

# Pond Plumbing Primer

## Ver. 2

**Those that can, do. Those that can't, teach!**

**As you can see this is version 2, so as I learn more I will try to update and correct my mistakes.**

Please keep this in mind when reading through the following pages. I'm a doer by nature but feel this is important enough to try and pass on. Try being the key word, I hope it helps some of you about to take on these huge endeavors we call ponds.

I don't know where to start as this subject is huge. Let me start by saying I'm no engineer or math wiz, all that I'll write about was pieced together from time spent here at Koiphen, other boards, and personal experiences while building my ponds. There may be more information available but this is a good starting point for most people wanting to build a pond. The good news is I'll try and speak in the absolute simplest terms I can. If I screw up some of the terminology I'm sure the technical types will let me know.

It's hard not to start with the basics of good **Koi** pond design but that's an entirely different subject and can be addressed elsewhere. The plumbing principles that I'll try to discuss are universal to all ponds.

The one overriding principle to keep in mind, as it weaves into all aspects of pond plumbing, is that water will try to seek its own level. Repeat after me: **Water will seek its own level!**

The next most important thing is to plan your pond and plumbing ahead of time.

Garrett

## **INDEX**

For easy reference I'll index page numbers here.

- 1) Intro
- 2) Index
- 3) Planning
- 4) Physical piping
- 5) Sweep Elbows
- 6) Flexible PVC
- 7) Pipe Elevations
- 8) Head Explained
- 9) Flooded Suction vs. Suction Lift
- 10) Measuring Head
- 11) Static Head Examples
- 12) Friction Head
- 13) Reading The Friction Loss Chart
- 14) Friction Loss Chart
- 15) Friction Example 2" Pipe
- 16) Friction Examples 2" Pipe w/Sweeps
- 17) Friction Example 3" Pipe
- 18) Friction Example Mixed 2" & 3"
- 19) Total Dynamic Head
- 20) Quick Review & A Note On Air Piping
- 21) Pressurized Filters
- 22) UV's (Ultra Violet Sterilizers)
- 23) UV Examples
- 24) Gravity Flow
- 25) A Draining Tank
- 26) Draining tanks Drawings
- 27) Propulsion Elevation Chart
- 28) Gravity Flow II - At Rest
- 29) Gravity Flow III – Pump Start
- 30) Gravity Flow IV – Chain Reaction
- 31) Calculate Draw Down
- 32) Velocity – Purge Valves
- 33) Draining Below Grade
- 34) Sizing Pumps
- 35) Flow Charts, Wave I & II
- 36) Flow Charts, Dragon & High Speed
- 37) Let's do a whole pond!
- 38) Pond Schematic
- 39) Calculating Energy Costs
- 40) Conclusion

## **PLANNING!**

I cannot emphasize how important this is. The good news is I'm not talking about every little detail, in my own experience I've found you need to be quite flexible once shovel hits dirt, but overall flow rates and pond turnover should be known.

For most ponds other than water gardens (no fish) the turnover rate should be in the 1-2 hour range. This means the entire volume of pond water should cycle through some sort of filtration (mechanical & biological) during that timeframe. Because larger ponds have more water and are generally more stable, they can be on the slower end and smaller ponds, 3000 gallons and under should aim for a faster turnover rate.

Not knowing what kind of pond you'd like to build we'll stay away from any lengthy discussion on this. There are many threads and books available on proper pond design and you should have that down pat when planning the plumbing portion. One thing I will note: you will notice as we go along the advantage of a pond being semi-raised out of the ground. It becomes more formal looking but will benefit ease of plumbing in many areas. Another way, if you are lucky, is to take advantage of a sloping property to accomplish much of the same.

***The thing to know ahead of time is how much water will flow from any given pick-up point to any given return point.*** It's only then that the proper pipe sizes can be determined. Once the plumbing is complete the math can be done for proper pump size to not only give you the flow that was planned for, but do it in the most efficient way; less watts per gallon pumped.

Some common rules of thumb that can be applied to help in figuring how much flow you want.

Waterfalls: for a sheet waterfall a good rule is 100 GPH per inch of waterfall. If your falls are 24" wide you will need a minimum of 2400 GPH. This is for a very smooth rock perfectly level. If in doubt and you want a nice healthy falls double that number.

Gravity Flow Bottom Drains: the typical flows for these are in the 3K GPH to 3.8K GPH range. There are many factors involved and will be discussed in detail later.

A little prompt on upper ponds and rivers: while these are a nice addition to any pond the amount of water contained in these has to be taken into account. On an upper pond, it takes a certain amount of water height to force water over the falls – the higher the flow rate the higher this will be. When the pump shuts off this water will lower until it evens out with the falls rock sending the extra to the pond below. Depending on sizes of ponds, etc., this could force water in the lower pond to overflow. The same can be said for rivers, though these seem to hold quite a bit more water. Surface area of the lower pond is the key. The larger the surface area the less the water height will raise.

## **LET'S TALK PIPING**

This obviously is the heart of the plumbing or more accurately the veins. I'll give a brief overview of pipe type and some of the fittings which can help save on operating costs.

PVC and ABS pipe are the main types of pipe we use in our systems. These are the cheapest and easiest to use for our purpose. PVC pipe can be dual-rated for pressure or DWV (Drain, Waste & Vent or sewer piping). ABS is always rated as DWV.

In some states ABS is not allowed and the box stores (Home Depot, Lowe's) will carry DWV fittings in PVC. In other states where ABS is allowed they typically stock the ABS as it's slightly cheaper. All states and stores carry PVC pressure pipe and fittings in 2" and under.

The piping we want to use is rated as Schedule 40. It's a fairly thick walled pipe and will withstand not only pressure from within but external pressures as well. They have thinner schedules but I would avoid them entirely for our needs. Because a lot of our piping is under heavy dirt and water loads this is the wrong place to try and save a penny.

With that said I would prefer to run all PVC but ABS, even though not rated for pressure, will work fine for our needs. Because it's not rated for pressure I had a hard time finding what it will handle and the best I could come up with was 20 PSI and under. If you do the piping calculations for the average pond you will see that the head rarely builds to those levels. (1 PSI = 2.3' head) So 20 PSI = 46' of head. If your system has that much head I failed in what I was trying to explain with this thread. Or you have a really, really high waterfall. ☺

You can also mix and match PVC & ABS. They are a different type of plastic and will require a special glue called transition glue for joining them. This does drop the rating for the PVC down to that level but once again it should never be a concern.

One thing I will mention is the size of the glue up area on the fittings. You will notice the area is much larger on pressure fittings versus DWV. This is usually not an issue until working with flex PVC which we will discuss later.

As mentioned PVC is fairly easy to work with even for the newest of pond builders. No expensive tools are needed and glues are fairly cheap. Here's a good link to learn more about pipe ratings and glue up techniques.

[Plastic Pipe & Fitting Association](#)

Lastly for those of you a little more daring, PVC can be heated and then bent to make sweeping bends or some small offsets. Just about anything that can generate a large amount of heat can be used, weed torches & grills to name a few. Something to keep in mind.

## **SWEEP ELBOWS**

When looking at the friction equivalent charts (included on page 14) you can see that the longer the sweep the less friction is produced. The standard off-the-shelf sweeps available are the DWV ones. They come in medium, medium as it's compared to pressure 90°s, and long sweep bends. The only downfall is that they do take up extra room but are well worth it for the reduced restriction in flow. If room is critical they also come in what's called a street configuration. One side of the fitting will have a nominal pipe size and can be glued into another fitting. Pretty handy sometimes. There are also the odd bend sizes, 22° & 66° another handy item to have in the arsenal. The thing to look out for is the industry gave them different names, plumbers refer to them as bends: 1/16 Bend = 22.5°, 1/8 Bend = 45°, 1/6 Bend = 60°, 1/4 Bend = 90°, just for quick reference these are based on a 360° circle. Divide 360 by the denominator to get the degree equivalent.

DWV fittings also have some lower restriction "T"s & "Y"s that can be incorporated. You'll find it very helpful when doing the physical plumbing to at least have an idea of what's available. There's always that odd corner you need to go around etc. Here's a good selection with pictures from Lasco Supply. Hopefully the link is good, if not a quick Google search for DWV fittings should produce some pictures.

### [Lasco Fittings](#)

As an option electrical sweeps can also be used. The good news is these are available in all PVC sizes and available in schedule 40 pipe. They range in size from a standard 12" sweep up to a 4' sweep. The odd size bends of 22.5° & 60° are longer stretched bends also. Definitely a nice option to overcome certain problems.



## **FLEXIBLE PVC**

Here's one of the best things invented for pond plumbing. It is basically a flexible pipe as the name implies. In 1½" & 2" sizes it's quite flexible and works well in filter pits to overcome some of the oddest of the bends needed to hook up filtration, etc. It also makes a nice vibration dampener to insulate the pump. If used right it can replace several fittings with one long sweeping multi-directional bend.

In 3" & 4" it will still bend but it's not as flexible for close quarter bends as the smaller sizes. It may be the only way to make certain connections though so it's another one of the items that's good to have in the arsenal.

For glue-up purposes it is best used with pressure fittings. The larger glue up area will ensure a better bond and hold. Because the flex has a slight ribbed spiral on the outer jacket, as much glue-up area as possible is needed. From all that I've read it's best to use one of the hotter blue glues and no primer. When in doubt always consult the manufacturer.

The plus side of using this product for long sweeping bend is offset by its higher friction. As with the outside, the inner wall is also a ribbed spiral. From what I can find on manufacturers data for friction losses, it is about 5% more than regular PVC. This may not seem like a lot but when coupled with the curving of the flex the friction increases even more. I would use 10% - 15% to compensate for the bending.

While it's tempting to use it for long curvy runs I wouldn't recommend it. Regular PVC in the smaller sizes (up to 2") is flexible enough to overcome some bending, and if buried, will easily stay in place.

As for burying flex PVC I'd recommend against it. In shorter runs breaking through the surface it would be fine but longer lengths buried at any kind of depth could flatten or oval out. This could lead to reduced flow, and if near a connector or coupler could possibly leak over time. Common sense would be your best guide here. Another drawback would be if you left a high spot in the piping. Air could accumulate in the high spot and further reduce flow.

This site has some good info.

[Flex PVC](#)

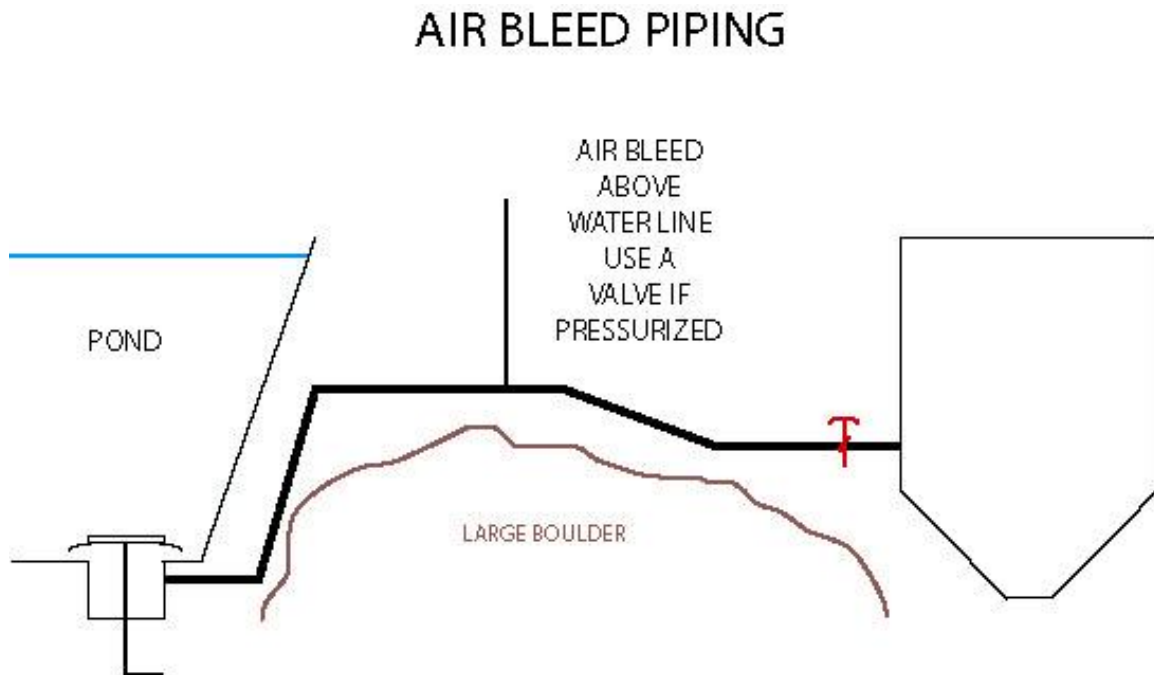
## PIPE ELEVATIONS

I touched on this with the flex, but it is important enough to make mention of again. When running pipes horizontally it is important not to create high spots. All water has gas entrained in it. For the purpose of our discussion we'll call it air. There are several things that could release this air in the piping; friction and turbulence being the biggest culprits. Suffice it to say that if air becomes trapped within the pipe it reduces the overall size internally and could greatly reduce flow.

This is especially important for gravity flow where the pipe sizes are larger and flow is slower. In smaller pipe size with higher flows the velocity within the pipe can pull the air along with it avoiding some of these problems, it's still good practice to avoid high spots anyway.

There are times though that you may have to go over something. In gravity flow where the pipes are generally deep this seems to happen more often. For these situations there is an answer though. You can add an air bleed at the high spot to allow air a way out (see drawing). Unfortunately this cannot be done the same for pressure piping. A valved bleed could be used, but would require your input to operate.

If possible all piping should be slightly elevated in the direction of flow to assist with air removal. Level works but a slight incline is better.



## **LET ME TRY AND EXPLAIN HEAD**

This is probably a term you've heard on the boards but don't fully understand. Head is a measure of elevation, suction, and friction pressures and is measured in feet of Head. Of course any fraction of Head can be applied, as you will see later when discussing calculations for solving for Head.

Just for general information so you can get a feel for what this pressure may be:

1 PSI = 2.3' of Head.

It doesn't seem like much but because we run our pumps 24/7 any pressure at all will cost us.

There are two basic types of head that effect what we do plumbing a pond. They are measured from pond water level for the most part as explained in the pictures (worth a thousand words).

*1) Static Head: This is actually a combination of discharge head and suction head. It basically is a vertical measurement from water surface to discharge height in an open ended pipe or water level height if pumping into a higher tank. It can also be referred to as elevation head.*

*Discharge Head: the vertical distance from the pump outlet to the discharge height as explained above.*

*Suction Head: the vertical distance from the water level to the pump inlet.*

*2) Friction Head: the resistance to the flow of water from friction on the inner pipe wall, varying velocities within the pipe, and other fittings and restrictions.*

When we add both Static Head & Friction Head together we get *Dynamic Head*. This has to be calculated for the suction side and the discharge (elevation) side of the pump. Adding both of those gives us *Total Dynamic Head*.

