Civil Engineering

Engineering Hydrology

Comprehensive Theory

with Solved Examples and Practice Questions

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CHAPTER 02

Precipitation

INTRODUCTION

Water evaporate from earth's surface in the form of water vapour. As the evaporation continues the amount of atmosphere vapour goes on increasing, a stage is reached when any further addition of vapour get condensed. Precipitation result when water droplet come together and join to form larger drop that can drop down. The water vapour condense over nuclei to form tiny water droplet of sizes less than 0.1 mm in diameter. *The nuclei are usually salt particle or product of combustion and are normally available in plenty.*

- Moisture holding capacity of air increases with increase of temperature and decreases with decrease of temperature.
- As the temperature increases the moisture holding capacity increases and the saturation vapour pressure also increases.
- The water vapour exerts a partial pressure on the water surface called vapour pressure. If the process of evaporation continues a stage is reached when the air is fully-saturated with water vapour. At this stage, whatever pressure is applied by the water vapour is called ***saturation vapour pressure***.
- Let us consider a volume of air at temperature T_m and vapour pressure e_m .
- At temperature T_m the saturation vapour pressure is e_n. The difference between saturation vapour pressure at point n and m that is $e_n - e_m$ is called *saturation deficit*.
- If we decrease the temperature from T_m to T_0, the moisture will be at saturation level and precipitation will start.
- If we increase the temperature from T_m to T_p, saturation deficit increases and it's moisture holding capacity increases.

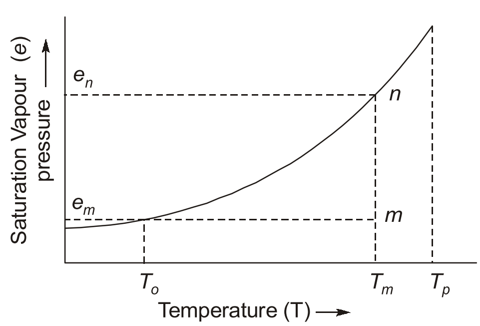


Fig. 2.1

2.1 Favourable Conditions for Precipitation

For precipitation to form, there are some necessary conditions in the environment:

(i) The atmosphere must have moisture

(ii) There must be sufficient nuclei present to aid condensation over them

(iii) Weather condition must be favourable for condensation of water vapour

(iv) The product of condensation must reach the earth.

NOTE: Air in atmosphere is cooled by many processes but the cooling by adiabatic process is most important. By this process moist air is lifted up.

2.2 Forms of Precipitation

Precipitation come to earth's surface in different forms, some of them are given below:

(i) Rain : It is the most common form of precipitation. In this the water droplet size are larger than *0.5 mm and smaller than 6 mm*. Any drop of water larger then size 6 mm, tends to break up into smaller size drops during its fall from cloud.

- On the basis of intensity, rainfall is classified as:

Type	Intensity (mm/hr)
Light rain	< 2.5
Moderate rain	2.5 - 7.5
Heavy rain	> 7.5

(ii) Snow Fall : Snow fall is another important form of precipitation. Snow are made up of ice crystals which usually combine to form *flakes*. When these flakes reaches to the earth's surface than snow fall occur. The snow fall occur when nearer to earth's surface the temperature is freezing (about 300 m from surface). *Average density of snow 0.1 g/cm*^{3}

(iii) Drizzle : A fine sprinkle of numerous water droplets which have *size less than 0.5 mm* and intensity of these water *droplet is less than 1 mm/hr* is called drizzle. As the size and intensity of Drizzle is very less, they appear to float in air.

(iv) Glaze: When the water droplet (rain or drizzle) comes in contact with ground which has temperature near about 0°C or less, these water drops freeze and form ice coating on ground surface which is called glaze or freezing rain.

(v) Sleet: It is frozen rain drops which have *transparent grains*. These are formed when rainfall is at subfreezing temperature.

- Sleet denotes both rain and snow.
- Usually the size of sleet is less than 5 mm.

(vi) Hail: It is a large size of snow which have *size greater than 8 mm*. They are in the form of irregular pellets or lumps of ice.

- They are very destructive in nature. They destroy the agriculture and are harmful for animal and human.

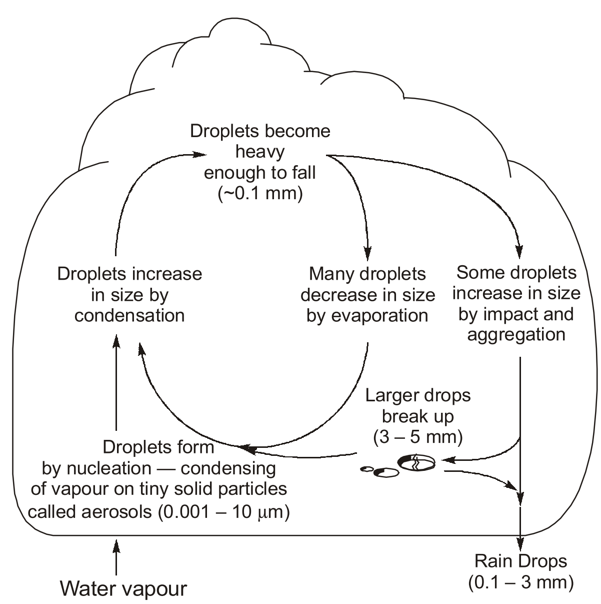


Fig. 2.2

- They occur when the vertical current of wind are very strong
- The general velocity of different types of precipitation are:

Form of Precipitation	Fall speed (m/sec)
Drizzle drops	1
Rain drops	10
Hail	20 - 50

2.3 Types of Precipitation

(i) **Orographic Precipitation:** This type of precipitation occur when moist air mass may get lifted up to higher altitude due to presence of mountain barriers because they can not move forward. Due to rise, air undergo cooling, condensation and precipitation.

