Measurement of rainfall

One can measure the rain falling at a place by placing a measuring cylinder graduated in a length scale, commonly in mm. In this way, we are not measuring the volume of water that is stored in the cylinder, but the ‘depth’ of rainfall. The cylinder can be of any diameter, and we would expect the same ‘depth’ even for large diameter cylinders provided the rain that is falling is uniformly distributed in space.

Now think of a cylinder with a diameter as large as a town, or a district or a catchment of a river. Naturally, the rain falling on the entire area at any time would not be the same and what one would get would be an ‘average depth’. Hence, to record the spatial variation of rain falling over an area, it is better to record the rain at a point using a standard sized measuring cylinder.

Modern technology has helped to develop Radars, which measures rainfall over an entire region. However, this method is rather costly compared to the conventional recording and non-recording rain gauges which can be monitored easily with cheap labour.

Rain gauge: The purpose of the rain gauge is to measure the depth and intensity of rain falling on a flat surface without considering infiltration, runoff or evaporation. The problems of measurements include effects of topography, nearby vegetation and the design of gage itself.

Non-recording Gauge

The standard raingage, known as Symon’s gage is recommended

This is a vertical, cylindrical container with top opening 127 cm in diameter. A funnel shaped hood is inserted to minimize evaporation losses. The water is funneled into an inner cylinder.

Considerations for Installation

1. The site should be an open place,
2. The distance between the raingauge and the nearest object should be at least twice the height of the object,
3. As for as possible it should be a level ground,
4. In the hills, the site should be so chosen where it is best shielded from high winds and wind does not cause eddies, and
5. If a fence is erected, it should be at least at a distance of twice the height.

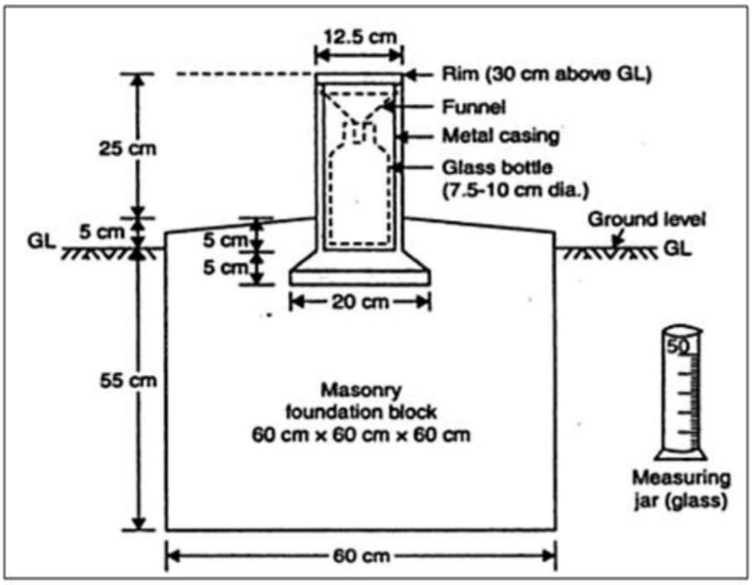


Fig. Symon's Rain gauge.

Recording or Automatic Rain gauge

Weighting Bucket Type Rain gauge - This gauge weighs the rain, which falls into a bucket set on a platform of a spring or level balance. The increasing weight of bucket and its counts are recorded on the chart held by a clock driven drum. The record shows the accumulation of precipitation with time in the shape of a mass curve of precipitation. The gage must be serviced about once a week when the clock is re-wound and the chart is replaced. For high rainfall, the recording mechanism reverses the direction of record immediately on reaching the upper edge of the recording chart.

Tipping Bucket Type Raingage - The tipping bucket raingage consists of a 30 cm diameter sharp edge receiver. At the end of the receiver a funnel is provided. A pair of buckets are pivoted under the funnel in such a way that when one bucket receives 0.25 mm of rainfall it tips, discharging its contents in to a tank bringing the other bucket under the funnel. Tipping of the bucket completes an electric circuit causing the movement of a pen to mark on a clock driven revolving drum which carries a record sheet.

