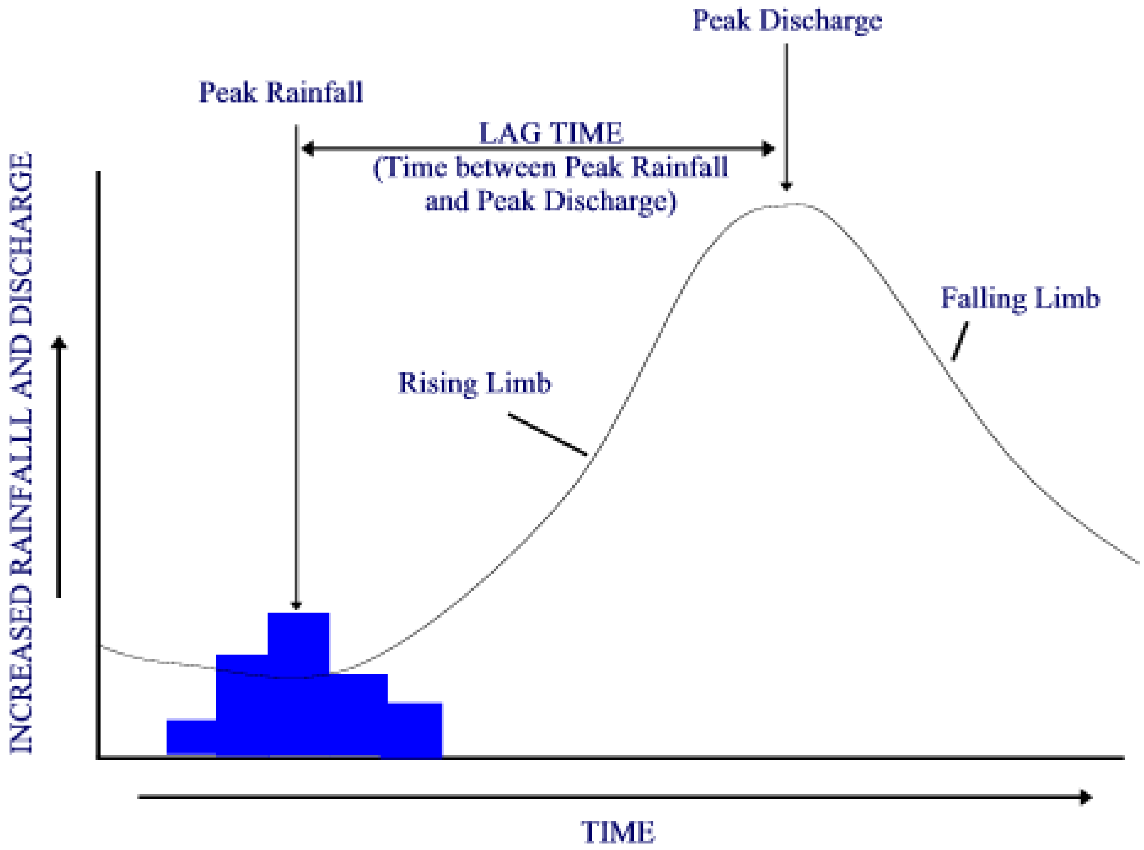
Rational Method

CALCULATING PEAK FLOW RATES



Announcements

- **HW #5 assigned today**

Rational Method / Used to Calculate Peak Flow Rates

- In many cases designs are based on peak flow rate only
- Rational Method
  - Empirical method developed in 1851
  - quick and simple procedure to estimate q_p
  - many limitations but still widely used

  - q_p (cfs) = 1.008CiA
    - C = coefficient (dimensionless)
    - i = rainfall intensity (in/hr)
      - with duration (D) = t_c
        - t_c = time of concentration
    - A = drainage area (ac)
    - 1.008 is conversion factor ➔ usually assumed to be 1

