CE 361A : Engineering Hydrology

Precipitation

Lecture -6

Revision

- Analysis of Rainfall
  - Present rainfall data
    - Hyetograph
    - Mass-curve
    - Time-series plot – rainfall depth, anomalies, moving average
  - Consistency of raingauge record
    - Reasons for inconsistencies
    - Double mass curve
  - Estimating Missing values
    - Arithmetic average and Normal ratio method

Analysis of Rainfall Data

Data collected from rain gauges

1. Present rainfall data
2. Check consistency
3. Estimate missing values
4. Adequacy of raingauge
5. Areal average rainfall
6. Depth-area-duration relationships (DAD)
7. Frequency analysis: Intensity-duration-frequency (IDF) curves
8. Probable maximum precipitation
9. Variability, Periodicity and Trends

special topic

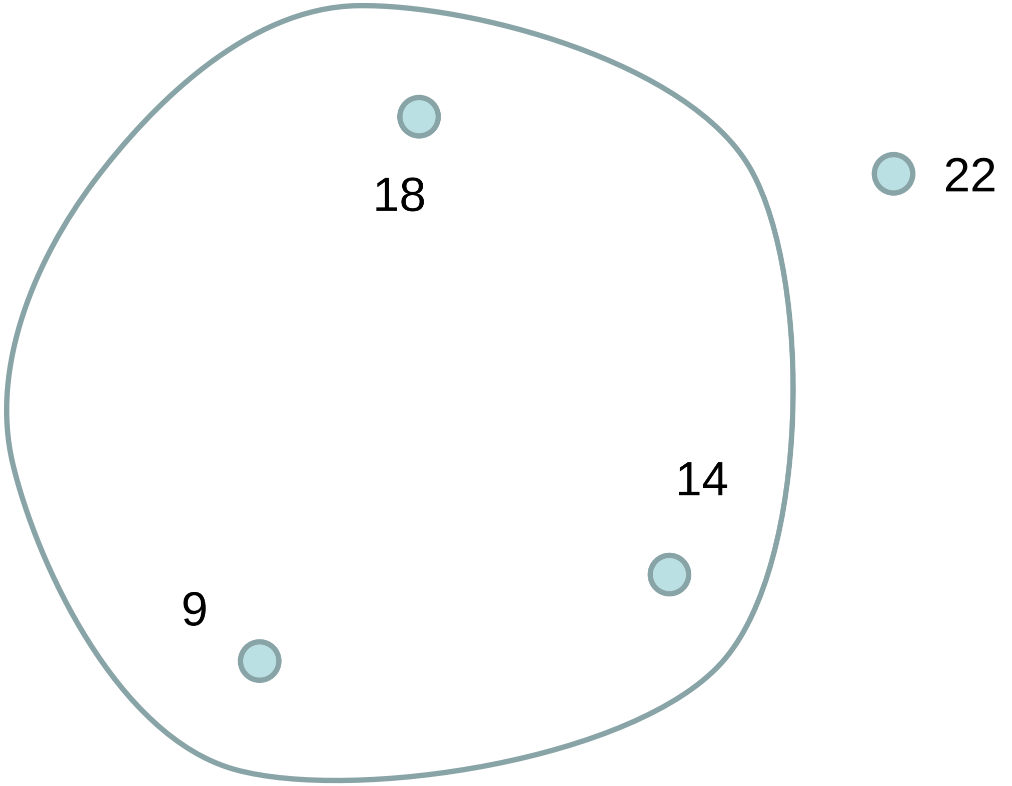
Areal Average Rainfall

Problem statement: Convert point rainfall values at various stations into an average value over an area

Why do we need an areal average value?

Available Methods

- Arithmetical mean method
- Thiessen mean method
- Isohyetal method
- Inverse distance square
- Kriging
- ...

