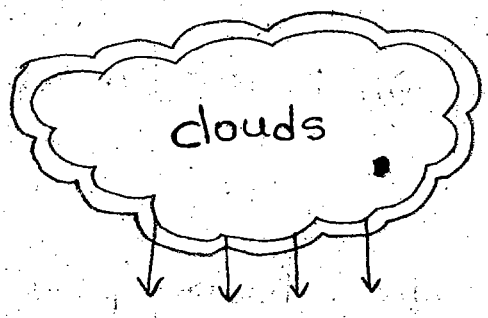
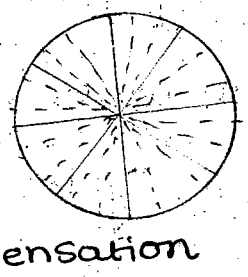
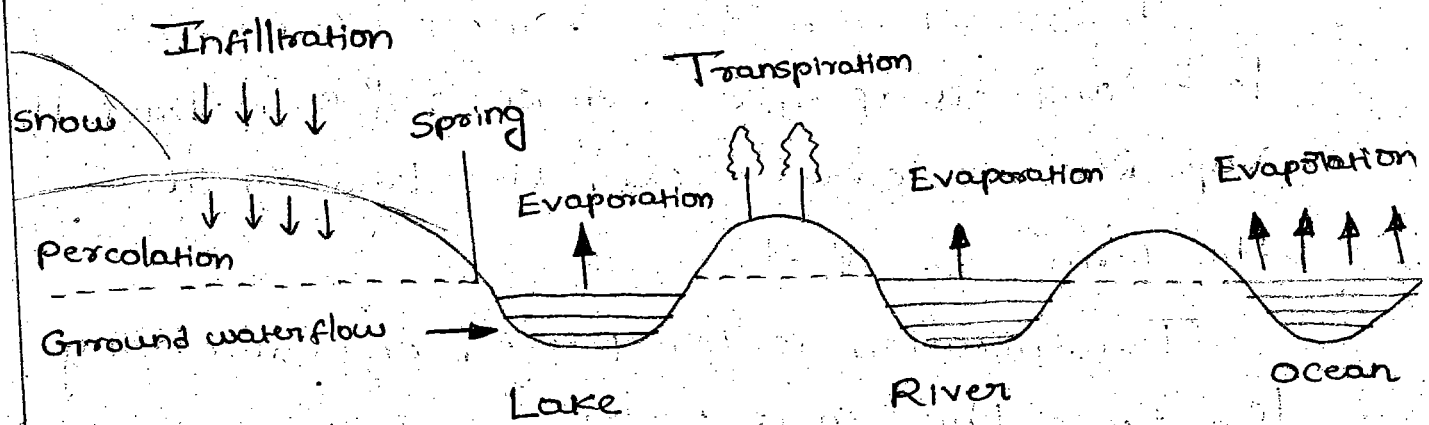
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UNIT - 1

Introduction







Hydrological cycle

Hydrology

Hydrology is the science which deals with the occurance distribution and movement of water on the earth including in the atmosphere and below the surface of the earth. Water occurs in the atmosphere in the form of vapour, on the surface as water, snow (or) ice and below the surface as ground water occuping all the voids within a geologic stratum.

* Hydrologic cycle:

Except for the deep groundwater the total water supply of the earth, is in constant circulation from earth to atmosphere and atmosphere to earth. This earth water circulatory system is known as "Hydrologic cycle."

* Hydrologic cycle consists of the following processes:

1. Evaporation and Transpiration.

The water from the surfaces of rivers, oceans, lakes and also from the moist soil evaporates. The vapours are carried over the land by air in the form of clouds.

Transpiration is the process of water being lost from the leaves of the plant from their poles. Thus the total evaporation from the inclusive of the transpiration consists of

(i) Surface Evaporation
(ii) Water surface evaporation
(a) From river surface.
(b) From oceans
(iii) Evaporation from plants and leaves (Transpiration)
(iv) Atmospheric evaporation

* Precipitation:

Percipitation may be defined as the fall of moisture from the atmosphere to the earths surface in any form precipitation may be in 2 forms.

1. Liquid precipitation i.e Rainfall
2. Frozen precipitation
   (i) Snow (iii) Sleet
   (ii) Hail (iv) Freezing Rain

* Run-Off

Run-off is the portion of precipitation i.e not evaporated. When moisture falls to the earth surface, as precipitation a part of it is evaporated from the water surface, soil, vegetation and through transpiration by plants and the remainder precipitation is available as run-off which ultimately runs to the ocean through surface (or) subsurface streams. The run-off may be classified as follows:

1. Surface run-off:

Water flows over the land and is first to reach the streams & Rivers, which ultimately discharge the water to the sea.

2. Subsurface run-off: A portion of precipitation infiltrates into the surface soil and depending upon the geology of the basins runs as subsurface run-off and reaches the streams & rivers.

3. Ground water flow (or) Base flow:

It is the portion of precipitation which after infiltration percolates down and joins the groundwater reservoir which is ultimately connected to the ocean

Thus the hydrologic cycle may be expressed by the following equations:

precipitation = evapotation + Run-off

$$P = E + R.$$

* Hydrological data:

In the hydrological data the main component of the hydrological cycle are::

1. Precipitation
2. Evaporation
3. Run-off

Apart from information about the above components, information about climate, metariology and geology is also required. Following hydrological data are required.

1. Weather & climate records:

Data about temperature, humidity, radiation, wind etc.., since these are directly effect hydrological parameters.

2. Precipitation data:

These data helps in predicting run-off volume and its peak. It is also helpful in extimating the water budget equation for the basin.

