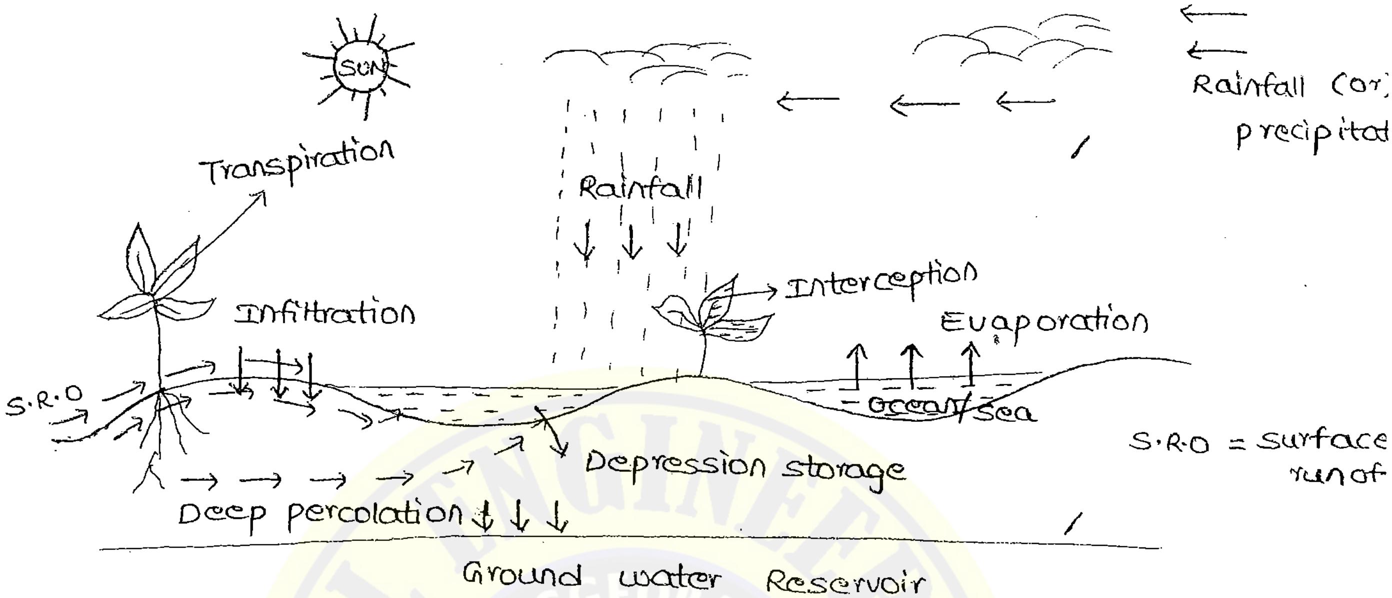
UNIT - I

A₃ -Civil

PRECIPITATION

Hydrological cycle (or) water cycle :-



The movement of water on surface is called surface runo

1. Hydrological cycle defined as transfer of water body into t atmosphere from the atmosphere to the ground and back to the water body. This endulus circulation of water is known a Hydrological cycle.
2. The various phases in hydrological cycle are evaporation, precipitation, infiltration, evapotranspiration, interception, surface runoff and sub surface runoff like interflow and ground waterfl
3. Interflow is the lateral movement of water which travels beneath the soil in the horizontal direction.

They are two types of interflows are

a. promt interflow:-

If the lag time is short called as promt interflo and it is more called delayed interflow.

b. Delayed interflow:-

If the lag time is more called as Delayed interflow.

Note :-

The lag time is defined as the time elapsed between the entry of water in to the soil and the time at which the ...

Precipitation:-

Total annual rainfall in India = 119.4 cm

Total runoff = 55 cm.

Forms of precipitation:-

Rainfall – Diameter of droplet >0.5 mm

Drizzle – Diameter of droplet ≥0.5 mm

Intensity of rainfall (mm/hr, cm/hr):-

Low intensity, 0 – 2.5 mm/hr

Moderate intensity, 2.5 – 7.5 mm/hr

High intensity, > 7.5 mm/hr

1. The movement of water droplet relative to the cloud colloid and the diameter of the water droplet increases this phenomena is called as coalsence.
2. To have this phenomena happen in the atmosphere and generate artificial range ice and silver iodide added to the system.

Sleet – diameter of ice pellets < 4 mm

Hail – diameter of ice pellets > 8 mm

Glaze – diameter of ice pellets

Glaze:-

Formation of a layer due to freezing of water at the ground level.

Snowfall:-

Formation of Ice crystals. Snowfall is always measured interms of an equivalent depth of water.

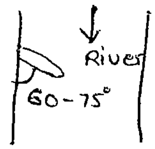
Types of precipitation:-

1. Cyclonic, precipitation:-

A low pressure occurs giving rise to heavy rainfall. Winds move in anticlock wise direction in the Northen Hemisphere and clockwise direction in southern Hemisphere.

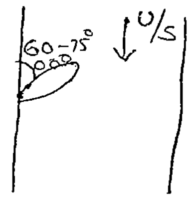
Attracting Gryone:-

Attracts water towards the bank reduces the velocity and erosion.



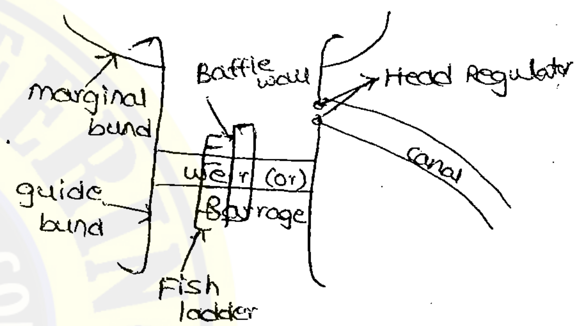
Repelling Gryone:-

Siltation takes place.



Functions of Head Regulator:-

1. To control the flow of water
2. controls flood water entering into the canal
3. prevents entry of silts into the canal.



Scouring sluice:-

To transport the silt deposited on the upstream side. Under sluices are operated by still pond regulation and semi open flow regulation.

Discharging capacity:-

1. Low quantities of flood waters can be disposed to the downstream side.

Highest amoung the following is selected.

1. Twice the canal capacity.
2. Maximum winter discharge
3. 10-15% of Maximum flood flow.

Divide wall:-

To seperate under sluice portion from the rest of the weir. To provide a straight approach to the flow and make a quite pocket infront of the regulator. It is alligned perpendicular to the weir.

Retrogression:-

Lowering of downstream river bed level is called Retrogression

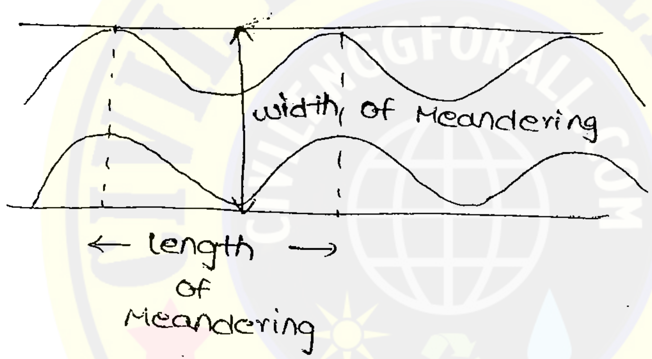
Afflux:-

Afflux increase in high flood level is called as a Afflux.

Both are used in weirs.

Meandering:-

The movement of a river in zigzag path is called Meandering of a river. Meandering takes place because of erosion and deposition of silt.



Guide bunds:-

To make the river flow in a straight path. prevent erosion of the structures.

Marginal bund:-

To confine flood waters

Spur:-

1. A pervious structure projecting into the water
2. Reduces the velocity and deflects water away from bank.

Gryones:-

Impression structures projecting into the river.

1. Attracting Gryone
2. Repelling Gryone
3. Deflecting Gryone

UNIT – 6

DIVERSION HEAD WORKS

Head work:-

Hydraulic structure across a river.

Types of headwork:-

1. storage headwork — Dams
2. Diversion headwork — weirs, Barrage.

Diversion headwork:-

Stages of a river

1. Rocky stage — Deep depth, velocity high (origin of a river)
2. Boulder stage — foot of a hill (velocity are reduced)
3. Alluvial stage — plane areas river moves
4. Delta stage — River meet the sea. △

Components of Diversion head works:-

1. Weir (or) (Barrage → Rise of water level and supply into the canal)
2. canal system
3. canal head regulator
4. Under sluices (or) Scouring slice
5. Divide wall
6. Fish ladder
7. River Training works
   a. Guide bund (Bell bunds)
   b. Marginal bund {
   c. Spurs, Gryones
8. Silt control devices
   a. Silt excluder → provided before canal head regulator
   b. Silt extractor (or) ejector → provided on the canal.

Weir	Barrage
1. Afflux is more	1. Afflux is less
2. Flood can be controlled through small gate	2. Flood can be controlled through large gate.
3. Less cost.	3. More cost

Lacey's equation:-

1. $f = 1.76\sqrt{d}$

where

f = Silt factor

d = mean diameter of particle, mm

2. Velocity, $V = \left[\frac{Qf^2}{140}\right]^{1/6}$ (or) $V = \sqrt{\frac{2}{5}(f \cdot R)} \rightarrow V \propto f^{1/2}$

$V \propto Q^{1/6}$

** 3. Wetted perimeter, $P = 4.75\sqrt{Q}$

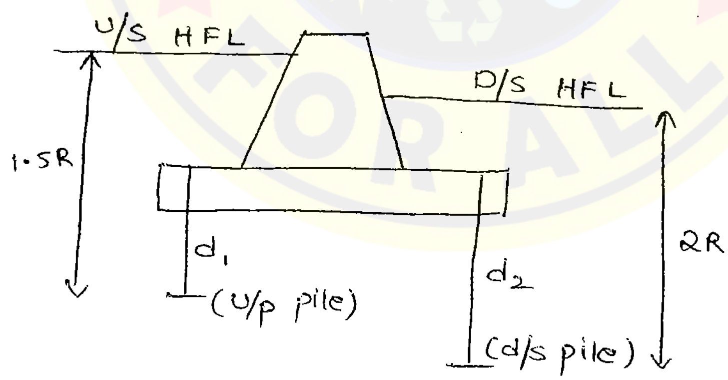
$Q = m^3/sec$, $P = m$

The above expression is used in determining th length of water way of any hydraulic structures like bridges, acquiducts etc.

Length of water way is defined as the passa through which the water is allowed to flow.

4. Lacey's scour depth, $R = 1.35\left(\frac{q^2}{f}\right)^{1/3}$

q = discharge per 'm' width $= \frac{Q}{B}$



$S = \frac{f^{5/3}}{3340\,Q^{1/6}}$

$S = \frac{f^{3/2}}{4980\sqrt{R}}$

(Lacey's diagrams)

Note:-

A channel constructed in clayey soil, remains in initial regime only.

P.g NO:- 68

2. $D = 1\,m$, $CVR = m = 0.9$

$V_K = 0.55\,m\,D^{0.64}$

$= 0.55\,(0.9)\,(1)^{0.64}$

3. Lindley proposed the term Regime theory which means stable.

True Regime conditions:-

Theoritical conditions only and cannot be practically achieved.

1. Channel should be in unlimited incoherant alluvium. Incoherant alluvium means loose granular material which can be easily scoured and deposited.
2. Silt grade is constant (diameter of particle should be in a particular range).
3. Silt concentration is constant (It means that the min-bed load from the active bed is constant).

Active bed is a bed which is subjected to scouring.

4. Discharge (Q) is constant

Initial Regime — Depth, slope is constant
Final Regime — width, Depth, slope is constant

Initial Regime the longitudinal slope and depth of flow attains constant values.

Final Regime the width, depth of flow, longitudinal slope attains constant values.

A channel which satisfies the initial and final Regime conditions is called as Regime channel.

Note:-

The side slopes of the channel should be half Horizontal to one verticle.

$$\text{Area, } A = BD + \frac{D^2}{2}$$

$$P = B + D\sqrt{5}$$

Lacey's diagrams are used to design Lacey's channel using Lacey's theory.

$$P = B + 2\sqrt{D^2 + z^2 D^2}$$

$$= B + 2D\sqrt{1+z^2}$$

put $z = \frac{1}{2}$

$$\boxed{P = B + D\sqrt{5}}$$

Hydraulic Radius, $R = \frac{A}{P}$

Equations used in the design are as follows:-

1. $Q = AV_k$
2. $V_k = 0.55\, m D^{0.64}$
3. Kutter's equation, $V = f(R, S)$

Kennedy's theory is a trial and error procedure

Note:-

1. Garrets diagram are used in the design of unlined channel using Kennedy's theory.
2. Kennedy's theory is based on side slope equal to Half horizontal to One verticle.

Drawbacks of kennedy's theory:-

1. The silt transport phenomena is based on a single factor 'm'.
2. Used kutters equation and the limitations of kutter's equation are included in his theory. It is a trial and erro procedure.
3. No slope equation is proposed.

Lacey's theory:-

1. "Lacey" a chief Engineer in Irrigation department in Uttar pradesh. He worked "Upper chenab canal system".
2. Regime channel is defined as a channel which has undergone modification by silting and scouring and have

DESIGN OF UNLINED ALLUVIAL CANALS BY SILT THEORIES

Lined channel	Unlined channel
1. No losses	1. Losses are more
2. High velocity	2. Low velocity
3. No silty, scouring	3. Silting, scouring occur
4. No change in shape	4. Change in shape of canal
5. Rigid channel	5. Mobile channel.

Channels in alluvial soil :-

Design — Bed width, Depth of flow, slope

Alluviam soil — Loose granular material.

Kennedy's theory :-

* 1. Stable canal

* 2. On upper barric Doab canal system

$$V_o = 0.55\, D^{0.64}$$ — Upper baric canal

V_o = critical velocity which is non silting and non scouring velocity

3. For other canals,

$$V_K = 0.55\, m\, D^{0.64}$$

m = critical velocity ratio $= \frac{V_K}{V_o}$

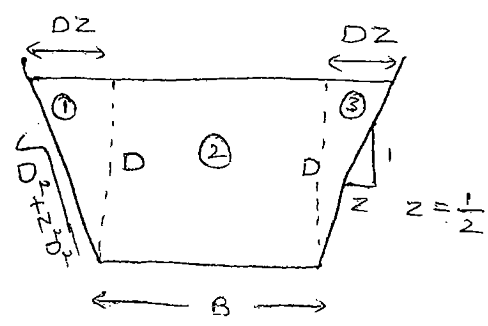
4. Adopted kutter's equation of velocity

5. No slope equation is given. Slope is determined using kutter's equation.

$A = BD + 2\left[\frac{1}{2} \times ZD \times D\right]$

$A = BD + D^2 Z$

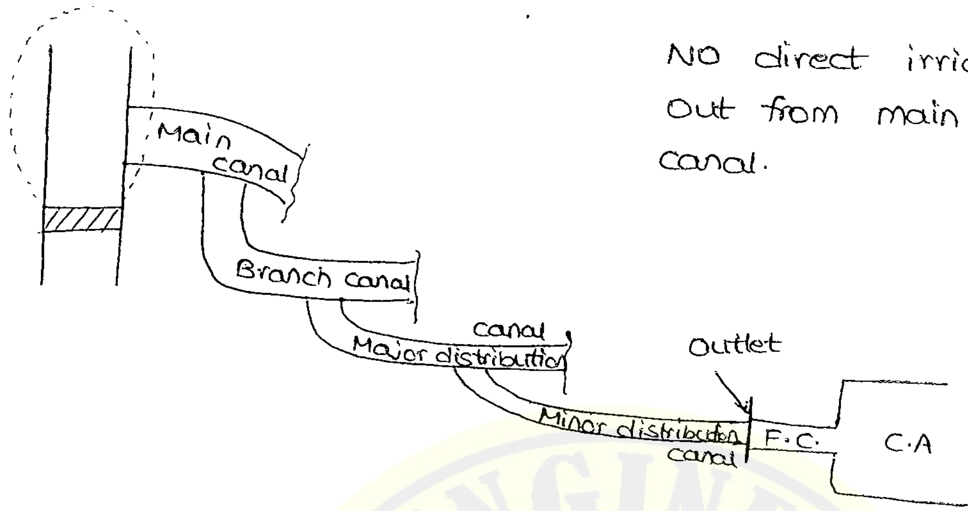
$$A = BD + \frac{D^2}{2}$$



UNIT - II

CANALS

Canals :-



No direct irrigation is carried out from main canal and branch canal.

