

Hydrology = MIDTERM
November 2, 2006

Problem 1 ~~25pts~~

$A = 8.6 \text{ km}^2$ (urban neighborhood)
Pre-development $\left\{ \begin{array}{l} c = 0.25 \\ t_c = 45 \text{ minutes} \end{array} \right.$

Post-development $\left\{ \begin{array}{l} c = 0.70 \\ t_c = 22 \text{ minutes} \end{array} \right.$

IDF curves Ottawa.

SOLUTION

Peak flow (Rational Method)

$$Q = 0.278 C_i A \text{ [SI units]}$$

$$Q \Rightarrow \text{m}^3/\text{s}$$

$C \Rightarrow$ non-dimensional

$$i \Rightarrow [\text{mm/hr}]$$

$$A \Rightarrow [\text{km}^2]$$

Pre-development stage

$$C_{\text{initial}} = 0.20$$

$t_{c1} = 45 \text{ minutes} \rightarrow t_{c2} = 45 \text{ minutes}$ (precipitation duration
is equal with t_c)

$$Q_{\text{initial}} = 0.278 C_i i A$$

initial = 41 mm/hr (based on $t_c = 45 \text{ min}$)

$$Q_{\text{initial}} = 0.278 \times 0.25 \times 41 \times 8.6 = 24.5 \text{ m}^3/\text{s}$$

Short duration rainfall - intensity - frequency data for the period 1905 to 1975 (25 y)
 based on recording rain gauge data for the period 1905 to 1975 (25 y)