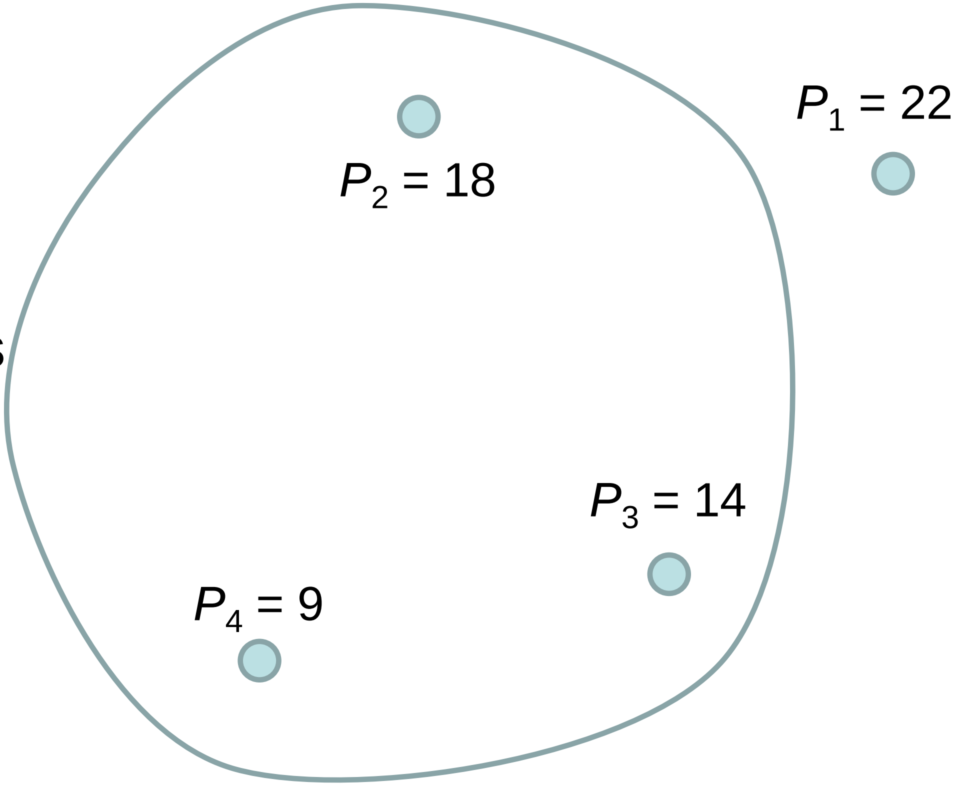


Arithmetical mean method

Average value over the area is estimated as the arithmetic mean of rainfall at the stations *within* the area

