# Water Garden Measurements
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The purpose of this article is to help you in calculating various requirements around your water garden. I have used information from my own experience, plus various articles and forums on web sites. If you are just starting out as a 'ponder' these calculations should help you get it right the first time. If you have an existing pond and are having problems, following these calculations may explain some of them. If you are thinking of changing your pond, these calculations will help guide you and lastly, if you are wondering if it's safe to add more fish, the answer is in the calculations below.

## Part 1

**Determining size of liner required**

For the length of liner required calculate Max. length of pond + (2 x max. depth of pond) + 2 feet overlap at each end.
For the width of liner required calculate Max. width of pond + (2 x max. depth of pond) + 2 feet overlap on each side.
Be sure to measure across the maximum length and width and at right angles to each other.

As an example, if you have decided on a location that measures 10 ft. by 13 ft. and you want 2 ft. deep and including a minimum liner overlap of 2 feet for both length and width, you determine a required liner size of 18' x 21'. (10 +(2+2) +(2 +2)) by (13 + (2+2) +) 2 +2))

Note - you may be able to use shorter overlaps. The overlap needs to be large enough so that it can go under the edging materials and then rise up a couple of inches at the back of the material to prevent overflow

When planning a new pond you may want to consider that liners often are sold at fixed sizes or at least in widths at 5' multiples. So in the example above you would be buying either 18' x 20' which would reduce the pond length by 1 foot or buy 18' by 25' which would allow a combination of greater length or depth in part or all of the pond.

### *Some common conversions*

To calculate power consumption: Volts x Amps = Watts

To calculate yearly cost of operation:
Watts divided by 1000 x the price of electricity in $ per kilowatt hour x 24 hours x number of days in use in a year

One U.S gallon = approx. 0.834 Imperial gallons
One U.S. gallon = approx. 3.78 liters
One Imperial gallon = approx. 1.2 U.S. gallon

Caution - most but not all items such as filter and pumps sold in Canada use US gallons but not all. Not understanding which measurement is meant in something you read can lead to improper sizing of equipment and incorrect dosing of medicine. If a product gives a liter value and a gallon value without indicating US or imperial gallons, you can use the ratio above to determine which it is.

To help with some dosage rates for medicine:

PPM (parts per million) = mg/liter or milligrams per liter
1000 milligrams = one gram
1000 milliliters = 1 liter
or one liter holds 1000 milliliters, abbreviated 1000 ml
ppt (parts per thousand) = ten times weight percent, since percent is simply parts per hundred
Each USA gallon holds 8.4 pounds of water, each imperial or UK gallon holds 10.0 pounds per gallon.
Each pound hold 454 grams.
A ml of water weighs very close to one gram and occupies a volume of one cubic centimeter or cc.

**Example**

Potassium permanganate is a powder used by some Koi keepers to control parasites. It is recommended to use at 4 PPM. First create a stock solution that can be used for multiple treatments. Measure a level teaspoon of PP powder (approx. 7 grams) and put in a container, which will hold a liter of water. Add a liter of water and mix until the powder is dissolved. You now have a stock solution, which has 0.007 grams per milliliter. If you are doing the treatment in a quarantine tank which holds 67 US gallons the calculation is - 67 times 8.4 pounds per gallon = 563 pounds of water. 563 times 454 grams per pound gives 255,000 grams of water, or 0.255 million grams of water. 0.255 million grams times 4 parts per million of PP gives 0.255 times 4 = 1.02 grams of PP needed. 1.02 grams of PP needed divided by 0.007 grams PP per ml = 146 ml of the stock solution described above to obtain a 4 PPM charge of PP to the 67-gallon tank.

You will find some articles, which give dosage rates in metric and quote rates per ton of water. One ton of water equals one cubic metre of water, which contains 1,000 liters and weighs 1,000 kilos. To calculate the tonnage of a system from imperial gallons divide the total pond volume by 220. For example if a pond contains 7,500 imperial gallons it holds 34.09 tons (7,500 divide by 220). To calculate the tonnage of a system from US Gallons divide the total pond volume by 264. For example if a pond contains 10,000 US Gallons it holds 37.87 tons (10,000 divide by 264).

