Observation and Processing of Precipitation data

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Precipitation refers to water released from clouds in the form of rain, freezing rain, sleet, snow, or hail. It is the primary mechanism by which atmospheric water is delivered to the Earth. Most precipitation in vast areas of the world falls as rain. Precipitation is a highly variable phenomenon; it does not fall by the same amounts over a large region or even in a city.

1.1 OBSERVATION OF RAINFALL

Precipitation is the most important meteorological input in hydrological studies. Its three features are important: amount, duration (intensity) and spatial distribution. The total amount of precipitation which reaches the ground in the given period is expressed as the depth to which it would cover a horizontal projection of the earth's surface. If any part of the precipitation is snow or ice, its depth when melted is recorded (WMO, 1994). The unit of precipitation is length and daily amounts should be read to the nearest 0.1 mm. Thus, rainfall of 1.51 cm over an area means that if all the rain fall in the given time is retained, it will form a 1.51 cm thick water layer on that area. Weekly, fortnightly, and monthly amounts should, however, be read to the nearest 1 mm at least. Daily observations of precipitation along with other meteorological variables are made at a fixed time in the morning which is different in different countries.

1.1.1 Rainfall Gages

Rainfall is measured by a gage which consists of a funnel to delineate the collection area and leads rain water to a storage jar. Different types of gages are used to measure liquid and solid (snow) precipitation. Basically, there are three types of rain gages: a) Standard or ordinary rain gages (ORG) are manually read, commonly once a day; b) self-recording rain gages (SRRG) record the rainfall as a continuous plot; and c) automatic rain gages with data logger.

1.1.2 Non-recording Rain Gages

Since the size, shape and exposure affect the rain trapped by a gage, standard gages are used so that the observations are correctly used in computations and compared. Different countries have adopted different rain gages as standard. The Symon's rain gage, for example, has been adopted as the standard rain gage in India. This gage is installed on a masonry or concrete platform, sunken in the ground and the gage is placed such that it is perfectly levelled and the rim is about 30 cm above the ground. The rainfall measured at 8:30 AM on any particular date is entered against that date. It is understood that this much rain has been received in the past 24 hours. For example, record showing rainfall of 22 mm against August 12, 2015, means 22 mm of rain has fallen between 8:30 am on August 11, 2015 and 8:30 am on August 12, 2015.

An ordinary rain gage (ORG) consists of a circular collector and a funnel (see Fig. 1.1). A standard Symon's rain gage consists of a collector funnel having rainfall collection area of either 200 cm^2 or 100 cm^2. The funnel leads to a base unit, partly embedded in the ground and containing, a polythene or glass collector bottle. The gage is read once (usually) or twice daily and any rain gathered in the collector is poured into a graduated measuring glass cylinder to determine the rainfall depth in mm.

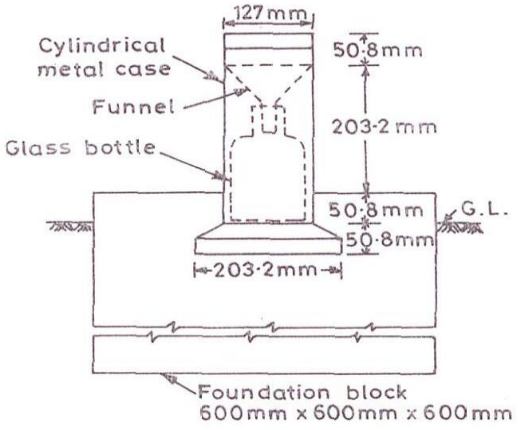

Fig. 1.1 Standard non-recording rain gage.

Since rainfall received is measured and noted manually, an observer may make errors. The observer may wrongly read the measuring cylinder; may wrongly note the amount; may read the gage at the wrong time; may note the amount against the wrong date; or may use the wrong measuring glass (e.g., 200 cm^2 glass for a 100 cm^2 gage or vice versa). Besides human errors, errors may also arise due to faulty instrument: damaged gage rim will change the collection area; water will not reach the collection bottle if the funnel is blocked; or collector bottle may be broken or might be leaking. Errors due to most of these causes will be difficult to detect, unless the magnitude of error is large. Errors in the observations at a station are easy to detect if there is a concurrent record from a recording rain gage at the same or nearby station.