1. Main canal carries large discharge
2. Branch canal : $Q > 5 \, m^3/s$
3. Major distributory : Q in between $0.25 - 5 \, m^3/s$
4. Minor distributary : $Q < 0.25 \, m^3/s$
5. Field channel : $Q < 0.1 \, m^3/s$

Contour canal :-

Canal alligned along a contour. Generally the main canals are contour canals.

Ridge canal :-

Canal alligned along a ridge line ~~also called~~ (or) water shed line is called a Ridge canal. Both the sides of a ridge canal crops can be cultivated no cross drianage works are required. However in the case of a contour canal no. of cross drainage works are required. Distributary canal also called Ridge canal

Side slope canal :-

Canal alligned perpendicular to the contour is a side slope canal.

Balancing depth :-

It is defined as the quantity of soil from excavation of the canal is sufficient to ...

Sprinkler Irrigation Method:-

Suitable for sandy soils. Distribution efficiency is high. Application efficiency (η_a) is 80%. Applied for water scared areas. NO soil erosion.

P.g NO:- 53

8. Area $= \frac{q}{I}$

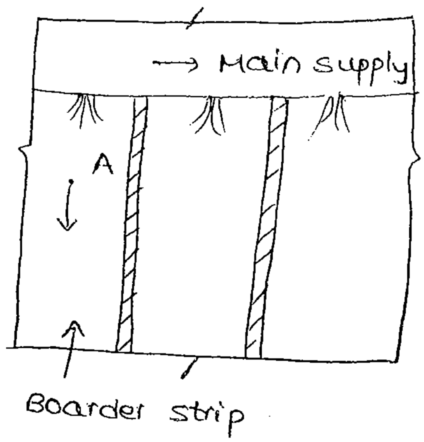
$$= \frac{0.04}{\frac{4}{100 \times 3600}}$$

$A = 3600\ m^2$ ∴ 1 hectare $= 10^4\ m^2$

$= 0.36$ ha

Boarder Irrigation method :-

$$t = \frac{y}{I} \log_e \left[\frac{q}{q - IA} \right]$$



t = time required to wet the area of strip 'A'.

y = avg. depth of flow

I = rate of infiltration

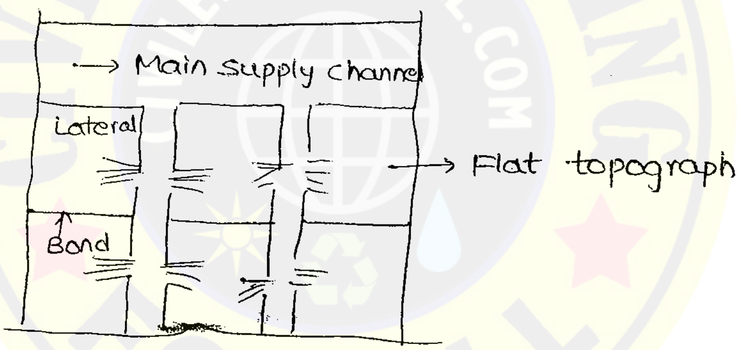
q = discharge

The maximum area that can be cultivated is

** $A_{max} = \frac{q}{I}$

Check (or) Leaves methods :-

Crops :- paddy, cerels etc



Method of plots and No slope is provided.

Furrow method :-

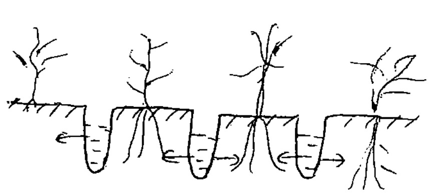
Long rectangular open channel

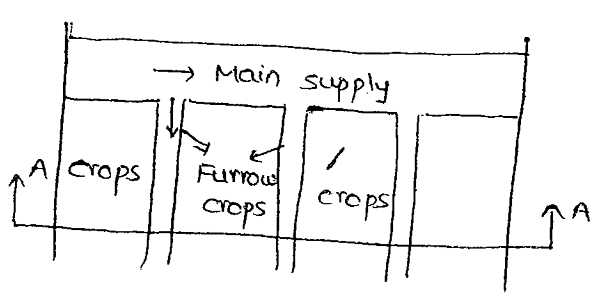
Length of furrow : 100 - 200 m

width of furrow : 25 cm

Depth of furrow : 8 - 10 cm

Slope : Mild





Crops :- Maize, Sugarcane, Tobacco

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UNIT- 2

METHODS OF IRRIGATION

Irrigation method

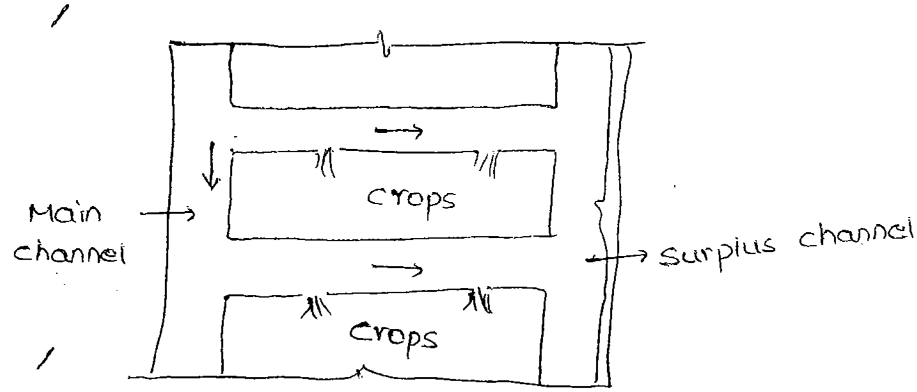
- Surface Irrigation method
- Sub surface irrigation method
  - Eg:- Drip method
  - Frickle method
- Sprinkler irrigation method.

Surface Irrigation method :-

Surface Irrigation method

- Flooding method
  - Uncontrolled Flooding method
  - Controlled Flooding method
    - Field channel method
    - Border Irrigation method
    - Checks (or) Leaves method
    - Basin method
- Furrow method
- contour farming method

Field channel method :-



14. Kharif season : Kharif crop + sugar cane → ①

Rabi season : Rabi crop + sugar cane → ②

Design Q = ① or ② whichever is higher.

17. Given

$D = 800$ ha/cumec, Loss = 20%

$\eta_c = 100 - 20 = 80\%$

$\therefore D_F = \frac{D_R}{\eta_c}$

$800 = \frac{D_R}{0.8}$

$D_R = 640$ ha/cumec

18. Given

$A = 2600$ ha, $\Delta = 17$ cm $= 0.17$ m, $B = 30$ days

$D = 8.64 \frac{B}{\Delta}$

$= 8.64 \times \frac{30}{0.17}$

$D = 1524.7$ ha/cumec

$\frac{A}{Q} = 1524.7$

$Q = \frac{2600}{1524.7}$

$Q = 1.705$ m³/s

5. Given

$D = 1428$ ha/cumec

$B = 120$ days

$D = 8.64 \frac{B}{\Delta}$

$1428 = 8.64 \times \frac{120}{\Delta}$

$\Delta = 0.73$

9. Given, $F.C = 25\%$, $PWP = 15\%$ $S = 1.5$ $d = 80$ cm
$= 0.8$ m

Storage capacity (y) $= S \times d\,[F.C - PWP]$

$= 1.5 \times 0.8\,[25 - 15]$

$= 1.5 \times 0.8\,[0.25 - 0.15]$

$= 12$ cm.

10. Given

$V = 10 \times 10^6\ m^3$, Loss $= 10\%$, $B = 120$ days, $\Delta = 40$cm $= 0.4$m

Net volume available $= 10 - \frac{10}{100} \times 10$

$= 9\ M.m^3$

Volume $= A \times \Delta$

$9 \times 10^6 = A \times 0.4$

$A = 2250 \times 10^4\ m^2$

$A = 2250$ ha

12. Kor depth $(\Delta) = 15.12$ cm
$= 0.1512$ m

Outlet factor i.e., duty $= ?$

$B = 4$ weeks

$B = 28$ days

$D = 8.64 \frac{B}{\Delta}$

$= 8.64 \times \frac{28}{0.1512}$

$= 1600$ ha/cumec

Crop seasons :

1. Kharif crops :-

It is also known as Monsoon crops. April - sep

Eg:- paddy, Maize (Jowar).

2. Rabi crops :-

It is also called winter crops. October to March

Eg:- Wheat, tobacco etc.

3. perennial crops :-

Eg:- Sugarcane

4. Month crop :-

Eg:- cotton

5. Wet crops :-

Crops grown by irrigation.

6. Dry crops :-

Crops grown without irrigation

7. Hot weather crops :-

March - June. Crops grown between kharif season and Rabi season.

Intensity of Irrigation

percentage of culturable command area under a crop.

Crop ratio :-

$$\text{Crop ratio} = \frac{\text{Area under Rabi}}{\text{Area under Kharif}}$$

Ex:- 1 : 2, 2 : 3 etc.

P.g. NO:- 48.

4. Given

$Q = 2\ m^3/s$; C.C.A = 1500 hec, $i = 50\%$ $B = 140$ days

Area = 0.5 × 1500 = 750 ha

Duty = $\frac{\text{Area}}{\ldots}$ = 750 ...

Culturable command area (CCA):-

CCA = GCA − Unculturable area (residential, paved areas)

Culturable cultivable area :-

= CCA − culturable uncultivated area

1. Lack of resources
2. Water logging
3. Fallow Land

Capacity factor (CF):-

$$CF = \frac{\text{Mean discharge}}{\text{Max. discharge (or) Design discharge}}$$

Time factor (TF):-

$$TF = \frac{\text{No. of days the canal is running}}{\text{No. of days the canal has to run}} = \frac{8}{10} = 0.1$$

(or)

$$TF = \frac{\text{Actual discharge}}{\text{design discharge}}$$

Ex:- $Q = 1\ m^3/s \longrightarrow 8$

Actual discharge $= 8 \times 1$

$= 8\ m^3/sec$

Total period = 10 days

Design discharge $= 1\ m^3/s \times 10$

$= 10\ m^3/s$

$$TF = \frac{8}{10} = 0.1$$

Design discharge:-

$$\text{Design discharge} = \frac{Q}{CF \times TF}$$

where,

$$Q = \frac{\text{Area}}{\text{duty}}$$

4. Water storage efficiency (η_s):-

$$\eta_s = \frac{\text{Quantity of water stored in the root zone}}{\text{Quantity of water required to bring the moisture content to field capacity.}}$$

5. Distribution efficiency (η_d):-

$$\eta_d = \left[1 - \frac{d}{D}\right] \times 100$$

D = average of depth of penetration of water

d = the average of absolute deviations from the mean

If $\eta_d = 90\%$, it indicates that 90% of area has received equal depth of moisture in the root zone. The remaining 10% is subjected to over irrigation or under irrigation.

Gross ~~comm~~ Irrigation requirements of crops:-

1. Consumptive use requirement (CIR):-

$$CIR = C_u - \text{Effective rainfall}$$

2. Net irrigation requirement (NIR):-

$$NIR = C_u - \text{Effective rainfall} + \text{water required for leaching}$$

$$NIR = CIR + \text{Leaching}$$

3. Field irrigation requirement (FIR):-

$$FIR = \frac{NIR}{\eta_a}$$

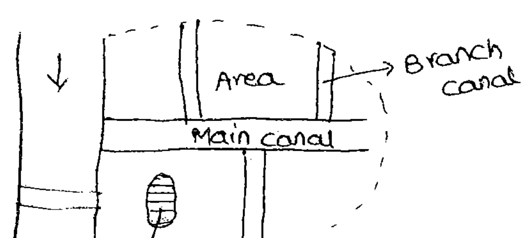
4. Gross irrigation requirement (GIR):-

$$GIR = \frac{FIR}{\eta_c}$$

** ∴ $GIR > FIR > NIR > CIR$

Gross command Area (GCA):-

It is defined as total area under a canal system



Paleo Irrigation:-

Watering done before sowing of a crop, for land preparation is called paleo irrigation.

Kor watering (or) Kor period (or) Kor depth:-

The watering done of the irrigation carried out when the plants have grown a few cm (young stage) is called kor watering and the period of watering is called kor period and the depth of water during this kor period is called kor depth.

Note:-

The demand for water by the crop is more in the younger stage and this demand is used in the design of canals.

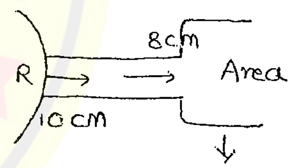
Irrigation efficiencies:-

1. Water application efficiency (η_a):-

$$\eta_a = \frac{\text{Quantity of water stocked in root zone}}{\text{Quantity of water delievered to field}}$$

$$= \frac{7}{8} \times 100$$

$$=$$



2. Water conveyance efficiency (η_c):-

$$\eta_c = \frac{\text{Quantity of water delivered to the field}}{\text{Quantity of water delivered into canal}}$$

$$= \frac{8}{10} \times 100$$

$$= 80\%$$

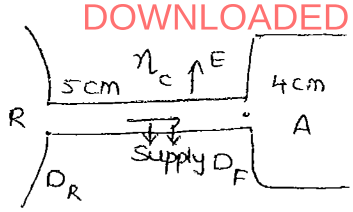
3. Water use efficiency (η_u):-

$$\eta_u = \frac{\text{Quantity of water beneficially used}}{\text{Quantity of water delievered to field}}$$

∴ Beneficiall use means amount of water stored in the root zone + amount of water used for Leaching.

Leaching is a technique washing away of the salts from the soils by adding water.

EX :-



η_c = conveyance efficiency

$$= \frac{\text{volume of water delievered to field}}{\text{volume of water delievered to canal}}$$

$$\eta_c = \frac{4}{5} \times 100$$

$$= 80\%$$

$$D_F = \frac{D_R}{\eta_c}$$

D_F = Duty on Field

D_R = Duty at head of canal

η_c = conveyance efficiency.

Delta (Δ) :-

Total depth of water over the irrigated land require the crop during entire base period.

** Relation between duty and delta :-

$$\Delta = 8.64 \frac{B}{D}$$

Δ = Depth of water in m

B = Base period, days

D = Duty in ha/cumec

Volumetric units :-

1. m^3
2. ha - m

   1 ha = 10^4 m^2

3. cumec - day

   If 1 m^3/s is supplied for 24 hours

   $= 1 \frac{m^3}{s} \times 24 \times 3600$

   1 cumec day = 8.64 ha - m

4. TMC = Thousand Million cusecs

Duty of water :-

1. Crop period :-

Time period between sowing and harvesting

2. Base period :-

Time period between first watering and last watering

∴ crop period > Base period

Duty :-

The area of land in hectares which can be irrigated for growing any crop if 1 m^3/s of water is continuously supply to the land for the entire base period of the crop.

Eg :- Duty = 1000 hec/cumec

It means that if 1 m^3/sec is continuosly supply to the crop for the entire base period, it can irrigate 1000 hectares

Duty gives a relationship between Area and Discharge.

$$\text{Duty} = \frac{\text{Area}}{\text{Discharge}}$$

Cumec = 1 m^3/sec

Units :- hec/cumec

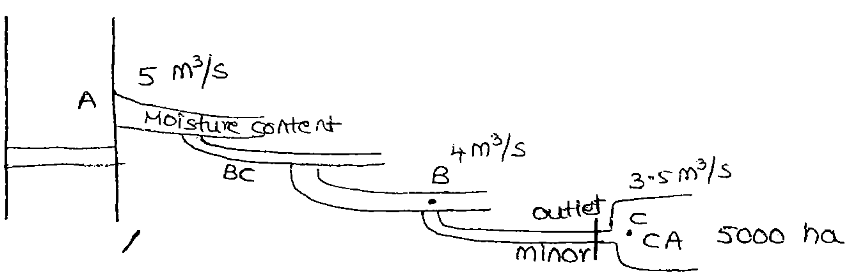
Outlet factor :-

It is also called Duty at Outlet. The duty measured at the outlet is called Outlet factor.

Note :-

Unless mentioned duty means duty on the field.

Ex :-



Duty at A = $D_A = \frac{A}{Q} = \frac{5000}{5} = 1000$ ha/cumec

Duty at B = $D_B = \frac{5000}{4} = 1250$ ha/cumec

Duty at C = $D_C = \frac{5000}{...} = 1425$ ha/cumec

Available moisture (AM) = F.C − P.W.P

Readily available moisture (RAM) = 75 − 80% of A.M.

The moisture which can be easily extracted by the plant

1. plant grows when moisture content (M.C) is above P.W.P.
2. yield decreases when moisture content is below O.M.C.
3. Irrigation to applied at Optimum Moisture content.

