HYDROLOGY

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A Handbook on

HYDROLOGY

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রাজশাহী প্রকৌশল ও প্রযুক্তি বিশ্ববিদ্যালয়
পুরকৌশল বিভাগ
রোল নং: ১৩০১১০

HYDROLOGY

MMM part.

Introduction

Q. What do you know about hydrology?

Answer: **Hydrology:-**

New latin hydrologia, from Latin hydor – + -logia – logy.

Hydrology is a science dealing with the properties, distribution, and circulation of water on and below the earth's surface and in the temperature.

Hydrology is the science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle.

⇒ What hydrologists Do?

1. Hydrologists apply scientific knowledge and mathematical principles to solve water-related problems in society: problems of quantity, quality and availability.

2. They may be concerned with finding water supplies for cities or irrigated farms, or controlling river flooding or soil erosion. Or, they may work in environmental protection: preventing or cleaning up pollution or locating sites for safe disposal of hazardous wastes.

3. Persons trained in hydrology may have a wide variety of job titles. Scientists and engineers in hydrology may be involved in both field investigations and office work. In the field, they may collect basic data, oversee testing of water quality, direct field crews and work with equipment. Many jobs require travel, some abroad.

4. In the office, hydrologists do many things such as interpreting hydrologic data and performing analyses for determining possible water supplies.

5. Much of their work relises on computers for organizing, summarizing and analyzing masses of data, and for modeling studies such that as the prediction of flooding and the consequences of reservoir releases or the effect of leaking underground oil storage tanks.

5. The work of hydrologists is as varied as the use of water and may range from planning multimillion dollar interstate water projects to advicing homeowners about backyard drainage problems.

⇒ Careers in Hydrology:

1. Students who plan to become hydrologists need a strong emphasis in mathematics, statistics, geology, physics, computer science, chemistry and biology.

2. In addition, sufficient background in other subjects – economics, public finance, environmental law, government policy – is needed to communicate with experts in these fields and to understand the implications of their work on hydrology.

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GROUND WATER

Introduction:-

- Over 70% of the earth's surface is covered in water.
- But of that water, just 1% is readily available for human use, and of that 1%, 99% of it is stored beneath our feet as groundwater.
- We all rely on groundwater in some way, so its important that we understand this vital resource.

Since the 1960's, groundwater has been used extensively as the main source of drinking and irrigation water supply. About 75 percent of cultivated land is irrigated by ground water and the remaining 25 percent by surface water. Of the abstracted groundwater about 70-90 percent is used for agricultural purposes and the rest for drinking and other water supplies.

What is Groundwater?

Answer: **Groundwater:** Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers.

The area where water fills the aquifer is called the saturated zone. The top of this zone is called the water table. The water table may be located only a foot below the grounds surface or it can sit hundreds of feet down.

⇒ How much we depend on groundwater?

Answer:-

(I) Groundwater supplies drinking water for 90% of the total ~~Bangladesh~~ population of Bangladesh.

(II) Groundwater helps grow our food. 70% to 90% of groundwater is used for irrigation to grow crops.

(III) Groundwater is an important component in many industrial processes.

(IV) Groundwater is a source of recharge for lakes rivers and wetlands.

⇒ Write down the Advantages of Groundwater over surface water. 01,08.

Answer: Advantages are given below:

(I) GW is clean, colorless. and almost free from turbidities

(II) GW is free from pathogenic organism which causes disease

(III) GW is rich with several minerals which are beneficial to health.

(IV) For most cases GW needs no treatment.

(V) GW have uniform temperature in all most all the year.

(VI) About 90% drikable water is stored as ground water.

(VII) GW is available for irrigation in dry season when surface water is not available.

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(VIII) Ground water storage is free from atomic attack.

* Saturated zone: The subsurface zone in which all rock openings are filled with water. is known as saturated zone.

Water Table: The upper surface of the zone of saturation is known as water Table.

Vadose zone: A subsurface zone in which rock openings are generally unsaturated and filled partly with air and partly with water; above the saturated zone, is known as vadose zone.

* Capillary fringe: A transition zone with higher moisture content at the base of the vadose zone just above the water table is known as capillary fringe.

⇒ The movement of ground water?

Answer:

(a) most ground water moves relatively slowly through rock underground.

(b) Because it moves in response to differences in water pressure and elevation, water within the upper part of the saturated zone tends to move downward following the slope of the water table.

⇒ Factors affecting the flow of ground water:-

(a) The slope of the water table - the steeper the water table, the faster ground water moves.

(b) Permeability - If rock pores are small and poorly connected, water moves slowly; when openings are large and well connected, the flow of water is more rapid.

Definitions:

Aquifer: An AQUIFER is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand or silt) from which ground water can be extracted using a water well.

Example. sand.

Aquiclude: The opposite of an aquifer. An aquiclude is a subsurface rock, soil or sediment unit that does not yield useful quantities of water. It may be porous and capable of containing water, but the transmission rate is so poor that it cannot be considered to be a water source.

Example Clay and shale are typical aquicludes.

Aquifuge: An aquifuge is an impermeable formation neigther containing nor transmitting water.

Example solid Granite, Basalt.

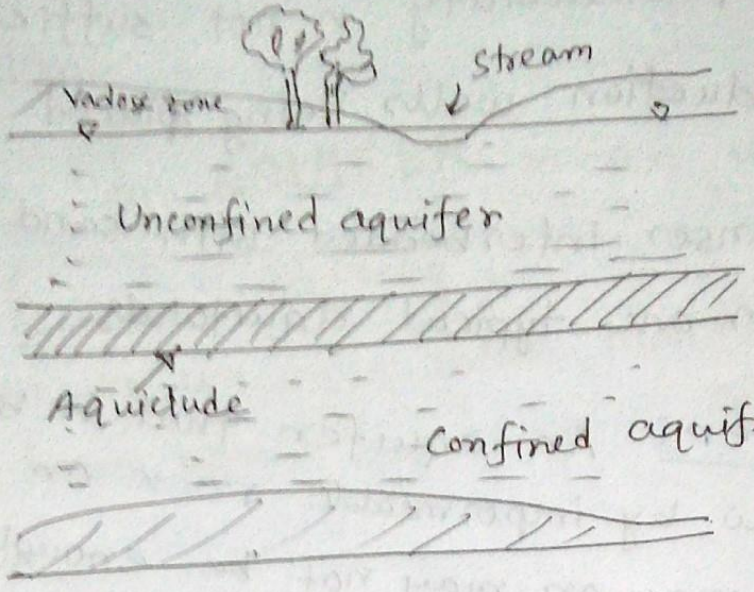
Aquitard: An aquitard is a geological unit that is permeable enough to transmit water in significant quantities when viewed over large areas and long periods, but its permeability is not sufficient to justify production wells being placed in it.

Examples: Clay lenses interbedded with sand, clays, loams and shales are typical aquitards.

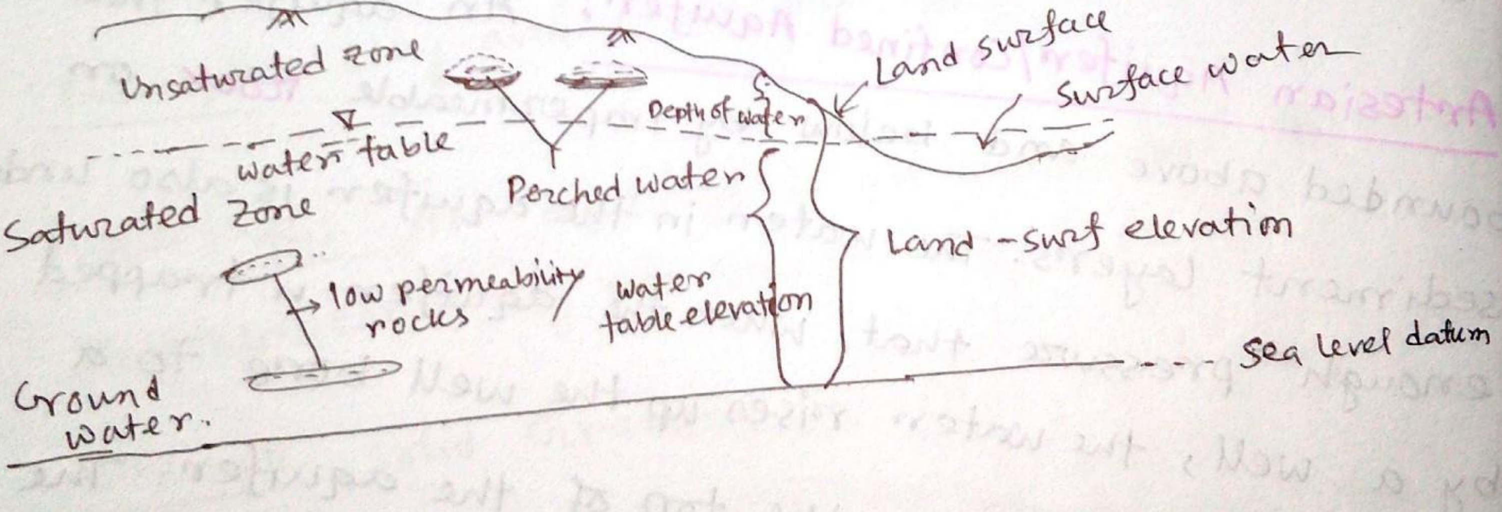
Confined Aquifer: An aquifer that is bounded above and below by impermeable rock or sediment layers. There may or may not be enough pressure in the aquifer to make it an "artesian aquifer".

Unconfined Aquifer: An aquifer that is not overlain by an impermeable rock unit. The water in this aquifer is under atmospheric pressure and is recharged by precipitation that falls on the land surface directly above the aquifer.

Artesian Aquifer/Confined Aquifer:- An aquifer that is bounded above and below by impermeable rock or sediment layers. The water in the aquifer is also under enough pressure that, when the aquifer is trapped by a well, the water rises up the well bore to a level that is above the top of the aquifer. The water may or may not flow onto the Land surface.



Perched Aquifer: A perched water table (or perched aquifer) is an aquifer that occurs above the regional water table, in the vadose zone. This occurs when there is an impermeable layer of rock or sediment (aquiclude) or relatively impermeable layer (aquitard) above the main water table/aquifer but below the surface of the land.



Leaky Aquifer:- A leaky aquifer, also known as a semi-confined aquifer, is an aquifer whose upper and lower boundaries are aquitards, or one boundary is an aquitard and the other is an aquiclude.

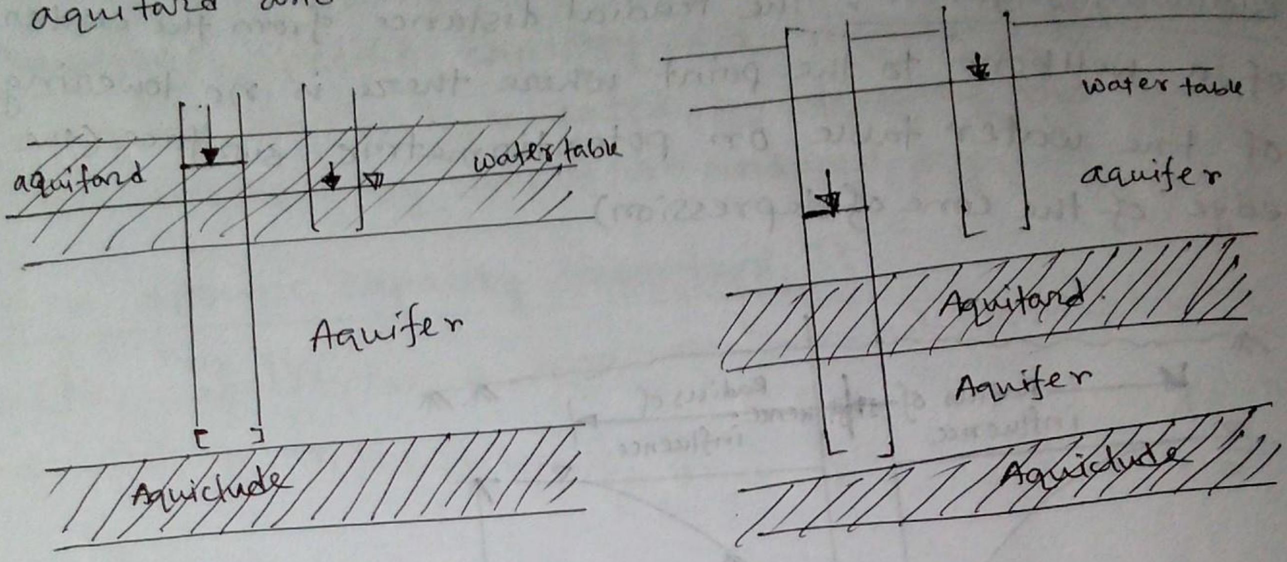
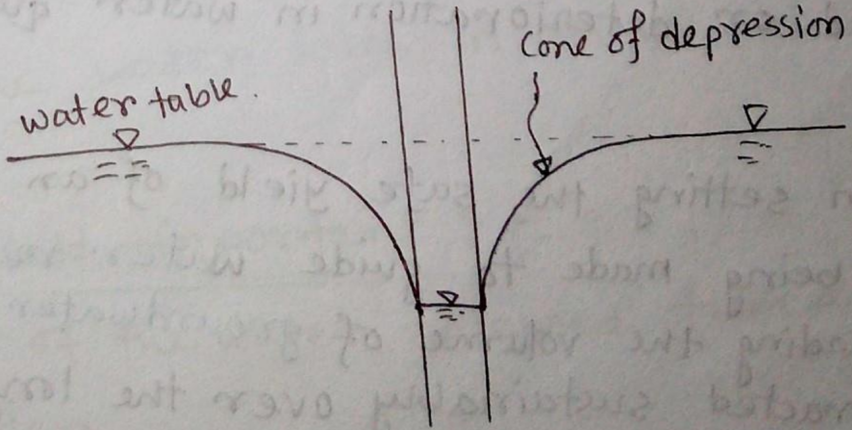


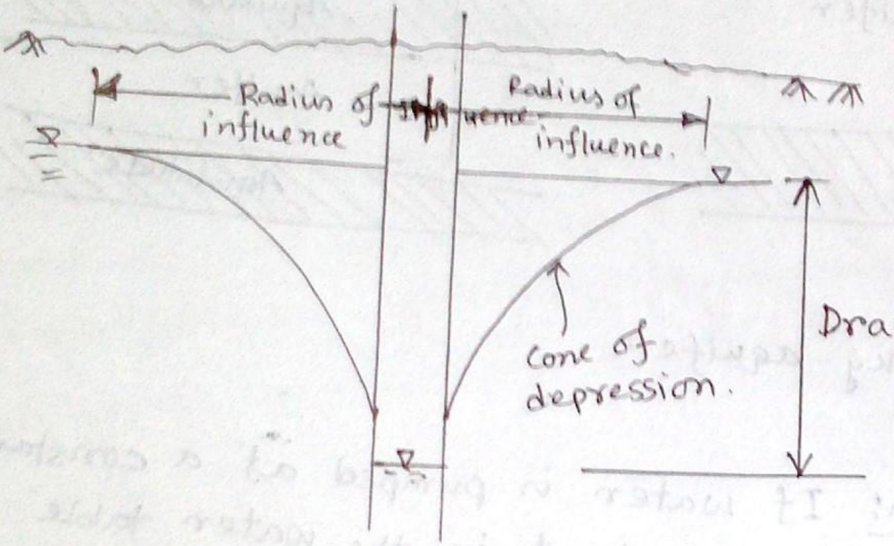
Fig. Leaky aquifer.

Cone of Depression: If water is pumped at a constant rate from the well, a gradient in the water table toward the well is created which results in a depressing ~~from~~ form of water table. This is called cone of depression.



Drawdown: The decrease in water level at the well with respect to initial ground water table is called drawdown. It is denoted by Sw.

Radius of Influence: The radial distance from the center of a wellbore to the point where there is no lowering of the water table or potentiometric surface (the edge of the cone of depression)



Safe Yield:- Safe Yield is defined as the maximum rate of withdrawal that can be sustained by an aquifer without causing an unacceptable decline in the hydraulic head or deterioration in water quality in the aquifer

When setting the safe yield of an aquifer an attempt is being made to guide water resource managers retarding the volume of groundwater that can be abstracted sustainably over the long-term.

Specific Capacity:

Definition: The rate of discharge from a borehole per unit of drawdown, is known as specific capacity. It is usually expressed as lpm/m

Description: Specific capacity is a measure of borehole performance and is calculated by dividing the yeld of the borehole by drawdown induced by abstraction

Why is specific capacity important?:-

Specific capacity is a measure borehole productivity and performance.

Specific Yield:-

Formal Definition: The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium. $S_y = \frac{W_y}{V}$

Description:-

Specific yield is a ratio between 0 and 1 indicating the amount of water released due to drainage, from lowering the water table in an unconfined aquifer.

Why is specific yield important?:-

This is a measure of the water released from an unconfined aquifer.

Aquifer Properties :

Specific Retention : specific retention of a soil or rock is the ratio of the volume of water it will retain after saturation against the force of gravity to its own volume. It is also expressed as percentage. It is denoted by Sr,

Thus, $S_r = \frac{W_r}{V} \times 100$

where. W_r is the volume of the retained water and

V is the bulk volume of the soil or rock.

Since, W_y and W_r constitutes the total volume of water in a saturated material it is apparent that porosity will be equal to sum of specific yield and the specific retention.

i.e, $n = S_y + S_r$.

Storage co-efficient (S):

Definition: The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head, is known as storage co-efficient. It is denoted by symbol S.

Description:-

It is a volume of water per volume of aquifer released as a result of a change in head. For a confined aquifer, the storage co-efficient is equal to the product of the specific storage and aquifer thickness.

Why is storage co-efficient important? :-

This is a measure of the volume of water stored and released in an aquifer and is used to quantity the safe yield of an aquifer system.

Transmitivity (T):

Defn: Transmitivity is the rate at which water is transmitted through a unit width of an aquifer under a hydraulic gradient. It is empressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.

It is commonly measured in gallons per day per foot (gal/day/foot) and can be empressed as:-

$T = bK$, b = saturation thickness of aquifer in feet
K = gal/day/ft.
T = transmitivity.

Description: Transmitivity is a measure of the ease with which ground water flows in the subsurface.

Why is transmitivity important?:

Transmitivity is used to calculate the yield of a bore hole, determine the safe yield of an aquifer system and predict groundwater movement.

→ Transmitivity (T)

(I) Discharge through thickness of aquifer per unit width per unit head gradient.

(II) Product of conductivity and thickness.

$T = Kb$,

Overdraft: Overdrafting is the process of extracting groundwater beyond the safe yield or equilibrium yield of the aquifer.

⇒ **Darcy's law:** "The rate of flow or discharge per unit time is proportional to the hydraulic gradients.

$$Q \propto iA$$

$$Q = K_v A \frac{dh_t}{dx}$$

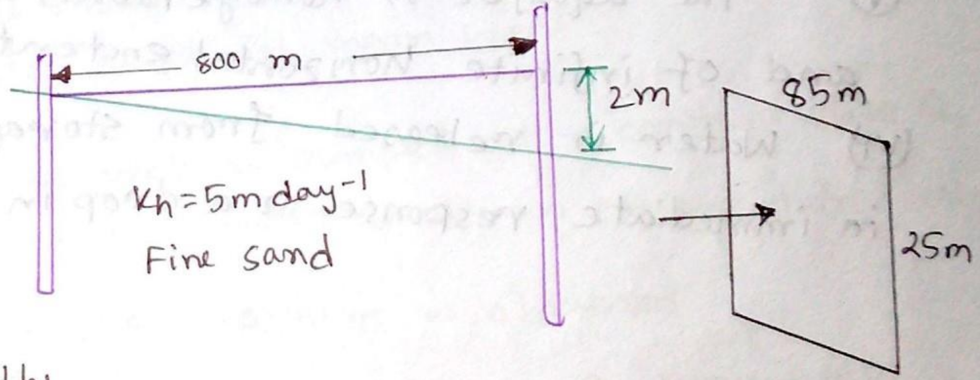
where, Q = discharge (L^3T^{-1})

K_v = hydraulic conductivity (LT^{-1})

A = area of flow (L^2) and

$\frac{dh_t}{dx}$ = hydraulic gradient.

Example:



Soln

$$Q = K_v A \frac{dh_t}{dx}$$

$$= 5\ \frac{m}{day} \times (25m \times 85m) \times \left(\frac{2m}{800m}\right)$$

$$= 26.6\ m^3/day$$ Ans

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Q. Write down ground water movement theory Based on followings assumption.

Answer: Ground water movement theory Based on following assumption:-

(I) The flow is horizontal and uniformly distributed in a vertical section.

(II) The velocity of flow is proportional to the tangent of the hydraulic gradient instead of sine of the hydraulic gradient.

The above two assumptions are called Dupuit-Forchheime assumption.

(III) The well is pumped at a constant rate.

(IV) The well fully penetrates the aquifer.

(V) The aquifer is homogeneous, isotropic, horizontal and of infinite horizontal extent.

(VI) Water is released from storage in the aquifer in immediate response to a drop in water table.

Q: Derive the equation for steady radial flow to a well in a unconfined aquifer.

Answer:

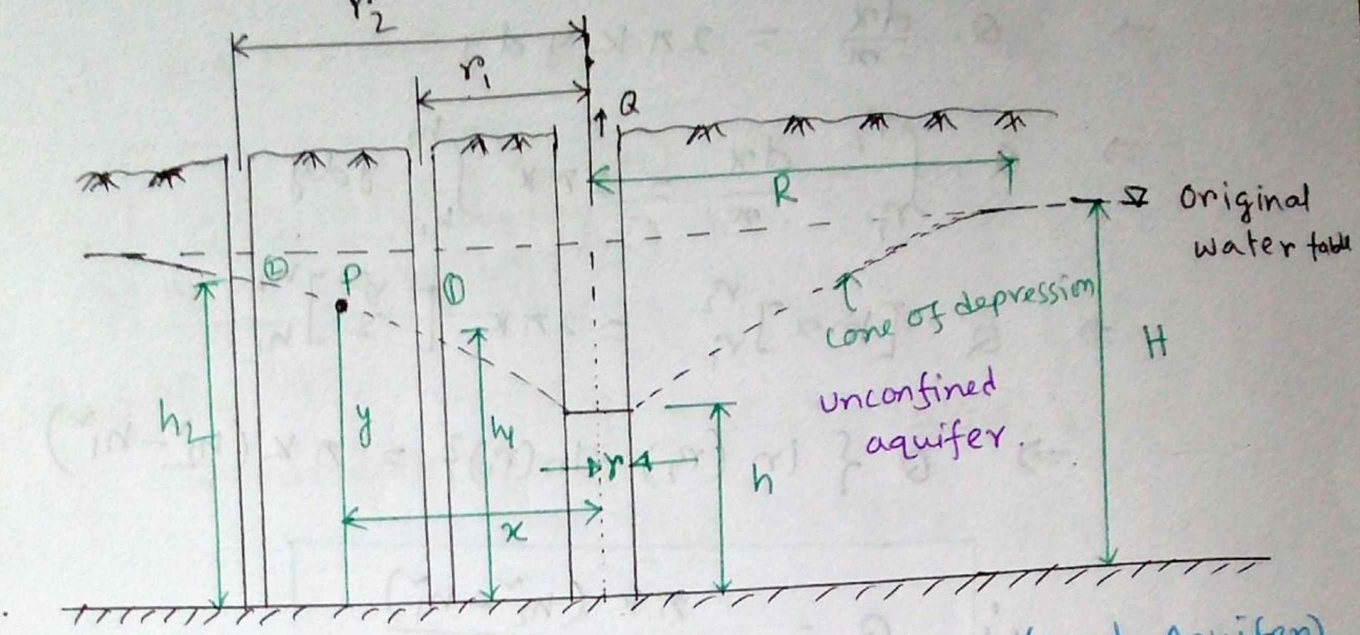


Fig. steady Flow to a well (In a unconfined Aquifer)

Let, 1, 2 = observation wells.

R = radius of influence.

r = well radius.

h = water level in main well.

Let us consider the well is pumped at a constant rate Q, for a long time and the water levels in observation wells have stabilized, i.e. equilibrium is obtained.

consider a point P as shown in figure. By Darcy's law,

$Q = kiA$.

where, i = hydraulic gradient = $\frac{dy}{dx}$

$A = 2\pi xy$

k = co-efficient of permeability.

Now, we get,

$$Q = K \frac{dy}{dx} \, 2\pi x y .$$

$$\Rightarrow \quad Q . \frac{dx}{x} = 2\pi K y \, dy$$

$$\Rightarrow \quad Q \int_{r_1}^{r_2} \frac{dx}{x} = 2\pi K \int_{h_1}^{h_2} y \, dy$$

$$\Rightarrow \quad Q \, [\ln x]_{r_1}^{r_2} = 2\pi K \left[\frac{y^2}{2} \right]_{h_1}^{h_2}$$

$$\Rightarrow \quad Q \{ \ln (r_2) - \ln (r_1) \} = \pi K (h_2^2 - h_1^2)$$

$$\therefore \quad \boxed{Q = \frac{\pi K (h_2^2 - h_1^2)}{\ln \left(\frac{r_2}{r_1} \right)}}$$

Again,

$$\boxed{Q = \frac{\pi K (h_2^2 - h_1^2)}{2.303 \log (r_2 / r_1)}}$$

This is the required equation.

Applying the equation between the face of well and point of zero drawdown,

Now, $h_1 = h$, $h_2 = H$

$r_1 = r$, $r_2 = R$.

Hence, we get,

$$\boxed{Q = \frac{\pi K (H^2 - h^2)}{2.303 \, \mathrm{Log} (R / r)}}$$

If the drawdown is very small then,

Here, $H^2 - h^2 = (H+h)(H-h)$

and, $H \sim h$.

∴ $H + h = 2H$.

$$\therefore \boxed{Q = \frac{2\pi KH(H-h)}{2.303 \log(R/r)}}$$

We know that,

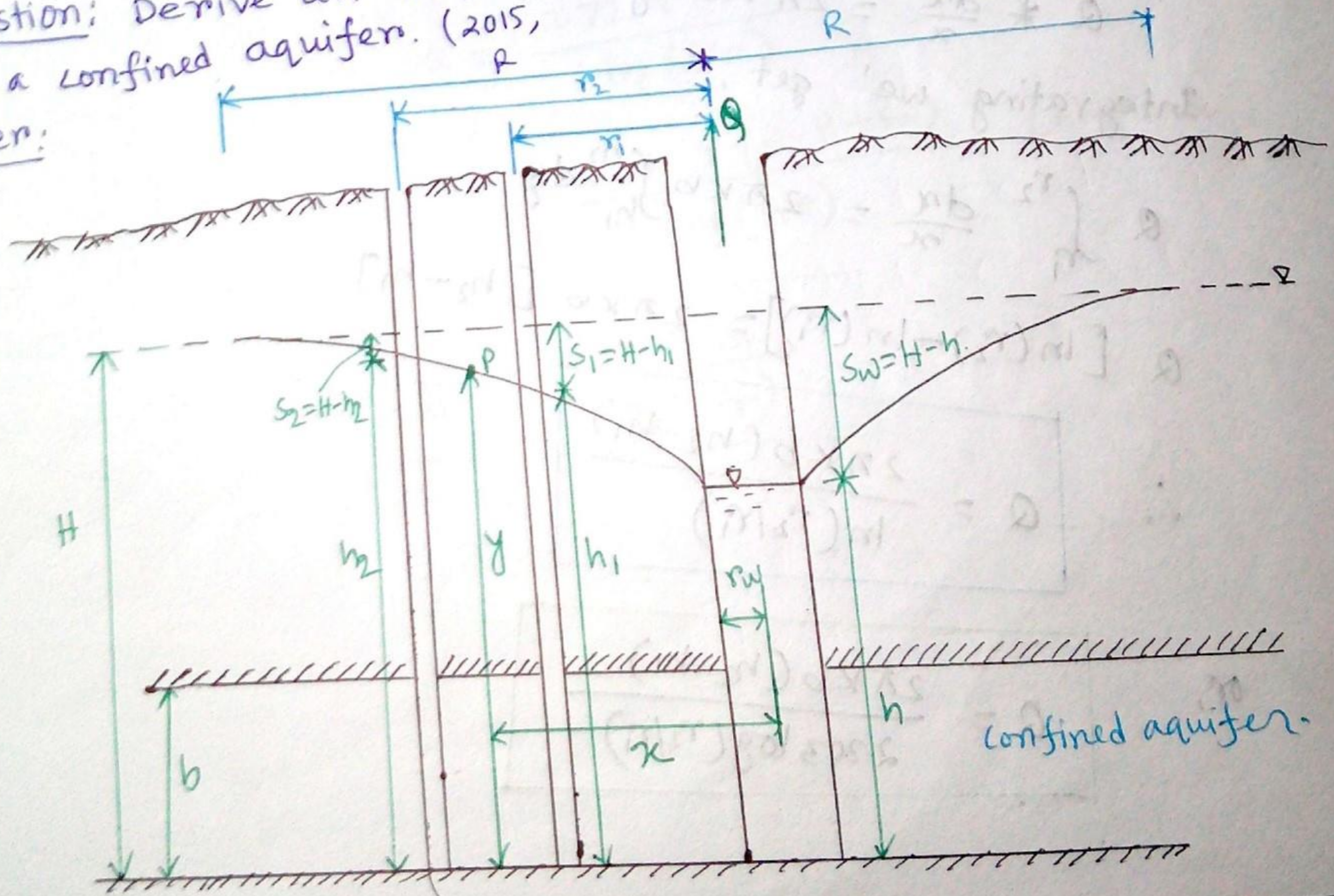
Transmissibility, $T = bK$, Here, $b = H$

∴ $T = HK$.

$$\therefore \boxed{Q = \frac{2.72\, T(H-h)}{\log(R/r)}}$$

Question: Derive an expression for steady state discharge of a well in a confined aquifer. (2015,

Answer:



Let, 1,2, = observation wells

R = radius of influence

r = well radius

h = water level in main well.

b = thickness of confined aquifer.