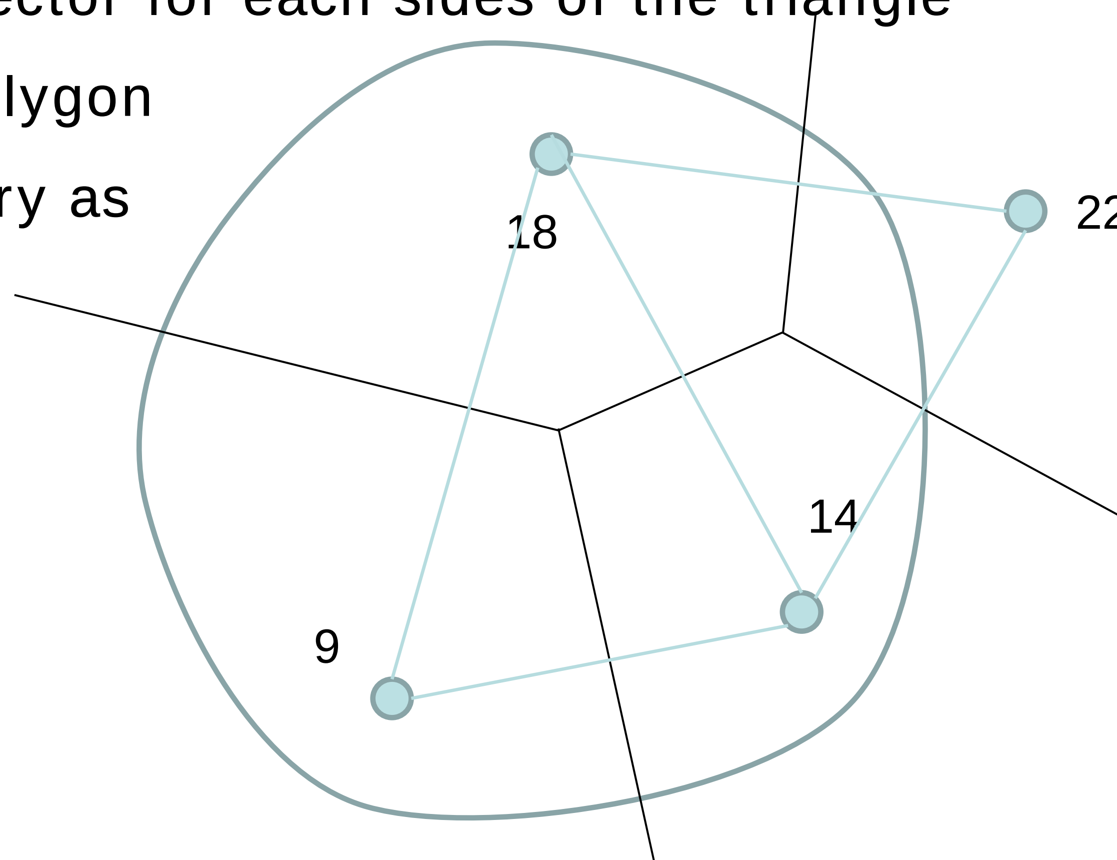
$$\bar{P} = \frac{1}{N}\sum_{i=1}^{N} P_i \qquad \bar{P} = \frac{1}{3}(P_2 + P_3 + P_4)$$

- Used when rainfall has little variations among the stations
- Rarely used



Thiessen mean (polygon) method

1. Join the stations by a network of triangles
   - *Delaunay triangulation* such that no points fall inside the circumcircle of any triangle
2. Draw perpendicular bisector for each sides of the triangle
3. The bisectors form a polygon with area of the boundary as an outer limit



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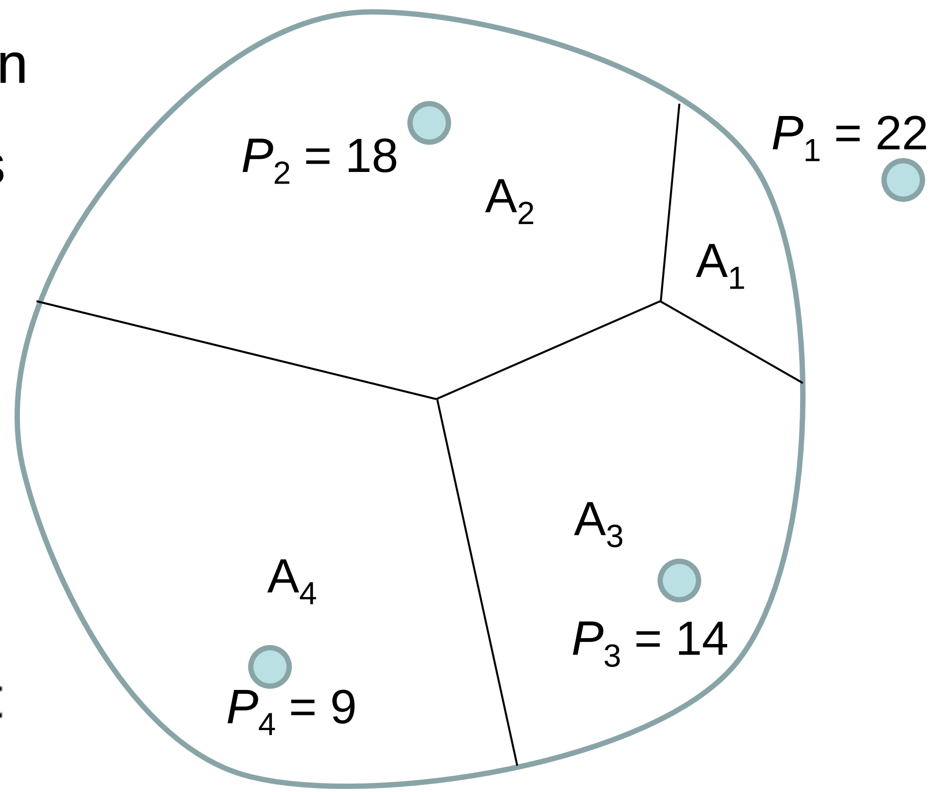
$$\bar{P} = \frac{\sum_{i=1}^{N} P_i A_i}{\sum_{i=1}^{N} A_i} = \sum_{i=1}^{N} P_i \frac{A_i}{A}$$