Equivalent moisture depth:-

$$F.C = \frac{\text{weight of water retained in an area}}{\text{weight of soil in an area}}$$

$$= \frac{\gamma_w \times \text{depth of water} \times A}{\gamma_d \times d \times A}$$

∴ Equivalent depth of moisture at $F.C = \frac{\gamma_d}{\gamma_w} \cdot d \times F.C$

$= S \times d \times F.C \longrightarrow ①$

Equivalent depth of moisture at $P.W.P = S \times d \times P.W.P \longrightarrow ②$

** ∴ Moisture holding capacity or water storage capacity or Available moisture $(y) = S \times d\,[F.C - P.W.P]$

** $R.A.M = d_w = 75 \text{ to } 80\% \text{ of } y$

(or)

$$d_w = S_w \times d\,[F.C - O.M.C]$$

S = specific gravity of soil

d = depth of soil

** Frequency of irrigation (f):-

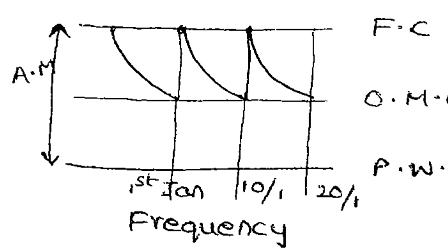
To determine the no. of terms of irrigation.

$$f = \frac{d_w}{CU}$$

f = frequency

d_w = Readily available moisture

CU = consumptive use (or) ET



Eg:- $d_w = 1\,cm$ $CU = 1\,mm/day$

$$f = \frac{d_w}{CU} = \frac{1}{...} = 10 \text{ days}$$

Saturation capacity :-

When all the voids i.e., capillary pores and non capillary pores are filled with water is called saturation capacity.

Field capacity :-

Amount of moisture retained in the soil (capillary pores) against pull of gravity is called Field capacity. At these stage the non capillary pores are filled with air.

Temporary wilting point :-

Plant can recover on its own during the cooler part of the day without addition of water.

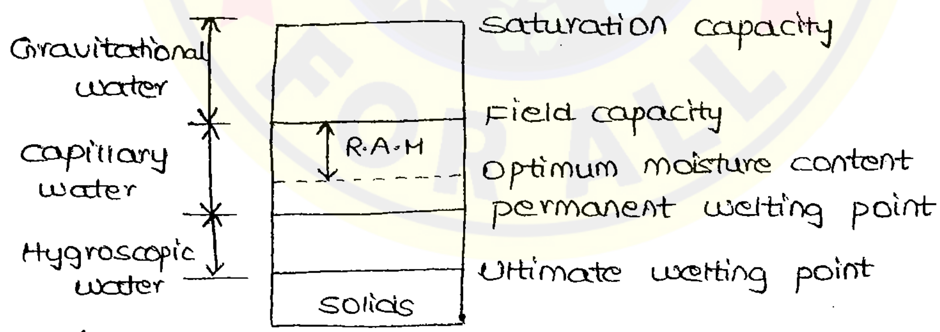
Permanent wilting point :-

plant can recover by the addition of water.

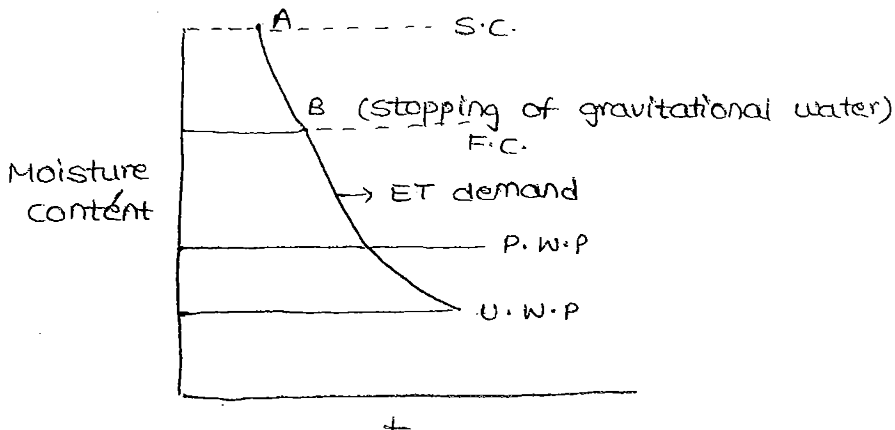
Ultimate welting point :-

Plant cannot recover even with an addition of water i.e., plant is dead.

Available moisture :-



R.A.M = Readily available moisture



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UNIT - I

WATER REQUIREMENTS OF CROPS

Irrigation:-

Artificial supply of water to cultivate crops is called Irrigation.

Irrigation system:-

It comprises of hydraulic structures like dam, weir, barriage, regulators, canal system, canal falls, canal escapes etc

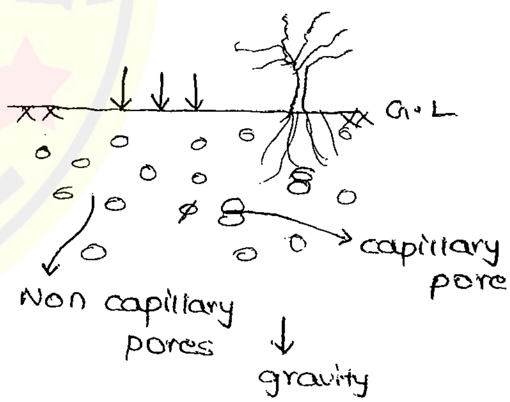
Crop water requirements:-

Amount of water required by the crop from sowing to harvesting period is crop water requirement. It is different for different crops. Crop water requirement for the same crop is different at different places.

Objective of the study:-

1. To design irrigation canals
2. To determine frequency of irrigation.

Soil moisture constants:-



Types of water:-

1. Gravitational water
2. Capillary or available water
3. Hygroscopic water

Gravitational water:-

Amount of water freely draining under the pull of gravity is called Gravitational water.

Capillary water:-

The amount of moisture present in capillary pores is called capillary water. It can be easily extracted by the plants.

Hygroscopic water:-

Amount of moisture absorb by the soil from the atmosphere.

In Alluvial soils if the water is pumped at a high rate the depression head will increase which may cause excess gradients resulting in loosening of sand particles. these limiting head is called critical depression head.

The safe working depression head = $\frac{1}{3}$ of critical depression head and the yield under this head is called the maximum safe yield of the well.

P.g No:-38

4. Given $S = 0.0005$

$\Delta p.s = 14\,m$

$A = 4.6\ km^2 = 4.6 \times 10^6\ m^2$

$\Delta GWS = A \times \Delta p.s \times S$

$= 4.6 \times 10^6 \times 14 \times 0.0005$

$= 32,200\ m^3$

5. Given $i = 0.003$

$K = 0.01\ m/day$

$\eta = 0.31$

$V = K \cdot i$ $\quad$ V = apparent (or) discharge velocity

$= 0.01 \times 0.003$

$V_a = \frac{V}{\eta}$

$= \frac{0.01 \times 0.003}{0.31}$

$= 9.7 \times 10^{-5}\ m/day$

Yield test of well :-

1. Recuperation test
2. Pumping test :-

$$Q = AV$$
$$= A \times Ki$$
$$= A \times K \times \frac{S}{L}$$
$$= A \times \frac{K}{L} \times S$$
$$Q = CAS$$

The pumping rate is adjusted so that the drawdown is constant. By measuring the rate of flow, A, S, determine 'c' value. For any drawdown S_1, $Q = CAS_1$

where,

S_1 = drawdown at any time period.
A = cross sectional area of the well
S = drawdown or depression head
C = constant $= \frac{K}{L}$

Recuperation test :-

$$Q = CAS$$
$$C = \frac{1}{T} \log_e \left(\frac{S_1}{S_2}\right)$$

Recuperate → Rise

where

T = time after which the pumping is stopped i.e., it is the time taken for the depression head or drawdown to change from AB to CD.

After pumping is stopped the water level increases or rises (recuperates). Therefore

S_1 = initial drawdown
S_2 = drawdown after pumping is stopped.

Safe yield of a well :-

It is defined as the amount of water which can be withdrawn annually without producing any undesirable effect.

Depression head = static water level (water level adjacent to well

1. $Q = \dfrac{\pi K (h_2^2 - h_1^2)}{\log_e\left(\frac{r_2}{r_1}\right)}$

$h = H - S$

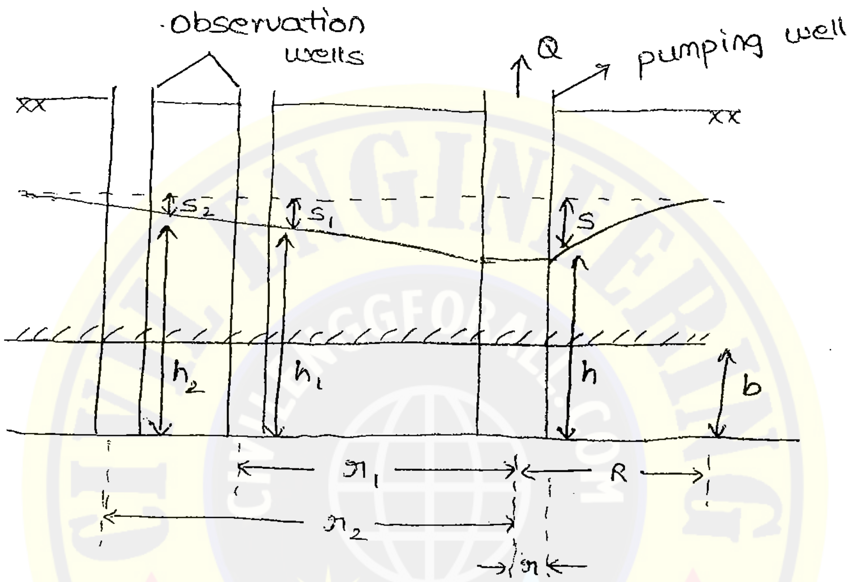
$h_1 = H - S_1$

$h_2 = H - S_2$

2. $Q = \dfrac{\pi K (H^2 - h_1^2)}{\log_e\left(\frac{R}{r_1}\right)}$

3. $Q = \dfrac{\pi K (H^2 - h_2^2)}{\log_e\left(\frac{R}{r_2}\right)}$

confined aquifer :-



$Q = \dfrac{2\pi K b (H - h)}{\log_e\left(\frac{R}{r}\right)}$

$= \dfrac{2\pi K b (h_2 - h_1)}{\log_e\left(\frac{r_2}{r_1}\right)}$

$= \dfrac{2\pi T (h_2 - h_1)}{\log_e\left(\frac{r_2}{r_1}\right)}$ $\quad \therefore T = Kb$

$= \dfrac{2\pi K b (H - h_f)}{\log_e\left(\frac{R}{r_1}\right)}$

$Q = \dfrac{2\pi K b (h_1 - h)}{\log_e\left(\frac{r_1}{r}\right)}$ → Theims equation.

**Specific Storage (S_s):-

It represents the volume of water from a unit volum of acquifer material due to their unit decrease in piezometric head.

$$S_s = \frac{A \times d}{1\text{ m drawdown}}$$

S_s = storage per aquifer depth

In a confined aquifer with increase in atmospheric press the piezometric surface decreases. As atmospheric pressure decreas piezometric surface increases. These is due to compressibility natu of water in confined aquifer.

Barometric efficiency:-

It is the ratio of water level change, due to atmospheric pressure head change.

BE for unconfined aquifer = 0

Formation loss:-

It is the head drop required to pass laminar flow.

Well loss:-

It is the total head drop required to sustain turbulent flow near the well and head loss through the well screened and casing.

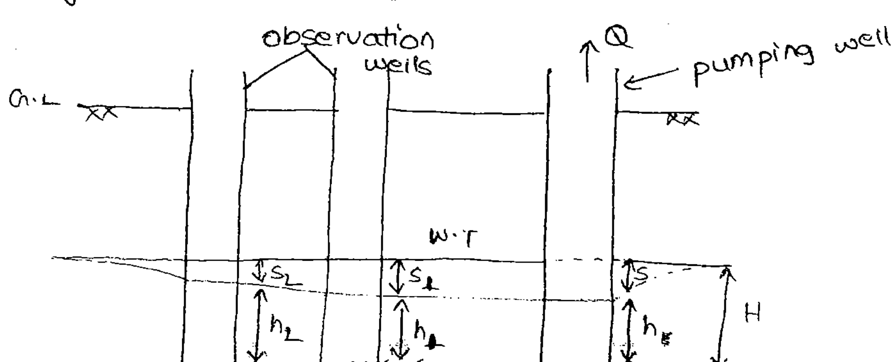
Note:-

Near the well Darcy law is not valid.

Steady flow to a well in unconfined aquifer:-

Assumptions:-

1. soil is homogeneous and isotropic
2. Flow is laminar
3. Darcy's law is valid



Coefficient of permeability (or) Hydraulic conductivity (K) :- (Large K)

It is defined as the rate of flow through a unit cross sectional area under a unit hydraulic gradient

Units :- cm/sec (or) m/sec

Intrinic permeability (k) :- (small k)

$$K = \frac{k \cdot \gamma}{\mu}$$

where,

γ = sp. wt. of fluid

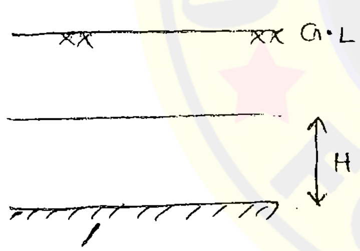
μ = dynamic viscosity of fluid.

'k' (small) is used in the studies of petroleum and natural gas exploration.

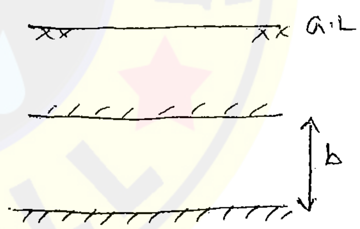
Units of 'k' are cm^2 (or) m^2 (or) Darcy

1 Darcy $= 9.87 \times 10^{-13}\ m^2$

Unconfined aquifer :-



confined aquifer



** Transmissivity (or) Transmibility (T) :-

The discharge through aquifer of 1m width under unit hydraulic gradient.

$T = KH$ (for unconfined aquifer)

$T = Kb$ (for confined aquifer)

Units :- m^2/day

Dimensions :- L^2T^{-1}

Specific capacity :-

It is the discharge per unit drawdown in a well is called specific capacity.

$$\frac{Q}{S_w} \propto T$$

Specific capacity decreases with increase in pumping rate

*** Note:-

1. The change in ground water storage due to fluctuations in the ground water table or piezometric surface is estimated as Δ.

$\Delta GWS = A \times \Delta GWT \times S_y$ for unconfined aquifer

$\Delta GWS = A \times \Delta p.s \times S$ for confined aquifer

GWS = Ground water storage

GWT = Ground water table

P.S = piezometric surface.

*** Darcy's Law:-

$V = -k \cdot i$, valid for $R_e \leq 1$

V = apparent (or) discharge velocity

k = coefficient of permeability

i = Hydraulic gradient

$$R_e = \frac{F_i}{F_v}$$

$$R_e = \frac{\rho V d}{\mu} \text{ (or) } \frac{\rho U L}{\mu}$$

$$\nu = \frac{\mu}{\rho}$$

$$R_e = \frac{Vd}{\nu} \text{ (or) } \frac{VL}{\nu} \leq 1$$

ρ = mass density

V = apparent velocity

L = characteristic length

μ = dynamic viscosity

d = mean particle size

∴ L = d

Actual velocity (or) Bulk pore velocity $(V_a) = \frac{V}{\eta}$

V = apparent velocity $= \frac{Q}{A}$

η = porosity

Cone of depression:-

If the water is pumped at a constant rate from a well, a gradient in water table towards the well is created resulting, in depression of water table. These is called as cone of depression.

The radial distance from the centre of the pumping well to the point where the drawdown is zero these is called Radius of Influence (R) and arial extent is called Area of influence.

The decrease in water level in the well due to pumping is called drawdown. The instrument used to identify a well is electrical resistivity meter.

Aquifer parameters:-

1. Specific yield (S_y):-

The discharging capacity at under the force of gravity.

2. specific / Retention (S_r):-

Volume of water retained in the soil

$$S_y + S_R = n$$

$$n > S_y$$

n = porosity.