Let us consider the well is pumped at constant rate Q for a long time and the water levels in the observation wells have stabilized, i.e. equilibrium is obtained.

Consider a point 'p' shown in figure,

By Darcy's law;

$$Q = KiA$$

$$Q = K\frac{dy}{dx}(2\pi xb)$$

$$Q * \frac{dx}{x} = 2\pi Kb\,dy$$

Integrating we get,

$$Q\int_{r_1}^{r_2}\frac{dx}{x} = 2\pi Kb\int_{h_1}^{h_2}dy$$

$$Q\left[\ln(r_2)-\ln(r_1)\right] = 2\pi Kb\left[h_2-h_1\right]$$

$$\therefore \boxed{Q = \frac{2\pi Kb(h_2-h_1)}{\ln(r_2/r_1)}}$$

or,

$$\boxed{Q = \frac{2\pi Kb(h_2-h_1)}{2.303\log(r_2/r_1)}}$$

or, $$Q = \frac{2\pi K b\,(H - S_2 - H + S_1)}{2.303 \log (r_2/r_1)}$$

or, $$\boxed{Q = \frac{2\pi K b\,(S_1 - S_2)}{2.303 \log (r_2/r_1)}}$$

Applying the equation between the face of well and point of zero drawdown.

$h_1 = h$, $r_1 = r$, $h_2 = H$, $r_2 = R$

Hence, $$\boxed{Q = \frac{2\pi K b\,(H - h)}{2.303 \log (R/r)}}$$

we know, transmissibility, $T = Kb$.

$$\therefore \quad Q = \frac{2\pi T\,(H - h)}{2.303 \log (R/r)}$$

$$\therefore \quad Q = \frac{2.72\, T\,(H - h)}{\log (R/r)}$$

$$= \frac{2.72\, T\,(H - H + Sw)}{\log (R/r)} \qquad [h = H - Sw]$$

$$\therefore \quad \boxed{Q = \frac{2.72\, T\, Sw}{\log (R/r)}}$$

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Design of Water Wells

Introduction: A water well has to be designed to get the optimum quantity of water, economically from a given geological formation.

⊞ The water requirements for the particular schemes – rural water supply, agricultural and industrial needs, has to be carefully determined.

⊞ The ~~col~~ choice of open wells or bore wells (tube wells) and the method of well design depends upon –

- → Topography.
- → Geological conditions of the underlying strata.
- → Depth of GW table.
- → Rainfall.
- → Climate.
- → The quantity of water required.

⊞ A water well design involves selection of proper dimensions like the diameter of the well and that of the casing, length and the location of the screen including slot size, shape and percentage of opening area.

Well diameter: The size of the well diameter should be properly chosen since it significantly affects the cost of well construction.

The diameter must be chosen to give the desired percentage of open area in the screen (15 to 18%), so that the entrance velocities near the screen do not exceed 3 to 6 cm/sec, so as to reduce the well losses and hence the drawdown, to exclude the finest particles of sand from migrating near the slots and prevent incrustation and corrosion at the strainer slots.

Depuit's equation,

$$Q \propto \frac{1}{\log_{10} \frac{R}{r_w}}$$

For R=300 m, a 60 cm well yields only 25% more than a 15 cm well and 12% more than a 30cm well, which shows that Drilling a large diameter well will not necessarily mean proportionally large yields

well diameter:

Anticipated well yield, lpm	Nominal size of pump bowl, cm	Size of well casing	
		Minimum, cm	Optimum, cm
400	10	12.5	15
400–600	12.5	15	20
600 –1400	15	20	25
1400 –2200	20	25	30
2200 –3000	25	30	35
3000 –4500	30	35	40
4500 – 6000	35	40	50

Well depth:

→ The depth of a well and the number of aquifers it has to penetrate is usually determined from the lithological log of the area and confirmed from electrical resistivity and drilling time logs.

→ An experienced driller can decide the depth at which drilling can be stopped after being advised by the hydrologist who analyses the samples collected during the drilling.

→ The well is usually drilled up to bottom of the aquifer so that the full aquifer thickness is available, permitting greater well yield.

Design of well screen:

* **Screen length:** In homogeneous artersian aquifer abou 70 to 80% (3/4) of the aquifer thickness is screened. Th screen should best be positioned at equal distance between the top and the bottom of the aquifer.

→ In case of the non-homogeneous artesian aquifer, it i best to screen the most permeable strata.

→ Theory and experienced have shown that screening th bottom $\frac{1}{3}$ of the aquifer provides the optimum design.

→ The principles of design in a non-homogeneous water table aquifer are the same as in the case of non-homogenegous artesian aquifer.

Design of Slot size:

→ The size of slots depends upon the gradation and size of the formation material.

→ In case of naturally developed wells the slot size is taken as 40 to 70% of the size of formation material

→ If the slot size selected on this basis becomes smaller than 0.75mm, then it calls for an artificial gravel pack

→ Artificial gravel pack is required when the aquifer material is homogeneous with Uniformity co-efficient less than 3.0 and effective grain size less than 0.25 mm.

Screen diameter:-

After the length of the screen (depending upon the aquifer thickness) and the slot size (based on the size and gradiation of the aquifer materials) have been selected, the screen diameter is determined so that the entrance velocities near the screen will not exceed 3 to 6 cm/sec to prevent in crustation and corrosion and to minimize friction losses.

Selection of screen:-

⇒ Selection of screen material depends on—

→ mineral content of water.

→ Presence of bacterial slimes.

→ strength requirements.

⇒ The screen material should be resistant to incrustation and corrosion and should have strength to withstand the column load and collapse pressure.

The principle indicators of corrosive ground water are—

→ Low pH

→ Presence of dissolved oxygen.

→ $CO_2 > 50$ ppm (parts per million or mg/Litter)

→ $Cl > 500$ ppm.

⇒ The principal indicators of incrusting ground water are –

→ total hardness > 330 ppm.

→ total alkalinity > 300 ppm.

→ Iron content > 2 ppm

→ pH > 8

Open wells Versus Bore wells

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In choosing the type of well of the following factors have to be considered :–

(I) Availability of space.

(II) Hydrological characteristics of the subsurface strata.

(III) Seasonal fluctuation of water levels.

(IV) Cost of well construction including provision of water lifting appliances.

(V) Economics and ease of water lifting operation.

Q. Write down the advantages and disadvantages of open wells and bore wells.

Answer:

Advantages of open wells:- SOR

(a) Storage capacity of water is available in the well itself.

(b) Do not require sophisticated equipment and skilled personnel for construction.

(c) Can be easily operated by installing a centrifugal pump at different settings for low and high water levels.

Imp (d) Can be revitalized by deepening by blasting or by putting a few vertical bores at the bottom or horizontal or inclined bores on the sides to intercept the water bearing strata.

Disadvantages of open wells:

(a) Large area is required for the well and for excavated material lying on the surface like a big mound.

(b) Construction is slow and laborious.

(c) Subject to high fluctuations of water table during different seasons.

(d) Susceptibility to dry up in years of drought.

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(e) High cost of construction as the depth increases in hard rock areas.

(f) Deep seated aquifer cannot be economically trapped

(g) Uncertainity of tapping water of good quality.

(h) Susceptibility for contamination or pollution unless sealed from surface water ingress.

Advantages of Tube wells (Bore-wells)

(I) Do not require much shape.

(II) Can be constructed quickly.

(III) Fairly sustained yield of water can be obtained even in years of scanty rainfall.

(IV) Economic when deep-seated aquifers are encountered.

(V) Flowing artesian wells can sometimes be struck.

(VI) Generally good quality of water is trapped.

Disadvantages of Tubewells (Bore-wells)

(I) Require costly and complicated drilling equipment and machinery.

(II) Require skilled workers and great care to drill and complete the tube wells.

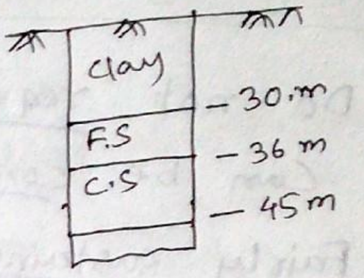
(III) Installation of costly turbine or submersible pumps is required.

(IV) Possibility of missing of the fracture, fissures and joints in hard rock areas resulting in many dry holes.

Problem 10.1 A bore hole log is shown in figure, and an yield of around 900 lpm is expected. Design all the components of the water well both for naturally developed and artificially gravel packed cases, assuming (a) Ground water level occurs under artesian conditions with piezometric head 6m below ground level, (b) Ground water occurs under water table conditions with water level 30.6 m below ground level.

Also given, $D_{10} = 0.69$ mm, $D_{50} = 1.75$ mm, $D_{60} = 2.03$ mm, $D_{30} = 1.27$ mm.

Solution: (a) Artesian aquifer:



Given, $Q = 900$ Litre per minute.

$$= \frac{900 \times 10^{-3}}{60}$$

$$= 0.015 \; m^3 s^{-1}$$

For $Q = 900$ litre per minute, $D = 20$ cm.

Length of coarse sand $= 45 - 36 = 9$ m.

Length of screen, $L = \frac{3}{4} * 9 = 6.75$ m.

Keeping 15% open area,

$$\therefore Q = 0.15 \, A \, V_e$$

$$\therefore V_e = \frac{Q}{0.15 A} = \frac{Q}{0.15 (\pi D L)}$$

$$= \frac{0.015}{0.15 * \pi * \frac{20}{100} \times 6.75}$$

$$= 0.0236 \; m/sec$$

$$= 2.36 \; cm/sec < 3 \; cm/sec.$$

$\therefore V_e$ is permissible (ok)

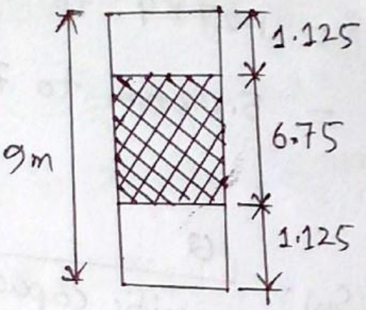
Uniformity co-efficient, $C_u = \frac{D_{60}}{D_{10}} = \frac{2.03}{0.69} = 2.94$

Since $C_u > 2.5$ and $D_{10} > 0.25$ mm, artificial gravel pack is not required.

When gravel pack is not required then slot size is equal to D_{50} to D_{60}.

$\therefore$ Selected slot size = 2 mm (say).

Since, it is artesian aquifer, the screen may be centrally located in coarse sand aquifer.



Case (b): water table aquifer:-

Recommended diameter, D = 20 cm.

Length of screen, $L = \frac{1}{3} \times 9 = 3$ m. Located at the bottom of coarse sand aquifer,

Given, $Q = 0.015$ m^3/s

Assuming 15% open area,

$$\therefore Q = 0.15 A V_e = 0.15 \pi D L V_e$$

$$\therefore V_e = \frac{Q}{0.15 \pi D L} = \frac{0.015}{0.15 \times \pi \times \frac{20}{100} \times 3} = 5.305 \text{ cm/sec}$$

which is slightly on the higher side.

Let, $L = 4.5$ m, opening area = 18%

$$\therefore V_e = \frac{Q}{0.18A} = \frac{Q}{0.18 \pi DL}$$

$$\therefore V_e = \frac{0.015}{0.18 \times \pi \times \frac{20}{100} \times 4.5} = 2.94 \text{ cm/sec, which is}$$

permissible.

Gravel pack design:

Given, $D_{30} = 1.27$ mm.

$\therefore$ Gravel pack material $= (D_{30}) * 4$ to 6 times.

$= 1.27 \times 4$ to 6×1.27

$= 5.08$ mm to 7.62 mm is provided.

Check for drawdown:

Probable drawdown, $S_W = \dfrac{Q}{\text{specific capacity}}$

$$= \frac{0.015}{\frac{T}{1.4} * E}$$

$$= \frac{0.015 \times 1.4}{T * E}$$

$$= \frac{0.015 \times 1.4}{0.0288 * 0.60}$$

Efficiency
$E = 60\%$

$= 1.21$ m, which is permissible.

$T = Kb$,

$K = \frac{2}{3} C D_{10}^2$

$= \frac{2}{3} \times 100 \times (0.069)^2$

$= 0.32$ cm/sec.

$\therefore T = Kb = 0.0032 \times 9$

$= 0.0288$ m^3/sec/m

Problem 10.2 Preliminary test shows that a tubewell can yield 1800 lpm when the drawdown is limited to 10m from an aquifer situated at a depth of 90–110 m below ground level. The corresponding radius of influence is estimated as 300m. The static water level in the well is about 12m b.g.l. The aquifer soil has $D_{10} = 0.23mm$, $D_{50} = 0.60mm$, $D_{60} = 0.67mm$. Determine the diameter, length of strainer, slot size and size of the gravel pack required.

Soln Given, $Q = 1800$ lpm.

$$= \frac{1800 \times 1000}{60} = 30000 \text{ cm}^3/\text{sec}$$

$$R = 300 \text{ m}. \quad = 30000 \text{ cm}$$

$$H - h_w = 10 \text{ m} = 1000 \text{ cm}.$$

$$K = \frac{2}{3} C D_{10}^2 = \frac{2}{3} \times 100 \times 0.23^2 = 0.0352 \text{ cm/sec}.$$

$$b = 110 - 90 = 20 \text{ m} = 2000 \text{ cm}.$$

$$Q = AV_e = P \pi D L V_e$$

$$\therefore \; DL = \frac{Q}{\pi P V_e}$$

let,
$P = 15\%$ opening area.
$V_e = 2.5$ cm/sec.

$$DL = \frac{30000}{\pi \times 0.15 \times 2.5}$$

$$\therefore \; L = \frac{25464.79}{D} \quad \text{—①}$$

For confined aquifer,

$$Q = \frac{2\pi K L (H - h_w)}{\ln(R/r_w)}$$

$$\Rightarrow 30000 = \frac{2\pi \times 0.0352 \times \frac{25464.79}{D} * 1000}{\ln\left(\frac{30000}{D/2}\right)}$$

$$\Rightarrow D * \ln\left(\frac{60000}{D}\right) = 187.73 \quad \text{—⑪}$$

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By solving, D = 24 cm.

Selected diameter, D = 25 cm.

Length of strainer, $L = \frac{25464.79}{25}$

$= 1018.6$ cm

$= 10.2$ m.

The strainer should be centrally located in the aquifer.

Design of gravel pack:

Uniformity co-efficient, $C_u = \frac{D_{60}}{D_{10}} = \frac{0.67}{0.23} = 2.91 \sim 3$

Since, $3 > C_u > 2.5$ and $D_{10} < 0.25$ mm, then artificial gravel pack in required.

Gravel pack's size $= 5 * D_{50}$

$= 5 \times 0.6$

$= 3$ mm

Check for drawdown:

Probable drawdown, $S_W = \frac{Q}{\text{specific capacity}}$ ——— ①

Specific capacity, $= \frac{T}{1.4} *$ Effeciency of well (E)

$= \frac{T}{1.4} * 0.6$

$= \frac{704}{1.4} \times 0.6$

$= 30.1714$

$E = 0.6$
$T = Kb$
$= 0.0352 \times 20000$
$= 704$

$\therefore \; S_W = \frac{30000}{30.1714} = 994.32$ cm $= 9.94$ m < 10 m.

which is permisible limit with a well efficiency 60%.

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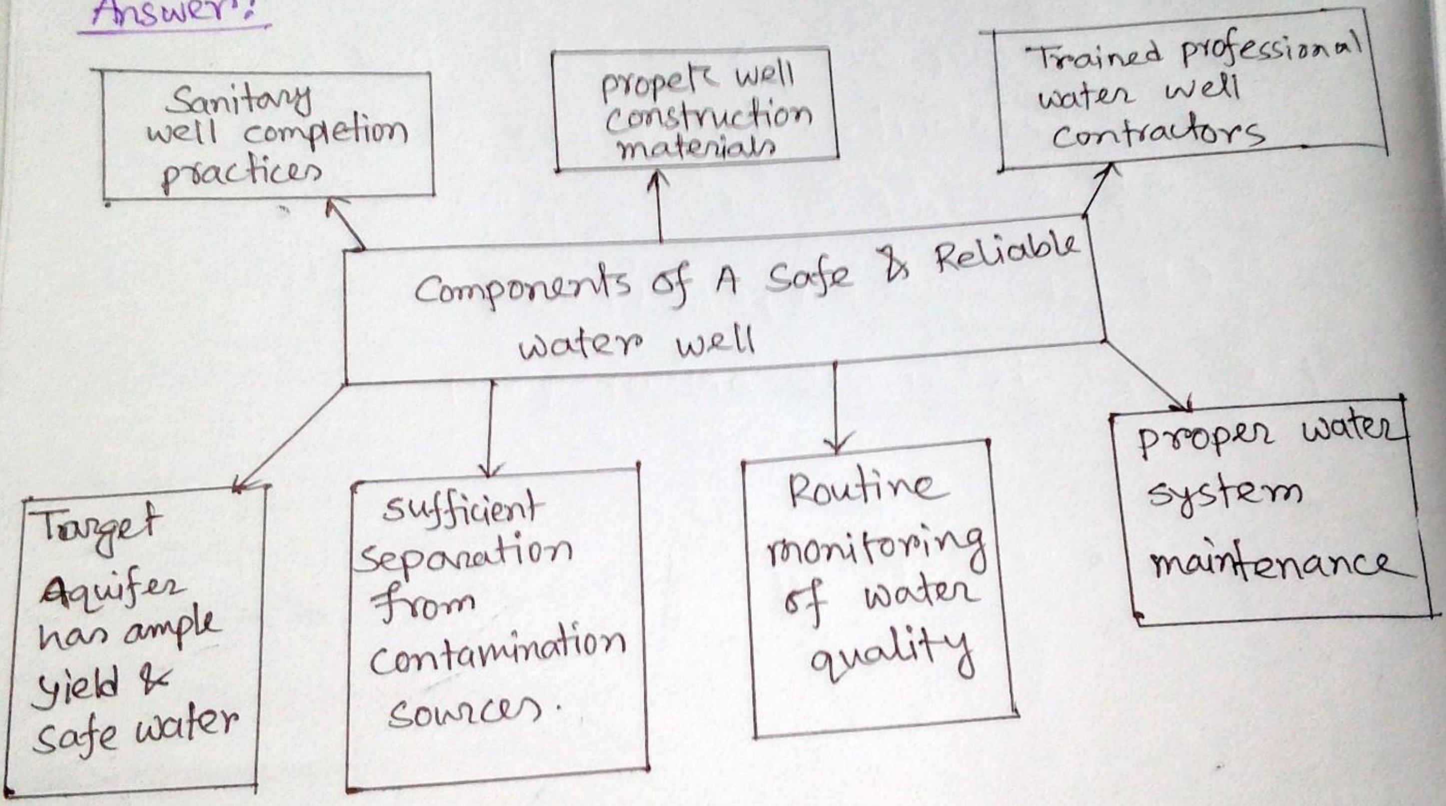
Water Well Drilling & Construction

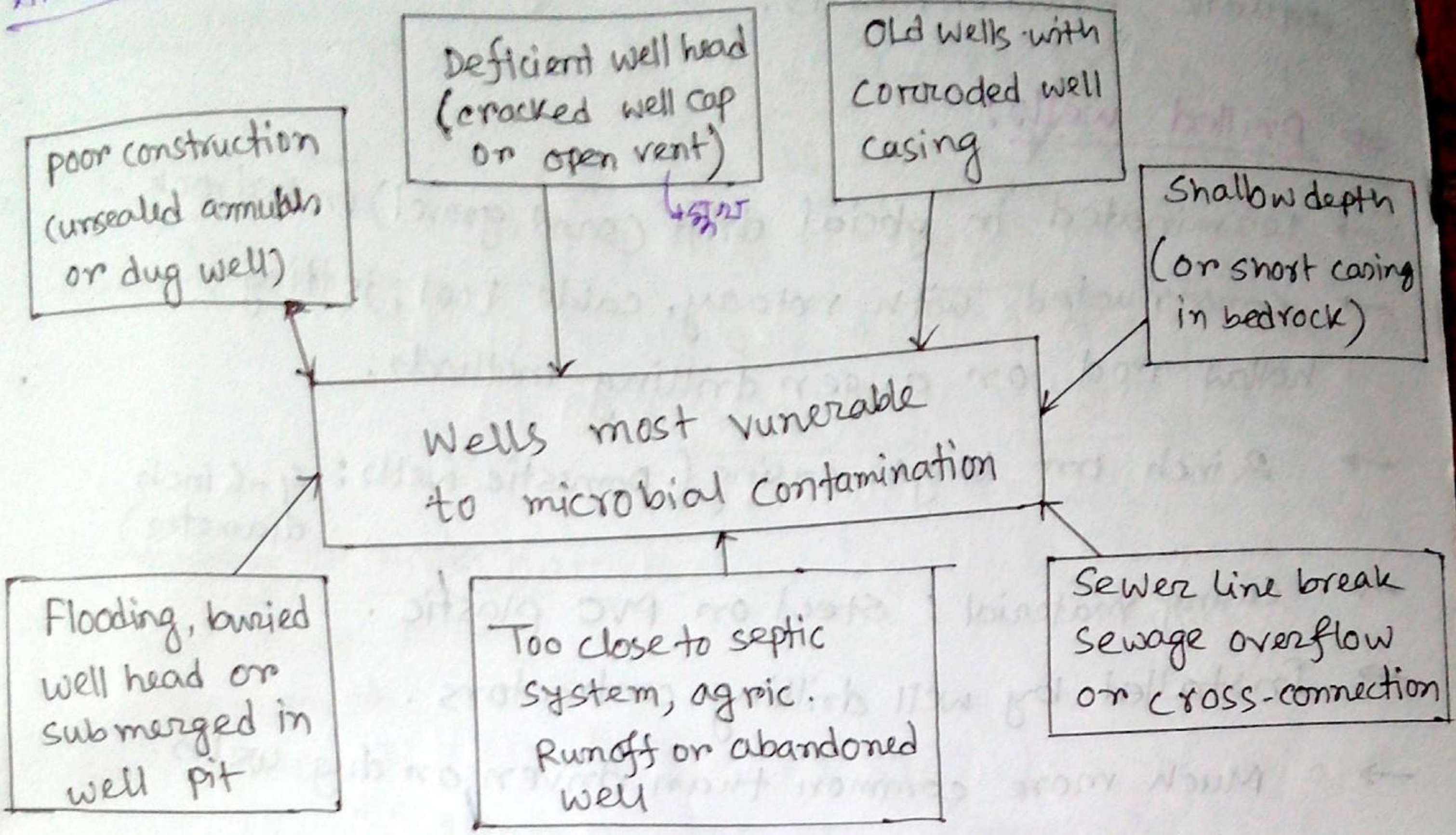
Q: what are the components of a safe & Reliable water well?

Answer:



Q: write down vunerable matter to microbial contamination

Answer:



Types of water wells: Three types.

(I) Drilled.

(II) Driven.

(III) Dug.

Write down the objectives of water well design.

Answer: Objectives are given below:

(I) Provide well that meets needs of owner.

(II) Obtain highest yield with minimum drawdown. (consistent w/ aquifer capabilities)

(III) Provide suitable quality of water (potable and turbidity free for drinking water wells).

(IV) Provide long service life (25+ years)

New: Minimize impacts on neighboring wells & aquatic environments.

⇒ Drilled wells:

- → Terminated in glacial drift (sand, gravel) or bedrock.
- → Constructed with rotary, cable tool, jetting, hollow rod or auger drilling methods.
- → 2 inch or larger casing (Domestic wells: 4-6 inch diameter)
- → Casing material: steel or PVC plastic.
- → Installed by well drilling contractors.
- → Much more common than driven or dug wells.
- → Most are >50 ft deep (average 125 ft)

Water well & pump record describes:

- → well depth
- → Casing length
- → Geologic materials penetrated.
- → Static water level.
- → pumping water level.
- → pumping rate.
- → Grouting materials.
- → well location.
- → pumping equipment.
- → Drillers name
- → Drilling rig operators.

ব্যবহারকারী

water well drilling method's in michigan:

Most common

Rotary (Mud & Air)
84%

Less common

Cable tool
10%

Auger
2.5%

Jetting
1%

Hollow rod
0.5%

Other
2%

Emerging technology:—

(I) Dual tube rotary.

(II) Horizontal

(III) sonic.

Typical rotary well construction sequence:

(1) oversized borehole drilled.

(2) Identify aquifer.

(3) Install casing (& screen)

(4) Grout annular space.

(5) well development.

(6) yield test & water sampling.

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v.v.I

Bentonite Drilling Fluid (functions):-

$\boxed{C_2RS_2FD}$

- → Removal of drill cuttings from borehole.
- → Stabilize the borehole.
- → Cool and lubricate drill bit. → তৈলাক্ত
- → Control fluid loss to geologic formation.
- → Drop drill cuttings into mud pit.
- → Facilitate collection of geologic data.
- → Suspend cuttings when drilling fluid circulation stops.

Disadvantages of using older style well cap:-

In older style well cap does not seal tightly to the well casing.

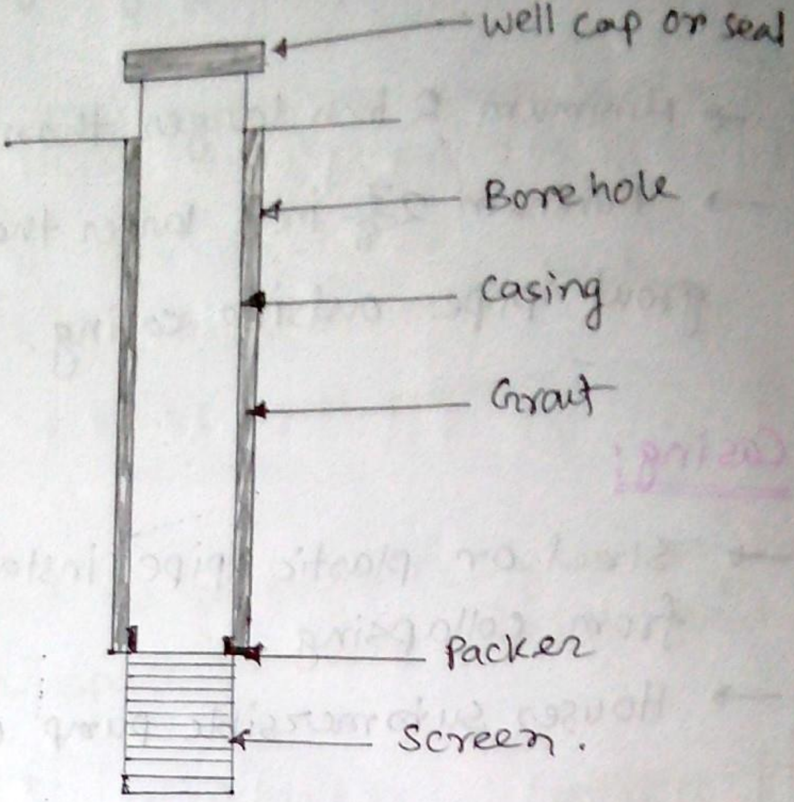
Insect and small animals can enter the well an contaminate the drinking water.

Caps of this design are not acceptable and should be replaced.

