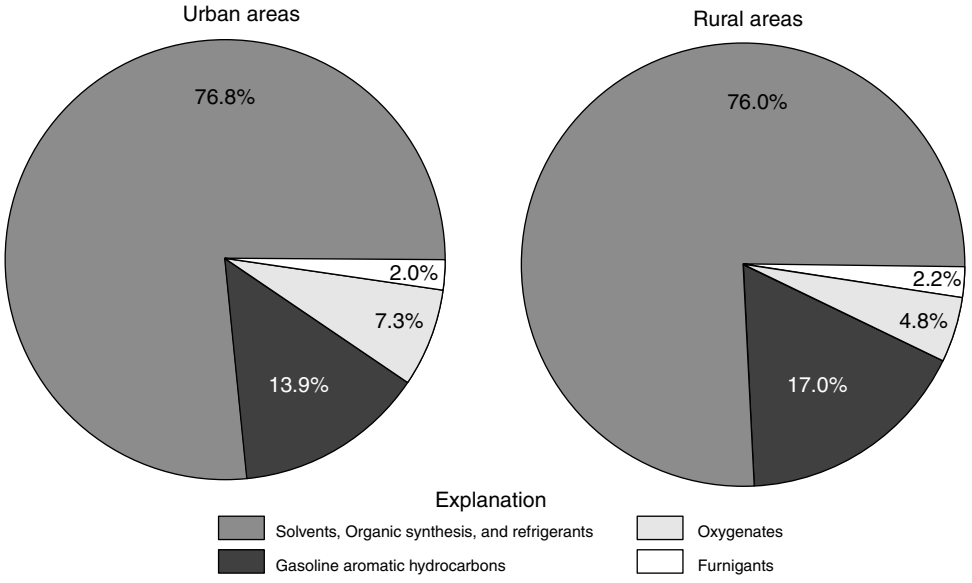


**Figure 10C.62** Percent detection of selected classes of VOCs in the United States in urban and rural areas, 1985–1995. (From Squillace, P.J. et al., 1999, volatile organic compounds in untreated ambient groundwater of the United States, 1985–1995, *Environ. Sci. Technol.*, 33, 4167–4187.)

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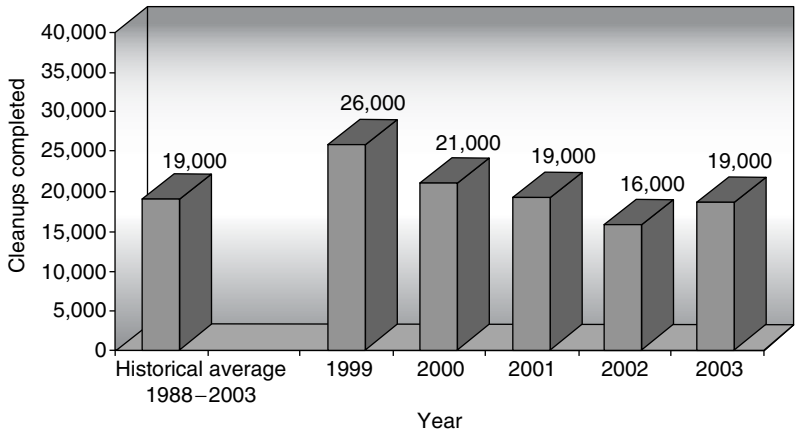
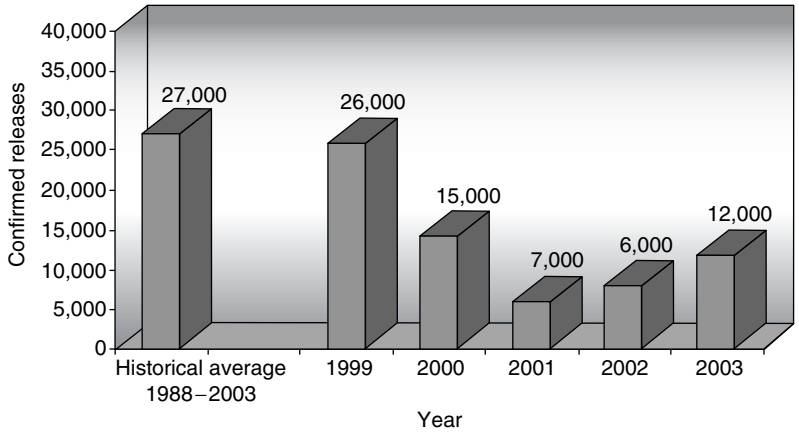
**Cleanups completed: Historical average, 1999–2003**




**Confirmed releases: Historical average, 1999–2003**




**All numbers rounded to nearest thousand.**

**Figure 10C.63** Confirmed underground storage tank releases and cleanups complete in the United States: historical average, 1999–2003. (From United States Environmental Protection Agency, 2004, *Underground Storage Tanks: Building On the Past to Protect the Future*, EPA 510-R-04-001, March 2004, www.epa.gov.)

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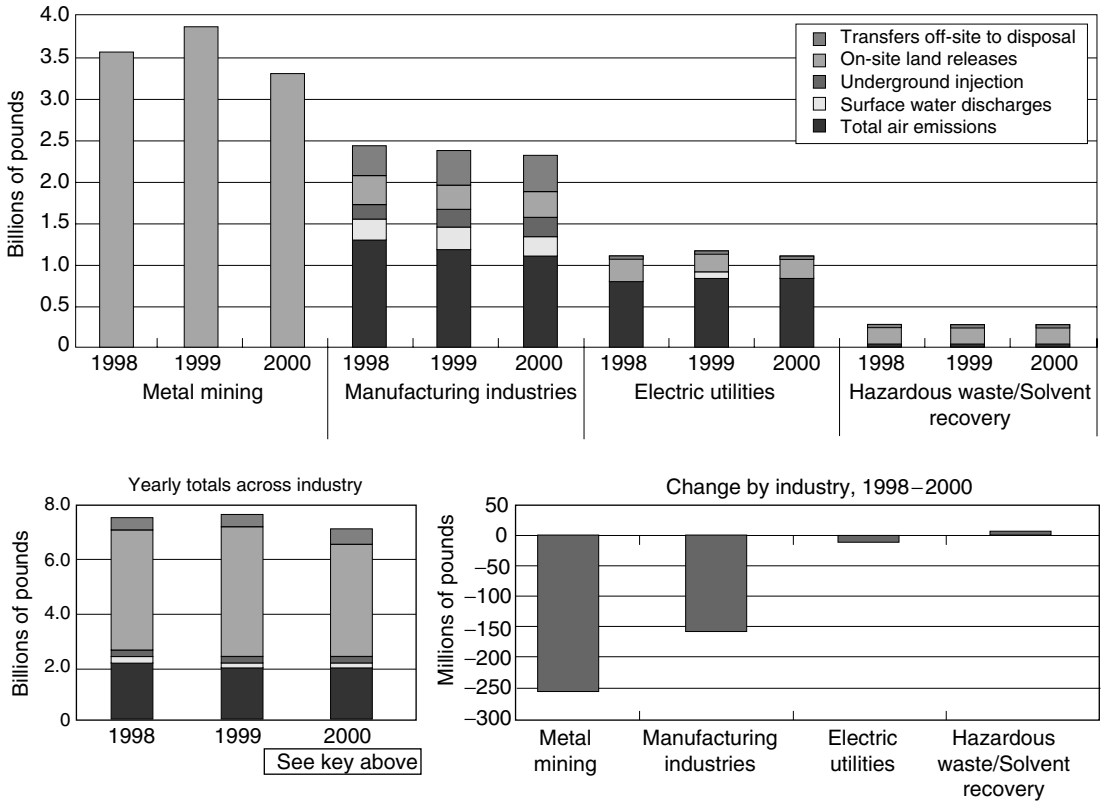


**Figure 10C.64** United Sates toxics release inventory (TRI) total releases and change by industry, 1998–2000. (From United States Environmental Protection Agency, 2003, *EPA's Draft Report on the Environment, 2003*, EPA 600-R-03-050, www.epa.gov.)

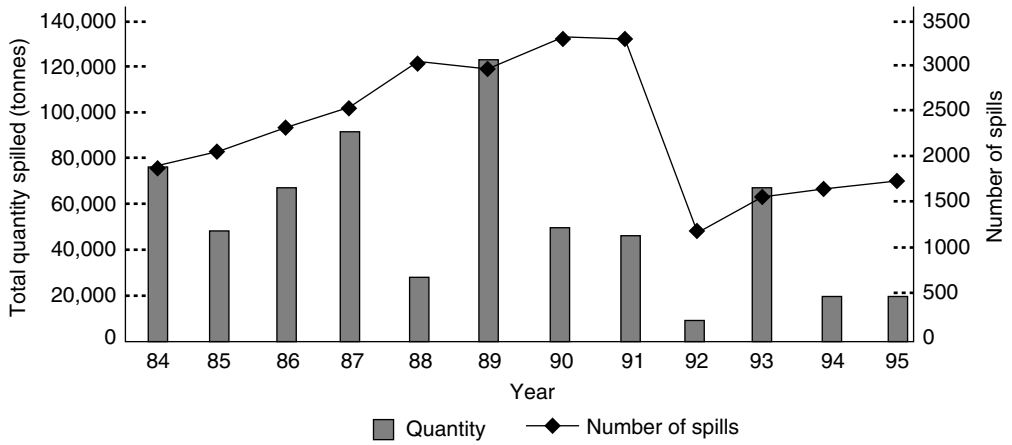


**Figure 10C.65** Petroleum sector—number of reported spills in Canada and total quantity, by year. (From *Summary of Spill Events in Canada, 1984–1995*, EPS 5/SP/3, Environment Canada, Canada Environmental Emergencies Program, 1998. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.)

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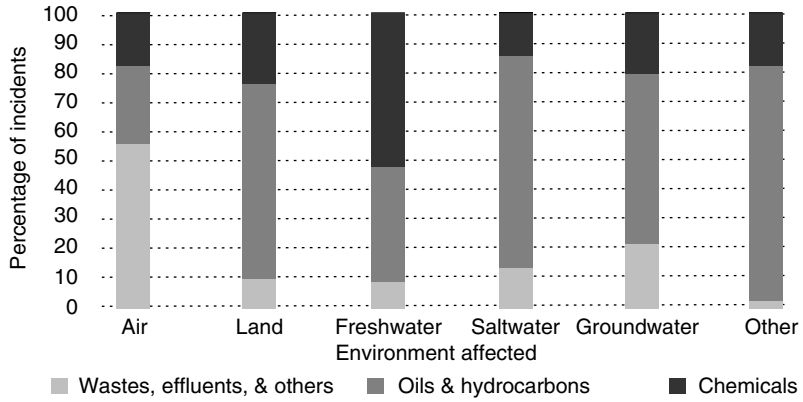


**Figure 10C.66** Percent distribution of environment affected by spill category in Canada. (From *Summary of Spill Events in Canada, 1984–1995*, EPS 5/SP/3, Environment Canada, Canada Environmental Emergencies Program, 1998. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.)

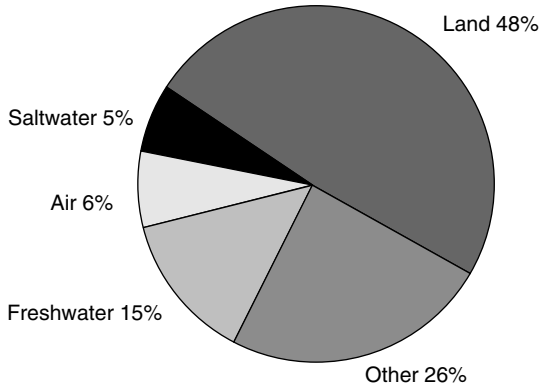


**Figure 10C.67** Percent distribution of environment affected by reported spills in Canada. (From *Summary of Spill Events in Canada, 1984–1995*, EPS 5/SP/3, Environment Canada, Canada Environmental Emergencies Program, 1998. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.)

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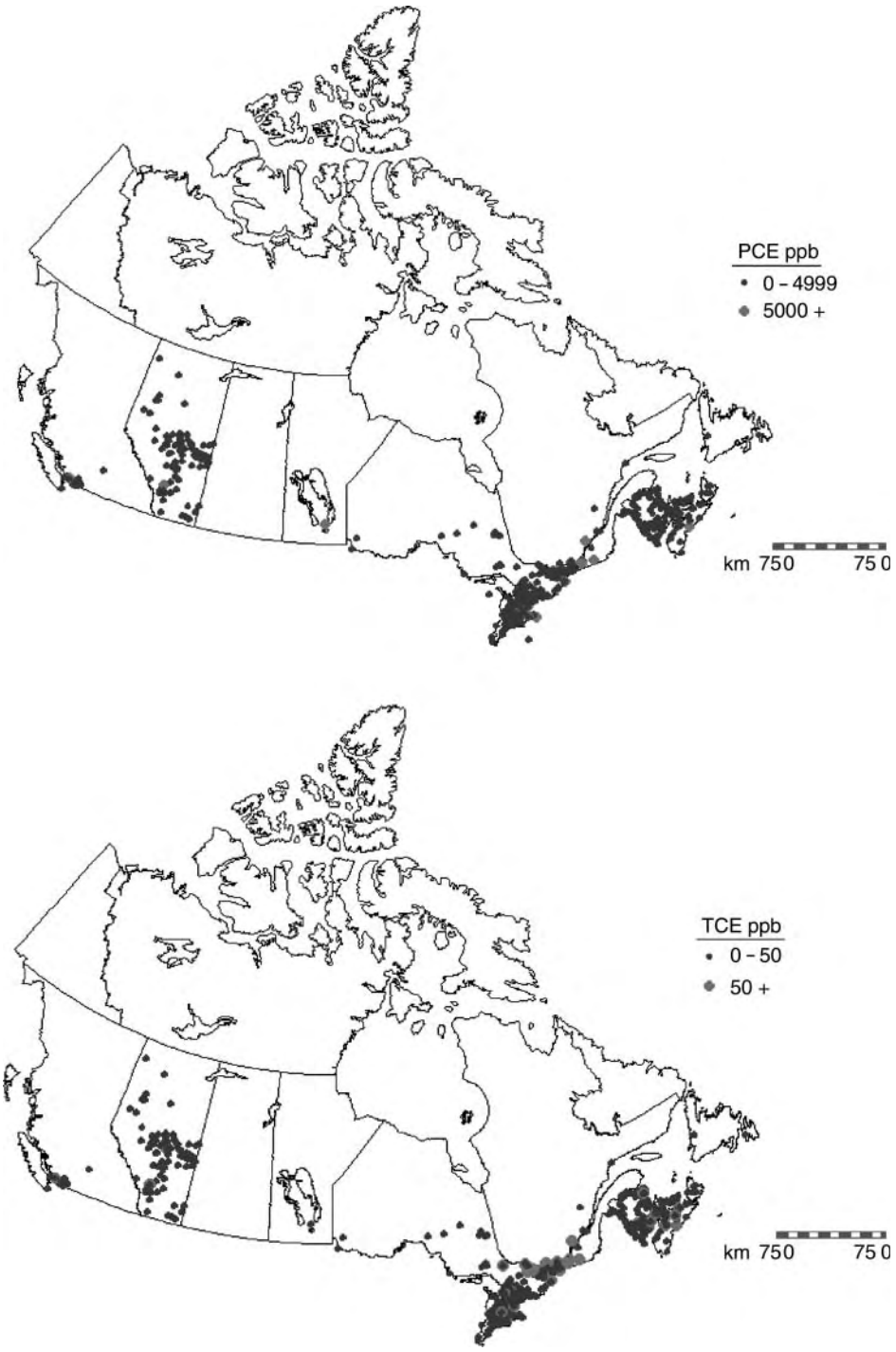


**Figure 10C.68** Distribution of tetrachloroethylene and trichloroethylene in groundwater throughout Canada. (From Bajjali, W., 2003, *Study of the Distribution of Tetrachloroetheylene and Trichloroethylene in Groundwater Throughout Canada Using SPANS-GIS*, frontpage.uwsuper.edu/bajjali/proj/can/c1.htm. With permission. Last updated on June 16, 2003.)

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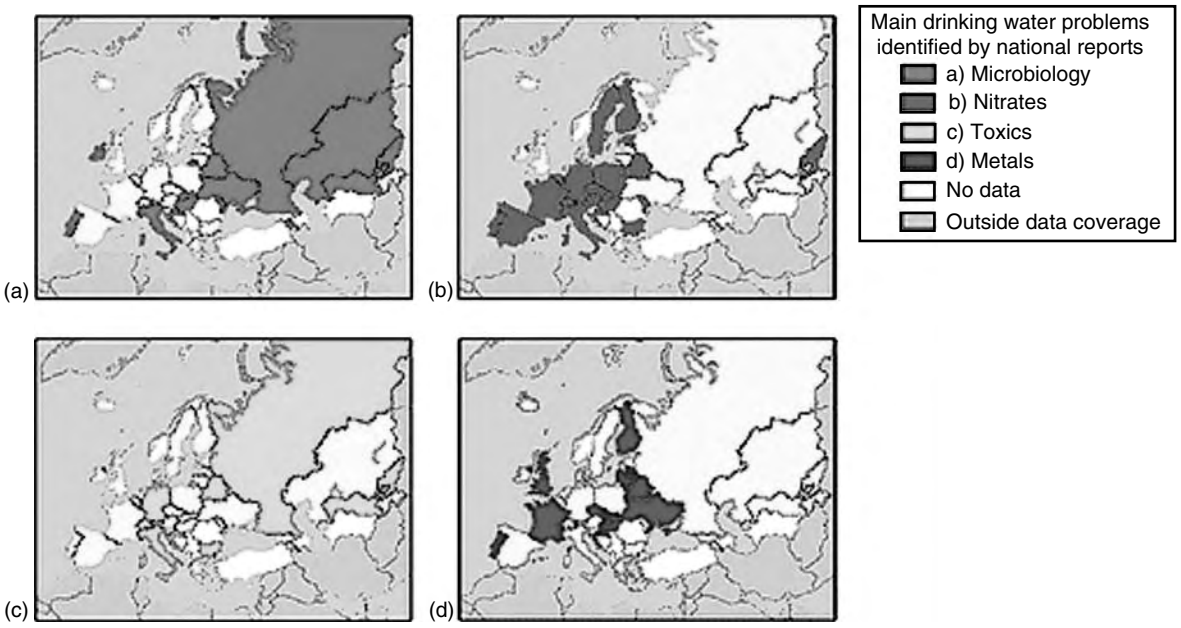


**Figure 10C.69** Main drinking water problems identified in the European Union. (From European Environmental Agency, *Indicator Fact Sheet Drinking Water Quality (WEU10) Verslon 13.10.03*, www.eea.europa.eu. Reprinted with permission © EEA.)

**Table 10C.83 Major Groundwater Contaminants Reported by States**

| | Reported as a Major Contaminant | |
|---|---|---|
| **Contaminant** | **No. of States[a]** | **% of States** |
| Sewage | 46 | 89 |
| Inorganic chemicals | | |
| Nitrates | 42 | 75 |
| Brine/Salinity | 36 | 69 |
| Arsenic | 19 | 37 |
| Fluorides | 18 | 35 |
| Sulfur compounds | 7 | 14 |
| Organic chemicals | | |
| Synthetic | 37 | 71 |
| Volatile | 36 | 69 |
| Metals | 34 | 65 |
| Pesticides | 31 | 60 |
| Petroleum | 21 | 40 |
| Radioactive materials | 12 | 23 |

[a] Based on a total of 52 States and territories which cited groundwater contaminants in their 305(b) submittals.

*Source*: From U.S. Environmental Protection Agency, *National Water Quality Inventory-1986 Report to Congress*, EPA-440/4-87-008.

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**Table 10C.84 Activities Contributing to Groundwater Contamination in the United States**

| Activity | States Citing | Estimated Sites[a] | Contaminants Frequently Cited as Result of Activity | Remarks |
|---|---|---|---|---|
| **Waste disposal** | | | | |
| Septic systems | 41 | 22 million | Bacteria, viruses, nitrate, phosphate, chloride, and organic compounds such as trichloroethylene | Between 820 and 1,460 billion gallons per year discharged to shallowest aquifers (Office of Technology Assessment, 1984) |
| Landfills (active) | 51 | 16,400 | Dissolved solids, iron, manganese, trace metals, acids, organic compounds, and pesticides | Traditional disposal method for municipal and industrial solid waste. Unknown number of abandoned landfills |
| Surface impoundments | 32 | 191,800 | Brines, acidic mine wastes, feedlot wastes, trace metals, and organic compounds | Used to store oil/gas brines (125,100 sites), mine wastes (19,800), agricultural wastes (17,200), industrial liquid wastes (16,200), municipal sewage sludges (2,400), other wastes (11,100) (U.S. Environmental Protection Agency, 1987) |
| Injection wells | 10 | 280,800 | Dissolved solids, bacteria, sodium, chloride, nitrate, phosphate, organic compounds, pesticides, and acids. | Wells used for injecting waste below drinking-water sources (550), oil/gas brine disposal (161,400), solution mining (22,700), injecting waste into or above drinking-water sources (14), and storm-water disposal, agricultural drainage, heat pumps (69,100) (U.S. Environmental Protection Agency, 1987) |
| Land application of wastes | 12 | 19,000 land application units | Bacteria, nitrate, phosphate, trace metals, and organic compounds | Waste disposal from municipal waste-treatment plants (11,900), industry (5,600), oil/gas production (730), petroleum and wood-preserving wastes (250), others (620) (U.S. Environmental Protection Agency, 1987) |
| **Storage and handling of materials** | | | | |
| Underground storage tanks | 39 | 2.4–4.8 million | Benzene, toluene, xylene, and petroleum products | Useful life of steel tanks, 15–20 yrs. About 25–30 percent of petroleum tanks may leak (Conservation Foundation, 1987) |
| Above-ground storage tanks | 16 | Unknown | Organic compounds, acids, metals, and petroleum products | Spills/overflows may contaminate groundwater |
| Material handling and transfers | 29 | 10,000–16,000 spills per year | Petroleum products, aluminum, iron, sulfate, and trace metals | Includes coal storage piles, bulk chemical storage, containers, and accidental spills |
| **Mining activities** | | | | |
| Mining and spoil disposal—coal mines | 23 | 15,000 active; 67,000 inactive | Acids, iron, manganese, sulfate, uranium, thorium, radium, molybdenum, selenium, and trace metals | Leachates from spoil piles of coal, metal, and nonmetallic mineral mining contain a variety of contaminants. Coal mines are sources of acid drainage |

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| | | | | |
|---|---|---|---|---|
| **Oil and gas activities** | | | | |
| Wells | 20 | 550,000 production; 1.2 million abandoned | Brines | Contamination from improperly plugged wells and oil brine stored in ponds or injected underground |
| **Agricultural activities** | | | | |
| Fertilizer and pesticide applications | 44 | 363 million acres[b] | Nitrate, phosphate, and pesticides | Fertilizer applied 1982–83, 42.3 million tons per year (U.S. Bureau of the Census, 1984); active ingredients of pesticides applied 1982, 660 million pounds (Gianessi, 1987) |
| Irrigation practices | 22 | 376,000 wells; 49 million acres irrigated[c] | Dissolved solids, nitrate, phosphate, and pesticides | Salts, fertilizers, pesticides can concentrate in groundwater. Improperly plugged abandoned wells contamination source |
| Animal feedlots | 17 | 1,900 | Nitrate, phosphate, and bacteria | Primarily in the Corn Belt and High Plains States (Office of Technology Assessment, 1984) |
| **Urban activities** | | | | |
| Runoff | 15 | 47.3 million acres urban land[d] | Bacteria, hydrocarbons, dissolved solids, lead, cadmium, and trace metals | Infiltration from detention basins, drainage wells, pits, shafts can reach groundwater. Karst areas particularly vulnerable |
| Deicing chemical storage and use | 14 | Not reported | Sodium chloride, ferric ferrocyanide, sodium ferrocyanide, phosphate, and chromate | Winter 1983, 9.35 million tons dry salts/abbrasives, 7.78 million gallons of liquid salts applied (Office of Technology Assessment 1984) |
| **Other** | | | | |
| Saline intrusion or upconing | 29 | Not reported | Dissolved solids and brines | Present in coastal areas and in many inland areas |

[a] Estimated number of sites from U.S. Environmental Protection Agency (1987) unless otherwise indicated.
[b] U.S. Bureau of the Census, 1984, p. 658, 1982 data.
[c] U.S. Bureau of the Census, 1984, p. 639, 1982 data.
[d] U.S. Bureau of the Census, 1984, p. 195, 1980 data.

*Source*: From U.S. Geological Survey, National Water Survey 1986, Water-Supply Paper 2325.



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**Table 10C.85 Profile of Sources of Groundwater Contamination in the United States**

| Source | Potential Contaminants | Number/Volume | Geographic Distribution |
|---|---|---|---|
| Subsurface percolation systems | Organics, metals, nitrates, phosphates, microorganisms | 22 million domestic systems 25,000 industrial systems | Highest concentration in eastern third of country and portions of west coast |
| Injection wells | Organics, metals, inorganic acids, microorganisms, radionuclides | 280,752 active wells | Varies by well type<br>Class I (hazardous waste)—Gulf Coast and Great Lakes<br>Class II (oil/gas)—throughout the U.S.<br>Class III (mining)—Southwest<br>Class V—agricultural wells in IA, ID, TX, CA; industrial wells in NY and NJ |
| Land application | Nitrogen, phosphorous, metals organics, microorganisms | 2,463 POTWs—sludge application<br>1,000 POTWs—land treatment<br>250 hazardous waste land treatment units<br>18,889 nonhazardous units | Unknown |
| Landfills | Organics, inorganics, microorganisms, radionuclides | 16,416 landfills<br>9,284 municipal<br>3,155 industrial | Urban locations nationwide |
| Open dumps | Organics, inorganics, microorganisms | 1,856–2,396 dumps | 55 states and territories |
| Residential disposal | Organics, metals, other inorganics, microorganisms | Unknown | Nationwide |
| Surface impoundments | Organics, metals and other inorganics, microorganisms, radionuclides | 191,822 surface impoundments<br>16,232 industrial<br>2,426 municipal<br>17,159 agricultural<br>19,813 mining<br>125,074 oil and gas<br>11,118 other | 70% in hydrogeologically vulnerable areas<br>37% over current groundwater sources of drinking water<br>Highest number of non-hazardous are in AR, KS, LA, MN, OH, OK, PA, TX, WV |
| Waster tailings and piles | Arsenic, sulfuric acid, copper, selenium, molybdenum, uranium, thorium, radium,<br>lead, manganese, vanadium | Total mining—2.3 billion tons/yr<br>Metal—250 million tons/yr<br>Uranium—215 million tons/yr.<br>Hazardous waste—0.39 billion tons | Unknown |
| Material stockpiles | Metals, inorganics, radionuclides | Annual materials production—3.4 billion tons/yr<br>Stockpiles—700 million tons/yr | Nationwide |
| Graveyards | Metals, nonmetals, microorganisms | Unknown | Nationwide |
| Animal burial | | Unknown | Unknown |
| Aboveground storage | Organics, inorganics, microorganisms, radionuclides | Unknown | Nationwide |
| Underground storage | Organics, inorganics, microorganisms, radionuclides | Steel—2.4–4.8 million tanks<br>Fiberglass—0.1 million tanks<br>Total capacity—25 billion gallons Hazardous storage—2,032 tanks | Nationwide |

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| | | | |
|---|---|---|---|
| Pipelines | Microorganisms, organics, inorganics | 175,000 miles of petroleum product pipelines (1976) carrying 9.63 billion bbls<br>700,000 miles of sewer pipeline (1976) carrying 5.6 trillion gallons | Nationwide |
| Materials transport | Organics, inorganics, microorganisms | 10,000–16,000 spills per year; spills account for approximately 0.35 percent of 4 billion tons shipped annually (1984) | Nationwide |
| Mining/mine drainage | Acids, metals, radionuclides | 15,000 active coal mines (1986)<br>67,000 inactive coal mines phospate mines; metalic ore mines | Varies by mining type |
| Production wells | Organics, inorganics, microorganisms | 548,000 oil wells produced approximately 3.1 billion bbls crude oil (1980)<br>376,000 irrigation wells for 126,000 farms Up to 1.2 million abandoned wells | Oil Wells—nationwide<br>Geothermal wells—primarily CA, NV, ID<br>Water wells—mostly in the Southwest, Central Plains, Idaho, and Florida |
| Other wells (monitoring and exploration) | Organics, inorganics, microorganisms radionuclides | Unknown | Unknown |
| Pesticide application | Organics—1,200–1,400 active ingredients<br>Approximately 280 million acre-treatments annually | 552 million pounds of active ingredients applied to crops in 1982 | 17 pesticides confirmed in 23 states (1986) due to normal agricultural application |
| Fertilizer applications | Nitrates, phosphates | Fertilizer use has declined from 54 million tons to 42.3 million tons (1980–1983); fertilizers in 1981–1982 contained 11 million tons of nitrogen, 4.8 million tons of phosphates, 5.6 million tons of potash | Highest fertilizer use in 1981–1982: CA, IL, IN, IO, TX |
| Deicing | Salts | 9.35 million tons dry salts, and abrasives; 1.78 million gallons liquid salts applied to U.S. highways (1982–1983) | Northeast, Mid-Atlantic, Midwest |
| Irrigation practices | Fertilizers, pesticides, naturally occurring contaminants (e.g., selenium), sediment | 14 percent of cropland is irrigated | Water, Central, and South Plains, Arkansas, Florida |
| Percolation of atmospheric pollutants | Sulfhur and nitrogen compounds, asbestos, heavy metals | Unknown | Acid rain around Great Lakes, Northeast<br>Distribution of other pollutants varies |
| Groundwater/surface water interaction | Organics, inorganics, microorganisms, radionuclides | Unknown | Unknown |
| Natural leaching | Inorganics, radionuclides | Unknown | Unknown, very localized |
| Salt water intrusion | Inorganics, radionuclides | Unknown | Predominantly coastal areas—CA, TX, LA, FL, NY, Southwest, Central Plains |

*Source*: From U.S. Environmental Protection Agency, Office of Groundwater Protection, 1987, *EPA Activities Related to Groundwater Contamination*.



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**Table 10C.86 Detections of Individual Volatile Organic Compounds in Groundwater from Rural, Untreated Self-Supplied Domestic Wells in the United States, 1986–1999**

| | | | Detected Concentrations (μg/L) | | | Type of Drinking-Water Standard, Health Criterion, or Taste/Odor Threshold | | | |
|---|---|---|---|---|---|---|---|---|---|
| Volatile Organic Compound | Predominant Use | Number of Detections/Samples | Min | Median | Max | MCL, HA, $10^{-4}$ CR (μg/L) | Number of Concentrations Exceeding Standard of Criterion | Taste/Odor Threshold[a] (μg/L) | Number of Concentrations Exceeding Taste/Odor Threshold |
| **VOCs Not Detected** | | | | | | | | | |
| Bromomethane | Fumigant | 0/1,677 | — | — | — | 10 (HA) | 0 | — | 0 |
| *cis*−1,3-Dichloropropene | Fumigant | 0/1,685 | — | — | — | 40 ($10^{-4}$ CR) | 0 | — | 0 |
| *trans*-1,3-Dichloropropene | Fumigant | 0/1,592 | — | — | — | 40 ($10^{-4}$ CR) | 0 | — | 0 |
| *n*-Butylbenzene | Gasoline hydrocarbon | 0/1,454 | — | — | — | — | 0 | — | 0 |
| 1,2-Dimethylbenzene | Gasoline hydrocarbon | 0/805 | — | — | — | 10,000 (MCL) | 0 | — | 0 |
| 1,3/1,4-Dimethylbenzene | Gasoline hydrocarbon | 0/799 | — | — | — | 10,000 (MCL) | 0 | 17[b] | 0 |
| Bromoethene | Organic synthesis | 0/688 | — | — | — | — | 0 | — | 0 |
| Hexachlorobutadiene | Organic synthesis | 0/1,347 | — | — | — | 1 (HA) | 0 | 6 | 0 |
| 2-Propenal | Organic synthesis | 0/472 | — | — | — | — | 0 | 110 | 0 |
| 2-Propenenitrile | Organic synthesis | 0/693[c] | — | — | — | 6 ($10^{-4}$ CR) | 0 | 9,100 | 0 |
| Ethenylbenzene | Organic synthesis | 0/1,915 | — | — | — | 100 (MCL and HA) | 0 | 11 | 0 |
| 1,2,3-Trichlorobenzene | Organic synthesis | 0/1,455 | — | — | — | — | 0 | 10 | 0 |
| Ethyl *tert*-butyl ether | Oxygenate | 0/688 | — | — | — | — | 0 | — | 0 |
| 1,2-Dichlorobenzene | Solvent | 0/1,911 | — | — | — | 600 (MCL) | 0 | 24 | 0 |
| 1,3-Dichlorobenzene | Solvent | 0/1,340 | — | — | — | 600 (HA) | 0 | 77 | 0 |
| Hexachloroethane | Solvent | 0/698 | — | — | — | 1 (HA) | 0 | 10 | 0 |
| 1,2,4-Trichlorobenzene | Solvent | 0/1,464 | — | — | — | 70 (MCL) | 0 | 5 | 0 |
| 1,1,2-Trichloroethane | Solvent | 0/1,686 | — | — | — | 5 (MCL) | 0 | 50,000 | 0 |
| **Detection Frequency Greater Than 0 and Less Than or Equal to 1 Percent** | | | | | | | | | |
| 1,2-Dibromoethane | Fumigant | [c]3/1,614 | 0.3 | 0.6 | 1.1 | 0.05 (MCL) | 3 | — | — |
| 1,4-Dichlorobenzene | Fumigant | 1/1,925 | 1.2 | 1.2 | 1.2 | 75 (MCL) | 0 | 4.5 | 0 |
| Benzene | Gasoline hydrocarbon | 6/1,892 | 0.2 | 0.5 | 4.4 | 5 (MCL) | 0 | 170 | 0 |
| Ethylbenzene | Gasoline hydrocarbon | 2/1,926 | 0.2 | 2.8 | 5.4 | 700 (MCL) | 0 | 29 | 0 |
| Naphthalene | Gasoline hydrocarbon | 2/1,464 | 1.8 | 2.1 | 2.5 | 20 (HA) | 0 | 2.5 | 0 |
| 1,2,4-Trimethylbenzene | Gasoline hydrocarbon | 6/1,415 | 0.2 | 0.3 | 12 | — | — | 500 | 0 |
| Chloroethene | Organic synthesis | 1/1,917 | 0.4 | 0.4 | 0.4 | 2 (MCL) | 0 | 3,400 | 0 |
| 1,1-Dichloroethene | Organic synthesis | 2/1,926 | 0.5 | 19.8 | 39 | 7 (MCL) | 1 | 1,500 | 0 |
| (1-Methylethyl) benzene | Organic synthesis | 2/1,371 | 0.4 | 0.6 | 0.8 | 233 ($10^{-4}$ CR) | 0 | 0.8 | 0 |
| *tert*-Amyl methyl ether | Oxygenate | 1/688 | 0.8 | 0.8 | 0.8 | — | — | — | — |
| Diisopropyl ether | Oxygenate | 1/581 | 22 | 22 | 22 | — | — | — | — |
| Chloromethane | Refrigerant | 2/1,565 | 1.1 | 1.8 | 2.5 | 3 (HA) | 0 | — | — |
| Trichlorofluoromethane | Refrigerant | 7/1,925 | 0.2 | 0.3 | 1.9 | 2,000 (HA) | 0 | 28 | 0 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | Refrigerant | 1/1,515 | 0.3 | 0.3 | 0.3 | 2,100,000 ($10^{-4}$ CR) | 0 | — | — |
| Chlorobenzene | Solvent | 1/1,926 | 3.5 | 3.5 | 3.5 | 100 (MCL) | 0 | 50 | 0 |
| Chloroethane | Solvent | 2/1,677 | 0.3 | 0.5 | 0.7 | — | — | 19 | 0 |
| 1,1-Dichloroethane | Solvent | 5/1,926 | 0.2 | 0.7 | 1.7 | — | — | — | — |
| 1,2-Dichloroethane | Solvent | 4/1,910 | 0.2 | 1.5 | 2.9 | 5 (MCL) | 0 | 7,000 | 0 |
| *cis*−1,2-Dichloroethene | Solvent | 2/1,705 | 3 | 3.7 | 4.4 | 70 (MCL) | 0 | — | — |
| *trans*-1,2-Dichloroethene | Solvent | 1/1,767 | 0.4 | 0.4 | 0.4 | 100 (MCL) | 0 | 4.3 | 0 |
| Dichloromethane | Solvent | 12/1,923 | 0.2 | 0.6 | 4 | 5 (MCL) | 0 | 910 | 0 |
| 1,2-Dichloropropane | Solvent | 15/1,926 | 0.2 | 0.5 | 19.4 | 5 (MCL) | 2 | 10 | 1 |
| *n*-Propylbenzene | Solvent | 1/1,454 | 0.6 | 0.6 | 0.6 | — | — | — | — |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tetrachloromethane | Solvent | 5/1,925 | 0.2 | 0.4 | 0.6 | 5 (MCL) | 0 | 520 | 0 |
| Trichloroethene | Solvent | 16/1,926 | 0.2 | 0.7 | 25 | 5 (MCL) | 3 | 310 | 0 |
| 1,2,3-Trichloropropane | Solvent | 10/1,615 | 0.2 | 0.4 | 2.1 | 40 (HA) | 0 | — | — |
| Bromodichloromethane[d] | Trihalomethane | 7/1,926 | 0.2 | 1.5 | 7 | 80 (MCL) | 0 | — | — |
| Chlorodibromomethane[d] | Trihalomethane | 7/1,926 | 0.3 | 0.6 | 11 | 80 (MCL) | 0 | — | — |
| Tribromomethane[d] | Trihalomethane | 4/1,925 | 0.3 | 0.7 | 8.2 | 80 (MCL) | 0 | 300 | 0 |
| **Detection Frequency Greater Than 1 and Less Than or Equal to 5 Percent** | | | | | | | | | |
| 1,2-Dibromo-3-chloropropane | Fumigant | 16/1,459[e] | 0.2 | 1.3 | 3.2 | 0.2 (MCL) | 16 | — | — |
| Methylbenzene | Gasoline hydrocarbon | 21/1,882 | 0.2 | 0.3 | 12 | 1,000 (MCL) | 0 | 42 | 0 |
| Methyl *tert*-butyl ether | Oxygenate | 30/1,335 | 0.2 | 0.7 | 30.2 | — | — | 20[f] | 1 |
| Dichlorodifluoromethane | Refrigerant | 23/1,916 | 0.2 | 0.3 | 2 | 1,000 (HA) | 0 | — | — |
| Tetrachloroethene | Solvent | 32/1,897 | 0.2 | 0.3 | 29 | 5 (MCL) | 3 | 190 | 0 |
| 1,1,1-Trichloroethane | Solvent | 22/1,926 | 0.2 | 0.4 | 120 | 200 (MCL) | 0 | 970 | 0 |
| Trichloromethane[d] | Trihalomethane | 83/1,926 | 0.2 | 0.5 | 74 | 80 (MCL) | 0 | 2,400 | 0 |

*Note:* VOC, volatile organic compound; Min, minimum; Max, maximum; MCL, Maximum Contaminant Level; HA, Health-Advisory Level, lifetime 70-km adult consuming 2 L of water per day; $10^{-4}$ CR, risk of one additional 70-km adult in ten thousand ($1 \times 10^{-4}$) contracting cancer over a lifetime of exposure consuming 2 L of water per day; μg/L, micrograms per liter; —, not applicable.

[a] Taste/odor thresholds from bender and others, 1999.
[b] 1,3-Dimethylbenzene.
[c] No additional detections exist below 0.2 μg/L.
[d] Bromodichloromethane, chlorodibromomethane, tribromomethane, and trichloromethane can also be classified as solvents or VOCs used in organic synthesis.
[e] When uncensored, the number of detections equals 19.
[f] Lower limit of U.S. Environmental Protection Agency Drinking Water Advisory.

*Source*: From Moran, M.J. et al., Occurrence and status of volatile organic comounds in groundwater from rural, untreated, self-supplied domestic wells in the United States, 1986–1999, United States Geological Survey, *Water Resources Investigation Report 02-4085*, www.usgs.gov.



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**Table 10C.87 Frequency of Detection and Concentrations of Volatile Organic Compounds in Groundwater Source Samples Collected from United States Drinking Water Supplies between May 3, 1999 and October 23, 2000**

| | Groundwater Statistics | | | | |
|---|---|---|---|---|---|
| **Compound** | **Number of Samples** | **Number of Detects** | **Detection Frequency** | **Min Concentration** | **Max Concentration** |
| **Gasoline Oxygenates** | | | | | |
| *tert*-Amyl methyl ether | 579 | 2 | 0.34 | 0.21 | 0.31 |
| Diisopropyl ether | 579 | 2 | 0.34 | 0.23 | 1.7 |
| Ethyl *tert*-butyl ether | 579 | 1 | 0.17 | 0.25 | 0.25 |
| Methyl *tert*-butyl ether | 571 | 31 | 5.4 | 0.20 | 6.3 |
| **Other Gasoline Compounds** | | | | | |
| Benzene | 578 | 2 | 0.34 | 0.75 | 3 |
| *n*-Butylbenzene | 579 | 1 | 0.17 | 0.21 | 0.21 |
| *sec*-Butylbenzene | 579 | 0 | 0 | <0.2 | <0.2 |
| *tert*-Butylbenzene | 579 | 0 | 0 | <0.2 | <0.2 |
| Ethylbenzene | 566 | 3 | 0.53 | 0.23 | 0.63 |
| Naphthalene | 579 | 1 | 0.17 | 0.22 | 0.22 |
| Toluene | 562 | 3 | 0.53 | 1.1 | 4.2 |
| 1,3,5-Trimethylbenzene | 579 | 0 | 0 | <0.2 | <0.2 |
| *o*-Xylene | 566 | 4 | 0.71 | 0.26 | 0.91 |
| *m*- *p*-Xylene | 564 | 4 | 0.71 | 0.33 | 1.6 |
| **Trihalomethanes** | | | | | |
| Bromodichloromethane | 578 | 34 | 5.9 | 0.2 | 7.4 |
| Bromoform | 579 | 27 | 4.7 | 0.21 | 49 |
| Chlorodibromomethane | 578 | 35 | 6.1 | 0.21 | 9.4 |
| Chloroform | 575 | 68 | 12 | 0.21 | 22 |
| **Organic Syntheses** | | | | | |
| Acrylonitrile | 579 | 0 | 0 | <0.2 | <0.2 |
| Bromobenzene | 579 | 0 | 0 | <0.2 | <0.2 |
| Bromochloromethane | 579 | 0 | 0 | <0.2 | <0.2 |
| Carbon tetrachloride | 579 | 5 | 0.86 | 0.38 | 1.8 |
| Chlorobenzene | 579 | 1 | 0.17 | 1.6 | 1.6 |
| Chloroethane | 579 | 1 | 0.17 | 2.6 | 2.6 |
| 2-Chlorotoluene | 579 | 0 | 0 | <0.2 | <0.2 |
| 4-Chlorotoluene | 579 | 0 | 0 | <0.2 | <0.2 |
| Dibromomethane | 562 | 2 | 0.36 | 0.33 | 0.75 |
| 1,2-Dichlorobenzene | 579 | 1 | 0.17 | 0.37 | 0.37 |
| 1,3-Dichlorobenzene | 579 | 0 | 0 | <0.2 | <0.2 |
| 1,1 –Dichloroethane | 579 | 11 | 1.9 | 0.21 | 10 |
| 1,2-Dichloroethane | 579 | 3 | 0.52 | 0.27 | 0.65 |
| 1,1 –Dichloroethene | 579 | 8 | 1.4 | 0.22 | 23 |
| *cis*-1,2-Dichloroethene | 579 | 11 | 1.9 | 0.33 | 14 |
| *trans*-1,2-Dichloroethene | 579 | 0 | 0 | <0.2 | <0.2 |
| 1,2-Dichloropropane | 561 | 1 | 0.18 | 0.47 | 0.47 |
| 1,3-Dichloropropane | 569 | 0 | 0 | <0.2 | <0.2 |
| 2,2-Dichloropropane | 579 | 0 | 0 | <0.2 | <0.2 |
| 1,1-Dichloropropene | 579 | 0 | 0 | <0.2 | <0.2 |
| Hexachlorobutadiene | 579 | 0 | 0 | <0.2 | <0.2 |
| Hexachloroethane | 579 | 0 | 0 | <0.2 | <0.2 |
| Isopropylbenzene | 573 | 1 | 0.17 | 0.38 | 0.38 |
| *p*-Isopropyltoluene | 579 | 0 | 0 | <0.2 | <0.2 |
| Methylene chloride | 577 | 1 | 0.17 | 1.6 | 1.6 |
| Methyl ethyl ketone | 577 | 2 | 0.35 | 3.4 | 5.8 |
| *n*-Propylbenzene | 579 | 0 | 0 | <0.2 | <0.2 |
| Styrene | 562 | 2 | 0.36 | 0.21 | 0.83 |
| 1,1,1,2-Tetrachloroethane | 579 | 0 | 0 | <0.2 | <0.2 |
| 1,1,2,2-Tetrachloroethane | 579 | 0 | 0 | <0.2 | <0.2 |
| Tetrachloroethene | 577 | 24 | 4.2 | 0.2 | 36 |
| 1,1,1 -Trichloroethane | 578 | 10 | 1.7 | 0.21 | 13 |
| 1,1,2-Trichloroethane | 579 | 0 | 0 | <0.2 | <0.2 |
| Trichloroethene | 576 | 19 | 3.3 | 0.23 | 170 |
| 1,2,3-Trichloropropane | 579 | 1 | 0.17 | 0.31 | 0.31 |

*(Continued)*

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**Table 10C.87 (Continued)**

| Compound | Groundwater Statistics | | | | |
|---|---|---|---|---|---|
| | Number of Samples | Number of Detects | Detection Frequency | Min Concentration | Max Concentration |
| 1,2,4-Trimethylbenzene | 571 | 1 | 0.18 | 0.46 | 0.46 |
| Vinyl bromide | 579 | 0 | 0 | <0.2 | <0.2 |
| Vinyl chloride | 579 | 1 | 0.17 | 3.2 | 3.2 |
| 1,2,3-Trichlorobenzene | 579 | 0 | 0 | <0.2 | <0.2 |
| 1,2,4-Trichlorobenzene | 579 | 0 | 0 | <0.2 | <0.2 |
| **Fumigants** | | | | | |
| Bromomethane | 579 | 1 | 0.17 | 6.4 | 6.4 |
| 1,4-Dichlorobenzene | 579 | 1 | 0.17 | 0.25 | 0.25 |
| *cis*-1,3-Dichloropropene | 579 | 0 | 0 | <0.2 | <0.2 |
| *trans*-1,3 –Dichloropropene | 579 | 0 | 0 | <0.2 | <0.2 |
| **Refrigerants** | | | | | |
| Chloromethane | 579 | 3 | 0.52 | 0.2 | 0.69 |
| Dichlorodifluoromethane | 579 | 4 | 0.69 | 1.1 | 18 |
| Trichlorofluoromethane | 579 | 5 | 0.86 | 0.24 | 1.3 |
| l,l,2-Trichloro-l,2,2-Trifluoroethane | 579 | 1 | 0.17 | 0.91 | 0.91 |

*Note:* Concentrations are in micrograms per liter.

*Source*: From Grady, S., 2003, *A National Survey of Methyl tert-Butyl Ether and Other Volatile Organic Compounds in Drinking Water Sources: Results of a Random Survey*, United States Geological Survey Water-Resource Investigations Report 02-4079, www.usgs.gov.

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**Table 10C.88 Summary Comparison of Occurrence of Phase II/V Contaminants In United States Water Systems Using Surface Water vs. Groundwater, from National Cross-Section States**

| | Percent > MRL | | Percent > ½ MCL | | Percent > MCL[a] | | | |
|---|---|---|---|---|---|---|---|---|
| Contaminant | Surface Water (%) | Groundwater (%) | Surface Water (%) | Groundwater (%) | Surface Water (%) | Groundwater (%) | National MCL Viol.-SW (%) | National MCL Viol.-GW (%) |
| **Inorganic Chemicals (IOCs)** | | | | | | | | |
| IOCs | | | | | | | | |
| Antimony (total) | 4.2 | 3.2 | 0.8 | 1.2 | 0.2 | 0.4 | 0.08 | 0.06 |
| Arsenic | 13.0 | 19.3 | 0.6 | 1.6 | 0.5 | 0.9 | 0.00 | 0.06 |
| Asbestos (MCL in fibers per liter) | 8.9 | 8.5 | 0.7 | 0.9 | 0.7 | 0.4 | 0.00 | 0.01 |
| Barium | 49.1 | 47.3 | 0.6 | 0.8 | 0.5 | 0.2 | 0.00 | 0.06 |
| Beryllium (total) | 2.5 | 2.1 | 0.4 | 0.5 | 0.0 | 0.2 | 0.02 | 0.02 |
| Cadmium | 5.1 | 4.9 | 1.3 | 1.2 | 0.2 | 0.6 | 0.05 | 0.06 |
| Chromium | 10.5 | 13.2 | 0.3 | 0.5 | 0.2 | 0.2 | 0.00 | 0.01 |
| Cyanide | 5.1 | 2.0 | 0.4 | 0.5 | 0.0 | 0.2 | 0.02 | 0.01 |
| Fluoride | 77.8 | 72.5 | 0.8 | 3.4 | 0.5 | 1.3 | 0.02 | 0.18 |
| Mercury | 9.0 | 4.5 | 1.3 | 0.7 | 0.5 | 0.4 | 0.03 | 0.04 |
| Nickel | 11.8 | 10.6 | 1.2 | 0.9 | 0.4 | 0.4 | 0.02 | 0.01 |
| Selenium | 11.2 | 8.6 | 0.2 | 0.3 | 0.0 | 0.2 | 0.03 | 0.07 |
| Thallium (total) | 2.5 | 3.6 | 0.8 | 1.3 | 0.0 | 0.4 | 0.12 | 0.06 |
| **Synthetic Organic Chemicals (SOCs)** | | | | | | | | |
| 2,3,7,8-TCDD (Dioxin) | 0.0 | 1.3 | 0.0 | 1.3 | 0.0 | 1.3 | 0.00 | 0.00 |
| 2,4,5-TP (Silvex) | 2.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| 2,4-D | 11.2 | 1.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.00 | <0.01 |
| Alachlor (Lasso) | 7.3 | 0.3 | 1.5 | 0.1 | 0.2 | 0.0 | 0.00 | 0.00 |
| Atrazine | 21.1 | 2.0 | 13.2 | 0.3 | 10.7 | 0.1 | 0.83 | 0.01 |
| Benzo[a]pyrene | 0.5 | 0.5 | 0.0 | 0.1 | 0.0 | 0.1 | 0.00 | 0.00 |
| bis(2-ethylhexyl) adipate | 4.9 | 6.8 | 0.5 | 0.4 | 0.5 | 0.3 | 0.02 | 0.00 |
| bis(2-ethylhexyl) phthalate | 28.9 | 14.9 | 3.2 | 2.7 | 2.8 | 1.7 | 0.03 | 0.01 |
| Carbofuran (Furadan) | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Chlordane | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Dalapon | 9.4 | 0.8 | 0.2 | 0.0 | 0.2 | 0.0 | 0.00 | 0.00 |
| Dibromo-chloropropane (DBCP) | 4.8 | 2.6 | 1.1 | 2.3 | 1.1 | 2.0 | 0.00 | <0.01 |
| Dinoseb | 2.5 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Diquat | 3.5 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Endothall | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Endrin | 2.1 | 0.2 | 0.2 | 0.1 | 0.2 | 0.0 | 0.02 | 0.00 |
| Ethylene Dibromide (EDB) | 4.2 | 1.0 | 3.8 | 1.0 | 3.7 | 0.7 | 0.07 | 0.04 |
| Glyphosate (Roundup) | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Heptachlor | 0.4 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.00 | 0.00 |
| Heptachlor Epoxide | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Hexachloro-benzene | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Hexachloro-cyclopentadiene | 9.6 | 0.1 | 1.0 | 0.0 | 0.6 | 0.0 | 0.00 | 0.00 |
| Lindane | 1.2 | 0.3 | 0.3 | 0.1 | 0.3 | 0.1 | 0.00 | 0.00 |
| Methoxychlor | 1.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Oxamyl (Vydate) | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Penta-chlorophenol | 3.1 | 0.7 | 0.4 | 0.1 | 0.2 | 0.0 | 0.00 | <0.01 |
| Picloram (Tordon) | 3.7 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | <0.01 |
| Simazine | 15.9 | 1.4 | 2.5 | 0.0 | 1.0 | 0.0 | 0.00 | 0.00 |
| Total PCBs | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 0.00 | <0.01 |
| *Aroclor* 1016 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| *Aroclor* 1221 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| *Aroclor* 1232 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| *Aroclor* 1242 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| *Aroclor* 1248 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| *Aroclor* 1254 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| *Aroclor* 1260 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| Toxaphene | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | <0.01 |
| **Volatile Organic Chemicals (VOCs)** | | | | | | | | |
| 1,1,1-Trichloroethane | 7.3 | 3.3 | 0.9 | 1.3 | 0.9 | 1.3 | 0.00 | 0.01 |
| 1,1,2-Trichloroethane | 5.7 | 0.7 | 0.6 | 0.4 | 0.3 | 0.3 | 0.00 | 0.01 |
| 1,1-Dichloroethene | 2.9 | 1.5 | 0.3 | 1.0 | 0.3 | 0.9 | 0.02 | 0.04 |

*(Continued)*

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**Table 10C.88 (Continued)**

| Contaminant | Percent > MRL | | Percent > ½ MCL | | Percent > MCL[a] | | | |
|---|---|---|---|---|---|---|---|---|
| | Surface Water (%) | Groundwater (%) | Surface Water (%) | Groundwater (%) | Surface Water (%) | Groundwater (%) | National MCL Viol.-SW (%) | National MCL Viol.-GW (%) |
| 1,2,4-Trichlorobenzene | 3.1 | 1.0 | 0.0 | 0.4 | 0.0 | 0.4 | 0.00 | 0.00 |
| 1,2-Dichloroethane | 3.1 | 1.4 | 0.3 | 0.6 | 0.3 | 0.4 | 0.00 | 0.02 |
| 1,2-Dichloropropane | 3.2 | 1.0 | 0.6 | 0.4 | 0.5 | 0.3 | 0.00 | 0.01 |
| Benzene | 3.9 | 1.2 | 0.5 | 0.5 | 0.3 | 0.4 | 0.02 | 0.04 |
| Carbon tetrachloride | 9.0 | 1.7 | 1.6 | 0.6 | 1.1 | 0.4 | 0.00 | 0.02 |
| Chlorobenzene | 8.1 | 1.0 | 0.2 | 0.3 | 0.2 | 0.3 | 0.00 | <0.01 |
| cis-1,2-Dichloroethylene | 3.3 | 1.9 | 0.3 | 0.7 | 0.3 | 0.6 | 0.00 | 0.01 |
| Ethyl benzene | 7.3 | 2.2 | 0.3 | 0.3 | 0.3 | 0.1 | 0.00 | <0.01 |
| Methylene chloride (Dichloromethane) | 25.6 | 11.1 | 10.4 | 3.3 | 4.7 | 2.3 | 0.03 | 0.05 |
| *o*-Dichlorobenzene | 3.7 | 1.2 | 0.2 | 0.6 | 0.0 | 0.5 | 0.00 | 0.00 |
| *p*-Dichlorobenzene | 6.2 | 2.0 | 0.0 | 0.9 | 0.0 | 0.8 | 0.00 | 0.00 |
| Styrene | 4.1 | 2.1 | 0.0 | 0.2 | 0.0 | 0.2 | 0.00 | 0.00 |
| Tetrachloroethylene (PCE) | 7.1 | 4.3 | 2.5 | 2.3 | 1.7 | 1.8 | 0.13 | 0.14 |
| Toluene | 11.9 | 3.8 | 1.0 | 0.7 | 0.5 | 0.4 | 0.00 | 0.00 |
| *trans*−1,2-Dichloroethylene | 2.7 | 0.7 | 0.0 | 0.2 | 0.0 | 0.2 | 0.00 | <0.01 |
| Trichloroethene (Trichloroethylene, TCE) | 5.6 | 3.1 | 1.9 | 1.8 | 1.2 | 1.5 | 0.05 | 0.12 |
| Vinyl chloride | 3.1 | 0.5 | 0.3 | 0.2 | 0.3 | 0.2 | 0.00 | 0.02 |
| Xylenes (Total) | 12.3 | 3.9 | 0.2 | 0.2 | 0.0 | 0.1 | 0.00 | 0.00 |
| **Group Summaries** | | | | | | | | |
| **IOCs** | | | | | | | | |
| IOCs-All Regulated | 83.7 | 83.5 | 6.8 | 9.2 | 2.5 | 4.2 | 0.3 | 0.6 |
| **SOCs** | | | | | | | 1.0 | 0.1 |
| SOCs-Group 1 | 21.9 | 2.4 | 13.2 | 0.3 | 10.7 | 0.1 | | |
| SOCs-Group 2 | 20.4 | 13.4 | 1.2 | 1.9 | 0.9 | 1.0 | | |
| **VOCs** | | | | | | | | |
| VOCs-All Regulated | 41.1 | 19.9 | 15.4 | 7.9 | 8.2 | 6.1 | 0.2 | 0.4 |
| VOCs-Group 1 | 19.5 | 6.6 | 1.7 | 1.3 | 0.9 | 0.9 | | |
| VOCs-Group 2 | 11.1 | 6.4 | 4.5 | 3.9 | 2.9 | 3.2 | | |

*Note:* IOC, Regulated: includes all the regulated IOCs; SOCs, Group 1: includes alachlor, atrazine, and simazine; SOCs, Group 2: includes bis(2-ethylhexyl)phthalate, bis(2-ethylhexyl)adipate, and benzo(a)pyrene; VOCs, Regulated: includes all the regulated VOCs; VOCs, Group 1: includes benzene, ethyl benzene, toluene, and total xylenes (LNAPLEs); VOCs, Group 2: includes cis-1, 2-dichloroethylene, trans-1,2-dichloroethylene, 1,1-dichloroethene, tetrachloroethylene, trichloroethene, and vinyl chloride (DNAPLEs). Percent MCL Violations Derived from SDWIS Information for 1/1/93-3/31/1998.

[a] % >MCL indicates the proportion of systems with any analytical results exceeding the concentration value of the MCL; it does not necessarily indicate an MCL violation. An MCL violation occurs when the MCL is exceeded by the average results from four quarterly samples or confirmation samples as required by the primacy State.

*Source*: From United States Environmental Protection Agency, 1999, *A Review of Contaminant Occurrence in Public Water Systems*, EPA 816-R-99-006, www.epa.gov.

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**Table 10C.89 United States Public Water System Unregulated Contaminant Monitoring Information System (UCRIS) (Round 1) 24-State Cross-Section Summary of Occurrence (1988–1992)**

| Chemical Name (Threshold in μg/L) | Total # PWS | # GW PWS | # SW PWS | % PWS > MRL | % GW PWS > MRL | % SW PWS > MRL | % PWS > Threshold | % GW PWS > Threshold | % SW PWS > Threshold | 99% Value (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Synthetic Organic Chemicals (SOCs)** | | | | | | | | | | |
| Dibromochloropropane (MCL = 0.2) | 12,827 | 11,446 | 1,511 | 2.49 | 2.51 | 2.32 | 1.32 | 1.35 | 0.99 | 1.03 |
| Ethylene dibromide[a] (MCL = 0.05) | 11,450 | 10,274 | 1,284 | 1.14 | 1.01 | 2.10 | 0.16 | 0.12 | 0.47 | 0.01 |
| **Volatile Organic Chemicals (VOCs)** | | | | | | | | | | |
| Benzene (MCL = 5) | 14,910 | 13,919 | 1,119 | 1.14 | 1.11 | 5.18 | 0.25 | 0.25 | 0.27 | <2.0 |
| Bromobenzene (N/A) | 16,450 | 14,862 | 1,726 | 0.19 | 0.14 | 0.64 | N/A | N/A | N/A | <2.0 |
| Bromochloromethane (MCL = 10) | 12,881 | 11,576 | 1,386 | 0.50 | 0.44 | 1.08 | 0.03 | 0.03 | 0.07 | <1.0 |
| Bromodichloromethane (HRL = 60) | 20,024 | 17,917 | 2,324 | 22.09 | 14.84 | 79.69 | 0.13 | 0.04 | 0.86 | 22.00 |
| Bromoform (HRL = 400) | 19,582 | 17,773 | 1,979 | 9.01 | 7.56 | 22.13 | 0.01 | 0.01 | 0.00 | 7.32 |
| Bromomethane (MCL = 10) | 20,198 | 18,472 | 1,886 | 0.77 | 0.71 | 1.22 | 0.09 | 0.08 | 0.16 | <4.0 |
| Carbon tetrachloride (MCL = 5) | 15,266 | 14,176 | 1,214 | 1.32 | 1.09 | 3.95 | 0.16 | 0.15 | 0.25 | 1.60 |
| Chlorobenzene (MCL = 100) | 20,038 | 18,337 | 1,859 | 0.53 | 0.26 | 3.17 | 0.00 | 0.00 | 0.00 | <1.0 |
| Chloroethane (N/A) | 20,236 | 18,507 | 1,882 | 0.39 | 0.29 | 1.33 | N/A | N/A | N/A | <2.0 |
| Chloroform (HRL = 600) | 20,039 | 17,874 | 2,385 | 28.84 | 21.69 | 84.40 | 0.02 | 0.01 | 0.17 | 87.00 |
| Chloromethane (MCL = 3) | 20,246 | 18,513 | 1,894 | 1.22 | 1.11 | 2.27 | 0.45 | 0.41 | 0.84 | <4.0 |
| *cis*-1,2-Dichloroethene (MCL = 70) | 16,705 | 15,026 | 1,832 | 1.47 | 1.45 | 1.53 | 0.03 | 0.03 | 0.00 | 2.18 |
| *cis*-1,2-Dichloropropene (N/A) | 9,211 | 8,438 | 836 | 0.61 | 0.52 | 1.44 | N/A | N/A | N/A | <1.0 |
| Dibromochloromethane (HRL = 60) | 19,750 | 17,785 | 2,158 | 18.01 | 12.41 | 64.55 | 0.06 | 0.02 | 0.32 | 12.70 |
| Dibromomethane (N/A) | 16,549 | 14,953 | 1,720 | 0.36 | 0.21 | 1.69 | N/A | N/A | N/A | <2.0 |
| Dichlorodifluoromethane (MCL = 1,000) | 16,076 | 14,617 | 1,588 | 1.37 | 1.38 | 1.39 | 0.00 | 0.00 | 0.00 | 0.50 |
| 1,1-Dichloroethane (MCL = 5) | 20,483 | 18,758 | 1,876 | 1.14 | 1.09 | 1.55 | 0.18 | 0.16 | 0.37 | 0.10 |
| 1,2-Dichloroethane (MCL = 5) | 15,282 | 14,192 | 1,215 | 1.16 | 1.10 | 1.73 | 0.19 | 0.17 | 0.41 | <5.0 |
| Dichloroethene (MCL = 7) | 15,430 | 14,180 | 1,380 | 1.17 | 1.06 | 1.45 | 0.20 | 0.20 | 0.22 | 1.80 |
| Dichloromethane (MCL = 5) | 19,287 | 17,602 | 1,836 | 4.05 | 3.31 | 11.06 | 0.77 | 0.52 | 3.27 | 1.30 |
| 1,2-Dichloropropane (MCL = 5) | 19,591 | 17,908 | 1,820 | 0.67 | 0.66 | 0.77 | 0.08 | 0.09 | 0.00 | <4.0 |
| 1,3-Dichloropropane (N/A) | 16,947 | 15,338 | 1,748 | 0.12 | 0.12 | 0.11 | N/A | N/A | N/A | <1.0 |
| 2,2-Dichloropropane (N/A) | 16,757 | 15,138 | 1,754 | 0.15 | 0.14 | 0.23 | N/A | N/A | N/A | <2.0 |
| 1,1-Dichloropropene (N/A) | 16,947 | 15,332 | 1,749 | 0.13 | 0.10 | 0.40 | N/A | N/A | N/A | <1.0 |
| 1,3-Dichloropropene (HRL = 40) | 9,164 | 8,303 | 898 | 0.16 | 0.12 | 0.56 | 0.00 | 0.00 | 0.00 | <1.0 |
| Ethyl benzene (MCL = 700) | 20,081 | 18,355 | 1,884 | 1.62 | 1.40 | 3.66 | 0.00 | 0.00 | 0.00 | <5.0 |
| Hexachlorobutadiene (HRL = 0.9) | 12,284 | 10,980 | 1,385 | 0.35 | 0.30 | 0.72 | 0.11 | 0.06 | 0.51 | <5.0 |
| Isopropylbenzene (N/A) | 12,771 | 11,480 | 1,359 | 0.27 | 0.28 | 0.22 | N/A | N/A | N/A | <2.0 |
| *m*-Dichlorobenzene (HAL = 600) | 20,429 | 18,752 | 1,819 | 0.25 | 0.20 | 0.77 | 0.00 | 0.00 | 0.00 | <5.0 |
| *m*-Xylene (N/A) | 11,329 | 10,145 | 1,276 | 1.55 | 1.47 | 2.12 | N/A | N/A | N/A | <4.0 |
| *n*-Butylbenzene (N/A) | 12,763 | 11,471 | 1,371 | 0.35 | 0.29 | 0.88 | N/A | N/A | N/A | <2.0 |
| *n*-Propylbenzene (N/A) | 12,724 | 11,440 | 1,363 | 0.33 | 0.34 | 0.22 | N/A | N/A | N/A | <2.0 |
| Naphthalene (HRL = 140) | 13,452 | 12,034 | 1,502 | 1.18 | 1.08 | 1.93 | 0.01 | 0.02 | 0.00 | <5.0 |
| *o*-Chlorotoluene (MCL = 100) | 15,721 | 14,154 | 1,702 | 0.20 | 0.16 | 0.53 | 0.00 | 0.00 | 0.00 | <1.0 |
| *o*-Dichlorobenzene (MCL = 600) | 19,953 | 18,300 | 1,795 | 0.28 | 0.20 | 1.00 | 0.00 | 0.00 | 0.00 | <5.0 |
| *o*-Xylene (N/A) | 13,987 | 12,638 | 1,450 | 1.76 | 1.69 | 2.41 | N/A | N/A | N/A | <5.0 |
| *p*-Chlorotoluene (MCL = 100) | 15,612 | 14,057 | 1,689 | 0.17 | 0.15 | 0.36 | 0.00 | 0.00 | 0.00 | <1.0 |
| *p*-Dichlorobenzene (MCL = 750) | 15,494 | 14,284 | 1,334 | 1.25 | 1.11 | 2.70 | 0.00 | 0.00 | 0.00 | <4.4 |
| *p*-Isopropyltoluene (N/A) | 12,167 | 10,953 | 1,282 | 0.25 | 0.26 | 0.08 | N/A | N/A | N/A | <2.0 |
| *p*-Xylene (N/A) | 10,127 | 8,956 | 1,230 | 1.58 | 1.49 | 2.36 | N/A | N/A | N/A | <5.0 |
| *sec*-Butylbenzene (N/A) | 12,343 | 11,071 | 1,337 | 0.23 | 0.23 | 0.22 | N/A | N/A | N/A | <2.0 |
| Styrene (MCL = 100) | 16,623 | 14,938 | 1,832 | 0.57 | 0.45 | 1.53 | 0.00 | 0.00 | 0.00 | <2.0 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *tert*-Butylbenzene (N/A) | 12,353 | 11,081 | 1,337 | 0.19 | 0.19 | 0.22 | N/A | N/A | N/A | <2.0 |
| 1,1,1,2-Tetrachloroethane (HAL=70) | 16,956 | 15,338 | 1,753 | 0.18 | 0.13 | 0.63 | 0.00 | 0.00 | 0.00 | <1.0 |
| 1,1,2,2-Tetrachloroethane (HAL=2) | 20,407 | 18,693 | 1,867 | 0.45 | 0.39 | 1.02 | 0.05 | 0.05 | 0.11 | <1.0 |
| Tetrachloroethylene (MCL=5) | 19,814 | 18,298 | 1,652 | 3.33 | 3.38 | 2.66 | 0.91 | 0.93 | 0.67 | 13.2 |
| Toluene (MCL=100) | 20,089 | 18,364 | 1,887 | 3.50 | 3.10 | 7.31 | 0.00 | 0.00 | 0.00 | 0.7 |
| *trans*-1,2-Dichloroethene (MCL=100) | 19,945 | 18,267 | 1,825 | 0.64 | 0.59 | 1.10 | 0.01 | 0.01 | 0.00 | <1.0 |
| *trans*-1,3-Dichloropropene (N/A) | 9,883 | 9,017 | 959 | 0.25 | 0.13 | 1.36 | N/A | N/A | N/A | <1.0 |
| 1,2,3-Trichlorobenzene (N/A) | 12,876 | 11,567 | 1,389 | 0.49 | 0.46 | 0.72 | N/A | N/A | N/A | <5.0 |
| 1,2,4-Trichlorobenzene (MCL=70) | 13,449 | 11,996 | 1,589 | 0.49 | 0.45 | 0.78 | 0.00 | 0.00 | 0.00 | <5.0 |
| 1,1,1-Trichloroethane (MCL=200) | 15,279 | 14,191 | 1,213 | 3.66 | 3.57 | 4.62 | 0.03 | 0.03 | 0.00 | 3.7 |
| 1,1,2-Trichloroethane (MCL=5) | 19,964 | 18,253 | 1,853 | 0.43 | 0.29 | 1.78 | 0.04 | 0.02 | 0.16 | <1.0 |
| Trichloroethylene (MCL=5) | 15,290 | 14,198 | 1,220 | 3.54 | 3.37 | 5.66 | 0.98 | 1.00 | 0.66 | 20.8 |
| Trichlorofluoromethane (HAL=175) | 16,851 | 15,347 | 1,637 | 1.48 | 1.39 | 2.32 | 0.01 | 0.01 | 0.00 | 0.6 |
| 1,2,3-Trichloropropane (MCL=40) | 17,392 | 15,771 | 1,758 | 0.25 | 0.25 | 0.23 | 0.01 | 0.01 | 0.00 | <2.0 |
| 1,2,4-Trimethylbenzene (N/A) | 12,755 | 11,462 | 1,372 | 0.83 | 0.76 | 1.38 | N/A | N/A | N/A | <2.0 |
| 1,3,5-Trimethylbenzene (N/A) | 12,671 | 11,379 | 1,370 | 0.61 | 0.59 | 0.66 | N/A | N/A | N/A | <2.0 |
| Vinyl chloride (MCL=2) | 15,184 | 14,099 | 1,209 | 0.50 | 0.44 | 1.24 | 0.28 | 0.23 | 0.83 | <2.0 |
| Xylenes (Total) (MCL=10,000) | 9,463 | 8,841 | 670 | 3.04 | 2.51 | 10.75 | 0.00 | 0.00 | 0.00 | 0.6 |

*Note:* MCL, maximum contaminant level; HAL, health advisory level (as of December 2000); HRL, health reference level (concentration values used only as reference levels for analyses in this report); MRL, minimum reporting level.
The MCL, HAL, HRL, and MRL values are used in this report only as reference levels to facilitate occurrence assessments.
"% PWS > Threshold" indicates the proportion of systems with any analytical results exceeding the concentration value of the HRL/MCL/HAL. (Note that results for % PWSs greater than an MCL value does not indicate a MCL violation. A formal MCL violation occurs when the MCL is exceeded by the average of four consecutive quarterly samples or confirmation samples as required by the primacy States.)
N/A, there is no HRL/MCL/HAL available.

[a] The high occurrence of ethylene dibromide are, in part, considered false positives related to analytical methods problems.

*Source*: From United States Environmental Protection Agency, 2001, *Occurrence of Unregulated Contaminants in Public Water Systems - A National Summary*, EPA 815-P-00-002, www.epa.gov.



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**Table 10C.90 United States Public Water System Safe Drinking Water Information System/Federal Version (SDWIS/FED) (Round 2) Data—20-State Cross-Section Summary of Occurrence (1993 to 1997)**

| Chemical Name (Threshold in μg/L) | Total PWS | # GW PWS | # SW PWS | % PWS> MRL | % GW PWS | % SW PWS | % PWS> Threshold | % GW PWS> | % SW PWS> | 99% Value |
|---|---|---|---|---|---|---|---|---|---|---|
| Inorganic chemicals (IOCs) | | | | | | | | | | |
| Sulfate (HRL=500,000) | 16,495 | 15,009 | 1,486 | 88.11 | 87.76 | 91.66 | 1.79 | 1.83 | 1.41 | 560,000 |
| Synthetic Organic Chemicals (SOCs) | | | | | | | | | | |
| Aldicarb[a] (HRL=7) | 11,972 | 10,509 | 1,463 | 0.01 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | <3.0 |
| Aldicarb sulfone[a] (HRL=7) | 11,968 | 10,512 | 1,456 | 0.08 | 0.04 | 0.41 | 0.00 | 0.00 | 0.00 | <2.0 |
| Aldicarb sulfoxide[a] (HRL=7) | 11,954 | 10,500 | 1,454 | 0.08 | 0.03 | 0.48 | 0.01 | 0.01 | 0.00 | <4.0 |
| Aldrin[a] (HRL=0.002) | 11,745 | 10,420 | 1,325 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | <2.0 |
| Butachlor[a] (N/A) | 11,940 | 10,482 | 1,458 | 0.04 | 0.01 | 0.27 | N/A | N/A | N/A | <10.0 |
| Carbaryl[a] (MCL=700) | 12,623 | 11,086 | 1,537 | 0.03 | 0.02 | 0.13 | 0.00 | 0.00 | 0.00 | <10.0 |
| Dicamba[a] (MCL=200) | 14,034 | 12,220 | 1,814 | 0.34 | 0.21 | 1.21 | 0.00 | 0.00 | 0.00 | <10.0 |
| Dieldrin[a] (HRL=0.002) | 11,788 | 10,329 | 1,459 | 0.09 | 0.09 | 0.14 | 0.09 | 0.09 | 0.14 | <1.0 |
| 3-Hydroxycarbofuran[a] (N/A) | 12,644 | 11,088 | 1,556 | 0.07 | 0.02 | 0.45 | N/A | N/A | N/A | <10.0 |
| Methomyl[a] (MCL=200) | 12,604 | 11,068 | 1,536 | 0.07 | 0.05 | 0.20 | 0.00 | 0.00 | 0.00 | <50.0 |
| Metolachlor[a] (HRL=70) | 12,953 | 11,503 | 1,450 | 0.83 | 0.11 | 6.55 | 0.00 | 0.00 | 0.00 | <5.0 |
| Metribuzin[a] (HRL=91) | 13,512 | 11,833 | 1,679 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | <2.0 |
| Propachlor[a] (MCL=90) | 12,050 | 10,600 | 1,450 | 0.05 | 0.02 | 0.28 | 0.00 | 0.00 | 0.00 | <5.0 |
| Volatile organic chemicals (VOCs) | | | | | | | | | | |
| Bromobenzene (N/A) | 24,125 | 21,461 | 2,664 | 0.13 | 0.12 | 0.23 | N/A | N/A | N/A | <1.0 |
| Bromochloromethane[b] (MCL=10) | 22,974 | 20,507 | 2,467 | 0.46 | 0.32 | 1.62 | 0.03 | 0.02 | 0.08 | <1.0 |
| Bromodichloromethane (HRL=60) | 23,858 | 21,152 | 2,706 | 21.97 | 16.14 | 67.52 | 0.08 | 0.05 | 0.30 | 18.8 |
| Bromoform (HRL=400) | 18,461 | 16,348 | 2,113 | 12.12 | 11.08 | 20.11 | 0.01 | 0.00 | 0.05 | 6.5 |
| Bromomethane (MCL=10) | 23,328 | 20,872 | 2,456 | 0.75 | 0.74 | 0.86 | 0.06 | 0.05 | 0.08 | <9.0 |
| Chloroethane (N/A) | 24,433 | 21,925 | 2,508 | 0.34 | 0.32 | 0.56 | N/A | N/A | N/A | <2.5 |
| Chloroform (HRL=600) | 23,737 | 21,021 | 2,716 | 27.42 | 21.84 | 70.54 | 0.04 | 0.01 | 0.26 | 110.0 |
| Chloromethane (MCL=3) | 23,478 | 21,030 | 2,448 | 2.25 | 2.04 | 4.08 | 0.58 | 0.55 | 0.78 | <2.5 |
| Dibromochloromethane (HRL=60) | 23,750 | 21,059 | 2,691 | 18.37 | 14.55 | 48.23 | 0.08 | 0.05 | 0.30 | 9.7 |
| Dibromomethane (N/A) | 23,006 | 20,454 | 2,552 | 0.46 | 0.32 | 1.53 | N/A | N/A | N/A | <1.0 |
| Dichlorodifluoromethane[b] (MCL=1,000) | 22,141 | 19,836 | 2,305 | 1.27 | 1.23 | 1.65 | 0.00 | 0.00 | 0.00 | <20.0 |
| 1,1-Dichloroethane (MCL=5) | 24,808 | 22,114 | 2,694 | 0.74 | 0.67 | 1.34 | 0.08 | 0.07 | 0.11 | <1.0 |
| 1,3-Dichloropropane (N/A) | 24,065 | 21,430 | 2,635 | 0.06 | 0.05 | 0.11 | N/A | N/A | N/A | <2.0 |
| 2,2-Dichloropropane (N/A) | 24,096 | 21,445 | 2,651 | 0.09 | 0.07 | 0.26 | N/A | N/A | N/A | <1.0 |
| 1,1-Dichloropropene (N/A) | 24,069 | 21,438 | 2,631 | 0.07 | 0.06 | 0.15 | N/A | N/A | N/A | <1.0 |
| 1,3-Dichloropropene (HRL=40) | 16,787 | 15,178 | 1,609 | 0.35 | 0.32 | 0.62 | 0.00 | 0.00 | 0.00 | <0.5 |
| Hexachlorobutadiene[b] (HRL=0.9) | 22,736 | 20,380 | 2,356 | 0.18 | 0.13 | 0.59 | 0.02 | 0.00 | 0.13 | <1.0 |
| Isopropylbenzene[b] (N/A) | 22,995 | 20,524 | 2,471 | 0.24 | 0.23 | 0.32 | N/A | N/A | N/A | <2.0 |
| *m*-Dichlorobenzene (HAL=600) | 24,119 | 21,457 | 2,662 | 0.26 | 0.22 | 0.53 | 0.00 | 0.00 | 0.00 | <1.0 |
| *n*-Butylbenzene[b] (N/A) | 22,972 | 20,509 | 2,463 | 0.13 | 0.12 | 0.20 | N/A | N/A | N/A | <2.0 |
| *n*-Propylbenzene[b] (N/A) | 22,969 | 20,501 | 2,468 | 0.23 | 0.19 | 0.57 | N/A | N/A | N/A | <2.0 |
| Naphthalene[b] (HRL=140) | 22,923 | 20,524 | 2,399 | 0.75 | 0.62 | 1.92 | 0.00 | 0.00 | 0.00 | <2.0 |
| *o*-Chlorotoluene (MCL=100) | 24,118 | 21,457 | 2,661 | 0.14 | 0.11 | 0.38 | 0.00 | 0.00 | 0.00 | <2.0 |
| *p*-Chlorotoluene (MCL=100) | 21,378 | 18,808 | 2,570 | 0.12 | 0.10 | 0.27 | 0.00 | 0.00 | 0.00 | <2.0 |
| *p*-Isopropyltoluene[b] (N/A) | 22,617 | 20,320 | 2,297 | 0.16 | 0.15 | 0.26 | N/A | N/A | N/A | <2.0 |
| *sec*-Butylbenzene[b] (N/A) | 22,973 | 20,509 | 2,464 | 0.14 | 0.14 | 0.20 | N/A | N/A | N/A | <2.0 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *tert*-Butylbenzene[b] (N/A) | 22,973 | 20,508 | 2,465 | 0.11 | 0.10 | 0.16 | N/A | N/A | N/A | <2.0 |
| 1,1,1,2-Tetrachloroethane (HAL=70) | 24,127 | 21,462 | 2,665 | 0.21 | 0.16 | 0.64 | 0.00 | 0.00 | 0.00 | <1.0 |
| 1,1,2,2-Tetrachloroethane (HAL=2) | 24,800 | 22,106 | 2,694 | 0.08 | 0.05 | 0.30 | 0.00 | 0.00 | 0.00 | <1.0 |
| 1,2,3-Trichlorobenzene[b] (N/A) | 22,532 | 20,144 | 2,388 | 0.19 | 0.15 | 0.50 | N/A | N/A | N/A | <2.0 |
| Trichlorofluoromethane[b] (HAL=175) | 22,659 | 20,329 | 2,330 | 1.17 | 0.93 | 3.22 | 0.00 | 0.00 | 0.00 | <2.5 |
| 1,2,3-Trichloropropane (MCL=40) | 24,088 | 21,441 | 2,647 | 0.08 | 0.06 | 0.23 | 0.00 | 0.00 | 0.00 | <1.0 |
| 1,2,4-Trimethylbenzene[b] (N/A) | 22,965 | 20,504 | 2,461 | 0.76 | 0.63 | 1.79 | N/A | N/A | N/A | <1.0 |
| 1,3,5-Trimethylbenzene[b] (N/A) | 22,974 | 20,513 | 2,461 | 0.43 | 0.35 | 1.10 | N/A | N/A | N/A | <2.0 |

*Note:* MCL, maximum contaminant level; HAL, health advisory level (as of December 2000); HRL, health reference level (concentration values used only as reference levels for analyses in this report); MRL, minimum reporting level.
The MCL, HAL, HRL, and MRL values are used in this report only as reference levels to facilitate occurrence assessments.
"% PWS > Threshold" indicates the proportion of systems with any analytical results exceeding the concentration value of the HRL/MCL/HAL. (Note that results for % PWSs greater than an MCL value does not indicate a MCL violation. A formal MCL violation occurs when the MCL is exceeded by the average of four consecutive quarterly samples or confirmation samples as required by the primacy States.)
N/A, there is no HRL/MCL/HAL available.

[a] Massachusetts data not included in summary statistics for this contaminant.
[b] New Hampshire data not included in summary statistics for this contaminant.

*Source*: From United States Environmental Protection Agency, 2001, *Occurrence of Unregulated Contaminants in Public Water Systems - A National Summary*, EPA 815-P-00-002, www.epa.gov.



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**Table 10C.91 Public Water-Supply Wells in the United States Closed Because of Contamination as of 1984**

| | Water-Supply Wells | | | | | |
|---|---|---|---|---|---|---|
| | In Service or Standby | | Closed by Man-Made or Chemical Contamination | | Closed by Natural Contamination | |
| State and Utility | Shallow (<100′) | Deep (>100′) | Shallow (<100′) | Deep (>100′) | Shallow (<100′) | Deep (>100′) |
| Arizona | | | | | | |
| Mesa | | 24 | | 2 | | 0 |
| Phoenix Wtr & Swr Dept. | | 115 | | 8 | | 5 |
| Tempe | | 6 | | 2 | | 0 |
| Tucson | | 272 | | 7 | | 0 |
| California | | | | | | |
| Alhambra | | 14 | | 3 | | 0 |
| Anaheim | | 31 | | 4 | | 0 |
| Burbank | | 4 | | 6 | | 0 |
| Fresno | | 100 | | 1 | | 0 |
| Fullerton | | 11 | | 0 | | 1 |
| Garden Grove | | 14 | | 0 | | 17 |
| Glendale | | 8 | | 4 | | 0 |
| La Puente/SW Suburban | | 40 | | 10 | | 2 |
| Long Beach/Dominguez Wtr Corp. | | 15 | | 0 | | 2 |
| Los Angeles Wtr & Power | | 180 | | 25 | | 0 |
| Modesto | 1 | 43 | 0 | 2 | 0 | 0 |
| Pomona | | 31 | | 2 | | 0 |
| Riverside | 4 | 70 | 4 | 28 | 0 | 0 |
| Sacremento/Arcade Cnty Wtr | | 60 | | 1 | | 0 |
| San Bernardino | 2 | 34 | 0 | 8 | 0 | 0 |
| San Jose/Great Oaks Wtr Co. | | 10 | | 3 | | 0 |
| Santa Barbara/Goleta Wtr Dist. | | 9 | | 0 | | 1 |
| Santa Barbara/Santa Barbara Pub. | | 7 | | 0 | | 2 |
| Colorado | | | | | | |
| Colorado Springs | 8 | | 0 | | 1 | |
| Connecticut | | | | | | |
| Clinton/Conn. Wtr Co. | 24 | 17 | 6 | 2 | 0 | 0 |
| Delaware | | | | | | |
| Newark/Artesian Wtr Co. | 7 | 35 | 0 | 3 | 0 | 0 |
| Florida | | | | | | |
| Boca Raton | | 50 | | 0 | | 1 |
| Daytona Beach | | 21 | | 0 | | 5 |
| Englewood | 47 | 9 | 0 | 0 | 7 | 0 |
| Hollywood | 17 | 6 | 0 | 1 | 0 | 0 |
| Miami | 73 | | 6 | | 0 | |
| Naples | 52 | 7 | 0 | 0 | 2 | 0 |
| Ocala/Gen. Dev. Util. | | 4 | | 1 | | 0 |
| Palm Bay/Gen. Dev. Util. | | 21 | | 1 | | 0 |
| Palm Beach Gdns/Seacoast Util. | 39 | | 2 | | 0 | |
| Tallahassee | | 24 | | 0 | | 2 |
| Hawaii | | | | | | |
| Honolulu | 60 | 73 | 0 | 9 | 0 | 0 |

*(Continued)*

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**Table 10C.91 (Continued)**

| State and Utility | Water-Supply Wells | | | | | |
|---|---|---|---|---|---|---|
| | In Service or Standby | | Closed by Man-Made or Chemical Contamination | | Closed by Natural Contamination | |
| | Shallow (<100′) | Deep (>100′) | Shallow (<100′) | Deep (>100′) | Shallow (<100′) | Deep (>100′) |
| Illinois | | | | | | |
| Elgin | | 11 | | 0 | | 2 |
| Indiana | | | | | | |
| Anderson | 4 | 9 | 2 | 0 | 0 | 2 |
| Richmond/Ind. Am. Wtr. Co. | 5 | | 2 | | 0 | |
| South Bend | | 23 | | 7 | | 0 |
| Iowa | | | | | | |
| Sioux City | 5 | 15 | 0 | 0 | 0 | 1 |
| Louisiana | | | | | | |
| Baton Rouge/B.R. Wtr Co. | | 50 | | 0 | | 2 |
| Michigan | | | | | | |
| Kalamazoo | 10 | 108 | 0 | 11 | 0 | 0 |
| Lansing | 3 | 124 | 0 | 1 | 0 | 0 |
| Minnesota | | | | | | |
| Rochester | | 19 | | 3 | | 0 |
| Nebraska | | | | | | |
| Grand Island | 9 | 30 | 0 | 2 | 0 | 0 |
| Nevada | | | | | | |
| Reno/Sierra Pac. Power Co. | 0 | 16 | 0 | 0 | 3 | 0 |
| New Jersey | | | | | | |
| Brick | 7 | 4 | 1 | 0 | 0 | 0 |
| Harrington Park/Hackensack Wtr Co. | 19 | 68 | 0 | 1 | 1 | 2 |
| Merchantville | | 15 | | 1 | | 1 |
| New Mexico | | | | | | |
| Albuquerque | | 86 | | 1 | | 0 |
| Santa Fe/Sangre de Cristo Wtr Co. | | 12 | | 1 | | 1 |
| New York | | | | | | |
| East Meadow/ Hempstead Wtr Dept. | | 35 | | 3 | | 3 |
| Elmira | 4 | 0 | 0 | 1 | 0 | 0 |
| Farmingdale | | 11 | | 0 | | 1 |
| Lake Success/ Jamaica Wtr Co. | 30 | 55 | 14 | 3 | 0 | 0 |
| Oakdale/Suffolk Wtr Auth. | 31 | 357 | 14 | 20 | 0 | 2 |
| West Nyack/Spring Valley Wtr Co. | 19 | 68 | 0 | 1 | 1 | 2 |
| Ohio | | | | | | |
| Mansfield | 3 | 6 | 0 | 0 | 0 | 1 |
| Oklahoma | | | | | | |
| Oklahoma City | | 4 | | 0 | | 2 |
| Pennsylvania | | | | | | |
| Pittsburgh/West View M.A. | 24 | | 12 | | 0 | |
| Rhode Island | | | | | | |
| Bristol/Bristol Cnty Wtr Co. | 2 | | 0 | | 1 | |
| West Warwick/Kent Cnty W.A. | 1 | 4 | 0 | 0 | 1 | 0 |

*(Continued)*

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**Table 10C.91 (Continued)**

| State and Utility | Water-Supply Wells | | | | | |
|---|---|---|---|---|---|---|
| | In Service or Standby | | Closed by Man-Made or Chemical Contamination | | Closed by Natural Contamination | |
| | Shallow (<100′) | Deep (>100′) | Shallow (<100′) | Deep (>100′) | Shallow (<100′) | Deep (>100′) |
| Texas | | | | | | |
| El Paso | | 140 | | 1 | | 0 |
| Lubbock | | 330 | | 3 | | 3 |
| Utah | | | | | | |
| Ogden | | 8 | | 0 | | 1 |
| Provo | | 10 | | 0 | | 2 |
| Salt Lake City/Salt Lake Wtr Dept. | 7 | 14 | 0 | 0 | 0 | 1 |
| Virginia | | | | | | |
| Woodbridge/Prince William Cnty | | 26 | | 1 | | 0 |
| Wyoming | | | | | | |
| Cheyenne | | 37 | | 1 | | 0 |

*Source*: From Compiled from 1984 Water Utility Operating Data issued by the American Water Works Association. Copyright 1986 AWWA.

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**Table 10C.92 Summary of Contaminant Source Type and Number Reported in the United States in 1998**

| Source Type | Number of States Reporting Information | Number of Aquifers or Hydrogeologic Settings for Which Information Was Reported | Total Sites | Number of Sites with Confirmed Releases | | Number of Sites with Confirmed Groundwater Contamination | | Number of Sites with Active Remediation | | Number of Sites with Cleanup Completed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Number | Percent of Total | Number | Percent of Total | Number | Percent of Total | Number | Percent of Total |
| LUST | 22 | 72 | 85,067 | 48,320 | 57 | 15,436 | 18 | 3,044 | 4 | 21,438 | 25 |
| Underground injection | 17 | 72 | 31,480 | 1,313 | 4 | 172 | <1 | 61 | <1 | 452 | <2 |
| State sites | 17 | 34 | 12,202 | 6,199 | 51 | 3,139 | 26 | 753 | 6 | 3,242 | 27 |
| DOD/DOE | 17 | 54 | 8,705 | 4,470 | 51 | 286 | 3 | 1,717 | 20 | 1,937 | 22 |
| CERCLA (non-NPL) | 19 | 59 | 3,506 | 1,381 | 39 | 802 | 23 | 229 | 7 | 316 | 9 |
| RCRA corrective action | 19 | 50 | 2,696 | 538 | 20 | 267 | 10 | 95 | 4 | 67 | 3 |
| Nonpoint sources | 8 | 29 | 2,030 | 44 | 2 | 31 | <2 | 5 | <1 | 3 | <1 |
| Landfills | 6 | 26 | 1,356 | 110 | 8 | 110 | 8 | 2 | <1 | — | — |
| NPL | 22 | 66 | 307 | 275 | 90 | 249 | 81 | 83 | 27 | 33 | 11 |

*Note:* CERCLA, Comprehensive Environmental Response, Compensation, and Liability Act; DOD/DOE = Department of Defense/Department of Energy; LUST, leaking underground storage tank; NPL, national priority list; RCRA, Resource Conversation and Recovery Act; —, not available.

*Source*: From United States Environmental Protection Agency, 2000, *National Water Quality Inventory 1998. Report to Congress, Groundwater and Drinking Water Chapters*, www.epa.gov.



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**Table 10C.93 Hazardous Waste Sites on the National Priority List by State and Outlying Area in the United States 2003**

| State and Outlying Area | Total Sites | Rank | Percent Distribution | Federal | Nonfederal |
|---|---|---|---|---|---|
| Alabama | 15 | 24 | 1.2 | 3 | 12 |
| Alaska | 6 | 44 | 0.5 | 5 | 1 |
| Arizona | 9 | 40 | 0.7 | 2 | 7 |
| Arkansas | 11 | 37 | 0.9 | — | 11 |
| California | 98 | 2 | 7.6 | 24 | 74 |
| Colorado | 18 | 22 | 1.4 | 3 | 15 |
| Connecticut | 16 | 23 | 1.2 | 1 | 15 |
| Delaware | 15 | 24 | 1.2 | 1 | 14 |
| District of Columbia | 1 | (X) | 0.1 | 1 | — |
| Florida | 52 | 6 | 4.1 | 6 | 46 |
| Georgia | 15 | 24 | 1.2 | 2 | 13 |
| Hawaii | 3 | 46 | 0.2 | 2 | 1 |
| Idaho | 9 | 41 | 0.7 | 2 | 7 |
| Illinois | 45 | 8 | 3.5 | 5 | 40 |
| Indiana | 29 | 14 | 2.3 | — | 29 |
| Iowa | 14 | 29 | 1.1 | 1 | 13 |
| Kansas | 12 | 32 | 0.9 | 2 | 10 |
| Kentucky | 14 | 30 | 1.1 | 1 | 13 |
| Louisiana | 15 | 24 | 1.2 | 1 | 14 |
| Maine | 12 | 33 | 0.9 | 3 | 9 |
| Maryland | 19 | 20 | 1.5 | 9 | 10 |
| Massachusetts | 32 | 12 | 2.5 | 7 | 25 |
| Michigan | 69 | 5 | 5.4 | 1 | 68 |
| Minnesota | 24 | 18 | 1.9 | 2 | 22 |
| Mississippi | 4 | 45 | 0.3 | — | 4 |
| Missouri | 25 | 16 | 1.9 | 3 | 22 |
| Montana | 15 | 24 | 1.2 | — | 15 |
| Nebraska | 11 | 38 | 0.9 | 1 | 10 |
| Nevada | 1 | 49 | 0.1 | — | 1 |
| New Hampshire | 20 | 19 | 1.6 | 1 | 19 |
| New Jersey | 116 | 1 | 9.0 | 8 | 108 |
| New Mexico | 12 | 34 | 0.9 | 1 | 11 |
| New York | 91 | 4 | 7.1 | 4 | 87 |
| North Carolina | 29 | 15 | 2.3 | 2 | 27 |
| North Dakota | — | 50 | — | — | — |
| Ohio | 35 | 11 | 2.7 | 5 | 30 |
| Oklahoma | 11 | 39 | 0.9 | 1 | 10 |
| Oregon | 12 | 35 | 0.9 | 2 | 10 |
| Pennsylvania | 95 | 3 | 7.4 | 6 | 89 |
| Rhode Island | 12 | 36 | 0.9 | 2 | 10 |
| South Carolina | 25 | 17 | 1.9 | 2 | 23 |
| South Dakota | 2 | 47 | 0.2 | 1 | 1 |
| Tennessee | 13 | 31 | 1.0 | 4 | 9 |
| Texas | 45 | 9 | 3.5 | 4 | 41 |
| Utah | 19 | 21 | 1.5 | 4 | 15 |
| Vermont | 9 | 42 | 0.7 | — | 9 |
| Virginia | 30 | 13 | 2.3 | 11 | 19 |
| Washington | 47 | 7 | 3.7 | 14 | 33 |
| West Virginia | 9 | 43 | 0.7 | 2 | 7 |
| Wisconsin | 40 | 10 | 3.1 | — | 40 |
| Wyoming | 2 | 47 | 0.2 | 1 | 1 |
| Guam | 2 | (X) | (X) | 1 | 1 |
| Puerto Rico | 9 | (X) | (X) | — | 9 |
| Virgin Islands | 2 | (X) | (X) | — | 2 |
| **United States** | **1,283** | **(X)** | **100.0** | **163** | **1,120** |
| **Total** | **1,296** | **(X)** | **(X)** | **164** | **1,132** |

*Note:* As of December 31. Includes both proposed and final sites listed on the National Priorities List for the Superfund program as authorized by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the Superfund Amendments and Reauthorization Act of 1986. —, represents zero.

*Source*: From U.S. Census Bureau, *Statistical Abstract of the United States: 2004–2005*, www.census.gov.

*Original Source*: From U.S. Environmental Protection Agency, *Supplementary Materials: National Priorities List, Proposed Rule*, December 2003.

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**Table 10C.94 Number of Injection Wells in the United States in 1998**

| Well Class | Number of Wells (Rounded to Nearest 100) | Description of Injection Practice |
|---|---|---|
| Class I | 500 | Inject fluids into deep, confined geologic formations Associated with municipal or industrial waste disposal, hazardous or radioactive waste sites |
| Class II | 164,300 | Inject fluids used in oil and gas production into deep, confined geologic formations |
| Class III | 29,600 | Inject fluids into shallower formations for mineral extraction |
| Class IV | Banned by all states and EPA under the Safe Drinking Water Act unless authorized for groundwater cleanup | Inject hazardous or radioactive wastes directly or indirectly into drinking water sources |
| Class V | Actual numbers unavailable | Includes all injection methods not included in other four categories |

*Source*: From United States Environmental Protection Agency, 2000, *National Water Quality Inventory 1998. Report to Congress, Groundwater and Drinking Water Chapters*, www.epa.gov.

*Original Source*: From U.S. EPA Office of Groundwater and Drinking Water, 1999.

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## Table 10C.95 United States Toxic Release Inventory On-Site and Off-Site Disposed or Other Releases, by State, 2003

| | On-site Disposal or Other Releases | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | On-site Disposal to Class I Underground Injection Wells, RCRA Subtitle C Landfills, and Other Landfills | | | | Other On-site Disposal or Other Releases | | | | | | | | | | | |
| State | Class I Wells Pounds | RCRA Subtitle C Landfills Pounds | Other On-site Landfills Pounds | Subtotal Pounds | Fugitive Air Emissions Pounds | Point Source Air Emissions Pounds | Surface Water Discharges Pounds | Class II–V Wells Pounds | Land Treatment Pounds | RCRA Subtitle C Surface Impound-ments Pounds | Other Surface Impound-ments Pounds | Other Land Disposal Pounds | Subtotal Pounds | Total On-Site Disposal or Other Releases Pounds | Total Off-Site Disposal or Other Releases Pounds | Total On-Site and Off-Site Disposal or Other Releases Pounds |
| Alabama | 0 | 7,739,591 | 10,578,722 | 18,318,313 | 10,050,670 | 48,028,693 | 7,805,767 | 8,305 | 147,954 | 0 | 14,642,205 | 464,575 | 81,148,169 | 99,466,482 | 18,982,157 | 118,448,639 |
| Alaska | 0 | 0 | 310 | 310 | 395,715 | 1,689,402 | 541,992 | 21,374,380 | 0 | 0 | 270,833,014 | 244,609,756 | 539,444,259 | 539,444,569 | 199,327 | 539,643,896 |
| American Samoa | 0 | 0 | 0 | 0 | 8,460 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 8,466 | 8,466 | 0 | 8,466 |
| Arizona | 0 | 1 | 5,854,841 | 5,854,842 | 1,063,942 | 3,605,620 | 6,965 | 0 | 167,809 | 0 | 6,854,241 | 30,027,815 | 41,726,391 | 47,581,233 | 632,299 | 48,213,532 |
| Arkansas | 3,303,538 | 295,473 | 2,439,167 | 6,038,178 | 6,279,944 | 14,018,639 | 5,419,186 | 93,481 | 501,024 | 1 | 2,039,402 | 43,324 | 28,395,002 | 34,433,180 | 6,168,633 | 40,801,813 |
| California | 0 | 25,491,811 | 608,973 | 26,100,784 | 3,946,761 | 14,238,606 | 4,617,780 | 30,086 | 675,350 | 5,134 | 130,552 | 444,069 | 24,088,337 | 50,189,121 | 7,682,581 | 57,871,702 |
| Colorado | 0 | 97 | 6,086,523 | 6,086,620 | 753,351 | 2,204,320 | 2,955,073 | 0 | 341 | 0 | 2,726,225 | 3,317,078 | 11,956,389 | 18,043,008 | 4,474,503 | 22,517,511 |
| Connecticut | 0 | 0 | 393 | 393 | 855,300 | 2,154,851 | 722,325 | 0 | 0 | 0 | 78 | 778 | 3,733,332 | 3,733,725 | 1,650,391 | 5,384,116 |
| Delaware | 0 | 0 | 1,252,178 | 1,252,178 | 290,367 | 7,003,978 | 918,650 | 0 | 9 | 0 | 8,178 | 48 | 8,221,230 | 9,473,408 | 4,139,175 | 13,612,583 |
| District of Columbia | 0 | 0 | 0 | 0 | 3,338 | 1 | 8,062 | 0 | 0 | 0 | 2,082 | 0 | 13,482 | 13,482 | 306 | 13,788 |
| Florida | 20,875,927 | 84 | 10,441,600 | 31,317,611 | 5,640,681 | 71,659,217 | 2,507,602 | 154,144 | 2,067,467 | 405,334 | 9,159,351 | 123,809 | 91,717,605 | 123,035,216 | 3,417,197 | 126,452,413 |
| Georgia | 0 | 90 | 522,944 | 523,034 | 9,084,590 | 90,203,030 | 9,573,187 | 0 | 431,299 | 35,472 | 13,660,727 | 748,427 | 123,736,732 | 124,259,766 | 2,391,094 | 126,650,860 |
| Guam | 0 | 12 | 10 | 22 | 1,926 | 162,669 | 71,627 | 0 | 0 | 0 | 7 | 3 | 236,233 | 236,255 | 2,048 | 238,303 |
| Hawaii | 0 | 0 | 0 | 0 | 180,874 | 1,900,899 | 364,067 | 2,670 | 19,681 | 0 | 0 | 229,586 | 2,697,777 | 2,697,777 | 419,791 | 3,117,568 |
| Idaho | 0 | 30,517,289 | 42,662 | 30,559,951 | 995,037 | 3,038,312 | 4,642,166 | 0 | 669,554 | 2,239,333 | 6,571,414 | 12,027,196 | 30,183,012 | 60,742,962 | 584,846 | 61,327,809 |
| Illinois | 794 | 23,219,451 | 4,464,352 | 27,684,597 | 8,628,864 | 47,405,033 | 7,221,378 | 0 | 477,550 | 29,315 | 8,987,454 | 447,772 | 73,197,365 | 100,881,962 | 31,519,211 | 132,401,173 |
| Indiana | 1,075,521 | 8,094,913 | 17,522,055 | 26,692,489 | 8,722,806 | 64,952,587 | 23,296,297 | 0 | 1,850,171 | 1,500 | 8,571,928 | 777,844 | 108,173,133 | 134,865,622 | 99,900,349 | 234,765,971 |
| Iowa | 0 | 0 | 1,889,630 | 1,889,630 | 3,791,907 | 18,311,363 | 3,274,619 | 0 | 750 | 0 | 2,611,789 | 39,658 | 28,030,086 | 29,919,715 | 7,482,328 | 37,402,043 |
| Kansas | 470,746 | 33,000 | 3,535,497 | 4,039,243 | 2,641,059 | 10,557,093 | 4,021,144 | 500 | 419,554 | 0 | 3,795,286 | 127,585 | 21,562,221 | 25,601,464 | 3,262,448 | 28,863,912 |
| Kentucky | 0 | 0 | 15,143,069 | 15,143,069 | 6,024,718 | 51,653,888 | 2,986,815 | 2,971 | 333,583 | 334,515 | 5,381,917 | 921,961 | 67,640,366 | 82,783,436 | 7,798,069 | 90,581,505 |
| Louisiana | 35,904,030 | 7,050,318 | 7,348,228 | 50,302,576 | 12,230,196 | 42,697,721 | 11,303,522 | 0 | 46,587 | 289,599 | 4,062,499 | 148,267 | 70,778,392 | 121,080,968 | 5,764,045 | 126,845,013 |
| Maine | 0 | 0 | 838,723 | 838,723 | 686,531 | 3,611,216 | 3,334,311 | 0 | 0 | 0 | 0 | 9,557 | 7,641,615 | 8,480,338 | 824,733 | 9,305,071 |
| Maryland | 0 | 0 | 1,827,936 | 1,827,936 | 596,281 | 35,266,724 | 2,704,113 | 50,375 | 159,930 | 0 | 34,954 | 119,632 | 38,932,009 | 40,759,945 | 4,739,560 | 45,499,505 |
| Massachusetts | 0 | 0 | 41,739 | 41,739 | 741,565 | 5,297,813 | 68,806 | 0 | 39 | 0 | 80,638 | 670,421 | 6,859,282 | 6,901,021 | 2,112,307 | 9,013,328 |
| Michigan | 1,907,236 | 1,046,569 | 3,757,600 | 6,711,405 | 3,915,701 | 46,250,106 | 1,218,195 | 0 | 123,547 | 0 | 5,389,756 | 1,062,639 | 57,959,944 | 64,671,349 | 36,933,939 | 101,605,288 |
| Minnesota | 0 | 251 | 5,528,048 | 5,526,299 | 3,110,524 | 10,522,357 | 1,246,533 | 0 | 71,993 | 0 | 5,284,791 | 63,705 | 20,299,903 | 25,826,201 | 5,622,420 | 31,448,621 |
| Mississippi | 12,654,379 | 65 | 1,985,150 | 14,639,593 | 5,810,502 | 25,988,162 | 7,751,711 | 0 | 393,645 | 15,268 | 6,767,118 | 221,233 | 46,947,640 | 61,587,233 | 1,489,728 | 63,076,960 |
| Missouri | 0 | 199,911 | 2,187,364 | 2,387,276 | 2,811,105 | 24,870,138 | 2,620,282 | 0 | 12,617 | 544 | 40,355,980 | 21,326,736 | 91,997,402 | 94,384,677 | 8,114,819 | 102,499,496 |
| Montana | 0 | 81 | 22,971,757 | 22,971,839 | 597,835 | 3,486,141 | 49,172 | 209,716 | 933 | 0 | 10,445,012 | 6,475,019 | 21,263,828 | 44,235,667 | 970,916 | 45,206,583 |
| Nebraska | 0 | 0 | 7,740,974 | 7,740,974 | 886,910 | 5,985,779 | 18,177,388 | 0 | 678,512 | 1,000 | 755 | 277,302 | 26,007,647 | 3,748,621 | 17,722,548 | 51,471,169 |
| Nevada | 0 | 29,771,405 | 2,606,310 | 32,377,715 | 588,282 | 1,253,025 | 88,601 | 3 | 43 | 0 | 188,495,103 | 185,492,867 | 375,917,924 | 408,295,639 | 758,761 | 409,054,400 |
| New Hampshire | 0 | 0 | 0 | 0 | 157,081 | 5,217,148 | 86,194 | 0 | 0 | 0 | 22,805 | 165 | 5,483,393 | 5,483,393 | 460,749 | 5,944,142 |
| New Jersey | 0 | 104,607 | 33,841 | 138,448 | 1,840,951 | 10,484,189 | 4,148,642 | 5 | 6,583 | 0 | 6,551 | 188,018 | 16,674,938 | 16,813,386 | 6,310,629 | 23,124,015 |
| New Mexico | 18,605 | 0 | 5,296,008 | 5,314,613 | 300,082 | 647,660 | 62,237 | 0 | 326,660 | 0 | 1,270,605 | 9,831,265 | 12,438,509 | 17,753,122 | 146,129 | 17,899,251 |
| New York | 0 | 2,919,297 | 1,137,787 | 4,057,084 | 2,855,774 | 24,254,524 | 7,937,611 | 0 | 23,565 | 0 | 257 | 398,503 | 35,470,235 | 39,527,319 | 4,499,897 | 44,027,216 |
| North Carolina | 0 | 2,023 | 3,265,168 | 3,267,191 | 6,936,819 | 93,358,632 | 8,592,474 | 0 | 245,329 | 0 | 6,096,625 | 609,420 | 115,839,298 | 119,106,489 | 10,039,033 | 129,145,522 |
| North Dakota | 0 | 0 | 2,263,167 | 2,263,167 | 251,193 | 4,621,269 | 248,831 | 0 | 17,123 | 0 | 7,020,805 | 2,975 | 12,162,196 | 14,425,362 | 9,213,436 | 23,638,798 |
| Northern Marianas | 0 | 0 | 0 | 0 | 324 | 5,701 | 0 | 0 | 0 | 0 | 2 | 0 | 6,027 | 6,027 | 0 | 6,027 |
| Ohio | 29,289,527 | 7,261,217 | 16,604,064 | 53,154,807 | 9,765,195 | 123,297,398 | 6,716,124 | 0 | 499,432 | 307,465 | 12,485,002 | 178,440 | 153,249,057 | 206,403,864 | 45,193,295 | 251,597,159 |
| Oklahoma | 1,307,526 | 1,757,603 | 1,814,396 | 4,879,525 | 2,467,942 | 13,460,673 | 3,451,751 | 0 | 13,387 | 1 | 547,749 | 524,632 | 20,466,134 | 25,345,659 | 4,622,081 | 29,967,740 |
| Oregon | 0 | 13,208,609 | 11,729,305 | 24,937,914 | 2,538,300 | 10,784,137 | 2,452,054 | 0 | 187,648 | 12,337 | 503 | 2,350 | 15,977,329 | 40,915,243 | 1,213,679 | 42,128,922 |
| Pennsylvania | 0 | 11,433 | 5,711,204 | 5,722,637 | 5,871,513 | 85,113,791 | 9,684,378 | 0 | 12,327 | 1,790,272 | 309,090 | 5,508,710 | 108,290,080 | 114,012,717 | 52,905,725 | 166,918,443 |
| Puerto Rico | 0 | 13,533 | 250 | 13,783 | 942,381 | 7,081,569 | 24,365 | 0 | 0 | 0 | 0 | 3,500 | 8,051,815 | 8,065,598 | 734,652 | 8,800,250 |
| Rhode Island | 0 | 250 | 0 | 250 | 236,638 | 390,168 | 6,947 | 0 | 0 | 0 | 0 | 0 | 633,753 | 634,003 | 258,275 | 892,279 |
| South Carolina | 0 | 62,318 | 2,387,601 | 2,449,919 | 6,720,209 | 45,438,879 | 3,473,022 | 0 | 37,514 | 85 | 2,944,266 | 327,757 | 58,941,732 | 61,391,651 | 22,316,357 | 83,708,008 |
| South Dakota | 0 | 0 | 5,533,657 | 5,533,657 | 656,431 | 807,101 | 3,199,143 | 101 | 685 | 0 | 23,556 | 5,350 | 4,692,347 | 10,226,004 | 94,109 | 10,320,113 |
| Tennessee | 0 | 54,792 | 18,926,296 | 18,981,088 | 11,030,628 | 77,689,173 | 2,410,104 | 0 | 26,760 | 0 | 22,765,611 | 2,457,322 | 116,379,598 | 135,360,685 | 7,178,908 | 142,539,594 |
| Texas | 85,633,991 | 3,619,830 | 24,058,727 | 113,312,547 | 35,163,397 | 56,502,383 | 21,670,283 | 42,000 | 3,090,383 | 11 | 3,684,426 | 1,953,398 | 122,106,261 | 235,418,808 | 26,485,939 | 261,904,747 |
| Utah | 0 | 7,672,552 | 12,978,810 | 20,651,362 | 1,857,825 | 7,268,894 | 56,978 | 0 | 292,689 | 0 | 130,057,726 | 78,732,740 | 218,266,853 | 238,918,214 | 3,077,073 | 241,995,287 |
| Vermont | 0 | 0 | 4 | 4 | 19,824 | 45,025 | 136,856 | 0 | 0 | 0 | 7 | 5 | 201,716 | 201,721 | 144,981 | 346,702 |
| Virgin Islands | 0 | 0 | 0 | 0 | 124,893 | 831,616 | 355,871 | 0 | 597 | 0 | 10,124 | 0 | 1,323,101 | 1,323,101 | 7,916 | 1,331,017 |
| Virginia | 0 | 344 | 3,317,037 | 3,317,381 | 5,233,866 | 45,714,310 | 8,198,926 | 0 | 203,048 | 0 | 1,887,312 | 244,389 | 61,481,850 | 64,799,231 | 9,431,206 | 74,230,438 |
| Washington | 0 | 633,020 | 191,652 | 824,673 | 1,560,909 | 11,772,038 | 1,397,187 | 0 | 29,989 | 0 | 5,035,903 | 517,707 | 20,313,733 | 21,138,405 | 1,741,529 | 22,879,934 |
| West Virginia | 10 | 7,844 | 7,700,777 | 7,708,631 | 3,840,246 | 75,083,656 | 4,194,526 | 87 | 597,291 | 21,088 | 4,937,887 | 342,718 | 89,017,499 | 96,726,130 | 5,443,463 | 102,169,593 |

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| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wisconsin | 0 | 1,677 | 655,225 | 656,902 | 2,873,281 | 21,768,989 | 4,595,302 | 0 | 821,747 | 49,651 | 21,242 | 302,494 | 30,423,707 | 31,080,609 | 19,717,618 | 50,798,227 |
| Wyoming | 7,960,400 | 2,909 | 7,064,110 | 15,027,419 | 513,877 | 1,638,924 | 10,990 | 0 | 1,564 | 4,341 | 1,019,873 | 12,290 | 3,201,858 | 18,229,277 | 1,034,080 | 19,263,357 |
| **Total** | **200,402,228** | **170,794,270** | **267,883,840** | **639,080,339** | **205,095,324** | **1,381,295,231** | **222,628,110** | **21,968,824** | **15,675,243** | **5,542,266** | **817,040,382** | **612,362,811** | **3,281,608,191** | **3,920,688,530** | **518,031,287** | **4,438,719,817** |

*Note:* This information does not indicate whether (or to what degree) the public has been exposed to toxic chemicals. Therefore, no conclusions on the potential risks can be made based solely on this information (including any ranking information). For more detailed information on this subject refer to *The Toxics Release Inventory (TRI) and Factors to Consider When Using TRI Data* document at www.epa.gov/trl/tridata.

On-site Disposal or Other Releases include Underground injection to Class I Wells (Section 5.4.1), RCRA Subtitle C Landfills (5.5.1A), Other Landfills (5.5.1B), Fugitive or Non-point Air Emissions (5.1), Stack or Point Source Air Emissions (5.2), Surface Water Discharges (5.3), Class II–V Wells (5.4.2), Land Treatment (5.5.2), RCRA Subtitle C Surface impoundments (5.5.3A), Other Surface Impoundments (5.5.3B) and Other Land Disposal (5.5.4). Off-site Disposal or Other Releases include from Section 6.2 Underground Injection to Class I Wells (M81), RCRA Subtitle C Landfills (M65), Other Landfills (M64, M72), Storage Only (M10), Solidification/Stabilization—Metals and Metal Category Compounds only (M41 or M40), Wastewater Treatment (excluding POTWs)—Metals and Metal Category Compounds only (M62 or M61), RCRA Subtitle C Surface Impoundments (M66), Other Surface Impoundments (M67, M63), Land Treatment (M73), Other Land Disposal (M79), Underground Injection to Class II–V Wells (M82, M71), Other Off-site Management (M90), Transfers to Waste Broker—Disposal (M94, M91), and Unknown (M99) and, from Section 6.1, Transfers to POTWs (metals and metal category compounds only).

Does not include Off-site Disposal or Other Releases transferred to other TRI facilities that reported the amounts as On-site Disposal or Other Releases.

*Source*: From United States Environmental Protection Agency, 2005, *2003 TRI Public Data Release eReport May 2005*, www.epa.gov.



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## Table 10C.96 United States Toxic Release Inventory On-Site and Off-Site Disposal or Other Releases, by Industry, 2003

| | On-site Disposal or Other Releases | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | On-site Disposal to Class I Underground Injection Wells, RCRA Subtitle C Landfills, and Other Landfills | | | | Other On-site Disposal or Other Releases | | | | | | | | | | | |
| SIC Code Industry | Class I Wells Pounds | RCRA Subtitle C Landfills Pounds | Other On-site Landfills Pounds | Subtotal Pounds | Fugitive Air Emissions Pounds | Point Source Air Emissions Pounds | Surface Water Discharges Pounds | Class II–V Wells Pounds | Land Treatment Pounds | RCRA Subtitle C Surface Impound-ments Pounds | Other Surface Impound-ments Pounds | Other Land Disposal Pounds | Subtotal Pounds | Total On-Site Disposal or Other Releases Pounds | Total Off-Site Disposal or Other Releases Pounds | Total On-Site and Off-Site Disposal or Other Releases Pounds |
| 10 Metal mining | 0 | 0 | 17,124,349 | 17,124,349 | 1,285,236 | 1,753,800 | 679,446 | 21,584,184 | 13,150 | 2,236,052 | 637,974,487 | 562,019,783 | 1,227,546,138 | 1,244,670,487 | 1,037,942 | 1,245,708,429 |
| 12 Coal mining | 0 | 0 | 7,952,585 | 7,952,585 | 842,399 | 64,775 | 199,797 | 58,768 | 1,154,725 | 21,088 | 1,817,948 | 795,570 | 4,955,069 | 12,907,654 | 4,925 | 12,912,580 |
| 20 Food | 63,205 | 546 | 41,361 | 105,112 | 16,998,226 | 35,055,551 | 83,136,183 | 17,044 | 9,873,967 | 89,218 | 140,913 | 428,500 | 145,739,602 | 145,844,714 | 7,340,634 | 153,185,349 |
| 21 Tobacco | 0 | 0 | 2,376 | 2,376 | 58,494 | 2,416,426 | 130,052 | 0 | 149,836 | 0 | 0 | 0 | 2,754,807 | 2,757,183 | 421,402 | 3,178,586 |
| 22 Textiles | 0 | 0 | 0 | 0 | 1,130,155 | 4,826,038 | 262,178 | 0 | 123,650 | 0 | 160,937 | 53 | 6,503,010 | 6,503,010 | 894,688 | 7,397,699 |
| 23 Apparel | 0 | 0 | 0 | 0 | 112,094 | 366,780 | 0 | 0 | 0 | 0 | 0 | 0 | 478,875 | 478,875 | 200,481 | 679,355 |
| 24 Lumber | 0 | 2,273 | 330,292 | 332,566 | 3,370,921 | 27,040,230 | 108,277 | 0 | 115,179 | 250 | 1,108 | 16,190 | 30,652,154 | 30,964,719 | 2,021,849 | 33,006,568 |
| 25 Furniture | 0 | 0 | 1 | 1 | 691,650 | 5,410,353 | 35 | 0 | 0 | 0 | 0 | 35,961 | 6,137,999 | 6,138,000 | 71,580 | 6,209,580 |
| 26 Paper | 0 | 42 | 12,545,504 | 12,545,546 | 27,019,698 | 146,219,717 | 18,715,017 | 0 | 1,064,035 | 128,025 | 3,635,346 | 307,503 | 197,089,341 | 209,634,887 | 5,327,919 | 214,962,805 |
| 27 Printing | 0 | 87 | 0 | 87 | 7,253,937 | 7,437,745 | 549 | 0 | 0 | 0 | 0 | 4,951 | 14,697,183 | 14,697,270 | 267,911 | 14,985,181 |
| 28 Chemicals | 177,818,769 | 3,804,019 | 24,987,711 | 206,610,499 | 62,053,840 | 168,589,153 | 44,537,842 | 273,096 | 557,537 | 23,290 | 12,922,181 | 4,731,869 | 293,688,809 | 500,299,307 | 44,440,173 | 544,739,481 |
| 29 Petroleum | 2,487,806 | 56 | 724,902 | 3,212,764 | 16,706,339 | 34,608,196 | 17,134,723 | 32,752 | 54,496 | 12 | 61,682 | 98,744 | 68,696,945 | 71,909,709 | 3,059,186 | 74,968,895 |
| 30 Plastics | 0 | 15,272 | 165,188 | 180,480 | 14,095,493 | 51,339,039 | 125,302 | 0 | 0 | 11 | 4,997 | 81,715 | 65,646,558 | 65,827,018 | 9,461,313 | 75,288,331 |
| 31 Leather | 0 | 0 | 6,725 | 6,725 | 269,382 | 655,731 | 27,908 | 0 | 60 | 0 | 0 | 5 | 953,086 | 959,811 | 1,139,481 | 2,099,292 |
| 32 Stone/ clay/glass | 0 | 94,933 | 3,332,388 | 3,427,320 | 1,556,565 | 38,084,142 | 2,133,677 | 2,971 | 195 | 169 | 230,674 | 337,690 | 42,346,084 | 45,773,404 | 5,469,229 | 51,242,633 |
| 33 Primary metals | 945,916 | 9,728,105 | 36,433,952 | 47,107,973 | 13,604,646 | 35,879,537 | 39,443,391 | 5 | 15,115 | 0 | 32,623,268 | 29,540,600 | 151,006,562 | 198,114,535 | 279,358,340 | 477,472,875 |
| 34 Fabricated metals | 0 | 14,789 | 48,262 | 63,051 | 12,327,229 | 23,708,658 | 2,331,208 | 0 | 17,556 | 125 | 8,368 | 340,049 | 38,733,193 | 38,796,244 | 19,827,879 | 58,624,123 |
| 35 Machinery | 0 | 11 | 3,688,102 | 3,688,112 | 2,666,073 | 4,127,143 | 209,418 | 0 | 210 | 0 | 8 | 20,986 | 7,023,837 | 10,711,949 | 3,627,929 | 14,339,878 |
| 36 Electrical Equip. | 0 | 239,206 | 198,932 | 438,140 | 3,281,807 | 6,476,571 | 3,628,323 | 0 | 0 | 750 | 2,466 | 5,939 | 13,395,857 | 13,833,997 | 6,444,050 | 20,278,047 |
| 37 Transportation Equip. | 6,354 | 2,676 | 236,433 | 245,463 | 11,936,992 | 51,064,653 | 207,966 | 0 | 0 | 0 | 34 | 92,279 | 63,301,924 | 63,547,387 | 11,228,710 | 74,776,098 |
| 38 Measure/Photo. | 0 | 5,765 | 168 | 5,933 | 1,694,548 | 5,123,745 | 1,018,609 | 0 | 341 | 0 | 5 | 82,747 | 7,919,995 | 7,925,928 | 788,458 | 8,714,386 |
| 39 Miscellaneous | 0 | 755 | 1,450 | 2,205 | 926,391 | 3,908,177 | 62,644 | 0 | 0 | 0 | 5 | 504 | 4,897,720 | 4,899,925 | 2,155,240 | 7,055,165 |
| 491/493 Electric utilities | 0 | 51,833 | 144,198,732 | 144,250,565 | 284,136 | 721,277,416 | 3,340,491 | 4 | 1,993,907 | 1,238,158 | 126,316,380 | 5,397,157 | 859,847,648 | 1,004,098,213 | 78,665,493 | 1,082,763,707 |
| 5,169 Chemical wholesale distributors | 0 | 0 | 0 | 0 | 634,593 | 839,584 | 1,218 | 0 | 0 | 5 | 5 | 6,067 | 1,281,472 | 1,281,472 | 117,925 | 1,399,396 |
| 5,171 Petroleum terminals/bulk storage | 0 | 12 | 0 | 12 | 974,868 | 1,820,524 | 12,614 | 0 | 0 | 0 | 14,333 | 7,393 | 2,829,733 | 2,829,745 | 349,073 | 3,178,818 |
| 7,389/4,953 Hazardous waste/solvent recovery | 19,080,178 | 156,200,572 | 15,801,796 | 191,082,546 | 287,991 | 498,873 | 300,944 | 0 | 10 | 1,803,701 | 2 | 127,109 | 3,018,630 | 194,101,176 | 33,007,422 | 227,108,598 |
| No codes | 0 | 633,316 | 62,631 | 695,947 | 3,131,619 | 2,902,674 | 4,880,299 | 0 | 541,275 | 1,412 | 1,125,238 | 7,883,444 | 20,465,982 | 21,161,909 | 1,282,055 | 22,443,964 |
| **Total** | **200,402,228** | **170,794,270** | **267,883,840** | **639,080,339** | **205,095,324** | **1,361,295,231** | **222,628,110** | **21,968,824** | **15,875,243** | **5,542,266** | **817,040,382** | **612,362,811** | **3,281,608,191** | **3,920,688,530** | **518,031,287** | **4,438,719,817** |

*Note:* This information does not indicate whether (or to what degree) the public has been exposed to toxic chemicals. Therefore, no conclusions on the potential risks can be made based solely on this information (including any ranking information). For more detailed information on this subject refer *Toxics Release Inventory (TRI) and Factors to Consider When Using TRI Data* document at www.epa.gov/tri/tridata.

On-site Disposal or Other Releases include Underground Injection to Class I Wells (Section 5.4.1), RCRA Subtitle C Landfills (5.5.1A), Other Landfills (5.5.1B), Fugitive or Non-point Air Emissions (5.1), Stack or Point Source Air Emissions (5.2), Surface Water Discharges (5.3), Class II–V Wells (5.4.2). Land Treatment (5.5.2), RCRA Subtitle C Surface Impoundments (5.5.3A), Other Surface Impoundments (5.5.3B) and Other Land Disposal (5.5.4). Off-site Disposal or Other Releases include from Section 6.2 Underground Injection to Class I Wells (M81), RCRA Subtitle C Landfills (M65), Other Landfills (M64, M72), Storage Only (M10), Solidification/Stabilization—Metals and Metal Category Compounds only (M41 or M40), Wastewater Treatment (excluding POTWs)—Metals and Metal Category Compounds only (M62 or M61), RCRA Subtitle C Surface Impoundments (M66), Other Surface Impoundments (M67, M63), Land Treatment (M73), Other Land Disposal (M79), Underground Injection to Class II–V Wells (M82, M71), Other Off-site Management (M90), Transfers to Waste Broker—Disposal (M94, M91), and Unknown (M99) and, from Section 6.1, Transfers to POTWs (metals and metal category compounds only).

Does not include Off-site Disposal or Other-Releases transferred to other TRI facilities that reported the amounts as On-site Disposal or Other Releases.

*Source*: From United States Environmental Protection Agency, 2005, *2003 TRI Public Data Release eReport*, May 2005, www.epa.gov.

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**Table 10C.97 Number of Reported Spills in Canada in Seven Sectors, 1984–1995**

| Year | Chemical | Government | Metallurgy | Mining | Petroleum | Pulp & Paper | Service Industry |
|---|---|---|---|---|---|---|---|
| 1984 | 70 | 223 | 31 | 153 | 1,831 | 38 | 94 |
| 1985 | 130 | 200 | 58 | 83 | 2,053 | 44 | 104 |
| 1986 | 206 | 206 | 181 | 118 | 2,398 | 73 | 157 |
| 1987 | 179 | 228 | 139 | 124 | 2,512 | 63 | 208 |
| 1988 | 405 | 981 | 360 | 172 | 3,021 | 148 | 281 |
| 1989 | 582 | 1,080 | 392 | 172 | 2,971 | 224 | 346 |
| 1990 | 588 | 1,320 | 361 | 191 | 3,157 | 312 | 408 |
| 1991 | 552 | 1,487 | 508 | 195 | 3,139 | 291 | 434 |
| 1992 | 667 | 1,991 | 703 | 194 | 1,144 | 340 | 427 |
| 1993 | 754 | 1,957 | 618 | 186 | 1,531 | 371 | 456 |
| 1994 | 784 | 2,165 | 599 | 199 | 1,577 | 458 | 464 |
| 1995 | 534 | 2,204 | 431 | 184 | 1,642 | 353 | 484 |
| **Total** | **5,451** | **14,042** | **4,381** | **1,971** | **26,976** | **2,715** | **3,863** |

*Source*: From *Summary of Spill Events in Canada, 1984–1995*, EPS 5/SP/3, Environment Canada, Canada Environmental Emergencies Program, 1998. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

**Table 10C.98 Total Quantity of Reported Spills in Canada in Seven Sectors (Tons), 1984–1995**

| Year | Chemical | Government | Metallurgy | Mining | Petroleum | Pulp & Paper | Service Industry |
|---|---|---|---|---|---|---|---|
| 1984 | 1,783 | 142,556 | 4,860 | 113,078 | 72,121 | 2,948 | 433 |
| 1985 | 12,399 | 140,820 | 314 | 16,105 | 46,029 | 35,447 | 211 |
| 1986 | 16,160 | 11,267 | 23,923 | 29,972 | 62,232 | 28,138 | 431,886 |
| 1987 | 17,128 | 133,863 | 87,665 | 126,939 | 89,773 | 90,608 | 616,308 |
| 1988 | 5,498 | 58,480 | 23,497 | 6,752 | 29,444 | 26,933 | 1,115 |
| 1989 | 7,194 | 189,169 | 51,266 | 42,899 | 120,765 | 16,322 | 228 |
| 1990 | 6,629 | 84,194 | 79,178 | 35,247 | 50,284 | 35,845 | 310 |
| 1991 | 1,619 | 184,449 | 32,449 | 26,172 | 43,963 | 46,491 | 5,106 |
| 1992 | 827 | 1,386,991 | 193,435 | 58,667 | 11,164 | 25,494 | 5,625 |
| 1993 | 1,519 | 677,529 | 1,425,753 | 12,094 | 62,725 | 35,612 | 190 |
| 1994 | 178 | 678,622 | 27,489 | 7,262 | 18,174 | 19,751 | 197 |
| 1995 | 325 | 1,576,576 | 11,791 | 4,783 | 18,176 | 49,224 | 763 |
| **Total** | **71,259** | **5,265,518** | **1,961,620** | **479,969** | **624,852** | **412,814** | **1,062,374** |

*Source*: From *Summary of Spill Events in Canada, 1984–1995*, EPS 5/SP/3, Environment Canada, Canada Environmental Emergencies Program, 1998. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

**Table 10C.99 Hydrocarbon Spills Reported in Canada, 1974–1983**

| Year | Condensates and Gases | Crude Oil | No. 2 Fuel | No. 6 Fuel | No. 4 & 5 Fuel | Gasoline | Other Oils | Waste Oil | Asphalt | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 3,623 | 14,823 | 1,046 | 1,106 | 5,594 | 810 | 222 | 631 | 82 | 27,935 |
| 1975 | 600 | 11,530 | 836 | 2,499 | 2,844 | 3,095 | 256 | 321 | 266 | 22,250 |
| 1976 | 7,429 | 10,901 | 1,650 | 2,084 | 2,231 | 2,156 | 220 | 38 | 372 | 27,085 |
| 1977 | 20,865 | 10,699 | 3,753 | 804 | 1,587 | 1,638 | 551 | 85 | 103 | 40,085 |
| 1978 | 845 | 12,067 | 2,801 | 3,288 | 1,932 | 1,237 | 454 | 72 | 476 | 23,170 |
| 1979 | 3,306 | 12,540 | 4,724 | 9,054 | 1,801 | 1,567 | 339 | 319 | 392 | 34,045 |
| 1980 | 705 | 15,274 | 3,517 | 585 | 649 | 918 | 278 | 108 | 479 | 22,510 |
| 1981 | 1,160 | 8,041 | 12,589 | 763 | 1,184 | 1,767 | 1,013 | 1,886 | 287 | 28,690 |
| 1982 | 281,181 | 10,658 | 4,602 | 915 | 1,067 | 847 | 609 | 46 | 147 | 300,070 |
| 1983 | 768 | 8,553 | 1,467 | 803 | 422 | 460 | 300 | 69 | 337 | 13,180 |
| Total | 320,482 | 115,086 | 36,985 | 21,901 | 19,311 | 14,495 | 4,242 | 3,575 | 2,941 | 539,020 |
| % | 59 | 21 | 7 | 4 | 4 | 3 | 1 | 1 | 1 | 100 |

*Note:* By type; volume in metric tons.

*Source*: From Environment Canada, 1987, Summary of Spill Events, 1974–1983, www.ec.gc.ca. With permission.

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**Table 10C.100 Quantity Spilled Annually for the Top Five MIACC List 1 Substances in Canada**

**Tonnes**

| Year | Anhydrous Ammonia | Chlorine | Gasoline | Hydrochloric Acid | Propane | Total |
|---|---|---|---|---|---|---|
| 1984 | 27 | 2.9 | 5,632 | 36 | 19 | 5,716 |
| 1985 | 25 | 0.2 | 1,746 | 57 | 1,591 | 3,418 |
| 1986 | 33 | 409.1 | 909 | 53 | 25 | 1,430 |
| 1987 | 7 | 0.3 | 837 | 189 | 1 | 1,035 |
| 1988 | 17 | 9.2 | 1,096 | 51 | 1 | 1,174 |
| 1989 | 27 | 1.1 | 746 | 250 | 11 | 1,035 |
| 1990 | 86 | 0.1 | 675 | 106 | 64 | 930 |
| 1991 | 4 | 0.2 | 508 | 55 | 137 | 704 |
| 1992 | 28 | 0.5 | 6,439 | 346 | 15 | 6,829 |
| 1993 | 70 | 0.4 | 689 | 37 | 57 | 853 |
| 1994 | 13 | 8.2 | 206 | 72 | 43 | 343 |
| 1995 | 18 | 16.3 | 247 | 25 | 2 | 308 |
| **Total** | **355** | **448.4** | **19,730** | **1,276** | **1,965** | **23,775** |

*Source*: From *Summary of Spill Events in Canada, 1984–1995*, EPS 5/SP/3, Environment Canada, Canada Environmental Emergencies Program, 1998. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

**Table 10C.101 Top Five On-Site Releases to Land in Canada, 1996 and 2001**

| Substance | Releases (Tons) | Share of Total (%) |
|---|---|---|
| **1996** | | |
| Zinc (and its compounds) | 4,989.7 | 35.9 |
| Ethylene glycol | 3,209.8 | 23.1 |
| Manganese (and its compounds) | 1,910.2 | 13.8 |
| Lead (and its compounds) | 894.3 | 6.4 |
| Asbestos (friable form) | 848.2 | 6.1 |
| **2001** | | |
| Calcium fluoride | 10,211.0 | 31.0 |
| Zinc (and its compounds) | 8,143.8 | 24.8 |
| Manganese (and its compounds) | 3,637.2 | 11.1 |
| Ethylene glycol | 2,044.5 | 6.2 |
| Lead (and its compounds) | 1,641.0 | 5.0 |

*Source*: From Environment Canada, Pollution Data Branch, National Pollutant Release Inventory Database, www.ec.gc.ca/pdb/npri, 2001. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

*Original Source*: From Environment Canada, *Pollution Data Branch, National Pollutant Release Inventory database*, www.gc.ca/pdb/npri/ (accessed April 1, 2003).

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**Table 10C.102 Trichloroethene Concentrations Detected in Municipal/Communal and Private/Domestic Water Supplies in Canada**

| Supply | Number of Supplies | Percentage of Supplies Where TCE Was Detected | Average Maximum Concentration |
|---|---|---|---|
| Municipal/communal | 481 | 8.3 | 25 ug/L |
| Private/domestic | 215 | 3.3 | 1,680 ug/L |

| TCE Concentration Range | Percentage of Sites within TCE Range | Percent of Population Supplied with Groundwater within TCE Range[a] |
|---|---|---|
| Nondetectable levels (<0.01–10 ug/L) | 93 | 49 |
| <1 ug/L | 3.6 | |
| 1–10 ug/L | 1.4 | 48 |
| 10–100 ug/L | 0.43 | 2.1 |
| >100 ug/L | 1.3 | 0.8 |

[a] 1.67 Million of the 7.1 million Canadians who relied on groundwater for household use in 1995 were covered this study. Most of sites were from Ontario and New Brunswick.

*Source*: Abstracted from Health Canada, 2005, *Guidelines for Canadian Drinking Water Quality: Supporting Documentation—Trichloroethene*. Water Quality and Health Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario, www.hc-sc.gc.ca. With permission.

**Table 10C.103 Sources of Groundwater Contamination Reported by European Countries**

| | EEA18 | | | | | | | Phare | | | | | | | T | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/ Pollutant | AT | DK | ES | FR | DE | SE | UK | BG | EE | HU | LT | RO | SK | SI | MD | CY |
| Heavy metals | | • | • | • | | • | • | • | • | • | | • | • | • | • | |
| Chlorinated hydrocarbons | • | • | • | • | • | | • | | | • | | • | • | • | | |
| Hydrocarbons | | | | • | • | | • | | • | • | • | • | • | | • | |
| Sulphate | | | | • | | | • | | • | | | | | | • | • |
| Metals | | • | | | | | | | | • | | | | | | |
| Phosphate | | | | | | | | | | | | • | | | | |
| Bacteria | | | | • | | | | | | | | • | | | | |

*Note:* T, Tacis; R Others, AT, Austria; DK, Denmark; ES, Spain; FR, France; CY, Cyprus; DE, Germany; SE, Sweden; UK, UK; BG, Bulgaria; EE, Estonia; HU, Hungary; LT, Lithuania; RO, Romania; SK, Slovak Rep; MD, Rep. of Moldova.

*Source*: From European Environmental Agency, 1999, *Groundwater Quality and Quantity in Europe*, Printed with permission, www.eca.europa.eu. Reprinted with permission © EEA.

**Table 10C.104 Known Occurrences of Hydrocarbon Contamination of Groundwater in Australia**

| State or Territory | Area | Source |
|---|---|---|
| Victoria | 9 sites | Industrial/manufacturing/storage facilities |
| | 2 sites in Melbourne–Geelong region | Landfill |
| | 1 site | Fuel station |
| Western Australia | 8 sites including 2 sites on the Swan Coastal Plain[a] | Fuel stations |
| NSW | 5 sites, including Anna Bay, Botany and Matraville | Industrial/manufacturing/storage facilities |
| | 1 site | Landfill |
| ACT | 3 sites | Fuel stations |
| Queensland | 1 site in Cairns | Fuel station |
| South Australia | 6 Sites Mt Gambler (2 sites), Bordertown, Jamestown, Fregon and Minlayton | Fuel stations |
| Northern Territory | 1 site Croker Island | Fuel station |
| Tasmania | Several (number and locations unknown) | Fuel stations |

[a] The two sites on the Swan Coastal Plain are documented in Davis et al. (1993).

*Source*: From Ball, J. et al., 2001, *Inland Waters, Australia State of Environment Report 2001 (Theme Report)*, CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra, www.deh.gov.au.

*Original Source*: Adapted from Knight 1993.

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## SECTION 10D SOLID WASTE

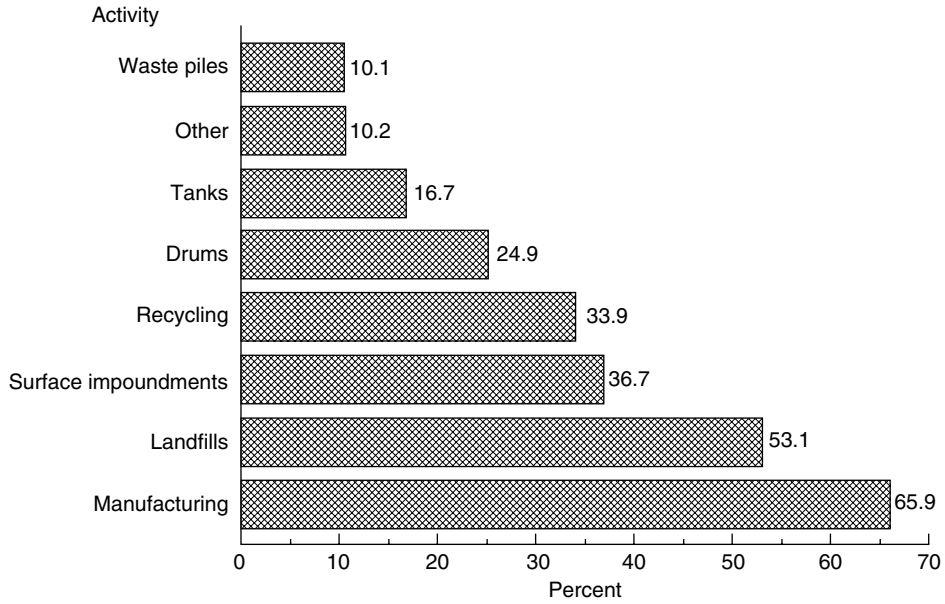


**Figure 10D.70** Types of activities at hazardous waste sites in the United States (percent of 1177 final and proposed sites on the National Priorities list as of June 1988; a site may have more than one type of activity). (From U.S. EPA, Office of Emergency Response, Washington, DC 20460.)

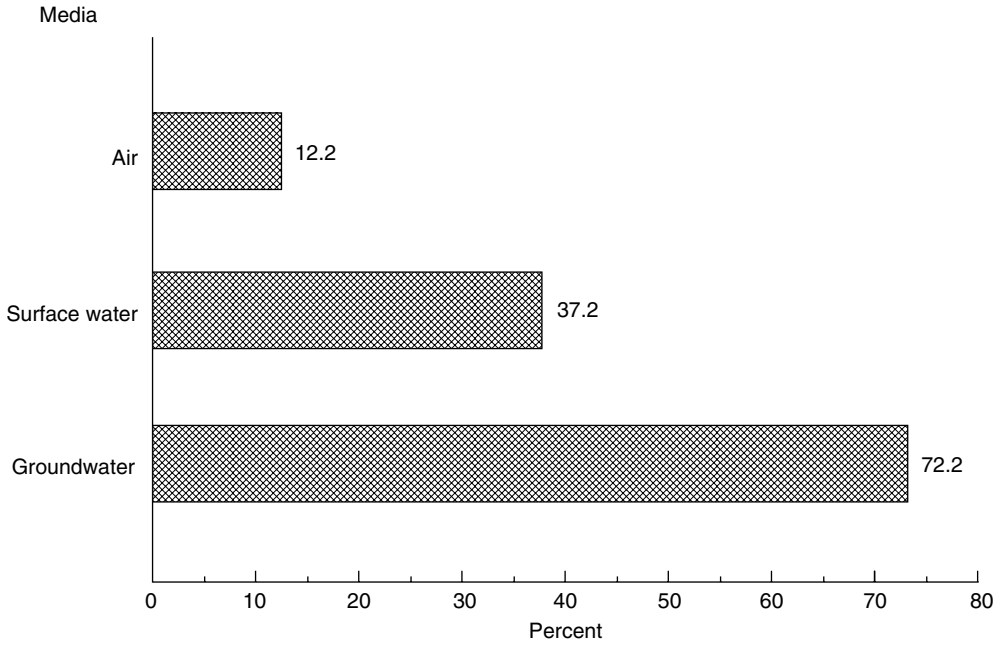


**Figure 10D.71** Observed contamination at hazardous waste sites in the United States (percent of 1177 final and proposed sites on the National Priorities list as of June 1988; a site may have more than one type of contamination). (From U.S. EPA, Office of Emergency Response, Washington, DC 20460.)

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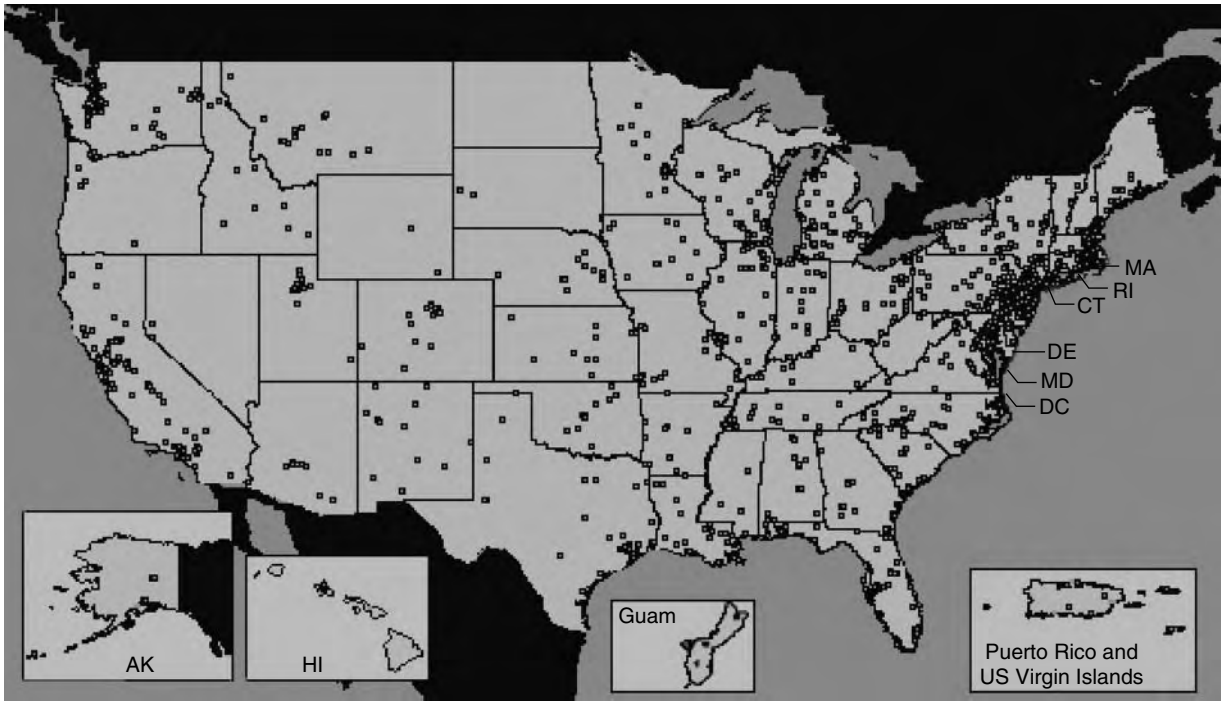
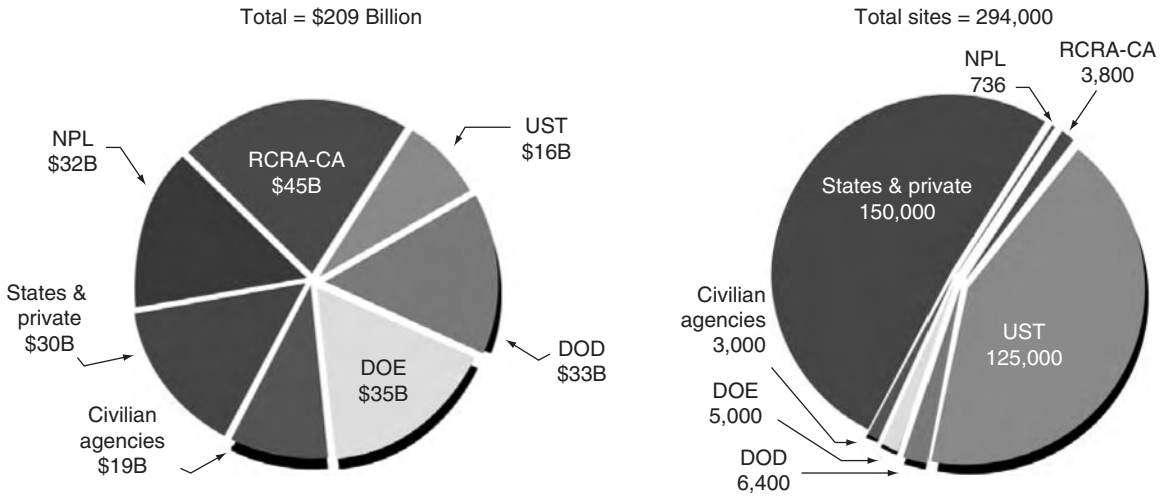



**Figure 10D.72** Superfund sites in the United States. (From www.images.google.com.)




These estimates are derived from judgements regarding the most likely scenarios within a range of estimates. The estimates described in the report, include a number of assumptions such as the average cleanup cost per site, number of new site discoveries, and future additons to the NPL.

NPL: National Priorites List, or Superfund; RCRA-CA: Resource Conservation and Recovery Act Corrective Action program; UST: Underground Storage Tanks; DOD; Department of Defense; DOE: Department of Energy; Civilian agencies: non-DOD and non-DOE federal agencies; and State & private: state mandatory, voluntary, and brownfields sites, and private sites.

Totals may not add due to rounding.

**Figure 10D.73** Estimated number of hazardous waste sites and cleanup costs: 2004–2033. (From clu-in.org/download/market/2004market.)

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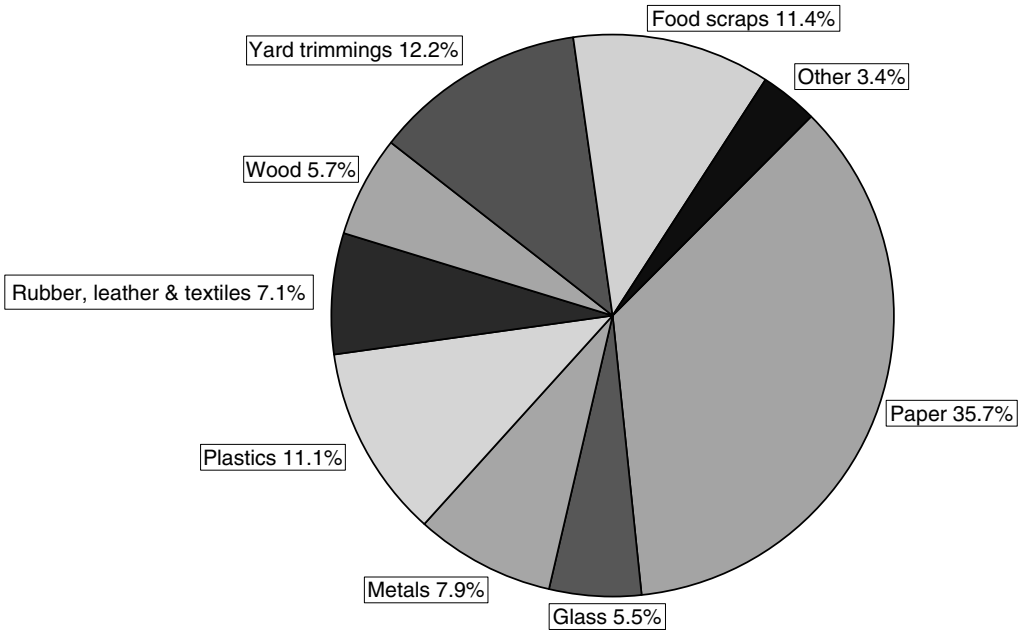


**Figure 10D.74** 2001 total MSW generation—229 million tons (before recycling). (From www.epa.gov.)

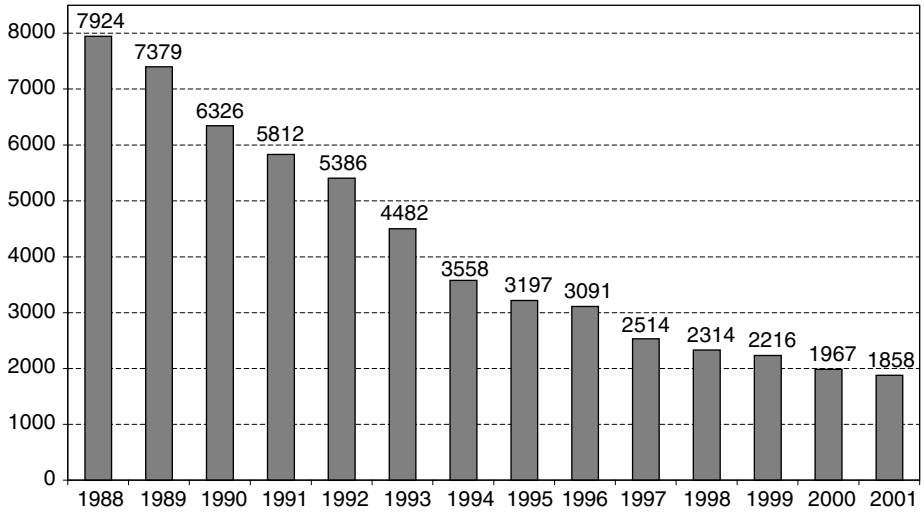


**Figure 10D.75** Number of landfills in the U.S. (From www.epa.gov.)

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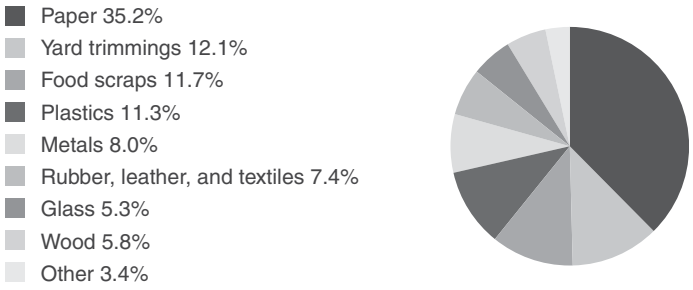


**Figure 10D.76** 2003 total waste generation—236 million tons (before recycling). (From www.epa.gov.)

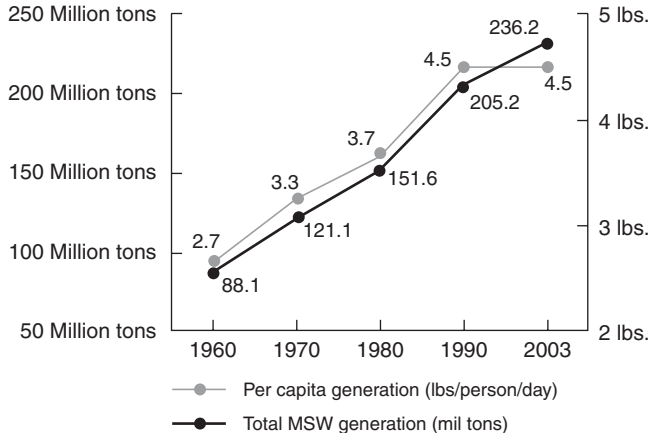


**Figure 10D.77** Trends in MSW generation 1960–2003. (From www.epa.gov.)

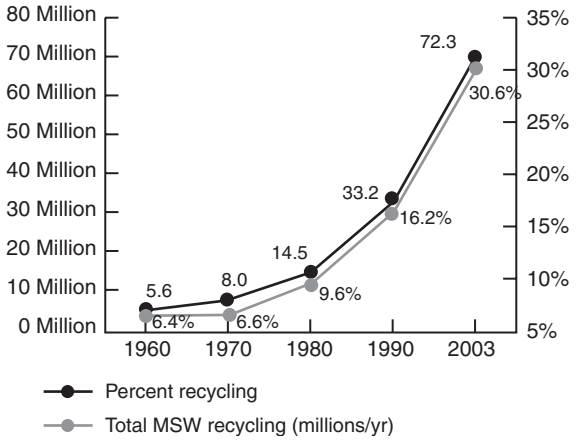


**Figure 10D.78** MSW recycling rates 1960–2003. (From www.epa.gov.)

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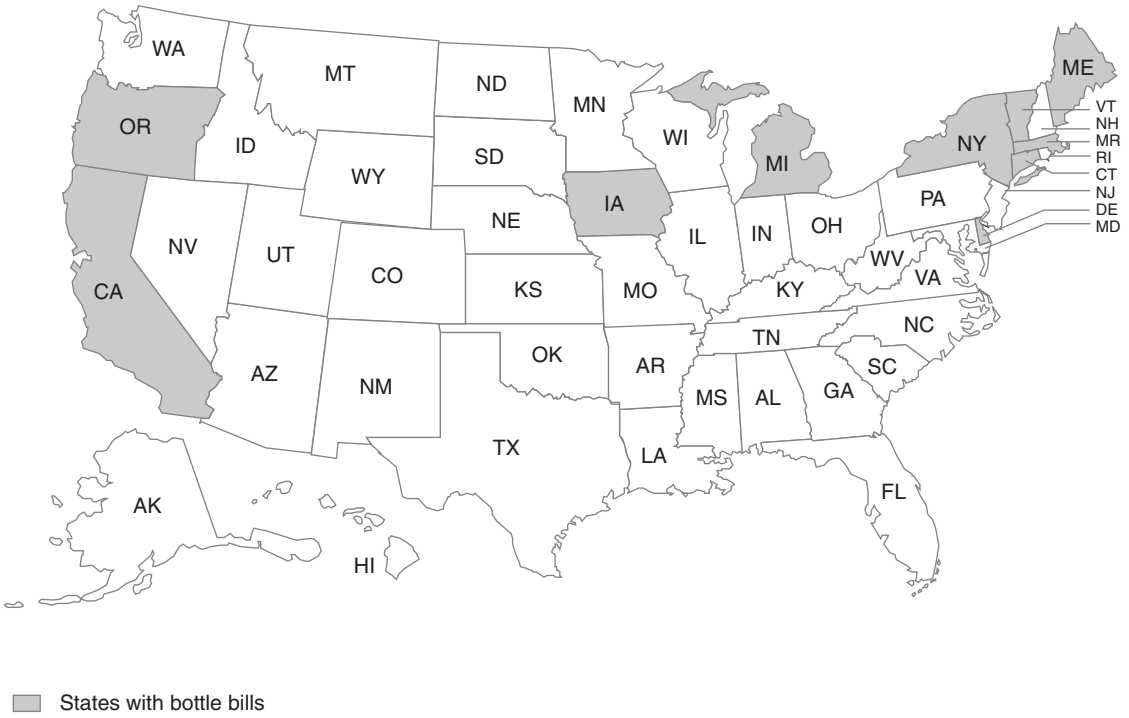


**Figure 10D.79** States with bottle deposit rules. (From The Container Recycling Institute 1999, www.epa.gov.)

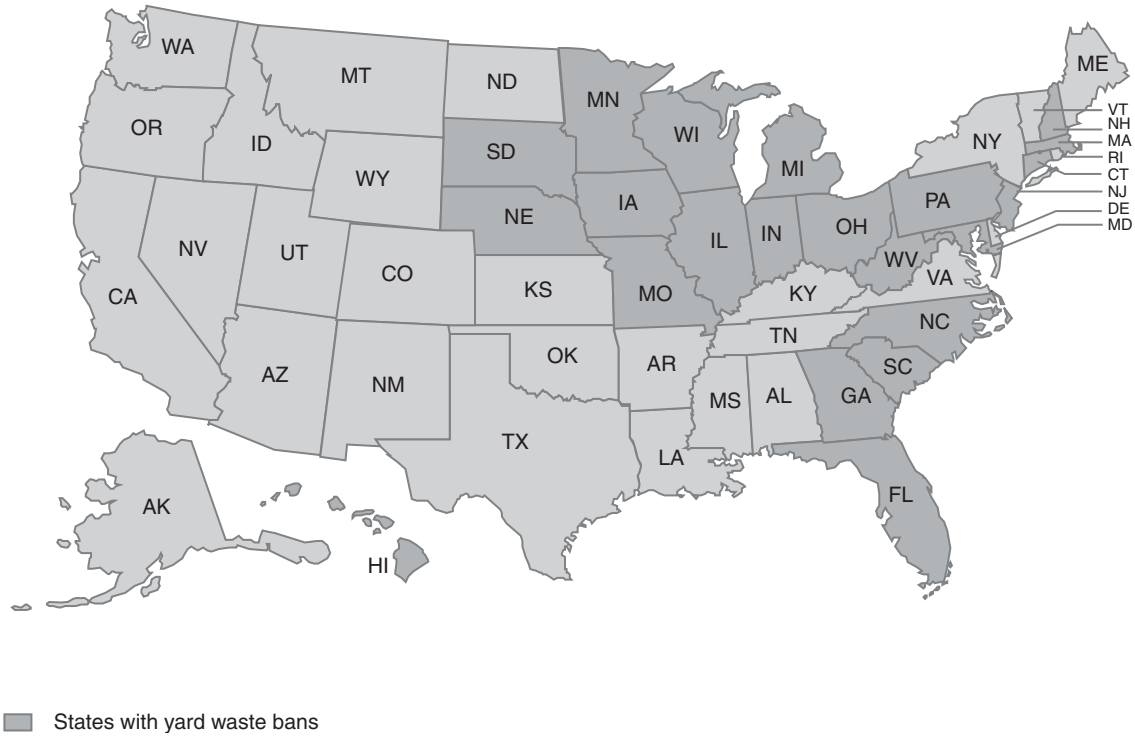


**Figure 10D.80** States with yard waste bans. (From *BioCycle Magazine*, May 1998, www.epa.gov.)

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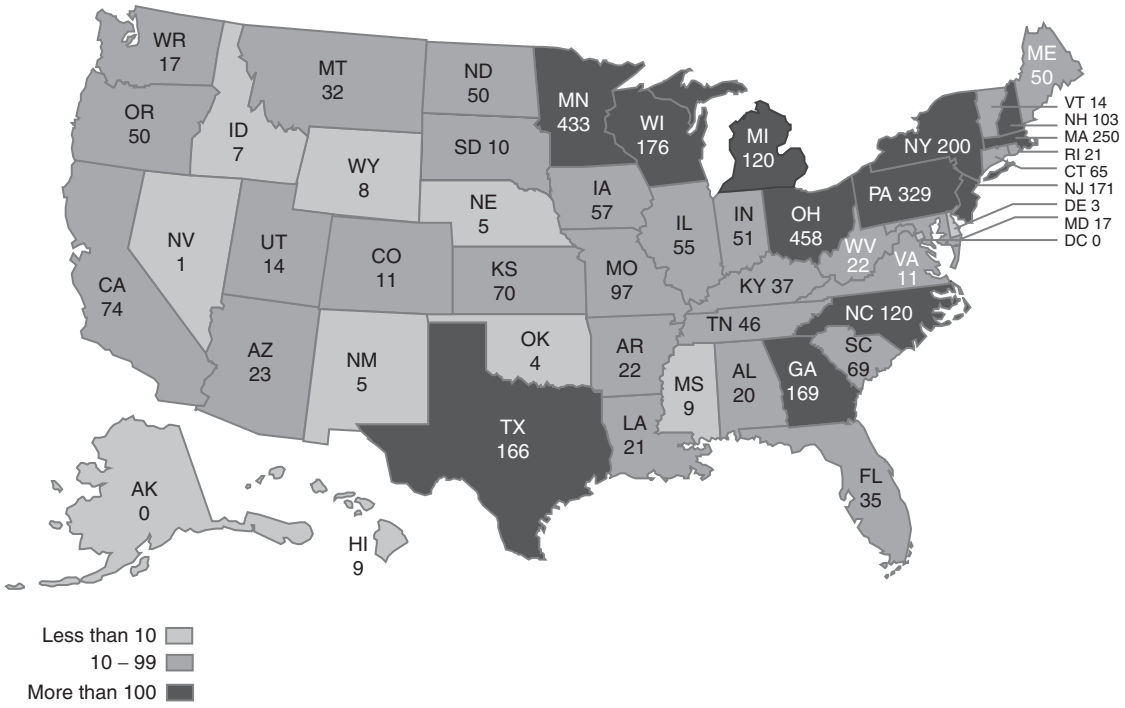


**Figure 10D.81** Number of yard waste composting programs. (From *BioCycle Magazine*, April 1999, www.epa.gov.)

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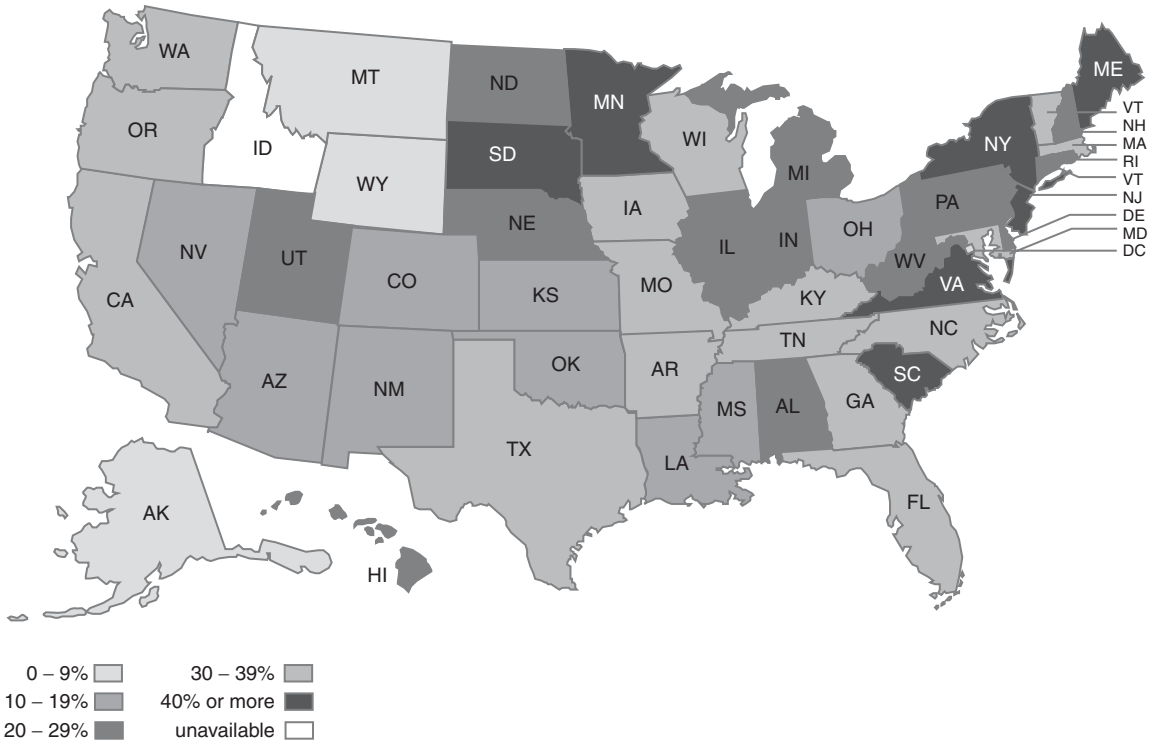


**Figure 10D.82** State recycling rates. (From *BioCycle Magazine*, April 1999, www.epa.gov.)

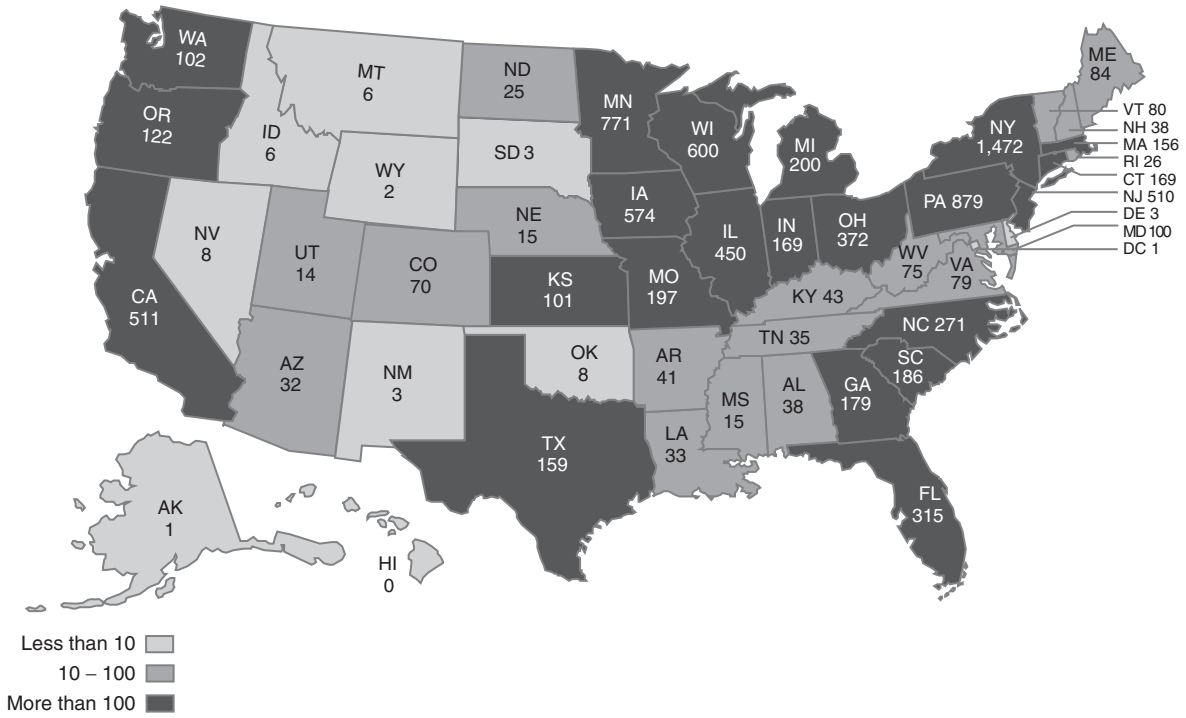


**Figure 10D.83** Number of curbside recycling programs. (From *BioCycle Magazine*, April 1999, www.epa.gov.)

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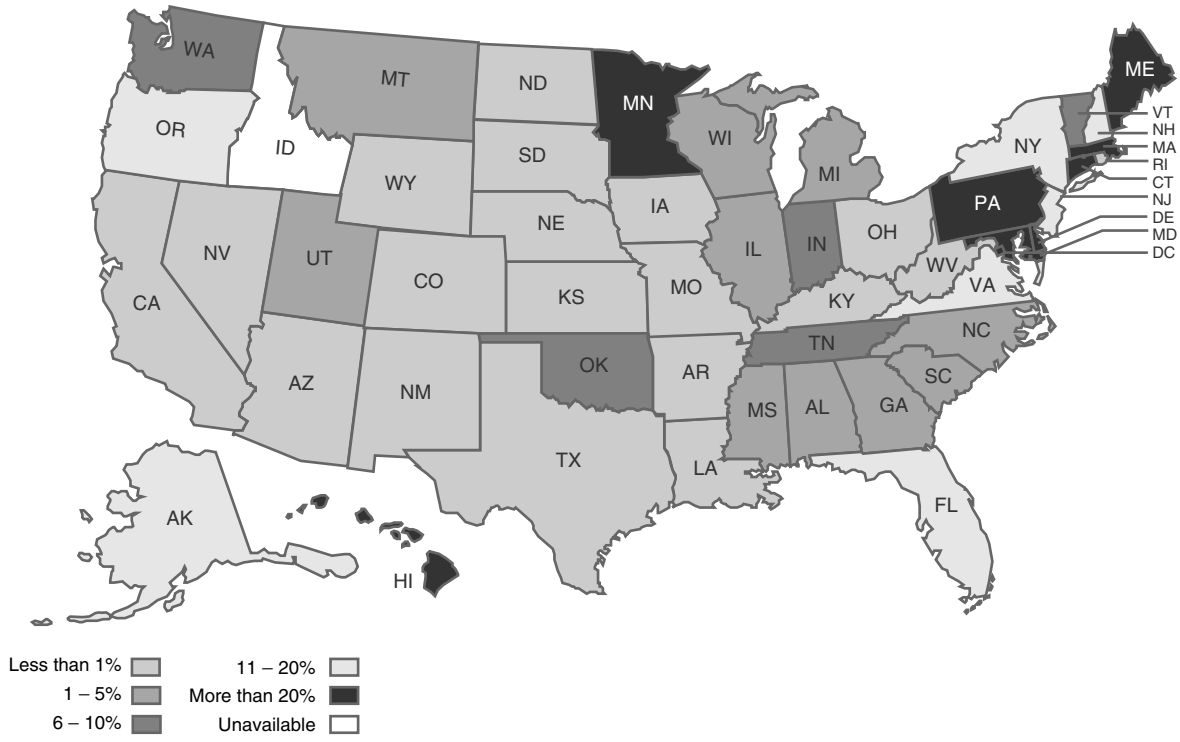


**Figure 10D.84** State combustion rates. (From *BioCycle Magazine*, April 1999, www.epa.gov.)

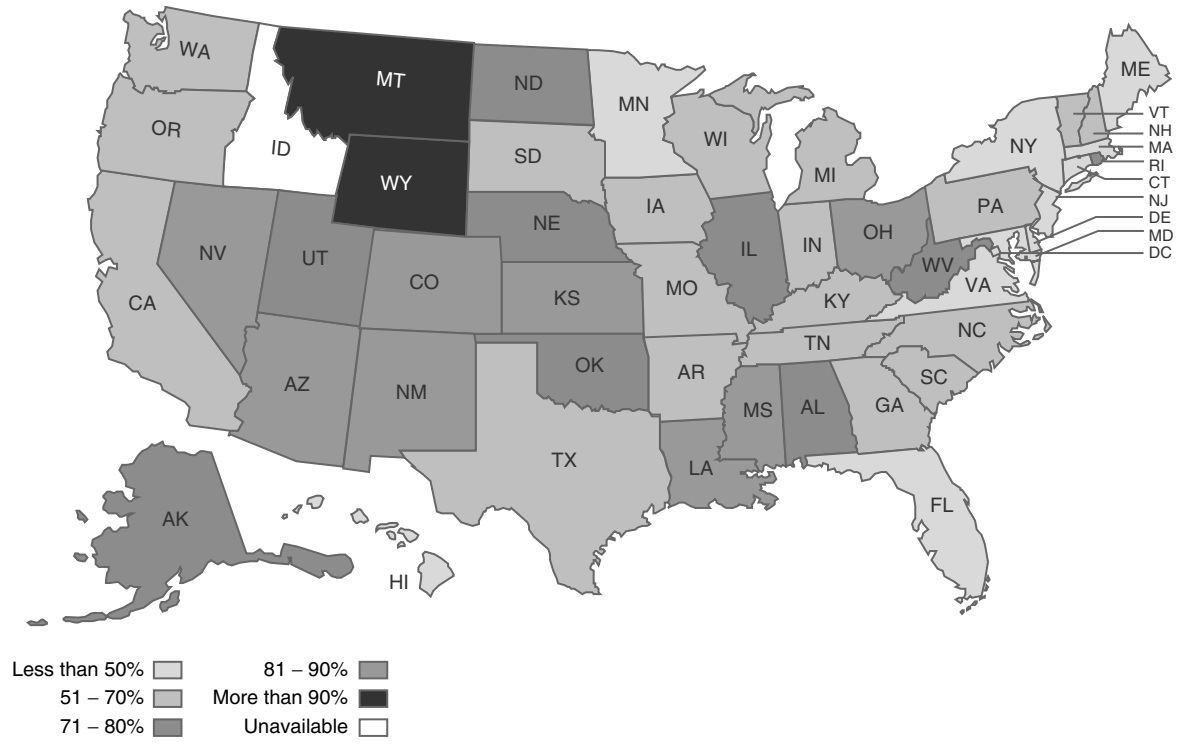


**Figure 10D.85** State land disposal rates. (From *BioCycle Magazine*, April 1999, www.epa.gov.)

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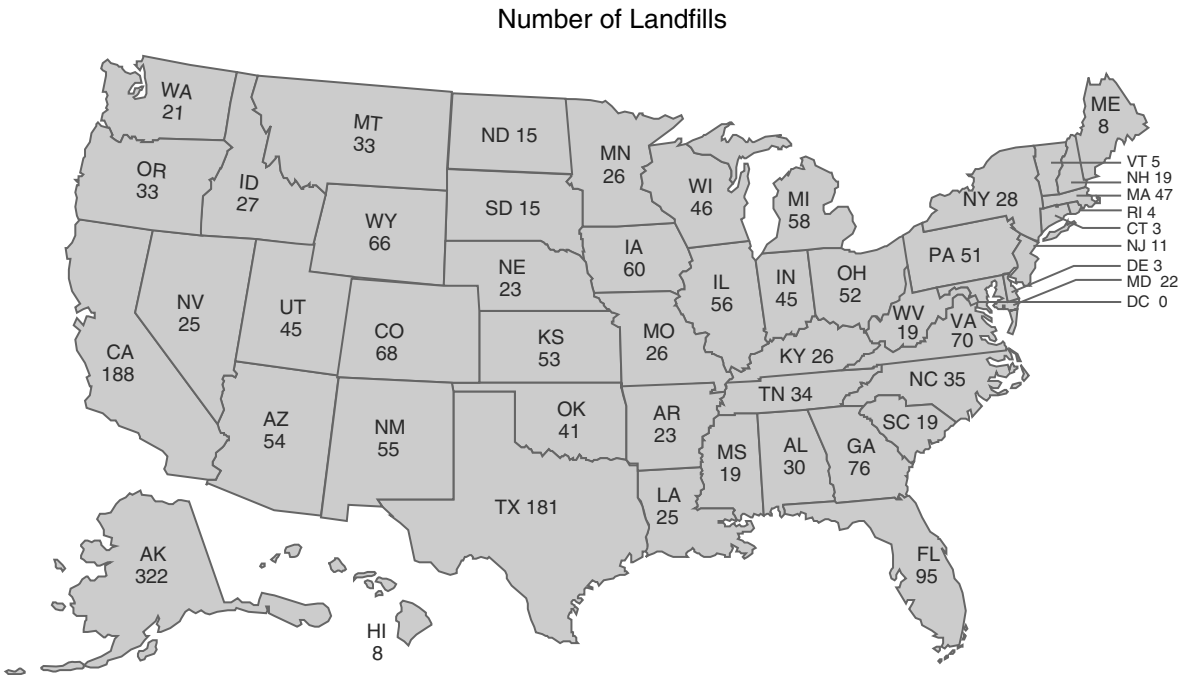


**Figure 10D.86** Number of landfills. (From *BioCycle Magazine*, April 1999, www.epa.gov.)

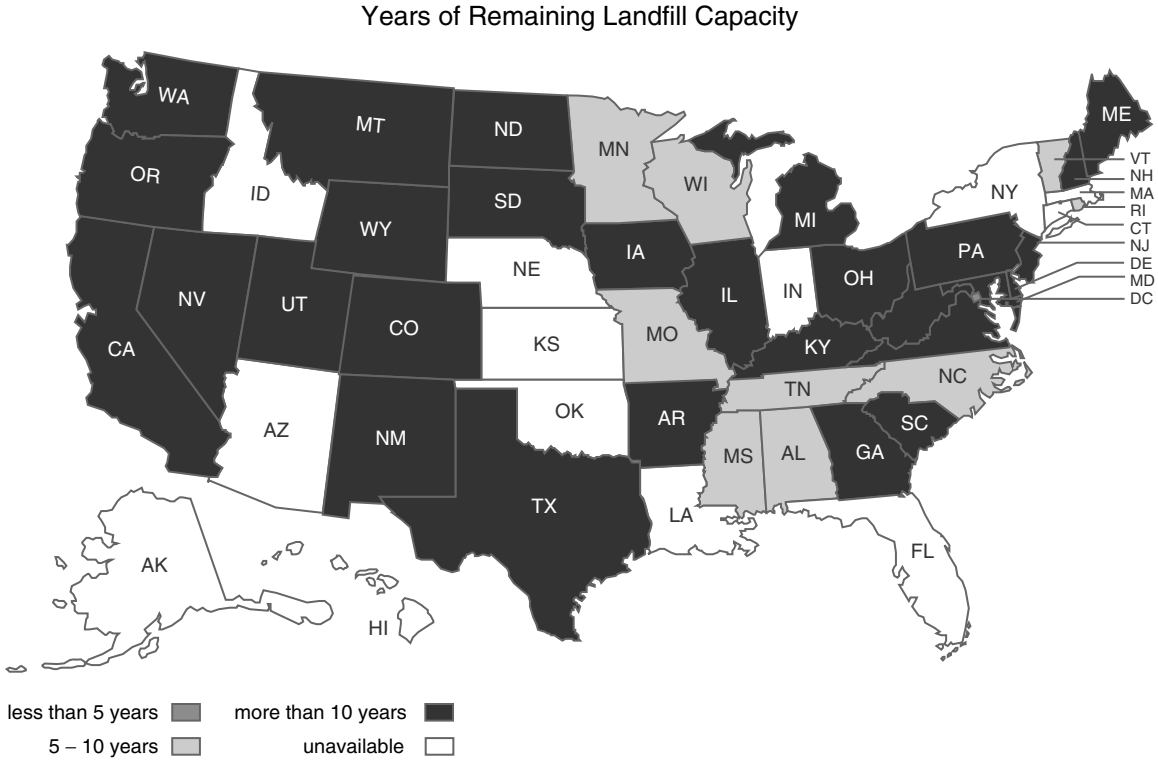


**Figure 10D.87** Years of remaining landfill capacity. (From *BioCycle Magazine*, April 1999, www.epa.gov.)

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**Table 10D.105 Composition of Municipal Solid Waste Discards by Organic and Inorganic Fractions in the United States, 1960–2000**

| Year | Organics | Inorganics |
|---|---|---|
| 1960 | 77.8 | 22.3 |
| 1965 | 78.3 | 21.7 |
| 1970 | 75.2 | 24.8 |
| 1975 | 75.5 | 24.5 |
| 1980 | 77.1 | 22.9 |
| 1981 | 77.5 | 22.5 |
| 1982 | 77.8 | 22.2 |
| 1983 | 78.7 | 21.3 |
| 1984 | 79.6 | 20.4 |
| 1985 | 80.4 | 19.6 |
| 1986 | 80.8 | 19.2 |
| 1990[a] | 80.8 | 19.2 |
| 1995[a] | 81.7 | 18.3 |
| 2000[a] | 82.5 | 17.5 |

*Note:* In percent of total net discards; discards after materials recovery has taken place, and before energy recovery.

[a] Estimate.

*Source*: From U.S. Environmental Protection Agency, 1988, *Characterization of Municipal Solid Waste in the United States 1960 to 2000 (Update 1988)*, PB88-232780. Based on study by Franklin Associates, Ltd.

**Table 10D.106 Composition of Municipal Solid Waste in the United States, 1960–2000**

| Materials | 1960 | 1965 | 1970 | 1975 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paper and paperboard | 24.5 | 32.2 | 36.5 | 34.4 | 42.0 | 43.6 | 41.4 | 45.8 | 49.4 | 48.7 | 50.1 | 54.9 | 60.2 | 66.0 |
| Glass | 6.4 | 8.5 | 12.5 | 13.2 | 14.2 | 14.3 | 11.8 | 13.3 | 12.8 | 12.2 | 11.8 | 12.3 | 12.2 | 12.0 |
| Metals | | | | | | | | | | | | | | |
| Ferrous | 9.9 | 10.0 | 12.4 | 12.0 | 11.2 | 11.1 | 11.0 | 11.1 | 11.0 | 10.4 | 10.6 | 11.1 | 11.3 | 11.3 |
| Aluminum | 0.4 | 0.5 | 0.8 | 1.0 | 1.4 | 1.4 | 1.3 | 1.5 | 1.5 | 1.6 | 1.7 | 2.0 | 2.4 | 2.7 |
| Other nonferrous | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 |
| Plastics | 0.4 | 1.4 | 3.0 | 4.4 | 7.6 | 7.8 | 8.4 | 9.1 | 9.6 | 9.7 | 10.3 | 11.8 | 13.7 | 15.6 |
| Rubber and leather | 1.7 | 2.2 | 3.0 | 3.7 | 4.1 | 4.1 | 3.8 | 3.4 | 3.3 | 3.4 | 3.9 | 3.5 | 3.6 | 3.8 |
| Textiles | 1.7 | 1.9 | 2.0 | 2.2 | 2.6 | 3.4 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 3.0 | 3.1 | 3.3 |
| Wood | 3.0 | 3.5 | 4.0 | 4.4 | 4.9 | 4.4 | 5.0 | 5.2 | 5.1 | 5.4 | 5.8 | 5.3 | 5.7 | 6.1 |
| Other | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Total nonfood product wastes | 48.2 | 60.5 | 74.7 | 75.6 | 88.6 | 90.5 | 87.8 | 92.6 | 95.9 | 94.5 | 97.4 | 104.2 | 112.5 | 121.3 |
| Food wastes | 12.2 | 12.4 | 12.8 | 13.4 | 11.9 | 12.1 | 12.0 | 12.0 | 12.2 | 12.3 | 12.5 | 12.5 | 12.4 | 12.3 |
| Yard wastes | 20.0 | 21.6 | 23.2 | 25.2 | 26.5 | 26.7 | 27.0 | 27.5 | 27.8 | 28.0 | 28.3 | 29.5 | 31.0 | 32.0 |
| Miscellaneous inorganic wastes | 1.3 | 1.6 | 1.8 | 2.0 | 2.2 | 2.3 | 2.4 | 2.4 | 2.4 | 2.5 | 2.6 | 2.8 | 3.0 | 3.2 |
| Total wastes discarded[a] | 81.7 | 96.1 | 112.5 | 116.2 | 129.2 | 131.6 | 129.1 | 134.5 | 138.3 | 137.3 | 140.8 | 149.0 | 158.9 | 168.8 |
| Energy recovery[b] | 0.0 | 0.2 | 0.4 | 0.7 | 2.7 | 2.3 | 3.5 | 5.0 | 6.5 | 7.6 | 9.6 | 13.3 | 22.5 | 32.0 |
| Net wastes discarded | 81.7 | 95.9 | 112.1 | 115.5 | 126.5 | 129.3 | 125.6 | 129.5 | 131.8 | 129.7 | 131.2 | 135.7 | 136.4 | 136.8 |

*Note:* In millions of tons.

[a] Wastes discarded after materials recovery has taken place.
[b] Municipal solid waste consumed for energy recovery. Does not include residues. Details may not add to totals due to rounding.

*Source*: From U.S. Environmental Protection Agency, 1988, *Characterization of Municipal Solid Waste in the United States 1960 to 2000 (Update 1988)*, PB88-232780. Based on a study prepared by Franklin Associates, Ltd.

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**Table 10D.107 Summary Data on Solid Waste Facilities in the United States**

| Percent of uncontrolled sites that are solid waste facilities | |
|---|---|
| Of 1,389 sites with actual or presumed problems of releases of hazardous substances | 18% |
| Of 550 sites on National Priority List | 20% |
| Two most prevalent effects at problem solid waste sites | |
| Leachate migration, groundwater pollution: at 89% of sites | |
| Drinking water contamination: at 49% of sites | |
| Mean size of problem solid wastes sites | 67.4 acres |
| Median hazard ranking score[a] | |
| Solid waste sites on the NPL | 40.8 |
| All NPL sites | 42.2 |
| Estimates for national number of solid waste sites | |
| Operating sanitary, municipal landfills | 14,000 |
| Closed sanitary, municipal landfills | 42,000 |
| Operating industrial landfills | 75,000 |
| Closed industrial landfills | 150,000 |
| Operating surface impoundments | 170,000 |
| Closed surface impoundments | 170,000 |
| Total | 621,000 |
| Estimate of need for future cleanup | |
| Low: 5% landfills, 1% impoundments likely to release toxic substances | 17,400 |
| High: 10% landfills, 2% impoundments likely to release toxic substances | 34,800 |
| Conservative figure used for cleanup by superfund | 5,000 |

[a] 28.5 required for placement on National Priorities List; current highest site score is 75.6.

*Source*: From Office of Technology Assessment, 1985.

**Table 10D.108 Solid Waste Disposal by Selected Industries in the United States, 1975–1983**

| | | | | | | | | | 1983 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Industry Group** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **Total** | **Hazardous Waste[a]** | **Non-hazardous Waste** |
| All industries[b] | 139.1 | 156.8 | 160.0 | 160.8 | 163.7 | 149.9 | 145.8 | 99.4 | 89.0 | 8.0 | 81.0 |
| Food | 12.6 | 15.0 | 13.1 | 13.4 | 14.0 | 14.4 | 13.2 | 9.8 | 9.6 | 0.2 | 9.4 |
| Lumber and wood | 8.1 | 9.3 | 6.3 | 6.7 | 6.5 | 5.9 | 6.4 | 3.7 | 4.0 | (Z) | 4.0 |
| Paper | 9.1 | 10.1 | 10.6 | 10.9 | 13.3 | 12.3 | 11.3 | 11.5 | 13.7 | 0.1 | 13.5 |
| Chemicals | 38.7 | 50.3 | 55.7 | 48.8 | 45.4 | 43.4 | 43.7 | 36.1 | 18.8 | 3.6 | 15.2 |
| Petroleum | 2.0 | 2.6 | 2.9 | 3.6 | 3.1 | 4.9 | 4.7 | 4.4 | 3.6 | 1.5 | 2.1 |
| Stone, clay, glass | 11.3 | 11.1 | 12.6 | 12.7 | 14.1 | 13.3 | 12.1 | 5.8 | 6.2 | 0.2 | 5.9 |
| Primary metal | 42.7 | 42.4 | 41.7 | 46.1 | 47.8 | 37.5 | 36.0 | 16.7 | 17.7 | 1.0 | 16.7 |
| Fabricated metals | 1.9 | 2.1 | 2.0 | 2.0 | 2.0 | 1.9 | 1.8 | 1.4 | 2.0 | 0.2 | 1.7 |
| Machinery exc. electrical | 2.7 | 3.1 | 3.6 | 3.4 | 3.5 | 3.0 | 2.8 | 1.6 | 1.8 | 0.2 | 1.7 |
| Electric equipment | 1.5 | 1.5 | 1.5 | 1.8 | 2.3 | 2.1 | 1.7 | 1.3 | 1.7 | 0.3 | 1.4 |
| Transportation equipment | 3.8 | 4.3 | 4.7 | 5.2 | 4.3 | 4.2 | 4.0 | 2.9 | 3.0 | 0.3 | 2.7 |

*Note:* In millions of short tons. Excludes recovered materials. Data included both wet and dry weight figures. Excludes apparel and other textiles, and, beginning 1978, establishments with less than 20 employees. Z, Less than 50,000 short tons.

[a] Covers waste, which because of its quantity, concentration, or physical, chemical, or infectious characteristics, may cause, or significantly contribute to an increase in serious irreversible, or incapacitating reversible illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of or managed. See Resource Conservation and Recovery Act 1976, Public Law 94-580, for listing of hazardous wastes.

[b] Includes industries not shown separately.

*Source*: From U.S. Department of Commerce, Statistical Abstract of the United States 1987.

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**Table 10D.109 Future Use of Containment Technologies for Cleanup of Hazardous Waste Sites in the United States**

| Technique | Applicability | Effectiveness | Confidence | Capital Cost | Cap/O&M | Projected Level of Use |
|---|---|---|---|---|---|---|
| Barriers | | | | | | |
| Slurry wall | 2 | 1 | 2 | 2 | 1 | Extensive |
| Grout curtain | 2–3 | 1 | 2 | 2–3 | 1 | Limited |
| Vibrating beam | 2 | 1 | 2–3 | 2–3 | 1 | Moderate |
| Sheet pile | 3 | 1–2 | 2 | 2–3 | 1 | Nil-Limited |
| Block displacement | 3 | 1 | 4 | 3 | 1 | Nil |
| Hydraulic controls (wells) | 2 | 1,3 | 1 | 1 | 3 | Extensive |
| Subsurface drains | 2 | 1 | 2 | 1 | 2 | Moderate |
| Runon/runoff controls | 1 | 3 | 1 | 1 | 2 | Extensive |
| Surface seals and caps | 1 | 2,3 | 2 | 1 | 1 | Extensive |
| Solidification, etc. | 2 | 1,3 | 3–4 | 2 | 1 | Moderate-Limited |

*Key*:
*Applicability*: (1) Very broadly applicable; little or no site dependency. (2) Broadly applicable; some sites unfavorable. (3) Limited to sites of specific characteristics. *Effectiveness*: (1) Can produce "leak-tight" containment. (2) Can reduce migration—some leakage likely. (3) Used as supporting technique in conjunction with other elements. *Confidence*: (1) Well proven—long-term effectiveness—high. (2) Well proven—long-term effectiveness—unknown. (3) Limited experience; used in other applications. (4) Developmental; little data. *Capital cost for function provided*: (1) Low. (2) Normal. (3) High. *Capital to operation and maintenance (O&M) cost ratio*: (1) Capital higher than O&M. (2) Capital about same as O&M. (3) Capital lower than O&M.

*Source*: From U.S. Congress, Office of Technology Assessment, 1985, *Superfund Strategy*.

*Original source*: Little, A.D., *Evaluation of Available Cleanup Technologies for Uncontrolled Sites*, contractor report prepared for the Office of Technology Assessment, Nov. 15, 1984.

**Table 10D.110 Future Use of Treatment Technologies for Cleanup of Hazardous Waste Sites in the United States**

| Technique | Applicability | Effectiveness | Confidence | Capital Cost | Cap/O&M | Secondary Disposal | Projected Level Use of |
|---|---|---|---|---|---|---|---|
| Biological treatment | Or, 1–2 | 2 | 1 | 1 | 1–2 | 3 | Moderate |
| Chemical treatment | | | | | | | |
| Neutralization/precipitation | In, 1 | 1 | 1 | 1 | 2 | 4 | Moderate–Extensive |
| Wet air oxidation | Or, 2 | 2 | 2 | 3 | 1–2 | 1 | Limited |
| Chlorination | In, 3 | 1 | 2 | 2 | 2 | 1 | Limited |
| Ozonation | Or, 3 | 2 | 3 | 3 | 2–3 | 2 | Nil |
| Reduction (Cr) | In, 3 | 1 | 2 | 2 | 2 | 3 | Limited |
| Physical treatment | | | | | | | |
| Carbon adsorption | Or, In, 1 | 1 | 1 | 2 | 2–3 | 2–3 | Moderate–Extensive |
| Sedimentation/filtration | Or, In, 1 | 1 | 1 | 1 | 2–3 | 4 | Moderate–Extensive |
| Stripping | Or, 2 | 1 | 1 | 1 | 2 | 4 | Moderate |
| Flotation | Or, 2 | 2 | 1 | 1 | 1 | 4 | Limited |
| Ion exchange | In, 3 | 1–3 | 3 | 3 | 3 | 4 | Nil |
| Reverse osmosis | Or, In, 3 | 1–2 | 3 | 3 | 3 | 4 | Nil |
| Gas stream controls | | | | | | | |
| Thermal oxidation | Or, 1 | 1 | 1 | 3 | 3 | 1 | Limited–Moderate |
| Carbon adsorption | Or, 1 | 1 | 1 | 3 | 2–3 | 2–3 | Limited–Moderate |

*(Continued)*

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**Table 10D.110 (Continued)**

| Technique | Applicability | Effectiveness | Confidence | Capital Cost | Cap/O&M | Secondary Disposal | Projected Level Use of |
|---|---|---|---|---|---|---|---|
| Incineration | | | | | | | |
| Onsite | Or, 1 | 1 | 2 | 3 | 1 | 3[a] | Limited |
| Offsite | Or, 1 | 1 | 1 | 3 | NA | 3[b] | Moderate |
| *In situ* biodegradation | Or, 3 | 2 | 3 | 2 | 3 | 1 | Limited |

*Key*:
*Class*: Or, Organic compounds. In, Inorganic compounds. *Range*: (1) Broadly applicable to compounds in indicated class. (2) Moderated applicable: depends on waste composition concentration. (3) Limited to special situations. *Effectiveness*: (1) Highest levels available. (2) Output may need further treatment; may have pockets untreated (in situ). *Confidence*: (1) Well proven—easily transferable to site cleanup. (2) Well proven—but not in clean-up settings. (3) Limited experience. (4) Developmental; little data. *Capital cost for function provided*: (1) Low. (2) Normal. (3) High. *Capital to operations and maintenance (O&M) cost basis*: (1) Capital higher than O&M. (2) Capital about the same. (3) Capital lower than O&M. *Secondary treatment or disposal*: (1) None. (2) Minor. (3) Major, but does not require hazardous waste techniques. (4) Basically a separation process; must be used with subsequent hazardous waste treatment or secure disposal step.

[a] Must dispose solid residues.
[b] Depends on reactive material used.

*Source*: From U.S. Congress, Office of Technology Assessment, 1985, Superfund Strategy.

*Original Source*: Little, A.D., *Evaluation of Available Cleanup Technologies for Uncontrolled Sites*, contractor report prepared for the Office of Technology Assessment, Nov. 15, 1984.

**Table 10D.111 Generation, Materials Recovery, Composting, and Discards of Municipal Solid Waste, 1960–2001**

| | Millions of Tons | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1960 | 1970 | 1980 | 1990 | 1995 | 1999 | 2000 | 2001 |
| Generation | 88.1 | 121.1 | 151.6 | 205.2 | 213.7 | 231.4 | 232.0 | 229.2 |
| Recovery for recycling | 5.6 | 8.0 | 14.5 | 29.0 | 46.2 | 50.8 | 51.2 | 51.4 |
| Recovery for composting[a] | Neg. | Neg. | Neg. | 4.2 | 9.6 | 14.7 | 16.5 | 16.6 |
| Total materials recovery | 5.6 | 8.0 | 14.5 | 33.2 | 55.8 | 65.5 | 67.7 | 68.0 |
| Discarded after recovery | 82.5 | 113.0 | 137.1 | 172.0 | 158.0 | 165.9 | 164.3 | 161.2 |

*Note:* In millions of tons. Details may not add to totals due to rounding.

[a] Composting of yard trimmings, food scraps and other MSW organic material. Does not include backyard composting.

*Source*: From Franklin Associates, Ltd., www.epa.gov/epaoswer.

**Table 10D.112 Generation, Materials Recovery, Composting, and Discard of Municipal Solid Waste, 1960–2001**

| | Percent of Total Generation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1960 | 1970 | 1980 | 1990 | 1995 | 1999 | 2000 | 2001 |
| Generation (%) | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Recovery for recycling (%) | 6.4 | 6.6 | 9.6 | 14.2 | 21.6 | 22.0 | 22.1 | 22.4 |
| Recovery for composting (%)[a] | Neg. | Neg. | Neg. | 2.0 | 4.5 | 6.4 | 7.1 | 7.2 |
| Total materials recovery (%) | 6.4 | 6.6 | 9.6 | 16.2 | 26.1 | 28.4 | 29.2 | 29.7 |
| Discarded after recovery (%) | 93.6 | 93.4 | 90.4 | 83.8 | 73.9 | 71.6 | 70.8 | 70.3 |

*Note:* In percent of total generation. Details may not add to totals due to rounding.

[a] Composting of yard trimmings, food scraps and other MSW organic material. Does not include backyard composting.

*Source*: From Franklin Associates, Ltd., www.epa.gov/epaoswer.

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**Table 10D.113 Generation and Recovery of Materials in MSW, 2001**

| | Weight Generated | Weight Recovered | Recovery as a Percent of Generation (%) |
|---|---|---|---|
| Paper and paperboard | 81.9 | 36.7 | 44.9 |
| Glass | 12.6 | 2.4 | 19.1 |
| Metals | | | |
| Steel | 13.5 | 4.6 | 33.8 |
| Aluminum | 3.2 | 0.8 | 24.5 |
| Other nonferrous metals[a] | 1.4 | 0.9 | 64.8 |
| *Total metals* | 18.1 | 6.3 | 34.5 |
| Plastics | 25.4 | 1.4 | 5.5 |
| Rubber and leather | 6.5 | 1.1 | 17.4 |
| Textiles | 9.8 | 1.4 | 14.6 |
| Wood | 13.2 | 1.3 | 9.5 |
| Other materials | 4.2 | 0.9 | 20.7 |
| *Total materials in products* | 171.5 | 51.4 | 30.0 |
| Other wastes | | | |
| Food, other[b] | 26.2 | 0.7 | 2.8 |
| Yard trimmings | 28.0 | 15.8 | 56.5 |
| Miscellaneous inorganic wastes | 3.5 | Neg. | Neg. |
| *Total other wastes* | 57.7 | 16.6 | 28.7 |
| *Total municipal solid waste* | 229.2 | 68.0 | 29.7 |

*Note:* In millions of tons and percent of generation of each material. Includes waste from residential, commercial, and institutional sources. Neg., less than 5,000 tons or 0.05 percent.

[a] Includes lead from lead–acid batteries.
[b] Includes recovery of other MSW organics for composting.

*Source*: From Franklin Associates, Ltd., www.epa.gov/epaoswer.

**Table 10D.114 Generation and Recovery by Products in MSW by Material, 2001**

| | Weight Generated | Weight Recovered | Recovery as a Percent of Generation (%) |
|---|---|---|---|
| **Durable goods** | | | |
| Steel | 10.9 | 3.0 | 27.8 |
| Aluminum | 1.0 | Neg. | Neg. |
| Other nonferrous metals[a] | 1.4 | 0.9 | 64.8 |
| *Total metals* | 13.3 | 4.0 | 29.6 |
| Glass | 1.7 | Neg. | Neg. |
| Plastics | 8.0 | 0.3 | 3.9 |
| Rubber and leather | 5.6 | 1.1 | 20.1 |
| Wood | 5.0 | Neg. | Neg. |
| Textiles | 2.9 | 0.3 | 118.8 |
| Other materials | 1.2 | 0.9 | 73.7 |
| *Total durable goods* | 37.6 | 3.6 | 17.5 |
| **Nondurable goods** | | | |
| Paper and paperboard | 43.5 | 15.6 | 35.9 |
| Plastics | 6.1 | Neg. | Neg. |
| Rubber and leather | 0.9 | Neg. | Neg. |
| Textiles | 6.7 | 1.1 | 16.1 |
| Other materials | 3.2 | Neg. | Neg. |
| *Total nondurable goods* | 60.4 | 16.7 | 27.7 |
| **Containers and packaging** | | | |
| Steel | 2.6 | 1.5 | 58.8 |
| Aluminum | 2.0 | 0.8 | 40.0 |
| *Total metals* | 4.6 | 2.3 | 50.8 |

*(Continued)*

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**Table 10D.114 (Continued)**

| | Weight Generated | Weight Recovered | Recovery as a Percent of Generation (%) |
|---|---|---|---|
| Glass | 10.9 | 2.4 | 22.0 |
| Paper and paperboard | 38.4 | 21.1 | 55.0 |
| Plastics | 11.2 | 1.1 | 9.6 |
| Wood | 8.2 | 1.3 | 15.2 |
| Other materials | 0.2 | Neg. | Neg. |
| *Total containers and packaging* | 73.5 | 28.1 | 38.3 |
| **Other wastes** | | | |
| Food, other[b] | 26.2 | 0.7 | 2.8 |
| Yard trimmings | 28.0 | 15.8 | 56.5 |
| Miscellaneous inorganic wastes | 3.5 | Neg. | Neg. |
| *Total other wastes* | 57.7 | 16.5 | 28.7 |
| *Total municipal solid waste* | 229.2 | 68.0 | 29.7 |

*Note:* In millions of tons and percent of generation of each product. Includes waste from residential, commercial, and institutional sources. Details may not add to totals due to rounding. Neg., less than 5,000 tons or 0.05 percent.

[a] Includes lead from lead–acid batteries.
[b] Includes recovery of other MSW organics for composting.

*Source*: From Franklin Associates, Ltd., www.epa.gov/epaoswer.

**Table 10D.115 Projections of Materials Generated in the Municipal Waste Stream: 2000 and 2005**

| | Million Tons | | % Of Total | |
|---|---|---|---|---|
| **Materials** | **2000** | **2005** | **2000** | **2005** |
| Paper and paperboard | 87.7 | 94.8 | 39.3 | 39.6 |
| Glass | 11.9 | 11.2 | 5.3 | 4.7 |
| Metals | 17.6 | 18.7 | 7.9 | 7.8 |
| Plastics | 23.4 | 26.7 | 10.5 | 11.2 |
| Wood | 14.0 | 15.8 | 6.3 | 6.6 |
| Others | 19.7 | 22.2 | 8.8 | 9.3 |
| *Total materials in products* | 174.3 | 189.4 | 78.1 | 79.1 |
| **Other wastes** | | | | |
| Food wastes | 22.5 | 23.5 | 10.1 | 9.8 |
| Yard trimmings | 23.0 | 23.0 | 10.3 | 9.6 |
| Miscellaneous inorganic wastes | 3.4 | 3.6 | 1.5 | 1.5 |
| *Total other wastes* | 48.9 | 50.1 | 21.9 | 20.9 |
| *Total MSW generated* | 223.2 | 239.5 | 100.0 | 100.0 |

*Note:* In thousands of tons and percent of total generation. Generation before materials recovery or combustion. Details may not add to totals due to rounding.

*Source*: From Franklin Associates, www.epa.gov/epaoswer.

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**Table 10D.116 Median Concentrations of Substances Found in MSW Landfill Leachate, in Comparison with Existing Exposure Standards**

| Substance[a] | Median Concentration (ppm) | Exposure Standards | |
|---|---|---|---|
| | | Type[f] | Value (ppm) |
| *Inorganics* | | | |
| Animony (11) | **4.52** | T | 0.01 |
| Arsenic (72) | 0.042 | N | 0.05 |
| Barium (60) | 0.853 | N | 1.0 |
| Beryllium (6) | 0.006 | T | 0.2 |
| Cadmium (46) | **0.022** | N | 0.01 |
| Chromium (total) (97) | **0.175** | N | 0.05 |
| Copper (68) | **0.168** | | 0.012 |
| | | W | 0.018 |
| Cyanide (21) | 0.063 | | 0.7 |
| Iron (120) | 221 | W | 1,000 |
| Lead (73) | **0.162** | N | 0.05 |
| Manganese (103) | **9.59** | W | 0.05 |
| Mercury (19) | 0.002 | N | 0.002 |
| Nickel (98) | **0.326** | T | 0.07 |
| Nitrate (38) | 1.88 | W | 10 |
| Selenium (18) | **0.012** | N | 0.01 |
| Silver (19) | 0.021 | N | 0.05 |
| Thallium (11) | **0.175** | W | 0.04 |
| Zinc (114) | **8.32** | W | 0.110 |
| *Organics* | | | |
| Acrolein (1) | | W | 21 |
| Benzene (35) | | T | 5 |
| Bromomethane (1) | **170** | T | 10 |
| Carbon tetrachloride (2) | **202** | T | 5 |
| Chlorobenzene (12) | 128 | T | 1,000 |
| Chloroform (8) | **195** | C | 5.7 |
| Bis(chloromethyl) ether (1) | **250** | C | 0.0037 |
| *p*-Cresol (10) | **2,394** | T | 2,000 |
| 2,4-D (7) | **129** | T | 100 |
| 4,4-DDT (16) | **0.103** | C | 0.1 |
| Di-*n*-butyl phthalate (5) | 70.2 | T | 4,000 |
| 1,2-Dichlorobenzene (8) | 11.8 | W | 763 |
| 1,4-Dichlorobenzene (12) | 13.2 | | |
| Dichlorodifluoromethane (6) | 237 | T | 7,000 |
| 1,1-Dichloroethane (34) | **1,715** | | 7 |
| | | N | 0.58 |
| 1,2-Dichloroethane (6) | **1,841** | T | 5 |
| 1,2-Dichloropropane (12) | 66.7 | W | 5,700 |
| 1,3-Dichloropropane (2) | | C | 0.19 |
| Diethyl phthalate (27) | 118 | | 30,000 |
| 2,4-Dimethyl phenol (2) | | W | 2,120 |
| Dimethyl phthalate (2) | 42.5 | W | 313,000 |
| Endrin (3) | **16.8** | T | 0.2 |
| Ethyl benzene (41) | 274 | W | 1,400 |
| Bis(2-ethylhexyl) phthalate (10) | 184 | T | |
| Isophorone (19) | 1,168 | W | 5,200 |
| Lindane (2) | 0.020 | T | 4 |
| Methylene chloride (68) | **5,352** | C | 4.7 |
| Methyl ethyl ketone (24) | **4,151** | W | 2,000 |
| Naphthalene (23) | 32.4 | W | 620 |
| Nitrobenzene (3) | **54.7** | T | 20 |
| 4-Nitrophenol (1) | 17 | W | 150 |
| Pentachlorophenol (3) | 173 | T | 1,000 |
| Phenol (45) | **2,456** | T | 1,000 |
| 1,1,2,2-Tetrachloroethane (1) | **210** | C | 1.75 |

*(Continued)*

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**Table 10D.116 (Continued)**

| Substance[a] | Median Concentration (ppm) | Exposure Standards | |
|---|---|---|---|
| | | Type[/] | Value (ppm) |
| Tetrachloroethylene (18) | **132** | C | 6.9 |
| Toluene (69) | 1,016 | T | 10,000 |
| Toxaphene (1) | 1 | N | 5 |
| 1,1,1-Trichloroethane (20) | **887** | N | 200 |
| | | T | 3,000 |
| 1,1,2-Trichloroethane (4) | **378** | C | 6.1 |
| Trichloroethylene (28) | **187** | N | 5 |
| | | T | 3.2 |
| Trichlorofluoromethane (10) | 56.1 | T | 10,000 |
| 1,2,3-Trichloropropane (1) | **230** | T | 20 |
| Vinyl chloride (10) | **36.1** | N | 2 |

*Note:* Types of exposure standards: C, EPA Human Health Criteria, based on carcenogenicity; N, National Interim Primary or Secondary Drinking Water Standard; T, EPA Human Health Criteria, based on systemic toxicity; W, Water-Quality Criteria.

[a] Number of samples in parentheses.

*Source*: From After U.S. Environmental Protection Agency, *Office of Solid Waste*, *Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics*, *Criteria for Municipal Solid Waste Landfills (40 CFR Pert 258)*, EPA/530-SW-88-038 (Washington, DC: July 1988), princeton.edu/cgi-bin.

**Table 10D.117 NPL Status (June 2004)**

| Number of Sites on Final NPL | |
|---|---|
| Total | 1,245 |
| General superfund section | 1,087 |
| Federal facilities section | 158 |
| Number of sites remaining on proposed NPL | |
| Total | 56 |
| General superfund section | 50 |
| Federal facilities section | 6 |
| Total number of final and proposed sites | 1,301 |
| Number of sites on the construction completion list | 899 |
| Number of sites deleted from final NPL | 282 |
| Number of sites with partial deletions | 45 partial deletions at 37 sites |

*Note:* These numbers reflect the status of sites as of June 29, 2004. Site status changes occurring after this date may affect these numbers at time of rule publication in the **Federal Register**.

*Source*: From www.epa.gov/superfund/sites.

**Table 10D.118 Number of NPL Site Actions and Milestones by Fiscal Year**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Action | | | | | | | | | | | | | | |
| Sites proposed to the NPL | 30 | 52 | 36 | 9 | 27 | 20 | 34 | 37 | 40 | 45 | 9 | 14 | 26 | 7 |
| Sites finalized on the NPL | 0 | 33 | 43 | 31 | 13 | 18 | 17 | 43 | 39 | 29 | 19 | 20 | 11 | 11 |
| Sites deleted from the NPL | 2 | 12 | 13 | 25 | 34 | 32 | 20 | 23 | 19 | 30 | 17 | 9 | 16 | 6 |
| *Milestone* | | | | | | | | | | | | | | |
| Partial deletions[a] | — | — | — | — | 0 | 6 | 7 | 3 | 5 | 4 | 7 | 7 | 7 | 4 |
| Construction completion | 88 | 68 | 61 | 68 | 64 | 88 | 87 | 85 | 87 | 48 | 42 | 40 | 40 | 7 |

*Note:* A fiscal year is October 1 through September 30. Partial deletion totals are not applicable until fiscal year 1996, when the policy was first implemented.

[a] These totals represent the total number of partial deletions by fiscal year and may include multiple partial deletions at a site. Currently, there are 50 partial deletions at 42 sites.

*Source*: From www.epa.gov/superfund/sites.

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**Table 10D.119 NPL Site Totals by Status and Milestone as of May 19, 2005**

| | Nonfederal (General) | Federal | Total Sites |
|---|---|---|---|
| *Status* | | | |
| Proposed sites | 58 | 6 | 64 |
| Final sites | 1,085 | 159 | 1,244 |
| Deleted sites | 283 | 13 | 296 |
| *Milestone* | | | |
| Partial deletions | 32 | 10 | 42[a] |
| Construction completions | 890 | 43 | 933 |

*Note:* Sites that have achieved these milestones are included in one of the three NPL status categories.

[a] 50 partial deletions have occurred at these 42 sites.

*Source*: From www.epa.gov/superfund.

**Table 10D.120 Municipal Landfills in the United States and Protectorates**

| State | Number of Active Municipal Landills |
|---|---|
| Alabama | 28 |
| Alaska | 217 |
| Arizona | 59 |
| Arkansas | 67 |
| California | 278 |
| Colorado | 72 |
| Connecticut | 11 |
| Delaware | 3 |
| Florida | 67 |
| Georgia | 159 |
| Hawaii | 10 |
| Idaho | 37 |
| Illinois | 61 |
| Indiana | 32 |
| Iowa | 77 |
| Kansas | 58 |
| Kentucky | 12 |
| Louisiana | 29 |
| Maine | 27 |
| Maryland | 25 |
| Massachusetts | 106 |
| Michigan | 54 |
| Minnesota | 26 |
| Mississippi | 14 |
| Missouri | 30 |
| Montana | 82 |
| Nebraska | 21 |
| Nevada | 56 |
| New Hampshire | 33 |
| New Jersey | 14 |
| New Mexico | 79 |
| New York | 42 |
| North Carolina | 114 |
| North Dakota | 12 |
| Ohio | 63 |
| Oklahoma | 94 |
| Oregon | 88 |
| Pennsylvania | 47 |
| Rhode Island | 4 |
| South Carolina | 37 |
| South Dakota | 13 |
| Tennesee | 81 |
| Texas | 678 |
| Utah | 54 |

*(Continued)*

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**Table 10D.120 (Continued)**

| State | Number of Active Municipal Landills |
|---|---|
| Vermont | 61 |
| Virginia | 152 |
| Washington | 25 |
| West Virginia | 22 |
| Wisconsin | 46 |
| Wyoming | 59 |
| *Subtotal* | 3,536 |
| Protectorates | |
| American Samoa | 4 |
| Guam | 3 |
| Northern Mariana Islands | 3 |
| Puerto Rico | 33 |
| U.S. Virgin Islands | 2 |
| *Total* | 3,581 |

*Source*: From ERG Estimates. 20-Mar-96, www.epa.gov/epaoswer/non-hw.

**Table 10D.121 Number and Population Served by Curbside Recyclables Collection Programs, 2001**

| Region | Number of Programs | Population (in 1000) | Population Served (in 1000) | Population Served Percent (%)[a] |
|---|---|---|---|---|
| Northeast | 3,421 | 53,805 | 43,981 | 82 |
| South | 1,677 | 101,833 | 26,496 | 26 |
| Midwest | 3,572 | 64,687 | 25,851 | 40 |
| West | 1,034 | 62,612 | 43,038 | 69 |
| *Total* | 9,704 | 233,931 | 139,366 | 60 |
| *Percent of total U.S. population* | | | | 49 |

[a] Percent of population served by curbside programs was calculated using population of states reporting data.

*Source*: From U.S. Census Bureau 2002, *BioCycle* December 2001, www.epa.gov/epaoswer/non-hw.

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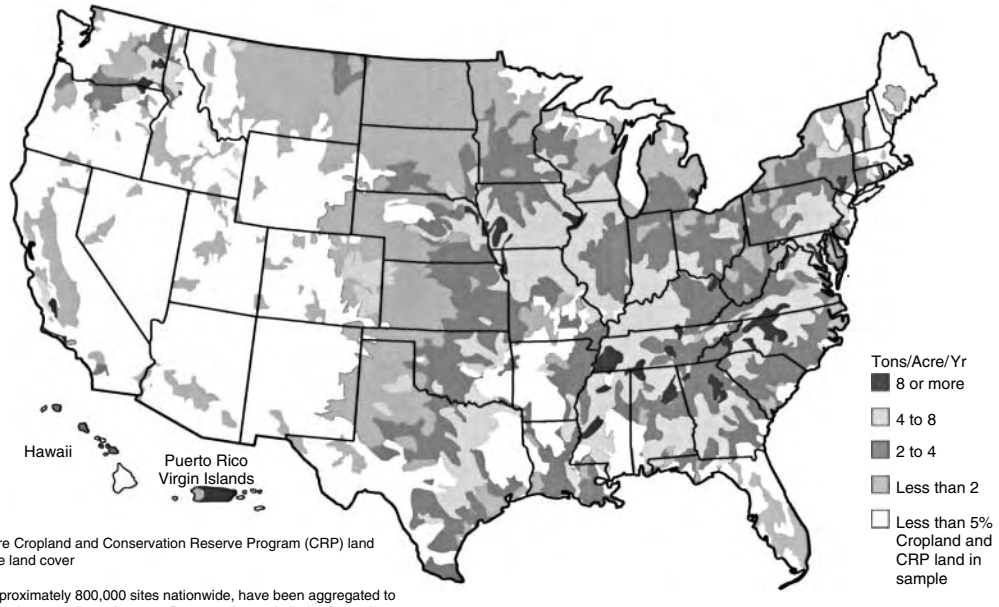
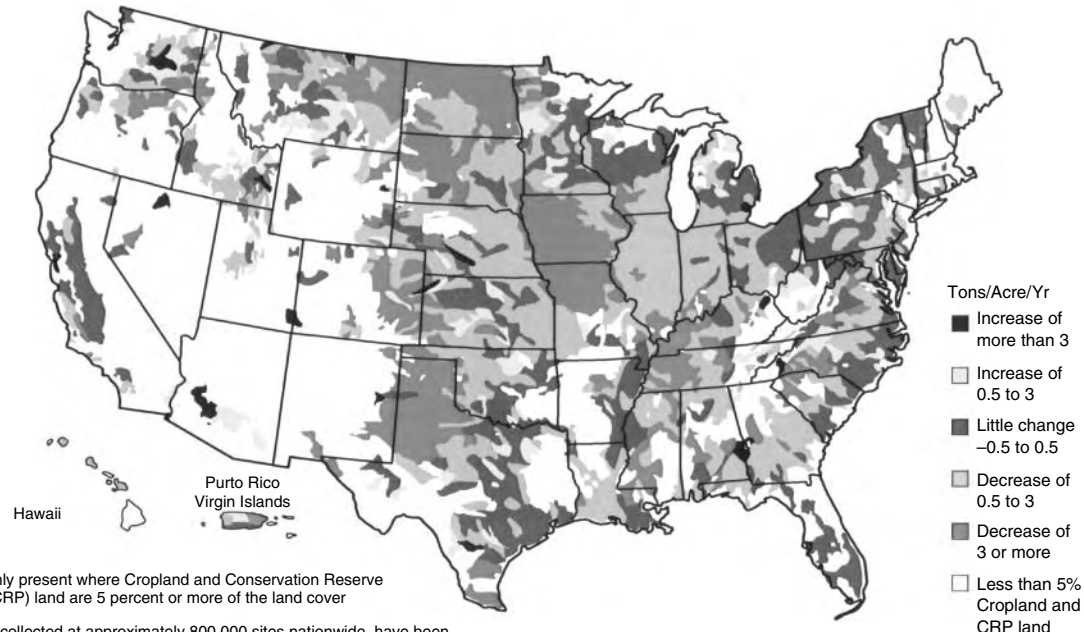
## SECTION 10E AGRICULTURAL ACTIVITIES




*Note:* Data are only present where Cropland and Conservation Reserve Program (CRP) land are 5 percent or more of the land cover

NRI sample data, collected a1 approximately 800,000 sites nationwide, have been aggregated to create estimates for USGS hydrologic cataloging unit areas. Because the statistical valiance in some of these areas may be large, the map reader should use this map only to identify broad spatial trends and avoid making highly localised interpretations

**Figure 10E.88** Average annual soil erosion by water on cropland and conservation reserve program land in the United States, 1992. (From United States Department of Agriculture, Natural Resources Conservation Services, 1997, *Water Quality and Agriculture, Status, Conditions, and Trends*, www.nrcs.usda.gov.)




*Note:* Data are only present where Cropland and Conservation Reserve Program (CRP) land are 5 percent or more of the land cover

NRI sample data, collected at approximately 800,000 sites nationwide, have been aggregated to create estimates for USGS hydrologic cataloging unit areas. Because the statistical vadance In some of these areas may be large, the map reader should use this map only to identify broad spatial trends and avoid making highly localized interpretations

**Figure 10E.89** Change in average annual soil erosion by wind and water on cropland and conservation reserve program land in the United States, 1982–1992. (From United States Department of Agriculture, Natural Resources Conservation Services, 1997, *Water Quality and Agriculture, Status, Conditions, and Trends*, www.nrcs.usda.gov.)

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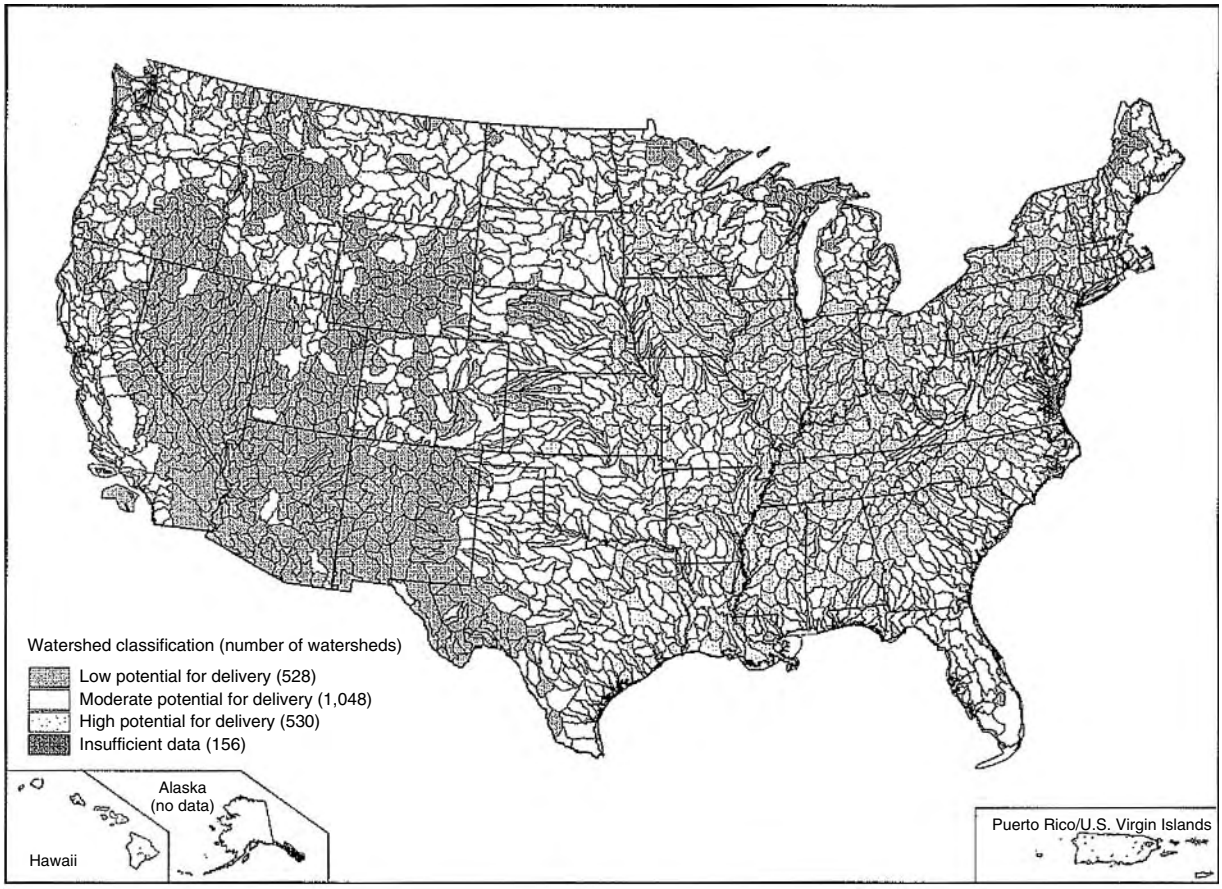


**Figure 10E.90** Sediment runoff potential from croplands and pasture lands, 1990–1995. (From United States Environmental Protection Agency, 2003, *EPA's Draft Report on the Environment, 2003*, EPA 600-R-03-050, www.epa.gov in the United States.)

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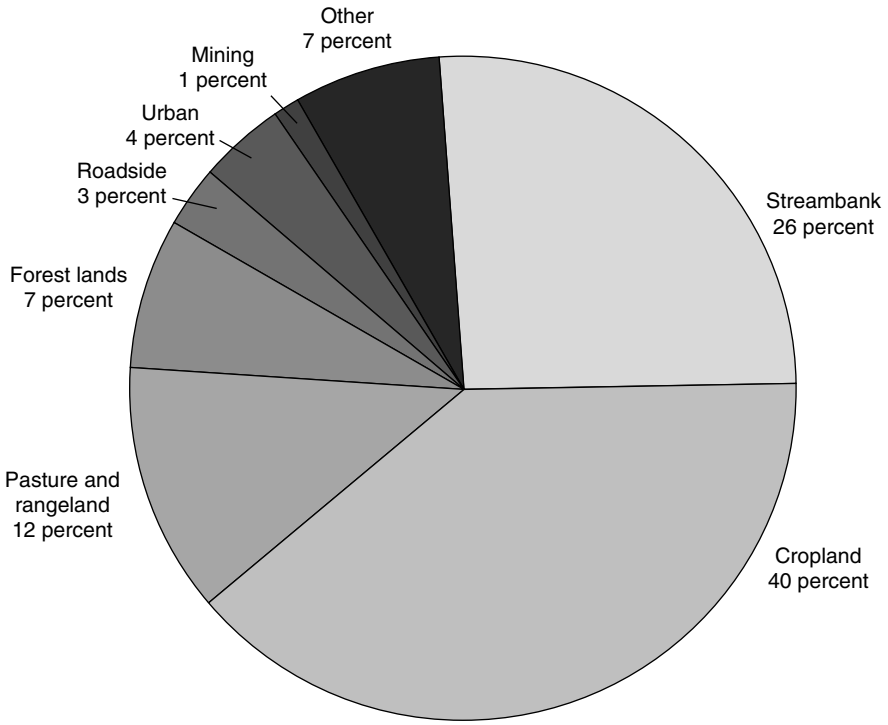


**Figure 10E.91** Sources of sediment discharge to surface waters in the United States, 1977. (From United States Department of Agriculture, Soil Conservation Service, 1978, *Environmental Impact Statement: Rural Clean Water Program.*)

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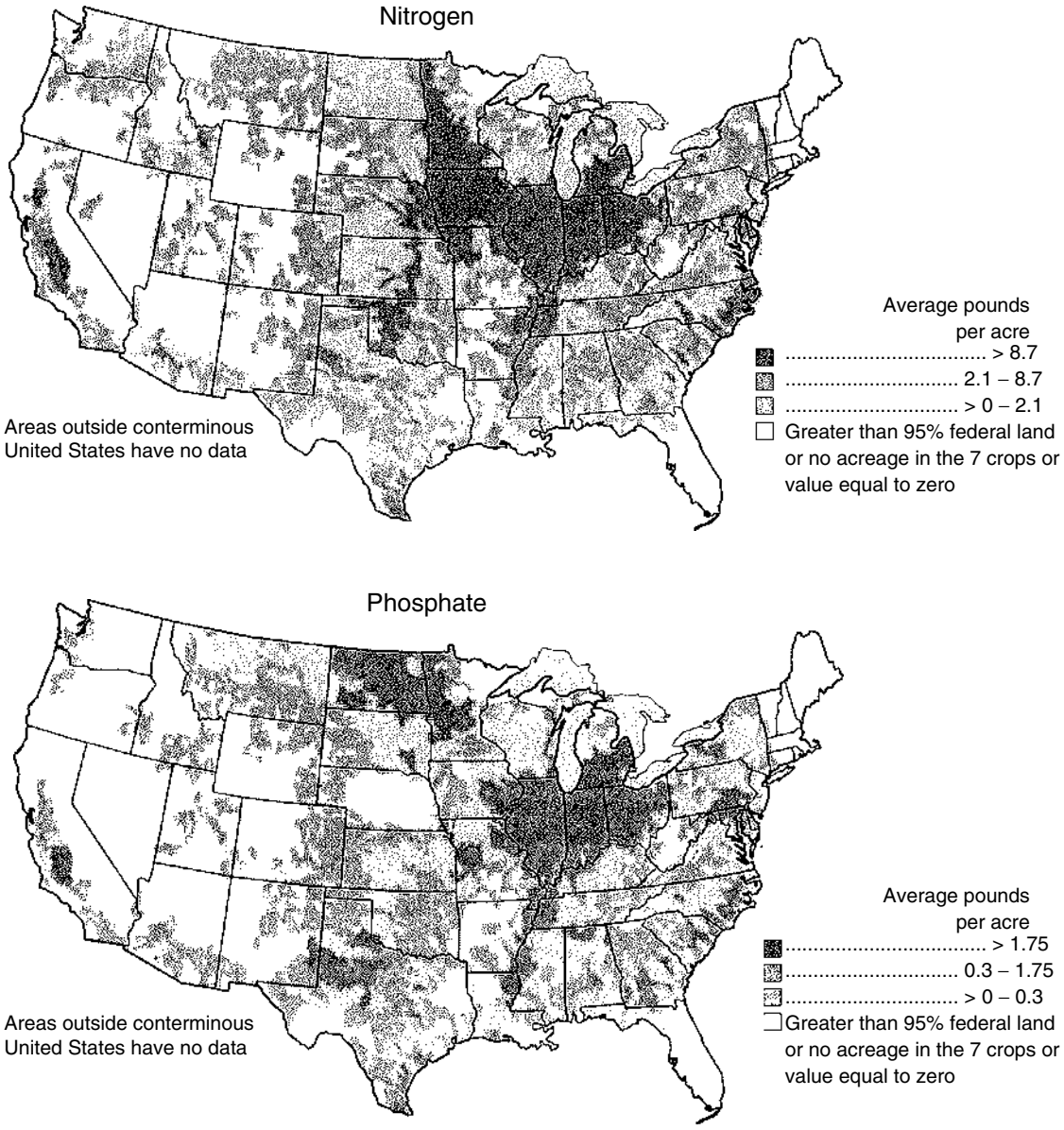


**Figure 10E.92** Potential nitrogen and phosphate fertilizer loss from farm fields. (From United States Department of Agriculture, Natural Resources Conservation Services, 1997, *Water Quality and Agriculture, Status, Conditions, and Trends, Working Paper No. 16*, www.nrcs.usda.gov.)

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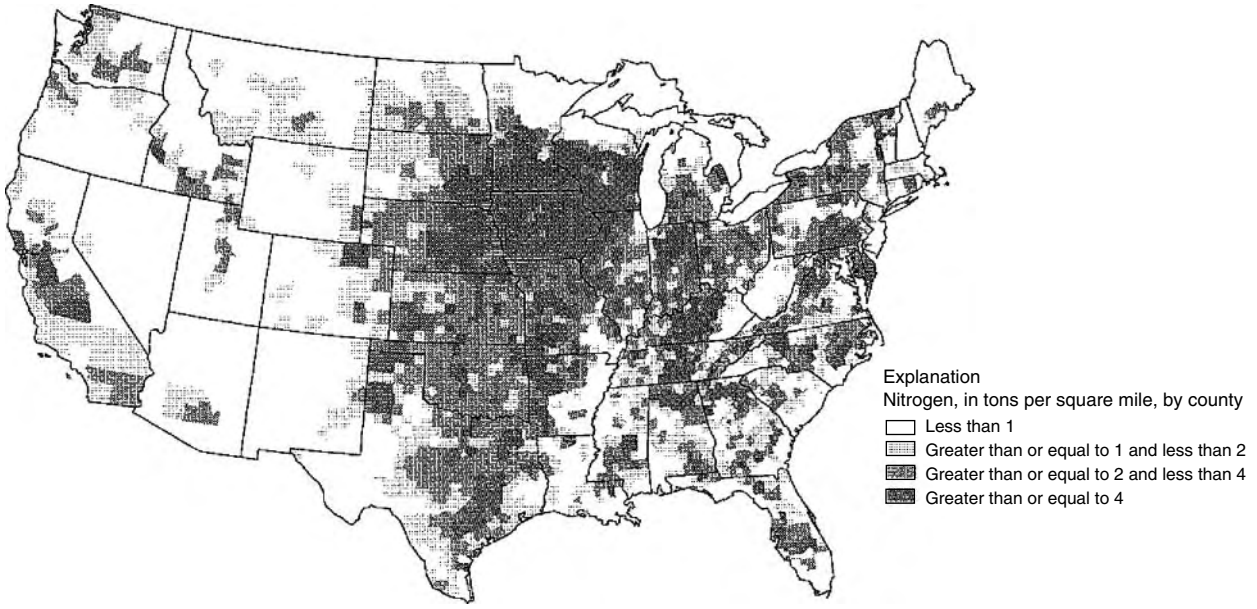


**Figure 10E.93** Estimated nonpoint-source inputs of nitrogen applied in animal manure, 1987. (From Nolan, B.T. and Stoner, J.D., Nutrients in groundwaters of the conterminous United States, 1992–1995, *Environmental Science and Technology*, vol. 34, no. 7, 2000, p. 1156–1165, www.usgs.gov.)

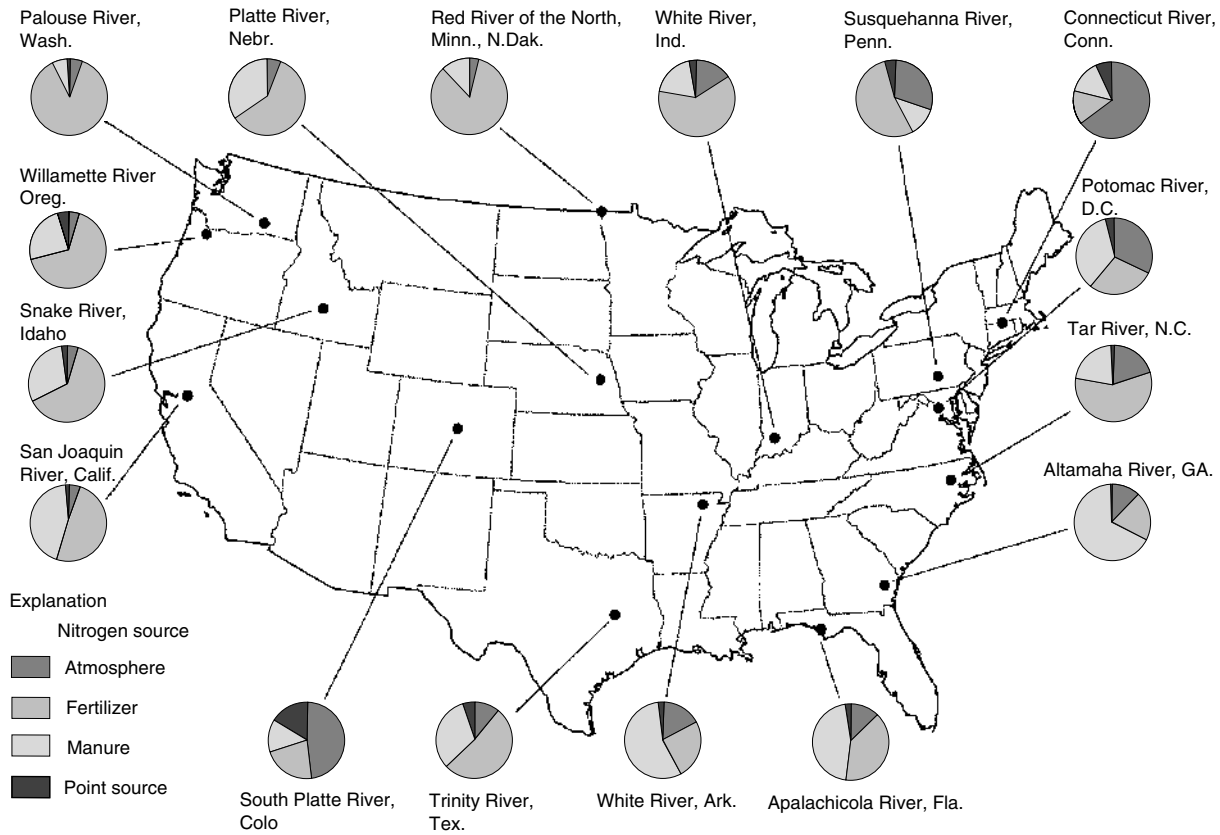


**Figure 10E.94** Proportions of nonpoint and point sources of nitrogen in selected United States national water-quality assessment program watersheds. (From Puckett, L.J., 1994, *Nonpoint and Point Sources of Nitrogen in Major Watersheds of the United States*, *U.S. Geological Survey Water-Resources Investigations Report 94-4001*, www.usgs.gov.)

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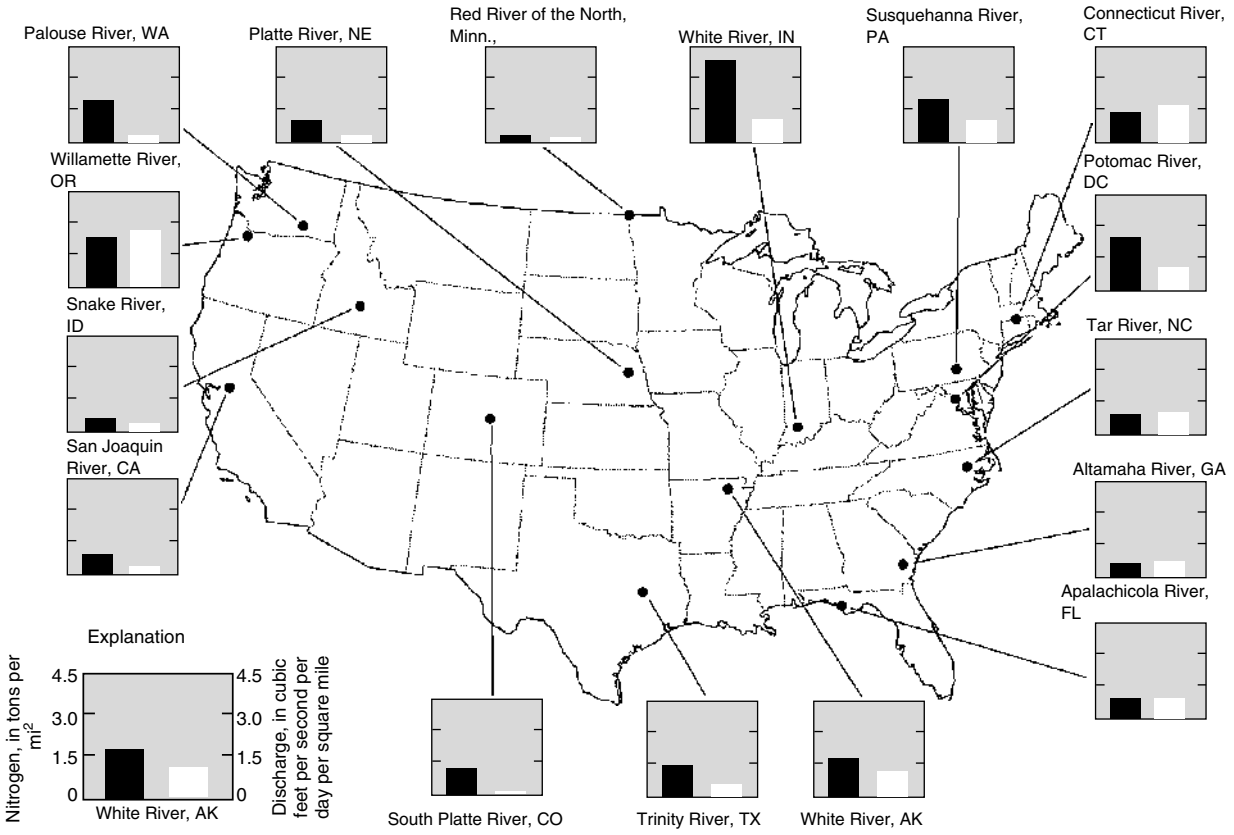


**Figure 10E.95** Annual amounts of nitrogen transported in streams and stream discharges in selected United States national water quality assessment program watersheds. (From Puckett, L.J., 1994, *Nonpoint and Point Sources of Nitrogen in Major Watersheds of the United States*, *U.S. Geological Survey Water-Resources Investigations Report 94-4001*, www.usgs.gov.)

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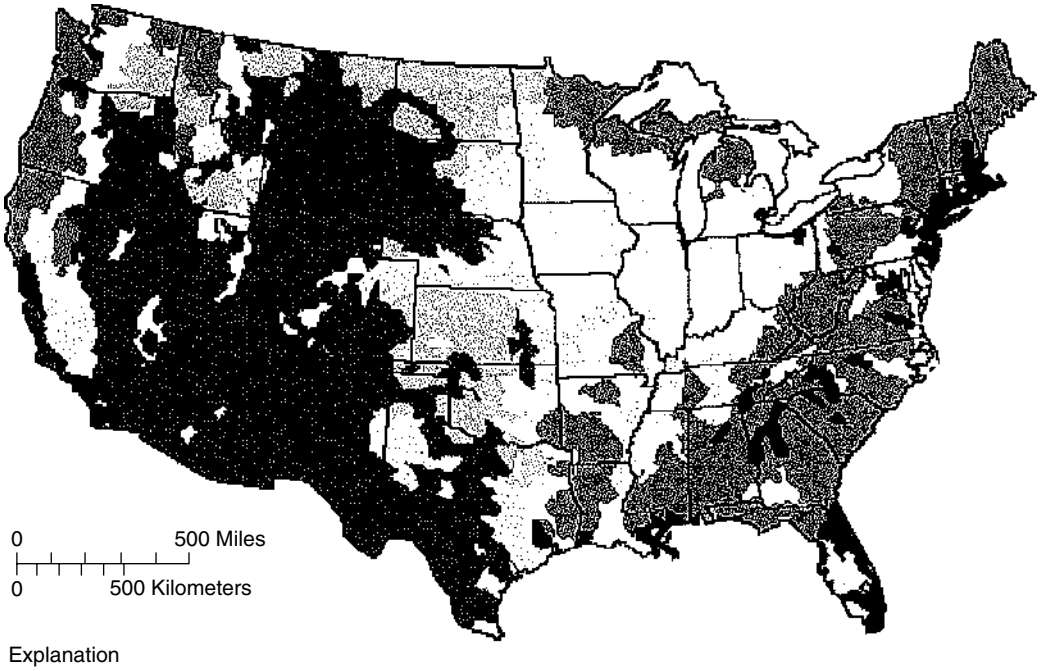


Explanation

| Land use shown on map | Nitrate 1980–89 | | Total phosphorus 1982–89 | | Suspended sediment 1980–89 | |
|---|---|---|---|---|---|---|
| | Yield, in tons per square mile per year | Percentage change per year | Yield, in tons per square mile per year | Percentage change per year | Yield, in tons per square mile per year | Percentage change per year |
| Agriculture wheat | 0.032 | * | 0.010 | –2.8 | 10 | +0.8 |
| Corn and soybeans | 0.932 | * | 0.163 | –2.1 | 100 | –1.0 |
| Mixed | 0.304 | * | 0.066 | –1.6 | 79 | –0.7 |
| Urban | 0.547 | +0.2 | 0.119 | –0.6 | 23 | –0.6 |
| Forest | 0.255 | * | 0.063 | –0.8 | 31 | –0.3 |
| Range | 0.031 | * | 0.017 | –1.9 | 33 | –0.2 |

* Between –0.1 and +0.1

**Figure 10E.96** Yield and percentage change in yield of nitrate, total phosphorous, and suspended sediment in hydrologic cataloging units in the conterminous United States. That are classified as having agricultural (wheat, corn and soybeans, and mixed), urban, forest, and range land use, 1980–1989. (From Smith, R.A., Alexander, R.B., and Lanfear, K.J., 1993, Stream water quality in the conterminous United States—status and trends of selected indicators during the 1980s in national water summary 1990–1991—stream water quality, *U.S. Geological Survey Water-Supply Paper 2400*, www.usgs.gov.)

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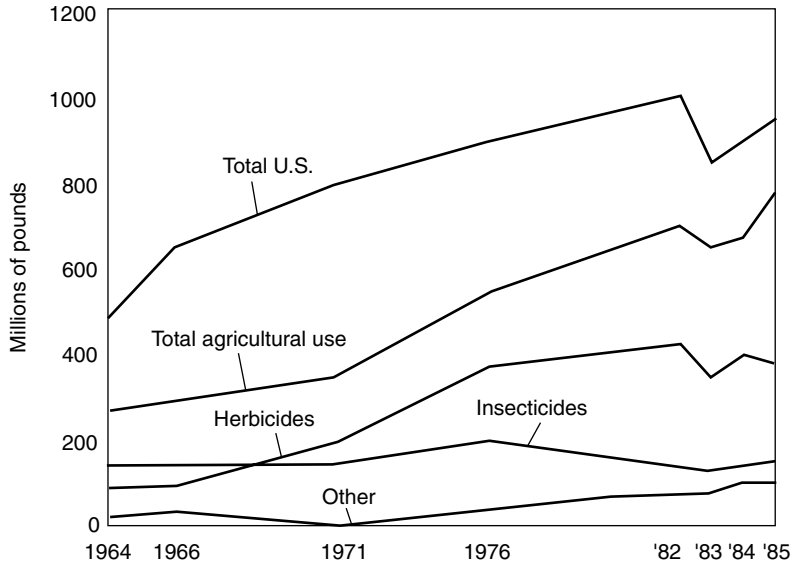


Note: Excludes wood preservatives, disinfectants, and sulfur

**Figure 10E.97** Use of pesticides in the United States, 1964–1984. (From U.S. Environmental Protection Agency, Office of Pesticide and Toxic Substances, 1987, *Agricultural Chemicals in Groundwater: Proposed Pesticide Strategy*.)

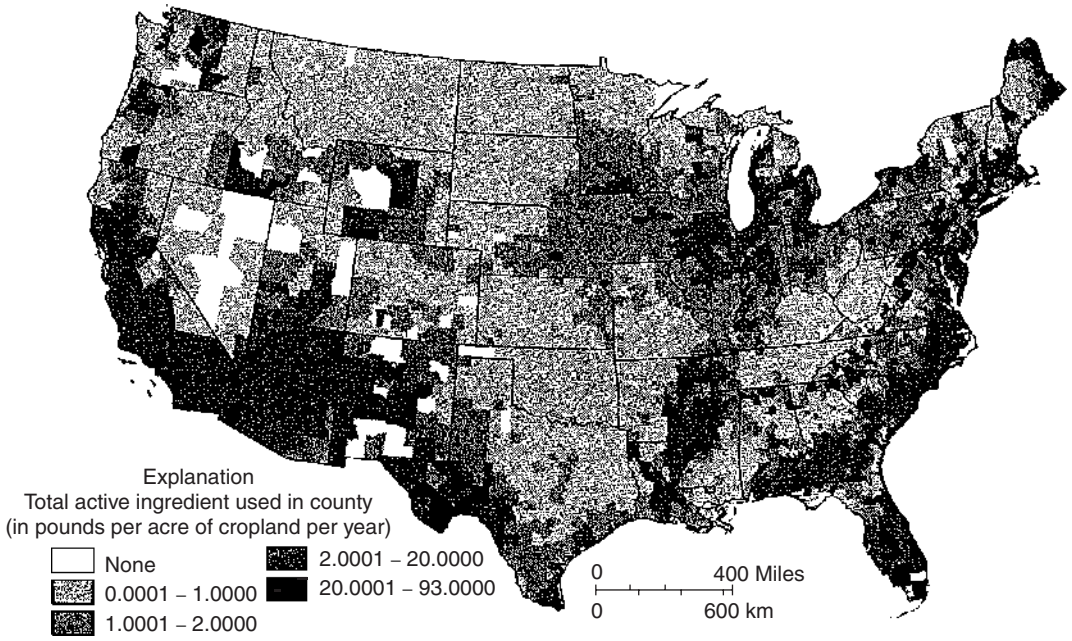


**Figure 10E.98** Annual estimated pesticide use per acre of agricultural land in each county in the conterminous United States, based on the index years from 1987 to 1991. (From Barbash, J.E. and Resek, E.A., 1996, *Pesticides in Groundwater Distribution, Trends and Governing Factors*, Ann Arbor Press, Chelsea, Michigan. Printed with permission.)

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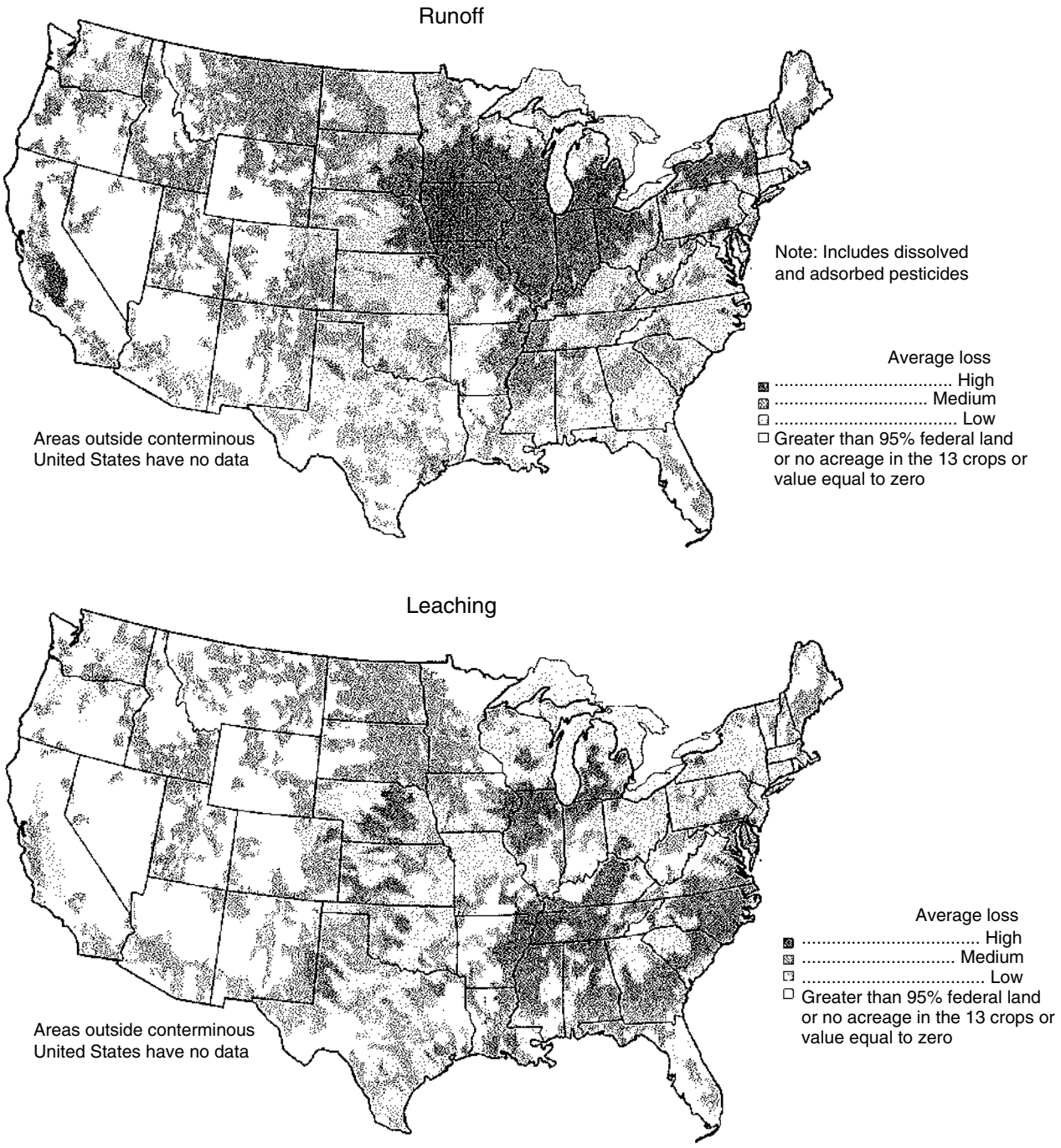


**Figure 10E.99** Pesticide runoff and leaching potential for field crop production. (From United States Department of Agriculture, Natural Resources Conservation Services, 1997, *Water Quality and Agriculture, Status, Conditions, and Trends, Working Paper No. 16*, www.nrcs.usda.gov.)

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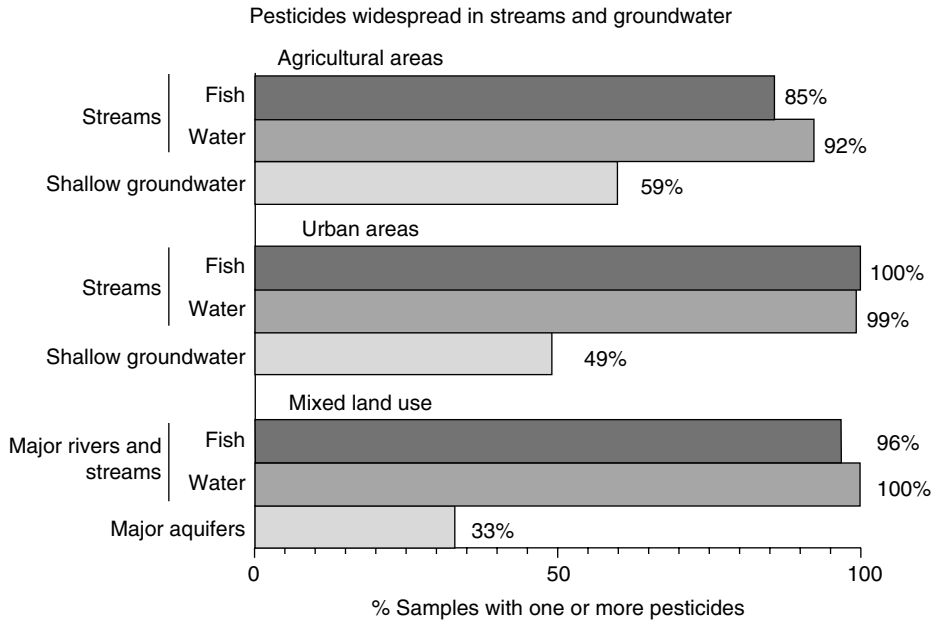


**Figure 10E.100** Percent samples collected from national water quality assessment (NAWQA). Pesticide National Synthesis Project with one or more Pesticides. (From United States Geological Survey, 1999, *Pesticides in the Nations Resources, National Water Quality Assessment* (NAWQA), Pesticide National Synthesis Project, April 1999, Powerpoint presentation, ca.water.usgs.gov/pnsp/present/water.)

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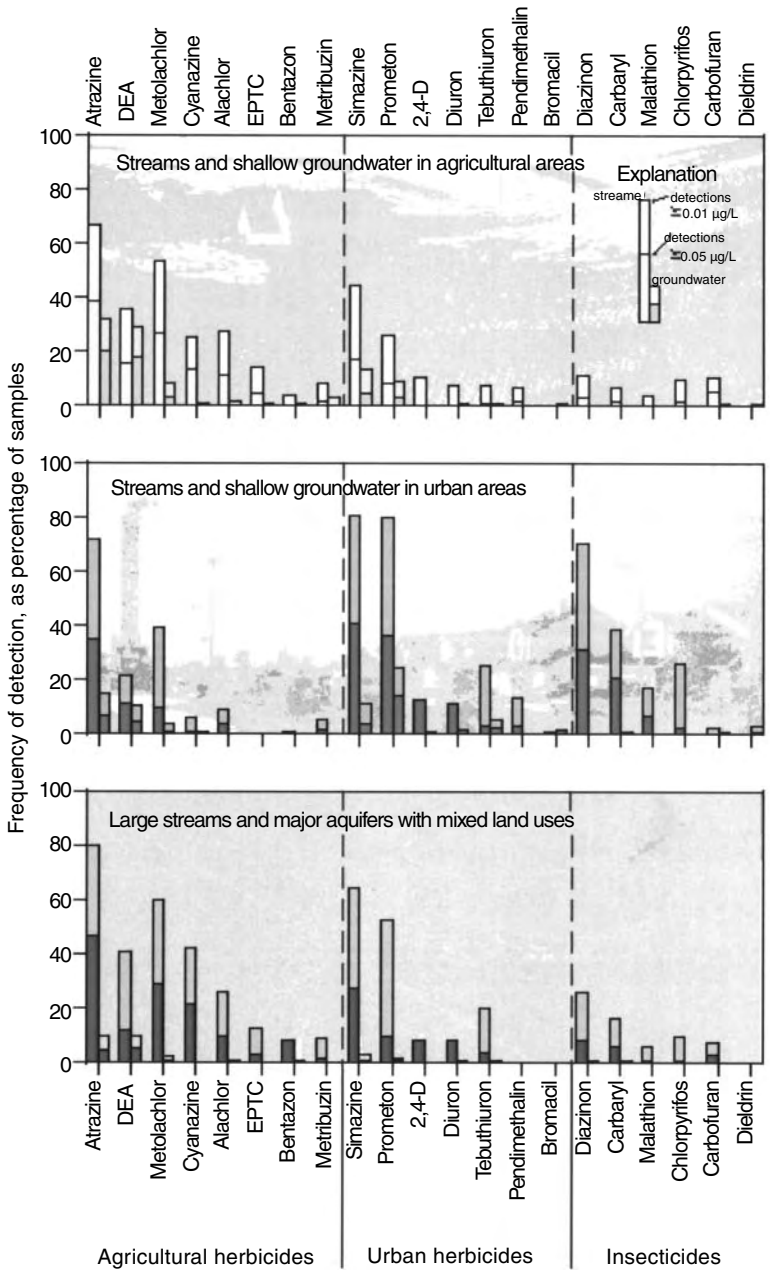


**Figure 10E.101** Patterns of occurrence to the 21 most detected compounds in surface and groundwater samples collected from areas included in the United States Geological Survey National Water Quality Assessment Program, 1992–1996. (From United States Geological Survey, 1998, *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program* (NAWQA), July 22, 1998, www.usgs.gov.)

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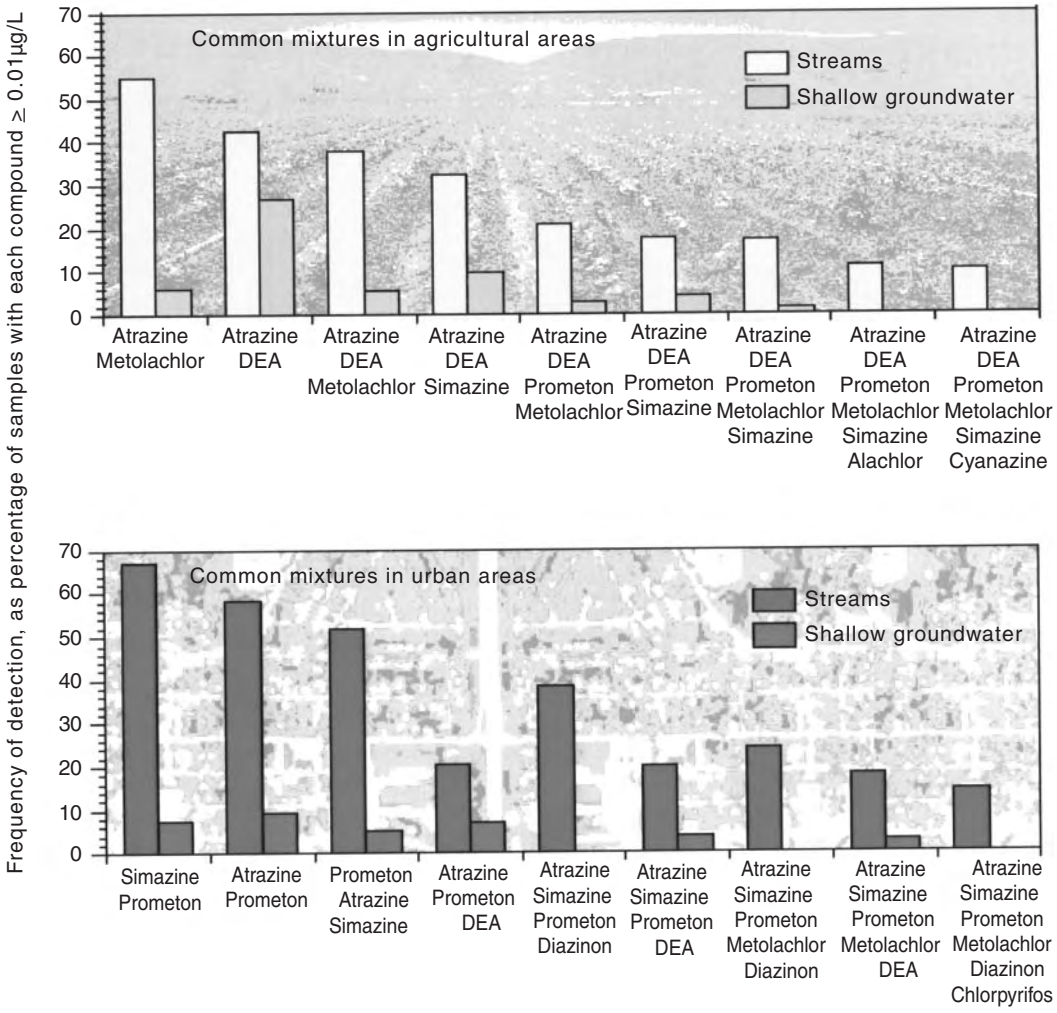


**Figure 10E.102** Frequency of composition of common mixtures in surface water and shallow groundwater samples with detections collected from areas included in the United States Geological Survey National Water Quality Assessment Program, 1992–1996. (From United States Geological Survey, 1998, *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program* (NAWQA), July 22, 1998, www.usgs.gov.)

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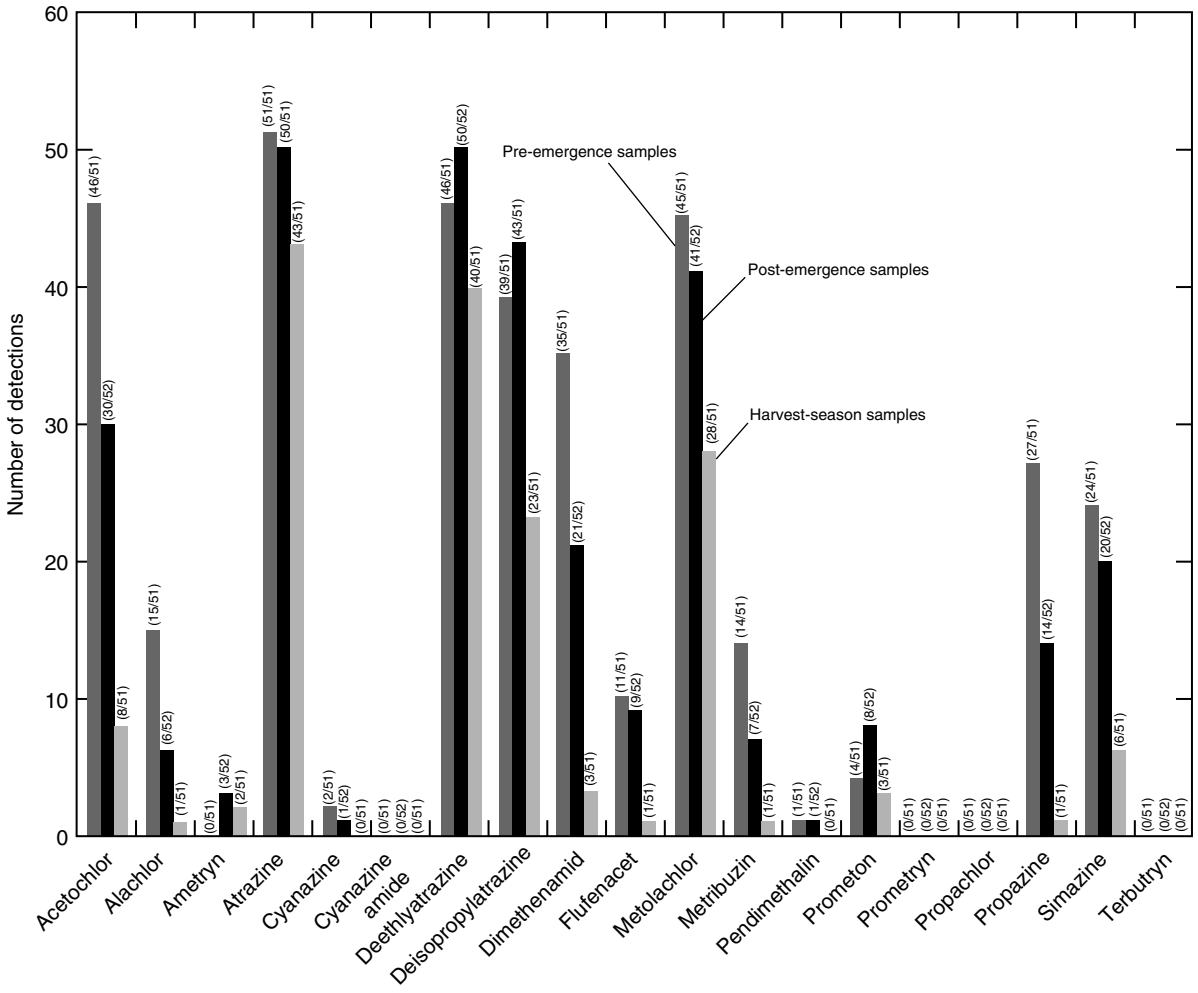


**Figure 10E.103** Number of detections of selected herbicides and degradation products for pre-emergence, post-emergence, and Harvest-season runoff samples collected from 51 streams in the Midwestern States, 2002. (From Scribner, E.A., Battaglin, W.A., Dietze, J.E., and Thurman, E.M., 2003, Reconnaissance Data for Glyphosate, Other Selected Herbicides, Their Degradation Products, and Antibiotics in 51 Streams in Nine Midwestern States, 2002, *U.S. Geological Survey Open-File Report 03-217*, www.usgs.gov.)

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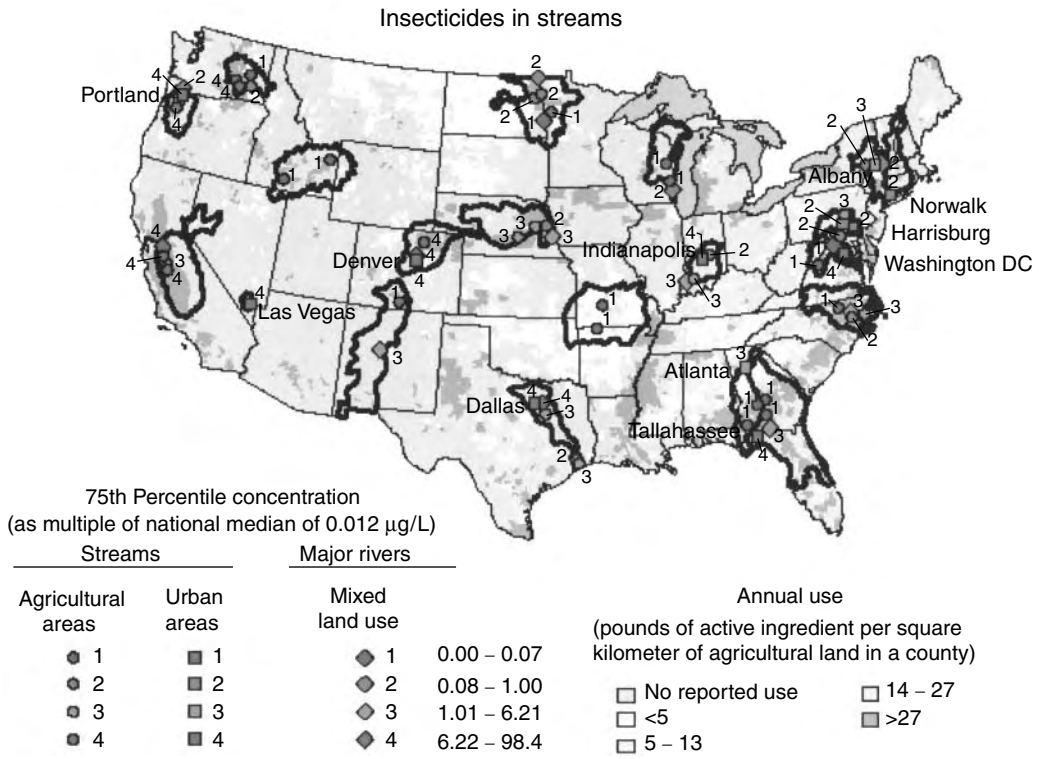


**Figure 10E.104** Geographic distribution of insecticides in surface water for streams included in the United States Geological Survey National Water Quality Assessment Program, 1992–1996. (From United States Geological Survey, 1998, *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program* (NAWQA), July 22, 1998, www.usgs.gov.)

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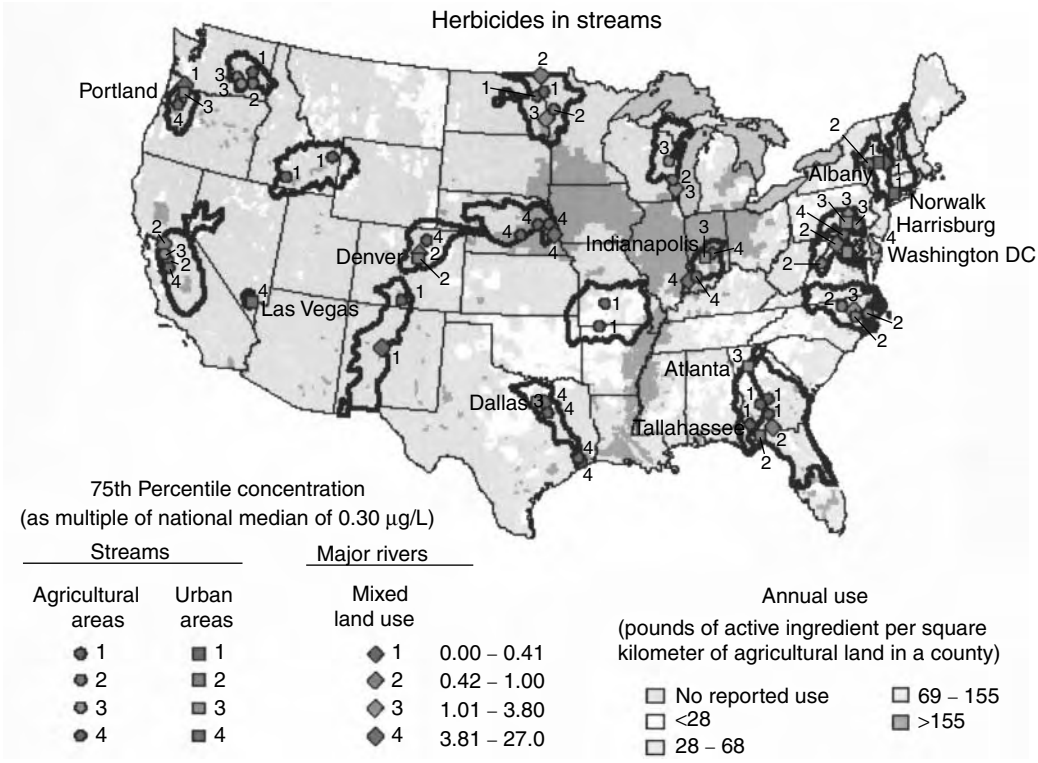


**Figure 10E.105** Geographic distribution of herbicides in surface water for streams included in the United States Geological Survey Pesticide National Water Quality Assessment Program, 1992–1996. (From United States Geological Survey, 1998, *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program* (NAWQA), July 22, 1998, www.usgs.gov.)

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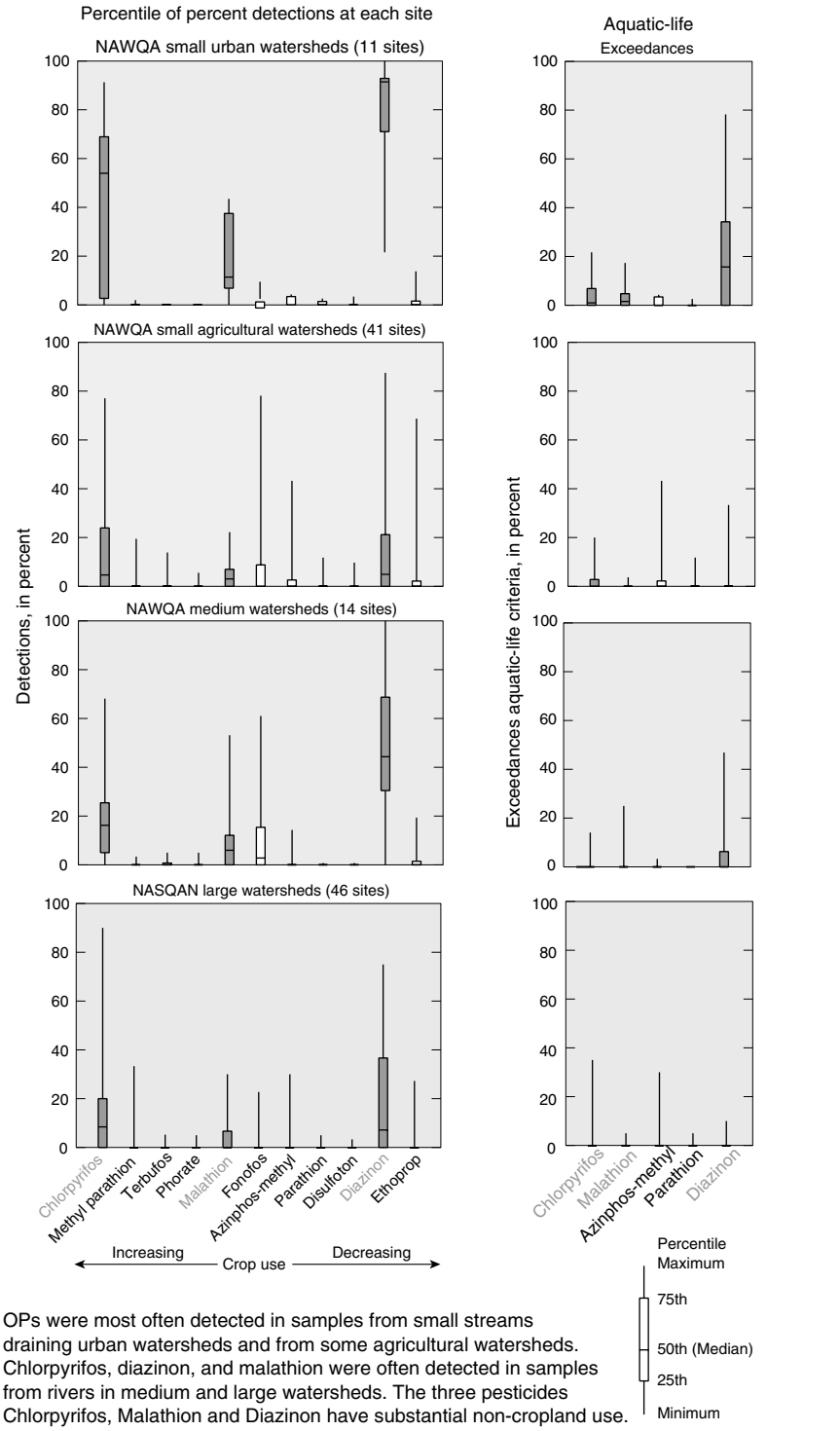


OPs were most often detected in samples from small streams draining urban watersheds and from some agricultural watersheds. Chlorpyrifos, diazinon, and malathion were often detected in samples from rivers in medium and large watersheds. The three pesticides Chlorpyrifos, Malathion and Diazinon have substantial non-cropland use. Aquatic-life criteria were exceeded most often in streams in small urban watersheds. Boxplots illustrate the distribution of percent detections (or percent aquatic-life exceedances) among sites. For example, the median percent detections of chlorpyrifos among the 46 NASQAN sites is 9%; percent detections range from no detections at the Snake River at Burbank, Washington, to 90% detections at the Arroyo Colorado at Harlingen, Texas. Percentiles presented are not adjusted for varied detection limits and sampling frequency

**Figure 10E.106** Organophosphorous pesticide occurrence in surface water for streams included in the United States Geological Survey National Water Quality Assessment Program, 1992–1997. (From Hopkins, E. H. et al., 2000, Organophosphorous Pesticide Occurrence and Distribution in Surface and Ground Water of the United States, 1992–1997, *U.S. Geological Survey Open-File Report 00-187*, www.usgs.gov.)

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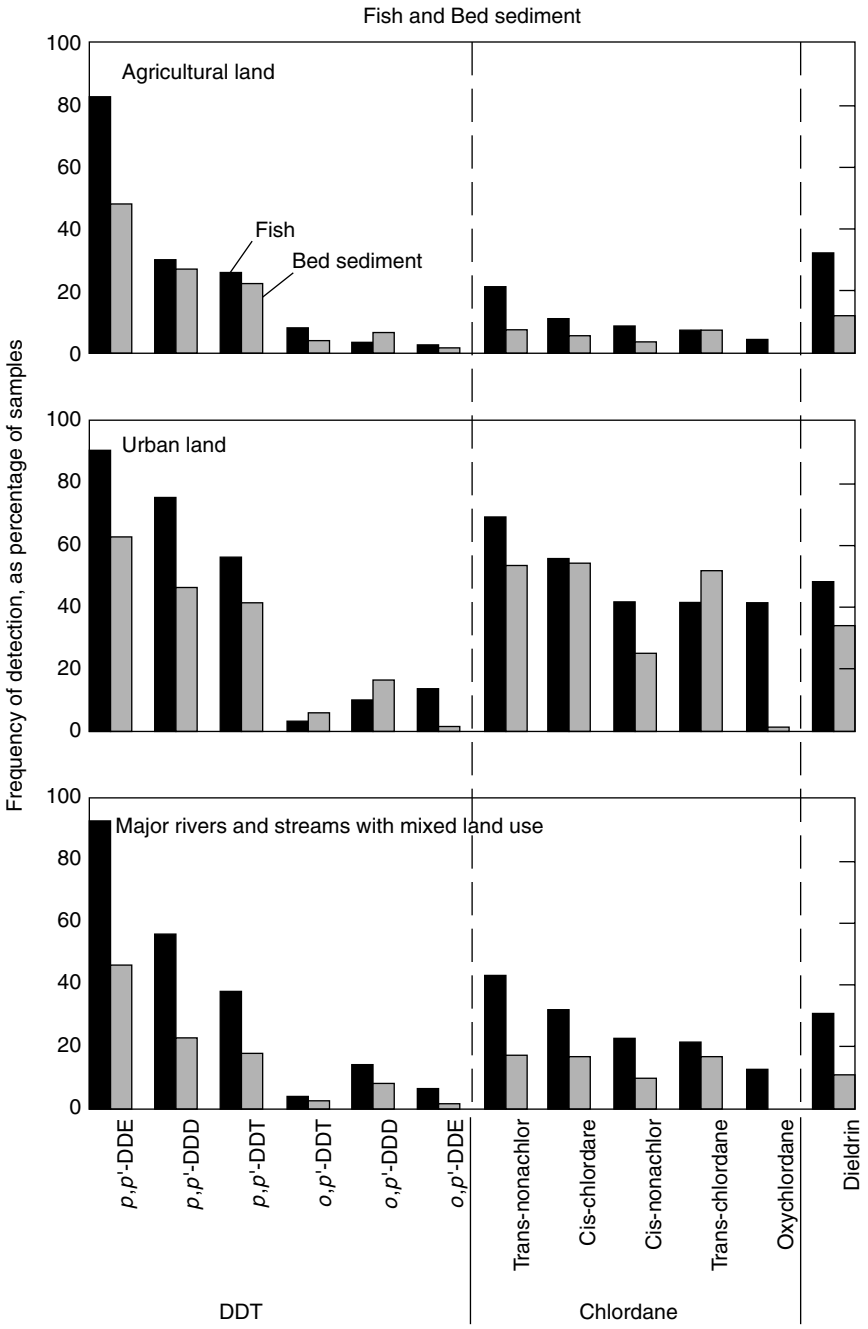


*Note:* The pesticide compounds found most often in fish and bed sediment are related to three major groups of insecticides that were heavily used in the 1960s. Organochlorine compounds related to DDT and dieldrin were widely used in both agricultural and urban areas, and chlordane was mainly used in urban areas.

**Figure 10E.107** The most frequently detected pesticides in fish and bed sediment in the United States, 1991–1996. (From United States Geological Survey, 1999, The Quality of Our Nation's Waters, Nutrients and Pesticides, *U.S. Geological Survey Circular. 1225*, www.usgs.gov.)

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**Figure 10E.108** DDT trends throughout the United States using sediment core data form 1970 to top of core. (From United States Environmental Protection Agency, The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, *National Sediment Quality Survey*, Second Edition, www.epa.gov.)

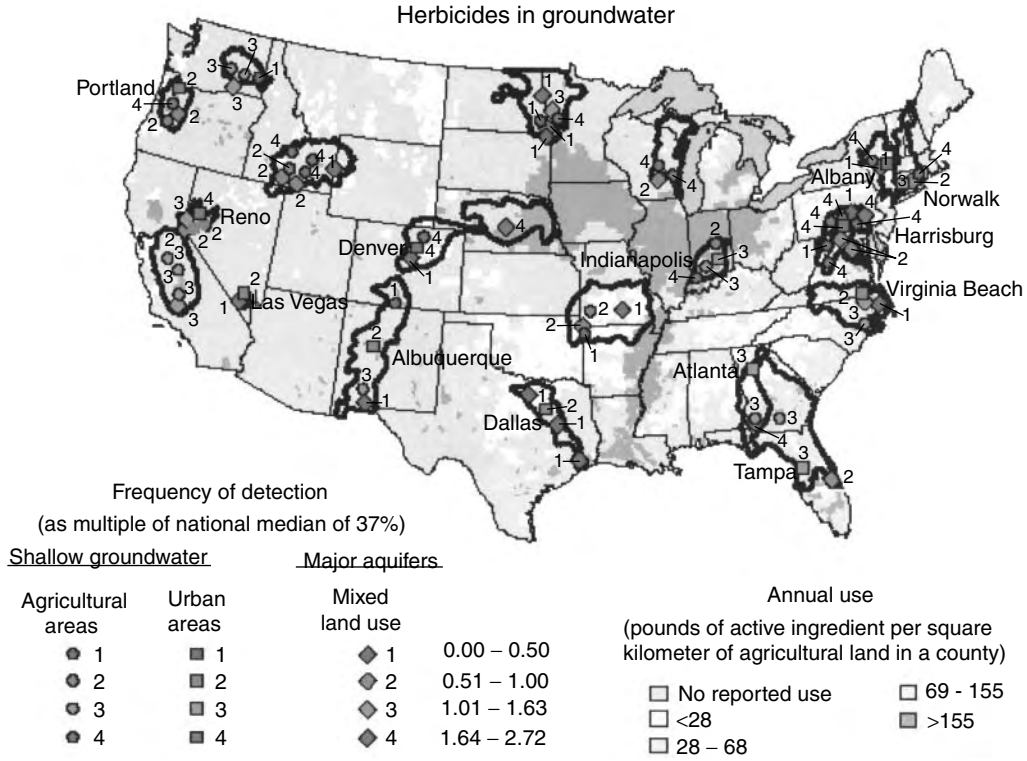


**Figure 10E.109** Geographic distribution of insecticides in groundwater in areas included in the United States Geological Survey National Water Quality Assessment Program, 1992–1996. (From United States Geological Survey, *Pesticides in Surface and Ground Water of the United State: Summary of Results of the National Water Quality Assessment Program* (NAWQA), www.usgs.gov.)

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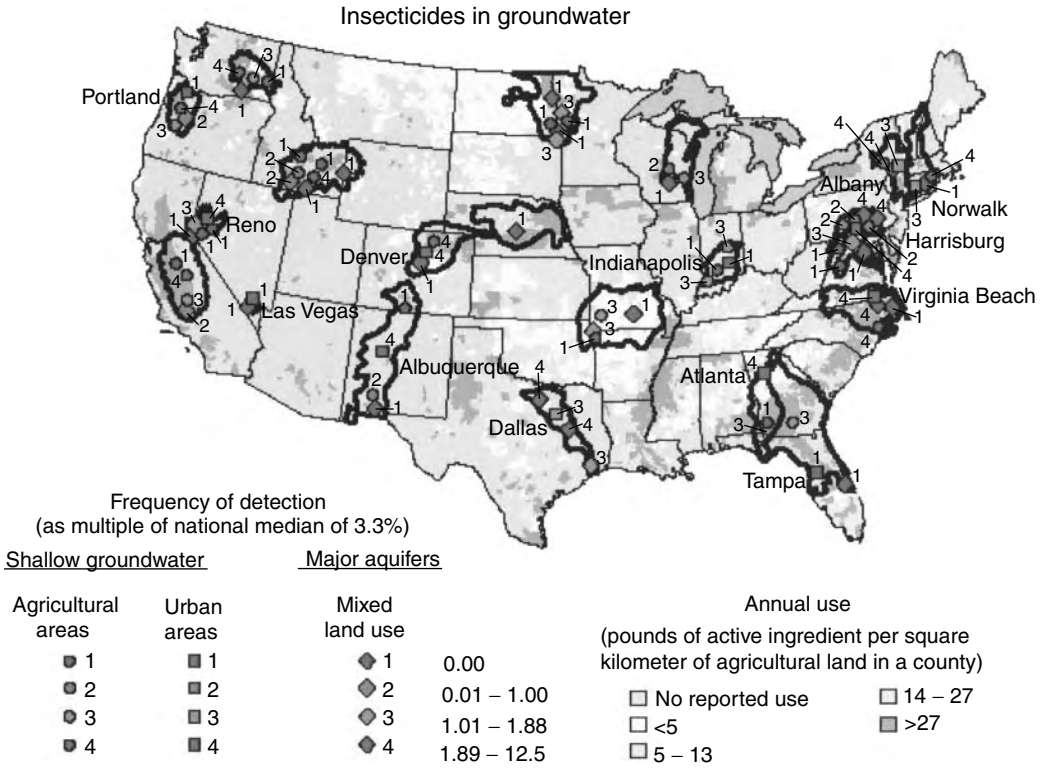


**Figure 10E.110** Geographic distribution of herbicides in groundwater in areas included in the United States Geological Survey Pesticide National Water Quality Assessment Program, 1992–1996. (From United States Geological Survey, *Pesticides in Surface and Ground Water of the United State: Summary of Results of the National Water Quality Assessment Program* (NAWQA), www.usgs.gov.)

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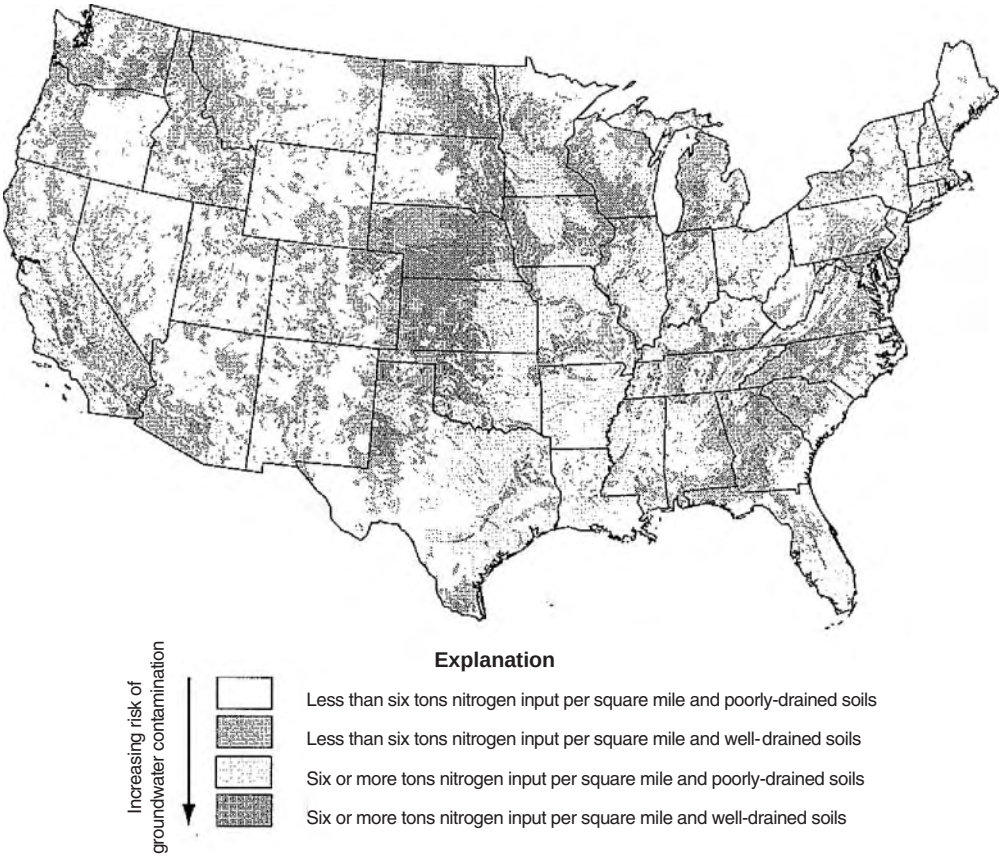


**Figure 10E.111** Areas in the United States most vulnerable to nitrate contamination of groundwater. (From Nolan, B. T. and Ruddy, B. C., Nitrate in Ground Waters of the United States-Assessing the Risk, *United States Geological Survey Fact Sheet FS-092-96*, www.usgs.gov.)