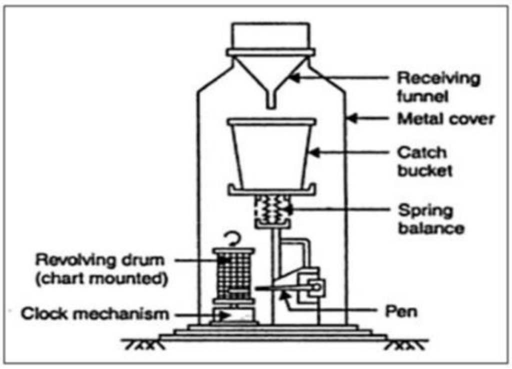


Fig..Weighing bucket type rain gauge.

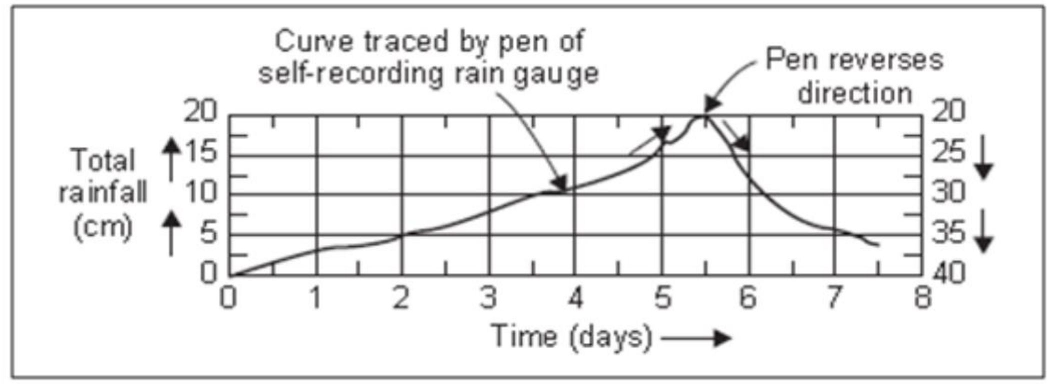


Fig. .Recorded mass curve of precipitation in weighing bucket type rain gauge.

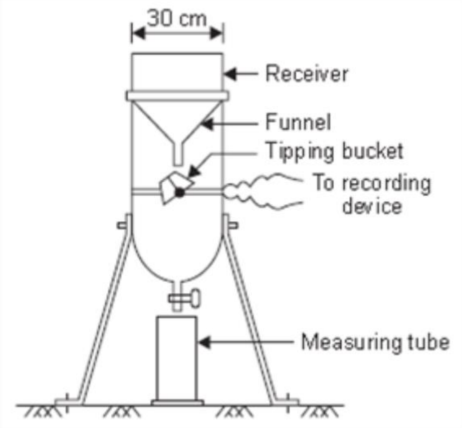


Fig. Tipping bucket type rain gauge.

Siphon Type Automatic Rainfall Recorder - In the siphon gage, also known as the float type of recording raingage, the rain is fed into a float chamber containing a light, hallow float. The vertical movement of the float, as the level of water rises, is transmitted by a suitable mechanism in to the movement of the pen on a revolving chart. By suitably adjusting the dimensions of the receiving funnel, float and float chamber, any desired scale value on the chart can be obtained. Siphoning arrangement is provided for emptying the float chamber quickly whenever it becomes full, the pen returns to the bottom of the chart.

