Pond Design Section

Koi Health Advisor Course

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Introduction

Almost every system is different and thus this information needs to be considered in the context of the system to which it is being applied.

The information in this section will hopefully be useful in planning ponds but it is primarily offered here to help solve problems with existing pond systems and is written from that perspecitive.

When you arrive at a troubled koi pond, your first mission as a KHA will be that of a detective. You must try to determine if the koi health problem is environmental or pathogenic or a combination of both.

This section will give you some tools to assist in determining if the problem is environmental (related to poor or improper pond design). Some environmental issues will be obvious, e.g., 200 koi in a 500 gallon pond or a 55 gallon barrel bioconverter with a 500 gallon per hour submersible pump the only filtration/bioconversion/aeration on a 10,000 gal. koi pond with a moderate stocking rate. These two obvious examples of environmental problems are not what you will normally face.

You may need to ask the owner many questions about the pond, filtration, plumbing, pumps, etc., then investigate, assess, evaluate and then make some decisions whether any part of the pond environment is the culprit, is a contributor or is a non-factor. In this section we will give you some basic guidelines that will assist you in determining if there are environmental issues affecting the health of the koi.

Remember that stressors on the koi from their environment affect their health just as stress on humans has similar consequences. Also keep in mind that the koi owner is under stress because his/her koi are not ‘right’ when you ask your questions. Remembering this should help you to present your questions in such a way that they don’t add to the stress of the koi owner. The following is a list of necessary questions. Again, please remember you are on a fact finding mission not an inquisition!

1. What is the total volume of the water in the pond, pre-filter, bioconverter, and plumbing, i.e., in the system?
2. How many bioconverters, type, and size?
3. Pumps, their location, flow rates?
4. Plumbing, drains, jets, venturis, skimmers?
5. Depth of pond?
6. Are all pumps running 24 hours a day?

7. Regular maintenance:
   a: how often are the bioconverters cleaned and how are they cleaned?
   b. what is the frequency of other regular maintenance, e.g., pre-filter, leaf traps, UV light bulb replacement?
8. Any recent maintenance, remodeling or other changes to the pond or system?
9. Regular water changes, how often and how much?
10. Any water treatments recently?
11. Salt in pond? If so, how much and when?
12. Parasite, bacterial or fungal water treatments in last 30-60 days?
13. Have there been any recent gardening applications of fertilizers, insecticides, etc. done by the pond owner or the neighbors such as sprays on bushes, trees or ground applications?
14. What has the owner observed his/her koi doing that is different and unusual from their normal behavior?

Don't be shocked or amazed by the answers supplied by the pond owner to your questions. Remember this house call is intended to be educational and instructional for the pond owner, not punitive or embarrassing. The answers will run the gamut from, "I don't know." to some very accurate answers. You will have to sift through these answers and quite frequently do your own investigation and calculations to get the correct information.

One of the first things to look for is a change that might result in a cause and effect situation, i.e., if the owner has recently made a change to the system, this could be what caused the deleterious effect.

Question one may be any of the aforementioned answers. So you may have to do your own calculations to determine the volume of the pond system. If the pond were a perfect rectangular box with a flat bottom, vertical sides and no slope to the bottom and no rounded corners, etc., the equation for water volume is: length times width times depth (all in feet) times 7.48 equals the total volume in gallons. For circular ponds, the volume in gallons equals the radius times the radius times the depth (again, all in feet) times 3.142 times 7.48. But alas no pond, or very few, happens to fit these criteria. So what do we do, punt? No, you will have to make some assumptions based on measurements you take. For instance in a square or rectangular pond, if the pond bottom goes from 2 feet deep to 4 feet deep at the other end, you would take an 'average' of 3 feet deep. The same must be considered if the walls are sloped and not vertical. If the pond water surface is 10 feet wide and the bottom width is 8 feet, you should use the 'average' of 9 feet wide. The same would apply for the length. Now for irregular shapes, you will have to again use averages. And, for really irregular shapes, you may have to break down the pond into several smaller sections to get the calculations you need.

Also and in general, larger volumes of water tend to remain more stable than smaller volumes. So in general, the bigger the pond, the more stable it's likely to be.

Question two is mainly to assist you in determining the turnover rate of the pond and later, when you know the plumbing system and pump capacity, you will be in a better position to make recommendations to the owner for any modifications to the pond system to improve the koi's environment. Most all filters have certain limitations whether they are bioconverters, mechanical filters or chemical filters. The section on filtration will discuss in detail their performance criteria both pro and con in detail. This section only addresses them as one part of the pond system and how it relates to the entire environment.

Questions three and four are extremely important and work in conjunction with each other and are the major factors in determining the efficiency and limitations of the pond system. For assessment of the plumbing, please see a quick reference guide to pipe sizing, length of pipe runs and head losses due to friction at the end of this section.

For pump limitations, see Part 11 of this section.

Now back to question three. If it is a small pond, it may have a submersible pump. These pumps normally have flow rates of 200 to 1200 gallons per hour and might be sufficient for a pond of less than 1000 gallons but would be too small for larger ponds. Question 14 could correlate very well with the use of a submersible pump as submersibles are notorious for developing electrical shorts. Depending on the owner's answer to question 14 you may have solved an environmental problem as the koi may be being electrocuted! It may be a minor electrical short and it is making the koi act skittish and avoiding an area near the pump or some may have crooked backs due to a fairly severe electrical shock.

You need to know the pump's capacity to determine if it is large enough to deliver the proper volume of water to the bioconverters so that a sufficient volume of water is being processed each hour to sufficiently reduce ammonia and nitrite which are stressors to the koi and can lead to their demise. As not all pumps deliver the flow claimed by the manufacturer, you can determine a pump's actual output by measuring the time it takes to fill a container of known volume and then divide the volume by the fill time (Don't forget to pay attention to the units, e.g., gallons per hour, cubic feet per second, or what ever you like.).

Understanding the difference between a low head, high volume pump designed for koi ponds and a high head, lower volume pump designed for swimming pools and spas is helpful. A low head, high volume pump usually delivers between 40 to 90 gallons per minute depending on the motor size (1/8, 1/6, ¼ HP), has certain limitations in that the pressure developed is lower (i.e., 4 to 8 psi.) and can not lift water as high or push water as far through pipes but generally delivers more water for less energy consumption. Whereas a high head, lower volume pump (swimming pool type) delivers less water but under a higher pressure (i.e., 14 – 30 psi.) and can lift water higher and push it further in a pipe. Additionally a swimming pool pump can use less efficient plumbing. More information on these two basically different pumps is given in Part 11.

There normally is an easy way to distinguish the difference – a swimming pool pump has an open faced impeller that must be adjusted to the front surface of the pump housing so you will find adjustment set screws on the shaft connecting the motor to the pump impeller. A low head koi pond pump has a fluted impeller that has no adjustment requirements thus no adjustment set screws on the impeller shaft.

How far the pump is from its intake water source effects its efficiency, a pump pushes water better than it pulls water. A pump located below water level insures it will not loose prime. Prime can be lost by a power outage or an air leak on the intake side of the pump on pumps that are located above the water surface. Normally swimming pool pumps are self priming so this doesn't create a big problem but koi pond pumps are not self priming thus the need to locate them below water level or install one way flapper valve (low loss check valve) to eliminate loss of prime. For a detailed description of prime, see Part 11 of this section.

Question four ties into pumps and their proper selection based on the plumbing restrictions. Pipe size and distances play a major role in whether a pump will be working at its maximum efficiency or at less than optimum. The quick reference chart (Figure 30) at the end of this section will show the limitations on flow rates through gravity flow versus pressure flows in the same size pipes. These flow rates coupled with the pump flow rates will show you when a 4" drain pipe is needed instead of a 3" pipe for gravity flow, yet a 2" pipe that is a pressure pipe (meaning connected to the intake or exhaust of the pump) will deliver a similar volume of water. The advantages and disadvantages are discussed in detail in Parts 4 and 11 of this section.

How drains are plumbed and sized will tell you if they are adequate to insure that detritus is continually eliminated from the pond bottom. If they are inadequate, mulm can build up (detritus, parasites, anaerobic bacteria, etc.) and can lead to a build up of hydrogen sulfide (a gas that is lethal to koi). Jets and venturis create currents that can eliminate stagnant water and low oxygen regions that are both stressors and need to be addressed. Skimmers and their placement are also important. They should be placed downwind relative to the prevailing wind and/or farthest away from the current created by jets or waterfalls so they will work effectively to remove debris from the pond's surface.

Question five is important for a couple of reasons: first, for a given volume, a deeper pond will have less temperature fluctuations, eliminating one more stressor. Second, a deeper pond provides the fish a greater sense of security or safety, another stressor removed.

Question six may seem like a silly question but you might be surprised at the answer. Owners sometimes shut off the pump at night as the waterfall is too noisy, or because they want to reduce the electricity bill! It's also not uncommon to see folks shut their bioconverters down for the winter for the same reasons. This question shouldn't be overlooked.

Question seven could be a clue to whether the bioconverters are functioning properly or not. A recently cleaned bioconverter using tap water and not pond water could have killed most or all of the nitrifying bacteria due to the chlorine or chloramines in tap water. So in effect it is a new bioconverter going through the "start-up" phase of ammonia and nitrite conversion.

Filters that have not been cleaned for a long time could be channeling and have lost their efficiency. Parts of the filter could have gone anaerobic and as a result of less efficiency, there could be a build up of ammonia and/or nitrites so you might have additional stressors created by improper or lack of maintenance. Also, a heavy build up of debris in the filters, is a haven for some parasites like Trichodina.

A quick look at the pond bottom will tell you if there is a detritus or mulm build up. The stressor consequences of such a build up were previously discussed in the discussion of question four.

Green water could be the result of the bioconverters not functioning properly or inadequate bioconverter size or too slow a turn over rate or … haven't replaced the UV bulb in 3 years! (This needs to be done annually or when you notice the water becoming tinged with yellow-green.)

Question eight could have many answers to the extreme, e.g., "I removed all plants, koi, etc. and pressure washed the entire pond and then put everything back in." They may have forgot to use AmQuel^{tm} or some other water treatment product with the new pond water! Major stressor!

Remodeling may be minor or major, e.g., adding a few rocks to the border or building a new waterfall. Some rocks, bricks or other masonry may leach toxins when coming in contact with the pond water.

Question nine may evoke the answer, "What water change?" which will be a clue to the water quality and another potential stressor. A recent large water change 30% - 75% with no water treatment added could be another stressor. The answer, whatever it is, will be a very good indicator as to the knowledge and care given to the koi by their owner. Again remember this is to be educational and instructive not punitive or embarrassing for the owner.

Question 10 refers to not just AmQuel^{tm} or salt but also any water treatment for parasites, bacteria, etc. It means anything that is added to the pond water.

Question 11 is important because when there is salt in the water, there may be adverse reactions that could be toxic or deadly to the koi when another treatment is added to the pond. If the owner has added salt but not changed any of the water since, it will be easy to calculate the percentage of salt content. But the safest way is to use a salt meter or salinity test and learn the salt content exactly.

Certain water treatments may be contraindicated when salt is present in the pond water as previously mentioned so knowing content is very important before determining a treatment protocol. The use of formalin has long been suspected of having an adverse effect when salt is present. Some people routinely use formalin with salt present and report no problems. Some report otherwise. Caution is indicated.

Not to beat a dead horse, question 12 is a repeat of questions 10 and 11 but is important, although redundant, and could also be a clue to the effectiveness of the bioconverters as well as explain some unusual behavior of the koi.

Question 13 is a continuation of your detective work and may entail some observations of the pond itself to determine if ground water (with contaminants) could have gotten into the system. You will need to look around the edges of the pond to determine if there are any areas low enough to allow ground water to enter the pond. Almost any gardening treatment could be toxic to koi or at the least, a serious stressor.

Question 14 answers will go a long way in providing you clues if the owner has been observant and can describe their unusual behavior as well as their normal behavior.

Now that you have all the questions answered it is now time for some observations of the pond system. There are several things you should look for, as they are common problems in many ponds.

Roof overhangs, if it has rained recently affect the pH and alkalinity but also bring in contaminants, all stressors. This must be connected with rain gutters to divert the roof runoff.

Aeration can be extremely important as the fish are lethargic with low oxygen levels and the bioconverters will not perform efficiently either. A long cascading waterfall creates much more oxygen than a high, single drop waterfall. Venturis create a good air mix with the pond water as well as adding currents. A skimmer actually improves the oxygen to the bioconverters because surface water is higher in oxygen O_2 content than deeper or bottom water entering the bottom drains. Jets assist in creating currents but also in moving surface water, thus increasing the oxygen content. Many ponds would benefit from just adding some air stones either in the pond (adds currents too) or in the pre-filters or bioconverter.

Trees and other flora that are close enough to the pond will add to the detritus and mulm 'load' on the pond system. Additionally, tree roots can break ponds, even concrete ponds.

Is the lip of edge of the pond elevated at least 4 to 6 inches above the ground? Does the ground slope down and away from the pond or is the ground sloped toward the pond? Ground water entering the pond is a very detrimental thing.

