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HYDROLOGY

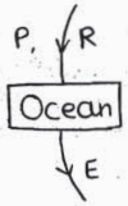
- Hydrology is the science of water which deals with occurence, circulation & distribution of water on earth surface & its atmosphere.

⇒ Hydrologic Cycle :- it is the cyclic movement of water in which water moves from one phase to the other having different residence time in each phase. This is achieved by the process of precipitation, evaporatio, runoff etc.

- Residence time :- this is the avg. time taken by a water particle in crossing one particular phase of the hydrologic cycle.

$$\left[t_r = \frac{V}{Q_{avg}} \right]$$

Note :-



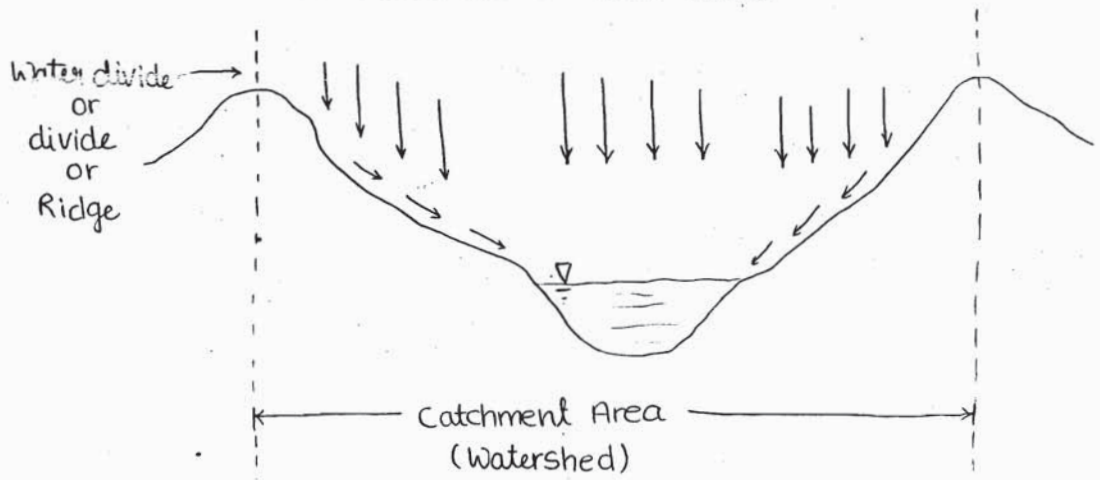
over the ocean surface evaporation is greater than precipitation (approx. 9%) whereas on the land mass Precipitation is greater than evaporation.

$(P+R = E \Rightarrow E > P)$

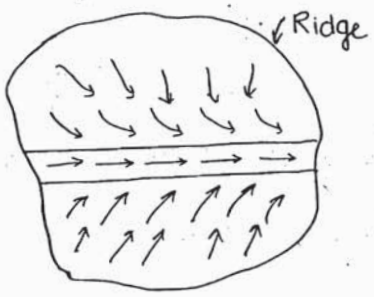
$P = E+R+T \Rightarrow (P > E)$

- Sun is the source of energy which derives the hydrologic cycle.

⇒ Catchment Area :- Area draining into a river or stream is called as catchment area of that particular river / stream at a given location. It is also called as a water shed.



• Ridge:- it is the line which differentiate or demarkets two adjacent catchment areas. It is also called as water divide or divide. In British English - it is also called as watershed.



Plan view.

⇒ Water- budget Equation - this equation is based on law on conservation of mass & it states that:- mass inflow = mass outflow = change in storage.

Q-20) Pg-83)

Inflow = $6\ m^3/s + 145mm$

$$= \frac{6 \times 30 \times 24 \times 60 \times 60}{5000 \times 10^4} + 0.145 = 0.456$$

Outflow = $6.5 m^3/s + 6.1cm$

$$= \frac{6.5 \times 30 \times 24 \times 60 \times 60}{5000 \times 10^4} + 0.061 = 0.397$$

Final elevation = $103.2 + 0.456 - 0.397$

$= 103.258$ m.