*Total Dynamic Head* is the number we will calculate for when sizing piping and then eventually pumps for your pond. Many people overlook these simple calculations and just buy bigger pumps. In this age of soaring electricity rates conserving energy should be one of our goals. When we get to sizing pumps we can do some cost breakdowns so you can see how correct sizing can save \$\$\$ in the long run.

Just a quick note, Head is not always a negative factor. It also can be a driving force. Above elevation head is mentioned and as you will see later in the gravity flow section this elevation is a positive factor in making water move

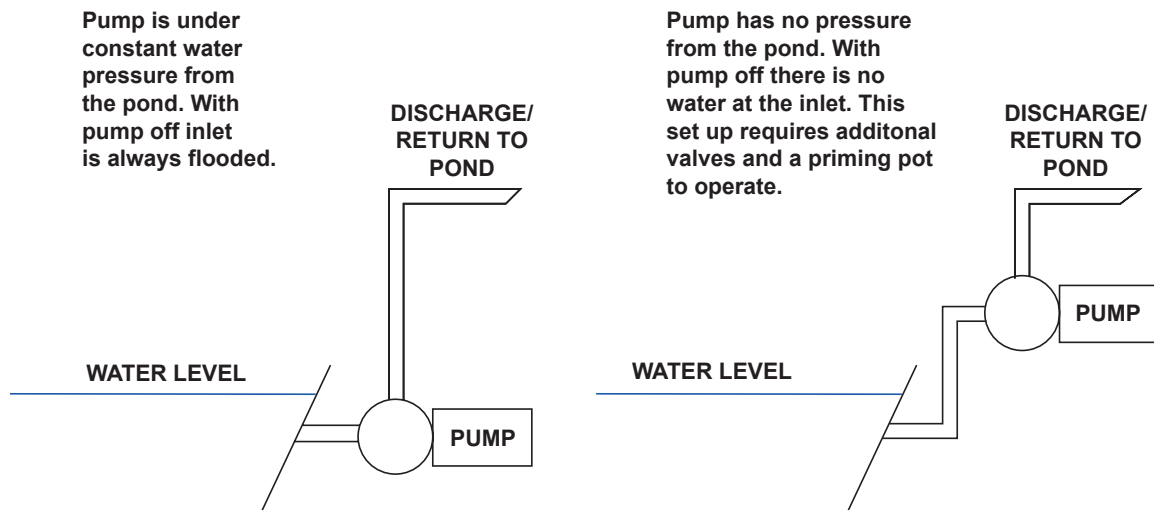
## **FLOODED SUCTION VERSUS SUCTION LIFT**

I'll add this before showing the head calculations, because it explains some of what was discussed previously.

Many people confuse flooded suction with gravity flow; it is not the same. Flooded suction will draw directly from a pond pick-up point (skimmer, mid level, or bottom drain) and the pump will be located below the water line. We are not talking about a submersible pump rather one located outside the pond but below water level. Gravity flow will be discussed later and you will see the difference.

Suction lift can come from any of those same points but the pump will be situated above the water line. You can see where the term comes from; water is actually lifted above the water line by the pumps suction.

### **FLOODED SUCTION vs. SUCTION LIFT**



## MEASURING HEAD

Please bear with me, this isn't easy to word but I did add pictures and we all know they speak a thousand words.

*Static Discharge Head:* this is probably the easiest of the measurements. No fancy math and most time a tape measure will do the trick. You can use a laser level if you want to be really exact. ☺ You would measure the vertical height from pump outlet to the discharge end of the pipe. If you are pumping into a raised barrel or upper pond the measurement would be from pump outlet to upper water level.

*Static Suction Head:* This can be a little trickier. This measurement is from water line to pump inlet. If the pump is located above the water line it will be a positive number and added to the elevation head. If it's located below the water line it becomes a negative number and is subtracted from the elevation head.

Adding both of these will give us *Total Static Head*.

This is half the equation for finding *Total Dynamic Head*, I will discuss the other half (friction head) later.

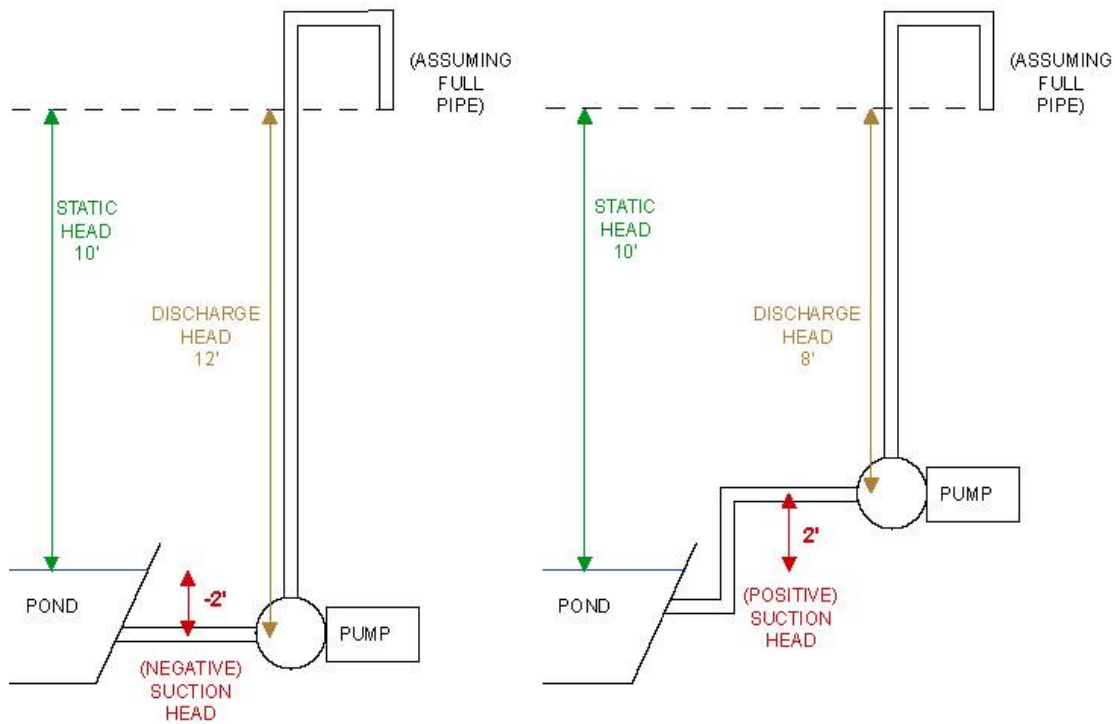
In the examples below of pumping to an upper pond or tank you'll notice the static head is measured to the upper water level. A quick note to clear some misconceptions that I've heard, the weight of the pond water does **not** play into the equation. Likewise if you used an 8" pipe to go up it wouldn't matter. The pressure at the pump discharge remains the same. Think of it this way, when you turn the pump on you're not lifting all the weight in any of these pipes or tanks, you're displacing the water in them. Sorry but that's the best explanation I can give. If you're really interested the Internet has a lot of info; just do a search or two.

**FYI:** Our pumps like to push water and not pull, so suction head should be kept to a minimum. A brief explanation of how our pumps work will show this.

In our centrifugal pumps the impeller throws water outward creating a low pressure area where that water was or simply a vacuum. If this vacuum becomes low enough, vaporization begins forming bubbles which will lead to cavitations and the impeller being ruined. If the vacuum becomes too low the water will boil even at room temperature. This boiling point is approximately 26' of suction head in the real world. Not that much as you will see later.

While I break down suction & discharge static Head the key is waterline to discharge point or upper water line. As you'll see later when doing friction calculations it may be better to separate them so making you aware of the difference is all I'm trying to accomplish.

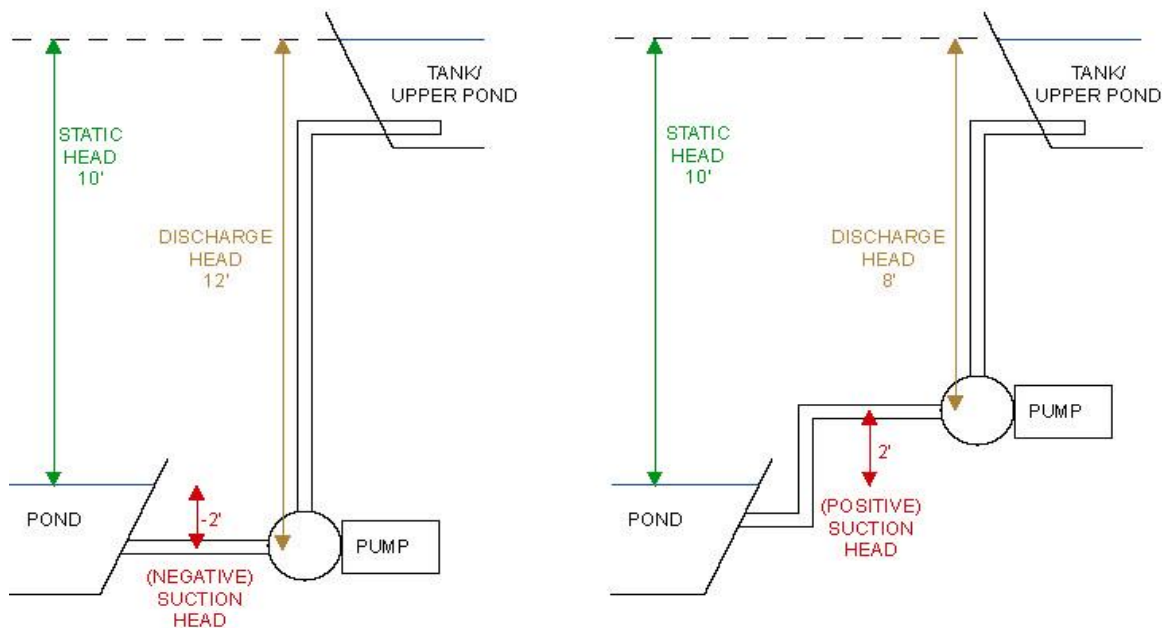
## STATIC HEAD, (STATIC) DISCHARGE HEAD, (STATIC) SUCTION HEAD



Note: Suction head and discharge head should = static head. Take note in the case of the flooded suction pump suction head would be a negative number.

## STATIC HEAD, (STATIC) DISCHARGE HEAD, (STATIC) SUCTION HEAD

PUMPING TO UPPER TANK OR POND



Note: Suction head and discharge head should = static head. Take note in the case of the flooded suction pump suction head would be a negative number.

## **FRICTION HEAD**

You knew we had to do math sooner or later, and this is where. Friction head as explained already is the resistance to the flow of water from friction on the inner pipe wall and other fittings and restrictions. ***Keep in mind the way to overcome friction is with pressure. Developing pressure costs money, so in the long run it's easier to alleviate the friction with a small up front cost in larger piping, rather than build pressure at a continual cost over the life of the pond.***

Why does friction increase with velocity? What causes the friction to rise in the pipes is turbulence. When water flows smoothly it takes less energy to move it. When water becomes turbulent it no longer flows in a straight path increasing the distance it moves, requiring more energy. That energy for us is the friction rating.

All materials have friction and for this discussion we'll call it drag. Because of this drag on the pipe wall, the water in the outer part of the pipe will move slower than the water moving in the inner part of the pipe. This is in part where the turbulence starts. The smoother the bore the less turbulent the flow. Even though PVC has a very smooth inner wall it does have some imperfections, these will also add to the turbulence. Then there are the bend fittings. When water travels through these it will have a faster velocity on the outside of the bend. If the bend is sharp enough it will cause little eddies to form on the inner curve because the speed differential is so much greater, contributing to more turbulent flow. This is why sweep fittings have less of a friction rating than normal bends, the speed differential between inner & outer bend is less and the inner bend will have less of a chance of forming these eddies.

Keep this in mind when doing the physical piping; you can see now why it's important to keep the ends of the pipe you cut square. Any added space or imperfection can cause turbulent flow over that area increasing friction.

With that in mind, as velocity increases so do all the factors driving up the friction within the pipe. This is not linear though, friction is a function of the square of the velocity – So when doubling the flow rate you're actually quadrupling the friction. While this can be discussed at length, I hope my plain English version helped explain it some.

There are actual complicated formulas for determining friction within piping at differing velocities. I will focus on PVC and ABS as they are the most commonly used pond piping materials. The good news is the manufacturers have done most of that math for us. There are friction loss charts available at many places on the Internet; a simple search should find one.

There are also friction loss charts for fittings in these pipe runs. These are measured in equivalent pipe lengths making the math easier for us in the end. The manufacturers have done the math for these lengths also.

There is still some math that needs to be done but it's relatively simple math so hang in there.

## **READING THE FRICTION LOSS CHART**

I took one of my favorite charts and copied the information for the most common pipe sizes and flows into this chart.

The top is pipe size. One thing to keep in mind is the numbers are for 100' of pipe. You may say I'll never have that much pipe on a run but when all the calculations are done you may be surprised. Either way it can be broken down to whatever lengths you end up with. I'll explain that later.

You'll notice velocity in gallons per minute on the left of the chart. This is important because as discussed friction within the piping increases with velocity. This is why it's so important certain decisions regarding flows be made prior to laying the first pipe in the ground.

This brings us to the second part of the chart. The manufacturers blessed us again by doing the work for us and making the math simple. For every fitting (almost) there is an equivalent pipe length assigned. Basically what this means is that for every fitting you'd be adding a certain amount of straight pipe to the system (for calculation purposes). In the chart you'll see a standard 2" elbow adds the equivalent of 6' of pipe. Sweeps add a little less.

I've made the chart its own page so it can be printed out. I recommend printing it so it can be referenced when discussing calculations later. A quick note on the sweep 90's & inlet/outlet fittings: there is little pipe friction information available on these because they are not regularly used for pressure applications. The numbers in my chart are the best I could come up with after discussions with several people more comfortable with the math than I am. The numbers may not be exact but will work for what we need to calculate.

