MEASUREMENT OF PRECIPITATION:

Rainfall may be measured by a network of rain gauges which may either be of non-recording or recording type.

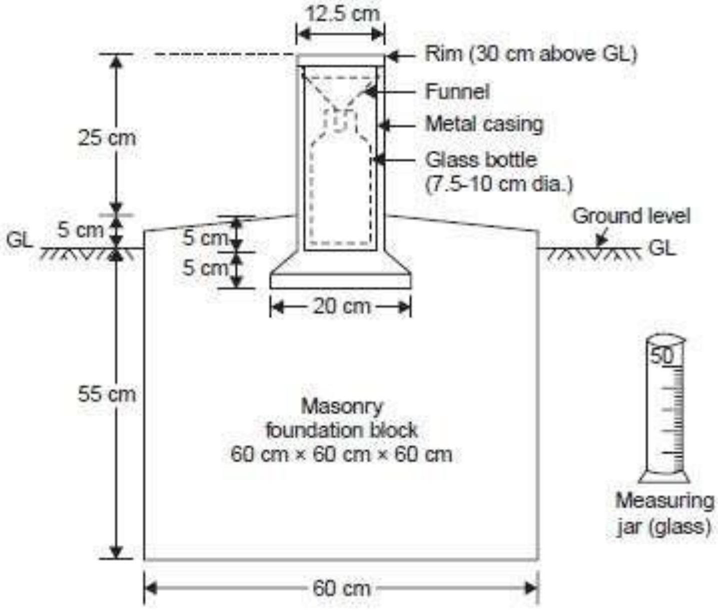


Figure 1.4: Symon's rain gauge

The non-recording rain gauge used in India is the Symon's rain gauge (Figure 1.4). It consists of a funnel with a circular rim of 12.7 cm diameter and a glass bottle as a receiver. The cylindrical metal casing is fixed vertically to the masonry foundation with the level rim 30.5 cm above the ground surface. The rain falling into the funnel is collected in the receiver and is measured in a special measuring glass graduated in mm of rainfall; when full it can measure 1.25 cm of rain.

The rainfall is measured every day at 08.30 hours IST. During heavy rains, it must be measured three or four times in the day, lest the receiver fill and overflow, but the last measurement should be at 08.30 hours IST and the sum total of all the measurements during the previous 24 hours entered as the rainfall of the day in the register. Usually, rainfall measurements are made at 08.30 hr IST and sometimes at 17.30 hr IST also. Thus the non-recording or the Symon's rain gauge gives only the total depth of rainfall for the previous 24 hours (*i.e.*, daily rainfall) and does not give the intensity and duration of rainfall during different time intervals of the day.

It is often desirable to protect the gauge from being damaged by cattle and for this purpose a barbed wire fence may be erected around it.

Recording Rain Gauge:

This is also called self-recording, automatic or integrating rain gauge. This type of rain gauge has an automatic mechanical arrangement consisting of clockwork, a drum with a graph paper fixed around it and a pencil point, which draws the mass curve of rainfall. From this mass curve, the depth of rainfall in a given time, the rate or intensity of rainfall at any instant during a storm, time of onset and cessation of rainfall, can be determined. The gauge is installed on a concrete or masonry platform 45 cm square in the observatory enclosure by the side of the ordinary rain gauge at a distance of 2-3 m from it. The gauge is so installed that the rim of the funnel is horizontal and at a height of exactly 75 cm above ground surface. The self-recording rain gauge is generally used in conjunction with an ordinary rain gauge exposed close by, for use as standard, by means of which the readings of the recording rain gauge can be checked and if necessary adjusted.

There are three types of recording rain gauges- tipping bucket gauge, weighing gauge and float gauge.

Tipping bucket rain gauge:

This consists of a cylindrical receiver 30 cm diameter with a funnel inside. Just below the funnel a pair of tipping buckets is pivoted such that when one of the bucket receives a rainfall of 0.25 mm it tips and empties into a tank below, while the other bucket takes its position and the process is repeated. The tipping of the bucket actuates on electric circuit which causes a pen to move on a chart wrapped round a drum which revolves by a clock mechanism. This type cannot record snow.

