KOI MATH 101

Norm Meck

I have often been frustrated when I hear stories about how someone over or under treated their pond medicinally or chemically with disastrous results. Why didn't they compute the dosage they needed and properly measure it? I have found that in many cases, the pond keeper didn't know how. The basic math that was learned in school a few or many years ago may be a bit or a lot rusty. Often the most challenging mathematical task they have attempted in the last several years is balancing their checkbook (and that may now be done by their computer). Let's look back at some of the basic math skills needed by a pond keeper and get the rust off of them. Some may have to work a bit to wade through this, for others it might seem a little mundane, but for all it should be a good review.

Addition, Subtraction, Multiplication, Division

We won't talk a great deal about these basics. Your hand calculator will help out here and do a good job. The only thing to keep in mind are the units, or how the measurements are made. Inches cannot be added to gallons nor can feet be subtracted from liters. For addition and subtraction, the units must be the same and the result will also have the same units. Multiplication and division are a little different, the units resulting from a multiplication or division will be the combination of both of the units used to calculate the result. For example, if a gallon measurement is divided by a minute measurement, the resulting units are also gallons divided by minutes (usually called gallons per minute).

Conversions

Converting from one set of units to another is the pond keepers most common math challenge. The concept of a units conversion is based on the principles that both sides of an equality can be divided by the same number (except zero) without changing its value and similarly, that multiplying any number by one does not change the value. We use the units just like another number. Let's go through an example in detail. The conversion factor equality:

12 inches = 1 foot

can be expressed as 12 times inches = 1 times foot. If we divide both sides by 1

Install Equation Editor and double-click here to view equation.

times foot, then:

Install Equation Editor and double-click here to view equation.

but 1 times foot divided by 1 times foot is just 1, the units are said to cancel out.

Install Equation Editor and double-click here to view equation.

Since we can multiply any number by 1 without changing its value, if we wish to convert a 10 foot measurement to inches, then:

but since foot divided by foot = 1 (the foot units cancel out);

we have completed the conversion and:

10 foot = 120 inches

This is all we have to do to make any conversion. We can take some shortcuts with practice but as long as we keep close track of the units, we can't go wrong. Normally the above conversion would just be written down as:

10 ~~foot~~ x 12 inches / ~~foot~~ = 120 inches

Notice how the foot units were canceled out. Whenever we divide units by the same units, they cancel out (equal 1).

The table at the end of the article provides a set of approximate conversion factors for normally encountered units. The units we may encounter include; feet, inches, yards, miles, meters, centimeters, kilometers, acres, seconds, minutes, hours, gallons, liters, milliliters, teaspoons, drops, cups, pints, quarts, pounds, tons, grams, kilograms, parts per million, parts per thousand, percent, Farenheit, Centigrade, etc. Whatever the units are, it is important that they are consistent throughout the calculations.

Let's try another conversion for practice. We have a pump putting out 5 gallons per minute and we want to convert the flow rate to cubic foot per hour. From the table, we see that 1 cubic foot = 7.48 gallons and 1 hour = 60 minutes. We write down:

5 ~~(gallons~~ / ~~minute~~) x (cubic foot / 7.48 ~~gallons~~) x (60 ~~minutes~~ / hour) =

5 / 7.48 x 60 (cubic foot / hour) = 40.1 (cubic foot/ hr)

Actually, when we got out our trusty calculator and divided 5 by 7.48 and multiplied by 60, the calculator showed us the value to be 40.10695187.

Rounding Off

For almost anything we are doing, the accuracy requirements never exceed 1 part in one thousand, so we "round off" the value to 40.1. In this case we rounded off to three significant digits which gives us all the accuracy we need and it is easier to write down. Since our conversion factors only contain three significant digits, any additional digits are meaningless anyway. Disregarding any leading zeros, if the fourth digit is five or greater, add one to the third digit and discard the rest of the digits.

Examples:
12.3456 rounds off to 12.3
34567.891 rounds off to 34600.
0.000534791 rounds off to 0.000535

One of the things we run into quite often is dealing with concentrations. How much of something should be put into the pond to give it a concentration of so many parts per million or so many parts per thousand. One part per million is simply one measure of a substance for every million equal measures of a second substance (usually the water). It is important that we measure the two substances the same way, again to keep the units the same. Technically, these measures are supposed to be the molecular weights of each substance so the number of molecules of each can be determined. It is easier for us to just use the weight of each substance and not worry about how many molecules are involved. Once in a while we run across someone who is using ppm (incorrectly) to refer to volume measurements, i.e. one gallon for every million gallons of liquid. If so, the units just have to be kept straight. Usually we are concerned with weight where 1 ppm is one pound for every million pounds and 1 ppt is one pound for every thousand pounds. Since we don't normally go out and weigh the water in our ponds, we are back to a conversion between gallons and pounds.