3. Stream flow data:

These data helps in the planning of reservoir design of spillways, bridges, culverts and water power development. This data is also utilized for determination of floods, flood magnitude, flood frequency and water budget etc....

4. Evaporation and Transpiration data:

These data help for water budget for the river basin and reservoir capacity for water resource development.

5. Infiltration data:

This data helps in determining excess rainfall effect and run-off computation.

6. Groundwater characteristics:

This data helps in estimation & location of groundwater reservoir and for groundwater development.

7. Physical & Geological data:

This data helps in the determination of run-off pattern silt loam movement 'Central water communication (CWC) mentions the stream flow data for major rivers.

Water Budget:

(i) Global water budget: The total quantity of water in the world is 136 million cubic kilometer out of which about 97.2% is held up in seas & oceans and while about 2.1% is frozen in ice caps and about 0.31% is available as deep ground water. Thus about 99.6% of total water is of no use to men.

(ii) India Water Budget:

India has a geographical area of nearly 3.3 million sq.cm normal annual rainfall varies from 100mm in western rajastan to over 11000mm at Chirapunji in Meghalaya. In annual average rainfall over the country is of the order of 1170mm depth which is nearly 4000 km^3.

Precipitation

Types: There are 4 types of precipitation

1. Cyclonic precipitation
2. Convecting
3. Orographic
4. Precipitation due to turbulent ascent.

Cyclonic precipitation: (CP)

CP results from lifting of air mass converging into low pressure area of cyclone. This may be divided into (a) Frontal (b) Non-Frontal.

(a) Frontal precipitation:

A boarder region to adjacent air masses having different characteristics such as temperature & humidity is called a "Front." When a flow of warm and moist air mass from the south meets cold air mass of polar region the cold air being heavier under run the warm air flow in the form of flat wedge. forcing the warm, air aloft. The lifted warm air mass cools down and higher attitudes and causing precipitation.

(b) Non-Frontal precipitation:

In the case NFP the moist warm air mass is stationary and the moving cold air mass meets it.

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Thus due to the warm air there is passive absence of warm air over cold air owing to the active undercutting. When the lifted warm air cools down at higher altitude precipitation occurs.

2. Convective Precipitation:

This is caused by natural rising of warmer lighter air in colder, denser surroundings, the difference in temperature may result from unequal heating at the surface, unequal cooling at the top of the air layer (or) mechanical lifting when air is forced to pass over a denser colder air mass.

3. Orographic precipitation:

This is due to the lifting of warm moisture ladent air masses due to topographic barriers such as mountains. As it reaches higher elevation it comes in contact with cold air and precipitation occurs the zone to the other side of the mountain will be the zone of rain shadow area where, the rainfall may not occur.

Hail: Hail is lumps of ice over 5mmϕ formed by alternate freezing (or) melting as they are carried up & down in highly turbulent air currents.

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4. Precipitation due to turbulent ascent:

Air mass is forced to rise up due to greater friction of earth surface after its travel over ocean. The air mass rises up because of increased turbulance and friction when it Ultimately condenses and precipitation occurs.

* Forms Of precipitation:

The various forms of precipitation are

Drizzle: When the size of water droplet is under 0.5mm & its intensity is less 1mm/hr because of the lightness the droplets appeared to be floating in air.

Rain: When the size of droplets is morethan 0.5mm. The max. size of water drop is generally 6.25mm as drops greater than there tend to breakup they call through the air.

Glaze: When the drizzle (or) rain freezes as it comes it contact with cold objects it is known glaze.

Sleet: It is frozen raindrops cools to the ice stage while falling through air at subfreezing temperature.

Snow: precipitation in the form of ice-crystals

Snowflakes: No. of ice crystals feesed together forms snowflake.

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29/11/18.

*Rainfall in India:

The major rainfall season in India is June to October India lies in the tropical belt and has the four distinct weather periods.

1. Monsoon Period [June to october]
2. Coast monsoon period [october to November]
3. Winter rainfall period [December to February]
4. summer rainfall period [March to May]

* Measurement of Rainfall:

The amount of precipitation is expressed as the depth in cm (or) inches which falls on a levelsurface and is measured by rain gauge. The following are the main types of raingauge.

1. Non-automatic Raingauge:

This is also known as non recording raingauge. Symon's Raingauge instrument prescribed by used at all Govt. raingauge stations throughout India.