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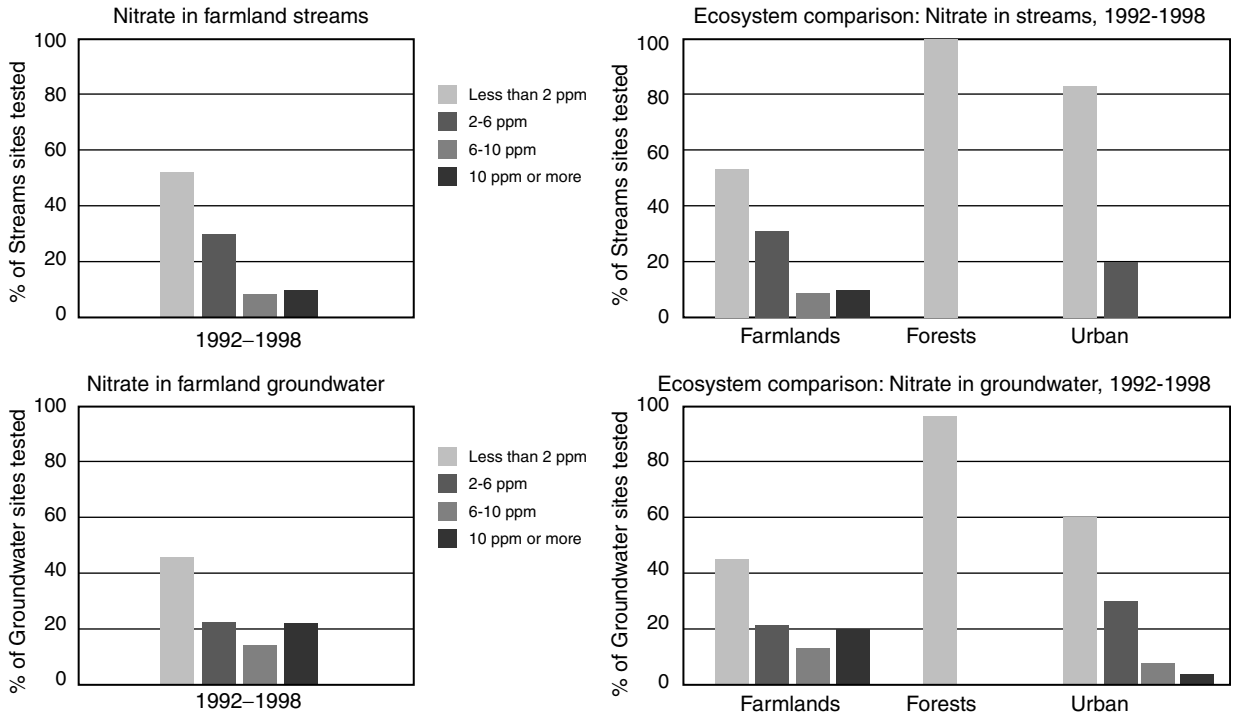


**Figure 10E.112** Nitrates in farmland streams and groundwater in the 36 major United States river basins and aquifers sampled by the National Water Quality Assessment Program, 1992–1998. (From United States Environmental Protection Agency, 2003, *EPA's Draft Report on the Environment*, 2003, EPA 600-R-03-050, www.epa.gov. The Heintz Cent, The State of the Nation's Ecosystem 2002.)

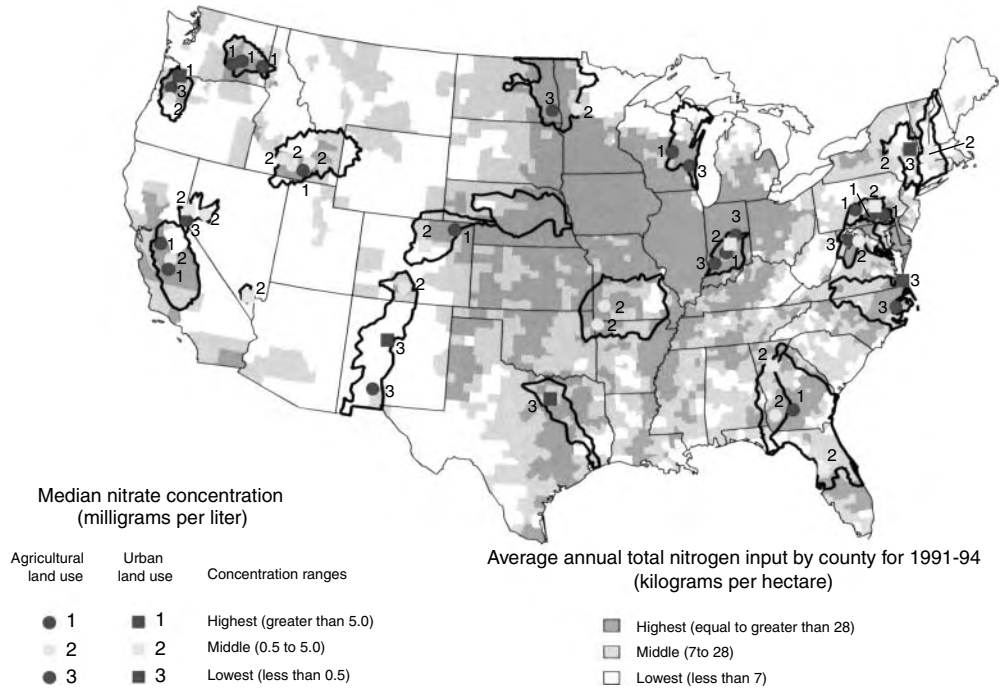


**Figure 10E.113** Median Nitrate Concentration in Shallow Groundwater Sampled by the NAWQA Program During 1992–1995. (From Nolan, B.T. and Stoner, J.D., Nutrients in groundwaters of the conterminous United States, 1992–1995, *Environmental Science and Technology*, vol. 34, no. 7, 2000, p. 1156–1165, www.usgs.gov.)

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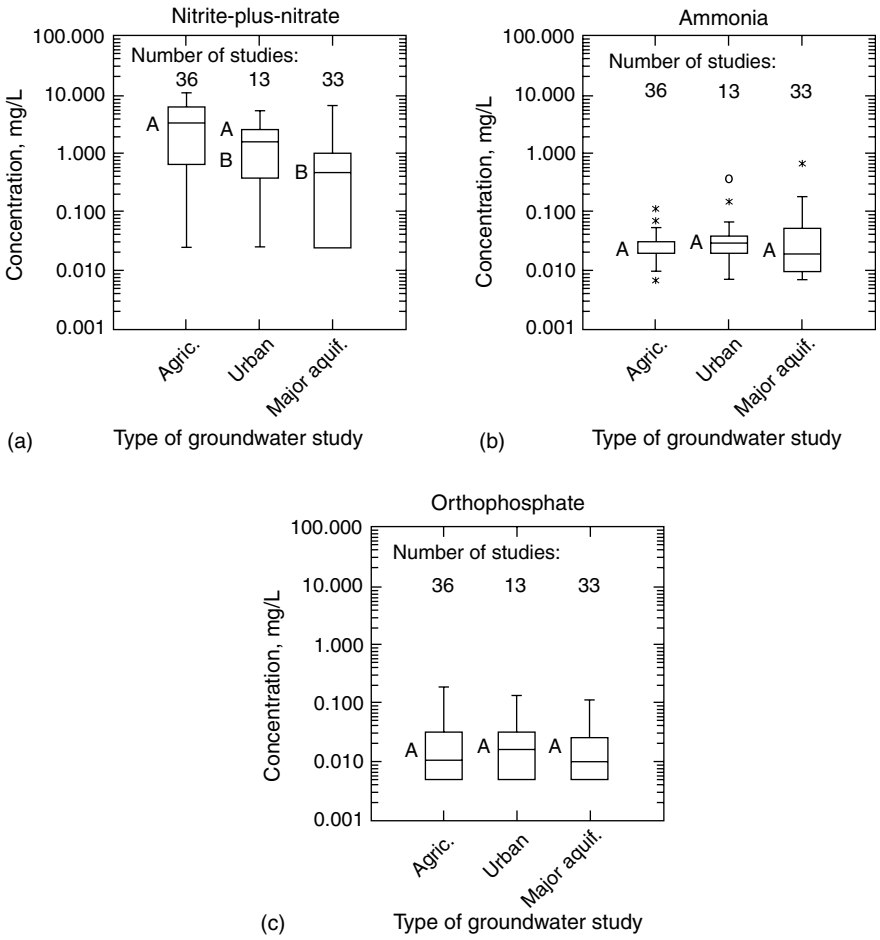


**Figure 10E.114** Distribution of nitrate-plus-nitrite, ammonia, and othrophosphate in groundwater samples from land-use studies and major aquifers. (From Nolan, B.T. and Stoner, J.D., Nutrients in groundwaters of the conterminous United States, 1992–1995, *Environmental Science and Technology*, vol. 34, no. 7, 2000, p. 1156–1165, www.usgs.gov.)

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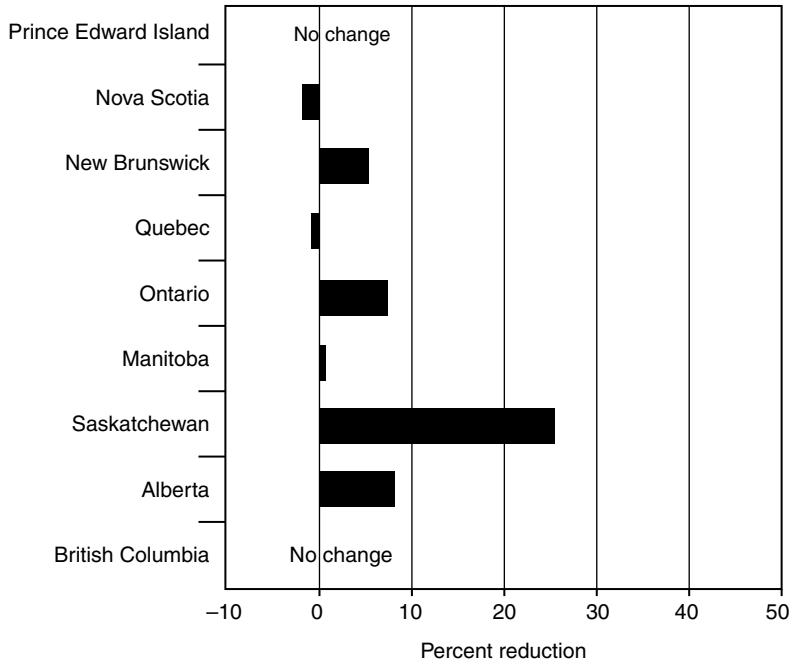
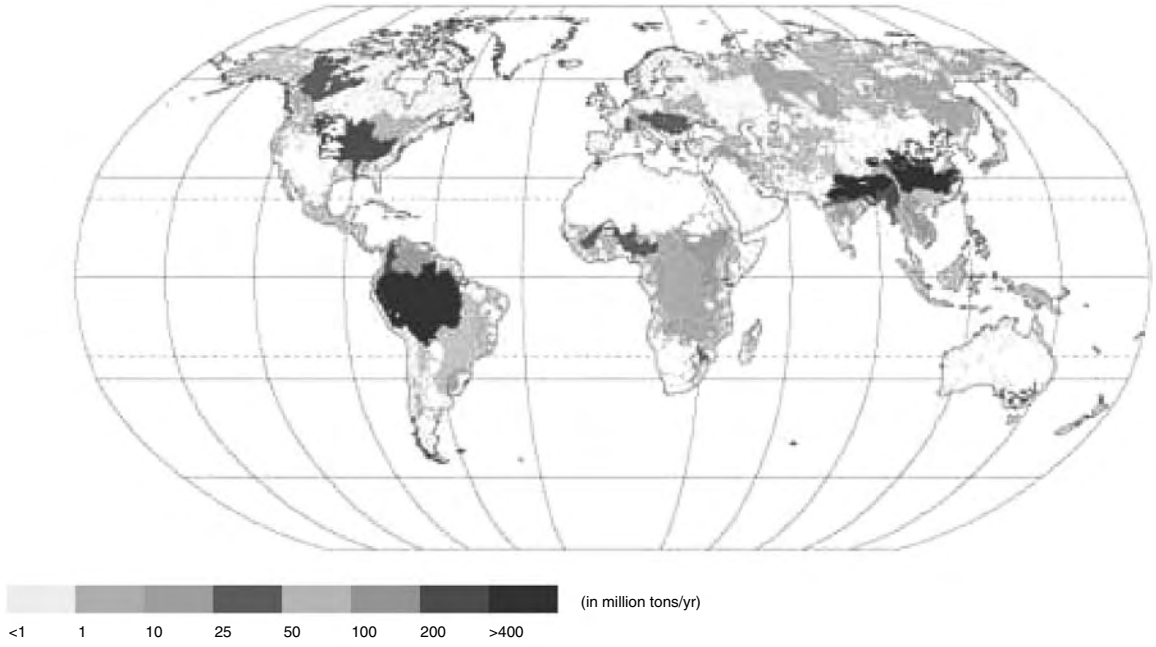



**Figure 10E.115** Changes in the area of Canadian cropland at risk of exceeding a tolerable level of water erosion between 1981 and 1996. (From *The Health of Our Water, Toward Sustainable Agriculture in Canada*, Publication 2020/E, Coote, D.R. and Gregorich, L.J. (eds.), Research Branch Agriculture and Agri-Food Canada, 2000. Original Source: McRae, T., Smith, C.A.S., and Gregorich, L.J., (eds.), 2000, Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Project. Agriculture and Agri-Food Canada, Ottawa, Ont. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2006.)




Changes in sediment yield reflect changes in basin conditions, including climate, solis, erosion rates, vegetation, topography and land use. It is influenced strongly by human actions, such as in the construction of dams and levees (see high sediment load in China and the Amason basin, where large dams have been implemeted), forest harvesting and farming in drainage basins

**Figure 10E.116** World sediment load by basin. (From *Water for People Water for Life*, The United Nations World Water Development, Copyright © United Nations Educational, Scientific and Cultural Organization — World Water Assessment Programme (UNESCO-WWAP), 2003. Reproduced by permission of UNESCO. www.unesco.org. Original Source: Reprinted from Marine Geology, vol. 154, Syvitski, J.P. and Morehead, M.D., Estimating River-Sediment Discharge to the Ocean: Application to the Eel Margin, Northern California, pp 13–28, 1999. With permission from Elsevier.)

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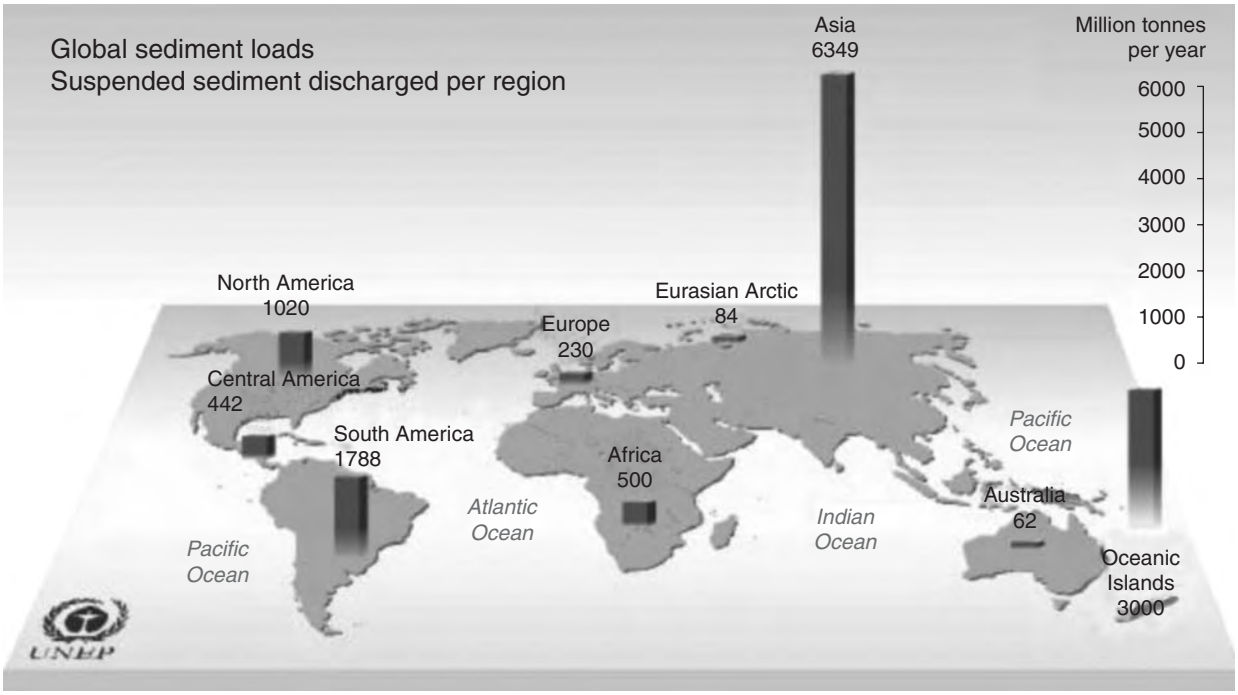


**Figure 10E.117** Global sediment loads, suspended sediment discharged by region. (From United Nations Environmental-Programme, UNEP/GRID-Arendal, *Vital Water Graphics, Global Sediment Loads Suspended Sediment Discharged per Region*, Downloaded 9/22/05, www.unep.org/vitalwater/freshwater.htm Data source for chart Gleick. P.H., 1993, Witter in Crisis: A Guide to the World's Fresh Wafer Resources, Oxford University Press, NY. Reprinted with permission.)

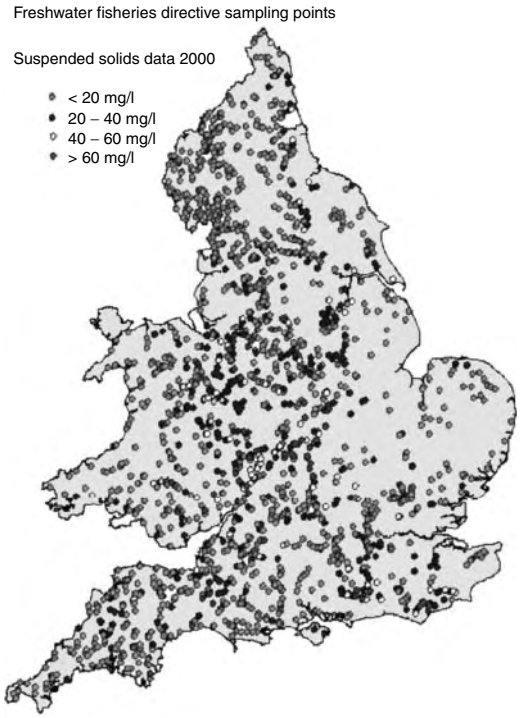


**Figure 10E.118** Suspended solids loads in sampling points in England and Wales monitored under the freshwater fish directive. (From Department of Environment, Food and Rural Affairs, 2002, *The Government's Strategic Review of Diffuse Water Pollution from Agriculture in England: Agriculture and Water: A Diffuse Pollution Review*, www.defra.gov.uk. Reproduced under the terms of the Click-Use Licence.)

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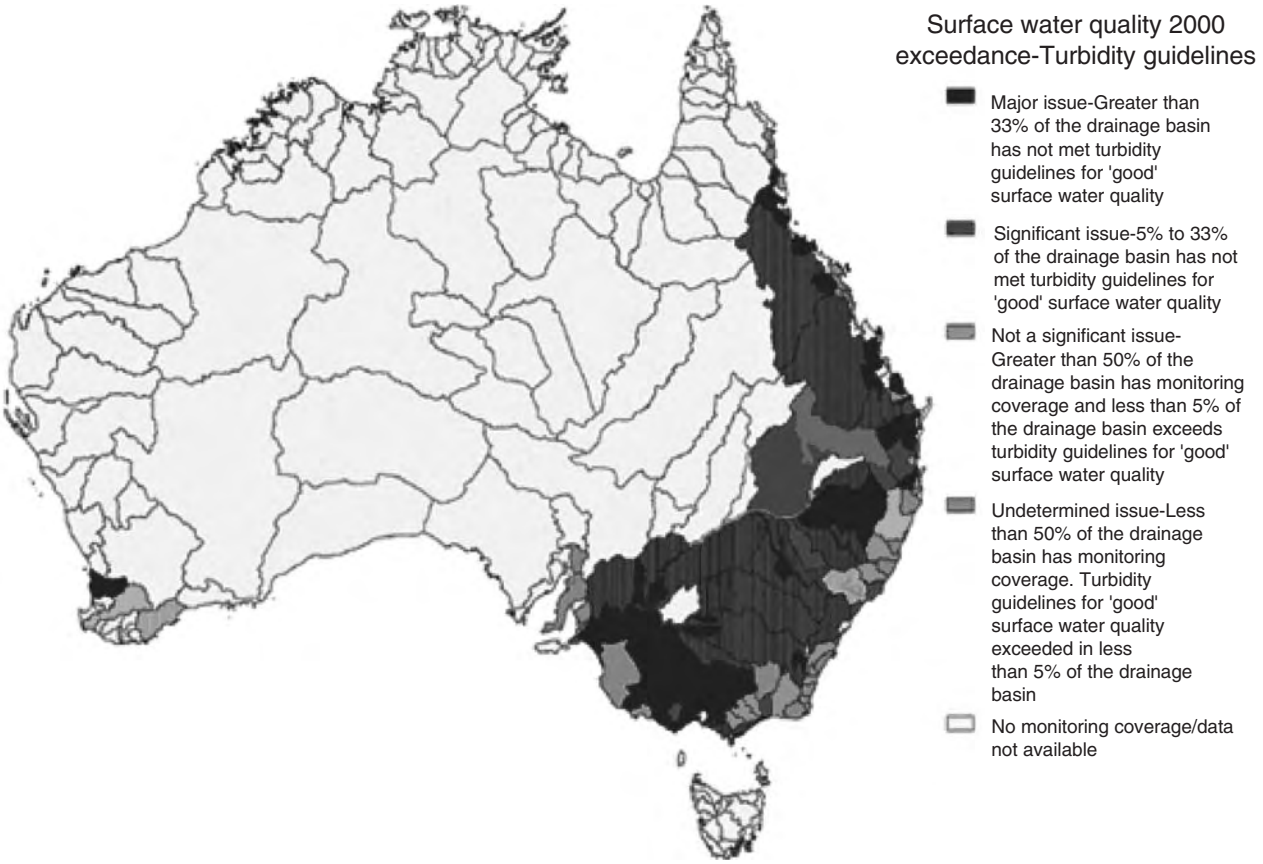


**Figure 10E.119** Australian catchments where turbidity is considered an environmental issue. (From Ball, J., Donnelley, L., Erlanger, P., Evans, R., Kollmorgen, A., Neal, B., and Shirley, M., 2001, *Inland Waters, Australia State of Environment Report 2001* (Theme Report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra. Original Source: National Land and Water Resources Audit, 2001a, Australian Water. Resources Assessment 2000, www.deh.gov.au. Copyright Commonwealth of Australia reproduced by permission.)

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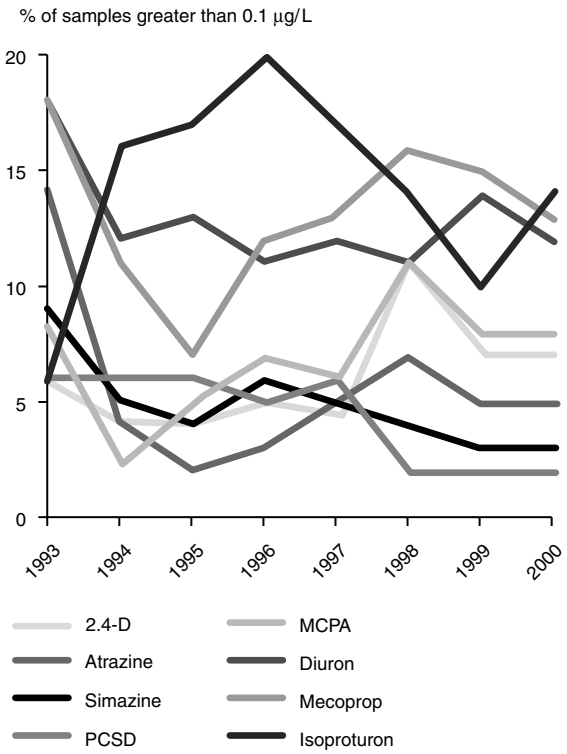


**Figure 10E.120** Occurrences of some commonly found pesticides in surface freshwaters in England and Wales, 1993–2000. (From European Environmental Agency (EEA), 2003, *Europe's Environment, The Third Assessment, Environmental Assessment Report No. 10*, EE1, Copenhagen, www.eea.europa.eu. Reprinted with permission © EEA.)

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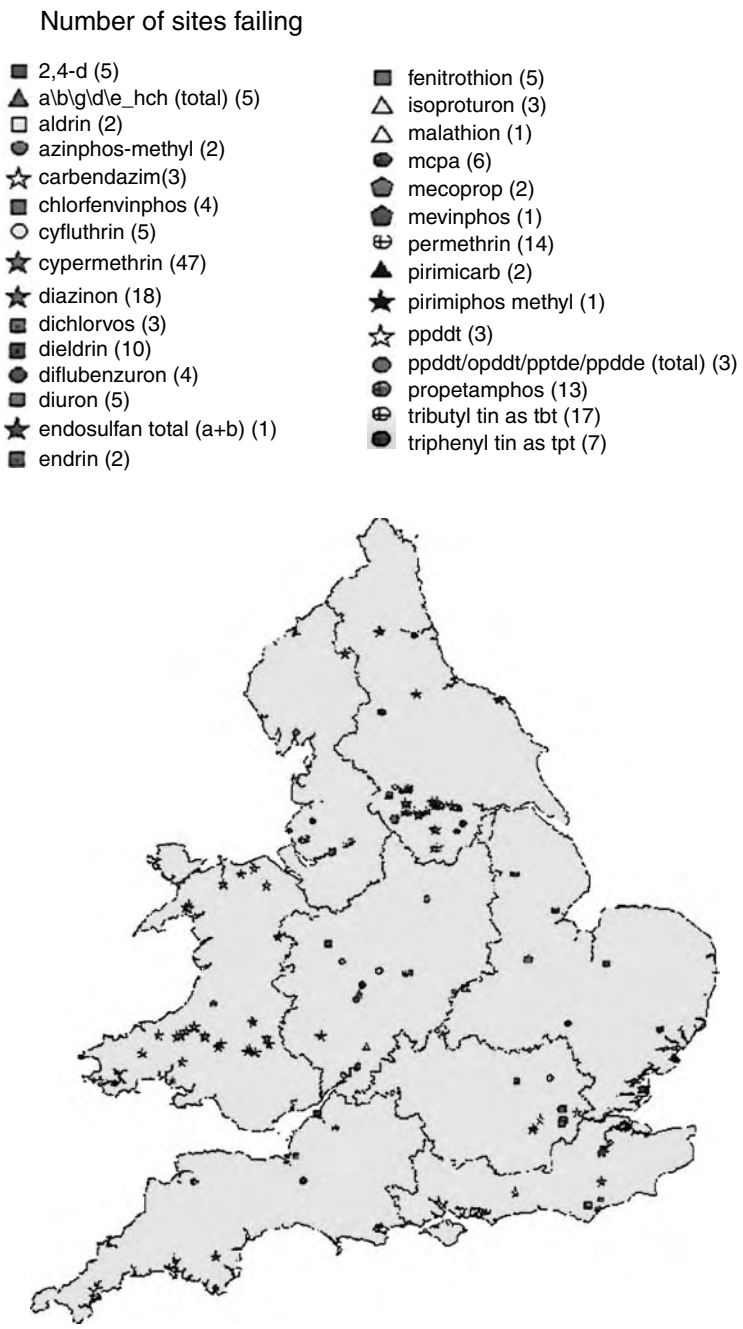


**Figure 10E.121** Surface freshwater sites exceeding pesticide environmental quality standards (EQS) For England and Wales, 2000. (From Department of Environment, Food and Rural Affairs, 2002, *The Government's Strategic Review of Diffuse Water Pollution from Agriculture in England: Agriculture and Water: A Diffuse Pollution Review*, www.defra.gov.uk. Reproduced under the terms of the Click-Use Licence.)

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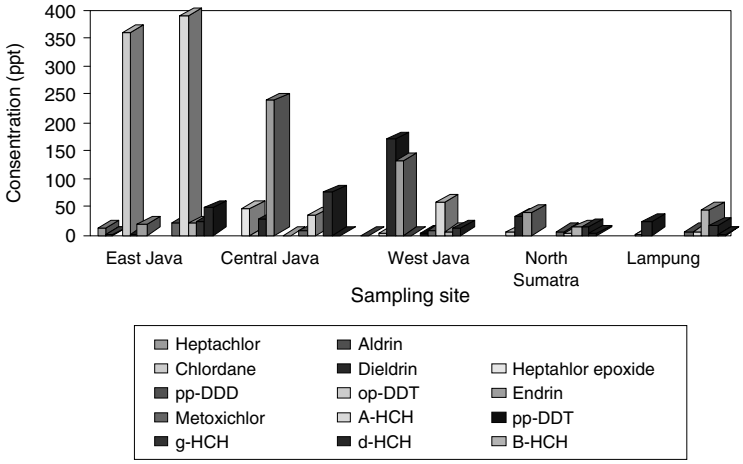


**Figure 10E.122** Highest concentrations of POPs and OCs compounds in Indonesian surface water in 2002. (From Syafrul, H., 2003, Environmental Standards Related to POPs in Indonesia in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1–2 September, 2003, UNUM Centre, Tokyo, www.unu.edu. Printed with permission.)

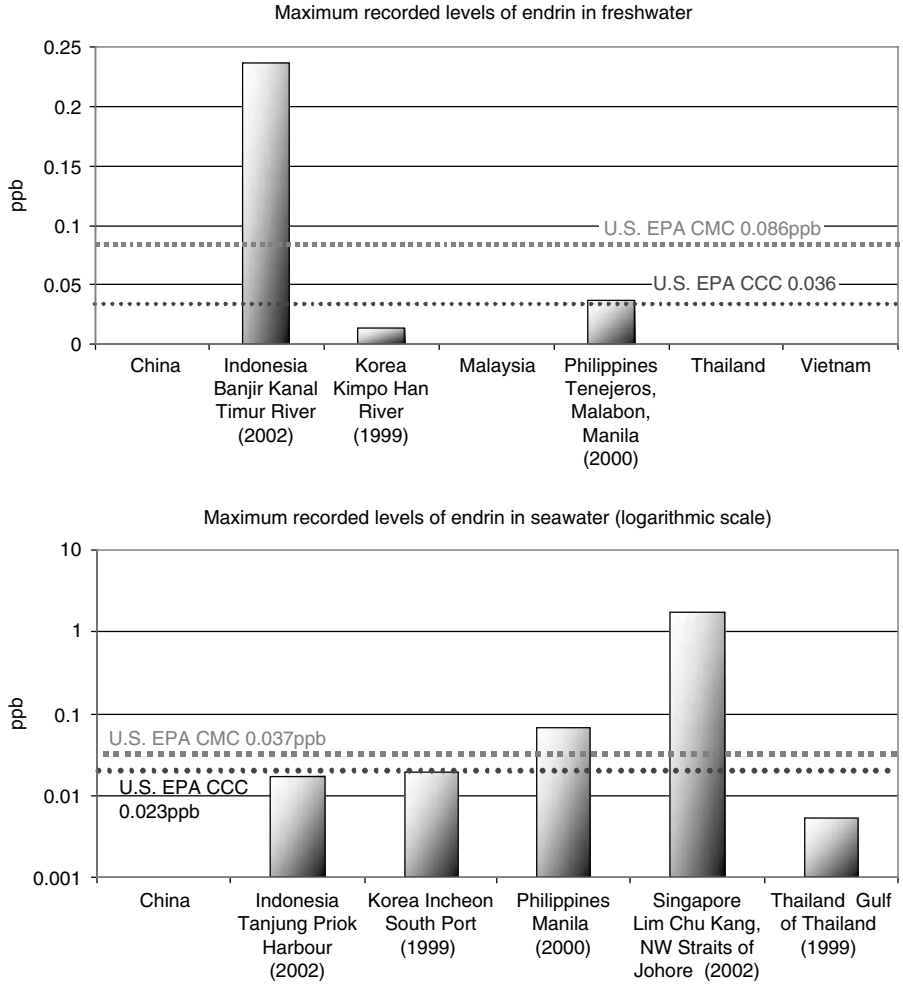


**Figure 10E.123** Maximum recorded levels of endrin in freshwater and seawater in East Asia. (From King, C., 2003, Capacity Development for Monitoring Major Persistent Organic Pollutants (POPs) in East Asian Waters: Examples of UNU Monitoring Activities in East Asia in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1–2 September, 2003, UNU Centre, Tokyo, www.unu.edu. Printed with permission.)

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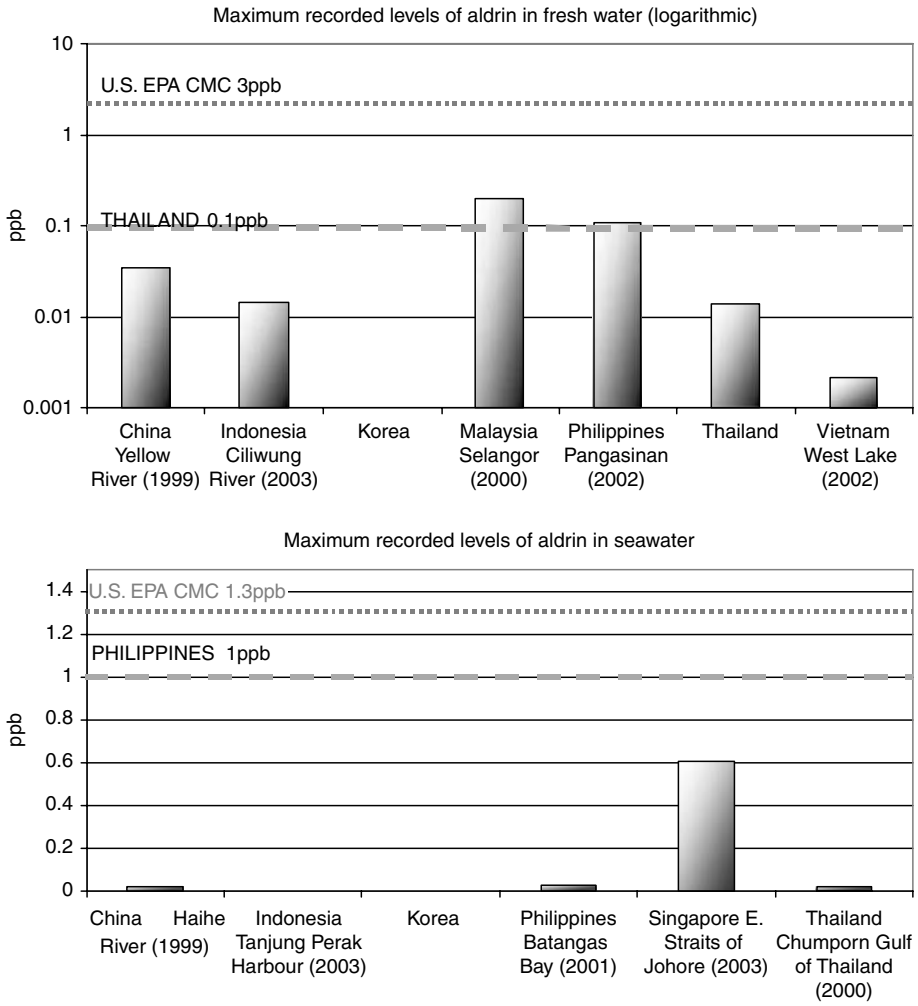


**Figure 10E.124** Maximum recorded levels of aldrin in freshwater and seawater in East Asia. (From King, C., 2003, Capacity Development for Monitoring Major Persistent Organic Pollutants (POPs) in East Asian Waters: Examples of UNU Monitoring Activities in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1–2 September, 2003, UNU Centre, Tokyo, www.unu.edu. Printed with permission.)

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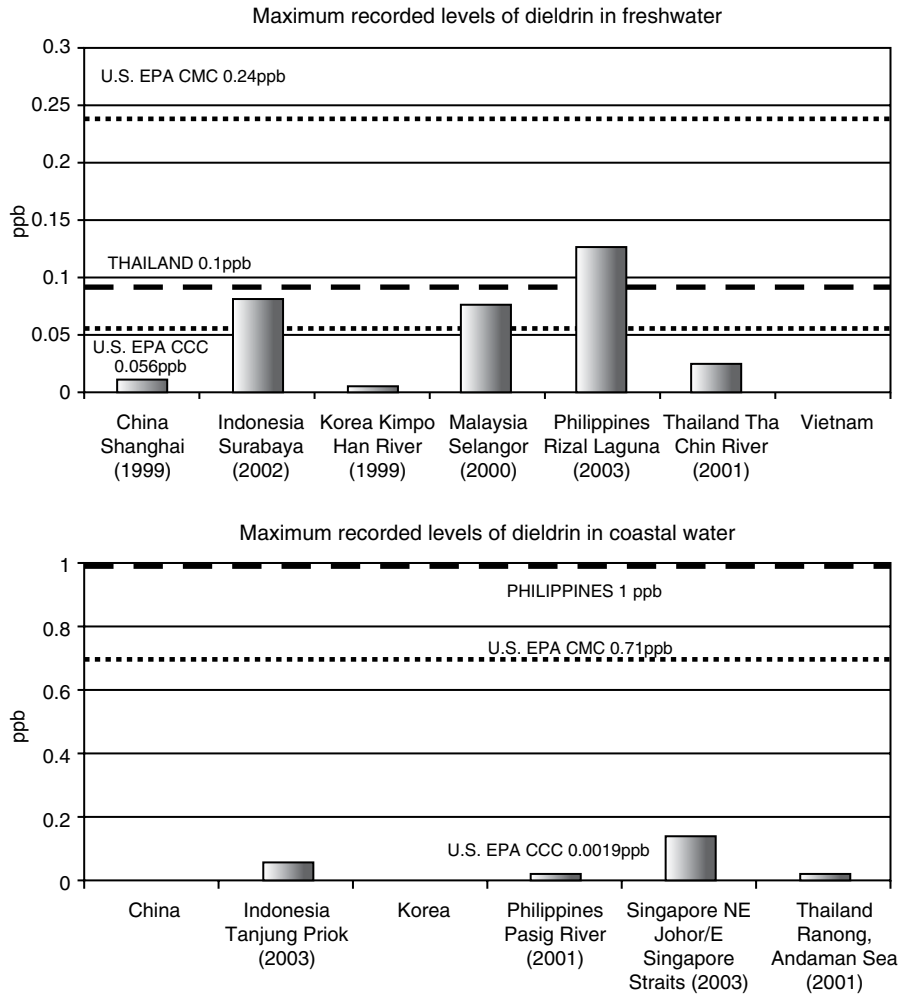


**Figure 10E.125** Maximum recorded levels of dieldrin in freshwater and seawater in East Asia. (From King, C., 2003, Capacity Development for Monitoring Major Persistent Organic Pollutants (POPs) in East Asian Waters: Examples of UNU Monitoring Activities in East Asia in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1–2 September, 2003, UNU Centre, Tokyo, www.unu.edu. Printed with permission.)

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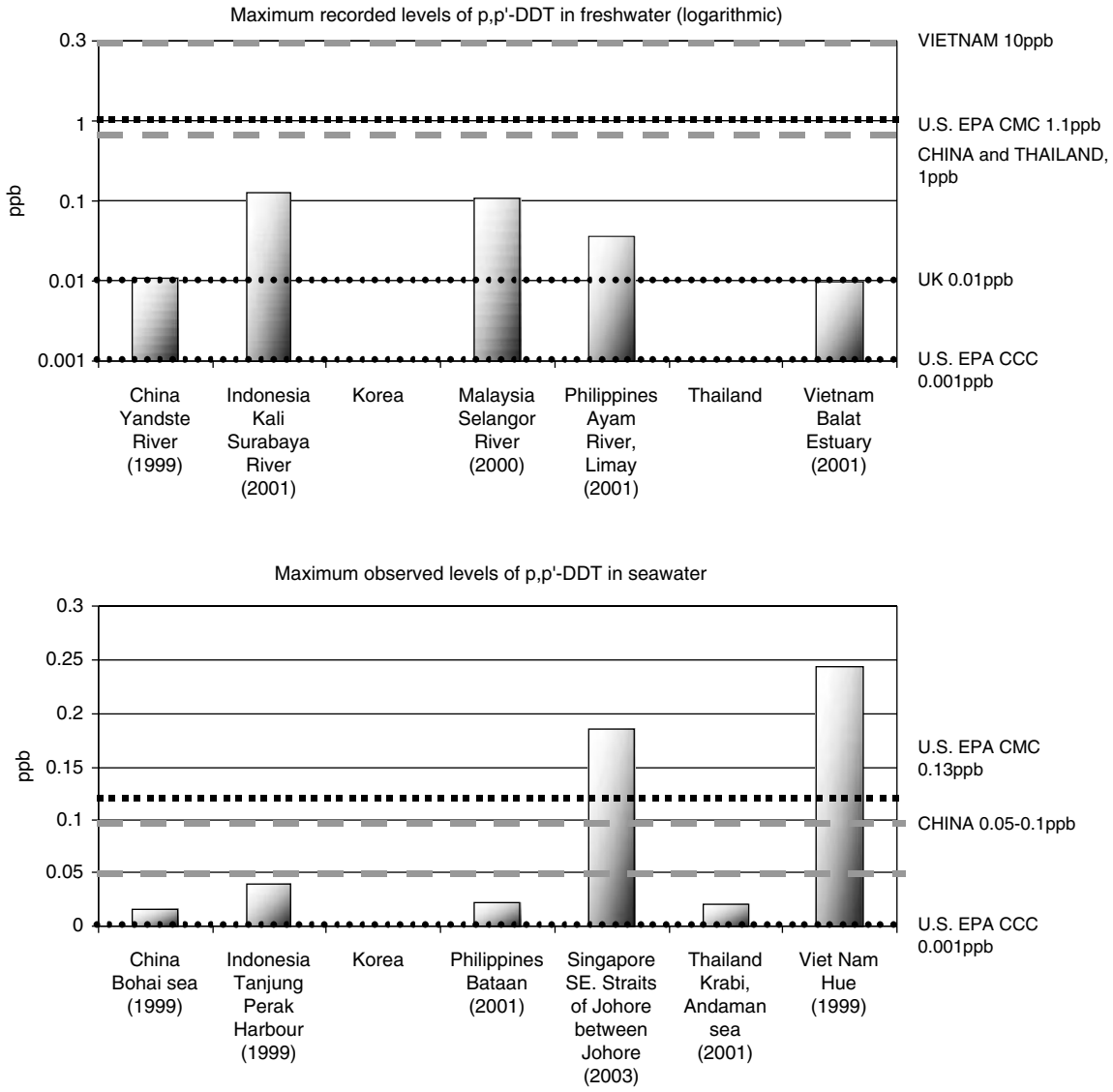


**Figure 10E.126** Maximum recorded levels of *p,p′*-DDT in freshwater and seawater 1999–2003. (From King, C., 2003, Capacity Development for Monitoring Major Persistent Organic Pollutants (POPs) in East Asian Waters: Examples of UNU Monitoring Activities in East Asia in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1–2 September, 2003, UNU Centre, Tokyo, www.unu.edu. Printed with permission.)

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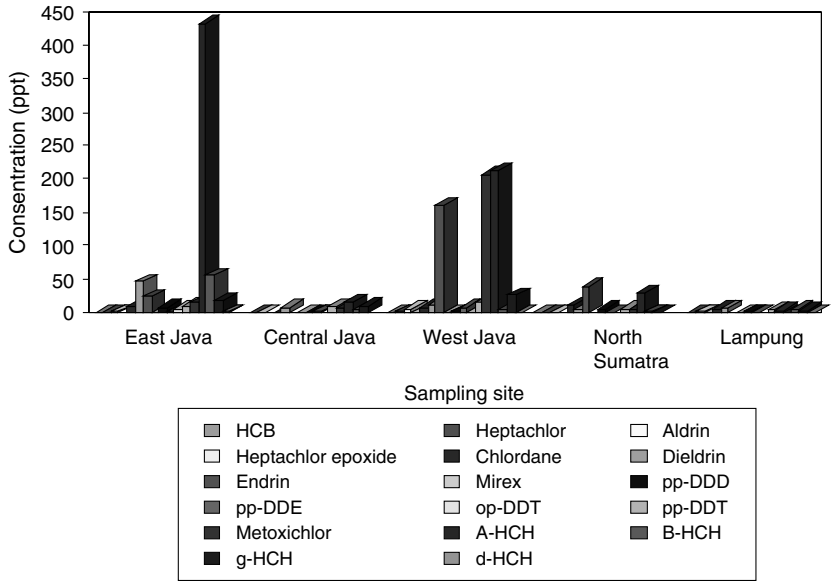


**Figure 10E.127** Highest concentrations of POPs and OCs compounds in Indonesian river sediment in 2002. (From Syafrul, H., 2003, Environmental Standards Related to POPs in Indonesia in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1–2 September, 2003, UNU Centre, Tokyo, www.unu.edu. With permission.)

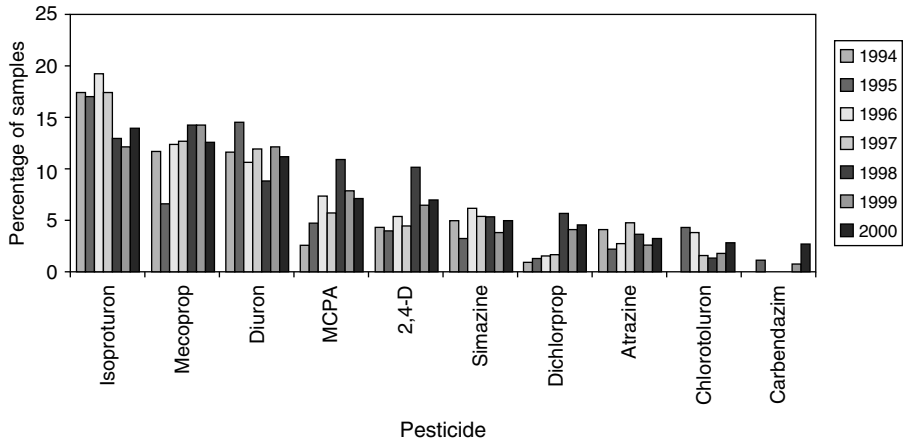


**Figure 10E.128** Trends in exceedance of 0.1 ug/L drinking water directive standard for England and Wales, 1994–2000. (From Department of Environment, Food and Rural Affairs, 2002, *The Government's Strategic Review of Diffuse Water Pollution from Agriculture in England: Agriculture and Water: A Diffuse Pollution Review*, www.defra.gov.uk. Reproduced under the terms of the Click-Use Licence.)

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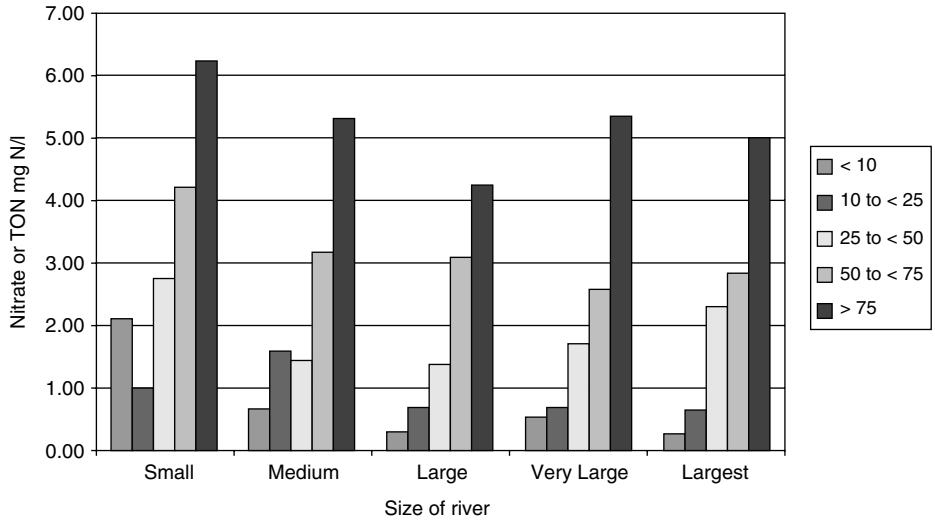


**Figure 10E.129** Median annual average nitrate or total oxidized nitrogen concentrations (mg N/L) at stations in different sized rivers in relation to the percentage total agricultural land use in upstream catchment. (From European Environment Agency, *YIR01WQ1 Nitrogen and Phosphorous in River Stations by River Size and Catchment Type*, www.eea.europa.eu. Reprinted with permission © EEA.)

Nitrate concentrations in rivers

Nitrate pollution in rivers is higher in the EU-15 than in the New -10 (but lowest of all in the Nordic countries). This reflects differences in agricultural intensity and practices. In 2000/2001, rivers in 14 European countries (out of 24 with available information) exceeded the EU drinking water directive's guide concentration for nitrate; five also exceeded the maximum allowable concentration. In general nitrate concentrations in rivers are declining: 25% of monitoring stations on Europe's rivers recorded a decrease between 1992 and 2001. However, around 15% of river monitoring stations showed an increasing trend in nitrate concentrations over the same period.

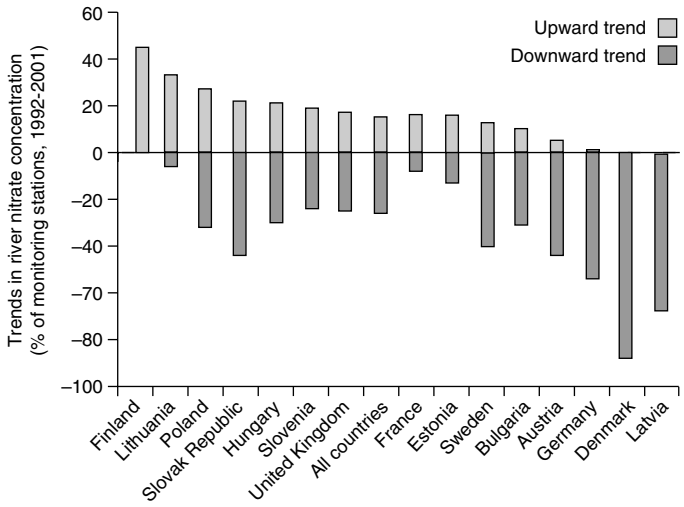


**Figure 10E.130** Nitrate concentration trends in European rivers. (From European Environmental Agency, 2004, EEA Signals 2004, *A European Environmental Update on Selected Issues*, www.eea.europa.eu. Reprinted with permission © EEA.)

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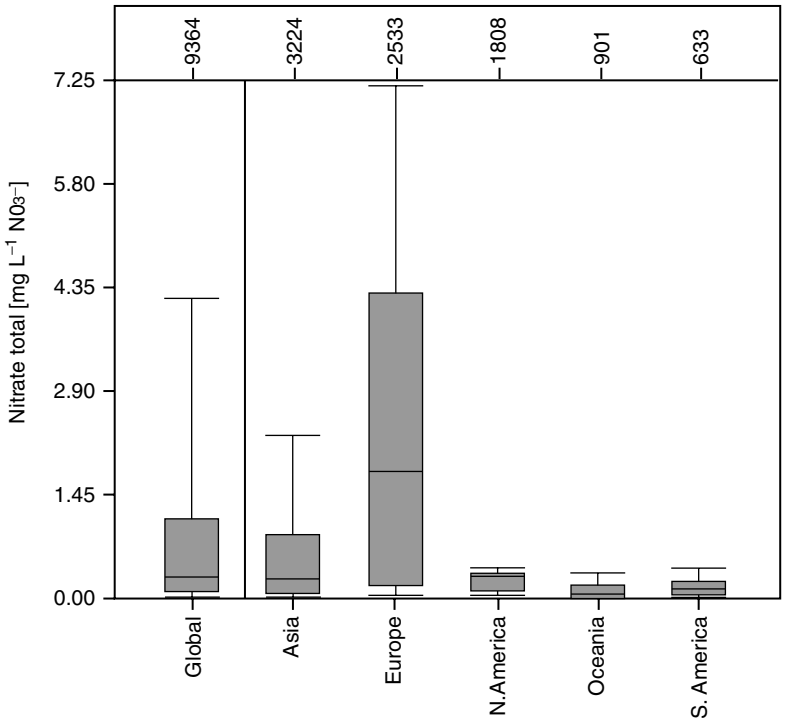


**Figure 10E.131** Statistical distribution of nitrate for major global watersheds, 1976–1990. (From United Nations Environmental Programme Global Environment Monitoring System, Water Programme (GEMS/WATER), *The Annotated Digital Atlas of Global Water Quality*, www.gemswater.org. Reprinted with permission.)

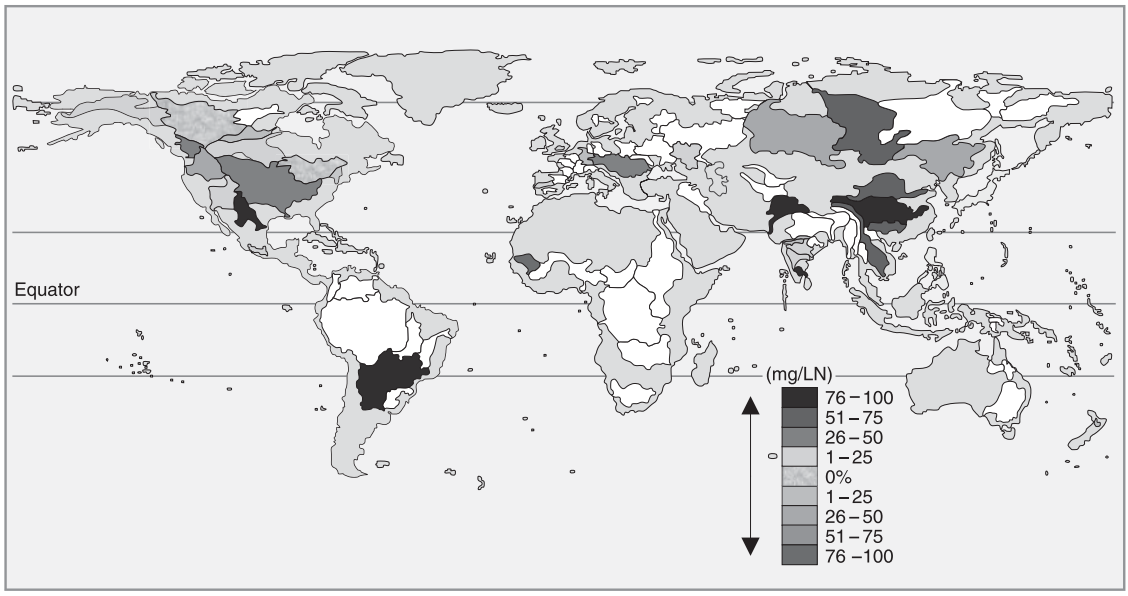


**Figure 10E.132** Percent change of nitrogen, nitrate + nitrite in selected 82 watersheds. (From United Nations Environment Program, *Global Environment Monitoring System (GEMS) Water Programs, 2005, 2004 State of the UNEP GEMS/Water Global Network and Annual Report*, 2005, www.gemswater.org. Printed with permission.)

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**Figure 10E.133** Nitrate in groundwater in Europe. (From European Environmental Agency (EEA), 1999, *Groundwater Quality and Quantity in Europe*, June 1999, www.eea.europa.eu. Reprinted with permission © EEA.)

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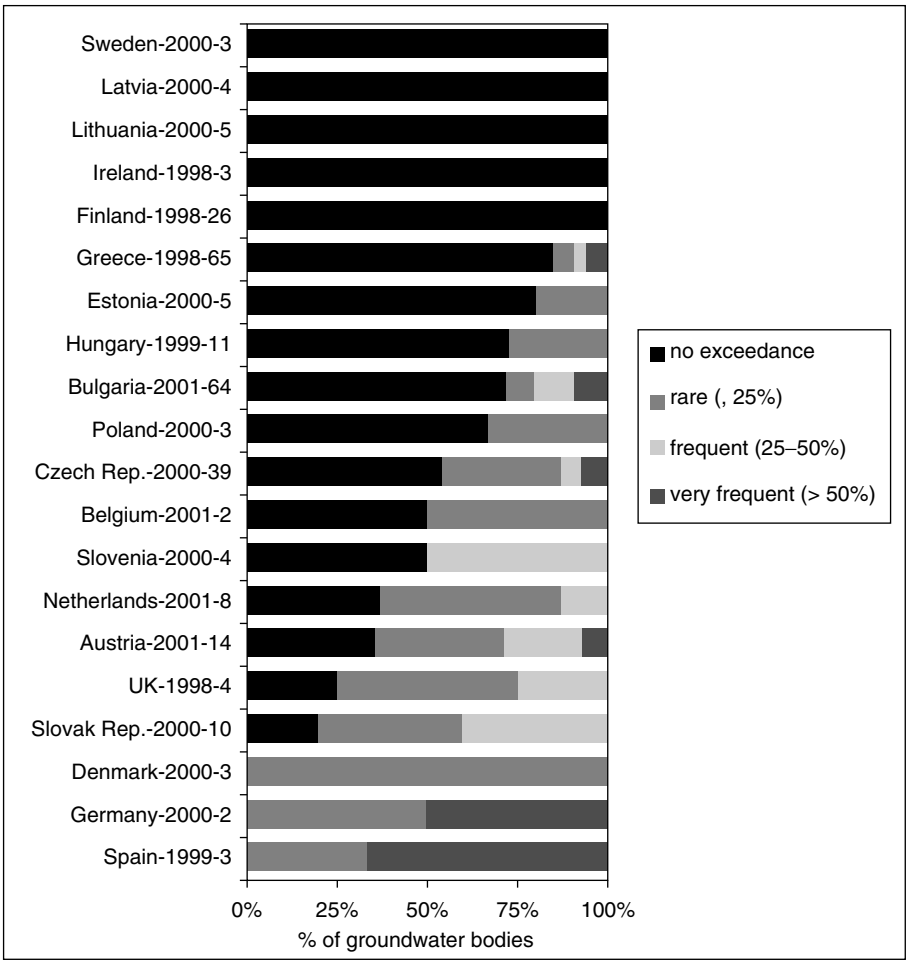


*Note*: The figure is based on the data for the latest year available (given after the country name). The numbers of groundwater bodies per country indluded in the presentation are given after the year. The four classes represent the percentage of sampling sites within each groundwater body where annual mean nitrate values exceed 50 mg $No_3$/litre.

**Figure 10E.134** Percentage of sampling sites in groundwater bodies where annual mean values exceed 50 mg/L. Nitrate (From European Environment Agency, *Nitrate in Groundwater, Indicator Fact Sheet WEU01*, www.eea.europa.eu. Reprinted with permission © EEA.)

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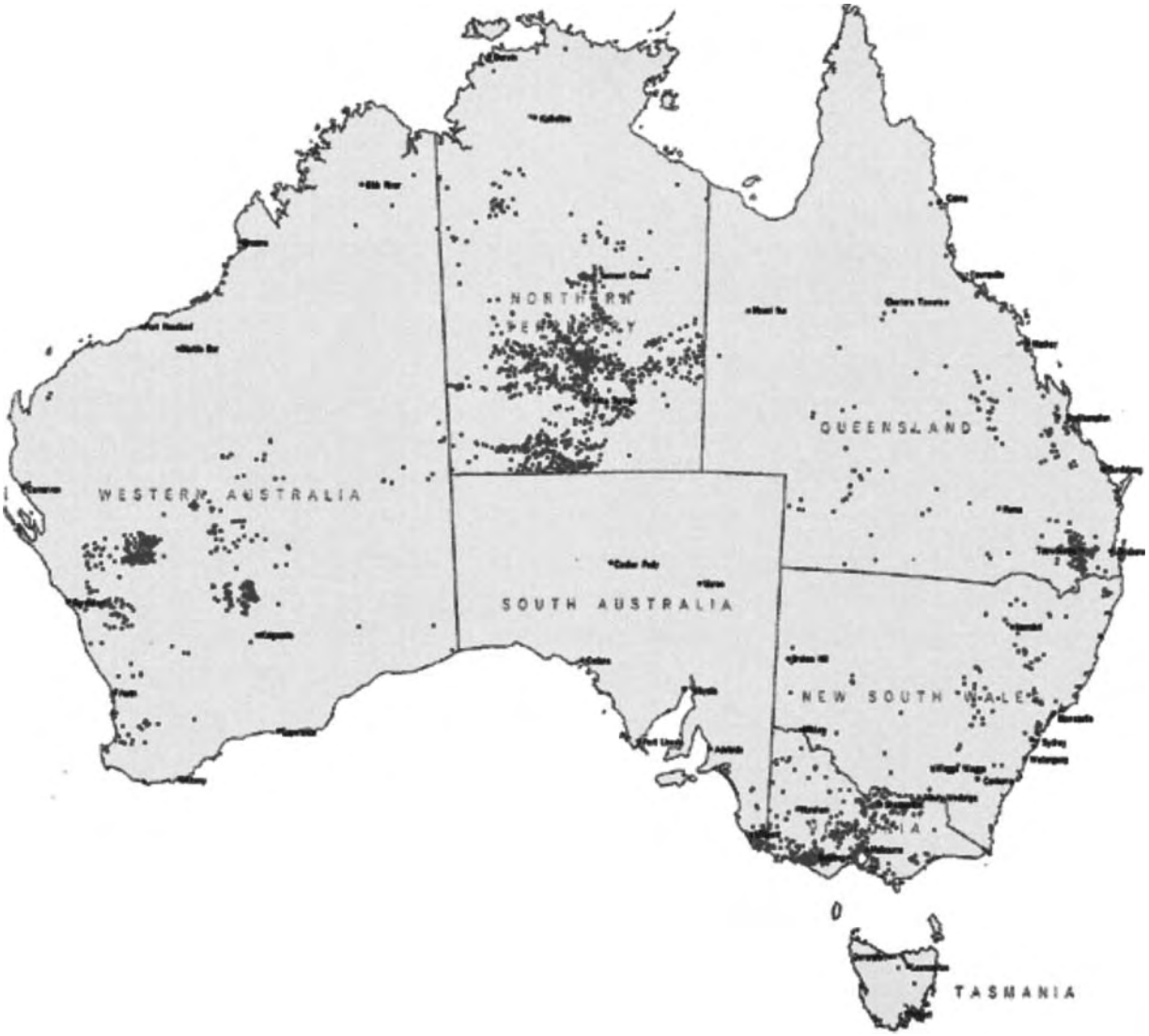


**Figure 10E.135** Distribution of bores across Australia, with nitrate levels greater than 10 mg/L. (From Ball, J., Donnelley, L., Erlanger, P., Evans, R., Kollmorgen, A., Neal, B., and Shirley, M., 2001, Inland Waters, *Australia State of Environment Report 2001* (Theme Report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra www.deh.gov.au. Original Source: LWRRDC, 1999, Contamination of Australian Groundwater Systems with Nitrate, Occasional Paper No. 03/99, Land and Water Resources Research and Development Corporation, Canberra, www.lwrrdc.gov.au. Copyright Commonwealth of Australia reproduced by permission.)

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**Table 10E.122 Trends in Regional Agricultural Activity and Soil Loss, 1975 and 2000 (High Growth Scenario)**

| | | Acres in Crop Production | | | | Soil Loss | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1975 | | 2000 | | 1975 | | 2000 | | Annual Average |
| | Region | Quantity ($10^6$ Acres) | Percent of National Total | Percent of 1975 Value | Percent of National Total | Quantity ($10^6$ Tons) | Percent of National Total | Percent of 1975 Value | Percent of National Total | Soil Loss Per Acre (Tons) |
| I. | New England | [a] | [b] | 129 | [b] | 2 | [b] | 126 | [b] | 13 |
| II. | New York-New Jersey | 1 | 1 | 119 | 1 | 17 | [b] | 120 | [b] | 14 |
| III. | Middle Atlantic | 5 | 2 | 127 | 2 | 180 | 5 | 127 | 5 | 36 |
| IV. | Southeast | 27 | 12 | 121 | 12 | 900 | 24 | 119 | 24 | 33 |
| V. | Great Lakes | 65 | 29 | 132 | 33 | 880 | 24 | 136 | 27 | 14 |
| VI. | South Central | 31 | 14 | 108 | 13 | 590 | 16 | 114 | 15 | 20 |
| VII. | Central | 58 | 26 | 107 | 24 | 960 | 26 | 113 | 24 | 18 |
| VIII. | Mountain | 26 | 12 | 105 | 10 | 72 | 1 | 100 | 2 | 3 |
| IX. | West | 4 | 2 | 140 | 2 | 10 | [b] | 144 | [b] | 3 |
| X. | Northwest | 7 | 3 | 129 | 3 | 86 | 2 | 129 | 2 | 13 |
| **Total**[c] | | **223** | **100** | **118** | **100** | **3,700** | **100** | **121** | **100** | **17** |

[a] Less than 0.5 million acres.
[b] Less than 0.5 percent.
[c] Rounding may creat inconsistencies in addition.

*Source*: From U.S. Environmental Protection Agency, 1980, *Environmental Outlook* 1980.

**Table 10E.123 Estimated Acreage and Erosion in the Contiguous United States, Selected Years, 1938–1997**

| Item | 1938 | 1967 | 1977 | 1982 | 1987 | 1992 | 1997 |
|---|---|---|---|---|---|---|---|
| **Acreage** | | | | **Million acres** | | | |
| Cropland and CRP combined | 398.8[a] | 438.2 | 413.3 | 421 | 406.6 | 382.3 | 377 |
| CRP land | — | — | — | — | 3.8 | 34 | 32.7 |
| Pasture | na | na | na | 131.9 | 127.6 | 125.9 | 120 |
| Range | na | na | na | 408.9 | 402.8 | 398.9 | 406 |
| **Total erosion** | | | | **Billion tons/year** | | | |
| Cropland and CRP combined | | | | | | | |
| Sheet and rill | na | 2.60[b] | 1.93 | 1.69 | 1.52 | 1.21 | 1.06 |
| Wind | na | na | na | 1.38 | 1.4 | 0.95 | 0.84 |
| Pasture | | | | | | | |
| Sheet and rill[c] | na | na | na | 1.45 | 1.28 | 1.26 | 1.08 |
| Wind[d] | na | na | na | 0.13 | 0.13 | 0.13 | 0.12 |
| Range | | | | | | | |
| Sheet and rill[c] | na | na | na | 0.49 | 0.48 | 0.48 | na |
| Wind[c] | na | na | na | 1.92 | 1.77 | 1.76 | na |
| Total cropland, pasture, range | na | na | na | 7.12 | 6.46 | 5.76 | na |
| **Erosion per acre** | | | | **Tons/acre/year** | | | |
| Cropland | | | | | | | |
| Sheet and rill | na | 5.9 | 4.7 | 4 | 3.7 | 3.1 | 2.8 |
| Wind | na | na | 5.3 | 3.3 | 3.2 | 2.4 | 2.2 |
| Subtotal | 8.9[d] | na | na | 7.3 | 6.9 | 5.5 | 5 |
| CRP | | | | | | | |
| Sheet and rill | — | — | — | — | 2 | 0.6 | 0.4 |
| Wind | — | — | — | — | 6.8 | 0.7 | 0.3 |

*(Continued)*

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**Table 10E.123 (Continued)**

| Item | 1938 | 1967 | 1977 | 1982 | 1987 | 1992 | 1997 |
|---|---|---|---|---|---|---|---|
| Subtotal | — | — | — | —— | 8.8 | 1.3 | 0.7 |
| Pasture | | | | | | | |
| Sheet and rill | na | na | na | 1.1 | 1 | 1 | 0.9 |
| Wind | na | na | na | 0.1 | 0.1 | 0.1 | 0.1 |
| Range | | | | | | | |
| Sheet and rill | na | na | na | 1.2 | 1.2 | 1.2 | na |
| Wind | na | na | na | 4.7 | 4.4 | 4.4 | na |

*Note:* na, not available; CRP, Conservation Reserve Program.

[a] Based on 1939 census estimate of cropland.
[b] Kimberlin (1976), based on 1967 Conservation Needs Inventory.
[c] Based on multiplying published per acre erosion estimates times acreage.
[d] Based on dividing sum of sheet, rill, and wind erosion by total U.S. cropland acres.

*Source*: From Heimlich, R., 2003, Agricultural Resources and Environmental Indicators 2003, *Agriculture Handbook No. (AH722)*, www.ers.usda.gov; based on data from USDA, ERS, NRCS National Resources Investigations of 1977, 1982, 1987, 1992, and 1997, except where noted.

**Table 10E.124 Representative Values for Nutrient Export and Input Rates for Various Land Uses in the United States**

| Land Use | Total Phosphorus | Total Nitrogen |
|---|---|---|
| A. Export rates (kg/ha/yr)[a,b] | | |
| Forest | 0.2 | 2.5 |
| Nonrow crops | 0.7 | 6.0 |
| Pasture | 0.8 | 14.5 |
| Mixed agriculture | 1.1 | 5.0 |
| Row crops | 2.2 | 9.0 |
| Feedlot, manure storage | 255.0 | 2,920.0 |
| B. Total atmospheric input rates (kg/ha/yr)[a,b] | | |
| Forest | 0.26 | 6.5 |
| Agricultural/rural | 0.28 | 13.1 |
| Urban industrial | 1.01 | 21.4 |
| C. Wastewater input rates (kg/capita/yr)[b] | | |
| Septic tank input[c] | 1.45 | 4.65 |

*Note:* All values are medians and are only approximations owing to the highly variable nature of data on these rates.

[a] Value in this table are all in kg/ha/yr, which is the standard for such measurements. To convert to pounds per acre per year, multiple by 0.892.
[b] *Source*: Reckhow et al., 1980.
[c] This is prior to absorption to soil during infiltration; generally, soils will absorb 80 percent or more of this phosphorus.

*Source*: From U.S. Environmental Protection Agency, 1988, *The Lake and Reservoir Restoration Guidance Manual*, EPA 440/5-88-002.

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**Table 10E.125 Contribution of Total Nitrogen and Phosphorous from Variable Nonpoint Sources (in Pounds per Acre per Year)**

| | Areal Loading Rates | |
|---|---|---|
| **Source** | **Nitrogen (N)** | **Phosphorus (P)** |
| Precipitation | 5.0–9.8 | 0.04–0.05 |
| Forest land | 2.7–12 | 0.03–0.8 |
| Range land | — | 0.07–0.08 |
| Crop land | 0.10–12 | 0.05–2.7 |
| Land receiving manure | 3.6–12 | 0.7–2.7 |
| Irrigation return flows | | |
| Surface | 3.0–27 | 1.0–4.1 |
| Subsurface | 4.0–18 | 2.9–10 |
| Urban land drainage | 6.4–8.9 | 1.1–5.4 |
| Animal feedlot runoff | 90–1,400 | 8.9–630 |

*Source*: From U.S. Geological Survey, 1984, National Water Summary 1983-Hydrologic Events and Issues, *Water Supply Paper 2250*; based on data from Loehr, R.C., 1974.

**Table 10E.126 Constituents of Livestock Waste**

| | Per Day (lb.) | 104 Days (lb.) | 360 Head/Acre/yr (Tons) |
|---|---|---|---|
| Wet manure and urine | 64 | 8,960 | 4,200 |
| Dry mineral matter | 2.1 | 294 | 144 |
| Dry organic matter | 8.2 | 1,148 | 540 |
| Water | 53.7 | 7,518 | 30.7 in. |
| Total nitrogen | 0.380 | 55.0 | 24.9 |
| Total phosphorus | 0.048 | 6.7 | 3.2 |
| Total potassium | 0.260 | 36.4 | 16.8 |

*Note:* Some constituents of waste of a 1,000-pound bovine on a daily and feeding period basis, and of 360 head per acre on an annual basis.

*Source*: From Hansen, R.W., 1971, Livestock Waste Disposal and Water Pollution Control, *Colorado State University Cooperative Extension Service Bulletin* 480a.

**Table 10E.127 Fertilizer Elements of Animal Excrements**

| | Dairy Cattle (lb./day) | Beef Cattle (lb./day) | Hens (lb./day) | Hogs (lb./day) | Sheep (lb./day) |
|---|---|---|---|---|---|
| Wet manure | 88 | 64 | 59 | 50 | 37 |
| Total mineral matter | 1.80 | 2.1 | 4.5 | 1.3 | 1.5 |
| Organic matter | 7.20 | 8.2 | 12.9 | 5.9 | 6.9 |
| Nitrogen (N) | 0.36 | 0.38 | 2 | 0.4 | |
| Phosphorus ($P_2O_5$) | 0.10 | 0.048 | 0.69 | 0.18 | |
| Potassium ($K_2O$) | 0.15 | 0.26 | 0.34 | 0.1 | |

*Note:* Fertilizer elements of various complete animal excrements per 1,000 pounds of liveweight.

*Source*: From Hansen, R.W., 1971, Livestock Waste Disposal and Water Pollution Control, *Colorado State University Cooperative Extension Service Bulletin* 480a.

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**Table 10E.128 Trends in Gross Nutrient Discharges in Agricultural Runoff in the United States, 1975 and 2000**

| | | 2000 (Tons) | |
|---|---|---|---|
| **Pollutant** | **1975 (Tons)** | **High Growth** | **Low Growth** |
| Nitrogen | 5,700 | 8,800 | 7,600 |
| Phosphorus | 3,000 | 5,700 | 4,900 |
| Potassium | 1,400 | 2,600 | 2,200 |
| Total[a] | 10,000 | 17,000 | 15,000 |

[a] Rounding may create inconsistencies in addition.

*Source*: From U.S. Environmental Protection Agency, *Environment Outlook* 1980.

**Table 10E.129 Trends in Gross Discharges of Sediment in Agricultural Runoff in the United States, 1975 and 2000**

| | | 2000 ($10^3$ Tons) | |
|---|---|---|---|
| **Pollutant** | **1975 ($10^3$ Tons)** | **High Growth** | **Low Growth** |
| Total suspended solids | 94,000 | 110,000 | 97,000 |
| Total dissolved solids | 40,000 | 49,000 | 42,000 |
| Biochemical oxygen demand | 630 | 760 | 650 |

*Note:* Conservative estimates; discharges may uniformly be too low by a factor of four of five.

*Source*: From U.S. Environmental Protection Agency, *Environmental Outlook* 1980.

**Table 10E.130 Yield and Percentage Change in Yield of Nitrate, Total Phosphorous, and Suspended Sediment in Water-Resource Regions of the Conterminous United States, 1980–1989**

| | Nitrate 1980–1989 | | Total Phosphorus 1982–1989 | | Suspended Sediment 1980–1989 | |
|---|---|---|---|---|---|---|
| **Water-Resources Region** | **Yield, in Tons Per Square Mile Per Year** | **Percentage Change Per Year** | **Yield, in Tons Per Square Mile Per Year** | **Percentage Change Per Year** | **Yield, in Tons Per Square Mile Per Year** | **Percentage Change Per Year** |
| North Atlantic | 0.558 | [a] | 0.077 | −1.4 | 32 | −0.4 |
| South Atlantic-Gulf | 0.226 | [a] | 0.092 | +0.1 | 20 | +0.2 |
| Great Lakes | 0.647 | [a] | 0.067 | −3.3 | 36 | +0.5 |
| Ohio-Tennessee | 0.847 | [a] | 0.125 | −1.0 | 85 | −1.3 |
| Upper Mississippi | 0.989 | −0.4 | 0.157 | −1.2 | 102 | −1.3 |
| Lower Mississippi | 0.333 | −1.6 | 0.103 | −3.8 | 111 | −1.2 |
| Souris-Red-Rainy | 0.011 | [a] | 0.008 | −0.8 | 4 | +1.2 |
| Missouri | 0.060 | [a] | 0.028 | −1.7 | 45 | −0.2 |
| Arkansas-White-Red | 0.056 | [a] | 0.039 | −3.1 | 31 | −0.7 |
| Texas-Gulf-Rio Grande | 0.012 | [a] | 0.014 | −0.9 | 15 | −0.6 |
| Colorado | 0.057 | [a] | 0.036 | −2.4 | 92 | −0.8 |
| Great Basin | 0.049 | [a] | 0.018 | −2.7 | 21 | −0.2 |
| Pacific Northwest | 0.225 | [a] | 0.063 | −1.7 | 40 | −0.1 |
| California | 0.047 | [a] | 0.060 | −1.4 | 21 | −0.6 |

[a] Between −0.1 and +0.1.

*Source*: From Smith, R. A., Alexander, R. B., and Lanfear, K. J., 1993, Stream water quality in the conterminous United States – status and trends of selected indicators during the 1980's in national water summary 1990–91 — stream water quality, *U.S. Geological Survey Water-Supply Paper 2400*, www.usgs.gov.

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**Table 10E.131 Nitrogen Runoff Estimates in Coastal Regions by Major Source Category, Selected Years 1982–1987**

| | Total Nitrogen (1,000 lbs/yr) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| EDA Group | WWTPs | Industries | Urban Runoff | Cropland Runoff | Pature/Range Runoff | Forest Runoff | Upstream Sources | Total |
| North Atlantic | 23,475 | 1,335 | 8,291 | 2,471 | 108 | 556 | 69,930 | 106,166 |
| Middle Atlantic | 178,810 | 22,237 | 46,367 | 36,277 | 780 | 1,166 | 314,539 | 600,177 |
| South Atlantic | 23,265 | 13,802 | 15,184 | 39,115 | 34 | 130 | 82,929 | 174,460 |
| Gulf of Mexico East | 27,516 | 11,154 | 17,131 | 42,310 | 29,362 | 51 | 3,057,405 | 3,184,927 |
| Gulf of Mexico West | 22,917 | 13,789 | 7,261 | 17,021 | 34,070 | 46 | 88,626 | 183,730 |
| Pacific-South | 83,163 | 1,530 | 9,437 | 32,472 | 33,811 | 5,589 | 58,784 | 224,786 |
| Pacific-North | 18,301 | 3,877 | 5,630 | 5,432 | 89,307 | 89,307 | 173,968 | 303,771 |

*Source*: From United States Department of Agriculture, Natural Resources Conservation Services, 1997, *Water Quality and Agriculture, Status, Conditions, and Trends*, www.nrcs.usda.gov.

*Original Source*: From NOAA, 1994.

**Table 10E.132 Phosphorus Runoff Estimates in Coastal Regions by Major Source Category, Selected Years 1982–1987**

| | Total Phosphorus (1,000 lbs/yr) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| EDA Group | WWTPs | Industries | Urban Runoff | Cropland Runoff | Pasture/Range Runoff | Forest Runoff | Upstream Sources | Total |
| North Atlantic | 14,826 | 312 | 1,368 | 132 | 1 | 6 | 4,114 | 20,760 |
| Middle Atlantic | 112,998 | 3,823 | 7,512 | 2,001 | 8 | 12 | 20,579 | 146,931 |
| South Atlantic | 14,580 | 10,872 | 2,311 | 2,664 | 0 | 1 | 17,159 | 47,588 |
| Gulf of Mexico East | 9,202 | 27,248 | 2,607 | 433 | 294 | 1 | 434,073 | 473,857 |
| Gulf of Mexico West | 13,990 | 6,580 | 1,105 | 173 | 341 | 0 | 20,458 | 42,646 |
| Pacific-South | 59,211 | 186 | 1,456 | 723 | 338 | 56 | 3,611 | 65,581 |
| Pacific-North | 13,749 | 304 | 886 | 113 | 73 | 893 | 27,452 | 43,470 |

*Source*: From United States Department of Agriculture, Natural Resources Conservation Services, 1997, *Water Quality and Agriculture, Status, Conditions, and Trends*, www.nrcs.usda.gov.

*Original Source*: From NOAA, 1994.

**Table 10E.133 Load Yield, and Percentage Change in Load and Yield of Nitrate, Total Phosphorous, and Suspended Sediment in Six Coastal Segments of the Conterminous United States, 1980–1989**

| | Nitrate 1980–1988 | | | Total Phosphorus 1982–1988 | | | Suspended Sediment 1980–1988 | | |
|---|---|---|---|---|---|---|---|---|---|
| Coastal Segment | Load (tons/yr) | Yield in Tons Per Square Mile Per Year | Percentage Change Per Year | Load (tons/yr) | Yield, in Tons Per Square Mile Per Year | Percentage Change Per Year | Load (tons/yr) | Yield, in Tons Per Square Mile Per Year | Percentage Change Per Year |
| North Atlantic | 171 | 0.972 | +1.8 | 18 | 0.101 | [a] | 1,177 | 67 | +8.0 |
| South Atlantic | 37 | 0.257 | [a] | 10 | 0.068 | [a] | 257 | 18 | −1.1 |
| Gulf of Mexico | 1,178 | 0.687 | −3.4 | 136 | 0.079 | −3.5 | 16,607 | 97 | −3.8 |
| Great Lakes | 205 | 1.570 | [a] | 14 | 0.108 | −2.6 | 1,484 | 114 | [a] |
| Pacific Northwest | 74 | 0.267 | [a] | 15 | 0.055 | −2.2 | 2,519 | 91 | [a] |
| California | 26 | 0.232 | +2.1 | 15 | 0.132 | [a] | 4,684 | 502 | −21.0 |
| Total load | 1,691 | — | — | 207 | — | — | 26,728 | — | — |
| Area-weighted average yield | — | 0.638 | — | — | 0.079 | — | — | 104 | — |
| Change in Total Load | — | — | −2.1 | — | — | −3.0 | — | — | −6.4 |

[a] Not statistically significant.

*Source*: From Smith, R.A., Alexander, R.B., and Lanfear, K.J., 1993, Stream water quality in the conterminous United States – status and trends of selected indicators during the 1980's in national water summary 1990–91 — stream water quality, *U.S. Geological Survey Water-Supply Paper 2400*, www.usgs.gov.

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**Table 10E.134 Farm Fertilizer Use in the United States, 1939–1998 (Millions of Tons of Primary Nutrients)**

| Year | Fertilizer Applied | Year | Fertilizer Applied | Year | Fertilizer Applied | Year | Fertilizer Applied |
|---|---|---|---|---|---|---|---|
| 1939 | 1.6 | 1954 | 5.9 | 1969 | 15.5 | 1984 | 21.8 |
| 1940 | 1.8 | 1955 | 6.1 | 1970 | 16.1 | 1985 | 21.7 |
| 1941 | 1.9 | 1956 | 6.1 | 1971 | 17.2 | 1986 | 19.7 |
| 1942 | 2.1 | 1957 | 6.4 | 1972 | 17.2 | 1987 | 19.1 |
| 1943 | 2.4 | 1958 | 6.5 | 1973 | 18 | 1988 | 19.6 |
| 1944 | 2.6 | 1959 | 7.4 | 1974 | 19.3 | 1989 | 19.6 |
| 1945 | 2.7 | 1960 | 7.5 | 1975 | 17.6 | 1990 | 20.6 |
| 1946 | 3.1 | 1961 | 7.8 | 1976 | 20.8 | 1991 | 20.5 |
| 1947 | 3.3 | 1962 | 8.4 | 1977 | 22.1 | 1992 | 20.7 |
| 1948 | 3.6 | 1963 | 9.5 | 1978 | 20.6 | 1993 | 20.9 |
| 1949 | 3.9 | 1964 | 10.5 | 1979 | 22.6 | 1994 | 22.4 |
| 1950 | 4.1 | 1965 | 11 | 1980 | 23.1 | 1995 | 21.3 |
| 1951 | 4.7 | 1966 | 12.4 | 1981 | 23.7 | 1996 | 22.1 |
| 1952 | 5.2 | 1967 | 14 | 1982 | 21.4 | 1997 | 22.4 |
| 1953 | 5.6 | 1968 | 15 | 1983 | 18.1 | 1998 | 22.3 |

*Source*: From U.S. Department of Commerce, Bureau of the Census, 1976. *Historical Statistics of the United States: Colonial Times to 1970*, Series K 193. Washington, DC; U.S. Department of Commerce, Bureau of the Census. 1985. *Statistical Abstracts of the United States*: 1986, no. 1161, p. 654. Washington, DC; U.S. Department of Agriculture, Economic Research Service. 1987. *Inputs Situation and Outlook Report.* AR-5. Washington, DC; U.S. Geological Survey National Water Summary 1986; Heimlich, 2003; Agricultural Resources and Environmental Indicators 2003, *Agriculture Handbook No. (AH722)*, February 2003.

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**Table 10E.135 United States Commercial Fertilizer Use, 1960–1998**

| Year | Total Materials[a] | Primary Nutrient Use | | | |
|---|---|---|---|---|---|
| | | Nitrogen (N) | Phosphate ($P_2O_5$) | Potash ($K_2O$) | Total[b] |
| | | *Million Ions* | | | |
| 1960 | 24.9 | 2.7 | 2.6 | 2.2 | 7.5 |
| 1961 | 25.6 | 3.0 | 2.6 | 1.2 | 7.8 |
| 1962 | 26.6 | 3.4 | 2.8 | 2.3 | 8.4 |
| 1963 | 28.8 | 3.9 | 3.1 | 2.5 | 9.5 |
| 1964 | 30.7 | 4.4 | 3.4 | 2.7 | 10.5 |
| 1965 | 31.8 | 4.6 | 3.5 | 2.8 | 10.9 |
| 1966 | 34.5 | 5.3 | 3.9 | 3.2 | 12.4 |
| 1967 | 37.1 | 6.0 | 4.3 | 3.6 | 14.0 |
| 1968 | 38.7 | 6.8 | 4.4 | 3.8 | 15.0 |
| 1969 | 38.9 | 6.9 | 4.7 | 3.9 | 15.5 |
| 1970 | 39.6 | 7.5 | 4.6 | 4.0 | 16.1 |
| 1971 | 41.1 | 8.1 | 4.8 | 4.2 | 17.2 |
| 1972 | 41.2 | 8.0 | 4.9 | 4.3 | 17.2 |
| 1973 | 43.3 | 8.3 | 5.1 | 4.6 | 18.0 |
| 1974 | 47.1 | 9.2 | 5.1 | 5.1 | 19.3 |
| 1975 | 42.5 | 8.6 | 4.5 | 4.4 | 17.6 |
| 1976 | 49.2 | 10.4 | 5.2 | 5.2 | 20.8 |
| 1977 | 51.6 | 10.6 | 5.6 | 5.8 | 22.1 |
| 1978 | 47.5 | 10.0 | 5.1 | 5.5 | 20.6 |
| 1979 | 51.5 | 10.7 | 5.6 | 6.2 | 22.6 |
| 1980 | 52.8 | 11.4 | 5.4 | 6.2 | 23.1 |
| 1981 | 54.0 | 11.9 | 5.4 | 6.3 | 23.7 |
| 1982 | 48.7 | 11.0 | 4.8 | 5.6 | 21.4 |
| 1983 | 41.8 | 9.1 | 4.1 | 4.8 | 18.1 |
| 1984 | 50.1 | 11.1 | 4.9 | 5.8 | 21.8 |
| 1985 | 49.1 | 11.5 | 4.7 | 5.6 | 21.7 |
| 1986 | 44.1 | 10.4 | 4.2 | 5.1 | 19.7 |
| 1987 | 43.0 | 10.2 | 4.0 | 4.8 | 19.1 |
| 1988 | 44.5 | 10.5 | 4.1 | 5.0 | 19.6 |
| 1989 | 44.9 | 10.6 | 4.1 | 4.8 | 19.6 |
| 1990 | 47.7 | 11.1 | 4.3 | 5.2 | 20.6 |
| 1991 | 47.3 | 11.3 | 4.2 | 5.0 | 20.5 |
| 1992 | 48.8 | 11.4 | 4.2 | 5.0 | 20.7 |
| 1993 | 49.2 | 11.4 | 4.4 | 5.1 | 20.9 |
| 1994 | 52.3 | 12.6 | 4.5 | 5.3 | 22.4 |
| 1995 | 50.7 | 11.7 | 4.4 | 5.1 | 21.3 |
| 1996 | 53.6 | 12.3 | 4.5 | 5.3 | 22.1 |
| 1997 | 55.0 | 12.4 | 4.6 | 5.4 | 22.4 |
| 1998 | 55.0 | 12.3 | 4.6 | 5.3 | 22.3 |

*Note:* Includes Puerto Rico. Detailed State data shown in (USDA, 1997). Fertilizer statistics used in this table include commercial fertilizers purchased for use on farms such as chemical fertilizers and natural processed and dried organic materials. Purchased natural processed and dried organic materials historically have represented about 1 percent of total nutrient use.

[a] Includes secondary and micronutrients. Most of the difference between total primary nutrient tons and total fertilizer materials is carrier or filler materials.

[b] Totals may not add due to rounding.

*Source*: From Heimlich, R., 2003, Agricultural Resources and Environmental Indicators 2003, *Agriculture Handbook No. (AH722)*, February 2003, www.ers.usda.gov.

*Original Source*: From Fertilizer use estimates for 1960–1984 are from USDA; *Commercial Fertilizers.* 1985 and earlier issues; those for 1985–1994 are from Tennessee Valley Authority (TVA), *Commercial Fertilizers,* 1994 and earlier issues; and those for 1995–1997 are from The Association of American Plant Food Control Officials, *Commercial Fertilizers,* 1995–1998.

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**Table 10E.136 United States Regional Commercial Nutrient Use for Year Ending June 30, 1989–1998**

| Region | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *1,000 tons* | | | | | |
| **Nitrogen** | | | | | | | | | | |
| Northeast | 313 | 306 | 299 | 328 | 350 | 376 | 349 | 334 | 354 | 351 |
| Lake States | 1,011 | 1,134 | 1,128 | 1,119 | 1,073 | 1,186 | 1,108 | 1,108 | 1,236 | 1,172 |
| Corn Belt | 3,041 | 3,215 | 3,280 | 3,279 | 3,003 | 3,562 | 3,228 | 3,354 | 3,243 | 3,220 |
| Northern Plains | 1,680 | 1,751 | 1,978 | 1,954 | 2,090 | 2,319 | 2,133 | 2,219 | 2,373 | 2,317 |
| Appalachia | 613 | 667 | 662 | 718 | 705 | 720 | 694 | 752 | 741 | 763 |
| Southeast | 643 | 670 | 627 | 65 | 682 | 701 | 640 | 694 | 660 | 635 |
| Delta States | 560 | 643 | 609 | 674 | 615 | 663 | 630 | 718 | 607 | 752 |
| Southern Plains | 1,217 | 1,117 | 1,223 | 1,192 | 1,235 | 1,377 | 1,208 | 1,186 | 1,258 | 1,282 |
| Mountain | 626 | 642 | 628 | 666 | 744 | 775 | 765 | 806 | 862 | 867 |
| Pacific | 916 | 921 | 838 | 849 | 886 | 953 | 953 | 1,122 | 1,010 | 938 |
| U.S. total[a] | 10,619 | 11,065 | 11,273 | 11,432 | 11,382 | 12,633 | 11,709 | 12,294 | 12,344 | 12,297 |
| **Phosphate** | | | | | | | | | | |
| Northeast | 188 | 197 | 188 | 208 | 211 | 232 | 203 | 183 | 184 | 171 |
| Lake States | 477 | 508 | 479 | 468 | 474 | 465 | 461 | 474 | 537 | 487 |
| Corn Belt | 1,254 | 1,334 | 1,262 | 1,269 | 1,312 | 1,317 | 1,257 | 1,340 | 1,304 | 1,275 |
| Northern Plains | 522 | 550 | 583 | 577 | 646 | 649 | 617 | 626 | 713 | 772 |
| Appalachia | 361 | 381 | 384 | 409 | 410 | 412 | 399 | 396 | 413 | 409 |
| Southeast | 297 | 308 | 281 | 295 | 314 | 297 | 313 | 332 | 318 | 328 |
| Delta States | 154 | 177 | 154 | 180 | 172 | 192 | 197 | 213 | 198 | 221 |
| Southern Plains | 342 | 315 | 334 | 288 | 340 | 363 | 341 | 313 | 319 | 330 |
| Mountain | 253 | 279 | 255 | 270 | 296 | 298 | 300 | 312 | 306 | 338 |
| Pacific | 270 | 289 | 274 | 248 | 257 | 291 | 326 | 335 | 316 | 290 |
| U.S. total[a] | 4,119 | 4,339 | 4,195 | 4,212 | 4,431 | 4,517 | 4,412 | 4,523 | 4,609 | 4,621 |
| **Potash** | | | | | | | | | | |
| Northeast | 232 | 261 | 262 | 267 | 262 | 299 | 280 | 230 | 234 | 228 |
| Lake States | 852 | 941 | 832 | 809 | 779 | 781 | 760 | 776 | 866 | 848 |
| Corn Belt | 1,974 | 2,132 | 2,044 | 1,987 | 2,034 | 2,133 | 1,996 | 2,098 | 2,153 | 2,074 |
| Northern Plains | 129 | 133 | 134 | 123 | 134 | 123 | 124 | 123 | 147 | 168 |
| Appalachia | 506 | 538 | 539 | 584 | 575 | 576 | 574 | 592 | 624 | 634 |
| Southeast | 558 | 559 | 517 | 556 | 581 | 535 | 563 | 587 | 563 | 564 |
| Delta States | 212 | 240 | 229 | 280 | 288 | 302 | 336 | 351 | 323 | 316 |
| Southern Plains | 149 | 143 | 150 | 146 | 168 | 191 | 168 | 172 | 178 | 172 |
| Mountain | 53 | 65 | 80 | 55 | 80 | 68 | 79 | 79 | 80 | 91 |
| Pacific | 155 | 179 | 200 | 220 | 230 | 252 | 231 | 240 | 249 | 242 |
| U.S. total[a] | 4,820 | 5,192 | 4,988 | 5,026 | 5,131 | 5,259 | 5,112 | 5,248 | 5,416 | 5,335 |

*Note:* Totals may not add due to rounding. Northeast, ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, and MD; Lake States, MI, WI, and MN; Corn Belt, OH, IN, IL, IA, and MO; Northern Plains, ND, SD, NE, and KS; Appalachia, VA, WV, NC, KY, and TN; Southeast, SC, GA, FL, and AL; Delta States, MS, AR, and LA; Southern Plains, OK and TX; Mountain, MT, ID, WY, CO, NM, AZ, UT, and NV; and Pacific, WA, OR, CA, AK, and HA.

[a] Excludes Puerto Rico. Detailed state data shown in (USDA, 1995).

*Source*: From Heimlich, R., 2003, Agricultural Resources and Environmental Indicators 2003, *Agriculture Handbook No. (AH722)*, February 2003, www.ers.usda.gov.

*Original Source*: From USDA, ERS, based on Tennessee Valley Authority, *Commercial Fertilizers*, 1994 and earlier issues; The Association of American Plant Food Control Officials, *Commercial Fertilizers,* 1995–1998.

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**Table 10E.137 Production and Sales of Synthetic Organic Pesticides in the United States, 1960–1984**

| Item | Unit | 1960 | 1965 | 1970 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production, total | Mil. lb | 648 | 877 | 1,034 | 1,603 | 1,364 | 1,388 | 1,416 | 1,429 | 1,468 | 1,430 | 1,113 | 1,017 | 1,189 |
| Herbicides | Mil. lb | 102 | 263 | 404 | 788 | 656 | 674 | 664 | 657 | 806 | 839 | 623 | 570 | 716 |
| Insecticides | Mil. lb | 366 | 490 | 490 | 660 | 566 | 570 | 605 | 617 | 506 | 448 | 379 | 324 | 350 |
| Fungicides | Mil. lb | 179 | 124 | 140 | 155 | 142 | 143 | 147 | 155 | 156 | 143 | 111 | 123 | 123 |
| Production value[a] | Mil. dol | 307 | 577 | 1,058 | 2,900 | 2,880 | 3,116 | 3,342 | 3,685 | 4,269 | 5,136 | 4,331 | 3,993 | 5,056 |
| Sales, total | Mil. lb | 570 | 764 | 881 | 1,317 | 1,193 | 1,263 | 1,300 | 1,369 | 1,406 | 1,291 | 1,147 | 1,017 | 1,108 |
| Sales value | Mil. dol | 262 | 497 | 870 | 2,359 | 2,410 | 2,808 | 3,041 | 3,631 | 4,078 | 4,652 | 4,432 | 4,054 | 4,730 |

*Note:* Includes a small quantity of soil conditioners.

[a] Manufacturers unit value multiplied by production.

*Source*: From U.S. Department of Commerce, *Statistical Abstract of the United States*, 1987.

**Table 10E.138 United States Production and Sales of Conventional Pesticides, 1994–2001**

| | 1994/1995 | 1996/1997 | 1998/1999 | 2000/2001 |
|---|---|---|---|---|
| Production-active ingredient (billions of pounds) | 1.3 | 1.3 | 1.6 | 1.6 |
| Sales Value (billons of dollars) | 7.0 | 7.9 | 9.6 | 9.3 |

*Source*: From Kiely, T., Donaldson, D., and Grube, A., 2004, *Pesticides Industry Sales and Usage 2000 and 2001 Market Estimates*, United States Environmental Agency, Office of Prevention, Pesticides and Toxic Substances, EPA-733-R-04-001, May 2004.
Donaldson, D., Kiely, T., and Grube, A., 2002, *Pesticides Industry Sales and Usage 1998 and 1999 Market Estimates*, United States Environmental Agency, Office of Prevention, Pesticides and Toxic Substances, EPA-733-R-02-001, August 2002.
Aspelin, A. and Grube, A., 1999, *Pesticides Industry Sales and Usage 1996 and 1997 Estimates*, United States Environmental Agency, Office of Prevention, Pesticides and Toxic, 733-R-99-001, November 1999.
Aspelin, A., 1997, *Pesticides Industry Sales and Usage 1994 and 1995 Market Estimates*, United States Environmental Agency, Office of Prevention, Pesticides and Toxic Substances, EPA-733-R-97-002, August 1997, www.epa.gov.

**Table 10E.139 Annual Amount of Pesticide Active Ingredient Used in the United States by Pesticide Type, 1982–2001 Estimates All Market Sectors**

| | Million Pounds of Active Ingredient | | | | | |
|---|---|---|---|---|---|---|
| Year | Herbicides/PGR | Insecticides | Fungicides | Other Conv[a] | Other[b] | Total |
| 1982 | 620 | 198 | 117 | 149 | 298 | 1,382 |
| 1983 | 573 | 185 | 115 | 148 | 287 | 1,308 |
| 1984 | 634 | 173 | 109 | 145 | 284 | 1,345 |
| 1985 | 611 | 161 | 110 | 138 | 284 | 1,304 |
| 1986 | 590 | 151 | 109 | 138 | 278 | 1,266 |
| 1987 | 532 | 141 | 100 | 133 | 269 | 1,175 |
| 1988 | 557 | 132 | 99 | 137 | 266 | 1,191 |
| 1989 | 567 | 123 | 98 | 154 | 251 | 1,193 |
| 1990 | 564 | 121 | 91 | 173 | 252 | 1,201 |
| 1991 | 546 | 114 | 86 | 182 | 226 | 1,154 |
| 1992 | 554 | 116 | 81 | 189 | 246 | 1,186 |
| 1993 | 527 | 115 | 80 | 192 | 248 | 1,162 |
| 1994 | 583 | 124 | 79 | 199 | 244 | 1,229 |
| 1995 | 556 | 125 | 77 | 203 | 249 | 1,210 |
| 1996 | 578 | 116 | 79 | 222 | 234 | 1,229 |
| 1997 | 568 | 112 | 81 | 197 | 270 | 1,228 |
| 1998 | 555 | 103 | 86 | 168 | 294 | 1,206 |
| 1999 | 534 | 126 | 79 | 173 | 332 | 1,244 |
| 2000 | 542 | 122 | 74 | 188 | 308 | 1,234 |
| 2001 | 553 | 105 | 73 | 157 | 315 | 1,203 |

*Note:* Excludes wood preservatives, specialty biocides, and chlorine/hypochlorites.

[a] Other conventional pesticides include nematicides, fumigants, and other conventional pesticides.
[b] "Other" includes sulfur, petroleum, and other chemicals used as pesticides (e.g., sulfuric acid and insect repellents).

*Source*: From Kiely, T., Donaldson, D., and Grube, A., 2004, *Pesticide Industry Sales and Usage, 2000 and 2001 Market Estimates*, United States Environmental Protection Agency, www.epa.gov, based on Croplife America annual surveys, USDA/NASS (www.usda.gov/nass), and EPA proprietary data.

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**Table 10E.140 Amount of Conventional Pesticide Active Ingredient Used in the United States by Pesticide Type and Market Sector, 2000 and 2001 Estimates**

| Year | Herbicides/Plant Growth Regulators | | Insecticides/Miticides | | Fungicides | | Nematicide/Fumigant | | Other Conventional[a] | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector | Mil. lbs of a.i. | % | Mil. lbs of a.i. | % | Mil. lbs of a.i. | % | Mil. lbs of a.i. | % | Mil. lbs of a.i. | % | Mil. lbs of a.i. | % |
| **2000** | | | | | | | | | | | | |
| Agriculture | 432 | 80 | 90 | 74 | 44 | 59 | 131 | 84 | 25 | 78 | 722 | 78 |
| Ind/Comm/Gov | 48 | 9 | 17 | 14 | 19 | 26 | 24 | 15 | 6 | 19 | 114 | 12 |
| Home & Garden | 62 | 11 | 15 | 12 | 11 | 15 | 1 | 1 | 1 | 3 | 90 | 10 |
| Total | 542 | 100 | 122 | 100 | 74 | 100 | 156 | 100 | 32 | 100 | 926 | 100 |
| **2001** | | | | | | | | | | | | |
| Agriculture | 433 | 78 | 73 | 70 | 42 | 58 | 102 | 80 | 25 | 83 | 675 | 76 |
| Ind/Comm/Gov | 49 | 9 | 15 | 14 | 19 | 26 | 24 | 19 | 4 | 13 | 111 | 13 |
| Home & Garden | 71 | 13 | 17 | 16 | 12 | 16 | 1 | 1 | 1 | 3 | 102 | 11 |
| Total | 553 | 100 | 105 | 100 | 73 | 100 | 127 | 100 | 30 | 100 | 888 | 100 |

*Note:* Totals may not add due to rounding. Table does not cover industrial wood preservatives, specialty biocides, chlorine/hypochlorites, and other chemicals used as pesticides (e.g., sulfur and petroleum oil). The abbreviation "a.i." stands for active ingredient.

[a] "Other Conventional" pesticides include rodenticides, molluscicides, aquatic and fish/bird pesticides, and other miscellaneous conventional pesticides.

*Source*: From Kiely, T., Donaldson, D., and Grube, A., 2004, *Pesticide Industry Sales and Usage, 2000 and 2001 Market Estimates*, United States Environmental Protection Agency, www.epa.gov, EPA estimates based on Croplife America annual surveys, USDA/NASS (www.usda.gov/nass), and EPA proprietary data.



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**Table 10E.141 Conventional Pesticide Active Ingredient Used in the United States Agricultural and Nonagricultural Market Sector Shares, 1964–2001**

| Year | Total U.S. Million Pounds of Active Ingredient | Agricultural Sector | | Nonagricultural Sector Million Pounds of Active Ingredient |
|---|---|---|---|---|
| | | Million Pounds of Active Ingredient | % of Total U.S. | |
| 1964 | 617 | 366 | 59 | 251 |
| 1965 | 658 | 396 | 60 | 262 |
| 1966 | 682 | 414 | 61 | 268 |
| 1967 | 712 | 429 | 60 | 283 |
| 1968 | 742 | 457 | 62 | 285 |
| 1969 | 763 | 491 | 64 | 272 |
| 1970 | 760 | 499 | 66 | 261 |
| 1971 | 793 | 528 | 67 | 265 |
| 1972 | 843 | 575 | 68 | 268 |
| 1973 | 882 | 607 | 69 | 275 |
| 1974 | 964 | 688 | 71 | 276 |
| 1975 | 1013 | 729 | 72 | 284 |
| 1976 | 1041 | 753 | 72 | 288 |
| 1977 | 1084 | 794 | 73 | 290 |
| 1978 | 1106 | 813 | 74 | 293 |
| 1979 | 1144 | 843 | 74 | 301 |
| 1980 | 1121 | 826 | 74 | 295 |
| 1981 | 1118 | 831 | 74 | 287 |
| 1982 | 1084 | 804 | 74 | 280 |
| 1983 | 1021 | 745 | 73 | 276 |
| 1984 | 1061 | 794 | 75 | 267 |
| 1985 | 1020 | 767 | 75 | 253 |
| 1986 | 988 | 739 | 75 | 249 |
| 1987 | 906 | 666 | 74 | 240 |
| 1988 | 925 | 690 | 75 | 235 |
| 1989 | 942 | 712 | 76 | 230 |
| 1990 | 949 | 720 | 76 | 229 |
| 1991 | 928 | 708 | 76 | 220 |
| 1992 | 940 | 723 | 77 | 217 |
| 1993 | 914 | 698 | 76 | 216 |
| 1994 | 984 | 776 | 79 | 208 |
| 1995 | 961 | 765 | 80 | 196 |
| 1996 | 996 | 803 | 81 | 193 |
| 1997 | 958 | 767 | 80 | 191 |
| 1998 | 912 | 724 | 79 | 188 |
| 1999 | 912 | 706 | 77 | 206 |
| 2000 | 926 | 722 | 78 | 204 |
| 2001 | 888 | 675 | 76 | 213 |

*Note:* Conventional pesticides only, excluding sulfur, petroleum oil, and other chemicals used as pesticides (e.g., sulfuric acid and insect repellants), wood preservatives, specialty biocides, and chlorine/hypochlorites.

*Source*: From Kiely, T., Donaldson, D., and Grube, A., 2004, *Pesticide Industry Sales and Usage, 2000 and 2001 Market Estimates*, United States Environmental Protection Agency, www.epa.gov, EPA estimates based on Croplife America annual surveys, USDA/NASS (www.usda.gov/nass), and EPA proprietary data.

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**Table 10E.142 Most Commonly Used Conventional Pesticide Active Ingredients United States, Agricultural Market Sector, 2001, 1999, 1997, and 1987 Estimates**

| | | 2001 | | 1999 | | 1997 | | 1987 | |
|---|---|---|---|---|---|---|---|---|---|
| **Active Ingredient** | **Type** | **Rank** | **Range** | **Rank** | **Range** | **Rank** | **Range** | **Rank** | **Range** |
| Glyphosate | H | 1 | 85–90 | 2 | 67–73 | 5 | 34–38 | 17 | 6–8 |
| Atrazine | H | 2 | 74–80 | 1 | 74–80 | 1 | 75–82 | 1 | 71–76 |
| Metam sodium | Fum | 3 | 57–62 | 3 | 60–64 | 3 | 53–58 | 15 | 5–8 |
| Acetochlor | H | 4 | 30–35 | 4 | 30–35 | 7 | 31–36 | NA | NA |
| 2,4-D | H | 5 | 28–33 | 6 | 28–33 | 8 | 29–33 | 5 | 29–33 |
| Malathion | I | 6 | 20–25 | 7 | 28–32 | NA | NA | NA | NA |
| Methyl bromide | Fum | 7 | 20–25 | 5 | 28–33 | 4 | 38–45 | NA | NA |
| Dichloropropene | Fum | 8 | 20–25 | 11 | 17–20 | 6 | 32–37 | 4 | 30–35 |
| Metolachlor-s | H | 9 | 20–24 | 12 | 16–19 | NA | NA | NA | NA |
| Metolachlor | H | 10 | 15–22 | 8 | 26–30 | 2 | 63–69 | 3 | 45–50 |
| Pendimethalin | H | 11 | 15–19 | 10 | 17–22 | 9 | 24–28 | 10 | 10–13 |
| Trifluralin | H | 12 | 12–16 | 9 | 18–23 | 10 | 21–25 | 6 | 25–30 |
| Chlorothalonil | F | 13 | 8–11 | 13 | 9–11 | 15 | 7–10 | 19 | 5–7 |
| Copper hydroxide | F | 14 | 8–10 | 15 | 8–10 | 13 | 10–13 | 19 | 5–7 |
| Chlorpyrifos | I | 15 | 8–10 | 16 | 8–10 | 14 | 9–13 | 14 | 6–9 |
| Alachlor | H | 16 | 6–9 | 17 | 7–10 | 12 | 13–16 | 2 | 55–60 |
| Propanil | H | 17 | 6–9 | 18 | 7–10 | 22 | 6–8 | 13 | 7–10 |
| Chloropicrin | Fum | 18 | 5–9 | 14 | 8–10 | 25 | 5–6 | NA | NA |
| Dimethenamid | H | 19 | 6–8 | 20 | 6–8 | 20 | 6–9 | NA | NA |
| Mancozeb | F | 20 | 6–8 | 21 | 6–8 | 17 | 7–10 | 21 | 4–6 |
| Ethephon | PGR | 21 | 5–8 | 24 | 5–6 | NA | NA | NA | NA |
| EPTC | H | 22 | 5–8 | 19 | 7–9 | 18 | 7–10 | 8 | 17–21 |
| Simazine | H | 23 | 5–7 | NA | NA | NA | NA | NA | NA |
| Dicamba | H | 24 | 5–7 | 22 | 6–8 | 16 | 7–10 | 23 | 4–6 |
| Sulfosate | H | 25 | 3–7 | NA | NA | NA | NA | NA | NA |

*Note:* List is limited to conventional pesticides and does not include sulfur and petroleum oil usage. Ranked by Range in Millions of Pounds of Active Ingredient. H indicates herbicide; I, insecticide; Fum, fumigant; F, fungicide; and PGR, plant growth regulator. NA indicates that an estimate is not available.

*Source*: From Kiely, T., Donaldson, D., and Grube, A., 2004, *Pesticide Industry Sales and Usage, 2000 and 2001 Market Estimates*, United States Environmental Protection Agency, www.epa.gov, EPA estimates based on USDA/NASS (www.usda.gov/nass) and EPA proprietary data.

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**Table 10E.143 Quantity of Pesticides Applied to Selected Crops in the United States, 1990–2001**

| Type of Pesticide and Commodity | 1990 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|
| Total | 497.7 | 543.3 | 575.8 | 579.3 | 544.4 | 553.7 | 539.4 | 511.1 |
| Herbicides | 344.6 | 324.9 | 365.7 | 362.6 | 340.3 | 316.8 | 308.6 | 307.5 |
| Insecticides | 57.4 | 69.9 | 59.2 | 60.2 | 52.0 | 75.4 | 77.4 | 62.0 |
| Fungicides | 27.8 | 47.5 | 46.8 | 48.5 | 45.7 | 42.3 | 36.6 | 33.2 |
| Other | 67.9 | 101.0 | 104.0 | 108.0 | 106.4 | 119.1 | 116.8 | 108.3 |
| Corn | 240.7 | 201.3 | 227.7 | 227.3 | 212.4 | 186.0 | 176.1 | 187.3 |
| Cotton | 50.9 | 83.7 | 65.6 | 68.4 | 55.4 | 90.6 | 94.5 | 72.8 |
| Wheat | 17.8 | 21.5 | 32.9 | 25.5 | 23.9 | 21.4 | 19.2 | 18.3 |
| Soybeans | 74.4 | 68.7 | 78.1 | 83.5 | 78.8 | 77.3 | 79.1 | 72.2 |
| Potatoes | 43.8 | 53.1 | 49.5 | 59.4 | 63.6 | 64.6 | 61.8 | 60.5 |
| Other vegetables | 39.8 | 78.0 | 82.8 | 73.3 | 67.8 | 70.5 | 70.1 | 66.5 |
| Citrus fruit | 11.0 | 14.0 | 14.5 | 15.0 | 14.1 | 13.3 | 13.0 | 12.8 |
| Apples | 8.3 | 9.0 | 9.7 | 10.6 | 9.3 | 7.9 | 7.6 | 7.6 |
| Other deciduous fruit | 10.9 | 14.1 | 14.9 | 16.4 | 19.2 | 22.2 | 18.1 | 13.1 |
| *Pounds of Active Ingredient Per Planted Acre* | | | | | | | | |
| Total | 2.2 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 |
| Herbicides | 1.5 | 1.4 | 1.5 | 1.5 | 1.4 | 1.3 | 1.3 | 1.3 |
| Insecticides | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 |
| Fungicides | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.1 |
| Other | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 |

*Note:* In million pounds of active ingredients, except as indicated (497.7 represents 497,700,000).

*Source*: From U.S. Census Bureau, Statistical Abstract of the United States, 2002, www.census.gov.

*Original Source*: From U.S. Dept. of Agriculture, Economic Research Service, *Production Practices for Major Crops in U.S. Agriculture, 1990–1997*, Statistical Bulletin No. 969, August 2000, and unpublished data.

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**Table 10E.144 Selected Characteristics and Uses of Pesticides Monitored by the U.S. Geological Survey-U.S. Environmental Protection Agency Pesticide Monitoring Network, 1975–1980**

| | Characteristics | | | | | | Uses | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Water-Quality Criteria[b] (μg/L) | | | | | National Use on Farms[e] (million lb/yr) | | | | |
| Chemical | Detection Limit[a] (μg/L) | Human Health | Aquatic Life | Solubility[c] (μg/L) | Relative Persistence within Pesticide Group[d] | Principal Uses and Sources | 1966 | 1971 | 1976 | 1982 | Total Use, 1981[f] (million lb/yr) |
| **Organochlorine insecticides** | | | | | | | | | | | |
| Aldrin | 0.01 | 0.0007 | 0.002 | 13 | Low | Corn | 15 | 7.9 | 0.9 | nr | 0.8 |
| | | | | | | | | | (Most farm uses cancelled 1974) | | |
| Dieldrin | 0.03 | 0.0007 | 0.002 | 22 | Medium | Termite control, degradation product of aldrin | 0.7 | 0.3 | nr | nr | 0 |
| | | | | | | | | | (Most farm uses cancelled 1974) | | |
| Chlordane | 0.15 | 0.005 | 0.004 | 56 | High | Corn, termites, general purpose | 0.5 | 1.9 | nr | nr | 9.6 |
| | | | | | | | | | (Most farm uses cancelled 1974) | | |
| DDD | 0.05 | 0.0002 | 0.001 | 5 | High | Fruits and vegetables, degradation product of DDT | 2.9 | 0.2 | nr | nr | 0 |
| | | | | | | | | | | (Cancelled 1972) | |
| DDE | 0.03 | 0.0002 | 0.001 | 10 | High | Degradation product of DDT and DDD | Nr | nr | nr | nr | 0 |
| DDT | 0.05 | 0.0002 | 0.001 | 17 | High | Cotton, fruits, vegetables, general purpose | 27 | 0.1 | nr | nr | 0 |
| | | | | | | | | | | (Cancelled 1972) | |
| Endrin | 0.05 | *1 | 0.002 | 14 | nd | Cotton, wheat | 0.6 | 1.4 | 0.8 | nr | 0.3 |
| Heptachlor epoxide | 0.01 | 0.003 | 0.004 | 30 | Low | Degradation product of heptachlor which is used on corn, and termite control | 1.5 | 1.2 | 0.6 | nrt | 2.0 |
| Lindane | 0.01 | *4 | 0.08 | 150 | Medium | Livestock, seed treatment, general purpose | 0.7 | 0.7 | 0.2 | nr | 0.8 |
| Methoxychlor | 0.10 | *100 | *.03 | 3 | nd | Livestock, alfalfa, general purpose | 2.6 | 3.0 | 3.8 | 0.6 | 5.0 |
| Toxaphene | 0.25 | 0.007 | 0.013 | 400 | nd | Cotton, livestock | 35 | 37 | 33 | 5.9 | 16 |
| **Organophosphate insecticides** | | | | | | | | | | | |
| Diazinon | 0.10 | nd | nd | 40,000 | High | Corn, general purpose | 5.6 | 3.2 | 1.6 | 0.3 | 9.0 |
| Ethion | 0.25 | nd | nd | 2,000 | nd | Citrus fruits | 2.0 | 2.3 | nr | nr | 2.0 |
| Malathion | 0.25 | nd | 0.1 | 145,000 | Low | General purpose | 5.2 | 3.6 | 2.8 | 1.6 | 28 |
| Methyl parathion | 0.25 | nd | nd | 57,000 | Low | Cotton and wheat | 8.0 | 28 | 23 | 11 | 20 |
| Methyl trithion | 0.50 | nd | nd | nd | nd | Not identified | nr | nr | nr | nr | 0.1 |
| Parathion | 0.25 | nd | 0.04 | 24,000 | Low | Wheat, corn, sorghum | 8.5 | 9.5 | | 4.0 | 5.0 |
| Trithion | 0.50 | nd | nd | 340 | nd | General purpose | nr | nr | nr | nr | 0.1 |
| **Chlorophenoxy and triazine herbicides** | | | | | | | | | | | |
| Atrazine | 0.5 | nd | nd | 33,000 | High | Corn | 24 | 54 | 90 | 76 | 92 |
| 2,4-D | 0.5 | *100 | nd | 900,000 | Low | Wheat, rangeland, general purpose | 4 | 31 | 38 | 23 | 60 |
| 2,4,5-T | 0.5 | *10 | nd | 240,000 | Medium | Rice, rangeland, general purpose | 0.8 | nr | nr | 0.2 | 2.2 |
| Silvex | 0.5 | nd | nd | 140,000 | nd | Sugarcane, rice, rangeland | nr | nr | nr | nr | 0.4 |

*Note:* μg/L, microgram per liter; lb/yr = pounds per year; nd, no available data; nr, none reported. *See footnote[b].

[a] Detection limits shown are for water samples. Bed-sediment reporting limits are 10 times greater and are expressed in units micrograms per kilogram (Lucas and others, 1980).

[b] All criteria are from U.S. Environmental Protection Agency (1980), except for values marked by asterisks, which are from U.S. Environmental Protection Agency (1976). The human-health criteria for all pesticides except endrin, lindane, methoxychlor, 2,4-D, and 2,4,5-T represent the estimated average concentrations associated with an incremental increase in cancer risk of $10^{-8}$ (one additional cancer per 100,000 people over a lifetime of exposure). The aquatic-life criteria are for freshwater and are 24-hour average concentrations.

[c] Data from Kenaga and Goring (1980).

[d] Relative persistence within each pesticide group as estimated from Hiltbold (1974) and Wauchope (1978).

[e] Data for 1966, from Eichers and others (1970); for 1971, Andrilenas (1974); for 1976, Eichers and others (1978); for 1982, U.S. Department of Agriculture (1983). Data for 1982 do not include use on livestock or use in California, Colorado, Connecticut, Maine, Massachusetts, Nevada, New Hampshire, New Jersey, New Mexico, Oregon, Rhode Island, Utah, Vermont, West Virginia, and Wyoming.

[f] Data from Mark H. Glaze (U.S. Environmental Protection Agency, written communication, 1983).

*Source*: From U.S. Geological Survey, 1985. *National Water Summary 1984*. Water-Supply Paper 2275.



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**Table 10E.145 Detection Frequency of Targeted Pesticides in Surface Waters in the United States, 1957–1992**

| | Sampling Sites | | | Samples | | |
|---|---|---|---|---|---|---|
| **Pesticide** | **Total Sites** | **Number of Sites with Detections** | **Percent of Sites with Detections** | **Total Samples** | **Number of Samples with Detections** | **Percent of Samples with Detections** |
| | | | **Insecticides** | | | |
| **Organochlorine Compounds** | | | | | | |
| Aldin | 951 | 65 | 7 | 3,910 | 224 | 6 |
| Chlordane | 838 | 154 | 18 | 3,366 | 948 | 28 |
| DDT[a] | 1,185 | 258 | 22 | 5,569 | 945 | 17 |
| DDT-total (sum of DDT, DDD, DDE) | 75 | 56 | 75 | 77 | 42 | 55 |
| Dieldrin | 1,016 | 459 | 45 | 4,995 | 1,412 | 28 |
| Endosulfan | 469 | 9 | 2 | 1,614 | 42 | 3 |
| Endrin | 944 | 136 | 14 | 4,255 | 359 | 8 |
| HCH (all isomers)[b] | 1,498 | 462 | 31 | 7,144 | 2,087 | 29 |
| Heptachlor | 948 | 102 | 11 | 3,877 | 287 | 7 |
| Kepone | 75 | nr | nr | 750 | nr | nr |
| Methoxychlor | 268 | 33 | 12 | 772 | 33 | 4 |
| Mirex | 212 | 2 | 1 | 512 | 13 | 3 |
| Perthane | 81 | 0 | 0 | 285 | 0 | 0 |
| Toxaphene | 215 | 16 | 7 | 1,490 | 84 | 6 |
| **Organophosphorus Compounds** | | | | | | |
| Azinphos-methyl | 79 | 0 | 0 | 402 | 0 | 0 |
| Chlorpyrifos | 108 | 7 | 6 | 987 | 13 | 1 |
| Crufomate | 33 | 0 | 0 | 33 | 0 | 0 |
| DEF | 4 | 2 | 50 | 4 | 2 | 50 |
| Diazinon | 193 | 36 | 18 | 1,836 | 256 | 14 |
| Dichlorvos (DDVP) | 2 | 0 | 0 | 30 | 0 | 0 |
| Dimethoate | 33 | 0 | 0 | 33 | 0 | 0 |
| Disulfoton | 40 | 0 | 0 | 349 | 0 | 0 |
| Disyston | 4 | 0 | 0 | 4 | 0 | 0 |
| Ethion | 326 | 0 | 0 | 1,046 | 0 | 0 |
| Ethoprop | 33 | 0 | 0 | 33 | 0 | 0 |
| Fenitrothion | 42 | 0 | 0 | 42 | 0 | 0 |
| Fensulfothion | 9 | 0 | 0 | 9 | 0 | 0 |
| Fenthion | 232 | 0 | 0 | 538 | 0 | 0 |
| Fonofos | 94 | 14 | 15 | 945 | 63 | 7 |
| Imidan | 33 | 0 | 0 | 33 | 0 | 0 |
| Malathion | 426 | 16 | 4 | 2,415 | 104 | 4 |
| Methamidophos | 10 | 0 | 0 | 100 | 0 | 0 |
| Methidathion | 2 | 2 | 100 | nr | nr | nr |
| Methyl parathion | 387 | 13 | 3 | 2,215 | 14 | 1 |
| Methyl trithion | 80 | 0 | 0 | 185 | 0 | 0 |
| Parathion | 326 | 4 | 1 | 1,493 | 5 | 0 |
| Phorate | 121 | 0 | 0 | 1,008 | 0 | 0 |
| Phosphamidon | 33 | 0 | 0 | 33 | 0 | 0 |
| Ronnel | 35 | 0 | 0 | 63 | 0 | 0 |
| Sulprofos | 33 | 0 | 0 | 33 | 0 | 0 |
| Terbufos | 94 | 10 | 11 | 945 | 2 | 0 |
| Trithion | 314 | 1 | 0 | 805 | 2 | 0 |
| **Other Insecticides[c]** | | | | | | |
| Aldicarb | 4 | 0 | 0 | 4 | 0 | 0 |
| Carbaryl | 24 | 6 | 25 | 333 | 32 | 10 |
| Carbofuran | 84 | 25 | 30 | 396 | 119 | 30 |
| Deet | 26 | 22 | 85 | nr | nr | nr |
| Dibutyltin (DBT) | 10 | 1 | 10 | 22 | 4 | 18 |
| Fenvalerate | 4 | 4 | 100 | nr | nr | nr |
| Methomyl | 8 | 0 | 0 | 8 | 0 | 0 |
| Oxamyl | 4 | 0 | 0 | 4 | 0 | 0 |
| Permethrin | 11 | 4 | 36 | 316 | 3 | 1 |
| Propargite | 7 | 3 | 43 | 316 | 3 | 1 |

*(Continued)*

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**Table 10E.145 (Continued)**

| Pesticide | Sampling Sites: Total Sites | Sampling Sites: Number of Sites with Detections | Sampling Sites: Percent of Sites with Detections | Samples: Total Samples | Samples: Number of Samples with Detections | Samples: Percent of Samples with Detections |
|---|---|---|---|---|---|---|
| Tributyltin (TBT) | 10 | 8 | 80 | 22 | 15 | 68 |
| | | | **Herbicides** | | | |
| **Triazines and Acetanilides** | | | | | | |
| Acrolein | 17 | nr | nr | 121 | nr | nr |
| Alachlor | 372 | 272 | 73 | 1,549 | 802 | 52 |
| Ametryn | 123 | 11 | 9 | 947 | 212 | 22 |
| Atratone | 15 | 0 | 0 | 27 | 0 | 0 |
| Atrazine | 497 | 440 | 89 | 4,650 | 3,928 | 84 |
| Cyanazine | 366 | 242 | 66 | 1,473 | 755 | 51 |
| Cyprazine | 15 | 0 | 0 | 27 | 0 | 0 |
| Hexazinone | 26 | 5 | 19 | nr | nr | nr |
| Metolachlor | 362 | 280 | 77 | 1,452 | 827 | 57 |
| Metribuzin | 349 | 147 | 42 | 1,469 | 245 | 17 |
| Prometon | 270 | 74 | 27 | 828 | 140 | 17 |
| Prometryn | 62 | 9 | 15 | 523 | 4 | 1 |
| Propachlor | 12 | 7 | 58 | 450 | 48 | 11 |
| Propazine | 244 | 70 | 29 | 827 | 28 | 3 |
| Simazine | 209 | 119 | 57 | 632 | 312 | 49 |
| Simetone | 15 | 0 | 0 | 27 | 0 | 0 |
| Simetryn | 22 | 0 | 0 | 36 | 0 | 0 |
| Terbutryn | 4 | 0 | 0 | 16 | 0 | 0 |
| **Phenoxy Acids** | | | | | | |
| 2,4-D | 215 | 110 | 51 | 1,721 | 359 | 21 |
| 2,4-D (methyl ester) | 6 | 0 | 0 | 84 | 0 | 0 |
| 2,4-DP | 50 | 2 | 4 | 141 | 4 | 3 |
| 2,4,5-T | 166 | 70 | 42 | 1,347 | 214 | 16 |
| 2,4,5-TP (silvex) | 196 | 27 | 14 | 1,576 | 79 | 5 |
| **Other Herbicides** | | | | | | |
| Bensulfuron-methyl | 3 | 2 | 67 | 54 | 16 | 30 |
| Butylate | 94 | 8 | 9 | 945 | 49 | 5 |
| Chloramben | 30 | 0 | 0 | 30 | 0 | 0 |
| Dacthal | 119 | nr | nr | 1,074 | nr | nr |
| Dicamba | 68 | 17 | 25 | 181 | 17 | 9 |
| Dinoseb | 4 | 0 | 0 | 16 | 0 | 0 |
| Diquat | 9 | 0 | 0 | 9 | 0 | 0 |
| EPTC | 15 | 7 | 47 | 316 | 63 | 20 |
| Fluometuron | 26 | 7 | 27 | nr | nr | nr |
| Linuron | 37 | 9 | 24 | 395 | 2 | 1 |
| Molinate | 27 | 7 | 26 | 16 | 16 | 100 |
| Norflurazon | 26 | 5 | 19 | nr | nr | nr |
| Paraquat | 9 | 0 | 0 | 9 | 0 | 0 |
| Pendimethalin | 15 | 14 | 93 | 316 | 25 | 8 |
| Picloram | 38 | 15 | 39 | 71 | 18 | 25 |
| Propham | 8 | 0 | 0 | 8 | 0 | 0 |
| Thiobencarb | 27 | 2 | 7 | 16 | 16 | 100 |
| Trifluralin | 104 | 24 | 23 | 1,087 | 113 | 10 |
| | | | **Fungicides** | | | |
| Captan | 30 | 0 | 0 | 580 | 0 | 0 |
| Chlorothalonil | 4 | 0 | 0 | 16 | 0 | 0 |
| HCB | 50 | 43 | 86 | 255 | 216 | 85 |
| PCNB | 4 | 0 | 0 | 16 | 0 | 0 |
| PCP | 11 | 8 | 73 | 11 | 8 | 73 |
| | | | **Transformation products** | | | |
| Azinhos-methyl oxon | 6 | 0 | 0 | 20 | 0 | 0 |
| Carbofuran phenol | 1 | 1 | 100 | 9 | 9 | 100 |
| 2-Chloro-2′,2′-diethylacetanilide | 26 | 8 | 31 | nr | nr | nr |

*(Continued)*

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**Table 10E.145 (Continued)**

| Pesticide | Sampling Sites | | | Samples | | |
|---|---|---|---|---|---|---|
| | Total Sites | Number of Sites with Detections | Percent of Sites with Detections | Total Samples | Number of Samples with Detections | Percent of Samples with Detections |
| Cyanazine amide | 26 | 16 | 62 | nr | nr | nr |
| DDD | 876 | 139 | 16 | 3,941 | 543 | 14 |
| DDE | 1,128 | 219 | 19 | 4,869 | 939 | 19 |
| Deethylatrazine | 291 | 254 | 87 | 685 | 559 | 82 |
| Deisopropylatrazine | 242 | 154 | 64 | 685 | 249 | 36 |
| Desmethyl norflurazon | 26 | 2 | 8 | nr | nr | nr |
| Endosulfan sulfate | 50 | 0 | 0 | 154 | 0 | 0 |
| Endrin aldehyde | 50 | 0 | 0 | 154 | 0 | 0 |
| ESA (alachlor metabolite) | 76 | 60 | 79 | 304 | 222 | 73 |
| Heptachlor epoxide | 922 | 181 | 20 | 3,714 | 552 | 15 |
| 2-Hydroxy-2′6′-diethylacetanilide | 26 | 19 | 73 | nr | nr | nr |
| 2-Ketomolinate | 1 | 1 | 100 | nr | nr | nr |
| 4-Ketomolinate | 1 | 1 | 100 | nr | nr | nr |
| Oxychlordane | 14 | 14 | 100 | 14 | 14 | 100 |
| Paranitrophenol | 1 | 1 | 100 | 9 | 9 | 100 |
| Photomirex | 14 | 0 | 0 | 14 | 0 | 0 |
| Terbufos sulfone | 33 | 0 | 0 | 33 | 0 | 0 |

*Note:* α, alpha; β, beta; γ, gamma; δ, delta. nr, not reported.

[a] Detection frequencies for DDT, DDD, and DDE include both *p,p′*-, and *o,p′*-isomers, as many studies did not report which isomer was targeted.

[b] HCH data for all isomers, including, α, β, γ (lindane), and δ.

[c] Includes compounds used as acaricides, miticides, and nematocides.

*Source*: From Larson, S.J., Capel, P.D., and Majewski, M.S., 1997, *Pesticides in Surface Waters Distribution, Trends, and Governing Factors, Volume Three of the Series Pesticides in the Hydrologic System*, Ann Arbor Press, Inc., Chelsea, Michigan.

**Table 10E.146 Statistical Summary of Concentrations of Glyphosate, Its Degradation Product, AMPA, and Glufosinate Determined for Water Samples Collected form 51 Streams in Nine Midwestern States, 2002**

| Herbicide | Number of Samples | Number at or Above MRL | 25th Percentile | Median | 75th Percentile | 95th Percentile | Maximum |
|---|---|---|---|---|---|---|---|
| **Pre-emergence runoff samples** | | | | | | | |
| Glyphosate | 51 | 18 | <0.10 | <0.10 | 0.20 | 0.58 | 1.00 |
| AMPA | 51 | 27 | <0.10 | 0.10 | 0.28 | 0.55 | 1.8 |
| Glufosinate | 51 | 0 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| **Post-emergence runoff samples** | | | | | | | |
| Glyphosate | 52 | 21 | <0.10 | <0.10 | 0.32 | 1.5 | 4.5 |
| AMPA | 52 | 43 | 0.18 | 0.27 | 0.42 | 0.94 | 2.0 |
| Glufosinate | 52 | 2 | <0.10 | <0.10 | <0.10 | <0.10 | 0.26 |
| **Harvest-season runoff samples** | | | | | | | |
| Glyphosate | 51 | 16 | <0.10 | <0.10 | 0.14 | 0.45 | 8.7 |
| AMPA | 51 | 37 | <0.10 | 0.21 | 0.51 | 1.3 | 3.6 |
| Glufosinate | 51 | 0 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |

*Note:* All concentrations in micrograms per liter. MRL, method reporting limit; <, less than; AMPA, aminomethylphosphonic acid.

*Source*: From Scribner, E.A., Battaglin, W.A., Dietze, J.E., and Thurman, E.M., 2003, Reconnaissance Data for Glyphosate, Other Selected Herbicides, Their Degradation Products, and Antibiotics in 51 Streams in Nine Midwestern States, 2002, *U.S. Geological Survey Open-File Report 03-217*, www.usgs.gov.

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**Table 10E.147 Average Pesticide Concentrations Detected in Sediments from Selected Estuaries in the United States, 1984–1992 (milligrams per kilogram dry weight)**

| Estuary | tDDT | TDieldrin | tCdane | Hexachl | Lindane | Mirex |
|---|---|---|---|---|---|---|
| Machias Bay, ME-Hog Island | 0.00 | 0.00 | 0.13 | 0.53 | 0.00 | 0.00 |
| Machias Bay, ME-Chance Island | 0.52 | 0.26 | 0.65 | 0.36 | 0.51 | 0.00 |
| Frenchman Bay, ME-Long Porcupine Island | 1.14 | 1.93 | 0.86 | 0.76 | 0.25 | 0.00 |
| Penobscot Bay, ME-Colt Head Island | 4.88 | 1.08 | 1.83 | 1.46 | 0.99 | 0.20 |
| Johns Bay, ME-Pemaquid Neck | 0.08 | 0.18 | 0.02 | 0.00 | 0.00 | 0.00 |
| Casco Bay, ME-Great Chebeague Island | 6.53 | 3.71 | 3.61 | 1.05 | 0.00 | 0.00 |
| Casco Bay, ME-Cousins Island | 6.60 | 0.23 | 1.63 | 1.43 | 0.25 | 1.00 |
| Cape Elizabeth, ME-Richmond Island | 0.32 | 0.15 | 0.07 | 0.07 | 0.07 | 0.00 |
| Merrimac River, MA-Plum Island | 0.00 | 0.17 | 0.89 | 0.70 | 0.21 | 0.00 |
| Salem Harbor, MA-Folger Point | 24.49 | 1.64 | 6.12 | 1.77 | 2.02 | 0.31 |
| Boston Harbor, MA-President Roads | 87.01 | 1.33 | 7.14 | 1.12 | 0.52 | 1.10 |
| Boston Harbor, MA-Deer Island | 7.21 | 1.03 | 7.04 | 1.23 | 0.08 | 0.25 |
| Boston Harbor, MA-Quincy Bay | 32.65 | 5.16 | 11.53 | 0.67 | 0.44 | 1.40 |
| Boston Harbor, MA-Hull Bay | 6.27 | 1.67 | 3.23 | 0.53 | 0.17 | 0.00 |
| Boston Harbor, MA-Mystic RIver | 43.67 | 8.33 | 22.43 | 0.67 | 0.00 | 0.00 |
| Massachusetts Bay, MA-Plymouth Entrance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Buzzards Bay, MA-West Island | 1.77 | 0.70 | 0.78 | 0.26 | 0.68 | 0.03 |
| New Bedford Harbor, MA-Clarks Point | 14.38 | 0.00 | 3.90 | 1.88 | 0.07 | 0.33 |
| Narragansett Bay, Rl-Prudence Island | 11.00 | 2.67 | 4.93 | 2.33 | 0.00 | 0.43 |
| Narragansett Bay, Rl-Conanicut Island | 8.12 | 6.14 | 4.03 | 0.98 | 2.56 | 0.52 |
| Niantic Bay, CON-Black Point | 1.85 | 0.83 | 0.40 | 0.37 | 0.05 | 0.05 |
| Long Island Sound, NY-New Haven | 7.33 | 0.00 | 4.00 | 2.00 | 0.00 | 0.33 |
| Long Island Sound, NY – Norwalk | 7.50 | 2.00 | 3.33 | 0.95 | 0.00 | 0.33 |
| Long Island Sound, NY-Long Island Shoal | 0.10 | 0.02 | 0.04 | 0.03 | 0.06 | 0.00 |
| Long Island Sound, NY-Rocky Point | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 |
| Long Island Sound, NY-Lloyd Point | 0.00 | 0.00 | 0.00 | 0.29 | 0.00 | 2.67 |
| Long Island Sound, NY-Oak Neck Point | 8.02 | 0.49 | 3.15 | 0.44 | 1.41 | 1.31 |
| Hudson River, NY | 26.63 | 3.50 | 5.00 | 0.77 | 0.00 | 0.67 |
| Raritan Bay, NY-Upper Bay | 9.10 | 1.25 | 2.08 | 0.29 | 0.16 | 0.22 |
| Raritan Bay, NY-Gravesend Bay | 17.48 | 1.83 | 4.35 | 0.97 | 0.52 | 0.27 |
| Raritan Bay, NY-West Reach | 31.10 | 3.50 | 7.04 | 0.83 | 0.71 | 0.58 |
| Raritan Bay, NJ-East Reach | 34.74 | 2.41 | 6.22 | 1.18 | 0.64 | 0.41 |
| Raritan Bay, NJ-Lower Bay | 35.75 | 2.05 | 7.79 | 1.89 | 1.23 | 35.40 |
| Great Bay, NJ-Wells Island | 6.97 | 0.67 | 1.93 | 1.30 | 0.67 | 0.00 |
| Great Bay, NJ-Seven Island | 8.36 | 0.75 | 2.29 | 0.41 | 0.16 | 0.29 |
| Great Bay, NJ-Intercoastal Waterway | 1.45 | 0.17 | 0.13 | 0.48 | 0.08 | 0.00 |
| Delaware Bay, DE-Cherry Island Range | 47.60 | 3.65 | 4.38 | 0.70 | 0.03 | 1.20 |
| Delaware Bay, DE-Brandywine Shoal | 4.05 | 0.75 | 6.15 | 1.03 | 0.89 | 0.00 |
| Delaware Bay, DE -The Shears | 4.63 | 0.00 | 0.53 | 0.60 | 0.17 | 0.00 |
| Baltimore Harbor, MD-Fort McHenry Channel | 30.13 | 2.18 | 8.97 | 6.18 | 0.00 | 0.42 |
| Baltimore Harbor, MD-Brewerton Channel | 15.83 | 3.75 | 5.69 | 5.90 | 1.70 | 0.31 |
| Chesapeake Bay, MD-Gibson Island | 10.52 | 0.80 | 2.45 | 1.06 | 0.79 | 0.00 |
| Chesapeake Bay, MD-Chester River | 5.32 | 1.65 | 1.55 | 0.35 | 0.70 | 0.58 |
| Chesapeake Bay, MD-Kent Island | 7.70 | 2.25 | 2.40 | 0.50 | 1.50 | 1.20 |
| Chesapeake Bay, MD-Patuxent River | 0.53 | 0.10 | 0.07 | 0.00 | 0.00 | 0.00 |
| Chesapeake Bay, MD-Smith Island | 1.11 | 0.19 | 0.99 | 0.14 | 0.50 | 0.00 |
| Chesapeake Bay, VA-James RIver | 3.33 | 0.90 | 0.67 | 0.20 | 0.00 | 0.00 |
| Chesapeake Bay, VA-York RIver | 2.11 | 0.19 | 1.02 | 0.36 | 0.59 | 0.00 |
| Chesapeake Bay, VA-Elizabeth RIver | 17.23 | 0.38 | 3.18 | 0.51 | 0.14 | 0.00 |
| Pamlico Sound, NC-Jones Bay | 1.43 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cape Fear River, NC-Horseshoe Shoal | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Charleston Harboar, SC – Coastal | 47.58 | 8.00 | 14.60 | 0.00 | 0.00 | 6.62 |
| Charleston Harboar, SC-South Channel | 1.77 | 0.00 | 0.03 | 0.08 | 0.00 | 0.14 |
| Savannah River, GA-Elba Island | 0.00 | 0.00 | 0.00 | 0.57 | 0.00 | 0.23 |
| Sapelo Sound, GA-High Point | 1.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| St. Johns River, FL -Trout River | 5.03 | 0.47 | 3.93 | 0.00 | 0.00 | 0.00 |
| St. Johns River, FL-West Mill Cove | 6.86 | 0.28 | 1.09 | 0.00 | 0.00 | 0.00 |
| St. Johns River, FL-Ortega River | 11.70 | 0.00 | 4.20 | 0.00 | 0.00 | 0.00 |
| St. Johns River, FL-Piney Point | 1.07 | 0.00 | 1.60 | 0.00 | 0.00 | 0.00 |

*(Continued)*

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**Table 10E.147 (Continued)**

| Estuary | tDDT | TDieldrin | tCdane | Hexachl | Lindane | Mirex |
|---|---|---|---|---|---|---|
| St. Johns River, FL-Orange Point | 0.00 | 0.00 | 0.49 | 0.00 | 0.00 | 0.00 |
| St. Lucie River, FL-Stuart | 6.93 | 0.40 | 1.17 | 0.00 | 0.00 | 0.00 |
| Biscayne Bay, FL-North Bay | 0.90 | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 |
| Biscayne Bay, FL-Chicken Key | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 |
| Charlotte Harbor, FL-Cape Haze | 0.14 | 0.00 | 0.06 | 0.10 | 0.00 | 0.00 |
| Tampa Bay, FL-Northern Tampa Bay | 0.27 | 0.06 | 0.02 | 0.06 | 0.00 | 0.00 |
| Apalachicola Bay, FL -St George Island | 2.05 | 0.78 | 0.30 | 0.19 | 0.00 | 0.00 |
| St. Andrew Bay, FL-Military Point | 718.50 | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 |
| Choctawhatchee Bay, FL | 2.50 | 0.43 | 0.47 | 0.00 | 1.00 | 0.07 |
| Pensacola Bay, FL | 0.39 | 0.20 | 0.39 | 0.00 | 0.00 | 0.00 |
| Mobile Bay, AL-North Point | 17.21 | 0.13 | 0.15 | 0.05 | 0.00 | 0.00 |
| Pascagoula River, MS-Escatawpa River | 5.30 | 1.20 | 1.67 | 0.00 | 0.33 | 0.00 |
| Pascagoula River, MS | 3.62 | 0.14 | 1.06 | 0.44 | 0.20 | 0.54 |
| Round Island, MS-Round Island | 0.38 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 |
| Herron Bay, MS-Heron Bay | 0.17 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| Mississippi River Delta, LA-Southeast Pass | 3.47 | 0.93 | 0.44 | 7.50 | 0.00 | 0.09 |
| Mississippi River Delta, LA-Head of Passes | 390.00 | 2.20 | 6.58 | 3.00 | 0.60 | 1.80 |
| Barataria Bay, LA-Barataria Pass | 0.04 | 0.11 | 0.01 | 0.02 | 0.03 | 0.01 |
| Calcasieu River, LA-Prien Lake | 473.00 | 2.00 | 6.07 | 3.67 | 0.70 | 3.33 |
| Calcasieu River, LA-West Cove | 25.67 | 0.83 | 0.00 | 0.00 | 0.00 | 0.23 |
| Galveston Bay, TX-East Bay | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Galveston Bay, TX-Trinity Bay | 0.00 | 0.00 | 0.00 | 0.00 | 0.43 | 0.00 |
| Galveston Bay, TX-Greens Bayou | 123.67 | 7.17 | 71.00 | 32.83 | 0.22 | 0.17 |
| Galveston Bay, TX-Goat Islands | 6.38 | 0.94 | 10.72 | 10.20 | 0.12 | 0.00 |
| Galveston Bay, TX-Morgans Point | 0.90 | 0.00 | 0.17 | 1.35 | 0.00 | 0.00 |
| Galveston Bay, TX-Eagle Point | 1.67 | 0.20 | 1.39 | 1.67 | 0.04 | 0.04 |
| Galveston Bay, TX-Texas City | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Lavaca Bay, TX | 0.52 | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 |
| San Antonio Bay, TX-Mosquito Point | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| San Antonio Bay, TX-San Antonio Bay | 0.65 | 0.09 | 0.03 | 0.02 | 0.03 | 0.00 |
| Corpus Christi Bay, TX-Long Reef | 0.42 | 0.00 | 0.00 | 2.03 | 0.00 | 0.00 |
| Lower Laguna Madre, TX -Laguna Heights | 0.00 | 0.00 | 0.00 | 0.05 | 0.03 | 0.00 |
| Lower Laguna Madre, TX -Long Island | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| San Diego Bay, CA-Outside | 14.71 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| San Diego Bay, CA-National City | 8.14 | 0.10 | 1.68 | 0.00 | 0.00 | 0.00 |
| San Diego Bay, CA-28th Street | 16.36 | 0.49 | 7.91 | 0.00 | 0.00 | 0.66 |
| San Diego Bay, CA-North | 7.33 | 0.18 | 2.01 | 0.03 | 0.00 | 0.12 |
| San Diego Bay, CA-Harbor Island | 37.93 | 0.00 | 1.12 | 0.00 | 0.00 | 0.00 |
| San Diego Bay, CA-Shelter Island | 3.89 | 0.00 | 0.86 | 0.27 | 0.04 | 0.00 |
| Mission Bay, CA-Outside | 0.33 | 0.00 | 0.17 | 0.23 | 0.00 | 0.00 |
| Dana Point Harbor, CA-Outside | 2.20 | 0.00 | 0.10 | 0.10 | 0.04 | 0.04 |
| San Pedro Bay, CA-Seal Beach | 31.26 | 0.00 | 1.60 | 0.00 | 0.02 | 0.09 |
| San Pedro Bay, CA-LongBeach | 97.60 | 0.75 | 8.19 | 0.18 | 0.03 | 0.17 |
| San Pedro Bay, CA-Outer Harbor | 498.66 | 0.94 | 0.78 | 0.09 | 0.17 | 0.02 |
| San Pedro Bay, CA-Cerritos Channel | 221.80 | 1.18 | 14.40 | 0.90 | 0.00 | 0.10 |
| Santa Monica Bay, CA-Southeast | 149.67 | 0.27 | 0.83 | 0.00 | 0.00 | 0.00 |
| Santa Monica Bay, CA-South | 833.67 | 0.32 | 1.12 | 0.03 | 0.12 | 0.05 |
| Santa Monica Bay, CA-Manhattan Beach | 2.51 | 0.00 | 0.31 | 0.00 | 0.01 | 0.00 |
| Santa Monica Bay, CA-West | 57.09 | 0.25 | 1.69 | 0.26 | 0.00 | 0.06 |
| Santa Monica Bay, CA-Deep | 24.85 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Santa Monica Bay, CA-North | 98.33 | 0.77 | 0.73 | 0.10 | 0.33 | 0.00 |
| San Luis Obispo, CA-San Luis Obispo | 6.90 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Estero Bay, CA-Estero Bay | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Monterrey Bay, CA-Indian Head Beach | 0.74 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| San Francisco Bay, CA-Redwood City | 11.42 | 2.00 | 2.27 | 0.68 | 0.20 | 0.12 |
| San Francisco Bay, CA-Hunters Point | 6.48 | 0.62 | 0.34 | 0.29 | 0.03 | 0.35 |
| San Francisco Bay, CA-Oakland Estuary | 27.33 | 2.10 | 5.56 | 0.79 | 0.18 | 0.29 |
| San Francisco Bay, CA-Southampton Shoal | 1.00 | 0.00 | 0.00 | 0.47 | 0.53 | 0.00 |
| San Francisco Bay, CA-Oakland Entrance | 5.3 | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 |
| San Francisco Bay, CA-Castro Creek | 6.6 | 0.78 | 1.08 | 0.75 | 0.17 | 0.12 |

*(Continued)*

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**Table 10E.147 (Continued)**

| Estuary | tDDT | TDieldrin | tCdane | Hexachl | Lindane | Mirex |
|---|---|---|---|---|---|---|
| San Francisco Bay, CA-San Pablo Bay | 3.7 | 0.28 | 0.33 | 0.28 | 0.12 | 0 |
| Bodega Bay, CA-North | 0.4 | 0.06 | 0.14 | 0.01 | 0.03 | 0.04 |
| Coos Bay, OR-North Bend | 0.83 | 0.15 | 0.08 | 0.14 | 0.03 | 0 |
| Columbia River Mouth, WA-Desdemona Sands | 0.15 | 0.08 | 0.04 | 0.03 | 0.00 | 0.04 |
| Puget Sound, Nisqually Reach, WA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Puget Sound, Commencement Bay, WA | 3.48 | 0.64 | 1.75 | 3.18 | 0.06 | 0.17 |
| Puget Sound, WA-Elliott Bay | 13.25 | 1.7 | 1.05 | 0.27 | 0.03 | 0.03 |
| Boca de Quadra, AK-Bacrian Point | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 |
| Lutak Inlet, AK-Chilkoot River Mouth | 2.17 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 |
| Skagway, AK-Skagway River | 1.00 | 0.00 | 0.00 | 0.47 | 0.53 | 0.00 |
| Nahku Bay, AK-East Side | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Prince William Sound, AK-Port Valdez | 1.00 | 0.00 | 0.00 | 0.47 | 0.53 | 0.00 |
| Gulf of Alaska, AK-Kamishak Bay | 0.00 | 0.00 | 0.00 | 0.73 | 0.70 | 0.00 |
| Bering Sea, AK,-Dutch Harbor | 1.83 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 |
| Bering Sea, AK,-Port Moller | 4.67 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| Chukchi Sea, AK-Red Dog Mine | 1.53 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 |
| Beaufort Sea, AK-Olitok Point | 0 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 |
| Beaufort Sea, AK-Prudhoe Bay | 0.17 | 0.17 | 0.08 | 0.22 | 0.2 | 0.06 |

*Note:* tDDT is the sum of 2,4′-DDD, 4,4′DDD, 2,4′-DDE, 4,4′-DDE, 2,4′DDT, 4,4′-DDT. TDieldrin is the sum of aldrin and dieldrin. tCdane is the sum of cis-chlordane and *trans*-nonachlor, heptachlor, and heptachlorepoxide.

*Source*: From Abstracted from Marmon, M.R., Gottholm, W., and Robertson, A., 1998, *A Summary of Chemical Contaminant Levels at Benthic Surveillance Project Sites (1984–1992)—NOAA Technical Memorandum NOS ORCA 124*, noa.gov.

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**Table 10E.148 Selected Results of Studies that Monitored Pesticides in Bed Sediment in the United States, 1960–1994**

| | All Monitoring Studies (Published 1960–1994) | | | | Recent Monitoring Studies (Published 1984–1994) | | | |
|---|---|---|---|---|---|---|---|---|
| | Concentration Range (μg/kg dry weight) | | Total Number of Studies that Reported Data | Percentage of Studies with Detectable Residues in at Least One Sample | Concentration Range (μg/kg dry weight) | | Total Number of Studies That Reported Data | Percentage of Studies with Detectable Residues in at Least One Sample |
| Target Analytes | In Detection Limits | In Maximum Concentrations | | | In Detection Limits | In Maximum Concentrations | | |
| Aldrin | nr, 0.05–480 | nd-1,065 | 119 | 28 | nr, 0.1–480 | nd-1,065 | 70 | 24 |
| Chlordane[a] | nr, 0.01–4,800 | nd-1,000 | 111 | 74 | nr, 0.1–4,800 | nd-510 | 62 | 69 |
| Chlordane, *cis*- | nr, 0.5–100 | nd-293 | 25 | 24 | nr, 0.5–100 | nd-90 | 22 | 14 |
| Chlordane, *trans*- | nr, 0.5–50 | nd-149 | 28 | 32 | nr, 0.5–50 | nd-149 | 25 | 24 |
| DDD[a] | nr, 0.01–38 | nd-5,100 | 95 | 91 | nr, 0.01–10 | nd-260 | 46 | 91 |
| DDD, *o,p′*- | nr, 0.1–50 | nd-1,312 | 29 | 28 | nr, 0.1–50 | nd-1,312 | 27 | 22 |
| DDD, *p,p′*- | nr, 0.05–960 | nd-5,820 | 50 | 52 | nr, 0.1–960 | nd-5,820 | 44 | 48 |
| DDE[a] | nr, 0.01–24 | nd-10,000 | 101 | 88 | nr, 0.01–20 | nd-430 | 48 | 90 |
| DDE, *o,p′*- | nr, 0.1–50 | nd-292 | 29 | 21 | nr, 0.1–50 | nd-292 | 27 | 15 |
| DDE, *p,p′*- | nr, 0.1–960 | nd-1,870 | 52 | 60 | nr, 0.1–960 | nd-1,870 | 45 | 53 |
| DDT[b] | nr, 0.01–10 | nd-6,480 | 96 | 80 | nr, 0.01–10 | nd-2,280 | 45 | 76 |
| DDT, *o,p′*- | nr, 0.1–50 | nd-807 | 35 | 37 | nr, 0.1–50 | nd-807 | 29 | 28 |
| DDT, *p,p′*- | nr, 0.1–960 | nd-3,752 | 51 | 53 | nr, 0.1–960 | nd-3,752 | 43 | 47 |
| DDT, total | nr, 0.01–50 | nd-30,200,000 | 44 | 80 | nr, 0.1–50 | nd-4,443,500 | 25 | 68 |
| Diazinon | nr, 0.1–100 | nd-13 | 42 | 19 | nr, 0.1–50 | nd-0.2 | 16 | 13 |
| Dieldrin | nr, 0.01–100 | nd-440 | 163 | 65 | nr, 0.01–100 | nd-440 | 97 | 54 |
| Endosulfan[a] | nr, 0.1–100 | nd-4,530 | 50 | 26 | nr, 0.1–10 | nd-339 | 34 | 21 |
| Endosulfan I | nr, 0.1–480 | nd-96 | 14 | 50 | nr, 0.1–480 | nd-96 | 13 | 46 |
| Endosulfan II | nr, 0.1–960 | nd-140 | 14 | 50 | nr, 0.1–960 | nd-140 | 13 | 46 |
| Endrin | nr, 0.01–100 | nd-120 | 131 | 25 | nr, 0.1–100 | nd-43 | 80 | 20 |
| HCH[a] | nr, 0.1–100 | nd-20 | 10 | 30 | nr, 0.1–100 | nd-20 | 9 | 22 |
| HCH, α- | 0.03–480 | nd-110 | 44 | 20 | nr, 0.1–480 | nd-65 | 39 | 13 |
| HCH, β- | nr, 0.1–480 | nd-2,800 | 33 | 15 | nr, 0.1–480 | nd-2,800 | 30 | 17 |
| HCH, δ- | nr, 0.1–480 | nd-0.8 | 25 | 4 | nr, 0.1–480 | nd-0.8 | 25 | 4 |
| Heptachlor | nr, 0.01–480 | nd-16.6 | 119 | 21 | nr, 0.1–480 | nd-12 | 72 | 22 |
| Heptchlor epoxide | nr, 0.01–480 | nd-106 | 123 | 32 | nr, 0.01–480 | nd-106 | 78 | 28 |
| Hexachlorobenzene | nr, 0.03–400 | nd-7,500,000 | 47 | 32 | nr, 0.1–400 | nd-7,500,000 | 41 | 24 |
| Lindane | nr, 0.05–480 | nd-221 | 128 | 19 | nr, 0.1–480 | nd-65 | 75 | 16 |
| Malathion | nr, 0.1–100 | 0 | 41 | 0 | nr, 0.1–50 | 0 | 14 | 0 |
| Methoxychlor[c] | nr, 0.1–4,800 | nd-366 | 70 | 20 | nr, 0.1–4,800 | nd-366 | 50 | 20 |
| Mirex | nr, 0.01–100 | nd-1,834 | 85 | 13 | nr, 0.01–50 | nd-310 | 64 | 9 |
| Nonachlor, *cis*- | nr, 0.5–100 | nd-5.5 | 22 | 9 | nr, 0.5–100 | nd-5.5 | 22 | 9 |
| Nonachlor, *trans*- | nr, 0.5–100 | nd-16 | 21 | 10 | nr, 0.5–100 | nd-16 | 21 | 10 |
| Pentachlorophenol | nr, 0.5–1,200 | nd-770 | 13 | 31 | nr, 0.1–1,200 | nd-770 | 8 | 25 |
| Toxaphene | nr, 0.05–9,600 | nd-1,858,000 | 100 | 12 | nr, 0.1–9,600 | nd-2,800 | 65 | 11 |

*Note:* Results are presented for all monitoring studies (published 1960–1994), and for recent monitoring studies (published 1984–1994) that are listed in Tables 2.1 and 2.2 of the publication. Concentration range in detection limits: "nr" indicates that one or more studies did not report detection limits. Abbreviations: nd, not detected; nr, not reported; μg/kg, microgram per kilogram.

[a] Total or unspecified.
[b] (*o,p′* + *p,p′*)- or unspecified.
[c] *p,p′*- or unspecified.

*Source*: From Nowell, L.H., Capel, P.D., and Dileanis, P.D., 1999, *Pesticides in Stream Sediment and Aquatic Biota, Distribution, Trends, and Governing Factors, Volume Four of the Series Pesticides in the Hydrologic System*, Lewis Publishers, Boca Raton.

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**Table 10E.149 Statistical Summary of Organochlorine Concentrations in Sediment, in the United States, 1992–1995**

| Target Analyte | Number of Samples | Concentration (μg/kg dry weight) at Given Percentile | | | | | | | | | Frequency of Detection (percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RL | 5 | 10 | 25 | 50 | 75 | 90 | 95 | 100 | |
| *p,p′*-DDE | 421 | 1 | <1 | <1 | <1 | <1 | 2.2 | 7.28 | 12.9 | 220 | 39.4 |
| Total PCBs[a] | 428 | 100 | <100 | <100 | <100 | <100 | <100 | <100 | 145.5 | 13,000 | 5.8 |
| Total PCBs[b] | 207 | 50 | <50 | <50 | <50 | <50 | <50 | 150 | 336 | 13,000 | 18.8 |
| *p,p′*-DDD | 350 | 1 | <1 | <1 | <1 | <1 | <1 | 4.19 | 9.24 | 130 | 24.9 |
| *trans*-Nonachlor | 411 | 1 | <1 | <1 | <1 | <1 | <1 | 2.08 | 3 | 18 | 15.8 |
| *p,p′*-DDT | 358 | 2 | <2 | <2 | <2 | <2 | <2 | 4.03 | 12.05 | 180 | 18.7 |
| Dieldrin | 413 | 1 | <1 | <1 | <1 | <1 | <1 | 1.5 | 3.23 | 18 | 14.3 |
| *cis*-Chlordane | 411 | 1 | <1 | <1 | <1 | <1 | <1 | 1.8 | 3.3 | 17 | 15.8 |
| *cis*-Nonachlor | 412 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | 1.6 | 10 | 9.2 |
| *trans*-Chlordane | 416 | 1 | <1 | <1 | <1 | <1 | <1 | 2.2 | 3.775 | 20 | 17.1 |
| Oxychlordane | 405 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 1.3 | 0.3 |
| *o,p′*-DDD | 350 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | 2.09 | 150 | 10.9 |
| Pentachloro-anisole | 430 | 50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | 0 |
| Hexachloro-benzene | 442 | 50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | 0 |
| *o,p′*-DDT | 354 | 2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | 30 | 3.1 |
| Heptachlor epoxide | 412 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 4.6 | 1.2 |
| *o,p′*-DDE | 405 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 22 | 2 |
| γ-HCH | 413 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 5.2 | 1 |
| Dacthal | 414 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 25 | 1.5 |
| Endrin | 412 | 2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | 0 |
| α-HCH | 415 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 0 |
| Toxaphene | 419 | 200 | <200 | <200 | <200 | <200 | <200 | <200 | <200 | 240 | 0.2 |
| Aldrin | 418 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 3 | 0.5 |
| Mirex | 418 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 4.4 | 1.9 |
| *o,p′*-Methoxychlor | 382 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0 |
| *p,p′*-Methoxychlor | 378 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 71 | 0.8 |
| β-HCH | 411 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 1.2 | 0.5 |
| Heptachlor | 419 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 0.2 |
| Endosulfan | 409 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 8.8 | 2.7 |
| *cis*-Permethrin | 344 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 26 | 1.2 |
| *trans*-Permethrin | 340 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 15 | 0.9 |
| Chloroneb | 396 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0 |
| Isodrin | 409 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 0 |

*Note:* All statistics apply to samples in the national data set. 5. Frequency of detection: percentage of samples with concentrations at or above the reporting limit. PCB, polychlorinated biphenyl; RL, reporting limit in microgram per kilogram dry weight; μg/kg, microgram per kilogram; <, less than.

[a] Total PCBs censored at a reporting limit of 100 μg/kg dry weight.
[b] Total PCBs censored at a reporting limit of 50 μg/kg dry weight.

*Source*: From Wong, C.S., Capel, P.D., and Nowell, L.H., 2000, Organochlorine Pesticides and PCBs in Stream Sediment and Aquatic Biota — Initial Results from the National Water-Quality Assessment Program, 1992–1995, *United States Geological Survey, Water-Resources Investigations Report 00-4053*, www.usgs.gov.

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**Table 10E.150 Comparison of Organochlorine Concentrations in Sediment in the United States with Sediment-Quality Guidelines, 1992–1995**

| | EPA Sediment-Quality Criteria | | Boundary Values and Tier Assignments | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | NAWQA Sites in Each Tier (percent) | | |
| Target Analytes | Criterion (μg/kg-oc) | Tier 1 Percent of Sites Exceeding Criterion | Tier 2–3 Boundary Value[a] (μg/kg dry weight) | Tier 1–2 Boundary Value[b] (mg/kg dry weight) | Tier 1 | Tier 2 | Tier 3 |
| Total chlordane | — | — | 0.5 | 6 | 10.4 | 8.3 | 81.3 |
| Total DDT | — | — | 1.58 | 46.1 | 4.7 | 32.1 | 63.2 |
| Dieldrin | 11,000 | 0 | 0.02 | 6.67[c] | 0 | 14.3 | 85.7 |
| Endosulfan I | — | — | 2.9 | i | — | 1.2 | 98.8 |
| Endrin | 4,200 | 0 | 0.02 | 45[c] | 0 | 0 | 100 |
| Total HCH | — | — | 0.32 | 3.7 | 0.2 | 1.2 | 98.5 |
| Heptachlor epoxide | — | — | 0.6 | i | — | 1.2 | 98.8 |
| Hexachlorobenzene | — | — | 22 | i | — | 0 | 100 |
| Lindane | — | — | 0.32 | 1.38 | 0.7 | 0.2 | 99 |
| Total methoxychlor | — | — | 19 | i | — | 0.5 | 99.5 |
| Total PCBs | — | — | 21.6 | 189 | 3.5 | 2.3 | 94.2 |
| Toxaphene | — | — | 1.5 | 100 | 0.2[d] | 0[d] | 99.8[d] |
| Probability of adverse effects | | High | | | High | Intermediate | No indication |

*Note:* Percentage of NAWQA sites in Tiers 1, 2, and 3 based on exceedance of sediment-quality guidelines. EPA sediment-quality criteria, and the percent exceedance, are shown because exceedance of this criterion triggers classification in Tier 1 for sites with sediment organic carbon data. Tier 1-2 and Tier 2-3 boundary values are also shown (see text for explanation). The probability of adverse effects on aquatic life is shown for each tier. I, insufficient guidelines to determine a Tier 1-2 boundary value; EPA, U.S. Environmental Protection Agency; PCB, polychlorinated biphenyl; wt., weight; μg/kg, microgram per kilogram; μg/kg-oc, microgram per kilogram of sediment organic carbon; —, no guideline available.

[a] Lowest of the lower screening values.
[b] Second lowest of the upper screening values.
[c] Values are appropriate only for site with no sediment organic carbon data; if sediment organic carbon data are available, the EPA sediment-quality criterion (column 1) should be used instead.
[d] Because the boundary values (1.5 and 100 μg/kg) for this compound are well below its detection limit in the present study (200 μg/kg), the percentage of sites in Tiers 1 and 2 must be considered as underestimates.

*Source*: From Wong, C.S., Capel, P.D., and Nowell, L.H., 2000, Organochlorine Pesticides and PCBs in Stream Sediment and Aquatic Biota — Initial Results from the National Water-Quality Assessment Program, 1992–1995, *United States Geological Survey, Water-Resources Investigations Report 00-4053*, www.usgs.gov.

**Table 10E.151 Current and Maximum Rates of Toxaphene Accumulation in Great Lakes Sediments**

| | | Accumulation Rates in Sediment ($ng/cm^2/yr$) | |
|---|---|---|---|
| Location | Number of Sediment Cores Analyzed | Present | Maximum Historical |
| Lake Superior | 3 | 0.097–0.14 | 0.25 |
| Northern Lake Michigan | 3 | 0.52–1.01 | 1.07 |
| Southern Lake Michigan near Chicago Urban Area | 1 | 0.24 | 0.32 |
| Lake Ontario | 3 | 0.39–0.60 | 1.4 |

*Note:* All accumulations are focus-corrected.

[a] Total or unspecified.
[b] ($O,p' + p,p'$)- or unspecified.
[c] $p,p'$- or total.

*Source*: From United States Environmental Protection Agency, 2000, *Deposition of Air Pollutants to the Great Waters Third Report to Congress*, EPA-453/R-00-005.

*Original Source*: From Pearson et al., 1997b, www.epa.gov.

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**Table 10E.152 Selected Results of Studies That Monitored Pesticides in Whole Fish and the Percentage of Those Studies That Exceeded Guidelines for the Protection of Fish-Eating Wildlife, 1960–1994**

| | Whole Fish: All Monitoring Studies (Published 1960–1994) | | | | | |
|---|---|---|---|---|---|---|
| | Concentration Range (μg/kg wet weight) | | | | | |
| Target Analytes | In Detection Limits | In Maximum Concentrations ($C_{max}$) | Total Number of Studies | Percentage of Studies with Detectable Residues | Percentage of Studies with $C_{max}$ that Exceeded NAS/NAE Guideline[a] | Percentage of Studies with $C_{max}$ that Exceeded NYSDEC Guideline[b] |
| Aldrin | nr, 0.01–50 | nd-12 | 32 | 19 | 0 | 0 |
| Acephate | 50 | nd | 1 | 0 | — | — |
| Alachlor | nr, 10–100 | nd | 2 | 0 | — | — |
| Aldicarb | 50 | nd | 1 | 0 | — | — |
| Atrazine | 10–8,000 | nd | 3 | 0 | — | — |
| Azinphos-methyl | 50–300 | nd | 2 | 0 | — | — |
| Carbaryl | 5–50 | nd-50 | 1 | 0 | — | — |
| Carbofuran | nr, 20–200 | nd-560 | 1 | 100 | — | — |
| Carbofuran, 3-hydroxy- | 20–200 | 1,490 | 1 | 100 | — | — |
| Carbophenothion | 50 | nd | 1 | 0 | — | — |
| Chlordane[a] | nr, 0.1–100 | nd-870 | 27 | 63 | 33 | 4 |
| Chlordane, *cis*- | nr, 0.01–100 | nd-1,090 | 44 | 61 | 20 | 5 |
| Chlordane, *trans*- | nr, 0.01–50 | nd-970 | 42 | 62 | 12 | 7 |
| Chlorpyrifos | nr, 10 | nd | 2 | 0 | — | — |
| Coumaphos | nr | nd | 1 | 0 | — | — |
| Cyanazine | 10 | nd | 1 | 0 | — | — |
| D, 2,4- | 1 | 6 | 1 | 100 | — | — |
| Dacthal (DCPA) | nr, 2–10 | nd-13,400 | 14 | 79 | — | — |
| DDD[a] | nr, 0.1–50 | nd-12,500 | 19 | 84 | 26 | 26 |
| DDD, *o,p′*- | nr, 0.01–50 | nd-420 | 34 | 29 | 0 | 9 |
| DDD, *p,p′*- | nr, 0.01–100 | nd-31,000 | 61 | 77 | 10 | 31 |
| DDE[a] | nr, 0.1–100 | nd-31,500 | 21 | 90 | 33 | 62 |
| DDE, *o,p′*- | nr, 0.01–50 | nd-360 | 35 | 23 | 0 | 3 |
| DDE, *p,p′*- | nr, 0.01–100 | nd-140,000 | 61 | 89 | 28 | 43 |
| DDT[a] | nr, 0.1–50 | nd-6,750 | 22 | 77 | 27 | 50 |
| DDT, *o,p′*- | nr, 0.01–50 | nd-720 | 37 | 35 | 0 | 5 |
| DDT, *p,p′*- | nr, 0.01–100 | nd-4,600 | 55 | 58 | 7 | 20 |
| DDT, total | nr, 0.1–100 | nd-28,880 | 34 | 100 | 50 | 82 |
| Demeton | 50 | nd | 1 | 0 | — | — |
| Diazinon | nr, 100 | nd | 2 | 0 | — | — |
| Dichlorvos | nr | nd | 1 | 0 | — | — |
| Dicofol | nr, 1–10 | nd-560 | 10 | 40 | — | — |
| Dieldrin | nr, 0.01–100 | nd-12,500 | 87 | 74 | 31 | 30 |
| Dimethoate | 41–50 | nd | 1 | 0 | — | — |
| Disulfoton | nr | nd | 1 | 0 | — | — |
| Endosulfan[a] | nr, 0.1–20 | nd-170 | 6 | 67 | 17 | — |
| Endosulfan I | nr, 0.02–10 | nd-285 | 8 | 38 | 13 | — |
| Endosulfan II | nr, 2–10 | nd-40 | 7 | 29 | 0 | — |
| Endosulfan sulfate | nr, 2–200 | nd-20 | 6 | 17 | — | — |
| Endrin | nr, 0.01–100 | nd-2,060 | 65 | 28 | 5 | 9 |
| Endrin aldehyde | nr, 200 | nd | 2 | 0 | — | — |
| Endrin ketone | nr | nd | 1 | 0 | — | — |
| EPN | 200 | nd | 1 | 0 | — | — |
| Ethoprop | nr | nd | 1 | 0 | — | — |
| Famphur | nr | nd | 1 | 0 | — | — |
| Fensulfothion | nr | nd | 1 | 0 | — | — |
| Fenthion | nr | nd | 1 | 0 | — | — |
| Fenvalerate | nr | nd-11 | 2 | 50 | — | — |
| HCH[a] | nr, 0.1–100 | nd-170 | 12 | 50 | 17 | 17 |
| HCH, α- | nr, 0.0.1–100 | nd-610 | 34 | 35 | — | — |
| HCH, β- | nr, 0.01–100 | nd-900 | 31 | 23 | — | — |
| HCH, δ- | nr, 0.01–100 | nd-41 | 25 | 12 | — | — |
| Heptachlor | nr, 0.01–50 | nd-600 | 34 | 35 | 6 | 6 |

*(Continued)*

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**Table 10E.152 (Continued)**

| | Whole Fish: All Monitoring Studies (Published 1960–1994) | | | | | |
|---|---|---|---|---|---|---|
| | Concentration Range (μg/kg wet weight) | | | | | |
| **Target Analytes** | **In Detection Limits** | **In Maximum Concentrations ($C_{max}$)** | **Total Number of Studies** | **Percentage of Studies with Detectable Residues** | **Percentage of Studies with $C_{max}$ that Exceeded NAS/NAE Guideline[a]** | **Percentage of Studies with $C_{max}$ that Exceeded NYSDEC Guideline[b]** |
| Heptachlor epoxide | nr, 0.01–104 | nd-480 | 64 | 50 | 5 | 2 |
| Hexachlorobenzene | nr, 0.01–100 | nd-27,000 | 51 | 45 | — | 14 |
| Kepone | nr, 10–50 | nd-2,800 | 6 | 50 | — | — |
| Lindane | nr, 0.01–100 | nd-120 | 42 | 24 | 2 | 2 |
| Malathion | nr, 1–50 | nd | 3 | 0 | — | — |
| Methamidophos | nr | nd | 1 | 0 | — | — |
| Methiocarb | nr | nd | 1 | 0 | — | — |
| Methomyl | nr | nd | 1 | 0 | — | — |
| Methoxychlor[c] | nr, 0.1–100 | nd-130 | 15 | 47 | — | — |
| Methyl parathion | nr, 50 | nd-60 | 3 | 33 | — | — |
| Metolachlor | nr | nd | 1 | 0 | — | — |
| Mevinphos | nr | nd | 1 | 0 | — | — |
| Mirex | nr, 0.01–100 | nd-1,810 | 46 | 28 | — | 11 |
| Monocrotophos | nr | nd | 1 | 0 | — | — |
| Nonachlor, *cis*- | nr, 0.01–100 | nd-156 | 38 | 29 | — | — |
| Nonachlor, *trans*- | nr, 0.01–107 | nd-1,550 | 45 | 64 | — | — |
| Oxadiazon | nr | 2,200 | 1 | 100 | — | — |
| Oxamyl | nr | nd | 1 | 0 | — | — |
| Oxychlordane | nr, 0.01–105 | nd-640 | 50 | 34 | — | — |
| Parathion | 30–50 | nd | 2 | 0 | — | — |
| Pentachloroanisole | nr | 33–160 | 2 | 100 | — | — |
| Pentachlorophenol | nr, 0.1–3,000 | nd-4,520 | 2 | 50 | — | — |
| Permethrin | nr | 0.53 | 1 | 100 | — | — |
| Perthane | 0.01–1 | nd | 3 | 0 | — | — |
| Phorate | 50 | nd | 1 | 0 | — | — |
| Phosdrin | 20 | nd | 1 | 0 | — | — |
| Photomirex | nr | 196–400 | 2 | 100 | — | — |
| T,2,4,5- | 0.2 | nd | 1 | 0 | — | — |
| Terbufos | 50 | nd | 1 | 0 | — | — |
| Tetrachlorvinphos | 20 | nd | 1 | 0 | — | — |
| Tetradifon | nr, 1–10 | nd-2 | 5 | 20 | — | — |
| Toxaphene | nr, 0.1–2,000 | nd-280,330 | 51 | 37 | 37 | — |
| Trichlorfon | 50–80 | nd | 2 | 0 | — | — |
| Trifluralin | nr, 2 | 7–126 | 2 | 100 | — | — |

*Note:* All concentrations are wet weight, NAS/NAE guideline, maximum recommended concentration for protection of fish-eating wildlife. NYSDEC guideline: New York fish flesh criterion for protection of piscivorous wildlife. Abbreviations and symbols: $C_{max}$, maximum concentration in the study; NAS/NAE, National Academy of Sciences and National Academy of Engineering; NYSDEC, New York State Department of Environmental Conservation; na, data not available; nd, not detected; nr, one or more studies did not report this information; μg/kg, microgram per kilogram; —, no guideline available.

[a] Total or unspecified.
[b] ($o,p' + p,p'$)- or unspecified.
[c] $p,p'$- or total.

*Source*: From Nowell, L.H., Capel, P.D., and Dileanis, P.D., 1999, *Pesticides in Stream Sediment and Aquatic Biota, Distribution, Trends, and Governing Factors, Volume Four of the Series Pesticides in the Hydrologic System*, Lewis Publishers, Boca Raton.

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**Table 10E.153 Statistical Summary of Organochlorine Concentrations in Fish in the United States, 1992–1995**

| | | Concentration (μg/kg wet weight) at Given Percentile | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Target Analyte | Number of Samples | RL | 5 | 10 | 25 | 50 | 75 | 90 | 95 | 100 | Frequency of Detection (percent) |
| *p,p′*-DDE | 233 | 5 | <5 | <5 | 6.9 | 27 | 80.5 | 186 | 326 | 2,400 | 79.8 |
| Total PCBs | 233 | 50 | <50 | <50 | <50 | <50 | 150 | 646 | 1,400 | 72,000 | 44.6 |
| *p,p′*-DDD | 224 | 5 | <5 | <5 | <5 | <5 | 14 | 33.5 | 46 | 1,200 | 42.4 |
| *trans*-Nonachlor | 231 | 5 | <5 | <5 | <5 | <5 | 9.2 | 21.8 | 29.4 | 120 | 33.8 |
| *p,p′*-DDT | 232 | 5 | <5 | <5 | <5 | <5 | 7.08 | 21.7 | 30.35 | 430 | 32.3 |
| Dieldrin | 232 | 5 | <5 | <5 | <5 | <5 | 6.15 | 21 | 36.05 | 260 | 28.9 |
| *cis*-Chlordane | 231 | 5 | <5 | <5 | <5 | <5 | <5 | 15.8 | 28.8 | 150 | 24.2 |
| *cis*-Nonachlor | 230 | 5 | <5 | <5 | <5 | <5 | <5 | 8.59 | 11.45 | 53 | 18.7 |
| *trans*-Chlordane | 232 | 5 | <5 | <5 | <5 | <5 | <5 | 8.61 | 15.35 | 56 | 16.8 |
| Oxychlordane | 232 | 5 | <5 | <5 | <5 | <5 | <5 | 5.77 | 11.35 | 30 | 12.1 |
| *o,p′*-DDD | 231 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | 8.82 | 360 | 9.5 |
| Pentachloro-anisole | 232 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | 7.56 | 87 | 8.2 |
| Hexachloro-benzene | 234 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | 8.875 | 33 | 7.3 |
| *o,p′*-DDT | 228 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | 5.2 | 140 | 5.7 |
| Heptachlor epoxide | 232 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | 7.335 | 24 | 5.6 |
| *o,p′*-DDE | 227 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | 5.06 | 130 | 4.9 |
| γ-HCH | 231 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 30 | 4.3 |
| Dacthal | 231 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 67 | 3 |
| Endrin | 232 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 16 | 1.7 |
| δ-HCH | 230 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 5.5 | 0.4 |
| α-HCH | 232 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 5.4 | 0.4 |
| Toxaphene | 233 | 200 | <200 | <200 | <200 | <200 | <200 | <200 | <200 | 210 | 0.4 |
| Aldrin | 233 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0 |
| Mirex | 233 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0 |
| *p,p′*-Methoxy-chlor | 233 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0 |
| *o,p′*-Methoxy-chlor | 231 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0 |
| β-HCH | 232 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0 |
| Heptachlor | 233 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0 |

*Note:* All Statistics apply to samples in the national data set. Compounds are listed in order of detection frequency. Frequency of detection: percentage of samples with concentrations at or above the reporting limit. PCB, polychlorinated biphenyl; RL, reporting limit in microgram per kilogram wet weight; μg/kg, microgram per kilogram; <, less than.

*Source*: From Wong, C.S., Capel, P.D., and Nowell, L.H., 2000, Organochlorine Pesticides and PCBs in Stream Sediment and Aquatic Biota - Initial Results from the National Water-Quality Assessment Program, 1992–1995, *United States Geological Survey, Water-Resources Investigations Report 00-4053*, www.usgs.gov.

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**Table 10E.154 Comparison of Organochlorine Concentrations in Whole Fish Samples Collected in the United States with Edible-Fish Guidelines for Protection of Human Health, 1992–1995**

| | | FDA Action Level[b] | | EPA Guidance for Use in Fish Advisories: Recommended Screening Value[a,c] | |
|---|---|---|---|---|---|
| Target Analytes | EPA Cancer Group[a] | Standard (μg/kg) | Percent of Sites Exceeding Standard | Guideline (μg/kg) | Percent of Sites Exceeding Guideline |
| Total chlordane | B2 | 300 | 0.4 | 80[d] | 5.7 |
| Total DDT | B2 | 5,000 | 0 | 300[d] | 7.8 |
| Total dieldrin | B2 | 300 | 0 | 7[d] | 23 |
| Endrin | D/E | 300 | 0 | 3,000 | 0 |
| Total heptachlor | B2 | 300 | 0 | 10[d] | 3 |
| Hexachlorobenzene | B2 | 300 | 0 | 10[d] | 0 |
| Lindane | B2/C | — | — | 70[d] | 0 |
| Mirex | —[e] | 100 | 0 | 2,000 | 0 |
| Total PCBs | B2 | 2,000[f] | 2.6 | 10[d] | 45 |
| Toxaphene | B2 | 5,000 | 0 | 100[d] | 0.4 |

*Note:* Because chemical concentrations are in whole fish, whereas standards and guidelines apply to edible fish tissues, exceedance indicates that additional sampling of game fish fillets may be warranted. All concentrations are wet weight. EPA cancer group: B2, probable human carcinogen; C, possible human carcinogen; D, not classified; E, no evidence of carcinogenicity. FDA, Food and Drug Administration; EPA, U.S. Environmental Protection Agency; μg/kg, microgram per kilogram; —, no standard or guideline available.

[a] From U.S. Environmental Protection Agency (1995).
[b] From Food and Drug Administration (1990), unless otherwise specified.
[c] Based on chronic toxicity, unless otherwise specified.
[d] Based on 1 in 100,000 cancer risk.
[e] Not classified by EPA; however, classified as a probable human carcinogen by International Agency for Research on Cancer.
[f] FDA tolerance level (from Food and Drug Administration, 1984).

*Source*: From Wong, C.S., Capel, P.D., and Nowell, L.H., 2000, Organochlorine Pesticides and PCBs in Stream Sediment and Aquatic Biota - Initial Results from the National Water-Quality Assessment Program, 1992–1995, *United States Geological Survey, Water-Resources Investigations Report 00-4053*, www.usgs.gov.

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**Table 10E.155 Potential Sources of Pesticide Contamination of Groundwater**

| | Manufacturer/ Formulator | Dealer | Industrial User | Land Application |
|---|---|---|---|---|
| **SPILLS AND LEAKS** | | | | |
| Storage areas | x | x | x | x |
| Storage tanks/pipelines | x | x | x | x |
| Loading/unloading | x | x | x | x |
| Transport accidents | x | x | x | x |
| **DISPOSAL** | | | | |
| Process Waste | x | | x | |
| Off-specification material | x | | | |
| Cancelled products | x | x | x | x |
| Containers | x | x | x | x |
| Rinsate | | | x | x |
| **LAND APPLICATION** | | | | x |
| Leaching | | | | x |
| Backflow to irrigation well | | | | x |
| Run-in to wells, sinkholes | | | | x |
| Mixing/loading areas | | | | x |
| Feed lots | | | | x |

*Source*: From U.S. Environmental Protection Agency, office of Pesticides and Toxic Substances, 1987, *Agricultural Chemicals in Ground Water: Proposed Pesticide Strategy*.

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**Table 10E.156 Pesticide Concentrations Measured in Groundwater during Multistate Studies and Studies from the Pesticides in Groundwater Database in Relation to Drinking-Water-Quality Criteria in the United States, 1971–1993**

| Pesticide or Transformation Product | USEPA Water-Quality Criteria for Drinking Water (µg/L) | | | | Ranges of Observed Concentrations (µg/L) in Groundwater | | | | | | Frequencies of Exceedance of MCL or HA (if MCL not available) Among Sampled Wells (percent) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MCL | HA | 10-kg Child | | MCPS | NPS | | NAWWS | MMS | PGWDB | MCPS | NPS | | NAWWS | MMS | PGWDB |
| | | | Acute (1 d) | Chronic (7 yrs) | | CWS | RD | | | | | CWS | RD | | | |
| Acifluorfen | nsr | nsr | 2,000 | 100 | ND | Q[a] | | | 0.003–0.025 | ND | NA | NA | | | NA | |
| Alachlor | 2 | nsr | 100 | NR | 0.003–4.270 | ND | 4.2 | 0.0385–6.185 | | 0.006–3,000 | 0.91[b] | ND | 0.13 | 0.02 | | 0.38 |
| Alachlor ESA | nsr | nsr | nsr | nsr | 0.100–8.630 | | | | | | NA | | | | | |
| 2,6-Diethylaniline | nsr | nsr | nsr | nsr | 0.002–0.022 | | | | | ND | NA | | | | | ND |
| Hydroxyalachlor | nsr | nsr | nsr | nsr | | | | | | 0.910 | | | | | | NA |
| Aldicarb | 3 | 1 | 1 | 1 | | ND | ND | | | 0.08–1,264.00 | | ND | ND | | | 4.6 |
| Aldicarb sulfone | 2 | 42 | 60 | 60 | | ND | ND | | | 0.01–153.00 | | ND | ND | | | 12 |
| Aldicarb sulfoxide | 4 | 9 | 10 | 10 | | ND | ND | | | 0.01–1030.00 | | ND | ND | | | 9.2 |
| Aldrin | nsr | nsr | 0.3 | 0.3 | | ND | ND | | | 0.0052–21 | | ND | ND | | | 0.033[c] |
| Ametryn | nsr | 60 | 9,000 | 900 | ND | ND | ND | | | 0.01–0.200 | ND | ND | ND | | | [0] |
| Arsenic | 50[d] | | | | | | | | | 1.6–680.0 | | | | | | 18 |
| Atrazine | 3 | 3 | 100 | 50 | 0.003–2.090 | Q-0.92 | Q-7.0 | 0.03–6.719 | | 0.001–1,500 | 0 | 0 | 0.13 | 0.1 | | 0.64 |
| Deethyl atrazine | nsr | nsr | nsr | nsr | 0.002–2.320 | ND | ND | | | 0.05–2.860 | NA | ND | ND | | | NA |
| Deisopropyl atrazine | nsr | nsr | nsr | nsr | 0.050–1.170 | | | | | 0.100–3.540 | NA | | | | | NA |
| Baygon (propoxur) | nsr | 3 | 40 | 40 | | ND | ND | | | 2.0–35.0 | | ND | ND | | | 0.019 |
| Bentazon | nsr | 20 | 300 | 300 | ND | ND | 2.9 | | | 0.10–41.89 | ND | ND | 0 | | | 0.28 |
| α-BHC | nsr | nsr | 50 | 50 | ND | ND | ND | | | 0.0014–0.16[e] | ND | ND | ND | | | NA |
| β-BHC | nsr | nsr | nsr | nsr | | ND | 0.04 | | | 0.0014–0.16[a] | | ND | ND | | | |
| δ-BHC | Nsr | nsr | nsr | nsr | | Q[a] | Q[a] | | | | NA | NA | | | | |
| γ-BHC (lindane) | 0.2 | 0.2 | 1,200 | 33 | | ND | Q-0.42 | | | 0.0006–180.000 | 0 | ND | 0.13 | | | 0.045 |
| Bromacil | nsr | 90 | 5,000 | 3,000 | | ND | ND | | | 0.03–951.6 | | ND | ND | | | 0.12 |
| Butylate | nsr | 350 | 2,000 | 1,000 | ND | ND | ND | | | 0.87–2.23 | ND | ND | ND | | | 0 |
| Carbaryl | nsr | 700 | 1,000 | 1,000 | ND | ND | ND | | | 0.03–610.00 | ND | ND | ND | | | 0 |
| Carbofuran | 40 | 36 | 50 | 50 | ND | ND | ND | | | 0.01–176.00 | ND | ND | ND | | | 0.26 |
| Carboxin | nsr | 700 | 1,000 | 1,000 | | ND | ND | | | ND | | ND | ND | | | ND |
| Chloramben | nsr | 100 | 3,000 | 200 | | Q[a] | Q[a] | | | 1.00 | | 0 | 0 | | | 0 |
| α-Chlordane | 2[f] | nsr | 60[f] | 0.5[f] | | Q-0.01 | Q-0.01 | | | 0.01–20.000[f] | | 0[f] | 0[f] | | | 0.20[f] |
| γ-Chlordane | | nsr | | | | ND | Q-0.01 | | | | | | | | | |
| Chlorothalonil | nsr | nsr | 200 | 200 | | | | | | 0.140–1.100 | | | | | | 0.18[c] |
| Chlorpyrifos | nsr | 20 | 30 | 30 | 0.005–0.024 | | | | | 0.05–0.654 | 0 | | | | | 0 |
| Cyanazine | nsr | 1 | 100 | 20 | 0.010–0.880 | ND | ND | 0.1205–0.1485 | | 0.002–29.0 | 0 | ND | ND | 0 | | 0.29 |
| Cyanazine amide | nsr | nsr | nsr | nsr | 0.050–0.550 | | | | | | NA | | | | | |
| 2,4-D | 70 | 70 | 1,000 | 100 | 0.100–0.890 | ND | ND | | | 0.0079–57.1 | 0 | ND | ND | | | 0.33[c] |
| Dacthal (DCPA) | nsr | 4,000 | 80,000 | 5,000 | ND | ND | ND | | | 0.010–300.0 | ND | ND | ND | | | 0 |
| DCPA hydrolysis products | nsr | nsr | nsr | nsr | 0.010–2.220 | Q-7.2 | Q-2.4 | | | 0.21–431.0 | NA | NA | NA | | | NA |
| Dalapon | 200 | 200 | 3,000 | 300 | | Q[a] | Q[a] | | | ND | | 0 | 0 | | | ND |
| Diazinon | nsr | 0.6 | 20 | 5 | ND | Q[a] | Q[a] | | | 0.01–3.2 | | 0 | ND | | | 0.051 |
| 1,2-Dibromo-3-chloropropane (DBCP) | 0.2 | nsr | 200 | NR | | Q | 0.48–0.71 | | | 0.001–8000.00 | | 0 | 0.27 | | | 5.5 |
| Dicamba | nsr | 200 | 300 | 300 | 0.100 | ND | ND | | | 0.006–44.0 | 0 | ND | ND | | | 0 |
| 1,3-Dichloropropene | nsr | nsr | 30[f] | 30[f] | | ND | ND | | | 0.279–140[f] | | ND | ND | | | NA |

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| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dieldrin | nsr | nsr | 0.5 | 0.5 | ND | ND | ND | | | 0.001–2.600 | ND | ND | ND | | | 0.095[c] |
| Dinoseb | 7 | 7 | 300 | 10 | | 3.5 | ND | | | 0.008–47.00 | | 0 | ND | | | 0.59 |
| Diphenamid | nsr | 200 | 300 | 300 | | ND | ND | | | ND | | ND | ND | | | ND |
| Diquat | 20 | 20 | nsr | nsr | | | | | | ND | | | | | | ND |
| Disulfoton | nsr | 0.3 | 10 | 3 | ND | Q[a] | Q[a] | | | 0.04–100.00 | | 0 | 0 | | | 0.61 |
| Diuron | nsr | 10 | 1,000 | 300 | | ND | ND | | | 0.01–5.37 | | ND | ND | | | 0 |
| Endothall | 100 | 140 | 800 | 200 | | | | | | ND | | | | | | ND |
| Endrin | 2 | 2 | 20 | 3 | | ND | ND | | | 0.001–3.5 | | ND | ND | | | 0.024 |
| Ethylene dibromide (EDB) | 0.05 | nsr | 8 | NR | | ND | 0.29 | | | 0.001–15,772.4 | | ND | 0.13 | | | 10.6 |
| Ethylene thiourea (ETU)[7] | nsr | nsr | 300 | 100 | | ND | Q-16 | | | 0.725 | | ND | NA | | | NA |
| Fenamiphos | nsr | 2 | 9 | 5 | | ND | ND | | | ND | | ND | ND | | | ND |
| Fluometuron | nsr | 90 | 2,000 | 2,000 | | ND | ND | | | 0.8–5.000 | | ND | ND | | | 0 |
| Fonofos | nsr | 10 | 20 | 20 | ND | | | | | 0.007–0.90 | ND | | | | | 0 |
| Glyphosate | 700 | 700 | 20,000 | 1,000 | | | | | | 0.004–150.0 | | | | | | 0 |
| Heptachlor | 0.4 | nsr | 10 | 5.0 | | ND | ND | | | 0.001–0.8 | | ND | ND | | | 0.12 |
| Heptachlor epoxide | 0.2 | nsr | nsr | 0.1 | | ND | ND | | | 0.01–0.22 | | ND | ND | | | 0.032 |
| Hexachlorobenzene | 1 | nsr | 50 | 50 | | Q-0.17 | ND | | | 0.0039–0.0056 | | 0 | ND | | | 0 |
| Hexazinone | nsr | 200 | 3,000 | 3,000 | | ND | ND | | | 0.060–0.720 | | ND | ND | | | 0 |
| Malathion | nsr | 200 | 200 | 200 | ND | | | | | 0.007–6.17 | ND | | | | | 0 |
| MCPA | nsr | 10 | 100 | 100 | | | | | | 0.13–5.5 | | | | | | 0 |
| Methomyl | nsr | 200 | 300 | 300 | | ND | ND | | | 1.0–20.00 | | ND | ND | | | 0 |
| Methoxychlor | 40 | 40 | 50 | 50 | | ND | ND | | | 0.01–0.312 | | ND | ND | | | 0 |
| Methyl parathion | nsr | 2 | 300 | 30 | ND | | | | | 0.01–0.256 | ND | | | | | 0 |
| Metolachlor | nsr | 100 | 2,000 | 2,000 | 0.003–1.460 | ND | ND | 0.0375–3.805 | ([h]) | 0.02–157.00 | 0 | ND | ND | 0 | 0 | 0.013 |
| Metribuzin | nsr | 200 | 5,000 | 300 | 0.050–0.220 | ND | ND | | | 0.001–25.10 | 0 | ND | ND | | | 0 |
| Metribuzin DA | nsr | nsr | nsr | nsr | | ND | ND | | | ND | | ND | ND | | | ND |
| Metribuzin DADK | nsr | nsr | nsr | nsr | | Q[a] | Q[a] | | | ND | | NA | NA | | | ND |
| Metribuzin DK | nsr | nsr | nsr | nsr | | Q[a] | Q[a] | | | ND | | NA | NA | | | ND |
| Oxamyl | 200 | 200 | 200 | 200 | | ND | ND | | | 0.01–395.00 | | ND | ND | | | 0.013 |
| Paraquat | nsr | 30 | 100 | 50 | | | | | | 0.01–100.0 | | | | | | 0.21 |
| Pentachlorophenol | 1 | NR | 1,000 | 300 | | ND | ND | | | 0.001–0.64 | | ND | ND | | | 0 |
| Picloram | 500 | 500 | 20,000 | 700 | 0.010–0.030 | ND | ND | | | 0.01–30.0 | 0 | ND | ND | | | 0 |
| Prometon | nsr | 100 | 200 | 200 | 0.050–1.350 | Q | Q-0.57 | | | 0.05–29.6 | 0 | 0 | 0 | | | 0 |
| Pronamide | nsr | 50 | 800 | 800 | ND | Q[a] | Q[a] | | | ND | ND | 0 | 0 | | | ND |
| Propachlor | nsr | 90 | 500 | 100 | 0.002 | ND | ND | | | 0.02–3.5 | 0 | ND | ND | | | 0 |
| Propazine | nsr | 10 | 1,000 | 500 | ND | ND | ND | | | 0.01–0.20 | ND | ND | ND | | | 0 |
| Propham | nsr | 100 | 5,000 | 5,000 | | ND | ND | | | 6.000 | | ND | ND | | | 0 |
| Simazine | 4 | 4 | 500 | 50 | 0.002–0.270 | Q-0.76 | Q | 0.043–8.359 | | 0.001–67.0 | 0 | 0 | 0 | <0.01 | | 0.40[i] |
| 2,4,5-T | nsr | 70 | 800 | 300 | 0.020 | ND | ND | | | 0.01–2.99 | 0 | ND | ND | | | 0 |
| Tebuthiuron | nsr | 500 | 3,000 | 700 | 0.050 | ND | ND | | | 20.700–380.0 | 0 | ND | ND | | | 0 |
| Terbacil | nsr | 90 | 300 | 300 | ND | ND | ND | | | 0.3–8.9 | ND | ND | ND | | | 0 |
| Terbufos | nsr | 0.9 | 5 | 1 | ND | Q[a] | Q[a] | | | 0.02–20.0 | ND | 0 | 0 | | | 0.19 |
| Toxaphene | 3 | nsr | 500 | nsr | | | | | | 1.15–18.000 | | | | | | 0.070 |
| 2,4,5-TP (silvex) | 50 | 50 | 200 | 70 | ND | ND | ND | | | 0.002–1.4 | ND | ND | ND | | | 0 |
| Trifluralin | nsr | 5 | 80 | 80 | 0.008–0.016 | ND | ND | | | 0.0018–14.890 | 0 | ND | ND | | | 0.018 |



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**Table 10E.156 (Continued)**

*Note:* Pesticide or Transformation Product: Compounds listed are those for which one or more of the multistate studies or the studies included in the Pesticides In Ground Water Database conducted analyses, and for which one or more of the indicated criteria were reported by Nowell and Resek (1994); Transformation products are indented. Criteria listed do not account for the protection of aquatic organisms. Ranges of Observed Concentrations: Numbers of significant figures given for concentrations in the original references have been retained; Concentration data for the Pesticides In Ground Water Database exclude values given in original reference (U.S. Environmental Protection Agency, 1992b) as "0," "trace" or "$<$X," where X is some maximum value. CWS, Community water system wells; HA, lifetime health advisory level for a 70-kg adult; MCL, maximum contaminant level (MCL values given are the most recent ones for which, according to Nowell and Resek [1994], a published rationale is available); MCPS, Midcontinent Pesticide Study (Kolpin and others, 1995; Kolpin, 1995b; data shown are based on all three years of sampling reported to date [1991–1993], unless otherwise indicated); MMS, Metolachlor Monitoring Study (Roux and others, 1991a); NA, not applicable; NAS, National Academy of Sciences: NAWWS, National Alachlor Well Water Survey (Holden and others, 1992; Klein, 1993); ND, not detected; NPS, National Pesticide Survey (U.S. Environmental Protection Agency, 1990a); NR, health advisories for exposures over the longer term are not recommended due to the carcinogenic risk associated with this compound; nsr, no standard or guideline reported by Nowell and Resek (1994) for this compound, unless states otherwise; PGWDB, Pesticides In Ground Water Database (U.S.Environmental Protection Agency, 1992b); Q, Compound may have been present, be "[could not] be quantified or reliable detected" (U.S.Environmental Protection Agency, 199a); RD, Rural domestic wells; USEPA, U.S. Environmental Protection Agency; Blank cells indicate no information applicable or available; $<$, less than; kg, kilograms; $\mu$g/L, micrograms per liter.

[a] Detection reported in the overall summary of analytical results (U.S. Environmental Protection Agency, 1990a), but not in the data reported for the individual wells sampled for the NPS (U.S. Environmental Protection Agency, 1994b). No distinction made between detections in CWS and RD wells.

[b] Value for frequency of exceedance of MCL for alachlor pertains to 1993 sampling only (Kolpin and Thurman, 1995). No samples exceeded the MCL for alachlor in 1991 or 1992 (Kolpin and others, 1995).

[c] Basis for reported MCL or HA exceedance not provided in original reference (U.S. Environmental Protection Agency, 1992b).

[d] Source: U.S. Environmental Protection Agency (1992b).

[e] Original reference did not differentiate between $\alpha$, $\beta$ and $\delta$ isomers.

[f] No isomers specified.

[g] Ethylenebis(dithiocarbamate) fungicide transformation product.

[h] Compound detected, but full concentration range not reported.

[i] Exceedance frequency based on an MCL (1 $\mu$g/L) that has been superceded by a higher value of 4 mg/L (Nowell and Resek, 1994) since the publication of the Pesticides In Ground Water Database (U.S. Environmental Protection Agency, 1992b.)

*Source*: From Barbash, J.E. and Resek, E.A., 1996, *Pesticides in Ground Water Distribution, Trends and Governing Factors*, Ann Arbor Press, Chelsea, Michigan. With permission.

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**Table 10E.157 Upper 90th-Percentile Concentrations of Seven Herbicides Measured in Groundwater by the National Water Quality Assessment Program (1993–1995) and Midwest Pesticide Study Investigations (1991–1994)**

| Study Name | Sampling Phase | Upper 90th-Percentile Herbicide Concentrations Measured in Groundwater (μg/L) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Atrazine | Cyanazine | Prometon | Simazine | Acetochlor | Alachlor | Metolachlor |
| NAWQA | SGW (agricultural areas) | 0.21 | ‡ | 0.008 | 0.013 | ‡ | ‡ | 0.006 |
| | SGW (urban areas) | 0.017 | ‡ | 0.078 | 0.010 | ‡ | ‡ | ‡ |
| | SGW (mixed land-use areas) | 0.010 | ‡ | ‡ | ‡ | ‡ | ‡ | 0.001 |
| | Deeper aquifers | 0.008 | ‡ | ‡ | ‡ | ‡ | ‡ | ‡ |
| | DWA | 0.056 | ‡ | 0.003 | 0.009 | ‡ | ‡ | 0.002 |
| MWPS | 7–8/92 (Random selection, postplanting) | 0.086 | ‡ | ‡ | 0.002 | NA | ‡ | 0.003 |

*Note:* Study Name: NAWQA, National Water-Quality Assessment; MWPS, Midwest Pesticide Study. Sampling Phase: DWA, drinking-water aquifers; SGW, shallow ground water. NA, not analyzed. ‡, compound detected at fewer than 10 percent of the sties sampled.

*Source*: From Barbash, J.E., Thelin, G.P., Kolpin, D.W., and Gillion, R.J., 1999, *Distribution of Major Herbicides in Ground Water of the United States*, USGS Water-Resources Investigations Report 98-4245, www.usgs.gov.

**Table 10E.158 Frequencies of Detection of Herbicide Degradates in Comparison with Those for the Corresponding Parent Compounds Measured in Groundwater by the National Water Quality Assessment Program (1993–1995) and the Midwest Pesticide Study Investigations (1991–1994)**

| Pesticide Compound (Degradates Indented) | Frequency of Detection During Different Study Phases (Percent of Sites) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NAWQA | | | | | MWPS | | CGAS | |
| | RL (μg/L) | SGW (ag) | SGW (urban) | SGW (mixed) | Deeper aquifers | RL (μg/L) | 1991–1994 | RL (μg/L) | All wells |
| Alachlor | 0.01 | 1.4 | 0 | 0.98 | 0.85 | — | — | — | — |
| | 0.05 | 0.5 | 0 | 0.98 | 0.42 | 0.05 | 3.3 | — | — |
| 2,6-Diethylaniline | 0.003 | 1.0 | 0 | 0 | 0 | 0.003 | 16.0 | — | — |
| | 0.01 | 0.4 | 0 | 0 | 0 | — | — | — | — |
| Alachlor ESA | — | — | — | — | — | 0.10 | 45.8 | — | — |
| Atrazine | 0.01 | 31.1 | 14.5 | 10.3 | 7.8 | — | — | — | — |
| | 0.05 | 19.5 | 6.3 | 3.9 | 2.8 | 0.05 | 22.4 | — | — |
| | — | — | — | — | — | — | — | 0.10 | 23.9 |
| DEA | 0.01 | 28.2 | 10.4 | 17.2 | 6.1 | — | — | — | — |
| | 0.05 | 17.5 | 1.3 | 2.5 | 1.5 | 0.05 | 22.8 | — | — |
| | — | — | — | — | — | — | — | 0.10 | 28.8 |
| DIA[a] | — | — | — | — | — | 0.05 | 10.2 | — | — |
| | — | — | — | — | — | — | — | 0.10 | 14.9 |
| Didealky-latrazine | — | — | — | — | — | — | — | 0.10 | 24.1 |
| Hydroxyatrazine | — | — | — | — | — | — | — | 0.10 | 4.5 |
| Deethyl hydroxyatrazine | — | — | — | — | — | — | — | 0.10 | 2.8 |
| Deisopropyl hydroxyatrazine | — | — | — | — | — | — | — | 0.10 | 0.3 |
| Didealkyl hydroxyatrazine | — | — | — | — | — | — | — | 0.10 | 0.5 |
| Cyanazine | 0.01 | 1.2 | 0.9 | 0 | 0.1 | — | — | — | — |
| | 0.05 | 0.5 | 0 | 0 | 0 | 0.05 | 2.3 | — | — |
| Cyanazine amide | — | — | — | — | — | 0.05 | 11.0 | — | — |

*(Continued)*

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**Table 10E.158 (Continued)**

| | Frequency of Detection During Different Study Phases (Percent of Sites) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NAWQA | | | | | MWPS | | CGAS | |
| Pesticide Compound (Degradates Indented) | RL (μg/L) | SGW (ag) | SGW (urban) | SGW (mixed) | Deeper aquifers | RL (μg/L) | 1991–1994 | RL (μg/L) | All wells |
| Deethylcyanazine | — | — | — | — | — | 0.05 | 0 | — | — |
| Deethylcyanazine amide | — | — | — | — | — | 0.05 | 0 | — | — |

*Note:* CGAS, Ciba-Geigy atrazine study; MWPS, Midwest Pesticide Study; NAWQA, National Water-Quality Assessment. MWPS data from Kolpin and others (1996b). CGAS data from Balu and others (1998).ag, agricultures; DEA, deethylatrazine; DIA, deisopropylatrazine; ESA, ethanesulfonic acid; RL, reporting limit; SGW, shallow groundwater, μg/L, microgram per liter. —, no data available from sources consulted.

[a] DIA may be produced from the transformation of either atrazine, cyanazine, or simazine.

*Source*: From Barbash, J.E., Thelin, G.P., Kolpin, D.W.,and Gillion, R.J., 1999, *Distribution of Major Herbicides in Ground Water of the United States*, USGS Water-Resources Investigations Report 98-4245, www.usgs.gov.

**Table 10E.159 Nitrate Concentrations in United States Groundwater by Land Use**

| Land Use Type | Median Concentration (mg/L) | Median Concentrations Exceeding Drinking-Water MCL (percent) |
|---|---|---|
| Forest land | 0.1 | 3.0 |
| Range land | 1.5 | 8.5 |
| Agricultural land | 3.4 | 21.1 |
| Urban land | 1.9 | 7.0 |

*Note:* Maximum contaminant level for drinking water = 10 mg/L

*Source*: From United States Department of Agriculture Natural Resources Conservation Services, 1997, *Water Quality and Agriculture, Status, Conditions, and Trends*, www.nrcs.usda.gov.

*Original Source*: From Mueller et al., 1995.

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**Table 10E.160 Summary of Nitrate Concentrations in Groundwater Below Agricultural Land, by Region**

| Region[a,b] | Median Nitrate Concentration (mg/L) | Samples with Concentrations >3 mg/L[c] (percent) | Samples with Concentrations > 10 mg/L[d] (percent) |
|---|---|---|---|
| Northeastern states | 4.3 | 58.2 | 19.6 |
| Appalachian and Southeastern states | 0.2 | 16.3 | 2.0 |
| Corn Belt states | 0.2 | 22.6 | 1.5 |
| Lake states | 0.1 | 25.5 | 14.6 |
| Northern Plains states | 6.0 | 60.6 | 35.2 |
| Southern Plains states | | (numbers requested) | |
| Mountain states | 0.7 | 24.9 | 8.1 |
| Pacific states | 5.5 | 75.0 | 26.9 |

[a] Only includes wells less than 100 ft below the earth's surface.
[b] Only 17 of the 20 study units fit easily into the regional classification. Regions are based on R.F. Spalding and Exner, 1991. *Nitrate contamination in the contiguous United States.* Berlin, Springer-Verlag, NATO ASI Series, vol. G 30, P. 12–48. The eight regions correspond to the 10 USDA Farm Production Regions, except that three USDA regions (Delta, Appalachian, and Southeast) are combined.
[c] May indicate elevated concentration resulting from human activities.
[d] Maximum contaminate level for drinking water.

*Source*: From United States Department of Agriculture Natural Resources Conservation Services, 1997, *Water Quality and Agriculture, Status, Conditions, and Trends*, www.nrcs.usda.gov.

*Original Source*: From Mueller et al., 1995.

**Table 10E.161 Median Concentrations of Nutrients in Samples from NAWQA Groundwater Studies, and Median Depth to Groundwater and to Sampled Zone within Aquifer**

| Water-Quality Variable or Well Parameter | MDL[a] (mg/L) | Agric. Land Use | Urban Land Use | Major Aquifer |
|---|---|---|---|---|
| Ammonia as N (mg/L) | 0.01, 0.015[b] | 0.02 | 0.03 | 0.02 |
| Nitrite as N (mg/L) | 0.01 | <0.01 | <0.01 | <0.01 |
| Ammonia-plus-organic nitrogen as N (mg/L) | 0.20 | <0.2 | <0.2 | <0.2 |
| Nitrite-plus-nitrate as N (mg/L) | 0.05 | 3.4 | 1.6 | 0.48 |
| Orthophosphate as P (mg/L) | 0.01 | 0.01 | 0.02 | 0.01 |
| Depth to groundwater (m) | — | 5.1 | 3.3 | 6.8 |
| Depth of top of open interval below water level (m) | — | 3.5 | 1.7 | 6.8 |

[a] Method detection limit.
[b] Ammonia method has two detection limits.

*Source*: From Nolan, B.T. and Stoner, J.D., Nutrients in ground waters of the conterminous United States, 1992–1995, *Environmental Science and Technology*, vol. 34, no. 7, 2000, p. 1156–1165.

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**Table 10E.162 The Largest Rivers in the World by Mean Annual Discharge with Their Loads**

| River | Basin Area ($km^2$) | Mean Annual Discharge ($m^3/s$) | Maximum Discharge ($m^3/s$) | Maximum Discharge ($m^3/s$) | Runoff (mm/yr) | Volume ($km^3$) | Suspended Solids (million tons/yr) | Dissolved Solids (million tons/yr) |
|---|---|---|---|---|---|---|---|---|
| Amazon (South America) | 4,640.300 | 155,432 | 176,067 | 133,267 | 3,653 | 4,901 | 275 | 1,200 |
| Congo (Central Africa) | 3,475,000 | 40,250 | 54,963 | 32,873 | 1,056 | 1,296 | 41 | 43 |
| Orinoco (Venezuela) | 836,000 | 31,061 | 37,593 | 21,540 | 1,172 | 980 | 32 | 150 |
| Yangtze (China) | 1,705,383 | 25,032 | 28,882 | 21,377 | 463 | 789 | 247 | 478 |
| Brahmaputra (India) | 636,130 | 19,674 | 21,753 | 18,147 | 975 | 620 | 61 | 540 |
| Yenisei (Russian Federation) | 2,440,000 | 17,847 | 20,966 | 15,543 | 231 | 563 | 68 | 13 |
| Lean (Russian Federation) | 2,430,000 | 16,622 | 19,978 | 13,234 | 216 | 524 | 49 | 18 |
| Parana (Argentina) | 1,950,000 | 16,595 | 54,500 | 4,092 | 265 | 516 | | |
| Mississippi (United States) | 3,923,799 | 14,703 | 20,420 | 10,202 | 118 | 464 | 125 | 210 |
| Ob (Russian Federation) | 2,949,998 | 12,504 | 17,812 | 8,791 | 134 | 394 | | |

*Note:* The world's largest river, the Amazon, contributes by itself some 16 percent of the global total annual stream water flow, and the Amazon and the other four largest river system (Congo, Orinoco, Yangtze, Brahmaputra) combined account for 27 percent.

*Source*: From *Water for People Water for Life*, The United Nations World Water Development, Copyright © United Nations Educational, Scientific, and Cultural Organization (UNESCO) - World Water Assessment Programme (UNESCO-WWAP), 2003. Reproduced by permission of UNESCO. www.unesco.org.

*Original Source*: From GRDC, 1996, Berner and Berner, 1987.

**Table 10E.163 Comparison of Phosphorus and Nitrogen Loading to Canadian Surface and Groundwaters from Various Sources, 1996**

| Nutrient Source | Nitrogen ($10^3$ t/yr) | Phosphorus ($10^3$ t/yr) |
|---|---|---|
| Municipality | | |
| Municipal wastewater treatment plants | 80.3 | 5.6 |
| Sewers | 11.8 | 2.3 |
| Septic systems | 15.4 | 1.9 |
| Industry[a] | 11.8 | 2.0 |
| Agriculture[b] (residual in the field after crop harvest) | 293 | 55 |
| Aquaculture | 2.3 | 0.5 |
| Atmospheric deposition to water | 182 ($NO_3-$ and $NH_4+$ only) | N/A |

[a] Industrial N loads are based on $NO_3 + NH_3$ and are thus DIN not TN; industrial loads do not include New Brunswick, Prince Edward Island or Nova Scotia. Quebec data are only for industries discharging to the St. Lawrence River.

[b] Agricultural residual is the difference between the amount of N or P available to the growing crop and the amount removed in the harvested crop; data are not available as to the portion of this residual that moves to surface or groundwaters.

*Source*: From *Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada*, page 24, Environment Canada, 2001. Reproduced with permission from the National Water Research Institute, Environment Canada, 2006.

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**Table 10E.164 Aspects of Water Quality of Some Alberta Canada Surface Waters**

| Water Body | Intensity of Farming | Nutrient | No. of Samples | Share That Exceeded Provincial Guidelines for Aquatic life[a] (%) |
|---|---|---|---|---|
| Streams (1995–1996) | High | Total nitrogen | 214 | 87 |
| | | Total phosphorus | 220 | 99 |
| | | Ammonia | 70 | 0 |
| | Moderate | Total nitrogen | 343 | 65 |
| | | Total phosphorus | 341 | 88 |
| | | Ammonia | 126 | 0 |
| | Low | Total nitrogen | 163 | 32 |
| | | Total phosphorus | 164 | 89 |
| | | Ammonia | 162 | 0 |
| Lakes (1995–1996) | High | Total phosphorus | 69 | 96 |
| | Low | Total phosphorus | 23 | 38 |
| Irrigation canals (1977–1996) | | Total phosphorus | | |
| Supply source | | | 183 | 16 |
| Return flow | | | 1,034 | 61 |

[a] The limits for aquatic life are the Alberta Environment Protection guidelines of 1 mg/L total nitrogen, 0.05 mg/L total phosphorous, and the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* maximum acceptable concentration of 1.13–1.81 mg/L ammonia-nitrogen (depending on temperature and pH).

*Source*: From *The Health of Our Water, Toward Sustainable Agriculture in Canada*, Publication 2020/E, Coote, D.R. and Gregorich, L.J., (eds.), Research Branch Agriculture and Agri-Food Canada, 2000.

*Original Source*: Canadian-Alberta Environmentally Sustainable Agriculture Water Quality Committee. 1998. Agricultural Impacts on Water Quality in Alberta: An Initial Assessment. CAESA Agreement. Lethbridge, Alta. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2006.

**Table 10E.165 Average Nitrogen Surplus for Selected OECD Countries (Kilograms Per Hectare Per Year)**

| Country | 1985–1987 | 1995–1997 | Percent Change |
|---|---|---|---|
| Canada | 7 | 14 | 113 |
| Denmark | 154 | 119 | −23 |
| France | 59 | 53 | −10 |
| Japan | 98 | 89 | −9 |
| New Zealand | 5 | 6 | 27 |
| Untied States | 25 | 31 | 24 |

*Source*: From *The Health of Our Water, Toward Sustainable Agriculture in Canada*, Pubiication 2020/E, Coote, D.R. and Gregorich, L.J., (eds.), Research Branch Agriculture and Agri-Food Canada, 2000.

*Original Source*: From McRae, T., Smith, C.A.S., and Gregorich, L.J., (eds.), 2000. Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Project. Agriculture and Agri-Food Canada, Ottawa, Ont. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2006.

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**Table 10E.166 Total Nutrient Emission for Selected Coastal Regions of Australia (1,000 kg)**

| | | Phosphorus | | Nitrogen | |
|---|---|---|---|---|---|
| **Coastal Region** | **Land Use** | **Point[a]** | **Diffuse[b]** | **Point[a]** | **Diffuse[b]** |
| Peel-Harvey (WA) | Agriculture | na | 260 | na | 1,800 |
| Esk/Tamar (Tas) | Agriculture | 150 | 360 | 390 | 1,600 |
| Dawson River (Qld) | Agriculture | 20 | 1,700 | 28 | 6,400 |
| Latrobe-Thomson (Vic) | Agriculture | 18 | 410 | 44 | 3,800 |
| Richmond River (NSW) | Agriculture | 5.8 | 250 | na | 1,700 |
| Darwin Harbour (NT) | Mix | 68 | 47 | 270 | 590 |
| South-east Queensland (Qld) | Mix | 1,300 | 1,500 | 3,300 | 7,000 |
| Water Catchment Adelaide (SA) | Urban/Industrial | 210 | 64 | 920 | 550 |
| Port Philip Bay (Vic) | Urban/Industrial | 2,500 | 190 | 8,500 | 2,300 |
| Botany Bay (NSW) | Urban/Industrial | 1,300 | 48 | 7,600 | 280 |
| Lake Illawarra (NSW) | Urban/Industrial | 190 | 25 | 970 | 170 |

*Note:* na, none reported.

[a] Emissions of Total Phosphorus and nitrogen from Reporting Facilities 1990–2000.

[b] Emissions of Total Phosphorus and Nitrogen to Water from Aggregate Sources 1999–2000. Diffuse source pollution represents aggregated data for which there may be significant error of estimation, ranging up to +/−50% for data for WA and 3–13 times for diffuse source estimates in Tasmania. There are significant qualifications to the National Pollutant Inventory estimates and information on the website should be consulted before quoting and/or interpreting these figures.

*Source*: From Australian State of the Environment Committee, 2001, *Coasts and Oceans, Australia State of Environment Report 2001* (Theme Report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra, www.deh.gov.au. With permission.

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**Table 10E.167 Annual Estimates (Tons) of Total United Kingdom Inputs (Direct Plus Riverine) of Pesticides from Great Britain to Marine Waters**

| | 1991 | | 1992 | | 1993 | | 1994 | | 1995 | | 1996 | | 1997 | | 1998 | | 1999 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| Atrazine | 7.36 | 9.11 | 4.41 | 11.65 | 2.33 | 7.68 | 0.85 | 1.28 | 0.41 | 1.20 | 0.45 | 1.01 | 0.53 | 1.14 | 0.39 | 1.64 | 0.45 | 1.69 |
| Azinphos-ethyl | 0.00 | 0.79 | 0.00 | 0.78 | 0.00 | 0.89 | 0.00 | 0.36 | 0.00 | 0.49 | 0.00 | 0.32 | 0.00 | 0.36 | 0.00 | 0.58 | 0.05 | 0.50 |
| Azinphos-methyl | 0.00 | 0.77 | 0.00 | 0.89 | 0.08 | 1.70 | 0.09 | 0.74 | 0.00 | 0.74 | 0.03 | 0.47 | 0.01 | 0.44 | 0.00 | 0.70 | 0.00 | 1.03 |
| DDT | 0.00 | 0.31 | 0.03 | 0.15 | 0.01 | 0.26 | 0.00 | 0.21 | 0.00 | 0.18 | 0.00 | 0.10 | 0.01 | 0.13 | 0.01 | 0.15 | 0.00 | 0.29 |
| Dichlorvos | 0.00 | 1.55 | 0.12 | 0.18 | 0.31 | 0.35 | 0.32 | 0.36 | 0.32 | 0.38 | 0.19 | 0.25 | 0.22 | 0.26 | 0.37 | 0.40 | 0.54 | 0.56 |
| Drins | 0.01 | 0.95 | 0.02 | 0.50 | 0.03 | 0.68 | 0.02 | 0.73 | 0.00 | 0.58 | 0.05 | 0.34 | 0.00 | 0.36 | 0.01 | 0.63 | 0.00 | 0.82 |
| Endosulphan | 0.04 | 0.37 | 0.09 | 0.36 | 0.01 | 0.27 | 0.00 | 0.35 | 0.00 | 0.21 | 0.00 | 0.14 | 0.07 | 0.16 | 0.00 | 0.26 | 0.01 | 0.45 |
| Fenitrothion | 0.04 | 0.80 | 0.00 | 0.40 | 0.05 | 0.89 | 0.01 | 0.45 | 0.00 | 0.59 | 0.00 | 0.29 | 0.01 | 0.33 | 0.01 | 0.59 | 0.00 | 0.63 |
| Fenthion | 0.01 | 0.36 | 0.06 | 0.38 | 0.00 | 0.47 | 0.00 | 0.31 | 0.00 | 0.42 | 0.00 | 0.25 | 0.01 | 0.33 | 0.00 | 0.55 | 0.00 | 0.45 |
| Lindane (gHCH) | 0.61 | 0.91 | 0.37 | 0.69 | 0.48 | 0.73 | 0.36 | 0.64 | 0.36 | 0.63 | 0.26 | 0.37 | 0.29 | 0.42 | 0.21 | 0.59 | 0.15 | 0.49 |
| Malathion | 0.01 | 0.93 | 0.01 | 1.20 | 0.00 | 0.93 | 0.00 | 0.45 | 0.00 | 0.51 | 0.01 | 0.25 | 0.15 | 0.41 | 0.25 | 0.77 | 0.01 | 0.57 |
| Parathion | 0.01 | 0.47 | 0.01 | 1.24 | 0.00 | 0.67 | 0.00 | 0.41 | 0.00 | 0.34 | 0.00 | 0.33 | 0.00 | 0.23 | 0.00 | 0.44 | 0.00 | 0.35 |
| Parathion-methyl | 0.00 | 0.36 | 0.04 | 1.46 | 0.00 | 1.05 | 0.00 | 0.45 | 0.00 | 0.52 | .00 | 0.17 | 0.00 | 0.12 | 0.00 | 0.29 | 0.00 | 0.34 |
| Simazine | 3.03 | 5.86 | 2.67 | 10.42 | 1.86 | 6.76 | 1.16 | 1.59 | 0.67 | 1.32 | 0.53 | 1.06 | 0.46 | 1.01 | 0.84 | 1.84 | 1.18 | 2.17 |
| Trifluralin | 0.01 | 0.37 | 0.01 | 0.14 | 0.07 | 0.33 | 0.11 | 0.33 | 0.02 | 0.35 | 0.00 | 0.20 | 0.07 | 0.23 | 0.03 | 0.38 | 0.05 | 0.56 |
| Triphenyltin | 0.03 | 0.03 | 0.00 | 0.01 | 0.00 | 0.06 | 0.02 | 0.09 | 0.02 | 0.12 | 0.02 | 0.23 | 0.00 | 0.23 | 0.01 | 0.47 | 0.04 | 0.25 |
| Flow Rate (Ml/d)[a] | 251,480 | | 289,500 | | 278,620 | | 305,470 | | 261,240 | | 223,270 | | 237,010 | | 314,480 | | 308,810 | |

*Note:* Data abstracted from UK submission of input estimates fro Annex 1a List substances to the fifth North Sea Conference.

[a] The flow rates are those provide in the OSPAR RID data report for 2000.

*Source*: From Department of Environment, Food and Rural Affairs, 2002, *The Government's Strategic Review of Diffuse Water Pollution from Agriculture in England: Agriculture and Water: A Diffuse Pollution Review*. www.defra.gov.uk. Reproduced under the terms of the Click-Use Licence.



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**Table 10E.168 Apparent Consumption of Commercial Fertilizers World 1980–2000**

1,000 tons

| | 1980 | 1985 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | 1,939 | 2,325 | 2,074 | 2,173 | 2,261 | 2,359 | 2,395 | 2,568 | 2,696 | 2,726 | 2,649 | 2,689 | 2,477 |
| Mexico | 1,238 | 1,764 | 1,798 | 1,619 | 1,616 | 1,592 | 1,648 | 1,286 | 1,636 | 1,644 | 1,804 | 1,776 | 1,832 |
| USA | 21,480 | 17,831 | 18,587 | 18,784 | 18,991 | 20,350 | 19,297 | 20,038 | 20,310 | 20,165 | 19,774 | 19,563 | 18,507 |
| Japan | 1,816 | 2,024 | 1,838 | 1,752 | 1,784 | 1,817 | 1,764 | 1,641 | 1,563 | 1,510 | 1,419 | 1,439 | 1,454 |
| Korea | 803 | 837 | 958 | 928 | 964 | 974 | 960 | 979 | 909 | 992 | 867 | 809 | 782 |
| Australia | 1,162 | 1,155 | 1,164 | 1,285 | 1,418 | 1,512 | 1,726 | 1,867 | 2,016 | 2,184 | 2,250 | 2,341 | 2,301 |
| N. Zealand | 464 | 427 | 343 | 439 | 535 | 626 | 647 | 683 | 660 | 648 | 662 | 713 | 838 |
| Austria | 407 | 388 | 303 | 289 | 267 | 262 | 250 | 237 | 265 | 248 | 247 | 230 | 223 |
| Belgium | 447 | 425 | 384 | 354 | 330 | 321 | 319 | 309 | 314 | 307 | 309 | 304 | 287 |
| Czech R. | 1,091 | 1,088 | 797 | 278 | 290 | 306 | 337 | 348 | 347 | 314 | 300 | 269 | 300 |
| Denmark | 627 | 634 | 633 | 581 | 507 | 483 | 466 | 438 | 449 | 437 | 412 | 380 | 366 |
| Finland | 489 | 498 | 443 | 339 | 345 | 341 | 355 | 341 | 313 | 314 | 309 | 310 | 308 |
| France | 5,609 | 5,695 | 5,683 | 5565 | 4,530 | 4,604 | 4,712 | 4,914 | 5,064 | 4,989 | 4,837 | 4,753 | 4,145 |
| Germany | 5,169 | 4,823 | 3,351 | 2,969 | 2,844 | 2,672 | 2,906 | 2,821 | 2,819 | 2,857 | 2,938 | 3,054 | 2,743 |
| Greece | 527 | 710 | 696 | 652 | 628 | 509 | 527 | 505 | 560 | 504 | 472 | 469 | 458 |
| Hungary | 1,399 | 1,338 | 680 | 326 | 189 | 293 | 314 | 368 | 455 | 427 | 371 | 433 | 472 |
| Iceland | 29 | 25 | 23 | 23 | 20 | 23 | 20 | 20 | 19 | 19 | 19 | 22 | 21 |
| Ireland | 601 | 630 | 692 | 665 | 668 | 716 | 752 | 748 | 682 | 660 | 712 | 671 | 626 |
| Italy | 2,111 | 2,150 | 1,944 | 1,987 | 1,922 | 1,904 | 1,892 | 1,822 | 1,865 | 1,758 | 1,748 | 1,784 | 1,726 |
| Netherlands | 679 | 701 | 561 | 561 | 546 | 519 | 534 | 535 | 527 | 508 | 485 | 477 | 425 |
| Norway | 259 | 234 | 210 | 208 | 206 | 206 | 207 | 210 | 209 | 205 | 201 | 199 | 196 |
| Poland | 3,468 | 3,315 | 2,144 | 1,175 | 1,192 | 1,282 | 1,428 | 1,512 | 1,596 | 1,700 | 1,557 | 1,526 | 1,518 |
| Portugal | 259 | 242 | 278 | 258 | 242 | 250 | 248 | 244 | 258 | 236 | 252 | 239 | 228 |
| Slovak R. | 639 | 646 | 506 | 147 | 100 | 96 | 99 | 108 | 119 | 107 | 120 | 89 | 101 |
| Spain | 1,662 | 1,734 | 1,976 | 1,882 | 1,575 | 1,818 | 1,927 | 1,869 | 2,192 | 2,108 | 2,367 | 2,319 | 2,149 |
| Sweden | 484 | 419 | 328 | 292 | 314 | 329 | 323 | 294 | 311 | 310 | 294 | 290 | 280 |
| Switzerland | 181 | 180 | 168 | 159 | 152 | 151 | 145 | 135 | 125 | 121 | 120 | 102 | 102 |
| Turkey | 1,456 | 1,427 | 1,888 | 1,771 | 1,928 | 2,207 | 1,507 | 1,700 | 1,799 | 1,826 | 2,181 | 2,204 | 2,089 |
| UK | 2,054 | 2,516 | 2,388 | 2,171 | 2,003 | 2,075 | 2,219 | 2,191 | 2,376 | 2,270 | 2,081 | 1,996 | 1,694 |
| Russian Fed. | 7,480 | 9,790 | 9,923 | 7,899 | 5,510 | 3,851 | 1,510 | 1,750 | 1,580 | 1,550 | 1,264 | 1,361 | 1,420 |
| N. America | 24,656 | 21,919 | 22,459 | 22,576 | 22,868 | 24,301 | 23,340 | 23,892 | 24,643 | 24,536 | 24,227 | 24,029 | 22,816 |
| Australia | 1,627 | 1,582 | 1,507 | 1,723 | 1,952 | 2,137 | 2,373 | 2,550 | 2,676 | 2,832 | 2,911 | 3,054 | 3,139 |
| OECD | 29,649 | 29,817 | 26,076 | 22,650 | 20,797 | 21,367 | 21,488 | 21,668 | 22,663 | 22,225 | 22,332 | 22,119 | 20,457 |
| EU | 21,126 | 21,565 | 19,660 | 18,563 | 16,720 | 16,803 | 17,431 | 17,268 | 17,995 | 17,506 | 17,463 | 17,275 | 15,658 |
| OECD | 58,551 | 56,179 | 52,838 | 49,629 | 48,365 | 50,596 | 49,924 | 50,730 | 52,454 | 52,094 | 51,756 | 51,450 | 48,648 |
| World | 116,720 | 129,499 | 137,829 | 134,606 | 125,339 | 120,480 | 122,046 | 129,681 | 134,579 | 137,224 | 138,159 | 140,537 | 136,435 |

*Note:* a), Includes estimates and provisional data, MEX, Fertilizer year: calendar year, U.S.A., Includes data for Puerto rico, KOR, Fertilizer year: calendar year, BEL, Data for Belgium include Luxembourg, CZE, Data before 1986 are Secretariat estimates, DNK, Fertilizer year: August-July, FRA, Data for phosphate and potash refer to the fertilizer year May-April, GRC, Fertilizer year: calendar year, HUN, Fertilizer year: calendar year; ISL, Fertilizer year: calendar year, SLO, Data before 1993 are Secretariat estimates, ESP, Fertilizer year: calendar year, JWE, Fertilizer year: June-May, TUR, Fertilizer year: calendar year, UKD, Fertilizer year: June-May.

*Source*: Table10.5c, *OECD Environmental Data Compendium 2002*, © OECD 2002, www.oecd.org.

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**Table 10E.169 World Fertilizer Consumption by Major Crops**

| | Share (%) in Total | Nutrients, Million Tons | | | p.a. (%) |
|---|---|---|---|---|---|
| | 1997/99 | 1997/99 | 2015 | 2030 | 1997/99–2030 |
| Wheat | 18.4 | 25.3 | 30.4 | 34.9 | 1.0 |
| Rice | 17.3 | 23.8 | 26.5 | 28.1 | 0.5 |
| Maize | 16.3 | 22.5 | 29.0 | 34.5 | 1.3 |
| Fodder | 6.2 | 8.5 | 9.3 | 10.0 | 0.5 |
| Seed cotton | 3.5 | 4.9 | 6.2 | 7.1 | 1.2 |
| Soybeans | 3.4 | 4.6 | 7.6 | 11.5 | 2.9 |
| Vegetables | 3.3 | 4.6 | 5.3 | 6.1 | 0.9 |
| Sugar cane | 3.2 | 4.4 | 5.5 | 6.6 | 1.3 |
| Fruit | 2.9 | 4.1 | 4.3 | 7.5 | 1.9 |
| Barley | 2.9 | 4.0 | 4.4 | 4.8 | 0.6 |
| Other cereals | 2.9 | 3.9 | 9.2 | 8.3 | 2.3 |
| Potato | 2.0 | 2.7 | 3.3 | 3.8 | 1.1 |
| Rapeseed | 1.5 | 2.1 | 3.5 | 5.1 | 2.8 |
| Sweet potato | 1.3 | 1.8 | 2.0 | 2.1 | 0.5 |
| Sugar beet | 1.0 | 1.4 | 1.6 | 1.7 | 0.6 |
| All cereals | | 79.5 | 99.5 | 110.6 | 1.0 |
| % of total | 57.7 | 57.7 | 64.8 | 58.8 | |
| All crops above | | 118.5 | 148.2 | 172.1 | 1.2 |
| % of total | 86.0 | 86.0 | 89.8 | 91.5 | |
| World total | | 137.7 | 165.1 | 188.0 | 1.0 |

*Note:* Crops with a 1997/99 share of at least 1 percent, ordered according to their 1997/99 share in fertilizer use; p.a., per annum

*Source*: From Food and Agriculture Organization of the United Nations (FAO), World Agriculture: Towards 2015/2030, An FAO Perspective, www.fao.org. Reprinted with permission.

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**Table 10E.170 World Fertilizer Consumption: Past and Projected**

| | Nutrients, Million Tons | | | | | % p.a. | | |
|---|---|---|---|---|---|---|---|---|
| **Total** | **1961/63** | **1979/81** | **1997/99** | **2015** | **2030** | **1961–1999** | **1989–1999** | **1997/99–2030** |
| Sub-Saharan Africa | 0.2 | 0.9 | 1.1 | 1.8 | 2.6 | 5.3 | −1.8 | 2.7 |
| Latin America and the Caribbean | 1.1 | 6.8 | 11.3 | 13.1 | 16.3 | 6.1 | 4.4 | 1.2 |
| Near East/North Africa | 0.5 | 3.5 | 6.1 | 7.5 | 9.1 | 7.3 | 0.8 | 1.3 |
| South Asia | 0.6 | 7.3 | 21.3 | 24.1 | 28.9 | 9.6 | 4.5 | 1.0 |
| excl. India | 0.2 | 1.6 | 4.2 | 5.4 | 6.9 | 9.2 | 4.6 | 1.5 |
| East Asia | 1.7 | 18.2 | 45.0 | 56.9 | 63.0 | 9.3 | 3.8 | 1.1 |
| excl. China | 0.9 | 4.1 | 9.4 | 13.8 | 10.3 | 7.0 | 3.2 | 0.3 |
| All above | 4.1 | 36.7 | 84.8 | 103.5 | 119.9 | 8.5 | 3.7 | 1.1 |
| excl. China | 3.3 | 22.6 | 49.2 | 60.4 | 67.3 | 7.6 | 3.5 | 1.0 |
| excl. China and India | 2.9 | 16.9 | 32.1 | 41.6 | 45.3 | 6.9 | 3.1 | 1.1 |
| Industrial countries | 24.3 | 49.1 | 45.2 | 52.3 | 58.0 | 1.4 | 0.1 | 0.8 |
| Transition countries | 5.6 | 28.4 | 7.6 | 9.3 | 10.1 | 0.7 | −14.9 | 0.9 |
| World | 34.1 | 114.2 | 137.7 | 165.1 | 188.0 | 3.6 | 0.2 | 1.0 |
| **Per Hectare** | **kg/ha (Arable Land)** | | | | | **% p.a** | | |
| Sub-Saharan Africa | 1 | 7 | 5 | 7 | 9 | 4.5 | −2.4 | 1.9 |
| Latin America and the Caribbean | 11 | 50 | 56 | 59 | 67 | 6.0 | 0.0 | 0.6 |
| Near East/North Africa | 6 | 38 | 71 | 84 | 99 | 5.7 | 3.9 | 1.0 |
| South Asia | 6 | 36 | 103 | 115 | 134 | 9.5 | 4.5 | 0.8 |
| excl. India | 6 | 48 | 113 | 142 | 178 | 8.8 | 4.3 | 1.4 |
| East Asia | 10 | 100 | 194 | 244 | 266 | 8.3 | 3.6 | 1.0 |
| excl. China | 12 | 50 | 96 | 131 | 92 | 6.1 | 3.3 | −0.1 |
| All above | 6 | 49 | 89 | 102 | 111 | 7.7 | 3.3 | 0.7 |
| excl. China | 6 | 35 | 60 | 68 | 71 | 6.9 | 3.2 | 0.5 |
| excl. China and India | 7 | 35 | 49 | 58 | 58 | 6.0 | 2.6 | 0.5 |
| Industrial countries | 64 | 124 | 117 | | | 1.3 | 0.3 | |
| Transition countries | 19 | 101 | 29 | | | 0.9 | −14.4 | |
| World | 25 | 80 | 92 | | | 3.3 | 0.1 | |

*Note:* Kg/ha for 1997/99 are for developing countries calculated on the basis of "adjusted" arable land data. For industrial and transition countries no projections of arable land were made; p.a., per annum.

*Source*: From Food and Agriculture Organization of the United Nations (FAO), *World Agriculture: Towards 2015/2030, An FAO Perspective*, www.fao.org. Reprinted with permission.

**Table 10E.171 World Fertilizer Production and Consumption**

| | Production (Million MT) | | | Consumption (Million MT) | | |
|---|---|---|---|---|---|---|
| **Fertilizer** | **1980/1981** | **1990/1991** | **2001/2002** | **1980/1981** | **1990/1991** | **2001/2002** |
| Nitrogen | 63 | 82 | 86 | 61 | 77 | 82 |
| Phosphate | 35 | 39 | 34 | 32 | 36 | 33 |
| Potash | 27 | 27 | 26 | 24 | 25 | 23 |
| **Total** | 125 | 148 | 146 | 117 | 138 | 138 |

*Source*: From Food and Agriculture Organization of the United Nations (FAO) 2003, *Summary of Food and Agricultural Statistics*, www.fao.org. Reprinted with permission.

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**Table 10E.172 Leading Fertilizer Producing and Consuming Countries**

| Producers | 2001/2002 Production (Million MT) | 2001/2002 % of World Production | Consumers | 2001/2002 Consumption (Million MT) | 2001/2002 % Word of Consumption |
|---|---|---|---|---|---|
| China | 30 | 21 | China | 35 | 25 |
| United States of America | 19 | 13 | United States of America | 20 | 14 |
| India | 15 | 10 | India | 17 | 12 |
| Russian Federation | 12 | 8 | Brazil | 7 | 5 |
| Canada | 12 | 8 | France | 4 | 3 |
| Rest of the Word | 58 | 40 | Rest of the World | 55 | 41 |

*Source*: From Food and Agriculture Organization of the United Nations (FAO), 2003, Summary of Food and Agricultural Statistics, www.fao.org. Reprinted with permission.

**Table 10E.173 Canadian Agricultural Pesticide Expenditures and Application Rates by Ecozone, 1970 and 1995**

| Ecozone[a] | Total Agricultural Pesticide Expenditures 1970 1990 Dollars | 1995 1990 Dollars | Change 1970–1995 Percent | Agricultural Pesticide Applied per km$^2$ of Cultivated Land 1970 1990 Dollars | 1995 1990 Dollars | Change 1970–1995 Percent |
|---|---|---|---|---|---|---|
| Boreal Shield | 2,607,889 | 7,660,443 | 193.7 | 298 | 1,098 | 268.4 |
| Atlantic Maritime | 13,100,429 | 33,109,343 | 152.7 | 1,080 | 3,545 | 228.3 |
| Mixed Wood Plains | 88,433,803 | 211,800,054 | 139.5 | 1,692 | 4,408 | 160.5 |
| Boreal Plains | 12,700,961 | 130,895,084 | 930.6 | 174 | 1,512 | 768.6 |
| Prairie | 47,033,763 | 540,946,447 | 1,050.1 | 169 | 1,807 | 966.3 |
| Montane Cordillera | 5,639,076 | 8,236,737 | 46.1 | 2,190 | 6,581 | 200.5 |
| Pacific Maritime | 3,489,107 | 8,639,126 | 147.6 | 2,076 | 2,290 | 10.3 |
| Canada | 173,005,028 | 941,287,234 | 444.1 | 404 | 2,067 | 411.3 |

*Note:* Figures may not add up to totals due to rounding. Farm input price indices were used to obtain 1990 constant dollar expenditures.

[a] Limited to those with agricultural activity.

*Source*: From Statistics Canada, Human Activity and the Environment Annual Statistics 2003, Catalogue 16-201-XPE, released December 3, 2003, page 20. *Statistics Canada information is used with the permission of Statistics Canada. Users are forbidden to copy this material and/or redisseminate the data, in an original or modified form, for commercial purposes, without the expressed permission of Statistics Canada. Information on the availability of the wide range of data from Statistics Canada can be obtained from Statistics Canada's Regional Offices, its World Wide Web site at www.statcan.ca, and its toll-free access number 1-800-263-1136.*

**Table 10E.174 World Production of Pesticides (Insecticides, Fungicides, Disinfectants, etc.)**

| Country | 1990 (Thousand MT) | 1995 | 1999 | Country | 1990 (Thousand MT) | 1995 | 1999 |
|---|---|---|---|---|---|---|---|
| **Total** | **2,318** | **2,045** | **2,254** | **Europe** | **1,377** | **1,051** | **1,006** |
| | | | | Albania | 9 | 0 | 0 |
| **Africa** | **60** | **75** | **85** | Austria | 17 | 12 | 12 |
| Algeria | 8 | — | — | Belgium[a] | 100 | 3 | 6 |
| Burundi | 4 | — | — | Bulgaria | 10 | 8 | 8 |
| Egypt | 21 | 25 | — | Croatia | — | 7 | — |
| Kenya | 3 | 1 | — | Czech Republic | — | 22 | 19 |
| South Africa[b] | 23 | 36 | — | Czechoslovakia (former) | 17 | — | — |
| Tanzania United Rep | 1 | — | — | Denmark[c] | — | 18 | 19 |
| **North America** | **127** | **169** | **228** | Finland | 14 | 14 | 4 |
| Mexico | 127 | 169 | 228 | France | 326 | — | — |
| **South America** | **88** | **85** | **88** | Germany[d] | 342 | 128 | — |
| Brazil | 64 | — | — | Greece[e] | 7 | 11 | — |
| Colombia | — | 21 | — | Hungary | 56 | 19 | 15 |
| Ecuador | — | 2 | — | Lithuania | — | 1 | 0 |
| **Asia** | **461** | **665** | **847** | Poland | 20 | 24 | 30 |
| China | 228 | 417 | 625 | Portugal | 25 | 15 | 21 |

*(Continued)*

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**Table 10E.174 (Continued)**

| Country | 1990 | 1995 (Thousand MT) | 1999 | Country | 1990 | 1995 (Thousand MT) | 1999 |
|---|---|---|---|---|---|---|---|
| Cyprus | — | 0 | — | Romania | 24 | 15 | 4 |
| Indonesia | 19 | 18 | — | Russian Federation | — | 16 | 10 |
| Korea, Rep. of | 182 | 166 | 173 | Serbia and Montenegro | — | 7 | 6 |
| Turkey | 23 | 32 | 26 | Slovakia | — | — | 3 |
| Uzbekistan | — | 15 | — | Slovenia | — | 6 | 1 |
| Vietnam[f] | 9 | 16 | 19 | Spain[g] | 83 | 91 | 99 |
| **USSR (former)** | 205 | | | Sweden | — | 9 | 2 |
| | | | | T.F.Yug.Rep. Macedonia | — | 0 | 0 |
| | | | | Ukraine | — | 4 | 2 |
| | | | | United Kingdom | — | 306.9 | — |

*Note:* Global and regional totals refer to the countries shown only and include estimates for mission data.

[a] Incomplete coverage.
[b] Excluding products usually measured in units of volume.
[c] Sales.
[d] Excluding disinfectants.
[e] Insecticides for household use in 1990.
[f] Insecticides only.
[g] Including insecticides for household use in 1990.

*Source*: From Food and Agriculture Organization of the United Nations (FAO), 2003, Summary of Food and Agricultural Statistics, www.fao.org. Reprinted with permission.

**Table 10E.175 World Consumption of Pesticides[a]**

| | Tons (Active Ingredients) | | | | | |
|---|---|---|---|---|---|---|
| | Year | Total Pesticides | Insecticides | Fungicides | Herbicdies | Other Pesticides |
| Canada | 1994 | 29,206 | 3,426 | 3,780 | 21,910 | 90 |
| Mexico | 1993 | 36,000 | — | — | — | — |
| USA | 1997 | 353,802 | 41,730 | 24,040 | 213,188 | 74,843 |
| Japan | 1993 | 645,000 | — | — | — | — |
| Korea | 1997 | 24,814 | 9,161 | 7,332 | 6,043 | 2,278 |
| Australia | 1999 | 34,200 | 8,700 | 3,000 | 22,000 | 500 |
| N.Zealand | 1998 | 3,368 | 718 | 702 | 1,847 | 102 |
| Austria | 2000 | 3,563 | 334 | 1,598 | 1,609 | 22 |
| Belgium | 2000 | 9,973 | 918 | 3057 | 5,217 | 373 |
| Czech Rep. | 2000 | 4,303 | 158 | 1,007 | 2,599 | 539 |
| Denmark | 2000 | 2,841 | 41 | 614 | 1,982 | 204 |
| Finland | 2000 | 1,150 | 55 | 178 | 862 | 55 |
| France | 2000 | 94,693 | 3103 | 52,834 | 30,845 | 7,911 |
| Germany | 2000 | 31,850 | 2,357 | 9,641 | 16,610 | 3,242 |
| Greece | 1998 | 11,479 | 2,505 | 4,731 | 2,303 | 1,940 |
| Hungary | 2000 | 5,472 | 771 | 1,590 | 2,682 | 429 |
| Icland | 2000 | 4 | 1 | 0 | 3 | 0 |
| Ireland | 1997 | 2,325 | 73 | 679 | 1,261 | 312 |
| Italy | 1996 | 48,050 | 8,992 | 25,074 | 9,888 | 4,096 |
| Luxembourg | 1999 | 421 | 19 | 186 | 198 | 18 |
| The Netherlands | 2000 | 9,644 | 1,008 | 4,460 | 2,605 | 1,571 |
| Norway | 2000 | 380 | 11 | 53 | 283 | 33 |
| Poland | 2001 | 8,855 | 549 | 2,815 | 4,748 | 743 |
| Portugal | 1998 | 14,382 | 1,079 | 10,475 | 1,914 | 914 |
| Slovak Rep. | 2001 | 3,444 | 178 | 537 | 2,144 | 585 |
| Spain | 1998 | 35,070 | 10,173 | 11,984 | 9,413 | 3,500 |

*(Continued)*

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**Table 10E.175 (Continued)**

| | Tons (Active Ingredients) | | | | | |
|---|---|---|---|---|---|---|
| | Year | Total Pesticides | Insecticides | Fungicides | Herbicdies | Other Pesticides |
| Sweden | 1998 | 1,629 | 27 | 300 | 1,269 | 33 |
| Switzerland | 1999 | 1,528 | 188 | 708 | 613 | 19 |
| Turkey | 1995 | 33,243 | 14,850 | 4,937 | 7,583 | 5,873 |
| UK | 2000 | 32,989 | 667 | 5,282 | 22,702 | 4,339 |
| Russian Fed. | 1997 | 25,961 | 1,686 | 12,110 | 12,152 | 13 |

*Note:* CAN, Data refer to agriculture uses only. Insecticides: data exclude Bacillus thuringiensis. Other pesticides; include growth regulators, animal repellents, rodenticides and fumigants; USA, Agricultural pesticides only. Other pesticides include fumigants, nematocides, rodenticides, molluscicides, insect regulators and other pesticides; JPN, Data refer to national production of pesticides; NZL, Data refer to use in agriculture; AUT, Data refer to sales; BEL, Data refer to sales; CZE, Data refer to agricultural pesticides and sales of chemical pesticides. Other pesticides: include growth regulators, rodenticides, animal repellents, additives, adhesives and other pesticides; DNK, Data refer to sales for use in plant production in open agriculture; FIN, Data refer to sales: other pesticides include growth regulators and forest pesticides; FRA, Data refer to quantities sold to agriculture. Fungicides: include copper and sulphur compounds but not elemental sulphur; DEU, Data refer to sales; GRC, Data refer to sales; IRL, Data based on pesticide imports, which gives a reasonable estimation of the quantities used as the country imports most of its pesticides; NLD, Data refer to sales of chemical pesticides; Other pesticides: include soil disinfectants which correspond, for the years presented, about the half of the total consumption; NOR, Data refer to sales to the agricultural sector; POL, Other pesticides: include growth regulators, rodenticides, animal repellents and other pesticides; PRT, Data refer to sales; ESP, Data refer to sales. Data is provisional; SWE, Data refer to sales; CHE, Data refer to sales and have been estimated to represent 95 percent of the total market volume; Liechtenstein included; TUR, Formulation weight. Powdered sulphur and copper sulphate excluded; UKD, Great Britain only. Insecticides: include acarides, insecticides nematocides and tar oil/acid. Fungicides: include fungicides and sulfur; Herbicides; include herbicides and dessicants.

[a] Unless otherwise specified, data refer to active ingredients. Insecticides: acaricides, molluscicides, nematocides, and mineral oils. Fungicides: bactericides and seed treatments. Herbicides; defoliants and dessicants. Other pesticides: plant growth regulators and rodenticides.

*Source*: Table 10.6a, *OECD Environmental Data Compendium 2002*, © OECD 2002, www.oecd.org.

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**Table 10E.176 Trends in the Consumption of Pesticides in the World[a], 1980–2000**

| | | Tons | | Index 1985 = 100[a] | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Base Year | | 1980 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| Canada | Insecticides | 3,172 | | — | 100 | 90 | 94 | 86 | — | 57 | — | — | — | 108 | — | — | — | — | — | — |
| | Fungicides | 2,823 | | — | 100 | 120 | 97 | 92 | — | 90 | — | — | — | 134 | — | — | — | — | — | — |
| | Herbicides | 30,181 | | — | 100 | 82 | 83 | 92 | — | 90 | — | — | — | 73 | — | — | — | — | — | — |
| | Other | 3,083 | | — | 100 | 66 | 99 | 79 | — | 82 | — | — | — | 3 | — | — | — | — | — | — |
| | Total pesticides | 39,259 | | — | 100 | 84 | 86 | 90 | — | 87 | — | — | — | 74 | — | — | — | — | — | — |
| Mexico | Insecticides | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Fungicides | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Herbicides | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Other | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Total pesticides | 36,000 | (1993) | — | — | — | — | — | — | — | — | — | 100 | — | — | — | — | — | — | — |
| U.S.A. | Insecticides | 58,513 | | 126 | 100 | 98 | 94 | 70 | 74 | 70 | 66 | 70 | 62 | 70 | 71 | 65 | 71 | — | — | — |
| | Fungicides | 26,762 | | 100 | 100 | 100 | 88 | 92 | 92 | 85 | 80 | 76 | 80 | 81 | 83 | 86 | 90 | — | — | — |
| | Herbicides | 227,250 | | 101 | 100 | 96 | 85 | 90 | 92 | 91 | 88 | 90 | 85 | 97 | 92 | 96 | 94 | — | — | — |
| | Other | 42,638 | | 106 | 100 | 100 | 97 | 101 | 120 | 141 | 153 | 160 | 164 | 173 | 181 | 202 | 176 | — | — | — |
| | Total pesticides | 355,163 | | 105 | 100 | 97 | 88 | 88 | 92 | 93 | 91 | 94 | 90 | 100 | 98 | 103 | 100 | — | — | — |
| Japan | Insecticides | 45,018 | | 100 | 100 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Fungicides | 18,622 | | 103 | 100 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Herbicides | 19,416 | | 133 | 100 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Other | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Total pesticides | 83,056 | | 108 | 100 | 95 | 92 | 84 | 83 | 82 | 79 | 78 | 78 | — | — | — | — | — | — | — |
| Korea | Insecticides | 7,834 | (1986) | — | — | 100 | 103 | 93 | 101 | 119 | 134 | 126 | 98 | 102 | 114 | 107 | 117 | — | — | — |
| | Fungicides | 7,054 | (1986) | — | — | 100 | 119 | 115 | 114 | 110 | 120 | 120 | 144 | 143 | 112 | 100 | 104 | — | — | — |
| | Herbicides | 4,454 | (1986) | — | — | 100 | 105 | 103 | 110 | 124 | 126 | 121 | 118 | 124 | 131 | 134 | 136 | — | — | — |
| | Other | 1,980 | (1986) | — | — | 100 | 107 | 100 | 122 | 124 | 145 | 153 | 149 | 134 | 162 | 157 | 115 | — | — | — |
| | Total pesticides | 21,322 | (1986) | — | — | 100 | 109 | 103 | 109 | 118 | 129 | 125 | 122 | 123 | 121 | 115 | 116 | — | — | — |
| Australia | Insecticides | 7,430 | (1992) | — | — | — | — | — | — | — | — | 100 | — | — | — | — | — | — | 117 | — |
| | Fungicides | 94,193 | (1992) | — | — | — | — | — | — | — | — | 100 | — | — | — | — | — | — | 3 | — |
| | Herbicides | 18,031 | (1992) | — | — | — | — | — | — | — | — | 100 | — | — | — | — | — | — | 122 | — |
| | Other | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Total pesticides | 119,654 | (1992) | — | — | — | — | — | — | — | — | 100 | — | — | — | — | — | — | 29 | — |
| N.Zealand | Insecticides | 473 | (1994) | — | — | — | — | — | — | — | — | — | — | 100 | 109 | 103 | — | 152 | — | — |
| | Fungicides | 910 | (1994) | — | — | — | — | — | — | — | — | — | — | 100 | 102 | 110 | — | 77 | — | — |
| | Herbicides | 2,039 | (1994) | — | — | — | — | — | — | — | — | — | — | 100 | 115 | 92 | — | 91 | — | — |
| | Other | 93 | (1994) | — | — | — | — | — | — | — | — | — | — | 100 | 132 | 135 | — | 109 | — | — |
| | Total pesticides | 3,515 | (1994) | — | 91 | — | 91 | — | — | — | — | — | 99 | 100 | 111 | 100 | — | 96 | — | — |

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| Austria | Insecticides | 428 | | 80 | 100 | 117 | — | — | 117 | 132 | 101 | 111 | 109 | 109 | 86 | 74 | 91 | 58 | 83 | 78 |
| | Fungicides | 2,072 | | 81 | 100 | 117 | — | — | 72 | 81 | 89 | 72 | 76 | 75 | 68 | 82 | 81 | 79 | 67 | 77 |
| | Herbicides | 2,648 | | 83 | 100 | 115 | — | — | 97 | 73 | 82 | 70 | 71 | 58 | 61 | 58 | 60 | 61 | 63 | 61 |
| | Other | 122 | | 88 | 100 | 74 | — | — | 33 | 33 | 37 | 66 | 53 | 36 | 15 | 13 | 9 | 11 | 6 | 18 |
| | Total pesticides | 5,270 | | 82 | 100 | 115 | — | — | 88 | 80 | 85 | 74 | 76 | 69 | 65 | 68 | 70 | 66 | 65 | 68 |
| Belgium | Insecticides | 1,669 | | 94 | 100 | 91 | 82 | 83 | 82 | 77 | 70 | 76 | 67 | 61 | 67 | 71 | 59 | 60 | 58 | 55 |
| | Fungicides | 2,123 | | 51 | 100 | 103 | 105 | 122 | 124 | 129 | 134 | 155 | 131 | 108 | 125 | 113 | 122 | 125 | 141 | 144 |
| | Herbicides | 4,617 | | 99 | 100 | 100 | 105 | 112 | 114 | 113 | 110 | 111 | 121 | 125 | 135 | 129 | 98 | 108 | 97 | 113 |
| | Other | 339 | | 101 | 100 | 128 | 131 | 135 | 169 | 201 | 160 | 104 | 113 | 128 | 154 | 131 | 120 | 130 | 116 | 110 |
| | Total pesticides | 8,748 | | 85 | 100 | 100 | 102 | 109 | 113 | 117 | 114 | 119 | 118 | 113 | 125 | 119 | 102 | 108 | 105 | 114 |
| Czech Rep. | Insecticides | 665 | (1989) | — | — | — | — | — | 100 | 78 | 54 | 49 | 28 | 21 | 17 | 16 | 15 | 19 | 18 | 24 |
| | Fungicides | 1,809 | (1989) | — | — | — | — | — | 100 | 98 | 84 | 58 | 52 | 44 | 54 | 62 | 50 | 49 | 50 | 56 |
| | Herbicides | 7,816 | (1989) | — | — | — | — | — | 100 | 80 | 52 | 40 | 29 | 32 | 32 | 31 | 33 | 34 | 33 | 33 |
| | Other | 927 | (1989) | — | — | — | — | — | 100 | 44 | 44 | 30 | 28 | 24 | 24 | 29 | 36 | 49 | 68 | 58 |
| | Total pesticides | 11,217 | (1989) | — | — | — | — | — | 100 | 80 | 57 | 43 | 32 | 33 | 34 | 35 | 35 | 37 | 37 | 38 |
| Denmark | Insecticides | 262 | | — | 100 | 89 | 60 | 57 | 86 | 99 | 56 | 49 | 41 | 36 | 62 | 14 | 19 | 21 | 18 | 16 |
| | Fungicides | 2,199 | | — | 100 | 76 | 51 | 49 | 58 | 63 | 65 | 61 | 47 | 41 | 48 | 29 | 36 | 35 | 33 | 28 |
| | Herbicides | 4,079 | | — | 100 | 93 | 96 | 92 | 97 | 77 | 70 | 69 | 65 | 66 | 80 | 71 | 67 | 64 | 46 | 49 |
| | Other | 323 | | — | 100 | 111 | 94 | 80 | 102 | 268 | 59 | 87 | 102 | 76 | 96 | 27 | 32 | 54 | 68 | 63 |
| | Total pesticides | 6,863 | | — | 100 | 89 | 80 | 77 | 84 | 82 | 67 | 67 | 60 | 57 | 70 | 53 | 54 | 53 | 42 | 41 |
| Finland | Insecticides | 144 | | 130 | 100 | 97 | 89 | 148 | 136 | 67 | 44 | 64 | 86 | 51 | 40 | 38 | 33 | 32 | 47 | 38 |
| | Fungicides | 110 | | 90 | 100 | 101 | 92 | 131 | 162 | 148 | 133 | 176 | 191 | 190 | 104 | 105 | 140 | 190 | 200 | 162 |
| | Herbicides | 1,566 | | 134 | 100 | 98 | 102 | 91 | 109 | 101 | 88 | 64 | 54 | 59 | 51 | 43 | 47 | 54 | 50 | 55 |
| | Other | 144 | | 120 | 100 | 104 | 111 | 95 | 128 | 138 | 103 | 81 | 58 | 59 | 64 | 60 | 56 | 53 | 44 | 38 |
| | Total pesticides | 1,964 | | 130 | 100 | 98 | 101 | 98 | 115 | 104 | 88 | 72 | 64 | 66 | 54 | 48 | 52 | 60 | 58 | 59 |
| France | Insecticides | 6,258 | | 75 | 100 | 114 | 104 | 106 | 114 | 123 | 113 | 98 | 86 | 73 | 113 | 86 | 97 | 75 | 58 | 50 |
| | Fungicides | 48,569 | | 82 | 100 | 101 | 93 | 102 | 95 | 85 | 114 | 92 | 112 | 102 | 88 | 100 | 132 | 123 | 130 | 109 |
| | Herbicides | 36,320 | | 89 | 100 | 99 | 94 | 99 | 100 | 103 | 93 | 75 | 72 | 82 | 75 | 99 | 92 | 100 | 117 | 85 |
| | Other | 6,880 | | 76 | 100 | 110 | 102 | 97 | 159 | 160 | 103 | 95 | 92 | 82 | 101 | 114 | 89 | 114 | 166 | 115 |
| | Total pesticides | 98,027 | | 84 | 100 | 102 | 95 | 101 | 102 | 100 | 106 | 86 | 94 | 91 | 86 | 100 | 112 | 111 | 123 | 97 |
| Germany | Insecticides | 4,094 | (1992) | — | — | — | — | — | — | — | — | 100 | 106 | 98 | 120 | 93 | 115 | 153 | 150 | 58 |
| | Fungicides | 9,368 | (1992) | — | — | — | — | — | — | — | — | 100 | 82 | 82 | 103 | 111 | 100 | 112 | 104 | 103 |
| | Herbicides | 15,622 | (1992) | — | — | — | — | — | — | — | — | 100 | 81 | 95 | 103 | 106 | 106 | 111 | 101 | 106 |
| | Other | 4,401 | (1992) | — | — | — | — | — | — | — | — | 100 | 97 | 73 | 88 | 99 | 92 | 109 | 85 | 74 |
| | Total pesticides | 33,485 | (1992) | — | — | — | — | — | — | — | — | 100 | 86 | 89 | 103 | 105 | 103 | 116 | 106 | 95 |
| W.Germany | Insecticides | 1,566 | | 149 | 100 | 93 | 86 | 82 | 85 | 97 | — | — | — | — | — | — | — | — | — | — |
| | Fungicides | 8,491 | | 77 | 100 | 102 | 110 | 135 | 127 | 129 | — | — | — | — | — | — | — | — | — | — |

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**Table 10E.176 (Continued)**

| | | Tons | | Index 1985=100[a] | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Base Year | | 1980 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| | Herbicides | 17,390 | | 120 | 100 | 107 | 97 | 99 | 109 | 98 | — | — | — | — | — | — | — | — | — | — |
| | Other | 2,606 | | 122 | 100 | 100 | 91 | 96 | 138 | 141 | — | — | — | — | — | — | — | — | — | — |
| | Total pesticides | 30,053 | | 110 | 100 | 105 | 100 | 108 | 115 | 110 | — | — | — | — | — | — | — | — | — | — |
| Greece | Insecticides | 3,119 | (1986) | — | — | 100 | 88 | 93 | 102 | — | 69 | 73 | 76 | 99 | 81 | 78 | 78 | 80 | — | — |
| | Fungicides | 2,056 | (1986) | — | — | 100 | 94 | 80 | 94 | — | 123 | 133 | 120 | 152 | 149 | 158 | 151 | 230 | — | — |
| | Herbicides | 2,158 | (1986) | — | — | 100 | 85 | 103 | 140 | — | 96 | 99 | 107 | 110 | 99 | 126 | 98 | 107 | — | — |
| | Other | 13 | (1986) | — | — | 100 | 62 | 108 | 92 | — | 8,462 | 10,815 | 11,092 | 10,615 | 6,100 | 11,269 | 10,600 | 14,923 | — | — |
| | Total pesticides | 7,346 | (1986) | — | — | 100 | 89 | 92 | 111 | — | 107 | 117 | 117 | 136 | 116 | 134 | 123 | 156 | — | — |
| Hungary | Insecticides | 5,577 | | 57 | 100 | 131 | 104 | 100 | 132 | 86 | 59 | 38 | 27 | 24 | 19 | 19 | 12 | 16 | 14 | 14 |
| | Fungicides | 9,157 | | 164 | 100 | 104 | 88 | 94 | 119 | 78 | 45 | 35 | 28 | 31 | 23 | 22 | 17 | 21 | 18 | 17 |
| | Herbicides | 10,761 | | 127 | 100 | 97 | 102 | 101 | 135 | 110 | 91 | 67 | 52 | 43 | 35 | 30 | 23 | 27 | 26 | 25 |
| | Other | 821 | | 219 | 100 | 63 | 82 | 106 | 141 | 116 | 78 | 64 | 62 | 91 | 101 | 72 | 69 | 67 | 57 | 52 |
| | Total pesticides | 26,316 | | 128 | 100 | 106 | 97 | 99 | 129 | 94 | 68 | 50 | 39 | 36 | 29 | 26 | 20 | 24 | 22 | 21 |
| Iceland | Insecticides | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Fungicides | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Herbicides | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Other | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | Total pesticides | — | | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Ireland | Insecticides | 40 | (1988) | 461 | — | — | — | 100 | — | 373 | 405 | 360 | — | 275 | 285 | 163 | 183 | 200 | — | — |
| | Fungicides | 544 | (1988) | 39 | — | — | — | 100 | 99 | 85 | 98 | 122 | 119 | 121 | 99 | 97 | 125 | — | — | — |
| | Herbicides | 1,089 | (1988) | 96 | — | — | — | 100 | 103 | 90 | 101 | 92 | 110 | 99 | 125 | 81 | 116 | 130 | — | — |
| | Other | 139 | (1988) | 18 | — | — | — | 100 | — | 109 | 87 | 96 | — | 222 | 178 | 193 | 224 | — | — | — |
| | Total pesticides | 1,812 | (1988) | 81 | — | — | — | 100 | 105 | 96 | 106 | 107 | 120 | 119 | 125 | 96 | 128 | — | — | — |
| Italy | Insecticides | 34,401 | | 95 | 100 | 97 | 96 | 107 | 104 | 101 | 96 | 95 | 98 | 92 | 102 | 98 | 114 | — | — | — |
| | Fungicides | 85,126 | | 187 | 100 | 110 | 135 | 136 | 124 | 125 | 105 | 111 | 111 | 98 | 99 | 97 | 99 | — | — | — |
| | Herbicides | 28,525 | | 78 | 100 | 104 | 110 | 109 | 101 | 94 | 91 | 79 | 86 | 87 | 95 | 101 | 101 | — | — | — |
| | Other | 18,787 | | 90 | 100 | 126 | 111 | 135 | 133 | 134 | 126 | 109 | 99 | 97 | 102 | 102 | 78 | — | — | — |
| | Total pesticides | 166,839 | | 139 | 100 | 108 | 120 | 125 | 117 | 115 | 103 | 102 | 10.3 | 95 | 99 | 99 | 100 | — | — | — |
| Luxembourg | Insecticides | 10 | (1991) | — | — | — | — | — | — | — | 100 | — | 90 | 120 | 120 | 100 | 90 | 110 | 190 | — |
| | Fungicides | 113 | (1991) | — | — | — | — | — | — | — | 100 | — | 142 | 140 | 136 | 160 | 161 | 198 | 165 | — |
| | Herbicides | 121 | (1991) | — | — | — | — | — | — | — | 100 | — | 95 | 115 | 136 | 122 | 100 | 151 | 164 | — |
| | Other | 9 | (1991) | — | — | — | — | — | — | — | 100 | — | 189 | 211 | 300 | 200 | 222 | 133 | 200 | — |
| | Total pesticides | 253 | (1991) | — | — | — | — | — | — | — | 100 | — | 119 | 130 | 141 | 141 | 131 | 170 | 166 | — |

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| The Netherlands | Insecticides | 634 | | — | 100 | 88 | 79 | 236 | 255 | 310 | 280 | 278 | 335 | 288 | 235 | 279 | 204 | 203 | 182 | 159 |
| | Fungicides | 4,363 | | — | 100 | 82 | 93 | 95 | 93 | 95 | 98 | 96 | 92 | 89 | 91 | 83 | 100 | 117 | 105 | 102 |
| | Herbicides | 3,977 | | — | 100 | 95 | 98 | 92 | 84 | 87 | 81 | 75 | 70 | 67 | 77 | 76 | 75 | 73 | 71 | 66 |
| | Other | 12,028 | | — | 100 | 114 | 80 | 74 | 84 | 77 | 66 | 58 | 24 | 23 | 20 | 16 | 15 | 12 | 14 | 13 |
| | Total pesticides | 21,002 | | — | 100 | 103 | 86 | 87 | 91 | 90 | 82 | 76 | 56 | 53 | 52 | 49 | 50 | 51 | 49 | 46 |
| Norway | Insecticides | 39 | | 93 | 100 | 122 | 83 | 98 | 71 | 49 | 48 | 70 | 44 | 57 | 53 | 41 | 50 | 59 | 64 | 28 |
| | Fungicides | 138 | | 69 | 100 | 104 | 80 | 78 | 86 | 111 | 104 | 107 | 130 | 113 | 121 | 101 | 127 | 190 | 158 | 38 |
| | Herbicides | 1,236 | | 97 | 100 | 96 | 86 | 74 | 69 | 78 | 46 | 45 | 41 | 51 | 56 | 41 | 41 | 44 | 36 | 23 |
| | Other | 116 | | 33 | 100 | 116 | 106 | 111 | 26 | 40 | 39 | 38 | 50 | 49 | 47 | 41 | 48 | 107 | 90 | 28 |
| | Total pesticides | 1,529 | | 90 | 100 | 99 | 87 | 78 | 68 | 77 | 50 | 51 | 50 | 56 | 61 | 46 | 49 | 62 | 52 | 25 |
| Poland | Insecticides | 1,305 | (1986) | — | — | 100 | 97 | 97 | 82 | — | 26 | 28 | 31 | 23 | 34 | 33 | 45 | 50 | 31 | 44 |
| | Fungicides | 3,622 | (1986) | — | — | 100 | 147 | 190 | 199 | — | 38 | 54 | 51 | 64 | 63 | 82 | 84 | 80 | 71 | 69 |
| | Herbicides | 9,035 | (1986) | — | — | 100 | 126 | 154 | 131 | — | 33 | 46 | 48 | 47 | 44 | 61 | 57 | 49 | 50 | 53 |
| | Other | 517 | (1986) | — | — | 100 | 101 | 255 | 92 | — | 111 | 51 | 47 | 85 | 59 | 90 | 134 | 143 | 180 | 189 |
| | Total pesticides | 14,479 | (1986) | 64 | 86 | 100 | 127 | 161 | 142 | 52 | 36 | 47 | 47 | 51 | 48 | 65 | 66 | 60 | 58 | 61 |
| Portugal | Insecticides | 763 | (1984) | 90 | — | — | — | — | — | — | 109 | 99 | 102 | 95 | 87 | 95 | 120 | 141 | — | — |
| | Fungicides | 14,021 | (1984) | 148 | — | — | — | — | — | — | 46 | 28 | 48 | 51 | 65 | 70 | 67 | 75 | — | — |
| | Herbicides | 1,074 | (1984) | 104 | — | — | — | — | — | — | 168 | 111 | 122 | 146 | 155 | 147 | 165 | 178 | — | — |
| | Other | 108 | (1984) | 101 | — | — | — | — | — | — | 196 | 221 | 180 | 137 | 382 | 370 | 619 | 846 | — | — |
| | Total pesticides | 15,966 | (1984) | 142 | — | — | — | — | — | — | 59 | 38 | 56 | 60 | 74 | 78 | 80 | 90 | — | — |
| Slovak Rep. | Insecticides | 495 | (1991) | — | — | — | — | — | — | — | 100 | 25 | 56 | 54 | 125 | 45 | 32 | 35 | 28 | 27 |
| | Fungicides | 1,102 | (1991) | — | — | — | — | — | — | — | 100 | 51 | 58 | 51 | 188 | 20 | 46 | 40 | 36 | 43 |
| | Herbicides | 3,115 | (1991) | — | — | — | — | — | — | — | 100 | 57 | 90 | 106 | 107 | 88 | 81 | 75 | 62 | 68 |
| | Other | 191 | (1991) | — | — | — | — | — | — | — | — | — | 100 | 139 | 210 | 363 | 170 | 400 | 248 | 326 |
| | Total pesticides | 4,713 | (1991) | — | — | — | — | — | — | — | 100 | 52 | 83 | 93 | 137 | 83 | 75 | 78 | 63 | 71 |
| Spain | Insecticides | 13,148 | (1986) | — | — | 100 | 121 | 112 | 102 | 70 | 70 | 51 | 45 | 81 | 73 | 74 | 76 | 77 | — | — |
| | Fungicides | 8,464 | (1986) | — | — | 100 | 130 | 152 | 153 | 145 | 137 | 121 | 110 | 122 | 107 | 120 | 133 | 142 | — | — |
| | Herbicides | 10,822 | (1986) | — | — | 100 | 93 | 107 | 106 | 124 | 127 | 111 | 98 | 67 | 58 | 80 | 85 | 87 | — | — |
| | Other | 6,700 | (1986) | — | — | 100 | 106 | 128 | 129 | 70 | 69 | 42 | 54 | 44 | 44 | 70 | 54 | 52 | — | — |
| | Total pesticides | 39,134 | (1986) | — | — | 100 | 113 | 122 | 119 | 101 | 100 | 81 | 75 | 80 | 71 | 85 | 87 | 90 | — | — |
| Sweden | Insecticides | 140 | | 122 | 100 | 108 | 37 | 74 | 28 | 19 | 14 | 21 | 11 | 29 | 12 | 14 | 17 | 19 | — | — |
| | Fungicides | 639 | | 78 | 100 | 156 | 80 | 106 | 78 | 101 | 113 | 81 | 50 | 58 | 31 | 38 | 40 | 47 | — | — |
| | Herbicides | 2,752 | | 136 | 100 | 152 | 64 | 73 | 67 | 59 | 38 | 34 | 40 | 55 | 35 | 45 | 47 | 46 | — | — |
| | Other | 129 | | 30 | 100 | 187 | 64 | 57 | 26 | 34 | 32 | 22 | 29 | 34 | 25 | 20 | 22 | 26 | — | — |
| | Total pesticides | 3,660 | | 121 | 100 | 153 | 66 | 78 | 66 | 64 | 50 | 41 | 40 | 54 | 33 | 42 | 44 | 45 | 46 | — |
| Switzerland | Insecticides | 385 | (1988) | 31 | — | — | — | 100 | 93 | 101 | 75 | 70 | 62 | 64 | 48 | 54 | 48 | 47 | 49 | — |
| | Fungicides | 1,120 | (1988) | 100 | — | — | — | 100 | 99 | 88 | 81 | 85 | 88 | 87 | 85 | 79 | 75 | 68 | 63 | — |

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**Table 10E.176 (Continued)**

| | | Tons | | Index 1985=100[a] | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Base Year | | 1980 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| | Herbicides | 885 | (1988) | 93 | — | — | — | 100 | 105 | 93 | 88 | 85 | 76 | 75 | 74 | 71 | 68 | 68 | 69 | — |
| | Other | 66 | (1988) | — | — | — | — | 100 | 103 | 123 | 111 | 76 | 61 | 52 | 53 | 35 | 32 | 27 | 29 | — |
| | Total pesticides | 2,456 | (1988) | 84 | — | — | — | 100 | 100 | 93 | 84 | 82 | 79 | 78 | 74 | 71 | 67 | 64 | 62 | — |
| Turkey | Insecticides | 20,336 | | 67 | 100 | 113 | 73 | 74 | 92 | 87 | 51 | 65 | 60 | 55 | 73 | — | — | — | — | — |
| | Fungicides | 5,804 | | 76 | 100 | 102 | 105 | 110 | 101 | 95 | 96 | 102 | 101 | 84 | 85 | — | — | — | — | — |
| | Herbicides | 6,839 | | 62 | 100 | 87 | 109 | 115 | 90 | 93 | 105 | 86 | 134 | 124 | 111 | — | — | — | — | — |
| | Other | 3,683 | | 122 | 100 | 119 | 125 | 130 | 127 | 124 | 136 | 129 | 138 | 118 | 159 | — | — | — | — | — |
| | Total pesticides | 36,662 | | 73 | 100 | 107 | 90 | 93 | 96 | 93 | 77 | 81 | 88 | 79 | 91 | 99 | 92 | — | — | — |
| UK | Insecticides | 1,348 | | 52 | 100 | 93 | 103 | 103 | 103 | 104 | 104 | 82 | 83 | 91 | 87 | 68 | 69 | 76 | 71 | 49 |
| | Fungicides | 5,125 | | 35 | 100 | 101 | 98 | 146 | 146 | 143 | 143 | 134 | 137 | 126 | 125 | 131 | 129 | 126 | 130 | 103 |
| | Herbicides | 30,715 | | 56 | 100 | 99 | 99 | 68 | 67 | 76 | 76 | 66 | 68 | 74 | 74 | 78 | 78 | 78 | 78 | 74 |
| | Other | 3,612 | | 9 | 100 | 104 | 105 | 88 | 88 | 104 | 93 | 94 | 94 | 98 | 95 | 107 | 107 | 107 | 107 | 120 |
| | Total pesticides | 40,801 | | 49 | 100 | 100 | 100 | 81 | 80 | 88 | 87 | 78 | 79 | 83 | 83 | 87 | 87 | 87 | 87 | 81 |
| Russian Federtion | Insecticides | 45,900 | (1989) | — | — | — | — | — | 100 | 52 | 51 | 23 | — | 2 | 2 | 2 | 4 | — | — | — |
| | Fungicides | 33,700 | (1989) | — | — | — | — | — | 100 | 77 | 67 | 29 | — | 1 | 3 | 2 | 36 | — | — | — |
| | Herbicides | 69,300 | (1989) | — | — | — | — | — | 100 | 51 | 65 | 48 | — | 30 | 31 | 21 | 18 | — | — | — |
| | Other | 1,500 | (1989) | — | — | — | — | — | 100 | 67 | 87 | 0 | — | 53 | 87 | 53 | 1 | — | — | — |
| | Total pesticides | 150,400 | (1989) | — | — | — | — | — | 100 | 57 | 61 | 36 | 29 | 15 | 17 | 11 | 17 | — | — | — |

*Note:* See next page.

CAN, Survey coverage has varied greatly (different active ingredients, registrants and products); survey trends therefore may not reflect actual trends but simply changes in the survey coverage. Data include non-agricultural uses, such as home and garden plants, golf course, etc; they represent, however, a small part of the total use (between 1 and 6% of the total depending on category). 1994: data refer to agriculture uses only (non-agricultural uses excluded). Insecticides: data exclude Bacillus thuringiensis. Total: includes animal repellents and fumigants; U.S.A., Agricultural pesticides only. Other pesticides include fumigants, nematocides, rodenticides, molluscicides, insect regulators and other pesticides; JPN, Data refer to national production of pesticides; NZL, Data refer to use in agriculture; AUT, Data refer to sales; BEL, Data refer to sales; CZE, Data refer to agricultural pesticides and sales of chemical pesticides. Other pesticides: include growth regulators, rodenticides, animal repellents, additives, adhesives and other pesticides; DNK, Data refer to sales for use in plant production in open agriculture; FIN, Data refer to sales; other pesticides include growth regulators and forest pesticides; FRA, Data refer to quantities sold to agriculture. Fungicides: include copper and sulphur compounds but not elemental sulphur; DEU, Data refer to sales; GRC, Data refer to sales; IRL, 1994–1997: data based on pesticide imports, which gives a reasonable estimation of the quantities used as the country imports most of its pesticides; ITA, From 1985, data include only agricultural pesticides. Data refer to formulation weight. 1996 total in active ingredients: 48 050 t; NLD, Sales of chemical pesticides. Total: includes soil disinfectants which correspond, for the years presented, to about the half of the total consumption. Insecticides: from 1988 onwards include mineral oils; NOR, Data refer to sales to the agricultural sector; POL, Other pesticides: growth regulators, rodenticides, animal repellents and other pesticides; PRT, Data refer to sales. 1991–1994 data do not include all sales (some enterprises trading in these substances are excluded); since 1995 data refer to all sales (all enterprises included). The increase in sales for 1995 corresponding to the increase in the number of enterprises covered was about 12%. The decrease of sales in 1992 results from the 1991–1992 years drought, which led to a decrease in the agricultural activity; ESP, Data refer to sales. Data is provisional; SWE, A special sales tax has been applied to pesticides since 1987. Another tax was applied in 1995. Data refer to sales; CHE, Data refer to sales and have been estimated to represent 95% of the total market volume; Liechtenstein included; TUR, Formulation weight. Powdered sulphur and copper sulphate excluded; UKD, Great Britain only. Insecticides: include acarides, insecticides nematocides and tar oil/acid. Fungicides: include fungicides and sulfur. Herbicides: include herbicides and dessicants.

[a] Unless otherwise specified, data refer to active ingredients and the reference year is 1985. Insecticides: acaricides, molluscicides, nematocides and mineral oils. Fungicides: bactericides and seed treatments. Herbicides: defoliants and dessicants. Total pesticides may include other pesticides such as plant growth regulators and rodenticides.

*Source*: Table 10.6b, *OECD Environmental Data Compendium 2002*, © OECD 2002, www.oecd.org.

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**Table 10E.177 Water Quality in Relation to Pesticides in Four Rivers Located in Quebec's Intensive Corn−Cropping Areas, 1992–1995**

| Pesticide | Frequency of Detection, 1992–1995 (%) | Frequency of Exceeding Canadian Water Quality Guildlines (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic Life Guidelines | | | | Drinking Water Guidelines | | | |
| | | 1992 | 1993 | 1994 | 1995 | 1992 | 1993 | 1994 | 1995 |
| **Herbicides: Atrazine** | 100 | 43 | 36 | 23 | 16 | 22 | 12 | 10 | 6 |
| Metolachlor | 94 | 0 | 2.5 | 2.8 | 1.7 | 0 | 0 | 0 | 0 |
| Cyanazine | 67 | 0 | 0.8 | 2.1 | 1.4 | 0 | 0 | 0.7 | 0 |
| **Insecticides: Carbaryl** | 6 | 0 | 0 | 8.5 | 5.6 | 0 | 0 | 0 | 0 |
| Diazinon | 3 | 0 | 0 | 4.3 | 6.3 | 0 | 0 | 0 | 0 |
| Malathion | 2 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0 |
| Azinphos-methyl | 2 | 0 | 0.8 | 4.3 | 1.4 | 0 | 0 | 0 | 0 |
| Chloropyrifos | 1 | 0 | 0 | 0 | 3.5 | 0 | 0 | 0 | 0 |

*Notes:* The total number of samples was 441. Seven other herbicides (phenoxy and benzoic compounds) were detected although their concentrations did not exceed *Canadian Water Quality Guidelines*. Among them, the frequency of detection was 66.4% for dicamba, 59.1% for 2,4-D, 44.3% for mecoprop and 31.2% for MCPA. Six other pesticides were detected in 3% to 67% of the samples and showed concentrations in water lower than the *Canadian Water Quality Guidelines*. Four additional pesticides, for which no water quality guidelines exist, were detected in trace amounts (from less than 0.2% to 20% of the samples).

*Source*: From *The Health of Our Water, Toward Sustainable Agriculture in Canada*, Publication 2020/E, Coote, D.R. and Gregorich, L.J., (eds.), Research Branch Agriculture and Agri-Food Canada, 2000.

*Original Source*: From Giroux, I., Duchemin, M., and Roy, M., 1997. Contamination de l'Eau par les Pesticides dans les Régions de Culture Intensive du Maís au Québec. Campagnes d'échantillonnage de 1994–1995. Envirodoq EN970099 PES-8. Direction des écosystèmes aquatiques, Ministère de l'Environnement et de la Faune du Québec, Ste-Foy, Que. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2006.

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**Table 10E.178 Summary of Median Flows and Concentrations in Six Lake Ontario Tributaries During 1987 and 1998**

| STN | Wet/Dry | N | Flow (CMS) | Susp Sol (μg/L) | TKN (μg/L) | TP (μg/L) | Al (μg/L) | Cd (μg/L) | Cr (μg/L) | Cu (μg/L) | Fe (μg/L) | Mn (μg/L) | Ni (μg/L) | Pb (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Credit | Dry | 8 | 3.59 | 6.00 | 0.43 | 0.014 | 59.30 | 0.00 | 4.74 | 2.56 | 93.45 | 10.24 | 0.00 | 0.00 |
| | Wet | 6 | 19.50 | 184.00 | 1.60 | **0.370** | 720.50 | 0.00 | 2.81 | **8.45** | **1,003.00** | 200.5 | 24.36 | **5.63** |
| Humber | Dry | 5 | 1.43 | 11.50 | 0.38 | 0.030 | 126.00 | 0.00 | 7.18 | 2.29 | 184.00 | 25.3 | 0.00 | 0.00 |
| | Wet | 7 | 15.23 | 125.00 | 1.16 | **0.250** | 737.00 | **0.22** | 5.91 | **11.30** | **1,200.00** | 181.00 | 3.85 | **8.71** |
| Ganaraska | Dry | 3 | 1.77 | 5.00 | 0.22 | 0.012 | 39.20 | **0.26** | 5.55 | 0.51 | 64.40 | 14.80 | 0.00 | 0.00 |
| | Wet | 9 | 7.15 | 60.50 | 0.96 | **0.110** | 218.00 | 0.00 | 3.28 | 1.30 | **411.00** | 68.60 | 0.00 | 0.00 |
| Trent | Dry | 4 | 45.90 | 2.00 | 0.45 | 0.024 | 12.60 | **0.53** | 3.43 | 0.65 | 27.80 | 11.25 | 0.00 | 0.00 |
| | Wet | 8 | 175.35 | 4.25 | 0.46 | 0.017 | 19.40 | 0.13 | 1.54 | 0.77 | 59.00 | 10.28 | 0.00 | 0.00 |
| 20 Mile Cr. | Dry | 7 | 0.08 | 4.00 | 0.72 | **0.086** | 77.30 | 0.00 | 3.53 | 1.44 | 92.90 | 52.60 | 2.90 | 0.00 |
| | Wet | 6 | 30.65 | 194.00 | 2.35 | **0.760** | 1,415.00 | 0.00 | 1.97 | **5.10** | **1,105.00** | 123.70 | 4.43 | 2.87 |
| 12 Mile Cr. | Dry | 6 | 213.80 | 7.75 | 0.26 | 0.025 | 88.85 | 0.00 | 2.68 | 1.35 | 98.10 | 8.55 | 0.00 | 0.00 |
| | Wet | 6 | 215.51 | 13.00 | 0.34 | **0.061** | 216.50 | 0.00 | 0.78 | 1.87 | 217.00 | 13.95 | 3.09 | 0.00 |

| STN | Wet/Dry | N | Flow (CMS) | Zn (μg/L) | PCB (μg/L) | BaP (μg/L) | TPAH (μg/L) | -BHC (μg/L) | LINDANE (μg/L) | HPTCHLR (μg/L) | ALDRIN (μg/L) | HPTCHLR EPOXIDE (μg/L) | CHLRDNE (μg/L) | ENDOSULFAN (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Credit | Dry | 8 | 3.59 | 5.72 | **4.2** | 0.66 | 22.25 | 0.06 | 0.15 | 0.00 | 0.00 | 0.03 | 0.00 | 0.03 |
| | Wet | 6 | 19.50 | **31.10** | **2.9** | 5.36 | 119.20 | 0.28 | 0.36 | 0.00 | 0.00 | 0.01 | 0.00 | 0.22 |
| Humber | Dry | 5 | 1.43 | 4.54 | **4.2** | 1.03 | 32.70 | 0.13 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| | Wet | 7 | 15.23 | **43.80** | **5.4** | 22.15 | 271.06 | 0.39 | 0.29 | 0.00 | 0.00 | 0.02 | 0.02 | 0.17 |
| Ganaraska | Dry | 3 | 1.77 | 1.32 | **3.5** | 0.09 | 8.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Wet | 9 | 7.15 | 5.06 | **3.2** | 0.15 | 18.05 | 0.17 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| Trent | Dry | 4 | 45.90 | 2.75 | **4.1** | 0.05 | 5.46 | 0.09 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| | Wet | 8 | 175.35 | 2.72 | **4.4** | 0.00 | 11.88 | 0.17 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| 20 Mile Cr. | Dry | 7 | 0.08 | 4.28 | **4.2** | 0.00 | 11.97 | 0.07 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| | Wet | 6 | 30.65 | **28.30** | **2.4** | 0.34 | 25.69 | 0.32 | 0.36 | 0.00 | 0.00 | 0.02 | 0.00 | 0.12 |
| 12 Mile Cr. | Dry | 6 | 213.80 | 1.63 | **6.4** | 0.23 | 13.17 | 0.27 | 0.28 | 0.00 | 0.00 | 0.03 | 0.00 | 0.03 |
| | Wet | 6 | 215.51 | 4.26 | **5.6** | 0.37 | 19.56 | 0.34 | 0.26 | 0.00 | 0.00 | 0.05 | 0.00 | 0.03 |

| STN | Wet/Dry | N | Flow (CMS) | CHLRDN (μg/L) | DIELDRIN (μg/L) | *p,p*-DDE (μg/L) | ENDRIN (μg/L) | ENDSLFN (μg/L) | *p,p*-DDD (μg/L) | *o,p*-DDT (μg/L) | *p,p*-DDT (μg/L) | MTHXY CHLR (μg/L) | MIREX (μg/L) | HCB (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Credit | Dry | 8 | 3.59 | 0.03 | 0.10 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.06 | 0.02 |
| | Wet | 6 | 19.50 | 0.02 | 0.06 | 0.00 | 0.00 | 0.20 | 0.02 | 0.00 | 0.07 | 0.00 | 0.02 | 0.03 |
| Humber | Dry | 5 | 1.43 | 0.04 | 0.10 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| | Wet | 7 | 15.23 | 0.04 | 0.07 | 0.00 | 0.00 | 0.12 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| Ganaraska | Dry | 3 | 1.77 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.01 |
| | Wet | 9 | 7.15 | 0.00 | 0.20 | 0.00 | 0.00 | 0.03 | 0.05 | 0.00 | 0.14 | 0.00 | 0.00 | 0.02 |
| Trent | Dry | 4 | 45.90 | 0.01 | 0.03 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 |
| | Wet | 8 | 175.35 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| 20 Mile Cr. | Dry | 7 | 0.08 | 0.01 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| | Wet | 6 | 30.65 | 0.00 | 0.06 | 0.00 | 0.00 | 0.12 | 0.01 | 0.00 | 0.10 | 0.00 | 0.00 | 0.03 |
| 12 Mile Cr. | Dry | 6 | 213.80 | 0.02 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| | Wet | 6 | 215.51 | 0.01 | 0.13 | 0.00 | 0.00 | 0.06 | 0.04 | 0.00 | 0.12 | 0.00 | 0.00 | 0.02 |

*Note:* Bold Value Indicates Concentration Greater Than PWQO; "0.00" Indicates "Not Detected."