1.1.2 Autographic rain gage

Among the self recording rain gages, natural siphon rain gage is frequently used to measure rainfall variability. It consists of a circular collector funnel and rainfall recording mechanism. The funnel leads to a chamber where a float is located. This float rises when rain water enters the chamber. Attached to the float is a pen which records rainfall in the form of rise of the float on a chart mounted on a drum. A siphon chamber is attached to the float chamber. After 10 mm of rain has fallen, the siphon action is initiated. After water is drained out, the float returns to the original position.

The drum moves with the help of a mechanical clock to complete one rotation in 24 hours. The horizontal axis of the chart is marked with hours and the vertical axis represents the depth of rainfall. The chart is changed every day at the set time and the hourly rainfalls are read and recorded in data sheets. On days with no rain, the pen traces a horizontal line on the chart. During the rain storm, the pen produces a sloping line; higher is the rainfall intensity, steeper will be the slope of the line. Rain water drained by the siphon action may be collected and measured when the chart is changed; this can be a check for the total rainfall. Fig. 1.2 shows a self recording rain gage assembly.

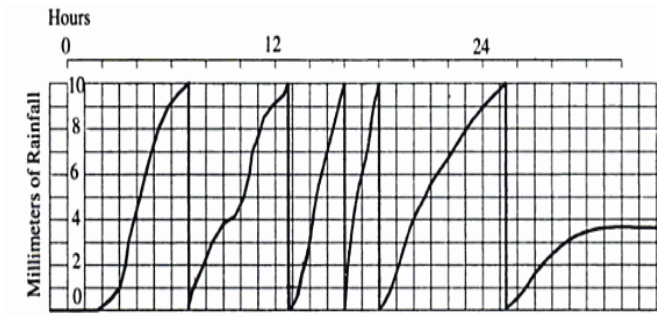

Fig. 1.2 A self recording rain gage with chart mounted on a drum (top) and rainfall recorded by the instrument on a chart.

Measurement errors can arise due to instrumental or observer's faults. If the float is wrongly adjusted, siphon action is initiated at a rainfall depth different than 10 mm. In very intense rainfall, the float and siphon may move so fast that individual pen traces cannot be distinguished. Further, the clock may malfunction – it may stop, or may be either slow or fast and the timings will be incorrect. If the float sticks to the walls of the chamber, rainfall will not be recorded correctly. Further, the observer may incorrectly read the data from the chart. Commonly a non-recording rain gage is also installed near the recording gage and the daily rainfall recorded by the two is compared. Traditionally, the ORG data is considered more reliable if there is a discrepancy between the two.

1.1.3 Tipping Bucket Rain Gage

It consists of a circular collector funnel that directs the rain into a pair of tipping buckets which sit on a knife edge (Fig. 1.3). After rain water has filled one side of the bucket with a small amount (say, 0.025 cm) of rain, the assembly tips. An electrical pulse is generated on each tilt and is recorded. After the tilt, rain water begins to fill the other side of bucket, and so on. A data logger records the occurrence of each tilt to provide data of rain fall vs time; the data may be downloaded later for use. Since the entire operation is automatic, there are little chances of errors. The instrument can be easily checked in the field by pouring a known amount of water in the collector funnel.

Measurement errors may occur when the funnel is (partially) blocked so that water enters in the buckets at a rate which is different than that of rainfall. If the buckets are damaged or out of balance, they may tip after non-standard rainfall or the tipping may be incorrectly recorded. A faculty reed switch may fail to register tips or may double register them. The gage electronics may fail due to some fault or lightning strike, etc.

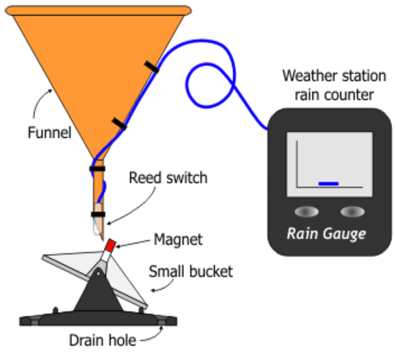

Fig. 1.3 Tipping bucket recording rain gage.

SRRG with Data Logger
Data are stored in digital form either as rainfall at fixed interval or as timings for each event of rainfall of fixed depth.

1.2 Processing of Rainfall Data

Raw precipitation data may have gaps and inconsistent values. Before the data is stored in a database or used in further analysis, it is necessary to carry out preliminary checks, scrutiny and validation. Processing of data is carried out with two major objectives: to examine the data for errors and remove them, and to organize the data in a form that is helpful for subsequent analyses. Rainfall data processing consists of a series of procedures. The various steps involved in processing are briefly described.