⇒ World water balance -

1386 M km^3

~ 1400 M km^3

- → 96.5%:- Ocean - Saline } 97.5%
- → 1%:- Land - Saline }

Fresh water (2.5%) - 35 M km^3

- 10.6 M km^3 (liquid)
- 24.4 M km^3 (Frozen)

Note:- About 3/4 of the earth surface (approx. 71%) is covered with water.

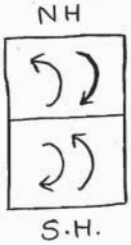
Precipitation

-it denote the different processes & ways by which water reaches the earth surface from the atmosphere. Following are the different type of precipitation -

1) Rain / Rainfall :- This is the most important type of ppt in India & it denotes water droplets with varying from 0.5mm to 6mm. On the basis of intensity, rainfall is classified as follows -

Rainfall intensity (mm/hr)	
0 - 2.5	- Light rain
2.5 - 7.5	- Medium/ Moderate rain
>7.5	- heavy rain.

-direction of wind in cyclone -

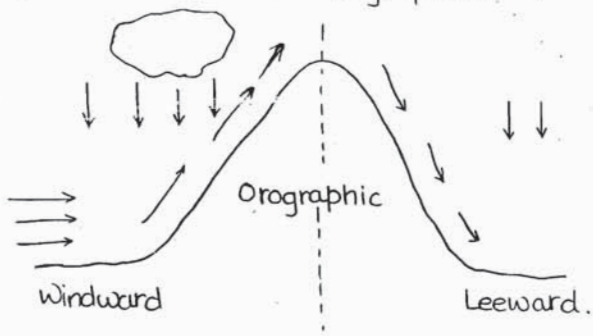


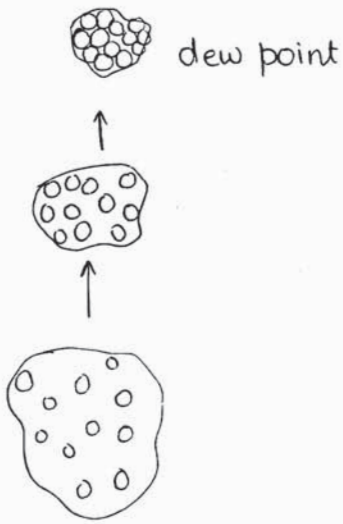
Cyclone (Low pressure or depression)

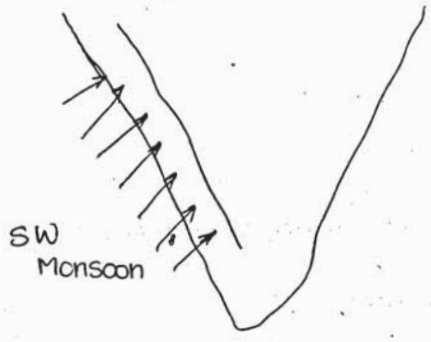
Anti cyclone.

-In India, Rainfall data is collected everyday at 8:30 AM & if rainfall on a particular day is more than 2.5mm then that day is called as a rainy day.

- In India Max. rainfall is orographic. -







- it hits the kerala around 1st week of June.

⇒ Rain water harvesting - read from theory book.

2) Snow :- these are ice crystals having a density of 0.1 gm/cm^3.

3) Drizzle :- these are fine droplets of water whose size is less than 0.5mm & intensity is less than 1 mm/hour.

) Glaze - When droplets of water comes in contact with cold ground surface then the droplet is converted into ice, which is called as glaze

) Sleet - these are frozen rain drops of transparent nature.

) hail :- these are lumps of ice whose size is more than 8mm.

WMO - as per international convention lumps of ice greater than 5mm is called as hail whereas lump smaller than 5mm is called as Graupel.

Note :- Dew is not a type of precipitation.

⇒ Average annual rainfall :- the amount of rain collected by a rain gauge in last 24 hour, is called as daily rainfall & the amount collected in 1 year is called as annual rainfall. Avg. value of this annual rainfall for a period of last 35 years (or any other suitable time interval) is called as avg. annual rainfall. Its value is approx 120 cm in India.