### FRICION LOSS CHART FOR PVC (PER 100' OF PIPE)

GPM	1½"		2"		3"		4"		6"	
	FPS	HEAD	FPS	HEAD	FPS	HEAD	FPS	HEAD	FPS	HEAD
10	1.62	0.72	0.98	0.21	0.44	0.03				
15	2.42	1.53	1.46	0.45	0.66	0.07				
20	3.23	2.61	1.95	0.76	0.88	0.11				
25	4.04	3.95	2.44	1.15	1.1	0.17				
30	4.85	5.53	2.93	1.62	1.33	0.23				
35	5.66	7.36	3.41	2.15	1.55	0.31				
40	6.47	9.43	3.9	2.75	1.77	0.4				
45	7.27	11.73	4.39	3.43	1.99	0.5	1.15	0.13		
50	8.08	14.25	4.88	4.16	2.21	0.6	1.28	0.16		
60	9.7	19.96	5.85	5.84	2.65	0.85	1.53	0.22		
70			6.83	7.76	3.09	1.13	1.79	0.3	0.79	0.04
75			7.32	8.82	3.31	1.28	1.92	0.34	0.84	0.05
80			7.8	9.94	3.53	1.44	2.05	0.38	0.9	0.05
90			8.78	12.37	3.98	1.8	2.3	0.47	1.01	0.06
100			9.75	15.03	4.42	2.18	2.56	0.58	1.12	0.08
125					5.52	3.31	3.2	0.88	1.41	0.12
150					6.63	4.63	3.84	1.22	1.69	0.16
175					7.73	6.16	4.48	1.63	1.97	0.22
200					8.83	7.88	5.11	2.08	2.25	0.28
250					11.04	11.93	6.4	3.15	2.81	0.43
300							7.67	4.41	3.37	0.6
350							8.95	5.87	3.94	0.79
400							10.23	7.52	4.49	1.01
450									5.06	1.26
500									5.62	1.53
750									8.43	3.5
1000									11.24	5.54

### FRICION LOSS IN PVC FITTINGS IN EQUIVALENT FEET OF STRAIGHT PIPE

	1½"	2"	3"	4"
90° Elbow, Standard	4	6	8	12
90° Medium Sweep	3	4.6	6.2	9.2
90° Long Sweep	2.12	3.2	4.3	6.4
45° Elbow, Standard	2	2.5	4	5
22° Elbow	.96	1.22	1.96	2.44
60° Elbow	3.04	3.8	5.4	7.6
Gate Valve	1	1.5	2	3
Water Inlet	1.3	2	3.1	4.2
Return outlet	1	1.5	2	3
Male-Female Adapters	3.5	4.5	6.5	9
Tee Flow-Thru Run	2.7	4.3	6.3	8.3
Tee Flow-Thru Branch	8	12	16	22

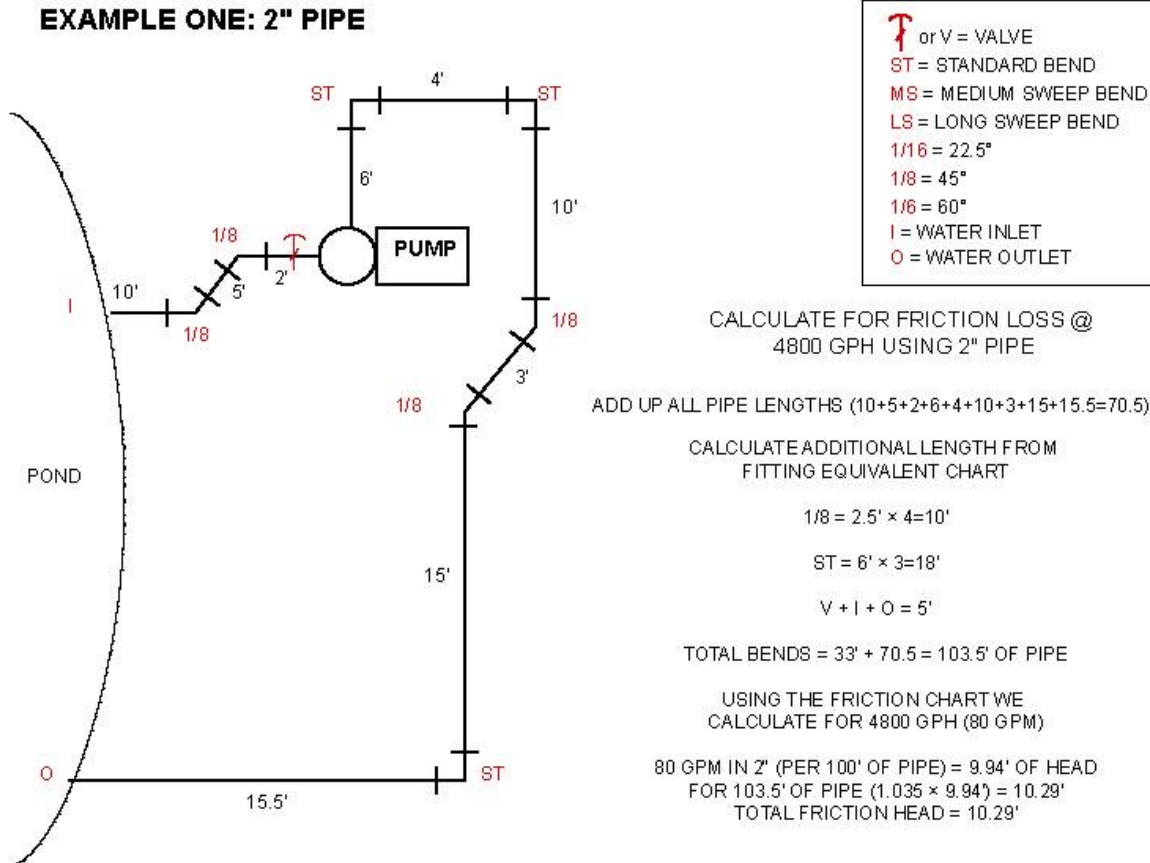
**GPM = Gallons per minute, multiply by 60 for gallons per hour**

**FPS = Feet per second, this is the velocity of the water within the pipe**

**Head = Head measured in feet.**

## SOME EXAMPLES:

You'll start to get a feel now why the flow rates need to be planned ahead of time. The flow rate needs to be known so the proper friction calculations can be done. I'll try and keep all the needed info in the drawing so it makes more sense. *The one thing to remember is that we'll only be discussing the friction end of the piping here. Elevation head comes into play when doing a final calculation to size the pump.*



Hopefully the above drawing explains how to add lengths of pipe and calculate in fittings. It may help to have the friction loss chart printed out and available while viewing these.

In the following two drawings, I'll attempt to show what changing a few fittings can do to lower head. It may not seem like much, but every foot of head on our low pressure pumps can make a difference. Depending on the piping, you may even be able to downsize a fraction of horse power on a pump saving money in operating expenses.

**NOTE:** The easiest way I can describe calculating for less or more than 100' of pipe would be to take the friction for 100' of pipe @ the given flow rate and make your pipe length a percentage of that. In the above example we have 103.5' of 2" pipe.

$$103.5\% = 1.035 \times 9.94' = 10.29' \text{ (9.94' from charts for 100' of 2" pipe)}$$

CALCULATE FRICTION LOSS @  
4800 GPH USING 2" PIPE  
WITH LONG SWEEP BENDS  
ADD UP ALL PIPE LENGTHS (10+5+2+6+4+10+3+15+15.5=70.5)  
CALCULATE ADDITIONAL LENGTH FROM  
FITTING EQUIVALENT CHART  
 $1/8 = 2.5' \times 4 = 10'$   
 $LS = 3.2' \times 3 = 9.6'$   
 $V + I + O = 5'$   
TOTAL BENDS = 24.6' + 70.5 = 95.1' OF PIPE  
USING THE FRICTION CHART WE  
CALCULATE FOR 4800 GPH (80 GPM)  
80 GPM IN 2" (PER 100' OF PIPE) = 9.94' OF HEAD  
FOR 95.1' OF PIPE (95.1 x 9.94) = 9.45'  
TOTAL FRICTION HEAD = 9.45'

**EXAMPLE ONE: 2" PIPE w/ SWEEP BEND**

The diagram illustrates a piping system layout. A curved line on the left represents a **POND**. The system includes a **PUMP** connected to a vertical riser pipe. Key components and dimensions are as follows:

- Horizontal Pipe (Left):** 10' long, with a **1/16"** valve.
- Horizontal Pipe (Bottom):** 15.5' long, with a **LS** (Locking Stop) at the right end.
- Vertical Pipe (Right):** 15' long, with a **LS** at the bottom and a **1/16"** valve near the top.
- Horizontal Pipe (Top):** 4' long, with **LS** at both ends.
- Vertical Pipe (Left of Pump):** 6' long, with a **LS** at the top.
- Pump Section:** A circle labeled **PUMP** is connected to a vertical riser pipe. A **1/16"** valve is located on the riser pipe, 2' above the pump.
- Horizontal Pipe (Top of Pump):** 5' long, with a **1/16"** valve.
- Horizontal Pipe (Bottom of Pump):** 2' long, with a **1/16"** valve.
- Horizontal Pipe (Right of Pump):** 3' long, with a **1/16"** valve.

5

CALCULATE FRICTION LOSS @  
4800 GPH USING 2" PIPE  
WITH LONG SWEEP BENDS

ADD UP ALL PIPE LENGTHS (10+5+2+6+4+10+3+15+15.5=70.5)

CALCULATE ADDITIONAL LENGTH FROM  
FITTING EQUIVALENT CHART

$$1/16 = 1.22 \times 4 = 4.88'$$
$$LS = 3.2' \times 3 = 9.6'$$
$$V + I + O = 5'$$

TOTAL BENDS = 19.48' + 70.5 = 89.98' OF PIPE

USING THE FRICTION CHART WE  
CALCULATE FOR 4800 GPM (80 GPM)

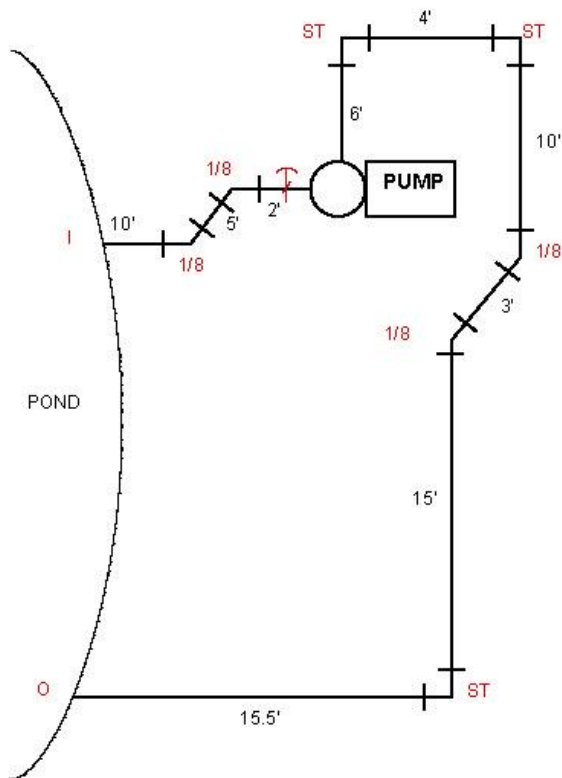
80 GPM IN 2" (PER 100' OF PIPE) = 9.94' OF HEAD  
FOR 89.98' OF PIPE (89.98 x 9.94) = 8.94'  
TOTAL FRICTION HEAD = 8.94'

16 ©2006 Garrett A. Klein

## NOW FOR SOME REAL REDUCTIONS

By enlarging the pipe size throughout, even with restrictive fittings, we can significantly reduce Head. Yes there is a cost increase for larger pipe and fittings, but this should easily be offset by the upfront cost of a smaller pump and in the long term by reducing operating costs over the life of the pond.

### EXAMPLE TWO: 3" PIPE



**T** = VALVE  
**ST** = STANDARD BEND  
**MS** = MEDIUM SWEEP BEND  
**LS** = LONG SWEEP BEND  
**1/16** = 22.5°  
**1/8** = 45°  
**1/6** = 60°  
**I** = WATER INLET  
**O** = WATER OUTLET

CALCULATE FOR FRICTION LOSS @  
4800 GPH USING 3" PIPE

ADD UP ALL PIPE LENGTHS ( $10+5+2+6+4+10+3+15+15.5=70.5$ )

CALCULATE ADDITIONAL LENGTH FROM  
FITTING EQUIVALENT CHART

$$1/8 = 4' \times 4 = 40'$$

$$ST = 8' \times 3 = 24'$$

$$V + I + O = 5.1'$$

TOTAL BENDS =  $69.1' + 70.5 = 139.6'$  OF PIPE

USING THE FRICTION CHART WE  
CALCULATE FOR 4800 GPH (80 GPM)

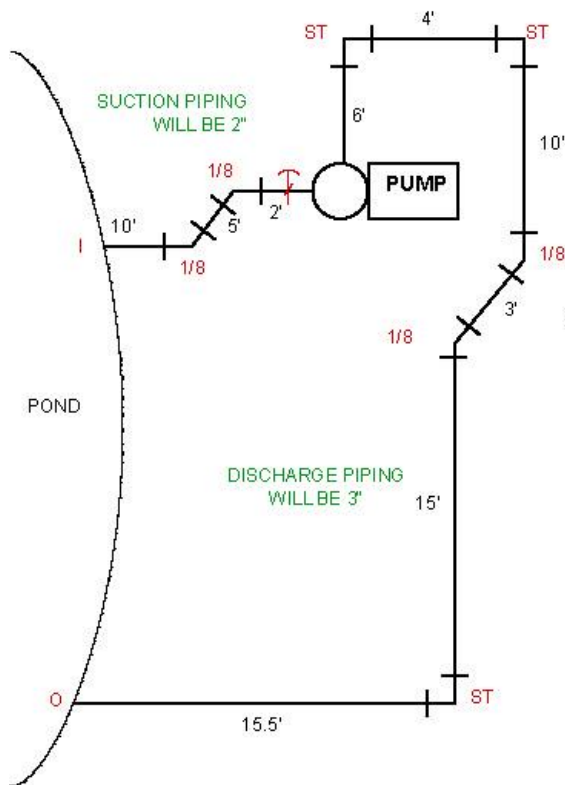
80 GPM IN 3' (PER 100' OF PIPE) = 1.44' OF HEAD  
FOR 139.6' OF PIPE ( $1.396 \times 1.44$ ) = 2'  
TOTAL FRICTION HEAD = 2'

You can see by using 3" pipe instead of 2", even the 2" with less restrictive fittings, we reduced head by  $(8.94' - 2') = 6.94'$ . As you'll see later when we size pumps this is huge.

Hopefully I did the math right. 😊

In the next examples I'll show some calculations for mixed piping sizes. Just to give an idea of how to calculate that. It's about the same as above, only you break the sections down for individual sizes.

## EXAMPLE TWO: MIXED 2" & 3" PIPE



CALCULATE FOR FRICTION LOSS @  
4800 GPH USING 2" & 3" PIPE  
ADD UP ALL PIPE LENGTHS FOR 2" (10+5+2= 17)  
ADD UP ALL PIPE LENGTHS FOR 3" (6+4+10+3+15+15.5 = 53.5)  
CALCULATE ADDITIONAL LENGTH FROM  
FITTING EQUIVALENT CHART  
2" PIPE = 17' + FITTINGS (1/8 × 2, + V + I = 8.5) = 23.5'  
FROM FRICTION CHART 23.5' OF 2" @ 80 GPM = 2.33' HEAD  
3" PIPE = 53.5' + FITTINGS (1/8 × 2 + ST × 3 = 32) = 85.5'  
FROM FRICTION CHART 85.5' OF 3" @ 80 GPM = 1.23' HEAD  
TOTAL FRICTION HEAD = (2") 2.33' + (3") 1.23' = 3.56'

In the above example 2" was used for the suction end, and 3" for the discharge. The head was calculated for the 2" section, and then for the 3" section and then both added together.