The rainfall data may have following errors:

- Entries on the wrong day - shifted entries,
- Entries made as accumulations,
- Missed entries, and
- Rainfall measurement missed on days of low rainfall.

These errors are also termed as "improper registering of data."

1.2.1 Internal consistency check

As the first step, observed data should be checked for the reasonableness, based on past experience and statistics of the station/region. Some of the statistical indices used to check rainfall data include the normal rainfall, highest observed rainfall, or rainfall corresponding to 25, 50 or 100 year return period.

Example 1.1: The daily precipitation reported from a station is 358.6 mm and the statistics of the reporting station are:

i.	Normal monthly rainfall of the corresponding month	:	350.0 mm
ii.	Mean maximum 1-day rainfall ($\bar{x}$)	:	210.6 mm

iii.	Standard deviation (σ) of maximum 1-day rainfall	:	51.0 mm
iv.	Highest observed 1-day rainfall	:	285.3 mm
v.	Value of 1-day max. rainfall of 100-year return period	:	300.0 mm
vi.	Value of 1-day probable maximum precipitation	:	370.8 mm

The reported daily rainfall is more than the normal monthly rainfall of the corresponding month and is, therefore, doubtful. This value is more than the mean maximum 1-day ($\bar{x}$) and ($\bar{x}$ +σ) which are 261.6 mm and 261.6 mm, respectively. The reported daily value is compared with 1-day Probable Maximum Precipitation (PMP) value. Since it is less than the PMP (370.8 mm), it is considered possible. At this stage, it is not advisable to reject this value. It should be flagged and further checked by spatial consistency.

The internal consistency or self consistency checks are applied by using statistical information based on historical data of the station and current data in case of short duration rainfall. An example of checking the data by the internal consistency follows.

Example 1.2: Hourly rainfall data reported at a station are as follows:

Hours →	1	2	3	4	5	6
Rainfall (mm)	8.0	10.8	85.8	28.5	19.8	15.0

The hourly rainfall reported during 3rd hour is suspected. Check its reasonability.

Solution: The hourly rainfall reported during the 3rd hour is suspected. We examine the total rainfall for 1-3 hours to check the value in the 3rd hour. The 3-hourly total rainfall was reported as 54.1 mm and this indicates that the rainfall in the 3rd hour could be 35.3 mm (assuming that the rainfalls in the 1st and 2nd hours are correct). When the 6 hour total rainfall is reported as 117.4 mm, the value of 35.3 mm is confirmed for the 3rd hour. Further checking for the erroneous value is carried out similarly.

This example shows that it is a good practice to report the hourly values as well as the sum of block of hours so that possible errors in conveying the data can be detected and corrected.

1.2.2 Scrutiny of Precipitation Data by Multiple Time Series Graphs

Precipitation data can be validated by plotting time series of data of multiple stations on the same graph. Such graphs can be drawn for hourly, daily, monthly and yearly rainfall. Validation of compiled monthly and yearly rainfall totals helps in flagging out the inconsistencies that are either due to a few very large errors or due to small systematic errors which persist unnoticed. A comparison of daily rainfall values at two stations is shown in Figure 1.4. This type of variation appears to be normal given the spatial structure of rainfall.

Scrutiny by tabulations of daily rainfall series of multiple stations

To scrutinize the data, rainfall data of various rain gage stations are tabulated in different columns in a table or spreadsheet. A careful examination of the table helps in revealing any anomalies that may be present in the data and which may be difficult to see in multiple time series graphs in some cases.

Checking against data limits for totals at longer durations
Many systematic errors are so small that individually they cannot be easily noticed. If the observed data are added for longer time durations then the accumulated errors become large and the resulting time series should again be checked against corresponding expected limits. Therefore, the daily rainfall data of each station should be aggregated to monthly and yearly values and then checked against the maximum monthly and yearly totals. If there is a significant difference, the data are cross-checked and verified with the available records of the same station (previous times) and at nearby stations.