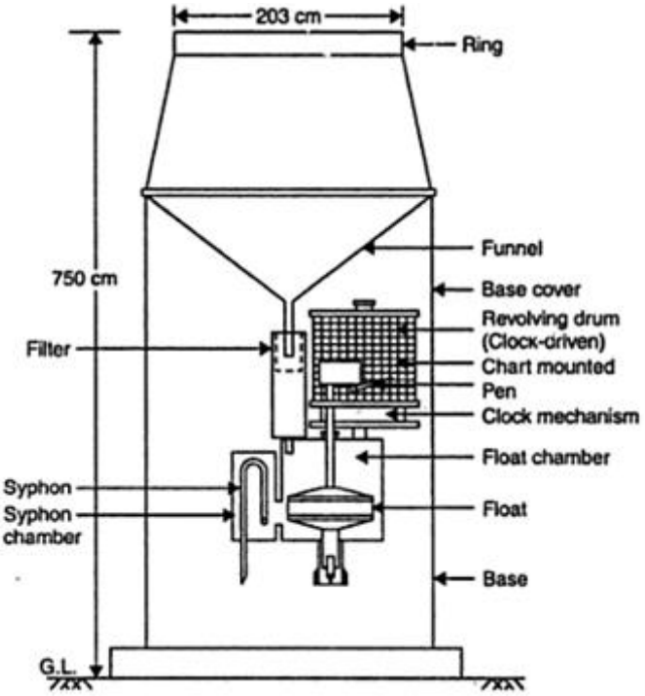


Fig.Siphon type automatic rainfall recorder.

Errors in Rainfall Measurements

There are three main sources of errors in rainfall measurements –

a) Instrumental defects,

b) Improper sitting (location) of the gage, and

c) Human errors

Each recording type gage has inherent errors caused by mechanical parts of the instrument. In addition to mechanical errors, some precipitation is also lost in wetting the collecting funnel and measuring cylinder surface if the gage is dry before it begins to collect measurable amount of water (approximately 25 mm per year). Similarly, evaporation from a non-recording gage could cause a small loss of measurable water over the year.

The improper location of the raingage can tend to either over- or under-catch rainfall. The largest errors in all gages are the effect of wind on the entrance of rain or snow into the instrument. Errors due to wind are greater for light rain than for heavy rains.

In order to avoid erroneous conclusions it is important to give the proper interpretation to precipitation data, which often cannot be accepted at face value. For example, a mean annual precipitation value for a station may have little significance if the gage site has been changed significantly during the period for which average is computed. Also, there are several ways of computing average precipitation over an area; each may give a different answer.

Raingage Network

There is no single answer to determining the mean areal rainfall because it is affected by so many factors. However, the denser the gage network, the more accurate is the representation. Gauges are not evenly spaced, high variability areas have more gages and relatively uniform rainfall areas have fewer gauges. In addition, costs of installation, maintenance of the network, as well as its accessibility to the observer, are also important consideration.

In general, the sampling errors of rainfall tends to increase with increasing mean areal rainfall, and decrease with increasing network density, duration of rainfall, and areal extend. Accordingly, larger average errors are produced by a particular network for storm rainfall than for monthly, seasonal or annual rainfall.

Standard Recommendation

- One station per 520 km^2 –in plains.
- One station per 260-390 km^2– in regions of average elevation of 1000 m.
- One station per 130 km^2 – in predominantly hilly areas with heavy rainfall.

Estimation of Mean Areal Rainfall

A single point precipitation measurement is quite often not representative of the volume of precipitation falling over a given catchment area. The representative precipitation over a defined area is required in many engineering applications, whereas the gauged observation pertains to the point precipitation. A dense network of point measurements and/or radar estimates can provide a better representation of the true volume over a given area. A network of precipitation measurement points can be converted to areal estimates using any of the following techniques:

1. Arithmetic or Station Average Method
2. Thiessen Polygon Method
3. Isohyetal Method.

Arithmetic Mean Method

This method consists of computing the arithmetic average of the values of the precipitation for all stations within the area. Since this method assigns equal weight to all stations irrespective of their relative location and other factors, it should be adopted in area where rainfall is uniformly distributed.

$$\overline{P} = \frac{1}{n}\sum_{i=1}^{n} P_i$$

Where average precipitation is over an area, P is the precipitations at individual station i, and n is the number of stations. The simplest of all is the Arithmetic Mean Method, which taken an average of all the rainfall depths as shown in Figure 2.