Let's say the filter area was small and you needed to exit it with 2" pipe through the second 90°. Even though part is on the suction side, and part on the discharge side, the process is still the same. The only added fitting would be a 2" to 3" enlarger after the second 90°, while the chart doesn't list this fitting, it's best to add something in as they do cause turbulence, I'll just use numbers for a male adapter (MA). (Refer to chart)

### 2" LEG

FITTINGS (I + [1/8 × 2] + V + [ST × 2] + MA) = 25'  
PIPE LENGTH = 27' + 25' = 52'  
FROM CHART 100' OF 2" PIPE @ 80 GPM = 9.94' HEAD.  
SOLVE FOR 52' OR 52% - .52 × 9.94' = 5.17' HEAD FOR 2" RUN

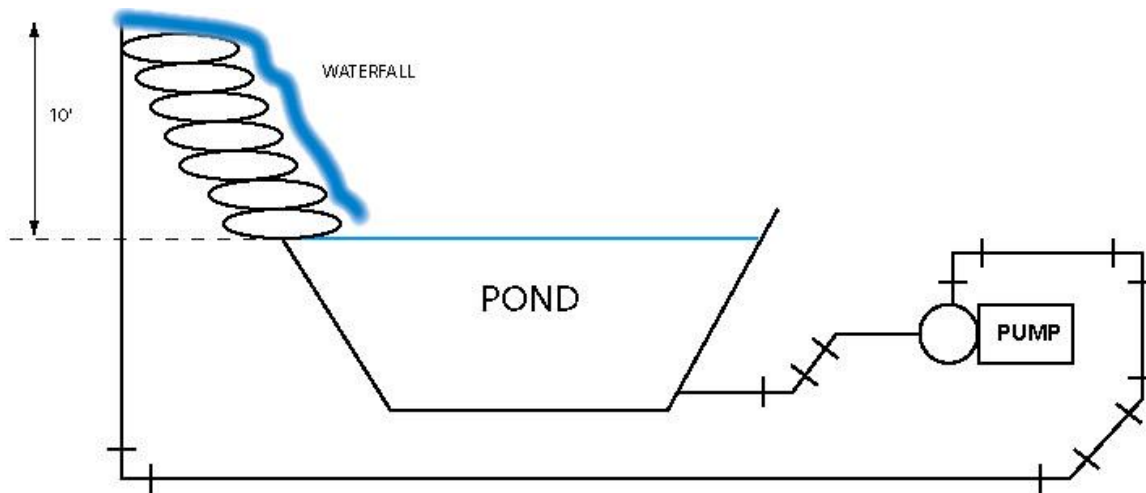
### 3" LEG

FITTINGS ([1/8 × 2] + ST + O) = 25'  
PIPE LENGTH = 43.5' + 25' = 68.5'  
FROM CHART 100' OF 3" PIPE @ 80 GPM = 1.44' HEAD  
SOLVE FOR 68.5' OR 68.5% - .685 × 1.44' = 0.99' HEAD FOR 3" RUN

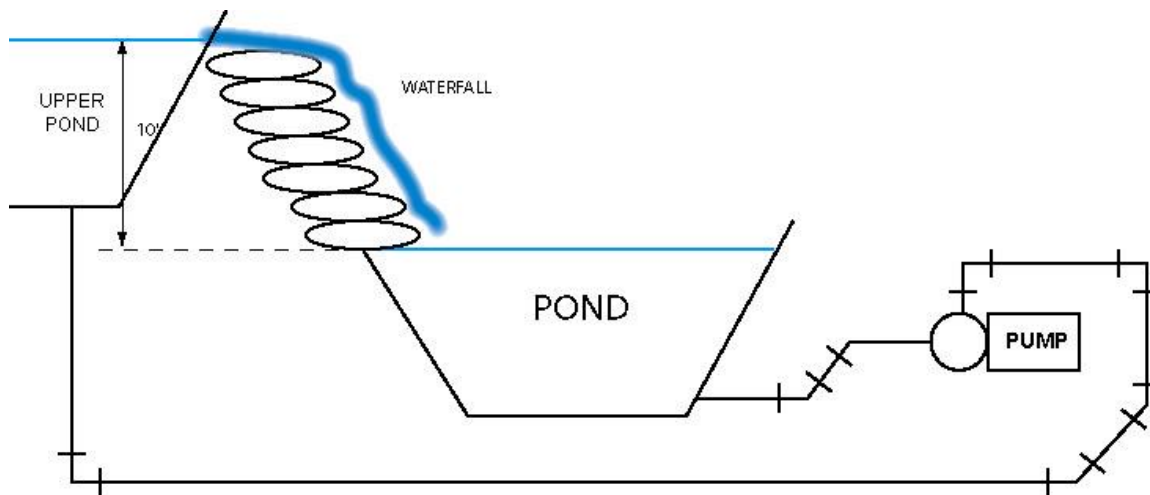
TOTAL FRICTION HEAD FOR ENTIRE RUN = 5.17' + .99' = 6.16' TOTAL FRICTION HEAD

## TOTAL DYNAMIC HEAD

I hope the previous examples have explained Friction Head enough for us to move on. Now that we can figure for Friction Head and Static Head, we can add them both up to calculate *Total Dynamic Head*.



Total Dynamic Head: I left the fittings the same in this drawing (assume same pipe lengths) to illustrate adding in static head to give us our final numbers. Because all the piping is below water level it will negate out and the only number we really need to add is the elevation. In this case we will use 10'; if that 10' of static head were added to any of the calculations for friction head in the previous examples we would come up with Total Dynamic Head. This is the number we need when sizing a pump to overcome this head and give us the flow rates we want.



In this example we pump to an upper pond which will flow to the lower pond. With all piping below ground we concentrate again on static elevation head. Remember from our earlier examples this is measured from water line to water line. The 10' can be added again to any of the piping calculations to give Total Dynamic Head.

## **QUICK REVIEW**

These are important numbers when we get to sizing pumps. The lower the better, so if your numbers seem to be getting high you may want to change some of your pipe sizes and fittings to try and bring it down. This is why it's important to plan ahead. If you sketch your initial plan and then find a boulder or something in the way when doing the actual piping, you can now add that in to see how it affects flow.

No discussion on friction would be complete without talking about pressurized filters. The next few sections will discuss these filters as well as UVs. I'll show how to calculate for head loss on these added items.

I hope no one is too bored. Some of this can be very dry and I didn't want to get too deep into some of the details. My initial plan was for a few pages of explanations and...well you're looking at the results. There is no easy way to shorten some of these steps. The good news is that for your own pond planning, it should only take a page or two to do the calculations.

Air has friction too:

A quick note before we get too far ahead: friction affects more than just water in a pipe. It affects air flow also. While I'm less familiar with that end I did find a chart for sizing air piping for volume & flow. Keep in mind the larger the pipe the less restriction applies here as well.

Aquatic Eco-Systems has [good technical specs for sizing air pumps](#).

Onward.....

## **ADDING PRESSURIZED FILTERS**

Bead filters are becoming very popular for their ease of set-up and use. I won't get into the merits or demerits of using this style filter; I'd rather just focus on plumbing them and adding calculations for friction loss, etc.

These are tricky to calculate for because like all piping, the friction will increase with flow. For this reason manufacturers rarely post any numbers that one could use. The rule of thumb for a medium- to high-pressure pump is 10' of Head. I think if you plug that number in, you'll probably be on the safe side.

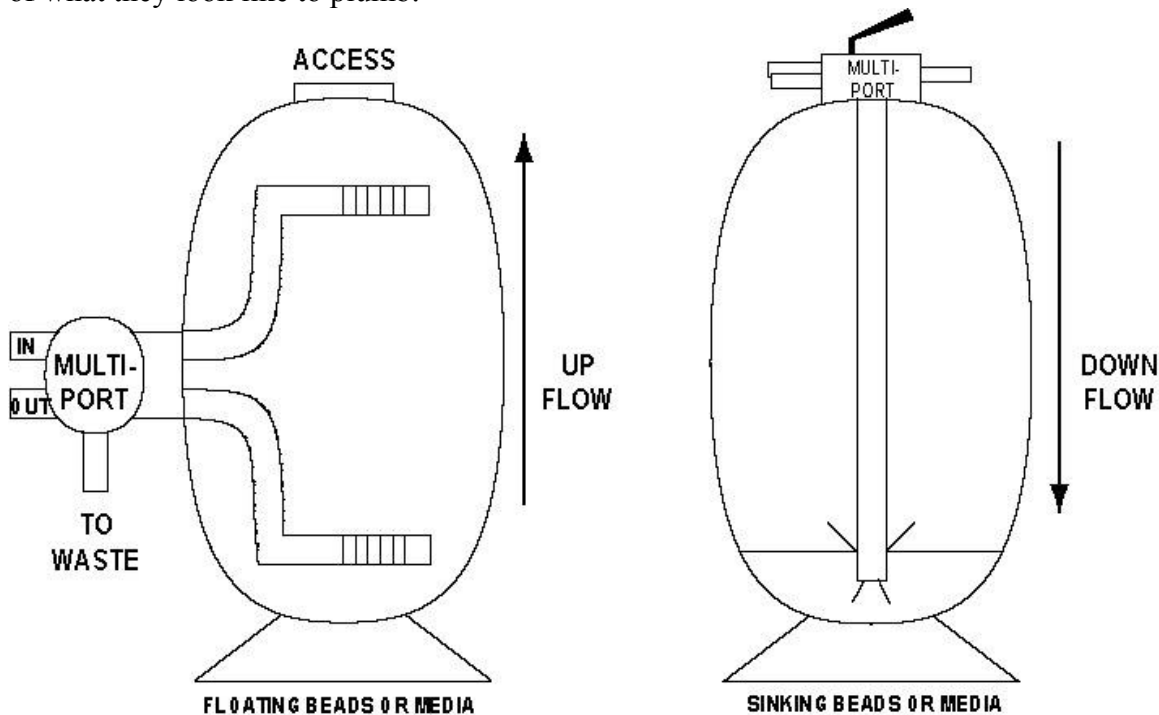
The Multiport Head on these units contribute a good portion of that 10', and the internals contribute the rest. Some brands have done work to their internals to reduce the restriction some, but I'd stick with the 10' rule of thumb.

Most come with pressure gauges, so after the fact you can see what you're up against. Remember that the gauge will read the bead filter and any piping, UVs, and elevation after it also.

These units are rather tall and I've found that flex PVC seems the best way to make the elevation changes & odd turns for the connections. We talked about flex PVC earlier and here is where it will really shine.

For draining & cleaning you have more options with bead filters because it's pressurized and can be pumped where needed. The drain can be hard piped or a flat pool drain hose can be used to roll out where you want the discharge.

Below is a quick drawing depicting two types. I won't get into the pros and cons, it's just for a rough idea of what they look like to plumb.



## **ADDING A UV**

UV stands for Ultra Violet Light and the name has stuck even though the units can be called clarifiers or sterilizers. These are used to combat green water for the most part. In a more powerful version it can also kill some bacteria and rate as a sterilizer. Manufacturers' data sheets should be used to size the UV for the gallonage of your pond and the flow rate you want to have go through it.

Flow rates through them are important as UV light has a hard time penetrating through water. By using the manufacturer's flow rates you'll ensure that the water flow past the bulb is slow enough to either kill the green water algae or bacteria.

The bad news is they are a major restriction in flow. They are typically (smaller & cheaper units) made of 2" PVC pipe. Inside that pipe is about a 1" quartz tube where the bulb rests. If we look at the annular space of a 2" pipe (area of a circle =  $\pi \cdot R^2$ ) (We will use  $\pi = 3.14$ ).

A 2" pipe has a radius of 1" applying the above formula  $1^2 = 1$ ,  $1 \times 3.14 = 3.14$

So a 2" pipe has an area of 3.14 square inches or in<sup>2</sup>.

The quartz tube has a radius of .5" apply formula  $.5^2 = .25$ ,  $.25 \times 3.14 = .785$

The 1" quartz tube has an area of .785 in<sup>2</sup>.

$3.14 - .785 = 2.355$  in<sup>2</sup> of remaining space. I'm sure there is an added friction coefficient for the extra drag along the quartz tube also. For comparison a 1½" pipe has 1.77 in<sup>2</sup> so it's still slightly better than that not factoring in the extra drag from the quartz tube.

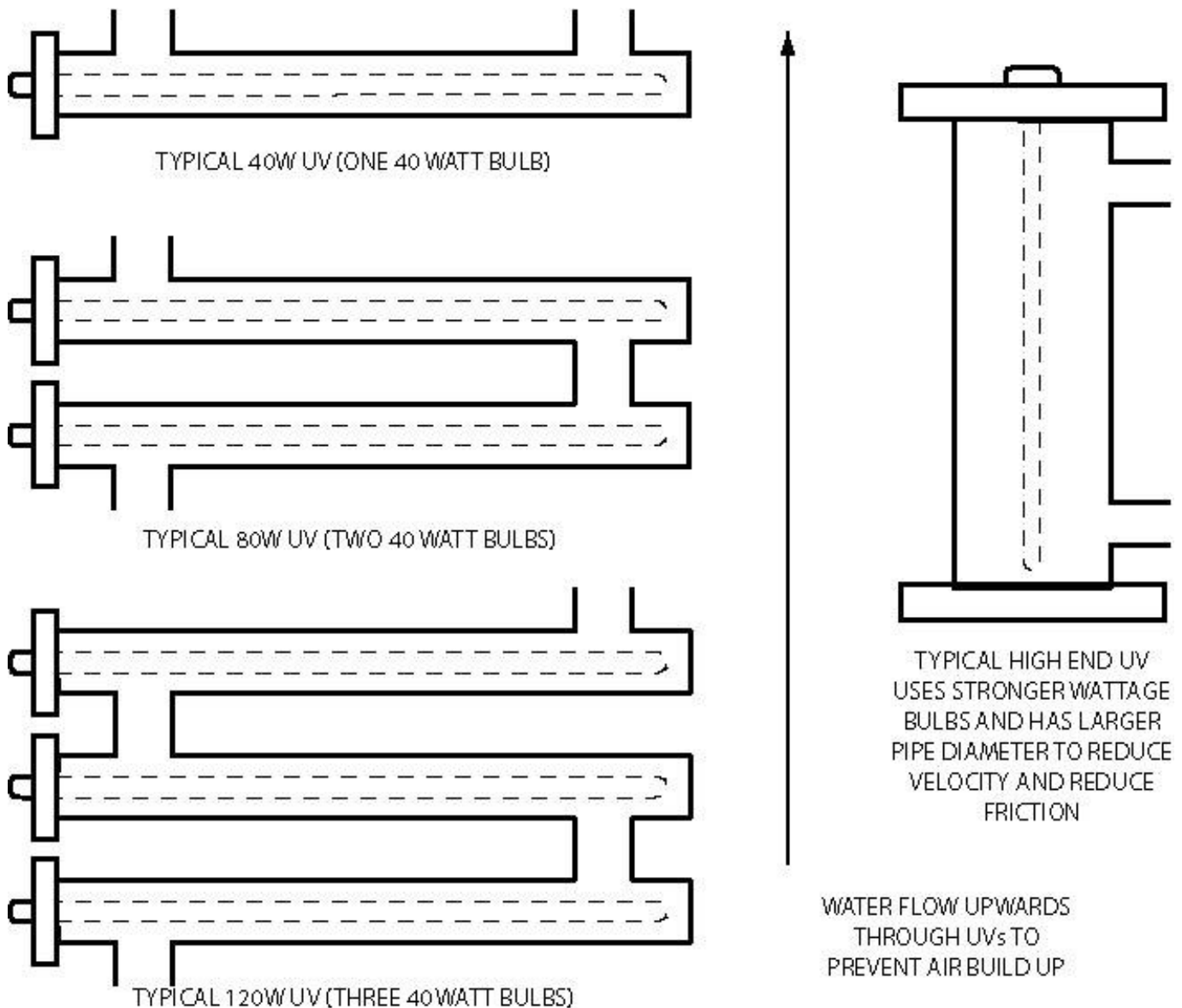
Many units also use very restrictive elbows for compactness. If I were to calculate a UV into the system, I'd use 1½" pipe for the lengths and standard elbows for the equivalent.