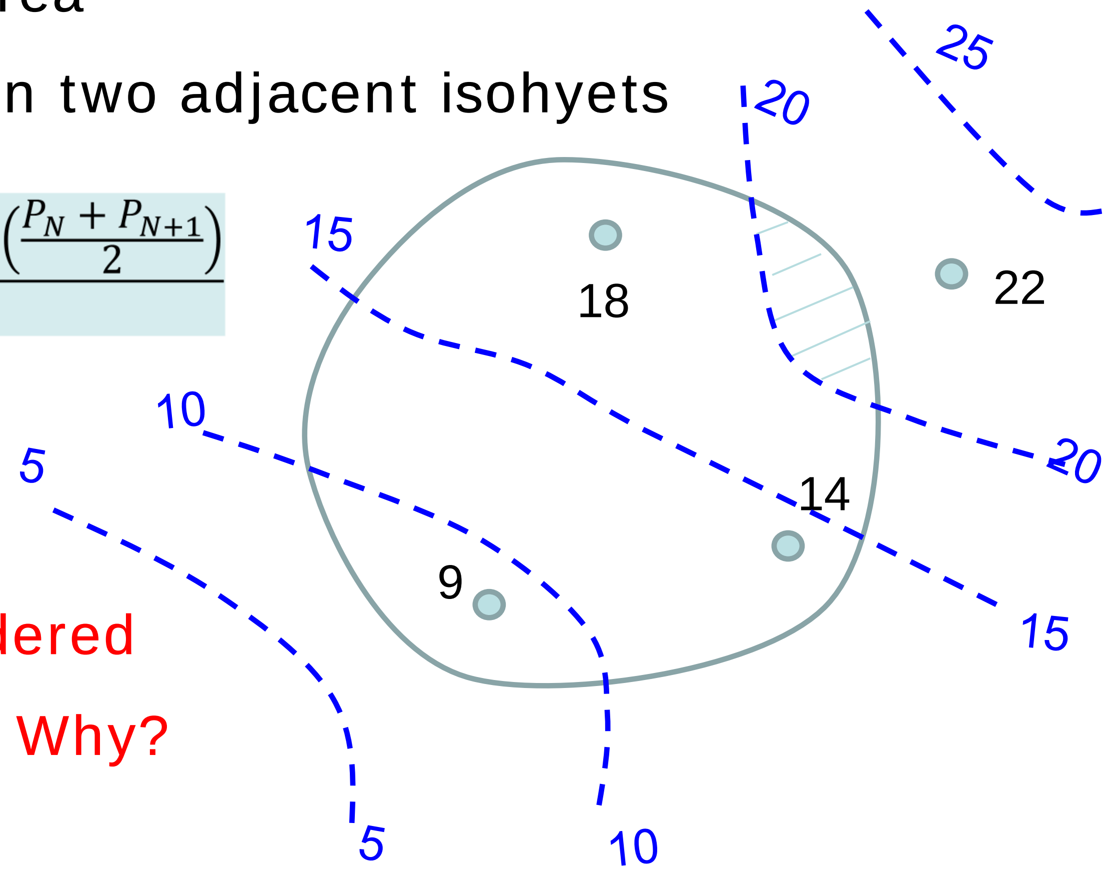
$\frac{A_i}{A}$ is called Thiessen weight