*Source*: From *Large Volume Sampling at Six Lake Ontario Tributaries During 1997 and 1998: Project Synopsis and Summary of Selected Results*, Boyd, D., Ontario Ministry of the Environment, and Biberhofer, J., Environment Canada, 1999, © Queen's Printer for Ontario, 1999. Reproduced with the permission.

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**Table 10E.179 Chlordane, Heptachlor and Hexachlorobenzene Concentrations Monitored by the United Nations University Project in River Water in China, 2002 (ng/L)**

| River or Reservoir | | Chlordane | Heptachlor | Hexachlorobenzene |
|---|---|---|---|---|
| Haihe River | Caihong Bridge | N.D. | N.D. | N.D.～1.37 |
| | Haimen Brideg | N.D. | N.D. | N.D.～6.64 |
| | Erdaozha Sluice Gate | N.D. | N.D. | N.D.～0.26 |
| | Jingang Bridge | N.D. | N.D. | N.D.～0.45 |
| | Bridge Belan | N.D. | N.D. | N.D.～0.36 |
| | Ziya River | N.D. | N.D. | N.D.～0.32 |
| Yongding River | Mentougou Sluice | N.D. | N.D. | N.D.～0.15 |
| | Mentougou | N.D. | N.D. | N.D. |
| | Xifeng Villa | N.D. | N.D. | N.D. |
| | Zhenzhu Lake | N.D. | N.D. | N.D.～0.17 |
| | Yanchi | N.D. | N.D. | N.D.～0.12 |
| Chaobai River | Niumutun Village | N.D. | N.D. | 0.38～9.80 |
| | Shamian Sands | N.D. | N.D. | N.D.～1.67 |
| | Baimaozhuang | N.D. | N.D. | N.D.～9.11 |
| | Chaobai River Left Embankment | N.D. | N.D. | N.D.～6.07 |
| | Leshan Bridge | N.D. | N.D. | N.D.～0.16 |
| | Yujialing Bridge | N.D. | N.D. | N.D.～0.26 |
| Guanting Reservoir | Guanting Reservoir | N.D. | N.D. | N.D. |
| | Guanting Bridge | N.D. | N.D. | N.D. |
| | Youzhou | N.D. | N.D. | N.D. |
| Miyun Reservoir | Miyun Rubber Dam | N.D. | N.D. | N.D.～1.59 |
| | Chaohe river Dam | N.D. | N.D. | N.D. |
| | Xinzhuang Bridge | N.D. | N.D. | N.D. |
| | Qikong Bridge | N.D. | N.D. | N.D. |

*Source*: From Yeru, H. et al., 2003, Water Quality Standards and POPs Pollution in China in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1-2 September, 2003, UNU Centre, Tokyo, www.unu.edu. With permission.

**Table 10E.180 DDT Concentrations Monitored by the United Nations University Project in Fresh Water in China (ng/L)**

| River | Year | DDE | DDD | DDT |
|---|---|---|---|---|
| Yellow River (Lanzhou) | 1999 | N.D.～1.06 | N.D.～39.8 | N.D. |
| | 2000 | N.D.～0.10 | N.D. | N.D.～0.77 |
| Jialing River (Chongging) | 1999 | 1.19～31.1 | N.D.～ 1.41 | N.D.～1.02 |
| Songhua River (Harbin) | 1999 | 34.8 | N.D. | 0.73 |
| Haihe River | 1999 | 1.64～1.65 | N.D.～1.37 | 1.29～5.16 |
| | 2002 | N.D. | N.D.～12.2 | N.D.～75.2 |
| Huangpu River (Shanghai) | 1999 | 2.08～22.1 | N.D.～0.34 | 0.77～1.75 |
| Chongging | 1999 | 1.08～28.3 | N.D.～1.49 | 1.11～13.8 |
| Shanghai | 2000 | 0.10 | N.D. | 0.79 |
| Yangtse River | | | | |
| Yongding River | 2002 | N.D. | N.D. | N.D. |
| Chaobai River | 2002 | N.D. | N.D. | N.D. |

*Source*: From Yeru, H. et al., 2003, Water Quality Standards and POPs Pollution in China in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1-2 September, 2003, UNU Centre, Tokyo, www.unu.edu. With permission.

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**Table 10E.181 DDT Concentrations Monitored by United Nations University Project in Seawater in China (ng/L)**

| Sea | Year | DDE | DDD | DDT |
|---|---|---|---|---|
| Bohai Sea | | | | |
| 8 | 1999 | 0.96～2.36 | N.D.～5.32 | N.D.～16.5 |
| 9 | 1999 | N.D.～0.63 | N.D.～3.85 | 1.04～ 2.34 |
| 12 | 2001 | N.D. | N.D. | 0.313 |
| 13 | 1999 | N.D.～25.5 | N.D.～5.28 | 0.83～2.71 |
| 16 | 2000 | 0.32 | N.D. | 3.86 |
| | 2001 | 0.369 | N.D. | 0.973 |
| 19 | 2001 | 0.420 | N.D. | 1.29 |
| Dalian Bay | 2001 | 0.310～0.450 | N.D. | 0.793～2.50 |
| Yellow Sea | 2000 | N.D.～ 1.7 | N.D.～ 2.2 | N.D.～ 3.1 |
| | 2001 | N.D.～0.414 | N.D.～1.01 | N.D.～1.30 |
| East Sea | 1999 | 1.65～2.45 | 0.53～2.15 | 0.88～3.34 |
| | 2000 | N.D. | N.D. | N.D. |
| | 2001 | N.D. | N.D. | N.D. |
| South Sea | | | | |
| Shenzhen | 1999 | N.D. | N.D. | 0.84 |
| Daya Bay | 2000 | N.D. | N.D. | N.D. |
| Shantou | 2000 | N.D. | N.D. | N.D. |
| Xiamen Bay | 2001 | 0.607～1.05 | 1.32～2.39 | 0.97～1.35 |

*Source*: From Yeru, H. et al., 2003, Water Quality Standards and POPs Pollution in China in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1-2 September, 2003, UNU Centre, Tokyo, www.unu.edu. With permission.

**Table 10E.182 Concentrations of Chlorinated Pesticides in Water (ng/L) in Babe and West Lake, Vietnam**

| | Babe Lake ($n$=20) | | West Lake ($n$=22) | |
|---|---|---|---|---|
| **Compounds** | **Rainy Season** | **Dry Season** | **Rainy Season** | **Dry Season** |
| α-HCH | 1.2 (<0.25–1.2) | 0.52 (<0.25–0.52) | <0.25 (<0.25) | 0.63 (<0.25–0.63) |
| β-HCH | <0.25 (<0.25) | 1.58 (<0.25–2.33) | <0.25 (<0.25) | <0.25 (<0.25) |
| γ-HCH | <0.25 (<0.25) | 1.55 (<0.25–1.76) | <0.25 (<0.25) | <0.25 (<0.25) |
| δ-HCH | <0.25 (<0.25) | <0.25 (<0.25–4.61) | <0.25 (<0.25) | <0.25 (<0.25) |
| HCHs | 21.1 (<0.25–19.9) | 3.39 (<0.25–1.76) | <0.25 (<0.25) | 0.63 (<0.25–0.63) |
| HCB | <0.2 (<0.2) | <0.2 (<0.2) | <0.2 (<0.2) | <0.2 (<0.2) |
| Heptachlor | <0.2 (<0.2) | 1.86 (<0.2–1.86) | 0.35 (<0.2–0.35) | 9.25 (<0.2–13.91) |
| Aldrin | <0.4 (<0.4) | 2.19 (<0.4–3.31) | <0.4 (<0.4) | <0.4 (<0.4) |
| *cis*-Chlordane | <0.45 (<0.45) | <0.45 (<0.45) | <0.45 (<0.45) | <0.45 (<0.45) |
| Dieldrin | <1.5 (<1.5) | <1.5 (<1.5) | <1.5 (<1.5) | <1.5 (<1.5) |
| Endrin | <2 (<2) | <2 (<2) | <2 (<2) | <2 (<2) |
| *p,p′*-DDE | <0.25 (<0.25) | 0.47 (<0.25–0.64) | <0.25 (<0.25) | 1.43 (<0.25–2.06) |
| *p,p′*-DDD | <0.5 (<0.5) | <0.5 (<0.5) | <0.5 (<0.5) | <0.5 (<0.5) |
| *p,p′*-DDT | <0.1 (<0.1) | 0.3 (<0.1–0.32) | <0.1 (<0.1) | <0.1 (<0.1) |
| DDTs | <0.1 (<0.1) | 0.77 (<0.1–0.32) | <0.1 (<0.1) | 1.43 (<0.1–2.06) |

*Note:* HCHs, sum of α,β and γ-HCH; DDTs, sum of *p,p′*-DDE, *p,p′*-DDD and *p,p′*-DDT.

*Source*: From Viet, P.H. et al., 2003, Occurrence of Persistent Chlorinated Pesticides in Lakes and Rivers in Vietnam: Levels, Fate, Trends and Environmental Implications in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1-2 September, 2003, UNU Centre, Tokyo, www.unu.edu. With permission.

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**Table 10E.183 A Summary of Pesticides Detected in Irrigation Districts of New South Wales, Australia**

| Catchment/Area | Pesticides Detected | Source of Contamination | Reference |
|---|---|---|---|
| Coleambally Irrigation Area (1991–1993) | **Endosulfan**, **Atrazine**, Diuron, Metolachlor, Simazine, **Diazinon**, **Malathion**, Thlobencarb & ***Molinate*** | *Where found:* Drainage water | Buchan (1994) |
| Coleambally Irrigation Area (1994–1995) | **Endosulfan**, Atrazine, Diuron, Simazine, MCPA, 2,4-D **Thiobencarb** & ***Molinate*** | *Where found:* Drainage & supply water | Bowmer et al. (1998) |
| Murrumbidgee Region NSW | **Molinate**, **Malathion, Chlorpyrifos & Atrazine** | *Crops:* Rice & maize *Where found:* Drainage water | Bowmer et al. (1998) |
| Murray Irrigation Area (1991–1993) | **Molinate**, **Malathion, Diuron, Atrazine &** Bromacil | *Where found:* Drainage water | Shepheard (1994) |
| Murray Irrigation Area (1994–1995) | **Endosulfan**, Atrazine, Diuron, Metolachlor, Simazine, Diazinon, Bromacil, MCPA, **2,4-D**, **Malathion**, **Thiobencarb** & **Molinate** | *Where found:* Drainage water, supply water, lakes, streams & rivers | Bowmer et al. (1998) |
| Gwydir River Basin | **Endosulfan**, Atrazine, Diuron, Prometryne & **Chlorpyriphos** | *Crops:* Irrigated cotton, sorphum, maize *Where found:* Rivers & streams | Cooper (1996) |
| Gwydir River Basin | **Endosulfan**, Atrazine, Amitraz, **Chlorpyrifos**, Profenofos, Diuron, Fluometuron, Metolachlor, Pendimethalin, Prometryn, Simazine & Trifluralin | *Crops:* Irrigated cotton, sorghum, maize *Where found:* Rivers & streams | Muschal (1998) |
| Border River Basins | **Endosulfan**, Atrazine, diuron, fluometuron, Metolachlor & Prometryn | *Crops:* Irrigated cotton, sorghum, maize *Where found:* Rivers & streams | Muschal 1998 |
| Border River Basins | **Endosulfan**, Atrazine, Diuron & Prometryne | *Crops:* Irrigated cotton, sorghum, maize *Where found:* Rivers & Streams | Cooper (1996) |
| Namoi River Basin | **Endosulfan**, Atrazine, **Chlorpyrifos**, **Dimethoate**, Diuron, Fluometuron, Metolachlor, Pendimethalin & Prometryn | *Crops:* Irrigated cotton, sorghum, maize *Where found:* Rivers & streams | Muschal 1998 |
| Namoi River Basin | **Endosulfan**, Atrazine, Prometryn, Diuron & **Chlorpyrifos** | *Crops:* Irrigated cotton, sorghum, maize *Where found:* Rivers & streams | Cooper (1996) |
| Macquire River Basin | **Endosulfan** & Diuron | *Crops:* Cotton, sorghum *Where found:* Rivers & streams | Cooper (1996) |
| Macquire River Basin | **Endosulfan** | *Crops:* Cotton, sorghum *Where found:* Rivers & streams | Muschal (1998) |
| Darling River | **Endosulfan**, Atrazine, Diuron, Fluometuron, Metolachlor & Prometryn | *Crops:* Irrigated cotton, sorghum, maize *Where found:* Rivers & streams | Muschal (1998) |

*Note:* A pesticide in bold indicates that the concentration of that pesticide exceeded guidelines for the protection of aquatic ecosystems. A pesticide in italics indicates that the concentration of that pesticide exceeded guidelines for drinking water.

*Source*: From Ball, J., Donnelley, L., Erlanger, P., Evans, R., Kollmorgen, A., Neal, B., and Shirley, M., 2001, *Inland Waters, Australia State of Environment Report 2001* (Theme Report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra, www.deh.gov.au. Copyright Commonwealth of Australia reproduced by permission.

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**Table 10E.184 Concentrations of Chlorinated Pesticides in Sediment (ng/g dry wt) in Babe and West Lake, Vietnam**

| | Babe Lake ($n=20$) | | West Lake ($n=22$) |
|---|---|---|---|
| **Compounds** | **Rainy Season** | **Dry Season** | **Dry Season** |
| α-HCH | 0.31 (<0.20–1.2) | 3.46 (<0.20–0.52) | 6.1 (<0.20–15.1) |
| β-HCH | 0.5 (<0.2–0.5) | <0.2 (<0.2) | 2.55 (<0.2–2.55) |
| γ-HCH | <0.2 (<0.2) | <0.2 (<0.2) | <0.2 (<0.2–2.36) |
| δ-HCH | <0.20 (<0.20–1.13) | <0.20 (<0.20) | 2.36 (<0.20–2.36) |
| HCHs | 0.59 (<0.2–1.13) | 3.46 (<0.2–5.26) | 6.92 (<0.2–15.1) |
| HCB | <0.2 (<0.2) | <0.2 (<0.2) | <0.2 (<0.2) |
| Heptachlor | 0.79 (<0.15–1.02) | 1.06 (<0.15–1.06) | <0.15 −0.15 |
| Aldrin | <0.25 (<0.25) | 0.78 (<0.25–1.4) | 1.04 (<0.25–1.04) |
| *cis*-Chlordane | <0.5 (<0.5) | <0.5 (<0.5) | <0.5 (<0.5) |
| Dieldrin | <1.5 (<1.5) | <1.5 (<1.5) | <1.5 (<1.5) |
| Endrin | <2 (<2) | <2 (<2) | <2 (<2) |
| *p,p′*-DDE | 2.47 (<0.35–8.92) | 0.84 (<0.35–1.85) | 29.64 (<0.35–80.45) |
| *p,p′*-DDD | 2.8 (<0.35–18.53) | 0.56 (<0.35–0.82) | 5.37 (<0.35–11.26) |
| *p,p′*-DDT | 1.03 (<0.15–1.93) | 1.99 (<0.15–3.35) | 0.73 (<0.15–1.87) |
| DDTs | 2.3 (<0.15–18.53) | 1.99 (<0.15–3.35) | 39.31 (<0.15–80.45) |

*Note:* HCHs, sum of α,β and γ-HCH; DDTs, sum of *p,p′*-DDE and *p,p′*-DDD and *p,p′*-DDT.

*Source*: From Viet, P.H. et al., 2003, Occurrence of Persistent Chlorinated Pesticides in Lakes and Rivers in Vietnam: Levels, Fate, Trends and Environmental Implications in United Nations University, *Capacity Development Training for Monitoring of POPS in the East Asian Hydrosphere*, 1-2 September, 2003, UNU Centre, Tokyo, www.unu.edu. With permission.

**Table 10E.185 Results of Ontario Canada Well Water Surveys**

| | Number of Wells | % of Wells | | |
|---|---|---|---|---|
| **Survey Years** | | **Nitrate-Nitrogen >10 mg N/L** | **Coliform Bacteria >10/100 mL** | **Pesticide Detections** |
| 1950–1954 | 484 | 14 | 15[a] | — |
| 1980 | 37 | 5 | 43 | — |
| 1954–1985 | 63 | 21 | — | — |
| c.1985 | 49 | 5 | — | — |
| 1979–1984 | 359 | — | — | 37 |
| 1981–1984 | 102 | — | — | 14 |
| 1984 | 91 | — | — | 13 |
| 1986 | 103 | 15 | — | 10 |
| 1987 | 76 | 7 | — | 5 |
| 1990 | 566 | 12 | 37 | — |
| 1991–1992 | 142 | 7 | 44[b] | — |
| 1991 | 301 | 15 | 34[b] | 10 |
| 1991–1992 | 1292 | 14 | 34, 25[a] | 12 |

[a] Data for *E. coll.*
[b] Data for fecal coliform.

*Source*: From *The Health of Our Water, Toward Sustainable Agriculture in Canada*, Publication 2020/E, Coote, D.R. and Gregorich, L.J., (eds.), Research Branch Agriculture and Agri-Food Canada, 2000. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2006

*Original Source*: From Reprinted from J. Contam, Hydrol., Volume 32, Goss, M.J., Barry, D.A.J., and Rudolph, D.L. Contamination in Ontario Farmstead Domestic Wells and its Association with agriculture. 1. Results from Drinking Water, pages 267–293, Copyright 1998, with permission from Elsevier.

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**Table 10E.186 Pesticide Concentrations in Groundwater in Atlantic Canada**

| Location | Date | Pesticide | Canadian Guideline for Drinking Water (μg/L) | Wells with Pesticide Detected | Mean or Median Pesticide Concentration (μg/L) |
|---|---|---|---|---|---|
| Kings Co., N.S. 102 wells | 1989 | Atrazine | 5 | 33 | 0.24 |
| | | Simazine | 10 | 5 | 0.52 |
| | | Metribuzin | 80 | 4 | 0.02 |
| | | Alachlor | No guideline | 3 | 0.05 |
| | | Metolachlor | 50 | 2 | 0.86[a] |
| | | Captan | No guideline | 1 | 0.05[a] |
| | | Chlorothalonil | No guideline | 1 | 0.065[a] |
| | | Dimethoate | 20 | 1 | 0.40[a] |
| N.B., P.E.I. On-farm tile drainage plots various locations | 1987–1990 | Dinoseb | 10 | NA | 0.2 |
| | | Metribuzin | 80 | NA | 0.22 |
| | | Atrazine | 5 | NA | 0.4–2.5 |
| | | Desethyl atrazine | 5 | NA | less than 1.0 |
| N.B. Wells | 1990 | Chlorothalonil | No guideline | 0 | Not detectable |
| N.B. Research multi-level wells | 1996–1998 | Hexazinone (Velpar) | No Canadian guideline (USEPA = 200) | 6 | 1.5 |
| N.B. Drainage water research wells | 1996 | Metalyxl (Ridomil) | No guideline | 10 | 1 |
| N.B. Research multi-level wells | 1992–1993 | 16 Pesticides | Various | NA | Generally not detectable or less than 1.0 |
| P.E.I. 60 wells | 1996 | 10 Pesticides | Various | 0 | Generally not detectable |

*Note:* NA, not applicable; Compiled from various published sources by Milburn, P.H., Agriculture and Agri-Food Canada, and by Fairchild, G.L., Eastern Canada Soil and Water Conservation Centre.

[a] Denotes limited number of samples.

*Source*: From *The Health of Our Water, Toward Sustainable Agriculture in Canada*, Publication 2020/E, Coote, D.R. and Gregorich, L.J., (eds.), Research Branch Agriculture and Agri-Food Canada, 2000. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2006.

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**Table 10E.187 Percentage of Sampling Sites with Greater Than 0.1μg/L in European Union Countries (Total Number of Sampling Site in Brackets)**

| | EEA18 | | | | | | | | PHARE | | | | | TACIS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AT | DK | FR | DE | ES | LU | NO | UK | CZ | HU | RO | SK | SI | MD | sum |
| Atrazine | 16.3 (1866) | 0 (625) | [a] | 4.1 (11690) | | [a] | | [a] | | 15.5 (174) | | | 32.1 (84) | | 8 |
| Simazine | 0.2 (1248) | 0.3 (625) | [a] | 0.9 (11630) | | [a] | | | | 6.8 (177) | | | 4.8 (84) | | 7 |
| Lindane | | | [a] | [a] | [a] | | | | 0 (215) | | | 25 (8) | | | 5 |
| Atrazine-Desethyl | 24.5 (1666) | | | 7.1 (11690) | | | | | | | | | 47.6 (84) | | 3 |
| Heptachlor | | | [a] | | [a] | | | | | | | 0 (12) | | | 3 |
| Metolachlor | 1.1 (1248) | | | | | [a] | | | | | | | 4.8 (84) | | 3 |
| Bentazone | | | | | | [a] | 80 (5) | | | | | | | | 2 |
| DDT | | | | | | | | | 0 (215) | | | 0 (12) | | | 2 |
| Dichlorprop | | 0.6 (623) | | | | | 83.3 (6) | | | | | | | | 2 |
| MCPA | | | | | | | 100 (2) | | | 4.8 (168) | | | | | 2 |
| Methoxychlor | | | | | | | | | 0 (206) | | | 8.3 (12) | | | 2 |
| 2,4-D | | | | | | | | | | 3.6 (168) | | | | | 1 |
| Atrazine-Desisopropyl | 1.3 (1666) | | | | | | | | | | | | | | 1 |
| Bromacil | | | | 3.5 (6650) | | | | | | | | | | | 1 |
| DDE, DDD, DDT | | | | | | | | | | | | | | [a] | 1 |
| DDD (p,p'), DDT (p, p') | | | | | | [a] | | | | | | | | | 1 |
| Chlortoluron | | | | | | | | [a] | | | | | | | 1 |
| Dichlorbenzamid | | 13.7 (102) | | | | | | | | | | | | | 1 |
| Dieldrin | | [a] | | | | | | | | | | | | | 1 |
| Diuron | | | | | | | | [a] | | | | | | | 11 |
| Endosulfan 1 | | | | | | [a] | | | | | | | | | 1 |
| Endosulfan sulphate | | | | | | [a] | | | | | | | | | 1 |
| GCCG-a, b | | | | | | | | | | | | | | [a] | 1 |
| HCH. a, b, d | | | | | | [a] | | | | | | | | | 1 |
| Hexachlorobenzene | | | | | | | | | | | | 0 (10) | | | 1 |
| Hexazinon | | | | [a] | | | | | | | | | | | 1 |
| Isoproturon | | | | | | | | [a] | | | | | | | 1 |
| Linuron | | | | | | | | [a] | | | | | | | 1 |
| Mecoprop (MCPP) | | 0.2 (625) | | | | | | | | | | | | | 1 |
| Metalaxyl | | | | | | | | | | | | | | [a] | 1 |
| Metazachlor | | | | | | | [a] | | | | | | | | 1 |
| Parathion-methyl | | | | | | [a] | | | | | | | | | 1 |
| Pentachlorophenol | | | | | | | | | 0 (207) | | | | | | 1 |
| Phosphamid | | | | | | | | | | | | | | [a] | 1 |
| Phozalon | | | | | | | | | | | | | | [a] | 1 |
| Prometryn | | | | | | | | | | | | | 2.4 (84) | | 1 |
| Propzine | | | 0.6 (10890) | | | | | | | | | | | | 1 |
| sum(HCH) | | | | | | | | | | | [a] | | | | 1 |
| sum(HCH + DDT) | | | | | | | | | | | [a] | | | | 1 |

Percentage of sampling sites with pesticide concentrations >0.1μg/L. Total number of sampling sites in brackets.

[a] Data available at the regional level only.

*Source*: From European Environmental Agency (EEA), 1999, *Groundwater Quality and Quantity in Europe*, June 1999, www.eea.europa.eu. Reprinted with permission © EEA.

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**Table 10E.188 Documented Cases of (Diffuse) Pesticide Contamination of Groundwater in Australia**

| State or Territory | Area | Principal Contaminant | Percentage of Groundwater Samples Contaminated |
|---|---|---|---|
| Victoria | Shepparton East[a] | Atrazine and Simazine | 50 |
| | Goulburn-Broken catchment[b] | Atrazine and Simazine | |
| | Strathmerton-Cobram | Atrazine and Simazine | 48 |
| | Shepparton East | Atrazine and Simazine | 49 |
| | Nagambie-Mangalore | Atrazine and Simazine | 5 |
| | Tongala-Kyabram | | 22 |
| | Ardmona[c] | Dieldrin, Chlorpyriphos and Amitrol | n/s[d] |
| | Girgarre[c] | No pesticides above ANZECC criteria | — |
| | Ky Valley[c] | No pesticides above ANZECC criteria | — |
| Western Australia | Kwinana industrial area near Perth[e] | Herbicides 2,4-D and 2,4,5-T | n/s |
| NSW | Lower Namoi Valley[e] | Atrazine | 4 |
| | Murray-Riverina catchment: Berriquin Denimein area[b] | Atrazine and Simazine | 16 |
| | Liverpool Plains[g] | Atrazine | 40 |
| | | Isolated detections of Simazine, Metolachlor, Trifluraline and Diuron | n/s |
| Queensland | Burdekin Delta[a] | Atrazine | 76 |
| | | To a lesser extent the Atrazine Degradation Product (DEA) | n/s |
| | Logan-Albert catchment (SE Qtd)[h] | No pesticides detected | — |
| | Border Rivers catchment: Western and Macintyre sectors[b] | Atrazine and Simazine | 16 |
| South Australia | Padthaway[a] | Atrazine and Simazine | 60 |
| | | to a lesser extent the DEA | n/s |
| | Piccadilly Valley, near Adelaide[i] | Atrazine | 5 |
| | Lower south-east of SA[j] | Dieldrin, Lindane, Chlorpyrifos and Alachlor | 15 |
| Northern Territory | Darwin rural region[k] | No pesticides detected | — |

[a] Bauld, 1994.
[b] Bauld et al., 1998.
[c] Wenig & Lawrence 1998.
[d] n/s, not stated.
[e] Appleyard 1993.
[f] Jiwan and Gates, 1994.
[g] Timms & Cooper 1998.
[h] Please et al., 1996.
[i] Ivkovic et al., 1998.
[j] Schmidt et al., 1996.
[k] Radke et al., 1998.

*Source*: From Ball, J., Donnelley, L., Erlanger, P., Evans, R., Kollmorgen, A., Neal, B., and Shirley, M., 2001, *Inland Waters, Australia State of Environment Report 2001* (Theme Report), CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra, www.deh.gov.au. Copyright Commonwealth of Australia reproduced by permission.

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**Table 10E.189 Average Nitrate Levels in Groundwater in the Maritime Provinces of Canada**

| Location and Type of Study | Date | Average Concentration of Nitrate-Nitrogen (mg/L) | Wells with Nitrogen Concentration Exceeding the Guideline (%) |
|---|---|---|---|
| Carleton County, N.B., 300 farm wells | 1984–1985 | 2–30 | 14–22 |
| 3 Farming regions in N.B., 47 farm wells | 1973–1976, 1988 | 9.5 | 20 |
| 4 Watersheds of Kings Co., N.S., 237 wells | 1989 | 4.6 | 13 |
| P.E.I., 2216 Drinking water analyses | 1991–1994 | 2.7 | 1 |
| 1 Watershed of Bedeque Bay, P.E.I., 283 wells | 1995 | 6 | 7 |
| P.E.I., 146 Dairy farm wells | 1997 | 9.9 | 44 |

Compiled from various published sources by Milburn, P.H., Agriculture and Agri-Food Canada, and by Fairchild, G.L., Eastern Canada Soil and Water Conservation Centre.

*Source*: From *The Health of Our Water, Toward Sustainable Agriculture in Canada*, Publication 2020/E, Coote, D.R. and Gregorich, L.J., (eds.), Research Branch Agriculture and Agri-Food Canada, 2000. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2006.

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**Table 10E.190 European Groundwater Quality—Nitrate, Frequency Distribution for the Latest Year Available**

| | Number of GW-Bodies | ≤10 | >10–≤25 | >25–≤50 | >50 |
|---|---|---|---|---|---|
| **AC 3** | 62 | 20 | 19 | 18 | 5 |
| Bulgaria (2003) | 62 | 20 | 19 | 18 | 5 |
| **EFTA 4** | 2 | 2 | | | |
| Liechtenstein (2003) | 1 | 1 | | | |
| Norway (2003) | 1 | 1 | | | |
| **EU 25** | 629 | 284 | 162 | 137 | 46 |
| Austria (2003) | 14 | 3 | 2 | 8 | 1 |
| Belgium (2002) | 1 | | | 1 | |
| Czech Republic (2003) | 39 | 20 | 10 | 7 | 2 |
| Denmark (2003) | 3 | | 1 | 2 | |
| Estonia (2003) | 5 | 5 | | | |
| Finland (2003) | 34 | 33 | 1 | | |
| France (2003) | 308 | 138 | 80 | 69 | 21 |
| Germany (2003) | 9 | 1 | 3 | 4 | 1 |
| Greece (1998) | 65 | 27 | 26 | 8 | 4 |
| Hungary (2002) | 16 | 12 | 4 | | |
| Ireland (2002) | 3 | 2 | 1 | | |
| Italy (2001) | 43 | 21 | 6 | 10 | 6 |
| Latvia (2003) | 1 | 1 | | | |
| Lithuania (2003) | 5 | 5 | | | |
| Luxembourg (2003) | 5 | 1 | 2 | 2 | |
| Malta (2003) | 2 | | | 1 | 1 |
| The Netherlands (2003) | 9 | 3 | 2 | 2 | 2 |
| Poland (2003) | 3 | 1 | 2 | | |
| Portugal (2003) | 8 | 2 | 3 | 2 | 1 |
| Slovakia (2003) | 10 | 4 | 6 | | |
| Slovenia (2003) | 5 | 1 | 2 | 2 | |
| Spain (1999) | 3 | | | 1 | 2 |
| Sweden (2003) | 3 | 3 | | | |
| United Kingdom (2003) | 35 | 1 | 11 | 18 | 5 |
| Western Balkans | 9 | 7 | 2 | | |
| Serbia and Montenegro (2003) | 9 | 7 | 2 | | |

*Note:* Disclaimer: The data in Waterbase are sub-samples of national data assembled for the purpose of providing comparable indicators of pressures, state and impact of waters on a Europe-wide scale and the data sets are not intended for assessing compliance with any European Directive or any other legal instrument. Information on the national and sub-national scales should be sought from other sources.
Values below the limit of quantification and values below the limit of detection were replaced by half the value. Interval/Individual classes: classes for nitrate rely on Council Directive 98/83/EC on the quality of water intended for human consumption and on 91/676/EEC the Nitrate Directive: 10 mg/L $NO_3$—Background level, 25 mg/L $NO_3$—Drinking water Guide Level (related to replaced 80/778/EC—Drinking water Directive), 50 mg/L $NO_3$—91/676/EEC and parametric value (98/83/EC).
Unit: The table gives the number of GW-bodies according to concentration classes for nitrate. Annual mean values of nitrate are calculated for each GW-body for the latest year available (based on the annual mean values of the sampling sites) and GW-bodies are assigned to frequency classes accordingly.

*Source*: From European Environment Agency, *The European Topic Center on Water, EEA Data Service, Waterbase-Groundwater*, Downloaded November 27, 2005, www.eea.europa.eu. Reprinted with permission © EEA.

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**Table 10E.191 Information on the Occurrence of Excessive Nitrate in Groundwaters in India**

| Name of State/Union Territory | Name of District | Number of Samples | Number of Samples with $NO_3$ >45 mg/L | Number of Samples with $NO_3$ >45 mg/L (%) |
|---|---|---|---|---|
| Andhra Pradesh | Kurnool | 143 | 26 | 18.2 |
| Bihar | Rohtas | 209 | 55 | 26.3 |
| Bihar | Palamu | 191 | 40 | 20.9 |
| Gujarat | Mehsana | 200 | 37 | 18.5 |
| Gujarat | Amreli | 49 | 0 | 0 |
| Haryana | Faridabad | 200 | 45 | 22.5 |
| Haryana | Gurgaon | 415 | 104 | 25.1 |
| Karnataka | Gulbarga | 529 | 261 | 49.3 |
| Lakshadweep | | 135 | 0 | 0 |
| Madhya Pradesh | Jhabua | 55 | 11 | 20.0 |
| Maharashtra | Nagpur (villages) | 114 | 47 | 41.2 |
| Maharashtra | Nagpur (city) | 100 | 82 | 82.0 |
| Maharashtra | Satara | 1,001 | 163 | 16.3 |
| Maharashtra | Latur | 220 | 92 | 41.8 |
| Orissa | Phulbani | 225 | 29 | 12.9 |
| Orissa | Koraput | 503 | 71 | 14.1 |
| Rajasthan | Barmer | 351 | 220 | 62.7 |
| Tamil Nadu | Ramanathapuram | 66 | 7 | 10.6 |
| | Total | 4,696 | 1,290 | 27.5 |

*Source*: From World Health Organization, 2004, Rolling Revision of the WHO Guidelines for Drinking Water Quality, Nitrates and Nitrites in Drinking Water, Draft for Review and Comments. Copyright © World Health Organization 2004, www.who.int.

*Original Source*: From National Environmental Engineering Research Institute (NEERI), 1991 Water Mission Report on Participation of NEERI. NEERI, Nagpur, India.

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## SECTION 10F URBAN RUNOFF/DEICING MATERIALS

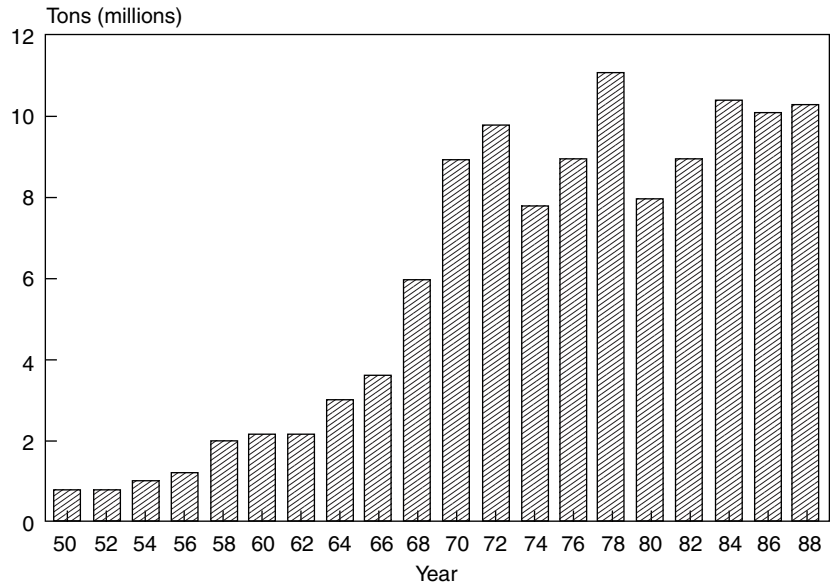


**Figure 10F.136** Trends in highway salt use, 1950–1988. (From Salt Institute gulliver.trb.org/publications/sr/sr235.html. With permission.)

**Table 10F.192 Trends in Gross Discharges of Major Pollutants in Urban Runoff in the United States (Thousands of Tons)**

| | High Growth | | | | Low Growth | | |
|---|---|---|---|---|---|---|---|
| **Pollutant** | **1975** | **1985** | **1990** | **2000** | **1985** | **1990** | **2000** |
| Biochemical oxygen demand | 370 | 400 | 420 | 450 | 390 | 400 | 420 |
| Chemical oxygen demand | 3,400 | 3,400 | 3,900 | 4,200 | 3,600 | 3,800 | 3,900 |
| Suspended solids | 6,300 | 6,800 | 7,100 | 7,600 | 6,500 | 6,900 | 7,100 |
| Dissolved solids | 4,000 | 4,400 | 4,600 | 4,900 | 4,300 | 4,400 | 4,600 |
| Phosphorus | 5 | 5 | 6 | 6 | 5 | 5 | 6 |
| Nitrogen | 58 | 63 | 65 | 70 | 61 | 63 | 65 |
| Oil and grease | 86 | 94 | 98 | 110 | 92 | 95 | 98 |

*Note:* Conservative estimates; discharges may uniformly be too low by a factor of 2–5.

*Source*: From U.S. Environmental Protection Agency, Environmental Outlook 1980.

**Table 10F.193 Average Concentrations of Heavy Metals in Street Sweepings and Urban Runoff**

| **Heavy Metal** | **Street Sweepings (mg/kg)** | **Urban Runoff (μg/L)** |
|---|---|---|
| Cadmium (Cd) | 3.4 | 18 |
| Chromium (Cr) | 211 | 33 |
| Copper (Cu) | 104 | 45 |
| Iron (Fe) | 22,000 | — |
| Lead (Pb) | 1,810 | 235 |
| Manganese (Mn) | 418 | — |
| Nickel (Ni) | 35 | 24 |
| Zinc (Zn) | 371 | 236 |

*Source*: From U.S. Geological Survey, 1984, National Water Summary 1983-Hydrologic Events and Issues, Water-Supply Paper 2250. Based on data from W.L. Bradford, 1977, and the U.S. Environmental Protection Agency.

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**Table 10F.194 Snow and Ice Control Materials Use in the United States, Winter 1982–1983**

| State | Population 1983 (thousands) | Total Lane (mil)[a] | Bare Pavement (mil)[a] | Control Materials Used | | | |
|---|---|---|---|---|---|---|---|
| | | | | Salt (metric tons) | Calcium Chloride | | Abrasives (metric tons)[b] |
| | | | | | Dry (metric tons)[b] | Liquid (l)[c] | |
| Alaska | 100 | 1,020 | 900 | 322 | 227 | 757,000 | 16,534 |
| Arizona | 2,178 | 16,650 | 0 | 375 | 23 | 0 | 50,803 |
| Arkansas | 2,178 | 34,852 | 0 | 777 | 223 | 0 | 8,305 |
| California | 22,000 | 53,000 | 12,900 | — | — | — | — |
| Colorado | 2,500 | 32,000 | 32,000 | 9,885 | 0 | 0 | 394,484 |
| Connecticut | 3,100 | 10,160 | 0 | 47,115 | 544 | 0 | 153,859 |
| Delaware | 611 | 9,971 | 2,543 | 6,400 | 0 | 0 | 6,998 |
| Florida | 9,740 | — | — | — | — | — | — |
| Georgia | 5,463 | 41,809 | 13,900 | 7,439 | 54 | 0 | 7,076 |
| Idaho | 944 | 11,512 | 0 | 9,979 | 0 | 0 | 174,182 |
| Illinois | 11,114 | 38,515 | — | 186,883 | 472 | 435,843 | — |
| Indiana | 5,300 | 31,036 | 14,559 | 105,825 | 40 | 341 | 98,539 |
| Iowa | 2,900 | 24,300 | 0 | 54,795 | 2,019 | 35,958 | 105,235 |
| Kansas | 2,364 | 22,371 | 5,688 | 28,695 | 0 | 0 | 58,968 |
| Kentucky | 3,661 | 53,846[e] | 4,966[e] | 29,905 | 97 | 0 | 0 |
| Louisiana | 5,000 | 38,191 | 0 | 21 | 0 | 0 | 0 |
| Maine | 1,125 | 7,877 | 1,178 | 44,636 | 485 | — | 428,652 |
| Maryland | 4,500 | 14,600 | 0 | 74,843 | 887 | — | 27,995 |
| Massachusetts | 5,737 | 12,000 | — | 161,935 | 2,578 | 0 | 86,184 |
| Michigan | 9,258 | 13,667 | 4,695 | 207,749 | 242 | 0 | 9,072 |
| Minnesota | 4,077 | 28,724 | 4,162 | 116,083 | 254 | 0 | 262,084 |
| Mississippi | 2,500 | 23,391 | 0 | 259 | — | — | — |
| Missouri | 4,917 | 69,664 | — | 68,141 | 3,060 | 0 | — |
| Montana | 700 | 18,790[a] | 18,790 | 2,944 | 25 | 0 | 181,440 |
| Nebraska | 1,600 | 22,000 | — | 22,588 | 504 | 98,312 | 78,385 |
| Nevada | 799 | 12,608 | 11,340 | 8,919 | 0 | 0 | 46,267 |
| New Hampshire | 921 | 8,630 | 8,406 | 85,107 | 207 | 0 | 137,279 |
| New Jersey | 7,364 | 10,366 | 10,366 | 32,387 | 526 | 862,980 | 3,810 |
| New Mexico | 1,400 | 27,450 | 20,000 | 20,866 | 0 | 0 | 72,576 |
| New York | 17,557 | 29,780 | 27,780 | 272,160 | 272 | 0 | 417,312 |
| North Carolina | 5,847 | 112,573 | 23,342 | 33,179 | 145 | 0 | — |
| North Dakota | 600 | 15,800 | — | 7,910 | 197,588[d] | 0 | 34,474 |
| Ohio | 10,797 | 42,192 | 0 | 167,234 | 177 | 428,806 | 117,007 |
| Oklahoma | 3,025 | 25,935 | 0 | 17,028 | 0 | — | 65,318 |
| Oregon | 2,656 | 17,895 | — | 414 | — | 1,608,580 | — |
| Pennsylvania | 11,867 | 77,000 | — | 209,563 | 4,536 | 0 | 594,216 |
| Rhode Island | 947 | 3,015 | 3,015 | 26,578 | 120 | 0 | 40,824 |
| South Carolina | 3,122 | 84,450 | 3,450 | 814 | 259 | 0 | 4,309 |
| South Dakota | 688 | 18,216 | — | 3,354 | 5 | 0 | 40,826 |
| Tennessee | 4,591 | 25,087 | 25,087 | — | — | 0 | — |
| Utah | 2,000 | 22,000 | — | 72,322 | 0 | 0 | 113,400 |
| Vermont | 511 | 6,079 | 6,079 | 59,555 | 0 | 0 | 96,757 |
| Virginia | 5,347 | 112,814 | 17,350 | 86,184 | 907 | 0 | 231,336 |
| Washington | 4,130 | 16,778 | 0 | 6,804 | 0 | 0 | 184,643 |
| West Virginia | 1,950 | 70,000 | 21,000 | 47,818 | 285 | 0 | 162,064 |
| Wisconsin | 4,705 | 25,774 | 25,774 | 208,477 | 588 | 151,400 | 23,508 |
| Wyoming | 430 | 15,743 | 0 | 5,752 | 0 | 0 | 115,214 |
| Total | 205,361 | 1,410,131 | 321,270 | 2,560,019 (2,821,141 tons) | 217,349 (239,519 tons) | 4,379,220 (1,156,990 gallons) | 4,650,235 (5,124,559 tons) |

*Note*: As reported by state departments of transportation/highways.

[a] To convert to kilometers, multiply amount by 1.609.
[b] To convert to short tons, multiply amount by 1.102.
[c] To convert to gallons, multiply amount by 0.2642.
[d] Sodium chloride liquid used.
[e] Includes parkways.

*Source*: From Salt Institute, 1983, Survey of Salt, Calcium Chloride and Abrasives in the United States and Canada for 81/82 ad 82/83. With permission.

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**Table 10F.195 Average Annual Salt Loadings on State Highways Where Salt Is Normally Applied**

| Region and State | Average Annual Loading (tons/lane-mile) |
|---|---|
| New England | |
| Maine | 8.0 |
| Massachusetts | 19.4 |
| New Hampshire | 16.4 |
| Vermont | 17.1 |
| Middle Atlantic | |
| Delaware | 9.0 |
| Maryland | 7.1 |
| New Jersey | 6.7 |
| New York | 16.6 |
| Virginia | 3.0 |
| West Virginia | 6.3 |
| Great Lakes | |
| Illinois | 6.6 |
| Indiana | 9.0 |
| Michigan | 12.9 |
| Ohio | 9.1 |
| Wisconsin | 9.2 |
| Plains | |
| Iowa | 3.8 |
| Minnesota | 5.0 |
| Missouri | 1.0 |
| Nebraska | 1.5 |
| Oklahoma | 1.5 |
| South Dakota | 1.0 |
| Mountain and West | |
| Alaska | 1.2 |
| California | 3.0 |
| Idaho | 0.3 |
| Nevada | 1.9 |
| New Mexico | 0.5 |

*Note:* Data are from only those states that responded to relevant questions in survey.

*Source*: From TRB survey of state highway agencies, gulliver.trb.org/publications/sr/sr235.html. With permission.

**Table 10F.196 State Spending on Prevention and Remediation of Drinking Water Contamination by Road Salt, 1989**

| State | State Expenditure[a] ($) | Amount of Salt Spread Annually by State[b] (tons) |
|---|---|---|
| Illinois | 200,000 | 275,000 |
| Indiana | 175,000 | 240,000 |
| Maine | 75,000 | 60,000 |
| Massachusetts | 500,000 | 225,000 |
| Michigan | 200,000 | 350,000 |
| New Hampshire | 195,000 | 125,000 |
| New York | 175,000 | 450,000 |
| Pennsylvania | 200,000 | 425,000 |
| Vermont | | 35,000 |
| Total | 1,755,000 | 2,250,000 |

[a] From survey of state highway departments.
[b] From survey of state highway departments and Salt Institute data.

*Source*: From gulliver.trb.org/publications/sr/sr235.html. With permission.

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## SECTION 10G AIR EMISSIONS/ACID RAIN/SEA LEVEL RISE

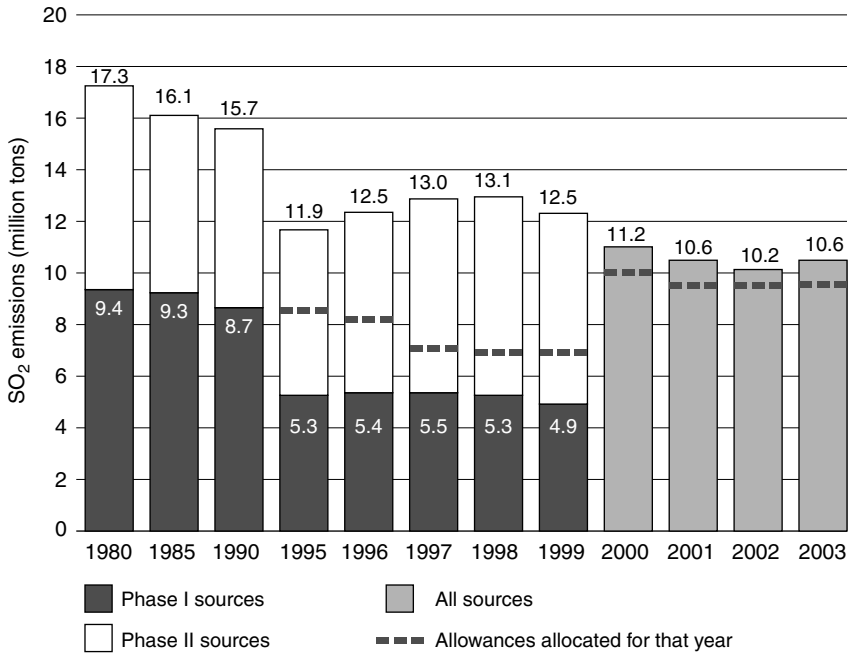


**Figure 10G.137** Trends in $SO_2$ emissions since 1980 for all Title IV affected sources, www.epa.gov/airmarkets.

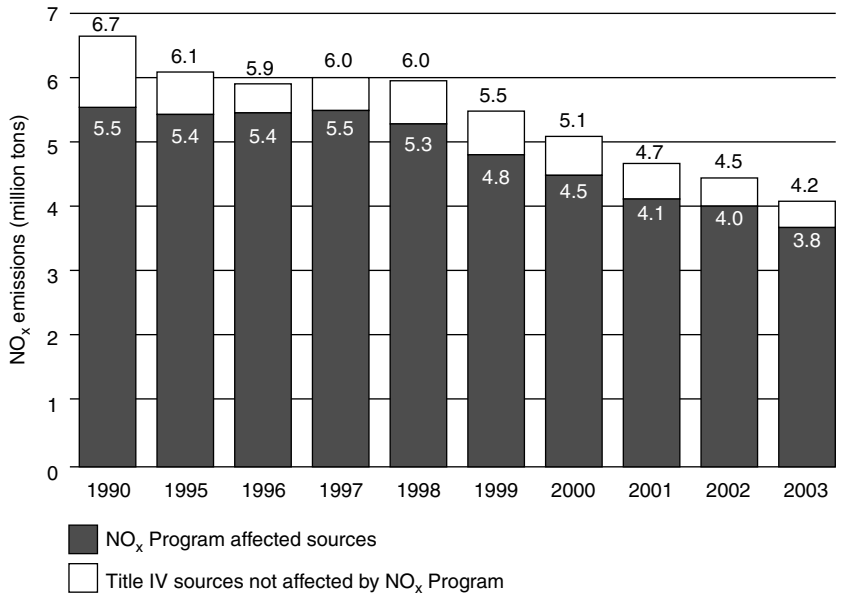


**Figure 10G.138** Trends in $NO_x$ emissions under the acid rain program, www.epa.gov/airmarkets.

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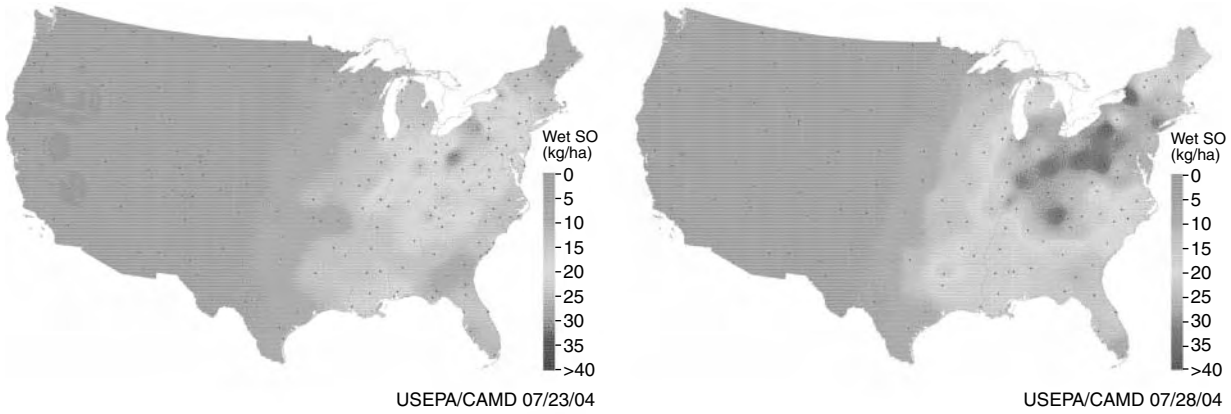


**Figure 10G.139** Wet sulfate deposition decreased throughout the early 1990s in much of the Ohio River Valley and Northeastern U.S. Other less dramatic reductions were observed across much of New England, portions of the Southern Appalachian Mountains and in the Midwest. Average decreases in wet deposition of sulfate range from 39 percent in the Northeast to 17 percent in the Southeast, www.epa.gov/airmarkets.

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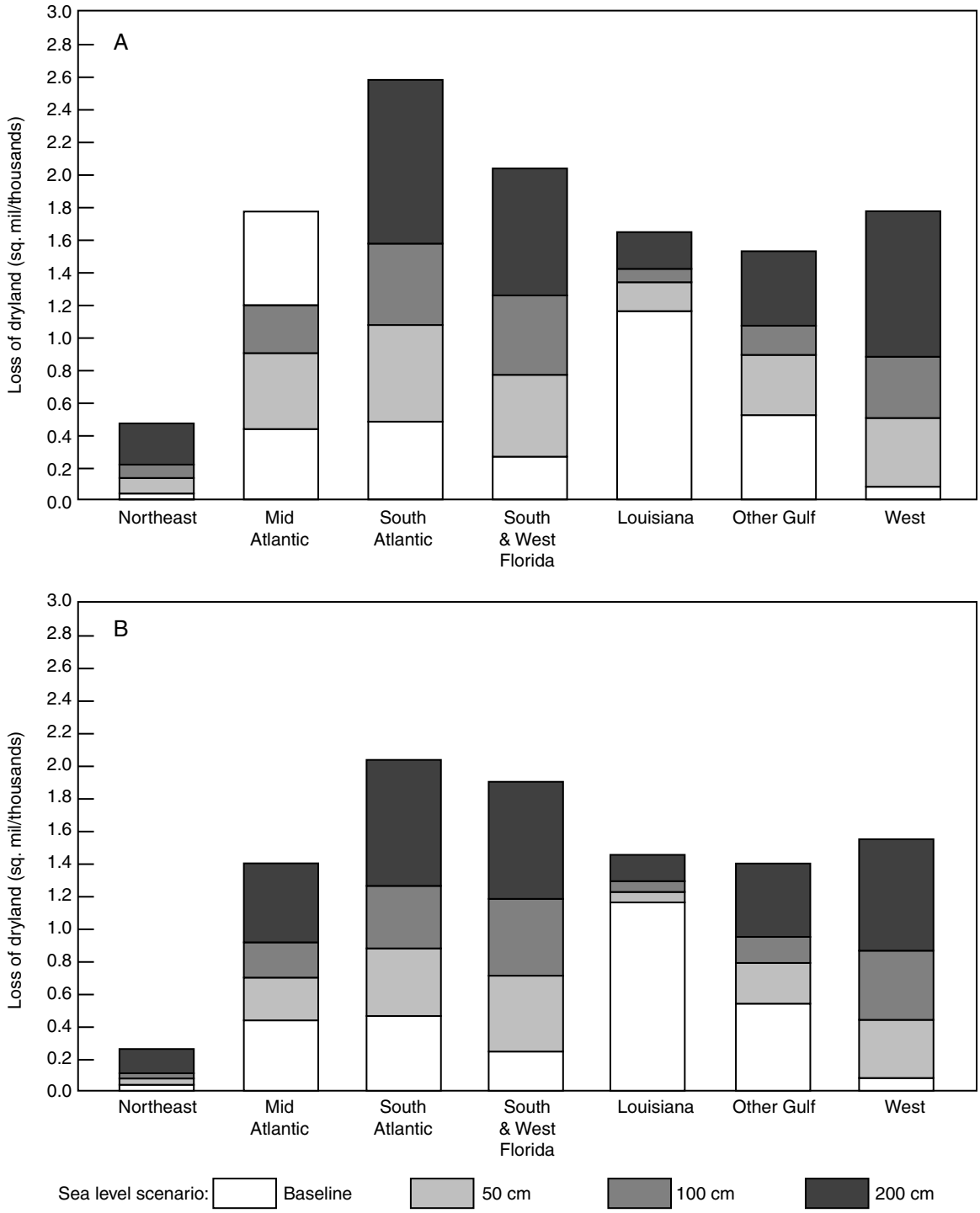


**Figure 10G.140** Loss of dry land in the United States by 2100 (A) if no shores are protected and (B) if developed areas are protected for sea level rise. (From U.S.EPA 1988. The Potential Effects of Global Climate Change on the U.S. Draft report to Congress. Prepared by Titus and Greene, adapted from Park and others.)

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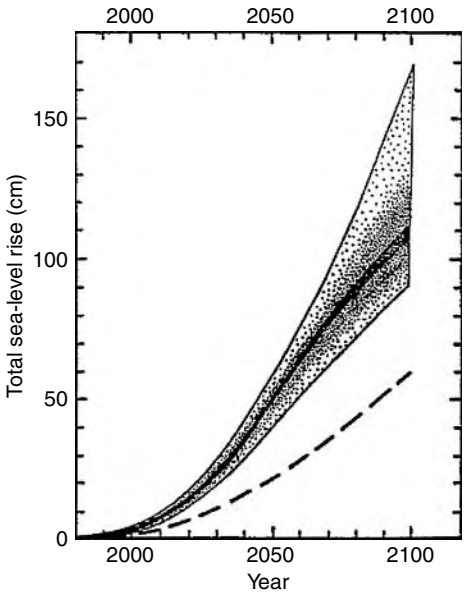
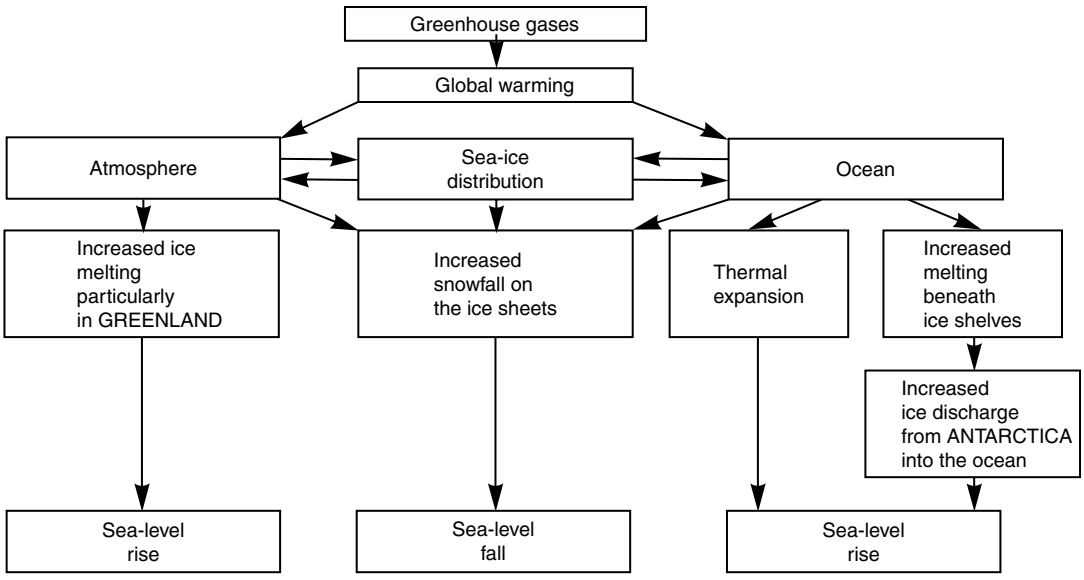



The dark shading indicates the most probable response to the climate scenario shown in Figure 10G-142. The broken line depicts the response to a warming trend delayed 100 years by thermal inertia of the ocean. A global warming of 6°C by 2100, which represents an extreme upper limit, would result in a sea level rise of about 2.3 m, but errors on this estimate are very large.

**Figure 10G.141** Total estimated sea-level rise, 1980–2100. (From Thomas, Robert 1986, Future sea-level rise and its early detection by satellite remote sensing, in *Effects of Change in Stratospheric Ozone and Global Climate*, vol. 4.)




Heat trapped by greenhouse gases raises the temperature of the atmosphere and the ocean. The response of sea level to this warming is strongly determined by the partition of available heat between these two processes. If most of the heat remains in the atmosphere, air temperatures rise rapidly and sea level is affected most by increased melting of ice. Alternatively, rapid transfer of heat into the sea would increase ocean temperatures, and sea level would rise because of thermal expansion and by accelerated Antarctic ice discharge associated with increased melting from beneath the floating ice shelves. Moreover, sea-ice distribution both influences, and is affected by, thermal interactions between atmosphere and ocean.

**Figure 10G.142** Major processes relating greenhouse warming to average worldwide sea level. (From Thomas Robert 1986, Future sea-level rise and its early detection by satellite remote sensing, in *Effects of Changes in Stratospheric Ozone and Global Climate*, vol. 4.)

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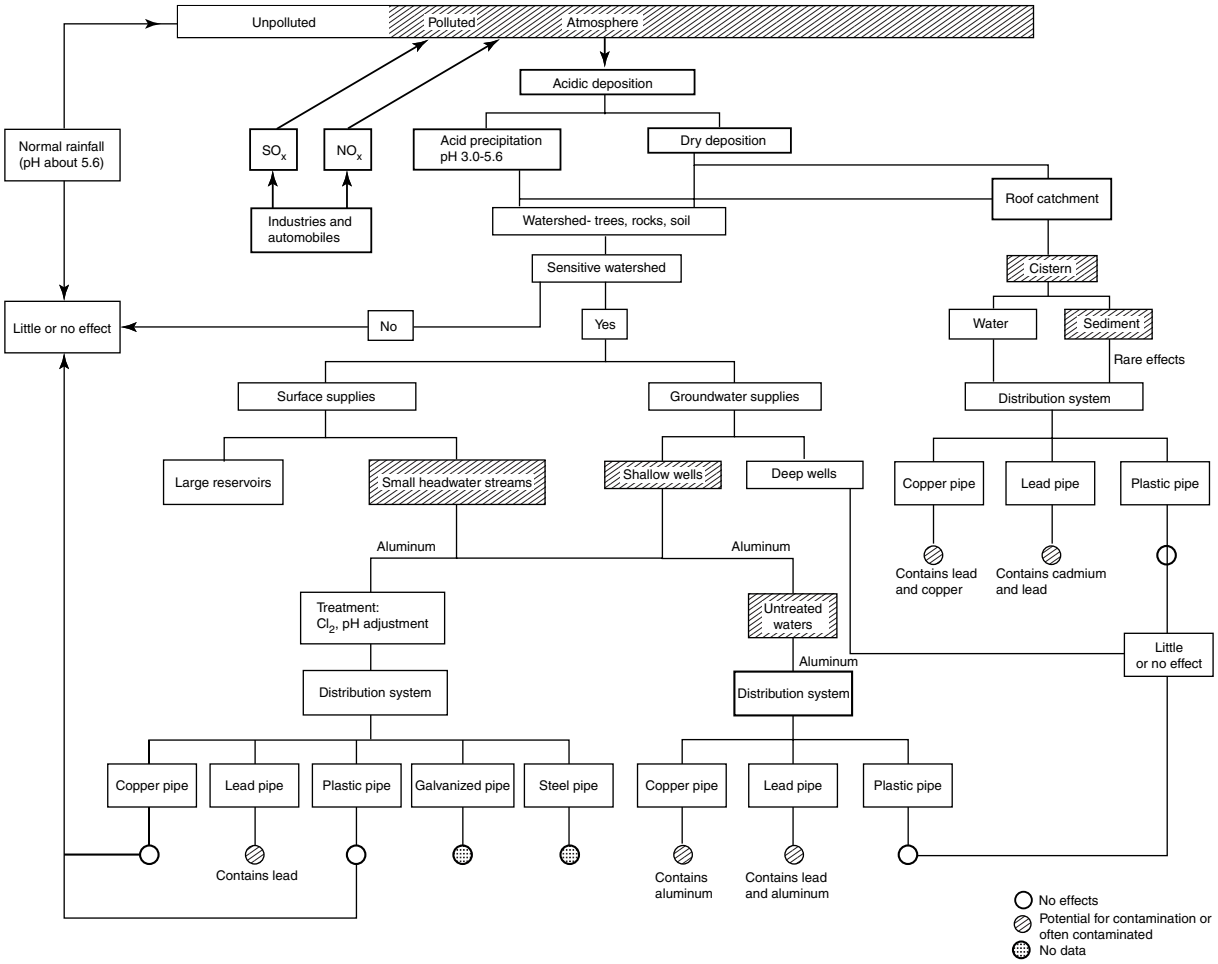


**Figure 10G.143** Probable effects of acid deposition on water supplies. (From Perry, J.A., 1984, Current research on the effects of acid deposition, *J. Am. Water Works Assoc.*, vol. 76, no. 3 Copyright. With permission.)

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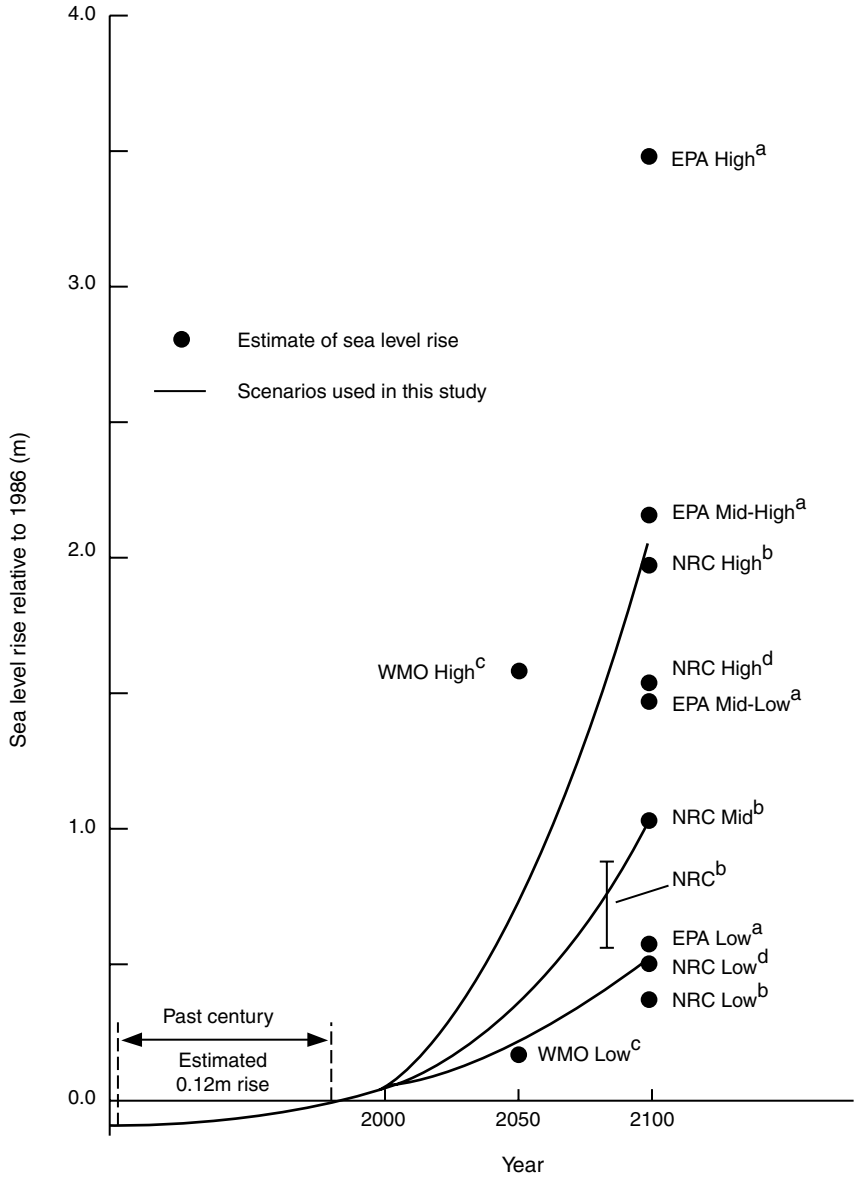


[a] Environmental Protection Agency, reported in JS Hoffman, D Keyes and JG Titus, *Projection Future Sea Level Rise*, US GPO, 1983. [b] Glacial volume estimate of National Research Council, reported in MF Meier et al, *Glaciers, Ice Sheets, and Sea Level*, National Academy Press, 1985, augmented with thermal expansion estimates of the NRC, reported in R Revelle, Probable future changes in sea level resulting from increased atmospheric carbon dioxide, in *Changing Climate*, NAP, 1983. [c] WMO International assessment of the role of carbon dioxide and other greenhouse gases in *Climate Variations and Associated Impacts*, WMO, 1985. [d] NRC, *Responding to Changes in Sea Level: Engineering Implications*, NAP, 1987.

**Figure 10G.144** Estimates of future sea level rise. (From yosemite.epa.gov.)

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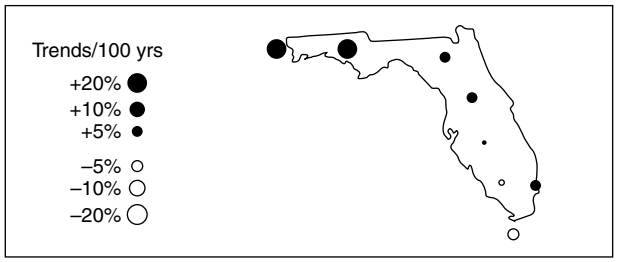


**Figure 10G.145** Precipitation trends from 1900 to present. (From Karl et al. (1996), yosemite.epa.gov.)

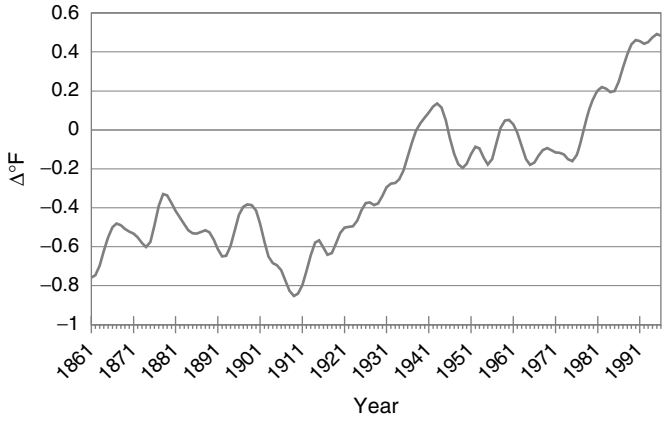


**Figure 10G.146** Global temperature changes (1861–1996). (From IPCC (1995), updated yosemite.epa.gov.)

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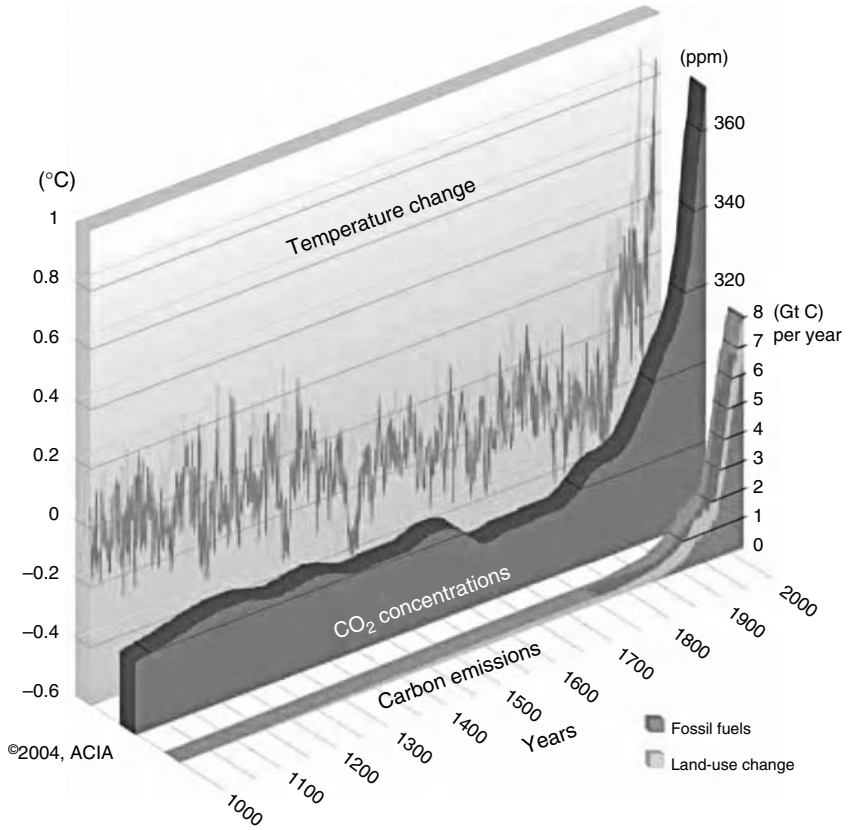


This 1000-year record tracks the rise in carbon emissions due to human activities (fossil fuel burning and land clearing) and the subsequent increase in atmospheric carbon dioxide concentrations, and air temperatures. The earlier parts of this Northern Hemisphere temperature reconstruction are derived from historical data, tree rings, and corals, while the later parts were directly measured. Measurements of carbon dioxide ($CO_2$) in air bubbles trapped in ice cores form the earlier part of the $CO_2$ record; direct atmospheric measurements of $CO_2$ concentration began in 1957.

**Figure 10G.147** 1000 years of changes in carbon emissions, $CO_2$ concentrations and temperature, www.amap.no/acia.

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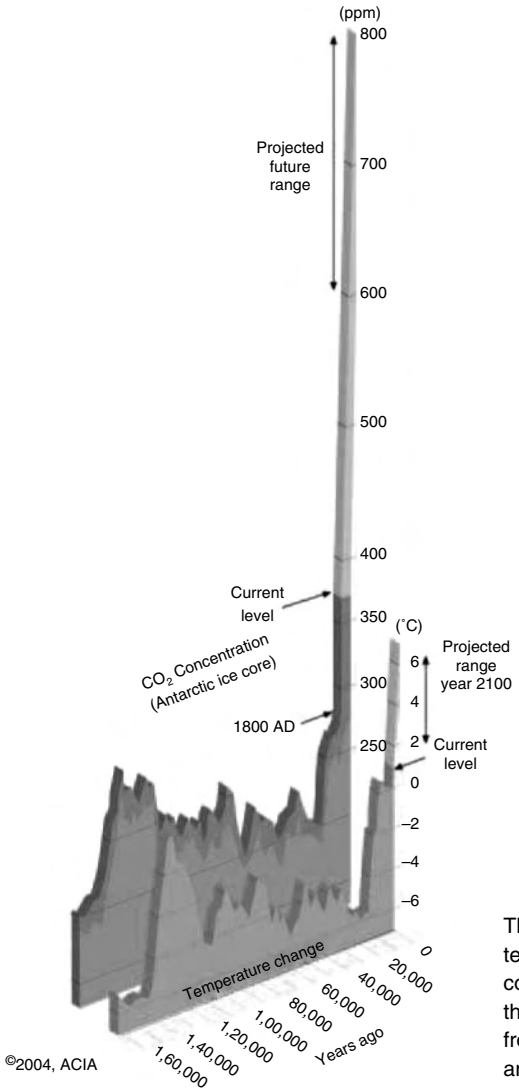


This record illustrates the relationship between temperature and atmospheric carbon dioxide concentrations over the past 160,000 yrs and the next 100 yrs. Historical data are derived from ice cores, recent data were directly measured, and model projections are used for the next 100 yrs.

**Figure 10G.148** Atmospheric carbon dioxide concentration and temperature change, www.amap.no/acia.

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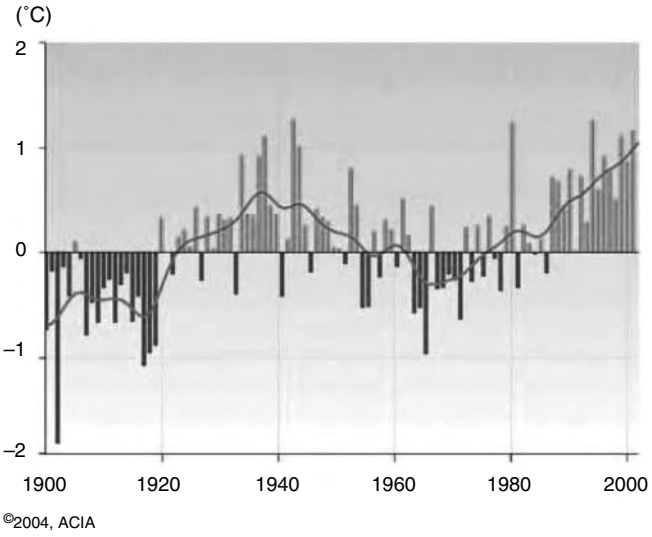
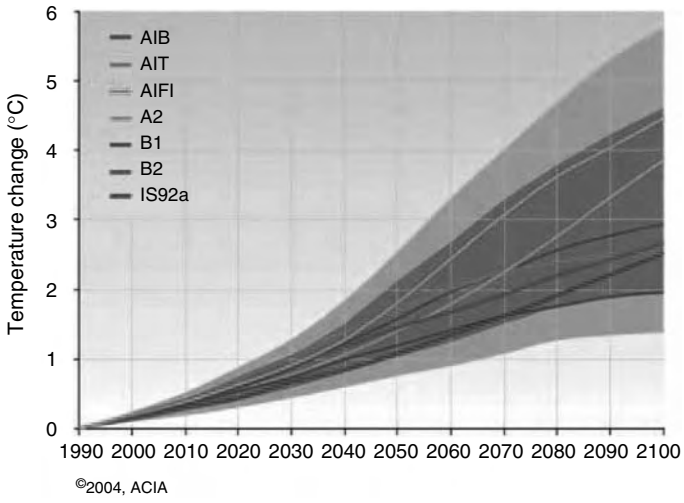



Annual average change in near surface air temperature from stations on land relative to the average for 1961–1990, for the region from 60 to 90˚N.

**Figure 10G.149** Observed arctic temperature, 1900 to present, www.amap.no/acia.




Projections of global temperature change (shown as departures from the 1990 temperature) from 1990 to 2100 for seven illustrative emissions scenarios. The brown line shows the projection of the B2 emissions scenario, the primary scenario used in this assessment and this scenario on which the maps in this report showing projected climate changes are based. The pink line shows the A2 emissions scenario, used to a lesser degree in this assessment. The dark gray band shows the range of results for all the SRES emissions scenarios with one everage model while the light gray band shows the full range of scenarios using climate models.

**Figure 10G.150** Projected global temperature rise, www.amap.no/acia.

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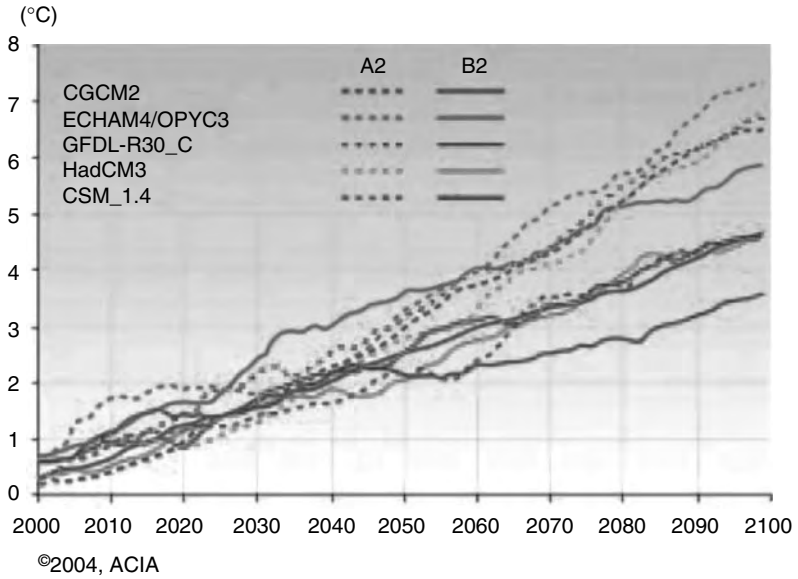
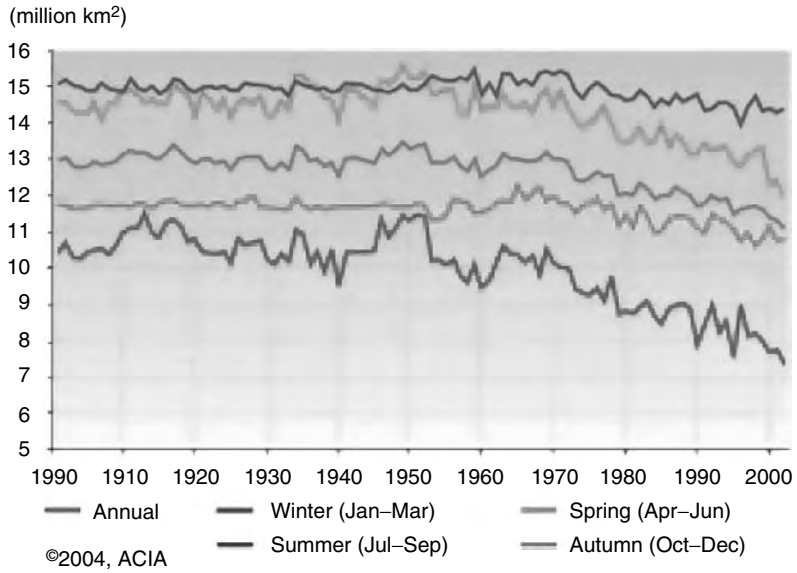



The ten lines show air temperatures for the region from 60˚N to the pole as projected by each of the five ACIA global climate models using two different emissions scenarios. The projections remain similar through about 2040, showing about a 2˚C temperature rise, but then diverge, showing increases from around 4˚ to over 7˚C by 2100. The full range of models and scenarios reviewed by the IPCC cover a wider range of possible futures. Those used in this assessment fall roughly in the middle of this range, and thus represent neither best- nor worst-case scenarios.

**Figure 10G.151** Projected arctic surface air temperatures 2000–2100 60°N—Pole: change from 1981–2000 average, www.amap.no/acia.




Annual average extent of arctic sea ice from 1900 to 2003. A decline in sea-ice extent began about 50 years ago and this decline sharpened in recent decades, corresponding with the arctic warming trend. The decrease in sea-ice extent during summer is the most dramatic of the trends.

**Figure 10G.152** Observed seasonal Arctic sea-ice extent (1900–2003), www.amap.no/acia.

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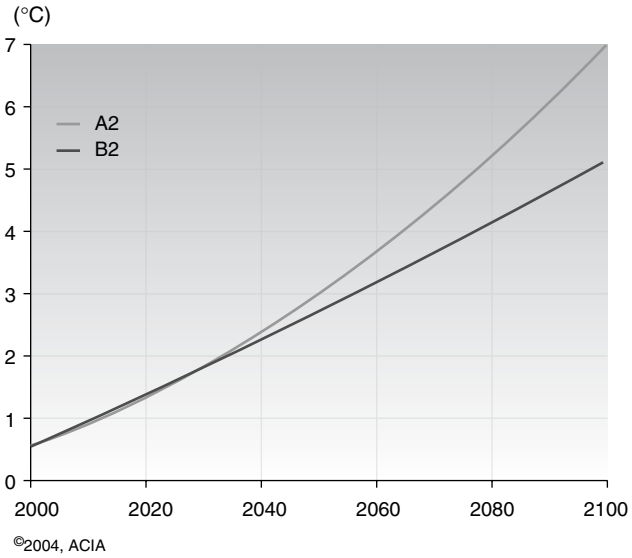


Increases in arctic temperature (for 60°–90°N) projected by an average of ACIA models for the A2 and B2 emissions scenarios, relative to 1981–2000.

**Figure 10G.153** Projected arctic temperature rise, www.amap.no/acia.

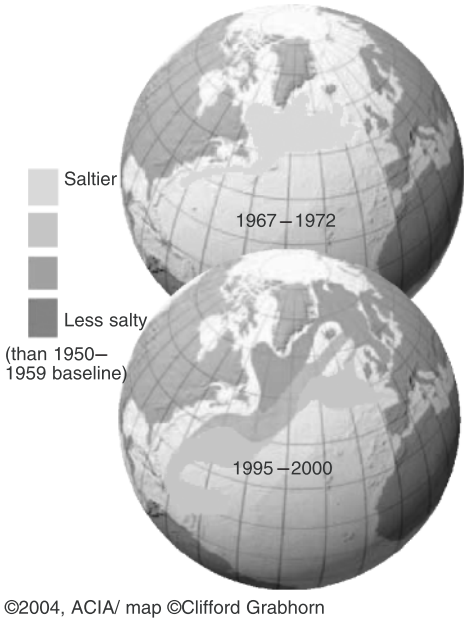


**Figure 10G.154** Reduced salinity of North Atlantic waters, www.amap.no/acia.

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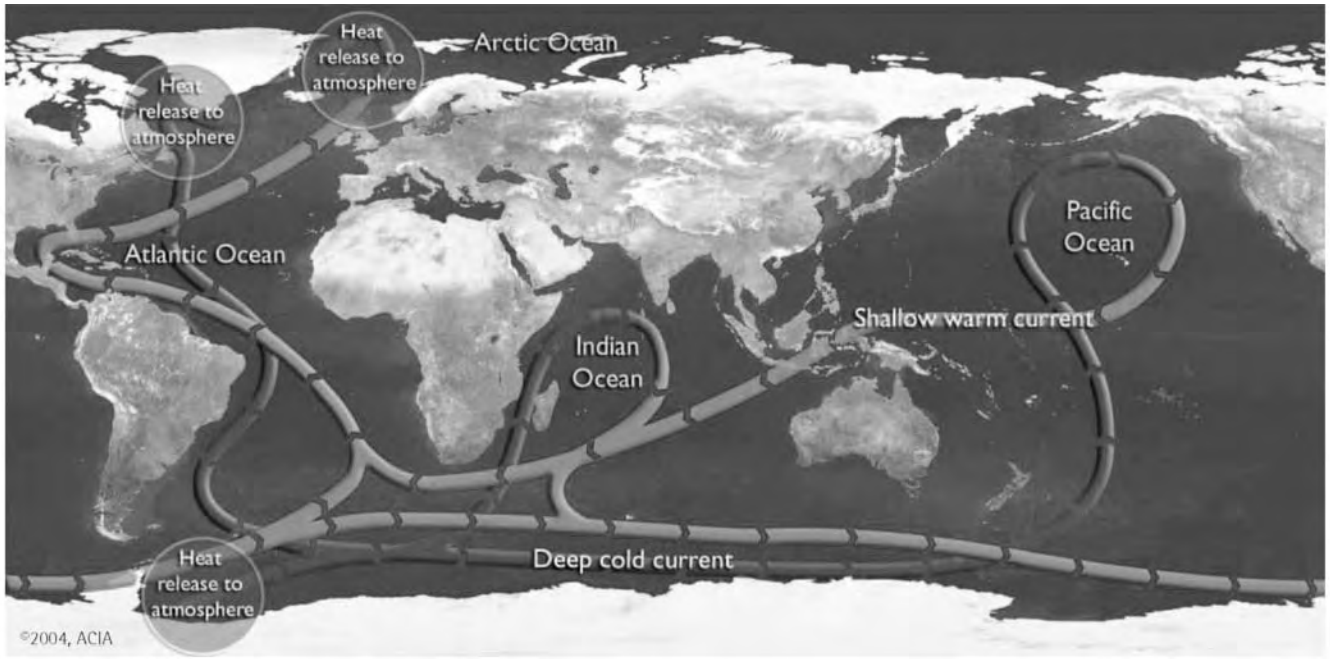


Changes in global ocean circulation can lead to abrupt climate change. Such change can be initiated by increases in arctic precipitation and river runoff, and the melting of arctic snow and ice, because these lead to reduced salinity of ocean waters in the North Atlantic.

**Figure 10G.155** Global ocean circulation, www.amap.no/acia.

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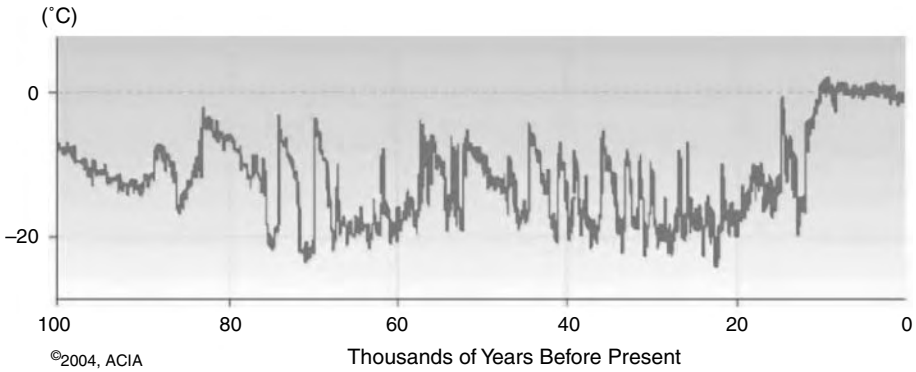
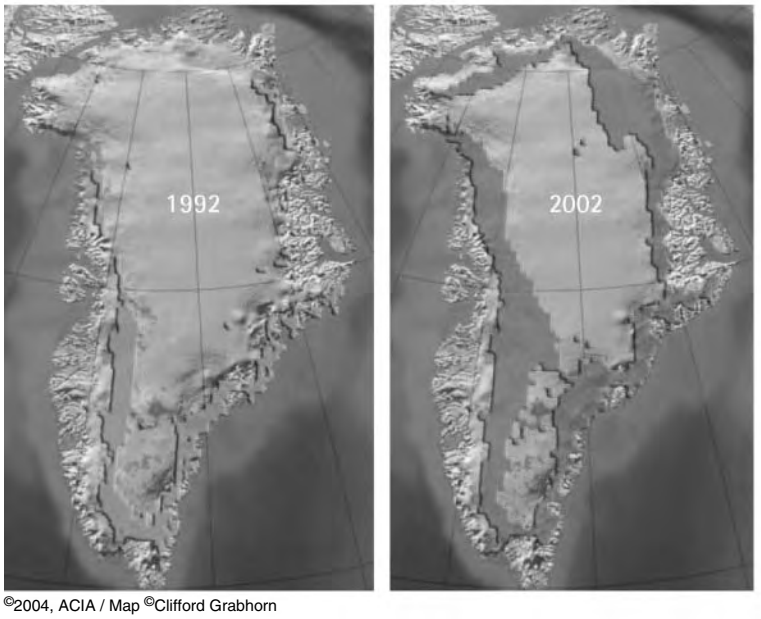
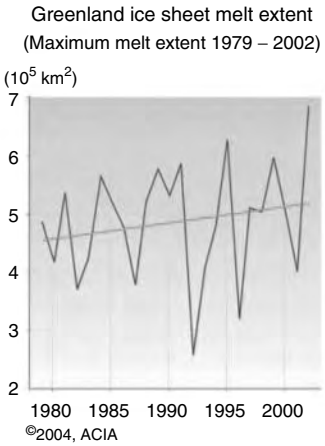



This record of temperature change (departures from present conditions) has been reconstructed from a Greenland ice core. The record demonstrates the high variability of the climate over the past 100,000 yrs. It also suggests that the climate of the past 10000 years or so, which was the time during which human civilization developed, has been unusually stable. There is concern that the rapid warming caused by the increasing concentrations of greenhouse gases due to human activities could destabilize this state.

**Figure 10G.156** 1000,000 yrs of temperature variation in Greenland, www.amap.no/acia.




©2004, ACIA / Map ©Clifford Grabhorn




Seasonal surface melt extent on the Greenland Ice Sheet has been observed by satellite since 1979 and shows an increasing trend. The melt zone, where summer warmth turns snow and ice around the edges of the ice sheet into slush and ponds of meltwater, has been expanding inland and to record high elevations in recent years. When the meltwater seeps down through cracks in the ice sheet, it may accelerate melting and, in some areas, allow the ice to slide more easily over the bedrock below, speeding its movement to the sea. In addition to contributing to global sea-level rise, this process adds fresh water to the ocean, with potential impacts on ocean circulation and thus regional climate.

**Figure 10G.157** Greenland ice sheet melt extent, www.amap.no/acia.

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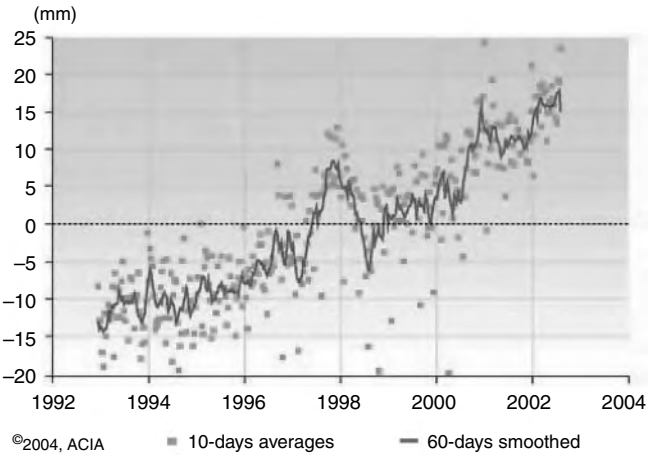
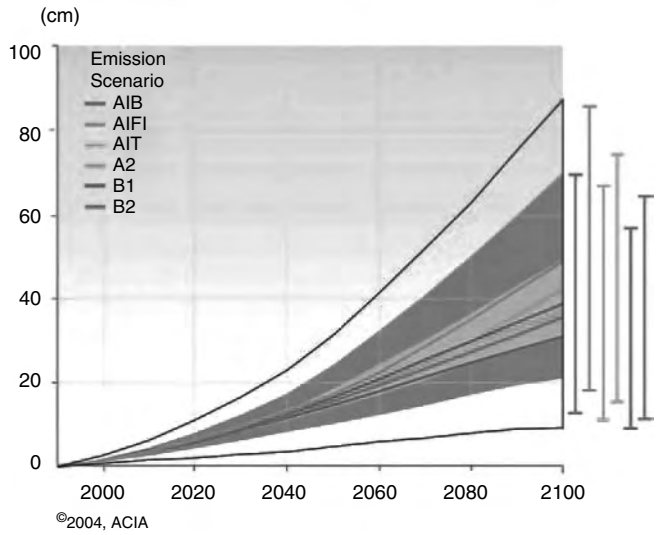



These data, from a satellite launched in 1992, show the rise in global average sea level over the past decade.

**Figure 10G.158** Observed global sea level rise, www.amap.no/acia.




The graph shows future increases in global average sea level in centimeters as projected by a suite of climate models using six IPCC emissions scenarios. The bars at right show the range projected by a group of models for the designated emissions scenarios.

**Figure 10G.159** Projected global sea level rise, www.amap.no/acia.

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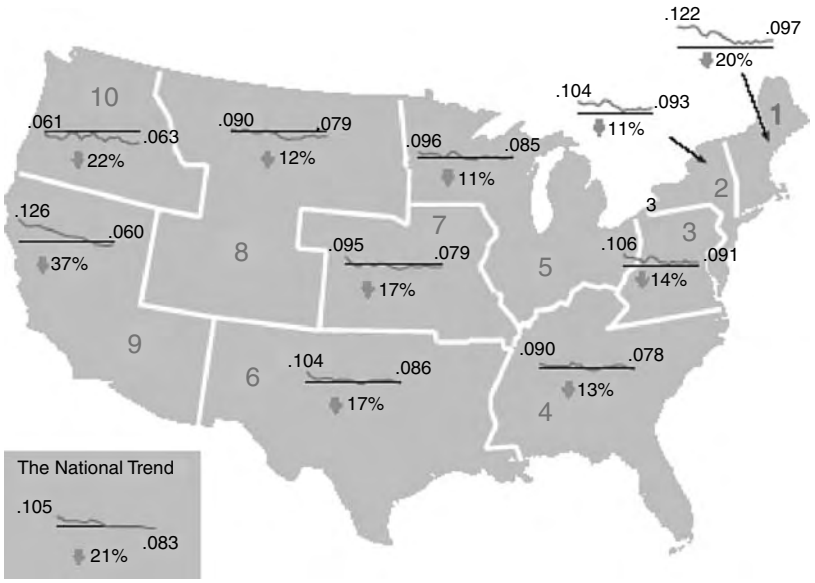


**Figure 10G.160** Trend in fourth highest daily maximum 8-hour ozone concentration (ppm) by EPA region, 1980–2003, www.epa.gov/airtrends.

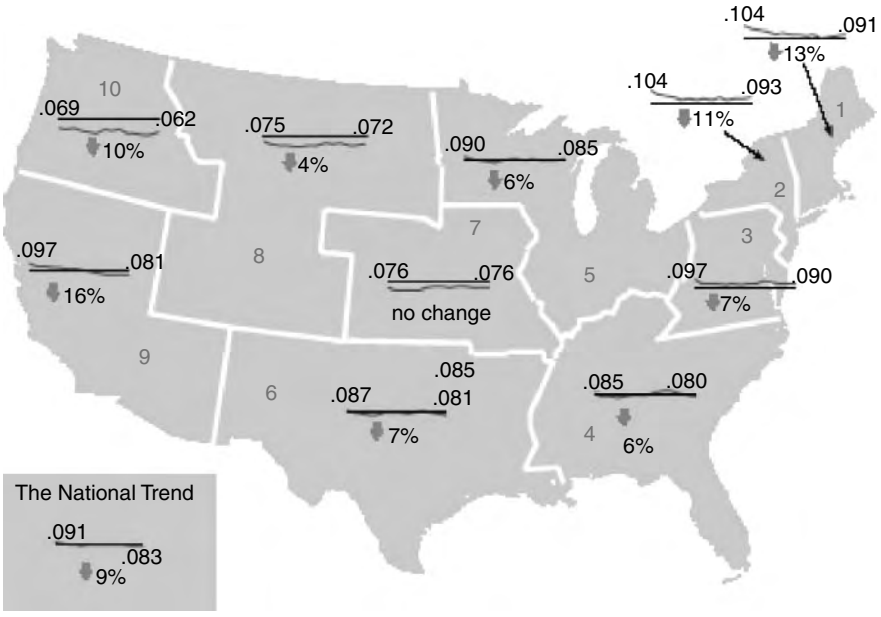


**Figure 10G.161** Trend in fourth highest daily maximum 8-hour ozone concentration (ppm) by EPA region 1990–2003, www.epa.gov/airtrends.

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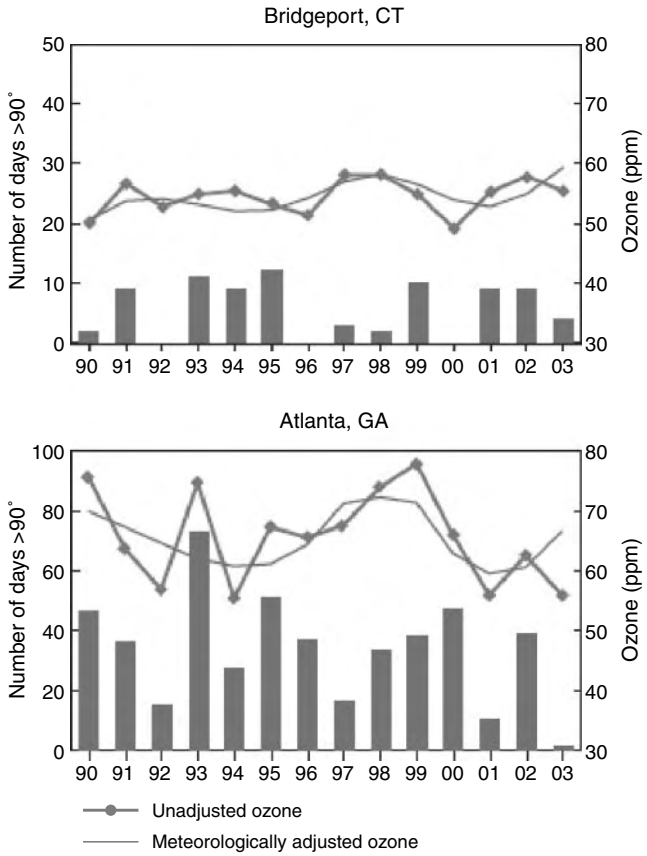


Ozone concentrations are Annual Average Daily Maximum 8-hr values between June and August.

**Figure 10G.162** Number of days daily maximum temperatures exceed 90° (bar) compared to unadjusted ozone (red line) and meteorologically adjusted ozone (blue line) for Bridgeport and Atlanta, 1990–2003. Ozone concentrations are annual average daily maximum 8-hr values between June and August, www.epa.gov/airtrends.

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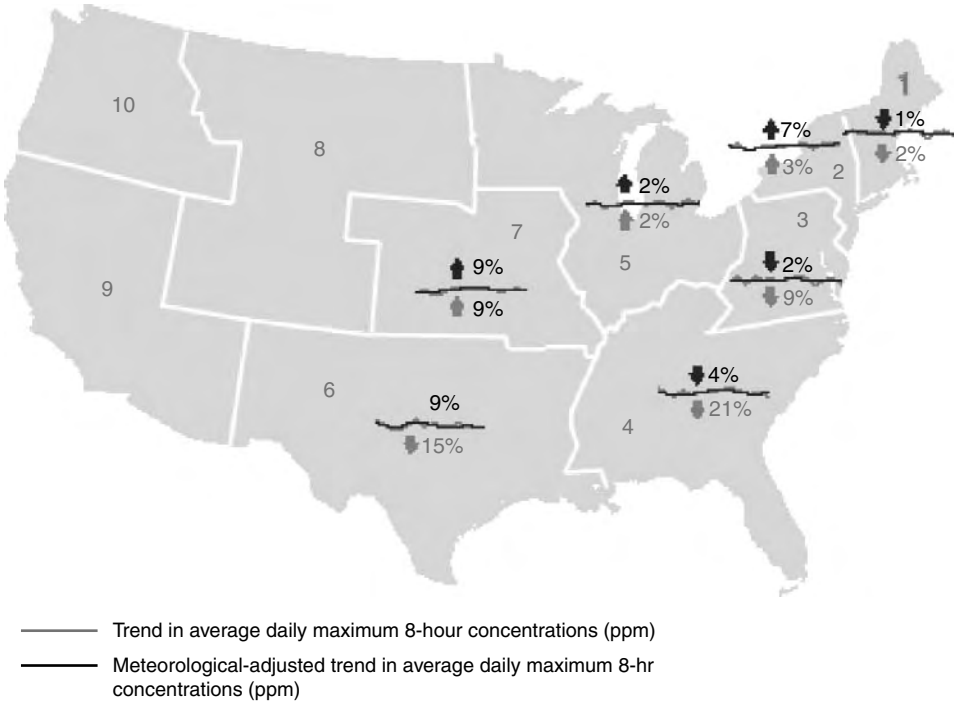


**Figure 10G.163** Trends in unadjusted and meteorologically adjusted ozone levels by EPA region, 1990–2003, www.epa.gov/airtrends.

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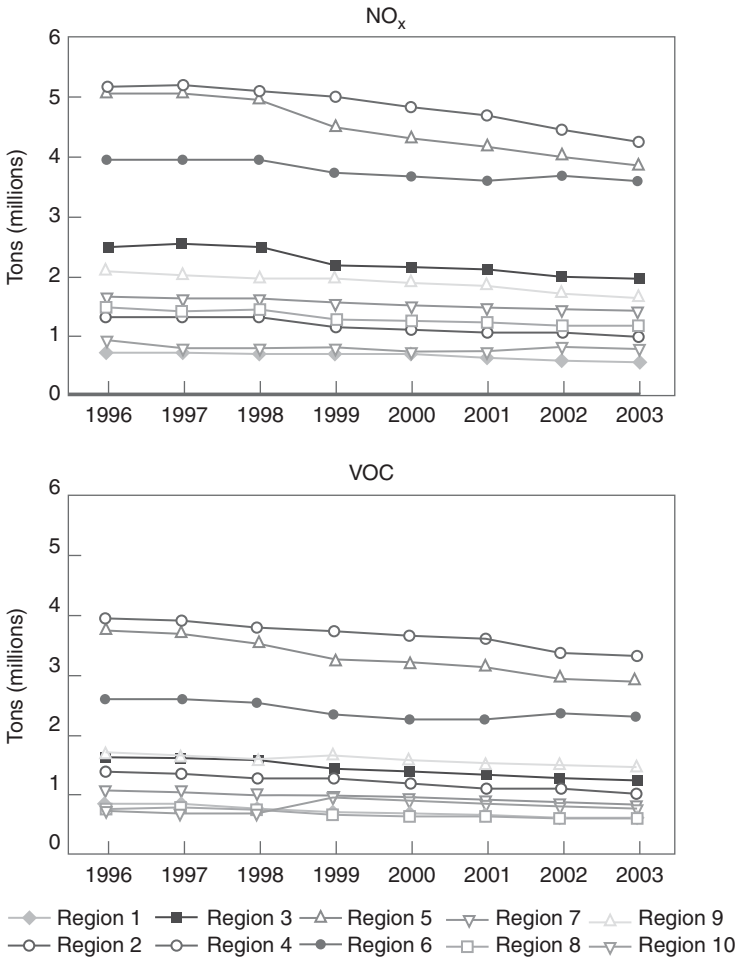


**Figure 10G.164** $NO_x$ and VOC emissions in Region 10 from 1998 to 1999 is due to a change in methodology rather than a true emission increase, www.epa.gov/airtrends.

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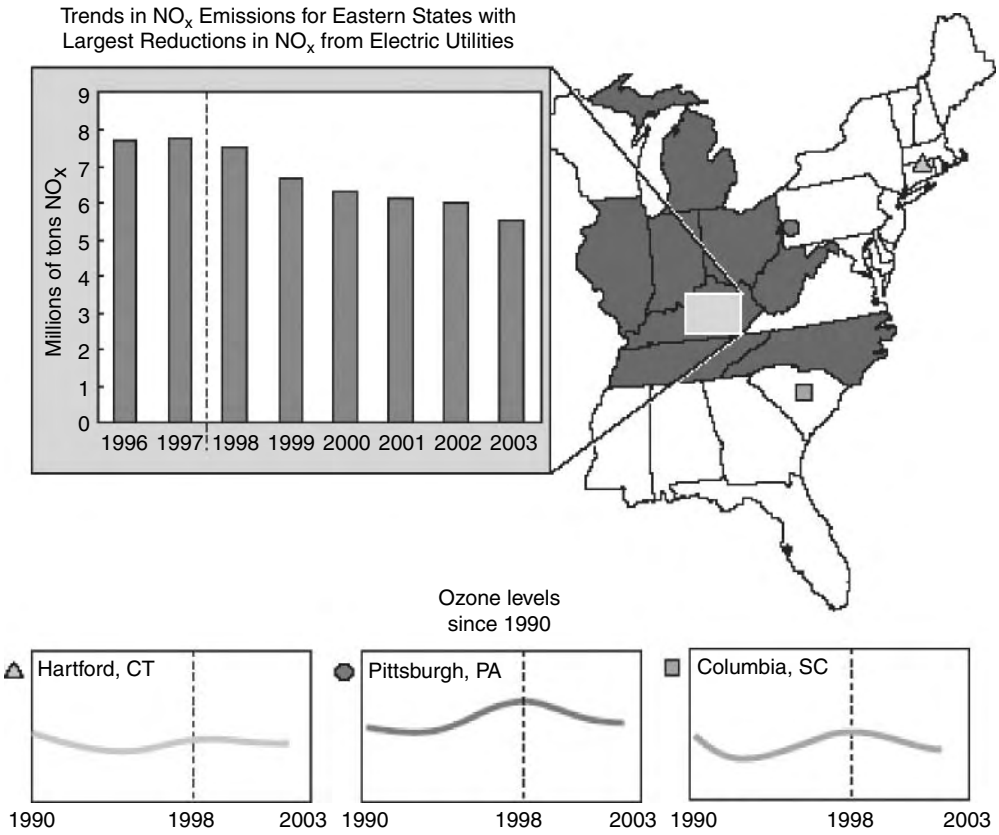


**Figure 10G.165** Ozone trends for selected urban areas and corresponding regional emission trends, www.epa.gov/airtrends.

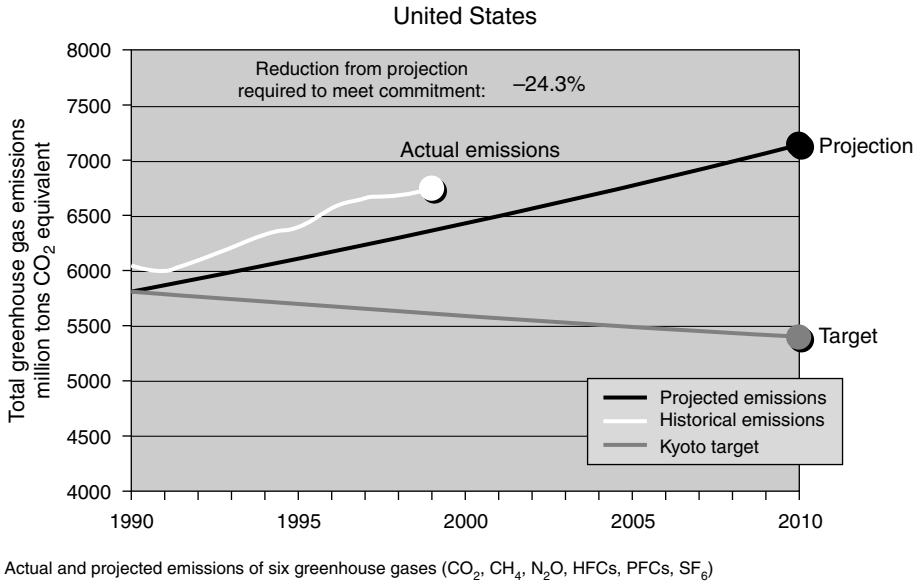


**Figure 10G.166** Actual and projected emission of six greenhouse gases ($CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$). (From Actual emissions UNFCCC/SB12000/11 Table B.1 Projected emissions UNFCCCM998/Add 2 Table C.6, www.epa.gov.)

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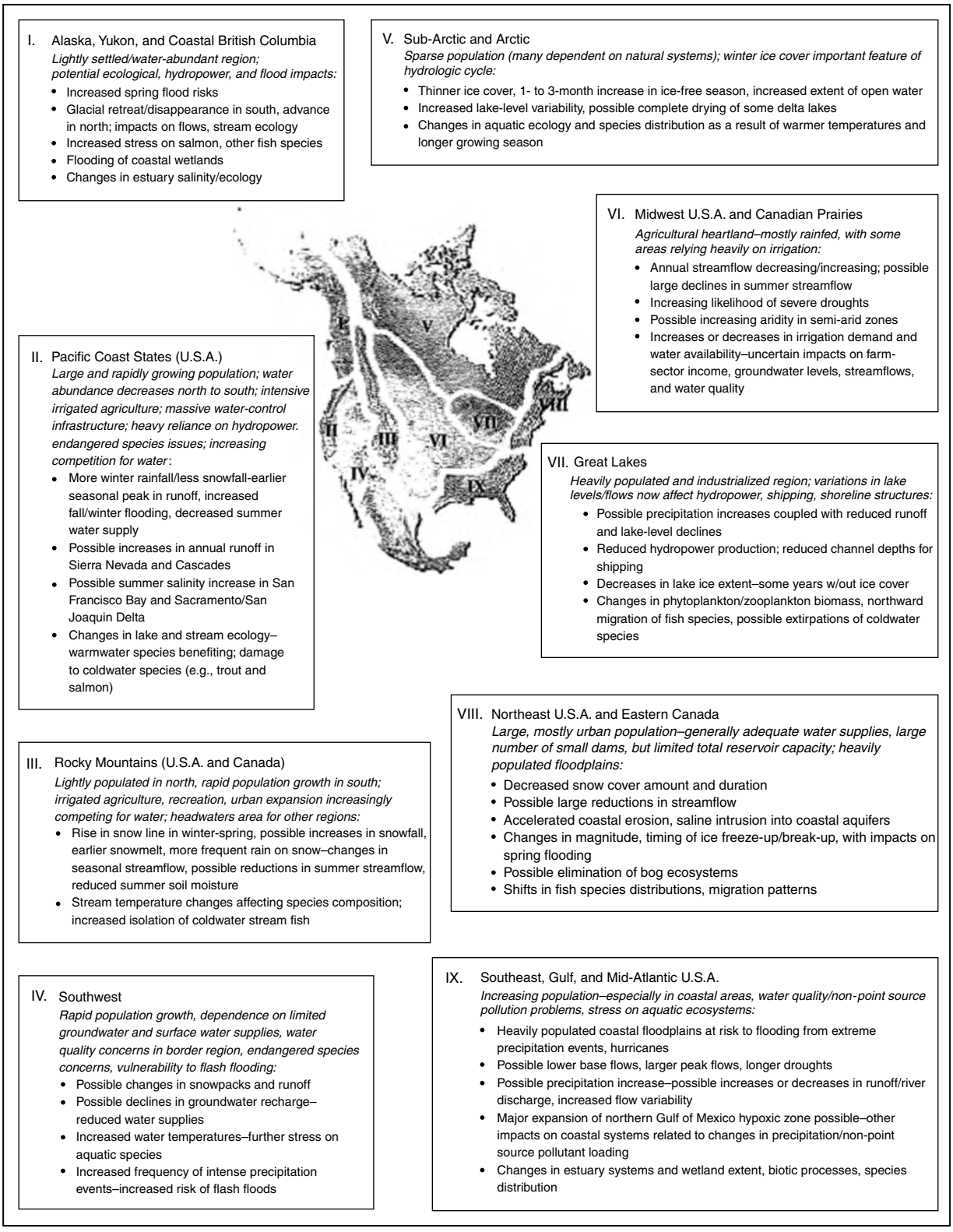


**Figure 10G.167** Possible water resources impacts in North America, www.epa.gov/oar.

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**Table 10G.197 Percent Change in Air Quality and Emissions**

| | Percent Change in Air Quality | |
|---|---|---|
| | **1983–2002** | **1993–2002** |
| $NO_2$ | −21 | −11 |
| $O_3$ | | |
| 1-h | −22 | −2[a] |
| 8-h | −14 | +4[a] |
| $SO_2$ | −54 | −39 |
| $PM_{10}$ | — | −13 |
| $PM_{2.5}$ | — | −8[b] |
| CO | −65 | −42 |
| Pb | −94 | −57 |
| | **Percent Change in Emissions** | |
| $NO_2$ | −15 | −12 |
| VOC | −40 | −25 |
| $SO_2$ | −33 | −31 |
| $PM_{10}$[c] | −34[d] | −22 |
| $PM_{2.5}$[c] | — | −17 |
| CO | −41 | −21 |
| Pb[e] | −93 | −5 |

*Note:* Trend data not available. Negative numbers indicate improvements in air quality or reductions in emission. Positive numbers show where emissions have increased or air quality has gotten worse.

[a] Not statistically significant.
[b] Based on percentage change from 1999.
[c] Includes only directly emitted particles.
[d] Based on percentage change from 1985. Emission estimates prior to 1985 are uncertain.
[e] Lead emissions are included in the toxic air pollutant emissions inventory and are presented for 1982–2001.

*Source*: From www.epa.gov/airtrends/images/enlarge/sixpoll-1lg.gif.

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**Table 10G.198 Lead (Pb) National Totals (Thousands of Tons)**

| Source Category | Lead (Pb) National Totals (Thousands of Tons) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1970 | 1975 | 1980 | 1985 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
| Fuel Comb. Elec. Util. | 0.327293 | 0.229773 | 0.128825 | 0.063955 | 0.064244 | 0.061487 | 0.058603 | 0.061661 | 0.062 | 0.057 | 0.061 | 0.063925 | 0.068881 | 0.532 |
| Fuel Comb. Industrial | 0.236916 | 0.075254 | 0.059612 | 0.03017 | 0.017612 | 0.017531 | 0.017872 | 0.018884 | 0.019 | 0.018 | 0.016 | 0.01581 | 0.014985 | 0.414 |
| Fuel Comb. Other | 10.05174 | 10.0423 | 4.110847 | 0.421131 | 0.417995 | 0.416037 | 0.414095 | 0.415973 | 0.415 | 0.415 | 0.415 | 0.413444 | 0.410383 | 0.014 |
| Chemical & Allied Product Mfg | 0.102811 | 0.120227 | 0.104387 | 0.118276 | 0.135801 | 0.132297 | 0.093402 | 0.092 | 0.096 | 0.163 | 0.167 | 0.187825 | 0.194212 | 0.027 |
| Metals Processing | 24.22351 | 9.923236 | 3.025672 | 2.096969 | 2.169625 | 1.974318 | 1.77442 | 1.899989 | 2.027 | 2.049 | 2.055 | 2.080743 | 1.991153 | 1.002 |
| Petroleum & Related Industries | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.013 |
| Other Industrial Processes | 2.028097 | 1.337357 | 0.807826 | 0.315972 | 0.168558 | 0.166802 | 0.056379 | 0.055 | 0.054 | 0.059 | 0.051 | 0.054315 | 0.053518 | 0.321 |
| Solvent Utilization | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.273 |
| Storage & Transport | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0007 |
| Waste Disposal & Recycling | 2.2 | 1.59515 | 1.21002 | 0.870866 | 0.804311 | 0.808 | 0.812 | 0.825 | 0.83 | 0.604 | 0.787782 | 0.798363 | 0.805779 | 0.178 |
| Highway Vehicles | 171.9611 | 130.2061 | 60.50133 | 18.05194 | 0.420736 | 0.017849 | 0.018332 | 0.018796 | 0.01903 | 0.019355 | 0.01919 | 0.019996 | 0.02116 | 0 |
| Off-highway | 9.737102 | 6.129554 | 4.204813 | 0.921121 | 0.776437 | 0.574333 | 0.565182 | 0.528556 | 0.525034 | 0.544384 | 0.505382 | 0.502712 | 0.497295 | 0.552 |
| Miscellaneous | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.029 |
| Total | 220.869 | 159.659 | 74.153 | 22.890 | 4.975 | 4.169 | 3.810 | 3.916 | 4.047 | 3.929 | 4.077 | 4.137 | 4.057 | 3.356 |
| Fires | 0 | 0 | 0 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Total without Fires | 220.869 | 159.659 | 74.153 | 22.890 | 4.975 | 4.169 | 3.810 | 3.916 | 4.047 | 3.929 | 4.077 | 4.137 | 4.057 | 3.356 |

*Source*: From www.epa.gov/airtrends/pdfs/leadnational.pdf.

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**Table 10G.199 Volatile Organic Compounds (VOC) National Totals (Thousands of Tons)**

| | Volatile Organic Compounds (VOC) National Totals (Thousands of Tons) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Source Category** | **1970** | **1975** | **1980** | **1985** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** |
| Fuel Comb. Elec. Util. | 30 | 40 | 45 | 32 | 47 | 44 | 44 | 45 | 45 | 44 | 50 | 52 | 56 | 54 | 62 | 61 | 52 | 56 |
| Fuel Comb. Industrial | 150 | 150 | 157 | 134 | 182 | 196 | 187 | 186 | 196 | 206 | 179 | 175 | 174 | 172 | 173 | 176 | 170 | 170 |
| Fuel Comb. Other | 541 | 470 | 848 | 1,403 | 776 | 835 | 884 | 762 | 748 | 823 | 893 | 893 | 889 | 919 | 949 | 950 | 790 | 878 |
| Chemical & Allied Product Mfg | 1,341 | 1,351 | 1,595 | 881 | 634 | 710 | 715 | 701 | 691 | 660 | 388 | 388 | 394 | 251 | 254 | 262 | 214 | 218 |
| Metals Processing | 394 | 336 | 273 | 76 | 122 | 123 | 124 | 124 | 126 | 125 | 73 | 78 | 78 | 66 | 67 | 71 | 69 | 72 |
| Petroleum & Related Industries | 1,194 | 1,342 | 1,440 | 703 | 611 | 640 | 632 | 649 | 647 | 642 | 477 | 487 | 485 | 457 | 428 | 441 | 375 | 380 |
| Other Industrial Processes | 270 | 235 | 237 | 390 | 401 | 391 | 414 | 442 | 438 | 450 | 435 | 438 | 443 | 438 | 454 | 420 | 406 | 412 |
| Solvent Utilization | 7,174 | 5,651 | 6,584 | 5,699 | 5,750 | 5,782 | 5,901 | 6,016 | 6,162 | 6,183 | 5,477 | 5,621 | 5,149 | 5,036 | 4,831 | 5,012 | 4,692 | 4,562 |
| Storage & Transport | 1,954 | 2,181 | 1,975 | 1,747 | 1,490 | 1,532 | 1,583 | 1,600 | 1,629 | 1,652 | 1,294 | 1,328 | 1,327 | 1,237 | 1,176 | 1,192 | 1,205 | 1,178 |
| Waste Disposal & Recycling | 1,984 | 984 | 758 | 979 | 986 | 999 | 1,010 | 1,046 | 1,046 | 1,067 | 509 | 518 | 535 | 487 | 415 | 420 | 457 | 427 |
| Highway Vehicles | 16,910 | 15,392 | 13,869 | 12,354 | 9,388 | 8,860 | 8,332 | 7,804 | 7,277 | 6,749 | 6,221 | 5,985 | 5,859 | 5,681 | 5,325 | 4,952 | 4,543 | 4,428 |
| Off-highway | 1,616 | 1,917 | 2,192 | 2,439 | 2,662 | 2,709 | 2,754 | 2,799 | 2,845 | 2,890 | 2,935 | 2,752 | 2,673 | 2,682 | 2,644 | 2,622 | 2,688 | 2,572 |
| Miscellaneous | 1,101 | 716 | 1,134 | 566 | 1,059 | 756 | 486 | 556 | 720 | 551 | 1,940 | 816 | 718 | 791 | 733 | 532 | 883 | 704 |
| Miscellaneous | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 34,659 | 30,765 | 31,106 | 27,404 | 24,108 | 23,577 | 23,066 | 22,730 | 22,569 | 22,041 | 20,871 | 19,530 | 18,782 | 18,270 | 17,512 | 17,111 | 16,544 | 16,056 |
| Fires | 917 | 587 | 1,024 | 465 | 983 | 678 | 407 | 478 | 638 | 464 | 1,870 | 744 | 645 | 667 | 615 | 412 | 785 | 627 |
| Total without Fires | 33,742 | 30,178 | 30,082 | 26,939 | 23,125 | 22,899 | 22,659 | 22,252 | 21,931 | 21,577 | 19,001 | 18,786 | 18,136 | 17,603 | 16,898 | 16,699 | 15,759 | 15,429 |

*Source*: From www.epa.gov/airtrends/pdfs/vocnational.



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**Table 10G.200 Sulfur Dioxide ($SO_2$) National Totals (Thousands of Tons)**

| | Sulfur Dioxide ($SO_2$) National Totals (Thousands of Tons) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Source Category** | **1970** | **1975** | **1980** | **1985** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** |
| Fuel Comb. Elec. Util. | 17,398 | 18,268 | 17,469 | 16,272 | 15,909 | 15,784 | 15,416 | 15,189 | 14,889 | 12,080 | 12,767 | 13,195 | 13,416 | 12,583 | 11,396 | 10,850 | 10,293 | 10,929 |
| Fuel Comb. Industrial | 4,568 | 3,310 | 2,951 | 3,169 | 3,550 | 3,256 | 3,292 | 3,284 | 3,218 | 3,357 | 2,849 | 2,805 | 2,740 | 2,135 | 2,139 | 2,243 | 2,299 | 2,227 |
| Fuel Comb. Other | 1,490 | 1,082 | 971 | 579 | 831 | 755 | 784 | 772 | 780 | 793 | 636 | 648 | 586 | 620 | 628 | 642 | 575 | 596 |
| Chemical & Allied Product Mfg | 591 | 367 | 280 | 456 | 297 | 280 | 279 | 269 | 275 | 286 | 255 | 259 | 261 | 325 | 338 | 342 | 328 | 329 |
| Metals Processing | 4,775 | 2,849 | 1,842 | 1,042 | 726 | 612 | 615 | 603 | 562 | 530 | 389 | 407 | 405 | 304 | 313 | 332 | 271 | 285 |
| Petroleum & Related Industries | 881 | 727 | 734 | 505 | 430 | 378 | 416 | 383 | 379 | 369 | 335 | 344 | 342 | 312 | 316 | 319 | 348 | 323 |
| Other Industrial Processes | 846 | 740 | 918 | 425 | 399 | 396 | 396 | 392 | 398 | 403 | 386 | 409 | 415 | 382 | 410 | 429 | 416 | 426 |
| Solvent Utilization | NA | NA | NA | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| Storage & Transport | NA | NA | NA | 4 | 7 | 10 | 9 | 5 | 2 | 2 | 5 | 5 | 5 | 6 | 6 | 7 | 5 | 6 |
| Waste Disposal & Recycling | 8 | 46 | 33 | 34 | 42 | 44 | 44 | 71 | 59 | 47 | 32 | 33 | 34 | 34 | 34 | 35 | 28 | 32 |
| Highway Vehicles | 273 | 334 | 394 | 455 | 503 | 469 | 436 | 402 | 369 | 335 | 302 | 304 | 300 | 300 | 260 | 248 | 275 | 256 |
| Off-highway | 278 | 301 | 323 | 354 | 371 | 379 | 385 | 392 | 399 | 406 | 413 | 422 | 432 | 475 | 437 | 440 | 420 | 443 |
| Miscellaneous | 110 | 20 | 11 | 11 | 12 | 11 | 10 | 10 | 15 | 10 | 15 | 7 | 6 | 67 | 70 | 44 | 91 | 88 |
| Miscellaneous | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 31,218 | 28,043 | 25,925 | 23,307 | 23,076 | 22,375 | 22,082 | 21,772 | 21,346 | 18,619 | 18,385 | 18,840 | 18,944 | 17,545 | 16,347 | 15,932 | 15,353 | 15,943 |
| Fires | NA | NA | NA | NA | 12 | 12 | 9 | 9 | 14 | 10 | 15 | 6 | 6 | 67 | 69 | 44 | 91 | 95 |
| Total without Fires | 31,218 | 28,043 | 25,925 | 23,307 | 23,064 | 22,363 | 22,073 | 21,763 | 21,332 | 18,609 | 18,370 | 18,834 | 18,939 | 17,478 | 16,278 | 15,888 | 15,263 | 15,848 |

*Source*: From www.epa.gov/airtrends/2005.

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**Table 10G.201 Nitrogen Oxides (Nox) National Emissions Totals (Thousands of Tons)**

| | Nitrogen Oxides ($NO_x$) National Emissions Totals (Thousands of Tons) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Source Category** | **1970** | **1975** | **1980** | **1985** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** |
| Fuel comb. Elec. Util. | 4,900 | 5,694 | 7,024 | 6,127 | 6,663 | 6,519 | 6,504 | 6,651 | 6,565 | 6,384 | 6,164 | 6,276 | 6,232 | 5,721 | 5,330 | 4,917 | 4,699 | 4,458 |
| Fuel Comb. Industrial | 4,325 | 4,007 | 3,555 | 3,209 | 3,035 | 2,979 | 3,071 | 3,151 | 3,147 | 3,144 | 3,151 | 3,101 | 3,050 | 2,709 | 2,723 | 2,757 | 2,870 | 2,775 |
| Fuel Comb. Other | 836 | 785 | 741 | 712 | 1,196 | 1,281 | 1,353 | 1,308 | 1,303 | 1,298 | 1,197 | 1,177 | 1,101 | 768 | 766 | 779 | 725 | 729 |
| Chemical & Allied Product Mfg | 271 | 221 | 213 | 262 | 168 | 165 | 163 | 155 | 160 | 158 | 125 | 127 | 129 | 102 | 105 | 107 | 105 | 102 |
| Metals Processing | 77 | 73 | 65 | 87 | 97 | 76 | 81 | 83 | 91 | 98 | 83 | 89 | 89 | 86 | 89 | 94 | 84 | 94 |
| Petroleum & Related Industries | 240 | 63 | 72 | 124 | 153 | 121 | 148 | 123 | 117 | 110 | 139 | 143 | 143 | 120 | 122 | 124 | 149 | 137 |
| Other Industrial Processes | 187 | 182 | 205 | 327 | 378 | 352 | 361 | 370 | 389 | 399 | 433 | 460 | 467 | 451 | 479 | 504 | 487 | 504 |
| Solvent Utilization | NA | NA | NA | 2 | 1 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 4 | 4 | 4 | 8 | 7 |
| Storage & Transport | NA | NA | NA | 2 | 3 | 6 | 5 | 5 | 5 | 6 | 15 | 16 | 16 | 14 | 15 | 16 | 16 | 16 |
| Waste Disposal & Recycling | 440 | 159 | 111 | 87 | 91 | 95 | 96 | 123 | 114 | 99 | 153 | 157 | 163 | 162 | 129 | 130 | 152 | 137 |
| Highway Vehicles | 12,624 | 12,061 | 11,493 | 10,932 | 9,592 | 9,449 | 9,306 | 9,162 | 9,019 | 8,876 | 8,733 | 8,792 | 8,619 | 8,371 | 8,394 | 7,774 | 7,365 | 7,381 |
| Off-highway | 2,652 | 2,968 | 3,353 | 3,576 | 3,781 | 3,849 | 3,915 | 3,981 | 4,047 | 4,113 | 4,179 | 4,178 | 4,156 | 4,084 | 4,167 | 4,156 | 4,086 | 4,103 |
| Miscellaneous | 330 | 165 | 248 | 310 | 369 | 286 | 255 | 241 | 390 | 267 | 412 | 187 | 179 | 251 | 276 | 184 | 356 | 289 |
| Miscellaneous | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 26,883 | 26,377 | 27,079 | 25,757 | 25,529 | 25,179 | 25,260 | 25,357 | 25,349 | 24,956 | 24,787 | 24,705 | 24,348 | 22,845 | 22,598 | 21,549 | 21,102 | 20,728 |
| Fires | NA | NA | NA | NA | 362 | 247 | 234 | 234 | 382 | 258 | 405 | 179 | 172 | 236 | 263 | 171 | 341 | 236 |
| Total without Fires | 26,883 | 26,377 | 27,079 | 25,757 | 25,167 | 24,932 | 25,026 | 25,123 | 24,967 | 24,698 | 24,382 | 24,526 | 24,176 | 22,609 | 22,335 | 21,378 | 20,761 | 20,492 |

*Source*: From www.epa.gov/airtrends/pdfs/noxnational.pdf.



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**Table 10G.202 National Air Pollutant Emissions Estimates (Fires and Dust Excluded) for Major Pollutants**

| | Millions of Tons Per Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1970** | **1975** | **1980** | **1985[a]** | **1990** | **1995** | **2000[a]** | **2004[b]** |
| Carbon monoxide (CO) | 197.3 | 184.0 | 177.8 | 169.6 | 143.6 | 120.0 | 102.4 | 87.2 |
| Nitrogen oxides ($NO_x$)[c] | 26.9 | 26.4 | 27.1 | 25.8 | 25.2 | 24.7 | 22.3 | 18.8 |
| Particulate matter (PM)[d] | | | | | | | | |
| PM10 | 12.2[a] | 7.0 | 6.2 | 3.6 | 3.2 | 3.1 | 2.3 | 2.5 |
| PM2.5[e] | NA | NA | NA | NA | 2.3 | 2.2 | 1.8 | 1.9 |
| Sulfur dioxide ($SO_2$) | 31.2 | 28.0 | 25.9 | 23.3 | 23.1 | 18.6 | 16.3 | 15.2 |
| Volatile organic compounds (VOC) | 33.7 | 30.2 | 30.1 | 26.9 | 23.1 | 21.6 | 16.9 | 15.0 |
| Lead[f] | 0.221 | 0.16 | 0.074 | 0.022 | 0.005 | 0.004 | 0.003 | 0.003 |
| Totals[g] | 301.5 | 275.8 | 267.2 | 249.2 | 218.2 | 188.0 | 160.2 | 138.7 |

[a] In 1985 and 1996 EPA refined its methods for estimating emissions. Between 1970 and 1975, EPA revised its methods for estimating particulate matter emissions.
[b] The estimates for 2004 are preliminary.
[c] $NO_x$ estimates prior to 1990 include emissions from fires. Fires would represent a small percentage of the $NO_x$ emissions.
[d] PM estimates do not include condensable PM, or the majority of PM2.5 that is formed in the atmosphere from "precursor" gases such as $SO_2$ and $NO_x$.
[e] EPA has not estimated PM2.5 emissions prior to 1990.
[f] The 1999 estimate for lead is used to represent 2000 and 2003 because lead estimates do not exist for these years.
[g] PM2.5 emissions are not added when calculating the total because they are included in the PM10 estimate.

*Source*: From www.epa.gov/airtrends/2005/econ-emission.html.

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**Table 10G.203 Carbon Monoxide (CO) National Emissions Totals (Thousands of Tons)**

| | Carbon Monoxide (CO) National Emissions Totals (Thousands of Tons) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Source Category** | **1970** | **1975** | **1980** | **1985** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** |
| Fuel Comb. Elec. Util. | 237 | 276 | 322 | 291 | 363 | 349 | 350 | 363 | 370 | 372 | 408 | 423 | 451 | 496 | 484 | 485 | 499 | 530 |
| Fuel Comb. Industrial | 770 | 763 | 750 | 670 | 879 | 920 | 955 | 1,043 | 1,041 | 1,056 | 1,188 | 1,162 | 1,151 | 1,213 | 1,219 | 1,253 | 1,436 | 1,377 |
| Fuel Comb. Other | 3,625 | 3,441 | 6,230 | 7,525 | 4,269 | 4,587 | 4,849 | 4,181 | 4,108 | 4,506 | 2,741 | 2,742 | 2,727 | 3,829 | 3,081 | 3,088 | 2,498 | 3,003 |
| Chemical & Allied Product Mfg | 3,397 | 2,204 | 2,151 | 1,845 | 1,183 | 1,127 | 1,112 | 1,093 | 1,171 | 1,223 | 1,053 | 1,071 | 1,081 | 350 | 361 | 372 | 337 | 329 |
| Metals Processing | 3,644 | 2,496 | 2,246 | 2,223 | 2,640 | 2,571 | 2,496 | 2,536 | 2,475 | 2,380 | 1,599 | 1,710 | 1,702 | 1,255 | 1,295 | 1,380 | 1,294 | 1,422 |
| Petroleum & Related Industries | 2,179 | 2,211 | 1,723 | 462 | 333 | 345 | 371 | 371 | 338 | 348 | 354 | 367 | 366 | 159 | 161 | 162 | 128 | 138 |
| Other Industrial Processes | 620 | 630 | 830 | 694 | 537 | 548 | 544 | 594 | 600 | 624 | 561 | 582 | 590 | 571 | 592 | 615 | 635 | 634 |
| Solvent Utilization | NA | NA | NA | 2 | 5 | 5 | 5 | 5 | 5 | 6 | 1 | 2 | 2 | 52 | 51 | 50 | 51 | 73 |
| Storage & Transport | NA | NA | NA | 49 | 76 | 28 | 17 | 51 | 24 | 25 | 70 | 71 | 72 | 163 | 169 | 178 | 215 | 241 |
| Waste Disposal & Recycling | 7,059 | 3,230 | 2,300 | 1,941 | 1,079 | 1,116 | 1,138 | 1,248 | 1,225 | 1,185 | 2,904 | 2,948 | 3,121 | 3,019 | 1,849 | 1,851 | 1,852 | 1,854 |
| Highway Vehicles | 163,231 | 153,555 | 143,827 | 134,187 | 110,255 | 104,980 | 99,705 | 94,431 | 89,156 | 83,881 | 78,606 | 75,849 | 73,244 | 68,708 | 68,061 | 63,476 | 62,161 | 58,807 |
| Off-highway | 11,371 | 14,329 | 16,685 | 19,029 | 21,447 | 21,934 | 22,419 | 22,904 | 23,389 | 23,874 | 24,358 | 23,668 | 23,689 | 23,316 | 24,178 | 24,677 | 24,450 | 24,446 |
| Miscellaneous | 7,909 | 5,263 | 8,344 | 7,927 | 11,122 | 8,618 | 6,934 | 7,082 | 9,658 | 7,298 | 15,016 | 7,316 | 7,184 | 11,410 | 12,964 | 8,676 | 16,498 | 14,033 |
| Miscellaneous | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 204,043 | 188,398 | 185,407 | 176,844 | 154,186 | 147,128 | 140,896 | 135,901 | 133,559 | 126,777 | 128,858 | 117,910 | 115,380 | 114,541 | 114,467 | 106,262 | 112,054 | 106,886 |
| Fires | 6,766 | 4,433 | 7,622 | 7,289 | 10,583 | 10,583 | 6,389 | 6,537 | 9,089 | 6,705 | 14,502 | 6,793 | 6,654 | 10,508 | 12,049 | 7,744 | 15,654 | 13,180 |
| Total without Fires | 197,277 | 183,965 | 177,785 | 169,555 | 143,603 | 136,545 | 134,507 | 129,364 | 124,470 | 120,072 | 114,356 | 111,117 | 108,726 | 104,033 | 102,418 | 98,518 | 96,401 | 93,706 |

*Source*: From www.epa.gov/airtrends/2005/pdfs/conational.pdf.



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**Table 10G.204 Estimated Sea-Level Change by Year 2100, as a Result of Ice Wastage in a Carbon Dioxide-Enhanced Environment**

| Ice Mass Contributing to Sea-Level Change | Estimated Sea-Level Change (Range, ft) |
|---|---|
| Glaciers and small ice caps | +0.3 to 1.0 |
| Greenland ice sheet | +0.3 to 1.0 |
| Antarctic ice sheet | −0.3 to 3[a] |

[a] Most likely the change will range from 0 to 0.7 foot.

*Source*: From National Academy of Sciences, Committee on Glaciology, 1985.

**Table 10G.205 Nationwide Impacts of Sea-Level Rise in the United States**

| | Sea-Level Rise | | |
|---|---|---|---|
| | **50 cm** | **100 cm** | **200 cm** |
| *If densely developed areas are protected* | | | |
| Shore protection costs ($ billions) | 32–43 | 73–111 | 169–309 |
| Dryland lost ($mi^2$) | 2,200–6,100 | 4,100–9,200 | 6,400–13,500 |
| Wetlands lost (%) | 20–45 | 29–69 | 33–80 |
| *If no shores are protected* | | | |
| Dryland lost ($mi^2$) | 3,300–7,300 | 5,100–10,300 | 8,200–15,400 |
| Wetlands lost (%) | 17–43 | 26–66 | 29–76 |
| *If all shores are protected* | | | |
| Wetlands lost (%) | 38–61 | 50–82 | 66–90 |

*Source*: From U.S. Environmental Protection Agency, 1988, *The potential effects of Global climate change on the United States*, Draft Report to Congress, Data assembled by Titus and Greene.

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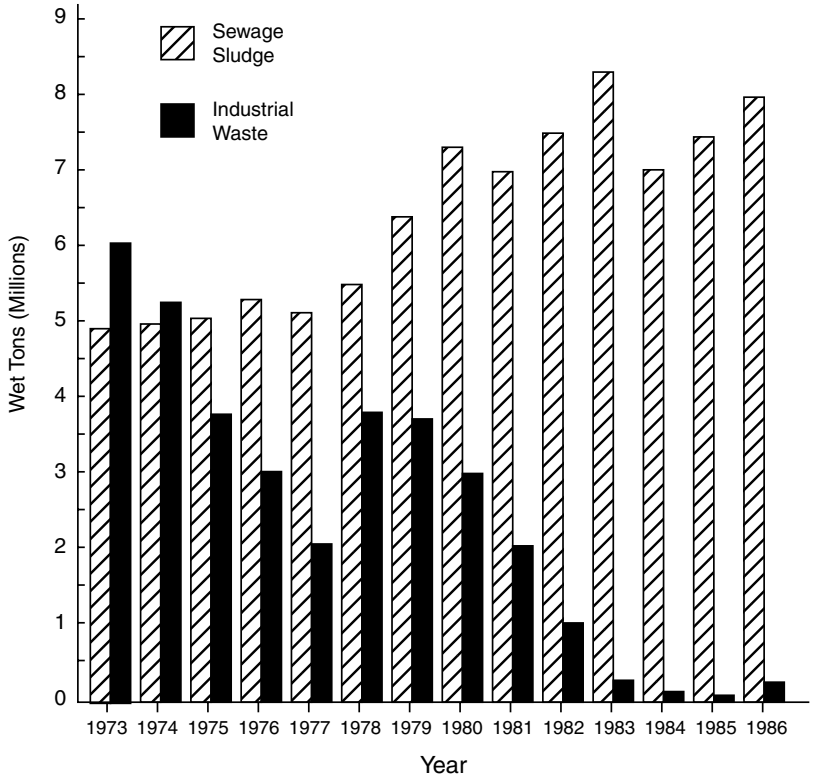
## SECTION 10H OFFSHORE WASTE DISPOSAL




*Note:* For the purpose of this graph, Industrial Waste Category also includes Fish Waste and Construction Debris.

**Figure 10H.168** Sewage sludge and industrial waste dumped in U.S. ocean waters from 1973 to 1986. (From U.S. EPA 1988, *Report to Congress on Administration of the Marine Protection Research, and Sanctuaries Act of 1972*, as Amended, 1984–1986, EPA-503/8-88/002.)

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**Table 10H.206 Offshore Waste Disposal in the United States, 1973–1983**

| | Offshore Waste Disposal in the United States, 1973–1983 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1973** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **1983** |
| **Atlantic (A)** | | | | | | | | | | | |
| Industrial waste | 3,643 | 3,642 | 3,322 | 2,633 | 1,784 | 2,548 | 2,577 | 2,928 | 2,271 | 1,063 | 283 |
| Sewage sludge | 4,898 | 5,010 | 5,040 | 5,271 | 5,134 | 5,535 | 6,442 | 7,309 | 6,703 | 7,670 | 8,312 |
| Construction debris | 974 | 770 | 396 | 315 | 379 | 241 | 107 | 89 | 0 | 0 | 0 |
| Solid waste/chemicals incinerated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Explosives | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0003 | 0 | 0 |
| Wood incinerated | 11 | 16 | 6 | 9 | 15 | 18 | 45 | 11 | 15 | 13 | 31 |
| **Gulf of Mexico (B)** | | | | | | | | | | | |
| Industrial waste | 1,408 | 938 | 120 | 100 | 60 | 0.17 | 0 | 0 | 0 | 0 | 0 |
| Sewage sludge/construction debris solid waste/explosives/wood incinerated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chemicals incinerated | 0 | 12.3 | 4.1 | 0 | 17.6 | 0 | 0 | 0 | 700[a] | 800[a] | 0 |
| **Pacific (C)** | | | | | | | | | | | |
| Industrial waste | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.26 | 23.3 | 18.8 | 21.5 |
| Sewage sludge/construction debris solid waste/explosives/wood incinerated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Solid waste | 240 | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wood incinerated | 0 | 0 | 0 | 0 | 12.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Totals of (A), (B), (C)** | | | | | | | | | | | |
| Industrial waste | 5,051 | 4,580 | 3,452 | 2,733 | 1,844 | 2,548.17 | 2,577 | 2,928.26 | 2,294.3 | 1,081.8 | 304.5 |
| Sewage sludge | 4,890 | 5,010 | 5,040 | 5,271 | 5,134 | 5,535 | 6,442 | 7,309 | 6,703 | 7,670 | 8,312 |
| Construction debris | 974 | 770 | 396 | 315 | 379 | 241 | 107 | 89 | 0 | 0 | 0 |
| Solid waste | 240 | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Explosives | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0003 | 0 | 0 |
| Wood incinerated | 11 | 16 | 6 | 9 | 15 | 18 | 45 | 11 | 15 | 13 | 31 |
| Chemical incinerated | 0 | 12.3 | 4.1 | 0 | 17.6 | 0 | 0 | 0 | 700[a] | 800[a] | 0 |
| Atlantic (A) | | | | | | | | | | | |

*Note:* Thousands of tons.

[a] Thousand gallons (prior to incineration).

*Source*: From U.S. Environmental Protection Agency, Report to Congress January 1981–December 1983.

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**Table 10H.207 Quantities of Sludge Dumped by Sewage Authorities in United States Ocean Waters, 1984–1986**

| | Quantities in Thousand Wet Tons | | |
|---|---|---|---|
| | **1984** | **1985** | **1986** |
| **Sewage Authorities** | | | |
| Bergen County Utilities Authority NJ | 255 | 309 | 353 |
| Joint Meeting of Essex and Union Counties NJ | 335 | 341 | 238 |
| Linden Roselle Sewerage Authority NJ | 235 | 95 | 93 |
| Middlesex County Utilities Authority NJ | 966 | 1,039 | 1,018 |
| Nassau County Dept. of Public Works NY | 520 | 576 | 709 |
| New York City Dept. of Environmental Protection NY | 3,085 | 3,345 | 3,591 |
| Passaic Valley Sewerage Commission NJ | 854 | 884 | 1,317 |
| Rahway Valley Sewerage Authority NJ | 160 | 187 | 98 |
| Westchester County Dept. of Environmental Facilities NY | 539 | 470 | 506 |
| | 6,999 | 7,246 | 7,923 |

*Note:* Nine municipal sewage authorities which had previously held interim permits are dumping sewage sludge pursuant to court orders issued by United States district courts in New York and New Jersey. These authorities have been required to submit permit applications to the USEPA, and currently are shifting their dumping from the 12-Mile Site to the Deepwater Municipal Sludge Dump Site, also known as the 106-Mile Site.

*Source*: From U.S. Environmental Protection Agency, 1988, *Report to Congress on Administration of the Marine Protection, Research, and Sanctuaries Act of 1972*, as Amended, 1984–1986, EPA-503/8-88/002.

**Table 10H.208 Quantities of Industrial Waste Materials Dumped in United States Ocean Waters by Special Permit, 1984–1986**

| | Quantities in Thousand Wet Tons | | |
|---|---|---|---|
| | **1984** | **1985** | **1986** |
| **USEPA Region II** | | | |
| Acid waste site (NY Bight Apex) Allied Chemical Corp.[a] NY | 40 | 40 | 34 |
| Deepwater Industrial Waste Site | | | |
| DuPont—Edge Moor[b] DE | 19 | 0 | 140 |
| DuPont — Grasselli[c] NJ | 146 | 100 | 73 |
| **USEPA Region IX** | | | |
| Fish Wastes Site | | | |
| Samoa Packing, American Samoa | 8 | 4.6 | 21.4 |
| Star Kist, American Samoa | 7.9 | 20.3 | 24.1 |
| Oil Drilling Muds and Cuttings THUMS Long Beach, CA | —[d] | 2.7 | 13.6 |
| | 220.9 | 167.6 | 306.1 |

[a] Hydrochloric acid waste.
[b] Aqueous iron and miscellaneous chlorides and hydrochloric acid wastes.
[c] Solution of alkaline sodium wastes.
[d] No permit issued.

*Source*: From U.S. Environmantal Protection Agency, 1988, *Report to Congress on Administration of the Marine Protection, Research, and Sanctuaries Act of 1972*, as Amended, 1984–1986, EPA-503/8-88/002.

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## SECTION 10I ENERGY DEVELOPMENT

**Table 10I.209 Water-Quality Impacts of Various Energy Processes**

| Process | Water-Quality Impacts | Frequency and Areal Scale | | Time Frame | Severity | Effectiveness of Control |
|---|---|---|---|---|---|---|
| | | Regional | Local | | | |
| Extraction and on-site processing | | | | | | |
| Coal mining | | | | | | |
| Underground mining | Most damaging problems are acid mines drainage and disruption of aquifers, which affect pH, dissolved solids and specific ion content, and thus impair utility of streams and groundwaters for other uses. | | | | | |
| | a. Surface waters | H | | L | 3 | Poor |
| | b. Groundwaters | | M | L | 3 | Ineffective |
| Surface mining | Surface disturbance results in high sediment transport potential. Discharge from mines may impair water quality through increase in dissolved solids and specific ions. | | | | | |
| | a. Surface waters | H | | M | 3 | Fair |
| | b. Groundwaters | | L | S | 1 | Good |
| Beneficiation | Release of chemical and physical treatment materials to streams can impair water quality. Leaching of solid wastes results in pollution similar to acid drainage. | | | | | |
| | a. Surface waters | H | | M | 2 | Fair |
| | b. Groundwaters | | L | M | 1 | Fair |
| Oil and gas extraction | | | | | | |
| Primary recovery | Principal problems are handling of saline waste waters. Leaks in casings, pipes, and storage ponds can release brines to groundwaters and streams. | | | | | |
| | a. Surface waters | M | | S | 2 | Good |
| | b. Groundwaters | | M | M | 3 | Fair |
| Secondary and tertiary recovery | Principal concerns are escape of oil and formation waters through casing, pipe, and storage tank leaks releasing organic and inorganic contaminants to the environment. | | | | | |
| | a. Surface waters | | L | S | 2 | Good |
| | b. Groundwaters | | L | L | 3 | Good |
| Offshore operation | Blowouts with resulting massive oil contamination are a rare but catastrophic problem. | L | | S | 3 | Good |
| Oil-shale extraction and processing | Most significant concerns relate to potential for escape of noxious organic and inorganic contaminants to streams. Disruption of aquifers likely, low hazard due to limited occurrence of oil shale. | | | | | |
| Undergoing mining | Concerns center on disruption of aquifers and disposal of sometimes saline dewatering by injection. | | | | | |
| | a. Surface waters | | L | L | 1 | Good |
| | b. Groundwaters | | L | L | 1 | Good |

*(Continued)*

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**Table 10I.209 (Continued)**

| Process | Water-Quality Impacts | Frequency and Areal Scale: Regional | Frequency and Areal Scale: Local | Time Frame | Severity | Effectiveness of Control |
|---|---|---|---|---|---|---|
| Surface mining | Surface disturbance results in high sediment transport potential. | | | | | |
| | a. Surface waters | | L | S | 2 | Excellent |
| | b. Groundwaters | | L | M | 1 | Excellent |
| Surface retorting | Concerns center on potential for escape of organic and inorganic contaminants from plant site to accidental leaks and spills. A more significant concern is escape of contaminants from waste piles through leaching. | | | | | |
| | a. Surface waters | | M | L | 2 | Good to fair |
| | b. Groundwater | | L | L | 1 | Good |
| In-situ recovery | Underground effects mainly involve contamination of groundwaters by organic and inorganic compounds produced in combustion; where applicable surface effects are similar to those of surface retorting. | | | | | |
| | a. Surface waters | | L | S | 2 | Excellent |
| | b. Groundwaters | | M | L | 3 | Untested |
| Tar-sands extraction and processing | | | | | | |
| Surface mining and processing | Main concerns are accidental release of organic contaminants to streams and potential for failure of waste impoundment structures leading to massive downstream damage from fine waste. | | | | | |
| | a. Surface waters | | M | S | 2 | Good to fair |
| | b. Groundwaters | | L | L | 1 | Untested |
| In-situ recovery | Concerns center on potential for escape of noxious organic and inorganic chemicals to groundwaters. | | | | | |
| | a. Surface waters | | L | S | 2 | Untested |
| | b. Groundwaters | | M | L | 3 | Untested |
| Geothermal extraction | | | | | | |
| Vapor-dominated systems | Main concerns are escape of noxious inorganic contaminants to groundwater from waste disposal, blowouts, and leaks in casings and pipes. | | | | | |
| | a. Surface waters | | L | S | 2 | Good |
| | b. Groundwaters | | M | L | 1 | Fair |
| Water-dominated systems | Main problems involve escape of noxious and toxic constituents of thermal waters to surface and groundwaters from production operations, waste disposal, blowouts, and leaks in casings and pipes. | | | | | |
| | a. Surface waters | H | | M | 4 | Fair |
| | b. Groundwaters | | H | L | 3 | Fair |

*(Continued)*

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**Table 10I.209 (Continued)**

| Process | Water-Quality Impacts | Frequency and Areal Scale: Regional | Frequency and Areal Scale: Local | Time Frame | Severity | Effectiveness of Control |
|---|---|---|---|---|---|---|
| Uranium mining and milling | | | | | | |
| Underground mining | Escape of radioactive and other inorganic contaminants to the environment through disposal of dewatering waste and escape from tailings ponds can seriously impair downstream water uses. | | | | | |
| | a. Surface waters | M | | S | 4 | Good |
| | b. Groundwaters | | M | L | 4 | Poor |
| Surface mining | Some concern about high sediment transport potential, but main source of concern is potential for radioactive contamination of streams and groundwaters through leakage from tailings disposal ponds. | | | | | |
| | a. Surface waters | M | | S | 4 | Good |
| | b. Groundwaters | | M | L | 4 | Poor |
| Solution mining | Main concern centers on escape of radioactive and inorganic process chemicals to off-site groundwaters. | | | | | |
| | a. Surface waters | | L | S | 1 | Excellent |
| | b. Groundwater | | L | L | 4 | Excellent |
| Transportation | | | | | | |
| Coal slurry lines | Main concern centers on pipeline breaks and the potential for contamination of streams. | | | | | |
| | a. Surface waters | | L | S | 2 | Excellent |
| | b. Groundwaters | | L | L | 1 | Excellent |
| Oil pipelines | Most significant problems are pipeline breaks and resulting oil pollution of streams. | | | | | |
| | a. Surface waters | | M | S | 2 | Fair |
| | b. Groundwaters | | L | L | 1 | Good |
| Oil tankers | Escape of oil to marine environment as result of shipwrecks can be catastrophic to marine life over wide areas. | L | | M | 3 | Poor |
| Refining | | | | | | |
| Oil refining | Controlled release of waste water and accidental releases of organic and inorganic contaminants are most significant issues; concerns center on impairment of water supplies of other water users. | | | | | |
| | a. Surface waters | | M | M | 3 | Good |
| | b. Groundwaters | | L | L | 3 | Good |
| Nuclear fuel cycle | Accidental releases of radioactive materials to surface and groundwaters from processing and reprocessing plants are main concern; both high- and low-level waste disposal also have potential for escape of radioactivity to the water environment. Controlled release of nonradioactive inorganic chemicals adds to chemical load of receiving waters. | | | | | |
| | a. Surface waters | | M | S | 4 | Good |
| | b. Groundwaters | | M | L | 4 | Fair to poor |

*(Continued)*

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**Table 10I.209 (Continued)**

| Process | Water-Quality Impacts | Frequency and Areal Scale | | Time Frame | Severity | Effectiveness of Control |
|---|---|---|---|---|---|---|
| | | Regional | Local | | | |
| Conversion | | | | | | |
| Fossil-fueled steam electric generation | Controlled release of cooling-system blowdown to streams and/or leakage from cooling ponds add dissolved solids and treatment chemicals to stream loads. Once-through cooling contributes to thermal pollution. | | | | | |
| | a. Surface waters | M | | M | 2 | Good |
| | b. Groundwater | | L | L | 1 | Good |
| Nuclear steam-electric generation | Small controlled releases of radioactive materials and discharge of cooling-system blowdown add radioactivity, dissolved solids, and treatment chemicals to stream loads. Accidental release of radioactivity through reactor containment failure could endanger human life over wide area. | | | | | |
| | a. Surface waters | M | | M | 5 | Good |
| | b. Groundwaters | | L | L | 4 | Good |
| Geothermal electric generation | Disposal of waste and condensate containing noxious inorganic compounds and thermal load to streams impair downstream uses and damages aquatic life. | | | | | |
| | a. Surface waters | H | | M | 4 | Fair |
| | b. Groundwaters | | H | L | 3 | Fair |
| Hydroelectric generation | Changes in stream temperature and dissolved gases due to storage and reservoir releases seriously alter the aquatic environment. | | | | | |
| | a. Surface waters | H | | L | 2 | Fair |
| | b. Groundwaters | | L | S | 1 | Good |
| Coal conversion processes | Controlled release of cooling system blowdown and accidental releases of organic and inorganic contaminants, as in oil refining and with similar concern about impairment of other water uses. | | | | | |
| | a. Surface waters | | M | M | 3 | Good |
| | b. Groundwaters | | L | L | 3 | Good |

*Note:* Frequency, H, high, M, medium, L, low. Time frame, L, longer than 10 yrs, M, 1 to 10 yrs, S, less than 1 yr, Severity, 5, direct threat to human life, 4, hazardous to human health, 3, severe economic damage, 2, damage to biota, 1, aesthetic or other Intangible harm.

*Source*: From Davis, G.H., 1985, *Water and Energy: Demand and Effects, Unesco Studies and Reports in Hydrology 42*. Copyright Unesco. Reprinted with permission.

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## SECTION 10J WATERBORNE DISEASES/HEALTH HAZARDS

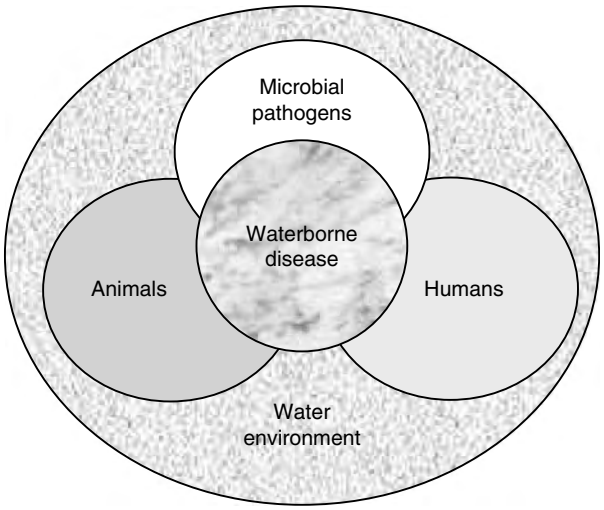
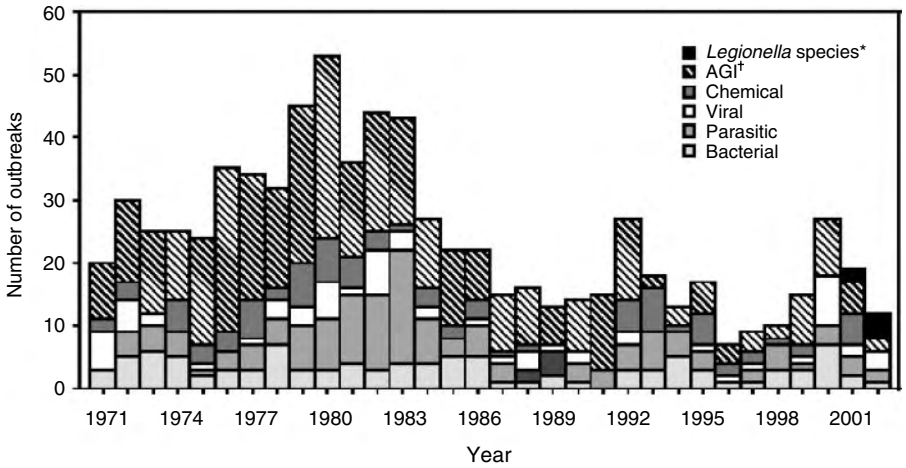



**Figure 10J.169** Waterborne disease interactions in the water environment, (From Cotruvo, J.A., et al., 2004, *Waterborne Zoonoses, Identification, Causes, and Control*, Published on Behalf of the World Health Organization by IWA Publishing, www.who.int.)




* Beginning in 2001, Legionnaires disease was added to the surveillance system, and *Legionella* species were classified separately.

† Acute gastrointestinal illness of unknown etiology.

**Figure 10J.170** Number of waterborne-disease outbreaks ($n=764$) associated with drinking water, by year and etiologic agent in the United States, 1971–2002. (From Blackburn, B.G. et al., 2004, Surveillance of waterborne-disease outbreaks associated with drinking water — United States, 2001–2002, *MMWR Surveillance Summaries*, vol. 53, no. SS-08, pp. 23–45, www.cdc.gov.)

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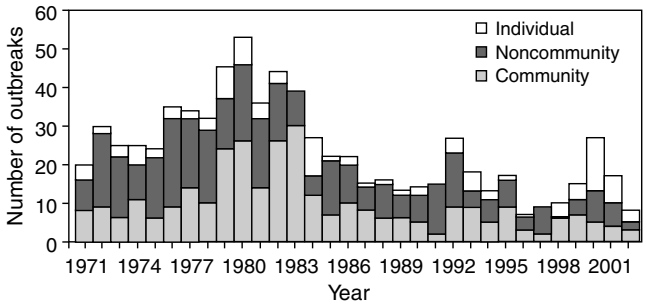


* Excludes outbreaks of Legionnaires disease

**Figure 10J.171** Number of waterborne disease outbreaks ($n=758$)* associated with drinking water, by year and type of water system — United States, 1971–2002. (From Cotruvo, J.A. et al., (ed.), 2004, Waterborne Zoonoses, Identification, Causes, and Control, Published on Behalf of the World Health Organization by IWA Publishing, Copyright © World Health Organization 2004, wlio.int.)

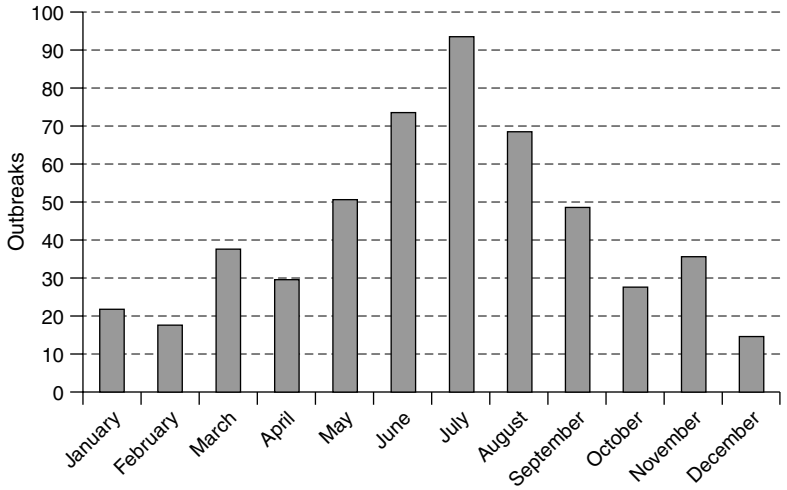


**Figure 10J.172** Outbreaks of waterborne disease by month, 1973–1998. (From Gleick, P.H. et al., 2004, The World's Water 2004–2005, *The Biennial Report on Freshwater Resources*, Island Press, Washington, www.worldwater.org.)

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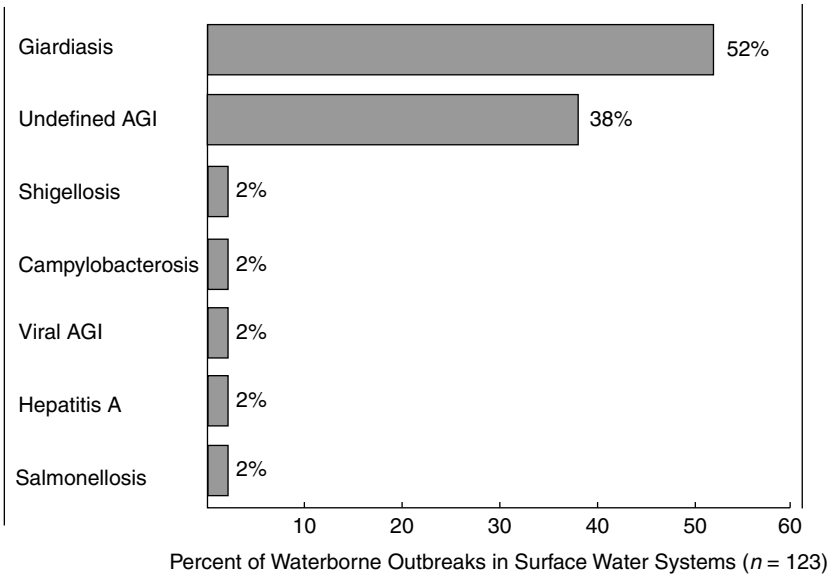


**Figure 10J.173** Etiology of waterborne disease outbreaks in untreated, disinfected-only, and filtered surface water systems in the United States, 1971–1985. (From Craun, G.F., 1988, Surface water supplies and health, *J. American Water Works Association*, vol. 80, no. 2. Copyright AWWA. Reproduced with permission.)

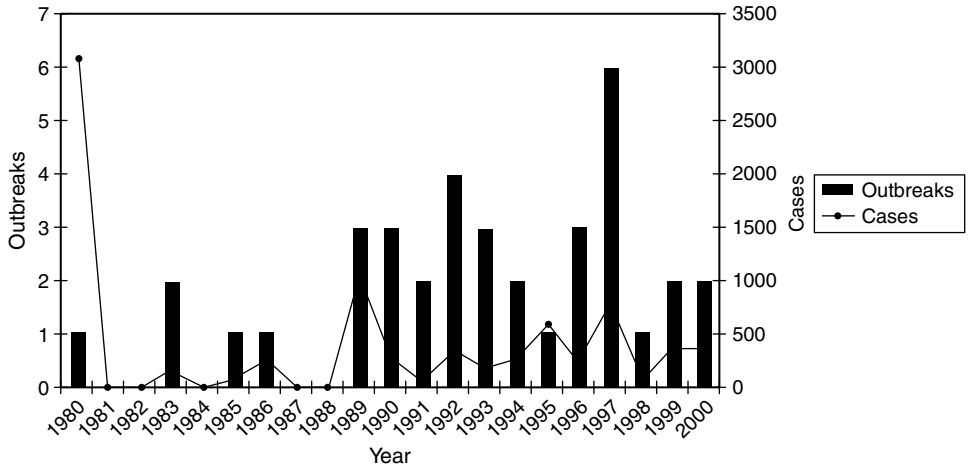


**Figure 10J.174** Outbreaks of Waterborne Disease by Month, 1973–1998 (From *World's Water 2004–2005*, by Peter H. Gleick. Copyright © 2004 Island Press. Reproduced by permission of Island Press, Washington, DC.)

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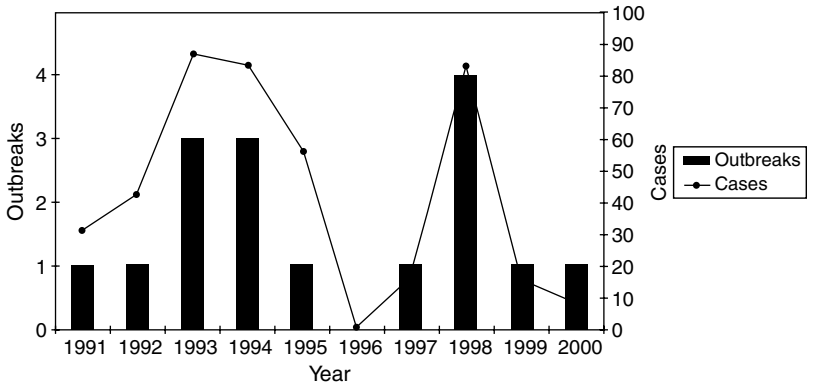


**Figure 10J.175** Outbreaks of waterborne disease associated with private water supplies in England and Wales from 1980–2000. (From Stanwell-Smith, R., Anderson, Y., and Levy, D., 2003, National surveillance systems in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, Florida. Reproduced with permission.)

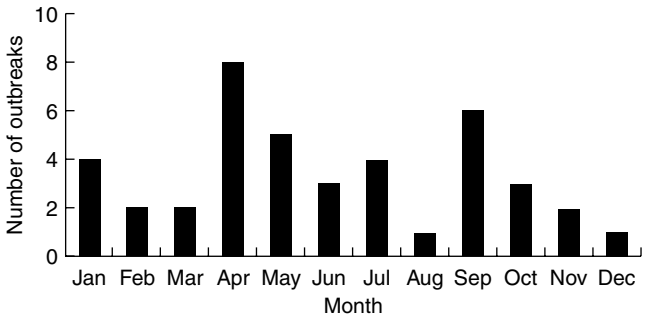


**Figure 10J.176** Seasonal distribution of outbreaks associated with both private and public drinking water supplies in England and Wales from 1991 to 2000. (From Stanwell-Smith, R., Anderson Y., and Levy, D., 2006, National Surveillance Systems in Hunter, P.R., Waite, M., and Ronchi, El. (eds.), Drinking Water and Infectious Disease Establishing the Links, CRC Press LLC, Boca Raton, Florida.)

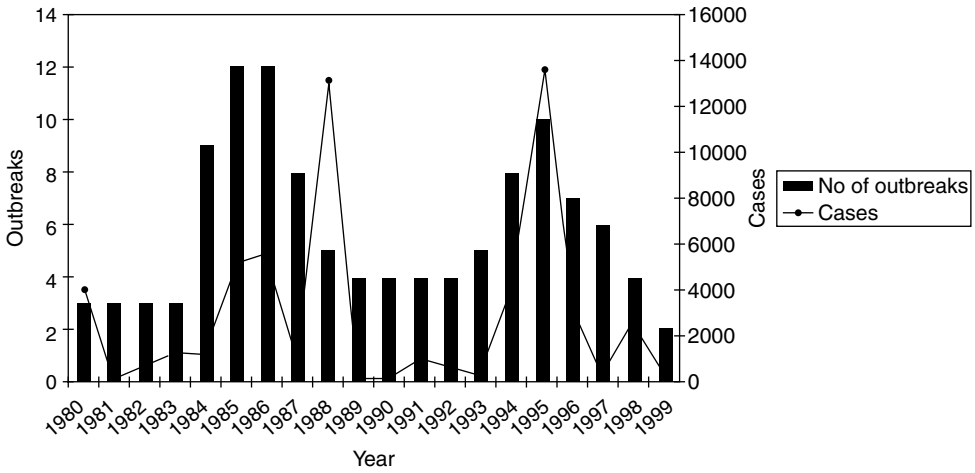


**Figure 10J.177** Outbreaks and cases of waterborne disease in Sweden, 1980–1999. (From Stanwell-Smith, R., Anderson Y., and Levy, D., 2006, National Surveillance Systems in Hunter, P.R., Waite, M., and Ronchi, El. (eds.), Drinking Water and Infectious Disease Establishing the Links, CRC Press LLC, Boca Raton, Florida.)

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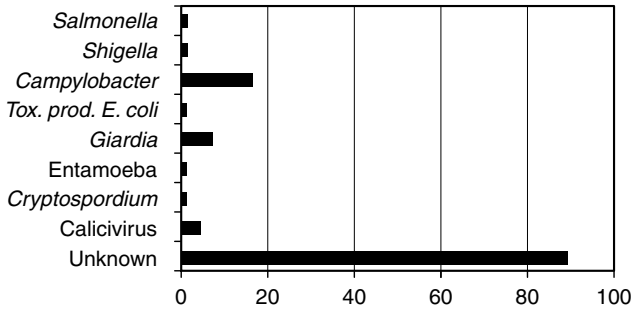
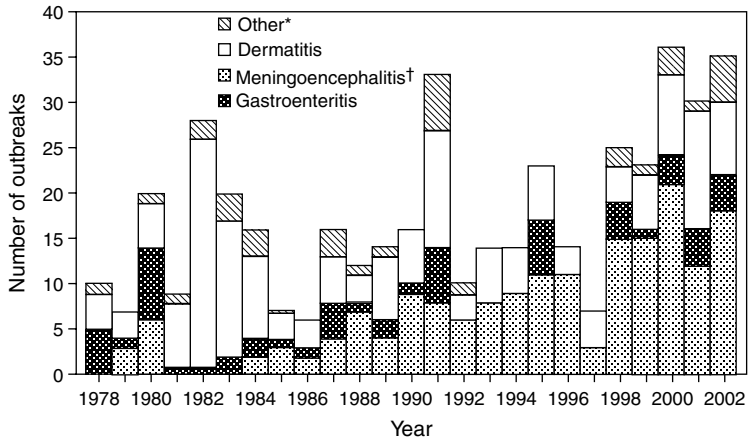


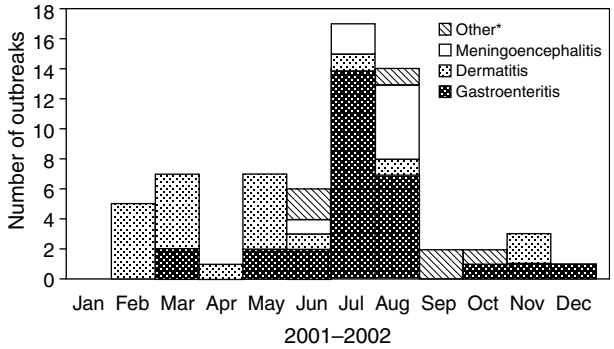

**Figure 10J.178** Microbial agents associated with waterborne outbreaks in Sweden, 1980–1999. (From Stanwell-Smith, R., Anderson, Y., and Levy, D., 2003, National surveillance systems in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, Florida. Reproduced with permission.)




* Includes keratitis, conjunctivitis, otitis, bronchitis, meningitis, hepatitis, leptospirosis, Pontiac fever, and acute respiratory illness.

† Also includes data from report of ameba infections.

**Figure 10J.179** Number of waterborne-disease related outbreaks ($n=445$) associated with recreational water by year and illness in the United States, 1978–2002. (From Yoder, J.S. et al., 2004. Surveillance for waterborne-disease outbreaks associated with recreation water — United States, 2001–2002, *MMWR Surveillance Summary*, vol. 53, no. SS08, pp 1–22, October 22, 2004, www.cdc.gov.)




* Acute respiratory illness, Pontiac fever, or chemical exposure.

**Figure 10J.180** Number of waterborne-disease related outbreaks ($n=65$) associated with recreational water by illness and month in the United States, 2001–2002. (From Yoder, J.S. et al., 2004, Surveillance for waterborne-disease outbreaks associated with recreation water — United States, 2001–2002, *MMWR Surveillance Summary*, vol. 53, no. SS08, pp 1–22, October 22, 2004, www.cdc.gov.)

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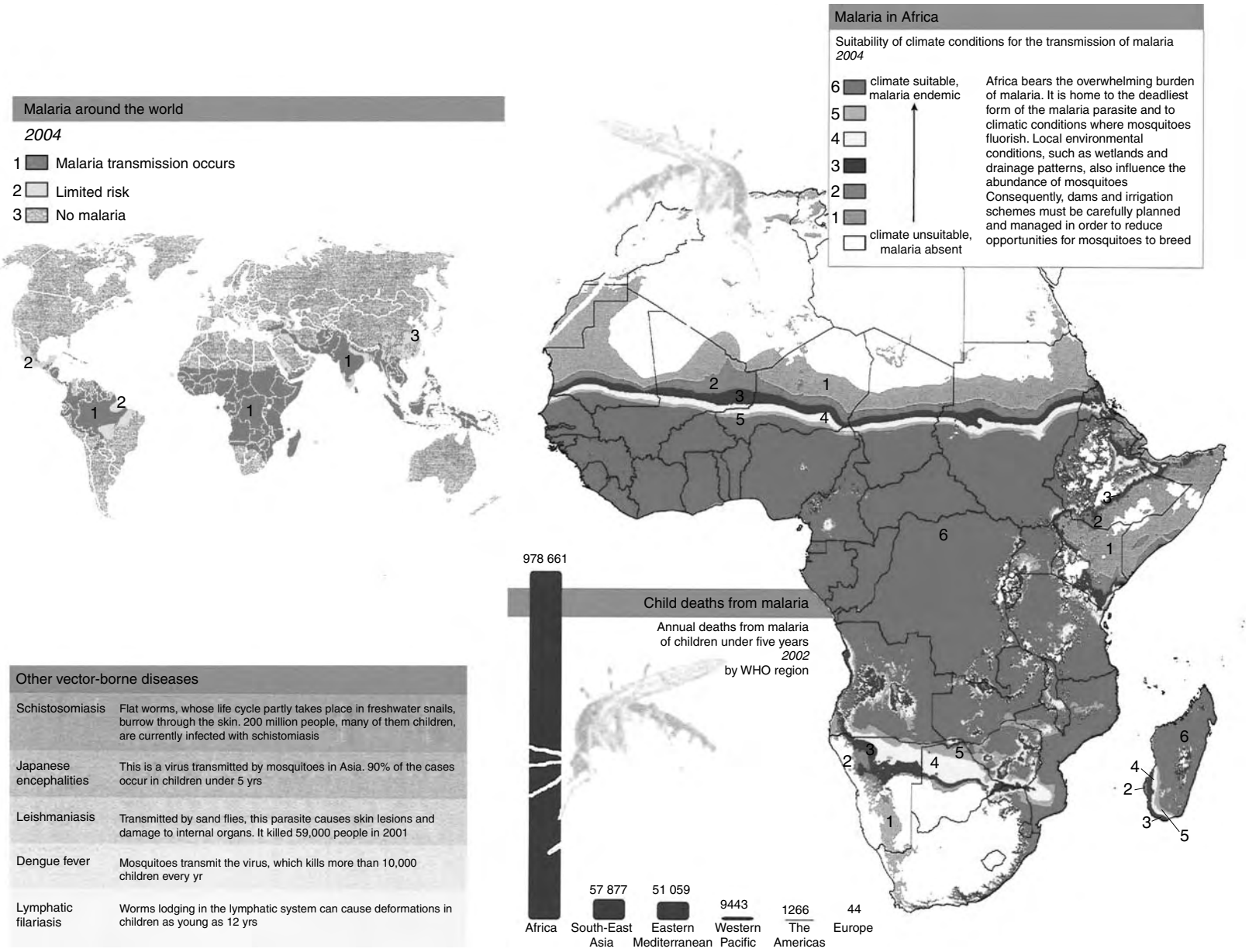


**Figure 10J.181** Malaria. (From Gordon, B., Mackay, R., and Rehfuess, E., 2004, *Inheriting the world: The Atlas of Children's Health and the Environment*, World Health Organization, www.who.int.)



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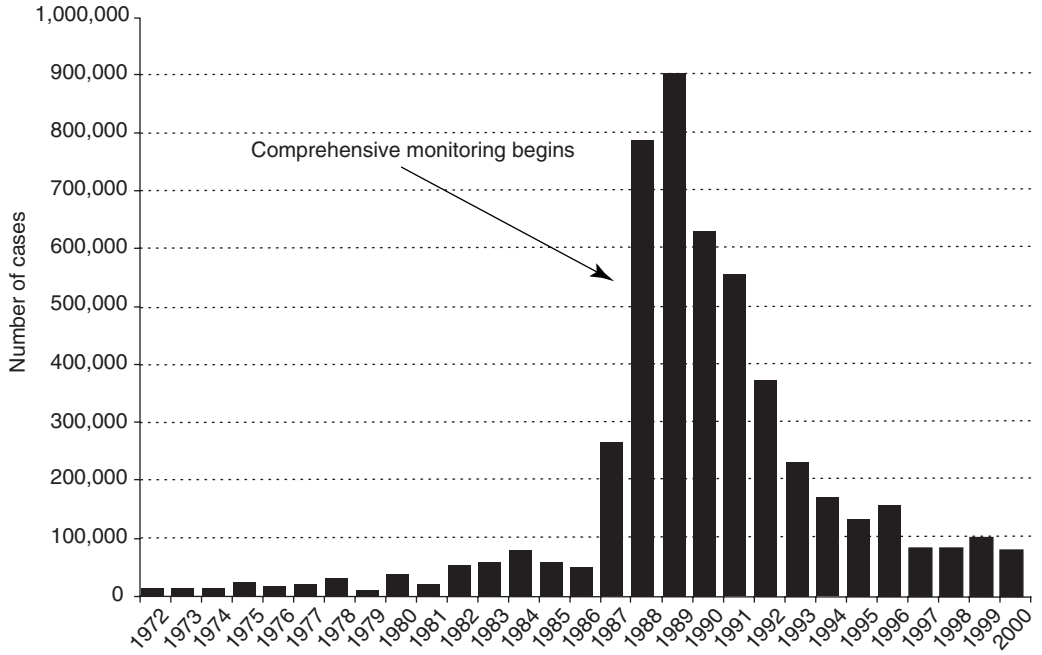


**Figure 10J.182** Dracunculiasis (guinea worm) cases worldwide, 1972–2000. (From Gleick. et al., 2002. The world's water, *The Biennial Report on Freshwater Resources*, 2002–2003, Island Press, Washington, www.worldwater.org. Reproduced with permission.)

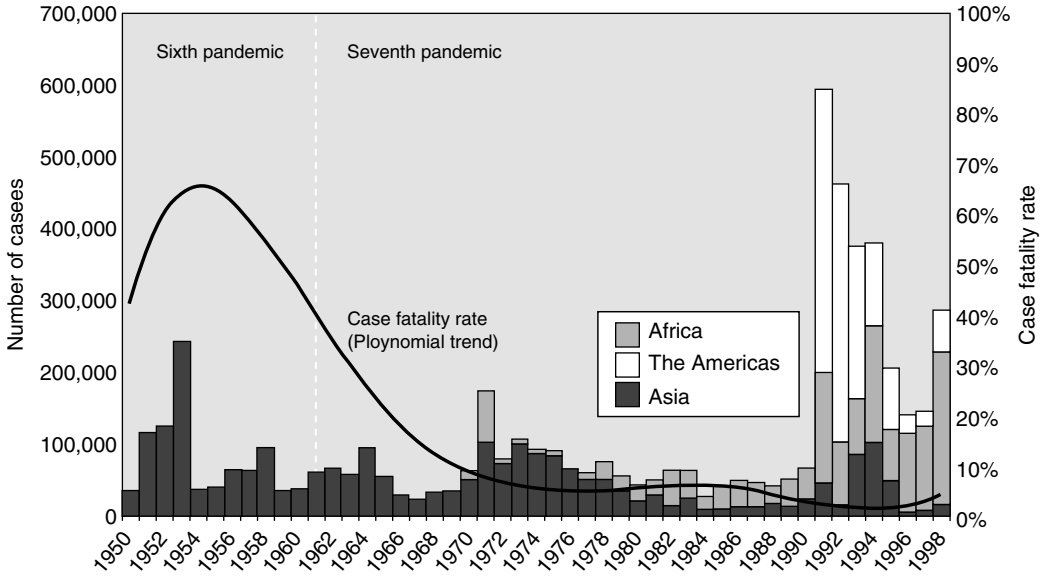


**Figure 10J.183** Cholera, reported number of cases and case fatality rates, 1950–1998. (From World Health Organization, WHO Report on Global Surveillance of Epidemic-Prone Infectious Diseases-Cholera, www.who.int.)

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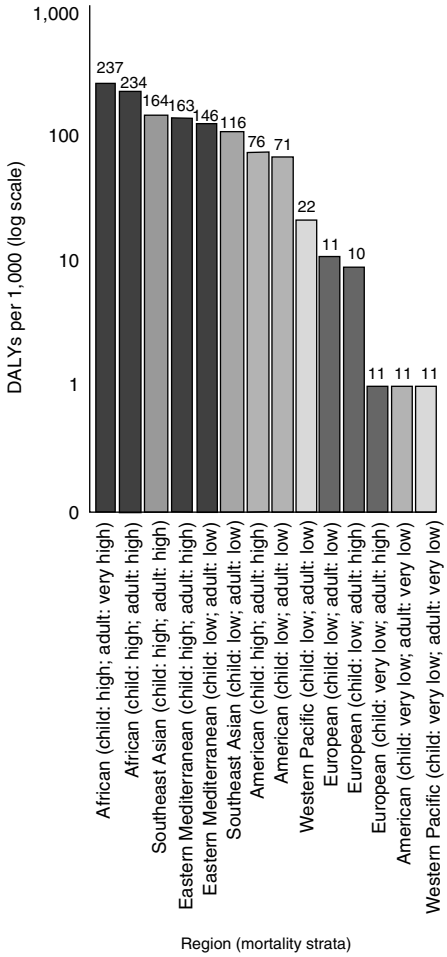


**Figure 10J.184** Diarrheal disease from water, sanitation, and hygiene: DALYs per 1,000 children (under 5 years old) by region. (From Prüss, A., Kay, D., Fewtrell, L., and Bartram, J., 2002, Estimating the burden of disease from water, sanitation, and hygiene at a global level, *Environmental Health Prerspectives*, vol. 110, no. 5, May 2002, www.ehponline.org.)

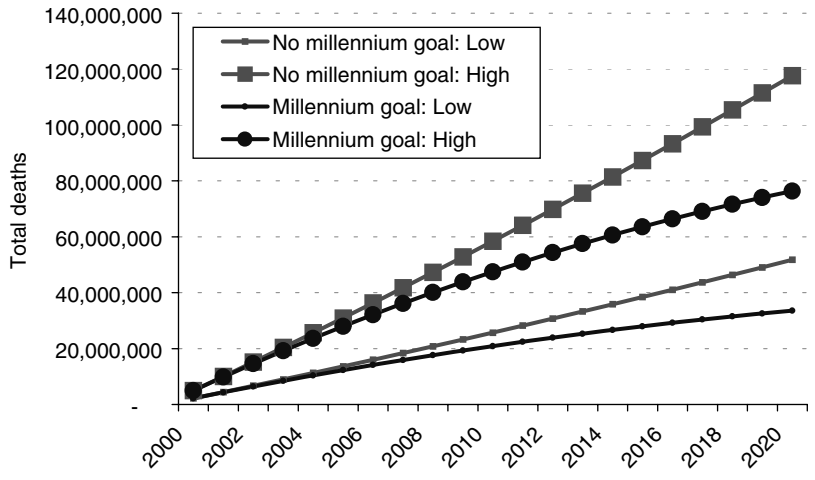


**Figure 10J.185** Total water-related deaths between 2000 and 2020. (From Gleick, P. H., 2002, Dirty water: estimated deaths from water-related diseases 2000–2020, *Pacific Institute Research Report*, © 2002 Pacific Institute for Studies in Development, Environment, and Security, on-line at www.pacinst.org.)

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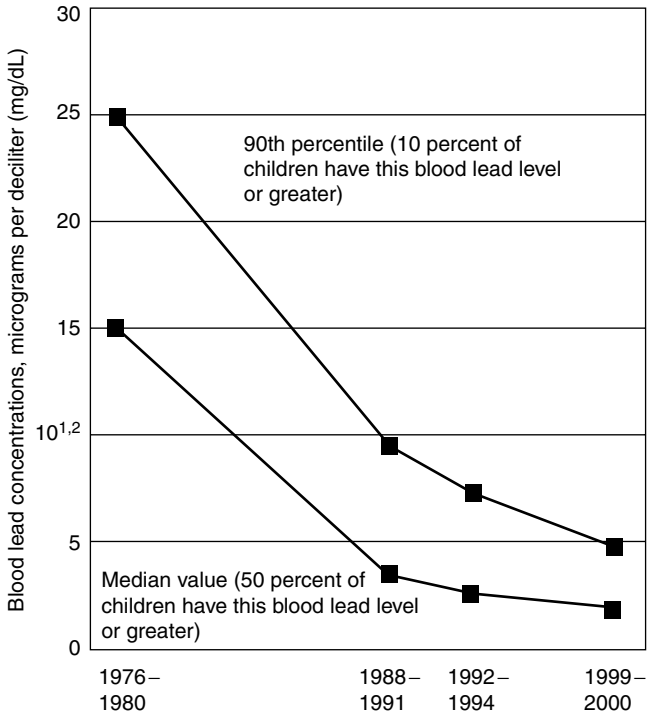


**Figure 10J.186** Concentration of lead in blood of children age 5 and under, 1976–1980, 1988–1991, 1992–1994, 1999–2000. (From United States Environmental Protection Agency, 2003, EPA's Draft Report on the Environment, 2003, EPA 600-R-03-050. U.S. Environmental Protection Agency. *America's Children and the Environment Measures of Contaminants, Body Burdens, and Illnesses, Second Edition*, February 2003. Data from CDC National Center for Health Statistics, National Health and Nutrition Examination Survey, 1976–2000, www.epa.gov.
[1] 10 μg/dL of blood lead has been identified by CDC as elevated, which indicates the need for interventions. (CDC *Preventing Lead Poisoning in Young Children*, 1991.)
[2] Recent research suggests that blood levels less than 10 μg/dL may still produce subtle, subclinical health effects in children. (Schmidt, C.W. *Poisoning Young Minds*, 1999.)

**Table 10J.210 Magnitude of Waterborne Disease Outbreaks in the United States, 1920–1980**

| | Frequency of Occurrence (Number of Outbreaks) | | | |
|---|---|---|---|---|
| **Size of Outbreak (Cases of Illness)** | **Community Systems** | **Noncommunity Systems** | **Individual Systems** | **All Systems** |
| <2 | 3 | 0 | 3 | 6 |
| 2–5 | 26 | 35 | 95 | 156 |
| 6–10 | 71 | 50 | 81 | 202 |
| 11–25 | 145 | 119 | 63 | 327 |
| 26–50 | 94 | 124 | 34 | 252 |
| 51–100 | 68 | 82 | 16 | 166 |
| 101–200 | 63 | 50 | 6 | 119 |
| 201–300 | 28 | 14 | 2 | 44 |
| 301–500 | 29 | 14 | 1 | 44 |
| 501–1,000 | 29 | 9 | 1 | 39 |
| 1,001–3,000 | 28 | 3 | 0 | 31 |
| 3,001–5,000 | 9 | 0 | 0 | 9 |
| 5,001–10,000 | 5 | 0 | 0 | 5 |
| >10,000 | 5 | 0 | 0 | 5 |
| Total | 603 | 500 | 302 | 1,405 |

*Source*: From Craun, G.F., 1986, *Waterborne Diseases in the United States*. Copyright CRC Press, Inc., Boca Raton, FL. Reprinted with permission.

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**Table 10J.211 Etiology of Waterborne Disease Outbreaks in the United States, 1920–1984**

| Time Period | Disease | Outbreaks | Cases | Deaths | Time Period | Disease | Outbreaks | Cases | Deaths |
|---|---|---|---|---|---|---|---|---|---|
| 1920–1925 | Typhoid fever | 127 | 7,294 | 435 | | Chemical poisoning | 5 | 30 | 6 |
| | Gastroenteritis | 11 | 27,756 | 0 | | Salmonellosis | 3 | 16,425 | 3 |
| 1926–1930 | Typhoid fever | 100 | 3,072 | 234 | | Giardiasis | 1 | 123 | 0 |
| | Gastroenteritis | 17 | 63,902 | 0 | | Paratyphoid fever | 1 | 5 | 0 |
| 1931–1935 | Typhoid fever | 85 | 2,114 | 140 | 1966–1970 | Gastroenteritis | 21 | 5,922 | 0 |
| | Gastroenteritis | 25 | 7,664 | 0 | | Hepatitis A | 19 | 562 | 1 |
| | Amebiasis | 1 | 1,412 | 98 | | Shigellosis | 14 | 1,215 | 0 |
| | Hepatitis A | 1 | 28 | 0 | | Typhoid fever | 4 | 45 | 0 |
| 1936–1940 | Gastroenteritis | 91 | 77,403 | 2 | | Salmonellosis | 4 | 226 | 0 |
| | Typhoid fever | 60 | 1,281 | 80 | | Toxigenic E. coil AGI | 4 | 188 | 4 |
| | Shigellosis | 10 | 3,308 | 0 | | Chemical poisoning | 4 | 15 | 0 |
| | Chemical poisoning | 1 | 92 | 0 | | Amebiasis | 3 | 39 | 2 |
| | Amebiasis | 1 | 4 | 0 | | Giardiasis | 2 | 53 | 0 |
| 1947–1945 | Gastroenteritis | 126 | 36,118 | 3 | 1971–1975 | Gastroenteritis | 63 | 17,752 | 0 |
| | Thyhoid fever | 56 | 1,450 | 46 | | Shigellosis | 14 | 2,803 | 0 |
| | Shigellosis | 10 | 2,817 | 6 | | Hepatitis A | 14 | 368 | 0 |
| | Salmonellosis | 1 | 12 | 0 | | Giardiasis | 13 | 5,136 | 0 |
| | Paratyphoid fever | 2 | 14 | 0 | | Chemical poisoning | 13 | 513 | 0 |
| | Chemical poisoning | 1 | 30 | 0 | | Typhoid fever | 4 | 222 | 0 |
| 1946–1950 | Gastroenteritis | 87 | 10,718 | 0 | | Salmonellosis | 2 | 37 | 0 |
| | Typhoid fever | 18 | 264 | 5 | | Toxigenic E. coil AGI | 1 | 1,000 | 0 |
| | Hepatitis A | 5 | 173 | 0 | 1976–1980 | Gastroenteritis | 114 | 22,093 | 0 |
| | Shigellosis | 4 | 2,321 | 1 | | Giardiasis | 26 | 14,416 | 0 |
| | Paratyphoid fever | 1 | 5 | 0 | | Chemical poisoning | 25 | 3,081 | 1 |
| | Leptospirosis | 1 | 9 | 0 | | Shigellosis | 10 | 2,392 | 0 |
| | Tularemia | 1 | 4 | 0 | | Viral gastroenteritis | 10 | 3,147 | 0 |
| 1951–1955 | Gastroenteritis | 31 | 5,297 | 0 | | Salmonellosis | 6 | 1,113 | 0 |
| | Typhoid fever | 7 | 103 | 0 | | Campylobacteriosis | 3 | 3,821 | 0 |
| | Hepatitis A | 7 | 340 | 0 | | Hepatitis A | 2 | 95 | 0 |
| | Shigellosis | 4 | 732 | 1 | 1981–1984 | | | | |
| | Amebiasis | 1 | 31 | 2 | | Gastroenteritis, undetermined etiology | 59 | 20,772 | 0 |
| | Salmonellosis | 1 | 2 | 0 | | Giardiasis | 48 | 4,048 | 0 |
| | Poliomyelitis | 1 | 16 | 0 | | Chemical poisoning | 11 | 179 | 0 |
| 1956–1960 | Gastroenteritis | 21 | 2,306 | 0 | | Shigellosis | 7 | 532 | 0 |
| | Typhoid fever | 13 | 128 | 3 | | Hepatitis A | 7 | 274 | 0 |
| | Hepatitis A | 11 | 417 | 0 | | | | | |
| | Shigellosis | 7 | 3,081 | 0 | | Viral gastroenteritis, Norwalk agent | 7 | 1,077 | 0 |
| | Chemical poisoning | 3 | 14 | 4 | | Salmonellosis | 2 | 1,150 | 0 |
| | Salmonellosis | 2 | 17 | 0 | | Campylobacterosis | 6 | 993 | 0 |
| | Amebiasis | 1 | 5 | 0 | | | | | |
| | Tularemia | 1 | 2 | 0 | | Viral gastroenteritis, rotavirus | 1 | 1,761 | 0 |
| 1961–1965 | Gastroenteritis | 18 | 20,627 | 0 | | Cholera | 1 | 17 | 0 |
| | Typhoid fever | 11 | 63 | 0 | | Yersiniosis | 1 | 16 | 0 |
| | Hepatitis A | 10 | 334 | 0 | | Cryptosporidium | 1 | 117 | 0 |
| | Shigellosis | 7 | 520 | 4 | | Entamoeba | 1 | 4 | 0 |

*Source*: From Craun, G.F., 1986, *Waterborne Diseases in the United States*, Copyright CRC Press, Inc., Boca Raton, FL. Reprinted with permission; amended with statistics from Center for Disease Control Annual Summaries, 1981–1984.

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**Table 10J.212 Etiologic Agents Most Frequently Identified in Waterborne Outbreaks of Infectious Diseases in the United States, 1971–1992**

| Etiologic Agent | Outbreaks | Cases of Illness |
|---|---|---|
| *Giardia* lamblia | 118 | 26,733 |
| *Shigella* | 57 | 9,967 |
| Norwalk-like virus | 24 | 10,908 |
| Hepatitis A | 29 | 807 |
| *Campylobacter* | 13 | 5,257 |
| *Salmonella* | 12 | 2,370 |
| *Cryptosporidium* parvum | 7 | 17,194 |
| All others[a] | 23 | 4,243 |
| Total | 283 | 77,479 |

[a] Toxigenic *E. coli*, Yersinia, rotavirus, S. typhi, V. cholera and others.

*Source*: From Chlorine Chemistry Council, 1997, Drinking Water Chrlorination White Paper, *A Review of Disinfection Practices and Issues*, June 12, 1997, www.c3.org.

**Table 10J.213 Etiology of Waterborne Disease Outbreaks in the United States, by Type of Water System, 1991–2000**

| | Community Water Systems[a] | | Non-community Water Systems[b] | | Individual Water Systems[c] | | All Systems | |
|---|---|---|---|---|---|---|---|---|
| Etiological Agent | Outbreaks | Cases | Outbreaks | Cases | Outbreaks | Cases | Outbreaks | Cases |
| *Giardia* | 11 | 2,073 | 5 | 167 | 6 | 16 | 22 | 2,256 |
| *Cryptosporidium*[d] | 7 | 407,642 | 2 | 578 | 2 | 39 | 11 | 408,259 |
| *Campylobacter jejuni* | 1 | 172 | 3 | 66 | 1 | 102 | 5 | 340 |
| *Salmonellae, nontyphoid* | 2 | 749 | 0 | 0 | 1 | 84 | 3 | 833 |
| *E. coli* | 3 | 208 | 3 | 39 | 3 | 12 | 9 | 259 |
| *E. coli O157:H7/C. jeuni* | 0 | 0 | 1 | 781 | 0 | 0 | 1 | 781 |
| *Shigella* | 1 | 83 | 5 | 484 | 2 | 38 | 8 | 605 |
| *Plesiomonas shigelloides* | 0 | 0 | 1 | 60 | 0 | 0 | 1 | 60 |
| *Non-01 V.cholerae* | 1 | 11 | 0 | 0 | 0 | 0 | 1 | 11 |
| *Hepatitis A virus* | 0 | 0 | 1 | 46 | 1 | 10 | 2 | 56 |
| *Norwalk-like viruses* | 1 | 594 | 4 | 1,806 | 0 | 0 | 3 | 2,400 |
| *Small, round-structured virus* | 1 | 148 | 1 | 70 | 0 | 0 | 2 | 218 |
| *Chemical* | 18 | 522 | 0 | 0 | 7 | 9 | 25 | 531 |
| *Undetermined* | 11 | 10,162 | 38 | 4,837 | 11 | 238 | 60 | 15,237 |
| Total | 57 | 422,364 | 64 | 8,934 | 34 | 548 | 155 | 431,846 |

*Note:* Data are compiled from CDC Morbidity and Mortality Weekly Report Surveillance Summaries for 1991–1992, 1993–1994, 1995–1996, 1997–1998 and 1999–2000. Figures include adjustments to numbers of outbreaks and illness cases originally reported, based on more recent CDC data.

[a] Community water systems are those that serve communities of an average of at least 25 year-round residents and have at least 15 service connections.

[b] Non-community water systems are those that serve an average of at least 25 residents and have at least 15 service connections and are used at least 60 days $y^{-1}$.

[c] Individual water systems are those serving less than 25 residents and have less than 15 service connections.

[d] There were 403,000 cases of illness reported in Milwaukee in 1993.

*Source*: From Chlorine Chemistry Council, 2003, Drinking Water Chlorination, *A Review of Disinfection Practices and Issues*, February 2003, www.c3.org.

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**Table 10J.214 Waterborne-Disease Outbreaks ($n=25$) Associated with Drinking Water, by Etiologic Agent and Type of Water System (Excluding Outbreaks Caused by *Legionella* Species) — United States, 2001–2002**

| | Type of Water System[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Community | | Noncommunity | | Individual | | Total | |
| Etiologic Agent | Outbreaks | Cases | Outbreaks | Cases | Outbreaks | Cases | Outbreaks | Cases |
| Unknown | 0 | 0 | 2 | 98 | 5 | 19 | 7 | 117 |
| AGI[b] | 0 | 0 | 2 | 98 | 5 | 19 | 7 | 117 |
| Viruses | 1 | 71 | 4 | 656 | 0 | 0 | 5 | 727 |
| Norovirus | 1 | 71 | 4 | 656 | 0 | 0 | 5 | 727 |
| Parasitic | 3 | 14 | 0 | 0 | 2 | 16 | 5 | 30 |
| *Giardia intestinalis* | 2 | 12 | 0 | 0 | 1 | 6 | 3 | 18 |
| *Cryptosporidium* species | 0 | 0 | 0 | 0 | 1 | 10 | 1 | 10 |
| *Naegleria* fowleri | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 2 |
| Chemical | 3 | 33 | 1 | 4 | 1 | 2 | 5 | 39 |
| Copper | 2 | 30 | 0 | 0 | 0 | 0 | 2 | 30 |
| Copper and other minerals | 0 | 0 | 1 | 4 | 0 | 0 | 1 | 4 |
| Ethyl benzene, toluene, xylene | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 2 |
| Ethylene glycol | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 3 |
| Bacterial (other than *Legionella* species) | 0 | 0 | 1 | 12 | 2 | 15 | 3 | 27 |
| *Campylobacterjejuni* | 0 | 0 | 0 | 0 | 1 | 13 | 1 | 13 |
| *C. jejuni and Yersinia enterocolitica* | 0 | 0 | 1 | 12 | 0 | 0 | 1 | 12 |
| *Escherichia coli* O157:H7 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 2 |
| Total | 7 | 118 | 8 | 770 | 10 | 52 | 25 | 940 |
| Percentage | (28.0) | (12.6) | (32.0) | (81.9) | (40.0) | (5.5) | (100.0) | (100.0) |

[a] Com, community; Ncom, noncommunity; Ind, individual. Community and noncommunity water systems are public water systems that serve $>15$ serv connections or an average of $\geq 25$ residents for $\geq 60$ days/year. A community water system serves year-round residents of a community, subdivision, mobile home park with $\geq 15$ service connections or an average of $\geq 25$ residents. A noncommunity water system can be nontransient or transient. Nontransient systems serve $\geq 25$ of the same persons for $>6$ months of the year, but not year-round (e.g., factories or schools), whereas transient systems provide water to places in which persons do not remain for long periods of time (e.g., restaurants, highway rest stations, or parks). Individual water systems are small systems not owned or operated by a water utility that serve $<15$ connections or $<25$ persons. Outbreaks associated with water not intended for drinking (e.g., lakes, springs and creeks used by campers and boaters, irrigation water, and other nonpotable sources with or without taps) are also classified individual systems.

[b] Acute gastrointestinal illness of unknown etiology.

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**Table 10J.215 Total Outbreaks of Drinking-Water Related Disease, United States, 1973–2000**

| Year | Heinz Center[a] Outbreaks | Schneider[b] Outbreaks | Schneider[b] Cases | CDC Data[c] Outbreaks | CDC Data[c] Cases |
|---|---|---|---|---|---|
| 1973 | 21 | | | | |
| 1974 | 20 | | | | |
| 1975 | 16 | | | | |
| 1976 | 29 | 22 | 3,860 | | |
| 1977 | 26 | 17 | 1,911 | | |
| 1978 | 22 | 33 | 11,435 | | |
| 1979 | 26 | 41 | 6,761 | | |
| 1980 | 29 | 49 | 20,005 | | |
| 1981 | 24 | 32 | 4,430 | | |
| 1982 | 30 | 40 | 3,456 | | |
| 1983 | 35 | 40 | 20,905 | | |
| 1984 | 20 | 26 | 1,755 | | |
| 1985 | 16 | 25 | 2,117 | | |
| 1986 | 18 | 22 | 1,569 | 22 | 25,846 (1986–1988) |
| 1987 | 11 | 15 | 22,149 | 15 | |
| 1988 | 15 | 15 | 2,159 | 13 | |
| 1989 | 12 | 12 | 2,540 | 13 | |
| 1990 | 10 | 14 | 1,748 | 14 | |
| 1991 | 11 | 15 | 12,960 | 15 | 17,464 (1991–1992) |
| 1992 | 18 | 27 | 4,724 | 27 | |
| 1993 | 8 | 17 | 404,183 | 18 | 405,366 (1993–1994) |
| 1994 | 11 | 13 | 1,178 | 12 | |
| 1995 | 11 | 16 | 2,375 | 16 | 2,567 (1995–1996) |
| 1996 | 3 | 6 | 192 | 6 | |
| 1997 | 4 | 7 | 304 | 7 | 2,038 (1997–1998) |
| 1998 | 7 | 10 | 1,734 | 10 | |
| 1999 | | | | 15 | 2,068 (1999–2000) |
| 2000 | | | | 24 | |
| Total | 453 | 514 | 534,450 | 227 | 455,349 |

[a] Heinz Center *State of the Nations*; *Ecosystem* report, heinzctr.org/ecosystems/fr_water/datasets/freshwater_waterborne_ disease_ outbreaks.shtm.

[b] Data compiled by Dr. Orren D. Schneider and used by permission, water.sesep.drexel.edu/outbreaks/US_summaryto1998.htm.

[c] Data part of the Center for Disease Control. Surveillance for Waterborne-Disease Outbreaks program. *Waterborne Disease Outbreaks, 1986–1988*, www.cdc.gov/epo.mmwr/preview/mmwrhtml/00001596.htm; *Waterborne-Disease Outbreaks, 1991–1992*, www.cdc.gov/epo.mmwr/preview/mmwrhtml/000025893.htm; *Waterborne-Disease Outbreaks, 1993–1994*, www.cdc.gov/epo.mmwr/preview/mmwrhtml/0004088.htm; *Waterborne-Disease Outbreaks, 1995–1996*, www.cdc.gov/epo.mmwr/preview/mmwrhtml/00055820.htm; *Waterborne-Disease Outbreaks, 1997–1998*, www.cdc.gov/epo.mmwr/preview/mmwrhtml/ss4904a1.htm; *Waterborne-Disease Outbreaks, 1999–2000*, www.cdc.gov/epo.mmwr/preview/mmwrhtml/ss5108a1.htm.

*Source*: From *World's Water 2004–2005*, by Peter Gleick. H. Copyright © 2004 Island Press. Reproduced by permission of Island Press, Washington, DC.

**Table 10J.216 Number of Waterborne Outbreaks by Type of Water System and Etiology in the United States, 1971–2000**

| Water System Type | Unidentified Agents | Protozoa | Viruses | Bacteria | Chemicals |
|---|---|---|---|---|---|
| Non-community | 228 | 31 | 27 | 43 | 11 |
| Community | 98 | 96 | 20 | 40 | 54 |
| Treated and untreated recreational water[a] | 40 | 98 | 18 | 97 | 5 |
| Individual | 39 | 16 | 9 | 18 | 21 |
| All water systems | 405 | 241 | 74 | 198 | 91 |

[a] An outbreak attributed to algal toxins is not included. An outbreak of both *Shigella* and *Cryptosporidium* is included in the protozoa category.

*Source*: From Cotruvo, J.A. et al., (ed.), 2004, Waterborne Zoonoses, Identification, Causes, and Control, Published on Behalf of the World Health Organization by IWA Publishing, Copyright © World Health Organization 2004, www.who.int.

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**Table 10J.217 Drinking-Waterborne Outbreaks of Zoonotic Agents in the United States, 1971–2000**

| | | Type of Water System[a] | | | Water Source[b] | | |
|---|---|---|---|---|---|---|---|
| **Etiologic Agent** | **Total** | **C** | **NC** | **I** | **GW** | **SW** | **M/U** |
| *Giardia* | 126 | 83 | 29 | 14 | 31 | 90 | 5 |
| *Campylobacter* | 19 | 9 | 7 | 3 | 12 | 3 | 4 |
| *Cryptosporidium* | 15 | 11 | 2 | 2 | 8 | 5 | 2 |
| *Salmonella* | 15 | 11 | 2 | 2 | 11 | 2 | 2 |
| *E. coli* O157:H7 | 11 | 4 | 4 | 3 | 8 | 2 | 1 |
| *Yersinia* | 2 | — | 1 | 1 | 2 | — | — |
| *E. coli* O6:H16 | 1 | — | 1 | — | 1 | — | — |
| *E. coli* O0157:H7 and *Campylobacter* | 1 | — | 1 | — | 1 | — | — |
| Total | 190 | 118 | 47 | 25 | 74 | 102 | 14 |

[a] C, community; NC, noncommunity; I, individual.
[b] GW, groundwater; SW, surface water; M/U, mixed or unknown.

*Source*: From Cotruvo, J.A. et al., (ed.), 2004, Waterborne Zoonoses, Identification, Causes, and Control, Published on Behalf of the World Health Organization by IWA Publishing, Copyright © World Health Organization 2004, www.who.int.

**Table 10J.218 Waterborne Outbreaks Reported in United States Drinking Water Systems by Type of System and Water Source, 1991–1998**

| | Number of Waterborne Outbreaks | | | |
|---|---|---|---|---|
| **Water Source** | **Community Systems** | **Non-Community Systems** | **Individual Systems** | **All Water Systems** |
| Groundwater[a] | 22 | 52 | 11 | 85 |
| Surface water[b] | 22 | 2 | 1 | 25 |
| Unknown | 3 | 8 | 5 | 16 |
| Totals | 47 | 62 | 17 | 126 |

[a] Surfacewater, lakes, reservoirs, rivers, streams.
[b] Groundwater, wells and springs.

*Source*: From Craun, G.F., Calderon, R.L., and Nwachuku, N., 2003, Causes of waterborne outbreaks reported in the United States, 1991-1998 in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, FL.

**Table 10J.219 Etiology of Waterborne Outbreaks in United States Drinking Water Systems, 1991–1998; Number of Outbreaks by Type of Water System and Water Source**

| | Community Water Systems | | | Non-Community Water Systems | | |
|---|---|---|---|---|---|---|
| **Etiological Agent** | **Surface-Water** | **Ground-Water** | **Unknown Source** | **Surface-Water** | **Ground-Water** | **Unknown Source** |
| Undetermined | 5 | 1 | 1 | 1 | 36 | 5 |
| Chemical | 7 | 9 | | | | 1 |
| *Giardia* | 6 | 4 | | | 3 | |
| *Cryptosporidium* | 3 | 3 | 1 | 1 | 1 | |
| Norwalk-like virus | 1 | 1 | | | | |
| *Campylobacter* | | 1 | | | 2 | 1 |
| *Salmonella,* non-typhoid | | 1 | | | | |
| *Escherichia coli* O157:H7 | | 1 | | | 3 | 1 |
| *Shigella* | | 1 | | | 5 | |
| *Vibrio cholerae* | | | 1 | | | |
| Hepatitis A virus | | | | | 1 | |
| *Plesiomonas shigelloides* | | | | | 1 | |
| Total | 22 | 22 | 3 | 2 | 52 | 8 |

*Source*: From Craun, G.F., Calderon, R.L., and Nwachuku, N., 2003, Causes of waterborne outbreaks reported in the United States, 1991–1998 in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, FL.

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**Table 10J.220 Etiology of Waterborne Outbreaks Reporting in United States Drinking Water Systems; Cases of Illness by Type of Water System and Water Source, 1991–1998**

| | Community Water Systems | | | Noncommunity Water Systems | | |
|---|---|---|---|---|---|---|
| **Etiological Agent** | **Surface-Water** | **Ground-Water** | **Unknown Source** | **Surface-Water** | **Ground-Water** | **Unknown Source** |
| Undetermined | 10,210 | 18 | 67 | 250 | 4,789 | 101 |
| Chemical | 104 | 409 | | | | 2 |
| *Giardia* | 1,937 | 49 | | | 128 | |
| *Cryptosporidium* | 403,343 | 4,294 | 77 | 27 | 551 | |
| Norwalk-like virus | 148 | 594 | | | | |
| *Campylobacter* | | 172 | | | 51 | 7 |
| *Salmonella,* non-typhoid | | 625 | | | | |
| *E. coli* O157:H7 | | 157 | | | 39 | 27 |
| *Shigella* | | 83 | | | 484 | |
| *Vibrio cholerae* | | | 11 | | | |
| Hepatitis A virus | | | | | 46 | |
| *Plesiomonas shigelloides* | | | | | 60 | |
| Total | 415,742 | 6,401 | 155 | 277 | 6,148 | 137 |

*Source*: From Craun, G.F., Calderon, R.L., and Nwachuku, N., 2003, Causes of waterborne outbreaks reported in the United States, 1991–1998 in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, FL.

**Table 10J.221 Etiology of Waterborne Outbreaks in Individual Water Systems in the United States Outbreaks and Cases of Illness by Water Source, 1991–1998**

| | Outbreaks | | | Cases of Illness | | |
|---|---|---|---|---|---|---|
| **Etiological Agent** | **Surface-Water** | **Ground-Water** | **Unknown Source** | **Surface-Water** | **Ground-Water** | **Unknown Source** |
| Undetermined | 0 | 2 | 1 | 0 | 43 | 8 |
| Chemical | 0 | 3 | 3 | 0 | 3 | 5 |
| *Giardia* | 1 | 1 | 0 | 2 | 10 | 0 |
| *Cryptosporidium* | 0 | 2 | 0 | 0 | 39 | 0 |
| *E. coli* | 0 | 1 | 0 | 0 | 3 | 0 |
| *Shigella* | 0 | 1 | 1 | 0 | 33 | 5 |
| Hepatitis A virus | 0 | 1 | 0 | 0 | 10 | 0 |
| Total | 1 | 11 | 5 | 2 | 141 | 18 |

*Source*: From Craun, G.F., Calderon, R.L., and Nwachuku, N., 2003, Causes of waterborne outbreaks reported in the United States, 1991–1998 in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, FL.

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**Table 10J.222 Waterborne Disease Outbreaks Caused by Use of Contaminated, Untreated Surface Water in the United States, 1920–1980**

| | Type of Water System | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Community | | Noncommunity | | Individual | | All | |
| Deficiency | OB[a] | Cases | OB[a] | Cases | OB[a] | Cases | OB[a] | Cases |
| Contamination on watershed | 26 | 3,498 | 3 | 57 | 12 | 257 | 41 | 3,812 |
| Use of surface water for supplemental source | 7 | 3,613 | 7 | 245 | 2 | 115 | 16 | 3,973 |
| Overflow of sewage or outfall near water intake | 3 | 103 | 3 | 39 | 5 | 87 | 11 | 229 |
| Flooding, heavy rains | 2 | 125 | 1 | 93 | 1 | 77 | 4 | 295 |
| Dead animals in reservoir | — | — | 1 | 100 | — | — | 1 | 100 |
| Insufficient data | 27 | 1,228 | 24 | 726 | 28 | 436 | 79 | 2,390 |
| Total | 65 | 8,567 | 39 | 1,260 | 48 | 972 | 152 | 10,799 |

[a] Number of outbreaks.

*Source*: From Craun, G.F., 1986, *Waterborne Diseases in the United States*. Copyright CRC Press, Inc., Boca Raton, FL. Reprinted with permission.

**Table 10J.223 Waterborne Disease Outbreaks Caused by Use of Contaminated, Untreated Groundwater (Springs) in the United States, 1920–1980**

| | Type of Water System | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Community | | Non-Community | | Individual | | All | |
| Deficiency | OB[a] | Cases | OB[a] | Cases | OB[a] | Cases | OB[a] | Cases |
| Overflow or seepage of sewage | 8 | 238 | 3 | 35 | 5 | 39 | 16 | 312 |
| Surface runoff | 11 | 265 | 5 | 162 | 7 | 75 | 23 | 502 |
| Flooding | 2 | 76 | 2 | 123 | — | — | 4 | 199 |
| Creviced limestone | 1 | 200 | 3 | 213 | — | — | 4 | 413 |
| Contamination of raw water transmission line | 2 | 284 | 1 | 7 | — | — | 3 | 291 |
| Improper construction | — | — | 1 | 26 | 1 | 9 | 2 | 35 |
| Insufficient data | 12 | 508 | 18 | 1,961 | 20 | 415 | 50 | 2,884 |
| Total | 36 | 1,571 | 33 | 2,527 | 33 | 538 | 102 | 4,636 |

[a] Number of outbreaks.

*Source*: From Craun, G.F., 1986, *Waterborne Diseases in the United States*. Copyright CRC Press, Inc., Boca Raton, FL. Reprinted with permission.

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**Table 10J.224 Waterborne Disease Outbreaks Caused by Use of Contaminated, Untreated Groundwater (Wells) in the United States, 1920–1980**

| | Type of Water System | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Community | | Noncommunity | | Individual | | All | |
| Deficiency | OB[a] | Cases | OB[a] | Cases | OB[a] | Cases | OB[a] | Cases |
| Overflow or seepage of sewage | 28 | 14,915 | 104 | 10,236 | 52 | 675 | 184 | 25,826 |
| Surface runoff, heavy rains | 25 | 2,492 | 26 | 947 | 34 | 824 | 85 | 4,263 |
| Creviced limestone, fissured rock | 9 | 1,404 | 19 | 2,044 | 12 | 660 | 40 | 4,108 |
| Improper construction, faulty well casing | 8 | 342 | 10 | 414 | 9 | 141 | 27 | 897 |
| Flooding | 9 | 5,883 | 3 | 107 | 5 | 211 | 17 | 6,201 |
| Chemical contamination | 3 | 77 | 2 | 16 | 10 | 68 | 15 | 161 |
| Contamination by stream or river | 3 | 445 | 6 | 392 | 3 | 48 | 12 | 885 |
| Contamination of raw water transmission line | 8 | 10,481 | — | — | — | — | 8 | 10,481 |
| Seepage from abandoned well | 3 | 144 | 1 | 50 | — | — | 4 | 194 |
| Animal in well | 1 | 34 | 1 | 238 | 2 | 19 | 4 | 291 |
| Insufficient data | 19 | 18,480 | 67 | 3,309 | 40 | 413 | 126 | 22,202 |
| Total | 116 | 54,697 | 239 | 17,753 | 167 | 3,059 | 522 | 75,509 |

[a] Number of outbreaks.

*Source*: From Craun, G.F., 1986, *Waterborne Diseases in the Untied States*, Copyright CRC Press, Inc. Boca Raton, FL. Reprinted with permission.

**Table 10J.225 Waterborne Disease Outbreak and Disease Rates Attributed to Source Contamination and Treatment Inadequacies in Community Systems in the United States Using Surface Water Sources, 1971–1985**

| Type of Community Water System | Waterborne Disease Outbreaks per 1,000 Water Systems | Waterborne Illnesses per Million-Person Years |
|---|---|---|
| Untreated | 32.5 | 370.9 |
| Disinfected only | 40.5 | 66.3 |
| Filtered and disinfected water | 5.0 | 4.7 |

*Source*: From U.S. Environmental Protection Agency, 1987; Craun, G.F., 1987.

**Table 10J.226 Water Supply Deficiencies Responsible for Waterborne Outbreaks in the United States, 1971–1985.**

| Source of Deficiency | Outbreaks | Reported Illnesses |
|---|---|---|
| Surface water source | | |
| No treatment | 31 | 1,647 |
| Disinfection only, or inadequate disinfection | 67 | 23,028 |
| Disinfection with other treatment (but no filtration) | 5 | 969 |
| Filtration and disinfection | 20 | 9,852 |
| Totals | 123 | 35,496 |
| Groundwater source | | |
| No treatment | 154 | 11,266 |
| Inadequate disinfection | 90 | 40,893 |
| Disinfection with other treatment | 1 | 22 |
| Totals | 245 | 52,181 |
| Distribution system | | |
| Cross-connection | 44 | 8,124 |
| Contamination of mains/plumbing | 14 | 3,413 |
| Contamination of storage | 11 | 6,244 |
| Corrosive water | 10 | 147 |
| Totals | 79 | 17,928 |
| Grand Total (reported) | | |
| Outbreaks | | 447 |
| Illnesses | | 105,605 |

*Source*: From U.S. Environmental Protection Agency, 1987; Craun, G.F., 1987.

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**Table 10J.227 Waterborne Outbreaks and Deficiencies in United States Public Water Systems Surfacewater Sources, 1991–1998**

| | Community Systems Surfacewater Source | | Noncommunity Systems Surfacewater Source | |
|---|---|---|---|---|
| **Type of Contamination** | **Outbreaks** | **Percent** | **Outbreaks** | **Percent** |
| Untreated surface water | 0 | 0 | 0 | 0 |
| Inadequate or interrupted disinfection; disinfection only treatment | 4 | 18 | 1 | 50 |
| Inadequate or interrupted filtration | 4 | 18 | 0 | 0 |
| Distribution system contamination | 9 | 41 | 0 | 0 |
| Inadequate control of chemical feed | 2 | 9 | 0 | 0 |
| Miscellaneous/unknown | 3 | 14 | 1 | 50 |
| Total | 22 | 100 | 2 | 100 |

*Source*: From Craun, G.F., Calderon, R.L., and Nwachuku, N., 2003, Causes of waterborne outbreaks reported in the United States, 1991–1998 in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, Florida.

**Table 10J.228 Waterborne Outbreaks and Deficiencies in United States Public Water Systems Groundwater Sources, 1991–1998**

| | Community Systems Groundwater Source | | Noncommunity Systems Groundwater Source | |
|---|---|---|---|---|
| **Type of Contamination** | **Outbreaks** | **Percent** | **Outbreaks** | **Percent** |
| Untreated groundwater | 5 | 23 | 18 | 35 |
| Inadequate or interrupted disinfection; disinfection only treatment | 3 | 14 | 21 | 40 |
| Inadequate or interrupted filtration | 1 | 4 | 0 | |
| Distribution system contamination | 8 | 36 | 8 | 15 |
| Inadequate control of chemical feed | 3 | 14 | 0 | |
| Miscellaneous/unknown | 2 | 9 | 5 | 10 |
| Total | 22 | 100 | 52 | 100 |

*Source*: From Craun, G.F., Calderon, R.L., and Nwachuku, N., 2003, Causes of waterborne outbreaks reported in the United States, 1991–1998 in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, Florida.

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**Table 10J.229 Causes of Waterborne Disease Outbreaks in Community Water Systems in the United States — 1971–1998**

| | | Outbreaks[a] — % | | | | |
|---|---|---|---|---|---|---|
| Time Period | Number of Outbreaks | Distribution System Deficiencies | Untreated Groundwater | Inadequate, Interrupted Disinfection of Groundwater | Inadequate Disinfection of Unfiltered Surface Water | Filtered Surface Water |
| 1971–74 | 34 | 32.4 | 14.7 | 17.6 | 20.6 | 2.9 |
| 1975–78 | 39 | 41.0 | 2.6 | 17.9 | 17.9 | 7.7 |
| 1979–82 | 90 | 24.4 | 8.0 | 16.7 | 23.3 | 11.1 |
| 1983–86 | 60 | 31.7 | 6.7 | 11.7 | 28.3 | 13.3 |
| 1987–90 | 24 | 16.7 | 12.5 | 16.7 | 29.2 | 12.5 |
| 1991–94 | 27 | 29.6 | 11.1 | 7.4 | 11.1 | 14.8 |
| 1995–98 | 20 | 45.0 | 10.0 | 10 | 5 | 10 |
| 1971–98 | 294 | 30.3 | 8.8 | 14.6 | 21.4 | 10.5 |

[a] Rows do not total 100% because miscellaneous and unknown causes of outbreaks are not tabulated.

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**Table 10J.230 Causes of Waterborne Disease Outbreaks in Noncommunity Water Systems in the United States — 1971–98**

| | | Outbreaks[a] — % | | | | |
|---|---|---|---|---|---|---|
| Time Period | Number of Outbreaks | Distribution System Deficiencies | Untreated Groundwater | Inadequate, Interrupted Disinfection of Groundwater | Inadequate Disinfection of Unfiltered Surface Water | Filtered Surface Water |
| 1971–74 | 51 | 0 | 40.4 | 28.8 | 11.5 | 1.9 |
| 1975–78 | 77 | 14.3 | 40.3 | 26 | 7.8 | 0 |
| 1979–82 | 67 | 4.5 | 49.3 | 26.9 | 4.5 | 3.0 |
| 1983–86 | 38 | 2.6 | 50.0 | 39.5 | 7.9 | 0 |
| 1987–90 | 29 | 3.4 | 34.5 | 41.4 | 5.1 | 0 |
| 1991–94 | 41 | 12.2 | 34.1 | 34.1 | 2.4 | 0 |
| 1995–98 | 21 | 14.3 | 19.0 | 33.3 | 0 | 0 |
| 1971–98 | 325 | 7.4 | 40.6 | 31.1 | 6.8 | 1.0 |

[a] Rows do not total 100% because miscellaneous and unknown causes of outbreaks are not tabulated.

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**Table 10J.231 Etiology of Outbreaks Caused by Distribution System Contamination in the United States — 1971–1998**

| | CWS[a] | | NCWS[b] | |
|---|---|---|---|---|
| Etiology | Outbreaks | % | Outbreaks | % |
| Chemical | 35 | 39.3 | 3 | 12.5 |
| Unidentified pathogen | 29 | 32.6 | 11 | 45.8 |
| *Giardia* | 8 | 9.0 | 4 | 16.7 |
| *Salmonella* | 4 | 4.5 | 1 | 4.2 |
| Norwalk-like virus | 3 | 3.4 | 1 | 4.2 |
| *Shigella* | 3 | 3.4 | 1 | 4.2 |
| *Campylobacter* | 3 | 3.4 | 1 | 4.2 |
| Hepatitis A | 1 | 1.1 | 1 | 4.1 |
| *Salmonella typhimurium* | 1 | 1.1 | | |
| *Cyclospora* | 1 | 1.1 | | |
| *Escherichia coil* 0157:H7 | 1 | 1.1 | | |
| *Vibrio cholerae* | | | 1 | 4.1 |
| Total | 89 | 100 | 24 | 100 |

[a] CWS — community water system.
[b] NCWS — noncommunity water system.

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**Table 10J.232 Number of Waterborne Outbreaks by Deficiencies in Drinking Systems, in the United States 1971–2000**

| Type of Contamination | *Giardia, Cryptospridium* | *Campylobacter, E. coli, Salmonella, Yersinia* |
|---|---|---|
| Distribution system contamination | 16 | 11 |
| Inadequate disinfection; only treatment, surface water[a] | 52 | 3 |
| Inadequate, interrupted, or bypass of filtration; surface water | 22 | — |
| Untreated groundwater | 14 | 14 |
| Untreated surface water | 14 | 2 |
| Inadequate or interrupted disinfection; groundwater[b] | 13 | 11 |
| Water not intended for drinking; contaminated faucet or ice; unknown | 10 | 8 |
| Total | 141 | 49 |

[a] Includes two outbreaks with surface water and groundwater sources.
[b] Includes three outbreaks where groundwater was filtered.

*Source*: From Cotruvo. J.A. et al., (ed.), 2004. Waterborne Zoonoses, Identification, Causes, and Control, Published on Behalf of the World Health Organization by IWA Publishing, Copyright © World Health Organization 2004, www.who.int.

**Table 10J.233 Epidemiological Characteristics of the Principal Pathogenic Agents in Wastewater**

| Agents | Quantity Excreted per g/feces | Latency[a] | Survival[b] | Multiplication in the Environment | Infecting Dose ID 50[c] |
|---|---|---|---|---|---|
| **Virus** | | | | | |
| Enterovirus (including polio, echo and coxsackie) | $10^7$ | 0 | 3 mo | no | 100 |
| Hepatitis A | $10^6$? | 0 | ? | no | ? |
| Rotavirus | $10^6$? | 0 | ? | no | ? |
| **Bacteria** | | | | | |
| Colibacilli | $10^8$ | 0 | 3 mo | yes | $\pm 10^9$ |
| Salmonella thyphi | $10^8$ | 0 | 2 mo | yes | $10^7$ |
| Other salmonellas | $10^8$ | 0 | 2–3 mo | yes | $10^6$ |
| Shigella | $10^7$ | 0 | 1 mo | yes | $10^4$ |
| Campylobacter | $10^7$ | 0 | 7 d | yes | $10^6$ |
| Cholera | $10^7$ | 0 | 1 mo | yes | $10^8$ |
| Yersinia enterocolitica | $10^5$ | 0 | 3 mo | yes | $10^9$ |
| Leptospira | urine | 0 | 7 d | no | low |
| **Parasites** | | | | | |
| Dysentery amoeba | $10^7$ | 0 | 25 d | no | 10–100 |
| Glardia | $10^5$ | 0 | 25 d | no | 25–100 |
| Balantidium coli | ? | 0 | 20 d? | no | 25–100 |
| Ascaris | $10^4$ | 10 d | 1 y | no | Several units |
| Ancyclostoma | $10^2$ | 7 d | 3 mo | no | 1 |
| Anguillula | 10 | 3 d | 3 wks | yes | 1 |
| Trichocephalus | $10^3$ | 20 d | 9 mo | no | Several units |
| Hymenolepis | ? | 0 | 10 d | no | 1 |
| Taenia | $10^4$ | 2 mo | 9 mo | no | 1 |
| Fasciola hepatica | ? | 2 mo | 4 mo | yes | Several units |
| Other flukes | $10^2$ | 6–8 wks | Life of Host | yes | Several units |

[a] Period necessary for excreted pathogenic agent to become infectious to receiving or susceptible individual; (0, is immediate).
[b] In environment, outside final host (man or animal).
[c] Dose sufficient to provoke the appearance of clinical symptoms in 50% of individuals tested.

*Source*: From Prost, A., 1987, Heath risks stemming from wastewater reutilization, *Water Quality Bulletin*, vol. 12, no. 2.

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**Table 10J.234 Microbial Pathogens Linked to Drinking Water or Recreational Water Contact**

| Organism | Disease | Transmission | Clinical Features |
|---|---|---|---|
| **Helminths** | | | |
| *Schistosoma* spp. | Schistosomaisis | Contact with surface water infected with free swimming cercariae | Urinary and intestinal damage. Bladder cancer |
| *Dracunculus medinentis* | Dracunculiasis | Drinking water | Painful ulcers on lower limbs and feet |
| **Protozoa** | | | |
| *Giardia duodenalis* | Giardiasis | Faecal oral spread through drinking water or recreational water | Diarrhoea and abdominal pain, weight loss and failure to thrive |
| *Cryptosporidium parvum* | Cryptosporidiosis | Faecal oral spread through drinking water or recreational water | Diarrhoea often prolonged |
| *Cyclospora cayetanensis* | Cyclosporiasis | Faecal oral spread through drinking water | Diarrhoea and abdominal pain, weight loss and failure to thrive |
| *Entamoeba histolytica* | Amebiasis | Faecal and spread through drinking water | Diarrhoea, may be severe dysentery |
| *Toxoplasma gondii* | Toxoplasmosis | Drinking water contaminated by feline animals | Glandular fever, foetal damage in pregnant women |
| Free-living amoebae | Amoebic meningoencephalitis | Aspiration of infected surface water into nose | Fatal encephalitis |
| **Algae** | | | |
| Cyanobacteria | Various | Toxins in drinking water or direct contact with surface water blooms | Dermatitis, hepatitis, respiratory symptoms, potentially fatal |
| *Pfesteria piscicida* | Estuary-associated syndrome | Toxins in water | Respiratory and eye irritation, deficiencies in learning and memory and acute confusional states |
| **Bacteria** | | | |
| *Vibrio cholerae* | Cholera | Drinking water | Watery diarrhoea, may be severe |
| *Salmonella* spp. | Salmonellosis | Occasional outbreaks with drinking water | Diarrhoea, colicky abdominal pain and fever |
| *Salmonella typhi* | Typhoid | Drinking water | Fever, malaise and abdominal pain with high mortality |
| *Shigella* spp. | Shigellosis (bacillary dysentery) | Both drinking and recreational water | Diarrhoea frequently with blood loss |
| *Campylobacter* spp. | Campylobacteriois | Both drinking and recreational water | Diarrhoea frequently with blood loss |
| Enterotoxigenic *E. coli* | | Drinking water | Watery diarrhoea |
| Enterohaemorrhagic *E. coli* | | Drinking water and recreational water contact | Bloody diarrhoea and haemolyic uraemic syndrome in children |
| *Yersinia* spp. | Yersiniosis | Drinking water | Fever, diarrhoea and abdominal pain |
| *Francisella tularensis* | Tularaemia | Drinking water | Typhoid-like or mucocutaneous with suppurative skin lesions |
| *Helicobacter pylori* | | Drinking water | Gastritis that can progress to gastric cancer |
| *Mycobacteria* spp. not *M. tuberculosis* | Varies | Potable water systems in hospitals, some recreation | Varies, includes respiratory disease, wound infections, skin disease |
| **Viruses** | | | |
| Hepatitis A and Hepatitis E viruses | Viral hepatitis | Drinking and recreational water contact | Hepatitis |
| Various, esp. Norwalk-like viruses | Viral gastroenteritis | Drinking and recreational water contact | Vomiting and diarrhoea |
| Enteroviruses | Various, including poliomyelitis | Drinking and recreational water contact | Various |

*Source*: From Hunter, P.R., 2003, Climate change and waterborne and vector-borne disease in Sartory, D., Jones, K., Semple, K., and Godfree, A., (eds.), The Society for Applied Microbiology Symposim Series no. 32, *Pathogens in the Environment and Changing Ecosystems*, Blackwell Publishing, Oxford, UK.

**Table 10J.235 Occurrence of Cryptosporidium Oocysts in Various Waters throughout the Western United States**

| Water Sampled | Number of Samples | Number of Samples Positive | Percent Positive | Oocysts/L[a] |
|---|---|---|---|---|
| Raw sewage | 11 | 10 | 91 | 28.4 |
| Treated sewage[b] | 22 | 20 | 91 | 17 |
| Reservoir, lake | 32 | 24 | 75 | 0.91 |
| Stream, river | 58 | 45 | 77 | 0.94 |
| Filtered drinking water | 10 | 2 | 20 | 0.001 |
| Nonfiltered drinking water | 4 | 2 | 50 | 0.006 |

[a] Geometric means.
[b] Activated sludge.

*Source*: From Craun, G.F., 1988. Surface water supplies and health, *J. Am. Water Works Assoc.*, vol. 80, no.2. Copyright AWWA. Reprinted with permission.

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**Table 10J.236 Cryptosporidiosis Case Reports by State/Area — United States, 1999–2002**

| | 1999 | | | | 2000 | | | | 2001 | | | | 2002 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State/Area | No. | (%) | Rate[a] | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases |
| Alabama | 16 | (0.6) | 0.4 | | 16 | (0.6) | 0.4 | | 18 | (0.5) | 0.4 | | 47 | (1.6) | 1.0 | |
| Alaska | NR[b] | | | | NR | (0.3) | | | 1 | (<0.1) | 0.2 | | 1 | (<0.1) | 0.2 | |
| Arizona | 16 | (0.6) | 0.3 | | 10 | (0.8) | 0.2 | | 11 | (0.3) | 0.2 | | 19 | (0.6) | 0.3 | |
| Arkansas | 2 | (0.1) | 0.1 | | 16 | (0.5) | 0.6 | | 10 | (0.3) | 0.4 | | 8 | (0.3) | 0.3 | |
| California | 279 | (10.1) | 0.8 | | 285 | (7.5) | 0.7 | | 229 | (6.0) | 0.7 | | 200 | (6.6) | 0.6 | |
| Colorado | 14 | (0.5) | 0.3 | | 72 | (2.3) | 1.7 | 14 | 44 | (1.2) | 1.0 | | 57 | (1.9) | 1.3 | |
| Connecticut | 22 | (0.8) | 0.6 | | 29 | (0.9) | 0.9 | | 17 | (0.4) | 0.5 | | 19 | (0.6) | 0.5 | |
| Delaware | 1 | (<0.1) | 0.1 | | 9 | (0.3) | 1.1 | | 6 | (0.2) | 0.8 | | 4 | (0.1) | 0.5 | |
| District of Columbia | 7 | (0.3) | 1.2 | | 18 | (0.6) | 3.1 | | 14 | (0.4) | 2.4 | | 5 | (0.2) | 0.9 | |
| Florida | 189 | (6.8) | 1.2 | 186 | 240 | (7.7) | 1.5 | 233 | 91 | (2.4) | 0.6 | | 106 | (3.5) | 0.6 | 97 |
| Georgia | 170 | (6.1) | 2.1 | | 191 | (6.1) | 2.3 | | 162 | (4.3) | 1.9 | | 123 | (4.1) | 1.4 | |
| Hawaii | NR | | | | NR | | | | 3 | (0.1) | 0.2 | 3 | 2 | (0.1) | 0.2 | 2 |
| Idaho | 8 | (0.3) | 0.6 | | 28 | (0.9) | 2.2 | | 23 | (0.6) | 1.7 | | 29 | (1.0) | 2.2 | |
| Illinois | 90 | (3.3) | 0.7 | | 126 | (4.0) | 1.0 | | 488 | (12.8) | 3.9 | 341 | 121 | (4.0) | 1.0 | |
| Indiana | 47 | (1.7) | 0.6 | 1 | 72 | (2.3) | 1.2 | | 90 | (2.4) | 1.5 | | 70 | (2.3) | 1.1 | |
| Iowa | 56 | (2.0) | 1.9 | | 77 | (2.5) | 2.6 | | 82 | (2.2) | 2.8 | | 49 | (1.6) | 1.7 | |
| Kansas | 2 | (0.1) | 0.1 | | 9 | (0.3) | 0.3 | | 7 | (0.1) | 0.1 | | 16 | (0.5) | 0.6 | |
| Kentucky | 7 | (0.3) | 0.2 | 7 | 7 | (0.2) | 0.2 | 7 | 5 | (0.1) | 0.1 | 5 | 10 | (0.3) | 0.2 | 10 |
| Louisiana | 24 | (0.9) | 0.5 | | 14 | (0.4) | 0.3 | | 8 | (0.2) | 0.2 | | 10 | (0.3) | 0.2 | |
| Maine | 81 | (1.1) | 2.4 | | 20 | (0.6) | 1.6 | | 19 | (0.5) | 1.5 | | 12 | (0.4) | 0.9 | |
| Maryland | 17 | (0.6) | 0.3 | | 14 | (0.4) | 0.3 | | 40 | (1.1) | 0.7 | | 19 | (0.6) | 0.3 | |
| Massachusetts | 71 | (2.6) | 1.1 | 55 | 87 | (1.2) | 0.6 | 2 | 55 | (1.5) | 0.9 | | 77 | (2.6) | 1.2 | 2 |
| Michigan | 52 | (1.9) | 0.5 | | 97 | (3.1) | 1.0 | | 187 | (4.9) | 1.9 | | 135 | (4.5) | 1.3 | |
| Minnesota | 91 | (3.3) | 1.9 | 2 | 190 | (6.1) | 3.9 | 4 | 197 | (5.2) | 4.0 | 11 | 206 | (6.8) | 4.1 | 32 |
| Mississippi | 12 | (0.4) | 0.4 | | 16 | (0.5) | 0.6 | | 15 | (0.4) | 0.5 | | 10 | (0.3) | 0.3 | |
| Missouri | 26 | (0.9) | 0.5 | | 31 | (1.0) | 0.6 | | 55 | (1.5) | 1.0 | | 41 | (1.4) | 0.7 | |
| Montana | 13 | (0.5) | 1.4 | | 10 | (0.3) | 1.1 | | 37 | (1.0) | 4.1 | | 6 | (0.2) | 0.7 | |
| Nebraska | 15 | (0.5) | 0.9 | | 82 | (2.6) | 4.8 | | 185 | (4.9) | 10.8 | | 52 | (1.7) | 3.0 | |
| Nevada | 9 | (0.3) | 0.5 | 4 | 4 | (0.1) | 0.2 | 8 | 7 | (0.2) | 0.3 | | 4 | (0.1) | 0.2 | |
| New Hampshire | 20 | (0.7) | 1.6 | 20 | 25 | (0.8) | 2.0 | 25 | 17 | (0.4) | 1.4 | 17 | 31 | (1.0) | 2.4 | 31 |
| New Jersey | 54 | (2.0) | 0.6 | | 19 | (0.6) | 0.2 | | 24 | (0.6) | 0.3 | | 17 | (0.6) | 0.2 | |
| New Mexico | 44 | (1.6) | 2.4 | | 26 | (0.8) | 1.4 | | 80 | (0.8) | 1.6 | | 20 | (0.7) | 1.1 | |
| New York[c] | 452 | (16.3) | 2.4 | 4 | 910 | (9.9) | 1.6 | | 248 | (6.5) | 1.3 | 4 | 300 | (9.9) | 1.6 | 3 |

*(Continued)*



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**Table 10J.236 (Continued)**

| State/Area | 1999 | | | | 2000 | | | | 2001 | | | | 2002 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | (%) | Rate[a] | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases |
| New York City | 260 | (9.4) | 3.5 | | 171 | (5.5) | 2.1 | | 123 | (3.2) | 1.5 | | 147 | (4.9) | 1.8 | |
| North Carolina | 85 | (1.3) | 0.4 | 4 | 28 | (0.9) | 0.3 | | 31 | (0.8) | 0.4 | | 40 | (1.3) | 0.5 | 1 |
| North Dakota | 20 | (0.7) | 3.1 | | 18 | (0.6) | 2.8 | | 15 | (0.4) | 2.4 | | 41 | (1.4) | 6.5 | |
| Ohio | 67 | (2.4) | 0.6 | | 260 | (8.3) | 2.3 | 134 | 185 | (4.9) | 1.6 | | 119 | (3.9) | 1.0 | |
| Oklahoma | 14 | (0.5) | 0.4 | | 30 | (1.0) | 0.9 | | 16 | (0.4) | 0.5 | | 16 | (0.5) | 0.5 | |
| Oregon | 98 | (3.5) | 2.9 | 61 | 20 | (0.6) | 0.6 | | 58 | (1.5) | 1.7 | | 40 | (1.3) | 1.1 | |
| Pennsylvania | 123 | (4.4) | 1.0 | | 64 | (2.0) | 0.5 | | 102 | (2.7) | 0.8 | | 111 | (3.7) | 0.9 | |
| Rhode Island | 6 | (0.2) | 0.6 | | 4 | (0.1) | 0.4 | | 10 | (0.3) | 0.9 | | 21 | (0.7) | 2.0 | |
| South Carolina | NR | | | | NR | | | | 7 | (0.2) | 0.2 | | 8 | (0.3) | 0.2 | |
| South Dakota | 7 | (0.3) | 0.9 | | 15 | (0.5) | 2.0 | | 8 | (0.2) | 1.1 | | 42 | (1.4) | 5.5 | 22 |
| Tennessee | 13 | (0.6) | 0.2 | | 12 | (0.4) | 0.2 | | 24 | (0.6) | 0.4 | | 61 | (2.0) | 1.1 | |
| Texas | 69 | (2.5) | 0.3 | | 115 | (3.7) | 0.6 | | 96 | (2.5) | 0.4 | | 34 | (1.1) | 0.2 | |
| Utah | 4 | (0.1) | 0.2 | | 26 | (0.9) | 1.3 | 1 | 84 | (2.2) | 3.7 | | 16 | (0.5) | 0.7 | |
| Vermont | 36 | (1.9) | 6.0 | 7 | 28 | (0.9) | 4.6 | | 34 | (0.9) | 5.5 | | 33 | (1.1) | 5.4 | |
| Virginia | 30 | (1.1) | 0.4 | | 21 | (0.7) | 0.3 | | 27 | (0.7) | 0.4 | | 35 | (1.2) | 0.5 | |
| Washington | NR | | | | NR | | | | NR | | | | 46 | (1.5) | 0.8 | |
| West Virginia | 3 | (0.1) | 0.2 | | 3 | (0.1) | 0.2 | | 2 | (0.1) | 0.1 | | 3 | (0.1) | 0.2 | |
| Wisconsin | 386 | (13.9) | 7.2 | 2 | 428 | (13.7) | 8.0 | 5 | 664 | (17.5) | 12.3 | 6 | 515 | (17.1) | 9.5 | 5 |
| Wyoming | 1 | (<0.1) | 0.2 | | 5 | (0.2) | 1.0 | | 7 | (0.2) | 1.4 | 2 | 9 | (0.3) | 1.8 | 2 |
| Total | 2,769 | (100.0)[d] | 1.0 | 353 | 3,128 | (100.0) | 1.1 | 428 | 3,787 | (100.0) | 1.3 | 389 | 3,016 | (100.0) | 1.0 | 207 |

*Note:* Population estimates are from the Population Division, U.S. Census Bureau. Estimates of the population of states: ST-99-4 State Rankings of Population Change and Demographic Components of Population Change for the Period July 1, 1998 to July 1, 1999, available at census.goalpopest/archives/1990s/ST-99-01.txt, and Table 1: Annual estimates of the population for the United States and States and Puerto Rico: April 1, 2001, to July 1, 2003 (NST-EST 2003 01), available at www.census.gov/popset/estates/tables/NST-EST2003-01.xls. Estimates of the New York City population: (SU-99-7) Population Estimates for Places (Sorted Alphabetical Within State): Annual Time Series, July 1, 1990 to July 1, 1999 (Includes April 1, 1990 Population Estimates Base), available at www.census.gov/popset/archives/1990a/su-99-07/SU-99-7_NY.txt, and Table 1: Annual Estimates of the Population for incorporated Places over 100,000, Ranked by July 1, 2003 Population; April 1, 2001, to July 1, 2003 (SUB-EST 2003-01) available at www.census.gov/popest/cities/tables/SUB-EST2003-01.xls.

[a] Per 100,000 population on the basis of U.S. Census Bureau population estimates.
[b] No cases reported.
[c] New York State case counts include New York City cases.
[d] Percentages might not total 100% because of rounding.

*Source*: From Hlavsa, M.C., Watson, J.C. and Beach, M.J., 2005, Cryptosporidiosis surveillance – United States 1999–2002, *MMWR Surveillance Summaries*, vol. 54, no. SS-01, January 28, 2005, www.cdc.gov.

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**Table 10J.237 Outbreaks and Cases of Cryptosporidiosis in England and Wales, 1983–1997**

| Year | Number of Outbreaks | Drinking Water Outbreaks[a] | Total Outbreak Cases | Total Drinking Water Cases[a] | Total Cases in England and Wales | Outbreak Cases as a Percentage of the Total | Drinking Water Outbreak Cases as a Percentage of the Total[a] |
|---|---|---|---|---|---|---|---|
| 1983 | 1 | 0 | 16 | 0 | 61 | 26 | 0 |
| 1984 | 1 | 0 | 19 | 0 | 876 | 2 | 0 |
| 1985 | 3 | 0 | 60 | 0 | 1875 | 3 | 0 |
| 1986 | 4 | 0 | 98 | 0 | 3560 | 3 | 0 |
| 1987 | 1 | 0 | 69 | 0 | 3277 | 2 | 0 |
| 1988 | 2 | 0 | 102 | 0 | 2750 | 4 | 0 |
| 1989 | 6 | 3 | 1,090 | 1,042 | 7,768 | 14 | 13 |
| 1990 | 4 | 2 | 92 | 49 | 4,682 | 2 | 1 |
| 1991 | 9 | 2 | 93 | 46 | 5,165 | 2 | 1 |
| 1992 | 12 | 4 | 549 | 343 | 5,211 | 11 | 7 |
| 1993 | 9 | 3 | 358 | 164 | 4,832 | 7 | 3 |
| 1994 | 7 | 2 | 373 | 257 | 4,432 | 8 | 6 |
| 1995 | 5 | 1 | 612 | 575 | 5,691 | 11 | 10 |
| 1996 | 4 | 3 | 244 | 236 | 3,660 | 7 | 6 |
| 1997 | 12 | 5 | 874 | 743 | 4,321 | 20 | 17 |
| Total | 80 | 25 | 4,649 | 3,455 | 58,161 | 8 | 6 |

[a] Cases include those with a strong probable or possible association with public drinking water.

*Source*: From Nichos, G., 2003, Using existing surveillance-based data in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, FL.

**Table 10J.238 Some Published Cases of Cryptosporidiosis Outbreaks in Recreational Waters, 1986–2001**

| Year | Location | Facility | Disinfectant | No. of Cases Estimated (Confirmed) |
|---|---|---|---|---|
| 1986 | New Mexico, United States | Lake | None | 56 |
| 1988 | Doncaster, England | Pool | Chlorine | (79) |
| 1988 | Los Angeles county, United States | Pool | Chlorine | 44 (5) |
| 1990 | British Columbia, Canada | Pool | Chlorine | 66 (23) |
| 1992 | Gloucestershire, England | Pool | Chlorine | (13) |
| 1992 | Idaho, United States | Water Slide | Ozone/Chlorine | 500 |
| 1992 | Oregon, United States | Pool (wave) | Chlorine | (52) |
| 1993 | Wisconsin, United States | Pool (motel) | Chlorine | 51 (22) |
| 1993 | Wisconsin, United States | Pool (motel) | Chlorine | 64 |
| 1993 | Wisconsin, United States | Pool | Chlorine | 5 |
| 1993 | Wisconsin, United States | Pool | Chlorine | 54 |
| 1994 | Missouri, United States | Pool (motel) | Chlorine | 101 (26) |
| 1994 | New Jersey, United States | Lake | None | 2,070 (46) |
| 1994 | South west England | Pool | Chlorine | 14 (8) |
| 1994 | Sutherland Australia | Pool | Chlorine | (70) |
| 1995 | Kansas, United States | Pool | [a] | 101 (2) |
| 1995 | Georgia, United States | Water Park | Chlorine | 2,470 (6) |
| 1995 | Nebraska, United States | Water Park | [a] | (14) |
| 1996 | Florida, United States | Pool | [a] | 22 (16) |
| 1996 | California, United States | Water Park | Chlorine | 3,000 (29) |
| 1996 | Andover, England | Pool | Chlorine | 8 |
| 1996 | Indiana, United States | Lake | None | 3 |
| 1997 | England and Wales | River | None | 27 (7) |
| 1997 | England and Wales | Pool | Ozone/Chlorine | (9) |
| 1997 | Minnesota, United States | Fountain | (Sand Filter) | 369 (73) |
| 1997 | Queensland, Australia | Pools | [a] | 129 |
| 1998 | Canberra, Australia | 3 Pools | [a] | (210) |
| 1998 | Oregon, United States | Pool | [a] | 51 (8) |

*(Continued)*

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**Table 10J.238 (Continued)**

| Year | Location | Facility | Disinfectant | No. of Cases Estimated (Confirmed) |
|---|---|---|---|---|
| 1998 | New South Wales, Australia | Pools | [a] | 370 |
| 1998 | Hutt Valley, New Zealand | Pools | [a] | (171) |
| 1998 | Minnesota, United States | Pool | [a] | (26) |
| 1999 | Florida, United States | Interactive water fountain | Chlorine | 38 (2) |
| 2000 | Ohio, United States | Pool | [a] | 700 (186) |
| 2000 | Nebraska, United States | Pool | [a] | 225 (65) |
| 2000 | Trent region, England | Pool | Chlorine | 41 (41) |
| 2000 | London, England | Pool | Chlorine | 3 (3) |
| 2001 | South west England | Pool | Chlorine | 14 (8) |
| 2001 | South west England | Stream onto Beach | None | 14 (6) |

[a] Data not available.

*Source*: From Pond, K., 2005. *Water Recreation and Disease Plausibility and Associated Infections: Acute Effects, Sequelae, and Mortality*, Published on behalf of the World Health Organization by IWA Publishing, London Copyright © World Health Organization 2005, www.who.int.

*Original Source*: From Fayer et al., 2002; CDR Weekly website: hpa.org.uk.

**Table 10J.239 Total Waterborne Outbreaks of Giardiasis in United States Water Systems, 1965–1995**

| Time Period | Number of Outbreaks |
|---|---|
| 1965–1970 | 3 |
| 1971–1975 | 12 |
| 1976–1980 | 26 |
| 1981–1985 | 49 |
| 1986–1990 | 16 |
| 1991–1995 | 11 |

*Source*: From United States Environmental Protection Agency, 1998, *Giardia: Human Health Criteria Document*, EPA-823-R-002, www.epa.gov.

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**Table 10J.240 Waterborne Outbreaks of Giardiasis by Type of Water System in the United States, 1965–1996**

| | Community Water Systems | | Noncommunity Water Systems | | Individual Systems & Nonpotable Water | | Total | |
|---|---|---|---|---|---|---|---|---|
| Year | Outbreaks | Cases | Outbreaks | Cases | Outbreaks | Cases | Outbreaks | Cases |
| 1965 | 1 | 123 | 0 | 0 | 0 | 0 | 1 | 123 |
| 1966–1968 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1969 | 0 | 0 | 1 | 19 | 0 | 0 | 1 | 19 |
| 1970 | 1 | 34 | 0 | 0 | 0 | 0 | 1 | 34 |
| 1971 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1972 | 1 | 12 | 3 | 112 | 0 | 0 | 3 | 124 |
| 1973 | 2 | 52 | 1 | 16 | 1 | 5 | 4 | 73 |
| 1974 | 2 | 4,878 | 1 | 18 | 1 | 34 | 4 | 4,930 |
| 1975 | 0 | 0 | 0 | 0 | 1 | 9 | 1 | 9 |
| 1976 | 1 | 600 | 2 | 39 | 0 | 0 | 3 | 639 |
| 1977 | 2 | 950 | 2 | 62 | 0 | 0 | 4 | 1,012 |
| 1978 | 2 | 5,130 | 1 | 23 | 1 | 18 | 4 | 5,171 |
| 1979 | 5 | 3,789 | 2 | 2,120 | 0 | 0 | 7 | 5,909 |
| 1980 | 7 | 1,724 | 0 | 0 | 1 | 6 | 8 | 1,730 |
| 1981 | 8 | 265 | 2 | 39 | 1 | 7 | 11 | 311 |
| 1982 | 9 | 497 | 2 | 60 | 1 | 4 | 12 | 561 |
| 1983 | 17 | 2,216 | 0 | 0 | 1 | 4 | 18 | 2,220 |
| 1984 | 3 | 463 | 1 | 400 | 1 | 3 | 5 | 866 |
| 1985 | 1 | 703 | 2 | 38 | 0 | 0 | 3 | 741 |
| 1986 | 4 | 251 | 1 | 23 | 0 | 0 | 5 | 274 |
| 1987 | 2 | 633 | 0 | 0 | 0 | 0 | 2 | 633 |
| 1988 | 2 | 262 | 0 | 0 | 0 | 0 | 2 | 262 |
| 1989 | 3 | 380 | 1 | 152 | 0 | 0 | 4 | 532 |
| 1990 | 1 | 123 | 2 | 42 | 0 | 0 | 3 | 165 |
| 1991 | 0 | 0 | 2 | 28 | 0 | 0 | 2 | 28 |
| 1992 | 2 | 95 | 0 | 0 | 0 | 0 | 2 | 95 |
| 1993 | 2 | 27 | 0 | 0 | 0 | 0 | 2 | 27 |
| 1994 | 3 | 358 | 0 | 0 | 0 | 0 | 3 | 358 |
| 1995 | 1 | 1,449 | 0 | 0 | 1 | 10 | 2 | 1,459 |
| 1996 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 82 | 25,014 | 26 | 3,191 | 10 | 100 | 117 | 28,305 |

*Source*: From United States Environmental Protection Agency, 1998, *Giardia: Human Health Criteria Document*, EPA-823-R-002, www.epa.gov.

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**Table 10J.241 Glardiasis Case Reports, by State/Area — United States, 1998–2002**

| | 1998 | | | | 1999 | | | | 2000 | | | | 2001 | | | | 2002 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State/Area | No. | (%) | Rate[a] | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases | No. | (%) | Rate | No. of Outbreak Cases |
| Alabama | 288 | (1.2) | 6.6 | | 340 | (1.5) | 7.8 | | 227 | (1.0) | 5.1 | | 231 | (1.2) | 5.2 | | 205 | (1.0) | 4.6 | |
| Alaska | 109 | (0.4) | 17.7 | | 96 | (0.4) | 15.5 | | 115 | (0.5) | 18.3 | | 121 | (0.6) | 19.1 | | 115 | (0.5) | 17.9 | 21 |
| Arizona | 250 | (1.0) | 5.4 | | 255 | (1.1) | 5.3 | | 313 | (1.4) | 6.1 | | 267 | (1.4) | 5.0 | 2 | 269 | (1.3) | 4.9 | 1 |
| Arkansas | 168 | (0.7) | 6.6 | | 152 | (0.7) | 6.0 | | 203 | (0.9) | 7.6 | | 160 | (0.8) | 5.9 | | 175 | (0.8) | 6.5 | |
| California | NR[b] | | | | NR | | | | NR | | | | NR | | | | 2,561 | (12.0) | 7.3 | |
| Colorado | 618 | (2.6) | 15.6 | | 704 | (3.0) | 17.4 | 4 | 695 | (3.2) | 16.2 | 5 | 632 | (3.2) | 14.3 | 2 | 571 | (2.7) | 12.7 | 5 |
| Connecticut | NR | | | | NR | | | | 462 | (2.1) | 13.6 | | 417 | (2.1) | 12.1 | | 260 | (1.2) | 7.5 | |
| Delaware | 39 | (0.2) | 5.2 | | 52 | (0.2) | 6.9 | | 92 | (0.4) | 11.7 | | 59 | (0.3) | 7.4 | | 54 | (0.3) | 6.7 | |
| District of Columbia | 34 | (0.1) | 6.5 | | 37 | (0.2) | 7.1 | | 38 | (0.2) | 6.6 | | 70 | (0.4) | 12.2 | | 47 | (0.2) | 8.3 | |
| Florida | 1,676 | (6.9) | 11.2 | 1,636 | 1,360 | (5.8) | 9.0 | 1,334 | 1,521 | (7.0) | 9.5 | 1,459 | 1,155 | (5.9) | 7.1 | | 1,318 | (6.2) | 7.9 | 1,226 |
| Georgia | 1,215 | (5.0) | 15.9 | | 1,355 | (5.8) | 17.4 | | 1,201 | (5.5) | 14.7 | | 963 | (4.9) | 11.5 | | 926 | (4.3) | 10.8 | |
| Hawaii | 123 | (0.5) | 10.3 | 99 | 117 | (0.5) | 9.9 | 117 | 105 | (0.5) | 8.7 | 105 | 118 | (0.6) | 9.6 | 118 | 91 | (0.4) | 7.3 | 91 |
| Idaho | 177 | (0.7) | 14.4 | 1 | 134 | (0.6) | 10.7 | 1 | 139 | 0.6 | 10.7 | | 172 | (0.9) | 13.0 | 1 | 137 | (0.6) | 10.2 | 1 |
| Illinois | 1,472 | (6.1) | 12.2 | | 1,458 | (6.3) | 12.0 | 11 | 1,093 | (5.0) | 8.8 | | 1,108 | (5.6) | 8.9 | | 1,011 | (4.8) | 8.0 | |
| Indiana | 772 | (3.2) | (13.1) | | 654 | (2.8) | 11.0 | 3 | 517 | (2.4) | 8.5 | | 3 | (<0.1) | <0.1 | | NR | | | |
| Iowa | 429 | (1.8) | 15.0 | 4 | 377 | (1.8) | 13.1 | | 420 | (1.9) | 14.4 | | 345 | (1.8) | 11.8 | | 314 | (1.5) | 10.7 | |
| Kansas | 226 | (0.9) | 8.6 | 7 | 220 | (0.9) | 8.3 | | 205 | (0.9) | 7.6 | | 178 | (0.9) | 6.6 | | 192 | (0.9) | 7.1 | |
| Kentucky | NR | | | | NR | | | | NR | | | | NR | | | | NR | | | |
| Louisiana | NR | | | | 21 | (0.1) | 0.5 | | 41 | (0.2) | 0.9 | | 14 | (0.1) | 0.3 | | 6 | (<0.1) | 0.1 | |
| Maine | 277 | (1.1) | 20.2 | | 236 | (1.0) | 19.0 | | 238 | (1.1) | 18.7 | | 197 | (1.0) | 15.3 | 1 | 213 | (1.0) | 16.4 | |
| Maryland | NR | | | | 119 | (0.5) | 2.3 | | 125 | (0.6) | 2.4 | 8 | NR | | | | 118 | (0.6) | 2.2 | 5 |
| Massachusetts | 833 | (3.4) | 13.6 | 637 | 851 | (3.7) | 13.8 | 640 | 632 | (2.9) | 10.0 | 12 | 906 | (4.6) | 14.2 | 27 | 935 | (4.4) | 14.6 | 1 |
| Michigan | 1,172 | (4.8) | 11.9 | 8 | 1,166 | (5.0) | 11.8 | 2 | 1,135 | (5.2) | 11.4 | 1 | 1,003 | (5.1) | 10.0 | 1 | 923 | (4.3) | 9.2 | |
| Minnesota | 1,324 | (5.5) | 28.0 | 8 | 1,555 | (6.7) | 32.6 | 9 | 1,227 | (5.6) | 24.9 | 22 | 1,061 | (6.4) | 21.3 | 16 | 982 | (4.6) | 19.5 | |
| Mississippi | 131 | (0.5) | 4.8 | 131 | 145 | (0.6) | 5.2 | | 116 | (0.5) | 4.1 | | NR | | | | NR | | | |
| Missouri | 790 | (3.3) | 14.5 | | 807 | (3.5) | 14.8 | | 839 | (3.8) | 15.0 | | 715 | (3.6) | 12.7 | | 512 | (2.4) | 9.0 | |
| Montana | 119 | (0.5) | 13.5 | 2 | 83 | (0.4) | 9.4 | 1 | 91 | (0.4) | 10.1 | 1 | 95 | (0.5) | 10.5 | | 94 | (0.4) | 10.3 | |
| Nebraska | 249 | (1.0) | 15.0 | | 288 | (1.0) | 14.3 | | 300 | (1.4) | 17.5 | 1 | 234 | (1.2) | 13.6 | | 191 | (0.9) | 11.1 | |
| Nevada | 222 | (0.9) | 12.7 | 140 | 215 | (0.9) | 11.9 | 121 | 211 | (1.0) | 10.6 | 138 | 208 | (1.1) | 9.9 | | 162 | (0.8) | 7.5 | |
| New Hampshire | 83 | (0.3 | 7.0 | 83 | 64 | (0.3) | 5.3 | 64 | 56 | (0.3) | 4.5 | 56 | 98 | (0.2) | 3.0 | 38 | 46 | (0.2) | 3.6 | 46 |
| New Jersey | 218 | (0.9) | 2.7 | | NR | | | | NR | | | | 494 | (2.5) | 5.8 | | 474 | (2.2) | 5.5 | |
| New Mexico | 238 | (1.0) | 13.7 | | 261 | (1.1) | 15.0 | 1 | 164 | (0.8) | 9.0 | | 148 | (0.8) | 8.1 | | 153 | (0.7) | 8.3 | |
| New York[c] | 3,789 | (15.4) | 20.6 | 55 | 3,696 | (15.9) | 20.3 | 78 | 3,346 | (15.3) | 17.6 | 83 | 2,903 | (14.7) | 15.2 | 66 | 2,764 | (13.0) | 14.4 | 80 |

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| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New York City | 2,079 | (8.6) | 28.1 | | 1,894 | (8.1) | 25.5 | | 1,797 | (8.0) | 21.7 | | 1,620 | (7.7) | 18.9 | | 1,417 | (6.7) | 17.6 | |
| North Carolina | NR | | | | NR | | | | NR | | | | NR | | | | NR | | | |
| North Dakota | 82 | (0.3) | 12.9 | | 104 | (0.4) | 16.4 | | 65 | (0.3) | 10.1 | | 78 | (0.4) | 12.3 | | 47 | (0.2) | 7.4 | |
| Ohio | 1,093 | (4.5) | 9.7 | 1 | 1,110 | (4.8) | 9.9 | 2 | 1,058 | (4.9) | 9.3 | 1 | 1,090 | (5.5) | 9.6 | 1 | 972 | (4.6) | 8.5 | 6 |
| Oklahoma | 148 | (0.6) | 4.4 | | 162 | (0.7) | 4.5 | | 96 | (0.4) | 2.8 | | NR | | | | 85 | (0.4) | 2.4 | |
| Oregon | 900 | 3.7 | 27.4 | | 808 | (3.5) | 24.4 | 2 | 654 | (3.0) | 19.1 | 13 | 543 | (2.8) | 15.6 | 4 | 447 | (2.1) | 12.7 | 4 |
| Pennsylvania | 1,681 | (6.0) | 12.2 | 2 | 1,124 | (4.8) | 9.4 | 4 | 1,083 | (5.0) | 8.8 | 10 | 1,150 | (5.8) | 9.4 | 8 | 1,066 | (5.0) | 8.6 | 1 |
| Rhode Island | 130 | (0.5) | 13.2 | | 149 | (0.6) | 15.0 | | 157 | (0.7) | 15.0 | | 168 | (0.9) | 15.9 | | 170 | (0.8) | 15.9 | |
| South Carolina | NR | | | | NR | | | | NR | | | | NR | | | | 149 | (0.7) | 3.6 | |
| South Dakota | 181 | (0.7) | 24.8 | | 143 | (0.6) | 19.5 | 5 | 108 | (0.5) | 14.3 | 16 | 106 | (0.5) | 14.0 | 15 | 83 | (0.4) | 10.9 | 7 |
| Tennessee | 220 | (0.9) | 4.0 | | 187 | (0.8) | 3.4 | | 187 | (0.9) | 3.3 | | 169 | (1.0) | 3.3 | | 191 | (0.9) | 3.3 | |
| Texas | NR | | | | NR | | | | NR | | | | NR | | | | 3 | (<0.1) | <0.1 | |
| Utah | 291 | (1.2) | 13.9 | | 256 | (1.1) | 12.0 | 19 | 281 | (1.3) | 12.6 | 42 | 284 | (1.4) | 12.5 | 3 | 335 | (1.6) | 14.4 | |
| Vermont | 326 | (1.9) | 55.2 | | 345 | (1.5) | 58.1 | 30 | 217 | (1.0) | 35.6 | | 220 | (1.1) | 35.9 | | 145 | (0.7) | 23.5 | |
| Virginia | 503 | (2.1) | 7.4 | | 471 | (2.0) | 6.9 | 1 | 487 | (2.0) | 6.2 | | 417 | (2.1) | 5.8 | | 386 | (1.8) | 5.3 | |
| Washington | 740 | (3.1) | 13.0 | | 560 | (2.4) | 9.7 | | 622 | (2.9) | 10.6 | | 512 | (2.6) | 8.5 | | 510 | (2.4) | 8.4 | |
| West Virginia | 90 | (0.4) | 5.0 | 4 | 93 | (0.4) | 5.1 | 1 | 80 | (0.4) | 4.4 | 3 | 89 | (0.4) | 4.6 | | 78 | (0.4) | 4.3 | |
| Wisconsin | 1,003 | (4.1) | 19.2 | | 936 | (4.0) | 17.8 | 10 | 811 | (3.7) | 15.1 | 3 | 765 | (3.9) | 14.2 | 12 | 691 | (3.2) | 12.7 | 5 |
| Wyoming | 45 | (0.2) | 9.4 | | 37 | (0.2) | 7.7 | | 49 | (0.2) | 9.9 | 1 | 87 | (0.2) | 7.5 | 1 | 29 | (0.1) | 5.8 | |
| Total state | 24,204 | (99.9) | 9.0 | 2,818 | 23,245 | (99.8) | 8.5 | 2,460 | 21,772 | (99.8) | 7.7 | 1,980 | 19,659 | (99.8) | 6.9 | 316 | 21,206 | (99.6) | 7.4 | 1,500 |
| Guam | 9 | (<0.1) | 6.0 | | 23 | (0.1) | 15.1 | | 17 | (0.1) | 10.9 | | 9 | (<0.1) | 5.7 | | 7 | (<0.1) | 4.3 | |
| Northern Mariana Islands | NR | | — | | NR | | — | | NR | | — | | NR | | — | | 1 | (<0.1) | 1.4 | |
| Puerto Rico | 13 | (0.1) | 0.3 | | 13 | (0.1) | 0.3 | | 24 | (0.1) | 0.6 | | 40 | (0.2) | 1.0 | 3 | 86 | (0.4) | 2.2 | 2 |
| Total | 24,226 | (100)[d] | | 2,818 | 23,281 | (100.0) | | 2,460 | 21,813 | (100.0) | | 1,980 | 19,706 | (100.0) | | 319 | 21,300 | (100.0) | | 1,502 |

*Note:* Population estimates are from the Population Division, U.S. Census Bureau, Estimates of the population of states: ST-99-4 State Rankings of Population Change and Demographic Components of Population Change for the Period July 1, 1998 to July 1, 1999, available at www.census.gov/popest/archives/states/1990s/ST-90-01.txt, and Table1: Annual estimates of the population for the United States and States and Puerto Rico: April 1, 2001, to July 2003 (NST-EST 2003 01), available at www.census.gov/popest/states/tables/NST-EST2003-01.xls. Estimates of the New York City population: (SU-99-7) Population Estimates for Places (Sorted Alphabetically With in State): Annual Time Series, July 1, 1990 to July 1, 1999 (includes April 1, 1990 Population Estimates Base), available at www.census.gov/popest/archives/1990s/su-99-07/SU-99-7_NY.txt, and Table 1: Annual Estimates of the Population for Incorporated Places over 100,000. Ranked by July 1, 2003 Population: April 1, 2001, to July 1, 2003 (SUB-EST 2003-01), available at www.census.gov/popest/cities/tables/SUB-EST2003-01.xls. Estimates of the population of Guam, the Northern Marians Islands, and Puerto Rico: International Data Base (IDB) Data access — Spreadsheet, available at www.census.gov/ipc/www/dbsprd.html.

[a] Per 100,000 population on the basis of U.S. Census Bureau population estimates.
[b] No cases reported to CDC.
[c] New York State counts include New York City cases.
[d] Percentages might not total 100% because of rounding.

*Source*: From Hlavsa, M.C., Watson, J.C. and Beach, M.J., 2005, Giardiasis surveillance – United States 1998-2002, *MMWR Surveillance Summaries*, vol. 54, no. SS-01, January 28, 2005, pp. 9–16, www.cdc.gov.



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**Table 10J.242 Causes of Waterborne Outbreaks of Giardiasis in the United States, 1971–1994**

| Water Source, Treatment, or Deficiency | Outbreaks |
|---|---|
| Surface water source | |
| Untreated | 13 |
| Chlorination only | 51 |
| Filtered (includes outbreaks when filtration was bypassed) | 17 |
| Groundwater source | |
| Untreated | 8 |
| Chlorination only | 7 |
| Filtration | 1 |
| Contamination of distribution system or storage | 12 |
| Use of water not intended for drinking or ingestion during water recreation or other water activities | 14 |
| Insufficient information | 4 |
| Total | 127 |

*Source*: From United States Environmental Protection Agency, 1998, *Giardia: Human Health Criteria Document*, EPA-823-R-002, www.epa.gov.

**Table 10J.243 Causes of Waterborne Diseases in England and Wales, 1971–2000**

| Decade | Cause | No. Outbreaks | No. Cases |
|---|---|---|---|
| **Public Supplies** | | | |
| 1971–1980 | Gastroenteritis | 2 | 3,114 |
| | *Giardia* | 1 | 60 |
| | Total | 3 | 322 |
| 1981–1990 | *Cryptosporidium* | 7 | 1,157 |
| | *Campylobacter* | 3 | 629 |
| | Gastroenteritis | 3 | 310 |
| | Total | 13 | 2,096 |
| 1981–2000 | *Cryptosporidium* | 23 | 2,837 |
| | *Campylobacter* | 1 | 281 |
| | Gastroenteritis | 1 | 229 |
| | Total | 25 | 3,347 |
| **Private Supplies** | | | |
| 1971–1980 | Paratyphoid | 1 | 6 |
| | Gastroenteritis | 1 | 160 |
| | Total | 2 | 166 |
| 1981–1990 | *Campylobacter* | 3 | 520 |
| | Streptobacillary fever | 1 | 304 |
| | Gastroenteritis | 1 | 56 |
| | Total | 5 | 962 |
| 1991–2000 | *Campylobacter* | 8 | 178 |
| | Mixed *Campylobacter* and *Cryptosporidium* | 1 | 43 |
| | *Cryptosporidium* | 3 | 74 |
| | Gastroenteritis | 2 | 81 |
| | *Giardia* | 1 | 31 |
| | *E. coli* O157 | 1 | 14 |
| | Total | | 421 |

*Source*: From Stanwell-Smith, R., Anderson, Y., and Levy, D., 2003, National surveillance systems in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, FL.

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**Table 10J.244 Etiology of Recreational Waterborne Outbreaks, Outbreaks, and Cases of Illness by Type of Water Source in the United States, 1991–1998**

| | Outbreaks | | | | Cases of Illness | | | |
|---|---|---|---|---|---|---|---|---|
| | Swim | | | | Swim | | | |
| Etiological Agent | Lake | Swim Pool[a] | River | Other[b] | Lake | Swim Pool | River | Other[b] |
| *Cryptosporidium* | 3 | 19 | | 1 | 429 | 9,477 | | 369 |
| *Naegleria* | 9 | | 4 | 4 | 9 | | 4 | 4 |
| *E. coli* O157:H7 | 9 | 2 | | | 293 | 44 | | |
| *Shigella* | 11 | | | 1 | 1,216 | | | 9 |
| Undetermined | 8 | 1 | 1 | 1 | 1,016 | 100 | 15 | 61 |
| *Giardia* | 3 | 5 | 1 | | 59 | 187 | 6 | |
| *Schistosoma* | 6 | | | 1 | 173 | | | 30 |
| *Pseudomonas* | | 5 | | | | 162 | | |
| *Leptospira* | 2 | | | 1 | 48 | | | 55 |
| *Norwalk-like virus* | 2 | | | 1 | 48 | | | 55 |
| Chemical | | 2 | | | | 29 | | |
| *Salmonella*, on-typhoid | | 1 | | | | 3 | | |
| Adenovirus | 1 | | | | 595 | | | |
| Total | 54 | 35 | 6 | 9 | 4,219 | 10,002 | 25 | 528 |

[a] Includes wading pools and pools and other activities at water parks.
[b] Water slide park, dunking booth, hot spring, canal, fountain, ocean unknown.

*Source*: From Craun, G.F., Calderon, R.L., and Nwachuku, N., 2003, Causes of waterborne outbreaks reported in the United States, 1991–1998 in Hunter, P.R., Waite, M., and Ronchi, El., (eds.), *Drinking Water and Infectious Disease Establishing the Links*, CRC Press LLC, Boca Raton, FL.

**Table 10J.245 Waterborne-Disease Outbreaks ($n=65$) Associated with Recreational Water, by Etiologic Agent and Type of Water in the United States, 2001–2002**

| | Type | | | | | |
|---|---|---|---|---|---|---|
| | Treated | | Fresh | | Total | |
| Etiologic Agent | Outbreaks | Cases | Outbreaks | Cases | Outbreaks | Cases |
| **Bacterial** | 24 | 571 | 3 | 69 | 27 | 640 |
| *Pseudomonas aeruginosa* | 18[a] | 393 | 0 | 0 | 18 | 393 |
| *Escherichia coli* (O157:H7, O26:NM) | 1 | 9 | 3[b] | 69 | 4 | 78 |
| *Shigella sonnei* | 2 | 78 | 0 | 0 | 2 | 78 |
| *Bacillus* species | 1 | 20 | 0 | 0 | 1 | 20 |
| *Legionella* species | 1 | 68 | 0 | 0 | 1 | 68 |
| *Staphylococcus* species | 1 | 3 | 0 | 0 | 1 | 3 |
| **Parasitic** | 9 | 1,469 | 12 | 34 | 21 | 1,503 |
| *Cryptosporidum* species | 9 | 1,469 | 2 | 5 | 11 | 1,474 |
| *Naagleria fowleri* | 0 | 0 | 8 | 8 | 8 | 8 |
| *Giardia intestinalis* | 0 | 0 | 1 | 2 | 1 | 2 |
| Avian schistosomes | 0 | 0 | 1[a] | 19 | 1 | 19 |
| **Unknown** | 5 | 63 | 3 | 82 | 8 | 145 |
| AGI[c] | 4 | 59 | 3 | 82 | 7 | 141 |
| ARI[d] | 1 | 4 | 0 | 0 | 1 | 4 |
| **Viruses** | 2 | 51 | 3[b] | 95 | 5 | 146 |
| Norovirus | 2 | 51 | 3[b] | 95 | 5 | 146 |
| **Chemical** | 4 | 102 | 0 | 0 | 4 | 102 |
| Chlorine gas | 2 | 50 | 0 | 0 | 2 | 50 |
| Chloramines | 2[a] | 52 | 0 | 0 | 2 | 52 |
| Total | 44 | 2,256 | 21 | 280 | 65 | 2,536 |
| Percentage | (67.7) | (89.0) | (32.3) | (11.0) | (100) | (100) |

[a] Includes outbreaks of suspected etiology on the basis of clinical syndrome and setting.
[b] Includes one mixed-pathogen outbreak.
[c] Acute gastrointestinal illness of unknown etiology.
[d] Acute respiratory illness of unknown etiology.

*Source*: From Yoder, J.S. et al., 2004, Surveillance for waterborne-disease outbreaks associated with recreation water – United States, 2001–2002, *MMWR*, vol. 53, no. SS08, pp 1–22, October 22, 2004, www.cdc.gov.

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**Table 10J.246 Causes of Waterborne Disease Outbreaks Associated with Recreational Water in the United States**

| Source of Contamination or Deficiency | Number of Outbreaks |
|---|---|
| Fecal accident or ill bather | 13 |
| Children in diapers | 8 |
| Poor maintenance, inadequate treatment or operation of swimming or wading pool | 9 |
| Bather overload or crowding | 3 |
| Floods | 1 |
| Livestock | 1 |
| Geese | 2 |
| Seepage or overflow of sewage | 3 |
| Total | 40 |

*Source*: From Craun, G.F., Calderon, R.L., and Nwachuku, N., 2003, Causes of waterborne outbreaks reported in the United States, 1991–1998 in *Drinking Water and Infectious Disease Establishing the Links*, Hunter, P.R., Waite, M., and Ronchi, El., (eds.), CRC Press LLC, Boca Raton, FL.

**Table 10J.247 Swimming-Associated Giardiasis Outbreaks Reported in the United States, 1982–1996**

| State | Year | Cases | Location | Additional Information |
|---|---|---|---|---|
| Washington | 1982 | 78 | Swimming pool | |
| Illinois | 1985 | 15 | Swimming pool | Fecal contamination |
| New Jersey | 1985 | 9 | Indoor pool | |
| Maryland | 1987 | 266 | Swimming pool | Inadequate chlorination |
| Maryland | 1988 | 34 | Swimming pool | |
| Georgia | 1991 | 9 | Swimming pool | Day-care center |
| Georgia | 1991 | 7 | Swimming pool | Day-care center |
| Maryland | 1991 | 14 | Pool | Park; fecal contamination |
| Washington | 1991 | 4 | Swimming pool | Wild animals near lake |
| Maryland | 1993 | 12 | Swimming pool | |
| New Jersey | 1993 | 43 | Swimming pool | Met water quality limits |
| Washington | 1993 | 6 | River | |
| Indiana | 1994 | 80 | Swimming pool | Filter malfunction |
| Florida | 1996 | 60 | Wading pool | |

*Source*: From United States Environmental Protection Agency, 1998, *Giardia: Human Health Criteria Document*, EPA-823-R-002, www.epa.gov.

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**Table 10J.248 Number of Cases of Shigellosis Associated with Recreational Waters in the United States, 1991–2000**

| State | Date | Etiologic Agent | Illness | No. of Cases | Source and Settings |
|---|---|---|---|---|---|
| Rhode Island | July 1991 | *S. sonnei* | GI | 23 | Lake, swimming area |
| Mass. | June 1991 | *S. sonnei* | GI | 203 | Lake, park |
| Virginia | July 1992 | *S. sonnei* | GI | 9 | Lake, camp |
| New Jersey | June 1992 | *S. sonnei* | GI | 54 | Lake, Campground |
| Ohio | July 1993 | *S. sonnei* | GI | 150 | Lake, park |
| New Jersey | June 1994 | *S. sonnei* | GI | 242 | Lake, park |
| Minnesota | May 1994 | *S. flexneri* | GI | 35 | Lake, park |
| Colorado | July 1995 | *S. sonnei* | GI | 81 | Lake, recreational area |
| Colorado | July 1995 | *S. sonnei* | GI | 39 | Lake, recreational area |
| Penn. | Aug 1995 | *S. sonnei* | GI | 70 | Lake, beach |
| Mass. | July 1997 | *S. sonnei* | GI | 9 | Pool/fountain, public park |
| Florida | 1999 | *S. sonnei* | GI | 38 | Interactive fountain, beach park |
| Missouri | Sept 2000 | *S. sonnei* | GI | 6 | Wading pool, municipal pool |
| Minnesota | July 2000 | *S. sonnei* | GI | 15 | Lake/pond, beach |
| Minnesota | Aug 2000 | *S. sonnei* | GI | 25 | Lake, public beach |

*Notes:* GI, gastroenteritis; Mass., Massachusetts; Penn., Pennsylvania.

*Source*: From Pond, K., 2005. Water Recreation and Disease Plausibility and Associated Infections: Acute Effects, Sequelae, and Mortality, Published on behalf of the World Health Organization by IWA Publishing, London Copyright © World Health Organization 2005, www.who.int.

*Original Source*: From Minnesota Department of Health 1974; Anonymous 1993; 1995; 1996b; Levy et al., 1998; Barwick et al., 2000; Lee 2002.

**Table 10J.249 Water- and Sanitation-Related Infections in Developing Countries and Their Control**

| | Importance of Alternate Control Methods[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Infections | Water Quality | Water Availability | Excreta Disposal | Excreta Treatment | Personal and Domestic Cleanliness | Drainage and Sullage Disposal | Food Hygiene | Public Health Importance[a] |
| Diarrhoeal diseases and enteric fevers | | | | | | | | |
| Viral agents | 2 | 3 | 2 | 1 | 3 | 0 | 2 | 3 |
| Bacterial agents | 3 | 3 | 2 | 1 | 3 | 0 | 3 | 3 |
| Protozoal agents | 1 | 3 | 2 | 1 | 3 | 0 | 2 | 2 |
| Poliomyelitis and hepatitis A | 1 | 3 | 2 | 1 | 3 | 0 | 1 | 3 |
| Worms with no intermediate host | | | | | | | | |
| *Ascaris* and *Trichuris* | 0 | 1 | 3 | 2 | 1 | 1 | 2 | 2 |
| Hookworms | 0 | 1 | 3 | 2 | 1 | 0 | 1 | 3 |
| Beef and pork tapeworms | 0 | 0 | 3 | 3 | 0 | 0 | 3 | 2 |
| Worms with intermediate stages | | | | | | | | |
| Schistosomiasis | 1 | 1 | 3 | 2 | 1 | 0 | 0 | 3 |
| Guinea worm | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Worms with two aquatic intermediate stages | 0 | 0 | 2 | 2 | 0 | 0 | 3 | 1 |
| Skin, eye and louse-borne infections | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 2 |
| Infections spread by water-related insects | | | | | | | | |
| Malaria | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 |
| Yellow fever and dengue | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 |
| Bancroftian filariasis | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 3 |

[a] 0, no importance; 1, little importance; 2, moderate importance; 3, great importance.

*Source*: From Feachem, R.G., 1984, The Health Dimension of the Decade, in world Water '83: the World Problem, Proceedings of July 1983 Conference of Institution of Civil Engineers, London.

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**Table 10J.250 Some Water-Associated Diseases by Cause and Sex Estimates for 2001**

| | Deaths (in Thousands) | | | | | | Burden of Disease (in Thousands) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Both Sexes | | Males | | Females | | Both Sexes | | Males | | Females | |
| | Number | % | Number | % | Number | % | Number | % | Number | % | Number | % |
| Total burden of disease (000s of DALYs) | | | | | | | 1.467,183 | 100 | 768,064 | 100 | 699,119 | 100 |
| Total deaths (000s) | 56,552 | 100 | 29,626 | 100 | 26,926 | 100 | | | | | | |
| Communicable diseases, matemal and perinatal conditions and nutritional deficiencies overall | 18,374 | 32.5 | 9,529 | 32.2 | 8,846 | 32.9 | 615,737 | 42.0 | 304,269 | 39.6 | 311.468 | 44.6 |
| Infectious and parasitic diseases altogether | 10,937 | 19.3 | 5,875 | 19.8 | 5,063 | 18.8 | 359,377 | 24.5 | 184,997 | 24.1 | 174,380 | 24.9 |
| Diarrhoeal diseases | 2,001 | 3.5 | 1,035 | 3.5 | 966 | 3.6 | 62,451 | 4.3 | 31,633 | 4.1 | 30,818 | 4.4 |
| Malaria | 1,123 | 2.0 | 532 | 1.8 | 591 | 2.2 | 42,280 | 2.9 | 20,024 | 2.6 | 22,256 | 3.2 |
| Schistosomiasis | 15 | 0.0 | 11 | 0.0 | 5 | 0.0 | 1,760 | 0.1 | 1,081 | 0.1 | 678 | 0.1 |
| Lymphatic filariasis | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 5,644 | 0.4 | 4,316 | 0.6 | 1,327 | 0.2 |
| Onchocerciasis | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 987 | 0.1 | 571 | 0.1 | 416 | 0.1 |
| Dengue | 21 | 0.0 | 10 | 0.0 | 11 | 0.0 | 653 | 0.0 | 287 | 0.0 | 365 | 0.0 |
| Japanese encephalitis | 15 | 0.0 | 8 | 0.0 | 8 | 0.0 | 767 | 0.1 | 367 | 0.0 | 400 | 0.1 |
| Trachoma | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3,997 | 0.3 | 1,082 | 0.1 | 2,915 | 0.4 |
| Intestinal nematode infections | 12 | 0.0 | 6 | 0.0 | 5 | 0.0 | 4,706 | 0.3 | 2,410 | 0.3 | 2,296 | 0.3 |
| Ascariasis | 4 | 0.0 | 2 | 0.0 | 2 | 0.0 | 1,181 | 0.1 | 604 | 0.1 | 577 | 0.1 |
| Trichuriasis | 2 | 0.0 | 1 | 0.0 | 1 | 0.0 | 1,649 | 0.1 | 849 | 0.1 | 800 | 0.1 |
| Hookworm infection | 4 | 0.0 | 2 | 0.0 | 2 | 0.0 | 1,825 | 0.1 | 932 | 0.1 | 893 | 0.1 |
| Unintentional injuries overall | 3,508 | 6.2 | 2,251 | 7.6 | 1,256 | 4.7 | 129,853 | 8.9 | 82,378 | 10.7 | 47,475 | 6.8 |
| Drowning | 402 | 0.7 | 276 | 1.0 | 126 | 0.5 | 11,778 | 0.8 | 8,150 | 1.1 | 3,628 | 0.5 |

*Note:* The burden of disease is calculated through an indicator of population health the DALY: a DALY represents a lost year of healthy life and is the unit used to estimate the gap between the current health of a population and an idea situation in which everyone in that population in which everyone in that population would live into old age in full health. This table shows the total deaths and burden of disease caused by communicable diseases, maternal and perinatal conditions and nutritional deficiencies noncommunicable diseases and injuries related to water.

*Source*: From *Water for People Water for Life*, The United Nations World Water Development, Copyright © United Nations Educational, Scientific and Cultural Organization (UNESCO)-World Water Assessment Programme (UNESCO-WWAP), 2003. Reproduced by permission of UNESCO. www.unesco.org.

*Original Source*: From WHO (World Health Organization), 2002, Report on the Status of the Dracunculiasis Eradication Campaign in 2001. Document WHO/CDS/CPE/CEE/2002.30, Geneva. Reprinted with permission.