As you'll see in the drawings, the higher wattage units will be very restrictive. It almost seems funny that they are rated for higher flow rates, because that too will increase the friction. That probably helps the manufacturers meet the exposure time needed. Remember that you're paying the price over the life of the pond in higher pumping costs.

That brings me to the higher-end units. While these cost substantially more, they are usually made of stainless steel and are sturdier units. They often have a larger diameter pipe, which if you look at the flow charts, will reduce velocity through the chamber. That coupled with higher wattage bulbs, will get the same exposure time and depths as the smaller units, only they are much less restrictive. Below are a few examples of what they look like.

## SOME TYPICAL EXAMPLES OF UV CONSTRUCTION

Even though it's noted in the drawing, I'll re-emphasize it here. It's important to allow any trapped air to be pushed out via the water flow. The bulbs in the UVs can become warm, making the plastic brittle over time. That, and without water to filter down the UV rays, could also lead to brittleness.



Looking at the cheaper units and all the 90° bends, you can see why they are very restrictive to flow. Couple that with the lost inner space, and they are an extreme bottleneck. I've always installed UVs with unions, and made a piece of pipe with unions to take its place. That way for the times of year when they're not necessary, they can be taken out of the system.

## **ON TO GRAVITY FLOW**

First and foremost are the advantages of gravity flow to some kind of settlement. Most fish waste is heavier than water and will sink to the bottom; usually the best point to collect the waste from. By using gravity flow versus a pumped suction, the waste is left intact for the most part and settled out of the water stream in the filters. By getting the waste out of the water stream, it will have less of a tendency to break down and sneak through the filtration and back to the pond or dissolve and be returned in the form of DOCs. While this accounts for a large portion of the waste, it by no means gets all of it out. Some waste is neutrally buoyant and some positively buoyant. These will not settle and need to be filtered further. Again this is another subject that needs lots of discussion but not in this article.

The disadvantages of gravity flow are reduced possible flow rates, having to dig a filter pit, the ensuing buried plumbing with valves, and the sheer size of settlement chambers or vortex/barrels (the latter is not always a disadvantage).

In modern ponds aerated bottom drains are often used. These help tremendously bringing waste to the drains. The downfall is it will bring in much of the neutrally buoyant and floating debris as well. Micro screens are employed in a lot of V/Bs to help stop this other debris. Some of these require spray bars to keep clean. We will touch on some of the plumbing for that also.

Gravity flow is usually done to some type of settlement or vortex. The key to settlement is velocity. We've touched on that a little and will again. For our purpose here velocity needs to be slow enough so that the forces keeping heavier debris in suspension become less than the gravitational forces trying to settle them out.

For pure settlement the chamber usually needs to be fairly large and long. As the water enters a larger chamber the velocity slows. The longer the water travels along a path at lower velocity, the more will settle out.

In a vortex we have something similar in that the vessel is usually large, yet has a smaller footprint than pure settlement to slow the velocity. The added factors present by spinning the water are centrifugal forces wanting to draw things to the center where velocity is lower yet, and boundary layer forces along the outer edge of the vessel. These boundary layer forces are similar to the pipe friction along wall of the pipe. They slow the water further and have a tendency to bring any debris in that water to the bottom.

As with everything I've talked about so far there is always more to it but this is a basic discussion so we'll leave it at that.

On the following pages I'll start with a draining tank. This is important because it will start to show the importance of elevation and how it affects the flow of water out of a tank.

So with all that said, let's continue.

## **A DRAINING TANK**

I'll go over the theory briefly but the math is way beyond me. The concept is in use constantly in one form or another in our plumbing. The same forces which compel water to seek its own level are at work. It's important to have a basic understanding of the theory though, as you will see in the next few pages.

With gravity flow a water height is needed as the driving force to push the water out of the tank. The lower the exit point below the water line the more driving force there is. The following site has a nice calculator for figuring flows from a tank; unfortunately it does not take piping friction into account. As you will see though adding in the friction won't be that difficult.

### **[Draining Tank Calculator](#)**

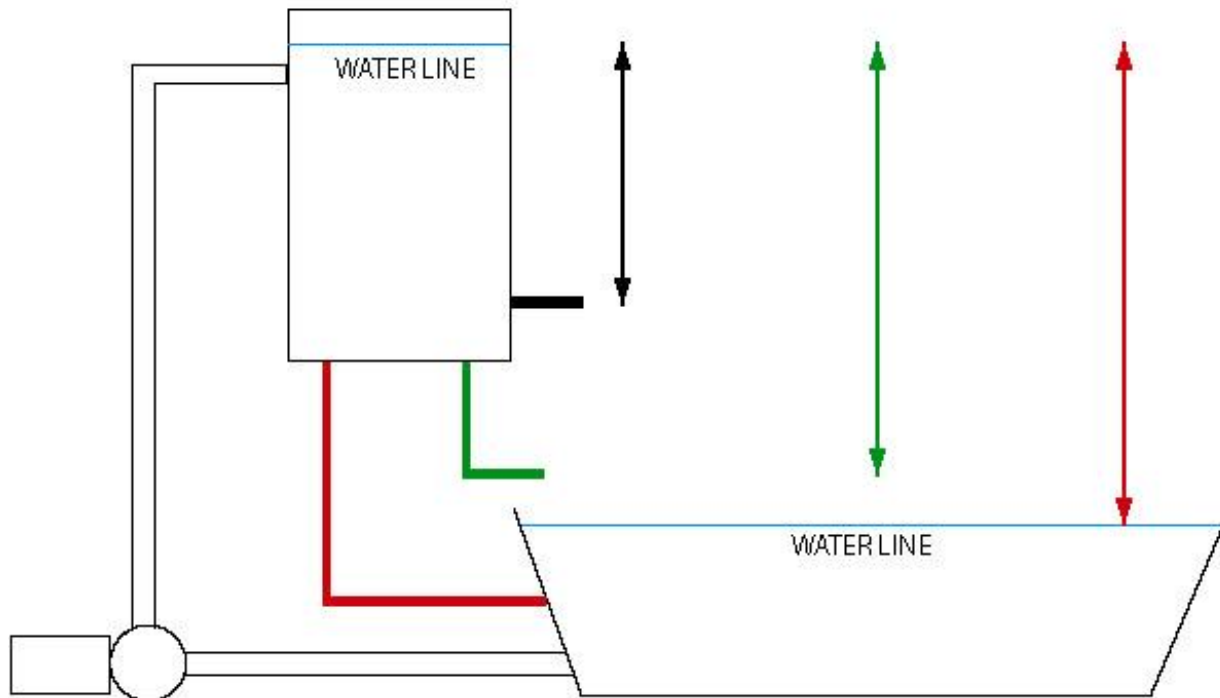
For friction head calculations, velocity in the piping is needed to do that math. While the above site will give you the velocity at the spout, this will be lowered by the friction in the piping. It's very difficult to make these backwards calculations to try and calculate flow. The good news is that we are the ones setting the flow rate. There are no magical barrels/tanks that will maintain their depth. By sizing a pump correctly for the friction and elevation we should know what the flow rate is.

With that information in hand we can do the friction calculations for the piping exiting the barrel. I'll use a simple rule of Head = Head to find depth of the spout for friction; I guess you could call it equilibrium. Once the friction head of the piping and the elevation head in the tank zero out that's where the depth of spout will be. There is one more calculation and that is the one the site above offers. Once we've reached an elevation head that is equal to the friction head the water would be for the most part at a standstill. I know this sounds wrong but bear with me and I'll try to explain further.

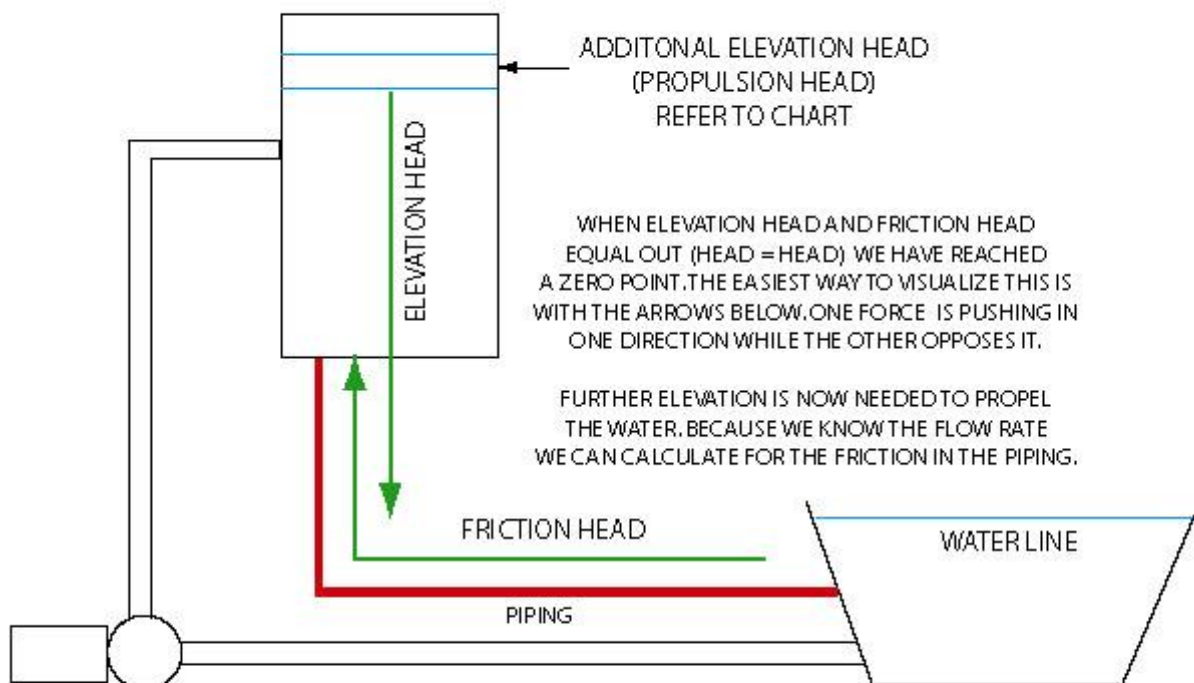
It takes a certain amount of energy to move water. This is different from the energy needed to overcome friction. Above we discussed what it takes to overcome the friction portion. I'd like to discuss the mathematics of how to figure the elevation needed to drive the water but it is way beyond me. So I had a friend help and came up with a chart showing the most common flow rates for the most common pipe sizes and elevation head needed to drive the water. The drawings below should help explain this a bit. For clarity I'll call the elevation that's needed *Propulsion Head* .

Remember that if you're draining from a tank into a pond, and the return pipe is below the water level in the pond, that the elevation head - or driving force - will be from the water level in the tank to the water level of the pond; NOT the exit point of the pipe. Once a pipe connects tank and pond they become one as far as water level is concerned. The top drawing below illustrates this with different colored pipes and the corresponding elevations.

## DRAINING TANK HEAD ELEVATIONS



## DRAINING TANK HEAD ELEVATIONS FOR PROPULSION



A KEY POINT TO REMEMBER IS THAT WHEN THE PUMP STARTS IT WILL LOWER THE WATER LEVEL IN THE POND TO FILL THE TANK. VICE VERSA WHEN THE PUMP SHUTS OFF IN THIS SCENARIO THE TANK WILL CONTINUE TO DRAIN BACK INTO THE POND POSSIBLY OVERFLOWING IT.