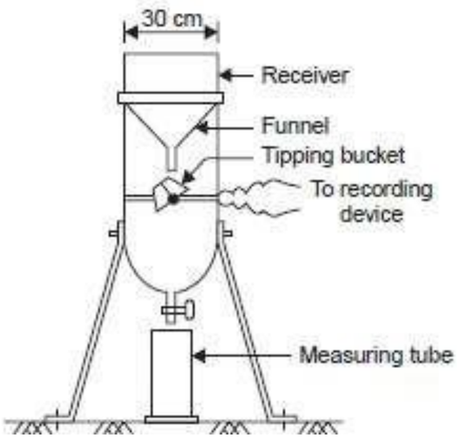


Figure 1.5: Tipping bucket gauge

Weighing type rain gauge:

In this type of rain-gauge, when a certain weight of rainfall is collected in a tank, which rests on a spring-lever balance, it makes a pen to move on a chart wrapped round a clockdriven drum. The rotation of the drum sets the time scale while the vertical motion of the pen records the cumulative precipitation.

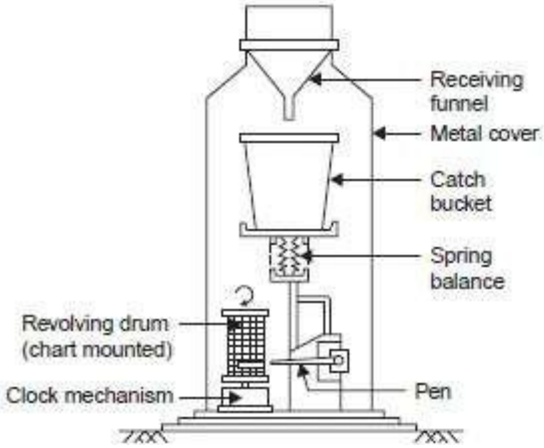


Figure 1.6: Weighing type rain gauge

Float type rain gauge:

In this type, as the rain is collected in a float chamber, the float moves up which makes a pen to move on a chart wrapped round a clock driven drum. When the float chamber fills up, the water siphons out automatically through a siphon tube kept in an interconnected siphon chamber. The clockwork revolves the drum once in 24 hours. The clock mechanism needs rewinding once in a week when the chart wrapped round the drum is also replaced. This type of gauge is used by IMD. The weighing and float type rain gauges can store a moderate snow fall which the operator can weigh or melt and record the equivalent depth of rain.