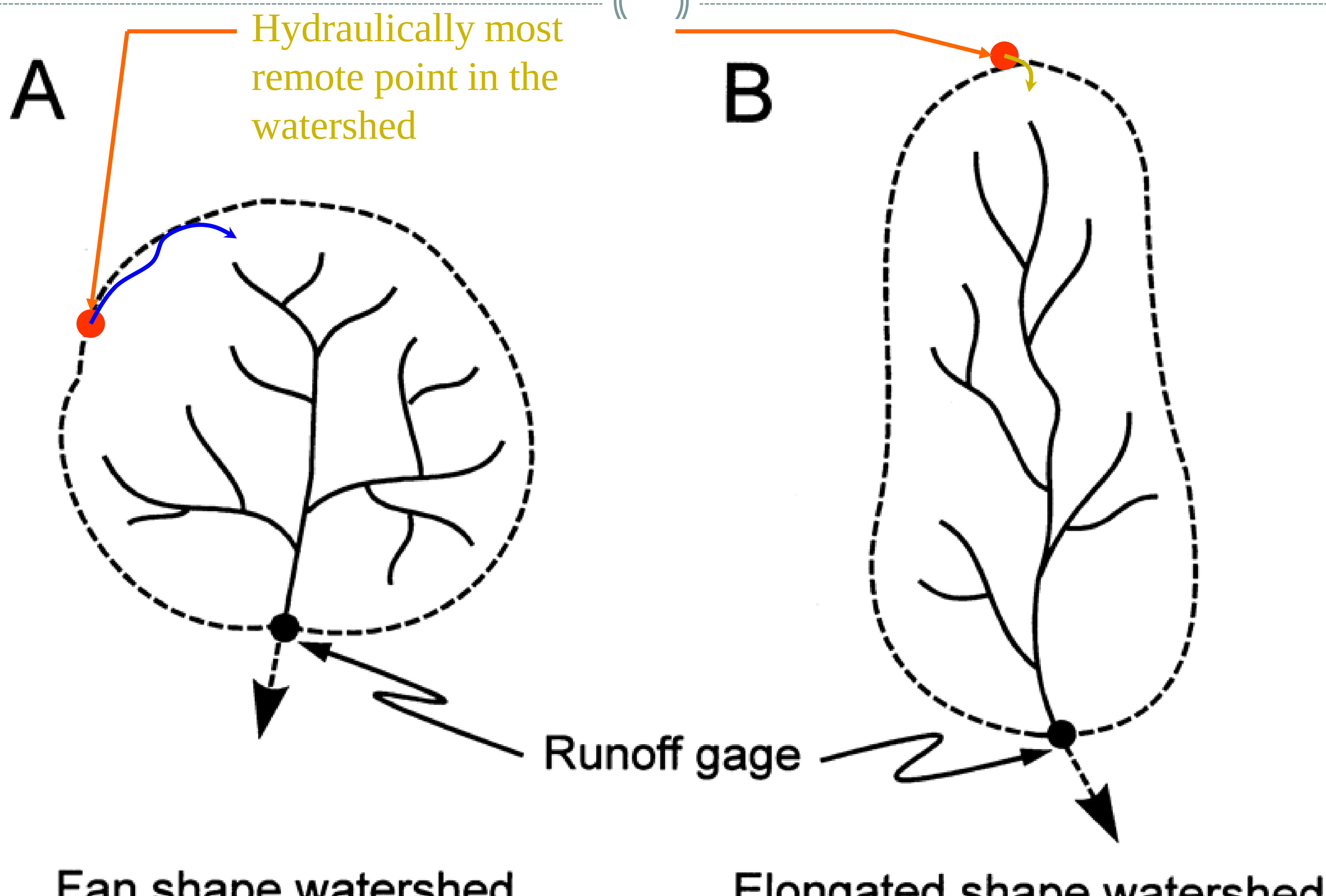
Rational Method

- Rationale of rational method:
  - As rain falls steadily across watershed runoff will increase until the entire watershed is contributing runoff
    - Occurs when rainfall duration (D) = t_c
    - If D ≠ t_c , runoff less than at D = t_c
    - q_p is at a maximum when D = t_c

- Assumptions of rational method:
  - Uniform rainfall over drainage area
  - Maximum q_p is a function of the average rain intensity
  - Runoff frequency = rainfall frequency used

Time of Concentration (t_c)

- The time it takes flow to move from the most hydraulically remote point in a watershed to the watershed outlet
  - The distance from the hydraulically most remote point to the outlet is called the hydraulic length
- t_c is the sum of flow times for the various flow segments as the water travels to the watershed outlet
  - Overland flow + shallow channel flow + open channel flow
- Travel time for each segment depends on length of travel and flow velocity



Hydraulically most remote point in the watershed
A
B
Runoff gage
Fan shape watershed
Elongated shape watershed

Rational Method

- Runoff Coefficient (C)
  - Difficult to accurately determine
  - Must reflect factors such as: interception, infiltration, surface detention, antecedent moisture conditions
  - Studies have shown that C is not a constant
    - C increases with wetter conditions
  - Table 5.5 contains a range of values for C
  - Compute average C for composite areas
    - Area weighted basis
    - $C_{avg} = \Sigma C_i A_i / \Sigma A_i$ (same method used with Curve Numbers)

Runoff Coefficients for the Rational Method

Table 5.3. Runoff coefficients, C, for use in the Rational Equation (Erie and Niagara Counties Regional Planning Board, 1981).