To calculate the square foot surface area of a pond:
For a rectangular pond - multiply average length by average width
For a circular pond - multiple half the diameter by half the diameter by 3.14

**Actual Pond Volume**

Average length (ft) x average width (ft) x average depth (ft) = total cubic feet x 7.48 = Actual Pond Volume (US gallons)
For Actual Pond Volume in Imperial gallons multiply total cubic feet by 6.25

**Example**

Pond is 12' avg. length x 10' avg. width x 2' avg. depth

U.S. Pond Volume: 12 x 10 x 2 = 240 cubic feet. C.f. x 7.48 = 1,795 gallons
Imperial Pond Volume: 12 x 10 x 2 = 240 cubic feet. C.f. x 6.25 = 1,500 gallons

Note - Unless your pond is box shape, you will not be using the same numbers used in calculating liner sizes. To calculate a good average, measurements should be taken at several points.

If starting with an empty pond options include using a flow meter, monitoring water tank measurement change or timing how long it takes in seconds to fill a bucket such as 10 gallon and then time how long it takes to fill the pond. If it takes 15 seconds to fill 10 gallons and it takes 3000 seconds to fill the pond then you have 2000-gallon pond. In determining the total water to be filtered, additions must be made for volume in the tubing, filters and any other areas such as a header pond for the waterfall.

**Effective Pond Volume**

When selecting the proper size equipment for your pond, actual volume alone is not enough. You must determine the effective volume of your pond, which is influenced by various environmental factors. Determine if your pond is affected by direct exposure to sunlight, shallow depth, or climate conditions, and add to the actual volume by the factors listed below:

If average pond water depth is less than 2' 6": add 25 % (This is a guide and is not meant that if your pond is 2' 5" add 25% and if 2' 7" then add 0% - shallow water heats up more and therefore requires more filtration so if around 2' 6" use a reasonable value).

Pond is located in full sunshine (6 plus hours): + 25 %
Pond is located in part sunshine (4 - 6 hours): + 15 %

Pond is located in Northern climate: + 0 % (if this will be used by someone in southern climate zones the factor would be + 35% for Florida and a descending amount as you go north towards 0% in Ontario. The zone ranges are 1-5 add 0%--6-7 add 15%--8-10 add 35%

***Example 1***

If you have a 2,500-gallon pond, 4' deep, located in full sunshine and you live in Ontario, the effective volume of your pond is 3,125 gallons (2,500 + 25 %).

***Example 2***

If you have a 1,500 gallon pond, 2' deep and exposed to part sunshine in Kentucky, your pump and/or pond filtration equipment would need to be increased by 55 % (25 + 15 + 15). You would therefore base your selection on a pond volume of 2,475 gallons.

Note - your filtration system needs to circulate the total effective pond volume every 1 to 2 hours

# Part 2

## Allowance for Fish Stocking Level

The information above does not take into account 'stocking level' of fish. The first consideration here is what kind of fish do you have. It is generally accepted that Koi are dirtier (waste wise) than goldfish and therefore require a better filtration system. I have not seen any kind of ratio of how much more is required for a quantity of Koi over the same quantity of goldfish. One of the big factors here is that Koi grow so much bigger and a bigger fish produces more waste. I will go into this more below where charts make it very clear that doubling the length of a fish adds a lot more than double to the overall size.

High stocking levels take different Koi practices over the conservative approach. It requires top-notch filtration system and more attention to all kinds of details. Calculating effective volume is never an exact science and when it comes to stocking levels, there are no golden rules that apply to all ponds.