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**Table 10J.251 Reported Dracunculasis Cases by Country, 1972–2000**

| Region and Country | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Africa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Benin | 1,480 | | 820 | | | | | | | | | | | | | 400 | 33,962 | 7,172 | 37,414 | 4,006 | 4,315 | 13,887 | 4,302 | 2,273 | 1,472 | 855 | 695 | 492 | 186 |
| Burkina Faso | 5,822 | 4,404 | 4,008 | 6,277 | 1,557 | | 2,885 | 2,694 | 2,565 | | | 4,362 | 1,739 | 458 | 2,558 | 1,957 | 1,266 | 45,004 | 42,187 | | 11,784 | 8,281 | 6,861 | 6,281 | 3,241 | 2,477 | 2,227 | 2,184 | 1,956 |
| Cameroon | | | | 251 | | | | | | | | | 0 | 168 | 86 | | 752 | 871 | 742 | 393 | 127 | 72 | 30 | 15 | 17 | 19 | 23 | 8 | 5 |
| Central African Republic | | | | | | | | | | | | | | | | | | | | | | | | 18 | 9 | 5 | 34 | 26 | 35 |
| Chad | | | | | | | 172 | | | | | | 1,472 | 9 | 314 | | | | | | 156 | 1,231 | 640 | 149 | 127 | 25 | 3 | 1 | 3 |
| Côte d'Ivoire | 4,891 | 4,654 | 6,283 | 4,971 | 4,656 | 5,207 | 6,993 | | 6,712 | 7,978 | | 2,259 | 2,573 | 1,889 | 1,177 | 1,272 | 1,370 | 1,555 | 1,360 | 12,690 | | 8,034 | 5,061 | 3,801 | 2,794 | 1,254 | 1,414 | 476 | 297 |
| Ethiopia | | | | | | | | | | | | | 2,882 | 1,467 | 3,385 | 2,302 | 1,487 | 3,565 | 2,233 | | 303 | 1,120 | 1,252 | 514 | 371 | 451 | 366 | 249 | 60 |
| Ghana | 693 | 1,606 | 1,226 | 4,052 | 1,421 | 1,617 | 1,676 | | 2,703 | 853 | 3,413 | 3,040 | 4,244 | 4,501 | 4,717 | 18,398 | 71,767 | 179,556 | 123,793 | 66,697 | 33,464 | 17,918 | 8,432 | 8,894 | 4,877 | 8,921 | 5,473 | 9,027 | 7,402 |
| Kenya | | | | | | | | | | | | | | | | | | 5 | 6 | | | 35 | 53 | 23 | 0 | 6 | 7 | 1 | 4 |
| Mali | 668 | 786 | 737 | 542 | 760 | 1,084 | | | 816 | 777 | 401 | 428 | 5,008 | 4,072 | 5,640 | 435 | 564 | 1,111 | 884 | 16,024 | | 12,011 | 5,581 | 4,218 | 2,402 | 1,099 | 650 | 410 | 290 |
| Mauritania | | | | | | 127 | | | 651 | 663 | 903 | 1,612 | 1,241 | 1,291 | | 227 | 608 | 447 | 8,036 | | 1,557 | 3,533 | 5,029 | 1,762 | 562 | 388 | 379 | 255 | 136 |
| Niger | | | | | 2,600 | 3,000 | 5,560 | | 1,906 | 2,113 | 1,530 | | | 1,373 | | 699 | | 288 | | 32,829 | 500 | 21,564 | 18,562 | 13,821 | 2,956 | 3,030 | 2,700 | 1,920 | 1,166 |
| Nigeria | 98 | | | 1,007 | | | | | 1,693 | | | | 8,777 | 5,234 | 2,821 | 216,848 | 653,492 | 640,008 | 394,082 | 281,937 | 183,169 | 75,752 | 39,774 | 16,374 | 12,282 | 12,590 | 13,420 | 13,237 | 7,869 |
| Senegal | | 334 | 208 | 65 | 137 | | | | 161 | | | | | 62 | 128 | 132 | 138 | | 38 | 1,341 | 728 | 630 | 195 | 76 | 19 | 4 | 0 | 0 | 0 |
| Sudan | | | | | | | | | | | | | | | 822 | 399 | 542 | | | | 2,447 | 2,984 | 53,271 | 64,608 | 118,578 | 43,596 | 47,977 | 66,097 | 54,890 |
| Togo | | | | 3,261 | 1,648 | | 2,617 | 2,673 | 1,748 | 951 | 2,592 | | 1,839 | 1,456 | 1,325 | | 178 | 2,749 | 3,042 | 5,118 | 8,179 | 10,349 | 5,044 | 2,073 | 1,626 | 1,762 | 2,128 | 1,589 | 828 |
| Uganda | | | | | | | | | | | | | 6,230 | 4,070 | | | 1,960 | 1,309 | 4,704 | | 126,852 | 42,852 | 10,425 | 4,810 | 1,455 | 1,374 | 1,061 | 321 | 96 |
| **Asia and Middle East** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| India | | | | | | 7,052 | 6,827 | 2,846 | 2,729 | 5,406 | 42,926 | 44,818 | 39,792 | 30,950 | 23,070 | 17,031 | 12,023 | 7,881 | 4,798 | 2,185 | 1,081 | 755 | 371 | 60 | 9 | 0 | 0 | 0 | 0 |
| Pakistan | | | | | | | 250 | | 14,155 | | | | | | | 2,400 | 1,110 | 534 | 160 | 106 | 23 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yemen | | 25 | | | | | | | | | | | | | | | | | | | | | 94 | 82 | 62 | 7 | 0 | 0 | 0 |
| Number of Countries Reporting | 6 | 6 | 6 | 8 | 7 | 6 | 8 | 3 | 11 | 7 | 6 | 6 | 12 | 14 | 12 | 13 | 15 | 15 | 15 | 11 | 15 | 18 | 19 | 20 | 20 | 20 | 20 | 20 | 20 |
| Number of Cases | 13,652 | 11,809 | 13,282 | 20,426 | 12,779 | 18,087 | 26,980 | 8,213 | 35,839 | 18,741 | 51,765 | 56,519 | 75,797 | 57,000 | 46,043 | 262,136 | 781,219 | 892,055 | 623,844 | 547,575 | 374,202 | 229,773 | 164,973 | 129,852 | 152,814 | 77,863 | 78,557 | 96,293 | 75,223 |

*Source*: From *World's Water 2002–2003*, by Peter H. Gleick. Copyright © 2002 Island Press. Reproduced by permission of Island Press, Washington, DC.



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**Table 10J.252 Deaths and DALYs from Selected Water-Related Diseases, 2000**

| | Deaths | DALYs |
|---|---|---|
| Diarrheal diseases | 2,019,585 | 63,345,722 |
| Childhood cluster diseases | | |
| Poliomyelitis | 1,136 | 188,543 |
| Diphtheria | 5,527 | 187,838 |
| Tropical-cluster diseases | | |
| Trypanosomiasis | 49,129 | 1,570,242 |
| Schistosomiasis | 15,335 | 1,711,522 |
| Trachoma | 72 | 3,892,326 |
| Intestinal nematode infections | | |
| Ascariasis | 4,929 | 1,204,384 |
| Trichuriasis | 2,393 | 1,661,689 |
| Hookworm disease | 3,477 | 1,785,539 |
| Other Intestinal Infections | 1,692 | 53,222 |
| Total | 2,103,274 | 75,601,028 |

*Notes*: DALYs, The DALY is a measure of population health that combines in a single indicator years of life lost from premature death and years of life lived with disabilities. One DALY can be thought of as one lost year of "healthy" life. This table excludes mortality and DALYs associated with water-related insect vectors, such as malaria, onchocerciasis, and dengue fever. Trachoma, while few deaths from trachoma are reported, approximately 5.9 million cases of blindness or severe complications occur annually.

*Source*: From *World's Water 2004–2005*, by Peter H. Gleick. Copyright © 2004 Island Press. Reproduced by permission of Island Press, Washington, DC.

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**Table 10J.253 Annual Number of Diarrhoeal Cases Avoided if the Combined Water and Sanitation Millennium Goals Are Achieved by WHO subregion**

| WHO Sub-Region | Region/ Country | Pop. (m) | Cases of Diarrhoea (million) | Number of Cases Avoided Per Year ('000s), by Intervention | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1[a] | 2[b] | 3[c] | 4[d] | 5[e] |
| 2 | AFR-E | 481 | 619 | 28′548 | 87′405 | 127′049 | 345′132 | 439′980 |
| 5 | AMR-D | 93 | 93 | 3′250 | 9′307 | 13′208 | 48′679 | 64′106 |
| 11 | EUR-D | 223 | 43 | 112 | 568 | 1′056 | 19′816 | 27′983 |
| 13 | SEAR-D | 1,689 | 1,491 | 26′895 | 146′829 | 272′361 | 807′596 | 1′04′922 |
| 15 | WPR-B1 | 1,488 | 1,193 | 39′454 | 131′171 | 239′104 | 659′687 | 844′381 |
| World | | 7,183 | 5,388 | 154′854 | 545′950 | 903′004 | 2′860′951 | 3′717′971 |

*Notes:* Therefore, in the analysis, account is taken of the proportion of populations in each country who did not have access to improved" water and sanitation in 2000.
Level VI, No improved water supply and no basic sanitation in a country which is not extensively covered by those services, and where water supply is not routinely controlled;
Level Vb, Improved water supply and no basic sanitation in a country which is not extensively covered by those services, and where water supply is not routinely controlled;
Level Va, Improved sanitation but no improved water supply in a country which is not extensively covered by those services, and where water supply is not routinely controlled;
Level IV, Improved water supply and improved sanitation in a country which is not extensively covered by those services, and where water supply is not routinely controlled;
Level III, Improved water supply and improved sanitation in a country which is not extensively covered by those services, and where water supply is not routinely controlled, plus household water treatment;
Level II, Regulated water supply and full sanitation coverage, with partial treatment for sewage, corresponding to a situation typically occurring in developed countries;
Level I, Ideal situation, corresponding to the absence of transmission of diarrhoeal disease through water, sanitation and hygiene.

[a] Intervention 1. Millennium targets: halving the proportion of people who do not have access to improved water sources by 2015, with priority given to those already with priority given to those already with improved sanitation. This means: Scenario Va to IV (applied to half the population without improved water supply).

[b] Intervention 2. Millennium targets with sanitation targets: halving the proportion of people who do not have access to improved water sources and improved sanitation facilities, by 2015. This means: Scenario VI to IV, or Scenario Va or Vb to IV (applied to half the population without improved water supply and half the population without improved sanitation).

[c] Intervention 3. Access for all to improved water and improved sanitation. This means: Scenario VI, Va and Vb to IV (applied to the entire population without improved water and the entire population without improved water and the entire population without improved sanitation).

[d] Intervention 4. A minimum of water disinfected at the point of use for all, on top of improved water and sanitation services. This means: Scenarios VI, Va, Vb and IV go to Scenario III.

[e] Intervention 5. Access for all to a regulated piped water supply and sewage connection into their houses. This means: Scenarios VI, Va, Vb, IV and III go to Scenario II. All the interventions were compared to the situation in 2000, which was defined as the baseline year.

*Source*: From Hutton, G. and Haller, L., 2004, Evaluation of Costs and Benefits of Water and Sanitation Improvements at the Global Level, Water, Sanitation and Health Protection of the Human Environment, Work Health Organization, Geneva. Copyright © World Health Organization 2004, www.who.int.

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**Table 10J.254 Clinical Syndromes and Incubation Periods of Infectious and Chemical Agents Causing Acute Waterborne Disease in the United States**

| Agent | Incubation Period | Clinical Syndrome |
|---|---|---|
| **Bacteria** | | |
| *Campylobacter jejuni* | 2–5 d | Gastroenteritis, often with fever |
| Enterotoxigenic *Escherichia coli* | 6–36 hr | Gastroenteritis |
| *Salmonella* | 6–48 hr | Either gastroenteritis (often with fever), enteric fever, or extraintestinal infection |
| *Salmonella typhi* | 10–14 d | Enteric fever — fever, anorexia, malaise, transient rash, splenomegaly, and leukopenia |
| *Shigella* | 12–48 hr | Gastroenteritis, often with fever and bloody diarrhea |
| *Vibrio cholerae 01* | 1–5 d | Gastroenteritis, often with significant dehydration |
| *Yersinia enterocolitica* | 3–7 d | Either gastroenteritis, mesenteric lymphadenitis, or acute terminal ileitis; may mimic appendicitis |
| **Viruses** | | |
| Hepatitis A | 2–6 wks | Hepatitis — nausea, anorexia, jaundice, dark urine |
| Norwalk virus | 24–48 hr | Gastroenteritis, of short duration |
| Rotavirus | 24–72 hr | Gastroenteritis, often with significant dehydration |
| **Parasites** | | |
| *Entamoeba histolytica* | 2–4 wks | Varies from mild gastroenteritis to acute fulminating dysentery with fever and bloody diarrhea |
| *Giardia lamblia* | 1–4 wks | Chronic diarrhea, epigastric pain, bloating, malabsorption, and weight loss |
| **Chemicals** | | |
| Fluoride | $<$1 hr | Nausea, vomiting, and abdominal cramps |
| **Heavy metals** | | |
| Antimony | | |
| Cadmium | | |
| Copper | | |
| Lead | | |
| Tin | | |
| Zinc, etc | $<$1 hr | Nausea, vomiting, and abdominal cramps, often accompanied by a metallic taste |
| **Others** | | |
| Pesticides | | |
| Petroleum products, etc | Variable | Variable |

*Source*: From Craun, G.F., 1986, *Waterborne Diseases in the United States*, Copyright CRC Press, Inc. Boca Raton, FL. Reprinted with permission.

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**Table 10J.255 Pathogens in Drinking Water, Infectious Dose, Estimated Incidence through Consumption of Drinking Water in the United States, Survival in Drinking Water, and Potential Survival Strategies**

| | Infectious Dose[a] | Estimated Incidence[b] | Survival in Drinking Water (Days) | Survival Strategies[c] |
|---|---|---|---|---|
| Bacteria | | | | |
| *Vibrio cholera* | $10^8$ | (very few)[c] | 30 | VNC, IC |
| *Salmonella spp.* | $10^{6-7}$ | 59,000 | 60–90 | VNC, IC |
| *Shigella spp.* | $10^2$ | 35,000 | 30 | VNC, IC |
| *Toxigenic Escherichia coli* | $10^{2-9}$ | 150,000 | 90 | VNC, IC |
| *Campylobacter spp.* | $10^6$ | 320,000 | 7 | VNC, IC |
| *Leptospira spp.* | 3 | ?[d] | ? | ? |
| *Francisella tularensis* | 10 | ? | ? | ? |
| *Yersinia enterocolitica* | $10^9$ | ? | 90 | ? |
| *Aeromonas spp.* | $10^8$ | ? | 90 | ? |
| *Helicobacter pylori* | ? | High | ? | ? |
| *Legionella pneumophila* | $>10$ | 13,000[e] | Long | VNC, IC |
| *Mycobacterium avium* | ? | ? | Long | IC |
| Protozoa | | | | |
| *Giardia lambia* | 1–10 | 260,000 | 25 | Cyst |
| *Cryptosporidium parvum* | 1–30 | 420,000 | ? | Oocyst |
| *Naegleria fowleri* | ? | ? | ? | Cyst |
| *Acanthamoeba spp.* | ? | ? | ? | Cyst |
| *Entamoeba histolica* | 10–100 | ? | 25 | Cyst |
| *Cyclospora cayetanensis* | ? | ? | ? | Oocyst |
| *Isospora belli* | ? | ? | ? | Oocyst |
| The microsporidia | ? | ? | ? | Spore, IC[d] |
| *Ballantidium coli* | 25–100 | ? | 20 | Cyst |
| *Toxoplasma gondii* | ? | ? | ? | Oocyst |
| Viruses[f] | | | | |
| Total estimates | 1–10 | 6,500,000 | 5–27[g] | Adsorption/ absorption |

*Note:* ?, unknown; IC, intracellular survival and/or growth; VNC, viable but not culturable.

[a] Infectious dose is number of infectious agents that produce symptoms in 50% of teted volunteers. Volunteers are not usually susceptible individuals, and therefore these numbers are not useful for risk estimates.
[b] U.S. point estimates.
[c] Very few outbreaks of cholera occur in the United States, and these are usually attributable to imported foods (14).
[d] Possible IC with microsporidialike organisms (15).
[e] Data form Breiman and Butler (14).
[f] Includes Norwalk virus, poliovirus, coxsachievirus, echovirus, reovirus, adenovirus, HAV, HEV, rotavirus, SRSV, astrovirus, coronavirus, calicivirus, and unknown viruses.
[g] Estimated for HAV, Norwalkvirus, and rotavirus (13).

*Source*: From Ford, T.E., 1999, Microbiological safety of drinking water: United States and global perspectives, *Environmental Health Perspectives Supplements*, vol. 107, no. S1, February 1999, www.ehponline.org

*Original Source*: Except where noted, data are compiled from Morris and Levin (2), WHO (10), Hazen and Toranzos (11), and Geldreich (12).

**Table 10J.256 Survival of Bacteria In Various Media**

| Organism | Survival Time | Media |
|---|---|---|
| E. coli | 63 days | Recharge well |
| E. coli | 3–3.5 months | Groundwater in the field |
| E. coli | 4–4.5 months | Groundwater held in lab |
| Coliforms | 17 hours-50 percent reduction | Well water |
| Salmonella | 44 days | Water infiltrating sand column |
| S. typhi | 2–85 days | Soil |
| S. typhi | 24–27 days | Septic tank |
| S. typhi | 25–41 days | Soil |
| Shigella | 24 days | Water infiltrating sand column |
| S. flexneri | 26.8 hours-50 percent reduction | Well water |
| Vibrio cholerae | 7.2 hours-50 percent reduction | Well water |

*Source*: From McGinnis, J.A. and DeWalle, F.B., 1983, The movement of typhoid organisms in saturated permeable soil, *J. Am. Water Works Assoc.*, Vol. 75, no. 6. Copyright AWWA. Reprinted with permission.

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**Table 10J.257 Survival Times of Organisms**

| Organism | Media | Survival Time Days |
|---|---|---|
| *Ascaris ova* | Vegetables | 27–35 |
| | Soil | 730–2010 |
| *Entamoeba histolytica* | Vegetables | 3 |
| | Soil | 6–8 |
| | Water | 60+ |
| *Mycobacterium tuberculosis* | Soil | 180+ |
| | Grass | 10–40 |
| | Water | 30–90 |
| *Salmonella* (spp.) | Vegetables | 3–40+ |
| | Soil | 15–280+ |
| | Pasture | 200+ |
| | Grass | 100+ |
| *Salmonella typhi* | Vegetables | 10–53 |
| | Lettuce | 18–21 |
| | Soil | 2–120 |
| | Water | 87–104 |
| *Shigella* (spp.) | Vegetables | 7 |
| | Grass | 42 |
| *Shigella sonnel* | Tomatoes | 2–10 |
| *Streptococcus faecalis* | Soil | 26–77 |
| *Vibrio cholerae* | Vegetables | 5–14 |
| *Vibrio comma* | Water | 32 |
| *Poliovirus* | Water | 20 |

*Source*: From Crook, James, 1985, Water reuse in California, *Journal American Water Works Assoc.*, Vol. 77, no. 7. Copyright AWWA. Reprinted with permission.

**Table 10J.258 Movement of Bacteria in Soil in Relation to Groundwater Velocity**

| Pollution | Organism | Length of Travel (m) | Medium | Velocity (m/d) |
|---|---|---|---|---|
| River water | *E. coli* | 0.30 | Dune sand | 0.11 |
| Sewage | Bacteria | 0.31 | Dense soil | 0.01[a] |
| Sewage | Bacteria | 0.61 | Porous soil | 0.10[a] |
| Sewage | *Coliforms* | 0.91 | Coarse sand | 0.08 |
| Sewage | Bacteria | 1.50 | Fine sand | 0.03[a] |
| Sewage | *E. coli* | 2.00 | Fine sand | 0.128 |
| River water | *E. coli* | 3.00 | Sand | 0.004 |
| Sewage | *B. coli* | 3.10 | Fine sand | 0.50 |
| Sewage | Bacteria | 4.50 | Fine sand | 0.03[a] |
| Wastewater | Coliforms | 6.10 | Fine sand | 0.03[a] |
| River water | Bacteria | 7.50 | Sand | 0.08 |
| Sewage | *B. coli* | 10.70 | Sand gravel | 1.50 |
| Sewage | *C. welchii* | 15.20 | Fine sand | 0.50 |
| Polluted water | Bacteria | 18.30 | Sand gravel | 0.53[a] |
| Sewage | *B. coli* | 19.80 | Fine sand | 0.11 |
| Sewage | *B. coli* | 24.40 | Sand gravel | 4.10 |
| Pure culture | *B. stearothermophilis* | 28.70 | Crystalline rock | 25.50 |
| Sewage | Coliforms | 30.50 | Sand | 21.80 |
| Sewage | Bacteria | 61.00 | Sand gravel | 30.50 |
| Sewage[b] | *S. typhi* | 64.00 | Gravel loam | 42.70 |
| Sewage | Bacteria | 70.70 | Fine sand | 0.11 |
| Sewage | Coliforms | 91.00 | Sand gravel | 0.24 |
| Sewage | Coliforms | 457.20 | Coarse gravel | 30.50 |
| Sewage | Coliforms | 830.00 | Sand gravel | 1.60 |
| Polluted water | Bacteria | 850.00 | Coarse gravel | 5.50[a] |
| Polluted water | Bacteria | 1,000.00 | Fractured limestone | 5.50[a] |

[a] Estiamted from soil description, using a hydraulic gradient of 0.01. Other groundwater velocity values were measured by other authors.
[b] Yakima outbreak.

*Source*: From McGinnis, J.A. and DeWalle, F.B., 1983, The movement of typhoid organisms in saturated permeable soil, *J. Am. Water Works Assoc.*, Vol. 75, no. 6. Copyright AWWA. Reprinted with permission.

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**Table 10J.259 Migration of Viruses Beneath Land Treatment Sites**

| Site Location | Site Type | Maximum Distance of Virus Migration (m) | |
|---|---|---|---|
| | | Depth | Horizontal |
| St. Petersburg, FL | S | 6.0 | — |
| Gainesville, FL | S | 3.0 | 7.0 |
| Lubbock, TX | S | 30.5 | — |
| Kerrville, TX | S | 1.4 | — |
| Muskegon, MI | S | 10.0 | — |
| San Angelo, TX | S | 27.5 | — |
| East Meadow, NY | R | 11.4 | 3.0 |
| Holbrook, NY | R | 6.1 | 45.7 |
| Sayville, NY | R | 2.4 | 3.0 |
| 12 Pines, NY | R | 6.4 | — |
| North Massapequa, NY | R | 9.1 | — |
| Babylon, NY | R | 22.8 | 408.0 |
| Ft. Devons, MA | R | 28.9 | 183.0 |
| Vineland, NJ | R | 16.8 | 250.0 |
| Lake George, NY | R | 45.7 | 400.0 |
| Phoenix, AZ | R | 18.3 | 3.0 |
| Dan Region, Israel | R | 31–67 | 60–270 |

*Note:* R, Rapid infiltration; S, Slow-rate infiltration.

*Source*: Adapted from Gerba, C.P. and Goyal, S.M., 1985, Pathogen removal from wastewater during groundwater recharge, in Asano, T., *Artificial Recharge of Groundwater*, Copyright Butterworth Publ, Boston. Reprinted with permission.

**Table 10J.260 Selected Human Health and Environmental Effects from Toxic Chemicals**

| Chemical | Human Health Effects[a] | | | Environmental Effects |
|---|---|---|---|---|
| | Carcinogen[b] | Teratogen[b] | Others | |
| Aldrin/dieldrin | ○ | | Tremors, convulsions, kidney damage | Toxic to aquatic organisms, reproductive failure in birds and fish, bioaccumulation in aquatic organisms |
| Arsenic | ● | ○ | Vomiting, poisoning, liver and kidney damage | Toxic to legume crops |
| Benzene | ● | | Anemia, bone marrow damage | Toxic to some fish and aquatic invertebrates |
| Cadmium | | ○ | Suspected causal factor in many human pathogies: tumors, renal dysfunction, hypertension, arteriosclerosis, Itai-itai disease (weakened bones), emphysema | Toxic to fish, bioaccumulates significantly in bivalve mollusks |
| Carbon tetrachloride | ● | | Kidney and liver damage, heart failure | |
| Chromium | | | Kidney and gastrointestinal damage, respiratory complications | Toxic to some aquatic organisms |
| Copper | | | Gastrointestinal irritant, liver damage | Toxic to juvenile fish & other aquatic organisms |
| DDT | ○ | ○ (minimal) | Tremors, convulsions, kidney damage | Reproductive failure of birds and fish, bioaccumulates in aquatic organisms, biomagnifies in food chain |
| Di-*n*-butyl phthalate | | | Central nervous system damage | Eggshell thinning in birds, toxic to some fish |
| Dioxin | ○ | ○ | Acute skin rashes, systemic damage, mortality | Bioaccumulates, lethal to aquatic organisms birds and mammals |
| Lead | | ○ | Convulsions, anemia, kidney and brain damage | Toxic to domestic plants and animals, bio-magnifies to some degree in food chain |

*(Continued)*

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**Table 10J.260 (Continued)**

| Chemical | Human Health Effects[a] | | | Environmental Effects |
|---|---|---|---|---|
| | Carcinogen[b] | Teratogen[b] | Others | |
| Methyl Mercury | | ○ | Irritability, depression, kidney and liver damage, Minamata disease | Reproductive failure in fish species, inhibits growth and kills fish; biomagnifies |
| PCBs | ○ | ○ | Vomiting, abdominal pain, temporary blindness, liver damage | Liver damage in mammals, kidney damage and eggshell thinning in birds, suspected reproductive failure in fish |
| Phenols | | | Effects on central nervous system, death at high doses | Reproductive effective in aquatic organisms toxic to fish |
| Toxaphene | ○ | ○ | Pathological changes in kidney & liver; changes in blood chemistry | Decreased productivity of phytoplankton communities, birth defects in fish and birds, toxic to fish and invertebrates |

[a] In many cases human health effects are based upon the results of animal tests.
[b] If a substance is identified as a carcinogen, there is evidence that it has the potential for causing cancer in humans; if it is identified as a teratogen, it has the potential for causing birth defects in humans.

*Source*: From U.S. Environmental Protection Agency; National Water Quality Inventory, 1984 Report to Congress and The Conservation Foundation, State of the Environment 1982.

**Table 10J.261 Chemicals Causing Distribution System Outbreaks in the United States — 1971–98**

| Chemical | CWS[a] | NCWS[b] |
|---|---|---|
| Copper | 16 | 2 |
| Chlordane | 3 | |
| Nitrite | 2 | |
| Unidentified herbicide | 2 | |
| Ethylene glycol | 2 | |
| Oil | 1 | 1 |
| Other chemicals[c] | 9 | |
| Total | 35 | 3 |

[a] CWS — community water system.
[b] NCWS — noncommunity water system.
[c] Each of the following was responsible for one outbreak; fluoride, lead, chromium, sodium hydroxide, chlorine, liquid soap, ethyl acrylate, morpholine, and hydroquinone.

*Source*: From Reprinted from *Journal AWWA*, vol. 93, no. 9 (September 2001), by permission. Copyright © 2001, American Water Works Association, www.awwa.org.

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**Table 10J.262 Potential Exposure to Lead in Tap Water**

| Age of House | pH of Water[a] | Percent of Samples >20 ug/L | |
|---|---|---|---|
| | | First-Flush (%) | Fully-Flushed (2 min) (%) |
| 0–2 yrs | <6.4 | 93 | 51 |
| | 7.0–7.4 | 83 | 5 |
| | ≥:8.0 | 72 | 0 |
| 2–5 yrs | ≤6.4 | 84 | 19 |
| | 7.0–7.4 | 28 | 7 |
| | ≥8.0 | 18 | 4 |
| 6+yrs | ≤6.4 | 51 | 4 |
| | 7.0–7.4 | 14 | 0 |
| | ≥8.0 | 13 | 3 |

*Note:* Percentage of samples taken from kitchen taps exceeding 20 ug/L of lead at different pH levels, by age of house. The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that lead is a health concern at certain levels of exposure. There is currently an action level of 15 parts per billion (μg/L). The most common cause of lead entering drinking water is corrosion, a reaction between the water and the lead pipes or the lead-based solder. When water stands in the pipes of a residence for several hours without use, there is a potential for lead to leach, or dissolve, into the water if a lead source is present. Soft water (water that makes soap suds easily) can be more corrosive and, therefore, has higher levels of dissolved lead. Some home water treatment devices may also make water more corrosive.

[a] A measure of the concentration of hydrogenions and potential electrochemical corrosion.

*Source*: From U.S. EPA, 1987, Preliminary Results from "Lead Solder Aging Study" More recent data are available at: U.S. EPA, 2005, Is there Lead in my Drinking Water? www.epa.gov/safewater/lead.

**Table 10J.263 Geometric Mean and Selected Percentiles of Lead in Blood in the United States. Population Aged 1 Yr and Older, National Health, and Nutrition Examination Survey, 1999–2002**

| | Survey Yrs | Geometric Mean (95% Conf. Interval) | Selected Percentiles (95% Confidence Interval) | | | | Sample Size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 1 and older** | 99–00 | 1.66 (1.66–1.72) | 1.60 (1.50–1.60) | 2.40 (2.30–2.60) | 3.80 (3.60–3.90) | 4.90 (4.60–5.30) | 7,970 |
| | 01–02 | 1.45 (1.39–1.51) | 1.40 (1.30–1.40) | 2.20 (2.10–2.20) | 3.40 (3.10–3.50) | 4.40 (4.20–4.70) | 8,945 |
| **Age group** | | | | | | | |
| 1–5 yrs | 99–00 | 2.23 (1.96–2.53) | 2.20 (1.90–2.50) | 3.30 (2.80–3.80) | 4.80 (4.00–6.60) | 7.00 (6.10–8.30) | 723 |
| | 01–02 | 1.70 (1.55–1.87) | 1.50 (1.40–1.70) | 2.50 (2.20–2.80) | 4.10 (3.40–5.00) | 5.80 (4.70–6.90) | 898 |
| 6–11 yrs | 99–00 | 1.51 (1.36–1.66) | 1.30 (1.20–1.50) | 2.00 (1.70–2.40) | 3.30 (2.70–3.60) | 4.50 (3.40–6.20) | 905 |
| | 01–02 | 1.25 (1.14–1.36) | 1.10 (1.00–1.30) | 1.60 (1.50–1.80) | 2.70 (2.40–3.00) | 3.70 (3.00–4.70) | 1,044 |
| 12–19 yrs | 99–00 | 1.10 (1.04–1.17) | 1.00 (0.900–1.10) | 1.40 (1.30–1.60) | 2.30 (2.10–2.30) | 2.80 (2.60–3.00) | 2,135 |
| | 01–02 | 0.942 (0.899–0.986) | 0.800 (0.800–0.900) | 1.20 (1.20–1.30) | 1.90 (1.80–2.00) | 2.70 (2.30–2.90) | 2,231 |
| 20 yrs and older | 99–00 | 1.75 (1.68–1.81) | 1.70 (1.60–1.70) | 2.50 (2.50–2.60) | 3.90 (3.70–4.00) | 5.20 (4.80–5.50) | 4,207 |
| | 01–02 | 1.56 (1.49–1.62) | 1.60 (1.50–1.60) | 2.20 (2.20–2.30) | 3.60 (3.30–3.70) | 4.60 (4.20–4.90) | 4,772 |
| **Gender** | | | | | | | |
| Males | 99–00 | 2.01 (1.93–2.09) | 1.80 (1.80–1.90) | 2.90 (2.80–3.00) | 4.40 (4.10–4.80) | 6.00 (5.40–6.40) | 3,913 |
| | 01–02 | 1.78 (1.71–1.86) | 1.70 (1.70–1.80) | 2.70 (2.50–2.80) | 3.90 (3.70–4.10) | 5.30 (5.00–5.50) | 4,339 |
| Females | 99–00 | 1.37 (1.32–1.43) | 1.30 (1.20–1.30) | 1.90 (1.90–2.10) | 3.00 (2.90–3.20) | 4.00 (3.70–4.20) | 4,057 |
| | 01–02 | 1.19 (1.14–1.25) | 1.10 (1.10–1.20) | 1.80 (1.70–1.80) | 2.60 (2.40–2.70) | 3.60 (3.00–3.80) | 4,606 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99–00 | 1.83 (1.75–1.91) | 1.80 (1.60–1.80) | 2.70 (2.60–2.90) | 4.20 (3.90–4.50) | 5.80 (5.10–6.60) | 2,742 |
| | 01–02 | 1.46 (1.34–1.60) | 1.50 (1.30–1.60) | 2.20 (2.00–2.60) | 3.60 (3.30–4.00) | 5.40 (4.40–6.60) | 2,268 |
| Nonhispanic blacks | 99–00 | 1.87 (1.75–2.00) | 1.70 (1.60–1.90) | 2.80 (2.50–2.90) | 4.20 (4.00–4.60) | 5.70 (5.20–6.10) | 1,842 |
| | 01–02 | 1.65 (1.52–1.80) | 1.60 (1.40–1.70) | 2.50 (2.30–2.80) | 4.20 (3.80–4.60) | 5.70 (5.30–6.50) | 2,219 |
| Nonhispanic whites | 99–00 | 1.62 (1.55–1.69) | 1.60 (1.50–1.60) | 2.40 (2.30–2.40) | 3.60 (3.40–3.70) | 5.00 (4.40–5.70) | 2,716 |
| | 01–02 | 1.43 (1.37–1.40) | 1.40 (1.30–1.40) | 2.10 (2.10–2.20) | 3.10 (3.00–3.40) | 4.10 (3.90–4.50) | 3,806 |

*Source*: From Department of Health and Human Services, Centers of Disease Control and Prevention, 2005, Third National Report on Human Exposure to Environmental Chemicals, NCEH Pub. No. 05-0570, July 2005, www.cdc.gov.

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**Table 10J.264 Pesticide Residues In Human Adipose Tissue in the United States**

| Pesticide Residues | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample size | 1,386 | 1,560 | 1,886 | 1,092 | 900 | 779 | 682 | 789 | 827 | 796 | 98 | 384 | 407 |
| DDT | 7.95 | 8.06 | 6.97 | 5.96 | 5.15 | 4.76 | 4.35 | 3.14 | 3.52 | 3.10 | 2.82 | 2.24 | 1.67 |
| Dieldrin | 0.16 | 0.22 | 0.18 | 0.17 | 0.14 | 0.12 | 0.09 | 0.09 | 0.09 | 0.08 | 0.10 | 0.05 | 0.06 |
| Oxchlordane | (NA) | (NA) | 0.10 | 0.12 | 0.12 | 0.11 | 0.11 | 0.10 | 0.11 | 0.10 | 0.12 | 0.09 | 0.09 |
| Heptachlor Epoxide | 0.09 | 0.09 | 0.07 | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.08 | 0.09 | 0.09 |
| Trans-Nonachlor | (NA) | (NA) | (NA) | (NA) | (NA) | 0.06 | 0.13 | 0.10 | 0.12 | 0.12 | 0.14 | 0.11 | 0.12 |
| Beta-Benzene Hexachloride | 0.37 | 0.35 | 0.19 | 0.25 | 0.21 | 0.19 | 0.18 | 0.14 | 0.14 | 0.15 | 0.12 | 0.09 | 0.10 |
| Hexachlorobenzene | (NA) | (NA) | (NA) | (NA) | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 |

*Note:* Concentration levels, 1970–1983 in parts per million (ppm), Data represent geometric means and are based on a sample of measurements of pesticide residues and associated chemicals found in human tissue collected by medical pathologists from selected cities in the conterminous 48 states as part of the National Human Adipose Tissue Monitoring Program. NA, Not available.

*Source*: From U.S. Department of Commerce, Statistical Abstract of the United States 1987.

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**Table 10J.265 Geometric Mean and Selected Percentiles of Blood Serum Concentrations for Organochlorine Pesticides in the United States Population Aged 12 Yrs and Older, National Health and Nutrition Examination Survey, 2001–2002**

| | | Selected Percentiles (95% Confidence Interval) | | | | |
|---|---|---|---|---|---|---|
| | Geometric Mean | 50th | 75th | 90th | 95th | Sample Size |
| Hexachlorobenzene | | | | | | |
| Lipid adjusted (ng/g of lipid) | —[a] | <LOD | <LOD | <LOD | <LOD | 2,277 |
| Whole weight (ng/g of serum) | —[a] | <LOD | <LOD | <LOD | <LOD | 2,277 |
| *p,p′*-DDT | | | | | | |
| Lipid adjusted (ng/g of lipid) | —[a] | <LOD | <LOD | <LOD | 26.5 (22.4–32.7) | 2,305 |
| Whole weight (ng/g of serum) | —[a] | <LOD | <LOD | <LOD | 0.184 (0.161–0.221) | 2,305 |
| *p,p′*-DDE | | | | | | |
| Lipid adjusted (ng/g of lipid) | 295 (267–327) | 250 (227–277) | 597 (521–699) | 1,400 (1,210–1,500) | 2,320 (1,830–2,780) | 2,298 |
| Whole weight (ng/g of serum) | 1.81 (1.64–2.01) | 1.57 (1.37–1.72) | 3.97 (3.43–4.59) | 8.81 (7.85–10.1) | 15.4 (12.9–17.6) | 2,298 |
| *o,p′*-DDT | | | | | | |
| Lipid adjusted (ng/g of lipid) | —[a] | <LOD | <LOD | <LOD | <LOD | 2,279 |
| Whole weight (ng/g of serum) | —[a] | <LOD | <LOD | <LOD | <LOD | 2,279 |
| Oxychlordane | | | | | | |
| Lipid adjusted (ng/g of lipid) | 11.4 (<LOD–12.5) | 11.1 (<LOD–12.5) | 21.7 (19.2–24.2) | 36.3 (31.4–41.4) | 49.7 (42.0–61.2) | 2,249 |
| Whole weight (ng/g of serum) | 0.070 (0.063–0.077) | 0.069 (0.058–0.078) | 0.143 (0.126–0.160) | 0.248 (0.215–0.297) | 0.352 (0.289–0.441) | 2,249 |
| *trans*-Nonachlor | | | | | | |
| Lipid adjusted (ng/g of lipid) | 17.0 (15.2–18.9) | 17.9 (15.5–20.5) | 33.7 (30.2–37.2) | 56.3 (49.6–65.9) | 78.2 (63.6–111) | 2,286 |
| Whole weight (ng/g of serum) | 0.104 (0.093–0.116) | 0.112 (0.097–0.124) | 0.217 (0.191–0.243) | 0.389 (0.328–0.470) | 0.589 (0.432–0.797) | 2,286 |
| Hetachlor epoxide | | | | | | |
| Lipid adjusted (ng/g of lipid) | —[a] | <LOD | <LOD | 14.8 (13.0–17.8) | 21.6 (18.1–26.2) | 2,259 |
| Whole weight (ng/g of serum) | —[a] | <LOD | <LOD | 0.102 (0.089–0.121) | 0.153 (0.125–0.179) | 2,259 |
| Mirex | | | | | | |
| Lipid adjusted (ng/g of lipid) | —[a] | <LOD | <LOD | 15.8 (<LOD–73.7) | 57.1 (13.2–230) | 2,257 |
| Whole weight (ng/g of serum) | —[a] | <LOD | <LOD | 0.101 (0.049–0.468) | 0.414 (0.080–1.73) | 2,257 |
| Aldrin | | | | | | |
| Lipid adjusted (ng/g of lipid) | —[a] | <LOD | <LOD | <LOD | <LOD | 2,275 |
| Whole weight (ng/g of serum) | —[a] | <LOD | <LOD | <LOD | <LOD | 2,275 |
| Dieldrin | | | | | | |
| Lipid adjusted (ng/g of lipid) | —[a] | <LOD | <LOD | 15.2 (14.3–17.0) | 20.3 (18.7–22.4) | 2,159 |
| Whole weight (ng/g of serum) | —[a] | <LOD | <LOD | 0.109 (0.099–0.121) | 0.146 (0.129–0.164) | 2,159 |
| Endrin | | | | | | |
| Lipid adjusted (ng/g of lipid) | —[a] | <LOD | <LOD | <LOD | 5.10 (<LOD–5.20) | 2,187 |
| Whole weight (ng/g of serum) | —[a] | <LOD | <LOD | <LOD | 0.021 (0.020–0.021) | 2,187 |

*Note:* <LOD means less than the limit of detection, which may vary for some chemicals by individual sample. Maximum detection limits (ng/g of lipid) for Hexachlorobenzene, *p,p′*-DDT, *o,p′*-DDT, Heptachlor epoxide, Mirex, Aldrin, Dieldrin, Endrin were 31.4, 17.4, 17.4, 10.5, 10.5, 5.94, 10.5, 5.09, respectively.

[a] Not calculated. Proportion of results below limit of detection was to high to provide a valid result.

*Source*: From Department of Health and Human Services, Centers of Disease Control and Prevention, 2005, Third National Report on Human Exposure to Environmental Chemicals, NCEH Pub. No. 05-0570, July 2005, www.cdc.gov.



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**Table 10J.266 Selected Synthetic Organic Chemicals Detected in Drinking Water Wells in the United States**

| Chemical | Cancer Classification |
|---|---|
| Benzene | A |
| α-BHC | C |
| β-BHC | B2 |
| γ-BHC (Lindane) | B2–C |
| Bis(2-ethylhexyl)phthalate | B2 |
| Bromoform | B2 |
| Butyl benzyl phthalate | C |
| Carbon tetrachtoride | B2 |
| Chloroform | B2 |
| Chloromethane | C |
| Cyclohexane | D |
| Dibromochloropropane (DBCP) | B2 |
| Dibromochloromethane | C |
| 1,1-Dichloroethane | C |
| 1,2-Dichloroethane | B2 |
| 1,1-Dichloroethylene | C |
| 1,2-Dichloroethylene | D |
| Di-n-butyl phthalate | D |
| Dioxane | B2 |
| Ethylenedibromide(EDB) | B2 |
| Isopropyl benzene | NTA |
| Methylene chloride | B2 |
| Parathion | C |
| Tetrachloroethylene | B2–C |
| Toluene | D |
| 1,1,1-Trichloroethane | D |
| 1,1,2-Trichloroethane | C |
| Trichloroethylene (TCE) | B2–C |
| Trifluorotrichloroethane | D |
| Vinyl chloride | A |
| Xylene | D |

*Note:* A, Known human carcinogen; B1, Probable human carcinogen — limited evidence in humans; B2, Probable human carcinogen — sufficient evidence in animals and inadequate data in humans; C, Possible human carcinogen — limited evidence in animals; D, Inadequate evidence to classify.

*Source*: From U.S. Environmental Protection Agency, *Integrated Risk Information System URL:* www.epa.gov/iris.

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**Table 10J.267 Summary of Toxic Effects of Some Organic and Inorganic Chemicals Known to Occur In Groundwater**

| Containment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aromatic Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | | |
| Alkyl benzene sulfonates | X | X | X | | | | | | | | | | | X | | | | | | | | | | |
| Aniline | | | | | | | | | X | | | | | | | X | | | | | | | | X |
| Anthracene | | | X | | | | | | | | | | | | | | | | | | | | X | X |
| Benzene | X | X | X | | | | | | X | X | X | X | | X | | | | | | | | | | X |
| Benzidine | | | | | | | | | | | | | | | | | | | | | | | | X |
| Benzyl alcohol | | X | | | | | | | | | | | | | | | | | | | | | | |
| Chrysene | | | | | | | | | | | | | | | | | | | | | | | | X |
| Dibenz (a.h.) anthracene | | | | | | | | | | | | | | | | | | | | | | | | X |
| 4,4-Dinitrosodiphenylamine | | | | | | | | | | | | | | | | | | | | | | | | X |
| Ethylbenzene | X | X | | X | | X | X | X | | | | | | | | | | | | | | | | |
| 4,4-Methylene-bis-2-chloroaniline (MOCA) | X | | | X | | X | X | | | | | | | | | X | | | | | | | X | X |
| Naphthalene | X | X | | X | | | | | | | X | | | | | | | X | | | | | | |
| *o*-Nitroaniline | | | | | | | | | | | | | | | | X | | | | | | | X | |
| Nitrobenzene | | | | | | X | X | | X | | X | | | | | X | | | X | X | X | | | |
| 4-Nitrophenol | | | | | X | | | | | | | | | | | X | | | | | | | | |
| *n*-Nitrosodiphenylamine | | | | | | X | | | | | | | | | | | | | | | | | | X |
| Phenanthrene | | | X | | | | | | | | | | | | | | | | | | | | X | X |
| *n*-Propylbenzene | | | | | | | | | | X | | | | | | | | | | | | | | |
| Pyrene | | X | | | X | X | | | | | X | | | X | | | | | | | | X | X | |
| Styrene (vinyl benzene) | X | X | | X | | X | X | | X | | | | | X | | | | | | | X | | X | |
| Toluene | X | X | | X | | X | X | | X | | | | X | | | | | | | | | | | |
| 1,2,4-Trimethylbenzene | | X | | | X | | | | X | | | | | | | | | | | | | | | |
| Xylenes (*m*,*o*,*p*) | X | | | X | | X | X | | X | | | | X | | | | | | | | | | | |
| **Oxygenated Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | | |
| Acetic acid | X | X | | X | X | | | | | | | | | | | | | | | | | | | |
| Acetone | X | | | X | | | | X | | | | | | | | | | | | | | | | |
| Benzophenone | | | X | | | | | | | | | | | | | | | | | | | | | |
| Di-*n*-butyl phthalate | X | | | X | | | | X | | | | | | | | | | | | | | | | |
| Diethyl ether | X | X | | X | | | | X | | | | | | | | | | | | | | | | |
| Diethyl phthalate | | X | | X | | | | | | | | | | | | | | | | | | | | |
| 1,4-Dioxane | X | | | X | | X | X | | | | | | | | | | | | | | | | | X |
| Formic acid | X | X | | X | | | | | X | | | | | | | | | | | | | | | |
| Methanol | X | | | | | X | | | X | | | | | | | | | X | | | | | | |
| Phenols (e.g.,*p*-*tert*-Butyl phenol) | | X | | | | | | | | | | | | | | | | | | | | | | |
| Tetrahydrofuran | | X | | X | | X | X | | X | | | | | | | | | | | | | | | |
| **Hydrocarbons with Specific Elements** | | | | | | | | | | | | | | | | | | | | | | | | |
| Aldicarb (sulfoxide and sulfone; Temik) | | | | | | | | | | | | | | | X | | | | | | | | | |
| Aldrin | | X | | | | X | X | | X | | | | | | | | | | | X | | | | X |
| Atrazine | | X | | | X | | | | X | | X | | | | | | | | | | X | | X | |
| Benzoyl chloride | | X | | X | | | | | | | | | | | | | | | | | | | | |
| Bromobenzene | X | X | | | X | X | | X | | | | | | | | | | | | | | | X | |
| Bromacil | | | | | | X | | | X | | | | | | | | | | | | | | | |
| Bromochloromethane | | | | | X | X | X | | X | | | | | | | | | | | | | | | |



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| Containment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bromoform | X | | | X | | X | | | X | | | | | | | | | | | | | | | |
| Carbofuran | | | | | | X | | | | | | | | | X | | | | | | | | | |
| Carbon tetrachloride | | | | | | X | X | | X | | | | | | | | | | | X | | | | X |
| Chlordane | | | | X | | X | | | X | | | | X | | | | | | | | | | | X |
| Chlorobenzene | X | | | X | X | X | X | | X | | | | | | | | | | | X | | | X | |
| Chloroform | X | X | | | | X | X | | X | | | | | X | | | | | | | X | | | X |
| Chloromethane | | | | | X | X | X | | X | | | | | | | | | | | | | | | |
| 2-Chloronaphthalene | | X | | | | X | | | | | | | | | | | | | | | | | | |
| Chlorpyrifos | | | | | | X | | | | | | | | | X | | | | | | | | | |
| *o*-Chlorotoluene | X | X | | | | | | | X | | | | | | | | | | | | | | | |
| Dibromochloromethane | | | | | | | | | | | | | | | | | | | | | | | X | |
| Dibromochloropropane (DBCP) | X | X | | | X | X | X | | | | | | | | | | | | | X | | | X | X |
| Dichlofenthion (DCFT) | | | | | | | | | | | | | | | X | | | | | | | | | |
| *o*-Dichlorobenzene | X | X | | X | X | X | X | | X | | X | | | | | | | | | | | | | |
| *p*-Dichlorobenzene | X | | | X | X | X | X | | X | | X | | | | | | | | | | | | | |
| Dichlorobenzidine | X | | | X | X | | | | | | | | | X | | | | | | | | | | X |
| Dichlorodiphenyldichlor-ethane (DDD, TDE) | | | | | | | | | | | | | | | | | | | **X** | | | | | **X** |
| Dichlorodiphenyltrichloro-ethane (DDT) | | | | | X | X | | | X | | X | | | | | | | | | X | | | X | X |
| 1,1-Dichloroethane | | | | | | X | X | | X | | | | | | | | | | | | X | | | |
| 1,2-Dichloroethane | X | X | | | X | X | X | | X | | | | X | X | | | | | X | X | | | X | X |
| 1,1-Dichloroethylene (vinylidiene chloride) | X | X | | X | X | X | X | | X | | | | X | | | | | | X | | X | | X | X |
| Dichloromethane (methylene chloride) | X | X | | | | X | X | | X | | | | | | | | | | | | X | | | |
| 2,4-Dichlorophenoxyacetic acid (2,4-D) | | | | | | | | | X | X | | | | | | | | | | | | X | X | |
| 1,2-Dichloropropane | | | | | | X | X | | | | | | | | | | | | | | | | X | |
| Dieldrin | | | | | | X | | | X | | | | | | | | | | | X | | | | X |
| Dimethyl disulfide | | | | | | | | | | | | | | | | | | | | | | X | | |
| 2,4-Dinotrophenol (Dinoseb, DNBP) | X | X | | | | | X | | X | | | | | | | | | | | X | | | | |
| Dioxins (e.g.,TCDD) | | | | | | X | | | X | X | | | | | | | X | | | X | | X | X | X |
| Dodecyl mercaptan (lauryl mercaptan) | X | X | X | | | | | | X | | | | | | | | | | | | | | X | |
| Endosulfan | | | | | | X | X | | X | | | | | | | | | | | | X | | X | |
| Endrin | | | | | | X | | | X | | | | | | | | | | | | | | | |
| Bis-2-ethylhexylphthalate | X | X | | | | X | | | | | | | | | | | | | | X | X | X | | X |
| Fluoroform | | | | | | | | | | | | | | | | | | | | | | | X | |
| Hexachlorocyclo-pentadiene | X | | | X | X | X | X | | | | | | X | | | | | | X | | | | | |
| Hexachloroethane | | | | | | X | X | | X | | | | | | | | | | | | X | | | X |
| Kepone | | | | | | X | X | | | | | | | | | | | | | X | X | | | X |
| Methoxychlor | | | | | | | X | | | | | | | | | | | | | X | | | | |
| Parathion | | | | | | | | | | | | | | | X | | | | | X | X | | | |
| Pentachlorophenol (PCP) | X | X | | X | | X | | | X | | | | | | | | | | | | X | | | |
| Phorate (Disulfoton) | | | | | | | | | | | | | | | X | | | | | | | | | |

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| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Polybrominated biphenyls (PBBs) | | | | | | X | | | | | X | | | | | | | | X | X | | | | |
| Polychlorinated biphenyls (PCBs) | | | | | X | X | | | | | X | X | X | | | | | X | X | X | X | X | | |
| RDX (Cyclonite) | | | | | | | | | | | | | | | | | | | | | X | | | |
| Simazine | | | | | | | | X | | | | | | | | | | | | | | | | |
| Tetrachloroethane (1,1,1,2) | | | | | | X | | | | | | | | | | | | | X | | X | | | |
| Tetrachloroethane (1,1,2,2) | | | | X | | X | X | | X | | | | X | | | | | | X | X | X | X | | |
| Tetrachloroethylene (1,1,2,2) (perchloroethylene, PCE) | X | | | X | X | | X | | X | | | | | | | | | | X | | | X | | |
| Toxaphene | | | | | | X | X | | X | | | | | | | | | | X | | X | X | | |
| Trichloroethanes (1,1,1 & 1,1,2) | X | X | | X | X | X | X | | X | | | X | | | | | | | | | X | X | | |
| 1,1,2-Trichloroethyelene (TCE) | | X | | | X | X | X | | X | | X | X | | | | | | | | | | X | | |
| Trichlorofluoromethane (Freon 11) | | | | | | | | | X | | | X | | | | | | | | | | | | |
| 2,4,6-Trichlorophenol | | | | | | X | | | | | | | | | | | | | | | X | X | | |
| 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) | | | | | | X | X | | X | | | | | | | | | | | X | X | | | |
| 2,4,5-Trichlorophenoxypropionic acid (2,4,5-TP, or Silvex) | | | | | | X | X | | X | | | | | | | | | | | | | | | |
| Vinyl chloride | | X | | | | X | X | | X | | X | | | | | | | | | | X | X | | |
| **Other Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | | |
| Alkyl sulfonates | X | X | X | | | | | | | | | | | | | | | | | | | | | |
| Cyclohexane | | | | | | X | X | | X | | | | | | | | | | | | | | | |
| Dicyclopentadiene (DCPD) | X | X | | X | X | | X | | X | | | | | | | | | | | | | | | |
| Fuel oil | | X | | | X | | X | | X | | | | X | | | | | | | | | | | |
| Gasoline | | X | | X | | | | | X | | | | X | | | | | | | | | | | |
| Jet fuels | | | | | | X | X | | X | X | | | | | | | | | | | | | | |
| Propane | | | | | | | | | | | | X | | | | | | | | | | | | |
| **Metals and Cations** | | | | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | | | | | | | | | | | | | X | | | | | | | | | | | |
| Antimony | | X | | | X | X | X | | | | X | | X | | | | | | | | | | | |
| Arsenic | | | | | X | | | | | X | | | X | | | X | | | X | | X | X | X | |
| Barium | | X | | X | X | | X | | | X | | | | | X | | | | | | | | | |
| Beryllium | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | X |
| Cadmium | | | | X | X | | X | | X | | | | | | | | | | X | X | X | | | X |
| Chromium | | X | X | X | X | X | | | | | | | | | | | | | | X | X | X | | X |
| Cobalt | X | X | X | | X | | | | | | X | | X | X | | | | | | | | | | |
| Copper | | | | | | X | X | | | | | X | | | | | | | | | | | | |
| Iron | | | | | X | X | | | | | | | X | | | | | | | | | | | |
| Lead | | | | | | | | | X | | X | | | | | | | | X | | | | | |
| Lithium | | | | | | | X | | X | | | | X | X | | | | | | | | | | |
| Magnesium | X | | | | | | | | X | | | | | | | | | | | | | | | |
| Manganese | | | | | X | X | | | X | | | | | | | | | | | | | | | |
| Mercury | | | | | | | X | | X | | | | | | | | X | | | | X | | | |
| Nickel | X | | X | X | X | | | | X | | | | X | | | | | | X | | | | | X |
| Palladium | | | | | | | X | | | | X | | | | | | | | | | | | | |
| Selenium | X | | | X | X | X | | | X | | | | X | | | | | | | | | | | |



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| Containment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silver | | | | | X | | X | | | | X | | | X | | | X | X | | | | | | |
| Thallium | | | | | | X | X | | X | | | | X | X | | | | | | X | | X | | |
| Vanadium | | | X | | X | X | X | | X | | X | | | | | | | | | | | | | |
| Zinc | X | X | | | | | | | | | X | | | | | | | | X | X | | | | |
| **Nonmetals and Anions** | | | | | | | | | | | | | | | | | | | | | | | | |
| Ammonia | X | X | | X | X | X | X | | X | | | | | | | | | | | | | | | |
| Cyanides | X | X | X | X | | | | | X | | | | | | | | | | | | | | | |
| Fluorides | | | | | | | X | | X | | | | | | | | | | | | | | | |

*Numerical key of toxic effects:* (1) Eye irritation, (2) Skin irritation, (3) Allergic sensitization, (4) Upper respiratory tract irritation, (5) Lung/respiratory effects, (6) Liver damage, (7) Kidney damage, (8) Pancreatic damage, (9) central nervous system, (CNS) effects, (10) Peripheral nervous system effects, (11) Blood cell disorders, (12) Immunological effects, (13) Cardiovascular effects, (14) Gastrointestinal effects, (15) Cholinesterase inhibition, (16) Methemoglobinemia, (17) Skin damage, (18) Visual damage, (19) Endocrine effects, (20) Reproductive effects, (21) Embryotoxicity, (22) Teratogenicity, (23) Mutagenicity, (24) Carcinogenicity.

*Source*: From Office of Technology Assessment. Compiled from a partial survey of literature conducted by Environ Corp., 1983.

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**Table 10J.268 Estimated Drinking Water Concentration Corresponding to a $1 \times 10^{-6}$ Excess Lifetime Cancer Risk for Selected Known, Probable, or Possible Carcinogens for a Lifetime Consumption of Water**

| Chemical | Drinking Water Concentration (μg/L) | Sex, Species | Tumor Type |
|---|---|---|---|
| Benzene | 1–10 | Human | Leukemia |
| α-BHC | 0.006 | M mouse | Hepatocellular carcinoma |
| β-BHC | 0.02 | M mouse | Hepatocellular carcinoma |
| Carbon tetrachloride | 0.3 | Various | Hepatocellular carcinoma |
| 1,2-Dichloroethane | 0.4 | M rat | Hemangiosarcoma of circulatory system |
| 1,4-Dioxane[a] | 3 | M rat | Nasal squamous cell carcinoma |
| Ethylene dibromide (EDB) | 0.02 | Mrat | Forestomach tumors, hemangiosarcomas, thyroid follicular cell adenomas or carcinomas |
| DDT | 0.1 | Mouse/rat | Benign and malignant liver tumors |
| Heptachlor | 0.008 | Mouse | Hepatocellular carcinomas |
| 1,1,2,2-Tetrachloroethane | 0.2 | Mouse | Hepatocellular carcinoma |
| 1,1,2-Trichloroethane | 0.5 | Mouse | Hepatocellular carcinoma |
| Vinyl chloride — continuous lifetime exposure from birth | 0.024 | F rat | Total of liver angiosarcoma, hepatocellular carcinoma, and neoplastic nodules |
| Vinyl chloride — continuous lifetime exposure during adulthood | 0.048 | F rat | Total of liver angiosarcoma, hepatocellular carcinoma, and neoplastic nodules |

[a] Toxicity values under review; revised assessment due in 2006 or 2007.

*Source*: From U.S. Environmental Protection Agency, *Integrated Risk Information System (IRIS)*, 2005, www.epa.gov/iris.

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CHAPTER 11

# Water Resources Management

**Gustavõ Suarez**

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## SECTION 11A DAMS

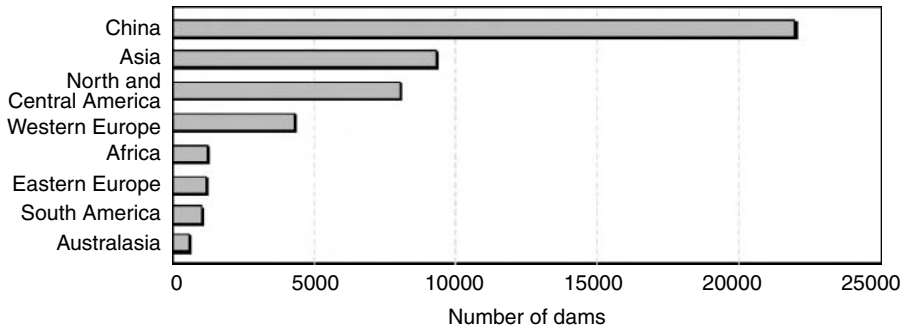


**Figure 11A.1** Regional distribution of large dams in 2000. (From WCD compilation of various sources and ICOLD, 1998. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

**Table 11A.1 World's Largest Dams**

| Dam | Location | Volume (Thousands) $m^3$ | Volume (Thousands) $yds^3$ | Year Completed |
|---|---|---|---|---|
| Syncrude Tailings | Canada | 540,000 | 706,320 | UC |
| Chapetón | Argentina | 296,200 | 387,410 | UC |
| Pati | Argentina | 238,180 | 274,026 | UC |
| New Cornelia Tailings | United States | 209,500 | 274,026 | 1973 |
| Tarbela | Pakistan | 121,720 | 159,210 | 1976 |
| Kambaratinsk | Kyrgyzstan | 112,200 | 146,758 | UC |
| Fort Peck | Montana | 96,049 | 125,628 | 1940 |
| Lower Usuma | Nigeria | 93,000 | 121,644 | 1990 |
| Cipasang | Indonesia | 90,000 | 117,720 | UC |
| Atatürk | Turkey | 84,500 | 110,522 | 1990 |
| Yacyretá-Apipe | Paraguay/Argentina | 18,000 | 105,944 | 1998 |
| Guri (Raul Leoni) | Venezuela | 78,000 | 102,014 | 1986 |
| Rogun | Tajikistan | 75,500 | 98,750 | 1985 |
| Oahe | South Dakota | 70,339 | 92,000 | 1963 |
| Mangla | Pakistan | 65,651 | 85,872 | 1967 |
| Gardiner | Canada | 65,440 | 85,592 | 1968 |
| Afsluitdijk | Netherlands | 63,400 | 82,927 | 1932 |
| Oroville | California | 59,639 | 78,008 | 1968 |
| San Luis | California | 59,405 | 77,700 | 1967 |
| Nurek | Tajikistan | 58,000 | 75,861 | 1980 |
| Garrison | North Dakota | 50,843 | 66,500 | 1956 |
| Cochiti | New Mexico | 48,052 | 62,850 | 1975 |
| Tabka (Thawra) | Syria | 46,000 | 60,168 | 1976 |
| Bennett WAC | Canada | 43,733 | 57,201 | 1967 |
| Tucuruíi | Brazil | 43,000 | 56,242 | 1984 |
| Boruca | Costa Rica | 43,000 | 56,242 | UC |
| High Aswan (Sadd-el-Aali) | Egypt | 43,000 | 56,242 | 1970 |
| San Roque | Philippines | 43,000 | 56,242 | UC |
| Kiev | Ukraine | 42,841 | 56,034 | 1964 |
| Dantiwada Left Embankment | India | 41,040 | 53,680 | 1965 |
| Saratov | Russia | 40,400 | 52,843 | 1967 |
| Mission Tailings 2 | Arizona | 40,088 | 52,435 | 1973 |
| Fort Randall | South Dakota | 38,227 | 50,000 | 1953 |
| Kanev | Ukraine | 37,860 | 49,520 | 1976 |
| Mosul | Iraq | 36,000 | 47,086 | 1982 |
| Kakhovka | Ukraine | 35,640 | 46,617 | 1055 |

*(Continued)*

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**Table 11A.1 (Continued)**

| Dam | Location | Volume (Thousands) $m^3$ | Volume (Thousands) $yds^3$ | Year Completed |
|---|---|---|---|---|
| Itumbiara | Brazil | 35,600 | 46,563 | 1980 |
| Lauwerszee | Netherlands | 35,575 | 46,532 | 1969 |
| Beas | India | 35,418 | 46,325 | 1974 |
| Oosterschelde | Netherlands | 35,000 | 45,778 | 1986 |

*Note:* UC, under construction in 2004. China's Three Gorges dam, on the Yangtze River, begun in 1993 and expected to be completed in 2009, will be the world's largest and highest dam.

*Source*: From Department of the Interior, Bureau of Reclamation and International Water Power and Dam Construction.

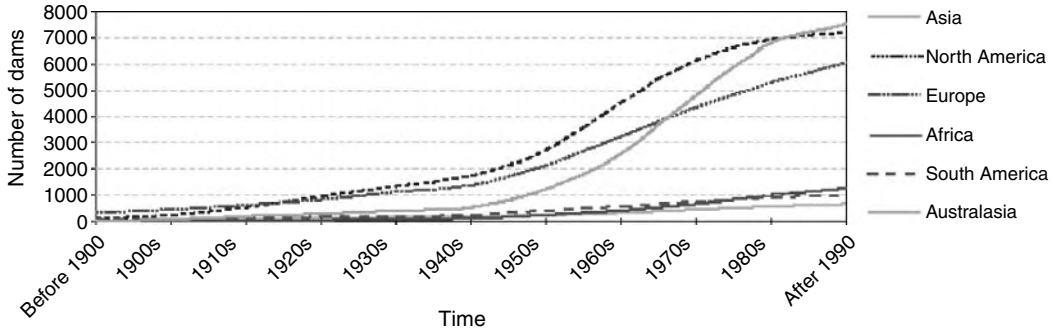


**Figure 11A.2** Cumulative commissioning of large dams in the 20th century. (From ICOLD 1998, excluding over 90% of large dams in China. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

**Table 11A.2 Number of Dams in the World in 1950 and 1982 by Continent**

| Continent | 1950 Dams | 1950 % | 1982 Dams | 1982 % |
|---|---|---|---|---|
| Europe | 1,292 | 25 | 3,800 | 11 |
| Asia | 1,541 | 30 | 22,701 | 65 |
| America | 2,090 | 40 | 7,241 | 21 |
| Africa | 123 | 2 | 610 | 2 |
| Australasia | 150 | 3 | 446 | 1 |
| Total | 5,196 | 100 | 34,798 | 100 |
| China | 8 | 0.2 | 18,595 | 53 |

*Source*: From International Commission on Large Dams, 1984, *Register of Dams; percentages rounded*.

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**Table 11A.3 Dams in 140 Countries**

| Regions and Countries | Number of Dams | Regions and Countries | Number of Dams | Regions and Countries | Number of Dams |
|---|---|---|---|---|---|
| **Africa** | | Finland | 55 | Nicaragua | 4 |
| South Africa | 539 | Cyprus | 52 | Trinidad & Tobago | 4 |
| Zimbabwe | 213 | Greece | 46 | Jamaica | 2 |
| Algeria | 107 | Iceland | 20 | Antigua | 1 |
| Morocco | 92 | Ireland | 16 | Haiti | 1 |
| Tunisia | 72 | Belgium | 15 | **Total** | **8,010** |
| Nigeria | 45 | Denmark | 10 | **Asia** | |
| Côte d'Ivoire | 22 | Netherlands | 10 | China | 22,000 |
| Angola | 15 | Luxembourg | 3 | India | 4,291 |
| Dem. Rep. of Congo | 14 | **Total** | **4,277** | Japan | 2,675 |
| Kenya | 14 | **South America** | | South Korea | 765 |
| Namibia | 13 | Brazil | 594 | Turkey | 625 |
| Libya | 12 | Argentina | 101 | Thailand | 204 |
| Madagascar | 10 | Chile | 88 | Indonesia | 96 |
| Cameroon | 9 | Venezuela | 74 | Russia | 91 |
| Mauritius | 9 | Colombia | 49 | Pakistan | 71 |
| Burkina Faso | 8 | Peru | 43 | North Korea | 70 |
| Ethiopia | 8 | Ecuador | 11 | Iran | 66 |
| Mozambique | 8 | Bolivia | 6 | Malaysia | 59 |
| Lesotho | 7 | Uruguay | 6 | Taipei China | 51 |
| Egypt | 6 | Paraguay | 4 | Sri Lanka | 46 |
| Swaziland | 6 | Guyana | 2 | Syria | 41 |
| Ghana | 5 | Suriname | 1 | Saudi Arabia | 38 |
| Sudan | 4 | **Total** | **979** | Azerbaijan | 17 |
| Zambia | 4 | **Eastern Europe** | | Armenia | 16 |
| Botswana | 3 | Albania | 306 | Philippines | 15 |
| Malawi | 3 | Romania | 246 | Georgia | 14 |
| Benin | 2 | Bulgaria | 180 | Uzbekistan | 14 |
| Congo | 2 | Czech Republic | 118 | Iraq | 13 |
| Guinea | 2 | Poland | 69 | Kazakstan | 12 |
| Mali | 2 | Yugoslavia | 69 | Kyrgyzstan | 11 |
| Senegal | 2 | Slovakia | 50 | Tajikistan | 7 |
| Seychelles | 2 | Slovenia | 30 | Jordan | 5 |
| Sierra Leone | 2 | Croatia | 29 | Lebanon | 5 |
| Tanzania | 2 | Bosnia Herzegovina | 25 | Myanmar | 5 |
| Togo | 2 | Ukraine | 21 | Nepal | 3 |
| Gabon | 1 | Lithuania | 20 | Vietnam | 3 |
| Liberia | 1 | Macedonia | 18 | Singapore | 3 |
| Uganda | 1 | Hungary | 15 | Afghanistan | 2 |
| **Total** | **1,209** | Latvia | 5 | Brunei | 2 |
| **Western Europe** | | Moldova | 2 | Cambodia | 2 |
| Spain | 1,196 | **Total** | **1,203** | Bangladesh | 1 |
| France | 569 | **North and Central America** | | Laos | 1 |
| Italy | 524 | United States | 6,575 | **Total** | **31,340** |
| United Kingdom | 517 | Canada | 793 | **Austral-Asia** | |
| Norway | 335 | Mexico | 537 | Australia | 436 |
| Germany | 311 | Cuba | 49 | New Zealand | 86 |
| Sweden | 190 | Dominican Republic | 11 | Papua New Guinea | 3 |
| Switzerland | 156 | Costa Rica | 9 | Fiji | 2 |
| Austria | 149 | Honduras | 9 | **Total** | **577** |
| Portugal | 103 | Panama | 6 | | |
| | | El Salvadaor | 5 | | |
| | | Guatemala | 4 | | |

*Source*: Based on ICOLD, 1998, ID, 1000 and other sources. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile. With permission.

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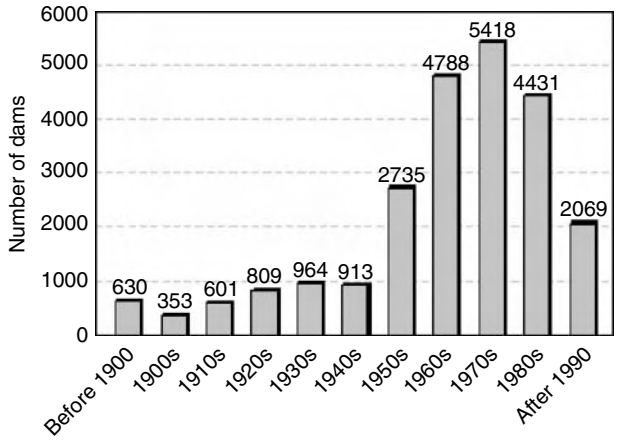


**Figure 11A.3** Commissioning of large dams globally by decade in the 20th century. (From ICOLD, 1998, excluding over 90% of large dams in China. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

**Table 11A.4 Countries with More Than 100 Dams in 1982**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| China | 18,595 | (16,500) | Brazil | 489 | (443) | Germany | 184 | (158) |
| U.S.A. | 5,338 | (5,046) | Mexico | 487 | (433) | Czechoslovakia | 142 | (131) |
| Japan | 2,142 | (2,006) | France | 432 | (388) | Sweden | 134 | (132) |
| India | 1,085 | (999) | Italy | 408 | (403) | Switzerland | 130 | (128) |
| Spain | 690 | (630) | Australia | 374 | (320) | Yugoslavia | 114 | (93) |
| Korea | 628 | (558) | South Africa | 342 | (316) | Austria | 112 | (97) |
| Canada | 580 | (494) | Norway | 219 | (205) | Bulgaria | 108 | (106) |
| Great Britain | 529 | (519) | | | | Romania | 106 | (81) |
| | 29,587 | | | 2,751 | | | 1,030 | |

*Note:* Numbers in brackets represent number of dams in service at the end of 1977.

*Source*: From International Commission on Large Dams, 1984, *Register of Dams*.

**Table 11A.5 Rate of Dam Construction in the World, 1950–1982**

| | Outside of China | | | China | | | |
|---|---|---|---|---|---|---|---|
| **Period** | **Number per Period** | **Total Number** | **Number per Annum** | **Number per Period** | **Total Number** | **Number per Annum** | **Ratio China Compared to Outside China** |
| Up to 1950 | 5,188 | 5,188 | | | 8 | | |
| 1951 to 1974 | 8,948 | 14,136 | 373 | | | | |
| 1975 to 1977 | 752 | 14,888 | 251 | | | | |
| 1951 to 1977 | 9,700 | 14,888 | 359 | 16,492 | 16,500 | 611 | 1.70 |
| 1978 to 1982 | 1,315 | 16,203 | 263 | 2,095 | 18,595 | 419 | 1.60 |
| 1975 to 1982 | 2,067 | 16,203 | 258 | | | | |
| 1951 to 1982 | 11,015 | 16,203 | 344 | 18,587 | 18,595 | 581 | 1.69 |

*Source*: From International Commission on Large Dams, 1984, *World Register of Dams*.

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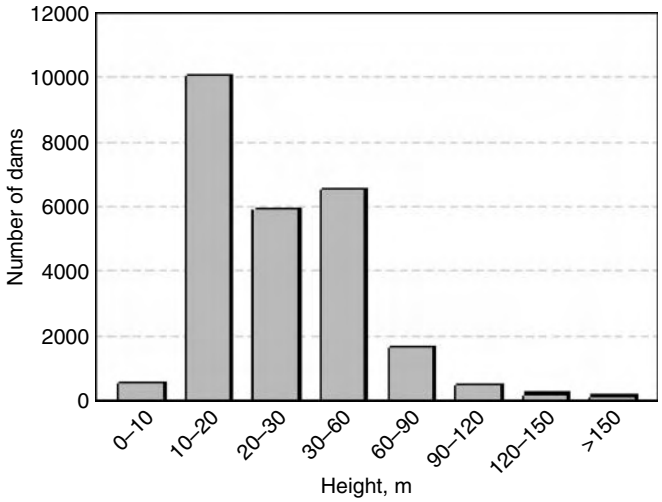


**Figure 11A.4** Global distribution of dam heights (m). (From ICOLD, 1998. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

**Table 11A.6 Classification of Dams in the World by Type and Height**

| | Number of Dams/Height | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Total** | **15–30 m** | **30–60 m** | **60–100 m** | **100–150 m** | **150–200 m** | **>200 m** |
| Earth (TE) and Rockfill (ER) | 28,844 | 24,567 | 3,657 | 477 | 116 | 21 | 6 |
| Gravity (PG) | 3,954 | 2,222 | 1,294 | 361 | 65 | 8 | 4 |
| Arch (VA) | 1,527 | 775 | 428 | 204 | 83 | 24 | 13 |
| Buttress (CB) | 337 | 175 | 110 | 40 | 12 | — | — |
| Multi-Arch (MV) | 136 | 74 | 48 | 13 | — | — | 1 |
| Total | 34,798 | 27,813 | 5,537 | 1,095 | 276 | 53 | 24 |

*Source*: From International Commission on Large Dams, 1984, *World Register of Dams*.

**Table 11A.7 World's Highest Dams**

| No | Height above Lowest Foundation (m) | Type[a] | Name | Country | Year |
|---|---|---|---|---|---|
| | 335 | TE/ER | Rogun | U.S.S.R. | U/C |
| 1 | 300 | TE | Nurek | U.S.S.R. | 1980 |
| 2 | 285 | PG | Grande Dixence | Switzerland | 1961 |
| 3 | 272 | VA | Inguri | U.S.S.R. | 1980 |
| 4 | 262 | VA | Vajont | Italy | 1961 |
| 5 | 261 | ER | Manuel Moreno Torres (Chicoasén) | Mexico | 1980 |
| | 261 | ER/TE | Tehri | India | U/C |
| | 253 | ER/TE | Kishau | India | U/C |
| | 245 | VA/PG | Sayano-Shushensk | U.S.S.R. | U/C |
| | 243 | ER | Guavio | Colombia | U/C |
| 6 | 242 | TE | Mica | Canada | 1972 |
| 7 | 237 | ER | Chivor | Colombia | 1975 |
| 8 | 237 | VA | Mauvoisin | Switzerland | 1957 |
| | 234 | VA | El Cajón | Honduras | U/C (1984) |
| 9 | 233 | VA | Chirkey | U.S.S.R. | 1978 |
| 10 | 230 | TE | Oroville | U.S.A. | 1968 |
| 11 | 226 | PG | Bhakra | India | 1963 |
| 12 | 221 | VA/PG | Hoover | U.S.A. | 1936 |

*(Continued)*

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**Table 11A.7 (Continued)**

| No | Height above Lowest Foundation (m) | Type[a] | Name | Country | Year |
|---|---|---|---|---|---|
| 13 | 220 | VA | Contra | Switzerland | 1965 |
| 14 | 220 | VA | Mratinje | Yugoslavia | 1976 |
| 15 | 219 | PG | Dworshak | U.S.A. | 1973 |
| 16 | 216 | VA | Glen Canyon | U.S.A. | 1966 |
| 17 | 215 | PG | Toktogul | U.S.S.R. | 1978 |
| 18 | 214 | MV | Daniel Johnson | Canada | 1968 |
| 19 | 213 | VA | Dez | Iran | 1962 |
| | 210 | ER | San Roque | Philippines | U/C |
| 20 | 208 | VA | Luzzone | Switzerland | 1963 |
| 21 | 207 | ER/PG | Keban | Turkey | 1974 |
| 22 | 202 | VA | Almendra | Spain | 1970 |
| | 201 | VA | Khudoni | U.S.S.R. | U/C |
| 23 | 200 | VA | Karoun | Iran | 1975 |
| 24 | 200 | VA | Kolnbrein | Austria | 1977 |
| 25 | 196 | PG/ER/TE | Itaipu | Brazil | 1982 |
| | 195 | ER | Altinkaya | Turkey | U/C |
| 26 | 194 | VA | New Bullard's Bar | U.S.A. | 1970 |
| | 192 | PG | Lakhwar | India | U/C |
| 27 | 191 | ER | New Melones | U.S.A. | 1979 |
| 28 | 186 | VA | Kurobe | Japan | 1964 |
| 29 | 186 | TE | Swift | U.S.A. | 1958 |
| | 186 | VA | Zillergründl | Austria | U/C |
| 30 | 185 | VA | Mossyrock | U.S.A. | 1968 |
| | 185 | VA | Oymapinar | Turkey | U/C |
| | 184 | ER | Atatürk | Turkey | U/C |
| 31 | 183 | PG | Shasta | U.S.A. | 1945 |
| 32 | 183 | TE | WAC Bennett | Canada | 1967 |
| 33 | 180 | VA | Amir Kabir | Iran | 1964 |
| 34 | 180 | ER | Dartmouth | Australia | 1979 |
| 35 | 180 | VA | Emmosson | Switzerland | 1974 |
| | 180 | VA | Tehchi | Taiwan | 1974 |
| 36 | 180 | VA | Tignes | France | 1952 |
| 37 | 176 | ER | Takase | Japan | 1978 |
| 38 | 175 | ER | Ayvacik | Turkey | 1981 |
| 39 | 174 | PG | Alpe Gera | Italy | 1964 |
| 40 | 173 | TE | Don Pedro | U.S.A. | 1971 |
| | 173 | VA | Karakaya | Turkey | U/C |
| 41 | 172 | VA | Hungry Horse | U.S.A. | 1953 |
| | 172 | PG | Longyangxia | China | U/C |
| | 171 | VA | Cabora Bassa | Mozambique | 1974 |
| 42 | 169 | VA | Idukki | India | 1974 |
| 43 | 168 | ER | Charyak | U.S.S.R. | 1977 |
| | 168 | ER | Gura Apelor | Romania | U/C |
| 44 | 168 | ER | La Grande 2 | Canada | 1978 |
| 45 | 168 | PG | Grand Coulée | U.S.A. | 1942 |
| 46 | 167 | ER | Fierze | Albania | 1978 |
| | 167 | VA/PG | Daniel Palacios | Ecuador | U/C |
| 47 | 166 | VA | Vidraru | Romania | 1965 |
| 48 | 165 | TE | Kremasta | Greece | 1965 |
| 49 | 165 | VA | Ross | U.S.A. | 1949 |
| 50 | 165 | PG | Wujiangdu | China | 1981 |
| | 164 | ER | Thomson | Australia | U/C |
| 51 | 164 | TE | Trinity | U.S.A. | 1962 |
| | 162 | PG/ER | Guri | Venezuela | U/C |
| 52 | 162 | ER | Talbingo | Australia | 1971 |
| 53 | 100 | ER | Foz de Areia | Brazil | 1980 |
| | 160 | TE/ER | Grand-Maison | France | U/C |
| | 160 | ER | Salvajina | Columbia | U/C |
| | 160 | ER/TE | Thein Dam Ranjit | India | U/C |
| 54 | 160 | VA | Yellowtail | U.S.A. | 1966 |

*(Continued)*

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**Table 11A.7 (Continued)**

| No | Height above Lowest Foundation (m) | Type[a] | Name | Country | Year |
|---|---|---|---|---|---|
| | 158 | ER | Canales | Spain | U/C |
| | 158 | TE | Yacambu | Venezuela | U/C |
| 55 | 158 | ER | Cougar | U.S.A. | 1964 |
| 56 | 158 | ER | Emborcacão | Brazil | 1982 |
| 57 | 158 | VA | Gökcekaya | Turkey | 1972 |
| | 158 | ER | Naramata | Japan | U/C |
| | 157 | VA | Dongjiang | China | U/C |
| 58 | 157 | PG | Okutadami | Japan | 1961 |
| 59 | 157 | VA | Speccheri | Italy | 1957 |
| 60 | 156 | PG | Sakuma | Japan | 1956 |
| 61 | 156 | VA–TE | Zeuzier | Switzerland | 1957 |
| 62 | 155 | ER | Goescheneralp | Switzerland | 1960 |
| 63 | 155 | VA | Monteynard | France | 1962 |
| 64 | 155 | VA | Nagawado | Japan | 1969 |
| 65 | 155 | VA | Place Moulin | Italy | 1965 |
| | 155 | PG | Sadar Sarovar | India | U/C |
| 66 | 154 | VA/PG | Bhumibol | Thailand | 1964 |
| 67 | 154 | ER | Tedorigawa | Japan | 1979 |
| 68 | 153 | VA | Curnera | Switzerland | 1967 |
| 69 | 153 | VA | Flaming George | U.S.A. | 1964 |
| 70 | 153 | ER | Gepatsch | Austria | 1965 |
| | 153 | PG/ER | Revelstoke | Canada | U/C |
| 71 | 153 | VA | Santa Giustina | Italy | 1950 |
| | 151 | PG | Dorna | Spain | U/C |
| | 151 | ER | Menzelet | Turkey | U/C |
| 72 | 151 | VA | Zervreila | Switzerland | 1957 |
| | 150 | PG | Baishan | China | U/C |
| 73 | 150 | VA | Canelles | Spain | 1960 |
| 74 | 150 | ER | Finstertal | Austria | 1980 |
| | 150 | ER | Kenyir | Malaysia | U/C |
| 75 | 150 | VA/CB | Roselend | France | 1961 |
| 76 | 150 | TE | Big Horn | Canada | 1972 |

*Note:* U/C, under construction.

[a] TE, Earth; ER, Rockfill; PG, Gravity; CB, Buttress; VA, Arch; MV, Multi-Arch.

*Source*: From International Commission on Large Dams, 1984, *World Register of Dams*.

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**Table 11A.8 High Dams of the World Arranged by Country**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Afghanistan* | | | | | | | | | | | |
| Kajakaiv | 1952 | Helmand | Kandahar | | ER | 98 | 274 | 3,230 | 2,680,000 | I | 9,300 |
| *Albania* | | | | | | | | | | | |
| Fierze | 1978 | Drin | B. Curri | Tropoje | ER | 167 | 400 | 8,000 | 2,700,000 | H | |
| Koman | C | Drin | Shkoder | Shkoder | ER | 133 | 275 | 4,500 | 450,000 | H | |
| *Algeria* | | | | | | | | | | | |
| Bou Hanifia | 1948 | El Hammam | Bou Hanifia | Mascara | ER | 99 | 464 | 1,530 | 73,000 | IS | 5,500 |
| Bou Roumi | C (1984) | Bou Roumi | Bou Medfa | Blida | TE | 100 | 300 | 4,200 | 188,000 | I | 800 |
| Keddara | C (1986) | Boudouaou | Boudouaou | Blida | ER | 108 | 560 | 4,380 | 146,000 | S | 380 |
| Sly | C (1985) | Sly | El Asnam | El Asnam | TE | 87 | 395 | 3,565 | 286,000 | I | 1,700 |
| *Argentina* | | | | | | | | | | | |
| Las Pirquitas | 1961 | Del Valle | Piedra Blanca | Catamarca | TE | 83 | 410 | 2,900 | 65,000 | ICH | 1,400 |
| Gral. M. Belgrano Cabra Corral Res. | 1973 | Juramento | Coronel Moldes | Salta | TE | 112 | 470 | 8,000 | 3,100,000 | IH | 1,500 |
| Las Maderas (B.L) | 1974 | Las Maderas | El Carmen | Jujuy | TE | 98 | 460 | 4,500 | 300,000 | IH | 30 |
| Futaleufu AmutuiQuimei Res. | 1976 | Futaleufú | Trevelin | Chubut | TE | 130 | 600 | 6,000 | 5,600,000 | H | 3,000 |
| Los Reyunos | 1980 | Diamante | 25 de Mayo | Mendoza | TE | 131 | 266 | 3,220 | 260,000 | IH | 2,300 |
| Alicura | C (1984) | Limay | S.C.de Bariloche | Rio Negro/ Neuquén | TE | 130 | 880 | 13,000 | 3,215,000 | H | 3,000 |
| Cerro Pelado | C (1985) | Grande | Amboy | Córdoba | TE | 104 | 410 | 3,700 | 370,000 | HICR | 3,300 |
| *Australia* | | | | | | | | | | | |
| Upper Yarra | 1957 | Yarra | Melbourne | Victoria | TE/ER | 89 | 610 | 5,660 | 207,200 | S | 2,165 |
| Eucumbane | 1958 | Eucumbene | Cooma | NSW | TE | 116 | 579 | 6,735 | 4,798,400 | H | 191 |
| South Para | 1958 | South Para | Adelaide | Sth Aust. | TE | 48 | 284 | 581 | 51,190 | S | 736 |
| Glenbawn | 1958 | Hunter | Scone | NSW | ER | 78 | 823 | 7,650 | 360,000 | IC | 1,700 |
| Warragamba | 1980 | Warragamba | Sydney | NSW | PG | 137 | 351 | 1,233 | 2,057,000 | SH | 12,740 |
| Geehi | 1966 | Geehi | Cooma | NSW | ER | 91 | 265 | 1,421 | 21,093 | H | 1,534 |
| Blowering | 1968 | Tumut | Tumut | NSW | ER | 112 | 808 | 8,563 | 1,628,000 | IH | 2,350 |
| Corin | 1968 | Cotter | Canberra | ACT | ER | 76 | 282 | 1,376 | 74,970 | S | 1,190 |
| Talbingo | 1971 | Tumut | Tumut | NSW | ER | 162 | 701 | 14,490 | 921,400 | H | 4,290 |
| Cethana | 1971 | Forth | Devonport | Tasmania | ER | 110 | 213 | 1,376 | 109,000 | H | 1,980 |
| Wyangla | 1971 | Lachlan | Cowra | NSW | ER | 85 | 1,510 | 3,580 | 1,220,000 | I | 14,700 |
| Ord River Lake Argyle (Res.) | 1972 | Ord | Wyndham | West Aust. | ER | 99 | 341 | 1,908 | 5,797,000 | I | 3,500 |
| Cardinia | 1973 | Cardinia Creak | Melbourne | Victoria | TE/ER | 86 | 1,542 | 5,150 | 288,905 | S | 13 |
| Copeton | 1976 | Gwydir | Inverell | NSW | ER | 113 | 1,484 | 8,333 | 1,364,000 | I | 14,800 |

*(Continued)*



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**Table 11A.8 (Continued)**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dartmouth | 1979 | Mitta Mitta | Mitta Mitta | Victoria | ER | 180 | 670 | 14,100 | 4,000,000 | IHS | 2,584 |
| Split-Yard Creek | 1980 | Pryde Creek | Ipswich | Queensland | ER | 76 | 1,140 | 3,371 | 28,700 | H | 570 |
| Winneke | 1980 | Sugarloaf Creek | Melbourne | Victoria | ER | 89 | 1,000 | 4,700 | 100,000 | S | 7 |
| Mangrove Creek | 1982 | Mangrove Creek | Wyong | NSW | ER | 80 | 380 | 1,340 | 170,000 | S | 570 |
| Blue Rock | C (1984) | Tanjil | Moe | Victoria | TE | 75 | 640 | 1,530 | 200,000 | S | 1,018 |
| Thomson | C (1984) | Thomson | Moe | Victoria | ER | 164 | 1,180 | 13,300 | 1,175,000 | SI | 1,040 |
| Lower Pieman | C (1985) | Pieman | Queenstown | Tasmania | ER | 122 | 374 | 2,950 | 641,000 | H | 4,714 |
| *Austria* | | | | | | | | | | | |
| Gepatch | 1965 | Faggenbach | Landeck | Tyrol | ER | 153 | 600 | 7,100 | 140,000 | H | 325 |
| Oschaniksee | 1972–1978 | tr. Fragant | Obervellach | Carinthia | ER | 116 | 530 | 2,250 | 33,000 | H | 6 |
| Kölnbrein | 1977 | Malta | Oͤmnd | Carinthia | VA | 200 | 626 | 1,580 | 205,000 | H | 188 |
| Rotlech | 1977 | tr. Lech | Reutte | Tyrol | PG/ER | 32 | 128 | 14/11 | 1,260 | H | 200 |
| Finstertal | 1980 | tr. Naderbach | Ötz | Tyrol | ER | 150 | 652 | 4,500 | 60,500 | H | 23 |
| Zillergründl | C (1986) | Ziller | Mayrhofen | Tyrol | VA | 186 | 506 | 1,355 | 90,000 | H | 215 |
| *Brazil* | | | | | | | | | | | |
| Euclides Da Cunha | 1960–1977 | Pardo | S.José do Rio Pardo | São Paulo | TE | 92 | 312 | 2,200 | 13,400 | H | 2,340 |
| Tres Marias | 1960 | São Francisco | Tres Marias | Minas Gerais | TE | 75 | 2,700 | 14,250 | 19,790,000 | CHI | 8,700 |
| Furnas | 1963 | Grande | Passos | Minas Gerais | ER/PG | 127 | 779 | 9,697 | 22,950,000 | HC | 13,000 |
| Estreito | 1969 | Grande | Pedregulho | M.Gerais/São Paulo | ER/PG | 92 | 715 | 4,446 | 1,418,000 | H | 13,000 |
| Xavantes | 1970 | Parana-panema | Xavantes | São Paulo | TE/ER | 92 | 500 | 6,000 | 8,750,000 | H | 3,200 |
| Paraitinga | 1975 | Paraitinga | Paraibuna | São Paulo | TE | 105 | 586 | 11,051 | 2,430,000 | HC | 600 |
| Paraitinga Dike Paraitinga Res. | 1975 | | Paraibuna | São Paulo | TE | 80 | 530 | 3,391 | 2,430,000 | | — |
| Itauba | 1975 | Jacui | Julio de Castilhos | Rio Grande do Sul | ER | 90 | 385 | 3,410 | 510,000 | H | 8,130 |
| Paraibuna | 1978 | Paraibuna | Paraibuna | São Paulo | TE | 94 | 1,285 | 7,892 | 2,463,000 | HCI | 1,500 |
| São Simão | 1978 | Paranaiba | São Simão | Minas Gerais (Goiás) | TE/ER/PG | 120 | 3,611 | 27,378 | 12,540,000 | H | 24,100 |
| Foz Do Areia | 1980 | Iguaçu | Bituruna | Paraná | ER | 160 | 850 | 13,000 | 6,100,000 | H | 11,000 |
| Itumbiara | 1980 | Paranaiba | Itumbiara | Golás/Minas Gerais | TE/PG | 106 | 6,780 | 38,820 | 17,030,000 | HC | 16,200 |
| Salto Santiago (Main) | 1980 | Iguaççú | Laranjeiras do Sul | Paraná | ER | 80 | 1,400 | 9,860 | 6,750,000 | H | 24,000 |
| Jequitai | 1981 | Jequital | Jequital | Minas Gerais | TE | 80 | 580 | 2,300 | 1,200,000 | I | 1,850 |
| Emborcação | 1982 | Paranaiba | Araguari | Minas Gerais/Goiás | ER | 158 | 1,607 | 25,000 | 17,600,000 | H | 7,800 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Itaipu | 1982 | Paraná | Foz do Iguaçu | Brasil/Paraguai | ER/PG/TE | 196 | 7,900 | 29,200 | 29,000,000 | H | 61,400 |
| Tucuruí | C (1983) | Tocantis | Tucuruí | Pará | TE/ER/PG | 93 | 10, 667 | 64,300 | 43,000,000 | HN | 110,000 |
| Itaparica | C (1986) | São Francisco | Petrolándia | Pernambuco | ER | 105 | 4,150 | 16,530 | 10,700,000 | IH | 28,700 |
| Pedra Do Cavalo | C | Paraguassu | Cachoeira de S. Félix | Bahia | ER | 142 | 510 | 6,500 | 5,330,000 | HCS | 12,000 |
| Segredo | C (1987) | Iguaçu | Pinhão | Paraná | ER | 140 | 700 | 6,700 | 3,000,000 | H | 13,000 |
| *Bulgaria* | | | | | | | | | | | |
| Belmeken | 1976 | Kriva | Sestrimo | S | ER | 94 | 760 | 3,560 | 145,000 | H | |
| *Canada* | | | | | | | | | | | |
| Kenney | 1952 | Nechako | Prince George | British Columbia | ER | 104 | 457 | 3,071 | 23,700,000 | H | — |
| Lajoie | 1955 | Bridge | Goldbridge | British Columbia | ER | 87 | 1,033 | 2,860 | 720,728 | H | 566 |
| WAC Bennett | 1967 | Peace | Hudson Hope | British Columbia | TE | 183 | 2,042 | 43,733 | 70,308,930 | H | 10,194 |
| Daniel Johnson (Manic 5) | 1968 | Manicouagan | Baie Comeau | Quebec | MV | 214 | 1,314 | 2,255 | 141,851,350 | H | |
| Outardes 4 No. 1 | 1968 | Outardes | Baie Comeau | Quebec | ER | 122 | 649 | 7,533 | | H | |
| Outardes 4 No. 2 | 1968 | Outardes | Baie Comeau | Quebec | ER | 108 | 726 | 4,688 | | H | |
| Lower Notch | 1971 | Montreal | North Bay | Ontario | TE/PG | 132 | 1,969 | 1,817 | 170,960 | H | 1,425 |
| Big Horn Abraham Lake Res. | 1972 | North Sask. | Nordeag | Alberta | TE | 150 | 472 | 4,330 | 1,768,000 | H | |
| Mica | 1972 | Columbia | Revelstoke | British Columbia | TE | 242 | 792 | 32,111 | 24,699,800 | H | 4,248 |
| Manicouagan 3 | 1975 | Manicouagan | Baie Comeau | Quebec | TE | 108 | 366 | 9,175 | 10,422,991 | H | |
| Revelstoke | C | Columbia | Revelstoke | British Columbia | PG/ER | 153 | 1,620 | 13,000 | 5,180,000 | H | 7,080 |
| Barrage principal | 1978 | La Grande Riviere | Radisson | Quebec | ER | 168 | 2,826 | 23,192 | 61,715,000 | H | 16,000 |
| Barrage Nord | 1981 | La Grande | Radisson | Quebec | ER | 93 | 2,156 | 13,511 | 60,020,000 | H | 9,970 |
| Sud | | Riviere | Radisson | | | 93 | 1,689 | 8,601 | | | |
| Barrage | 1981 | La Grande Riviere | Radisson | Quebec | TE/ER | 125 | 3,780 | 18,800 | 19,530 | H | 7,350 |
| Digue QA-1 | 1981 | R. aux Meandres | Radisson | Quebec | TE | 95 | 1,435 | 3,000 | — | H | — |
| Digue QA-8 | 1982 | Riviere Stephane | Radisson | Quebec | TE | 90 | 1,940 | 10,100 | — | H | — |
| *Chile* | | | | | | | | | | | |
| Paloma | 1967 | Grande | Ovalle | IV Región | TE | 96 | 1,000 | 7,350 | 740,000 | I | 6,500 |
| Digua | 1968 | Cato | Parral | VII Región | TE | 89 | 420 | 3,650 | 220,000 | I | 300 |
| Colihues A | 1981 | Cauquenes | Rancagua | VI Región | TE | 83 | 1,200 | 9,400 | 170,000 | T | 220 |
| Los Leones – 1st stage | 1981 | Los Leones | Los Andes | V Región | TE | 128 | 330 | 4,360 | 42,500 | T | 10 |
| Colbun | C (1985) | Maule | Linares | VII Región | TE | 116 | 530 | 13,870 | 1,490,000 | I–H | 7,570 |
| *China* | | | | | | | | | | | |
| Shuifeng | 1943 | Yalu Jiang | Kuandian | Liaoning | PG | 106 | 899 | 3,400 | 14,700,000 | H | 37,500 |
| Fengman | 1955 | Songhua Jiang | Jilin | Jilin | PG | 81 | 1,080 | 1,940 | 10,778 | CIH | 10,000 |
| Nangudong | 1960 | Loushui He | Linxian | Henan | ER | 78 | 164 | 1,750 | 64,500 | IC | 3,285 |
| Sanmenxia | 1960 | Huang He | Sanmenxia | Henan | PG | 106 | 713 | 1,630 | 35,400,000 | HI | 3,843 |

*(Continued)*



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**Table 11A.8 (Continued)**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Xin'Anjiang | 1960 | Xin'an Jiang | Hangzhou | Zhejiang | PG | 105 | 462 | 1,380 | 21,626 | CI | 14,000 |
| Songtao | 1970 | Nandu Jiang | Woxian | Guangdong | TE | 80 | 730 | 4,915 | 3,340,000 | HIS | 6,300 |
| Yunfeng | 1970 | Yalu Jiang | Jian | Jilin | PG | 114 | 828 | 2,740 | 3,911,000 | H | 24,200 |
| Huairen | 1972 | Hun Jiang | Huairen | Liaoning | PG | 79 | 593 | 1,196 | 3,450,000 | HI | 23,910 |
| Shanmei | 1972 | tr. Dong Jiang | Nan'an | Fujian | ER | 76 | 305 | 3,464 | 655,000 | HIS | 8,570 |
| Nanshui | 1973 | Bel Jiang | Shaoguan | Guangdong | ER | 81 | 215 | 1,711 | 1,218,000 | CH | 400 |
| Zhaikou | 1973 | Hongnong He | Lingbao | Henan | TE | 76 | 245 | 4,660 | 168,000 | H | 1,950 |
| Danjiangkou | 1974 | Han Jiang | Xiangfan | Hubei | PG | 97 | 246 | 2,928 | 20,900 | CIHM | 4,700 |
| Bikou | 1976 | Bailong Jiang | Wenxian | Gansu | ER | 101 | 297 | 4,241 | 521,000 | IH | 2,310 |
| Zhuzhuang | 1979 | Nanli He | Xingtai | Hebei | VA | 95 | | 1,040 | | I | |
| Fengtan | 1980 | Youshui | Yuanling | Hunan | PG | 111 | 488 | 1,080 | 1,550,000 | IHC | 23,300 |
| Wujiangdu | 1981 | Wu Jiang | Zun'yi | Guizhou | VA | 165 | 368 | 1,930 | 2,300,000 | H | 19,796 |
| Ankang | C | Han Jiang | Ankang | Shaanxi | PG | 120 | 542 | 2,100 | 2,580,000 | HN | 30,900 |
| Baishan | C | Songhua Jiang | Huadian | Jilin | VA | 150 | 670 | 1,630 | 6,215,000 | H | 6,300 |
| Baoquan | C | Luo He | Huixian | Henan | PG | 116 | | 2,790 | 46,000 | HIC | |
| Guxian | C | Luo He | Luoning | Henan | PG | 121 | 315 | 1,340 | 1,200,000 | HC | |
| Hunanzhen | C | Wuxi Jiang | Juzhou | Zhejiang | CB | 129 | 440 | 1,450 | 2,060,000 | HNS | 10,600 |
| Longyangxia | C | Huang He | Gonghw | Qinghai | VA | 172 | 342 | 1,750 | 24,700,000 | HIS | 10,500 |
| Lubuge | C | Huangni He | Luoping | Yunnan | ER | 97 | | 1,850 | 110,000 | IH | |
| Shibianyu | C | | Changan | Shaanxi | ER | 85 | | 2,080 | 28,000 | I | |
| Shitouhe | C | tr. Wei He | Meixian | Shaanxi | ER | 105 | 600 | 8,550 | 147,000 | IH | 7,150 |
| Wuqiangxi | C | Yuan Shui | Yuanling | Hunan | PG | 104 | | 2,670 | 10,800,000 | HI | |
| *Colombia* | | | | | | | | | | | |
| Calima I | 1965 | Calima | Buga | Valle | ER | 115 | 240 | 2,820 | 563,000 | H | 370 |
| Prado | 1971 | Prado | Ibagué | Tolima | TE | 90 | 260 | 2,000 | 1,400,000 | HI | 1,200 |
| Alto Anchicaya | 1974 | Anchicayá | Cali | Valle | ER | 140 | 240 | 2,500 | 45,000 | H | 46,000 |
| Chivor(La Esmeralda) | 1975 | Batá | Guateque | Boyacá | ER | 237 | 280 | 10,800 | 815,000 | H | 10,600 |
| Chuza (Golillas) | 1978 | Chuza | Bogotá | Cundinamarca | ER | 135 | 106 | 1,400 | 257,000 | S | 545 |
| Punchina | 1982 | Guatape | Medellin | Antioquía | TE | 77 | 750 | 5,800 | 72,000 | H | 7,500 |
| Betania | C (1984) | Magdalena | Neiva | Huila | ER/PG | 90 | 670 | 6,300 | 1,971,000 | HICS | 19,000 |
| Salvajina | C (1985) | Cauca | Popayan | Cauca | ER | 160 | 360 | 3,500 | 904,000 | H | 3,550 |
| Guavio | C (1987) | Guavio | Gachalá | Cundinamarca | ER | 243 | 390 | 17,755 | 1,020,000 | H | 3,500 |
| *Czechoslovakia* | | | | | | | | | | | |
| Orlik | 1963 | Vitava | Pribram | Bohéme C. | PG | 91 | 550 | 1,030 | 703,800 | HCS | 2,555 |
| Dalesice | 1979 | Jihlava | Trebíc | Moravie S. | ER | 100 | 330 | 1,800 | 127,300 | HSRI | 442 |
| *Dominican Republic* | | | | | | | | | | | |
| Tavera | 1974 | Yaque del Norte | Tavera | Santiago | TE | 82 | 405 | 1,850 | 170,000 | IH | 6,900 |
| Sabana Yegua | 1978 | Yaque del Sur | Los Bancos | San Juan | TE | 90 | 1,200 | 14,700 | 677,000 | IHC | 1,885 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tavera-Bao | C (1980) | Bao | Sabana Iglesia | Santiago | TE | 112 | 425 | 3,050 | 280,000 | HIS | [a] |
| *Ecuador* | | | | | | | | | | | |
| Daniel Palacios (Amaluza Res.) | C (1983) | Paute | Cuenca | Azuay | PG/VA | 167 | 420 | 1,200 | 120,000 | H | 7,700 |
| Daule-Peripa | C (1980) | Daule | Quevedo | Los Ríos | TE/ER | 90 | 250 | 3,000 | 6,000,000 | M | 3,600 |
| *Egypt* | | | | | | | | | | | |
| Aswan High Dam (Sadd-el-Aali) | 1970 | Daule | Aswan | Egypt | TE/ER | 111 | 3,830 | 44,300 | 168,900,000 | GR | 11,000 |
| *El salvador* | | | | | | | | | | | |
| Cerron Granda (Silencio) | 1973 | Lempa | Hutyapa | | ER | 80 | 900 | 5,100 | 1,430,000 | H | 11,000 |
| *Fiji* | | | | | | | | | | | |
| Monasavu | 1982 | Nanuku Ck | Suva | Fiji | ER | 85 | 485 | 1,738 | 133,000 | H | 625 |
| *Germany (F.R.)* | | | | | | | | | | | |
| Rur | 1959 | Rur | Heimbach | Nordrhein | TE | 77 | 480 | 2,600 | 181,800 | CNH | 450 |
| Frauenau | C (1983) | Kleiner Regen | Zwiesel | Bayern | ER | 86 | 640 | 2,263 | 20,300 | SNCH | 58 |
| *France* | | | | | | | | | | | |
| Serre-Poncon | 1960 | Durance | Gap | Htes Alpes | TE | 129 | 600 | 14,100 | 1,270,000 | HI | 3,430 |
| Mont-Cenis | 1968 | Cenise | Modane | Savoie | TE/ER | 120 | 1,400 | 14,850 | 332,200 | H | 265 |
| Grand'Maison | C (1985) | Eau d'Olle | Grenoble | Isère | TE/ER | 160 | 550 | 12,500 | 140,000 | H | 65 |
| Pla De Soulcem | C (1983) | Mounicou | Tarascon | Ariège | TE | 76 | 275 | 1,675 | 29,300 | H | 134 |
| *Ghana* | | | | | | | | | | | |
| Akosombo (Main) | 1965 | Volta | Accra/Tema | Ghana | ER | 134 | 671 | 7,991 | 147,960,000 | H | 14,160 |
| *Great Britain* | | | | | | | | | | | |
| Scammonden | 1970 | Black Brook | Huddersfield | Best Yorkshire | TE/ER | 76 | 624 | 4,304 | 7,873 | S | |
| Llyn Brianne | 1972 | Towy | Llandovery | Dyfed | ER | 91 | 274 | 2,085 | 60,000 | S | 850 |
| *Greece* | | | | | | | | | | | |
| Kremasta | 1965 | Achelöos | Agrinion | Etolo-Akarnanie | TE | 165 | 460 | 8,170 | 4,750,000 | H | 3,000 |
| Polyphyton | 1974 | Aliakmon | Kozani | Makedhonia | ER | 112 | 298 | 3,459 | 2,244,000 | HI | 1,375 |
| Mornos | 1979 | Mornos | Lidhoriki | Phocide | TE | 126 | 815 | 17,000 | 780,000 | S | 1,135 |
| Pournari | 1980 | Arachthos | Arta | Ipiro | TE | 102 | 574 | 9,500 | 730,000 | H | 6,100 |
| Sfikia | C (1984) | Aliakmon | Veria | Makedhonia | ER | 80 | 230 | 1,620 | 99,000 | H | 1,600 |
| Peghai (Main Dam) | C (1987) | Aöos | Metsovon | Ipiro | TE | 78 | 295 | 2,800 | 262,000 | H | 160 |
| *Guatemala* | | | | | | | | | | | |
| Pueblo Viejo | C (1983) | Chixoy | San Cristobel | Alta Verapaz | ER | 130 | 230 | 3,200 | 460,000 | H | 3,850 |
| *Hong Kong* | | | | | | | | | | | |
| High Island East | 1977 | Kwun Mun | Sai Kung | New Territories | ER | 85 | 457 | 3443 | 284,375 | S | 435 |
| High Island West | 1977 | Kwun Mun | Sai Kung | New Territories | ER | 76 | 762 | 6120 | | | |
| *India* | | | | | | | | | | | |
| Koyna (Shivaji Sagar) | 1961 | Koyna | Karad | Maharashtra | PG | 103 | 808 | 1,555 | 2,796,500 | H | 3,823 |
| Rihand (Gobind Ballabh Pant Sagar) | 1962 | Rihan | Mirzapur | Uttar Pradesh | PG | 93 | 934 | 1,680 | 10,600,000 | H | 13,339 |
| Bhakra Dam (Gobind Sagar) | 1963 | Satluj | Nangal Township | Himachal Pradesh | PG | 226 | 518 | 4,130 | 9,621,000 | IH | 8,372 |

*(Continued)*



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**Table 11A.8 (Continued)**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sholayar | 1972 | Sholayar | Colmbatore | Tamil Nadu | TE,PG | 105 | 1,282 | 2,496 | 160,660 | IH | 1,474 |
| Ukai Dam | 1972 | Tapi | Fort Songadh | Gujarat | TE,PG | 81 | 5,065 | 25,180 | 8,511,000 | IHC | 35,960 |
| Nagarjunasagar Dam | 1974 | Krishna | Hyderabad | Andhra Pradesh | TE,PG | 125 | 4,865 | 7,960 | 11,550,000 | IH | 53,450 |
| Pong Dam (Beas Project) | 1974 | Beas | Mukerian | Himachal Pradesh | TE | 133 | 1,950 | 35,500 | 8,570,000 | IH | 12,374 |
| Cheruthoni | 1976 | Cheruthoni | Idukki | Kerala | PG | 138 | 650 | 1,700 | 1,996,000 | H | 5,012 |
| Balimela Dam | 1977 | Sileru | Jeypur | Orissa | TE | 75 | 4,363 | 19,096 | 3,610,000 | IH | 10,930 |
| Ramganga | 1978 | Ramganga | Dhampur | Uttar Pradesh | TE | 128 | 743 | 11,013 | 2,442,600 | IH | 8,467 |
| Bhatsa | C | Bhatsa | Bombay | Maharashtra | PG | 89 | 938 | 1,679 | 915,000 | SIH | 3,775 |
| Chakra | C | Chakra | Shimoga | Karnataka | TE,ER | 84 | 568 | 1,715 | 219,000 | H | 1,416 |
| Dudhganga | C | Dudhganga | Kolhapur | Maharashtra | TE,PG | 89 | 1,264 | 1,449 | 708,260 | I | 2,247 |
| Hasdeo Project | C | Hasdeo | Bilaspur | Madhya Pradesh | TE,PG | 86 | 2,688 | 3,219 | 3,417,000 | IH | 20,530 |
| Karjan (Lower) | C | Karjan | Rajpipla | Gujarat | PG | 100 | 903 | 1,937 | 630,000 | I | 17,275 |
| Lakhwar | C | Yamuna | Dehradun | Uttar Pradesh | PG | 192 | 440 | 2,000 | 580,000 | IH | 8,000 |
| Sardar Sarovar | C | Narmada | Rajpipla | Gujarat | PG | 155 | 1,210 | 4,100 | 9,500,000 | IHC | 62,269 |
| Srisailam H.E. Project | C | Krishna | Hyderabad | Andhra Pradesh | PG | 143 | 512 | 1,953 | 8,722,000 | H | 37,400 |
| Supa (Kalinadi Project) | C | Kali | Dandeli | Karnataka | PG | 101 | 322 | 1,150 | 4,418,000 | H | 2,830 |
| Tehri Dam | C | Bhagirathi | Tehri | Uttar Pradesh | TE,ER | 261 | 570 | 22,750 | 3,539,000 | IH | 13,150 |
| Thein Dam Ranjit Sagar (Res.) | C | Ravi | Pathankot | Punjab | ER,TE | 160 | 565 | 16,187 | 3,280,000 | IHC | 21,890 |
| Warna | C | Warna | Kolhapur | Maharashtra | TE,PG | 91 | 1,580 | 15,310 | 964,000 | I | 3,222 |
| *Indonesia* | | | | | | | | | | | |
| IR.H.Juanda (Jatiluhur) | 1967 | Citarum | Purwakarta | W–Java | ER | 100 | 1,225 | 9,000 | 3,345,000 | IHCSR | 3,000 |
| Karangkates | 1972 | Brantas | Malang | E–Java | ER | 100 | 823 | 6,156 | 342,000 | IHCR | 1,310 |
| Saguling | C | Citarum | Cianjur | W–Java | ER | 98 | 300 | 2,570 | 609,000 | HCR | 2,400 |
| *Iran* | | | | | | | | | | | |
| Karoon | 1975 | Karun | Masjed Soliman | Iran | VA | 200 | 380 | 1,570 | 3,005,000 | IH | 16,200 |
| Ghesh-Lagh | 1978 | Ghesh-Lagh | Sanandaj | Iran | TE | 80 | 300 | 2,000 | 224,000 | S | 2,600 |
| Lar | 1982 | Lar | Tehran | Iran | TE | 105 | 1,500 | 1,300 | 960, 000 | IH | 1,700 |
| *Iraq* | | | | | | | | | | | |
| Derbendikhan | 1951 | Diyala | Sulaymaniya | Sulaymaniya | ER | 128 | 535 | 7,480 | 3,000,000 | ICH | 11,400 |
| Mosul | 1983 | Tigris | Mosul | Nienava | ER | 131 | 3,500 | 23,000 | 12,500,000 | ICH | 17,000 |
| *Italy* | | | | | | | | | | | |
| Alpe Gera | 1964 | Cormor | Sondrio | Adige Lombardia | PG | 174 | 628 | 1,700 | 68,088 | H | 59 |
| Place Moulin | 1965 | Buthier | Aosta | Valle d'Aosta | VA | 155 | 678 | 1,510 | 105,000 | H | 473 |
| *Japan* | | | | | | | | | | | |
| Sakuma | 1956 | Tenryu | Toyohashi | Aichi | PG | 156 | 294 | 1,120 | 327,000 | H | 7,700 |
| Ogochi | 1957 | Tama | Ome | Tokyo | PG | 149 | 353 | 1,680 | 189,000 | SH | 1,800 |
| Miboro | 1960 | Sho | Gifu | Gifu | ER | 131 | 405 | 7,950 | 370,000 | H | 1,800 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Tagokura | 1960 | Tadami | Aizuwa-kamatsu | Fukushima | PG | 145 | 462 | 1,990 | 494,000 | H | 2,200 |
| Arimine | 1961 | Joganji | Toyama | Toyama | PG | 140 | 500 | 1,570 | 218,000 | H | 380 |
| Makio | 1961 | Kiso | Matsumoto | Nagano | ER | 105 | 260 | 2,616 | 75,000 | IHS | 3,200 |
| Okutadami | 1961 | Tadami | Koide | Fukushima | PG | 157 | 480 | 1,640 | 601,000 | H | 1,500 |
| Kurobe | 1964 | Kurobe | Omachi | Toyama | VA | 186 | 489 | 1,360 | 199,000 | H | 1,500 |
| Oshirakawa | 1964 | Oshirakawa | Gifu | Gifu | ER | 95 | 390 | 1,700 | 14,200 | H | 330 |
| Tsuruta | 1965 | Sendai | Kagoshima | Kagoshima | PG | 118 | 448 | 1,124 | 123,000 | Ch | 4,965 |
| Yanase | 1965 | Nabari | Aki | Kochi | ER | 115 | 202 | 2,842 | 105,000 | H | 1,900 |
| Kuzuryu | 1968 | Kuzuryu | Ono | Fukui | ER | 128 | 355 | 6,300 | 320,000 | HC | 1,560 |
| Shimokubo | 1968 | Kanna, tr. Tone | Fujioka | Saitama | PG | 129 | 626 | 1,190 | 130,000 | HIS | 1,600 |
| Kisenyama | 1969 | Samutani, tr. Yodo | Uji | Kyoto | ER | 91 | 255 | 2,338 | 7,230 | H | 6 |
| Koshibu | 1969 | Koshibu, tr. Tenryu | Iida | Nagano | VA | 105 | 293 | 311 | 58,000 | IHC | 2,160 |
| Misakubo | 1969 | Misakubo, tr. Tenryu | Tenryu | Shizuoka | ER | 105 | 268 | 2,410 | 30,000 | H | 900 |
| Shimokotori | 1973 | Kotori, tr. Jintsu | Takayama | Gifu | ER | 119 | 321 | 3,530 | 123 037 | H | 1,920 |
| Aburatani | 1974 | Aburatani, tr. Kuma | Yatsushiro | Kumamoto | er | 82 | 189 | 1,277 | 5,420 | h | 430 |
| Fukuchi | 1974 | Fukuchi | Nago | Okinawa | ER | 92 | 260 | 1,622 | 51,500 | ICS | 800 |
| Kajigawa | 1974 | Kaji | Shibata | Niigata | PG | 107 | 286 | 433 | 22,500 | C | 1,920 |
| Kurokawa | 1974 | Ichi | Himeji | Hyogo | ER | 98 | 325 | 3,623 | 33,390 | H | 175 |
| Matsukawa | 1974 | Matsu, tr Tenryu | Iida | Nagano | PG | 84 | 165 | 263 | 7,400 | CIS | 900 |
| Miyama | 1974 | Naka | Kuroiso | Tochigi | ER | 76 | 334 | 1,967 | 25,800 | IHS | 840 |
| Niikappu | 1974 | Niikappu | Tomakomai | Hokkaido | ER | 103 | 326 | 3,071 | 145,000 | H | 1,500 |
| Sameura | 1974 | Yoshino | Nankoku | Kochi | PG | 106 | 400 | 1,200 | 316,000 | IHCS | 6,000 |
| Taisetsu | 1974 | Ishikari | Asahikawa | Hokkaido | ER | 87 | 440 | 3,874 | 66,000 | CHIS | 1,000 |
| Hirose | 1975 | Fufuki, tr. Fuji | Enzan | Yamanashi | ER | 75 | 255 | 1,400 | 14,300 | IHCS | 1,380 |
| Nabara | 1975 | Nabara, tr. Ota | Hiroshima | Hiroshima | ER | 86 | 305 | 2,213 | 5,658 | H | 475 |
| Iwaya | 1976 | Mase, tr. Kiso | Minokamo | Gifu | ER | 128 | 366 | 5,780 | 173,500 | IHCS | 2,950 |
| Kusaki | 1976 | Watarase, tr. Tone | Kiryu | Gunma | PG | 140 | 405 | 1,374 | 60,500 | IHCS | 4,320 |
| Myojin | 1976 | Nabara, tr. Ota | Hiroshima | Hiroshima | ER | 89 | 402 | 3,268 | 6,145 | H | 80 |
| Terauchi | 1977 | Sada, tr. Chikugo | Amagi | Fukuoka | ER | 83 | 420 | 3,012 | 18,000 | ICS | 1,300 |
| Futai | 1978 | Kiyotsu | Nagaoka | Niigata | ER | 87 | 280 | 2,350 | 18,300 | H | 1,950 |
| Kassa | 1978 | Kassa | Nagaoka | Niigata | ER | 90 | 487 | 4,450 | 13,500 | H | 114 |
| Miho | 1978 | Sakawa | Minamia-shigara | Kanagawa | ER | 95 | 588 | 5,816 | 64,900 | CHS | 3,100 |
| Nanakura | 1978 | Takase | Omachi | Nagano | ER | 125 | 340 | 7,380 | 32,500 | H | 1,950 |

*(Continued)*



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**Table 11A.8 (Continued)**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Takase | 1978 | Takase | Omachi | Nagano | ER | 176 | 362 | 11,600 | 76,200 | H | 1,700 |
| Seto | 1978 | Setodani | Gojo | Nara | ER | 111 | 343 | 3,740 | 16 850 | H | 230 |
| Tedorigawa | 1979 | Tedori | Kanazawa | Ishikawa | ER | 154 | 420 | 10,050 | 231,000 | HCSI | 3,500 |
| Terauchi | 1980 | Sada | Amagi | Fukuoka | ER | 83 | 420 | 3,000 | 18,000 | CIS | 1,300 |
| Urushizawa | 1980 | Naruse | Furusawa | Miyagi | ER | 80 | 310 | 2,143 | 18,000 | HCS | 1,500 |
| Inamura | 1981 | Seto | Kochi | Kochi | ER | 88 | 325 | 3,100 | 5,800 | H | 230 |
| Tamahara | 1982 | Hotchi | Numata | Gunma | ER | 116 | 570 | 5,435 | 14,800 | H | 160 |
| Agigawa | C (1986) | Kiso | Ena | Gifu | ER | 102 | 430 | 4,400 | 48,000 | CS | 2,000 |
| Arakawa | C (1985) | Ara | Kofu | Yamanashi | ER | 88 | 320 | 3,000 | 10,800 | CS | 1,680 |
| Arima | C (1985) | Iruma | Hanno | Saitama | ER | 84 | 260 | 1,600 | 7,600 | CS | 670 |
| Doyo | C (1984) | Doyo | Yonago | Tottori | ER | 87 | 480 | 2,700 | 7,680 | H | 80 |
| Igarashigawa | C (1990) | Igarashi | Sanjo | Niigata | ER | 76 | 360 | 2,278 | 21,100 | CS | 1,420 |
| Jozankei | C (1986) | Ishikari | Sapporo | Hokkaido | PG | 113 | 405 | 1,150 | 82,300 | CS | 675 |
| Kuriyama | C (1985) | Nebesawa | Imaichi | Tochigi | ER | 89 | 340 | 2,200 | 6,890 | H | 52 |
| Kyuragi | C (1985) | Matsuura | Taku | Saga | PG | 117 | 386 | 1,045 | 7,400 | CSH | 1,080 |
| Naramata | C (1986) | Naramata | Numata | Gunma | ER | 158 | 520 | 12,300 | 90,000 | CIS | 1,650 |
| Nitchu | C (1986) | Oshikiri | Kitakata | Fukushima | ER | 106 | 468 | 5,010 | 24,600 | ICS | 1,120 |
| Ogaki | C (1985) | Ukedo | Haramachi | Fukushima | ER | 85 | 262 | 1,729 | 19,500 | I | 1,680 |
| Okawa | C (1984) | Agano | Aizuwa-kamatsu | Fukushima | PG | 78 | 407 | 1,000 | 57,500 | CSIH | 5,230 |
| Ouchi | C (1985) | Ono | Aizuwa-kamatsu | Fukushima | ER | 102 | 340 | 4,400 | 18,500 | H | 176 |
| Sagae | C (1985) | Mogami | Sagae | Yamagata | ER | 115 | 510 | 9,490 | 109,000 | CSIH | 2,600 |
| Sagurigawa | C (1988) | Saguri | Ojiya | Niigata | ER | 116 | 420 | 7,214 | 27,500 | CS | 1,690 |
| Takami | C (1984) | Shizunai | Tomakomai | Hokkaido | ER | 120 | 427 | 5,120 | 229,000 | CH | 2,400 |
| Tamagawa | C (1987) | Omono | Omagari | Akita | PG | 100 | 432 | 1,105 | 254,000 | CISH | 3,500 |
| Shichigashuku | C (1988) | Abukuma | Shiroishi | Miyagi | ER | 93 | 565 | 5,050 | 109,000 | CSI | 2,620 |
| Shintsuruko | C (1985) | Nyu | Obanazawa | Yamagata | ER | 93 | 303 | 2,645 | 31,500 | I | 1,100 |
| Shitoki | C (1984) | Shitoki | Iwaki | Fukushima | ER | 84 | 300 | 2,580 | 12,100 | CSI | 1,540 |
| Tokachi | C (1984) | Tokachi | Obihiro | Hokkaido | ER | 84 | 443 | 3,658 | 112,000 | CH | 2,600 |
| Yasaka | C (1987) | Oze | Iwakuni | Yamaguchi | PG | 120 | 540 | 1,600 | 48,000 | CS | 4,050 |
| *Jordan* | | | | | | | | | | | |
| King Talal Dam | 1977 | Zarqa River | Jarash | Salt District | TE/ER | 94 | 330 | 4,216 | 52,000 | IC | 2,950 |
| Wadi Arab Dam | C (1985) | Wadi Arab | North Shuneii | Irbid District | ER | 82 | 482 | 2,968 | 20,000 | IS | 430 |
| *Libya* | | | | | | | | | | | |
| Ghan | 1982 | Ghan | Ghrian | NE/Ghrian | ER | 80 | 316 | 1,650 | 39,500 | IC | 1,640 |
| *Malaysia* | | | | | | | | | | | |
| Temengor | 1978 | S. Perak | Grik | Perak | ER | 115 | 128 | 6,980 | 570,000 | HC | 2,720 |
| Kenyir | C (1984) | S. Trengganu | Kuala Brang | Trengganu | ER | 150 | 800 | 16,500 | 13,600,000 | HC | 7,000 |
| Batang Ai | C (1985) | Batang Ai | Lubok Antu | Sarawak | ER | 85 | 810 | 4,000 | 2,360,000 | H | 2,175 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mexico* | | | | | | | | | | | |
| Lazaro Cardenas (El Palmito) | 1947 | Nazas | C. Lerdo | Durango | TE | 95 | 330 | 5,300 | 3,152,000 | IC | 6,000 |
| Sanalona | 1948 | Tamazula | Culiacán | Sinaloa | TE | 81 | 1,031 | 4,900 | 845,000 | IH | 6,300 |
| Alvaro Obregon (Oviachic) | 1952 | Yaqui | Obregón | Sonora | TE | 90 | 1,457 | 8,773 | 3,237,000 | IHC | 11,100 |
| Adolfo Ruiz Cortines (Mocúzari) | 1955 | Río Mayo | Navojoa | Sonora | TE | 81 | 780 | 4,196 | 1,014,700 | IHC | 8,000 |
| Presidente Aleman (Temascal) | 1955 | Río Tonto | C.Alemán | Oaxaca | TE | 76 | 830 | 4,059 | 6,515,000 | ICH | 5,500 |
| Migual Hidalgo (El Mahone) | 1956 | Río Fuerte | El Fuerte | Sinaloa | TE | 86 | 3,230 | 10,200 | 3,290,000 | IGH | 16,450 |
| Presidente Benito Juarez (El Marques) | 1961 | Tehuantepec | Tehuantepec | Oaxaca | TE | 86 | 375 | 3,540 | 942,000 | IC | 5,500 |
| El Infiernillo | 1963 | Balsas | Apatzingan | Michoacán | TE | 148 | 350 | 5,500 | 9,340,000 | H | 10,350 |
| Netzahualcoyoti | 1964 | Grijalva | Cárdenas | Chiapas | TE | 138 | 478 | 5,077 | 8,300,000 | HC | 21,750 |
| Pte.Adolfo Lopez Mateos (Humaya) | 1964 | Humaya | Culiacán | Sinaloa | TE | 107 | 820 | 7,141 | 3,150,000 | IC | 5,600 |
| Internacional La Amistad | 1968 | Bravo | Acuña | Coahuila | PG/TE | 87 | 9, 760 | 11,620 | 4,379,000 | IHCS | 43,690 |
| La Angostura | 1974 | Grijalva | Tuxtla Gutierrez | Chiapas | TE | 146 | 323 | 4,030 | 9,200,000 | H | 6,900 |
| Manuel Moreno Torres (Chicoasén) | 1980 | Grijalva | Tuxtla Gutiérrez | Chiapas | TE | 261 | 485 | 15,370 | 1,613,000 | H | 15,000 |
| Jose Lopez Portillo Pte. (Comedero) | 1981 | San Lorenzo | Cosalá | Sinaloa | TE | 136 | 400 | 7,090 | 2,850,000 | IHC | 5,000 |
| Gustavo Diaz Ordaz Pdte. (Bacurato) | 1982 | Sinaloa | Guamuchil | Sinaloa | TE | 114 | 800 | 9,315 | 1,800,000 | IHC | 7,000 |
| El Sabinal | C (1985) | Ocoroni | Guasave | Sinaloa | TE | 79 | 400 | 2,367 | 300,000 | IC | 2,450 |
| Carlos Ramirez Ulloa (Caracol) | C (1985) | Balsas | Iguala | Guerrero | TE | 126 | 347 | 6,327 | 782,000 | H | 17,000 |
| Chilatan | C (1986) | Tepalcatepec | Apatzingan | Jalisco | TE | 104 | 1,150 | 5,898 | 600,000 | IC | 7,000 |
| *Morocco* | | | | | | | | | | | |
| Moulay Youssef | 1970 | Tessaout | Marrakech | Marrakech | TE | 100 | 725 | 5,300 | 200,000 | IH | 3,000 |
| Hassan Addakhil | 1971 | Ziz | Er Rachidia | Er Rachidia | TE | 85 | 785 | 5,800 | 380,000 | I | 1,700 |
| Youssf Ben Tachfine | 1973 | Masa | Tiznit | Tiznit | ER | 85 | 670 | 3,700 | 310,000 | IS | 3,400 |
| Sidi Mohamed Ben Abdellah | 1974 | Bou Regreg | Rabat | Rabat | ER | 100 | 340 | 3,000 | 493,000 | SI | 5,000 |
| Ait Chouarit | C (1986) | Lakhdar | Demnate | Azilal | TE | 145 | 380 | 9,500 | 270,000 | IHS | 1,820 |
| *Nepal* | | | | | | | | | | | |
| Kulekhani Dam | 1981 | Kulekhani | Kathmandu | Nepal | ER | 114 | 406 | 4,419 | 85,300 | H | 2,540 |
| *New Zealand* | | | | | | | | | | | |
| Benmore | 1965 | Waitaki | Oamaru | Otago | TE | 118 | 957 | 12,500 | 2,200,000 | H | 3,400 |
| Matahina | 1965 | Rangataiki | Whakatane | South Auckland | TE | 86 | 345 | 3,500 | 25,000 | H | 1,900 |
| Mangatangi | 1977 | Mangatangi | Manukau | South Auckland | TE | 78 | 340 | 2,240 | 39,000 | S | 510 |

*(Continued)*



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**Table 11A.8 (Continued)**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Patea | C | Patea | Wanganui | Taranaki | TE | 82 | 190 | 1,100 | 138,000 | H | 2,800 |
| *Nigeria* | | | | | | | | | | | |
| Shiroro | C (1984) | Kaduna/ Dinya | Minna | Niger | ER | 125 | 700 | 3,457 | 7,000 000 | H | 7,500 |
| *Norway* | | | | | | | | | | | |
| Hyttejuvet | 1965 | Walldaiselv | Haugesund | Hordaland | ER | 90 | 350 | 1,450 | | H | 375 |
| Digea | 1970 | Sira-Digea | Flekkefjord | Vest-Agder | ER | 90 | 400 | 2,700 | | H | 45 |
| Svartevatn | 1977 | Sira | Stavanger | Vest-Agder | ER | 129 | 420 | 4,715 | | H | |
| Sysenvatn | 1979 | Leiro | Bergen | | ER | 84 | 1,140 | 3,624 | | H | 250 |
| Oddatjorn Blasjo | C (1987) | Oddeana | Haugesund | Rogaland | ER | 140 | 500 | 5,400 | see Storvatn | H | |
| Storvatn Reservoir | C (1987) | Brattliana | Haugesund | Rogaland | ER | 98 | 1,460 | 9,700 | 3,105,000 | H | 600 |
| *Pakistan* | | | | | | | | | | | |
| Mangla | 1967 | Jehlum | Dehlum | Punjab | TE | 138 | 3,139 | 65,379 | 7,251,811 | HI | 31,144 |
| Tarbela | 1976 | Indus | Taxila | NWFP | TE/ER | 143 | 2,743 | 105,570 | 13,689,644 | IH | 42,186 |
| Auxiliary-1 Jari | 1967 | Saddle Dam | Mirpur | A. Kashmir | TE | 84 | 2,073 | 26,240 | | I | — |
| *Paraguay* | | | | | | | | | | | |
| Itaipu | 1982 | Paraná | Hernandarias | Brazil/Paraguay | ER/PG/TE | 190 | 7,655 | 33,690 | 29,000,000 | H | 62,000 |
| *Peru* | | | | | | | | | | | |
| Yauliyacu Arriba | 1982 | Yauliyacu | Casapalca | Lima | TE | 75 | 220 | 3,000 | 7,500 | M | |
| Condorma | C (1985) | Colca | Chivay | Arequipa | ER | 92 | 503 | 4,300 | 260,000 | I | 1,300 |
| Gallito Ciego | C (1987) | Jequete-peque | Pacasmayo | Cajamarca | ER | 112 | 750 | 14,200 | 400,000 | IH | 1,830 |
| Chinchan | C (2007) | Yuracocha | Casapalca | Lima | TE | 90 | 230 | 5,800 | 13,500 | M | |
| *Philippines* | | | | | | | | | | | |
| Ambuklao | 1956 | Agno | Baguio | Benguet | ER | 129 | 452 | 6,000 | 327,170 | H | 7,300 |
| Binga | 1960 | Agno | Baguio | Benguet | ER | 107 | 215 | 2,000 | 63,000 | H | 5,200 |
| Angat | 1967 | Angat | Manila | Bulacan | ER | 131 | 368 | 7,000 | 1,099,000 | IH | 7,500 |
| Pantabangan | 1977 | Upper Pampanga | Cabanatuan | Neva Ecija | TE | 107 | 1,615 | 12,300 | 2,996,000 | IHC | 4,200 |
| Magat | 1982 | Magat | Santiago | Isabela | TE/ER | 106 | 2,925 | 13,200 | 1,250,000 | IH | 30,400 |
| San Roque | C | Agno | Dagupan | Pangesinan | ER | 210 | 1,130 | 43,150 | 990,000 | IHC | 12,600 |
| *Portugal* | | | | | | | | | | | |
| Paradela | 1958 | Cávado | Chaves | Vila Real | ER | 110 | 540 | 2,700 | 164,500 | H | 720 |
| Alto Rabagão | 1964 | Rabagão | Chaves | Vila Real | VA/PG | 94 | 1,897 | 1,117 | 569,000 | H | 500 |
| Santa Clara | 1968 | Mira | Odemira | Beja | TE | 86 | 428 | 3,966 | 485,000 | I | 208 |
| *Romania* | | | | | | | | | | | |
| Izvorul Muntelui (Bicaz) | 1961 | Bistrita | P.Nearnt | Nearnt | PG | 127 | 430 | 1,625 | 1,230,000 | H | 2,400 |
| Fintinele Somes | 1978 | Somesul Cald | Huedin | Cluj | ER | 92 | 400 | 2,320 | 225,000 | HR | 700 |
| Cerna Principal | 1979 | Cerna | Tg.Jiu | Gorj | ER | 110 | 342 | 2,550 | 124,000 | SHI | 1,080 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Oasa | 1979 | Sebes | Sebes | Alba | ER | 91 | 300 | 1,600 | 136,000 | HCR | 264 |
| Colibita | C (1983) | Bistrita | Bistrita | Bistrita Násâud | ER | 92 | 250 | 1,600 | 90,000 | SH | 650 |
| Gura Apelor | C (1984) | Rîul Mare | Hateg | Hunedoara | ER | 168 | 450 | 9,020 | 225,000 | H | 1,750 |
| Pecineagu | C (1984) | Dîmbovita | Tirgoviste | Dimbovita | TE | 105 | 270 | 2,400 | 68,900 | SHI | 600 |
| Mineciu | C (1985) | Teleajen | Vâlenii de Munte | Prahova | TE | 75 | 720 | 5,000 | 60,000 | SCHI | 1,200 |
| Riusor | C (1985) | R. Tirgului | Cimpulung | Arges | ER | 120 | 380 | 3,500 | 60,000 | SH | 620 |
| Siriu | C (1985) | Buzàu | Nehoiu | Buzâu | ER | 122 | 440 | 8,800 | 155,000 | CISH | 3,400 |
| Vija | C (1986) | Bistrita | Tg.Jiu | Gorj | ER | 93 | 270 | 1,700 | 29,400 | HS | 800 |
| Poiana Marului | C (1987) | Bistra Mârului | Otelul Rosu | Caras Severin | ER | 130 | 400 | 5,320 | 96,000 | HI | 830 |
| *South Africa* | | | | | | | | | | | |
| P K Le Roux | 1977 | Orange | Petrusville | Orange Free State | VA | 107 | 853 | 1,300 | 3,237,000 | IH | 20,400 |
| Sterkfontein | 1980 | Nue Jaar Spruit | Harrismith | Orange Free State | TE | 93 | 3,060 | 19,800 | 2,656,000 | S | — |
| Goedertrouw | 1982 | Mhlatuze | Eshowe | Natal | TE | 88 | 660 | 5,330 | 321,000 | IS | 7,000 |
| *South Korea* | | | | | | | | | | | |
| So Yang Gang | 1973 | Han | Chunchon | Kangwondo | ER | 123 | 530 | 9,591 | 2,900,000 | IHCR | 5,500 |
| Sam Rang Jin Upper part Dam | C | Nakdong | Samrangjin | Kyeongsang-namdo | ER | 85 | 250 | 1,003 | 6,140 | H | |
| An Dong | 1976 | Nakdong | Andong | Keongsang-namdo | ER | 83 | 624 | 4,015 | 1,248,000 | IHCS | 5,360 |
| *Spain* | | | | | | | | | | | |
| Mequinenza | 1966 | Ebro | Mequinenza | Zaragoza | PG | 81 | 451 | 1,000 | 1,533,800 | H | 12,800 |
| Porto De Mouros | 1967 | Ulla | Arzua | La Coruña | ER | 93 | 460 | 2,337 | 297,000 | H | 1,550 |
| Grado I | 1969 | Cinca | El Grado | Huesca | PG | 130 | 958 | 1,225 | 399,000 | IH | 3,420 |
| Iznajar | 1969 | Genil | Rute | Cordoba | PG | 122 | 407 | 1,450 | 980,000 | HIS | 6,550 |
| Almandra | 1970 | Tormes | Almendra | Salamanca | VA | 202 | 557 | 2,186 | 2,649,000 | H | 3,000 |
| El Atazar | 1972 | Lozoya | Atazar | Madrid | VA | 134 | 484 | 1,200 | 426,000 | S | 410 |
| Arenos | 1979 | Mijares | Montanejos | Castellon | ER | 108 | 428 | 3,014 | 132,000 | I | 1,300 |
| Beninar | 1983 | Grande De Adra | Beninar | Almeria | ER | 87 | 386 | 3,800 | 70,000 | IS | 232 |
| Limonero | 1983 | Guadal-medina | Malaga | Malaga | ER | 93 | 410 | 3,188 | 27,000 | S | 283 |
| Canales | C (1983) | Benil | Guejar Sierra | Granada | ER | 159 | 340 | 1,217 | 71,000 | IS | 226 |
| Cuevas De Almanzora | C (1983) | Almanzora | Cuevas De Almanzora | Almeria | ER | 113 | 623 | 6,510 | 191,000 | IH | 2,520 |
| Negratin | C (1983) | Guadiana Menor | Freila | Granada | PG/ER | 75 | 439 | 1,150 | 546,000 | IH | 3,440 |
| Sallente | C (1983) | Flamisell | Torre De Capdella | Lerida | ER | 89 | 398 | 1,100 | 6,000 | H | 63 |
| La Viñuela | C (1983) | Guaro | La Viñuela | Malaga | ER/TE | 94 | 460 | 3,345 | 25,000 | IS | 120 |
| Zahara | C (1983) | Guadalete | Zahara | Cadiz | ER | 85 | 500 | 2,011 | 212,000 | I | 1,000 |
| *Sri Lanka* | | | | | | | | | | | |
| Kotmale | C (1985) | Kotmale Oya | Gampola | CP | ER | 87 | 600 | 4,159 | 175,000 | H | 5,550 |
| Randenigala | C (1986) | Mahaweli | Mahiyangana | UP | ER | 94 | 495 | 3,700 | 860,000 | HIC | 8,085 |

*(Continued)*



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**Table 11A.8 (Continued)**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sweden* | | | | | | | | | | | |
| Trangsist | 1961 | Dalälven | Mora | Kopparberg,M | ER | 125 | 850 | 7,200 | 880,000 | H | 1,000 |
| Holjes | 1961 | Klarälven | Hagfors | Värmland,M | ER/TE | 80 | 400 | 1,750 | 270,000 | H | 1,280 |
| Messaure | 1963 | Lule älv | Jokkmokk | Norrbotten,N | TE | 101 | 1,900 | 10,500 | 50,000 | H | 2,300 |
| Letsi | 1967 | Lule älv | Jokkmokk | Norrbotten,N | ER | 85 | 570 | 2,300 | 67,000 | H | 1,500 |
| Seitevare | 1968 | Lule älv | Porius | Norrbotten,N | ER | 106 | 1,450 | 4,900 | 1,650,000 | H | 875 |
| *Switzerland* | | | | | | | | | | | |
| Marmorera (Castilleto) | 1954 | Julia | Bivio | Grisons | TE | 91 | 400 | 2,700 | 62,600 | H | 200 |
| Mauvolsin | 1957 | Drance de Bagnes | Fionnay | Valais | VA | 237 | 520 | 2,030 | 181,500 | H | 100 |
| Goeschenealp | 1950 | Göschen-erreuss | Göschenen | Uri | ER | 155 | 540 | 9,300 | 76,000 | H | 200 |
| Grande Dixence | 1961 | Dixence | Hérémence | Valais | PG | 285 | 695 | 6,000 | 401,000 | H | — |
| Luzzone | 1963 | Brenno di Luzzona | Olivone | Tessin | VA | 208 | 530 | 1,330 | 88,000 | H | 88 |
| Mattmark | 1967 | Seaser Vispa | Saas-Fee | Valais | TE | 120 | 780 | 10,500 | 101,000 | H | 150 |
| Emosson | 1974 | Barberine | Finhaut | Valais | VA | 180 | 555 | 1,090 | 227,000 | H | 60 |
| *Taiwan* | | | | | | | | | | | |
| Shihmen | 1964 | Tahan | Chungli | Taiwan | ER | 133 | 360 | 7,059 | 309,120 | IHCS | 13,400 |
| Tsengwen | 1973 | Tsengwen | Tainan | Taiwan | TE | 133 | 400 | 9,296 | 707,530 | ICSH | 9,470 |
| *Thailand* | | | | | | | | | | | |
| Sirikit | 1972 | Nan | Uttaradit | N | TE | 114 | 800 | 9,800 | 10,550,000 | IHC | 3,250 |
| Bang Lang | 1981 | Pattani | Yala | S | TE/ER | 85 | 422 | 2,900 | 1,360,000 | IHC | 4,500 |
| Srinagarind | 1981 | Quae Yai | Kanchanaburi | Central Region | ER | 140 | 610 | 12,100 | 17,745,000 | IHC | 2,420 |
| Khao Laem | C(1984) | Quae Noi | Kanchanaburi | Central Region | ER | 90 | 910 | 8,000 | 7,450,000 | IHC | 3,200 |
| *Turkey* | | | | | | | | | | | |
| Seyhan | 1956 | Seyhan | Adana | South A | TE | 77 | 1,955 | 7,500 | 1,200,000 | ICB | 2,500 |
| Hirfanli | 1959 | Kizilirmak | Kirsehir | Inner A | ER | 83 | 364 | 2,000 | 5,980,000 | ICH | 2,300 |
| Demirköprü | 1960 | Gediz | Manisa | West.A | TE | 77 | 543 | 4,300 | 1,320,000 | ICH | 200+6272 |
| Almus | 1965 | Yesilirmak | Tokat | NEA | TE | 95 | 371 | 3,500 | 950,000 | IH | 1,550 |
| Kozan | 1972 | Kilgen | Adana | South.A | TE/ER | 83 | 289 | 1,195 | 163,000 | I | 1,250 |
| Keban | 1974 | Firat | Elazig | East | PG/ER | 207 | 1,126 | 15,585 | 30,600,000 | CH | 17,000 |
| Ayvacik | 1981 | Yesilirmak | Samsun | North | ER | 175 | 405 | 2,327 | 10,800,000 | CH | 11,000 |
| Güzelhisar | 1982 | Güzelhisar | Izmir | West | ER | 89 | 511 | 3,204 | 158,000 | IS | 2,550 |
| Gönen | C | Gönen | Balikesir | West | TE | 78 | 293 | 2,036 | 164,000 | I | 2,785 |
| Doganci | C | Nilüfer | Bursa | West | ER | 82 | 288 | 2,278 | 50,000 | S | 1,978 |
| Çamlidere | C | Bayindir | Ankara | Inner A | TE/ER | 106 | 278 | 2,487 | 133,000 | IS | 662 |
| Aslantas | C | Ceyhan | Adana | South | TE/ER | 95 | 566 | 8,000 | 1,150,000 | ICH | 11,930 |
| Adigüzel | C | B.Menderes | Denizli | West | ER | 145 | 377 | 5,892 | 1,188,000 | ICH | 4,260 |
| Kiliçkaya | C | Kelkit | Sivas | Inner | ER | 135 | 405 | 6,030 | 14,000 000 | ICH | 2,450 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Karakaya | C | First | Diyarbakir | SE | VA | 173 | 462 | 2,000 | 9,580,000 | H | 17,000 |
| Çatalan | C | Seyhan | Adana | South | TE | 95 | 309 | 7,664 | 1,629,000 | ICH | 8,900 |
| Karacaoren | C | Asagiaksu | Burdur | West | TE | 95 | 428 | 3,500 | 1,340,000 | ICH | 4,495 |
| Uluborlu | C | Pupa | Isparta | SE | TE | 75 | 315 | 1,800 | 24,000 | I | 295 |
| Gezende | C | Göksu | Mersin | South | TE | 75 | 171 | 1,110 | 66,000 | H | 4,385 |
| Altinkaya | C | Kizilirmak | Samsun | North | ER | 195 | 604 | 2,600 | 5,763,000 | ICH | 11,800 |
| Menzelet | C | Ceyhan | K.Maras | | ER | 151 | 425 | 8,000 | 19,500 | IH | 4,850 |
| Ataturk | C | Firat | Diyarbakir | East | ER | 184 | 746 | 85,000 | 48,700 | ICH | 16,800 |
| *United States* | | | | | | | | | | | |
| Ashokan | 1916 | Esopus Creek | Olive Bridge | New York | TE | 77 | 1,417 | 1,950 | 484,018 | S | 5,938 |
| Calaveras | 1925 | Calaveras Creek | Sunol | California | ER | 75 | 366 | 2,646 | 123,348 | S | 702 |
| Dix | 1925 | Dix | High Bridge | Kentucky | ER | 87 | 311 | 1,343 | 222,027 | H | 1,300 |
| Tieton | 1925 | Tieton | Naches | Washington | TE | 97 | 280 | 1,567 | 244,229 | ICR | 1,416 |
| Cobble Mountain Reservoir | 1931 | Little | Westfield | Mass. | TE | 80 | 221 | 2,294 | 86,380 | S | 113 |
| New Exchequer | 1926 | Merced | Snelling | California | ER | 146 | 378 | 3,952 | 1,265,552 | H | 9,911 |
| Salt Springs | 1931 | N Fork Mokelumne | | California | ER | 9 | 396 | 2,294 | 171,947 | HS | 1,580 |
| El Capitan | 1934 | San Diego | Lakeside | California | TE/ER | 82 | 357 | 2,049 | 88,811 | S | 4,831 |
| Hoover (Boulder) | 1936 | Colorado | Boulder | Nevada | VA | 221 | 379 | 364 | 34,852,028 | IHCN | 11,327 |
| Fort Peck | 1937 | Missouri | Frazer | Montana | TE | 76 | 6,534 | 96,050 | 22,118,763 | CHIN | 6,514 |
| Alcova | 1938 | North Platte | Casper | Wyoming | TE/ER | 81 | 233 | 1,250 | 227,577 | IHR | 1,557 |
| Mathews | 1938 | Tr Cajalco Creek | Corona | California | TE | 84 | 1,988 | 7,309 | 224,494 | S | 382 |
| Tygart | 1938 | Tygart | Grafton | W Virginia | PG | 76 | 586 | 1,055 | 135,190 | NC | 8,948 |
| Quabbin Winsor | 1939 | Swift | Ware | Mass. | TE | 85 | 805 | 3,058 | 1,561,256 | S | 425 |
| San Gabriel No 1 | 1939 | San Gabriel | Azusa | California | ER | 123 | 463 | 8,104 | 54,725 | CS | 7,524 |
| Friant | 1942 | San Joaquin | Fresno | California | PG | 97 | 1,063 | 1,632 | 642,027 | ISCR | 2,350 |
| Grand Coulee | 1942 | Columbia | Coulee Dam | Washington | PG | 168 | 1,272 | 8,093 | 11,794,553 | ICHN | 26,986 |
| Marshall Ford Lake Travis (res) | 1942 | Colorado | Austin | Texas | TE | 85 | 1,230 | 1,251 | 1,446,381 | HCSR | 16,197 |
| Nantahala Lake | 1942 | Nantahala | Nantahala | N Carolina | TE | 76 | 318 | 5,532 | 142,590 | H | 2,503 |
| Green Mountain | 1942 | Blue | Hot Sulphur Springs | Colorado | TE/ER | 94 | 351 | 3,333 | 190,696 | IHR | 708 |
| Fontana | 1944 | Little Tennessee | Fontana Village | N Carolina | PG | 146 | 721 | 2,734 | 603,715 | H | 4,474 |
| Merriman | 1945 | Roundout Creek | Lackawack | New York | TE | 114 | 732 | 4,434 | 189,956 | S | 5,097 |
| Shasta | 1945 | Sacramento | Redding | California | PG | 183 | 1,055 | 6,660 | 5,614,809 | ISHN | 5,239 |
| Mud Mountain | 1948 | White | Buckley | Washington | ER | 130 | 213 | 1,758 | 130,698 | C | 3,892 |
| Watauga | 1948 | Watauga | Elizabethton | Tennessee | ER | 97 | 274 | 2,660 | 398,415 | CHNR | 1,756 |
| Anderson Ranch | 1950 | S Fork Boise | Boise | Idaho | TE | 139 | 411 | 7,380 | 620,071 | ICRH | 566 |
| Leroy Anderson | 1950 | Coyote Creek | San Jose | California | TE | 77 | 421 | 2,485 | 112,617 | I | 1,195 |

*(Continued)*



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**Table 11A.8 (Continued)**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| South Holston | 1950 | S Fork Holston | Bluff City | Tennessee | ER | 87 | 488 | 4,499 | 402,115 | CHNR | 1,756 |
| Bull Shoals | 1951 | White | Cotter | Arkansas | PG | 78 | 688 | 1,606 | 3,759,653 | CH | 14,158 |
| Center Hill | 1951 | Caney Fork | Lancaster | Tennessee | TE/PG | 76 | 658 | 2,736 | 1,033,658 | CHR | 12,856 |
| Wolf Creek | 1951 | Cumberland | Burkesville | Kentucky | TE | 79 | 1,748 | 8,713 | 4,927,760 | HCR | 15,659 |
| Bradbury | 1953 | Santa Ynez | Santa Barbara | California | TE | 85 | 1,021 | 5,119 | 252,864 | ISR | 4,559 |
| Detroit | 1953 | N Santiam | Mill City | Oregon | PG | 141 | 482 | 1,147 | 561,152 | HCRI | 4,984 |
| Hungry Horse | 1953 | S Fork Flathead | Kalispell | Montana | VA | 172 | 645 | 2,359 | 4,277,715 | IHCN | 1,501 |
| Lookout Point | 1953 | Middle Fork Whillamette | Eugene | Oregon | TE | 84 | 968 | 5,892 | 562,385 | CINH | 7,646 |
| Yale | 1953 | Lewis | Woodland | Washington | TE | 98 | 472 | 3,211 | 495,860 | HCR | 4,899 |
| Lucky Peak | 1954 | Boise | Boise | Idaho | TE | 104 | 713 | 4,511 | 377,445 | CRI | 2,642 |
| Pine Flat Lake | 1954 | Kings | Piedra | California | PG | 134 | 561 | 1,835 | 1,233,492 | CIRH | 11,072 |
| Folsom | 1956 | American | Sacramento | California | PG | 104 | 3,109 | 6,866 | 1,245,817 | ISHC | 16,056 |
| Beardsley | 1957 | Mid Fk Stanislaus | Melones | California | TE | 85 | 250 | 2,294 | 120,264 | H | 2,027 |
| Brownlee | 1958 | Snake | Oxbow Village | Idaho | ER | 120 | 421 | 4,587 | 1,759,808 | HCR | 8,593 |
| Courtwright | 1958 | Helms Creek | Piedra | California | ER | 95 | 263 | 1,193 | 152,088 | HS | 400 |
| Oahe | 1958 | Missouri | Pierre | So. Dakota | TE | 75 | 2,890 | 70,339 | 27,432,595 | CHIN | 2,266 |
| Swift | 1958 | Lewis | Woodland | Washington | TE | 186 | 640 | 11,774 | 932,512 | HCR | 4,106 |
| Wishon | 1958 | N Fk Kings | Piedra | California | ER | 80 | 1,021 | 2,829 | 157,886 | HS | 1,379 |
| Casitas | 1959 | Coyote Creek | Santa Barbara | California | TE | 102 | 610 | 6,967 | 313,304 | ISC | 210 |
| Table Rock | 1959 | White | Branson | Missouri | TE/PG | 77 | 1,958 | 3,479 | 3,332,900 | CH | 15,801 |
| Mammoth Pool | 1960 | San Joaquin | | California | TE | 124 | 250 | 4,094 | 151,718 | HS | 4,757 |
| Arthur R. Bowman (Prineville) | 1961 | Crooked | Bend | Oregon | TE | 75 | 244 | 1,089 | 190,573 | IRC | 230 |
| Ball Mountain | 1961 | West | Jamaica | Vermont | TE | 83 | 279 | 1,767 | 2,760 | CR | 4,248 |
| Lewis Smith | 1961 | Dipsey Fork | Dilworth | Alabama | TE | 93 | 671 | 3,930 | 1,714,540 | HCR | 5,873 |
| Sly Creek | 1961 | Lost Crook | Oroville | California | TE | 83 | 640 | 4,000 | 80,238 | H | 328 |
| Hills Creek | 1962 | M Fk Willamette | Oakridge | Oregon | TE | 104 | 703 | 8,257 | 439,055 | CHIS | 4,010 |
| Smith | 1962 | Smith | Belknap Springs | Oregon | TE | 101 | 351 | 1,911 | 18,502 | H | 255 |
| Trinity | 1962 | Trinity | Redding | California | TE | 164 | 747 | 22,486 | 3,019,563 | IHCR | 680 |
| Abiquiu | 1963 | Rio Chama | Abiquiu | New Mexico | TE | 99 | 469 | 9,017 | | CR | 447 |
| Dillon | 1963 | Blue | Silverthorne | Colorado | TE | 94 | 1,798 | 9,140 | 311,674 | S | 333 |
| Lermon | 1963 | Florida | Durango | Colorado | TE | 87 | 415 | 2,326 | 49,463 | I | 272 |
| Navajo | 1963 | San Juan | Blanco | New Mexico | TE | 123 | 1,112 | 20,521 | 2,108,020 | IR | 963 |
| Union Valley | 1963 | Silver Crk | Coloma | California | TE | 138 | 549 | 7,646 | 334,274 | S | 1,260 |
| Whiskeytown | 1963 | Clear Creek | Redding | California | TE | 86 | 1,190 | 3,412 | 297,269 | IHCR | 815 |
| Briones | 1964 | Bear Creek | El Sobrante | California | TE | 87 | 629 | 7,578 | 83,285 | S | 93 |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cougar | 1964 | S Fork Mckenzie | Springfield | Oregon | ER | 158 | 488 | 9,939 | 270,463 | HCIR | 2,152 |
| Homestake | 1964 | M Fk Home-stake | Minturn | Colorado | ER | 81 | 608 | 2,628 | 53,780 | S | 99 |
| Round Butte | 1964 | Deschutes | Warm Springs | Oregon | TE | 134 | 442 | 7,340 | 659,913 | HR | 1,286 |
| Summersville | 1965 | Gauley | Swiss | W Virginia | ER | 119 | 695 | 10,371 | 236,215 | CRS | 11,667 |
| Blue Mesa | 1966 | Gunnison | Montrose | Colorado | TE/ER | 119 | 239 | 2,355 | 1,160,706 | HCR | 954 |
| Glen Canyon | 1966 | Colorado | Less Ferry | Arizona | VA | 216 | 475 | 3,747 | 33,304,009 | HSCR | 7,815 |
| John W. Flannagan | 1966 | Pound | Elkhorn City | Virginia | TE | 79 | 279 | 1,824 | 83,261 | CR | 1,240 |
| Lost Creek | 1966 | Lost Creek | Devils Slide | Utah | TE | 76 | 329 | 1,401 | 27,753 | ISRC | 70 |
| Lower Hell Hole | 1966 | Rubicon | Auburn | California | ER | 125 | 472 | 6,357 | 257,058 | SH | 132 |
| Millwood | 1966 | Little | Ashdown | Arkansas | ER | 89 | 5,350 | 6,117 | 189,000 | CS | 13,403 |
| Yellowtail | 1966 | Bighorn | Hardin | Montana | VA | 160 | 451 | 1,182 | 1,076,830 | ICHR | 2,605 |
| San Luis | 1967 | San Luis Creek | Los Banos | California | TE | 116 | 5,639 | 59,559 | 2,517,536 | ISHR | 29 |
| Alamo (res) | 1968 | Bill Williams | Parker | Arizona | TE | 105 | 297 | 2,328 | 539,350 | CRI | 1,175 |
| Blue River | 1968 | Blue | Springfield | Oregon | TE | 95 | 381 | 3,726 | 110,380 | CR | 1,501 |
| Oroville | 1968 | Feather | Oroville | California | TE | 230 | 2,073 | 59,635 | 4,297,451 | SCHR | 4,248 |
| Ruedi | 1968 | Fryingpan | Basalt | Colorado | TE/ER | 98 | 318 | 2,863 | 126,432 | IRC | 157 |
| International Amistad | 1969 | Rio Grande | Del Rio | Texas/Mex. | TE/PG | 77 | 9,754 | 2,652 | 4,323,847 | CIHR | 42,673 |
| Lopez | 1969 | Arroyo Grande Crk | Arroyo Grande | California | TE | 85 | 341 | 2,705 | 64,758 | S | 1,256 |
| New Bullards Bar | 1970 | North Yuba | Marysville | California | VA | 194 | 671 | 1,988 | 1,195,984 | SH | 4,219 |
| Coedar Springs | 1971 | W Fk Mojave | Victorville | California | ER | 76 | 725 | 6,040 | 96,212 | IRS | 913 |
| Don Pedro | 1971 | Tuolumne | La Grange | California | TE | 173 | 549 | 12,233 | 2,503,968 | H | 13,380 |
| Heron | 1971 | Willow Creek | Tierra Amarillo | New Mexico | TE/ER | 84 | 372 | 2,317 | 495,243 | ISR | 19 |
| Castaic | 1973 | Castaic Creek | Castaic | California | TE | 125 | 1,585 | 33,640 | 431,719 | IRS | 2,220 |
| Dworshak | 1973 | N. Fork Clearwater | Ahsahka | Idaho | PG | 219 | 1,002 | 4,931 | 4,259,213 | HCR | 6,258 |
| Jocassee | 1973 | Keowee | | S Carolina | ER | 133 | 549 | 8,869 | 1,431,206 | H | 1,761 |
| Libby | 1973 | Kootenai | Libby | Montana | PG | 129 | 881 | 2,875 | 7,165,296 | HCR | 4,060 |
| Pyramid | 1973 | Piru Creek | Piru | California | ER | 122 | 329 | 5,315 | 220,793 | IRSH | 4,248 |
| Soldier Creek | 1973 | Strawberry | Duchesne | Utah | TE | 77 | 393 | 2,440 | 1,365,464 | ICR | |
| Carters | 1974 | Coosawattee | Carters | Georgia | ER | 141 | 594 | 11,468 | 465,146 | CHR | 520 |
| Cochiti | 1975 | Bio Grande and Santa Fe | Cochiti Pueblo | New Mexico | TE | 77 | 8,785 | 50,228 | 52,726 | CIR | 4,280 |
| Lost Creek | 1976 | Rogue | Shady Cove | Oregon | ER | 105 | 1,097 | 8,257 | 573,485 | CHSR | 4,474 |
| Ririe | 1976 | Willow Creek | Idaho Falls | Idaho | TE | 77 | 326 | 2,046 | 123,348 | IC | 1,133 |
| Gross | 1977 | South Boulder Crk | Louisville | Colorado | PG | 104 | 332 | 7,809 | 50,557 | SH | 444 |

*(Continued)*



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**Table 11A.8 (Continued)**

| Name of Dam | Year of Completion | River | Nearest City | State Province or Country | Type | Height above Lowest Foundation (m) | Length of Crest (m) | Volume Content of Dam (103 $m^3$) | Gross Capacity of Reservoir ($10^3$ $m^3$) | Purpose | Maximum Discharge Capacity of Spillways ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Little Blue Run | 1977 | Little Blue Run of Ohio | East Liverpool | Penn. | TE | 122 | 640 | 9,939 | 13,568 | | 48 |
| Gathright | 1978 | Jackson | Covington | Virginia | ER | 78 | 368 | 1,988 | 152,582 | RC | 173 |
| New Melones | 1979 | Stanislaus | Modesto | California | ER | 191 | 475 | 12,233 | 2, 960,356 | CIHR | 3,171 |
| Bloomington | 1981 | N Branch of Potomac | Bloomington | Maryland | ER | 90 | 649 | 7,646 | 116,793 | CSR | 5,465 |
| Bath County Upper | C | Little Back Creek | Warm Springs | Virginia | ER/TE | 143 | 731 | 18,000 | 43,790 | H | 509 |
| Warm Springs | C | Dry Creek | Cloverdale | California | TE | 97 | 914 | 22,920 | 469,365 | CSR | 1,056 |
| *U.S.S.R.* | | | | | | | | | | | |
| Mingechaur | 1953 | Kura | Mingechaur | Azerb. SSR | TE | 80 | 1,550 | 15,600 | 16,000,000 | HNIC | 3,600 |
| Bukhtarma | 1960 | Irtysh | Ust-Kamenogorsk | Kazakh, SSR | PG | 90 | 380 | 1,170 | 49,800,000 | HN | 1,000 |
| Sioni | 1963 | Iori | Tbilisi | Georg. SSR | TE | 86 | 780 | 6,300 | 325,000 | IH | 596 |
| Bratsk | 1964 | Angara | Bratsk | Irkutsk | PG | 125 | 1,430 | 4,415 | 169,000,000 | HNS | 7,090 |
| | | | | | TE | 36 | 2,987 | 6,547 | | | |
| | | | | | TE | 40 | 723 | 2,147 | | | |
| Serebrianka No 1 | 1970 | Voronlya | Murmansk | Murmansk | ER | 78 | 2,625 | 5,660 | 4,170,000 | H | 675 |
| Sarsang | 1976 | Terter | Yevlakh | Azerb. SSR | TE | 125 | 590 | 5,820 | 560,000 | IH | 800 |
| Charvak | 1977 | Chirchik | Tashkent | Uzbek. SSR | ER | 168 | 764 | 21,600 | 2,000,000 | HI | 1,200 |
| Medeo | 1977 | Malaya Almaatinka | Alma-Ata | Kazakh. SSR | ER | 144 | 530 | 8,500 | — | C | — |
| Ust-Ilim | 1977 | Angara | Ust-Ilimsk | Irkutsk | PG | 102 | 1,477 | 3,800 | 59,300,000 | HN | 9,700 |
| | | | | | TE/ER | 47 | 2,248 | 5,066 | | | |
| Chirkey | 1978 | Sulak | Makhachkala | Daghest. SSR | VA | 233 | 333 | 1,358 | 2,780,000 | HIS | 2,870 |
| Toktogul | 1978 | Naryn | Naryn | Kirgh. SSR | PG | 215 | 293 | 3,345 | 19,500,000 | HI | 2,340 |
| Zeya | 1978 | Zeye | Blagoveshchensk | Amur. | CB | 115 | 758 | 2,160 | 68,400,000 | HCN | 6,600 |
| Andizhan | 1980 | Karadarya | Osh | Kirghiz. SSR | CB | 115 | 920 | 3,700 | 1,750,000 | HI | 2,392 |
| Inguri | 1980 | Inguri | Zugdidi | Georgian SSR | VA | 272 | 680 | 3,960 | 1,100,000 | HI | 2,500 |
| Nurek | 1980 | Vakhsh | Nurek | Tadjik SSR | TE | 300 | 74 | 58,000 | 10,500,000 | HI | 4,000 |
| Sayano-Shushensk | C | Yenisei | Minusinsk | Krasnoyarsk | VA/PG | 245 | 1,066 | 9,075 | 31,300,000 | NH | 13,600 |
| Bureya | C | Bureya | Blagoveshchensk | Kharbarovsk | PG | 139 | 810 | 3,561 | 20,900,000 | HC | 19,100 |
| Irganai | C | Avar Koisu | Makhachkala | Daghest. SSR | TE/ER | 111 | 312 | 5,827 | 705,000 | H | 2,760 |
| Khudoni | C | Kolyma | Magadan | Magadan | ER | 126 | 759 | 12,550 | 14,600,000 | H | 17,500 |
| Rogun | C | Vakhsh | Nurek | Tajik SSR | TE/ER | 335 | 660 | 75,500 | 13,300,000 | HI | 3,500 |
| Spandarian | C | Vorotan | Sisian | Armen. SSR | TE | 87 | 317 | 2,250 | 277,000 | HI | 160 |
| Zhinvali | C | Aragvi | Tbilisi | Georg. SSR | TE | 102 | 412 | 5,200 | 520,000 | HS | 2,500 |
| *Venezuela* | | | | | | | | | | | |
| Onia | 1978 | Onia | El Vigia | Mórida | TE | 301 | 450 | 1,300 | 6,600 | C | 435 |
| Tucupido | C | Tucupido | Guanare | Portuguesa | TE | 92 | 290 | | 3,300 | IHC | — |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yacambú | C | Yacambú | Sanare | Lara | TE | 158 | 107 | 3,000 | 427,000 | ICS | 480 |
| Las Palmas | C | Cojedes | Acarigua | Cojedes | TE | 77 | 750 | 7,000 | 810,000 | IHC | |
| Las Cuevas | C | | San Cristóbal | Tachira | TE | 108 | | 7,500 | 1,400,000 | H | |
| La Vueltosa | C | Caparo | Buena Vista | Mérida | TE | 118 | | 15,000 | 5,300,000 | H | |
| Borde Seco | C | Camburito | San Cristobal | Táchira | TE | 120 | | 6,600 | | H | |
| Taguaza | C | Taguaza | Sta. Lucia | Miranda | TE | 100 | 300 | 2,000 | 212,000 | S | 430 |
| La Honda | C | Uribante | San Cristóbal | Táchira | TE | 108 | | 7,800 | 770,000 | H | |
| *Yugoslavia* | | | | | | | | | | | |
| Kokin Brod | 1962 | Uvac | Nova Varos | SR Srbija | ER | 82 | 1,220 | 2,480 | 250,000 | H | 1,500 |
| Tikves | 1968 | Crna Reka | Kavadarci | SR Makedonija | ER | 114 | 338 | 2,722 | 475,000 | J | 2,050 |
| Spilje | 1969 | Crni Drim | Debar | SR Makedonija | ER | 112 | 330 | 2,699 | 520,000 | H | 2,890 |
| Rama | 1969 | Rama | Prozor | SR Bosna and Hercegovina | ER | 103 | 230 | 1,510 | 487,000 | H | 400 |
| Turija | 1970 | Turija | Strumica | SR Makedonija | ER | 93 | 417 | 1,978 | 65,000 | J | 76 |
| Gazivode | 1977 | Ibar | Titova Mitrovica | SAP Kosovo | ER | 108 | 520 | 5,000 | 370,000 | H | 720 |
| Sjenica | 1979 | Veliki Uvac | Nova Varos | SR Srbija | ER | 106 | 310 | 2,430 | 190,000 | H | 1,000 |
| Lazici | C (1983) | Beli Rzav | Bajina Basta | SR Srbija | ER | 123 | 120 | 2,170 | 150,000 | H | 180 |
| Zavoj | C (1987) | Visocica | Pirot | SR Srbija | ER | 80 | 250 | 1,400 | 16,000 | H | 1,800 |
| *Zambia/Zimbabwe* | | | | | | | | | | | |
| Kariba | 1959 | Zambezi | Lusaka | Zambia/ Zimbabwe | VA | 128 | 579 | 1,032 | 160,368 | H | 9,500 |

*Note:* Height—over 75 m; Volume—over 1,000,000 cubic m. Dam types are identified by the following abbreviations: Earth TE; Rockfill ER; Gravity PG; Buttress CB; Arch VA; Multi-Arch MV. Purpose for which reservoir is used is indicated by the following abbreviations: Irrigation I; Hydroelectric H; Flood Control C; Navigation N; Water Supply S; Mine Tailings T; Recreational R. Under year of completion, C is under construction and P is planned.

*Source*: Compiled from *World Register of Dams*, 1984, published by the International Commission on Large Dams, 151 Boulevard Haussmann, 75008 Paris.



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**Table 11A.9 World's Highest Dams**

| Name | River, Location | Structural Height | | Gross Reservoir Capacity | | Year Completed |
|---|---|---|---|---|---|---|
| | | ft | m | Thousands of acre ft | Millions of cum | |
| Rogun | Vakhsh, Tajikistan | 1,099 | 335 | 9,404 | 11,600 | 1985 |
| Nurek | Vakhsh, Tajikistan | 984 | 300 | 8,512 | 10,500 | 1980 |
| Grande Dixence | Dixence, Switzerland | 935 | 285 | 324 | 400 | 1962 |
| Inguri | Inguri, Georgia | 892 | 272 | 801 | 1,100 | 1984 |
| Vaiont | Vaiont, Italy | 859 | 262 | 137 | 169 | 1961 |
| Manuel M. Torres | Grijalva, Mexico | 856 | 261 | 1,346 | 1,660 | 1981 |
| Tehri | Bhagirathi, India | 856 | 261 | 2,869 | 3,540 | UC |
| Alvaro Obregon | Mextiquic, Mexico | 853 | 260 | n.a. | n.a. | 1926 |
| Mauvoisin | Drance de Bagnes, Switzerland | 820 | 250 | 146 | 180 | 1957 |
| Alberto Lleras | Orinoco, Colombia | 797 | 243 | 811 | 1,000 | 1989 |
| Mica | British Columbia, Canada | 797 | 243 | 20,000 | 24,670 | 1972 |
| Sayano-Shushenskaya | Yenisei, Russia | 794 | 242 | 25,353 | 31,300 | 1980 |
| Ertan | Yangtze/Yalong, China | 797 | 240 | 4,720 | 5,800 | 1999 |
| La Esmeralda | Batá, Colombia | 778 | 237 | 661 | 815 | 1975 |
| Kishau | Tons, India | 774 | 236 | 1,946 | 2,400 | 1985 |
| Oroville | Feather, CA, U.S.A. | 770 | 235 | 3,538 | 4,299 | 1968 |
| El Cajón | Humuya, Honduras | 768 | 234 | 4,580 | 5,650 | 1984 |
| Chirkey | Sulak, Russia | 764 | 233 | 2,252 | 2,780 | 1977 |
| Bhakra | Sutlej, India | 741 | 226 | 8,002 | 9,870 | 1963 |
| Luzzone | Brenno di Luzzone, Switzerland | 738 | 225 | 71 | 87 | 1963 |
| Hoover | Colorado, AZ-NV, U.S.A. | 732 | 223 | 28,500 | 35,154 | 1936 |
| Contra | Verzasca, Switzerland | 722 | 220 | 70 | 86 | 1965 |
| Mratinje | Piva, Herzegovina | 722 | 220 | 713 | 880 | 1973 |
| Dworshak | North Fork Clearwater, ID, U.S.A. | 717 | 219 | 3,453 | 4,259 | 1974 |
| Glen Canyon | Colorado, AZ, U.S.A. | 710 | 216 | 27,000 | 33,304 | 1964 |
| Toktogul | Naryn, Kyrgyzstan | 705 | 215 | 15,800 | 19,500 | 1978 |
| Daniel Johnson | Manicouagan, Canada | 703 | 214 | 115,000 | 141,852 | 1968 |
| Keban | Firat, Turkey | 689 | 210 | 25,110 | 31,000 | 1974 |
| Zimapan | Moctezuma, Mexico | 679 | 207 | n.a. | n.a. | 1994 |
| Karun | Karun, Iran | 673 | 205 | 2,351 | 2,900 | 1976 |
| Lakhwar | Yamuna, India | 669 | 204 | 470 | 580 | 1985 |
| Dez | Dez, Abi, Iran | 666 | 203 | 2,707 | 3,340 | 1963 |
| Almendra | Tormes, Spain | 662 | 202 | 2,148 | 2,649 | 1970 |
| Berke | Ceyhan, Turkey | 659 | 201 | n.a. | n.a. | 2000 |
| Khudoni | Inguri, Georgia | 659 | 201 | n.a. | n.a. | n.a. |
| Kölnbrein | Malta, Austria | 656 | 200 | 166 | 205 | 1977 |
| Altinkaya | Kizil Irmak, Turkey | 640 | 195 | 4,672 | 5,763 | 1986 |
| New Bullards Bar | No. Yuba, CA, U.S.A. | 637 | 194 | 960 | 1,184 | 1968 |
| New Melones | Stanislaus, CA, U.S.A. | 625 | 191 | 2,400 | 2,960 | 1979 |
| Itaipu | Paraná, Brazil/Paraguay | 623 | 190 | 23,510 | 29,000 | 1982 |
| Kurobe 4 | Kurobe, Japan | 610 | 186 | 162 | 199 | 1964 |
| Swift | Lewis, WA, U.S.A. | 610 | 186 | 756 | 932 | 1958 |
| Mossyrock | Cowlitz, WA, U.S.A. | 607 | 185 | 1,300 | 1,603 | 1968 |
| Oymopinar | Manavgat, Turkey | 607 | 185 | 251 | 310 | 1983 |
| Atatürk | Firat, Turkey | 604 | 184 | 39,482 | 48,700 | 1990 |
| Shasta | Sacramento, CA, U.S.A. | 602 | 183 | 4,550 | 5,612 | 1945 |
| Bennett WAC | Peace, Canada | 600 | 183 | 57,006 | 70,309 | 1967 |
| Karakaya | Firat, Turkey | 591 | 180 | 7,767 | 9,580 | 1986 |
| Tignes | Isère, France | 591 | 180 | 186 | 230 | 1952 |
| Amir Kabir (Karad) | Karadj, Iran | 591 | 180 | 166 | 205 | 1962 |
| Tachien | Tachia, Taiwan | 591 | 180 | 188 | 232 | 1974 |
| Dartmouth | Mitta-Mitta, Australia | 591 | 180 | 3,243 | 4,000 | 1978 |
| Özköy | Gediz, Turkey | 591 | 180 | 762 | 940 | 1983 |
| Emosson | Barberine, Switzerland | 590 | 180 | 184 | 225 | 1974 |
| Zillergrundl | Ziller, Austria | 590 | 180 | 73 | 90 | 1986 |
| Los Leones | Los Leones, Chile | 587 | 1799 | 86 | 106 | 1986 |
| New Don Pedro | Tuolumne, CA, U.S.A. | 585 | 178 | 2,030 | 2,504 | 1971 |

*(Continued)*

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**Table 11A.9 (Continued)**

| Name | River, Location | Structural Height ft | Structural Height m | Gross Reservoir Capacity Thousands of acre ft | Gross Reservoir Capacity Millions of cum | Year Completed |
|---|---|---|---|---|---|---|
| Alpa-Gera | Cormor, Italy | 584 | 178 | 53 | 65 | 1965 |
| Kopperston Tailings 3 | Jones Branch, WV, U.S.A. | 580 | 177 | — | — | 1963 |
| Takase | Takase, Japan | 577 | 176 | 62 | 76 | 1979 |
| Nader Shah | Marun, Iran | 574 | 175 | 1,313 | 1,620 | 1978 |
| Hasan Ugurlu | Yesil Irmak, Turkey | 574 | 175 | 874 | 1,078 | 1980 |
| Revelstoke | Columbia, B.C., Canada | 574 | 175 | 4,298 | 5,300 | 1984 |
| Hungry Horse | S.Fk., Flathead, MT, U.S.A. | 564 | 172 | 3,470 | 4,280 | 1953 |
| Longyangxia | Huanghe, China | 564 | 172 | 20,025 | 24,700 | 1983 |
| Cabora Bassa | Zambezi, Mozambique | 561 | 171 | 51,075 | 63,000 | 1974 |
| Maqarin | Yarmuk, Jordan | 561 | 171 | 259 | 320 | 1987 |
| Amaluza | Paute, Ecuador | 558 | 170 | 81 | 100 | 1982 |
| Idikki | Periyar, India | 554 | 169 | 1,618 | 1,996 | 1974 |
| Charvak | Chirchik, Uzbekistan | 552 | 168 | 1,620 | 2,000 | 1970 |
| Gura Apelor Retezat | Riul Mare, Romania | 552 | 168 | 182 | 225 | 1980 |
| Grand Coulee | Columbia, Washington | 550 | 168 | 9,390 | 11,582 | 1942 |
| Boruca | Terraba, Costa Rica | 548 | 167 | 12,128 | 14,960 | UC |
| Vidraru | Arges, Romania | 545 | 166 | 380 | 465 | 1965 |
| Kremasta (King Paul) | Achelöus, Greece | 541 | 165 | 3,850 | 4,750 | 1965 |
| Pauti-Mazar | Mazar, Ecuador | 541 | 165 | 405 | 500 | 1984 |

*Note:* UC, under construction in 2004, n.a., not available. China's Three Gorges dam on the Yangtze River, begun in 1993 and expected to be completed in 2009, will be the world's largest and highest dam.

*Source*: From International Commission on Large Dams, *World Register of Dams 1998*, and other sources.

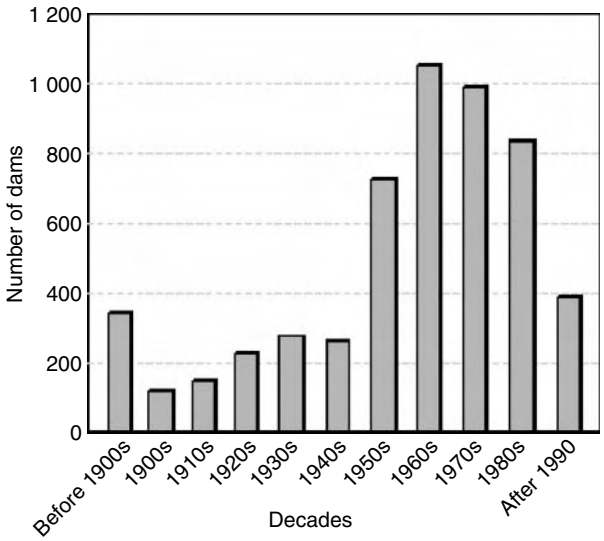


**Figure 11A.5** Large dams commissioned per decade in Europe. (From ICOLD, 1998. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

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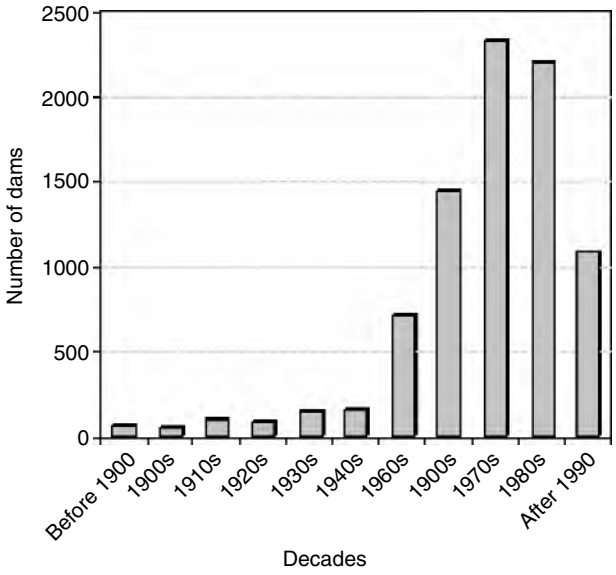


**Figure 11A.6** Large dams commissioned per decade in Asia. (From ICOLD, 1998. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

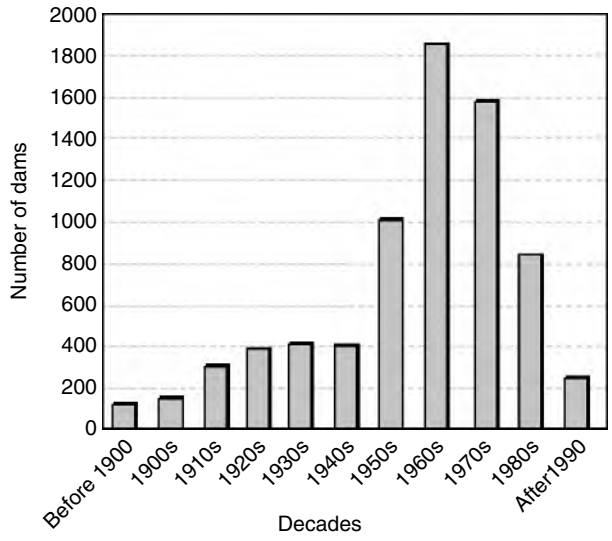


**Figure 11A.7** Large dams commissioned per decade in North and Central America. (From ICOLD, 1998. Note: Rates of dam commissioning in the 1990s are underreported. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

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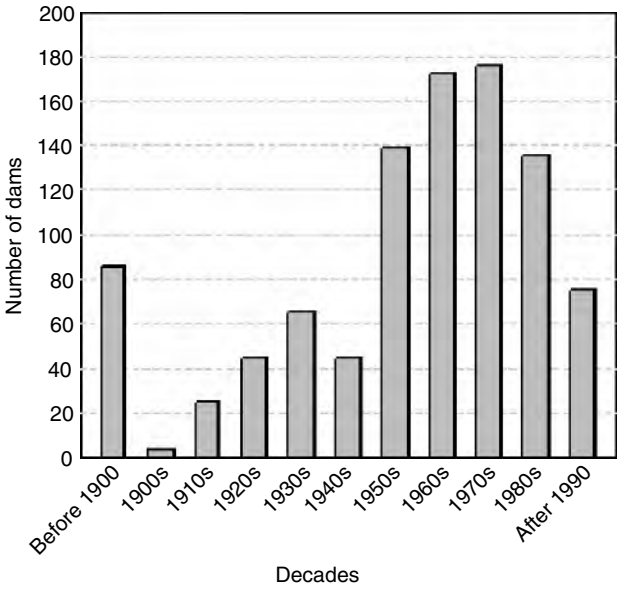


**Figure 11A.8** Large dams commissioned per decade in South America. (From ICOLD, 1998. Note: Rates of dam commissioning in the 1990s are underreported.)

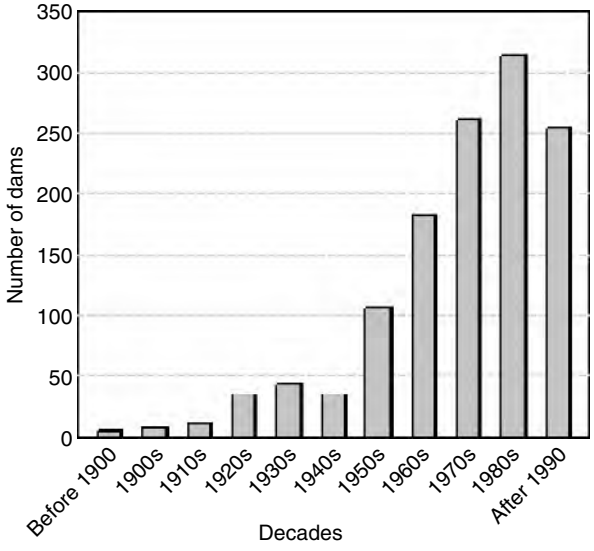


**Figure 11A.9** Large dams commissioned per decade in Africa. (From ICOLD, 1998. Note: Rates of dam commissioning in the 1990s are underreported. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

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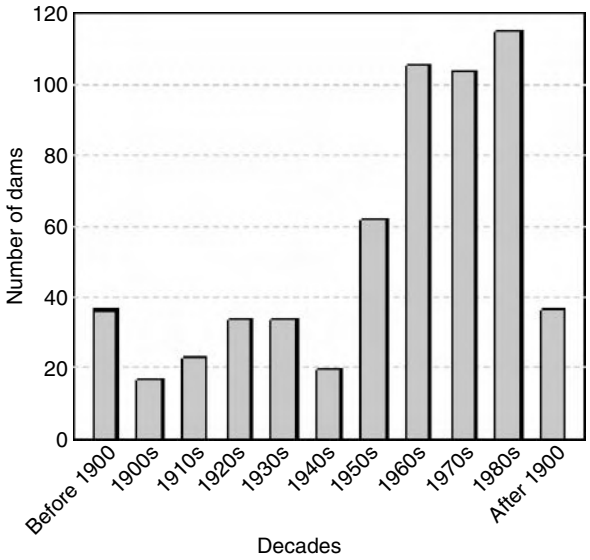


**Figure 11A.10** Large dams commissioned per decade in Austral-Asia. (From ICOLD, 1998. Note: Rates of dam commissioning in the 1990s are underreported. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile.)

**Table 11A.10 Modes and Causes of Earth Dam Failures**

| Form | General Characteristics | Causes | Preventive or Corrective Measures |
|---|---|---|---|
| | | **Hydraulic Failures (30% of all failures)** | |
| Overtopping | Flow over embankment, washing out dam | Inadequate spillway capacity | Spillway designed for maximum flood |
| | | Clogging of spillway with debris | Maintenance, trash booms, clean design |
| | | Insufficient freeboard due to settlement, skimpy design | Allowance for freeboard and settlement in design; increase crest height or add flood parapet |
| Wave erosion | Notching of upstream face by waves, currents | Lack of riprap, too small riprap | Property designed riprap |
| Toe erosion | Erosion of toe by outlet discharge | Spillway too close to dam | Training walls |
| | | Inadequate riprap | Properly designed riprap |
| Gullying | Rainfall erosion of dam face | Lack of sod or poor surface drainage | Sod, fine riprap; surface drains |
| | | **Seepage Failures (40% of all failures)** | |
| Loss of water | Excessive loss of water from reservoir and/or occasionally increased seepage or increased groundwater levels near reservoir | Previous reservoir rim or bottom | Blanket reservoir with compacted clay or chemical admix; grout seams, cavities |
| | | Previous dam foundation | Use foundation cutoff; grout; upstream blanket |
| | | Pervious dam | Impervious core |
| | | Leaking conduits | Watertight joints; waterstops; grouting |
| | | Settlement cracks in dam | Remove compressible foundation, avoid sharp changes in abutment slope, compact soils at high moisture |
| | | Shrinkage cracks in dam | Use low-plasticity clays for core, adequate compaction |

*(Continued)*

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**Table 11A.10 (Continued)**

| Form | General Characteristics | Causes | Preventive or Corrective Measures |
|---|---|---|---|
| Seepage erosion or piping | Progressive internal erosion of soil from downstream side of dam or foundation backward toward the upstream side to form an open conduit or "pipe." Often leads to a washout of a section of the dam | Settlement cracks in dam | Remove compressible foundation, avoid sharp changes, internal drainage with protective filters |
| | | Shrinkage cracks in dam | Low-plasticity soil; adequate compaction; internal drainage with protective filters |
| | | Pervious seams in foundation | Foundation relief drain with filter; cutoff |
| | | Pervious seams, roots, etc. in dam | Construction control; core; internal drainage with protective filter |
| | | Concentration of seepage at face | Toe drain; internal drainage with filter |
| | | Boundary seepage along conduits, walls | Stub cutoff walls, collars; good soil compaction |
| | | Leaking conduits | Watertight joints; waterstops; materials |
| | | Animal burrows | Riprap, wire mesh |
| | **Structural Failures (30% of all failures)** | | |
| Foundation slide | Sliding of entire dam, one face, or both faces in opposite directions, with bulging of foundation in the direction of movement | Soft or weak foundation | Flatten slope; employ broad berms; remove weak material; stabilize soil |
| | | Excess water pressure in confined sand or silt seams | Drainage by deep drain trenches with protective filters; relief wells |
| Upstream slope | Slide in upstream face with little or no bulging in foundation below toe | Steep slope | Flatten slope or employ berm at toe |
| | | Weak embankment soil | Increased compaction; better soil |
| | | Sudden drawdown of pond | Flatten slope, rock berms; operating rules |
| Downstream slope | Slide in downstream face | Steel slope | Flatten slope or employ berm at toe |
| | | Weak soil | Increased compaction; better soil |
| | | Loss of soil strength by seepage pressure or saturation by seepage or rainfall | Core; internal drainage with protective filters; surface drainage |
| Flow slide | Collapse and flow of soil in either upstream or downstream direction | Loose embankment soil at low cohesion, triggered by shock, vibration, seepage, or foundation movements | Adequate compaction |

*Source*: From National Academy Press, 1983, Safety of existing dams: evaluation and improvement. With permission.

*Original Source*: From Sowers, G.F., 1961, *The Use and Misuse of Earth Dams, Consulting Engineering*, July.

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**Table 11A.11 World's Largest Dams According to Spillway Capacity**

| No | Capacity, ($m^3$ sec) | Name | Country | Year |
|---|---|---|---|---|
| | 113,000 | Gezhouba | China | U/C |
| | 110,000 | Tucurui | Brazil | U/C |
| 1 | 82,300 | Dajiangkou | China | 1974 |
| 2 | 64,845 | The Dalles | U.S.A. | 1957 |
| | 64,600 | Burdekin Falls | Australia | U/C |
| 3 | 63,713 | John Day Lock and Dam | U.S.A. | 1968 |
| 4 | 62,297 | MacNary Lock and Dam | U.S.A. | 1957 |
| | 62,296 | Sardar Sarovar | India | U/C |
| 5 | 61,400 | Itaipu | Brazil | 1982 |
| | 60,000 | Oosterscheldekering | Netherlands | U/C |
| 6 | 59,000 | Shuifeng | China/Korea | 1943 |
| 7 | 58,500 | Saratov | U.S.S.R. | 1967 |
| 8 | 58,400 | Gavins Point | U.S.A. | 1958 |
| 9 | 57,000 | Salto Grande | Uruguay/Argentina | 1979 |
| | 54,862 | Jhuj | India | U/C |
| 10 | 54,400 | Panjiakou | China | 1979 |
| 11 | 53,450 | Nagarjuna Sagar | India | 1974 |
| | 52,000 | Porto Primavera | Brazil | U/C |
| 12 | 50,000 | Jupia | Brazil | 1968 |
| | 49,800 | Wanan | China | U/C |
| 13 | 49,600 | Kadana | India | 1978 |
| | 47,000 | Ankang | China | U/C |
| | 46,970 | Gohira | India | U/C |
| 14 | 46,259 | Alvin Wirtz | U.S.A. | 1950 |
| | 45,312 | Sri Rama Sagar | India | U/C |
| 15 | 45,307 | Bonneville | U.S.A. | 1937 |
| | 44,752 | Bargi | India | U/C |
| | 43,000 | Owen Falls | Uganda | 1954 |
| 16 | 43,690 | International la Amistad | U.S.A./Mexico | 1969 |
| 17 | 42,459 | Hirakud | India | 1957 |
| 18 | 42,186 | Tarbela | Pakistan | 1976 |
| 19 | 41,280 | Xinanjiang | China | 1965 |
| 20 | 40,300 | Kuibyshev | U.S.S.R. | 1955 |
| 21 | 40,000 | Ilha Solteira | Brazil | 1973 |
| 22 | 39,644 | Priest Rapids | U.S.A. | 1959 |
| 23 | 39,644 | Wanapum | U.S.A. | 1963 |
| 24 | 39,158 | Tom Miller | U.S.A. | 1939 |
| | 37,945 | Narayanpur | India | U/C |
| 25 | 37,500 | Shuifeng | China | 1943 |
| | 37,400 | Srisailam HE | India | 1943 |
| 26 | 36,200 | Fengman | China | 1954 |
| 27 | 25,960 | Ukai | India | 1972 |
| 28 | 35,620 | Daheiting | China | 1980 |
| | 35,000 | Guri | Venezuela | U/C |
| 29 | 33,980 | Kentucky | U.S.A. | 1944 |
| 30 | 33,800 | Fuchunjing | China | 1968 |
| 31 | 33,600 | Chief Joseph | U.S.A. | 1955 |
| 32 | 33,414 | Wells | U.S.A. | 1967 |
| 33 | 33,131 | Conowingo | U.S.A. | 1928 |
| 34 | 31,400 | Xijin | China | 1966 |
| 35 | 31,152 | Marala | Pakistan | 1968 |
| 36 | 31,144 | Mangla | Pakistan | 1967 |

*Note:* U/C, under construction.

*Source*: From International Commission on Large Dams, 1984, *World Register of Dams*.

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**Table 11A.12 Summary of Regional Statistics on Large Dams**

| | World[a] | Europe | Asia | North and Central America | South America | Africa | Austral-Asia |
|---|---|---|---|---|---|---|---|
| Total number of large dams | 25,420[a]–48,000[a] | 5,480 | 31,340 | 8,010 | 979 | 1,269 | 577 |
| Average height[b](m) | 31 | 33 | 33 | 28 | 37 | 28 | 33 |
| Average reservoir area[b] ($km^2$) | 23 | 7 | 44 | 13 | 30 | 43 | 17 |
| Avg. reservoir capacity[b] (million $m^3$) | 269 | 70 | 268 | 998 | 1,011 | 883 | 205 |
| Technically feasible hydroelectric potential[c] (TWh/yr) | 14,370 | 1,225 | 6,800 | 1,660 | 2,665 | 1,750 | 270 |
| Annual hydroelectric production[c] (TWh/yr) | 2,643 | 552 | 753 | 700 | 534 | 62 | 42 |
| Exploited technically feasible hydroelectric potential[c] (%) | >18% | >45% | >11% | >42% | >20% | >3.5% | |

[a] The primary source of data is ICOLD 1998, but the regional divisions in this Table and in Figure V.16 through Figure V.27 follow those described in Table V.3. The 1998 ICOLD Register has 25,420 dams registered. Reporting depends on the member countries. Table V.I indicates how the global estimate of neatly 48,000 large dams is arrived at, with the main issue being the number of dams in China.
[b] The ICOLD 1998 database was used to calculate the average dam height, reservoir capacity, and surface area by region.
[c] I/HD 2000. Technical Flexibility is based on the conversion of all river lead and flow in the major rivers in region into energy.

*Source*: Based on ICOLD, 1998. damsreport.org. Annex V, Dams, Water and Energy: A Statistical Profile. With permission.

**Table 11A.13 Dam Incident Summary**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| CO00203 | Maple Grove | 2/1979 | Vandalism | Yes |
| DE00018 | Millsboro Pond | 2/1979 | Piping | Yes |
| DE00052 | Wiggins Mill Pond Dam | 2/1979 | Internal Erosion | Yes |
| FL00723 | Martin Plant Cooling Water Reservoir | 10/30/1979 | Piping | Yes |
| IDS00011 | Mud Creek Dam | 1/12/1979 | Inflow Flood—Hydrologic Event | Yes |
| KYS00004 | Samsel | 2/2/1979 | Seepage | No |
| MS00128 | Spring Lake | 9/1979 | Erosion | No |
| MS02734 | Pine Lake Dam | 4/1979 | Erosion | Unknown |
| MS01731 | Vance Lake | 4/13/1979 | Piping | Yes |
| MDS00002 | Big Millpond (Route 50) | 2/25/1979 | Undermining | Yes |
| IDS00013 | Dam on Pierce Park Gulch | 2/12/1979 | Inflow Flood—Hydrologic Event | Yes |
| IA01967 | Fertile Mill Dam | 8/22/1979 | Piping | Yes |
| NJ00235 | Gropps Lake Dam | 5/27/1979 | Sliding | Yes |
| NM00445 | United Nuclear Churchrock | 7/16/1979 | Cracking and Internal Erosion | Yes |
| NYS00007 | Swimming Poll Dam | 1979 | Inflow Flood—Hydrologic Event | Unknown |
| SC01458 | Huttos Lake Dam | 9/9/1979 | Inflow Flood—Hydrologic Event | Yes |
| UT00379 | Goshen | 2/14/1979 | Inflow Flood—Hydrologic Event | Yes |
| WI00160 | Pulcifer | 6/1979 | Deterioration | No |
| WI00053 | Little Falls | 4/1979 | Gate Structural Failure | Unknown |
| TN15712 | Edwards | 4/2/1979 | Piping | No |
| NYS00018 | Sherman Dam | 9/14/1979 | Inflow Flood—Hydrologic Event | Yes |
| NMS00006 | Phelps Dodge Corporation Tailings Dam No. 3 | 10/13/1980 | Structural Failure | Yes |
| SD00921 | East Lemmon | 6/5/1980 | Inflow Flood—Hydrologic Even | Yes |
| VTS00016 | Steward | 1980 | Piping | Yes |
| VT00122 | Fairfield Swamp Pond | 4/13/1980 | Piping | Yes |
| UTS00009 | Lower North Eden Reservoir | 4/20/1980 | Inflow Flood—Hydrologic Event | Yes |
| UTS00008 | South Eden Reservoir | 4/20/1980 | Inflow Flood—Hydrologic Event | Yes |
| SCS00004 | Tutens Mill Pond | 3/14/1980 | Inflow Flood—Hydrologic Event | Yes |
| NY13130 | Tannersville Reservoir #1 Dam | 3/22/1980 | Embankment Erosion | Yes |
| OR00185 | Crump Reservoir | 4/19/1980 | Piping | Yes |
| NY00561 | Snow BIrd Lake Dam | 9/1/1980 | Piping | Yes |
| WIS00005 | Kohlsville Dam | 4/1980 | Seepage | Yes |
| WI10607 | Lepper | 3/1980 | Gate Structural Failure | Unknown |
| WI00248 | Wyocena | 1/1/1980 | Abutment Erosion | Unknown |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| COS00006 | Prospect Reservoir Dam | 2/10/1980 | Piping | Yes |
| DE00028 | Lake Como Dam | 7/29/1980 | Inflow Flood—Hydrologic Event | Yes |
| GAS00214 | Rail Road Lake Dam | 5/23/1980 | Concrete Deterioration | Yes |
| MN00519 | Pickwick | 9/21/1980 | Inflow Flood—Hydrologic Event | Yes |
| ID00001 | Saint John | 5/7/1980 | Piping | Yes |
| CA10268 | Cascade | 1981 | Earthquake | Yes |
| KYS00006 | Eastover Mining Company Dam | 12/18/1981 | Sabotage—Other | Yes |
| NHS00007 | Mascoma River Dam No. 2 | 2/12/1981 | Structural Failure | Yes |
| TXS00002 | Unnamed Dam (TXS00002) | 1981 | Inflow Flood—Hydrologic Event | No |
| UTS00011 | Upper North Eden Reservoir | 4/20/1981 | Spillway Failure | Yes |
| WI00146 | Necedah | 9/20/1981 | Not Known | Unknown |
| ORS00005 | Mann Creek Dam | 11/8/1982 | Piping | Yes |
| WA00240 | Alexander Lake Dam | 12/3/1982 | Inflow Flood—Hydrologic Event; Animal Attack | Yes |
| WAS00013 | Alexander Lake | 12/3/1982 | Inflow Flood—Hydrologic Event | Yes |
| UTS00006 | Milk Pond Dam | 6/23/1982 | Inflow Flood—Hydrologic Event | Yes |
| COS00004 | Lawn Lake | 7/15/1982 | Piping | Yes |
| CT00157 | Gorton Pond | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CT00396 | Jennings Pond | 6/4/1982 | Inflow Flood—Hydrologic Event | Unknown |
| CT00417 | Upper Millpond | 6/4/1982 | Inflow Flood—Hydrologic Event | Unknown |
| CT00426 | Bushy Hill Pond | 6/1982 | Inflow Flood—Hydrologic Event | Yes |
| CT00545 | Holbrook Pond | 6/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00008 | Comstock Pond (CT 424 | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00007 | C. D. Batchelor Pond | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00006 | Bushy Pond (CT 391) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00005 | Bronson Company Dam (CT 691) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00003 | Urban Pond | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00002 | Hempstead Pond | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00001 | Crystal Lake | 6/4/1982 | Inflow Flood—Hydrologic Event | No |
| CT00662 | Leesville Dam | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CT00427 | Pratt Read | 6/4/1982 | Erosion | Unknown |
| IDS00009 | Cameron Dam | 4/24/1982 | Inflow Flood—Hydrologic Event | Yes |
| IDS00008 | Howard Dam | 4/24/1982 | Inflow Flood—Upstream Dam Failure | Yes |
| CTS00017 | Whalebone Creek Pond (CT 1024) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00016 | Upper Pond (CT 433) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00015 | Mansure Pond (CT 517) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00014 | Main Street Pond (CT 880) | 6/4/1982 | Inflow Flood—Hydrologic Event | Unknown |
| CTS00013 | Lower Mill Pond (CT 1190) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00012 | Lower Pond (CT 1512) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00011 | Ivoryton Pond (CT 882) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00010 | Forman Pond | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00009 | Falls River Pond (CT 884) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00023 | Abbott Pond (CT 774) | 6/4/1982 | Inflow Flood—Hydrologic Event | Unknown |
| CTS00022 | Dennison Road Pond (CT 1504) | 6/4/1982 | Inflow Flood—Hydrologic Event | Unknown |
| CTS00021 | Dolan Pond (CT 883) | 6/4/1982 | Inflow Flood—Hydrologic Event | Unknown |
| CTS00020 | Hunts Brook Dam | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CTS00019 | Mile Creek Pond (CT 1191) | 6/4/1982 | Inflow Flood—Hydrologic Event | Unknown |
| CTS00018 | Shady Brook Pond (CT 846) | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CT00423 | Mill Pond | 6/4/1982 | Inflow Flood—Hydrologic Event | Yes |
| CT00404 | Deer Lake | 6/1982 | Inflow Flood—Hydrologic Event | Yes |
| CT00339 | Johnson Pond | 6/4/1982 | Inflow Flow—Hydrologic Event | Yes |
| COS00005 | Cascade Lake Dam | 7/15/1982 | Inflow Flow—Hydrologic Event | Yes |
| MNS00002 | Fishhook River Dam Cofferdam | 10/1983 | Seepage | No |
| MS01738 | Lakeview Reservoir Dam | 11/27/1983 | Not Known | Yes |
| UT00080 | Dmad | 6/23/1983 | Not Known | Unknown |
| WAS00010 | Peters Reservoir No. 2 | 3/10/1983 | Not Known | Yes |
| WAS00009 | Peters Reservoir No. 1 | 3/10/1983 | Not Known | Yes |
| NJS00062 | Unnamed Dam (NJS00062) | 1984 | Inflow Flood—Hydrologic | No |

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| WIS00003 | Grettum Flowage | 6/13/1984 | Inflow Flow—Hydrologic Event | Unknown |
| VTS00015 | Halls Lake | 5/31/1984 | Piping | Yes |
| VTS00014 | Laraway | 6/7/1984 | Inflow Flow—Hydrologic Event | Yes |
| VTS00013 | Wards Pond | 6/7/1984 | Inflow Flow—Hydrologic Event; Piping | Yes |
| VT00081 | North Montpelier Pond | 6/7/1984 | Inflow Flow—Hydrologic Event | Yes |
| UTS00001 | Doty-Tex Johnson (Utah) | 4/12/1984 | Inflow Flow—Hydrologic Event | Yes |
| TX05119 | Bass Haven Lake Dam | 8/17/1984 | Embankment Erosion | Yes |
| TNS00017 | Unnamed Dam on Del Rio Creek | 5/6/1984 | Piping | Yes |
| TNS00011 | Shangri La Lake | 9/1984 | Sliding | No |
| SD00695 | Dimock | 6/20/1984 | Inflow Flow—Hydrologic Event | Yes |
| CTS00004 | Haas Pond Dam | 5/20/1984 | Piping | Yes |
| NE02138 | Merlyn Schrunk Dam | 4/1984 | Inflow Flow—Hydrologic Event | Yes |
| NES00003 | Atkinson Reservoir | 4/8/1984 | Spillway Failure | No |
| MTS00006 | Brownes Lake | 6/20/1984 | Plugged Spillway | Yes |
| IL00712 | Riverview Dam | 11/21/1985 | Seepage | Yes |
| MO31374 | Richardet Dam | 12/1985 | Seepage; Embankment Slide | Yes |
| WI00726 | Port Wing | 9/1/1985 | Inflow Flow—Hydrologic Event | Yes |
| OK00663 | Scs-Upper Red Rock Creek Site–20 | 10/3/1986 | Seepage; Piping | Yes |
| OK11073 | Cedar Lake | 11/8/1986 | Not Known; Seepage; Piping | Yes |
| WA00074 | Upriver Dam | 5/20/1986 | Gate Closure | Yes |
| VTS00012 | Noonan | 1986 | Piping | Yes |
| UT00301 | Trial Lake | 6/7/1986 | Seepage; Piping | Yes |
| PAS00005 | Unnamed Dam (PAS00005) | 1986 | Not Known | No |
| TNS00014 | Demery's Lake | 4/1986 | Inflow Flood—Hydrologic Event | Yes |
| MI00209 | Barryton Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MI00573 | Danaher Lake Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MI00616 | Rainbow Lake Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MIS00001 | Bruce Nordland Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| NE00492 | Haeker Dam | 8/1986 | Inflow Flood—Hydrologic Event | Yes |
| ND00426 | Simpson Dam; Alvin | 7/17/1986 | Inflow Flood—Hydrologic Event; Seepage; Piping | Yes |
| MIS00004 | Childsdale Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MIS00003 | Cat Creek Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MIS00002 | Carson City Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MI00678 | Hesperia Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MI00574 | Luther Pond Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MI00526 | White Cloud Dam | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| MI00281 | Hart Lake | 9/10/1986 | Inflow Flood—Hydrologic Event | Yes |
| OK20844 | Scs—Little Washita River Site–13 | 9/1987 | Piping | Yes |
| TNS00008 | Tomkins Lake | 12/25/1987 | Inflow Flood—Hydrologic | Yes |
| TNS00009 | Sky Lake No. 1 | 12/24/1987 | Piping | Yes |
| TN10305 | Rebecca Lake | 12/25/1987 | Inflow Flood—Hydrologic Event | No |
| WI00638 | Bog Brook | 5/1988 | Inflow Flood—Hydrologic Event; Animal Attack | Yes |
| WI00330 | Bischel | 3/1988 | Piping | Yes |
| UT00514 | Quail Creek | 12/31/1988 | Seepage; Piping; Embankment Erosion | Yes |
| MO31923 | Marschke Lake Dam | 4/19/1988 | Not Known | Yes |
| MTS00002 | Hein Coulee Structure (Lower Birch Creek Watershed) | 7/6/1988 | Piping | Yes |
| KYS00005 | Unnamed Dam (KYS00005) | 1989 | Inflow Flood—Hydrologic Event | Yes |
| MNS00004 | Unnamed Dam (MNS00004) | 1989 | Embankment Failure | No |
| MNS00005 | Unnamed Dam (MNS00005) | 1989 | Embankment Failure | No |
| NC02149 | Evans Dam | 9/15/1989 | Not Known | Yes |
| NC02152 | Lockwood Dam | 9/15/1989 | Not Known | Yes |
| MNS00006 | Unnamed Dam (MNS00006) | 1989 | Embankment Failure | No |
| MNS00007 | Unnamed Dam (MNS00007) | 1989 | Embankment Failure | No |

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| NJS00014 | Holmdel Park Dam | 7/1989 | Inflow Flood—Hydrologic Event; Seepage; Piping | Yes |
| NYS00015 | Unnamed Dam (NYS00015) | 1989 | Not Known | Unknown |
| TNS00010 | Southern Clay Company Dam No. 2 | 9/8/1989 | Piping | Yes |
| ORS00004 | Avion Water District | 1989 | Faulty Design and Construction | Yes |
| TNS00018 | Summit Landfill Dam | 9/29/1989 | Inflow Flood—Hydrologic Event | Yes |
| TNS00025 | Summit Landfill | 10/1/1989 | Inflow Flood—Hydrologic Event | Yes |
| TX03546 | Nix Lake Dam | 3/29/1989 | Inflow Flood—Hydrologic Event | Yes |
| TNS00019 | Unnamed Dam (TNS00019) | 6/23/1989 | Inflow Flood—Hydrologic Event | Yes |
| OH00575 | Acton Lake Dam | 1990 | Drain Gate Failure | No |
| VAS00006 | Cockram Mill Dam | 7/14/1990 | Inflow Flood—Hydrologic Event | Yes |
| VT00217 | Beaver Pond | 7/23/1990 | Inflow Flood—Hydrologic Event | Yes |
| VTS00011 | Eight Trout Club | 3/15/1990 | Piping | Yes |
| WAS00015 | Unnamed Dam (WAS00015) | 11/1990 | Inadequate Spillway Capacity | Yes |
| WI00191 | Leland | 6/1990 | Inflow Flood—Hydrologic Event | Yes |
| WA01707 | Chinook Water District Dam | 11/1990 | Inflow Flood—Hydrologic Event; Inadequate Spillway Capacity | Yes |
| VTS00010 | Riddel Pond | 5/1990 | Piping | Yes |
| SCS00005 | Unnamed Dam (SCS00005) | 7/18/1990 | Piping | Yes |
| SC02298 | Brewer Gold Company Dam 1 | 10/10/1990 | Not Known | Yes |
| SC00459 | Kendall Lake Dam | 10/10/1990 | Inflow Flood—Hydrologic Event | Yes |
| AL00539 | Caddis Lake Dam | 1990 | Inflow Flood—Hydrologic Event | No |
| ALS00006 | Campbell | 1990 | Inflow Flood—Hydrologic Event | Yes |
| ALS00007 | Unnamed Dam (ALS00007) | 1990 | Inflow Flood—Hydrologic Event | Yes |
| NE02363 | Timperley Wildlife Res | 12/1990 | Animal Attack | Yes |
| NC03195 | Landrum Lake Dam(Failer) | 2/16/1990 | Structural Failure | Yes |
| MOS00004 | St. Joe State Park Sediment Impoundment | 2/15/1990 | Inflow Flood—Hydrologic Event; Inadequate Spillway Capacity | Yes |
| MO20145 | Christiansen Lake Dam | 5/1990 | Embankment Erosion | Yes |
| MO12279 | Hester Lake Dam | 6/27/1990 | Not Known | Yes |
| IL50319 | Wilmington Dam (Kankakee River Mill Race Dam) | 6/1990 | Not Known | Yes |
| IL50233 | Lake Carroll Sedimentation Pond 2 Dam | 5/1990 | Inflow Flood—Hydrologic Event | Yes |
| IDS00002 | Kirby Dam (Manns Lake; Atlanta Dam) | 7/9/1990 | Not Known; Seepage; Embankment Erosion | Yes |
| ALS00008 | Unnamed Dam (ALS00008) | 1990 | Inflow Flood—Hydrologic Event | Yes |
| NCS00039 | Unnamed Dam (NCS00039) | 4/29/1991 | Not Known | Yes |
| NHS00006 | Unnamed Dam (NHS00006) | 8/8/1991 | Seepage | Yes |
| NYS00009 | Unnamed Dam (NYS00009) | 1991 | Not Known | Unknown |
| TX00309 | Lake Center Dam | 8/4/1991 | Not Known | Yes |
| SCS00002 | Upper Twin Lake Dam | 8/2/1991 | Inflow Flood—Hydrologic Event | Yes |
| SCS00001 | Lower Twin Lakes Dam | 8/2/1991 | Inflow Flood—Upstream Dam Failure | Yes |
| RIS00003 | Unnamed Dam (RIS00003) | 1991 | Not Known | Unknown |
| RIS00002 | Unnamed Dam (RIS00002) | 1991 | Not Known | Unknown |
| RI04258 | Burton Pond Dam | 1991 | Concrete Deterioration | Yes |
| NYS00010 | Unnamed Dam (NYS00010) | 1991 | Not Known | Unknown |
| NYS00011 | Unnamed Dam (NYS00011) | 1991 | Not Known | Unknown |
| NYS00012 | Unnamed Dam (NYS00012) | 1991 | Not Known | Unknown |
| NYS00014 | Unnamed Dam (NYS00014) | 1991 | Not | Unknown |
| NYS00013 | Unnamed Dam (NYS00013) | 1991 | Not | Unknown |
| WVS0005 | Unnamed Dam (WVS00005) | 1991 | Inflow Flood—Hydrologic Event | Unknown |
| WAS00001 | Seminary Hill Reservoir, City of Centralia | 10/5/1991 | Landslide; Seepage; Concrete Deterioration | Yes |
| VTS00009 | Swanson | 4/1991 | Piping | Yes |
| NJ00541 | Port Republic dam | 1992 | Inflow Flood—Hydrologic Event | Yes |
| OK01437 | Scs-Upper Black Creek Site–62 | 1992 | Inflow Flood—Hydrologic Event | No |
| WY00037 | Wyoming Hereford Ranch No. 2 | 1992 | Not Known | Yes |

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| WI00468 | La Blonde | 7/1992 | Inflow Flood—Hydrologic Event; Debris-Reservoir | Yes |
| NV00024 | Bilk Creek Res | 1992 | Inflow Flood—Hydrologic | Yes |
| MDS00001 | Black Rock Estates Pond | 4/21/1992 | Inflow Flood—Hydrologic Event; Piping | Yes |
| MOS00015 | Unnamed Dam (MOS00015) | 6/5/1992 | Erosion | Yes |
| COS00007 | Greeley | 1/1993 | Animal Burrows | Yes |
| NE01419 | Krone Dam | 1993 | Inflow Flood—Hydrologic Event | Yes |
| ND00107 | Jund (Zeeland) Dam | 7/16/1993 | Inflow Flood—Hydrologic Event; Biological Attack (i.e. bush, tree growth); Embankment Erosion; Inadequate Spillway Capacity | Yes |
| MOS00002 | Norman Swinney's Dam | 5/26/1993 | Inadequate Compaction | Yes |
| MO32026 | Freddies Lake Dam | 9/26/1993 | Inflow Flood—Hydrologic Event | Yes |
| MO31996 | Boyd Lake Dam | 9/25/1993 | Embankment Slide | Yes |
| MO31526 | Bockelman Lake Dam | 7/1993 | Inflow Flood—Hydrologic Event | Yes |
| MO12370 | Harrison County Lake | 1/3/1993 | Inflow Flood—Hydrologic Event | Yes |
| MO10107 | Stevens Lake Dam | 6/1993 | Inflow Flood—Hydrologic Event | Yes |
| MD00330 | Annapolis Mall Swm Pond | 3/4/1993 | Inflow Flood—Hydrologic Event | Yes |
| OHS00002 | Middletown Hydraulic Dam | 5/13/1993 | Undermining | Yes |
| WI00112 | Rock | 6/20/1993 | Inflow Flood—Hydrologic Event | Yes |
| WI00158 | Briggsville | 3/23/1993 | Reconstruction | Yes |
| WI12788 | Hatfield Headrace | 7/20/1993 | Inflow Flood—Hydrologic Event | Yes |
| WI10130 | Lake Family | 4/23/1993 | Inflow Flood—Hydrologic Event | Yes |
| WI01073 | Fairchild | 6/1993 | Inflow Flood—Hydrologic Event | Yes |
| WI00154 | Partridge Lake | 1/1993 | Piping | Yes |
| WI00035 | Cambria | 6/26/1993 | Inflow Flood—Hydrologic Event; Gate Misoperation | Yes |
| OHS00005 | Unnamed Dam (OHS00005) | 1993 | Inflow Flood—Hydrologic Event | Unknown |
| OHS00004 | Unnamed Dam (OHS00004) | 1993 | Inflow Flood—Hydrologic Event | Unknown |
| WI00016 | Hatfiled | 6/18/1993 | Inflow Flood—Hydrologic Event; Seepage; Piping; Gate Structural Failure | Yes |
| WA00408 | Iowa Beef Processors Waste Pond No. 1 | 1/25/1993 | Inflow Flood—Hydrologic Event; Animal Attack; Seepage; Inadequate Spillway Capacity | Yes |
| OHS00003 | Unnamed Dam (OHS00003) | 1993 | Inflow Flood—Hydrologic Event | Unknown |
| NV10311 | Buckskin Tailings | 9/12/1994 | Earthquake | No |
| WI00791 | Ladysmith | 9/15/1994 | Inflow Flood—Hydrologic Event | Yes |
| WI00502 | Gomulak And Profit | 9/16/1994 | Inflow Flood—Hydrologic Event | Yes |
| WA00063 | Sherry Lake Dam | 1994 | Inflow Flood—Hydrologic Event | Yes |
| VT00035 | Newport No. 11 Diversion Dam | 5/1/1994 | Inflow Flood—Hydrologic Event; Embankment Erosion | Yes |
| TX04210 | Cade Lake Number 3 Dam | 1994 | Inadequate Spillway Capacity | Yes |
| TX03916 | Bearfoot Lake Dam | 1994 | Spillway Failure | No |
| TX03876 | Lake Tinkle Dam | 1994 | Spillway Failure | Yes |
| WI10532 | Eleva Roller Mill | 3/26/1994 | Piping; Biological Attack (i.e. bush, tree growth) | Yes |
| SC00167 | Lake Pauline Dam | 6/27/1994 | Inflow Flood—Upstream Dam Failure | Yes |
| SC00149 | Crystal Lake Dam | 6/27/1994 | Inflow Flood—Upstream Dam Failure | Yes |
| SC00142 | Saxe-Gotha Millpond Dam | 6/27/1994 | Inflow Flood—Hydrologic Event; Gate Misoperation | Yes |
| PA00899 | Fishpond | 4/28/1994 | Concrete Deterioration | Yes |
| PA00780 | Arrowhead Lake | 4/26/1994 | Piping | Yes |
| OH00355 | Invex of Ohio Upper Lake Dam | 8/13/1994 | Inflow Flood—Hydrologic Event | Yes |
| OH00088 | Chopper's Lake Dam | 4/10/1994 | Inflow Flood—Hydrologic Event | Yes |

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| FLS00001 | IMC–AGRICO Hopewell Mine | 11/19/1994 | Inflow Flood—Hydrologic Event; Seepage; Piping | Yes |
| GA00211 | Gibson—Cary Development Corp Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA00238 | Houston Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA00239 | Mossy Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA00287 | Giles Lake Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA00831 | Grisp County (Warwick) | 7/9/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA02902 | Holoka Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA02899 | Mulkey Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA02746 | Whatley Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA02744 | Rustins Pond Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA02743 | Hortmans Pond Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA02677 | Goose Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01679 | McGill Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01419 | Philema Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01070 | Phillips Pond Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03574 | Lies Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03572 | Coffin Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03571 | Wolhwender Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03568 | Shellhouse Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03567 | Merritt Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03540 | Lake Yohola Dam | 7/7/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03527 | McKemie Lake North Dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03526 | McKemie Lake Dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03203 | Thomas Millpond Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00005 | Cordrays Pond Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00004 | City of Senoia Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00003 | Birch Creek Farms | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00002 | Baker/Austin Pond Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00001 | 6 acre lake on Forrest Road | 7/8/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA04987 | Suggs Millpond | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00086 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00085 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00084 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00083 | Unnamed small dam S of US 27 By-Pass & Webster St. | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00082 | Unnamed small dam 2 miles SW of Cuthbert | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00081 | Unnamed small dam 3 miles S of Cuthbert, u/s of US | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00080 | Unnamed small dam SE of County Rds. #134 & #152 | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00079 | Unnamed small dam SE of County Rds. #134 &152 | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00078 | Unnamed small dam on Collins Mill Creek | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00077 | Unnamed small dam north of Bethlehem Church | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00076 | Unnamed small dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00075 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00074 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00073 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00072 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00071 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00070 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00069 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00068 | Unnamed small dam 1 mile NW of Buena Vista Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00067 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| GAS00066 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00065 | Unnamed dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00064 | Unnamed dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00063 | Unnamed small dam west of SR 214, north of SR26 | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00062 | Unnamed small dam west of SR 128 | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00061 | Unnamed small dam at RR, SE of Montezuma | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00060 | Unnamed small dam on Meadow Creek | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00059 | Unnamed small dam 1 mile SW of Marshallville | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00058 | Unnamed small dam 1 mile E of Marshallville Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00057 | Unnamed small dam on Gin Creek, west of Flint River | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00056 | Unnamed dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00055 | Unnamed dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00054 | Unnamed dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00053 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00052 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00051 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00050 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00049 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00048 | Unnamed small dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00047 | Unnamed small dam | 7/14/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00046 | Unnamed small dam 1 mile east of Felder Lake Dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00045 | Unnamed small dam 1.5 miles NW of Sutton's Corner | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00044 | Unnamed small dam 2 miles SE of Bluffton | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00043 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00042 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00041 | Underwood Millpond Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00040 | Thorton Place Pond Dam | 7/14/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00039 | Taylor's Mill Pond Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00038 | Swearingen Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00037 | Small Rovoli Lake Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00036 | Small Lake above Double "O" Ranch | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00035 | Shofill Lake Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00034 | Scout Lake Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00033 | Rockhill Lake Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00032 | Parish Lake Dam South | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00031 | Owens Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00030 | Old Farm Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00029 | Minor's Millpond Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00028 | McNeil Lake Dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00027 | McMath Millpond Upper | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00026 | McMath Millpond Lower | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00025 | Lower Leisure Lake Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00024 | Loki Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00023 | Levee @ Macon | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00022 | Lamar County Reservoir Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00021 | Lake Jennifer Upper | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00020 | Lake Jennifer Lower | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00019 | Lake Corinth Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00018 | Iris "B" Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00017 | Hutcheson Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00016 | Housers Millpond Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| GAS00015 | Harell Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00014 | Hancock | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| NE00419 | Waterman Dam | 8/1994 | Inflow Flood—Hydrologic Event | Yes |
| NE00212 | Morgan Dam | 1994 | Inflow Flood—Hydrologic Event | Yes |
| IL50330 | East Peoria Dredge Disposal Facility | 11/11/1994 | Seepage; Piping | Yes |
| GAS00210 | Unnamed Dam (GAS00210) | 1994 | Flood | Yes |
| GAS00183 | Williamson Downs Lake Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00182 | Wells Millpond Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00181 | Wainwright Lake Dam (2) | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00180 | Wainwright Lake Dam (1) | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00179 | Vinny Mill Pond Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00178 | Upper & Lower Marimac | 7/8/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00177 | Upper Jackson north of County Road #152 | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00176 | Upper Iris “A” | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00175 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00174 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00173 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00172 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00171 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00170 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00169 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00168 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00167 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00166 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00165 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00164 | Leverett Pond Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00163 | Unnamed small dam within city limits of Weston | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00162 | Unnamed small dam 1.5 miles NE of Weston | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00161 | Unnamed small dam N of County Rd #18, E of PBS tower | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00160 | Unnamed small dam N of County Rd #18, E of PBS tower | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00159 | Unnamed small dam just upstream of Kennedy | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00158 | Unnamed small dam upstream of Holoka Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00157 | Unnamed small dam North of Bear Creek | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00156 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00155 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00154 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00153 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00152 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00151 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00150 | Unnamed small dam 1/2 mile U/S SR 45 on Mossy Creek | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00149 | Unnamed small dam above Taylor Mill Pond Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00148 | Unnamed small dam above Taylor Mill Pond Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00147 | Unnamed small dam above Taylor Mill Pond Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00146 | Unnamed small dam above Taylor Mill Pond Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00145 | Unnamed small dam, Bottsford quad in draw, E. of T | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| GAS00144 | Unnamed small dam above Tharpe Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00143 | Unnamed dam in NW part of Sumeter County | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00142 | Unnamed dam in NW part of Sumter County | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00141 | Unnamed small dam 1m. SW of Powell Dairy Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00140 | Unnamed small dam NW of Plains | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00139 | Unnamed small dam 0.75 miles SW of Lake Collins | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00138 | Unnamed small dam below Kornonia Lake | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00137 | Unnamed small dam below Kornonia Lake | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00136 | Unnamed small dam below Kornonia Lake | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00135 | Unnamed small dam 1 mile west of Americus | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00134 | Unnamed small dam 1 mile north of Americus | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00133 | Unnamed small dam 1 mile east of Americus | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00132 | Unnamed small dam S. of SR27, 1 mile E. of Americus | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00131 | Unnamed dam in Americus | 7/9/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00130 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00129 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00128 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00127 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00126 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00125 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00124 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00123 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00122 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00121 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00120 | Unnamed dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00119 | Unnamed dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00118 | Unnamed dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00117 | Unnamed dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00116 | Unnamed dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00115 | Unnamed dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00114 | Unnamed small dam south of Gussie Lake Dam | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00113 | Unnamed dam 1 mile north of Union | 9/12/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00112 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00111 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00110 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00109 | Unnamed small dam upstream of Wolhwender | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00108 | Unnamed small dam SW of intersect. Of US #19 & SR 2 | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00107 | Unnamed small dam S of Ebenezer Rd on Little Mucka | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00106 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00105 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00104 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00103 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00102 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| GAS00101 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00100 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00099 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00098 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00097 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00096 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00095 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00094 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00093 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00092 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00091 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00090 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00089 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00088 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00087 | Unnamed small dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00013 | Goodroe Lake Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00012 | Goffs Mill Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00011 | Free Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00010 | Fountain Lake Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00009 | Forbes Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00008 | Ferguson Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00007 | English Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GAS00006 | Edgemon | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA04904 | Andrews Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA04832 | Silberman Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA04765 | Harper Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA04764 | Yara Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA04763 | Pace Lake Dam South | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA04712 | Kennedy Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA04537 | West Leisure Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03189 | Pace Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03188 | Esperanza Farms Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03187 | Tharpe Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03186 | Reeves Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03042 | Horsehead Creek Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03041 | Whitewater Creek Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03018 | Flat Creek Lake Dam | 6/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA03017 | Kersey Lake Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01067 | Cloud Lake Dam | 8/17/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01050 | Barnesville Reservior Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01029 | Hicks Millpond Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01019 | Garant Lake Dam | 7/21/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA00835 | Flint River | 7/7/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01417 | Statham Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01412 | Browns Millpond Lake Dam | 7/9/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01411 | Shipp Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01410 | Able Acres Lake Dam | 7/29/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01364 | Tyrone Lake Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01235 | Kraftsmans Association Lake Dam | 7/5/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA01193 | McKnight Lake Dam | 7/6/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA00289 | Lake Clopine Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| GA00242 | Wilkinson Lake Dam | 8/30/1994 | Inflow Flood—Hydrologic Event | Yes |
| CO00390 | Frenchman Creek | 6/4/1995 | Piping | Yes |
| MI00109 | Barnes Dam | 5/29/1995 | Inflow Flood—Hydrologic Event | Yes |
| MS03334 | Lake Gary Dam | 9/1995 | Seepage; Piping | Yes |
| NC01137 | Lake Lynn Dam | 6/19/1995 | Inflow Flood—Hydrologic Event; Piping | Yes |
| NC04944 | Jaycees Pond Dam | 6/19/1995 | Inflow Flood—Hydrologic Event; Seepage | Yes |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| NCS00004 | McReady Chicken Waste Lagoon Dike | 7/5/1995 | Not Known | Yes |
| NHS00001 | Willey House Dam | 10/28/1995 | Inflow Flood—Hydrologic Event | Unknown |
| ND00339 | Appert | 7/15/1995 | Inflow Flood—Hydrologic Event; Seepage | Yes |
| NCS00013 | Unnamed small dam | 6/19/1995 | Inflow Flood—Hydrologic Event | Yes |
| NCS00011 | Southern Pines Country Club Golf Course Dam 3 | 7/1995 | Inflow Flood—Hydrologic Event | Yes |
| NSC00010 | Southern Pines Country Club Golf Course Dam 2 | 7/1995 | Not Known | Yes |
| NCS00009 | Southern Pines Country Club Golf Course Dam 1 | 7/1995 | Inflow Flood—Hydrologic Event | Yes |
| NCS00007 | Reedy Swine Farm Lagoon Dike | 7/18/1995 | Rupture | Yes |
| NCS00003 | Lancaster Dam | 6/26/1995 | Inflow Flood—Hydrologic Event | Yes |
| NC02159 | Moose Lodge Dam | 6/19/1995 | Inflow Flood—Hydrologic Event | Yes |
| MT03839 | Eureka Holding Pond Dike | 7/8/1995 | Piping | Yes |
| CO01967 | Vincent No. 2 | 6/9/1995 | Inflow Flood—Hydrologic Event | Yes |
| ID00151 | Troy | 2/5/1995 | Seepage; Piping | Yes |
| NJ00408 | Kenilworth Lake Dam | 1/18/1995 | Partial Dam Breach | Yes |
| WY02028 | Cottonwood | 7/1995 | Not Known | Unknown |
| WI12794 | Hazel Lake | 12/15/1995 | Piping | Yes |
| WI00092 | Mount Morris Dam | 8/29/1995 | Inflow Flood—Hydrologic Event; Inflow Flood—Upstream Dam Failure; Seepage; Piping | Yes |
| WAS00002 | CSC Orchards, Frost Protection Pond | 7/1995 | Seepage; Piping | Yes |
| VT00182 | Wolcott Pond | 8/5/1995 | Inflow Flood—Hydrologic Event | Yes |
| VA03102 | Timber Lake Dam | 6/22/1995 | Inflow Flood—Hydrologic Event | Yes |
| NV00051 | Boyd Reservoir | 1/1995 | Piping | Yes |
| NV00070 | Milk Ranch Dam | 7/8/1995 | Inflow Flood—Hydrologic Event; Embankment Erosion | Yes |
| NJS00001 | Mendham Reservoir Dam | 4/1996 | Piping | Yes |
| PA00422 | Brookville Waterworks | 7/19/1996 | Inflow Flood—Hydrologic Event; Embankment Erosion | Yes |
| TNS00001 | Dillard Dam | 12/17/1996 | Inflow Flood—Hydrologic Event | Yes |
| WA01045 | Olufson Dam | 12/11/1996 | Seepage | No |
| WV07719 | Bruceton Mills Dam | 1/19/1996 | Inflow Flood—Hydrologic Event | Yes |
| WI10386 | Hamilton Mill | 4/20/1996 | Seepage | Yes |
| WI01102 | Vernon Marsh-Ref. Flowage | 5/19/1996 | Piping | Yes |
| WI00450 | Cranberry Creek | 4/21/1996 | Not Known; Piping | Yes |
| WA01782 | Boeing Creek North Stormwater Pond | 12/31/1996 | Inadequate Spillway Capacity | Yes |
| WA01406 | Yelm Diversion | 2/7/1996 | Inflow Flood—Hydrologic Event | Unknown |
| VTS00008 | Rinse | 6/14/1996 | Piping | Yes |
| TX07035 | Casa Monte Dam | 11/26/1996 | Inflow Flood—Hydrologic Event | Yes |
| TX01961 | Roberts Tank Dam | 7/14/1996 | Inflow Flood—Hydrologic Event | Yes |
| TN15768 | Mallard Lake | 11/3/1996 | Animal Attack; Piping; Embankment Erosion; Embankment Slide | Yes |
| CO01122 | Henry | 4/10/1996 | Piping | Yes |
| KSS00002 | Speer Dam | 11/14/1996 | Inflow Flood—Hydrologic Event | Yes |
| NH00600 | Bergerson Dam | 3/13/1996 | Piping | Yes |
| MT01173 | Canyon Lake | 7/1/1996 | Inflow Flood—Hydrologic Event | Yes |
| MI00876 | Hollenbeck Dam | 1996 | Inflow Flood—Hydrologic Event | Yes |
| ME00072 | Highland Lake Dam | 10/20/1996 | Inflow Flood—Hydrologic Event | Yes |
| KSS00001 | Decker Dam | 1996 | Inflow Flood—Hydrologic Event | Yes |
| IL00918 | Aurora-West Dam | 7/17/1996 | Inflow Flood—Hydrologic Event | Yes |
| IL01110 | Puddle Pond Dam | 7/17/1996 | Inflow Flood—Hydrologic Event | Yes |
| IL50394 | Channahon Dam | 7/17/1996 | Inflow Flood—Hydrologic Event | Yes |
| AZ00187 | Udall | 8/11/1997 | Piping | Yes |
| AZS00003 | Centennial Narrows Dam | 9/26/1997 | Inflow Flood—Hydrologic Event; Piping | Yes |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| AZS00001 | Middle Goose Tailings Dam (No. 2 Tailings Impoundment) | 10/21/1997 | Liquefaction Failure | Yes |
| NE00695 | Scott Dam | 4/7/1997 | Inflow Flood—Hydrologic Event | Yes |
| MTS00001 | Anita Dam | 3/26/1997 | Piping | Yes |
| MO20164 | Lake Venita Dam | 2/21/1997 | Seepage; Piping | Yes |
| MI00496 | Hamilton Dam | 6/20/1997 | Inflow Flood—Hydrologic Event | Yes |
| ME00567 | Apple Valley Lake Dam | 4/16/1997 | Debris—Reservoir; Piping | Yes |
| MA00376 | East Head Pond Dam | 1997 | Not Known; Seepage; Piping | Yes |
| GA04975 | Forsyth Reservoir | 12/24/1997 | Inflow Flood—Hydrologic Event; Seepage; Piping; Concrete Deterioration | Yes |
| FLS00003 | Ridgewood Avenue Dam (Lake Apopka Dam) | 11/27/1997 | Not Known; Seepage; Piping | No |
| FLS00002 | RGC Minerals Containment | 4/27/1997 | Inflow Flood—Hydrologic Event | Yes |
| NJ00716 | Moss Mill Lake Dam | 8/20/1997 | Inflow Flood—Hydrologic Event | Yes |
| NJS00009 | Stockton College Dam | 8/20/1997 | Inflow Flood—Hydrologic Event | Yes |
| NJS00006 | Tarkiln Pond Dam (Route 548 Dam) | 8/20/1997 | Inflow Flood—Hydrologic Event | Yes |
| WA01377 | Horn Rapids Dam | 2/1997 | Inflow Flood—Hydrologic Event | Yes |
| WA00133 | Wishkah Reservoir No. 2 Dam | 3/19/1997 | Inflow Flood—Hydrologic Event; Seepage; Piping | Yes |
| VTS00007 | Sibley | 1997 | Spillway Failure | Yes |
| TX02021 | Holland Dam Site A | 1/1/1997 | Piping | Yes |
| TNS00003 | Patton | 3/1/1997 | Inflow Flood—Hydrologic Event | Yes |
| TNS00002 | Mullens Farm Pond | 3/5/1997 | Inflow Flood—Hydrologic Event | Yes |
| TN11306 | Johnson Ck #4 | 3/1/1997 | Inflow Flood—Hydrologic Event | Yes |
| SD00025 | Woodruff (Breached 1997) | 3/22/1997 | Inflow Flood—Hydrologic Event | Yes |
| SC00377 | Starnes/Brown Dam | 7/24/1997 | Inflow Flood—Upstream Dam Failure | Yes |
| WI10610 | Linnie Lac Dam | 6/21/1997 | Inflow Flood—Hydrologic Event | No |
| WA01741 | Galbreath Sediment Dam | 1/18/1997 | Piping | Yes |
| SC00307 | Malcolm B. Rawls Dam | 7/24/1997 | Inflow Flood—Upstream Dam Failure | Yes |
| OH02964 | Green Acres Levee | 3/4/1997 | Inflow Flood—Hydrologic Event | Yes |
| OH02900 | Thomas Pond Dam | 3/1/1997 | Inflow Flood—Hydrologic Event | Yes |
| NY13600 | Henry Kaufman Pond Dam | 6/14/1997 | Inflow Flood—Hydrologic Event | Yes |
| NV00223 | Carson City Wastewater Dam | 10/30/1998 | Earthquake | No |
| ORS00002 | Lacomb Diversion | 5/11/1998 | Inflow Flood—Hydrologic Event | Yes |
| VTS00006 | Name Unknown | 1/7/1998 | Piping | Yes |
| VTS00005 | Sanville | 1/16/1998 | Inflow Flood—Hydrologic Event | Yes |
| VTS00004 | Name Unknown | 6/27/1998 | Inflow Flood—Hydrologic Event | Yes |
| VTS00003 | Name Unknown | 6/27/1998 | Inflow Flood—Hydrologic Event | Yes |
| VTS00002 | Clay Brook Water Supply | 6/27/1998 | Inflow Flood—Hydrologic Event | Yes |
| VTS00001 | Golf Course Pond | 6/27/1998 | Inflow Flood—Hydrologic Event | Yes |
| VT00241 | Sunset Lake | 8/11/1998 | Spillway Failure | Yes |
| VT00229 | Lake Runnemede | 7/18/1998 | Piping | Yes |
| TX01580 | Jan Land Company Lake No. 1 Dam | 10/1998 | Inflow Flood—Hydrologic Event | Yes |
| TN09910 | Johnson Lake | 7/13/1998 | Inflow Flood—Hydrologic Event; Inadequate Spillway Capacity | Yes |
| TN09902 | Bennett Lake | 7/13/1998 | Inflow Flood—Hydrologic Event | Yes |
| WA01756 | Klickitat Mill Pond Dam | 2/8/1998 | Fire | Yes |
| RI03201 | Peace Dale Pond Dam | 2/18/1998 | Inflow Flood—Hydrologic Event | Yes |
| NY00494 | Camp Weona Dam | 6/8/1998 | Inflow Flood—Hydrologic Event | Yes |
| NY13643 | Peru Water Supply Dam | 6/27/1998 | Inadequate Spillway Capacity | Yes |
| OH01978 | Bookhamer Lake Dam | 7/5/1998 | Spillway Failure | Yes |
| NY01539 | Gouldtown-Mill 5 West Channel | 1/7/1998 | Inflow Flood—Hydrologic Event | Yes |
| NY12015 | Natural Dam | 1/7/1998 | Inflow Flood—Hydrologic Event | Yes |
| CO00508 | Vertrees | 5/29/1998 | Piping | Yes |
| GA00084 | Little Ocmulgee Lake Dam | 3/11/1998 | Inflow Flood—Hydrologic Event | Yes |
| GAS00185 | Bay Meadows | 3/7/1998 | Inflow Flood—Hydrologic Event | Yes |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| GAS00188 | Pine Cove Pond Dam | 4/5/1998 | Inflow Flood—Hydrologic Event | Yes |
| GAS00191 | County Road 15 Dam | 3/8/1998 | Inflow Flood—Hydrologic Event | Yes |
| NC00725 | Ramseur Lake Dam | 2/19/1998 | Inflow Flood—Hydrologic Event | Yes |
| MS01402 | Archusa Crk Wtr Park Lk | 1/8/1998 | Inflow Flood—Hydrologic Event | Yes |
| JY00174 | Hematite | 6/11/1998 | Not Known; Seepage; Piping | Yes |
| GAS00189 | Boy Scout Camp Lake Dam | 2/2/1998 | Inflow Flood—Hydrologic Event; Embankment Erosion | Yes |
| GAS00186 | Not Named (Exempt) Dam | 3/7/1998 | Inflow Flood—Hydrologic Event | Yes |
| GA05053 | Big Sandy Plantation, Inc. Lake Dam | 2/2/1998 | Inflow Flood—Hydrologic Event | Yes |
| GA01826 | Southern States Lake Dam | 2/9/1998 | Seepage | Yes |
| CO00629 | Carl Smith | 5/2/1998 | Embankment Slide | Yes |
| FLS00004 | E.R. Jahna-Independent North Sand Mine Tailings | 7/2/1999 | Inflow Flood—Hydrologic Event; Piping | Yes |
| MD00074 | Nagels Mill Pond | 9/16/1999 | Piping | Yes |
| NCS00031 | Colee Naylor Pond Dam | 9/20/1999 | Inflow Flood—Hydrologic Event | Yes |
| NCS00029 | House Autry Mill Dam | 9/21/1999 | Inflow Flood—Hydrologic Event | Yes |
| NCS00022 | Hog Waste Lagoon Dike | 4/18/1999 | Sabotage—Other | Yes |
| NC03056 | Winkler Lake Dam Lower (Flat Rock Lakes) | 4/20/1999 | Seepage | Yes |
| NC01191 | Dubose Lake Dam | 9/21/1999 | Inflow Flood—Hydrologic Event | Yes |
| NC01084 | Hall Lake Dam | 9/21/1999 | Inflow Flood—Hydrologic Event | Yes |
| NC00946 | Kellys Pond Dam | 9/15/1999 | Inflow Flood—Hydrologic Event | Yes |
| MD00345 | Rolling Green Community Lake | 2/11/1999 | Piping | Yes |
| NH00598 | Nubble Pond Dam | 10/1/1999 | Not Known | Yes |
| NH00270 | Cold Brook | 10/1/1999 | Not Known | Yes |
| MD00342 | Not Known | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| MD00319 | Stubbs Farm Dam | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| MD00190 | Riley Mill Pond | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| MD00189 | Foreman Branch Dam | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| MD00170 | Jones Lake Dam | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| MD00152 | Lake Lanahan | 5/7/1999 | Inflow Flood—Hydrologic Event; Embankment Erosion | Yes |
| MD00149 | Tuckahoe State Park Dam | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| MD00098 | Frazers Dam | 9/15/1999 | Inflow Flood—Hydrologic Event | Yes |
| NJ00039 | Bostwicks Pond Dam | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| NHS00002 | Unregistered Dam (No Name) | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| MDS00003 | Stubbs | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| MD00025 | Sassafras Mill Dam | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| GAS00194 | Lake “Jimmy Carter” | 6/28/1999 | Inflow Flood—Hydrologic Event | Yes |
| MA00537 | Lake Bray Dam | 9/17/1999 | Inflow Flood—Hydrologic Event | Yes |
| MA01258 | J.B. Dunnell Dam | 9/17/1999 | Inflow Flood—Hydrologic Event | Yes |
| MA02531 | Veteran’s Memorial State Park Dam | 9/17/1999 | Inflow Flood—Hydrologic Event | Yes |
| IL50396 | Pittsfield Dredge Disposal Pond Dam | 4/29/1999 | Seepage; Piping | Yes |
| FLS00005 | Caloosa Sand Mine Reclamation Lake | 8/25/1999 | Inflow Flood—Hydrologic Event | Yes |
| NJ00565 | Lookover Lake Dam | 3/21/1999 | Embankment Erosion | Yes |
| NJ00634 | Kirbys Mill Dam | 9/16/1999 | Inflow Flood—Hydrologic Event | Yes |
| VAS00005 | Unnamed Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VAS00003 | Saddler Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VAS00002 | Unnamed Dam (at Williamsburg Country Club) | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA13303 | Sydnors Millpond Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA12709 | Old Forge Pond Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA11912 | Lower Rosegill Lake Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA11911 | Town Bridge Pond Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA11906 | Rosegill Upper Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA09704 | Allens Mill Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA09512 | Lake Powell Dam | 9/1999 | Inflow Flood—Hydrologic Event; Wind; Animal Attack; Biological Attack (i.e., bush, tree growth) | Yes |

*(Continued)*

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**Table 11A.13 (Continued)**

| NPDP ID | Dam Name | Incident Date | Incident Type | Dam Failure |
|---|---|---|---|---|
| VA07308 | Cypress Shores | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA07305 | Cow Creek Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| VA05707 | Essex Mill Dam | 9/1999 | Inflow Flood—Hydrologic Event | Yes |
| TNS00007 | Deer Creek | 7/1/1999 | Inflow Flood—Hydrologic Event | Yes |
| TNS00006 | Bent Tree Dam | 4/22/1999 | Piping | Yes |
| SD00536 | Covey Dam | 5/9/1999 | Inflow Flood—Hydrologic Event | Yes |
| SD00444 | W. Day | 9/3/1999 | Inflow Flood—Hydrologic Event | Yes |
| PAS00002 | Longo Pond Dam | 1/26/1999 | Inflow Flood—Hydrologic Event | Yes |
| OH02867 | Beldon Pond Lake Dam | 4/1999 | Piping | Yes |
| OH02795 | Crown City Mining Pond No. 24 Dam | 5/19/1999 | Inflow Flood—Hydrologic Event | Yes |
| NY13278 | Lake Hyenga Dam | 9/17/1999 | Inflow Flood—Hydrologic Event | Yes |
| NJS00028 | Spencer/Estates Detention Basin | 9/16/1999 | Piping | Yes |
| NY01345 | High Falls | 11/27/1999 | Concrete Spillway Cap | Yes |
| NJ00768 | Seneca Lake Dam | 8/12/2000 | Inflow Flood—Hydrologic Event | Yes |
| RI04389 | Mill Pond | 8/6/2000 | Embankment Erosion | Yes |
| WIS00002 | Chenowith Dam | 3/14/2000 | Not Known | Yes |
| TX09244 | Camp La Junta Dam | 10/23/2000 | Inflow Flood—Hydrologic Event | Yes |
| TX03797 | Powell Lake Dam | 3/22/2000 | Inflow Flood—Hydrologic Event | Yes |
| NY14821 | Murtha Pond Dam | 7/5/2000 | Inflow Flood—Hydrologic Event | Yes |
| NJS00046 | Furnace Pond Dam | 8/12/2000 | Inflow Flood—Hydrologic Event | Yes |
| NJS00050 | Edison Pond Dam | 8/12/2000 | Inflow Flood—Hydrologic Event | Yes |
| AK00144 | City Of Kake Dam | 7/24/2000 | Inflow Flood—Hydrologic Event | Yes |
| NJ00010 | Tomahawk Lake Dam | 8/12/2000 | Not Known | Yes |
| NHS00004 | Middle Pond | 6/7/2000 | Animal Attack; Inadequate Spillway Capacity | Yes |
| NH01364 | Mountain Lake | 1/7/2000 | Not Known | Yes |
| ND00540 | Grand Forks Co. Com. #1 | 6/12/2000 | Inflow Flood—Hydrologic Event | Yes |
| MS01687 | Ascalmore Creek Str Y-17a-11 | 4/4/2000 | Animal Attack | Yes |
| GAS00196 | Lott Dam | 9/18/2000 | Deterioration | Yes |
| ARS00001 | Ponca Dam | 6/2000 | Inflow Flood—Hydrologic Event | Yes |
| GA00459 | Pritchard Lake Dam | 3/16/2001 | Deterioration | Yes |
| GAS00203 | Ingles Shopping Center | 6/13/2001 | Inflow Flood—Hydrologic Event | Yes |
| IL01077 | Wardens Pond North Dam | 7/19/2001 | Not Known | Yes |
| NY16046 | Eagle Lake Dam | 7/16/2001 | Piping | Yes |
| TN03510 | HIll #1 | 2001 | Inflow Flood—Hydrologic Event | Yes |
| OR00467 | Smith River Lbr. Co. Pond | 5/31/2002 | Piping | Yes |
| RIS00006 | Sweet's Mill | 5/8/2002 | Biological Attack (i.e., bush, tree growth); Embankment Erosion) | Yes |
| WA83006 | Swift No 2 Hydroelectric Project | 4/21/2002 | Seepage; Piping | Yes |
| GAS00205 | Clarke Apple Orchard Lake Dam No. 1 | 12/24/2002 | Piping | Yes |
| MS01611 | Big Sand Creek Str Y-32-32 | 4/2002 | Not Known; Animal Attack; Piping | Yes |
| MN00486 | Wild Rice River | 6/2002 | Inflow Flood—Hydrologic Event | Yes |
| CA00724 | Las Tablas Cr | 3/17/2004 | Earthquake | |
| CA00812 | Nacimiento | 3/17/2004 | Earthquake | |
| CA00813 | San Antonio | 3/17/2004 | Earthquake | |
| CA10122 | El Piojo | 3/17/2004 | Earthquake | |
| CA10123 | Hughes | 3/17/2004 | Earthquake | |

*Note:* Number of Events Found: 680. Time period: 1979 to 2004; Incident: all; Dam type: all; Dam failure: all; State: all.

*Source*: From npdp.standford.edu. With permission.

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**Table 11A.14 Causes of Dam Incidents in the United States**

| | Type of Dam | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Concrete | | Embankment | | Other[a] | | Totals | | |
| **Cause** | **F** | **A** | **F** | **A** | **F** | **A** | **F** | **A** | **F&A** |
| Overtopping | 6 | 3 | 18 | 7 | 3 | | 27 | 10 | 37 |
| Flow erosion | 3 | | 14 | 17 | | | 17 | 17 | 34 |
| Slope protection damage | | | | 13 | | | | 13 | 13 |
| Embankment leakage, piping | | | 23 | 14 | | | 23 | 14 | 37 |
| Foundation leakage, piping | 5 | 6 | 11 | 43 | 1 | | 17 | 49 | 66 |
| Sliding | 2 | | 5 | 28 | | | 7 | 28 | 35 |
| Deformation | | 2 | 3 | 29 | 3 | | 6 | 31 | 37 |
| Deterioration | | 6 | 2 | 3 | | | 2 | 9 | 11 |
| Earthquake instability | | | | 3 | | | | 3 | 3 |
| Faulty construction | 2 | | | 3 | | | 2 | 3 | 5 |
| Gate failures | 1 | 2 | 1 | 3 | | | 2 | 5 | 7 |
| Total | 19 | 19 | 77 | 163 | 7 | | 103 | 182 | 285 |

*Note:* F, failure; A, accident (an incident where failure was prevented by remedial work or operating procedures, such as drawing down the pool).

[a] Steel, masonry-wood, or timber crib.

*Source*: From National Academy Press, 1983, Safety of Existing Dams: Evaluation and Improvement. Based on Schnitter, 1979, Lessons from Dam Incidents U.S.A., ASCE/USCOLD, and supplementary date supplied by U.S. Committee on Large Dams for period to 1979.

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## SECTION 11B RESERVOIRS

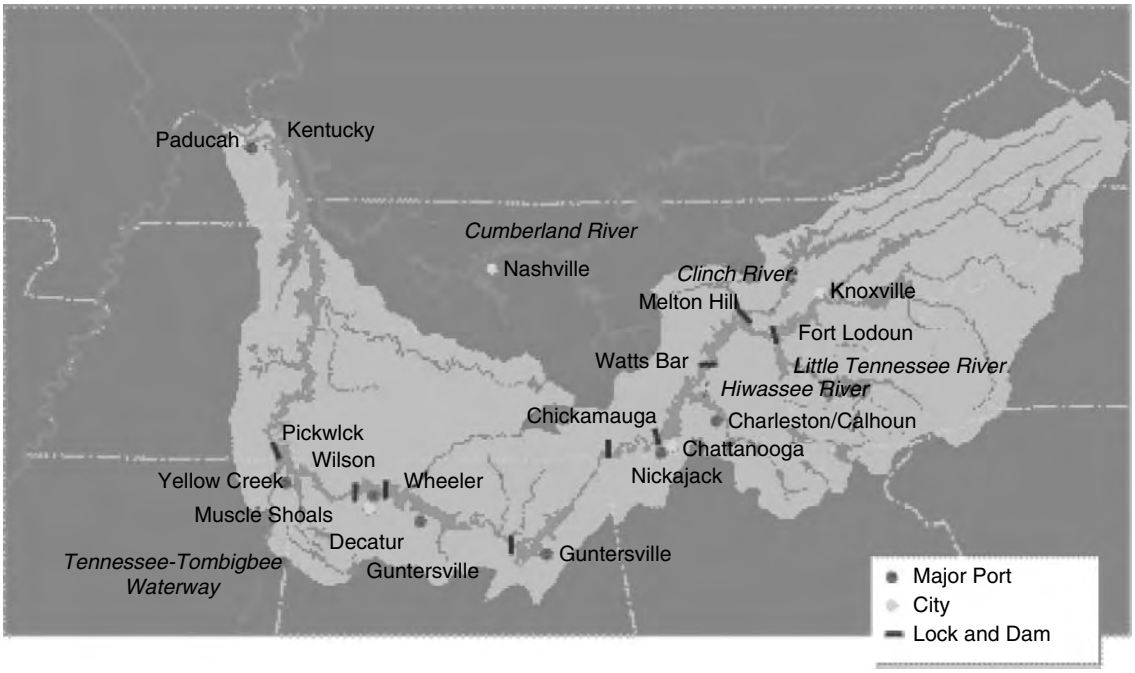


**Figure 11B.11** Route of the river. The Tennessee River's main navigable channel is 652 miles long. It officially begins a mile above Knoxville, Tennessee, and eventually empties into the Ohio River at Paducah, Kentucky. Commercial navigation also extends into three major tributaries: 61 miles up the Clinch River, 29 miles up the Little Tennessee River, and 21 miles up the Hiwassee River. Another 150 miles of channel—too shallow for commercial traffic—is marked for recreational use. (From www.tva.gov.)

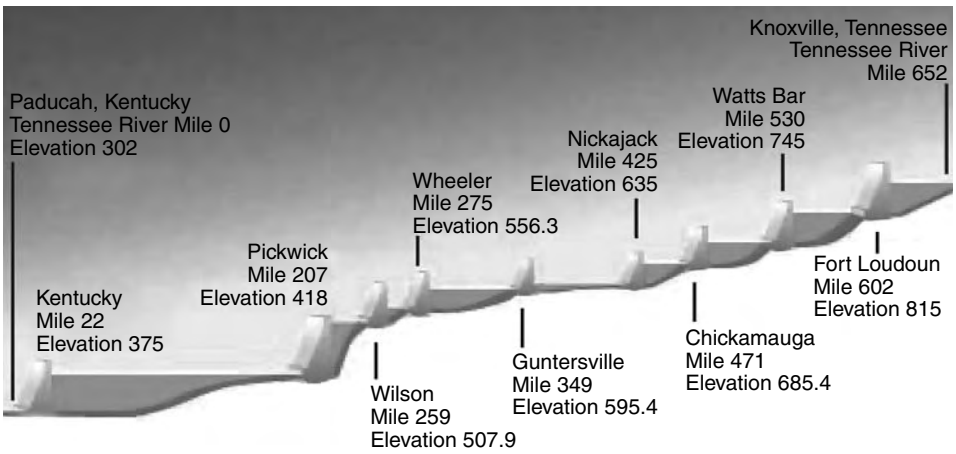


**Figure 11B.12** Tennessee river system. Nine main-river dams form a "staircase" of quiet, pooled water, and controlled current—a continuous series of reservoirs that stretches along the entire length of the Tennessee River. From its beginning just above Knoxville, the Tennessee drops a total of 513 ft in elevation before it empties into the Ohio River. (From www.tva.gov.)

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**Table 11B.15 The Tennessee Valley Authority Multipurpose Reservoir System**

The TVA reservoir system was designed to provide for navigation, flood control, and the production of hydroelectricity. Today the reservoir system is also operated for such other purposes as providing municipal and industrial water supplies, regulating flows to minimize the effects of effluents including thermal discharges, fluctuating water levels for control of mosquitos and troublesome aquatic vegetation, and controlling flows and levels for various recreational uses

This reservoir system encompasses more than 11,000 miles of shoreline and 600,000 acres of water. The overall benefit of this system to the Nation and the region are incalculable, but some indication is provided by a consideration of the more quantifiable benefits: flood damages prevented, transportation savings, hydroelectric power production, and recreation visits

There are 39 dams operating in the Tennessee Valley's integrated water control system. They are:

35 TVA dams — Apalachia, Blue Ridge, Boone, Chatuge, Cherokee, Chickamauga, Douglas, Fontana, Fort Loudoun, Fort Patrick Henry, Guntersville, Hiwassee, Kentucky, Melton Hill, Nickajack, Normandy, Norris, Nottely, Ocoee No. 1, Ocoee No. 2, Ocoee No. 3, Pickwick Landing, South Holston, Tellico, Tims Ford, Watauga, Watts Bar, Wheeler, Wilson, Bear Creek, Little Bear Creek, Nolichucky, Upper Bear Creek, Cedar Creek, and Wilbur

4 Alcoa dams — Calderwood, Cheoah, Chilhowee, and Santeetlah

Raccoon Mountain Pumped Storage Project stores energy (generated elsewhere) to meet peak power demands.

There are 9 dams in the Cumberland River basin for which TVA distributes power generation. They include one TVA dam, Great Falls, and 8 Corps of Engineer dams — Barkley, Center Hill, Cheatham, Cordell Hull, Dale Hollow, J. Percy Priest, Old Hickory, and Wolf Creek

The 4 Bear Creek projects (Bear, Little Bear, and Upper Bear and Cedar), the 2 Duck River projects (Normandy and Columbia), and the Tims Ford dam were planned under Tributary Area Development programs but have been counted among those in the Integrated Water Control System because they were all partially justified as having system flood control value. Tims Ford also contributes power to the system

In the 1960's TVA built two systems of small dams in tributary watersheds:

Beech River Project — Beech, Cedar, Dogwood, Lost Creek, Pine, Pin Oak, Redbud, and Sycamore

Bristol Project — Beaver Creek and Clear

There are 12 dams owned by Alcoa in The Little Tennessee River Valley which are not included in TVA's integrated water control system

The Elk River Dam operated by the Air Force, the Burnett Dam operated by the city of Asheville, and the Walters Dam of the Carolina Power and Light Company are other structures in the Tennessee Valley, but are not controlled by TVA

**Table 11B.16 Tennessee Valley Authority Reservoirs**

| Main River Projects | Length of Lake (Miles) | Length of Lake Shoreline (Miles) | Area of Lake (Acres) | Lake Elevation (Feet above Sea Level) | | Lake Volume (Acre-Feet) at Top of Gates | Useful Controlled Storage in Reservoir (Acre-Feet) |
|---|---|---|---|---|---|---|---|
| | | | | Normal Minimum | Top of Gates | | |
| Kentucky | 184.3 | 2,380 | 160,300 | 354 | 375 | 6,129,000 | 4,008,000 |
| Pickwick Landing | 52.7 | 496 | 43,100 | 408 | 418 | 1,105,000 | 417,700 |
| Wilson | 15.5 | 154 | 15,500 | 504.5 | 507.88 | 640,200 | 53,600 |
| Wheeler | 74.1 | 1,063 | 67,100 | 550 | 556.28 | 1,069,000 | 349,000 |
| Guntersville | 75.7 | 949 | 67,900 | 593 | 595.44 | 1,049,000 | 162,400 |
| Nickajack | 46.3 | 192 | 10,370 | 632 | 635 | 251,600 | 31,500 |
| Chickamauga | 58.9 | 810 | 35,400 | 675 | 685.44 | 737,300 | 345,300 |
| Watts Bar | 95.5 | 771 | 39,000 | 735 | 745 | 1,175,000 | 379,000 |
| Fort Loudoun | 60.8 | 360 | 14,600 | 807 | 815 | 393,000 | 111,000 |
| Raccoon Mtn. (Pumped Storage Project) | — | — | 528 | 1,530 | — | 37,310 | 35,110 |
| **Tributary Projects** | | | | | | | |
| Columbia | 54 | 236 | 12,600 | 603 | 635 | 363,000 | 283,000 |
| Normandy | 17 | 73 | 3,160 | 859 | 880 | 126,100 | 60,500 |
| Tims Ford | 34.2 | 246 | 10,600 | 865 | 895 | 608,000 | 282,600 |
| Apalachia | 9.8 | 31 | 1,100 | 1,272 | 1,280 | 57,800 | 8,650 |
| Hiwassee | 22.2 | 163 | 6,090 | 1,450 | 1,526.5 | 434,000 | 306,000 |
| Chatuge | 13 | 132 | 7,050 | 1,905 | 1,928 | 240,500 | 123,000 |
| Ocoee No. 1 | 7.5 | 47 | 1,890 | 811 | 830.76 | 83,300 | 31,030 |
| Ocoee No. 2 | — | — | — | — | 1,115.2 | — | Silted |

*(Continued)*

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**Table 11B.16 (Continued)**

| Main River Projects | Length of Lake (Miles) | Length of Lake Shoreline (Miles) | Area of Lake (Acres) | Lake Elevation (Feet above Sea Level) | | Lake Volume (Acre-Feet) at Top of Gates | Useful Controlled Storage in Reservoir (Acre-Feet) |
|---|---|---|---|---|---|---|---|
| | | | | Normal Minimum | Top of Gates | | |
| Ocoee No. 3 | 7 | 24 | 480 | 1,413 | 1,435 | 4,180 | 3,629 |
| Blue Ridge | 11 | 65 | 3,290 | 1,590 | 1,691 | 195,900 | 183,900 |
| Nottely | 20.2 | 106 | 4,180 | 1,735 | 1,780 | 174,300 | 117,140 |
| Melton Hill | 44 | 173 | 5,690 | 790 | 796 | 126,000 | 31,900 |
| Norris | 129 | 800 | 34,200 | 960 | 1,034 | 2,552,000 | 1,922,000 |
| Tellico | 33.2 | 373 | 15,860 | 807 | 815 | 424,000 | 120,000 |
| Fontana | 29 | 248 | 10,640 | 1,580 | 1,710 | 1,443,000 | 946,000 |
| Douglas | 43.1 | 555 | 30,400 | 940 | 1,002 | 1,461,000 | 1,251,000 |
| Cherokee | 54 | 393 | 30,300 | 1,020 | 1,075 | 1,541,000 | 1,148,000 |
| Ft. Patrick Henry | 10.4 | 37 | 872 | 1,258 | 1,263 | 26,900 | 4,250 |
| Boone | 32.7 | 130 | 4,310 | 1,330 | 1,385 | 193,400 | 148,400 |
| S. Holston | 23.7 | 168 | 7,580 | 1,675 | 1,742 | 764,000 | 438,300 |
| Watauga | 16.3 | 106 | 6,430 | 1,915 | 1,975 | 677,000 | 353,000 |
| Wilbur | 1.8 | 3.6 | 72 | 1,645 | 1,650 | 715 | 327 |
| Great Falls | 22 | 120 | 3,080 | 780 | 805.3 | 50,200 | 35,700 |
| Nolichucky | — | 26 | 383 | 1,238.9 | 1,240.9 | 2,003 | 496 |
| Totals[a] | | 11,195 | 641,455 | | | 23,771,708 | 13,408,432 |

[a] Does not include the Columbia Dam Project.

*Source*: From Tennessee Valley Authority, 1988.

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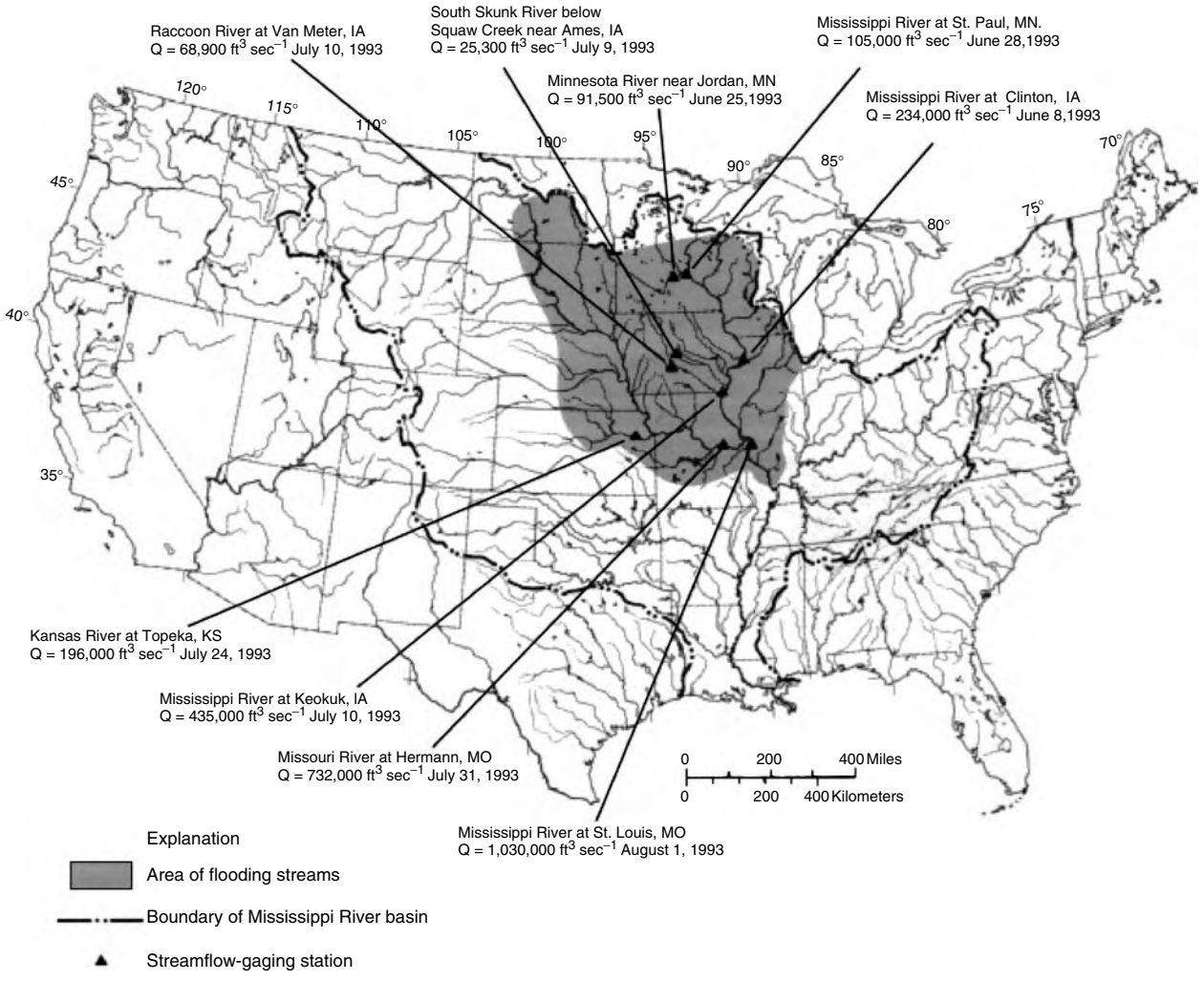


**Figure 11B.13** Peak discharges (Q) and dates of occurrence for the 1993 flood at selected streamflow-gaging stations in the upper Mississippi River basin. (From www.geo.mtu.edu.)

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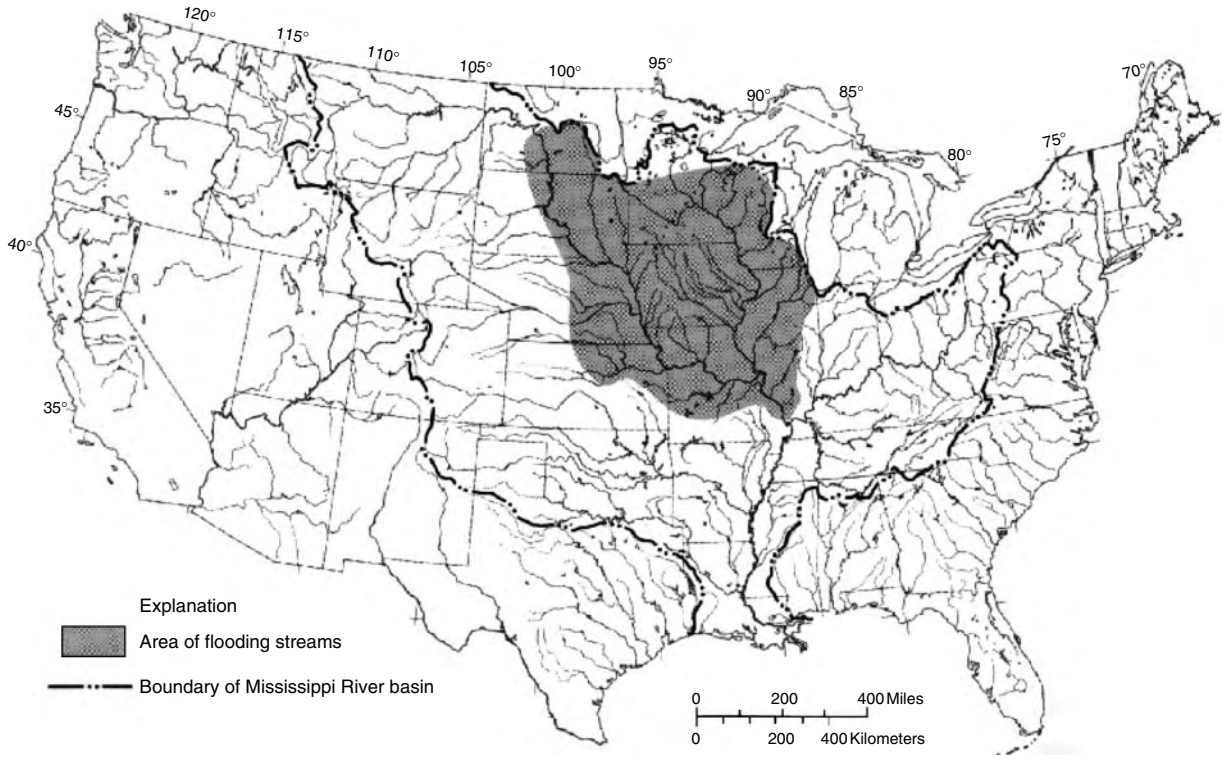


**Figure 11B.14** The Mississippi River basin and general area of flooding streams, June to August 1993. (From www.geo.mtu.edu.)

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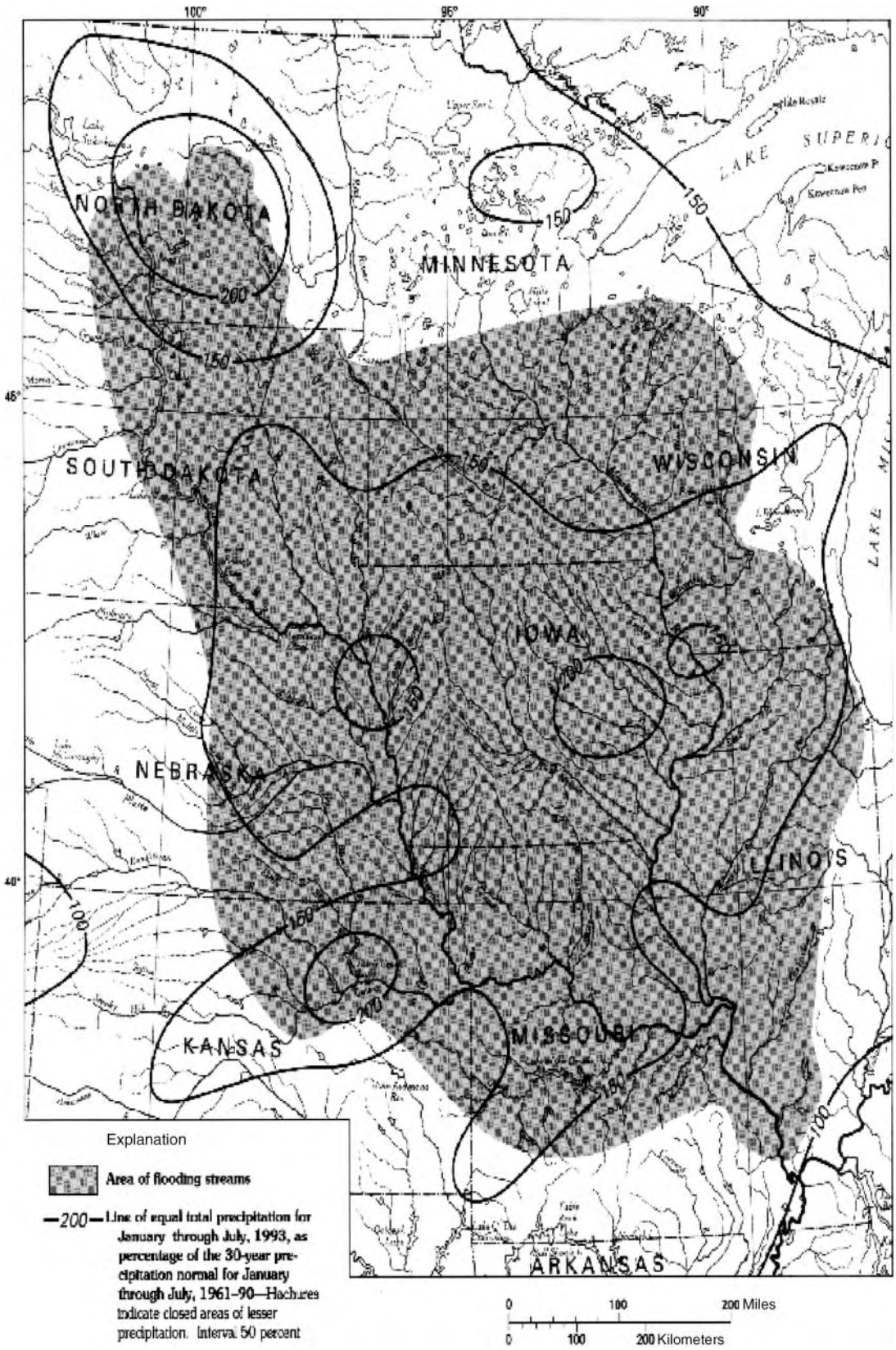


**Figure 11B.15** Areal distribution of total precipitation in the area of flooding in the upper Mississippi River basin, January to July 1993. (From www.geo.mtu.edu.)

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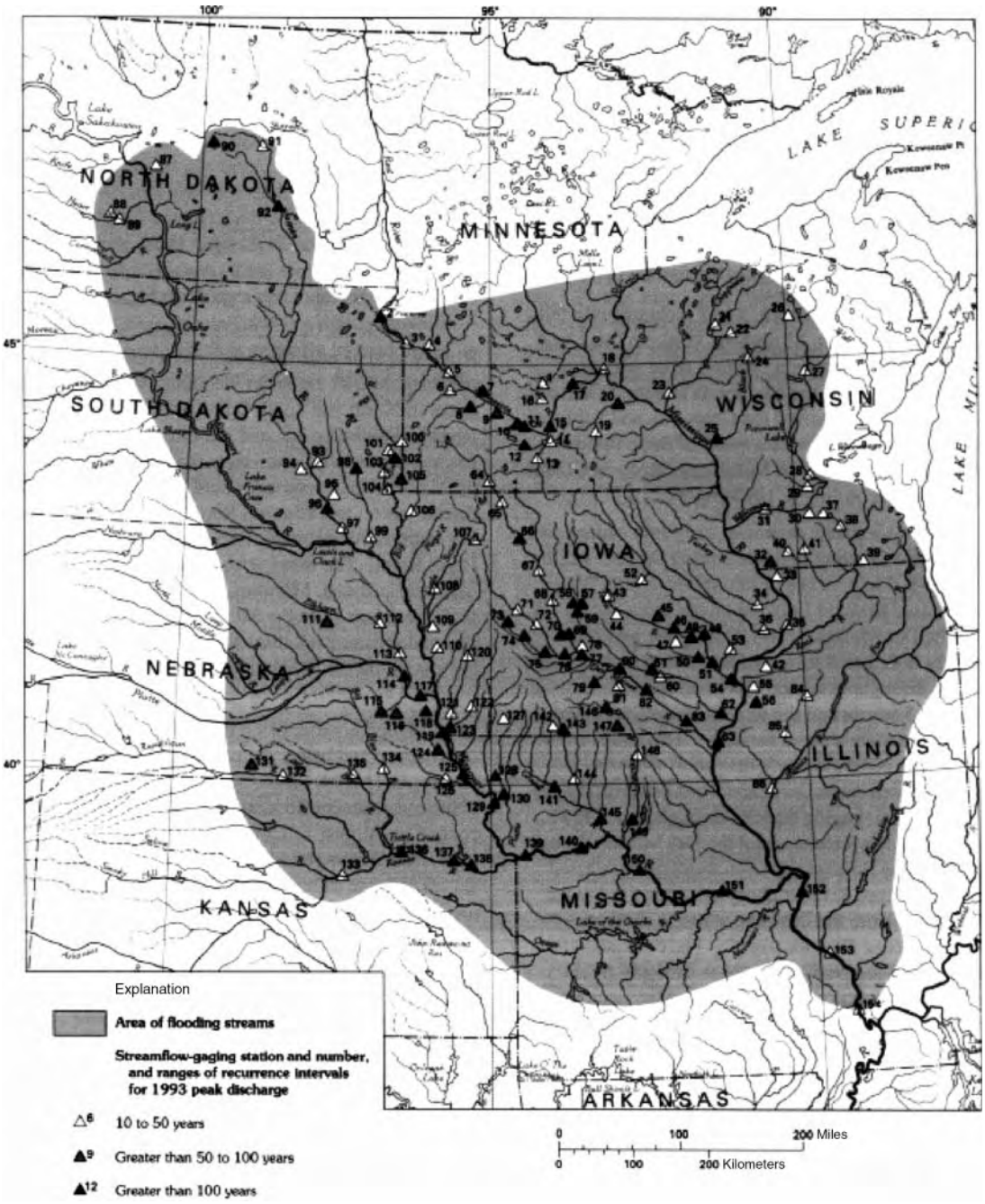


**Figure 11B.16** Location of selected streamflow-gaging stations and ranges in recurrence interval for the 1993 peak discharges in the upper Mississippi River basin. (From www.geo.mtu.edu.)

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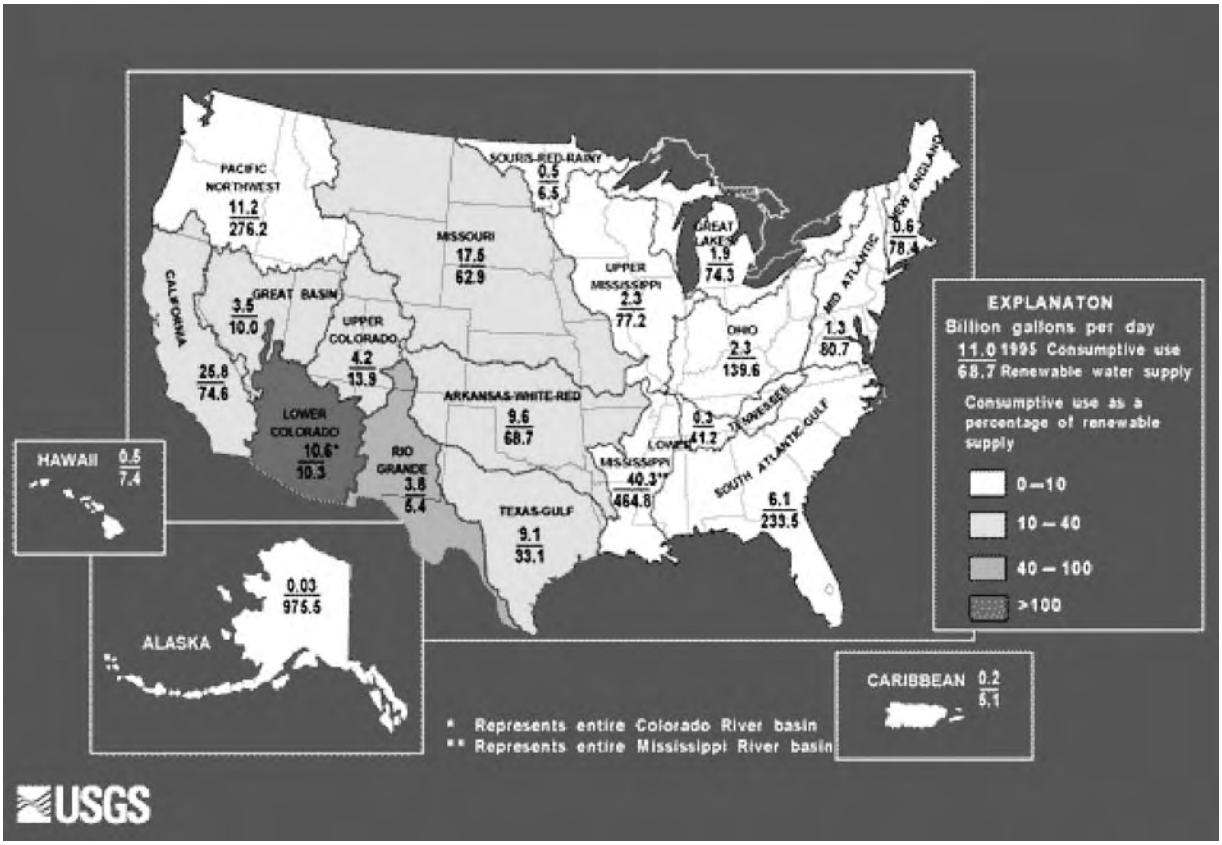


**Figure 11B.17** Consumptive use and renewable water supply by water resources region. (From *U.S. Geological Survey, 1984*, updated using 1995 estimates of water use.)

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*(Data are provisional and subject to change)*

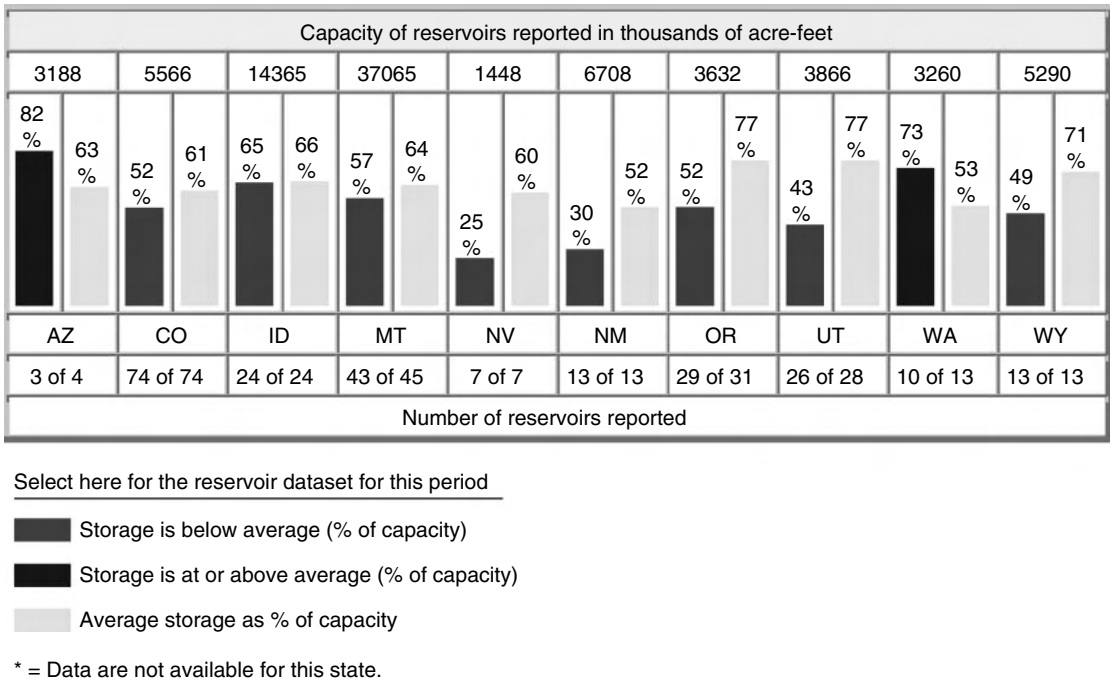


**Figure 11B.18** Reservoir storage as percent of capacity for April 1, water year 2005. (From www.wcc.nrcs.usda.gov.)

**Figure 11B.19** Water resources regions of the United States. (From U.S. Geological Survey.)

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**Table 11B.17 Normal Surface-Water Reservoir Capacity in the United States**

| Water Resources Region | Area of Region, in Thousands of Square Miles | Average Renewable Supply, in Billion Gallons per Day[a] | Normal Reservoir Capacity[b] | | |
|---|---|---|---|---|---|
| | | | In Million Acre-feet | In Acre-feet of Storage per Square Mile | As a Percentage of Annual Renewable Supply |
| New England | 69 | 78.4 | 13.0 | 188 | 15 |
| Mid-Atlantic | 103 | 80.7 | 10.3 | 100 | 11 |
| South Atlantic-Gulf | 271 | 233.5 | 38.7 | 143 | 15 |
| Great Lakes | 134 | 74.3 | 6.9 | 51 | 8 |
| Ohio (exclusive of Tennessee Region) | 160 | 139.5 | 19.6 | 123 | 13 |
| Tennessee | 43 | 41.2 | 11.2 | 260 | 24 |
| Upper Mississippi (exclusive of Missouri Region) | 181 | 77.2 | 12.2 | 67 | 14 |
| Mississippi (entire basin) | 1241 | 464.3 | 164.8 | 133 | 32 |
| Souris-Red Rainy | 55 | 6.5 | 8.0 | 145 | 110 |
| Missouri | 511 | 62.5 | 84.3 | 165 | 120 |
| Arkansas-White-Red | 244 | 68.6 | 31.8 | 130 | 41 |
| Texas-Gulf | 178 | 33.1 | 24.7 | 139 | 67 |
| Rio Grande | 137 | 5.1 | 10.4 | 76 | 182 |
| Upper Colorado | 103 | 14.7 | 37.7 | 366 | 229 |
| Colorado (entire basin) | 258 | 15.6 | 70.4 | 273 | 403 |
| Great Basin | 139 | 9.9 | 3.3 | 24 | 30 |
| Pacific Northwest | 271 | 276.2 | 60.9 | 225 | 20 |
| California | 165 | 70.2 | 38.8 | 235 | 49 |
| Alaska | 586 | 975.5 | 1.5 | 3 | 0.1 |
| Hawaii | 6 | 7.4 | 0.0 | 2 | 0.1 |
| Caribbean | 4 | 5.1 | 0.3 | 90 | 5 |

[a] Adjusted by adding exports and subtracting imports.
[b] About two-thirds of maximum capacity.

*Source*: From U.S. Geological Survey, 1984, National Water-Summary 1983—Hydrologic Events and Issues, Water—Supply Paper 2250.

**Table 11B.18 Summary of Reservoir Storage, Including Controlled Natural Lakes, in the United States and Puerto Rico**

| Reservoir Storage (Range, in Acre-feet) | Number of Reservoirs | Total Reservoir Storage | |
|---|---|---|---|
| | | Acre-feet | Percentage of Total |
| Greater than 10,000,000 | 5 | 107,655,000 | 22.4 |
| 100,000–10,000,000 | 569 | 322,852,000 | 67.3 |
| 50,000–100,000 | 295 | 20,557,000 | 4.3 |
| 25,000–50,000 | 374 | 13,092,000 | 2.7 |
| 5,000–25,000 | 1,411 | 15,632,000 | 3.3 |
| Total[a] | 2,654 | 479,788,000 | 100.0 |

*Note*: Reservoir storage is expressed as normal capacity, which is the total storage space in a reservoir below the normal retention level, including dead storage and inactive storage, and excluding any flood control or surcharge storage.

[a] In addition, there are perhaps at least 50,000 reservoirs with capacities ranging from 50 to 5,000 acre-feet, and about 2 million smaller farm ponds used for storage.

*Source*: From U.S. Army Corps of Engineers, 1981.