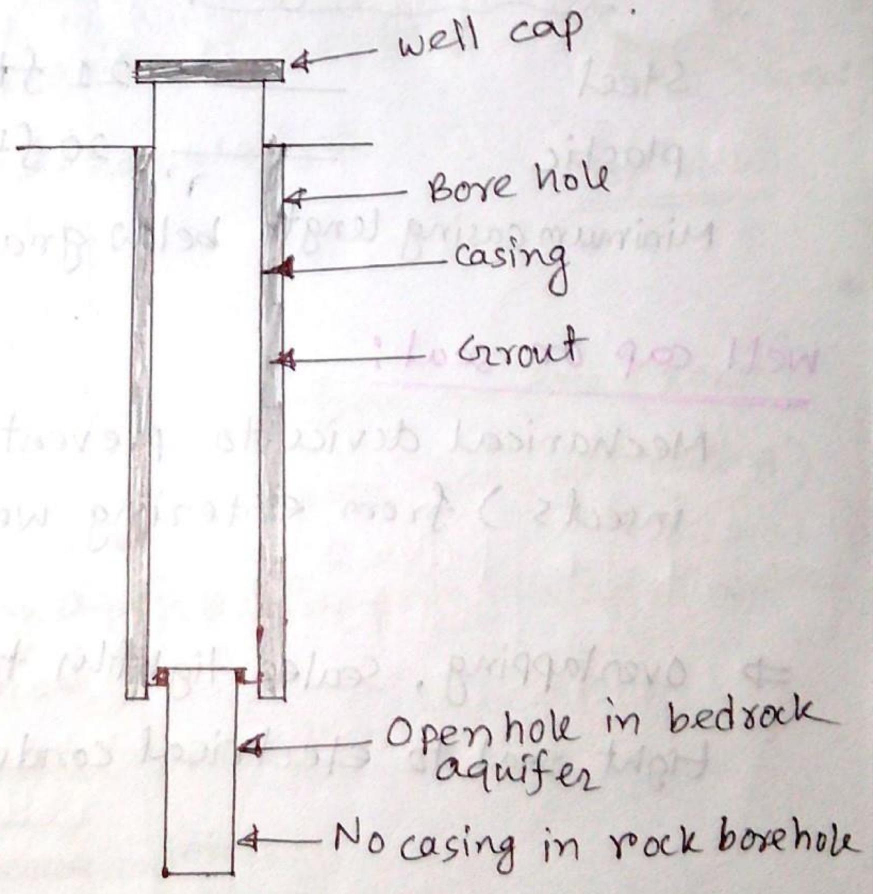
Q. Sketch Drilled well components.

Answer:

Screened well:



Bed rock well:



Borehole: Vertical circular boring to reach aquifer (water bearing geologic material)

→ Minimum 2 inch larger than casing if grouting thru ca

→ Mininum $2\frac{7}{8}$ inch larger than casing if grouting wi
grout pipe outside casing.

Casing:

→ Steel or plastic pipe installed to keep borehole wall from collapsing.

→ Houses submersible pump or turbine bowls & drop Pipe

Standard lengths:

Steel	21 ft.
plastic	20 ft.

Minimum casing length below grade — 25 ft.

well cap or seal:

Mechanical device to prevent contaminants (including insects) from entering well casing.

⇒ overlapping, sealed tightly to casing, screened air ve
tight seal to electrical conduit.

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Packer: Device that seals space between casing & telescoped screen to keep sand out of well.

Screen: (a) Intake device to allow water to enter well and keep sand out.

(b) Structural support of aquifer material.

(c) Wire - wrapped screen most common.

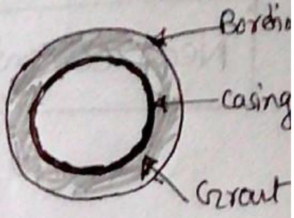
v.v.I

Grout: Impermeable cement or bentonite clay slurry placed in annular space between borehole and casing to:—

(*) prevent well contamination.

(**) maintain separation of aquifers.

(***) Preserve artesian aquifers.



Top view.

Benefits of well Grouting:

(I) Prevent contaminant migration from surface (keeps surface runoff from moving downward along well casing)

(II) Seal off poor quality aquifers (Prevents mixing of water from different aquifers)

(III) Preserve artesian aquifer properties.

(IV) Added sealing of casing joints.

⇒ well grouting materials: V.V.I

Types	Composition	characteristics
Bentonite slurry	→ powdered bentonite & water → Granular bentonite, polymer & water	→ Flexible lower strength seal. → May subside in vadose zone. → Most popular due to lower cost and targeted markets → Wash-out under artesian pressure. → No heat of hydration
Neat cement	→ portland cement & water	→ More widely used in oil field than water wells. → Higher strength rigid seal. → Best choice for bedrock wells & flowing wells → Heat of hydration & microannulus concerns.
Concrete Grout	→ portland cement, sand & water	→ More permeable than neat cement grout. → More difficult to pump (Abrasive) → Good choice for large diameter wells.

→ significant rainfall over shallow carbonate bedrock can cause:—

→ Surge in water levels (increase hydraulic pressure)

→ Increased surface water-to-groundwater interchange.

→ Flushing of turbidity & organic matter into ground water.

Benefits of extending well casing through upper fractured bedrock:—

(I) Travel time of aquifer recharge water is increased.

(II) Die-off of pathogens more likely to occur.

(III) Improves chances of coliform-free water.

Casing Materials Comparison

PVC Plastic	Vs	Steel
(I) Non-corroding		(I) corrodes
(II) Lower strength		(II) Higher strength.
(III) Fewer water quality complaints		(III) Rusty water. মরিচাযুক্ত
(IV) Rotary construction only		(IV) Suitable for any drilling method
(V) 1/3 cost of steel.		(V) No heat of hydration impact from cement grout

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Well diameter:

Myth :– Doubling well diameter appreciably increases well yield.

Fact : → Doubling well diameter → 10% yield increase.

→ Doubling screen length → Doubles well yield.

V.V.I

Benefits of FILTER-PACK :-

EFGH$_2$	ILR$_3$

(I) Greater porosity.

(II) Higher hydraulic conductivity.

(III) Reduced drawdown.

(IV) Higher yield.

(V) Reduced entrance velocity.

(VI) Reduce sand pumping.

(VII) Improved well rehabilitation. → पुनर्वास

(VIII) Longer well life.

(IX) Easier grouting.

(X) Faster development.

NB: Filter pack is not allowed to extend more than 10 feet above top of screen.

$$\text{Entrance velocity} = \frac{\text{Pumping rate}}{\text{Screen open area}}.$$

DRIVEN WELLS

Driven wells:

(I) Installed in glacial grift only cannot be driven thru boulders or into bedrock.

(II) Well point driven into ground with post-driver, tripod. w/ weight or sledge hammer.

(III) $1\frac{1}{4}$ inch to 2inch diameter.

(IV) Installed by property owners.

(V) common around lakes and high water table areas.

(VI) Most <35ft deep. limited yield (7 gpm or less)

NB: More susceptible to surface contamination than drilled wells.

DUG WELLS

Dug wells:

→ Large diameter (18-48 inch)

→ Found in low yield areas.

→ Casing material - concrete crocks w/ loss joints.

→ Older wells; stones, brick - lined.

→ water enters well through loose casing joints.

→ Older wells - hand dug.

→ Now installed (onvery limited basis) w/bucket augers (backhoes - phased out)

→ Low well yield - storage in casing (100's of gallons)

→ Highly vulnerable to contamination.

CDC Findings on Dug wells:

→ Dug / bored wells had a positive coliform bacteria rates of about 85%.

→ Wells with brick, concrete or wood casing (dug wells) had coliform positive rates of 60 – 90%

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রোল নং: ১৩০১১০

রবিউল

HYDROGRAPH

* Define Hydrograph. Draw a single peaked hydrograph and indicates its various coponents or phases.
2003, 05, 06, 08, 11, 13

Hydrograph: The term Hydrograph is used for representing the plot of instaneous discharge rate against time..

Sometimes it is also known as storm hydrograph or flood hydrograph.

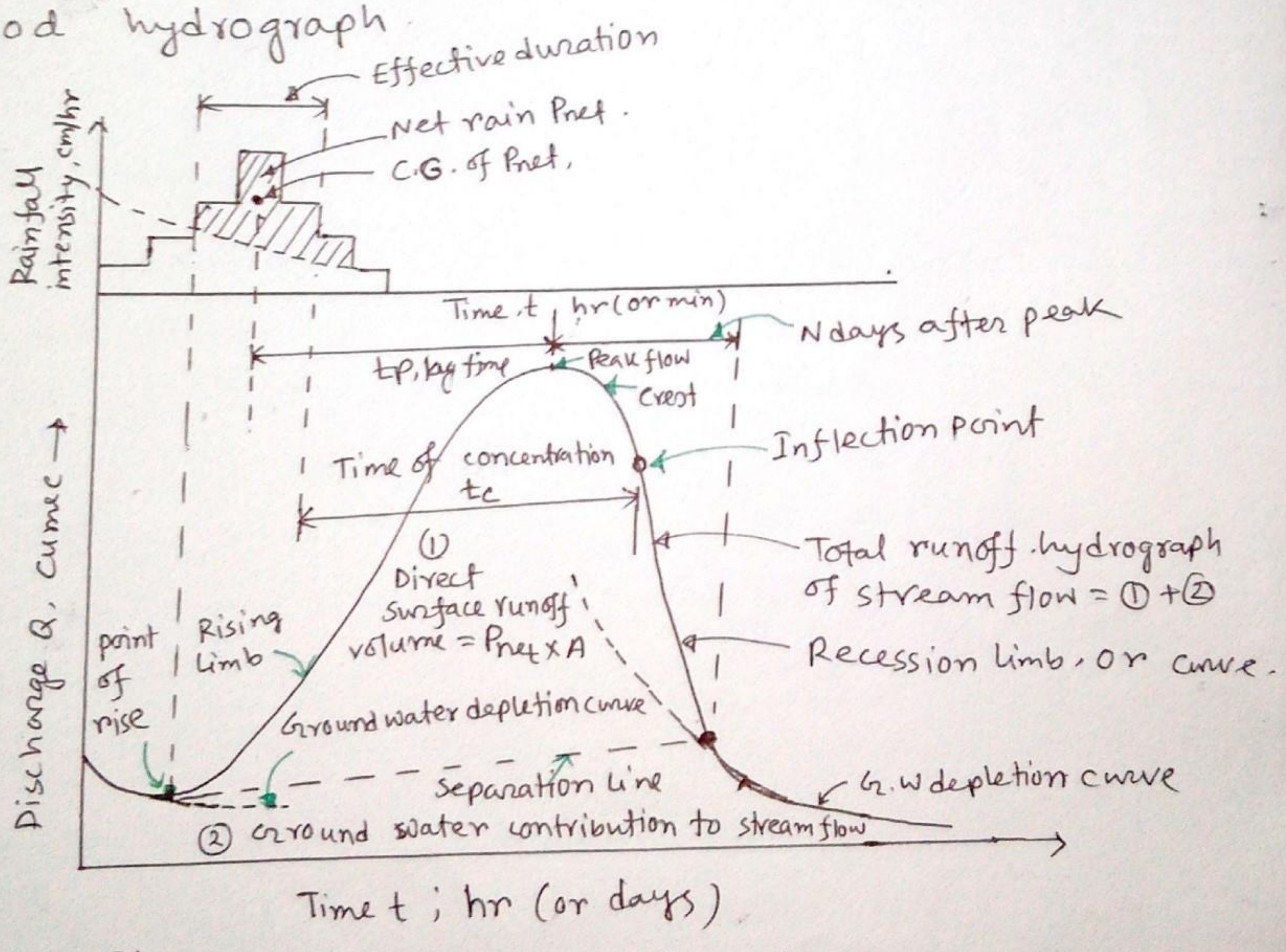

Fig. components of streamflow Hydrograph.

2015, 14, 13, 11, 10, 07. 05

* Describe with the help of a neat sketch any three methods of separation of base flow from the hydrograph of runoff.

Answer: For the derivation of unit hydrograph, the base flow has to be separated from the total runoff hydrograph. Some of the well-known base flow separation procedures are given below:-

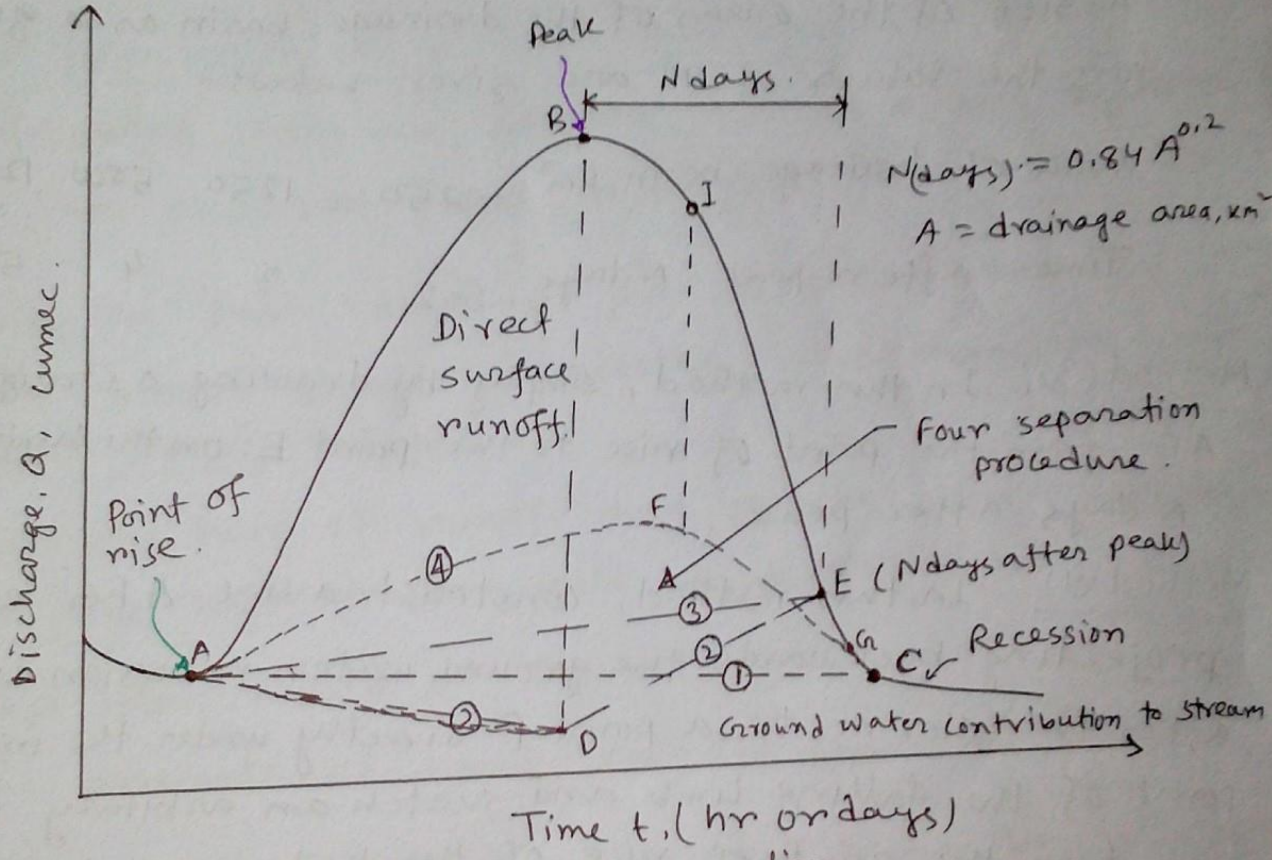

Fig. Hydrograph separation.

Method ①: In this method the base flow separation line is obtained by drawing a line AC tangential to both the limbs at their lower portion. This method is very simple but is approximate and can be used only for preliminary estimates.

Method (2): In this method ; extending the recession curve existing prior to the occurrance of the storm upto the point D directly under the peak of the hydrograph and then drawing a straight line DE, where E is a point on the hydrograph N days after the peak and N (in days) is given by,

$$N = 0.83 A^{0.2}$$

where, A = area of the drainage basin, km^2

The size of the areas of the drainage basin as a guide for the values of N are given below:-

Area of drainage basin, km^2,	250	1250	5000	12500	25000
Time after peak, N days,	2	3	4	5	6

Method (3): In this method, simply by drawing a straight line AE, from the point of rise to the point E, on the hydrograph-N days after peak.

Method (4): In this method, construct a line AFG by projecting backwards the ground water recession curve after the storm, to a point F directly under the inflection point of the falling limb and sketch an arbitary rising line from the point of rise of the hydrograph to connect with the projected base flow recession. This type of separation is preferred where the ground water storage is relatively large and reaches the stream fairly rapidly, as in lime-stone terrains.

↓

ভূখণ্ড

* Define Unit Hydrograph

[3hr 6h একক বলা থাকলে
some এর জায়গায় 3-h, 6-h দিতে হবে]

Unit Hydrograph: The unit hydrograph is defined as the hydrograph of storm runoff resulting from an isolated rainfall of some unit duration occurring uniformly over the entire area of the catchment produces a unit volume of runoff.

* Discuss the steps of derivation of unit Hydrograph.

Answer: **Derivation of the Unit Hydrograph:-**

The following steps are adopted to derive a unit hydrograph from an observed flood hydrograph :-

(I) Using the past record of the several storms, an isolated storm should be selected which has some unit period of heavy rainfall.

(II) With the help of runoff data obtained from selected storm the hydrograph should be developed.

(III) Base flow should be separated.

(IV) The ordinate of direct runoff should be found.

(V) Total depth of effective rainfall should be calculated.

It may be obtained by using the following equation.

$$\text{Effective rainfall depth (cm)} = \frac{(\Sigma O) \cdot t}{A}.$$

Here, Σo = sum of all direct runoff ordinates of the hydrograph. (m^3/sec)

t = time interval between successive ordinates (hr)

A = watershed area (km^2)

(VI) The ordinates of unit hydrograph should be determined using the following relation,

$$\text{Ordinate of U.H} = \frac{\text{Ordinate of direct runoff}}{\text{Effective rainfall depth (cm)}}$$

(VII) All obtained ordinates of unit hydrograph versus corresponding time should be plotted ; The obtained hydrograph is the unit hydrograph, which has unit area , below the curve.

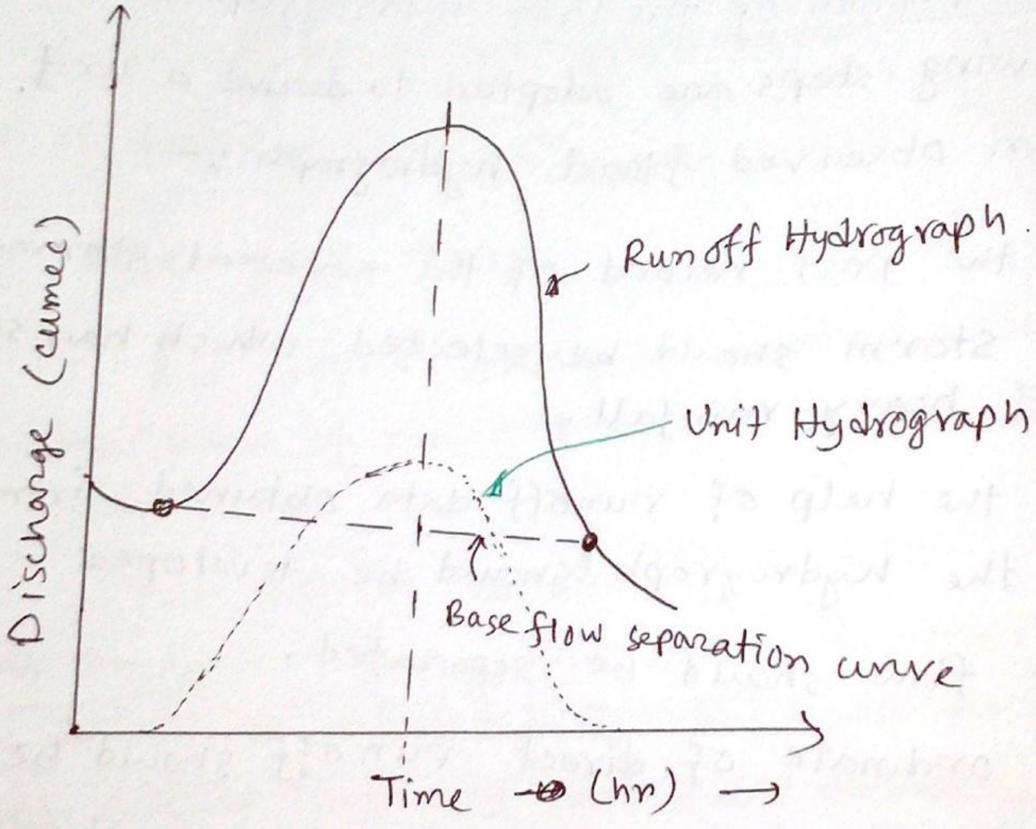

Fig. Derivation of unit Hydrograph.

Q. Describe the Elements of Unit Hydrograph.

Answer: Elements of Unit Hydrograph: The various elements of a unit graph is shown below.

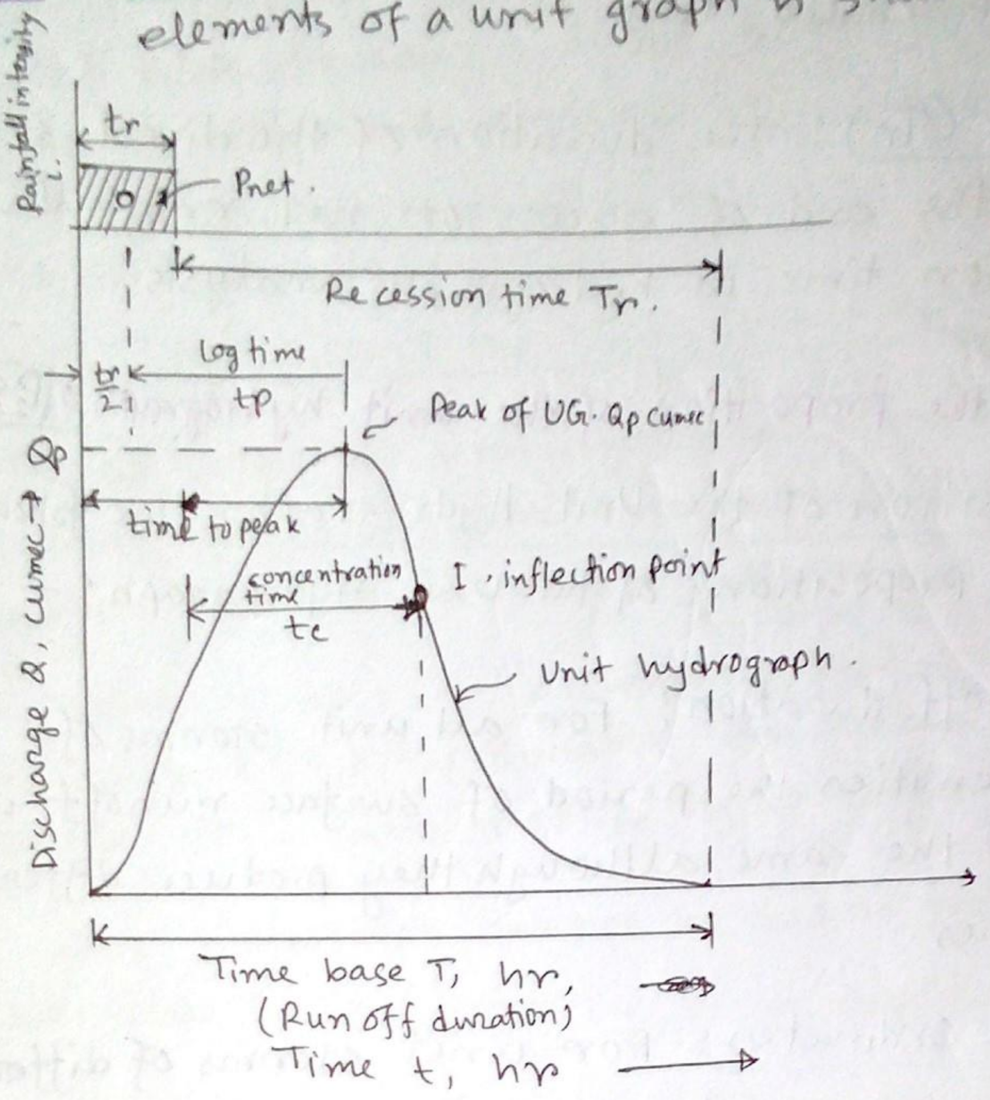

Fig. Elements of unit Hydrograph.

Base width (T): The period of direct surface runoff (due to a unit storm) of the unit hydrograph is called the time base or the base width.

Unit storm: The storm of unit duration (i.e duration of the unit hydrograph) regardless of its intensity is called unit storm.

Unit period: The time duration of the unit storm (i.e. the duration of the unit hydrograph) is called unit period.

Lag time (tp): The time from the centre of a unit storm to the peak discharge of the corresponding unit hydrograph is called Lag time.

Recession time (Tr): The duration of the direct surface runoff after the end of excess or net rainfall is called recession time in hydrograph analysis.

*** What are the proposition of the unit hydrograph,? $\boxed{P_2S_2}$
2012, 08

Answer: **Proposition of the Unit Hydrograph:** The following are the basic propositions of the unit Hydrograph:—

(I) **Same runoff duration:** For all unit storms of different intensities, the period of surface runoff is approximately the same, although they produce different runoff volumes.

(II) **Proportional Ordinates:** For unit storms of different intensities the ordinates of the hydrograph at any given time, are in the same proportion as the rainfall intensities.

(III) **Principle of superposition:** If there is a continuous storm and/or isolated storms of uniform intensity net rain, they may be divided into unit storm and hydrographs of runoff for each storm obtained and the ordinates added with the appropriate time lag to get the combined hydrograph.

[illegible]

(IV) Same distribution percentages: If the total period of surface runoff is divided into equal time intervals the percentage of surface runoff that occurs during each of these periods will be same for all unit storms of different intensities.

2015, 14, 13, 12, 08, 06, 05, 03

**** What are the limitations of unit hydrograph?

Answer: Limitations of the Unit Hydrograph:-

(I) The derivation of unit hydrograph assumes that, rainfall is uniformly distributed througout the watershed and its duration, but it is never satisfied.

(II) There is also an assumption, that rainfall intensity is constant for the duration of emcess rainfall. In practice it is also not satisfied in the field.

(III) Unit hydrograph can not be derived from a storm, which takes place in snow form i.e it is applicable only for rainfall.

(IV) Unit hydrograph of one day storm can not be derived, particularly where infiltration rate is greater than rainfall intensity.

(V) For the area less than 25 km^2, it is not applicable.

(VI) This method of estimating the runoff, requires a lot of observations rainfall data, for which it is essential to install the raingauge in large numbers, this involves additional investment of money.

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** What are the assumption of unit hydrograph? [Reddi-371]

Answer: Assumptions of Unit Hydrograph:

(I) The effective rainfall is uniformly distributed within its duration.

(II) The effective rainfall is uniformly distributed throughout the whole area of the basin.

(III) The base periods of the direct runoff hydrographs produced by effective rainfall ~~to~~ of same duration are also same.

(IV) The ordinates of the direct runoff hydrographs of a common base period are directly proportional to the total volume of direct runoff represented by the respective hydrographs.

(V) For a given drainage basin the hydrograph of runoff due to a given period of rainfall reflects the unchanging characteristics of the basin.

* What are the applications of unit hydrograph? 2011

Answer: Application of Unit Hydrograph: The application of unit hydrograph consists of two aspects:-

(I) From a unit hydrograph of a known duration to obtain a unit hydrograph of the desired duration, either by the S-curve method or by the principle of superposition.

(II) From the unit hydrograph so derived, to obtain the flood hydrograph corresponding to a single storm or multiple storm.

* what is an instantaneous unit hydrograph?