2. Automatic Raingauge:

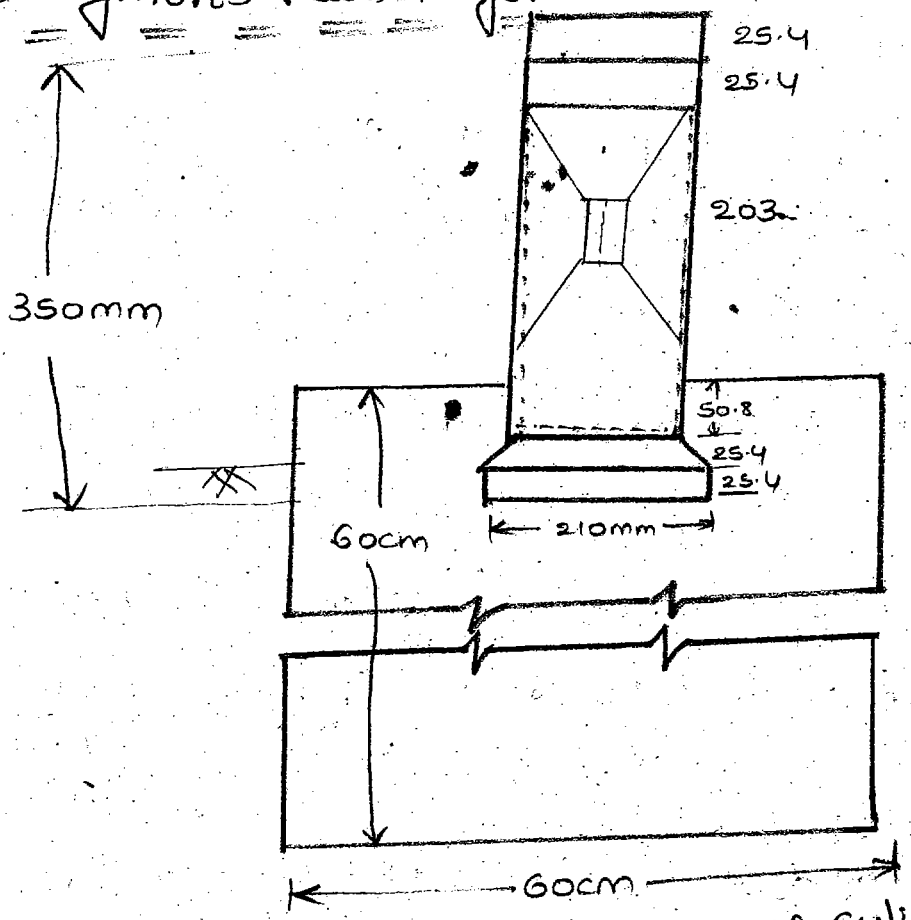
There are 3 types

(i) Weighing bucket raingauge

(ii) Tipping bucket raingauge

(iii) Float type raingauge

(i) Symon's Rain Gauge:



Symson's raingauge consits of cylindrical vessel 127mm India with a base enlarged to 210mm diameter. The top section is a funnel provided with circular brass rim exactly 127mm in internal diameter. The funnel shank is inserted in the neck of a receiving bottle which is 75 to 100mm diameter. A receiving bottle of raingauge has a capacity of about 75 to 100mm of rainfall and as during in heavy rainfall this quantity is frequently exceeded, the rain should be measured in a 3 (or) 4 times in a day on day of heavy rainfall. The receiver fill should overflow. A cylindrical graduated measuring glass is furnished with each instrument which reads to 0.2mm. The rainfall should be estimated to nearest 0.1mm.

The raingauge is setup in a concrete block 60cmx60cmx60c

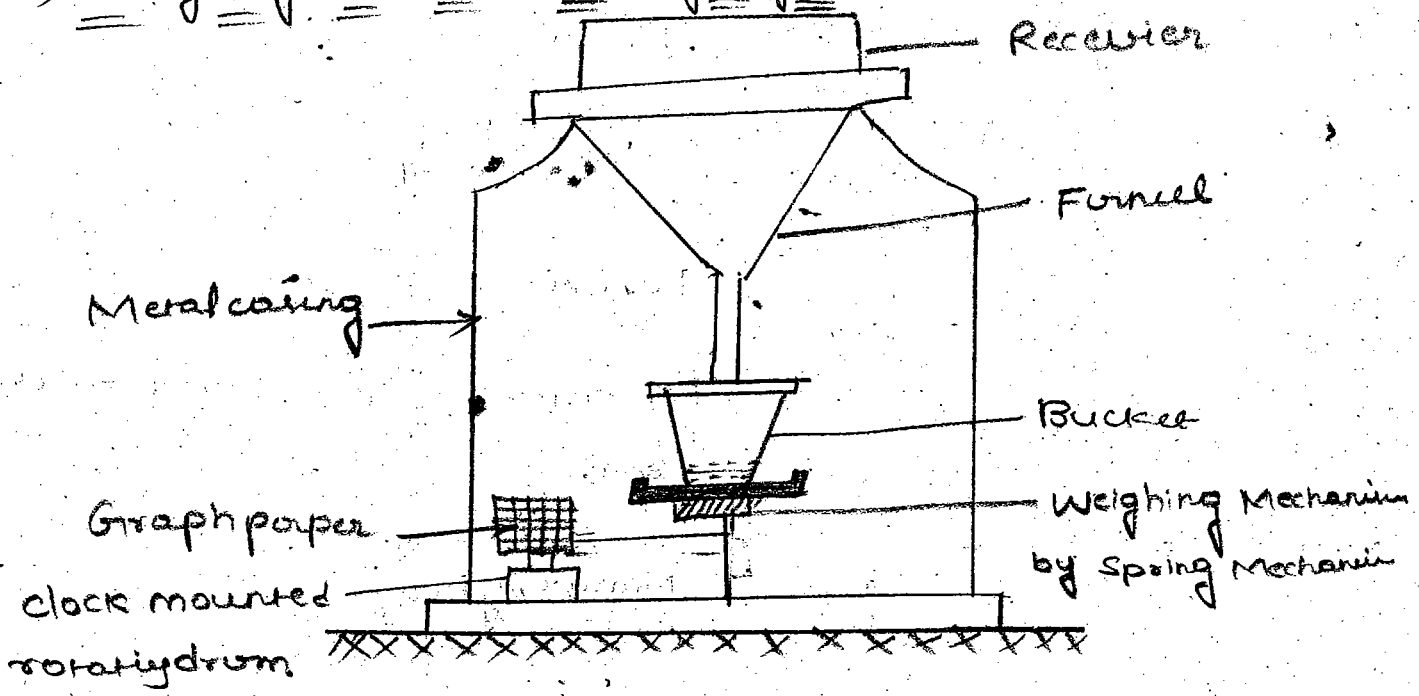
The following important points should be kept in mind while selecting site for a raingauge station. [common for all type of RG]

- The site where a Raingauge is setup should be an openplace
- The distance b|w the raingauge and the nearest object should atleast twice the height of the object.