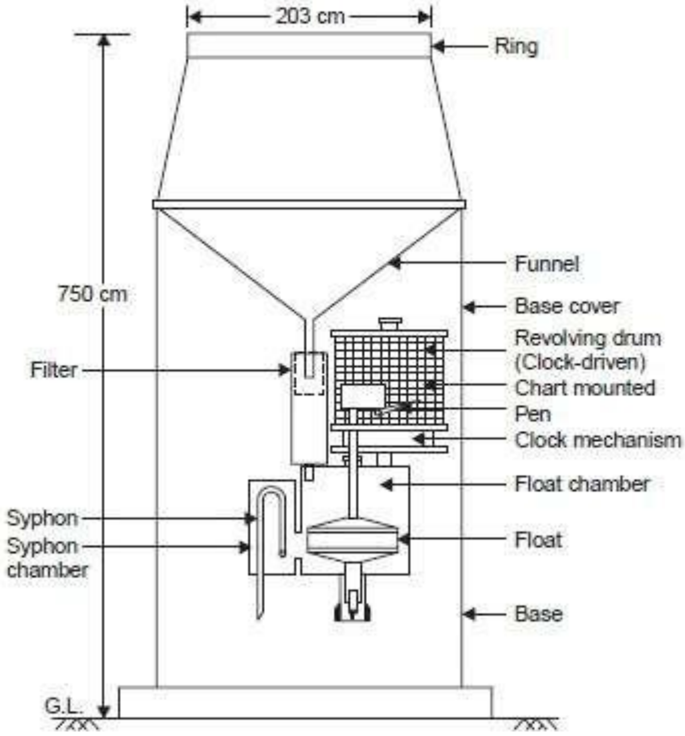


Figure 1.7: Float type rain gauge

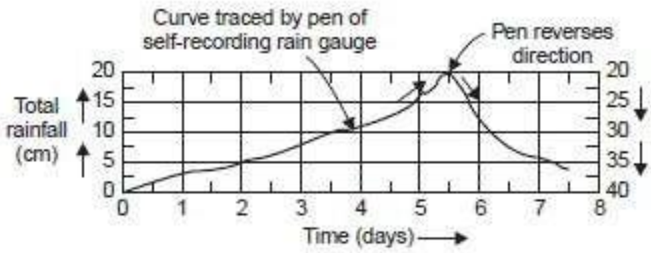


Figure 1.8: Mass curve of rainfall

Raingauge Network: The rain gauge density or network density is defined as the ratio of total area of catchment to the total number of gauges in the catchment. Thus raingauge density gives the average area served by each gauge.

The World Meteorological Organisation, WMO, has laid down certain norms regarding the minimum network density as given below:

Region I : Flat regions of temperate, mediterranean and tropical zones:

Minimum = 1 gauge for 600 to 900 km^2

Tolerance = 1 gauge for 900 to 3000 km^2

Region II : Mountainous areas of temperate, mediterranean and tropical zones:

Minimum = 1 gauge for 100 to 250 km^2

Tolerance = 1 gauge for 250 to 1000 km^2

Region III : Arid zones :

Minimum = 1 gauge for 1500 to 10000 km^2

For small mountainous islands with irregular precipitation one gauge for every 25 km^2 is suggested. Ten percent of these gauges should be of recording type to enable the determination of rainfall intensities.

IS code recommendations(IS: 4987-1968):

1. One guage per 520km^2 in plain areas, with denser network for the areas lying in the path of low pressure systems.
2. One guage per 260 to 390 km^2 in regions with average elevation of 1000m above mean sea level.
3. One guage per 130 km^2 in predominantly hilly regions with heavy rainfall, higher density being preferred wherever possible.

OPTIMUM RAIN-GAUGE NETWORK DESIGN: The aim of the optimum rain-gauge network design is to obtain all quantitative data averages and extremes that define the statistical distribution of the hydro meteorological elements, with sufficient accuracy for practical purposes. When the mean areal depth of rainfall is calculated by the simple arithmetic average, the optimum number of rain-gauge stations to be established in a given basin is given by the equation (IS, 1968)

$$N = \left(\frac{C_v}{p}\right)^2 \quad \text{---------------Eq.1.2}$$

where N = optimum number of raingauge stations to be established in the basin
C_v = Coefficient of variation of the rainfall of the existing rain gauge stations (say, n)
p = desired degree of percentage error in the estimate of the average depth of rainfall over the basin.

The number of additional rain-gauge stations (N–n) should be distributed in the different zones (caused by isohyets) in proportion to their areas, *i.e.*, depending upon the spatial distribution of the existing rain-gauge stations and the variability of the rainfall over the basin.

Average rainfall over a basin:
Point rainfall - It is the rainfall at a single station. For small areas less than 50 km2, point rainfall may be taken as the average depth over the area. In large areas, there will be a network of rain-gauge stations. As the rainfall over a large area is not uniform, the average depth of rainfall over the area is determined by one of the following three methods:

(i) Arithmetic average method - It is obtained by simply averaging arithmetically the amounts of rainfall at the individual rain-gauge stations in the area, *i.e.*,

$$P_{ave} = \frac{\Sigma P_1}{n} \quad \text{-------------- Eq.1.3}$$

where P_{ave} = average depth of rainfall over the area
$\sum P1$ = sum of rainfall amounts at individual rain-gauge stations
n = number of rain-gauge stations in the area

This method is fast and simple and yields good estimates in flat country if the gauges are uniformly distributed and the rainfall at different stations do not vary very widely from the mean. These limitations can be partially overcome if topographic influences and aerial representativity are considered in the selection of gauge sites.