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**Table 11B.19 Hydraulic Test Data from Aquifer Storage and Recovery Well Systems in Southern Florida**

| | Production Well Identifier | Open Interval Tested (ft) | Test Type | Monitoring Well | Pumping Rate (gal/min) | Length of Test (hr) | Transmissivity ($ft^2/d$) | Storage Coefficient (unitless) | Leakance (1/day) | Method of Analysis | Specific Capacity (gallons per minute per foot) | Background Measurements | Problems and Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Broward County | | | | | | | | | | | | | |
| Deerfield Beach West WTP | | | | | | | | | | | | | |
| NR | ASR-1 | 956–1130[a] | S | — | 950–2,100 | NR | — | — | — | — | 42.6–32.0 | NR | Step-drawdown test was performed prior to multiwell, but date of test was not given in report |
| 12/10/92 | ASR-1 | 956–1130[a] | M | MW-1 | 1,200 | 5.7 | 24,200 | $1.33\times10^{-6}$ | $6.3\times10^{-2}$ | H-J | | | |
| Broward County WTP 2A | | | | | | | | | | | | | |
| 11/21/96 | ASR-1 | 995–1200[a] | S | — | 1,050–2,950 | 8 | — | — | — | — | 90.6–51.1 | Data collected for multiwell test but no information on whether corrections were made | Walton method should give same transmissivity if no leakance as C-J method Curve matches look okay |
| 11/26/96 | ASR-1 | 995–1200[a] | M | MW-1 | 1,000 | 24 | 28,900 | $1.1\times10^{-4}$ | None | Walton | — | | |
| 11/26/96 | ASR-1 | 995–1200[a] | M | MW-1 | 1,000 | 24 | 37,200 | $5.3\times10^{-5}$ | — | C-J | — | | |
| 11/26/96 | ASR-1 | 995–1200[a] | M | ASR-1 | 1,000 | 24 | 44,000 | — | — | Theis Rec | NR | | |
| 9/19/96 | MW-1 | 990–1200[a] | S | — | 48 | 6 | — | — | — | — | NR | | |
| Springtree WTP | | | | | | | | | | | | | |
| 6/6/97 | ASR-1 | 1,110–1,270[a] | S | — | 700–1,900 | 8 | | — | — | — | 18.4–16.5 | NR | Acidization of well done after step test and before constant rate test. Interpretation of recovery data favored late time data |
| 7/28/97 | ASR-1 | 1,110–1,270[a] | R | — | 2,115 | 48 | 5,700 | — | — | Theis Rec | 22.75 | | |
| Fiveash WTP | | | | | | | | | | | | | |
| 1/12/98 | FMW-1 | 998–1,028 | P, R | — | 160 | 4 | 4,700 | — | — | Theis Rec | 4.7 | NR | Third packer test showed apparent failure after about 10 min, which may have affected data. FMW-1 apparently not used in 24-hour test of ASR-1 |
| 1/13/98 | FMW-1 | 998–1,042 | P, R | — | 160 | 4 | 8,000 | — | — | Theis Rec | 5 | | |
| 1/15/98 | FMW-1 | 1,058–1,175[a] | P | — | 600 | 10 min | 23,500 | — | — | C-J | 46 | | |
| 3/16/98 | FMW-1 | 1,055–1,175[a] | S | — | 100–160 | 4 | — | — | — | — | 3.8–3.6 | | |
| 3/17/98 | FMW-1 | 1,055–1,175[a] | S | — | 164 | 24 | NR | — | — | — | ~3.5 | | |
| 3/25/98 | ASR-1 | 1,055–1,200[a] | S | — | 968–2,104 | 4 | — | — | — | — | 25.5–17.7 | | |
| 3/30/98 | ASR-1 | 1,055–1,200[a] | R | — | 2,100 | 24 | 19,500 | — | — | Theis Rec | ~17.5 | | |
| Charlotte County | | | | | | | | | | | | | |
| Shell Creek WtP | | | | | | | | | | | | | |
| 11/5/97 | ASR-1 | 700–755 | P | — | 300–550 | NR | — | — | — | — | 10.0–5.6 | NR | |
| 11/17/97 | ASR-1 | 700–764 | S | — | 231–597 | 12 | — | — | — | — | 5.3–4.6 | | |
| 11/18/97 | ASR-1 | 700–764 | R | — | 546 | 54 | 1,300 | — | — | SC | 4.4 | | |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/28/99 | ASR-1 | 764–933[a] | S | — | 610–600 | 8 | — | — | — | — | 10.6 | | |
| Englewood South Regional WWTP | | | | | | | | | | | | | |
| NR | TPW-1 | 563–583 | P, R | — | 10 | 1.33 | 450 | — | — | Theis Rec | 1 | NR | Multiwell aquifer test planned in the future |
| 3/7/00 | TPW-1 | 630–807 | P | — | 131 | 4 | 1,300 | — | — | SC | 5 | | |
| 3/31/00 | TPW-1 | 507–700[a] | S | — | 490–1,050 | NR | 4,700 | — | — | SC | 17.34 (avg) | | |
| 4/20/00 | SZMW-1 | 510–700[a] | S | — | 31–101 | NR | 3,700 | — | — | SC | 13.87 (avg) | | |
| 4/18/00 | IMW-1 | 280–320 | S | — | 28.3–59.5 | NR | 2,300 | — | — | SC | 5.5–4.0 | | |
| 4/18/00 | SMW-1 | 170–205 | S | — | 9.3–17.7 | NR | 300 | — | — | SC | 1 (avg) | | |
| Collier County | | | | | | | | | | | | | |
| Manatee Road | | | | | | | | | | | | | |
| 11–90 | MW-A | 360–460 | P, S | — | NR | NR | 2,400 | — | — | See comment | NR | NR | All of the step-drawdown tests are indicated to be packer tests; however, some could have been a test of an open interval below casing. For step test, transmissivity was determined at each step by an unspecified method in Walton (1970). |
| 11-90 | MW-A | 465–530[a] | P, S | — | NR | NR | 20,000 | — | — | See comment | NR | | |
| 11–90 | MW-A | 680–760 | P, S | — | NR | NR | 15,000 | — | — | See comment | NR | | |
| 11–90 | MW-A | 930–1020 | P, S | — | NR | NR | 6,700 | — | — | See comment | NR | | |
| 11–90 | MW-A | 1,180–1,220 | P, S | — | NR | NR | 6,300 | — | — | See comment | NR | | |
| 11–90 | MW-A | 1,345–1,606 | P, S | — | NR | NR | 5,700 | — | — | See comment | NR | | |
| NR | ASR-1 | 465–528[a] | M | MW-B | 670 | 17 | 9,400 | $1.00\times10^{-4}$ | $3.7\times10^{-4}$ | H-J | — | | |
| NR | ASR-1 | 465–528 | M | MW-B | 670 | 17 | 12,000 | — | — | Theis Rec | — | | |
| Macro Lakes | | | | | | | | | | | | | |
| NR | DZMW | 296–399 | S | — | 220–600 | NR | 67,000 | — | — | Walton | 220–170 | NR | Estimated transmissivity in lower Hawthorn zone I (550 to 622 ft) was too low for consideration as an aquifer storage and recovery interval. No dates were reported for any tests. Good agreement between tests |
| NR | DZMW | 296–399 | R | — | 600 | 3 | 42,400 | — | — | Theis Rec | NR | | |
| NR | DZMW | 550–622 | P, R | — | 5 | 4 | 47 | — | — | Theis Rec | NR | | |
| NR | DZMW | 745–811[a] | R | — | 187 | 4.5 | 8,200 | — | — | Theis Rec | NR | | |
| NR | ASR-1 | 745–790[a] | M | ASR-1 | 463 | 8.3 | 16,300 | — | — | Theis Rec | NR | | |
| NR | ASR-1 | 745–790[a] | M | DZMW | 463 | 8.3 | 9,100 | $6.5\times10^{-5}$ | $7\times10^{-}4$ | H-J | — | | |
| NR | ASR-1 | 745–790[a] | M | DZMW | 463 | 8.3 | 12,000 | — | — | Theis Rec | — | | |
| NR | ASR-2 | 736–780[a] | S | ASR-1 | 400–650 | NR | — | — | — | Theis Rec | 25–24 | | |
| NR | ASR-3 | 736–780[a] | S, M | ASR-2, | | ASRZMW | 400–820 | NR | 8,000–8,100 | — | — | C-J | 17.4–15 |
| Lee County | | | | | | | | | | | | | |
| Lee County WTP | | | | | | | | | | | | | |

*(Continued)*



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**Table 11B.19 (Continued)**

| | Production Well Identifier | Open Interval Tested (ft) | Test Type | Monitoring Well | Pumping Rate (gal/min) | Length of Test (hr) | Transmissivity ($ft^2/d$) | Storage Coefficient (unitless) | Leakance (1/day) | Method of Analysis | Specific Capacity (gallons per minute per foot) | Back-Ground Measurements | Problems and Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NR | ASR-1 | 445–600a | M | NR | 350 | 48 | 800 | $1.00\times10^{-4}$ | | H-J | NR | NR | Storage zone in ASR-1 is located in the lower Hawthorn producing zone of the Upper Floridan aquifer as defined by Reese (2000) |
| Corkscrew WTP | | | | | | | | | | | | | |
| 08–94 | MW-A | 428–515 | P | — | NR | NR | 500 | — | — | SC | 2.5 | Data collected for multiwell test in September 1995 | Test of MW-A, interval 744 to 778 ft, was of upper 34 of 240 ft thick Suwannee Limestone. Second multiwell test of ASR-1 followed back-plugging of MW-A to injection zone. Transmissivity values for step-drawdown test of ASR-2, 3, 4, and 5 were obtained |
| 8/17/94 | MW-A | 524–578 | P | — | 39 | 5 min. | 500 | — | — | SC | NR | | |
| 8/24/94 | MW-A | 744–778 | P, S | — | 15–74 | 4 | 13,000 | — | — | SC | 1.3–0.6 | | |
| NR | MW-B | 452–504 | NR | — | NR | NR | 100 | NR | NR | NR | NR | | |
| 09–95 | ASR-1 | 328–397[a] | M | MW-C | 400 | 115.5 | 3,410 | $7.70\times10^{-5}$ | $1.6\times10^{-5}$ | Hantush | — | | |
| 09–95 | ASR-1 | 328–397[a] | M | MW-C | 400 | 115.5 | 3,380 | $6.70\times10^{-5}$ | — | C-J | — | | |
| 09–95 | ASR-1 | 328–397[a] | M | MW-C | 400 | 115.5 | 3,460 | — | — | Theis Rec | — | | |
| 06–96 | ASR-1 | 328–397[a] | M | MW-A | 415 | 120 | 1,760 | $2.30\times10^{-4}$ | — | Theis | | | |
| 06–96 | ASR-1 | 328–397[a] | M | MW-A | 415 | 120 | 1,900 | $1.70\times10^{-4}$ | — | C-J | — | | |
| 06–96 | ASR-1 | 328–397[a] | M | MW-C | 415 | 120 | 3,180 | $5.70\times10^{-5}$ | — | Theis | — | | |
| 06–96 | ASR-1 | 328–397[a] | M | MW-C | 415 | 120 | 3,410 | $4.90\times10^{-5}$ | — | C-J | — | | |
| 7/13/99 | ASR-2 | 337–397[a] | S | — | 115–410 | NR | 2,040 | — | — | SC | 7.8–6.6 | | |
| 2/12/99 | ASR-3 | 285–347[a] | S | — | 129–497 | NR | 7,350 | — | — | SC | 26.9–19.4 | | |
| 6/25/99 | ASR-4 | 310–368[a] | S | — | 153–450 | NR | 4,020 | — | — | SC | 15.0–11.7 | | |
| 7/8/99 | ASR-5 | 253–291[a] | S | — | 163–380 | NR | — | — | — | — | 7.4–5.2 | | |
| 7/20/99 | ASR-5 | 253–291[a] | S | — | 130–490 | NR | 13,400 | — | — | SC | 50.0–36.1 | | |
| North Reservoir | | | | | | | | | | | | | |
| 12/7/98 | MW-1 | 480–518 | S | — | 92–430 | NR | 14,400 | — | — | SC | 44.4–41.3 | Data collected for 3 days prior to the multiwell test | Fit of line to ASR-1 recovery data for multiwell test is poor |
| 12/9/98 | MW-1 | 529–619[a] | P, S | — | 73–295 | NR | 5,200 | — | — | SC | 9.7–3.5 | | |
| 12/11/98 | MW-1 | 640–703 | P, S | — | 79–281 | NR | 2,040 | — | — | SC | 6.6–2.8 | | |
| 12/16/98 | MW-1 | 808–890 | P, S | — | 55–190 | NR | 680 | — | — | SC | 2.8–1.8 | | |
| 12/18/98 | MW-1 | 904–977 | P, S | — | 85–322 | NR | 9,590 | — | — | SC | 10.5–3.1 | | |
| 3/3/99 | ASR-1 | 540–642[a] | S | — | 162–590 | 4 | 2,220 | — | — | SC | 8.65–7.00 | | |
| 3/8/99 | ASR-1 | 540–642[a] | M | MW-1 | 379 | 72 | 8,290 | $3.27\times10^{-4}$ | $7.33\times10^{-4}$ | H-J | — | | |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/8/99 | ASR-1 | 540–642[a] | M | MW-1 | 379 | 72 | 8,740 | $4.64\times10^{-4}$ | — | C-J (recovery) | — | | |
| 3/8/99 | ASR-1 | 540–642[a] | M | ASR-1 | 379 | 72 | 8,570 | — | — | C-J (recovery) | NR | | |
| Winkler Avenue | | | | | | | | | | | | | |
| NR | ASR-1 | 455–554[a] | S | — | 135 | 15 min | — | — | — | — | 59.7 | Ninety hours collected prior to multiwell test, but apparently not used to correct drawdown data | Pumping rate for multiwell test was 1,540 for first 6.5 hr, then changed to 1,400. No attempt was made to analyze multiwell test data for storage coefficient or leakance. Storage zone is located in the lower Hawthorn producing zone of Upper Florida |
| NR | ASR-1 | 455–647 | S | — | 160 | 15 min | — | — | — | — | 86.3 | | |
| 6/16/99 | ASR-1 | 455–574[a] | P | — | 479 | 70 min | 29,100 | — | — | C-J (recovery) | NR | | |
| 6/17/99 | ASR-1 | 455–575[a] | P | — | 483 | 18 min | 26,600 | — | — | C-J (recovery) | NR | | |
| 10/23/99 | ASR-1 | 455–553[a] | M | ASR-1 | 1,540–1,400 | 27 | 24,700 | — | — | C-J | NR | | |
| 10/23/99 | ASR-1 | 455–553[a] | M | ASR-1 | 1,540–1,400 | 27 | 25,400 | — | — | C-J (recovery) | — | | |
| 10/23/99 | ASR-1 | 455–553[a] | M | SZMW-1 | 1,540–1,400 | 27 | 27,400 | NR | NR | C-J | — | | |
| 10/23/99 | ASR-1 | 455–553[a] | M | SZMW-1 | 1,540–1,400 | 27 | 29,000 | — | — | C-J (recovery) | — | | |
| San Carlos Estates | | | | | | | | | | | | | |
| 6/7/99 | TPW-1 | 650–701[a] | S | — | 710–1,480 | 8 | — | — | — | — | 250–130 | Unknown for multiwell test. Test followed 10 days of recharge at 1,955 gal $min^{-1}$ and then 6-day static period | High specific capacity in TPW-1 due to two pilot holes in open interval. Pumping rate for test on 11/10/99 of 985 gallons per minute was natural flow. C-J solution for drawdown in SZMW-1R is suspect. Solution is for very late time only, and background changes due to prior recharge may have affected response |
| 7/29/99 | SZMW-1R | 659–721[a] | S | — | 170–350 | 8 | — | — | — | — | 15–9.0 | | |
| 8/2/99 | SMW-1 | 234–321 | S | — | 150–220 | 8 | — | — | — | — | 8.9–6.5 | | |
| 11/10/99 | TPW-1 | 650–701[a] | M | SZMW-1R | 985 | 8 | 39,000 | $1.00\times10^{-2}$ | — | C-J | — | | |
| 11/10/99 | TPW-1 | 650–701[a] | M | SZMW-1R | 985 | 8 | 70,000 | — | — | Theis Rec | — | | |
| Olga WTP | | | | | | | | | | | | | |
| 1/5/99 | MW-1 | 515–605 | S | — | 110–400 | NR | 2,500 | — | — | SC | NR | Measured for multiwell test, but unknown if used to correct drawdown | H-J results for multiwell test agree better with single well and packer test than C-J results. A second constant rate test was run but is not reported here. Storage zone is about 150 ft below top of Suwannee Limestone |
| 1/7/99 | MW-1 | 612–689 | P | — | 70–200 | NR | 1,300 | — | — | SC | NR | | |
| 2/3/99 | MW-1 | 835–935[a] | P | — | 70–355 | NR | 7,600 | — | — | SC | NR | | |
| 2/4/99 | MW-1 | 710–935 | P | — | 70–350 | NR | 7,600 | — | — | SC | NR | | |
| 2/4/99 | MW-1 | 835–935[a] | P | — | 70–350 | NR | 7,600 | — | — | SC | NR | | |

*(Continued)*



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**Table 11B.19 (Continued)**

| | Production Well Identifier | Open Interval Tested (ft) | Test Type | Monitoring Well | Pumping Rate (gal/min) | Length of Test (hr) | Transmissivity ($ft^2/d$) | Storage Coefficient (unitless) | Leakance (1/day) | Method of Analysis | Specific Capacity (gallons per minute per foot) | Back-Ground Measurements | Problems and Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/8/99 | MW-1 | 945–1,101 | P | — | 6–15 | NR | 33 | — | — | SC | NR | | |
| 3/17/99 | MW-3 | 740–820 | S | — | 78–480 | NR | 1,900 | — | — | SC | NR | | |
| 3/25/99 | MW-3 | 830–945[a] | P | — | 80–340 | NR | 9,000 | — | — | SC | NR | | |
| 3/25/99 | MW-3 | 854–945[a] | P | — | 75–350 | NR | 6,400 | — | — | SC | NR | | |
| 3/26/99 | MW-3 | 857–945[a] | R | — | 300 | NR | 8,700 | — | — | Theis Rec | NR | | |
| 11/1/99 | ASR-1 | 859–920[a] | S | — | 112–545 | 5 | 5,000 | — | — | SC | 14.9–8.5 | | |
| 11/3/99 | ASR-1 | 859–920[a] | M | MW-1 | 500 | 60 | 7,200 | $5.10\times10^{-5}$ | $5.2\times10^{-3}$ | H-J | — | | |
| 11/3/99 | ASR-1 | 859–920[a] | M | MW-1 | 500 | 60 | 12,000 | $4.10\times10^{-5}$ | — | C-J | — | | |
| 11/3/99 | ASR-1 | 859–920[a] | M | MW-3 | 500 | 60 | 9,400 | $5.50\times10^{-5}$ | $6.0\times10^{-2}$ | H-J | — | | |
| 11/3/99 | ASR-1 | 859–920[a] | M | MW-3 | 500 | 60 | 11,000 | $4.20\times10^{-4}$ | — | C-J | — | | |
| Miami-Dade County | | | | | | | | | | | | | |
| Hialeah | | | | | | | | | | | | | |
| 2/10/75 | MW-1 | 953–1,060[a] | M | ASR-1 | 250 | 1.66 | 11,000 | $8.4\times10^{-5}$ | — | J-L | — | NR | Transmissivity estimate from Meyer (1989b). Storage coefficient estimated by model simulation of pumping test |
| West Well Field | | | | | | | | | | | | | |
| 1/26/97 | ASR-1 | 850–1,302[a] | S | — | 1,400–4,000 | 8 | — | — | — | — | 269–52.1 | Measured for Multiwell test. Correction was not done, due to negligibility | All three aquifer storage and recovery wells were heavily acidized prior to all tests. Late time drawdown data problematic because of pump going down several times |
| 2/25/97 | ASR-2 | 845–1,250[a] | S | — | 1,500–3,800 | 8 | — | — | — | — | 126.6–51.1 | | |
| 4/8/97 | ASR-3 | 835–1,210[a] | S | — | 1,500–3,800 | 8 | — | — | — | — | 46.1–38.2 | | |
| 12/9/97 | ASR-1 | 850–1,302[a] | M | ASR-1 | 3,500 | 72 | 10,300 | N/A | N/A | C-J | NR | | |
| 12/9/97 | ASR-1 | 850–1,302[a] | M | ASR-2 | 3,500 | 72 | 15,400 | $3.90\times10^{-4}$ | $1.6\times10^{-3}$ | Walton | — | | |
| 12/9/97 | ASR-1 | 850–1,302[a] | M | ASR-2 | 3,500 | 72 | 18,200 | $2.90\times10^{-4}$ | N/A | C-J | — | | |
| 12/9/97 | ASR-1 | 850–1,302[a] | M | ASR-3 | 3,500 | 72 | 15,400 | $4.40\times10^{-4}$ | $3.90\times10^{-5}$ | Walton | — | | |
| 12/9/97 | ASR-1 | 850–1,302[a] | M | ASR-3 | 3,500 | 72 | 19,700 | $3.30\times10^{-4}$ | N/A | C-J | — | | |
| Monroe County | | | | | | | | | | | | | |
| Marathon | | | | | | | | | | | | | |
| 5/3/90 | ASR-1 | 387–432[a] | M | OW-1 | 105 | 25 | 2,290 | $3.20\times10^{-4}$ | NR | Walton | — | Measured for 3 weeks prior to multiwell test. A regional increasing trend in water level was determined | Leakance using Walton (1962) method not determined |
| 5/3/90 | ASR-1 | 387–432[a] | M | OW-1 | 105 | 25 | 2,510 | $3.70\times10^{-4}$ | — | C-J | — | | |
| 5/3/90 | ASR-1 | 387–432[a] | M | OW-1 | 105 | 25 | 1,760 | — | — | Theis-Rec | — | | |
| 5/3/90 | ASR-1 | 387–432[a] | M | OW-2 | 105 | 25 | 2,180 | $5.20\times10^{-4}$ | NR | Walton | — | | |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/3/90 | ASR-1 | 387–432[a] | M | OW-2 | 105 | 25 | 4,090 | — | — | Theis-Rec | — | | |
| 5/6/90 | ASR-1 | 387–432[a] | S | — | 95–350 | NR | — | — | — | — | 3.9–2.7 | | |
| Okeechobee County | | | | | | | | | | | | | |
| Taylor Creek-Nubbin Slough (Lake Okeechobee) | | | | | | | | | | | | | |
| 4/20/98 | MW-1 | 1,175–1,227 | P | — | 10 | 6.4 | 706 | NR | — | C-J | NR | Water-level data taken for 5 days prior to constant rate test; corrections made using a long-term increasing trend | Leakance derived by extrapolation; longer pumping period required for more accurate value |
| 4/20/98 | MW-1 | 1,175–1,227 | P, R | — | 10 | 6.4 | 2,940 | — | — | Recovery | NR | | |
| 8/2/98 | ASR-1 | 1,268–1,710[a] | M | ASR-1 | 6,500 | 24 | 620,000 | N/A | N/A | C-j (recovery) | 1,600 | | |
| 8/2/98 | ASR-1 | 1,268–1710[a] | M | MW-1 | 6,500 | 24 | 586,000 | $1.25\times10^{-3}$ | 0.01–0.001 | H-J | 1,600 | | |
| 8/2/98 | ASR-1 | 1,268–1,710[a] | M | MW-1 | 6,500 | 24 | 765,000 | $1.90\times10^{-4}$ | N/A | C-J (recovery) | 1,600 | | |
| Palm Beach County | | | | | | | | | | | | | |
| Boynton Beach East WTP | | | | | | | | | | | | | |
| 4/9/92 | ASR-1 | 804–900[a] | S | — | 320–2,100 | NR | 6,800–13,000 | NR | — | C-J | 18–28 | NR | Second step test is with permanent equipment installed in well. Average of estimates for transmissivity was 70,000 gallons per day per foot |
| 10/15/92 | ASR-1 | 804–909[a] | S | — | 798–1,723 | NR | Not calculated | — | — | C-J | 29–27 | | |
| Delray Beach North Storage Reservoir | | | | | | | | | | | | | |
| 6/5/96 | ASR-1 | 849–899 | P | — | 49 | NR | — | — | — | — | 0.37 | NR | Second step test performed after acidization of well. For the second step test, pump malfunctioned after about 10 min of pumping during the last step at 2,550 gal $min^{-1}$ |
| 6/11/96 | ASR-1 | 900–952 | P | — | 83 | NR | — | — | — | — | 0.9 | | |
| 6/14/96 | AR-1 | 974–1,020 | P | — | 90 | NR | — | — | — | — | 2.4 | | |
| 6/18/96 | ASR-1 | 1,020–1,100 | P | — | 98 | NR | — | — | — | — | 2 | | |
| 9/20/96 | ASR-1 | 1,020–1,200[a] | S | — | 575–1,100 | 24 | — | — | — | — | 10.8–7.8 | | |
| 2/24/98 | ASR-1 | 1,020–1,200[a] | S | — | 760–2,550 | 13.2 | — | — | — | — | 17.2–15.7 | | |
| West Palm Beach WTP | | | | | | | | | | | | | |
| 8/22/96 | FAMW | 975–1,091 | P, S | — | 64–142 | NR | — | — | — | — | 194–86 | NR | Recovery was allowed following step test of ASR-1 before multiwell test was begun. Large deviation from Theis curve during late time, but leaky aquifer solution not used |
| 9/14/96 | FAMW | 1,304–1,384 | P, S | — | 55–110 | NR | — | — | — | — | 220–110 | | |
| 8/29/96 | FAMW | 975–1,090 | S | — | 300–584 | NR | — | — | — | — | 75–58 | | |
| 9/1/96 | FAMW | 975–1,190[a] | S | — | 300–584 | NR | — | — | — | — | 110–101 | | |
| 9/4/96 | FAMW | 975–1,290 | S | — | 550–740 | NR | — | — | — | — | 116–105 | | |
| 9/6/96 | FAMW | 975–1,384 | S | — | 550–740 | NR | — | — | — | — | 116–99 | | |

*(Continued)*



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**Table 11B.19 (Continued)**

| | Production Well Identifier | Open Interval Tested (ft) | Test Type | Monitoring Well | Pumping Rate (gal/min) | Length of Test (hr) | Transmissivity ($ft^2/d$) | Storage Coefficient (unitless) | Leakance (1/day) | Method of Analysis | Specific Capacity (gallons per minute per foot) | Background Measurements | Problems and Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/19/96 | FAMW | 975–1,191[a] | S | — | 550–732 | NR | — | — | — | — | 62–42 | | |
| 1/30/97 | ASR-1 | 985–1,200[a] | S | — | 508–704 | 24 | — | — | — | — | 390–306 | | |
| 2/1/97 | ASR-1 | 985–1,200[a] | M | FAMW | 700 | 24 | 138,000 | $1.00\times10^{-4}$ | — | C-J | — | | |
| 2/1/97 | ASR-1 | 985–1,200[a] | M | FAMW | 700 | 24 | 108,000 | $8.00\times10^{-4}$ | — | Theis | — | | |
| Western Hillsboro Canal, Site 1 | | | | | | | | | | | | | |
| 4/5/00 | EXW-1 | 1,160–1,225 | P | — | 95 | NR | — | — | — | — | 22.6 | NR | Acidized EXW-1 with 4,300 gallons of 36 percent HCl on 6-2-00 |
| 4/10/00 | EXW-1 | 1,015–1,150 | P | — | 105 | NR | — | — | — | — | 10.9 | | |
| 5/25/00 | EXW-1 | 1,015–1,225[a] | S | — | 1,000–3,000 | NR | — | — | — | — | 31.1–26.2 | | |
| St. Lucie County | | | | | | | | | | | | | |
| 8/24/82 | MW-1 | 600–775[a] | M | ASR-1 | 388 | 72 | 5,910 | $1.64\times10^{-4}$ | $4.3\times10^{-2}$ | H-J (drawdown) | — | NR | Also conducted four pump tests of ASR-1 during drilling with total depth ranging from 627 to 1,000 ft and casing at 600 feet. Transmissivity was calculated from these tests based on recovery data from ASR-1 |
| 8/24/82 | MW-1 | 600–775[a] | M | ASR-1 | 388 | 72 | 6,430 | $2.67\times10^{-4}$ | $4.7\times10^{-4}$ | H-J (recovery) | — | | |

*Note*: Depths are in feet below land surface. Test type: M, multiwell constant rate; P, Packer test; R, single well constant rate recovery; S, step drawdown. Method of analysis; SC, specific capacity; Theis, Theis (1935) confined aquifer; C-J, Cooper and Jacob (1946) confined aquifer; Theis (1935) residual drawdown recovery; H-J, Hantush and Jacob (1955) leaky aquifer; Walton, Walton (1962) leaky aquifer; J-L, Jacob and Lohman (1952). Other annotations: WTP, water treatment plant; WWTP, wastewater treatment plant; —, not applicable; NR, not reported.

[a] Open interval tested is the same (or about the same) as the storage zone.

*Source*: From damsreport.org.

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**Table 11B.20 Reservoir Storage Required to Produce Selected Dependable Flows in the United States**

| Region | Storage Required to Produce Indicated Flow 100% of Time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Flow | Storage | Flow | Storage | Flow | Storage | Flow | Storage | Flow | Storage |
| New England | 6,300 | 1,300 | 9,700 | 1,900 | 16,000 | 4,200 | 22,000 | 7,300 | 39,000 | 26,000 |
| Delaware and Hudson Rivers | 3,200 | 590 | 4,800 | 900 | 7,800 | 2,000 | 11,000 | 3,800 | 19,000 | 11,000 |
| Chesapeake Bay | 5,600 | 960 | 8,400 | 1,400 | 13,000 | 3,400 | 18,000 | 6,000 | 32,000 | 20,000 |
| Southeast | 21,000 | 4,900 | 31,000 | 7,800 | 49,000 | 14,000 | 71,000 | 25,000 | 126,000 | 78,000 |
| Western Great Lakes | 8,400 | 780 | 12,000 | 1,100 | 16,000 | 2,800 | 21,000 | 5,100 | 32,000 | 20,000 |
| Eastern Great Lakes | 2,300 | 720 | 3,700 | 1,100 | 6,500 | 2,200 | 9,700 | 3,700 | 19,000 | 11,000 |
| Ohio River | 7,400 | 4,100 | 9,400 | 5,200 | 15,000 | 7,200 | 21,000 | 11,000 | 46,000 | 29,000 |
| Cumberland River | 1,500 | 160 | 2,100 | 290 | 3,300 | 620 | 4,500 | 1,100 | 7,800 | 3,100 |
| Tennessee River | 9,000 | 400 | 11,000 | 600 | 15,000 | 1,200 | 19,000 | 2,500 | 28,000 | 9,600 |
| Upper Mississippi River | 7,800 | 1,100 | 12,000 | 2,300 | 18,000 | 5,200 | 25,000 | 8,700 | 41,000 | 26,000 |
| Upper Missouri River | 1,200 | 340 | 1,800 | 660 | 3,200 | 1,200 | 4,500 | 2,100 | 9,000 | 5,700 |
| Lower Missouri River | 410 | 660 | 550 | 840 | 1,200 | 1,300 | 2,200 | 2,300 | 5,800 | 5,200 |
| Upper Arkansas-Red Rivers | 410 | 250 | 700 | 410 | 1,300 | 720 | 2,100 | 1,200 | 4,500 | 3,000 |
| Lower Arkansas-Red and White Rivers | 1,000 | 1,400 | 2,100 | 2,500 | 4,400 | 5,000 | 8,400 | 9,400 | 20,000 | 22,000 |
| Lower Mississippi River | 2,100 | 900 | 3,600 | 1800 | 6,500 | 3,200 | 10,000 | 5,500 | 21,000 | 14,000 |
| Upper Rio Grande and Pecos Rivers | [a] | [a] | [a] | [a] | [a] | [a] | [a] | [a] | [a] | [a] |
| Western Gulf | 920 | 1,300 | 1,700 | 1,700 | 3,400 | 3,800 | 5,900 | 5,500 | 14,000 | 12,000 |
| Colorado | 210 | 90 | 320 | 120 | 560 | 230 | 830 | 380 | 1,700 | 1,200 |
| Great Basin | 300 | 72 | 470 | 100 | 780 | 240 | 1,200 | 420 | 2,100 | 1,000 |
| South Pacific | 30 | 10 | 40 | 13 | 60 | 26 | 100 | 43 | 180 | 119 |
| Central Pacific | 1,000 | 880 | 1,900 | 1,760 | 3,800 | 3,100 | 6,300 | 5,300 | 16,000 | 11,400 |
| Pacific Northwest | 9,700 | 2,600 | 21,000 | 6,600 | 26,000 | 9,300 | 39,000 | 16,000 | 76,000 | 47,000 |
| United States | 90,000 | 24,000 | 140,000 | 40,000 | 210,000 | 71,000 | 300,000 | 120,000 | 560,000 | 350,000 |

*Note*: Flow is in millions of gallons per day, and storage is in thousands of acre-feet.

[a] Appropriations currently exceed supply.

*Source*: From Select Committee on National Water Resources, U.S. Senate 1960.



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**Table 11B.21 Advantages and Disadvantages of Subsurface and Surface Reservoirs**

| Subsurface Reservoirs | Surface Reservoirs |
|---|---|
| **Advantages** | **Disadvantages** |
| 1. Many large-capacity sites available | 1. Few new sites available |
| 2. Slight to no evaporation loss | 2. High evaporation loss even in humid climate |
| 3. Require little land area | 3. Require large land area |
| 4. Slight to no danger of catastrophic structural failure | 4. Ever-present danger of catastrophic failure |
| 5. Uniform water temperature | 5. Fluctuating water temperature |
| 6. High biological purity | 6. Easily contaminated |
| 7. Safe from immediate radioactive fallout | 7. Easily contaminated by radioactive material |
| 8. Serve as conveyance systems—canals or pipeline across lands of others unnecessary | 8. Water must be conveyed |
| **Disadvantages** | **Advantages** |
| 1. Water must be pumped | 1. Water may be available by gravity flow |
| 2. Storage and conveyance use only | 2. Multiple use |
| 3. Water may be mineralized | 3. Water generally of relatively low mineral content |
| 4. Minor flood control value | 4. Maximum flood control value |
| 5. Limited flow at any point | 5. Large flows |
| 6. Power head usually not available | 6. Power head available |
| 7. Difficult and costly to investigate, evaluate, and manage | 7. Relatively easy to evaluate, investigate, and manage |
| 8. Recharge opportunity usually dependent on surplus surface flows | 8. Recharge dependent on annual precipitation |
| 9. Recharge water may require expensive treatment | 9. No treatment required of recharge water |
| 10. Continuous expensive maintenance of recharge areas or wells | 10. Little maintenance required of facilities |

*Source*: From U.S. Bureau of Reclamation, 1977, *Groundwater Manual*, U.S. Department of the Interior.

**Table 11B.22 Summary of Storage Reservoirs on United States Bureau of Reclamation Projects**

| | | Active Capacity | | Total Capacity | |
|---|---|---|---|---|---|
| **Category** | **No. of Reservoirs** | **1000 $m^3$** | **Acre-Feet** | **1000 $m^3$** | **Acre-Feet** |
| Constructed and operated by Bureau of Reclamation | 110 | 106,709,244 | 86,510,251 | 144,632,109 | 117,254,697 |
| Rehabilitated and operated by Bureau of Reclamation | 10 | 247,069 | 200,302 | 248,694 | 201,618 |
| Constructed by others, operated by Bureau of Reclamation | 11 | 6,337,601 | 5,137,957 | 7,009,548 | 5,682,711 |
| Under construction by Bureau of Reclamation | 8 | 837,118 | 678,660 | 5,469,294 | 4,434,012 |
| Constructed by Bureau of Reclamation, operated by others | 109 | 18,183,188 | 14,741,292 | 19,878,391 | 16,115,611 |
| Rehabilitated by Bureau of Reclamation, operated by others | 14 | 852 561 | 691,180 | 865,130 | 701,370 |
| Constructed and operated by others | 71 | 78,238,538 | 63,428,765 | 100,529,146 | 81,499,984 |
| Constructed or rehabilitated under loan program | 22 | 444,806 | 360,609 | 493,310 | 399,932 |
| Total | 355 | 211,850,129 | 171,749,017 | 279,125,626 | 226,289,936 |

*Note*: As of September 30, 1986.

*Source*: From U.S. Department of the Interior, Bureau of Reclamation, 1986, *Statistical Compilation of Engineering Features on Bureau of Reclamation Projects*.

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**Table 11B.23 Results of Bathymetric Surveys of 14 Reservoirs in Puerto Rico**

| Reservoir | Original Capacity $(Mm)^3$ | Const. Year | Study Year | Age | Storage Capacity $(Mm)^3$ | Total Vol. Loss $(Mm)^3$ | Long-Term Volume Loss $(m^3/yr)$ | Loss in Percent | Long-Term Storage Loss per Year (Percent) | Drainage Area $(km)^2$ | Surface Area $(km)^2$ | Deposition Rate (cm/yr) | Sediment Yield $(m^3/km^2/yr)$ | Storage Loss $(m^3/km^2/yr)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Caonillas | 55.66 | 1948 | 2000 | 52 | 42.27 | 13.39 | 257,500 | 24 | 0.5 | 126.65 | 2.70 | 9.5 | 2,186 | 2,033 |
| Carite | 13.95 | 1913 | 1999 | 86 | 10.74 | 3.21 | 37,326 | 23 | 0.3 | 20.51 | 1.20 | 3.1 | 1,938 | 1,820 |
| Cidra | 6.54 | 1946 | 1997 | 51 | 5.76 | 0.78 | 15,294 | 12 | 0.2 | 21.39 | 1.08 | 1.4 | 768 | 715 |
| Dos Bocas | 37.50 | 1942 | 1999 | 57 | 18.04 | 19.46 | 341,404 | 52 | 0.9 | 310.00 | 1.78 | 19.2 | 1,299 | 1,103 |
| Garzas | 5.80 | 1943 | 1996 | 53 | 5.11 | 0.69 | 13,019 | 12 | 0.2 | 15.60 | 0.40 | 3.2 | 878 | 834 |
| Guajataca | 48.46 | 1928 | 1999 | 71 | 42.28 | 6.18 | 87,042 | 13 | 0.2 | 79.77 | 3.42 | 2.5 | 1,188 | 1,091 |
| Guayo | 19.20 | 1956 | 1997 | 41 | 16.57 | 2.63 | 64,146 | 14 | 0.3 | 24.86 | 1.09 | 5.9 | 2,660 | 2,580 |
| La Plata | 40.21 | 1974 | 1998 | 24 | 35.46 | 4.75 | 197,917 | 12 | 0.5 | 469.00 | 3.09 | 6.4 | 483 | 422 |
| Loiza | 26.81 | 1953 | 1994 | 41 | 14.20 | 12.61 | 307,561 | 47 | 1.1 | 538.00 | 2.67 | 11.5 | 750 | 572 |
| Loco | 2.40 | 1951 | 2000 | 49 | 0.87 | 1.53 | 31,224 | 64 | 1.3 | 21.76 | 0.29 | 10.8 | 1,774 | 1,435 |
| Lucchetti | 20.35 | 1952 | 2000 | 48 | 11.88 | 8.47 | 176,458 | 42 | 0.9 | 44.81 | 1.11 | 15.9 | 4,102 | 3,937 |
| Patillas | 17.64 | 1914 | 1997 | 83 | 13.84 | 3.80 | 102,703 | 22 | 0.6 | 65.27 | 1.35 | 7.6 | 1,739 | 1,617 |
| Prieto | 0.76 | 1955 | 1997 | 42 | 0.22 | 0.54 | 12,857 | 71 | 1.7 | 24.80 | 0.06 | 21.4 | 900 | 518 |
| Yahuecas | 1.76 | 1956 | 1997 | 41 | 0.33 | 1.43 | 34,878 | 81 | 2.0 | 45.17 | 0.22 | 15.8 | 1,430 | 772 |
| Average | | | | | | | 119,952 | 35 | 0.7 | | | 9.6 | 1,578 | 1,389 |

*Note*: Const., construction; vol., volume; $m^3/yr$, cubic meter per year; $Mm^3$, mega cubic meter; $km^2$, square kilometer; cm/yr, centimeter per year; $m^3/km^2/yr$, cubic meter per square kilometer per year.

*Source*: From www.usgs.gov.



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**Table 11B.24 Percent of Annual Inflow Storage and Water Demand Storage for Lago Caonillas, Lago Cidra, Lago Dos Bocas, Lago Guajataca, Lago Loiza, and Lago La Plata**

| Reservoir | Average Annual Inflow (Million Cubic Meters) | Percent of Annual Inflow Stored | Annual Demand ($Mm^3$) | Ability to Store Annual Water Demand (Percent) |
|---|---|---|---|---|
| Lago Cidra | 14.5 | 40.0 | 6.9 | 83 |
| Lago Dos Bocas | 400.00 | 4.0 | 103.61 | 17 |
| Lago Guajataca | 104.50 | 40.0 | 62.16 | 68 |
| Lago Loiza | 363.85 | 4.0 | 138.15 | 10 |
| Lago La Plata | 270.98 | 13.1 | 96.52 | 37 |

*Note*: $Mm^3$, mega cubic meter.

*Source*: From www.usgs.gov.

**Table 11B.25 Major Storage Reservoirs on United States Bureau of Reclamation Projects**

| Project, State, Reservoir Name (Dam Name), Stream, Operator | Category | Purpose | Active Capacity Acre-Feet | Total Capacity Acre-Feet | Reservoir Area Acres | Year Completed |
|---|---|---|---|---|---|---|
| Pacific Northwest Region | | | | | | |
| Boise ID-OR | | | | | | |
| Cascade Reservoir North Fork Payette River | A | I–P–FC | 653,000 | 703,000 | 28,300 | 1948 |
| Columbia Basin, WA | | | | | | |
| Banks Lake (North and dry falls) Offstream | A | I | 715,000 | 1,280,000 | 27,000 | 1951[b] |
| Billy Clapp Lake (Pinto) Offstream | A | I–FC | 21,200 | 64,200 | 1,010 | 1948 |
| Franklin D. Roosevelt LK (Grand Coulee) Columbia River | A | I–P–FC–RR–N | 5,190,000 | 9,390,000 | 82,300 | 1942 |
| Potholes Reservoir (O Sullivan) Lower Crab Creek | A | I–FC | 332,000 | 512,000 | 27,800 | 1949 |
| Hungry Horse, MT | | | | | | |
| Hungry Horse Reservoir South Fork Flathead River | A | I–P–FC–N | 2,980,000 | 3,470,000 | 23,800 | 1953 |
| Minidoka-Palisades, ID-WY | | | | | | |
| American Falls Reservoir Snake River | B | I–FC–MI | 1,670,000 | 1,670,000 | 58,100 | 1978[c] |
| Island Park Reservoir Henrys Fork River | A | I–FC | 127,500 | 1,280,000 | 7,794 | 1938[c] |
| Jackson Lake Snake River | A | I–FC | 624,000 | 847,000 | 25,500 | 1916[c,e] |
| Palisades Reservoir South Fork Snake River | A | I–P–FC–FW | 1,200,000 | 1,401,000 | 16,150 | 1957 |
| Owyhee, ID-OR | | | | | | |
| Lake Owyhee Owyhee River Owyhee Project North Board of Control | D | I–FC | 715,000 | 1,120,000 | 12,700 | 1932 |
| Yakima, WA | | | | | | |
| Cle Elum Lake Cle Elum River | A | I | 437,000 | 710,000 | 4,812 | 1933 |
| Mid-Pacific Region | | | | | | |
| Central Valley, CA | | | | | | |
| Clair Engle Lake (Trinity) Trinity River | A | I–P | 2,140,000 | 2,450,000 | 16,500 | 1962 |

*(Continued)*

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**Table 11B.25 (Continued)**

| Project, State, Reservoir Name (Dam Name), Stream, Operator | Category | Purpose | Active Capacity Acre-Feet | Total Capacity Acre-Feet | Reservoir Area Acres | Year Completed |
|---|---|---|---|---|---|---|
| Folsom Lake<br>American River | B | I–P–FC | 920,000 | 1,010,000 | 11,400 | 1956 |
| Lake Isabella<br>Kern River<br>U.S. Corps of Engineers | E | I–FC | 567,900 | 570,000 | 11,400 | 1953 |
| Millerton Lake (Friant)<br>San Joaquin River | A | I–FC | 434,000 | 521,000 | 4,900 | 1942 |
| New Hogan Lake<br>Calaveras River<br>U.S. Corps of Engineers | E | I–FC | 309,000 | 324,000 | 4,410 | 1964 |
| New Melones Lake<br>Stanislaus River | B | I–P–FC | 2,100,000 | 2,400,000 | 12,500 | 1979 |
| O Neill Reservoir<br>San Luis Creek<br>California Department of Water Resources | D | I–P | 20,800 | 56,400 | 2,250 | 1967 |
| Pine Flat Lake<br>Kings River<br>U.S. Corps of Engineers | E | I–FC | 1,000,000 | 1,000,000 | 5,970 | 1954 |
| San Luis Reservoir<br>San Luis Creek<br>California Department of Water Resources | D | I–P | 1,960,000 | 2,040,000 | 13,000 | 1967 |
| Shasta Lake<br>Sacramento River | A | I–P–FC–RR–N–MI | 3,970,000 | 4,550,000 | 29,700 | 1945 |
| Klamath, CA-OR | | | | | | |
| Clear Lake Reservoir<br>Lost River | A | I–FC | 513,000 | 527,000 | 25,800 | 1910 |
| Gerber Reservoir<br>Miller Creek | A | I | 94,300 | 94,300 | 3,830 | 1925[c] |
| Upper Klamath Lake<br>Upper Klamath Lake Outlet<br>Pacific Power and Light | E | I–P | 465,000 | 873,000 | 90,900 | 1921[a,c] |
| Newlands, NV | | | | | | |
| Lake Tahoe<br>Truckee River<br>Truckee-Carson Irrigation District | D | I–P | 732,000 | 732,000 | 120,000 | 1913[c] |
| Solano, CA | | | | | | |
| Lake Berryessa (Monticello)<br>Putah Creek | A | I–FC–MI | 1,590,000 | 1,600,000 | 20,700 | 1957 |
| Lower Colorado Region | | | | | | |
| Boulder Canyon, AZ-CA-NV | | | | | | |
| Lake Mead (Hoover)<br>Colorado River | A | I–P–FC–RR–N–MI | 17,400,000 | 2,8500,000 | 163,000 | 1936 |
| Colo R Front Work-Levee System<br>Senator Wash Reservoir | A | | 12,300 | 13,800 | 470 | 1966[b] |

*(Continued)*

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**Table 11B.25 (Continued)**

| Project, State, Reservoir Name (Dam Name), Stream, Operator | Category | Purpose | Active Capacity Acre-Feet | Total Capacity Acre-Feet | Reservoir Area Acres | Year Completed |
|---|---|---|---|---|---|---|
| Senator Wash | | | | | | |
| Parker-Davis, AZ-CA-NV | | | | | | |
| Lake Havasu (Parker) | A | P–FC–MI | 180,000 | 619,400 | 20,400 | 1938 |
| Colorado River | | | | | | |
| Salt River, AZ | | | | | | |
| Theodore Roosevelt Lake | D | I–P–MI | 1,336,700 | 1,336,700 | 17,315 | 1936[e] |
| Salt River | | | | | | |
| Salt River Valley Water Users Assoc. | | | | | | |
| Upper Colorado Region | | | | | | |
| Central Utah, UT | | | | | | |
| Strawberry Reservoir | A | I–MI–FC | 951,000 | 1,106,500 | 17,000 | 1974 |
| Strawberry River | | | | | | |
| Colorado River Storage | A | I–P–FC | 748,500 | 940,800 | 9,180 | 1966 |
| Blue Mesa Reservoir | | | | | | |
| Gunnison River | | | | | | |
| Flaming Gorge Reservoir | A | I–P | 3,515,700 | 3,788,700 | 42,020 | 1964 |
| Green River | | | | | | |
| Lake Powell (Glen Canyon) | A | P–R | 20,876,000 | 27,000,000 | 161,390 | 1964 |
| Colorado River | | | | | | |
| Navajo Reservoir | A | I–FC–RR | 1,036,100 | 1,708,600 | 15,610 | 1963 |
| San Juan River | | | | | | |
| Southwest Region | | | | | | |
| Brantley, NM | | | | | | |
| Brantley Reservoir | C | FC–I | 42,000 | 3,485,000 | 15,320 | |
| Canadian River, TX | | | | | | |
| Lake Meredith (Sanford) | D | FC–MI–FW | 1,304,554 | 1,382,478 | 16,513 | 1965 |
| Canadian River | | | | | | |
| Canadian River Municipal Water Authority | | | | | | |
| Colorado River, TX | | | | | | |
| Marshall Ford Reservoir | D | I–P–FC–RR–N | 1,590,763 | 1,953,936 | 18,929 | 1942 |
| Colorado River | | | | | | |
| Lower Colorado River Authority | | | | | | |
| Middle Rio Grande, NM | | | | | | |
| Cochiti Lake | E | I–FC–S–FW | 676,217 | 722,000 | 10,690 | 1975 |
| Rio Grande River | | | | | | |
| U.S. Corps of Engineers | | | | | | |
| Nueces River, TX | | | | | | |
| Choke Canyon Reservoir | A | MI–FW | 689,480 | 691,130 | 25,733 | 1982 |
| Frio River | | | | | | |
| Rio Grande, NM-TX | | | | | | |
| Elephant Butte Reservoir | A | I–P | 2,060,000 | 2,110,000 | 36,521 | 1916 |
| Rio Grande River | | | | | | |
| San Angelo, TX | | | | | | |
| Twin Buttes Reservoir | D | I–FC–MI–FW | 632,214 | 640,568 | 9,079 | 1963 |
| Middle South Concho River; Spring Creek | | | | | | |
| San Angelo Water Supply Corporation | | | | | | |
| Tucumcari, NM | | | | | | |
| Conchas Lake | E | I–FC | 451,161 | 528,951 | 13,664 | 1940 |
| Canadian River | | | | | | |

*(Continued)*

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**Table 11B.25 (Continued)**

| Project, State, Reservoir Name (Dam Name), Stream, Operator | Category | Purpose | Active Capacity Acre-Feet | Total Capacity Acre-Feet | Reservoir Area Acres | Year Completed |
|---|---|---|---|---|---|---|
| U.S. Corps of Engineers | | | | | | |
| Missouri Basin Region | | | | | | |
| Colorado-Big Thompson, CO | | | | | | |
| Lake Granby Colorado River | A | I–P | 466,000 | 540,000 | 7,260 | 1950 |
| Fort Peck, MT | | | | | | |
| Fort Peck Lake Missouri River U.S. Corps of Engineers | E | I–P–FC–N | 14,626,000 | 18,909,000 | 249,000 | 1940 |
| Kendrick, WY | | | | | | |
| Seminoe Reservoir North Platte River | A | I–P | 985,603 | 1,017,273 | 20,300 | 1939 |
| North Platte, NE-WY | | | | | | |
| Pathfinder Reservoir North Platte River | A | I–P | 985,102 | 1,016,507 | 22,000 | 1909 |
| Pick-Sloan Missouri Basin Program | | | | | | |
| Lake Francis Case (Fort Randall) Missouri River U.S. Corps of Engineers | E | P–FC–N | 4,033,000 | 5,603,000 | 102,100 | 1953 |
| Lake Oahe Missouri River U.S. Corps of Engineers | E | I–P–FC | 17,886,400 | 23,337,600 | 372,800 | 1962 |
| Lake Sharpe (Big Bend) Missouri River U.S. Corps of Engineers | E | P | 1,882,302 | 1,884,000 | 64,000 | 1964 |
| Lewis and Clark Lake (Gavins Point) Missouri River U.S. Corps of Engineers | E | P–FC–N | 156,000 | 504,000 | 32,000 | 1955 |
| Bostwick Division, KS-NE | | | | | | |
| Harlan County Lake Republican River U.S. Corps of Engineers | E | I–FC | 691,121 | 825,782 | 23,064 | 1952 |
| Boysen Division, WY | | | | | | |
| Boysen Unit | | | | | | |
| Boysen Reservoir Wind River | A | I–P–FC | 802,000 | 952,400 | 22,166 | 1952 |
| Garrison Division, ND | | | | | | |
| Audubon Lake (Snake Creek) Offstream | B | I | 356,000 | 500,000 | 19,400 | 1965[d] |
| Lake Sakakawea (Garrison) Missouri River U.S. Corps of Engineers | E | I–P–FC–N–MI–FW | 18,933,500 | 23,923,000 | 381,900 | 1956[a] |
| Helena-Great Falls Div, MT | | | | | | |
| (Canyon Ferry Unit) | | | | | | |

*(Continued)*

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**Table 11B.25 (Continued)**

| Project, State, Reservoir Name (Dam Name), Stream, Operator | Category | Purpose | Active Capacity Acre-Feet | Total Capacity Acre-Feet | Reservoir Area Acres | Year Completed |
|---|---|---|---|---|---|---|
| Canyon Ferry Lake<br>Missouri River | A | I–FC–P–MI–F–W | 1,605,057 | 2,050,519 | 35,181 | 1954 |
| Lower Bighorn Div, MT-WY<br>(Yellowtail Unit) | | | | | | |
| Bighorn Lake (Yellowtail Dam)<br>Bighorn River | A | P | 834,776 | 1,328,360 | 17,298 | 1966 |
| Marias Division, MT<br>(Lower Marias Unit) | | | | | | |
| Lake Elwell (Tiber)<br>Marias River | A | I–FW | 790,533 | 1,368,157 | 23,152 | 1956[f] |
| Oregon Trail Div, NE-WY<br>(Glendo Unit) | | | | | | |
| Glendo Reservoir<br>North Platte River | A | I–P–FC | 726,254 | 789,402 | 12,400 | 1958 |
| Solomon Division, KS<br>(Glen Elder Unit) | | | | | | |
| Waconda Lake (Glen Elder)<br>Solomon River | A | I–FC–MI | 927,104 | 963,775 | 12,600 | 1969 |

*Note*: As of September 30, 1986; total capacity of 500,000 acre-feet or more. Purpose, FW, fish wildlife; FC, flood control; I, irrigation; MI, municipal industrial; N, navigation; P, power; RR, river regulation; S, sediment. Capacity-active, storage available for project, usually the storage above the lowest point of release. Total, storage at highest controlled water surface. Reservoir area, water surface area at active conservation capacity. Year completed, date original construction completed except as indicated in footnote e. Operating agency, agency directly and officially responsible for operation and maintenance of feature. Does not include agencies that may administer recreational or other secondary function as a service to the primary operator. Category, A, constructed and operated by bureau of reclamation; B, constructed by others, operated by bureau of reclamation; C, under construction by bureau of reclamation; D, constructed by bureau of reclamation, operated by others; E, constructed and operated by others.

[a] The bureau of reclamation has responsibility for the proper care and management of five reservoirs by special agreement.
[b] Reregulating reservoir.
[c] Dead storage not evaluated.
[d] Not yet in operation.
[e] Date indicates bureau of reclamation rehabilitation work.
[f] Tiber dam modification completed in 1981.

*Source*: From U.S. Department of the Interior Bureau of Reclamation, 1986, *Statistical Compilation of Engineering Features on Bureau of Reclamation Projects*.

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**Table 11B.26 Flood Control Reservoirs in the United States**

| Name | River Basin | Stream | Community in Vicinity | Year Placed in Operation | Total Storage (acre-ft) | Permanent Pool (Acreage) or No Pool (NPP) | Project Functions[a] | Characteristics of Dam | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Type | Height (ft) | Length (ft) |
| Alaska | | | | | | | | | | |
| Chena River Lakes | Yukon-Kuskokwim | Chena River | Fairbanks | 1981 | 2,000 | NPP | FR | Earth | 50 | 40,200 |
| Arizona | | | | | | | | | | |
| Adobe | Gila | Skunk Creek | Phoenix | 1982 | 18,350 | NPP | FR | Earth | 109 | 2,275 |
| Alamo | Colorado | Bill Williams River | Wenden | 1968 | 1,046,310 | 560 | FRWX | Earth | 283 | 975 |
| Cave Buttes | Gila | Cave Creek | Phoenix | 1979 | 46,600 | NPP | FRX | Earth | 109 | 2,275 |
| Dreamy Draw | Gila | Dreamy Draw | Phoenix | 1973 | 320 | NPP | FRX | Earth | 50 | 448 |
| New River | Gila | New River | Phoenix | 1985 | 43,520 | NPP | F | Earth | 104 | 2,320 |
| Painted Rock | Gila | Gila River | Gila Bend | 1959 | 2,491,700 | NPP | FRWX | Earth | 181 | 4,780 |
| Tat Momolikot | Gila | Santa Rosa Wash | Casa Grande | 1974 | 198,550 | NPP | FWX | Earth | 75.5 | 12,500 |
| Whitlow Ranch | Gila | Queen Creek | Superior | 1960 | 35,500 | NPP | FX | Earth | 149 | 837 |
| Arkansas | | | | | | | | | | |
| Blakely Mountain Dam | Ouachita | Ouachita | Hot Springs | 1955 | 2,768,500 | 20,900 | FP | Earth | 235 | 1,100 |
| Blue Mountain | Arkansas | Petit Jean River | Paris | 1947 | 257,900 | 2,910 | FRWX | Earth | 115 | 2,800 |
| DeGray | Ouachita | Caddo | Arkadelphia | 1971 | 881,900 | 6,400 | FPQRS | Earth | 243 | 3,400 |
| DeQueen | Red | Rolling Fork River | DeQueen | 1977 | 136,100 | 1,680 | FSQRW | Earth | 160 | 2,360 |
| Dierks | Red | Saline River | Dierks | 1975 | 96,800 | 1,360 | FSRAW | Earth and Rock | 153 | 2,500 |
| Gillham | Red | Cossatot River | Gillham | 1975 | 221,800 | 1,370 | FSQW | Earth and Rock | 160 | 1,750 |
| Millwood | Red | Little River | Ashdown | 1966 | 1,854,930 | 29,200 | FSW | Earth | 88 | 17,554 |
| Narrows Dam | Ouachita | Little Missouri | Murfreesboro | 1949 | 407,900 | 2,500 | FP | Concrete | 175 | 941 |
| Nimrod | Arkansas | Fourche La Fave River | Plainview | 1942 | 336,010 | 3,550 | FSWX | Concrete | 97 | 1,012 |
| California | | | | | | | | | | |
| Black Butte | Sacramento | Stony Creek | Orland | 1963 | 160,000 | 770 | FIRX | Earth | 156 | 2,970 |
| Brea | Santa Ana | Brea Creek | Fullerton | 1942 | 4,010 | NPP | FRX | Earth | 87 | 1,765 |
| Buchanan Dam-H.V. Eastman Lake | San Joaquin | Chowchilla River | Chowchilla | 1975 | 150,000 | 470 | FIRW | Earth and Rock | 205.5 | 1,800 |
| Carbon Canyon | Santa Ana | Carbon Canyon River | Brea | 1961 | 6,610 | NPP | FRX | Earth | 99 | 2,610 |
| Coyote Valley | Russian | East Fork Russian River | Ukiah | 1959 | 122,500 | 1,700 | FRX | Earth | 160 | 3,500 |
| Dry Creek (Warm Springs) Lake and Channel | Russian | Dry Creek | Healdsburg | 1983 | 381,000 | 500 | FRSW | Earth | 319 | 3,000 |
| Farmington | San Joaquin | Littlejohn Creek | Farmington | 1952 | 52,000 | NPP | F | Earth | 60 | 7,800 |
| Fullerton | Santa Ana | East Fullerton Creek | Fullerton | 1941 | 760 | NPP | FRX | Earth | 46 | 575 |
| Hansen | Los Angeles | Big Tujunga Wash | Los Angeles | 1940 | 25,450 | 120 | FRWX | Earth | 97 | 10,475 |
| Harry L. Englebright | Sacramento | Yuba River | Marysville | 1941 | 69,000 | 400 | DR | Concrete | 280 | 1,142 |
| Hidden Dam-Hensley Lake | San Joaquin | Fresno River | Madera | 1975 | 90,000 | 5,000 | FIRW | Earth | 163 | 5,730 |
| Isabella | San Joaquin | Kern River | Bakersfield | 1953 | 570,000 | 1,850 | FIRW | Earth | 185 | 4,952 |
| Lopez | Los Angeles | Pacoima Wash | San Fernando | 1954 | 440 | NPP | FX | Earth | 50 | 1,300 |

*(Continued)*



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**Table 11B.26 (Continued)**

| Name | River Basin | Stream | Community in Vicinity | Year Placed in Operation | Total Storage (acre-ft) | Permanent Pool (Acreage) or No Pool (NPP) | Project Functions[a] | Characteristics of Dam | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Type | Height (ft) | Length (ft) |
| Martis Creek | Sacramento | Martis Creek | Reno | 1971 | 20,400 | 71 | FSR | Earth | 113 | 2,670 |
| Merced County Stream Group | | | | | | | | | | |
| Bear | San Joaquin | Bear Creek | Merced | 1954 | 7,700 | NPP | F | Earth | 92 | 1,830 |
| Burns | San Joaquin | Burns Creek | Merced | 1950 | 7,000 | NPP | F | Earth | 55 | 4,075 |
| Mariposa | San Joaquin | Mariposa Creek | Merced | 1948 | 15,000 | NPP | F | Earth | 88 | 1,330 |
| Owens | San Joaquin | Owens Creek | Merced | 1949 | 3,600 | NPP | F | Earth | 75 | 790 |
| Mojave River | Mojave | Mojave | Victorville | 1971 | 89,670 | NPP | FRWX | Earth | 200 | 2,200 |
| New Hogan | San Joaquin | Calaveras | Valley Springs | 1963 | 325,000 | 715 | FIRX | Earth and Rock | 210 | 1,960 |
| North Fork | Sacramento | American River | Auburn | 1939 | 14,700 | 280 | DR | Concrete | 155 | 620 |
| Pine Flat | San Joaquin | Kings River | Piedra | 1954 | 1,000,000 | NPP | FIRX | Concrete | 429 | 1,820 |
| Prado | Santa Ana | Santa Ana River | Corona | 1941 | 196,240 | NPP | FRX | Earth | 106 | 2,280 |
| San Antonio | Santa Ana | San Antonio Creek | Upland | 1956 | 7,700 | NPP | FX | Earth | 160 | 3,850 |
| Santa Fe | San Gabriel | San Gabriel River | Duarte | 1948 | 32,110 | NPP | FRX | Earth | 92 | 23,800 |
| Sepulveda | Los Angeles | Los Angeles River | Van Nuys | 1941 | 17,430 | NPP | FRX | Earth | 57 | 15,444 |
| Success | San Joaquin | Tule River | Porterville | 1960 | 85,000 | 400 | FIRX | Earth | 142 | 3,490 |
| Terminus | San Joaquin | Kaweah River | Visalia | 1961 | 150,000 | 345 | FIRX | Earth | 250 | 2,375 |
| Whittier Narrows | San Gabriel | San Gabriel River and Rio Hondo | El Monte | 1957 | 35,150 | NPP | FRWX | Earth | 56 | 16,960 |
| Colorado | | | | | | | | | | |
| Bear Creek | Missouri | Bear Creek | Denver | 1978 | 30,810 | 109 | FRX | Earth | 180 | 5,300 |
| Chatfield | Missouri | South Platte River | Denver | 1974 | 231,429 | 1,412 | FRX | Earth | 148 | 12,500 |
| Cherry Creek | Missouri | Cherry Creek | Denver | 1950 | 93,920 | 852 | FRX | Earth | 141 | 14,300 |
| John Martin | Arkansas | Arkansas River | Lamar | 1943 | 615,500 | 1,844 | FIR | Concrete and Earth | 106 | 13,274 |
| Trinidad | Arkansas | Purgatoire River | Trinidad | 1977 | 123,500 | 280 | FIRX | Earth | 200 | 6,610 |
| Connecticut | | | | | | | | | | |
| Black Rock | Housatonic | Branch Brook | Thomaston | 1970 | 8,700 | 20 | FR | Earth | 154 | 933 |
| Colebrook River | Connecticut | West Branch, Farmington River | Riverton | 1969 | 97,700 | 760 | FRSX | Earth | 223 | 1,300 |
| Hancock Brook | Housatonic | Hancock Brook | Plymouth | 1960 | 4,030 | 40 | FRW | Earth | 57 | 630 |
| Hop Brook | Housatonic | Hop Brook | Middlebury | 1968 | 6,970 | 21 | FR | Earth | 97 | 520 |
| Mansfield Hollow | Thames | Natchaug River | Willimantic | 1952 | 52,000 | 450 | FRW | Earth | 68 | 12,420 |
| Northfield Brook | Thames | Northfield Brook | Thomaston | 1965 | 2,430 | 8 | FRW | Earth | 118 | 810 |
| Thomaston | Housatonic | Naugatuck River | Thomaston | 1960 | 42,000 | NPP | F | Earth | 142 | 2,000 |
| West Thompson | Thames | Quinebaug | Thompson | 1965 | 26,800 | 200 | FRW | Earth | 70 | 2,550 |
| Idaho | | | | | | | | | | |
| Lucky Peak | Columbia | Boise River | Boise | 1956 | 306,000 | 2,850 | FIR | Earth | 250 | 1,700 |
| Illinois | | | | | | | | | | |
| Cariyle | Upper Mississippi | Kaskaskia River | Carlyle | 1967 | 983,000 | 26,000 | FSNRWA | Earth | 67 | 6,570 |
| Farmdale | Upper Mississippi | Farm Creek | East Peoria | 1951 | 15,500 | NPP | F | Earth | 80 | 1,275 |
| Fondulac | Upper Mississippi | Fondulac Creek | East Peoria | 1951 | 3,780 | NPP | F | Earth | 67 | 1,000 |
| Shelbyville | Upper Mississippi | Kaskaskia River | Shelbyville | 1970 | 684,000 | 11,100 | FSNRW | Earth | 108 | 3,000 |
| Rend Lake | Upper Mississippi | Big Muddy River | Benton | 1970 | 294,000 | 18,900 | FQRSW | Earth | 54 | 10,600 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Indiana | | | | | | | | | | |
| Brookville | Ohio | East Fork of Whitewater River | Brookville | 1974 | 359,600 | 2,250 | FRSW | Earth and Rock | 182 | 3,000 |
| Cagles Mill | Ohio | Mill Creek | Terre Haute | 1952 | 228,120 | 1,400 | FRX | Earth | 150 | 950 |
| Cecil M. Harden | Ohio | Raccoon Creek | Rockville | 1960 | 132,800 | 1,100 | FRX | Earth | 117 | 1,790 |
| Huntington | Ohio | Wabash River | Huntington | 1969 | 153,100 | 500 | FRW | Earth | 91 | 5,332 |
| Mississinewa | Ohio | Mississinewa | Peru | 1967 | 368,400 | 1,100 | FRW | Earth | 137 | 8,100 |
| Monroe | Ohio | Salt Creek | Harrodsburg | 1964 | 441,000 | 3,280 | FARS | Earth | 93 | 1,400 |
| Patoka | Ohio | Patoka River | Ellsworth | 1978 | 301,600 | 2,010 | FRSQW | Earth and Rock | 84 | 1,550 |
| Salamonie | Ohio | Salamonie | Wabash | 1966 | 263,600 | 976 | FRW | Earth | 133 | 6,100 |
| Iowa | | | | | | | | | | |
| Coralville | Upper Mississippi | Iowa River | Iowa City | 1958 | 492,000 | 1,820 | FARW | Earth | 100 | 1,400 |
| Rathbun | Missouri | Chariton River | Centerville | 1969 | 552,000 | 11,000 | FNRWXQ | Earth | 86 | 10,600 |
| Red Rock | Upper Mississippi | Des Moines River | Des Moines | 1969 | 1,830,000 | 8,950 | FARWQ | Earth | 110 | 5,676 |
| Saylorville | Upper Mississippi | Des Moines River | Des Moines | 1975 | 602,000 | 74,000 | FARWQ | Earth | 125 | 6,750 |
| Kansas | | | | | | | | | | |
| Clinton | Missouri | Wakarusa River | Lawrence | 1977 | 397,200 | 7,000 | FSWAXR | Earth | 114 | 9,250 |
| Council Grove | Arkansas | Grand (Neosho) | Council Grove | 1964 | 112,265 | 3,235 | FSQR | Earth | 96 | 6,500 |
| El Dorado | Arkansas | Walnut River | El Dorado | 1981 | 236,200 | 8,000 | FSQR | Earth | 99 | 20,930 |
| Elk City | Arkansas | Elk River | Independence | 1966 | 284,300 | 4,450 | FSQ | Earth | 107 | 4,840 |
| Fall River | Arkansas | Fall River | Fall River | 1949 | 256,400 | 2,350 | FSX | Earth | 94 | 6,015 |
| Hillsdale | Missouri | Big Bull Creek | Kansas City | 1981 | 160,000 | 4,580 | FSQR | Earth | 75 | 11,600 |
| John Redmond | Arkansas | Grand (Neosho) | Burlington | 1964 | 630,250 | 9,280 | FSQR | Earth | 86.5 | 21,790 |
| Kanopolis | Missouri | Smoky Hill River | Salina | 1948 | 450,000 | 3,815 | FRWX | Earth | 131 | 15,360 |
| Marion | Arkansas | Cottonwood River | Marion | 1968 | 143,850 | 6,200 | FRQS | Earth | 67 | 8,375 |
| Melvern | Missouri | Marias Des Cygnes | Melvern | 1972 | 363,000 | 6,930 | FRQWX | Earth | 98 | 9,700 |
| Milford | Missouri | Republican River | Junction City | 1965 | 1,160,000 | 15,600 | FRSXWQ | Earth and Rock | 126 | 6,300 |
| Pearson Skubitz Big Hill | Arkansas | Big Hill Creek | Cherryvale | 1981 | 40,600 | 1,240 | FSR | Earth | 83 | 3,870 |
| Perry | Missouri | Delaware River | Perry | 1969 | 770,000 | 12,200 | FRSXW | Earth and Rock | 95 | 7,750 |
| Pomona | Missouri | 110 Mile Creek | Pomona | 1963 | 230,000 | 4,000 | FRSWXQ | Earth and Rock | 85 | 7,750 |
| Toronto | Arkansas | Verdigris River | Toronto | 1960 | 200,800 | 2,660 | FX | Earth | 90 | 4,712 |
| Tuttle Creek | Missouri | Big Blue River | Manhattan | 1962 | 2,346,000 | 15,800 | FRWXQAN | Earth and Rock | 157 | 7,500 |
| Wilson | Missouri | Saline River | Wilson | 1964 | 776,000 | 9,000 | FIRWXNA | Earth | 160 | 5,600 |
| Kentucky | | | | | | | | | | |
| Barren River | Ohio | Barren River | Glasgow | 1964 | 815,200 | 4,340 | FARS | Earth | 146 | 3,970 |
| Buckhorn | Ohio | Middle Fork of Kentucky River | Buckhorn | 1960 | 168,000 | 550 | FR | Earth | 162 | 1,020 |
| Carr Fork | Ohio | Carr Fork | Hazard | 1976 | 47,700 | 530 | FQRW | Earth and Rock | 130 | 720 |
| Cave Run | Ohio | Licking River | Farmers | 1974 | 614,100 | 6,790 | FQRW | Earth and Rock | 148 | 2,740 |
| Dewey | Ohio | Johns Creek | Paintsille | 1949 | 93,000 | 1,100 | FARW | Earth | 118 | 913 |
| Fishtrap | Ohio | Levisa Fork, Big Sandy River | Pikeville | 1968 | 164,360 | 569 | FARW | Rock | 195 | 1,100 |
| Grayson | Ohio | Little Sandy | Grayson | 1967 | 118,990 | 1,050 | FQRW | Earth and Rock | 120 | 1,460 |
| Green River | Ohio | Green River | Campbellsville | 1969 | 723,200 | 5,070 | FRSQW | Earth and Rock | 142 | 2,350 |
| Martins Fork | Cumberland | Martins Fork | Harlan | 1978 | 21,000 | 578 | FQ | Concrete | 97 | 574 |
| Paintsville | Ohio | Paint Creek | Paintsville | 1983 | 73,500 | 261 | FQRW | Earth and Rock | 160 | 1,600 |
| Nolin | Ohio | Nolin River | Kyrock | 1963 | 609,400 | 2,890 | FAR | Earth and Rock | 174 | 990 |
| Rough River | Ohio | Rough River | Leitchfield | 1958 | 334,400 | 2,180 | FRX | Earth and Rock | 124 | 1,530 |

*(Continued)*



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**Table 11B.26 (Continued)**

| Name | River Basin | Stream | Community in Vicinity | Year Placed in Operation | Total Storage (acre-ft) | Permanent Pool (Acreage) or No Pool (NPP) | Project Functions[a] | Characteristics of Dam | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Type | Height (ft) | Length (ft) |
| Taylorsville | Ohio | Salt River | Taylorsville | 1983 | 291,670 | 1,625 | FQRW | Earth and Rock | 164 | 1,280 |
| Louisiana | | | | | | | | | | |
| Bayou Bodcau | Red | Bayou Bodcau | Shreveport | 1949 | 357,300 | NPP | FRW | Earth | 76 | 12,850 |
| Caddo Lake | Red | Cypress Bayou | Shreveport | 1971 | 175,000 | 32,700 | NFRS | Concrete and Earth | | 3,600 |
| Wallace Lake | Red | Cypress Bayou | Shreveport | 1946 | 88,300 | 2,300 | FR | Earth | 48 | 4,934 |
| Maryland | | | | | | | | | | |
| Jennings Randolph Lake | Potomac | North Branch | Barnum | 1981 | 130,900 | 952 | FQRS | Earth and Rock | 296 | 2,130 |
| Massachusetts | | | | | | | | | | |
| Barre Falls | Connecticut | Ware River | Barre | 1958 | 24,000 | NPP | FRW | Earth and Rock | 62 | 885 |
| Birch Hill | Connecticut | Millers River | So.Royalston | 1941 | 49,900 | NPP | FRW | Earth and Rock | 56 | 1,400 |
| Buffumville | Thames | Little River | Charlton | 1958 | 12,700 | 200 | FRW | Earth and Rock | 66 | 3,255 |
| Charles River Natural Valley Storage | Charles | Charles River | Millis | 1983 | 35,000 | NPP | F | Nonstructural | — | — |
| Conant Brook | Connecticut | Conant Brook | Monson | 1966 | 3,740 | NPP | F | Earth and Rock | 85 | 1,060 |
| East Brimfield | Connecticut | Quinebaug River | Fiskdale | 1960 | 30,000 | 360 | FRW | Earth and Rock | 55 | 520 |
| Hodges Village | Connecticut | French River | Oxford | 1959 | 12,800 | NPP | FRW | Earth and Rock | 55 | 2,140 |
| Knightville | Connecticut | Westfield River | Huntington | 1941 | 49,000 | NPP | FRW | Earth and Rock | 160 | 1,200 |
| Littleville | Connecticut | Middle Branch, Westfield River | Chester | 1965 | 32,400 | 275 | FRWS | Earth and Rock | 1,164 | 1,360 |
| Tully | Connecticut | Tully River | Fryville | 1949 | 22,000 | 300 | FRW | Earth and Rock | 62 | 1,570 |
| West Hill | Blackstone | West River | Uxbridge | 1960 | 12,350 | NPP | FRW | Earth and Rock | 51 | 2,400 |
| Westville | Thames | Quinebaug River | Sturbridge | 1961 | 11,100 | 23 | FRW | Earth and Rock | 78 | 560 |
| Minnesota | | | | | | | | | | |
| Big Stone Lake-Whetstone River | Upper Mississippi | Minnesota River | Ortonville | 1973 | 45,000 | 12,700 | FRW | Earth | 25 | 13,700 |
| Lac Qui Parle Chippewa River | Upper Mississippi | Chippewa River | Montevideo | 1950 | — | NPP | FRWX | Earth and Rock | 23.3 | 17,975 |
| Lac Qui Parle | Upper Mississippi | Minnesota River | Montevideo | 1950 | 122,800 | 6,500 | FRWX | Earth and Rock | 21 | 4,100 |
| Marsh Lake | Upper Mississippi | Minnesota River | Montevideo | 1950 | 35,000 | 5,100 | FRWX | Earth and Rock | 19.5 | 11,800 |
| Orwell | Red River of the North | Otter Tail River | Fergus Falls | 1953 | 14,100 | 210 | FARS | Earth and Rock | 47 | 1,355 |
| Red Lake | Red River of the North | Red Lake River | Red River | 1951 | 2,680,000 | 279,000 | FARSX | Earth and Rock | 15.5 | 36,500 |
| Mississippi | | | | | | | | | | |
| Arkabutla Lake | Lower Mississippi | Coldwater River | Arkabutla | 1943 | 525,300 | 5,100 | F | Earth and Rock | 81 | 11,500 |
| Enid Lake | Lower Mississippi | Yocona River | Enid | 1951 | 660,000 | 6,100 | F | Earth and Rock | 99 | 8,400 |
| Grenada Lake | Lower Mississippi | Yalobusha River | Grenada | 1954 | 1,337,400 | 9,800 | F | Earth and Rock | 102 | 13,900 |
| Okatibbee | Pascagoula | Okatibbee Creek | Meridian | 1969 | 142,400 | 1,280 | FQSR | Earth | 67 | 6,543 |
| Sardis Lake | Lower Mississippi | Little Tailahatchie River | Sardis | 1940 | 1,570,000 | 10,700 | F | Earth and Rock | 117 | 15,300 |
| Missouri | | | | | | | | | | |
| Clearwater | White | Black River | Piedmont | 1948 | 413,700 | 1,630 | FRWX | Earth and Rock | 154 | 4,225 |
| Long Branch | Grande Chariton | Little Chariton | Macon | 1980 | 65,000 | 2,430 | FRSQW | Earth | 71 | 3,800 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Longview | Missouri | Little Blue River | Kansas City | 1986 | 46,900 | 930 | FRWQ | Earth and Rock | 120 | 1,900 |
| Pomme de Terre | Missouri | Pomme de Terre River | Hermitage | 1961 | 650,000 | 7,820 | FRWX | Earth and Rock | 155 | 4,630 |
| Smithville | Missouri | Little Platte River | Smithville | 1982 | 246,500 | 7,190 | FSQRW | Earth | 95 | 4,200 |
| Wappapello | Lower Mississippi | St. Francis River | Wappapello | 1941 | 613,200 | 4,100 | FR | Earth and Rock | 109 | 2,700 |
| Nebraska | | | | | | | | | | |
| Harlan County | Missouri | Republican River | Republican City | 1952 | 850,000 | 13,600 | FIRWX | Earth and Rock | 107 | 11,827 |
| Papillion Creek and Tributaries: | | | | | | | | | | |
| Glenn Cunningham (Site 11) | Missouri | Knight Creek | Omaha | 1975 | 17,910 | 392 | FQRX | Earth | 67 | 1,940 |
| Standing Bear Lake (Site 16) | Missouri | Trib. of Big Papillion Creek | Omaha | 1973 | 5,220 | 137 | FRX | Earth | 70 | 1,460 |
| Salt Creek and Tributaries | | | | | | | | | | |
| Olive Creek (Site 2) | Missouri | S. Trib. Olive Br. Creek | Kramer | 1964 | 5,470 | 174 | FR | Earth | 45 | 3,020 |
| Blue Stem (Site 4) | Missouri | N. Trib. Olive Br. Creek | Sprague | 1963 | 10,260 | 315 | FR | Earth | 57 | 2,760 |
| Wagon Train (Site 8) | Missouri | N. Trib. Hickman Creek | Holland | 1963 | 9,280 | 303 | FR | Earth | 52 | 1,650 |
| Stagecoach (Site 9) | Missouri | S. Trib. Hickman Creek | Hickman | 1964 | 6,640 | 196 | FR | Earth | 48 | 2,250 |
| Yankee Hill (Site 10) | Missouri | Cardwell Creek | Denton | 1966 | 7,560 | 208 | FR | Earth | 52 | 3,100 |
| Conestoga (Site 12) | Missouri | Holmes Creek | Denton | 1964 | 10,640 | 230 | FR | Earth | 63 | 3,000 |
| Twin Lake (Site 13) | Missouri | Middle Creek | Pleasantdale | 1966 | 8,080 | 255 | FR | Earth | 58 | 2,075 |
| Pawnee (Site 14) | Missouri | N. Middle Creek | Emerald | 1965 | 29,520 | 728 | FR | Earth | 65 | 5,000 |
| Holmes Park Lake (Site 17) | Missouri | Antelope Creek | Lincoln | 1963 | 6,510 | 100 | FR | Earth | 55 | 7,700 |
| Branched Oak (Site 18) | Missouri | Oak Creek | Raymond | 1968 | 97,560 | 1,780 | FR | Earth | 70 | 5,200 |
| Nevada | | | | | | | | | | |
| Mathews Canyon | Colorado | Mathews Canyon | Caliente | 1957 | 6,270 | NPP | FX | Earth | 71 | 800 |
| Pine Canyon | Colorado | Pine Canyon | Caliente | 1957 | 7,750 | NPP | FX | Earth | 92 | 884 |
| New Hampshire | | | | | | | | | | |
| Blackwater | Merrimack | Blackwater River | Webster | 1941 | 46,000 | NPP | FRW | Earth | 75 | 1,150 |
| Edward MacDowell | Merrimack | Nubanusit Brook | West Peterborough | 1950 | 12,800 | NPP | FRW | Earth | 67 | 1,030 |
| Franklin Falls | Merrimack | Pemigewasset River | Franklin | 1943 | 154,000 | NPP | FRW | Earth | 140 | 1,740 |
| Hopkinton-Everett | Merrimack | Contoocook River | West Hopkinton | 1962 | 71,500 | 200 | FRW | Earth | 76 | 790 |
| | Merrimack | Piscataquog River | East Weare | 1962 | 87,500 | 120 | FRW | Earth | 115 | 2,000 |
| Otter Brook | Connecticut | Otter Brook | Keene | 1958 | 18,300 | 85 | FRW | Earth | 133 | 1,288 |
| Surry Mountain | Connecticut | Ashuelot River | Keene | 1941 | 32,500 | 265 | FRW | Earth | 86 | 1,670 |
| New Mexico | | | | | | | | | | |
| Abiquiu | Rio Grande | Rio Chama | Abiquiu | 1963 | 1,212,000 | NPP | FXS | Earth | 325 | 1,540 |
| Cochiti | Rio Grande | Rio Grande | Pena Blanca | 1975 | 596,300 | 1,200 | FRWX | Earth | 251 | 28,300 |
| Conchas | Arkansas | Canadian River | Tucumcari | 1939 | 529,000 | 3,000 | FI | Concrete and Earth | 200 | 19,400 |
| Galisteo | Rio Grande | Galisteo Creek | Albuquerque | 1970 | 89,000 | NPP | FX | Earth | 158 | 2,820 |
| Jemez Canyon | Rio Grande | Jemez River | Bernalillo | 1953 | 102,700 | NPP | FX | Earth | 135 | 780 |
| Two Rivers | | | | | | | | | | |
| Diamond “A” Dam | Rio Grande | Rio Hondo | Roswell | 1963 | 168,000 | NPP | FX | Earth | 98 | 4,885 |

*(Continued)*



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**Table 11B.26 (Continued)**

| Name | River Basin | Stream | Community in Vicinity | Year Placed in Operation | Total Storage (acre-ft) | Permanent Pool (Acreage) or No Pool (NPP) | Project Functions[a] | Characteristics of Dam | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Type | Height (ft) | Length (ft) |
| Rocky Dam | Rio Grande | Rocky Arroyo | | | | | | | 118 | 2,940 |
| Santa Rosa Dam Reservoir | Pecos | Pecos | Santa Rosa | 1979 | 447,000 | NPP | FIX | Earth | 212 | 1,950 |
| New York | | | | | | | | | | |
| Almond | Susquehanna | Canacadea Creek | Hornell | 1949 | 14,600 | 124 | FRW | Earth | 90 | 1,260 |
| Arkport | Susquehanna | Canisteo Creek | Arkport | 1940 | 7,900 | NPP | F | Earth | 113 | 1,200 |
| East Sidney | Susquehanna | Ouleout Creek | Franklin | 1950 | 33,550 | 210 | FRW | Concrete and Earth | 130 | 2,010 |
| Mount Morris | Genesee | Genesee River | Mount Morris | 1952 | 337,000 | 170 | FR | Concrete | 210 | 1,028 |
| Whitney Point | Susquehanna | Otselic River | Whitney Point | 1942 | 86,440 | 1,200 | FRW | Earth | 95 | 4,900 |
| North Carolina | | | | | | | | | | |
| B. Everett Jordan | Cape Fear | New Hope | Durham | 1982 | 753,500 | 14,300 | FQRSWX | Earth | 112 | 1,330 |
| Falls | Neuse | Neuse | Raleigh | 1983 | 335,600 | 11,300 | FQRSWX | Earth | 92 | 1,915 |
| W. Kerr Scott | Yadkin-Pee Dee | Yadkin | Wilkesboro | 1963 | 153,000 | 1,470 | FARSX | Earth | 148 | 1,740 |
| North Dakota | | | | | | | | | | |
| Baldhill | Red River of the North | Sheyenne River | Valley City | 1950 | 70,000 | 325 | FARS | Earth | 61 | 1,650 |
| Bowman-Haley | Missouri | North Fork, Grand River | Haley | 1967 | 92,980 | 1,750 | FSRWX | Earth | 79 | 5,730 |
| Homme | Red River of the North | South Branch of Park River | Park River | 1951 | 3,650 | 51 | FARS | Earth | 67 | 865 |
| Pipestem | James River | Pipestem Creek | Jamestown | 1974 | 146,880 | 885 | FRWX | Earth | 108 | 4,000 |
| Ohio | | | | | | | | | | |
| Alum Creek | Ohio | Alum Creek | Africa | 1975 | 134,800 | 348 | FRSW | Concrete and Earth | 93 | 10,000 |
| Berlin | Ohio | Mahoning River | Deerfield | 1943 | 91,200 | 240 | FARSWQ | Concrete and Earth | 96 | 5,750 |
| Caesar Creek | Ohio | Caesar Creek | Wilmington | 1978 | 242,200 | 13,300 | FRSQW | Earth and Rock | 165 | 2,750 |
| Clarence J. Brown | Ohio | Buck Creek | Springfield | 1974 | 63,700 | 1,010 | FQRW | Earth and Rock | 72 | 6,620 |
| Deer Creek | Ohio | Deer Creek | New Holland | 1968 | 102,500 | 727 | FRW | Earth | 93 | 3,880 |
| Delaware | Ohio | Olentangy River | Delaware | 1951 | 132,000 | 950 | FARWX | Earth | 92 | 18,600 |
| Dillon | Ohio | Licking River | Zanesville | 1961 | 273,000 | 1,325 | FRWX | Earth | 118 | 1,400 |
| Michael J. Kirwan | Ohio | West Branch, Mahoning River | Newton Falls | 1966 | 78,700 | 580 | FAQRSW | Earth | 83 | 9,900 |
| Mosquito Creek | Ohio | Mosquito Creek | Cortland | 1944 | 104,100 | 700 | FARSWQ | Earth | 47 | 5,650 |
| Muskingum River Reservoirs | | | | | | | | | | |
| Atwood | Ohio | Indian Fork | New Cumberland | 1937 | 49,700 | 1,540 | FRX | Earth | 65 | 3,700 |
| Beach City | Ohio | Sugar Creek | Beach City | 1937 | 71,700 | 420 | FRX | Earth | 64 | 5,600 |
| Bolivar | Ohio | Sandy Creek | Bolivar | 1938 | 149,600 | NPP | FR | Earth | 87 | 6,300 |
| Charles Mill | Ohio | Black Fork | Mufflin | 1936 | 88,000 | 1,350 | FRX | Earth | 48 | 1,390 |
| Clendening | Ohio | Brushy Fork | Tippecanoe | 1937 | 54,000 | 1,800 | FRX | Earth | 64 | 950 |
| Dover | Ohio | Tuscarawas River | Dover | 1938 | 203,000 | 350 | FRX | Concrete | 83 | 824 |
| Leesville | Ohio | McGuire Creek | Leesville | 1937 | 37,400 | 1,000 | FRX | Earth | 74 | 1,694 |
| Mohawk | Ohio | Walhonding River | Nellie | 1937 | 285,000 | NPP | FR | Earth | 111 | 2,330 |
| Mohicanville | Ohio | Lake Fork | Mohicanville | 1936 | 102,000 | NPP | FR | Earth | 46 | 1,220 |
| Piedmont | Ohio | Stillwater Creek | Piedmont | 1937 | 65,000 | 2,270 | FRX | Earth | 56 | 1,750 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pleasant Hill | Ohio | Clear Fork | Perrysville | 1938 | 87,700 | 850 | FRX | Earth | 113 | 775 |
| Senecaville | Ohio | Seneca Fork | Senecaville | 1937 | 88,500 | 3,550 | FRSX | Earth | 45 | 2,350 |
| Tappan | Ohio | Little Stillwater Creek | Tappan | 1936 | 61,600 | 2,350 | FRX | Earth | 52 | 1,550 |
| Wills Creek | Ohio | Wills Creek | Conesville | 1937 | 196,000 | 900 | FRX | Earth | 87 | 1,950 |
| North Branch, Kokosing River Lake | Ohio | North Branch of Kokosing River | Fredericktown | 1973 | 14,900 | 98 | FRW | Earth | 71 | 1,400 |
| Paint Creek | Ohio | Paint Creek | New Petersburg | 1972 | 145,000 | 710 | FRSQW | Earth and Rock | 118 | 700 |
| Tom Jenkins | Ohio | East Branch, Sunday Creek | Gloucester | 1951 | 26,900 | 394 | FRSWX | Concrete | 84 | 944 |
| West Fork Mill Creek | Ohio | Mill Creek | Mount Healthy | 1952 | 11,380 | 200 | FRX | Earth | 100 | 1,100 |
| William H. Harsha | Ohio | Little Miami River | Williamsburg | 1978 | 284,500 | 18,760 | FRSQW | Earth | 200 | 1,450 |
| Oklahoma | | | | | | | | | | |
| Birch | Arkansas | Birch Creek | Barnsdall | 1977 | 58,200 | 1,137 | FSQRW | Earth | 97 | 3,193 |
| Canton | Arkansas | North Canadian River | Canton | 1948 | 377,100 | 7,910 | FSI | Earth | 73 | 15,140 |
| Copan | Arkansas | Little Caney River | Copan | 1983 | 227,700 | 4,850 | FSQRW | Earth | 70 | 7,730 |
| Fort Supply | Arkansas | Wolf Creek | Fort Supply | 1942 | 100,700 | 1,820 | FSX | Earth | 85 | 12,225 |
| Great Salt Plains | Arkansas | Salt Fork, Arkansas River | Cherokee | 1941 | 271,400 | 8,690 | FRWX | Earth | 68 | 6,010 |
| Heyburn | Arkansas | Polecat Creek | Sapulpa | 1950 | 55,030 | 880 | FRWXS | Earth | 89 | 2,920 |
| Hugo | Red | Kiamichi River | Hugo | 1974 | 966,700 | 13,250 | FSQRW | Earth | 101 | 10,200 |
| Hulah | Arkansas | Caney River | Caney | 1951 | 289,000 | 3,570 | FSAX | Earth | 94 | 5,200 |
| Kaw | Arkansas | Arkansas River | Ponca City | 1976 | 1,348,000 | 17,040 | FSQRW | Earth | 125 | 9,466 |
| Oologah | Arkansas | Verdigris River | Oologah | 1963 | 1,519,000 | 29,460 | FSN | Earth | 137 | 4,000 |
| Optima | Arkansas | North Canadian River | Hardesty | 1978 | 229,500 | 5,340 | FSRW | Earth | 120 | 15,200 |
| Pine Creek | Red | Little River | Wright City | 1969 | 465,780 | 3,750 | FSQW | Earth | 124 | 7,712 |
| Sardis | Red | Jackfork Creek | Clayton | 1983 | 429,600 | 14,360 | FSRW | Earth | 81 | 14,138 |
| Skiatook | Arkansas | Hominy Creek | Skiatook | 1985 | 500,700 | 10,190 | FSQRW | Earth | 143 | 3,590 |
| Waurika | Red | Beaver Creek | Waurika | 1977 | 343,500 | 10,100 | FISQWR | Earth | 106 | 16,600 |
| Wister | Arkansas | Poteau River | Wister | 1949 | 427,900 | 5,360 | FSAX | Earth | 99 | 5,700 |
| Oregon | | | | | | | | | | |
| Applegate | Rogue River | Applegate River | Medford | 1981 | 82,000 | 988 | AFIQRSW | Gravel Embankment | 242 | 1,300 |
| Blue River | Columbia | Blue River | Blue River | 1968 | 85,000 | 975 | FINR | Earth | 319 | 1,329 |
| Cottage Grove | Columbia | Coast Fork, Willamette River | Cottage Grove | 1942 | 30,060 | 1,155 | FINR | Concrete and Earth | 114 | 2,110 |
| Dorena | Columbia | Row River | Cottage Grove | 1949 | 70,500 | 1,885 | FINR | Concrete and Earth | 145 | 3,352 |
| Fall Creek | Columbia | Middle Fork, Willamette River | Eugene | 1965 | 115,000 | 1,865 | FINR | Rockfill and Concrete | 193 | 5,100 |
| Fern Ridge | Columbia | Long Tom River | Eugene | 1941 | 110,000 | 10,305 | FINR | Rockfill and Concrete | 49 | 6,624 |
| Willow Creek | Columbia | Willow Creek | Heppner | 1983 | 13,250 | 96 | FRN | Roller Compacted Concrete | 160 | 1,780 |
| Pennsylvania | | | | | | | | | | |
| Alvin R. Bush | Susquehanna | Kettle Creek | Renovo | 1962 | 75,000 | 160 | FRW | Earth and Rock | 165 | 1,350 |
| Aylesworth Creek | Susquehanna | Aylesworth Creek | Archbald | 1970 | 1,700 | NPP | F | Earth and Rock | 90 | 1,270 |
| Beltzville | Delaware | Pohopoco | Lehighton | 1971 | 68,250 | 947 | FQRSW | Earth and Rock | 170 | 4,300 |
| Blue Marsh | Delaware | Tulephocken | Blue Marsh | 1978 | 22,900 | 963 | FAQRS | Earth and Rock | 98 | 1,775 |

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**Table 11B.26 (Continued)**

| Name | River Basin | Stream | Community in Vicinity | Year Placed in Operation | Total Storage (acre-ft) | Permanent Pool (Acreage) or No Pool (NPP) | Project Functions[a] | Characteristics of Dam | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Type | Height (ft) | Length (ft) |
| Conemaugh | Ohio | Conemaugh River | Saltsburg | 1952 | 274,000 | 300 | FW | Concrete and Earth | 137 | 1,265 |
| Cowanesque | Susquehanna | Cowanesque River | Lawrenceville | 1980 | 89,000 | 410 | FR | Earth and Rock | 151 | 3,100 |
| Crooked Creek | Ohio | Crooked Creek | Ford City | 1940 | 93,900 | 350 | FRW | Earth | 143 | 1,480 |
| Curwensville | Susquehanna River | West Branch, Susquehanna River | Curwensville | 1965 | 124,200 | 790 | FR | Earth | 131 | 2,850 |
| East Branch, Clarion River | Ohio | East Branch, Clarion River | Wilcox | 1952 | 84,300 | 90 | FARQW | Earth | 184 | 1,725 |
| Foster Joseph Sayers | Susquehanna | Bald Eagle Creek | Blanchard | 1969 | 99,000 | 1,730 | FRW | Earth | 100 | 6,835 |
| Francis E. Walter (Bear Creek) | Delaware | Lehigh River | White Haven | 1961 | 110,000 | 90 | FNRW | Earth and Rock | 234 | 3,000 |
| Gen. Edgar Jadwin | Delaware | Dyberry Creek | Honesdale | 1960 | 24,500 | NPP | F | Earth | 109 | 1,225 |
| Indian Rock | Susquehanna | Codorus Creek | York | 1942 | 28,000 | NPP | FRW | Earth | 83 | 1,000 |
| Kinsua | Ohio | Allegheny River | Warren | 1965 | 1,180,000 | 1,900 | PFAQRW | Concrete and Earth | 177 | 1,877 |
| Loyalhanna | Ohio | Loyalhanna Creek | Saltsburg | 1942 | 95,300 | 210 | FRW | Concrete and Earth | 114 | 960 |
| Mahoning Creek | Ohio | Mahoning Creek | New Bethlehem | 1941 | 74,200 | 170 | FRW | Concrete | 162 | 926 |
| Prompton | Delaware | Lackawaxen River | Honesdale | 1960 | 52,000 | 290 | FNRW | Earth | 140 | 1,230 |
| Raystown | Susquehanna | Raystown Branch, Juniata River | Huntingdon | 1973 | 762,000 | 8,300 | FRW | Earth and Rock | 225 | 1,700 |
| Shenango | Ohio | Shenanago River | Sharpsville | 1966 | 191,400 | 1,910 | FAQRW | Concrete | 68 | 720 |
| Stillwater | Susquehanna | Lackawanna River | Uniondale | 1960 | 12,000 | 85 | FS | Earth | 77 | 1,700 |
| Tioga-Hammond Lakes | Susquehanna | Tioga River | Tioga | 1978 | 62,000 | 470 | FR | Earth and Rock | 140 | 2,710 |
| Hammond Lakes | Susquehanna | Crooked Creek | Tioga | 1978 | 63,000 | 680 | FR | Earth and Rock | 122 | 6,450 |
| Tionesta | Ohio | Tionesta Creek | Tionesta | 1940 | 133,400 | 480 | FRW | Earth | 154 | 1,050 |
| Union City | Ohio | French Creek | Union City | 1970 | 47,640 | NPP | F | Earth | 88 | 1,420 |
| Woodcock Creek | Ohio | French Creek | Meadville | 1973 | 20,000 | 118 | FQRA | Earth | 90 | 4,650 |
| Youghiogheny River | Ohio | Youghiogheny River | Confluence | 1943 | 254,000 | 450 | FARWQ | Earth | 184 | 1,610 |
| South Dakota | | | | | | | | | | |
| Cold Brook | Missouri | Cold Brook | Hot Springs | 1953 | 7,200 | 36 | FRWX | Earth | 127 | 925 |
| Cottonwood Springs | Missouri | Cottonwood Springs Creek | Hot Springs | 1970 | 8,385 | 41 | FRWX | Earth | 123 | 1,190 |
| Lake Traverse Reservation Control Dam | Red River of the North | Bois de Sioux River | Wheaton | 1941 | 164,500 | 10,925 | FRX | Earth | 14 | 9,100 |
| White Rock | Red River of the North | Bois de Sioux River | Wheaton | 1941 | 85,000 | 6,500 | FRX | Earth | 16 | 14,400 |
| Texas | | | | | | | | | | |
| Addicks | San Jacinto | South Mayde Creek | Addicks | 1948 | 204,500 | NPP | FX | Earth | 49 | 61,166 |
| Aquilla | Brazos | Aquilla Creek | Hillsboro | 1983 | 146,000 | 3,280 | FSX | Earth | 104.5 | 11,890 |
| Bardwell | Trinity | Waxahachie Creek | Ennis | 1965 | 140,000 | 3,570 | FRSX | Earth | 82 | 15,400 |
| Barker | San Jacinto | Buffalo Bayou | Barker | 1945 | 207,000 | NPP | FX | Earth | 37 | 72,844 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Belton | Brazos | Leon River | Belton | 1954 | 1,097,600 | 12,300 | FIRSX | Earth | 192 | 5,524 |
| Benbrook | Trinity | Clear Fork, Trinity River | Fort Worth | 1952 | 258,600 | 3,770 | FNRXA | Earth | 130 | 9,130 |
| Canyon | Guadalupe | Guadalupe | New Braunfeis | 1964 | 740,900 | 8,240 | FRSX | Earth | 224 | 6,830 |
| Ferrells Bridge Dam Lake O' the Pines | Red | Cypress Creek | Jefferson | 1959 | 842,100 | 18,700 | FRS | Earth | 97 | 10,600 |
| Granger Dam and Lake | Brazos | San Gabriel River | Granger | 1980 | 244,200 | 4,400 | FRSWX | Earth | 115 | 16,320 |
| Grapevine | Trinity | Denton Creek | Grapevine | 1952 | 425,500 | 7,280 | FNRSXA | Earth | 137 | 12,850 |
| Hords Creek | Colorado | Hords Creek | Coleman | 1948 | 25,310 | 510 | FARSX | Earth | 91 | 6,800 |
| Lake Kemp | Red | Wichita River | Wichita Falls | 1972 | 502,900 | 15,590 | FX | Earth and Rock | 115 | 8,890 |
| Lavon | Trinity | East Fork, Trinity River | Fort Worth | 1953 | 748,200 | 21,400 | FRSX | Earth | 81 | 19,483 |
| Lewisville | Trinity | Elm Fork, Trinity River | Lewisville | 1954 | 989,700 | 23,280 | FRSX | Earth | 125 | 32,888 |
| Navarro Mills | Trinity | Richland Creek | Corsicana | 1962 | 212,200 | 5,070 | FRSX | Earth | 82 | 7,570 |
| North San Gabriel Dam, Lake Georgetown | Brazos | North Fork, San Gabriel River | Georgetown | 1980 | 130,800 | 1,310 | FRSWX | Rock | 164 | 6,700 |
| O. C. Fisher | Colorado | North Concho River | San Angelo | 1952 | 396,400 | 5,440 | FRSX | Earth | 128 | 40,885 |
| Pat Mayse | Red | Sanders Creek | Paris | 1967 | 189,100 | 5,993 | FRSX | Earth | 96 | 7,080 |
| Proctor | Brazos | Leon River | Comanche | 1963 | 374,200 | 4,610 | FRSX | Earth | 86 | 13,460 |
| Somerville | Brazos | Yegua Creek | Somerville | 1967 | 507,500 | 11,460 | FRSX | Earth | 80 | 26,175 |
| Stillhouse Hollow | Brazos | Lampasas River | Belton | 1968 | 630,400 | 6,430 | FRSX | Earth | 200 | 15,624 |
| Waco | Brazos | Bosque River | Waco | 1965 | 726,400 | 7,270 | FRSX | Concrete and Earth | 140 | 24,618 |
| Wright Patman | Red | Sulphur River | Texarkana | 1957 | 2,654,300 | 20,300 | FRSX | Earth | 100 | 18,500 |
| Vermont | | | | | | | | | | |
| Ball Mountain | Connecticut | West River | Jamaica | 1961 | 54,600 | 75 | FRW | Concrete and Earth | 265 | 915 |
| North Hartland | Connecticut | Ottauguechee River | North Hartland | 1960 | 71,420 | 220 | FRW | Concrete and Earth | 185 | 1,520 |
| North Springfield | Connecticut | Black River | Springfield | 1960 | 51,067 | 290 | FRW | Concrete and Earth | 120 | 2,940 |
| Townshend | Connecticut | West River | Townshend | 1961 | 33,700 | 100 | FRW | Concrete and Earth | 133 | 1,700 |
| Union Village | Connecticut | Ompompanoosuc River | Union Village | 1950 | 38,000 | NPP | FRW | Concrete and Earth | 170 | 1,100 |
| Virginia | | | | | | | | | | |
| John W. Flannagan | Ohio | Pound River | Haysi | 1963 | 145,700 | 310 | FAQR | Concrete and Earth | 250 | 960 |
| Gathright Dam and Lake Moomaw | James | Jackson | Alleghany | 1979 | 123,739 | 2,532 | FQR | Earth and Rock | 257 | 1,172 |
| North Fork of Pound River | Ohio | North Fork, Pound River | Pound | 1966 | 11,293 | 106 | FR | Rock | 122 | 600 |
| Washington | | | | | | | | | | |
| Howard A. Hanson | Green | Green River | Kanaskat | 1961 | 106,000 | 1,600 | FAS | Rock | 235 | 675 |
| Mill Creek | Columbia | Mill Creek | Walla Walla | 1942 | 8,300 | 225 | FR | Earth | 145 | 3,200 |
| Mud Mountain | Puyallup | White River | Enumclaw | 1953 | 106,000 | NPP | FR | Rock | 425 | 700 |
| Wynoochee | Chehalis | Wynoochee River | Montesano | 1972 | 70,000 | 1,150 | FSARI | Concrete and Earth | 177 | 1,700 |
| West Virginia | | | | | | | | | | |
| Beech Fork | Ohio | Beech Fork | Lavalette | 1977 | 37,540 | 450 | FRW | Earth | 86 | 1,080 |
| Bluestone | Ohio | New River | Hinton | 1952 | 631,000 | 1,800 | FRWX | Concrete | 180 | 2,048 |

*Note*: Operable as of September 30, 1986.

[a] Project Functions: A, Low Flow Augmentation; D, Debris Control; F, Flood Control; I, Irrigation; N, Navigation; P, Power; Q, Water Quality Control; R, Public Recreation (Annual Attendance exceeding 5,000); S, Water Supply; W, Fish and Wildlife (Federal and State); X, Water Conservation and Sedimentation.



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**Table 11B.27 Largest Manmade Reservoirs in the United States**

| Dam Name | Reservoir | Location | Owner | Acre-Feet | Completed |
|---|---|---|---|---|---|
| Hoover | Lake Mead | Nevada | Bureau of Reclamation | 28,255,000 | 1936 |
| Glen Canyon | Lake Powell | Arizona | Bureau of Reclamation | 27,000,000 | 1964 |
| Oahe | Lake Oahe | South Dakota | Corps of Engineers | 19,300,000 | 1966 |
| Garrison | Lake Sakakawea | North Dakota | Corps of Engineers | 18,500,000 | 1953 |
| Fort Peck | Fort Peck Lake | Montana | Corps of Engineers | 15,400,000 | 1957 |
| Grand Coulee | F D Roosevelt Reservoir | Washington | Bureau of Reclamation | 9,562,000 | 1942 |
| Libby | Lake Koocanusa | Montana | Corps of Engineers | 5,809,000 | 1973 |
| Shasta | Lake Shasta | California | Bureau of Reclamation | 4,552,000 | 1966 |
| Toledo Bend | Toledo Bend Reservoir | Louisiana | Sabine River Authority | 4,477,000 | 1966 |
| Fort Randall | Lake Francis Case | South Dakota | Corps of Engineers | 3,800,000 | 1954 |
| Flaming Gorge | Flaming Gorge Reservoir | Utah | Bureau of Reclamation | 3,788,900 | 1964 |
| Oroville | Lake Oroville | California | California DWR | 3,540,000 | 1968 |
| Hungry Horse | Hungry Horse Reservoir | Montana | Bureau of Reclamation | 3,468,000 | 1953 |
| Dworshak | Dworshak Reservoir | Idaho | Corps of Engineers | 3,468,000 | 1973 |
| Amistad | Amistad International Reservoir | Texas | International Boundary Water Commission | 3,384,000 | 1969 |
| Bull Shoals | Bull Shoals Lake | Arkansas | Corps of Engineers | 3,048,000 | 1951 |
| Sam Rayburn Dam | Sam Rayburn Reservoir | Texas | Corps of Engineers | 2,898,200 | 1965 |

*Source*: From USBR Register of Dams, www.usbr.gov.

**Table 11B.28 World's Largest Reservoirs in Terms of Capacity**

| No | Capacity, $10^8$ m$^3$ | Name | Country | Year |
|---|---|---|---|---|
| 1 | 204,800 | Owen Falls[a] | Uganda | 1954 |
| 2 | 169,270 | Bratsk | U.S.S.R. | 1964 |
| 3 | 168,900 | High Aswan | Egypt | 1970 |
| 4 | 160,368 | Kariba | Zimbabwe/Zambia | 1959 |
| 5 | 147,960 | Akosombo | Ghana | 1965 |
| 6 | 141,851 | Daniel Johnson | Canada | 1968 |
| | 135,000 | Guri | Venezuela | U/C |
| 7 | 73,300 | Krasnoyarsk | U.S.S.R. | 1967 |
| 8 | 70,309 | W A C Bennett | Canada | 1967 |
| 9 | 68,400 | Zeya | U.S.S.R. | 1978 |
| | 63,000 | Cabora Bassa | Mozambique | 1974 |
| 10 | 61,715 | La Grande 2 | Canada | 1978 |
| 11 | 60,020 | La Grande 3 | Canada | 1981 |
| 12 | 59,300 | Ust-Ilim | U.S.S.R. | 1977 |
| 13 | 58,000 | Kuibyshev | U.S.S.R. | 1955 |
| 14 | 53,790 | Caniapiscau Barrage KA 3 | Canada | 1980 |
| | 50,700 | Upper Wainganga | India | U/C |
| 15 | 49,800 | Bukhtarma | U.S.S.R. | 1960 |
| | 48,000 | Atatürk | Turkey | U/C |
| 16 | 46,000 | Irkutsk | U.S.S.R. | 1956 |
| | 43,000 | Tucurui | Brazil | U/C |
| 17 | 35,900 | Vilyui | U.S.S.R. | 1967 |
| 18 | 35,400 | Sanmenxia | China | 1960 |
| 19 | 34,852 | Hoover | U.S.A. | 1936 |
| 20 | 34,100 | Sobradinho | Brazil | 1979 |

*(Continued)*

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**Table 11B.28 (Continued)**

| No | Capacity, $10^8$ $m^3$ | Name | Country | Year |
|---|---|---|---|---|
| 21 | 33,304 | Glen Canyon | U.S.A. | 1966 |
| 22 | 32,203 | Skins Lake No 1 | Canada | 1953 |
| 23 | 31,790 | Jenpeg | Canada | 1975 |
| 24 | 31,500 | Volgograd | U.S.S.R. | 1958 |
| | 31,300 | Sayano-Shushensk | U.S.S.R. | U/C |
| 25 | 30,600 | Keban | Turkey | 1974 |
| 26 | 29,959 | Iroquois | Canada | 1958 |
| 27 | 29,000 | Itaipu | Brazil | 1982 |
| 28 | 28,973 | Churchill Falls (GR-1) | Canada | 1971 |
| 29 | 28,370 | Missi Falls Control | Canada | 1976 |
| 30 | 28,100 | Kapchagay | U.S.S.R. | 1970 |
| 31 | 29,000 | Loma de la Lata | Argentina | 1977 |
| 32 | 27,920 | Garrison | U.S.A. | 1953 |
| 33 | 27,675 | Kossou | Ivory Coast | 1972 |
| 34 | 27,433 | Oahe | U.S.A. | 1958 |
| 35 | 26,000 | Razzaza Dyke | Iraq | 1970 |
| 36 | 25,400 | Rybinsk | U.S.S.R. | 1941 |
| | 24,700 | Longyangxia | China | U/C |
| 37 | 24,700 | Mica | Canada | 1972 |
| 38 | 24,700 | Tsimlyansk | U.S.S.R. | 1952 |
| 39 | 23,700 | Kenney | Canada | 1952 |
| 40 | 23,550 | Ust-Khantaika | U.S.S.R. | 1970 |
| 41 | 22,950 | Furnas | Brazil | 1963 |
| 42 | 22,119 | Fort Peck | U.S.A. | 1937 |
| 43 | 21,626 | Xinanjiang | China | 1960 |
| 44 | 21,166 | Ilha Solteira | Brazil | 1973 |

*Note*: U/C, under construction.

[a] This capacity is not fully obtained by a dam; the major part of it is the natural capacity of a lake; Owen Falls is not the greatest manmade lake.

*Source*: From International Commission on Large Dams, 1984, *World Register of Dams*.

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**Table 11B.29 Depth of Reservoirs in the United States and Loss by Evaporation**

| Region | Median Depth (ft) | Loss (ft/acre) |
|---|---|---|
| New England | 19 | 0.55 |
| Delaware and Hudson | 29 | 0.96 |
| Chesapeake Bay | 25 | 0.64 |
| Southeast | 23 | 0.53 |
| Eastern Great Lakes | 16 | 0.68 |
| Western Great Lakes | 18 | 0.79 |
| Ohio | 24 | 0.47 |
| Cumberland | 44 | 0.54 |
| Tennessee | 40 | 0.36 |
| Upper Mississippi | 7 | 0.83 |
| Lower Mississippi | 20 | 0.81 |
| Upper Missouri | 25 | 1.97 |
| Lower Missouri | 21 | 1.11 |
| Upper Arkansas-White-Red | 9 (15) | 3.27 |
| Lower Arkansas-White-Red | 10 | 1.33 |
| Western Gulf | 8 (15) | 2.75 |
| Upper Rio Grande and Pecos | 20 | 4.26 |
| Colorado | 16 | 3.79 |
| Great Basin | 15 | 3.00 |
| Pacific Northwest | 25 | 1.44 |
| Central Pacific | 33 | 2.58 |
| South Pacific | 44 | 4.81 |

*Source*: From U.S. Geological Survey, 1960.

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**Table 11B.30 Multipurpose Reservoirs in the United States**

| Project | River | Community in Vicinity | Total Storage Capability (acre-ft)[a] | Flood Control and/or Nav. Feature Placed in Useful Operation | Initial Power In FY | Existing Installation (kW) | Schedu-led Instal-lation (kW) | Ultimate Installation (kW) | Project Functions | Type[b] | Height (ft) | Length (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Albeni Falls, ID | Pend Oreille | Newport, WA | 1,153,000 | 1952 | 1955 | 42,600 | | 42,600 | NFPR | C | 90 | 1,055 |
| Allatoona Lake, GA | Etowah | Cartersville, GA | 670,000 | 1950 | 1950 | 74,000 | | 74,000 | FPRW | C | 190 | 1,250 |
| Barkley Dam and Lake Barkley, KY and TN | Cumberland | Grand Rivers, KY | 2,082,000 | 1964 | 1966 | 130,000 | | 130,000 | NPFR | CE | 157 | 9,959 |
| Beaver Lake, AR | White | Eureka Springs, AR | 1,952,000 | 1963 | 1965 | 112,000 | | 112,000 | FPSR | CE | 228 | 2,575 |
| Big Bend Dam (Lake Sharpe), SD | Missouri | Chamberlain, SD | 1,883,000 | 1964 | 1965 | 468,000 | | 468,000 | FPRIW | E | 95 | 10,570 |
| Blakely Mountain Dam-Lake Ouachita, AR | Ouachita | Mt. Pine, AR | 2,768,000 | 1953 | 1956 | 75,000 | | 75,000 | FPRW | E | 235 | 1,100 |
| Bonneville L&D Lake Bonneville, OR & WA | Columbia | Bonneville, OR | 537,000 | 1938 | 1938 | 1,076,600 | | 1,076,600 | NPR | C | 122 | 2,690 |
| Broken Bow Lake, OK | Mountain Fork | Broken Bow, OK | 1,368,230 | 1968 | 1970 | 100,000 | | 100,000 | FPWSR | E | 225 | 2,690 |
| Buford Dam Lanier, GA | Chattahoochee | Buford, GA | 2,554,000 | 1956 | 1957 | 86,000 | | 86,000 | NFPW | E | 192 | 5,400 |
| Bull Shoals Lake, AR & MO | White | Mountain Home, AR | 5,408,000 | 1952 | 1953 | 340,000 | | 340,000 | FPR | C | 258 | 2,256 |
| Clarence Cannon Dam | Salt | Perry, MO | 1,428,000 | 1983 | 1985 | 58,000 | | 58,000 | FNPRSW | CE | 138 | 1,700 |
| Carters Dam, GA | Coosawatte | Carters, GA | 472,756 | 1975 | 1975 | 500,000 | | 500,000 | FPRW | ER | 450 | 1,950 |
| Center Hill Lake, TN | Caney Fork | Lancaster, TN | 2,092,000 | 1948 | 1951 | 135,000 | | 135,000 | FPR | CE | 250 | 2,160 |
| Cheatham L&D, TN | Cumberland | Ashland City, TN | 104,000 | 1952 | 1958 | 36,000 | | 36,000 | NPR | C | 75 | 801 |
| Chief Joseph Dam (Rufus Woods Lake), WA | Columbia | Bridgeport, WA | 593,100 | 1955 | 1956 | 2,069,000 | 204,160[c] | 2,273,160 | PIR | C | 220 | 4,300 |
| Clarks Hill Lake, GA & SC | Savannah | Augusta, GA | 2,900,000 | 1952 | 1953 | 280,000 | | 280,000 | NFPRSW | CE | 200 | 5,680 |
| Cooper River, Charleston Harbor, SC | Santee | St. Stephen, SC | 2,580,000 | N/A | 1985 | 84,000 | | 84,000 | PW | CE | 86 | 876 |
| Cordell Hull L&D, TN | Cumberland | Carthage, TN | 310,900 | 1973 | 1974 | 100,000 | | 100,000 | NPR | CE | 445 | 1,738 |
| Cougar Lake, OR | S. Fork McKenzie | Blue River, OR | 219,000 | 1963 | 1964 | 25,000 | | 64,600 | NFPRI | ER | 445 | 1,738 |
| Dale Hollow Lake, TN & KY | Obey | Celina, TN | 1,706,000 | 1943 | 1949 | 54,000 | | 54,000 | FPR | C | 200 | 1,717 |
| Dardanelle L&D, AR | Arkansas | Dardanelle, AR | 486,200 | 1969 | 1965 | 124,000 | | 124,000 | NPR | C | 68 | 2,683 |
| DeGray Lake, AR | Caddo | Arkadelphia, AR | 831,900 | 1969 | 1972 | 68,000 | | 108,000 | FNPRS | E | 243 | 3,400 |
| Denison Dam (Lake Texoma), TX & OK | Red | Denison, TX | 5,312,300 | 1944 | 1945 | 70,000 | | 175,000 | FPSRN | E | 165 | 17,200 |
| Detroit Lake, OR, including Big Cliff Lake, OR | North Santiam | Mill City, OR | 461,000 | 1963 | 1954 | 118,000 | | 118,000 | NFPRI | C | 382 | 1,528 |
| Dworshak Dam and Reservoir, ID | N. Fork, Clearwater | Orofino, ID | 3,453,000 | 1972 | 1973 | 400,000 | | 1,060,000 | PNFR | C | 717 | 3,300 |
| Eufaula Lake, OK | Canadian | Eufaula, OK | 3,825,400 | 1964 | 1964 | 90,000 | | 90,000 | ENPS | E | 114 | 3,200 |
| Fort Gibson Lake, OK | Grand (Neosho) | Ft. Gibson, OK | 1,284,400 | 1950 | 1953 | 45,000 | | 67,500 | FP | CE | 110 | 2,990 |
| Fort Peck Lake, MT | Missouri | Glasgow, MT | 18,909,000 | 1938 | 1944 | 185,250 | | 185,250 | NFPRIW | E | 251 | 21,026 |

*(Continued)*



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**Table 11B.30 (Continued)**

| Project | River | Community in Vicinity | Total Storage Capability (acre-ft)[a] | Flood Control and/or Nav. Feature Placed in Useful Operation | Initial Power In FY | Existing Installation (kW) | Schedu-led Instal-lation (kW) | Ultimate Installation (kW) | Project Functions | Type[b] | Height (ft) | Length (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fort Randal Dam (Lake Francis Case), SD | Missouri | Lake Andes, SD | 5,574,000 | 1953 | 1954 | 320,000 | | 320,000 | NFPRIW | E | 165 | 10,700 |
| Garrison Dam (Lake Sakakawea), ND | Missouri | Riverdale, ND | 24,137,000 | 1954 | 1956 | 430,000 | | 430,000 | NFPRIW | E | 210 | 11,300 |
| Gavins Point Dam (Lewis and Clark Lake), SD & NE | Missouri | Yankton, SD | 504,000 | 1956 | 1957 | 100,000 | | 100,000 | NFPRIW | E | 74 | 8,700 |
| Green Peter Lake, OR, including Foster Lake, OR | Middle Santiam | Sweet Home, OR | 491,000 | 1967 | 1967 | 100,000 | | 100,000 | PFNIR | C | 340 | 1,380 |
| Greers Ferry Lake, AR | Little Red | Heber Springs, AR | 2,844,000 | 1962 | 1964 | 96,000 | | 96,000 | FPRW | CE | 96 | 5,000 |
| Harry S. Truman Dam and Res. | Osage | Warsaw, MO | 5,202,000 | 1982 | 1982[d] | 160,000 | | 160,000 | FPRW | CE | 96 | 5,000 |
| Hartwell Lake, GA & SC | Sevannah | Hartwell, GA | 2,842,700 | 1961 | 1962 | 344,000 | | 344,000 | NFPRS | CE | 204 | 17,852 |
| Hills Creek Lake, OR | Middle Fork Willamette | Oakridge, OR | 356,000 | 1961 | 1962 | 30,000 | | 30,000 | NFPRI | GE | 304 | 2,150 |
| Ice Harbor L&D (Lake Sacajawea), WA | Snake | Pasco, WA | 417,000 | 1962 | 1962 | 603,000 | | 603,000 | NPRI | CE | 130 | 2,790 |
| Jim Woodruff Dam (Lake Seminole), FL, GA & AL | Appalachicola | Chattahoochee, FL | 367,300 | 1957 | 1957 | 30,000 | | 30,000 | NPRW | CE | 67 | 6,150 |
| John Day L&D (Lake Umatilla), OR & WA | Columbia | Rufus, OR | 2,500,000 | 1968 | 1969 | 2,160,000 | | 2,700,000 | NPRFI | CE | 161 | 5,900 |
| John H. Kerr Dam and Reservoir, NC & VA | Roanoke | Boydton, VA | 2,750,300 | 1952 | 1953 | 204,000 | | 204,000 | FPRW | CE | 144 | 22,285 |
| Robert F. Henry L&D, AL | Alabama | Benton, AL | 234,200 | 1972 | 1975 | 68,000 | | 68,000 | NPRW | CE | 101 | 14,962 |
| J. Percy Priest Dam and Reservoir, TN | Stones | Nashville, TN | 652,000 | 1967 | 1970 | 28,000 | | 28,000 | FPRW | CE | 147 | 2,716 |
| Keystone Lake, OK | Arkansas | Tulsa, OK | 1,737,600 | 1964 | 1968 | 70,000 | | 70,000 | FNPWS | E | 121 | 4,600 |
| Laurel River Lake, KY | Laurel | London, KY | 435,600 | 1973 | 1978 | 61,000 | | 61,000 | FPRW | R | 282 | 1,420 |
| Libby Dam, Lake Koocanusa, MT | Kootenai | Libby, MT | 5,809,000 | 1972 | 1975 | 525,000 | | 840,000 | FPR | C | 420 | 3,055 |
| Little Goose L&D (Lake Bryan), WA | Snake | Starbuck, WA | 565,000 | 1970 | 1970 | 810,000 | | 810,000 | NPRI | CE | 160 | 2,670 |
| Lookout Point Lake, Including Dexter Lake, OR | Willamette Middle Fork, Willamette | Lowell, OR | 483,000 | 1954 | 1955 | 135,000 | | 135,000 | NFPRI | CE | 243 | 3,381 |
| Lost Creek Lake, OR | Rogue | Trail, OR | 465,000 | 1977 | 1977 | 49,000 | | 49,000 | DFPISWR | CE | 345 | 3,600 |
| Lower Granite L&D, WA | Snake | Pomeroy, WA | 484,000 | 1975 | 1975 | 810,000 | | 810,000 | NPRIF | CE | 146 | 3,200 |
| Lower Monumental L&D, WA | Snake | Kahlotus, WA | 376,000 | 1969 | 1969 | 810,000 | | 810,000 | NPRI | CE | 135 | 3,800 |
| McNary L&D—Lake Wallula, OR & WA | Columbia | Umatilla, OR | 1,550,000 | 1953 | 1954 | 980,000 | | 1,625,000 | NPRI | CE | 183 | 7,300 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Millers Ferry L&D, AL | Alabama | Camden, AL | 331,800 | 1969 | 1970 | 75,000 | | 75,000 | NPRW | CE | 90 | 11,380 |
| Narrows Dam—Lake Greeson, AR | Little Missouri | Murfreesboro, AR | 407,900 | 1950 | 1950 | 25,500 | | 25,500 | FPRW | C | 183.5 | 941 |
| New Melones Lake, CA[e] | Stanislaus | Oakdale, CA | 2,400,000 | 1978 | 1979 | 300,000 | | 300,000 | FIPRW | ER | 625 | 1,560 |
| Norfolk Lake, AR& MO | North Fork | Norfolk, AR | 1,983,000 | 1943 | 1944 | 80,550 | | 163,000 | FPRS | C | 216 | 2,624 |
| Oahe Dam (Lake Oahe), SD & ND | Missouri | Pierre, SD | 23,337,000 | 1959 | 1962 | 595,000 | | 595,000 | NFPRIW | E | 245 | 9,300 |
| Old Hickory L&D, TN | Cumberland | Hendersonville, TN | 545,000 | 1954 | 1957 | 100,000 | | 100,000 | NPR | CE | 98 | 3,605 |
| Ozark-Jeta Taylor L&D, AR | Arkansas | Ozark, AR | 148,400 | 1969 | 1973 | 100,000 | | 100,000 | NPR | C | 58 | 2,480 |
| Philpott Lake, VA | Roanoke | Bassett, VA | 318,500 | 1951 | 1954 | 14,000 | | 14,000 | FPR | C | 220 | 892 |
| Robert S. Kerr L&D and Reservoir, OK | Arkansas | Sallisaw, OK | 525,700 | 1970 | 1971 | 110,000 | | 110,000 | NPR | E | 75 | 7,230 |
| Sam Rayburn Dam and Reservoir, TX | Angelina | Jasper, TX | 3,997,600 | 1965 | 1966 | 52,000 | | 52,000 | FPWR | CE | 120 | 19,430 |
| St. Mary's River, MI | Great Lakes | Sault Ste. Marie, MI | — | 1855 | 1952 | 18.400 | | 18,400 | NP | Control Gate | | |
| Snettisham, AK[f] | Speel | Juneau, AK | 352,400 | | 1973 | 46,700 | 27,000[g] | 73,700 | P | C[h] | 18 | 338 |
| Stockton Lake, MO | Sac | Stockton, MO | 1,647,000 | 1969 | 1973 | 45,200 | | 45,200 | FPRW | CE | 128 | 5,100 |
| Table Rock Lake, AR & MO | White | Branson, MO | 3,462,000 | 1958 | 1959 | 200,000 | | 200,000 | FPR | CE | 252 | 6,423 |
| Tenkiller Lake, OK | Illinois | Gore, OK | 1,230,800 | 1952 | 1953 | 34,000 | | 34,000 | FP | E | 197 | 3,000 |
| The Dalles L&D (Lake Celilo), WA & OR | Columbia | The Dalles, OR | 53,000 | 1957 | 1957 | 1,806,800 | | 1,806,800 | NPR | CR | 300 | 8,875 |
| Walter F. George L&D, GA & FL | Chattahoochea | Fort Gaines, GA | 934,000 | 1963 | 1963 | 130,000 | | 130,000 | NPRW | CE | 114 | 13,585 |
| Webbers Falls L&D, OK | Arkansas | Webbers Falls, OK | 170,100 | 1970 | 1973 | 60,000 | | 60,000 | NP | E | 84 | 4,370 |
| West Point Lake, AL & GA | Chattahoochee | West Point, GA | 604,500 | 1975 | 1975 | 73,375 | | 108,375 | FPRW | CE | 97 | 7,250 |
| Whitney Lake, TX | Brazos | Whitney, TX | 1,999,500 | 1953 | 1954 | 30,000 | | 30,000 | FPR | CE | 159 | 17,695 |
| Wolf Creek Dam (Lake Cumberland), KY | Cumberland | Jamestown, KY | 6,089,000 | 1950 | 1952 | 270,000 | | 270,000 | FPR | CE | 258 | 5,736 |

*Note*: In operation September 30, 1986. Nomenclature for project functions: Fy, Fiscal year; D, debris control; F, flood control; I, irrigation; N, navigation; P, power; R, public recreation (annual attendance exceeding 5000); W, fish and wildlife (federal or state).

[a] Total of all storage functions, including inactive and dead storage to normal full pool level.
[b] G, gravel; R, rock; C, concrete; E, earth.
[c] Chief Joseph Additional Units and Operating Units 1–16.
[d] All units are synchronized-to-line and two units have passed the pumpback test. However, due to damaging effects to fish, no further pumping will be done for their testing or operation until a solution to the problem is found.
[e] Being operated for the Department of Interior by the Bureau of Reclamation.
[f] Being operated by the Alaska Power Administration.
[g] Crater Lake Unit.
[h] Weir for Long Lake.

*Source*: From Department of the Army Annual Report FY86 of the Secretary of the Army on Civil Works Activities, Washington, D.C.



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## SECTION 11C HYDROELECTRIC POWER

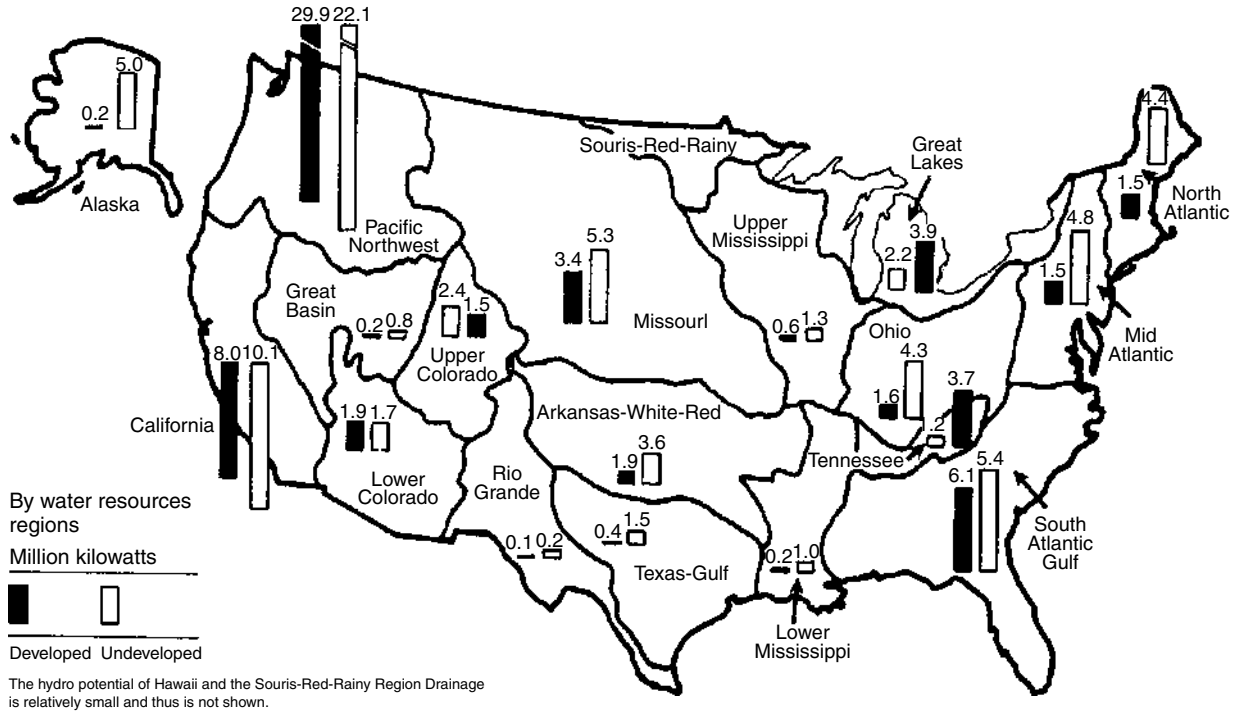


**Figure 11C.20** Conventional hydroelectric power developed and undeveloped, January 1, 1984. (From Federal Energy Regulatory Commission, 1984.)

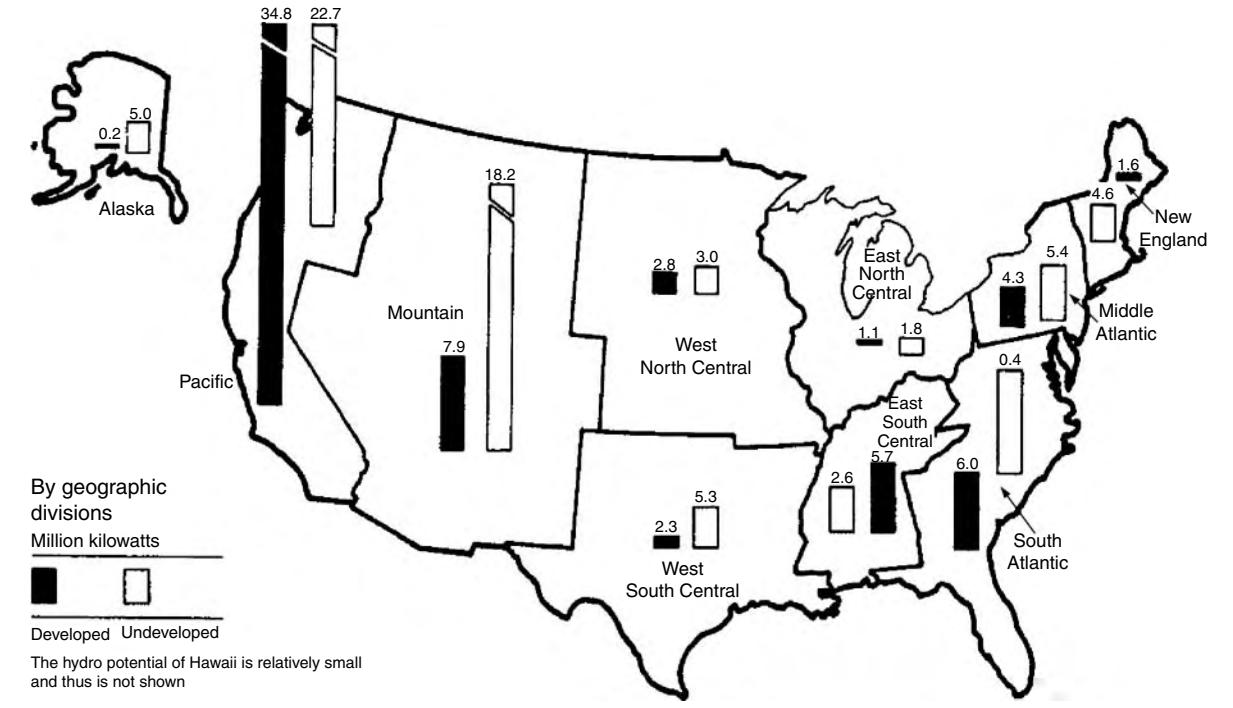


**Figure 11C.21** Conventional hydroelectric power developed and underdeveloped, January 1, 1984. (From Federal Energy Regulatory Commission, 1984.)

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**Table 11C.31 Conventional and Pumped Storage Hydroelectric Plants in the United States**

| Plant | Stream | State | Year of Initial Oper. | Gross Static Head (ft) | Usable Power Storage 1000 Acre-Feet[a] | Installed Capacity — Kilowatts[b] | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Developed | Under Construction | Authorized |
| *Corps of Engineers* | | | | | | | | |
| Lincoln School | St John R | ME | — | 76 | 32 | — | — | 70,000 |
| Tocks Island | Delaware R | NJ | — | 107 | 426 | — | — | 70,000 |
| Gathright | Jackson R | VA | — | 194 | 61 | — | — | 49,000 |
| John H Kerr | Roanoke R | VA | 1952 | 90 | 1029 | 204,000 | — | 204,000 |
| Philpott | Smith R | VA | 1953 | 164 | 111 | 14,000 | — | 14,000 |
| St. Stephen | Santee & Cooper R | SC | — | 70 | 1420 | | 84,000 | 84,000 |
| Clark Hill | Savannah R | GA | 1953 | 152 | 1510 | 280,000 | — | 280,000 |
| Richard B Russell | Savannah R | GA | — | 162 | 127 | — | 3,00,000 | 300,000 |
| Richard B Russell | Savannah R | GA | — | 162 | 127 | — | 3,00,000 R | 300,000 R |
| Hartwell | Savannah R | GA | 1962 | 178 | 1415 | 344,000 | — | 344,000 |
| Jim Woodruff L&D | Apalachicola R | FL | 1957 | 31 | 37 | 30,000 | — | 30,000 |
| Walter F George L&D | Chattahoochee R | GA | 1963 | 92 | 207 | 130,000 | — | 130,000 |
| West Point | Chattahoochee R | GA | 1975 | 78 | 86 | 73,375 | — | 108,375 |
| Buford | Chattahoochee R | GA | 1957 | 155 | 1049 | 86,000 | — | 86,000 |
| Lower Auchumpkee | Flint R | GA | — | 84 | 124 | — | — | 77,000 |
| Lazer Creek | Flint R | GA | — | 123 | 60 | — | — | 83,000 |
| Spewrell Bluff | Flint R | GA | — | 144 | 242 | — | — | 100,000 |
| Spewrell Bluff | Flint R | GA | — | 144 | 242 | — | — | 50,000 R |
| Millers Ferry L&D | Alabama R | AL | 1970 | 49 | 17 | 75,000 | — | 75,000 |
| Jones Bluff | Alabama R | AL | 1975 | 45 | 12 | 68,000 | — | 68,000 |
| Carters | Coosawattee R | GA | 1975 | 387 | 135 | 250,000 | — | 250,000 |
| Carters | Coosawattee R | GA | 1977 | 387 | 135 | 250,000 R | — | 250,000 |
| Allatoona | Etowah R | GA | 1950 | 145 | 284 | 74,000 | — | 110,000 |
| St. Marys Falls | St Marys R | MI | 1951 | 21 | NA | 18,400 | — | 18,400 |
| Barkley | Cumberland R | KY | 1966 | 46 | 258 | 130,000 | — | 130,000 |
| Cheatham L&D | Cumberland R | TN | 1958 | 22 | 19 | 36,000 | — | 36,000 |
| J Percy Priest | Stones R | TN | 1970 | 85 | 34 | 28,000 | — | 28,000 |
| Old Hickory L&D | Cumberland R | TN | 1957 | 46 | 63 | 100,000 | — | 100,000 |
| Center Hill | Caney Fk, Cumberland R | TN | 1950 | 161 | 492 | 135,000 | — | 135,000 |
| Cordell Hull | Cumberland R | TN | 1973 | 49 | 54 | 100,000 | — | 100,000 |
| Dale Hollow | Obey R | TN | 1948 | 135 | 496 | 54,000 | — | 54,000 |
| Celina | Cumberland R | KY | — | 60 | 15 | — | — | 108,000 |
| Wolf Creek | Cumberland R | KY | 1951 | 163 | 2142 | 270,000 | — | 270,000 |
| Laurel | Laurel R | KY | 1977 | 251 | 185 | 61,000 | — | 61,000 |
| Booneville | S Fk Kentucky R | KY | — | 140 | 258 | — | — | 7,300 |
| Bluestone | New R | WV | — | 125 | 238 | — | — | 180,000 |
| Rowlesburg | Cheat R | WV | — | 938 | 8 | — | — | 350,000 R |
| Clarence F Cannon | Salt R | MO | — | 107 | 437 | — | 27,000 | 27,000 |

*(Continued)*



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**Table 11C.31 (Continued)**

| Plant | Stream | State | Year of Initial Oper. | Gross Static Head (ft) | Usable Power Storage 1000 Acre-Feet[a] | Installed Capacity — Kilowatts[b] | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Developed | Under Construction | Authorized |
| Clarence F Cannon | Salt R | MO | — | 107 | 437 | — | 31,000 R | 31,000 R |
| Red Rock | Des Moines R | IA | — | 53 | 400 | — | — | 17,200 |
| Rock Island L&D 15[c] | Sylvan Slough, Miss R | IL | 1919 | 16 | NA | 2,752 | — | 2,752 |
| Narrows | Little Missouri R | AR | 1950 | 145 | 202 | 25,500 | — | 25,500 |
| Degray | Caddo R | AR | 1971 | 188 | 393 | 40,000 | — | 80,000 |
| Degray | Caddo R | AR | 1971 | 188 | 393 | 28,000 R | — | 28,000 R |
| Blakely Mountain | Ouachita R | AR | 1955 | 181 | 1286 | 75,000 | — | 75,000 |
| Harry S Truman | Osage R | MO | 1979 | 46 | 90 | 160,000 R | — | 160,000 R |
| Pomme de Terre | Pomme de Terre R | MO | — | 117 | 165 | — | — | 16,800 |
| Stockton | Sac R | MO | 1973 | 86 | 660 | 45,200 | — | 45,200 |
| Gavins Point | Missouri R | NE | 1956 | 44 | 100 | 100,000 | — | 100,000 |
| Fort Randall | Missouri R | SD | 1954 | 131 | 3500 | 320,000 | — | 320,000 |
| *Corps of Engineers* | | | | | | | | |
| Big Bend | Missouri R | SD | 1964 | 67 | 260 | 468,000 | — | 468,000 |
| Oahe | Missouri R | SD | 1962 | 189 | 17000 | 595,000 | — | 595,000 |
| Garrison | Missouri R | ND | 1956 | 172 | 17900 | 430,000 | — | 430,000 |
| Fort Peck | Missouri R | MT | 1943 | 213 | 13800 | 185,300 | — | 185,300 |
| Broken Bow | Mountain Fk R, Little R | OK | 1970 | 194 | 9 | 100,000 | — | 100,000 |
| Denison | Red R | TX | 1944 | 108 | 1730 | 70,000 | — | 175,000 |
| Dardanelle | Arkansas R | AR | 1965 | 49 | 65 | 124,000 | — | 124,000 |
| Ozark | Arkansas R | AR | 1973 | 23 | 19 | 100,000 | — | 100,000 |
| Robert S Kerr | Arkansas R | OK | 1971 | 42 | NA | 110,000 | — | 110,000 |
| Eufula | Canadian R | OK | 1964 | 82 | 1481 | 90,000 | — | 90,000 |
| Tenkiller Ferry | Illinois R | OK | 1953 | 143 | 345 | 39,100 | — | 39,100 |
| Webbers Falls | Arkanasas R | OK | 1973 | 30 | NA | 60,000 | — | 60,000 |
| Fort Gibson | Neosho R | OK | 1953 | 60 | NA | 45,000 | — | 67,500 |
| Keystone | Arkansas R | OK | 1968 | 76 | 351 | 70,000 | — | 70,000 |
| Greers Ferry | Little Red R | AR | 1964 | 183 | 763 | 96,000 | — | 96,000 |
| Norfork[d] | North Fork R | AR | 1944 | 174 | 445 | 80,550 | — | 165,550 |
| Bull Shoals | White R | AR | 1952 | 194 | 952 | 340,000 | — | 340,000 |
| Table Rock | White R | MO | 1959 | 204 | 1098 | 200,000 | — | 200,000 |
| Beaver | White R | AR | 1965 | 190 | 956 | 112,000 | — | 112,000 |
| Town Bluff | Neches R | TX | — | 24 | NA | — | — | 3,000 |
| Sam Rayburn | Angelina R | TX | 1966 | 71 | 1400 | 52,000 | — | 52,000 |
| Dam A | Neches R | TX | — | 13 | NA | — | — | 2,700 |
| Rockland | Neches R | TX | — | 61 | 1488 | — | — | 13,500 |
| Belton | Leon R | TX | — | 110 | 399 | — | — | 19,000 |
| Whitney | Brazos R | TX | 1953 | 89 | 133 | 30,000 | — | 30,000 |
| Big Cliff RRG | N Santiam R | OR | 1954 | 97 | 243 | 18,000 | — | 18,000 |
| Detroit | N Santiam R | OR | 1953 | 357 | 40 | 100,000 | — | 100,000 |
| Foster RRG | S Santiam R | OR | 1968 | 284 | 28 | 20,000 | — | 20,000 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Green Peter | M Fk Santiam R | OR | 1967 | 310 | 63 | 80,000 | — | 80,000 |
| Strube RRG | S Fk Mckenzie R | OR | — | 64 | 3 | — | — | 4,500 |
| Cougar | S Fk Mckenzie R | OR | 1964 | 435 | 10 | 25,000 | — | 60,000 |
| Dexter RRG | M Fk Willamette R | OR | 1955 | 48 | 4 | 15,000 | — | 15,000 |
| Lookout Point | M Fk Willamette R | OR | 1954 | 231 | 12 | 120,000 | — | 120,000 |
| Hills Creek | M Fk Willamette R | OR | 1962 | 318 | 49 | 30,000 | — | 30,000 |
| Bonneville | Columbia R | OR | 1938 | 59 | 87 | 518,400 | — | 544,600 |
| Bonneville 2nd Ph | Columbia R | WA | 1981 | 59 | 87 | 558,220 | — | 558,220 |
| The Dalles | Columbia R | WA | 1957 | 83 | 53 | 1,806,800 | — | 1,806,800 |
| John Day | Columbia R | OR | 1968 | 105 | 300 | 1,957,500 | — | 1,957,500 |
| John Day | Columbia R | WA | 1968 | 105 | 300 | 202,500 | — | 742,500 |
| McNary | Columbia R | OR | 1953 | 74 | 185 | 980,000 | — | 980,000 |
| Ice Harbor | Snake R | WA | 1961 | 98 | 24 | 603,000 | — | 603,000 |
| Lower Monumental | Snake R | WA | 1969 | 100 | 20 | 810,000 | — | 810,000 |
| Little Goose | Snake R | WA | 1970 | 98 | 49 | 810,000 | — | 810,000 |
| Lower Granite | Snake R | WA | 1975 | 100 | 44 | 810,000 | — | 810,000 |
| Dworshak | N Fk Clearwater R | ID | 1973 | 630 | 2000 | 400,000 | — | 1,060,000 |
| Chief Joseph | Columbia R | WA | 1955 | 167 | NA | 2,069,000 | — | 2,069,000 |
| Albeni Falls | Pend Oreille R | ID | 1955 | 28 | 1153 | 42,600 | — | 42,600 |
| Libby | Kootenai R | MT | 1975 | 341 | 4934 | 420,000 | 420,000 | 840,000 |
| Lost Creek | Rogue R | OR | 1977 | 321 | 315 | 49,000 | — | 49,000 |
| Maryville | Yube R | CA | — | 210 | 775 | — | — | 50,000 |
| Total Conventional | | | | | | 19,011,197 | 831,000 | 22,297,897 |
| Total Reversible | | | | | | 438,000 R | 331,000 R | 1,169,000 R |
| *Bureau of Reclamation* | | | | | | | | |
| Prairie Creek | Prairie Cr, Platte R | NE | — | 51 | NA | — | — | 16,800 R |
| Flatiron 1 and 2 | Rattlesnake Cr, Big Thoom | CO | 1954 | 1113 | 1 | 74,500[e] | — | 74,500 |
| Flatiron 3 | Dry Cr, Big Thompson R | CO | 1954 | 292 | 100 | 8,500 R | — | 8,500 R |
| Big Thompson | Big Thompson R | CO | 1954 | 835 | NA | 4,500 | — | 4,500 |
| Pole Hill | Dry Cr, Big Thompson R | CO | 1954 | 835 | NA | 33,250 | — | 33,250 |
| Estes | Big Thompson R | CO | 1950 | 570 | NA | 45,000 | — | 45,000 |
| Marys Lake | Fish Cr, Big Thompson R | CO | 1951 | 217 | NA | 8,100 | — | 8,100 |
| Guernsey | N Platte R | WY | 1927 | 92 | 41 | 4,800 | — | 4,800 |
| Glendo | N Platte R | WY | 1958 | 133 | 511 | 24,000 | — | 24,000 |
| Alcova | N Platte R | WY | 1955 | 164 | 1842 | 36,000 | — | 36,000 |
| Fremont Canyon | N Platte R | WY | 1960 | 350 | 1015 | 48,000 | — | 48,000 |
| Kortes | N Platte R | WY | 1950 | 204 | 4 | 36,000 | — | 36,000 |
| Seminoe | N Platte R | WY | 1939 | 218 | 1011 | 45,000 | — | 45,000 |
| Yellowtail | Bighorn R | MT | 1966 | 463 | 613 | 250,000 | — | 250,000 |
| Heart Mountain | Shoshone R | WY | 1948 | 275 | 421 | 5,000[f] | — | 5,000 |
| Boysen | Bighorn R | WY | 1952 | 110 | 742 | 15,000 | — | 15,000 |
| Pilot Butte | Wyoming Cnl (Wind R) | WY | 1935 | 106 | NA | 1,600 | — | 1,600 |
| Canyon Ferry | Missouri R | MT | 1953 | 147 | 1512 | 50,000 | — | 50,000 |
| Otero | Arkansas Cnl (Arkansas R) | CO | — | 270 | 93 | — | — | 11,000 |

*(Continued)*



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**Table 11C.31 (Continued)**

| Plant | Stream | State | Year of Initial Oper. | Gross Static Head (ft) | Usable Power Storage 1000 Acre-Feet[a] | Installed Capacity — Kilowatts[b] | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Developed | Under Construction | Authorized |
| Mt Elbert | Arkansas Cnl (Arkansas R) | CO | 1981 | 464 | 7 | 100,000 R | 100,000 R | 200,000 R |
| Elephant Butte | Rio Grande | NM | 1940 | 190 | 1730 | 24,300 | — | 24,300 |
| Glen Canyon | Colorado R | AZ | 1964 | 566 | 20876 | 1,042,000 | — | 1,042,000 |
| Flaming Gorge | Green R | UT | 1963 | 435 | 3516 | 108,000 | — | 108,000 |
| Fontenelle | Green R | WY | 1968 | 110 | 149 | 10,000 | — | 10,000 |
| Crystal | Gunnison R | CO | 1977 | 220 | 18 | 28,000 | — | 28,000 |
| Morrolw Point | Gunnison R | CO | 1970 | 403 | 42 | 120,000 | — | 120,000 |
| Blue Mesa | Gunnison R | CO | 1967 | 356 | 774 | 60,000 | — | 60,000 |
| Upper Molina | Cottonwood Cr, Plateau Cr | CO | 1962 | 2663 | 6 | 8,640 | — | 8,640 |
| Lower Molina[g] | Plateau Cr, Colorado R | CO | 1962 | 1600 | 6 | 4,860 | — | 4,860 |
| Green Mountain | Blue R | CO | 1943 | 261 | 146 | 26,000 | — | 26,000 |
| Senator Wash | Senator Wash Cr | CA | — | 74 | 9 | — | — | 7,210 R |
| Parker | Colorado R | CA | 1942 | 78 | 218 | 120,000 | — | 120,000 |
| Davis | Colorado R | AZ | 1951 | 131 | 1809 | 240,000 | — | 240,000 |
| Hoover | Colorado R | AZ | 1936 | 530 | 7227 | 717,000 | — | 717,000 |
| Hoover | Colorado R | NV | 1936 | 530 | 7927 | 717,000 | — | 717,000 |
| Stampede | L Truckee R | CA | — | 183 | NA | — | — | 3,000 |
| Watasheamu | E Fk Carson R | NV | — | 236 | 90 | — | — | 8,000 |
| Deer Creek | Provo R | UT | 1958 | 144 | 149 | 4,950 | — | 4,950 |
| Dyne | Diamond Fk Pipeline | UT | — | 848 | 700[h] | — | — | 33,000 |
| Sixth Water | Sixth Water Cr, Diamond | UT | — | 823 | 700[h] | — | — | 90,000 |
| Syar | Strawberry Offstream | UT | — | 431 | 700 | — | — | 10,500 |
| Black Canyon | Payette R | ID | 1925 | 94 | NA | 8,000 | — | 8,000 |
| Boise | Boise R | ID | 1912 | 40 | NA | 1,500 | — | 1,500 |
| Anderson Ranch | S Fk Boise R | ID | 1950 | 300 | 423[i] | 40,000 | — | 40,000 |
| Minidoka | Snake R | ID | 1909 | 48 | 95[j] | 13,000 | — | 13,400 |
| Palisades | Snake R | ID | 1957 | 244 | 1200 | 118,750 | — | 118,750 |
| Chandler | Chandler Pwr Cnl (Yakima R) | WA | 1956 | 121 | NA | 12,000 | — | 12,000 |
| Roza(Canal) | Roza Cnl (Yakima R) | WA | 1958 | 160 | NA | 11,250 | — | 11,250 |
| Grand Coulee | Columbia R | WA | 1941 | 343 | 5232[k] | 6,180,000[l] | — | 6,180,000 |
| Grand Coulee P/G | Columbia R | WA | 1974 | 280 | 53 | 150,000 R | 150,000 R | 300,000 R |
| Hungry Horse | S Fk Flathead R | MT | 1952 | 477 | 2982[m] | 285,000 | — | 285,000 |
| Green Springs | Emigrant Cr, Bear Cr | OR | 1960 | 1984 | U | 16,000 | — | 16,000 |
| Trinity | Trinity R | CA | 1964 | 469 | 2285 | 105,556 | — | 105,556 |
| Nimbus | American R | CA | 1955 | 43 | 2 | 13,500 | — | 13,500 |
| Folsom | American R | CA | 1955 | 333 | 920 | 198,720 | — | 198,720 |
| Auburn | N Fk American R | CA | — | 675 | 1966 | — | — | 300,000 |
| Judge Francis Carr | Clear Cr Tnl (Trinity R) | CA | 1963 | 695 | 2289 | 160,000 | — | 160,000 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Keswick | Sacramento R | CA | 1949 | 87 | 23 | 75,000 | — | 75,000 |
| Spring Creek | Spring Cr, Sacramento R | CA | 1964 | 625 | 2517 | 150,000 | — | 150,000 |
| Shasta | Sacramento R | CA | 1944 | 482 | 4050 | 539,000[o] | — | 539,000 |
| New Melones | Stanislaus R | CA | 1979 | 583 | 2050 | 300,000[n] | — | 300,000 |
| O'Neill | Delta Mendota Cnl (San Jose) | CA | 1967 | 56 | 20 | 25,200R | — | 25,200 R |
| San Luis | Calif Aqueduct | CA | 1968 | 327 | 1961 | 424,000 R[p] | — | 424,000 R |
| Siphon Drop | Yuma Main Cnl (New R) | CA | — | 15 | NA | — | — | 1,600 |
| Total Conventional | | | | | 12,139,176 | | 12,596,276 | |
| Total Reversiable | | | | | 707,700R | 250,000R | 981,710R | |
| *Tennessee Valley Authority* | | | | | | | | |
| Great Falls | Caney Fk, Cumberland R | TN | 1916 | 148 | 39 | 31,860 | — | 31,860 |
| Kentucky | Tennessee R | KY | 1944 | 50 | 715 | 175,000 | — | 175,000 |
| Pickwick landing | Tennessee R | TN | 1938 | 46 | 236 | 220,040 | — | 220,040 |
| Wilson | Tennessee R | AL | 1942 | 88 | 47 | 629,840 | — | 629,840 |
| Wheeler | Tennessee R | AL | 1936 | 48 | 328 | 361,800 | — | 361,800 |
| Tims Ford | Elk R | TN | 1972 | 133 | 240 | 45,000 | — | 45,000 |
| Guntersville | Tennessee R | AL | 1939 | 39 | 131 | 115,200 | — | 115,200 |
| Nickajack | Tennessee R | TN | 1968 | 35 | 21 | 103,950 | — | 103,950 |
| Raccoon MT | Tennessee R | TN | 1979 | 1040 | 35 | 1,530,000 R | — | 1,530,000 R |
| Chickamauga | Tennessee R | TN | 1940 | 45 | 220 | 120,000 | — | 120,000 |
| Ocoee 1 | Ocoee R | TN | 1912 | 111 | 33 | 18,000 | — | 18,000 |
| Ocoee 2 | Ocoee R | TN | 1913 | 245 | NA | 21,000 | — | 21,000 |
| Ocoee 3 | Ocoee R | TN | 1943 | 308 | 4 | 28,800 | — | 28,800 |
| Blue Ridge | Toccoa R | GA | 1931 | 148 | 186 | 20,000 | — | 20,000 |
| Apalachia | Hiwassee R | TN | 1943 | 440 | 35 | 82,800 | — | 82,800 |
| Hiwassee/ | Hiwassee R | NC | 1940 | 246 | 350 | 57,600 | — | 57,600 |
| Hiwassee | Hiwassee R | NC | 1956 | 246 | 352 | 59,500 R | — | 59,500 R |
| Nottely | Nottely R | GA | 1956 | 168 | 171 | 15,000 | — | 15,000 |
| Chatuge | Hiwassee R | NC | 1954 | 124 | 229 | 10,000 | — | 10,000 |
| Watts Bar | Tennessee R | TN | 1942 | 54 | 214 | 166,500 | — | 166,500 |
| Melton Hill | Clinch R | TN | 1964 | 58 | 25 | 72,000 | — | 72,000 |
| Norris | Clinch R | TN | 1936 | 193 | 1761 | 100,800 | — | 100,800 |
| Fonatna | Little Tennessee R | NC | 1945 | 430 | 1136 | 238,500 | — | 238,500 |
| Fort Londoun | Tennessee R | TN | 1943 | 70 | 81 | 139,140 | — | 139,140 |
| Douglas | French Broad R | TN | 1943 | 135 | 1136 | 120,600 | — | 120,600 |
| Cherokee | Holston R | TN | 1942 | 147 | 1411 | 135,180 | — | 135,180 |
| Ft Patrick | S Fk Holston R | TN | 1953 | 67 | 4 | 36,000 | — | 36,000 |
| Boonce | S Fk Holston R | TN | 19583 | 119 | 150 | 75,000 | — | 75,000 |
| Wlbur | Watauga R | TN | 1912 | 65 | U | 10,700 | — | 10,700 |
| Watauga | Watauga R | TN | 1949 | 312 | 518 | 57,600 | — | 57,600 |
| South Holston | S Fk Holston R | TN | 1951 | 240 | 519 | 35,000 | — | 35,000 |
| Total Conventional | | | | | 3,242,910 | | 3,242,91 | |
| Total Reversible | | | | | 1,589,500 R | R | 1,589,500 R | |

*(Continued)*



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**Table 11C.31 (Continued)**

| Plant | Stream | State | Year of Initial Oper. | Gross Static Head (ft) | Usable Power Storage 1000 Acre-Feet[a] | Installed Capacity — Kilowatts[b] | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Developed | Under Construction | Authorized |
| National Park Service | | | | | | | | |
| Cascades | Merced R | CA | 1918 | 356 | NA | 2,000 | — | 2,000 |
| Total Conventional | | | | | 2,000 | | 2,000 | |
| International Boundary & Water Commission | | | | | | | | |
| Falcon | Rio Grande | TX | 1954 | 115 | 2767 | 31,500 | — | 31,500 |
| Amistad | Rio Garnde | TX | 1983 | 213 | 500 | 66,000 | — | 66,000 |
| Total Conventional | | | | | 97,500 | — | 97,500 | |
| Bureau of Indian Affairs | | | | | | | | |
| Coolidge | Gila R | AZ | 1929 | 204 | 1164 | 10,000 | — | 10,000 |
| Drop 2 | Yakima R (offstream) | WA | 1942 | 30 | NA | 2,500 | — | 2,500 |
| Drop 3 | Yakima R (offstream) | WA | 1932 | 34 | NA | 1,700 | — | 1,700 |
| Big Creek | Big Cr, Flathead R | MT | 1916 | 585 | NA | 360 | — | 360 |
| Total Conventional | | | | | 14,560 | | 14,560 | |
| Alaska Power Administration | | | | | | | | |
| Eklutna[q] | Eklutna R | AK | 1955 | 851 | 174 | 30,000 | — | 30,000 |
| Snettisham[r] | Speel R | AK | 1973 | 823 | 138 | 47,160 | — | 74,160 |
| Total Conventional | | | | | 77,160 | | 104,160 | |
| Grand Total Conventional | | | | | 34,584,503 | 831,000 | 38,355,303 | |
| Grand Total Reversible | | | | | 2,735,200 R | 581,000 R | 3,740,210 R | |

*Note:* Federally owned, developed, under construction, and authorized January 1, 1984. R Capacity shown is in reversible equipment.

[a] U—Less than 1,000 acre-ft. NA—Data not available.
[b] Includes main generating units only.
[c] Operated by Rock island Army Arsenal. Nameplate rating is 3,440 kilowatts which cannot be obtained.
[d] Storage Capacity for ultimate development is 420,000 acre-ft.
[e] All water used for generation must be returned by pumping.
[f] Storage in Buffalo Bill Reservoir is used jointly for irrigation and power.
[g] Pipeline collects water form Big Creek and Cottonwood Creek, tributaries of Plateau Creek.
[h] Water to be stored in the enlarged Strawberry Reservoir which is located upstream.
[i] Used jointly for irrigation, power, and flood control.
[j] Used jointly for irrigation and power.
[k] Used jointly for irrigation, power, flood control, and navigation.
[l] Includes two of three 10,000 kilowatt station service units used to supply commercial power.
[m] Used jointly for power and flood control.
[n] Dam and reservoir were constructed by the Corps of Engineers.
[o] Includes one of two 2,000 kilowatt station service units used to supply commercial power.
[p] 222,000 kilowatts are allocated to the state of California under contact.
[q] Constructed by the Bureau of Reclamation.
[r] Constructed by the Corps of Engineers.

*Source*: From Federal Energy Regulatory Commission, 1984, *Hydroelectric Power Resources of the United States—Developed and Undeveloped*, FERC-0070, Washington, DC.

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**Table 11C.32 Trends in Pumped Storage Capacity Development in the United States**

| | Installed Capacity in Reversible Units (millions of kilowatts) | | | | | |
|---|---|---|---|---|---|---|
| | Developed | | | Under Construction | | |
| Year as of January 1 | Pure | Combined | Total | Pure | Combined | Total |
| 1960 | 0 | 0.1 | 0.1 | 0 | 0.2 | 0.2 |
| 1964 | 0.4 | 0.3 | 0.7 | 0.7 | 0.5 | 1.2 |
| 1968 | 1.6 | 0.5 | 2.1 | 1.2 | 1.6 | 2.8 |
| 1972 | 2.6 | 1.3 | 3.9 | 6.0 | 1.4 | 7.4 |
| 1976 | 7.3 | 2.4 | 9.7 | 2.7 | 1.6 | 4.3 |
| 1980 | 9.3 | 3.6 | 12.9 | 3.2 | 1.5 | 4.7 |
| 1984 | 10.1 | 3.7 | 13.8 | 4.9 | 0.4 | 5.3 |

*Note:* A pure pumped storage project with a large peaking capacity can be developed at a site with two potential reservoirs of reasonable size in close proximity and with a relatively large difference in elevations. Projects are usually more economically developed at sites with high usable heads; consequently, the more favorable sites are normally located in mountainous terrain. However, consideration has been given to the construction of pumped storage projects in areas of level terrain by placing the lower reservoir in an underground cavern or excavated area. For any development, an assured supply of water at least sufficient to replace evaporation, seepage, and other losses is essential.

*Source*: From Federal Energy Regulatory Commission, 1984.

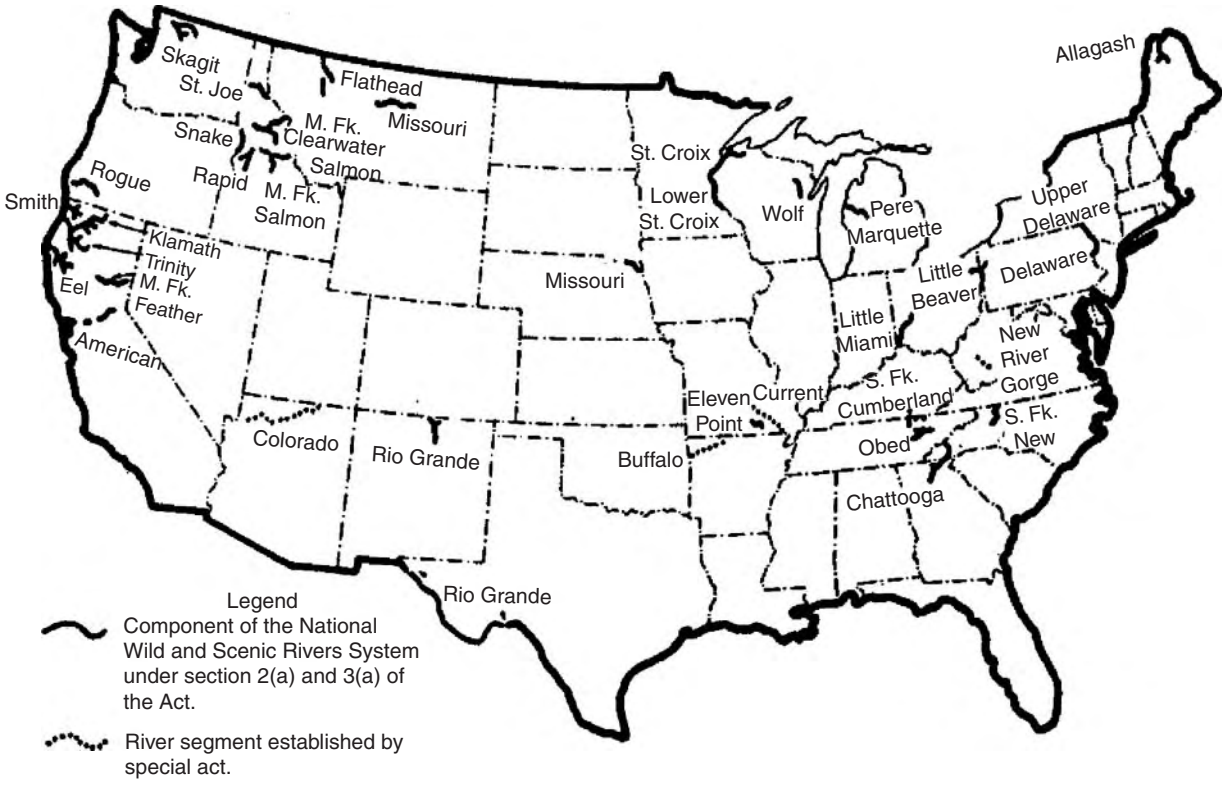


**Figure 11C.22** River segments covered by the Wild and Scenic Rivers Act and special acts precluded from hydroelectric development. (From Federal Energy Regulation Commission, 1984.)

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**Figure 11C.23** River segments designated for study under section 5(a) of the Wild and Scenic Rivers Act. (From Federal Energy Regulation Commission, 1984.)

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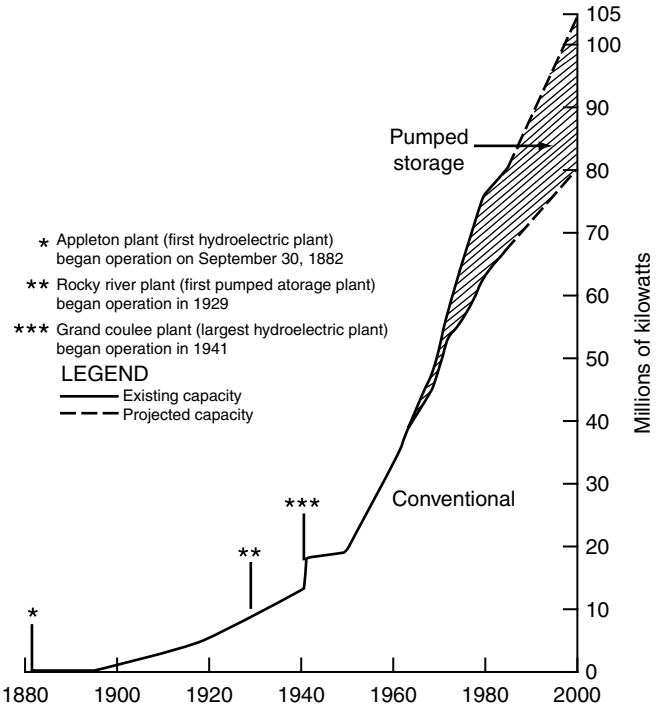


**Figure 11C.24** Hydroelectric capacity in the United States 1882–2000. (From Federal Energy Regulatory Commission, 1984.)

**Table 11C.33 Small Hydroelectric Capacity in the United States**

| | 5,000 kW and Less | | 15,000 kW and Less | | 30,000 kW and Less | |
|---|---|---|---|---|---|---|
| **Category** | **1980** | **1984** | **1980** | **1984** | **1980** | **1984** |
| Developed | | | | | | |
| Number of sites | 751 | 864 | 946 | 1,124 | 1,071 | 1,252 |
| Capacity (MW) | 1,194.6 | 1,351.1 | 3,294.7 | 3,729.7 | 5,834.6 | 6,574.0 |
| Generation (GWh) | 4.8 | 16.8 | 16.8 | 18.8 | 28.0 | 30.8 |
| Under Construction | | | | | | |
| Number of sites | 16 | 137 | 29 | 153 | 33 | 158 |
| Capacity (MW) | 23.5 | 168.6 | 135.6 | 325.8 | 229.9 | 444.8 |
| Generation (GWh) | 0.1 | 0.7 | 1.0 | 1.4 | 1.3 | 2.0 |
| Planned (NERC)[a] | | | | | | |
| Number of sites | 12 | 25 | 23 | 39 | 25 | 50 |
| Capacity (MW) | 34.2 | 54.3 | 136.2 | 191.4 | 182.4 | 436.8 |
| Generation (GWh) | 0.1 | 0.3 | 0.5 | 0.9 | 0.6 | 1.9 |
| Projected[b] | | | | | | |
| Number of sites | 157 | 1,699 | 227 | 2,278 | 279 | 2,367 |
| Capacity (MW) | 317.5 | 2,587.1 | 1,241.8 | 6,669.4 | 2,317.5 | 8,5724.4 |
| Generation (GWh) | 1.2 | 20.0 | 4.9 | 29.4 | 8.9 | 37.3 |
| Totals | | | | | | |
| Number of sites | 936 | 2,725 | 1,225 | 3,594 | 1,408 | 3,827 |
| Capacity (MW) | 1,569.8 | 4,160.8 | 4,808.3 | 10,916.3 | 8,564.4 | 16,028.0 |
| Generation (GWh) | 6.2 | 27.6 | 23.2 | 50.3 | 38.8 | 72.0 |

*Note:* Developed, Under Construction, and Projected.

[a] In reports of the Regional Electric Reliability Councils.

[b] Potential developments not under construction or included in NERC reports but which have FERC licensing or exemption status, are authorized or recommended for Federal construction, or have structural provisions for plant additions.

*Source*: From Federal Energy Regulatory Commission, 1984.

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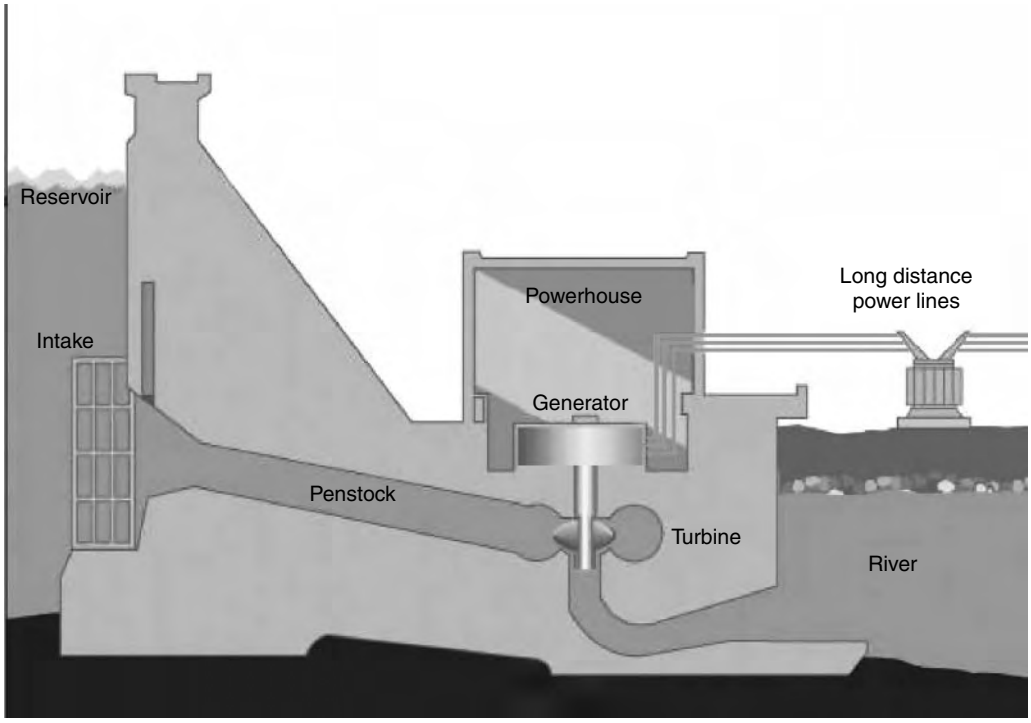


**Figure 11C.25** Hydroelectric dam. (From www.tva.gov.)

**Table 11C.34 Hydroelectric Plants Having Potential Conventional Capacity over 1,000,000 Kilowatts**

| | | | Installed Capacity in Conventional Units Kilowatts | | |
|---|---|---|---|---|---|
| **Plant** | **River** | **Owner[a]** | **Developed** | **Under Construction** | **Ultimate Authorized** |
| Grand Coulee | Columbia | Bureau | 6,180,000 | 0 | 6,180,000 |
| John Day | Columbia | COE | 2,160,000 | 0 | 2,700,000 |
| Chief Joseph | Columbia | COE | 2,069,000 | 0 | 2,069,000 |
| R. Moses Niagara | Niagara | PASNY | 1,950,000 | 0 | 1,950,000 |
| The Dalles | Columbia | COE | 1,806,800 | 0 | 1,806,800 |
| Hoover | Colorado | Bureau | 1,434,000 | 0 | 1,434,000 |
| Rocky Reach | Columbia | CC PUD No. 1 | 1,213,950 | 0 | 1,213,950 |
| Wanapum | Columbia | GC PUD No. 2 | 831,250 | 0 | 1,151,250 |
| Priest Rapids | Columbia | GC PUD No. 2 | 788,500 | 0 | 1,108,500 |
| Bonneville | Columbia | COE | 1,076,620 | 0 | 1,102,820 |
| Dworshak | N. Fork Clearwater | COE | 400,000 | 0 | 1,060,000 |
| Glen Canyon | Colorado | Bureau | 1,042,000 | 0 | 1,042,000 |
| Boundary | Pend Oreille | Seattle | 634,600 | 392,000 | 1,026,600 |
| Total | | 21,586,720 | 392,000 | 23,834,920 | |

[a] Bureau, Bureau of Reclamation; COE, Corps of Engineers; PASNY, Power Authority, State of New York; GC, Grant County; CC, Chelan County; and Seattle, Seattle Dept. of Lighting.

*Source*: From Federal Energy Regulatory Commission, 1984.

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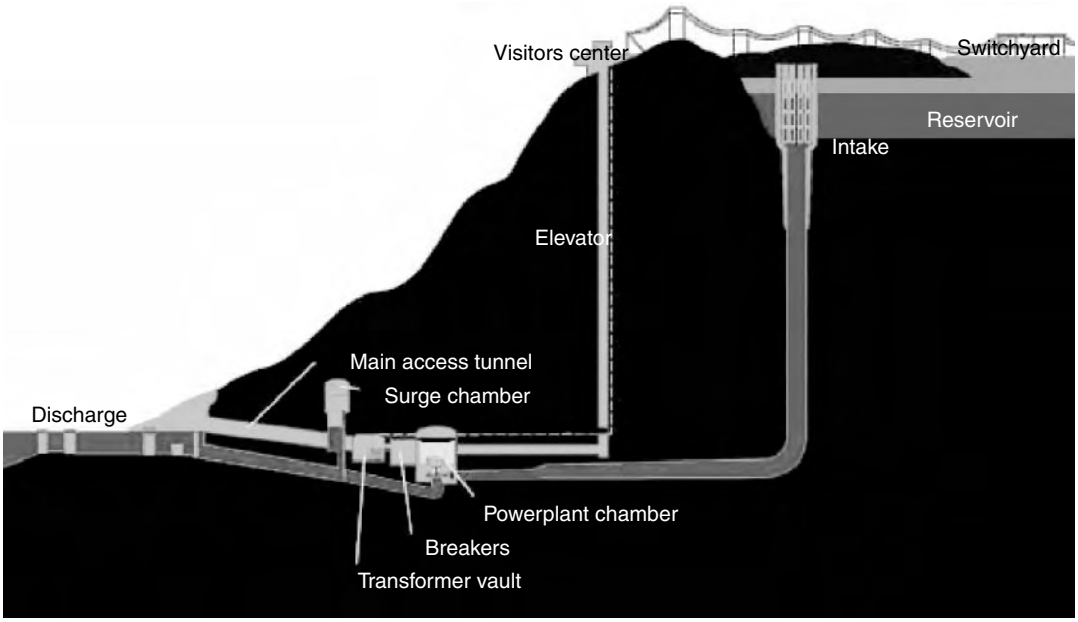
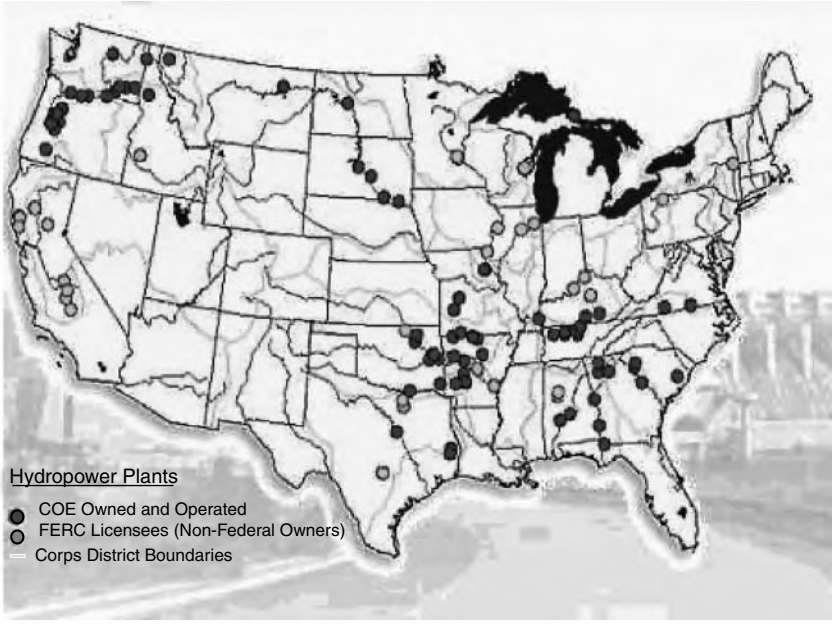



**Figure 11C.26** Pumped-storage plant. (From www.tva.gov.)




**Background**. The Corps of Engineers (Corps) is the single largest owner and operator of hydropower in the U.S., with 24% of the nation's hydropower generating capacity. The percentage is 16% for the Bureau of Reclamation and 6% for the Tennessee Valley Authority. Corps dams have a total nameplate capacity of close to 21,000 megawatts (MW) and produce an average of almost 100 million kilowatt-hours (kWh) of energy annually. Nonfederal power plants at Corps facilities add about another 2,000 MW of capacity.

**Figure 11C.27** Hydropower plants. (From nwd-wc.usace.army.)

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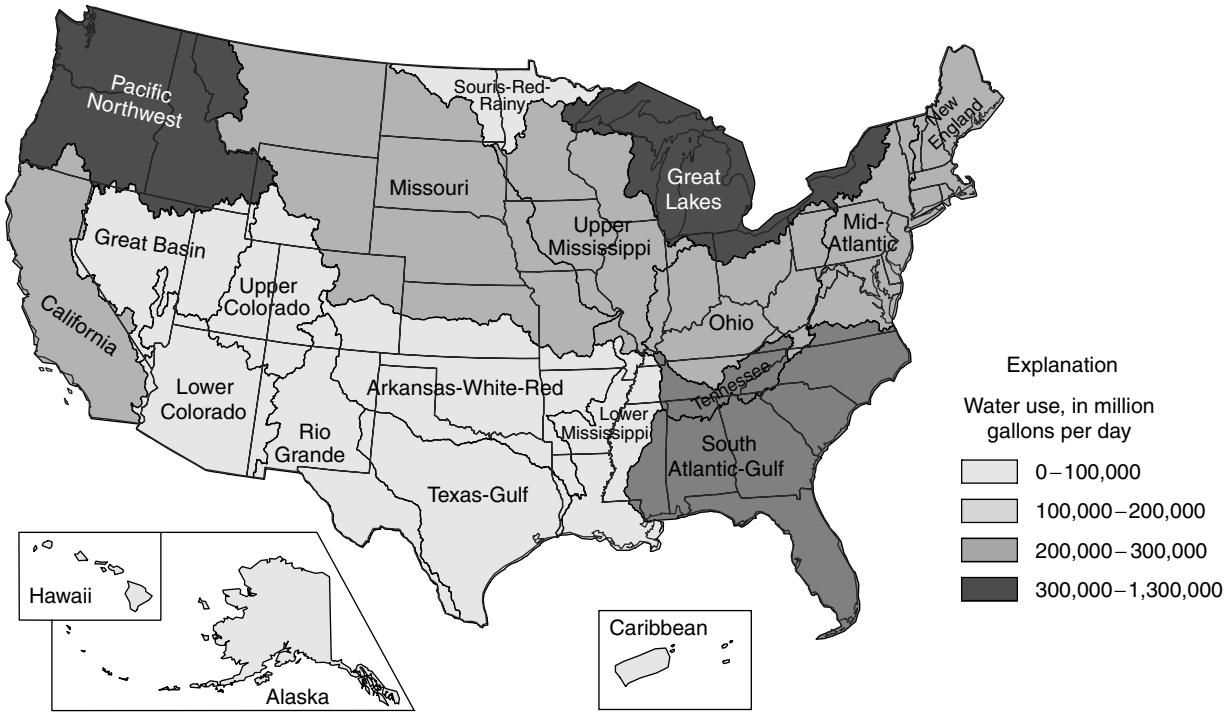


**Figure 11C.28** Hydroelectric power water use by water resources region, 1995. (From www.usgs.gov.)

**Table 11C.35 Hydroelectric Power Water Use by Water Resources Region, 1995**

| | Water Use | | |
|---|---|---|---|
| **Region** | **Mgal/d** | **1000 acre-ft/yr** | **Power Generated (million kWh)** |
| New England | 156,000 | 175,000 | 6,720 |
| Mid-Atlantic | 144,000 | 162,000 | 5,260 |
| South Atlantic-Gulf | 229,000 | 258,000 | 17,100 |
| Great Lakes | 340,000 | 382,000 | 24,200 |
| Ohio | 172,000 | 192,000 | 5,250 |
| Tennessee | 209,000 | 235,000 | 16,000 |
| Upper Mississippi | 119,000 | 133,000 | 2,990 |
| Lower Mississippi | 78,200 | 87,700 | 1,320 |
| Souris-Red-Rainy | 3,970 | 4,450 | 100 |
| Missouri Basin | 141,000 | 159,000 | 16,000 |
| Arkansas-White-Red | 95,400 | 107,000 | 6,740 |
| Texas-Gulf | 14,500 | 16,300 | 1,050 |
| Rio Grende | 3,860 | 4,320 | 464 |
| Upper Colorado | 17,900 | 20,000 | 7,220 |
| Lower Colorado | 23,400 | 26,300 | 9,740 |
| Great Basin | 5,060 | 5,670 | 633 |
| Pacific Northwest | 1,260,000 | 1,140,000 | 140,000 |
| California | 140,000 | 157,000 | 47,000 |
| Alaska | 2,090 | 2,340 | 1,440 |
| Hawaii | 229 | 256 | 148 |
| Caribbean | 349 | 391 | 101 |
| Total | 3,160,000 | 3,540,000 | 310,000 |

*Note:* Figures may not add to totals because of independent rounding. Mgal/d, million gallons per day; kWh, kilowatt-hour.

*Source*: From http://npdp.stanford.edu; www.usgs.gov.

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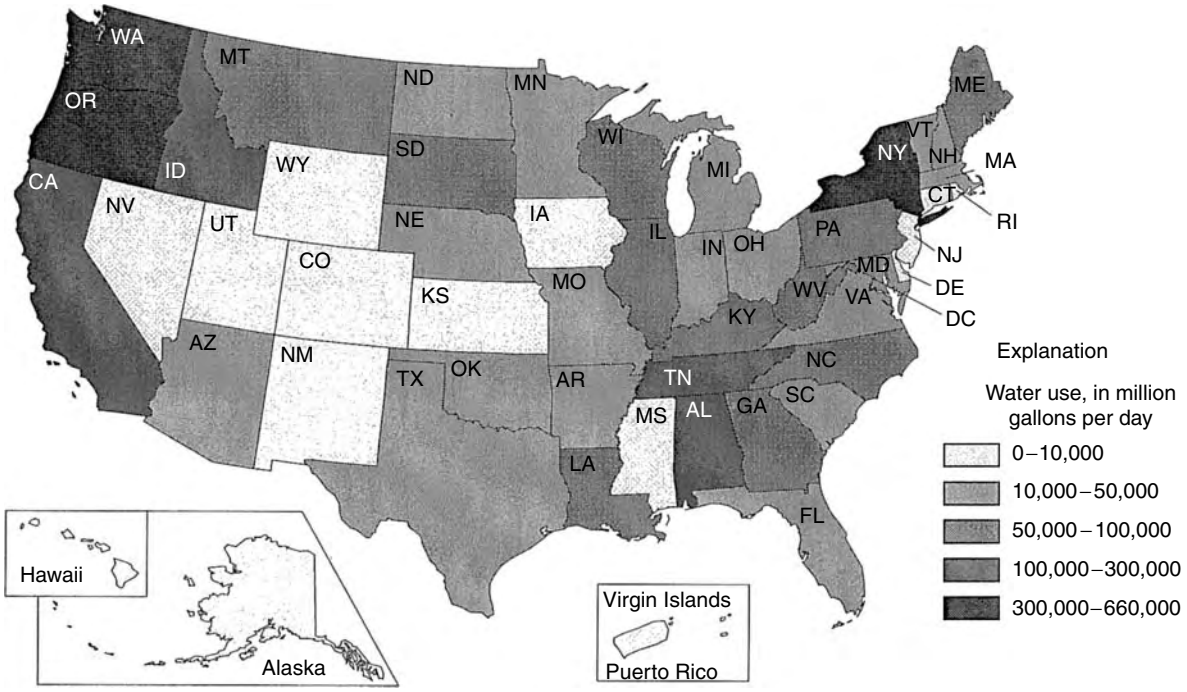


**Figure 11C.29** Hydroelectric power water use by state, 1995. (From www.usgs.gov.)

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**Table 11C.36 Hydroelectric Power Water Use by State, 1995**

| State | Water Use | | Power Generated (million kWh) |
|---|---|---|---|
| | Mgal/d | 1000 acre-ft/yr | |
| Alabama | 157,000 | 177,000 | 9,510 |
| Alaska | 2,090 | 2,340 | 1,440 |
| Arizona | 21,200 | 23,700 | 7,960 |
| Arkonsas | 42,700 | 47,900 | 2,630 |
| California | 146,000 | 164,000 | 47,100 |
| Colorado | 6,810 | 7,630 | 2,140 |
| Connecticut | 3,610 | 4,050 | 317 |
| Delaware | 0 | 0 | 0 |
| District of Columbia | 0 | 0 | 0 |
| Florida | 16,900 | 19,000 | 443 |
| Georgia | 50,900 | 57,100 | 4,850 |
| Hawaii | 229 | 256 | 148 |
| Idaho | 115,000 | 129,000 | 11,300 |
| Illinois | 55,800 | 62,500 | 1,010 |
| Indiana | 12,300 | 13,800 | 467 |
| Iowa | 2,350 | 2,630 | 21 |
| Kansas | 1,250 | 1,410 | 11 |
| Kentucky | 83,000 | 93,100 | 2,880 |
| Louisiana | 76,100 | 85,400 | 1,110 |
| Maine | 85,200 | 95,500 | 3,440 |
| Maryland | 14,400 | 16,100 | 1,450 |
| Massachusetts | 24,200 | 27,100 | 992 |
| Michigan | 39,800 | 44,600 | 1,410 |
| Minnesota | 19,800 | 22,200 | 1,030 |
| Mississippi | 0 | 0 | 0 |
| Missouri | 17,100 | 19,200 | 1,920 |
| Montana | 66,200 | 74,200 | 10,400 |
| Nebraska | 15,000 | 16,800 | 1,040 |
| Nevada | 6,080 | 6,810 | 6,320 |
| New Hampshire | 33,000 | 37,000 | 1,460 |
| New Jersey | 309 | 346 | 241 |
| New Mexico | 2,750 | 3,090 | 353 |
| New York | 356,000 | 399,000 | 24,600 |
| North Carolina | 56,400 | 63,200 | 5,810 |
| North Dakota | 13,900 | 15,600 | 2,480 |
| Ohio | 14,200 | 15,900 | 227 |
| Oklahoma | 49,100 | 55,100 | 3,300 |
| Oregon | 458,000 | 511,000 | 40,400 |
| Pennsylvania | 55,900 | 62,600 | 352 |
| Rhode Island | 339 | 380 | 6.1 |
| South Carolina | 42,200 | 47,300 | 3,070 |
| South Dakota | 62,400 | 69,900 | 6,420 |
| Tennessee | 122,000 | 137,000 | 9,430 |
| Texas | 18,600 | 20,900 | 1,520 |
| Utah | 3,720 | 4,170 | 931 |
| Vermont | 17,500 | 19,600 | 983 |
| Virginia | 14,800 | 16,600 | 922 |
| Washington | 653,000 | 733,000 | 82,300 |
| West Virginia | 51,500 | 57,700 | 1,210 |
| Wisconsin | 50,800 | 57,000 | 1,600 |
| Wyoming | 5,150 | 5,770 | 793 |
| Puerto Rico | 349 | 391 | 101 |
| Virgin Islands | 0 | 0 | 0 |
| Total | 3,160,000 | 3,540,000 | 310,000 |

*Note:* Figures may not add to totals because of independent rounding, Mgal/d, million gallons per day; kWh, kilowatt-hour.

*Source*: From npdp.stanford.edu. 1988.

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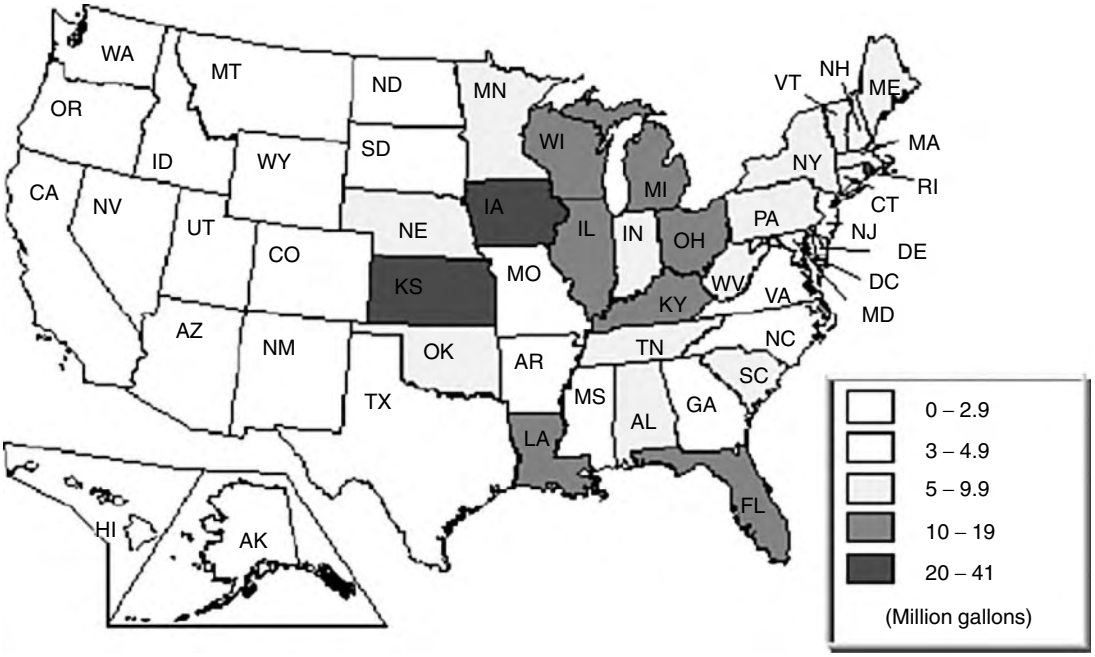


**Figure 11C.30** Water used to produce 1 kWh of hydroelectric power in the United States in 1990. (From ga.water.usgs.gov.)

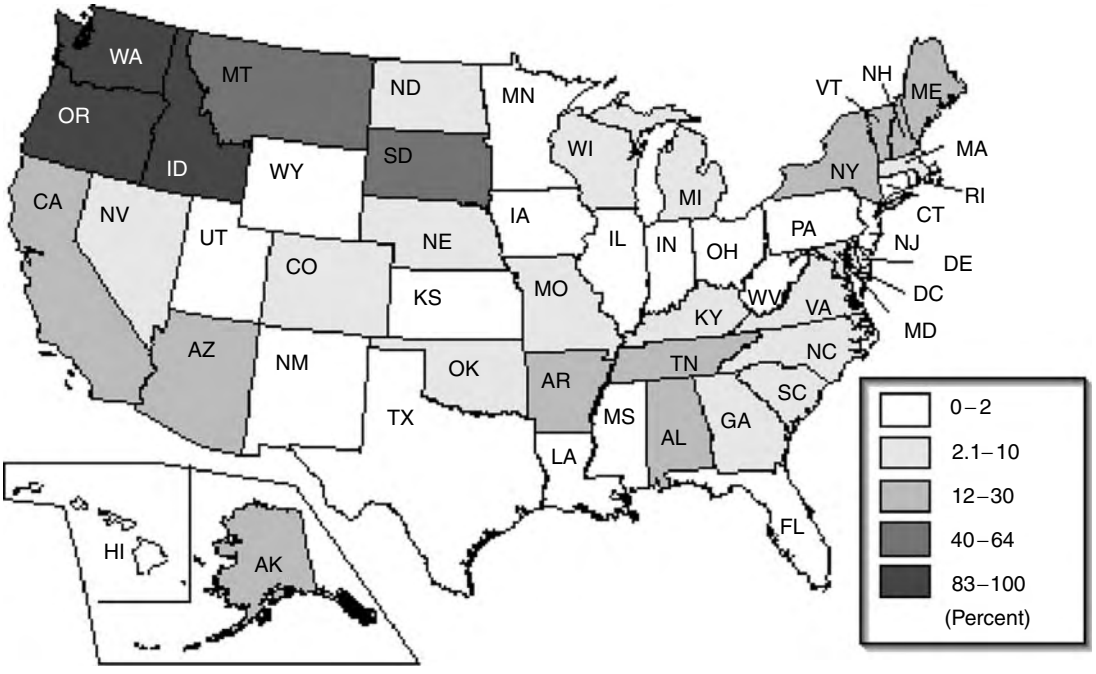


**Figure 11C.31** Percent of total power produced coming from hydroelectric sources in the United States in 1990. (From ga.water.usgs.gov.)

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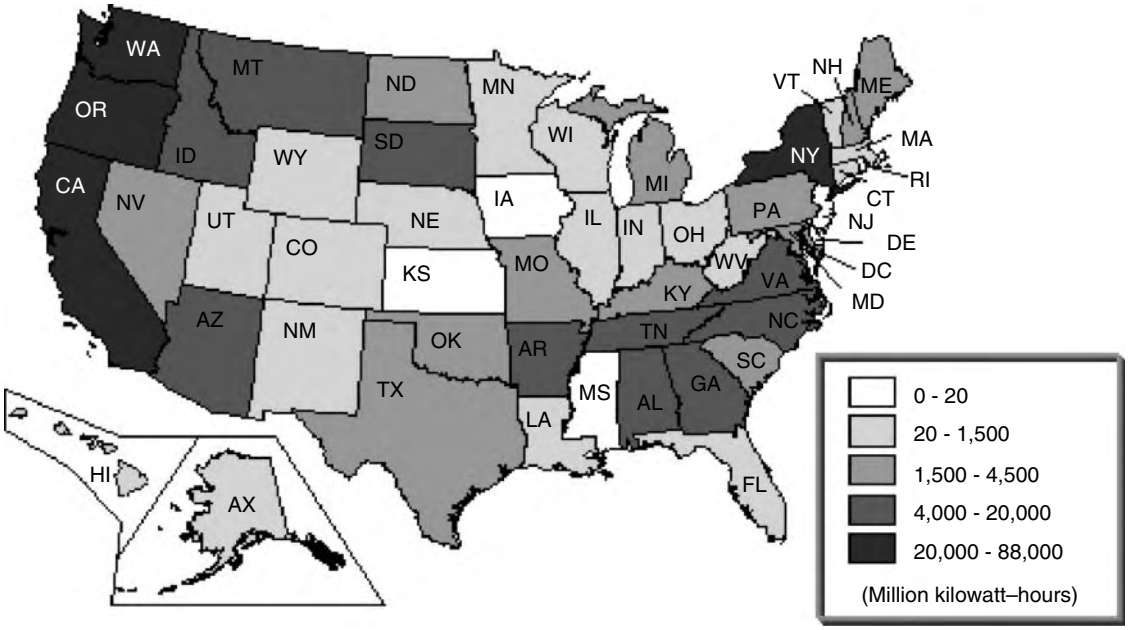


**Figure 11C.32** Hydroelectric power production in the United States in 1990. (From ga.water.usgs.gov.)

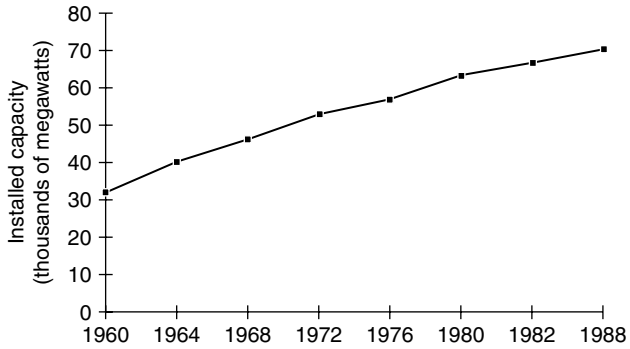


**Figure 11C.33** Developed conventional hydroelectric capacity in the United States (From FERC, 1988a, xix. With permission.)

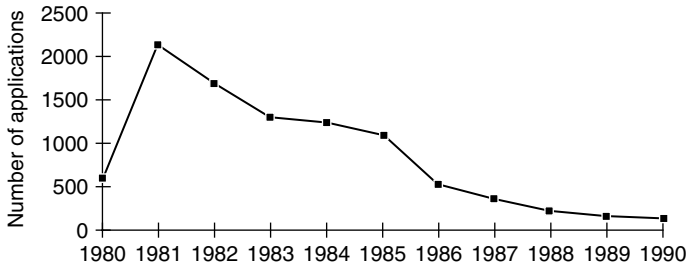


**Figure 11C.34** U.S. Hydro applications a 1980–1990. (From FERC, 1988a, xix. With permission.)

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**Table 11C.37 U.S. Hydro Operations and Potential 1988**

| | Conventional | Pumped Storage[a] | Total |
|---|---|---|---|
| # Plants in operation | 2010 | 37 | 2047 |
| Developed capacity | 70,800 MW | 17,100 MW | 87,900 MW |
| Mean plant capacity | 35 MW | 462 MW | 43 MW |
| % of developed capacity under FERC jurisdiction | 46.2% | 81.3% | 53.0% |
| Total potential capacity | 146,900 MW | 19,100 MW[b] | 166,000 MW[b] |
| % of potential capacity developed | 48.2% | 89.5% | 53.0% |

[a] Includes both pure pumped storage and combined conventional and pumped storage facilities.
[b] Because of the enormous number of sites potentially suitable for pumped storage, only developed facilities and those actually under construction are included in the total potential capacity estimates for pumped storage facilities.

*Source*: From FERC, 1988a, vii–viii.

**Table 11C.38 Hydro Development and Potential in the UMRB 1988**

| | Number of Plants | Average Plant Size | Developed Capacity (MW) | Undeveloped Capacity (MW) | Total Potential Capacity (MW) | Percentage of Total Potential Developed |
|---|---|---|---|---|---|---|
| Illinois | 7 | 4,268 | 29.9 | 285.9 | 315.8 | 9 |
| Iowa | 6 | 21,939 | 131.6 | 388.0 | 519.6 | 25 |
| Minnesota | 31 | 6,121 | 189.7 | 299.9 | 489.6 | 39 |
| Missouri | 8 | 133,000 | 1,064.0 | 857.8 | 1,921.8 | 55 |
| Wisconsin | 116 | 4,045 | 469.2 | 492.4 | 961.6 | 49 |
| 5 states | 168 | 11,217 | 1,884.5 | 2,324.0 | 4,208.5 | 45 |
| United States | 2047 | 42,936 | 87,889.7 | 78,048.5 | 165,938.2 | 53 |

*Source*: From FERC, 1988a, pp. 101, 132–41, 264.

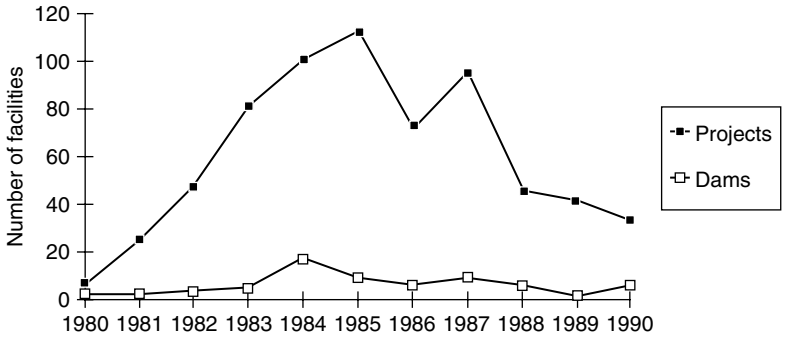


**Figure 11C.35** New conventional hydro projects and dams in the United States (From FERC, 1988a, xix. With permission.)

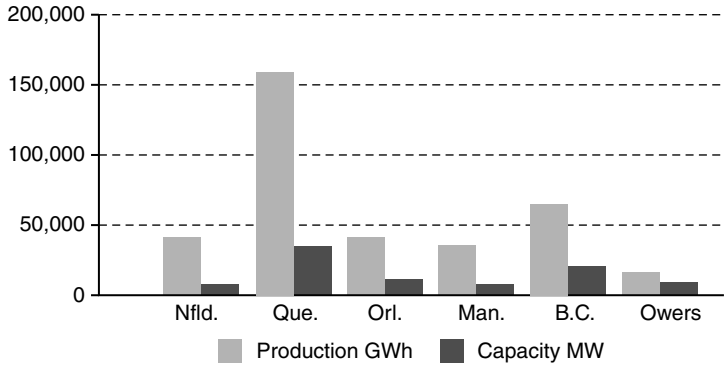


**Figure 11C.36** Hydroelectricity by province. (From nrcan.gc.ca.)

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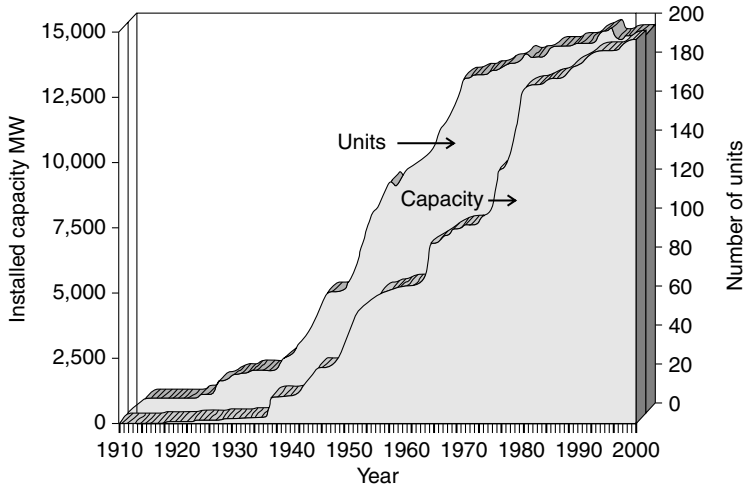


**Figure 11C.37** Reclamation hydroelectric development 1909–2000. (From U.S. Department of the Interior, Bureau of Reclamation Power Resources Office—October 2004.)

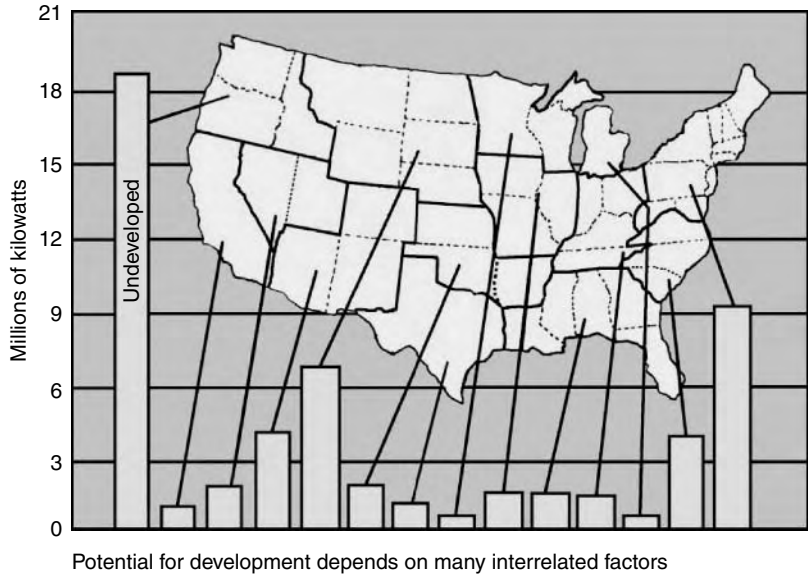


**Figure 11C.38** Undeveloped hydroelectric power. (From U.S. Department of the Interior, Bureau of Reclamation Power Resources Office—October 2004.)

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**Table 11C.39 Conventional Hydroelectric Power in the United States Developed, Undeveloped, and Total Potential — January 1, 1984**

| Water Resource Region | Developed | | | Undeveloped | | | Total Potential | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of Plants | Installed Capacity kW | Average Annual Generation 1,000 kWh | No. of Sites | Installed Capacity kW[a] | Average Annual Generation 1,000 kWh | Installed Capacity kW | Average Annual Generation 1,000 kWh | Percent Total Potential Cap. Now Developed |
| North Atlantic Region | 248 | 1,538,631 | 6,359,847 | 669 | 4,387,567 | 13,299,262 | 5,926,198 | 19,659,209 | 25.9 |
| Mid Atlantic Region | 122 | 1,506,299 | 6,091,861 | 409 | 4,786,750 | 13,732,622 | 6,293,049 | 19,824,483 | 23.9 |
| South Atlantic-Gulf Region | 128 | 6,094,348 | 16,190,853 | 261 | 5,396,194 | 10,633,130 | 11,490,542 | 26,826,983 | 53.0 |
| Great Lakes Region | 209 | 3,895,123 | 24,354,228 | 229 | 2,243,431 | 9,852,598 | 6,138,554 | 34,206,826 | 63.4 |
| Ohio Region | 36 | 1,646,672 | 6,104,170 | 200 | 4,313,176 | 13,330,111 | 5,959,848 | 19,443,281 | 27.6 |
| Tennessee Region | 47 | 3,749,075 | 16,249,440 | 33 | 1,150,985 | 2,777,781 | 4,900,060 | 19,027,221 | 76.5 |
| Upper Mississippi Region | 105 | 617,237 | 3,187,639 | 104 | 1,267,796 | 5,459,595 | 1,885,033 | 8,47,234 | 32.7 |
| Lower Mississippi Region | 5 | 205,800 | 430,400 | 29 | 1,000,075 | 3,106,275 | 1,205,875 | 3,536,675 | 17.0 |
| Souris-Red-Rainy Region | 8 | 13,000 | 68,000 | 8 | 45,880 | 158,290 | 58,880 | 226,290 | 22.0 |
| Missouri Region | 62 | 3,462,023 | 15,549,519 | 234 | 5,307,568 | 17,595,761 | 8,769,591 | 33,145,280 | 39.4 |
| Arkansas-White-Red Region | 23 | 1,854,460 | 5,341,446 | 128 | 3,581,693 | 9,065,790 | 5,436,153 | 14,407,236 | 34.1 |
| Texas-Gulf Region | 18 | 393,970 | 1,066,359 | 87 | 1,481,627 | 3,032,279 | 1,875,597 | 4,098,638 | 21.0 |
| Rio Grande Region | 5 | 131,408 | 389,521 | 25 | 233,886 | 632,431 | 365,294 | 1,021,952 | 35.9 |
| Upper Colorado Region | 26 | 1,452,497 | 5,923,214 | 137 | 2,370,246 | 6,221,787 | 3,822,743 | 12,145,001 | 37.9 |
| Lower Colorado Region | 17 | 1,910,463 | 6,601,700 | 33 | 1,650,983 | 5,085,441 | 3,561,446 | 11,687,141 | 53.6 |
| Great Basin Region | 60 | 188,422 | 655,837 | 112 | 765,697 | 1,862,008 | 954,119 | 2,517,845 | 19.7 |
| Pacific Northwest Region | 176 | 29,909,275 | 143,542,447 | 1,128 | 22,104,337 | 67,221,564 | 52,013,612 | 210,764,011 | 57.5 |
| California Region | 211 | 8,033,509 | 37,644,560 | 740 | 10,099,470 | 25,983,648 | 18,132,979 | 63,628,208 | 44.3 |
| Alaska Region | 26 | 155,737 | 634,082 | 96 | 5,041,107 | 22,192,656 | 5,196,844 | 22,826,738 | 2.9 |
| Hawaii Region | 14 | 17,652 | 104,100 | 15 | 62,890 | 310,950 | 80,542 | 415,050 | 21.9 |
| Total United States | 1,546 | 66,775,601 | 296,489,223 | 4,677 | 77,291,358 | 231,563,079 | 144,066,959 | 528,052,302 | 46.3 |

[a] Includes potential capacity additions or subtractions at existing plants.

*Source*: From Federal Energy Regulatory Commission, 1984.



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**Table 11C.40 Conventional Hydroelectric Power in the United States Developed, Undeveloped, and Total Potential — January 1, 1984**

| | Developed | | | Undeveloped | | | Total Potential | | |
|---|---|---|---|---|---|---|---|---|---|
| Geographic Division | No. of Plants | Installed Capacity kW | Average Annual Generation 1,000 kWh | No. of Sites | Installed Capacity kW[a] | Average Annual Generation 1,000 kWh | Installed Capacity kW | Average Annual Generation 1,000 kWh | Percent Total Potential Cap. Now Developed |
| New England | 279 | 1,618,739 | 6,684,066 | 74 | 4,555,434 | 13,887,230 | 6,174,170 | 20,571,296 | 26.2 |
| Middle Atlantic | 157 | 4,297,372 | 25,703,831 | 421 | 5,370,969 | 18,152,584 | 9,668,341 | 43,856,415 | 44.4 |
| East North Central | 210 | 1,087,054 | 5,159,366 | 208 | 1,789,913 | 7,158,041 | 2,876,967 | 12,317,407 | 37.7 |
| West North Central | 65 | 2,808,465 | 12,187,539 | 157 | 3,011,876 | 9,999,018 | 5,820,341 | 22,186,557 | 48.2 |
| South Atlantic | 166 | 6,013,182 | 17,216,643 | 355 | 8,395,423 | 17,795,208 | 14,408,605 | 35,011,851 | 41.7 |
| East South Central | 57 | 5,734,292 | 22,024,618 | 119 | 2,842,266 | 9,337,538 | 8,576,558 | 31,362,156 | 66.8 |
| West South Central | 43 | 2,338,020 | 6,516,705 | 214 | 5,328,495 | 12,734,953 | 7,666,515 | 19,251,658 | 30.4 |
| Mountain | 192 | 7,869,611 | 32,866,583 | 876 | 18,201,259 | 53,698,630 | 26,070,870 | 86,565,213 | 30.1 |
| Pacific | 337 | 34,835,480 | 167,391,690 | 1,472 | 22,691,726 | 66,296,271 | 57,527,206 | 233,687,961 | 60.5 |
| Alaska | 26 | 155,737 | 634,082 | 96 | 5,041,107 | 22,192,656 | 5,196,844 | 22,826,738 | 2.9 |
| Hawaii | 14 | 17,652 | 104,100 | 15 | 62,890 | 310,950 | 80,542 | 415,050 | 21.9 |
| Total United States | 1,546 | 66,775,601 | 296,489,223 | 4,677 | 77,291,358 | 231,563,079 | 144,066,959 | 528,052,302 | 46.3 |

[a] Includes potential capacity additions or subtractions at existing plants.

*Source*: From Federal Energy Regulatory Commission, 1984.

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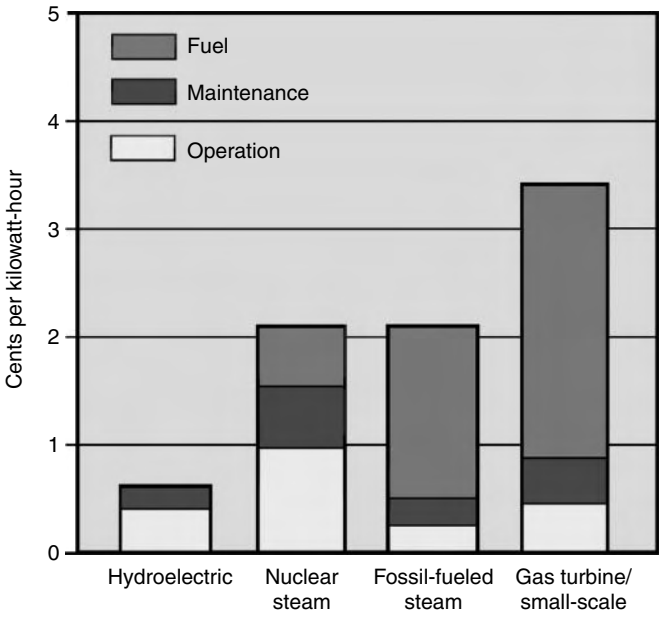


**Figure 11C.39** Average power production expenses per kWh, 1995–1999. (From Energy Information Administration Financial Statistics of Major U.S. Investor-Owned Utilities.)

**Table 11C.41 Federal Hydroelectric Capacity by Operating Agency, January 1, 1984**

| | Installed Capacity Conventional and Reversible (Kilowatts) | | |
|---|---|---|---|
| | **In Operation** | **Under Construction** | **Ultimate Authorized** |
| Corps of Engineers | 19,449,197 | 1,162,000 | 23,466,897 |
| Bureau of Reclamation | 12,846,876 | 250,000 | 13,577,986 |
| Tennessee Valley Authority | 4,832,410 | — | 4,832,410 |
| International Boundary and Water Commission | 97,500 | — | 97,500 |
| Alaska Power Administration | 77,160 | — | 104,160 |
| Bureau of Indian Affairs | 14,560 | — | 14,560 |
| National Park Service | 2,000 | — | 2,000 |
| Total | 37,319,703 | 1,412,000 | 42,095,513 |

*Source*: From Federal Energy Regulatory Commission, 1984.

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**Table 11C.42 TVA's Hydro Plants**

| | Dam Height (ft) | Dam Length (ft) | Reservoir Length (mil) | Capacity[a] (MW) | Construction Span |
|---|---|---|---|---|---|
| Tennessee River | | | | | |
| Fort Loudeun | 125 | 4,190 | 61 | 123 | 1940–43 |
| Watts Bar | 122 | 2,960 | 96 | 175 | 1939–42 |
| Chickamauga | 129 | 5,800 | 59 | 129 | 1936–40 |
| Nickajack | 86 | 3,767 | 46 | 100 | 1964–67 |
| Guntersville | 97 | 3,979 | 76 | 114 | 1935–39 |
| Wheeler | 72 | 6,342 | 74 | 355 | 1933–36 |
| Wilson | 137 | 4,541 | 16 | 611 | 1918–24 |
| Pickwick Landing | 113 | 7,715 | 53 | 193 | 1934–38 |
| Kentucky | 206 | 8,422 | 184 | 199 | 1938–44 |
| Raccoon Mountain Pumped Storage | 230 | 8,500 | 1.2 | 1,532 | 1970–78 |
| Clinch River | | | | | |
| Norris | 265 | 1,860 | 129 | 111 | 1933–36 |
| Melton Hill | 103 | 1,020 | 44 | 72 | 1960–63 |
| French Broad River | | | | | |
| Douglas | 215 | 1,705 | 43 | 90 | 1942–43 |
| Holston River | | | | | |
| South Holston | 285 | 1,600 | 24 | 46 | 1942–50 |
| Boone | 168 | 1,697 | 33 | 83 | 1950–52 |
| Fort Patrick Henry | 95 | 737 | 10 | 32 | 1951–53 |
| Cherokee | 183 | 6,760 | 59 | 126 | 1940–41 |
| Walauga River | | | | | |
| Walauga | 331 | 925 | 16 | 68 | 1942–48 |
| Wilbur | 77 | 375 | 2 | 12 | 1912 |
| Little Tennessee River | | | | | |
| Fontana | 480 | 2,365 | 29 | 241 | 1942–44 |
| Hiwassee River | | | | | |
| Chaluge | 150 | 3,336 | 13 | 10 | 1941–42 |
| Nottety | 199 | 3,915 | 20 | 16 | 1941–42 |
| Hiwassee | 307 | 1,376 | 22 | 121 | 1936–40 |
| Apalachia | 150 | 1,308 | 10 | 74 | 1941–43 |
| Ocoee River | | | | | |
| Blue Ridge | 174 | 1,553 | 11 | 13 | 1925–30 |
| Ocoee 1 | 135 | 840 | 8 | 25 | 1910–11 |
| Ocoee 2 | 30 | 450 | 0.8 | 19 | 1912–13 |
| Ocoee 3 | 110 | 612 | 7 | 28 | 1941–42 |
| Elk River | | | | | |
| Tims Ford | 175 | 1,580 | 34 | 37 | 1966–70 |
| Caney Fork River | | | | | |
| Great Falls | 92 | 800 | 22 | 37 | 1915–16 |

*Note:* To find information on dam releases, reservoir levels, and other river system data, go to http://lakeinfo.tva.com.

[a] Net winter dependable capacity; the amount of power a plant can produce on an average winter day, minus the electricity used by the plant itself.

*Source*: From www.tva.com.

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**Table 11C.43 Bureau of Reclamation Power Facilities**

| Region | Project | Plant | State Location | River | Initial Date in Service | Number of Units | Installed Capacity (kW) | Gross Generation (kWh) |
|---|---|---|---|---|---|---|---|---|
| PN | Boise | Anderson Ranch | Idaho | So. Fork, Boise | 12–50 | 2 | 40,000 | 117,267,000 |
| | | Black Canyon | Idaho | Payette | 12–25 | 2 | 10,200 | 66,221,000 |
| | | Boise River div. | Idaho | Boise | 5–12 | 3 | 3,450 | 7,054,000 |
| | Columbia Basin | Grand Coulee | Washington | Columbia | 3–41 | 33 | 6,809,000 | 18,854,034,875 |
| | Hungary Horse | Hungry Horse | Montana | So. Fork, flathead | 10–52 | 4 | 428,000 | 851,474,000 |
| | Minidoka | Minidoka | Idaho | Snake | 5–09 | 4 | 27,700 | 84,345,000 |
| | Palisades | Palisades | Idaho | So. Fork, Snake | 2–57 | 4 | 176,564 | 422,987,000 |
| | Rogue River Basin | Green Springs | Oregon | Trans. Mtn. Div. | 5–60 | 1 | 17,290 | 53,649,000 |
| | Yakima | Chandler | Washington | Yakima | 2–56 | 2 | 12,000 | 40,885,000 |
| | | Roza | Washington | Yakima | 8–58 | 1 | 12,937 | 59,568,700 |
| Total | | | | | | 56 | 7,537,141 | 20,557,485,575 |
| MP | Central Valley | Judge F. Carr | California | Tunnel, Lewiston | 5–63 | 2 | 154,400 | 494,153,000 |
| | | Folsom | California | American | 6–55 | 3 | 198,720 | 493,687,000 |
| | | Keswick | California | Sacramento | 10–49 | 3 | 117,000 | 470,903,000 |
| | | New Melones | California | Stanislaus | 6–79 | 2 | 300,000 | 342,689,000 |
| | | Nimbus | California | American | 5–55 | 2 | 13,500 | 55,253,000 |
| | | O'Neill | California | San Luis Creek | 11–67 | 6 | 25,200 | 6,094,000 |
| | | San Luis | California | San Luis Creek | 3–68 | 8 | [a]202,000 | 176,083,000 |
| | | Shasta | California | Sacramento | 6–44 | 7 | 646,000 | 2,209,689,300 |
| | | Spring Creek | California | Tunnel, Clear Creek | 1–64 | 2 | 180,000 | 582,083,000 |
| | | Trinity | California | Trinity | 2–64 | 2 | 140,000 | 594,842,000 |
| | | Lewiston | California | Trinity | 2–64 | 1 | 350 | 3,075,000 |
| | Washoe | Stampede | California | Little Truckee | 9–87 | 2 | 3,650 | 13,657,130 |
| Total | | | | | | 40 | 1,980,820 | 5,442,208,430 |
| LC | Boulder Canyon | Hoover | Arizona/Nevada | Colorado | 9–36 | 19 | 2,078,800 | 4,040,245,040 |
| | Parker-Davis | Davis | Arizona | Colorado | 1–51 | 5 | 255,000 | 1,170,088,000 |
| | | Parker | California | Colorado | 12–42 | 4 | 120,000 | 458,320,999 |
| Total | | | | | | 28 | 2,453,800 | 5,668,654,039 |
| UC | Collbran | Lower Molina | Colorado | Pipeline | 12–62 | 1 | 4,860 | 14,369,675 |
| | | Upper Molina | Colorado | Pipeline | 12–62 | 1 | 8,640 | 24,818,100 |
| | Colo. River Storage | Blue Mesa | Colorado | Gunnison | 9–67 | 2 | 86,400 | 142,539,000 |
| | | Crystal | Colorado | Gunnison | 6–78 | 1 | 28,000 | 4,705,000 |

*(Continued)*



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**Table 11C.43 (Continued)**

| Region | Project | Plant | State Location | River | Initial Date in Service | Number of Units | Installed Capacity (kW) | Gross Generation (kWh) |
|---|---|---|---|---|---|---|---|---|
| | | Flaming Gorge | Utah | Green | 11–63 | 3 | 151,950 | 236,681,000 |
| | | Glen Canyon | Arizona | Colorado | 9–64 | 8 | 1,296,000 | 3,328,793,000 |
| | | Morrow Point | Colorado | Gunnison | 12–70 | 2 | 173,334 | 195,118,000 |
| | Provo River | Deer Creek | Utah | Provo | 2–58 | 2 | 4,950 | 14,261,154 |
| | Rio Grande | Elephant Butte | New Mexico | Rio Grande | 11–40 | 3 | 27,945 | 28,224,800 |
| | Seedskadee | Fontenelle | Wyoming | Green | 5–68 | 1 | 10,000 | 45,472,000 |
| | Dolores | McPhee | Colorado | Dolores | 12–92 | 1 | 1,283 | 2,655,481 |
| | | Towaoc | Colorado | Towaoc Canal | 5–93 | 1 | 11,495 | 16,486,900 |
| Total | | | | | | 26 | 1,804,857 | 4,054,124,110 |
| GP | Colo.-Big Thompson | Big Thompson | Colorado | Trans. Mtn. Div. | 4–59 | 1 | 4,500 | 10,010,000 |
| | | Estes | Colorado | Trans. Mtn. Div. | 9–50 | 3 | 45,000 | 107,647,000 |
| | | Flatiron | Colorado | Trans. Mtn. Div. | 1–54 | 3 | 94,500 | 229,031,000 |
| | | Green Mountain | Colorado | Blue | 5–43 | 2 | 26,000 | 27,690,000 |
| | | Marys Lake | Colorado | Trans. Mtn. Div. | 5–51 | 1 | 8,100 | 38,686,000 |
| | | Pole Hill | Colorado | Trans. Mtn. Div. | 1–54 | 1 | 38,200 | 180,065,000 |
| | Frying Pan-Arkansas | Mt. Elbert | Colorado | Trans. Mtn. Div. | 6–81 | 2 | 200,000 | 347,142,760 |
| | Kendrick | Alcova | Wyoming | North Platte | 7–55 | 2 | 41,400 | 70,301,000 |
| | | Seminoe | Wyoming | North Platte | 8–39 | 3 | 51,750 | 63,319,000 |
| | North Platte | Guernsey | Wyoming | North Platte | 7–27 | 2 | 6,400 | 10,150,000 |
| | Pick-Sloan mo. Basin | Boysen | Wyoming | Wind | 8–52 | 2 | 15,000 | 30,139,000 |
| | | Canyon Ferry | Montana | Missouri | 12–53 | 3 | 50,000 | 239,121,000 |
| | | Fremont Canyon | Wyoming | North Platte | 12–60 | 2 | 66,880 | 144,776,000 |
| | | Glendo | Wyoming | North Platte | 12–58 | 2 | 38,000 | 46,405,000 |
| | | Kortes | Wyoming | North Platte | 6–50 | 3 | 36,000 | 83,793,000 |
| | | Yellowtail | Montana | Big Horn | 8–66 | 4 | 250,000 | 322,981,000 |
| | Shoshone | Buffalo Bill | Wyoming | Shoshone | 7–92 | 3 | 18,000 | 47,604,000 |
| | | Heart Mountain | Wyoming | Shoshone | 12–48 | 1 | 5,000 | 9,115,000 |
| | | Pilot Butte | Wyoming | Wind | 1–25 | 2 | 1,600 | 4,416,000 |
| | | Shoshone | Wyoming | Shoshone | 6–92 | 1 | 3,000 | 18,413,000 |
| | | Spirit Mountain | Wyoming | Shoshone | 10–94 | 1 | 4,500 | 17,087,000 |
| Total | | | | | | 44 | 1,003,750 | 2,047,891,760 |

*Note:* Hydroelectric powerplants for which the bureau of reclamation has operating responsibility fiscal year 2004. Grand Total Number of Plants, 58; Grand Total Number of Units, 194; Grand Total Installed Capacity, 14,780,368 kW; Grand Total Gross Generation, 37,770,363,914 kWh. Revised December 16, 2004.

[a] Federal share of 424,000 kW installed capacity-plant operated by the State of California-Navajo stem plant: reclamation share is 546,750 kW installed capacity with 2004 gross generation of 4,713,459,920 kWh.

*Source*: From www.usbr.gov.

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**Table 11C.44 Number of Dams Found: 160**

| NPDP ID | Dam Name | State | Dam Type | Dam Height (ft) | Primary Purpose | Secondary Purpose |
|---|---|---|---|---|---|---|
| VA17702 | North Anna Dam | VA | Earth | 90 | Hydroelectric | Flood Control and Storm Water Management |
| VA01706 | Bath Co. Pumped Storage—Upper Dam | VA | Earth | 381 | Hydroelectric | Flood Control and Storm Water Management |
| VA01707 | Bath Co. Pumped Storage—Lower Dam | VA | Earth | 136 | Hydroelectric | Flood Control and Storm Water Management |
| UT00310 | Logan No. 3 | UT | Concrete Gravity | 31.5 | Hydroelectric | Flood Control and Storm Water Management |
| TN02702 | Dale Hollow Dam | TN | Gravity | 200 | Hydroelectric | Flood Control and Storm Water Management |
| OR00015 | Cougar | OR | Rockfill | 519 | Hydroelectric | Flood Control and Storm Water Management |
| OR00004 | Detroit | OR | Gravity | 463 | Hydroelectric | Flood Control and Storm Water Management |
| OR00011 | John Day Dam | OR | Earth | 230 | Hydroelectric | Flood Control and Storm Water Management |
| OR00012 | Foster | OR | Rockfill | 126 | Hydroelectric | Flood Control and Storm Water Management |
| OK83001 | Salina Dike | OK | Earth | 45 | Hydroelectric | Flood Control and Storm Water Management |
| OK10314 | Fort Gibson Lake | OK | Earth Gravity | 110 | Hydroelectric | Flood Control and Storm Water Management |
| OK00134 | Robert S. Kerr | OK | Gravity Earth | 87 | Hydroelectric | Flood Control and Storm Water Management |
| OK00135 | Pensacola | OK | Multiple Arch Gravity | 151 | Hydroelectric | Flood Control and Storm Water Management |
| NY83112 | Bennetts Bridge—Dike A | NY | Earth | 5 | Hydroelectric | Flood Control and Storm Water Management |
| NY83028 | Stillwater—South Dam | NY | Earth | 20 | Hydroelectric | Flood Control and Storm Water Management |
| NY00374 | Bennetts Bridge | NY | Concrete Gravity | 45 | Hydroelectric | Flood Control and Storm Water Management |
| NY00375 | Bennetts Bridge—Dike B | NY | Earth | 13 | Hydroelectric | Flood Control and Storm Water Management |
| NY00376 | Bennetts Bridge—Dike C | NY | Earth | 10 | Hydroelectric | Flood Control and Storm Water Management |
| NY00397 | Cranberry Lake | NY | Gravity Concrete | 19 | Hydroelectric | Flood Control and Storm Water Management |
| NY00316 | Stillwater—North Dam | NY | Earth Concrete Gravity | 55 | Hydroelectric | Flood Control and Storm Water Management |
| NY00146 | Conklingville | NY | Earth | 95 | Hydroelectric | Flood Control and Storm Water Management |
| NY00120 | Clark Mills Upper | NY | Concrete Buttress | 23 | Hydroelectric | Flood Control and Storm Water Management |
| NH127 | Stone Dam | NH | Stone | 16.5 | Hydroelectric | Flood Control and Storm Water Management |
| NH00052 | Shelburne | NH | Concrete Timber Crib | 17 | Hydroelectric | Flood Control and Storm Water Management |
| MT00652 | Libby | MT | Gravity | 422 | Hydroelectric | Flood Control and Storm Water Management |
| MT00561 | Madison Dam | MT | Timber Crib | 39 | Hydroelectric | Flood Control and Storm Water Management |
| MT00568 | Canyon Ferry | MT | Concrete Gravity | 225 | Hydroelectric | Flood Control and Storm Water Management |
| MT00559 | Holter Dam | MT | Gravity | 124 | Hydroelectric | Flood Control and Storm Water Management |
| MT00560 | Hauser Dam | MT | Gravity | 125 | Hydroelectric | Flood Control and Storm Water Management |
| MT00134 | Hebgen Dam | MT | Earth | 88 | Hydroelectric | Flood Control and Storm Water Management |
| MO30014 | Osage | MO | Gravity | 148 | Hydroelectric | Flood Control and Storm Water Management |

*(Continued)*



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**Table 11C.44 (Continued)**

| NPDP ID | Dam Name | State | Dam Type | Dam Height (ft) | Primary Purpose | Secondary Purpose |
|---|---|---|---|---|---|---|
| MO20725 | Harry S. Truman Dam | MO | Earth Rockfill Gravity | 98 | Hydroelectric | Flood Control and Storm Water Management |
| MN83002 | International Falls | MN | Gravity Masonry | 29 | Hydroelectric | Flood Control and Storm Water Management |
| MI00547 | Secord | MI | Gravity | 57 | Hydroelectric | Flood Control and Storm Water Management |
| MI00548 | Smallwood | MI | Gravity Earth | 36 | Hydroelectric | Flood Control and Storm Water Management |
| MI00549 | Edenville | MI | Gravity Earth | 54 | Hydroelectric | Flood Control and Storm Water Management |
| ME96172 | Pleasant Pond Dam | ME | Concrete Rockfill | 12 | Hydroelectric | Flood Control and Storm Water Management |
| ME83048 | North Twin—Dike 4 | ME | Earth | 11 | Hydroelectric | Flood Control and Storm Water Management |
| ME83049 | North Twin—Dike 5 | ME | Earth | 11 | Hydroelectric | Flood Control and Storm Water Management |
| ME83050 | North Twin—Dike 6 | ME | Earth | 13 | Hydroelectric | Flood Control and Storm Water Management |
| ME83051 | Stone Dam—Dike 8 | ME | Earth | 9 | Hydroelectric | Flood Control and Storm Water Management |
| ME96079 | Davee Brook #1 Dam | ME | Concrete Earth | 26 | Hydroelectric | Flood Control and Storm Water Management |
| ME96100 | Andres Mill Dam | ME | Concrete Timber Crib | 4 | Hydroelectric | Flood Control and Storm Water Management |
| ME83006 | Gilman Falls Dam | ME | Concrete Gravity | 18 | Hydroelectric | Flood Control and Storm Water Management |
| ME83038 | Stone Dam—Dike 1 | ME | Earth | 10 | Hydroelectric | Flood Control and Storm Water Management |
| ME83039 | Stone Dam—Dike 2 | ME | Earth | 10 | Hydroelectric | Flood Control and Storm Water Management |
| ME83040 | Stone Dam—Dike 3 | ME | Earth | 10 | Hydroelectric | Flood Control and Storm Water Management |
| ME83041 | Stone Dam—Dike 4 | ME | Earth | 9 | Hydroelectric | Flood Control and Storm Water Management |
| ME83042 | Stone Dam—Dike 5 | ME | Earth | 9 | Hydroelectric | Flood Control and Storm Water Management |
| ME83043 | Stone Dam—Dike 6 | ME | Earth | 9 | Hydroelectric | Flood Control and Storm Water Management |
| ME83044 | Stone Dam—Dike 7 | ME | Earth | 9 | Hydroelectric | Flood Control and Storm Water Management |
| ME83045 | North Twin—Dike 1 | ME | Earth | 11 | Hydroelectric | Flood Control and Storm Water Management |
| ME83046 | North Twin—Dike 2 | ME | Earth | 11 | Hydroelectric | Flood Control and Storm Water Management |
| ME83047 | North Twin—Dike 3 | ME | Earth | 15 | Hydroelectric | Flood Control and Storm Water Management |
| ME10103 | Automatic Dam Messalonskee #4 | ME | Concrete Gravity | 40 | Hydroelectric | Flood Control and Storm Water Management |
| ME00534 | #1 Fitch's Mill Pond Dam | ME | Concrete Earth Stone | 18 | Hydroelectric | Flood Control and Storm Water Management |
| ME00535 | Rich Mill Dam | ME | Earth Rockfill Stone | 9 | Hydroelectric | Flood Control and Storm Water Management |
| ME00508 | Rainbow Lake Dam | ME | Timber Crib Gravity Rockfill | 9 | Hydroelectric | Flood Control and Storm Water Management |
| ME00518 | Ripley Pond Dam | ME | Earth | 6 | Hydroelectric | Flood Control and Storm Water Management |
| ME00468 | Long Pond Storage Dam | ME | Timber Crib Rockfill Gravity | 7 | Hydroelectric | Flood Control and Storm Water Management |

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| | | | | | | |
|---|---|---|---|---|---|---|
| ME00483 | Mapleton Dam | ME | Timber Crib Rockfill Gravity | 11 | Hydroelectric | Flood Control and Storm Water Management |
| ME00430 | Parson's Mill Dam | ME | Concrete | 10 | Hydroelectric | Flood Control and Storm Water Management |
| ME00398 | Long Pond Dam | ME | Stone Earth | 8 | Hydroelectric | Flood Control and Storm Water Management |
| ME00352 | Morneau's Dam | ME | Timber Crib Gravity | 10 | Hydroelectric | Flood Control and Storm Water Management |
| ME00360 | Blake Dam | ME | Concrete Earth Rockfill | 16 | Hydroelectric | Flood Control and Storm Water Management |
| ME00341 | Upper Dam | ME | Concrete | 8 | Hydroelectric | Flood Control and Storm Water Management |
| ME00283 | Behind The Mill Dam | ME | Concrete Gravity | 20 | Hydroelectric | Flood Control and Storm Water Management |
| ME00291 | Mainstream Dam, Main Stem | ME | Concrete Timber Crib Stone | 21 | Hydroelectric | Flood Control and Storm Water Management |
| ME00305 | Sokokis Lake Dam | ME | Concrete Stone Gravity | 15 | Hydroelectric | Flood Control and Storm Water Management |
| ME00254 | Alford Lake Dam | ME | Concrete Earth Stone | 7 | Hydroelectric | Flood Control and Storm Water Management |
| ME00225 | Mars Hill Dam | ME | Concrete Earth Gravity | 14 | Hydroelectric | Flood Control and Storm Water Management |
| ME00198 | Lock Dam | ME | Timber Crib Earth Gravity | 14 | Hydroelectric | Flood Control and Storm Water Management |
| ME00200 | East Millinocket | ME | Concrete Gravity Earth | 28 | Hydroelectric | Flood Control and Storm Water Management |
| ME00201 | Dolby | ME | Concrete Gravity Earth | 66 | Hydroelectric | Flood Control and Storm Water Management |
| ME00202 | Stone Dam | ME | Concrete Gravity | 27 | Hydroelectric | Flood Control and Storm Water Management |
| ME00203 | North Twin | ME | Earth Concrete Gravity | 35 | Hydroelectric | Flood Control and Storm Water Management |
| ME00204 | Ripogenus | ME | Concrete Gravity Earth | 83 | Hydroelectric | Flood Control and Storm Water Management |
| ME00205 | Millinocket Lake | ME | Concrete Gravity Earth | 20 | Hydroelectric | Flood Control and Storm Water Management |
| ME00206 | Seboomook | ME | Concrete Gravity Earth | 60 | Hydroelectric | Flood Control and Storm Water Management |
| ME00209 | Ragged Lake | ME | Earth Concrete Gravity | 30 | Hydroelectric | Flood Control and Storm Water Management |
| ME00211 | Caucomgomoc | ME | Earth Concrete Gravity | 16 | Hydroelectric | Flood Control and Storm Water Management |
| ME00215 | Canada Falls | ME | Concrete Gravity | 50 | Hydroelectric | Flood Control and Storm Water Management |
| ME00166 | Branns Mill Dam | ME | Timber Crib Earth Stone | 14 | Hydroelectric | Flood Control and Storm Water Management |

*(Continued)*



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**Table 11C.44 (Continued)**

| NPDP ID | Dam Name | State | Dam Type | Dam Height (ft) | Primary Purpose | Secondary Purpose |
|---|---|---|---|---|---|---|
| ME00187 | Bridge Street | ME | Masonry Gravity | 8 | Hydroelectric | Flood Control and Storm Water Management |
| ME00128 | Spencer Lake Dam | ME | Concrete Timber Crib | 14 | Hydroelectric | Flood Control and Storm Water Management |
| ME00133 | Brassua | ME | Concrete Buttress Earth | 50 | Hydroelectric | Flood Control and Storm Water Management |
| ME00135 | First Roach Dam | ME | Concrete Rockfill Gravity | 18 | Hydroelectric | Flood Control and Storm Water Management |
| ME00143 | Mattaceunk | ME | Concrete Gravity Earth | 45 | Hydroelectric | Flood Control and Storm Water Management |
| ME00157 | Upper Dam | ME | Concrete Gravity | 12 | Hydroelectric | Flood Control and Storm Water Management |
| ME00125 | Mill Pond Dam | ME | Concrete Earth Gravity | 9 | Hydroelectric | Flood Control and Storm Water Management |
| ME00127 | Flagstaff | ME | Earth Concrete Gravity | 43 | Hydroelectric | Flood Control and Storm Water Management |
| ME00071 | Sebago Lake Dam | ME | Concrete Earth Stone | 32 | Hydroelectric | Flood Control and Storm Water Management |
| ME00091 | Moosehead—East Outlet | ME | Concrete Gravity Earth | 20 | Hydroelectric | Flood Control and Storm Water Management |
| ME00092 | Moosehead—West Outlet | ME | Concrete Gravity Earth | 17.5 | Hydroelectric | Flood Control and Storm Water Management |
| ME00095 | Gardiner Water District Dam | ME | Concrete Timber Crib Masonry | 21 | Hydroelectric | Flood Control and Storm Water Management |
| ME00029 | Rangeley Lake Dam | ME | Concrete Gravity | 17 | Hydroelectric | Flood Control and Storm Water Management |
| ME00058 | Lermond Pond Dam | ME | Concrete Earth | 12 | Hydroelectric | Flood Control and Storm Water Management |
| ME00062 | Great Works Pond Dam | ME | Concrete Masonry Gravity | 38 | Hydroelectric | Flood Control and Storm Water Management |
| ME00002 | Brunswick Dam/Topsham Dam | ME | Concrete Gravity | 45 | Hydroelectric | Flood Control and Storm Water Management |
| MA83013 | Collins | MA | Gravity Rockfill Timber Crib | 14 | Hydroelectric | Flood Control and Storm Water Management |
| MA00719 | Chicopee | MA | Masonry Gravity | 10 | Hydroelectric | Flood Control and Storm Water Management |
| MA00501 | New Home | MA | Gravity | 9 | Hydroelectric | Flood Control and Storm Water Management |
| KY03001 | Barkley Dam | KY | Earth Gravity | 157 | Hydroelectric | Flood Control and Storm Water Management |
| KY03010 | Wolf Creek | KY | Earth Gravity | 258 | Hydroelectric | Flood Control and Storm Water Management |
| IL83003 | Upper Sterling | IL | Gravity | 9 | Hydroelectric | Flood Control and Storm Water Management |

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| | | | | | | |
|---|---|---|---|---|---|---|
| ID00319 | Albeni Falls | ID | Gravity | 180 | Hydroelectric | Flood Control and Storm Water Management |
| ID00056 | Brownlee | ID | Rockfill Gravity | 395 | Hydroelectric | Flood Control and Storm Water Management |
| GA01701 | J. Storm Thurmond Dam | GA | Concrete Gravity Earth | 200 | Hydroelectric | Flood Control and Storm Water Management |
| GA01702 | Hartwell Dam | GA | Concrete Gravity Earth | 204 | Hydroelectric | Flood Control and Storm Water Management |
| GA00068 | Richard B. Russell Dam | GA | Concrete Gravity Earth | 195 | Hydroelectric | Flood Control and Storm Water Management |
| CT01677 | Putnam | CT | Other Concrete Gravity | 24 | Hydroelectric | Flood Control and Storm Water Management |
| CA01352 | Collett Afterbay | CA | Earth | 13 | Hydroelectric | Flood Control and Storm Water Management |
| CA00863 | New Bullards Bar | CA | Concrete Arch | 645 | Hydroelectric | Flood Control and Storm Water Management |
| CA00421 | New Drum Afterbay | CA | Arch | 95 | Hydroelectric | Flood Control and Storm Water Management |
| CA00200 | San Gabriel | CA | Earth Rockfill | 381 | Hydroelectric | Flood Control and Storm Water Management |
| CA00095 | Upper Gorge Pp | CA | Gravity | 57 | Hydroelectric | Flood Control and Storm Water Management |
| AR00150 | Blakely Mountain Dam | AR | Earth | 240 | Hydroelectric | Flood Control and Storm Water Management |
| AL01420 | Lewis Smith | AL | Rockfill | 300 | Hydroelectric | Flood Control and Storm Water Management |
| AL01425 | Martin | AL | Gravity Earth | 175 | Hydroelectric | Flood Control and Storm Water Management |
| AL01413 | Point “A” | AL | Gravity Earth | 41 | Hydroelectric | Flood Control and Storm Water Management |
| AL01414 | Gantt | AL | Buttress Earth | 35 | Hydroelectric | Flood Control and Storm Water Management |
| AL01417 | Logan Martin | AL | Gravity Earth | 142 | Hydroelectric | Flood Control and Storm Water Management |
| WA00004 | Chelan | WA | Gravity | 40 | Hydroelectric | Flood Control and Storm Water Management |
| WA00084 | Rock Island | WA | Gravity | 128 | Hydroelectric | Flood Control and Storm Water Management |
| WA00085 | Wanapum | WA | Gravity Rockfill Concrete | 205.5 | Hydroelectric | Flood Control and Storm Water Management |
| WA00086 | Rocky Reach | WA | Gravity | 130 | Hydroelectric | Flood Control and Storm Water Management |
| WA00088 | Priest Rapids | WA | Gravity Rockfill Concrete | 187 | Hydroelectric | Flood Control and Storm Water Management |
| WA00135 | Yale Saddle Dam | WA | Earth Arch | 40 | Hydroelectric | Flood Control and Storm Water Management |
| WA00147 | Swift No. 1 | WA | Earth | 412 | Hydroelectric | Flood Control and Storm Water Management |
| WA00148 | Yale | WA | Earth | 323 | Hydroelectric | Flood Control and Storm Water Management |
| WA00151 | Mossyrock | WA | Arch Gravity | 606 | Hydroelectric | Flood Control and Storm Water Management |
| WI00141 | Lower Watertown Dam | WI | Gravity | 10 | Hydroelectric | Flood Control and Storm Water Management |
| WI00724 | Castle Rock | WI | Gravity Earth Concrete | 38 | Hydroelectric | Flood Control and Storm Water Management |
| WI00740 | Petenwell | WI | Gravity Earth Concrete | 50 | Hydroelectric | Flood Control and Storm Water Management |
| WI00741 | Rice | WI | Gravity Earth Concrete | 19 | Hydroelectric | Flood Control and Storm Water Management |
| WI00749 | Spirit | WI | Gravity Earth Concrete | 26 | Hydroelectric | Flood Control and Storm Water Management |
| WI00764 | Burnt Rollways | WI | Gravity Earth Concrete | 16 | Hydroelectric | Flood Control and Storm Water Management |
| WI00765 | Seven Mile | WI | Gravity Earth Concrete | 10 | Hydroelectric | Flood Control and Storm Water Management |

*(Continued)*



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**Table 11C.44 (Continued)**

| NPDP ID | Dam Name | State | Dam Type | Dam Height (ft) | Primary Purpose | Secondary Purpose |
|---|---|---|---|---|---|---|
| WI00766 | Sugar Camp | WI | Gravity Earth Concrete | 10 | Hydroelectric | Flood Control and Storm Water Management |
| WI00767 | Minocqua | WI | Gravity Concrete Earth | 9 | Hydroelectric | Flood Control and Storm Water Management |
| WI00772 | North Pelican | WI | Gravity Earth Concrete | 11 | Hydroelectric | Flood Control and Storm Water Management |
| WI00774 | Willow | WI | Gravity Earth Concrete | 35 | Hydroelectric | Flood Control and Storm Water Management |
| WI00775 | Rainbow | WI | Gravity Earth Concrete | 39 | Hydroelectric | Flood Control and Storm Water Management |
| WI00777 | Combined Locks | WI | Gravity Concrete | 28 | Hydroelectric | Flood Control and Storm Water Management |
| WI00784 | Du Bay | WI | Concrete Gravity Earth | 40 | Hydroelectric | Flood Control and Storm Water Management |
| WI00804 | Buckatahpon | WI | Gravity Earth Concrete | 8 | Hydroelectric | Flood Control and Storm Water Management |
| WI00808 | Twin Lakes | WI | Gravity Earth Concrete | 10 | Hydroelectric | Flood Control and Storm Water Management |
| WI01005 | Long-On-Deerskin | WI | Gravity Earth Concrete | 10 | Hydroelectric | Flood Control and Storm Water Management |
| WI01017 | Little St Germain | WI | Gravity Earth Concrete | 9 | Hydroelectric | Flood Control and Storm Water Management |
| WI01138 | Lac Vieux Desert | WI | Gravity Earth Concrete | 8.5 | Hydroelectric | Flood Control and Storm Water Management |
| WI01146 | Big St Germain | WI | Gravity Earth Concrete | 7 | Hydroelectric | Flood Control and Storm Water Management |
| WI83003 | Squirrel Lake | WI | Gravity Earth Concrete | 7 | Hydroelectric | Flood Control and Storm Water Management |
| WI83005 | Old Badger | WI | Gravity Concrete | 21.5 | Hydroelectric | Flood Control and Storm Water Management |
| WI83006 | New Badger | WI | Gravity Concrete | 24 | Hydroelectric | Flood Control and Storm Water Management |
| WI83007 | Rapide Croche | WI | Gravity Concrete | 23.6 | Hydroelectric | Flood Control and Storm Water Management |
| WI83010 | Eau Pleine | WI | Gravity Earth Concrete | 45 | Hydroelectric | Flood Control and Storm Water Management |
| WI83012 | Sawyer Dike | WI | Earth | 20 | Hydroelectric | Flood Control and Storm Water Management |
| WI83014 | Cth “E” Dike | WI | Earth | 24 | Hydroelectric | Flood Control and Storm Water Management |
| WI83015 | Jim Hall Dike | WI | Earth | 22 | Hydroelectric | Flood Control and Storm Water Management |
| WI83034 | Willow Doberstein Dike | WI | Earth | 10 | Hydroelectric | Flood Control and Storm Water Management |

*Source*: From http://npdp.stanford.edu.

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**Table 11C.45 Hydro Development in UMRB States 1/1/88 to 9/12/90**

| | Developed Capacity 1988 (MW) | Developed Capacity 1990 (MW) | Percent Change | Change in Number of Plants |
|---|---|---|---|---|
| Illinois | 29.9 | 32.6 | 9.2 | +2 |
| Iowa | 131.6 | 131.9 | 0.2 | +1 |
| Minnesota | 189.7 | 209.1 | 10.2 | +3 |
| Missouri | 1,064.0 | 1,062.3 | −0.2 | +1 |
| Wisconsin | 469.2 | 502.3 | 7.0 | −4 |
| 5 states | 1,884.5 | 1,938.2 | 2.9 | +3 |

*Source*: From FERC, 1988a, pp. 101, 132–41; FERC, 1990j.

**Table 11C.46 Hydro Capacity on the Upper Mississippi River and Illinois Waterway**

| Mississippi River Site | Owner | Class of Ownership[a] | Developed Capacity (MW) | Potential Capacity (MW) | Status of Potential Capacity[b] |
|---|---|---|---|---|---|
| Bemidji | Otter Tail Power Co | P | 0.7 | | |
| Lake Winnibigoshish | Ball Club Association | R | | 1.0 | |
| Grand Rapids[c,d] | Blandin Paper Co | I | 2.1 | 3.2 | |
| Brainerd[c,d] | Potlatch Corp. NW Ppr | I | 3.3 | 7.0 | |
| Little Falls 2[c,d] | Minnesota Pwr & Lt Co | P | 0.6 | | |
| Little Falls 1[c,d] | Minnesota Pwr & Lt Co | P | 3.9 | | |
| Blanchard[c] | Minnesota Pwr & Lt Co | P | 18.0 | | |
| Sartell[c] | Champion Intl Corp | I | 3.2 | 6.3 | |
| St. Cloud[c] | St. Cloud, City of | M | 8.0 | | |
| St. Cloud | St. Cloud Association | R | | 2.1 | |
| Clearwater | | | | 11.2 | |
| Monticello | | | | 11.2 | |
| Bailey | | | | 11.2 | |
| Coon Rapids | Coon Rapids Hydro Assoc | M | | 10.5 | PO |
| St. Anthony Falls—Upper[c] | Northern States Power | P | 12.4 | 2.0 | |
| St. Anthony Falls—Lower[c] | Northern States Power Co. | P | | 16.0 | LA |
| L&D 1[c] | Ford Motor Co. | I | 17.9 | 7.2 | |
| L&D 2[c] | Hastings, City of | I | 4.0 | | |
| Lake Pepin[e] | Southern Minn Municipal Power Agency | P | | 500.0 | PO |
| L&D 5 | Winona Hydro Partners | R | | 10.0 | |
| L&D 5A | Mountain City Assoc. | R | | 6.0 | |
| L&D 6 | Trempealeau Assoc. | R | | 10.8 | |
| L&D 7 | Wisc. Public Power Inc. | M | 12.7 | | |
| L&D 8 | Upper Mississippi Hydro Assoc. | R | | 10.5 | PO |
| L&D 9 | United Hydro Partnership | R | | 10.0 | |
| L&D 10 | Guttenburg Partners Ltd. | R | | 10.0 | |
| L&D 11 | Three City Miss. R. Hydro | M | | 18.4 | |
| L&D 12 | Bellevue, City of | M | | 19.3 | |
| L&D 13 | Winnetka, Village of | M | | 6.8 | |
| L&D 14 | LeClaire, City of | M | | 24.0 | MA |
| L&D 15 | Iowa-Illinois G&E Co. | P | 3.6 | 19.7 | |
| L&D 15 | Corps of Engineers | F | 2.8 | | |
| L&D 15 | Davenport Hydro Assoc. | R | | 28.0 | MA |
| L&D 16 | Lock 16 Assoc. | R | | 14.0 | |
| L&D 17 | Wapello Assoc. | R | | 10.5 | |
| L&D 18 | Burlington Hydro Assoc. | R | | 28.0 | |
| L&D 19 | Union Electric Co. | P | 124.8 | | |
| L&D 19 | Corps of Engineers | F | | 103.8 | |
| L&D 20 | Canton Assoc. | R | | 30.0 | |
| L&D 21 | Quincy Assoc. | R | | 10.0 | |
| L&D 22 | Hannibal Assoc. | R | | 10.0 | |
| L&D 24 | Clarksville Hydro Assoc. | R | | 50.0 | PO |
| L&D 25 | Winfield Hydro Assoc. | R | | 50.0 | PO |

*(Continued)*

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**Table 11C.46 (Continued)**

| Mississippi River Site | Owner | Class of Ownership[a] | Developed Capacity (MW) | Potential Capacity (MW) | Status of Potential Capacity[b] |
|---|---|---|---|---|---|
| L&D 26 | Missouri Joint Mun. Elec. Uty. Comm. | M | | 78.0 | |
| L&D 27 | Corps of Engineers | F | | 15.3 | |
| Mississippi Total | | | 205.3 | 1139.4 | |
| **Illinois Waterway Site** | **Owner** | **Class of Ownership[a]** | **Developed Capacity (MW)** | **Potential Capacity (MW)** | **Status of Potential Capacity[b]** |
| Calumet/e | Edc Fndtn of Chicago | M | | 30.0 | |
| Lockport | Sanitary Dist. of Chicago | | 13.6 | | |
| Brandon Road | Rockdale, Village of | M | | 7.3 | MO |
| Dresden Island | Channahon, Village of | M | | 7.76 | MO |
| Marseilles | Illinois Power Co. | P | 2.0 | | |
| Marseilles | Marseilles, City of | M | | 11.0 | PO |
| Starved Rock | Peru, City of | M | | 7.6 | |
| Illinois Total | | | 15.6 | 63.5 | |
| UMRS Total | | | 220.9 | 1202.9 | |

[a] F, federally owned; I, industrially owned; M, nonfederal publicly owned; P, private utility owned; R, private non-utility owned.
[b] LA, License amendment pending; PO, Preliminary permit outstanding; MA, Major license applied for (>1.5 MW); MO, Major license outstanding (>1.5 MW).
[c] Existing plant is operating under a FERC license or exemption. Other plants are either federal or are not under FERC's jurisdiction because of their age.
[d] License expires December 31,1993.
[e] Pumped storage facility.

*Relicensing*: In addition to the development of new projects, decisions regarding the relicensing of existing projects will have an important effect on the character of hydropower in the UMRB. Hydro projects are typically licensed for a period of 30 to 50 years. Many projects under FERC's jurisdiction are due for relicensing in the next few years. Nationwide, the licenses for 227 projects will expire between 1990 and 1999. Twenty-two percent of these projects are in the five UMRB states, which is far greater than the region's proportion of hydro plants. Wisconsin has the highest relicensing workload of any state in the country between 1990 and 1999. (See Appendix C.)

*Source*: From FERC, 1988a; FERC, 1990j.

**Table 11C.47 River Segments Protected from Hydro Development in UMRB States**

| | State | Exiting Plants | Capacity of Undeveloped Sites (MW) |
|---|---|---|---|
| Wild and Scenic Rivers | | | |
| Wolf | WI | 0 | 16.0 |
| Lower St. Croix | MN–WI | 1 | 26.2 |
| Eleven Point | MO | 0 | 14.2 |
| St. Croix | MN–WI | 2 | 47.5 |
| Vermillion, Middle Fork | IL | 0 | NA |
| Special Act | | | |
| Current and Jacks Fork (Ozark National Scenic Riverway) | MO | 0 | 170.7 |
| | | | 274.6 |

*Source*: From FERC, 1988a, pp. 222–23.

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**Table 11C.48 Existing Plants in Upper Mississippi River Basin States**

| Project Number[a] | Plant Name | River | Owner | State | County | Project Status[b] | Capacity (kW) | Exp. Date (YYMMDD) |
|---|---|---|---|---|---|---|---|---|
| | Waverly (East Hydro) | Cedar R | Waverly, City of | IA | Bremer | | 495 | |
| | Maquoketa | Maquoketa R | Iowa Elec Lt and Pwr Co. | IA | Jackson | | 1,200 | |
| | Keokuk L&D 19 | Mississippi R | Union Electric Co | IA | Lee | | 124,800 | |
| | Iowa Falls | Iowa R | Iowa Elec Lt and Pwr Co. | IA | Hardin | | 540 | |
| 925 | Ottumwa | Des Moines R | Ottumwa, City of | IA | Wapello | MO | 3,000 | 080430 |
| 4344 | Five-In-One Dam | Cedar R | Cedar Rapids, City of | IA | Linn | LE | 1,600 | |
| 8364 | Anamusa | Wapsipinicon R | Iowa Elec Lt and Pwr Co. | IA | Jones | LE | 288 | |
| | Moline L&D 15 | Sylvan Slough, Mississippi R | Iowa IL G & E Co. | IL | Rock Island | | 3,600 | |
| | Marseilles | Illinois R | Illinois Power Co. | IL | La Salle | | 2,024 | |
| | Rock Island L&D 15 | Sylvan Slough, Mississippi R | Corps of Engineers | IL | Rock Island | FA | 2,752 | |
| 287 | Dayton | Fox R | Hydro-Op One Assoc. | IL | La Salle | MO | 3,600 | 040410 |
| 2373 | Rockton | Rock R | South Beloit WG & E Co. | IL | Winnebago | NO | 1,100 | 931231 |
| 2446 | Dixon | Rock R | Commonwealth Edison Co. | IL | Lee | MO | 3,200 | 931231 |
| 2866 | Lockport | Chicago Sani & Ship Cnl, Des Plaines | Sanitary Dist of Chicago | IL | Will | MO | 13,600 | 011130 |
| 2936 | Sears | Rock R | White Hydropower Co. | IL | Rock Island | LE | 746 | |
| 7004 | Upper Sterling | Rock R | Rock Falls, City of | IL | Whiteside | LE | 2,000 | |
| | Rochester | Zumbro R | Rochester, City of | MN | Wabasha | | 2,680 | |
| | Lanesboro Hy | S Br Root R | Lanesboro, City of | MN | Fillmore | | 477 | |
| | Redwood Falls | Redwood R | Redwood Falls, City of | MN | Redwood | | 500 | |
| | Bemidji | Mississippi R | Otter Tail Power Co. | MN | Beltrami | | 740 | |
| | Thief River Falls | Red Lake R | Thief River Falls, City of | MN | Pennington | | 550 | |
| 346 | Blanchard | Mississippi R | Minnesota Pwr and Lt Co. | MN | Morrison | MO | 18,000 | 030824 |
| 362 | Twin City L&D 1 | Mississippi R | Ford Motor Co. | MN | Hennepin | MO | 17,920 | 030606 |
| 469 | Winton | Kawishiwi R | Minnesota Pwr and Lt Co. | MN | Lake | MO | 4,000 | 031031 |

*(Continued)*



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**Table 11C.48 (Continued)**

| Project Number[a] | Plant Name | River | Owner | State | County | Project Status[b] | Capacity (kW) | Exp. Date (YYMMDD) |
|---|---|---|---|---|---|---|---|---|
| 2056B | Hennepin Island | Mississippi R | Northern States Power Co. | MN | Hennepin | MO | 12,400 | 001231 |
| 2056A | Lower Dam | Mississippi R | Northern States Power Co. | MN | Hennepin | MO | 8,000 | 001231 |
| 2360C | Scanlon | St. Louis R | Minnesota Pwr and Lt Co. | MN | Carlton | MO | 1,600 | 931231 |
| 2360D | Knife Falls | St. Louis R | Minnesota Pwr and Lt Co. | MN | Carlton | MO | 2,400 | 931231 |
| 2360B | Thompson | St. Louis R | Minnesota Pwr and Lt Co. | MN | Carlton | MO | 68,600 | 931231 |
| 2360A | Fond Du Lac | St. Louis R | Minnesota Pwr and Lt Co. | MN | Carlton | MO | 12,000 | 931231 |
| 2361 | Prairie River | Prairie R | Minnesota Pwr and Lt Co. | MN | Itasca | NO | 1,084 | 931231 |
| 2362 | Grand Rapids | Mississippi R | Blandin Paper Co. | MN | Itasca | MO | 2,100 | 931231 |
| 2363 | Cloquet | St. Louis R | Potlatch Corp. | MN | Carlton | MO | 6,514 | 931231 |
| 2454 | Sylvan | Crow Wing R | Minnesota Pwr and Lt Co. | MN | Morrison | MO | 1,800 | 931231 |
| 2532B | Little Falls 2 | Mississippi R | Minnesota Pwr and Lt Co. | MN | Morrison | MO | 600 | 931231 |
| 2532A | Little Falls 1 | Mississippi R | Minnesota Pwr and Lt Co. | MN | Morrison | MO | 3,900 | 931231 |
| 2533 | Brainerd | Mississippi R | Potlatch Corp, NW Ppr | MN | Crow Wing | MO | 3,342 | 931231 |
| 2663 | Pillager | Crow Wing R | Minnesota Pwr and Lt Co. | MN | Morrison | MO | 1,600 | 970511 |
| 3071 | Rapidan | Blue Earth R | Rapidan Revelopment Ltd. | MN | Blue Earth | LE | 5,000 | |
| 4108 | St. Cloud | Mississippi R | St. Cloud, City of | MN | Stearns | MO | 8,000 | 241130 |
| 4306 | Mississippi L&D 2 | Mississippi R | Hastings, City of | MN | Dakota | MO | 4,000 | 330630 |
| 5223 | International Falls | Rainy R | International Falls Pwr Co. | MN | Koochiching | MO | 10,800 | 271130 |
| 6299 | Lake Byllesby | Cannon R | Dakota & Goodhue Counties | MN | Dakota | LE | 2,500 | |
| 8315 | Startell | Mississippi R | Champion Intl Corp. | MN | Benton | MO | 3,172 | 250228 |
| 8423 | Granite Falls | Minnesota R | Granite Falls, City of | MN | Chippewa | LE | 1,367 | |
| 10853D | Hoot Lake | Otter Tail R | Otter Tail Power Co. | MN | Otter Tail | MA | 1,000 | |
| 10853C | Central (Wright) | Otter Tail R | Otter Tail Power Co. | MN | Otter Tail | MA | 400 | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10853B | Pisgah | Otter Tail R | Otter Tail Power Co. | MN | Otter Tail | MA | 520 | |
| 10853E | Friberg (Tablin Gorge) | Otter Tail R | Otter Tail Power Co. | MN | Otter Tail | MA | 560 | |
| 10853A | Dayton Hollow | Otter Tail R | Otter Tail Power Co. | MN | Otter Tail | MA | 970 | |
| | Clarence F. Cannon | Salt R | Corps of Engineers | MO | Ralls | FA | 27,000 | |
| | Clarence F. Cannon[c] | Salt R | Corps of Engineers | MO | Ralls | FA | 31,000 | |
| | Harry S. Truman[c] | Osage R | Corps of Engineers | MO | Benton | FA | 160,000[d] | |
| | Stockton | Sac R. | Corps of Engineers | MO | Cedar | FA | 45,200 | |
| | Table Rock | White R | Corps of Engineers | MO | Taney | FA | 200,000 | |
| | Riverdale | Finley Cr., James R | Turner, Glenn O. Frances | MO | Christian | | 112 | |
| 459 | Osage (Bagnell) | Osage R | Union Electric Co. | MO | Miller | MO | 172,000 | 060228 |
| 2221 | Ozark Beach | White R | Empire Dist Elec Co. | MO | Taney | MO | 16,000 | 930831 |
| 2277 | Taum Sauk[c] | E Fk Black R | Union Electric Co. | MO | Reynolds | MO | 408,000 | 100630 |
| 2561 | Niangua | Niangua R | Sho Me Power Corp. | MO | Camden | MO | 3,000 | 931231 |
| | Figor | Duck Cr, Tagatz Cr | Figor, D.J. | WI | Marquette | | 38 | |
| | Lawrence | Duck Cr., Tagatz Cr | Pioneer Pwr & Lt Co. | WI | Marquette | | 200 | |
| | Montello | Montello Lk, Montello R | Montello Granite Co. | WI | Marquette | | 379 | |
| | Harrisville | Montello R | Miller, Duane J. | WI | Marquette | | 187 | |
| | Wautoma | Wautoma R | North Amer Hydro Inc. | WI | Waushara | | 252 | |
| | Pardeeville | Fox R | Pardeeville Elec Comm. | WI | Columbia | | 50 | |
| | Appleton | Fox R | Wisconsin Elec Pwr Co. | WI | Outagamie | | 1,940 | |
| | Appleton (Lower) | Fox R | Consolidated Papers Inc. | WI | Outagamie | | 1,445 | |
| | Neenah Dam | Fox R | Bergstrom Paper Co. | WI | Winnebago | | 400 | |
| | Nepco Lake | Four Mile Cr., Wisconsin R | Nekoosa Papers Inc. | WI | Wood | | 2,920 | |
| | Merillan | Halls Cr., Black R | Merillan, Village of | WI | Jackson | | 100 | |
| | Kilbourn | Wisconsin R | Wisconsin Power & Light Co. | WI | Sauk | | 8,200 | |

*(Continued)*



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**Table 11C.48 (Continued)**

| Project Number[a] | Plant Name | River | Owner | State | County | Project Status[b] | Capacity (kW) | Exp. Date (YYMMDD) |
|---|---|---|---|---|---|---|---|---|
| | Barron | Yellow R | Barron, City of | WI | Barron | | 100 | |
| | Merrill | Prairie R | Ward Paper Company | WI | Lincoln | | 135 | |
| | La Valle | Baraboo R | La Valle El Co. | WI | Sauk | | 50 | |
| | Pine River | Pine R | Miller, Clair | WI | Richland | | 100 | |
| | Island Woolen | Baraboo R | Island Woolen Co. | WI | Sauk | | 412 | |
| | Radisson | Couderay R | North Central Power Co. | WI | Sawyer | | 393 | |
| | Linen Mill | Baraboo R | McArthur, George and Son | WI | Sauk | | 100 | |
| | Oak Street | Baraboo R | McArthur, George and Son | WI | Sauk | | 156 | |
| | Prairie Du Sac | Wisconsin R | Wisconsin Power & Light Co. | WI | Sauk | | 28,440 | |
| | Nancy | Totagatic R | Dahlberg Lt and Pwr Co. | WI | Washburn | | 450 | |
| | Clam Falls | Clam R | Northwestern Wis Elec Co. | WI | Burnett | | 112 | |
| | St. Croix Falls | St. Croix R | Northern States Power Co. | WI | Polk | | 23,200 | |
| | Gordon | Eau Claire R | Dahlberg Lt and Pwr Co. | WI | Douglas | | 257 | |
| | Balsam Lake | Balsam R, Apple R | Northerwestern Wis Elec Co. | WI | Polk | | 68 | |
| | Barton (Gadow Milling) | Milwaukee R | Roy Kleisch | WI | Washington | | 17 | |
| | Muscoda | Mill Cr, Wisconsin R | Muscoda, Village of | WI | Richland | | 60 | |
| 710 | Shawano (Upper) | Wolf R | Wisconsin Power & Light Co. | WI | Shawano | MO | 700 | 770719 |
| 1510 | Kaukauna (Lower) | Fox R | Kaukauna, City of | WI | Outagamie | MO | 4,800 | 190331 |
| 1940 | Tomahawk | Wisconsin R | Wisconsin Public Service Corp | WI | Lincoln | MO | 2,600 | 161231 |
| 1953 | Du Bay | Wisconsin R | Consolidated Water Pwr Co. | WI | Portage | MO | 7,200 | 910630 |
| 1957 | Otter Rapids | Wisconsin R | Wisconsin Public Service Corp | WI | Vilas | NO | 500 | 300630 |
| 1960 | Flambeau | Flambeau R | Dairyland Power Coop | WI | Rusk | MO | 15,000 | 010228 |
| 1966 | Grandfather Falls | Wisconsin R | Wisconsin Public Service Corp | WI | Lincoln | MO | 17,240 | 180331 |
| 1968 | Hat Rapids | Wisconsin R | Wisconsin Public Service Corp | WI | Oneida | LE | 1,700 | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1979 | Alexander | Wisconsin R. | Wisconsin Public Service Corp | WI | Lincoln | MO | 4,200 | 040630 |
| 1981 | Stiles | Oconto R. | Oconto Elec Coop | WI | Oconto | MO | 1,000 | 000229 |
| 1982 | Holcombe | Chippewa R. | Northern States Power Co. | WI | Chippewa | MO | 33,900 | 980630 |
| 1984B | Petenwell | Wisconsin R. | Wisconsin River Power Co. | WI | Adams | MO | 20,000 | 980131 |
| 1984A | Castle Rock | Wisconsin R. | Wisconsin River Power Co. | WI | Adams | MO | 15,000 | 980131 |
| 1989 | Merrill | Wisconsin R. | Wisconsin Public Service Corp | WI | Lincoln | LE | 2,340 | |
| 1999 | Wausau | Wisconsin R. | Wisconsin Public Service Corp | WI | Marathon | MO | 5,400 | 950630 |
| 2064 | Last Fork (Winter) | E Fk Chippewa R. | North Central Power Co. | WI | Sawyer | MO | 600 | 011130 |
| 2110 | Stevens Point | Wisconsin R. | Consolidated Water Pwr Co. | WI | Portage | MO | 4,800 | 000630 |
| 2161 | Rhinelander | Wisconsin R. | Rhinelander Paper Co. | WI | Oneida | MO | 2,120 | 000630 |
| 2180 | Grandmother | Wisconsin R. | Nekoosa Corp. | WI | Lincoln | MO | 3,000 | 030630 |
| 2181 | Menomonie | Red Cedar R. | Northern States Power Co | WI | Dunn | MO | 5,400 | 050331 |
| 2192 | Biron 2 | Wisconsin R. | Consolidated Water Pwr Co. | WI | Wood | MO | 3,800 | 000630 |
| 2207 | Mosinee | Wisconsin R. | Mosinee Paper Mills Co. | WI | Marathon | MO | 3,050 | 041231 |
| 2212 | Rothschild | Wisconsin R. | Weyerhaeuser Co. | WI | Marathon | MO | 3,640 | 930731 |
| 2239 | Kings | Wisconsin R. | Tomahawk Pwer & Pulp Co. | WI | Lincoln | MO | 320 | 930731 |
| 2255 | Centralia | Wisconsin R. | Nekoosa Papers Inc. | WI | Wood | MO | 3,200 | 930731 |
| 2256 | Wis Rpds 1 | Wisconsin R. | Consolidated Water Pwr Co. | WI | Wood | MO | 4,400 | 930731 |
| 2291 | Port Edwards | Wisconsin R. | Nekoosa Papers Inc. | WI | Wood | MO | 2,920 | 930731 |
| 2292 | Nekoosa | Wisconsin R. | Nekoosa Papers Inc. | WI | Wood | MO | 3,800 | 930731 |
| 2347 | Central (Janesville) | Rock R. | Wisconsin Power & Light Co. | WI | Rock | NO | 500 | 931231 |
| 2348 | Blackhawk | Rock R. | Wisconsin Power & Light Co. | WI | Rock | NO | 380 | 931231 |
| 2390 | Big Falls | Flambeau R. | Northern States Power Co. | WI | Rusk | MO | 9,000 | 931231 |
| 2395 | Pixley | N Fk Flambeau R. | Flambeau Paper Corp. | WI | Price | NO | 960 | 931231 |

*(Continued)*



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**Table 11C.48 (Continued)**

| Project Number[a] | Plant Name | River | Owner | State | County | Project Status[b] | Capacity (kW) | Exp. Date (YYMMDD) |
|---|---|---|---|---|---|---|---|---|
| 2417 | Hayward | Namekagon R. | Northern States Power Co. | WI | Sawyer | NO | 200 | 931231 |
| 2421 | Lower Hydro | N Fk Flambeau R. | Flambeau Paper Corp. | WI | Price | NO | 1,200 | 931231 |
| 2430 | Ladysmith | Flambeau R. | Lake Superior Dist Pwr Co. | WI | Rusk | LE | 3,900 | |
| 2440 | Chippewa Falls | Chippewa R. | Northern States Power Co. | WI | Chippewa | MO | 21,600 | 931231 |
| 2444 | White River | White R. | Northern States Power Co. | WI | Ashland | NO | 1,000 | 931231 |
| 2464 | Weed Dam | Red R. | Gresham, Village of | WI | Shawano | NO | 700 | 150630 |
| 2473 | Crowley Rapids | N Fk Flambeau R. | Flambeau Paper Corp. | WI | Price | NO | 1,500 | 931231 |
| 2475 | Thornapple | Flambeau R. | Northern States Power Co. | WI | Rusk | NO | 1,400 | 931231 |
| 2476 | Jersey | Tomahawk R. | Wisconsin Public Service Corp | WI | Lincoln | NO | 512 | 931231 |
| 2484 | Gresham | Red R. | Gresham, Village of | WI | Shawano | NO | 423 | 191231 |
| 2486 | Pine | Pine R. | Wisconsin Elec Pwr Co. | WI | Florence | MO | 3,600 | 931231 |
| 2491 | Jim Falls | Chippewa R. | Northern States Power Co. | WI | Chippewa | MO | 48,600 | 330930 |
| 2522 | Johnson Falls | Peshtigo R. | Wisconsin Public Service Corp | WI | Marinette | MO | 3,520 | 931231 |
| 2523 | Oconto Falls (Upper) | Oconto R. | Wisconsin Elec Pwr Co. | WI | Oconto | NO | 1,320 | 931231 |
| 2525 | Caldron Falls | Peshtigo R. | Wisconsin Public Service Corp | WI | Marinette | MO | 6,400 | 931231 |
| 2536 | Little Quinnesec Falls | Menominee R. | Niagara of Wis Paper Corp. | WI | Marinette | MO | 8,388 | 930630 |
| 2546 | Sandstone Rapids | Peshtigo R. | Wisconsin Public Service Corp | WI | Marinette | MO | 3,840 | 931231 |
| 2550 | Weyauwega | Waupaca R. | Wisconsin Elec Pwr Co. | WI | Waupaca | NO | 400 | 931231 |
| 2560 | Potato Rapids | Peshtigo R. | Wisconsin Public Service Corp | WI | Marinette | NO | 1,380 | 931231 |
| 2567 | Wissota | Chippewa R. | Northern States Power Co. | WI | Chippewa | MO | 35,280 | 000630 |
| 2581 | Peshtigo | Peshtigo R. | Wisconsin Public Service Corp | WI | Marinette | NO | 584 | 931231 |
| 2588 | Little Chute | Fox R. | Kaukauna, City of | WI | Outagamie | MO | 3,300 | 000731 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2590 | Wisconsin R. Div. | Wisconsin R. | Consolidated Water Pwr Co. | WI | Portage | MO | 1,800 | 930630 |
| 2595 | High Falls | Peshtigo R. | Wisconsin Public Service Corp | WI | Marinette | MO | 7,000 | 931231 |
| 2639 | Cornell | Chippewa R. | Northern States Power Co. | WI | Chippewa | MO | 30,800 | 231130 |
| 2640 | Upper Hydro | N Fk Flambeau R. | Flambeau Paper Corp. | WI | Price | NO | 900 | 931231 |
| 2670 | Dells | Chippewa R. | Northern States Power Co et al | WI | Eau Claire | MO | 9,500 | 000831 |
| 2677B | Badger (Old) | Fox R. | Kaukauna, City of | WI | Outagamie | MO | 2,000 | 191231 |
| 2677A | Rapid Croche | Fox R. | Kaukauna, City of | WI | Outagamie | MO | 2,400 | 191231 |
| 2677C | Badger (New) | Fox R. | Kaukauna, City of | WI | Outagamie | MO | 3,600 | 191231 |
| 2684 | Arpin | E Fk Chippewa R. | North Central Power Co. | WI | Sawyer | NO | 1,450 | 190430 |
| 2689 | Oconto Falls | Oconto R. | Scott Paper Co. | WI | Oconto | MO | 1,810 | 931231 |
| 2697 | Cedar Falls | Red Cedar R. | Northern States Power Co. | WI | Dunn | MO | 6,000 | 010130 |
| 2711 | Trego | Namekagon R. | Northern States Power Co. | WI | Washburn | NO | 1,200 | 930331 |
| 2715 | Combined Locks | Fox R. | Kaukauna, City of | WI | Outagamie | MO | 7,000 | 240729 |
| 2744B | Park Mill | Menominee R. | Menominee Co. | WI | Marinette | MO | 1,724 | 150228 |
| 2894 | Black Brook | Apple R. | Northwestern Wis Elec Co. | WI | Polk | NO | 650 | 201231 |
| 2970 | Argyle | E Pecatonica R. | Argyle, Village of | WI | Lafayette | LE | 50 | |
| 3052 | Black River Falls | Black R. | Black River Falls, City of | WI | Jackson | NO | 900 | 010830 |
| 4914 | West De Pere | Fox R. | International Paper Co. | WI | Brown | NO | 1,078 | 041130 |
| 6476 | Neshonoc | La Crosse R. | North Amer Hydro Inc. | WI | La Crosse | LE | 500 | |
| 7264 | Appleton (Middle) | Fox R. | Fox Valley Corp. et al. | WI | Outagamie | NO | 1,290 | 050630 |
| 8015 | Shawano | Wolf R. | Little Rapids Corp. | WI | Shawano | LE | 380 | |
| 8286 | Chippewa | Chippewa R. | Northern States Power Co. et al. | WI | Sawyer | LE | 3,100 | |
| 9002 | Apple River | Apple R. | Northern States Power Co. | WI | St. Croix | LE | 3,700 | |
| 9003 | Riverdale | Apple R. | Northern States Power Co. | WI | St.Croix | LE | 620 | |
| 9184 | Danbury | Yellow R. | Northwestern Wis Elec Co. | WI | Burnett | NO | 1,076 | 070531 |
| 9185 | Clam River | Clam R. | Northwestern Wis Elec Co. | WI | Burnett | NO | 1,200 | 070331 |
| 10489A | Junction | Kinnickinnic R. | River Falls, City of | WI | Pierce | NO | 250 | 180831 |
| 10489B | River Falls | Kinnickinnic R. | River Falls, City of | WI | Pierce | NO | 125 | 180831 |

*(Continued)*



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**Table 11C.48 (Continued)**

| Project Number[a] | Plant Name | River | Owner | State | County | Project Status[b] | Capacity (kW) | Exp. Date (YYMMDD) |
|---|---|---|---|---|---|---|---|---|
| 10674 | Midtec | Fox R. | Midtec Paper Corp. | WI | Outagamie | MA | 2,700 | |
| 10805 | Hatfield | Black R. | Midwest Hydraulic Co. | WI | Jackson | PO | 4,800 | 920931 |

[a] Plants without project numbers are not under FERC jurisdiction and thus have no entries under the project status or license expiration columns.
[b] Project Status: FA, Federally authorized; LE, Exempted from licensing; MA, Major license applied for (>1.5 MW); MO, Major license outstanding or annual license during major relicensing proceeding (>1.5 MW); NO, Minor license outstanding or annual license during minor relicensing proceeding (≤1.5 MW); PO, Preliminary Permit Outstanding.
[c] Pumped storage.
[d] Reversible capacity could be used for conventional generation.

*Source*: From FERC, 1990j.

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**Table 11C.49 Small Hydroelectric Capacity in the United States**

| | 5,000 kW and Less | | 15,000 kW and Less | | 30,000 kW and Less | |
|---|---|---|---|---|---|---|
| **Category** | **1980** | **1984** | **1980** | **1984** | **1980** | **1984** |
| Developed | | | | | | |
| Number of sites | 751 | 864 | 946 | 1,124 | 1,071 | 1,252 |
| Capacity (MW) | 1,194.6 | 1,351.1 | 3,294.7 | 3,729.7 | 5,834.6 | 6,574.0 |
| Generation (GWh) | 4.8 | 16.8 | 16.8 | 18.6 | 28.0 | 30.8 |
| Under Construction | | | | | | |
| Number of sites | 16 | 137 | 29 | 153 | 33 | 158 |
| Capacity (MW) | 23.5 | 168.6 | 135.6 | 325.8 | 229.9 | 444.8 |
| Generation (GWh) | 0.1 | 0.7 | 1.0 | 1.4 | 1.3 | 2.0 |
| Planned (NERC)[a] | | | | | | |
| Number of sites | 12 | 25 | 23 | 39 | 25 | 50 |
| Capacity (MW) | 34.2 | 54.3 | 136.2 | 191.4 | 182.4 | 436.8 |
| Generation (GWh) | 0.1 | 0.3 | 0.5 | 0.9 | 0.6 | 1.9 |
| Projected[b] | | | | | | |
| Number of sites | 157 | 1,699 | 227 | 2,278 | 279 | 2,367 |
| Capacity (MW) | 317.5 | 2,587.1 | 1,241.8 | 6,669.4 | 2,317.5 | 8,572.4 |
| Generation (GWh) | 1.2 | 20.0 | 4.9 | 29.4 | 8.9 | 37.3 |
| Totals | | | | | | |
| Number of sites | 936 | 2,725 | 1,225 | 3,594 | 1,408 | 3,827 |
| Capacity (MW) | 1,569.8 | 4,160.8 | 4,808.3 | 10,916.3 | 8,564.4 | 16,028.0 |
| Generation (GWh) | 6.2 | 27.6 | 23.2 | 50.3 | 38.8 | 72.0 |

*Note:* Developed, Under Construction, and Projected.

[a] In reports of the Regional Electric Reliability Councils.
[b] Potential developments not under construction or included in NERC reports but which have FERC licensing or exemption status, are authorized or recommended for Federal construction, or have structural provisions for plant additions.

*Source*: From Federal Energy Regulatory Commission, 1984.

**Table 11C.50 Trends in Pumped Storage Capacity Development in the United States**

| | Installed Capacity in Reversible Units (Millions kW) | | | | | |
|---|---|---|---|---|---|---|
| | Developed | | | Under Construction | | |
| **Year as of January 1** | **Pure** | **Combined** | **Total** | **Pure** | **Combined** | **Total** |
| 1960 | 0 | 0.1 | 0.1 | 0 | 0.2 | 0.2 |
| 1964 | 0.4 | 0.3 | 0.7 | 0.7 | 0.5 | 1.2 |
| 1968 | 1.6 | 0.5 | 2.1 | 1.2 | 1.6 | 2.8 |
| 1972 | 2.6 | 1.3 | 3.9 | 6.0 | 1.4 | 7.4 |
| 1976 | 7.3 | 2.4 | 9.7 | 2.7 | 1.6 | 4.3 |
| 1980 | 9.3 | 3.6 | 12.9 | 3.2 | 1.5 | 4.7 |
| 1984 | 10.1 | 3.7 | 13.8 | 4.9 | 0.4 | 5.3 |

*Note*: A pure pumped storage project with a large peaking capacity can be developed at a site with two potential reservoirs of reasonable size in close proximity and with a relatively large difference in elevations. Projects are usually more economically developed at sites with high usable heads; consequently, the more favorable sites are normally located in mountainous terrain. However, consideration has been given to the construction of pumped storage projects in areas of level terrain by placing the lower reservoir in an underground cavern or excavated area. For any development, an assured supply of water at least sufficient to replace evaporation, seepage, and other losses is essential.

*Source*: From Federal Energy Regulatory Commission, 1984.

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**Table 11C.51 Hydroelectric Plants Having Potential Conventional Capacity over 1,000,000 kW**

| | | | Installed Capacity in Conventional Units Kilowatts | | |
|---|---|---|---|---|---|
| **Plant** | **River** | **Owner[a]** | **Developed** | **Under Construction** | **Ultimate Authorized** |
| Grand Coulee | Columbia | Bureau | 6,180,000 | 0 | 6,180,000 |
| John Day | Columbia | COE | 2,160,000 | 0 | 2,700,000 |
| Chief Joseph | Columbia | COE | 2,069,000 | 0 | 2,069,000 |
| R. Moses Niagara | Niagara | PASNY | 1,950,000 | 0 | 1,950,000 |
| The Dalles | Columbia | COE | 1,806,800 | 0 | 1,806,800 |
| Hoover | Colorado | Bureau | 1,434,000 | 0 | 1,434,000 |
| Rocky Reach | Columbia | CC PUD No. 1 | 1,213,950 | 0 | 1,213,950 |
| Wanapum | Columbia | GC PUD No. 2 | 831,250 | 0 | 1,151,250 |
| Priest Rapids | Columbia | GC PUD No. 2 | 788,500 | 0 | 1,108,500 |
| Bonneville | Columbia | COE | 1,076,620 | 0 | 1,102,820 |
| Dworshak | N. Fork Clearwater | COE | 400,000 | 0 | 1,060,000 |
| Glen Canyon | Colorado | Bureau | 1,042,000 | 0 | 1,042,000 |
| Boundary | Pend Oreille | Seattle | 634,600 | 392,000 | 1,026,600 |
| | Total | | 21,586,720 | 392,000 | 23,834,920 |

[a] Bureau, Bureau of Reclamation; COE, Corps of Engineers; PASNY, Power Authority, State of New York; GC, Grant County; CC, Chelan County; and Seattle, Seattle Dept. of Lighting.

*Source*: From Federal Energy Regulatory Commission, 1984.

**Table 11C.52 Federal Hydroelectric Capacity by Operating Agency, January 1, 1984**

| | Installed Capacity Conventional and Reversible (kW) | | |
|---|---|---|---|
| | **In Operation** | **Under Construction** | **Ultimate Authorized** |
| Corps of Engineers | 19,449,197 | 1,162,000 | 23,466,897 |
| Bureau of Reclamation | 12,846,876 | 250,000 | 13,577,986 |
| Tennessee Valley Authority | 4,832,410 | — | 4,832,410 |
| International Boundary and Water Commission | 97,500 | — | 97,500 |
| Alaska Power Administration | 77,160 | — | 104,160 |
| Bureau of Indian Affairs | 14,560 | — | 14,560 |
| National Park Service | 2,000 | — | 2,000 |
| Total | 37,319,703 | 1,412,000 | 42,095,513 |

*Source*: From Federal Energy Regulatory Commission, 1984.

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## SECTION 11D COSTS OF WATER PROJECTS

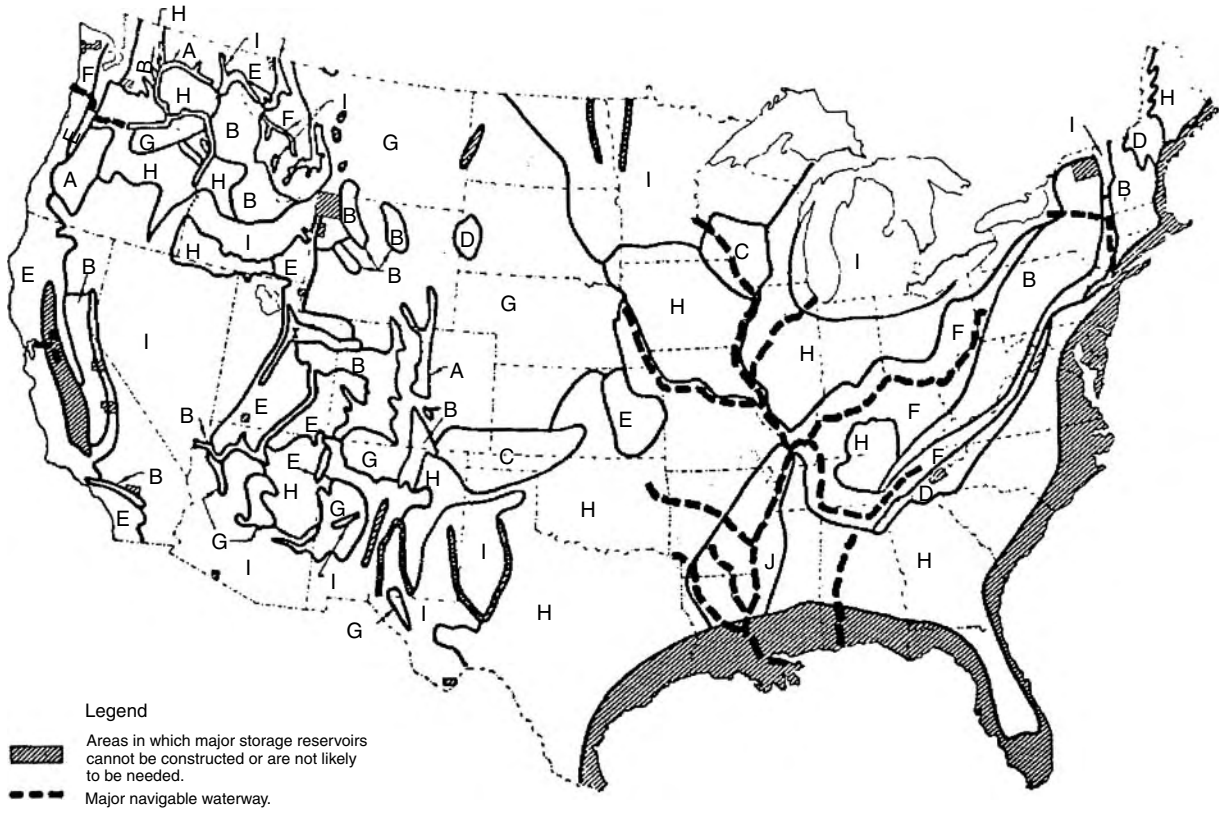


**Figure 11D.40** Map of physiographic regions in the United States (for reservoir costs). (From Corps of Engineers, U.S. Army, 1960.)

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**Table 11D.53 Costs of Reservoirs in the Physiographic Regions of the United States**

| Physiographic Region | Size Class | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **10** | **30** | **50** | **80** | **150** | **300** | **700** | **1500** | **3000** | **7000** | **30,000** |
| A | $230 | $190 | $175 | $162 | $145 | $130 | $113 | $100 | $88 | $77 | $60 |
| B | 200 | 160 | 145 | 132 | 115 | 100 | 85 | 75 | 64 | 55 | 40 |
| C | 180 | 135 | 120 | 110 | 95 | 80 | 66 | 56 | 49 | 40 | 28 |
| D | 160 | 120 | 105 | 93 | 78 | 65 | 52 | 42 | 35 | 28 | 18 |
| E | 155 | 115 | 98 | 85 | 73 | 60 | 47 | 38 | 32 | 25 | 16 |
| F | 145 | 106 | 90 | 80 | 65 | 55 | 43 | 34 | 28 | 21 | 14 |
| G | 140 | 103 | 87 | 75 | 60 | 50 | 38 | 30 | 25 | 19 | 12 |
| H | 120 | 86 | 73 | 62 | 50 | 40 | 30 | 24 | 18 | 14 | 10 |
| I | 95 | 65 | 55 | 46 | 38 | 30 | 22 | 18 | 15 | 10 | 8 |
| J | 65 | 43 | 37 | 32 | 25 | 20 | 15 | 12 | 10 | 8 | 6 |

*Note:* Values are costs in dollars of reservoir storage per acre-feet. Size class in thousand acre-feet.