# PROPULSION ELEVATIONS

## PIPE SIZE IN INCHES

FLOW RATE IN ↓ ↓ GPH ↓ ↓	1.5"	2"	3"	4"
2000	6.83	2.16	0.43	0.14
2100	7.53	2.38	0.47	0.15
2200	8.27	2.62	0.52	0.16
2300	9.03	2.85	0.56	0.18
2400	9.84	3.11	0.61	0.19
2500	10.67	3.38	0.67	0.21
2600	11.54	3.65	0.72	0.23
2700	12.44	3.94	0.79	0.25
2800	13.39	4.24	0.84	0.26
2900	14.36	4.54	0.9	0.28
3000	15.37	4.86	0.96	0.3
3100	16.41	5.19	1.03	0.32
3200	17.48	5.53	1.09	0.35
3300	18.59	5.88	1.16	0.37
3400	19.74	6.25	1.23	0.39
3500	20.92	6.62	1.31	0.41
3600	22.13	7	1.38	0.44
3700	23.38	7.4	1.46	0.46
3800	24.66	7.8	1.54	0.49
3900	25.97	8.22	1.62	0.51
4000	27.32	8.65	1.71	0.54
4100	28.71	9.08	1.79	0.57
4200	30.12	9.53	1.88	0.6
4300	31.58	10	1.97	0.62
4400	33.06	10.46	2.07	0.65
4500	34.58	10.94	2.16	0.68
4600	36.14	11.43	2.26	0.71
4700	37.72	11.94	2.36	0.75
4800	39.35	12.45	2.46	0.78
4900	41	12.97	2.56	0.81
5000	42.69	13.5	2.69	0.84
5100	44.42	14.05	2.78	0.88
5200	46.18	14.61	2.89	0.91
5300	47.97	15.19	3	0.95
5400	49.8	15.76	3.11	0.98
5500	51.66	16.35	3.23	1.02
5600	53.55	16.94	3.35	1.06
5700	55.48	17.56	3.47	1.1
5800	57.45	18.18	3.59	1.14
5900	59.45	18.8	3.71	1.18

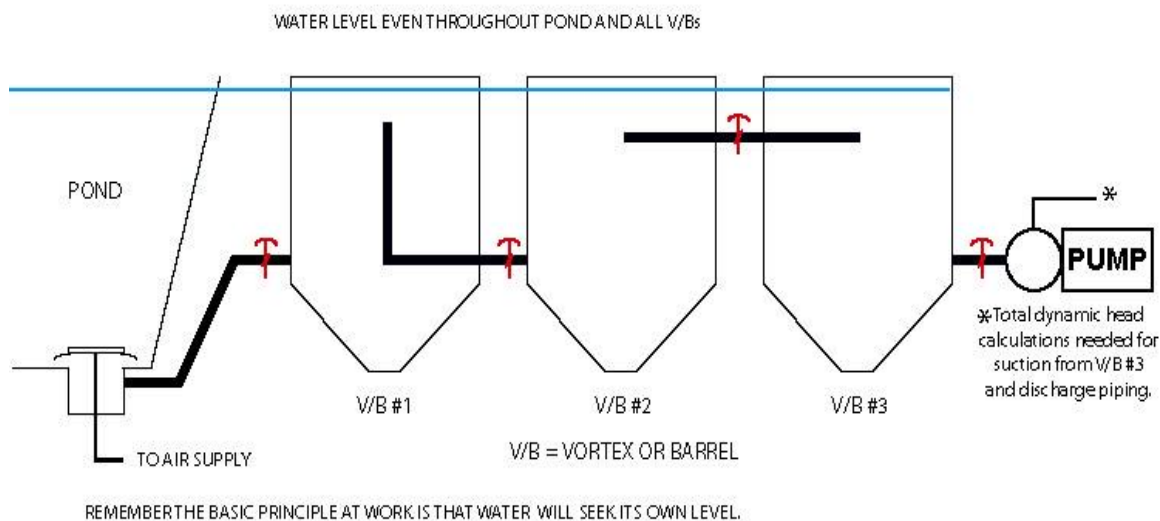
## GRAVITY FLOW PART II

This is probably one of the most misunderstood aspects of pond plumbing.

**The basic principle applied is water will seek its own level.** This is important as everything to do with gravity flow needs to be built at the same level. The water level in the pond will be the same water level in the filters.

I'll show illustrations for a three vortex/barrel filter set up. There are other variations that can be made but the same rules we discuss will be applied. Having a 3 V/B set up also shows how important pipe sizing is in relation to draw down in the V/Bs.

### GRAVITY FLOW THROUGH 3 V/Bs PUMP OFF - WATER AT REST



The three V/Bs above could represent settlement in #1, Bio in #2 and possibly some finer mechanical in #3. It could be set up many different ways; this is entirely up to the needs of the end-user. We won't get into the types of filtration but rather the piping from the pond and between them. Once this is understood any combination can be made.

## GRAVITY FLOW PART III, DID SOMEONE SAY DRAW DOWN?

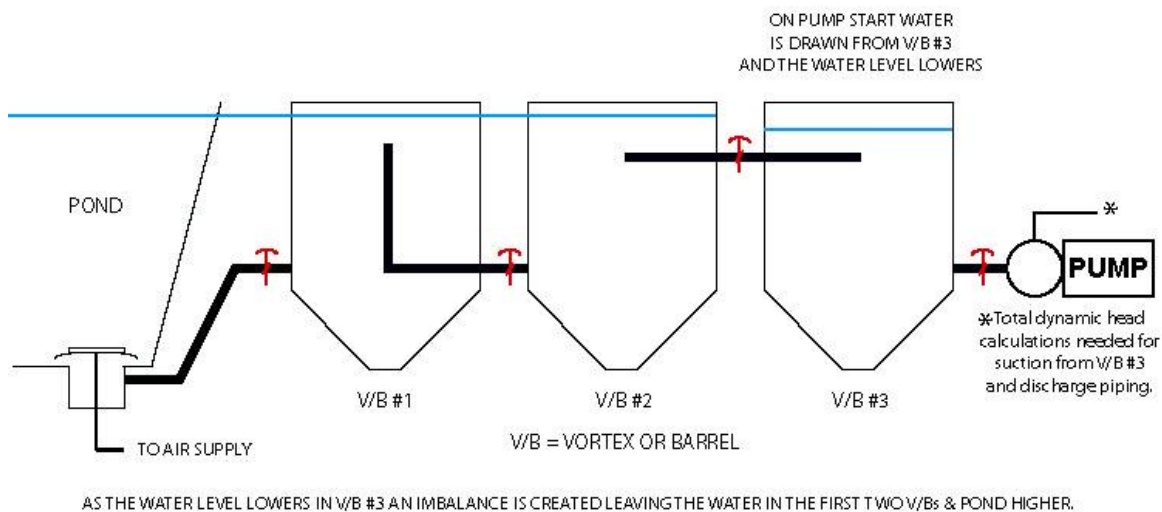
Now that we see the water in the system and the levels between pond and V/Bs, we need to discuss what makes it move. Many people believe that you're actually pulling the water through the system. ***This is not true.*** While you are pulling water from the last V/B, it is gravity and the tendency of water to seek its own level that ***pushes*** the water from the pond to replenish the V/Bs. It's important to understand this because it goes right back to friction loss in piping.

***Draw down:*** in simple terms is the difference in water height between the pond and the V/Bs. When you turn the pump on it ***draws down*** the water level in the last V/B. Because all the V/Bs are connected via piping, a chain reaction starts. "Woohoo! A nuclear pond," you say! Well not quite, but a chain reaction none the less. As the water level lowers in the last V/B, water does that funny thing of wanting to find its own level. So with the water in V/B #2 higher than #3, gravity now pushes the water out of #2 into #3. I don't know how else to explain this.

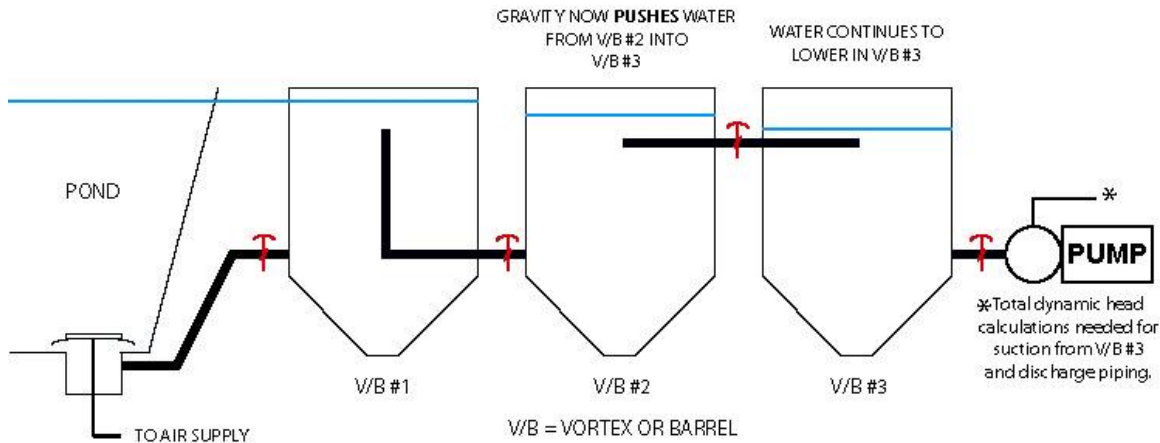
Here's the key though: there's something fighting this whole process. For our discussion I'll stick to the friction aspect. There are other factors involved in how water will flow into a pipe from a barrel or other chamber but they seem for the most part negligible to our calculations. There's always a fudge factor that can be added to compensate for this. But we do need to take into account what I call ***Propulsion Head***. Depending on flow rate and pipe size this could add up also.

Remember that the friction of the piping from pond to V/B and between V/Bs is not included in TDH calculations for the pumping circuit. The only piping that counts is from the last V/B to the pump.

### GRAVITY FLOW THROUGH 3 V/Bs PUMP START

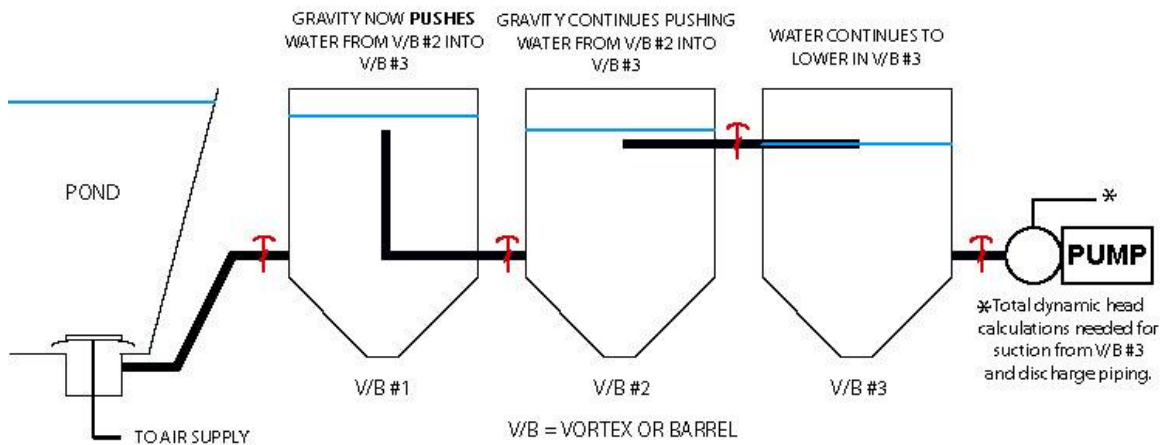


## GRAVITY FLOW THROUGH 3 V/Bs FIRST GRAVITY MOVEMENT



AS THE WATER CONTINUES TO LOWER IN V/B #3 THE FIRST GRAVITY MOVEMENT STARTS. WITH THE DOWNWARD FORCE OF GRAVITY PUSHING ON THE ALL WATER THE WATER IN V/B #2 STARTS TO MOVE. THERE HAS TO BE A WATER LEVEL DIFFERENCE FOR THIS TO HAPPEN. SO EVEN THOUGH V/B #2 IS SUPPLYING V/B #3 IT MUST BE LOWER IN LEVEL TO MAINTAIN THIS FLOW.

## GRAVITY FLOW THROUGH 3 V/Bs SECOND GRAVITY MOVEMENT



THE CHAIN REACTION CONTINUES. WITH THE WATER LEVEL LOWER IN V/B #2 WATER FROM V/B #1 IS NOW PUSHED INTO V/B #2. THE LARGEST FORCE STOPPING ALL THIS FROM HAPPENING INSTANTLY IS FRICTION. WHAT WE LEARNED EARLIER ABOUT FRICTION IN PIPING CAN NOW BE APPLIED TO THE GRAVITY FLOWING WATER THROUGH THE V/Bs.

Hopefully the pictures explain it well enough. Gravity pushes water through the pipes and friction is what tries to stop it. The amount of friction in the piping will determine the water level differences, not only from pond to V/Bs, but between them as well. This is known as draw down or elevation difference. There is a little more to this that will be explained further.

## HOW TO CALCULATE DRAW DOWN

I'll start by saying that math is an exacting science; it's the numbers that we enter that will make the calculations work. Because the variables in pipe lengths and fittings are usually an estimate, the numbers coming out are also just that. If you're fairly accurate on your input the output should be fairly accurate. Again for our discussion here, friction will usually play the biggest part in stopping water from seeking its own level. This is what we will calculate for plus *Propulsion Head* in order to see how much draw down each V/B suffers. This becomes very important when using multiple V/Bs, as the plumbing inside the V/Bs needs to be able to operate at these lowered water levels.

Again the first thing to know is what flow rate we want through our bottom drains. Just as a rule of thumb it's typically in the 3K GPH – 3.5K GPH range. But we can do some calculations for higher flow rates.

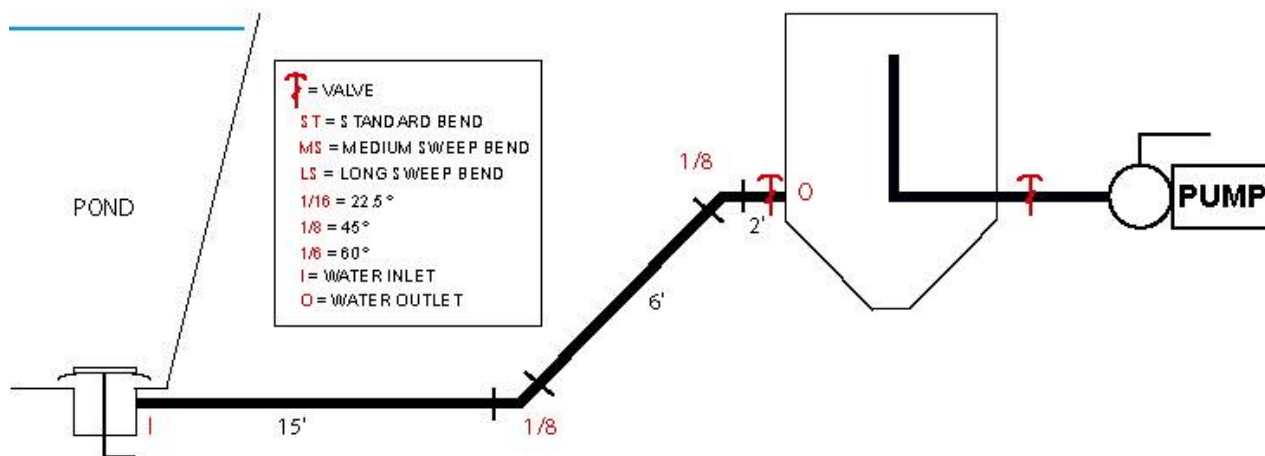
One thing I will say when piping for bottom drains, is that length and bends are your enemy. I for one found it best to have my filters away from the pond for aesthetic reasons. Because of this added length my draw down was a little higher than most. It can be done, but needs to be taken into account again when designing the V/Bs.

In the following examples we will do calculations for 3" & 4" piping. These are the most common sizes for bottom drains. Anything smaller just has too much friction for our purposes. One thing to keep in mind is the Elevation Head has to equal the Friction Head for the first calculation. A simple formula is Head = Head. As with a draining tank this is the zero state, then there is *Propulsion Head* to make the water move. So if there is 1" of friction head in the piping there has to be 1" of elevation difference + *Propulsion Head* elevation between pond and V/B. The *Propulsion Head* number can be attained from the chart I enclosed on page 27. Notice I didn't say 1" of draw down, as we move water from the V/B to pond, the pond level will raise. Depending on the surface area of the pond and the size of the V/Bs, this could be practically nothing to almost half of the calculated draw down. For our purposes again we will be much safer assuming all will be draw down in the V/Bs.