I have seen rules for fish that include no more than 100 in. per 1000 gallon with a 1-% increase in effective volume for every inch over 100. This rule just said 'fish' and I assume this means goldfish. Another rule seen for Koi - if the total "fish length" is more than 32 inches per 1000 gallons then an extra percentage must be allowed. By example a pond of 500 gallons could contain 16 inches of fish, but if the stocking level was 32 inches then a 50% increase would need to be applied - thus meaning that the filter and pump must cope as though the pond is 750 gallons. Both of these rules only take into account the current size of the fish. You need to plan for the future. Goldfish often get to around 10 in. and reproduce very easily. Koi often get into the 24 - 26-in. range or larger but do not reproduce as easily in a water garden pond. Other rules seen are - for one lb. of Koi per 400 gallon, one lb. per 500 - 2000 gallon, one lb. per 100 gallon in a highly controlled pond and 1 in.

of Koi per square foot of surface area.

Two additional stocking formulas are:

1) These derivations are the gallons needed by the fish to feel comfortable with reasonable filtration. For home care of fish, wherein the hobbyist wants to know how many fish to keep in a pond and expect reasonable health and growth, try this formula.

Account for each fish and record its length in inches as accurately as possible (measured from tip of nose to tip of tail).
Total all the inches up.
Multiply that sum by itself. (squaring it.)
Multiply the product of this by two.
Divide the product by 231
Multiply that dividend by 10 for a comfortable minimum amount of water needed.
Double that result for an ideal, growth-potential number.

*Example.* A person is just starting out, and they have 20 fish of a seven to eight inch length.

Sum it = Roughly 150 inches of fish.
Square it = 22,500
Double it = 45,000
Divide by 231 = 195 is the dividend.
Multiply dividend by ten = 1,950 gallons is the ideal product.
Double = 3,900 gallons is a lofty, luxurious number.

Another person has obtained 5 large Koi, all thirty inches in length. The sum of the inches is also 150 and the final minimum analysis yields a 1,950-gallon pond for these five lunkers. Ideally, a 3,900-gallon facility would be provided. As these numbers are based on current size, they would need to be revised as any material increase in length occurs. Overstocking can lead to slower growth, (especially with goldfish) and consistently sicker fish

2) Another measure of stocking density is gallons of water per pound of Koi.

To determine your stocking level, you'll need to take inventory of your pond. If it is not practical to actually weigh your fish, measure fish in inches as above. Also note whether the fish is normal, skinny, or fat. A very skinny fish may weigh 25 - 50 % less than a normal Koi. A very fat fish may weigh 25 - 50 % more than normal. Now, using the chart below along with the build of your fish, estimate the weight of each fish.

Fish Length (inches) - Weight (ounces)

| | | |
|---|---|---|
| 2" = .06 oz | 13"= 15 oz | 24" = 96 oz |
| 3"=.19 oz | 14"= 19 oz | 25"= 109 oz |
| 4"=. 4 oz. | 15"= 23 oz. | 26"= 122 oz. |
| 5"=0.9 oz. | 16"= 28 oz. | 27"= 137 oz. |
| 6"=1.5 oz. | 17"= 34 oz. | 28"= 152 oz. |
| 7"=2.4 oz. | 18"= 41 oz. | 29"= 169 oz. |
| 8"=3.6 oz. | 19"= 48 oz | 30"= 188 oz. |
| 9"=5.1 oz. | 20"= 56 oz. | 31"= 207 oz. |
| 10"=6.9 oz | 21"= 64 oz. | 32"= 228 oz. |
| 11"=9.2 oz. | 22"= 74 oz | 33"= 250 oz |
| 12"= 12 oz | 23"= 84 oz | 34"= 273 oz |

Listed below are (very rough) stocking densities for a range of situations - select the situation that is appropriate for you.

1 gal: 1lb high density fish farm
10 gal: 1lb medium density fish farm, very high density Koi pond
100 gal: 1lb low density fish farm, medium density Koi pond
1000 gal: 1lb high density Japanese mud pond, very low density Koi pond
10000 gal: 1lb low density Japanese mud pond
100000 gal: 1lb well stocked fishing lake
1000000 gal: 1lb nature

So, now that you know your stocking density (total weight) and the density level you're targeting, you can determine if you are overstocked or not. For example, you determine you have 560 oz. of fish (35lb.) and have decided on a medium density pond. So, at 100 gallon per pound you will need 3,500 gallons.