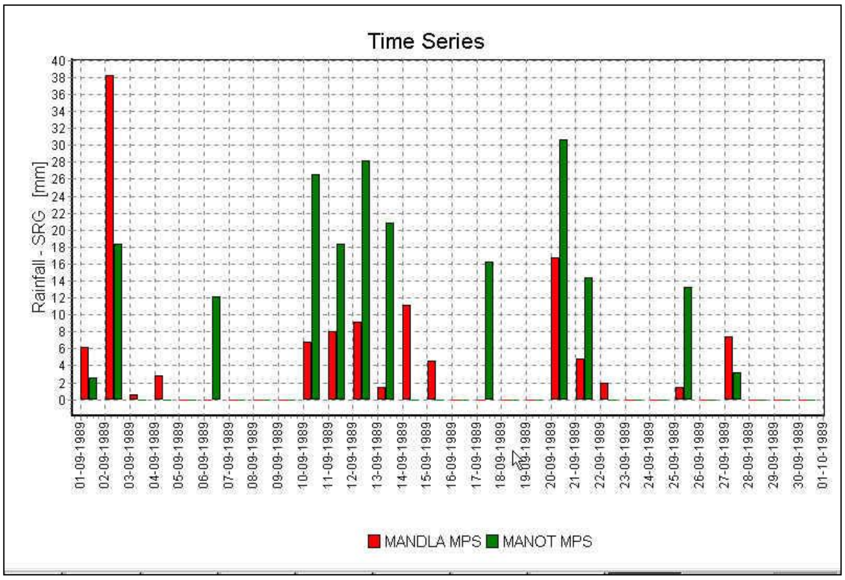

Figure 1.4: Comparison of daily rainfall at multiple stations.

Test for means (t-Test)

The most common parametric test to check whether or not two samples are from the same population is the Student's *t*- test. The main assumptions of this test are: (i) the observations are independent, (ii) the observations are drawn from normally distributed populations, and (iii) these populations have the same variance. Hence, this test is useful to determine whether the mean values of the samples are significantly different from each other and whether both the series belong to the same population or not. According to this test, the '*t*' statistic of the samples is determined by:

$$t = \left|\overline{X_1} - \overline{X_2}\right| \Big/ S\sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \qquad (1.2)$$

where, $\overline{X_1}$ and $\overline{X_2}$ are the arithmetic mean values of the two samples of size n_1 and n_2, respectively; S is the unknown population standard deviation estimated from the sample variances s_1 and s_2 as:

$$S = \frac{(n_1 - 1)s_1 + (n_2 - 1)s_2}{n_1 + n_2 - 2} \qquad (1.3)$$

If the value of the statistic t is less than the tabulated value of Student's distribution at some chosen significance level α and (n_1+n_2-1) degrees of freedom, then the hypothesis that "the means of both the samples are not significantly different" may be accepted at the chosen significance level.

Test for variances (F-test)

The F-test is commonly used for testing whether or not the variances of two samples are significantly different. According to this test, the F statistic of the samples is determined as:

$$F = s_1^2 / s_2^2 \qquad (1.4)$$

If the computed F is less than the tabulated value of F distribution at some chosen significance level α, and n_1-1 and n_2-1 degrees of freedom then the hypothesis that "the variances of both the samples are not significantly different" may be accepted at the chosen significance level.

These statistical tests (t-test and F-test) are discussed in Chapter xx in more detail.

1.2.3 Spatial Consistency Check

Rainfall data exhibit some spatial consistency and this forms the basis for investigating the observed rainfall values. An estimate of the interpolated rainfall value at a station is obtained on the basis of the weighted average of rainfall observed at the surrounding stations. If the difference between the observed and the estimated values exceeds the expected limiting value, such values are considered as suspect and are flagged for further investigation and ascertaining the possible causes of departures.

Spatial consistency checks for rainfall data are carried out by relating the observations from surrounding stations for the same duration with the rainfall observed at the station. This is achieved by interpolating rainfall at the station under question with rainfall data of neighboring stations. The station being considered is called the test station. The interpolated value is estimated by computing the weighted average of the rainfall observed at neighboring stations. Ideally, the stations selected as neighbors should be physically representative of the area in which the station under scrutiny is situated. The following criteria are used to select the neighboring stations:

(a) The distance between the test and the neighboring station must be less than a specified maximum correlation distance;

(b) too many neighboring stations should not be considered for interpolation; and

(c) to reduce the spatial bias in selection, it is advisable to consider an equal number of stations in each quadrant.

Example 1.3: Rainfall reported at a group of five stations (see Fig. 1.5) is as follows.