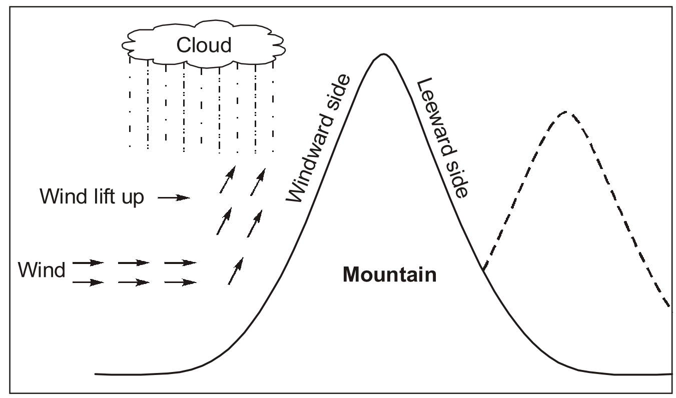


Fig.2.3 *Orographic Precipitaiton*

Remember

- In India, most of the precipitation occur due to ***orographic precipitation***.
- The greatest amount of precipitation falls on the windward side, and the leeward side has often very little precipitation.

(ii) **Convective Precipitation:** It is caused due to pocket of air is warmer than the surrounding air. The warmer air is lesser dense in comparison to colder one. Due to localised heating, air becomes warm and rises up and air from colder area flow towards to fill the void. The warmer air continue to rise, undergo cooling and result in precipitation.

- Usually the areal extent of such type of rain is small, limited to a diameter of about 10 km.
- Convective precipitation occurs in the form of ***showers of high intensity*** and ***short duration***.

(iii) **Cyclonic Precipitation:** A cyclone is a large low pressure region with circular wind motion. In low pressure area, air will flow horizontally from the surrounding area, causing the air in the low pressure area to lift causing precipitation.

2.4 Types of Cyclone

(i) **Tropical Cyclone:** A tropical cycle in India is called cyclone. In it isobars are closely spaced and winds are anticlockwise in northern hemisphere.

- The wind speed gradually decreases towards the outer edge of tropical cyclone.
- Pressure increases towards outer edge of cyclone.

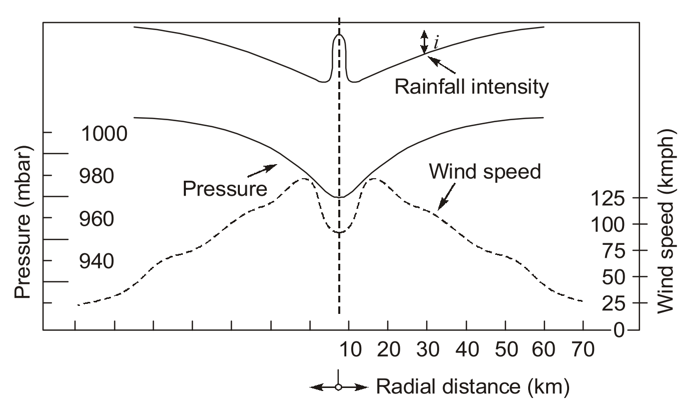


Fig.2.4 *Schematic Section of a Tropical Cyclone*

- These are called tropical cyclone as these occur in tropical region of world.
- The centre of storm is called eye, which may have the size of about 10-50 km in diameter.
- The area of eye is quiet in comparison to other part of cyclone.
- Just right outside of the eye's area, there is very strong winds.

(ii) **Extra Tropical Cyclone:** These cyclone are formed in location outside the ***Tropical Zone*** of world. This type of cyclone posses a strong *counter-clockwise wind circulation in the northern hemisphere.*

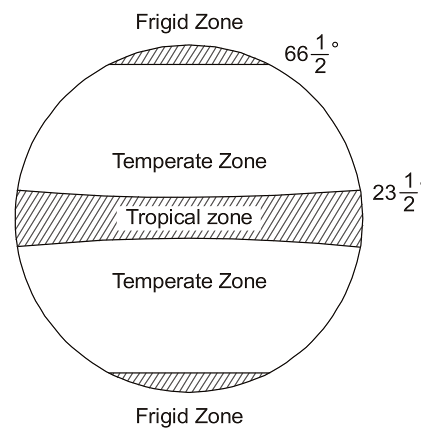


Fig.2.5 *Temperature zones*

- The magnitude of precipitation and wind velocities are relatively lower than those of tropical cyclone.
- The duration of precipitation is usually longer and areal extent is also larger.

(iii) **Anti Cyclone:** In such type of cyclone wind circulation is clockwise in the northern hemisphere.
- The weather is usually calm at the centre
- Winds flow with the moderate speed.

(iv) **Frontal Cyclone:** This is also a type of cyclone but the formation of it is different, when a warm air mass and cold air mass meet under favourable conditions, as the warm air are less dense so they rise up and colder air mass due to high density settle down. The ascending warmer air cools adiabatically and form the cloud and precipitates.

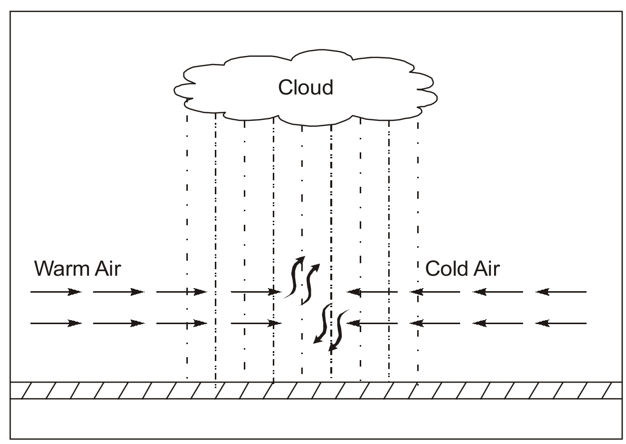


Fig.2.6 *Frontal Cyclone*

NOTE: A ***Front*** is the interface between two distinct air mass.