In no case should it be nearer to the obstruction than 30m.

- The raingauge should never be situated on the site (or) top of a hill if a suitable site on a level ground can be found.
- In the hills where it is difficult to find levelspace, this site for the gauge should be choosen where it is best sheaded from high winds and where the wind does not cause eddy's.
- A fence if errected to protect the cage from cattle etc.... It should be located that distance of the fence is not lessthan twice it's height.

2) Weighing bucket raingauge:



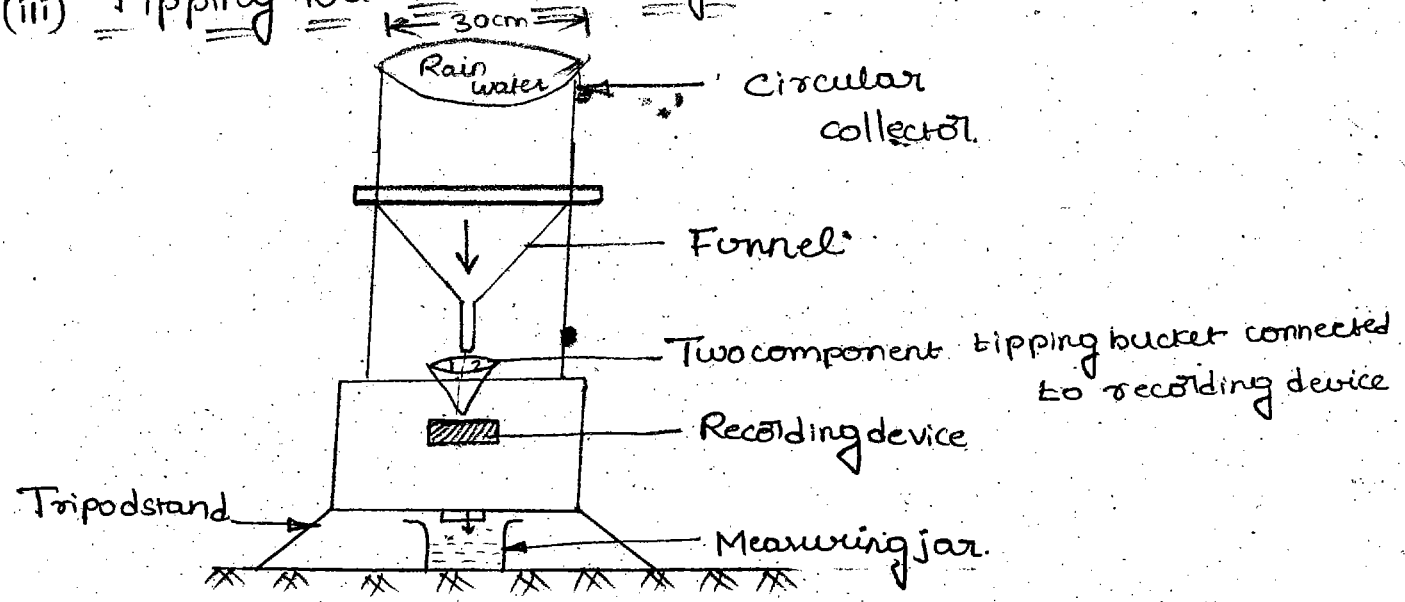
Weighing bucket rain gauge

Self recording gauges are used to determine rates of rainfall over short periods of time. The most common type of self recording gauge is the weighing bucket type.

This raingauge essentially consists of a receiver bucket supported by a string (or) lever balance (or) any other weighing mechanism the movement of the bucket due to increasing weight is transmitted to a pen which traces the record on a clock driven chart.

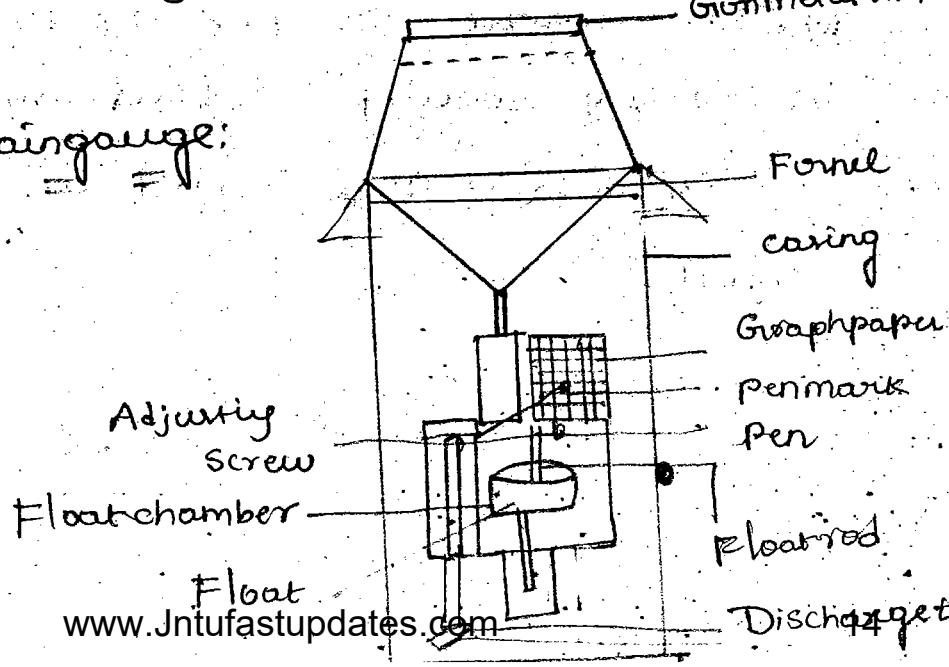
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(iii) Tipping Bucket Rain Gauge:



A stevens tipping bucket type raingauge consist of 300mm diameter sharp edge, receiver, 1 at the end of the receiver is provided in funnel. A pair of buckets are pivoted under the funnel in such a way one bucket receives 0.25mm of precipitation it tips, discharging its contains into a container bringing the other bucket under the funnel. Tipping of the bucket complets an electric circuit causing the movement of pen to mark on clock driven revolving drum which carries a record sheet.