Here is a place we have to be careful. In the English system, we must know whether we are talking about weight or liquid (volume) measurements. One fluid ounce (volume) by volume is NOT equal to one ounce by weight (although it is pretty close). You also have to know where you are for any of the liquid gallon measurements. The gallon (Imperial) used by Canada and England (and others) isn't the same size as the U.S. gallon. Be sure which applies to your calculations since you may need to include another conversion factor. Originally, the metric system was set up so that, by definition, one milliliter of water weighs one gram. If, for no other reason, this should convince everyone that world wide conversion to the metric system is warranted.

Let's get back to the conversion problems.

1ppm = (1 ~~pound~~ / 1000000 ~~pounds~~) x (8.34 ~~pound~~ / 1 gal) x (16 oz / 1 ~~pound~~) =
8.34 x 16 / 1000000 oz / gal = .000133 oz / gallon = 1 oz / 7500 gal

It gets a little trickier when we have a treatment that has already been mixed to one concentration and we want to add some of it to the pond to give us a different concentration. Again, as long as we keep the units straight, we can't go wrong. Suppose we buy a bottle of 0.75% malachite green solution and we want to treat our pond at a 0.25 ppm concentration.

0.75~~%~~ x 1/100~~%~~ x (1000 mg / 1 ml) = 7.5 mg / ml

or 1 milliliter of the solution contains 7.5 milligrams of pure malachite green. We want a 0.25 ppm concentration in the pond which we calculate to require

0.25 ~~ppm~~ x (1 / 1000000 ~~ppm~~) x (1000000 mg / ~~kg~~) x (379 ~~kg~~/100 gal)= 94.8 mg / 100 gal.

then:

(1 ml / 7.5 ~~mg~~) x (94.8 ~~mg~~ / 100 gallons) = 12.6 milliliters / 100 gallons

We have determined that for every 100 gallons in our pond, we should add 12.6 milliliters of the solution to achieve a 0.25 ppm concentration in the pond.

Length (L)

When we make a length measurement, most of the foot and inch measuring devices are calibrated in eighths or sixteenths of an inch. It is normally easier to convert these measurements to decimal parts of an inch before using them in our calculations. If we measure a length to be 14 7/8 inches, divide the 7 by 8 and add it to the 14, or 14.875 which we will probably round off to 14.9 inches.

Average

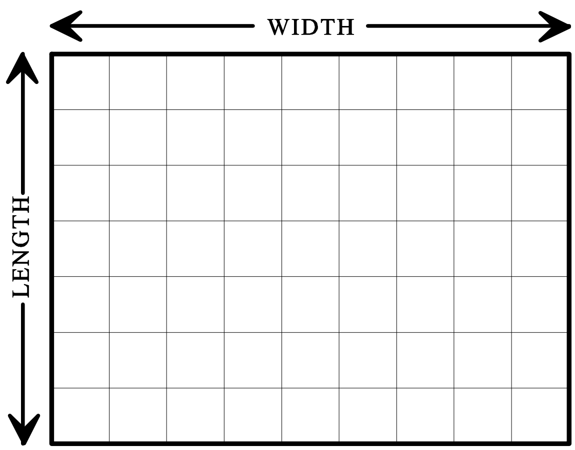
An average is a sum of samples divided by the number of samples. For example, if we measure the length of each of the five Koi in our pond and find them to be 5", 8 3/4", 9 1/2", 12" and 15 1/4" long. The average length is:

(5"+8.75"+9.5"+12"+15.3")/5 Koi or 50.5"/5 Koi or 10.1 inches per Koi

Remember that since we are adding the samples together, they must all have the same units, in this case, inches. Also note that the units include Koi since we divided by the number of Koi.