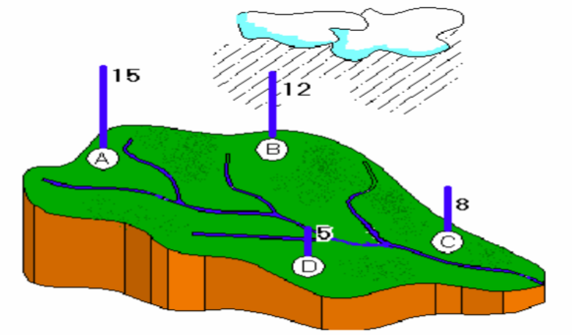


FIGURE 2. Representation of the rainfall recorded in the four rain gauges (values in mm)

Average rainfall as the arithmetic mean of all the records of the four rain gauges, as shown below:

[(15+12+8+5)/4]=10.0mm

Theissen polygon method

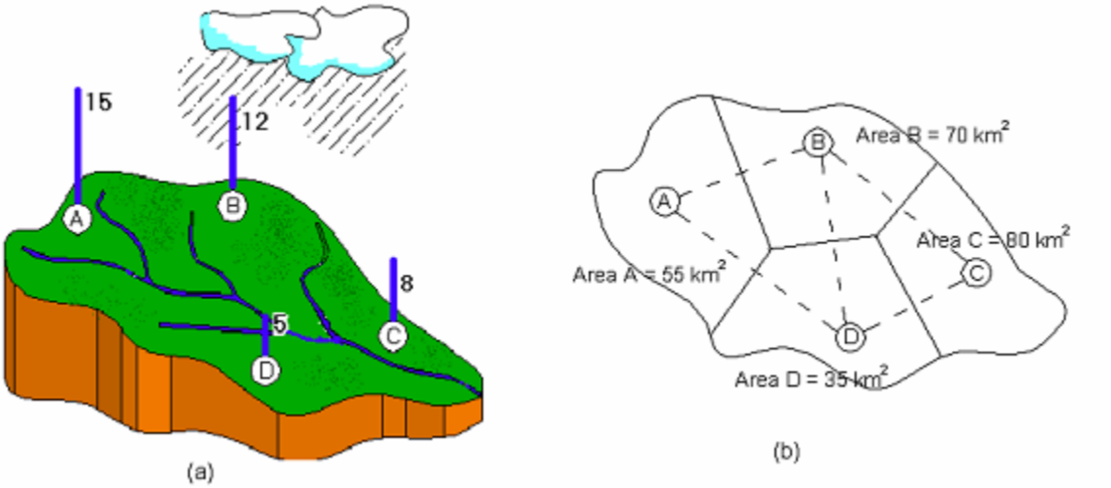
This is a graphical technique which calculates station weights based on the relative areas of each measurement station in the Thiessen polygon network. Rainfall varies in intensity and duration from one place to other; hence rainfall recorded by each station should be weighed according to the area (polygons) it is assumed to influence. The individual weights are multiplied by the station observation and the values are summed to obtain the areal average precipitation. This method is useful for areas, which are more or less plain and are of intermediate size (500 to 5000 km^2). This method is also used when there are a few raingage stations compared to size. The polygons are formed as follows:

1. The stations are plotted on a map of the area drawn to a scale.
2. The adjoining stations are connected by the dashed lines.
3. Perpendicular bisectors are constructed on each of these dashed lines.
4. These bisectors form polygons around each station (effective area for the station within the polygon). For stations close to the boundary, the boundary lines form the closing limit of the polygons.

Area of each polygon (A_i) is determined and the average precipitation is calculated using the following equation

$$\overline{P} = \frac{\sum_{i=1}^{n} P_i A_i}{A}$$

This method, first proposed by Thiessen in 1911, considers the representative area for each rain gauge. These could also be thought of as the areas of influence of each rain gauge, as shown in Figure 3



(a) (b)

For the given example, the “weighted” average rainfall over the catchment is determined as,

{[(55x15)+(70x12)+(35x8)+(80x5)] / [(55+70+35+80)] } =10.5mm.