Isohyetal Method

1. Draw isohyets which are lines joining points of equal rainfall magnitude
   - neighboring gauges
   - topography of the area
2. Determine area between two adjacent isohyets

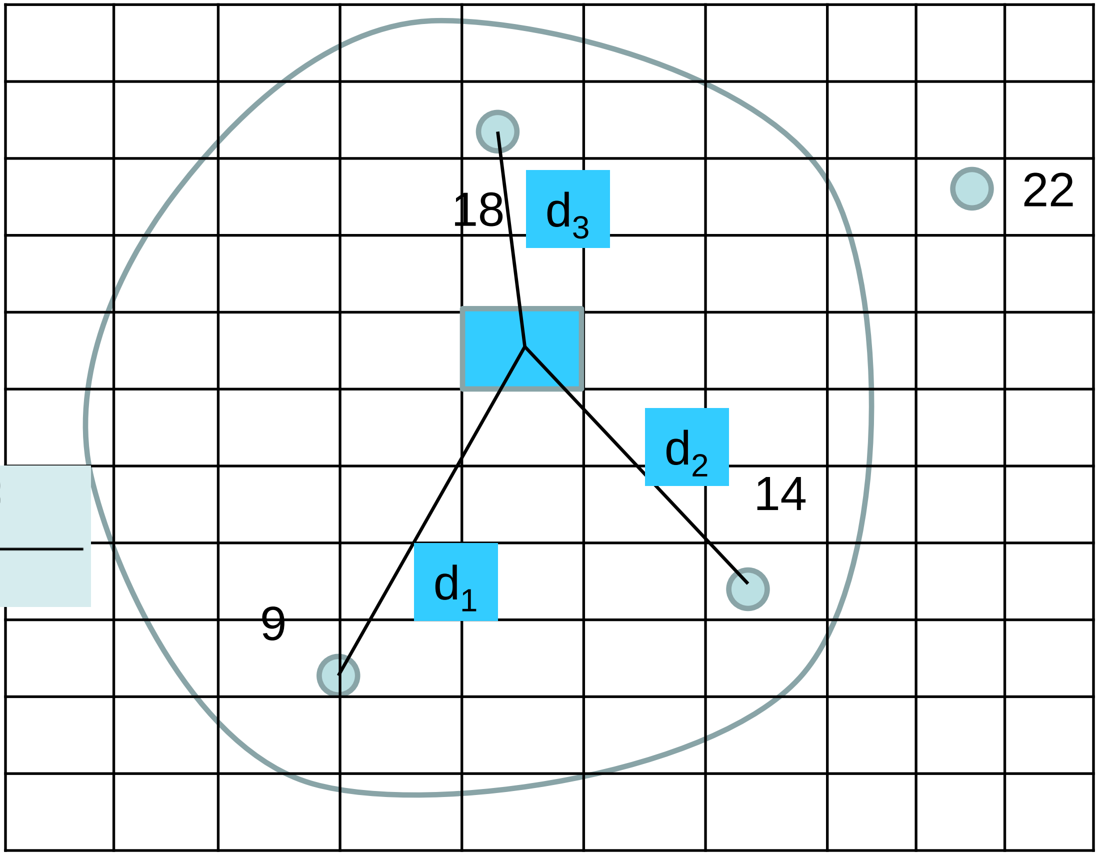
$$\bar{P} = \frac{A_1\left(\frac{P_1+P_2}{2}\right) + A_2\left(\frac{P_2+P_3}{2}\right) + \cdots + A_N\left(\frac{P_N+P_{N+1}}{2}\right)}{\sum_{i=1}^{N} A_i}$$



Isohyetal method is considered superior to other methods. Why?