Land Use	A 0-2%	A 2-6%	A 6%+	B 0-2%	B 2-6%	B 6%+	C 0-2%	C 2-6%	C 6%+	D 0-2%	D 2-6%	D 6%+
Industrial	0.67[1] 0.85[2]	0.68 0.85	0.68 0.86	0.68 0.85	0.68 0.86	0.69 0.86	0.68 0.86	0.69 0.86	0.69 0.87	0.69 0.86	0.69 0.86	0.70 0.88
Commercial	0.71 0.88	0.71 0.89	0.72 0.89	0.71 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.90	0.72 0.89	0.72 0.89	0.72 0.90
High Density[3] Residential	0.47 0.58	0.49 0.60	0.50 0.61	0.48 0.59	0.50 0.61	0.52 0.64	0.49 0.60	0.51 0.62	0.54 0.66	0.51 0.62	0.53 0.64	0.56 0.69
Medium Density[4] Residential	0.25 0.33	0.28 0.37	0.31 0.40	0.27 0.35	0.30 0.39	0.35 0.44	0.30 0.38	0.33 0.42	0.38 0.49	0.33 0.41	0.36 0.45	0.42 0.54
Low Density[5] Residential	0.14 0.22	0.19 0.26	0.22 0.29	0.17 0.24	0.21 0.28	0.26 0.34	0.20 0.28	0.25 0.32	0.31 0.40	0.24 0.31	0.28 0.35	0.35 0.46
Agricultural	0.08 0.14	0.13 0.18	0.16 0.22	0.11 0.16	0.15 0.21	0.21 0.28	0.14 0.20	0.19 0.25	0.26 0.34	0.18 0.24	0.23 0.29	0.31 0.41
Open Space[6] (Grass/Forest)	0.05 0.11	0.10 0.16	0.14 0.20	0.08 0.14	0.13 0.19	0.19 0.26	0.12 0.18	0.17 0.23	0.24 0.32	0.16 0.22	0.21 0.27	0.28 0.39
Freeways and Expressways	0.57 0.70	0.59 0.71	0.60 0.72	0.58 0.71	0.60 0.72	0.61 0.74	0.59 0.72	0.61 0.73	0.63 0.76	0.60 0.73	0.62 0.75	0.64 0.78

Hydrologic Soil Group and Slope Range: A, B, C, D.

1. Lower runoff coefficients for use with storm recurrence intervals less than 25 years.
2. Higher runoff coefficients for use with storm recurrence intervals of 25 years or more.
3. High density residential areas have more than 15 dwelling units per acre.
4. Medium density residential areas have 4 to 15 dwelling units per acre.
5. Low density residential areas have 1 to 4 dwelling units per acre.
6. For pastures and forests we recommend using the lower runoff coefficients which are listed for open spaces (our addition to original source).

Rational Method Summary

- Peak flow equation only
- Cannot predict time to the peak (t_p)
- Should not be used to develop hydrographs

Example Problem

Given:

- Location: St. Louis, MO
- Watershed area: 40 ha (1 ha = 2.47 ac)
  - 30 ha, medium density residential / 7% slope / HSG = A
  - 3 ha, high density residential / 1% slope / HSG = C
  - 7 ha , agricultural / 4% slope / HSG = B
- t_c = 60 min.
- Rainfall event: 5-yr storm
- Required:
- Find the peak runoff (q_p)