Area (A)

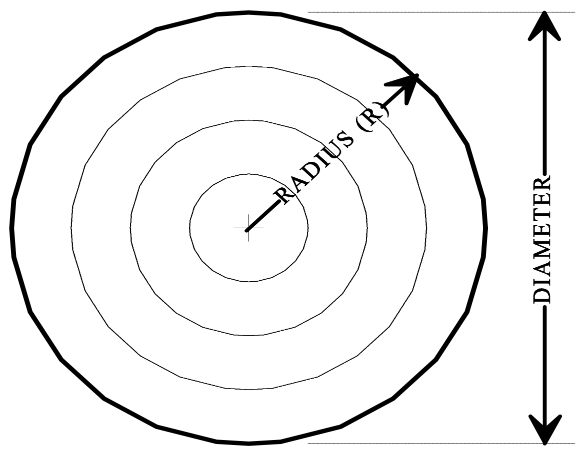
Multiplying a length measurement times another length measurement with the same units will give area. If the measurements are in feet, the result will be in square feet (usually designated as ft^2). The circumference (C) of an area is total length bounding the area or how far it is around it.. When working with circular shapes we run into the magic number Pi, where π= 3.14XXX(again only to three significant digits). Pi is defined as the circumference divided by the diameter (D) of any circle.



Rectangle (or Square)

$C = 2L + 2W$

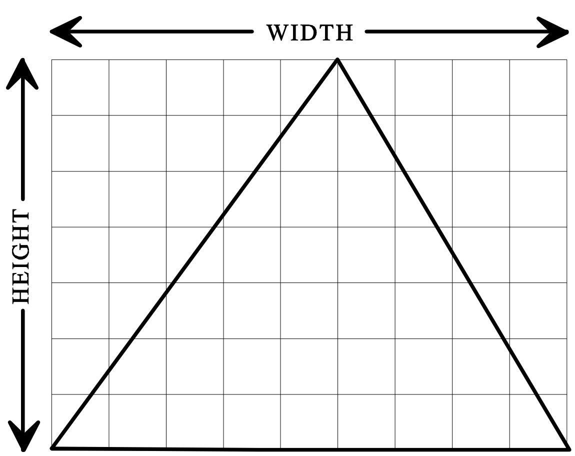
$A = LW$



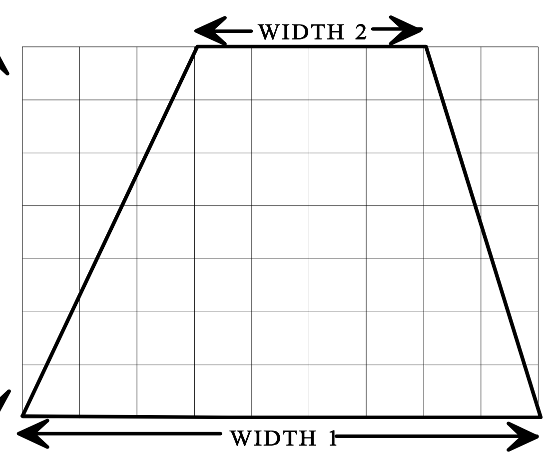
Circle

$C = 2\pi R$ or πD

$A = \pi R^2$ or $\pi D^2/4$



Triangle
A= 2 HW

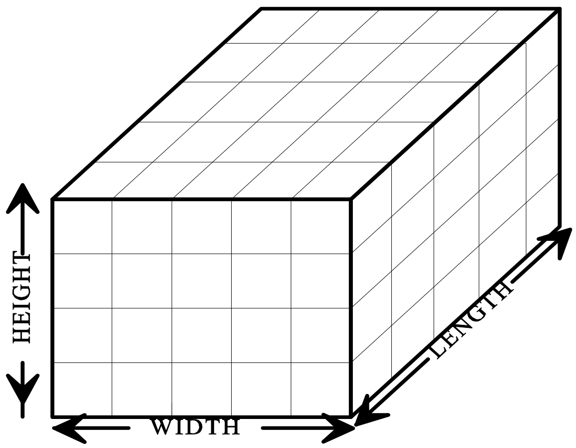


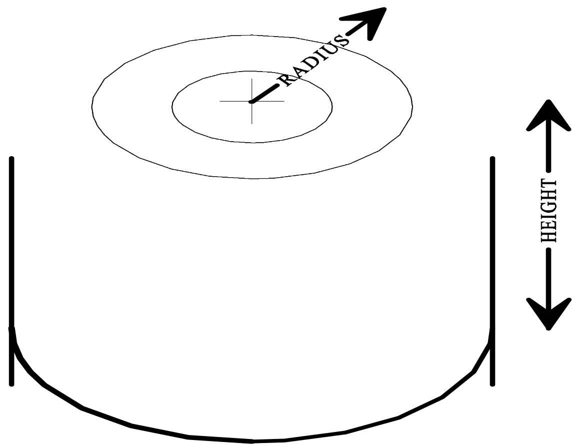
Trapazoid
A=2 H(W1+W2)