3. Storage coefficient (or) storativity:- (S)

It is used in confined aquifer. It is a dimensionless parameter.

$$S = \gamma_w \, n \, b \left[\frac{1}{K_w} + \frac{1}{n \cdot E_s} \right]$$

where,

S = storage coefficient

n = porosity

γ_w = specific weight of water

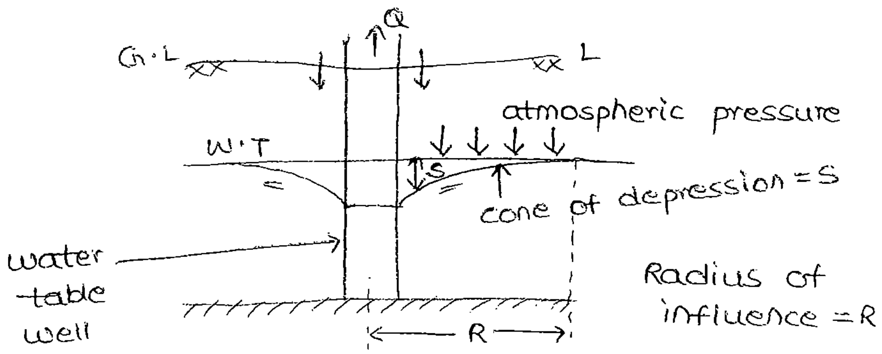
b = thickness of aquifer

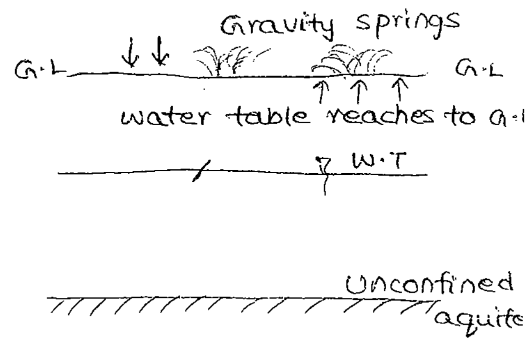
K_w = bulk modulus of elasticity of water

E_s = Modulus of elasticity of soil

Types of Aquifer:-

1. Unconfined Aquifer (or) Water table Aquifer:-

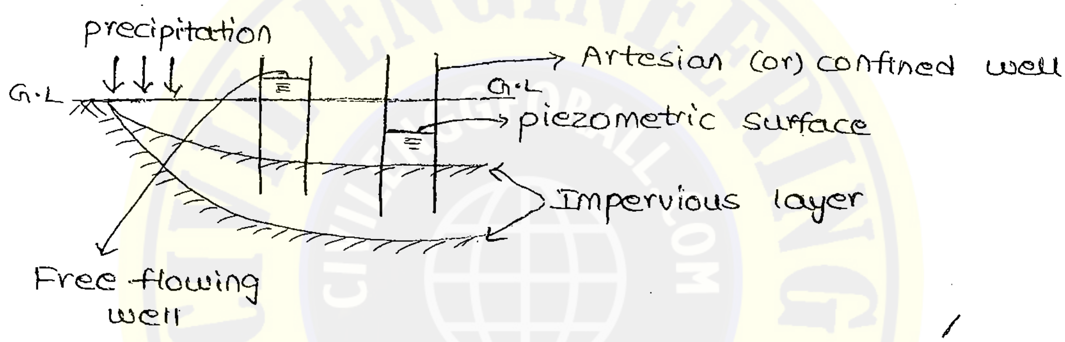




Source : Rainfall Process: Infiltration

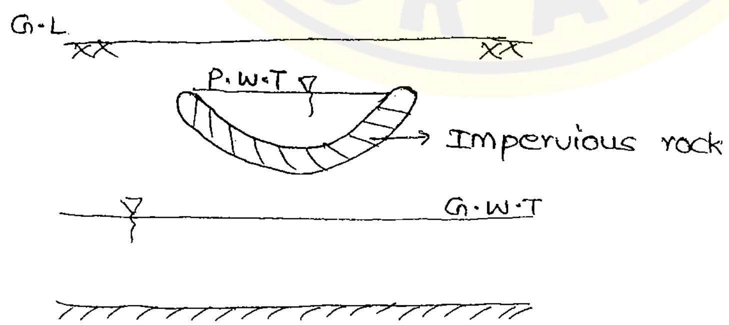
It has a free surface i.e., water table exists.

2. Confined Aquifer (or) Artesian Aquifer:-



Water is under pressure.

3. Perched Aquifer:-



P.W.T = perched water table

The water table is retained locally in impervious stratum. A localised geological body present in unconfined acquifer. It yields temporarily.

4. Leaky aquifer:-

A confined aquifer bounded on one side or both by aquitards is called leaky aquifer.

UNIT – II

WELL HYDRAULICS

Geological Formations :-

1. Aquifer :-

Unconsolidated gravel, sand

2. Aquitard :-

Less yield

Eg:- clay lenses in sand

3. Aquiclude :-

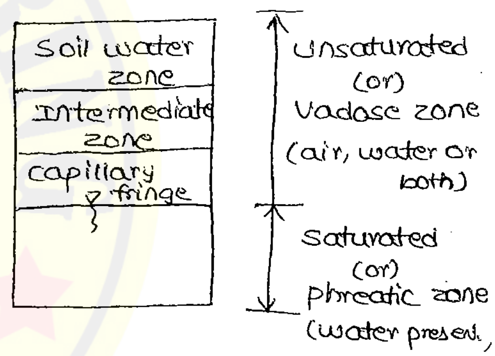
Clayey

4. Aquifuge :-

Granites, Basalt.

Well Hydraulics :-

1. Ground water source is infiltration
2. Flow is laminar
3. V = 1 to 500 m/year
4. 22% of available fresh water.



Aquifer :-

Which can store water and yield good amounts.

Eg:- Unconsolidated gravel, sand.

Aquitard :-

Has storage capacity, yields less amount of water

Eg:- clay lenses embedded in sandy layers.

Aquiclude :-

It stores water but does not yield water

Eg:- clayey soil.

Aquifuge :-

It can neither store water nor yield water.

Eg:- Granites, Basalts etc.

The routing interval 'Δt' such that

$$K > \Delta t > 2Kx$$

Generally $\boxed{\Delta t = \frac{1}{2} \text{ to } \frac{1}{3} K}$

Linear Reservoir:-

If the storage is proportional to outflow is called as Linear Reservoir.

$$S \propto Q$$

Linear channel:-

It is an imaginary channel where there is no attunuation. The Inflow hydrograph passes through the channel without causing any decrease in the peak.

Muskingum method:

Storage = Prism storage + wedge storage

$$S = [KQ] + [Kx(I - Q)] \rightarrow \text{Muskingum storage eq.}$$

$$S = K[xI + (1-x)Q] \rightarrow ②$$

where

K, x = Routing constants

x = dimensionless quantity ≈ 0 to 0.3

K = storage time constant with dimensions of time

'K' indicates the time of travel of a flood wave through a channel reach.

solving eq ① and eq ②

$$Q_2 = C_0 I_2 + C_1 I_1 + C_2 Q_1$$

where

C_0, C_1, C_2 are routing coefficients. If routing technique is correct then $C_0 + C_1 + C_2 = 1.0$

$$C_0 = \frac{0.5\Delta t - Kx}{K(1-x) + 0.5\Delta t}$$

$$C_1 = \frac{0.5\Delta t + Kx}{K(1-x) + 0.5\Delta t}$$

$$C_2 = \frac{K(1-x) - 0.5\Delta t}{K(1-x) + 0.5\Delta t}$$

Prism storage:-

Volume formed by an imaginary plane parallel to the bottom of the channel drawn at the outflow section water surface. Therefore storage is a function of outflow.

Wedge storage:-

Volume formed between actual water surface profile and top surface of prism storage. Therefore wedge storage is a function of inflow and outflow.

In the above equations of C_0, C_1, C_2

Δt = Routing interval.

2. Channel Routing:-

In these method the changes in shape of the hydrograph is studied as it travels down the channel.

Attenuation:-

When a flood hydrograph is routed, due to the storage effect, the peak of outflow hydrograph will be smaller than the inflow hydrograph. These reduction in peak value is called Attenuation.

Lag period:-

The time difference between the peaks of inflow and outflow hydrograph is called Lag period.

Note:-

Flood flow in a river is a category of gradually varied unsteady flow.

Routing methods:-

1. Hydrologic routing method:

Continuity equation is used

$$I - Q = \frac{ds}{dt}$$

$$\frac{I_1 + I_2}{2} - \frac{Q_1 + Q_2}{2} = \frac{S_2 - S_1}{\Delta t} \rightarrow (1)$$

2. Hydraulic routing method:-

When compare to Hydrologic routing method it gives accurate peak results. Continuity and momentum equations are used. They are expressed in differential form known as St. Venant equations.

3. Hydrologic Reservoir routing method:-

Methods are Modified Pulse method, Goodrich method. Storage is always a function of outflow.

4. Hydrologic channel Routing:-

Method used here is Muskingum method. Muskingum means name of a river in U.S.A. Proposed by Mc. carthy

UNIT - 10

FLOOD ROUTING

Flood Routing:-

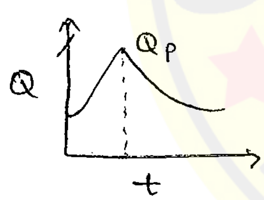
It is defined as a technique where the shape of a flood hydrograph at a particular location is determined from a known flood hydrograph on upstream. It is used in the hydrologic analysis of problems like flood forecasting, flood protection and reservoir design.

Flood routing is divided into Reservoir routing and channel routing (or) Stream flow routing.

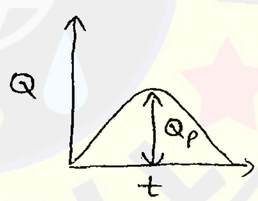
1. Reservoir routing:-

$S = S(h)$

$Q = Q(h)$

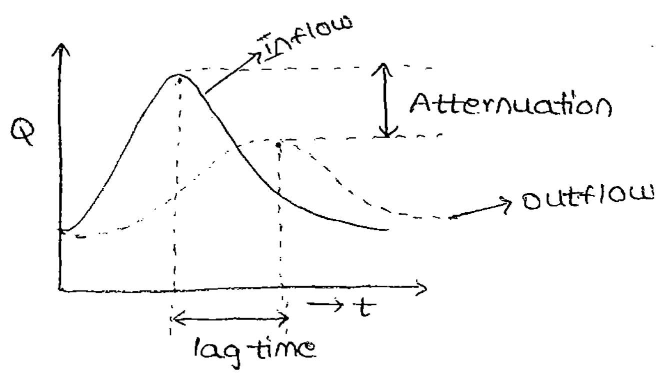


Inflow hydrograph



Outflow hydrograph

Outflow peak < Inflow peak



In these technique the effect of flood wave and entering the reservoir is studied to predict the variations of reservoir elevation and outflow discharges with time.

It is used in the design of spill way capacities.

Ex:- For a river the mean of maximum flood is 40-100 m and standard deviation is 1705 m^3/sec. If the frequency factor for the corresponding return period is 3.13, then the maximum flood corresponding to the return period is ___ m^3/s

A. Given $\bar{x} = 4200\ m^3/sec$

$\sigma = 1705\ m^3/sec$

$K = 3.13$

$x_T = ?$

$x_T = \bar{x} + K\sigma$

$= 4200 + 1705(3.13)$

x_T or $Q_p = 9536.65\ m^3/sec$

Ex:- An urban catchment area has 9 hectares of roads with runoff coefficient of 0.7, 18 hectares of long with runoff coefficient of 0.1 and 50 hectares of residential area of runoff coefficient 0.3. The weighted runoff coefficient for this area which is to be used in the rational formula is [b]

a) 0.37 b) 0.3 c) 0.1 d) 0.7

A. Given $A_1 = 9$ ha $C_1 = 0.7$

$A_2 = 18$ ha $C_2 = 0.1$

$A_3 = 50$ ha $C_3 = 0.3$

$$C = \frac{C_1A_1 + C_2A_2 + C_3A_3}{A_1 + A_2 + A_3}$$

$$= \frac{0.7(9) + 0.1(18) + 0.3(50)}{9 + 18 + 50}$$

$= 0.3$

Probable Maximum flood (PMF) :-

The extreme flood event which is physically possible which considers the rare event also. Whenever there is loss of life and property, PMF is adopted.

Eg:- Design of spillways, dams etc.

Standard Project flood (SPF) :-

The extreme flood event which occurs, excluding rare event.

Eg:- Adopted in the design of barriages.

$$\therefore SPF = 40 \text{ to } 60\% \text{ of } PMF$$

(or)

$$\therefore SPF < PMF$$

Item	Design Flood
1. Major and Medium projects with capacity more than 60 million m^3 (dams)	1. PMF. If PMF is not available we adopt Flood frequency study with T = 1000 years.
2. capacity /< 60 million m^3 (barriages)	2. SPF (or) Flood frequency is study with T = 100 years whichever is higher.
3. Irrigation structures like Aqueducts, small culverts etc.	3. We adopt flood frequency study with T = 50 years.
4. Inadequate data	4. Adopt Emprical formulae

P.g No:- 29

2. Given $A = 90$ hectares $= \frac{90 \times 10^4}{10^6} = 0.9$ km^2

$K = 0.4$

$I = 4.5$ cm/hr

$Q_p = 2.78\, K A I$

$= 2.78 \times 0.4 \times 0.9 \times 4.5$

$Q_p = 4.5$ m^3/sec

2. Ryue's formulae:

It is used in Karnataka, A.P, Telangana etc.

$$Q_p = C A^{2/3}$$

3. Inglis formula:-

It is used in Western ghats in Maharashtra.

$$Q_p = \frac{124 A}{\sqrt{A + 10.4}}$$

Flood Frequency method:-

1. Gumbel's method
2. Log - pearson Type III distribution
3. Log normal distribution.
4. Weibul distribution method.

Gumbel's method:-

$$X_T = \bar{x} + K \cdot \sigma$$

X_T = value of the variate 'x' of a random hydrolog series with a return period T

$\bar{x}$ = mean of variate

σ = standard deviation

K = frequency factor which depends on written peric and assumed frequency distribution.

Gumbel's distribution has a property which gives T = 2.33 y for the average of annual series when the data set is large. The value of flood with T = 2.33 years is called Mean annual flood.

Design Flood:-

The peak flood event used in the design of any hydraulic structure is called Design Flood.

Spill way design flood:-

The magnitude of the flood event used in the design of spillways is called spillway design flood. The two types of design floods are:

1. Probable maximum flood

UNIT - 9

MAXIMUM FLOOD ESTIMATION

Flood Estimation:-

In the Hydrograph, the important parameter is the flood peak. The various methods to determine the flood peak are

1. Rational formulae
2. Emprical formulae
3. Hydrographs
4. Flood frequency methods

Rational formulae:-

$$Q_p = 2.78\, C A I$$

Q_p = peak discharge in m^3/s

A = catchment area, km^2

I = Intensity of rainfall, cm/hr for a given return period

K (or) C = Runoff coefficient

$$R = K \cdot P$$

$$K = \frac{R}{P}$$

R = Runoff

K = Runoff coefficient

P = precipitation.

Limitation:-

1. $A \ngtr 50\ km^2$.
2. $D \geq t_c$

D = Duration of rainfall

t_c = time of concentration.