* Float Type Raingauge:



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The working of a float type raingauge is similar to the weighing bucket type raingauge. A funnel receives the rainwater which is collected in a rectangular container. A float is provided at the bottom of the container the float is rised as waterlevel rises in the container, its movement being regarded been recorded by pen moving on a recoldigdrom actuated by a clock work.

* Advantages Of Recording time over Non-Recording type Raingauges.

Advantage

→ continous record of rainfall.
→ Intensity of rainfall can be measured
→ Installed in Remote areas
→ Eliminations of manual errors

Disadvantage

→ There may costly
→ Mechanical & electrical errors may occurs sometimes.

05/12/18.

* Raingauge Network:

It is defined as the ratio of total area of catchement to the total no. of gauges in the catchement

Area (km^2)	No. of gauges
0-80	1
80-160	2
160-320	3
320-560	4
560-800	5
800-1200	6

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* Optimum no. of Raingauges:

By using of statical method.

$$N = \left[\frac{C_v}{P}\right]^2 \qquad P = \text{percentage of error.}$$

N = no. of gauges

C_v = coefficent of variance

$$C_v = \frac{100\sigma}{\bar{P}} \qquad \bar{P} = \frac{\Sigma P}{n}$$

$$\sigma = \sqrt{\frac{n}{(n-1)}\left[\bar{P}^2 - [\bar{P}]^2\right]}$$

* Four raingauge stations are located in catchement area whose average precipitations are 100cm, 120cm, 150cm & 135cm Determine optimum no. of raingauges required in that catchement area are if allowable % is 8. How many no. of additional gauges are required.

Sol: Total no. of readings $n = 4$.

$$\bar{P} = \frac{\Sigma P}{n}$$

$$= \frac{100+120+150+135}{4}$$

$$= 126.25.$$

$$(\bar{P})^2 = 15939.06.$$

$$\bar{P}^2 = \frac{\Sigma P^2}{n} = \left[\frac{100^2+120^2+150^2+135^2}{4}\right] = 16281.25$$

$$\bar{P}^2 = 16281.25.$$

$$\sigma = \sqrt{\frac{n}{n-1}\left[\bar{P}^2 - [\bar{P}]^2\right]}$$

$$= \sqrt{\frac{4}{4-1}\left[16281.25 - 159.39.06\right]}$$

$$= \sqrt{456.25} = 21.36.$$

$$Cv = \frac{100\sigma}{\bar{P}} = \frac{100 \times 21.36}{126.25} = 16.91.$$

$$N = \left(\frac{16.91}{8}\right)^2 = 4.467 \sim 5 \text{ No's.}$$

Five number of additional raingauges are required.

* The rainfall readings at 4 raingauge stations are located in river catchement of 800, 620, 400 & 540mm respectively. Determine optimum no. of. rain gauges in catchement if it is design to measurement of mean rainfall in the catchement upto 10%. Howmany more no. of. raingauges are to be required.

Sol: Total no. of. readings $n = 4$

$$\bar{P} = \frac{\Sigma P}{n} = \frac{800+620+400+540}{4} = \frac{2360}{4}$$

$$\bar{P} = 590$$

$$(\bar{P})^2 = 348100$$

$$\bar{P}^2 = \frac{\Sigma P^2}{n} = \frac{[800^2+620^2+400^2+540^2]}{4} = 3,69,000$$

$$\bar{P}^2 = 3,69,000$$

$$\sigma = \sqrt{\frac{n}{n-1}\left[\bar{P}^2 - (\bar{P})^2\right]}$$

$$= \sqrt{\frac{4}{4-1} \times \left[3,69,000 - 3,48,100\right]}$$

$$= 166.933.$$

$$C_v = \frac{100\sigma}{\bar{P}} = \frac{166.933 \times 100}{590} = 28.29$$

$$N = \left[\frac{28.29}{10}\right]^2 = 8.00$$

Eight number of additional raingauges are required

06/12/18.

* Missing Data Interpretation of Rainfall

The interpretation of missing rainfall data is estimated by using two methods

1. Arthematic average method.

collecting the average rainfall values at 3 different locations near to place where data is missing

- Average annual rainfalls can be obtained from old records.

$$P_x = \frac{P_1 + P_2 + P_3 + \cdots \cdots P_n}{N}$$

This method is adopted only corresponding change b/w any two locations rainfall record is < 10%.

Normal Ratio Method:

If the corresponding change b/w any two locations rainfall record is morethan 10%, the normal ratio method is to be adopted.

$$P_X = \frac{N_X}{N}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_3}{N_3} + \ldots\ldots + \frac{P_n}{N_n}\right]$$

* Precipitation station X was inoperative for a part of month in which a storm occur the respective storms totals at the 3 surroding stations a, b & c 107, 89, 122mm. The normal average precipitation X, a, b & c are respectively 978, 1120, 935 and 1200mm. Estimate the strom precipitation at station X.