2.5 Measurement of Rainfall

All forms of precipitation are measured as the vertical depth of water that would accumulate on a level surface, if the entire precipitation remained where it fall.

- If 1 cm rainfall occur over an area of 1 km^2, then it represents that the total volume of water over that area is 10^4 m^3.

$$\text{Volume of water} = \text{Rainfall depth} \times \text{Area}$$

- In case of snowfall, an equivalent depth of water is used as the depth of precipitation.
- As it is not possible to collect all the precipitation which comes down on an area. We use an instrument for measurement of rainfall called as ***raingauge***. They should be placed in place, so that it clearly represent the precipitation of that area.
- These raingauge also called as *pluviometer*, *ombrometer*, ***hyetometer*** and *udometer*.

- For placing a raingauge in an area, following guidelines should be followed:
  - (i) The ground must be in the open, levelled and the instrument must present a horizontal catch surface.
  - (ii) It must be set as near the ground as possible to reduce wind effect but it must be sufficiently high to prevent from flooding.
  - (iii) It must be surrounded by an open fenced area of atleast 5.5 m × 5.5 m.
  - (iv) There should not be any object nearer to the instrument in a radius of 30 m.
  - (v) If there is any obstruction within 30 m radius than the raingauge should be kept at same distance from the obstruction and that distance should be more than *twice the height of obstruction*.

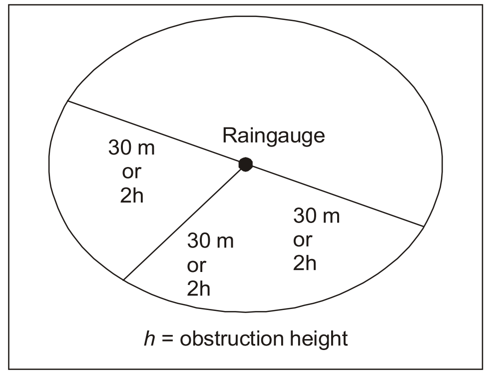


Fig.2.7 *Location of Raingauge*

2.6 Measurement of Snowfall

- Snowfall is a form of precipitation, which is accumulated over a surface and after some time when it gets melted, runoff is produced.
- *Depth of snowfall is measured* by ***snow stake***, these are 40 cm wide square box placed permanently to find out total depth of snow.

  Water Equivalent of Snow: Water equivalent of snow is the depth of water that would result in melting of a unit of snow.
- This parameter is very useful to estimate the stream flow due to melting of snow.
- For finding the equivalent depth of water, we assume the density of snow is 0.1 g/cm^3.

  Water equivalent of snow is obtained by two method:
  - **(i) Snow gauge :** They are similar to Raingauge. Melting agents or heating sometime are provided to reduce the size of container. Weighing type recording gauge can also be used for measuring the snow precipitation. For it, funnel is removed.
  - **(ii) Snow Tubes :** To extract a sample, the tube is driven into the snow deposit till it reaches the bottom of the deposit and then by twisting it, cut a core. The core is extracted and we obtain water equivalent of snow.

2.7 Types of Gauges

The raingauge can be broadly classified as:

(i) Non Recording Raingauge

(ii) Recording Raingauge

(i) Non Recording Raingauge: These raingauge are most widely adopted in India. They are known as '*Non Recording type*' because they do not record the rain but only collect the rain.

- In India, mostly used is "***Symon's***" non recording type raingauge till the year 1969. But since 1969, Indian meteorological department has adopted another model called "Standard Gauge".
- Now the symon's type raingauge is obsolete in India.