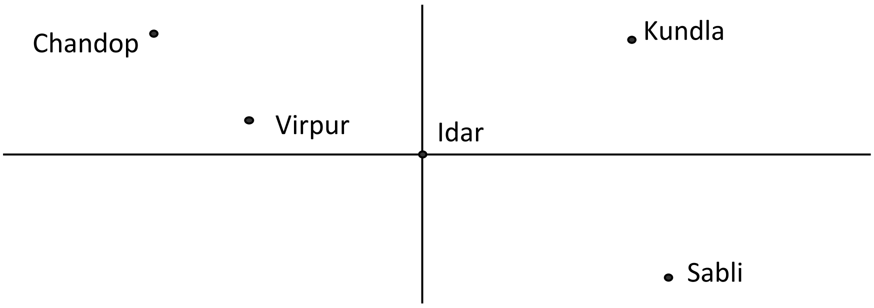

Fig. 1.5 Locations of stations for spatial consistency check.

Station	Kundla	Idar	Virpur	Chandop	Sabli
Rainfall (mm)	132.1	12.1	103.3	125.7	149.8

During the quality control process, the data at Idar is identified as doubtful. Check this data for spatial consistency.

Solution: The rainfall at Idar is estimated using the distance power method and compared with the observed value. From the four quadrants around Idar (Fig. 1.5), the station nearest from each quadrant is selected for the estimation of rainfall at Idar. Using the reference coordinate system, the distance of each of the estimator stations from Idar is determined and the rainfall at Idar is estimated.

S. N.	Station	Distance from Idar D_i (km)	$1/D_i^2$	R_i/D_i^2
1.	Kundla	42	$5.67*10^{-4}$	0.075
2.	Virpur	39	$6.57*10^{-4}$	0.068
3.	Sabli	75	$1.78*10^{-4}$	0.027
	Total		$14.02*10^{-4}$	0.170

$$\text{Rainfall at Idar} = [\sum(R_i/D_i^2)] / [\sum(1/D_i^2)] = 0.17/14.02*10^{-4} = 121.25 \text{ mm.}$$

Since the observed value is very much different from the estimated value, it is rejected and replaced by the estimated value. Note that there is a possibility that the decimal point was wrongly placed while recording the data at Idar.

1.3 Spatial Averaging of Rainfall Data

Precipitation observations from gages are point measurements. However, in the hydrological analysis and design, we frequently require mean areal precipitation over an area. A characteristic of the precipitation process is that it exhibits appreciable spatial variation, though the values at relatively short distances may have good correlation.

Numerous methods of computing areal rainfall from point measurements have been developed.

While using precipitation data, one often comes across missing data situations. Data for the period of missing rainfall could be filled using various techniques. Due to the spatial structure of precipitation data, some type of interpolation making use of the data of nearby stations is commonly adopted.

Let the precipitation data be available at *n* stations, spread over an area and P_i be the observed depth of precipitation at the i^{th} station. Using a linear interpolation technique, an estimate of precipitation over the area can be expressed by

$$P^* = \sum_{i=1}^{n} P_i W_i \qquad (1.6)$$

where W_i is the weight of the i^{th} station. The spatial averaging techniques differ in the method of evaluation of these weights. Weights of an optimal interpolation technique are decided such that the variance of error in the estimation is the minimum.

The most commonly used methods are for Spatial Averaging of Precipitation Data:

(a) Arithmetic average,
(b) Normal ratio method,
(c) Distance power method,
(d) Thiessen polygon method, and
(e) Isohyetal method.

The choice of a method depends on the quality and nature of data, importance of use and required precision, availability of time and computer. Some of the commonly used methods are described below.

1.3.1 Arithmetic Average

The simplest technique to compute the average precipitation depth over a catchment area is to take an arithmetic average of the observed precipitation depths at gages within the catchment area for the time period of concern. The average precipitation can be expressed as:

$$P = \frac{\sum_{i=1}^{n} P_i W_i}{n} \qquad (1.7)$$

where P is the average catchment precipitation from the data of n stations, P_i is the precipitation at station i, and W_i is the weight of i^{th} station. If the gages are relatively uniformly distributed over the catchment and the rainfall values do not have a wide variation, this technique yields good results.

1.3.2 Thiessen Polygon

The Thiessen Polygon method is based on the concept of proximal mapping. Weights are assigned to each station according to the catchment area which is closer to that station than to any other station. This area is found by drawing perpendicular bisectors of the lines joining the nearby stations so that the polygons are formed around each station (Fig. 1.6). It is assumed that these polygons are the boundaries of the catchment area which is represented by the station lying inside the polygon. The area represented by each station is measured and is expressed as a percentage of the total area. The weighted average precipitation for the basin is computed by multiplying the precipitation received at each station by its weight and summing. The weighted average precipitation is given by:

$$P = \sum_{i=1}^{n} P_i W_i \tag{1.8}$$

in which $W_i = A_i/A$, where A_i is the area represented by the station I, and A is the total catchment area. Clearly, the weights will sum to unity.