Isohyetal Method

This is a graphical technique which involves drawing estimated lines of equal rainfall over an area based on point measurements. Then multiply the area between each contour by the average precipitation in the area to get the rainfall volume in the area.

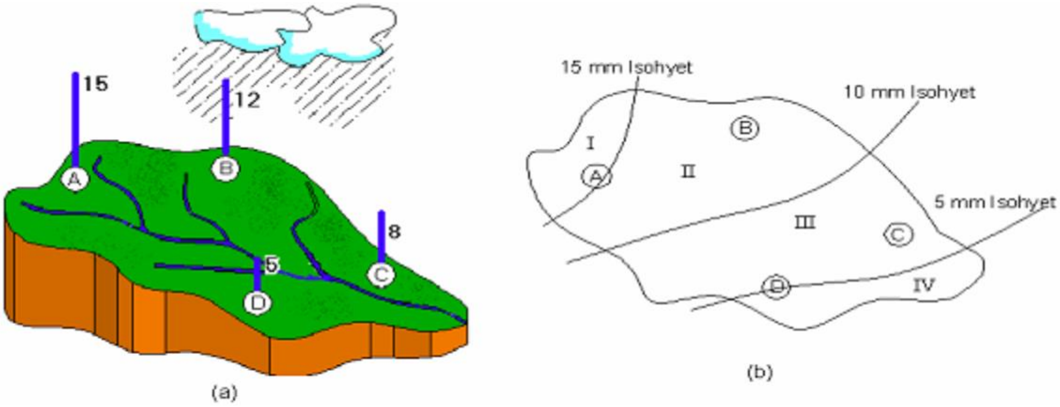
Sum these volumes to get the total rainfall volume, and then divide the total rainfall volume by the area of the watershed to get the average areal precipitation in the watershed.

Let's take it step by step:

Step1: Determine what contours of equal precipitation (called isohyets) you will use.
This varies from situation to situation, but you want to have as many contours as necessary to get an accurate model, but not so many that your construction becomes cluttered.
Step2: Draw a line between gauges that will be separated by isohyets.
Step3: Plot points on those lines that correspond to the isohyets determined in Step 2.
Step4: Now sketch the isohyets.

Step5: Redraw the construction onto graph paper with the isohyetal lines. Then count the boxes between each of the isohyetal lines.
Step6: Find the actual watershed area between each isohyet. These areas will be lettered starting with A at the top and moving alphabetically toward the bottom of the construction.
Step7: Multiply the areas found in Step 6 by the average precipitation in the area.
Step8: Divide the sum of the values found in Step 7 by the total area of the watershed to get the average rainfall in the area.

This is considered as one of the most accurate methods, but it is dependent on the skill and experience of the analyst. The method requires the plotting of ***isohyets*** as shown in the figure and calculating the areas enclosed either between the isohyets or between an isohyet and the catchment boundary. The areas may be measured with a ***planimeter*** if the catchment map is drawn to a scale.



Rainfall measurement by the Isohyetal method. (a) Recorded rainfall; (b) Isohyets and the areas enclosed bewteen two consecutive isohyets.

For the problem shown in Figure 4, the following may be assumed to be the areas enclosed between two consecutive isohyets and are calculated as under:

Area I = 40 km^2
Area II = 80 km^2
Area III = 70 km^2
Area IV = 50 km^2

Total catchment area = 240 km^2

The areas II and III fall between two isohyets each. Hence, these areas may be thought of as corresponding to the following rainfall depths:

Area II : Corresponds to (10 + 15)/2 = 12.5 mm rainfall depth

Area III : Corresponds to (5 + 10)/2 = 7.5 mm rainfall depth

For Area I, we would expect rainfall to be more than 15mm but since there is no record, a rainfall depth of 15mm is accepted. Similarly, for Area IV, a rainfall depth of 5mm has to be taken. Hence, the average precipitation by the isohyetal method is calculated to be

{[(40x15)+ (80x12.5)+(70x7.5)+(50x5)]/ 240} = 9.9mm

Isohyets: Lines drawn on a map passing through places having equal amount of rainfall recorded during the same period at these places (these lines are drawn after giving consideration to the topography of the region). ***Planimeter***: This is a drafting instrument used to measure the area of a graphically represented planar region.