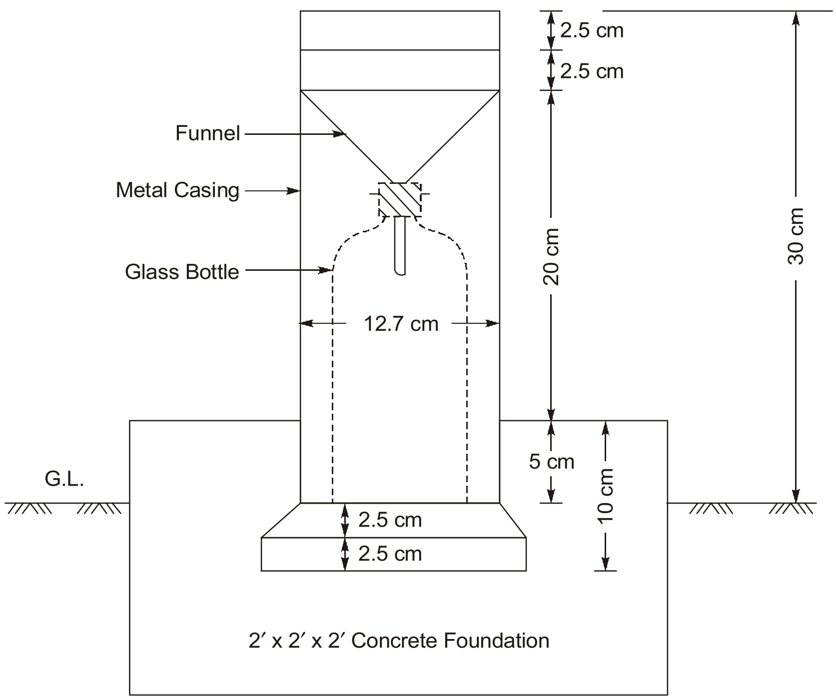


Fig.2.8 *Symon's non-recording rainguage*

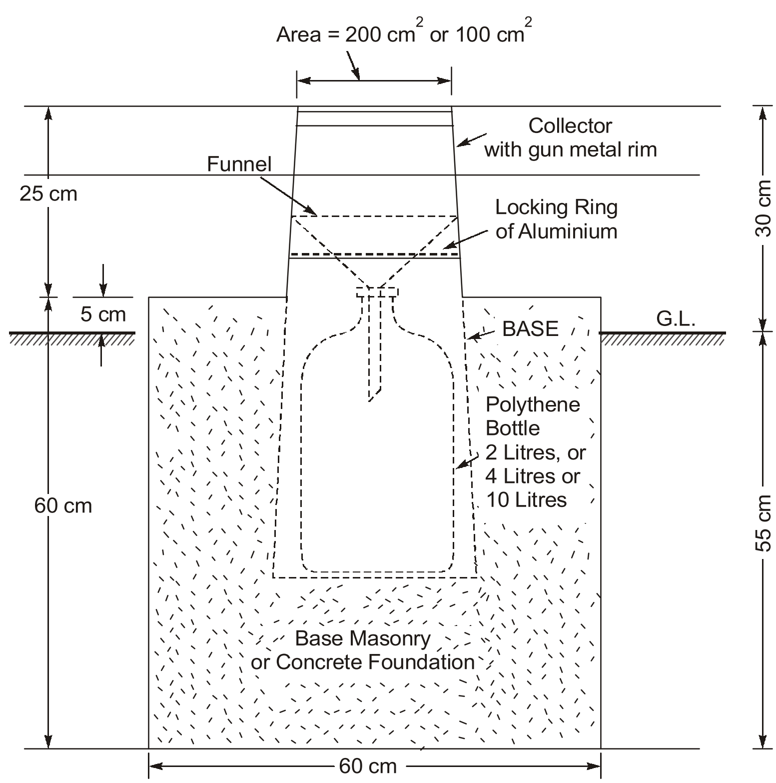


Fig.2.9 *Standard non-recording rainguage of Indian Meteorological Department*

- These raingauge can also be used to measure snowfall, when snow is expected. In the case of snow, the funnel and bottle is removed and snow is allowed to collect in the outer metal container. When the snow is melted, the depth of resulting water is measured.
- $$\frac{\text{Volume of water collected in bottle (cm}^3\text{)}}{\text{Area of the gauge (cm}^2\text{)}} = \text{Depth of rainfall (cm)}$$

Do you know? The rainfall in raingauge is measured everyday at 8:30 AM (*IST*) and is recorded as the rainfall of that day.

(ii) **Recording Type Raingauges:** This type of raingauge can give us a permanent automatic rainfall record. There is some mechanical arrangement by which *rain fallen vs. time plot* come on graph paper.

- These are sometimes called as *Integrating raingauges* or *continuous raingauges*.
- They are of great use in hills and for opposite areas, where it is not practically feasible to daily visit the gauge station.

The commonly used *recording raingauges* are:

(a) Tipping Bucket Type (b) Weighing Bucket Type (c) Natural Syphon Type

(a) **Tipping Bucket Type:** In this, rain water is first caught in a collector and passed through a funnel. The funnel discharge the water into a two bucket compartment when some amount of rain (0.10 - 0.25 mm) gets filled up in one compartment the bucket tips, emptying into a reservoir and moving the second compartment into place beneath the funnel.

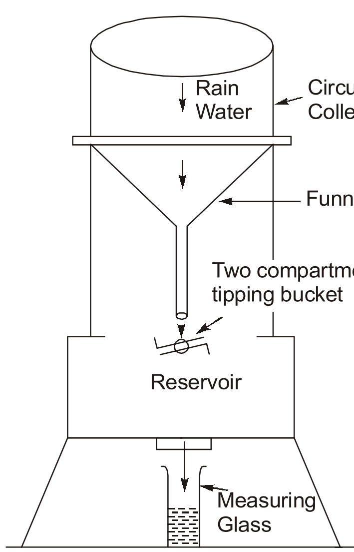


Fig.2.10 Indicating the recording mechanism of a 'Tipping Bucket' type of a recording rainguage

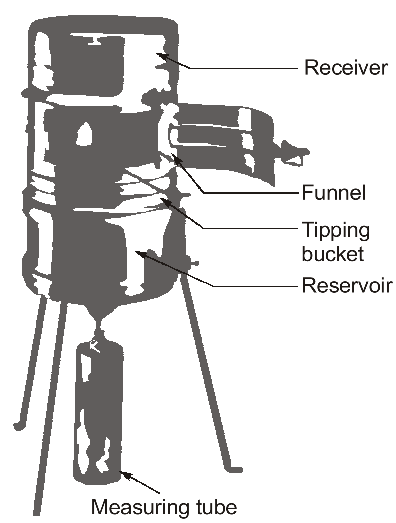


Fig.2.11 Photographic view of a Tipping Bucket type of a rainguage

- The movement of the tipping of the bucket can be transmitted electronically over distances. So such gauges can be installed in ***hilly or inaccessible areas***, from where they can supply measurements directly in the control room.

- The record from the tipping bucket type of raingauge gives the data of the ***intensity of rainfall.***

(b) Weighing-Bucket Type Gauges: In this type of raingauge, the weight of rain which falls into a bucket placed on the platform of a spacing on other weighing mechanism. The increasing weight of bucket helps in recording the increasing quantity of collected rain with time, by moving a pen on recording drum.