### DRAW DOWN CALCULATIONS

3" - PIPE ~15' + 6' + 2' = 23' FITTINGS ~ (1 + [1/8 × 2] + V + O) = 15.1 TOTAL = 38.1

4" - PIPE ~ 15' + 6' + 2' = 23' FITTINGS ~ (1 + [1/8 × 2] + V + O) = 20.2 TOTAL = 43.2



FLOW RATES	PER 100' ~ 3"	FOR 38.1'	DRAW DOWN 3"	PER 100' ~ 4"	FOR 43.2'	DRAW DOWN 4"
3000 GPH	.6'	.23'	2.76" + .96" = 3.72"	.16'	.069'	.8" + .3" = 1.1"
3400 GPH	.78'	.3'	3.6" + 1.23" = 4.83"	.2'	.086'	1" + .39" = 1.39"
3800 GPH	.93'	.35'	4.2" + 1.54" = 5.74"	.24'	.10'	1.2" + .49" = 1.69"
4200 GPH	1.13'	.43'	5.16" + 1.88" = 7.04"	.3'	.13'	1.6" + .6" = 2.2"

The first number in draw down is friction from the piping and the second is the elevation needed for propulsion.

## MORE ABOUT VELOCITY

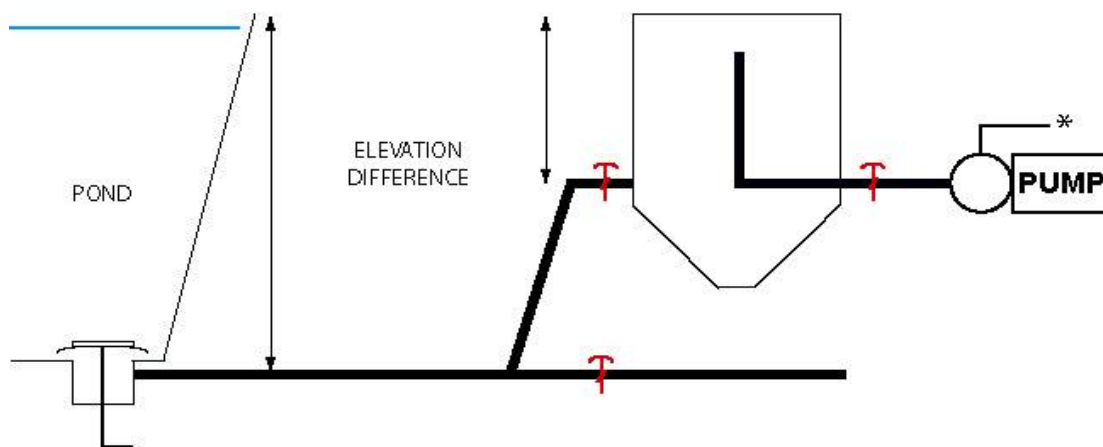
Velocity is the speed at which the water travels through the piping. We've discussed how it affects friction but there is another end we need to look at. Settlement – as touched on earlier in the gravity flow section. We noted earlier that a good portion of fish waste is heavier than water and will have a tendency to sink. If the water velocity is low enough this can happen even in piping with moving water not just in settlement chambers or vortex.

For now we'll focus on settlement within the piping. Based on what we've discussed, a larger pipe is good to overcome friction and reduce draw down within the V/Bs. But if the flow rate is too low, some waste will settle inside the actual pipe. Even at the recommended rule of thumb flow rates, some settling will occur. This can be cleaned out with some added velocity in the piping. There are two ways to accomplish this: with one obviously better than the other.

The first is the empty V/B. With the incoming water from the pond shut off for cleaning the V/Bs they can be emptied. Once empty, the water height difference from pond to entry point of the V/B is great – usually a few feet. This added water height difference (Head) will increase the pressure available to overcome the friction in the piping, thus increasing velocity. Water will gush into the empty V/B, hopefully cleaning out the piping with the added velocity of the water within the pipe. The drawback is that once the water in the V/B reaches the inlet, you start to lose steam. As the water rises over the inlet pipe, pressure (Head) decreases and with it the velocity. Depending on length of pipe run and size of V/B, the entire volume of the piping could be drained at this higher velocity or not.

The second is a purge valve. This is a valve that should be installed at the lowest point possible on your BD piping. The lower the valve the more driving Head there will be available. As you can see in the drawing, the head developed to this point could be almost double that of the inlet to the V/B. If you do the math, you can see that even with a 4" going straight into the V/B this lower valve could be a smaller size, maybe down to a 2" and *still* increase the velocity in the piping. Also, with only the dropping water level in the pond, it could be operated for whatever amount of time is needed to completely purge the piping. The biggest drawback to this is the depth needed to accomplish it. For those of you with sloping yards, draining not only the purge but the V/Bs will be easier. For those of you on level ground we'll discuss that next.

### PURGE VALVE ELEVATION



## **DRAINING YOUR GRAVITY FLOW V/Bs**

There are many ways to accomplish this so I'll just scan over it briefly. If you're having difficulty deciding what to do ask around as I'm sure others have faced something similar.

As mentioned earlier, draining gravity flow filtration can be difficult depending on your pond elevations. For most we have fairly flat ground and need to get the water away from the pond. This can be done with a sump pit/pipe/barrel.

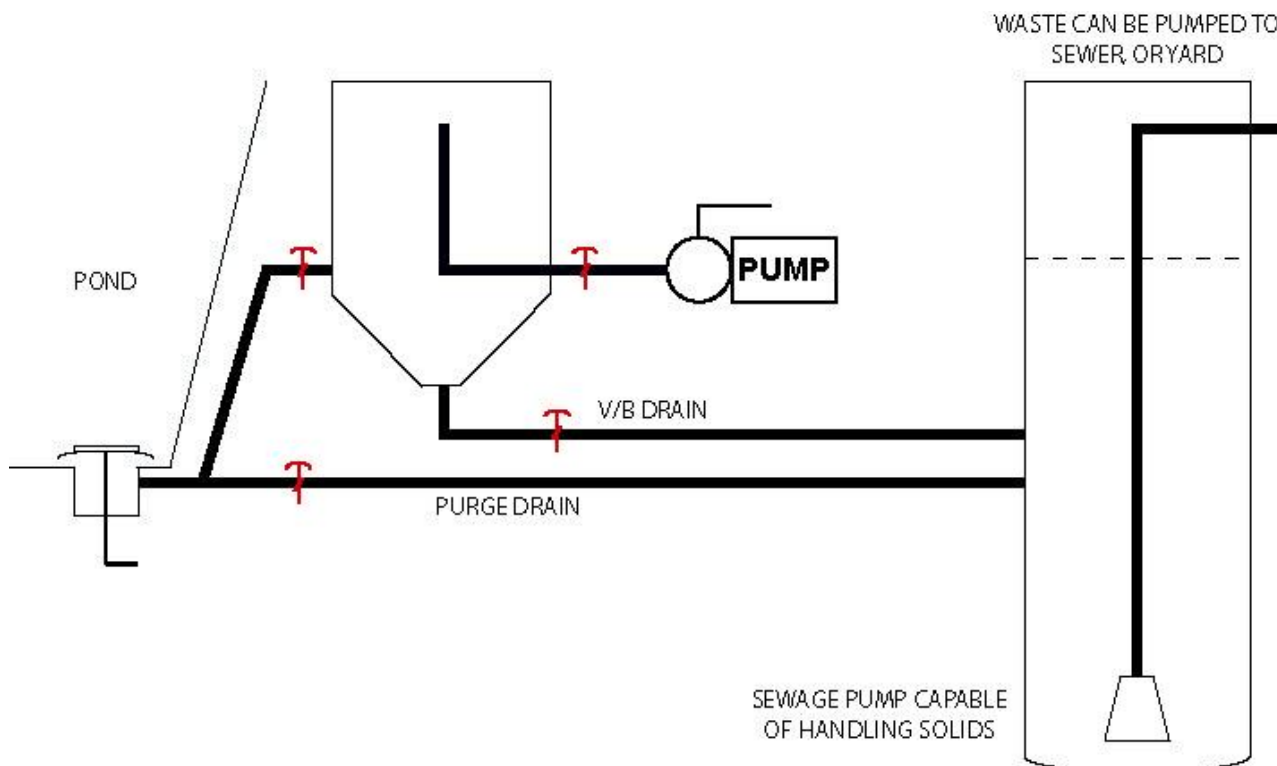
There's different ways to look at draining your V/Bs, just a drain and then hose them down or a higher velocity drain that will also be able to handle larger debris (leaves etc). Either to me will work – one is a little more effective.

Once again using the elevation head principles, we know that the sump – to get maximum flow – should be lower than the exit pipe of the V/Bs and/or the purge valve. It may be a lot of work and expense, but the largest pipe possible and deepest depth make for the best sump. Other depths will work but drain flow will suffer as a result.

The water then has to be pumped out of the sump to either a sewage/storm drain or around the yard/garden/trees, etc. The same principles apply to the pump in the sump, as they do anywhere else in the system that you're pumping water. The elevation head to pump the water up, and the pipe size to overcome friction.

I'll show one illustration for a deeper sump, and you should be able to imagine how a shallow one would work.

As a side note some people have submersible pumps right in their V/Bs to drain them. While this will work it's by far not the best set up. But as with anything, when building a pond, you do what you have to to overcome obstacles.



## **AND THE BEST PART.....SIZING THE PUMPS**

If you're sizing the pumps it means all your plumbing is done and you're almost ready to fire the pond up. Seriously, no use buying a pump before you know what piping was laid vs. what was planned for.

So all the math we did previously needs to be applied now. We know what flow rates we want and piped for, we did the math to find *Total Dynamic Head*, and now we need to size the pump using the manufacturer's flow charts.

The flow charts will have two points to intersect. On the bottom line of the graph we have the flow we want, on the side, the head we have to overcome. When you find the pump that meets these criteria, you will have the most efficient pump for your pond. I will include some of WLim's flow charts for his Wave & Dragon pumps. Out of the pumps I've used, these seem to hold the truest to the flow charts. Other manufacturers will also have flow charts and should be checked to see if they meet your needs.

Remember the math you did was for the flow you wanted. If looking at the charts you see a pump that's just a little more powerful and you want that option just plug the new flow numbers into your calculations for *Total Dynamic Head*.

The flow charts are on the next two pages and are printable. This may make it easier to see what we're describing.

Let's say you want a flow of 4000 GPH and your calculated head is 20'. Part of that head is a bead filter so you want a stronger pump to help with backwashing and flow. We'll look at the Wave II series. Looking at the chart, the flow lists GPM so we'd look for 67. You would run a line up from that point. Then look at the side of the chart and find 20' of head. Run a line across from that point: where the two intersect is the point you'd look for a pump curve to cross. There are three pumps close in the curve. Obviously they are all the higher powered ones to overcome the 20' of Head. Follow the head line in either direction and see where the pump curves cross that line. The ½ and ¾ HP models both seem to intersect so if you can live with slightly less flow these would be the two pumps to look at. Remember that because the flow slowed slightly, the Head came down so it wouldn't be completely down to that 60 GPM mark.

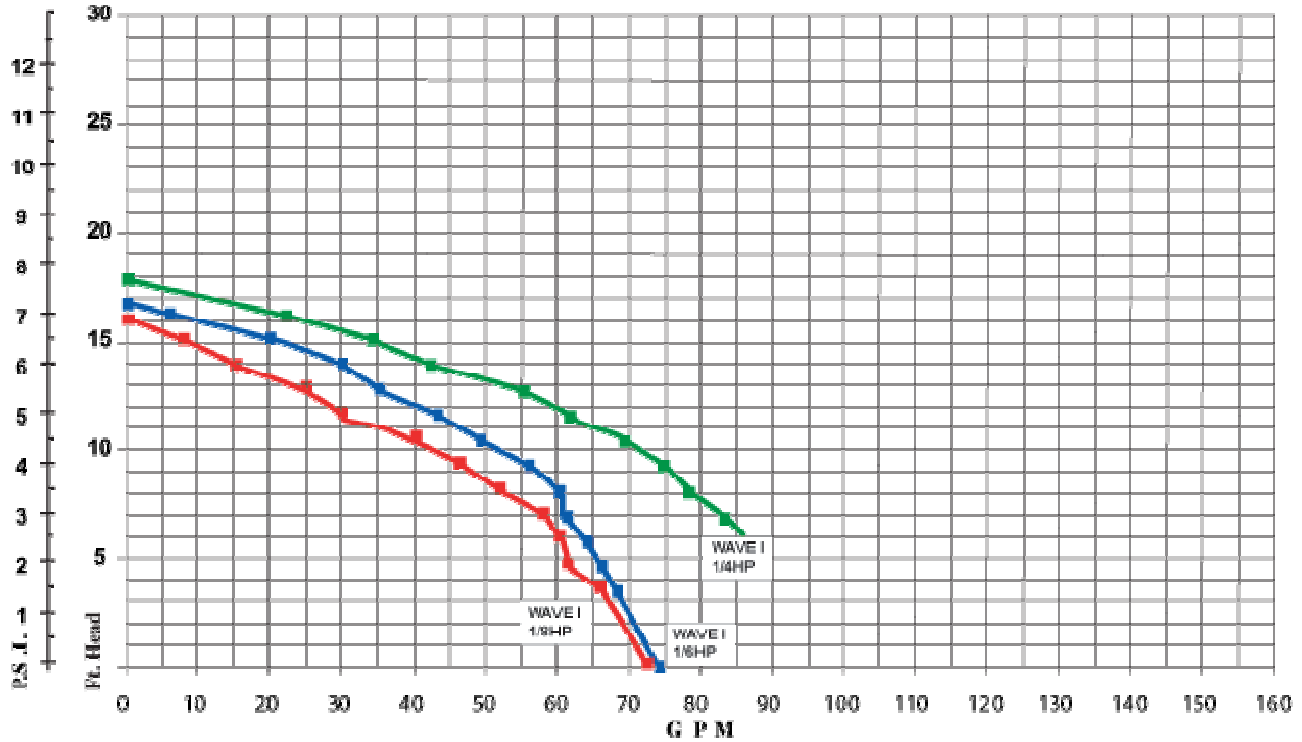
You may ask yourself how two different sized pumps can have the same flow for a given Head. Pumps have operating ranges and sweet spots. You can see the lower-powered pump dies off quickly after the 20' of Head, while the more powerful pump could handle more.

You'll also notice some pumps on the charts start off around 5' of head. This is due to impeller design and to keep the motor from over-amping (basically spinning out of control), there needs to be at least some pressure on them.