If your pond is smaller than 3,500 gallons you are overstocked and if it is over 3,500 you still have room for growth.

Hopefully, these scenarios will put your pond's requirements into perspective.

# Part 3

**In deciding how densely you can stock your Koi pond, you should consider the following:**

- How much time are you willing to devote to care and maintenance?
- How often are you willing to perform maintenance?
- How much money are you willing to spend on: water, filters, electricity, food, backup systems, etc.?
- How long must the pond survive situations like power outages or pump failures?
- How skilled are you at identifying and fixing health problems?

As mentioned above, you also need to factor in the growth of your fish. Lets suppose that you start with 6 Koi that are 6" long. Your initial fish weight is only 9 ounces. If they are well cared for, they could easily be 10" long in a year and 14" in just two years. At 14" each, you now have 114 ounces of fish, almost 13 times what you started with only two years earlier - and they're not done growing! You need to plan for this growth when designing your pond and filters and when deciding on whether your pond can handle "just one more Koi".

So if we want our fish to remain healthy for many years, we should expect that we will have to provide the necessary level of care. In a commercial farm, if a fish gets sick, they just dispose of it. Unless you want to do the same, you can't stock your pond like it's a fish stick factory. For goldfish, the process will be similar but with the differences being they don't grow as fast or as large and generally require less care.

Besides using these figures to determine filter and pond sizes, they may also be used when calculating doses of medications, adding salt or when determining how much to feed. Calculations for medicine or food would be based on actual volume and not the effective volume.

This table also allows you to predict how much your fish will weigh in the future. Having some idea of future weight will help you make decisions such as "When do I need to upgrade my filter?" and "How big does my filter need to be?" Growth rates vary greatly. The chart below shows some (very rough) Koi lengths (in inches) for three situations: maximum growth, normal pond, and low growth. In the maximum growth scenario, the Koi are kept in water that is around 70°F to 75°F year round and are fed around 5% of their body weight daily (spread out over 8 to 12 feedings). The normal pond rate assumes that the Koi are fed twice a day in warm weather, less in the spring and fall, and none in winter. The low growth scenario assumes that the Koi are fed a little every few days in summer.

| Year | Max. | Norm. | Low |
|---|---|---|---|
| 1 | 6 | 4 | 3 |
| 2 | 12 | 8 | 5 |
| 3 | 16 | 11 | 7 |
| 4 | 20 | 14 | 9 |
| 5 | 24 | 17 | 11 |
| 6 | 28 | 20 | 13 |

**Impact of Total Head**

The terms "head" or "lift" are used to indicate the rise, measuring how high the water must be pumped for a particular application. The higher the pump must push the water, the less water will be pumped.

Pumping water through tubing (to a waterfall, for example) adds resistance. To allow for friction loss inside the tubing, add one foot of head for every 10 feet of horizontal tubing run.

Add the allowance for friction loss to the vertical distance (in feet) that you will be pumping the water. The vertical lift is measured from the surface of the pond. The resulting sum will be the TOTAL head that the pump will be required to pump. You should compare the amount of flow that you require to the flow rate that the pump provides at this specific head.

*Example* Vertical distance between pond surface level and the top of the waterfall is 3 feet. You have 20 feet of tubing between the pump and the waterfall. Your total head is 5 feet. When purchasing a pump, the manufactures instructions or the dealer should help in determining the impact of 'total head' on performance. For the effect of each additional foot, there is no common ratio that could be applied to all pumps. A couple examples are a pump rated at 950GPH is 850 at 3' and 750 at 5', and one rated at 2,400GPH is 2,000 at 3' and 1800 at 5'.