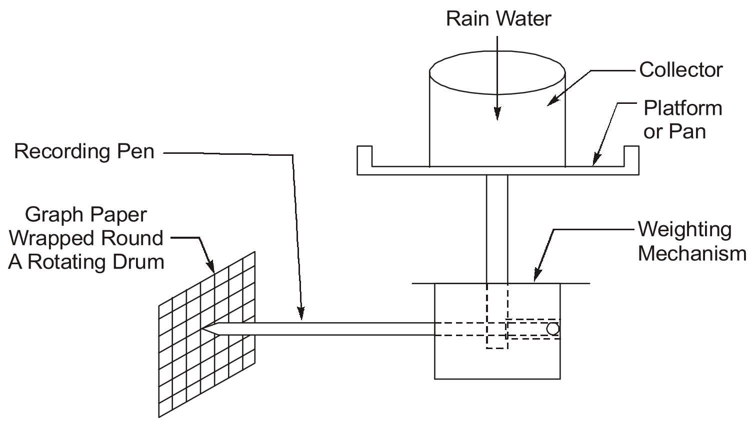


Fig.2.12 *Recording mechanism of a 'Weighing' type of a recording rainguage*

NOTE: This instrument gives a plot of *accumulated rainfall against the elapsed time*, means it provides mass curve of rainfall.

(c) Natural-Syphon Type: In this raingauge, the rainfall collected by a funnel-shaped collector and lead into a float chamber due to this float which rise. As the float rises, a pen attached to the float through a lever system records the elevation of the float on a rotating drum.

- A syphon arrangement empties the float chamber as the float has reached a pre-set maximum level and again the reading starts from initial point.

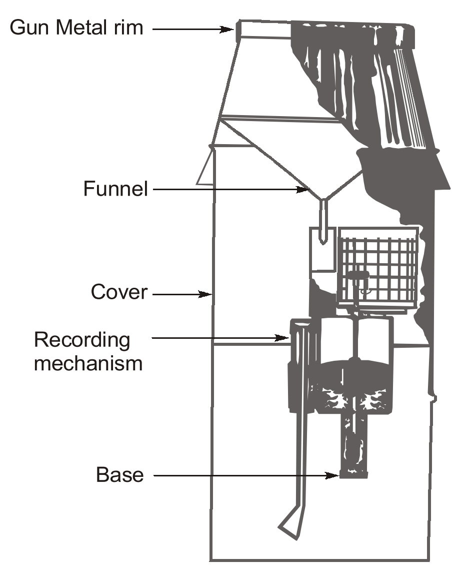


Fig.2.13 *Section through an automatic rainguage (Floating type)*

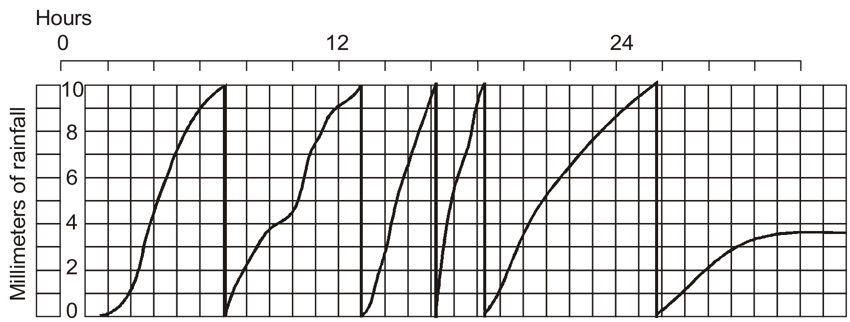


Fig.2.14 *Recording from a Natural Syphon-type Guage (Schematic)*

NOTE: This gauge gives mass curve of rainfall.

2.8 Other Methods of Precipitation Measurement

(i) **Telemetering Raingauges:** These raingauges are of *recording type* and contain electronic units to transmit the data of rainfall to a base station, both at regular interval or continuous.

- Telemetering Raingauges are mostly useful in collecting rainfall data from mountain or *inaccessible place*.

(ii) **Radar Measurement of Rainfall:** Radar is a powerful instrument for measuring the *areal cover, location and movement of rain storm.*

- Radar can measure the amount of rainfall over a large period with good accuracy.
- Meteorological radar use the wavelength of the order of 5-10 cm.
- For observing heavy rain, we use 10 cm wavelength while for the light rain, 5 cm wavelength is used
- A radar can cover the area for observation as much as 100000 km^2.
- The hydrological range of the radar is of the order of 200 km.

(iii) **Satellites Technique:** This is very modern or advanced technique to find the precipitation amount, area cover and location in which the image is taken by satellite and sent to the control station. By this technique, we can have the knowledge about the precipitation.

(iv) **Storage Gauges:** These type of gauges are used in a remote area where daily visit is not possible. By this type of gauges, we find the rainfall reasonably early.

2.9 Raingauge Network

Rainfall records is most important for hydrological investigations, so a well distributed network of raingauge station within the catchment is essential. The raingauge should be evenly and uniformly distributed within a given catchment.

- The total number of raingauge in a given area should neither be too many, because it will increase the cost and nor be too low to give reliable result.
- A lesser density of raingauge (less number of gauge per unit area) is used for studies of general storm and the high density of raingauge (high number of gauge per unit area) is used for studies of rainfall pattern of a thunderstorm.

Hence, our aim is to provide a optimum density of gauges from practical consideration.

The Indian standard (IS : 4987-1968) recommends the following densities:

(i) In ***plain area*** → 1 station per 520 km^2

(ii) In region of ***average elevation 1000 m*** → 1 station per 260-390 km^2

(iii) In predominantly ***hilly areas with heavy rainfall*** → 1 station per 130 km^2

NOTE: To know the intensities of rainfall, 10 percent of total raingauge in a area should be of self-recording type.

2.10 Optimal Number of Raingauges (N)

- A certain number of raingauge stations are necessary to give average rainfall with a certain percentage of error.
- If the allowable percentage error is more than lesser number of gauge would be required and vice-versa.
- Statistics has been used in determining the optimum number of raingauge required to be installed in a given catchment.
- For finding the optimum number of raingauge in a particular catchment area with a certain percentage of error, following steps should be taken.

Step I : Calculate the ***mean rainfall*** over that area by the use of data of existing raingauge

$$\bar{P} = \frac{P_1 + P_2 + P_3 \ldots\ldots P_n}{n}$$

Here P_1, P_2, P_3 .... P_n are the average rainfall.

