Water math

Few people are driven to work on water resources by a love of math, but math is a necessary part of managing aquatic resources. This document identifies three skills the Aquatics Team believes Envirothon students should be able to use: volume calculations, units conversions, and load calculations.

Someone's got to have these skills. It might as well be you!

Volume calculations:

The volume of a block is LENGTH X WIDTH X HEIGHT. If you want to keep track of the volume of water in a watershed, however, you may be in trouble. Unlike blocks, watersheds don't usually have shapes easily described by length and width.

Instead, you can think of the volume of the block as BASE X HEIGHT. For a block, the BASE is calculated as LENGTH X WIDTH. For a watershed, the base is calculated as the watershed area.

Question: If one inch of rain falls on a 1-acre watershed, how much water is that? This leads right to units conversion.

Volume = BASE X HEIGHT

BASE = 43,560 SF (for SQUARE FEET, or Ft^2. See Footnote below[1])
HEIGHT = 1 inch = 1/12 feet

VOLUME = 43,560 FT * 1/12 FT = 3,630 CF (for CUBIC FEET, or Ft^3)

Unit conversion

Who wants an answer in cubic feet? Gallons is a much easier volume unit to think about. How do we convert 3,630 CF to gallons?

Please recall the following from math classes.

If Y=X, and X is not 0, then Y/X = 1.

Z x 1 = Z.

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[1] How do you remember 43,560 ft^2 per acre? 1. Practice. 2. Think of it as ten square fields that are 66 feet on a side (10 x 66 x 66 = 43,560). By the way, 66 feet is the same as one CHAIN, which is a unit used in old surveys. 3. Think of trying to drop a ball on a mountain that is 4.5 miles away. Your first shot doesn't go far enough, so it hits 4 and rolls down to 3. Your second shot goes too far and hits 5 and rolls down to 6. Out of disappointment, you say "O."

How does this help? To convert 3,630 CF to gallons, we multiply it by a conversion factor. That conversion factor must be equal to 1.

1 CF = 7.5 gallons (see note two[2])

$$1 = \frac{7.5\ gal}{CF}$$

So the answer, in gallons, is

$$1 \text{ acre X 1 inch} = 3{,}630 \text{ CF X} \frac{7.5\ gal}{CF} = 27{,}225 \text{ gal}$$

Notes on Unit Conversion

1. If you have a quantity in a unit you don't like (like CF), that unit will usually be in the numerator–the top part of a fraction. To convert away from it, you want the unit to show up in the denominator–the bottom part of the fraction. Then they cancel. You can cross them both out! Sometimes the unit you don't like is in the denominator, for example, when you convert gallons per minute to gallons per second. See below.
2. Use common sense. If you are converting from a bigger unit (like CF) to a smaller unit (like gal), make sure you wind up with a bigger number than you started with (27,225 for gal is bigger than 3,630 for CF, because 1 CF is bigger than 1 gal).

Load calculations

In a load calculation, you multiply the concentration of a substance the water is carrying by the amount of water flowing past a particular point, and your answer is the amount of the substance passing a particular point. For example, if there is 1 mg/L of iron in the water, and 100 liters of water are flowing past a particular point in a second, then 100 mg/s of iron are passing by in the water.

Why is this an important skill?

Let's say we have a stream flowing at a rate of 10,000 L/s, and it carries 2 mg/L of manganese (manganese is Mn. don't confuse it with magnesium, which is Mg!). The standard for manganese is 1 mg/L. 2 mg/L is too much.We need to get some pollution out of the stream.

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[2] If you look it up, you might find more decimal places: 1 CF = 7.48052 gallons. Remember as much of it as you like!

We have found an abandoned mine land (AML) that is discharging 100 gpm with a manganese concentration of 100 mg/L. If we fix this, how much of a dent will it make in the manganese concentration in the river? Since we need to get that 2 mg/L down to 1 mg/L, we have to take out half of the manganese.

River load = River flow X River concentration
=10,000 L/s X 2 mg/L
=20,000 mg/s X (1 g/1,000 mg)
= 20 g/s

So to fix the river, we have to decrease the load by about 10 grams per second (g/s). If we fix the AML load, will that do the trick?

AML load =AML flow X AML concentration
=100 gpm X 100 mg/L

Oh dear! We have to convert gallons per minute (gpm) to liters per second (L/s)!

100 gpm = 100 gpm X 1
= 100 gpm X (3.785 L/gal)
= 378.5 liters/minute
=378.5 liters/minute X 1
=378.5 liters/minute X (1 minute/60 seconds)
=6.31 liters/second

OK, let's try again!

AML load =AML flow X AML concentration
=6.31 L/s X 100 mg/L
=631 mg/s X (1 g/1000 mg)
=0.631 g/s

So, fixing the abandoned mine land will bring the load from 20 g/s to about 19.4 g/s. It would be good to decrease that pollution source, but if we are going to fix the river, we better not kid ourselves about what fixing that one problem will do!