An advantage of this method is that the data of stations outside the catchment may also be used if these are believed to help in capturing the variation of rainfall in the catchment. The method works well with non-uniform spacing of stations.

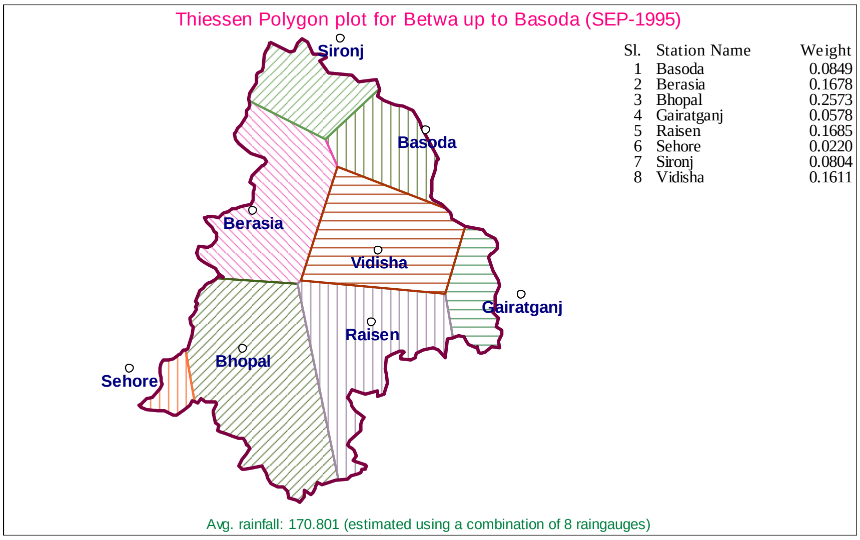

Fig. 1.6 Thiessen polygon method for computing mean areal rainfall.

A major drawback of this method is the assumption that precipitation between two stations varies linearly and the method does not make allowance for variation due to orography. In this method, the precipitation depth changes abruptly at the boundary of polygons. Also, whenever a set of stations are added to or removed from the network, a new set of polygons have to be drawn. The method fails to give any idea as to the accuracy of the results. If a few observations are missing, it may be more convenient to estimate the missing data than to construct the new set of polygons.
Software have been developed to compute Thiessen weights and average rainfall by using this method (see Panigrahy et al., 2009).

Example 1.4: For a catchment, the rainfall data at six stations for the month of July along with their weights are as given in Table 1.4. Find the weighted average rainfall for the catchment by using the Thiessen polygon method.

Solution: Using the observed rainfall and station weight, weighted rainfall at each station is computed. Summation of these values gives the weighted average rainfall for the catchment. The computations are shown in Table 1.1.

Table 1.1 Estimation of the mean areal rainfall by the Thiessen polygon method.

S. N.	Station Name	Station weight	Rainfall (mm)	Weighted rainfall (mm)
1.	Sohela	0.06	262.0	15.7
2.	Bijepur	0.12	521.0	62.5
3.	Padampur	0.42	177.0	74.3
4.	Paikmal	0.28	338.0	94.6
5.	Binka	0.04	158.0	16.1
6.	Bolangir	0.08	401.6	12.6
	Weighted catchment rainfall			275.8

1.3.3 Isohyetal Method

The isohyetal method employs the area encompassed between isohyetal lines. Rainfall values are plotted at their respective stations on a suitable base map and contours of equal rainfall, called isohyets, are drawn. In regions of little or no physiographic influence, drawing of isohyets is relatively a simple matter of interpolation. The isohyets may be drawn, taking into account the spacing of stations, the quality, and variability of data. In regions of pronounced orography where precipitation is influenced by topography, the analyst should take into consideration the orographic effects, storm orientation, etc. to adjust or interpolate between station values.