Emprical formulae:-

1. Dicken's formula :-

It is used in North India and central part of India

$$Q_p = C A^{3/4} \text{ (or) } K A^{3/4}$$

Q_p = peak flow, m^3/s

C (or) K = Runoff coefficient

11. Given $A = 36\ km^2$ $\quad Q_e = ?$ $\quad D = 2hrs$

$$Q_e = 2.778 \times A \times \frac{1}{D}$$

$$= 2.778 \times 36 \times \frac{1}{2}$$

$$Q_e = 50\ m^3/sec$$

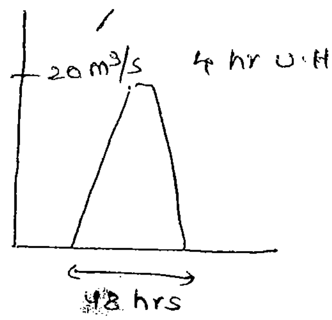
14. $$R.O.\ depth = \frac{R.O.\ volume}{Area}$$

$$0.01 = \frac{Area\ of\ triangle}{Area}$$

$$0.01 = \frac{\frac{1}{2} \times 48 \times 3600 \times 200}{A}$$

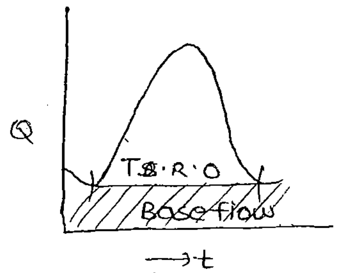
$$A = 1728 \times 10^6\ m^2$$

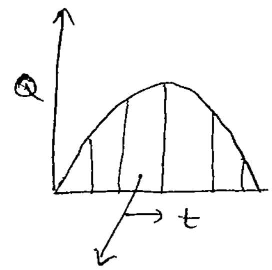
$$= 1728\ km^2$$



The correct sequence of these steps is

A) 3 2 1 4 B) 2 3 4 1 C) 3 1 2 4 D) 4 3 2 1





R.O depth = $\frac{\text{volume}}{\text{area}}$

= 3 cm

P.g No:- 25

4. Given A = 720 km^2 4 hr U.H

$Q_e = 2.778 A \cdot \frac{1}{D}$ ∴ D = Duration of U.H

$= 2.778 \times 720 \times \frac{1}{4}$

$Q_e = 500\ m^3/sec$

P.g No:- 26

2. Effective rainfall (or) = supra rainfall / Area (or) D.R.O volume / Area

3. Given / i = 1.5 cm/hr D = 4 hr Runoff depth = 40 mm

Infiltration = Rainfall − Runoff depth

Rainfall depth = 4 × 1.5 = 6 cm

R.O. depth = 40 mm = 4 cm

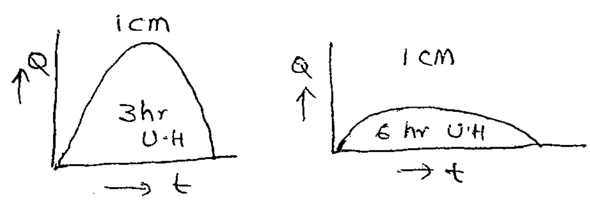
∴ Infiltration = 6 − 4 = 2 cm

Rate of infiltration = $\frac{2}{4}$ = 0.5 cm/hr

= 5 mm/hr

4. 3 hr UH $Q_p = 50\ m^3/sec$

6 hr UH $Q_p = < 50\ m^3/sec$



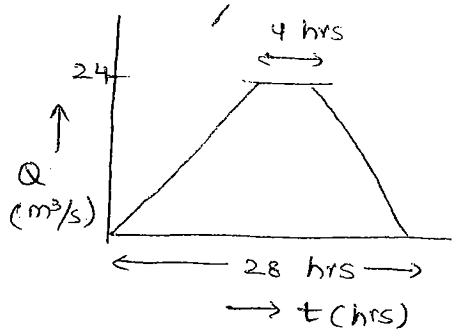
5. A = 10 km^2 = $10 \times 10^6\ m^2$

V = $10^7\ m^3$

depth = $\frac{\text{volume}}{\text{}} = \frac{10^7}{}$ = 1 m

 2 hr U.H

A. Runoff depth = $\frac{\text{volume}}{\text{Area}}$



Runoff depth = $\frac{\text{Area of trapezium}}{\text{catchment Area}}$

$0.01 = \frac{\frac{1}{2}[4+28] \times 3600 \times 24}{A}$

$A = 138.24 \times 10^6 \ m^2$

$= 138.24 \ km^2$

4. Theoretical equilibrium discharge in m³/sec for an effective rainfall of intensity 20 mm/hr continuously falling over a drainage area of 100 km² is

A.
$Q_e = 2.778 \cdot A \cdot \frac{1}{D}$

$= 2.778 \times 100 \times 2 \ cm^3/hr$

$= 555.6 \ m^3/sec$

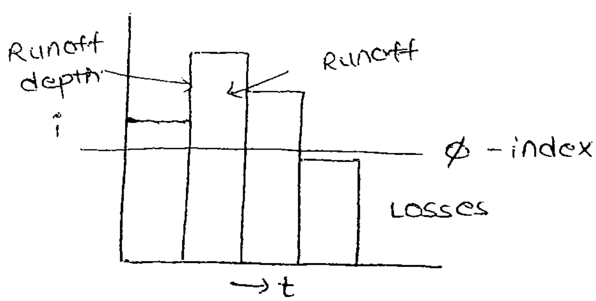
5. The following four hydrological features have to be estimated as inputs before one can compute the flood hydrograph at any catchment outlet [C]

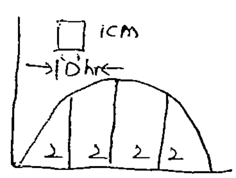
A) Unit Hydrograph B) Rainfall Hyetograph

c) Infiltration index D) Base flow.

The correct order in which they have to be employed or used in determining flood Hydrograph is

A) A, B, C, D B) B A D C c) B C A D D) D A C B





6. The following steps are involved in arriving the U.H

1. Estimating S.R.O in terms of depth

2. Estimating S.R.O in volume

3. Separation of baseflow

Duration of Unit Hydrograph:-

It is the time elapsed between begining and end off effective rainfall.

1. It should not exceed the least of
   a. Time of rise
   b. Basin lag
   c. t_c (time of concentration)

Instantaneous Unit Hydrograph:-

The unit hydrograph of zero duration is called Instantaneous Unit Hydrograph. It is imaginary conceptional U.H. It is independent of rainfall duration and indicates the catchment storage characteristics.

Ex:- S - curve is obtained by [C]
   A) summation of flood hydrograph
   B) Differentiation of flow mass curve
   C) summation of U.H D) using flow duration curve

2. The ordinates of 4 hr U.H of a basin in m^3/sec are 40, 250, 440, 600, 700 at 2 hr intervals. The area of the basin is [A]
   A) $1461.6\ km^2$ B) $1561.6\ km^2$ C) $1000\ km^2$ D) None

A) Runoff depth $= 0.36\ \Sigma Q \cdot \frac{\Delta t}{A}$

$1\ cm = 0.36\ \Sigma Q \cdot \frac{\Delta t}{A}$

$\Sigma Q = 40 + 250 + 440 + 600 + 700$

$= 2030\ m^3/sec$

$\therefore 1\ cm = 0.36 \times 2030 \times \frac{2}{A}$

$A = 1461.6\ km^2$

3. A 2 hour U.H can be approximated as trapezoidal. The U.H refers to a catchment area. [A]
   A) $138.24\ km^2$ B) $0.0384\ km^2$ C) $384\ m^2$ D) $3840\ m^2$

The S-curve reaches the maximum equilibrium discharge at time equal to the time base of the first U.H.

$$Q_e = 2.778 \cdot A\left(\frac{I}{D}\right) \quad m^3/sec$$

where

Q_e = equillibrium discharge, m^3/s

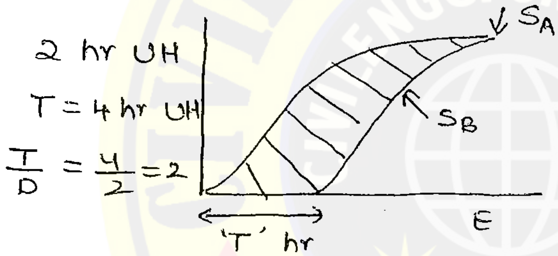
A = catchment area, Km^2

D = Duration of rainfall, hr

$\frac{I}{D}$ = Intensity of rainfall, cm/hr

Determine the 't' hours U.H from 'D' hr U.H:-

1. Develop S-curve for 'D' hr unit hydrograph
2. Lag S-curve obtained by 'T' hour
3. Find the ordinates of $(S_A - S_B)$ which represents the ordinate resulting from rainfall excess of $\frac{T}{D}$



Synthetic unit hydrograph:-

There may be some basins which do not have rainfall runoff relationships to derive unit hydrograph. In such situations a synthetic unit hydrograph is developed by using U.H of adjacent stations.

Synthetic U.H is not a U.H but however it is derived from U.H available for nearby stations.

It is developed by Synder.

Distibution graph:-

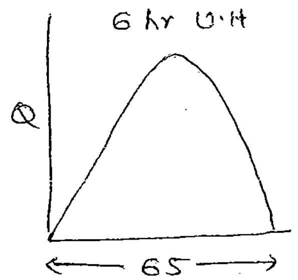
It is developed by Bernard in 1935.

1. It is a plot between percentage of surface runoff and time
2. It is used to study the variation of a U.H.
3. Distribution graphs are useful in comparing runoff characteristics of different catchments.

7. A 6hr U.H of an catchment of area 117 km^2 is triangular in shape with a base width of 65 hrs the DRO hydrograph of these catchment due to 2cm of effective rainfall in 6 hrs will have a peak flow rate in m^3/sec

A) 60 m^3/sec B) 37.5 m^3/sec C) 20 m^3/sec D) 12.5 m^3/sec

A) Given $A = 117\ km^2$



$$R.O.\ depth = \frac{\frac{1}{2} \times 65 \times 3600 \times Q_p}{117 \times 10^6}$$

(0.01) = 1 cm

$Q_p = 10\ m^3/sec$ in 1 cm of rainfall.

If a rainfall of 2cm, $Q_p = 20\ m^3/sec$

Defination of unit hydrograph:-

It is defined as hydrograph of D.R.O presenting from one unit depth (1cm) of rainfall excess occuring uniformly over the basin of the uniform rate for specified duration 't' hours.

1. Unit hydrograph is used to estimate flood hydrograph
2. It relates the DRO to the rainfall excess
3. The area of unit hydrograph represents the volume given by 1cm of rainfall excess over the catchment.
4. The term unit hydrograph represents unit diagram

Defination of S-curve:-

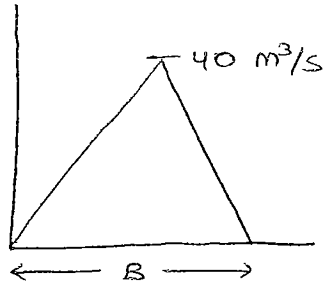
The method of super position can be used only when 'm' is a integer 1.

where, n = 1, 2, 3, 4, - - - -

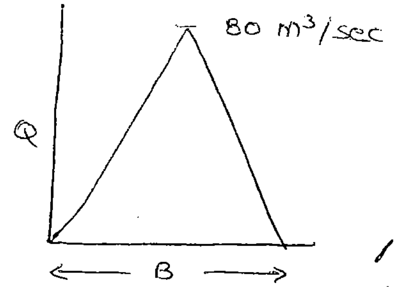
i.e., Given 2hr U.H I can develop 4hr U.H, 6hr U.H so on

1. when 'n' is a fraction method of super position can't be applied
2. In such cases 'S' curve method is used
3. 'S' curve hydrograph is defined as a hydrograph produced by a continuous effective rainfall at constant minute for an infinite period.
4. It is a curve obtained by summation of an infinite series of 't' hr unit hydrographs spaced 'D' hrs apart.

3 hr U.H



3 hr U.H



$A_1 = 250\ km^2$ $\qquad$ $A_2 = ?$

$$\underset{(0.01)}{R.O.\ depth} = \frac{volume}{area} = \frac{\frac{1}{2} \times B \times Q_{P_1}}{A_1} \rightarrow ①$$

$$0.01 = \frac{\frac{1}{2} B \times Q_{P_2}}{A_2} \rightarrow ②$$

① = ②

$A_2 = 500$ km

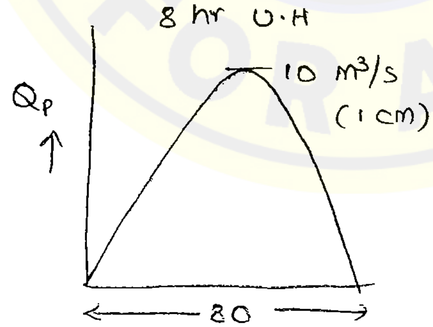
5. An 8 hr U.H of a catchment as a base of 80 hr and a peak of 10 m^3/s. If 2cm rainfall excess occurs in 8 hrs, the resulting DRO hydrograph will have [D]

A) a base of 160 hrs $\qquad$ B) A base of 40 hrs.

c) a peak of 5 m^3/sec $\qquad$ D) a peak of 20 m^3/sec

A)

8 hr U.H



1 cm - $Q_p = 10\ m^3/sec$

2 cm - $Q_p = 20\ m^3/sec$

6. A 596 km^2 catchment has a 12 hr U.H which can be approximated as a triangle. If its time base is 144 hrs, its peak ordinate is

A) 23 m^3/sec $\qquad$ B) 2 m^3/sec $\qquad$ C) 50 m^3/sec $\qquad$ D) 13 m^3/sec

A.

$$\underset{(0.01)}{R.O.\ depth} = \frac{\frac{1}{2} \times (144 \times 60 \times 60) \times Q_p}{596 \times 10^6}$$

$$= 23\ m^3/sec$$

2. As the duration of rainfall increases, intensity decreases and peak flow decreases.

7. Given $P = 1.2$ cm $D = 6$ hrs $\phi = 0.25$ cm/hr

Rainfall increases i.e., ~~Rainfall de~~ RO depth = ?

Excess ppt (or) RO depth = Total rainfall − losses

$= ~~1200~~ 1.2 \text{ cm} - 6 \times 0.25$

$= -0.3$ cm

$\cong 0$

Ex:- Indicate the Incorrect statement ↖ (incorrect statement for 1st Q only)

1. The chief components of ~~unit~~ hydrograph are [C]

A) Crest segment B) Rising limb C) Base flow D) Recession limb

2. Base flow seperation is performed on a [B]

A. Unit hydrograph to get DRO hydrograph

B. Flood hydrograph to obtain DRO hydrograph

C. Flood hydrograph to obtain rainfall hyetograph

D. Unit hydrograph to obtain S-curve

3. The effective rainfall hyetograph will have an area [C]

A) equal to the area of DRO hydrograph

B) equal to the total rainfall of the storm

C) which when multiplied by the catchment area gives area of the DRO hydrograph.

D) which when multiplied by the area gives area of flood hydrograph.

4. A 3hr unit hydrograph U_1 of a catchment of area 250 km² is in the form of a triangle with peak discharge of 40 m³/s Another 3 hr U.H U_2 is also triangular in shape and has same base width has U_1 but with a peak flow of 80 m³/s the catchment of which U_2 refers to an area of [D]

A) 125 km² B) 250 km² C) 1000 km² d) 500 km²

A) Given $U_1 = 40$ m³/s $U_2 = 80$ m³/s

Unit hydrographs are used to determine flood hydrographs (or) DRO hydrographs.

A t-hour unit hydrograph can be used to develop unit hydrographs of different duration by two methods.

1. Method of super position
2. S-curve technique.

Limitation:-

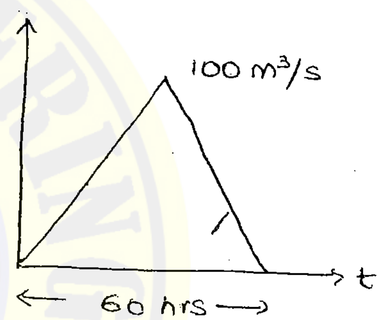
1. The unit hydrograph is applied for areas less than 5000 km^2 and more than 2 km^2

P.g NO:- 25

1. Area of catchment = 500 km^2

$= 500 \times 10^6 \, m^2$

Effective rainfall = ?



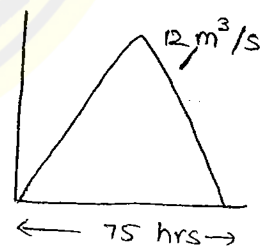
$$R.O.\ depth = \frac{RO\ volume}{catchment\ area}$$

$$R.O.\ volume = \frac{1}{2} \times (60 \times 3600) \times \frac{100}{500 \times 10^6}$$

$= 21.6$ cm

2. R.O. depth = 1 cm

$= 0.01$ m (6hr U.H is given)



$$D.R.O\ volume = \frac{1}{2} \times 75 \times 3600 \times 12$$

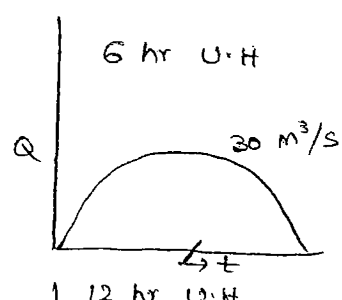
$$R.O.\ depth = \frac{volume}{area}$$

$$0.01 = \frac{\frac{1}{2} \times 75 \times 3600 \times 12}{A}$$

$A = 162 \, km^2$

3. ~~As the duration increases~~

1. For both 6hr U.H and 12hr U.H, the areas are same. In a 12hr U.H, as the duration is more its base time increases and to maintain the same area,



Unit hydrograph:-

It is proposed by shermen in 1935.

Assumptions:-

1. Rainfall is uniformly distributed over the entire area
2. Rainfall is uniformly distributed in a given duration.
3. ~~Time in-variance~~

Time Invariance:-

It means the direct runoff hyetograph for a given effective rainfall in a catchment area is same, irrespective of when it occurs.

3. Liner responge (or) Method of super position:-

If rainfall excess in a given duration is 'R' times the unit depth, the resulting direct runoff hydrograph will have ordinates equal to 'R' times the unit hydrograph ordinate.