The shape of the pond can be a detriment to a quality environment for our koi. If the pond shape has too many nooks and crannies, there will be poor water circulation and 'dead' water, or stagnant areas. Some of these problems can be eliminated by adding jets or air stones in the dead areas.

Sharp inside corners between walls and/or bottoms will create 'dead' areas and peninsulas can also cut off currents.

Bottom drain placement can create a self-cleaning bottom or a nightmare of high maintenance. See Part 4 of this section regarding proper placement of bottom drains.

Sloping walls versus vertical walls - Sloping walls allow for easier access of predators, and build up of detritus. Sloping walls are also like a launching ramp for koi to guide them in jumping out of the pond!

No pre-filter or sump means that all the detritus from the pond is going directly into the pump, which acts like a blender to grind it all up and deliver this milkshake to the bioconverters. This, in turn, means the bioconverters must work harder, clog quicker and need more frequent cleaning.

Rocks and other sharp objects in the pond or overhanging the pond water are an accident waiting to happen.

Pump placement will affect the efficiency of the pump. It should be as close to the pond or pre-filter as possible. The distance and height the bioconverters are from the pump also affects its efficiency. The type of bioconverter, open or pressurized, is another efficiency factor. The size of the plumbing and the length of the pipes affect the pump's efficiency as well. See Parts 4, 10 and 11 for more details.

Shade and a 'safe zone' are important as koi can get sunburned in a shallow pond with no shade and clear water. Additionally, predators (i.e., herons, egret, fish hawks, etc.) will be attracted while they fly overhead if they can see the pond. The 'safe zone' is preferably a deep area of the pond that the koi can go to get away from danger, perceived or real. Without this zone, stress!

Foam around the waterfall or skimmers means dissolved organic carbons, or DOCs for short, are likely present. This would indicate an inadequate functioning or a malfunctioning of the bioconverter, inadequate filtration, too heavy a fish load, or a combination of any or all of these.

Electrical circuits can be a 'can of worms' with extension cords all over the place, no watertight electrical receptacles and most important …no GFCI (ground fault circuit interrupter). A GFCI is made to sense electrical currents in a circuit and to trip the circuit breaker within milliseconds of any abnormality beyond a preset threshold. This is an important necessity any time electricity is around water and can save koi, other pets and humans! It virtually eliminates electrocutions! Additionally, all electrical work should be protected from the elements.

1. Location

The location of a pond can be either a plus or a minus. Things that can have a negative impact on water quality, which is the bane of koi hobbyists, are many times overlooked when determining the location of a pond.

Shade & sun - A pond in full sun will require greater filtration to maintain clear water. Hair or string algae and pea soup water are both unsightly and can have some deleterious effects on the pond system's function by leading to water quality problems. If you can't see your koi (less enjoyment), you can't determine their health. A pond and the koi needs some shade, either manmade or natural (trees, water plants, etc.)

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Trees - Although they create shade, they drop leaves that if not removed regularly will affect water quality adversely. Their roots can damage a pond, even cement, thus creating leaks. Over-hangs from buildings can dump rainwater that is normally acidic into ponds with the added problem of also dumping anything else that has settled on the roof before the rained. All of this leads to dramatic water quality changes and is bad for koi. A 20 to 30 percent water change after rain will help to dilute this sudden deterioration in water quality but a long-term solution must be done to alleviate this problem. It may be as simple as putting up rain gutters and redirecting the roof's rainwater runoff.

A pond located in a valley or gully, or even just up against a house or fence can be extremely dangerous to the koi. If ground water runoff (from rains or just sprinklers) can get trapped next to the pond as the water increases it may raise high enough to over flow into the pond, taking any garden treatments (insecticides, fertilizers, etc.) into the pond and creating many times not only a water quality deterioration but a poisoning of the pond water! This may not be as easy to fix as the rain-gutters. It may entail creating a higher 'lip' to the pond and/or installing drains to eliminate the flow of ground water into the pond.

Part 2. Pond Shapes

The shape of a pond perimeter, the walls and the floor all can be a positive or a negative. Figures1, 2 and 3 for pond shapes are all positives. Figures 4, 5 and 6 are all negatives. The plus or minus attributed to a pond shape are based on water movement (i.e., good circulation with no stagnant areas). The problems created in Figures 4, 5 and 6 can be somewhat alleviated by the proper placement of jets, venturis or bottom drains which will be discussed in more detail in Part 3. For now a jet, venturi or bottom drain strategically placed can eliminate 'dead water.' Waterfall placement can also enhance water circulation.

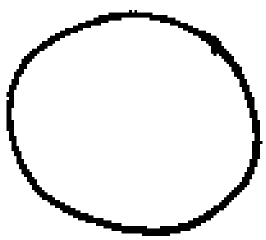


Figure 1

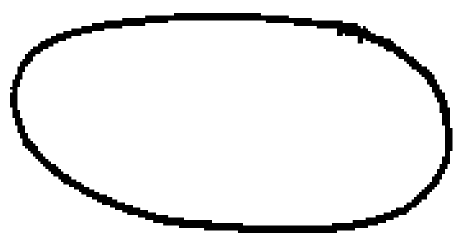


Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

The shaded areas in Figures 4 - 6 show probable dead water areas whereas Figures 1-3 have no discernible ‘dead water’ areas. One or more jets, venturis, bottom drains or a waterfall placed in the shaded areas could relieve these problems. You must remember that whenever moving water strikes an impediment (a wall, peninsula, etc.) it must change direction as water doesn’t compress as gas does so eddies are formed with the resultant still water next to the eddies. This is a formula for deteriorating water quality.

Pond walls should be almost vertical with a maximum outward slope of 10E to 15E. A greater slope creates a ‘launching ramp’ for a spooked koi to jump out of the pond or an inviting entry for predators (i.e., herons, cranes, raccoons, etc.). Both are things we want to avoid. See Figure 7. On the positive side, sloping walls near the top of the water can be a potential benefit in very cold climates where the pond surface can freeze in winter and if the ice slides up the wall as it expands, it may keep the pond from cracking.

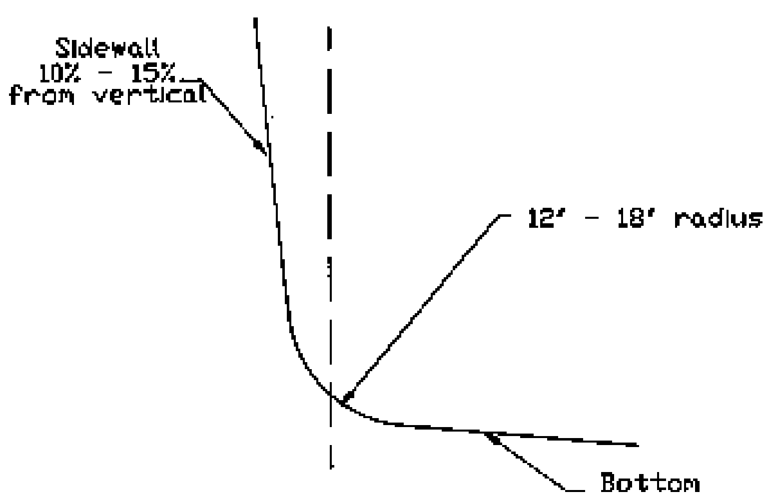


Figure 7

Bottom contours and shapes are many times overlooked or at best given minimal consideration. Ideally anything that sinks to the bottom of the pond will be picked up in the bottom drains and transported to our pre-filter (hopefully we have one). A bottom drain will be working continuously so if they are placed properly in a properly sloped bottom, the pond will be self-cleaning and eliminate the need to vacuum the pond. A rule of thumb is that a bottom drain will pick up detritus from a 4 to 6 foot radius if there is a slope of at least one inch per lineal foot towards the drain. A 2 inch or 3 inch per foot slope is even better as it will remove the detritus even quicker. Where the walls join the floor, a 12" to 18" radius curve will help detritus move toward the bottom drains. See Figure 7.

The layout for the bottom drains will be discussed in detail in Part 3.

Where waterfalls, jets, venturis, water returns, skimmers and streams are located will greatly effect the water circulation in a pond. In essence, you are trying to create a ‘toilet bowl effect’ in your pond with no ‘dead water’ areas. If waterfalls and jets are placed in opposing directions they destroy this ‘toilet bowl effect.’ All sources of water movement should be in harmony to enhance this effect. Ideally the waterfall or stream should be facing downwind and the skimmer should be at the most downwind position to the prevailing winds to assist in removal of surface detritus (leaves, etc.). None of these are absolute necessities but should be considered as they all help to create a minimal maintenance koi pond that doesn’t have to overcome many impediments to good water quality and happy koi.

The lip of the pond was briefly mentioned in Part 1 for good reason. It should ideally be a minimum of 6" above grade and can be accomplished by use of rocks (if mortared between them to preclude ground water from entering the pond) or a raised cement lip, or the liner lip raised on a 6 “ berm. Whatever building material used for the pond should ideally allow for this 6" elevation to avoid groundwater entering the pond.

Part 3. Plumbing

Plumbing connects all the necessities of a properly running pond. The plumbing moves the water and detritus to the pre-filter, to the pump, to the bioconverters, the jets, venturis, skimmers, ultraviolet sterilizers, foam fractionator, etc. And as previously discussed, plumbing can make the pond a nightmare of maintenance with poor water quality or an almost completely self cleaning koi pond with minimal maintenance and few, if any, water quality problems.

Starting at the bottom, drains should usually be either 3" or 4" piping if gravity fed to a pre-filter and on some rare occasions 6" drainpipes may be necessary. About the only time 2" bottom drains could be used effectively would be on very small ponds of less than 500 gallons, when used in multiples where there is one drain for each 500 gallons of water being drained or when the bottom drains are plumbed directly to the pump intake. To determine approximate pipe size based on needed flow rates in gravity fed pipes or drainpipes plumbed to the pump intake, see the quick-reference plumbing chart Figure 30 at the end of this Section. It will help in determining flow rate friction losses due to length of piping, what impact elbows and other changes of direction fittings have on flow rates, etc. Please note for example, that two 2" pipes will not produce a flow equivalent to a 4" pipe. Two 2" pipes will produce a flow of about ½ of what a 4" pipe will under similar conditions.

As previously stated, a bottom drain will draw detritus and water from a 4' to 6' radius as long as the floor has a t least a 1" slope per lineal foot down toward the drain. The bottom drain functions best if it has a domed cover over it that is close enough to the bottom to not allow curious koi to get into the bottom drains. A bottom drain cover can be made using an inverted trash can lid, filling it with concrete and placing 3 pieces of PVC anchored in the concrete as legs. See Figures 9 and 10, a section and bottom view, respectively.

Figure 9

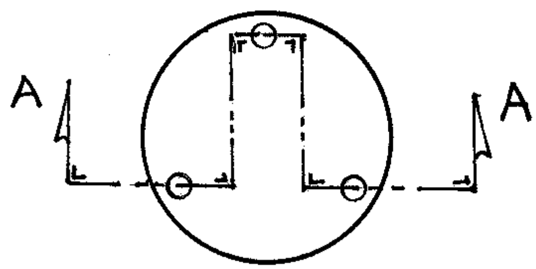


Figure 10

From the quick reference chart at the end of this section, you can see that gravity fed pipes require a much larger diameter than a pressurized pipe to deliver the same amount of water. The need for proper pump sizing to achieve adequate turnover rates will be discussed in more detail in Parts 8, 10 and 11.

When we talk of gravity fed pipes versus pressure pipes what we are referring to is that a gravity fed pipe is moving water only by gravity as the result of a difference in static head pressures (the height difference in the water's surface between two vessels). Remember 'water seeks its own level.' Thus when you have two containers of water with a pipe joining them together at the bottoms, when you remove water from one bucket, water from the other bucket will flow thru this pipe connection until the water level in each bucket is the same.

A pressure pipe is when the water is either being pushed or pulled thru the pipe by a pump. Different pumps with different capabilities will drive different amounts of water through a given length of pipe and/or raise it to different heights. Friction loss reduces the flow rate of water thru a pipe. The longer the pipe, the more friction loss and the less water delivered. The higher the water needs to be lifted, less water delivered.

Venturis and jets normally require the water to be delivered via a pressure pipe. A venturi generally requires a higher pressure than a jet as a venturi generally has a smaller restriction in it so that a reduced pressure area is formed by the fast moving water, thus drawing air into the stream and mixing it with the water. Usually a 1" dia. pipe works well for jets and venturis as it produces less pressure drop thus delivering more pressure (and more flow) than smaller piping.

Skimmers can either be gravity fed or pressure piped. ‘Gravity fed’ means plumbing the skimmer to the pre-filter and ‘pressure piped’ means plumbing to the pump intake. Gravity fed tends to keep the detritus in the pre-filter and doesn’t allow it to be emulsified by the pump impeller.