C= Sum of the lengths of each side

Volume (V)

Multiplying an area times another length measurement gives us volume. All three measurements must be in the same units. Again if our measurements are in feet, the result is in cubic feet (usually designated as ft^3). We can also compute the external surface area of a volume by adding the areas of each exterior side.





Box

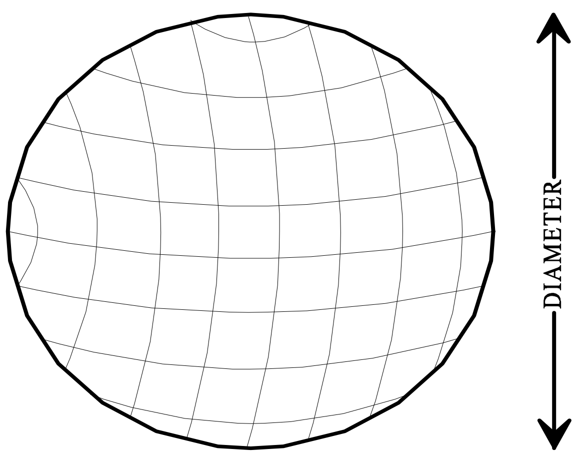
$A = 2(HW + LW + HL)$

$V = HWL$

Cylinder

$A = 2\pi R(R + H)$

$V = \pi R^2 H$

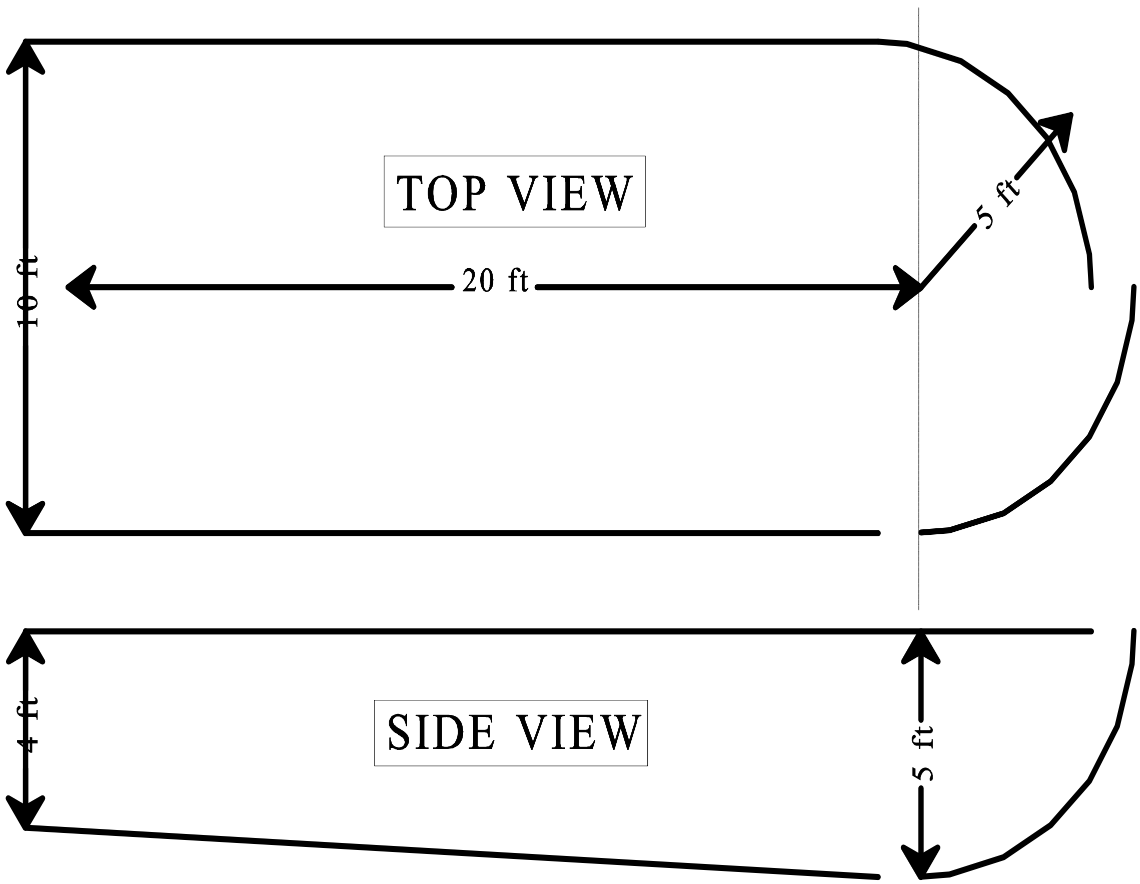


Sphere (Ball)

$A = \pi D^2$ or $4\pi R^2$

$V = \pi D^3/6$ or $4/3\pi R^3$

It is very important to know how much water is in your pond system. This includes not only the water in the pond but also that in any mechanical filter and in the bio-converter. Of course the best way to determine this is to measure it with a water meter when the pond is first filled but if this wasn't done, we can calculate it. If a pond layout is fairly straight forward, it is often easy to divide it into several of the basic shapes. The computations for each of the basic shapes can be made and then added together. My larger pond fits this case as shown.



Looking at the pond from the top, the surface area equals length times width of a 10 by 20 foot rectangle plus one-half of a five foot radius circle.

$$A=(10x20) + 1/2(\pi x5^2) = 200 + 39.3 = 239.3 \text{ sq ft } (239 \text{ ft}^2)$$