Source: From Corps of Engineers, U.S. Army, 1960.

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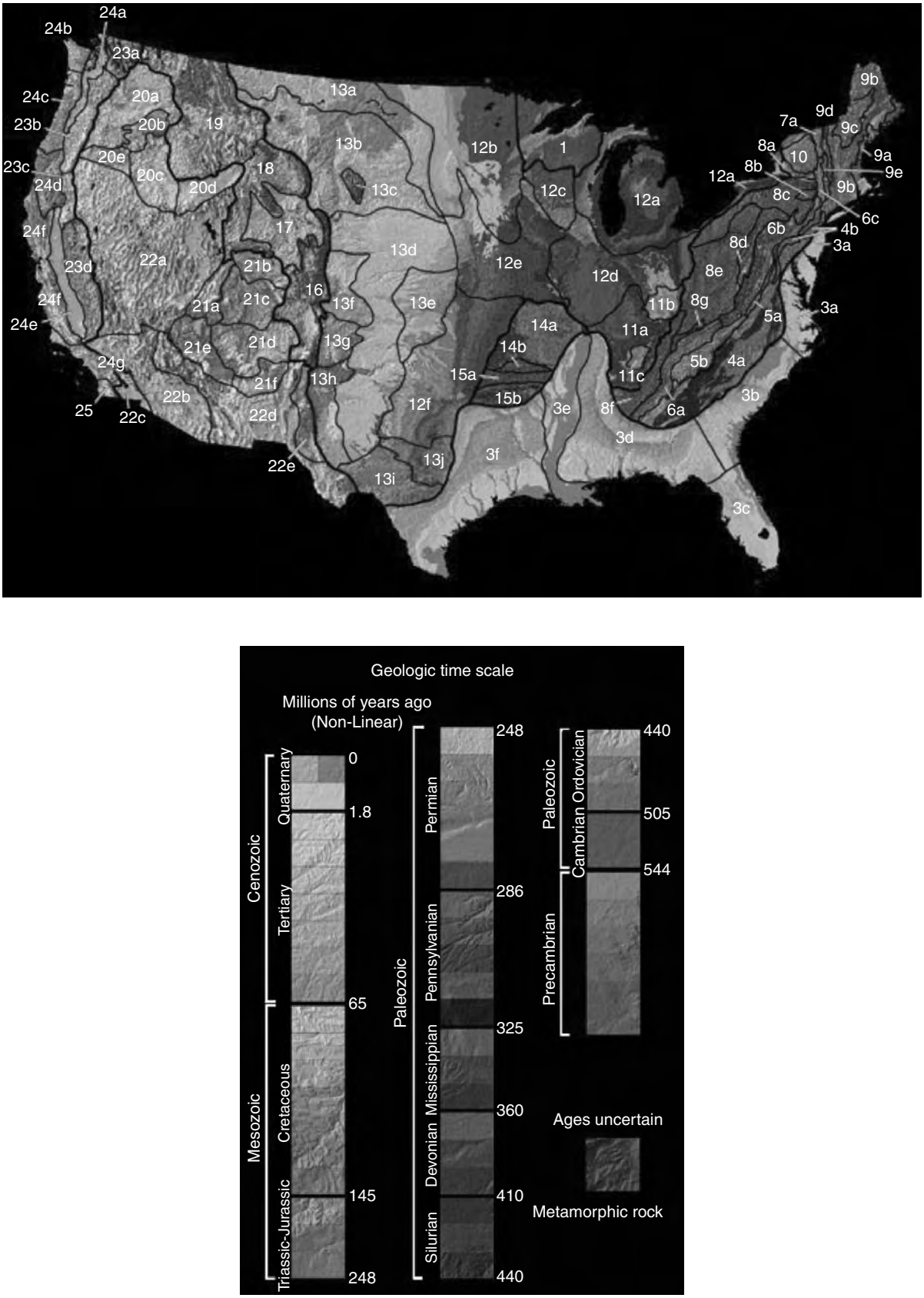





**Figure 11D.41** U.S. physiographic region. (From www.tapestry.usgs.gov.)

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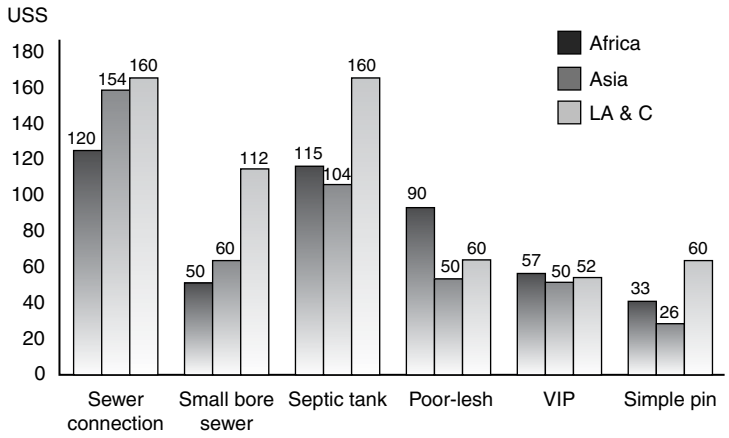


**Figure 11D.42** Average construction cost of sanitation facilities for Africa, Asia, and Latin America and the Caribbean, 1990–2000. (From www.who.int.)

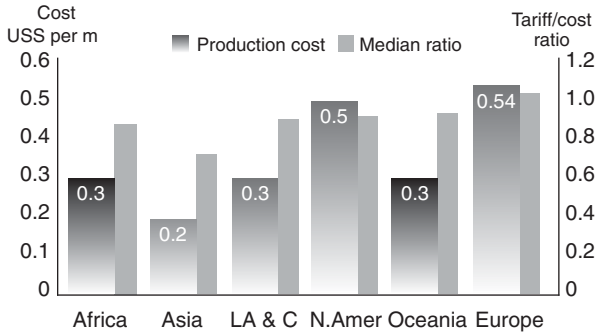


**Figure 11D.43** A comparison of the median unit production cost of urban water supply and the median tariff/production cost ratio by region 1990–2000. (From www.who.int.)

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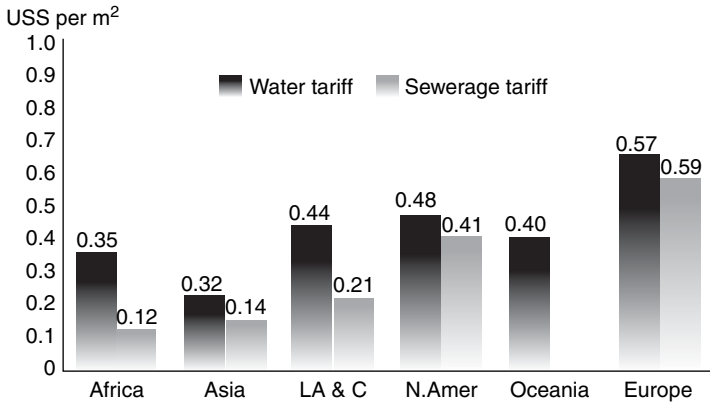


**Figure 11D.44** Median water supply and sewerage tariffs by region, 1990–2000. Average construction cost per person served of water supply facilities for Africa, Asia and Latin America and the Caribbean 1990–2000. (From www.who.int.)

**Table 11D.54 Typical Costs of Irrigation Development in Latin America, Africa, Asia, and Far East**

| Region | $/ha | Gravity Schemes Share in Total (%) | Pump and Tubewells ($/ha) | All Schemes Weighted Average Cost ($/ha) |
|---|---|---|---|---|
| Latin America | 6,000 | 50 | 3000 | 4000 |
| Africa (excl. Sudan) | 11,000 | 70 | 6000 | 9500 |
| Sudan | 5,000 | 50 | 4000 | 4500 |
| Near East | 7,000 | 70 | 4000 | 6100 |
| Asia and Far East (excl. South Asia) | 4,000 | 60 | 2000 | 3200 |
| South Asia (Bangladesh, India, Pakistan) | 2,500 | 40 | 1000 | 1600 |
| Rehabilitation in all regions except South Asia, $1760/ha | | | | |
| Rehabilitation in South Asia, $800/ha | | | | |

*Note:* 1980 prices; US $ per hectare.

*Source*: From FA0, 1982, The State of Food and Agriculture.

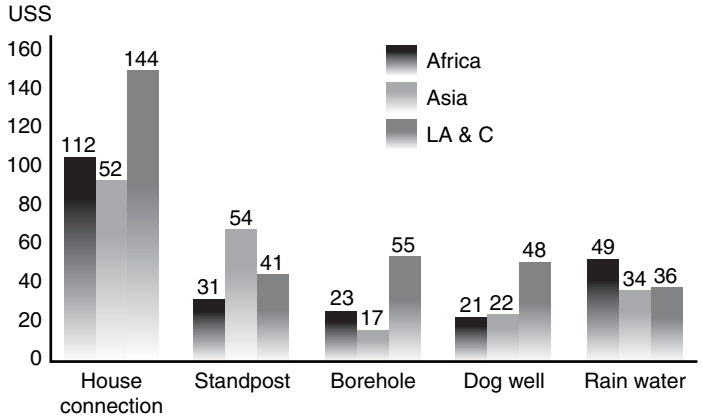


**Figure 11D.45** Average construction cost per person served of water supply facilities for Africa, Asia, and Latin America and the Caribbean, 1990–2000. (From www.who.int.)

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**Table 11D.55 Typical Cost Structures for Water-Supply Systems in the United States**

| | Small Systems[a] | | Large Systems[b] | |
|---|---|---|---|---|
| | Percentage of Operating Expenses | Percentage of Operating Expenses Excluding Interest Charges | Percentage of Operating Expenses | Percentage of Operating Expenses Excluding Interest Charges |
| Acquisition | 19 | 22 | 15 | 19 |
| Treatment | 15 | 18 | 10 | 13 |
| Distribution and Transmission | 36 | 43 | 31 | 38 |
| Support Services | 14 | 17 | 25 | 30 |
| Interest Charges | 16 | — | 19 | — |
| Total | 100 | 100 | 100 | 100 |

[a] Serving between 300 and 75,000 people.
[b] Serving over 75,000 people.

*Source*: From U.S. Environmental Protection Agency, 1986, *Guidelines for Ground Water Classification under the EPA Ground Water Protection Strategy*; ACT Systems Inc., 1977, 1979.

**Table 11D.56 Typical Water System Costs in the United States (1984 $/million of gallons produced)**

| | Source | |
|---|---|---|
| Population Served by System | Surface Water | Groundwater |
| 1000–3300 | 1,085 | 1,493 |
| 3300–10,000 | 1,063 | 924 |
| 10,000–25,000 | 795 | 718 |
| 25,000–75,000 | 727 | 710 |
| 75,000–500,000 | 596 | 606 |
| Over 5,00,000 | 457 | 574 |

*Note:* Operating expenses (including depreciation and capital charges), inflated to 1984 dollars.

*Source*: From U.S. Environmental Protection Agency, 1986, *Guidelines for Ground Water Classification under the EPA Ground Water Protection Strategy*; Survey of Operating and Financial Characteristics of Community Water Systems, Temple, Barker and Sloane, Inc. 1982.

**Table 11D.57 Costs of Groundwater Supply Systems in the United States**

| Population Served by System | Annual Cost |
|---|---|
| 25–1000 | 4,616 |
| 1000–3300 | 1,493 |
| 3300–10,000 | 924 |
| 10,000–25,000 | 718 |
| 25,000–75,000 | 710 |
| 75,000–5,00,000 | 606 |
| Over 5,00,000 | 574 |

*Note:* By population size category; 1984 $/million gallons produced. Operating expenses (including depreciation and capital charges, inflated to 1984 dollars).

*Source*: From U.S. Environmental Protection Agency, 1986, *Guidelines for Ground Water Classification under the EPA Ground Water Protection Strategy*; Survey of Operating and Financial Characteristics of Community Water Systems, Temple, Barker and Sloane, Inc. 1982.

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**Table 11D.58 Costs of Community Water Supply Technology in Developing Countries**

| | Low | | | High | | |
|---|---|---|---|---|---|---|
| **Technology** | **Handpumps** | **Standpipes** | **Yardtaps** | **Handpumps** | **Standpipes** | **Yardtaps** |
| Capital cost (US$) | | | | | | |
| Wells[a] | 4000 | 2,000 | 2,500 | 10,000 | 5,000 | 6,000 |
| Pumps (hand/motor) | 1300 | 4,000 | 4,500 | 2,500 | 8,000 | 9,000 |
| Distribution[b] | None | 4,500 | 16,000 | None | 10,000 | 30,000 |
| Sub-total | 5300 | 10,500 | 23,000 | 12,500 | 23,000 | 45,000 |
| Cost per capita | 13.3 | 26.3 | 57.5 | 31.2 | 57.5 | 112.5 |
| Annual cost (US$/year) | | | | | | |
| Annualized capital[c] | 700 | 1,500 | 3,200 | 1,400 | 3,000 | 6,000 |
| Maintenance | 200 | 600 | 1,000 | 400 | 1,200 | 2,000 |
| Operation (fuel) | None | 150 | 450 | None | 300 | 900 |
| Sub-total (cash) | 900 | 2,250 | 4,650 | 1,800 | 4,700 | 8,900 |
| Haul costs (labor)[d] | 1400 | 1,100 | None | 3,000 | 2,200 | None |
| Total (including labor) | 2300 | 3,350 | 4,650 | 4,800 | 6,900 | 8,900 |
| Total annualized cost per capita | | | | | | |
| Cash only | 2.3 | 5.6 | 11.6 | 4.5 | 11.8 | 22.3 |
| Cash + labor | 5.8 | 8.4 | 11.6 | 12.0 | 17.3 | 22.3 |

*Note:* Capital and recurrent costs for a community of 400 people.

[a] Pumping water level assumed to be 20 m. Two wells assumed for handpump system (200 persons per handpump).
[b] Distribution system includes storage, piping, and taps with soakaway pits.
[c] Capital costs with replacement of mechanical equipment after 10 years annualized at a discount rate of 10% over 20 years.
[d] Labour costs for walking to the water point, queuing, filling the container, and carrying the water back to the house. Time valued at US $ 125/h.

*Source*: From Arlosoroff, Saul, and others, 1987, *Community Water Supply: The Handpump Option*, The World Bank, Washington, DC.

**Table 11D.59 Projection of Irrigation Expansion in Developing Countries and Related Costs (1993–2000)**

| | **Total Irrigated Land-1990 (millions of hectacres)** | **Projected Increases** | **Unit Cost (US dollars)** | **Total Costs (billions of dollars)** |
|---|---|---|---|---|
| Asia (30 countries) | 132.11 | 2.02 | 400 | 2.88 |
| Near East (10 countries) | 9.50 | 0.45 | 800 | 2.32 |
| Latin America (40 countries) | 16.31 | 0.84 | 000 | 7.20 |
| Africa (50 countries) | 14.21 | 0.07 | 200 | 7.20 |
| Total (130 countries) | 172.11 | 5.24 | | 5.52 |

*Source*: From www.munfw.org.

**Table 11D.60 Estimated Targets and Costs for the Modernization of Existing Irrigation Schemes (1990–2000)**

| | **Total Irrigated Area-1990 (millions of hectacres)** | **Total Area Upgraded** | **Unit Cost (US dollars)** | **Total Costs (US dollars)** |
|---|---|---|---|---|
| Asia | 132.11 | 3.21 | 600 | |
| Near East | 95.9 | 5.1 | 450 | 1.4 |
| Latin America | 16.3 | 1.63 | 1000 | 1.6 |
| Africa | 14.2 | 1.42 | 1800 | 2.52 |
| Developing Countries—130 | 172.11 | 7.2 | 113.1 | 4 |

*Source*: From www.munfw.org.

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**Table 11D.61 Options for Community Water Supply: A Comparative Study**

| Step | Type Of Service | Water Source | Quality Protection | Water Use LPC[a] | Energy Source | Operation and Maintenance Needs | Costs | General Remarks |
|---|---|---|---|---|---|---|---|---|
| 5 | House connections | Groundwater<br>Surface water<br>Spring | Good, no treatment<br>May need treatment<br>Good, no treatment | 100 to 150 | Gravity, Electric, Diesel | Well trained operator; Reliable fuel and chemical supplies; many spare parts: wastewater disposal | High capital and O&M costs, except for gravity schemes | Most desirable service level, but high resources needs |
| 4 | Yardtaps | Groundwater<br>Surface water<br>Spring | Good, no treatment<br>May need treatment<br>Good, no treatment | 50 to 100 | Gravity, Electric, Diesel | Well trained operator; reliable fuel and chemical supplies: many spare parts | High capital and O&M costs, except gravity schemes | Very good access to safe water: fuel and institutional support critical |
| 3 | Stand pipes | Groundwater<br>Surface water<br>Spring | Good, no treatment<br>May need treatment<br>Good, no treatment | 10 to 40 | Gravity, Electric, Diesel, Wind, Solar | Well trained operator; reliable fuel and chemical supplies: many spare parts | Moderate capital and O&M costs, except gravity schemes; collection time | Good access to safe water: cost competitive with handpumps at high pumping lifts |
| 2 | Handpumps | Groundwater | Good, no treatment | 10 to 40 | Manual | Trained repairer: few spare parts | Low capital and O&M costs; collection time | Good access to safe water: sustainable by villagers |
| 1 | Improved traditional sources (partially protected) | Groundwater<br>Surface water<br>Spring<br>Rainwater | Variable<br>Poor<br>Variable<br>Good, If protected | 10 to 40 | Manual | General upkeep | Very low capital and O&M costs: collection time | Improvement if traditional source was badly contaminated |
| 0 | Traditional Sources (unprotected) | Surface water<br>Groundwater<br>Spring<br>Rainwater | Poor<br>Poor | 10 to 40 | Manual | General upkeep | Low O&M costs (buckets, etc.) collection time | Starting point for supply improvement |

[a] Liters per capita per day.

*Source*: From www.skipumps.com.

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## SECTION 11E PROJECT PLANNING AND ANALYSIS

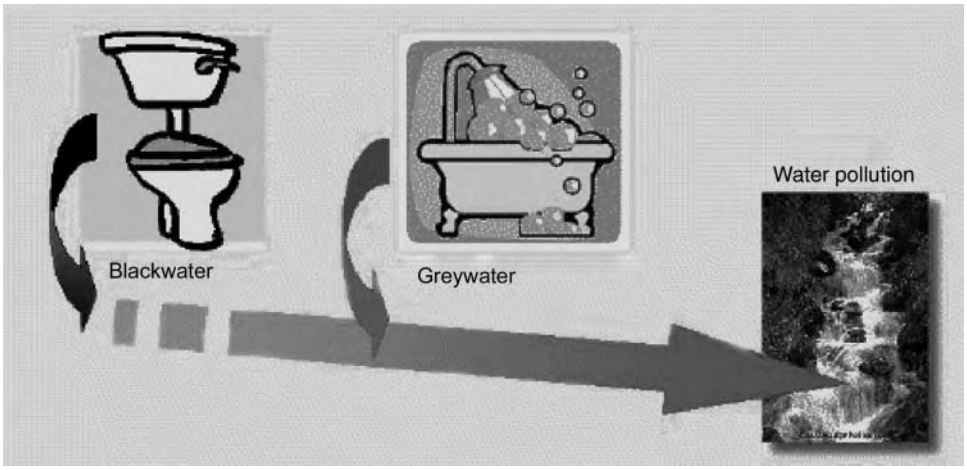


**Figure 11E.46** Linear flows. (From The African Water Page, adapted from Esrey et al. 2001, www.thewaterpage.com. With permission.)

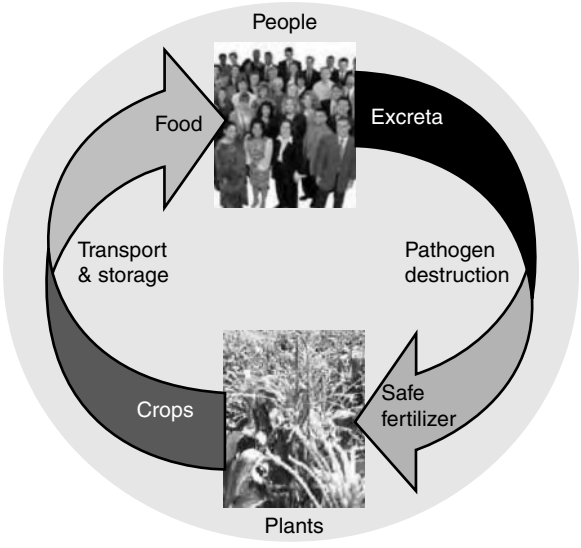


**Figure 11E.47** Circular flows. (From The African Water Page, www.thewaterpage.com. With permission.)

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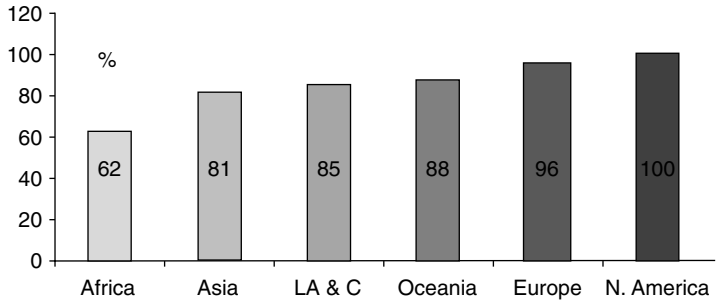


**Figure 11E.48** Proportion (%) of population with water supply services. (From The African Water Page, www.thewaterpage.com. WHO/UNICEF, 2000.)

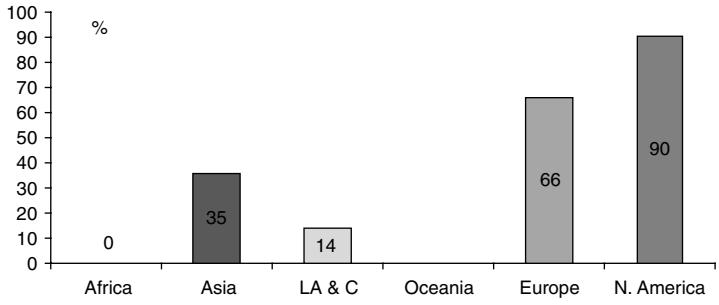


**Figure 11E.49** Lack of treatment of waste water. (From The African Water Page, www.thewaterpage.com. WHO/UNICEF, 2000.)

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**Table 11E.62 Elements Comprising a Water Resources Project Investigation**

A. Purposes of a multiple-purpose project
1. Irrigation
2. Drainage
3. Domestic or industrial water supply
4. Flood control
5. Hydro-power generation
6. Navigation
7. Fish and wildlife conservation
8. Recreation
9. Water quality control
10. Salinity control
11. Watershed management
12. National defense
13. International relation

B. Land resources
1. Land classification
2. Land use and capabilities
3. Development
4. Settlement
5. Drainage

C. Water resources
1. Water supply, surface and groundwater and salvage
2. Water quality and treatment
3. Water requirements, all purposes
4. Water rights including international treaties
5. Flood studies
6. Sediment, including transport, erosion and aggradation

7. Project operation studies
8. Forecasting for operation
9. Hydraulic design requirements

D. Engineering and geology
1. Aerial photography, surveying and mapping
2. Geology, foundation and materials

3. Anticipated construction problems
4. Plans and cost estimates, physical plan formulation
5. Anticipated operation, maintenance and replacement problems and estimates of cost

E. Economics
1. Existing economy and resource use
2. Future economy without the project
3. Future economy with the project, and regional and national impact
4. Economic criteria for plan formulation
5. Economic justification

F. Financial considerations
1. Cost allocation to various purposes
2. Repayment of capital investment
3. Payment of annual operation, maintenance and replacement costs

G. Legal considerations
1. Right to use of water
2. International agreements and treaties
3. Land acquisition and rights-of-way

H. Public relations
1. Determination of public interest in contemplated development
2. Dissemination of factual information on progress and objectives of investigation
3. Establishment of government policy and enabling legislation

I. Reports
1. Reconnaissance reports
   (a) Basin plan
   (b) Preliminary project report
2. Special interim or progress reports
3. Feasibility
4. Definite plan

J. Administration
1. Organizational requirements for supervision of construction and operation of proposed projects
2. Program and budget requirements and control

*Source*: From ECAFE, United Nations, 1964.

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**Table 11E.63 Purposes of a Water Resources Project**

| Purpose | Description | Type of Works and Measures |
|---|---|---|
| Flood control | Flood-damage prevention or reduction, protection of economic development, conservation storage, river regulation, recharging of groundwater, water supply, development of power, protection of life | Dams, storage reservoirs, levees, floodwalls, channel improvements, floodways, pumping stations, floodplain zoning, flood forecasting |
| Irrigation | Agricultural production | Dams, reservoirs, wells, canals, pumps and pumping plants, weed-control and desilting works, distribution systems, drainage facilities, farmland grading |
| Hydroelectric | Provision of power for economic development and improved living standards | Dams, reservoirs, penstocks, power plants, transmission lines |
| Navigation | Transportation of goods and passengers | Dams, reservoirs, canals, locks, open-channel improvements, harbor improvements |
| Domestic and industrial water supply | Provision of water for domestic, industrial, commercial, municipal, and other uses | Dams, reservoirs, wells, conduits, pumping plants, treatment plants, saline-water conversion, distribution systems |
| Watershed management | Conservation and improvement of the soil, sediment abatement, runoff retardation, forests and grassland improvement, and protection of water supply | Soil-conservation practices, forest and range management practices, debris-detention dams, small reservoirs, and farm ponds |
| Recreational use of water | Increased well-being and health of the people | Reservoirs, facilities for recreational use, works for pollution control, reservations of scenic and wilderness areas |
| Fish and wildlife | Improvement of habitat for fish and wildlife, reduction or prevention of fish or wildlife losses associated with man's works, enhancement of sports opportunities, provision for expansion of commercial fishing | Wildlife refuges, fish hatcheries, fish ladders and screens, reservoir storage, regulation of streamflows, stocking of streams and reservoirs with fish, pollution control, and land management |
| Pollution abatement | Protection or improvement of water supplies for municipal, domestic, industrial, and agricultural use and for aquatic life and recreation | Treatment facilities, reservoir storage for augmenting low flows, sewage-collection systems, legal control measures |
| Insect control | Public health, protection of recreational values, protection of forests and crops | Proper design and operation of reservoirs and associated works, drainage, and extermination measures |
| Drainage | Agricultural production, urban development, and protection of public health | Ditches, tile drains, levees, pumping stations, soil treatment |
| Sediment control | Reduction of control of slit load in streams and protection of reservoirs | Soil conservation, sound forest practices, proper highway and railroad construction, desilting works, channel and revetment works, bank stabilization, special dam construction and reservoir operations |
| Salinity control | Abatement or prevention of salt-water contamination of agricultural, industrial, and municipal water supplies | Reservoirs for augmenting low streamflow, barriers, groundwater recharge, coastal jetties |

*(Continued)*

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**Table 11E.63 (Continued)**

| Purpose | Description | Type of Works and Measures |
|---|---|---|
| Artificial precipitation | Control of precipitation within meteorological limits | Portable cloud-seeding equipment, ground generators |
| Employment | Stimulation of employment and sources for increased income in depressed areas of unemployment and underdevelopment | Area Redevelopment Act and Area Redevelopment Administration |
| Public works acceleration | Acceleration of Federal, state, and local constructions of public works on cost-sharing basis | Public Law 87–658 |
| New water-resources policies | New policies to be used by Federal agencies, according to S. Document no. 97 (27), approved by the President May 15, 1962, affecting the economies of project justification as well as project formulation and composition | Senate Document no. 97 |

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**Table 11E.64 Items to be Considered in Planning a Multiple-Purpose Water Resources Project**

A. Physical and Related Items

1. Project area
   a. Physical geography: location and size; physiography; climate; soils
   b. Settlement: history; population; cultural background, both rural and urban
   c. Development: industry; transportation; communication; commerce; power; land uses; water uses; minerals; undeveloped resources
   d. Economic conditions: general; relief problems; community needs; national needs
   e. Investigations and reports: previous investigations; history; scope
2. Hydrologic data
   a. Hydrologic records and networks: gaging and observation stations; data-collecting agencies
   b. Hydrometeorological data: precipitation; evaporation and evapotranspiration
   c. Surface water: low flows; normal flows; maximum floods; "design floods;" drought; quality
   d. Groundwater: aquifers; recharge; quality
3. Supply of water
   a. Sources of supply: surface-water supply; groundwater supply; reservoirs
   b. Variation of supply: variability; consumptive use; regulation; diversion requirements; return flow; evapotranspiration losses; seepage losses or gains
   c. Quality of water: physical, chemical, biological and radioactive qualities; quality requirements; pollution
   d. Legal rights: water rights; development of project rights; operation rights
4. General considerations for design and planning
   a. Geology: explorations; geological formations; foundation problems
   b. Design problems: design criteria; methods of analysis; project operation and maintenance
   c. Construction problems: accessibility to project site; rights of way and relocation; construction materials; construction period; flow diversion; manpower; equipment, accessibility
   d. Alternative plans: comparison of alternative plans; supplementary plans; possible alternative plans; relationships to areas to be served
   e. Estimates of costs
   f. Intrastate, interstate, and international problems
   g. Organizations involved: public and/or private; technical, social, and political
5. Flood control
   a. Flood characteristics of the project area: Historical floods; flood magnitude and frequency
   b. Design criteria: project design storms and floods; degree of protection
   c. Damage: survey of flooding areas and things affected by floods, nearby or quite a distance away, including commerce, good will, dates of delivery of goods, etc.
   d. Measure of control: reduction of peak flow by reservoirs; confinement of flow by levees, floodwalls, or a closed conduit; reduction of peak stage by channel improvement; diversion of floodwater through bypasses or floodways; flood-plain zoning and evacuation; floodproofing and flood insurance of specific properties; reduction of flood runoff by watershed management
   e. Existing remedial works
6. Agricultural use of water (irrigation and related drainage)
   a. Factors for land classification: soil texture; depth to sand, gravel, shale, raw soil, or penetrable lime zone; alkalinity; salinity; slopes; surface cover and profile; drainage; water logging
   b. Present and anticipated development: crops; livestock; financial resources; improvements; organizations; development period
   c. Water requirements, if any: total crop requirement; irrigation-water demand; farm-delivery losses; diversion amounts
   d. Available water: sources; quality; quantity; distribution
   e. Irrigation methods: flooding; furrow irrigation; sprinkling; subirrigation; supplemental irrigation
   f. Structural works: storage reservoirs; dams; spillways; diversion works; canals and distribution systems
7. Hydroelectric power
   a. Development: sources; present potential and future capacities
   b. Alternative sources of power: stream; oil; gas; nuclear power; interties

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c. Types of power plants: run-of-river; storage; pumped storage
d. Structural components: dams; canals; tunnels; penstock; forebay; powerhouse; tailrace
e. Power problems: load demand and distribution; interties (interconnections with other power transmission systems)
f. Markets; revenues; costs

8. Navigation
   a. Water traffic: present and future needs and savings in shipping costs, if any, on the basis of which the justifications are primarily judged at the present time
   b. Alternative means of transportation: air; land
   c. Navigation requirements: depth, width, and alignment of channels; locking time; current velocity; terminal facilities
   d. Methods of improving navigation: channel improvement by reservoir regulation; contraction works; bank stabilization, straightening, and snag removal; lock-and-dam construction; canalization; dredging
9. Domestic and industrial water supply
   a. Sources of supply: surface and/or groundwater; location and capacity; desalination
   b. Water demand: climate; population characteristics; industry and commerce; water rates and metering; size of project area; fluctuation
   c. Water requirements: quantity; pressure; quality (tastes, odors, color, turbidity, bacteria content, chemicals, temperature, etc.)
   d. Methods of purification: plain sedimentation; chemical sedimentation or coagulation; filtration; disinfection; aeration; water softening
   e. Treatment plant: location; design; purpose or purposes
   f. Distribution systems: reservoirs; pumping stations; elevated storage; layout and size of pipe systems; location of fire hydrants
   g. Waterworks organizations: maintenance and operation of supply, distribution, and treatment facilities
10. Recreational use of water
   a. Population tributary (population near enough to the project area to use it for recreational purposes)
   b. Facilities: boating; fishing; swimming; etc.
   c. Water requirements: depth of water; area of water surface; sanitation
11. Fish and wildlife
   a. Biological data: species; habits
   b. Facilities: reservoirs; fish ladders
   c. Water requirements: temperature; current velocity; biological qualities
12. Drainage
   a. Existing projects
   b. Drainage conditions: rainfall excess; soil condition; topography; disposal of water
   c. Drainage system: urban; farmland
13. Water-quality control
   a. Problems involved: sources; nature and degree of pollution; sediment; salinity; temperature; oxygen content; radioactive contamination
   b. Hydrologic information and measurement
   c. Methods of control

B. Economic Aspects of Project Formulation
1. Benefits and damages: identification and evaluation
2. Costs: identification and estimation
3. Financial feasibility
4. Allocation of costs
5. Reimbursement requirements and sharing of allocated costs
6. Methods and costs of financing the project, whether federal, state, or local, bringing all benefits and all costs to an annual basis and recognizing interest on the investment not only during construction, but throughout the entire proposed “life of the project”
7. Benefit-cost-ratio analysis: alternative plans

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**Table 11E.65 Potential Benefits of Water Quality Improvements**

| | |
|---|---|
| In-Stream use | Commercial fisheries, shell fisheries, and aquaculture; navigation |
| | Recreation (e.g., fishing, hunting, boating, swimming) |
| | Subsistence fishing |
| | Human health risk reductions |
| Near-stream use | Water-enhanced noncontact recreation (e.g., picnicking, photography, jogging, biking, camping) |
| | Nonconsumptive use (e.g., wildlife viewing, hiking near water) |
| | Flood control (reduced property loss and risk to health and safety) |
| Diversionary use | Industry/commercial (process and cooling waters) |
| | Agriculture/irrigation |
| | Municipal drinking water (treatment cost savings, water storage dredging and construction savings, and human health risk reduction) |
| Aesthetic use | Residing, working, traveling, and owning property near water, etc. |
| Passive use | Existence (satisfaction gained from knowing the resources exist and knowing others enjoy the resources; ecologic value, including reduced mortality and morbidity, improved reproductive success, increased diversity of aquatic and piscivorous wildlife, improved habitat for threatened and endangered species, and improved integrity of aquatic and aquatic-dependent ecosystems) |
| | Bequest (intergenerational equity) |

*Note:* Previous analyses have included option value as a potential benefit of environmental improvement. For this analysis, EPA adopted Freeman's (1993) conclusion that option value does not exist as a separate benefit category.

*Source*: From www.epa.gov.

**Table 11E.66 Some Examples of Water Management Purposes and the Need for Planning**

| Function | Primary Responsibility[a] | Capital Investment | Operating Plans |
|---|---|---|---|
| Irrigation | F, S, L, P | Best construction of systems | Best use of water and money |
| Municipal water supply | L | Cost effectiveness | Contingencies, best use of facilities |
| Industrial water supply | P | Cost effectiveness | Contingencies, best use of facilities |
| Energy cooling water | P | Development of supplies | Best use of facilities, meeting standards |
| Hydropower | F, P | Development of economic power | Maximization of energy production |
| Wastewater treatment | L | Cost effectiveness | Meeting standards, reducing costs |
| Navigation | F | National economic efficiency | Operation of facilities |
| Flood damage reduction | F, S, L | Optimum facilities | Optimum operation |
| Urban drainage | L | Plans for economical systems | Maintenance, warning, etc |
| Agricultural drainage | L | Plans for systems | Operation of systems |
| Recreation | F, S, L | Development of facilities | Effective operation |
| Fish and wildlife | F, S | Preservation and enhancement of species | Effective operation |
| Watershed management | L | Best plans | Maintenance and operation |
| Preservation of ecological systems | F, S | Preservation of systems | NA |
| Preservation of systems of unique value | F, S | Preservation of systems | NA |

[a] F = Federal
S = State
L = Local
P = Private

*Source*: From Grigg, N.S., 1985, *Water Resources Planning*. Copyright 1985 McGraw-Hill, Inc. Reprinted with permission.

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**Table 11E.67 Stages of Planning for Water Resources Management**

| Policy Planning Examples of Activities | Framework Planning Examples of Activities | General Appraisal Planning Examples of Activities | Implementation Planning Examples of Activities |
|---|---|---|---|
| Assess broad national needs | From viewpoint of broad regionwide totals and on "no-project" basis | On basis of local projects or measures, and over regional of watershed areas | For specific projects or measures |
| Hypothesize national goals and objectives | Inventory and evaluate available data | Estimate present and future water use and environmental needs | Evaluate specific water use and environmental needs |
| Identify problems and opportunities in achieving goals | Assess present and future water use and environmental needs | Estimate available water and related land resources | Evaluate available water and related land resources |
| Identify costs and benefits in achieving goals | Assess available water and related land resources | Make preliminary evaluations of alternative water quality management approaches | Evaluate regulation potential for different degrees of storage |
| Recommend policy choices | Evaluate general regulation potential and identify water quality management approaches | Make preliminary estimates of costs, benefits and consequences of specific alternative projects and measures | Evaluate degree of water quality control with different types of facility |
| Coordinate national priorities | Inventory present status of development | Compare alternative projects and measures | Prepare conceptual designs and cost estimates |
| Review programs for achievement of goals | Inventory general means available to satisfy needs | Devise alternative early action and future programs | Make economic analyses of benefits and consequences |
| | Assess general alternatives to meet different goals | Recommend specific early action and alternative future programs, including selection of projects or measures for implementation study | Make financial analyses to demonstrate payout |
| | Identify problem areas that need priority attention | | Compare alternatives on basis of costs, benefits and payout |
| | Recommend actions that can be taken at present and those that require further study | | Recommend an alternative to be selected |
| | | | Recommend concerning authorization |

*Source*: From National Water Commission, 1972, *Water Resources Planning*.

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**Table 11E.68 Water Body Classification Categories**

| Description of Desired Use[a] | Guidelines for Desired Use[b] |
|---|---|
| *Category I*: Water bodies typically used for direct contact recreational activities, including swimming, scuba diving, snorkeling and waterskiing | Minimum summer Secchi disc depth of at least 1.0 meters; summer average of at least 1.4 meters. Total phosphorus concentrations less than 45 g/L. Chlorophyll-a concentrations less than 20 g/L. Carlson TSI index (Secchi disc based) no greater than 55 |
| *Category II*: Water bodies typically used for indirect contact recreational activities, including sail boating, motor boating, canoeing, and fishing. These activities involve incidental contact with lake water, but do not generally require the water clarity found in direct contact recreational waters. Algal blooms in mid- to late-summer may limit direct contact recreational activities such as swimming and waterskiing | Mean summer Secchi disc depth of at least 0.9 meters, but less than 1.4 meters Total phosphorus concentration of at least 45 g/L, but less than 75 g/L Chlorophyll-a concentration of at least 20 g/L, but less than 40 g/L Carlson TSI index (Secchi disc based) should be no greater than 60 |
| *Category III*: Water bodies that typically serve important functions such as wildlife habitat and aesthetics. May also provide opportunities for warm water fishing, provided winterkill does not occur. Generally accessible to the public for education, interpretation, and nature appreciation. | Of primary importance are guidelines related to aesthetic enjoyment and wildlife habitat to maintain/improve desired use of these water bodies — see Table 5.2 for a listing of aesthetic and habitat indicators. Of secondary importance are the following water quality guidelines: Mean summer Secchi disc depth of at least 0.7 meters Total phosphorus concentration of at least 75 g/L, but less than 105 g/L Chlorophyll-a concentration of at least 40 g/L, but less than 60 g/L Carlson TSI index (Secchi disc based) no greater than 65 |
| *Category IV — Nutrient Traps*: The intended use of these water bodies is to reduce downstream loading of phosphorus and other nutrients that contribute to water pollution. These ponds are generally artificially modified to improve their nutrient trapping capacity. These ponds may become hypereutrophic, and frequent summer algal blooms would be considered normal | Design for phosphorus removal efficiencies of at least 50%. Depth should be managed to prevent or reduce odors associated with algal blooms. No numeric standards for water quality parameters are defined for this category |
| *Category V — Sediment Traps*: These water bodies are similar to Category IV water bodies, but too small to effectively remove a significant fraction of nutrients | Generally have phosphorus removal efficiencies less than 50%. No numeric standards for water quality parameters are defined for this category |

[a] Categories I–III could also include ecologically or biologically unique resources, or water bodies that directly or indirectly affect such a resource.

[b] The water quality criteria for Categories I–III may not apply in the case of ecologically or biologically unique resource; resource-specific criteria may be required.

*Source*: From Black Dog Watershed Management Organization, www.dakotacountyswcd.org. With permission.

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**Table 11E.69 Aesthetic and Habitat Indicators and Recommended City Actions**

| Indicator | Prevalence | Recommended Actions[a] |
|---|---|---|
| Localized shoreline erosion | 10% or less of shore | A (note # of sites), B |
| | 10% to 25% | A (note # of sites), B, C |
| | 25% or more | A (note # of sites), B, D |
| Shoreline erosion resulting from upstream activity | Present | E |
| Sedimentation/deltas | Present | E |
| | 10 cubic yards or more | F |
| Shoreline buffer/percent vegetated[b] | >75% | A |
| | 50% to 75% | A, B |
| | 25% to 50% | A, B, Computer |
| | <25% | A, B, D |
| Purple loosestrife, non-native invasive species | Present | A (note # of colonies), G, H |
| | Not present | A |
| Glossy and common buckthorn, non-native invasive species | Present | A, G, I |
| | Not present | A |
| Average density of shallow water aquatic plants[c] | <1.5 | A, B (to encourage growth of desirable plants), J |
| | 1.5 to 2.5 | A |
| | >2.5 | A, K |
| Non-native invasive shallow water aquatic plants[d] | Present | A, B (to encourage growth of desirable plants), L |
| | Not present | A |

[a] Key to recommended city actions: A, Monitor annually; B, Targeted education materials regarding the importance of lakescaping and buffers; C, Lakescaping demonstration project; D, Lakescaping incentive program (e.g. small grants to encourage residents to implement lakescaping techniques); E, Evaluate source of problem and develop methods to address problem; F, Excavate sediment; G, Targeted education materials regarding the detrimental impacts of the plants, the importance of removing them, methods to remove them, and replacement plantings; H, Recruit citizens to take part in the DNR's purple loosestrife (beetle) program to eradicate plants; I, Recruit citizens to remove/replace plants; J, Evaluation needed to determine why so few plants are present and if more are needed; K, Evaluate extent of plant growth and develop/implement aquatic plant management plan; L, Evaluate extent of plant growth and develop/implement aquatic plant management plan — may not include eradication of non-native invasive plants, especially if they are the only aquatic plants present.

[b] Percent vegetated — percent of shoreline that is vegetated, exclusive of landscaped lawns, with buffer at least 10 f in width.

[c] Based on density ratings given for numerous locations within the littoral zone of each water body; density of 1, low, 2, moderate, 3, high.

[d] Non-native invasive aquatic plants include Eurasian watermilfoil and curly leaf pondweed.

*Source*: From Black Dog Watershed Management Organization, www.dakotacountyswcd.org. With permission.

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**Table 11E.70 Recommended Lake Water Quality Management Actions for Category I and II Lakes**

| | | Type(s) of Management Action Needed | | |
|---|---|---|---|---|
| **Most Recent Summer Average Lake Water Quality, as Compared to Management Action Level** | **5–10-Year Water Quality Trend** | **Watershed Management** | **Lake Monitoring** | **Runoff Monitoring or Equivalent** |
| Better than | No trend analysis available | No action | Continue existing water quality monitoring program: Survey Level—Category I Secchi Disc—Category II | None |
| | Improving | No action | Survey Level—Category I Secchi Disc—Category II | None |
| | Steady | No action | Survey Level—Category I Secchi Disc—Category II | None |
| | Degrading | No action | Management Level—Category I Survey Level—Category II | Watershed land use review |
| Worse than | No trend analysis available | No action | Management Level—Category I Survey Level—Category II | None |
| | Improving | Implementation of runoff BMPs assumed; no further action required | Management Level—Category I Survey Level—Category II | None |
| | Steady | Diagnostic study (e.g., P8 modeling) | Management Level—Category I Survey Level—Category II | Watershed land use review; And subsequent, focused runoff water quality monitoring in potential problem subwatersheds |
| | Degrading | Comprehensive lake/watershed diagnostic feasibility study | Intensive lake monitoring as part of diagnostic feasibility study | Detailed runoff water quality monitoring as part of diagnostic feasibility study |

*Source*: From Black Dog Watershed Management Organization, www.dakotacountyswcd.org. With permission.

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**Table 11E.71 Detailed Listing of Possible Best Management Practices**

| Type of Practice | Area of Benefit | Storm Protection Benefit | Pollutants Controlled | Construction Requirements |
|---|---|---|---|---|
| **Institutional Source Controls** | | | | |
| Public education (billing inserts, news releases, radio public service announcements, school programs, and pamphlets) | Not applicable | Reduced pollutant load to storm drain system | Can reduce improper disposal of paints, varnishes, thinners, pesticides, fertilizers, and household cleansers, and chemicals, etc. | None |
| Litter control | Site dependent | Reduced potential for clogging and discharge | Household and restaurant paper, plastics, and glass | Increase number of trash receptacles and regularly service |
| Recycling programs | Site dependent | Reduction in potential for clogging and harmful discharge | Household paper, glass, aluminum, and plastics. Oil and grease from auto maintenance | Collection and sorting stations |
| "No Littering" ordinance | Storm drain system and receiving water | Prohibits littering and prevents litter from entering storm drains | Paper, plastics, glass, food wrappers, and containers | None |
| "Pooper Scooper" ordinance | Storm drain system and receiving water | Requires animal owners to clean up and properly dispose of animal wastes | Coliform bacteria and nitrogen/urea | None |
| Develop and enact spill response plan | Site dependent | Prevent pollutants from entering storm drain | Hazardous chemical, harmful chemicals, oil, and grease | None |
| Clean up vacant lots | Site dependent | Prevent debris from accumulating on lot. Prevent site from appearing as a "dump" for others to use for disposal. Eliminate sources of hazardous waste | Hazardous and/or harmful chemicals, wind blown for water borne debris | None |
| Prohibit illegal and illicit connections and dumping into storm drain system | Storm drain system and receiving water | Reduces pollutant load entering storm drains | Coliform bacteria, nitrogen, contaminants, and toxic or harmful chemicals | None |
| Identify, locate, and prohibit illegal or illicit discharge to storm drain system | Area-wide | Halt hazardous and harmful discharges, whether intentional or negligent | Sewage from cross connections, oil, grease, direct disposal of pesticides and fertilizers, contaminated water, paint, varnish, solvents, water from site dewatering, swimming pool and spa water, flushing water from radiators and cooling systems, and hazardous or harmful chemicals | Monitor storm drain system for flows and water quality |

*(Continued)*



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**Table 11E.71 (Continued)**

| Type of Practice | Area of Benefit | Storm Protection Benefit | Pollutants Controlled | Construction Requirements |
|---|---|---|---|---|
| Require proper storage, use, and disposal of fertilizers, pesticides, solvents, paints and varnishes, and other household chemicals (oil, grease, and antifreeze, etc.) | Site dependent (city, state, or county-wide) | Reduce pollutant load to storm system | Household hazardous materials | None |
| Restrict paving and use of nonporous cover materials in recharge areas | Recharge area site | Promotes infiltration to groundwater and reduces runoff volume and velocity. Filters pollutants | | Establishment of vegetation or use of recharge/infiltration materials |
| **Nonstructural Source Controls** | | | | |
| Street sweeping | Street right-of-way | Reduction in potential for clogging storm drains with debris. Some oil and grease control possible | Paper and plastics, leaves and twigs, dust, and oil and grease | Acquire street sweeping equipment |
| Sidewalk cleaning | Sidewalk right-of-way in areas of heavy foot traffic | Reduction in pollutants entering storm drain | Oil and dirt | None |
| Clean and maintain storm drain channels annually | Channel capacity and receiving water. Upstream flood control benefits. Includes benefits to channel wildlife habitat and vegetation | Prevent erosion in channel. Improve capacity by removing silt and sedimentation. Remove debris that is habitat destroying or toxic to wildlife | Silt and sediment and the contaminants contained therein. Plastic, glass, paper, and metal thrown or washed in channel | None |
| Clean and inspect storm inlets and catch basins annually | Site dependent flood control benefits | Allows proper drainage to prevent flooding and continued proper operation of facilities | Silt and sediment and the contaminants contained therein. Plastic, glass, paper, and metal thrown or washed into facilities | None |
| Clean and inspect debris basins annually | Site dependent flood control benefits | Allows proper drainage to prevent flooding and continued proper operation of facilities | Silt and sediment and the contaminants contained therein. Plastic, glass, paper, and metal thrown or washed into facilities | None |
| Storm drains cleaned and maintained every 3 to 6 years | Flood control and water quality benefits | Allows proper drainage to prevent flooding and continued proper operation of facilities | Silt and sediment and the contaminants contained therein. Plastic, glass, paper, and metal thrown or washed into facilities | None |
| Storm system pump stations cleaned and maintained annually | Site dependent flood control and water quality benefits | Prevents flooding and allows continued proper operation of facilities | Silt and sediment and the contaminants contained therein. Plastic, glass, paper, and metal thrown or washed into facilities | None |

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| | | | | |
|---|---|---|---|---|
| Inspect and maintain sewer system | Storm drain system and receiving water | Prevents and eliminates sewer system surcharges | Contaminants, toxics, and coliform bacteria | None |
| **Minor Structural Source Controls** | | | | |
| Storm drain inlet protection | Storm drain drainage area | Prevent debris from entering storm drain | Dirt, leaves, twigs, paper, plastic, and other incidentals | Not available |
| Outlet protection | Storm drain receiving water | Prevent erosion at the outlet of pipes or paved channels and protect downstream water quality | Turbidity and sediment | Structural apron lining at the outlet location. Made of riprap, grouted riprap, concrete, or other structural materials |
| Slope stabilization and erosion control measures | Site and topography dependent | Reduce silt and sediment load to storm drains | Silt and sediment and the contaminants therein | None |
| Interceptor swale | Dependent on flow velocity. Max. velocity for earth channel is 6 fps. Max. velocity for vegetated or riprap channel is 8 fps | Shorten length of exposed slopes and intercept and divert storm runoff from erodible areas | Sediments and silt and the contaminants contained therein | Excavation drainageway across disturbed areas or rights-of-way |
| Improve and maintain natural channels | Channel capacity and receiving water. Upstream flood control benefits. Includes benefits to channel wildlife habitat and vegetation | Prevent erosion in channel. Improve capacity by removing silt and sedimentation. Remove debris that is habitat destroying or toxic to wildlife | Silt and sediment and the contaminants contained therein. Plastic, glass, paper, and metal thrown or washed in channel | None |
| Diversion channel | Dependent of flow velocity. Maximum velocities: 5 fps for vegetated channel and 8 fps for riprap channel. Not for use on slopes greater than 15%. Drainage area should be 5 acres of less | Intercept and convey runoff to outlets at nonerosive velocity | Sediment and erosion controls | Lined drainageway of trapezoidal cross section |
| Grass-lined channel | Site dependent but of larger capacity than interceptor or perimeter swales | Intercept runoff and convey runoff from site | Sediment and silt and the contaminants contained therein | Excavation of channel or improvements to natural channel. Stabilization with vegetation |
| Storm drain drop inlet protection | Areas less than 1 to 2 acres | Filters sediment from runoff before it enters inlet. Provides relatively good protection | Sediment and the contaminants contained therein | Barrier around storm drain inlet. Useful for areas where storm drain is operational before area runoff area is stabilized |
| Riprap | Site dependent | Provides stabilization and erosion control for stream banks and channels, outlet, and slopes | Erosion and sediment | Placement of rock on area to be stabilized. May also require use of filter fabric liner |

*(Continued)*



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**Table 11E.71 (Continued)**

| Type of Practice | Area of Benefit | Storm Protection Benefit | Pollutants Controlled | Construction Requirements |
|---|---|---|---|---|
| Gabions | Site dependent | Provides stabilization and erosion control for stream banks, outlet, and slopes | Erosion and sediment | Placement of wire cage will with rocks over area to be stabilized. May also require use of filter fabric liner |
| Vegetative control | Applicable and effective for most sites | Provides stabilization and erosion control for streambanks, swales, channels, outlets, slopes, open disturbed areas. Can be up to 99% effective with established cover. Temporary seeding can be up to 90% effective | Erosion and sediment | Site preparation (can include land leveling and installation of irrigation system), seeding or planting, and netting or mulching to establish seed. Can also include other sodding, ground cover, shrubs, trees, and native plants |
| Filter strips | Site dependent | Receives overland flow slowing runoff and trapping particulates. Can be 30 to 50% effective for sediment control | Silt, sediment, trash, organic matter, and to an extent, soluble pollutants through infiltration | Grading and vegetative establishment. Should have a minimum width of 15 to 20 feet. Good performance is achieved with a 50- to 75-foot width |
| Fence open channels | Site dependent | Prevent windblown trash from entering channel. Prevents illegal dumping in channel | Trash and pollutants | Construction of fences |
| **Discharge Elimination Methods** | | | | |
| French drains and subsurface drains | Dependent on site topography and soil permeability | Provides drainage of "wet" soils to allow establishment of vegetation. Can reduce runoff | Sediment | Underground perforated pipe leading to a surface water outlet. Pipe size, bedding and depth is dependent on site conditions |
| Infiltration trench and dry well | Small drainage areas. Runoff from rooftops, parking lots, residential, etc. | Provides temporary storage of runoff and infiltration to soil. Not for use in areas where groundwater could become contaminated | Prevents 100% of pollutants from entering surface water. Oil, grease, floating organic matter, and settleable solids should be removed before water enters trench | Excavation of a shallow trench 2′ to 10′ deep. Backfilled with coarse stone aggregate |
| Exfiltration trench | Site dependent | Prevent silting on underlying filter gravel or rock bed. Retain first flush, reduce runoff volume and peak discharge rate and promote water quality improvement | Prevents pollutants from entering surface water. Oil, grease, floating organic matter, and settleable solids should be removed before water enters trench | Uses perforated pipe with suitable membrane filter material. Installed before receiving water outlet or in groundwater recharge area |

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| | | | | |
|---|---|---|---|---|
| Porous pavement | Site dependent. Requires relatively flat surface | Allow infiltration of surface runoff. Reduce runoff volume and pollutant loadings from low volume traffic areas | Oil and grease | Install porous pavement. May require twice as much paving materials as standard asphalt to achieve same strength |
| Retention basin | Best for sites of 5 to 50 acres | Promotes infiltration to groundwater and reduces runoff volume and velocity. Filters pollutants | Sediment, trace metals, nutrients, and oxygen-demanding substances | Excavation of a basin over permeable soils. Size is site dependent. Depth is 3 to 12 feet |
| **Floatables and Oil Removal** | | | | |
| Clarifies and oil and water separators on parking structures | Parking lot structure and receiving water | Collect debris before it can enter storm drain | Oil, grease, and antifreeze from vehicles and foods and food wrappers | Install grit and separators |
| Oil and grit separators | Site dependent. For heavy traffic areas or areas with high potential for oil spills | Remove pollutants | Sediments and hydrocarbons | Install oil and grit separators on storm drains |
| Sediment/grease trap | Installed on storm drain inlets | Intercept and trap sediment and grease from runoff | Sediment, oil, and grease | Install sediment and grease traps |
| **Solids Removal** | | | | |
| Detention basin | Four acres of drainage area for each acre/foot of storage provided to retain a permanent pool of water | Temporary storage of storm runoff until release. Can also improve water quality | Sediment, trace metals, hydrocarbons, nutrients, and pesticides | Excavation of a basin over soils which will cause excessive seepage. May require a liner. Can be used aesthetically as a small pond in landscaping |
| Extended detention basin | Size for a minimum detention time of 24 hours | Temporary storage of runoff for an extended period of time. Can improve water quality | Sediment, trace metals, hydrocarbons, nutrients, and pesticides | Excavation of a basin over soils which will cause excessive seepage. May require a liner. Can be used aesthetically as a small pond in landscaping |
| Bar screens | Site dependent | Restrict passage of objects which may obstruct pump station suction bays | Large debris | Install bar screens before pump station suction bays |
| Wetlands | Requires large area, 3% of the watershed area | Remove pollutants. Provide habitat and recreational area | Hydrocarbons, silt and sediment, oxygen-demanding substances, bacteria, and nutrients | Create a new wetlands area or use existing wetlands |
| **Microorganism Removal** | | | | |
| Conversion of wastewater treatment plants to wet weather facilities | Site dependent. Is abandoned treatment facility available? | Treats stormwater flows prior to discharge | Process dependent. Chlorination facilities may be added to remove microorganisms | Treatment conversion |

*(Continued)*

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**Table 11E.71 (Continued)**

| Type of Practice | Area of Benefit | Storm Protection Benefit | Pollutants Controlled | Construction Requirements |
|---|---|---|---|---|
| Install treatment facilities on "Dirty" storm drains | Site and need dependent | Treats stormwater flows. Dry weather flows should be halted or routed to existing wastewater treatment facility if possible | Microorganisms | Site specific |
| Swirl concentrators and chlorination/dechlorination | Site and need dependent | Treats stormwater flows prior to discharge | Floatables, settleable solids, suspended solids, and coliform bacteria | Install concentrators |
| Chlorination/dechlorination facilities | Site and need dependent | Treats stormwater flows prior to discharge | Microorganisms | Install chlorination/ dechlorination facilities |
| Primary clarifiers | Site and need dependent | Treats stormwater flows prior to discharge | Floatables, settleable solids, suspended solids, and coliform bacteria | Install primary clarifiers |
| Primary clarifiers and filters | Site and need dependent | Treats stormwater flows prior to discharge | Suspended solids, nutrients and coliform bacteria | Construct sedimentation basins and filters |
| **Metals Removal** | | | | |
| Primary clarifiers and lime precipitation | Site and need dependent | Treats stormwater flows prior to discharge | Floatable, settleable solids, suspended solids, coliform bacteria, and metals | Install primary clarifiers and lime precipitation facilities |
| Detention basin and wetland treatment | Requires large area, 3% of the watershed area | Remove pollutants. Provide habitat and recreational area | Hydrocarbons, silt and sediment, oxygen-demanding substances, bacteria, metals, and nutrients | Create a new wetlands area or use existing wetland |

*Source*: From Black Dog Watershed Management Organization ENR 4900, www.dakotacountyswcd.org. With permission.

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**Table 11E.72 Recommended Best Management Practices According to Watershed**

| | Watersheds Tributary to a Ponding Area that Treats Stormwater Runoff (Treated Watershed) | | | | Watersheds Receiving No Treatment | |
|---|---|---|---|---|---|---|
| **Best Management Practice** | **No Outlet[a]** | **NURP Detention[b]** | **Wet Detention[c]** | **Dry Detention[d]** | **No Detention[e]** | **Direct Discharge[f]** |
| Retrofit dry ponds to wet detention ponds | | | | X | | |
| Retrofit dry ponds to constructed water quality wetlands | | | | X | | |
| Retrofit dry ponds to extended detention basins | | | | X | | |
| Construct sedimentation (pretreatment) basins, when opportunity arises | | | X | | X | X |
| Create additional water quality storage to meet NURP standards | | | X | | | |
| Perform stormwater system maintenance in accordance with local plan | X | X | X | X | X | |
| Install "Stormceptors" or other precast stormwater treatment systems | | | | | X | |
| Prioritize street sweeping | X | X | X | X | X | X |
| Construct skimmers to prevent downstream discharge of oil and floatables | | X | X | X | | |
| Develop/implement lawn fertilizer ordinance | X | X | X | X | X | X |
| Construct filter strips/grassed swales | | | | | X | X |
| Increase opportunities for infiltration | X | X | X | X | X | X |
| Stabilize slopes and implement other permanent erosion/sediment controls | X | X | X | X | X | X |
| Develop and implement education program emphasizing good housekeeping practices[g] | X | X | X | X | X | X |
| Provide vegetative buffers around ponds and wetlands | X | X | X | X | X | X |

[a] No outlet watershed — area tributary to a landlocked basins (i.e., no outlet); receives highest level of treatment (i.e., 100% total phosphorus removal).
[b] NURP watershed — area tributary to a wet detention pond that provides treatment to NURP standards (i.e., 40%–60% total phosphorus removal).
[c] Wet detention watershed — area tributary to a wet detention pond that provides treatment to less than NURP standards (i.e., 5%–40% total phosphorus removal).
[d] Dry detention watershed — area tributary to a dry detention basin that provides for settlement of larger particles and traps floatables, but provides minimal water quality treatment (i.e., 0%–10% total phosphorus removal).
[e] No detention watershed — area tributary to a storm sewer system that does not receive any type of detention storage or treatment.
[f] Direct watershed — area that directly discharges as sheet flow into a major waterbody without any treatment.
[g] "Good housekeeping practices" include: fertilizer and chemical management, lawn and garden care guidelines, litter control, control of illegal dumping/illicit discharges, pet waste management, vacant lot cleanup, recycling programs, etc. See also Table 5.4.

*Source:* From Black Dog Watershed Management Organization, www.dakotacountyswcd.org. With permission.

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**Table 11E.73 Current Status the WHO/UNICEF/WSSCC Global Water Supply and Sanitation Assessment 2000 Report Provides Information on the Current Status of Basic Water and Sanitation Services throughout the World**

| | 1990 Population (Millions) (76% of Global Population Represented) | | | | 2000 Population (Millions) (89% of Global Population Represented) | | | |
|---|---|---|---|---|---|---|---|---|
| | Total Population | Population Served | Population Unserved | % Served | Total Population | Population Served | Population Unserved | % Served |
| **Global** | | | | | | | | |
| Urban water supply | 2292 | 2179 | 113 | 95 | 2845 | 2672 | 173 | 94 |
| Rural water supply | 2974 | 1961 | 1013 | 66 | 3210 | 2284 | 926 | 71 |
| Total water supply | 5266 | 4140 | 1126 | 79 | 6055 | 4956 | 1099 | 82 |
| Urban sanitation | 2292 | 1877 | 415 | 82 | 2845 | 2442 | 403 | 86 |
| Rural sanitation | 2974 | 1028 | 1946 | 35 | 3210 | 1210 | 2000 | 38 |
| Total sanitation | 5266 | 2905 | 2361 | 55 | 6055 | 3652 | 2403 | 60 |
| **Africa** | (72% of regional population represented) | | | | (96% of regional population represented) | | | |
| Urban water supply | 197 | 166 | 31 | 84 | 297 | 253 | 44 | 85 |
| Rural water supply | 418 | 183 | 235 | 44 | 487 | 231 | 256 | 47 |
| Total water supply | 615 | 349 | 266 | 57 | 784 | 484 | 300 | 62 |
| Urban sanitation | 197 | 167 | 30 | 85 | 297 | 251 | 46 | 84 |
| Rural sanitation | 418 | 206 | 212 | 49 | 487 | 220 | 267 | 45 |
| Total sanitation | 615 | 373 | 242 | 61 | 784 | 471 | 313 | 60 |
| **Asia** | (88% of regional population represented) | | | | (94% of regional population represented) | | | |
| Urban water supply | 1029 | 972 | 57 | 94 | 1352 | 1254 | 98 | 93 |
| Rural water supply | 2151 | 1433 | 718 | 67 | 2331 | 1736 | 595 | 75 |
| Total water supply | 3180 | 2405 | 775 | 76 | 3683 | 2990 | 693 | 81 |
| Urban sanitation | 1029 | 690 | 339 | 67 | 1352 | 1055 | 297 | 78 |
| Rural sanitation | 2151 | 496 | 1655 | 23 | 2331 | 712 | 1619 | 31 |
| Total sanitation | 3180 | 1186 | 1994 | 37 | 3683 | 1767 | 1916 | 48 |
| **Latin American and the Caribbean** | (77% of regional population represented) | | | | (99% of regional population represented) | | | |
| Urban water supply | 313 | 287 | 26 | 92 | 391 | 362 | 29 | 93 |
| Rural water supply | 128 | 72 | 56 | 56 | 128 | 79 | 49 | 62 |
| Total water supply | 441 | 359 | 82 | 82 | 519 | 441 | 78 | 85 |
| Urban sanitation | 313 | 267 | 46 | 85 | 391 | 340 | 51 | 87 |
| Rural sanitation | 128 | 50 | 78 | 39 | 128 | 62 | 66 | 49 |
| Total sanitation | 441 | 317 | 124 | 72 | 519 | 402 | 117 | 78 |
| **Oceania** | (64% of regional population represented) | | | | (85% of regional population represented) | | | |
| Urban water supply | 18 | 18 | 0 | 100 | 21 | 21 | 0 | 98 |
| Rural water supply | 8 | 5 | 3 | 62 | 9 | 6 | 3 | 63 |
| Total water supply | 26 | 23 | 3 | 88 | 30 | 27 | 3 | 88 |
| Urban sanitation | 18 | 18 | 0 | 99 | 21 | 21 | 0 | 99 |
| Rural sanitation | 8 | 7 | 1 | 89 | 9 | 7 | 2 | 81 |
| Total sanitation | 26 | 25 | 1 | 96 | 30 | 28 | 2 | 93 |
| **Europe** | (15% of regional population represented) | | | | (44% of regional population represented) | | | |
| Urban water supply | 522 | 522 | 0 | 100 | 545 | 542 | 3 | 100 |
| Rural water supply | 200 | 199 | 1 | 100 | 184 | 161 | 23 | 87 |
| Total water supply | 722 | 721 | 1 | 100 | 729 | 703 | 26 | 96 |
| Urban sanitation | 522 | 522 | 0 | 100 | 545 | 537 | 8 | 99 |
| Rural sanitation | 200 | 199 | 1 | 100 | 184 | 137 | 47 | 74 |
| Total sanitation | 722 | 721 | 1 | 100 | 729 | 674 | 55 | 92 |
| **Northern America** | (99.9% of regional population represented) | | | | (99.9% of regional population represented) | | | |
| Urban water supply | 213 | 213 | 0 | 100 | 239 | 239 | 0 | 100 |
| Rural water supply | 69 0 | 69 | 0 | 100 | 71 | 71 | 0 | 100 |
| Total water supply | 282 | 282 | 0 | 100 | 310 | 310 | 0 | 100 |
| Urban sanitation | 213 | 213 | 0 | 100 | 239 | 239 | 0 | 100 |
| Rural sanitation | 69 | 69 | 0 | 100 | 71 | 71 | 0 | 100 |
| Total sanitation | 282 | 282 | 0 | 100 | 310 | 310 | 0 | 100 |

*Note:* The report charts the developments since 1990. The current status is provided in the table above.

*Source*: From thewaterpage.com. With permission.

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**Table 11E.74 Table Annual Investments in Water Supply and Sanitation Indicating Proportional Disparity**

| Region | Water Supply (US$ Billion) | % | Sanitation (US$ Billion) | % |
|---|---|---|---|---|
| Africa | 4.091 | 88 | 0.542 | 12 |
| Asia | 6.063 | 85 | 1.104 | 15 |
| LA & C | 2.41 | 62 | 1.503 | 38 |
| Total | 12.564 | 80 | 3.148 | 20 |

*Note:* Investment figures indicate that a higher priority has been given over the 90s for water supply as opposed to sanitation, both through national governments and by the international community.

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## SECTION 11F RESEARCH AND EXPENDITURES

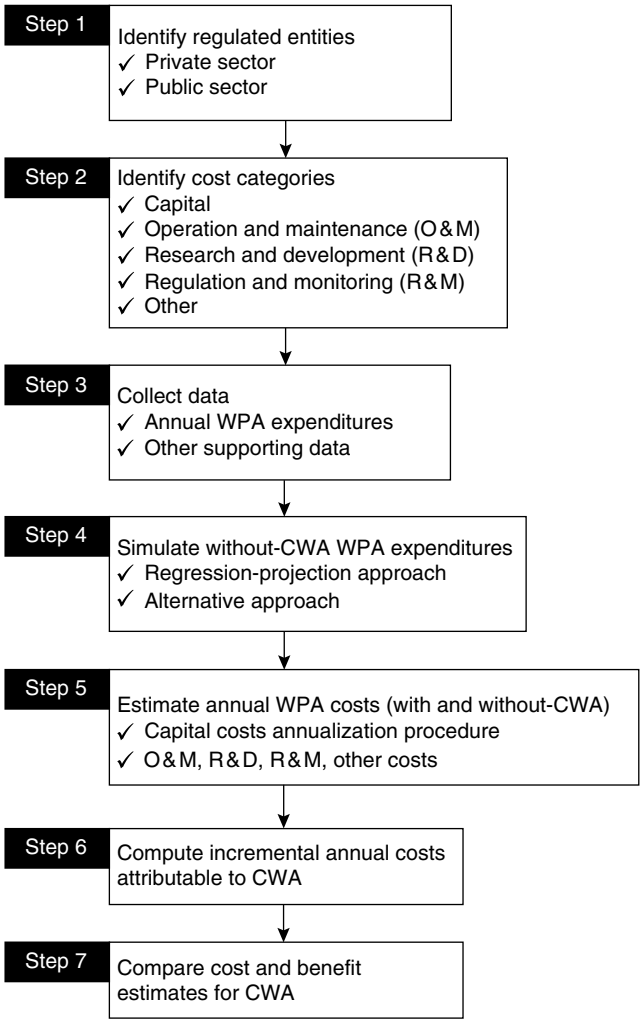


**Figure 11F.50** Outline of methodology for assessing CWA costs. (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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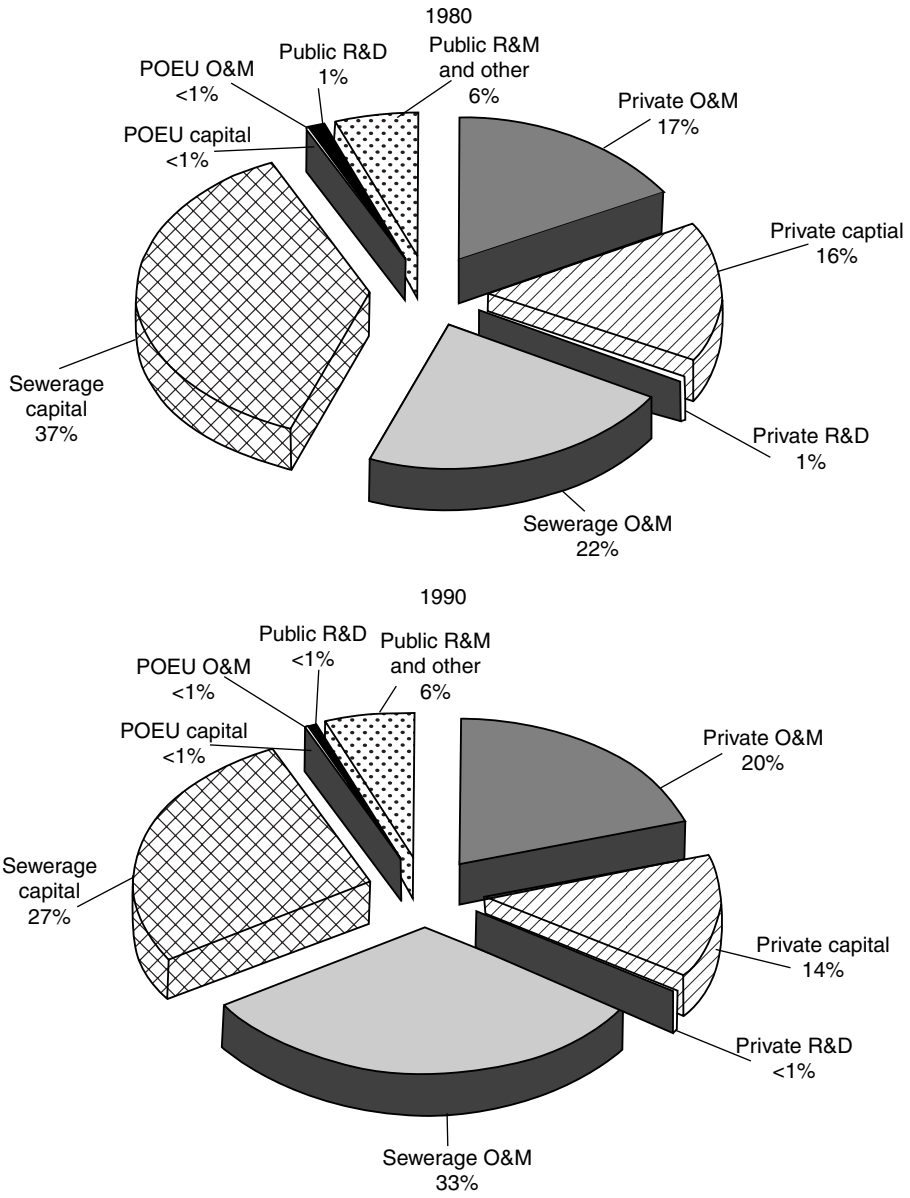


**Figure 11F.51** Distribution of estimated water pollution abatement expenditures, 1980 and 1990. (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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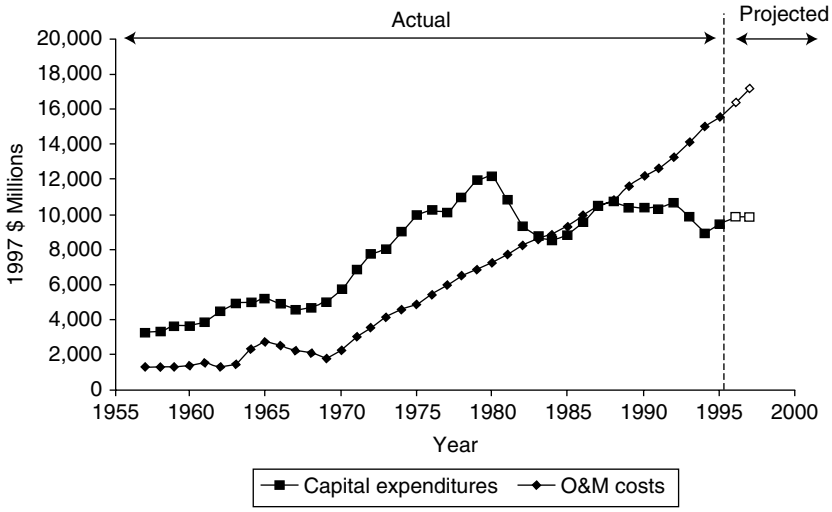


**Figure 11F.52** Public sewerage expenditures, 1957–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

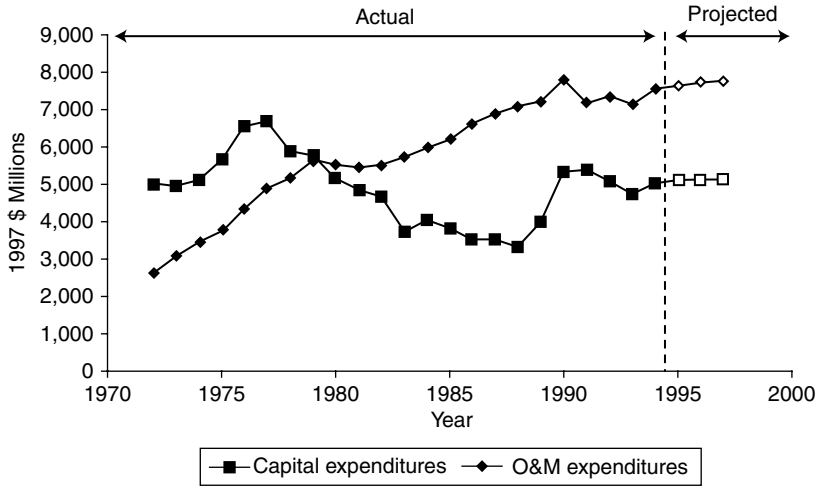


**Figure 11F.53** Private water pollution abatement expenditures, 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

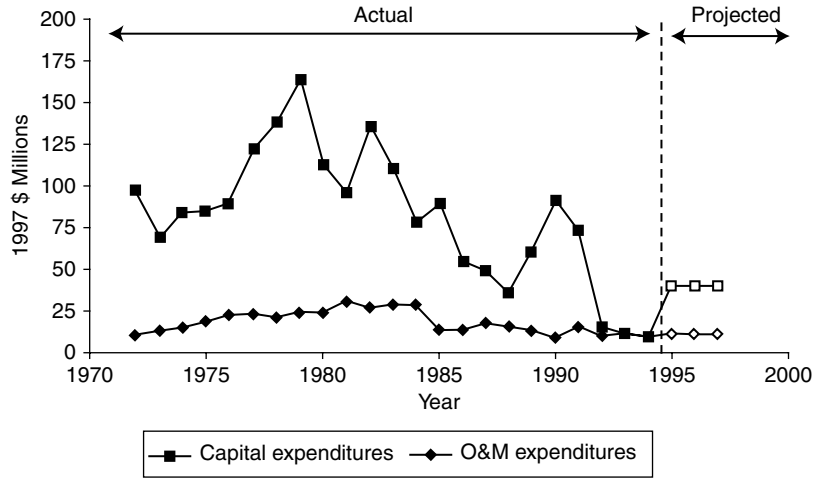


**Figure 11F.54** Water pollution abatement expenditures by publicly owned electric utilities, 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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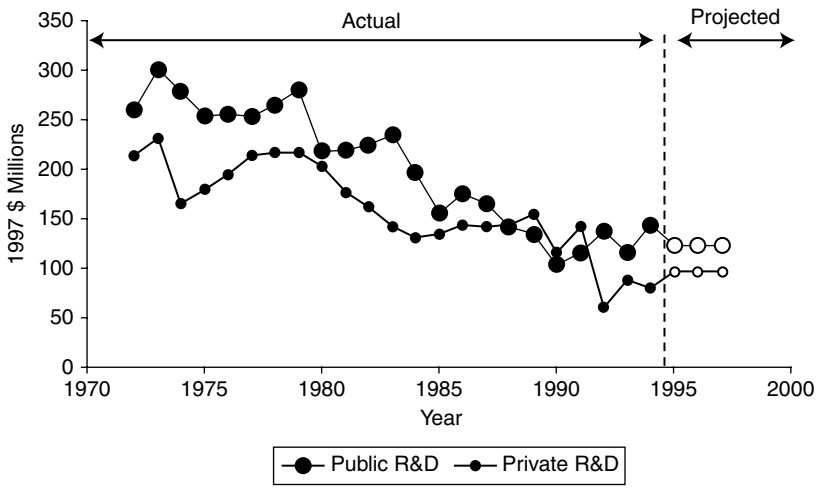


**Figure 11F.55** Public and private R&D expenditures for water pollution abatement 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

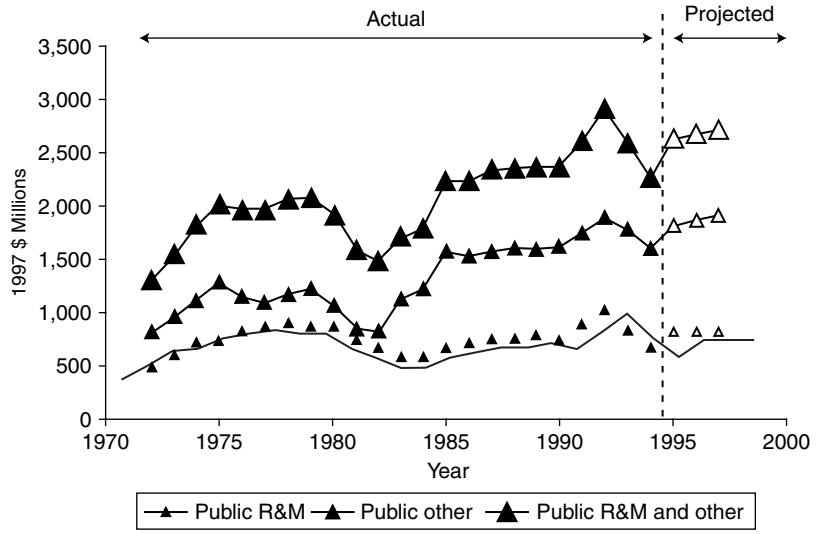


**Figure 11F.56** Public water pollution abatement expenditures for R&M and other costs not elsewhere classified, 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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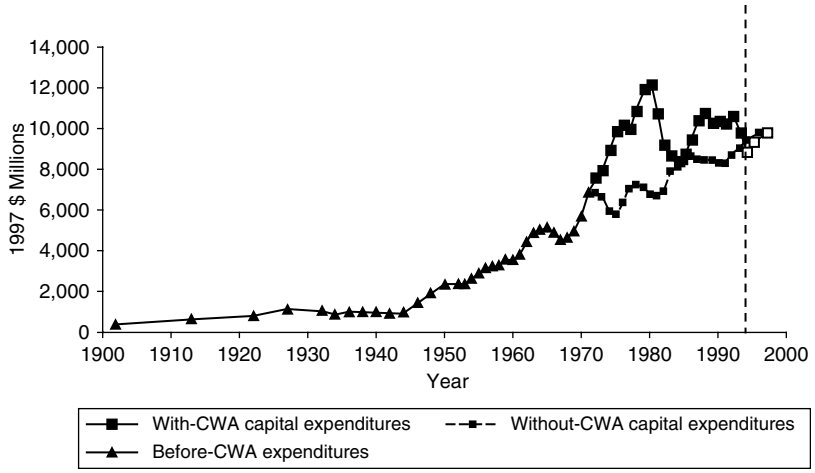


**Figure 11F.57** Annual sewerage capital expenditures under the with-CWA and without-CWA scenarios, 1902–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

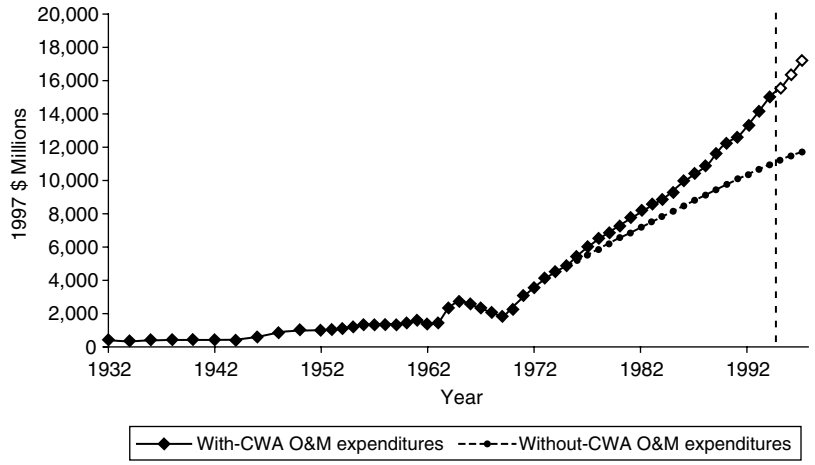


**Figure 11F.58** Annual sewerage O&M expenditures under the with-CWA and without-CWA scenarios, 1932–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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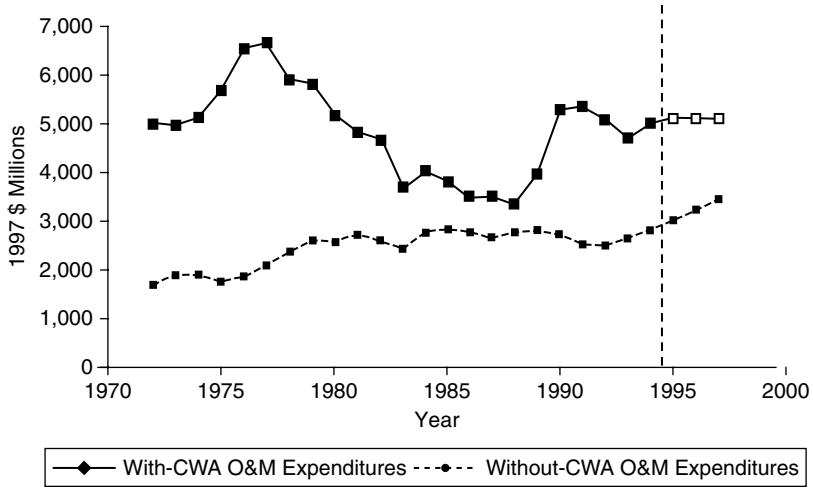


**Figure 11F.59** Annual private capital expenditures for water pollution abatement under the with-CWA and without-CWA scenarios, 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

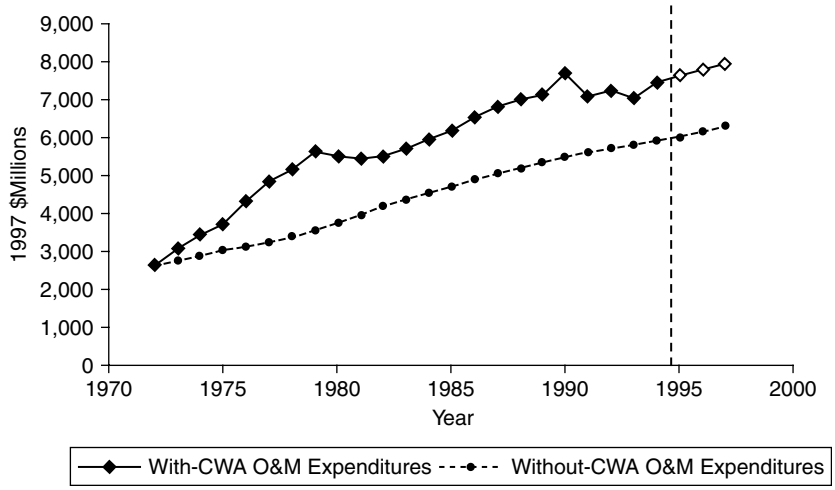


**Figure 11F.60** Annual private O&M expenditures for water pollution abatement under the with-CWA and without-CWA scenarios, 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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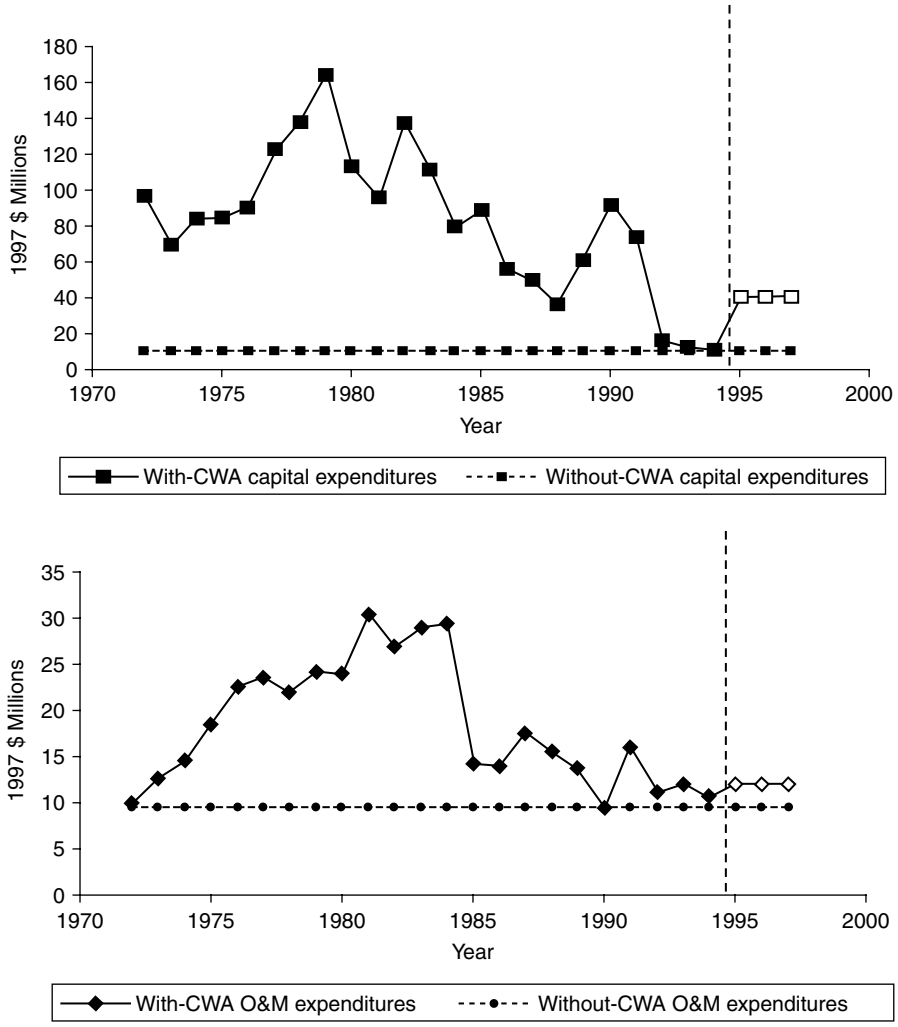


**Figure 11F.61** Water pollution abatement expenditures by publicly owned electric utilities, with and without the CWA, 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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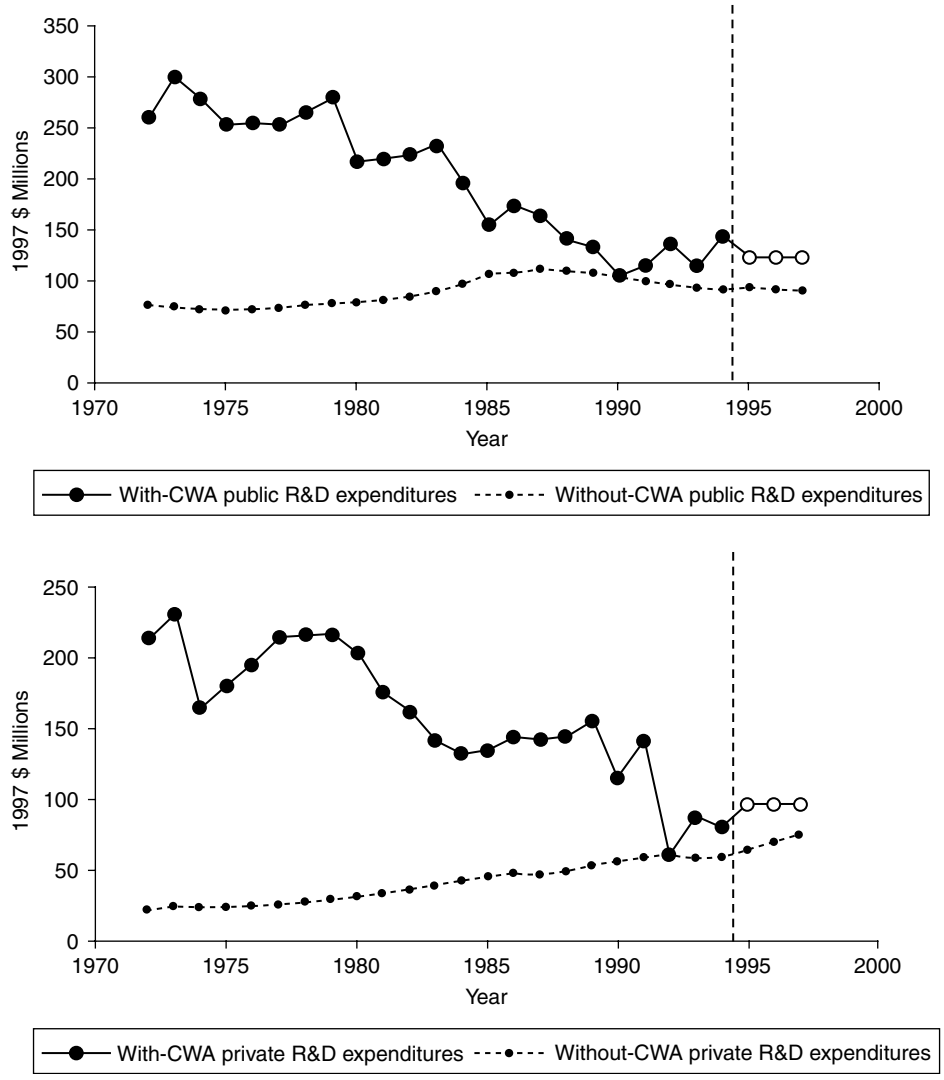


**Figure 11F.62** R&D expenditures for water pollution abatement, with and without the CWA, 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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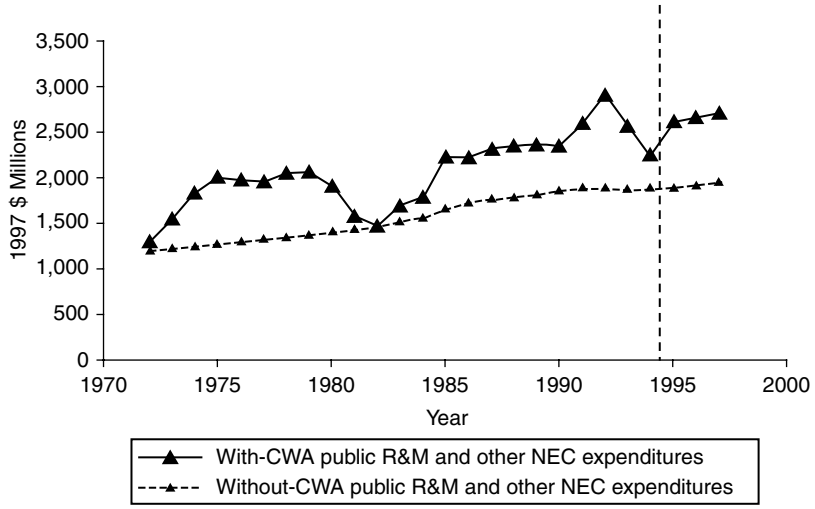


**Figure 11F.63** Public R&M and other expenditures related to water pollution abatement, with and without the CWA, 1972–1997 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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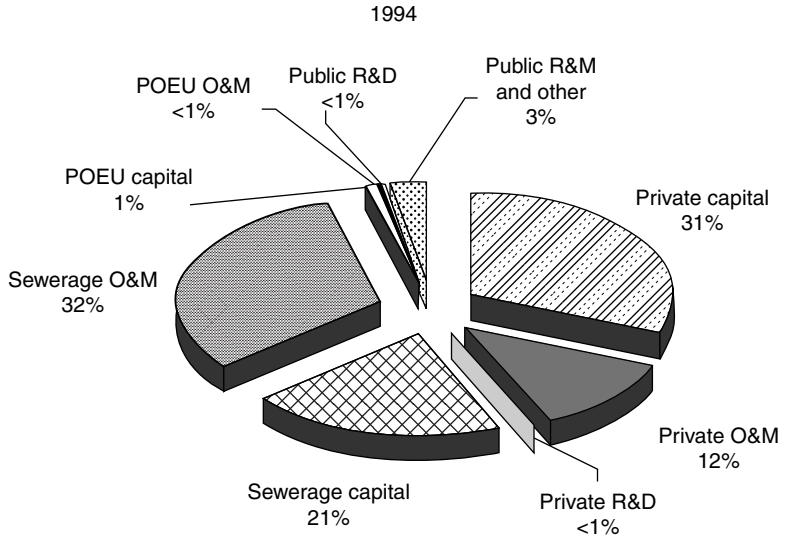
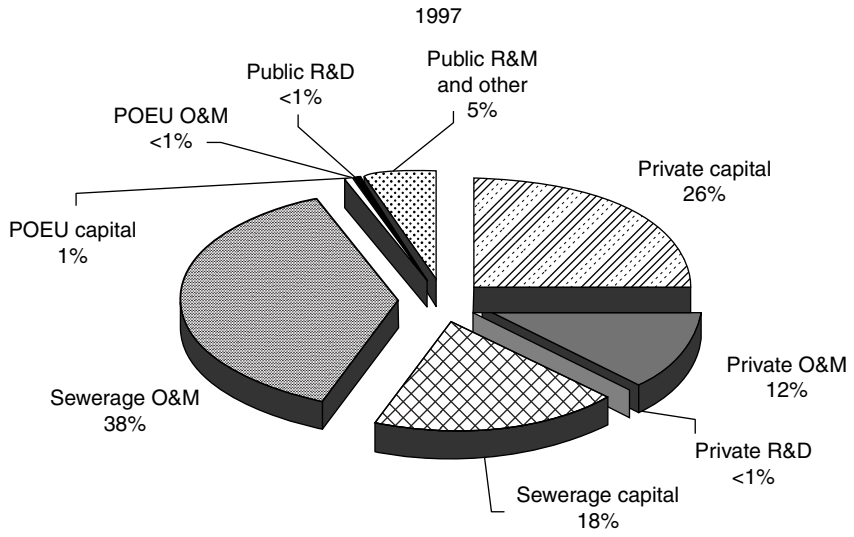



(a) Total incremental costs: $12.6 billion[a]




(b) Total incremental costs: $14.1 billion[a]

**Figure 11F.64** The distribution of the incremental annual costs attributable to the CWA (3 percent discount rate). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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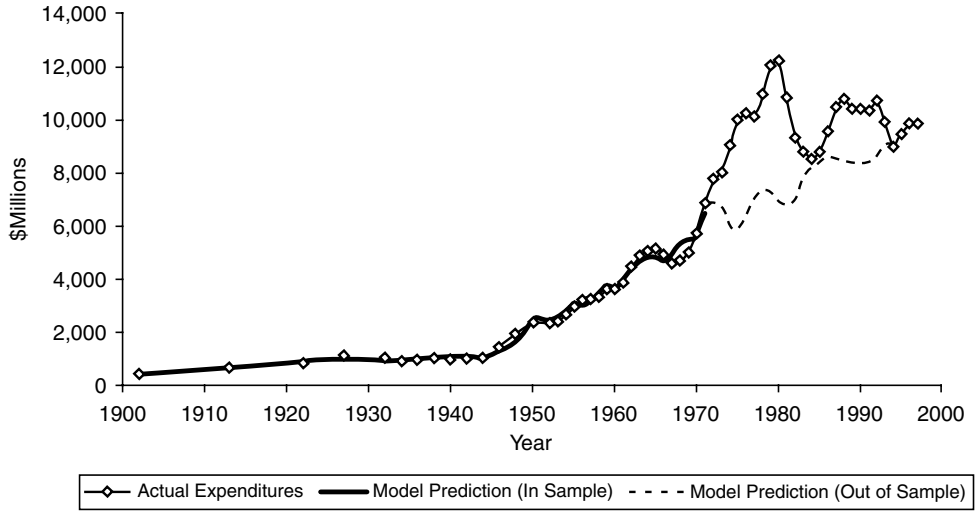


**Figure 11F.65** Public sewerage capital expenditures, actual vs. model predictions, 1902–1997 (1997 $). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

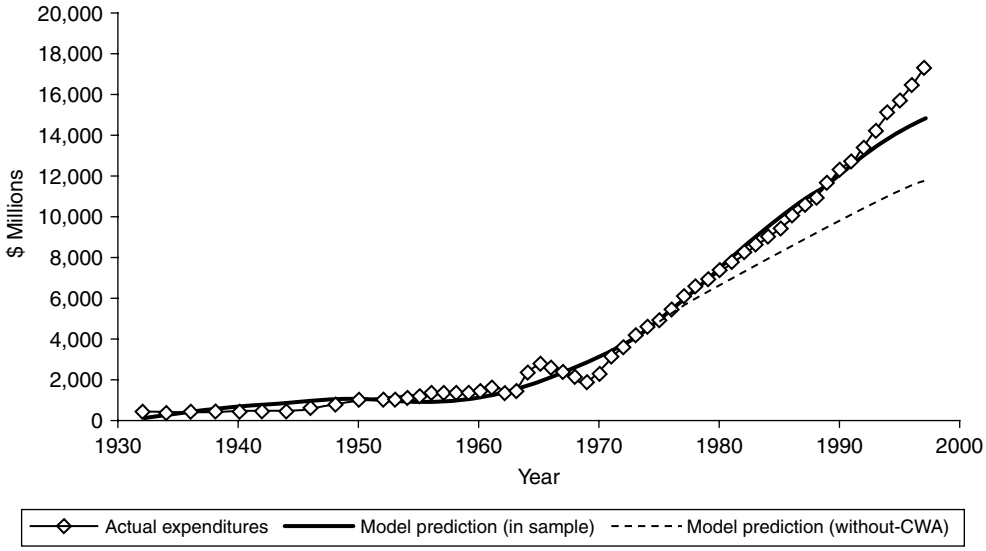


**Figure 11F.66** Public sewerage O&M expenditures, actual vs. model predictions, 1932–1997 (1997 $). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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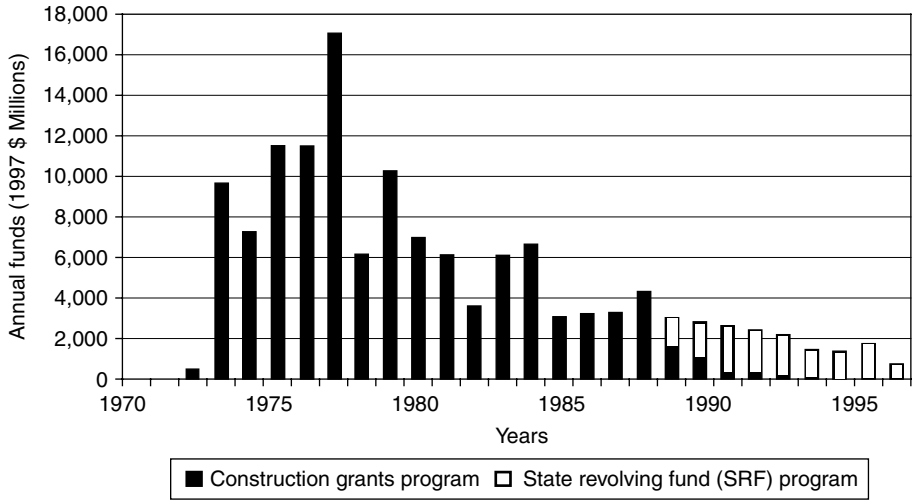


**Figure 11F.67** EPA's municipal water pollution control programs annual funds: 1970–1999 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

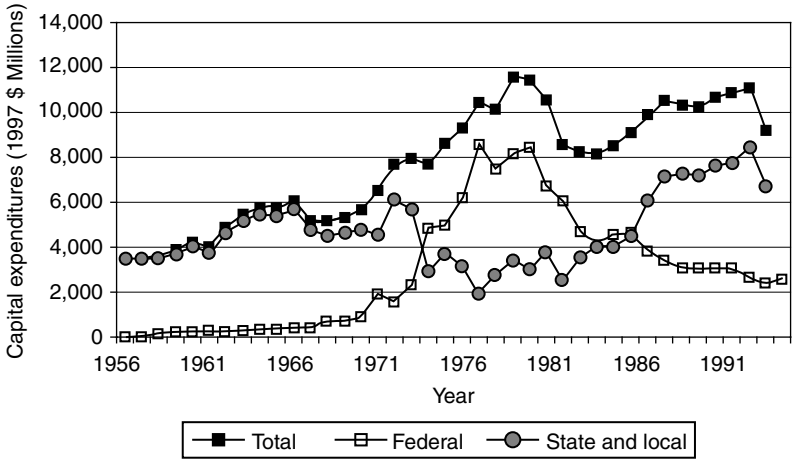


**Figure 11F.68** Public wastewater capital expenditures 1956–1995 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

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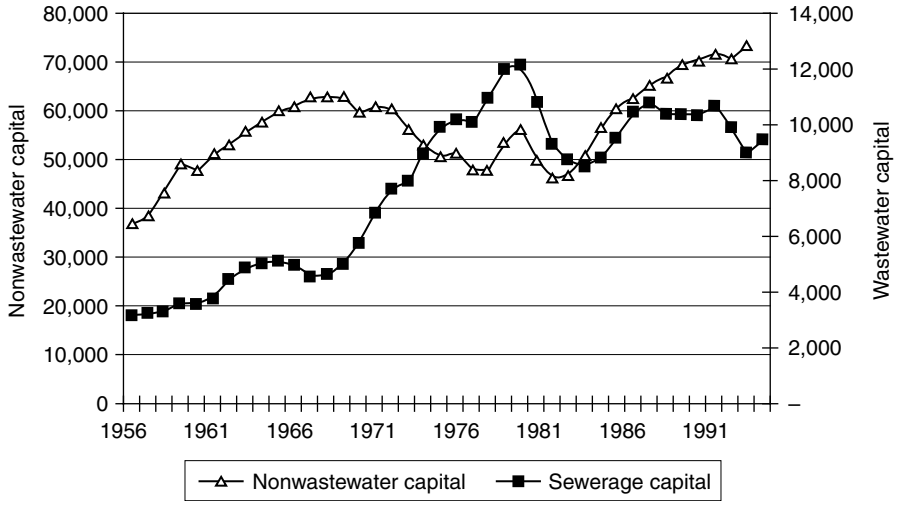


**Figure 11F.69** Public infrastructure capital expenditures, 1956–1995 (1997 $ millions). (From A Retrospective Assessment of the Costs of the Clean Water Act—1972–1997 Final Report, www.epa.gov.)

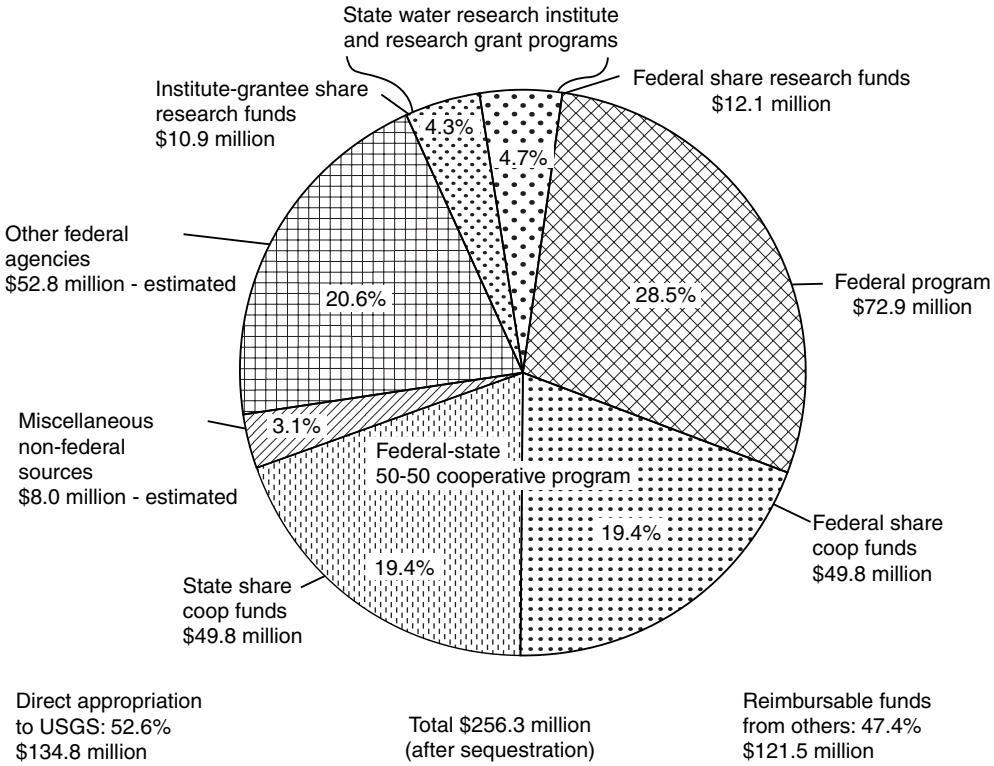


**Figure 11F.70** Source of funds for U.S. Geological Survey water resources investigations in 1986. (From Cardin, G.W. et al., 1986, Water Resources Division in the 1980s, *U.S. Geological Survey Circular 1005*.)

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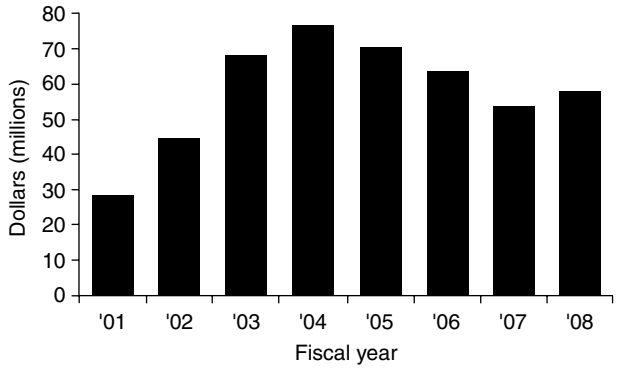


**Figure 11F.71** WMD water resource development funding levels. (From dep.state.fl.us.gov.)

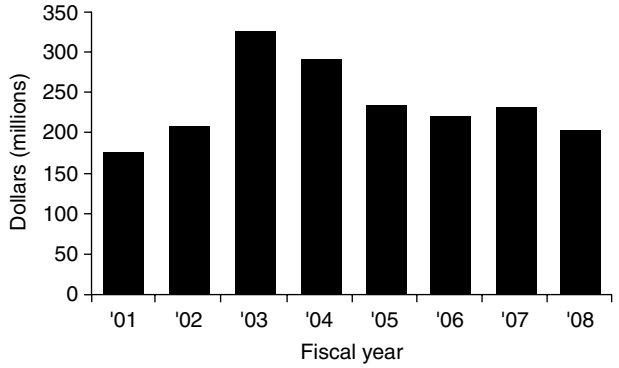


**Figure 11F.72** CERP water resource development funding levels. (From dep.state.fl.us.gov.)

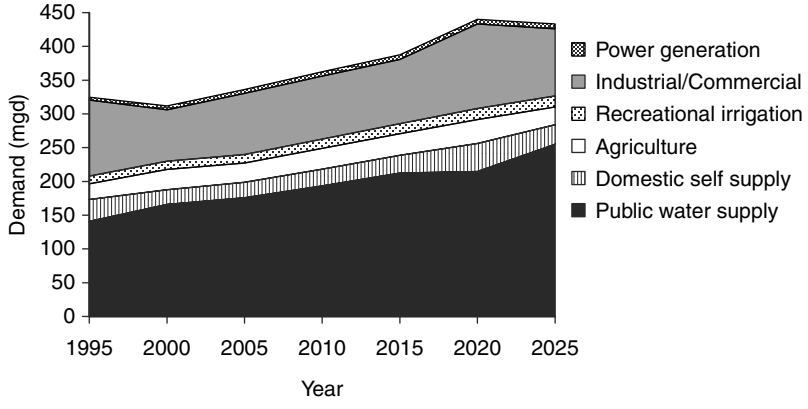


**Figure 11F.73** NWFWMD districtwide demand projections. (From dep.state.fl.us.gov.)

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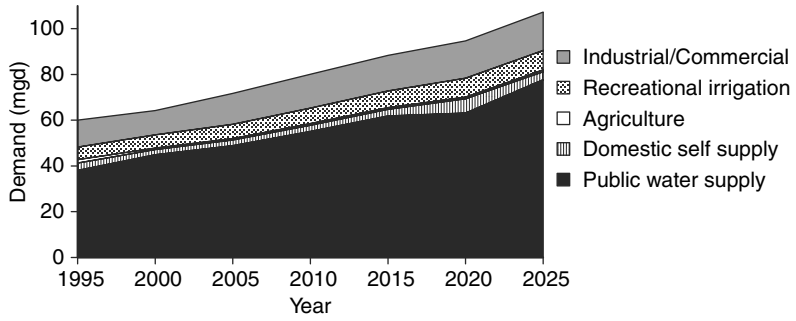


**Figure 11F.74** NWFWMD planning region II demand projections. (From www.dep.state.fl.us.gov.)

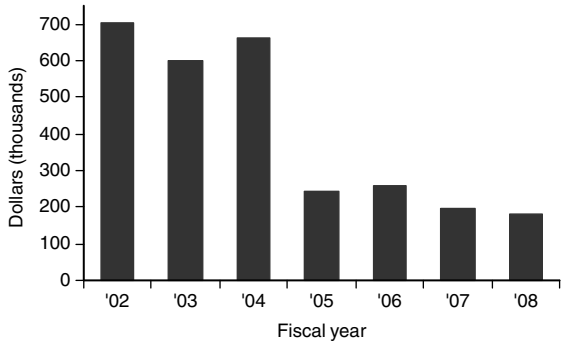


**Figure 11F.75** NWFWMD funding for water resource development. (From www.dep.state.fl.us.gov.)

**Table 11F.75 Northwest Florida Water Management District**

| | FY 96–97 | | FY 96–97 | | FY 97–98 | |
|---|---|---|---|---|---|---|
| | % of Total | Budgeted Amount | % of Total | Actual Amount | % of Total | Budgeted Amount |
| Ad Valorem Taxes | 7.25% | 1,538,980 | 7.13% | 1,463,439 | 3.73% | 1,683,660 |
| Ag Privilege Tax | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Canyover | 36.20% | 7,687,168 | 36.69% | 7,530,026 | 19.01% | 8,586,614 |
| Permit and License Fees | 1.92% | 407,125 | 2.07% | 424,295 | 0.91% | 411,725 |
| Local Revenues | 1.04% | 221,093 | 0.84% | 172,132 | 0.25% | 111,117 |
| Ecosystem Management Trust Fund | 6.66% | 1,415,000 | 3.40% | 697,804 | 3.25% | 1,466,951 |
| Water Management Lands Trust Fund | 26.79% | 5,688,528 | 26.50% | 5,439,483 | 63.84% | 28,832,639 |
| Other State Revenues | 16.81% | 3,569,188 | 12.75% | 2,617,545 | 4.83% | 2,181,521 |
| Federal Revenues | 1.61% | 341,886 | 1.36% | 279,957 | 2.72% | 1,230,603 |
| Miscellaneous Revenues | 1.71% | 363,730 | 9.26% | 1,900,201 | 1.46% | 660,835 |
| Total Revenues | 100.00% | 21,232,428 | 100.00% | 20,524,882 | 100.00% | 45,165,665 |
| Salaries and Benefits | 19.81% | 4,206,979 | 34.14% | 3,769,000 | 10.26% | 4,634,713 |
| Other Personal Services | 7.72% | 1,639,961 | 7.92% | 874,258 | 5.05% | 2,279,983 |
| Expenses | 5.55% | 1,178,662 | 8.19% | 904,625 | 2.58% | 1,164,141 |
| Operating Capital Outlay | 2.40% | 503,961 | 3.65% | 402,946 | 0.65% | 293,450 |
| Fixed Capital Outlay | 11.89% | 2,523,840 | 22.66% | 2,501,328 | 56.50% | 25,519,900 |
| Interagency Expenditures | 0.07% | 15,000 | 0.00% | 0 | 1.47% | 664,500 |
| Debt | 12.18% | 2,586,888 | 23.43% | 2,586,888 | 5.71% | 2,578,682 |
| Reserves | 40.37% | 8,571,137 | 0.00% | 0 | 4.66% | 8,030,296 |
| Transfers | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Total Expenditures | 100.00% | 21,232,428 | 100.00% | 11,039,045 | 100.00% | 45,165,665 |

*(Continued)*

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**Table 11F.75 (Continued)**

| | FY 96–97 | | FY 96–97 | | FY 97–98 | |
|---|---|---|---|---|---|---|
| | % of Total | Budgeted Amount | % of Total | Actual Amount | % of Total | Budgeted Amount |
| Water Resources Planning and Monitoring | 24.61% | 5,226,032 | 20.39% | 2,251,404 | 11.03% | 4,982,451 |
| Acquisition, Restoration and Public Works | 29.93% | 6,355,196 | 48.71% | 5,376,872 | 65.57% | 29,614,245 |
| Operation and Maint. of Lands and Works | 16.79% | 3,564,120 | 11.94% | 1,317,559 | 9.74% | 4,397,358 |
| Regulation | 5.10% | 1,083,356 | 12.46% | 1,375,545 | 3.25% | 1,468,615 |
| Outreach | 1.84% | 391,361 | 2.70% | 297,348 | 0.92% | 416,903 |
| District Management and Administration | 21.72% | 4,612,363 | 3.80% | 419,717 | 9.48% | 4,286,093 |
| **Total Allocations by Program** | **100.00%** | **21,232,428** | **100.00%** | **11,039,045** | **100.00%** | **45,165,665** |

*Note:* Budget summary comparison.

*Source*: From www.myflorida.com. With permission.

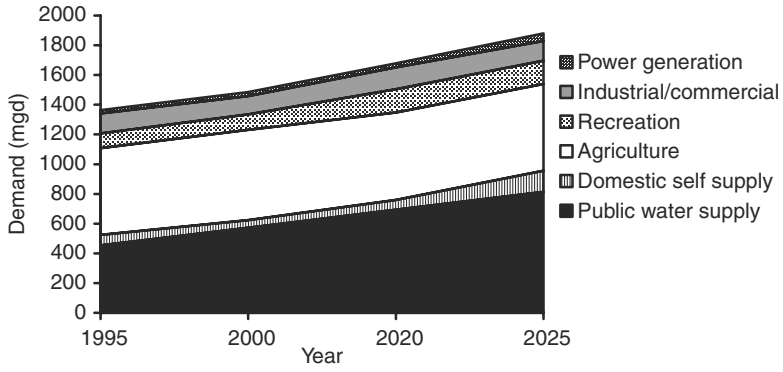


**Figure 11F.76** SJRWMD demand projections. (From www.dep.state.fl.us.gov.)

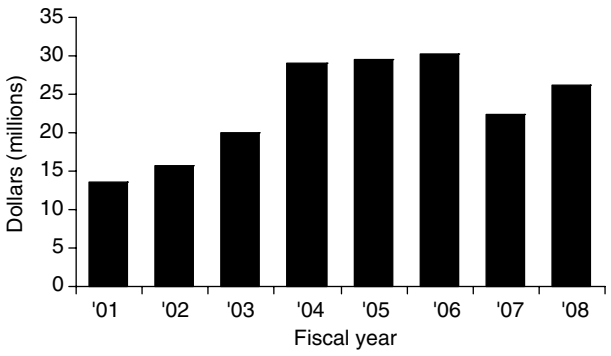


**Figure 11F.77** SJRWMD funding for water resource development. (From www.dep.state.fl.us.gov.)

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**Table 11F.76 St. Johns River Water Management District**

| | FY 96–97 | | FY 96–97 | | FY 97–98 | |
|---|---|---|---|---|---|---|
| | % of Total | Budgeted Amount | % of Total | Actual Amount | % of Total | Budgeted Amount |
| Ad Valorem Taxes | 31.63% | 53,154,717 | 42.335 | 53,821,960 | 40.91% | 56,165,728 |
| Ag Privilege Tax | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Canyover | 22.91% | 38,494,743 | 0.00% | 0 | 27.50% | 37,752,891 |
| Permit and License Fees | 0.85% | 1,435,000 | 1.56% | 1,985,787 | 1.05% | 1,435,000 |
| Local Revenues | 2.74% | 4,596,176 | 5.02% | 6,382,236 | 2.44% | 3,351,826 |
| Ecosystem Management Trust Fund | 1.18% | 1,975,000 | 0.00% | 0 | 0.29% | 398,334 |
| Water Management Lands Trust Fund | 36.88% | 61,971,000 | 38.87% | 49,433,409 | 21.64% | 29,700,000 |
| Other State Revenues | 2.85% | 4,789,693 | 1.38% | 1,753,092 | 3.83% | 5,256,395 |
| Federal Revenues | 0.81% | 1,367,657 | 10.71% | 13,623,113 | 2.08% | 2,851,000 |
| Miscellaneous Revenues | 0.15% | 250,350 | 0.13% | 161,352 | 0.26% | 363,475 |
| Total Revenues | 100.00% | 168,034,336 | 100.00% | 127,160,949 | 100.00% | 137,274,649 |
| Salaries and Benefits | 19.28% | 32,391,440 | 27.93% | 32,023,319 | 25.62% | 35,175,920 |
| Other Personal Services | 8.36% | 14,053,875 | 7.96% | 9,125,788 | 12.40% | 17,023,288 |
| Expenses | 17.32% | 29,101,707 | 15.09% | 17,301,201 | 2.58% | 28,874,227 |
| Operating Capital Outlay | 2.44% | 4,092,823 | 2.65% | 3,035,139 | 2.58% | 3,547,346 |
| Fixed Capital Outlay | 47.48% | 79,778,928 | 40.26% | 46,158,710 | 31.29% | 42,958,743 |
| Interagency Expenditures | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Debt | 4.16% | 6,995,563 | 6.10% | 6,995,563 | 5.10% | 6,995,313 |
| Reserves | 0.96% | 1,620,000 | 0.02% | 21,000 | 1.97% | 2,699,812 |
| Transfers | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Total Expenditures | 100.00% | 168,034,336 | 100.00% | 114,660,720 | 100.00% | 137,274,649 |
| Water Resources Planning and Monitoring | 8.99% | 15,100,215 | 10.37% | 11,889,183 | 13.36% | 18,333,253 |
| Acquisition, Restoration and Public Works | 63.68% | 106,997,469 | 56.06% | 64,275,456 | 51.43% | 70,597,860 |
| Operation and Maint. of Lands and Works | 9.85% | 16,544,807 | 11.55% | 13,247,852 | 14.34% | 19,687,942 |
| Regulation | 5.23% | 8,786,502 | 7.03% | 8,055,333 | 6.64% | 9,116,784 |
| Outreach | 2.79% | 4,691,488 | 2.42% | 2,771,517 | 2.53% | 3,479,199 |
| District Management and Administration | 9.47% | 15,913,855 | 12.58% | 14,421,379 | 11.70% | 16,059,611 |
| **Total Allocations by Program** | **100.00%** | **168,034,336** | **100.00%** | **114,660,720** | **100.00%** | **137,274,649** |

*Note:* Budget summary comparison.

*Source*: From www.myflorida.com. With permission.

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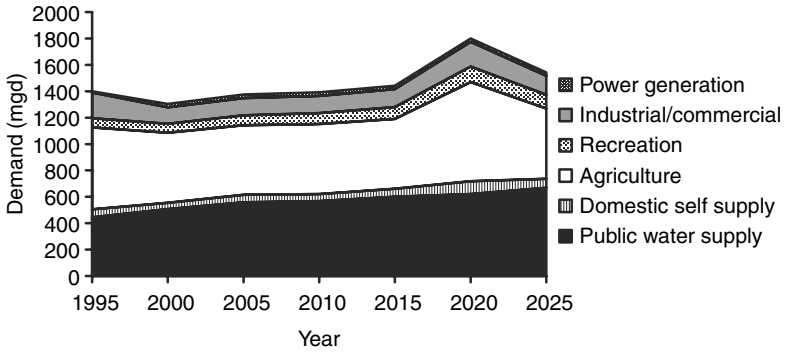


**Figure 11F.78** SWFWMD districtwide demand projections. (From www.dep.state.fl.us.gov.)

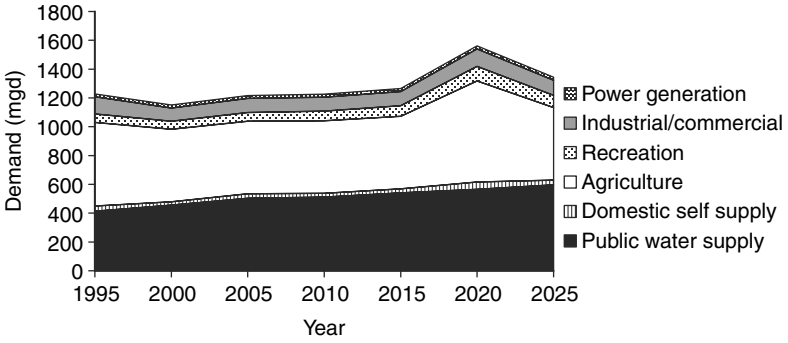


**Figure 11F.79** SWFWMD demand projections for RWSP planning region. (From www.dep.state.fl.us.gov.)

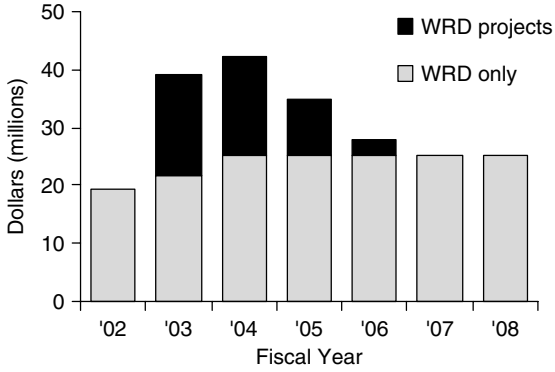


**Figure 11F.80** SWFWMD funding for water resource development. (From www.dep.state.fl.us.gov.)

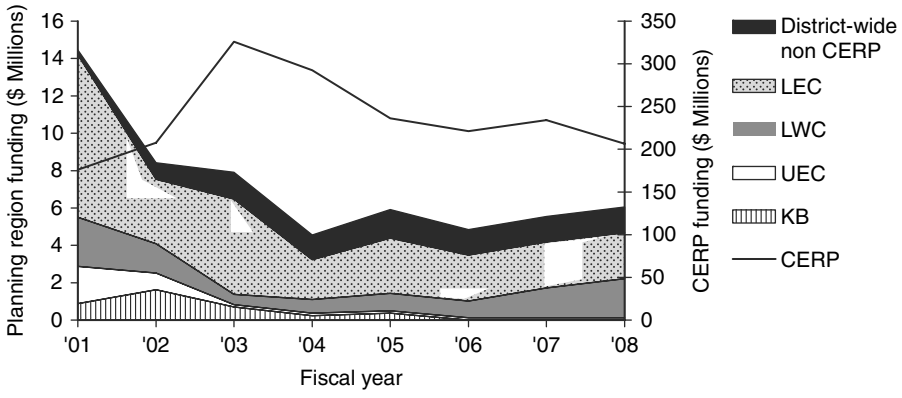


**Figure 11F.81** SFWMD funding for water resource development. (From www.dep.state.fl.us.gov.)

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**Table 11F.77 Southwest Florida Water Management District**

| | FY 96–97 | | FY 96–97 | | FY 97–98 | |
|---|---|---|---|---|---|---|
| | % of Total | Budgeted Amount | % of Total | Actual Amount | % of Total | Budgeted Amount |
| Ad Valorem Taxes | 56.08% | 84,214,617 | 65.85% | 84,602,369 | 57.61% | 88,033,728 |
| Ag Privilege Tax | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Canyover | 11.85% | 17,790,898 | 13.85% | 17,790,898 | 8.12% | 12,408,347 |
| Permit and License Fees | 1.00% | 1,500,000 | 1.49% | 1,914,065 | 1.10% | 1,680,000 |
| Local Revenues | 1.49% | 2,241,900 | 0.35% | 455,762 | 1.80% | 2,747,000 |
| Ecosystem Management Trust Fund | 1.32% | 1,975,000 | 0.92% | 1,176,059 | 0.26% | 398,333 |
| Water Management Lands Trust Fund | 22.90% | 34,390,755 | 7.33% | 9,423,549 | 23.25% | 35,522,479 |
| Other State Revenues | 0.65% | 982,628 | 1.34% | 1,717,221 | 1.85% | 2,833,327 |
| Federal Revenues | 0.07% | 100,000 | 0.00% | 0 | 0.00% | 0 |
| Miscellaneous Revenues | 4.65% | 6,979,138 | 8.88% | 11,403,192 | 6.01% | 9,183,821 |
| Total Revenues | 100.00% | 15,174,936 | 100.00% | 128,483,105 | 100.00% | 152,807,035 |
| Salaries and Benefits | 23.53% | 35,342,618 | 37.85% | 35,343,410 | 24.13% | 36,879,607 |
| Other Personal Services | 10.90% | 16,366,679 | 13.12% | 12,252,750 | 11.02% | 16,843,524 |
| Expenses | 8.05% | 12,092,405 | 12.55% | 11,719,061 | 8.17% | 12,479,555 |
| Operating Capital Outlay | 1.23% | 1,845,113 | 2.93% | 2,739,702 | 1.48% | 2,255,571 |
| Fixed Capital Outlay | 20.61% | 30,947,900 | 9.05% | 8,449,110 | 20.84% | 31,837,414 |
| Interagency Expenditures | 26.21% | 39,365,754 | 23.58% | 22,017,359 | 27.91% | 42,648,355 |
| Debt | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Reserves | 8.34% | 12,530,329 | 0.00% | 0 | 4.66% | 7,123,188 |
| Transfers | 1.12% | 1,684,138 | 0.91% | 847,700 | 1.79% | 2,739,821 |
| Total Expenditures | 100.00% | 150,174,936 | 100.00% | 93,369,092 | 100.00% | 152,807,035 |
| Water Resources Planning and Monitoring | 5.38% | 8,077,256 | 9.69% | 9,050,500 | 6.63% | 10,130,046 |
| Acquisition, Restoration and Public Works | 27.92% | 41,933,068 | 17.00% | 15,870,244 | 28.31% | 43,263,249 |
| Operation and Maint. of Lands and Works | 7.07% | 10,623,684 | 10.47% | 9,771,258 | 7.00% | 10,701,419 |
| Regulation | 8.11% | 12,178,886 | 11.94% | 11,147,497 | 8.19% | 12,520,095 |
| Outreach | 35.61% | 53,483,156 | 28.54% | 26,646,697 | 33.42% | 51,064,962 |
| District Management and Administration | 15.90% | 23,878,886 | 22.37% | 20,882,896 | 16.44% | 25,127,264 |
| **Total Allocations by Program** | **100.00%** | **150,174,936** | **100.00%** | **93,369,092** | **100.00%** | **152,807,035** |

*Note:* Budget summary comparison.

*Source*: From www.myflorida.com. With permission.

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**Table 11F.78 South Florida Water Management District**

| | FY 96–97 | | FY 96–97 | | FY 97–98 | |
|---|---|---|---|---|---|---|
| | % of Total | Budgeted Amount | % of Total | Actual Amount | % of Total | Budgeted Amount |
| Ad Valorem Taxes | 37.53% | 177,099,989 | 56.61% | 179,297,173 | 45.42% | 195,363,519 |
| Ag Privilege Tax | 2.73% | 12,880,532 | 3.86% | 12,230,695 | 2.87% | 12,357,026 |
| Canyover | 22.85% | 107,813,178 | 0.00% | 0 | 21.37% | 91,904,398 |
| Permit and License Fees | 0.49% | 2,328,250 | 0.65% | 2,062,164 | 0.45% | 1,941,075 |
| Local Revenues | 0.03% | 156,140 | 0.14% | 441,006 | 0.11% | 477,000 |
| Ecosystem Management Trust Fund | 0.45% | 2,100,000 | 0.06% | 183,791 | 0.09% | 398,000 |
| Water Management Lands Trust Fund | 2.47% | 11,640,000 | 3.93% | 12,459,257 | 2.99% | 12,875,000 |
| Other State Revenues | 15.88% | 74,939,224 | 15.51% | 49,133,150 | 8.51% | 36,610,955 |
| Federal Revenues | 14.44% | 68,118,314 | 11.51% | 36,455,517 | 14.37% | 61,824,950 |
| Miscellaneous Revenues | 3.13% | 14,751,946 | 7.73% | 24,475,208 | 3.81% | 16,401,080 |
| Total Revenues | 100.00% | 471,827,573 | 100.00% | 316,737,961 | 100.00% | 439,152,903 |
| Salaries and Benefits | 20.71% | 97,718,919 | 31.82% | 91,204,979 | 17.14% | 73,712,088 |
| Other Personal Services | 7.08% | 33,426,318 | 6.76% | 19,368,300 | 14.32% | 61,606,721 |
| Expenses | 10.44% | 49,257,512 | 12.84% | 36,796,249 | 10.63% | 45,744,725 |
| Operating Capital Outlay | 3.81% | 17,957,747 | 2.59% | 7,434,809 | 3.59% | 15,430,762 |
| Fixed Capital Outlay | 45.59% | 215,111,342 | 39.37% | 112,841,705 | 40.85% | 175,702,565 |
| Interagency Expenditures | 5.13% | 24,203,548 | 4.46% | 12,784,047 | 9.98% | 42,935,634 |
| Debt | 1.31% | 6,172,033 | 2.15% | 6,172,033 | 1.83% | 7,866,097 |
| Reserves | 5.93% | 27,980,154 | 0.00% | 0 | 1.66% | 7,154,311 |
| Transfers | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Total Expenditures | 100.00% | 471,827,573 | 100.00% | 286,602,122 | 100.00% | 430,152,903 |
| Water Resources Planning and Monitoring | 9.71% | 45,811,978 | 12.19% | 34,941,956 | 14.41% | 61,969,108 |
| Acquisition, Restoration and Public Works | 61.28% | 289,154,312 | 48.75% | 139,727,913 | 51.64% | 222,144,554 |
| Operation and Maint. of Lands and Works | 12.93% | 61,020,642 | 19.07% | 54,649,903 | 14.58% | 62,711,481 |
| Regulation | 2.37% | 11,162,461 | 3.67% | 10,518,609 | 2.79% | 12,009,635 |
| Outreach | 2.76% | 13,034,200 | 2.60% | 7,441,626 | 5.25% | 22,571,014 |
| District Management and Administration | 10.95% | 51,643,980 | 13.72% | 39,322,115 | 11.33% | 48,747,111 |
| **Total Allocations by Program** | **100.00%** | **471,827,573** | **100.00%** | **286,602,122** | **100.00%** | **430,152,903** |

*Note:* Budget summary comparison.

*Source*: From www.myflorida.com. With permission.

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**Table 11F.79 Suwannee River Water Management District**

| | FY 96–97 | | FY 96–97 | | FY 97–98 | |
|---|---|---|---|---|---|---|
| | % of Total | Budgeted Amount | % of Total | Actual Amount | % of Total | Budgeted Amount |
| Ad Valorem Taxes | 12.99% | 2,500,000 | 12.85% | 2,504,734 | 12.49% | 2,675,000 |
| Ag Privilege Tax | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Canyover | 12.30% | 2,367,000 | 3.40% | 663,536 | 9.80% | 2,099,000 |
| Permit and License Fees | 1.12% | 2,15,000 | 1.02% | 198,318 | 1.00% | 215,000 |
| Local Revenues | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Ecosystem Management Trust Fund | 9.74% | 1,875,000 | 0.92% | 179,841 | 5.51% | 1,179,700 |
| Water Management Lands Trust Fund | 53.30% | 1,0,259,200 | 68.76% | 3,401,803 | 49.03% | 10,500,000 |
| Other State Revenues | 7.75% | 1,492,000 | 7.77% | 1,515,299 | 18.48% | 3,957,700 |
| Federal Revenues | 0.78% | 1,49,500 | 0.44% | 86,606 | 1.84% | 395,000 |
| Miscellaneous Revenues | 2.03% | 390,000 | 4.83% | 941,828 | 1.84% | 394,400 |
| Total Revenues | 100.00% | 1,9,247,700 | 100.00% | 19,491,965 | 100.00% | 21,415,800 |
| Salaries and Benefits | 20.41% | 3,929,000 | 27.65% | 3,544,152 | 17.95% | 3,843,100 |
| Other Personal Services | 26.54% | 5,108,300 | 22.45% | 2,877,909 | 29.47% | 6,310,300 |
| Expenses | 5.82% | 1,120,000 | 5.77% | 739,199 | 5.89% | 1,261,200 |
| Operating Capital Outlay | 2.09% | 402,300 | 2.67% | 341,992 | 1.23% | 263,200 |
| Fixed Capital Outlay | 38.54% | 7,418,000 | 31.55% | 4,044,309 | 39.34% | 8,426,000 |
| Interagency Expenditures | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Debt | 6.60% | 1,270,100 | 9.91% | 1,269,591 | 5.89% | 1,262,000 |
| Reserves | 0.00% | 0 | 0.00% | 0 | 0.23% | 50,000 |
| Transfers | 0.00% | 0 | 0.00% | 0 | 0.00% | 0 |
| Total Expenditures | 100.00% | 19,247,700 | 100.00% | 12,817,152 | 100.00% | 21,415,800 |
| Water Resources Planning and Monitoring | 23.17% | 4,459,500 | 21.08% | 2,702,432 | 19.23% | 4,117,900 |
| Acquisition, Restoration and Public Works | 48.50% | 9,334,300 | 46.95% | 6,017,836 | 43.88% | 9,398,200 |
| Operation and Maint. of Lands and Works | 6.70% | 1,289,900 | 7.48% | 958,889 | 7.26% | 1,554,200 |
| Regulation | 7.28% | 1,401,500 | 7.75% | 992,874 | 16.09% | 3,445,300 |
| Outreach | 1.92% | 369,900 | 2.60% | 333,180 | 2.03% | 435,500 |
| District Management and Administration | 12.43% | 2,392,600 | 14.14% | 1,811,941 | 11.51% | 2,464,700 |
| **Total Allocations by Program** | **100.00%** | **19,247,700** | **100.00%** | **12,817,152** | **100.00%** | **21,415,800** |

*Note:* Budget summary comparison.

*Source*: From www.myflorida.com. With permission.

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**Table 11F.80 Water Resources Research Categories**

I. Nature of Water

Category I deals with fundamental research on the water substance

A. *Properties of water*—Study of the physical and chemical properties of pure water and its thermodynamic behavior in its various states

B. *Aqueous solutions and suspensions*—Study of the effects of various solutes on the properties of water; surface interactions; colloidal suspensions

II Water Cycle

Category II covers generally research on the natural processes involving water. It is an essential supporting effort to applied problems in later categories

A. *General*—Studies involving two or more phases of the water cycle such as hydrologic models; rainfall-runoff relations; surface and groundwater relationships; watershed studies, etc.

B. *Precipitation*—Investigation of spatial and temporal variations of precipitation; physiographic effects; time trends; extremes; probable maximum precipitation; structure of storms, etc.

C. *Snow, ice, and frost*—Studies of the occurrence and thermodynamics of water in the solid state in nature; spatial variations of snow and frost; formation of ice and frost; breakup of river and lake ice; glaciers, permafrost, etc.

D. *Evaporation and transpiration*—Investigation of the process of evaporation from lakes, soil, and snow and of the transpiration process in plants; methods of estimating actual evapotranspiration; energy balance; etc.

E. *Streamflow*—Mechanics of flow in streams; flood routing; bank storage; space and time variations (includes high and low-flow frequency); droughts; floods, etc.

F. *Groundwater*—Study of the mechanics of groundwater movements; multiphase systems; sources of natural recharge; mechanics of flow to wells and drains; subsidence; properties of aquifers; etc.

G. *Water in soils*—Infiltration, movement and storage of water in the zone of aeration, including soil

H. *Lakes*—Hydrologic, hydrochemical, and thermal regimes of lakes; water level fluctuations; currents and waves

I. *Water and plants*—Role of plants in hydrologic cycle; water requirements of plants; interception

J. *Erosion and sedimentation*—Studies of the erosion process; prediction of sediment yield; sedimentation in lakes and reservoirs; stream erosion; sediment transport, etc.

K. *Chemical processes*—Chemical interactions between water and its natural environment; chemistry of precipitation

L. *Estuarine problems*—Special problems of the estuarine environment; effect of tides on flow and stage; deposition of sediments; sea water intrusion in estuaries

III Water Supply Augmentation and Conservation

As water use increases we must pay increasing attention to methods for augmenting and conserving available supplies. Research in Category III is largely applied research devoted to this problem area

A. *Saline water conversion*—Research and development related to methods of desalting sea water and brackish water

B. *Water yield improvement*—Increasing streamflow or improving its distribution through land management; water harvesting from impervious areas; phreatophyte control; reservoir evaporation suppression

C. *Use of water of impaired quality*—Research on methods of agricultural use of water of high salinity; use of poor quality water in industry; crop tolerance to salinity

D. *Conservation in domestic use*—Methods for reducing domestic water needs without impairment of service

E. *Conservation in industry*—Reduction in both consumption and diversion requirements for industry

F. *Conservation in agriculture*—More efficient irrigation practices. Chemical control of evaporation and transpiration; lower water use plants, etc.

IV Water Quantity Management and Control

Category IV includes research directed to the management of water, exclusive of conservation, and the effects of related activities on water

A. *Control of water on the land*—Effects of land management on runoff; land drainage, potholes; etc.

B. *Groundwater management*—Artificial recharge; conjunctive operation; relation to irrigation

C. *Effects of man's related activities on water*—Impact of urbanization, highways, logging, etc. on water yields and flow rates

D. *Watershed protection*—Methods of controlling erosion to reduce sediment load of streams and conserve soil

V Water Quality Management and Protection

An increasing population increases the wastes and other pollutants entering our water supplies. Category V deals with methods of identifying, describing and controlling this pollution

A. *Identification of pollutants*—Techniques of identification of physical, chemical and biological pollutants; rational measures of character and strength of wastes

B. *Sources and fate of pollution*—Determination of the sources of pollutants in water; the nature of the pollution from various sources; path of pollutant from source to stream of groundwater

C. *Effects of pollution*—Definition of the effect of pollutants, singly and in combination, on man, aquatic life, agriculture and industry under conditions of sustained use; eutrophication

D. *Waste treatment processes*—Research to improve conventional treatment methods to gain efficiency or reduce cost; processes to treat new types of waste; advanced treatment methods ofr more complete removal of pollutants including purification for direct reuse

E. *Ultimate disposal of wastes*—Disposal of residual material removed from water and sewage during the treatment process; disposal of waste brines

*(Continued)*

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**Table 11F.80 (Continued)**

| | |
|---|---|
| | F. *Water treatment*—Development of more efficient and economical methods of making water suitable for domestic or industrial use |
| | G. *Water quality control*—Research on methods to control stream and reservoir water quality such as flow augmentation; stream and reservoir aeration; control of natural pollution; control of pollution from pesticides and agricultural chemicals; control of acid mine drainage; etc. |
| VI | Water Resources Planning |
| | The problems of achieving an optimal plan of water development are becoming increasingly complex. Category VI covers research devoted to determining the best way to plan, the appropriate criteria for planning and the nature of the economic, legal and institutional aspects of the planning process |
| | A. *Techniques of planning*—Application of systems analysis to project planning; treatment of uncertainty; probability studies |
| | B. *Evaluation process*—Development of methods, concepts and criteria for evaluating project benefits; discount rate; project life; methods for economic, social and technological projections; reliability of projections; research on the value of water in various uses |
| | C. *Cost allocation, cost sharing, pricing/repayment*—Research on methods of calculating repayment and establishing prices for vendible products; techniques of cost allocation; cost sharing, pricing and repayment policy |
| | D. *Water demand*—Research on the water quantity and quality requirements of various uses, both diversion and consumption |
| | E. *Water law and institutions*—A study of state and Federal water law looking to changes and additions which will encourage greater efficiency in use; investigation of institutional structures and constraints which influence decisions on water at all levels of government |
| | F. *Nonstructural alternatives*—Exploration of methods to achieve water development aims by nonstructural methods such as flood plain zoning |
| | G. *Ecologic impact of water development*—Effects of water management operations on overall ecology of the area. Excludes effect of pollution under V-C |
| VII | Resources Data |
| | Planning and management of our water resources require information. Category VII includes research oriented to data needs and the most efficiency method of meeting these needs |
| | A. *Network design*—Studies of data requirements and of the most effective methods of collecting the data |
| | B. *Data acquisition*—Research on new and improved instruments and techniques for collection of water resources data; telemetering equipment |
| | C. *Evaluation, processing and publication*—Studies of effective methods of processing data, form and nature of published data; maps of data |
| VIII | Engineering Works |
| | To implement water development plans requires engineering works. Category VIII describes research on design, materials and construction which is generally useful to all aspects of water management. Works relevant to a single specific goal, such as water treatment or desalination, are included elsewhere if an appropriate category exists |
| | A. *Design*—Research leading to improved design of dams, canals, pipelines, locks, fishways, and other works required for water resource development |
| | B. *Materials*—Research to improve existing structural materials and to develop new materials; subsurface exploration of foundations; corrosion; etc. |
| | C. *Construction and operation*—Research on efficient construction methods, operating systems, and maintenance procedures |
| IX | Manpower, Grants and Facilities |
| | Trained manpower is an essential ingredient of research on water resources and the planning and design of water development projects. Category IX describes plans for support of education and training. It also includes grant and contract programs for which advance distribution to specific categories is impossible |
| | A. *Education*—extramural—Support of education in water resources at universities (not including reaerch support under other categories) |
| | B. *Education*—in-house—Government employee training programs |
| | C. *Research facilities*—Laboratories, field stations, etc. |
| | D. *Grants, contracts and research and allotments*—Allotments to University Water Resources Research Institutes under P.L. 88–379; OWRR, HEW, NSF, CSRS, and other grants which cannot be distributed to categories in advance |

*Source*: From Committee on Water Resources Research, *Federal Council for Science and Technology*, 1966.

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**Table 11F.81 Water Resources Research in the United States — Areas of Interest in 1989**

General Areas of Interest

1. Aspects of the hydrologic cycle
2. Supply and demand for water
3. Demineralization of saline and other impaired waters
4. Conservation and best use of available supplies of water and methods of increasing such supplies
5. Water reuse
6. Depletion and degradation of groundwater supplies
7. Improvements in the productivity of water when used for agricultural, municipal, and commercial purposes
8. The economic, legal, engineering, social, recreational, biological, geographic, ecological, and other aspects of water problems
9. Scientific information-dissemination activities, including identifying, assembling and interpreting the result of scientific and engineering research on water resources problems
10. Providing means for improved communications of research results, having due regard for the varying conditions and needs for the respective States and regions

*Specific Areas of Interest*

A. Groundwater quality

1. An improved understanding of the transport and fate of contaminants in groundwater and in the unsaturated zone, from both field and modeling studies. This will require attention to the physical, microbial, and chemical interactions encountered by dissolved, miscible, and immiscible substances in groundwater transport
2. Better equipment and methodology for monitoring and characterizing the chemical, physical, and biological conditions of the subsurface environment, including sampling strategies that lead to an approved understanding of groundwater contamination at scales larger than single contamination sources

B. Water quality management

1. An improved understanding of hazardous substances in water, including interactions of synthetic and natural organics, interactions of waterborne toxic materials with organisms, the binding of chemical species to waterborne sediments, and microbial alteration of organic compounds in aqueous environments
2. Improved methods for treatment or control of contaminants in natural water systems, emphasizing reduction, removal, or alteration to prevent further contamination or to increase potable supplies
3. Applications of biotechnology to water resources, including detection of specific pollutants using DNA probes and genetic engineering of microorganisms for water quality management
4. Use of waters of impaired quality, including improved physical and chemical methods for treatment of impaired waters and the cost-effective utilization of brackish waters

C. Institutional change in water resource management

1. Analysis of the social aspects and the distributive consequences of alternative institutional arrangements
2. Description and evaluation of institutions for consideration/compensation of third-party interests; i.e., those individuals or groups affected by, but external to, reallocation decisions
3. A description of the market structure that has evolved or is likely to evolve if institutional change involves development of water markets
4. Representative case studies providing estimates of economic efficiency gains and the distributive consequences from institutional changes

*Source*: From *U.S. Geological Survey*, 1988, Announcement 7442, Request for Applications Under the Water Resources Research Act of 1984 (Section 105).

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**Table 11F.82 Demand and Funding Summary of Planning Regions**

| | Dates for RWSPs | | Current and Projected Water Demands (mgd) | | | Funding and Water Made Available | |
|---|---|---|---|---|---|---|---|
| Planning Region | Completed | Update | 2000 Demand | Previously Projected 2020 Demand | Current Projected 2025 Demand | WRD for Next 5 Years ($ millions) | Additional Water to Be Made Available by WRD (mgd) |
| NWFWMD (Region II) | 2001 | Oct. 2005 | 64 | 95 | 107 | 1.5 | 81 by 2020 |
| SJRWMD (Entire WMD) | 2000 | Oct. 2005 | 1,485 | 1,679 | 1,880 | 136.8 | 751 total potential |
| SWFWMD (Central and Southern part of WMD) | 2001 | Dec. 2005 | 1,151 | 1,562 | 1,432 | 155.5 | 42 by 2004, 678 total potential |
| SFWMD | | | | | | | |
| Kissimmee Basin | 2000 | July 2005 | 264 | 663 | 398 | 0.61 | 71 by 2008 |
| Upper East Coast | 2000 | June 2004 | 292 | 660 | 338 | 0.63 | 63 by 2008 |
| Lower West Coast | 2000 | Oct. 2005 | Not available | 1,099 | Not available | 6.2 | 190 by 2008 |
| Lower East Coast | 2000 | Dec. 2005 | Not available | 2,521 | Not available | 12.5 | 155 by 2008 |
| Districtwide Projects | | | | | | 6.95 | |

*Source*: From USGS Water Use Data 2000.

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**Table 11F.83 Funding Source Water Protection Activities**

| Funding Sources | Polluted Runoff Control | | | | | | Resource Protection and Restoration | | | | | | Wastewater | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | Forestry | Mining | Brownfields | Storage Tanks (above ground & underground) | Landfills | Hydromodification/ Habitat Modification | Wetlands/Riparian Zone | Land Acquisition/ Conservation Easements | Groundwater Protection Measures | Land Use Controls | Public Education | Stormwater | On-Site Sewage |
| EPA Brownfields Cleanup Revolving Loan Fund Pilots FY '03—Grants to $1M | | • | • | | | | | | | | | • | | |
| EPA Chesapeake Bay Program Grants FY '02—$750,000 FY '03—$2M | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| EPA Clean Water State Revolving Fund Loans FY '02—$4.4B FY '03—$4.0B (est.) | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| EPA Drinking Water State Revolving Fund Set-Asides Up to 31% Cap. Grant | • | • | | | • | | • | • | • | • | • | • | • | • |
| EPA Great Lakes Program FY '02—$5.7M FY '03—$5.7M (est.) | | | | | | | • | • | | • | | • | | |
| EPA Nonpoint (319) Source Implementation Grants FY '02—$237.5M FY '03—$238.4M | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| EPA Pollution Prevention Incentives for States FY '02—$5M FY '03—$5M | | | | | | | | | | • | • | • | | |
| EPA Tribal DW Capacity Building/SWP Grants FY '02—$1.9M FY '03—$1.9M | • | • | | | | | • | • | • | • | | | | |



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| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPA | Tribal Grants for Surface/ Grandwater Protection<br>FY '02—$447,700<br>FY '03—$445,500 | • | | | | | | • | • | • | • | | • | | | | | | |
| EPA | Underground Injection Control Grants<br>FY '02—$10M<br>FY '03—$10M | | | | | | | | | | • | | • | | | | | | |
| EPA | Water Pollution Control (106) Program Support<br>FY '02—$192.5M<br>FY '03—$180.4M | • | | | | | | | | | • | • | • | • | | | | | |
| EPA | Water Quality Cooperative Agreements<br>FY '02—$18.96M<br>FY '03—$18.84M | • | • | • | • | • | • | • | • | | • | | • | • | • | | | | |

**Funding Source Details and Contact Information**

Brownfields Cleanup Revolving Loan Fund Pilots: The objective of the Brownfields Cleanup Loan Fund grants is to capitalize loan funds that can make loans or grants to facilitate cleanup of brownfield sites contaminated with hazardous substances or petroleum products, as well as mine scarred land and 'drug labs.' Eligible organizations include businesses, nonprofit groups, local governments, state/territorial agencies, or tribal agencies. For more information see: www.epa.gov/brownfields

Chesapeake Bay Program Grants: Provides grant awards to reduce and prevent pollution and to improve the living resources of the Chesapeake Bay Watershed. Grants may be provided to state and local governments and nonprofit organizations for implementation projects, as well as monitoring and other related activities in the Chesapeake Bay Basin (Maryland, Pennsylvania, Virginia, and District of Columbia). For more information see: www.chesapeakebay.net

Clean Water State Revolving Fund Loans: Funds are used to make low interest loans to communities, individuals and others for water-quality improvement activities. Traditionally the funds have been used for wastewater treatment facilities, however loans are used increasingly for other water quality management activities including nonpoint source and estuary projects. The CWSRF is currently funding approximately $4 billion annually. For more information see: www.epa.gov/owm/cwfinance/cwsrf

Drinking Water State Revolving Fund Set-Asides: Up to 31% of the DWSRF capitalization grant may be used for set-aside activities including loans for the acquisition of land or easements for source water protection or for implementation of source water protection measures, or direct assistance for wellhead protection programs. For more information see; www.epa.gov/safewater/dwsrf.html

Great Lakes Program: EPA's Great Lakes Program issues awards to monitor Great Lakes ecosystem indicators; provide public access to Great Lakes data; help communities address contaminated sediments; support local protection and restoration activities; promote pollution prevention; and provide assistance to implement community-based Remedial Action Plans and for Lakewide Management Plans. For more information see: www.epa.gov/glnpo/fund/glf.html

Nonpoint (319) Source Implementation Grants: Provides grants to states and tribes to implement nonpoint source projects and programs. These include Best Management Practices (BMP) installation for animal wastes and sediment, pesticide and fertilizer control, stream bank restoration, lake protection/restoration, septic system restoration and management, etc. Al beneficiaries, except for tribes, are required to provide 40% of the total project or program costs. For more information see: www.epa.gov/owow/nps/cwact.html

Pollution Prevention Incentives for States: Provides grants focused on institutionalizing multimedia (air, water, land) pollution prevention techniques. Eligible entities include state and local agencies, universities, nonprofit organizations, and private business. Projects include technical assistance, data collection, education and outreach, training, environmental auditing, demonstration projects, and the integration of pollution prevention into state regulatory programs. For more information see: www.epa.gov/p2/grants/

Tribal Drinking Water Capacity Building/Source Water Protection Grants: Grants are intended to increase tribal capability to provide safe drinking water to consumers, and to prevent tribal sources of drinking water from being contaminated. Eligible projects might include source water assessments and the development and implementation of a source water protection program, and projects to improve a drinking water system's technical, financial and managerial capacity. For more information see: www.epa.gov/safewater/protect.html

Tribal Grants for Surface and Groundwater Protection, Pesticide Management Planning: Funds are available for tribes to develop Pesticide Management Plans (PMPs) and to address other pesticide-related groundwater concerns. The funding is intended for short term projects, stand alone components of larger projects, or projects that are expected to be self-sustaining once funding is used. For more information see: www.epa.gov/oppfead1/rstfield/

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Underground Injection Control Grants: Provides grant funds to states for such purposes as state regulation review, program plan developments, data management, inventory of injection facilities, identification of aquifers, public participation, technical assistance and review, permit approval and enforcement, and surveillance and investigation. For more information see: epa.gov/opwdw000/uic.html

Water Pollution Control (106) Program Support: Provides grants to states, tribes and interstate water pollution control agencies to support the prevention and abatement of surface and groundwater pollution from point and nonpoint sources. Eligible activities include water quality planning, monitoring, permitting, surveillance, enforcement, advice and assistance to local agencies, etc. for the purpose of establishing and maintaining water pollution control programs. For more information see: epa.gov/cwfinance/pollutioncontrol.htm

Water Quality Cooperative Agreements (104(b)(3) Grants): Provides grants to support innovative demonstration projects for addressing stormwater, combined sewer overflows, sludge, pretreatment, mining, animal feeding operations, and other sources relating to the National Pollutant Discharge Elimination System (NPDES) program. This includes research, investigations, experiments, training, surveys, and studies related to the causes, effects, and prevention of pollution. For more information see: epa.gov/owm/cwfinance/waterquality.htm

| Funding Sources | Polluted Runoff Control | | | | | | Resource Protection and Restoration | | | | | | Wastewater | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | Forestry | Mining | Brownfields | Storage Tanks (above ground & underground) | Landfills | Hydromodification/ Habitat Modification | Wetlands/Riparian Zone | Land Acquisition/ Conservation Easements | Groundwater Protection Measures | Land Use Controls | Public Education | Stormwater | On-Site Sewage |
| EPA Watershed Assistance Grants<br>FY '02—$200,000<br>FY '03—$200,000 | | | | | | | | | | • | | • | | |
| EPA Wetlands Program Development Grants<br>FY '02—$15M<br>FY '03—$14.9M | | • | | | | | • | • | | | | • | • | |
| USDA Conservation Reserve Program<br>FY '02—Not Available<br>FY '03—Not Available | • | | | | | | • | • | | | | | | |
| USDA Conservation Security Program<br>FY '03—$2B<br>(authorized) | • | • | | | | | | | | | | | | |
| USDA Environmental Quality Incentives Program<br>FY '02—$387M<br>FY '03—$695M | • | | | | | | • | • | • | • | | • | | |
| USDA Farmland Protection Program<br>FY '02—$50M<br>FY '03—$100M | • | • | | | | | | • | • | | | | | |



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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USDA | Natural Resources Conservation Foundation<br>FY '02—$3M<br>FY '03—$3M | • | • | • | | | | • | • | • | • | | | • | | |
| USDA | Resource Conservation and Development Program<br>FY '02—Not Available<br>FY '03—Not Available | • | • | | | | | • | • | | | | | • | • | • |
| USDA | RUS Water and Waste Disposal Loans and Grants<br>FY '02—$1.3B<br>FY '03—$1.6B | | | | | | | | | | • | | | | • | • |
| USDA | Sustainable Agriculture Research and Education<br>FY '02—Not Available<br>FY '03—$18.5M | • | | | | | | | | | | | | • | | |
| USDA | Watershed Processes and Water Resources Program<br>FY '02—Not Available<br>FY '03—$4.2M | • | • | | | | | | | | | | | | | |
| USDA | Watershed Protection and Flood Prevention Program<br>FY '02—$106M<br>FY '03—$110M | • | | | | | | • | • | | • | • | | • | | |

**Funding Source Details and Contact Information**

Watershed Assistance Grants (WAG): Builds cooperative agreements between nonprofits and other eligible to support watershed partnerships and long-term effectiveness. Funding then supports organizational development and capacity building for watershed partnerships with a diverse membership. Grants will be distributed to a pool of applicants, which are diverse in terms of geography, watershed issues, the type of partnership, and approaches. For more information see: rivernetwork.org/howwecanhelp/index.cfm?doc_id=94#wag

Wetlands Program Development Grants: Provides financial assistance to states, tribes and local governments to support development or enhancement of wetland protection, management or restoration programs. Projects must demonstrate a direct link to an increase in the states, tribes, or local governments ability to protect wetland resources. Funding may only be used to enhance and develop new and existing state wetlands programs, not for their operational support. For more information see: www.epa.gov/owow/wetlands/grantguidelines

Conservation Reserve Program: Voluntary program that offers long-term rental payments and cost-sharing assistance to establish protective covering on cropland and marginal pasture land. Protective covering reduces soil erosion, improves water quality, and enhances wildlife habitat. The land must be owned or operated by the applicant for at least 12 months, enrolled in the Water Bank Program (WBP), or contain other environmentally sensitive land. For more information see: www.nrcs.usda.gov/programs/crp

Conservation Security Program (CSP): Managed through the NRCS, the CSP will provide payments to farmers/producers who already are practicing good stewardship on agricultural lands and incentives for those who want to do more. Land enrolled in the Conservation Reserve Program, Wetlands Reserve Program, or Grassland Reserve Program are not eligible. Neither are those converted to cropland after 2002. For more information see: usda.gov/farmbill

Environmental Quality Incentives Program (NRCS): Voluntary locally-led conservation program that provides technical, education and financial assistance to farmers and ranchers who establish conservation practices and system that will address soil, water, and related natural resource problems. Cost-sharing and incentive payments are provided through five to ten year contracts to help producers in complying with environmental laws and regulations, including clean water. For more information see: www.nrcs.usda.gov/programs/eqip

Farmland Protection Program: Provides matching funds to existing farmland protection programs for the purchase of conservation easements. Eligible property includes farm or ranch lands that have prime, unique, statewide, or locally important soil and includes all cropland, rangeland, grassland, pasture land, incidental forest land, or wetlands. For more information see: usda.gov/farmbill

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Natural Resources Conservation Foundation: Funding for the Foundation will come from private donations or grants from individuals, corporations, businesses, and nonprofit organizations and agencies. The Foundation will have the authority to enter into cooperative agreements and contracts with federal, state, tribal, and local agencies and organizations and to grant monies for conservation activities to conserve natural resources on private lands. For more information see: usda.gov/farmbill/conservation_fb.html

Resource Conservation and Development Program: Provides technical assistance for planning and installation of approved projects in RC and D area plans, for land conservation, water management, community development, and environmental enhancement. Not a grant program, individuals work with local RC and D Councils to find funding. For more information see: www.nrcs.usda.gov/programs/rcd

Rural Utilities Service Water and Waste Disposal Loans and Grants: Provides assistance for water and waste disposal facilities to low income rural communities whose residents face significant health risks. Project grants and direct loans are available for local governments, Indian tribes, US Territories, nonprofit associations, state governments, and cooperations.For more information see: usda.gov/rus/water.programs.htm

Sustainable Agriculture Research and Education Program (SARE): Provides grants to advance farming systems that are more profitable and environmentally sound. SARE funds scientific investigation and education to reduce the use of chemical pesticides, to improve management of on-farm resources; to optimize conservation practices; and to promote partnership activities. Research and Education Projects are conducted by interdisciplinary research teams to include farmers as participants. For more information see:www.sare.org/htdocs/sare/cfp.html

Watershed Processes and Water Resources Program: Sponsors research that address two areas: 1) understanding fundamental processes controlling source areas, the flow pathways of water, and the fate of water, sediment, and organisms within forest, rangeland, and agricultural environments as influenced by watershed characteristics; and 2) developing appropriate technology and management practices for improving the effective sue of water and water quality for agricultural and forestry production. For more information see: reeusda.gov/

Watershed Protection and Flood Prevention Program: The 'Watershed,' or 'PL 566,' program provides technical and financial assistance for water resource challenges on a watershed basis. Projects related to flood mitigation, water supply, water quality, erosion and sediment control, wetland creation and restoration, fish and wildlife habitat enhancement, and public recreation are eligible for assistance. Technical and financial assistance is also available for planning new watershed surveys. For more information see: www.nrcs.usda.gov/programs/watershed/

| | Polluted Runoff Control | | | | | | Resource Protection and Restoration | | | | | | Wastewater | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Funding Sources** | **Agriculture** | **Forestry** | **Mining** | **Brownfields** | **Storage Tanks (above ground & underground)** | **Landfills** | **Hydromodification/ Habitat Modification** | **Wetlands/Riparian Zone** | **Land Acquisition/ Conservation Easements** | **Groundwater Protection Measures** | **Land Use Controls** | **Public Education** | **Stormwater** | **On-Site Sewage** |
| Wetlands Reserve Program<br>FY '02—250,000 acres<br>FY '03—Not Available | • | • | | | | | • | • | • | | | | • | |
| Wildlife Habitat Incentives Program<br>FY '02—$15M<br>FY '03—$30M (est.) | • | • | | | | | • | • | | | | • | | |
| Abandoned Mine Land Reclamation Program<br>FY '02—$159.6M<br>FY '03—$144M | | | • | | | | | | | • | | | | |
| Acid Mine Drainage<br>FY '02—$2.75M<br>FY '03—$2.75M (est.) | | | • | | | | | | | • | | | | |
| Environmental Mgmt on Indian Lands | | | | | • | • | | | | | | • | • | • |

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| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY '02—Not Available<br>FY '03—Not Available | | | | | | | | | | | | | | | | |
| | Land and Water Conservation Fund<br>FY '02—$140M<br>FY '03—$94.4M | • | • | • | | | | • | • | • | | • | | | | | |
| | Landowner Incentive Program (non-tribal)<br>FY '02—$40M | • | • | | | | | • | • | • | • | • | • | • | | | |
| | Partners for Fish and Wildlife Program<br>FY '02—$20.5M<br>FY '03—$19M | • | • | | | | | | • | • | | | • | | | | |
| | Water Resources on Indian Lands<br>FY '02—Not Available<br>FY '03—Not Available | | | | | | | | | | • | | | | | | |
| | NOAA's Community-Based Restoration Program<br>FY '02—$10M<br>FY '03—$10M | | | | | | | • | • | | | | | | | | |
| | HUD Community Development Block Grants<br>FY '02—$4.4B<br>FY '03—$4.4B | | | | • | | | | | • | | • | • | • | • | | |
| | Transportation Equity Act for the 21st Century<br>FY '02—Not Available<br>FY '04—$10.96B | | | | | | | • | • | • | • | • | • | • | | | |

**Funding Source Details and Contact Information**

Wetlands Reserve Program: Voluntary program to restore wetlands on private property. The program provides landowners with financial incentives and technical assistance to enhance, restore and protect wetlands in exchange for retiring marginal agricultural land. Participants must have owned the land for at least 12 months and it must be restorable and he suitable to provide wildlife benefits. For more information see: nrcs.usda/gov./programs/wrp

Wildlife Habitat Incentives Program (WHIP): WHIP is a voluntary program for people who want to develop and improve wildlife habitat primarily on private land. This program provides both technical assistance and up to 75% cost-share assistance to establish and improve fish and wildlife habitat. For more information see: www.nrcs.usda.gov/programs/whip

Abandoned Mine Land Reclamation Program: Provides grants to states and tribes to correct environmental damage caused primarily by coal mining that occurred prior to August 3, 1977. The program provides for the restoration of eligible lands and waters mined and abandoned or left inadequately restored after mining. The Appalachian Clean Streams Initiative (a subprogram) also provides funding as seed money to accelerate the clean up of water pollution related to acidity, metals, and toxicity. For more information see: www.osmre.gov/osmaml.htm

Acid Mine Drainage (AMD) Reclamation Program: Designed to support for efforts of local not-for-profit organizations, especially watershed groups, to complete construction projects designed to clean streams impacted by AMD. Eligible organizations include community watershed groups, nonprofit groups, and conservation districts. For more information see: www.osmre.gov/acsifunding.htm

Environmental Management on Indian Lands: The program provides funds to improve environmental management in Indian Country and at Bureau of Indian Affairs facilities, under all environmental statutes, including hazardous waste handling, drinking and wastewater systems, solid waste management and open dump closures, fuel storage in underground and above storage tanks, and management of PCBs, lead-based paint, and asbestos in schools. For more information see: www.doi.gov/bureau-indian-affairs.html

Land and Water Conservation Fund (LWCF): LwCF uses offshore oil leasing revenues to support grants to States, and through States, local units of government for the acquisition and development of state and local park and recreation areas that guarantee public use in perpetuity. All funded projects must be available for public recreational use. For more information see: www.nps.gov/lwef/

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Landowner Incentive Program (non-tribal): Provides matching grants to states, territories, and DC to establish or supplement landowner incentive programs. Programs can provide technical and financial assistance to landowners for projects that protect or restore habitats. Projects can involve the removal of exotic plants, changes in grazing practices, instream structural improvements, road closures, and conservation easements. Although not directly eligible, nonprofits may work directly with their states. For more information see: fws.gov

Partners for Fish and Wildlife Program: Since 1987, the program has partnered with more than 28,725 landowners to restore over 639,000 acres of wetlands; 1,070,000 acres of prairie, native grassland, and other upland habitats; and 4,740 miles of in-stream aquatic and riparian habitat. In addition, the program has reopened more than 300 miles of stream habitat for fish and other aquatic species by removing barriers to passage. For more information see: partners.fws.gov/

Water Resources on Indian Lands: This program assists Indian tribes with the management, planning, protection, and development of their water resources and related land resources. Previously funded projects have included geographic and hydrologic quantitative and qualitative analysis of water, groundwater and surface water quality and quantity monitoring, aquifer classification, and stream gauging. For more information see: www.doi.gov/bureau-indian-affairs.html

NOAA's Community-Based Restoration Program (CRP): Provides funds for small-scale, locally driven habitat restoration projects that foster natural resource stewardship within communities. The program seeks to bring together diverse partners to implement habitat restoration projects to benefit living marine resources. Partnerships are sought at the national and local level to contribute funding, land, technical assistance, workforce support, or other in-kind services. For more information see: www.nmfs.noaa.gov/habitat/restoration

HUD Community Development Block Grants: Provides grants to develop viable urban communities by providing housing and a suitable living environment. Activities include water, sewer and other facilities. Entitlement communities must be either a central city in a Metropolitan Statistical Area (MSA), a city with population above 50,000 in the MSA or an urban county of at least 200,000 people. Funds are also awarded to states for distribution to smaller (non-entitlement) communities. For more information see: www.hud.gov/progdesc/cdbg-st.cfm

Transportation Equity Act for the 21st Century Funding Programs (TEA-21): TEA-21 funds numerous programs such as the Surface Transportation Program (STP) ($5.9B) and the National Highway System ($5.06B). States may spend up to 20% of their STP dollars for restoration and pollution abatement projects. Each state may also set aside 10 percent of STP funds for transportation enhancement projects, including conservation easements, wetland mitigation, and pollution abatement. For more information see: thwa.dot.gov/tea21/

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*Source*: From www.epa.gov, www.nalusda.gov, and cfda.gov.



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**Table 11F.84 Expenditures for Water Management Projects by the United States Corps of Engineers, 1977–1986**

| Item | 1986 | 1985 | 1984 | 1983 | 1982 | 1981 | 1980 | 1979 | 1978 | 1977 |
|---|---|---|---|---|---|---|---|---|---|---|
| Appropriations ($ Millions) | | | | | | | | | | |
| Navigation | 299 | 304 | 257 | 577 | 552 | 607 | 485 | 395 | 357 | 261 |
| Flood control total | 673 | 676 | 647 | 647 | 882 | 774 | 772 | 873 | 802 | 859 |
| Flood control Mississippi River and tributaries[a] | (227) | (225) | (203) | (291) | (177) | (145) | (211) | (158) | (188) | (173) |
| Multipurpose, including power | 93 | 112 | 171 | 221 | 247 | 275 | 538 | 358 | 155 | 464 |
| Beach erosion control | 17 | 12 | 25 | 5 | 7 | 12 | 9 | 12 | 12 | 16 |
| Total new work[b] | 1,082 | 1,104 | 1,127 | 1,685 | 1,580 | 1,666 | 1,905 | 1,567 | 1,719 | 1,600 |
| Other work[c] | 1,658 | 1,797 | 1,561 | 1,734 | 1,417 | 1,331 | 1,296 | 1,223 | 1,070 | 887 |
| Total | 2,740 | 2,901 | 2,688 | 3,419 | 2,997 | 2,997 | 3,201 | 2,790 | 2,789 | 2,487 |

[a] Included in flood control total.
[b] Advance engineering and design, and construction (including major rehabilitation projects). Savings and slippage applied to projects.
[c] Operation and maintenance, surveys, administration and miscellaneous programs and activities.

*Source*: From Department of the Army Annual Report FY88 of the Secretary of the Army on Civil Works Activities, Washingon, DC.

**Table 11F.85 United States Geological Survey Budget for Water-Resources Investigations, 1981–1986**

| Budget Activity | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|
| Water Resources Investigations | 194,016 | 190,096 | 199,697 | 220,390 | 238,131 | 248,598 |
| Direct program | 115,458 | 108,637 | 1,15,096 | 1,29,441 | 1,33,408 | 135,152 |
| Reimbursable program | 78,558 | 81,459 | 84,601 | 90,949 | 104,723 | 113,446 |
| States, counties, and municipalities | 45,138 | 46,938 | 48,782 | 52,113 | 56,500 | 56,650 |
| Miscellaneous non-Federal sources | 2,088 | 2,679 | 3,914 | 3,600 | 3,327 | 2,161 |
| Other Federal agencies | 31,332 | 31,842 | 31,905 | 35,236 | 44,896 | 54,635 |

*Note:* By sources of funds; dollars in thousands.

*Source*: From U.S. Geological Survey Yearbook Fiscal Year 1986.

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**Table 11F.86 United States Geological Survey Budget for Water-Resources Investigations for Fiscal Year 1986**

| Activity/Subactivity/Program Element | Fiscal Year 1986[a] Enacted |
|---|---|
| Water Resources Investigations | $1,34,802 |
| National Water Resources Research and Information System—Federal Program | 72,875 |
| Data Collection and Analysis | 19,492 |
| National Water Data and Information Access Program | 2,090 |
| Coordination of National Water Data Activities | 903 |
| Regional Aquifer System Analysis | 13,474 |
| Core Program Hydrologic Research | 8,082 |
| Improved Instrumentation | 1,888 |
| Water Resources Assessment | 1,287 |
| Toxic Substances Hydrology | 11,182 |
| Nuclear Waste Hydrology | 7,020 |
| Acid Rain | 2,998 |
| Scientific and Technical Publications | 2,081 |
| National Water Resources Research and Information System—Federal–State Cooperative Program | 49,774 |
| Data Collection and Analysis, Areal Appraisals, and Special Hydrological Studies | 41,956 |
| Water Use | 3,670 |
| Coal Hydrology | 4,148 |
| National Water Resources Research and Information System—State Research Institute and Information Grants Program | 12,153 |
| State Water Resources Research Institutes | 6,159 |
| National Water Resources Research Grants Program | 4,767 |
| Program Administration | 1,227 |

*Note:* By activity and program element; dollars in thousands.

[a] Funding shown represents appropriated dollars and does not include reimbursable funding from federal, state, and other non-federal sources.

*Source*: From U.S. Geological Survey Yearbook Fiscal Year 1986.

**Table 11F.87 Water Resources Investigations**

| Program | FY 2000 Estimate | Uncontrol and Related Changes | Program Changes[a] | FY 2001 Budget Request | Change from FY 2000 |
|---|---|---|---|---|---|
| Water Resources Assessments and Research | 91,037 | +2,012 | −2,694 | 90,355 | −682 |
| Water Data Collection and Management | 29,167 | +949 | +9,159 | 39,275 | +10,108 |
| Federal-State Cooperative Water Program | 60,553 | +2,326 | 0 | 62,879 | +2,326 |
| Water Resources Research Act Program | 5,062 | +5 | 0 | 5,067 | +5 |
| Total Requirements $000 | 185,819 | +5,292 | +6,465 | 197,576 | +11,757 |

[a] See Program Change section for details.

*Source*: From U.S. Geological Survey Activity Summary.

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**Table 11F.88 Water Pollution Abatement Expenditures in the United States, 1975–1984**

| | | Industrial | | Public Sewer Systems[c] | |
|---|---|---|---|---|---|
| Year | Total[b] | Facilities | Operations[a] | Facilities | Operations[a] |
| 1975 | 22,840 | 4200 | 2950 | 8,997 | 3428 |
| 1976 | 24,445 | 4625 | 3375 | 9,370 | 3713 |
| 1977 | 24,652 | 4415 | 3706 | 9,409 | 4055 |
| 1978 | 26,631 | 4277 | 3934 | 10,090 | 4392 |
| 1979 | 26,470 | 4013 | 4222 | 9,758 | 4583 |
| 1980 | 24,647 | 3725 | 4081 | 8,942 | 4694 |
| 1981 | 21,984 | 3259 | 4180 | 6,882 | 4880 |
| 1982 | 21,199 | 3080 | 4022 | 6,148 | 5156 |
| 1983 | 21,461 | 2813 | 4402 | 5,551 | 5475 |
| 1984, preliminary | 23,192 | 2902 | 4651 | 6,353 | 5773 |

*Note:* In millions of dollars.

[a] Operation of facilities.
[b] Includes nonpoint sources not shown separately.
[c] Includes expenditures for private connectors to sewer systems, by owners of feedlots, and by government enterprises.

*Source*: From U.S. Department of Commerce, 1987 Statistical Abstract of the United States.

**Table 11F.89 Proposed Cost Sharing for New Water Projects after 1983**

| Project Purpose | Up-front Nonfederal Share of Costs, % |
|---|---|
| Hydropower | 100 |
| Municipal and industrial supply | 100 |
| Flood control | 35 |
| Recreation | 50[a] |
| Commercial navigation | 75[b] |
| Irrigation | 35 |
| Beach erosion | 50 |

[a] Could be repayment instead of up-front payment.
[b] Twenty-five percent of federal financing is reimbursable; the rest must be an up-front cash contribution.

*Source*: From Grigg, N.S., 1985, *Water Resources Planning*. Copyright 1985 McGraw-Hill, Inc. Reprinted with permission.

*Original Source*: S, 1031.

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**Table 11F.90 Federal Groundwater Quality Research and Development in the United States**

| Federal Organization | Categories of Groundwater Quality R and D[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| National Science Foundation | | | X | | X | | | | X | |
| Department of Agriculture | | | | | | | | | | |
| Agricultural Research Services | | | X | | | X | | | | |
| Forest Service | | | X | | | | | | | |
| Soil Conservation Service | | | | | X | X | | | X | |
| Department of Commerce | | | | | | | | | | |
| National Bureau of Standards | X | | | | | | | | | |
| Department of Defense | | | | | | | | | | |
| Army Corps of Engineers | | X | | | X | X | | | X | X |
| Army Medical Bioengineering R and D Laboratory | X | | | | | | | | X | |
| Army Toxic and Hazardous Materials Agency | X | | | | | | | | | |
| Department of Energy | | X | | | | | | | | |
| Department of Interior | | | | | | | | | | |
| Bureau of Indian Affairs | | | | | X | | | | | |
| Bureau of Land Management | | | | | X | | | | | |
| Bureau of Reclamation | | | | | X | X | | | | |
| Fish and Wildlife Service | | | | | X | | | | | |
| Geological Survey | | X | X | X | X | X | X | | | |
| National Park Service | | | | X | X | | | | | |
| Office of Surface Mining | | | | | X | | X | | | |
| Office of Water Policy | | X | X | | | | | X | X | X |
| Environmental Protection Agency | | | | | | | | | | |
| Environmental Monitoring Systems Laboratory | X | | X | | | | | | | |
| R.S. Kerr Environmental Research Laboratory | | | X | | | | | | | |
| Environmental Research Laboratory | | | X | | | | | | | |
| Office of Pesticide Programs | | | X | | | | | | | |
| Office of Radiation Programs | X | | | | X | | | | | |
| Office of Research and Development | | X | X | | X | | | | X | X |
| Office of Solid Waste | | | | | X | | | | | |
| Office of Water | | | | | | | | X | | |
| Nuclear Regulatory Commission | | X | X | | | | | | | |

The listing is not exhaustive but covers principal programs and activities related to groundwater quality R and D. Examples of other Federal R and D activities omitted here address quantity estimates, use patterns, source inventories, recharge information exchange, socioeconomic effects of alternative supplies, and environmental effect of contamination

[a] Key for categories of groundwater research and development: 1, Standards certification, quality assurance, and water quality criteria; 2, Hydrogeologic investigations and dynamics of groundwater flow; 3, Subsurface fate and transport of contaminants; 4, Background monitoring of groundwater quality; 5, Detection of groundwater contamination from various sources; 6, Salt-water intrusion and salinity problems; 7, Surface water–groundwater interactions; 8, Control of groundwater contamination from various sources; 9, Treatment technologies; 10, Evaluation of alternatives.

*Source*: From Office of Technology Assessment, 1984, Protecting the Nation's Groundwater from Contamination.

**Table 11F.91 Federal Funds Authorized for Implementation of the Safe Drinking Water Act (as Amended)**

| Area Funded | Fiscal Year | | | | |
|---|---|---|---|---|---|
| | 87 | 88 | 89 | 90 | 91 |
| | Millions of Dollars | | | | |
| Sole source aquifer demonstration program | $10 | $15 | $17.5 | $17.5 | $17.5 |
| Wellhead protection areas | 20 | 20 | 35 | 35 | 35 |
| Grants to alleviate emergency situations | 7.65 | 7.65 | 8.05 | 8.05 | 8.05 |
| Technical assistance and training | 35.6 | 35.6 | 38.02 | 38.02 | 38.02 |
| Technical assistance to small public water systems | 10 | 10 | 10 | 10 | 10 |
| State program grants | | | | | |
| PWS program | 37.2 | 37.2 | 40.15 | 40.15 | 40.15 |
| UIC program | 19.7 | 19.7 | 20.85 | 20.85 | 20.85 |
| Assistance to small systems for monitoring unregulated contaminants | 30 | — | — | — | — |

*Source*: From American Water Resources Assoc., 1988, *New Dimensions in Safe Drinking Water*. Copyright AWWA. Reprinted with permission.

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**Table 11F.92 Annual Expenditures of the Water Industry in the United States in 1984**

| | Annual Expenditures, U.S. $ Billions |
|---|---|
| Local water supply operations | 12.0 |
| Local wastewater operations | 14.0 |
| Local water management, other than above | 2.5 |
| Hydropower and thermoelectric cooling | 8.5 |
| Industrial pollution control | 3.0 |
| Industrial water supply | 7.5 |
| Regional water management | 8.0 |
| Federal agency operations | 3.0 |
| Dams, ports, harbors, and waterways | 7.5 |
| Home water treatment | 1.0 |
| Bottled water and sparkling water | 0.8 |
| Well drilling | 3.0 |
| Irrigation | 6.0 |
| State government | 0.2 |
| Education, research, publishing | 0.2 |
| | 77.2 |

*Source*: From Grigg, N.S. 1985, *Water Resources Planning*. Copyright 1985 McGraw-Hill, Inc. Reprinted with permission.

**Table 11F.93 Incremental Annual Costs of the CWA Assuming a 3 Percent Discount Rate (1997 $million)**

| | 1994 Costs | | | 1997 Costs | | |
|---|---|---|---|---|---|---|
| | Actual (A) | Without-CWA (B) | Incremental (C)=(A)+(B) | Actual (D) | Without-CWA (E) | Incremental (F)=(D)−(E) |
| Industry | | | | | | |
| Capital | 6,490.3 | 2,520.9 | 3,969.4 | 6,345.0 | 2,694.6 | 3,650.4 |
| O&M | 7,492.1 | 5,946.1 | 1,546.1 | 8,005.2 | 6,356.0 | 1,649.2 |
| R&D | 80.7 | 60.2 | 20.5 | 97.6 | 76.1 | 21.5 |
| Offsets | −312.1 | −121.2 | −190.9 | −267.5 | −113.6 | −153.9 |
| Public | | | | | | |
| Sewerage, capital | 13,308.0 | 10,676.4 | 2,631.6 | 13,979.9 | 11,375.9 | 2,604.0 |
| Sewerage, O&M | 15,035.5 | 10,912.8 | 4,122.8 | 17,171.4 | 11,704.8 | 5,466.6 |
| Electric, capital | 114.6 | 14.3 | 100.3 | 103.3 | 14.3 | 89.0 |
| Electric, O&M | 10.6 | 9.5 | 1.1 | 11.9 | 9.5 | 2.3 |
| R&D | 144.4 | 93.7 | 50.7 | 124.0 | 91.5 | 32.5 |
| R&M and other | 2,259.3 | 1,891.4 | 367.9 | 2,707.5 | 1,962.0 | 745.5 |
| Total | 44,623.3 | 32,003.9 | 12,619.4 | 48,278.1 | 34,171.0 | 14,107.1 |

*Source*: From "A Retrospective Assessment of the Costs of the Clean Water Act: 1972 to 1997. Final Report—October 2000." Prepared for USEPA, Office of Water, Office of Policy, Economic and Innovation.

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**Table 11F.94 Federal Water Pollution Control Laws**

| Title | Year of Enactment | Key Provisions |
|---|---|---|
| Water Pollution Control Act | 1948 | Authorized federal research |
| Water Pollution Control Act Amendments | 1956 | State responsibility to establish water quality criteria<br>Discretionary federal responsibility to convene enforcement conferences |
| Water Quality Act | 1965 | Ambient standards<br>State implementation and enforcement responsibility |
| Federal Water Pollution Control Act (Clean Water Act) | 1972 | Technology-based standards for conventional pollutants<br>Federal share of municipal treatment plant construction costs set at 75 percent<br>Federal implementation and enforcement responsibility |
| Coastal Zone Management Act | 1972 | Directed towards coastal water pollution problems |
| Clean Water Act Amendments | 1977 | Increased coverage to toxic pollutants |
| Municipal Wastewater Treatment Construction Grant Amendments | 1981 | Reduced federal share of municipal treatment plant financing to 55 percent |
| Clean Water Act Reauthorization | 1987 | Increased focus on nonpoint source pollution<br>Fedral support for municipal treatment plant construction converted from grant assistance to loans |

*Source*: From Adapted from Freeman, A. Myrick. 1990. "Water Pollution Policy." In *Public Policies for Environmental Protection*, Washington, DC: Resources for the Future.

**Table 11F.95 Regulated Entities under the CWA**

| Group | SIC Codes |
|---|---|
| *Manufacturing Industries* | |
| Food | 20 |
| Paper | 26 |
| Chemical | 28 |
| Petroleum and coal products | 29 |
| Other nondurables | 21, 22, 23, 27, 30, 31 |
| Primary metals | 33 |
| Machinery | 35 |
| Motor vehicles | 37 |
| Other durables | 24, 25, 32, 34, 36, 38, 39 |
| *Nonmanufacturing Industries* | |
| Mining | 10, 12, 13, 14 |
| Public and cooperative electric utilities | Part of 491, 493 |
| Other nonmanufacturing | |
| Construction | 15, 16, 17 |
| Transportation | 40–47 |
| Services | 492, 494–497, 70–89 |
| Wholesale and retail | 50–59 |
| Finance etc. | 60–67 |
| *Public Enterprises* | |
| Publicly owned sewerage treatment plants | Part of 4952 |
| Publicly owned electric utilities | Part of 491, 493 |

*Source*: From usepa.gov.

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**Table 11F.96 Annual Private Water Pollution Abatement Capital Costs under the with CWA and without CWA Scenarios, 1992–1997 (1997 $ millions)**

| | Discount Rate = 3% | | Discount Rate = 7% | |
|---|---|---|---|---|
| Year | With CWA | Without CWA | With CWA | Without CWA |
| 1992 | 6504.0 | 2443.4 | 9133.8 | 3431.4 |
| 1993 | 6507.1 | 2484.0 | 9138.1 | 3488.4 |
| 1994 | 6490.3 | 2520.9 | 9114.5 | 3450.1 |
| 1995 | 6482.9 | 2565.4 | 9104.2 | 3602.7 |
| 1996 | 6442.3 | 2627.4 | 9047.1 | 3689.7 |
| 1997 | 6345.0 | 2694.6 | 8910.5 | 3784.2 |

*Source*: From www.usepa.gov.

**Table 11F.97 Annual Public Sewerage Capital Costs under the with CWA and without CWA Scenarios, 1992–1997 (1997 $ millions)**

| | Discount Rate = 3% | | Discount Rate = 7% | |
|---|---|---|---|---|
| Year | With CWA | Without CWA | With CWA | Without CWA |
| 1992 | 12,733.2 | 10,244.6 | 20,112.5 | 16,181.7 |
| 1993 | 13,051.6 | 10,463.0 | 20,615.4 | 16,526.6 |
| 1994 | 13,308.0 | 10,676.4 | 21,020.3 | 16,863.6 |
| 1995 | 13,509.2 | 10,903.5 | 21,338.1 | 17,222.3 |
| 1996 | 13,728.1 | 11,125.8 | 21,683.9 | 17,573.4 |
| 1997 | 13,979.9 | 11,375.9 | 22,081.7 | 17,968.5 |

*Source*: From www.usepa.gov.

**Table 11F.98 Annual Water Pollution Abatement Capital Costs for Publicly Owned Electric Utilities under the with CWA and without CWA Scenarios, 1992–1997 (1997 $ millions)**

| | Discount Rate = 3% | | Discount Rate = 7% | |
|---|---|---|---|---|
| Year | With CWA | Without CWA | With CWA | Without CWA |
| 1992 | 123.9 | 14.3 | 174.0 | 20.0 |
| 1993 | 118.4 | 14.3 | 166.3 | 20.0 |
| 1994 | 114.6 | 14.3 | 160.9 | 20.0 |
| 1995 | 109.6 | 14.3 | 153.9 | 20.0 |
| 1996 | 106.6 | 14.3 | 149.8 | 20.0 |
| 1997 | 103.3 | 14.3 | 145.1 | 20.0 |

*Source*: From www.usepa.gov.

**Table 11F.99 Private Cost Offsets with and without the CWA, 1992–1997 (1997 $ millions)**

| Year | With CWA | Without CWA |
|---|---|---|
| 1992 | 379 | 143 |
| 1993 | 305 | 117 |
| 1994 | 312 | 121 |
| 1995 | 296 | 117 |
| 1996 | 282 | 115 |
| 1997 | 268 | 114 |

*Source*: From www.usepa.gov.

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**Table 11F.100 Incremental Annual Costs of the CWA (Assuming a 3 Percent Discount Rate) (1997 $ millions)**

| | 1992 Costs | | | 1993 Costs | | |
|---|---|---|---|---|---|---|
| | **Actual** | **Without CWA** | **Incremental** | **Actual** | **Without CWA** | **Incremental** |
| **Industry** | | | | | | |
| Capital | 6,504.0 | 2,443.4 | 4,060.6 | 6,507.1 | 2,484.0 | 4,023.0 |
| O&M | 7,276.6 | 5,763.4 | 1,513.2 | 7,079.7 | 5,859.3 | 1,220.4 |
| R&D | 61.4 | 61.4 | 0.0 | 88.0 | 60.0 | 28.1 |
| Offsets | −379.3 | −142.5 | −236.8 | −305.4 | −116.6 | −188.8 |
| **Public** | | | | | | |
| Sewerage, capital | 12,733.2 | 10,244.6 | 2,488.6 | 13,051.6 | 10,463.0 | 2,588.6 |
| Sewerage, O&M | 13,309.2 | 10,405.1 | 2,904.1 | 14,171.6 | 10,668.6 | 3,503.0 |
| Electric, capital | 123.9 | 14.3 | 109.6 | 118.4 | 14.3 | 104.2 |
| Electric, O&M | 11.2 | 9.5 | 1.6 | 12.0 | 9.5 | 2.4 |
| R&D | 137.2 | 98.3 | 38.9 | 116.3 | 95.3 | 21.0 |
| R&D and other | 2,913.1 | 1,893.7 | 1,019.4 | 2,581.5 | 1,887.2 | 694.3 |
| **Total** | **42,690.4** | **30,791.2** | **11,899.1** | **43,420.7** | **31,424.6** | **11,996.1** |

| | 1994 Costs | | | 1995 Costs | | |
|---|---|---|---|---|---|---|
| | **Actual** | **Without CWA** | **Incremental** | **Actual** | **Without CWA** | **Incremental** |
| **Industry** | | | | | | |
| Capital | 6,490.3 | 2,520.9 | 3,969.4 | 6,482.9 | 2,565.4 | 3,917.5 |
| O&M | 7,492.1 | 5,946.1 | 1,546.1 | 7,694.0 | 6,051.2 | 1,642.8 |
| R&D | 80.7 | 60.2 | 20.5 | 97.6 | 65.7 | 31.8 |
| Offsets | −312.1 | −121.2 | −190.9 | −296.5 | −117.3 | −179.2 |
| **Public** | | | | | | |
| Sewerage, capital | 13,308.0 | 10,676.4 | 2,631.6 | 13,590.2 | 10,903.5 | 2,605.7 |
| Sewerage, O&M | 15,035.5 | 10,912.8 | 4,122.8 | 15,581.6 | 11,166.5 | 4,415.2 |
| Electric, capital | 114.6 | 14.3 | 100.3 | 109.6 | 14.3 | 95.3 |
| Electric, O&M | 10.6 | 9.5 | 1.1 | 11.9 | 9.5 | 2.3 |
| R&D | 144.4 | 93.7 | 50.7 | 124.0 | 95.3 | 28.6 |
| R&D and other | 2,259.3 | 1,891.4 | 367.9 | 2,614.6 | 1,900.7 | 713.9 |
| **Total** | **44,623.3** | **32,003.9** | **12,619.4** | **45,928.8** | **32,654.7** | **13,274.1** |

| | 1996 Costs | | | 1997 Costs | | |
|---|---|---|---|---|---|---|
| | **Actual** | **Without CWA** | **Incremental** | **Actual** | **Without CWA** | **Incremental** |
| **Industry** | | | | | | |
| Capital | 6,442.3 | 2,627.4 | 3,814.9 | 6,345.0 | 2,694.6 | 3,650.4 |
| O&M | 7,852.5 | 6,197.3 | 1,655.2 | 8,005.2 | 6,356.0 | 1,649.2 |
| R&D | 97.6 | 70.4 | 27.2 | 97.6 | 76.1 | 21.5 |
| Offsets | −281.6 | −114.9 | −166.8 | −267.5 | −113.6 | −153.9 |
| **Public** | | | | | | |
| Sewerage, capital | 13,728.1 | 11,125.8 | 2,602.3 | 13,979.9 | 11,375.9 | 2,604.0 |
| Sewerage, O&M | 16,357.2 | 11,417.0 | 4,940.2 | 17,171.4 | 11,704.8 | 5,466.6 |
| Electric, capital | 106.6 | 14.3 | 92.4 | 103.3 | 14.3 | 89.0 |
| Electric, O&M | 11.9 | 9.5 | 2.3 | 11.9 | 9.5 | 2.3 |
| R&D | 124.0 | 93.1 | 30.8 | 124.0 | 91.5 | 32.5 |
| R&D and other | 2,661.0 | 1,926.8 | 734.3 | 2,707.5 | 1,962.0 | 745.5 |
| **Total** | **47,099.5** | **33,366.7** | **13,732.8** | **48,252.6** | **34,171.0** | **14,107.1** |

*Source*: From www.usepa.gov.

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**Table 11F.101 Incremental Annual Costs of the CWA (Assuming a 7 Percent Discount Rate) (1997 $ millions)**

| | 1992 Costs | | | 1993 Costs | | |
|---|---|---|---|---|---|---|
| | **Actual** | **Without CWA** | **Incremental** | **Actual** | **Without CWA** | **Incremental** |
| **Industry** | | | | | | |
| Capital | 9,133.8 | 3,431.4 | 5,702.4 | 9,138.1 | 3,488.4 | 5,649.6 |
| O&M | 7,276.6 | 5,763.4 | 1,513.2 | 7,079.7 | 5,859.3 | 1,220.4 |
| R&D | 61.4 | 61.4 | 0.0 | 88.0 | 60.0 | 28.1 |
| Offsets | −379.3 | −142.5 | −236.8 | −305.4 | −116.6 | −188.8 |
| **Public** | | | | | | |
| Sewerage, capital | 20,112.5 | 16,181.7 | 3,930.8 | 20,615.4 | 16,526.6 | 4,088.8 |
| Sewerage, O&M | 13,309.2 | 10,405.1 | 2,904.1 | 14,171.6 | 10,668.6 | 3,503.0 |
| Electric, capital | 174.0 | 20.0 | 153.9 | 166.3 | 20.0 | 146.3 |
| Electric, O&M | 11.2 | 9.5 | 1.6 | 12.0 | 9.5 | 2.4 |
| R&D | 137.2 | 98.3 | 38.9 | 116.3 | 95.3 | 21.0 |
| R&D and other | 2,913.1 | 1,893.7 | 1,019.4 | 2,581.5 | 1,887.2 | 694.3 |
| **Total** | **52,749.5** | **37,722.0** | **15,027.5** | **53,663.4** | **38,498.3** | **15,165.1** |

| | 1994 Costs | | | 1995 Costs | | |
|---|---|---|---|---|---|---|
| | **Actual** | **Without CWA** | **Incremental** | **Actual** | **Without CWA** | **Incremental** |
| **Industry** | | | | | | |
| Capital | 9,114.5 | 3,540.1 | 5,574.3 | 9,104.2 | 3,602.7 | 5,501.5 |
| O&M | 7,492.1 | 5,946.1 | 1,546.1 | 7,694.0 | 6,051.2 | 1,642.8 |
| R&D | 80.7 | 60.2 | 20.5 | 97.6 | 65.7 | 31.8 |
| Offsets | −312.1 | −121.2 | −190.9 | −296.5 | −117.3 | −179.2 |
| **Public** | | | | | | |
| Sewerage, capital | 21,020.3 | 16,863.6 | 4,156.7 | 21,338.1 | 17,222.3 | 4,115.8 |
| Sewerage, O&M | 15,035.5 | 10,912.8 | 4,122.8 | 15,581.6 | 11,166.5 | 4,415.2 |
| Electric, capital | 160.9 | 20.0 | 140.8 | 153.9 | 20.0 | 133.9 |
| Electric, O&M | 10.6 | 9.5 | 1.1 | 11.9 | 9.5 | 2.3 |
| R&D | 144.4 | 93.7 | 50.7 | 124.0 | 95.3 | 28.6 |
| R&D and other | 2,259.3 | 1,891.4 | 367.9 | 2,614.6 | 1,900.7 | 713.9 |
| **Total** | **55,006.2** | **39,216.2** | **15,790.0** | **56,423.4** | **40,016.6** | **16,406.7** |

| | 1996 Costs | | | 1997 Costs | | |
|---|---|---|---|---|---|---|
| | **Actual** | **Without CWA** | **Incremental** | **Actual** | **Without CWA** | **Incremental** |
| **Industry** | | | | | | |
| Capital | 9,047.1 | 3,689.7 | 5,357.4 | 8,910.5 | 3,784.2 | 5,126.3 |
| O&M | 7,852.5 | 6,197.3 | 1,655.2 | 8,005.2 | 6,356.0 | 1,649.2 |
| R&D | 97.6 | 70.4 | 27.2 | 97.6 | 76.1 | 21.5 |
| Offsets | −281.6 | −114.9 | −166.8 | −267.5 | −113.6 | −153.9 |
| **Public** | | | | | | |
| Sewerage, capital | 21,683.9 | 17,573.4 | 4,110.5 | 22,081.7 | 17,968.5 | 4,113.2 |
| Sewerage, O&M | 16,357.2 | 11,417.0 | 4,940.2 | 17,171.4 | 11,704.8 | 5,466.6 |
| Electric, capital | 149.8 | 20.0 | 129.7 | 145.1 | 20.0 | 125.1 |
| Electric, O&M | 11.9 | 9.5 | 2.3 | 11.9 | 9.5 | 2.3 |
| R&D | 124.0 | 93.1 | 30.8 | 124.0 | 91.5 | 32.5 |
| R&D and other | 2,661.0 | 1,926.8 | 734.3 | 2,707.5 | 1,962.0 | 745.5 |
| **Total** | **57,703.3** | **40,882.5** | **16,820.8** | **58,946.8** | **41,859.0** | **17,128.2** |

*Source*: From www.usepa.gov.

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**Table 11F.102 Private Capital Expenditures for Water Pollution Abatement: 1972–1994 (Current $ millions)**

| | Manufacturing | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Primary Metals | Transportation Equipment | Machinery | Other Durables | Chem-ical | Paper | Petroleum and Coal | Food | Other Non-Durables | All Manu-facturing* |
| 1972 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1973 | 84.7[a] | 41.7[a] | 15.6[a] | 81.4[a] | 214.6[a] | 161.0[a] | 96.1[a] | 104.8[a] | 28.0[a] | 827.8[a] |
| 1974 | 132.7[a] | 41.5[a] | 17.6[a] | 91.2[a] | 264.4[a] | 193.2[a] | 119.7[a] | 111.7[a] | 36.7[a] | 1,008.8[a] |
| 1975 | 187.5[a] | 36.4[a] | 20.8[a] | 99.0[a] | 385.7[a] | 266.0[a] | 155.7[a] | 93.9[a] | 34.9[a] | 1,280.1[a] |
| 1976 | 197.8[a] | 53.6[a] | 21.8[a] | 109.3[a] | 577.4[a] | 278.6[a] | 199.8[a] | 97.6[a] | 54.5[a] | 1,599.2[a] |
| 1977 | 250.7[a] | 39.4[a] | 42.4[a] | 150.5[a] | 603.8[a] | 261.9[a] | 196.0[a] | 109.3[a] | 41.1[a] | 1,695.1[a] |
| 1978 | 219.5[a] | 57.9[a] | 27.8[a] | 129.6[a] | 392.9[a] | 189.2[a] | 100.7[a] | 99.6[a] | 24.5[a] | 1,262.9[a] |
| 1979 | 227.7[a] | 59.5[a] | 38.2[a] | 117.0[a] | 367.2[a] | 180.8[a] | 119.6[a] | 117.6[a] | 26.4[a] | 1,262.2[a] |
| 1980 | 180.7[b] | 60.7[b] | 34.9[b] | 113.7[b] | 350.0[b] | 111.2[b] | 114.2[b] | 133.0[b] | 32.2[b] | 1,146.5[b] |
| 1981 | 144.1[b] | 60.0[b] | 28.0[b] | 125.4[b] | 322.2[b] | 86.5[b] | 131.7[b] | 104.8[b] | 24.0[b] | 1,028.4[b] |
| 1982 | 133.7[b] | 36.5[b] | 42.2[b] | 122.6[b] | 256.5[b] | 93.7[b] | 165.7[b] | 110.9[b] | 15.3[b] | 977.4[b] |
| 1983 | 100.2[b] | 55.0[b] | 19.0[b] | 105.2[b] | 187.4[b] | 65.9[b] | 164.7[b] | 105.1[b] | 13.3[b] | 819.0[b] |
| 1984 | 72.9[b] | 116.9[b] | 22.6[b] | 185.7[b] | 212.4[b] | 68.2[b] | 96.8[b] | 91.8[b] | 16.5[b] | 887.8[b] |
| 1985 | 84.3[c] | 165.1[c] | 35.1[c] | 159.6[c] | 271.5[c] | 106.0[c] | 88.4[c] | 77.4[c] | 19.4[c] | 1,017.9[c] |
| 1986 | 74.6[c] | 81.8[c] | 25.7[c] | 173.0[c] | 325.5[c] | 96.9[c] | 121.5[c] | 108.2[c] | 25.6[c] | 1,038.7[c] |
| 1987 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1988 | 100.6[c] | 80.4[c] | 33.2[c] | 169.5[c] | 487.8[c] | 97.2[c] | 203.7[c] | 91.0[c] | 25.8[c] | 1,289.4[c] |
| 1989 | 138.7[c] | 84.6[c] | 54.8[c] | 233.6[c] | 598.6[c] | 261.0[c] | 230.4[c] | 183.6[c] | 39.2[c] | 1,824.5[c] |
| 1990 | 166.8[d] | 142.6[d] | 41.3[d] | 184.5[d] | 995.0[d] | 509.6[d] | 400.8[d] | 163.3[d] | 47.5[d] | 2,651.4[d] |
| 1991 | 131.9[d] | 94.7[d] | 27.6[d] | 276.0[d] | 942.3[d] | 552.7[d] | 373.3[d] | 359.5[d] | 56.5[d] | 2,814.6[d] |
| 1992 | 123.5[d] | 69.2[d] | 31.7[d] | 146.7[d] | 1017.3[d] | 373.4[d] | 492.6[d] | 202.6[d] | 48.1[d] | 2,509.8[d] |
| 1993 | 92.0[d] | 67.1[d] | 20.2[d] | 157.4[d] | 937.9[d] | 289.2[d] | 567.2[d] | 113.6[d] | 46.8[d] | 2,294.9[d] |
| 1994 | 98.5[d] | 60.8[d] | 152.1[d] | 239.6[d] | 1005.6[d] | 195.9[d] | 466.9[d] | 152.8[d] | 56.7[d] | 2,428.9[d] |

| | Non-manufacturing | | | | | |
|---|---|---|---|---|---|---|
| Year | Mining | Electric | Petroleum and Coal | All Non-manufacturing | PACE Aggregate[i] | BEA Total |
| 1972 | NA | NA | NA | NA | NA | 1501 |
| 1973 | 70[e] | 410[e] | | 620[e] | 1,447.8 | 1,570[g] |
| 1974 | 60[e] | 430[e] | | 630[e] | 1,638.8 | 1,765[g] |
| 1975 | 60[e] | 400[e] | | 650[e] | 1,930.1 | 2,145[g] |
| 1976 | 100[e] | 540[e] | | 850[e] | 2,449.2 | 2,607[g] |
| 1977 | 100[e] | 650[e] | | 920[e] | 2,651.1 | 2,827[g] |
| 1978 | 230[e] | 900[e] | | 1,310[e] | 2572.9 | 2,683[g] |
| 1979 | 180[e] | 1,010[e] | | 3,350[e] | 2612.2 | 2,873[g] |
| 1980 | 110[e] | 890[e] | | 1,140[e] | 2,286.5 | 2,795[g] |
| 1981 | 90[e] | 810[e] | | 1,030[e] | 2,058.4 | 2,848[g] |
| 1982 | 110[e] | 900[e] | | 1,170[e] | 2,147.4 | 2,937[g] |
| 1983 | 100[e] | 750[e] | | 980[e] | 1,799.0 | 2,422[g] |
| 1984 | 180[e] | 900[e] | | 1,230[e] | 2,117.8 | 2,730[g] |
| 1985 | 120[f] | 870[f] | | 1,150[f] | 2,167.9 | 2,670[g] |
| 1986 | 130[f] | 650[f] | | 930[f] | 1,968.7 | 2,534[g] |
| 1987 | 56[h] | 599[h] | 1186.3[h] | | NA | 2,614[g] |
| 1988 | 84[h] | 526[h] | 998.9[h] | | 2,694.6 | 2,581[g] |
| 1989 | 113[h] | 482[h] | 1,174.5[h] | | 3,363.4 | 3196[g] |
| 1990 | 138[i] | 673[i] | 1,643.6[i] | | 4,705.4 | 4,430[g] |
| 1991 | 120[i] | 573[i] | 1,503.3[i] | | 4,637.3 | 4,666[g] |
| 1992 | 145[i] | 567[i] | 1,380.5[i] | | 4,109.4 | 4532[g] |
| 1993 | 161[i] | 621[i] | 1,115.1[i] | | 3,624.4 | 4335[g] |
| 1994 | 191[j] | 606[i] | 1,113.6[i] | | 3,872.0 | 4,720[g] |

*Note:* NA, not available.

* The manufacturing category is complied separately by the PACE reports; it does not always equal the sum of the individual columns. It does not include SIC code group 23, Apparel and Other Textile Products.

[a] U.S. Department of Commerce. 1981. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1979." Table 1A. Pollution Abatement Capital Expenditure and Operating Costs, by Form of Abatement and Major Industry Group: 1973–1979. Washington, DC: Government Printing Office.

*(Continued)*

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**Table 11F.102 (Continued)**

[b] U.S. Department of Commerce. 1986. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1984." Table 1. Pollution Abatement Capital Expenditures and Operating Costs, by Form of Abatement by Major Group: 1980–1984. Washington, DC: Government Printing Office.
[c] U.S. Department of Commerce. 1991. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1989." Table 1. Pollution Abatement Capital Expenditures and Operating Costs, by Form of Abatement for Major Groups: 1985–1989. Washington, DC: Government Printing Office.
[d] U.S. Department of Commerce. 1996. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1994." Table 1.Summary Capital Expenditures and Operating Costs, by Major Groups: 1990–1994. Washington, DC: Government Printing Office.
[e] Environmental Economic Division. February 1986. *Survey of Current Business*. "Plant and Equipment Expenditures by Business for Pollution Abatement." Table 1. New Plant and Equipment Expenditures by U.S. Nonfarm Business: Total and for Pollution Abatement.
[f] Rutledge, Gary L. and Nikolaos A. Stergioulas. November 1988. *Survey of Current Business*. "Plant and Equipment Expenditures by Business for Pollution Abatement, 1987 and 1988." Table 1. New Plant and Equipment Expenditures by U.S. Nonfarm Business: Total and for Pollution Abatement.
[g] Vogan, Christine R. September 1996. *Survey of Current Business*. "Pollution Abatement and Control Expenditures, 1972–1994." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972–1994.
[h] U.S. Department of Commerce. 1992. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1990." Table A. New Capital Expenditures for Companies in Mining, Petroleum, and Electric Utilities: Total and for Pollution Abatement 1987–1990. Washington, DC: Government Printing Office.
[i] U.S. Department of Commerce. 1996. *Current Industrial Reports*. "Pollution Abatement Costs and Expenditures, 1994." Table 14. Summary New Capital Expenditures by Companies in Mining, Petroleum, and Electric Utilities for all Media: 1990–1994. Washington, DC: Government Printing Office.
[j] Calculated based on all available data from *Current Industrial Reports* for manufacturing and nonmanufacturing categories. For years 1973 through 1986, data for nonmanufacturing sector are from the BEA source (Vogan, 1996). For 1988 through 1994, total includes PACE nonmanufacturing data for the mining, electric utilities, and petroleum and coal sectors and PACE manufacturing data (minus the petroleum and coal sectors to avoid double counting).

*Source*: From www.usepa.gov.

**Table 11F.103 Real Private Water Pollution Abatement Expenditures, 1972–1997 (1997 $ millions)**

| Year | Capital Expenditures[a] | Operation and Maintenance Expenditures[b] |
|---|---|---|
| 1972 | 5,011.0 | 2,634.0 |
| 1973 | 4,962.2 | 3,072.1 |
| 1974 | 5,120.2 | 3,446.3 |
| 1975 | 5,685.9 | 3,734.9 |
| 1976 | 5,528.9 | 4,322.6 |
| 1977 | 6,651.4 | 4,856.2 |
| 1978 | 5,883.3 | 5,168.4 |
| 1979 | 5,804.8 | 5,633.1 |
| 1980 | 5,168.0 | 5,519.3 |
| 1981 | 4,813.7 | 5,425.5 |
| 1982 | 4,669.2 | 5,510.1 |
| 1983 | 3,693.6 | 5,723.4 |
| 1984 | 4,011.9 | 5,954.7 |
| 1985 | 3,793.4 | 6,180.2 |
| 1986 | 3,508.5 | 6,564.3 |
| 1987 | 3,511.2 | 6,834.4 |
| 1988 | 3,344.5 | 7,032.4 |
| 1989 | 3,974.3 | 7,171.5 |
| 1990 | 5,278.2 | 7,735.1 |
| 1991 | 5,349.2 | 7,134.2 |
| 1992 | 5,056.4 | 7,276.6 |
| 1993 | 4,712.2 | 7,079.7 |
| 1994 | 5,011.0 | 7,492.1 |
| 1995 | 5,081.4 | 7,570.2 |
| 1996 | 5,081.4 | 7,649.0 |
| 1997 | 5,081.4 | 7,728.6 |

[a] Values for 1995 through 1997 are assumed to be equal to the average observed value for 1990 through 1994.
[b] Values for 1995 through 1997 are projected based on observed trend from 1972 through 1994.

*Source*: From Vogan, Christine R. September 1996. *Survey of Current Business*, "Pollution Abatement and Control Expenditures, 1972–1994" Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972–94. With permission.

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**Table 11F.104 Water Pollution Abatement Expenditures under the with and without CWA Scenarios, 1972–1997**

| | | With CWA WPA Capital Expenditures[b] | | Without CWA WPA Capital Expenditures[b] (1997 $ millions) | |
|---|---|---|---|---|---|
| Year | Total Industrial Capital Expenditures[a] (1997 $ millions) | 1997 $ millions | Percent of Total Capital Expenditures | 0.3% of Total Capital Expenditures | 0.5% of Total Capital Expenditures |
| 1972 | 420,974 | 5,011.0 | 1.19% | 1,262.9 | 2,104.9 |
| 1973 | 474,093 | 4,962.2 | 1.05% | 1,422.3 | 2,370.5 |
| 1974 | 480,395 | 5,120.2 | 1.07% | 1,441.2 | 2,402.0 |
| 1975 | 447,976 | 5,685.9 | 1.27% | 1,343.9 | 2,239.9 |
| 1976 | 468,819 | 6,528.9 | 1.39% | 1,406.5 | 2,344.1 |
| 1977 | 525,146 | 6,651.4 | 1.27% | 1,575.4 | 2,625.7 |
| 1978 | 596,443 | 5,883.3 | 0.99% | 1,789.3 | 2,982.2 |
| 1979 | 652,609 | 5,804.8 | 0.89% | 1,957.8 | 3,263.0 |
| 1980 | 647,712 | 5,168.0 | 0.80% | 1,943.1 | 3,238.6 |
| 1981 | 685,206 | 4,813.7 | 0.70% | 2,055.6 | 3,426.0 |
| 1982 | 651,646 | 4,669.2 | 0.72% | 1,954.9 | 3,258.2 |
| 1983 | 609,090 | 3,693.6 | 0.61% | 1,827.3 | 3,045.5 |
| 1984 | 688,201 | 4,011.9 | 0.58% | 2,064.6 | 3,441.0 |
| 1985 | 713,206 | 3,793.4 | 0.53% | 2,139.6 | 3,566.0 |
| 1986 | 685,093 | 3,508.5 | 0.51% | 2,055.3 | 3,425.5 |
| 1987 | 665,444 | 3,511.2 | 0.53% | 1,996.3 | 3,327.2 |
| 1988 | 687,561 | 3,344.5 | 0.49% | 2,062.7 | 3,437.8 |
| 1989 | 704,089 | 3,974.3 | 0.56% | 2,112.3 | 3,520.4 |
| 1990 | 686,172 | 5,278.2 | 0.77% | 2,058.5 | 3,430.9 |
| 1991 | 627,437 | 5,349.2 | 0.85% | 1,882.3 | 3,137.2 |
| 1992 | 622,449 | 5,056.4 | 0.81% | 1,867.3 | 3,112.2 |
| 1993 | 656,658 | 4,712.2 | 0.72% | 1,970.0 | 3,283.3 |
| 1994 | 701,333 | 5,011.0 | 0.71% | 2,104.0 | 3,506.7 |
| 1995 | 755,180 | 4,707.9 | 0.62% | 2,265.5 | 3,775.9 |
| 1996 | 802,501 | 4,620.7 | 0.58% | 2,407.5 | 4,012.5 |
| 1997 | 860,700 | 4,536.6 | 0.53% | 2,582.1 | 4,303.5 |

[a] As estimated by private gross nonresidential fixed investment in NIPA (CEA, 2000).

[b] Vogan, Christine R. September 1996. *Survey of Current Business*. "Pollution Abatement and Control Expenditures, 1972–1994." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972–1994. 1995 through 1997 are average of 1990 through 1994.

*Source*: From Vogan, Christine R. September 1996. *Survey of Current Business*, "Pollution Abatement and Control Expenditures, 1972–1994" Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972–94. 1995 through 1997 are average of 1990 through 1994. With permission.

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**Table 11F.105 Annualized Private Water Pollution Abatement Capital Costs under the with CWA and without CWA Scenarios, 1972–1997 (1997 $ millions)**

| | With CWA | | | Without CWA | | |
|---|---|---|---|---|---|---|
| Year | WPA Capital Expenditures[a] | Estimated Gross WPA Capital Stock | Annualized WPA Capital Cost | WPA Capital Expenditures[b] | Estimated Gross WPA Capital Stock | Annualized WPA Capital Cost |
| 1972 | 5,011.0 | | | 1,262.9 | | |
| 1973 | 4,962.2 | | | 1,422.3 | | |
| 1974 | 5,120.2 | | | 1,441.2 | | |
| 1975 | 5,685.9 | | | 1,343.9 | | |
| 1976 | 6,528.9 | | | 1,406.5 | | |
| 1977 | 6,651.4 | | | 1,575.4 | | |
| 1978 | 5,883.3 | | | 1,789.3 | | |
| 1979 | 5,804.8 | | | 1,957.8 | | |
| 1980 | 5,168.0 | | | 1,943.1 | | |
| 1981 | 4,813.7 | | | 2,055.6 | | |
| 1982 | 4,669.2 | | | 1,954.9 | | |
| 1983 | 3,693.6 | | | 1,827.3 | | |
| 1984 | 4,011.9 | | | 2,064.6 | | |
| 1985 | 3,793.4 | | | 2,139.6 | | |
| 1986 | 3,508.5 | | | 2,055.3 | | |
| 1987 | 3,511.2 | | | 1,996.2 | | |
| 1988 | 3,344.5 | | | 2,062.7 | | |
| 1989 | 3,974.3 | | | 2,112.3 | | |
| 1990 | 5,278.2 | | | 2,058.5 | | |
| 1991 | 5,349.2 | | | 1,882.3 | | |
| 1992 | 5,056.4 | 96,763.4 | 6,504.0 | 1,867.3 | 36,352.0 | 2,443.4 |
| 1993 | 4,712.2 | 96,808.7 | 6,507.1 | 1,970.0 | 36,956.4 | 2,484.0 |
| 1994 | 5,011.0 | 96,558.7 | 6,490.3 | 2,104.0 | 37,504.1 | 2,520.9 |
| 1995 | 5,081.4 | 96,449.6 | 6,482.9 | 2,265.5 | 38,166.9 | 2,565.4 |
| 1996 | 5,081.4 | 95,845.2 | 6,442.3 | 2,407.5 | 39,088.5 | 2,627.4 |
| 1997 | 5,081.4 | 94,397.7 | 6,345.0 | 2,582.1 | 40,089.6 | 2,694.6 |

*Note:* Capital Life: 20 Years Discount Rate: 3 percent.

[a] 1995 through 1997 expenditures are average of 1990 through 1994 expenditures.
[b] Without-CWA based on 0.3% of total private capital.

*Source*: From Vogan, Christine R. September 1996. *Survey of Current Business*, ''Pollution Abatement and Control Expenditures, 1972–1994'' Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972–94. U.S. Bureau of Economic Analysis. Summary National Income and Product Time Series, 1929–1997. (Computer file). With permission.

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**Table 11F.106 Approximated Total Gross Private Capital Stock, 1972–1997 (1997 $ millions)**

| Year | Total Industrial Capital Expenditures[a] | Approximated Gross Industrial Capital Stock[b] | Annual Growth Rate (%) |
|---|---|---|---|
| 1952 | 178,669 | | |
| 1953 | 194,059 | | |
| 1954 | 189,685 | | |
| 1955 | 210,103 | | |
| 1956 | 231,570 | | |
| 1957 | 238,935 | | |
| 1958 | 208,703 | | |
| 1959 | 226,057 | | |
| 1960 | 235,894 | | |
| 1961 | 230,344 | | |
| 1962 | 247,101 | | |
| 1963 | 257,185 | | |
| 1964 | 284,394 | | |
| 1965 | 331,356 | | |
| 1966 | 366,972 | | |
| 1967 | 358,979 | | |
| 1968 | 371,765 | | |
| 1969 | 396,702 | | |
| 1970 | 390,568 | | |
| 1971 | 388,841 | | |
| 1972 | 420,975 | 1,247,400 | |
| 1973 | 474,093 | 1,341,600 | 7.6 |
| 1974 | 480,395 | 1,456,500 | 8.6 |
| 1975 | 447,976 | 1,587,400 | 9.0 |
| 1976 | 468,819 | 1,717,400 | 8.2 |
| 1977 | 525,146 | 1,860,100 | 8.3 |
| 1978 | 596,443 | 2,035,800 | 9.4 |
| 1979 | 652,610 | 2,265,300 | 11.3 |
| 1980 | 647,712 | 2,541,800 | 12.2 |
| 1981 | 685,206 | 2,842,900 | 11.8 |
| 1982 | 651,646 | 3,199,700 | 12.6 |
| 1983 | 609,090 | 3,556,800 | 11.2 |
| 1984 | 688,201 | 3,900,600 | 9.7 |
| 1985 | 713,207 | 4,306,500 | 10.4 |
| 1986 | 685,094 | 4,734,400 | 9.9 |
| 1987 | 665,444 | 5,144,800 | 8.7 |
| 1988 | 687,561 | 5,555,000 | 8.0 |
| 1989 | 704,090 | 5,993,500 | 7.9 |
| 1990 | 686,172 | 6,456,800 | 7.7 |
| 1991 | 627,438 | 6,926,000 | 7.3 |
| 1992 | 622,449 | 7,361,600 | 6.3 |
| 1993 | 656,659 | 7,793,400 | 5.9 |
| 1994 | 701,334 | 8,247,500 | 5.8 |
| 1995 | 755,181 | 8,742,500 | 6.0 |
| 1996 | 802,501 | 9,301,200 | 6.4 |
| 1997 | 860,700 | 9,901,900 | 6.5 |

[a] U.S. Bureau of Economic Analysis. Summary National Income and Product Time Series, 1929–1997. [Computer file].
[b] Assumes 20-year capital life.

*Source*: From www.usepa.gov.

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**Table 11F.107 Private O&M Expenditures for Water Pollution Abatement under with CWA and without CWA Scenarios, 1972–1997 (1997 $ millions)**

| Year | With CWA O&M Expenditures[a,b] | Without CWA O&M Expenditures |
|---|---|---|
| 1972 | 2634.0 | 2634.0 |
| 1973 | 3072.1 | 2749.3 |
| 1974 | 3446.3 | 2882.5 |
| 1975 | 3734.9 | 3020.7 |
| 1976 | 4322.6 | 3133.9 |
| 1977 | 4856.2 | 3246.7 |
| 1978 | 5168.4 | 3382.8 |
| 1979 | 5633.1 | 3567.3 |
| 1980 | 5519.3 | 3770.2 |
| 1981 | 5425.5 | 3966.0 |
| 1982 | 5510.1 | 4182.4 |
| 1983 | 5723.4 | 4374.8 |
| 1984 | 5954.7 | 4542.2 |
| 1985 | 6180.2 | 4734.2 |
| 1986 | 6564.3 | 4915.9 |
| 1987 | 6834.4 | 5067.2 |
| 1988 | 7032.4 | 5212.9 |
| 1989 | 7171.5 | 5363.1 |
| 1990 | 7735.1 | 5509.3 |
| 1991 | 7134.2 | 5649.9 |
| 1992 | 7276.6 | 5763.4 |
| 1993 | 7079.7 | 5859.3 |
| 1994 | 7492.1 | 5946.1 |
| 1995 | 7694.0 | 6051.2 |
| 1996 | 7852.5 | 6197.3 |
| 1997 | 8005.2 | 6356.0 |

[a] Vogan, Christine R. September 1996. *Survey of Current Business*. "Pollution Abatement and Control Expenditures, 1972–1994." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972–1994. 1995 through 1997 estimated with regression on time.

[b] 1995 through 1997 are projected based on the trend from 1972 through 1994.

*Source*: From www.usepa.gov.

**Table 11F.108 Public Sewerage and Other Sanitation Expenditures, 1902–1996 Fiscal Years (current $ millions)**

| | Sewerage | | | |
|---|---|---|---|---|
| Fiscal Year | Capital | O&M | Total | Total Sanitation |
| 1902 | | | | 51[e] |
| 1913 | | | | 97[e] |
| 1922 | | | | 189[e] |
| 1927 | | | | 312[e] |
| 1932 | | | | 223[e] |
| 1934 | | | | 177[e] |
| 1936 | | | | 204[e] |
| 1938 | | | | 226[e] |
| 1940 | | | | 207[e] |
| 1942 | | | | 229[e] |
| 1944 | | | | 245[e] |
| 1946 | | | | 370[e] |
| 1948 | | | | 670[e] |
| 1950 | | | | 834[e] |
| 1952 | | | | 992[e] |
| 1953 | | | | 908[e] |
| 1954 | | | | 1,058[e] |
| 1955 | | | | 1,142[e] |
| 1956 | | | | 1,326[e] |

*(Continued)*

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**Table 11F.108 (Continued)**

| | Sewerage | | | |
|---|---|---|---|---|
| **Fiscal Year** | **Capital** | **O&M** | **Total** | **Total Sanitation** |
| 1957 | | | 906[d] | 1,443[e] |
| 1958 | 649[a] | 254[a] | 903[a] | 1,505[e] |
| 1959 | 708[a] | 273[a] | 981[a] | 1,609[e] |
| 1960 | 767[a] | 266[a] | 1,033[a] | 1,727[e] |
| 1961 | 726[a] | 304[a] | 1,030[a] | 1,774[e] |
| 1962 | 886[a] | 344[a] | 1,230[a] | 1,958[e] |
| 1963 | 1,019[a] | 204[a] | 1,223[a] | 1,996[e] |
| 1964 | 1,095[a] | 408[a] | 1,503[a] | 2,267[e] |
| 1965 | 1,107[a] | 605[a] | 1,712[a] | 2,360[e] |
| 1966 | 1,202[a] | 614[a] | 1,816[a] | 2,571[e] |
| 1967 | 1,069[a] | 555[a] | 1,624[a] | 2,523[e] |
| 1968 | 1,107[a] | 524[a] | 1,631[a] | 2,707[e] |
| 1969 | 1,207[a] | 510[a] | 1,717[a] | 2,969[e] |
| 1970 | 1,385[a] | 423[a] | 1,808[a] | 3,413[e] |
| 1971 | 1,744[a] | 781[a] | 2,525[a] | |
| 1972 | 2,202[a] | 962[a] | 3,164[a] | |
| 1973 | 2,428[a] | 1,176[a] | 3,604[a] | |
| 1974 | 2,640[a] | 1,440[a] | 4,080[a] | |
| 1975 | 3,569[b] | 1,693[b] | 5,262[b] | |
| 1976 | 3,955[b] | 1,982[b] | 5,937[b] | |
| 1977 | 4,208[b] | 2,329[b] | 6,537[b] | |
| 1978 | 4,365[b] | 2,777[b] | 7,142[b] | |
| 1979 | 5,619[b] | 3,176[b] | 8,795[b] | |
| 1980 | 6,271[b] | 3,621[b] | 9,892[b] | |
| 1981 | 6,912[b] | 4,209[b] | 11,121[b] | |
| 1982 | 5,895[b] | 4,902[b] | 10,797[b] | |
| 1983 | 5,806[b] | 5,433[b] | 11,239[b] | |
| 1984 | 5,663[b] | 5,853[b] | 11,516[a] | |
| 1985 | 5,925[b] | 6,260[b] | 12,185[b] | |
| 1986 | 6,461[b] | 6,847[b] | 13,308[b] | |
| 1987 | 7,306[b] | 7,555[b] | 14,861[b] | |
| 1988 | 8,300[c] | 8,029[c] | 16,329[c] | |
| 1989 | 8,343[c] | 8,696[c] | 17,039[c] | |
| 1990 | 8,356[c] | 9,953[c] | 18,309[c] | |
| 1991 | 9,104[b] | 10,571[b] | 19,675[b] | |
| 1992 | 8,926[c] | 11,418[c] | 20,344[c] | |
| 1993 | 10,252[c] | 12,440[c] | 22,692[c] | |
| 1994 | 7,989[c] | 13,635[c] | 21,624[c] | |
| 1995 | 8,894[c] | 14,690[c] | 23,583[c] | |
| 1996 | 9,326[c] | 15,339[c] | 24,665[c] | |

[a] U.S. Bureau of the Census, *Government Finance*. Annual, as reported by Clark, Edwin. Council on Environmental Quality. "Estimating Baseline Pollution Abatement Expenditures." Table 7. Expenditures for Municipal Wastewater Treatment Facilities 1958–1974.

[b] U.S. Bureau of the Census. *Government Finances*.

[c] U.S. Bureau of the Census. State and Local Government Finance Estimates, by State. census.gov/govs/www/estimate.html Last revised April 26, 1999.

[d] Government Finance Data (BOC, Census of Governments, Compendium of Government Finance, Fiscal Years 1957, 1962, 1967. Table 8. Direct General Expenditure by Function, by Type of Government.)

[e] U.S. Department of Commerce, Bureau of the Census. 1975. *Historical Statistics of the United States, Colonial Times to 1970*. Series Y 533–566. Federal, State, and Local Government Expenditure, By Function: 1902 to 1970. Washington, DC: Government Printing Office.

*Source*: From usepa.gov.

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**Table 11F.109 Estimated Public Sewerage Expenditures Before the CWA: FY1902-FY1971**

| Fiscal Year | Total Sanitation (TS)[a] (Current $ million) | Total Sewerage (S)[b] (Current $ million) | Total Sewerage (S)[b] (As Percentage of TS) (%) | Sewerage Capital[c] (Current $ million) | Sewerage Capital[c] (As Percentage of S) (%) | Sewerage O&M[c] (Current $ million) |
|---|---|---|---|---|---|---|
| 1902 | 51 | | | 23 | | 9 |
| 1913 | 97 | | | 43 | | 17 |
| 1922 | 189 | | | 84 | | 34 |
| 1927 | 312 | | | 138 | | 56 |
| 1932 | 223 | | | 99 | | 40 |
| 1934 | 177 | | | 78 | | 32 |
| 1936 | 204 | | | 90 | | 36 |
| 1938 | 226 | | | 100 | | 40 |
| 1940 | 207 | | | 92 | | 37 |
| 1942 | 229 | | | 101 | | 41 |
| 1944 | 245 | | | 109 | | 44 |
| 1946 | 370 | | | 164 | | 66 |
| 1948 | 670 | | | 297 | | 120 |
| 1950 | 834 | | | 370 | | 149 |
| 1952 | 992 | | | 440 | | 177 |
| 1953 | 908 | | | 402 | | 162 |
| 1954 | 1,058 | | | 469 | | 189 |
| 1955 | 1,142 | | | 506 | | 204 |
| 1956 | 1,326 | | | 588 | | 237 |
| 1957 | 1,443 | 906 | 63 | 646 | 71 | 260 |
| 1958 | 1,505 | 903 | 60 | 649 | 72 | 254 |
| 1959 | 1,609 | 981 | 61 | 708 | 72 | 273 |
| 1960 | 1,727 | 1,033 | 60 | 767 | 74 | 266 |
| 1961 | 1,774 | 1,030 | 58 | 726 | 70 | 304 |
| 1962 | 1,958 | 1,230 | 63 | 886 | 72 | 344 |
| 1963 | 1,996 | 1,223 | 61 | 1,019 | 83 | 204 |
| 1964 | 2,267 | 1,503 | 66 | 1,095 | 73 | 408 |
| 1965 | 2,360 | 1,712 | 73 | 1,107 | 65 | 605 |
| 1966 | 2,571 | 1,816 | 71 | 1,202 | 66 | 614 |
| 1967 | 2,523 | 1,624 | 64 | 1,069 | 66 | 555 |
| 1968 | 2,707 | 1,631 | 60 | 1,107 | 68 | 524 |
| 1969 | 2,969 | 1,717 | 58 | 1,207 | 70 | 510 |
| 1970 | 3,413 | 1,808 | 53 | 1,385 | 77 | 423 |
| 1971 | | 2,524 | | 1,744 | 69 | 781 |

[a] U.S. Department of Commerce, Bureau of the Census. 1975. *Historical Statistics of the United States, Colonial Times to 1970.* Series Y 533–566. Federal, State, and Local Government Expenditure, By Function: 1902 to 1970. Washington, DC: Government Printing Office.

[b] Government Finance Data (BOC, Census of Governments, Compendium of Government Finance, Fiscal Years 1957, 1962, 1967. Table 8. Direct General Expenditure by Function, by Type of Government.)

[c] Estimated for 1902 through 1957 assuming that the ratio of capital to total sewerage expenditures is constant and equal to the average ratio observed in 1958 through 1971 (71 percent). For 1902 through 1956, total sewerage expenditures are assumed to be 62 percent of total sanitation expenditures, based on data for 1957 through 1970.

*Source*: From www.usepa.gov.

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**Table 11F.110 Comparison of Total U.S. Population, Housing Starts, and Public Sewerage Capital Expenditures (Actual and Projected), 1902–1997**

| Calendar Year | U.S. Population (millions)[a] | Housing Starts (thousands)[a] | Sewerage Capital Expenditures (1997 $ millions) |
|---|---|---|---|
| | | | Actual before CWA[b] |
| 1902 | 79 | 157 | 427 |
| 1913 | 97 | 307 | 665 |
| 1922 | 110 | 574 | 773 |
| 1927 | 119 | 643 | 1,123 |
| 1932 | 125 | 64 | 1,040 |
| 1934 | 126 | 49 | 884 |
| 1936 | 128 | 211 | 979 |
| 1938 | 130 | 262 | 1,017 |
| 1940 | 132 | 397 | 979 |
| 1942 | 135 | 227 | 933 |
| 1944 | 138 | 96 | 1,021 |
| 1946 | 141 | 738 | 1,433 |
| 1948 | 147 | 977 | 1,944 |
| 1950 | 152 | 1,387 | 2,365 |
| 1952 | 158 | 1,051 | 2,358 |
| 1953 | 160 | 1,019 | 2,408 |
| 1954 | 163 | 1,113 | 2,664 |
| 1955 | 166 | 1,182 | 2,946 |
| 1956 | 169 | 963 | 3,208 |
| 1957 | 172 | 854 | 3,256 |
| 1958 | 176 | 955 | 3,332 |
| 1959 | 178 | 1,076 | 3,585 |
| 1960 | 181 | 888 | 3,579 |
| 1961 | 184 | 946 | 3,820 |
| 1962 | 187 | 1,053 | 4,458 |
| 1963 | 189 | 1,149 | 4,889 |
| 1964 | 192 | 1,118 | 5,018 |
| 1965 | 194 | 1,012 | 5,163 |
| 1966 | 197 | 788 | 4,937 |
| 1967 | 199 | 903 | 4,584 |
| 1968 | 201 | 1,096 | 4,670 |
| 1969 | 203 | 1,079 | 4,996 |
| 1970 | 205 | 1,018 | 5,727 |
| 1971 | 208 | 1,502 | 6,868 |

| Calendar Year | U.S. Population (millions)[a] | Housing Starts (thousands)[a] | Sewerage Capital Expenditures (1997 $ millions) | |
|---|---|---|---|---|
| | | | Actual with CWA[b] | Projected without CWA[c] |
| 1972 | 210 | 1,720 | 7,728 | 6,897 |
| 1973 | 212 | 1,495 | 8,009 | 6,695 |
| 1974 | 214 | 923 | 9,006 | 5,968 |
| 1975 | 216 | 760 | 9,972 | 5,867 |
| 1976 | 218 | 1,044 | 10,222 | 6,429 |
| 1977 | 220 | 1,377 | 10,085 | 7,076 |
| 1978 | 223 | 1,432 | 10,946 | 7,315 |
| 1979 | 225 | 1,241 | 12,012 | 7,194 |
| 1980 | 227 | 914 | 12,188 | 6,851 |
| 1981 | 229 | 760 | 10,823 | 6,771 |
| 1982 | 232 | 785 | 9,301 | 6,955 |
| 1983 | 234 | 1,351 | 8,745 | 7,945 |
| 1984 | 236 | 1,415 | 8,515 | 8,176 |
| 1985 | 238 | 1,494 | 8,799 | 8,435 |
| 1986 | 240 | 1,546 | 9,531 | 8,662 |
| 1987 | 242 | 1,372 | 10,481 | 8,546 |
| 1988 | 244 | 1,243 | 10,783 | 8,501 |

*(Continued)*

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**Table 11F.110 (Continued)**

| Calendar Year | U.S. Population (millions)[a] | Housing Starts (thousands)[a] | Sewerage Capital Expenditures (1997 $ millions) | |
|---|---|---|---|---|
| | | | Actual with CWA[b] | Projected without CWA[c] |
| 1989 | 247 | 1,128 | 10,383 | 8,484 |
| 1990 | 249 | 947 | 10,402 | 8,388 |
| 1991 | 252 | 789 | 10,335 | 8,333 |
| 1992 | 255 | 932 | 10,698 | 8,738 |
| 1993 | 258 | 1,032 | 9,914 | 9,072 |
| 1994 | 260 | 1,183 | 8,962 | 9,469 |
| 1995 | 263 | 1,106 | 9,454 | 9,520 |
| | | | **Projected with CWA** | **Projected without CWA** |
| 1996 | 265 | 1,211 | 9,873 | 9,839 |
| 1997 | 268 | 1,221 | 9,873 | 10,025 |

[a] U.S. Bureau of the Census. Historical Housing Starts. Inside Standard Metropolitan Areas. Received Fax November 8, 1999. 1946 through 1958 based on average share that SMSA housing starts were of all private housing starts from 1902 through 1998.
[b] Values for 1996 through 1997 are an average of values for 1990 through 1994.
[c] Values for 1972 through 1997 estimated based on the estimated historical relationship (1902 through 1971) between capital expenditures, and housing starts (see Eq. [6.1]).

*Source*: From www.usepa.gov.

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**Table 11F.111 Comparison of Total Public Sewerage Operation and Maintenance Expenditures (Actual and Projected), 1902–1997**

| Calendar Year | Sewerage O&M Expenditures (1997 $ millions) Actual before CWA[a] |
|---|---|
| 1902 | 172 |
| 1913 | 268 |
| 1922 | 312 |
| 1927 | 453 |
| 1932 | 420 |
| 1934 | 357 |
| 1936 | 395 |
| 1938 | 411 |
| 1940 | 395 |
| 1942 | 377 |
| 1944 | 412 |
| 1946 | 578 |
| 1948 | 784 |
| 1950 | 954 |
| 1952 | 951 |
| 1953 | 972 |
| 1954 | 1,075 |
| 1955 | 1,189 |
| 1956 | 1,295 |
| 1957 | 1,294 |
| 1958 | 1,294 |
| 1959 | 1,310 |
| 1960 | 1,366 |
| 1961 | 1,536 |
| 1962 | 1,282 |
| 1963 | 1,415 |
| 1964 | 2,308 |
| 1965 | 2,726 |
| 1966 | 2,541 |
| 1967 | 2,273 |
| 1968 | 2,087 |
| 1969 | 1,798 |
| 1970 | 2,204 |
| 1971 | 3,034 |

| Calendar Year | Sewerage O&M Expenditures (1997 $ millions) Actual with CWA[a] | Projected without CWA[b] |
|---|---|---|
| 1972 | 3,569 | 3,705 |
| 1973 | 4,134 | 4,069 |
| 1974 | 4,544 | 4,433 |
| 1975 | 4,871 | 4,796 |
| 1976 | 5,398 | 5,154 |
| 1977 | 6,007 | 5,497 |
| 1978 | 6,527 | 5,866 |
| 1979 | 6,867 | 6,197 |
| 1980 | 7,239 | 6,551 |
| 1981 | 7,700 | 6,848 |
| 1982 | 8,215 | 7,170 |
| 1983 | 8,606 | 7,487 |
| 1984 | 8,900 | 7,834 |
| 1985 | 9,311 | 8,174 |
| 1986 | 9,970 | 8,505 |
| 1987 | 10,467 | 8,828 |
| 1988 | 10,836 | 9,154 |
| 1989 | 11,595 | 9,480 |

*(Continued)*

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**Table 11F.111 (Continued)**

| Calendar Year | Sewerage O&M Expenditures (1997 $ millions) | |
|---|---|---|
| | Actual with CWA[a] | Projected without CWA[b] |
| 1990 | 12,227 | 9,791 |
| 1991 | 12,604 | 10,106 |
| 1992 | 13,309 | 10,405 |
| 1993 | 14,172 | 10,669 |
| 1994 | 15,036 | 10,913 |
| 1995 | 15,582 | 11,166 |
| | **Projected with CWA** | **Projected without CWA** |
| 1996 | 16,357 | 11,417 |
| 1997 | 17,171 | 11,705 |

[a] Values for 1996 and 1997 are projected based on the observed time trend between 1972 and 1995.
[b] Values for 1972 through 1997 estimated based on the estimated historical relationship (1932 through 1971) between O&M expenditures and the estimated size and average age of the sewerage capital stock (see Eq. [6.2]).

*Source*: From www.usepa.gov.

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**Table 11F.112 Public Sewerage Capital Costs under the with CWA and without CWA Scenarios (1997 $ millions)**

| | With CWA | | | Without CWA | | |
|---|---|---|---|---|---|---|
| Year | Capital Expenditures | Estimated Capital Stock[a] | Annualized Capital Costs | Capital Expenditures | Estimated Capital Stock[a] | Annualized Capital Costs |
| 1952 | 2,358 | | | 2,358 | | |
| 1953 | 2,408 | | | 2,408 | | |
| 1954 | 2,664 | | | 2,664 | | |
| 1955 | 2,946 | | | 2,946 | | |
| 1956 | 3,208 | | | 3,208 | | |
| 1957 | 3,256 | | | 3,256 | | |
| 1958 | 3,332 | | | 3,332 | | |
| 1959 | 3,585 | | | 3,585 | | |
| 1960 | 3,579 | | | 3,579 | | |
| 1961 | 3,820 | | | 3,820 | | |
| 1962 | 4,458 | | | 4,458 | | |
| 1963 | 4,889 | | | 4,889 | | |
| 1964 | 5,018 | | | 5,018 | | |
| 1965 | 5,163 | | | 5,163 | | |
| 1966 | 4,937 | | | 4,937 | | |
| 1967 | 4,584 | | | 4,584 | | |
| 1968 | 4,670 | | | 4,670 | | |
| 1969 | 4,996 | | | 4,996 | | |
| 1970 | 5,727 | | | 5,727 | | |
| 1971 | 6,868 | | | 6,868 | | |
| 1972 | 7,728 | | | 6,897 | | |
| 1973 | 8,009 | | | 6,695 | | |
| 1974 | 9,006 | | | 5,968 | | |
| 1975 | 9,972 | | | 5,867 | | |
| 1976 | 10,222 | | | 6,429 | | |
| 1977 | 10,085 | | | 7,076 | | |
| 1978 | 10,946 | | | 7,315 | | |
| 1979 | 12,012 | | | 7,194 | | |
| 1980 | 12,188 | | | 6,851 | | |
| 1981 | 10,823 | | | 6,771 | | |
| 1982 | 9,301 | 183,458 | 9,360 | 6,955 | 149,530 | 7,629 |
| 1983 | 8,745 | 190,402 | 9,714 | 7,945 | 154,128 | 7,863 |
| 1984 | 8,515 | 196,739 | 10,037 | 8,176 | 159,665 | 8,146 |
| 1985 | 8,799 | 202,589 | 10,336 | 8,435 | 165,176 | 8,427 |
| 1986 | 9,531 | 208,442 | 10,635 | 8,662 | 170,666 | 8,707 |
| 1987 | 10,481 | 214,764 | 10,957 | 8,546 | 176,120 | 8,986 |
| 1988 | 10,783 | 221,990 | 11,326 | 8,501 | 181,410 | 9,255 |
| 1989 | 10,383 | 229,441 | 11,706 | 8,484 | 186,578 | 9,519 |
| 1990 | 10,402 | 236,239 | 12,053 | 8,388 | 191,477 | 9,769 |
| 1991 | 10,335 | 243,061 | 12,401 | 8,333 | 196,286 | 10,014 |
| 1992 | 10,698 | 249,576 | 12,733 | 8,738 | 200,799 | 10,245 |
| 1993 | 9,914 | 255,817 | 13,052 | 9,072 | 205,079 | 10,463 |
| 1994 | 8,962 | 260,842 | 13,308 | 9,469 | 209,262 | 10,676 |
| 1995 | 9,454 | 264,786 | 13,509 | 9,520 | 213,712 | 10,903 |
| 1996 | 9,873 | 269,077 | 13,728 | 9,839 | 218,070 | 11,126 |
| 1997 | 9,873 | 274,012 | 13,980 | 10,025 | 222,972 | 11,376 |

[a] Based on 30-year life of capital and a 3 percent discount rate.

*Source*: From www.usepa.gov.

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**Table 11F.113 Water Pollution Abatement Capital and O&M Expenditures by Publicly Owned Electric Utilities, 1972–1997**

| | Expenditures (current $ millions)[a] | | Expenditures (1997 $ millions)[b] | |
|---|---|---|---|---|
| Year | Capital | O&M | Capital | O&M |
| 1972 | 29 | 3 | 97 | 10 |
| 1973 | 22 | 4 | 70 | 13 |
| 1974 | 29 | 5 | 84 | 15 |
| 1975 | 32 | 7 | 85 | 19 |
| 1976 | 36 | 9 | 90 | 23 |
| 1977 | 52 | 10 | 122 | 24 |
| 1978 | 63 | 10 | 138 | 22 |
| 1979 | 81 | 12 | 164 | 24 |
| 1980 | 61 | 13 | 113 | 24 |
| 1981 | 57 | 18 | 96 | 30 |
| 1982 | 86 | 17 | 137 | 27 |
| 1983 | 73 | 19 | 111 | 29 |
| 1984 | 54 | 20 | 79 | 29 |
| 1985 | 63 | 10 | 90 | 14 |
| 1986 | 40 | 10 | 55 | 14 |
| 1987 | 37 | 13 | 50 | 17 |
| 1988 | 28 | 12 | 36 | 16 |
| 1989 | 49 | 11 | 61 | 14 |
| 1990 | 77 | 8 | 92 | 10 |
| 1991 | 64 | 14 | 73 | 16 |
| 1992 | 14 | 10 | 16 | 11 |
| 1993 | 11 | 11 | 12 | 12 |
| 1994 | 10 | 10 | 11 | 11 |
| 1995 | | | 41 | 12 |
| 1996 | | | 41 | 12 |
| 1997 | | | 41 | 12 |

[a] Vogan, Christine R. September 1996. *Survey of Current Business*. "Pollution Abatement and Control Expenditures, 1972–1994." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972–1994.

[b] Values for 1995 through 1997 are assumed to be equal to the average observed value for 1990 through 1994.

*Source*: From www.usepa.gov.

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**Table 11F.114 Water Pollution Abatement O&M Expenditures by Publicly Owned Electric Utilities without the CWA, 1972–1997 (1997 $ millions)**

| Year | O&M Expenditures[a] | Without CWA O&M Expenditures[b] |
|---|---|---|
| 1972 | 10 | 10 |
| 1973 | 13 | 10 |
| 1974 | 15 | 10 |
| 1975 | 19 | 10 |
| 1976 | 23 | 10 |
| 1977 | 24 | 10 |
| 1978 | 22 | 10 |
| 1979 | 24 | 10 |
| 1980 | 24 | 10 |
| 1981 | 30 | 10 |
| 1982 | 27 | 10 |
| 1983 | 29 | 10 |
| 1984 | 29 | 10 |
| 1985 | 14 | 10 |
| 1986 | 14 | 10 |
| 1987 | 17 | 10 |
| 1988 | 16 | 10 |
| 1989 | 14 | 10 |
| 1990 | 10 | 10 |
| 1991 | 16 | 10 |
| 1992 | 11 | 10 |
| 1993 | 12 | 10 |
| 1994 | 11 | 10 |
| 1995 | 12 | 10 |
| 1996 | 12 | 10 |
| 1997 | 12 | 10 |

[a] Values for 1995 through 1997 are assumed to be equal to the average observed value for 1990 through 1994.
[b] Assumed to be equal to the minimum observed value for WPA O&M expenditures with the CWA (1972 through 1997).

*Source*: From www.usepa.gov.

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**Table 11F.115 Water Pollution Abatement Capital Expenditures and Costs by Publicly Owned Electric Utilities without the CWA, 1972–1997 (1997 $ millions)**

| | With CWA | | | Without CWA | | |
|---|---|---|---|---|---|---|
| Year | Capital Expenditures[a] | Estimated Gross Capital Stock | Capital Cost | Capital Expenditures[b] | Estimated Gross Capital Stock | Capital Cost |
| 1972 | 97 | | | 11 | | |
| 1973 | 70 | | | 11 | | |
| 1974 | 84 | | | 11 | | |
| 1975 | 85 | | | 11 | | |
| 1976 | 90 | | | 11 | | |
| 1977 | 122 | | | 11 | | |
| 1978 | 138 | | | 11 | | |
| 1979 | 164 | | | 11 | | |
| 1980 | 113 | | | 11 | | |
| 1981 | 96 | | | 11 | | |
| 1982 | 137 | | | 11 | | |
| 1983 | 111 | | | 11 | | |
| 1984 | 79 | | | 11 | | |
| 1985 | 90 | | | 11 | | |
| 1986 | 55 | | | 11 | | |
| 1987 | 50 | | | 11 | | |
| 1988 | 36 | | | 11 | | |
| 1989 | 61 | | | 11 | | |
| 1990 | 92 | | | 11 | | |
| 1991 | 73 | | | 11 | | |
| 1992 | 16 | 1,843 | | 11 | 212 | |
| 1993 | 12 | 1,762 | | 11 | 212 | |
| 1994 | 11 | 1,704 | | 11 | 212 | |
| 1995 | 41 | 1,631 | | 11 | 212 | |
| 1996 | 41 | 1,587 | | 11 | 212 | |
| 1997 | 41 | 1,537 | | 11 | 212 | |

[a] Based on a 20-year life of capital and a 3 percent discount rate. Vogan, Christine R. September 1996. *Survey of Current Business.* "Pollution Abatement and Control Expenditures, 1972–1994." Table 12. Business and Government Expenditures for Air and Water Pollution Abatement in Current Dollars and Chain-Type Quantity and Price Indexes, 1972–1994. Values for 1995 through 1997 are assumed to be equal to the average observed value for 1990 through 1994.

[b] Assumed to be equal to the minimum observed value for WPA capital expenditures with the CWA (1972 through 1997).

*Source*: From www.usepa.gov.

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**Table 11F.116 Public and Private R&D, R&M, and Other Not-Elsewhere-Classified Expenditures for Water Pollution Abatement, 1972–1994 (current $ millions)**

| | Public | | | Private |
|---|---|---|---|---|
| Year | R&D | R&M | Other | R&D |
| 1972 | 78 | 145 | 171 | 64 |
| 1973 | 95 | 190 | 171 | 73 |
| 1974 | 96 | 247 | 189 | 57 |
| 1975 | 96 | 279 | 210 | 68 |
| 1976 | 102 | 328 | 204 | 78 |
| 1977 | 108 | 370 | 188 | 91 |
| 1978 | 121 | 405 | 218 | 99 |
| 1979 | 139 | 425 | 257 | 107 |
| 1980 | 118 | 465 | 299 | 110 |
| 1981 | 130 | 434 | 286 | 104 |
| 1982 | 141 | 416 | 276 | 102 |
| 1983 | 153 | 381 | 290 | 93 |
| 1984 | 134 | 388 | 337 | 90 |
| 1985 | 110 | 464 | 391 | 95 |
| 1986 | 126 | 510 | 426 | 104 |
| 1987 | 123 | 560 | 542 | 106 |
| 1988 | 110 | 580 | 484 | 112 |
| 1989 | 108 | 626 | 489 | 125 |
| 1990 | 89 | 620 | 514 | 97 |
| 1991 | 101 | 761 | 537 | 124 |
| 1992 | 123 | 922 | 538 | 55 |
| 1993 | 107 | 750 | 575 | 81 |
| 1994 | 136 | 622 | 472 | 76 |

*Source*: From www.usepa.gov.

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**Table 11F.117 Comparison of R&D Expenditures for Water Pollution Abatement and Total R&D Expenditures, 1972–1997 (1997 $ millions)**

| | Public | | | Private | | |
|---|---|---|---|---|---|---|
| | Total R&D[a] | WPA R&D | | Total R&D[a] | WPA R&D | |
| Year | 1997 $millions | 1997 $millions | % of Total | 1997 $millions | 1997 $millions | % of Total |
| 1972 | 54,264 | 260 | 0.48% | 39,109 | 214 | 0.55% |
| 1973 | 53,290 | 300 | 0.56% | 42,023 | 231 | 0.55% |
| 1974 | 50,789 | 279 | 0.55% | 43,174 | 165 | 0.38% |
| 1975 | 49,797 | 254 | 0.51% | 41,937 | 180 | 0.43% |
| 1976 | 51,455 | 255 | 0.50% | 44,323 | 195 | 0.44% |
| 1977 | 52,640 | 254 | 0.48% | 46,205 | 214 | 0.46% |
| 1978 | 54,184 | 265 | 0.49% | 49,246 | 217 | 0.44% |
| 1979 | 55,722 | 281 | 0.50% | 52,722 | 216 | 0.41% |
| 1980 | 56,143 | 218 | 0.39% | 57,186 | 203 | 0.36% |
| 1981 | 57,860 | 220 | 0.38% | 60,778 | 176 | 0.29% |
| 1982 | 59,987 | 224 | 0.37% | 64,714 | 162 | 0.25% |
| 1983 | 64,060 | 233 | 0.36% | 69,047 | 142 | 0.21% |
| 1984 | 69,104 | 197 | 0.28% | 76,745 | 132 | 0.17% |
| 1985 | 75,701 | 156 | 0.21% | 82,417 | 135 | 0.16% |
| 1986 | 76,734 | 174 | 0.23% | 84,574 | 144 | 0.17% |
| 1987 | 79,648 | 165 | 0.21% | 84,176 | 142 | 0.17% |
| 1988 | 79,130 | 143 | 0.18% | 88,216 | 145 | 0.16% |
| 1989 | 76,534 | 134 | 0.18% | 93,374 | 155 | 0.17% |
| 1990 | 74,845 | 106 | 0.14% | 99,338 | 116 | 0.12% |
| 1991 | 71,123 | 116 | 0.16% | 106,023 | 142 | 0.13% |
| 1992 | 69,398 | 137 | 0.20% | 107,558 | 61 | 0.06% |
| 1993 | 67,295 | 116 | 0.17% | 105,113 | 88 | 0.08% |
| 1994 | 66,122 | 144 | 0.22% | 105,459 | 81 | 0.08% |
| 1995 | 67,265 | 124 | 0.18% | 115,191 | 98 | 0.08% |
| 1996 | 65,743 | 124 | 0.19% | 123,402 | 98 | 0.08% |
| 1997 | 64,566 | 124 | 0.19% | 133,308 | 98 | 0.07% |

[a] U.S. Bureau of the Census. October 2, 1998. *Statistical Abstract of the United States*: 1998. "No. 988. R&D Expenditures: 1960–1997."

*Source*: From www.usepa.gov.

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**Table 11F.118 Public and Private R&D Expenditures for Water Pollution Abatement, with and without the CWA, 1972–1997 (1997 $ millions)**

| Year | Public R&D Expenditures | | Private R&D Expenditures | |
|---|---|---|---|---|
| | With CWA | Without CWA[a] | With CWA | Without CWA[a] |
| 1972 | 260.4 | 76.9 | 213.7 | 22.3 |
| 1973 | 300.3 | 75.5 | 230.7 | 24.0 |
| 1974 | 278.5 | 72.0 | 165.4 | 24.6 |
| 1975 | 254.4 | 70.5 | 180.2 | 23.9 |
| 1976 | 255.4 | 72.9 | 195.3 | 25.3 |
| 1977 | 254.1 | 74.6 | 214.1 | 26.4 |
| 1978 | 265.4 | 76.8 | 217.1 | 28.1 |
| 1979 | 280.9 | 78.9 | 216.2 | 30.1 |
| 1980 | 218.2 | 79.5 | 203.4 | 32.6 |
| 1981 | 219.7 | 82.0 | 175.8 | 34.7 |
| 1982 | 224.2 | 85.0 | 162.2 | 36.9 |
| 1983 | 233.3 | 90.8 | 141.8 | 39.4 |
| 1984 | 196.9 | 97.9 | 132.3 | 43.8 |
| 1985 | 156.3 | 107.3 | 135.0 | 47.0 |
| 1986 | 174.5 | 108.7 | 144.0 | 48.3 |
| 1987 | 165.2 | 112.8 | 142.4 | 48.0 |
| 1988 | 142.5 | 112.1 | 145.1 | 50.3 |
| 1989 | 134.3 | 108.4 | 155.4 | 53.3 |
| 1990 | 106.0 | 106.0 | 115.6 | 56.7 |
| 1991 | 115.8 | 100.8 | 142.2 | 60.5 |
| 1992 | 137.2 | 98.3 | 61.4 | 61.4 |
| 1993 | 116.3 | 95.3 | 88.0 | 60.0 |
| 1994 | 144.4 | 93.7 | 80.7 | 60.2 |
| 1995 | 124.0 | 95.3 | 98.0 | 65.7 |
| 1996 | 124.0 | 93.1 | 98.0 | 70.4 |
| 1997 | 124.0 | 91.5 | 98.0 | 76.1 |

[a] Values estimated based on observed minimum ratio of public WPA R&D to total public R&D from 1972 through 1994.

*Source*: From www.usepa.gov.

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**Table 11F.119 Comparison of Public R&M and Other Not-Elsewhere-Classified Expenditures for Water Pollution Abatement and Total Public Consumption Expenditures, 1972–1997 (1997 $ millions)**

| Year | Total Public Consumption Expenditures[a] 1997 $ millions | Public R&M and Other NEC WPA Expenditures[b] | |
|---|---|---|---|
| | | 1997 $millions | % of Total |
| 1972 | 746,578 | 1,306 | 0.17% |
| 1973 | 756,637 | 1,561 | 0.21% |
| 1974 | 775,167 | 1,833 | 0.24% |
| 1975 | 794,858 | 2,014 | 0.25% |
| 1976 | 804,909 | 1,976 | 0.25% |
| 1977 | 827,059 | 1,969 | 0.24% |
| 1978 | 840,570 | 2,059 | 0.24% |
| 1979 | 852,293 | 2,079 | 0.24% |
| 1980 | 880,917 | 1,919 | 0.22% |
| 1981 | 898,073 | 1,589 | 0.18% |
| 1982 | 918,760 | 1,479 | 0.16% |
| 1983 | 944,334 | 1,699 | 0.18% |
| 1984 | 977,076 | 1,788 | 0.18% |
| 1985 | 1,030,118 | 2,235 | 0.22% |
| 1986 | 1,073,110 | 2,235 | 0.21% |
| 1987 | 1,100,470 | 2,326 | 0.21% |
| 1988 | 1,113,256 | 2,349 | 0.21% |
| 1989 | 1,134,544 | 2,364 | 0.21% |
| 1990 | 1,163,708 | 2,356 | 0.20% |
| 1991 | 1,175,513 | 2,609 | 0.22% |
| 1992 | 1,176,727 | 2,913 | 0.25% |
| 1993 | 1,172,717 | 2,582 | 0.22% |
| 1994 | 1,175,284 | 2,259 | 0.19% |
| 1995 | 1,181,092 | 2,615 | 0.22% |
| 1996 | 1,197,291 | 2,661 | 0.22% |
| 1997 | 1,219,200 | 2,707 | 0.22% |

[a] Council of Economic Advisers. *Economic Report of the President.* "B-83. Federal and State and Local Government Receipts and Current Expenditures, National Income and Product Accounts, 1959–1998." www.access.gpo.gov/usbudget/fy01/erp.html. As obtained on December 3, 1999.

[b] Values for 1995 through 1997 are projected based on the observed time trend between 1972 and 1994.

*Source*: From www.usepa.gov.

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**Table 11F.120 Public Water Pollution Abatement Expenditures for Regulation and Monitoring and Other Expenditures Not Elsewhere Classified, with and without the CWA, 1972–1997 (1997 $millions)**

| Year | With CWA R&M and Other Expenditures | Without CWA R&M and Other Expenditures[a] |
|---|---|---|
| 1972 | 1,305.5 | 1,201.4 |
| 1973 | 1,561.3 | 1,217.6 |
| 1974 | 1,833.5 | 1,247.5 |
| 1975 | 2,014.3 | 1,279.1 |
| 1976 | 1,976.0 | 1,295.3 |
| 1977 | 1,969.4 | 1,331.0 |
| 1978 | 2,059.2 | 1,352.7 |
| 1979 | 2,079.2 | 1,371.6 |
| 1980 | 1,919.4 | 1,417.6 |
| 1981 | 1,588.9 | 1,445.2 |
| 1982 | 1,478.5 | 1,478.5 |
| 1983 | 1,698.9 | 1,519.7 |
| 1984 | 1,788.4 | 1,572.4 |
| 1985 | 2,234.7 | 1,657.7 |
| 1986 | 2,234.8 | 1,726.9 |
| 1987 | 2,326.4 | 1,771.0 |
| 1988 | 2,349.4 | 1,791.5 |
| 1989 | 2,363.8 | 1,825.8 |
| 1990 | 2,355.5 | 1,872.7 |
| 1991 | 2,609.2 | 1,891.7 |
| 1992 | 2,913.1 | 1,893.7 |
| 1993 | 2,581.5 | 1,887.2 |
| 1994 | 2,259.3 | 1,891.4 |
| 1995 | 2,614.6 | 1,900.7 |
| 1996 | 2,661.0 | 1,926.8 |
| 1997 | 2,707.5 | 1,962.0 |

[a] Values estimated based on observed minimum ratio of public WPA R&M and other not-elsewhere-classified expenditures to all government consumption expenditures from 1972 through 1994.

*Source*: From www.usepa.gov.

**Table 11F.121 Canadian Federal Resources Directed to Water-Related Programs by Type of Program, Fiscal Year 1985–1986**

| | | Person Years | | Expenditures | |
|---|---|---|---|---|---|
| Program | Agencies | Number | % of Total | Millions of $ | % of Total |
| 1. Research and Information | | | | | |
| Water research | Environment, Fisheries and Oceans | 725 | 20 | 60 | 16 |
| Water data collection | Environment, Fisheries and Oceans | 750 | 21 | 54 | 14 |
| 2. Water Quality | | | | | |
| Water pollution control | Environment, Fisheries and Oceans | 630 | 18 | 44 | 12 |
| Drinking water | Agriculture, Indian Affairs and Northern Development, Health and Welfare | 10 | — | 41 | 11 |
| 3. Navigation and Ports | | | | | |
| Canals and channels | Environment, transport, Public Works | 420 | 12 | 51 | 14 |
| Ports and harbors | Fisheries and Oceans, Transport | 60 | 2 | 36 | 10 |
| 4. Water Supplies | | | | | |
| Irrigation | Agriculture | 500 | 14 | 38 | 10 |
| Flood control | Environment, Transport | 160 | 5 | 18 | 5 |
| 5. International and Interprovincial Agreements | | | | | |
| | Environment, External Affairs, International Joint Commission | 230 | 6 | 24 | 6 |
| 6. Administration of Northern Waters | | | | | |
| | Indian Affairs and Northern Development | 55 | 2 | 7 | 2 |
| Total | | 3,540 | 100 | 373 | 100 |

*Note:* Expenditures in Canadian dollars.

*Source*: From Pearse, P.H., and others, *Currents of Change*, Final Report on Federal Water Policy, Ottawa, Canada, 1985.

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**Table 11F.122 Canadian Federal Resources Directed to Water-Related Programs by Department, Fiscal Year 1985–1986**

| | | Expenditures | |
|---|---|---|---|
| **Agencies** | **Person Years** | **Millions of $** | **% of Total** |
| Environment | 1,880 | 169 | 45 |
| Fisheries and Oceans | 620 | 62 | 17 |
| Indian Affairs and Northern Development | 60 | 39 | 10 |
| Transport and Public Works | 270 | 37 | 10 |
| Agriculture | 545 | 50 | 13 |
| Energy, Mines and Resources | 80 | 8 | 3 |
| External Affairs | 25 | 4 | 1 |
| International Joint Commission | 45 | 3 | 1 |
| Other | 15 | 1 | — |
| Total | 3,540 | 373 | 100 |

*Note:* Expenditures in Canadian dollars.

*Source*: From Pearse, P.H., and others, *Currents of Change*, Final Report on Federal Water Policy, Ottawa, Canada, 1985. With permission.

**Table 11F.123 World Bank Lending for Water Supply and Sewerage Projects, 1985–1987**

| | 1985 | | 1986 | | 1987 | | 1985–1987 | |
|---|---|---|---|---|---|---|---|---|
| **Region** | **$** | **%** | **$** | **%** | **$** | **%** | **$** | **%** |
| Eastern and Southern Africa | 49.00 | 6.3 | 9.50 | 1.6 | 54.80 | 5.6 | 113.30 | 4.8 |
| Western Africa | 101.00 | 12.9 | 10.00 | 1.7 | 7.00 | 0.7 | 118.00 | 5.0 |
| East Asia and Pacific | 175.00 | 22.4 | 212.30 | 35.1 | — | — | 387.30 | 16.4 |
| South Asia | — | — | 78.00 | 12.9 | 284.00 | 29.3 | 362.00 | 15.4 |
| Europe, Middle East and N Africa | 292.00 | 37.4 | 120.00 | 19.8 | 559.60 | 57.7 | 971.60 | 41.3 |
| Latin America and Caribbean | 163.80 | 21.0 | 175.00 | 28.9 | 64.00 | 6.6 | 402.80 | 17.1 |
| Total | 780.80 | 100.0 | 604.80 | 100.0 | 969.40 | 100.00 | 2,355.00 | 100.0 |

*Note:* Millions of United States dollars.

*Source*: From World Water, *Mediterranean Region Swamps World Bank's Lending.* Thomas Telford Ltd, Box 124, Liverpool L69 2LQ, England, 1987. With permission.

**Table 11F.124 Water Pollution Abatement Expenditures in the United States, 1975–1984**

| | | Industrial | | Public Sewer Systems[c] | |
|---|---|---|---|---|---|
| **Year** | **Total[b]** | **Facilities** | **Operations[a]** | **Facilities** | **Operations[a]** |
| 1975 | 22,840 | 4,200 | 2,950 | 8,997 | 3,428 |
| 1976 | 24,445 | 4,625 | 3,375 | 9,370 | 3,713 |
| 1977 | 24,652 | 4,415 | 3,706 | 9,409 | 4,055 |
| 1978 | 26,631 | 4,277 | 3,934 | 10,090 | 4,392 |
| 1979 | 26,470 | 4,013 | 4,222 | 9,758 | 4,583 |
| 1980 | 24,647 | 3,725 | 4,081 | 8,942 | 4,694 |
| 1981 | 21,984 | 3,259 | 4,180 | 6,882 | 4,880 |
| 1982 | 21,199 | 3,080 | 4,022 | 6,148 | 5,156 |
| 1983 | 21,461 | 2,813 | 4,402 | 5,551 | 5,475 |
| 1984, preliminary | 23,192 | 2,902 | 4,651 | 6,353 | 5,773 |

*Note:* In millions of dollars.

[a] Operation of facilities.
[b] Includes nonpoint sources not shown separately.
[c] Includes expenditures for private connectors to sewer systems, by owners of animal feedlots, and by government enterprises.

*Source*: From U.S. Department of Commerce, Statistical Abstract of the United States, 1987.

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## SECTION 11G DESALINATION

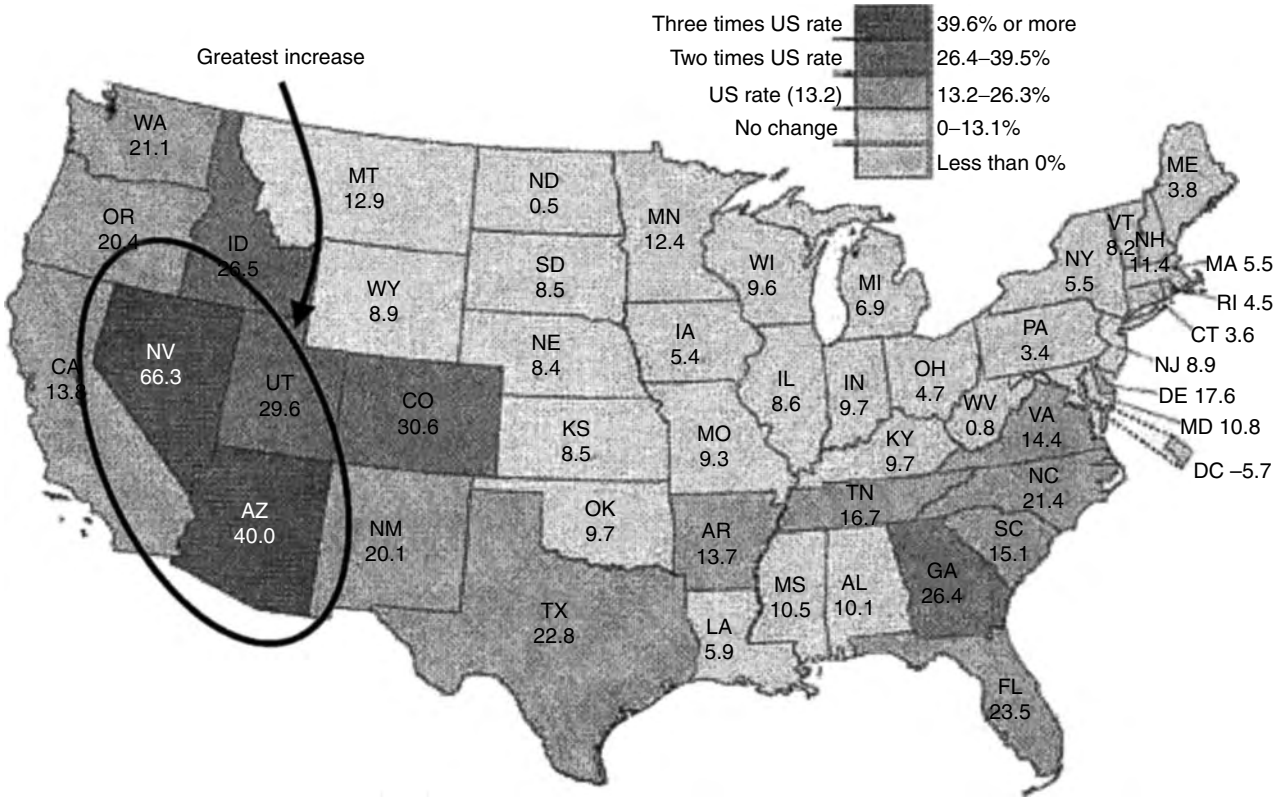


**Figure 11G.82** Federal interest in desalination: change in population 1900–2000. (From www.worldbank.org. With permission.)

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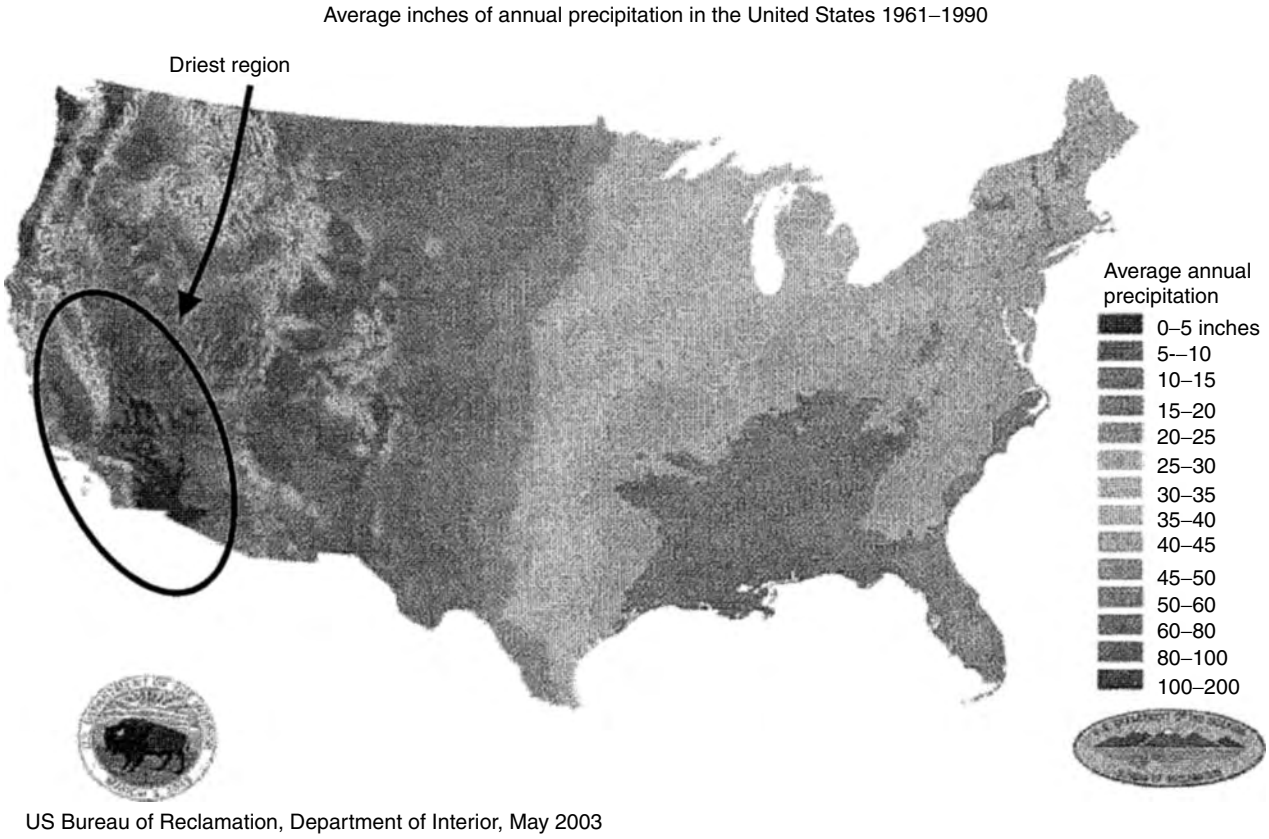


**Figure 11G.83** Federal interest in desalination: precipitation. (From www.worldbank.org. With permission.)

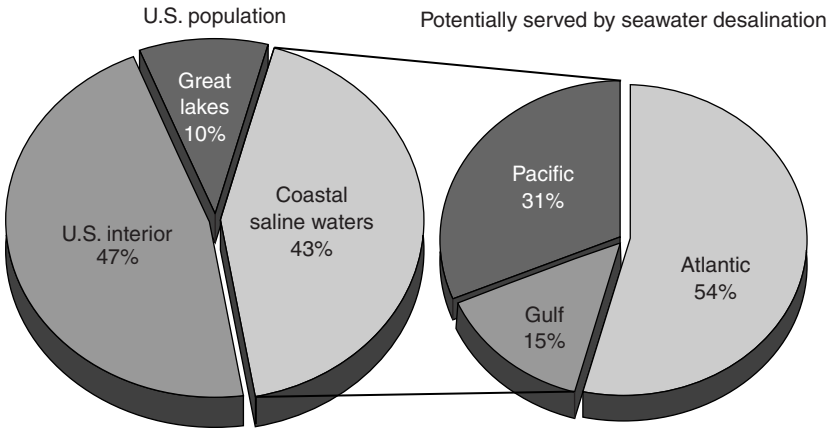


**Figure 11G.84** Federal interest in desalination: potential for seawater desalination. (From www.worldbank.org. With permission.)

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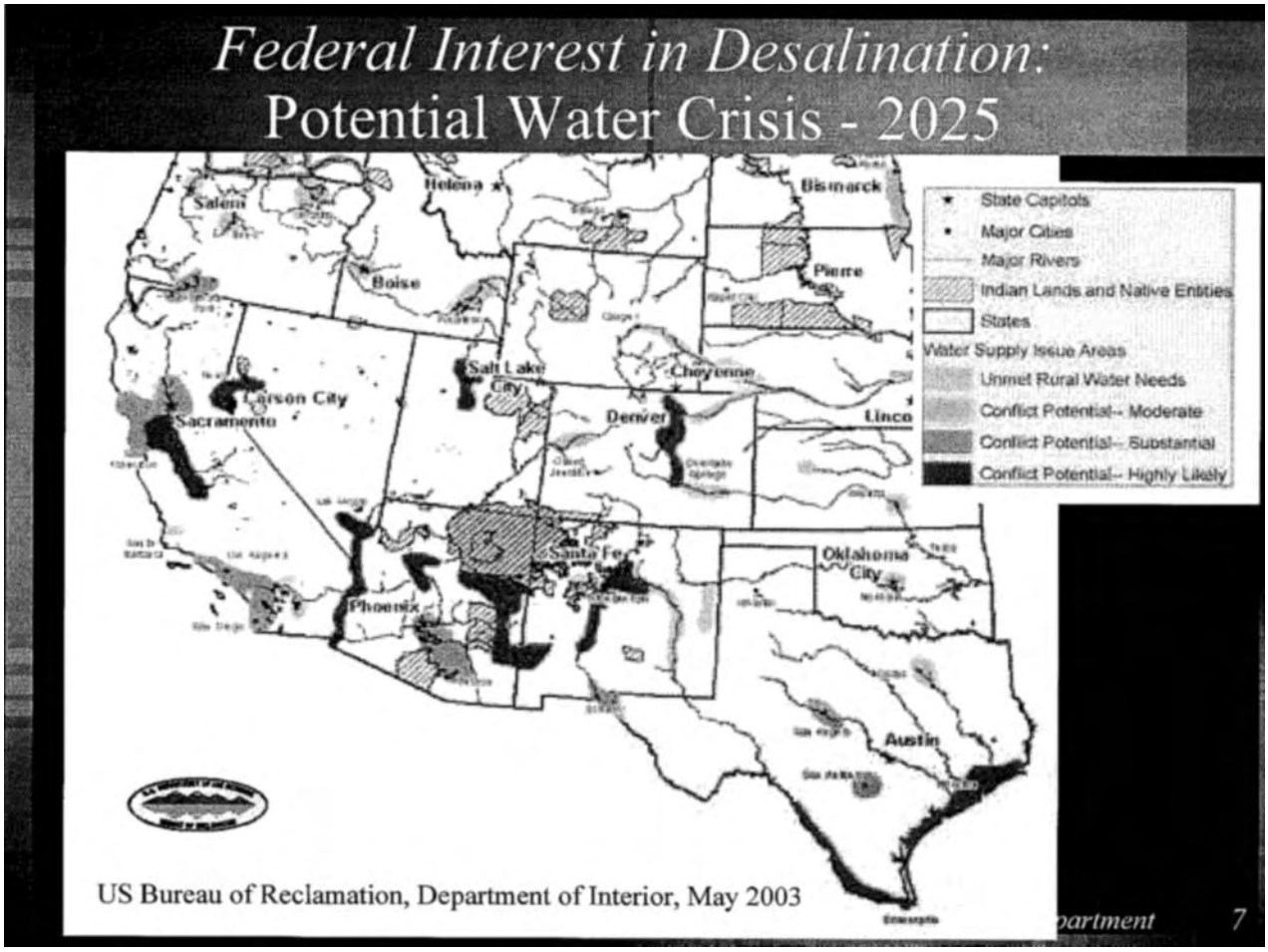


**Figure 11G.85** Federal interest in desalination: potential water crisis—2025. (From www.worldbank.org. With permission.)

**Table 11G.125 Classification of Desalting Processes Based on Properties of Solids and Liquids**

| |
|---|
| A. Processes dependent on phase changes of water |
| 1. Evaporation |
| Multiple-effect distillation, in which the latent heat comes from a solid surface |
| Multiple stage flash distillation, in which the latent heat comes from cooling of the liquid being evaporated |
| Supercritical distillation, in which all evaporation occurs above the critical temperature of pure water |
| Solar distillation in which the latent heat is derived from direct solar radiation |
| Vapor compression distillation, in which the latent heat is obtained regeneratively |
| 2. Crystallization |
| Freeze-separation, in which the crystals involved are those of pure water |
| Hydrate-separation, in which the crystals contain molecules of the hydrating agent |
| B. Processes dependent on the surface properties of membranes in contact with water |
| 1. Electrodialysis, in which the unwanted ions are caused to migrate through membranes due to electrical forces |
| 2. Hyperfiltration or reverse osmosis, in which water is caused to migrate through membranes preferentially to the salt ions, due to pressure |
| C. Processes dependent on the properties of solids and liquids in contact with water |
| 1. Ion exchange, in which unwanted ions are exchanged for less offensive ions loosely bonded to certain double salts in solid form |
| 2. Solvent extraction, in which certain liquids dissolve water more readily than the salt ions contained in the saline water |

*Source*: From Howe, University of California, Berkeley, 1968. With permission.

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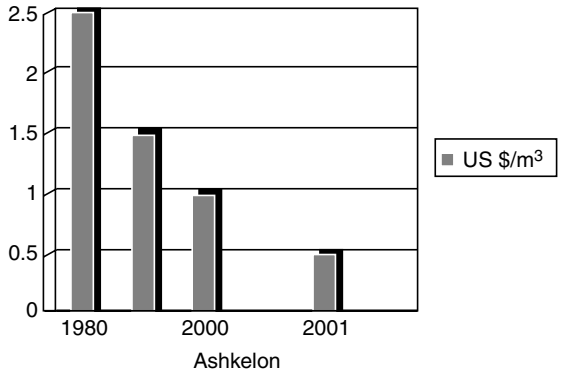


**Figure 11G.86** Desalination cost trend. (From www.worldbank.org. With permission.)

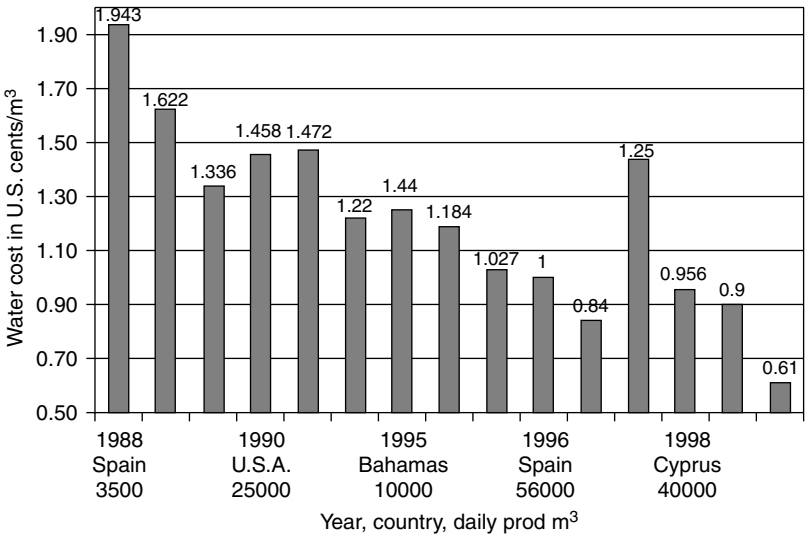


**Figure 11G.87** Desalination cost trend: seawater desalination (reverse osmosis) in cents/$m^3$ from boot schemes from international tenders years 1988–1999. (From www.worldbank.org. With permission.)

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**Table 11G.126 Desalination Costs in the United States**

| | Plant Size (mgd) | Overall Cost (1985 dollars/1,000 gal) |
|---|---|---|
| Brackish Water | | |
| Reverse osmosis | 1 | 1.67 |
| | 3 | 1.41 |
| | 5 | 1.33 |
| | 10 | 1.23 |
| | 25 | 1.21 |
| Electrodialysis (reversing) | 1 | 1.72 |
| | 5 | 1.47 |
| | 10 | 1.37 |
| | 25 | 1.26 |
| Seawater | | |
| Distillation | | |
| Multi-stage flash | 1[a] | 9.73 |
| | 5[a] | 6.78 |
| | 10[a] | 6.50 |
| | 25[a] | 6.10[b] |
| Multiple-effect | 1 | 8.31 |
| | 5[a] | 5.70 |
| | 10[a] | 5.36 |
| | 25[a] | 5.36[b] |
| Reverse osmosis | 0.01 | 13.42 |
| | 0.1 | 9.88 |
| | 1 | 7.40 |
| | 3 | 6.64 |
| | 5[a] | 6.36 |
| | 10[a] | 6.03[c] |
| | 25[a] | 5.96[c] |

[a] Theoretical costs, since no plants of this size are operating in the United States.
[b] Approximated from Reed.
[c] Extrapolated cost.

*Source*: From United Nations, "The Use of Nonconventional Water Resources in Developing Countries," adapted from Reed, S.A., "Desalting Seawater and Brackish Water: 1981 Cost Update." With permission.

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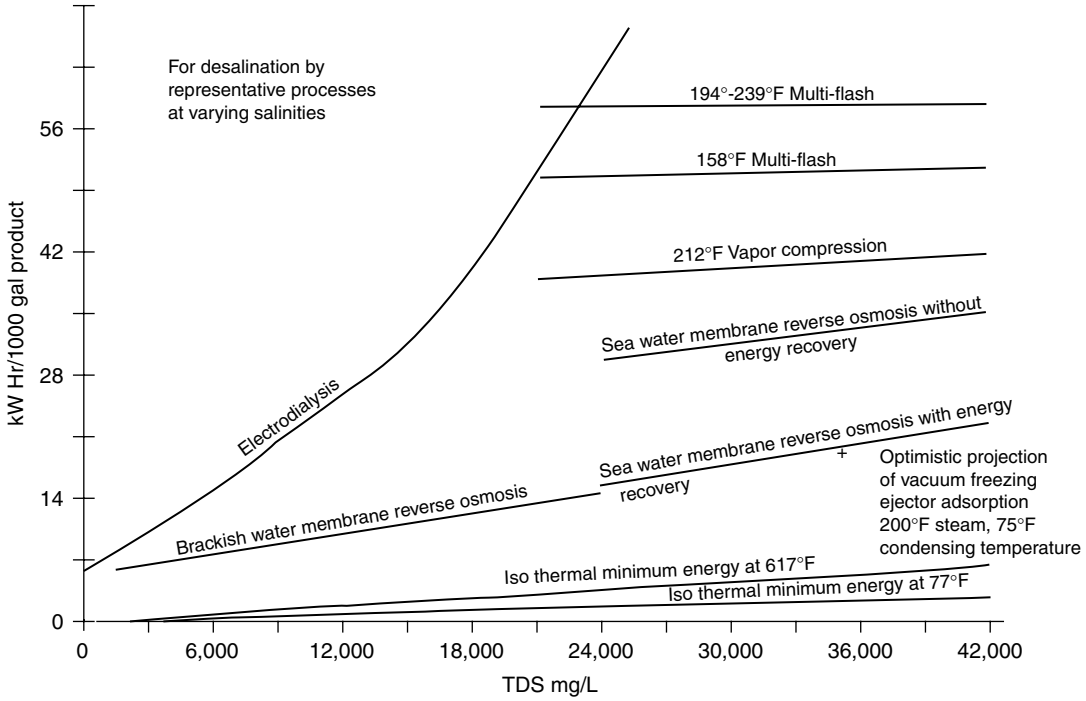


**Figure 11G.88** Energy consumption. (From www.usace.army.mil.)

**Table 11G.127 Classification of Desalting Processes Based on Type of Energy Required**

| | |
|---|---|
| A. Processes requiring thermal energy | C. Processes requiring electrical energy |
| Multiple effect distillation | Electrodialysis |
| Multistage flash distillation | |
| Solar distillation | |
| Supercritical distillation | |
| B. Processes requiring mechanical energy | D. Processes requiring chemical energy |
| Vapor compression distillation | Ion exchange |
| Freeze separation | Solvent extraction |
| Hydrate separation | |
| Hyperfiltration or reverse osmosis | |

*Source*: From Howe, University of California, Berkeley, 1968. With permission.

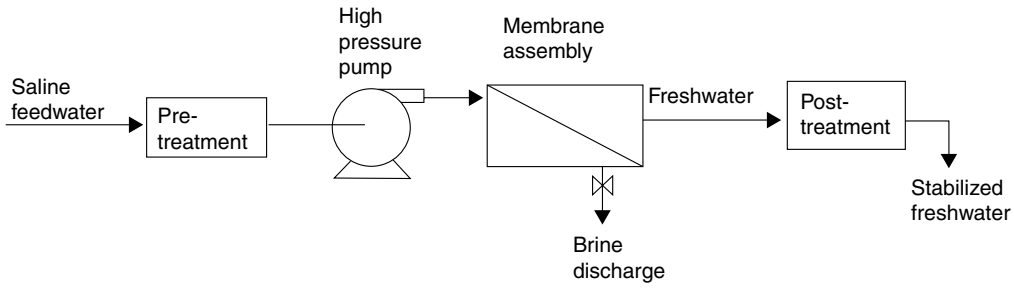


**Figure 11G.89** Flow diagram of a reverse osmosis system (courtesy of USAID) (Kahn, 1986). (From www.coastal.ca.gov.)

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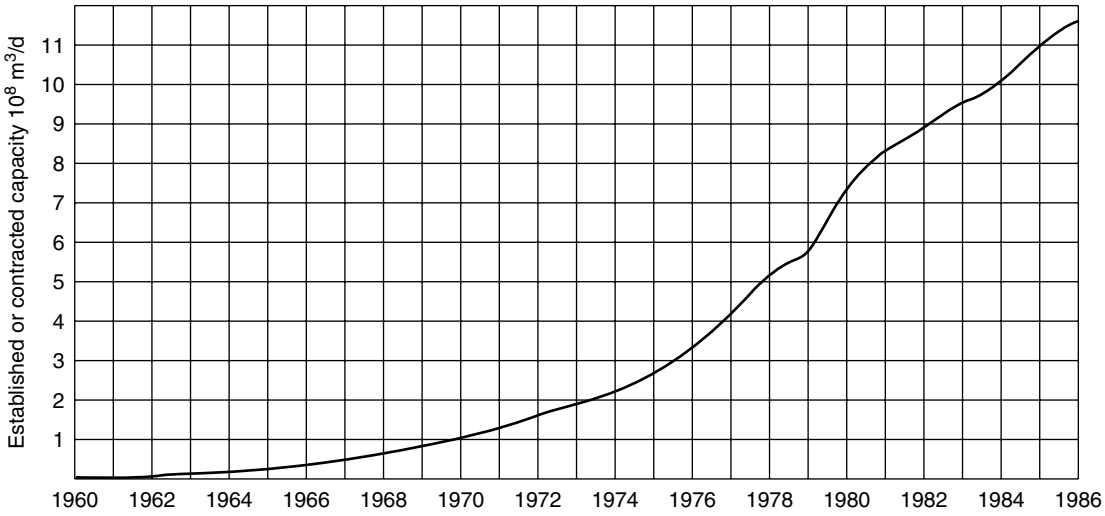


**Figure 11G.90** Cumulative worldwide capacity of land-based desalting plants (Plants capable of producing 100 $m^3$/unit or more of fresh water). (From Wangnick, Klaus, 1987, 1986 World Market of Desalting Plants, *The IDA Magazine*, Vol. 1, No. 4, Copyright International Desalting Assoc. Reproduced with permission.)