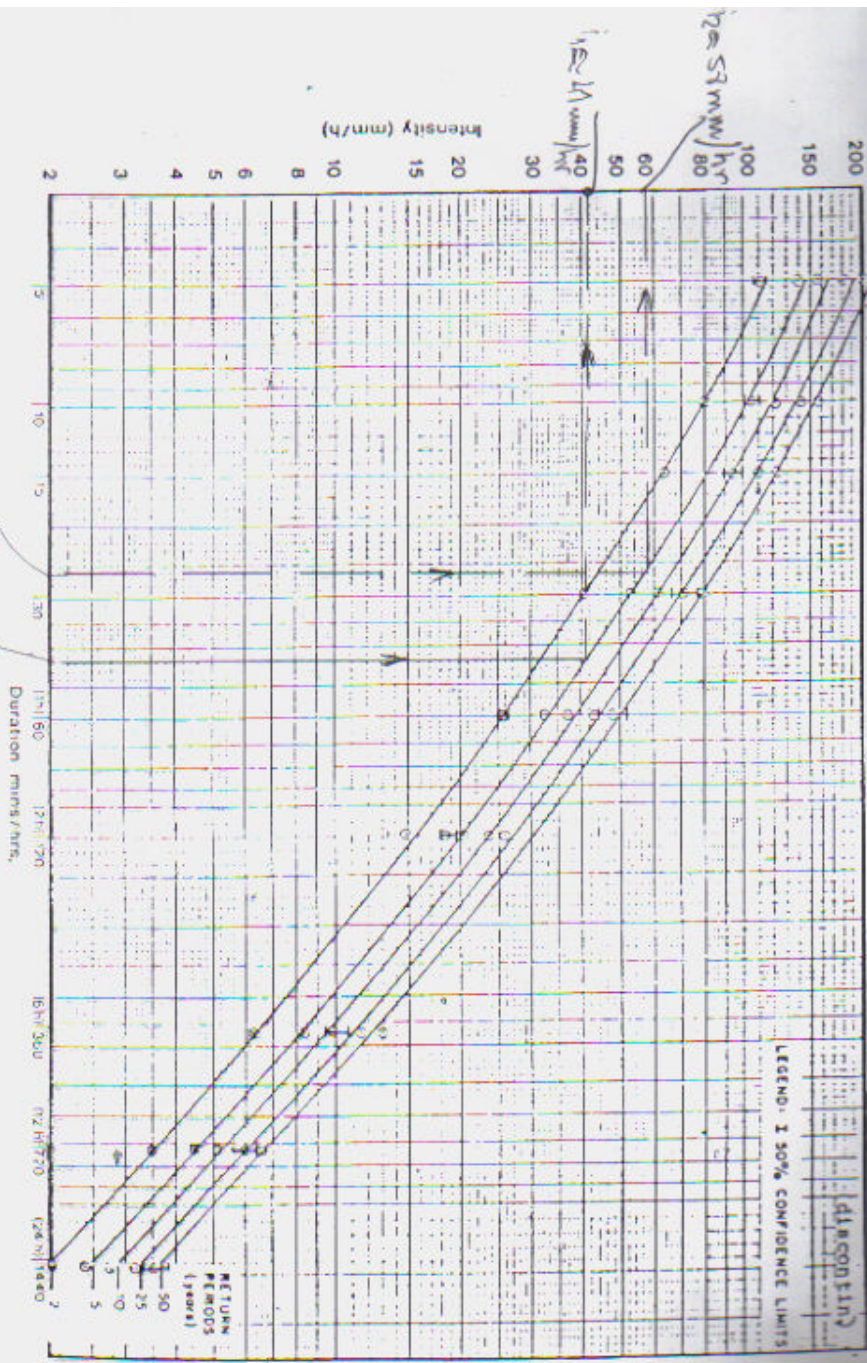


Figure 2.3.1 - Typical intensity-duration-frequency curves (20)

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Post-development stage

$$C_{\text{post-development}} = 0.70$$

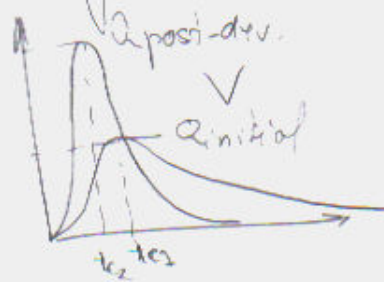
$$t_{c2} = 22 \text{ minutes} \Rightarrow I_{\text{post-development}} = 58 \text{ mm/hr}$$

$$Q_{\text{post-development}} = 0.278 C_2 i_2 A = 0.278 \times 0.70 \times 59 \times 0.6 \Rightarrow$$

$$\Rightarrow Q_{\text{post-development}} = 97.07 \text{ m}^3/\text{s}$$

$$Q_{\text{initial}} = 24.51 \text{ m}^3/\text{s}$$

⇒ The development of the area decreased infiltration and increased runoff. As a result there is an increase in runoff volume, flow, and a decrease in concentration time



Question 2

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(a) Probability that a 100-year storm to occur at least once in a 50-year interval?

Probability of occurrence = Risk = $1 - \left(1 - \frac{1}{T}\right)^n$

where T = return period
n = number of years (in question)

$P_{100} = 1 - \left(1 - \frac{1}{100}\right)^{50} = 0.395 \Rightarrow 39.5\%$

(b) Find the return period for a dam with 200 years design life with an acceptable risk of 2%

$R = 1 - \left(1 - \frac{1}{T}\right)^n \Rightarrow 1 - R = \left(1 - \frac{1}{T}\right)^n \Rightarrow$

$\Rightarrow \sqrt[n]{1 - R} = 1 - \frac{1}{T} \Rightarrow T = \frac{1}{1 - \sqrt[n]{1 - R}} \Rightarrow$

$\Rightarrow T = \frac{1}{1 - \sqrt[200]{1 - 0.02}} = 9900 \text{ years} \Rightarrow$

$\Rightarrow T = 10,000 \text{ years}$

Question 2

25

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$P = 75 \text{ mm} = 2.95 \text{ in}$

(A) Initial area $S = 19.4 \text{ ha}$. (wooded area, soil A, good condition)

(B) $A_1 = 10 \text{ ha}$ (residential area, class A soil, 1/2 acres type)
 $A_2 = 19.4 - 10 = 9.4 \text{ ha}$

$CN_{II}^1 = 54 \Rightarrow CN_{III}^1 = \frac{23 \cdot CN_{II}^1}{10 + 0.13 \cdot CN_{II}^1} = \frac{23 \times 54}{10 + 0.13 \times 54} \approx 73$

$A_2 \Rightarrow CN_{II}^2 = 25 \Rightarrow CN_{III}^2 = \frac{23 \cdot CN_{II}^2}{10 + 0.13 \cdot CN_{II}^2} = \frac{23 \times 25}{10 + 0.13 \times 25} \approx 43$