Sol: Normal annual Rainfall $N_X = 978$

$N_X + 10\%$ of $N_X = 978 + 97.8 = 1075.8$.

$$P_X = \frac{N_X}{N}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_3}{N_3}\right]$$

$$= \frac{978}{3}\left[\frac{107}{1120} + \frac{89}{935} + \frac{122}{1200}\right]$$

$$= 95.31 \text{ mm}$$

* Presentation of rainfall data:

The data set by different types of gauges are plotted by some methods

And parameters some required for the analysis are 1. Intensity 2. Duration and 3. Frequence

* Intensity:

The rate at which the rain is falling

* Duration:

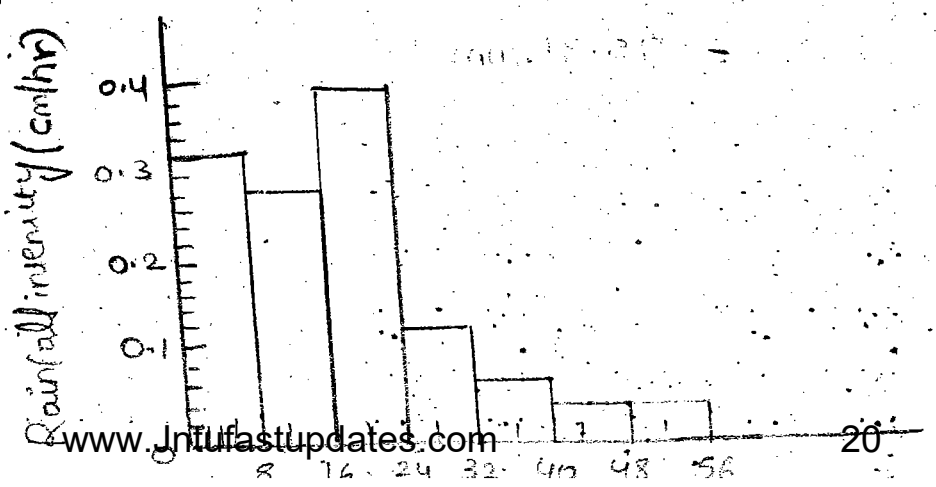
The time for which it is falling with a given intensity

* Frequency

How many times does it occur

Hyetograph / Hydro graph.

A Hyetograph is plot of the intensity of the rainfall aganist the time interval and is represented as a bar chart is known as a "Hydrograph."

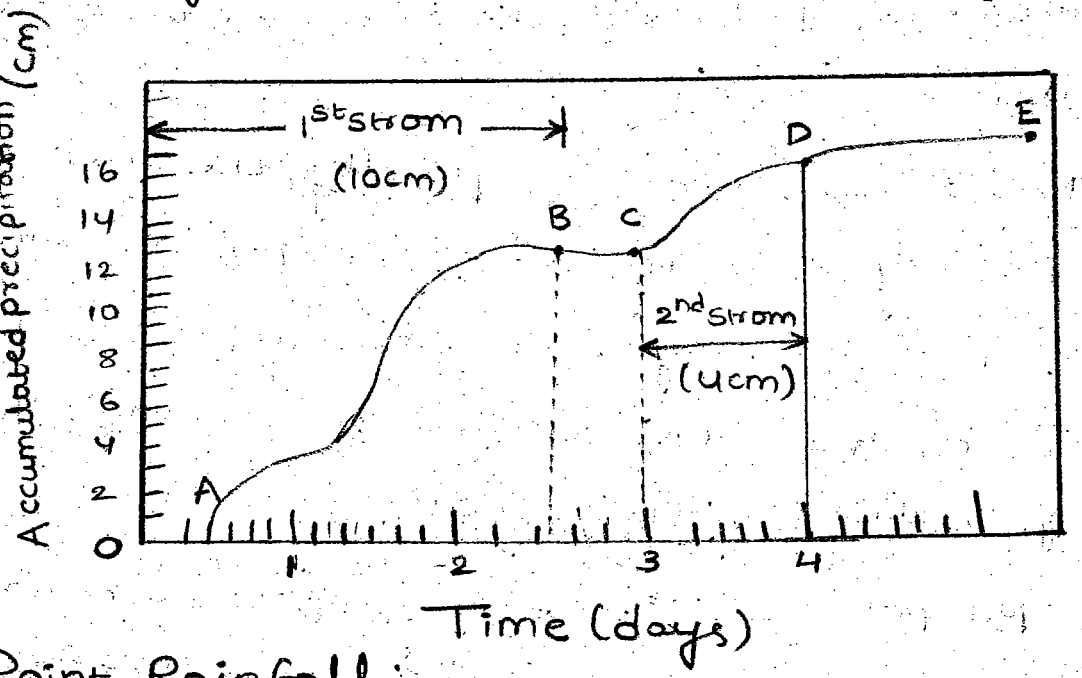


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* Mass Curve of Rainfall

The mass curve of Rainfall is plot after the accumulated precipitation aganist the time in cromological order. Mass curve of rainfall are very useful in (estab) extarting information on the duration and magnitude of the strom

- The graph is obtained from a recording type raingauge and it is always a rising curve.