- LPA (long Period Average) - this is the avg. value of rainfall which is happening in monsoon/rainy season and is calculated on the basis of 50 year record (1951-2000). This value approx. comes out to be 89 cm.

- Index of Wetness :- this is used to find variation & deviation of rainfall & is given as follows -

$$\text{Index of Wetness} = \frac{\text{Rainfall in a year}}{\text{Avg. Annual rainfall}} \times 100$$

Ex:- Rainfall = 90cm

$$IOW = \frac{90}{120} \times 100 = 75\%$$

deficiency = 25%

- on the basis of rainfall deficiency, region is classified as follows -

Rainfall deficiency -

30-45	:- Large
45-60	:- Serious
>60	:- disastrous.

- on the basis of index of wetness, a particular year is classified as follows.

IOW (%)

100 %	- Normal year
> 100%	- Good year
< 100%	- Bad year

Note:- Occurence of flood & drought (which are region specific phenomenon cannot be directly co-related with IOW.

- Drought :- This is the climatic situation characterised by deficiency of water. drought can be furthur classified as follows -

i) Meteorological drought - this type of drought is characterised by deficiency of rainfall. If rainfall deficiency >25% it is called as drought. 25-50% - Moderate drought, >50% severe drought

If more than 20% of the area of a country is under the influence of drought then that particular year is called as a drought year.

if Draught occurs in an area with a Prob. b/w 0.2-0.4%, then that area is called as drought prone area.

If this Prob. is greater than 0.4 then the area is called as chronically drought prone area.

Note:- About 33% of India's area comes under the category of either drought prone or chronically drought prone area.

ii) Hydrological drought - this type of drought is characterised by below avg. value of stream flow, water content in lakes, reservoir, underground water etc.

ii) Agricultural drought :- this type of drought is characterized by deficiency of water which is required in order to meet the evapo-transpiration needs of the crop. It is denoted by a factor called as aridity index, which is given as-

$$\left[\text{Aridity index} \downarrow \text{dry} = \frac{PET - AET}{PET} \times 100\right]$$

$\frac{AET}{PET} = ?$

a) ≤ 1
b) $[0,1)$
c) $[0,1]$ ✓ (both values included)
d) $(0,1]$

- PET is Potential evapo-transpiration & is the water required by plants for its full growth.
- AET is actual evapo-transpiration & is the actual water which is available & consumed by Plants.

- On the basis of aridity index, region is classified as follows -

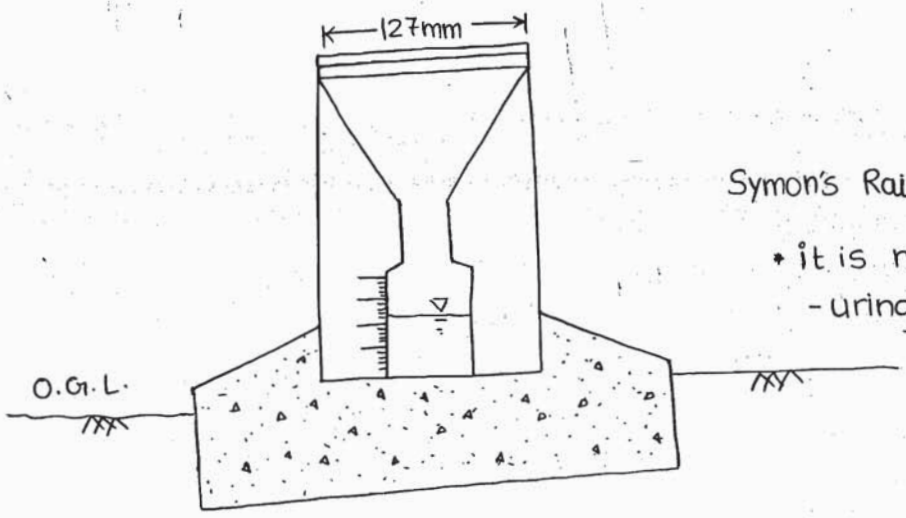
0-25% - Mild
25-50% - Moderate
>50% - Severe.