(ii) Thiessen polygon method - This method attempts to allow for non-uniform distribution of gauges by providing a weighting factor for each gauge. The stations are plotted on a base map and are connected by straight lines. Perpendicular bisectors are drawn to the straight lines, joining adjacent stations to form polygons, known as Thiessen polygons (Fig. 1.9). Each polygon area is assumed to be influenced by the raingauge station inside it, *i.e.*, if $P1$, $P2$, $P3$, ... are the rainfalls at the individual stations, and $A1$, $A2$, $A3$, are the areas of the polygons surrounding these stations, (influence areas) respectively, the average depth of rainfall for the entire basin is given by

$$P_{ave} = \frac{\Sigma A_1 P_1}{\Sigma A_1} \quad \text{- ------------ Eq.1.4}$$

where $\sum A_1 = A$ = total area of the basin.

The results obtained are usually more accurate than those obtained by simple arithmetic averaging. The gauges should be properly located over the catchment to get regular shaped polygons. However, one of the serious limitations of the Thiessen method is its non-flexibility since a new Thiessen diagram has to be constructed every time if there is a change in the raingauge network.

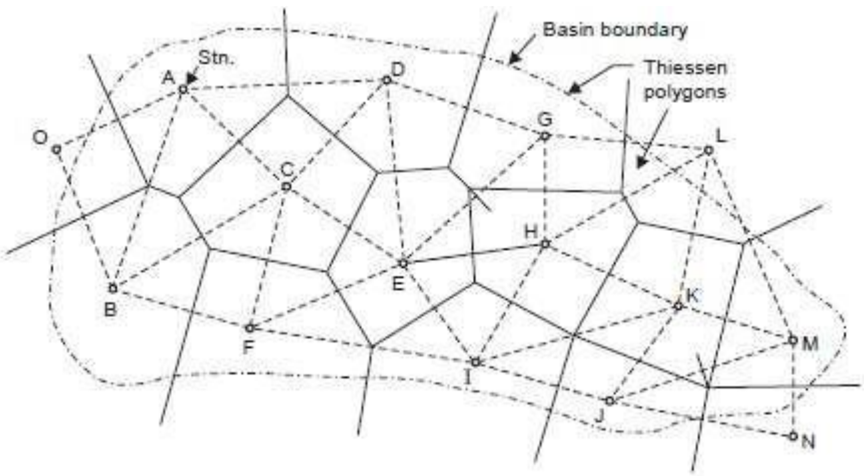


Figure 1.9 Thiessen polygon method

(iii) The isohyetal method - In this method, the point rainfalls are plotted on a suitable base map and the lines of equal rainfall (isohyets) are drawn giving consideration to orographic effects and storm morphology, Fig.1.10. The average rainfall between the succesive isohyets taken as the average of the two isohyetal values are weighted with the area between the isohyets, added up and divided by the total area which gives the average depth of rainfall over the entire basin, *i.e.*,

$$P_{ave} = \frac{\Sigma A_{1-2} P_{1-2}}{\Sigma A_{1-2}} \quad \text{---------------Eq.1.5}$$

where A_{1-2} = area between the two successive isohyets $P1$ and $P2$

$$P_{1-2} = \frac{P_1 + P_2}{2} \quad \text{- ------------ Eq.1.6}$$

$\sum A1\text{–}2 = A$ = total area of the basin.

This method if analysed properly gives the best results.

