Computation of Average Rainfall over a Basin:

To compute the average rainfall over a catchment area or basin, rainfall is measured at a number of gauges by suitable type of measuring devices. A rough idea of the number of the needed rain gauges to be installed in a practical area is depending on experience of the hydrologist although this was determined by the regulation of the World Meteorological Organization (WMO).

In areas where more than one rain gauge is established, following methods may be employed to compute the average rainfall:
- Arithmetic average method
- Weighing mean method or Thiessen polygon method
- Isohyetal method.

5.3.1 Arithmetic Average Method:

This is the simplest method of computing the average rainfall over a basin. As the name suggests, the result is obtained by the division of the sum of rain depths recorded at different rain gauge stations of the basin by the number of the stations.

If the rain gauges are uniformly distributed over the area and the rainfall varies in a very regular manner, the results obtained by this method will be quite satisfactory and will not differ much than those obtained by other methods. This method can be used for the storm rainfall, monthly or annual rainfall average computations.

Example: During a storm the rainfall observations in a selected basin were found as follows:

Table 3: Computation of average precipitation over a basin using Arithmetic mean method

| Station No.	Precipitation in [mm]	Average precipitation [mm]
1	15	**P = 120.6/6 = 30.1 mm**
2	19	
3	20	
4	16.6	
5	22	
6	28	
Total [mm]	**120.6**	

5.3.2 Thiessen Polygon Method

This is the weighted mean method. The rainfall is never uniform over the entire area of the basin or catchment, but varies in intensity and duration from place to place. Thus the rainfall recorded by each rain gauge station should be weighted according to the area, it represents. This method is more suitable under the following conditions:

- For areas of moderate size.
- When rainfall stations are few compared to the size of the basin.
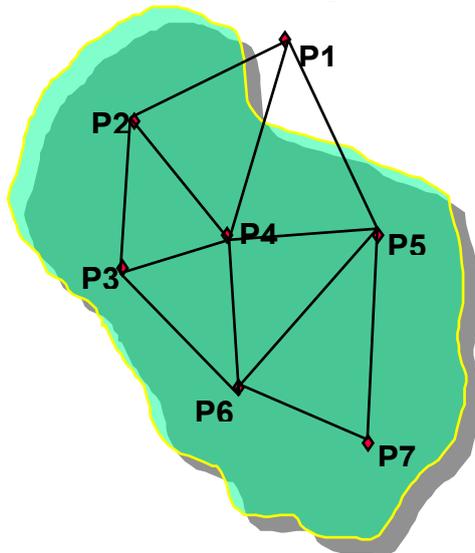- In moderate rugged areas.

For the construction of the polygon, the following procedure is to be followed:

Figure (1):Basin and location of stations
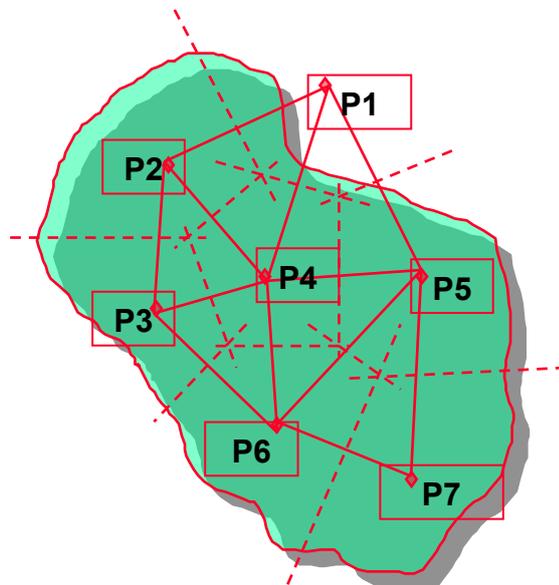