Step II : Calculate ***standard deviation*** (σ)

$$\sigma_{n-1} = \sqrt{\frac{(P_1 - \bar{P})^2 + (P_2 - \bar{P})^2 + (P_3 - \bar{P})^2 \ldots\ldots (P_n - \bar{P})^2}{n-1}}$$

$$= \sqrt{\frac{\sum_{i=1}^{n} (P_i - \bar{P})^2}{n-1}}$$

Step III : Calculate ***coefficient of variation*** (C_v)

$$C_v = \frac{\sigma_{n-1}}{\bar{P}} \times 100$$

Step IV : The optimal number of raingauge with allowable percentage error in the estimate on basic mean rainfall are calculated as

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

Here N = Optimal number of raingauge stations

ϵ = Allowable percentage error in the estimate of basic mean rainfall

Step V : Additional number of raingauge required = $N - n$

NOTE: In general the value of allowable error should be kept 10%.

Example 2.1 There are four raingauge stations existing in the catchment of a river. The average annual rainfall values at these stations are 800, 620, 400 and 540 mm respectively

(a) Determine the optimum number of raingauge in the catchment.

(b) How many more gauges will be required to be installed.

Allowable percentage error in mean value of rainfall in the catchment is 10%.

Solution:

$$\text{Mean Rainfall } \bar{P} = \frac{P_1 + P_2 + P_3 + P_4}{4} = \frac{800 + 620 + 400 + 540}{4} = 590 \text{ mm}$$

$$\text{Standard deviation } \sigma_{n-1} = \sqrt{\frac{\sum_{i=1}^{4}(P_i - \bar{P})^2}{n-1}}$$

$$= \sqrt{\frac{(800-590)^2 + (620-590)^2 + (400-590)^2 + (540-590)^2}{4-1}}$$

$$= 166.93$$

Coefficient of variation

$$C_v = \frac{\sigma_{n-1}}{\bar{P}} \times 100 = \frac{166.93}{590} \times 100 = 28.29\%$$

Optimum number of raingauge

$$N = \left(\frac{C_v}{\epsilon}\right)^2 = \left(\frac{28.29}{10}\right)^2 = 8.004 \simeq 8 \text{ numbers}$$

Additional gauges required

$$= N - n = 8 - 4 = 4$$

Example 2.2 A watershed has five non-recording raingauges, installed in its area. The amount of rainfall recorded for one of the years is given below:

Raingauge stations	Annual rainfall (cm)
I	100
II	120
III	190
IV	95
V	125

Find the required optimum number of non-recording and recording raingauges for this watershed. Assume an error of 10% in the estimation of mean rainfall.

Solution:

$$\Sigma P = 100 + 120 + 190 + 95 + 125 = 630 \text{ cm}$$

$$\therefore \quad \bar{P} = \frac{\Sigma P}{5} = \frac{630}{5} = 126 \text{ cm}$$

Optimum number of stations can be calculated as

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

Now, $$C_v = \frac{\sigma_{m-1} \times 100}{\bar{P}}$$

where $$\sigma_{m-1} = \sqrt{\frac{\sum_{i=1}^{m}(P_i - \bar{P})^2}{m-1}}$$

$\therefore$ $$\sigma_{m-1} = \sqrt{\frac{(100-126)^2 + (120-126)^2 + (190-126)^2 + (95-126^2) + (125-126)^2}{5-1}}$$

$\Rightarrow$ $$\sigma_{m-1} = 37.98 \text{ cm}$$

$\therefore$ $$C_v = \frac{37.98 \times 100}{126} = 30.14\%$$

$\Rightarrow$ $$N = \left(\frac{30.14}{10}\right)^2 = 9.09 \approx 10 \text{ stations}$$

So, 9 non-recording type and 1 recording type raingauge must be provided for this watershed.

2.11 Estimation of Missing Data

Before estimation let us go through some general terms used:

- **Average Annual Rainfall:** The total amount of rainfall collected in 1 year is called annual rainfall and the average of annual rainfall data of last 35 years is called the average annual rainfall. The amount of rain collected in last 24 hours is called daily rainfall.
- **Normal Precipitation:** The normal rainfall is the average value of rainfall of a particular date, month or year over a specified 30 year period.

  Example : Normal rainfall of 21^{st} December, normal rainfall of April, normal rainfall of year.

  The 30-year normal rainfall is recomputed every decade. Because in this time period there are several changes like environment change, land use change, etc. and these factors may affect the rainfall on that area.
- **Preparation of Data:** It is necessary to check the rainfall data for continuity and consistency of a station before using it. The continuity of a record may be broken with missing data due to many reasons such as the damage of raingauge instrument. The rainfall data should be consistent with present environmental condition and land use condition. If some change occur then the data will not be consistent

Sometimes station has break in giving a consistent record due to absence of observer or failure of instrument for calculating the missing data, so we choose the nearby station data. Following are the ***methods of calculating the missing data:***

(i) **Arithmetic Mean Method:** If the normal annual precipitation of the nearby stations is 10% of within the normal annual precipitation at station X, then we use this method.

$$P_x = \frac{P_1 + P_2 + P_3 + P_4 ......P_n}{n}$$

Here P_1, P_2, P_3 ..... P_n are respective annual precipitation at stations 1, 2, 3, ... *n*.

(ii) Normal Ratio Method: If normal precipitation at any of these selected stations differ by more than 10% of selected station then we use normal ratio method.

$$P_x = \frac{N_x}{n}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_3}{N_3} .... \frac{P_n}{N_n}\right]$$

Here N_1, N_2, N_3 .... N_n are normal precipitation at station 1, 2, 3 ...... *n* and N_x is normal precipitation at station where the data is missing.