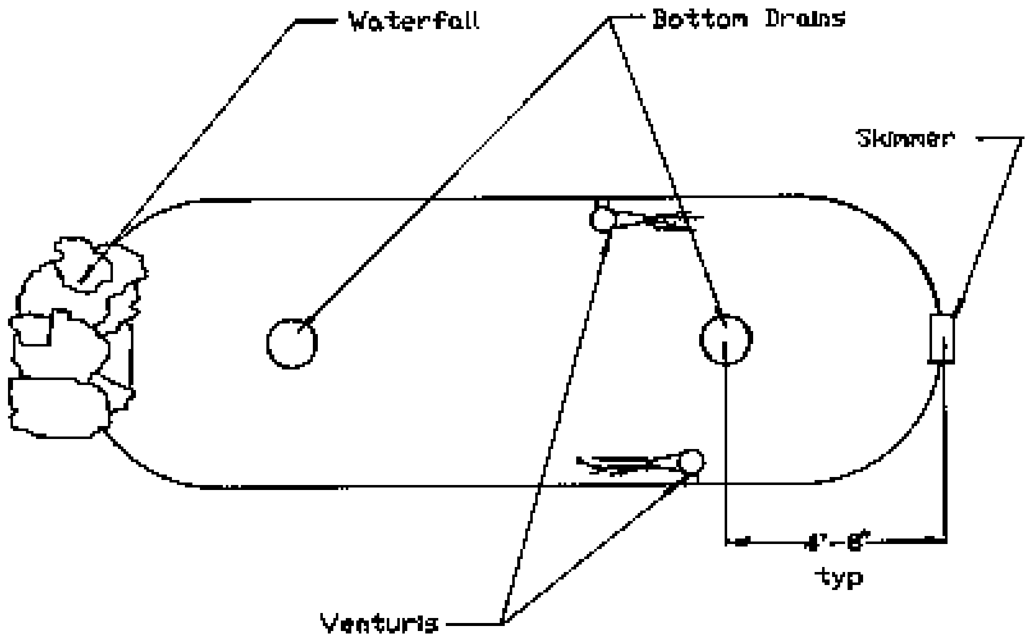
Over flow pipes are almost what the name implies, instead of the pond overflowing into the yard and possibly the Koi being washed out, the overflow pipe collects all water above a preset level and delivers it to a predetermined place therefore keeping the pond from overflowing. A 3" overflow pipe usually is adequate for most any size pond and can sometimes be plumbed to a lawn drain.

All the aforementioned plumbing must be assembled and joined properly to create a pond system that functions properly.

First, bottom drains should be spread out so that their effective areas overlap each other such that the entire bottom will deliver detritus to at least one of the bottom drains.

Next, the waterfalls, streams, jets, skimmers, water returns and prevailing winds should work in concert to create the ‘toilet bowl effect’ with the currents working to make the pond self cleaning thus promoting good water quality and exercise for the koi.

Figure 11 below is an example of a pond layout with bottom drains, skimmer, venturi jets and a waterfall that are working in concert.



Pond 6 ft. wide by 10ft. long

Figure 11

Normally bigger is better in a koi pond but one must be careful in choosing bottom drainpipe sizes. An oversized bottom drainpipe can become a settling chamber if the flow is too slow. That means detritus build up in the pipe and reduced water quality. So again it is important to determine the volume of water that must be moved thru a given length of pipe and then refer to the quick reverence chart for proper sizing.

What we have not yet discussed in this part are ponds that have submersible pumps, in pond bioconverters and pressurized bioconverters and pre-filters.

Submersible pumps usually are used on very small ponds, 500 gallons or less and have very basic plumbing, a tube from the pump to the waterfall or fountainhead and a tube from the intake to an in-pond bioconverter/filter. The alternatives might be a tube from the exhaust port to an out-of-pond bioconverter/filter, then to back to the pond. Usually a 3/4" flexible tube is used. These small ponds frequently have no skimmers, bottom drains, jets or overflow plumbing. The reason to use a submersible pump would be for a very small pond as submersibles are notoriously inefficient, meaning low flow rates, usually 1000 gallons per hour or less and very high energy draws.

In-pond bioconverter/filters reduce the amount of plumbing but are difficult to maintain and clean. Plus they reduce the swimming water for the fish.

Pressurized bioconverters and pressurized pre-filters usually require pumps with specific pressure requirements that are identified by their manufacturers. Since these specifics vary by manufacturer, we will not discuss the plumbing for them but the rest of the plumbing as previously discussed would apply. The special pump requirements for these pressurized systems will be discussed further in Part 11.

A rule of thumb for gravity fed pipes is that for ‘normal’ flow you would need ½” of vertical drop per lineal (horizontal) foot of pipe. A simple example would be an upflow barrel bioconverter that returns the water to the pond by gravity thru 30 feet of piping. In this instance, the bioconverter water surface would need to be at least 15" higher than the outlet static head, i.e., 30 ft X ½"/ft = 15". This rule relates to the change in head pressure at the two ends of the pipe. If both are under water, then the change is essentially the difference in height between the water surfaces of the source and destination vessels.

Please refer to the quick reference chart at the end of this section for specific applications of pipe size for the pond you are investigating. Also remember that 1) gravity fed pipes will generally always have to be larger than pressurized plumbing; 2) shorter pipes mean less friction loss; 3) the less abrupt the direction change (fittings - i.e., 90's, 45's, etc) the less the pressure loss; and, lastly and critical to pump selection is 4) the less height to which you need to raise the water, the less energy will be required.

Part 4. Aeration - not too controversial but frequently overlooked to varying degrees.

Waterfalls are the most frequently used form of aeration and can be very effective or inefficient depending on how they are designed.

First we must understand some basics of gas (air) exchange with regard to water. Contact time is critical, the longer the better. Water oxygenation levels are increased only when the water is in contact with oxygen or air. So the surface of the pond is a significant gas exchange area because the water surface is in contact with the air all the time. The effectiveness of the water/air interface can be increased by water movement at the interface, i.e., jets, venturis, waterfalls, fountains, air stones, etc. Another example of contact time is when you use air stones, if they are put on the bottom of the pond, the air bubbles rising to the surface are in contact with water for much longer time than if they are only 6" under the surface. There are theories that conclude that most of the gas transfer happens as the bubble is forming. (A series of related articles on the subject can be found in the “Odds and Ends” section [by Joe Cuny] of Koi USA, Jan/Feb ‘99 thru Nov/Dec ‘99.) An added benefit to deep air stones is that as the bubbles rise to the surface, they draw bottom water toward the surface in addition to adding surface movement. Now a surprise to some people is that the finer the air bubbles, the greater the gas transferred. This is because the smaller bubbles have a greater surface area for a given volume of gas. The smaller bubbles also rise slower than larger bubbles that increases the contact time.

Now we will give you some examples of efficient and inefficient water falls as they pertain to increasing the oxygen content in the water.

A very efficient waterfall: 2 feet high, 20 feet long with pebbles and rocks in the raceway and many small cascades along the entire path.

A very inefficient waterfall: a 20-foot high fall with only one drop, that is directly into the pond.

These two examples may at first seem puzzling because the 20 foot high fall can be quite spectacular and the water crashes into the pond. But if you consider that only the water in contact with the air will gain oxygen and for only the time it takes to fall, you can see that the contact time is very small in the high fall and much greater in the longer, smaller drop falls. Additionally, the 20 foot long cascading falls continue to churn the water thus mixing the oxygen into it. For any given height of falls, two drops are better than one; three are better than two, etc.

Jets can aerate or not. Bottoms jets that are not directed nearly straight up create currents but very little if any aeration. Bottom jets directed straight up can both bring bottom water to the surface and create surface rippling. Both these affects add to the aeration of the water. Such an arrangement is more common in smaller ponds and is usually achieved by directing the discharge of a submersible pump upward. Jets near or above the surface can create surface movement that in turn, increases aeration.

Venturis enhance gas exchange (aeration) by two means: adding bubbles to the water and causing surface currents. For given water and airflows, the deeper in the pond the venturis are placed, the greater the aeration effect. However, the deeper they are placed, the greater the power required to drive them such that a suction of air is created. Also there is an increased risk of supersaturation of gas in the water though the author has never seen a case of supersaturation in any pond.

Ways to increase aeration all involve water movement. A simple way without increasing energy usage is seen in figure 13. Note that in figure 12 the water is moving through a horizontal pipe but there is only a small amount of air-water surface interface. In figures 13 and 13a, the only the top or surface water enters the pipe; this is the most oxygenated water. If air is also sucked in and entrained in the water, this just adds to the oxygenating effect.

Figure 12

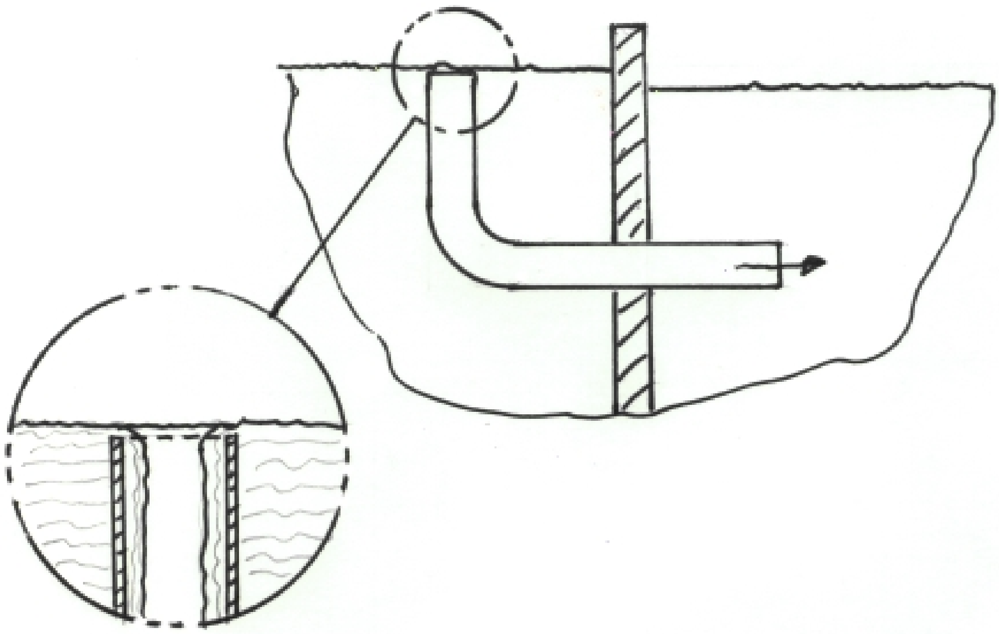


Figure 13

Figure 13a

Water movements in pre-filters, through foam fractionators and all water returns to the pond are opportunities to increase the oxygen in the water. Almost everything we value in the system works better at the higher levels of oxygen (an exception being anaerobic nitrate conversion). Aeration is more important during the summer, in warm climates and during the night and early morning hours.

As the water temperature rises, it's ability to hold oxygen decreases. During non-daylight hours all algae and other submerged plants absorb oxygen and give off CO_2 thus competing with the fish for oxygen (the additional CO_2 combines with water to form carbonic acid which tends to lower the pH). The converse is true during the daylight hours. The algae and other plants give off O_2 and absorb CO_2. Overcast days reduce the rate of photosynthesis and thus retard this normal process. Oxygen levels in the pond are the lowest in the very early part of the day.

Lethargic koi in warm water can often be 'brought to life' by the addition of a few well-placed air stones.

Supersaturating pond water with gas is so rare that this author has never seen it in over 30 years in the hobby. Reported symptoms are bulging eyes and erratic swimming.

Part 5. Water changes

Water changes are generally a ‘good thing’ and 5% to 10% per day is not considered too much if the incoming water parameters are satisfactory. Minimum recommended water changes would be in the order of 10% per week. Proper conditioning of the water may be necessary, e.g., the addition of a dechlorinator and possibly an ammonia binder if the source water contains chloramines.

Part 6. Electrical

Watch out! Any electrical equipment associated with ponds should have a GFCI (ground fault circuit interrupter), usually in the fuse or circuit breaker box or incorporated into the receptacle. The GFCI measures the current flowing to and from it (thru the equipment). If the currents don’t match, the GFCI automatically breaks the circuit. An easy way to tell if a circuit is protected by a GFCI is to look for a test button. If there isn’t one, the device is not a GFCI. The operation of these devices should be tested regularly (monthly is recommended) to confirm proper functioning. To test the device, press the ‘test’ button. If the circuit does not break (disconnect), the device is defective and should be replaced immediately.

The purpose of the GFCI is to prevent electrocution and/or fire. Since they are mechanical devices and require some time (albeit small) to work, they don’t prevent electrocution in all cases but will certainly do so in many and help make the situation better in most. GFCIs in the breaker box are usually better than in receptacles as there they monitor the entire circuit as opposed to only one branch of it.

Most building codes require the use of GFCI devices around water but many people don’t use them due to lack of knowledge or the increased cost or both.

All exterior electrical equipment should be grounded which means at least the use of three-pronged-plug type wiring. All hard wiring (wiring w/o a plug on one end) should be in conduit and boxes and fixtures especially made for outdoor use should be utilized. Most, if not all, cities have building codes that specify how electrical installations need to be made.