Estimation of Missing Rainfall Data

Estimating Missing Data

The point observation from a precipitation gage may have a short break in the record because of instrument failure or absence of the observer. Thus, it is often necessary to estimate the missing record using data from the neighboring station. The following methods are most commonly used for estimating the missing records.

1. Simple Arithmetic Method
2. Normal Ratio Method
3. Modified normal ratio method
4. Inverse distance method
5. Linear programming method

For m stations, 1, 2, 3, …,m, the annual precipitation values are P1, P2, P3, …, Pm, respectively. At station x (not included in the above m stations), the missing annual precipitation (Px) should be found out. The normal annual precipitation N1, N2, N3, …,Ni at each of the above (m+1) stations including the station x is known.

1. Normal Precipitation - It is the average value of precipitation at a particular date, month or year over a specified 30 year period. Thus, the term normal annual precipitation at station A means the average annual precipitation at A based on a specified 30 year of record.

2. Simple Arithmetic Average - The missing precipitation Px can be determined using simple arithmetic average, if the normal annual precipitation at various stations are within 10% of the normal precipitation at station, x, as follows:

$$Px = \frac{1}{m}\left[P1 + P2 + \cdots + Pm\right]$$

3. Normal Ratio Method - If the normal precipitations vary considerably then Px is estimated by weighting the precipitation at various stations by the ratios of normal annual precipitation. The normal ration method gives Px as:

$$Px = \frac{Nx}{m}\left[\frac{P1}{N1} + \frac{P2}{N2} + \cdots + \frac{Pm}{Nm}\right]$$

This method is based selecting m (m is usually 3) stations that are near and approximately evenly spaced around the station with the missing record.

4.Modified Normal Ratio Method

Normal ratio method is modified to incorporate the effect of distance in the estimation of missing rainfall.

$$r_x = \frac{\sum_{i=1}^{n} {D_i}^{1/b} \left(\frac{\bar{r}_x}{\bar{r}_i}\right) r_i}{\sum_{i=1}^{n} {D_i}^{1/b}}$$

Where is normal rainfall, is the distance between the index station i and the gauge station with missing data or un gauged station, n is the number of index stations and b is the constant by which the distance is weighted (normally 1.5-2.0) commonly used $D^{0.5}$

5. Inverse Distance Method

The inverse distance method has been advocated to be the most accurate method as compare to other two methods discussed above.

Amount of rainfall to be estimated at a location is a function of;

1. rainfall measured at the surrounding index stations
2. distance to each index station from the un gauged location

Rainfall r_x at station x is given by;

$$r_x = \frac{\sum_{i=1}^{n} \left(\frac{r_i}{{D_i}^b} \right)}{\sum_{i=1}^{n} \left(\frac{1}{{D_i}^b} \right)}$$

b = 2 is commonly used.

As in inverse distance method the weighting is strictly based on distance, hence this method is not satisfactory for hilly regions.

Rainfall intensity This is the amount of rainfall for a given rainfall event recorded at a station divided by the time of record, counted from the beginning of the event.

Effective rainfall

A part of the rainfall reaching the earth's surface infiltrates into the ground and finally joins the ground water reservoirs or moves laterally as interflow. Of the interflow, only the quick response or prompt interflow contributes to the immediate rise of the stream flow hydrograph. Hence, the rainfall component causing perceptible change in the stream flow is only a portion of the total rainfall recorded over the catchment. This rainfall is called the effective rainfall.

The infiltration capacity varies from soil to soil and is also different for the same soil in its moist and dry states. If a soil is initially dry, the infiltration rate (or the infiltration capacity of the soil) is high. If the precipitation is lower than the infiltration capacity of the soil, there will be no overland flow, though interflow may still occur. As the rainfall persists, the soil become moist and infiltration rate decreases, causing the balance precipitation to produce surface runoff.

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