Inverse (Reciprocal) Distance Method

1. Divide the area into square grids
2. Determine the value at each grid using inverse distance equation



$$P_i = \frac{P_1(d_1)^{-2} + P_2(d_2)^{-2} + P_3(d_3)^{-2}}{(d_1)^{-2} + (d_2)^{-2} + (d_3)^{-2}}$$

Amenable to computer programming

Kriging

1. Based on the assumption of Gaussian processes and linear regression
2. Best linear unbiased estimator
3. Developed by D. G. Krige for gold mining application in South Africa
4. Gives an estimate of uncertainty

Summary: Areal Average Rainfall

Many methods are available

- Arithmetical mean method
- Thiessen mean method
- Isohyetal method
- Inverse distance square
- Kriging
- ...

- Isohyetal method is considered more accurate because other relevant information like topography can be used in drawing isohyets
- Unlike isohyets, Thiessen weights do not change from storm to storm.

Adequacy of rain gauges

- Indian standard IS 4987:1994
  - –Plains : 1 per 500 km^2
  - –Region with average elevation 1 km: 1 per 250-400 km^2
  - –Hilly regions: 1 per 150 km^2

World Meteorological Organization (WMO) recommendations

Region	Minimum density in km^2/gauge	
	Non-recording (SRG)	Recording (ARG)
Hilly region	250	2,500
Semi-hilly region	500	5,000
Plains, high rainfall region	500	5,000
Plains, low rainfall region	900	9,000
Arid region	10,000	100,000

10% stations of the stations should be recording type

Adequacy of Rain Gauges

Allowable error in estimation of mean

The optimal number of rain gauges (*N*) needed to have an assigned percentage error in estimation of mean rainfall (ε)

$$N = \left(\frac{C_v}{\varepsilon}\right)^2$$

where C_v is coefficeint of variation

Relative standard error (ε) is usually taken as 10%

Adequacy of Rain Gauges

Example : A catchment has 4 rain gauges with values given below. Is the number of rain gauges adequate? If not, how many more gauges are required to have error in estimate of mean rainfall is not more than 10%?

Stations	Observed rainfall (X, mm)
E	800
F	540
G	445
H	410

Adequacy of Rain Gauges

Stations	Observed rainfall (X, mm)
E	800
F	540
G	445
H	410

1. Mean $\bar{X} = 548.75\ \text{mm}$
2. Standard deviation $\sigma_x = 176.28\ \text{mm}$
3. Coefficient of variation $C_v = \frac{\sigma_x}{\bar{X}} \times 100 = 32.12$
4. Optimum number of stations $N = \left(\frac{C_v}{\varepsilon}\right)^2 = \left(\frac{32.12}{10}\right)^2 = 10.32 = 11$
5. Extra gauges = 11 – 4 = 7

Adequacy of Rain Gauges

Allowable coefficient of varaition

The optimal number of rain gauges ($N_{desired}$) to achieve a desired coefficient of variation $Cv_{desired}$ can be estimated as

$$N_{desired} = \left(\frac{CV_{existing}}{CV_{desired}} \right)^2 N_{existing}$$

Assumption: mean and sum of squared deviations do not change significantly by addition of new rain gauges

Usual value of desired CV is less than 20%

Adequacy of Rain Gauges

Stations	Observed rainfall (X, mm)
E	800
F	540
G	445
H	410

$$CV_{existing} = 32.12$$

$$N_{existing} = 4$$

$$CV_{desired} = 20$$

$$N_{desired} = \left(\frac{CV_{existing}}{CV_{desired}} \right)^2 N_{existing} = 10.37 = 11$$

Extra gauges = 11-4 = 7