Answer: Instantaneous Unit Hydrograph (IUH):

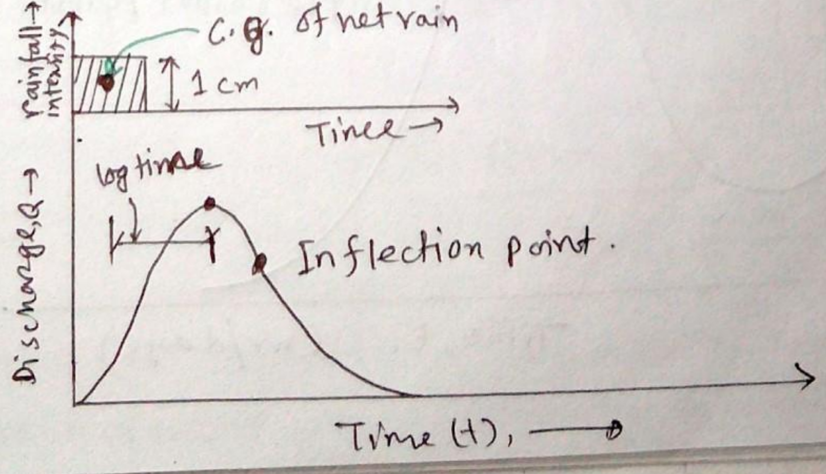
The instantaneous unit hydrograph is a hydrograph of runoff resulting from the instantaneous application of 1cm net rain on the drainage basin. The IUH was first proposed by Clark in 1945. The IUH can be developed either directly from the observed data or by adopting conceptual models.

* what do you mean by $\underset{3}{6}$·hour unit hydrograph? Discuss with diagram.

3 hour হলেও Ans. 6 এর জায়গায় 3

Answer: 6-h unit hydrograph: $\underset{3}{6}$-h unit hydrograph means the hydrograph of surface runoff resulting from an isolated rainfall of $\underset{3}{6}$ hour unit duration occuring uniformly over the entire basin and producing a unit volume of runoff (i.e. 1cm depth)

Let us consider a storm of 6 hour unit duration which occurs uniformly over the basin and produces 1cm of net rain. If we plot discharge with respect to time from begining of direct runoff, we will obtain a unit hydrograph which is a 6 hour unit hydrograph.



* State the significance of the inflection point on the recession side of hydrograph.

Answer: Significance of the Inflection Point:

~~Inflection point indicates the end of surface~~.

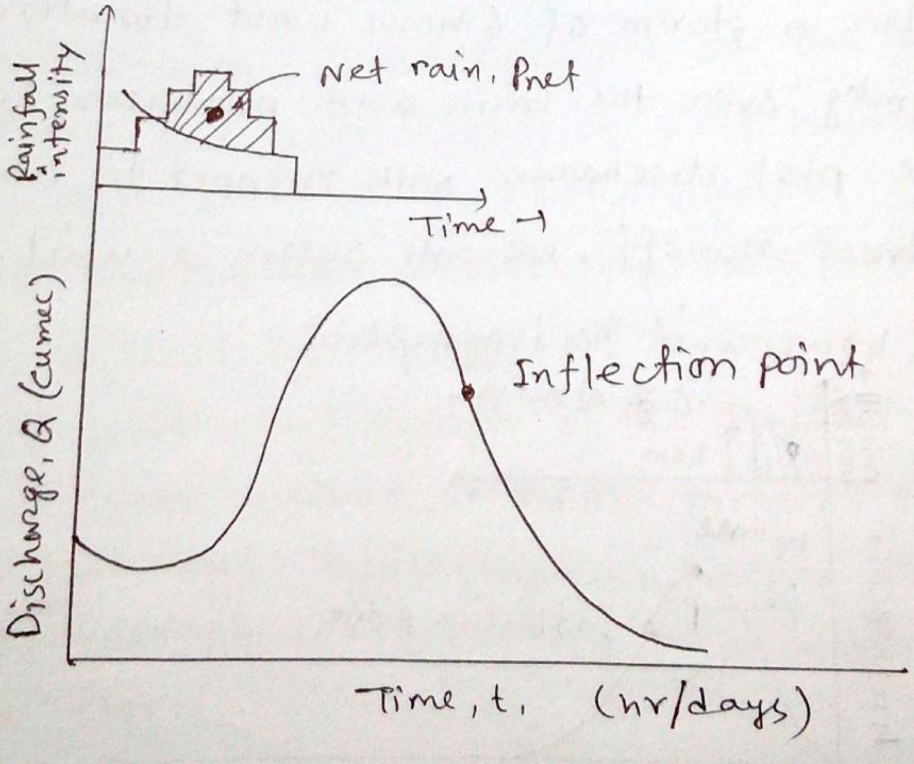
Inflection point is a point on the recession limb where there is a change in slope. Significance of this point is given below:–

(I) ~~If~~ Inflection point indicates the end of surface inflow to the channel.

(II) It represents the condition of maximum storage.

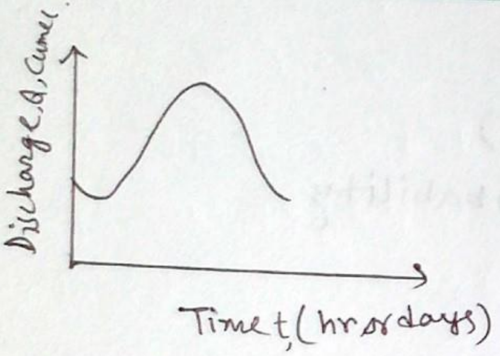
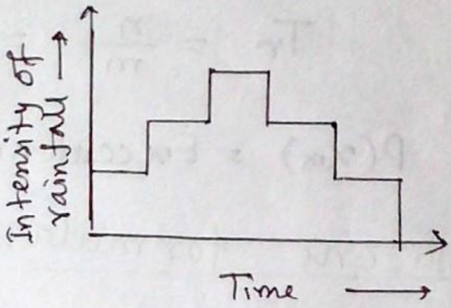
(III) It is the point after which gradual withdrawl of catchment storage is started.

(IV) It is the point after which the hydrograph is independent of storm characteristics and dependent only on basin characteristics.



* Distinguish between (I) Hydrograph & hyetograph.
(II) Return period and exceedence probability 2007

Answer: (I) Differences between hydrograph and the hyetograph is given below:-

Hydrograph	~~Hyetograph~~ Hyetograph
(I) The graph shows the variation of discharge with respect to time is called the Hydrograph.	(I) The graph shows the variation of intensity of rainfall with respect to the time is called the hyetograph.
	

(II)

Return period	Exceedence probability.
(I) It indicates average number of years within which a given event will be equalled or exceeded.	(I) It is opposite of the return period.
(II) It is denoted by Tr.	(II) It is denoted by $P(x_m)$
(III) **Formula:** $T_r = \frac{n}{m}$ where, n = no of events. m = order or rank of event.	(III) **Formula:** $P(x_m) = \frac{m}{n}$ where, m = order or rank of event n = no of events.

* what do you mean by return period? Give some formulas to determine the return period.

Answer: Return period: It indicates the average number of years, within which a given event will be equalled or exceeded. It is usually denoted by Tr. It is also known as recurrence interval or simply the frequency.

Formulas:

(I) California formula:

$$Tr = \frac{n}{m} = \frac{1}{P(x_m)}$$

$P(x_m)$ = Exceedence probability.

(II) Hazen's formula:

$$Tr = \frac{2n}{2m-1}.$$

(III) Weibul's formula:

$$Tr = \frac{n+1}{m}.$$

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Floods - Estimation and Control

* Define flood, SPF, MPF, PMP, Design flood.

Answer:

Flood: A flood is an unusual high stage of a river due to runoff from rainfall and/or melting of snow in quantities too great to confined in the normal water surface elevations of the river or stream, as the result of unusual meteorological combination.

2015
Standard Project Flood (SPF): This is the estimate of the flood likely to occur from the most severe combination of the meteorological and hydrological conditions which are reasonably characteristic of the drainage basin being considered, but excluding extreamly rare combination.

2015, 2013
Maximum probable Flood (MPF): It includes the extreamly rare and catastrophic floods and is usually confined to spillway design of very high dams.
The SPF is usually around 80% of the MPF for the basin.

Probable Maximum Precipitation (PMP):

The moisture inflow index in the storm is determined by:-

(I) Observation of air moisture from maximum due-point

(II) Temperature recorded.

(III) Air inflow.

The best known upward adjustment to be applied to the historical and hypothetical major storms is the maximisation with respect to moisture change. The adjusted storm rainfall is assumed to bear the same ratio to the observed storm. ~~rainfall is the~~ From the critical combinations of storms and moisture adjusted probable maximum precipitation is derived.

Occasionally when enough storm data for the given basin is not available PMP can be estimated by adopting a serve storm over neighbouring catchment and transposing it to the catchment under consideration.

Application: After minimising losses, PMP can be applied on the design unit hydrograph to produce MPF.

2015, 2013

*** Design flood: The flood adopted for the design of hydraulic structures like spillways, bridge openings, flood banks etc. is called Design Flood. Design flood is usually selected after making cost benefit analysis.

* What are the methods to determine the maximum flood discharge?

Answer:

FORE[illegible] CUP
[illegible] [illegible]

FORCE UP

Estimation of Peak Flood:

(I) Physical indications of past floods.
(II) Empirical formulae and curves. PECORUF
(III) Concentration time method.
(IV) Overland flow hydrograph.
(V) Rational method.
(VI) Unit hydrograph.
(VII) Flood frequency studies.

Concentration time Method: The concentration time method of estimating the peak discharge consists of two steps.

(I) Determination of the concentration time.
(II) Selection of the period of maximum net rainfall for the concentration time duration. This method can be used for design storms or in conjuction with intensity-duration-frequency curves.

2015

Rational Method: The rational method is based on the application of the formula,

$$\boxed{Q = CIA}$$

where, C = co-efficient of runoff (varies 0.2 to 0.8)
A = catchment area.
Q = total discharge.

i = Intensity of rainfall.

The intensity of rainfall i is equal to the design intensity of rainfall i_c corresponding to the time of concentration t_c for a given recurrence interval T.

If the maximum precipitation of P ~~and~~ cm occurs during a storm period of t_R hours, then,

$$\boxed{i_c = \frac{P}{t_R}\left(\frac{t_R+1}{t_c+1}\right)}$$

when t_c is not know then $\boxed{i_c \approx \frac{P}{t_R}}$.

* Distinguish between Annual series & partial series.

Annual series	Partial series.
(I) If the extreame floods are of primary concern wherein the flood magnitude with an emceedence probability of 0.5 or less are estimated, annual series is used.	(I) When estimates of very frequent events with return periods of less than 5 years are required, then the partial series is so preferable.
(II) The largest flood observed in each water year only is taken.	(II) All flood events above a selected base value are included.

* Write down the procedure to estimate the design flood for any return period using Gumbel's distribution 2013

Answer: The procedure to estimate the design flood for any return period using Gumbel's distribution is given below:-

Step 1: From the given data on flood peaks for n years, the mean $\bar{x}$ and standard deviation S_x are computed from,

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$$

$$S_x = \sqrt{\frac{1}{(n-1)} \sum_{t=1}^{n} (x_i - \bar{x})^2}$$

Step 2: For the known sample size n, the value of $\bar{y}_n$ and σ_n are obtained from table.

Step 3: For the given return period Tr, the reduced variate y_T is found from

$$y_T = -\ln\left[\ln\left(\frac{Tr}{Tr-1}\right)\right]$$

Step-4: With the values of $\bar{y}_n$ and σ_n obtained in step 2 and y_T obtained in step-3, the frequency factor K_T is calculated using,

$$K_T = \frac{y_T - \bar{y}_n}{\sigma_n}$$

Step 5: With the value of $\bar{x}$ and S_x obtained in step-1 and K_T obtained in step 4, the magnitude of the flood x_T is computed using,

$$\boxed{x_T = \bar{x} + K_T \cdot S_x}$$

* What do you mean by frequency factor? How is it determined for ~~Gu~~ Gumbel's distribution?

Frequency factor: The magnitude of the flood

$$x_T = \bar{x} + K_T \cdot S_x$$

where, $\bar{x}$ = mean, S_x = standard deviation,

K_T = Frequency factor.

Frequency factor K_T is given by,

$$K_T = \frac{y_T - \bar{y}_n}{\sigma_n}$$

The frequency factor K_T depends on the type of distribution and the return period.

Determination আগের page step 4 মতো

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FLOOD ROUTING

* Define flood routing ? what are the use of it. 2013

Answer: **Flood Routing:** Flood Routing may be defined as the procedure where by the shape of a flood hydrograph at a particular location on the stream is determined from the known or assumed flood hydrograph at some other location up stream.

Uses of Flood Routing:

(I) It is establishing the height of a flood peak at a downstream location in short term flood forecasting.

(II) It is estimating the protection that would result from construction of a reservoir.

বাঁধ

(III) It's used for determining~~on~~ required levee heights for flood protection.

(IV) It is used for determining the adequacy of spillways.

(V) Predicting the behaviour of a river after a change in channel conditions.

(VI) It is used for the derivation of synthetic unit graphs.

* Distinguish between channel routing & reservoir routing.

Channel Routing	Reservoir Routing
(I) It analyses the effect of storage of a specified channel reach on the flood hydrograph.	(I) It analyses the effect of reservoir storage on the flood hydrograph.
(II) This gives an information about flood occurance in the river/stream.	(II) For this purpose information such as ; storage vs elevation curve, outflow vs elevation curve, inflow hydrograph are required.
(III) Some channel routing method are:- (a) Muskingum method. (b) Musking um crest segment method (c) Graphical method.	(III) Some reservoir routing methods are :- (a) I.S.D. method. (b) Modified puls method. (c) Trial and error method. (d) Graphical method.

Prism storage	Wedge storage.
(I) The prism storage in formed by a volume of ~~con~~ constant cross section a long the length of the prismatic channel.	(I) Wedge storage may be taken as a fraction of the volume of the prism corresponding to (I − Q), I = inflow, Q = outflow.
(II) Prism storage depends on the outflow alone.	(II) Wedge storage depends on the difference (I − Q).
(III) Prism storage = K Q	(III) Wedge storage = $K.x(I-Q)$

* Explain the methods of determining the Muskingum parameters K and x of a reach from a pair of observed inflow and outflow hydrograph.

Answer: **Explanation:**

. When a pair of observed inflow and outflow hydrograph is available for a reach the values of K and x of of the reach can be determined using graphs. When these two groups are plotted it will be seen that both will cross on the recessian side of the inflow hydrograph.

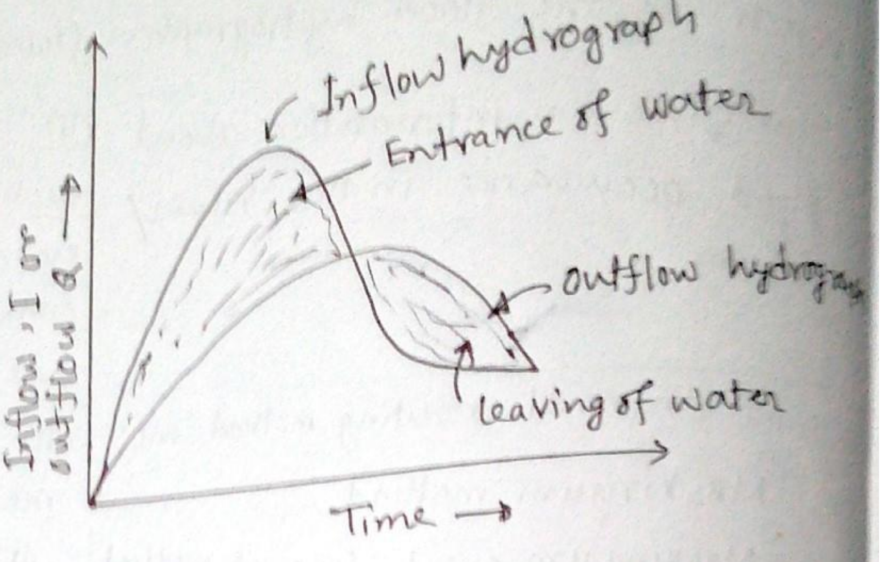

Fig. Inflow and outflow hydrograph

The routing equation is,

$$I - Q = \frac{\partial s}{\partial t} \quad \text{and,} \quad S = K[xI + (1-x)Q]$$

$$\frac{\partial S}{\partial t} = K\left[x\frac{\partial I}{\partial t} + (1-x)\frac{\partial Q}{\partial t}\right]$$

$$\therefore I - Q = K\left[x\frac{\partial I}{\partial t} + (1-x)\frac{\partial Q}{\partial t}\right] \text{ —— ①}$$

When the hydrographs two are crossing. $I = Q$ and $I - Q = 0$

$$\therefore x = \frac{\frac{\partial Q}{\partial t}}{\frac{\partial Q}{\partial t} - \frac{\partial I}{\partial t}} \text{ —— ⑪}$$

Finding the slope of outflow and inflow at crossing, and putting in equation ⑪, the x will be got.

Then the shapes of the hydrographs are found out at any other time, and hence the slopes along with the known values of x are substituted in equation ① to determine the value of K.

* Write down the two basic equations of differential of hydraulic routing method and explain each term.

Answer: Basic two differential equations;-

when there is no laterial inflow into the channel reach, the unsteady flow in the channel is described by the ~~fol~~ following two equations which are known as saint - venant equations.

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0 \quad \text{——} ①$$

$$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + g.\left(\frac{\partial y}{\partial x} - S_o + S_f\right) = 0 \quad \text{——} ⑪$$

where,

x = The distance measured along the flow direction from some references point to the section under consideration

Q = Discharge at the section.

A = Area of the flow at the section.

t = the time variable.

V = Average velocity of flow.

y = the depth of flow at section.

g = Acceleration due to gravity.

S_o, S_f = Slope at bed and energy line of channel.

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HYDROLOGY

INTRODUCTION

Q. Define Hydrology. Explain the scope of hydrology in water resource development.

2011, 07

Answer: **HYDROLOGY:** Hydrology is a branch of earth science. The word "hydrology" is derived from Greek word "hydor" and "logos" which means water and science respectively. Thus hydrology is the science of water. The complete defn of hydrology can be written as follows:-

> "Hydrology is the science which deals with the occurrence, distribution and disposal of water on the planet earth, it is the science which deals with the various phases of the hydrologic cycle.

Scope of Hydrology:-

2007, 12,13,

The study of hydrology helps us to know:-

(I) The max^m probable flood that may occur at a given site and its frequency; this is required for the safe design of drains, bridges and culverts, dams and reservoirs, channels and other flood control structures.

(II) The water yield from a basin – its occurrence, quantity and frequency etc; this is necessary for the design of dams, municipal water supply, water power, river navigation etc.

(III) The ground water development for which a knowledge of the hydrogeology of the area. i.e. of the formation soil, recharge facilities like streams and reservoirs, rainfall pattern, climate, cropping pattern, etc are required.

(IV) The maximum intensity of strom and its frequency for the design of a drainage project in the area.

Q. Mention the hydrological data required for the analysis and design of any hydrologic project. 2014

Answer: The basic hydrological data required are:–

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(I) climatological data.

(II) hydro-meteorological data like temperature, wind velocity, humidity etc.

(III) Precipitation records.

(IV) stream-flow records.

(V) seasonal fluctuation of ground water table.

(VI) evaporation data.

(VII) cropping pattern, crops & their consumptive use.

(VIII) water quality data of surface streams and ground water.

(IX) Hydrometeorological characteristics of the basin.

~~(X) cropping pattern — crops and their seasons.~~

~~(XI) water balance studies of the basin.~~

~~(XII) soil conservation and methods of flood control.~~

2004

Q. What are the importance of hydrology in water development

Answer: The importance of hydrology in water development is given below:—

(a) It gives an estimate of water resources potential of the river basin.

(b) It provides an idea about probability of flood occurrence their pattern and magnitude.

(c) The dependable yields for irrigation and hydro-electric power station can be determined.

(d) spillway capacity, dam height, dam safety etc can be designed.

(e) Formulation of flood control measures can be carried out.

(f) It helps in improvement of navigations, sediment carrying capacity.

(g) It gives a guideline for erosion control.

(h) Maximum expected flood discharge and its volume entering a reservoir can be determined.

Q. Describe the hydrometeorological characteristics of the basin development? ADICC DSW

Answer:- The basic hydrometeorological characteristics. The basic hydrometeorological characteristics for a river basin development are which are required for a river basin development are.

(a) Average annual rainfall (a.a.r), long term precipitation, space average over the basin using isohyets and several other methods.

(b) Depth-area-duration (DAD) curves for critical stroms

(c) Isohyetal maps - Isohyets may be drawn for long term average, annual and monthly precipitation for individual years and months.

(d) cropping pattern - crops and their seasons.

(e) Daily, monthly and annual evaporation from water surfaces in the basin.

(f) Water balance studies of the basin.

(g) Chronic problems in the basin due to a flood-meancing river.

(h) Soil conservation and methods of flood control.

Q. Define Hydrologic cycle? Explain the hydrologic cycle with diagram. 2010, 2011

Answer: **HYDROLOGIC CYCLE:** The hydrologic cycle is defined as the water transfer cycle in which water is tranferred from the ocean or sea to the atmosphere, then from atmosphere to the earth and ultimately again return back to the sea.

There are three important phases of hydraulic cycle as

(a) Evaporation and evapotranspiration.

(b) Precipitation.

(c) Run-off.

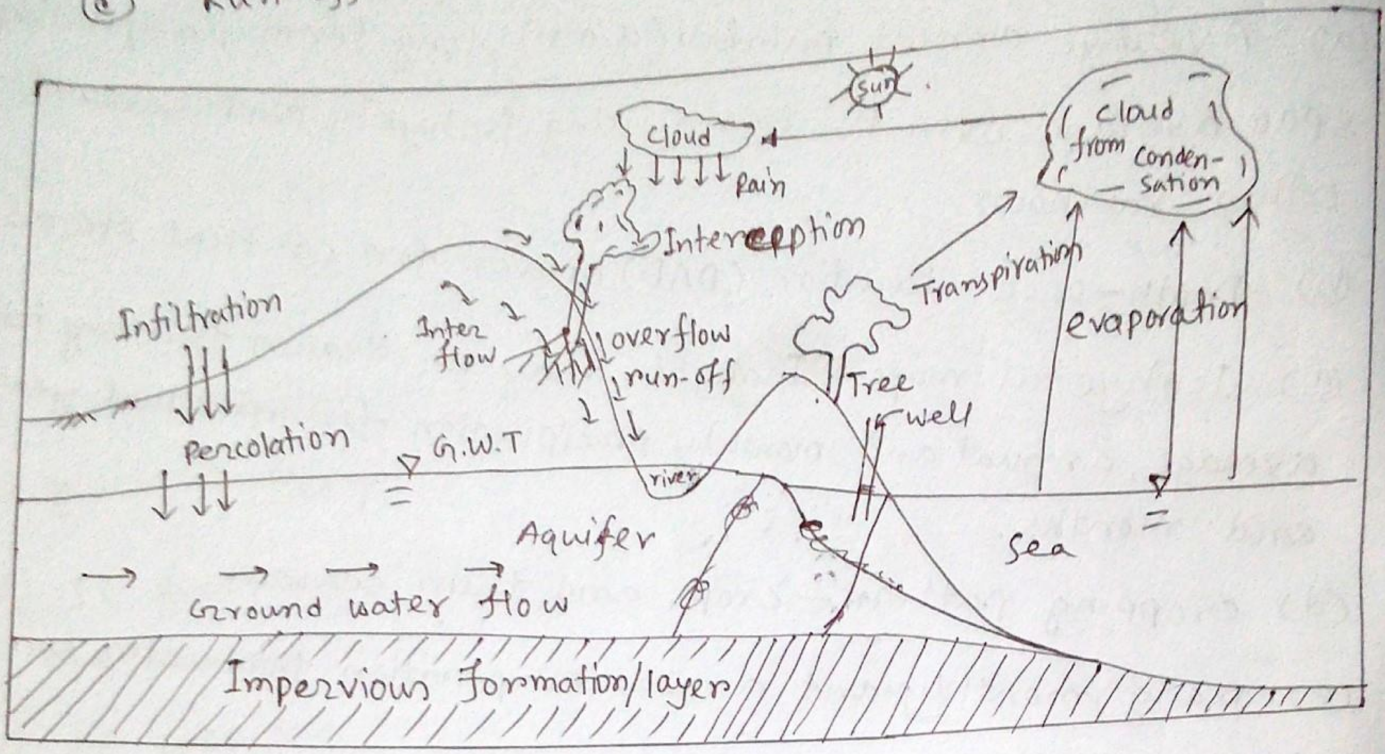

Fig. Hydrologic Cycle.

(a) Evaporation and evapotranspiration:-

These two are processed by the fact that water or moisture from water-body or soil surface is removed continuously under temperature effect. Evaporation takes place at the surface of ponds, rivers, lakes and oceans. Transpiration takes place in case of tree leaves, cropped land, forests etc.

→ অধঃক্ষেপণ

(b) Precipitation: Precipitation takes place due to lifting of evaporated moisture into the atmosphere and subsequently formation of clouds at some heights, water from these clouds comes in surface in different forms of precipitation and is distributed among oceans, rivers, lakes etc.

(c) Run-off: During precipitation, a portion of precipitated water flows over the land which is called runoff. It is the most important phase of hydrologic cycle in Civil Engineering point of view, as the civil engineers are concerned with storage of run-off for irrigation and other uses.

→ 2014, 2013

Q. What is hydrologic equation? Write down the scope of it.

Answer: Hydrologic equation: The hydrologic equation is simply the statement of the law of conservation of matter and is given by,

$$I = O + \Delta S,$$

where, I = Inflow

O = Outflow

ΔS = Change in Storage.

This law states that, during a given period, the total inflow of water into a given area must be equal to the total outflow plus the change in storage.

Scope of hydrologic equation:-

The hydrologic equation is very useful in water balance studies.

Q. Explain the difference between evaporation, transpiration and evapotranspiration. 2014

Answer:

Evaporation	Transpiration	Evapotranspiration
(a) Conservation of water on its liquit phase to vapour phase is called evaportation.	(b) The process by which the living plants leave water from their leaves is called transpiration.	(c) Combined process in which both evaporation and transpiration takes place is called evapotranspiration.
(b) It is caused by temperature effect.	(b) It is caused due to respiration process of plants.	(b) It takes place by the combination of respiration and temperature effect
(c) Expressed as a depth	(c) Expressed as a ratio called transpiration ratio	(c) Expressed as a depth over the area.

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Q: 1 The hydrologic cycle is an unending process; Explain

Answer: We know that the hydrologic cycle is the combination of three successive phases such as

(I) Evaporation and evapotranspiration.

(II) precipitation and.

(III) Run-off.

These three phases occurs continuously and never stops. water is always evaporating from lake, sea, river and other water bodies due to temperature. This process may be stopped only if temperature is nullified which is not possible and thus evaporation must continue. The evaporated water is condensed in the atmosphere to some height and in the precipitation phase, it comes to earth surface. Due to slope of earth surface some of these water flows which is called runoff. Ultimately the water return back to the sea and other water again takes place evaporation. Similarly condensation, precipitation and runoff occurs again and again. And hence ~~maintation~~, maintaining the Law of conservation of mass, the phases of hydrologic cycle continues to occour again and again; endlessly.

The above discussion may be concluded that the hydrologic cycle is an unending process.

Q. "Hydrology is a highly inter-disciplinary science" Justify it

07.09

Answer: Hydrology uses various principles from other branches of science like physics, chemistry, Biology, Geology, Fluid Mechanics, matheamatics, statistics etc, which indicates that it is a highly inter-disciplinary subject/science.

As water is transported into air, hydrology interacts with science related to air such as Hydrometeorology, Meteorology and climatology, where Hydrology deals with surface water, it includes the knowledge from Limnology, Glaciology, Oceanology etc.

Similarly when hydrology deals with ground water, it includes agronomy, hydrogeology, Geophysics etc.

As water affects plants and animals, ~~et~~ hydrology extends into plant ecology, Biohydrology, Hydrobiology etc.

The other brances of science such as Forestry, Geography water supply, Hydropower. Economics, political science etc have also influence on Hydrology.

So, we can say that, "Hydrology is a highly inter-disciplinary science."

Question: Write down the different forms of Precipitation.

Answer: Precipitation occurs in the following different forms:-

→ ঝিরঝিরে বৃষ্টিপাত

Drizzle: A lingth steady rain in fine drops (0.5mm) and intensity < 1mm/hr.

→ ঘনীভূত হওয়া

Rain: The condensed water vapour of the atmosphere falling in drops (>0.5mm, max^m size 6mm) from the clouds.

→ চকচকে হওয়া

Glaze: Freezing of drizzle or rain when they come in contact with cold objects.

→ শিলাবৃষ্টি

Sleet: Frozen rain drops while falling through air at subfreezing temperature.

→ তুষার

Snow: Ice crystals resulting from sublimation (i.e. water vapour condenses to ice)

Mist: A very thin fog.

Snow flakes: Ice crystals fused together.

→ শিলাবৃষ্টি

Hail: Small lumps of ice (>5mm dia) formed by alternate freezing and melting, when they are carried up and down in highly turbulent air current.

→ শিশির

Dew: Moisture condensed from the atmosphere in small drops upon cool surfaces.