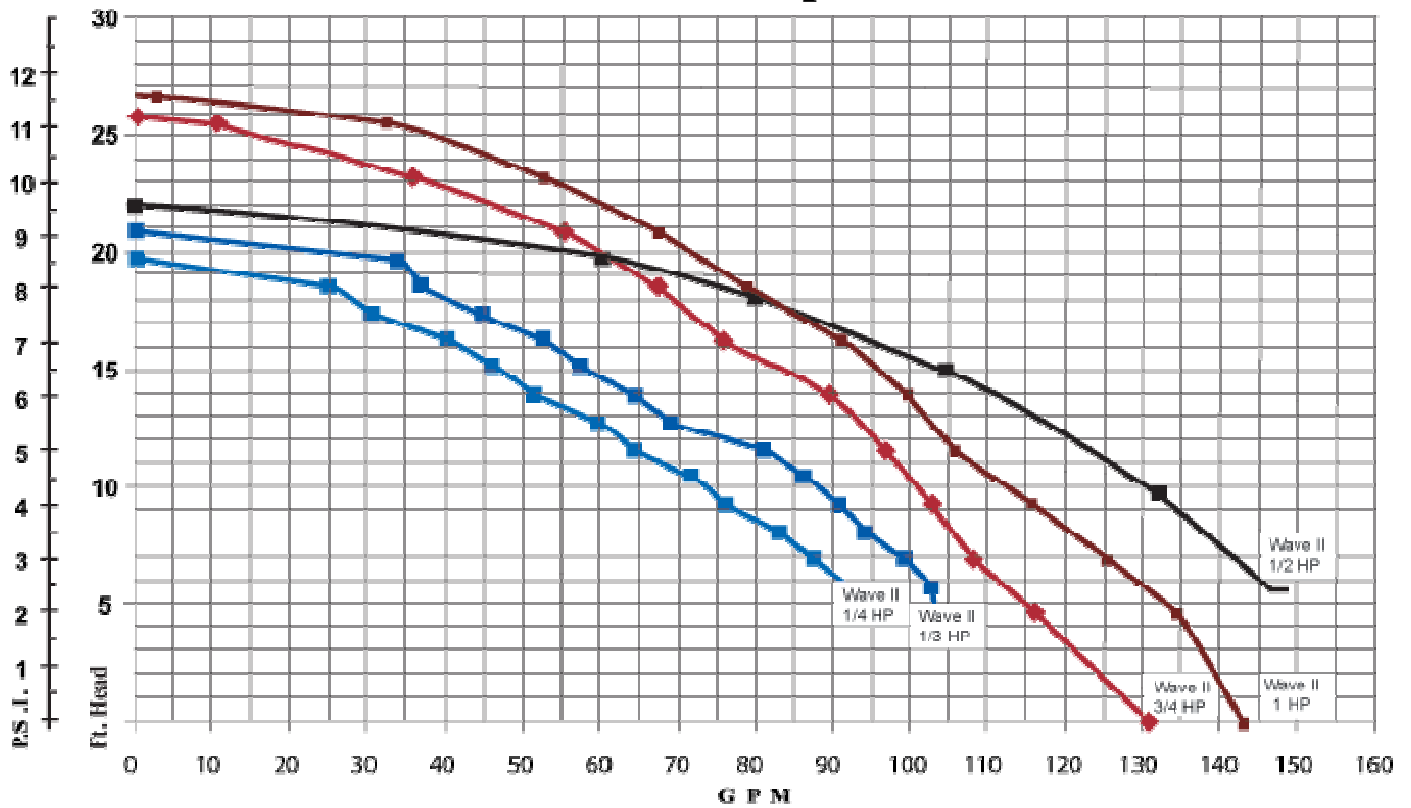
If you have more questions about pumps I suggest you call WLim and speak direct with the manufacturer. He's more than helpful and quite knowledgeable not only in pump technology but in all aspects of pond plumbing as well.

# Flow charts courtesy of WLim Corporation

## Wave I Pumps

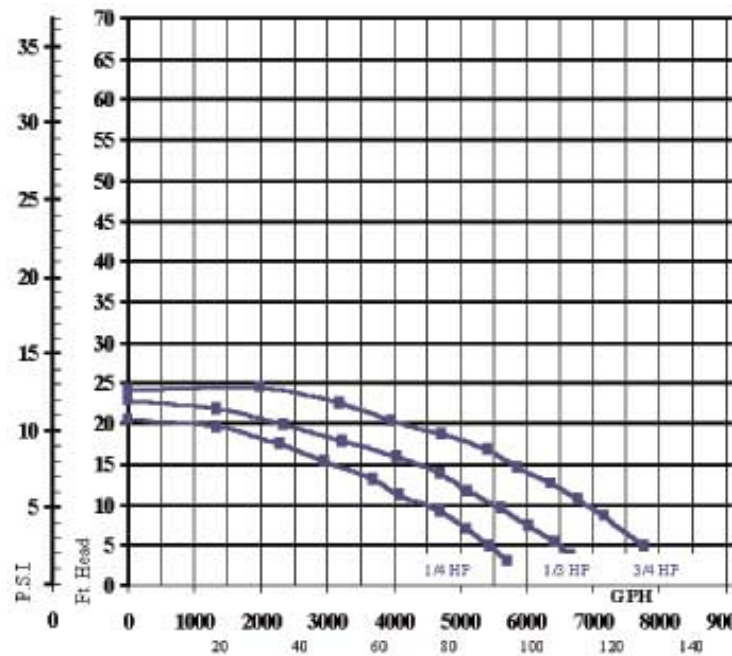


## Wave II Pumps

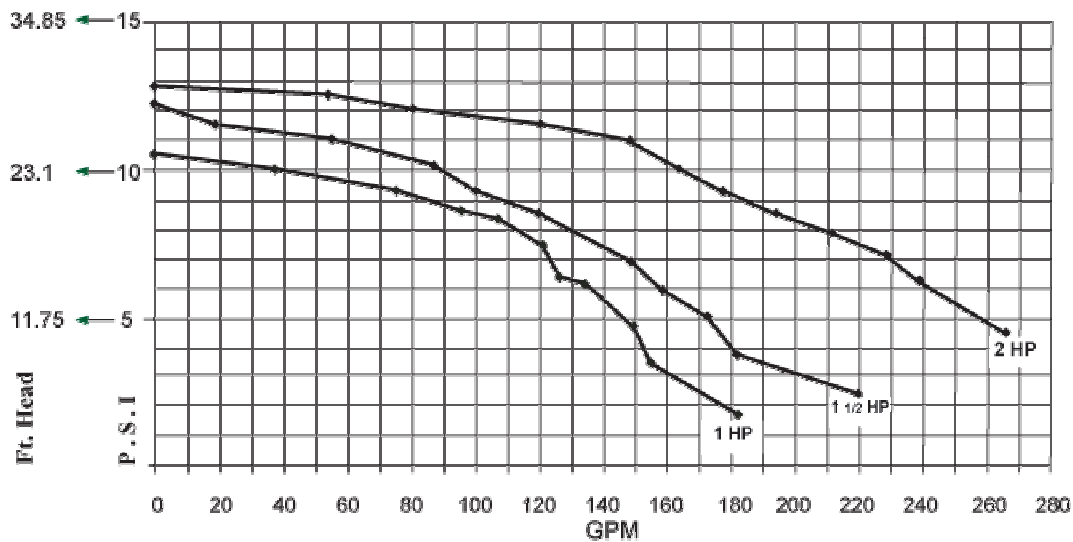


# Flow charts courtesy of WLim Corporation

## Wave II Dragon Series



## Wave II Dragon Series – Max Flow



The pumps come with **2 1/2"** unions for IN and OUT. A 2 1/2" pipe will give you higher pressure, but the flow will slightly decrease. **You must increase to 3" pipe to get 100% max flow.** This will not over-amp the motor; and will match the performance curve we have provided.

## **LET'S DO A WHOLE POND**

All references will be from the drawing on the next page. I will just add the pipe length equivalents for the flows we want rather than show the work. If it's confusing, the previous calculation examples can be referenced. The only thing new is the tee. It is listed on the friction chart as flow-through or branch, and because we are reducing to 1½", I will use that sized pipe numbers. I will also cut the flow in half for each run, even though the flow may not be even, this should get us close enough. You would probably restrict the first TPR to try to even the flow.

Now that we have all the needed skills to design a pond plumbing system, let's just make a quick one up and see where the numbers fall. This will be an average-sized pond with 2 bottom drains and a skimmer. The pond is elevated and the pumps have flooded suction. The only elevation is the rise to the top of the waterfall.

We want a nice looking falls, so we're shooting for 6000 GPH over those from the skimmer circuit, knowing this GPH leads to higher friction we will make everything after the UV 3" pipe.

For each bottom drain circuit, we'll do 3000 GPH returning to two TPRs each. From pump to tee we will use 2" and drop to 1½" to the TPRs.

---

### **PUMP #1 PIPING**

Suction Head:  $2' + 2' + 4.6' + 1.5' = 10.1'$  @ 3000 GPH = .42' of Head

Discharge Head: (2")  $1.5' + 6' = 7.5'$  @ 3000 GPH = .31' of Head

Tee flow through: (1½")  $2.7' + 2' + 1' = 5.7'$  @ 1500 GPH = 0.23' of Head

Tee branch: (1½")  $8' + 8' + 1.4' + 2' + 1' = 20.4'$  @ 1500 GPH = 0.81' of Head

Total Dynamic Head = 1.77'

---

### **PUMP #2 PIPING**

Suction Head:  $2' + 2' + 4.6' + 1.5' = 10.1'$  @ 3000 GPH = .42' of Head

Discharge Head: (2")  $1.5' + 5' + 3.8' + 9' + 3.2' + 10' + 3.2' + 5' = 40.7'$  @ 3000 GPH = 1.69' of Head

Tee flow through: (1½")  $2.7' + 9' + 1.4' + 2' + 1' = 16.1'$  @ 1500 GPH = .64' of Head

Tee branch: (1½")  $8' + 2' + 1' = 11'$  @ 1500 GPH = 0.44' of Head

Total Dynamic Head = 3.19'

---

### **PUMP #3 PIPING**

Suction Head:  $2' + 2' + 4.6' + 7' + 4.6' + 1.5' = 21.7'$  @ 6000 GPH = 3.26' of Head

Discharge Head: (2")  $3.3'$  (10% for flex & bend) +  $1.5' + 10'$  (Bead) +  $2.2' = 17'$  @ 6000 GPH = 2.6'

120 Watt UV: (using 2" pipe)  $8' + 13.5'$  (6 standard bends) =  $21.5'$  @ 6000 GPH = 3.2' of Head

Discharge Head: (3")  $4' + 2' + 4' + 15' + 4.3' + 9' + 2' = 40.3'$  @ 6000 GPH = 0.88' of Head

Elevation Head: 6'

Total Dynamic Head = 15.94'

---

Let's pick the pumps:

As you can see both bottom drain circuits have minimal Head. For these circuits, I would use WLim's 1/15 HP pumps. They are not listed on the flow charts, but flow 3K GPH against minimal Head such as our circuits.

For the skimmer though, we have fairly high Head. Two pumps come close in the range we want. The Dragon ¾ HP comes close, and the Wave II 1 HP is on the money. If you can live with slightly less flow, the Dragon would be the better choice, saving on energy over the long term.



## **CALCULATING ENERGY USE**

I throw this in to the plumbing part mostly because it will tie in directly to what I've been talking about in regards to energy conservation. One of the main reasons to spend the money up front on proper piping and fittings is to make your energy use as low as possible. In the 24/7 world of pond plumbing though, it's hard no matter what.

Power usage is billed in Kilo Watt Hours (KWH). Kilo or K is the equivalent of 1,000, so each unit is 1,000 watts. All houses have Watt-Hour meters on the main electric panel to measure electrical use. Watts are the electrical term for Power. Power is what it takes to run things, so this makes sense.

For those of you a little more familiar with electrical, you'll have heard of Ohms Law. This is the mathematical way to calculate for power. Current or amperes (A) multiplied by the voltage or volts (V) will give you power ( $A \times V = P$ ). In the US, we have 120V available at our plugs. If you plug in a device that draws .5 amps of power it will use 60 watts. The only time this strays a little is with inductive loads, and a power factor is involved. To most of us this isn't too important because the manufacturers have done that math and will list watts used on most of the devices we purchase for ponds.

The safest way to check is with a watt meter. A relatively cheap one I like is called the Kill-A-Watt. It will measure true wattage as your house meter does, so it gives an accurate reading of what you'll be billed for. The site is for reference; shop it around for the best price.

### **Kill-A-Watt Meter**

Enough Electric 101, once you know what a device will draw power-wise (watts) you can figure your monthly operating costs. Let's say a pump is drawing 200 watts.

Remember this is for monthly:

30 days = 720 hours.

$200 \text{ watts} \times 720 \text{ hours} = 144,000 \text{ Watts}$

$144,000 \div 1,000 \text{ (your billed per 1,000)} = 144 \text{ KWH}$

You'll have to look at your electric bill to see what the going rate is per KWH in your area. We'll use 10¢ per KWH for our purpose.

$.10 \times 144 = \$14.40$  per month to run that pump.

Let's say you plumbed the most efficient way and are able to use a 150W pump instead.

$150 \times 720 \div 1000 \times .10 = \$10.80$  per month for a savings of \$3.60

When looking at the pump ratings compared to the flow charts, you will see there's a huge leap in wattage as you increase pump size to overcome the Head increases. This was just an example to show you the math.

## **CONCLUSION:**

I'll end it here, as the basics have been covered. There is so much more to talk about, but it leads into other discussions about filtration and pond design. The good news is what you've learned here can be applied to anything you add to your system.

Just for fun, let's apply the energy calculations from the small pond we drew to see how the numbers will fall. For space reasons only one vortex was shown. Let's assume it's a three vortex set-up with an aerated bed biofilter on each loop. We'll use an 80L air pump for each. We will also have an 80L air pump running both aerated bottom drains.

Dragon ¾ HP		600 Watts
Wave I-1/15 HP	×2	300 W
120W UV		130 W
80L Air Pump	×3	<u>258 W</u>
Total		1,288 W

Using the formulas from above:

$$1,288 \times 720 = 927,360$$

$$927,360 \div 1,000 = 927.36 \text{ KWH}$$

Multiply that by your electric rate, I'll again use 10¢ per KWH

$$927.36 \times .10 = \$92.74 \text{ monthly running costs.}$$

As you can see when designing a more advanced pond that the energy costs add up. On the example pond, we switched to 3" for the run to the waterfall. Had we stayed all 2", the Head would have increased by 4.49' for a total of 20.43'. To maintain the flow we wanted, the pump would now have to be a 1.5 HP pump running at 1256 watts. (We have to go an extra .5 HP to overcome the smaller piping.) Do the math for the extra 656 watts per month.

$$656 \times 720 = 472,320$$

$$472,320 \div 1,000 = 472.32 \text{ KWH @ } 10\text{¢ ea} = \$47.23 \text{ a month.}$$

That 3" pipe looks cheaper all the time, doesn't it?

Happy Pondering,

Garrett