Water Quality Volume Exercise

**Problem 1:**
A site with a 2 acre drainage area is being developed and plans show 1.4 acres of impervious area are proposed. Calculate the water quality volume that will require treatment.

**Solution 1:**
The water quality volume is the volume of runoff from 1.5 inches of rain based on the Option 2 treatment requirements. The equation to calculate the water quality volume is shown below and can be found in Chapter 1.2 of the Water Quality Section in the Technical Manual.

\[
R_v = 0.05 + 0.009(I)
\]
where:
- \(R_v\) = volumetric runoff coefficient
- \(I\) = percent of impervious cover (%)

\[
WQ_v = \frac{1.5 \times R_v \times A}{12}
\]
where:
- \(WQ_v\) = water quality volume (acre-feet)
- \(A\) = total drainage area (acres)

The percent of impervious cover is equal to the impervious area divided by the drainage area:

\[
I = \frac{1.4}{2} = 0.70 = 70\%
\]

Then the volumetric runoff coefficient \((R_v)\) is calculated using the percent of impervious cover:

\[
R_v = 0.05 + 0.009(70) = 0.68
\]

Finally, the water quality volume is calculated for the 1.5 inch rainfall:

\[
WQ_v = \frac{1.5 \times R_v \times A}{12} = \frac{1.5(0.68)(2)}{12} = 0.17 \text{ acre-feet}
\]
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Problem 2:
Assume the development wants to use an off-line water quality BMP to treat the water quality volume. Calculate the flow that must be diverted to the water quality BMP. Assume a time of concentration of 15 minutes.

Solution 2:
An off-line BMP means that only the water quality volume portion of flow will enter the BMP, not all the site flow as in Problem 1. This means that a diverter should be installed to split the runoff from the site so only the required water quality flow enters the BMP and the remainder of the flow bypasses the BMP. In order to size the diverter you must calculate the amount of flow in cubic feet per second (cfs) that is equivalent to the water quality volume. This is done using the following calculation which is also found in Chapter 1.4 of the Water Quality Section in the Technical Manual.

\[ Q_{wq} = q_u \times A \times Q_{wv} \]

where:
- \( Q_{wq} \) = water quality peak flow rate (cfs)
- \( q_u \) = unit peak discharge obtained from Figure 1.10 of Hydrology Manual (cfs/mi²/in)
- \( A \) = drainage area (mi²)
- \( Q_{wv} \) = water quality volume in inches

The drainage area was given as 2 acres and must be converted to square miles. 1 square mile equals 640 acres, therefore 2 acres equals 0.003125 square miles.

The water quality volume in inches is calculated using the following equation:

\[ Q_{wv} = 1.5 \times R_v \]

where:
- \( Q_{wv} \) = water quality volume in inches
- \( R_v \) = volumetric runoff coefficient

\( R_v \) was already determined in Problem 1 to be 0.68 so the water quality volume in inches is:

\[ Q_{wv} = 1.5 \times 0.68 = 1.02 \text{ inches} \]

The unit peak discharge (\( q_u \)) is calculated from Figure 1.10 of Hydrology Manual which is shown on the following pages.

In order to use the chart you must have the time of concentration and \( I_a/P \) which is the initial abstraction over the depth of rainfall. The time of concentration was provided in the Problem 2 statement as 15 minutes which is 0.25 hours. The depth of rainfall (\( P \)) for the water quality volume is 1.5 inches based on the requirements of Option 2. The initial abstraction \( I_a \) is calculated with the following steps.
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Step 1: Calculate the curve number (CN)

\[
CN = \frac{1000}{[10 + 5P + 10Q_{wv} - 10(Q_{wv}^2 + 1.25Q_{wv}P)^{1/2}]}
\]

where:
- CN = curve number
- \(Q_{wv}\) = water quality volume in inches
- \(P\) = rainfall depth (1.5 inches)

\[
CN = \frac{1000}{[10 + 5(1.5) + 10(1.02) - 10(1.02^2 + 1.25(1.02)(1.5))^{1/2}]} = 95.1
\]

Step 2: Calculate the maximum potential abstraction (S)

\[
S = \frac{1000}{CN - 10}
\]

where:
- \(S\) = maximum potential abstraction
- \(CN\) = curve number

\[
S = \frac{1000}{95.1 - 10} = 0.52
\]

Step 3: Calculate the initial abstraction (Ia)

\[
I_a = 0.2 \times S
\]

where:
- \(I_a\) = initial abstraction
- \(S\) = maximum potential abstraction

\[
I_a = 0.2 \times 0.52 = 0.10
\]

Step 4: Calculate \(I_a/P\)

\[
\frac{I_a}{P} = \frac{0.10}{1.5} = 0.07
\]

Now Figure 1.10 can be used to estimate the unit peak discharge \((q_u)\). As from the red lines shown on the Figure, the unit peak discharge can be estimated as 800 cfs/mi²/in.

This allows the water quality peak flow rate to be calculated as flows:

\[
Q_{wq} = q_u \times A \times Q_{wv} = 800 \times 0.003125 \times 1.02 = 2.45 \text{ cfs}
\]

This means that a diverter would have to direct at least 2.45 cfs of flow towards the water quality BMP to meet the water quality requirements of Option 2.
Figure 1.10 SCS Type II Unit Peak Discharge Graph