The volume equals average depth times the area of the rectangle plus one-fourth the volume of a five foot radius sphere.

$$V=((4+5)/2)x10x20 + 1/4(4/3x\pi x5^3) = 900 + 183 =1083 \text{ cubic ft } (1080 \text{ ft}^3)$$

1080 ~~cubic ft~~ x 7.48 gal/~~cubic ft~~ = 8080 gal

I know that the mechanical pre-filter contains 400 gallons and the bio-converter also contains 400 gallons so my total pond system contains 8880 gallons. One inch in depth at the surface contains:

239 square ft x 1 ft/12 in = 19.9 cubic ft / inch

converting to gallons:

19.9 ~~cubic ft~~ / in x 7.48 gal/~~cubic ft~~ = 149 gal per in

If I want to do a 10% water changeout, 8880 x 0.10 = 888 gallons. I need to drop the level of the pond 888 ~~gal~~ / 149 ~~gal~~ / in = 5.96 inches (I would probably use 6 inches), and then refill it.

In liters, 8880 ~~gallons~~ x 1 liter/0.264 ~~gallons~~ = 33600 liters and a 1 ppm chemical or medicinal dosage by volume would be:

33600/1000000 = 0.336 liters per ppm = 336 milliliters per ppm

By weight:

8880 ~~gallons~~ x 8.34 pounds/~~gallon~~ = 74100 pounds

and a dosage of 1 ppm by weight would be:

74100/1000000 = 0.0741 pounds per ppm

0.0741 ~~pounds~~ per ppm x 16 ounces/~~pound~~ = 1.19 ounces per ppm

1 ppt by weight would be 74100/1000 = 74.1 pounds per ppt

Knowing these values makes it easy to determine amounts of any treatment. If I want to raise the salinity of the pond by 2 ppt, I know I should add

2 ~~ppt~~ x 74.1 pounds/~~ppt~~ = 148 pounds of salt.