Frost: A feathery deposit of ice formed on the ground or on the surface of enposed objects by dew or water vapour that has frozen.

Fog: A thin cloud of varying size formed at the surface or the earth by condensation of atmospheric vapour.

অনাবৃষ্টি

Question: In your district affected by floods or droughts? Explain how hydrology is useful in proposing the measures

কমানো

to mitigate the natural disasters.

Answer: Yes, My district is Rajshahi which is affected both flood and drought. The knowledge of hydrology is useful in proposing the measure to mitigate these natural disasters.

Hydrology provides the essential information about the probability of natural disaster. Various flood control structures are constructed on the basis of the information provided by hydrology. On the other hand, the techniques of flood routing is essential for planning an economic flood control project.

Not only flood control, if adequate hydrometeorological information is available, drought and other natural disasters can also be mitigated.

The above discussion makes it clear that hydrology is very useful in mitigating natural disasters.

Q. List out various practical applications of hydrology. Describe them in brief.

MD. HIFEN

Answer:- The subject "Hydrology" has a lot of practical application in our life. Some of them are listed below:-

(I) **Design of hydraulic structure:** The design of any structure related to water such as spillway, dam, culvert, bridge etc largely depends on the knowledge of hydrology.

(II) **Municipal and Industrial water supply:-**
The availability of water is often the most important factor in locating suitable place for industries and it has considerable effect on the growth of municipalities. Hydrology helps us to ensure water supply's availability.

(III) **Irrigation:** Storage of water is one of the most important factors for development of irrigation for which evaporation, seepage and other losses must be considered, Hydrology helps to measure these looses.

(IV) **Hydropower:** Hydrologic studies are essential for the planning of any ~~planning of any~~ water power department.

(V) **FLood control:** The techniques of flood routine is essential for an economic planning of flood control project which can be known from the study of hydrology.

(VI) **Navigation:** To solve the hydrologic problems in navigation project some essential informations are required which are supplied by hydrology.

(VII) **Erosion and sediment control:** The problems in erosion control is mainly related to overland flow and infiltration which are studied in hydrology.

Q. Define, Air mass, Air front, occluded front. Discuss the characteristics of cold and warm air mass.

Air mass: A vast and deep body of the air in which the temperature and humidity characteristics are relatively homogeneous at any given elevation is called an air mass.

Air front: The surface of contact between two ~~adjoining~~ adjacent air masses or between an air mass and the surrounding atmosphere is called a frontal surface or simply air front.

Occluded front: Sometimes along the surface front there may be a cold front and warm front. On certain occasions a cold front may overtake a warm front in such a manner that the warm air between them is displaced upward then it is called an occluded front.

Characteristics:

Cold Air mass:

(1) It is heated from below, therefore it is often unstable

(11) It is colder than the surface over which it moves.

warm air mass:

(1) It is cooled from below and becomes more stable

(11) It is warmer than the surface over which it moves.

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Precipitation

Q. Define precipitation; Explain the formation of precipitation. 2006

Answer: **Precipitation:** From the hydrological view point, any form of moisture reaching the earth's surface from the atmosphere is called precipitation.

Formation of precipitation: There are four essential requisties for the formation of precipitation as.

(I) **Accumulation of moisture:** First water is evaporated to the atmosphere and transfer into the water vapour.

(II) **cooling:** Then, condensation of liquid or water vapour occurs, before cooling.

(III) **Condensation:** By the condensation small drops at first and then gradually big drops of rain will be formed from the clouds.

(IV) **Growth of droplets:** Finally, due to their collision, the drop of rain will be fallen down to the earth surface.

And finally, we have seen, by the above ways the precipitation is formed.

Q. Discuss various types of precipitation.

Answer: **Types of Precipitation**: There are generally four types of precipitation:

(I) Convectional precipitation.
(II) Frontal precipitation.
(III) Orographic precipitation.
(IV) Cyclonic precipitation.

These are discussed below:-

Convectional Precipitation: This type of precipitation is in the form of local revoling thunder (→ বজ্রধ্বনি) stroms and is typical of the tropices (→ নিরক্ষীয় বৃত্তের এবং ক্রান্তীয় বৃত্তের নিকট হয়). The air close to the warm earth gets heated and rises due to its low density, cools adiabatically to form a cauliflower shaped cloud which finally bursts into a thunder strom. When accompanied by destructive winds, they are called "tornados".

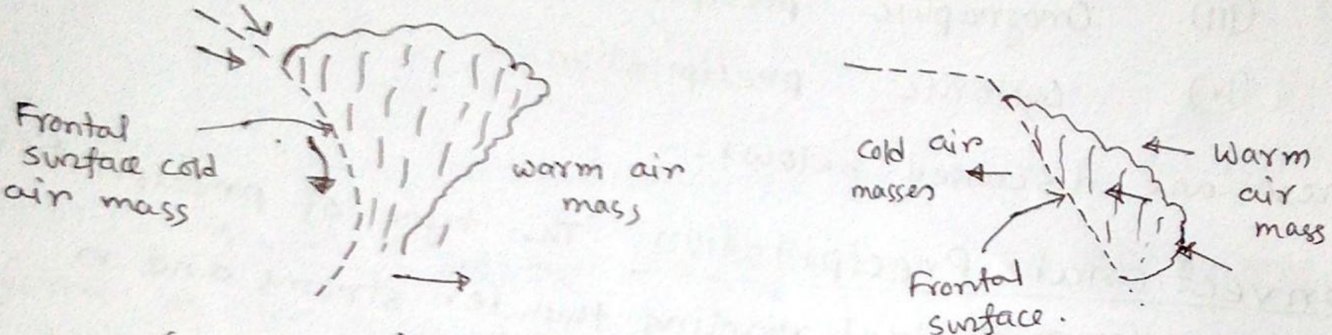
Frontal precipitation: When two air masses due to contrasting (→ বিপরীত) temperature and densities, clash with each other, condensation and precipitation occur at the surface of contact. This surface of contact is called "Frontal surface".

Frontal precipitation may be of three type.

(I) **Cold front**: If cold air masses drives out a warm air masses, it is called cold front.

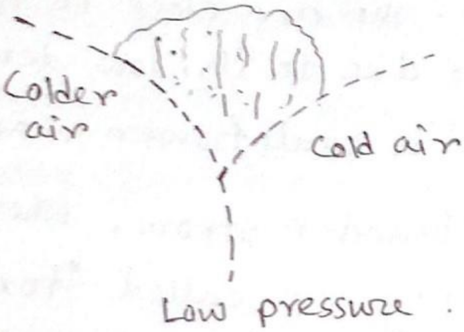
(II) Warm front: If warm air masses replace the retreating cold air mass, it is called a "warm front".

(III) Stationary front: If warm & cold air masses are drawn simultaneously towards a low pressure area, the developed front is called 'stationary front'



(a) cold front.

(b) Warm front.



(c) stationary front.

Fig. Frontal precipitation.

Orographic precipitation: The mechanical lifting of moist air over mountain barriers causes heavy precipitation on the wind ward side. This is called orographic precipitation.

Example: Cherrapanji in the Himalayan range get very heavy orographic precipitation of 1250 cm.

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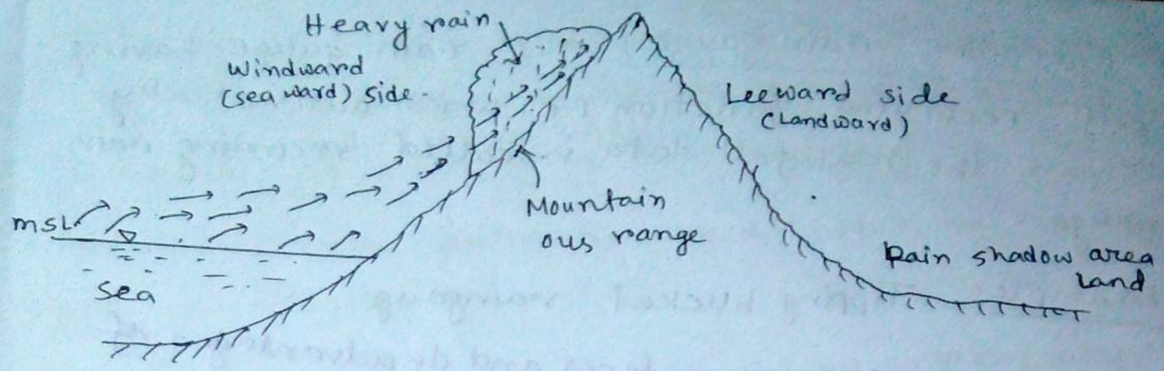


Fig. Orographic precipitation.

Cyclonic precipitation: Due to pressure difference created by unequal heating of the earth's surface, cyclonic precipitation takes place. Here, the wind blow spirally inward counterclockwise in the northern hemisphere and clockwise in the southern hemisphere.

* Define Raingauge and classify it.

Answer: **Raingauge:** The instrument by which precipitation is measured is called rain gauge. It is also known as hyetometer, ombrometer or pulviometer.

The raingauges are at two types as

(1) **Non-recording rain gauge:** The rain gauge having no self recording function i.e. which does not automatically show the rainfall data is called non-recording raingauge.

Example: Symons raingauge, U.S. weather Bureau raingauge.

(ii) Recording rain gauge: The rain gauge having self recording function i.e. which automatically shows the rainfall data is called recording rain gauge.

Example: Tipping bucket raingauge.

* Write down the advantages and disadvantages of recording type raingauge.

Answer: Advantages of Recording Type raingauge:

(I) It provides a detail information about the rainfall such as rainfall depth and its duration (i.e. rainfall intensity)

(II) As it automatically records the rainfall amount with respect to time, so there is need to engage any attendant for recording the same.

(III) The introduction of error in the rainfall data by man mistakes is completely eliminated.

(IV) Recording type raingauge is the only means to record the rainfall data in hilly area.

(V) It provides the information about onset and ceration of rainfall.

(VI) It denotes the entire rainfall information in the form of graph, which is used as permanent tool for making the analysis of storm.

(VII) Measuring capacity of recording type raingauge is more to that of non-recording type rain gauge

(VIII) Duration of rainfall is also recorded.

(IX) Provides more authentic result then the non-recording type rain gauge.

Disadvantages: Apart from several advantages, it has some disadvantages also, which are given as under:-

(I) It's cost is more than the non-recording type gauge.

(II) It requires a regular service for its proper working.

(III) Its maintenance cost is comparitively high.

(IV) Additional precaution are required to operate this gauge.

(V) Recording of the rainfall data may be interrupted due to some mechanical faults incurred in the gauge.

* Distinguish between recording and non recording type rain gauges. 2007

Answer:

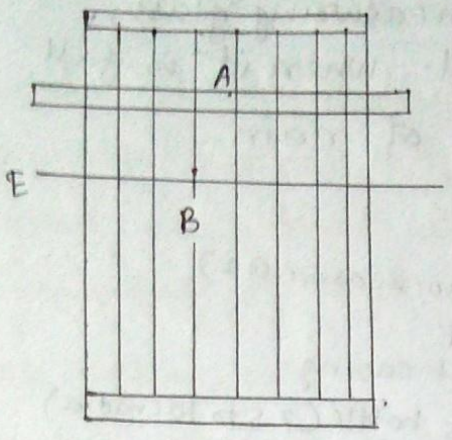
Recording raingauge	Non-recording raingauge.
(I) It can measure duration of rainfall.	(I) Duration of rainfall can not be measured.
(II) Initial cost is more than that of non-recording raingauge.	(II) Initial cost is comparatively less.

(III) Error by men-mistake is completely eliminated.	(III) There is a possibility of error by men-mistake.
(IV) Measuring capacity is comperatively more.	(IV) Measuring capacity is comperatively less.
(V) Maintenance cost is comperatively high.	(V) Maintenance cost is comperatively less.
(VI) Rainfall in hilly area can be measured accurately.	(VI) Rainfall data in hilly area cannot be measured accurately.

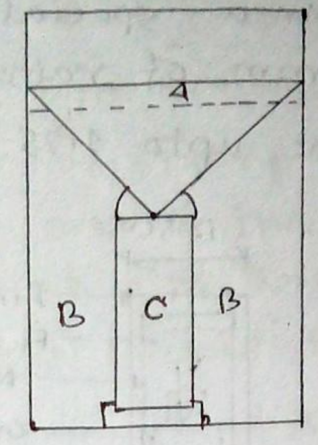
Q. Explain the components and working of a Non-recording raingauge / U.S. weather Bureau raingauge.

Answer: Components of U.S. Weather Burea raingauge:-

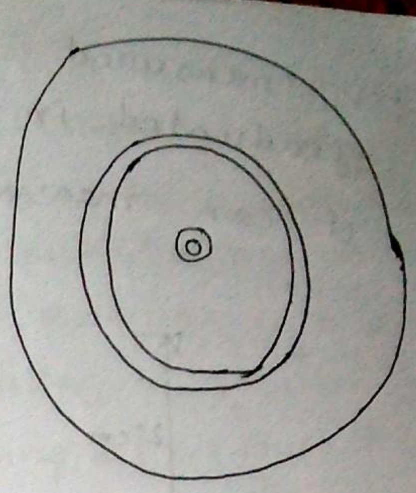
The U.S. weather Bureu raingauge consists of a can B, 8" in diameter and 24" in depth. It is fitted over a copper receiver A. whose top rim in a knife edge and bottom cosists of a funnel. A measuring tube C under the funnel takes water from the funnel. A measuring stick 24" long $\frac{3}{8}$" wide and $\frac{1}{8}$" thick completes the equipment. The crosssection area of measuring stick is exactly one tenth of the opening area of the receiver.



Elevation



Vertical section



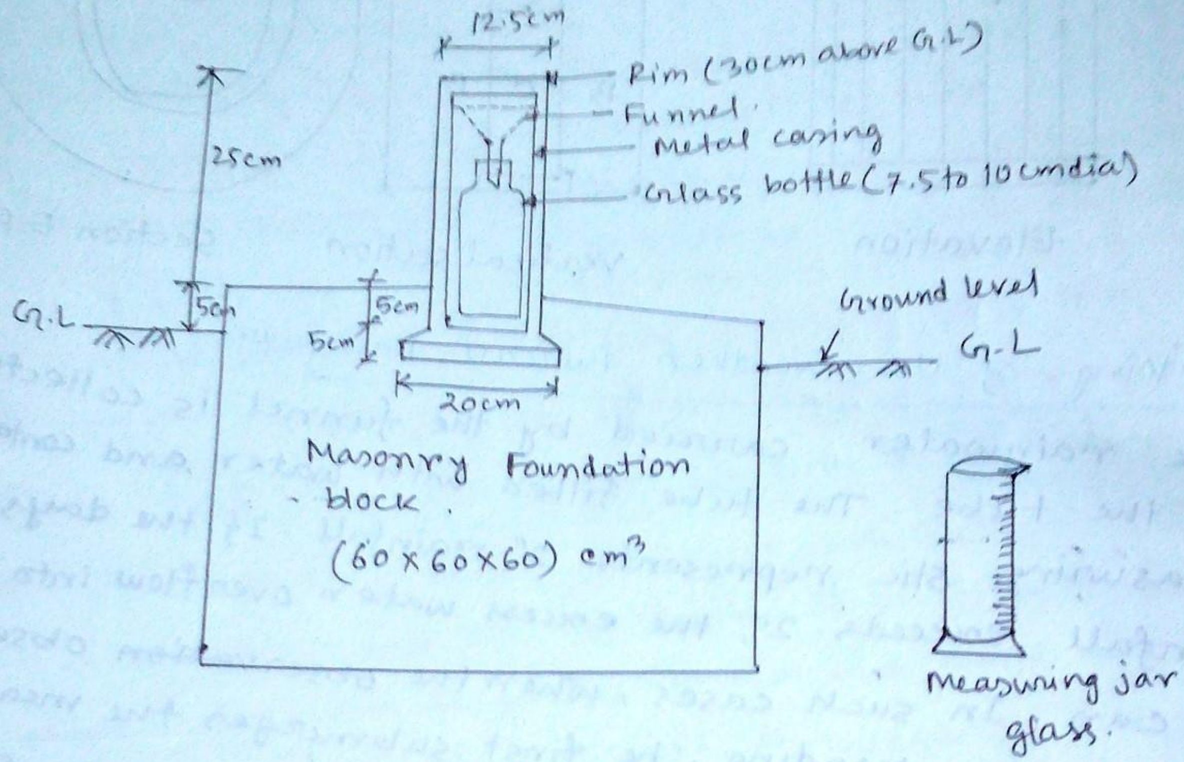
Section EF

Working of U.S. weather Bureau Raingauge:

The rainwater carried by the funnel is collected in the tube. The tube filled with water and containing measuring stic represents 2" rainfall. If the days rainfall exceeds 2", the excess water overflow into the 8" can. In such cases, when the ~~observation~~ observer makes the reading, he first submerges the measuring stick, empties the measuring tube and pours excess water into the tube for measurement.

Q. Write short notes on symons raingauge.

Symons raingauge: It is a non-recording type rain gauge. It consists of a funnel with a circular rim of 12.5 cm diameter and a glass bottle as a reciver. The cylindrical metal casing is fixed vertically to the masonry foundation with the level rim 30cm above the ground surface. The rainfalling into the funnel is collected in the reciver. The rain is measured in a special measuring glass, graduated in mm of rainfall. when it is fall it can measure upto 1.25 cm of rain.



* Write short notes on recording type raingauge.

Answer: Recording type raingauge: There are three types of recording type raingauge.

(I) Tipping Bucket Gauge.

(II) Weighing Type Rain Gauge.

(III) Float type raingauge.

Tipping Bucket Gauge: This consists of a cylindrical receiver 30 cm diameter with a funnel inside. Just below the funnel a pair of tipping buckets is ~~provided~~ pivoted such that when one of the bucket receives a rainfall of 0.25 mm it tips and empties into a tank below, while the other bucket takes its position and the process is repeated. The tipping of the bucket actuates on electric circuit which causes a pen to move on a chart wrapped round a drum which revolves by a clock mechanism.

Limitation:- This type cannot record snow.

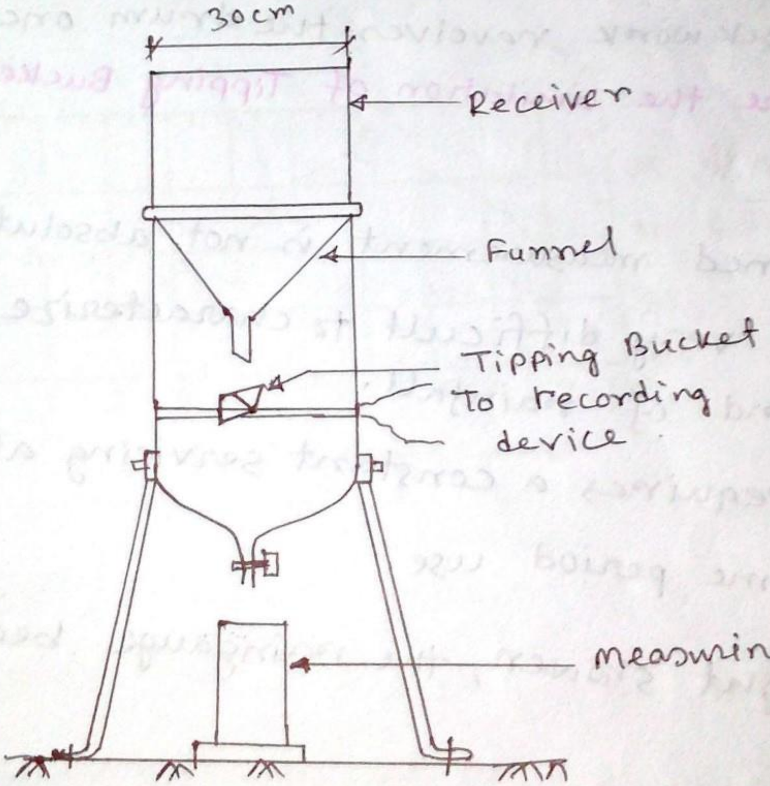


Fig. Tipping Bucket Gauge.

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

Float type rain-gauge: In this type, as the rain is ~~cot~~ ~~cumulative pr~~ collected in a float chamber. the float moves ~~up~~ which makes a pen to move on a chart wrapped round a clock driven drum. The clockwork revolves the drum once in 24 hours.

Q. what are the limitation of Tipping Bucket raingauge?

Limitation:

(I) Obtained measurement is not absolutely correct.

(II) It is very difficult to characterize the start and end of rainfall.

(III) It requires a constant servicing after a fixed time period use.

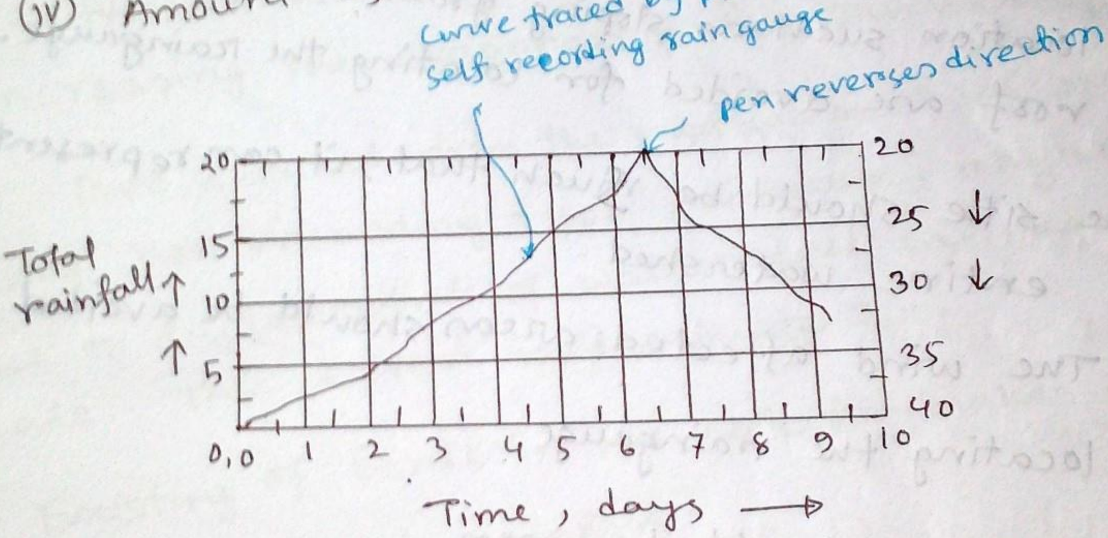
(IV) In light shower, the raingauge becomes useless.

Q. Define Mass curve of rainfall and also explain it.

Answer: Mass curve of rainfall: The curve shows the relation between the time and total rainfall where time is in X axis and total rainfall in Y-axis as taken is called mass curve of rainfall.

It gives the followings:-

(I) Duration of rainfall.
(II) Starting and ending of rainfall.
(III) Intensity of rainfall.
(IV) Amount of rainfall.



Q. What are the conditions to be provided for location of raingauge? 2003, 06, 08, 10

or, Explain the methodology of raingauge installation → 2015

or, What are the factor that influence the selection of site for a rain gauging station?

or, Write down the points that should be kept in view for installing the raingauge

Answer: The following points should be kept in view for installing the raingauge.

(I) The ground surface must be level. Generally the location such as sloping ground, terrace well or roof are avoided for locating the raingauge.

(II) The site should be such that, it can represents the entire watershed.

(III) The wind affected areas should be avoided for locating the raingauge.

(IV) The site should be open.

(V) Location of raingauge should be neglected in the valley or at ridge point of the area.

(VI) Raingauge should be installed in vertical position.

(VII) The installation of raingauge should be preferred in easily accessible area.

(VIII) Horizontal distance between the raingauge and nearest object should be twice the height of object.

(IX) The percent of total number of rain gauge stations of any basin should be self-recording.

(X) The observer must visit the site regularly to ensure its proper readings for measurement.

Q. Mention the common errors in rainfall measurement.

Common errors in rainfall Measurement:-

(i) Atmospheric temperature yields some error by increasing the evaporation loss. This value upto 2%.

(II) Data obtained from the measurement of rainfall, using non recording type raingauge, may be erroreus due to displacement of water level by measuring scale. This error ranges upto 2%.

(III) Existing of bends in the collector makes inaccurate measurement of rainfall.

(IV) Frictional effect in recording mechanism, introduces erroneus result.

(V) Inaccurate recording of observation, produces errors in the measurement.

(VI) Obstruction like trees, buildings etc. creates errors by affecting the wind pattern of the location.

(VII) Some volume of water is lost in wetting of initially dried surfaces of measuring gauge. About 0.25 mm rainfall depth is lost in this process.

(VIII) Splashing of water from the collecting funnel, yields some error.

Q. Define A.A.R. what factors does it depends? 2006, 14, 15

Answer: A.A.R: A.A.R means Average Annual Rainfall. The mean of yearly rainfall observed for a period of 35 consecutive year is called ~~an~~ the average annual rainfall (a.a.r).

The A.A.R. of place depends on:— 2015

TADID

(I) Distance from the ocean.

(II) Direction of the prevailing winds. → প্রবহমান

(III) The mean annual temperature.

(IV) Altitude of the place.

(V) It's topography.

Q. Define. Raingauge density. 2009, 2014

Raingauge Density: The number of rain-gauges to be elected in a given area is termed as the raingauge density.

The specification for raingauge density is given below:—

Area   Rain gauge density.

1. plain → 1 in 520 km²
2. Elevated regions → 1 in 260–390 km²
3. Hilly and very heavy rainfall areas → 1 in 130 km². preferably with 10% of the raingauge stations equipped with self recording type.

* In Bangladesh, given by Bangladesh Metrology Department → 1 in 220–225 km² for 35 stations.

Q. Write short notes on RADARS:-

RADARS: The application of radars in the study of storm mechanics i.e. (i) The areal extent, (ii) Orientation (iii) movement of rain storms etc. The radar signals reflected by the rain are helpful in determining the magnitude of storm precipitation and its areal distribution. By.

IDM → Indian Metrology Department.

BMD → Bangladesh Metrology Department.

⇒ Effect of raingauge density on rainfall measurement:-

The accuracy of rainfall measurement largely depends on the number of raingauges and the number of raingauge station installed in the area. If the number of raingauge for a particular area is increased, then percentage of error in rainfall measurement is reduced.

Q. Write the methods of estimating missing rainfall data.

2011

Answer: (I) Arithmatic average Method: If normal annual rainfall at the missing station is within 10% of the normall annual ~~raifo~~ rainfall at the adjacent stations, arithmatic average method can be applied.

If missing rainfall at station X is P_x and $P_1, P_2 \cdots P_n$ are the rainfall at n surrounding station,

$$P_x = \frac{1}{n}[P_1 + P_2 + P_3 + \cdots + P_n]$$

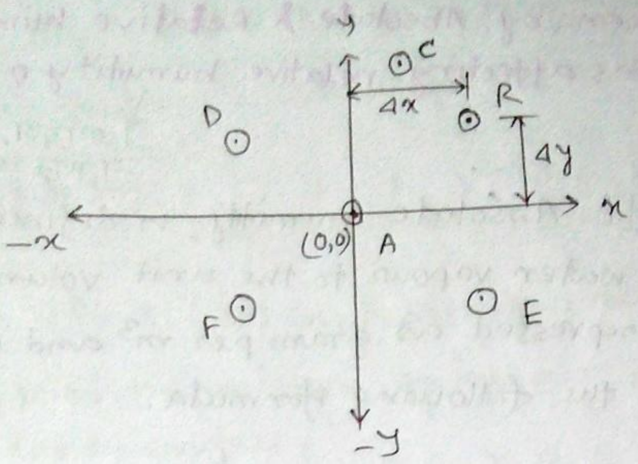
(II) Normal ratio method: If ~~ro~~ normaal annual rainfall at the missing station differ more than 10% of the normal annual rainfall at the adjacent station normal ratio method is preferred.

→ 2015

If N_x is the normal annual rainfall at station X ... $N_1, N_2, \cdots N_n$ are the normal annual rainfall at the n surrounding stations respectively & $P_1, P_2 \cdots P_n$ are rainfall recorded at the surrounding stations.

∴ Missing rainfall data, $P_x = \frac{1}{n}\left[\frac{N_x P_1}{N_1} + \frac{N_x P_2}{N_2} + \cdots + \frac{N_x P_n}{N_n}\right]$

(III) Inverse distance method: In this method a rectangular co-ordinate system is superimposed over the map marked with raingauge station in such a way that the origin (0,0) represents the missing station as shown in figure.