Wiring is similar to plumbing in that the longer the run, the larger the pipe or wire needs to be. To continue the fluid flow analogy, voltage in electrical circuitry is analogous to pressure in a fluid circuit and electrical amperes (amps) are equivalent to fluid flow.

There are two types of voltages and wiring used in homes, 110 volt and 220 volt. The normal house voltage and wiring is for 110 volts. Some applications requiring high power, like stoves, ovens and electric clothes dryers, may use 220 volt circuits. The 220 volt wiring can carry twice the power for a given wire size.

This is not an attempt to make students into electricians rather to give an understanding of the basics. Wire sizes are specified with numbers. Number 12 wire is common in household electrical circuits. A #10 wire is larger (the smaller the number, the larger the wire.). Long wire runs and heavy amp draws require larger wire. Wiring that is undersized for the load can overheat and cause electrocution, equipment failure, fire or all three. Building codes are very specific as to the length of the run and the allowable loads.

When approaching an unfamiliar pond and before touching the water, check to see if the fish are swimming erratically or if any have bent backs. If either of these situations exists, ask the owner to shut off the electricity to all pond devices. If the fish change their behavior when the power is shut off, there may be an electrical short applying voltage to the water. If this is suspected, do not proceed but rather have the owner contact a licensed electrician immediately.

With energy costs on the rise, minimizing the cost of operating a pond is certainly of concern. This will be discussed in some detail in Parts, 8, 10 and 11.

Part 7 - Pre-filters

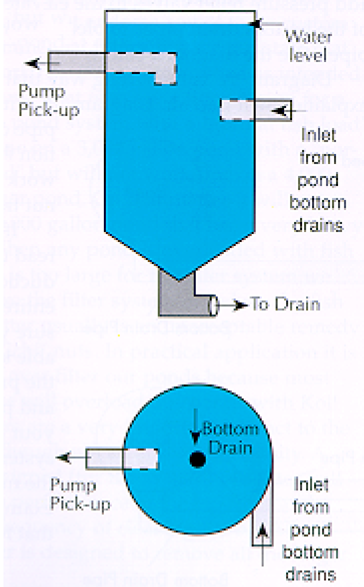
Pre-filters are a virtual necessity on all but the smallest ponds. The advantage and function of a pre-filter is that they remove solid material prior to entering the pump and bio-converter. Keeping the bio-converter clean keeps it performing better longer.

A bioconverter that has mostly or only to process the dissolved gasses (that is. ammonia, nitrites) and not also filter all the solids is far more efficient and has a greater capacity to perform the functions for which it was intended and for a longer time. That said, we will not discuss bioconversion any further here as this part is about pre-filters.

Many pre-filter design philosophies exist, but this part will address only those few types that I have found to be the most frequently used and, in my opinion, are the most effective. All of these are gravity fed but vary in design.

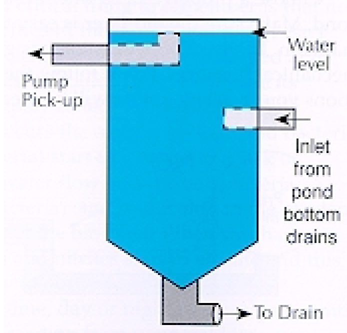
The first is a vortex system that is basically a barrel with a coned bottom and a drainpipe in the center (bottom) of the cone that allows for removing the settled solids. Water from the pond (usually from it’s bottom drains) is typically fed into the vortex at a tangent to the barrel’s circumference somewhere in the middle third of its height (see Figure 14).

Figure 14



The larger the pipe size entering this vortex settling chamber, the slower the water spins resulting in less turbulence which in turn facilitates solid settling. The water is sometimes picked up for transport to the pump from the top third of the barrel and near the outside of the barrel. This allows the pump to pick up the water with few sinking solids and delivers this water to the bioconverters. Some pump pickups are at the very top of the water in the center, even further reducing the sinking solids that are picked up (see Figure 15). Some people add a screen to the water pickup. That reduces the transfer of suspended (particularly buoyant) solids, but necessitates periodic cleaning of the screen. This is a settling chamber where gravity works to remove the non-buoyant solids.

Figure 15



To improve the solids removal, you can place a row of brushes that bisect the barrel approximately half way around from the inflow (see Figure 16). These brushes will trap many of the suspended solids that won't settle to the bottom before being picked up in the outlet. Once you add brushes or screens or any other materials inside this vortex barrel, it becomes a pre-filter, not just a settling chamber. Additionally the brushes, screens, and so forth are diffusers and help to slow down the current in the chamber.

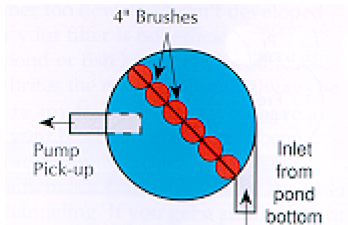


Figure 16

These vortex pre-filters work better as they get bigger. Three feet in diameter is about the practical minimum for reasonable efficiency; 4' being far superior. I am trying to avoid a sales pitch for any products, but Hydra makes a prefab vortex pre-filter that is popular with those who choose not to design and build their own.

If space is a problem, an inside sediment tank may be the solution, although again, the bigger the better. Although this configuration is better than bottom drains delivering water directly to the pump, there are several limitations. One limitation is that this cannot be done with a liner pond. Further, this is only a settling chamber, not a true pre-filter. But with these considerations in mind, let me explain this system. The settlement tank is placed in the bottom of the pond at the deepest point (see Figure 17). Pond water enters the chamber around the edges of the bottom drain cover and the heavy solids tend to settle out to the bottom of the coned chamber and the water going to the bioconverter is picked up in the center of the underside of the drain cover, thus picking up only the buoyant suspended and the lighter sinking solids. The heavier solids that settle to the bottom of the chamber are periodically flushed out the drainpipe that is connected to the bottom of this coned portion of the chamber.

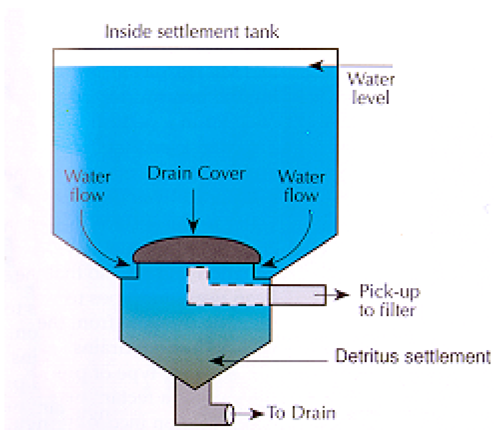


Figure 17

Regarding the shape of pre-filters, my personal preference is a rectangle-shaped chamber with two coned bottom drains. But, the configurations are endless. So, I will discuss only a few examples that I know work quite well.

I'll digress for a moment to provide a glimpse of the different philosophies for these various configurations. When I was designing the conversion of my swimming pool to a Koi pond, I solicited the opinions of several knowledgeable koi pond people. The consensus was that I needed a larger pre-filter than I had space to accommodate. Since I didn't have space for a "proper" pre-filter, I went with what space I had and built a 30"x42" x 24" deep pre-filter for my 22,000 gallon swimming pool/koi pond conversion. I felt that this would be better than not having a pre-filter. As I previously stated, a pre-filter is very advantageous. After nine years in operation, I must admit it has exceeded my expectations! As an example, I check the leaf traps on my two $^{1}/_{4}$ hp Wave pumps a couple times a year, but they are always clean! Additionally, when I back flush any of my six 300 gallon updraft barrel bioconverters, there is hardly any flock in them and none of the bioconverters has ever channeled! The only chore is pulling the brushes out every few months and hosing them off with a garden hose, which takes about 10 minutes. Since the pond is over 8' deep, very good bioconversion is a must; otherwise, the water clarity would suffer. The water is clear at the deepest point, and water chemistry is excellent with virtually no perceptible ammonia or nitrite readings ever, and pH in 7.5-7.8 range. Now, I'll admit on two occasions that my clarity has suffered, caused by my experimentation with back flushing the bioconverters and over-medicating the pond when the bioconverters were not well established. During these two times, the clarity suffered but not the water chemistry. Although this pre-filter works great, I know if it were bigger it would work better!

Now, back to specifics. My pre-filter is rectangular and has a flat bottom (a no-no). It has six inlets from the bottom drains that come in at one end on the bottom. Then the water goes through four rows of brushes and then is picked up by the pumps. There is a bottom drain in the pre-filter chamber that I can open to flush the sediment out (see Figure 18). The six inlets have separate standpipes and are connected to one bottom drain each, thus I can regulate the pickup of each bottom drain as necessary (by employing various sized side holes or numbers of holes in the standpipes). With this system, I never have to vacuum the pond, but I did once as an experiment to see if there was any detritus laying on the bottom. There wasn't and I haven't vacuumed since!

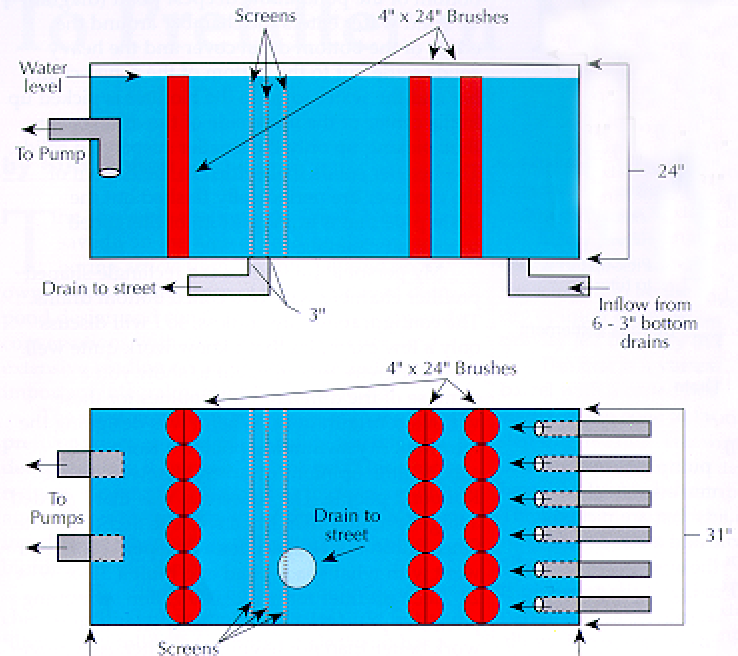
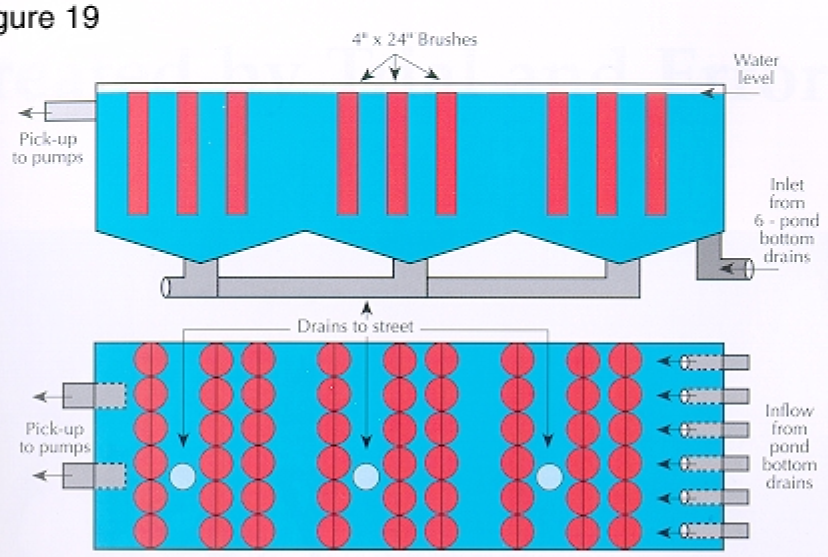
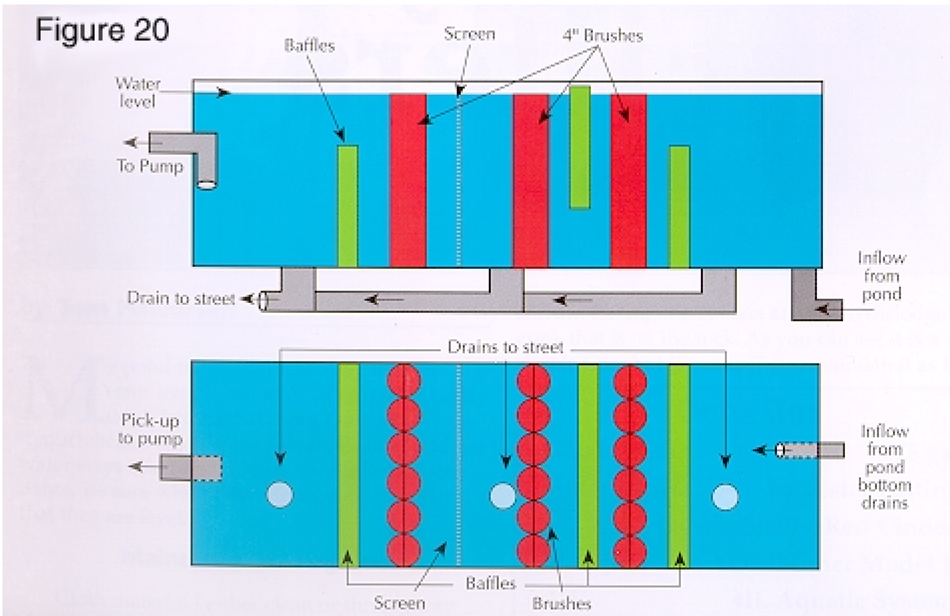


Figure 18

Now that my bragging is over, I'll tell you how I would have designed the pre-filter had I had the room. It would have been at least 10' long and 4' wide, but still only 24" deep. The other important consideration is that I would have had three coned bottom drains to accommodate flushing the detritus out (see Figure 19). I would have put at least nine rows of brushes, spaced at least 6" apart, three rows over each coned bottom drain and eliminate the three screens. By the way, I did eliminate the three screens in my pre-filter and replaced them with a fourth row of brushes because I am convinced that the brushes are far superior.