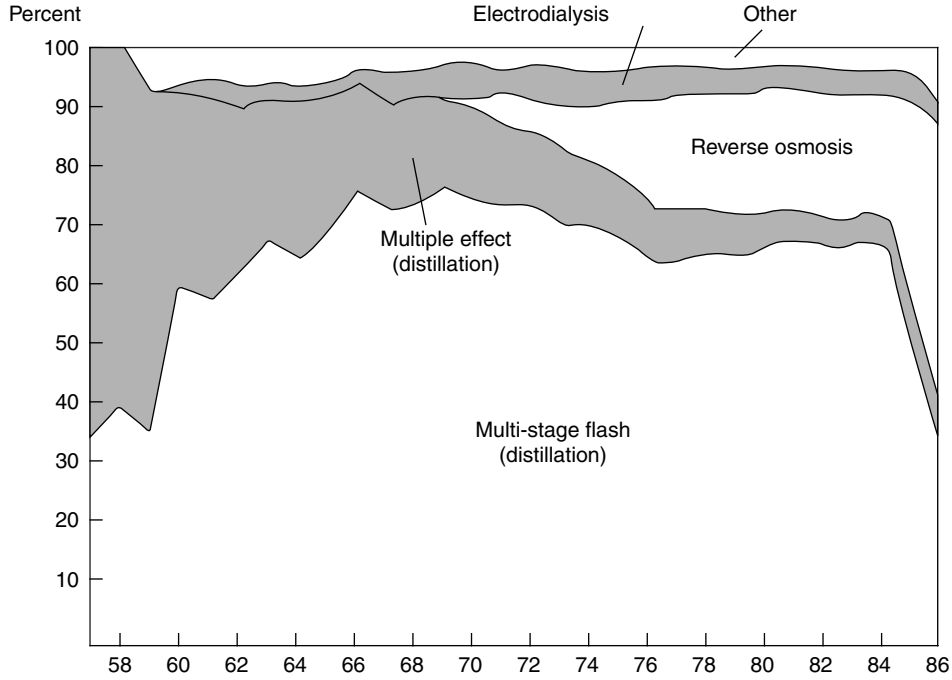


**Figure 11G.91** Processes used by land-based desalting plants worldwide. (From Wangnick, Klaus, 1987, 1986 World Market of Desalting Plants, *The IDA Magazine*, Vol. 1, No. 4, Copyright International Desalting Assoc. Reproduced with permission.)

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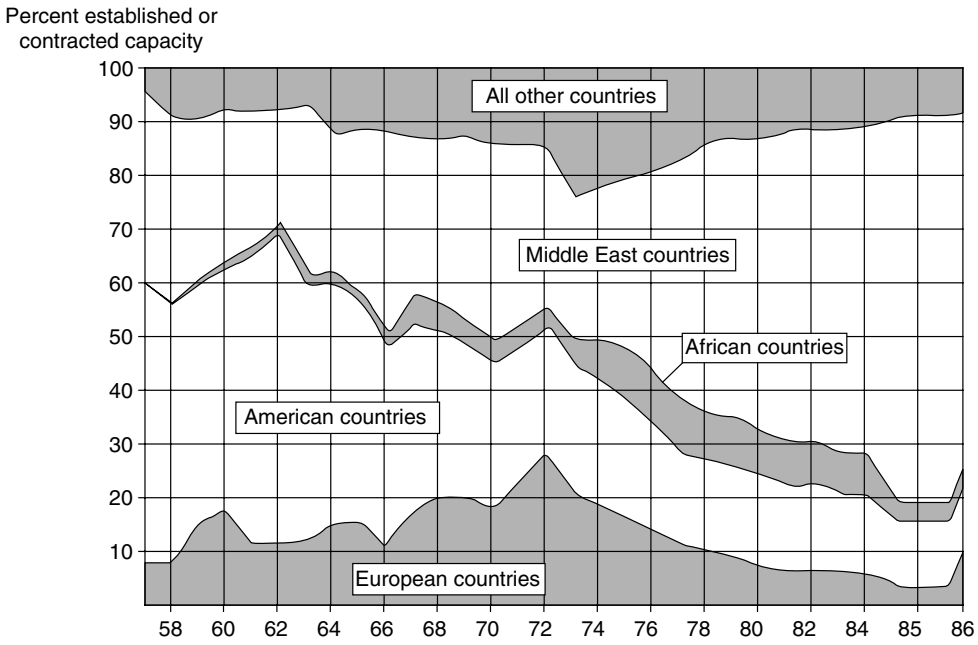


**Figure 11G.92** Worldwide distribution of desalting plant capacity. (From Wangnick, Klaus, 1987, 1986 World Market of Desalting Plants, *The IDA Magazine*, Vol. 1, Copyright International Desalting Assoc. Reproduced with permission.)

**Table 11G.128 Summary of Worldwide Desalination Capacity to 1998, Split by Plant Type and Process Capacity Range**

| Desalting Process | Percent | Capacity ($\times 10^6$ m$^3$ d$^{-1}$) | Capacity ($10^6$ gal d$^{-1}$) | No. of Plants |
|---|---|---|---|---|
| **Unit capacity** 100–60,000 m$^3$ d$^{-1}$ | | | | |
| Multistage flash | 44.4 | 10.02 | 2204 | 1244 |
| Reverse osmosis | 39.1 | 8.83 | 1943 | 7851 |
| Multiple effect | 4.1 | 0.92 | 202 | 682 |
| Electrodialysis | 5.6 | 1.27 | 279 | 1470 |
| Vapor compression | 4.3 | 0.97 | 213 | 903 |
| Membrane softening | 2.0 | 0.45 | 99 | 101 |
| Hybrid | 0.2 | 0.05 | 11 | 62 |
| Others | 0.3 | 0.06 | 13 | 120 |
| | 100.0 | 22.57 | 4965 | 12,433 |
| **Unit capacity** 500–60,000 m$^3$ d$^{-1}$ | | | | |
| Multistage flash | 46.8 | 10.00 | 2200 | 1033 |
| Reverse osmosis | 37.9 | 8.10 | 1782 | 3835 |
| Multiple effect | 3.8 | 0.81 | 178 | 653 |
| Electrodialysis | 4.7 | 1.00 | 220 | 230 |
| Vapor compression | 4.2 | 0.90 | 198 | 486 |
| Membrane softening | 2.1 | 0.45 | 99 | 64 |
| Hybrid | 0.2 | 0.04 | 9 | 27 |
| Others | 0.23 | 0.05 | 11 | 11 |
| EDI | 0.05 | 0.01 | 2 | 97 |
| | 100.0 | 21.36 | 4699 | 6436 |
| **Unit capacity** 4000–60,000 m$^3$ d$^{-1}$ | | | | |
| Multistage flash | 64.0 | 9.27 | 2039 | 496 |
| Reverse osmosis | 25.7 | 3.72 | 818 | 613 |
| Multiple effect | 3.6 | 0.52 | 114 | 48 |
| Electrodialysis | 2.1 | 0.31 | 68 | 60 |

*(Continued)*

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**Table 11G.128 (Continued)**

| Desalting Process | Percent | Capacity ($\times 10^6$ m$^3$ d$^{-1}$) | Capacity ($10^6$ gal d$^{-1}$) | No. of Plants |
|---|---|---|---|---|
| Vapor compression | 1.9 | 0.28 | 62 | 42 |
| Membrane softening | 2 | 0.36 | 79 | 50 |
| Hybrid | 0 | 0.02 | 4 | 2 |
| Others | 0 | 0.00 | 0 | 0 |
| | 100.0 | 14.48 | 3186 | 1311 |

*Source*: From 1998 *IDA Worldwide Desalting Plants*. Inventory Report No. 15. Wangnick Consulting GmbH. With permission.

**Table 11G.129 Summary of Worldwide Desalination Capacity, to 1998 Showing Contribution Made by Arab Nations**

| Desalting Process | % of Total World Capacity | Capacity ($10^6$ m$^3$ d$^{-1}$) | Capacity ($10^6$ gal d$^{-1}$) |
|---|---|---|---|
| **Global** | | | |
| Multistage flash | 44.4 | 10.02 | 2204 |
| Reverse osmosis | 39.1 | 8.83 | 1943 |
| Multiple effect | 4.1 | 0.92 | 202 |
| Electrodialysis | 5.6 | 1.27 | 279 |
| Vapor compression | 4.3 | 0.97 | 213 |
| Membrane softening | 2.0 | 0.45 | 99 |
| Hybrid | 0.2 | 0.05 | 11 |
| Others | 0.3 | 0.07 | 15 |
| | 100.0 | 22.58 | 4968 |
| **Arab States** | | | |
| Multistage flash | 37.6 | 8.50 | 1870 |
| Reverse osmosis | 12.0 | 2.70 | 594 |
| Multiple effect | 0.5 | 0.12 | 26 |
| Electrodialysis | 1.6 | 0.35 | 77 |
| Vapor compression | 1.6 | 0.36 | 79 |
| Membrane softening | 0.0 | 0.00 | 0 |
| Hybrid | 0.0 | 0.01 | 2 |
| Others | 0 | 0 | 0 |
| | 53.3 | 12.04 | 2649 |
| **AGCC States** | | | |
| Multistage flash | 35.0 | 7.90 | 1738 |
| Reverse osmosis | 9.1 | 2.05 | 451 |
| Multiple effect | 0.2 | 0.05 | 11 |
| Electrodialysis | 0.5 | 0.12 | 26 |
| Vapor compression | 1.0 | 0.22 | 48 |
| Membrane softening | 0 | 0 | 0 |
| Hybrid | 0 | 0 | 0 |
| Others | 0 | 0 | 0 |
| | 45.8 | 10.34 | 2275 |

*Note:* AGCC, Arabian Gulf Co-operation Council.

*Source*: From 1998 *IDA Wordwide Desalting Plants*. Inventory Report No. 15. Wangnick Consulting. With permission.

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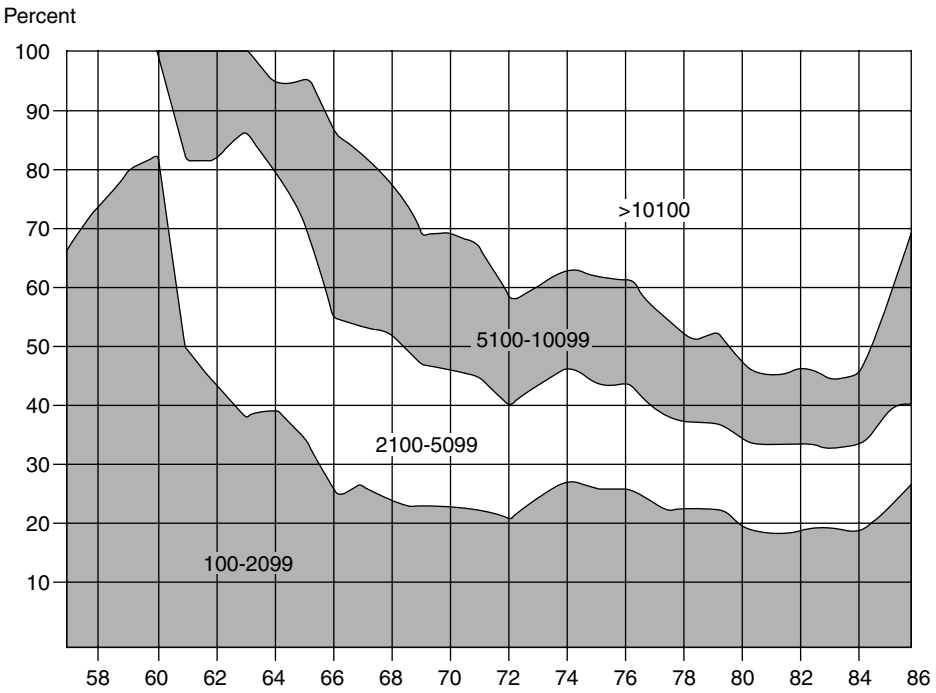


**Figure 11G.93** Individual capacity of desalting plants worldwide (in $m^3$/d). (From Wangnick, Klaus, 1987, 1986 World Market of Desalting Plants, *The IDA Magazine*, Vol. 1. Copyright International Desalting Assoc. Reproduced with permission.)

**Table 11G.130 Preliminary Desalination Process Selection**

| Rule | A<br>If the Freshest Source of Water Is | B<br>And if the Desired Output Water Will Be | C<br>And if Electricity Is to Be Generated | D<br>And if the Projected Cost Ratio of (264°F Steam)/ (Electricity) | E<br>Then Investigate the Cost of | F<br>And Have the Following Tests Performed |
|---|---|---|---|---|---|---|
| 1 | More salty than sea water | Potable water | | | Transportation of fresher water: distillation can be used but at great expense | TDS |
| 2 | Sea water | High-pressure boller feed water | By steam turbine | | Distillation followed by ion exchange | TDS, $Ca^{++}$, $SO_4^{=}$, $CO_3^{=}$, pH refer to water testing requirements in Appendix B |
| 3 | Sea water | Potable water | By steam turbine | Greater than ($10\times10^6$ BTU)/1 kWhr | Thermal distillation with or without vapor compression | TDS, $Ca^{++}$, $SO_4^{=}$, $CO_3^{=}$, pH |
| 4 | Sea water | Potable water | By internal combustion engine | | Vapor compression distillation and waste heat | TDS, bacterial count, turbidity |
| 5 | Sea water | Potable water | No | Less than ($10\times10^6$ BTU)/1 kWh | Reverse osmosis | TDS, $Ca^{++}$, $SO_4^{=}$, $CO_3^{=}$, pH, bacterial count, silt density index, turbidity, oil & grease refer to list for reverse osmosis, Appendix B |
| 6 | Brackish water | Potable water | | | Reverse osmosis | TDS, $Ca^{++}$, $SO_4^{=}$, $CO_3^{=}$, pH, bacterial count, silt density index, turbidity, oil & grease |

*(Continued)*

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**Table 11G.130 (Continued)**

| Rule | A<br>If the Freshest Source of Water Is | B<br>And if the Desired Output Water Will Be | C<br>And if Electricity Is to Be Generated | D<br>And if the Projected Cost Ratio of (264°F Steam)/ (Electricity) | E<br>Then Investigate the Cost of | F<br>And Have the Following Tests Performed |
|---|---|---|---|---|---|---|
| 7 | Slightly saline brackish water | Potable water | | | Electrodialysis reversal | TDS, full ionic breakdown, bacterial count, turbidity refer to list for electrodialysis reversal, Appendix B |

*Source*: From www.usace.army.mil.

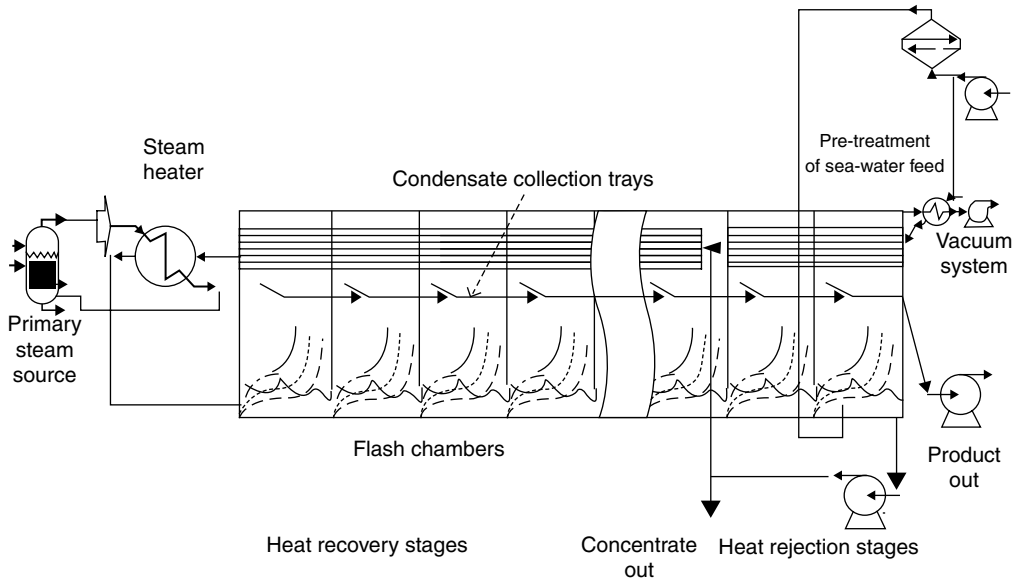


**Figure 11G.94** Schematic presentation of a multi-stage flash desalination plant. (From IWRA, *Water International*, Vol. 25, March 2000. With permission.)

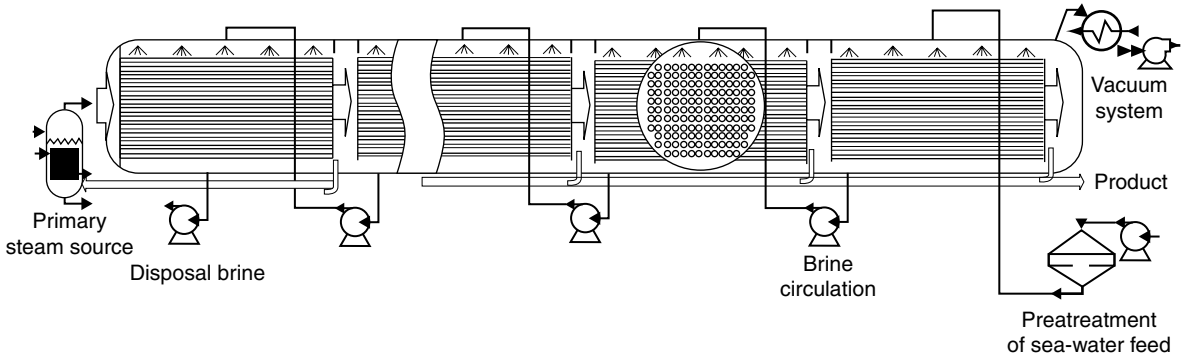


**Figure 11G.95** Schematics of a horizontal tube multiple effect distillation plant. (From IWRA *Water International*, Vol. 25, March 2000. With permission.)

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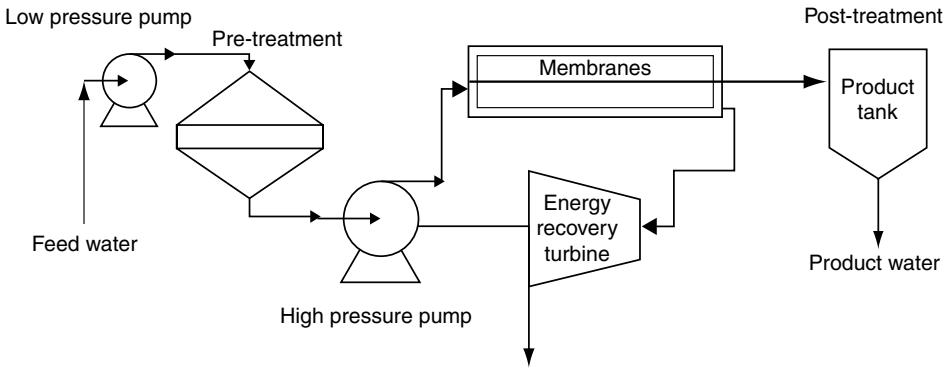


**Figure 11G.96** Schematic presentation of a reverse osmosis desalination plant. (From IWRA *Water International*, Vol. 25, March 2000. With permission.)

**Table 11G.131 Seawater Desalination Plants Using Reverse Osmosis Permasep Permeators**

| | | Capacity | | |
|---|---|---|---|---|
| **Location** | **Country** | **1000 GPD** | **$m^3/d$** | **Start-Up** |
| **Installed** | | | | |
| Ras Abu-Jarjur[a] | Bahrain | 12,000 | 45,420 | 84 |
| Ghar Lapsi | Malta | 5,300 | 20,000 | 83 |
| Ghar Lapsi Expansion | Malta | 1,060 | 4,600 | 86 |
| Ras Tanajib | Saudi Arabia | 3,500 | 13,248 | 85 |
| Key West | U.S.A. | 3,000 | 11,355 | 80 |
| Yanbu | Saudi Arabia | 1,300 | 4,920 | 80 |
| Cadafe I | Venezuela | 1,000 | 3,788 | 80 |
| Cadafe II | Venezuela | 1,000 | 3,788 | 83 |
| Al Birk | Saudi Arabia | 600 | 2,271 | 83 |
| Jeddah Air Defense | Saudi Arabia | 600 | 2,271 | 83 |
| KISR | Kuwait | 264 | 1,000 | 84 |
| Paradise Island | Bahamas | 240 | 908 | 81 |
| Grand Cayman | U.S.A. | 160 | 600 | 86 |
| Cape Verde | Cape Verde Islands | 150 | 568 | 83 |
| PRASA | Puerto Rico | 150 | 568 | 82 |
| Jeddah Conference Palace | Saudi Arabia | 150 | 568 | 84 |
| Magna | Saudi Arabia | 150 | 568 | 84 |
| Mykonos | Greek Island | 132 | 500 | 81 |
| Ithaki | Greek Island | 132 | 500 | 83 |
| Puerto Santo | Madeira Island | 132 | 500 | 80 |
| Formentera | Spain | 132 | 500 | 85 |
| Raymond Int. | Ras Al Khaimah, UAE | 125 | 473 | 78 |
| Dura | Saudi Arabia | 100 | 379 | 84 |
| Al-Wajh (Coast Guard) | Saudi Arabia | 100 | 379 | 85 |
| Hakato Cho | Japan | 79 | 300 | 81 |
| Ras Al Mishab | Saudi Arabia | 75 | 284 | 80 |
| **Under Construction** | | | | |
| Al-Dur (SWCC Gift) | Bahrain | 12,100 | 46,000 | 87/88 |
| Lanzarote | Spain | 1,300 | 5,000 | 86 |
| Safaniya | Saudi Arabia | 1,044 | 4,000 | 86 |
| Kutch Lignite[a] | India | 1,000 | 3,788 | 87 |
| St. Maarten | Netherlands | 400 | 1,514 | 85/86 |
| Codelco | Chile | 160 | 600 | 86 |
| Mullet Bay, St. Maarten | Netherlands | 150 | 568 | 85/86 |
| Shipyard | Italy | 135 | 511 | 85/86 |
| Misurata | Libya | 132 | 500 | 86 |
| Maho Bay | U.S.A. | 100 | 379 | 86 |
| WED Remote Islands | Abu Dhabi, UAE | 4,800 | 18,168 | 86/87 |

[a] Highly brackish.

*Source*: From *The IDA Magazine*, Vol. 1, no. 4, 1987. Copyright International Desalting Association. Reprinted with permission.

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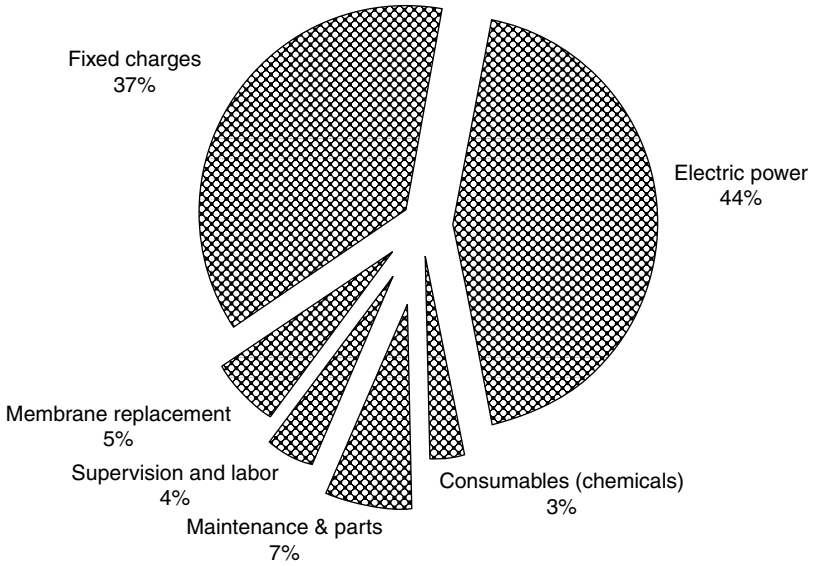


**Figure 11G.97** Typical sea water reverse osmosis water cost. (From IWRA, *Water International*, Vol. 25, March 2000. With permission.)

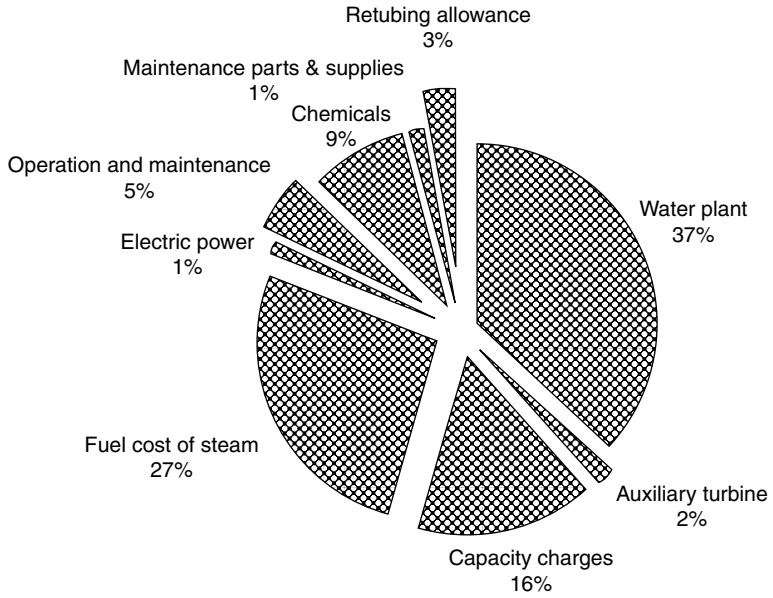


**Figure 11G.98** Cost parameters of the MWD Tower MED desalination design. (From IWRA, *Water International*, Vol. 25, March 2000. With permission.)

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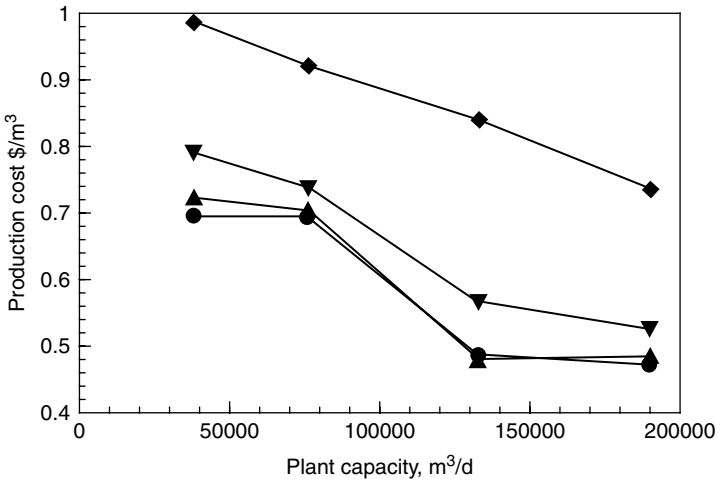


**Figure 11G.99** Water cost dependence on plant production. Cost calculation for the four runners-up bidder at the Tampa Bay project. RO Seawater desalination. (From IWRA, *Water International*, Vol. 25, March 2000. With permission.)

**Table 11G.132 Developer's Nominal Costs for Desalinated Water, Tampa Bay Project (Using Tax Exempt Financing), 94,625 $m^3/d$**

| Developer | First Year Cost $/m$^3$ | 30 Years Average Cost $/m$^3$ |
|---|---|---|
| Florida seawater desalination company | 0.54 | 0.65 |
| Florida water partners (Parsons & IDE Technologies) | 0.53 | 0.60 |
| Progress energy corp. ionics partnership | 0.56 | 0.67 |
| Stone & Webster — TIC — Citizens Utilities | 0.45 | 0.55 |

*Source*: From IWRA, *Water International*, Vol. 25, No. 1, March 2000. With permission.

**Table 11G.133 Classification of Water Demineralization Processes Based on the Variation of Energy Requirement with Initial Salinity**

| Type of Energy | Conversion Process | |
|---|---|---|
| Processes in which the energy requirement is essentially independent of initial salinity | Multiple effect distillation | Vacuum flash distillation |
| | Multistage flash distillation | Solar distillation |
| | Vapor compression distillation | Freezing |
| | Supercritical distillation | Reverse osmosis |
| Processes in which the energy requirement depends on initial salinity | Electrodialysis | |
| | Ion exchange | |
| | Chemical precipitation | |

*Source*: From California Department of Water Resources, 1960.

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**Table 11G.134 Typical Applications of Desalination Techniques**

| | Typical Applications | | | |
|---|---|---|---|---|
| | Brackish Water | | | |
| Technique | 0–3,000 ppm | 3,000–10,000 ppm | Seawater 35,000 ppm | Higher Salinity Brines |
| Distillation | T | S | P | P |
| Electrodialysis | P | S | T | P |
| Reverse osmosis | P | P | P | S |
| Ion exchange | P | | | |

P = Primary application
S = Secondary application
T = Technically possible, but not economic

*Source*: From Office of Technology Assessment, 1987; Office of Technology Assessment, 1988, *Using Desalination Technologies for Water Treatment*, OTA-BP-0-46. With permission.

**Table 11G.135 Relative Distribution of Different Types of Desalination Plants Worldwide**

| Process | Number of Plants | Percent of Total | Capacity (mgd) | Percent of Total |
|---|---|---|---|---|
| **Distillation** | | | | |
| Multi-Stage Flash (MSF) | 532 | 15.1 | 1,955 | 64.5 |
| Multiple Effect (ME) | 329 | 9.3 | 145 | 4.8 |
| Vapor Compression (VC) | 275 | 7.8 | 66 | 2.2 |
| **Membrane** | | | | |
| Reverse Osmosis (RO) | 1,742 | 49.4 | 709 | 23.4 |
| Electrodialysis (ED) | 564 | 16.0 | 139 | 4.6 |
| Other | 85 | 2.4 | 18 | 0.6 |
| **Total** | 3,527 | 100 | 3,032 | 100 |

*Source*: From International Desalination Association desalination plant inventory, 1987; Office of Technology Assessment, 1988, *Using Desalination Technologies for Water Treatment*, OTA-BP-0-46. With permission.

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**Table 11G.136 BOOT Contract Costs**

| | Tampa Bay | Trinidad | Larnaca | Dheke lia | Singapore | Ashkelon | Algeirs |
|---|---|---|---|---|---|---|---|
| Design capacity, t/d | 95,000 | 135,000 | 40,000 | 40,000 | 136,000 | 274,000 | 200,000 |
| Developer | Poseidon | Ionics | IDE | Caramondani Desalination Plants Ltd | Hyflux | V.I.D. Desalination Company Ltd | Ionics |
| Feedwater | Power plant condenser discharge | Open water intake | Open water intake | Open water intake | | Open water intake | |
| Seawater salinity, ppm | 26,000 | 38,000 | 40,000 | 40,000 | | 40,000 | 40,000 |
| Energy cost, $/kWh | 0.04 | 0.04 | 0.057 | 0.053 | | | |
| Contract term, yr | 30 | 23 | 10 | 10 | 20 | 25 | 25 |
| Contract year | | | 2000 | 1996 | 2002 | 2002 | 2003 |
| Contracted water price, $/m$^3$ | | | | | | | |
| Capital recovery | 0.21 | * | 0.37 | 0.56 | | 0.30 | |
| Non-capital components | 0.25 | * | 0.43 | 0.53 | | 0.22 | |
| Total first-year water price | 0.46 | 0.71 | 0.80 | 1.09 | | 0.52 | |
| Normalized water price for energy cost of $0.04/kWh: | | | | 1.02 | | | |
| Reduction in water price for energy cost of $0.04/kWh | — | — | (0.07) | 0.068 | | | |
| Total first-year water price (US$/m$^3$) | 0.46 | 0.71 | 0.73 | 1.09 | 0.45 | 0.52 | 0.8182 |

*Source*: From worldbank.org. With permission.

**Table 11G.137 Discharge of Dissolved Solids from Surface and Groundwater into the Oceans**

| Continent | Surface Water; Dissolved Solids Discharge (million t/yr) | Average Salinity of River Water (g/L) | Groundwater; Dissolved Solids Discharge (million t/yr) | Average Dissolved Solids of Groundwater (g/L) |
|---|---|---|---|---|
| Europe | 240 | 0.077 | 30 | 0.4 |
| Asia | 850 | 0.065 | 296 | 0.9 |
| Africa | 310 | 0.072 | 288 | 1.0 |
| North America | 410 | 0.069 | 149 | 0.4 |
| South America | 550 | 0.053 | 113 | 0.3 |
| Australia (including Tasmania, New Guinea, New Zealand) | 120 | 0.060 | 199 | 0.5 |
| World's Total | 2,480 | 0.063 | 1,045 | 0.6 |
| Percent of surface water; dissolved solids discharge | | | 42 | |

*Note:* Data on surface water discharge of dissolved solids and average river water salinity are according to Lvovich, 1974, "World's Water Resources and Their Future"; data on discharge of dissolved solids in groundwater on islands excluded.

*Source*: From Zektser, I.S. and others, 1984, The Effect of Groundwater on the Salt Balance of Seas and Oceans, *Water Quality Bulletin*, Vol. 9, no. 1.

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**Table 11G.138 Selecting Desalination Processes after Water Quality Data Are Obtained**

| Rule | A<br>If the Feed Water TDS Is (Mg/L) | B<br>And if the Raw Feed Water Suspended Solids Are | C<br>And if the Product of the $(Ca^{++})$ $(SO_4^{=})$ Moles$^2$/Lr$^2$ Is in the Reject Brine (See Sample Problem A-3) | D<br>And if the Oil and Grease in the Raw Feed Water Is | E<br>Then Investigate the Cost of | F<br>And Have the Following Pretreatment Processes Investigated for Effectiveness |
|---|---|---|---|---|---|---|
| 1 | Greater than 50,000 | | | | Transportion of fresher water; distillation of this water is extremely expensive | Precipitation of less soluble salts |
| 2 | Between 20,000–50,000 | Over 20 NTU | Considerably less than $2\times10^{-4}$ | Greater than 10 mg/L | Reverse osmosis or distillation and steam and electricity | Alum jar tests, pH adjustment 10-micron or smaller filter plugging |
| 3 | Between 20,000–50,000 | Over 1 NTU | | Less than 10 mg/L | Reverse osmosis | Alum jar tests 10-micron or smaller filter plugging UV sterilization |
| 4 | Between 20,000–50,000 | Less than 1 NTU SDI greater than 3 | | Less than 10 mg/L | Spiral-wound membrane reverse osmosis | PH adjustment, UV sterilization, chlorine disinfection, chlorine residual |
| 5 | Between 20,000–50,000 | SDI under 3 | | Less than 10 mg/L | Hollow fine-fiber membrane reverse osmosis | 10-micron or smaller filter test, UV sterilization |
| 6 | Between 3,000–20,000 | Over 1,000 mg/L | Considerably less than $2\times10^{-4}$ | Greater than 10 mg/L | Distillation | PH adjustment, alum jar test |
| 7 | Between 3,000–20,000 | | | Less than 10 mg/L | Reverse osmosis | PH adjustment, alum jar test, silt density index, UV sterilization |
| 8 | Between 500–4,000 | | | | Electrodialysis reversal | PH adjustment, alum jar test, 10-micron filter plugging, chlorine disinfection |

*Source*: From www.usace.army.mil.

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**Table 11G.139 Final Selection of a Desalination Technique from Treatability Data**

| Rule | A<br>If the Treated Feed Water Salinity (mg/1) Will Be (See Note) | B<br>And the Cost Ratio of (264(F Steam)/(1 kwh Electricity) Will Be | C<br>Alkaline Earths on the Raw Water Are Such That (See Sample Problem A-3) | D<br>And the Treated Suspended Solids Are | E<br>And the Designated Chlorine Residual Is | F<br>Then Investigate the Cost of | G<br>With the Following Pre- and Post-Treatment Technique Costs |
|---|---|---|---|---|---|---|---|
| 1 | Between 20,000–50,000 | | Within 65% of saturation | Less than 1 NTU but SDI greater than 3 | 0.0 mg/L | Spiral-wound membrane reverse osmosis | Whatever treatment is necessary to produce D and E |
| 2 | Between 20,000–50,000 | | Within 66% of saturation | SDI less than 3 | 0.0 mg/L | Hollow fine-fiber membrane reverse osmosis | Whatever treatment is necessary to produce D and E |
| 3 | Between 20,000–50,000 | | | Less than 1 NTU | Between 1.0 and 0.0 mg/L | Chlorine-resistant membrane reverse osmosis | Whatever treatment is necessary to produce D and E |
| 4 | Between 20,000–50,000 | Greater than 10× 106 BTU/1 kWhr | Within 50% of saturation | Greater than 1 NTU | More than 1 mg/L | Some form of distillation under 185°F | Anti-scalent |
| 5 | Between 20,000–50,000 | Greater than 10× 106 BTU/1 kWhr | | Greater than 1 NTU | More than 1 mg/L | Some form of distillation | Acid feed (hydrochloric is best) |
| 6 | Between 20,000–50,000 | Greater than 10× 106 BTU/1 kWhr | [Ca++] multiplied by $[SO_4^2]$ Well Under 2 ( 10×5 | Greater than 1 NTU | More than 1 mg/K | Some form of distillation | No pretreatment for calcium sulfata scale control |
| 7 | Between 3,000–20,000 | | | Less than 1 NTU but SDI greater than 3 | Less than 1.0 mg/L** | Brackish water spiral-wound membrane reverse osmosis | Whatever treatment is necessary to produce D and E |
| 8 | Between 3,000–20,000 | | | SDI less than 3 | Less than 1.0 mg/L** | Brackish water hollow fine-fiber membrane reverse osmosis | Whatever treatment is necessary to produce D and E |
| 9 | Between 500–4,000 and especially when expected to vary by more than 15% | | | Will not plug 10-micron filter | 0.0 mg/L** | Electrodialysis reversal | Turbidity removal to 1 NTU and disinfection to less than 1/100 ml. |
| 10 | Is stable at some value between 500–1000 | | | SDI less than 3 | Less than 1.0 mg/L | Low pressure/high flux membrane reverse osmosis | Whatever treatment is necessary to produce D and E |

*Source*: From www.usace.army.mil.

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**Table 11G.140 Cost Comparison for Different Desalination Techniques**

| | | MSF | MSF (Singapore)[a] | MED | MED-MWD[a] | VC | RO | RO-Tampa Bay[a] |
|---|---|---|---|---|---|---|---|---|
| Installation costs | $/m$^3$/d | 1,200–1,500 | 2,300 | 900–1,000 | 660 | 950–1,000 | 700–900 | 1,000–1,350 |
| Product costs | Cents/m$^3$ | 110–125 | 150 | 75–85 | 46 | 87–95 | 68–92 | 45–56 |

[a] Estimation, based on publications or recent proposals.

*Source*: From IWRA, *Water International*, Vol. 25, No. 1, MARCH 2000. With permission.

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## SECTION 11H WATER TRANSFER

**Figure 11H.100** Aqueduct systems in California. (From www.wsu.edu. With permission.)

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**Table 11H.141 Major Aqueducts in California**

| | Capacity ($ft^3/s$)[a] | Length (mi) | Owner | Initial Year of Operation |
|---|---|---|---|---|
| Los Angeles | 710 | 244 | LADWP | 1913 |
| Mokelumne River | 590 | 90 | EBMUD | 1929 |
| Hetch Hetchy | 460 | 152 | SF | 1934 |
| All American | 15,100 | 80 | USBR | 1938 |
| Contra Costa | 350 | 48 | USBR | 1940 |
| Colorado Rive | 1,600 | 242 | MWD | 1941 |
| Friant-Kern | 4,000 | 152 | USBR | 1944 |
| Coachella | 2,500 | 123 | USBR | 1947 |
| San Diego No. 1 | 200 | 71 | SD | 1947 |
| Delta-Mendota | 4,600 | 116 | USBR | 1951 |
| Madera | 1,000 | 36 | USBR | 1952 |
| Putah South | 960 | 35 | USBR | 1957 |
| Santa Rosa-Sonoma | 62 | 31 | SCWA | 1959 |
| San Diego No. 2 | 1,000 | 93 | SD | 1960 |
| Corning | 500 | 21 | USBR | 1960 |
| Petaluma | 16 | 26 | SCWA | 1961 |
| Tehama-Colusa | 2,530 | 113 | USBR | 1961[b] |
| South Bay | 360 | 43 | DWR | 1965 |
| North Bay | 46 | 27 | DWR | 1968[c] |
| California | 13,100 | 444 | DWR | 1972[d] |
| Folsom South | 3,500 | 27 | USBR | 1973[e] |
| Cross Valley | 740 | 20 | KCWA | 1975 |

*Note:* DWR, California Department of Water Resources; EBMUD, East Bay Municipal Utility District; KCWA, Kern County Water Agency; LADWP, Los Angeles Department of Water and Power; MWD, Metropolitan Water District of Southern California; SCWA, Sonoma County Water Agency; SD, City of San Diego; SF, City and County of San Francisco; USBR, U.S. Bureau of Reclamation.

[a] Initial reach only for most irrigation canals.
[b] Tehama and Glenn Counties.
[c] Interim facilities.
[d] To Southern California.
[e] Reaches 1 and 2.

*Source*: From California Department of Water Resources, 1987. California Water: Looking to the Future, Bulletin 160-87.

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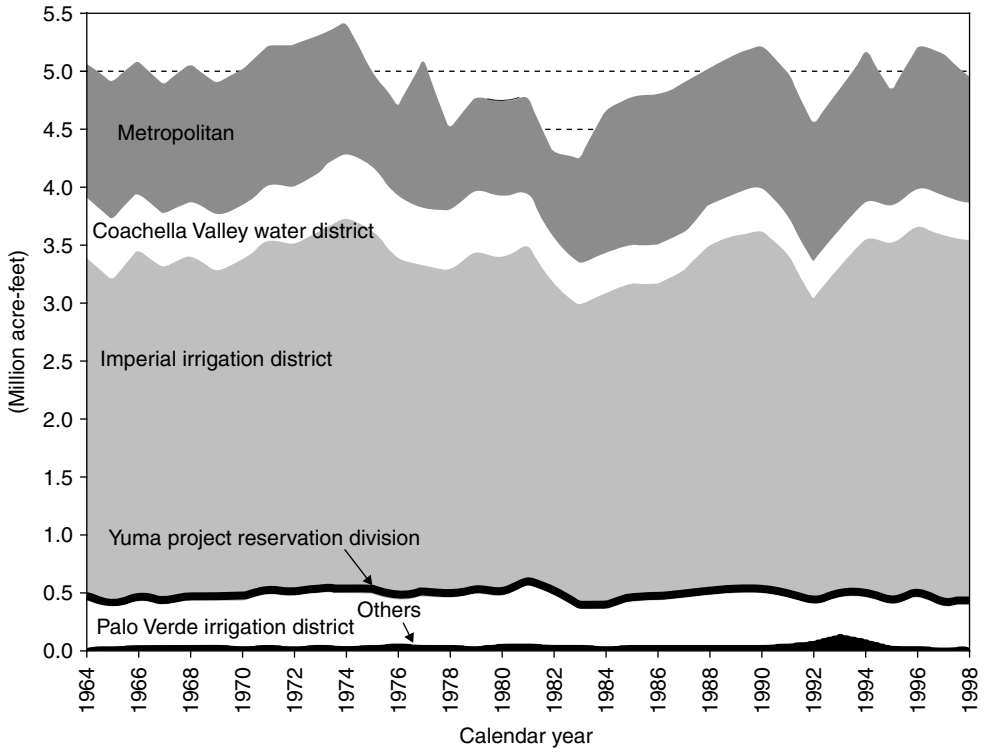


**Figure 11H.101** California's net diversions from the Colorado River, includes reductions for unmeasured returns estimated since 1994. (From California's Colorado River Water Use Plan, June 2, 2000, www.crb.ca.gov. With permission.)

**Table 11H.142 Apportionment of Colorado River Water Supply in California**

| Agency and Description of Service Area | | Beneficial Consumptive Use in Acre-Feet per Year | |
|---|---|---|---|
| **Priority Number** | | **Per California Seven-Party Agreement** | **After Start of Central Arizona Project** |
| 1 | Palo Verde irrigation district | | |
| 2 | Yuma project, California portion | | |
| 3 | Imperial irrigation district | 3,850,000 | 3,850,000 |
| | Coachella Valley water district | | |
| | Palo Verde irrigation district (mesa lands) | | |
| 4 | Metropolitan water district | | |
| 5 | Metropolitan water district | 550,000[a] | 550,000[a] |
| | | 662,000 | 0 |
| 6 | Imperial irrigation district | | |
| | Coachella Valley water district | 300,000 | 0 |
| | Palo Verde irrigation district (mesa lands) | | |
| | Totals | 5,362,000[b] | 4,400,000[b] |

[a] Includes Indian water rights and miscellaneous present perfected rights totalling 58,000 acre-ft that reduce Metropolitan's entitlement to 492,000 acre-ft.

[b] Plus not more than one-half of any excess or surplus water in the lower Colorado River.

*Source*: From California Department of Water Resources, 1987. California Water: Looking to the Future, Bulletin 160-87.

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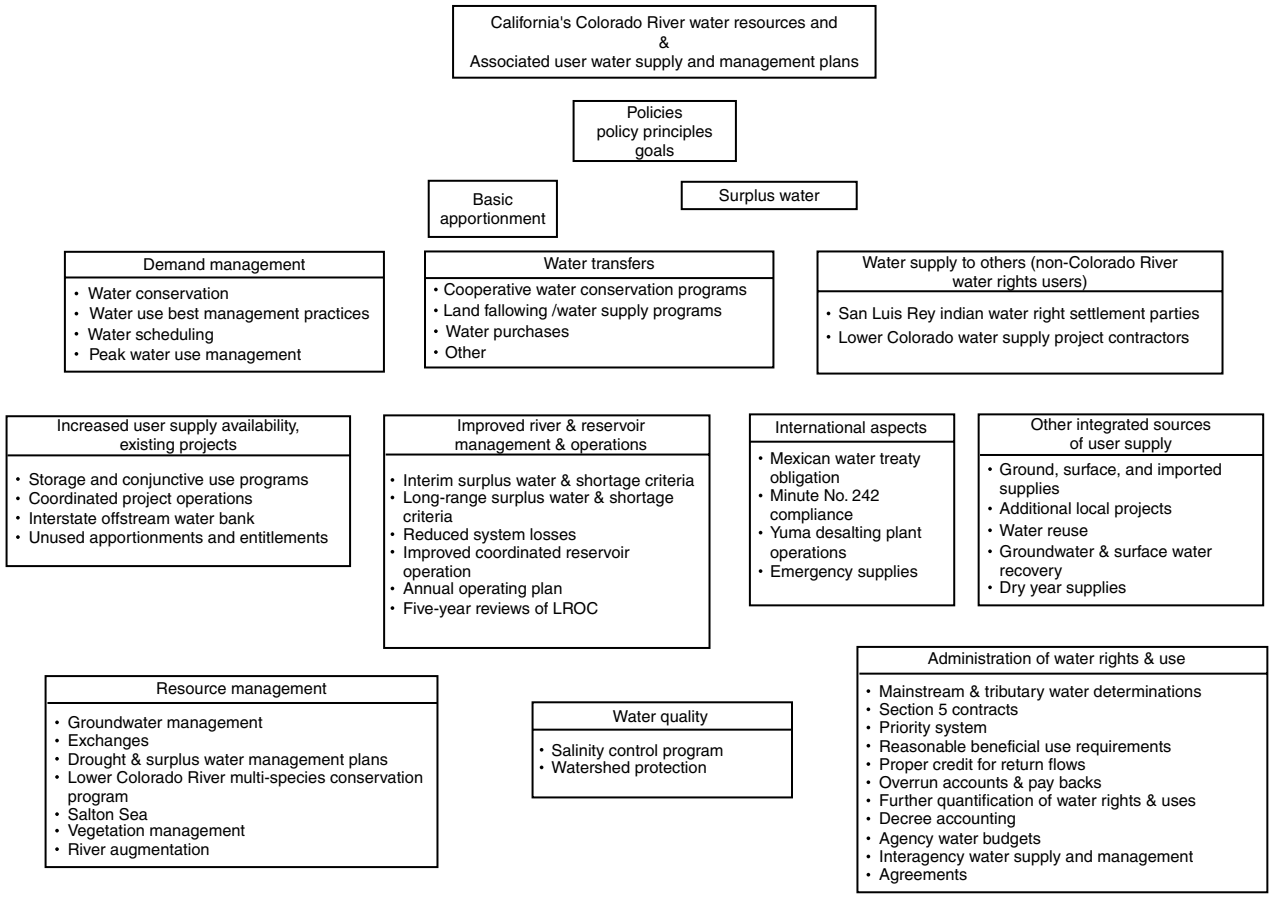


**Figure 11H.102** Framework components of California's Colorado River water use plan. (From California's Colorado River Water Use Plan, June 2, 2000, www.crb.ca.gov. With permission.)

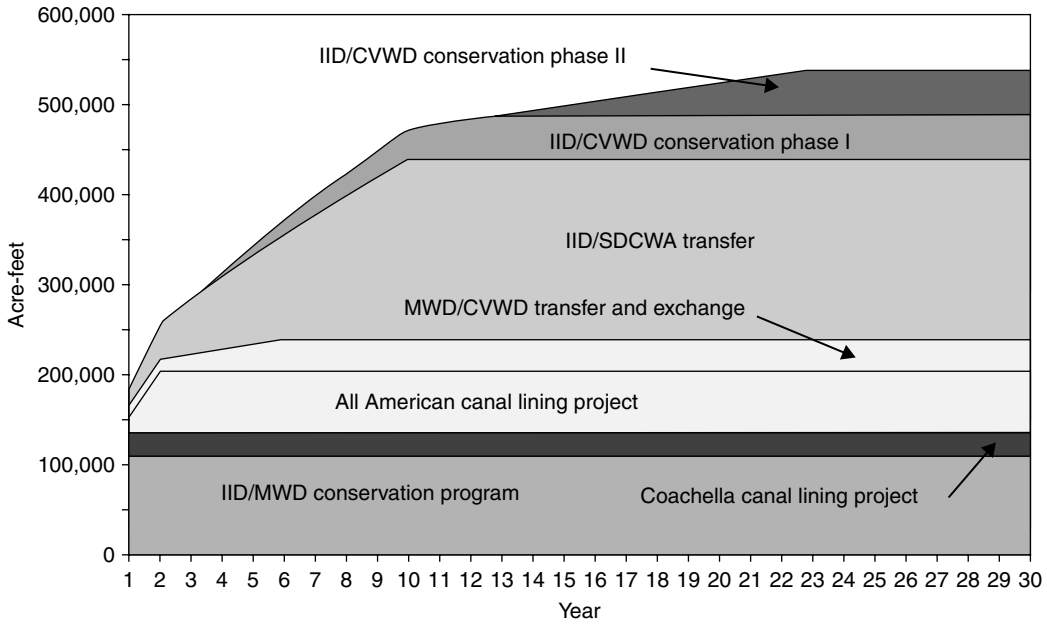


**Figure 11H.103** Core water conservation/transfer projects, and exchanges. (From California's Colorado River Water Use Plan, June 2, 2000, www.crb.ca.gov. With permission.)

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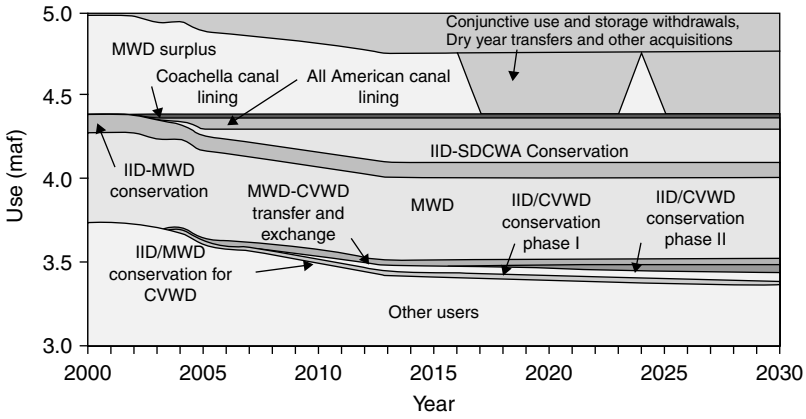
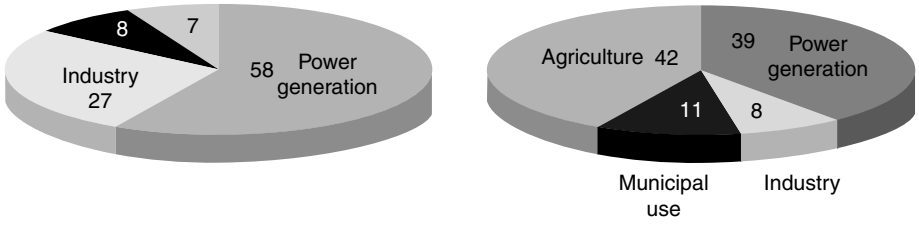



**Figure 11H.104** California use of water. (From California's Colorado River Water Use Plan, June 2, 2000, www.crb.ca.gov. With permission.)




Withdrawals of renewable supplies :

| | |
|---|---|
| Canada: | 1.6% |
| United States: | 18.9% |

**Figure 11H.105** Freshwater withdrawals by sector. (From www.unep.org. With permission.)

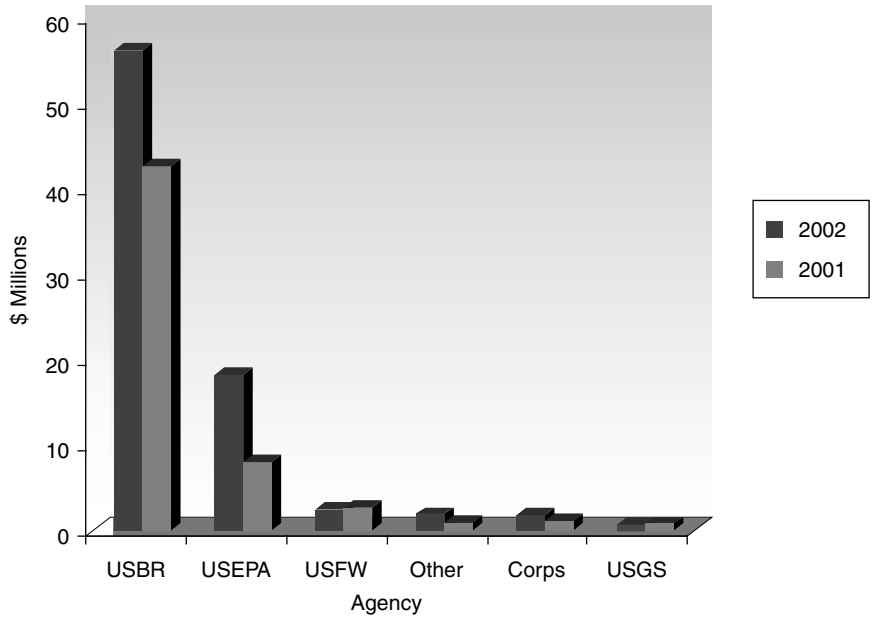



**Figure 11H.106** Federal appropriations for Calfed funding by agency (FY 2001 and 2002). (From Calfed Annual Report 2001, www.swf.usace.army.mil. With permission.)

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**Table 11H.143 Calfed Bay-Delta Program Funding by Source for Stage 1 Program Implementation (California Fiscal Year 2001)**

| Program | Total Year 1 Funding | State | | | | | Federal | | | | Local Subtotal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | General Funds | Prop 204 | Prop 13 | Other | Subtotal | USBR | Corps | Other | Subtotal | |
| Ecosystem restoration | $236.0 | $3.5 | $134.9 | $46.2 | $6.1 | $190.7 | $4.3 | $0.4 | $6.3 | $11.0 | $34.3 |
| Environmental | $59.1 | $59.1 | — | — | — | $59.1 | — | — | — | — | — |
| Water use efficiency | $204.1 | $17.0 | — | $12.3 | — | $29.3 | $26.0 | — | — | $26.0 | $148.8 |
| Water conservation | ($31.2) | ($17.0) | — | ($3.2) | — | ($20.2) | ($1.9) | — | — | ($1.9) | ($9.1) |
| Water recycling | ($172.9) | — | — | ($9.1) | — | ($9.1) | ($24.1) | — | — | ($24.1) | ($139.7) |
| Water transfers | $1.1 | $1.1 | — | — | — | $1.1 | — | — | — | — | — |
| Watershed | $33.0 | $18.9 | $1.3 | — | $1.0 | $21.2 | — | — | $2.3 | $2.3 | $9.5 |
| Drinking water quality | $37.5 | $13.5 | — | $24.0 | — | $37.5 | — | — | — | — | — |
| Levees | $35.4 | $0.1 | $1.7 | $28.5 | — | $30.3 | — | — | — | — | $5.1 |
| Storage | $95.5 | $24.7 | — | $69.0 | — | $93.7 | $1.8 | — | — | $1.8 | — |
| Oversight and coordination | ($2.9) | ($2.9) | — | — | — | ($2.9) | — | — | — | — | — |
| Surface | ($13.8) | ($13.8) | — | — | — | ($12.0) | ($1.8) | — | — | ($1.8) | — |
| Groundwater | ($78.8) | ($78.8) | — | ($69.0) | — | ($78.8) | — | — | — | — | — |
| Conveyance | $22.3 | $4.2 | — | $4.8 | — | $9.0 | $2.6 | — | — | $2.6 | $10.7 |
| Science | $28.2 | $13.2 | — | — | $2.3 | $15.5 | $4.0 | $0.2 | $1.9 | $6.1 | $6.6 |
| Calfed science | ($13.8) | ($13.8) | — | — | — | ($13.0) | — | — | ($0.8) | ($0.8) | — |
| Interagency ecological program | ($14.4) | ($14.4) | — | — | — | ($2.5) | ($4.0) | ($0.2) | ($1.1) | ($5.3) | ($6.6) |
| Oversight and coordination | $13.8 | $13.5 | — | — | — | $13.5 | — | $0.3 | — | $0.3 | — |
| Total | $766.0 | $168.8 | — | $184.8 | $9.4 | $500.9 | $38.7 | $0.9 | $10.5 | $50.1 | $215.0 |

*Note:* Local funds include State Water Project Funds and Central Valley Project Improvement Act (CVPIA) that are collected from state water contractors and Central Valley Project water users.

*Source*: From www.swf.usace.army.mil.



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**Table 11H.144 Calfed Bay-Delta Program Funding by Source for Stage 1 Program Implementation (California Fiscal Year 2002)**

| Program | Total Year 2 Funding | State | | | | | Federal | | | | Local Subtotal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | General Funds | Prop 204 | Prop 13 | Other | Subtotal | USBR | Corps | Other | Subtotal | |
| Ecosystem restoration | $188.2 | $2.8 | $126.3 | $10.0 | — | $139.1 | $2.2 | $1.2 | $3.1 | $6.5 | $42.6 |
| Environmental water account | $48.0 | $1.0 | $28.2 | $6.3 | — | $35.5 | $12.5 | — | — | $12.5 | — |
| Water use efficiency | $333.7 | $11.8 | — | $43.3 | $57.9 | $113.0 | $19.8 | — | $18.2 | $38.0 | $182.7 |
| Water conservation | ($37.1) | ($11.8) | — | ($18.3) | — | ($30.1) | ($2.3) | — | — | ($2.3) | ($4.7) |
| Water recycling | ($296.6) | — | — | ($25.3) | ($57.9) | ($82.9) | ($82.9) | — | ($18.2) | ($35.7) | ($178.0) |
| Water transfers | $1.1 | $0.9 | — | — | — | $0.9 | $0.2 | — | — | $0.2 | — |
| Watershed | $17.3 | $7.3 | — | $10.0 | — | $17.3 | — | — | — | — | — |
| Drinking water quality | $16.2 | $4.1 | — | $12.1 | — | $16.2 | — | — | — | — | — |
| Levees | $17.2 | $4.9 | $8.4 | — | — | $13.3 | — | $0.3 | — | $0.3 | $3.6 |
| Storage | $123.2 | $14.1 | — | $103.0 | — | $117.1 | $6.2 | — | — | $6.2 | — |
| Oversight and coordination | ($1.5) | ($1.5) | — | — | — | ($1.5) | — | — | — | — | — |
| Surface | ($15.0) | ($8.8) | — | — | — | ($8.8) | ($6.2) | — | — | ($6.2) | — |
| Groundwater | ($106.8) | ($3.8) | — | ($103.0) | — | ($106.8) | — | — | — | — | — |
| Conveyance | $72.2 | $3.3 | — | $37.6 | | $40.9 | $4.0 | — | — | $4.0 | $27.3 |
| Science | $20.1 | $5.1 | — | — | $2.3 | $7.4 | $3.9 | $0.2 | $2.0 | $6.1 | $6.6 |
| Calfed science | ($6.6) | ($4.9) | — | — | — | ($4.9) | — | — | ($1.7) | ($1.7) | — |
| Interagency ecological program | ($13.5) | ($0.2) | — | — | ($2.3) | ($2.5) | ($3.9) | ($0.2) | ($0.3) | ($4.4) | ($6.6) |
| Oversight and coordination | $14.9 | $7.3 | — | — | — | $7.3 | $7.5 | $0.1 | — | $7.6 | — |
| Total | $852.2 | $62.6 | $162.9 | $222.3 | $60.2 | $508.0 | $56.3 | $1.8 | $23.3 | $81.4 | $262.8 |

*Note:* Local funds include State Water Project Funds and Central Valley Project Improvement Act (CVPIA) that are collected from state water contractors and Central Valley Project water users.

*Source*: From www.swf.usace.army.mil.

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**Table 11H.145 Interbasin Water Transfers in the Western United States**

| West Resources Regions Origin | Exported to | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|
| Missouri | Upper Mississippi | 267 | 511 | 754 | 1,005 | 1,257 |
| | Arkansas-White-Red | 15,980 | 15,980 | 17,269 | 6,327 | 11,226 |
| | Upper Colorado | NA | NA | NA | NA | NA |
| | Total | 16,247 | 16,491 | 18,023 | 7,332 | 12,483 |
| Arkansas-White-Red | Missouri | 12,669 | 12,539 | 9,429 | 12,519 | 2,329 |
| Texas-Gulf | Lower Mississippi | — | — | — | 32,570 | 32,430 |
| | Arkansas-White-Red | | | | 460 | 8,940 |
| | Total | | | | 33,030 | 41,370 |
| Rio Grande | Arkansas-White-Red | 517 | 1,460 | 900 | 181 | 1,290 |
| Upper Colorado | Missouri | 511,409 | 354,254 | 272,346 | 437,214 | 437,222 |
| | Arkansas-White-Red | 126,114 | 156,661 | 128,461 | 102,357 | 173,600 |
| | Rio Grande | 108,351 | 167,852 | 147,439 | 57,711 | 132,388 |
| | Great Basin | 98,440 | 116,820 | 83,330 | 111,080 | 77,340 |
| | Total | 844,314 | 795,587 | 631,576 | 708,362 | 820,550 |
| Lower Colorado | Great Basin | 3,060 | 3,420 | 3,780 | 4,170 | 3,420 |
| | California | 4,107,730 | 4,060,690 | 4,174,130 | 4,234,260 | 3,808,170 |
| | Mexico | 274,720 | 253,326 | 284,510 | 241,830 | 255,800 |
| | Total | 4,385,510 | 4,317,436 | 4,462,420 | 4,480,260 | 4,067,390 |
| Great Basin | California | 3,130 | 3,940 | 3,950 | 3,740 | 5,010 |
| Pacific Northwest | Great Basin | 900 | 1,000 | 1,000 | 1,300 | 1,400 |
| California | Pacific Northwest | 25,540 | 21,000 | 20,900 | 21,400 | 23,300 |
| Grand total | | 5,288,827 | 5,169,453 | 5,148,198 | 5,268,124 | 4,975,122 |

*Note:* Between Water Resources Regions, water years 1978–1982; in acre-ft.

*Source*: Compiled from Petsch, H. E., Jr., 1985, Inventory of interbasin transfers of water in the conterminous United States, *U.S. Geological Survey Open-File Report 85–166*.

**Table 11H.146 Cooperative Water Conservation/Transfer Projects**

| Cooperative Water Conservation/Transfer Projects | Annual Yield (af) | Estimated Start Date |
|---|---|---|
| MWD/IID 1988 Water Conservation Program | 100,000–110,000[a] | Completed |
| SDCWA/IID Transfer and SDCWA/MWD exchange | 130,000–200,000[b] | 2002 |
| MWD/CVWD SWP Water Transfer/Colorado River water exchange | 35,000 | 2003 |
| Coachella Canal lining MWD/SLR[c] | 26,000 | 2005[d] |
| All American Canal lining MWD/SLR[c] | 67,700 | 2006[d] |
| IID/CVWD/MWD Conservation program | 100,000[e] | 2007 |

[a] Yield to MWD, except for 20,000 acre-ft yr to be made available to CVWD.
[b] Yield to SDCWA.
[c] Yield to MWD and San Luis Rey Indian Water Rights Settlement Parties.
[d] Date by which full conservation benefits will be achieved.
[e] Yield to CVWD, MWD has an option to acquire water CVWD does not need. MWD assumes responsibility for 50,000 acre-ft/yr to CVWD after year 45 of Quantification Agreement.

*Source*: From California's Colorado River Water Use Plan. www.crb.ca.gov.

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**Table 11H.147 Major Canals on United States Bureau of Reclamation Projects**

| Project, State, and Canal Name | Length (km) | Initial Capacity ($m^3$ s) | Initial Reach Width (m) | Initial Reach Depth (m) | Date Constructed |
|---|---|---|---|---|---|
| Boise, ID, Main South Side (New York) Canal | 64 | 79.3 | 21.3 | 2.4 | 1906–1908 |
| Columbia Basin, WA | | | | | |
| East Low Canal | 132.6 | 127.4 | 20.7 | 4.7 | 1946–1954 |
| Feeder Canal | 2.9 | 736.3 | 24.4 | 7.6 | 1946–1951 |
| Main Canal | 20.8 | 373.8 | 15.2 | 6.3 | 1946–1951 |
| Potholes East Canal | 100.4 | 110.4 | 14.6 | 4.8 | 1949–1953 |
| West Canal | 132.3 | 144.4 | 11.6 | 5.0 | 1946–1955 |
| Minidoka-Palisades, ID-WY | | | | | |
| Milner-Gooding Canal | 112.7 | 76.5 | 15.2 | 3.8 | 1928–1932 |
| Yakima, WA | | | | | |
| Roza Div. Roza Canal | 145.5 | 62.3 | 16.8 | 3.7 | — |
| Central Valley, CA | | | | | |
| Delta Cross Channel | 1.9 | 99.1 | 64.0 | 7.9 | 1950–1951 |
| Folsom South Canal | 43.0 | 99.1 | 10.4 | 5.4 | 1970–1973 |
| Friant-Kern Canal | 243.3 | 141.6 | 11.0 | 5.2 | 1945–1951 |
| O'Neill Forebay Inlet Channel | .8 | 118.9 | 24.4 | — | 1965–1966 |
| San Luis Canal | 163.5 | 371.0 | 33.5 | 10.0 | 1963–1968 |
| Tehama-Colusa Canal | 88.8 | 71.6 | 7.3 | 4.8 | 1965–1980 |
| Klamath, CA-OR | | | | | |
| Lost river diversion Channel | 12.6 | 85.0 | 18.3 | — | 1911–1912 |
| Boulder Canyon, AZ-CA-NV | | | | | |
| All American Canal | 128.7 | 429.1 | 48.8 | 6.3 | 1934–1940 |
| Coachella Canal | 199.6 | 70.8 | 18.3 | 3.1 | 1938–1948 |
| Central Arizona, AZ | | | | | |
| Granite Ref Aqueduct | 279.4 | 85.0 | 7.3 | 5.0 | 1974–1985 |
| Salt Gila Aqueduct | 92.4 | 77.9 | 7.3 | 4.8 | 1981 |
| Tucson Aqueduct | 60.7 | 63.7 | 6.7 | 4.3 | 1984 |
| Gila, AZ | | | | | |
| Gila Gravity Main Canal | 32.2 | 62.3 | 6.7 | 4.1 | 1936–1939 |
| Salt River, AZ | | | | | |
| Arizona Canal | 62.0 | 53.8 | 15.2 | 2.1 | 1911–1912 |
| Yuma, AZ-CA | | | | | |
| Yuma Main Canal | 7.6 | 56.6 | 15.2 | 2.7 | 1907–1909 |
| Harlingen Irr. Dist., TX | | | | | |
| Project Canals | 47.0 | 99.1 | 6.1 | 1.2 | 1960 |
| North Platte, NE-WY | | | | | |
| Interstate Canal | 152.2 | 59.5 | 13.4 | 3.0 | 1905–1915 |
| Garrison Division, ND | | | | | |
| McClusky Canal | 118.4 | 55.2 | 7.6 | 5.3 | 1970–1978 |
| Wind division, WY: Riverton unit | | | | | |
| Wyoming Canal | 100.4 | 62.3 | 19.8 | 3.0 | 1920–1951 |

*Note:* Canals with capacity of 50 $m^3$/s or greater.

*Source*: Adapted from U.S. Department of the Interior Bureau of Reclamation, 1986, Statistical Compilation of Engineering Features on Bureau of Reclamation Projects.

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**Table 11H.148 Physical Features and Population**

| | | Superior | Michigan | Huron | Erie | Ontario | Totals |
|---|---|---|---|---|---|---|---|
| Elevation[a] | (ft)[f] | 600 | 577 | 577 | 569 | 243 | |
| | (m) | 183 | 176 | 176 | 173 | 74 | |
| Length | (mil)[e] | 350 | 307 | 206 | 241 | 193 | |
| | (km) | 563 | 494 | 332 | 388 | 311 | |
| Breadth | (mil)[e] | 160 | 118 | 183 | 57 | 53 | |
| | (km) | 257 | 190 | 245 | 92 | 85 | |
| Average depth[a] | (ft)[f] | 483 | 279 | 195 | 62 | 283 | |
| | (m) | 147 | 85 | 59 | 19 | 86 | |
| Maximum depth[a] | (ft)[e] | 1,332 | 925 | 750 | 210 | 802 | |
| | (m) | 406 | 282 | 229 | 64 | 244 | |
| Volume[a] | ($mi^3$)[e] | 2,900 | 1,180 | 850 | 116 | 393 | 5,439 |
| | ($km^3$) | 12,100 | 4,920 | 3,540 | 484 | 1,640 | 22,684 |
| Water area | (sq. mi)[e] | 31,700 | 22,300 | 23,000 | 9,910 | 7,340 | 94,250 |
| | ($km^2$) | 82,100 | 57,800 | 59,600 | 25,700 | 18,960 | 244,160 |
| Land drainage area[b] | (sq. mi)[e] | 49,300 | 45,600 | 51,700 | 30,140 | 24,720 | 201,460 |
| | ($km^2$) | 127,700 | 118,000 | 134,100 | 78,000 | 64,030 | 521,830 |
| Total area | (sq. mi)[e] | 81,000 | 67,900 | 74,700 | 40,050 | 32,060 | 295,710 |
| | ($km^2$) | 209,800 | 175,800 | 193,700 | 103,700 | 82,990 | 765,990 |
| Shoreline length[c] | (mil)[e] | 2,726 | 1,638 | 3,827 | 871 | 712 | 10,210[d] |
| | (km) | 4,385 | 2,633 | 6,157 | 1,402 | 1,146 | 17,017[d] |
| Retention time | (ys)[f] | 191 | 99 | 22 | 2.6 | 6 | |
| Population: | U.S. (1990)[g] | 425,548 | 10,057,026 | 1,502,687 | 10,017,530 | 2,704,284 | 24,707,075 |
| | Canada (1991) | 181,573 | | 1,191,467 | 1,664,639 | 5,446,611 | 8,484,290 |
| | Totals | 607,121 | 10,057,026 | 2,694,154 | 11,682,169 | 8,150,895 | 33,191,365 |
| | Outlet | St. Marys River | Straits of Mackinac | St. Clair River | Niagara River/ Welland Canal | St. Lawrence River | |

[a] Measured at low water datum.
[b] Land Drainage Area for Lake Huron includes St. Marys River. Lake Erie includes the St. Clair-Detroit system. Lake Ontario includes the Niagara River.
[c] Including islands.
[d] These totals are greater than the sum of the shoreline length for the lakes because they include the connecting channels (excluding the St. Lawrence River).
[e] Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, *Coordinated Great Lakes Physical Data* May, 1992.
[f] *Extension Bulletins E-1866–70*, Michigan Sea Grant College Program, Cooperative Extension Service, Michigan State University, E. Lansing, Michigan, 1985.
[g] 1990–1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years.

*Source*: From www.epa.gov.

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**Table 11H.149 Water Withdrawals**

| | | Superior | Michigan | Huron | Erie | Ontario | Totals |
|---|---|---|---|---|---|---|---|
| Municipal | Canada[a,b] | 40 | | 120 | 190 | 660 | 1,010 |
| | | 36 | | 107 | 170 | 589 | 902 |
| | U.S.[a,b] | 70 | 2,940 | 310 | 2,820 | 380 | 6,520 |
| | | 62 | 2,262 | 277 | 2,515 | 339 | 5,455 |
| | Total[a,b] | 110 | 2,940 | 430 | 3,010 | 1,040 | 7,530 |
| | | 98 | 2,622 | 384 | 2,685 | 927 | 6,716 |
| Manufacturing | Canada[a,b] | 860 | | 1,360 | 1,900 | 2,760 | 6,880 |
| | | 767 | | 1,213 | 1,694 | 2,462 | 6,136 |
| | U.S.[a,b] | 410 | 9,650 | 1,060 | 9,110 | 530 | 20,760 |
| | | 366 | 8,608 | 945 | 8,126 | 473 | 18,518 |
| | Total[a,b] | 1,270 | 9,650 | 2,420 | 11,010 | 3,290 | 27,640 |
| | | 1,133 | 8,608 | 2,158 | 9,820 | 2,935 | 24,652 |
| Power production | Canada[a,b] | 70 | | 2,870 | 1,160 | 8,370 | 12,470 |
| | | 62 | | 2,560 | 1,035 | 7,466 | 11,123 |
| | U.S.[a,b] | 760 | 13,600 | 2,570 | 13,180 | 6,520 | 36,360 |
| | | 678 | 12,131 | 2,292 | 11,757 | 5,816 | 32,674 |
| | Total[a,b] | 830 | 13,600 | 5,440 | 14,340 | 14,890 | 49,100 |
| | | 740 | 12,131 | 4,852 | 12,791 | 13,282 | 43,796 |
| Grand totals | [a,b] | 2,210 | 26,190 | 8,290 | 28,360 | 19,220 | 84,270 |
| | | 1,971 | 23,361 | 7,394 | 25,296 | 17,144 | 75,166 |

[a] Cubic feet per second.
[b] Millions of cubic meters per year.

*Source*: From www.epa.gov. *Bulletins E-1866-70*, Sea Grant College Program, Cooperative Extension Service, Michigan State University, E. Lansing, Michigan, 1985.

**Table 11H.150 Water Consumed**

| | | Superior | Michigan | Huron | Erie | Ontario | Totals |
|---|---|---|---|---|---|---|---|
| Municipal | Canada[a,b] | 10 | | 20 | 30 | 100 | 160 |
| | | 9 | | 18 | 27 | 89 | 143 |
| | U.S.[a,b] | 10 | 190 | 170 | 280 | 70 | 720 |
| | | 9 | 169 | 152 | 249 | 62 | 641 |
| | Total[a,b] | 20 | 190 | 190 | 310 | 170 | 880 |
| | | 18 | 169 | 170 | 276 | 152 | 783 |
| Manufacturing | Canada[a,b] | 20 | | 70 | 80 | 100 | 270 |
| | | 18 | | 62 | 71 | 89 | 240 |
| | U.S.[a,b] | 60 | 880 | 30 | 1,500 | 40 | 2,510 |
| | | 53 | 785 | 27 | 1,338 | 36 | 2,239 |
| | Total[a,b] | 80 | 880 | 100 | 1,580 | 140 | 2,780 |
| | | 71 | 785 | 89 | 1,409 | 125 | 2,479 |
| Power production | Canada[a,b] | 0 | | 20 | 10 | 60 | 90 |
| | | 0 | | 18 | 9 | 54 | 81 |
| | U.S.[a,b] | 10 | 240 | 50 | 190 | 120 | 610 |
| | | 9 | 214 | 45 | 169 | 108 | 545 |
| | Total[a,b] | 10 | 240 | 70 | 200 | 180 | 700 |
| | | 9 | 214 | 62 | 178 | 174 | 673 |
| Grand Totals | [a,b] | 110 | 1,310 | 360 | 2,090 | 490 | 4,360 |
| | | 98 | 1,168 | 321 | 1,863 | 450 | 3,935 |

[a] Cubic feet per second.
[b] Millions of cubic meters per year.

*Source*: From www.epa.gov. *Bulletins E-1866*–70, Sea Grant College Program, Cooperative Extension Service, Michigan State University, E. Lansing, Michigan, 1985.

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**Table 11H.151 Water Diversions in and Affecting Canada, 1985**

| No. | Jurisdiction | Project | Contributing Basin(s) | Receiving Basin | Average Annual Diversion (cfs) | Uses | Operational Date | Owner |
|---|---|---|---|---|---|---|---|---|
| 1 | British Columbia | Kemano | Nechako (Fraser) | Kemano | 4,060 | Hydro | 1952 | Alcan Ltd. |
| 2 | British Columbia | | Bridge | Seton Lake | 3,250 | Hydro | (1934) 1959 | British Columbia Hydro |
| 3 | British Columbia | | Cheakamus | Squamish | 1,300 | Hydro | 1957 | British Columbia Hydro |
| 4 | British Columbia | | Coquitam Lake | Buntzen Lake | 1,000 | Hydro | (1902) 1912 | British Columbia Hydro |
| 5 | Saskatchewan | | Tazin Lake | Charlot (Lake Athabasca) | 1,000 | Hydro | 1958 | Eldorado Nuclear |
| 6 | Manitoba | Churchill Diversion | Churchill (Southern Indian Lake) | Rat. Burntwood (Nelson) | 27,350 | Hydro | 1976 | Manitoba Hydro |
| 7 | Ontario | | Lake St. Joseph (Albany) | Root (Winnipeg) | 3,020 | Hydro | 1957 | Ontario Hydro |
| 8 | Ontario | | Ogoki (Albany) | Lake Nipigon (Superior) | 3,990 | Hydro | 1943 | Ontario Hydro |
| 9 | Ontario | | Long Lake (Albany) | Lake Superior | 1,480 | Hydro/logging | 1939 | Ontario Hydro |
| 10 | Ontario | | Little Abitibi (Moose) | Abitibi (Moose) | 1,410 | Hydro | 1963 | Ontario Hydro |
| 11 | Ontario | Welland | Lake Erie | Lake Ontario | 8,830 | Hydro navigation | (1829) 1951) | Government of Canada |
| 12 | Quebec | James Bay | Eastmain-Opinaca | La Grande | 28,600 | Hydro | 1980 | J.B. Energy Corp. |
| 13 | Quebec | James Bay | Fregate | La Grande | 1,090 | Hydro | 1982 | J.B. Energy Corp. |
| 14 | Quebec | James Bay | Caniapiscau | La Grande | | Hydro | 1983 | J.B. Energy Corp. |
| 15 | Newfoundland | Churchill Falls | Julian-Unknown | Churchill | 27,400 | Hydro | 1971 | Newfoundland and Labrador Hydro |
| 16 | Newfoundland | Churchill Falls | Naskaupi | Churchill | 7,060 | Hydro | 1971 | Newfoundland and Labrador Hydro |
| 17 | Newfoundland | Churchill Falls | Kanairktok | Churchill | 4,590 | Hydro | 1971 | Newfoundland and Labrador Hydro |
| 18 | Newfoundland | Bay d'Espoir | Victoria, White Bear, Grey, and Salmon | Norhtwest Brook (Bay d'Espoir) | 6,530 | Hydro | 1969 | Newfoundland and Labrador hydro |
| 19 | Illinois | Chicago | Lake Michigan | Illinois (Mississippi) | 3,200 sanitation | Municipal | (1848) 1900 | Chicago Sanitary Dist. |

*Source*: From Quinn, F., *Interbasin Water Diversions: A Canadian Perspective*. Journal of Soil & Water Conservation, November–December, 1987. Copyright Soil and Water Conservation Society. Reprinted with permission.



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**Table 11H.152 Proposed Interbasin Water Transfer Schemes from Canada into the United States**

| Proposal (Author) | Year Proposed | Water Source | Annual Diversion ($km^3$) | Estimated Construction Costs (billions of $) |
|---|---|---|---|---|
| Grand Canal Plan (Kierans) | 1959–1983 | James Bay diked, water diverted to Great Lakes and United States | 347 | 100 |
| Great Lakes-Pacific Waterways Plan (Decker) | 1963 | Skeena, Nechako & Fraser of B.C., Peace, Athabasca, Saskatchewan of Prairie Provinces | 142 | Not Available |
| North America Water & Power Alliance (NAWAPA) (Parsons) | 1964 | Primarily the Pacific & Yukon and B.C.; also tributaries of James Bay | 310 | 100 |
| Magnum Plan (Magnusson) | 1965 | Peace, Athabasca & N. Saskatchewan in Alberta | 31 at border | Not Available |
| Kuiper Plan (Kuiper) | 1967 | Peace, Athabasca & N. Saskatchewan in Alberta, Nelson & Churchill in Manitoba | 185 | 50 |
| Central North American Water Project (CeNAWP) (Tinney) | 1967 | Mackenzie, Peace, Athabasca, N. Saskatchewan, Nelson & Churchill | 185 | 30–50 |
| Western States Water Augmentation Concept (Smith) | 1968 | Primarily Liard & Mackenzie drainages | 49 at border | 90 |
| NAWAPA-MUSHEC or Mexican-United States Hydroelectric Commission (Parsons) | 1968 | NAWAPA sources + lower Mississippi & Sierra Madre Oriental Rivers of Southern Mexico | 195 + 159 Nawapa Muschec | Not Available |
| North American Waters, A Master Plan (NAWAMP) (Tweed) | 1968 | Yukon & Mackenzie Rivers, drainage to Hudson Bay | 1850 | Not Available |

*Source*: From Pearse, P.H., Bertrand, F., and MacLaren, J.W., 1985, *Currents of Change, Final Report on Federal Water Policy*, Ottawa, Canada. With permission.

**Table 11H.153 Costs of Some Water Transfer Projects**

| Country | Project | Capacity $km^3/yr$ | Route Length (km) | Lift Height (m) | Approximate Cost Billion Dollars | | Year of Plan |
|---|---|---|---|---|---|---|---|
| | | | | | Total | Per 1 ($km^3$) | |
| U.S.A. | | | | | | | |
| Canada | NAWAPA | 100–300 | 2,000 | — | 100 | 0.33–1.0 | Project of 1964 |
| U.S.A. | Beck Plan | 12.2 | 1,000 | 840 | 3.5 | 0.29 | Project of 1968 |
| U.S.A. | Grand Canal | 20.0 | — | — | 5.0 | 0.25 | Project of 1959 |
| U.S.A. | Texas Water Plan | 20.5 | 1,800 | 1,300 | 9.0 | 0.44 | Project of 1968 |
| U.S.A. | Hudson Institute Plan | 41.5 | 1,800 | — | 12.2 | 0.29 | Project of 1968 |
| U.S.A. | California Aqueduct | 5.2 | 300 | 1,100 | 2.3 | 0.44 | 1973 |
| U.S.S.R. | Irtysh-Central Asia | 25 | 2,300 | 130 | 19 | 0.76 | Project of 1980 |
| U.S.S.R. | Sukhona-Volga | 4.0 | 480 | 6 | 0.43 | 0.11 | Project of 1980 |
| U.S.S.R. | Onega R. (upper)-Volga | 2.0 | 390 | 9 | 0.22 | 0.11 | Project of 1980 |
| U.S.S.R. | Pechora-Kama | 9.8 | 300 | 30 | 2.3 | 0.24 | Project of 1980 |
| U.S.S.R. | Onega Bay | 38 | 800 | 130 | 8.2 | 0.22 | Project of 1981 |
| India | Rajasthan Canal | 16.5 | 180 | — | 0.56 | 0.034 | Under construction |
| India | Sarda Sahayak | 15.4 | 260 | — | 0.23 | 0.015 | Under construction |
| Australia | Snowy Mountains | 2.4 | 220 | — | 0.80 | 0.33 | 1974 |
| Israel | Yarkon-Negev | 0.23 | 110 | 220 | 0.051 | 0.22 | In operation |
| Israel | Jordan Waterway | 0.32 | 240 | 350 | 0.115 | 0.36 | In operation |

*Source*: From Shiklomanov, I.A., 1985, *Large Scale Water Transfers*. Chapter 12 of Facets of Hydrology II, edited by John C. Rodda. Copyright 1985 John Wiley and Sons. Reprinted with permission.

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**Table 11H.154 Authorizations for Water Supply, Water Quality and Related Infrastructure Projects and Studies**

| Act Section | Provision | T, Traditional | NT, Non-traditional | New Federal $(000)[b] | State(s) |
|---|---|---|---|---|---|
| WRDA 1986, PL 99-662, 17 November 1986 | | | | | |
| 401(a) | Santa Ana River Mainstem, CA. Study to investigate the feasibility of including water supply and conservation storage at Prado Dam | T | | 0 | CA |
| 707 | Capital Investment Needs for Water Resources. Authorized the Assistant Secretary of the Army for Civil Works to estimate long-term capital investment needs for, among other things, municipal and industrial water supply | T | | 0 | Nationwide |
| 729 | Study of Water Resources Needs of River Basins and Regions. Requires the Assistant Secretary of the Army for Civil Works, in coordination with the Secretary of the Interior and in consultation with other governmental agencies, to study "water resources needs of river basins and regions of the United States." This section specifically requires consultation with "State, interstate, and local governments" | T | | 5,000 | Nationwide |
| 818 | Brazos River Basin, TX. Modifies Section 10 of the 1946 FCA to insert "or water supply" after "irrigation" | T | | 0 | TX |
| 834 | Curwensville Lake. Authorization to construct a water line with pumps in order to provide water for municipal use | | NT | 225 | PA |
| 838 | Denison Dam (Lake Texoma). Authorization to reallocate 300,000 acre-ft of hydropower storage to municipal and industrial water supply | T | | 0 | OK & TX |
| 843 | Beaver Lake. Authorization to study and undertake a project to preserve and enhance water quality of the lake | | NT | 3,825 | AR |
| 931 | Interim use of Water Supply for Irrigation. Authorizes the temporary use of unused municipal and industrial water supply storage for irrigation | T | | 0 | Nationwide |
| 1103 | Upper Mississippi River Plan. This is a major environmental restoration authorization for the Corps. This authorization recognized the Upper Mississippi River as a nationally significant ecosystem and a nationally significant commercial navigation system. It authorized the Secretary of the Army to enter into agreements with basin states and to transfer funds to the DOI as necessary to carry out the provisions of the section. In consultation with the DOI and the basin states the Secretary of the Army was also authorized to determine the need for river rehabilitation and environmental enhancement and protection based on the conditions of the environmental, project developments, and projected environmental impacts from implementing any proposal resulting from recommendations made under provisions of the section | T | | 188,000 over 10-years | IL, IA, MN, MO and WI, |

*(Continued)*



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**Table 11H.154 (Continued)**

| Act Section | Provision | T, Traditional | NT, Non-traditional | New Federal $(000)[b] | State(s) |
|---|---|---|---|---|---|
| 1121 | Ogallala Aquifer. To establish a comprehensive research and development program to assist those portions of the High Plains region dependent on water from the Ogallala Aquifer | | NT | 65,000 | CO, KS, NE, NM, OK, SD, TX, & WY |
| 1135 | Project Modifications for Improvement of Environment. Authorizes the review of water resources projects to determine the need for modifications in the structures and operations of such projects for the purpose improving the quality of the environment in the public interest | T | | 0 | Nationwide |
| 1141 | Groundwater Recharge. Authorization to plan, engineer and design a project for recharge of groundwater in the drainage basis of the Tucson and Scottsdale, AZ metropolitan areas | | NT | 250 | AZ |
| 1157 | Miami River Water Quality Commision. Authority to make a grant to establish a commission to develop a plan for improving the water quality of the Miami River and tributaries | | NT | 50 | FL |
| Total WRDA '86 | 13 Sections (4 of which apply nationwide); 8 sections traditional and 5 non-traditional | | | 262,350 | 18 |
| WRDA 1988, PL 101-676,17 November 1988 | | | | | |
| 23 | Louisiana Water Supply. Authorized to review the water supply problems related to drought at a water supply reservoir and to respond as appropriate | | NT | 0 | LA |
| Total WRDA '88 | 1 Section; non-traditional | | | 0 | 1 |
| WRDA 1990 PL 101-640, 28 November 1990 | | | | | |
| 116(d) | Southern California Infrastructure Restoration. Conduct a feasibility study, in consultation with FEMA, on the problems and alternative solutions of the infrastructure of the region | | NT | 1,500 | CA |
| 116(g) | Santa Rosa, CA. Authorize a study to evaluate storage facilities associated with wastewater reclamation and irrigation | | NT | 0 | CA |
| 116(p) | Water Supply, Minnesota and North Dakota. Conduct a study to determine alternate plans to augment flows in the Red River of the North including plans to supplement flows for municipal, industrial, agricultural, and fish and wildlife purposes | | NT | 0 | MN & ND |
| 116(w) | Buffalo, New York. To evaluate a city plan on flooding and associated water quality problems (including those associated with combined sewer over flow, sewer backups and riverside outfalls) | | NT | 0 | NY |
| 116(x) | Caesar's Creek Lake, Ohio. To conduct a study of the water supply needs of Clinton County, Ohio | | NT | 0 | OH |

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| | | | | |
|---|---|---|---|---|
| 116(y) | Liberty, Ohio. To conduct a study of the water supply needs of the city | NT | 0 | OH |
| 116(z) | Washingtonville, Ohio. To conduct a study of the water supply needs of the city | NT | 0 | OH |
| 116(dd) | Radium Removal. To study and provide technical assistance to small communities on methods of mitigating radium contamination in groundwater used as a source of public drinking water | NT | 0 | Nationwide |
| Total WRDA '90 | 8 Sections (including one nationwide); all non-traditional | | 1,500 | 5 |
| WRDA 1992, PL 102-580, 31 October 1992 | | | | |
| 114 | Brockton MA. Study of water supply needs and of water quality and quantity to meet future needs | NT | 0 | MA |
| 217 | Reuse of Wastewater. Authorizes assistance to non-Federal interests for planning and design of reuse systems | NT | 5,000 | CA |
| 218 | Demonstration of Waste Water Technology, Santa Clara Valley Water District and San Jose, CA. Authorized, in cooperation with EPA, to provide design and construction assistance to the Water District for demonstrating and field testing public use innovative processes which advance the technology of waste water reuse and treatment and which promote the use of treated waste water for critical water supply purposes | NT | 10,000 | CA |
| 219 | Environmental Infrastructure. Authorizes technical and planning and design assistance | NT | 5,000 * | Nationwide |
| 220 | Environmental Infrastructure Assistance. Authorizes assistance in design and construction of water transmission line | NT | 5,000 | AR |
| 221 | Environmental Infrastructure Assistance. Authorizes design and construction assistance for Combined Sewer System and storm water projects | NT | 7,000 | NY |
| 222 | Environmental Infrastructure Assistance. Authorizes design and construction assistance for storm water project | NT | 200 | PA |
| 304 | Broad Top Region of Pennsylvania. Authorizes a Watershed Reclamation and Wetlands Pilot Project along the Juniata River and its tributaries, PA | NT | 5,500 * | PA |
| 307 | Water Quality Projects. Authorizes design and construction of storm water projects | NT | 70,000 * | LA, ME, NY, & RI |
| 313 | South Central Pennsylvania Environmental Restoration Infrastructure and Resource Protection Development. Establishes a pilot program for design and construction of wastewater treatment facilities, water supply storage, treatment and distribution facilities and surface water development and protection | NT | 17,000 | PA |

*(Continued)*



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**Table 11H.154 (Continued)**

| Act Section | Provision | T, Traditional | NT, Non-traditional | New Federal $(000)[b] | State(s) |
|---|---|---|---|---|---|
| 322 | Water Supply needs of Mahoning Valley Sanitary District, Ohio. Cooperate with the state in review of water supply needs | | NT | 0 | OH |
| 324 | Hackensack Meadowlands Area. Authorizes design and construction assistance for an environmental improvement program | | NT | 5,000 | NJ |
| 340 | Southern West Virginia Environmental Restoration and Infrastructure Resources Protection Development Project. Modified by Section 359 of WRDA '96 | | NT | 5,000 * | WV |
| 362 | Quonset Point-Davisville, Rhode Island. Authority to construct two water supply towers and relocate sewer lines | | NT | 1,875 | RI |
| Total WRDA '92 | 14 sections (including one nationwide); all non-traditional | | | 136,075 | 11 |
| WRDA 1996. Public Law 104-303, 12 October 1996 | | | | | |
| 359 | Southern West Virginia. Modifies cost sharing and increases funding levels of Section 340 of WRDA '92 | | NT | 15,000 * | VW |
| 401 | Rural Sanitation Projects. Authorize a study to report on the advisability and capability of the Corps to implement rural sanitation projects for rural and native villages in Alaska | | NT | 0 | AK |
| 503 | Watershed Management, Restoration and Development. Authority to provide technical, planning and design assistance to non-Federal interests for carrying out watershed management, restoration and development projects at specific locations | | NT | 15,000 | AZ, CA, GA, NE, WV |
| 504 | Environmental Infrastructure. Amend Section 219 of WRDA '92 by adding specific authorizations of appropriations for construction assistance for six specific environmental infrastructure projects | | NT | 73,000 * | DC & MD, GA, KY, MI, MS, NH |
| 522 | Jackson County, AL. Authority to provide technical, planning and design assistance for wastewater treatment and related facilities, remediation of point and non-point sources of pollution and contaminated riverbed sediments | | NT | 3,000 | AL |
| 531 | Southern and Eastern Kentucky. Authority to establish a program to provide environmental assistance to non-Federal interests to design and construct water related environmental infrastructure including wastewater treatment, water supply and surface water protection and development | | NT | 10,000 | KY |
| 552 | New York City Watershed. Authority to provide design and construction assistance for environmental infrastructure and resource protection and development projects in the watershed to protect and enhance the quality and quantity of the New York City water supply | | NT | 22,500 | NY |

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| | | | | | |
|---|---|---|---|---|---|
| 566 | Southeastern Pennsylvania. Authority to establish a program to provide environmental assistance to non-Federal interests to design and construct water related environmental infrastructure including wastewater treatment, water supply, and surface water protection and development | | NT | 25,000 | PA |
| 585 | Overflow Management Facility. Authority to provide assistance to Narragansett Bay Commission for the construction of a combined river overflow management facility | | NT | 30,000 | RI |
| Total WRDA '96 | 9 Sections; all non-traditional | | | 188,500 | 15 |
| WRDA 1999, Public Law 106-53, 17 August 1999 | | | | | |
| 101(b)(4) | Success Dam, Tule River Basin, CA. Authorizes a project for flood damage reduction and water supply | T | | 11,635 | CA |
| 101(b)(15) | Howard Hanson Dam, WA. Authorizes a project for water supply and ecosystem restoration | | NT | 36,900 | WA |
| 211 | Watershed Management, Restoration and Development. Expands Section 503 of WRDA '96 to extend authorization assistance to sites in six additional states | | NT | 0 | FL, IL, NV, NC, OR |
| 212 | Flood Mitigation and Riverine Restoration Program. Authorizes a program for the purpose of conducting projects to reduce flood hazards and restore the natural functions and values of rivers throughout the United States | T | | 200,000 | AZ, CA, KY, MN, ND, NH, NJ, NM, NY, NC, OH, OR, PA, RI, SD, VA, WI |
| 331 | Jackson County Mississippi. Modifies Section 219(c)(5) of WRDA '92 to provide cost sharing credit | | NT | 0 | MS |
| 340 | New York City Watershed. Modifies Section 552 of WRDA '96 to change local cooperation wording. Increases $22.5 million to $42.5 million | | NT | 20,000 * | NY |
| 343 | Broken Bow Lake. Project modified to require a seasonal adjustment to the top of the conservation pool in the interest of water and related resources | T | | 0 | OK |
| 351 | South Central Pennsylvania. Modifies Section 313(g)(3) of WRDA '92 to increase appropriations and cost sharing (increases $80 million to $180 million) | | NT | 100,000 * | PA |
| 374 | White River Basin, AR and MO. Authorizes project operation modifications and storage reallocations in the interest of trout fisheries | | NT | 0 | AR & MO |
| 403 | Green Ferry Lake, AR. Conduct a study to determine the feasibility of constructing water intake facilities | | NT | 0 | AR |

*(Continued)*



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**Table 11H.154 (Continued)**

| Act Section | Provision | T, Traditional | NT, Non-traditional | New Federal $(000)[b] | State(s) |
|---|---|---|---|---|---|
| 502 | Environmental Infrastructure. Modifies Section 219(e) of WRDA '92 to increase appropriations and to authorize additional assistance at 43 projects in 20 different states. The assistance to include, but not necessarily limited: to eliminate or control combined sewer overflows, or for water related infrastructure, or groundwater recharge, or wastewater infrastructure projects, or wastewater treatment, or to provide water supply facilities, or for a project for recycled water or for industrial water reuse project | | NT | 494,000 * | CA, CT, GA, IN, LA, MA, MI, MO, MS, NC, NH, NJ, NY, OR, OK, PA, SC, TN, UT & VA |
| 513 | Design and Construction Assistance. Modifies Section 507 of WRDA '96 to include "expansion and improvement of Long Pine Run Dam, PA and associated water infrastructure." | | NT | 5,000 | PA |
| 521 | Beaver Lake, AR. Reallocate storage in Beaver Lake at no cost to the local water districts | | NT | 0 | AR |
| 531 | Kanopolis Lake, KS. Offers the State of Kansas the right to purchase storage at certain prescribed costs. | | NT | 0 | KS |
| 532 | Southeastern and Eastern Kentucky. Modifies Section 531 of WRDA '96 to increase (from $10 to $25 million) funding and to expand to include "small stream flooding, local storm water drainage, and related problems | | NT | 15,000 * | KY |
| 545 | Sardis Reservoir, OK. Offers the State of Oklahoma the right to purchase storage a certain prescribed costs. | | NT | 0 | OK |
| 548 | Bradford and Sullivan Counties, PA. Authority to provide assistance for water-related infrastructure and resource protection and development projects | | NT | 0 | PA |
| 552 | Southeastern Pennsylvania. Modifies Section 566(b) of WRDA '96 to include "environmental restoration" as well as the originally authorized water supply and related facilities. | | NT | 0 | PA |
| 560 | Abandoned and Inactive Noncoal Mine Restoration. Authority to provide technical, planning and design assistance to Federal and non-Federal interests for carrying out projects to address water quality problems caused by drainage and related activities from abandoned and inactive noncoal mines | | NT | 5,000 | Nationwide |
| 569 | Northeastern Minnesota. Authorizes a pilot program to provide environmental infrastructure assistance to non-Federal interests to include design and construction for wastewater treatment and related facilities, water supply and related facilities, environmental restoration, and surface water resource protection and development | | NT | 40,000 | MN |

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| | | | | |
|---|---|---|---|---|
| 570 | Alaska. Authorizes a pilot program to provide environmental assistance to non-Federal interests to include design and construction for wastewater treatment and related facilities, water supply and related facilities, and surface water resource protection and development | NT | 25,000 | AK |
| 571 | Central West Virginia. Authorizes a pilot program to provide environmental assistance to non-Federal interests to include design and construction for wastewater treatment and related facilities, water supply and related facilities, and surface water resource protection and development | NT | 10,000 * | WV |
| 573 | Onondaga Lake, NY. Authorization to plan, design and construct projects that are consistent with the Onondaga Lake Management Plan and comply with the amended consent judgment and the project labor agreement for the environmental restoration, conservation and management of Onondaga Lake, NY | NT | 1,000 * | NY |
| 592 | Mississippi. Authorizes a pilot program to provide environmental assistance to non-Federal interests to include design and construction assistance for projects for wastewater treatment and related facilities, elimination or control of combined sewer overflows, water supply and related facilities environmental restoration, and surface water resource protection and development | NT | 25,000 | MS |
| 593 | Central New Mexico. Authorizes a pilot program to provide environmental assistance to non-Federal interests to include design and construction assistance for projects for wastewater treatment and related facilities, water supply, conservation, and related facilities, storm water resource protection and development | NT | 25,000 * | NM |
| 594 | Ohio. Authorizes a program to provide environmental assistance in the form of design and construction to non-Federal interests to include wastewater treatment and related facilities; combined sewer overflow, water supply, storage, treatment, and related facilities; mine drainage; environmental restoration; and surface water resources protection and development | NT | 60,000 | OH |
| 595 | Rural Nevada and Montana. Authorizes a program to provide environmental assistance to non-Federal interests in the form of design and construction assistance for projects for wastewater treatment and related facilities, water supply and related facilities, environmental restoration ad surface water resource projection and development | NT | 50,000 | MT & NV |
| Total WRDA '99 | 27 Sections (including one nationwide); 3 traditional and 24 non-traditional | | 1,123,535 | 33 |

*(Continued)*



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**Table 11H.154 (Continued)**

| Act Section | Provision | T, Traditional | NT, Non-traditional | New Federal $(000)[b] | State(s) |
|---|---|---|---|---|---|
| 337 | Buchanan, Dickenson, and Russell Counties, VA. Authority to reallocate storage to water supply in the John Flannagan Reservoir under the authority of Section 322 of WRDA '90 | | NT | 0 | VA |
| 447 | Fremont, Ohio. To conduct a study to determine the feasibility of carrying out projects for water supply and environmental restoration at the Ballville Dam | | NT | 0 | OH |
| Total WRDA 00 | 2 Sections; both non-traditional | | | 0 | 2 |

[a] While detailed records are not available, traditional provisions are more than likely part of the Administration's proposal and non-traditional provisions are more than likely Congressional adds.

[b] Dollar values shown are the authorized appropriations in the legislation. Sections with an asterisk (*), (available only for Fiscal Years 1992–2002, indicate funding was received. Actual funding, however, may have been greater than, less than, or as authorized.)

*Source*: From www.swf.usace.army.mil.

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## SECTION 11I GROUNDWATER

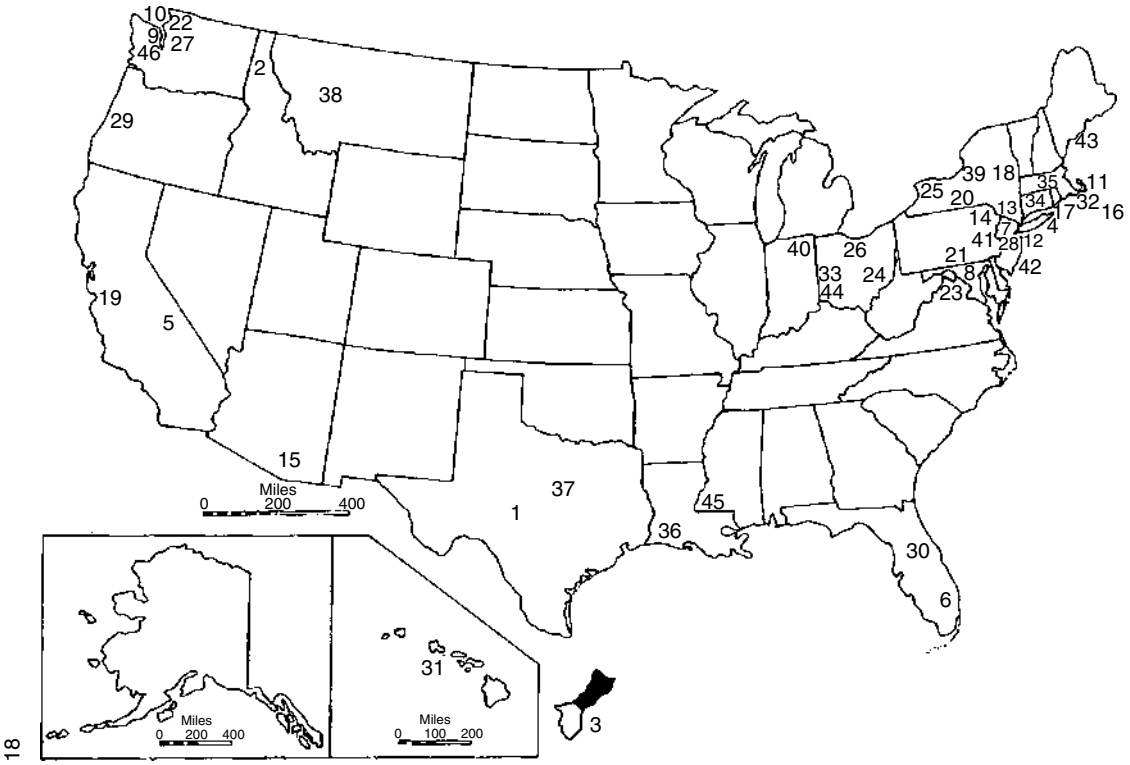


**Figure 11I.107** Designated sole-source aquifers in the United States. [For explanation and listing of aquifers see Table 11I.17. (From U.S. Environmental Protection Agency, 1988. With permission.)]

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**Table 11I.155 Designated Sole-Source Aquifers in the United States**

| USEPA Region | Map Number | Aquifer and/or Location | State | Date Filed | Federal Register Notice | |
|---|---|---|---|---|---|---|
| | | | | | Citation | Publication Date |
| VI | 1 | Edwards Aquifers | TX | 1/03/75 | 40 FR 58344 | 12/16/75 |
| X | 2 | Spokane Valley Rathdrum Prairie Aquifer | WA-ID | fall of 76 | 43 FR 5566 | 02/09/78 |
| IX | 3 | Northern Guem | Guam | 11/20/75 | 43 FR 17868 | 04/26/78 |
| II | 4 | Nassau/Suffolk Counties Long Island | NY | 1/21/75 | 43 FR 26611 | 06/21/78 |
| IX | 5 | Fresno County | CA | 8/09/76 | 44 FR 52751 | 09/10/79 |
| IV | 6 | Biscayne Aquifer | FL | 5/08/78 | 44 FR 58797 | 10/11/79 |
| II | 7 | Buried Valley Aquifer System | NJ | 1/15/78 | 45 FR 30537 | 05/08/80 |
| III | 8 | Maryland Piedmont Aquifer Montgomery, Frederick, Howard, Carroll Counties | MD | 09/12/75 | 45 FR 57165 | 08/27/80 |
| X | 9 | Camano Island Aquifer | WA | 4/13/81 | 47 FR 14779 | 04/06/82 |
| X | 10 | Whidbey Island Aquifer | WA | 4/13/81 | 47 FR 14779 | 04/06/82 |
| I | 11 | Cape Cod Aquifer | MA | 3/04/81 | 47 FR 30282 | 07/13/82 |
| II | 12 | Kings/Queens Counties | NY | 6/18/79 | 49 Fr 2950 | 01/24/84 |
| II | 13 | Ridgewood Area | NY/NJ | 7/04/79 | 49 FR 2943 | 01/24/84 |
| II | 14 | Upper Rockaway River Basin Area | NJ | 11/30/79 | 49 FR 2946 | 01/24/84 |
| IX | 15 | Upper Santa Cruz & Avra Altar Basin Aquifers | AZ | 6/29/81 | 49 FR 2948 | 01/24/84 |
| I | 16 | Nantucket Island Aquifer | MA | 12/02/82 | 49 FR 2952 | 01/24/84 |
| I | 17 | Block Island Aquifer | RI | 2/18/83 | 49 FR 2952 | 01/24/84 |
| II | 18 | Schenectady/Niskayuna Schenectady, Saratoga and Albany Counties | NY | 8/20/82 | 50 FR 2022 | 01/14/85 |
| IX | 19 | Santa Marqarita Aquifer Scotts Valley, Santa Cruz County | CA | 9/07/77 | 50 FR 2023 | 01/14/85 |
| II | 20 | Clinton Street-Ballpark Valley, Aquifer System, Broome and Tioga Counties | NY | 2/26/81 | 50 FR 2025 | 01/14/85 |
| III | 21 | Seven Valleys Aquifer York County | PA | 9/24/81 | 50 FR 9126 | 03/06/85 |
| X | 22 | Cross Valley Aquifer | WA | 7/29/83 | 52 FR 18606 | 05/18/87 |
| III | 23 | Prospect Hill Aquifer Clark County | VA | 6/27/85 | 52 FR 21733 | 06/09/87 |
| V | 24 | Pleasant City Aquifer | OH | 8/27/84 | 52 FR 32342 | 08/27/87 |
| II | 25 | Cattaraugus Creek-Sardinia | NY | 2/28/85 | 52 FR 36100 | 09/25/87 |
| V | 26 | Bass Island Aquifer Catawba Island | OH | 3/17/86 | 52 FR 37009 | 10/02/87 |
| X | 27 | Newberg Area Aquifer | WA | 1/16/84 | 52 FR 42474 | 11/5/87 |
| II | 28 | Highlands Aquifer system | NY/NJ | 3/14/85 | 52 FR 37213 | 10/05/87 |
| X | 29 | North Florence Dunal Aquifer | OR | 6/02/85 | 52 FR 37519 | 10/07/87 |
| IV | 30 | Volusia-Florida Aquifer | FL | 6/18/82 | 52 FR 44221 | 11/18/87 |
| IX | 31 | Southern Oahu Basal Aquifer | HI | 5/03/83 | 52 FR 45496 | 11/30/87 |
| I | 32 | Martha's Vineyard Regional Aquifer | MA | 6/16/87 | 53 FR 3451 | 02/05/88 |
| V | 33 | Buried Valley Aquifer System (BVAS) | OH | 11/25/87 | 53 FR 15876 | 05/04/88 |
| I | 34 | Pawcatuck Basin Aquifer System | RI/CT | 11/30/87 | 53 FR 17108 | 05/13/88 |
| I | 35 | Hunt-Annaquatucket-Pettaquamscutt Aquifer | RI | 12/30/87 | 53 FR 19026 | 05/26/88 |
| VI | 36 | Chicot Aqufier | LA | 12/05/86 | 53 FR 20893 | 06/09/88 |
| VI | 37 | Edwards Aquifer Austin Area | TX | 08/29/86 | 53 FR 20897 | 06/07/88 |
| VIII | 38 | Missoula Valley Aquifer | MT | 11/23/87 | 53 FR 20895 | 06/07/88 |

*(Continued)*

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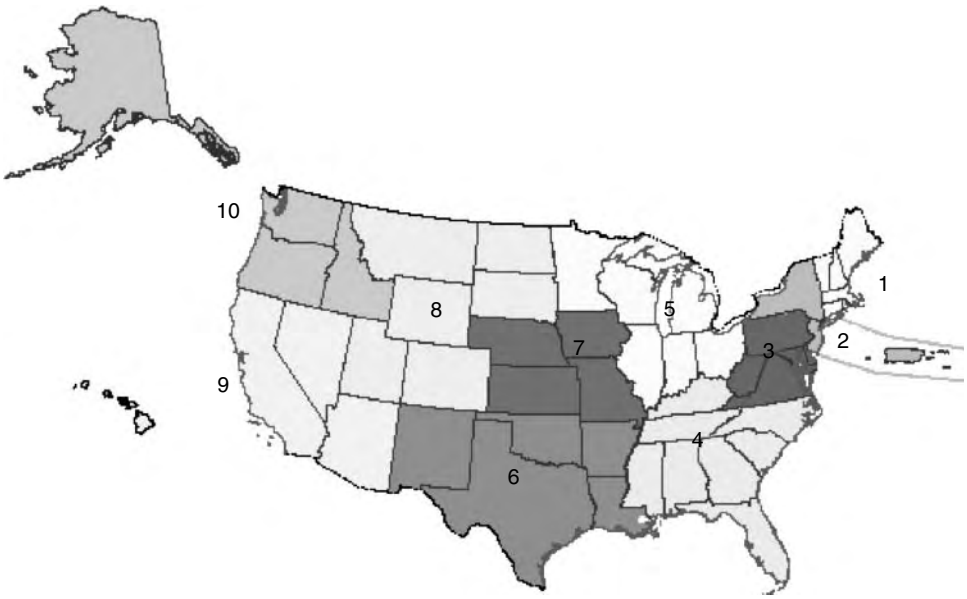
**Table 11I.155 (Continued)**

| USEPA Region | Map Number | Aquifer and/or Location | State | Date Filed | Federal Register Notice | |
|---|---|---|---|---|---|---|
| | | | | | Citation | Publication Date |
| II | 39 | Cortland-Horner-Preble Aquifer System | NY | 9/15/87 | 53 FR 22045 | 06/13/88 |
| V | 40 | St. Joseph Aquifer System (Elkhart Co) | IN | 12/11/87 | 53 FR 23682 | 06/23/88 |
| II | 41 | N.J. Fifteen Basin Aquifer Systems | NJ/NY | 11/18/85 | 53 FR 23685 | 06/23/88 |
| II | 42 | N.J. Coastal Plain Aquifer System | NJ | 12/04/78 | 53 FR 23791 | 06/24/88 |
| I | 43 | Monhegan Island | ME | 5/16/88 | 53 FR 24496 | 06/29/88 |
| V | 44 | OKI-Miami Buried Valley Aquifer | OH | 03/10/88 | 53 FR 25670 | 07/08/88 |
| VI | 45 | Southern Hills Aquifer System | LA/MS | 5/19/80 | 53 FR 25538 | 07/07/88 |
| X | 46 | Cedar Valley Aquifer | WA | 1/88 | | |

*Note:* As of July 1988; the Sole Source Aquifer (SSA) program allows individuals and organizations to petition the Environmental Protection Agency (EPA) to designate aquifers as the "sole or principal" source of drinking water for an area. The program was established under Section 1424(e) of the Safe Drinking Water Act (SDWA) of 1974. The primary purpose of the designation is to provide EPA review of Federal financially assisted projects planned for the area to determine their potential for contaminating the aquifer. Based on this review, no commitment of Federal financial assistance may be made for projects "which the Administrator (of EPA) determines may contaminate such (an) aquifer," although Federal funds may be used to modify projects to ensure that they will not contaminate the aquifer; for location of aquifers see Figure 8.17.

*Source*: From U.S. Environmental Protection Agency, 1988.




Reg. 1 (CT, MA, ME, NH, RI, VT) ~ Reg. 2 (NY, NJ, PR, VI)
Reg. 3 (DC, DE, MD, PA, VA, WV) ~ Reg. 4 (AL, FL, GA, KY, MS, NC, SC, TN)
Reg. 5 (IL, IN, MI, MN, OH, WI) ~ Reg. 6 (AR, LA, NM, OK, TX)
Reg. 7 (IA, KS, MO, NE) ~ Reg. 8 (CO, MT, ND, SD, UT, WY)
Reg. 9 (AZ, CA, HI, NV,AS,GU) ~ Reg. 10 (AK, ID, OR, WA)

**Figure 11I.108** EPA regions. (From www.epa.gov. With permission.)

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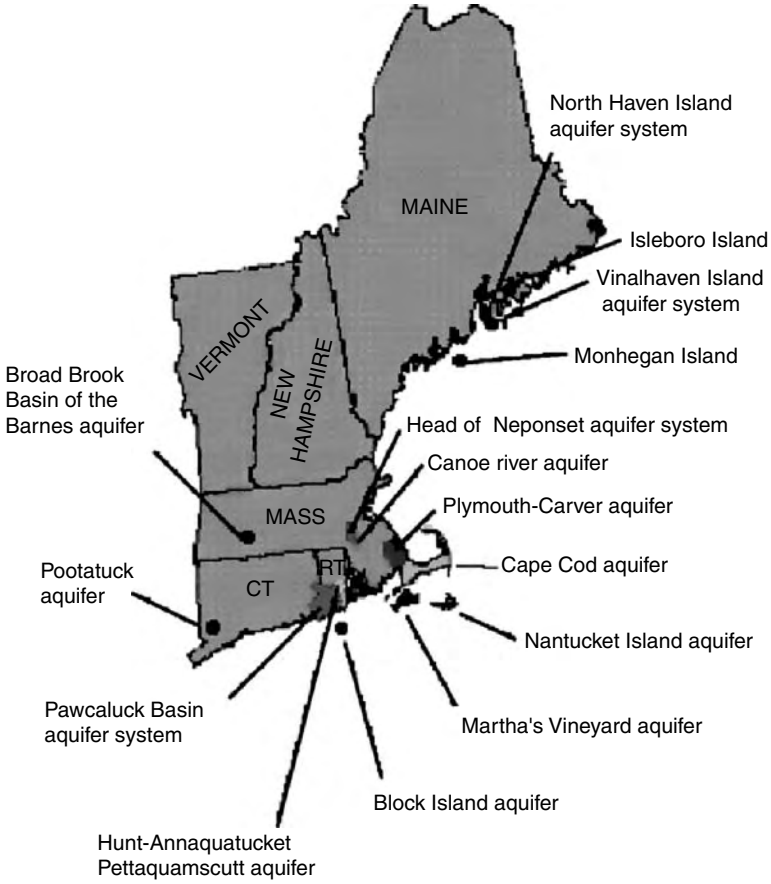


**Figure 11I.109** Designated sole source aquifers in EPA region I, Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont. (From www.epa.gov. With permission.)

**Table 11I.156 Sole Source Aquifer Designations in Region I**

| State | Sole Source Aquifer Name | Federal Reg. Citation | Public Date |
|---|---|---|---|
| CT | Pootatuck Aquifer | 55 FR 11056 | 03/26/90 |
| MA | Cape Cod Aquifer | 47 FR 30282 | 07/13/82 |
| MA | Nantucket Island Aquifer | 49 FR 2952 | 01/24/84 |
| MA | Martha's Vineyard Aquifer | 53 FR 3451 | 02/05/88 |
| MA | Head of Neponset Aquifer System | 53 FR 49920 | 12/12/88 |
| MA | Plymouth-Carver Aquifer | 55 FR 32137 | 08/07/90 |
| MA | Canoe River Aquifer | 58 FR 28402 | 05/13/93 |
| MA | Broad Brook Basin of the Barnes | 60 FR 20989 | 04/28/95 |
| ME | Monhegan Island | 53 FR 24496 | 06/29/88 |
| ME | Vinalhaven Island Aquifer System | 54 FR 29779 | 07/14/89 |
| ME | North Haven Island Aquifer System | 54 FR 29934 | 07/17/89 |
| ME | Isleboro Island Aquifer System | 64 FR 186 | 09/27/99 |
| RI | Block Island Aquifer | 49 FR 2952 | 01/24/84 |
| RI/CT | Pawcatuck Basin Aquifer System | 53 FR 17108 | 05/13/88 |
| RI | Hunt-Annaquatucket Pettaquamscutt | 53 FR 19026 | 05/26/88 |

*Source*: From www.epa.gov.

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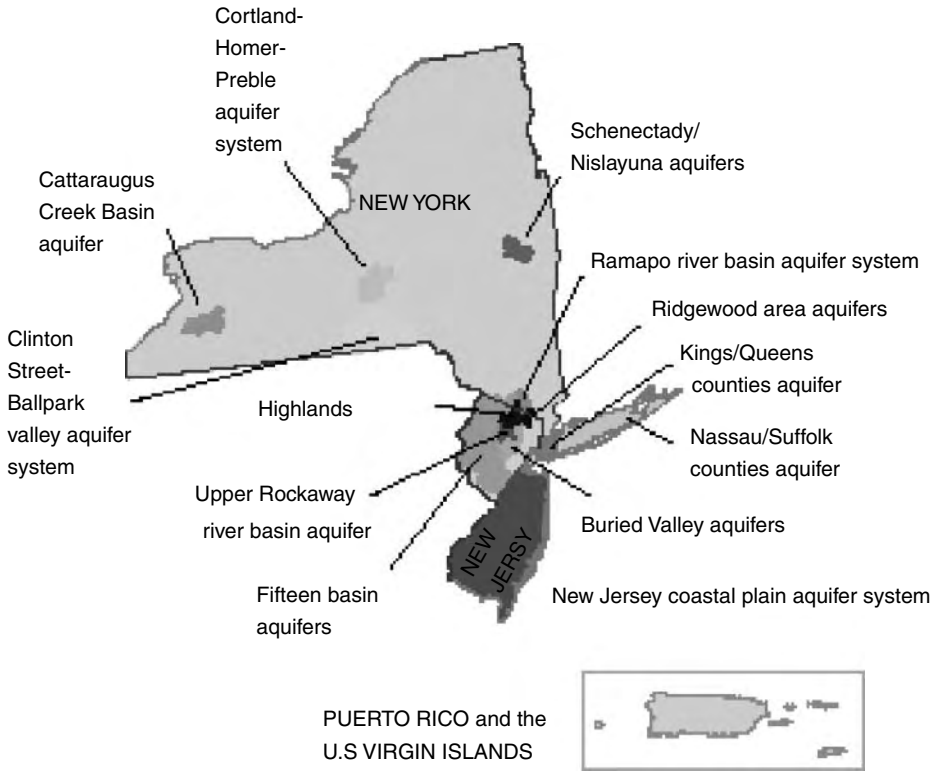


**Figure 11I.110** Designated sole-source aquifers in EPA Region II, New York, New Jersey, Puerto Rico, U.S. Virgin Islands. (From www.epa.gov. With permission.)

**Table 11I.157 Designated Sole Source Aquifers in Region II**

| State | Sole Source Aquifer Name | Federal Register Cit. | Public. Date |
|---|---|---|---|
| NJ | Buried Valley Aquifers, Central Basin, Essex and Morris Counties | 45 FR 30537 | 05/08/80 |
| NJ | Upper Rockaway River Basin | 49 FR 2946 | 01/24/84 |
| NJ | Ridgewood Area Aquifers | 49 FR 2943 | 01/24/84 |
| NJ/NY | Highlands Aquifer System Passaic, Morris & Essex Co's NJ; Orange Co. NY | 52 FR 37213 | 10/05/87 |
| [a]NJ/DE/PA | NJ Coastal Plain Aquifer System | 53 FR 23791 | 06/24/88 |
| NJ/NY | NJ Fifteen Basin Aquifers | 53 FR 23685 | 06/23/88 |
| NJ/NY | Ramapo River Basin Aquifer Systems | 57 FR 39201 | O8/28/92 |
| NY | Nassau/Suffolk Co., Long Island | 43 FR 26611 | 06/21/78 |
| NY | Kings/Queens Counties | 49 FR 2950 | 01/24/84 |
| NY | Schenectady/Niskayuna | 50 FR 2022 | 01/14/85 |
| NY | Clinton Streen-Ballpark Valley Aquifer System, Broome and Tioga Co's. | 50 FR 2025 | 01/14/85 |
| NY | Cattaraugus Creek Basin Aquifer, WY & Allegany Cos. | 52 FR 36100 | 09/25/87 |
| NY | Cortland-Homer-Preble Aquifer System | 53 FR 22045 | 06/13/88 |

[a] The New Jersey Coastal Plains Aquifer is jointly managed with Region 3. While listed in both regions it is counted only once in the national total of 70.

*Source*: From www.epa.gov.

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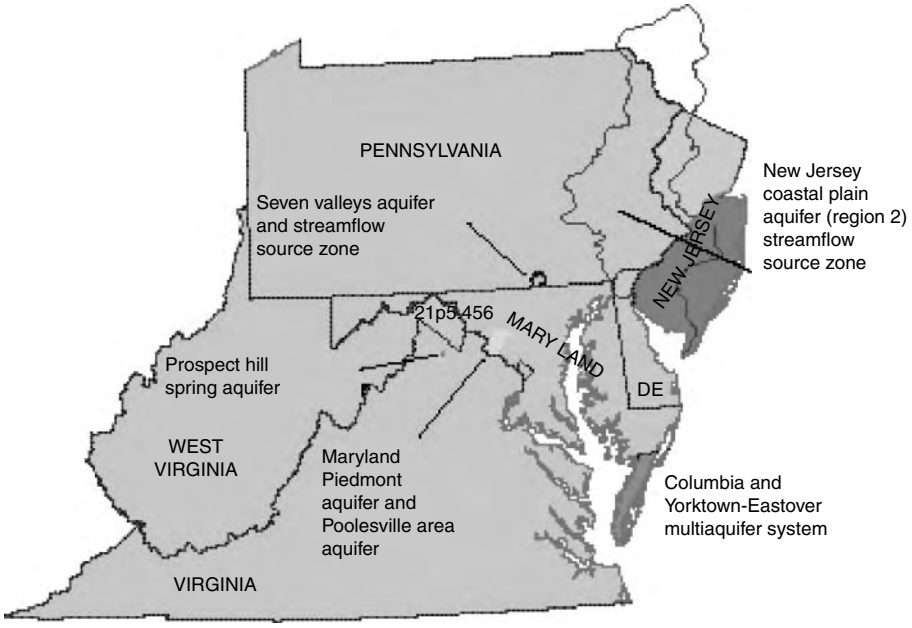


**Figure 11I.111** Designated sole source aquifers in EPA Region III, District of Columbia, Delaware, Maryland, Pennsylvania, Virginia, West Virginia. (From www.epa.gov. With permission.)

**Table 11I.158 Sole Source Aquifers in Region III**

| State | Sole Source Aquifer Name | Federal Register Citation | Publication Date |
|---|---|---|---|
| [a]DE/PA/NJ | New Jersey Coastal Plain Aquifer | 53 FR 23791 | 06/24/88 |
| MD | Maryland Piedmont Aquifer Montgomery, Howard, Carroll Counties | 45 FR 57165 | 08/27/80 |
| MD | Poolesville Area Aquifer Extension of the Maryland Piedmont Aquifer | 98 FR 3042 | 02/06/98 |
| PA | Seven Valleys Aquifer, York County | 50 FR 9126 | 03/06/85 |
| VA | Prospect Hill Aquifer, Clark County | 2 FR 21733 | 06/09/87 |
| VA | Columbia and Yorktown, Eastover Multi-aquifer System Accomack and North Hampton Counties | 62 FR 17187 | 04/09/97 |

[a] The New Jersey Coastal Plains Aquifer is jointly managed with Region II.

*Source*: From www.epa.gov.

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**Figure 11I.112** Designated sole source aquifers in EPA Region IV, Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee. (From www.epa.gov. With permission.)

**Table 11I.159 Designated Sole Source Aquifers in Region IV**

| State | Sole Source Aquifer Name | Federal Register Cit. | Public. Date |
|---|---|---|---|
| FL | Biscayne Aquifer, Broward, Dade, Monroe & Palm Beach Counties | 44 FR 58797 | 10/11/79 |
| FL | Volusia-Floridan Aquifer, Flagler & Putnam Counties | 52 FR 44221 | 11/18/87 |
| [a]LA/MS | Southern Hills Regional Aquifer System | 53 FR 25538 | 07/07/88 |

[a] The Southern Hills Regional Aquifer system is jointly managed with Region VI. While listed in both regions, it is counted only once in the national total of 70.

*Source*: From www.epa.gov.

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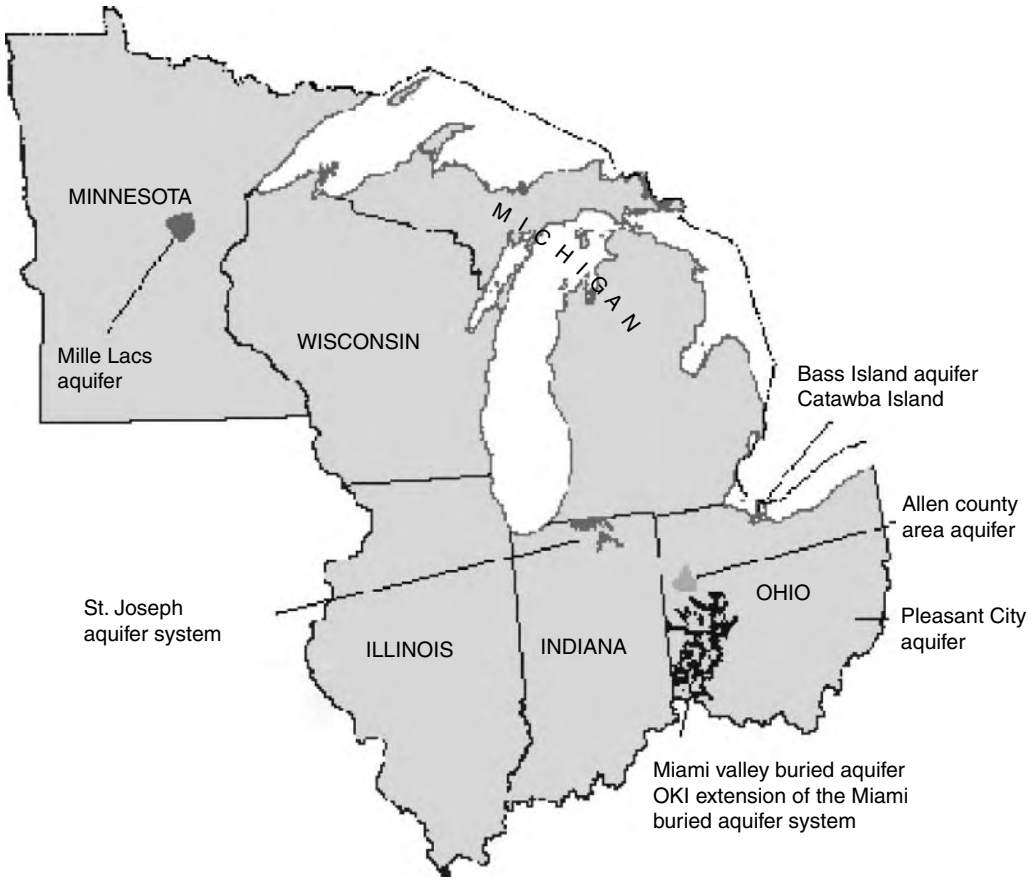


**Figure 11I.113** Designated sole source aquifers in EPA Region V, Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin. (From www.epa.gov. With permission.)

**Table 11I.160 Designated Sole Source Aquifers in Region V**

| State | Sole Source Aquifer Name | Federal Register Cit. | Public. Date |
|---|---|---|---|
| IN | St. Joseph Aquifer System | 53 FR 23682 | 06/23/88 |
| MN | Mille Lacs Aquifer | 55 FR 43407 | 10/29/90 |
| OH | Pleasant City Aquifer | 52 FR 32342 | 08/27/87 |
| OH | Bass Island Aq., Catawba Island | 52 FR 37009 | 10/02/87 |
| OH | Miami Valley Buried Aquifer | 53 FR 15876 | 05/04/88 |
| OH | OKI extension of the Miami Buried Valley Aquifer | 53 FR 25670 | 07/08/88 |
| OH | Allan County Area Combined Aquifer System | 57 FR 53111 | 11/06/92 |

*Source*: From www.epa.gov.

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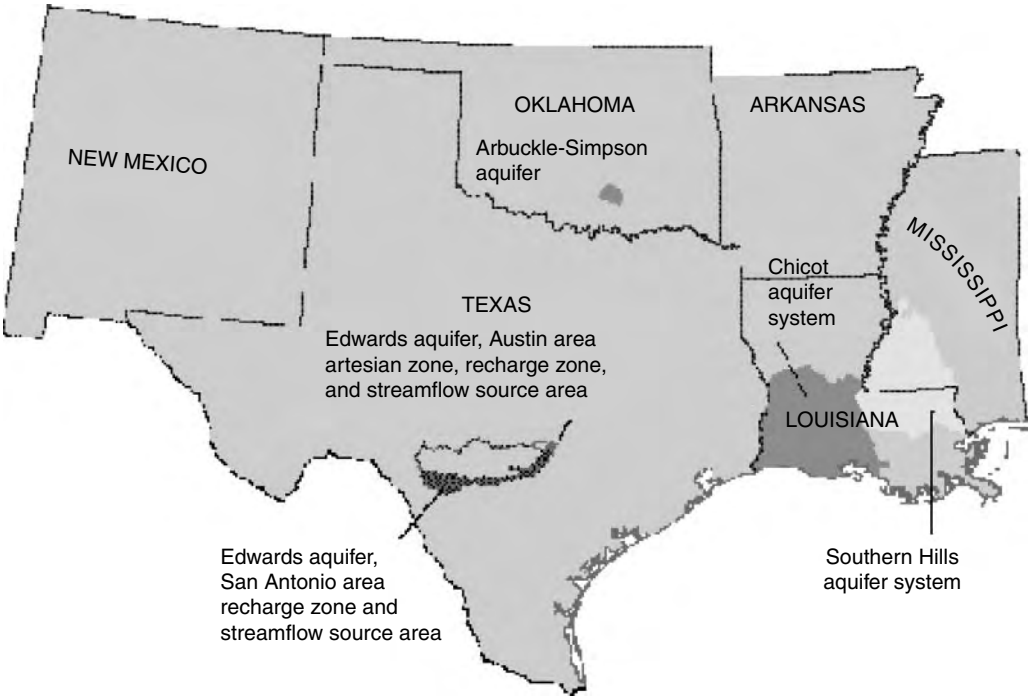


**Figure 11I.114** Designated sole source aquifers in EPA region VI, Arkansas, Louisiana, New Mexico, Oklahoma, Texas. (From www.epa.gov. With permission.)

**Table 11I.161 Designated Sole Source Aquifers in Region 6**

| State | Sole Source Aquifer Name | Federal Reg. Cit. | Public. Date |
|---|---|---|---|
| LA | Chicot Aquifer System | 53 FR 20893 | 06/07/88 |
| [a]LA/MS | Southern Hills Aquifer System | 53 FR 25538 | 07/07/88 |
| OK | Arbuckle-Simpson Aquifer, South Central Oklahoma | 54 FR 39230 | 09/25/89 |
| TX | Edwards Aquifer, San Antonio Area | 40 FR 58344 | 12/16/75 |
| TX | Edwards Aquifer, Austin Area | 53 FR 20897 | 06/07/88 |

[a] The Southern Hills Regional Aquifer system is jointly managed with Region IV. While listed in both regions, it is counted only once in the national total of 70.

*Source*: From www.epa.gov.

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**Figure 11I.115** Designated sole source aquifers in EPA region VII. Iowa, Kansas, Missouri, Nebraska. (From www.epa.gov. With permission.)

**Figure 11I.116** Designated sole source aquifers in EPA region VIII, Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming. (From www.epa.gov. With permission.)

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**Table 11I.162 Designated Sole Source Aquifers in Region VIII**

| State | Sole Source Aquifer Name | Federal Reg. Cit. | Publ. Date |
|---|---|---|---|
| MT | Missoula Valley Aquifer | 53 FR 20895 | 06/07/1988 |
| UT | Castle Valley Aquifer System | 66 FR 41027 | 08/06/2001 |
| UT | Western Unita Arch Paleozoic Aquifer System at Oakley, UT | 65 FR 232 | 12/01/2000 |
| UT | Glen Canyon Aquifer System | 67 FR 736 | 01/07/2000 |
| WY[a] | Eastern Snake River Plain Aquifer Stream Flow Source Area | 56 FR 50638 | 10/07/1991 |
| WY | Elk Mountain Aquifer | 63 FR 38167 | 07/15/1998 |

[a] The Eastern Snake River Plain Aquifer is jointly managed with Region X. While listed in both regions, it is counted only once in the national total of 73.

*Source*: From www.epa.gov.

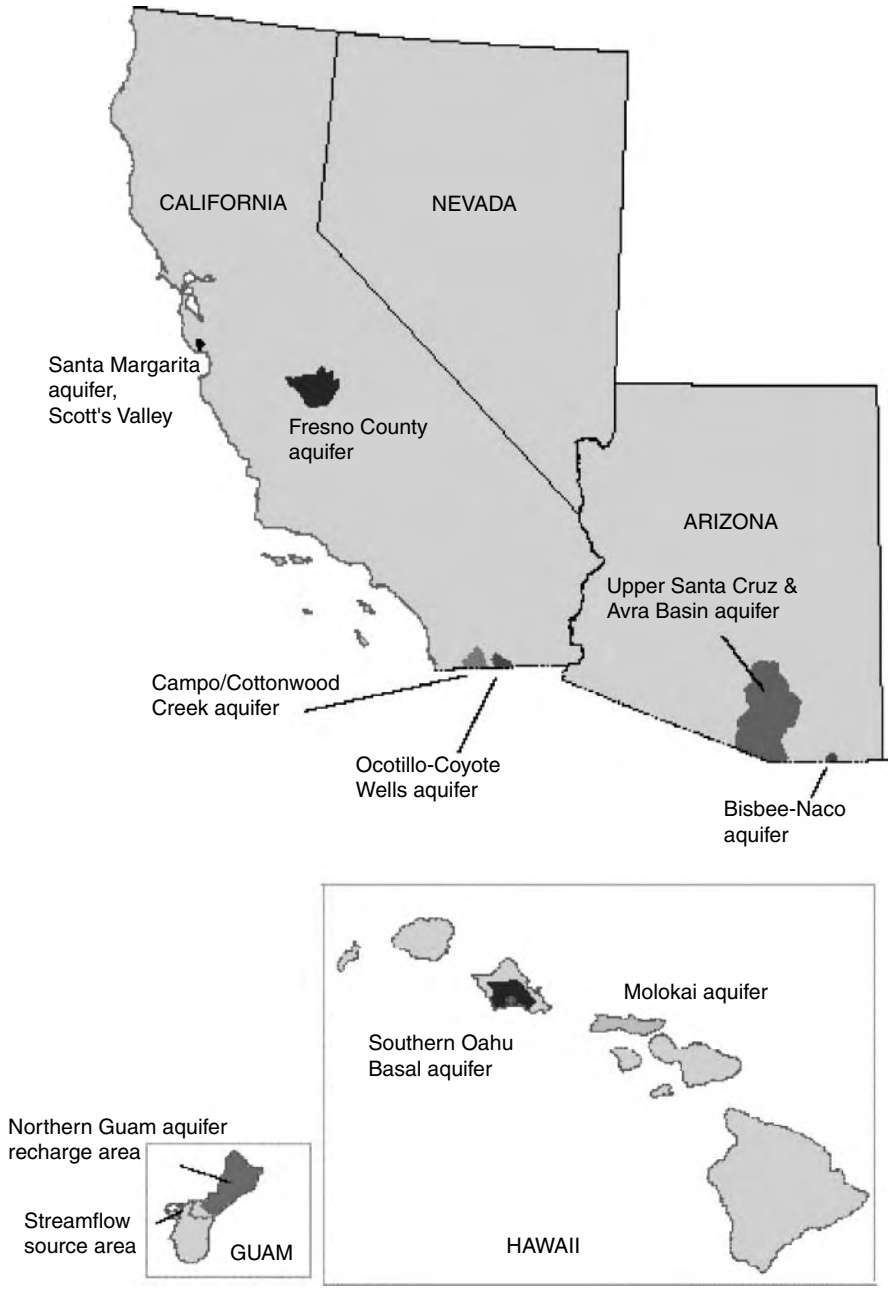


**Figure 11I.117** Designated sole source aquifers in EPA region IX, Arizona, California, Hawaii, Nevada, Guam, and American Samoa. (From www.epa.gov. With permission.)

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**Table 11I.163 Designated Sole Source Aquifers in Region IX**

| State | Sole Source Aquifer Name | Federal Reg. Cit. | Publ. Date |
|---|---|---|---|
| AZ | Upper Santa Cruz & Avra Basin Aquifer | 49 FR 2948 | 01/24/84 |
| AZ | Bisbee-Naco Aquifer | 53 FR 38337 | 09/30/88 |
| CA | Fresno County Aquifer | 44 FR 52751 | 09/10/79 |
| CA | Santa Margarita Aquifer, Scotts Valley | 50 FR 2023 | 01/14/85 |
| CA | Campo/Cottonwood Creek | 58 FR 31024 | 05/28/93 |
| CA | Ocotillo-Coyote Wells Aquifer | 61 FR 47752 | 09/10/96 |
| GU | Northern Guam Aquifer System | 43 FR 17867 | 04/26/78 |
| HI | Southern Oahu Basal Aquifer | 52 FR 45496 | 11/30/87 |
| HI | Molokai Aquifer | 59 FR 23063 | 04/20/93 |

*Source*: From www.epa.gov.

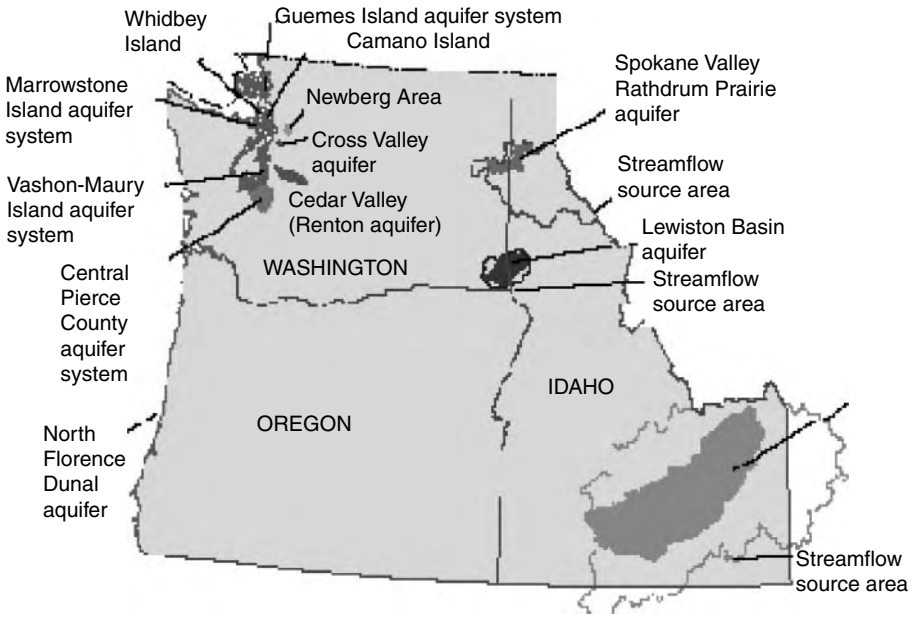


**Figure 11I.118** Designated sole source aquifers in EPA region X, Alaska, Idaho, Oregon, Washington. (From www.epa.gov. With permission.)

**Table 11I.164 Designated Sole Source Aquifers in Region X**

| State | Sole Source Aquifer Name | Federal Reg. Cit. | Publ. Date |
|---|---|---|---|
| ID/WY | Eastern Snake River Plain Aquifer | 56 FR 50638 | 10/07/91 |
| OR | North Florence-Dunal Aquifer | 52 FR 37519 | 10/07/87 |
| WA/ID | Spokane Valley Rathdrum Prairie Aquifer | 42 FR 5566 | 02/09/78 |
| WA | Camano Island Aquifer | 47 FR 14779 | 04/06/82 |
| WA | Whidbey Island Aquifer | 47 FR 14779 | 04/06/82 |
| WA | Cross Valley Aquifer | 52 FR 18606 | 05/18/87 |
| WA | Newberg Area Aquifer | 52 FR 37215 | 10/05/87 |
| WA | Cedar Valley (Renton Aquifer) | 53 FR 38779 | 10/03/88 |
| WA/ID | Lewiston Basin Aquifer | 53 FR 49920 | 12/12/88 |
| WA | Central Pierce Cty. Aquifer Syst. | 59 FR 224 | 01/03/94 |
| WA | Marrowstone Island Aquifer Syst. | 59 FR 28752 | 06/02/94 |
| WA | Vashon-Maury Island Aquifer Syst. | 59 FR 34468 | 07/05/94 |
| WA | Guemes Island Aquifer System | 62 FR 5928–3 | 12/01/97 |

*Source*: From www.epa.gov.

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**Figure 11I.119** The Biscayne aquifer underlies part of four counties in southeastern Florida, and consists predominantly of limestone. (From www.capp.water.usgs.gov. With permission.)

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**Table 11I.165 Relative Evaluation of the Elements of the Biscayne Aquifer Protection Plan (Florida)**

| Category | Element Number | Description | Ease of Implementation | Effectiveness | Personnel Resources[a] | Cost[b] | Time to Implement[c] | Public Acceptability[d] |
|---|---|---|---|---|---|---|---|---|
| Regulation | 2 | Regulate land use within well field protection zones | Difficult | High | Moderate | Moderate | Moderate | Moderate |
| Regulation | 3 | Surveillance over small quantity generators | Moderately difficult | Moderate | Moderate | Low | Short | Moderate |
| Regulation | 4 | Regulate activities of small quantity generators | Difficult | High | High | Moderate | Long | Moderate |
| Regulation | 6 | Regulate storage tanks | Moderately difficult | High | Moderate | High | Moderate | Moderate |
| Regulation | 7 | Control handling/disposal by commercial haulers | Moderately difficult | High | Low | Low | Short | High |
| Regulation | 18 | Stormwater/ wastewater review | Easy | Moderate | Moderate | Moderate | Short | Moderate |
| Waste Management | 1 | Local waste storage/transfer facilities for small generators, individuals | Moderately difficult | High | Low | Moderate | Short | Moderate |
| Waste Management | 5 | Public awareness/ education program | Easy | High | Moderate | Moderate | Moderate | High |
| Waste Management | 9 | Spill prevention, control, and countermeasure program | Moderately difficult | High | Moderate | Moderate | Moderate | High |
| Waste Management | 12 | Adopt liability policy | Moderately difficult | High | Low | Low | Moderate | High |
| Waste Management | 13 | Emergency spill cleanup program | Difficult | Moderate | Low | High | Moderate | High |
| Waste Management | 15 | Control agricultural groundwater pollution | Difficult | Moderate | Moderate | Moderate | Moderate | Moderate |
| Waste Management | 16 | Collect/recycle automobile drain oils | Easy | Moderate | Low | Low | Short | High |
| Construction/Treatment | 8 | Construct leak-proof sewers | Difficult | Moderate | Low | High | Moderate | High |
| Construction/Treatment | 10 | Pretreat commercial/ industrial waste | Moderately difficult | Moderate | Moderate | Moderate | Short | High |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Construction/Treatment | 11 | Control sewer exfiltration | Difficult | Moderate | Moderate | Moderate | Long | High |
| Information Needs | 14 | Public reporting program on improper disposal | Easy | Moderate | Low | Low | Short | High |
| Information Needs | 17 | Tri-county coordinating committee | Easy | Low | Low | Low | Short | High |
| Information Needs | 19 | Determine safe soil contamination levels | Difficult | Moderate | Moderate | Moderate | Long | Moderate |
| Information Needs | 20 | Monitor groundwater | Moderately difficult | Moderate | Moderate | High | Moderate | High |

[a] "Personnel Resources" refers to the manpower needed by each county to develop and implement each program. Low? 1 to 4 full-time persons from each county; Moderate? 5 to 10 ful-time persons; High? More than 10 full-time persons.
[b] Includes cost of development and implementation of the program by county agencies as well as costs incurred by the public or the industries.
[c] Short? 0 to 2 years; Moderate? 2 to 5 years; Long? Greater than 5 years.
[d] Public acceptability tended to be lower for a specific program if large numbers of people were directly affected.

*Source*: From Sing, U.P., Orban, J.E., and Docal, A.L., 1985, *The Biscayne Aquifer Protection Plan*, American Water Resources Association Proceeding Tucson AZ Symposium on Groundwater Contamination and Reclamation. Copyright AWWA. Reprinted with permission.



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| Series | Stratigraphic and hydrologic units | | Lithology and water-yielding characteristics | Thickness (ft) |
|---|---|---|---|---|
| Holocene | Organic soils<br>Lake Flirt marl | Confining Unit | Peat and muck; water has high color content. Almost impermeable, Lake Flirt is shelly, calcaroous mud | 0–18 |
| Pleistocene | Pamlico sand | Biscayne Aquifer | Quartz sand; water high in iron. Small yields to domestic wells | 0–40 |
| | Miami oolite | | Sandy, oolitic limestone. Large yields | 0–40 |
| | Fort Thompson formation | | Alternating marine shell beds and freshwater limestone. Generally high permeability. Large yields | 0–150 |
| | Anastesia formation | | Coquina, sand, sandy limestone, marl. Moderate to large yields. | 0–120 |
| | Key Largo limestone | | Coralline reef rock. Large yields | 0–60 |
| Pliocene | Caloosahatchee marl | | Sand, shell, silt, and marl. Moderate yields | 0–25 |
| | Tamiami formation | Confining Unit | Limestone, clay, and marl. Occasional moderate yields in upper few feet. Remainder forms upper part of basal confining unit. | 25–220 |

Stratigraphic Limits are equivalent in part. Order does not necessarily reflect relative age.

Modified from Klein and Causaraa, 1982

**Figure 11I.120** Several geologic units comprise the Biscayne aquifer. Most of these units are of Pleistocene age. (From www.capp.water.usgs.gov. With permission.)

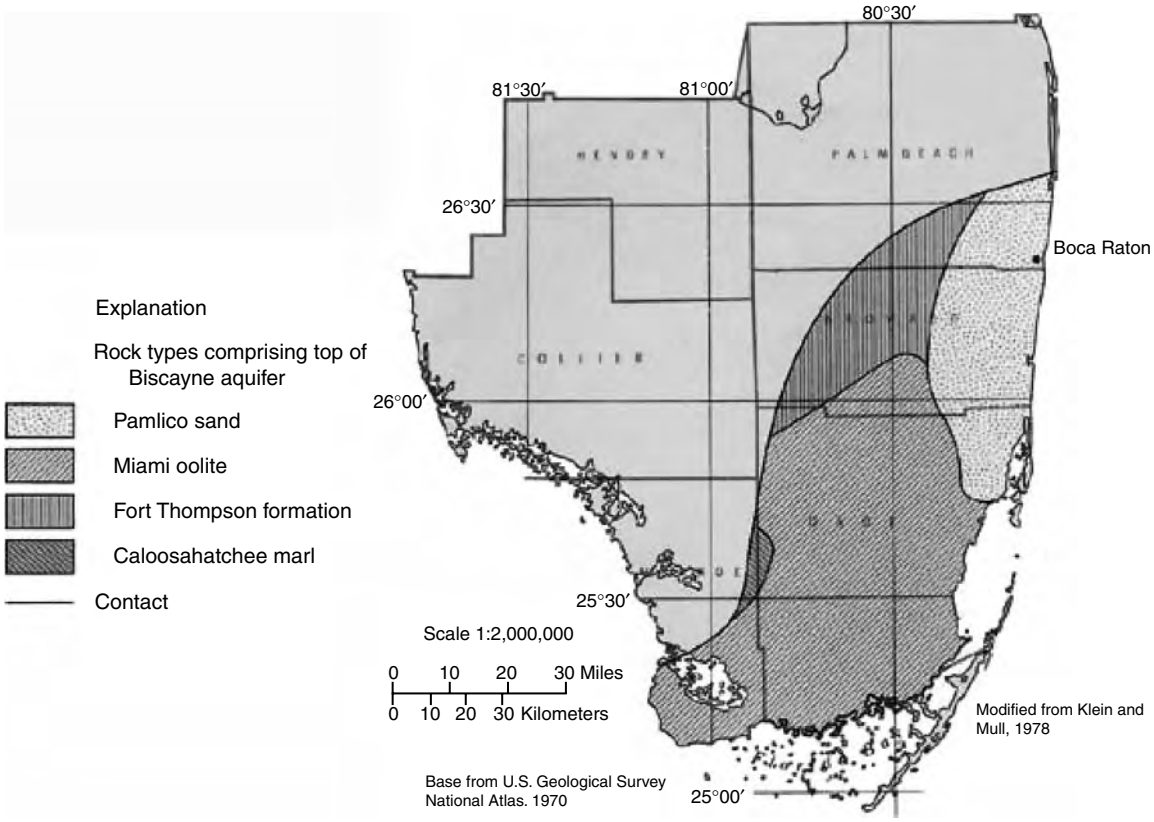


**Figure 11I.121** The rocks that comprise the top of the Biscayne aquifer vary in character. They are mostly limestone, but sand marks the top of the aquifer to the northeast. (From www.capp.water.usgs.gov. With permission.)

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**Table 11I.166 Implementation Phases of the Biscayne Aquifer Protection Plan**

| | | | | |
|---|---|---|---|---|
| 1 | Local waste storage/transfer facilities for small generators, individuals | Immediate Implementation (Basic Program) | Strong Program | Complete Program |
| 2 | Regulate land use within well field protection zones | | | |
| 3 | Surveillance over small quantity generators | | | |
| 4 | Regulate activities of small quantity generators | | | |
| 5 | Public awareness/education program | | | |
| 6 | Regulate storage tanks | | | |
| 7 | Control handling/disposal by commercial haulers | | | |
| 8 | Construct leak-proof sewers | Short-Term Implementation | | |
| 9 | Spill prevention, control, and countermeasure program | | | |
| 10 | Pretreat commercial/industrial waste | | | |
| 11 | Control sewer exfiltration | | | |
| 12 | Adopt liability policy | | | |
| 13 | Emergency spill cleanup program | | | |
| 14 | Public reporting program on improper disposal | | | |
| 15 | Control agriculture groundwater pollution | Future Implementation | | |
| 16 | Collect/recycle automobile drain oils | | | |
| 17 | Tri-county coordinating committee | | | |
| 18 | Stormwater/wastewater review | | | |
| 19 | Determine “safe” soil contamination levels | | | |
| 20 | Monitor groundwater | | | |

*Source*: From Sing, U.P., Orban, J.E., and Docal, A.L., 1985, *The Biscayne Aquifer Protection Plan*, American Water Resources Association Proceedings, Tucson AZ Symposium on Groundwater Protection and Reclamation. Copyright AWWA. Reprinted with permission.

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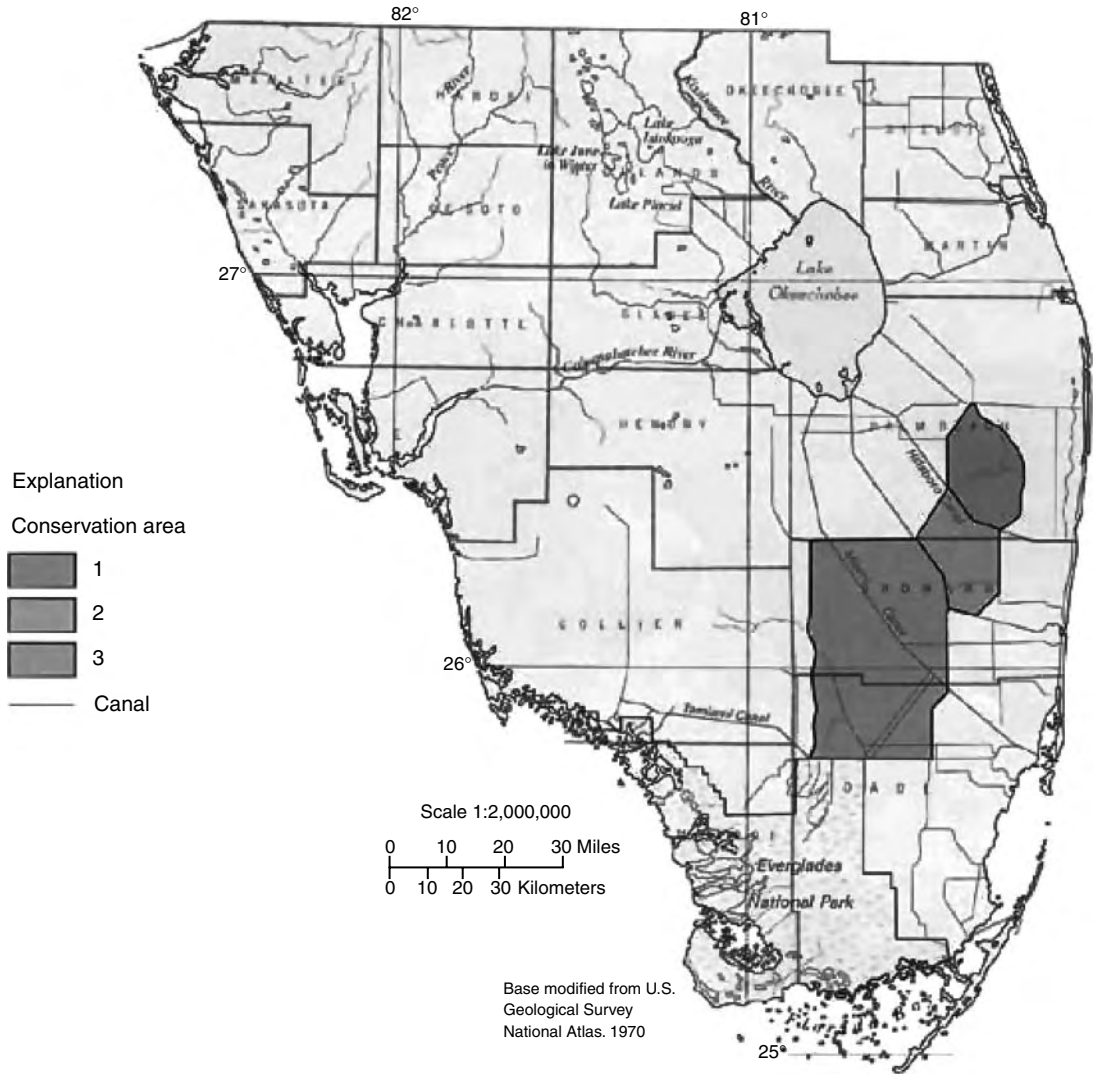


**Figure 11l.122** Lake Okeechobee, an extensive canal system, and three water-conservation areas are all linked as parts of a sophisticated water-management system. Dikes, pumps, and control structures on the canals are used to store stormwater and release it when and where it is later needed. (From www.capp.water.usgs.gov. With permission.)

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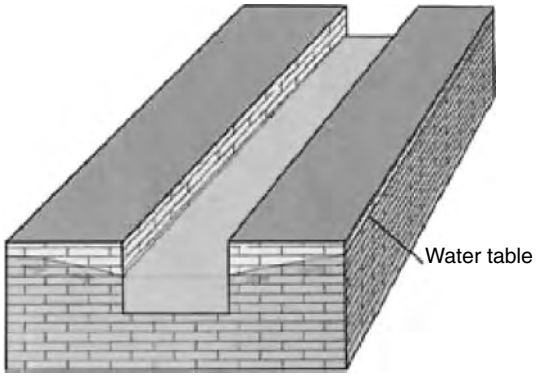
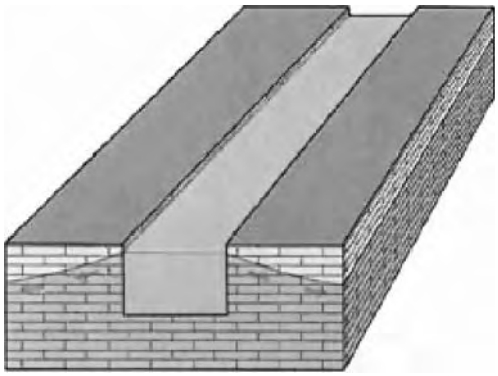


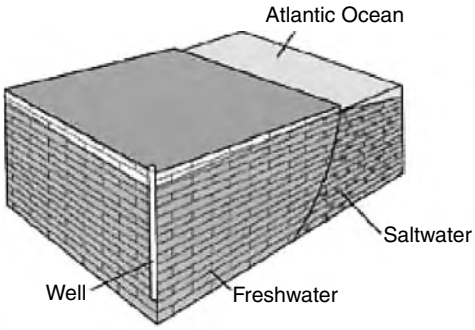

(a) When the water level in an aquifer is higher than that in a canal that penetrates it, water moves toward the canal.



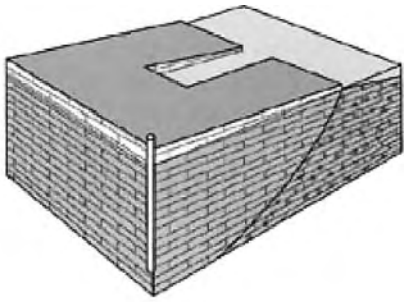
(b) When the water level in a canal is higher than that in the aquifer it penetrates, water moves into the aquifer.

Modified from Klein and others, 1975.

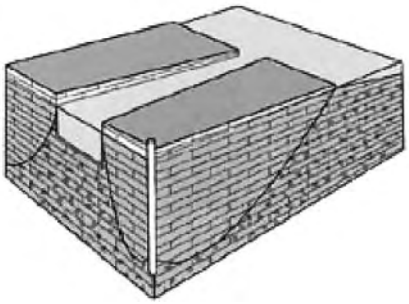
**Figure 11I.123** (a) During periods of less than normal precipitation, water passes freely from the aquifer into canals that are dug into it. (b) When storm runoff raises canal water levels, the movement of water is reversed. (From www.capp.water.usgs.gov. With permission.)



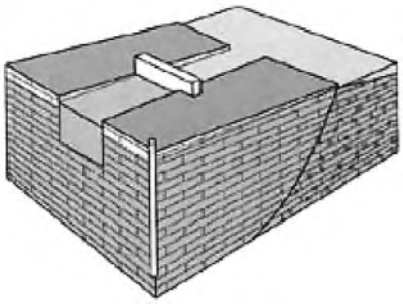

(a) The freshwater-saltwater interface was nearly stable before coastal canals were built.



(c) Uncontrolled tidal canals cause saltwater encroachment by lowering freshwater levels and providing open channels to the sea. The interface in the aquifer shifts inland adjacent to the canal.



(b) An uncontrolled canal that extends into an area of heavy pumping can convey saltwater inland to contaminate freshwater supplies.



(d) In contrast, a controlled canal can provide a perennial supply of freshwater to prevent saltwater encroachment and to recharge a well field by bringing in freshwater from upgradient areas.

**Figure 11I.124** The original, virtually stable freshwater–saltwater interface (a) was disturbed by construction of drainage canals (b). Uncontrolled canals (c) are open conduits, allowing saltwater to migrate inland, contaminating the aquifer, and in places, encroaching into pumped wells. A properly located control structure (d) prohibits the saltwater encroachment. (From www.capp.water.usgs.gov. With permission.)

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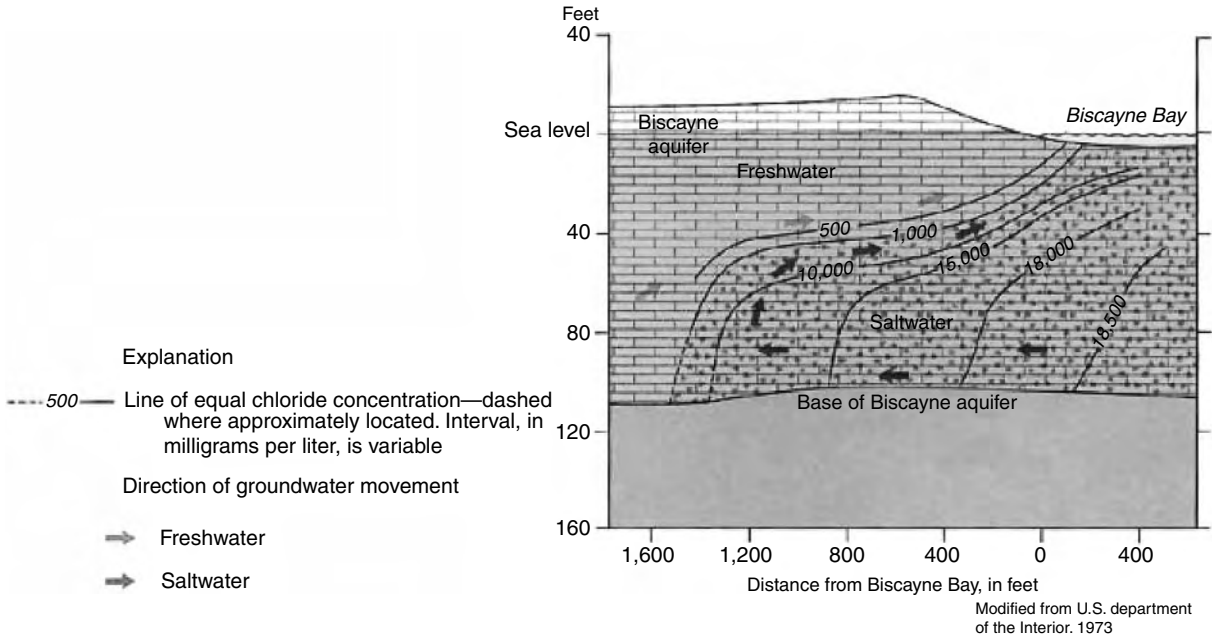


**Figure 11I.125** Saltwater extends farther inland near the base of the Biscayne aquifer rather than near the top of it. (From www.capp.water.usgs.gov. With permission.)

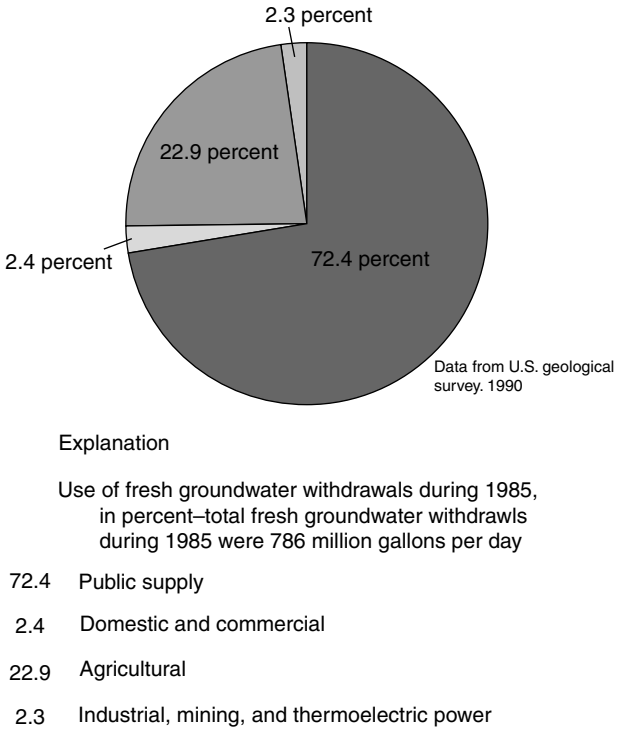


**Figure 11I.126** Most of the freshwater withdrawn from the Biscayne aquifer during 1985 was used for public supply and agricultural purposes. (From www.capp.water.usgs.gov. With permission.)

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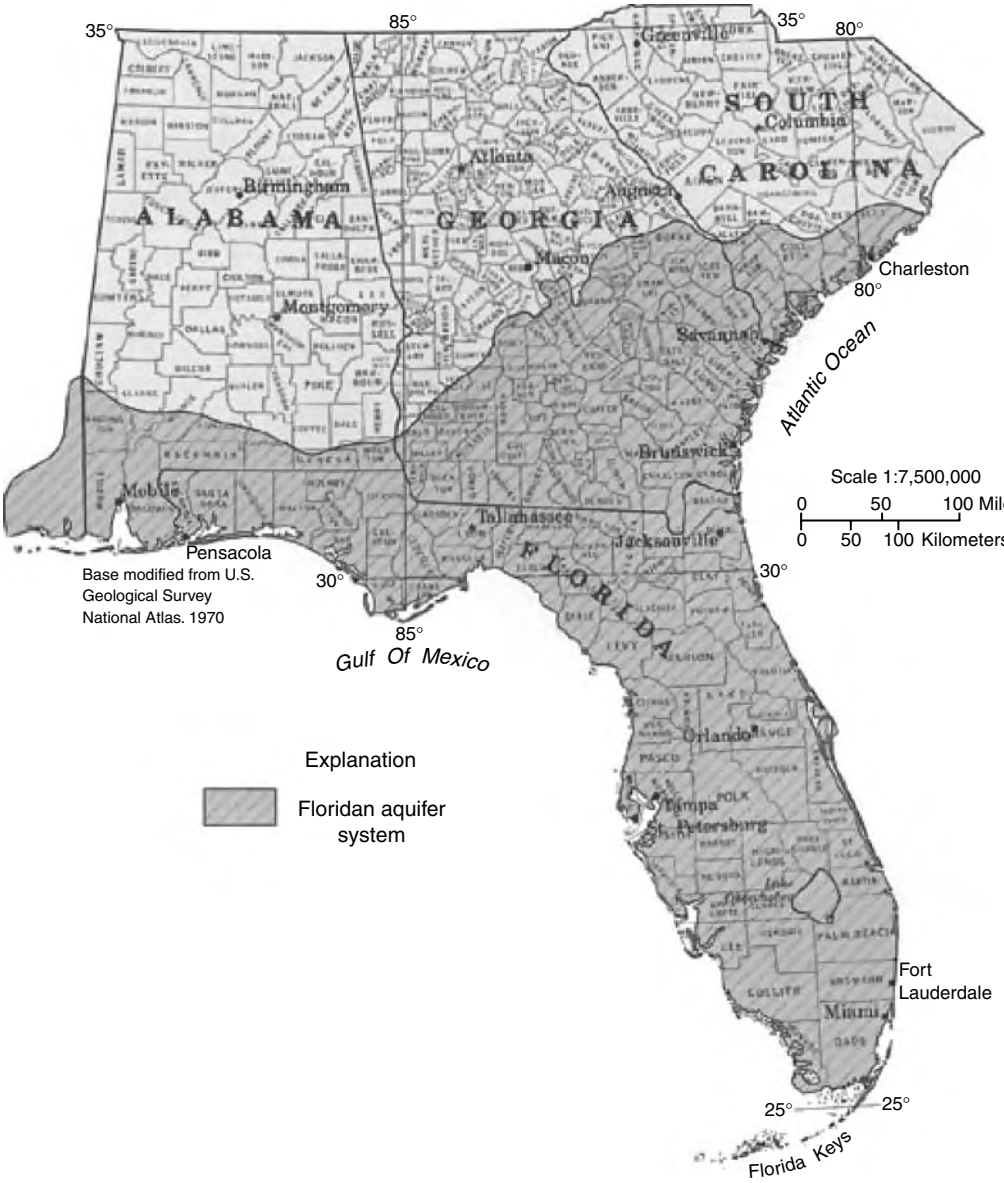


**Figure 11I.127** The carbonate rocks of the Floridan aquifer system underlie all of Florida, most of the coastal plain of Georgia, and extend for short distances into Alabama and South Carolina. (From www.capp.water.usgs.gov. With permission.)

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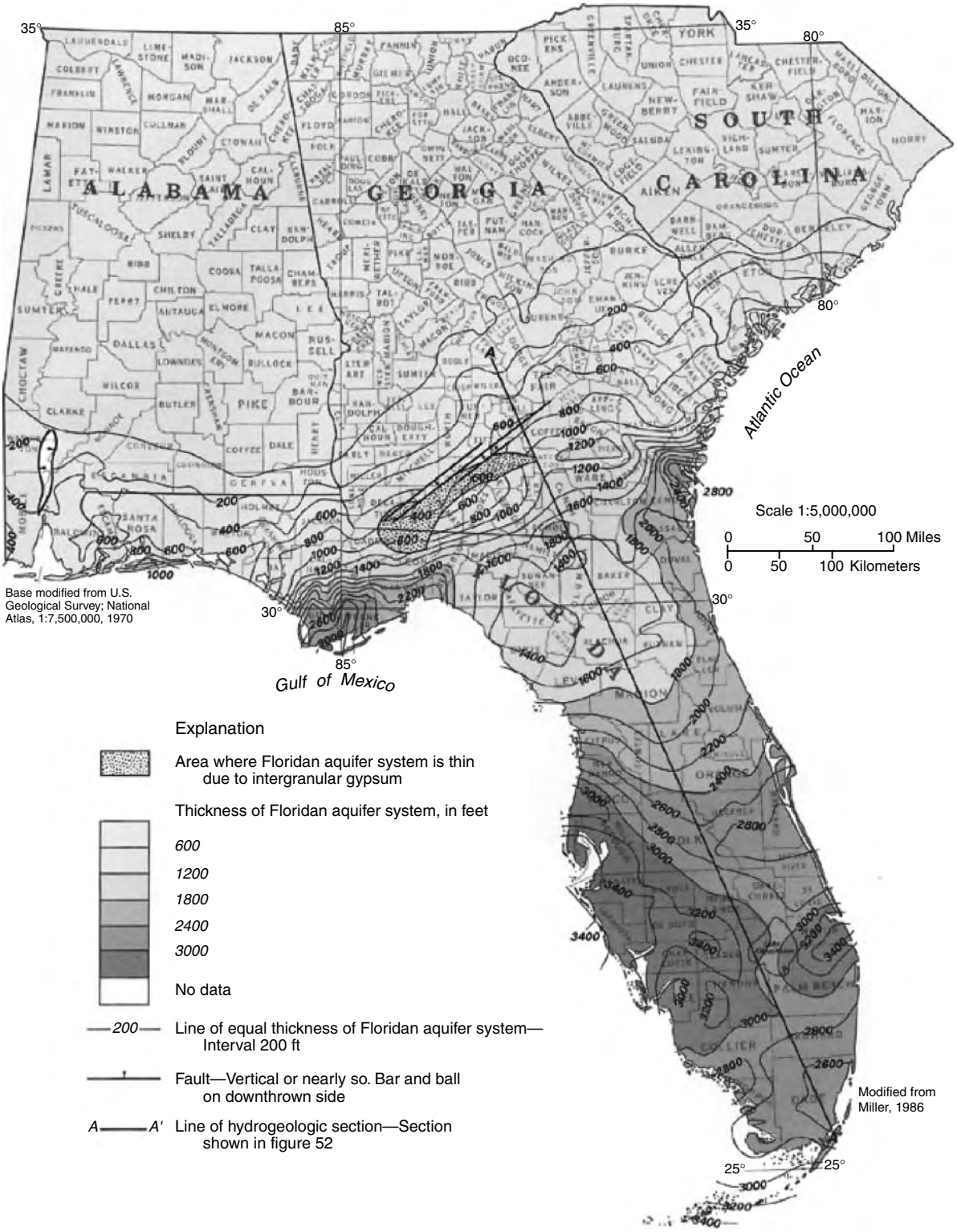


**Figure 11I.128** The thickness of the Floridan aquifer system varies considerably and reflects some major warping during deposition and fracturing following deposition. (From www.capp.water.usgs.gov. With permission.)

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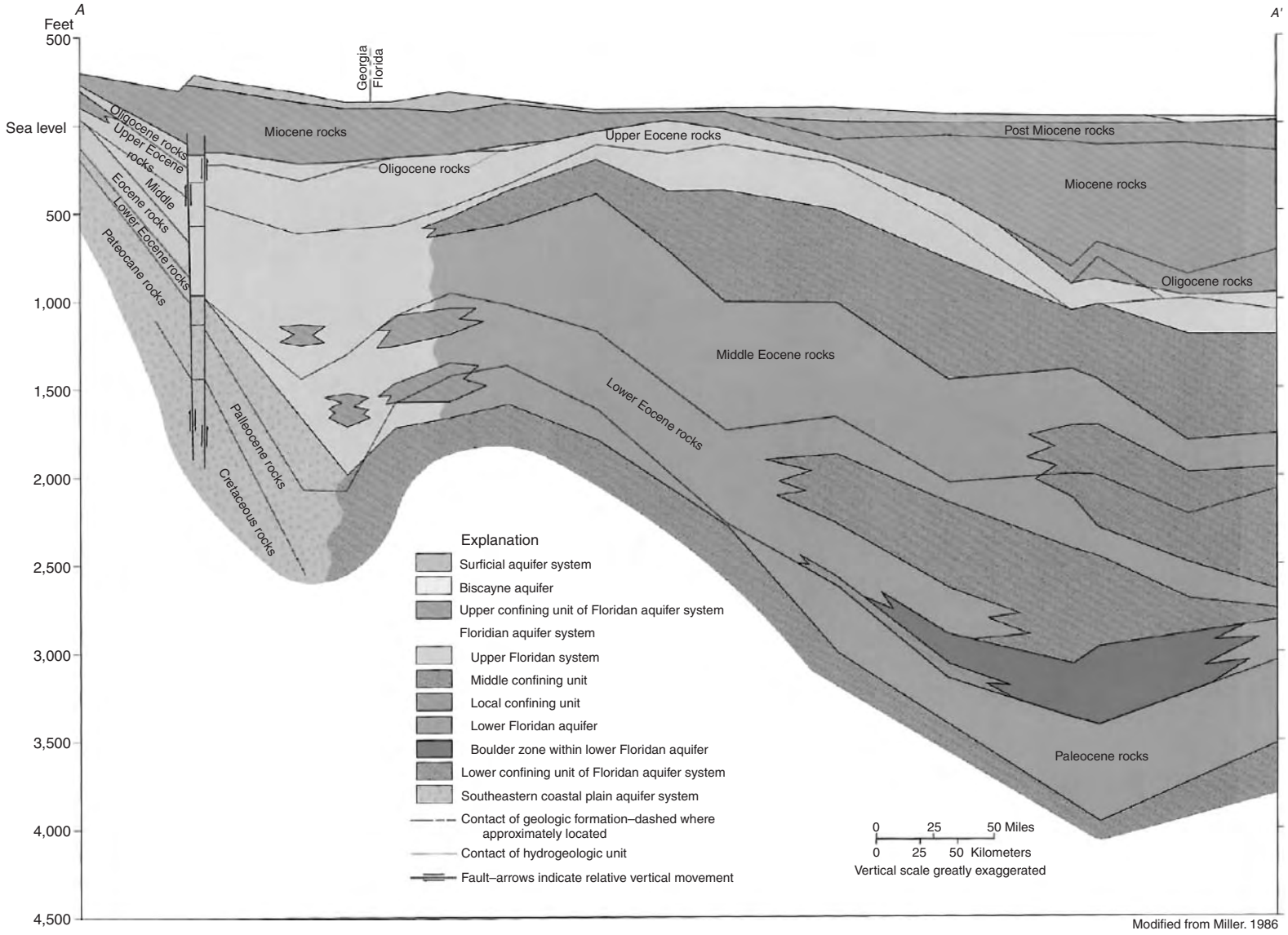


**Figure 11I.129** The Floridan aquifer system changes significantly from south-central Georgia to southern Florida. Aquifers and confining units in the system thicken and thin from well to well, and generally resemble complexly interlingering, lens-shaped bodies of rock. (From www.capp.water.usgs.gov. With permission.)



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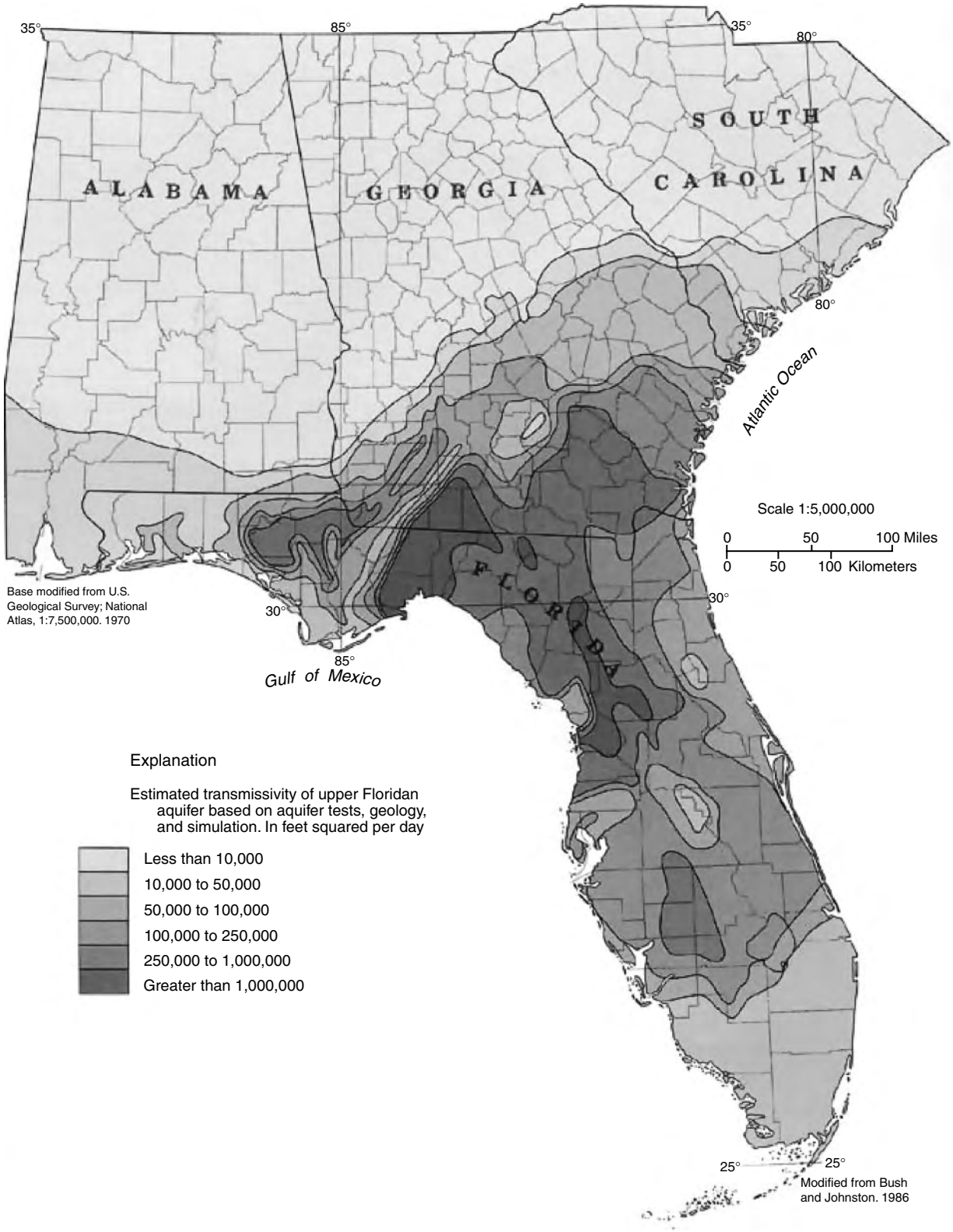


**Figure 11I.130** Transmissivity is a measure of the ease with which an aquifer transmits water. The most transmissive parts of the upper Floridan aquifer are located where many solution openings have formed. Such transmissivity not only means that water will move more easily, but also that wells will yield large volumes of water. (From www.capp.water.usgs.gov. With permission.)

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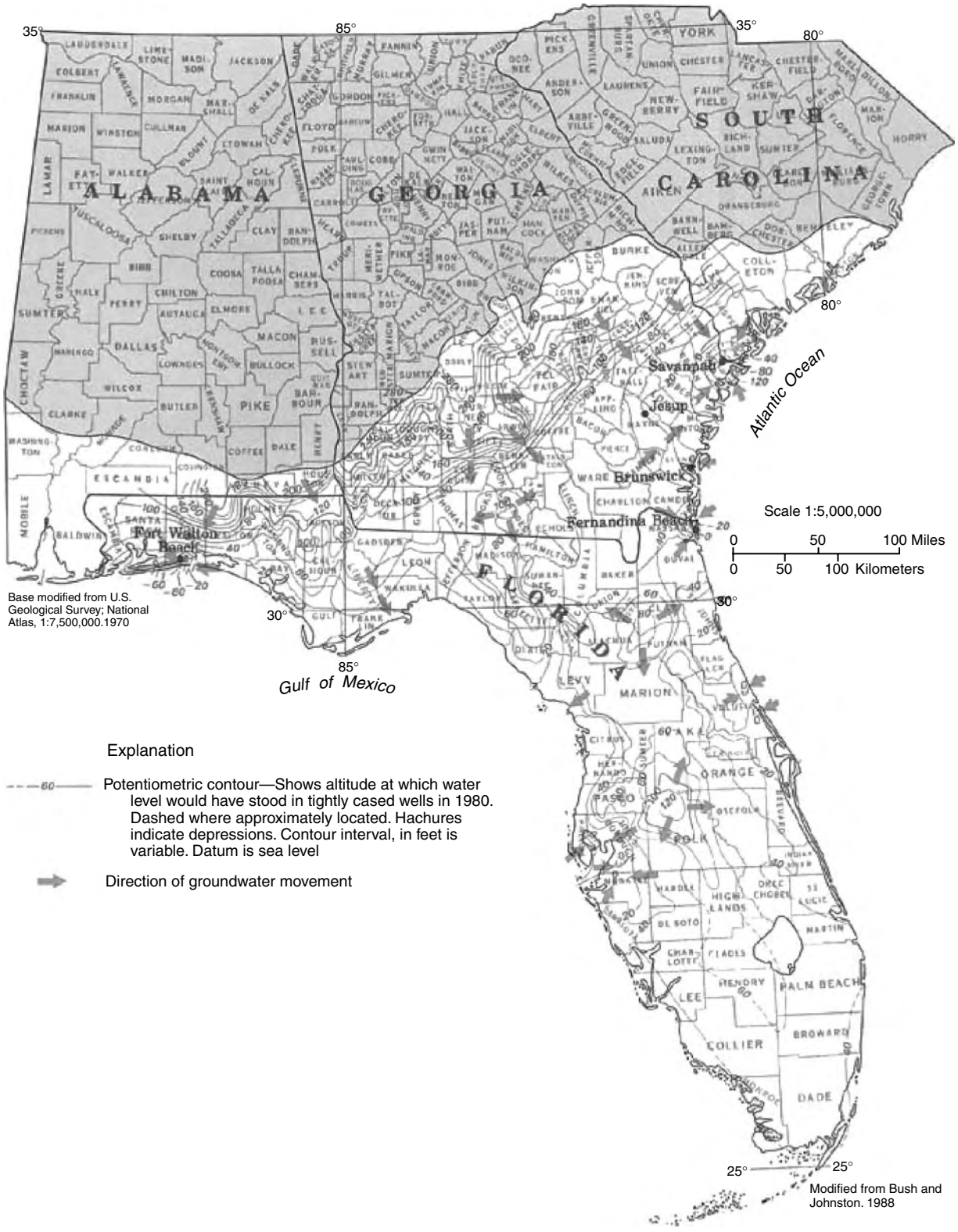


**Figure 11I.131** Withdrawals from the Floridan aquifer system had developed deep cones of depression in several places by 1980. The direction of groundwater flow was locally changed, even reversed in places, by the pumpage. (From www.capp.water.usgs.gov. With permission.)

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**Table 11I.167 Major Components of an Information System Needed for Groundwater Management Decisions**

| |
|---|
| Hydrogeology |
| Soil and unsaturated zone characteristics |
| Aquifer characteristics |
| Depths involved |
| Flow patterns |
| Recharge characteristics |
| Transmissive and storage properties |
| Amblent water quality |
| Interaction with surface water |
| Boundary conditions |
| Mineralogy, including organic content |
| Water extraction (withdrawals) and use patterns |
| Locations |
| Amounts |
| Purpose (domestic, industrial, agricultural) |
| Trends |
| Potential contamination sources and characteristics |
| Point sources |
| Industrial and mining waste discharges |
| Commercial waste discharges |
| Hazardous material and waste storage |
| Domestic waste discharges |
| Nonpoint sources |
| Agricultural |
| Septic tanks |
| Land applications of waste |
| Urban runoff |
| Transportation spills (can also be considered a print source) |
| Pipelines (energy and waste) (can also be considered a point source) |
| Population patterns |
| Demographic |
| Economic trends |
| Land-use patterns |

*Source*: From U.S. Geological Survey, *National Water Summary 1986*; modified from National Research Council, 1986.

**Table 11I.168 Criteria for Effective Groundwater Protection Programs**

| Criterion | Scope |
|---|---|
| Goals and objectives | Protection programs should clearly define goals and objectives, reflect understanding of groundwater problems, have adequate legal authority, and have criteria for evaluating program success and the need for modifications |
| Information | Programs should be based on information that permits resources and issues to be defined and preventive strategies to be evaluated |
| Technical basis | Effective programs require a sound technical basis with which to link actions to results |
| Source elimination and control | Long-term program goal should be to eliminate or reduce the sources of groundwater contamination |
| Intergovernmental and interagency linkages | Comprehensive protection program must link actions at every level of government into coherent, coordinated action |
| Effective implementation and adequate funding | Programs must have adequate legal authority, resources, and stable institutional structures to be effective |
| Economic, social, political, and environmental impacts | A preventive program assumes that groundwater protection is the least costly strategy in the long run. Protective actions should be evaluated in terms of their economic, social, political, and environmental effects |
| Public support and responsiveness | Programs must be responsive and credible to the public |

*Source*: From U.S. Geological Survey, *National Water Summary 1986;* modified from National Research Council, 1986.

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**Table 11I.169 Common Elements of "MATURE" Groundwater Protection Programs**

**Setting Goals and Documenting Progress**

- Groundwater protection goals which accounts for present and future uses of the resource
- Yearly action plan for achieving the goal, which includes a mechanism for evaluating progress toward accomplishing the goal and provides for periodic review

**Characterizing the Resource and Setting Priorities for Actions**

- Comprehensive assessment of aquifer systems and their associated recharge and discharge areas
- Procedure for inventorying and ranking potential sources of contamination that may cause an adverse effect on human health, or ecological systems
- Process used for setting priorities for actions taken to protect or remediate the resource, such as a use designation/classification scheme that considers use, value, vulnerability, yield, current quality, etc., including wellhead protection and cost benefit analyses

**Developing and Implementing Prevention and Control Programs**

- A Coordinated pollution prevention and source reduction program aimed at eliminating and reducing the amount of pollution that could potentially affect groundwater, including wellhead and recharge area protection programs, sitting criteria, improved management practices and technology standards, etc.
- Enforceable quality standards that are health based for drinking water supplies and ecologically based in areas where groundwater is closely hydrologocally connected to surface water (Note: For actions under State law that are independent of any Federally authorized program, it is the State's prerogitive to determine whether to establish its own standards or to use EPA's standard)
- Regulatory and nonregulatory authorities to control sources of contamination currently under State or local jurisdictions, e.g., permitting, sitting and zoning authorities on State and local level
- Monitoring, data collection, and data analysis activities to determine the extent of contamination, update control strategies and assess any needed changes in order to meet the groundwater protection goal
- Compliance and enforcement authorities given to the appropriate State and local officials through legislative or administrative processes
- Water well programs, including private drinking water wells, covering areas such as well testing, driller certification, well construction, and plugging abandoned wells
- Statement of how Federal, State and local resources will be used to adequately fund the program
- Public participation activities to involve the public in the development and implementation of the program

**Defining Roles Within the State and the Relationship to Federal Programs**

- Delineation of State agencies' responsibilities in the groundwater program covering areas such as planning, implementation, enforcement and coordination
- Statement indicating how the State will or does provide local governments with authorities to address local groundwater protection issues
- Statement of the State's role under groundwater related EPA statues, including RCRA, CERCLA SDWA, CWA, and FIFRA, e.g., EPA-approved program such as a RCRA authorization should be listed and integrated, as a part of the State's overall groundwater protection program yet continue operating as free-standing programs
- Mechanisms for dealing with other Federal agencies that affect State groundwater programs (e.g., MOUs or other arrangements with USDA, DOI, DOD)
- Statement indicating how the State intends to integrate water quantity and quality management
- Corodination of groundwater programs with other relevant natural resource protection programs, including surface water managment

*Source*: From Protecting the Nation's groundwater: EPA's strategy for the 1990's—The final report of the EPA groundwater task force. www.epa.gov.

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**Table 11I.170 EPA's Groundwater Related Grants**

| Statutory Authority | Match | Eligible Activities | Limitations[a] | FY 91 $ Appropriation |
|---|---|---|---|---|
| | | **Clean Water Act** | | |
| 106 | None | General: Prevention & abatement of surface & groundwater pollution<br>Specific: Permitting, pollution control studies, planning, surveillance & enforcement, assistance to locals, training & public information | Allotment based on extent of pollution problem, not the quality of the State program. No authorization ceiling in FY91 | $81.7 million (Groundwater portion $12.2m) |
| 104 (b) (3) | None | General: Pollution prevention, reduction, & elimination programs<br>Specific: Research, experiments, training, demonstrations, surveys, studies, investigations | Not for program operation | $16.5 million |
| 205 (g) | None | Delegated administration of construction grants program, 402 or 404 permit program, 208(b)(4) planning program, & construction grants management for small communities | | 0 (Congress cut off funding) |
| 205 (j) (1) 604 (b) | None | Develop water quality management plans | Not for implementation; 40% to regional comprehensive planning agencies | 0 $16 million |
| 205 (j) (5) 201 (g) (1) (b) | None | Develop & implement nonpoint source management programs | 201(g)(1)(b): Construction grant deobligations and allotment funds available | 0 (Congress cut off funding) |
| 319 (h) | 40% | Implement nonpoint source management programs | No more than 15% of total available to any one State. Financial assistance for demonstrations only (cannot be used for cost sharing programs. Limits on administration costs | $51 million |
| 319 (i) | 50% | Carry out groundwater protection activities | $150K per State | See 319(h) |

*(Continued)*

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**Table 11I.170 (Continued)**

| Statutory Authority | Match | Eligible Activities | Limitations[a] | FY 91 $ Appropriation |
|---|---|---|---|---|
| | | **Federal Insecticide, Fungicide and Rodenticide Act** | | |
| 23(a)(1) | 15% | General: Implement pesticide enforcement programs | | $26.8 million (Groundwater portion $5m) |
| | | **Toxic Substances Control Act** | | |
| 28 | 25% | General: Establish & operate toxics control programs | Authorization expired in 1982. Appropriations committees should be notified before funds are used for new groundwater program | $8.1 million |
| | | Specific: Monitoring, analysis, surveillance & general program activities (currently used for asbestos & SARA Title III activities) | | |
| | | **Resource Conservation and Recovery Act** | | |
| 3011 | 25% | General: State hazardous waste management programs<br>Specific: Planning for hazardous waste treatment, storage & disposal facilities | | $83 million |
| | | **Safe Drinking Water Act** | | |
| 1443 (a) | 25% | Public water system supervision; State drinking water programs | Funds available only to States with primacy | $47.5 million |
| 1443 (b) | 25% | General: Underground injection control programs<br>Specific: Program costs, inventories, data management, technical assistance, etc | Funds available only to State with primacy | $10.5 million |
| | | **Comprehensive Environmental Response, Compensation & Liability Act** | | |
| 104 (b) | 10% | General: Superfund activities under core program cooperative agreements<br>Specific: Implementation, coordination, enforcement, training, community relations, site inventory and assessment, administration of remedial activities, legal assistance relating to CERCLA implementation | Not for site-specific activities | $14 million |

[a] Authorities in this matrix may be used to fund groundwater activities either in separate categorical grants or consolidated grants. Further, the scope of eligible groundwater activities varies among authorities. Regions should consult their Grants Management Office and Regional Counsel regarding these issues.

*Source*: From Protecting the Nation's groundwater: EPA's strategy for the 1990's—The final report of the EPA groundwater task force. www.epa.gov.

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**Table 11I.171 Overview of Activities Included in State Groundwater Protection Programs**

| Activities | Number of States Initiating | Percent of States Initiating |
|---|---|---|
| Groundwater Mapping/Resource Assessment | 51 | 91 |
| Groundwater Monitoring Program | 46 | 82 |
| Policy/Strategy Development | 38 | 68 |
| Groundwater Discharge Permit Program | 26 | 46 |
| Groundwater Classification System | 23 | 41 |
| Public Information/Education Program | 23 | 41 |
| Groundwater Standards Development | 22 | 39 |
| Data Management System | 14 | 25 |
| Local Management Plan Development | 2 | 4 |
| Specific Source Control | | |
| Underground Injection Control Program | 47 | 84 |
| Septic Management | 38 | 68 |
| Underground Storage Tank Program | 30 | 54 |
| Hazardous Waste Sites | 34 | 61 |
| Agricultural Contamination | 23 | 41 |
| Landfill Sites | 20 | 36 |
| Surface Impoundments | 14 | 25 |

*Source*: From U.S. Environmental Protection Agency, *National Water Quality Inventory—1986 Report to Congress*. EPA-440/4-87-008.

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## SECTION 11J WATER CONSERVATION

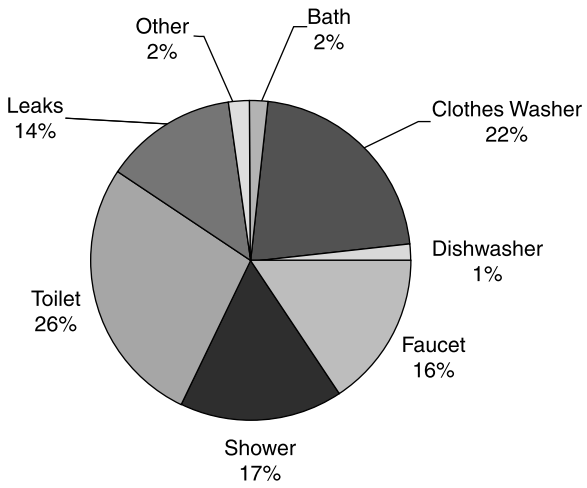


**Figure 11J.132** Indoor per capita use by fixture source. (From www.usagreen.org.)

**Table 11J.172 Federal Water Efficiency Standards for Plumbing Fixtures and Fixture Fittings Required by the U.S. Energy Policy Act of 1992**

| Product | Maximum Water Use | Compliance Date |
|---|---|---|
| Toilets[a] | | |
| Gravity tank-type | 1.6 gal/flush | 1/1/94 |
| Flushometer tank | 1.6 gal/flush | 1/1/94 |
| Electromechanical hydraulic | 1.6 gal/flush | 1/1/94 |
| Blowout[b] | 3.5 gal/flush | 1/1/94 |
| Commercial gravity tank-type, white two-piece[d] | 3.5 gal/flush | 1/1/94 to 12/31/96 |
| Commercial gravity tank-type, white two-piece[d] | 1.6 gal/flush | 1/1/97 |
| Flushometer valve[c] | 1.6 gal/flush | 1/1/97 |
| Uritials[b,c] | 1.0 gal/flush | 1/1/94 |
| Showerheads[d] | 2.5 gpm (80 psi) | 1/1/94 |
| Faucets[d] | | |
| Lavatory[d] | 2.5 gpm (80 psi) | 1/1/94 |
| Lavatory replacement aerators | 2.5 gpm (80 psi) | 1/1/94 |
| Kitchen | 2.5 gpm (80 psi) | 1/1/94 |
| Kitchen replacement aerators | 2.5 gpm (80 psi) | 1/1/94 |
| Metering | 0.25 gal/cycle (80 psi) | 1/1/94 |

[a] Compliance with ASME–ANSI Standards A 112.19.2M-1990 and A112.19.6–1990.
[b] No data on conversion to lower volume.
[c] Must bear conspicuous label that states “For Commercial Use Only.”
[d] Compliance with ASME–ANSI Standard A112.18.1M-1989.

*Source*: From cepis.ops-oms.org.

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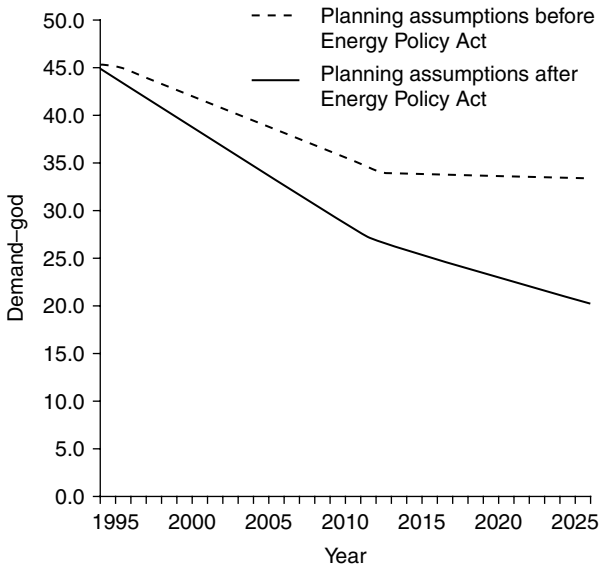


**Figure 11J.133** Estimated daily residential water demand by toilets, shower heads, and faucets per person. (From www.cepis.ops-oms.org.)

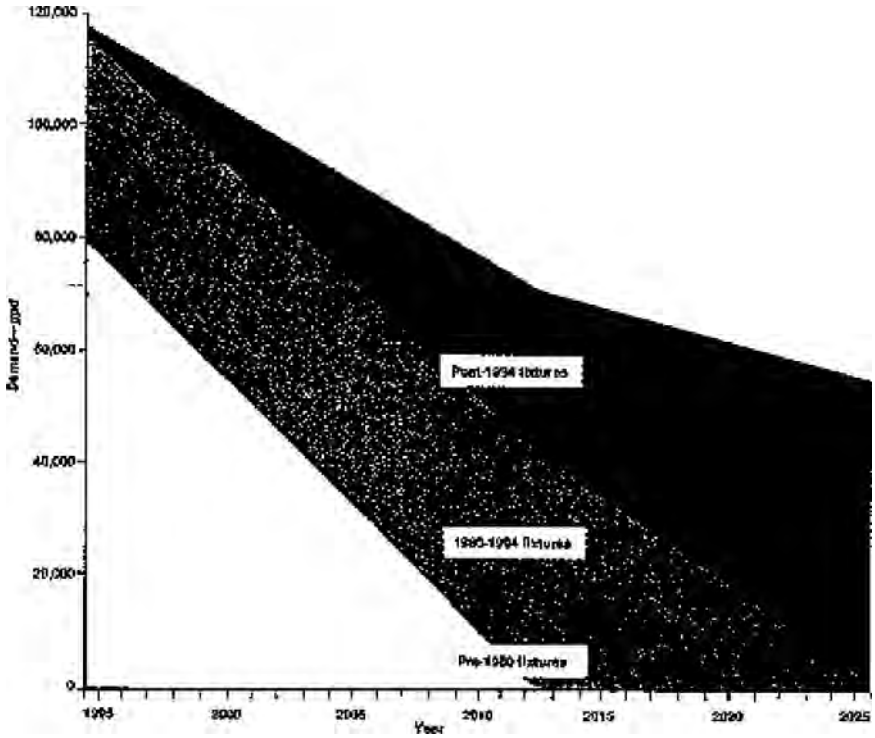


**Figure 11J.134** Estimated daily residential water demand by toilets, shower heads, and faucets per 1,000 households (assuming 2.63 persons per household). (From cepis.ops-oms.org.)

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**Table 11J.173 Estimated Residential Water Saving with 1.6-gal/Flush Toilet, 2.5-gpm Showerhead, and 2.5-gpm Faucet Replacement**

| | Maximum Water Use — gpd[a] | | Water Savings — gpd | |
|---|---|---|---|---|
| Water Use, All Fixtures | Per Capita | Per 2.63-Person Household[b] | Per Capita | Per 2.63-Person Household[b] |
| Post-1994 | 21.4 | 56.3 | | |
| 1980–1994 | 33.9 | 91.5 | 12.9 | 34.8 |
| Pre-1980 | 54.5 | 143.3 | 33.1 | 87.1 |

[a] Assumes an average of 4.0 toilet flushes, 4.8-minute showering time, and 4.0-minute faucet-use time daily per person, with adjustments for throttleback effect with showerhead and faucet use; factors based on findings derived from 1984 HUD study.
[b] Per 2.63-person household based on 1990 US census.

*Source*: From cepis.ops-oms.org.

**Table 11J.174 Water Conservation Measures**

| Management | Regulations | Education |
|---|---|---|
| Metering | Federal and state laws and policies | Direct mail |
| Meter maintenance | Local codes and ordinances | Pamphlets |
| Pressure regulation | Plumbing codes for new structures | Leaflets |
| Leak detection and repair | Retrofitting resolutions | Posters |
| System rehabilitation | Sprinkling ordinances | Bill inserts |
| Pricing (conservation oriented) | Changes in landscape design | Newsletters |
| Marginal cost pricing | Reduction in lawn sizes | Handbooks |
| Seasonal peak load pricing | Increases in impervious area | Buttons |
| Uniform unit pricing | Planting of low-water using plants | Bumper stickers |
| Demand changes | Water recycling | News media |
| Summer surcharge | Hook-up moratorium | Radio/tv ads |
| Excess-use charge | Restrictions | Movie |
| Increasing unit | Rationing by | Radio announcements |
| Hook-up fees | Fixed allocations | Newspaper articles |
| Penalty charges | Variable percentage plan | Personal contact |
| Economic incentives | Per capita use | Speaker program |
| Rebates | Prior use bases | Slide show |
| Tax credits | Determination of priority uses | Booths at fairs |
| Subsidies | Restrictions on private and public recreational uses | Customer assistance |
| Penalties | Restrictions on commercial and institutional uses | Special events |
| Implementing water-saving devices | Banned wasteful practices | School talks |
| Devices for new construction | Car washing | Slogan/poster contests |
| Shallow trap toilet | Pool filling | Posters around town |
| Pressurized tank toiled | Landscape irrigation | Billboards |
| Vacuum toilet | Watering with hand-held hose only | Displays |
| Incinerator toilet | Scheduled irrigation | Reminder items |
| Pressurized flush toilet | | Decals |
| Wastewater recycling toilet | | Serving water on request in restaurants |
| Oil flush toilet | | County fair exhibit |
| Composer toilet | | |
| Dual flush toilet | | |
| Micropore toilet | | |
| Premixed water system | | |
| Water recycling system | | |
| Compressed air toilet | | |
| Retrofit devices | | |
| Water closet inserts | | |
| Water dams | | |
| Toilet flush adapters | | |
| Flush valve toilets | | |
| Shower mixing valves | | |
| Shower flow-control devices | | |
| Air-assisted showerheads | | |
| Pressure-reducing valves | | |

*(Continued)*

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**Table 11J.174 (Continued)**

| Management | Regulations | Education |
|---|---|---|
| Toilet inserts | | |
| Faucet aerators | | |
| Faucet flow restrictors | | |
| Spray taps | | |
| Pressure balancing mixing valves | | |
| Hot water pipe insulation | | |
| Swimming pool covers | | |
| Low water-using diswashers | | |
| Low flush toilets | | |
| Thermostatic mixing valves | | |
| Minimum use showers | | |
| Low flow shortheads | | |
| Low water-using clothes washers | | |
| Devices for landscape irrigation | | |
| Moisture sensors | | |
| Hose meters | | |
| Sprinklers timers | | |
| Distribution of water conservation kits | | |
| Free distribution and installation of water-saving devices | | |
| Distribution of leak detection kits | | |
| Reuse of water works facility washwater | | |

*Source*: From U.S. Army Corps of Engineers, Engineer Institute for Water Resources, Analytical Bibliography for Water Supply and Conservation Techniques, Contract Report 82-C07, 1982.

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**Table 11J.175 Water Conservation Techniques**

Inspect the plumbing system for leaks
Install flow control devices in showers
Turn off all water during vacations or long periods of absence
Check the frequency with which home water softening equipment regenerates and backwashes. It can use as much as 100 gallons of water each time it does this
Insulate hot water pipes to avoid having to clear the "hot" line of cold water during use
Check all faucets, inside and out, for drips. Make repairs promptly. These problems get worse—never better
Reduce the volume of water in the toilet flush tank with a quart plastic bottle filled with water (bricks lose particles, which can damage the valve)
Never use the toilet as a trash basket for facial tissues, etc. Each flush uses 5 to 7 gallons of water. Items carelessly thrown in could clog the sewage disposal system
Accumulate a full laundry load before washing, or use a lower water level setting
Take showers instead of baths
Turn off shower water while soaping body, lathering hair, and massaging scalp
Bottle and refrigerate water to avoid running excess water from the lines to get cold water for meals. Shake bottle before serving to incorporate air in the water so that it doesnot taste flat
To get warm water, turn hot water on first; then add cold water as needed. This is quicker this way and saves water, too
Wash only full loads of dishes. A dishwasher uses about 9 to 13 gallons to water per cycle
When washing dishes by hand, use one pan of soapy water for washing and a second pan of hot water for rinsing. Rinsing in a pan requires less water than rinsing under a running faucet
Use rinse water—"gray water"—saved from bathing or clothes washing to water indoor plants. Do not use soapy water on indoor plants. It could damage them
Vegetables requiring more water should be grouped together in the garden to make maximum use of water applications
Mulch shrubs and other plants to retain moisture in the soil longer
Spread leaves, lawn clippings, chopped bark or cobs, or plastic around the plants. Mulching also controls weeds that complete with garden plants for water
Mulches should permit water to soak into the soil
Try "trickle" or "drip" irrigation systems in outdoor gardens. These methods use 25 to 50 percent less water than hose or sprinkler methods. The tube for the trickle system has many tiny holes to water closely spaced plants. The drip system tubing contains holes or openings at strategic places for tomatoes and other plants that are more widely spaced
Less frequent but heavier lawn watering encourages a deeper root system to withstand dry weather better
Plan landscaping and gardening to minimize watering requirements
When building or remodeling, consider
— Installing smaller than standard bath tubs to save water
— Locating the water heater near where hottest water is needed
— usually in the kitchen/laundry area

*Source*: From U.S. Environmental Protection Agency, 1988, *The Lake and Reservoir Restoration Guidance Manual*, EPA 440/5-88-002.

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**Table 11J.176 Means to Improve Effective Use of Water and Energy for Irrigation**

| | |
|---|---|
| Direct Means | More efficient irrigation |
| 1. Reduce water applied | More uniform irrigation |
| | Better use of natural rainfall |
| | Reduction of losses |
| | Compromise yield (Optimize yield ratio) |
| 2. Reduce operating pressures | Use different irrigation devices |
| | Use different irrigation practices |
| Indirect Means | |
| 1. Change irrigation practices to allow | Less tillage |
| | Fewer secondary operations |
| | Spraying |
| | Fertilizing |
| | Cultivating |
| 2. Change irrigation practices to prevent | Need for ripping |
| | Need for land preparation |
| | Loss of fertilizer and nutrients |
| 3. Substitute irrigation for other more energy consumptive operations | Environmental control |
| | Sprinkling for frost protection vs. wind machines or heaters |
| 4. Improve yields thereby reducing acreage needed | Control amount and timing of water application |
| | Irrigation scheduling |
| 5. Time irrigation to better use limited energy resource | Peak use avoidance (load management). Irrigation scheduling |

*Source*: From von Bernuth, R.D., 1980, *New Concepts in AG Sprinklers*, Copyright, The Irrigation Assoc., 1980 Technical Conference Proceedings. Reprinted with permission.

**Table 11J.177 Drought Tolerant Varieties Recommended for Nebraska**

| **Trees** | | **Mature Size (ft)** |
|---|---|---|
| Acre ginnala | Amur Maple | 25 |
| Acer platanoides | Norway Maple | 50’ |
| Carya sps. | Hickory | 45’ |
| Celtis occidentalis | Common Hackberry | 60’ |
| Cercis canadensis | Eastern Redbud | 20’ |
| Crataegus crusgalli inermis | Thornless Cockspur Hawthorn | 20’ |
| Crataegus phaenapyrum | Washington Hawthorn | 25’ |
| Fraxinus pennsylvanica | Green Ash | 60’ |
| Ginko Bilboa | Ginko | 60’ |
| Gleditsia triacanthos inermis | Thornless Common Honeylocust | 60’ |
| Gymnocladus dioicus | Kentucky Coffeetree | 60’ |
| Juniperus spp. | Junipers | 25–35’ |
| Koelreuteria paniculata | Golden Raintree | 30’ |
| Maclura pimifera | Osage-orange (thornless male) | 50’ |
| Malus cultivars | Crabapple | 15–25’ |
| Picea pungens | Colorado Spruce | 50’ |
| Picea glauca, densata | Black Hills Spruce | 45’ |
| Pinus banksiana | Jack Pine | 35’–40’ |
| Pinus nigra | Austrian Pine | 50’ |
| Pinus ponderosa | Ponderosa Pine | 60’ |
| Pinus sylvestris | Scotch Pine | 60’ |
| Pseudotsuga menziesii | Douglas Fir | 50’ |
| Quercus coccinea | Scarlet Oak | 65’ |
| Quercus imbricaria | Shingle Oak | 40’ |
| Quercus macrocarpa | Bur Oak | 50’ |
| Quercus marilandica | Blackjack Oak | 25’ |
| Quercus velutina | Black Oak | 55’ |
| Quercus bicolor | Swamp White Oak | 50’ |
| Robinia speudoacadia | Black Locust | 60’ |
| Taxodium distichum | Baldcypress | 50’ |
| **Shrubs** | | |
| Amelancher alnifolia | Saskatoon Serviceberry | 6’ |
| Amorpha canescens | Leadplant Amorpha | 8’–20’ |
| Aronia meloncarpa | Black Chokeberry | 10’ |

*(Continued)*

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**Table 11J.177 (Continued)**

| | | |
|---|---|---|
| Berberis X mentorensis | Mentor Barberry | 7’ |
| Berberis thunbergii | Japanese Barberry | 7’ |
| Caragana arborescens | Siberian Peashrub | 15–20’ |
| Ceanothus americanus | New Jersey Tea | 3’ |
| Chaenomeles species | Flowering Quince | 3’–6’ |
| Cornus mas | Corneliancherry Dogwood | 20’ |
| Cornus racemosa | Gray Dogwood | 12’ |
| Cotinus coggygria | Smoketree | 15’ |
| Diervilla lanicera | Bush Honeysuckle | 5–6’ |
| Hamamelis virginiana | Common Witchhazel | 15’ |
| Juniperus chinensis | Juniper | 10’–15’ |
| Kolkwitzia amabilis | Beautybush | 10’ |
| Ligustrum species | Privet | 15’–20’ |
| Lonicera korolkowii | Blueleaf Honeysuckle | 15’ |
| Lonicera X, Emerald Mound | Emerald Mound Honeysuckle | 2’ |
| Physocarpus opulifolius | Common Ninebark | 10’ |
| Pine mugo | Mugo Pine | 5’–15’ |
| Prunus tomentosa | Nanking Cherry | 15’ |
| Prunus besseyi | Western Sandcherry | 4’ |
| Pyracantha coccinea | Scarlet Firethorn | 6’ |
| Rhus species | Sumac | 6’ |
| Ribes missourense | Missouri Gooseberry | 3’ |
| Ribes odoratum | Clove Currant | 8’ |
| Rosa rugosa | Rugose Rose | 4’ |
| Sambucus candensis | Elderberry | 8’ |
| Spiraea X vanhouttei | Vanhoutteis Spirea | 5’ |
| Symphoricarpos occidentalis | Western Snowberry | 3’–4’ |
| Symphoricarpos orbiculatus | Coralberry | 3’ |
| Syringa species | Lilac | 10’ |
| Viburnum lantana | Wayfaringtree | 10’ |
| Viburnum lentago | Nannyberry | 25’ |
| Viburnum prunifolium | Blackhaw Viburnum | 15’ |
| Yucca glauca | Soapweed | 3’ |
| Yucca filamentosa | Adams-Needle or Yucca | 3’ |
| **Forbs (wildflowers & perennials)** | | |
| Achillea sps. | Yarrow | |
| Antennaria species | Pussytoes | |
| Artemisia sps. | Artemisia | |
| Aster novae-angliae | New England Aster | |
| Asclepias tuberosa | Butterfly Milkweed | |
| Baptisia sps. | False Indigo | |
| Coreopsis sps. | Coreopsis cultivars | |
| Dalea purpurea | Purple Prairie Clover | |
| Echinacea purpurea | Purple Coneflower | |
| Gaillarada species | Blanket Flower | |
| Hemerocallis sps. | Daylily | |
| Iris sps. | Iris species | |
| Liatris sps. | Gayfeather | |
| Monarda species | Beebalm | |
| Sedum sps. | Sedum | |
| Sempervirens sps. | Hens-N-Chickens | |
| **Turfgrasses** | | |
| Buchloe dacryloides | Buffalograss | |
| Festuca arundinacea | Tall Fescue (turf types) | |
| **Ornamental Grasses** | | |
| Andropogon gerardia | Big Bluestem | |
| Bouteloua curtipendula | Sideoats Grama | |
| Calamagrostis acutiflora | Feather Reedgrass | |
| Eragrostis tricbodes | Sand Lovegrass | |
| Miscanthus sps. | Eulaliagrass | |
| Panicum virgatum | Switchgrass | |
| Pennisetum sps. | Fountaingrass | |
| Schizachyrium scoparium | Little Bluestem | |
| Sorghastrum nutans | Indiangrass | |

*Source*: From ianrpubs.unl.edu. With permission.

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**Table 11J.178 A Selection of Drought-Tolerant Landscape Plants**

| | |
|---|---|
| **Shade Trees** | |
| Red Maple | (Acer rubrum) (wet or dry situations, and depends on seed source) |
| Green Ash | (Fraxinus pennsylvanica) |
| Ginkgo | (Ginkgo biloba) |
| Tupelo | (Nyssa sylvatica) |
| Red Oak | (Quercus rubra) |
| Pin Oak | (Quercus palustris) |
| Zelkova | (Zelkova serrata) |
| Japanese Pagodatree | (Sophora japonica) |
| Golden Raintree | (Kolreuteria paniculata) |
| Japanese Tree Lilac | (Syringa reticulata) |
| Crapemyrtle | (Lagerstroemia indica) |
| Tulip Poplar | (Liriodendron tulipfera) |
| **Evergreen Trees** | |
| Atlas Cedar | (Cedrus atlantica) |
| Colorado Blue Spruce | (Picea pungens glauca) |
| American Holly | (Ilex opaca) |
| Red Cedar | (Juniperus virginiana) |
| **Deciduous Shrubs** | |
| Red Chokeberry | (Aronia arbutifolia) |
| Smoketree | (Cotinus coggyria) |
| Pinxterbloom Azalea | (Rhododendron nudiflorum) |
| Flameleaf Sumac | (Rhus copallina) |
| Burning Bush | (Euonymus alatus) |
| Fragrant Wintersweet | (Chimonanthus praecox) |
| Japanese Barberry | (Berberis thunbergii) |
| **Evergreen Shrubs** | |
| Heavenly Bamboo | (Nandina domestica) |
| False-Holly | (Osmanthus heterophyllus) |
| Mugo Pine | (Pinus mugo) |
| Pyracantha | (Pyracantha coccinea) |
| Glossy Abelia | (Abelia x grandiflora) |
| Junipers | (Juniperus species) |
| **Herbaceous Plants** | |
| *May–June Blooming* | |
| Cushion Spurge | (Euphorbia sp) |
| Candy tuft | (Iberis sempervirens) |
| Dwarf Crested Iris | (Iris cristata) |
| Sea Pink | (Armeria maritima) |
| Perennial Bachelor's Button | (Centaurea montana) |
| Gas Plant | (Dictamnus albus) |
| Day Lily | (Hemerocallis) |
| Beaded Iris | (Iris sp.) |
| Iceland Poppy | (Papaver nudicaule) |
| *June–Sept Blooming* | |
| Black Eyed Susan | (Rudbeckia hirta) |
| Yarrow | (Achillea filipendulina) |
| Coreopsis | (Corepsis lanceolata) |
| Coreopsis | (Coreopsis verticillata) |
| Foxtail Lily | (Eremurus x isabellinus) |
| Blanket Flower | (Gaillardia x grandiflora) |
| Perennial Baby's Breath | (Gypsophila paniculata) |
| Red-Hot Poker | (Kniphofia uvaria) |
| Moneywort | (Lysimachia nummularia) |
| Perennial Salvia | (Salvia x superba) |
| Yucca | (Yucca filamentosa) |
| Blue Fescue | (Festuca glauca) |
| Hens and Chicks | (Sempervivum tectorum) |
| Goldenrod | Spp. (Solidago) |
| Lamb's Ear | (Stachys byzantina) |
| Pearly Everlasting | (Anaphalis margaritacea) |
| Silvermound | (Artemesia schmidtiana) |
| Liatris | (Liatris spicata) |
| Sedum | (Sedum spectabile) |

*Note:* The plants listed are some that generally survive well under dry, hot conditions that would normally harm most other plants. It must be kept in mind that even these plants will require regular watering during the first season they are planted. The frequency of watering of established landscapes will vary based on the plant species, its conditions and maturity and soil conditions of the site.

*Source*: From agnr.umd.edu. With permission.

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**Table 11J.179 Hydrozones for Urban Landscape Water Conservation**

| | Area with Highest Intensity of Watering | Area with Lowest Intensity of Watering |
|---|---|---|
| Level of human contact and activity | Most direct, active, intense | Least direct and intense; most passive |
| Level of visibility | Highly visible | Least visible |
| Maximum compatible water use | Most intense water use | Least intense water use |
| Priority for watering during drought | First priority | Last priority |
| Typical types of plants | Turf; exotic ornamentals | Native and drought-tolerant trees and shrubs |
| Examples on golf course | Greens | Rough or fairway |
| Examples in commercial area | Urban plaza; building entry area | Parking and service screens |
| Examples in residential community | Play area; building entry area; central common area | Buffer zones; parking screens |
| Examples in single-family residence | Active areas in rear yard | Side yard; privacy screens |

*Note:* Allocation of different intensities of irrigation to different areas.

*Source*: From Ferguson, B.K., 1987, *Water Conservation Methods in Urban Landscape Irrigation: An Exploratory Overview, Water Resources Bull.*, vol. 23, no. 1. Copyright American Water Resources Assoc. Reprinted with permission.

**Table 11J.180 Water Conserving Plants, Shrubs, and Trees in the Western United States**

| Plant | Mature Size | Flower Color | Water Requirements |
|---|---|---|---|
| **Flowering Plants** | | | |
| Callistemon citrinus | 25’ high | O,R | S |
| Lemon bottlebrush | 15’ wide | | |
| Cassia artemisiodes | 3’ to 5’ high | Y | V |
| Feathery cassia | | | |
| Cistus | 2’ to 6’ high | V | V |
| Rockrose | 6’ wide | | |
| Coreopsis verticillata | 2–1/2’ high, 2’ wide | Y | C |
| Cytisus and Spartium | 3’ to 8’ high | V | V |
| Broom | 4’ to 6’ wide | | |
| Escallonia | 3’ to 15’ | V | V |
| Lantana | 1’ to 6’ high | V | V |
| Nerium oleander | 8’ to 12’ high | V | S |
| Oleander | 8’ to 12’ wide | | |
| Ochna serrulata | 4’ to 8’ high | Y | V |
| Mickey Mouse plant | | | |
| Plumbago auriculata | To 6’ high | B,W | V |
| Cape plumbago | 8’ to 10’ wide | | |
| Poinciana gilliesii | 10’ high and | Y | V |
| Bird of paradise bush | nearly as wide | | |
| Limonium Perezil | 2’ to 4’ high | L | V |
| Sea Lavender | | | |
| **Foliage Plants** | | | |
| Arbutus unedo | 8’ to 35’ high | W | V |
| Strawberry tree | and wide | | |
| Dodonaea viscose | 12’ high | — | C |
| Hopseed bush | 6’ to 8’ wide | | |
| Elaeagnus | Mostiy very big shrubs | — | V |
| Prunus lyoni | | | |
| P. ilicifolia | | | |
| P. caroliniana | 6’ to 40’ high | W | C |
| Rhus ovata | 2–1/2’ to 10’ high | P | C |
| Sugar bush | and wide | | |
| Xylosma congestum | 8’ to 10’ high and often wider | — | V |
| Yucca | 2’ to 20’ high and more | W | V |
| **Vines** | | | |
| Bougainvillea | Big mound or huge vine | V | V |
| Campsis | Can bury a | O,R | V |
| trumpet creeper | house or yard | | |

*(Continued)*

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**Table 11J.180 (Continued)**

| Plant | Mature Size | Flower Color | Water Requirements |
|---|---|---|---|
| Solanum jasminoides<br>Potato vine | To 30' | W | S |
| Tecomaria capensis<br>Cape honeysuckle | Bush or fence<br>Vine | R | V |
| Wisteria | 100' or more | B,W | V |
| **Trees** | | | |
| Acacia<br>Certain species | Large shrubs<br>Small trees | Y | V |
| Cupressus glabra | 20' to 40' high | — | C |
| Eucalyptus | Shrubs or trees | V | C |
| Geijera parvifolia | To 30' high, 20' high | — | C |
| Heteromeles arbutifolia<br>Toyon | Shrub to 10' or<br>25' tree | W | C |
| Olea europaea<br>Olive | 25' to 30' | — | V |
| Palms | 20' to 100' | — | V |
| Rhus lancea | To 25' spreading | — | V |
| Robinia (tree forms)<br>Locust | 40' to 70' high | P,W | V |
| **Ground Cover** | | | |
| Aloe | 1' to 18' high | O,R | V |
| Baccharis pilularis<br>Dwarf coyote bush | 8" to 24" mat<br>with 6' spread | — | V |
| Gazania | 6" to 8" high | V | S |
| Pennisetum setaceum<br>Fountain grass | 2' to 4' clumps | G | C |
| Rosmarinus officinalis<br>Prostrata | Up to 3' | B | V |
| **Other** | | | |
| Ceanothus | Mat, shrubs trees 2' to 14' | B | C |
| Juniperus<br>Juniper | Ground covers,<br>shrubs, trees | — | S |

*Note:* Flower Colors: B, Blue; G, Gray; L, Lavender; O, Orange; P, Pink; R, Red; V, Varies; W, White; Y, Yellow. Water Requirements: S, Somewhat unthirsty, more than 6 waterings annually; V, Very unthirsty, 4 to 6 waterings annually; C, Completely unthirsty, annual rainfall sufficient.

*Source*: From Los Angeles Department of Water and Power, October 1986.

**Table 11J.181 Potential Water Savings of Household Fixtures**

| Water User | Without Conservation | With Conservation |
|---|---|---|
| Toilet | 5–7 gallons per flush | 3–4 gall per flush<br>British dual cycle water closets use 2.5 gall to flush solids and 1.25 gall to flush liquids<br>One-gallon toilets have recently become available for about $150<br>One-half gallon toilets which are aided by compressed air are also available |
| Showers | 6–10 gal/min | 2–3 gal/min |
| Faucets | 5 gal/min | 1.5 gal/min |
| Dishwasher | 10–14 gall per load | 8.5–10 gall per load |
| Washing machine | 47.5 gall per load | 42 gall per load |

*Source*: From New York State Senate Research Service Task Force on Critical Problems, 1986, *Water Conservation*, The Hidden Supply, Albany, NY. With permission.

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**Table 11J.182 Water Saving Equipment in Place of Conventional Plumbing Fixtures, Fittings, and Appliances**

| Fixture/Fitting/Appliance | Water Use in Gallons Per |
|---|---|
| Vintage Toilet[a] | 4–6 flush |
| Conventional Toilet[b] | 3.5 flush |
| Low Consumption Toilet[c] | 1.6 flush |
| Conventional Showerhead[a] | 3–10 min |
| Low-Flow Showerhead | 2–2.5 min |
| Faucet Aerator[a] | 3–6 min |
| Flow Regulating Aerator | 0.5–2.5 min |
| Top-Loading Washer | 40–55 load |
| Front-Loading Washer | 22–25 load |
| Dishwasher | 8–12 load |

[a] Manufactured before 1978.
[b] Manufactured from 1978 to 1993.
[c] Manufactured since January 1, 1994.

*Source*: From usangreen.org.

**Table 11J.183 Annual Utility Electric Energy Demands Associated with Water Used by Residential Plumbing Fixtures[a]**

| Fixture | Per Capita kWh[b] | Per Household[c] kWh[b] | Per 1,000 Households kWh[b] |
|---|---|---|---|
| Post-1994 fixtures | 22 | 59 | 59,463 |
| 1980–1994 fixtures | 35 | 94 | 94,206 |
| Pre-1980 fixtures | 57 | 151 | 151,776 |

[a] Toilets, showerheads, and faucets.
[b] Combined average energy use for water treatment (1,500 kWh/mgd) and wastewater treatment (1,400 kWh/mgd)
[c] Per 2.63-person household based on 1990 US census.

*Source*: From cepis.ops-oms.org.

**Table 11J.184 Annual Utility Emissions of Carbon Dioxide, Nitrogen Oxides, and Sulfur Dioxide Associated with Energy Demand Created by Plumbing Fixture Water Use**

| | Utility | | |
|---|---|---|---|
| Fixture | Per Capita lb/kWh[a] | Per Household lb/kWh[a] | Per 1,000 Households lb/kWh[a] |
| Post-1994 fixtures | 43.4 | 114.1 | 114,088 |
| 1980–1994 fixtures | 68.7 | 180.8 | 180,747 |
| Pre-1980 fixtures | 110.7 | 291.2 | 291,203 |

*Note:* For water use by toilets, showerheads, and faucets.

[a] Emissions per kWh — 1.89 lb carbon dioxide, 0.00914 lb nitrogen oxides, and 0.0195 lb sulfur dioxide, based on total electric energy demands.

*Source*: From cepis.ops-oms.org.

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CHAPTER 12

# Agencies and Organizations

**Pedro Fierro, Jr.**

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# SECTION 12A FEDERAL AGENCIES

**Table 12A.1 Federal Agencies Concerned with Water-Related Matters**

**Federal Citizen Information Center (http://www.firstgov.gov)**
Phone: (800) 333-4636
Since 1970, the Federal Citizen Information Center (FCIC) has provided information related to government services. Serves as the official gateway to all government information

**Bureau of Land Management (http://www.blm.gov)**
Office of Public Affairs, 1849 C Street, Room 406-LS, Washington, DC 20240, Phone: (202) 452-5125

**Bureau of Reclamation (http://www.usbr.gov)**
Commissioner, Bureau of Reclamation, 1849 C Street NW, Washington DC 20240-0001, Phone: (202) 513-0501

**Council on Environmental Quality (http://www.whitehouse.gov/ceq)**
722 Jackson Place, N.W., Washington, DC 20503, Phone: (202) 395-5750

**Extension Service, Department of Agriculture (reeusda.gov)**
1400 Independence Ave., SW, Washington, DC 20250-0003, Phone: (202) 720-7441

**Federal Emergency Management Agency (http://www.fema.gov)**
500 C Street, SW, Washington, DC 20472, Phone: (202) 566-1600

**Federal Highway Administration (FHWA) (http://www.fhwa.dot.gov)**
Federal Highway Administration, 400 Seventh Street, SW, Washington, DC 20590, FHWA Personnel Locator (202) 366-0537

**Forest Service, U.S. Department of Agriculture (http://www.fs.fed.us/)**
USDA Forest Service, 1400 Independence Ave., SW, Washington, DC 20250-0003, Phone: (202) 205-8333

**Minerals Management Service (http://www.mms.gov)**
Chief of Public Affairs, 1849 C Street, N. W., Washington, DC 20240, Phone: (202) 208-3985

**National Geodetic Survey (NGS) (http://www.ngs.noaa.gov)**
NGS Information Services, NOAA, N/NGS12, National Geodetic Survey, SSMC-3, #9202, 1315 East-West Highway, Silver Spring, MD 20910-3282, Phone: (301) 713-3242, Fax: (301) 713-4172

**National Marine Fisheries Service (http://www.nmfs.noaa.gov)**
NOAA Fisheries, 1315 East West Highway, SSMC3, Silver Spring, MD 20910, Phone: (301) 713-2239

**National Oceanic and Atmospheric Administration (NOAA) (http://www.noaa.gov)**
14th Street & Constitution Avenue, NW, Room 6217, Washington, DC 20230, Phone: (202) 482-6090

**National Park Service (http://www.nps.gov)**
1849 C Street NW, Washington, DC 20240, Phone: (202) 208-6843

**Natural Resources Conservation Service (NRCS) (http://www.nrcs.usda.gov)**
National Headquarters, Postal Mail, Natural Resources Conservation Service, Attn: Conservation Communications Staff, P.O. Box 2890, Washington, DC 20013

Street Address
Natural Resources Conservation Service, 14th and Independence Avenue, SW, Washington, DC 20250

**National Science Foundation (http://www.nsf.gov)**
4201 Wilson Boulevard, Arlington, VA 22230, Phone: (703) 292-5111

**National Sea Grant College Program (http://www.nsgo.seagrant.org)**
NOAA/Sea Grant, R/SG, 1315 East-West Highway, SSMC-3, Eleventh Floor, Silver Spring, MD 20910, Phone: (301) 713-2448

**National Weather Service (http://www.nws.noaa.gov)**
1325 East West Highway, Silver Spring, MD 20910, Phone: (301) 713-4000

**National Wetlands Inventory (enterprise.nwi.fws.gov)**
National Wetlands Inventory Center, 9720 Executive Center Drive North, Monroe Building, Suite 101, Saint Petersburg, FL 33702, Phone: (727) 570-5400

**Ocean Pollution Data and Information Network (http://www.nodc.noaa.gov)**
NOAA/NESDIS E/OC, SSMC3, 4th Floor, 1315 East-West Highway, Silver Spring, MD 20910-3282, Phone: (301) 713-3277

*(Continued)*

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**Table 12A.1 (Continued)**

**Office of Ocean and Coastal Resource Management (http://www.ocrm.nos.noaa.gov)**
N/ORM 10th Floor SSMC4, 1305 East-West Highway, Silver Spring, MD 20910, Phone: (301) 713-3155

**Office of Surface Mining (http://www.osmre.gov)**
1951 Constitution Ave. N.W., Washington, DC 20240, Phone: (202) 208-2719

**Saint Lawrence Seaway Development Corporation (http://www.seaway.dot.gov)**
400 7th Street, S.W., Room 5424, Washington, DC 20590, Phone: (202) 366-0091

**Soil Conservation Service (http://www.nrcs.usda.gov)**
14th and Independence Ave, SW, Room 5006-S, Washington, DC 20250, Phone: (202) 720-4630

**Tennessee Valley Authority (http://www.tva.gov)**
400 W. Summit Hill Dr., Knoxville, TN 37902-1499, Phone: (865) 632-2101

**UNIDATA Integrated Earth Information Server (atm.geo.nsf.gov)**
UCAR Office of Programs, Unidata Program Center, P.O. Box 3000, Boulder, CO 80307-3000, Phone: (303) 497-8643

**U.S. Army Corps of Engineers (USACE) (see separate listing)**

**U.S. Bureau of Land Management (USBLM) (http://www.blm.gov)**
Bureau of Land Management - Eastern States, State Director's Office; Mail Stop ES-910, 7450 Boston Boulevard, Springfield, VA 22153-3121, Phone: (703) 440-1703, Fax: (703) 440-1701

**U.S. Bureau of Reclamation (USBR) (http://www.usbr.gov)**
Trudy Harlow, Chief, Public Affairs, Bureau of Reclamation, 1849 C Street NW, Washington DC 20240-0001, Phone: (202) 513-0575

**U.S. Coast Guard (http://www.uscg.mil)**
Commandant, U.S. Coast Guard, 2100 Second Street, SW, Washington, DC 20593, Phone: (202) 267-1587

**U.S. Department of Agriculture — (http:www.ks.nrcs.usda.gov/)**
Natural Resources Conservation Service, USDA, NRCS, 760 South Broadway, Salina, KS 67401, Phone: (785) 823-4500, Fax: (785) 823-4540

**U.S. Department of Energy (http://www.energy.gov)**
1000 Independence Ave., SW, Washington, DC 20585, Phone: (800) 342-5363

**U.S. Department of the Interior (USDOI) (http://www.doi.gov)**
Department of the Interior, 1849 C Street, N.W., Washington, DC 20240, Phone: Phone: (202) 208-3100

**U.S. Environmental Protection Agency (see separate listing)**

**U.S. Fish and Wildlife Service (http://www.fws.gov)**
1849 C Street. N.W., Number 3256, Washington, DC 20240, (202) 208-4717

**U.S. Geological Survey Water Resources Information (see separate listing)**

**U.S. Nuclear Regulatory Agency (USNRC) (http:www.nrc.gov)**
U.S. Nuclear Regulatory Commission, Office of Public Affairs (OPA), Washington, DC 20555, Toll-free: (800) 368-5642, Local: (301) 415-8200

**U.S. Office of Surface Mining (USOSM) (http://www.osmre.gov)**
Office of Surface Mining, 1951 Constitution Ave. N.W., Washington, DC 20240, Phone: (202) 208-2719

*Source*: From www.epa.gov.

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**Table 12A.2 U.S. Army Corps of Engineers**

The U.S. Army Corps of Engineers is the Federal government's largest water resources development and management agency. The Corps began its water resources (Civil Works) program in 1824 when Congress for the first time appropriated money for improving navigation. Since then, the Corps has been involved in improving river navigation and harbors, reducing flood damage and controlling beach erosion. At projects designed for these missions, the Corps also generates hydropower; supplies water for cities, industry and agriculture; and manages a recreation and natural resources program. The Corps also has a legal mandate to regulate development by others in the Nation's waterways and wet lands, and at sea and lakeshores.

The Civil Works Program is serviced by 40 district offices, along with the divisions that supervise the districts, and the Washington Headquarters (202-761-1878).

| | | |
|---|---|---|
| Headquarters U.S. Army Corps of Engineers (http://www.hq.usace.army.mil) 441 G St., N.W., Washington, DC 20314-1000, Phone: (202) 761-0000 Fax: (202) 761-1683 | U.S. Army Engineer District, Huntington (155.80.20.141/) 502 8th Street, Huntington, WV 25701-2070, Phone: (304) 529-5395 Fax: (304) 529-5591 | U.S. Army Engineer District, New Orleans P.O. Box 60267, [*7400 Leake Ave.*] New Orleans, LA 70160-0267 [*70118*], Phone: (504) 862-2204, Fax: (504) 862-1259 |
| U.S. Army Engr. Div., Great Lakes & Ohio River, Great Lakes *Regional HQ* (http://www.usace.army.mil/ncd) 111 N. Canal St., Suite 1200, Chicago IL 60606-7205, Phone: (312) 353-6310 Fax: (312) 353-5233 | U.S. Army Engineer District, Louisville (http://www.orn.usace.army.mil/) P.O. Bx 59 [*600 Dr. Martin Luther King Pl.*] Louisville, KY 40201-0059 [*40202*], Phone: (502) 315-6102 Fax: (502) 315-6771 | U.S. Army Engineer District, Rock Island (ncr.usace.army.mil) Clock Tower Bldg., P.O. Box 2004, Rock Island, IL 61204-2004, Phone: (309) 794-5224, Fax: (309) 794-5181 |
| Ohio River *Regional HQ* (usace.mil/ceord.html) P.O. Box 1159 [*550 Main St., Rm. 10001*] Cincinnati, OH 45201-1159, Phone: (513) 684-3002, Fax: (513) 684-2085 | U.S. Army Engineer District, Nashville (http://www.orn.usace.army.mil) P.O. Box 1070 [*110 Ninth Ave S.*] Nashville, TN 37202-1070 [*37203-3863*], Phone: (615) 736-5626 Fax: (615) 736-2052 | U.S. Army Engineer District, St. Louis (lms61.lms.usace.army.mil) 1222 Spruce St., St. Louis, MO 63103-2833, Phone: (314) 331-8010 Fax: (314) 331-8770 |
| U.S. Army Engineer District, Buffalo (www.ncb.usace.army.mil) 1776 Niagara Street, Buffalo, NY 14207-3199, Phone: (716) 879-4200 Fax: (716) 879-4195 | U.S. Army Engineer District, Pittsburgh (orp-wc.usace.army.mil) Wm. S. Moorhead Federal Bldg. 1000 Liberty Avenue, Rm. 1828, Pittsburgh, PA 15222-4186, Phone: (412) 395-7103 Fax: (412) 644-4093 | U.S. Army Engineer District, St. Paul 190 Fifth St. East, St. Paul, MN 55101-1638, Phone: (651) 290-5300, Fax: (651) 290-5478 |
| U.S. Army Engineer District, Chicago (http://www.usace.army.mil/ncc) 111 N. Canal Street, Suite 600, Chicago, IL 60606-7206, Phone: (312) 353-6400 Fax: (312) 353-2525 | U.S. Army Engr. Division, Mississippi Valley (lmv.usace.army.mil) P.O. Box 80 [*1400 Walnut St.*], Vicksburg, MS 39180-0080 [*39181*], Phone: (601) 634-5750 Fax (601) 634-5666 | U.S. Army Engineer District, Vicksburg 4155 Clay St., Vicksburg, MS 39183-3435, Phone: (601) 631-5010 Fax: (601) 631-5296 |
| U.S. Army Engineer District, Detroit (sparky.nce.usace.army.mil) P.O. Box 1027 [*477 Michigan Ave.*] Detroit, MI 48231-1027 [*48226*], Phone: (313) 226-6762, Fax: (313) 226-6009 | U.S. Army Engineer District, Memphis (lmv.usace.army.mil/lmm.html) 167 N. Main St., Rm. B-202, Memphis, TN 38103-1894, Phone: (901) 544-3221, Fax: (901) 544-3628 | U.S. Army Engineer Division, North Atlantic (http://www.usace.mil/cenad.html) 302 General Lee Ave., Fort Hamilton, NY 11252-6700, Phone: (718) 765-7000 |
| U.S. Army Engineer District, Europe USAEDE, CMR 410, Box 1, APO AE 09096, [*Konrad Adenauer Ring 31, Box 1 65187 Wiesbaden, Germany*], Phone: 011-49-611-816-2700 DSN 703-695-0441, Fax: 011-49-611-816-2705 | U.S. Army Engineer District, Omaha (mro.usace.army.mil) 215 N.17th Street, Omaha, NE 68102-4978, Phone: (402) 221-3900, Fax: (402) 221-3128 | U.S. Army Engineer District, Baltimore P.O. Box 1715, [*10 S Howard St Rm 11000*], Baltimore, MD 21201-1715 [*21201*], Phone: (410) 962-4545, Fax: (410) 962-7516 |
| U.S. Army Engineer District, New England 696 Virginia Road, Concord, MA 01742-2751, Phone: (978) 318-8220, Fax: (978) 318-8821 | U.S. Army Engineer District, Portland (npd.usace.army.mil/cenpp.html) P.O. Box 2946, [*333 S.W. First Ave.*], Portland, OR 97208-2946 [*97204-3495*], Phone: (503) 808-4500, Fax: (503) 808-4505 | U.S. Army Engineer District, Japan USAED-J, APO AP 96343-0061, [*Bg. 250, Camp Zama, Zama-shi, Kanagawa-ken 228, Japan*], Phone: 011-81-311-763-3025 (DSN 315-263-3025), Fax: 011-81-311-763-4887 |

*(Continued)*

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**Table 12A.2 (Continued)**

U.S. Army Engineer District, New York
26 Federal Plaza, New York, NY 10278-0090, Phone: (212) 264-0100, Fax: (212) 264-5490

U.S. Army Engineer District, Norfolk
(155.78.30.111)
Waterfield Bg., 803 Front Street, Norfolk, VA 23510-1096, Phone: (757) 441-7601, Fax: (757) 441-7115

U.S. Army Engineer District, Philadelphia
(nap-wc.usace.army.mil)
Wannamaker Building, 100 Penn Square East, Philadelphia, PA 19107-3390, Phone: (215) 656-6501, Fax: (215) 656-6899

U.S. Army Engineer Division, Northwestern
(mrd.usace.army.mil)
Missouri River Regional HQ, 12565 West Center Rd., Omaha, NE 68144, Phone: (402) 697-2400, Fax: (402) 697-2720

North Pacific Regional HQ
P.O. Box 2870, [*220 N.W. Eighth Ave.*], Portland, OR 97208-2870 [*97209*], Phone: (503) 808-3700, Fax: (503) 808-3706

U.S. Army Engineer District, Kansas City
(mrk-wc.usace.army.mil)
700 Federal Building, 601 E. 12th Street, Kansas City, MO 64106-2896, Phone: (816) 983-3206

U.S. Army Engineer District, Albuquerque
(swa-wc.usace.army.mil)
4101 Jefferson Plaza, NE, Albuquerque, NM 87109-3435, Phone: (505) 342-3432, Fax: (505) 342-3199

U.S. Army Engineer District, Los Angeles P.O. Box 532711, [*911 Wilshire Blvd.*], Los Angeles, CA 90053-2325 [*90017*], Phone: (213) 452-3967, Fax: (213) 452-4214

U.S. Army Engineer District, Sacramento
(http://www.usace.mil/cespk.html)
1325 J Street, Sacramento, CA 95814-2922, Phone: (916) 557-7490, Fax: (916) 557-7859

U.S. Army Engineer District, Seattle
(nps.usace.army.mil)
P.O. Box 3755 [*4735 E. Marginal Way S.*], Seattle, WA 98124-2255, [*98134-2385*], Phone: (206) 764-3690, Fax: (206) 764-6544

U.S. Army Engineer District, Walla Walla
(npw.usace.army.mil)
201 N. Third Avenue, Walla Walla, WA 99362-1876, Phone: (509) 527-7700, Fax: (509) 527-7804

U.S. Army Engineer Division, Pacific Ocean
(http://www.pod.usace.army.mil)
Building 525, Fort Shafter, HI 96858-5440, Phone: (808) 438-1500, Fax: (808) 438-8387

U.S. Army Engineer District, Alaska
(usace.army.mil/alaska)
P.O. Box 898, Anchorage, AK 99506-0898, [*2201 3rd St.; Elmendorf AFB, AK 99506*], Phone: (907) 753-2504, Fax: (907) 753-5610

U.S. Army Engineer District, Far East [*Korea*]
Far East Unit #15546, APO AP 96205-0610, Phone: 011-82-2-270-7300 (DSN 351-721-7300), Fax: 011-82-2-265-8440

U.S. Army Engineer District, Honolulu
Building 230, Fort Shafter, HI 96858-5440, Phone: (808) 438-1069, Fax: (808) 438-8351

U.S. Army Engineer District, Tulsa
1645 S. 101-East Avenue, Tulsa, OK 74128-4609, Phone: (918) 669-7201, Fax: (918) 669-7207

***Centers***

U.S. Army Engr. Support Center, Huntsville
(http://www.hnd.usace.army.mil)
P.O. Box 1600 [*4820 University Square*], Huntsville, AL 35807-4301 [*35816-1822*], Phone: (205) 895-1300, Fax: (205) 895-1910

U.S. Army Engr. Transatlantic Programs Center
(usace.army.mil/hypertext)
P.O. Box 2250, [*201 Prince Frederick Dr.*], Winchester, VA 22604-1450 [*22602*], Phone: (540) 665-4073, Fax: (540) 665-4023

U.S. Army Engineer Division, South Atlantic
(usace.army.mil/sad)
60 Forsyth Street, SW, Rm. 9M15, Atlanta, GA 30303-8801, Phone: (404) 562-5003, Fax: (404) 562-5002

U.S. Army Engineer District, Charleston
P.O. Box 919 [*4600 Goer Dr*], Charleston, SC 29402-0919, Phone: (843) 329-8000

U.S. Army Engineer District, Jacksonville
(http://www.saj.usace.army.mil)
P.O. Box 4970, [*400 West Bay St.*], Jacksonville, FL 32232-0019 [*33202*], Phone: (904) 232-2241, Fax: (904) 232-1213

U.S. Army Engineer District, Mobile
(sam.usace.army.mil)
P.O. Box 2288, [*109 Saint Joseph St.*], Mobile, AL 36628-0001, [*36602-3630*], Phone: (334) 690-2511, Fax: (334) 690-2525

U.S. Army Engineer District, Savannah
(http://mac.sas.usace.army.mil)
P.O. Box 889, [*100 W. Oglethorpe Ave.*], Savannah, GA 31402-0889 [*31401-3640*], Phone: (912) 652-5226, Fax: (912) 652-5222

U.S. Army Engineer District, Wilmington
P.O. Box 1890, [*69 Darlington Ave.*], Wilmington, NC 28402-1890 [*28403*], Phone: (910) 251-4501, Fax: (910) 251-4185

U.S. Army Engineer Division, South Pacific
(usace.mil/cespd.html)
333 Market Street, Suite 1101, San Francisco, CA 94105-2195, Phone: (415) 977-8001, Fax: (415) 977-8316

***Field Operating Agencies***

U.S. Army Corps of Engrs. Finance Center
5720 Integrity Drive, Millington, TN 38054-5005, Phone: (901) 874-8410, Fax: (901) 874-8622

U.S. Army Humphreys Engr. Ctr. Spt. Activity, 7701 Telegraph Rd., Alexandria, VA 22310-3860, Phone: (703) 428-6169, Fax: (703) 428-6188

*(Continued)*

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**Table 12A.2 (Continued)**

U.S. Army Engineer District, San Francisco
333 Market Street, Rm. 923, San Francisco, CA 94105, Phone: (415) 977-8600, Fax: (415) 977-8316

U.S. Army Engineer Division, Southwestern
(usace.mil/ceswd.html)

U.S. Army Engineer District, Fort Worth
(usace.army.mil/swf)
P.O. Box 17300 [*819 Taylor St., Rm. 3A24*], Fort Worth, TX 76102-0300, Phone: (817) 978-2300, Fax: (817) 978-3311

U.S. Army Engineer District, Galveston
(usace.army.mil/swg)
P.O. Box 1229, [*2000 Fort Point Road*], Galveston, TX 77553-1229 [*77550*], Phone: (409) 766-3001, Fax: (409) 766-3951

U.S. Army Engineer District, Little Rock
P.O. Box 867 [*700 W. Capitol St.*], Little Rock, AR 72203-0867 [*72201*], Phone: (501) 324-5531, Fax: (501) 324-6968

***Laboratories***

U.S. Army Engineer Research & Development Center, 3903 Halls Ferry Road, Vicksburg, MS 39180-6199, Phone: (601) 634-2513, Fax: (601) 634-2388

U.S. Army, Cold Regions
Research & Eng. Lab, 72 Lyme Rd., Hanover, NH 03755-1290, Phone: (603) 646-4200, Fax: (603) 646-4448

U.S.Army, Construction
Engr'g Research Lab., P.O. Box 9005, [*2902 Newmark Dr.*], Champaign, IL 61826-9005 [*61821-1076*], Phone: (217) 373-7203, Fax: (217) 373-6776

U.S. Army, Topographic Engineering Center
7701 Telegraph Rd., Bldg. 2592, Rm. L-1A, Alexandria, VA 22315-3864, Phone: (703) 428-6602, Fax: (703) 428-8154

USACE
Installation Support Center, 7701 Telegraph Rd., Alexandria, VA 22315-3862, Phone: (703) 428-6933, Fax (703) 428-2805

U.S. Army
Institute for Water Resources, Casey Bldg., 7701 Telegraph Rd., Alexandria, VA 22315-3868, Phone: (703) 428-8250, Fax: (703) 428-8171

U.S. Army
Marine Design Center, Wannamaker Bldg. Rm. 630 South, 100 Penn Square East, Philadelphia, PA 19107-3390, Phone: (215) 656-6850, Fax: (215) 656-6868

249th Engineer Battalion, (Prime Power), Fort Belvoir, VA 22050, Phone: (703) 805-2656

*Source*: From www.usace.army.mil.

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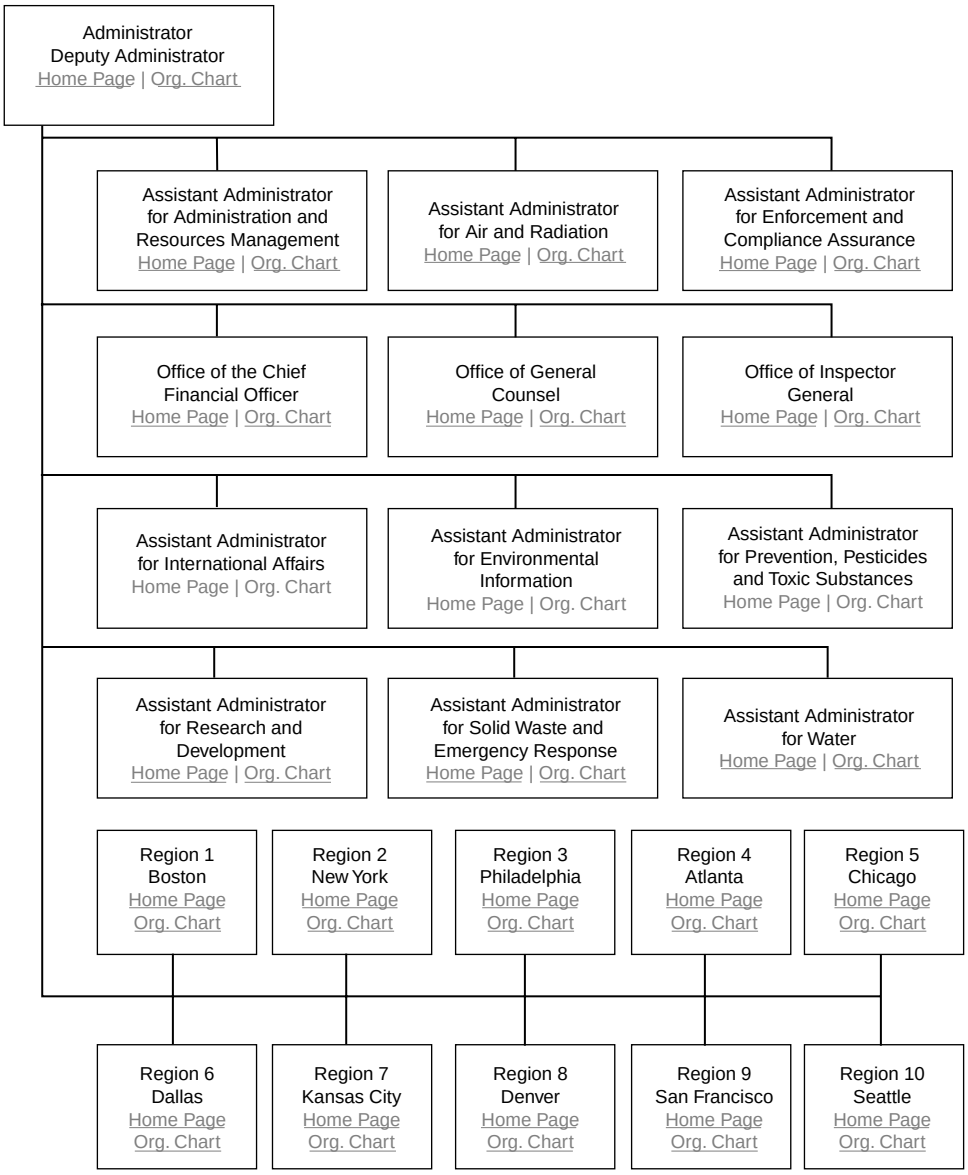


**Figure 12A.1** Organization of the U.S. Environmental Protection Agency (www.epa.gov).

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**Table 12A.3 Organization of the U.S. Environmental Protection Agency Home Page Addresses**

**Administrator**
**Deputy Administrator**
http://www.epa.gov/adminweb/

**Assistant Administrator for Administration and Resource Management**
http://www.epa.gov/oarmweb1/index.htm

**Assistant Administrator for Air and Radiation**
http://www.epa.gov/oar/

**Assistant Administrator for Enforcement and Compliance Assurance**
http://www.epa.gov/compliance/

**Office of the Chief Financial Officer**
http://www.epa.gov/ocfopage/

**Office of General Counsel**
http://www.epa.gov/ogc/

**Office of Inspector General**
http://www.epa.gov/oigearth/

**Assistant Administrator for International Affairs**
http://www.epa.gov/oia/

**Assistant Administrator for Environmental Information**
http://www.epa.gov/oei/

**Assistant Administrator for Prevention, Pesticides, and Toxic Substances**
http://www.epa.gov/oppts/

**Assistant Administrator for Research and Development**
http://www.epa.gov/ORD/

**Assistant Administrator for Solid Waste and Emergency Response**
http://www.epa.gov/swerrims/

**Assistant Administrator for Water**
http://www.epa.gov/OW/

**Region 1 — Boston**
http://www.epa.gov/region1/

**Region 2 — New York**
http://www.epa.gov/region2/

**Region 3 — Philadelphia**
http://www.epa.gov/region03/index.htm

**Region 4 — Atlanta**
http://www.epa.gov/region4/

**Region 5 — Chicago**
http://www.epa.gov/region5/
**Region 6 — Dallas**
http://www.epa.gov/region6/

**Region 7 — Kansas City**
http://www.epa.gov/region7/

**Region 8 — Denver**
http://www.epa.gov/region7/

**Region 9 — San Francisco**
http://www.epa.gov/region9/

**Region 10 — Seattle**
http://www.epa.gov/region10/

*Source*: From www.epa.gov.

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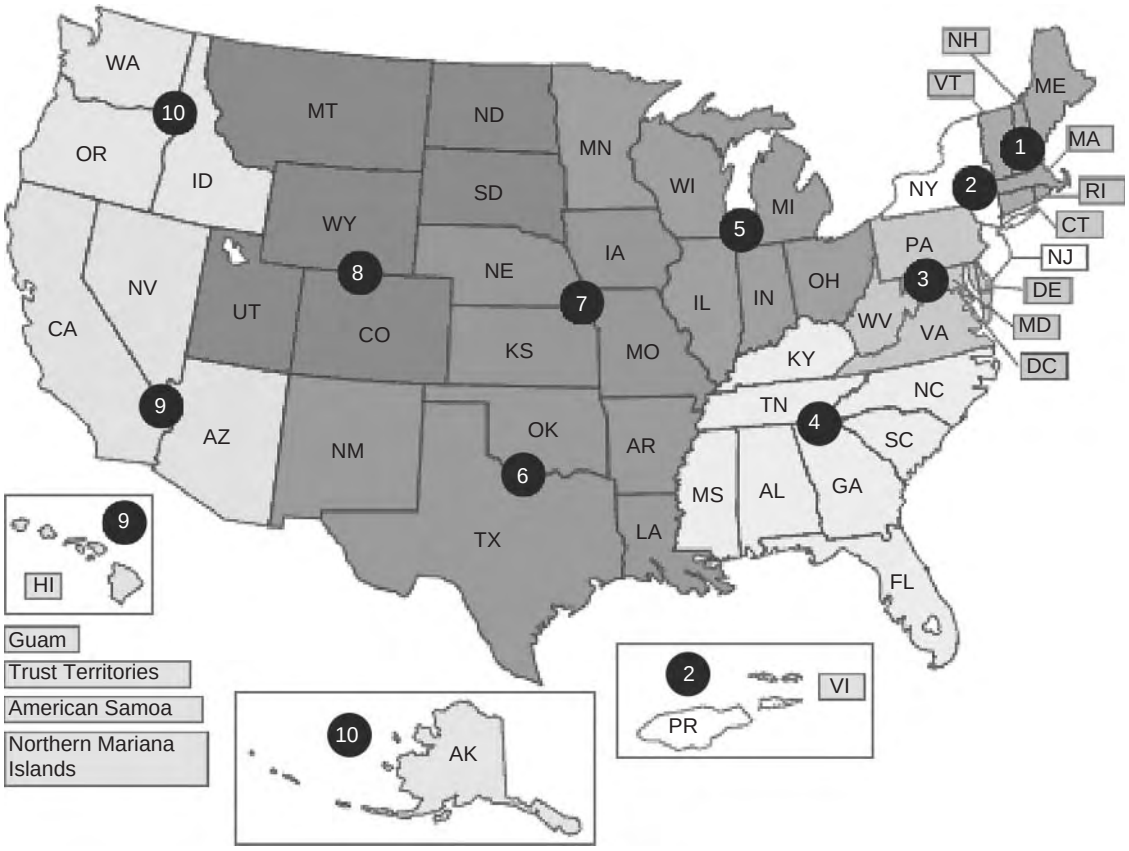


| REGIONS | | | REGIONS | | | REGIONS | | |
|---|---|---|---|---|---|---|---|---|
| Alabama | — | 4 | Maine | — | 1 | Pennsylvania | — | 3 |
| Alaska | — | 10 | Maryland | — | 3 | Rhode Island | — | 1 |
| Arizona | — | 9 | Massachusetts | — | 1 | South Carolina | — | 4 |
| Arkansas | — | 6 | Michigan | — | 5 | South Dakota | — | 8 |
| California | — | 9 | Minnesota | — | 5 | Tennessee | — | 4 |
| Colorado | — | 8 | Mississippi | — | 4 | Texas | — | 6 |
| Connecticut | — | 1 | Missouri | — | 7 | Utah | — | 8 |
| Delaware | — | 3 | Montana | — | 8 | Vermont | — | 1 |
| District of Columbia | — | 3 | Nebraska | — | 7 | Virginia | — | 3 |
| Florida | — | 4 | Nevada | — | 9 | Washington | — | 10 |
| Georgia | — | 4 | New Hampshire | — | 1 | West Virginia | — | 3 |
| Hawaii | — | 9 | New Jersey | — | 2 | Wisconsin | — | 5 |
| Idaho | — | 10 | New Mexico | — | 6 | Wyoming | — | 8 |
| Illinois | — | 5 | New York | — | 2 | American Samoa | — | 9 |
| Indiana | — | 5 | North Carolina | — | 4 | Guam | — | 9 |
| Iowa | — | 7 | North Dakota | — | 8 | Puerto Rico | — | 2 |
| Kansas | — | 7 | Ohio | — | 5 | Virgin Islands | — | 2 |
| Kentucky | — | 4 | Oklahoma | — | 6 | | | |
| Louisiana | — | 6 | Oregon | — | 10 | | | |

**Figure 12A.2** States covered by U.S. Environmental Protection Agency regional offices (www.epa.gov).

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**Table 12A.4 Environmental Protection Agency Headquarters, Regional Offices, and Laboratories**

### EPA Headquarters

**Standard Mailing Address**

Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Avenue, N.W., Washington, DC 20460, Phone: (202) 272-0167

**Overnight Package Delivery Mailing Addresses**

Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Avenue N.W., Washington, DC 20004

Environmental Protection Agency, EPA East Building, 1201 Constitution Avenue N.W., Washington, DC 20004

Environmental Protection Agency, EPA West Building, 1301 Constitution Avenue N.W., Washington, DC 20004

Environmental Protection Agency, Ronald Reagan Building, 1300 Pennsylvania Avenue N.W., Washington, DC 20004

### EPA Regional Offices

**Region 1 (CT, MA, ME, NH, RI, VT)**

Environmental Protection Agency, 1 Congress St. Suite 1100, Boston, MA 02114-2023, http://www.epa.gov/region01/, Phone: (617) 918-1111, Fax: (617) 565-3660, Toll free within Region 1: (888) 372-7341

**Region 2 (NJ, NY, PR, VI)**

Environmental Protection Agency, 290 Broadway, New York, NY 10007-1866, http://www.epa.gov/region02/, Phone: (212) 637-3000, Fax: (212) 637-3526

**Region 3 (DC, DE, MD, PA, VA, WV)**

Environmental Protection Agency, 1650 Arch Street, Philadelphia, PA 19103-2029, http://www.epa.gov/region03/, Phone: (215) 814-5000, Fax: (215) 814-5103, Toll free: (800) 438-2474, Email: r3public@epa.gov

**Region 4 (AL, FL, GA, KY, MS, NC, SC, TN)**

Environmental Protection Agency, Atlanta Federal Center, 61 Forsyth Street, SW, Atlanta, GA 30303-3104, http://www.epa.gov/region04/, Phone: (404) 562-9900, Fax: (404) 562-8174, Toll free: (800) 241-1754

**Region 5 (IL, IN, MI, MN, OH, WI)**

Environmental Protection Agency, 77 West Jackson Boulevard, Chicago, IL 60604-3507, http://www.epa.gov/region5/, Phone: (312) 353-2000, Fax: (312) 353-4135, Toll free within Region 5: (800) 621-8431

**Region 6 (AR, LA, NM, OK, TX)**

Environmental Protection Agency, Fountain Place 12th Floor, Suite 1200, 1445 Ross Avenue, Dallas, TX 75202-2733, http://www.epa.gov/region06/, Phone: (214) 665-2200, Fax: (214) 665-7113

**Region 7 (IA, KS, MO, NE)**

Environmental Protection Agency, 901 North 5th Street, Kansas City, KS 66101, http://www.epa.gov/region07/, Phone: (913) 551-7003, Toll free: (800) 223-0425

**Region 8 (CO, MT, ND, SD, UT, WY)**

Environmental Protection Agency, 999 18th Street Suite 500, Denver, CO 80202-2466, http://www.epa.gov/region08/, Phone: (303) 312-6312, Fax: (303) 312-6339, Toll free: (800) 227-8917, Email: r8eisc@epa.gov

**Region 9 (AZ, CA, HI, NV)**

Environmental Protection Agency, 75 Hawthorne Street, San Francisco, CA 94105, http://www.epa.gov/region09/, Phone: (415) 947-8000, (866) EPA-WEST (toll free in Region 9), Fax: (415) 947-3553, Email: r9.info@epa.gov

**Region 10 (AK, ID, OR, WA)**

Environmental Protection Agency, 1200 Sixth Avenue, Seattle, WA 98101, http:www.epa.gov/region10/, Phone: (206) 553-1200, Fax: (206) 553-0149, Toll free: (800) 424-4372

### Other Locations

U.S. EPA, 26 Martin Luther King Drive, Cincinnati, OH 45268

U.S. EPA, Research Triangle Park, NC 27711, http://www.epa.gov/rtp/

### Satellite Locations and Laboratories

U.S. EPA National Air and Radiation Environmental Laboratory (NAREL), 540 South Morris Avenue, Montgomery, AL 36115-2601, http://www.epa.gov/narel/, Phone: (334) 270-3400, Fax: (334) 270-3454

U.S. EPA National Enforcement Investigations Center Laboratory, Box 25277, Bldg. 53, Denver Federal Center, Denver, CO 80225, http://www.epa.gov/compliance/criminal/forensics/laboratory/index.html, Phone: (303) 236-5132

U.S. EPA National Exposure Research Laboratory (NERL), Mail Code: D305-01, Research Triangle Park, NC 27711, http://www.epa.gov/nerl/, Phone: (919) 541-2106, Fax: (919) 541-0445

U.S. EPA National Health and Environmental Effects Research Laboratory (NHEERL), Mid-Continent Ecology Division, 6201 Congden Boulevard, Duluth, MN 55804, http://www.epa.gov/med/, Fax: (218) 720-5703

U.S. EPA National Health and Environmental Effects Research Laboratory (NHEERL), Western Ecology Division, 200 SW 35th Street, Corvallis, OR 97333, http://www.epa.gov/wed/, Phone: (541) 754-4600, Fax: (541) 754-4799

National Risk Management Research Laboratory, 26 Martin Luther King Drive, Cincinnati, Ohio 45268, http://www.epa.gov/ordntrnt/ORD/NRMRL/, Fax: (513) 569-7680

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**Table 12A.4 (Continued)**

U.S. EPA National Exposure Research Laboratory (NERL), Ecosystems Research Division, 960 College Station Road, Athens, GA 30605-2700, http://www.epa.gov/AthensR/, Phone: (706) 355-8005

U.S. EPA National Exposure Research Laboratory (NERL), Environmental Sciences Division, P.O. Box 93478, Las Vegas, NV 89193-3478, http://www.epa.gov/nerlesd1/, Phone: (702) 798-2100, Fax: (702) 798-2637

U.S. EPA National Health and Environmental Effects Research Laboratory (NHEERL), Mail Code: B305-01, Research Triangle Park, NC 27711, http://www.epa.gov/nheerl/, Phone: (919) 541-2281, Fax: (919) 541-4324

U.S. EPA National Health and Environmental Effects Research Laboratory (NHEERL), Atlantic Ecology Division, 27 Tarzwell Drive, Narragansett, RI 02882, http://www.epa.gov/aed/, Phone: (401) 782-3001, Fax: (401) 782-3030

U.S. EPA National Health and Environmental Effects Research Laboratory (NHEERL) Gulf Ecology Division, Sabine Island Drive, Gulf Breeze, FL 32561, http://www.epa.gov/ged/, Phone: (850) 934-9200, Fax: (850) 934-9201

National Risk Management Research Laboratory (NRMRL), Subsurface Protection and Remediation Division, P.O. Box 1198, Ada, OK 74820, http:www.epa.gov/ada/, Phone: (580) 436-8500

National Risk Management Research Laboratory (NRMRL), Water Supply and Resources Division, Urban Watershed Management Branch, 2890 Woodbridge Avenue (MS-104), Edison, NJ 08837, http://www.epa.gov/ednnrmrl/

National Risk Management Research Laboratory (NRMRL), Air Pollution Prevention and Control Division, Mail Code E343-04, Research Triangle Park, NC 27711, http://www.epa.gov/appcdwww/, Phone: (919) 541-2821, Fax: (919) 541-5227

U.S. EPA National Vehicle and Fuel Emissions Laboratory (NVFEL), 2000 Traverwood Drive, Ann Arbor, MI 48105, http://www.epa.gov/otaq/01-nvfel.htm, Phone: (734) 214-4200

U.S. EPA Radiation and Indoor Environments National Laboratory, P.O. Box 98517, Las Vegas, NV 89193-8517, http://www.epa.gov/radiation/rienl/, Phone: (702) 798-2476

*Source*: From www.epa.gov.

**Table 12A.5 EPA Libraries and Information Centers**

The U.S. Environmental Protection Agency {EPA) is comprised of a Headquarters Office in Washington, DC, 10 Regional offices, and 13 specialized, scientific laboratories located throughout the country. There are 28 EPA network libraries located in Headquarters and all Regional offices and laboratories to support this organizational structure.

The libraries contain a combined collection of over 122,422 books, 5,414 journals, 377,217 hard copy reports, 3,075,443 documents on microfilm and microfiche, 9,000 journal article reprints and 2,000 maps. Most of the EPA library network's holdings are cataloged on OCLC, a national cataloging system.

**Headquarters Library — Washington, D.C.**
Lucy Park, Library Manager, ASRC Aerospace Corp., contractor to U.S. EPA, 1200 Pennsylvania Ave, NW (3404T), Washington, DC 20460, Phone:(202) 566-0556, http://www.epa.gov/natlibra/hqirc/

**U.S. EPA Office of Congressional & Intergovernmental Relations**
ATTN: Craig Freer, 1200 Pennsylvania Avenue, NW, Mail Code 1301A, Washington, D.C. 20460, Phone: (202) 564-5200, Fax: (202) 501-1519, http://www.epa.gov/ocirpage/leglibrary/index.htm

**Office of General Counsel Law Library**
U.S. Environmental Protection Agency, Office of General Counsel Law Library, 1200 Pennsylvania Ave., N.W, Ariel Rios North Building, Room 1315, Washington, D.C. 20460, Phone: (202) 564-3971, http://www.epa.gov/natlibra/libraries/law.htm

**Prevention, Pesticides & Toxic Substances (OPPTS) Chemical Library**
EPA Headquarters, 1301 Constitution Avenue NW, 3231 EPA West, Washington, D.C. 20004, Phone: (202) 566-0800, http://www.epa.gov/opptintr/library/

**Water Resource Center** (RC-4100) (Mailing Address),
U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue NW, Washington, D.C. 20460, Phone: (202) 566-1729, Phone: (800) 832-7828 (Wetlands Helpline), http://www.epa.gov/safewater/resource/

**Water Resource Center** (Physical Address),
U.S. Environmental Protection Agency, EPA West Room 1119, 1301 Constitution Avenue NW, Washington, D.C. 20004

**Libraries in Research Triangle Park, North Carolina**

**NERL — Atmospheric Modeling Division Library**
Phone: (919) 541-4536, Fax: (919) 541-1379, epa.gov/asmdnerl/library/library.htm

**EPA — RTP Library**
U.S. Environmental Protection Agency, 109 TW Alexander Drive, Durham, NC 27709, Phone: (919) 541-7645, http://www.epa.gov/rtp/library/index.htm

**EPA Region 1 Library, Boston**
1 Congress St, Suite 1100, Boston, MA 02114-2023, Phone: (617) 918-1990, Fax: (617) 918-1992 http://www.epa.gov/region01/oarm/index.html

**EPA Region 1 RCRA Research Library, Boston**
1 Congress St, Suite 1100, Boston, MA 02114-2023, Phone: (617) 918-1990, Fax: (617) 918-1992 http://www.epa.gov/region01/oarm/index.html

**EPA Region 2 Library, New York City**
http://www.epa.gov/Region2/library/

**MAIN REGIONAL OFFICE**
290 Broadway, New York, NY 10007-1866, Phone: (212) 637-5000

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**Table 12A.5 (Continued)**

**EDISON LABORATORIES**
2890 Woodbridge Ave., Ms100, Edison, NJ 08837-3679, Phone: (732) 321-6754, Fax: (732) 321-4381

**CARIBBEAN ENVIRONMENTAL PROTECTION DIVISION**
Centro Europa Building, 1492 Ponce Deleon Avenue, Suite 417, San Juan, PR 00907-4127, Phone: (787) 977-5870, Fax: (787) 729-7747

**VIRGIN ISLANDS FIELD OFFICE**
Tunick Building, Suite 102, 1336 Beltjen Road, St. Thomas, VI 00801, Phone: (340) 714-2333, Fax: (340) 714-2332

**HUDSON RIVER FIELD OFFICE**
421 Lower Main Street, Hudson Falls, NY 12839, Phone: (518) 747-4389, Fax: (518) 747-8149

**NIAGARA FALLS PUBLIC INFORMATION CENTER**
345 Third Street, Suite 530, Niagara Falls, NY 14303, Phone: (716) 285-8842, Fax: (716) 285-8788

**Region 3 Regional Center for Environmental Information, Philadelphia**
US Environmental Protection Agency, Regional Center for Environmental Information, Second Floor (3PM52), 1650 Arch Street, Philadelphia, PA 19103, Phone: (215) 814-5254, Fax: (215) 814-5253, epa.gov/reg3rcei/contacts2.htm

**Region 4 Library, Atlanta**
United States Environmental Protection Agency, Region 4, Sam Nunn Atlanta Federal Center, 61 Forsyth Street, SW, Atlanta, GA 30303-3104, Phone: (404) 562-9900, Fax: (404) 562-8174, epa.gov/region4/library/index.htm

**Region 5 Library, Chicago**
77 W. Jackson Blvd., Chicago, IL 60604, 12th floor, Phone: (312) 353-2022, Fax: (312) 353-2001, epa.gov/region5/library/

**Region 6 Library, Dallas**
EPA Region 6 Main Office, 1445 Ross Avenue *(maps)*, Suite 1200, Dallas, TX 75202, Phone: (214) 665-6444, epa.gov/earth1r6/6md/6lib/index.htm

**Houston Laboratory**
10625 Fallstone Road, Houston, TX 77099, Phone: (281) 983-2100, Fax: (281) 983-2248

**Border Liaison Office**
4050 Rio Bravo, Suite 100, El Paso, TX 79902, Phone: (915) 533-7273, Fax: (915) 533-2327

**Brownsville Border Outreach Office**
3505 Boca Chica, Suite 302, Brownsville, TX 78521, Phone: (956) 548-0898

**Underground Injection Control**
Pawhuska Section, Osage Nations Federal Programs, 627 Grandview Ave., Pawhuska, OK 74056, Phone: (918) 287-4041, Fax: (918) 287-2322

**Water Quality Field Office**
707 Florida Street, Room B21, Baton Rouge, LA 70801, Phone: (225) 389-0735, Fax: (225) 389-0704

**Region 7 Information Resource Center, Kansas City**
U.S. EPA Region 7, 901 N. 5th Street, Kansas City, KS 66101, Phone: (913) 551-7241, Fax (913) 551-8762, r7-library@epa.gov

**Region 8 Environmental Information Service Center, Denver**
U.S. EPA Region 8 Environmental Information Svc Ctr., 999 18th Street, Suite 300 OC-L, Denver, CO 80202-2466, Phone: (800) 227-8917, Phone: (303) 312-6312, r8eisc@epa.gov

**U.S. EPA Region 8 Technical Library**
999 18th Street, Suite 300 OC-L, Denver, CO 80202-2466, Phone: (303) 312-6312 or Phone: (800)227-8917 in Region 8 states, Fax: (303) 312-7061, library-reg8@epa.gov

**U.S. EPA Region 9**
75 Hawthorne Street, San Francisco, CA 94105, Phone: (866) EPA-WEST, Phone: (415) 947-8000, http://www.epa.gov/region09/visitor.html

**U.S. EPA Region 10**
1200 Sixth Avenue, Seattle, WA 98101, Phone: (800) 424-4EPA, Fax: (206) 553-6346, library-reg10@epa.gov

**Laboratory Libraries**

**Andrew W. Breidenbach Environmental Research Center**
U.S. Environmental Protection Agency, 26 W. Martin Luther King Dr., Cincinnati, OH 45268, Phone: (513) 569-7703, Fax: (513) 569-7709, http://www.epa.gov/oarmcinc/library.htm

**U.S. Environmental Protection Agency, Environmental Science Center Library**
701 Mapes Road, Fort Meade, MD 20755-5350, Phone: (410) 305-2603, Fax: (410) 305-3099, http://www.epa.gov/region3/esc/library/

**NERL — Atmospheric Sciences Modeling Division Library**
MD-267-02, Environmental Protection Agency, 109 T.W. Alexander Drive, Research Triangle Park, NC 27711, Phone: (919) 541-4536, Fax: (919) 541-1379, epa.gov/asmdnerl/library/general.htm

**NERL — Environmental Sciences Division Technical Research Center**
U.S. Environmental Protection Agency, National Environmental Research Laboratory, Environmental Sciences Division, 944 East Harmon, Las Vegas, NV 89119, Phone: (702) 798-2100, Fax: (702) 798-8147, epa.gov/nerlesd1/trc/home6.htm

**NERL — Ecosystem Research Division Library NERL/ERD Library**
U.S. EPA, 960 College Station Road, Athens, GA 30605-2700, Phone: (706) 355-8011, Fax: (706) 355-8440, http://www.epa.gov/natlibra/libraries/athens.htm

**NHEERL — Atlantic Ecology Division Library, U.S. EPA AED — NHEERL Library**
27 Tarzwell Drive, Narragansett, RI 02882, Phone: (401) 782-3025, Fax: (401) 782-3025, http://www.epa.gov/natlibra/libraries/aed.htm

**NHEERL — Gulf Ecology Division Library**
1 Sabine Island Drive, Gulf Breeze, FL 32561; Phone: (850) 934-9208, Fax (850) 934-2406, http://www.epa.gov/ged/overview_dw.htm

**NHEERL — Midcontinent Ecology Division Library**
U.S. EPA — Mid-Continent Ecology Division—Duluth, 6201 Congdon Boulevard, Duluth, MN 55804-2595, Phone: (218) 529-5000, Fax: (218) 529-5003, epa.gov/med/facilities/scientific_library.htm

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**Table 12A.5 (Continued)**

**NHEERL — Western Ecology Division Library**
U.S. Environmental Protection Agency, NHEERL WED Library, 200 SW 35th Street, Corvallis, OR 97333, Phone: (541) 754-4731, Fax: (541) 754-4799, http://www.epa.gov/natlibra/libraries/wed.htm

**NRMRL — Groundwater and Ecosystems Restoration Division Library**
919 Kerr Research Drive, P.O. Box 1198, Ada, OK 74821-1198, Phone: (580) 436-8505, Fax: (580) 436-8503, http://www.epa.gov/natlibra/libraries/ada.htm

**National Vehicle & Fuel Emissions Laboratory Library**
U.S. EPA NVFEL Library, 2000 Traverwood, Ann Arbor, MI 48105, Phone: (734) 214-4311, Fax: (734) 214-4525, http://www.epa.gov/natlibra/libraries/nvfel.htm

**RTP Library Services**
U.S. Environmental Protection Agency, 109 TW Alexander Drive, Durham, NC 27709, Phone: (919) 541-7645, http://www.epa.gov/rtp/library/index.htm

**Environmental Financing Information Network**
U.S. Environmental Protection Agency, Office of the Comptroller, Environmental Finance Program (Mail Code) 2731R, Ariel Rios Building 1200 Pennsylvania Ave., NW, Washington, D.C. 20460, Phone: (202) 564-4994, Fax: (202) 565-2587, http://www.epa.gov/efinpage/efp.htm

**National Enforcement Investigations, Center Environmental Forensics, Library**
U.S. EPA NEIC Library, P.O. Box 25277, Bldg. 53, Denver Federal Center, Denver, CO 80225, Phone: (303) 236-6136, Fax: (303) 236-3218 epa.gov/compliance/criminal/forensics/neiclibrary/index.html

*Source*: From www.epa.gov.