* Point Rainfall:

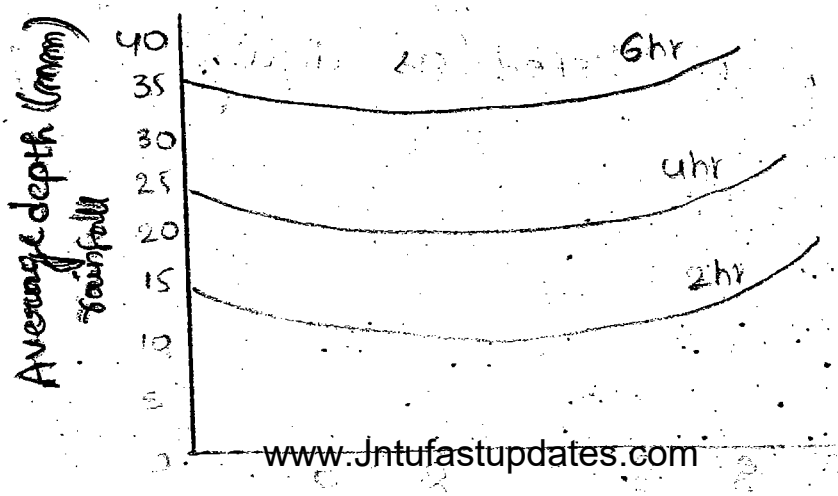
The rainfall during a given time interval measured in a rain gauge the amount which might have been measured at given point. The can be listed as daily, weekly etc.....

07/12/18.

Depth Area Duration (DAD) and curve relationship

The rainfall rarely occurs uniformly over the whole area of the catchment.

- A Raingauge station gives the point rainfall which donot actually represent the rainfall in that area.
- To findout how much of rainfall will occur in an area converting the point rainfall data to aricel rainfall data, depth area duration curve used
- A DAD curve expres graphically the relation b/w progressivley decreasing average depth of rainfall over a progressively increasing area from the centre of the strom outward to its edges for a given duration of rainfall
- The purpose of DAD analysis of a particular strom is to determine the largest average depth of rainfall that fall over various sizes of area during the standard passage of time.



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- To make the DAD curve the following steps are to be taken.

1) From the rainfall data prepare the isohyets
2) Plot the catchement area on paper with the help of planimeter. find the area b/w the isohytes.
3) The volume of rainfall is calculated b/w the isohytes by taking average of isohytes multiplied with the area b/w the isohytes.
4) Calculate volume of rainfall of all area b/w the isohyets.
5) Calculate the cumulative volume and cumulative area
6) This cumulative volume is divided by cumulative area and average depth of rainfall over the area for that strom is foundout
7) Same procedure is applied for other strom also.
8) The graph b/w average depth and cumulative area is plotted i.e is called

Depth area Duration curve for that strom.

Isohyets.

= A line (or) on a map which is connecting the points having the same amount of rainfall in a given duration is called "Isohytes".

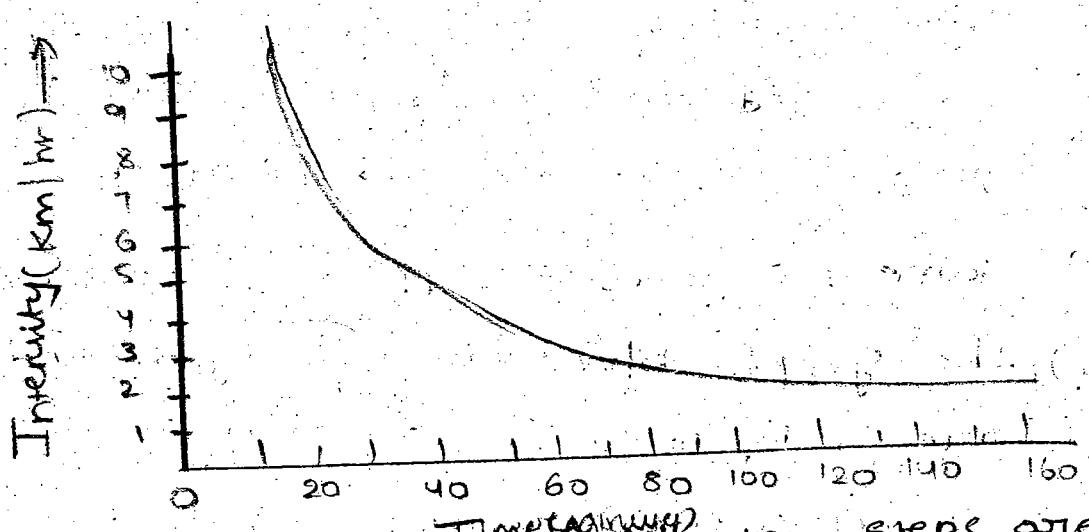
3/12/18.

Intensity Duration Frequency curves (IDF) & Relationships:

For the design of any hydraulic structure we should know about the peak flood what will be it's frequency So this can be easily computed from intensity duration frequency curve. It is a plot b/w average rainfall intensity and that duration.

- It has generally been observed that greater the intensity of rainfall, shorter is the length of time it continous. As the duration of storm increases the max. intensity of storm decreas

$$\text{Intensity} = \frac{\text{Rainfall depth}}{\text{Duration.}}$$



* For plotting the curve the following steps are to be taken

(i) Arrange the data in descending order of magnitude of all time interval which has to be taken

(ii) For finding the intensity of particular frequency the precipitation which is given for particular time period.

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10/12/18.