NOTE: *n* is number of stations surrounding to station x.

Example 2.3 A raingauge was inoperative for sometimes, during which storm occur at three station A, B, C surrounding area the total precipitation recorded during the storm was 75, 58, 47 mm respectively. The normal precipitation was 826, 618 and 482 mm respectively. And at the station where rainfall data missing the normal precipitation was 752 mm. Estimate the missing rainfall data.

Solution:

N_x = 757 mm P_x = ?

N_A = 826 mm P_A = 75 mm

N_B = 618 mm P_B = 58 mm

N_C = 482 mm P_C = 47 mm

N_x + 10% of N_x = 757 × 1.1 = 832.7 mm

N_x – 10% of N_x = 757 × 0.9 = 681.3 mm

As the neighbouring station normal annual rainfall data are not in range so we apply the normal ratio method.

$$P_x = \frac{N_x}{n}\left[\frac{P_A}{N_A} + \frac{P_B}{N_B} + \frac{P_C}{N_C}\right] = \frac{757}{3}\left[\frac{75}{826} + \frac{58}{618} + \frac{47}{482}\right] = 71.198 \text{ mm}$$

2.12 Inconsistency of Record

If the condition relevant to the recording of data of a raingauge station have undergone a significant change during the period of record, inconsistency would arise in data of that station from that time period in which condition is changed.

Some common cause for inconsistency of record:

(i) Shifting of raingauge station to a new location.

(ii) The neighbourhood of the station undergoing a major change, etc.

(iii) Change in ecosystem due to calamities such as forest fires, land slides.

(iv) Occurrence of observational error.

The checking and correction for inconsistency of a record is done by ***double-mass curve technique***. Through this technique the old data can be simulated with present environment and land use condition.

Iso-Pluvial: The intensity duration frequency curves are prepared for various adjoining areas. A combined map for the large area can be prepared for maximum rainfall depth for various combinations of a return period of durations.

Such maps for a region for various rainfall depths, return periods and durations are called Iso-Pluvial.

Objective Brain Teasers

Q.1 The average normal size of a rain drop may be of the order of :
(a) 0.5 – 4 mm (b) 5 – 10 mm
(c) 10 – 50 mm (d) none of these

Q.2 Precipitation occurring in droplets of size more than 10 mm, and fall speed of more than 20 m/s, will be in the form of :
(a) rain (b) hail
(c) sleet (d) none of these

Q.3 The convective precipitation is cause when :
(a) upward movement of moist air is produced by surface heating
(b) a disturbance on the air front develops into a cyclone
(c) the colder air mass forms a wedge, lifting the warm air mass
(d) the orographic cooling takes place over a mountainous slope

Q.4 Telemetering raingauges are of the type :
(a) weighing type
(b) tipping bucket type
(c) syphon type
(d) none of these

Q.5 You are asked to install raingauges in areas, which become inaccessible during rainy season. Which type of gauges would you recommend?
(a) symon's type
(b) syphon type
(c) tipping bucket type
(d) weighing bucket type

Q.6 Mass curve of precipitation is produced by a raingauge of :
(a) symon's type
(b) tipping bucket type
(c) storage type
(d) natural syphon type

Q.7 The minimum percentage of recording gauges in a total network of raingauges, as recommended by Indian Standards, is:
(a) 10% (b) 20%
(c) 50% (d) 90%

Q.8 The average annual rainfall at stations *A*, *B* and *C* are 160, 180 and 200 cm, respectively. In 1990, the station B became inoperative, and stations A and C recorded annual rainfall of 170 and 180 cm, respectively. The annual rainfall of station *B* for 1990, would then be estimated as :
(a) 175 cm (b) 176.6 cm
(c) 178.6 cm (d) 180 cm

Q.9 If absolutely no error is allowed in the measurement of mean rainfall in a catchment, the optimum number of raingauge stations required, would be :
(a) zero (b) infinite
(c) any value (d) none of these

Q.10 How many additional gauges are required in a catchment, if the error allowed in estimation of mean rainfall is to be reduced by half than the present one ?
(a) equal to its present number
(b) twice of its present number
(c) three times that of its present number
(d) four times that of its present number

Q.11 The highest raingauge density has been adopted in :
(a) India (b) USA
(c) U.K. (d) Israel

Q.12 A rainfall hyetograph is a graph between :
(a) simulative rainfall and time
(b) rainfall intensity and time
(c) rainfall depth and area
(d) rainfall intensity and cumulative rainfall

Q.13 Index of wetness (x) and rainfall deficiency (y) at a place, are related by the equation :
(a) $x = (100 - y)\%$
(b) $x = (100 + y)\%$
(c) $\frac{x}{y} = 100\%$
(d) None of the above

Q.14 The hydrologic happenings from the time a heavy rainfall occurs, and up to the time the movement of the fallen rain water is completed, is called :
(a) hydrologic cycle
(b) runoff cycle
(c) precipitation cycle
(d) all of the above

Q.15 The areal characteristics of a rain storm are represented by a:
(a) DAD curve
(b) Hyetograph
(c) Mass curve
(d) Double mass curve

Q.16 For a storm of a given duration, the average depth of rainfall over an area
(a) increases with the area
(b) decreases linearly with the area
(c) has no relation with the area
(d) decreases exponentially with the area

Q.17 Through DAD analysis, the maximum average depth of rainfall over 100 km^2 area caused by a 1 day storm is found to be 22 cm. For the same area, the maximum average depth caused by a 3-day storm, will be :
(a) more than 22 cm
(b) less than 22 cm
(c) equal to 22 cm
(d) more or less than 22 cm, depending upon the type of rainfall

Q.18 The DAD analysis for a catchment would indicate that :
(a) for a given area, the maximum average depth of rainfall increases with increase in storm duration
(b) for a given area, the maximum average depth of rainfall decreases with increases in storm duration
(c) for a given duration storm, the maximum average depth of rainfall increases with increases in the area
(d) the maximum average depth of rainfall has no relation with either the duration or the area