The composite number for the entire area,

$CN = \frac{A_1}{A_T} \cdot CN_{III}^1 + \frac{A_2}{A_T} \cdot CN_{III}^2 \Rightarrow$

$\Rightarrow CN = \frac{10}{19.4} \times 73 + \frac{9.4}{19.4} \times 43 = 37.63 + 20.84 = 58.47 \approx 59$

$S = \frac{1000}{CN} - 10 = \frac{1000}{59} - 10 = 6.95 \text{ in}$

The volume of runoff for the composite area (19.4 ha) is

$V_Q^{TOT} = \frac{(P - 0.25)^2}{P + 0.8S} = \frac{(2.95 - 0.25 \times 6.95)^2}{2.95 + 0.8 \times 6.95} = 0.29 \text{ in} \approx 0.73 \text{ in}$

$V_Q^{TOT} = 7.3 \text{ mm} \rightarrow$ (depth of precipitation)

To size the storage pond (reservoir),

$V_{res}^{TOT} = V_Q^{TOT} \times A_T = 0.0073 \times 19.4 \times 10000 \approx 1416 \text{ m}^3$

$V_{res} = 1450 \text{ m}^3$

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If only water from the developed area is collected,

$$CX_{III} = 73 \rightarrow S = \frac{1000}{CX_{III}} - 10 = \frac{1000}{73} - 10 = 3.7 \text{ in}$$

The volume of runoff from this surface would be

$$V_{Q, \text{resid.}} = \frac{(P-0.2S)^2}{P+0.8S} = \frac{(2.95-0.2 \times 3.7)^2}{2.95+0.8 \times 3.7} = 0.83 \text{ in} = 21 \text{ mm}$$

Therefore, the size of the reservoir,

$$V_{\text{res}} = 0.021 \times 10 \times 10000 = \underline{\underline{2100 \text{ m}^3}}$$

SOLUTION?

Separate reservoir for the developed area?

Why? - - - - -

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Problem 4 (Horton method)

$$\left. \begin{array}{l} f_0 = 17.78 \text{ mm/h} \\ f_c = 5.08 \text{ mm/h} \\ k = 0.5 \text{ h}^{-1} \end{array} \right\} \text{Initial data} + i_p = 25.4 \text{ mm/h}$$

Compute depth of losses and excessive rainfall.

SOLUTION

$$f(t) = f_c + (f_0 - f_c) \exp(-kt)$$

[mm/h]



$$f(t) = 5.08 + (17.78 - 5.08) \exp(-0.5t)$$

$$\boxed{f(t) = 5.08 + 12.7e^{-0.5t}}$$

$$V = \int_0^{3h} (5.08 + 12.7e^{-0.5t}) dt =$$

$$= 5.08t \Big|_0^3 - \frac{12.7}{0.5} (e^{-0.5t}) \Big|_0^3 =$$

$$= 5.08(3-0) - \frac{12.7}{0.5} (e^{-0.5 \times 3} - e^{-0.5(0)}) = \underline{\underline{34.97 \text{ mm}}}$$

$$\text{Total rainfall depth as precipitation} = 3h \times 25.4 = 76.2 \text{ mm}$$

Excessive (effective) rainfall is therefore =

$$= \text{Total depth} - \text{losses} = 76.2 - 34.97 =$$

$$\underline{\underline{\text{Excessive rainfall} = 41.23 \text{ mm}}}$$

Question no. 6 – 10 pts

True or false? Circle the correct answer:

- T F Relative humidity is a measure of the amount of water vapor in an air sample relative to its value if the air were saturated.
- T F Stage-discharge relationship is independent of the geometry of the river cross section.
- T F Size of the water body affects the evaporation
- T F The storm hydrograph at the exit of an elongated watershed has a smaller peak as opposed to a circular watershed of the same surface.
- T F In the Soil Conservation Service (SCS) CN method, the initial abstractions have a precise proportion to the precipitation.
- T F The rational method uses the linear Φ -index method.
- T F Salt water evaporation is stronger than freshwater water evaporation.
- T F The antecedent moisture condition depends on the time between the rainfall events.
- T F The return period of a hydrograph is approximately the same as the return period of the hyetograph which generated the hydrograph.
- T F The albedo is the ratio of total solar energy to the reflected energy.