Flow Rate

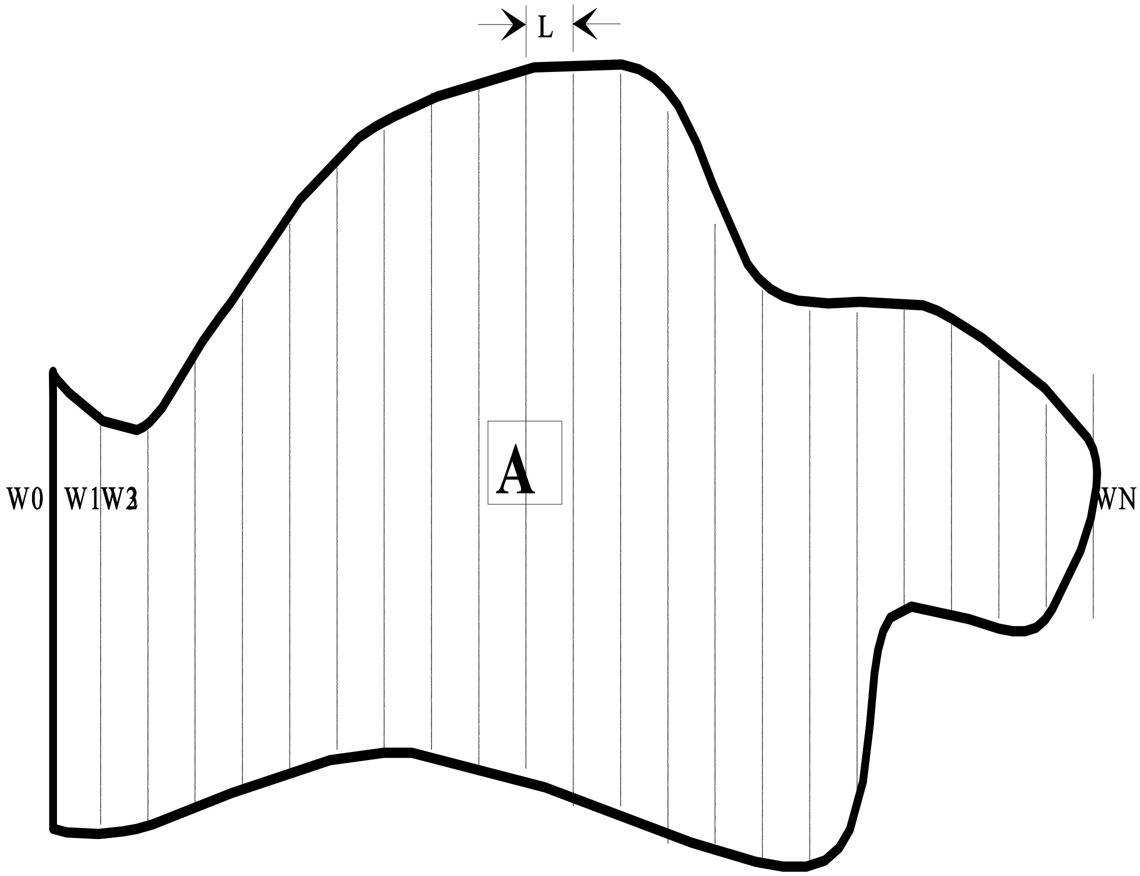
The true flow rate of a pond's pump system should be known but is often difficult to determine. This flow rate is of course related to the pump ratings but usually is less (sometimes a lot less) due to piping configuration and discharge height. If all the water from the pump system renters the pond over the waterfall and a bucket can be placed under the waterfall to catch all the water, the flow rate can be fairly easy to measure. If we take a container with a known capacity, G and time how long it takes to fill, we can then compute the flow rate. We will actually make several fill time measurements and then average them. My five measurements to fill a 25 gallon container were: 15, 16, 17, 15, and 15 seconds for an average of 15.6 seconds.

25 gals / 15.6 ~~secs~~ x 3600 ~~secs~~ / 1 hour = 5770 gal/hour

The pond turnover rate is how long it takes the pump to move the amount of water in the pond system through the bio-converter or:

8880 ~~gal~~ / 5770 ~~gal~~/hour = 1.54 hour

The more free formed ponds take a little more work. For example:



Trapezoidal Rule

Divide the surface area, A, into N equidistant chords

of lengths, W0, W1, W2, W3, ..., WN (W0 and/or WN can be zero).

Then, approximately,

$$A = L(2W0 + W1 + W2 + ... + WN-1 + 2WN)$$

In other words, take measurements of the width of the pond (W) every few inches (L). The smaller L is, the more accurate the result and the smaller the pond, the smaller L should be. Try to pick L to be somewhere between one tenth and one twentieth the length of the pond. Essentially what we are doing is just dividing the surface area of the pond into 10 to 20 small rectangles, computing the area of each rectangle, and then adding them all together.

To determine the volume we need to take a lot more measurements. Take five to ten depth measurements along each chord and average them together to find the average depth at each chord, DN. Then the approximate volume is:

$$V = L(2W0*D0 + W1*D1 + W2*D2 + ... + WN-1*DN-1 + 2WN*DN)$$

This takes a bit of work but it only has to be done once. (Now don't you wish you had used that water meter when you first filled the pond?)