The following relation may be used,

$$P_x = \frac{\sum_{i=1}^{n} P_i w_i}{\sum_{i=1}^{n} w_i}$$

, where, $w_i = \frac{1}{D^2}$

and, $D^2 = \Delta x^2 + \Delta y^2$

Q. why or when the rainfall data is in-consistent?

Answer: The following points are responsible for making the rainfall data inconsistent as given below; –

(I) Due to change in location of rain gauge station. This is might be due to the shifting or rain gauge to a new location.

(II) When neighbourhoods of the station have gone significantly changed.

(III) Repetation of observational error from a certain period.

(IV) Due to change in exposure of station, caused by construction of new buildings, development of forest or occurence of land slides in hilly regions etc.

Q. What do you mean by Absolute & Relative humidity? What are the factors affecting relative humidity?

[আদ্রতা, বাতাসে জলীয় বাষ্পের অনুপাত]

Answer:

Absolute humidity: Absolute humidity is defined as the ratio of mass of water vapour to the unit volume of space. It is generally expressed as gram per m^3 and can be computed by using the following formula.

$$a_h = \frac{e}{T_a} \times 217,$$

where, e = Vapour pressure

a_h = Absolute humidity

T_a = Absolute Temperature.

Relative humidity: It can be defined as the ratio of the actual vapour (e) pressure to the saturation vapour (e_s) pressure, given as,

$$f = \frac{e}{e_s} \times 100.$$

It is generally expressed as in percentage.

If temperature of air and dew point are known, then relative humidity can be directly computed by the using of following expression,

$$R.H = \frac{112 - 0.1T + T_d}{112 + 0,9T}$$

where, T = Air temperature (°C)

T_d = Dew point temperature (°C).

Factors affecting Relative humidity: AVOLAD

The various factors, which affect the relative humidity are described as under :-

(I) **Altitude Effect:** तुंगता ऊँचाई/ऊँचाई Relative humidity increases with increase in altitude.

(II) **Vegetation Effect:** It increases the relative humidity, as it directly supplies the moisture to the air passing over the vegetated land surface.

(III) **Orographic effect:** It is observed that the maximum amount of moisture is present up to the elevation of 8000m. In this way, at higher elevation than 8000m, the atmospheric moisture is comparatively less, than the sea level. Regarding orographic effect on relative humidity, it is higher at mountaneous region then that measured in the air at the same elevation in plane lands.

(III) **Land and water masses:** The relative humidity is greatly affected by the presence of water bodies over the land surface. If all the factors are remained same then it is found greater over the water surface than the land surface. For example over the oceans then some moisture content is relatively higher over the same distance away from the same.

(IV) **Annual variation:** It is presented by the season-wise variations in the moisture content. In summer season, it is found maximum and minimum during winter season of the year.

(V) **Diurnal variation:** Diurnal variation indicates the variation of relative humidity with reference to different periods (i.e. morning, evening and night) of the day hour.

in arly morning it is maximum level, while minimum the early afternoon of the day.

Q. Write a short notes on the mean areal depth of precipitation determination. 2015

Answer: **Mean Areal Depth of Precipitation ; Pave :-**

Point rainfall: It is the rainfall at a single station. For small areas less than $50\ km^2$ point rainfall may be taken as the average depth over the area. In large areas, there will be a network of rain-gauge stations. As the rainfall over a large area is not uniform, the average depth of rainfall over the area is determined by one of the following three methods:-

(1) **Arithmetic Average Method:** It is obtained by simply averaging arithmetically the amounts of rainfall at the individual rain-gauge stations in that area. i-e.

$$P_{ave} = \frac{\Sigma P_1}{n}$$

where, P_{ave} = Average depth of rainfall over the area.

ΣP_1 = sum of rainfall amounts at individual rain-gauge stations.

n = number of rain-gauge stations in the area.

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

(2) Thiessen polygon method:

This method attempts to allow for non-uniform distribution of gauges by providing a weighting factor for each gauge. The stations are plotted on a base map and are connected by straight lines. Perpendicular bisectors are drawn to the straight lines, joining ~~to~~ adjacent stations to form polygons, known as Thiessan polygons. The polygon area is influenced by the rain-gauge stations.

If $P_1, P_2, P_3 \ldots$ are the rainfalls at the individual stations and $A_1, A_2, A_3 \ldots$ are the areas of the polygons surrounding these stations respectively, then the average depth of rainfall for the entire basin is given by,

$$P_{ave} = \frac{\Sigma A_1 P_1}{\Sigma A_1}$$

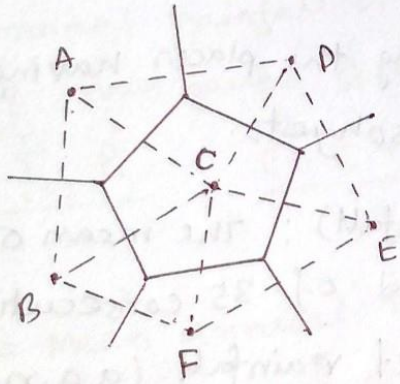


Fig. Thiessen polygon method.

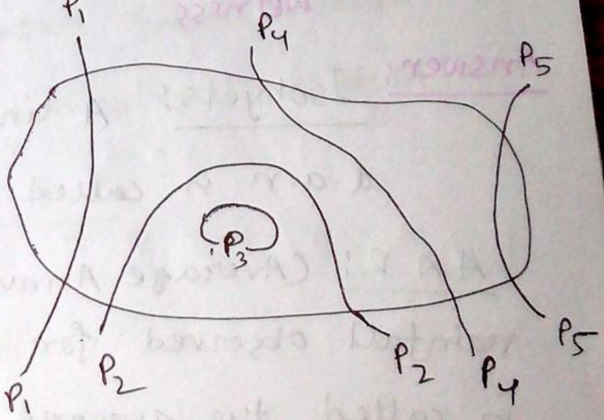


Fig. Isohyetal Method.

(3) Isohyeta method: In this method the point rainfalls are plotted on a suitable base map and the lines of equal rainfall (isohyets) are then drawn giving consideration to orographic effects and storm morphology.

The average rainfall between the succesive isohyets taken as the average of the two isohyetal values are weighted with the area between the isohyets, added up and divided by the total area which gives the average depth of rainfall over the entire basin. It is repres as follows,

$$P_{ave} = \frac{\Sigma A_{1-2} P_{1-2}}{\Sigma A_{1-2}}$$

where, A_{1-2} = area between the two successive isohyets

$$P_{1-2} = \frac{P_1 + P_2}{2}$$

$\Sigma A_{1-2} = A$ = total area of the basin.

This method if analysed properly gives the best results.

* Define, Isohyets, Arid, semi Arid, humid regions, Index o wetness.

Answer; **Isohyets;** A line joining the places having the same a.a.r is called an Isohyets.

A.A.R; (Average Annual Rainfall): The mean of yearly rainfall observed for a period of 35 consecutive years is called the average annual rainfall (a.a.r).

[illegible]

Arid; If the a.a.r < 40 cm then it is called ~~arin~~ arid climate, a drought is a normal state of affairs.

Semi-arid; If the a.a.r is 40 to 75 cm then it is called semi arid climate. In a semi-arid climate, a drought (অনাবৃষ্টি) occurs at least once a year except in abnormal years

Humid or standard: If the a.a.r > 75 cm. then it is called standard or humid climate. In a humid climate a drought does not occured ordinary years.

2015
Index of wetness: The ratio of rainfall in a particular year to the a.a.r is called the "index of wetness". For example, an index of wetness of 60% in a particular year indicates a rainfall deficiency of 40%.

★ Explain how you could determined the optimum number of raingauges to be erected in a given basin.

Answer: Optimum Rain-gauge Network design:-

The procedure for determining the optimum number of rain-gauge to be installed in a given basin is explained below:-

(I) Mean annual rainfall is calculated from the data recorded at existing rain gauge station by using the relation.

$$\bar{P} = \frac{\sum_{i=1}^{n} P_i}{n} = \frac{P_1 + P_2 + P_3 + \cdots + P_n}{n}$$

where. $\bar{P}$ = Mean annual rainfall.

n = tatal number of raingauges.

$P_1, P_2 \cdots P_n$ = annual rainfall recorded in $1, 2 \cdots n$ raingauges station respectively.

(II) The standard deviation σ is determined from existing stations record using the relation,

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

(iii) co-efficient of variation Cv is calculated as,

$$Cv = \frac{\sigma}{\overline{P}} \times 100 .$$

(iv) Optimum number of raingauges required to install is calculated from the following relation,

$$N = \left(\frac{Cv}{\varepsilon}\right)^2$$

where, Cv = co-efficient of variation of the rainfall of the existing raingauge station.

ε = Percentage allowable error.

N = optimum number of raingauges required

⇒ Wet year/Good year: The year in which rainfall is greater than mean rainfall is called wet year or good ye

According to Bland Ford, wet year $= (1.24 \text{ to } 2.54)\,\overline{x}$,

According to Alexander Binnie, wet year $= 1.51\,\overline{x}$.

Dry year/ Bad year: The ~~at~~ year in which rainfall is less than mean rainfall is called bad year.

According to Bland Ford in a bad year rainfall should be 0.27 to 0.78 times of a.a.r.

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Q. what are the Limitations of Theissen Polygon method?

Answer: Limitation:

(1) If the position of raingauge changes, the boundary of polygon also changes, hence requires to sketch new polygons. Thus it involves further calculation for getting the mean areal precipitation additionally.

(2) This method is not suitable for mountaneous regions because of orographic influence on the rainfall.

(3) The influence of barriers atmospheric pressures, wind velocity etc. on the rainfall distribution is not taken into consideration.

* what are the special features of Isohyetal Method?

Special Features:

(I) This method requires more number of raingauge stations in the catchment to sketch the isohyet map.

(II) It provides more accurate result than the other methods.

(III) It needs skilled and experienced staff to sketch the isohyet map for computing the mean areal precipitatio

(IV) This method is more suitable for hilly and rugged topography having command area more than 5000 Km^2.

Q. What are the factors is accounted for selection of suita method for computing the mean area precipitation?

Answer: The selection of suitable method among arithmatic mean method, ~~thiess~~ thiessen polygon method and isohy method, for computing the mean areal precipitation, depen on the following three main factors:-

(I) Raingauge Network of the catchment.

(II) Catchment area.

(III) Topographical feature of the catchment.

They are discussed below:-

Raingauge Network: It is expressed by the number of raingauge stations present in the catchment area. The Network is categorized into two groups, in which one is equip with the sufficient number of stations and other is with limited number of stations. The choice of accurate method based on this is given below:-

(a) Watershed with sufficient gauges: The catchment, which has dense rain gauge network, the selection of isohyetal and thiessen polygon method accomplish best estimate of mean areal precipitation.

(b) Watershed with limited gauges: The arithmatic mean and thiessen polygon methods are preferably used.

(c) watershed with one raingauges: Only point rainfall is determined not any method can be used.

Catchment Area: The areal extent of catchment affects greatly the choice of method to be used for computing the mean areal precipitation. The selection of methods based on catchment size is given below:-

Catchment area (km^2)	Suitable method
Less than 500	→ Arithmatic mean method.
500 – 5000	→ Thiessen polygon method.
more than 5000	→ Isohyetal method.

Topography of the Area/ Topographical feature of the Catchment:

Regarding selection of suitable methods for computing the mean areal precipitation, the topographical feature of the area and suitable methods for them are given below:-

(a) Mountain → Arithmatic mean method.
(b) Plain land → Thiessen polygon method.
(c) Hilly and rugged terrain → Isohyetal method.

Question: Explain a method for testing the consistency of rainfall records at a station and necessary adjustment. double mass analysis method.

Or, Procedure for double mass analysis method for testing the consistency of rainfall records and necessary adjustment is described next page.

Answer: The double mass analysis method for testing the consistency of rainfall records and necessary adjustment is described next page.

Double mass analysis Method: The rainfall records of a station may slightly change after some years due to change in the environment either due to coming of new building, planting of trees etc, or cutting of forest nearby. Due to these reasons wind pattern changes and thus leads to change in rainfall data.

The consistency of records of such stations (such as station-X) is tested by a double mass curve by plotting the cumulative annual (or seasonal) rainfall of station X against the concurrent cumulative values of mean annual (or seasonal) rainfall for a group of surrounding stations for the number of years of record. In this plot, the year in which a changed is occured is indicated by change in slope of the straight line plot. The records are then adjusted by multiplying the recorded value of rainfall by the ratio of slopes of straight line before and after change in environment.

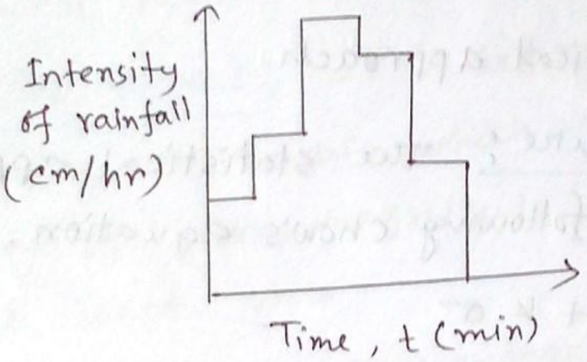
*** What do you mean by graphical representation of rainfall?

Answer: **Graphical Representation of Rainfall:**

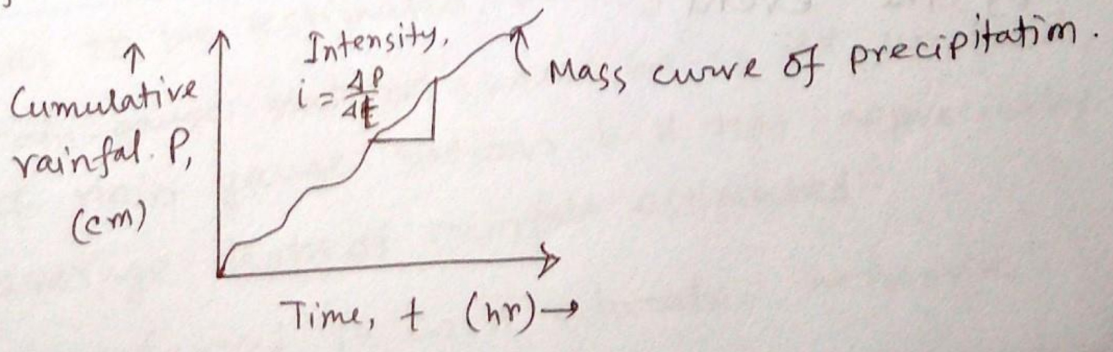
The variation of rainfall with respect to time may be shown graphically by

(a) A hyetograph and (b) A mass curve.

HYEOTOGRAPH: A hyetograph is a bar graph showing the intensity of rainfall with respect to time. It is useful to determining the maximum intensities of rainfall during a particular storm as is required in land drainage and design of culverts.



Mass curve: A mass curve of rainfall is a plot of cumulative depth of rainfall to time. From the mass curve, the total depth of rainfall and intensity of rainfall at any instant of time can be found.



* What is meant by Probable maximimum precipitation (PMP)? Describe methods of estimating PMP. what are its design application?

Probable Maximum Precipitation :-

Probable maximum precipitation (PMP) is defined as the estim of the emtreme maximum rainfall of given duration that is physically possible over the basin under critical, hydrological and meteorological condition.

Methods of estimating PMP: Two available methods of PMP estimation are —

(I) Statistical procedure.

(II) Meteorological approach.

Statistical procedure: The statistical approach of PMP uses the ~~flowing~~ following chow's equation,

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

where, $\bar{P}$ = Mean of annual maximum values.

σ = standard deviation.

K = frequency factor (5-35)

This method gives a rough estimate of the magnitude of the event.

Meteorological approach: In meteorological approach, the storm experience of the basin is maximised by ~~talking~~ · taking all the storms of the basin and adjoining areas which are meteorologically homogenious.

Steps involved in obtaining PMP are —

(a) Depth area duration analysis of major storms of the region.

(b) Maximisation of the storm.

(c) Enveloping the maximised values of all the storms to obtain DAD curve of PMP.

* Define Return Period! 2018 Staturated Network design.

Answer: **Return period:** It is defined as the average interval of time T within which flood or any other extreme event of given magnitude will be equal or exceeded at least once.

If P is the probability in percentage then,

Return period, $\boxed{T = \frac{1}{P}}$ —— ①

Here, Return period = Recurrence interval = frequency.

Saturated Network design:- If the project is very important the rainfall has to be estimated with great accuracy, then a network of rain-gauge stations should be so set up that any addition of rain gauge stations will not appreciably alter the average depth of rainfall estimated. Such network is referred to as a saturated network.

⇒ what are the characteristics of a rain storm.

Answer: **Characteristics of rain storm:**

(I) Intensity (cm/hr)

(II) Duration (min, hr, days).

(III) Frequency [once in 5 years, once in 10, 20, 40, 60 or 100 yea

(IV) Areal extent [i.e. area over which it is distributed]

2014,13

*** Define DAD curves.

Answer: **DAD CURVES:**

The intensity of depth of rainfall in Y-axis and area in X-axis are taken then a curve is got after plotting values with respect to time which is called Depth-Area-Duration curve.

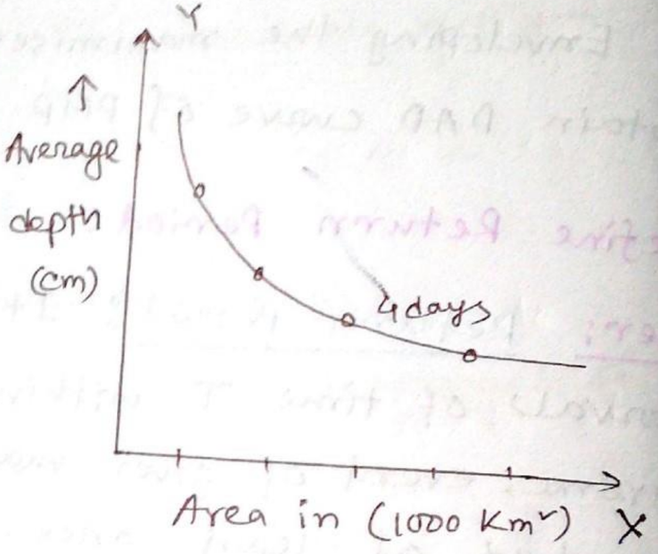


Fig. DAD curves.

In fig we see it, that Increasing of area, depth will be reduced with time.

* write short notes on moving average curve.

Answer: Moving Average curve: In hydrology, rainfall data are plotted chronologically between in x-axis time and precipitation in Y-axis. A rain event is associated with randomness to overcome the random component. A simple moving average of order 3 or 5 is used. This helps to isolate the trend in the rainfall data. From the graph, the wet period mean, overall mean and dry period. mean can be identified. If x_1, x_2, x_3, x_4, x_5 ... are annual precipitation at a station and a 5 year moving average is applied to the series the followings moving mean are computed.

$$X_1 = \frac{x_1 + x_2 + x_3 + x_4 + x_5}{5}$$

$$X_2 = \frac{x_2 + x_3 + x_4 + x_5 + x_6}{5}$$

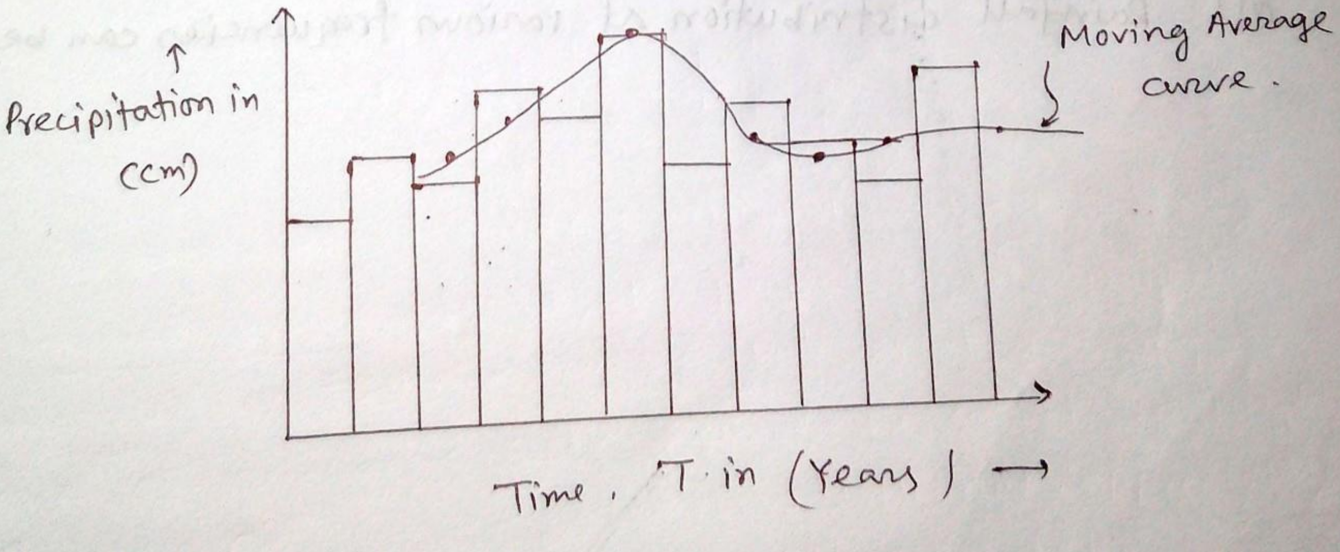


Fig. Moving Average curve.

* what do you mean by 75% dependable rainfall?

Answer: 75% dependable Rainfall:

It means that 75% of the average rainfall is considered for the design of any hydrological subject matter such as irrigation, flood level, etc which is known as the 75% dependable rainfall.

*** what are the importance of analysis of rainfall data?

Answer: Importance of Analysis of Rainfall Data:—

(I) It provides an estimate of future rainfall trend.

(II) Determines the rainfall intensity and occurance of flood producing storm.

(III) Adjustment of rainfall data can be made.

(IV) Seasonal and annual rainfall variation can be determined.

(V) The maximum and minimum rainfall are also determined

(VI) Rainfall distribution at various frequencies can be studied

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Water Losses

IIEETW

* Enumurate various water losses.
or Explain Briefly water losses project.

Answer: Water Losses :-

(I) Interception loss – due to surface vegetation, i.e. held by plant leaves.

(II) Evaporation, (a) From water surface i.e, reservoirs, lakes ponds, river channels etc.

(b) From soil surface, appreciably when the ground water table is very near the soil surface.

(III) Transpiration – From plant leaves.

(IV) Evapotranspiration or consumptive use – from irrigated or cropped land.

(V) Infiltration – Into the soil at the ground surface.

(VI) watershed leakage – Ground water movement from one basin to another or into the sea.

* What is the basic difference between consumptive ~~use~~ use and conjuctive use of water?

Answer: Water loss due to evapotranspiration, water used in ~~to~~ trealage purposed and water loss by deep seepage is combinely called consumptive use of water.

On the other hand, the combined use of ground water and surface water is called conjuctive use of water.

This is the basic difference between consumptive use and conjuctive use of water.

* What are the factors affecting evaporation rate?

Answer: The various factors, which affect the evaporation are listed below:-

(I) Surface area of the water body.
(II) Depth of water in the reservoir.
(III) Nature of the rainfall.
(IV) Humidity.
(V) Wind velocity.
(VI) Temperature of water and atmosphere.
(VII) Salinity of water.

Define:

⇒ **Interception Loss:** The precipitation intercepted by foliage and buildings and returned to atmosphere without reaching the ground surface is called interception loss.

পাতাগুলো

~~Infil~~ Interception loss is high in the beginning of storms and gradually decreases. The following figure shows "~~Horton's~~ mean curve", for interception loss.

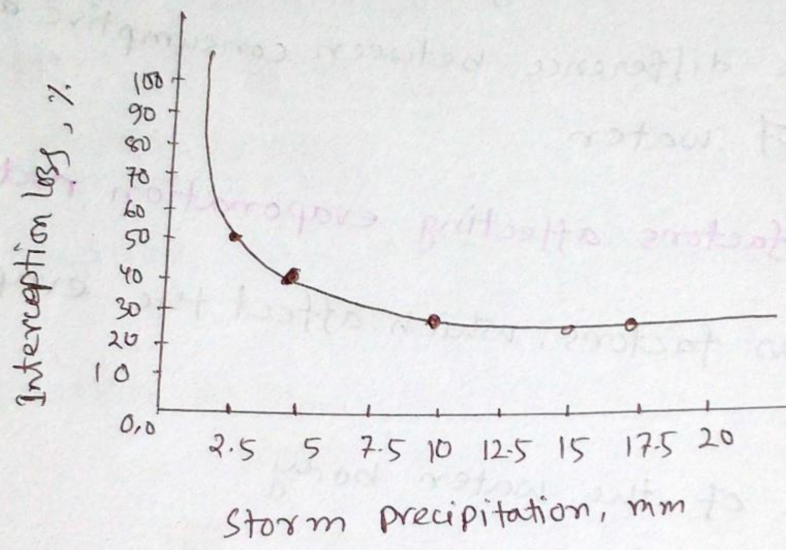


Fig. Interception loss (Horton)

⇒ Factors affecting evaporation:

ABRSSWW

(I) Air.
(II) Water temperature.
(III) Relative humidity.
(IV) wind velocity.
(V) Surface area (exposed)
(VI) Barometric pressure.
(VII) Salinity of the water.

* what are the methods of estimating lake evaporation.

Methods of estimating evaporation: Evaporation from water surfaces can be determined from the following methods.

(I) The storage equation,

$$P + I \pm O_g = E + O \pm S.$$

where, P = Precipitation, I = surface inflow, E = Evaporation, O = surface outflow.

O_g = subsurface inflow or outflow,

S = change in surface water storage.

(II) Auxilary pans like land pans, floating pans, colardo sunken pans etc.

(III) Evaporation formula like that of Dalton's law.

$$E = K(e_w - e_a)$$

where, E = daily evaporation, K = a constant.

e_w = saturated vapour pressure at the temperature of water.

e_a = vapour pressure of the air (about 2m above

(IV) Humidity and wind velocity gradients.

(V) The energy budget.

(VI) The water budget.

(VII) Combination of aerodynamic and energy balance equations – penman's equation.

Scanned by CamScanner

Defn: Pan $\xrightarrow{2015, 2014}$ co-efficient: It is defined as the ratio of lake evaporation to pan evaporation, that is.

$$\text{Pan co-efficient} = \frac{\text{Lake evaporation}}{\text{pan evaporation}}.$$

The experimental values for pan co-efficient range from 0.67 to 0.82 with an average of 0.7.

* * what are the measures to reduce lake / reservoir evaporation? 2014, 13, 10

Answer: Measures to reduce lake Evaporation:

(I) Storage reservoirs of more depth and less surface area helps to reduce lake evaporation.

(II) By growing tall trees like "causerina" on the winward side of the reservoir to act as wind breakers.

(III) By removing water loving weeds and plants like phreatophytes from the periphery of the reservoir.

(IV) By allowing flow of water, temperature is reduced and evaporation is reduced.

(V) By strengthening the stream channels.

(VI) By providing mechanical coverings.

(VII) By developing underground reservoirs.

(VIII) If the reservoir is surrounded by huge ~~trees~~ trees and forest, the evaporation loss will be less due to cooler environment.

* write short note on Evaporation pans.

Answer:

(I) **Floating pans;** (I) 90 cm square.
(II) 45 cm deep
(III) Mounted on a raft floating in water.
(IV) Evaporation is determined by knowing the volume of water to fill the daily mark.

(II) **Land pans;** (I) Lake evaporation can be determine.
(II) 122 cm diameter and 25.5 cm deep.
(III) Made of unpainted GI sheet.
(IV) It has also other arrangements to get the data.

(III) **Colardo sunken pan;** (I) 92 cm square & 42-92 cm deep.
(II) sunk in ground as 5-15 cm from it.
(III) Evaporation is measured by point gauge.
(IV) Evaporation is maintained at the ground level.

* Define soil evaporation and evaporation opportunity.

Answer; **Soil Evaporation:** The evaporation from wet soil surface immediately after rain or escape of water molecules with more resistance when the water table lies within a meter from the ground is called soil evaporation.

Evaporation opportunity: The evaporation from free water surface is called evaporation opportunity. It is expressed as percentage.

$$\text{Evaporation opportunity} = \frac{\text{Actual evaporation from the land (soil) at a given time}}{\text{Evaporation from an equivalent water surface}} \times 100$$

* Define transpiration and Transpiration Ratio:

Answer: Transpiration : Transpiration is the process by which the water vapour escapes from the living plant leaves and enters the atmosphere.

Transpiration ratio: Transpiration ratio is the ratio of the weight of water absorbed (through the root system), conveyed through and transpired from a plant during the growing season to the weight of the dry matter produced exclusive of roots.

$$\text{Transpiration ratio} = \frac{\text{weight of water transpired}}{\text{weight of dry matter produced}}.$$

* "Evaporation is less on a humid day" — Explain.