Computers software are available these days to draw isohyetal maps. As an example, the isohyetal map for an area is shown in Fig. 1.7. The total depth of precipitation is computed by measuring the area between successive isohyets, multiplying this area by the average rainfall of the two ishohyets, and totaling. The average depth of precipitation is obtained by dividing this sum by the total area. The average depth of precipitation (P_i) over this area is obtained by:

$$P = \frac{\sum_{i=1}^{n} P_i \quad A_i}{\sum_{i=1}^{n} A_i} \qquad (1.9)$$

where A_i is the area between successive isohyets and P_i is the average rainfall between the two isohyets.

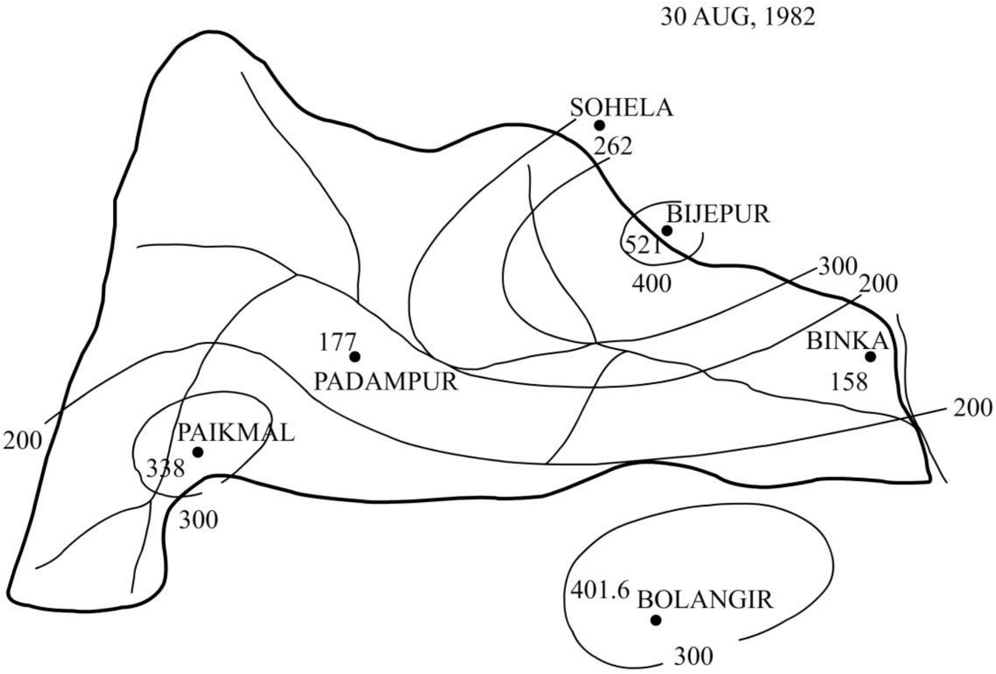

Fig. 1.7 Isohyetal method for computing mean areal rainfall.

Table. 1.2 Estimation of mean areal catchment rainfall by isohyetal method

Isohyetal range (mm)	Average value (mm)	Area (km^2)	Volume ($10^5 m^3$)
521.0 - 500.0	510.5	70	357.4
500.0 – 300.0	400.0	530	2120.0
338.0 – 300.0	319.0	100	319.0
200.0 – 300.0	250.0	2080	5200.0
158.0 – 200.0	179.0	2820	5047.8
		5600	**13044.2**

$$\text{Average catchment rainfall} = \frac{13044.2}{5600} = 232.9mm$$

Example 1.5: Using the point rainfall data for a catchment, isohyetal lines are drawn, as shown in Fig. 1.7. The area enclosed by each isohyet is calculated, as given in Table 1.3. Compute the average catchment rainfall.

Solution: For each isohyet, the average value is worked out (the maximum observed rainfall is 108 cm and the minimum 38 cm). This, multiplied by the area enclosed by that isohyet gives the volume of rainfall for that isohyet. Now the volumes for different isohyetals are summed and divided by the area of the catchment to get the average catchment rainfall. The computations are shown in Table 1.3.

Table 1.3 Estimation of mean areal rainfall by the isohyetal method.

Isohyet value (cm)	Average value (cm)	Area enclosed (km^2)	Net area (km^2)	Rainfall volume (km^2-cm)
105	106.5	0.79	0.79	84.14
100	102.5	1.52	0.73	74.83
90	95	2.57	1.05	99.75
80	85	3.47	0.90	76.50
70	75	4.50	1.03	77.25
60	65	5.18	0.68	44.20
50	55	5.39	0.21	2.20
< 40	39	5.41	0.02	0.78
	Total		5.41	459.65
Average catchment rainfall = 459.65/5.41= 84.96 cm				

1.4 ESTIMATION OF MISSING DATA

Data for the period of missing rainfall data can be filled using an estimation technique. The length of period up to which the data can be filled is dependent on individual judgment. Generally, rainfall for the missing period is estimated either by using the normal ratio method or the distance power method.