P1

P2

P4   P5

P3

P6

P7
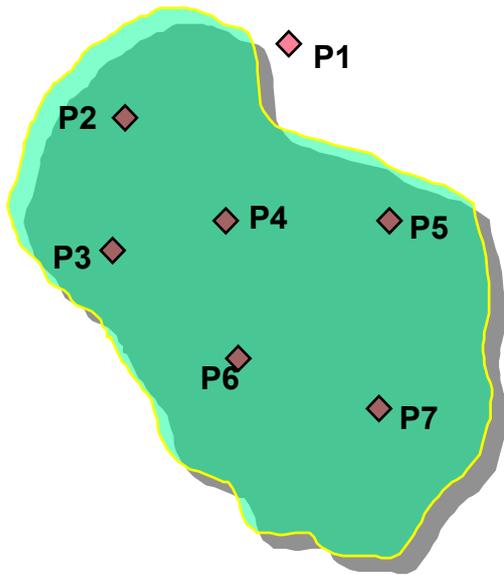
Step 1: Draw the area concerned to a suitable scale, showing its *boundary*, *locations of the raingauges* in the area and outside but close to the boundary
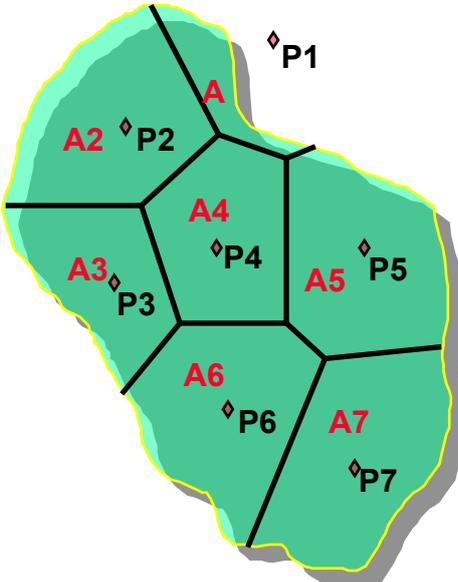
Figure (2): Drawing of the triangles

P1

P2

P4   P5

P3

P6

P7

Step 2: Join location of the raingauges to form a network of triangles

Figure (3): Drawing the perpendicular bi-sectors of the triangles

P1

P2

P4   P5

P3

P6

P7

Figure (4): Drawing of the polgons

If the calculated or measured sectional areas of the polygon, and the measured precipitation are given by the values presented in the following table (3) below.

Table (4): Bi-sectional areas (A) of Theissen polygon, and the measured precipitation (P) for stations

Station No.	Bi-sectional areas (Ai) [km^2]	Measured precipitation (Pi) [mm]	(Col. 2 * Col. 3) (Ai *Pi)
P1	25	10	250
P2	125	15	1875
P3	80	20	1600
P4	90	17	1530
P5	120	25	3000
P6	115	40	4600
P7	130	12	1560
Total	**685**		**14415**

Then the average precipitation over the catchment will be computed by the total of the column 4 to the total area in column 2. The result will be found as: 21.04 mm.

isoyetal Method:

An isohyetal is a line joining places where the rainfall amounts are equal on a rainfall map of a basin. An isohyetal map showing contours of equal rainfall is more accurate picture of the rainfall over the basin. This method is more suited under the following conditions:

- For hilly and rugged areas.

- For large areas over 5000 km^2.

- For areas where the network of rainfall stations within the storm area is sufficiently dense, isohyetal method gives more accurate distribution of rainfall.

For explaining of drawing an isohyetal map for a basin, the following procedure is usually applied:

Step 1: Draw the area under study to scale and mark rain gauges on it. Put at each of the raingauge location the recorded values of rainfall at the station, for the period within which the average is required to be determined.
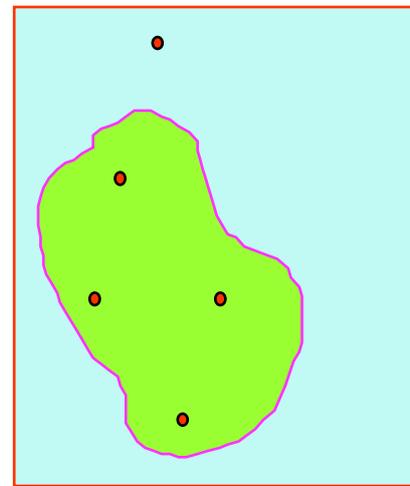