* Consistency of rainfall data at a gauge station:

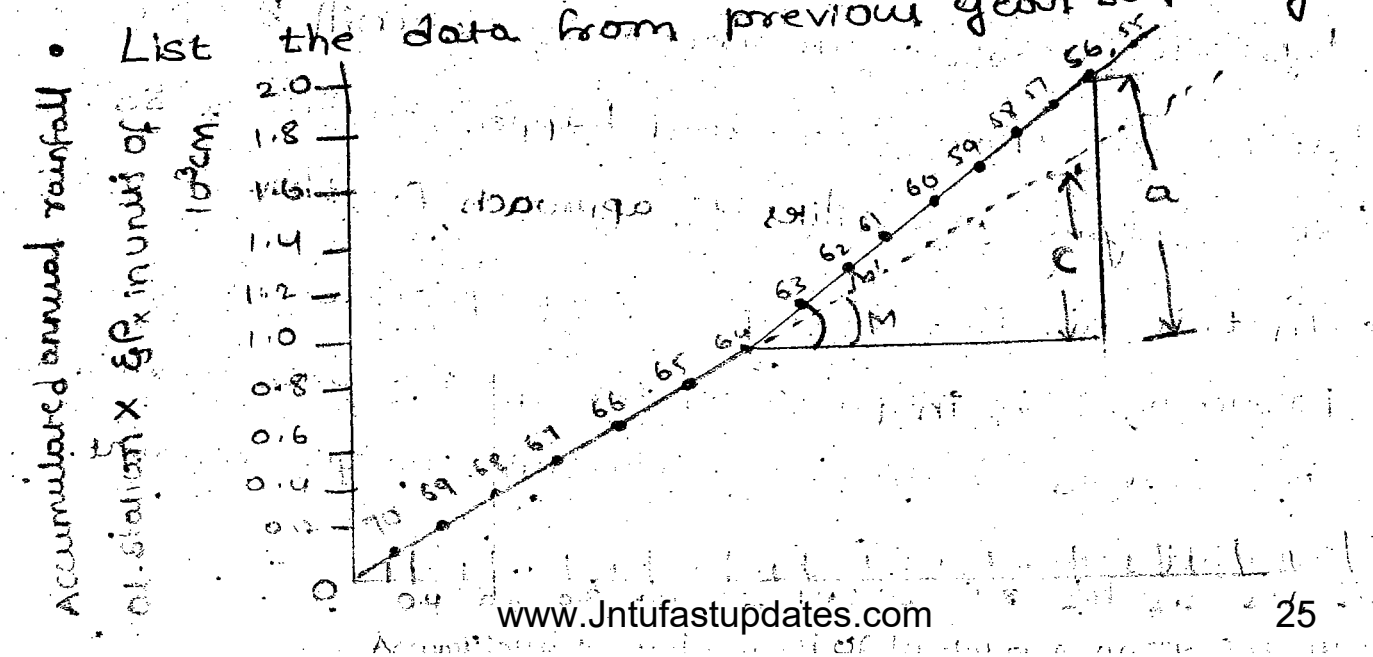
- Reasons for consistency:

If the change of station of gauge is unreported to IMD (Indian Metrological Department)

- Increased in built up area
- Change in environment around gauge station due to natural climates.
- Some extend due to manual errors.

* Elemination of Inconsistency by using of DMC Techque (Double Mass curve)

- Select 8 to 6 gauge stations around the station where the station found is with inconsistant data.
- Collect and analyse the rainfall data of those selected 6 stations from a period of past 35 years. Calculate average rainfall for every year.
- Collect the data of inconsitent station for past 35 years
- Compare the rainfall data of inconsitent station with average rainfall of near by stations.
- List the data from previous year to past years



* Calculate cumulative rainfall of 6 stations (Aveg. rainfall and also at station X).

* The graph plotted b/w cumulative rainfall would be a straight line for consistent data. If there is a change in linear curve data found inconsistent.

* If inconsistent period is greater than 5 years previous data is to be collected with that of "U"

Corrected rainfall, $P' = P \times \frac{M'}{M}$

M' – Now slope

M – Old slope.

11/12/18. Frequency of Point Rainfall:

- When we design hydraulic structures we design for a particular hydraulic structure also and design for a particular lifespan. If the flow value dosent exceed from the design value in b/w the design life of hydraulic structure than our structure will be fine.
- As we not know what will happen in future so we applying probabilites to approach for this.
- In this we find the probability of occurance of particular strom in particular time period such information is obtained from the frequency analysis of point rainfall data.

- In this method the following steps are to be taken

1) Arrarage all the rainfall data in pronological order constituing a time series.

2. Arrange the series in desending order of magnitude of rainfall and provide a number to each position. The position - 1 is given to largest magnitude rainfall and N is given to least magnitude of rainfall.

3. Now the probability of the rainfall can be find from following formula.

(i) Weibull's formula $= P = \frac{m}{N+1}$

(ii) Hazeen formula $P = \frac{m - 0.5}{N}$

(iii) California formula $P = \frac{m}{N}$

Here N = Total no.of years / Total no.of.record.

m = Position of that rainfall.

* Probable Maximum Precipitation (PMP):

The probable Maximum Precipitation (PMP) is the max. possible precipitation that can reasonably be expected at a given location.

- PMP is defined as the greatest (or) extreme rainfall for a given duration i.e physically possible over a station (or) Basin.
- PMP can be statically estimated as

$$PMP = \bar{P} + K\sigma$$

σ = standard deviation.

K = Frequency factor which depends upon the statical distribution

Here $\bar{P}$ = Mean of annual rainfall series

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- In the design of hydraulic structures the study of PMP is very much important.

* World's Greatest Observed Rainfall Data:

A list of world greatest rainfall is made with the available data and plotted on logarithmic scale The data seems to be in line can be used for other data also.

$$P_m = 42.16\, D^{0.475}$$

Where P_m = extreme rainfall depth in cm

D = Duration in hours.

* Index of Wetness:

The ratio of the actual rainfall in a particular year at a given place to the average annual rainfall of the place is known as "Index of wetness."

$$\text{Index of wetness} = \frac{\text{actual rainfall in a given year at a given place}}{\text{Average annual rainfall of that place}} \times 100$$