Q.19 Which type of snow pack will have maximum snow density?
(a) freshly falling snow on ground
(b) snow pack of the last 24 hours
(c) snow packed in glaciers
(d) none of the above

Q.20 In which of the following, the snow density would be minimum?
(a) fresh powder snow (b) virgin snow
(c) coarse snow (d) glacier snow

Q.21 A snow density of 0.1 may be considered for :
(a) fresh powder snow
(b) snow pack of the past 24 hours or so
(c) snow pack of the entire snow season
(d) snow packed in glaciers

Q.22 The portion of the rainfall which infiltrates into the ground, moves laterally, and joins the stream, is known as :
(a) ground water flow (b) sub-surface flow
(c) virgin flow (d) overland flow

Q.23 A raingauge should preferably be fixed
(a) near the building (b) under the tree
(c) in an open space (d) in a closed space

Q.24 Rate of evaporation from a water surface increases if
1. difference of vapour pressure between saturated air and actual prevailing increases

(a) mm, sec (b) cm, sec
(c) mm, hr (d) cm, hr

Q.58 **Statement (I):** Condensation of water vapour into droplets precedes the precipitation process.
Statement (II): Formation of precipitation droplets is predicted on the presence of condensation nuclei.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

Q.59 Hydrology is the science which deals with:
(a) surface water
(b) ground water
(c) surface as well as ground water
(d) flood water

Q.60 The average annual runoff in depth for the world is about:
(a) 17 cm (b) 32 cm
(c) 51 cm (d) 119 cm

Q.61 The National water policy (2002), of India, gives the top priority to:
(a) drinking water (b) hydro power
(c) irrigation water (d) None of the above

Q.62 All India forecasts of rainfall are prepared at :
(a) Bombay (b) New Delhi
(c) Calcutta (d) Pune

Q.63 The circulation of water from the earth's surface to the atmosphere, and vice versa, is called:
(a) hydrologic cycle
(b) runoff cycle
(c) precipitation cycle
(d) all of the above

Answers

1. (a)	2. (b)	3. (a)	4. (b)	5. (c)
6. (d)	7. (a)	8. (b)	9. (b)	10. (c)
11. (d)	12. (b)	13. (a)	14. (b)	15. (a)
16. (d)	17. (a)	18. (a)	19. (c)	20. (a)
21. (b)	22. (b)	23. (c)	24. (b)	25. (b)
26. (c)	27. (c)	28. (a)	29. (c)	30. (c)
31. (a)	32. (d)	33. (b)	34. (c)	35. (d)
36. (d)	37. (c)	38. (d)	39. (a)	40. (b)
41. (b)	42. (c)	43. (d)	44. (d)	45. (b)
46. (d)	47. (a)	48. (b)	49. (c)	50. (b)
51. (b)	52. (b)	53. (d)	54. (a)	55. (c)
56. (c)	57. (d)	58. (a)	59. (c)	60. (b)
61. (a)	62. (b)	63. (a)		

Conventional Practice Questions

Q.1 The normal annual precipitation of five raingauge stations, *P*, *Q*, *R*, *S* and T are respectively 125, 102, 76, 113 and 137 cm. During a particular storm the precipitation recorded by stations *P*, *Q*, *R* and *S* are 13.2, 9.2, 6.8 and 10.2 cm respectively. The instrument at station *T* was inoperative during that storm. Estimate the rainfall at station *T* during that storm.

Ans. [12.86 cm]

Q.2 For a drainage basin of 600 km^2, isohyetals drawn for a storm gave the following data:

Isohyetals (interval) (cm)	15-12	12-9	9-6	6-3	3-1
Inter-isohyetal area (km^2)	92	128	120	175	85

Estimate the average depth of precipitation over the catchment.

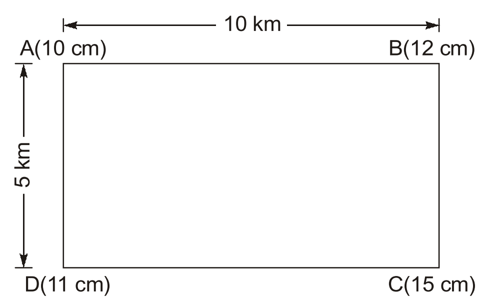
Ans. [7.41 cm]

Year	Annual Rainfall of Station A (mm)	Average Annual Rainfall of 8 Station Groups (mm)	Years	Annual Rainfall of Station A (mm)	Average Annual Rainfall of 8 Station Groups (mm)
1946	177	143	1957	158	164
1947	144	132	1958	145	155
1948	178	146	1959	132	143
1949	162	147	1960	95	115
1950	194	161	1961	148	135
1951	168	155	1962	142	163
1952	196	152	1963	140	135
1953	144	117	1964	130	143
1954	160	128	1965	137	130
1955	196	193	1966	130	146
1956	141	156	1967	163	161

(a) In what year is the change in regime indicated?
(b) Adjust the recorded data at station A and determine the mean annual precipitation.

Ans. [(a) 1955, (b) Correction ratio = 0.805, mean P_A = 143.9 cm]

Q.11 Explain the three different methods employed to determine the mean precipitation over a given area. Find the mean precipitation for a rectangular area given with precipitations marked in figure, by any two method.



Ans. [12 cm by arithmetic as well as the Thiessen's methods]

Q.12 The value of annual precipitations at a raingauge station expressed in cm per year in chronological sequence from 1967 to 1976 are indicated below:

70.2	31.7	68.8	50.9	60.3
58.7	43.9	50.3	48.7	67.5

Using Hazen's or any other suitable method, estimate the value of precipitation, which has a recurrence interval of 5 year.

Ans. [68.8 cm]

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