Figure (5): basin and rainfall stations

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Step 2: Draw the isohyetes of various values by considering the point rainfall data as guidelines and interpolating between them. Also, incorporate the knowledge of orographic effects.
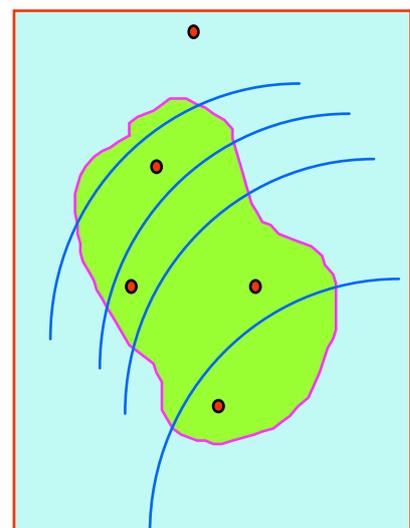

Figure (6): Drawing the isohyetal lines

Step 3: Determine the area between each pair of the isohyet lines, either by a planimeter or by converting the areas into smaller regular geometric shapes.

Step 4: Calculate the average rainfall using the following formula:

$$P_{av} = \frac{A_1 (P_1 + P_2)/2 + A_2 (P_2 + P_3)/2 + \ldots + A_{n-1}(P_{n-1} + P_n)/2}{(A_1 + A_2 + \ldots + A_n)}$$

P_i = Value of Isohyet lines
A_i = Area between pair of isohyet lines.

Example: Calculate the average rainfall over the area given in the figure using Isohyetal method.

Table (5): Rainfall computation by Isohyetal Method

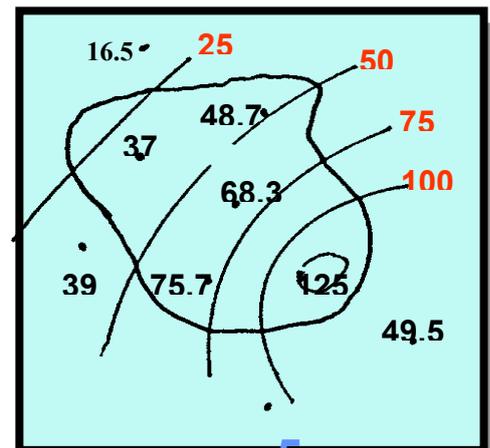| Isohyet (mm)	Area Between Isohyets (sq.Km)	Average Rainfall (mm)	Rainfall volume (col 3 x col4) (mm-Sq.Km)
125	33.28	125.0	4,160.00
100	197.12	112.5	22,176.00
75	296.96	87.5	25,984.00
50	501.76	62.5	31,360.00
25	494.11	37.5	18,529.13
less 25	79.36	21.0	1,666.56
Total	1602.59		103,875.69

Figure (7): Isohyetal map

$$Pav = 103, 875.69/1,602.59 = \underline{64.82 \ mm}$$

Comparison Between the Three Methods:

Arithmetic mean method:

1- This is the simplest and easiest method to compute average rainfall.

2- In this method every station has equal weight regardless its location.

3- If the recording stations and rainfall is uniformly distributed over the entire catchment, then this method is equally accurate.

Thiessen method

1-This method is also mechanical

2-In this method the rainfall stations located at a short distance beyond the boundary of drainage are also used to determine the mean rainfall of the basin, but their influence diminishes as the distance from the boundary increases.

3-It is commonly used for flat and low rugged areas.

Isohyetal method:

1- It is the best method for rugged areas and hilly regions.

2- It is the most accurate method if the contours are drawn correctly. However to obtain the best results good judgment in drawing the isohyets and in assigning the proper mean rainfall values to the area between them is required.

3- Other points are as for Thiessen method.

Summary for Basin Average Rainfall Analysis Techniques

The Isohyetal method allows the use of judgment and experience in drawing the contour map. The accuracy is largely dependent on the skill of the person performing the analysis and the number of gauges. If simple linear interpolation between stations is used for drawing the contours, the results will be essentially the same as those obtained by the Thiessen method.

The advantages of both the Thiessen and Isohyetal methods can be combined where the area closes to the gauge is defined by the polygons but the rainfall over that area is defined by the contours from the Isohyetal method. This combination also eliminates the disadvantage of having to draw different polygon patterns when analyzing several different storm events with a variety of reporting gauges. Regardless of the technique selected for analysis of basin average rainfall, a regional map of areal distribution for the total storm event is also produced.