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**Table 12A.6 Databases Used by EPA Libraries**

**Accidental Release Information Program (ARIP)**
The *Accidental Release Information Program (ARIP) database (July, 1999)* is contained in a zip file (around 1 MB) that contains the ARIP database file (DBF format) and supporting documentation. http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/ds-epds.htm#arip

**Acid Rain Program**
Acid Rain Program quarterly reports use Electronic Data Reporting (EDR) format version 2.1 and are due 30 days following every calendar quarter. http://www.epa.gov/airmarkets/reporting/#arp

**Agricultural Pollution Prevention**
Shows how farmers can save money and reduce pollution by sensible use of fertilizers, pesticides and herbicides. agpp.html. http://www.epa.gov/seahome/agpp.html

**Air CHIEF CD-ROM, Version 11 April 2004 — Released June 2004**
The U. S. Environmental Protection Agency is working to provide current emissions data to federal, state, and local regulatory agencies, businesses, and the general public. The Air Clearing House For Inventories And Emission Factors (*Air CHIEF*) gives the public and private sector user's access to air emission data specific to estimating the types and quantities of pollutants that may be emitted from a wide variety of sources. Updated annually, *Air CHIEF* offers thousands of pages contained in some of EPA's most widely used and requested documents. Included are the U.S. EPA Emission Inventory Group's most popular emission estimation tools. http://www.epa.gov/ttn/chief/software/airchief/index.html

**Air Facility System (AFS)**
The Air Facility System (AFS) contains compliance and permit data for stationary sources regulated by the U.S. EPA and state and local air pollution agencies. http://www.epa.gov/Compliance/planning/data/air/afssystem.html

**Air Quality Index**
The Air Quality Index (AQI) is an index for reporting daily air quality. It tells you how clean or polluted your outdoor air is, and what associated health effects might be a concern for you. http://www.epa.gov/airnow/background.html

**AQS Web Home**
AQS has been migrated and deployed on the Web to eliminate the installation and updates of the AQS software on users' machines and to eliminate the need for the SecuRemote software. epa.gov/ttn/airs/airsaqs/aqsweb/aqswebhome.html

**AirData**
The site gives you access to air pollution data for the entire United States. AirData produces reports and maps of air pollution data based on criteria that you specify. http://www.epa.gov/air/data/index.html

**AIRS Executive Software**
A personal computer software and database that contains air pollution data extracted from the AIRS database. The Windows interface makes it easy to generate many different reports, charts, and maps. AIRS Executive for Windows provides ambient air quality data from monitoring sites across the U.S.A., and pollutant emissions estimates for stationary sources regulated by the EPA. AIRS Executive for Windows also includes ambient air quality data from about 50 nations that voluntarily provided data in the early 1990s to the GEMS/AIR Programme sponsored by the United Nations World Health Organization. http://www.epa.gov/airs/aexec.html

**Alternatives for Unsewered Communities**
This program is an extensive guide to the facilities planning process for small communities. Topics covered include needs documentation, development of alternative solutions and selection of the best response, as well as treatment management and implementation. An improved and expanded section on sludge is included as well. http://www.epa.gov/seahome/unsewer.html

**Applicability Determination Index**
EPA is committed to helping entities comply with regulatory requirements and improve environmental performance through compliance assistance (CA). Compliance assistance is defined by EPA to include activities, tools or technical assistance which provide clear and consistent information for helping the regulated community understand and meet its obligations under environmental laws and regulations. http://cfpub.epa.gov/adi/

**AQUATOX Model**
AQUATOX is a simulation model for aquatic systems that predicts the fate of various pollutants, such as nutrients and organic chemicals, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants. AQUATOX is a valuable tool for ecologists, biologists, water quality modelers, and anyone involved in the performing ecological risk assessments for aquatic ecosystems. http://www.epa.gov/waterscience/models/aquatox/

**ArcHydro**
Redlands, California — ArcHydro: GIS for Water Resources, the latest title from ESRI Press, describes how a water resources data model, ArcHydro, is being applied within geographic information system (GIS) technology to provide a wide variety of hydrologic solutions. esri.com/news/releases/02_3qtr/archydro.html

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**Table 12A.6 (Continued)**

**ASSESS Software**
A computer-based tool for statistically assessing measurement errors in the collection of soil samples. http://www.epa.gov/nerlesd1/databases/assess/abstract.htm

**Assessment Database Software**
The Assessment Database (ADB) is a relational database application for tracking water quality assessment data, including use attainment, and causes and sources of impairment. States need to track this information and many other types of assessment data for thousands of waterbodies, and integrate it into meaningful reports. The ADB is designed to make this process accurate, straightforward and user-friendly for participating States, territories, tribes and basin commissions. http://www.epa.gov/waters/adb/

**BEACH Watch**
National Health Protection Survey of Beaches for the 2002 Swimming Seas. http://yosemite.epa.gov/water/beach2003.nsf

**Benchmark Dose Software (BMDS)**
Benchmark dose risk assessment software (BMDS) was designed by EPA to generate dose-response curves and facilitate the analysis, interpretation and synthesis of toxicological data. lhttp://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm

**Best Management Practices for Soil Erosion**
This program uses graphics and hypertext to provide information about soil erosion. Information is provided about the severity of erosion worldwide, in the U.S. and in the Midwest in particular. The types of water erosion are described and illustrated along with detailed descriptions of management and structural practices to control erosion.erosion.html http://www.epa.gov/seahome/erosion.html

**Better Assessment Science Integrating Point & Nonpoint Sources (Basins)**
A multi-purpose environmental analysis system that integrates a geographical information system (GIS), national watershed data, and state-of-the-art environmental assessment and modeling tools into one convenient package. http://www.epa.gov/waterscience/basins/

**BIOPLUME III Software**
BIOPLUME III is a 2D, finite difference model for simulating the natural attenuation of organic contaminants in groundwater due to the processes of advection, dispersion, sorption, and biodegradation. Biotransformation processes are potentially important in the restoration of aquifers contaminated with organic pollutants. http://www.epa.gov/ada/csmos/models/bioplume3.html

**Biennial Reporting System (BRS)**
The Hazardous Waste Report (Biennial Report) collects data on the generation, management, and minimization of hazardous waste. This provides detailed data on the generation of hazardous waste from large quantity generators and data on waste management practices from treatment, storage, and disposal facilities. http://www.epa.gov/enviro/html/brs/

**Biogenic Emissions Inventory System (BEIS)**
BEIS estimates volatile organic compound (VOC) emissions from vegetation and nitric oxide (NO) emissions from soils. Non-air-quality model users may wish to consider GloBEIS. http://www.epa.gov/asmdnerl/biogen.html

**Building for Environmental and Economic Sustainability (BEES)**
BEES software provides a technique for selecting cost-effective, environmentally preferable building products. BEES reduces complex, science-based technical content (e.g. over 400 environmental flows from raw material acquisition through product disposal) to decision-enabling results and delivers them in a graphical format. http://www.epa.gov/oppt/epp/tools/bees.htm

**Catalog of Federal Funding Sources for Watershed Protection**
A searchable database of financial assistance sources (grants, loans, cost-sharing) available to fund a variety of watershed protection projects. http://cfpub.epa.gov/fedfund/

**Center for Exposure Assessment Modeling Software**
CEAM provides proven predictive exposure assessment techniques for aquatic, terrestrial, and multimedia pathways for organic chemicals and metals. http://www.epa.gov/ceampubl/

**Center for Subsurface Modeling Support (CSMoS)**
The Center for Subsurface Modeling Support (CSMoS) provides public domain groundwater and vadose zone modeling software and services to public agencies and private companies throughout the nation. The primary aims of CSMoS are to provide direct technical support to EPA and State decision makers in subsurface model applications and to manage and support the groundwater models and databases resulting from the research at NRMRL. http://www.epa.gov/ada/csmos.html

**Central Data Exchange**
The Central Data Exchange (CDX) enables fast, efficient, and more accurate environmental data submissions from state and local governments, industry and tribes to the Environmental Protection Agency (EPA) and participating program offices. EPA's CDX is the point of entry on the Environmental Information Exchange Network (Exchange Network) for environmental data submissions to the Agency. http://www.epa.gov/cdx/

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**Table 12A.6 (Continued)**

**Certification and Fuel Economy Information System (CFEIS)**
Information about the process of entering data into the EPA's Certification and Fuel Economy Information System for light-duty vehicle and truck manufacturers. http://www.epa.gov/otaq/cfeis.htm

**CHEMFLO Software**
A program that enables users to simulate water movement and chemical transport in unsaturated soils by solving the Richards equation (water) and the convection-dispersion equation (chemicals). http://www.epa.gov/nerlesd1/databases/chemflo/access.htm

**Chemical Contamination in Fish**
A Windows based update of the original FISH program, it contains video clips illustrating concepts such as bioaccumulation, and risk reduction techniques (including cooking and filleting tips). Users can search a list of chemical contaminants and learn about their effects, or see photos and video of target species. Included are an updated list of contaminants from 1997 guidance, as well as references to an online database of fish advisories and state contacts. http://www.epa.gov/seahome/fish.html

**Chemical Hazard Information Profiles (CHIPS)**
CHIPS summarize readily available information on health and environmental effects and exposure relating to a specific chemical substance. The database contains information about chemical substances that have been referenced in these profiles. The Existing Chemicals Program currently managed by OPPT, has superseded these profiles. http://oaspub.epa.gov/srs/srs_proc_qry.navigate?P_REG_AUTH_ID=1&P_DATA_ID=11681&P_VERSION=1

**Chemical Screening Tool For Exposures & Environmental Releases (ChemSTEER)**
Estimates occupational inhalation and dermal exposure to a chemical during industrial and commercial manufacturing, processing, and use operations involving the chemical. Estimates releases of a chemical to air, water, and land that are associated with industrial and commercial manufacturing, processing, and use of the chemical. http://www.epa.gov/opptintr/exposure/docs/chemsteer.htm

**Children's Environmental Health & Safety Inventory of Research (CHESIR)**
Children's Environmental Health and Safety Inventory of Research is a publicly accessible database created and maintained to ensure that researchers and Federal research agencies have access to information on all research conducted or funded by the Federal Government that is related to adverse health risks in children resulting from exposure to environmental health risks or safety risks. http://oaspub.epa.gov/chehsir/chehsir.page

**Chemicals On Reporting Rules (CORR) Database**
The CORR database contains information on chemicals which are regulated under specific sections of the Toxic Substances Control Act (TSCA), or section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA). http://www.epa.gov/oppt/CORR/

**Clean Water State Revolving Fund National Information Management System**
The Clean Water State Revolving Fund (CWSRF) program is an innovative method of financing a wide range of projects related to water quality. The CWSRF National Information Management System produces annual reports that provide a record of progress and accountability for the program. http://www.epa.gov/r5water/cwsrf/

**Clean Watersheds Needs Survey**
The Office of Wastewater Management conducts the Clean Watersheds Needs Survey (CWNS) on a periodic basis. The CWNS, a joint effort between States and EPA, is conducted in response to Section 205(a) and 516 of the Clean Water Act. The CWNS has information on publicly-owned wastewater collection and treatment facilities, facilities for control of sanitary sewer overflows (SSOs), combined sewer overflows (CSOs), stormwater control activities, nonpoint sources, and programs designed to protect the nation's estuaries. http://www.epa.gov/owm/mtb/cwns/

**COMMUTER Model**
Reports and information that relate to the U.S. Department of Transportation's Congestion Mitigation and Air Quality Improvement Program, the environmental impacts of transportation, induced travel/induced demand, intelligent transportation systems, EPA's Commuter Model, and other transportation/air quality issues. http://www.epa.gov/otaq/transp/traqmodl.htm

**Comparative Risk Assessment Software**
Comparative risk assessment is a methodology which uses sound science, policy, economic analysis and stakeholder participation to identify and address the areas of greatest environmental risks and provide a framework for prioritizing environmental problems. http://www.epa.gov/seahome/comprisk.html

**Comply Software**
A computerized screening tool for evaluating radiation exposure from atmospheric releases of radionuclides. May be used for demonstrating compliance with some EPA and Nuclear Regulatory Commission regulations. http://www.epa.gov/radiation/assessment/comply.html

**Computational Toxicology**
Computational toxicology is the integration of modern computing and information technology with molecular biology and chemistry to improve EPA's prioritization of data requirements and risk assessments for toxic chemicals. http://www.epa.gov/comptox/

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**Table 12A.6 (Continued)**

**Computer Aided Management of Emergency Operations (CAMEO)**
CAMEO® is a system of software applications used widely to plan for and respond to chemical emergencies. CAMEO can be used to access, store, and evaluate information critical for developing emergency plans and support regulatory compliance by helping users meet the chemical inventory reporting requirements of the Emergency Planning and Community Right-to-Know Act (EPCRA, also known as SARA Title III). http://www.epa.gov/ceppo/cameo/

**Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS)**
Superfund is a program administered by the EPA to locate, investigate, and clean up the worst hazardous waste sites throughout the United States. http://www.epa.gov/enviro/html/cerclis/

**Confidence Interval Calculation for Source Partitioning Using Stable Isotopes**
ISOERROR1_04 is a Microsoft Excel 2000™ spreadsheet which calculates estimates and confidence intervals of source proportional contributions to a mixture, using stable isotope analyses. http://www.epa.gov/wed/pages/models/isotopes/isoerror1_04.htm

**Consolidated Human Activity Database (CHAD)**
Consolidated Human Activity Database (CHAD) contains data obtained from pre-existing human activity studies that were collected at city, state, and national levels. CHAD is intended to be an input file for exposure/intake dose modeling and/or statistical analysis. http://www.epa.gov/chadnet1/

**Cornell Mixing Zone Expert System (CORMIX)**
Cornell Mixing Zone Expert System (CORMIX) is no longer distributed or supported by the EPA Center for Exposure Assessment Modeling (CEAM). Information on a Windows version of CORMIX is available from the CORMIX Home Page. http://www.epa.gov/ceampubl/swater/cormix/index.htm

**Decentralized Onsite Management for Treatment of Domestic Wastes Software**
This program provides operation and maintenance information for on-site wastewater treatment systems, such as septic systems. http://www.epa.gov/seahome/decent.html

**DEFT Software**
A program that allows users to evaluate the financial feasibility of incorporating selected data quality objective (DQO) constrains into a statistical sampling design before developing a final plan — the program assists with the seven-step DQO process, which is used to develop statistical sampling design plans. http://www.epa.gov/nerlesd1/databases/deft/access.htm

**Delisting Risk Assessment Software (DRAS)**
The Delisting Risk Assessment Software (DRAS) is a Windows-based computer program that predicts risks to human health and the environment from the disposal of wastes to a landfill or surface impoundment. The DRAS is used to calculate potential chemical releases, fate and transport of the chemicals and to determine risk associated with exposure to the chemicals released. epa.gov/region6/6pd/rcra_c/pd-o/dras/dras.htm

**DFLOW Software**
DFLOW is a Windows-based tool developed to estimate user selected design stream flows for low flow analysis and water quality standards. http://epa.gov/waterscience/dflow/

**Dietary Exposure Potential Model**
A Model Using Extant Food Databases to Estimate Dietary Exposure to Chemical Residues. http://www.epa.gov/nerlcwww/depm.htm

**Drinking Water Contaminant Candidate List**
The drinking water Contaminant Candidate List (CCL) is the primary source of priority contaminants for evaluation by EPA's drinking water program. The Safe Drinking Water Act (SDWA), as amended in 1996, requires EPA to publish a list of contaminants every five years which, at the time of publication, are not subject to any proposed or promulgated national primary drinking water regulations. Contaminants on the CCL are known or anticipated to occur in public water systems and may require regulations under SDWA. http://www.epa.gov/safewater/ccl/cclfs.html

**Ecological Structure Activity Relationships (ECOSAR)**
ECOSAR (Ecological Structure Activity Relationships) is a personal computer software program that is used to estimate the toxicity of chemicals used in industry and discharged into water. The program predicts the toxicity of industrial chemicals to aquatic organisms such as fish, invertebrates, and algae by using Structure Activity Relationships (SARs). The program estimates a chemical's acute (short-term) toxicity and, when available, chronic (long-term or delayed) toxicity. http://www.epa.gov/opptintr/newchems/21ecosar.htm

**ECOTOX Database**
The ECOTOXicology database is a source for locating single chemical toxicity data for aquatic life, terrestrial plants and wildlife. ECOTOX integrates three toxicology effects databases: AQUIRE (aquatic life), PHYTOTOX (terrestrial plants), and TERRETOX (terrestrial wildlife). These databases were created by the U.S. EPA, Office of Research and Development (ORD), and the National Health and Environmental Effects Research Laboratory (NHEERL), Mid-Continent Ecology Division. http://www.epa.gov/ecotox/

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**Table 12A.6 (Continued)**

**8(e) TRIAGE Chemical Studies Database**
The primary purpose of this information product is to make TSCA 8(e) submission information accessible to the general public and organizations whose efforts are associated with protection of health and safety. http://www.epa.gov/opptintr/8e_triag/

**Electronic Wetlands Herbarium**
A detailed look at the plants typical of 11 different wetland types from bog to wet prairie. Each entry gives detailed botanical information as well as a photo of the plant. The outstanding photos are identification quality. Examples are taken from the U.S. Midwest region. http://www.epa.gov/seahome/wetherb.html

**Emergency Response Notification System**
The Emergency Response Notification System (ERNS) is a computer database containing information on release notifications of oil and hazardous substances that have occurred throughout the United States and have been reported to the National Response Center (NRC) and/or one of the 10 EPA Regions. http://www.epa.gov/region08/community_resources/ppt/pptemerge.html

**Emissions & Generation Resource Integrated Database (eGRID)**
eGRID is a database that provides information on the air quality attributes of almost all the electric power generated in the United States. eGRID provides you with many search options, including information for individual power plants, generating companies, states, and regions of the power grid. http://www.epa.gov/cleanenergy/egrid/index.html

**Endangered Species Protection Program Databases**
Provides the endangered species by county and the species information database. http://www.epa.gov/espp/database.htm

**Energy Star Software Tools**
Energy star is a government-backed program helping businesses and individuals protect the environment through superior energy efficiency. http://www.energystar.gov

**Enforcement & Compliance History Online (ECHO)**
Use ECHO to determine whether compliance inspections have been conducted by EPA or State/local governments; violations were detected; and enforcement actions were taken and penalties were assessed in response to environmental law violations. http://www.epa.gov/echo/

**Enforcement Economic Models — ABEL, BEN, CASHOUT, PROJECT, INDIPAY, MUNIPAY**
The economic enforcement models are used to analyze the financial aspects of enforcement actions. http://www.epa.gov/compliance/civil/programs/econmodels/index.html#models

**Enhanced Stream Water Quality Model, Windows (QUAL2E)**
The Enhanced Stream Water Quality Model (QUAL2E) is a steady state model for conventional pollutants in branching streams and well mixed lakes. The model can be used to study impact of waste loads on in-stream water quality and identify magnitude and quality characteristics of nonpoint waste loads. http://www.epa.gov/ceampubl/swater/qual2eu/index.htm

**Envirofacts**
Envirofacts, is a single point of access to select U.S. EPA environmental data. This website provides access to several EPA databases to provide information about environmental activities that may affect air, water, and land anywhere in the United States. http://www.epa.gov/enviro/index.html

**Environmental Assessment Case Study**
A companion to the 1992 Environmental Assessment Resource Guide, the program utilizes real-life examples of an environmental impact assessment and leads the user through the environmental assessment process. http://www.epa.gov/seahome/eacase.html

**Environmental Assessment Resource Guide**
EARG is a generic source of information to help assist in the conduct of environmental assessments of virtually any type of project. Topics covered include scoping, generation of alternatives, impact identification and analysis, mitigation, decision-making and post-decision analysis. http://www.epa.gov/seahome/earg.html

**Environmental Data Registry (EDR)**
The Environmental Data Registry (EDR) is a comprehensive, authoritative reference for information about the definition, source, and uses of environmental data. The EDR supports the creation and implementation of data standards that are designed to promote the efficient sharing of environmental information among EPA, states, tribes, and other information trading partners. The EDR also catalogs data elements in application systems. The EDR does not contain environmental data—it provides descriptive information to make the data more meaningful. http://www.epa.gov/edr/

**Environmental Financing Information Network (EFIN)**
The Environmental Financing Information Network (EFIN) provides information services needed by state, sub-state, municipal and EPA officials and small business owners involved in funding environmental programs and projects. These information services include maintaining the EFP Web site and the EFIN database, which are the main methods for disseminating information on environmental financing altermatives; an infoline that provides referrals and assistance with locating environmental financing information, and distribution of EPA publications on the topic of environmental finance. http://www.epa.gov/efinpage/efin.htm#desc

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**Table 12A.6 (Continued)**

**Environmental Information Management System (EIMS)**
EPA's Office of Research and Development (ORD) has developed a scientific environmental information management system (EIMS) that stores, manages, and delivers descriptive information (metadata) for data sets, databases, documents, models, multimedia, projects, and spatial information. The EIMS design also provides a repository for scientific documentation that can be easily accessed with standard Web browsers to place a virtual library on the desktop of EPA staff and others with Internet access. epa.gov/eims/

**Environmental Planning for Small Communities (TRILOGY)**
This program offers a complete one-stop introduction to a wide range of environmental issues and decisions that affect small to medium-sized communities. It offers communities the chance to judge their own needs and preferences, and to make informed decisions on their own. Major sections cover Environmental laws and regulations, Self-assessment, Planning and comparative risk analysis, Financial tools and financial self-analysis, Case studies, and Contact and information directory. http://www.epa.gov/seahome/trilogy.html

**Environmentally Preferable Purchasing (EPP) Database**
The Environmentally Preferable Purchasing (EPP) Database — a tool to make it easier to purchase products and services with reduced environmental impacts. Environmental information on over 600 products and services is included in this database. epa.gov/opptintr/epp/database.htm

**Environmental Radiation Ambient Monitoring System (ERAMS) Database**
The Environmental Radiation Ambient Monitoring System (ERAMS) is a national network of monitoring stations that regularly collect air, precipitation, drinking water, and milk samples for analysis of radioactivity. The ERAMS network has been used to track environmental releases resulting from nuclear emergencies and to provide baseline data during routine conditions. Data generated from ERAMS provides the information base for making decisions necessary to ensure the protection of public health. http://www.epa.gov/enviro/html/erams/

**Enviro$en$e Solvent Substitution Data Systems**
Enviro$en$e, part of the U.S. EPA's web site, provides a single repository for pollution prevention, compliance assurance, and enforcement information and data bases. The search engine searches multiple web sites (inside and outside the EPA), and offers assistance in preparing a search. http://es.epa.gov/ssds/ssds.html

**Enviro$en$e VendInfo**
Vendor Information (VendInfo) search page, a repository of more than 1200 listings of pollution prevention equipment, products, or services. This page provides listings using a free text method, or by selecting from the various equipment categories. http://es.epa.gov/vendors/

**EPANET Software**
EPANET is a Windows 95/98/NT program that performs extended period simulation of hydraulic and water-quality behavior within pressurized pipe networks. A network can consist of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised multiple time steps. In addition to chemical species, water age and source tracing can also be simulated. http://www.epa.gov/ORD/NRMRL/wswrd/epanet.html

**EPA REACH IT — Remediation and Characterization Innovative Technologies**
EPA REACH IT, sponsored by EPA's Office of Superfund Remediation and Technology Innovation (OSRTI), is a system that lets environmental professionals use the Internet to search, view, download, and print information about innovative remediation and characterization technologies. epareachit.org/

**Estimation Program Interface (EPI) Suite**
The EPI (Estimation Programs Interface) SuiteTM is a Windows® based suite of physical/chemical property and environmental fate estimation models developed by the EPA's Office of Pollution Prevention Toxics and Syracuse Research Corporation (SRC). EPI SuiteTM uses a single input to run the following estimation models: KOWWINTM, AOPWINTM, HENRYWINTM, MPBPWINTM, BIOWINTM, PCKOCWINTM, WSKOWWINTM, BCFWINTM, HYDROWINTM, and STPWINTM, WVOLWINTM, and LEV3EPITM. EPI SuiteTM was previously called EPIWIN. epa.gov/opptintr/exposure/docs/episuite.htm

**Exposure Analysis Modeling System (EXAMS)**
The Exposure Analysis Modeling System (EXAMS) is an interactive software application for formulating aquatic ecosystem models and rapidly evaluating the fate, transport, and exposure concentrations of synthetic organic chemicals including pesticides, industrial materials, and leachates from disposal sites. http://www.epa.gov/ceampubl/swater/exams/index.htm

**Exposure, Fate Assessment Screening Tool**
Provides screening-level estimates of the concentrations of chemicals released to air, surface water, landfills, and from consumer products. E-FAST Version 2 is being designed to support both new chemicals and existing chemical programs. Estimates provided are potential inhalation, dermal and ingestion dose rates resulting from these releases. Modeled estimates of concentrations and doses are designed to reasonably overestimate exposures, for use in screening level assessment. http://www.epa.gov/opptintr/exposure/docs/efast.htm

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**Table 12A.6 (Continued)**

**Extremely Hazardous Substances (EHS) Chemical Profiles and Emergency First Aid Guides**

This is information about each of the 300+ EHS currently listed as part of Section 302 of the Emergency Planning and Community Right-to-Know Act. Each chemical profile includes physical/chemical properties, health hazards, fire and explosion hazards, reactivity data, precautions for safe handling and use, and protective equipment for emergency situations. The first aid guide provides signs and symptoms of poisoning and emergency treatment for first responders. The chemical profiles and first aid guides may be accessed from either the CAS No. or alphabetical list of EHS. http://yosemite.epa.gov/oswer/ceppoehs.nsf/EHS_Profile?openform

**Facility Registry System (FRS)**

The Facility Registry System (FRS) is a centrally managed database that identifies facilities, sites or places subject to environmental regulations or of environmental interest. FRS creates high-quality, accurate, and authoritative facility identification records through rigorous verification and management procedures that incorporate information from program national systems, state master facility records, data collected from EPA's Central Data Exchange registrations and data management personnel. The FRS provides Internet access to a single integrated source of comprehensive (air, water, and waste) environmental information about facilities, sites or places. http://www.epa.gov/enviro/html/fii/index.html

**Factor Information REtrieval (FIRE)**

The Factor Information REtrieval (FIRE) Data System is a database containing EPA's emission estimation factors for criteria and hazardous air pollutants in an easy to use Windows program. Users can browse through records in the database or select specific emission factors by source category, source classification code (SCC), pollutant name, CAS number, or control device. FIRE 6.25 contains emission factors from the Compilation of Air Pollutant Emission Factors (AP-42 Fifth Edition) for all AP42 sections posted by September 1, 2004, the Locating and Estimating (L&E) series of documents, and the retired AFSEF and XATEF documents. All EPA Source Classification Codes (SCC) through September 1, 2004 are in the FIRE database. http://www.epa.gov/ttn/chief/software/fire/index.html

**Federal Energy Management Program (FEMP) Software**

Analytical software tools are intended to help choose conservation measures that are most cost effective and environmentally friendly. Used at the facility evaluation and assessment stage of energy project development, the tools compare potential energy conservation measures by performing complex energy consumption analyses and modeling, as well as comparative life-cycle costing analyses. eere.energy.gov/femp/information/access_tools.cfm

**FEMWATER/LEWASTE Model**

Three-Dimensional Finite Element Model of Water Flow Through Saturated-Unsaturated Media (3DFEMWATER) and Three-Dimensional Lagrangian–Eulerian Finite Element Model of Waste Transport Through Saturated–Unsaturated Media (3DLEWASTE) are related and can be used together to model flow and transport in three-dimensional, variably-saturated porous media under transient conditions with multiple distributed and point sources/sinks. These models can be used to apply the assimilative capacity criterion to development of wellhead protection areas, as each U.S. state is required to do under the 1986 Amendments to the Safe Drinking Water Act. http://www.epa.gov/ceampubl/gwater/femwater/index.htm

**Fertilizer Storage and Handling Software**

This HTML program gives a general overview of fertilizer handling and storage, and features a risk assessment section, and recommendations for correcting fertilizer storage problems. http://www.epa.gov/seahome/farmfert.html

**FIFRA Section 18 Database**

The EPA FIFRA Section 18 Emergency Exemption database provides information about current and recent actions under Section 18. For detailed information about the tolerances associated with a particular action, the Federal Register can be accessed to locate the tolerance document according to the date it was published. This database is updated approximately every 2 weeks. http://www.epa.gov/opprd001/section18/#dbinfo

**FLOW-CALC Software**

FLOW-CALC is a software tool developed by EPA's Clean Air Markets Division for stack testers who perform flow RATAs for units under the Acid Rain Program, the OTC NOx Budget Program and the SIP Call NOx Budget Trading Program. The software is designed to improve data quality and facilitate the entry of flow RATA data into EDR v2.1 format. http://www.epa.gov/airmarkets/monitoring/mdc/flowcalc.html

**Food and Gill Exchange of Toxic Substances (FGETS) Software Model**

Food and Gill Exchange of Toxic Substances (FGETS) is a FORTRAN simulation model that predicts temporal dynamics of fish whole body concentration [ug chemical/(g live weight fish)] of non ionic, nonmetabolized, organic chemicals that are bioaccumulated from either: (a) water only — the predominant route of exchange during acute exposures, or (b) water and food jointly — characteristic of chronic exposures. http://www.epa.gov/ceampubl/fchain/fgets/index.htm

**Fuel Storage Practices on the Farm**

An overview of the importance and techniques of proper fuel storage. The risk assessment portion prompts the user to describe how petroleum products are stored and then evaluates the safety of these practices and provides detailed information about any problems discovered through the questionnaire. http://www.epa.gov/seahome/farmfuel.html

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**Table 12A.6 (Continued)**

**Fuels Models**
This Web page provides information on models estimating emissions impacts to changes in fuel properties and composition. http://www.epa.gov/otaq/fuelsmodel.htm

**GCSOLAR Model**
GCSOLAR program is a set of routines that computes direct photolysis rates and half-lives of pollutants in the aquatic environment. The half-lives are calculated as a function of season, latitude, time-of-day, depth in water bodies, and ozone layer thickness. This program operates in an interactive screen mode to facilitate data and program command entry by the user. Input values, with few restrictions, are format free. The user controls program flow by entering program execution commands. http://www.epa.gov/ceampubl/swater/gcsolar/index.htm

**Geo-EAS Software**
A collection of interactive software tools for performing two-dimensional geostatistical analyses of spatially distributed data. The principal functions of the package are the production of grids and contour maps of interpolated (kriged) estimates from sample data. Geo-EAS can produce data maps, univariate statistics, scatter plots/linear regression, and variogram computation and model fitting. http://www.epa.gov/nerlesd1/databases/geo-eas/access.htm

**GEOPACK Software**
A comprehensive geostatistical software package that allows both novice and advanced users to undertake geostatistical analyses of spatially correlated data. The program generates graphics (i.e. linear or logarithmic line plots, contour and block diagrams); computes basic statistics (i.e., mean, median, variance, standard deviation, skew, and kurtosis); runs programs for linear regression, polynomial regression, and Kolomogorov-Smirnov tests; calculates linear estimations and nonlinear estimations; and determines sample semivariograms and cross-semivariograms. http://www.epa.gov/nerlesd1/databases/geo-pack/access.htm

**Geophysics Advisor Software**
This program aids in the sampling and monitoring of hazardous waste sites. Utilizing an initial set of questions, the program develops an initial profile that is further refined by additional question based upon earlier answers. The program considers several geophysical methods: electromagnetic induction; resistivity; ground-penetrating radar; magnetic; seismic; soil gas; gravity; and radiometric. The program recommends the type(s) of geophysics that will most likely fit the site requirements for determining the location of contamination and providing site characterization. various methods is shown on screen, indicating the degree of superiority of one method over another. This version contains a database of the physical and chemical properties of 94 substances selected from EPA's first priority list. http://www.epa.gov/nerlesd1/databases/geophy-adv/geophysi.htm

**GEOS Software**
A public-domain software package developed by EPA to facilitate the collection and analysis of geoenvironmental data. The term "geoenvironmental" includes soil, geologic, and groundwater data collected to assess or monitor environmental conditions at a site. Major GEOS functions include easy data entry (standard database format allows the user to enter data in a spreadsheet format); simple data management and reporting (such as sorts and queries); preliminary site visualization (contouring of soil and groundwater chemical concentration isopleths, creation of actual and interpolated geologic cross sections, and viewing of well screen intervals in relation to subsurface geology); data exchange (existing GRITS/STAT facility data can be imported into GEOS for contouring of groundwater quality data using the PSV module); access to other geoenvironmental software (GEOS provides a convenient framework for moving between multiple programs). http://www.epa.gov/nerlesd1/databases/geos/abstract.htm

**Geospatial Data Clearinghouse**
The U.S. Environmental Protection Agency (EPA) Node of the National Geospatial Data Clearinghouse is a component of the *National Spatial Data Infrastructure (NSDI)*. This node provides a pathway to find information about geospatial data available from the EPA. Geospatial data is used in Geographic Information Systems (GIS) to identify the geographic location and characteristics of natural or man-made features and boundaries on the earth. http://www.epa.gov/nsdi/

**Global Endocrine Disruptor Research Inventory (GEDRI)**
This compilation of on going research projects related to endocrine disruptions was assembled following the recommendation of the Intergovernmental Forum on Chemical Safety (IFCS) and the 1997 Declaration of the Environment Leaders of the Eight on Children's Environmental Health. The initial goal was to bring together and update the existing United States Inventory with those of the Canadian government and the European Union. With this accomplished, the organization is now encouraging and accepting submission of research projects by other countries and private industry. http://oaspub.epa.gov/endocrine/pack_edri.All_Page

**EPA Grant Writing Tutorial Software**
This interactive software tool walks the user through the grant-writing process and helps them learn to write more competitive grants. The program includes: detailed information and tips on writing a grant proposal; how to complete a grant application package; program-specific sections on three EPA grant programs: (1) Environmental Justice, (2) Environmental Justice through Pollution Prevention; and (3) Environmental Education; examples of good, complete grant packages; references; a glossary of terms; resources and contacts; and a mock grant-writing activity where the user is able to compare their results to a successful grant application epa.gov/seahome/grants.html

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**Table 12A.6 (Continued)**

**Grants Information and Control System (GICS)**
EPA's management information system for grants programs is the Grants Information and Control System (GICS), which awards, administers, and monitors grants. Grants are regularly awarded to Federal, State, or local government agencies, universities, and other institutions that support EPA's environmental programs. Specific types of agreements include assistance agreements, grants, cooperative agreements, interagency agreements, and other types of program support agreements administered by Headquarters or EPA regions. These program support agreements provide for research, demonstration projects, training, fellowships, investigations, surveys, studies, and other types of program support activities. http://www.epa.gov/enviro/html/gics/

**Great Lakes Adventure Software**
This program (Teacher and Student versions) is aimed at a youth audience (grades 9–12) and will run on both Wintel and Mac computers. Investigate the natural history of the basin, the water cycle, stratification and turnover of the lakes. Explore six Hot Topics: (1) Habitat loss; (2) Beach closures; (3) Fish communities; (4) Toxics; (5) Exotic Species; and (6) Eutrophication

**Great Lakes Environmental Database**
The *Great Lakes National Program Office* (GLNPO) collects environmental data on a wide variety of constituents in water, biota, sediment, and air. Central to the data management effort is a computerized relational database system to house *Lake Michigan Mass Balance* and other project results. That system, the Great Lakes Environmental Database (GLENDA), was developed to provide data entry, storage, access and analysis capabilities to meet the needs of mass balance modelers and other potential users of Great Lakes data. http://www.epa.gov/glnpo/monitoring/data_proj/glenda/

**Green Chemistry Expert System**
Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation or hazardous waste. The Microsoft Access driven GCES software is a stand-alone version of the program designed to perform custom applications. http://www.epa.gov/greenchemistry/gces.html

**GRITS/STA Software**
A comprehensive database system for storing, analyzing, and reporting information from groundwater monitoring programs at RCRA, CERCLA, and other regulated facilities and sites. This software program integrates EPA's Groundwater Information Tracking System, a database of groundwater information, with STAT, a statistical analysis system. The package provides a nationally responsive system that incorporates data elements from appropriate EPA program offices. The system supports data entry, report generation, export of data to other software applications (e.g., modeling programs), and statistical analysis. http://www.epa.gov/nerlesd1/databases/grits-stat/abstract.htm

**Ground Water Primer**
This update of the original groundwater program educates users about the nature of groundwater and the principles of groundwater protection. It contains a detailed introduction to hydrogeology, information on numerous drinking water contaminants, and a section on what you can do to protect your groundwater. http://www.epa.gov/seahome/gwprimer.html

**Hazards Analysis for Toxics Analysis (HATS) Software**
EPA and NOAA developed this web site to facilitate the use of CAMEO and to offer online technical support. http://www.epa.gov/ceppo/cameo/

**Hazardous Waste Management on the Farm Software**
This tutorial is intended to serve as a guide towards proper hazardous waste management. Knowing the regulations, different methods of disposal of hazardous waste, and how to provide a safer environment are all part of proper hazardous waste management. A risk assessment included in this program will allow you to identify high risk practices on farms. http://www.epa.gov/seahome/farmhaz.html

**Health Effects Notebook for Hazardous Air Pollutants**
The fact sheets available on this Web page describe the effects on human health of substances that are *defined as hazardous* by the 1990 amendments of the *Clean Air Act*. These substances include certain volatile organic chemicals, pesticides, herbicides, and radionuclides that present tangible hazard, based on scientific studies of exposure to humans and other mammals. There is uncertainty in the precise degree of hazard, and readers are cautioned that the fact sheets may be revised as additional data become available. http://www.epa.gov/ttnatw01/hlthef/hapindex.html

**HELP Software**
A quasi-two-dimensional modeling program that simulates water movement into and out of landfills based on a waste management systems particular design. The user can conduct water-balance analyses of solid waste disposal and containment facilities. The program allows comparison of proposed landfill designs by estimating runoff, evapotranspiration, drainage, leachate collection, and liner leakage. Modeling incorporates information on cover soils, waste cells, lateral drain layers, low permeability barrier soils, synthetic geomembrane liners, and weather. Results are expressed as daily, monthly, annual, and long-term water budgets. Although applicable to most landfills, HELP was developed specifically for modeling hazardous and municipal solid waste landfills as required by RCRA. http://www.epa.gov/nerlesd1/databases/help/abstract.htm

**High Production Volume (HPV) Voluntary Challenge Chemical List**
Searchable database of the 1990 or 1994 list by CAS Number, Chemical Name, Indicator value, Chemical Sponsorship Status, or Sponsor Commitment Status. epa.gov/chemrtk/opptsrch.htm

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**Table 12A.6 (Continued)**

**The Hotelling/Williams Test for the Difference between Two Dependent Correlations**
The Hotelling/Williams procedure tests the null hypothesis of equality between two dependent product-moment correlations. Specifically, it tests whether the correlation between Z and X differs from the correlation between Z and Y, where X, Y and Z are three variables measured on the same set of observational units. http://www.epa.gov/wed/pages/models/correlations/correlations.htm

**Household Waste Management Software**
This HTML program teaches the user how to safely and efficiently manage waste, and particularly hazardous waste, in the home. Users can visit a 'virtual house' and choose extended discussions of the many products they might encounter there. Safe homemade alternatives are presented and evaluated. An enormous state-by-state database of mail, telephone, and Internet contacts puts users in touch with a wealth of free downloadable publications. Provides over 30 quizzes and activities for K-12 students, sorted by grade level. http://www.epa.gov/seahome/hwaste.html

**Human Exposure Database Software**
HEDS is the Human Exposure Database System. HEDS is an integrated database system that contains chemical measurements, questionnaire responses, documents, and other information related to EPA research studies of the exposure of people to Environmental contaminants. http://www.epa.gov/heds/index.htm

**Human Exposure Model (HEM)**
The Human Exposure Model (HEM) is used primarily for performing risk assessments for major point sources (usually producers or large users of specified chemicals) of air toxics. The HEM only addresses the inhalation pathway of exposure, and is designed to predict risks associated with emitted chemicals in the ambient air (i.e., in the vicinity of an emitting facility but beyond the facility's property boundary). The HEM provides ambient air concentrations, as surrogates for lifetime exposure, for use with unit risk estimates and inhalation reference concentrations to produce estimates of cancer risk and noncancer hazard, respectively, for the air toxics modeled. http://www.epa.gov/ttn/fera/human_hem.html

**Hydrodynamic, Sediment, and Contaminant Transport Model (HSCTM2D)**
The Hydrodynamic, Sediment, and Contaminant Transport Model (HSCTM2D) is a finite element modeling system for simulating two-dimensional, vertically-integrated, surface water flow (typically riverine or estuarine hydrodynamics), sediment transport, and contaminant transport. The modeling system consists of two modules, one for hydrodynamic modeling (HYDRO2D) and the other for sediment and contaminant transport modeling (CS2D). One example problem is included. The HSCTM2D modeling system may be used to simulate both short term (less than 1 year) and long term scour and/or sedimentation rates and contaminant transport and fate in vertically well mixed bodies of water. http://www.epa.gov/ceampubl/swater/hsctm2d/index.htm

**Hydrological Simulation Program — FORTRAN (HSPF)**
Hydrological Simulation Program — FORTRAN (HSPF) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates watershed-scale ARM and NPS models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with In-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at any point in a watershed. HSPF simulates three sediment types (sand, silt, and clay) in addition to a single organic chemical and transformation products of that chemical. http://www.epa.gov/ceampubl/swater/hspf/

**IMES Software**
A computer-based tool for matching a site's characteristics with the appropriate model or models. This integrated system for model evaluation has three elements: (1) A selection system for use in choosing an exposure assessment model (currently for air, groundwater, nonpoint source, and surface water media models); (2) A validation database that includes information on models for air, groundwater, nonpoint source, and surface water assessment; and (3) A model uncertainty database (currently only for six surface water models). Each IMES element can be used independently. Once a model(s) has been selected, information on model uncertainty can be accessed. http://www.epa.gov/nerlesd1/databases/imes/abstract.htm

**Improving Silage Storage on the Farm Software**
To prevent possible well contamination, silos should be located as far away from wells as practical. This program gives a general overview of silage storage, and features a risk assessment section, and recommendations for correcting silage storage problems. http://www.epa.gov/seahome/silage.html

**Indoor Air Quality Software**
Indoor air quality problems carry a high degree of human health risk. This program explores how the environment of a typical home or office affects indoor air quality. Colorful building cross-sections offer users self-guided home, office and pollutant tours. Sources of various indoor air pollutants are discussed, along with associated health risks for each pollutant, and how to reduce pollutant levels. http://www.epa.gov/seahome/indoor.html

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**Table 12A.6 (Continued)**

**Industrial Waste Air Model (IWAIR)**
EPA developed IWAIR to assist facility managers and regulatory agency staff in evaluating inhalation risks. Workers and residents in the vicinity of a unit may be exposed to volatile chemicals from the unit in the air they breathe. Exposure to some of these chemicals at sufficient concentrations may cause a variety of cancer and noncancer health effects (such as developmental effects in a fetus or neurological effects in an adult). With a limited amount of site-specific information, IWAIR can estimate whether specific wastes or waste management practices may pose an unacceptable risk to human health. http://www.epa.gov/epaoswer/non-hw/industd/iwair.htm

**Industrial Waste Management Evaluation Model (IWEM)**
The IWEM software is designed to assist in determining the most appropriate waste management unit design to minimize or avoid adverse groundwater impacts, by evaluating types of liners, the hydrogeologic conditions of the site, and the toxicity and expected leachate concentrations of the anticipated waste constituents. The software compares the groundwater protection afforded by various liner systems with the anticipated leachate concentrations to determine what minimum liner system is needed to be protective of human health and groundwater resources (or in the case of land application units (LAUs), determine whether or not land application is recommended). http://www.epa.gov/epaoswer/non-hw/industd/iwem.htm

**Integrated Compliance Information System (ICIS)**
The Integrated Compliance Information System (ICIS) supports the information needs of the National Enforcement and Compliance program as well as the unique needs of the National Pollutant Discharge Elimination System (NPDES) program. ICIS will integrate data that is currently located in more than a dozen separate data systems. The Web-based system will eventually enable individuals from states, communities, facilities, and EPA to access integrated enforcement and compliance data from any desktop connected to the Internet. EPA's ability to target the most critical environmental problems will improve as the system integrates data from all media. epa.gov/Compliance/planning/data/modernization/index.html

**Integrated Data for Enforcement Analysis System (IDEA)**
The Integrated Data for Enforcement Analysis system (IDEA) is a comprehensive single-source of environmental performance data on regulated facilities within the EPA. IDEA provides a comprehensive historical profile of inspections, enforcement actions, penalties assessed, toxic chemicals released, and emergency hazardous spills for any EPA regulated facility. This single point of access provides information from the Agency's Air, Water, Hazardous Waste, Toxic Chemical Release Inventory, and Emergency Response Notification Systems. epa.gov/Compliance/planning/data/multimedia/idea/index.html

**Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK)**
Lead poisoning presents potentially significant risks to the health and welfare of children all over the world today. The Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) attempts to predict blood-lead concentrations (PbBs) for children exposed to lead in their environment. http://www.epa.gov/superfund/programs/lead/ieubk.htm

**Integrated Risk Information System (IRIS)**
The Integrated Risk Information System (IRIS) is prepared and maintained by the U.S. Environmental Protection Agency (U.S. EPA), is an electronic database containing information on human health effects that may result from exposure to various chemicals in the environment. IRIS was initially developed for EPA staff in response to a growing demand for consistent information on chemical substances for use in risk assessments, decision-making and regulatory activities. The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences. http://www.epa.gov/iris/intro.htm

**Internet Geographical Exposure Modeling System (IGEMS)**
The IGEMS is a modernization of OPPT's older Graphical Exposure Modeling System and PCGEMS tools. IGEMS brings together in one system several EPA environmental fate and transport models and some of the environmental data needed to run them. IGEMS includes models and data for ambient air, surface water, soil, and groundwater, and makes the models much easier to use than their stand-alone counterparts. IGEMS will have graphics and Geographical Information System (GIS) capabilities for displaying environmental modeling results. http://www.epa.gov/opptintr/exposure/docs/gems.htm

**IsoConc: Concentration-Dependent Stable Isotope Mixing Model**
ISOCONC1_01.xls is a Microsoft Excel 2000™ spreadsheet which performs calculations for the concentration-weighted stable isotope mixing model outlined in Phillips DL & Koch PL (2002) Incorporating concentration dependence in stable isotope mixing models, Oecologia 130: 114–125. This dual-isotope model takes into account isotopic element concentration differences among the sources in determining the proportional contributions of sources to a mixture. epa.gov/wed/pages/models/isoconc/isoconc1_01.htm

**IsoConc: Confidence Interval Calculation for Source Partitioning Using Stable Isotopes**
ISOERROR1_04 is a Microsoft Excel 2000™ spreadsheet which calculates estimates and confidence intervals of source proportional contributions to a mixture, using stable isotope analyses. Examples include the proportions of different food sources in an animal's diet, C3 vs. C4 plant inputs to soil organic carbon, etc. Linear mixing models are used to partition two sources with a single isotopic signature (e.g., d13C) or three sources with a second isotopic signature (e.g., d15N). epa.gov/wed/pages/models/isotopes/isoerror1_04.htm

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**Table 12A.6 (Continued)**

**IsoSource: Stable Isotope Mixing Model for Partitioning an Excess Number of Sources**
IsoSource is a Microsoft Visual Basic™ software package which calculates ranges of source proportional contributions to a mixture based on stable isotope analyses when the number of sources is too large to permit a unique solution ($>$ number of isotope systems $+1$). Examples include partitioning of pollutant sources in a waste stream, food sources in an animal's diet, water sources for plant uptake, carbon sources in soil organic matter, and many others. epa.gov/wed/pages/models/isosource/isosource.htm

**Landfill Air Emissions Estimation Model**
The Landfill Air Emissions Model is PC-based software for estimating emissions of methane, carbon dioxide, nonmethane organic compounds, and hazardous air pollutants from municipal solid waste landfills. These emissions are generated by decomposition of refuse in landfills. The mathematical model used in Landfill is based on a first order decay equation that can be run using site-specific data supplied by the user for the parameters needed to estimate emissions or, if data are not available, using default value sets included in Landfill. epa.gov/oar/oaqps/landfill.html

**LandView® 5**
LandView 5 contains selected Census 2000 demographic data from Summary File 1 (SF1) and maps based on the Census 2000 TIGER/Line® files for all states, the District of Columbia and Puerto Rico. These maps show both streets and Census 2000 legal and statistical areas (including Census 2000 Urban/Rural delineations). LandView 5 also contains recent EPA and USGS Geographic Names Information System (GNIS) data and maps. http://www.census.gov/geo/landview/lv5/lv5.html

**LC50 (Lethal Concentration, 50%) Software Model**
LC50 (lethal concentration, 50%) estimates LC50 values using the Trimmed Spearman-Karber Method. This program originated at Montana State University and has been modified by data processing staffs at the Duluth and Athens National Exposure Research Laboratories. http://www.epa.gov/ceampubl/fchain/lc50/index.htm

**The Lead Contamination Information System (Lead in Drinking Water)**
The dangers of lead in drinking water are explained using graphics and hypertext. The program provides basic facts about this vital topic, answering common questions on the effects of lead in drinking water, and presenting techniques for reducing lead exposure. leaddw.html http://www.epa.gov/seahome/leaddw.html

**Lead in the Environment Software**
A detailed look at the health problems posed by lead. Learn about testing children for lead poisoning. This hypertext program presents sources of lead, health effects, and techniques for reducing lead exposure in and around the home. A quiz helps users review what they have learned, and the reference section points them to local, regional and national sources of information and help. http://www.epa.gov/seahome/leadenv.html

**List of Lists Database — Consolidated list of Chemicals Subject to the Emergency Planning and Community Right-to-Know Act (EPCRA and Section 112® of the Clean Air Act**
This is a searchable database of EPA's October 2001 Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-to-Know Act (EPCRA) and Section 112(r) of the Clean Air Act. The entire database is available as a PDF file. epa.gov/ceppo/pubs/title3.pdf

**Local Emergency Planning Committee (LEPC) Database**
The Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 required each state's Governor to establish a state emergency response commission (SERC) which in turn resulted in the formation of local emergency planning committees. The database provides information related to data compiled by LEPCs nationwide. epa.gov/ceppo/lepclist.htm

**Livestock Manure Handling**
Similar in content to Livestock Manure Storage, this program gives an overview of manure types and proper management systems for different animals including cattle, swine, sheep, poultry, and horses. Users can evaluate their own risk through the interactive questionnaire, and receive suggestions for reducing the threat to their water supply. http://www.epa.gov/seahome/manure-handle.html

**Mean Similarity Analysis**
MEANSIM6 contains software for Mean Similarity Analysis, a method of assessing the strength of a classification of many objects (sites) into a relatively small number of groups. Classification strength is measured by the extent to which sites within the same groups are more similar to each other, on average, than they are to sites in different groups. Users supply a matrix of pairwise similarities (or dissimilarities) for all possible pairs of sites to a program (RNDTST6) that calculates mean between and within-group similarities. http://www.epa.gov/wed/pages/models/dendro/mean_similarity_analysis.htm

**Mercury in Medical Facilities**
This HTML program teaches health care professionals (and anyone else) about the hazards of mercury as commonly used in medical care facilities, especially hospitals and clinics. Mercury can pose a significant health problem for these professionals and also for patients and the environment in general. The program explains the impact of mercury on human health and the integrity of ecosystems, and a 'virtual hospital' allow users to see sources of mercury and their alternatives. http://www.epa.gov/seahome/mercury.html

**Meteorological Data**
The meteorological data files contain measurements taken at 237 weather stations located throughout the United States for a period extending from 1961 to 1990. Exact collection dates vary by weather station. http://www.epa.gov/ceampubl/tools/metdata/index.htm

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**Table 12A.6 (Continued)**

**Milking Center Wastewater Treatment**
Considers the special problems posed by milkhouse wastewater. Explores design of the milking facility for cleaning management, determining strength and volume of effluent flow, and devising facilities to receive, treat, and safely dispose of the wastewater. A risk assessment questionnaire evaluates the soundness of the user's situation and suggests improvements. http://www.epa.gov/seahome/milking.html

**MINTEQA2**
MINTEQA2 is a equilibrium speciation model that can be used to calculate the equilibrium composition of dilute aqueous solutions in the laboratory or in natural aqueous systems. The model is useful for calculating the equilibrium mass distribution among dissolved species, adsorbed species, and multiple solid phases under a variety of conditions including a gas phase with constant partial pressures. A comprehensive data base is included that is adequate for solving a broad range of problems without need for additional user-supplied equilibrium constants. http://www.epa.gov/ceampubl/mmedia/minteq/index.htm

**MOBILE Model (On-Road Vehicles)**
This web page contains information on the MOBILE vehicle emission factor model, which is a software tool for predicting gram per mile emissions of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), carbon dioxide ($CO_2$), particulate matter (PM) and air toxics from cars, trucks, and motorcycles under various conditions. http://www.epa.gov/otaq/mobile.htm

**Models-3 Air Quality Modeling System**
The primary goals for the Models-3/Community Multiscale Air Quality (CMAQ) modeling system are to improve 1) the environmental management community's ability to evaluate the impact of air quality management practices for multiple pollutants at multiple scales and 2) the scientist's ability to better probe, understand, and simulate chemical and physical interactions in the atmosphere. epa.gov/asmdnerl/models3/index.html

**MOFAT Software**
A two-dimensional, finite element model for simulating coupled multiphase flow and multicomponent transport in planar or radically symmetric vertical sections. MOFAT evaluates flow and transport for water, nonaqueous phase liquid (NAPL), and gas. The program also can be used when gas and/or NAPL phases are absent in part or all of the domain. The flow module can analyze either two-phase flow of water and NAPL in a system of constant gas pressure or explicit three-phase flow of water. The transport module can accommodate up to five components partitioning among water, NAPL, gas, and solid phases, assuming either local equilibrium interphase mass transfer or first-order kinetically controlled mass transfer. http://www.epa.gov/nerlesd1/databases/mofat/abstract.htm

**Most Probable Number of Microorganisms**
This program can be used to calculate Most Probable Number (MPN) values for the quantitation of microorganisms. http://www.epa.gov/nerlcwww/other.htm

**AIRMaster+**
AIRMaster+ provides comprehensive information on assessing compressed air systems, including modeling, existing and future system upgrades, and evaluating savings and effectiveness of energy efficiency measures. oit.doe.gov/bestpractices/software_tools.shtml

**MOVES (Motor Vehicle Emission Simulator)**
To keep pace with new analysis needs, modeling approaches, and data, the EPA's Office of Transportation and Air Quality (OTAQ) is developing a modeling system termed the MOtor Vehicle Emission Simulator (MOVES). This system will estimate emissions for on-road and nonroad sources, cover a broad range of pollutants, and allow multiple scale analysis, from fine-scale analysis to national inventory estimation. When fully implemented MOVES will serve as the replacement for MOBILE6 and NONROAD. http://www.epa.gov/otaq/ngm.htm

**Multi-Chamber Concentration and Exposure Model (MCCEM) Version 1.2**
Estimates average and peak indoor air concentrations of chemicals released from products or materials in houses, apartments, townhouses, or other residences. The data libraries contained in MCCEM are limited to residential settings. However, the model can be used to assess other indoor environments (e.g., schools, offices) if the user can supply the necessary inputs. Estimates inhalation exposures to these chemicals, calculated as single day doses, chronic average daily doses, or lifetime average daily doses. epa.gov/opptintr/exposure/docs/mccem.htm

**MULTIMED 2.0 BETA**
The Multimedia Exposure Assessment Model (MULTIMED) for exposure assessment simulates the movement of contaminants leaching from a waste disposal facility. The model consists of a number of modules which predict concentrations at a receptor due to transport in the subsurface, surface air, or air. http://www.epa.gov/ceampubl/mmedia/multim2/index.htm

**MULTIMED Daughter Process Model**
The Multimedia Exposure Assessment Model (MULTIMED) for exposure assessment simulates the movement of contaminants leaching from a waste disposal facility. The MULTIMED model has been modified (MULTIMDP) to simulate the transport and fate of first and second-generation transformation (daughter) products that migrate from a waste source through the unsaturated and saturated zones to a down gradient receptor well. http://www.epa.gov/ceampubl/mmedia/multidp/index.htm

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**Table 12A.6 (Continued)**

**The Multimedia Contaminant Fate, Transport, and Exposure Model (MMSOILS)**

The Multimedia Contaminant Fate, Transport, and Exposure Model (MMSOILS) estimates the human exposure and health risk associated with releases of contamination from hazardous waste sites. The methodology consists of a multimedia model that addresses the transport of a chemical in groundwater, surface water, soil erosion, the atmosphere, and accumulation in the food chain. The human exposure pathways considered in the methodology include: soil ingestion, air inhalation of volatiles and particulates, dermal contact, ingestion of drinking water, consumption of fish, consumption of plants grown in contaminated soil, and consumption of animals grazing on contaminated pasture. For multimedia exposures, the methodology provides estimates of human exposure through individual pathways and combined exposure through all pathways considered. The risk associated with the total exposure dose is calculated based on chemical-specific toxicity data. http://www.epa.gov/ceampubl/mmedia/mmsoils/index.htm

**Multimedia Exposure Assessment Model (MULTIMED)**

The Multimedia Exposure Assessment Model (MULTIMED) for exposure assessment simulates the movement of contaminants leaching from a waste disposal facility. The model consists of a number of modules which predict concentrations at a receptor due to transport in the subsurface, surface air, or air. http://www.epa.gov/ceampubl/mmedia/multim1/index.htm

**Multimedia Integrated Modeling System**

Numerical models are being developed in response to a growing interest in studying and addressing issues that have influences and effects that cross physical media, such as air, water, and soil. Numerical models provide an important tool in studying and addressing such issues. The models are used to test our understanding of ecosystems, diagnose causes of problems, and predict conditions given assumptions about future influences on the environment. EPA's Multimedia Integrated Modeling System (MIMS) project is researching and developing solutions for some of those challenges. epa.gov/AMD/mims/index.html

**Multimedia, Multi-Pathway, Multi-Receptor Exposure, and Risk Assessment (3MRA)**

The Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment (3MRA) technology provides the ability to conduct screening-level risk-based assessment of potential human and ecological health risks resulting from long term (chronic) exposure to HWIR chemicals released from land-based waste management units (WMUs) containing currently listed waste streams. The 3MRA system consists of a series of components within a system framework. The new modeling system, dubbed 3MRA technology, is envisioned as the foundation for eventually integrating other regulatory support decision tool needs anticipated in the future. http://www.epa.gov/ceampubl/mmedia/3mra/index.htm

**Municipal Pollution Prevention Diagnostic Planner Software**

This hypertext-based program serves as an early warning system for wastewater treatment plant operators. The user supplies information on influent loadings, discharge monitoring data, pretreatment, financial status, failures and upsets, and other aspects of plant operation and maintenance. http://www.epa.gov/seahome/cmar.html

**National Asbestos Registry System**

The National Asbestos Registry System (NARS) may be used by building owners to assist in evaluating which asbestos contractors should be hired, or by the general public to determine the compliance history of asbestos contractors working at a specific locale. NARS is also used by delegated agencies to assist in targeting inspections and by EPA managers as a general tool for evaluating the asbestos program. http://cfpub.epa.gov/nars/

**National Compliance Data Base System (NCDB)**

The National Compliance Data Base System (NCDB) tracks regional compliance and enforcement activity, and manages the Pesticides and Toxic Substances Compliance and Enforcement program at a national level. The system tracks all compliance monitoring and enforcement activities from the time an inspector conducts an inspection until the time the inspector closes the case or settles the enforcement action. epa.gov/Compliance/planning/data/toxics/ncdbsys.html

**National Contaminant Occurrence Database (NCOD)**

EPA has developed NCOD to satisfy the statutory requirements set by Congress in the 1996 amendments to the *Safe Drinking Water Act (SDWA)* to maintain a national drinking water contaminant occurrence database using occurrence data for both regulated and unregulated contaminants in public water systems. This site provides a library of water sample analytical data (or "samples data") that EPA is currently using and has used in the past for analysis, rulemaking, and rule evaluation. The drinking water sample data, collected at Public Water Systems, are for both regulated and unregulated contaminants. http://www.epa.gov/safewater/data/ncod.html

**National Emissions Inventory**

The U.S. EPA prepares a national emissions inventory with input from numerous State and local air agencies. These data are used for air dispersion modeling, regional strategy development, regulation setting, air toxics risk assessment, and tracking trends in emissions over time. http://www.epa.gov/ttn/chief/eiinformation.html

**National Hydrography Dataset**

The National Hydrography Dataset (NHD) is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells. These linkages enable the analysis and display of these water-related data in upstream and downstream order. http://nhd.usgs.gov/

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**Table 12A.6 (Continued)**

**National Listing of Fish Consumption Advisories**
Fish may contain chemicals that could pose health risks. When contaminant levels are unsafe, consumption advisories may recommend that people limit or avoid eating certain species of fish caught in certain places. http://www.epa.gov/OST/fishadvice/

**National Water Quality Inventory**
Water Quality Reports, required by Section 305(b) of the Clean Water Act, contain information on the attainment of water quality standards. States, Tribes, and Territories classify assessed waters as either Fully Supporting, Threatened, or Not Supporting their designated use(s). http://www.epa.gov/waters/305b/

**NONROAD Model**
The Draft Nonroad Model is used for estimation of air pollution inventories by professional mobile source modelers, such as state air quality officials and consultants. The model is still draft, so some emission rates and activity levels predicted by the model may substantially change. http://www.epa.gov/otaq/nonrdmdl.htm

**NPS (Nonpoint Source) Modeling**
Nonpoint source assessment procedures and modeling techniques are reviewed and discussed for both urban and nonurban land areas. Detailed reviews of specific methodologies and models are presented, along with overview discussions focusing on urban methods and models, and on non-urban (primarily agricultural) methods and models. http://www.epa.gov/ceampubl/tools/nps/index.htm

**Nutrient Criteria Database**
EPA has developed a National Nutrient Database to store and analyze nutrient water quality data and to serve as an information resource for states, tribes, and others in establishing scientifically defensible numeric nutrient criteria. It contains ambient data from EPA's Legacy STOrage and RETrieval (STORET) data system, the U.S. Geological Survey's National Stream Quality Accounting Network (NASQAN) data and National Water Quality Assessment (NAWQA) data, and other relevant sources such as universities and states/tribes. The ultimate use of the data is to derive ecoregional waterbody-specific numeric nutrient criteria. http://www.epa.gov/waterscience/criteria/nutrient/database/index.html

**Oil Spill Exercise Generator**
This database-driven program can construct an oil spill exercise or response drill in a matter of hours, and fill out checklists for use in a final evaluation report. http://www.epa.gov/seahome/oilspill.html

**On-Site: The On-line Site Assessment Tool**
On-Site was developed to provide modelers and model reviewers with prepackaged tools ("calculators") for performing site assessment calculations. The philosophy behind On-Site is that the convenience of the prepackaged calculators helps provide consistency for simple calculations, and access to methods and data that are not commonly available. The latter include data on fuel composition and models for leaching from fuel lenses. http://www.epa.gov/athens/learn2model/part-two/onsite/index.html

**Online Tracking Information System (OTIS)**
The OnlineTracking Information System (OTIS) is a collection of search engines which enables EPA staff, state/local/tribal governments, and federal agencies to access a wide range of data relating to enforcement and compliance. OTIS is a web application that sends queries to the Integrated Data for Enforcement Analysis (IDEA) system. Only State and Federal agencies have access to the OTIS data system. http://www.epa.gov/Compliance/planning/data/multimedia/aboutotis.html

**Oxygen Requirements of Fishes (OXYREF) Model**
The Oxygen Requirements of Fishes (OXYREF) database contains test results reported in the published literature on the respiratory oxygen requirements of fishes. This file is based on results of a computerized literature search, over the time period 1969–1986, of three separate journal referencing services: Biological Sciences Information Service (BIOSIS PREVIEWS), Aquatic Sciences and Fisheries Abstracts (ASFA), and Canadian Water Resources References (AQUAREF). http://www.epa.gov/ceampubl/swater/oxyref/index.htm

**Ozone Depletion Software**
This program includes information and graphics depicting the ozone layer, how ozone is created, causes and effects of ozone depletion, the ozone hole, the greenhouse effect, and how an individual can help prevent ozone depletion. The program also examines applicable government legislation, including portions of the Clean Air Act Amendments of 1990. http://www.epa.gov/seahome/ozone.html

**Polychlorinated Biphenyls (PCBs)**
EPA provides various paths for the public to access information about PCBs. This website provides information on the health effects of PCBs, laws and regulations that govern PCBs, lists of approved companies that can handle PCB wastes including storage and disposal companies, alternative decontamination procedures and scrap metal recovery ovens. EPA also maintains two databases-PCB Activity Database (PADS) and Transformer Registration and applicable forms. http://www.epa.gov/opptintr/pcb/index.html

**Permit Application Software System (PASS) for NPDES**
The Permit Application Software System (PASS) is a software solution provided by the United States Environmental Protection Agency (U.S. EPA) to facilitate applications for National Pollutant Discharge Elimination System (NPDES) permits. http://cfpub2.epa.gov/npdes/permitissuance/pass.cfm

**Permit Compliance System (PCS)**
The Permit Compliance System (PCS) provides information on companies which have been issued permits to discharge waste water into rivers, when a permit was issued and expires, how much the company is permitted to discharge, and the actual monitoring data showing what the company has discharged. http://www.epa.gov/enviro/html/pcs/index.html

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**Table 12A.6 (Continued)**

**Personal Greenhouse Gas Calculator**
EPA has developed tools to help individuals reduce household greenhouse gas emissions. These tools are designed for individuals who want to take action and for businesses and organizations interested in reaching their employees and members about what they can do at home to help protect our climate. http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html

**PESTAN Software**
A model used to estimate the vertical migration of dissolved organic solutes through the vadose zone to groundwater. Estimates are based on a closed-form analytical solution of the advective–dispersive–reactive transport equation. The model is intended for use in conducting initial screening assessments of the potential for contamination of groundwater from currently registered pesticides and those submitted for registration. http://www.epa.gov/nerlesd1/databases/pestan/abstract.htm

**Pesticide Assessment Tool for Rating Investigations of Transport (PATRIOT)**
Pesticide Assessment Tool for Rating Investigations of Transport (PATRIOT) provides rapid analyses of groundwater vulnerability to pesticides on a regional, state, or local level. PATRIOT assesses groundwater vulnerability by quantifying pesticide leaching potential in terms of pesticide mass transported to the water table. PATRIOT is composed of: (1) a pesticide fate and transport model (PRZM2), (2) a comprehensive database, (3) an interface that facilitates database exploration, (4) a directed sequence of interactions that guide the user in providing necessary information to perform alternative model analyses, and (5) user-selected methods for summarizing and visualizing results. http://www.epa.gov/ceampubl/gwater/patriot/index.htm

**Pesticide Data Submitters List (PDSL)**
The Pesticide Data Submitters List is a compilation of names and addresses of registrants who wish to be notified and offered compensation for use of their data. It was developed to assist pesticide applicants in fulfilling their obligation as required by sections 3(c)(1)(f) and 3(c)(2)(D) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and 40 CFR Part 152 sub part E regarding ownership of data used to support registration. http://www.epa.gov/opppmsd1/DataSubmittersList/

**Pesticide Database Descriptions**
The Office of Pesticide Programs has five environmental databases that it uses to assess hazards to the environment and to wildlife, aquatic organisms, and plants. Some of these databases are in the initial phases of development, while others are fully operational. http://www.epa.gov/oppefed1/general/databasesdescription.htm

**Pesticide Product Information System (PPIS)**
The Pesticide Product Information System (PPIS) contains information concerning all pesticide products registered in the United States. http://www.epa.gov/opppmsd1/PPISdata/

**Pesticide Product Label System (PPLS)**
The Pesticide Product Label System is a collection of images of pesticide labels which have been approved by the Office of Pesticide Programs (OPP) under Section 3 of the Federal Insecticide, Fungicide, and Rodenticide Act. The collection contains the initially approved label for pesticide products registered under *FIFRA Section 3* as well as subsequent versions of labels which have changed via amendment or notification. http://www.epa.gov/pesticides/pestlabels/

**Pesticide Reregistration Status**
EPA is reviewing older pesticides (those initially registered prior to November 1984) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to ensure that they meet current scientific and regulatory standards. This process, called reregistration, considers the human health and ecological effects of pesticides and results in actions to reduce risks that are of concern. EPA also is reassessing tolerances (pesticide residue limits in food) to ensure that they met the safety standard established by the Food Quality Protection Act (FQPA) of 1996. http://cfpub.epa.gov/oppref/rereg/status.cfm?show=rereg

**Pesticide-Restricted Use Products Report (RUP)**
The Restricted Use Products Report is a compilation of both active and cancelled pesticide products classified as “Restricted Use”. The “Restricted Use” classification restricts a product, or its uses, to use by a certificated pesticide applicator or under the direct supervision of a certified applicator. http://www.epa.gov/opprd001/rup/index.htm

**Pesticide Storage and Handling Practices on the Farm**
Explains proper handling and storage of pesticides on farmsteads. Provides a general overview of pesticide handling and storage, a risk assessment section, and recommendations for correcting problems related to pesticide storage. http://www.epa.gov/seahome/farmpest.html

**Pesticide Water Models**
Scientists in the Office of Pesticide Programs (OPP) in the Environmental Protection Agency (EPA) frequently use simulation models to predict pesticide concentrations in surface and groundwater for use in both human health and aquatic ecological exposure assessments. http://www.epa.gov/oppefed1/models/water/index.htm

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**Table 12A.6 (Continued)**

**PLUMES Models**
PLUMES includes two initial dilution plume models (RSB and UM) and a model interface manager for preparing common input and running the models. Two farfield algorithms are automatically initiated beyond the zone of initial dilution. PLUMES also incorporates the flow classification scheme of the Cornell Mixing Zone Models (CORMIX) with recommendations for model usage, thereby providing a linkage between the systems. PLUMES models are intended for use with plumes discharged to marine and some freshwater bodies. Both buoyant and dense plumes, single sources, and many diffuser outfall configurations can be modeled. http://www.epa.gov/ceampubl/swater/plumes/index.htm

**PM (Particulate Matter) Calculator**
EPA has replaced the PM-10 Calculator program with new software that will estimate filterable PM2.5 emissions. PM Calculator is applicable to point sources only and requires the user to input uncontrolled emissions (either total filterable particulate or filterable PM10) for each source, the source category classification (SCC) and the control device, if any. The program will then calculate controlled emissions for filterable PM2.5 and filterable PM10 for each point source. http://www.epa.gov/ttn/chief/software/pmcalc/index.html

**Pollution Prevention Software**
The Pollution Prevention Act of 1990 established source reduction as the preferred approach to environmental protection. P2 can save money, reduce liability, and improve efficiency, worker safety, and competitiveness. This program outlines the relevant environmental legislation and addresses P2 in industry, agriculture, energy, government, and consumer sectors. Examples include more efficient manufacturing processes, alternative products and procedures that generate less or more benign end products, and ways to reduce the amount of raw materials used. http://www.epa.gov/seahome/prevent.html

**PRESTO Software**
PRESTO (Prediction of Radiological Effects Due to Shallow Trench Operations) is a computer model for evaluating radiation exposure from contaminated soil layers, including waste disposal, soil cleanup, agricultural land application, and land reclamation. http://www.epa.gov/radiation/assessment/presto.html

**Principles and Design of On-site Waste Disposal with Septic Systems Software**
The software teaches the basics of on-site treatment using diagrams and animations: septic tanks, drainfields, mounds, water conservation. It covers principles of treatment, design, and siting, as well as soil basics and water conservation. http://www.epa.gov/seahome/onsite.html

**Private Pesticide Applicator Training Software**
This is an interactive guide to the Federal regulatory requirements and user health concerns for pesticide handling and application. It includes an extended tutorial on pesticide laws and reglulations, a guide to safe handling and mixing, and a short course in reading and interpreting the labels and health warnings. http://www.epa.gov/seahome/privpest.html

**Private Water Systems**
A complete minicourse in design and construction of private drinking water systems (wells and piping) includes water quantities required, water pumps, systems controls, design considerations and piping. http://www.epa.gov/seahome/private.html

**Program to Assist in Tracking Critical Habitat (PATCH)**
PATCH is a spatially explicit, individual-based, life history simulator designed to project populations of territorial terrestrial vertebrate species through time. PATCH is ideal for investigations involving wildlife species that are mobile habitat specialists. PATCH's data requirements are minimal: provided with habitat maps, specifications for habitat use (territory size and habitat affinity), vital rates (survival and reproduction), and parameters for species' movement behavior, a simulation can be generated.PATCH's outputs fall into two general categories: pattern-based metrics and demographic analyses. http://www.epa.gov/wed/pages/models/patch/patchmain.htm

**Protecting Children's Health in Schools Software**
Intended for the decision-maker in a school system, the software aids in identification of potential hazards to assist in protecting the environment and the health of those who use the school. The guide will discuss what those hazards might be, how to test for them, and how to remedy problems found. http://www.epa.gov/seahome/child.html

**PRZM3 Model**
PRZM3 is the most recent version of a modeling system that links two subordinate models, PRZM and VADOFT, in order to predict pesticide transport and transformation down through the crop root and unsaturated zone. PRZM is a one-dimensional, finite-difference model that accounts for pesticide and nitrogen fate in the crop root zone. PRZM3 includes modeling capabilities for such phenomena as soil temperature simulation, volatilization and vapor phase transport in soils, irrigation simulation, microbial transformation, and a method of characteristics (MOC) algorithm to eliminate numerical dispersion. PRZM is capable of simulating transport and transformation of the parent compound and as many as two daughter species. VADOFT is a one-dimensional, finite-element code that solves Richard's equation for flow in the unsaturated zone. The user may make use of constitutive relationships between pressure, water content, and hydraulic conductivity to solve the flow equations. VADOFT may also simulate the fate of two parent and two daughter products. http://www.epa.gov/ceampubl/gwater/przm3/index.htm

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**Table 12A.6 (Continued)**

**Radiation Risk Assessment Software: CAP88 PC**
CAP88-PC is a personal computer software system used for calculating dose and risk from annual average releases of radionuclides to the air. http://www.epa.gov/radiation/assessment/CAP88/index.html

**Radionuclide Carcinogenicity Slope Factors Software**
The source provides the latest information and guidance on using radionuclide slope factors from the Health Effects Assessment Summary Tables (HEAST) — Radionuclides Table (formerly Table 12A.4). EPA, other federal agencies, states and contractors who are responsible for the identification, characterization and remediation of sites contaminated with radioactive materials use radionuclide slope factors in risk assessments to calculate potential risks to the general public. http://www.epa.gov/radiation/heast/download.htm

**RCRA Boiler & Industrial Furnace Regulations**
In February 1991, the USEPA promulgated a final rule that expands controls on hazardous waste combustion by regulating the burning of hazardous waste in boilers and industrial furnaces (BIFs). The BIF rule sets levels of control for emissions of toxic organic compounds, toxic metals, HCl, chlorine gas and particulate matter. Owners and operators of BIFs are subject to permitting and other standards applicable to hazardous waste treatment, storage and disposal facilities. The site helps to understand the applicability, terms, definitions, technology and requirements associated with the BIF rule. http://www.epa.gov/seahome/bif.html

**RCRA Corrective Action Processs**
The Corrective Action Process aims to identify, develop, and implement appropriate corrective measures to protect human health and the environment at facilities where hazardous wastes or pollutants are handled or managed. The purpose of CAP is to guide facilities through the many governing authorities and laws while providing an easy to follow path to proper and legal corrective action. Menu items cover interim and stabilization measures, a detailed breakdown of the quality assurance plan, health and ecological assessment, remediation technologies, public participation, an extensive guide to statutory authorities, and a glossary and a bibliography of guidance documents. http://www.epa.gov/seahome/cap.html

**RCRAInfo**
RCRAInfo is EPA's comprehensive information system, providing access to data supporting the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments (HSWA) of 1984. RCRAInfo replaces the data recording and reporting abilities of the Resource Conservation and Recovery Information System (RCRIS) and the Biennial Reporting System (BRS). RCRAInfo characterizes facility status, regulated activities, and compliance histories and captures detailed data on the generation of hazardous waste from large quantity generators and on waste management practices from treatment, storage, and disposal facilities. http://www.epa.gov/epaoswer/hazwaste/data/index.htm

**ReduceIt Companion Software to Source Reduction Program Potential Manual**
This companion software is designed to be used in connection with the *Source Reduction Program Potential Manual* to help solid waste managers plan for a source reduction program and determine the impact of various source reduction options on their community. The *Source Reduction Program Potential Manual and Software* estimate the program potential for six source reduction options: three residential (grasscycling, home composting, and clothing reuse) and three commercial and industrial (office paper reduction, converting to multi-use pallets, and paper towel reduction). http://www.epa.gov/epaoswer/non-hw/reduce/reduceit/index.htm

**Regional Air Pollutant Inventory Development System (RAPIDS)**
As the principle component of the Great Lakes Regional Air Toxic Emissions Inventory project, the Regional Air Pollutant Inventory Development System (RAPIDS) is the first ever multi-jurisdictional pollutant emissions inventory software that has been developed. The focus of the study was on the Commission defined list of 49 toxic pollutants, in addition to several other important nontoxic compounds. Now, RAPIDS is used by each Great Lakes state and Province of Ontario. The latest regional inventory for 1997 contains over 80 toxic pollutants for point, area, and mobile (onroad and nonroad source) emissions. http://www.glc.org/air/rapids/rpdsover.html

**Regional Vulnerability Assessment (ReVA) Program**
EPA's Regional Vulnerability Assessment (ReVA) program is an approach to regional scale, priority-setting assessment being developed by EPA's Office of Research and Development (ORD). ReVA will expand cooperation among the laboratories and centers of ORD, by integrating research on human and environmental health, ecorestoration, landscape analysis, regional exposure and process modeling, problem formulation, and ecological risk guidelines. http://www.epa.gov/reva/#

**Registry of EPA Applications and Databases**
The Registry of EPA Applications and Databases (READ) is an authoritative registry that uniquely identifies the Environmental Protection Agency's (EPA) diverse information resources including computer application systems, databases, and models. As a catalog of available EPA information, READ provides a single point of entry to identify, locate, and access Agency information resources. READ supports EPA's metadata vision to: create and store metadata in as few places as possible; improve the quality and consistency of metadata; and provide a central point of access to the complete collection of all Agency information resources metadata. http://www.epa.gov/read/

**Regulatory Air Models**
This website is a source of information on atmospheric dispersion (air quality) models that support regulatory programs required by the Clean Air Act. Documentation and guidance for these computerized models are a major feature of this website. The computer code, data and technical documents offered deal with mathematical modeling for the dispersion of air pollutants. http://www.epa.gov/scram001/

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**Table 12A.6 (Continued)**

**Remediation Annual Status Report**
The Annual Status Report (ASR) Remediation Database documents the status and achievements of 1,811 technology applications identified for Superfund remedial action sites, including 1,760 treatment applications for soil, other solid wastes, and groundwater and 51 applications of groundwater containment using vertical engineered barriers (VEB). http://cfpub.epa.gov/asr/index.cfm

**Reporting on Municipal Solid Waste: A Local Issue**
The "Reporter's Guide" is a software application that presents background information to assist print and broadcast media in understanding municipal solid waste (MSW) issues. Examines the role of federal, state, and local governments in MSW management; options for solid waste management (source reduction, recycling, incineration, and landfilling); and regulations for solid waste landfills. http://www.epa.gov/epaoswer/non-hw/muncpl/reporting.htm

**Residential Energy Efficiency**
This program shows effective ways to reduce home energy consumption. Topics include insulation, windows, doors, weather-stripping, and caulking. The expert system feature allows users to calculate how much they will save by making their homes more energy efficient. http://www.epa.gov/seahome/energy.html

**Residential Water Conservation Techniques Software**
With more than 100 color graphic screens and animation, this program shows effective ways to save water inside and outside the house. Topics include efficient toilets, showerheads, faucets; leak detection, water efficient lawn care and gardening; car washing and pool operation. http://www.epa.gov/grtlakes/seahome/watcon.html

**RETC Software**
A program for analyzing the hydraulic conductivity properties of unsaturated soils. The parametric models of Brooks-Corey and van Genuchten are used to represent the soil water retention curve, and the theoretical pore-size distribution models of Mualem and Burdine predict the unsaturated hydraulic conductivity function. http://www.epa.gov/nerlesd1/databases/retc/abstract.htm

**Risk Management Plans (via RTK–NET)**
These provides a searchable database of relevant information to assist in citizen participation during the preparation of risk management plans. http://www.rtknet.org/rmphelp.html

**RMP*Comp**
RMP*Comp is a free program you can use to complete the offsite consequence analyses (both worst case scenarios and alternative scenarios) required under the Risk Management Planning Rule. http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/rmp-comp.htm

**RMP*Review**
RMP*Review is a free software program designed for reviewing and analyzing Risk Management Plans (RMPs) submitted under the Clean Air Act, Section 112(r). http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/rmp_review.htm

**RMP*Submit**
RMP*Submit 2004 is the free, official EPA, personal computer software for facilities to use in submitting Risk Management Plans (RMP) required under the Risk Management Program. http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/ap-rmsb.htm#rmpsub

**Safe Drinking Water Information System (SDWIS)**
The Safe Drinking Water Information System (SDWIS) contains information about public water systems and their violations of EPA's drinking water regulations, as reported to EPA by the states. These regulations establish maximum contaminant levels, treatment techniques, and monitoring and reporting requirements to ensure that water systems provide safe water to their customers. http://www.epa.gov/enviro/html/sdwis/sdwis_query.html

**Science Inventory**
The Science Inventory (SI) is a searchable database of EPA science activities and scientific/technical work products. The Science Inventory provides information about current or recently completed activities, providing a snapshot of what science EPA is conducting in its research laboratories and centers, program and regional offices, and through grants and other assistance agreements to universities and other institutions. The Science Inventory currently contains 5,646 records. http://cfpub.epa.gov/si/

**Scout Software**
A univariate and multivariate data analysis tool with several classical and robust procedures (e.g., outlier testing, interactive 2D/3D graphics), making it a useful package for environmental and ecological applications. Scout can transform data, assess variable normality, produce histograms and Q–Q plots of raw data and principal component scores (PCSs), and produce scatter plots of raw data, PCSs, and discriminant scores. http://www.epa.gov/nerlesd1/databases/scout/abstract.htm

**Section Seven Tracking System (SSTS)**
SSTS is one of the major systems that supports the Pesticide Program at EPA. SSTS is the only automated system that EPA uses to track pesticide producing establishments and the amount of pesticides they produce. SSTS records the registration of new establishments and records pesticide production at each establishment. http://www.epa.gov/Compliance/planning/data/toxics/sstsys.html

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**Table 12A.6 (Continued)**

**Sector Facility Indexing Project (SFIP)**
The Sector Facility Indexing Project focused on compiling information on facilities within five industry categories (automobile assembly, pulp manufacturing, petroleum refining, iron and steel production, and the primary smelting and refining of aluminum, copper, lead, and zinc (nonferrous metals), and selected major federal facilities). SFIP contained records for 591 facilities from the five industry sectors, as well as 273 federal facilities. SFIP information related to compliance and inspection history, chemical releases and spills, and demographics of the surrounding population. http://www.epa.gov/sfipmtn1/access.html

**Simplified Method Program — Variable Complexity Stream Toxics Model (SMPTOX3)**
U.S. EPA regulatory programs have sponsored development of an interactive computer program for performing waste load allocations for toxics — Simplified Method Program — Variable Complexity Stream Toxics Model (SMPTOX3). SMPTOX3 provides user-friendly access to a technique for calculating water column and stream bed toxic substance concentrations resulting from point source discharges into streams and rivers. It predicts pollutant concentrations in dissolved and particulate phases for water column and bed sediments and total suspended solid. http://www.epa.gov/ceampubl/swater/smptox3/index.htm

**Smart Travel Resource Center**
EPA makes more than 100 information campaigns that focus on encouraging individuals to make travel decisions which have positive impacts on air quality, congestion, and quality of life. The goal being that the users can learn from one another in designing, implementing, and evaluating these innovative programs. http://yosemite.epa.gov/aa/strc.nsf

**Software for Environmental Awareness**
Resulting from a partnership between EPA Region 5 and the students and faculty at Purdue University, SEA has produced a number of software programs from simple linear tutorials to expert systems requiring the user to input data in order to receive a computer-calculated solution. The collection includes water-related topics, solid waste, air pollution, and environmental assessment. http://www.epa.gov/glnpo/seahome/

**Soil and Geologic Site Evaluation Software**
This software provides information about the roles that soils, geology and depth to groundwater play in the protection of groundwater. A risk assessment portion helps determine the potential for contamination at a site based on information supplied by the user. http://www.epa.gov/seahome/farmsite.html

**Source Ranking Database**
Performs a systematic screening-level review of over 12,000 potential indoor pollution sources to identify high-priority product and material categories for further evaluation. Can also identify the products that contain a specific chemical. epa.gov/opptintr/exposure/docs/srd.htm

**Spatial Grid Networks Software**
Software and documentation for generating regular grids of hexagons and other shaped cells for the earth as a whole, or for parts of it, as well as the existing grid for the USGS-BRD GAP program. These materials are for the geometric and cartographic components of such grids. http://www.epa.gov/wed/pages/staff/white/getgrid.htm

**SPECIATE Software**
SPECIATE is EPA's repository of Total Organic Compound (TOC) and Particulate Matter (PM) speciated profiles for a variety of sources for use in source apportionment studies. This release of SPECIATE no longer contains profiles assigned to SCC's. Instead, searching for profiles by keyword has been improved and of course the user can still browse through the profiles. http://www.epa.gov/ttn/chief/software/speciate/index.html

**STF Software**
A computer-based tool for selecting data on chemicals in the environment and for simulating their fate and transport in site-specific conditions is available. The software system consists of three components: (1) STF 2.0 (Soil Transport and Fate Database), which provides information on the behavior of chemicals in soil environments for use as input data on, for example, degradation rates and partition coefficients. (2) RITZ (Regulatory and Investigative Treatment Zone) and VIP 3.0 models. RITZ simulates hazardous chemical movement and fate during land treatment of oily wastes. VIP evaluates data using six different output options. (3) RITZ and VIP model editors that are directly interfaced with STF 2.0 and aid in the creation of input files for the RITZ and VIP models. http://www.epa.gov/nerlesd1/databases/stf/abstract.htm

**STORET**
The U.S. Environmental Protection Agency (EPA) maintains two data management systems containing water quality information for the nation's waters: the Legacy Data Center (LDC), and STORET. The LDC is a static, archived database and STORET is an operational system actively being populated with water quality data. http://www.epa.gov/STORET/about.html

**Storm Water Management Model (SWMM)**
The Storm Water Management Model (SWMM) is a comprehensive computer model for analysis of quantity and quality problems associated with urban runoff. Both single-event and continuous simulation can be performed on catchments having storm sewers, or combined sewers and natural drainage, for prediction of flows, stages and pollutant concentrations. http://www.epa.gov/ceampubl/swater/swmm/index.htm

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**Table 12A.6 (Continued)**

**Substance Registry System (SRS)**
The Substance Registry System (SRS) provides information on substances and how they are represented in the Environmental Protection Agency (EPA) regulations and information systems. http://www.epa.gov/srs/index.htm

**Subsurface Characterization and Monitoring Techniques**
An interactive, multimedia version of the two-volume, EPA reference entitled "Subsurface Characterization and Monitoring Techniques" by R. Boulding. The documents include 1- to 2-page descriptions of more than 280 site characterization and field monitoring methods for detecting groundwater contamination and other aspects of the subsurface at hazardous waste sites. Geological and hydrogeological characterization topics covered include surface and borehole approaches, geophysical methods, and solids sampling; drilling; aquifer tests and groundwater sampling; water-state measurement and monitoring; vadose zone hydraulic conductivity/flux measurement; vadose zone water budget characterization; vadose zone soil-solute sampling and gas monitoring; and field chemical analytical methods. http://www.epa.gov/nerlesd1/databases/subsurface/abstract.htm

**Superfund Chemical Data Matrix (SCDM)**
The Superfund Chemical Data Matrix (SCDM) is a source for factor values and benchmark values applied when evaluating potential National Priorities List (NPL) sites using the Hazard Ranking System (HRS). Factor values are part of the HRS mathematical equation for determining the relative threat posed by a hazardous waste site and reflect hazardous substance characteristics, such as toxicity and persistence in the environment, substance mobility, and potential for bioaccumulation. Benchmarks are environment- or health-based substance concentration limits developed by or used in other EPA regulatory programs. http://www.epa.gov/superfund/sites/npl/hrsres/tools/scdm.htm

**Superfund Information Systems**
Site provides links to the various Superfund-related information tracking systems that are maintained by the EPA. Included in the list are CERCLIS (general information about sites), Archived Sites (sites with completed site assessment and no further action required), Records of Decision (sites where remedial options have been selected), Five Year Reviews (sites that have been undergoing remediation for an extended time provide 5-year reviews of activities), Site Assessment Documentation (provides preliminary assessment of sites that have recently been identified), Site Spill IDs (tracks logistical issues at Superfund sites), Data Element Dictionary (lexicon of Superfund related terms), and Site Information Products (collection of Superfund Information reports and products). http://www.epa.gov/superfund/sites/siteinfo.htm

**Superfund Innovative Technologies**
A searchable database of treatment technology applications for soil, groundwater, and other media at Superfund sites. The information in this database was gathered from Superfund decision documents and project managers at Superfund remedial and removal sites. It contains information about source control technologies (addressing soil, sludge, sediment, and other solid-matrix wastes), innovative (*in situ*) groundwater treatment technologies, and subsurface barrier groundwater containment technologies (vertical engineered barriers). The database is searchable by site name, site identification number (CERCLIS ID), state, technology type, contaminant, and media. http://www.epa.gov/tio/databases/

**Surf Your Watershed**
Surf Your Watershed is a service to help you locate, use, and share environmental information about your state and watershed. http://www.epa.gov/surf/

**Surface Water Education System Software**
Topics include a general overview of the importance and quantity of surface water, a detailed look at this resource for Indiana, and a discussion of how surface water can become contaminated. Hypertext and numerous photos and graphics illustrate an extensive discussion of agricultural best management practices to protect surface water resources. http://www.epa.gov/seahome/surfwat.html

**TANKS Emission Estimation Software**
*TANKS* is a computer software program that estimates volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions from fixed- and floating-roof storage tanks. *TANKS* is based on the emission estimation procedures from *Chapter 7* of EPA's *Compilation Of Air Pollutant Emission Factors (AP-42)*. http://www.epa.gov/ttn/chief/software/tanks/index.html

**Terminology Reference System (TRS)**
The Terminology Reference System (TRS) was created to provide a single source of Environmental Protection Agency (EPA) terminology. The TRS is part of the centralized System of Registries (SoR), which provides access to the Agency's core registry systems. http://www.epa.gov/trs/index.htm

**Three-Dimensional Numerical Model of Hydrodynamics and Sediment Transport in Lakes and Estuaries (SED3D)**
The Three-Dimensional Numerical Model of Hydrodynamics and Sediment Transport in Lakes and Estuaries (SED3D) simulates the flow and sediment transport in lakes, estuaries, harbors, and coastal waters. SED3D is a dynamic modeling system that can be used to simulate the flow and sediment transport in various water bodies under the forcing of winds, tides, freshwater inflows, and density gradients with the influence of the Coriolis acceleration, complex bathymetry, and shoreline geometry. http://www.epa.gov/ceampubl/swater/sed3d/index.htm

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**Table 12A.6 (Continued)**

**Tier2 Submit Software**
EPA has developed Tier2 Submit 2004 to help facilities prepare an electronic chemical inventory report. Twenty-two states are accepting Tier2 Submit from facilities for the 2004 reporting year. http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/tier2.htm#t2forms

**The Total Maximum Daily Load (TMDL) Universal Soil Loss Equation (USLE)**
The Total Maximum Daily Load (TMDL) Universal Soil Loss Equation (USLE) model is a software application for estimating diffuse sediment source loads within a watershed framework. The user interface is similar to a spreadsheet and allows users to easily select and enter parameters used to estimate sediment loading. http://www.epa.gov/ceampubl/swater/usle/index.htm

**Total Maximum Daily Loads (TMDL)**
TMDL or Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. Water quality standards are set by States, Territories, and Tribes. They identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing), and the scientific criteria to support that use. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the State has designated. The calculation must also account for seasonal variation in water quality. http://www.epa.gov/owow/tmdl/intro.html#definition

**Total Risk Integrated Methodology (TRIM) Models**
The *TRIM design* includes three individual modules: The *Environmental Fate, Transport, and Ecological Exposure* module, *TRIM.FaTE*, accounts for movement of a chemical through a comprehensive system of discrete compartments (e.g. media and biota) that represent possible locations of the chemical in the physical and biological environments of the modeled ecosystem and provides an inventory, over time, of a chemical throughout the entire system. In addition to providing exposure estimates relevant to ecological risk assessment. The Exposure-Event module, *TRIM.Expo*. evaluates human exposures by tracking either randomly selected individuals that represent an area's population or population groups referred to as "cohorts" and their inhalation and ingestion through time and space. In the Risk Characterization module, *TRIM.Risk*, estimates of human exposures or doses are characterized with regard to potential risk using the corresponding exposure- or dose-response relationships. The *TRIM.Risk* module is also designed to characterize ecological risks from multimedia exposures. The output from TRIM.Risk is intended to include documentation of the input data, assumptions in the analysis, and measures of uncertainty, as well as the results of risk calculations and exposure analysis. http://www.epa.gov/ttn/fera/trim_gen.html

**Toxics Release Inventory (TRI) Program**
The Toxics Release Inventory (TRI) is a publicly available EPA database that contains information on toxic chemical releases and other waste management activities reported annually by certain covered industry groups as well as federal facilities. http://www.epa.gov/tri/

**Toxic Substances Control Act Chemical Substance Inventory**
EPA classifies chemical substances as either "existing" chemicals or "new" chemicals. The only way to determine if the substance is a new chemical is by consulting EPA's Toxic Substances Control Act Chemical Substance Inventory (commonly referred to as the TSCA Inventory or just the Inventory).There are approximately 75,000 chemical substances, as defined in Section 3 of the TSCA, on the Inventory at this time. epa.gov/opptintr/newchems/invntory.htm

**TRI-ME Toxics Release Inventory Made Easy Software**
The Toxics Release Inventory - Made Easy (TRI-ME) software is a tool to help facilities determine and complete their Emergency Planning and Community Right-to-Know Act (EPCRA) section 313 (TRI) reporting obligations. http://www.epa.gov/triinter/report/software/index.htm

**TSCATS Standard Reports (via RTK-NET)**
TSCATS (Toxic Substances Control Act Test Submissions) is an online index to unpublished, nonconfidential studies covering chemical testing results and adverse effects of chemicals on health and ecological systems. The studies are submitted by U.S. industry to EPA under several sections of the Toxic Substance Control Act (TSCA). There are four types of documents in the database: Section 4 chemical testing results, Section 8(d) health and safety studies, Section 8(e) substantial risk of injury to health or the environment notices, and voluntary documents submitted to EPA known as a For Your Information (FYI) notice. http://www.rtknet.org/tsc/

**UIC Class V Injection Wells Software**
USEPA's Underground Injection Control (UIC) program is explained in this hypertext-based software package, with a focus on Class V injection wells in particular. These wells inject wastewater directly into or above underground sources of drinking water, so it is important to understand why they exist, why they may pose a danger to the environment, and how they may be operated and maintained safely. http://www.epa.gov/seahome/inject.html

**Urban Airshed Model (UAM)**
The Atmospheric Sciences Modeling Division (ASMD) of NOAA's Air Resources Laboratory (ARL) collaborates with the U.S. Environmental Protection Agency (EPA) and its predecessor agencies in developing advanced air quality models that can simulate the transport and fate of pollutants in the atmosphere. http://www.epa.gov/asmdnerl/

**Vehicle and Engine Emissions Modeling Software**
Modeling is EPA's method for estimating emissions from on-road vehicles, nonroad sources, and fuels. Inventories are calculations of total emissions of a pollutant for a given area at a defined time and set of conditions. http://www.epa.gov/otaq/models.htm

*(Continued)*

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**Table 12A.6 (Continued)**

**Visual Plumes Model**
The Visual Plumes model system is a software application for simulating surface water jets and plumes. It also assists in the preparation of mixing zone analyses, Total Maximum Daily Loads (TMDLs), and other water quality applications. http://www.epa.gov/ceampubl/swater/vplume/index.htm

**VLEACH Software**
A one-dimensional, finite difference model for making preliminary assessments of the effects on groundwater from the leaching of volatile, sorbed contaminants through the vadose zone. The program models four main processes: liquid-phase advection, solid-phase sorption, vapor-phase diffusion, and three-phase equilibration. http://www.epa.gov/nerlesd1/databases/vleach/abstract.htm

**Wall Paint Exposure Assessment Model (WPEM)**
The Wall Paints Exposure Assessment Model (WPEM) estimates the potential exposure of consumers and workers to the chemicals emitted from wall paint which is applied using a roller or a brush. epa.gov/opptintr/exposure/docs/wpem.htm

**WAste Reduction Model**
EPA created the WAste Reduction Mode (WARM) to help solid waste planners and organizations track and voluntarily report greenhouse gas emissions reductions from several different waste management practices. WARM calculates and totals GHG emissions of baseline and alternative waste management practices — source reduction, recycling, combustion, composting, and landfilling. The model calculates emissions in metric tons of carbon equivalent (MTCE), metric tons of carbon dioxide equivalent ($MTCO_2E$), and energy units (million BTU) across a wide range of material types commonly found in municipal solid waste (MSW). http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteWARM.html

**Water-Effect Ratio of Metals**
This program is based on the EPA's 1994 "Interim Guidance on the Determination and Use of Water-Effect Ratios (WERs) for Metals." The WER procedure is one of three protocols which may be used to derive site-specific water quality criteria for the protection of aquatic life. http://www.epa.gov/seahome/wer.html

**Water Efficient Landscape Planner**
The Water Efficient Landscape Planner was developed to explain the advantages and principles of water efficient landscaping. The program covers the basics of landscape planning and provides guidelines and suggestions to help users select the most appropriate plants for their needs. It is intended for use by homeowners who are considering changes to residential landscaping. http://www.epa.gov/seahome/landscp.html

**Water Quality Analysis Simulation Program (WASP)**
WASP is a generalized framework for modeling contaminant fate and transport in surface waters. WASP has been used to answer questions regarding biochemical oxygen demand, dissolved oxygen dynamics, nutrients and eutrophication, bacterial contamination, and organic chemical and heavy metal contamination. http://www.epa.gov/athens/research/modeling/wasp.html

**Water Quality Standards and Criteria**
Water Quality Standards (WQS) provide a framework for maintenance and improvement of water quality when adopted by States, U.S. Territories, and Indian Tribes. This software presents the three components of State and Tribal WQS: waterbody uses (e.g., swimming, boating); water quality criteria or limits on chemical concentrations that may be present the waterbody; and antidegradation policy to protect existing water quality http://www.epa.gov/seahome/wqs.html

**WQS Database**
The WQSDB provides access to EPA and state WQS information in text, tables, and maps. This Web site provides access to several WQS reports with information about designated uses, waterbody names, state numeric water quality criteria, and EPA recommended numeric water quality criteria. http://www.epa.gov/wqsdatabase/

**Water Radioactivity Software Development Project (WRSDP)**
The EPA — Region 1, Radiation Unit has created a number of computer programs to help make necessary decisions regarding groundwater radioactivity, water radiation regulations, and radon mitigation in New England. These programs are specifically intended for the use of people in the water supply community working with water use, supply, and treatment. http://www.epa.gov/ne/eco/software/index.html

**WATERSHEDSS Documentation**
An Internet-based decision support and educational software system, WATERSHEDSS (WATER, Soil, and Hydro-Environmental Decision Support System) was developed to assist managers of predominantly agricultural watersheds in defining water-quality problems and selecting appropriate nonpoint source (NPS) pollution control measures. epa.gov/ceampubl/tools/watrshed/

**WATER9 Software**
WATER9, the wastewater treatment model, is a computer program and consists of analytical expressions for estimating air emissions of individual waste constituents in wastewater collection, storage, treatment, and disposal facilities; a database listing many of the organic compounds; and procedures for obtaining reports of constituent fates, including air emissions and treatment effectiveness. epa.gov/ttn/chief/software/water/index.html

*(Continued)*

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**Table 12A.6 (Continued)**

**Well Water Location and Condition on the Farm Software**
Well contamination may occur from farmstead activities near drinking water wells. The condition of your well and its proximity to pollution sources determine how much of a risk each source poses to the water you drink. This program contains information useful for identifying and correcting high-risk management and site conditions, and a water well risk assessment program. http://www.epa.gov/seahome/welloc.html

**WhAEM2000**
The U.S. EPA's Wellhead Analytic Element Model, WhAEM2000, is a groundwater geohydrology computer program. WhAEM2000 is a public domain, groundwater flow model designed to facilitate capture zone delineation and protection area mapping in support of the State's Wellhead Protection Programs (WHPP) and Source Water Assessment Planning (SWAP) for public water supplies in the United States. WhAEM2000 provides an interactive computer environment for design of protection areas based on radius methods, well in uniform flow solutions, and geohydrologic modeling methods. Protection areas are designed and overlaid upon U.S. Geological Survey Digital Line Graph (DLG) or other electronic base maps. Geohydrologic modeling for steady pumping wells, including the influence of hydrological boundaries, such as rivers, recharge, and no-flow contacts, is accomplished using the analytic element method. http://www.epa.gov/ceampubl/gwater/whaem/index.htm

**Wellhead Protection Software**
Hypertext and graphics explain protection of public water supplies as presented in the Safe Drinking Water Act Amendments of 1986. General concepts reviewed include building a planning team, delineating a wellhead protection area, conducting a contaminant source inventory, managing potential contaminant sources, and planning for the future. It is intended for local/Tribal officials, water supply managers and interested groups or citizens whose community relies on groundwater for its public water supply. Many of the concepts presented in this software may also be useful for protecting private wells. http://www.epa.gov/seahome/wellhead.html

**WhAEM Software**
A computer-based tool used in the wellhead protection decision-making process to delineate groundwater capture zones and isochrones of residence time — Unlike similar programs, WhAEM can accommodate fairly realistic boundary conditions, such as streams, lakes, and aquifer recharge due to precipitation. http://www.epa.gov/nerlesd1/databases/whaem/abstract.htm

**WHPA Software**
A semi-analytical groundwater flow simulation program used for delineating capture zones in a wellhead protection area. The program consists of four computational modules (RESSQC, MWCAP, GPTRAC, MONTEC). WHPA is applicable to homogeneous aquifers exhibiting two-dimensional, steady groundwater flow in an areal plane and appropriate for evaluating multiple aquifer types (i.e. confined, leaky-confined, and unconfined). The model is capable of simulating barrier or stream boundary conditions that exist over the entire depth of the aquifer. WHPA can account for multiple pumping and injection wells and can quantitatively assesses the effects of uncertain input parameters on a delineated capture zone(s). http://www.epa.gov/nerlesd1/databases/whpa/abstract.htm

**Window to My Environment**
"Window To My Environment" (WME) is a web-based tool that provides a wide range of federal, state, and local information about environmental conditions and features in selected areas. This application is provided by U.S. EPA in partnership with federal, state and local government and other organizations. http://www.epa.gov/enviro/wme/

*Source*: From www.epa.gov.

**Table 12A.7 EPA Public Listservs**

**AGCENTER**
National Agriculture Compliance Assistance Center

**AGING_INITIATIV**
List server of the EPA Aging Initiative

**AIR_INSPECTOR**

**ARCHITECTURES**

**BASINSINFO**
Private list for basins users

**BOPSAT**
BOPSAT group

**BROWNFIELDS**
EPA Brownfields Program news

**CALLCENTER_OSWER**
RCRA, Superfund & EPCRA Call Center

**CAMEO**
EPA-NOAA CAMEO Team

**CEAM-USERS**
CEAM Software Product Updates and Releases

**CERIPUBS**
A periodic announcement of new technology transfer products from U.S. EPA's Center for Environmental Research Information

**CFEIS**
CFEIS System status updates

*(Continued)*

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**Table 12A.7 (Continued)**

**CHIEF**
Emission Factor & Inventory Group

**CLEANNEWS**
Cleanup Newsletter

**CLIMATE_COMMUNICATORS**
Climate change communications, outreach, and education

**DECENTRALIZED**
Onsite/decentralized wastewater management issues

**EJ_Hispanic_Outreach**
Environmental Justice info (Spanish)

**EMWGLIST**
Exposure Modeling Work Group, pesticide exposure modeling

**ENVIROTECHNEWS**
Information for the environmental technology industry

**EPA-AIR**
Federal Register AIR documents

**EPA-CEPP**
U.S. EPA Chemical Emergency Preparedness and Prevention Office (CEPPO)

**EPA-ECON-FORUM**

**EPA-EJ**
Environmental Justice Information

**EPA-GENERAL**
Federal Register GENERAL Documents

**EPA-HUDSON**
Hudson River PCBs

**EPA-IMPACT**
Federal Register IMPACT documents

**EPA-MEETINGS**
Federal Register documents for Meetings

**EPA-MOBILENEWS**
Emission factors/emission inventories for mobile sources

**EPA-PEST**
Federal Register PESTICIDE documents

**EPA-R2-PRESS**

**EPA_RandD_News**
Weekly news briefs regarding Science and Research

**EPA-SAB**
Federal Register SCIENCE ADVISORY BOARD

**EPA-SPECIES**
Federal Register SPECIES documents

**EPA-TOX**
Federal register TOXIC documents

**EPA-TRI**
Federal Register TOXIC RELEASE INVENTORY documents

**EPA-WASTE**
Federal Register WASTE documents

**EPA-WATER**
Federal Register WATER documents

**EPA-WTC**
World Trade Center monitoring and cleanup

**EPAFR-CONTENTS**
Federal Register CONTENTS documents

**EPANEWS**
EPA news releases

**EPANEWS-ESPANOL**
EPA news releases in Spanish

**EPAWEB-OWNERS**

**ETVOICE**
Environmental Verification Technology Program info

**FEDENVIRONEWS**
Federal facilities environmental news

**FEDGB**
Limited to Federal Employees Working on green buildings issues

**GHGINVENTORY-L**
Greenhouse gas emissions data

**GreatLakesNews**
Funding and project news from Great Lakes National Program Office of USEPA

**GREENBYTES-NE**
EPA New England newsletter

**GREENVEHICLES**
Updates and Hot Topics of Green Vehicle Guide

**INNOVATION**
National Center for Environmental Innovation/OA — General Distribution

**Inthenews**
New England Environmental News

**JTRNET**
Public and non-profit recycling market developers

**K12_ENVIRONET**
K-12 New England educators

**MWRAPERMIT**
Proposed Modifications to Ambient Monitoring Plan

**NCEE-ANNOUNCE**
U.S. EPA's National Center for Environmental Economics

**NEI-USERGROUP**
National Emission Inventory User Group

**NEWS-NOTES**
Distribution of the publication Nonpoint Source News-Notes

**NPPTAC-EPA**
Parties Interested in information related to EPA's NPPTAC

*(Continued)*

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**Table 12A.7 (Continued)**

| | |
|---|---|
| **NPSINFO**<br>NPS Information Exchange | **NRMRL**<br>U.S. EPA National Risk Management Research Laboratory |
| **OCORELINK**<br>Office of Enforcement and Compliance Assurance Information | **OEISTAKEHOLDER**<br>OEI Stakeholders and Partners |
| **OIG-News**<br>Announcements of new postings to the EPA's Office of the Inspector General's web site | **ONLNCALC**<br>Online Calculators and Internet Modeling Course |
| **OSWER_VISION**<br>OSWER Quarterly Newsletter | **OTAQ-ANNOUNCE**<br>EPA Office of Transportation and Air Quality (OTAQ) Announcements |
| **P2NEWS2**<br>Pollution Prevention Activities at EPA | **PBTCHEMFOCUS**<br>Waste minimization |
| **PPDCFORUM**<br>Pesticide Program Dialogue Committee | **R3MOUNTAINTOP** |
| **R3NEWSRELEASE**<br>EPA Mid-Atlantic Region News Releases | **R5NEWS**<br>Region 5 news releases |
| **RPO-LISTSERV**<br>Regional Planning Organizations Activities | **SMOKEIMPACT** |
| **STATEPRETCOORD**<br>Discussion forum for State Pretreatment Coordinators | **STORETINFO**<br>STORET news and information |
| **SUNPROTECTION**<br>Sun protection, ultraviolet (UV) radiation exposure | **TECHDIRECT**<br>Info for site remediation/site assessment professionals |
| **U.S._MEXBORDER**<br>U.S. EPA U.S. Mexican Border Discussions | **USEPAR3NEWS**<br>U.S. EPA Region 3 news |
| **USEPAR9NEWS**<br>U.S. EPA Region 9 Press Releases | **VOLMONITOR**<br>Volunteer water monitoring |
| **WASTEWISE**<br>All WasteWise Partners and Endorsers | **WATERNEWS**<br>Water quality information |
| **WATERSHED-NEWS**<br>Information for watershed groups and others working at the grass roots level to protect and restore watersheds | **WEB-AMBASSADOR**<br>EPA web site updates |
| **WIPP-NEWS**<br>Periodic information regarding EPA's role at the WIPP | **WQS-NEWS**<br>Office of water Standards and Applied Science Division |

*Note:* On-line subscription services offered by EPA providing periodic informational updates. Subscriptions may be made at www.lists.epa.gov/cgi-bin/1yris.pl.

*Source*: From www.epa.gov.

**Table 12A.8 EPA Newsletters**

*Activities Update* (http://www.epa.gov/epahome/announce.htm) — a monthly publication of EPA highlights and activities including: summaries of press releases, upcoming public meetings, upcoming congressional hearings, EPA senior management statements and testimonies, reports and publications, enforcement actions, Federal Register notices and highlights of EPA rulemakings

*AIEO Update* (http://www.epa.gov/indian/1up.htm) — quarterly publication from the American Indian Environmental Office

*AMTIC News* (http://www.epa.gov/ttnamti1/improv2.html) — a quarterly publication of the ambient monitoring technology information center, which describes events, regulations, and technology relating to the measurement of air pollution

*Audit Policy Update* (http://www.epa.gov/Compliance/resources/newsletters/incentives/auditupdate/index.html) — published periodically for the assistant administrator for enforcement and compliance assurance by its office of regulatory enforcement. The Update is intended to provide information to the public and regulated communities regarding developments under the EPA Audit Policy

*(Continued)*

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**Table 12A.8 (Continued)**

*Chief Newsletter* (epa.gov/ttn/chief/newsletter.html) — quarterly publication of the emission factor and inventory group, which keeps the public informed about new emission estimation tools, conferences, and other information relating to emission factors and inventories

*CleanupNews* (http://www.epa.gov/compliance/resources/newsletters/cleanup/cleanupnews.html) — a quarterly published by the office of site remediation enforcement that highlights hazardous waste cleanup news, policy updates, court cases, technology, events, publications, and more

*Coastlines* (http://www.epa.gov/nep/coastlines) — information about estuaries and near coastal waters from the national estuary program

*Community Based Environmental Protection (CBEP) News Online Newsletter* (epa.gov/ecocommunity/news.htm) — a bi-weekly electronic newsletter about CBEP activities within and beyond EPA

*EIIP Update* (http://www.epa.gov/ttn/chief/eiip/update/index.html) — a newsletter designed to inform the emissions community about the emission inventory improvement program and its mission, goals, and benefits

*ENERGY STAR News* (www.energystar.gov/index.cfm?c = newsletter.nr_newsletter) — news concerning energy star labeled products

*Enforcement Alert* (http://www.epa.gov/compliance/resources/newsletters/civil/enfalert/index.html) — an electronic newsletter from the office of enforcement compliance and assurance intended to inform and educate the public and regulated community of important environmental enforcement issues, recent trends and significant enforcement actions

*EPA Journal* (epa.gov/history/collection/aid10.htm) — back issues of this agency publication on national and global environmental perspectives last published spring 1995

*FedFacs* (http://www.epa.gov/compliance/resources/newsletters/civil/fedfac/index.html) — an environmental bulletin for federal facilities from EPA's federal facilities enforcement office

*GMPO Newsletter* (epa.gov/gmpo/newsletters.html) — current activities related to the economic and environmental health of the gulf of Mexico published by the gulf of Mexico program

*Green Lights and Energy Star Buildings Update and Bulletin* (http://www.energystar.gov/index.cfm?c = bldrs_lenders_raters.pt_homes_newsletter) — a quarterly publication that provides in-depth information about participant accomplishments and program developments

*Ground Water Currents* http:// (www.clu-in.org/products/newsltrs/gwc/default.htm) — developments in innovative groundwater treatment from the Technology Innovation Office of the U.S. EPA office of solid waste

*Inside the Greenhouse* (epa.gov/globalwarming/greenhouse/index.html) — focuses on innovative state and local programs to reduce greenhouse gas emissions; Inside the greenhouse is a quarterly, electronic publication produced by the EPA's state and local climate change program

*National Small Flows Clearinghouse* (http://www.nesc.wvu.edu/nsfc/nsfc_index.htm) — offers two quarterly newsletters, small flows and pipeline, focusing on wastewater information for small communities

*Native American Network Newsletter* (epa.gov/epaoswer/non-hw/tribal/fednews.htm#nan) — provides information to help interested parties stay on top of municipal solid waste management issues affecting indian country

*NERL Research News* (http://www.epa.gov/nerl/publications/bulletins/index.html) — information about recent research from the national exposure research laboratory

*Nonpoint Source News-Notes* (http://www.epa.gov/OWOW/info/NewsNotes/) — is an occasional bulletin dealing with the condition of the water-related environment, the control of nonpoint sources of water pollution, and the ecosystem-driven management and restoration of watersheds

*Oil Spill Program Update* (http://www.epa.gov/oilspill/document.htm#update) — quarterly update of the activities of EPA's oil spill program

*OPPT Tribal News* (http://www.epa.gov/opptintr/tribal/pubs/index.html) — Environmental news for Indian tribes from the office of pollution prevention and toxics

*P2 News2* (epa.gov/p2/resources/p2news2.htm) — an electronic newsletter produced by the pollution prevention programs of the U.S. EPA Office of Pollution Prevention and Toxics (OPPT)

*PESP Update* (http://www.epa.gov/oppbppd1/PESP/publications.htm) — a periodical news brief on the pesticide environmental stewardship program

*RCRA/UST, Superfund & EPCRA Hotline Reports* http:// (www.epa.gov/epaoswer/hotline/mrqs.htm) — a monthly compilation of frequently asked regulatory questions for which EPA has provided answers and prepares them in a question and answer format

*Reusable News Newsletters* (http://www.epa.gov/epaoswer/non-hw/recycle/reuse.htm) — a collection of information from the U.S. EPA's office of solid waste

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**Table 12A.8 (Continued)**

*Science Advisory Board Newsletter* (http://www.epa.gov/science1/news.htm) — news and events pertaining to the activities of the science advisory board

*SRF's UP* (http://www.epa.gov/safewater/dwsrf.html?Facts) — a quarterly newsletter providing up-to-date information about the clean water and drinking water state revolving fund programs

*Tech Trends* (http://www.clu-in.org/pub1.cfm) — a newsletter that provides descriptions and performance data for innovative source control technologies that have been applied in the field

*Tribal Waste Journal* (http://www.epa.gov/epaoswer/non-hw/tribal/fednews.htm?twj) — from the waste management in Indian country program, each issue features a different topic and includes a kids section. Published annually, EPA's tribal waste journal replaces the native American network newsletter

*Volunteer Monitor* (http://www.epa.gov/OWOW/monitoring/volunteer/vm_index.html) — the national newsletter of volunteer water quality monitoring

*Water Quality Criteria and Standards Newsletter* (http://www.epa.gov/OST/pc/wqnews/) — a periodic newsletter about issues affecting water quality standards from the office of water's office of science and technology

*Water Talk* (yosemite.epa.gov/R10/WATER.NSF/webpage/WaterTalk?OpenDocument) — is published quarterly by the U.S. EPA, Region 10 and seeks to be a useful tool for those who protect water resources and ecosystems in communities of the Greater Pacific Northwest

*Waternews* (http://www.epa.gov/ow/waternews/) — a weekly on-line publication that announces publications, policies, and activities of the U.S. EPA's office of water

*Watershed Events* (http://www.epa.gov/OWOW/info/WaterEventsNews/index.html) — is intended to update interested parties on the development and use of watershed protection approaches

*Source*: From www.epa.gov.

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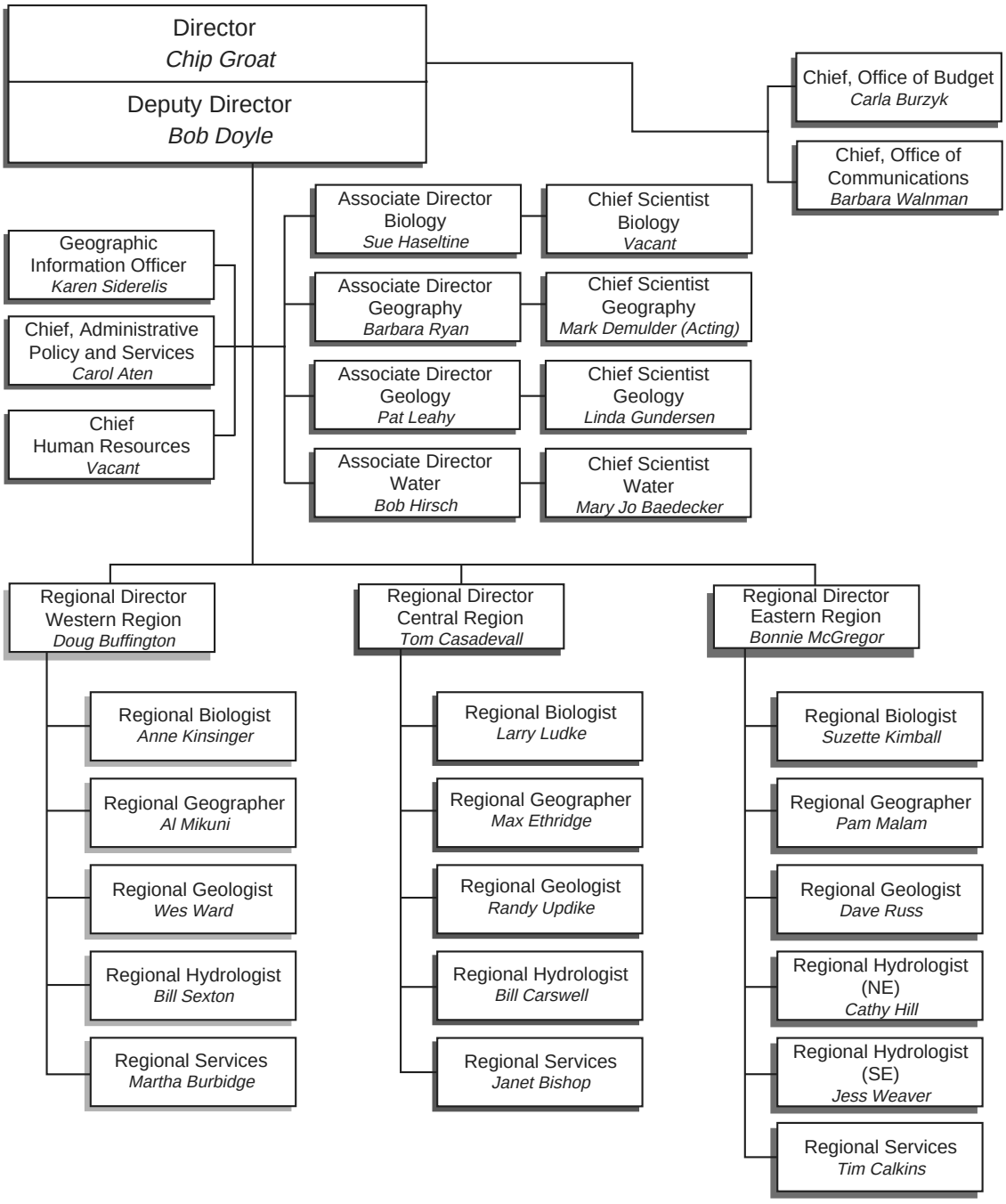


**Figure 12A.3** Organization of the U.S. Geological Survey (www.epa.gov).

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**Table 12A.9 Directory — U.S. Geological Survey Water Resources Division**

| Office of the Director, U.S. Geological Survey | |
|---|---|
| **Title, Name, Mail Stop** | **Phone Number** |
| Director Charles G Groat MS 100 | (703) 648-7411 |
| Staff Assistant Janet N Arneson MS 100 | (703) 648-7411 |
| Deputy Director Robert E Doyle MS 101 | (703) 648-7412 |
| Staff Assistant Deborah A Riggsbee MS 101 | (703) 648-7412 |
| Senior Advisor to the Director Suzanne D Weedman MS 104 | (703) 648-4760 |
| Senior Advisor to the Director Amy L Holley MS 104 | (703) 648-4411 |
| Education Program Coordinator Robert W Ridky MS 104 | (703) 648-4713 |
| Staff Assistant for Special Issues Judy Nowakowski MS 121 | (703) 648-4554 |
| Senior Advisor for Science Applications James F Devine MS 106 | (703) 648-4423 |
| Secretary Joyce K Copeland MS 106 | (703) 648-4191 |
| Associate Director for Water Robert M Hirsch MS 409 | (703) 648-5215 |
| Staff Assistant Georgia J Diersing MS 409 | (703) 648-5215 |
| Chief Scientist for Hydrology Mary Jo Baedecker MS 436 | (703) 648-5041 |
| Secretary Paula A McMahon MS 436 | (703) 648-5041 |
| Staff Assistant/Strategic Planning Gail E Mallard MS 409 | (401) 322-0902 |
| Staff Assistant/Special Issues, Vacant, MS 409 | |
| Senior Science Advisor for Surface Water Stephen F Blanchard MS 415 | (703) 648-5629 |
| Secretary, Maria Calderon, MS 415 | (703) 648-5301 |
| Chief, Office of Water Information Katherine Lins, MS 440 | (703) 648-5014 |
| Secretary Alice C Dilandro MS 440 | (703) 648-5032 |
| Senior Management Officer for Water Gene A Summerhill MS 440 | (703) 648-5309 |
| National Coordinator, Cooperative Water Program Glenn G Patterson MS 409 | (703) 648-6876 |
| Chief, National Water-Quality Assessment (NAWQA) Program Donna N Myers MS 413 | (703) 648-5012 |
| Secretary Sarahnell L Laible MS 413 | (703) 648-5715 |
| Chief, Office of Ground Water William M Alley MS 411 | (703) 648-5035 |
| Secretary Carolyn L Wakelee MS 411 | (703) 648-5001 |
| Chief, Office of Water Quality Timothy L Miller, MS 412 | (703) 648-6868 |
| Secretary Nana L Snow MS 412 | |

*Note:* U.S. Geological Survey Headquarters, John W. Powell Federal Building, 12201 Sunrise Valley Drive, Reston, Virginia 20192.

*Source*: From www.usgs.gov.

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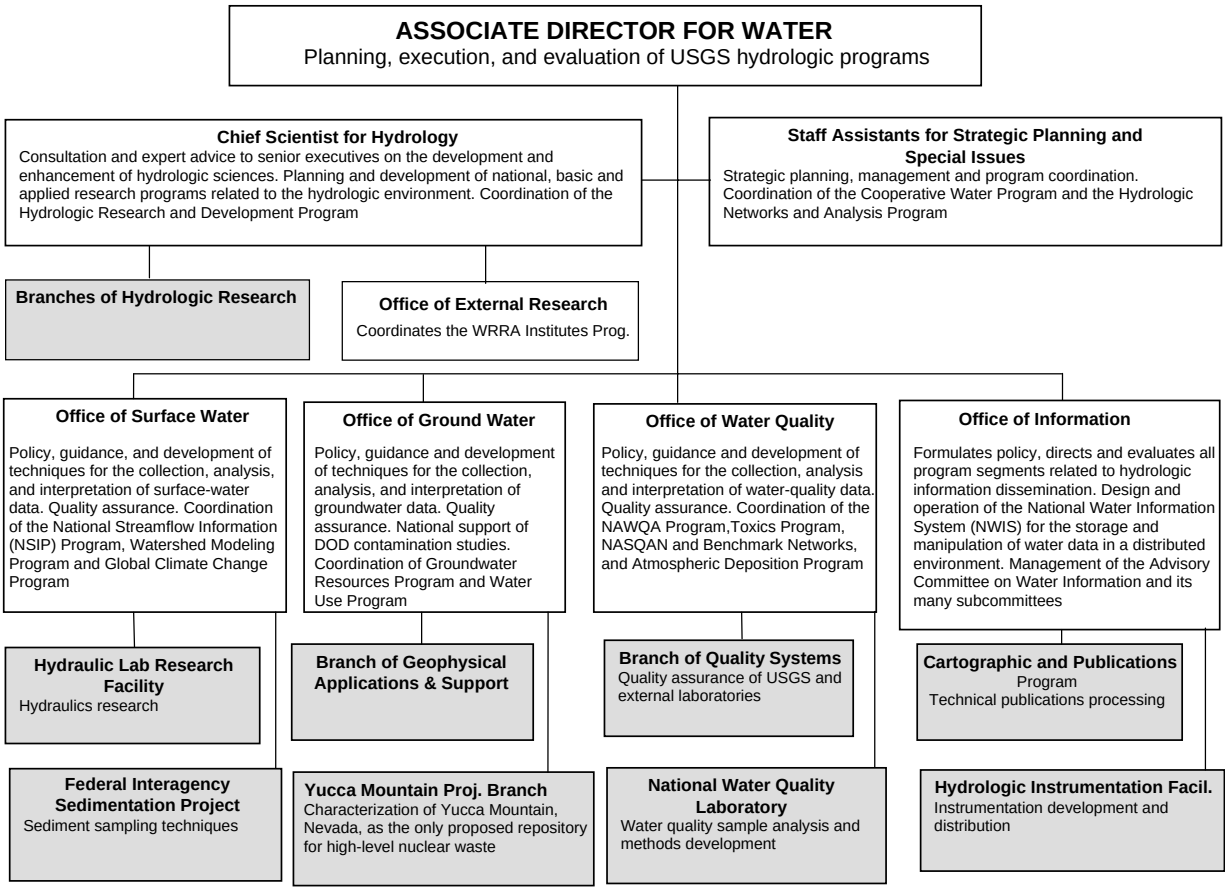


**Figure 12A.4** Organization of the water resources division of the U.S. Geological Survey (www.epa.gov).

**Table 12A.10 USGS Water Resources District Chiefs**

Alabama, Athena P. Clark, dc_al@usgs.gov, 2350 Fairlane Drive, Suite 120, Montgomery, AL 36116, Phone: (334) 213-2332, Fax: (334) 213-2348, Office hours: 7:30 a.m. to 4:00 p.m. Central Time

Alaska, Steven A. Frenzel, dc_ak@usgs.gov, U.S. Geological Survey, 4230 University Dr., Suite 201, Anchorage, AK 99508-4664, Phone: (907) 786-7100, Fax: (907) 786-7150, Office hours: 8:00 a.m. to 4:30 p.m. Alaska Time

Arizona, Nick B. Melcher, dc_az@usgs.gov, U.S. Geological Survey Water Resources Division, 520 N. Park Avenue, Suite 221, Tucson, AZ 85719, Phone: (520) 670-6671, ext. 221, Fax: (520) 670-5592, Office hours: 7:30 a.m. to 4:00 p.m. Mountain Time

Arkansas, John E. Terry JR., dc_ar@usgs.gov, 401 Hardin Rd., Little Rock, AR 72211, Phone: (501) 228-3600, Fax: (501) 228-3601, Office hours: 7:30 a.m. to 4:00 p.m. Central Time

California, Point of contact: Frederick J. Heimes, Michael V. Shulters, dc_ca@usgs.gov, Placer Hall, 6000 J Street, Sacramento, CA 95819-6129, Phone: (916) 278-3000, Fax: (916) 278-3070, Office hours: 7:30 a.m. to 4:00 p.m. Pacific Time

Caribbean, Pedro L. Diaz, dc_pr@usgs.gov, GSA Center, 651 Federal Drive, Suite 400-15, Guaynabo, PR 00965, Phone: (787) 749-4346, Fax: (787) 787 749-4301, Office hours: 7:45 a.m. to 4:30 p.m. Atlantic Time

Colorado, William F. Horak, dc_co@usgs.gov, Bldg. 53, Denver Federal Center, Mail Stop 415, Box 25046, Lakewood, CO 80225-0046, Phone: (303) 236-4882, ext. 258, Fax: (303) 236-4912, Office hours: 8:00 a.m. to 4:30 p.m. Mountain Time

Connecticut, Virginia A. Delima, dc_ct@usgs.gov, 101 Pitkin Street, East Hartford, CT 06108, Phone: (860) 291-6740, Fax: (860) 291-6799, Office hours: 7:45 a.m. to 4:15 p.m. Eastern Time

Delaware, William Guertal, dc_de@usgs.gov, 1289 McD Dr., Dover, DE 19901-4907, Phone: (302) 734-2506, Fax: (302) 734-2964, Office hours: 8:00 a.m. to 4:30 p.m. Eastern Time

District of Columbia, see Maryland

*(Continued)*

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**Table 12A.10 (Continued)**

Florida, Carl R. Goodwin, dc_fl@usgs.gov, 9100 NW 36th St., Suite 107, Miami, FL 33178, Phone: (305) 717-5845, Fax: (305) 717-5801, St. Pete Offic: (727) 803-8747 (x3070), St. Pete Fax: (727) 803-2031, Office hours: 7:45 a.m. to 4:30 p.m. Eastern Time

Georgia, Edward H. Martin, dc_ga@usgs.gov, Peachtree Business Center, Suite 130, 3039 Amwiler Rd., Atlanta, GA 30360-2824, Phone: (770) 903-9100, Fax: (770) 903-9199, Office hours: 8:00 a.m. to 4:30 p.m. Eastern Time

Guam, see Hawaii

Hawaii, Gordon Tribble, dc_hi@usgs.gov, 677 Ala Moana Blvd., Suite 415, Honolulu, HI 96813, Phone: (808) 587-2405, Fax: (808) 587-2401, Office hours: 8:00 a.m. to 4:30 p.m. Hawaii-Aleutian Time

Idaho, Kathy D. Peter, dc_id@usgs.gov, 230 Collins Rd., Boise, ID 83702-4520, Phone: (208) 387-1300, Fax: (208) 387-1372, Office hours: 7:45 a.m. to 4:15 p.m. Mountain Time

Illinois, Bob Holmes, dc_il@usgs.gov, 221 North Broadway Avenue, Urbana, IL 61801, Phone: (217) 344-0037, ext. 3005, Fax: (217) 344-0082, Office hours: 8:00 a.m. to 4:30 p.m. Central Time

Indiana, James A. Stewart, dc_in@usgs.gov, 5957 Lakeside Blvd., Indianapolis, IN 46278-1996, Phone: (317) 290-3333, Fax: (317) 290-3313, Office hours: 7:30 a.m. to 4:00 p.m. Eastern Time

Iowa, Rob G. Middlemis-Brown, dc_ia@usgs.gov, P.O. Box 1230, Iowa City, IA 52244, Phone: (319) 358-3600, Fax: (319) 358-3606, Office hours: 7:45 a.m. to 4:30 p.m. Central Time

Kansas, Walter R. Aucott, dc_ks@usgs.gov, 4821 Quail Crest Place, Lawrence, KS 66049, Phone: (785) 842-9909, Fax: (785) 832-3500, Office hours: 8:00 a.m. to 4:30 p.m. Central Time

Kentucky, Mark A. Ayers, dc_ky@usgs.gov, 9818 Bluegrass Parkway, Louisville, KY 40299, Phone: (502) 493-1900, Fax: (502) 493-1909, Office hours: 8:00 a.m. to 4:45 p.m. Eastern Time

Louisiana, Charles R. Demas, dc_la@usgs.gov, 3535 S. Sherwood Forest Blvd., Suite 120, Baton Rouge, LA 70816, Phone: (225) 298-5481, Fax: (225) 298-5490, Office hours: 7:45 a.m. to 4:30 p.m. Central Time

Maine, Robert M. Lent, dc_me@usgs.gov, 196 Whitten Road, Augusta, ME 04330, Phone: (207) 622-8202, Fax: (207) 622-8204, Office hours: 7:30 a.m. to 4:15 p.m. Eastern Time

Maryland, James M. Gerhart, dc_md@usgs.gov, U.S. Geological Survey, 8987 Yellow Brick Road, Baltimore, MD 21237, Phone: (410) 238-4200, Fax: (410) 238-4210, Office hours: 8:00 a.m. to 4:30 p.m. Eastern Time

Massachusetts, Wayne H. Sonntag, dc_ma@usgs.gov, 10 Bear Foot Road, Northborough, MA 01532, Phone: (508) 490-5000, Fax: (508) 490-5068, Office hours: 8:00 a.m. to 4:30 p.m. Eastern Time

Michigan, James R. Nicholas, dc_mi@usgs.gov, 6520 Mercantile Way, Suite 5, Lansing, MI 48911, Telephone: (517) 887-8903, Fax: (517) 887-8937, Office hours: 7:45 a.m. to 4:15 p.m. Eastern Time

Minnesota, Jeffrey D. Stoner, dc_mn@usgs.gov, 2280 Woodale Dr., Mounds View, MN 55112, Phone: (763) 783-3100, Fax: (763) 783-3103, Office hours: 8:00 a.m. to 4:30 p.m. Central Time

Mississippi, Michael L. Plunkett, dc_ms@usgs.gov, 308 South Airport Road, Pearl, MS 39208-6649, Phone: (601) 933-2940, Fax: (601) 933-2901, Office hours: 8:00 a.m. to 4:30 p.m. Central Time

Missouri, Michael E. Slifer, dc_mo@usgs.gov, 1400 Independence Rd., Mail Stop 200, Rolla, MO 65401, Phone: (573) 308-3664, Fax: (573) 308-3645, Office hours: 7:30 a.m. to 4:00 p.m. Central Time

Montana, Robert E. Davis, dc_mt@usgs.gov, USGS, WRD, 3162 Bozeman Avenue, Helena, MT 59601, Phone: (406) 457-5900, Fax: (406) 457-5990, Office hours: 8:00 a.m. to 4:30 p.m. Mountain Time

Nebraska, James E. Kircher (Acting), dc_ne@usgs.gov, 100 Centennial Mall North, Lincoln, NE 68508, Phone: (402) 437-5082, Fax: (402) 437-5139, Office hours: 7:45 a.m. to 4:30 p.m. Central Time

Nevada, Kimball Goddard, dc_nv@usgs.gov, 333 West Nye Lane, Rm 203, Carson City, NV 89706, Phone: (775) 887-7600, Fax: (775) 887-7621, Office hours: 8:00 a.m. to 4:30 p.m. Pacific Time

New Hampshire, Brian R. Mrazik, dc_nh@usgs.gov, 361 Commerce Way, Pembroke, NH 03275-3718, Phone: (603) 226-7800, Fax: (603) 226-7894, Office hours: 7:45 a.m. to 4:15 p.m. Eastern Time

New Jersey, Richard H. Kropp, dc_nj@usgs.gov, 810 Bear Tavern Rd., Suite 206, West Trenton, NJ 08628, Phone: (609) 771-3900, Fax: (609) 771-3915, Office hours: 7:45 a.m. to 4:15 p.m. Eastern Time

New Mexico, Linda S. Weiss, dc_nm@usgs.gov, 5338 Montgomery, NE, Suite 400 (for the District Office), Suite 300 (for the Albuquerque Field Office), Albuquerque, NM 87109-1311, Phone: (505) 830-7900, Fax: (505) 830-7998, Office hours: 8:00 a.m. to 4:30 p.m. Mountain Time

New York, Rafael M. Rodriguez, dc_ny@usgs.gov, 425 Jordan Rd. Troy, NY 12180, Phone: (518) 285-5600 Fax: (518) 285-5601 Office hours: 7:30 a.m. to 4:00 p.m. Eastern Time

North Carolina, Gerald L. Ryan, dc_nc@usgs.gov, 3916 Sunset Ridge Road Raleigh, NC 27607, Phone: (919) 571-4000, Fax: (919) 571-4041, Office hours: 8:00 a.m. to 4:45 p.m. Eastern Time

*(Continued)*

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**Table 12A.10 (Continued)**

North Dakota, Gregg J. Wiche, dc_nd@usgs.gov, 821 E. Interstate Ave., Bismarck, ND 58501-1199, Phone: (701) 250-7401, Fax: (701) 250-7492, Office hours: 8:00 a.m. to 5:00 p.m. Central Time

Oklahoma, Kimberly T. Winton, dc_ok@usgs.gov, 202 N.W. 66 St., Building 7 Oklahoma City, OK 73116, Phone: (405) 810-4400, Fax: (405) 843-7712, Office hours: 8:00 a.m. to 4:45 p.m. Central Time

Pennsylvania, Patricia L. Lietman, dc_pa@usgs.gov, 215 Limekiln Road New Cumberland, PA 17043-1586, Phone: (717) 730-6900, Fax: (717) 730-6997, Office hours: 7:30 a.m. to 4:00 p.m. Eastern Time

South Carolina, Marjorie S. Davenport dc_sc@usgs.gov 720 Gracern Rd. Stephenson Center, Suite 129 Columbia, SC 29210, Phone: (803) 750-6100, Fax: (803) 750-6181, Office hours: 7:45 a.m. to 4:30 p.m. Eastern Time

Tennessee, W. Scott Gain, dc_tn@usgs.gov, 640 Grassmere Park Drive, Suite 100 Nashville, TN 37211, Phone: (615) 837-4700, Fax: (615) 837-4799, Office hours: 7:45 a.m. to 4:45 p.m. Central Time

Utah, Patrick M. Lambert, dc_ut@usgs.gov, U.S. Geological Survey 2329 W. Orton Circle West Valley City, UT 84119-2047, Phone: (801) 908-5000, Fax: (801) 908-5001, Office hours: 8:00 a.m. to 4:30 p.m. Mountain Time

Virginia, Ward W. Staubitz, dc_va@usgs.gov, 1730 East Parham Road Richmond, VA 23228, Phone: (804) 261-2600, Fax: (804) 261-2659, Office hours: 8:00 a.m. to 4:45 p.m. Eastern Time

West Virginia, Hugh E. Bevans, dc_wv@usgs.gov, 11 Dunbar St. Charleston, WV 25301, Phone: (304) 347-5130, Fax: (304) 347-5133, Office hours: 7:30 a.m. to 4:00 p.m. Eastern Time

Wyoming, Myron H. Brooks, state_rep_wy@usgs.gov, 2617 E. Lincolnway, Suite B Cheyenne, WY 82001, Phone: (307) 778-2931, ext. 2728, Fax: (307) 778-2764, Office hours: 8:00 a.m. to 4:30 p.m. Mountain Time

Ohio, James R. Morris, dc_oh@usgs.gov, 6480 Doubletree Avenue, Columbus, OH 43229-1111, Phone: (614) 430-7702, Fax: (614) 430-7777, Office hours: 7:30 a.m. to 4:30 p.m. Eastern Time

Oregon, Dennis D. Lynch, dc_or@usgs.gov, 10615 S.E. Cherry Blossom Dr., Portland, OR 97216, Phone: (503) 251-3200, Fax: (503) 251-3470, Office hours: 7:30 a.m. to 4:30 p.m. Pacific Time

Rhode Island, James B. Campbell, dc_ri@usgs.gov, 275 Promenade St., Suite 150 Providence, RI 02908, Phone: (401) 331-9050, Fax: (401) 331-9062, Office hours: 8:00 a.m. to 4:30 p.m. Eastern Time

South Dakota, Daniel J. Fitzpatrick, dc_sd@usgs.gov, 1608 Mt. View Rd., Rapid City, SD 57702, Phone: (605) 355-4560, Fax: (605) 355-4523, Office hours: 6:30 a.m. to 4:30 p.m. Mountain Time

Texas, Robert L. Joseph, dc_tx@usgs.gov, USGS WRD 8027 Exchange Drive Austin, TX 78754-4733, Phone: (512) 927-3500, Fax: (512) 927-3590, Office hours: 7:45 a.m. to 4:30 p.m. Central Time

Vermont, Brian R. Mrazik, dc_nh@usgs.gov, 361 Commerce Way Pembroke, NH 03275-3718 Phone: (603) 226-7800, Fax: (603) 226-7894, Office hours: 7:45 a.m. to 4:15 p.m. Eastern Time

Washington, Cynthia Barton, dc_wa@usgs.gov, 1201 Pacific Ave., Suite 600 Tacoma, WA 98402, Phone: (253) 428-3600, ext. 2602, Fax: (253) 428-3614, Office hours: 7:45 a.m. to 4:30 p.m. Pacific Time

Wisconsin, Charles A. Peters, dc_wi@usgs.gov, 8505 Research Way Middleton, WI 53562-3581, Phone: (608) 821-3801, Fax: (608) 821-3817, Office hours: 8:00 a.m. to 4:30 p.m. Central Time

*Source*: From www.usgs.gov.

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**Table 12A.11 USGS Programs**

**Biological Informatics — http://biology.usgs.gov/bio**
The Biological Informatics Program develops and applies innovative information technologies and practices to the management of biological data, information, and knowledge resulting from research, thereby increasing the value of that research to scientists, planners, policy makers, teachers, students, and private citizens

**Coastal and Marine Geology — http://marine.usgs.gov**
Provides information relative to marine science for making management decisions that affect all 35 coastal states and the island territories. Monitors changes within the coastal and marine environment, whether naturally occurring or human induced

**Contaminant Biology — http://biology.usgs.gov/pub_aff/cont-over.htm**
The Contaminants Program conducts research, assessments and monitoring to provide the nation and its natural resource managers with information on the exposure, effects and fate of deleterious substances in the environment

**Cooperative Research Units — Biology http://www.coopunits.org**
**Wildlife and Terrestrial Resources**
**Terrestrial, Freshwater, and Marine Ecosystems**
The Cooperative Research Units Program is a unique collaborative relationship between States, Universities, the Federal government and a non-profit organization. Coop Units conduct research on renewable natural resource questions, participate in the education of graduate students destined to join the natural resource profession, provide technical assistance and consultation to parties who have interests in natural resource issues, and provide various forms of continuing education for natural resource professionals

**Cooperative Topographic Mapping — http://nationalmap.usgs.gov**
The National Map is a consistent framework for geographic knowledge. It provides public access to high-quality, geospatial data and information from multiple partners to help support decision making by resource managers and the public. The National Map is the product of a consortium of Federal, State, and local partners who provide geospatial data to enhance America's ability to access, integrate, and apply geospatial data at global, national, and local scales

**Cooperative Water Program — http://water.usgs.gov/coop**
As the primary Federal science agency for water resource information, the USGS Cooperative Water Program provides reliable, impartial, and timely information needed to understand the Nation's water resources through a program of shared efforts and funding with State, Tribal, and local partners to enable decision makers to manage the Nation's water resources

**Earth Surface Dynamics — http://geochange.er.usgs.gov**
The USGS Global Change Research activities strive to achieve a whole-system understanding of the interrelationships among earth surface processes, ecological systems, and human activities. Activities of the program focus on documenting, analyzing, and modeling the character of past and present environments and the geological, biological, hydrological, and geochemical processes involved in environmental change so that future environmental changes and impacts can be anticipated

**Earthquake Hazards — http://earthquake.usgs.gov**
**Global Seismic Network http://earthquake.usgs.gov/networks/global.html**
This web site is provided by the USGS Earthquake Hazards Program as part of the effort to reduce earthquake hazard in the United States

**Energy Resources — http://energy.usgs.gov**
The USGS Energy Resources Program addresses the challenge of increasing demand for affordable energy from environmentally acceptable energy sources by conducting basic and applied research on geologic energy resources and on the environmental, economic, and human health impacts of their production and use. The Program provides reliable and impartial scientific information and comprehensive analyses of oil, natural gas, and coal resources of the Nation and the World

**Fisheries and Aquatic Resources — http://far.nbii.gov/**
To aid conservation and restoration efforts, the Fisheries and Aquatic Resources (FAR) node was established to provide an integrated, comprehensive web-based resource that will: 1) serve and access fishery and aquatic databases, 2) link to fishery and aquatic resource information sites, and 3) act as larger scale coordinating site for fisheries and aquatic resources standards

**Geographic Analysis and Monitoring — http://gam.usgs.gov**
Geographic Analysis and Monitoring Program conducts geographic assessments to improve the understanding of the rates, causes, and consequences of natural and human-induced processes that shape and change the landscape over time

**Geomagnetism — http://geomag.usgs.gov**
The USGS Geomagnetism Program monitors the field through a network of magnetic observatories and conducts scientific analysis on those data. The Program collects, transports, and can disseminate these data in near-real time, and it also has significant data-processing and management capacities

**Groundwater Resources — http://water.usgs.gov/ogw**
These pages are designed to provide useful information about groundwater resources of the Nation and groundwater activities of the USGS

*(Continued)*

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**Table 12A.11 (Continued)**

**Hydrologic Networks and Analysis**

**Hydrologic Research and Development — http://water.usgs.gov/nrp**
The National Research Program (NRP) conducts basic and problem oriented hydrologic research in support of the U.S. Geological Survey (USGS)

**Invasive Species and Emerging Diseases — http://www.usgs.gov/invasive_species/plw**
Provides updates on invasive plants, exotic animals and microbes

**Land Remote Sensing — http://remotesensing.usgs.gov**
The fundamental goal of the LRS Program is to provide the Federal Government and the public with a primary source of remotely sensed data and applications and to be a leader in defining the future of land remote sensing, nationally, and internationally

**Landslide Hazards — http://landslides.usgs.gov/index.html**
The Landslides Hazards Group conducts research, gathers information, responds to emergencies and disasters, and produces scientific reports and other products for a broad-based user community. The group provides the results of investigations to private consultants in geology and geotechnical engineering, and to government planners and decision makers

**Mineral Resources — http://minerals.usgs.gov**
The Mineral Resources Program funds science to provide and communicate current, impartial information on the occurrence, quality, quantity, and availability of mineral resources

**National Cooperative Geologic Mapping — http://ncgmp.usgs.gov**
The program coordinates an expanded geologic mapping effort by the USGS, the State geological surveys, and universities. The primary goal of the program is to collect, process, analyze, translate, and disseminate earth-science information through geologic maps

**National Streamflow Information — http://water.usgs.gov/nsip**
Provides information on the quantity and timing of the streamflow in the Nation's rivers. The USGS operates and maintains approximately 7,000 streamgages which provide long-term, accurate, and unbiased information that meets the needs of many diverse users

**National Water Quality Assessment — http://water.usgs.gov/nawqa**
The NAWQA program has been collecting and analyzing data and information in more than 50 major river basins and aquifers across the Nation. The goal is to develop long-term consistent and comparable information on streams, groundwater, and aquatic ecosystems to support sound management and policy decisions

**State Water Resources Research Institute Program — http://water.usgs.gov/wrri**
The program cooperates with the USGS in establishing total programmatic direction, reporting on the activities of the Institutes, coordinating and facilitating regional research and information and technology transfer, and in operating the NIWR-USGS Student Internship Program

**Toxic Substances Hydrology — http://toxics.usgs.gov**
Provides objective scientific information to improve characterization and management of contaminated sites, to protect human and environmental health, and to reduce potential future contamination problems

**Volcano Hazards — http://volcanoes.usgs.gov**
Provides scientific information on volcanoes including current and historical volcanic activities and reducing associated risks

*Source*: From www.usgs.gov.

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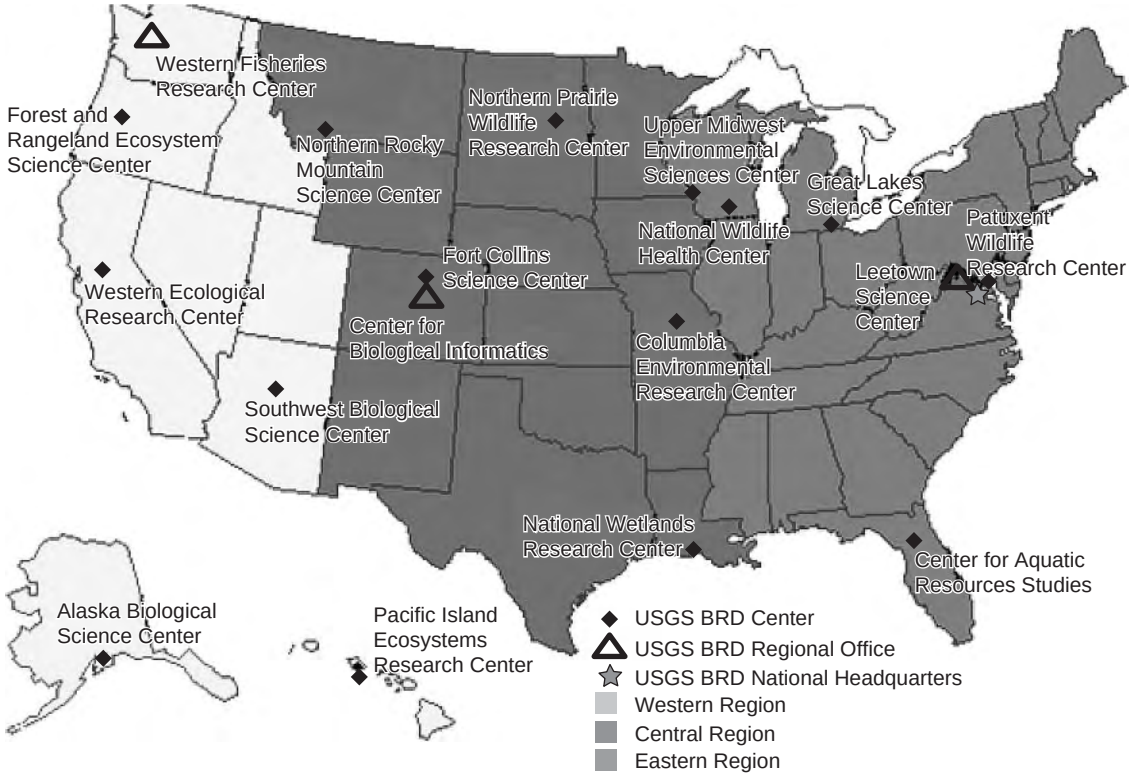


**Figure 12A.5** USGS biological resources discipline locations — regional offices (www.usgs.gov).

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## SECTION 12B STATE WATER AGENCIES

**Table 12B.12 State Agency Contacts**

**Alabama**

Alabama Department of Environmental Management, http://www.adem.state.al.us/, 1400 Coliseum Blvd., Montgomery, AL 36110, Phone (334) 271-7700, Fax (334) 271-7950

Alabama Department of Conservation and Natural Resources, http://www.dcnr.state.al.us/, 64 N. Union Street, Suite 468, Montgomery, AL 36130, Phone: (334) 242-3486

**Alaska**

Department of Environmental Conservation, state.ak.us/dec/, Water Quality Standards Assessment & Reporting Program, Division of Water, 555 Cordova St., Anchorage, AK 99501-2617, Phone: (907) 269-7595, Fax: (907) 269-7649

**Arizona**

Arizona Department of Environmental Quality, http://www.azdeq.gov/, 1110 W. Washington St., Phoenix, AZ 85007, Phone (602) 771-2300, Fax: (602) 771-4426

Arizona Fish & Game Department, http://www.gf.state.az.us/, Main Office: Phoenix, 2221 W. Greenway Rd., Phoenix, AZ 85023-4399, Phone: (602) 942-3000

**Arkansas**

Arkansas Department of Environmental Quality, http://www.adeq.state.ar.us/, 8001 National Drive, Little Rock, AR 72209, P.O. Box 8913, Little Rock, AR 72219, Phone: (501) 682-0744

**California**

California Environmental Protection Agency, http://www.calepa.ca.gov/, 1001 I Street, P.O. Box 2815, Sacramento, CA 95812-2815, Phone: (916) 445-3846

California Department of Conservation, http://www.consrv.ca.gov/ index/, DOC Headquarters, 801 K Street, MS 24-01, Sacramento, CA 95814, Phone (916) 322-1080, Fax: (916) 445-0732

California Air Resources Board, http://www.arb.ca.gov/homepage.htm, 1001 "l" Street, P.O. Box 2815, Sacramento, CA 95812, Phone: (916) 322-2990, Fax: (916) 445-5025

Department of Water Resources, http://www.water.ca.gov/, 1416 9th Street, Sacramento, CA 95814, Mailing Address: P. O. Box 942836, Sacramento, CA 94236, Phone: (916) 653-5791

California Integrated Waste Management Board, http://www.ciwmb.ca.gov/, 1001 I Street, P.O. Box 4025, Sacramento, CA 95812-4025, Phone: (916) 341-6000

**Colorado**

Colorado Revised Statutes, aescon.com/iway/entry.htm, Suite 3175, 1660 Lincoln Street, Denver, CO 80264

Colorado Department of Public Health and Environment, http://www.cdphe.state.co.us/cdphehom.asp, 4300 Cherry Creek Drive South, Denver, CO 80246-1530, Phone: (303) 692-2000

**Connecticut**

Department of Environmental Protection, http://dep.state.ct.us/, 79 Elm Street, Hartford, CT 06106-5127, Phone (860) 424-3001, Fax (860) 424-4051

**Delaware**

Delaware Department of Natural Resources and Environmental Control, http://www.dnrec.state.de.us/dnrec2000/, 89 Kings Hwy, Dover, DE 19901, Phone (302) 739-5072

**District of Columbia**

Environmental Health Administration, http://dchealth.dc.gov/, 51 N Street, NE, Washington, DC 20002, Phone: (202) 535-2500

**Florida**

**Florida Department of Environmental Protection,** http://www.dep.state.fl.us/, 3900 Commonwealth Boulevard M.S. 49, Tallahassee, FL 32399, Phone: (850) 245-2118, Fax: (850) 245-2128

**Georgia**

Georgia Department of Natural Resources, http://www.gadnr.org/, 2 Martin Luther King, Jr. Drive, S. E., Suite 1252 East Tower, Atlanta, GA 30334, Phone: (404) 656-3500

Georgia Environmental Protection Division, http://www.ganet.org/dnr/environ/, 2 Martin Luther King, Jr. Drive, Suite 1152 East Tower, Atlanta, GA 30334, Phone: (404) 657-5947, Fax: (404) 651-5778

**Hawaii**

State of Hawaii, Department of Land and Natural Resources, http://www.hawaii.gov/dlnr/, Kalanimoku Bldg., 1151 Punchbowl St., Honolulu, HI 96813, Phone: (808) 587-0400, Fax: (808) 587-0390

**Idaho**

Idaho Bureau of Homeland Security, http://www.bhs.idaho.gov/, 4040 Guard Street, Building 600, Boise, ID 83705-5004, Phone: (208) 334-3460, Fax: (208) 334-2322

*(Continued)*

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**Table 12B.12 (Continued)**

Idaho Department of Environmental Quality, http://www.deq.state.id.us/index.cfm, 1410 N. Hilton, Boise, ID 83706, Phone: (208) 373-0502, Fax: (208) 373-0417
Idaho Department of Water Resources, http://www.idwr.state.id.us/, 322 E. Front St, P.O. Box 83720, Boise, ID 83720-0098, Phone: (208) 287-4800, Fax: (208) 287-6700

**Illinois**
Illinois Environmental Protection Agency, http://www.epa.state.il.us/, 1021 North Grand Avenue East, P.O. Box 19276, Springfield, IL 62794-9276, Phone: (217) 782-3397
Illinois Pollution Control Board, http://www.ipcb.state.il.us/, 1021 North Grand Avenue East, P.O. Box 19274, Springfield, IL 62794-9274, Phone: (217) 524-8500

**Indiana**
Indiana Department of Environmental Management, http://www.ai.org/idem/, Indiana Government Center-North, 100 N. Senate Ave., Indianapolis, IN 46204, Phone: (317) 232-8603
Indiana Department of Natural Resources, http://www.in.gov/dnr/, Department of Natural Resources, 402 West Washington Street, Indianapolis, IN 46204, Phone: (317) 232-4699, Fax: (317) 233-2977

**Iowa**
Iowa Department of Natural Resources, http://www.iowadnr.com/, 502 E. 9th Street, Des Moines, IA 50319-0034, Phone: (515) 281-5918

**Kansas**
The Kansas Department of Health and Environment, http://www.kdhe.state.ks.us/, Curtis State Office Building, 1000 SW Jackson, Topeka, KS 66612, Phone: (785) 296-1500, Fax: (785) 368-6368

**Kentucky**
Kentucky Environmental Quality Commission, eqc.ky.gov/, 14 Reilly Road, Frankfort, KY 40601, Phone: (502) 564-2150, Fax: (502) 564-9729
Department for Natural Resources, naturalresources.ky.gov/, 663 Teton Trail, Frankfort, KY 40601, Phone: (502) 564-2184, Fax: (502) 564-6193

**Louisiana**
Louisiana Department of Environmental Quality, http://www.deq.state.la.us/, P.O. Box 4301, Baton Rouge, LA 70821-4301, Phone: (225) 219-3953, Fax: (225) 219-3971

**Maine**
Maine Department of Environmental Protection, http://www.state.me.us/dep/index.shtml, 17 State House Station, Augusta, ME 04333-0017, Phone: (207) 287-7688 • (800) 452-1942

**Maryland**
Maryland Department of the Environment, http://www.mde.state.md.us/, 1800 Washington Blvd, Baltimore, MD 21230, Phone: (410) 537-3000
Maryland Department of Natural Resources, dnr.state.md.us/, 580 Taylor Avenue, Annapolis, MD 21401, Phone: (877) 620-8367

**Massachusetts**
Massachusetts Department of Environmental Protection, http://www.mass.gov/dep/dephome.htm, One Winter Street, Boston, MA 02108-4746, Phone: (617) 292-5500

**Michigan**
Division of Water Supply, Michigan Department of Public Health, P.O. Box 30035, Lansing, MI 48909, Phone: (517) 335-8318

**Minnesota**
Minnesota Department of Natural Resources, http://www.dnr.state.mn.us/index.html, 500 Lafayette Road, St. Paul, MN 55155-4040, Phone: (651) 296-6157
Minnesota Pollution Control Agency, http://www.pca.state.mn.us/, 520 Lafayette Road, St. Paul, MN 55155-4194, Phone: (651) 296-6300

**Mississippi**
Mississippi Department of Environmental Quality, http://www.deq.state.ms.us/MDEQ.nsf/, P.O. Box 20305, Jackson, MS 39289-1305, Phone: (601) 961-5171

**Missouri**
Department of Natural Resources, dnr.state.mo.us/, P.O. Box 176, Jefferson City, MO 65102, Phone: (573) 751-3443
Missouri DNR, Air and Land Protection Division, dnr.state.mo.us/alpd/, Department of Natural Resources, P.O. Box 176, Jefferson City, MO 65102, Phone: (573) 751-3443
Missouri DNR, Water Protection and Soil and Conservation Division, dnr.state.mo.us/wpscd/, Department of Natural Resources, P.O. Box 176, Jefferson City, MO 65102, Phone: (573) 751-3443
Missouri Department of Conservation, http://www.conservation.state.mo.us/, P.O. Box 180 (zip 65102), 2901 W. Truman Blvd., Jefferson City, MO 65109, Phone: (573) 751-4115, Fax: (573) 751-4467

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**Table 12B.12 (Continued)**

**Montana**

Montana Department of Environmental Quality, http://www.deq.state.mt.us/index.asp, Metcalf Building Office, 1520 E. Sixth Avenue, P.O. Box 200901, Helena, MT 59620-0901, Phone: (406) 444-2544, Fax: (406) 444-4384

Montana Natural Resource Information System, http://www.nris.state.mt.us/, Montana State Library, 1515 East 6th Avenue, P.O. Box 201800, Helena, MT 59620-1800, Phone: (406) 444-3115, Fax: (406) 444-0266

Montana GIS Data Library, http://www.nris.state.mt.us/gis/default.htm, Montana State Library, 1515 East 6th Avenue, P.O. Box 201800, Helena, MT 59620-1800, Phone: (406) 444-3115, Fax: (406) 444-0266

**Nebraska**

Nebraska Department of Environmental Quality, http://www.deq.state.ne.us/, 1200 "N" Street, Suite 400, P.O. Box 98922, Lincoln, NE 68509, Phone: (402) 471-2186, Fax: (402) 471-2909

**Nevada**

Nevada Division of Forestry, http://www.forestry.nv.gov/, 2525 South Carson Street, Carson City, NV 89701, Phone: (775) 684-2500, Fax: (775) 687-4244

Nevada Department of Conservation and Natural Resources, http://dcnr.nv.gov/, 123 W. Nye Lane, Room 230, Carson City, NV 89706-0818, Phone: (775) 687-4360, Fax: (775) 687-6122

Nevada Division of Environmental Protection, http://ndep.nv.gov/, 333 W. Nye Lane, Room 138, Carson City, NV 89706-0851, Phone: (775) 687-4670, Fax: (775) 687-5856

**New Hampshire**

N.H. Department of Environmental Services, des.state.nh.us/, 29 Hazen Drive, P.O. Box 95, Concord, NH 03302-0095, Phone: (603) 271-3503, Fax: (603) 271-2867

**New Jersey**

New Jersey Department of Environmental Protection, http://www.state.nj.us/dep/, P.O. Box 402, Trenton, NJ 08625-0402, Post Office Box CN-029, Phone: (609) 777-3373

**New Mexico**

New Mexico Environment Department, http://www.nmenv.state.nm.us/, P.O. Box 26110 - 1190 St. Francis Drive N4050, Santa Fe, NM 87502-0110, Phone: (800) 219-6157, (505) 827-2855

**New York**

The New York State Department of Environmental Conservation, http://www.dec.state.ny.us/, 625 Broadway, Albany, NY 12233, Phone: (518) 402-8233, Fax: (518) 402-9029

**North Carolina**

North Carolina Department of Environment & Natural Resources, http://www.enr.state.nc.us/, 1601 Mail Service Center, Raleigh, NC 27699-1601, Phone: (919) 733-4984, Fax: (919) 715-3060

North Carolina Division of Pollution Prevention and Environmental Assistance (DPPEA), http://www.p2pays.org/, 1639 Mail Service Center, Raleigh NC 27699-1639, Phone: (919) 715-6500, (800) 763-0136

North Carolina GIS Database, http://cgia.cgia.state.nc.us/, 301 N. Wilmington St., Suite 700, Raleigh, NC 27601, Phone: (919) 733-2090, Fax: (919) 715-0725

**North Dakota**

North Dakota State Water Commission, http://www.swc.state.nd.us/, 900 East Boulevard, Bismarck, ND 58505-0850, Phone: (701) 328-2750, Fax: (701) 328-3696

North Dakota Geological Survey, http://www.state.nd.us/ndgs/, 600 East Boulevard Avenue, Bismarck, ND 58505-0840, Phone: (701) 328-8000, Fax: (701) 328-8010

ND Department of Health, Environmental Health Section, http://www.health.state.nd.us/ehs/, 1200 Missouri Ave., P.O. Box 5520, Bismarck, ND 58506-5520, Phone: (701) 328-5150, Fax: (701) 328-5200

**Ohio**

Ohio Environmental Protection Agency, http://www.epa.state.oh.us/new/divs.html, 122 S Front St., Columbus, OH 43215, Phone: (614) 644-3020

Ohio Air Quality Development Authority, http:www.ohioairquality.org/, 50 W. Broad Street, Suite 1718, Columbus, OH 43215, Phone: (614) 224-3383, Fax: (614) 752-9188

**Oklahoma**

Oklahoma Conservation Commission, http://www.okcc.state.ok.us/, 2800 N. Lincoln Blvd., Suite 160, Oklahoma City, OK 73105, Phone: (405) 521-2384, Fax: (405) 521-6686

Oklahoma Department of Environmental Quality, http://www.deq.state.ok.us/, P.O. Box 1677, Oklahoma City, OK 73101-1677, Phone: (405) 702-1000, Fax: (405) 702-1001

**Oregon**

Oregon Department of Environmental Quality, http://www.deq.state.or.us/, 811 SW Sixth Avenue, Portland, OR 97204-1390, Phone: (503) 229-5696, Fax: (503) 229-6124

Oregon Department of Fish and Wildlife, http://www.dfw.state.or.us/, 3406 Cherry Avenue, N.E., Salem, OR 97303, Phone (503) 947-6000

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**Table 12B.12 (Continued)**

**Pennsylvania**

Pennsylvania Department of Environmental Protection, http://www.dep.state.pa.us/, 16th Floor, Rachel Carson State Office Building, P.O. Box 2063, 400 Market Street, Harrisburg, PA 17105-2063, Phone (717) 787-2814

Pennsylvania Department of Conservation and Natural Resources, http://www.dcnr.state.pa.us/, Rachel Carson State Office Building, P.O. Box 8767, 400 Market Street, Harrisburg, PA 17105-8767, Phone: (717) 787-2869, Fax: (717) 772-9106

**Rhode Island**

Rhode Island Department of Environmental Management, http://204.139.0.230/, 235 Promenade Street, Providence, RI 02908-5767, Phone: (401) 222-6800

**South Carolina**

South Carolina Department of Health & Environmental Control, http://www.scdhec.net/, 2600 Bull Street, Columbia, SC 29201, Phone: (803) 898-3432

South Carolina Department of Natural Resources, http://water.dnr.state.sc.us/, P.O. Box 167, Rembert C. Dennis Building, Columbia, SC 29202, Phone: (803) 734-3979, Fax: (803) 734-6310

**South Dakota**

South Dakota Department of Environment & Natural Resources, http://www.state.sd.us/denr/denr.html, Joe Foss Building, 523 E Capitol, Pierre, SD 57501, Phone: (605) 773-3151, Fax: (605) 773-6035

**Tennessee**

Tennessee Department of Environment & Conservation, http://www.state.tn.us/environment/, 401 Church Street, L & C Annex, 1st Floor, Nashville, TN 37243-0435, Phone: (615) 532-0109

**Texas**

Texas Commission on Environmental Quality, http://www.tceq.state.tx.us/, P.O. Box 13087, Austin, TX 78711-3087, 12100 Park 35 Circle, Austin, TX 78753, Phone: (512) 239-1000

City of Dallas Air Pollution Control Program, http://www.dallasair.org/, 320 E. Jefferson St. Room LL13, Dallas, TX 75203, Phone: (214) 948-4435, Fax: (214) 948-4412

**Utah**

Utah Department of Environmental Quality, http://www.eq.state.ut.us/, 168 North 1950 West, 2nd Floor, P.O. Box 144810, Salt Lake City, UT 84114-4810, Phone: (801) 536-4410, Fax: (801) 536-4273

Utah Automated Geographic Reference Center (AGRC), http://agrc.its.state.ut.us/, 5130 State Office Building, Salt Lake City, UT 84114, Phone: (801) 538-3665, Fax: (801) 538-3317

**Vermont**

Vermont Agency of Natural Resources, 103 South Main Street, Center Building, Waterbury, VT 05671-0301, Phone: (802) 241-3600, Fax: (802) 244-1102

**Virginia**

Virginia Department of Environmental Quality, http://www.deq.state.va.us/, 629 East Main Street, P.O. Box 10009, Richmond, VA 23240-0009, Phone: (804) 698-4000

**Washington**

Washington Department of Ecology, http://www.ecy.wa.gov/, Washington State Department of Ecology, P.O. Box 47600, Olympia, WA 98504-7600, Phone: (360) 407-6000

Washington State Department of Natural Resources, http://www.dnr.wa.gov/, P.O. Box 47001, Olympia, WA 98504-7001, Phone: (360) 902-1004, Fax: (360) 902-1775

Washington State Department of Transportation, http://www.wsdot.wa.gov/environment/default.htm, Transportation Building, Washington State Department of Transportation, 310 Maple Park Avenue SE, P.O. Box 47300, Olympia, WA 98504-7300, Phone: (360) 705-7000

**West Virginia**

West Virginia Division of Environmental Protection, http://www.dep.state.wv.us/, 601 57th Street, Charleston, WV 25304, Phone: (304) 926-0440

**Wisconsin**

Wisconsin Department of Natural Resources, http://www.dnr.state.wi.us/, 101 S Webster St, P.O. Box 7921, Madison, WI 53707-7921, Phone: (608) 266-2621, Fax: (608) 261-4380

**Wyoming**

Department of Environmental Quality, http://deq.state.wy.us/, 122 West 25th St, Herschler Building, Cheyenne, WY 82002, Phone: (307) 777-7937, Fax: (307) 777-7682

*Source*: From www.epa.gov.

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## SECTION 12C WATER RESOURCES RESEARCH

**Table 12C.13 Universities Council on Water Resources**
About 90 universities in the United States and throughout the world comprise the Universities Council on Water Resources (UCOWR) organization. Member institutions engage in education, research, public service, international activities, and information support for policy development related to water resources. Each member university appoints four faculty members as UCOWR lead delegates. Others may join as individual members. See history and goals for more information.

**Alabama**
Auburn University

**Alaska**
University of Alaska

**Arizona**
University of Arizona
Arizona State University

**Arkansas**
University of Arkansas

**California**
California State, Sacramento
University of California, Davis
University of California, Riverside
University of Southern California

**Colorado**
Colorado State University
National Technological University
University of Colorado

**Connecticut**
Yale University

**District of Columbia**
The Catholic University of America

**Delaware**
University of Delaware

**Florida**
University of Central Florida
University of Florida

**Georgia**
Georgia Institute of Technology
University of Georgia

**Guam**
University of Guam

**Hawaii**
University of Hawaii

**Iowa**
Iowa State University
University of Iowa

**Idaho**
University of Idaho

**Illinois**
Southern Illinois University Carbondale
University of Illinois

*(Continued)*

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**Table 12C.13 (Continued)**

**Indiana**
Purdue University

**Kansas**
University of Kansas

**Louisiana**
Louisiana State University
University of New Orleans

**Massachusetts**
Massachusetts Institute of Tech
University of Massachusetts

**Maryland**
Johns Hopkins University

**Maine**
Bates College
University of Maine

**Michigan**
Michigan State University
University of Michigan

**Minnesota**
University of Minnesota

**Missouri**
University of Missouri

**Mississippi**
Mississippi State University

**Montana**
Montana State University
University of Montana

**North Carolina**
Duke University
North Carolina State University
University of North Carolina

**Nebraska**
University of Nebraska

**New Hampshire**
University of New Hampshire

**New Jersey**
Rutgers, The State University of New Jersey

**New Mexico**
New Mexico Institute of Mining/Tech
New Mexico State University
University of New Mexico

**Nevada**
University of Nevada System

**New York**
City University of New York
Cornell University
State University of New York, College at Brockport
State University of New York, ES&F, Syracuse
Syracuse University
United States Military Academy

*(Continued)*

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**Table 12C.13 (Continued)**

**Ohio**
Central State University
The Ohio State University
University of Cincinnati

**Oklahoma**
Oklahoma State University
University of Oklahoma

**Oregon**
Oregon State University

**Pennsylvania**
Pennsylvania State University
Drexel University

**Puerto Rico**
University of Puerto Rico

**South Carolina**
Clemson University

**South Dakota**
South Dakota State University

**Tennessee**
Tennessee Tech University
University of Tennessee

**Texas**
Texas State University
Tarleton State University
Texas A&M University
Texas Tech University
University of Texas at Austin
University of Texas at El Paso
University of Texas at San Antonio

**Utah**
Utah State University

**Virginia**
University of Virginia
Virginia Polytechnic Institute

**U.S. Virgin Islands**
University of the Virgin Islands

**Washington**
Washington State University

**Wisconsin**
University of Wisconsin

**Wyoming**
University of Wyoming

**Affiliates**
Asian Institute of Technology
University of Calgary
University of New England

*Source*: From www.ucowr.siu.edu.

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**Table 12C.14 Water Resources Research Institutes**

The Water Resources Research Act authorized by P.L. 101-397 provides for Water Resources Research Institutes in each of the 50 states, the trust territories, and the District of Columbia. Under the Act, these institutes are to:

1. plan, conduct, or otherwise arrange for competent research that fosters (A) the entry of new research scientists into the water resources fields, (B) the training and education of future scientists, engineers, and technicians, (C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and (D) the dissemination of research results to water managers and the public.
2. cooperate closely with other colleges and universities in the State that have demonstrated capabilities for research, information dissemination, and graduate training in order to develop a statewide program designed to resolve State and regional water and related land problems.

Each institute shall also cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the institutes and for the purpose of promoting regional coordination.

The state-based program promotes research, training, information dissemination, and other activities meeting the needs of the States and Nation, and encourages regional cooperation among institutes in research into areas of water management, development, and conservation that have a regional or national character.

**Alabama**

Dr. Upton Hatch, Director, Auburn University Environmental Institute, 101 Comer Hall, Auburn University, Auburn, AL 36849-5431, Phone: (334) 844-4132, Fax: (334) 844-4462, email: hatchlu@auburn.edu

**Alaska**

Dr. Douglas Kane, Water and Environmental Research Center, University of Alaska-Fairbanks, Fairbanks, AK 99775-5860, Phone: (907) 474-7808, Fax: (907) 474-7979, email: ffdlk@uaf.edu, http://www.uaf.edu/water/

**Arizona**

Dr. Sharon Megdal, Water Resources Research Center, 350 N. Campbell Ave., The University of Arizona, Tucson, AZ 85721, Phone: (520) 792-9591, Fax: (520) 792-8518, email: wrrc@ag.arizona.edu, http://ag.arizona.edu/AZWATER/

**Arkansas**

Dr. Ralph Davis, Arkansas Water Resources Center, 112 Ozark Hall, University of Arkansas, Fayetteville, AK 72701, Phone: (501) 575-4515, Fax: (501) 575-3177, email: ralphd@uark.edu, http://www.uark.edu/depts/awrc/

**California**

Dr. John Letey, Director, Center for Water Resources, Ruibidoux Hall -094, University of California, Riverside, CA 92521-0436, Phone: (909) 787-4327, Fax: (909) 787-5295, email: john.letey@ucr.edu, http://www.waterresources.ucr.edu/

**Colorado**

Dr. Robert C. Ward, Colorado Water Resources Research Institute, E-102 Engineering Building, Colorado State University, Fort Collins, CO 80523, Phone: (970) 491-6308, Fax: (970) 491-1636, email: robert.ward@colostate.edu, http://cwrri.colostate.edu/

**Connecticut**

Dr. Glenn Warner, Director, Connecicut Institute of Water Resources, WB Young Building, Room 308, 1376 Storrs Road Unit 4018, The University of Connecticut, Storrs, CT 06269-4018, Phone: (860) 486-2840, Fax: (860) 486-5408, email: gwarner@canrl.cag.uconn.edu, http://www.ctiwr.uconn.edu/

**Delaware**

Dr. J. Thomas Sims, Delaware Water Resources Center, 113 Townsend Hall, University of Delaware, Newark, DE 19716-2103, Phone: (302) 831-6757, Fax: (302) 831-6758, email: jtsims@udel.edu, http://ag.udel.edu/dwrc/

**District of Columbia**

Dr. William W. Hare, Director, D.C. Water Resource Research Institute, 4200 Connecticut Ave NW, Building 52, Suite 322D University of the District of Columbia, Washington, DC 20008, Phone: (202) 409-0319, Fax: (202) 274-7016, email: whare@udc.edu, http://www.udc.edu/WRRI/

**Florida**

Dr. Kirk Hatfield, Interim Director, Water Resources Research Center, Department of Civil Engineering, 124 Yon Hall, P.O. Box 116580, University of Florida, Gainesville, FL 32611-6580, Phone: (352) 392-9537, Fax: (352) 392-3394, email: khatf@ce.ufl.edu, http://www.ce.ufl.edu/~wrrc/

**Georgia**

Dr. Aris P. Georgakakos, Environmental Resources Center, School of Civil & Environmental Engineering, 790 Atlantic Drive, Georgia Institute of Technology, Atlanta, GA 30332-0335, Phone: (404) 894-2240, Fax: (404) 894-2677, email: ageorgak@ce.gatech.edu, http://www.gwri.org/

**Guam**

Dr. Leroy F. Heitz, Director, Water and Environmental Research Institute of the Western Pacific, University of Guam, 303 University Drive, Mangilao, Guam 96923, Phone: 011 671 7352685, Fax: 011 671 734-8890, email: lheitz@uog.edu, http://www.uog.edu/weri/index.html

*(Continued)*

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**Table 12C.14 (Continued)**

**Hawaii**
Dr. James Moncur, Water Resources Research Center, 2540 Dole Street, Holmes Hall 283, University of Hawaii at Manoa, Honolulu, HI 96822, Phone: (808) 956-7847, Fax: (808) 956-5044, email: jmoncur@hawaii.edu, http://www.wrrc.hawaii.edu/

**Idaho**
Dr. John C. Tracy, Director, Idaho Water Resources Research Institute, 322 Front Street, University of Idaho, Boise, ID 83702, Phone: (208) 364-9921, Fax: (208) 885-6431, email: iwrri@uidaho.edu, http://www.uidaho.edu/rsrch/iwrri/

**Illinois**
Dr. Richard Warner, Illinois Water Resources Center, MC-635, University of Illinois at Urbana-Champaign, 1101 West Peabody Drive, Urbana, IL 61801, Phone: (217) 333-0536, Fax: (217) 333-8046, email: dickw@uiuc.edu, http://www.environ.uiuc.edu/iwrc/

**Indiana**
Dr. Ronald F. Turco, Jr., Indiana Water Resources Research Center, A. A. Potter Engineering Center, Purdue University, West Lafayette, IN 47907-1295, Phone: (765) 494-8041, Fax: (765) 496-3210, email: rturco@purdue.edu, http://ce.ecn.purdue.edu/wrrc.html

**Iowa**
vacant, Iowa State Water Resources Research Institute, 100 Davidson Hall, Iowa State University, Ames, IA 50011, Phone: (515) 294-1880, Fax: (515) 294-4250, email: http://www.water.iastate.edu/

**Kansas**
Dr. Jim Koelliker, Interim Director, Kansas Water Resources Research Institute, 44 Waters Hall, Kansas State University, Manhattan, KS 66506, Phone: (913) 532-7419, Fax: (913) 532-6563, email: koellik@ksu.edu

**Kentucky**
Dr. Lindell E. Ormsbee, Director, Kentucky Water Resources Research Institute, 233 Mining and Mineral Resources Building, University of Kentucky, Lexington, KY 40506-0107, Phone: (606) 257-1299, Fax: (606) 257-6329, email: lormsbee@engr.uky.edu, http://www.uky.edu/WaterResources/

**Louisiana**
Dr. John Pardue, Director, Louisiana Water Resources Research Institute, 3221 CEBA Building, Louisiana State University, Baton Rouge, LA 70803, Phone: (255) 578-8661, Fax: (255) 578-5043, email: jpardue@lsu.edu, http://www.lwrri.lsu.edu/

**Maine**
Dr. Steve Kahl, Senator George J. Mitchell Center for Environmental and Watershed Research, 5764 Sawyer Environmental Research Center, University of Maine, Orono, ME 04469-5764, Phone: (207) 581-3286, Fax: (207) 581-3290, email: kahl@maine.edu, http://www.umaine.edu/WaterResearch

**Maryland**
Prof. Allen P. Davis, Director, Water Resources Research Center, Department of Civil and Environmental Engineering, University of Maryland, College Park, MD 20742-5595, Phone: (301) 405-1958, Fax: (301) 405-2585, email: apdavis@umail.umd.edu, http://www.waterresources.umd.edu/

**Massachusetts**
Dr. David A. Reckhow, Interim Director, Water Resources Research Center, Dept. of Civil and Environmental Engineering, 18 Marston Hall, University of Massachusetts, Amherst, MA 01003, Phone: (413) 545-5392, Fax: (413) 545-2202, email: reckhow@ecs.umass.edu, http://www.umass.edu/tei/wrrc/

**Michigan**
Dr. Jon Bartholic, Institute of Water Research, 115 Manly Miles Building, 1405 South Harrison Road, Michigan State University, East Lansing, MI 48823-5243, Phone: (517) 353-3742, Fax: (517) 353-1812, email: bartholi@pilot.msu.edu, http://www.iwr.msu.edu/

**Minnesota**
Dr. Deborah Swackhamer, Water Resources Center, 173 McNeal Hall, 1985 Buford Avenue, University of Minnesota, St. Paul, MN 55108, Phone: (612) 624-9282, Fax: (612) 625-1263, email: dswack@umn.edu, http://wrc.coafes.umn.edu/

**Mississippi**
Dr. David Shaw, Director, Mississippi Water Resources Research Institute, GeoResources Institute P.O. Box 9652, Mississippi State University, Mississippi State, MS 39762-9652, Phone: (662) 325-9573, Fax: (662) 325-3621, email: dshaw@gri.msstate.edu, http://www.gri.msstate.edu/

**Missouri**
Dr. Thomas E. Clevenger, Water Resources Research Center, E1511A Engineering Bldg. East, University of Missouri, Columbia, MO 65211, Phone: (314) 882-3132, Fax: (314) 882-4784, email: Clevengert@missouri.edu, http://web.missouri.edu/~mowrrc/

**Montana**
Gretchen Rupp, P.E., Director, Montana Water Center, 101 Hoffman Building, Montana State University, Bozeman, MT 59717, Phone: (406) 994-6690, Fax: (406) 994-1774, email: wwwrc@montana.edu, http://water.montana.edu/

*(Continued)*

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**Table 12C.14 (Continued)**

**Nebraska**
Dr. Kyle D. Hoagland, Director, Nebraska Water Resources Center, 103 Natural Resources Hall, University of Nebraska, EastCampus, Lincoln, NE 68583-0844, Phone: (402) 472-3305, Fax: (402) 472-3574, email: khoagland@unl.edu, http://watercenter.unl.edu/

**Nevada**
Dr. John J. Warwick, Director, Water Resources Center, Desert Research Institute, 2215 Raggio Parkway, Reno, NV 89512, Phone: (775) 673-7379, Fax: (775) 673-7363, email: warwick@dri.edu, http://www.dri.edu/

**New Hampshire**
Dr. William H. McDowell, Director, Water Resources Research Center, c/o Department of Natural Resources, 219 James Hall, University of New Hampshire, Durham, NH 03824-3525, Phone: (603) 862-2249, Fax: (603) 862-4976, email: bill.mcdowell@unh.edu, http://www.wrrc.unh.edu

**New Jersey**
Dr. Joan G. Ehrenfeld, New Jersey Water Resources Research Institute, Dept. of Ecology, Evolution and Natural Resources, Cook College, Rutgers University, New Brunswick, NJ 08903, Phone: (732) 932-1081, Fax: (732) 932-8746, email: ehrenfel@rci.rutgers.edu, http://njwrri.rutgers.edu/

**New Mexico**
Dr. Karl Wood, Director, Water Resources Research Institute, Box 30001, Dept. 3167, New Mexico State University, Las Cruces, NM 88003-0001, Phone: (505) 646-4337, Fax: (505) 646-6418, email: kwood@wrri.nmsu.edu, http://wrri.nmsu.edu/

**New York**
Mr. Keith S. Porter, New York State Water Resources Institute, Rice Hall, Cornell University, Ithaca, NY 14853-5601, Phone: (607) 255-5941, Fax: (607) 255-5945, email: nyswri@cornell.edu, cfe.cornell.edu/wri/

**North Carolina**
Dr. Greg Jennings, Interim Director, Water Resources Research Institute of the University of North Carolina, Campus Box 7912, North Carolina State University, Raleigh, NC 27695-7912, Phone: (919) 515-2815, Fax: (919) 515-2839, email: water_resources@ncsu.edu, ncsu.edu/ncsu/CIL/WRRI/

**North Dakota**
Dr. Wei Lin, Interim Director, North Dakota Water Resources Research Institute, Civil/Ind. Building 201A, North Dakota State University, Fargo, ND 58105, Phone: (701) 231-7193, Fax: (701) 231-8831, email: Wei.Lin@ndsu.nodak.edu, http://http://www.ce.ndsu.nodak.edu/wrri/

**Ohio**
Dr. E. Whitlatch, Water Resources Center, 470 Hitchcock Hall, 2070 Neil Avenue, Ohio State University, Columbus, OH 43210, Phone: (614) 292-6108, Fax: (614) 292-3780, email: whitlatch.1@osu.edu

**Oklahoma**
Dr. Will Focht, Director, Oklahoma Water Resources Research Institute, 003 Life Sciences East, Oklahoma State University, Stillwater, OK 74078-3011, Phone: (405) 744-9994, Fax: (405) 744-7673, email: wfocht@okstate.edu, http://environ.okstate.edu/

**Oregon**
Dr. Kenneth Williamson, Center for Water and Environmental Sustainability (CWESt), 210 Strand Agricultural Hall, Oregon State University, Corvallis, OR 97331, Phone: (541) 737-4022, Fax: (541) 737-2735, email: kenneth.williamson@orst.edu, http://cwest.orst.edu/

**Pennsylvania**
Dr. David R. DeWalle, Penn State Institutes of the Environment, 107 Land and Water Research Building, Pennsylvania State University, University Park, PA 16802, Phone: (814) 863-0291, Fax: (814) 865-3378, email: drdewalle@psu.edu, http://www.pawatercenter.psu.edu/

**Puerto Rico**
Dr. Jorge Rivera Santos, Water Resources Research Institute, P.O. Box 9040 - College of Engineering, Mayaguez, Puerto Rico 00681-9040, Phone: (787) 265-3826, Fax: (787) 832-0119, email: wrri_rum@rumac.uprm.edu, http://www.ece.uprm.edu/rumhp/prwrri/

**Rhode Island**
Dr. Leon Thiem, Director, Water Resources Center, Department of Civil & Environmental Engineering, 1 Lippitt Road, University of Rhode Island, Kingston, RI 02881, Phone: (401) 874-2693, Fax: (401) 874-2786, email: thiem@egr.uri.edu, http://www.egr.uri.edu/centers/d.htm#D-3

**South Carolina**
Dr. Jeffery S. Allen, South Carolina Water Resources Research Institute, Strom Thurmond Institute, Clemson University, Box 345203, Clemson, SC 29634-0125, Phone: (864) 656-4700, Fax: (864) 656-4780, email: jeff@strom.clemson.edu, strom.clemson.edu/teams/water_resources/index.html/

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**Table 12C.14 (Continued)**

**South Dakota**
Dr. Van Kelley, Acting Director, South Dakota Water Research Institute, Agricultural Experiment Station, AE Bldg., Rm 211, Box 2120, South Dakota State University, Brookings, SD 57007, Phone: (605) 688-4910, Fax: (605) 688-4917, email: van_kelley@sdstate.edu, http://wri.sdstate.edu/

**Tennessee**
Dr. Tim Gangaware, Associate Director, Tennessee Water Resources Research Center, 600 Henley Street, Suite 311, The University of Tennessee, Knoxville, TN 37996-4134, Phone: (865) 974-2151, Fax: (865) 974-1838, email: gangwrrc@utk.edu, http://eerc.ra.utk.edu/WRRC.html

**Texas**
Dr. C. Alan Jones, Director, Texas Water Resources Institute, Texas A&M University, 1500 Research Pkwy., College Station, TX 77843-2118, Phone: (979) 845-1851, Fax: (979) 845-8454, email: cajones@tamu.edu, http://twri.tamu.edu

**Utah**
Dr. Mac McKee, Interim Director, Center for Water Resources Research, Utah State University, 8200 Old Main Hill, Logan, UT 84322-8200, Phone: (435) 797-3188, Fax: (435) 797-3663, email: mmckee@cc.usu.edu, http://www.engineering.usu.edu/uwrl/niwr/

**Vermont**
Dr. Breck Bowden, Director, Vermont Water Resources and Lake Studies Center, George D. Aiken Center for Natural Resources, The University of Vermont, Burlington, VT 05405, Phone: (802) 656-4057, Fax: (802) 656-8683, email: Breck.Bowden@uvm.edu, http://www.uvm.edu/envnr/vtwater

**Virginia**
Dr. Tamim Younos, Interim Director, Virginia Water Resources Research Center, 10 Sandy Hall, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060, Phone: (540) 231-5624, Fax: (540) 231-6673, email: tyounos@vt.edu, http://www.vwrrc.vt.edu/

**Virgin Islands**
Dr. Henry H. Smith, Virgin Islands Water Resources Research Institute, University of the Virgin Islands, St. Thomas, Virgin Islands 00802, Phone: (809) 693-1021, Fax: (809) 693-1025, email: hsmith@uvi.edu, http://rps.uvi.edu/WRRI/wrri.htm

**Washington**
Dr. Michael E. Barber, Director, State of Washington Water Research Center, P.O. Box 643002, Washington State University, Pullman, WA 99164-3002, Phone: (509) 335-6633, Fax: (509) 335-1590, email: meb@wsc.edu, http://www.swwrc.wsu.edu/

**West Virginia**
Dr. Paul Ziemkiewicz, West Virginia Water Research Institute, P.O. Box 6064, 617 Spruce Street, West Virginia University, Morgantown, WV 26506-6064, Phone: (304) 293-2867 ext 5441, Fax: (304) 293-7822, email: pziemkie@wvu.edu, nrcce.wvu.edu/wvwrri/index.htm

**Wisconsin**
Dr. Anders W. Andren, University of Wisconsin - Water Resources Institute, 1975 Willow Drive - 2nd Floor, The University of Wisconsin-Madison, Madison, WI 53706, Phone: (608) 262-0905, Fax: (608) 262-0591, email: awandren@aqua.wisc.edu, http://www.wri.wisc.edu/

**Wyoming**
Dr. Larry O. Pochop, Director, Wyoming Water Research Program, University of Wyoming, Civil & Arch. Engineering Dept., P.O. Box 3295, Laramie, WY 82071, Phone: (307) 766-3326, Fax: (307) 766-2221, email: pochop@uwyo.edu, http://wwweng.uwyo.edu/civil/research/wwrp/

*Source*: From niwr.montana.edu.

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## SECTION 12D PROFESSIONAL, TRADE, AND ENVIRONMENTAL GROUPS

**Table 12D.15 Professional, Trade, and Environmental Groups**

**African Wildlife Foundation — http://www.awf.org/**
1400 16th Street, N.W. Suite 120, Washington, DC 20036, Phone: (202) 939-3333, Fax: (202) 939-3332

**The Alliance for Justice — http://www.afj.org/**
11 Dupont Circle NW, 2nd Floor, Washington, DC 20036, Phone: (202) 822-6070, Fax: (202) 822-6068

**American Association for the Advancement of Science — http://www.aaas.org/**
AAAS, 1200 New York Avenue NW, Washington, DC 20005, Phone: 202-326-6400

**American Association of Pesticide Safety Educators — http://aapse.ext.vt.edu/**
495 Borlaug Hall, 41991 Upper Buford Circle, St. Paul, MN 55108, Phone: (612) 624-3477

**American Chemical Society (ACS) — http://www.chemistry.org/portal/a/c/s/1/home.html**
American Chemical Society, 1155 16th St., NW, Washington, DC 20036, Phone: (800) 227-5558 (U.S. only), Phone: (202) 872-4600 (outside the U.S.), Fax: (202) 776-8258

**The American Council for an Energy-Efficient Economy (ACEEE) — http://www.aceee.org/**
1001 Connecticut Avenue, NW Suite 801, Washington, DC 20036, Phone: (202) 429-8873, Fax: (202) 429-2248

**American Crop Protection Association — http://www.acpa.org/**
CropLife America, 1156 15th Street, NW. Suite 400, Washington, DC 20005, Phone: (202) 296-1585, Fax: (202) 463-0474

**American Fisheries Society — fisheries.org/html/index.shtml**
American Fisheries Society, 5410 Grosvenor Lane, Bethesda, MD 20814, Phone: (301) 897-8616, Fax (301) 897-8096

**American Geological Institute — http://www.agiweb.org/**
American Geological Institute, 4220 King Street, Alexandria, VA 22302-1502, Phone: (703) 379-2480 (Voice), Fax: (703) 379-7563

**American Geophysical Union — http://www.agiweb.org/**
2000 Florida Avenue NW, Washington, DC 20009-1277, Phone: (202) 462-6900 (Toll Free in North America: (800) 966-2481), Fax: (202) 328-0566

**American Institute of Chemical Engineers — http://www.aiche.org/**
American Institute of Chemical Engineers, 3 Park Avenue, New York, NY 10016-5991, Phone (301) 374-2522

**American Institute of Hydrology — http://www.aihydro.org/**
300 Village Green Circle, Suite 201, Smyrna, GA 30080, Phone: (770) 384-1634, Fax: (770) 438-6172

**American Institute of Professional Geologists (AIPG) — aipg.org**
1400 W. 122nd Avenue, Suite 250, Westminster, CO 80234, Phone: (303) 412-6205, Fax (303) 253-9220

**American National Standards Institute (ANSI) — http://www.ansi.org/**
1819 L Street, NW, 6th floor, Washington, DC 20036, Phone: (202) 293.8020, Fax: (202) 293.9287

**American Public Health Association — http://www.apha.org/**
800 I Street, NW, Washington, DC 20001, Phone: (202) 777-2742, Fax: (202) 777-2534

**American Public Works Association (APWA) — http://www.apwa.net/**
Washington DC Office, 1401 K Street, NW, 11th Floor, Washington, DC 20005, Phone: (202) 408-9541, Fax: (202) 408-9542

**American Society of Agricultural Engineers (ASAE) — http://www.asae.org/**
2950 Niles Road, St. Joseph, MI 49085, Phone: (269) 429-0300, Fax: (269) 429-3852

**American Society of Agronomy — http://www.agronomy.org/**
677 S. Segoe Road, Madison, WI 53711, Phone: (608) 273-8080, Fax: (608) 273-2021

**American Society of Civil Engineers — http://www.asce.org/**
ASCE World Headquarters, 1801 Alexander Bell Drive, Reston, VA 20191-4400, Phone: (800) 548-2723, Fax: (703) 295-6222

**American Society of Ichthyologists and Herpetologists — http://www.asih.org/**
Florida International University, Biological Sciences, 11200 SW 8th St. Miami, FL 33199, Phone: (305) 348-1235, Fax: (305) 348-1986

**American Society of Limnology and Oceanography — http://www.aslo.org/**
ASLO Business Office, 5400 Bosque Boulevard, Suite 680, Waco, TX 76710-4446, Phone: (254) 399-9635, Fax: (254) 776-3767

**American Society of Sanitary Engineers — http://www.asse-plumbing.org/**
901 Canterbury, Suite A, Westlake, OH 44145, Phone: (440) 835-3040, Fax: (440) 835-3488

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**Table 12D.15 (Continued)**

**American Society for Microbiology — http://www.asm.org/**
1752 N Street, NW, Washington, DC 20036, Phone: (202) 737-3600

**American Society of Testing Materials — http://www.astm.org**
100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Phone: (610) 832-9585, Fax: (610) 832-9555

**American Water Resources Association (AWRA) — http://www.awra.org/**
American Water Resources Association, 4 West Federal Street, P.O. Box 1626, Middleburg, VA 20118-1626, Phone: (540) 687-8390, Fax: (540) 687-8395

**American Water Works Association — http://www.awwa.org/**
6666 W. Quincy Ave., Denver, CO 80235, Phone: (303) 794-7711, Fax (303) 347-0804

**AOAC International — http://www.aoac.org/**
481 North Frederick Avenue Suite 500, Gaithersburg, MD 20877

**Association of American State Geologists — http://www.stategeologists.org/**
Karl Muessig, State Geologist, New Jersey Geological Survey, Department of Environmental Protection, P.O. Box 427, Trenton, NJ 08625-0427

**Association of Engineering Geologists (AEG) — http://www.aegweb.org/**
P.O. Box 460518, Denver, CO 80246, Phone: (303) 757-2926, Fax: (303) 757-2969

**Association of Metropolitan Sewerage Agencies — http://www.amsa-cleanwater.org/**
1816 Jefferson Place, NW, Washington, DC 20036-2505, Phone (202) 833-2672, Fax (202) 833-4657

**Association of Metropolitan Water Agencies — http://www.amwa.net/**
1620 I Street, NW, Suite 500, Washington, DC 20006, Phone (202) 331-2820, FAX (202) 785-1845

**Association of State Drinking Water Administrators — asdwa.org/**
1025 Connecticut Avenue, NW — Suite 903, Washington, DC 20036, Phone: (202) 293-7655, Fax: (202) 293-7656

**Association of State and Interstate Water Pollution Control Administrators — http://www.asiwpca.org/**
750 First Street, NE Suite 1010, Washington, DC 20002

**British Hydrological Society (BHS) -http://www.hydrology.org.uk/**
Institution of Civil Engineers/Thomas Telford Ltd, 1 Great George Street, London, SW1P 3AA United Kingdom, Phone: +44 207 2227722, Fax: +44 207 2227500

**Canada Centre for Inland Waters (CCIW) — cciw.ca**
National Water Research Institute, Environment Canada, 867 Lakeshore Road, P.O. Box 5050, Burlington, ON L7R 4A6

**Canadian Ground Water Association — http://www.cgwa.org/**
1600 Bedford Highway Suite 100–409, Bedford, NS B4A 1E8, Phone: (902) 845-1885, Fax: (902) 845-1886

**Center for Watershed Protection — http://www.cwp.org/**
8390 Main Street, Second Floor, Ellicott City, MD 21043-4605, Phone: (410) 461-8323, Fax: (410) 461-8324

**Clean Water Action Project — http://www.cleanwateraction.org/**
4455 Connecticut Avenue, NW Suite A300, Washington, DC 20008, Phone: (202) 895-0420

**Clean Water Network — http://www.cwn.org/cwn/**
1200 New York Avenue, NW, Suite 400, Washington, DC 20005, Phone: (202) 289-2395, Fax: (202) 289-1060

**Coastal Conservation Association — http://www.joincca.org/**
6919 Portwest, Suite 100, Houston, TX 77024, Phone: (713) 626-4234

**Coastal Society — http://www.thecoastalsociety.org/**
P.O. Box 25408, Alexandria, VA 22313-5408, Phone: (703) 933-1599, Fax: (703) 933-1596

**CONCERN — http://www.concern.net/**
104 East 40th Street, Room 903, New York, NY 10016, Phone: (212) 557-8000, Fax: (212) 557-8004

**Conservation International — http://www.conservation.org/**
1919 M Street, NW Suite 600, Washington, DC 20036, Phone: (202) 912-1000

**Consumer's Union — http://www.consumersunion.org/**
1666 Connecticut Avenue, NW, Suite 310, Washington, DC 20009-1039, Phone: (202) 462-6262, Fax: (202) 265-9548

**Conservation Foundation — http://www.conservationfoundation.co.uk/**
1 Kensington Gore, London SW7 2AR, UK, Phone: +44 207 5913111, Fax: +44 207 5913110

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**Table 12D.15 (Continued)**

**Cousteau Society — http://www.cousteau.org/**
710 Settlers Landing Road, Hampton, VA 23669, Phone: (757) 722-9300, Fax: (757) 722-8185

**CREST — http://www.crest.org/**
1612 K Street, NW, Suite 202, Washington, DC 20006, Phone: (202) 293-2898, Fax: (202) 293-5857

**Defenders of Wildlife — http://www.defenders.org**
National Headquarters, 1130 17th Street, NW, Washington, DC 20036, Phone: (202) 682-9400

**Ducks Unlimited — http://www.ducks.org/**
One Waterfowl Way, Memphis, TN 38120, Phone (901) 758-3825

**Earth First! — http://www.earthfirstjournal.org**
P.O. Box 3023, Tucson, AZ 85702, Phone: (520) 620-6900, Fax: (413) 254-0057

**Earth Island Institute — http://www.earthisland.org/**
300 Broadway, Suite 28, San Francisco, CA 94133, Phone: (415) 788-3666

**Earth Share — http://www.earthshare.org/**
7735 Old Georgetown Road, Suite 900, Bethesda, MD 20814, Phone: (240) 333-0300

**Earthjustice Legal Defense Fund — http://www.earthjustice.org/**
426 17th Street, 6th Floor, Oakland, CA 94612-2820, Phone: (510) 550-6700, Fax: (510) 550-6740

**Earthwatch — http://www.earthwatch.org/**
3 Clock Tower Place, Suite 100, Box 75, Maynard, MA 01754, Phone: (978) 461-0081, Fax (978) 461-2332

**Energy & Environmental Research Center (EERC) — http://www.eerc.und.nodak.edu/**
University of North Dakota, P.O. Box 9018, 15 North 23rd Street, Grand Forks, ND 58202-9018, Phone: (701) 777-5000, Fax: (701) 777-5181

**Environment Canada — http://www.ec.gc.ca/water/index.htm**
Sustainable Water Use Branch, Water Policy and Coordination Directorate, Environmental Conservation Service, Environment Canada, 351 St. Joseph Blvd., 7-PVM, Gatineau, Quebec K1A 0H3, Phone: (819) 994-0237

**Environmental Action Foundation — http://www.agc.org**
333 John Carlyle Street, Suite 200, Alexandria, VA 22314, Phone: (703) 548-3118, Fax: (703) 548-3119

**Environmental Defense — http://www.environmentaldefense.org/**
257 Park Avenue South, New York, NY 10010, Phone: (212) 505-2100, Fax: (212) 505-2375

**Environmental Law Institute — http://www.eli.org**
2000 L Street, NW, Suite 620, Washington, DC 20036, Phone: (202) 939-3800, Fax: (202) 939-3868

**Environmental Policy Institute — http://www.nepi.org/**
1401 K Street, NW Suite M-103, Washington, DC 20005, Phone: (202) 857-4784, Fax: (202) 833-5977

**Environmental Working Group — http://www.ewg.org/**
1436 U Street, NW Suite 100, Washington, DC 20009, Phone: (202) 667-6982

**Estuarine Research Federation — http://erf.org/**
P.O. Box 510, Port Republic, MD 20676, Phone: (410) 586-0997, Fax: (410) 586-9226

**Food and Agriculture Organization of the United Nations (FAO) — http://www.fao.org/**
FAO HEADQUARTERS, Viale delle Terme di Caracalla, 00100 Rome, Italy, Phone: +39 06 57051, Fax: +39 06 57053

**Freshwater Foundation — http://www.spiretech.com/~dafoxx/fresh/**
2500 Shadywood Road, Box 90, Navarre, MN 55392-0900, Phone: (612) 481-8407

**Friends of the Earth U.S.A. — http://www.foe.org/**
1717 Massachusetts Avenue, NW, 600, Washington, DC 20036-2002, Phone: (877) 843-8687 — toll free, Fax: (202) 783-0444

**Geological Society of America (GSA) — http://www.geosociety.org/index.htm**
The Geological Society of America, P.O. Box 9140, Boulder, CO 80301-9140, Phone: (303) 447-2020, Fax: (303) 357-1070

**Global Energy and Water Cycle Experiment (GEWEX) — http://www.gewex.org/**
1010 Wayne Avenue, Suite 450, Silver Springs, MD 20910-5641, Phone: (301) 565-8345, Fax: (301) 565-8279

**Global Environmental Sanitation Initiative (GESI) — http://www.africanwater.org/gesi.htm**
Water Web Management Ltd, 1 Dome Hill, Caterham, Surrey CR3 6EE, UK

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**Table 12D.15 (Continued)**

**Global Environment Facility (GEF) — http://www.gefweb.org/**
1818 H Street, NW, Washington, DC 20433, Call or send a fax to the Secretariat at: Phone: (202) 473-0508, Fax: (202) 522-3240/3245

**Global Rivers Environment Education Network (GREEN) — http://www.earthforce.org/section/programs/green/**
Earth Force, 1908 Mount Vernon Avenue, Second Floor, Alexandria, VA 22301, Phone: (703) 299-9400, Fax: (703) 299-9485

**Global Water — http://www.globalwater.org/**
3600 S. Harbor Blvd., #514, Oxnard, CA 93035, Phone: (805) 985-3057, Fax: (805) 985-3688

**Global Water Partnership (GWP) — http://www.gwpforum.org**
GWP Central America, c/o ASOTEM, 14-5000 Liberia, Guanacaste, Costa Rica, Phone: +506 666 1596, Fax: +506 666 2967

**Global Water Unit of the World Bank Group — http://www.gwp.sida.se**
The World Bank, 1818 H Street, NW, Washington, DC 20433, Phone: (202) 473-1000, Fax: (202) 477-6391

**Greenpeace — http://www.greenpeace.org/international_en/**
Ottho Heldringstraat 5, 1066 AZ Amsterdam, The Netherlands, Phone: +31 20 5148150, Fax: +31 20 5148151

**Groundwater Protection Council — http://www.gwpc.org/**
Ground Water Protection Council, 13308 N. MacArthur, Oklahoma City, OK 73142, Phone: (405) 516-4972, Fax: (405) 516-4973

**GSA Hydrogeology Division — http://gsahydrodiv.unl.edu/**
The Geological Society of America, P.O. Box 9140, Boulder, CO 80301-9140, Phone: (303) 447-2020, Fax: (303) 357-1070

**Groundwater Management Districts Association — http://www.gmdausa.org/**
P.O. Box 905, Colby, KS 67701-0905, Phone: (785) 462-3915

**Hydrology and Water Resources Programme (HWRP) — http://www.wmo.ch/web/homs/hwrpframes.html**
World Meteorological Organization, 7 bis, Avenue de la Paix, CP 2300, CH-1211 Genève 2, Switzerland, Phone: +41 22 73083, Fax: +41 22 730 80 43

**Illinois Groundwater Consortium — http://www.siu.edu/worda/igc/**
Illinois Groundwater Consortium, Office of Research Development and Administration, Southern Illinois University Carbondale, Carbondale, IL 62901-4709, Phone: (618) 453-4531, Fax: (618) 453-8038

**Inter-American Association for Environmental Quality (AIDIS-CANADA) — http://www.rcc.ryerson.ca**
AIDIS — Canada, 3750 NW 87th Ave. Suite 300, Miami, FL 33178, Phone: (305) 716-5120, Fax: (305) 716-5155

**Inter-American Water Resources Network (IWRN) — http://www.iwrn.net/**
1889 F Street, NW, Washington, DC 20006, Phone: (202) 458-3556, Fax: (202) 458-3560

**Inter-Islamic Network on Water Resources Development and Management (INWRDAM) — http://www.inwrdam.org/**
P.O. Box 1460, Jubieha: Amman, PC 11941, Jordan, Phone: +962 6 5332993, Fax: +962 6 5332969

**International Association for Environmental Hydrology (IAEH) — http://www.hydroweb.com/**
International Association for Environmental Hydrology, Alexandria, VA 22313, Phone: (703) 683-9768, Fax: (703) 683-6137

**International Association for Great Lakes Research — http://www.iaglr.org/index.php**
IAGLR Business Office, 2205 Commonwealth Blvd., Ann Arbor, MI 48105, Phone: (734) 665-5303, Fax: (734) 741-2055

**International Association for Hydraulic Engineering and Research (IAHR) — http://www.iahr.org**
IAHR Secretariat, Paseo Bajo Virgen del Puerto, 3, 28005 Madrid, Spain, Phone: +34 91 3357964, Fax: +34 91 3357935

**International Association of Hydrogeology (IAH/AIH) — http://www.iah.org/**
IAH Secretariat, P.O. Box 9, Kenilworth, CV8 1JG, United Kingdom, Fax: +44 192 6856561

**International Association of Hydrological Sciences (IAHS) — http://www.cig.ensmp.fr/~iahs/**
IAHS Press, Centre for Ecology and Hydrology, Wallingford, Oxfordshire OX10 8BB, UK, Phone: 44 1491 692288, Fax: 44 1491 692448/692424

**International Association of Theoretical and Applied Limnology (Societas Internationalis Limnologiae) (SIL) — http://www.limnology.org/**

**International Bottled Water Association — http://www.bottledwater.org/**
1700 Diagonal Road, Suite 650, Alexandria, VA 22314, Phone: (703) 683-5213, Fax: (703) 683-4074

**International Association on Water Quality (IAWQ) — http://www.iawq.org.uk/**
Alliance House, 12 Caxton Street, London SW1H 0QS, UK, Phone: +44 207 6545500, Fax: +44 207 6545555

**International Commission on Irrigation and Drainage (ICID) — http://www.icid.org**
48 Nyaya Marg, Chanakyapuri, New Delhi 110021, India, Phone: 91-112 6116837, Fax: 91-112 6115962

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**Table 12D.15 (Continued)**

**International Commission on Large Dams (ICOLD) — http://www.icold-cigb.net/**
Bureau Central de la CIGB, 151 Boulevard Haussmann, 75008 Paris, France, Phone: +33 14 0426824, Fax: +33 14 0426071

**International Fund for Agricultural Development (IFAD) — http://www.ifad.org/**
International Fund for Agricultural Development, Via del Serafico, 107, 00142 Rome, Italy, Phone: +39 0654591, Fax: +39 06 5043463

**International Ground Water Modeling Center (IGWMC) — mines.edu/igwmc/**
International Ground Water Modeling Center, Colorado School of Mines, Golden, CO 80401-1887, Phone: (303) 273-3103, Fax: (303) 384-2037

**International Groundwater Resources Assessment Centre (IGRAC) — http://www.igrac.nl/**
P.O. Box 17, 8200 AA Lelystad, The Netherlands, Phone: +31 32 0298894, Fax: +31 32 0297642

**International Hydrological Programme — http://www.unesco.org/water/ihp/**
7, Place de Fontenoy, 75352 Paris 07 SP, France, Phone: +33 14 5681000, Fax: +33 14 5671690

**International Hydropower Association (IHA) — http://www.hydropower.org/**
IHA Central Office, Westmead House (Suite 55), 123 Westmead Road, Sutton, Surrey SM1 4JH, UK, Phone: +44 208 2881918, Fax: +44 208 7701744

**International Institute for Land Reclamation and Improvement (ILRI) — http://www.ilri.nl/**
Address: Lawickse Allee 11, Wageningen, The Netherlands, Correspondence: Postbus 45, 6700 AA, Wageningen, The Netherlands, Phone: +31 31 7495549, Fax: +31 31 7495590

**International Office for Water — http://www.oieau.fr/index.html**
International Office for Water, Documentation and Data Department, Rue Edouard Chamberland, 87065 Limoges Cedex, France

**International Programme for Technology Research in Irrigation and Drainage (IPTRID) — http://www.hrwallingford.co.uk/projects/IPTRID/**
Land and Water Development Division, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00100 Rome, Italy

**International Water and Sanitation Centre (IRC) — http://www.irc.nl/**
P.O. Box 2869, 2601 CW Delft, The Netherlands, Phone: +31 15 2192939, Fax: +31 15 2190955

**International Water Association — http://www.iawq.org.uk/**
International Water Association, Alliance House, 12 Caxton Street, London SW1H 0QS, UK, Phone: +44 20 7 654 5500, Fax: +44 20 7 654 5555

**International Water Management Institute (IWMI) — http://www.iwmi.cgiar.org/**
P.O. Box 2075, Colombo, Sri Lanka, Phone: +94 11 2787404, Fax: +94 11 2786854

**International Water Resources Association (IWRA) — http://www.iwra.siu.edu/**
IWRA Headquarters, 4535 Faner Hall, Southern Illinois University, Carbondale, IL 62901-4516, Fax: (618) 453-6465

**International Water Services Association (IWSA) — http://www.iwahq.org.uk**
International Water Association, Alliance House, 12 Caxton Street, London SW1H 0QS, UK, Phone: +44 207 6545500, Fax: +44 (0)207 6545555

**Izaak Walton League of America — http://www.iwla.org/**
707 Conservation Lane, Gaithersburg, MD 20878, Phone: (301) 548-0150, Fax: (301) 548-0146

**LakeNet — http://www.worldlakes.org**
P.O. Box 3250, Annapolis, MD 21403, Phone: (410) 268-5155, Fax: (410) 268-8788

**League of Conservation Voters — http://www.lcv.org/**
1920 L Street, NW, Suite 800, Washington, DC 20036, Phone: (202) 785-8683, Fax: (202) 835-0491

**League of Women Voters of the U.S. — http://www.lwv.org/**
1730 M Street, NW, Suite 1000, Washington, DC 20036-4508, Phone: (202) 429-1965, Fax: (202) 429-0854

**Mekong River Commission (MRC) — http://www.mrcmekong.org/**
Mekong River Commission Secretariat, P.O. Box 6101, Unit 18 Ban Sithane Neua, Sikhottabong District, Vientiane 01000, Lao PDR, Phone: +856 2 1263263:, Fax: +856 2 1263264

**Mexican Institute of Water Technology (IMTA) — http://www.imta.mx/english/**
Paseo Cuauhnáhuac 8532, Jiutepec, Morelos, Mexico, Switchboard: +52 777 3293600

**National Academy of Sciences (NAS) — http://www.nas.edu/**
500 Fifth St. NW Washington, DC 20001, Phone: (202) 334-2000

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**Table 12D.15 (Continued)**

**National Audubon Society — http://www.audubon.org/**
National Audubon Society, 700 Broadway, New York, NY 10003, Phone: (212) 979-3000, Fax: (212) 979-3188

**National Coalition for Marine Conservation — http://www.savethefish.org/**
4 Royal Street SE, Leesburg, VA 20175, Phone: (703) 777-0037, Fax: (703) 777-1107

**National Environmental Health Association (NEHA) — http://www.neha.org/**
720 S. Colorado Blvd., Suite 970-S, Denver, CO 80246-1925, Phone: (303) 756-9090, Fax: (303) 691-9490

**National Environmental Trust — http://www.environet.policy.net/**
1200 18th St. NW, Fifth Floor, Washington, DC 20036, Phone: (202) 887-8800, Fax: (202) 887-8877

**National Fish and Wildlife Foundation — http://www.nfwf.org/**
1120 Connecticut Avenue, NW, Suite 900, Washington, DC 20036, Phone: (202) 857-0166, Fax: (202) 857-0162

**National Ground Water Association — http://www.ngwa.org/**
601 Dempsey Road, Westerville, OH 43081-8978, Phone: (614) 898-7791, Fax: (614) 898-7786

**National Parks and Conservation Association (NPCA) — http://www.eparks.org/**
1300 19th Street, NW, Suite 300, Washington, DC 20036, Phone: (800) 628-7275, Fax: (202) 659-0650

**National Religious Partnership for the Environment — http://www.nrpe.org/**
49 South Pleasant Street Suite 301, Amherst, MA 01002, Phone: (413) 253-1515, Fax: (413) 523-1414

**National Rural Water Association — http://www.nrwa.org/**
2915 South 13th St. Duncan, OK 73533, Phone: (580) 252-0629, Fax: (580) 255-4476

**National Sanitation Foundation — http://www.nsf.org**
P.O. Box 130140, 789 N. Dixboro Road, Ann Arbor, MI 48113-0140, Phone: (734) 769-8010, Fax: (734) 769-0109

**National Science Foundation (NSF) — http://www.nsf.gov/**
4201 Wilson Blvd, Arlington, VA 22230, Phone: (703) 292-5111

**National Solid Wastes Management Association — http://www.nswma.org/**
4301 Connecticut Avenue, NW, Suite 300, Washington, DC 20008-2304, Phone: (202) 244-4700, Fax: (202) 364-3792

**National Water Resources Association — http://www.nwra.org/**
3800 North Fairfax Drive, Suite 4, Arlington, VA 22203, Phone: (703) 524-1544, Fax: (703) 524-1548

**National Water Resources Institute (NWRI) — http://www.nwri.ca/**
70 Crémazie St., Gatineau, Quebec K1A 0H3, Phone: (819) 997-2800 or (800) 668-6767, Fax: (819) 994-1412

**National Waterways Conference — http://www.waterways.org/**
1130 17th Street, NW Washington, DC 20036-4676, Phone: (202) 296-4415, Fax: (202) 835-3861

**National Wildlife Federation — http://www.nwf.org/**
National Wildlife Federation, 11100 Wildlife Center Drive, Reston, VA 20190-5362, Phone: (800) 822-9919

**Natural Resources Defense Council — http://www.nrdc.org/**
Natural Resources Defense Council, 40 West 20th Street, New York, NY 10011, Phone: (212) 727-2700, Fax: (212) 727-1773

**The Nature Conservancy — http://nature.org/**
The Nature Conservancy, 4245 North Fairfax Drive, Suite 100, Arlington, VA 22203-1606, Phone: (800) 628-6860

**North American Lake Management Society — http://www.nalms.org/**
P.O. Box 5443, 4513 Vernon Blvd., Suite 100, Madison, WI 53705-0443, Phone: (608) 233-2836, Fax: (608) 233-3186

**Northeast Midwest Institute — http://www.nemw.org/**
218 D Street, SE, Washington, DC 20003-1900, Phone: (202) 544-5200, Fax: (202) 544-0043

**Nuclear Control Institute — http://www.nci.org/**
The Nuclear Control Institute, 1000 Connecticut Avenue NW, Suite 410, Washington, DC 20036, Phone: (202) 822-8444, Fax: (202) 452-0892

**Oceana — http://www.oceana.org/**
2501 M Street, NW, Suite 300, Washington, DC 20037-1311, Phone: (202) 833-3900, Fax: (202) 833-2070

**Pacific Institute for Studies in Development, Environment and Security — http://www.pacinst.org/**
654 13th Street, Preservation Park, Oakland, CA 94612, Phone: (510) 251-1600, Fax: (510) 251-2203

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**Table 12D.15 (Continued)**

**Pacific Water Association — http://pwa.org.fj/index.html**
Private Mail Bag, GPO, Suva Fiji Islands, 16 Loa Street, Suva, Fiji Islands, Phone: (679) 337-0402, Fax: (679) 337-0412

**Project WET (Water Education for Teachers) — http://www.projectwet.org/**
201 Culbertson Hall, Montana State University, P.O. Box 170575, Bozeman, MT 59717-0575, Phone: (406) 994-5392, Fax: (406) 994-1919

**Public Agenda — publicagenda.org/issues/frontdoor.cfm?issue_type=environment**
Public Agenda, 6 East 39th Street, New York, NY 10016, Phone: (212) 686-6610, Fax: (212) 889-3461

**Public Interest Research Group (PIRG) — http://www.pirg.org/**
218 D Street, SE, Washington, DC 20003, Phone: (202) 546-9707, Fax: (202) 546-2461

**Rainforest Action Network — http://www.ran.org/**
221 Pine St., Suite 500, San Francisco, CA 94104, Phone: (415) 398-4404, Fax: (415) 398-2732

**Rainforest Alliance — http://www.rainforest-alliance.org/**
665 Broadway, Suite 500, New York, NY 10012, Phone: (212) 677-1900

**Resources for the Future — http://www.rff.org/**
1616 P Street, NW, Washington, DC 20036, Phone: (202) 328-5000

**Royal Society of Chemistry (RSC) — http://www.rsc.org/**
Royal Society of Chemistry, Burlington House, Piccadilly, London W1J 0BA, UK, Phone: +44 207 4378656, Fax: +44 207 4378883

**Scenic America — http://www.scenic.org/**
1634 I Street, NW, Suite 510, Washington, DC 20006, Phone: (202) 638-0550, Fax: (202) 638-3171

**Sierra Club — http://www.sierraclub.org/**
National Headquarters, 85 Second Street, 2nd Floor, San Francisco, CA 94105, Phone: (415) 977-5500, Fax: (415) 977-5799

**Society of Environmental Journalists — http://www.sej.org/**
P.O. Box 2492, Jenkintown, PA 19046, Phone: (215) 884-8174, Fax: (215) 884-8175

**Society of Environmental Toxicology and Chemistry (SETAC) — http://www.setac.org/**
SETAC North America, 1010 North 12th Avenue, Pensacola, FL 32501-3367, Phone: (850) 469-1500, Fax: (850) 469-9778

**Society of Wetland Scientists — http://www.sws.org/**
1313 Dolley Madison Boulevard, Suite 402, McLean, VA 22101, Phone: (703) 790-1745, Fax: (703) 790-2672

**Soil Science Society of America (SSSA) — http://www.soils.org/**
677 S. Segoe Rd, Madison, WI 53711, Phone: (608) 273-8080, Fax: (608) 273-2021

**Soil and Water Conservation Society — http://www.swcs.org/**
945 SW Ankeny Road, Ankeny, IA 50021-9764, Phone: (515) 289-2331, Fax: (515) 289-1227

**Southern Environmental Law Center — http://www.southernenvironment.org/**
201 West Main St., Suite 14, Charlottesville, VA 22902-5065, Phone: (434) 977-4090, Fax: (434) 977-1483

**Southern Utah Wilderness Alliance — http://www.suwa.org/**
1471 South 1100 East, Salt Lake City, UT 84105, Phone: (801) 486-3161

**Stockholm Environment Institute (SEI) — http://www.sei.se/**
Lilla Nygatan, 1, Box 2142, S-103 14 Stockholm, Sweden, Phone: +46 8 4121400, Fax: +46 8 7230348

**Stockholm International Water Institute (SIWI) — http://www.siwi.org/menu/menu.html**
Hantverkargatan 5, 112 21 Stockholm, Sweden, Phone: +46 85 2213960, Fax: +46 85 2213961

**Trout Unlimited — http://www.tu.org**
1300 N. 17th St., Suite 500, Arlington, VA 22209-2404, Phone: (703) 522-0200, Fax: (703) 284-9400

**UNDP/World Bank Water and Sanitation Program — http://www.wsp.org/**
Water and Sanitation Program, 1818 H Street, N.W., Washington, DC 20433, Phone: (202) 473-9785, Fax: (202) 522-3313, 522-3228

**UNESCO-IHE Institute for Water Education — http://www.unesco-ihe.org/vmp/articles/contentsHomePage.html**
P.O. Box 3015, 2601 DA Delft, The Netherlands, Phone: +31 15 2151715, Fax: +31 15 2122921

**Union of Concerned Scientists — http://www.ucsusa.org/**
National Headquarters, 2 Brattle Square, Cambridge, MA 02238-9105, Phone: (617) 547-5552, Fax: (617) 864-9405

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**United Nations Development Programme (UNDP) — www.undp.org**
Presidente Masaryk 29, piso 8, Col. Polanco 11570, México, D.F., Phone: +52 (55) 5 2639600, Fax: +52 (55) 5 2550095

**United Nations Educational, Scientific and Cultural Organization (UNESCO) — http://unesco.org/**
7, Place de Fontenoy, 75352 Paris 07 SP, France, Phone: +33 14 5681000, Fax: +33 14 5671690

**United Nations Environment Programme — Fresh Water Unit — http://www.unep.org/themes/freshwater/**
United Nations Avenue, Gigiri, P.O. Box 30552, 00100 Nairobi, Kenya, Phone: +254 2 0621234, Fax: +254 2 0624489

**United Nations Environment Programme — Global Programme of Action — http://www.undp.org/**
United Nations Avenue, Gigiri, P.O. Box 30552, 00100 Nairobi, Kenya, Phone: +254 2 0621234, Fax: +254 2 0624489

**United Nations Environment Programme — Regional Seas Programme — http://www.undp.org/**
United Nations Avenue, Gigiri, P.O. Box 30552, 00100 Nairobi, Kenya, Phone: +254 20 621234, Fax: +254 20 624489/90

**United Nations Environment Programme — Water Branch — http://www.undp.org/**
United Nations Avenue, Gigiri, P.O. Box 30552, 00100 Nairobi, Kenya, Phone: +254 20 621234, Fax: +254 20 624489/90

**United Nations World Health Organization (WHO) — http://www.who.int/en/**
Avenue Appia 20, 1211 Geneva 27, Switzerland, Phone: +41 22 7912111, Fax: +41 22 7913111

**United States Agency for International Development (USAID) — http://www.usaid.gov/**
U.S. Agency for International Development, Ronald Reagan Building, Washington, DC 20523-1000, Phone: (202) 712-0000. Fax: (202) 216-3524

**United States Public Interest Research Group — http://uspirg.org/**
218 D Street, SE, Washington, DC 20003, Phone: (202) 546-9707, Fax: (202) 546-2461

**Universities' Water Information Network (UWIN) — http://www.ucowr.siu.edu/**
1000 Faner Drive, Room 4543, Southern Illinois University Carbondale, Carbondale, IL 62901, Phone (618) 536-7571, Fax: (618) 453-2671

**Wateraid — http://www.wateraid.org.uk/**
Prince Consort House, 27-29 Albert Embankment, London SE1 7UB, UK, Phone: +44 20 77934500, Fax: +44 20 77934545

**Water Center for the Humid Tropics of Latin America and the Caribbean — http://www.cathalac.org/**
TCCC Regional Coordination, Antigua Base de Albrook, P.O. Box 873372, Panama 7, Republic of Panama, Phone: +507 2326851, Fax: +507 2326834

**Water Engineering and Development Centre (WEDC) — http://wedc.lboro.ac.uk/**
Loughborough University, Leicestershire LE11 3TU, UK, Phone: +44 150 9222885, Fax: +44 150 9211079

**Water Environment Federation — http://www.wef.org/index.jhtml**
601 Wythe Street, Alexandria, VA, 22314-1994, Phone: (703) 684-2452, Fax: (703) 684-2492

**Water For People (WFP) — http://www.water4people.org/**
6666 W. Quincy Avenue, Denver, CO 80235, Phone: (303) 734-3490, Fax: (303) 734-3499

**Water Online — http://www.wateronline.com/**
5340 Fryling Road, Suite 101, Erie, PA 16510

**WaterPartners International — http://www.water.org/**
P.O. Box 70310, Seattle, WA 98127, Phone: (206) 297-3024

**Water Quality Association — http://www.wqa.org/**
International Headquarters & Laboratory, 4151 Naperville Road, Lisle, IL 60532-1088, Phone: (630) 505-0160, Fax: (630) 505-9637

**Water and Sanitation in Developing Countries (SANDEC) — http://www.sandec.ch/**
EAWAG/SANDEC, Ueberlandstrasse 133, P.O. Box 611, CH-8600 Duebendorf, Switzerland, Phone: +41 1 8235286, Fax: +41 1 8235399

**Water and Wastewater Equipment Manufacturers Association — http://www.wwema.org/**
P.O. Box 17402, Washington, DC 20041, Phone: (703) 444-1777, Fax: (703) 444-1779

**Water Supply and Sanitation Collaborative Council (WSSCC) — http://www.wsscc.org/**
International Environment House, Chemin des Anémones 9, 1219 Châtelaine, Geneva, Switzerland

**WaterWeb — http://www.waterweb.org/**
e-mail: webmaster@ces.fau.edu

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**Table 12D.15 (Continued)**

**The Wilderness Society — http://www.wilderness.org/**
1615 M Street, NW, Washington, DC 20036, Phone: (800) 843-9453

**Wildlife Conservation Society — http://www.wcs.org/**
North America Program, Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, NY 10460, Phone: (718) 220-1442

**Wisconsin Ground Water Association — http://www.wgwa.org**
P.O. Box 8593, Madison, WI 53708-8593

**The Woods Hole Research Center — http://www.whrc.org/**
P.O. Box 296, Woods Hole, MA 02543-0296, Phone: (508) 540-9900, Fax: (508) 540-9700

**The World Bank — http://www.worldbank.org/**
1818 H Street, NW, Washington, DC 20433, Phone: (202) 473-1000, Fax: (202) 477-6391

**World Bank Institute: Water Policy Reform Program — http://www.worldwater.org/links.htm**
The World Bank Institute, 1818 H Street, NW, Washington, DC 20433, Phone: (202) 473-2049, Fax: (202) 522-0401

**The World Conservation Union (IUCN) — http://www.iucn.org/**
IUCN National Committee for Canada, Canadian Museum of Nature; P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4, Phone: (613) 566-4795, Fax: (613) 364-4022

**World Conservation Union (IUCN) Wetlands and Water Resources Programme — http://www.iucn.org/themes/wetlands**
Rue Mauverney 28, 1196 Gland, Switzerland, Phone: +41 22 9990001, Fax: +41 22 9990025

**World Conservation Union (IUCN) Water & Nature Initiative — http://www.waterandnature.org**
Rue Mauverney 28, 1196 Gland, Switzerland, Phone: +41 22 9990000, Fax: +41 22 9990002

**World Meteorological Organization: Hydrology and Water Resources Programme — http://www.wmo.ch/index-en.html**
7bis, Avenue de la Paix, Case postale No. 2300, CH-1211 Geneva 2, Switzerland, Phone: +41 22 7308111, Fax: +41 22 7308181

**World Resources Institute (WRI) — http://www.wri.org/**
10 G Street, NE (Suite 800), Washington, DC 20002, Phone: (202) 729-7600, Fax: (202) 729-7610

**The World's Water — http://www.worldwater.org/**
Pacific Institute, 654 13th Street, Preservation Park, Oakland, CA 94612, Phone: (510) 251-1600, Fax: (510) 251-2203

**Worldwatch Institute — http://www.worldwatch.org/**
Worldwatch Institute, 1776 Massachusetts Ave., NW, Washington, DC 20036-1904, Phone: (202) 452-1999, Fax: (202) 296-7365

**World Water Council (WWC) — http://www.worldwatercouncil.org/**
Les Docks Atrium 10.3, 10, place de la Joliette, 13002 Marseille, France, Phone: +33 4 91994100, Fax: +33 4 91994101

**World Wide Fund for Nature (WWF) — http://www.panda.org/**
WWF-United States, Washington DC, 1250 24th Street NW Washington, Phone: (202) 293-4800, Fax: (202) 293-9211

**World Wildlife Fund (U.S.) — http://www.wwf.org/**
World Wildlife Fund, 1250 24th Street, NW, Washington, DC 20037, Phone: (202) 293-4800

*Note:* Selected List of Professional Organizations, Trade Associations and Environmental Groups Concerned with Water Related Matters. For making International calls, please contact your service provider for dialing instructions.

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CHAPTER 13

# Constants and Conversion Factors

**Pedro Fierro, Jr.**

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# SECTION 13A PHYSICAL PROPERTIES OF WATER

**Table 13A.1 Variation of Properties of Pure Water with Temperature**

| Temperature (°C) | Temperature (°F) | Density at 1 Atmosphere ($gm/cm^3$) | Dynamic Viscosity, in Centipoises ($10^{-2}$ dyne-sec/$cm^2$) | Kinematic Viscosity, in Centistokes ($10^{-2}$ $cm^2$/sec) | Surface Tension Against Air (dyne/cm) | Vapor Pressure (mm Hg) |
|---|---|---|---|---|---|---|
| 5 | 41.0 | 0.999965 | 1.5188 | 1.5189 | 74.92 | 6.543 |
| 6 | 42.8 | 0.999941 | 1.4726 | 1.4727 | 74.78 | 7.013 |
| 7 | 44.6 | 0.999902 | 1.4288 | 1.4289 | 74.64 | 7.513 |
| 8 | 46.4 | 0.999849 | 1.3872 | 1.3874 | 74.50 | 8.045 |
| 9 | 48.2 | 0.999781 | 1.3476 | 1.3479 | 74.36 | 8.609 |
| 10 | 50.0 | 0.999700 | 1.3097 | 1.3101 | 74.22 | 9.209 |
| 11 | 51.8 | 0.999605 | 1.2735 | 1.2740 | 74.07 | 9.844 |
| 12 | 53.6 | 0.999498 | 1.2390 | 1.2396 | 73.93 | 10.518 |
| 13 | 55.4 | 0.999377 | 1.2061 | 1.2069 | 73.78 | 11.231 |
| 14 | 57.2 | 0.999244 | 1.1748 | 1.1757 | 73.64 | 11.987 |
| 15 | 59.0 | 0.999099 | 1.1447 | 1.1457 | 73.49 | 12.788 |
| 16 | 60.8 | 0.998943 | 1.1156 | 1.1168 | 73.34 | 13.634 |
| 17 | 62.6 | 0.998774 | 1.0875 | 1.0889 | 73.19 | 14.530 |
| 18 | 64.4 | 0.998595 | 1.0603 | 1.0618 | 73.05 | 15.477 |
| 19 | 66.2 | 0.998405 | 1.0340 | 1.0357 | 72.90 | 16.477 |
| 20 | 68.0 | 0.998203 | 1.0087 | 1.0105 | 72.75 | 17.535 |
| 21 | 69.8 | 0.997992 | 0.9843 | 0.9863 | 72.59 | 18.650 |
| 22 | 71.6 | 0.997770 | 0.9608 | 0.9629 | 72.44 | 19.827 |
| 23 | 73.4 | 0.997538 | 0.9380 | 0.9403 | 72.28 | 21.068 |
| 24 | 75.2 | 0.997296 | 0.9161 | 0.9186 | 72.13 | 22.377 |
| 25 | 77.0 | 0.997044 | 0.8949 | 0.8976 | 71.97 | 23.756 |
| 26 | 78.8 | 0.996783 | 0.8746 | 0.8774 | 71.82 | 25.209 |
| 27 | 80.6 | 0.996512 | 0.8551 | 0.8581 | 71.66 | 26.739 |
| 28 | 82.4 | 0.996232 | 0.8363 | 0.8395 | 71.50 | 28.349 |
| 29 | 84.2 | 0.995944 | 0.8181 | 0.8214 | 71.35 | 30.043 |
| 30 | 86.0 | 0.995646 | 0.8004 | 0.8039 | 71.18 | 31.824 |
| 31 | 87.8 | 0.995340 | 0.7834 | 0.7871 | 71.02[a] | 33.695 |
| 32 | 89.6 | 0.995025 | 0.7670 | 0.7708 | 70.86[a] | 35.663 |
| 33 | 91.4 | 0.994702 | 0.7511 | 0.7551 | 70.70[a] | 37.729 |
| 34 | 93.2 | 0.994371 | 0.7357 | 0.7399 | 70.53[a] | 39.898 |
| 35 | 95.0 | 0.99403 | 0.7208 | 0.7251 | 70.38 | 42.175 |
| 36 | 96.8 | 0.99368 | 0.7064 | 0.7109 | 70.21[a] | 44.563 |
| 37 | 98.6 | 0.99333 | 0.6925 | 0.6971 | 70.05[a] | 47.067 |
| 38 | 100.4 | 0.99296 | 0.6791 | 0.6839 | 69.88[a] | 49.692 |

[a] Interpolated.

*Source*: From U.S. Department of the Interior, Bureau of Reclamation, 1977, *Ground Water Manual*.

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**Table 13A.2 Density of Water**

| Temperature (°F) | Density (gm/cm$^3$) |
|---|---|
| 32 | 0.99987 |
| 35 | 0.99996 |
| 39.2 | 1.00000 |
| 40 | 0.99999 |
| 50 | 0.99975 |
| 60 | 0.99907 |
| 70 | 0.99802 |
| 80 | 0.99669 |
| 90 | 0.99510 |
| 100 | 0.99318 |
| 120 | 0.98870 |
| 140 | 0.98338 |
| 160 | 0.97729 |
| 180 | 0.97056 |
| 200 | 0.96333 |
| 212 | 0.95865 |

*Note:* Density of sea water: approximately 1.025 gm/cm$^3$ at 15°C.

**Table 13A.3 Weight of Water**

| Temperature | Weight (lb/ft$^3$) |
|---|---|
| 32 | 62.416 |
| 35 | 62.421 |
| 39.2 | 62.424 |
| 40 | 62.423 |
| 50 | 62.408 |
| 60 | 62.366 |
| 70 | 62.300 |
| 80 | 62.217 |
| 90 | 62.118 |
| 100 | 61.998 |
| 120 | 61.719 |
| 140 | 61.386 |
| 160 | 61.006 |
| 180 | 60.586 |
| 200 | 60.135 |
| 212 | 59.843 |

*Note:* 1 cu in. = 0.0360 lb; 1 cu ft = 62.4 lb; 1 gal = 8.33 lb; 1 Imperial gal = 10.0 lb; Weight of sea water: Approximately 63.93 lb/ft$^3$ at 15°C.

**Table 13A.4 Properties of Water at Various Altitudes**

| Altitude (Feet) | Barometric Pressure (Inches Hg) | Atmospheric Pressure (psia) | Feet Water |
|---|---|---|---|
| −500 | 30.5 | 15.0 | 34.6 |
| 0 (Seasonal) | 29.9 | 14.7 | 33.9 |
| 500 | 29.4 | 14.5 | 33.4 |
| 1000 | 28.9 | 14.2 | 32.8 |
| 1500 | 28.3 | 13.9 | 32.1 |
| 2000 | 27.8 | 13.7 | 31.5 |
| 4000 | 25.8 | 12.7 | 29.2 |
| 6000 | 24.0 | 11.8 | 27.2 |
| 8000 | 22.2 | 10.9 | 25.2 |

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**Table 13A.5 Properties of Water at Various Temperatures**

| Temperature (°F) | Vapor Pressure | | Specific Weight pcf | Specific Gravity |
|---|---|---|---|---|
| | psfa | Feet Water | | |
| 32.0 | 12.7 | 0.20 | 62.42 | 0.9999 |
| 39.2[a] | 16.9 | 0.27 | 62.427 | 1.0000 |
| 50.0 | 25.6 | 0.41 | 62.41 | 0.9997 |
| 60.0 | 36.8 | 0.59 | 62.37 | 0.9990 |
| 70.0 | 52.3 | 0.84 | 62.30 | 0.9980 |
| 80.0 | 73.0 | 1.17 | 62.22 | 0.9966 |
| 100.0 | 136.0 | 2.19 | 62.00 | 0.9931 |

[a] Temperature when specific gravity = 1.0000.

*Source*: From Soil Conservation Service, U.S. Department of Agriculture, 1971, Drainage of Agricultural Land.

**Table 13A.6 Variation of Boiling Point of Water with Elevation**

| Elevation, Feet above Mean Sea Level | Boiling Point (°F) |
|---|---|
| −1,000 | 213.8 |
| 0 | 212.0 |
| 1,000 | 210.2 |
| 2,000 | 208.4 |
| 3,000 | 206.5 |
| 4,000 | 204.7 |
| 5,000 | 202.9 |
| 6,000 | 201.1 |
| 7,000 | 199.2 |
| 8,000 | 197.4 |
| 9,000 | 195.6 |
| 10,000 | 193.7 |
| 11,000 | 191.9 |
| 12,000 | 190.1 |
| 13,000 | 188.2 |
| 14,000 | 186.4 |

*Note:* U.S. standard atmosphere is assumed.

**Table 13A.7 Heat of Vaporization, Viscosity, Vapor Pressure, Surface Tension, and Elastic Modulus of Water**

| Temperature (°F) | Heat Vaporization (Btu/lb) | Viscosity | | Vapor Pressure | | Surface Tension (lb/ft) | Elastic Modulus (lb/in.$^2$) |
|---|---|---|---|---|---|---|---|
| | | Absolute (lb-sec/ft$^2$) | Kinematic (ft$^2$/sec) | Millibars | lb/in.$^2$ | | |
| 32 | 1073 | $0.374\times10^{-4}$ | $1.93\times10^{-5}$ | 6.11 | 0.09 | 0.00518 | 287,000 |
| 40 | 1066 | 0.323 | 1.67 | 8.36 | 0.12 | 0.00514 | 296,000 |
| 50 | 1059 | 0.273 | 1.41 | 12.19 | 0.18 | 0.00508 | 305,000 |
| 60 | 1054 | 0.235 | 1.21 | 17.51 | 0.26 | 0.00504 | 313,000 |
| 70 | 1049 | 0.205 | 1.06 | 24.79 | 0.36 | 0.00497 | 319,000 |
| 80 | 1044 | 0.180 | 0.929 | 34.61 | 0.51 | 0.00492 | 325,000 |
| 90 | 1039 | 0.160 | 0.828 | 47.68 | 0.70 | 0.00486 | 329,000 |
| 100 | 1033 | 0.143 | 0.741 | 64.88 | 0.95 | 0.00479 | 331,000 |
| 120 | 1021 | 0.117 | 0.610 | — | 1.69 | 0.00466 | 332,000 |
| 140 | 1010 | 0.0979 | 0.513 | — | 2.89 | | |
| 160 | 999 | 0.0835 | 0.440 | — | 4.74 | | |
| 180 | 988 | 0.0726 | 0.385 | — | 7.51 | | |
| 200 | 977 | 0.0637 | 0.341 | — | 11.52 | | |
| 212 | 970 | 0.0593 | 0.319 | — | 14.70 | | |

*Note:* Heat of fusion at 32°F: 143.5 Btu/lb.

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**Table 13A.8 Thermal Conductivity of Water**

| Temperature °C (°F) | Cal/sec/cm$^2$ under 1°C/cm | Btu/sec/ft$^2$ under 1°F/in. |
|---|---|---|
| 0 (32) | 0.00139 | 0.00111 |
| 4 (39.2) | 0.00138 | 0.00110 |
| 15 (59.0) | 0.00144 | 0.00115 |
| 20 (68.0) | 0.00143 | 0.00114 |

**Table 13A.9 Velocity of Sound in Water and Sea Water**

| Temperature (°C) | Pure Water (m/sec) | Sea Water (m/sec) |
|---|---|---|
| 0 | 1,400 | 1,445 |
| 10 | 1,445 | 1,485 |
| 20 | 1,480 | 1,520 |
| 30 | 1,505 | 1,545 |

*Note:* Assuming atmospheric pressure and sea water salinity of 35,000 ppm.

*Source*: From Berry, Bollay, and Beers, *Handbook of Meteorology*, McGraw-Hill, Copyright 1945. With permission.

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## SECTION 13B WATER QUALITY

**Table 13B.10 Constants and Conversion Factors for Water Quality**

| To Convert | To | Multiply By |
|---|---|---|
| Grains per Imperial gallon | Parts per million | 14.3 |
| Grains per gallon | Parts per million | 17.12 |
| Parts per million | Grains per gallon | 0.05841 |
| Parts per million | Tons per acre-foot | 0.00136 |
| Parts per million | Tons per day | Second-feet $\times$ 0.0027 |
| $Ca^{+2}$ | $CaCO_3$ | 2.497 |
| $CaCl_2$ | $CaCO_3$ | 0.9018 |
| $HCO_3^{-1}$ | $CaCO_3$ | 0.8202 |
| $HCO_3^{-1}$ | $CO_3^{-2}$ | 0.4917 |
| $Mg^{+2}$ | $CaCO_3$ | 4.116 |
| $MgCl_2$ | $CaCO_3$ | 1.051 |
| $Na_2CO_3$ | $CaCO_3$ | 0.9442 |
| $Fe^{+3}$ | $H_2SO_4$ | 2.634 |
| $NO_3^{-1}$ | N | 0.2259 |
| N | $NO_3^{-1}$ | 4.4266 |

**Parts Per Million to Equivalent Per Million**

| Ion | Multiply By | Ion | Multiply By |
|---|---|---|---|
| Aluminum ($Al^{+3}$) | 0.11119 | Iron ($Fe^{+3}$) | 0.05372 |
| Barium ($Ba^{+2}$) | 0.01456 | Lead ($Pb^{+3}$) | 0.00965 |
| Bicarbonate ($HCO_3^{-1}$) | 0.01639 | Lithium ($Li^{+1}$) | 0.14409 |
| Bromide ($Br^{-1}$) | 0.01251 | Magnesium ($Mg^{+2}$) | 0.08224 |
| Calcium ($Ca^{+2}$) | 0.04990 | Manganese ($Mn^{+2}$) | 0.03640 |
| Carbonate ($CO_3^{-1}$) | 0.03333 | Manganese ($Mn^{+4}$) | 0.07281 |
| Chloride ($Cl^{-1}$) | 0.02820 | Nitrate ($NO_3^{-1}$) | 0.01613 |
| Chromium ($Cr^{+6}$) | 0.11536 | Phosphate ($PO_4^{-3}$) | 0.03159 |
| Copper ($Cu^{+2}$) | 0.03148 | Potassium ($K^{+1}$) | 0.02558 |
| Fluoride ($F^{-1}$) | 0.05263 | Sodium ($Na^{+1}$) | 0.04350 |
| Hydrogen ($H^{+1}$) | 0.99206 | Strontium ($Sr^{+2}$) | 0.02282 |
| Hydroxide ($OH^{-1}$) | 0.05880 | Sulfate ($SO_4^{-2}$) | 0.02082 |
| Iodide ($I^{-1}$) | 0.00788 | Sulfide($S^{-1}$) | 0.06237 |
| Iron ($Fe^{+2}$) | 0.03581 | Zinc ($Zn^{+2}$) | 0.03059 |

**Expressions of Hardness**

| | |
|---|---|
| 1 grain per gallon | = 1 grain $CaCO_3$ per U.S. gallon |
| 1 part per million | = 1 part $CaCO_3$ per 1,000,000 parts of water |
| 1 English, or Clark, degree | = 1 grain $CaCO_3$ per Imperial gallon |
| 1 French degree | = 1 part $CaCO_3$ per 100,000 parts of water |
| 1 German degree | = 1 part CaO per 100,000 parts of water |

**Conversions**

| | |
|---|---|
| 1 grain per U.S. gallon | = 17.1 ppm, as $CaCO_3$ |
| 1 English degree | = 14.3 ppm, as $CaCO_3$ |
| 1 French degree | = 10 ppm, as $CaCO_3$ |
| 1 German degree | = 17.9 ppm, as CaCO |

For most waters, 1 part per million = 1 mg/l. The U.S. Geological Survey has arbitrarily selected 7,000 ppm as the concentration above which a density correction must be made: the determined concentration of each constituent must be divided by the density to give the correct parts per million. The computation is made before rounding the results.

Parts per million are converted to equivalents per million by multiplying ppm by the reciprocals of combining weights of the appropriate ions (see table). The combining weight is equal to the molecular or ionic weight divided by the ionic charge, or valence.

**Specific Conductance Relations (Adapted from USGS Water Supply Paper 1454)**

For most natural waters of a mixed type, the specific conductance, in micromhos (1 micromho = $10^{-6}$ mho. The mho is unit of conductance; thus, a body has a conductance of one mho if one ampere of electric current flows when the potential difference is one volt. The conductance of a body in mhos is the reciprocal of the value of its resistance in ohms.), multiplied by 0.65 approximates the residue on evaporation in parts per million. This does not approach an exact relation, and usually increases as the total dissolved solids exceed 2000–3000 ppm. For waters containing appreciable concentrations of free acid, caustic alkalinity, or sodium chloride, the factor may be much less than 0.65. The relationship for any water becomes indefinite as saturation is approached.

With similar limitations, the specific conductance divided by 100 approximates the equivalents per million of cations or anions.

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**Table 13B.11 Formula Weights and Equivalent Weights of Ions Found in Water**

| Ion | Formula Weight | Equivalent Weight |
|---|---|---|
| $Al^{+3}$ | 27.00 | 9.00 |
| $Ba^{+2}$ | 137.00 | 68.70 |
| $HCO_3^{-1}$ | 61.00 | 61.00 |
| $Br^{-1}$ | 79.90 | 79.90 |
| $Ca^{+2}$ | 40.10 | 20.00 |
| $CO_3^{-2}$ | 60.00 | 30.00 |
| $Cl^{-1}$ | 35.50 | 35.50 |
| $Cr^{+6}$ | 52.00 | 8.67 |
| $Cu^{+2}$ | 63.60 | 31.80 |
| $F^{+1}$ | 19.00 | 19.00 |
| $H^{+1}$ | 1.01 | 1.01 |
| $OH^{-1}$ | 17.00 | 17.00 |
| $I^{-1}$ | 127.00 | 127.00 |
| $Fe^{+2}$ | 55.80 | 27.90 |
| $Fe^{+3}$ | 55.80 | 18.60 |
| $Pb^{+2}$ | 207.00 | 104.00 |
| $Li^{+1}$ | 6.94 | 6.94 |
| $Mn^{+2}$ | 54.90 | 27.50 |
| $Mn^{+4}$ | 54.90 | 13.70 |
| $NO_3^{-1}$ | 62.00 | 62.00 |
| $PO_4^{-3}$ | 95.00 | 31.70 |
| $K^{+1}$ | 39.10 | 39.10 |
| $Na^{+1}$ | 23.00 | 23.00 |
| $Sr^{+2}$ | 87.60 | 43.80 |
| $SO_4^{-2}$ | 96.10 | 48.00 |
| $S^{-2}$ | 32.10 | 16.00 |
| $Zn^{+2}$ | 65.40 | 32.70 |

*Note:* Weights expressed to three significant figures.

## SECTION 13C LENGTH

**Table 13C.12 Conversion Factors for Length**

| | |
|---|---|
| 1 mil | $=1\times10^{-3}$ in. |
| | $=0.0254$ mm |
| 1 in. | $=0.08333$ ft |
| | $=0.0278$ yd |
| | $=25.4$ mm |
| | $=2.54$ cm |
| | $=0.0254$ m |
| 1 ft | $=12$ in. |
| | $=0.3333$ yd |
| | $=1.89\times10^{-4}$ mi |
| | $=30.48$ cm |
| | $=0.3048$ m |
| | $=3.048\times10^{-4}$ km |
| 1 yd | $=36$ in. |
| | $=3$ ft |
| | $=5.68\times10^{-4}$ mi |
| | $=91.44$ cm |
| | $=0.9144$ m |
| | $=9.144\times10^{-4}$ km |
| 1 mi | $=5280$ ft |
| | $=1760$ yd |
| | $=1609.3$ m |
| | $=1.609$ km |

*(Continued)*

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**Table 13C.12 (Continued)**

| | |
|---|---|
| 1 μm | $=1\times10^{-3}$ mm |
| | $=3.937\times10^{-5}$ in. |
| 1 mm | $=0.03937$ in. |
| | $=0.1$ cm |
| | $=1\times10^{-3}$ m |
| 1 cm | $=0.3937$ in. |
| | $=0.03281$ ft |
| | $=0.01094$ yd |
| | $=10$ mm |
| | $=1\times10^{-5}$ km |
| 1 m | $=39.37$ in. |
| | $=3.281$ ft |
| | $=1.094$ yd |
| | $=6.21\times10^{-4}$ mi |
| | $=1000$ mm |
| | $=100$ cm |
| | $=1\times10^{-3}$ km |
| 1 km | $=3280.8$ ft |
| | $=1093.6$ yd |
| | $=0.621$ mi |
| | $=1\times10^{5}$ cm |
| | $=1000$ m |
| 1 fathom | $=6$ ft |
| 1 league (land) | $=5280$ yd |
| | $=3$ mi |
| | $=4.828$ km |
| 1 International nautical mile | $=6076.1$ ft |
| | $=1.151$ mi |
| | $=1.852$ km |
| 10 mm | $=1$ cm |
| 10 cm | $=1$ dm |
| 10 dm | $=1$ m |
| 10 m | $=1$ dam |
| 10 dam | $=1$ hm |
| 10 hm | $=1$ km |

## SECTION 13D AREA

**Table 13D.13 Conversion Factors for Area**

| | |
|---|---|
| 1 sq in. | $=6.944\times10^{-3}$ ft$^2$ |
| | $=7.716\times10^{4}$ yd$^2$ |
| | $=6.452$ cm$^2$ |
| 1 sq ft | $=144$ in.$^2$ |
| | $=0.1111$ yd$^2$ |
| | $=2.296\times10^{-5}$ acre |
| | $=3.587\times10^{-8}$ mi$^2$ |
| | $=929.0$ cm$^2$ |
| 1 sq yd | $=1296$ in.$^2$ |
| | $=9$ ft$^2$ |
| | $=2.066\times10^{4}$ acres |
| | $=3.228\times10^{-7}$ mi$^2$ |
| | $=0.8361$ m$^2$ |
| | $=8.361\times10^{-5}$ hectare |
| 1 Acre | $=43{,}560$ ft$^2$ |
| | $=4840$ yd$^2$ |
| | $=1.562\times10^{-3}$ mi$^2$ |
| | $=4046.9$ m$^2$ |
| | $=0.4047$ hectare |
| | $=4.047\times10^{-3}$ km$^2$ |

*(Continued)*

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**Table 13D.13 (Continued)**

| | |
|---|---|
| 1 sq mi | $=2.788\times10^{7}$ ft$^2$ |
| | $=3.098\times10^{6}$ yd$^2$ |
| | $=640$ acres |
| | $=2.590\times10^{6}$ m$^2$ |
| | $=259.0$ hectares |
| | $=2.590$ km$^2$ |
| | $=1$ section (of land) |
| 1 Township | $=36$ mi$^2$ |
| | $=36$ sections (of land) |
| 1 sq cm | $=0.1550$ in.$^2$ |
| | $=1.076\times10^{-3}$ ft$^2$ |
| | $=1.196\times10^{-4}$ yd$^2$ |
| | $=1\times10^{-4}$ yd$^2$ |
| 1 sq m | $=1550.0$ in.$^2$ |
| | $=10.76$ ft$^2$ |
| | $=1.196$ yd$^2$ |
| | $=2.471\times10^{-4}$ acre |
| | $=1\times10^{-4}$ hectare |
| | $=1\times10^{8}$ km$^2$ |
| 1 Hectare | $=1.076\times10^{5}$ ft$^2$ |
| | $=1.196\times10^{4}$ yd$^2$ |
| | $=2.471$ acres |
| | $=3.861\times10^{-3}$ mi$^2$ |
| | $=1\times10^{4}$m$^2$ |
| | $=0.01$ km$^2$ |
| 1 sq km | $=1.076\times10^{7}$ ft$^2$ |
| | $=1.196\times10^{6}$ yd$^2$ |
| | $=247.1$ acres |
| | $=0.3861$ mi$^2$ |
| | $=1\times10^{6}$ mi$^2$ |
| | $=100$ hectares |

## SECTION 13E VOLUME

**Table 13E.14 Conversion Factors for Volume**

| | |
|---|---|
| 1 cu in. | $=4.329\times10^{-3}$ gal |
| | $=5.787\times10^{4}$ ft$^3$ |
| | $=16.39$ cm$^3$ |
| | $=0.01639$ l |
| 1 gal | $=231$ in.$^3$ |
| | $=0.1337$ ft$^3$ |
| | $=4.951\times10^{-3}$ yd$^3$ |
| | $=3.785\times10^{-3}$ cm$^3$ |
| | $=3.785$ l |
| | $=3.785\times10^{-3}$ m$^3$ |
| 1 cu ft | $=1728$ in.$^3$ |
| | $=7.481$ gal |
| | $=0.03704$ yd$^3$ |
| | $=2.832\times10^{4}$ cm$^3$ |
| | $=28.32$ l |
| | $=0.02832$ m$^3$ |
| 1 cu yd | $=4.666\times10^{4}$ in.$^3$ |
| | $=27$ ft$^3$ |
| | $=0.7646$ m$^3$ |
| | $=6.198\times10^{-4}$ acre-ft |
| 1 Acre-in. | $=2.715\times10^{4}$ gal |
| | $=3630$ ft$^3$ |
| 1 Acre-ft | $=3.259\times10^{5}$ gal |
| | $=43{,}560$ ft$^3$ |
| | $=1234$ m$^3$ |

*(Continued)*

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**Table 13E.14 (Continued)**

| | |
|---|---|
| 1 cu cm | $=0.06102$ in.$^3$ |
| | $=2.642\times10^4$ gal |
| | $=3.532\times10^{-5}$ ft$^3$ |
| | $=1\times10^{-3}$ l |
| 1 l | $=61.02$ in.$^3$ |
| | $=0.2642$ gal |
| | $=0.03532$ ft$^3$ |
| | $=1000$ cm$^3$ |
| | $=1\times10^{-3}$ m$^3$ |
| 1 cu m | $=264.2$ gal |
| | $=35.32$ ft$^3$ |
| | $=1.307$ yd$^3$ |
| | $=1\times10^6$ cm$^3$ |
| | $=1000$ l |
| 1 Imperial gallon | $=277.4$ in.$^3$ |
| | $=1.201$ gal |
| | $=0.1604$ ft$^3$ |
| | $=4.546$ l |
| 1 cfs-day | $=1.98$ acre-ft |
| | $=0.0372$ in. mi$^2$ |
| 1 in. of rain | $=5.610$ gal/yd$^2$ |
| | $=2.715\times10^4$gal/acre |
| 1 in.-mi$^2$ | $=2.323\times10^6$ ft$^3$ |
| | $=53.3$ acre-ft |
| | $=26.9$ cfs-days |
| 1 Barrel (oil) | $=42$ gal |
| 1 Million gallons | $=3.069$ acre-ft |
| 1 Pint | $=28.875$ in.$^3$ |
| | $=0.5$ qt |
| | $=0.473$ l |
| 1 Quart | $=57.75$ in.$^3$ |
| | $=2$ pt |
| | $=0.25$ gal |
| | $=0.946$ l |

**Table 13E.15 Areas and Volumes of Vertical Cylindrical Tanks and Wells**

| Diameter | Area, sq ft or cu ft per ft of Depth | U.S. gal per ft of Depth | Diameter | Area, sq ft or cu ft per ft of Depth | U.S. gal per ft of Depth | Diameter | Area, sq ft or cu ft per ft of Depth | U.S. gal per ft of Depth |
|---|---|---|---|---|---|---|---|---|
| 1′ | 0.785 | 5.87 | 6′ | 28.27 | 211.5 | 28′ | 615.8 | 4,606 |
| 1′1″ | 0.922 | 6.89 | 6′3″ | 30.68 | 229.5 | 28′6″ | 637.9 | 4,772 |
| 1′2″ | 1.069 | 8.00 | 6′6″ | 33.18 | 248.2 | 29′ | 660.5 | 4,941 |
| 1′3″ | 1.227 | 9.18 | 6′9″ | 35.78 | 267.7 | 29′6″ | 683.5 | 5,113 |
| 1′4″ | 1.396 | 10.44 | 7′ | 38.48 | 287.9 | 30′ | 706.9 | 5,288 |
| 1′5″ | 1.576 | 11.79 | 7′3″ | 41.28 | 308.8 | 31′ | 754.8 | 5,646 |
| 1′6″ | 1.767 | 13.22 | 7′6″ | 44.18 | 330.5 | 32′ | 804.3 | 6,016 |
| 1′7″ | 1.969 | 14.73 | 7′9″ | 47.17 | 352.9 | 33′ | 855.3 | 6,398 |
| 1′8″ | 2.182 | 16.32 | 8′ | 50.27 | 376.0 | 34′ | 907.9 | 6,792 |
| 1′9″ | 2.405 | 17.99 | 8′3″ | 53.46 | 399.9 | 35′ | 962.1 | 7,197 |
| 1′10″ | 2.640 | 19.75 | 8′6″ | 56.75 | 424.5 | 36′ | 1,018 | 7,616 |
| 1′11″ | 2.885 | 21.58 | 8′9″ | 60.13 | 449.8 | 37′ | 1,075 | 8,043 |
| 2′ | 3.142 | 23.50 | 9′ | 63.62 | 475.9 | 38′ | 1,134 | 8,483 |
| 2′1″ | 3.409 | 25.50 | 9′3″ | 67.20 | 502.7 | 39′ | 1,195 | 8,940 |
| 2′2″ | 3.637 | 27.58 | 9′6″ | 70.88 | 530.2 | 40′ | 1,257 | 9,404 |
| 2′3″ | 3.976 | 29.74 | 9′9″ | 74.66 | 558.5 | 41′ | 1,320 | 9,876 |
| 2′4″ | 4.276 | 31.99 | 10′ | 78.54 | 587.5 | 42′ | 1,385 | 10,360 |
| 2′5″ | 4.587 | 34.31 | 10′6″ | 86.59 | 647.7 | 43′ | 1,452 | 10,860 |
| 2′6″ | 4.909 | 36.72 | 11′ | 95.03 | 710.9 | 44′ | 1,521 | 11,370 |
| 2′7″ | 5.241 | 39.21 | 11′6″ | 103.9 | 777.0 | 45′ | 1,590 | 11,900 |

*(Continued)*

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**Table 13E.15 (Continued)**

| Diameter | Area, sq ft or cu ft per ft of Depth | U.S. gal per ft of Depth | Diameter | Area, sq ft or cu ft per ft of Depth | U.S. gal per ft of Depth | Diameter | Area, sq ft or cu ft per ft of Depth | U.S. gal per ft of Depth |
|---|---|---|---|---|---|---|---|---|
| 2′8″ | 5.585 | 41.78 | 12′ | 113.1 | 846.0 | 46′ | 1,662 | 12,430 |
| 2′9″ | 5.940 | 44.43 | 12′6″ | 122.7 | 918.0 | 47′ | 1,735 | 12,980 |
| 2′10″ | 6.305 | 47.16 | 13′ | 132.7 | 992.9 | 48′ | 1,810 | 13,540 |
| 2′11″ | 6.681 | 49.98 | 13′6″ | 143.1 | 1,071 | 49′ | 1,886 | 14,110 |
| 3′ | 7.069 | 52.88 | 14′ | 153.9 | 1,152 | 50′ | 1,964 | 14,690 |
| 3′1″ | 7.467 | 55.86 | 14′6″ | 165.1 | 1,235 | 52′ | 2,124 | 15,890 |
| 3′2″ | 7.876 | 58.92 | 15′ | 176.7 | 1,322 | 54′ | 2,290 | 17,130 |
| 3′3″ | 8.296 | 62.06 | 15′6″ | 188.7 | 1,412 | 56′ | 2,463 | 18,420 |
| 3′4″ | 8.727 | 65.28 | 16′ | 201.1 | 1,504 | 58′ | 2,642 | 19,760 |
| 3′5″ | 9.168 | 68.58 | 16′6″ | 213.8 | 1,600 | 60′ | 2,827 | 21,150 |
| 3′6″ | 9.621 | 71.97 | 17′ | 227.0 | 1,698 | 62′ | 3,019 | 22,580 |
| 3′7″ | 10.08 | 75.44 | 17′6″ | 240.5 | 1,799 | 64′ | 3,217 | 24,060 |
| 3′8″ | 10.56 | 78.99 | 18′ | 254.5 | 1,904 | 66′ | 3,421 | 25,590 |
| 3′9″ | 11.04 | 82.62 | 18′6″ | 268.8 | 2,011 | 68′ | 3,632 | 27,170 |
| 3′10″ | 11.54 | 86.33 | 19′ | 283.5 | 2,121 | 70′ | 3,848 | 28,790 |
| 3′11″ | 12.05 | 90.13 | 19′6″ | 298.6 | 2,234 | 72′ | 4,072 | 30,450 |
| 4′ | 12.57 | 94.00 | 20′ | 314.2 | 2,350 | 74′ | 4,301 | 32,170 |
| 4′1″ | 13.10 | 97.96 | 20′6″ | 330.1 | 2,469 | 76′ | 4,536 | 33,930 |
| 4′2″ | 13.64 | 102.0 | 21′ | 346.4 | 2,591 | 78′ | 4,778 | 35,740 |
| 4′3″ | 14.19 | 106.1 | 21′6″ | 363.1 | 2,716 | 80′ | 5,027 | 37,600 |
| 4′4″ | 14.75 | 110.3 | 22′ | 380.1 | 2,844 | 82′ | 5,281 | 39,500 |
| 4′5″ | 15.32 | 114.6 | 22′6″ | 397.6 | 2,974 | 84′ | 5,542 | 41,450 |
| 4′6″ | 15.90 | 119.0 | 23′ | 415.5 | 3,108 | 86′ | 5,809 | 43,450 |
| 4′7″ | 16.50 | 123.4 | 23′6″ | 433.7 | 3,245 | 88′ | 6,082 | 45,490 |
| 4′8″ | 17.10 | 128.0 | 24′ | 452.4 | 3,384 | 90′ | 6,362 | 47,590 |
| 4′9″ | 17.72 | 132.6 | 24′6″ | 471.4 | 3,527 | 92′ | 6,648 | 49,720 |
| 4′10″ | 18.35 | 137.3 | 25′ | 490.9 | 3,672 | 94′ | 6,940 | 51,920 |
| 4′11″ | 18.99 | 142.0 | 25′6″ | 510.7 | 3,820 | 96′ | 7,238 | 54,140 |
| 5′ | 19.63 | 146.9 | 26′ | 530.9 | 3,972 | 98′ | 7,543 | 56,420 |
| 5′3″ | 21.65 | 161.9 | 26′6″ | 551.5 | 4,126 | 100′ | 7,854 | 58,750 |
| 5′6″ | 23.76 | 177.7 | 27′ | 572.6 | 4,283 | | | |
| 5′9″ | 25.97 | 194.3 | 27′6″ | 594.0 | 4,443 | | | |

**Table 13 E.16 Volumes of Horizontal Cylindrical Tanks**

| | Percent Full | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Diameter (ft)** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| 1 | 0.3 | 0.8 | 1.4 | 2.1 | 2.9 | 3.6 | 4.3 | 4.9 | 5.5 | 5.87 |
| 2 | 1.2 | 3.3 | 5.9 | 8.8 | 11.7 | 14.7 | 17.5 | 20.6 | 22.2 | 23.50 |
| 3 | 2.7 | 7.5 | 13.6 | 19.8 | 26.4 | 33.0 | 39.4 | 45.2 | 50.1 | 52.88 |
| 4 | 4.9 | 13.4 | 23.8 | 35.0 | 47.0 | 59.0 | 70.2 | 80.5 | 89.0 | 94.00 |
| 5 | 7.6 | 20.0 | 37.0 | 55.0 | 73.0 | 92.0 | 110.0 | 126.0 | 139.0 | 146.9 |
| 6 | 11.0 | 30.0 | 53.0 | 78.0 | 106.0 | 133.0 | 158.0 | 182.0 | 201.0 | 211.5 |
| 7 | 15.0 | 41.0 | 73.0 | 107.0 | 144.0 | 181.0 | 215.0 | 247.0 | 272.0 | 287.9 |
| 8 | 19.0 | 52.0 | 96.0 | 140.0 | 188.0 | 235.0 | 281.0 | 322.0 | 356.0 | 376.0 |
| 9 | 25.0 | 67.0 | 112.0 | 178.0 | 238.0 | 298.0 | 352.0 | 408.0 | 450.0 | 475.9 |
| 10 | 30.0 | 83.0 | 149.0 | 219.0 | 294.0 | 368.0 | 440.0 | 504.0 | 556.0 | 587.5 |
| 11 | 37.0 | 101.0 | 179.0 | 265.0 | 356.0 | 445.0 | 531.0 | 610.0 | 672.0 | 710.9 |
| 12 | 44.0 | 120.0 | 214.0 | 315.0 | 423.0 | 530.0 | 632.0 | 714.0 | 800.0 | 846.0 |
| 13 | 51.0 | 141.0 | 250.0 | 370.0 | 496.0 | 621.0 | 740.0 | 850.0 | 940.0 | 992.9 |
| 14 | 60.0 | 164.0 | 291.0 | 430.0 | 576.0 | 722.0 | 862.0 | 989.0 | 1084.0 | 1152.0 |
| 15 | 68.0 | 188.0 | 334.0 | 494.0 | 661.0 | 829.0 | 988.0 | 1134.0 | 1253.0 | 1322.0 |

*Note:* U.S. gallons per foot of length.

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## SECTION 13F VELOCITY

**Table 13F.17 Conversion Factors for Velocity**

| | |
|---|---|
| 1 ft/sec | = 0.682 mi/h |
| | = 0.3048 m/sec |
| 1 mi/h | = 1.467 ft/sec |
| | = 0.869 International knots |
| | = 1.609 km/h |
| 1 International knot | = 1.151 mi/h |
| | = 1.852 km/h |
| 1 m/sec | = 3.6 km/h |
| | = 3.28 ft/sec |
| | = 2.237 mi/h |
| | = 1.94 knots |
| 1 km/h | = 0.621 mi/h |
| | = 0.540 International knot |

## SECTION 13G FLOW RATE

**Table 13G.18 Conversion Factors for Flow Rate**

| | |
|---|---|
| 1 gal/min | $= 1.44 \times 10^{-3}$ mgd |
| | $= 2.23 \times 10^{-3}$ cfs |
| | $= 4.42 \times 10^{-3}$ AF/day |
| | = 0.0631 l/sec |
| | $= 6.31 \times 10^{-5}$ $m^3$/sec |
| | = 5.42 $m^3$/day |
| 1 Million gallons per day | = 694 gpm |
| | = 1.55 cfs |
| | = 3.07 AF/day |
| | = 43.7 l/sec |
| | = 0.0437 $m^3$/sec |
| | = 3770 $m^3$/day |
| 1 Cubic foot per second | = 449 gpm |
| | = 0.646 mgd |
| | = 1.98 AF/day |
| | = 28.3 l/sec |
| | = 0.0283 $m^3$/sec |
| | = 2450 $m^3$/day |
| 1 acre-foot per day | = 226 gpm |
| | = 0.326 mgd |
| | = 0.505 cfs |
| | = 14.2 l/sec |
| | = 0.0142 $m^3$/sec |
| | = 1230 $m^3$/day |
| 1 l/sec | = 15.9 gpm |
| | = 0.0228 mgd |
| | = 0.0353 cfs. |
| | = 0.0703 AF/day |
| | = 0.001 $m^3$/sec |
| | = 86.4 $m^3$/day |
| 1 Cubic meter per day second | $= 1.58 \times 10^4$ gpm |
| | = 22.8 mgd |
| | = 35.3 cfs |
| | = 70.0 AF/day |
| | = 1000 l/sec |
| | $= 8.64 \times 10^4$ $m^3$/day |
| 1 Cubic per day | = 0.183 gpm |
| | $= 2.64 \times 10^{-4}$ mgd |
| | = 4.09 x $10^{-4}$ cfs |

*(Continued)*

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**Table 13G.18 (Continued)**

| | |
|---|---|
| | $=8.11\times10^{-4}$ AF/day |
| | $=0.0116$ l/sec |
| | $=1.16\times10^{-5}$ $m^3$/sec |
| 1 Miner's inch | $=0.025$ cubic foot per second (in Arizona, California, Montana, and Oregon) |
| | $=0.02$ cubic foot per second (in Idaho, Kansas, Nebraska, New Mexico, North and South Dakota, and Utah) |
| | $=0.026$ cubic foot per second (in Colorado) |
| | $=0.028$ cubic foot per second (in British Columbia) |

**Table 13G.19 Conversion of Daily Consumptive Use Rates to Equivalent Continuous Flow Rates per Unit Area**

| Consumptive Use of Water by Crop | | Equivalent Continuous Flow Rates | | | |
|---|---|---|---|---|---|
| | | per Hectare | | per Acre | |
| Millimetres per Day | Inches per Day | Litres per Second | Cubic Metres per Day | Cubic Feet per Second | U.S. Gallons per Minute[a] |
| 2 | 0.08 | 0.23 | 20 | 0.0033 | 1.5 |
| 3 | 0.12 | 0.35 | 30 | 0.0050 | 2.2 |
| 4 | 0.16 | 0.46 | 40 | 0.0067 | 3.0 |
| 5 | 0.20 | 0.58 | 50 | 0.0083 | 3.7 |
| 6 | 0.24 | 0.69 | 60 | 0.0100 | 4.5 |
| 7 | 0.28 | 0.81 | 70 | 0.0117 | 5.2 |
| 8 | 0.32 | 0.92 | 80 | 0.0133 | 6.0 |
| 9 | 0.36 | 1.04 | 90 | 0.0150 | 6.7 |
| 10 | 0.40 | 1.15 | 100 | 0.0167 | 7.5 |

[a] To convert to imperial gallons per minute, multiply values by 0.833.

*Source*: From Food and Agriculture Organization of the United Nations, 1974, *Surface Irrigation*. Copyright FAO. Reprinted with permission.

**Table 13G.20 Time Required to Supply One Acre with 1 in. of Water**

| Flow Rate | | Time | |
|---|---|---|---|
| gpm | cfs | Hr | Min |
| 100 | 0.22 | 4 | 32 |
| 150 | 0.33 | 3 | 01 |
| 200 | 0.45 | 2 | 16 |
| 250 | 0.56 | 1 | 48 |
| 300 | 0.67 | 1 | 30 |
| 350 | 0.78 | 1 | 18 |
| 400 | 0.89 | 1 | 08 |
| 450 | 1.00 | 1 | 00 |
| 500 | 1.11 | 0 | 54 |
| 600 | 1.34 | 0 | 46 |
| 700 | 1.56 | 0 | 39 |
| 800 | 1.78 | 0 | 34 |
| 900 | 2.01 | 0 | 30 |
| 1000 | 2.23 | 0 | 27 |
| 1100 | 2.45 | 0 | 24 |
| 1200 | 2.67 | 0 | 22 |
| 1300 | 2.90 | 0 | 21 |
| 1400 | 3.12 | 0 | 20 |
| 1500 | 3.34 | 0 | 18 |

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## SECTION 13H WEIGHT

**Table 13H.21 Conversion Factors for Weight**

| | |
|---|---|
| 1 Grain | $=2.286\times10^{-3}$ oz |
| | $=1.429\times10^{-4}$ lb |
| 1 Ounce | =437.5 gr |
| | =0.0625 lb |
| | =28.35 gm |
| 1 Pound | =7000 gr |
| | =16 oz |
| | =453.6 gm |
| | =0.4536 kg |
| 1 Short ton | =2000 lb |
| | =907.2 kg |
| | =0.9072 m ton |
| 1 Long ton | =2240 lb |
| | =1016.0 kg |
| | =1.016 m ton |
| 1 Metric ton | =2204.6 lb |
| | =1000 kg |
| | =1.102 short ton |
| | =0.9842 long ton |
| 1 g | =15.43 gr |
| | =0.03527 oz |
| | $=2.205\times10^{-3}$ lb |
| | =0.001 kg |
| 1 kilogram | =35.27 oz |
| | =2.205 lb |
| | =1000 gm |
| | =0.001 m ton |

## SECTION 13I PRESSURE

**Table 13I.22 Conversion Factors for Pressure**

| | |
|---|---|
| 1 in. of water at 62°F | $=0.0361$ lb/in.$^2$ |
| | $=5.196$ lb/ft$^2$ |
| | =0.0735 in. of mercury at 62°F |
| 1 ft of water at 62°F | $=0.433$ lb/in.$^2$ |
| | $=62.36$ lb/ft$^2$ |
| | =0.833 in. of mercury at 62°F |
| | $=2.950\times10^{-2}$ atmosphere |
| 1 Atmosphere | $=14.7$ lb/in.$^2$ |
| | $=2116$ lb/ft$^2$ |
| | =33.95 feet of water at 62°F |
| | =29.92 in. of mercury at 32°F |
| | =1013.2 millibars |
| | =760 mm of mercury at 32°F |
| | $=1033$ gm/cm$^2$ |
| | $=1.033$ kg/cm$^2$ |
| 1 Pound per sq in. | =2.309 feet of water at 62°F |
| | =2.036 in. of mercury at 32°F |
| | =0.06804 atmosphere |
| | $=0.07031$ kg/cm$^2$ |
| 1 in. of mercury at 32°F | $=0.4192$ lb/in.$^2$ |
| | =1.133 feet of water at 32°F |
| 1 kg/sq cm | $=14.22$ lb/in.$^2$ |
| 1 Bar | $=1\times10^6$ dynes/cm$^2$ |
| | $=1019.8$ gm/cm$^2$ |
| | =0.9869 atmosphere |
| | $=14.50$ lb/in.$^2$ |
| | =1000 millibars |

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## SECTION 13J PERMEABILITY

**Table 13J.23 Units and Conversion Factors for Permeability**

| | |
|---|---|
| **Permeability Units**[a] | |
| Laboratory (standard) coefficient of permeability | $1K_s = \dfrac{1 \text{ gal. of water at } 60^\circ\text{F/day}}{(1 \text{ ft}^2)(1 \text{ ft/ft})}$ |
| Field coefficient of permeability | $1K_f = \dfrac{1 \text{ gal. of water at field temperature/day}}{(1 \text{ ft} \times 1 \text{ mi})(1 \text{ ft/mi})}$ |
| Specific (intrinsic) permeability | $1 \text{ darcy} = \dfrac{1 \text{ centipoise} \times 1 \text{ cm}^3/\text{sec})/1 \text{ cm}^2}{1 \text{ atmosphere}/1 \text{ cm}}$ |
| **Conversion Factors** | |
| *Permeability* | |
| 1 $K_s$ | $=4.72\times10^{-5}$ cm/sec |
| | $=0.0408$ m/day |
| | $=0.134$ ft/day |
| | $=1.43\times10^{-6}$ ft/sec |
| 1 Darcy | $=0.987\times10^{-8}$ cm$^2$ |
| | $=1.062\times10^{-11}$ ft$^2$ |
| | $=18.2$ $K_s$ for water at 60°F |
| | $=0.966\times10^{-3}$ cm/sec for water at 20°C |
| 1 Millidarcy | $=1.82\times10^{-2}$ $K_s$ for water at 60°F |
| 1 cm/sec | $=1.02\times10^{-5}$ cm$^2$ for water at 20°C |
| 1 m/sec | $=2.12\times10^{6}$ gpd/ft$^2$ |
| 1 m/day | $=24.5$ gpd/ft$^2$ |
| *Transmissivity* | |
| 1 m$^2$/sec | $=6.96\times10^{6}$ gpd/ft |
| 1 m$^2$/day | $=80.5$ gpd/ft |

[a] In groundwater investigations, the water-transmitting capability of an aquifer is commonly expressed in terms of a Coefficient of Transmissivity, which is the product of the Coefficient of Permeability of the aquifer material and the thickness of the aquifer.

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## SECTION 13K POWER

**Table 13K.24 Conversion Factors for Power**

| | |
|---|---|
| 1 hp | = .746 kW or 746 W<br>= 33,000 ft lb/min<br>= 550 ft lb/sec<br>= 8760 hp-h/yr<br>= 6535 kWh/yr |
| H.P. Input | = Horsepower input to motor<br>= 1.34 × kilowatts input to motor |
| Water H.P. | = H.P. required to lift water at a definite rate to a given distance assuming 100% efficiency<br>$= \frac{\text{G.P.M.} \times \text{total head (in. ft)}}{3960}$ |
| Brake H.P. | = H.P. delivered by motor<br>= H.P. required by pump<br>= H.P. input motor × efficiency<br>= 1.34 × KW input × motor efficiency<br>$= \frac{\text{Water H.P.}}{\text{pump efficiency}}$<br>$= \frac{\text{G.P.M.} \times \text{total head(ft)}}{3960 \times \text{pump efficiency}}$<br>$= \frac{\text{G.P.H.} \times \text{total head(lb/sq in.)}}{103,000 \times \text{pump efficiency}}$ |
| 1 kilowatt | = 1.3405 Horsepower<br>= 8760 kWh/yr |
| Efficiency | $= \frac{\text{Power output}}{\text{Power input}}$ |
| Motor Efficiency | $= \frac{\text{H.P. output}}{\text{KW input} \times 1.34}$ |
| Pump Efficiency | $= \frac{\text{G.P.M.} \times \text{total head(ft)}}{3960 \times \text{B.H.P}}$ |
| Plant Efficiency | $= \frac{\text{G.P.M.} \times \text{total head(ft)}}{5300 \times \text{KW input}}$ |

**Table 13K.25 Horsepower Required to Pump Water**

| Gallons per Minute | Cubic Feet per Second | Horsepower Required for Elevations of | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 10 ft | 20 ft | 30 ft | 40 ft | 50 ft | 60 ft | 70 ft | 80 ft |
| 100 | 0.22 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 |
| 150 | 0.33 | 0.8 | 1.5 | 2.3 | 3.0 | 3.8 | 4.6 | 5.3 | 6.1 |
| 200 | 0.45 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.1 | 7.1 | 8.1 |
| 250 | 0.56 | 1.3 | 2.5 | 3.8 | 5.0 | 6.3 | 7.6 | 8.8 | 10.1 |
| 300 | 0.67 | 1.5 | 3.0 | 4.6 | 6.1 | 7.6 | 9.1 | 10.6 | 12.1 |
| 350 | 0.78 | 1.8 | 3.5 | 5.3 | 7.1 | 8.8 | 10.6 | 12.4 | 14.1 |
| 400 | 0.89 | 2.0 | 4.0 | 6.1 | 8.1 | 10.1 | 12.1 | 14.1 | 16.2 |
| 450 | 1.00 | 2.3 | 4.6 | 6.8 | 9.1 | 11.4 | 13.6 | 15.9 | 18.2 |
| 500 | 1.11 | 2.5 | 5.0 | 6.7 | 10.1 | 12.6 | 15.2 | 17.7 | 20.2 |
| 600 | 1.34 | 3.0 | 6.1 | 9.1 | 12.1 | 15.2 | 18.2 | 21.2 | 24.2 |
| 700 | 1.56 | 3.5 | 7.1 | 10.6 | 14.1 | 17.7 | 21.2 | 24.8 | 28.3 |
| 800 | 1.78 | 4.0 | 8.1 | 12.1 | 16.2 | 20.2 | 24.2 | 28.3 | 32.3 |
| 900 | 2.01 | 4.6 | 9.1 | 13.6 | 18.2 | 22.7 | 27.3 | 31.8 | 36.4 |
| 1000 | 2.23 | 5.0 | 10.1 | 15.2 | 20.2 | 25.2 | 30.3 | 35.4 | 40.4 |
| 1250 | 2.78 | 6.3 | 12.6 | 18.9 | 25.2 | 31.6 | 37.9 | 44.2 | 50.5 |
| 1500 | 3.34 | 7.6 | 15.2 | 22.7 | 30.3 | 37.9 | 45.4 | 53.0 | 60.6 |

*Note:* Efficiency of pumping plant 50 percent of theoretical. Use for estimating only.

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**Table 13K.26 Theoretical Power of American Multiblade Windmills of Different Diameters for Several Wind Velocities**

| Wind Velocity (mi/h) | Horsepower[a] from Wheel Diameter (in feet) of | | | | | | |
|---|---|---|---|---|---|---|---|
| | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 6 | | | | 0.05 | 0.06 | 0.08 | 0.09 |
| 8 | | 0.05 | 0.07 | 0.10 | 0.14 | 0.18 | 0.23 |
| 10 | 0.05 | 0.09 | 0.14 | 0.21 | 0.28 | 0.36 | 0.46 |
| 12 | 0.09 | 0.15 | 0.24 | 0.36 | 0.49 | 0.63 | 0.81 |
| 15 | 0.18 | 0.31 | 0.48 | 0.68 | 0.94 | 1.21 | 1.55 |
| 20 | 0.40 | 0.72 | 1.12 | 1.62 | 2.20 | 2.88 | 3.65 |
| 25 | 0.79 | 1.41 | 2.21 | 3.20 | 4.34 | 5.67 | 7.20 |

[a] Horsepower $= CD^2\ V^3$. Where $C$, the power coefficient for American multiblade type wheel $= 0.45 \times 10^{-6}$, when the tip speed is approximately the same as the velocity of the wind; $D$ = diameter of the wheel in feet; and $V$ = indicated velocity of the wind in feet per second (Robinson anemometer).

*Source*: From U.S. Dept. of Agriculture.

## SECTION 13L TEMPERATURE

**Table 13L.27 Conversion Factors for Temperature, Temperature Conversion Fahrenheit ↔ Centigrade**

| °F to °C (Range 0–279°F) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| °F | °C | °F | °C | °F | °C | °F | °C | °F | °C |
| 0 | −17.78 | 56 | 13.33 | 112 | 44.44 | 168 | 75.56 | 224 | 106.67 |
| 1 | −17.22 | 57 | 13.89 | 113 | 45.00 | 169 | 76.11 | 225 | 107.22 |
| 2 | −16.67 | 58 | 14.44 | 114 | 45.56 | 170 | 76.67 | 226 | 107.78 |
| 3 | −16.11 | 59 | 15.00 | 115 | 46.11 | 171 | 77.22 | 227 | 108.33 |
| 4 | −15.56 | 60 | 15.56 | 116 | 46.67 | 172 | 77.78 | 228 | 108.89 |
| 5 | −15.00 | 61 | 16.11 | 117 | 47.22 | 173 | 78.33 | 229 | 109.44 |
| 6 | −14.44 | 62 | 16.67 | 118 | 47.78 | 174 | 78.89 | 230 | 110.00 |
| 7 | −13.89 | 63 | 17.22 | 119 | 48.33 | 175 | 79.44 | 231 | 110.56 |
| 8 | −13.33 | 64 | 17.78 | 120 | 48.89 | 176 | 80.00 | 232 | 111.11 |
| 9 | −12.78 | 65 | 18.33 | 121 | 49.44 | 177 | 80.56 | 233 | 111.67 |
| 10 | −12.22 | 66 | 18.89 | 122 | 50.00 | 178 | 81.11 | 234 | 112.22 |
| 11 | −11.67 | 67 | 19.44 | 123 | 50.56 | 179 | 81.67 | 235 | 112.78 |
| 12 | −11.11 | 68 | 20.00 | 124 | 51.11 | 180 | 82.22 | 236 | 113.33 |
| 13 | −10.56 | 69 | 20.56 | 125 | 51.67 | 181 | 82.78 | 237 | 113.89 |
| 14 | −10.00 | 70 | 21.11 | 126 | 52.22 | 182 | 83.33 | 238 | 114.44 |
| 15 | −9.44 | 71 | 21.67 | 127 | 52.78 | 183 | 83.89 | 239 | 115.00 |
| 16 | −8.89 | 72 | 22.22 | 128 | 53.33 | 184 | 84.44 | 240 | 115.56 |
| 17 | −8.33 | 73 | 22.78 | 129 | 53.89 | 185 | 85.00 | 241 | 116.11 |
| 18 | −7.78 | 74 | 23.33 | 130 | 54.44 | 186 | 85.56 | 242 | 116.67 |
| 19 | −7.22 | 75 | 23.89 | 131 | 55.00 | 187 | 86.11 | 243 | 117.22 |
| 20 | −6.67 | 76 | 24.44 | 132 | 55.56 | 188 | 86.67 | 244 | 117.78 |
| 21 | −6.11 | 77 | 25.00 | 133 | 56.11 | 189 | 87.22 | 245 | 118.33 |
| 22 | −5.56 | 78 | 25.56 | 134 | 56.67 | 190 | 87.78 | 246 | 118.89 |
| 23 | −5.00 | 79 | 26.11 | 135 | 57.22 | 191 | 88.33 | 247 | 119.44 |
| 24 | −4.44 | 80 | 26.67 | 136 | 57.78 | 192 | 88.89 | 248 | 120.00 |
| 25 | −3.89 | 81 | 27.22 | 137 | 58.33 | 193 | 89.44 | 249 | 120.56 |
| 26 | −3.33 | 82 | 27.78 | 138 | 58.89 | 194 | 90.00 | 250 | 121.11 |
| 27 | −2.78 | 83 | 28.33 | 139 | 59.44 | 195 | 90.56 | 251 | 121.67 |
| 28 | −2.22 | 84 | 28.89 | 140 | 60.00 | 196 | 91.11 | 252 | 122.22 |
| 29 | −1.67 | 85 | 29.44 | 141 | 60.56 | 197 | 91.67 | 253 | 122.78 |
| 30 | −1.11 | 86 | 30.00 | 142 | 61.11 | 198 | 92.22 | 254 | 123.33 |
| 31 | −0.56 | 87 | 30.56 | 143 | 61.67 | 199 | 92.78 | 255 | 123.89 |
| 32 | 0.00 | 88 | 31.11 | 144 | 62.22 | 200 | 93.33 | 256 | 124.44 |
| 33 | 0.56 | 89 | 31.67 | 145 | 62.78 | 201 | 93.89 | 257 | 125.00 |

*(Continued)*

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**Table 13L.27 (Continued)**

**°F to °C (Range 0–279°F)**

| °F | °C | °F | °C | °F | °C | °F | °C | °F | °C |
|---|---|---|---|---|---|---|---|---|---|
| 34 | 1.11 | 90 | 32.22 | 146 | 63.33 | 202 | 94.44 | 258 | 125.56 |
| 35 | 1.67 | 91 | 32.78 | 147 | 63.89 | 203 | 95.00 | 259 | 126.11 |
| 36 | 2.22 | 92 | 33.33 | 148 | 64.44 | 204 | 95.56 | 260 | 126.67 |
| 37 | 2.78 | 93 | 33.89 | 149 | 65.00 | 205 | 96.11 | 261 | 127.22 |
| 38 | 3.33 | 94 | 34.44 | 150 | 65.56 | 206 | 96.67 | 262 | 127.78 |
| 39 | 3.89 | 95 | 35.00 | 151 | 66.11 | 207 | 97.22 | 263 | 128.33 |
| 40 | 4.44 | 96 | 35.56 | 152 | 66.67 | 208 | 97.78 | 264 | 128.89 |
| 41 | 5.00 | 97 | 36.11 | 153 | 67.22 | 209 | 98.33 | 265 | 129.44 |
| 42 | 5.56 | 98 | 36.67 | 154 | 67.78 | 210 | 98.89 | 266 | 130.00 |
| 43 | 6.11 | 99 | 37.22 | 155 | 68.33 | 211 | 99.44 | 267 | 130.56 |
| 44 | 6.67 | 100 | 37.78 | 156 | 68.89 | 212 | 100.00 | 268 | 131.11 |
| 45 | 7.22 | 101 | 38.33 | 157 | 69.44 | 213 | 100.56 | 269 | 131.67 |
| 46 | 7.78 | 102 | 38.89 | 158 | 70.00 | 214 | 101.11 | 270 | 132.22 |
| 47 | 8.33 | 103 | 39.44 | 159 | 70.56 | 215 | 101.67 | 271 | 132.78 |
| 48 | 8.89 | 104 | 40.00 | 160 | 71.11 | 216 | 102.22 | 272 | 133.33 |
| 49 | 9.44 | 105 | 40.56 | 161 | 71.67 | 217 | 102.78 | 273 | 133.89 |
| 50 | 10.00 | 106 | 41.11 | 162 | 72.22 | 218 | 103.33 | 274 | 134.44 |
| 51 | 10.56 | 107 | 41.67 | 163 | 72.78 | 219 | 103.89 | 275 | 135.00 |
| 52 | 11.11 | 108 | 42.22 | 164 | 73.33 | 220 | 104.44 | 276 | 135.56 |
| 53 | 11.67 | 109 | 42.78 | 165 | 73.89 | 221 | 105.00 | 277 | 136.11 |
| 54 | 12.22 | 110 | 43.33 | 166 | 74.44 | 222 | 105.56 | 278 | 136.67 |
| 55 | 12.78 | 111 | 43.89 | 167 | 75.00 | 223 | 106.11 | 279 | 137.22 |

**°F to °C (Range 280–300°F)**

| °F | °C |
|---|---|
| 280 | 137.78 |
| 281 | 138.33 |
| 282 | 138.89 |
| 283 | 139.44 |
| 284 | 140.00 |
| 285 | 140.56 |
| 286 | 141.11 |
| 287 | 141.67 |
| 288 | 142.22 |
| 289 | 142.78 |
| 290 | 143.33 |
| 291 | 143.89 |
| 292 | 144.44 |
| 293 | 145.00 |
| 294 | 145.56 |
| 295 | 146.11 |
| 296 | 146.67 |
| 297 | 147.22 |
| 298 | 147.78 |
| 299 | 148.33 |
| 300 | 148.89 |

**°C to °F (Range 0–150°C)**

| °C | °F | °C | °F | °C | °F | °C | °F |
|---|---|---|---|---|---|---|---|
| 0 | 32.0 | 21 | 69.8 | 56 | 132.8 | 112 | 233.6 |
| 1 | 33.8 | 22 | 71.6 | 57 | 134.6 | 113 | 235.4 |
| 2 | 35.6 | 23 | 73.4 | 58 | 136.4 | 114 | 237.2 |
| 3 | 37.4 | 24 | 75.2 | 59 | 138.2 | 115 | 239.0 |
| 4 | 39.2 | 25 | 77.0 | 60 | 140.0 | 116 | 240.8 |
| 5 | 41.0 | 26 | 78.8 | 61 | 141.8 | 117 | 242.6 |
| 6 | 42.8 | 27 | 80.6 | 62 | 143.6 | 118 | 244.4 |
| 7 | 44.6 | 28 | 82.4 | 63 | 145.4 | 119 | 246.2 |
| 8 | 46.4 | 29 | 84.2 | 64 | 147.2 | 120 | 248.0 |
| 9 | 48.2 | 30 | 86.0 | 65 | 149.0 | 121 | 249.8 |
| 10 | 50.0 | 31 | 87.8 | 66 | 150.8 | 122 | 251.6 |
| 11 | 51.8 | 32 | 89.6 | 67 | 152.6 | 123 | 253.4 |
| 12 | 53.6 | | | 68 | 154.4 | 124 | 255.2 |
| 13 | 55.4 | | | 69 | 156.2 | 125 | 257.0 |
| 14 | 57.2 | | | 70 | 158.0 | 126 | 258.8 |
| 15 | 59.0 | | | 71 | 159.8 | 127 | 260.6 |
| 16 | 60.8 | | | 72 | 161.6 | 128 | 262.4 |
| 17 | 62.6 | | | 73 | 163.4 | 129 | 264.2 |
| 18 | 64.4 | | | 74 | 165.2 | 130 | 266.0 |
| 19 | 66.2 | | | 75 | 167.0 | 131 | 267.8 |
| 20 | 68.0 | | | 76 | 168.8 | 132 | 269.6 |

*(Continued)*

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**Table 13L.27 (Continued)**

| °C to °F (Range 0–150°C) | | | | | |
|---|---|---|---|---|---|
| **°C** | **°F** | **°C** | **°F** | **°C** | **°F** |
| 33 | 91.4 | 89 | 192.2 | 145 | 293.0 |
| 34 | 93.2 | 90 | 194.0 | 146 | 294.8 |
| 35 | 95.0 | 91 | 195.8 | 147 | 296.6 |
| 36 | 96.8 | 92 | 197.6 | 148 | 298.4 |
| 37 | 98.6 | 93 | 199.4 | 149 | 300.2 |
| 38 | 100.4 | 94 | 201.2 | 150 | 302.0 |
| 39 | 102.2 | 95 | 203.0 | | |
| 40 | 104.0 | 96 | 204.8 | | |
| 41 | 105.8 | 97 | 206.6 | | |
| 42 | 107.6 | 98 | 208.4 | | |
| 43 | 109.4 | 99 | 210.2 | | |
| 44 | 112.2 | 100 | 212.0 | | |
| 45 | 113.0 | 101 | 213.8 | | |
| 46 | 114.8 | 102 | 215.6 | | |
| 47 | 116.6 | 103 | 217.4 | | |
| 48 | 118.4 | 104 | 219.2 | | |
| 49 | 120.2 | 105 | 221.0 | | |
| 50 | 122.0 | 106 | 222.8 | | |
| 51 | 123.8 | 107 | 224.6 | | |
| 52 | 125.6 | 108 | 226.4 | | |
| 53 | 127.4 | 109 | 228.2 | | |
| 54 | 129.2 | 110 | 230.0 | | |
| 55 | 131.0 | 111 | 231.8 | | |

*Note:* Temperature Conversions: °F = 9/5 (°C) + 32; °C = 5/9 (°F − 32).

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