Note - Apart from aridity index, certain other indices such as - moisture availability index & Palmer index can also be used for finding agricultural drought.

⇒ Measurement of rainfall :- Rainfall can be measured by an instrument called as rain gauge, which is also known as Pluviometer, Ombrometer hyetometer, Udometer. Rainfall is expressed in terms of depth to which water would stand on an area if all the rain water was collected on it. (4)

Rain-gauges can be broadly classified under two heads-

i) Non-recording rain gauge :- this type of rain gauge consist of a cyllindrical vessel assembly whose base area is known & which is having graduations. In India, the most commonly used non-recording rain gauge is symon's rain gauge which has a collecting diameter of 127 mm.

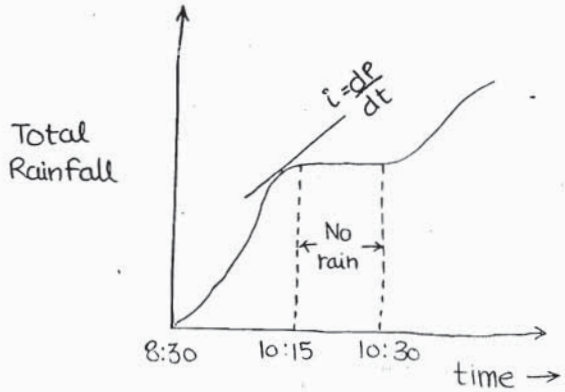


Symon's Raingauge

* it is non-recording, measuring rain fall gauge

- later on IMD switched over to the use of fiberglass reinforced Polyster type rain gauge, which comes in two variants having a collecting area of 100 cm^2 & 200 cm^2.

ii) Recording Raingauge :- This type of raingauge produces a continuous variation of rainfall with time. Using this data, rainfall intensity & rain fall intensity V/S time graph can also be obtained.



Mass Curve

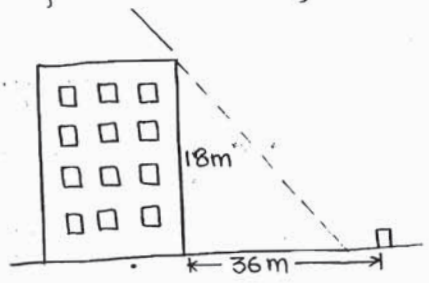
↓

Total, Cumulative, Accumulative

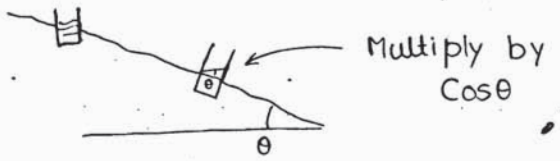
- Typical example of this type of raingauge includes - tipping bucket raingauge, weighing bucket raingauge, natural Syphon (float type) raingauge.
- In India, the most commonly used recording raingauge is natural Syphon type raingauge
- diagram from theory book.
- Recent advancement in raingauge technology has led to the development of following rain-gauges.
  - Telemetering raingauge - it is basically a recording type rain gauge which contains electronic equipment so as to transfer rainfall data to the base station. As such it can be used for remote & inaccessible locations. Its working is similar to tipping bucket raingauge.
  - RADAR based raingauge - Rainfall over a large area can be accurately measure with this type of raingauge. Meteorological RADAR operate at a wavelength range of (3-10cm) (5cm-10cm) for heavy rainfall 10cm wavelength is used whereas for light rain and snow 3cm wavelength is used.
- Prior to installation of a rain gauge, following requirements must be satisfied.

a) Raingauge must be surrounded by open fenced area of at least 5.5m x 5.5m.

b) Raingauge must be installed at a distance of at least 30m or twice the height of building or obstruction.



c) Raingauge must be installed on level ground surface which is free from undulations.