Answer: Humidity of atmosphere affects evaporation. If humidity is greater evaporation will be smaller. It is due to the fact that during evaporation process the water molecules move from higher moisture to lower moisture places. The rate of this movement is governed by the difference of moisture content of air. Thus, if the air humidity is more, evaporation will be less. In other words, evaporation is less on a humid day.

* Define evapotranspiration, Explain the factors affecting evapotranspiration.

Answer: Evapotranspiration: Evapotranspiration (E_t) or consumptive use (U) is the total water lost from a cropped land due to evaporation from the soil and transpiration by the plants or used by the plants in building up of plant tissue.

Factors affecting evapotranspiration: SPAC

Soil factors: Soil controls evapotranspiration in the following ways:-

(I) Supplying limited water for evaporation.
(II) Altering absorption of radient energy.
(III) Altering heat transmission for evaporation.

Plant factors: A plant affects the evapotranspiration by its species, rooting behavior, leaf geometry, growth stage etc.

Atmospheric factor: Various atmospheric factor affecting evapotranspiration are temperature, wind velocity, humidity, solar radiation etc.

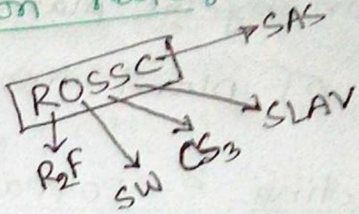
Cultural Practic Factor: Cultural practices like irrigation rate and its method used etc. affect evapotranspiration.

** Define Infiltration. Discuss the factors affecting infiltration

Answer: 2001, 02, 04, 06, 07, 08, 11, 14.

Infiltration: water entering the soil at the ground surface is called infiltration. It is counted as a form of hydrologic loss.

Factors affecting infiltration rate:-



(1) Rainfall factors:

(I) Rainfall intensity.
(II) Rainfall duration.
(III) Forms of precipitation.

Soil Factors:

(I) Soil type
(II) Soil surface slope.
(III) Soil moisture.
(IV) Cultivation practice.

Surface cover factors:

(I) vegetation type.
(II) Agricultural crops.
(III) Litter.
(IV) Snow cover.

Climate factor:

(I) Atmospheric temperature.
(II) Soil temperature.
(III) Seasonal variation.

Other factors:

(I) Water quality.
(II) Salinity and contamination of water.

* Draw a typical infiltration curve and give its equation.

Answer: Equation of infiltration curve suggested by Horton-

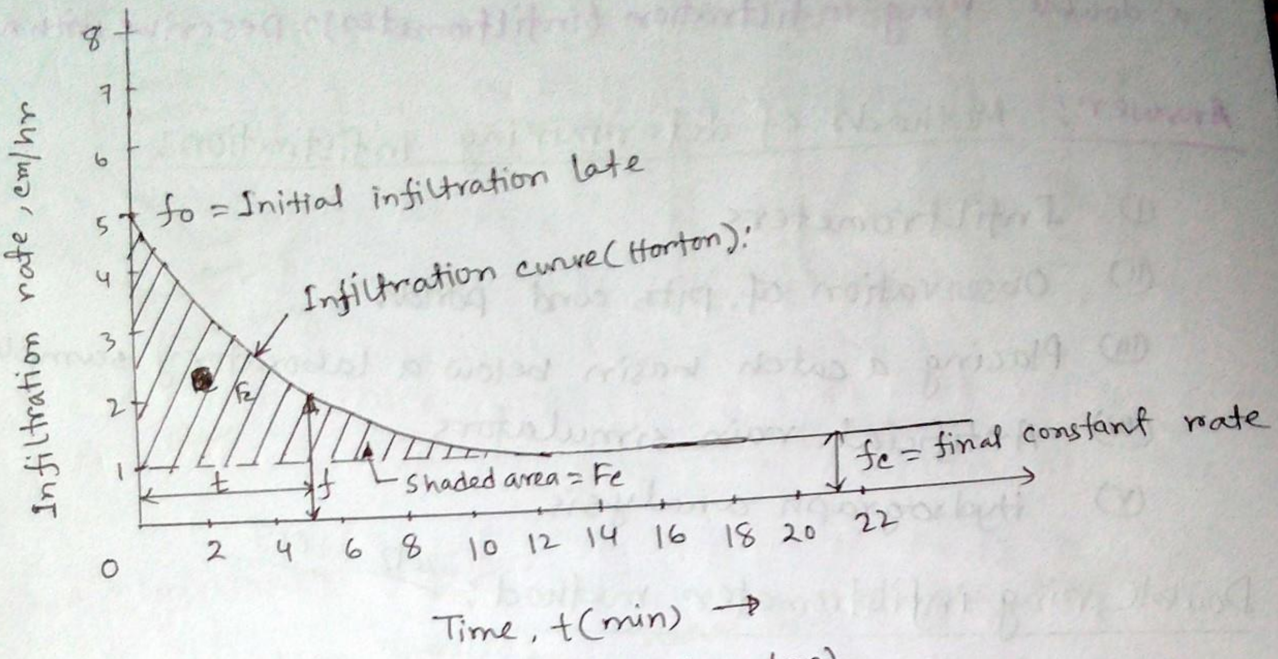


Fig. Infiltration curve (Horton)

Hortons equation,

$$f = f_c + (f_o + f_c) e^{-kt} \quad \text{where, } K = \frac{f_o - f_c}{F_c}$$

where, f_o = initial rate of infiltration capacity.

f_c = final constant rate of infiltration at saturation.

K = a constant depending primarily upon soil and vegetatio

e = base of the Napierian logarithm

F_c = shaded area

t = time from begining of the storm

where, infiltration rate in Y-axis and time in X-axis are taken and Horton infiltration curve is formed. Here, infiltratio takes place at capacity rates only when the intensity of rainfalls equal or exceeds fp.

* Explain any method of determining infiltration capacity of soil surface.

Or, How infiltration capacity rate can be measured using a double ring infiltration (infiltrometers)? Describe with neat sketch

Answer: Methods of determining infiltration:

(I) Infiltrometers.
(II) Observation of pits and ponds.
(III) Placing a catch basin below a laboratory sample.
(IV) Artificial rain-simulators.
(V) Hydrograph analysis.

Double ring infiltrometer method: 2012, 2015

(I) A double ring infiltrometer is penetrated into the soil to a depth of 15 cm with a hammer.

(II) the disturbed soil, if any adjacent to the sides is tamped.

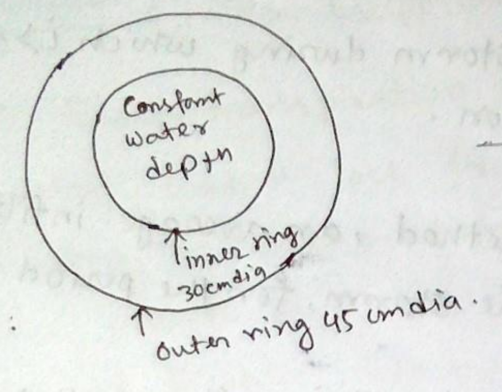
(III) Point gauges are fixed in the centre of the rings and in the annular space between the two rings.

(IV) Water is poured into the ring to a desire depth.

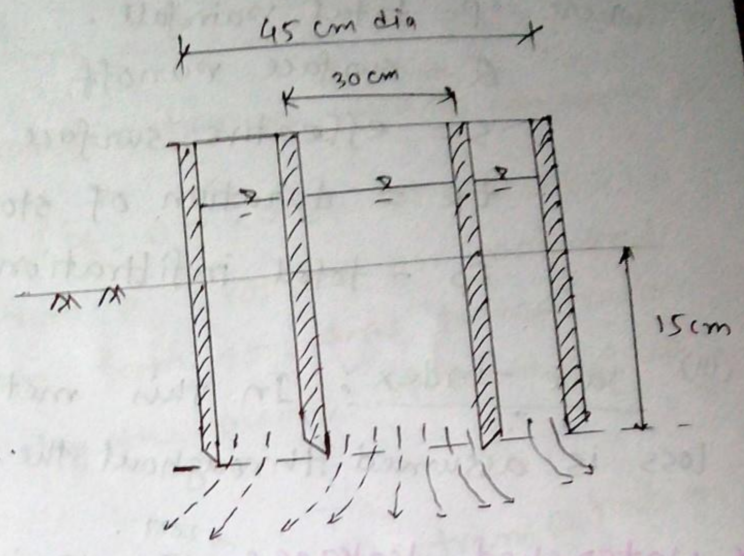
(V) To maintain constant depth, water is added continuously and water requirement forregular time interval is recorded upto a period of ~~atte~~ at least 6 hours.

(VI) The result are plotted as infiltration rate cm/hr versus time in minutes.

Infiltration capacity is determined from this curve.



plan



section.

* Explain infiltration indices.

Answer: **Infiltration indices:** There are three types of infiltration indices.

(I) φ – index.

(II) W – index.

(III) f_{ave} – index.

φ-index: The φ-index is defined as that rate of rainfall above which the rainfall volume equals the runoff volume.

$$\phi\text{-index} = \frac{\text{basin recharge}}{\text{duration of rainfall}}$$

W-index: The W-index is the average infiltration rate during the time rainfall intensity exceeds the infiltration capacity rate.

$$W\text{-index} = \frac{F_b}{t_R} = \frac{P-Q-S}{t_R}$$

where . P = total rainfall .
Q = surface runoff
S = effective surface retention .
t_R = duration of storm during which $i > f_p$
f_p = total infiltration .

(III) **fave -index:** In this method, an average infiltration loss is assumed throughout the storm, for the period $i > f$.

* **watershed leakage:** →2007 The rain water after infiltering into the ground may percolate through the water bearing strata may flow into the adjacent basin or directly into the sea if the water bearing ~~strata~~ strata outcrops into the sea. This is called watershed leakage .

* **Water balance:** →2007 The input items into a basin are essentially precipitation (P) and subsurface inflow (G_i) while the water losses are evaporation (E), evapotranspiration (E_t) and subsurface outflow (G_o). The balance goes to recharge ground water (G_r), increase the soil moisture (SMA) and as surface runoff (streamflow, R). The water balance equation can be written as,

$$P + G_i = E + E_t + G_o + SMA + G_r + R$$

2014

** Is Evapotranspiration same as consumptive use? Explain.

Explanation: Yes, Evapotranspiration is same to consumptive use.

where, Evapotranspiration (E_t) or consumptive use (U) is the total water lost from a cropped or irrigated land due to evaporation from soil and transpiration by the plants or used by the plants in building up of plant tissue.

Potential evapotranspiration is the evapotranspiration from the short green vegetation when the roots are supplied with unlimited water covering the soil. It is usually expressed as a depth (cm, mm) over area.

** Distinguish between infiltration rate and infiltration capacity.

Answer: The difference between infiltration rate and infiltration capacity given below:-

Infiltration rate	Infiltration capacity
(I) The entering of the water into the soil per unit time is called the infiltration rate.	(I) It is the maximum rate at which the soil can absorb the water for any given condition is called the infiltration capacity.
(II) It is expressed by f.	(II) It is expressed by fp.

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RUN-OFF

* Define Runoff. Discuss about different types of run-off.

Answer: Run-off: The portion of precipitation which appears in the surface streams of either perennial or intermitte nature is called run-off.

The total run-off may be expresses as,

Run-off = Surface run-off + Sub surface runoff + ground water runoff or Base flow.

Types of run-off: Run-off is broadly classified into following three types.

(i) Surface run-off
(ii) Sub surface runoff
(iii) Base flow.

They are described below:-

Surface runoff: The portion of rainfall which enters the streams, channels etc. immediately after occuring the rainfall is called surface runoff.

Sub-surface runoff: The amount of rainfall, which first Reaches into the soil and then starts flowing laterally without joining water table, is called as subsurface runoff.

Base flow: The part of rainfall, which after falling over the ground surface, percolates into the soil and meets water table and finally joins to the streams, oceans etc, is called Base flow.

2003
** Define depression storage and detention storage.

Answer: **Depression storage:** When the overland flow starts some flowing water is held in puddles, pits and small ponds; this water stored is called depression storage.

Detention storage: In the overland flow, the volume of water in transit, which has not yet reached the stream channel is called surface detention or detention storage.

⇒ **Influent stream:** If the GWT is below the bed of stream bed, then seepage from the stream feeds the ground water resulting in the build up of water mound, such streams is known as influent stream.

⇒ **Intermittent stream:** If the ground water table lies above the stream bed during wet season and below stream bed during dry season, such stream is called intermittent stream.

* Define Distribution co-efficient.

Answer: Distribution co-efficient: It is defined as the ratio of maximum rainfall at a point to the mean rainfall of the concern catchment, that is,

$$\text{Distribution co-effient}, C_d = \frac{\text{Maximum rainfall amount}}{\text{Mean rainfall}}.$$

2013
** Define Bank storage with figure.

Answer: Bank storage: The portion of run-off in a rising flood in a stream, which is absorbed by permeable boundaries of stream above the normal phreatic surface is called "Bank storage".

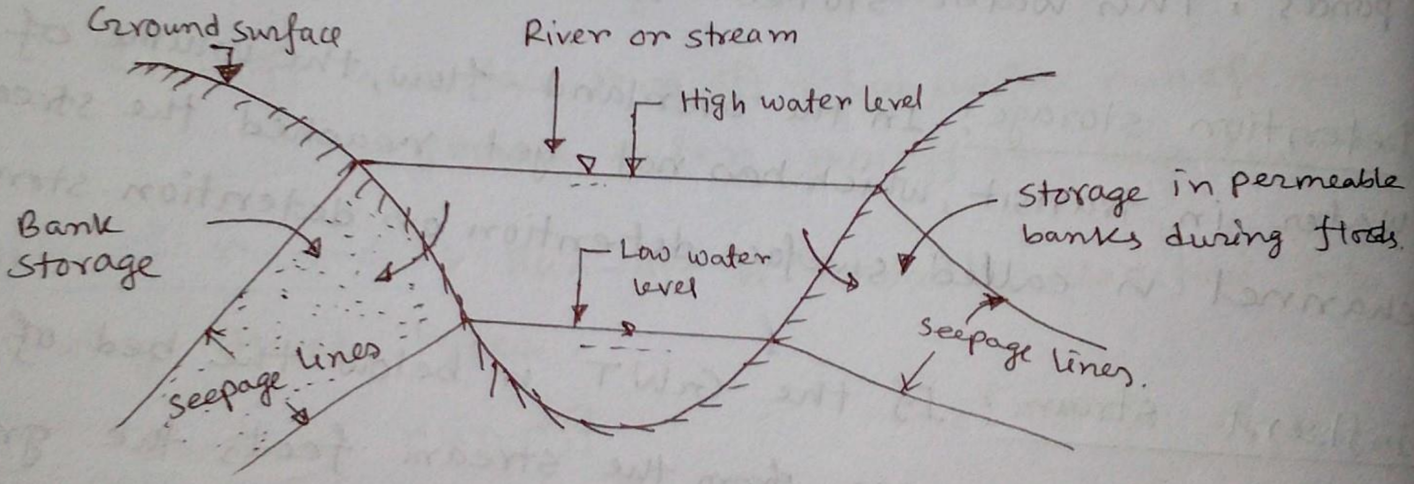


Fig. Bank storage.

* Explain the catchment characteristics.

Answer: Catchment characteristics:

(I) Drainage basin, watershed or catchment area:

The entire area of a river basin whose surface runoff drains into the river in the basin is considered as a hydrologic unit and is called drainage basin, watershed or catchment area of the river flowing.

(II) Drainage divide: The boundary line, along a topographic ridge, separating two adjacent drainage basin is called drainage divide.

(III) Concentration point or measuring point: The single point or location at which all surface drainage from a basin comes together or concentrates as outflow from the basin in the stream channel is called concentration point or measuring point.

(IV) Concentration time: The time required for the rain falling at the most distant point in a drainage area to reach the concentration point is called the concentation time.

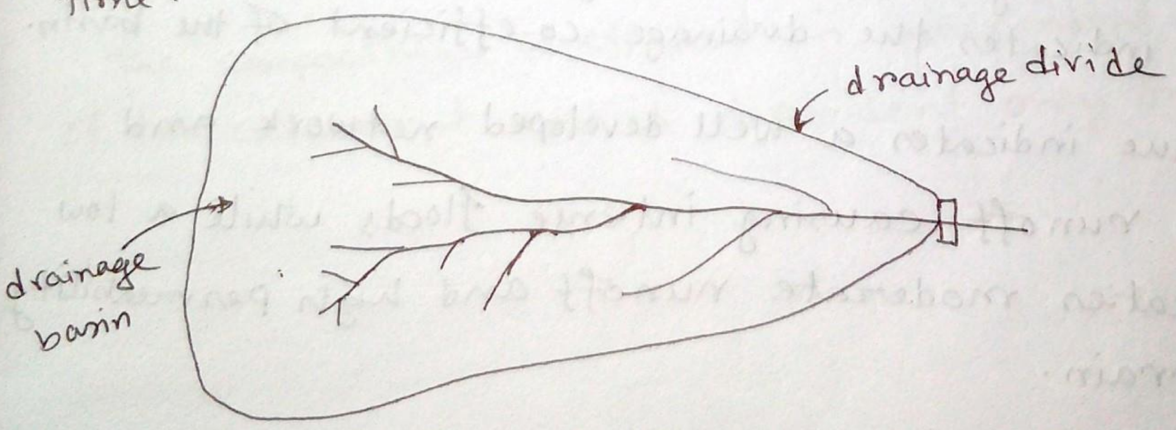


Fig. Drainage basin characteristics.

Write short note on the followings.

Stream density, D_s : The stream density of a drainage basin is empressed as the number of streams per square kilometere. Mathematically.

Stream density, $\boxed{D_s = \frac{N_s}{A}}$. where, N_s = number of streams.
A = Area of the basin.

Drainage density, D_d : The total length of all stream channels (perennial [অনুবন্ধ] and intermittent) per unit area of the basin is called drainage density (D_d). It servey as an index of the areal channel development of ~~to~~ the basin. Mathematically,

Drainage density, $\boxed{D_d = \frac{L_s}{A}}$

where, L_s = total length of all stream channels in the basin
A = Area of basin.

Drainage density varies inversely as the length of overland flow and indicates the drainage co-efficient of the basin.

A high value indicates a well developed network and torrential runoff causing intense floods while a low value indicates moderate runoff and high permeability of the terrain.

Form factor: Form factor suggested by Horton is an indicator of basin shape. Mathematically it can be expressed as,

$$\boxed{F_f = \frac{W_b}{L_b} = \frac{A}{L_b^2}}$$

, where, W_b = Axial width of basin

L_b = Axial Length of basin

A = Area of basin = $W_b \cdot L_b$

Values of F_f varies from 0 to 1 [0 = highly elongated shape]
[1 = perfect circular shape].

Compactness co-efficient: Compactness co-efficient is another expressions of shape of drainage basin. It is expressed mathematically as,

$$\boxed{C_c = \frac{P_b}{2\sqrt{\pi A}}}$$

where, P_b = Perimeter of the basin.

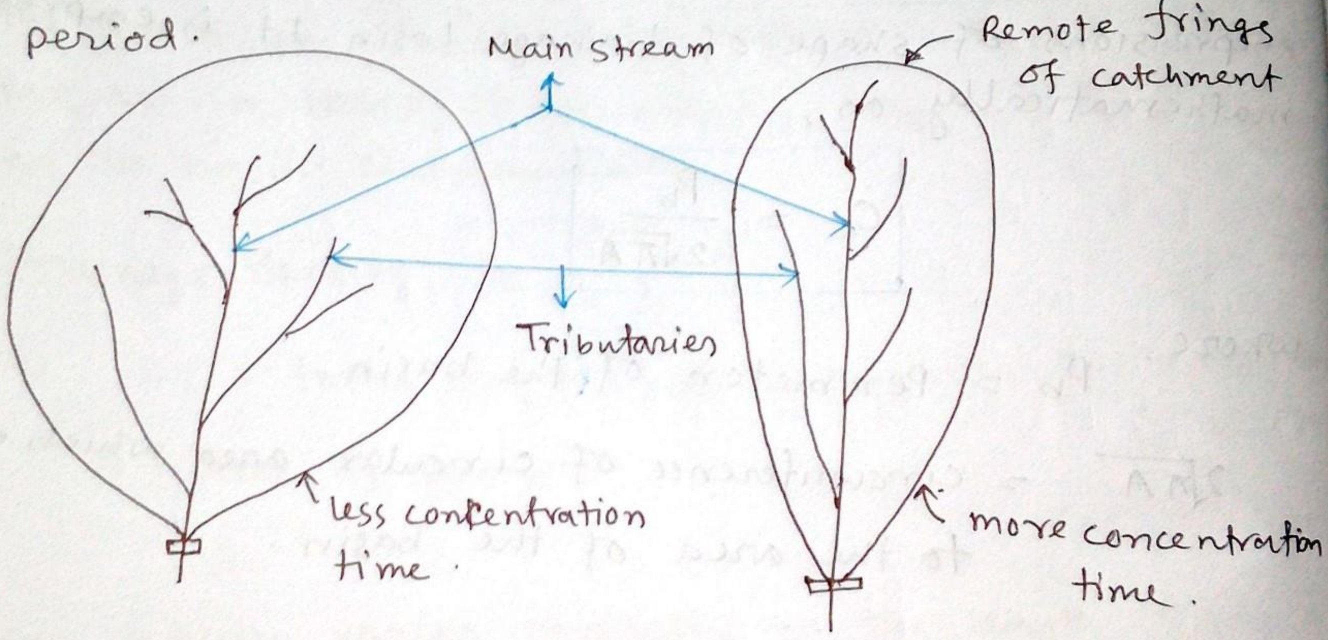
$2\sqrt{\pi A}$ = circumference of circular area which equals to the area of the basin.

The compactness co-efficient is independent of the size of the catchment and is dependent only on the slope.

** Explain, in fern shaped catchment the concentration time is more than that of fan shaped catchment.

Answer: **Explanation:** Since all the tributaries are nearly of the same length, a fan shaped catchment produces greater flood intensity. Hence the time of concentration is nearly the same and is less.

In case of fern shaped catchment the tributraries are of different length and so time of concentration is more and the discharge is distributed over a long period.



(a) Fan shaped (b) Fern shaped.

* write short note.

Perennial streams: If the groundwater table lies above the bed of stream during the whole period of year. such stream are called perennial streams.

Intermittent stream: If the groundwater table lies above the stream bed during wet season and below the stream bed during dry season such stream is called intermittent stream.

Influent stream: If the GWT is below the stream bed, seepage from stream feeds the groundwater, such streams are called influent streams.

Effluent stream: If the GWT is above the stream bed elevation then Ground water feeds the stream and such streams are called effluent stream.

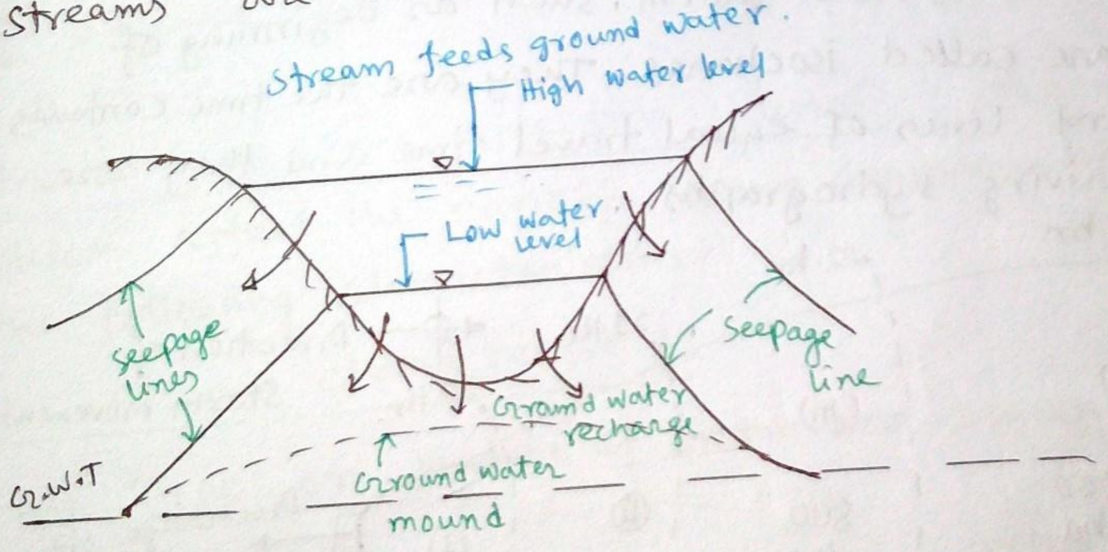


Fig. Influent streams.

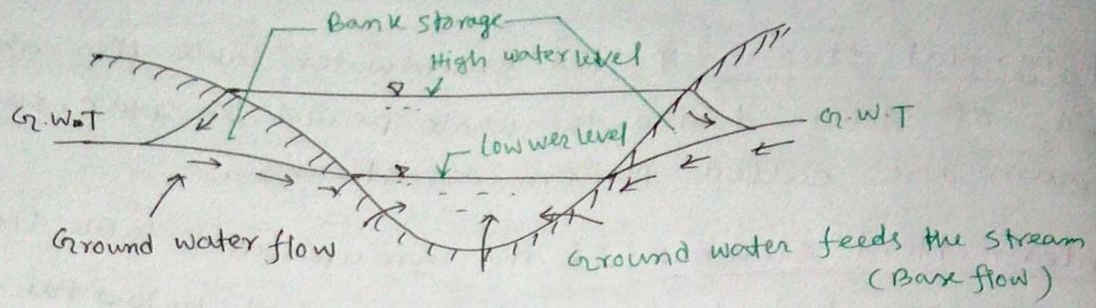


Fig. Effluent streams.

~~Emp~~ **Ephemeral Stream:** The streams which becomes completely dry in rainless period are called ephemeral stream. These are usually found in arid regions. It flows for only a few hours after rainfall.

Isochrones: The lines joining all points in a basin of some key time elements in a storm, such as beginning of precipitation, are called isochones. They are the time contours and represent lines of equal travel time and they are helpful in deriving hydrographs.

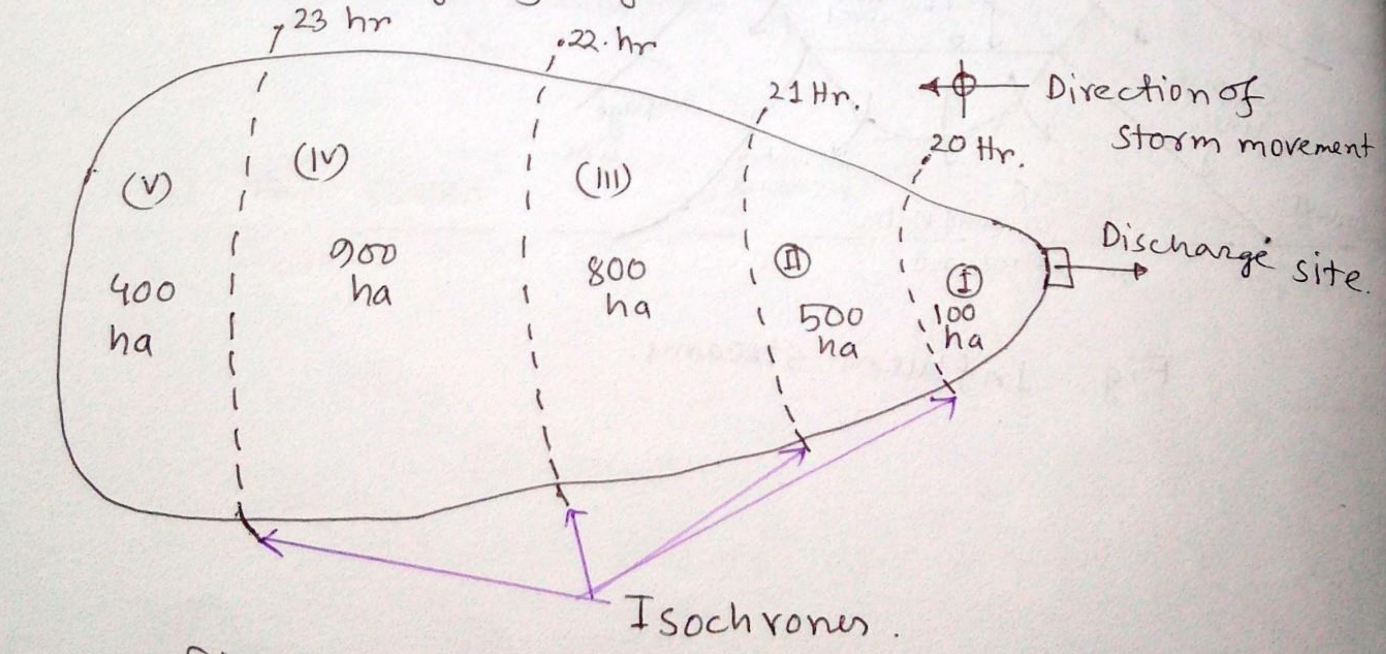


Fig. Isochrones.