Derivation of unit hydrograph:-

1. A hydrograph caused by rainfall excess of a given duration is selected.
2. Base flow is seperated.
3. The area under direct runoff hydrograph gives DRO volume
4. The runoff depth = Direct runoff volume / catchment Area

(or)

$$d\,(cm) = 0.36\, \Sigma Q \frac{\Delta t}{A}$$

where

ΣQ = sum of DRO ordinates in m^3/sec

Δt = uniform time interval in hours

A = catchment area in km^2

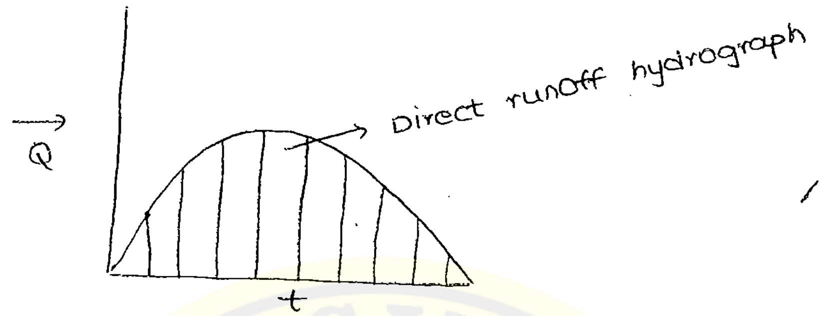
5. Divide the DRO ordinates by the runoff depth which gives the ordinates of unit hydrograph.

** Method : 2

1. Identify the point 'E' by using the formula. $N = 0.827 A^{0.2}$ day

N = No. of days from the peak.

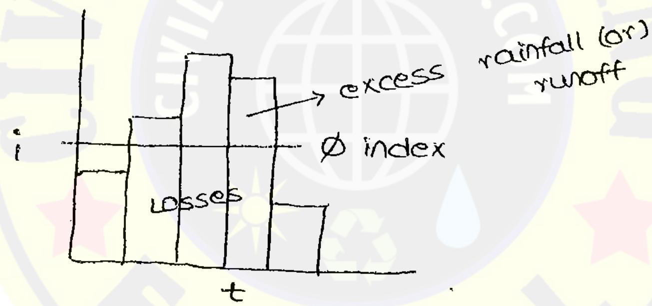
A = catchment Area in kms.



Area under DRO hydrograph given DRO volume

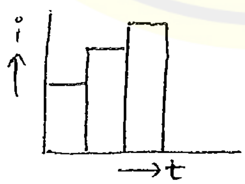
DRO volume = (ΣQ) time interval

RO depth or excess rainfall = $\frac{\text{DRO volume}}{A}$



Area under hyetograph ⟶ Total rainfall

Effective rainfall = Total rainfall − Losses



Area gives effective rainfall or supra rainfall or excess rainfall.

Both direct runoff hyetograph and effective rainfall hyetograph represent the same quantity i.e., rainfall excess but in different units.

The area of effective rainfall hyetograph gives the effective rainfall, which when multiplied by the catchment area gives the runoff volume.

Base flow hydrograph:-

Rising limb is controlled by climatic factors like Intensity of Rainfall, Duration of rainfall. The peak is attained after stopping of rainfall.

Basin Lag:-

Time difference between centroid of rainfall excess diagram to the centroid of hydrograph also called Lag time.

Lag time:-

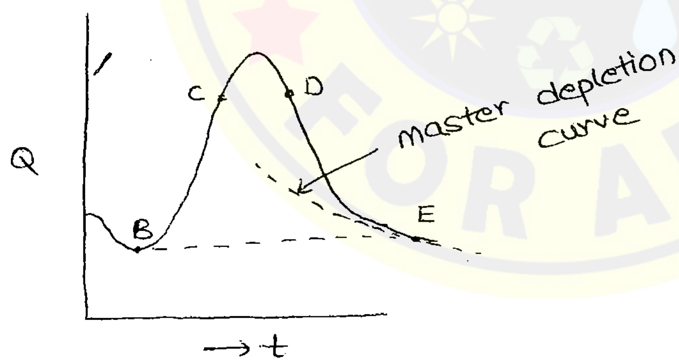
It is defined as the mean time of travel of water particles from all parts of the catchment to outlet during a given storm.

Separation of Base flow:-

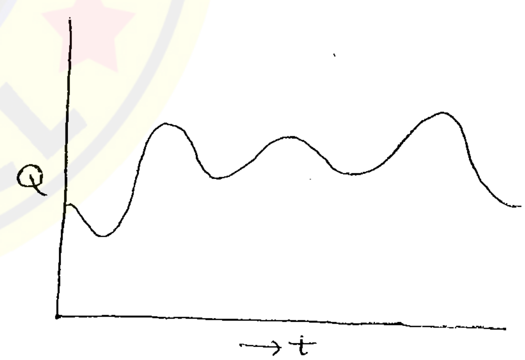
TRO = DRO + Base flow

DRO = TRO - Base flow

Master depletion curve technique is used to separate Base flow.



Isolated storm



Complex storm

The lower portions of recession limbs in a complex storms are plotted in a graph sheet.

A curve is drawn which overlaps all the lower portion of recession limbs called as Master depletion curve.

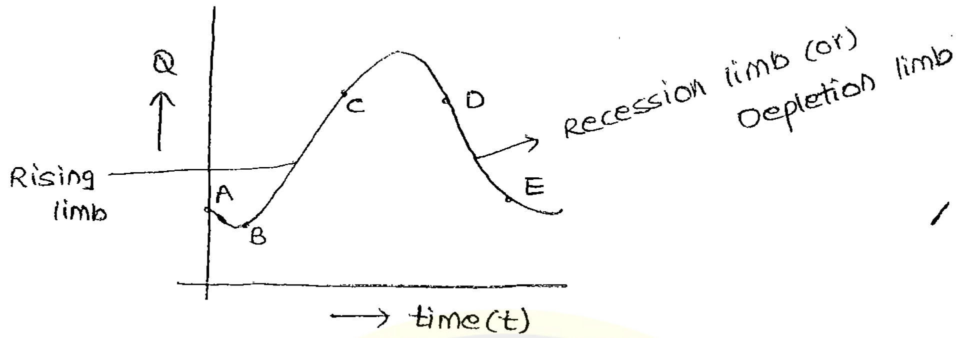
The master depletion curve is super imposed on the Hydrograph which meets the recession limb at point E. Join B and E points by drawing a line. The area below the BE line is called Base flow.

4-1-2015

UNIT – 8

** HYDRO GRAPHS

Hydro graph:-



AB = approach segment

B = point of raise

BC = Rising limb (or) concentration curve, which depends upon climatic factor.

B, C, D, E = Inflection points

C = stop or ceasing of rainfall

CD = crest portion which contains peak flow.

D = ceasing or stopping of surface runoff.

E = ceasing of prompt interflow or direct runoff anc commencement of base flow contribution.

Area under the hydrograph gives total Runoff volume i.e., from storm hydrograph (or) Flood Hydrograph.

Hydrograph are useful in the determination of flood flo

The lower most portion of total Runoff hydrograph represents base flow.

∴ DRO = TRO – Base flow

DRO = direct runoff

TRO = Total runoff

Recession limb is controlled by physiographic characteristic of catchment like shape of catchment, size of the catchment, slope of the catchment.

Relation between stream discharge and gauge height :-

$$Q = C_R (H - h_o)^n$$

H = gauge height

h_o = gauge reading corresponding to zero discharge

Area velocity method:-

It is used to determine the discharge in a river.

$$Q = Q_1 + Q_2 + Q_3 + \cdots$$

Dilution technique (or) chemical method (or) salt concentration method:-

Continuity equation is used.

Stage discharge Relation:-

Knowing the stage of River discharge can be measured using rating curve.

Note:-

Discharge can be measured by venturi flume (or) standing wave flume (or) partial flume.

To find out the mean velocity of flow the following methods are used:

1. Single point method — Depth of flow is less — velocity at y = 0.6

2. Two point method — Depth is moderate — $V_{mean} = \frac{V_{0.2y} + V_{0.8}}{2}$

~~3. Three point method~~ — Depth is very large — $V_{0.2y}$ = velocity at a depth of 0.2y from free surf

$V_{0.8y}$ = velocity at a depth of 0.8y from free surfa

3. Three point method — Depth is very large — $V_{mean} = \frac{V_{0.2y} + V_{0.6y} + V_{0.}}{4}$

Stage:-

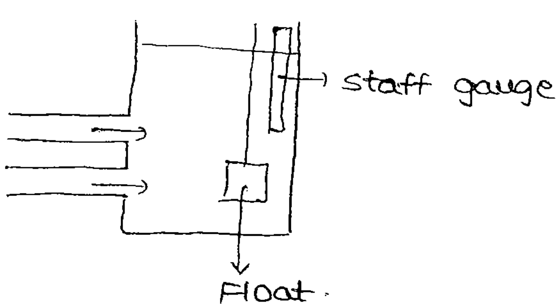
Stage is defined as water surface elevation w.r.t any datum like mean sea level.

Measurements:-

1. Staff gauge
2. Marking levels on abutments, piers etc by paint
3. Automatic stage recorder
4. Gauge well

Gauge well:-

It prevents the wave action on measurement of stag



Stream gauging:-

1. It measures the discharge in a river.
2. A station where stream flow is measure is called stream gauging station (or) Hydro metric station.
3. Stream flow measurement is essential in identifying the peak flows.
4. peak flows are needed in the design of Hydraulic structures like dams, weirs, barrages etc.

Determination of depth of flow:-

1. sounding rod technique
2. sounding cable

Determination of velocity of flow:-

1. Surface float method
2. Sub surface float method
3. Velocity rod method
4. current meter

Surface float method:-

$$V_s = \frac{distance}{time}$$

$$V_{mean} = K \cdot V_s$$

$$K = 0.85$$

$$\boxed{V_{mean} = 0.85\, V_s}$$

Current meter:-

It is used to measure velocity of flow. They are two types of current meters

1. price current meter:-

$$V = aN + b$$

V = velocity

N = No. of revolutions / unit time

a, b = constants.

Runoff estimation:-

1. Binnies % use in Madhya pradesh
2. Barlow tables use in Uttar pradesh
3. Strange tables use in karnataka, Tamilnadu

$$\text{Runoff} = \text{Runoff coefficient} \times \text{precipitation}$$

$$\text{Runoff} = K \cdot P$$

Emprical methods:-

1. Khosla's method :-

$$R_m = P_m - L_m$$

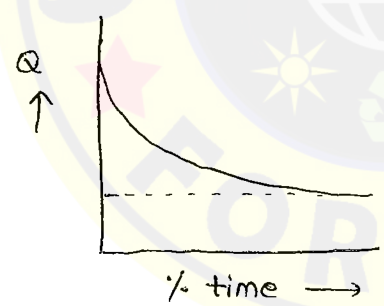
$$L_m = 4 T_m, \quad T > 4^\circ C$$

R_m = monthly runoff

P_m = monthly precipitation

L_m = monthly loss

Flow duration curve :-



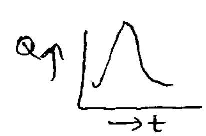
$$\text{Drainage density} = \frac{\text{Total length of channel}}{A}$$

$$\text{stream density} = \frac{\text{No. of streams}}{\text{Area}}$$

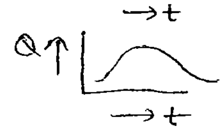
To qualitatively expressed shape,

$$\text{Form factor} = \frac{(\text{Axial length})^2}{A}$$

If Area increases, Drainage density increases



If Area increases, Drainage density decreases



Axial length of the basin:-

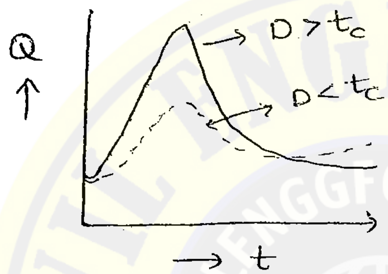
It is the horizontal distance between from the remotest point to the outlet point.

Factors affecting Runoff:-

a. Climatic factors:-

1. Intensity of Rainfall increases Runoff increases
2. Duration of Rainfall increases Runoff increases
3. $D > t_c$, maximum runoff peak is generated

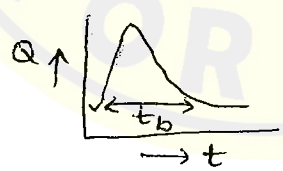
   $D < t_c$, maximum runoff peak cannot be generated.



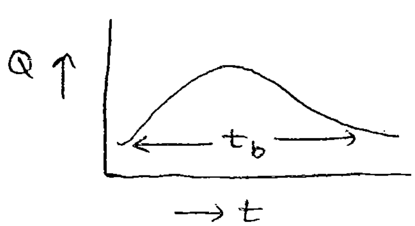
b. physiographic factors:-

1. shape of basin:-

→ Fan shaped catchment, quick peak is attained and the base time of the hydrograph is small



→ Fern shaped catchment, less peak is obtained and the base time is elongated.



Antecedent precipitation:-

The amount of moisture present in the soil prior to rainfall is called Antecedent precipitation. If Antecedent precipitation is more, runoff is more.

Virgin flow:-

The stream flow unaffected by the construction of hydraulic structures is called virgin flow.

Watershed (or) catchment (or) Drainage basin:-

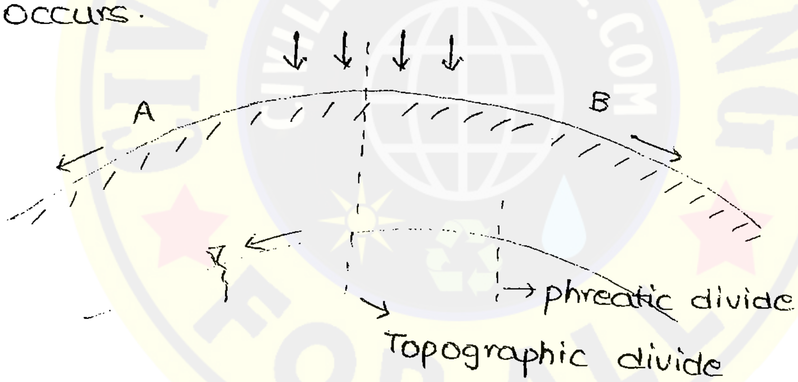
It is defined as the area which generate surface Runoff.

Topographic divide:-

The line which divides the surface runoff between two adjacent basin is called Topographic divide or watershed divide.

Phreatic divide (or) Ground water divide:-

The line which fixes the boundary of the area that contributes ground water runoff to the stream is called phreatic divide. When the two divides are not coincidence, watershed leakage occurs.



** Time of concentration (t_c):-

The time taken by the water to move from the remotest (or) Highest elevated point to the ~~outlet~~ outlet is known as Time of concentration (t_c).

Isochrone:-

Line joining points of equal time of concentration is called as an ~~eon~~ Isochrone.

Time of concentration is determined by Kirpitch formula

$$t_c = f(L, S)$$

UNIT - 6

RUNOFF

Runoff :-

It is defined as the excess precipitation absorbed on the surface of the land after meeting soil moisture deficite condition.

Interflow :-

The lateral seepage of water beneath the soil is called interflow (or) throughflow (or) seepage flow.

promt interflow :-

If the time taken for the interflow to come on to the surface is short called promt interflow (or) quick return flow.

Delayed interflow :-

If the time taken for the interflow to come on to the surface is long called as Delayed interflow.

Total Runoff :-

TRO = Direct Runoff (DRO) + Base flow

DRO = surface runoff + channel precipitation + promt interflow.

Base flow = Delayed interflow + Ground water flow.

Water year :-

1st June - 31st May is called water year.

Types of streams :-

1. perennial stream :-

Always carries some flow of water.

2. Intermittent stream :-

Less contribution of ground water

3. Ephemeral stream :-

No ground water contribution.