Figure 19


My reasons for bringing the pond water in at one end in a vertical direction is so that the bottom pond water will rise vertically and roll the water to the surface, creating additional oxygenation and also so that I can use standpipes to regulate the flow from the various bottom drains. Another type of pre-filter using a rectangular configuration incorporates baffles to redirect the flow of water up and down to assist in the settling of solids - see Figure 20. As you will notice, this configuration is quite similar to Figure 19 with the addition of the baffles to change the water direction.



I have used this system on my 800 gallon pond. It does not have a coned bottom because the pre-filter is only 12" x 34" x 21"deep. Because of its small size, each compartment flushes clean when you pull a standpipe to the drain. The three rows of brushes and one screen remove the suspended solids well enough that my 1/25 hp Grundfos recirculating pump never clogs. The pump does not have a leaf trap and for those familiar with Grundfos pumps, you know that its impeller is very sensitive to the smallest of solids and clogs very easily. If your pre-filter with baffles is very much larger than this aforementioned one, I would recommend coning the drains. You could add more baffles and drains to create more filtration of the suspended solids.

As you can see, the configurations are endless, and only limited by your imagination. I have touched on only a few examples but I would remind you that whatever the design, there are a few things to keep in mind.

1. Deliver the pond water to your pre-filter in the largest diameter pipe that's still practical.
2. In general, bigger is better.
3. The longer the time that the pond water is in the pre-filter, the more suspended solids it will remove.
4. The more brushes, screens, other mechanical filtering materials in the pre-filter, the more solids they remove.

5. The pre-filter should be gravity fed. If a pump delivers the water to it, the impeller will grind the solids up finer and make it harder to remove them from suspension.

Keeping these thoughts in mind will help you to designing a very efficient pre-filter or evaluate an existing one.

There are some pressurized canister pre-filters you may encounter that are plumbed between the pond and the pump. Their purpose is the same as other pre-filters, to remove debris prior to entering the leaftrap and/or pump. Their efficiency will vary with size and design but they will reduce the output of the pump - see Part 11.

No matter the size or design, any pre-filter will improve the efficiency of the bioconverter and the overall pond system. And, they reduce the maintenance and frequency of same.

Part 8 - Pond Turnover Rates

Pond turnover rate is how frequently the volume of the system is cycled thru the bioconverter(s). In general, the smaller the pond, the faster the turnover rate should be. For example, a 4,000 gallon pond should have a turnover rate of once per hour or more; a 10,000 gallon pond should be turned at least once every 1.5 to 2 hours. For larger ponds up to 25,000 gallons, a turnover rate of not less than once every 3 hours is recommended. Other factors that can influence the desired minimum turnover rate are: fish population, amount of sun on the pond, the presence of water plants and the types of bioconverters and their media.

Higher stocking densities will require faster turnover rates. The presence of water plants will assist the filtration process and thus decrease the required turnover rate slightly. Since plants do not affect this parameter dramatically, they may generally be disregarded.

A long accepted general rule has been that for each square foot of bioconverter media (cross-sectional flow area - taken perpendicular to the direction of flow), the water flow should be between 1.5 to 2 gpm; above 2 gpm, the bacteria would not have enough contact time to perform the necessary chemical conversions. This has proven to not be the case. Several hobbyists successfully run their bioconverters at 3 to 4 gpm/sq ft and find that the ambient ammonia and nitrites in their pond are reduced. Some people even report successfully running at higher than 4 gpm/sq ft.

Another generally accepted rule is that the media depth should not exceed 14". Many hobbyists report running media 30" deep and having excellent results. Much depends on the bioconverter design and the media. Graded media which is designed to compensate for a less than perfect pre-filter, may present large, open media to the first incoming water and gradually reduce the media size until the final media is relatively fine and has both a high specific surface area (surface area per volume of media) and the ability to ‘polish’ the water (remove suspended fine particles from the water). Also this rule of thumb came about some time ago when mostly gravel and sand were used for media. Today’s new media expand the possibilities. Various media will be further discussed in Part 10 of this section.

Another generally accepted idea is that bioconverters use large amounts of oxygen to perform their water purifying functions. In fact this is not the case. There is very little difference between the oxygen content of the water entering the bioconverter and the water exiting.

What almost everyone seems to agree on is that the bacteria react on contact with the ammonia and nitrite in the water. Based on this premise, the faster the water flows thru the bioconverters, the more ammonia and nitrite will be processed and converted to the less toxic nitrate (good). Faster turnover in general means more oxygen brought to the pond via waterfalls, jets, venturis and streams (good) and more solids and harmful chemicals will be brought into the pre-filter and bioconverter (good). And logically the converse is true.

The system, as operating, must be able to adequately take care of the waste products the koi produce. If it is not and the situation continues, the fish health will deteriorate and disease is the logical result. To compensate, one of two things must take place (or some combination of the two): the load on the system must be decreased to a manageable level or the system's capacity must be increased to handle the load.

Part 9 - Ultraviolet Sterilizers - Necessary?

A UV system can provide a 'boost' to a system as the Springtime approaches in colder climates. With the bioconverter bacteria coming out of dormancy, they are not yet able to cope with the single cell algae and 'pea soup' water may occur. UV lights can help kill the floating algae and clear the water. UV lights can also kill bacteria tho significantly more radiation is required than to kill floating algae.

In warmer climes such as the southern US and Southern California, bio converters don't usually go dormant and UVs could become detrimental as they can mask the inadequacy of the bioconverter. In these areas, systems with properly sized bioconverters should stay clear year around. Water testing can help determine if the UVs are masking inadequate filtration.

UV lamps usually require replacement annually as beyond one year they loose significant effectiveness.

UV lights are always properly installed after (down stream from) the bioconverter, never before. UVs operate better on cleaner water; hence post bioconverter installation is preferred. UV manufacturers have very specific parameters as to the flow rates through their sterilizers.

Part 10 - Bioconverters

This part will only briefly discuss the various types of bioconverters, their applications and the many media types as they relate to the complete pond system. More detailed information can be found in the Filtration Section of this course.

Updraft (or upflow) and downdraft (or downflow) bioconverters refer to the direction of the water flow in these units. The water flows upward in the updraft (or upflow) units and flows down in the downdraft (or downflow) units. In horizontal (or sideflow) units, the water flows across the unit sideways. These units can either have water pumped into or out of them. In gravity fed units, the water is pumped out of the bioconverters.

Figure 22 below is an example of a pond where the water is pumped to the bioconverters and Figure 23 is an example of a gravity flow system.

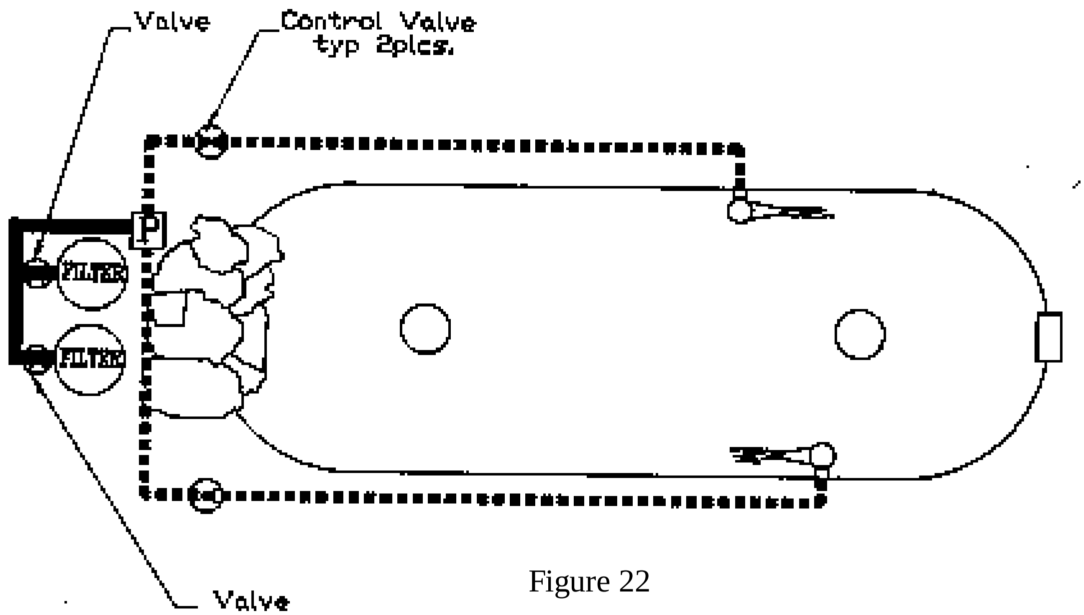


Figure 22

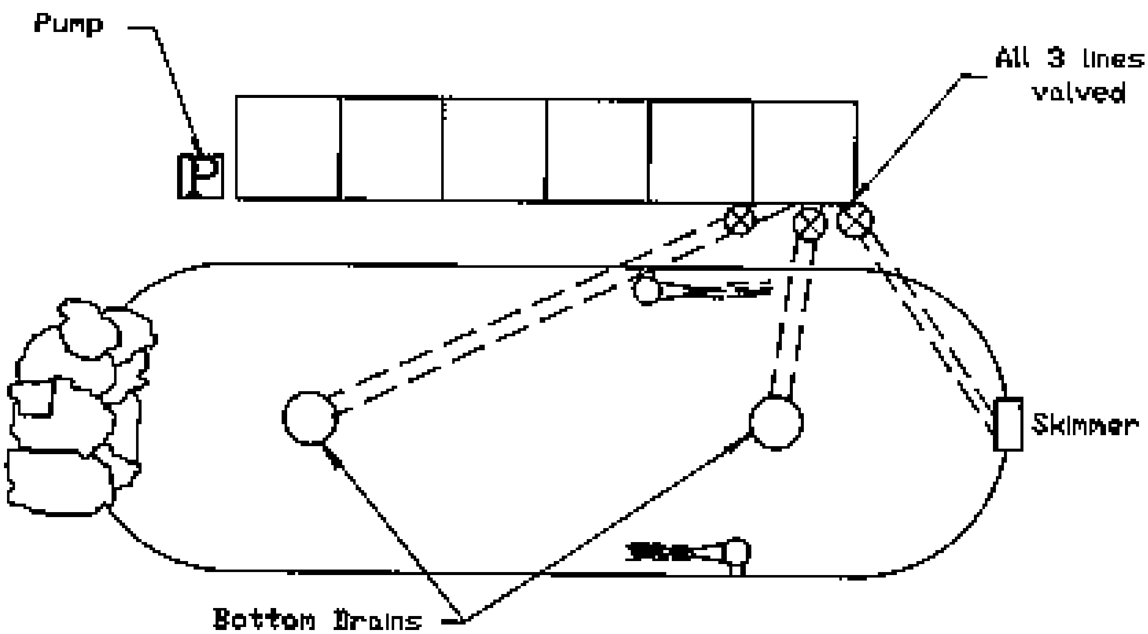


Figure 23

Pond size 6 ft. wide by 18 ft. long

Figure 24 below is an example of an in-pond combination bioconverter/filter with plumbing. There are several major drawbacks to this type bioconverter/filter. First, it has no bottom drains and would likely require frequent vacuuming or the addition of a bottom drains plumbed directly to the pump. The pump would then mix filtered water with that from the bottom drains macerating the solid wastes from the drains and returning it to the pond. Bad idea.