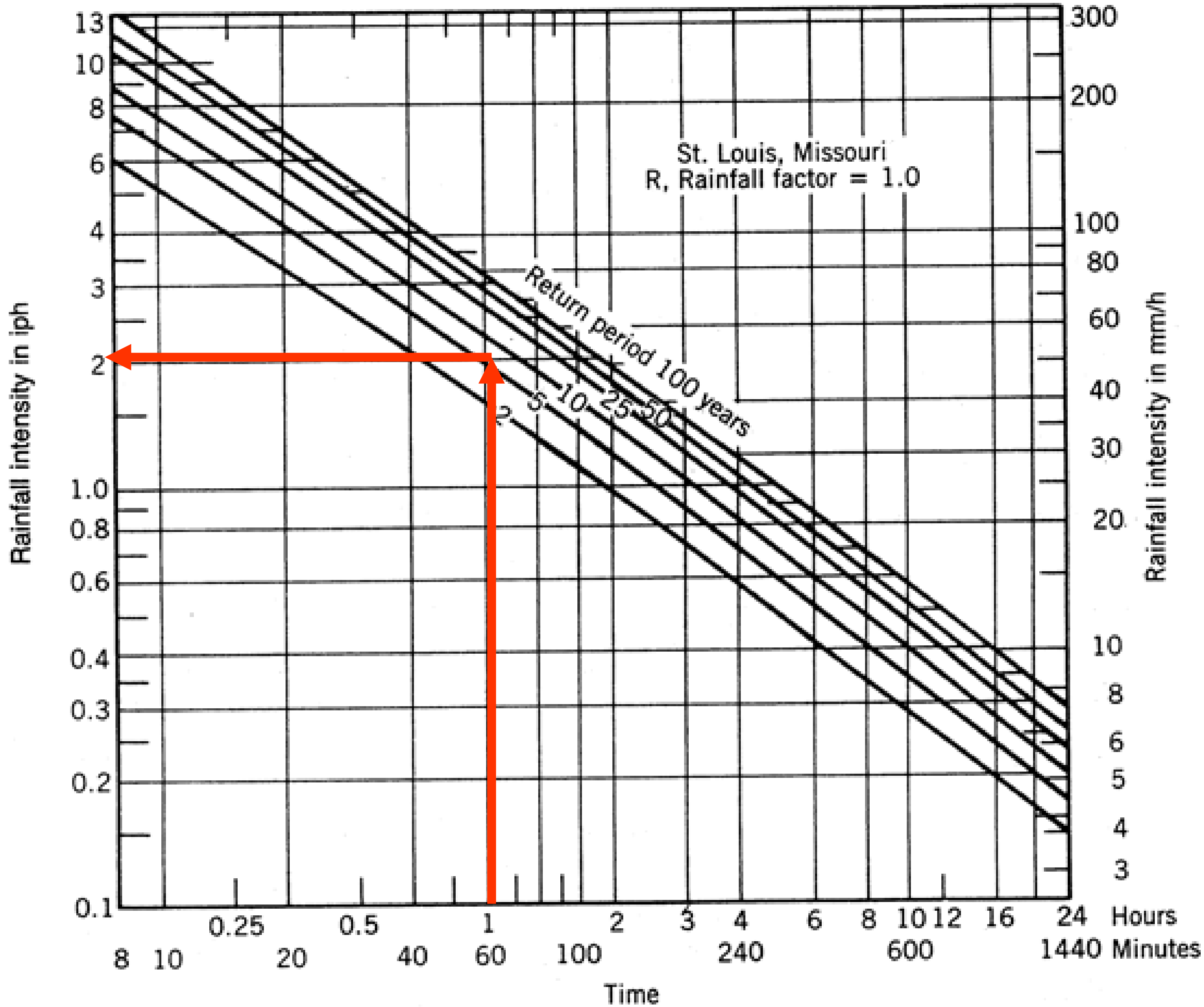


Figure 2.17. Rainfall rate-duration-frequency distribution for St. Louis, Missouri (Hershfield, 1961 and Weiss, 1962).

Example Problem

Solution:

- Rainfall intensity (i) = 2.0 iph (Figure 2.17)
- Land Use Area Area C

Land Use	Area (ha)	Area (%)	C (Table 5.5)
Med. Residential	30	75.0	.40 - .31 ➔ 0.36
High Residential	3	7.5	.60 - .49 ➔ 0.55
Agricultural	7	17.5	.15 - .21 ➔ 0.18

- $C_{avg} = 0.36(0.75) + 0.55(0.075) + 0.18(0.175) = 0.34$
- Area = 40 ha = 98.8 ac
- $q_p = CiA = 0.34(2.0 \text{ in./hr})98.8 \text{ ac} \rightarrow q_p = 67.2 \text{ cfs}$
- $q_p = 1.008CiA = 0.34(2.0 \text{ in./hr})98.8 \text{ ac} \rightarrow q_p = 67.7 \text{ cfs}$


BRING IN
THE DUTCH!
WATER YOU
THINKING?