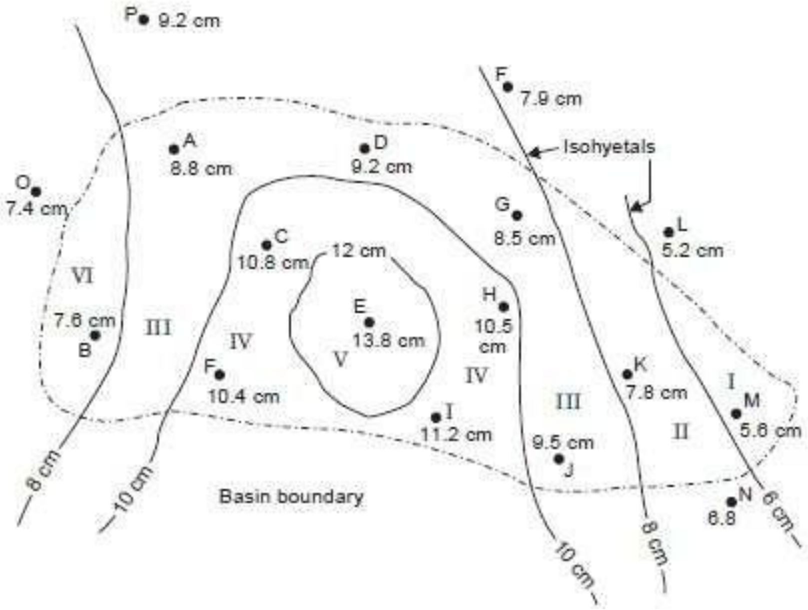
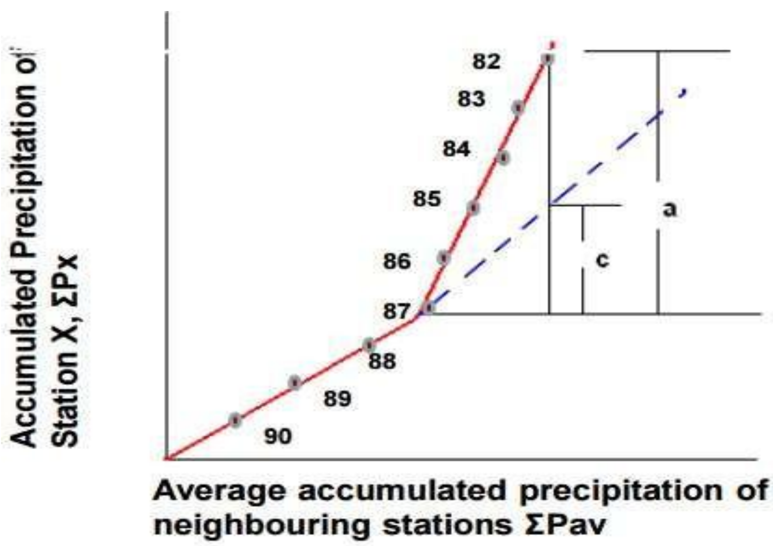


Figure 1.10 Isohyetal method

Consistency of rain fall data

Double Mass Curve Technique: The trend of the rainfall records at a station may slightly change after some years due to a change in the environment (or exposure) of a station either due to coming of a new building, fence, planting of trees or cutting of forest nearby, which affect the catch of the gauge due to change in the wind pattern or exposure. It is a commonly used data analysis approach for investigating the behaviour of records made of hydrological or meteorological data at a number of locations. It is used to determine whether there is a need for corrections to the data - to account for changes in data collection procedures or other local conditions. Double mass analysis for checking consistency of a hydrological or meteorological record is considered to be an essential tool before taking it for analysis purpose.



Correction Ratio : $M_c/M_a = c/a$

$P_{cx} = P_x * M_c / M_a$

Pcx – corrected precipitation at any time period t1 at station X

Px – Original recorded precipitation at time period t1 at station X

M_c – corrected slope of the double mass curve M_a – original slope of the mass curve

Frequency of rainfall: The frequency of rainfall of a specified period is determined by assuming that the rainfall is a random variable and mathematical theory of probability is applicable. The frequency of a rainfall is the number of time that a given magnitude of rainfall may occur in a given period. The study of the probability of occurrence of a particular extreme rain fall is of extreme importance to the determination of design flood. This is determined with help of frequency analysis. The recurrence interval is the interval in years for occurrence of the event of the same magnitude and is the reciprocal of the frequency. The recurrence interval, also known as return period

California formula : P_r= m/N or T= N/m N=number of years of record , m=descending order of magnitude

Hazen formula : p_r = 2m-1/2N

Weibull formula : p_r = m/(n+1) most commonly used formula

Frequency (f) : The probability of occurrence of an event, expressed as percentage is known as frequency, f=100*p_r