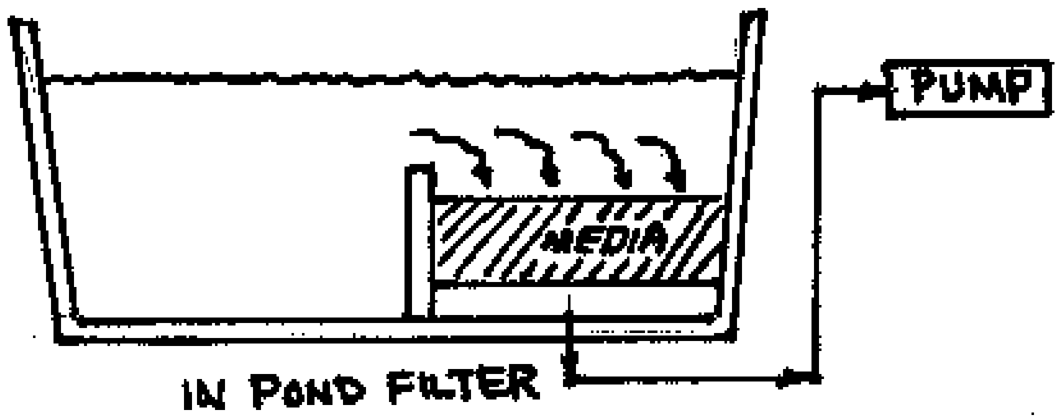


Figure 24

Another problem is that the mid-level water entering the bioconverter/filter is not the worst water in the pond. Maintenance is a real problem. In order to clean the media w/o totally polluting the pond, the water level must be lowered to below the lip of the filter box. The media must then be physically removed or agitated while it is being flushed/washed depending on the media. Circulation in such systems is also poor in most instances.

Trickle tower or wet and dry bioconverters are very efficient but may require more energy to operate (a more powerful pump), a very good pre-filter to eliminate detritus, excreta and other solids especially string algae. Whatever the media, water is sprayed down from above or trickled down from above over the media. Due to the large air/water interface, the water contains high oxygen and can support a larger colony of bacteria than an equivalent amount of submerged media. Also due to the thin layer of water, virtually all substances within the water will come in contact with the media on a single pass, unless the flow rate is too high.

There are numerous pressurized bioconverters that, depending on the type, size and media, are effective. Each manufacturer will give specifics as to pond size, flow rates and plumbing requirements. Regardless of the type, it will have both manufacturer's limitation and application limitations. One thing to keep in mind is that the manufacturers' claims are usually based on optimum conditions and are rarely achievable. A good rule of thumb would be to de-rate the stated capacity by 25% to 50% based on fish load, etc.

Additionally, pressurized bioconverters require very good pre-filtered water, frequent cleaning (some as often as every 2 or 3 days), and more powerful pumps (say, more energy consumption). The two real advantages of pressurized bioconverters are that they take up less space than other types and, since they are pressurized, they can be placed almost anywhere that is convenient and/or accessible.

Chemical filters remove toxins, e.g., ammonia, nitrite, chlorine, etc. The media can be activated carbon, zeolite or various resins. On large ponds, they are not very practical or economical as carbon must be replaced and the zeolite and the resins replaced or recharged, all unnecessary expenses.

No matter which bioconverter system is used, a good rule of thumb is to have the bioconverter volume represent 15% to 25% of the total pond system, e.g., a 4000 gallon pond should have 600 to 1000 gallons of bioconverter capacity. Flow rates thru the bioconverters will vary based on the media used, plumbing size (see Part 3 chart) and pump capacity. Most bioconverters can be placed remote to the pond to facilitate aesthetics (hide them) and performance. Every bioconverter has limitations, e.g., a bioconverter that returns water to the pond via gravity cannot have its water level at or below that of the pond's surface.

Remember that a bioconverter is designed to remove gases (ammonia and nitrite) and if there are any detectable levels (with any but the most sensitive test kits or meters) of these gases in the pond, the system has not matured (less than 4 months old), has too slow a flow rate or is too small to handle the fish load. Flow rates thru bioconverters exceeding 4 gpm/sq. ft. usually indicate the need to add filtration capacity, e.g., add a bioconverter.

The fluidized bed bioconverter is extremely efficient at removing ammonia and nitrites. It does, however, require high pressure, does not tolerate flow rate increases beyond a narrow limit and does little for water clarity. The media is usually fine sand (e.g., #60 to #90 sand). The chamber is a column into which the water is injected at the bottom in such a way as to cause the media to rise up and then fall thru the water at a rate equivalent to the rate the rising water is pushing the media up. This causes the media to be essentially at a constant height in the chamber while tumbling in the water. As the water flow increases, the top of the media bed rises. If the flow is increased too much, the media is washed out of the chamber. These bioconverters are somewhat popular in commercial applications as they respond to rapid changes in ammonia. It is doubtful that KHA would encounter these systems. One system you may encounter is a fluidized bed system combined with a floating bead system where there are both floating and sinking beads in a closed or 'pressurized' system. The sinking beads utilize the fluidized bed principle.

There are many different types of media in use today. We will mention only a few here together with some of their advantages and disadvantages.

A. Rock (various sizes, any type), i.e., crushed aggregate (angular), river rock (rounded), volcanic - advantages: cost and with some river rock applications, ease of cleaning. Disadvantages: clog easily, heavy.
B. Sand - advantages: cost, good for water clarity (removes fines). Disadvantages: weight, clogs easily
C. Matting - Japanese, Matala, Enkamat - advantages: doesn't clog easily, is self-supporting, light weight. Disadvantages: cost, cleaning
D. Bioballs, rings, etc. - Advantages: large surface area compared to volume, light weight, easy to clean (normally). Disadvantages: cost, does nothing for water clarity.
E. Reticulated foam (open cell foam) - Advantages: large surface to volume ratio, self-supporting, light weight when dry. Disadvantages: cost, heavy when wet, difficult to clean, will need replacement in a few years.

F. Brushes - Advantages: light weight, easy to clean, large surface area. Disadvantages: cost, minimal effect on water clarity.

G. Screening & meshes (various) - Advantages: light weight, easy to clean. Disadvantages: cost, may clog quick with fine mesh, need a large volume to be effective on all but small ponds, water clarity questionable. Izeki netting: light weight, easy to install (drapes over horizontal pipe at top and has weighted pipe at bottom [in a loop]), good water clarity (assessed from photos). Disadvantages: cost.

H. Plastic shapes (forks, hair curlers, etc.) - Advantages: light weight, may be cheap, good water clarity. Disadvantages: bacteria may not grow well on some smooth plastics

I. Manufactured media -
1. Siporax - Advantages: doesn't clog, good water clarity. Disadvantages: very expensive, weight.
2. Balance - Advantages: lighter than gravel & with larger surface area, water clarity. Disadvantages: cost, clogs
3. Spring flo, PVC ribbon - Advantages: large surface area, light weight, doesn't clog, comparative water quality, easy to clean. Disadvantages: cost.

The many different types of media and their advantages and disadvantages will be discussed in more detail in the Filtration Section of this course. The selection of properties is dictated by the application.

Before leaving this part, here is a small discussion of operating bioconverters in parallel vs. series operation. Whether the system is gravity or pressure fed, it is relatively easy to plumb them in parallel with only a few extra fittings and valves. Fig.25 below shows a gravity fed system plumbed in parallel. Fig 26 shows a system in series and gravity fed. Fig 27 is parallel with gravity return to pond. Fig. 28 is series with gravity return to pond.

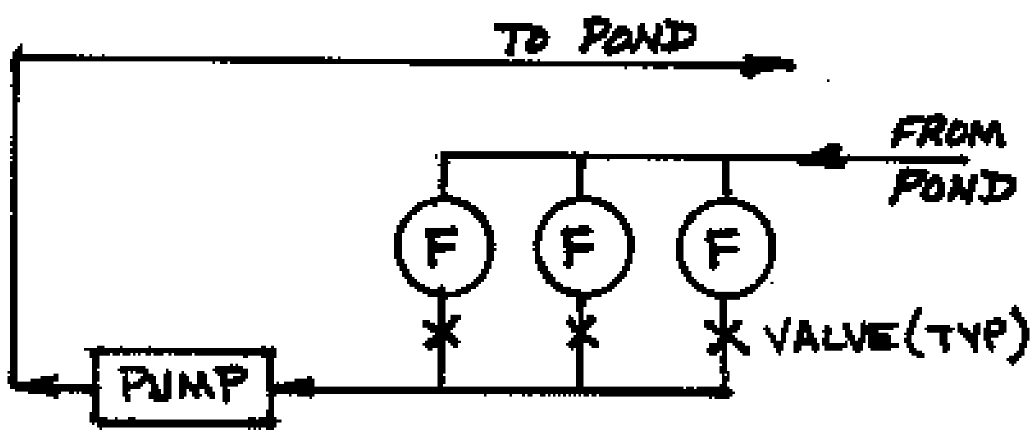


Figure 25

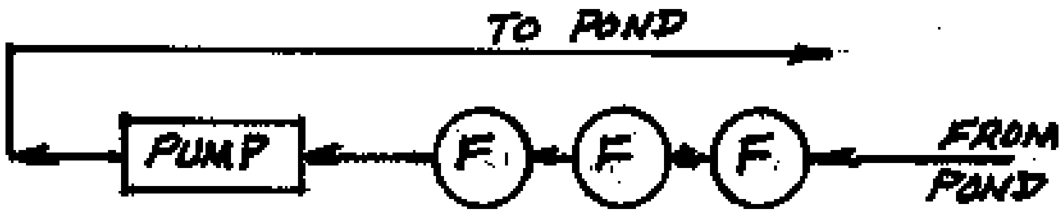


Figure 26

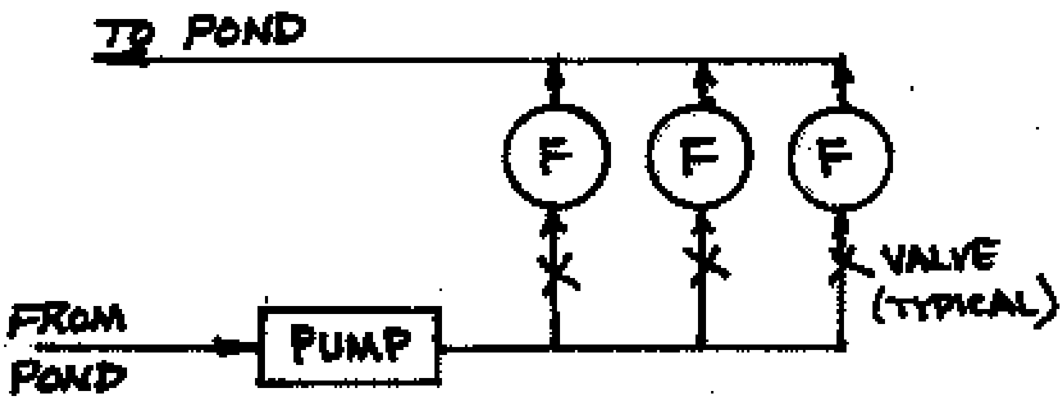


Figure 27

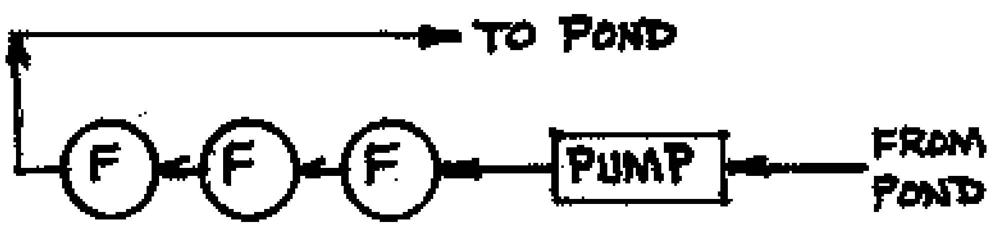


Figure 28

In gravity fed systems, the pump is placed after the bioconverters and before the bioconverters in a gravity return system. Gravity fed systems must have the bioconverters at the same level as the pond. In gravity return systems, the bioconverters must be higher than the pond.

As you can see, there is a little less plumbing in the series configuration. However, the performance advantages of the parallel configuration far outweigh the slight increase in plumbing complexity and its small added cost.

In the parallel system we can dramatically increase the flow rate thru the system with less increase in water flow thru any one bioconverter when compared to an equivalent increase in flow rate thru a series system. A simple example will explain. If our pump delivers, 3000 gph it is pushing or pulling 1000 gph thru each bioconverter chamber if plumbed in parallel but 3000 gph are going thru each bioconverter chamber if plumbed in series. If we need to double the turnover rate in our pond (bioconvert 6000 gph) to accommodate ammonia levels, the parallel plumbed bioconverters would increase from 1000 gph to 2000 gph in each chamber. The series plumbed system would have to increase to 6000 gph and the bioconverter chambers would have to be huge to accommodate this increase.

Those are simple facts. Now comes my theory which I have no proof for but by deductive reasoning it appears correct. Bioconverters in series receive all the pond water in the first chamber where the bacteria perform their duties on the ammonia, etc. Then this water moves to the second chamber and again the bacteria react to the remaining ammonia and nitrites, then the water is off to the third chamber for the same process and so on. Everybody agrees that the bacteria volume is limited by the amount of nutrients they receive. My premise is that by the time the water reaches the second, third or fourth chamber, there are no nutrients or very few nutrients (ammonia and nitrites) so these bioconverters in essence become mechanical filters, not bioconverters. I have no knowledge of anybody ever identifying and counting these bacteria scientifically since there is still scientific argument as to what these bacteria are and how they perform.