Total rainfall = 63.4 cm

Runoff = 24.4 cm

$$W\text{-index} = \frac{P - R - \text{loss}}{t}$$

$$= \frac{63.4 - 24.4 - 0}{12}$$

$$= 3.25$$

$$\therefore \phi\text{-index} = \frac{P_e - R}{t_e}$$

$$P_e = (7.8 + 3.9 + 10.6 + 5.4 + 7.8 + 9.2 + 6.5 + 4.4)$$

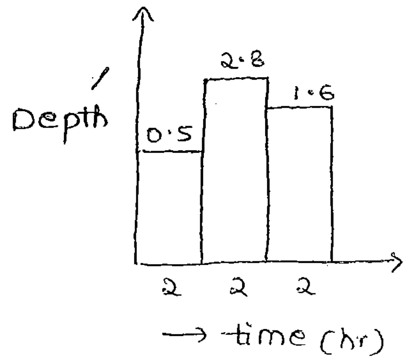
$$= 55.6$$

$$\therefore \phi\text{-index} = \frac{55.6 - 24.4}{8}$$

$$= 3.9 \text{ cm/hr}$$

Ex:- The rainfall during three successive 2 hour periods are 0·5, 2·8 and 1·6 cm. The surface runoff resulting from the storm is 3·2 cm. The ϕ-index is

A)



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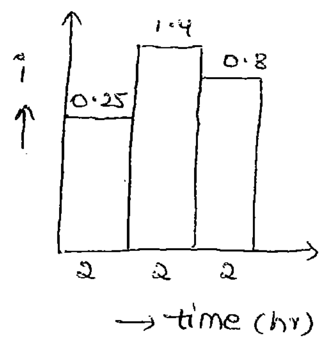


Total rainfall = 4·9 cm

Runoff = 3·2 cm

$$W\text{-index} = \frac{P - R - loss}{t}$$

$$= \frac{4\cdot9 - 3\cdot2 - 0}{6}$$

$$= 0\cdot28$$

$$\therefore \phi\text{-index} = \frac{P_e - R}{t_e}$$

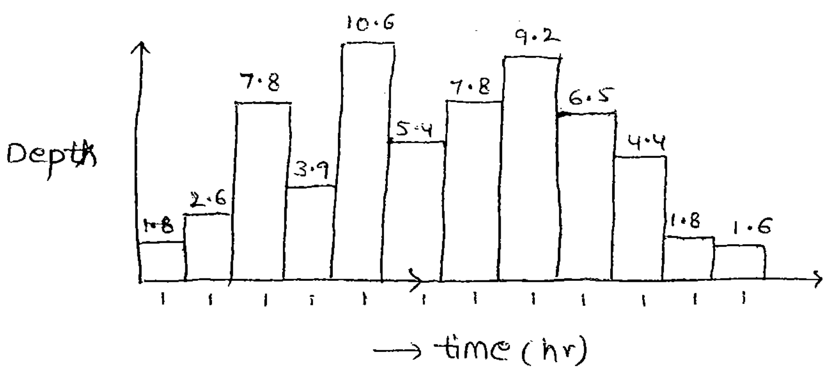
$$P_e = (1\cdot4 + \cdot8)\,2 = 4\cdot4$$

$$\phi\text{-index} = \frac{4\cdot4 - 3\cdot2}{4} = 0\cdot3 \text{ cm/hr}$$

Ex:- A 12 hr storm had the following depths for each hour occuring over a basin 1·8, 2·6, 7·8, 3·9, 10·6, 5·4, 7·8, 9·2 6·5, 4·4, 1·8 and 1·6 cm. The surface runoff is found to be 24·4 cm. The average infiltration index for the storm is

Ans:- 3·9 cm/hr

A.



Average rate of infiltration, $f = \frac{1.8}{6} = 0.3$ cm/hr

Note:-

1. ϕ - index represents rate of infiltration during period of runoff. Therefore

$$\phi\text{-index} = \frac{\text{Infiltration during period of runoff}}{\text{Duration of runoff}}$$

2. W - index represents rate of infiltration during the entire storm.

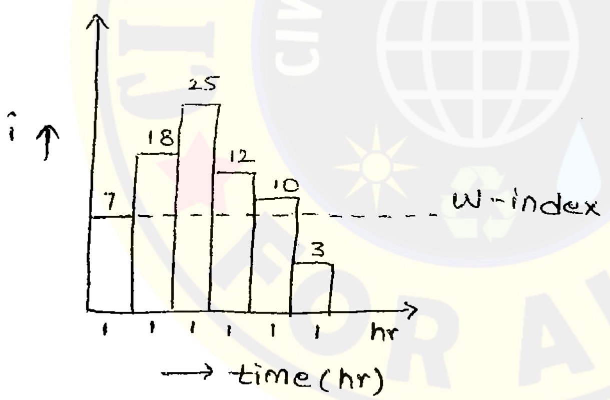
$$\therefore W\text{-index} = \frac{\text{Total infiltration during entire storm}}{\text{Duration of the storm}}$$

P.g No:- 18

3. Given

$i = 7, 18, 25, 12, 10, 3$ mm/hr

Runoff = 33 mm



T = 6 hours

Total rainfall = 7 + 18 + 25 + 12 + 10 + 3

$\therefore P = 75$ mm

Assuming losses = 0

$$W\text{-index} = \frac{P - R - L}{t}$$

$$= \frac{75 - 33 - 0}{6}$$

$$= 7 \text{ mm/hr}$$

Effective rainfall = 18 + 25 + 12 + 10 ⇒ 65 mm

ϕ - index = $P_e - R$ = $65 - 33$ = 8 mm/hr

2. W - index :-

$$W\text{-index} = \frac{P - R - \text{initial loss}}{\text{Time of excess}}$$

$\therefore \phi\text{-index} > W\text{-index}$

the ϕ-index line is called initial extractions like intersection, evaporation, and infiltration. Infiltration is the major contribution to the loss.

P.9 No:- 17

4. Given ϕ-index = 0.5 cm/hr

Rainfall = 2 cm

D = 6 hrs

Direct runoff = ?

Direct runoff = P - Loss

= 2 - (6 x 0.5)

= -1 ≈ 0

"-ve runoff means there is no runoff."

5.

$$\phi\text{-index} = \frac{P_{e_1} - R_1}{t_{e_1}} = \frac{P_{e_2} - R_2}{t_{e_2}}$$

$$= \frac{8-4}{8} = \frac{12 - R_2}{15}$$

$R_2 = 4.5$ cm.

7. Given i = 1.5 cm/hr D = 6 hrs, Runoff volume = 21.6×10^6 m^3

A = 300 km^2 = 300×10^6 m^2

Total rainfall depth = 6x1.5 = 9 cm

$$\text{Runoff depth} = \frac{\text{Runoff volume}}{\text{area}}$$

$$= \frac{21.6 \times 10^6}{300 \times 10^6} \text{ m}$$

= 7.2 cm

Infiltration depth = total rainfall - Runoff depth

= 9.0 - 7.2

= 1.8 cm

Factors affecting infiltration

1. Type of soil :-

   Sand, gravel, f_{cap} increases

   clayey soil, f_{cap} decreases

2. Nature of soil :-

   Dry soil, f_{cap} increases

   wet soil, f_{cap} decreases

3. Vegetative cover :-

   f_{cap} increases

4. Natural or artificial compaction of soil :-

   f_{cap} decreases. In temperature, f_{cap} increases

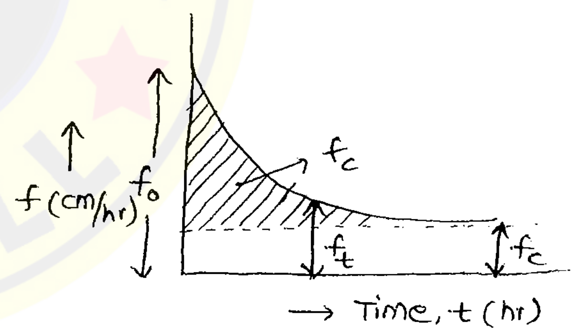
Measurement of Infiltration :-

1. Flooding type Infiltrometer
2. Rainfall simulator

** Horton's equation :-

$$f_t = f_c + (f_0 - f_c)\, e^{-K \cdot t}$$

$$K = \frac{f_0 - f_c}{F_c}$$



where

f_t = infiltration rate at any time, t

f_c = final infiltration rate

f_0 = initial rate of infiltration

t = time from beginning of the storm (rainfall)

Infiltration indices :-

1. ϕ - index :-

   The average rate of infiltration is known as infiltration index.

$$\phi\text{-index} = \frac{\text{effective rainfall} - \text{Run off}}{\text{time of excess}} = \frac{P_e - R}{t_e}$$

Blaney criddle method :-

$$PET = 2.54 \cdot \frac{K \cdot t \cdot p}{100}$$

K = crop coefficient

t = mean monthly temperature in °F.

$t°F = 1.8°C + 32$

P = percentage, monthly day light hours expressed as percentage of day light hours of an year.

The other methods are Penman method, Modified penman method, Thronawaite method.

Ex:- A reservoir has a water surface area of 100 hectares if the evaporation measured in IS pan is 0.4 cm/day, the volume of water evaporated in a month of 30 days, in m^3

a) 1, 20,000 b) 84,000 c) 72,000 d) 96,000.

A. Given $A = 100$ ha

$= 100 \times 10^4 \; m^2$ 1 hectare $= 10^4 m^2$

$E_p = 0.4$ cm/day

$t = 30$ days

$V = A \times C_p \cdot E_p$

$$= 100 \times 10^4 \times 0.8 \times \frac{0.4}{100} \times 30$$

$V = 96,000 \; m^3$

Ex:- A river has an average surface width of 20m. If the evaporation measured in the vicinity of the river by class A pan is 0.5 cm/day, the volume of water evapourated in a 60 km stretch of the river in a month of 30 days is

A. Given $B = 20m$, $L = 60km = 60000m$, $E_p = 0.5$ cm/day $= \frac{0.5}{100}$ m/d

$C_p = 0.70$, $A = 20 \times 60000$

$V = C_p \cdot E_p \times A$

$$= 0.7 \times \frac{0.5}{100} \times 30 \times 20 \times 60000$$

UNIT - 5

INFILTRATION

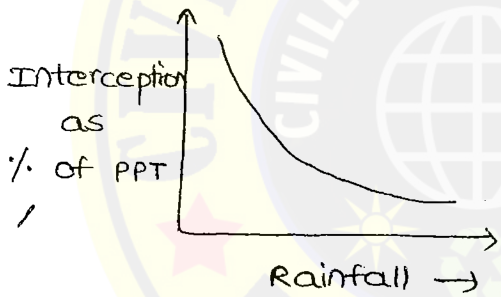
Infiltration:-

The movement of water from the surface into the surface of earth is called Infiltration. Initial loss and initial ~~obstruction~~ abstraction.

Interception loss :-

The amount of water lost from the liquid to the vapour state from vegetation. It does not include throughflow and stemflow.

1. Throughflow is the amount of water transferred from the leaf to the ground directly.
2. Steamflow is the amount of water transferred from the leaf to the branch, to the steam and to the ground.



As rainfall increases, interception decreases.

Infiltration capacity (f_{cap}) :-

1. It is the maximum rate at which a given soil can absorb water in a given time.
2. If 'i' is intensity of rainfall and 'f' is actual rate of infiltration.

$$i > f_{cap}, \quad f = f_{cap}$$

$$i < f_{cap}, \quad f = i$$

Units :-

$f =$ cm/hr (or) mm/hr

Control measures:-

1. Surface area to be minimum with maximum storage.
2. provide mechanical covers.
3. spraying of chemicals like cetyl alcohol, stearyl alcohol both are organic compounds. These form a mono layer on the water surface which prevents evaporation.

Emprical methods:-

1. Meyer's method
2. Rohwer's method
3.

Analytical methods:-

1. Water budget method

$$\text{Inflow} - \text{Outflow} = \frac{ds}{dt}$$

2. Energy balance method
3. Mass - transfer method

Evapotranspiration or consumptive use:-

It is the sum of Evaporation and transpiration.

$$ET = E + T$$

$$CU = E + T + (\text{water used by the plant for metabolic activity}) \rightarrow \text{negligible}$$

$$\therefore \boxed{ET \approx CU}$$

Factors affecting transpiration:-

1. plant factors:-

   Leave, size, shape

2. Soil factor:-

   Field capacity, permanent wilting point, available moisture

3. Climate factor:-

   Temperature, wind velocity, Humidity etc.

Field capacity:-

Field capacity is defined as the amount of moisture retained on the soil against the full of gravity is called ~~Pull of gravity~~. Field capacity.

Available Moisture = Field capacity − permanent wetting point

Measurement of Evapotranspiration:-

1. Lysimeter :-

It is an instrument use to measure evapotranspiration.

Potential Evapotranspiration :- (PET)

It is defined as evapotranspiration which occurs when sufficient moisture is always available to completely meet the needs of vegetation fully covering the area.

Actual Evapotranspiration (AET):-

It is the actual rate of evapotranspiration that will occur at a given time and place.

PET for clayey soil :-

PET for clayey soil = 1 (unity)

1. When moisture content at Field capacity, $\frac{AET}{PET} = 1$

$\therefore AET = PET$

2. When moisture content is < F.C, $\frac{AET}{PET} < 1$

$\therefore AET < PET$

3. When moisture content is Permanent welting point, AET = 0

Note:-

Highest PET in India, Rajkot (Gujarat) ≈ 215 cm

Isopleth :-

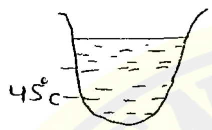
Line joining points of equal PET is called Isopleth.

Factors affecting evaporation process:-

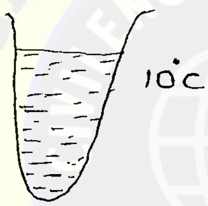
1. Surface area of water body increases, E_L increases
2. Temperature increases, E_L increases
3. Humidity increases, E_L decreases
4. Wind velocity increases, E_L increases

Depth of water:-

1. In shallow depth, E_L is more in summer and E_L is less in winter.



2. In deeper depth, E_L is decrease in summer and E_L is more in winter.



Atmospheric pressure:-

Dalton's Law:-

$$E_L \propto (e_w - e_a)$$

where,

e_w = Saturated vapour pressure of water

e_a = Saturated vapour pressure of air.

As ~~temperature~~ atmospheric pressure increases, e_a decreases $(e_w - e_a)$ decreases, e_L increases.

Atm pressure ↑, e_a ↓, $(e_w - e_a)$ ↓, e_L ↑

presence of solute or salt:-

$$E_L \propto (e_w - e_a)$$

As salt content ↑, e_w ↓, e_L ↓

For every 1% increase in salinity, evaporation decreases by

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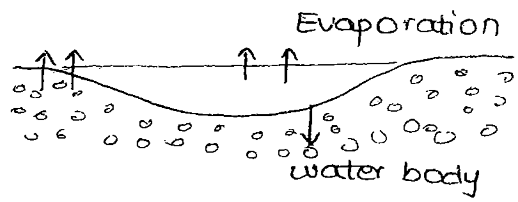
UNIT - 4

EVAPORATION AND EVAPOTRANSPIRATION

Evaporation process:-



Conversion of water from liquid state to vapour state is called Evaporation. It takes place during day and night.

Sublimation:-

Conversion of solid state to vapour state directly without passing the liquid phase

Ex:- Dry ice. (At a temperature of $-78°c$)

Transpiration:-

Conversion of liquid state to vapour state through plant metabolism. Transpiration is confined to day time only. Transpiration is measured by phytometer. Evaporation is measured by Atamometer and Evaporimeter.

Evaporimeter types:-

1. Class A pan:-

   Generally adopted in U.S.A. $C_p = 0.70$

2. Modified class A pan:-

   It is also called ISI pan, $C_p = 0.80$

3. Floating pan, $C_p = 0.80$

4. Colarado sunken pan

   $C_p = 0.78$

Lake evaporation, $E_L = C_p \cdot E_p$

volume of evaporation $= A \cdot E_L$

$$V = A \cdot C_p \cdot E_p$$

$N_B = 180.3 + 10\%$ of 180.3

$= 198.33$

$N_B = 180.3 - 10\%$ of 180.3

$= 162.27$

$P = \frac{1}{2}(153 + 145.1)$

$= 149.05$ cm

A station year method is used to determine the rainfall data by considering rainfall data of adiacent stations and also by considering return periods.

P.g NO:- 7

1. $N = \left(\frac{C_v}{e}\right)^2$

$C_v = \frac{\sigma}{\bar{P}}$

$= \frac{30.7}{92.8} \times 100$

$C_v = 33.08\%$

$N = \left(\frac{33.08}{10}\right)^2$

$N = 10.94 \approx 11$ NO's

2. 1 per 520 km^2 for plain areas

For 1000 km^2 = 2 NO's

3. Given

$C_v = 33\%$, $N = 5$

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

$e^2 = \frac{C_v^2}{N}$

$= \frac{33^2}{5}$

$e = 85.24\%$

5. Given

$N_A = 170.6$ $P_A = 153$ cm

$N_B = 180.3$ $P_B = ?$

$N_C = 165.3$ $P_C = 145.1$ cm

$\frac{P_B}{N_B} = \frac{1}{m}\left(\frac{P_A}{N_A} + \frac{P_C}{N_C}\right)$ for $N_A, N_C > N_B \pm 10\%\ N_B$

$P_B = \frac{1}{m}(P_A + P_C)$ for $N_A, N_C = N_B \pm 10\%\ N_B$

$N_B = 180.3 \pm 10\%$ of N_B

Instruments which records variation of atmospheric pressure use barograph.