Homework and Final Exam

Pond Volume (ft^3)		Pond Volume (gal)	
Pre Filter (ft^3)		Pre Filter (gal)	
Bio-Converter (ft^3)		Bio-Converter (gal)	
System Total (ft^3)		System Total (gal)	
1 ppm (ml)		1 ppm (oz)	
1 ppt (gal)		1 ppt (pounds)	
Surface Area (ft^2)		Gallons per inch	
Flow Rate (gal/hr)		Turnover Time (hr)	

Remember to keep your units straight and double check your work. When you are sure your values are right, keep a copy for future use and you are then entitled to sign and display the following certificate of achievement. Play "Pomp and Circumstance" on the boom box and have a glass of champagne alongside your pond to celebrate. Your Koi will be very proud and appreciate your efforts.

DIPLOMA

This is to certify that

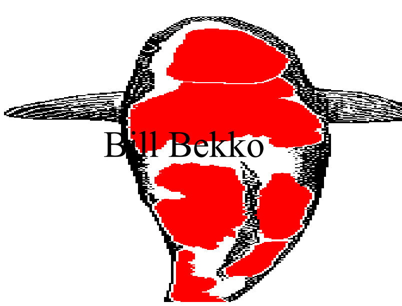
____

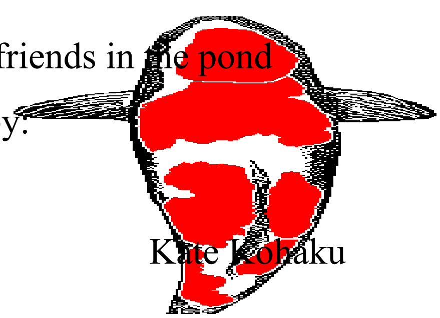
has successfully completed

KOI MATH 101

for the benefit of all the finny friends in the pond

as witnessed by:





Bill Bekko Kate Kohaku

Approximate Conversion Factors

1 percent (%) = 10 parts per thousand (ppt) = 10000 parts per million (ppm)
1 liter (l) = 1000 milliliters (ml) = 0.264 gal = 61.0 cu in = 0.001 cu meters
1 kilogram (kg) = 1000 grams (g) = 1000000 milligrams (mg)
1 ppm = 1 mg/l = 1 gram per 265 gallons = 1 ounce per 7500 gallons
1 pound per hundred gallons = 1200 ppm = 1.20 ppt = 0.120 %
1 cu ft = 1728 cu in = 7.48 gal = 28.3 liters
1 cu in = 0.00433 gal = .0164 liters = 16.4 ml
1 gallon = 231 cu in = 3.79 liters = 8.34 lbs (pure water weight)
Note: 1 English (Imperial gallon) = 1.2 U.S. gallons
1 gallon = 4 quarts = 8 pints = 16 cups = 128 fluid ounces
1 fluid ounce = 1.04 ounces (avoirdupois)
1 gallon/hr = 3.82 cu in/min
1 gallon/minute = 60 gallons/hour
1 gallon/second = 60 gallons/min = 3600 gallons/hour
1 liter/hr = 1.02 cu in/min
110 drops = 1 teaspoon = 5 ml
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup = 8 ounces
2 cups = 1 pint = 16 ounces
2 pints = 1 quart = 4 cups = 32 ounces
1 ton = 2000 pounds = 240 gallons
1 ml water = 1 gram = 1 cubic centimeter
1 ounce = 28.35 grams
1 lb = 16.0 ounces (avoirdupois) = 454 grams
1 kg = 2.20 lb = 1000 grams
1 yard = 3.00 feet = 36.0 inches = .914 meters
1 foot = 12.0 inches = 0.305 meters
1 meter = 100 centimeters = 3.28 feet = 39.4 inches = 1.09 yards
1 kilometer = 1000 meters = 0.621 miles
1 acre = 4356 square feet
1 mile = 1.61 kilometers
1 minute = 60 seconds
1 hour = 60 minutes = 3600 seconds
1 centimeter = 10 millimeters
1 micron = 0.000001 meters = .0001 centimeter
Temperature Farenheit <=> Centigrade

$^{O}F = 9/5\ ^{O}C + 32$

$^{O}C = (^{O}F - 32)\ 5/9$