⇒ Network density :- in order to get correct value of rainfall, a proper distribution of rain gauge station is required, whose network density depends upon the following factors.

i) Magnitude of rainfall :-

ii) Topography of the region

iii) desired level of accuracy

- following are the recommendations of WMO regarding network density of rain gauges -

i) for flat regions of temperate, tropical & mediterranean zone - 1 Station / 600-900 km^2.

ii) for mountaneous regions of temperate, tropical & mediterranean zone - 1 Station / 100-250 km^2.

iii) for arid & polar regions - 1 Station / 1500-10000 km^2.

- IS recommendations given by IMD :-

i) for plane regions - 1 Stations / 520 km^2

ii) for regions having avg. elevation of 1000 m - 1 Station / 260-390 km^2.

iii) for hilly areas with heavy rainfall - 1 Station / 130 km^2.

- As per actual data available, India is having a raingauge intensity of 1 Station / 600km^2, which is insufficient.

- Israel is the country having max. density of raingauge stations - 37 stations / 1000km^2.

- above mentioned density is only for IMD maintained rain gauges. Apart from IMD, certain other agencies such as Indian Railways. NHAI, AAI etc. have their own network. Data of which is not made public.

Note- As per recommendation of WMO, atleast 10% of the rain-gauges should be of recording type.

- Cloud Seeding :- It is the process of artificial introduction of condensation nuclie into the atmosphere so as to bring about rainfall. This type of rainfall is called as artificial rain & the compound that is most commonly used for this process is silver iodide (AgI).
It has been observed that normal rainfall of places subjected to cloud seeding is getting adversely affected & hence this technique is not being used very frequently.

- Optimum network of raingauges :- this can be calculated on the basis of variation or deviation in the given rainfall data.

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

where, $C_v = \frac{\sigma}{\bar{x}} \cdot 100$ $\quad \bar{x}$ = mean of given data

σ = standard deviation = $\sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{(n-1)}}$

ϵ = allowable % error

on the basis of given no. of raingauges standard error (ϵ_s) is given as-

$$\epsilon_s = \frac{C_v}{\sqrt{n}}$$

Note:- above method of finding optimum no. of raingauges is purely statistical in nature.

Q-16) (WB) Pg-79)

i) $C_v = \frac{\sigma}{\bar{x}} \times 100$ $\quad \sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{(n-1)}}$ $\quad \bar{x} = (82.6 + 102.9 + 180.3 + 110.3 + 98.8 + 136.7)/6$

$\bar{x} = 118.6$

$C_v = 29.54$ $\quad \sigma = 35.04$

$$\epsilon = \frac{C_v}{\sqrt{N}} = \frac{29.54}{\sqrt{6}} = 12.06\%$$

ii) $\epsilon = 10$

$$N = \left(\frac{C_v}{\epsilon}\right)^2 = \left(\frac{29.54}{10}\right)^2 = 8.73$$

$\simeq 9$ raingauges.

iii) how many of the raingauges should be of recording type- (6)

at least 10% of 9

- at least 1 raingauge.

(WB)

Q-18) Pg-79)

$\epsilon = 10\%$ $\quad \bar{x} = \frac{100+120+140+80}{4} = 110$

$$\sigma = \sqrt{\frac{\sum(x_i-\bar{x})^2}{n-1}} = 25.82$$

$$C_V = \frac{\sigma}{\bar{x}} \times 100 = 23.47$$

$$N = \left(\frac{C_V}{\epsilon}\right)^2 = \left(\frac{23.47}{10}\right)^2 = 5.51 \simeq 6 \text{ raingauges}$$

Non-recording raingauge = 5

Recording raingauge = 1.

⇒ Inconsistency of rainfall data :- Whenever there is change in the condition prevailing at any of the raingauge station, there will be inconsistency of record available for that period, this inconsistency may be due to the following factors -

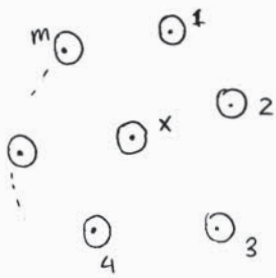
a) Shifting of raingauge station to a new location.

b) Neighbourhood of the area undergoing a significant change.