1. wind velocity – Enemometer
2. wind direction – wind vane
3. Humidity – Hygrometer (or) psychrometer
4. Radiation – pyranometer
5. Sunshine – sunshine recorder
6. Evaporation – Atmometer (or) Evaporimeter

Continuous recording of Humidity by an automatic recording instrument is hydrograph.

P.g No:- 12

2. Given $T = 100$ years $N = 50$ years

$$P = \frac{1}{T} = \frac{1}{100} = 0.01$$

$$P = 1 - q^n \qquad \therefore q = 1 - P$$

$$= 1 - (1 - 0.01)^{50}$$

$$= 0.3949$$

$$P = 39.49\%$$

Risk : probability of occurence of an event atleast once.

Ex:- A rainfall of certain high intensity expected to occur once in 20 years. What is the probability that this event may occur in next 12 years.

A. Given $T = 20$ years, $P = \frac{1}{T} = \frac{1}{20} = 0.05$

$$P_1 = 1 - q^n$$

$$= 1 - (1 - 0.05)^{12}$$

$$P_1 = 45.96\%$$

Ex:- The return period for annual maximum flood of a given magnitude is 8 years. The probability that this flood magnitude will be exceeded once during next 5 years?

A. Given $T = 8$ years $P = \frac{1}{T} = \frac{1}{8}$

$$P = 1 - q^n$$

2. It can be observed that has the area increases the maximum depth of rainfall decreases.

3. For a given area has duration of rainfall increases the maximum depth of rainfall increases.

Depth - area relations :-

$$\bar{P} = P_0 \times exp(-K \cdot A^n)$$

(or)

$$\bar{P} = P_0 \cdot e^{-K \cdot A^n}$$

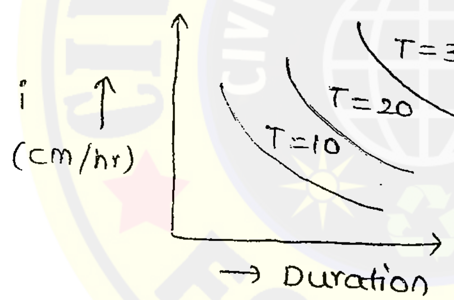
where,

$\bar{P}$ = Average depth of rainfall in cm over an area (A) in km^2

P_0 = highest amount of rainfall in cm

K, n = are constants for a given region.

Intensity - duration - frequency Relationship :-



1. As duration of rainfall increases the intensity of rainfall decreases.

2. For a given duration, has return period increases, intensity of rainfall increases i.e., storms of higher intensity in that duration become true.

Isopulvial line :-

It is defined as line joining points of equal depth of rainfall for a given duration and return period.

Instruments used to measure various meteriological data. The details are recorded in the weather station twice a day, 8·30 AM and 5·30 PM.

Atmospheric pressure measured by barometer, and Aneroid barometer.

$$P_{r,n} = {}^{n}C_{r} \times p^{r} \times q^{(n-r)}$$

$$\boxed{P_{r;n} = \frac{n!}{r!\,(n-r)!} \times p^{r} \times q^{(n-r)}}$$

3. probability of an event not occuring

$$\boxed{P_{0,n} = q^{n}}$$

4. probability of an event occuring at least once (Risk in failure of hydraulic structure).

$$\boxed{P_{1} = 1 - q^{n}}$$

Weibul formulae:-

Arrange the data in descending order

Rainfall data	Rank order (M)
1200 mm	1
1100 mm	2
900 mm	3
⋮	⋮

$$P = \frac{M}{n+1}$$

$$\text{(or)} \quad T = \frac{1}{P} = \frac{(n+1)}{M}$$

where,

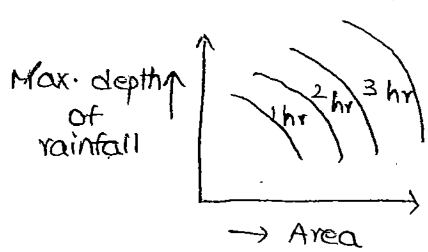
n = total no. of observations

M = Rank (or) Order number.

California formula:-

$$T = \frac{n}{M}$$

Depth - area - duration (D·A·D) analysis:-



1. DAD analysis is used in the design of culverts, estimation of

UNIT - 3

FREQUENCY OF POINT RAINFALL & PROBABILITY

Point Rainfall :-

It is the average depth of rainfall of a rain gauge station. It can be daily rainfall data (or) weekly (or) monthly (or) annually.

Probable maximum precipitation (PMP) :-

It is defined as the greatest depth of rainfall that can occur in a given duration at a given locations. This is used in the estimation of probable maximum flood.

$$PMP = \bar{P} \times K \cdot \sigma$$

$\bar{P}$ = Average rainfall

σ = standard deviation of rainfall

K = frequency factor.

Return period (or) Reccurance interval (or) frequency :-

The probability of occurance of an event whose magnitude is equal to (or) in excess of a specified magnitude is called a return period.

$$P = \frac{1}{T} \quad (\text{or}) \quad T = \frac{1}{P}$$

Ex:- Event = 24 cm of rainfall in 24 hrs (or) > 24 cm say the above event is occuring in once in 10 years.

∴ probability of occurance of this event

$$P = \frac{1}{T} = \frac{1}{10} = 0.1$$

$$T = \frac{1}{P}$$

where

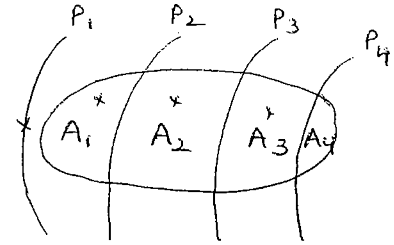
T = Return period

P = probability of occurance of an event

1. probability of non- occurance of an event, $q = 1 - p$
2. Probability of occurance of an event occuring, r times in 'n' years.

Iso hyetal method :-

Line joining points of equal rainfall is known as Isohyete.



$$\bar{P} = \frac{A_1\left(\frac{P_1+P_2}{2}\right) + A_2\left(\frac{P_2+P_3}{2}\right) + \cdots}{A_1 + A_2 + \cdots}$$

It is best method.

where

A_1 A_2 A_3 = areas enclosed between succesive Isohyete

P_1 P_2 P_3 = average rainfall values.

Out of all the three methods, Isohyetal method is an accurate method which gives the true average rainfall representation in the basin.

P.9 No:-9

3. Given $A_1 = 75$ $A_2 = 125$ $A_3 = 150$ $A_4 = 150\ km^2$

$P_1 = 3$ $P_2 = 5$ $P_3 = 4$ $P_4 = 6\ cm$

$$\bar{P} = \frac{A_1P_1 + A_2P_2 + A_3P_3 + A_4P_4}{A_1 + A_2 + A_3 + A_4}$$

$$\bar{P} = \frac{75\times3 + 125\times5 + 150\times4 + 150\times6}{75 + 125 + 150 + 150}$$

$\bar{P} = 4.7\ cm$

4. Given $P_1 = 10$, $P_2 = 15$, $P_3 = 20$, $P_4 = 25\ cm$

$\frac{A_1}{A} = 0.1$ $\frac{A_2}{A} = 0.2$ $\frac{A_3}{A} = 0.3$ $\frac{A_4}{A} = 0.4$

$$\bar{P} = \left(\frac{A_1}{A}\right)P_1 + \left(\frac{A_2}{A}\right)P_2 + \left(\frac{A_3}{A}\right)P_3 + \left(\frac{A_4}{A}\right)P_4$$

$= 0.1\times10 + 0.2\times15 + 0.3\times20 + 0.4\times25$

1-1-2015

UNIT - 2

MEAN PRECIPITATION CALCULATION

Average depth of rainfall over an area /also called as equivalent uniform depth of rainfall. It can be determined by following methods.

1. Arithmatic mean method
2. Theissen polygon method
3. Isohyetal method.

Arithmatic mean method (or) Un weighted mean method :-

$$\bar{P} = \frac{P_1 + P_2 + \cdots + P_m}{m}$$

$$\bar{P} = \frac{1}{m} \sum_{i=1}^{m} P_i$$

Theissen polygon method (or) weighted mean method :-

$$\bar{P} = \frac{A_1 P_1 + A_2 P_2 + \cdots + A_n P_n}{A_1 + A_2 + \cdots + A_n}$$

$$\boxed{\bar{P} = \frac{A_1 P_1 + A_2 P_2 + \cdots + A_n P_n}{A}}$$

$$\bar{P} = \frac{A_1}{A} \cdot P_1 + \frac{A_2}{A} \cdot P_2 + \cdots$$

$\frac{A_1}{A}, \frac{A_2}{A} \cdots$ Theissen weight (or) weighted factor

$$\frac{A_1}{A} + \frac{A_2}{A} + \cdots = 1.0$$

where

$\bar{P}$ = Average precipitation.

A_1, A_2, A_3 = Areas of polygon

P_1, P_2, P_3 = precipitation (or) rainfall values at raingauge stations.

Theissen polygon method is better when compared to arithmati mean method.

Rain gauge network :-

1. 10% of total no. of raingauges should be recording type.
2. As per the IS code, 1 rain gauge for every 520 km^2 to be provided in plain topographic areas.
3. In hilly areas, 1 rain gauge for every 130 km^2 to be provided
4. An area at an elevation of 1000 m above mean sea level 1 rain gauge station for an area of 260 to 390 km^2.

Optimal no. of rain gauges (or) Adequecy of Rain gauges :-

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

where,

N = optimal no. of rain gauge

C_v = coefficient of variation

e/ = percentage error

General error in % ≈ 10%.

$$C_v = \frac{\text{Standard deviation}}{\text{Average Rainfall}}$$

$$C_v = \frac{\sigma}{P \text{ (or) } P_0}$$

1. Used to check the consistancy of rainfall data.
2. Rainfall data can be inconsistant due to the following reasons.
   i. change in location of rain gauge station.
   ii. change in surroundings of a rain gauge station.
   iii. change in instrument.

$$(P_x)_c = P_x \times \frac{m_c}{m_a}$$

$(P_x)_c$ = corrected precipitation at station - x.

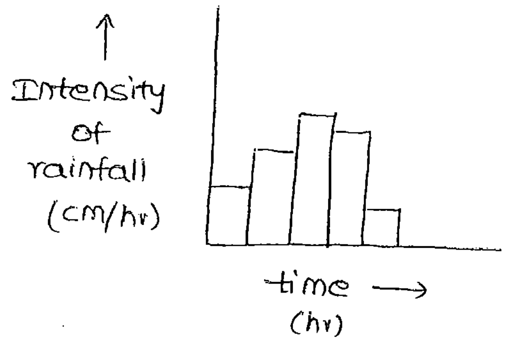
P_x = precipitation at station x which is not consistant

M_c = slope of the actual line which is extended

M_a = slope of actual line BC

Double mass curve is plot between the cumulative rainfall @ station - x and consideration on y-axis and cumulative depth of rainfall

Hyetograph :-



1. plot between intensity of rainfall and time period.
2. Mass curve and hyetograph gives the pattern of rainfall
3. The area under the hyetograph gives the total depth of rainfall in a given duration

Normal Rainfall :-

It is defined as the average amount of rainfall for period of 30 years.

Normal ratio method :-

To determined the missing rainfall data. this method is adopted.

Let P_1 P_2 P_3 .P_x . . P_m be the annual precipitation values of different rain gauge stations.

Let N_1 N_2 N_3 .N_x . . N_m be the normal annual precipitation

For a given data 'P_x' is to be determined.

$$\frac{P_x}{N_x} = \frac{1}{m}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \cdots + \frac{P_m}{N_m}\right]$$

where

m = total no. of rain gauges stations excluding stations and under test.

$N_1, N_2 \cdots > N_x \pm 10\%$ of N_x

$N_1, N_2, \cdots = N_x \pm 10\%$ of N_x

$$P_x = \frac{1}{m}\left[P_1 + P_2 + \cdots + P_m\right]$$

Note:-

520 km² – provide 1 rain gauge (plain areas)

130 km² – provide 1 rain gauge (hill areas)

Anticyclone :-

Rainfall occurs due to high pressure and the winds mov in the clock wise direction in the northern hemisphere and anticlock wise in southern Hemisphere. It gives less rainfall.

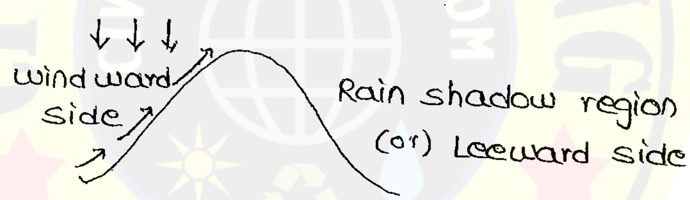
2. Convective precipitation:-

The surface of the ground gets heated up, airmass above the ground receives high temperature, air mass moves t higher altitudes cools down and condenses in the form of rainfa called as convective precipitation.

3. Orographic precipitation:-

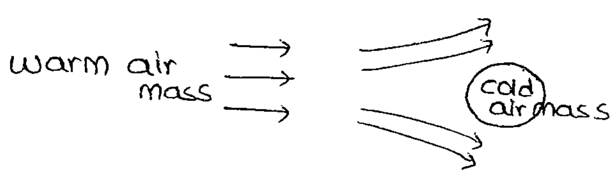
When the moist air mass is obstructed by a barrier like mountains, the moist air mass moves to higher altitudes and gives precipitation called as Orographic precipitation.

Windward side receives more amount of rainfall. Leward side receives less amount of rainfall (or) Rain shadow region

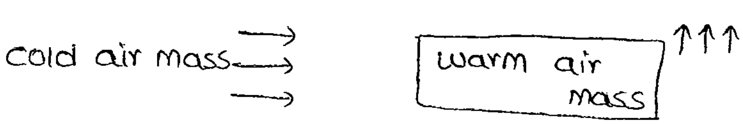


Warm front and cold front :-

When warm air mass is obstructed by cold airmass the warm air mass moves up to higher altitudes and cools down known as warm moist.



When cold air mass is encounters (or) comes across a warm airmass, the warm air mass is displaced upwards. In both cases light precipitation is received called as Frontal precipitatio



Note:-

Cyclonic precipitation is non-frontal precipitation.

Measurement of rainfall :-

Rainfall is measured by Rain guage is also called pluviometer, Ombrometer, hyetometer.

Types of Rain gauges:-

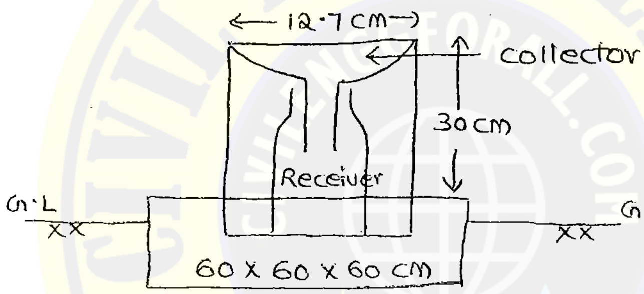
1. Non recording type :-

It measures only the depth of rainfall and does not give other details of rainfall.

2. Recording type:-

It gives the details of rainfall like time of rainfall, end of rainfall, depth of rainfall etc.

The Indian standard non-recording type is simon's rain gauge.



simon's raingauge.

Tipping bucket type (or) Telemetric gauge:-

1. Used in inaxisible area (or) hilly region.
2. Intensity of rainfall can be measured and hyetograph can be developed.
3. Weighing time and siphon type measure rainfall and gives mass curve.
4. weighing type also measures snow fall.
5. The standard recording type is siphon type (or) float type rain gauge.

Mass curve :-

Mass curve is a plot between cumulative rainfall on y-axis and time period on x-axis.

The slope of the line joining of two points on mass curve gives intensity of rainfall.

Fish ladder:-

To make the fish move from upstream to downstream and downstream to upstream baffle walls are provided to lower the velocity. The limiting velocity is 3.5 m/s

Silt control devices:-

Silt excluder:-

Excludes entry of silt into the canal. It is provided infront of the regulator.

Silt ejector:-

It is provided on the canal where the silt is collected and later pumped out from the canal.

** Failures of weirs on permeable foundations:-

1. Surface failures:-

1. Rupture ofn the surface of floor due to hydraulic jum
2. Scouring of floor or erosion.

2. Subsurface failure:-

1. piping (or) Under mining
2. Uplift pressure.

Remedial measures:-

1.
1. provide more thickness of floor near the hydraulic jum formation area.
2. provide launching aprons and upstream, downstream pile

2.
1. To increase the percolating passage of water by providing the impervious floors, upstream and downstream piles.
2. Due to seepage of water, uplift pressure is exerted on the floor of the weir. on the upstream side uplift is resisted by water. therefore nominal thickness is sufficient On the downstream side as there is no water the