Note - on top of height and distance, you will need to add additional values if you are using rigid piping with elbows. For a 90-degree elbow add 32 times the pipe bore converted to feet. A 3" elbow has the same resistance as 8' of pipe (32 x 3"/12"). Add 8' for each 90-degree elbow to the total tubing when doing the total head calculation. For a 45-degree elbow use 15 instead of 32 in the calculation. If at all possible design your system without requiring these turns.

**Tubing Flow Rates**

The tubing size running from the pump is determined by the maximum flow rate of the pump you select. Pick the tubing diameter that is most appropriate for the volume of water coming from the pump. A hose adapter or a combination of adapters is required to attach the hose to most pumps. Following are the maximum flow rates in GPH for various tubing diameters:

| Max Flow<br>(GPH) | Required Tubing Size<br>(inside diameter - inches) |
|---|---|
| 300 | 1/2 " |
| 720 | 3/4" |
| 1200 | 1" |
| 3000 | 1-1/2" |
| 4800 | 2" |

Hint: If your pump does not deliver the amount of water it is rated for, perhaps you are using tubing that is the wrong size.

**Waterfall Flow Rates**

Appearance is an important consideration when operating a waterfall. The volume of water required too achieve different effects (robust waterfall vs. just a trickle) will depend upon the width of the waterfall lip (weir) or stream and the material that it is constructed from. The chart below will tell you how much water is required PER inch of waterfall width to achieve different thickness of water over the entire width of the waterfall weir. Using this chart and your 'total head' calculated above, it becomes quite easy to determine which pump to use.

| Desired Water Thickness - in inches | | | Required GPH Per inch waterfall width |
|---|---|---|---|
| Sharp Metal Weir | Stone Weir 6" to 11" wide | Stone Weir 12" or wider | |
| 1/4 | 3/16 | 1/8 | 30 |
| 3/8 | 5/16 | 1/4 | 50 |
| 1/2 | 3/8 | 5/16 | 75 |
| 3/4 | 9/16 | 7/16 | 140 |
| 1 | 3/4 | 5/8 | 200 |
| 1-1/4 | 1 | 3/4 | 275 |
| 1-1/2 | 1-1/4 | 1 | 375 |

*Example* You have a 3.5' tall (above the surface of the pond) waterfall and will have 15' of tubing run between the pump and the top of the waterfall. The total head is thus 5'. To achieve a 3/4" water thickness over the width of an 8" wide stone waterfall weir, you would require a pump that would produce 1600 GPH (200 GPH per inch x 8 inches total width - 5th line) at a total head of 5'. The earlier examples for 'total head' show a 2,400 GPH pump produces 1,800 GPH at 5' head, so for this waterfall example a pump rated around 2,250 GPH. should be about right.

You can also use this chart to predict the effect that you will get from different volumes of water.

*Example* If you use the same 3' tall and 8" wide waterfall as above with 15' tubing run, and you have a pump that only supplies 500 GPH at 4.5' total head, you would expect to get 62.5 GPH per inch (500 divided by 8) over the 8" width of the waterfall weir. As 62.5 is midway between 50 and 75 (line 2 and 3), the resulting water thickness would be between 5/16 and 3/8" thickness.

**How to Measure a Flow Rate**

This formula can be used to measure the flow rate of your pump. This is helpful to determine is a manufactures claim is correct or if an old pump is still working effectively.

Take a container of known volume (i.e. a 5-gallon bucket) and time how long it takes to fill it (in seconds) at the flow that you have. Then divide 3600 by the number of seconds it takes to fill the container and multiply by the volume (gallons) of the container. The result will be the flow rate in gallons per hour.

*Example*: It takes 10 seconds to fill a 5-gallon bucket.

3600 / 10 seconds x 5 gallons = 1,800 GPH

You can also use this formula to decide how much flow you would like over a waterfall by placing a garden hose at the top of the waterfall and adjusting the volume of water until you find the flow that you like. Measure this flow and you will have an idea of the volume required to get the effect you desire. For more robust flow you would likely need multiple hoses.

Using all these different calculations you should be able to determine any requirements for pumps and filters.