WASTEWATER TECHNOLOGY
TRAINERS

Transforming today's operators into tomorrow's water quality professionals

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Problem of the Day

2014.Sept.25

Discussion

As discussed in yesterday's Problem of the Day (2014.Sept.24), most operators taking certification exams abhor "pond problems," but we really make them way harder than they need to be. In most pond problems, influent flow is given in Mgal/d (MGD) and the area of the pond is given in acres or can be easily converted to acres with the well known conversion factor:

$$\frac{43{,}560\ ft^2}{ac} \quad \text{or} \quad \frac{ac}{43{,}560\ ft^2}$$

If ac and Mgal are both in a pond problem either on opposite sides of the equals sign (=) or on opposite sides of the railroad track, the holy grail conversion factor of pond problems is:

$$\frac{3.069\ ac\cdot ft}{Mgal} \quad \text{or} \quad \frac{Mgal}{3.069\ ac\cdot ft}$$

Problem

Today's pond problem is the same as yesterday's but seeking something different.

Problem of the Day: It takes 43 days for the level in a 45-acre pond to be raised from 2 feet to 6 feet at which it discharges. Assuming the flow into the pond was constant and ignoring evaporation and precipitation, calculate the flow, in Mgal/d, into the pond over this time period.

Solution

There are at least two ways to approach this problem. The relationship between time, volume and flow rate was discussed in the 2014.Sept.22 Problem of the Day. Wastewater treatment plant operators often have to calculate how long it takes to fill a tank or a reservoir, how long it takes to empty a tank or a reservoir, or what the detention time is in a tank or a reservoir. Whenever a question arises asking about time and includes a volume (V) and flow rate (Q), the equation will be the same:

$$\text{Time} = \frac{V}{Q}$$

Again, this is the equation that will be used for every question asking about fill time, empty time or detention time. All that is needed to do the calculation is the volume and flow rate and the units required in the answer.

Our situation here is somewhat different: we know how long it takes to fill the pond from the the 2-ft level to the 6-ft level (43 days), and we can calculate volume (V = A x depth). In this case, we have to calculate the flow rate.

The equation above can be rearranged to solve for Q, a simple algebraic manipulation:

$$Q = \frac{V}{\text{Time}}$$

This equation is what is used to populate the railroad track, which is started by identifying the units needed in the answer, putting those units between heavy vertical lines followed by an equals sign and the blank track.

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$$\left|\frac{\text{Mgal}}{\text{d}}\right| = \text{\_\_\_\_\_}$$

As mentioned, volume of any channel, tank, reservoir, pond, even an ocean, is equal to the surface area times the depth. The area of this pond is 45 acres. The depth is the difference between the water surface level at the beginning of the fill period (2 feet) and the water surface level when the pond discharges (6 feet), or 4 feet.

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$$\left|\frac{\text{Mgal}}{\text{d}}\right| = \left|\frac{45\text{ ac}}{\ }\right| \left|\frac{4\text{ ft}}{\ }\right| \left|\ \text{\_\_\_\_\_}\ \right|$$

The equation above directs us to now divide by the time it takes to fill the 4 feet of depth, or 43 days.

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$$\frac{\text{Mgal}}{\textbf{d}} = \frac{45 \text{ ac}}{} \times \frac{4 \text{ ft}}{} \times \frac{}{43 \textbf{ d}}$$

Notice that Mgal and ac are on opposite sides of the equals sign. This calls for the use of the conversion factor referenced above. The other instance that calls for the use of this conversion factor is when Mgal and ac are on opposite sides of the railroad track, but on the same side of the equals sign. The use of this conversion factor greatly simplifies almost all pond problems. Using this one conversion factor finishes the current problem.

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$$\frac{\textbf{Mgal}}{\textbf{d}} = \frac{45 \text{ ~~ac~~}}{} \times \frac{4 \text{ ~~ft~~}}{} \times \frac{}{43 \textbf{ d}} \times \frac{\textbf{Mgal}}{3.069 \text{ ~~ac ft~~}}$$

45 x 4 ÷ 43 ÷ 3.069 = 1.36 Mgal/d.

There's at least one other way to do this problem.

In yesterday's Problem of the Day the hydraulic loading to this pond during this fill period was calculated: 1.116 in/d. Note the units on hydraulic loading are inches per day (unique to pond systems) which, generically, is length per time or L/T. Units of L/T, no matter what the specific units on L or T are, indicate units of velocity (think: miles/hour, L/T).

Velocity is very important in wastewater conveyance and treatment. Maintaining a velocity of wastewater flow in gravity sewers of greater than 2 ft/s is important to keep solids in suspension, lowering the velocity of wastewater flow to approximately 1 ft/s in a grit channel is important because grit and inorganic solids will settle out but organic solids won't, and the velocity of the flow exiting clarifiers is an important consideration in their performance. Velocity will be discussed again in a future Problem of the Day. For now, it is sufficient to know that the relationship between velocity (v), flow rate (Q) and the area through which the flow is passing (A) is another simple equation.

$$v = \frac{Q}{A}$$

In the current problem, however, we know v (here, the hydraulic loading rate, 1.116 in/d) and area (45 ac), so this equation has to be arranged to solve for Q, again a simple algebraic manipulation:

$$Q = v \times A$$

This equation is used to populate the railroad track (remember: in this problem v is equal to the hydraulic loading rate calculated yesterday).

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$$\frac{\textbf{Mgal}}{\textbf{d}} = \frac{1.116 \text{ in}}{\textbf{d}} \times \frac{45 \text{ ac}}{} \times \frac{}{}$$

Again, Mgal and ac are on opposite sides of the equals sign so the appropriate conversion factor is entered. When entering this conversion factor (3.069 ac·ft/Mgal), most of the time, find “ac” in the railroad track and enter “3.069 ac·ft” on the opposite side. Remember when “per” comes off your lips (this is what you’re saying to yourself when you are entering the conversion factor, “3.069 ac·ft **per** Mgal”), you go to the opposite side of the railroad track and enter whatever follows after “per,” in this case, “Mgal,” then cancel the units you can.

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$$\frac{\textbf{Mgal}}{\textbf{d}} = \frac{1.116 \text{ in}}{\textbf{d}} \quad \frac{45 \text{ ~~ac~~}}{} \quad \frac{\textbf{Mgal}}{3.069 \text{ ~~ac~~ft}}$$

As can be seen, the units needed in the answer, Mgal/d, are now in the railroad track. The problem is in and ft need to be canceled. Entering the appropriate conversion factor, known by all operators (12 in/ft) is the final step in solving this problem.

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$$\frac{\textbf{Mgal}}{\textbf{d}} = \frac{1.116 \text{ ~~in~~}}{\textbf{d}} \quad \frac{45 \text{ ~~ac~~}}{} \quad \frac{\textbf{Mgal}}{3.069 \text{ ~~ac·ft~~}} \quad \frac{\text{~~ft~~}}{12 \text{ ~~in~~}}$$

The arithmetic gives the answer: 1.116 x 45 ÷ 3.069 ÷ 12 = <u>1.36 Mgal/d</u>.

Same answer! (As well it should be.)

Pond problems are fun!