1.4.1 Normal Ratio Method

In the normal ratio method, the rainfall P_A at station A is estimated as a function of the normal monthly or annual rainfall of the station under question and those of the neighboring stations for the period of missing data at the station under question.

$$P_A = \frac{\sum_{i=1}^{n} \frac{NR_A}{NR_i} \times P_i}{n} \tag{1.10}$$

where P_i is the rainfall at the ith surrounding station, NR_A is the normal monthly or seasonal rainfall at station A, NR_i is the normal monthly or seasonal rainfall at station i, and n is the number of surrounding stations whose data are used for estimation.

Example 1.6: A catchment has four rain gage stations A, B, C & D. Normal monthly rainfall at these stations is known. The observed rainfall at the stations B, C & D for a storm event is known and is given in the following table. Find the missing rainfall at station A.

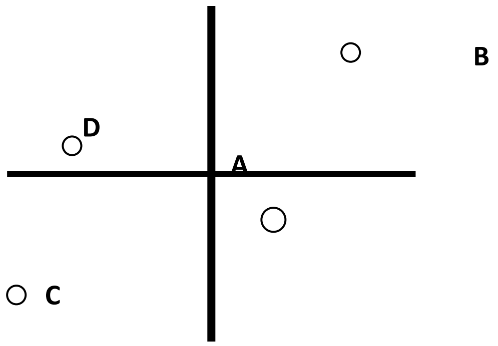

Figure 1.8: Location of Stations

Solution: The ratio of normal rainfall at station A to normal rainfall at station i or NR_A/NR_i is calculated, as given in table below.

Station →	A	B	C	D
Normal Rainfall (mm)	331.3	290.8	325.9	360.5
Event Rainfall (mm)	**?**	98.9	120.5	110.0
NR_A/NR_i	1	1.14	1.02	0.92

The estimated rainfall at station A is:

$$P_A = \frac{1.14*98.9+1.02*120.5+0.92*110.0}{3} = 112.3mm$$

1.4.2 Distance power method

The rainfall at a station is estimated as a weighted average of the observed rainfall at the neighboring stations. The weights are equal to the reciprocal of the distance or some power of the reciprocal of the distance of the estimator stations from the estimated stations. Let D_i be the distance of the estimator station from the estimated station. If the weights are an inverse square of distance, the estimated rainfall at station A is:

$$P_A = \sum_{i=1}^{n} P_i / D_i^2 \Big/ \sum_{i=1}^{n} 1/D_i^2 \qquad (1.11)$$

Note that the weights go on reducing with increasing distance and approach zero at large distances. A major shortcoming of this method is that the orographic features and spatial distribution of the variables are not considered. The extra information, if stations are close to each other, is not properly used. The procedure for estimating the rainfall data by this technique is illustrated through an example. If A, B, C, D are the location of stations discussed in the example of the normal ratio method, the distance of each estimator station (B, C, and D) from station (A) whose data is to be estimated is computed with the help of the coordinates using the formula:

$D_i^2 = [(x - x_i)^2 + (y - y_i)^2]$ (1.12)

where x and y are the coordinates of the station whose data is estimated and x_i and y_i are the coordinates of stations whose data are used in the estimation.

Example 1.7: Using the data of Example 1.6, estimate rainfall at station A using the distance power method.

Solution: Since the coordinates of the stations are known, their distances from station A can be calculated. The weights $1/D_i^2$ are then computed for each station and the rainfall at station A is estimated as follows:

Station	Distance from station A	$1/D_i^2$	Rainfall P_i (mm)	Weighted rainfall $P_i*(1/D_i^2)$ (mm)
B	28.0	$1.29*10^{-3}$	98.9	$125.6*10^{-3}$
C	17.7	$3.19*10^{-3}$	120.5	$384.6*10^{-3}$
D	42.5	$0.55*10^{-3}$	110.0	$60.5*10^{-3}$
Total		$5.01*10^{-3}$		$570.7*10^{-3}$

$$\text{Rainfall at station A} = = \frac{570.7\times10^{-3}}{5.01\times10^{-3}} = 113.9\ mm$$

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