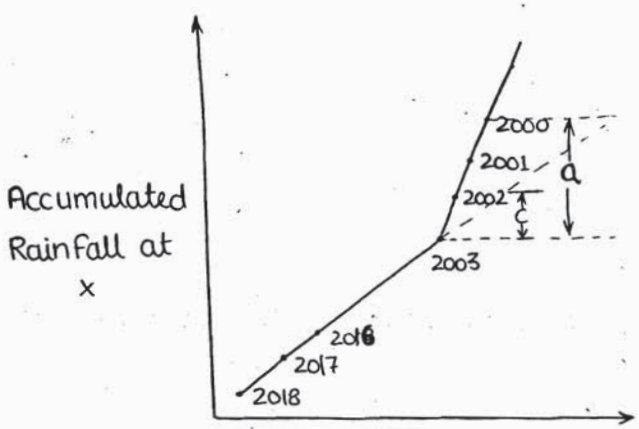
c) Change in the ecosystem which may be due to factors like forest fire, landslides etc.

d) due to observational error.

- This inconsistency can be found out by a method called as- double mass curve method.



Year	x	1	2	----	m	Mean of 'm' station



Double Mass curve

- In order to find inconsistency, following Method is adopted - few Stateon close to suspected station x are selected & a graph is plotted between accumulated rainfall at station x & accumulated mean of rainfall at m nearby stations. Plotting of this graph is done in reverse chronological order. Change in the slope of line indicates the year in which inconsistency took place. Corrected value of rainfall at station x is then given as -

$$\left[P_{cx} = P_x \times \frac{c}{a} \right]$$

$\frac{c}{a}$ = correction ratio or correction factor

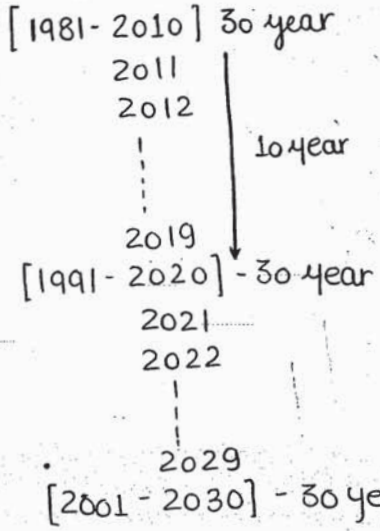
- double mass curve method can also be used for finding arithmetical error that may happen while transferring rainfall data from one record to the other.

- Estimation of missing rainfall data :- Whenever rainfall data at Station x could not be obtained due to defective raingauge station or otherwise but it is still req. to find an approx. value of the missing rainfall data, following method is to be adopted -

· few stations close to defective Station x are selected & rainfall values at these Stations is noted down as $P_1, P_2, P_3, \cdots P_n$. P_x is the missing rainfall data whose approx. value is to be obtained

Let $N_1, N_2, N_3, \cdots N_m$ & N_x be the normal annual ppt. value for the station 1, 2, --- m & x. (7)

- Normal Precipitation/rainfall - this is the average value of rainfall for a day, month or year or any other suitable time intervel on the basis of records of last 30 years.



- Missing rainfall data P_x can then be calculated as follows -

Case-1 :- When $N_1, N_2, \cdots N_m$ defers from N_x by less than 10% then the value of P_x is given as -

$$\left[P_x = \frac{P_1 + P_2 + P_3 + \cdots P_m}{m} \right]$$

Case-2 :- When one or more of $N_1, N_2, N_3, \cdots N_m$ defers from N_x by 10% or more then the value of P_x is given by -

$$\left[P_x = \frac{N_x}{m} \left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \cdots + \frac{P_m}{N_m} \right] \right]$$ - Normal ratio method.

(WB)

Q-1) Pg-77) $N_1 = 60$, $N_2 = 75$, $N_4 = 100$, $N_3 = 80$

$P_1 = 90$, $P_2 = 60$, $P_4 = 70$, $P_3 = ?$

$$P_3 = \frac{N_3}{m} \left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_4}{N_4} \right]$$

$$= \frac{80}{3} \left[\frac{90}{60} + \frac{60}{75} + \frac{70}{100} \right]$$

$$\left[P_3 = 80 \text{cm} \right]$$