I do know from past experience that converting several multi-filtered ponds from a series to parallel arrangement has shown a marked improvement in the water clarity, ambient ammonia, nitrites and marked improvement in koi's behavior.

Part 11 - Pumps

There are generally two types of pumps used in koi ponds, in-pond (submersible) and out-of-pond pumps.

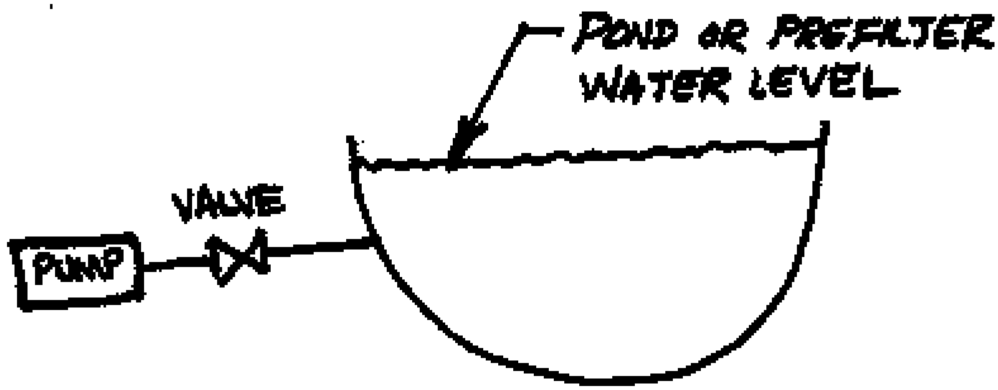
Submersibles are the simplest from a plumbing standpoint; no bottom drains, no skimmers, no pre-filters, etc. just plumb the pump exhaust to where you want the water to go and set the pump in the water. It sounds very attractive doesn't it? These are a few reasons why you would choose and out-of-pond pump vs. the submersible. First is long-term cost. A submersible is typically inefficient, uses a lot of energy and delivers very little water. Most don't deliver more than 1000 gph. You can get some that deliver 2000 gph and more but their amp draw usually is over 10 amps (very high!). That said, there are reports of more efficient submersible pumps being introduced in Europe and it shouldn’t be long before such pumps show up in the US and Canada. The main attraction for submersibles is simple plumbing and low initial cost (many under $100). For a very small pond or quarantine tank, they may be the answer for some people. But as previously stated, no bottom drains, skimmers, pre-filters, jets (all the things that you now know make for a better pond system and less maintenance) equals an inferior system and more work for the owner.

Another negative is their service life. The power cords frequently short out and the pump housings crack, causing electrical shorts in the pond that can electrocute the koi, a person or a pet. Enough said about submersibles.

Out-of-pond pumps generally fall into two categories, high head or low head. A high head pump is what is normally used on swimming pools and spas. High head meaning it develops high pressure (psi) so that it can move water without too much loss in volume even when the plumbing is long, has many bends, or has to lift the water high (over eight feet for example). It sacrifices efficiency, meaning much higher energy usage for this more constant performance. Later, we will show an example of both pumps’ performance that is quite vivid.
Another feature of a high head pump is that they are normally self-priming, since most swimming pools are set on timers to conserve energy the pump must be able to stop and start without any assistance. Self-priming only means that if air gets into the plumbing, the pump can start up and draw water to itself without burning up the pump. Because of this self-priming feature, they can be installed above the pond’s water surface level and still perform satisfactorily. A high head pump can lift water 30 feet high or more, depending on the pump, whereas a low head pump couldn’t lift the water near that high with out stalling the flow. The question is now, how many 30' high water falls have you seen on koi ponds?

Low head pumps have sacrificed pressure (psi) performance for efficiency. They deliver a greater amount of water for substantially less energy. They are **not** self priming so during installation, this must be considered as sometimes there will be a power outage and the pump will have to restart on its own.

The safest and surest way to eliminate the loss-of-prime problem is to install the pump below the pond’s water surface level (say, in a chamber next to the pre-filter, or the bioconverters in a gravity fed system). Below is a simple diagram showing this example (see Figure 29).



Another way is to place the pump above the pond level and put a flapper check valve in the plumbing **before** the pump and as far below the ponds surface as possible and as far away from the pumps intake as practical. Then if power is lost, the flapper check valve will close keeping the pipe to the pump full of water. Unfortunately, flapper valves fail occasionally or get jammed with debris. One way to avoid the jams is another vote for the pre-filter; it traps all or most of the debris before it can get to the pump or valve. Since low head pumps cannot fight restrictions in the plumbing to maintain their flow rates, it is imperative that the plumbing and leaf trap basket be kept clean at all times or the flow rate will lessen dramatically.

One fact that is common to both high and low head pumps is that they both push water better than they pull water. That means the best place to locate either pump is as close as possible to the water source. Meaning a pump located 12" from the pond or pre-filter works much better than a pump located 12' from the pond or pre-filter.

Both pumps are far more expensive than submersible pumps initially but will recoup this excess expenditure in six months to a year depending on the size pump and price, usually $250 to $400 versus the submersible at $100 or less.

Choosing the right pump for the pond system needs to include several factors: volume of the pond water, desired turnover rate, type of bioconverters, location of the bioconverters and pre-filters in relation to the pond, height the water must be lifted and the length of the plumbing. Size of plumbing is more important with a low head pump than with a high head pump as the latter can better overcome inefficiencies in plumbing. An example of the difference in a low head pump verses a high head pump is as follows:

A 3/4hp high head pump will normally deliver about 62 gpm for 9 to 11 amps.

A 1/4hp low head pump can deliver 89 gpm for 2.5 amps.

As you can see, not only is the flow in the low head pump vastly superior in gpm but the amp draw is about 25% of the high head pump. Both of these advantages make the low head pump the right choice for many pond owners.

Part 12 - Pond Construction

No, we are not going to teach you how to build a pond. We will discuss the various materials used to construct ponds, their advantages and disadvantages and some consequences if the pond is poorly designed. Pond system maintenance will be discussed in Part 13.

First we must consider some basic guide lines for proper pond design, including pre-filters, bioconverters, waterfalls, etc. We don't want the pond or any of its parts to leak! The pond system needs to be as automated as humanly practical (easy & self cleaning) it must be a stress free environment for the koi, it should be pleasing to the owner and it must be constructed within the owner's budget (plus or minus $100,000 or so ha, ha!).

The simplest pond to install is the preformed polyethylene pond. It already has properly rounded corners, sloping floors, pre-located bottom drains, etc. After digging the hole and doing the plumbing, making sure it is set level (top of the pond), you only have to fill it, back fill the walls, build the waterfall and complete the aesthetics and the pond is ready for koi! Now, some disadvantages: cost, limited design (it's already made in a specific shape), if the pre-filter, bioconverter media and water returns (waterfalls, jets, etc.) are also made of the chemically inert materials such as plastics, etc. this type pond is prone to a sudden pH crash which could be disastrous and possibly fatal to the koi.

This pH crash could be avoided in several ways, e.g., build the waterfall out of rocks and cement, use cement for bottom drain covers, use rocks in the bioconverter with oyster shells or some other way to create a continuous source of alkalinity to the water. Such things tend to stabilize the pH. This will be discussed in other sections of the curriculum.

The next easiest pond is a liner pond. It has some advantages to the preformed pond and some very distinct disadvantages. It can be almost any size, shape and depth you desire. The biggest drawbacks are leaks (from punctures, tears, plumbing fittings thru the liner) and wrinkles or folds in the liner. These folds or wrinkles catch detritus and can interrupt the circulation in the pond. The liner will deteriorate if exposed to the elements and it is sometimes difficult to hide the liner edge that is above the water line. It is very quick to install once the hole is dug, or once the structural form is completed if an above ground installation is the choice. Punctures and through lines plumbing leaks are the greatest disadvantage but again, like the preformed pond, you must watch for possible pH crashes for the same reasons mentioned earlier. Another advantage is cost as this is usually the least expensive of all pond materials.

Fiberglass ponds have many advantages with only the following two disadvantages: cost and the possibility of a pH crash. The cost of installation can exceed even concrete due to the material and labor costs. If a person has knowledge of using fiberglass or is willing to learn, you can save considerably on the cost. You can make it any shape, size, depth with no wrinkles so no detritus build up or circulation problems can be eliminated. The surface is very smooth and allows less algae buildup, it is inert, there is no long curing time, and best of all can be remodeled and added to without the typical leak or construction worries. This is the one building material that has this advantage over preformed, liner or concrete construction. Fiberglass ponds are also very durable.

One of the 'watch outs' with fiberglass ponds is that non fully cured resins are capable of leaching sufficient styrene monomers into the water which can be lethal to koi. This can be avoided several ways: 1) during the lay up process, a wax can be added to the last coat or 2) the pond can be left empty (no water) for some months until the resin has gone bartol hard (a term that indicates the resin has become completely polymerized, hard all the way thru, and is less flexible), 3) use epoxy as a final coat to seal the surface or 4) don't use styrene as a thinner for the polyester resin; rather use it as it is supplied by the manufacturer (presuming the manufacturer has not used too much thinner in the product as supplied).

Concrete ponds can be constructed using several methods. Before we discuss the various types, we will consider the pros and cons of concrete construction. It can be as costly as fiberglass, can not be remodeled easily without engineering considerations and expertise, otherwise the remodel will most certainly leak and it can crack and leak if not built properly. But even with these negatives, the positives are significant. It is extremely durable, can create virtually any shape, size, etc. It can support massive rockwork weight, and most importantly, after it is cured, it will stabilize the pH, which no other common material will do.

Curing concrete is essential to the construction process otherwise concrete can be weak, crack and leak or increase the pH to the lethal levels for koi. You will know the concrete pond was improperly cured if the pH is extremely high. Curing concrete is a simple process and can be done by filling the pond with water and adding swimming pool (muriatic) acid then allowing it to 'soak' for 30 days to lower the pH, or by adding vinegar to acidify the water, or by acid washing the pond. For more information on curing concrete, see the AKCA Pond Construction Guide.

Freeform concrete ponds are the easiest and quickest to build, the concrete is poured all in one process once the rebar and the plumbing are installed and the pond is filled within hours to slow the curing process (concrete curing/or drying too fast can mean cracks!)

Ponds built above or below grade with bricks, cinder blocks or other types of masonry require rebar and a plaster coat (or some other waterproofing material) to create a waterproof membrane on the inside. This plaster coat is usually a thin layer of sand and cement 1/8" to ½" thick on the entire inside surface and is applied all at one time. This plaster coat is required on gunnite or shotcrete ponds as well just like a swimming pool has a plaster coat. Masonry ponds can be built at the owner's pace, stopped and started at will, but the final plaster coat must be done all at once in a monolithic process. The reason for this is that for concrete to be waterproof there can be no 'cold joints.' A cold joint is jargon for two edges of concrete touching each other when they cured at different times. That's why we say monolithic process (all at the same time) where both edges of the plaster coat are touching each other and curing at the same time.

Part 13 - Pond Maintenance and Troubleshooting.

If the pond, pre-filter, bioconverter, waterfall, stream, jets, etc were built properly with low maintenance and self claiming in mind, chances are that you will find a pond system that has minimal water quality problems. A system that requires a great deal of work to keep it functioning properly (bioconverters hard to clean, no pre-filter, no bottom drains, have to vacuum the pond regularly, dead water areas in the pond, low oxygen levels in the water, no skimmer, overhanging trees or roofs) is a disaster waiting to happen and it will! The more work a system requires, the greater the likelihood for disaster. Very few people are conscientious enough to keep to a strict regimen of maintenance if it requires a great deal of effort. And, conversely, a pond that is self-cleaning does most of the work for itself, thus preserving water quality on a continual basis.

Troubleshooting the possible problems have either been touched on, discussed in detail or are in other sections. We will now discuss a very important problem solving skill: "Leak Detection."

Leak detection is detective work and usually employs the process of elimination. The obvious is to look for water seeping from around the pond, the plumbing, the waterfall, etc. If this fails, on to plan B: ask the owner questions to try to narrow the range of possibilities. Questions to ask include: How long has the pond been in service? When was the leak discovered? How much water is lost each day (is it leaking or just evaporating due to summer heat and wind)? Most common leaks in a pond are where the plumping passes thru the walls or floor of the pond, bioconverter, sump, etc. The most notorious of leaks is the near truth that <u>all</u> waterfalls and streams leak.

This process of elimination will unfortunately take some time if the leak was not obvious such as a crack in the concrete or puncture in the liner by a tree root or something else just as obvious.

To eliminate the waterfall and stream as the culprit, you will have to bypass them for a time sufficient to see if the leak has stopped (usually about 24 hours).