Intensity-Duration-Frequency (IDF) curves

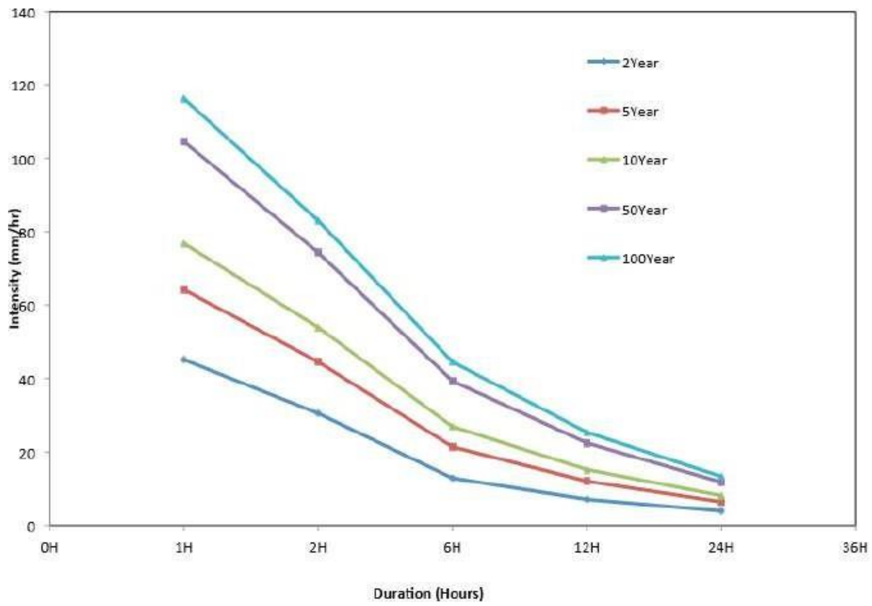
It is necessary to know the rainfall intensities of different durations and different return periods, in case of many design problems such as runoff disposal , erosion control, highway construction, culvert design etc. The curve that shows the inter-dependency between i (cm/hr), D (hour) and T (year) is called IDF curve.

The relation can be expressed in general form as:

i = i – Intensity (cm/hr), T – Return period

D – Duration (hours)

K, x, a, n – are constant for a given catchment



Depth-Area-Duration relationships

It indicates the areal distribution characteristic of a storm of given duration.

The development of maximum depth-area-duration relationship is known as DAD analysis. It is an important aspect of hydro-meteorological study.

Depth-Area relationship

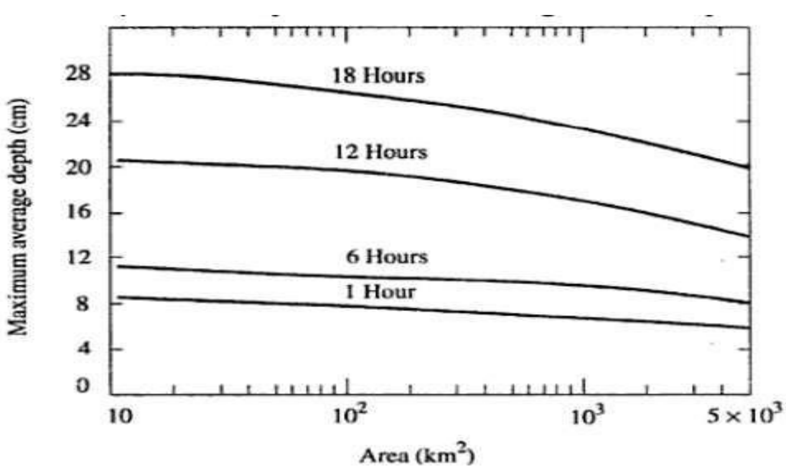
For a rainfall of given duration, the average depth decreases with the area in an exponential fashion given by:

$P=P_0 \exp(-kA^n)$

where :P= average depth in cms over an area A km^2,

Po : highest amount of rainfall in cm at the storm centre

K, n : constants for a given region



Depth area duration curves

Probable Maximum Precipitation (PMP)

- This is the amount of rainfall over a region which cannot be exceeded over at that place.
- The PMP will of course vary over the Earth's surface according to the local climatic factors.
- Naturally, it would be expected to be much higher in the hot humid equatorial regions than in the colder regions of the mid-latitudes when the atmospheric is not able to hold as much moisture.
- PMP also varies within India, between the extremes of the dry deserts of Rajasthan to the ever humid regions of South Meghalaya plateau**.**

PMP = P +Ks

P = mean of annual maximum rainfall

series s = standard deviation of the

series

K = frequency factor