If you or the owner suspect a leak in the pond or the pre-filter (if it is a gravity fed pre-filter), you would not refill the lost water each day allowing the water level to continue to drop until no further water loss is evident. Remember, of course, you can't let all the water leak out with koi in the system! Hopefully in a day or two, the water will stop dropping in the pond. If this happens, you must suspect the leak is within 1.5" of the new water line. If you still can't locate the leak looking closely around the perimeter of the entire pond 1.5" to 5" above or below the water line, you may have to brush all the algae and detritus off the walls a couple of inches on each side of the waterline.

If water keeps dropping with the waterfalls and stream off or bypassed, you may have a leak in the bottom drain. Horrors! You may have to drain the pond and put the koi in a temporary holding pond or tank. If this is necessary, meaning you have checked all other possibilities, you can remove the koi and turn off the pump and just allow the pond to keep losing water and hope at some time it will stop and you can then locate the leak. If you can make a good seal with a standpipe in the bottom drain(s) hole(s), you can check to see if the water drops in the standpipe while not dropping in the pond. If so, the leak is not in the pond but in the system connected to the standpipe. Another way to test plumbing is to have a professional or at least someone who knows how do it. Murphy's Law says the leak will be in the most inaccessible part of the system. If the plumbing pressure tests OK and the bioconverter, pre-filter, waterfall and stream are no longer suspect, you may have to clean all or most of the pond's inside surface to assist in locating the leak.

If before all this, you have determined that the leak is in the waterfall or stream, the owner will have to correct this problem. Most waterfall leaks are not easy to correct but in the AKCA Pond Construction Guide, there are examples of how to build a waterfall or stream that the owners could be advised of.

As for pond maintenance problems, simple observation will provide the best clues. If there are leaves, pine needles, or other detritus floating in the pond or on the bottom, you will need to explain why they need to be removed regularly (organics are bad for water quality). What does the water look like? Green pea soup, yellow or brownish with tannins, foam on the top are all symptoms of problems that could relate to pond maintenance, bioconverters too new, bioconverter needs cleaning, fish overload, inadequate filtration or a multitude of other related problems.

Questions to the owner regarding their maintenance and cleaning regimen will uncover most of these answers. The owner must understand the need for regular scheduled bioconverter and pre-filter cleaning, pond cleaning/vacuuming if not self-cleaning, leaf trap basket and skimmer basket cleaning, 10% to 20% water changes weekly and any other necessary maintenance to maintain good water quality. Also, you must impress upon the owner the consequences of poor pond maintenance. You may have to tell him/her some horror stories you know about without scaring him/her out of the hobby.

Part 14 - Predator control

If the pond wasn't constructed with predators in mind, this may be a difficult problem to resolve. Proper construction for predator deterrent might include vertical walls, water 3 feet deep or deeper, edges of pond having no shallow shelves for raccoons, herons, etc. to stand on, high rocks along the edges so that predators can't approach easily, loose small rocks so that they can't find a comfortable place to stand and/or plant barriers. A net over the pond or an enclosure are very effective but frequently unsightly. An overhead shade cover is a good deterrent for birds as what they can't see, they can't eat! If none of these are practical, a low voltage wire around the pond is effective against raccoons, herons and other wading birds. There are several systems such as 'Fido Shock' that work well and do not hurt animals or people.

Water snakes and alligators will not be deterred by the electric wire system unless they touch it, so for these predators, an enclosure is almost the only solution.

Part 15 - Holding tanks, quarantine and treatment tanks

If the owner does not have a permanent holding tank or no space for one, a perfect holding tank is a 6' dia show tank. It can be set up temporarily and, if some preparation for the bioconverter/filter has been made beforehand, they would have an instant hospital tank.

To have a functioning bioconverter/filter when suddenly needed can be accomplished by taking some bioconverter media such a Japanese mat, Matala mat, reticulated foam, springflo or other media and place it in the top of a updraft barrel bioconverter, in the pre-filter, in front of the pond return, anywhere in the pond system that ensures good water flow thru the media. Keep this media in the pond system at all times.

When a temporary hospital/quarantine tank is needed, set up the tank, get a submersible pump, place it in the tank and plumb it to a plastic trash can, bucket or whatever bioconverter barrel device that was previously chosen to put the aforementioned bioconverter media in. You now have a temporary holding tank/quarantine tank complete with a fully functional bioconverter/filter.

Remember when catching a koi to move to your quarantine/temporary treatment tank, don't lift anything but small koi out of the water with a net. Use the net to guide the koi into a tub, than lift the tub, koi and its water out of the pond and transport it to the temporary holding tank. Again, never use the net to lift anything but very small koi out of the water.

Figure 30 below is the quick-reference plumbing guide we have been referring to throughout this section. It should prove quite useful in your detective work.

The following sections on filtration, water quality, health assessment and maintenance, etc. will add to your expertise allowing you to become a happier hobbyist or KHA.

To find your Total Head Loss for your pond plumbing setup:

1. Take your Total length in Feet of All your Vertical & Horizontal Pipe that's run hopefully in the same Diameter & call this <A>.
2. Now count the number of 90° Elbows used and Add the correct amount of "Elbow friction feet" <B> from the Elbow Loss Chart below to the Total <A>.
3. This will give you your "Total Straight Pipe Run" which is used in the "Friction Loss Chart" below. Find your pumps size in GPH in the chart and using your pipes size (ID) find the Friction Head Loss per 10 Feet or move the Decimal to the left once for Head Loss per 1 Foot.
4. Now take the Friction Loss Number & Multiply by figures <A> + <B> for Friction Head Loss Total per 10 feet.
5. Finally take any Vertical Head Height Above water that's used for say a waterfall and Add it to figure #4.
6. This is the Height in feet to apply to your pumps "Head Curve Chart" which will show you just how many GPH you'll receive at that height from the output.

If John has a 2100 GPH Pump and has a Total of 20' of 1.25" OD Pipe run to his 5' High waterfall and he's using 4 -1.25" 90° Elbows to get it there then his Straight Pipe Length would be 20'. Add to this the 4 Elbows at 3.8' x 4 or another 15.2' to Add to 20' for 35.2' Total of Straight Pipe Run.

Going to the chart @ 2100 GPH pump flow & 1.25" ID Pipe gives us 1.58 x 3.52' = 5.56 Feet for the Total Pipe Friction Loss (Since we're using a 10' length as a standard we move the decimal on 35.2' one place to the left). Then Add the 5' for the waterfall to 5.56' to get your Total Pump Head Loss of 10.56'. Now going to his Pump Head Curve Chart that comes with it he looks up 10.6 feet and sees that at this Height the pump will only put out 1200 GPH.

Charts are courtesy of the the Plastics Pipe Institute

90° Elbow Loss Chart **(Elbow friction feet will ADD to the Total Feet of straight pipe)** **Using 90° Electrical Sweeps & 45° Elbows will Halve the losses**	
1/2" Elbows Add 1.5 Feet for each	3/4" Elbows Add 2 Feet for each
1" Elbows Add 2.5 Feet for each	1.25" Elbows Add 3.8 Feet for each
1.5" Elbows Add 4 Feet for each	

"Friction Loss in "Feet of Head" for **10 FEET** of Straight Schedule 40 Pipe

Gallons/Minute / Hour	1/2 Inch Pipe	3/4"	1"	1.25"	1.5"	2"
1 GPM / 60 GPH	0.21	0.05				
2 GPM / 120 GPH	0.42	0.10	0.06	0.01		
5 GPM / 300 GPH	2.34	0.57	0.17	0.04	0.02	
7 GPM / 420 GPH	4.31	1.05	0.32	0.08	0.04	
10 GPM / 600 GPH	8.20	2.0	0.60	0.16	0.07	0.02
15 GPM / 900 GPH	45.23	4.25	1.28	0.33	0.15	0.05
20 GPM / 1200 GPH	NA	7.23	2.18	0.56	0.26	0.08
25 GPM / 1500 GPH		16.34	3.29	0.85	0.40	0.12
30 GPM / 1800 GPH		22.53	4.61	1.19	0.55	0.16
35 GPM / 2100 GPH		NA	6.91	1.58	0.75	0.22
40 GPM / 2400 GPH			9.63	2.02	0.94	0.28
45 GPM / 2700 GPH			12.41	2.51	1.17	0.34
50 GPM / 3000 GPH			15.22	3.05	1.43	0.42

60 GPM / 3600 GPH			20.07	6.83	2.01	0.58
70 GPM / 4200 GPH			NA	8.23	3.42	0.78
75 GPM / 4500 GPH				9.54	4.12	0.88
80 GPM / 4800 GPH				12.21	4.53	0.99
90 GPM / 5400 GPH				NA	5.55	1.24
100 GPM / 6000 GPH					6.91	1.50
Gallons/Minute / Hour	1/2 Inch Pipe	3/4	1"	1.25"	1.5"	2"

Friction loss chart (courtesy Multi Duty Manufacturing)

Friction Loss Per 100 Feet of Pipe of plastic pipe

Pipe Diameter	1 in.		1 1/2 in.		2 in.		2 1/2 in.		3 in.		4 in	
USgph	SCH 40	SCH 80	SCH 40	SCH 80	SCH 40	SCH 80	SCH 40	SCH 80	SCH 40	SCH 80	SCH 40	SCH 80
120	0.55	0.88	0.07	0.10	-	-	-	-	-	-	-	-
300	1.72	2.75	0.22	0.30	0.066	0.10	0.038	0.05	0.015	0.02	-	-
420	3.17	5.04	0.38	0.55	0.11	0.15	0.051	0.07	0.021	0.028	-	-
600	6.02	9.61	0.72	1.04	0.21	0.29	0.09	0.12	0.03	0.04	-	-
900	12.77	20.36	1.53	2.20	0.45	0.62	0.19	0.26	0.07	0.09	-	-
1200	21.75	34.68	2.61	3.75	0.76	1.06	0.32	0.44	0.11	0.15	0.03	0.04
1500	32.88	52.43	3.95	5.67	1.15	1.60	0.49	0.67	0.17	0.22	0.04	0.06
1800	46.08	73.48	5.53	7.95	1.62	2.25	0.68	0.94	0.23	0.31	0.06	0.08
2100	-	-	7.36	10.58	2.15	2.99	0.91	1.25	0.31	0.42	0.08	0.11
2400	-	-	9.43	13.55	2.75	3.83	1.16	1.60	0.40	0.54	0.11	0.14
2700	-	-	11.73	16.85	3.43	4.76	1.44	1.99	0.50	0.67	0.13	0.17
3000	-	-	14.25	20.48	4.16	5.79	1.75	2.42	0.60	0.81	0.16	0.21
3600	-	-	19.98	28.70	5.84	8.12	2.46	3.39	0.85	1.14	0.22	0.30
4200	-	-	-	-	7.76	10.80	3.27	4.51	1.13	1.51	0.30	0.39
4500	-	-	-	-	8.82	12.27	3.71	5.12	1.28	1.72	0.34	0.45
4800	-	-	-	-	9.94	13.83	4.19	5.77	1.44	1.94	0.38	0.50
5400	-	-	-	-	12.37	17.20	5.21	7.18	1.80	2.41	0.47	0.63
6000	-	-	-	-	15.03	20.90	6.33	8.72	2.18	2.93	0.58	0.76
7500	-	-	-	-	-	-	9.58	13.21	3.31	4.43	0.88	1.16
9000	-	-	-	-	-	-	13.41	18.48	4.63	6.20	1.22	1.61

10500	-	-	-	-	-	-	-	-	6.16	8.26	1.63	2.15
12000	-	-	-	-	-	-	-	-	7.88	10.57	2.08	2.75
15000	-	-	-	-	-	-	-	-	11.93	16.00	3.15	4.16
18000	-	-	-	-	-	-	-	-	-	-	4.41	5.83
21000	-	-	-	-	-	-	-	-	-	-	5.87	7.76
24000	-	-	-	-	-	-	-	-	-	-	7.52	9.93

Friction loss in PVC fittings in equivalent feet of straight pipe

This chart gives friction losses for your given flow rate per 100 feet of pipe. Example: If you have 60 gallons per minute and you're using 2 inch schedule 80 pipe and you have a 160 feet of pipe, your friction loss is 8.12 x 1.6 = 12.99 feet. Note: It is best to keep your friction loss (per 100 feet of pipe) to less than five feet.

NORMAL PIPE SIZE (IN)	**1"**	**1 1/2"**	**2"**	**2 1/2"**	**3"**	**4"**
90° ELBOW, STANDARD	2.25	4.0	6.0	8.0	8.0	12.0
45° ELBOW, STANDARD	1.4	2.0	2.5	3.0	4.0	5.0
INSERT COUPLING	1.0	1.5	2.0	3.0	3.0	4.0
GATE VALUE	.6	1.0	1.5	1.6	2.0	3.0
MALE-FEMALE ADAPTERS	2.0	3.5	4.5	-	6.5	9.0
TEE - FLOW through RUN	1.7	2.7	4.3	5.1	6.3	8.3
TEE - FLOW THROUGH BRANCH	6.0	8.0	12.0	15.0	16.0	22.0