Overland flow: The portion of the precipated water which over the land surface flows as a thin sheet of water is called overland flow.

Interflow: If there is a relatively impermeable stratum in the subsoil, the infiltrating water moves laterally in the surface soil and join the stream flow. The flow is called interflow or subsurface flow.

Groundwater flow/ Base flow: If there is no subsoil impermeable layer, then infiltrated water percolates and meets ground water tables. If G.W.T.'s elevation is higher than stream surface elevation, it contributes to the stream as a slow moving flow called G.W. flow or base flow.

Q. Discuss the various factors, which affect the runoff from a basin.

Answer; **Factors affecting Runoff:** The various factors which affect the runoff from a drainage basin depend upon the following characteristics.

(1) Storm characteristics:

(a) Type or nature of storm and season.

(b) Intensity.

TIDA FAD

(c) Duration.

(d) Areal extent.

(e) Frequency.

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(f) Antecedent precipitation.

(g) Direction of storm movement.

(ii) Meteorological characteristics;

(a) Temperature.
(b) Humidity.
(c) Wind velocity.
(d) Pressure variation.

THWP

(III) Basin characteristics; 3S 2T PAGOL

(a) Size
(b) Shape
(c) Slope.
(d) Altitude
(e) Topography
(f) Geology.
(g) Land use / vegetation.
(h) Type of drainage net.
(i) Orientation.
(j) Proximity to ocean & mountain ranges.

(IV) Storage characteristics;

(I) Depressions.
(II) Pools and ponds / lakes.
(III) Stream.
(IV) Channels.
(V) Check dams.
(VI) Upstreams reservoir.
(VII) Flood plains, swamps.
(VIII) Ground water storage in previous deposits.

** Distinguish between:-

Influent stream	Effluent stream.
(I) If the GWT is below the stream bed. seepage from streams feeds the GW, such streams are called influent streams.	(I) If the GWT is above the stream bed elevation then GW feeds the streams and such streams are called effluent stream.
(II) G.W.T is built up.	(II) Stream is built up.
(III) Example, Irrigation channel.	(III) Example. Most of the perennial streams.

Drainage Density	Drainage Divide
(I) The total length of all stream channels per unit area is called drainage density.	(I) The boundary line, along a topographic ridge, separating two adjacent drainage basin is called drainage divide.
(II) It is the ratio of basin length to basin area.	(II) It is the separating line between two drainage basin.

Detention storage	Depression storage.
(I) In the overlanflow, the volm of water in transit, which has not yet reached the stream channel is called detention storage.	(I) when the overland flow starts some flowing ~~waters~~ waters is held in puddels, pits and small ponds; this water is called depression storage.
(II) Amount is more than depression storage	(II) Amount is less than detention storage.

Perennial stream	Intermittent stream.
(I) If the GWT lies above the bed of stream during the whole period of year, such stream are called perennial stream.	(I) If the GWT lies above the stream bed during wet season and below the stream bed during dry season such stream is called intermittent stream.
(II) Power can be generated without the provision of storage facilities.	(II) To generate power, storage facilities must be provided.

Overland flow	Inter flow	Base flow.
(I) Flow over surface.	(I) Flow in subsoil over impermeable layer	(I) Flow in ground water through subsoil.
(II) Fast flow	(II) Slower flow	(II) Slowest flow.

Run-off	Yield	Maximum flood storage.
It is that balance of rain water, which flows or runs over the natural ground surface after losses be evaporation, interception and infiltration.	It is the net quantity of water available for storage, afterall losses for the purpose of water resource utilization as irrigation water supply etc.	It is the discharge during flood period of catchment area; i-e. when rainfall intensity is greatest and catchment condition is also favourable for an appreciable runoff.

* What are various runoff estimation method ? Explain the rational method.

Answer; Runoff estimation: The runoff from rainfall may be estimated by the following methods.

(I) Empirical formulae, curves and tables.
(II) Infiltration method.
(III) Rational method.
(IV) Overland flow hydrograph.
(V) Unit hydrograph method.

Rational Method: This method includes a Rational approach to obtain the yield of a catchment by assuming a suitable runoff co-efficient. By this method.

Yield = CAP , where, C = run off co-efficient
A = Area of catchment.
P = Precipitation.

The value of runoff co-efficient C varies depending upon soil type, vegetation, geology etc.

In this method,

(I) The drainage area is divided into a number of sub-areas, ~~and~~.

(II) From the known times of concentration for different sub-areas, the runoff contribution from each area is determined.

(III) A suitable value of runoff co-efficient is choosen and runoff is calculated.

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রোল নং: ১৬০০১১০.

Stream Gauging

* Define stream gauging. what are the methods of stream gauging
[05, 02]

Answer: **Stream gauging:** The most satisfactory determinatio of the runoff from a catchment is by measuring the discharge of the stream draining it, which is termed as stream gauging.

Methods of stream gauging:

(I) Venturiflumes or standing wave flumes for small channels.

(II) weirs or anicuts.

(III) slope area method.

(IV) contracted area methods.

(V) Sluiceways, spilways and power conduits.

(VI) Salt -concentration method.

(VII) Area - velocity methods.

*** what are the factors that influence the selection of a site for a stream gauging station? 2008, 09, 10, 13, 15

Answer: **Factors influencing the selection of a site for stream gauging station:-**

(I) The sections should be straight and uniform for a length of about 10 to 20 times the width of the stream.

(II) The bed and banks of the stream should be firm and stable so as to ensure consistency of area discharge relationship

(III) The bed and banks should be free from vegetal growth, boulders or other obstructions like bridge piers etc.

(IV) There should be no larger overflow section at flood stage. The best cross section is one with V-shape.

(V) The part of the reach having the most regular tansverse section and steady flow with the current normal to the metering section and velocities in the range of 0.3 – 1.2 m/sec should be selected.

(VI) To ensure consistency between stage and discharge, there should be a good control section far downstream of the gauging site.

(VII) The sites above the confluence of rivers are best avoided if the flow is affected by back water condition.

(VIII) The stream gauging station should be easily accessible.

* Explain "Current Meter Gaugings/Rating curve". How is it prepared ? sketch a typical rating curve.

Answer:

Preparation of current meter rating curve:

The relationship between the revolution per second (N, rps) of the meter and the velocity of flow past the meter (v, m/sec) has to be first established or if the reating equation is given by the maker it has to be verified. This process of calibration of the meter is called "rating of the current meter".

The rating equation ~~of~~ is of the form.

$$v = aN + b$$

where, a and b are constants (determined from rating of the current meter)

A current meter rating curve is drawn as "pushing velocity" vs "rps" which plots a straight line and the constants a and b are determined as shown in fig.

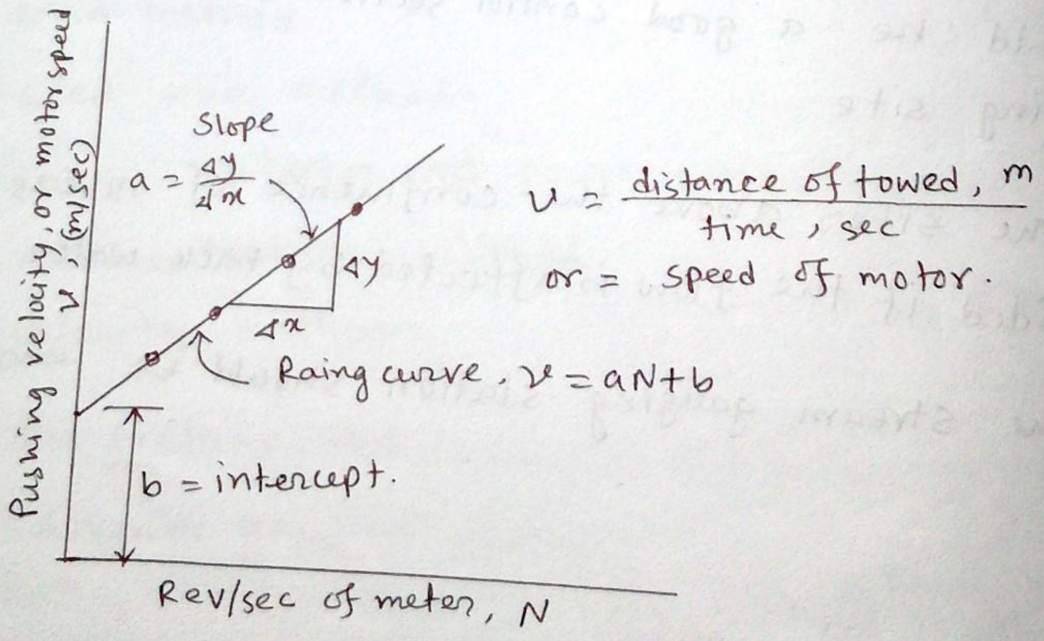


Fig. Current Meter Rating curve.

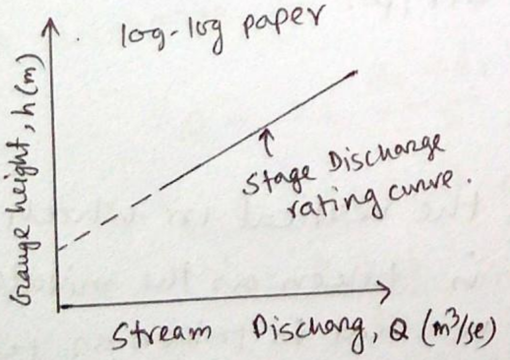
** what is stage-discharge rating curve? Explain it use? sketch a typical stage-discharge rating curve.

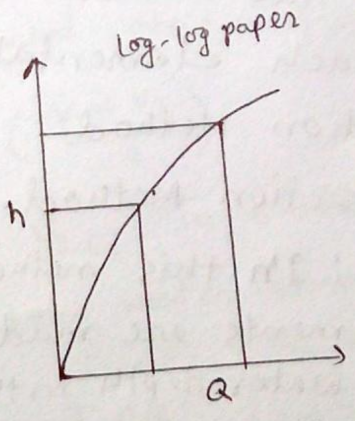
Answer: Stage discharge Rating curve: Once the rating equation of the current meter is known, actual stream gauging can be done from bridges, cradle, boat or launch. The cross section of the stream at the gauging site is divided into elemental stips of equal width b and the current meter is lowered to a depth of 0.6d below the water surface in shallow depth and to depths of 0.2d and 0.8d in deep waters, at the centre of each strip. The mean depth (d) at the centre of each strip is determined by sounding. The velocities at the appropriate depths are determined from -

$$v = aN + b.$$

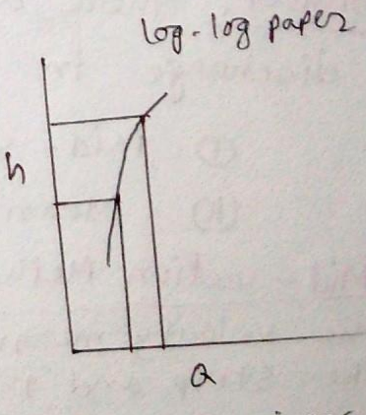
It may be Noted that the mean velocity as that at 0.6d below the water surface in shallow water (one point method) and as the average of velocities at 0.2d and 0.8d below the water surface (two point method).

The discharge in each elemental strip is determined and the discharge in the stream is the sum of the discharge in all the elemental strips.





for big river



for small river

Adjustment: Due to the rising and falling stages adjustment of rating curve is possible by the loop formation. And a doted line is drawn a middle of loop which showes, the uniform flow.

Correction: During rising or falling stage in flood the correction is applied for Q_o discharge, Δh_o is the difference of gauge reading between main and auxiliary gauge reading.

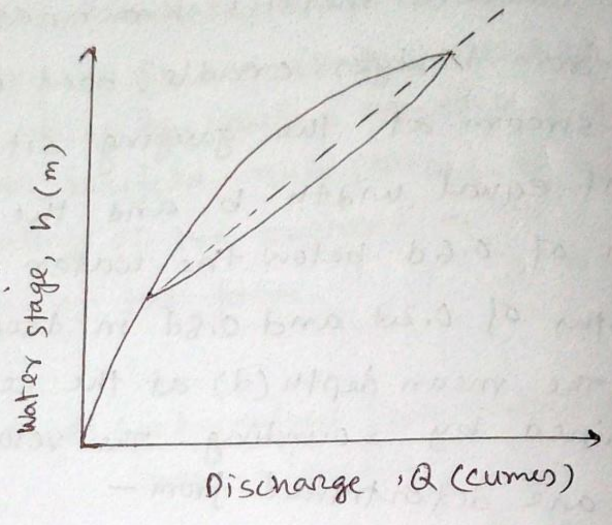


Fig. stage discharge rating curve.

For Q_a discharge, Δh_a reading,

So, $$\boxed{\frac{Q_a}{Q_o} = \left(\frac{\Delta h_a}{\Delta h_o}\right)^n}$$

where, $n = 0.5$

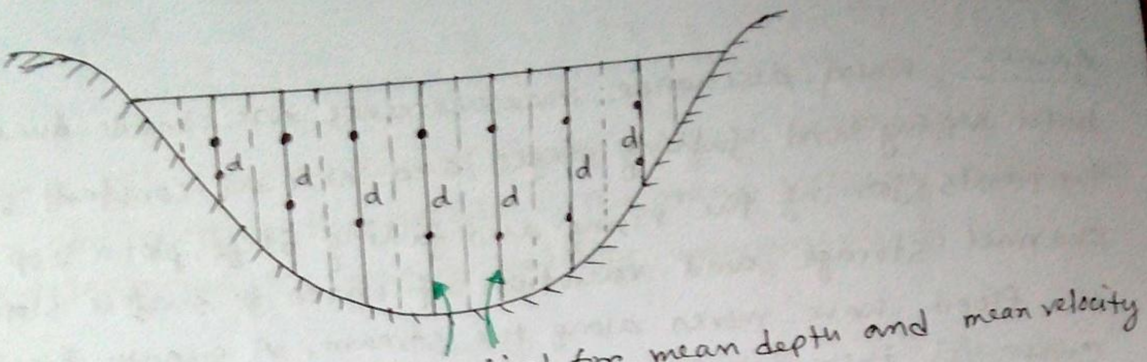
* How can you determined the discharge in elemental strip?

Answer: There are two methods of determining the discharge in each elemental strip.

(I) Mid-section Method.

(II) Mean section Method.

Mid-section Method: In this method the vertical in which the velocity measurements are made is taken as the middle of the strip and the water depth in the vertical is taken as the mean depth of the strip.



If b is the width of strip then the discharge in the elemental strip is given by.

$\Delta Q = (bd)V_{0.6d}$ in shallow strips.

$\Delta Q = (bd) \frac{V_{0.2d} + V_{0.8d}}{2}$ in deep water strips.

stream discharge, $Q = \Sigma \Delta Q$.

Mean section Method: In this method the elemental strip is taken between two ~~adjacent~~ verticals and the mean depth is taken as the average of the depths in the two verticals. The width of the strip is distance b between the two verticals. The velocity in the strip is taken as the average of the mean velocity determined in the two verticals (by one point or two point method).

The discharge in the elemental strip is given by,

$$Q = b\left(\frac{d_1 + d_2}{2}\right)\left(\frac{V_1 + V_2}{2}\right)$$

V_1, V_2 determined as $V_{0.6d}$ in shallow strip.

and, $\frac{V_{0.2d} + V_{0.8d}}{2}$ in deep water strips.

$\therefore$ stream discharge, $Q = \Sigma \Delta Q$.

The mean section method is considered to be slightly more accurate, but the mid section method is faster and is generally used.

* What is a flow rating curve? Explain its use. Sketch a flow rating curve.

Answer: When discharge measurements are made during both rising and falling stages and also at constant stage, the points joining the rising and falling stages plot a loop due to channel storage and variation of water surface slope as a flood wave moves along the stream. A smooth discharge curve is then drawn along the median line passing through or near the points that were obtained at constant stage. It is known as a flow rating curve.

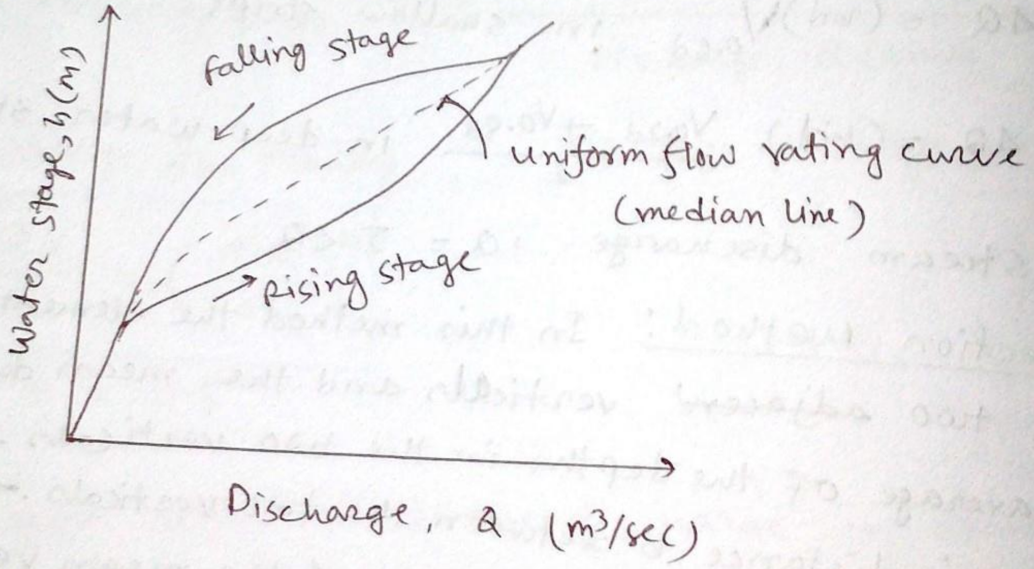


Fig. Adjustment of flow rating curve.

* Explain briefly the method of stream gauging by area-velocity method. 2003

nswer: **Area velocity method of stream gauging:**

The area of cross-section of flow may be determined by sounding and plotting the profile. The mean velocity of flow (v) may be determined by making velocity measurements.

So, $Q = AV$ —①

where the methods of velocity measurement are followings

Surface floats: Surface floats consists of wooden dics 7-15cm diameter and time (t) taken by float travel a certain distance (L) is measured and the surface velocity V_s mean velocity V are calculated as, $V_s = \frac{L}{t}$ and $V \approx 0.85 V_s$. The reach of the river for float measurements should be straight and uniform.

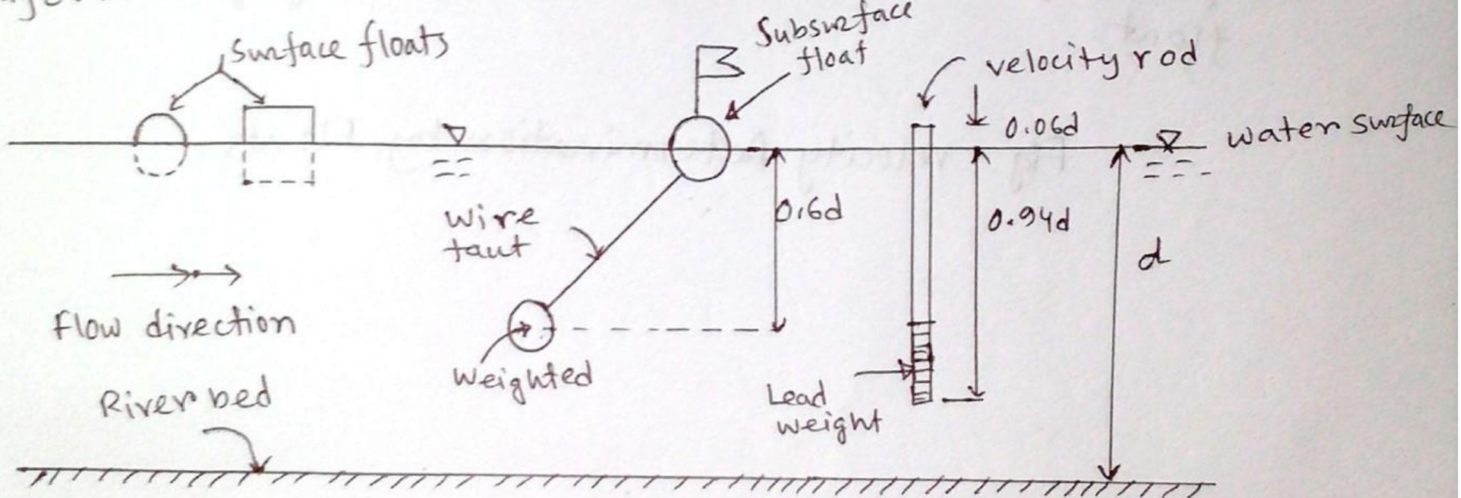


Fig. Surface float.

velocity rods: velocity rods consists of a wooden rod, square or round in section. It is weighted at the bottom by means of lead or cast iron rings to immerse it to a depth of 0.94d, where d is the depth of stream to give the mean velocity of flow (V).

At the beginning of the gauge run, a surface or rod float is released at the centre of a compartment. The time taken for the float to reach the end of the gauge run is noted. Knowing the length of the gauge run the velocity of flow is determined.

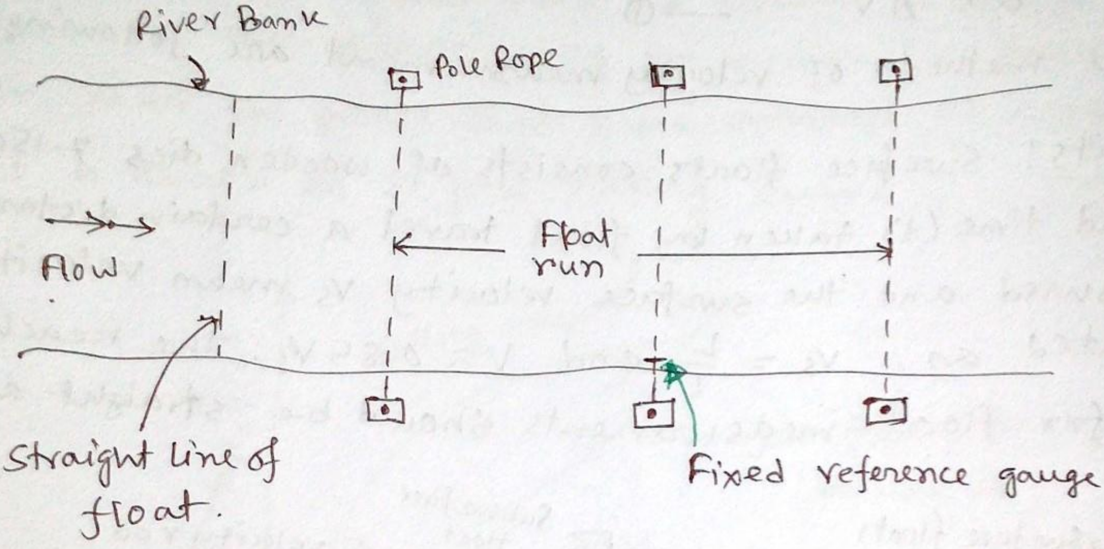


Fig. velocity Determination by Floats.

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রোল নং: ১৬০১১০

HYDROLOGY

Matin's part

HYDROGRAPH

Formula:

$$P_{net} = \frac{\text{DRO peak}}{\text{UG peak}}$$

DRO peak = TRO peak − BFO

$P = P_{net} + \text{losses}$.

$$\text{Duration} = \frac{P_{net}}{\text{Intensity}}$$

$$\text{Run-off co-efficient} = \frac{\text{Runoff}}{\text{Rainfall}}$$

Volume of water over basin = Area of UG triangle.

where,

P = total rainfall

P_{net} = net precipitation or direct runoff

Losses = due to infiltration (f_p)

A = Area of drainage basin,

DRO = Direct runoff ordinate.

TRO = total runoff ordinate

BFO = Base flow ordinate.

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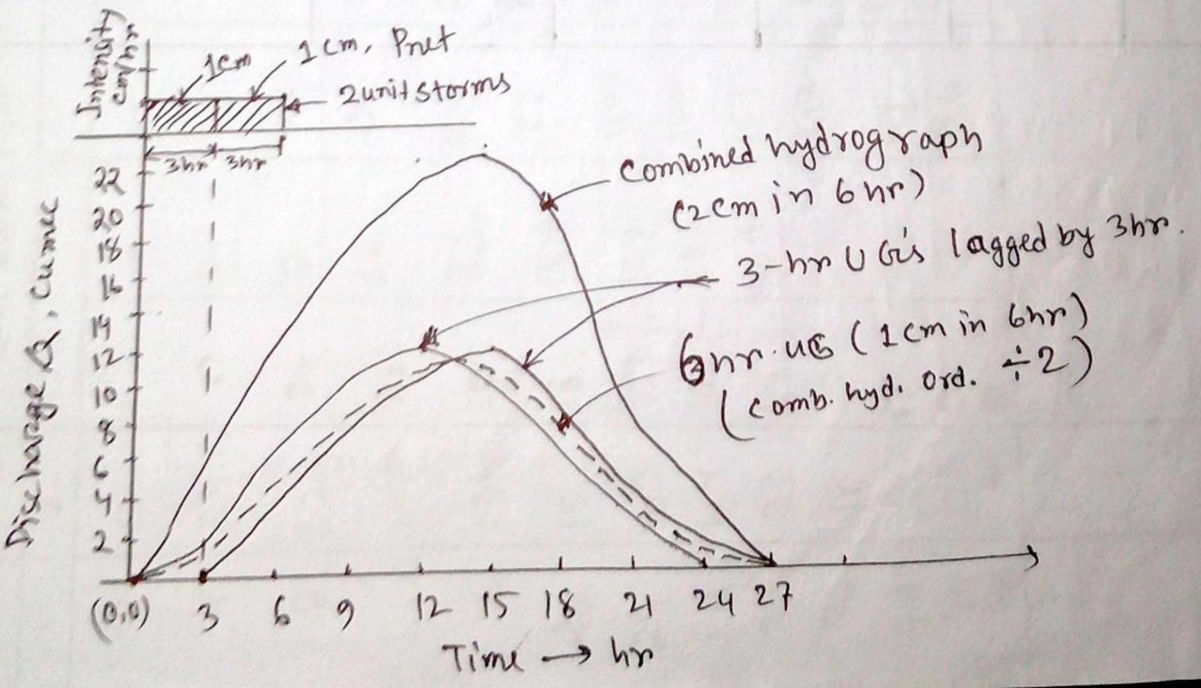
Sheet → 29

2010

Derivation of 6-hour unit hydrograph from 3hrUG

Time hr	3hr ~~unit~~ UGO cumec	3hr UGO (lagged) cumec	Total (2)+(3)	6hr UGO (4) ÷ 2 cumec
1	2	3	4	5
0	0	–	0	0
3	1.5	0	1.5	0.75
6	4.5	1.5	6	3
9	8.6	4.5	13.1	6.55
12	12.0	8.6	20.6	10.3
15	9.4	12.0	21.4	10.7
18	4.6	9.4	14	7
21	2.3	4.6	6.9	3.45
24	0.8	2.3	3.1	1.55
27	–	0.8	0.8	0.4



Sheet-30
2012, 2014

Derivation of 9hr UGO from 3-hr UG.

Time, hr	3.hr UGO cumec	3hr UGO (lagged 3hr) cumec	3hr UGO (lagged 6hr) cumec	Total (2)+(3)+(4)	9-hr UGO (5) ÷ 3 cumec
1	2	3	4	5	6
0	0	–	–	0	0
3	50	0	–	50	16.67
6	75	50	0	125	41.67
9	150	75	50	275	91.67
12	80	150	75	305	101.67
15	50	80	150	280	93.33
18	30	50	80	160	53.33
21	0	30	50	80	26.67
24	–	0	30	30	10
27	–	–	0	0	0

Sheet-31

2011.2006

Derivation of the S-curve and 8-hr unit hydrographs. (S-curve)

Time, hr	4 hr UGO cumec	S-curve additions (cumec) Unit storms after every 4hr=tr										Scurve ordinates (cumec) (2)+(3)	lagged S-curve (cumec) (tr′=8hr)	Scurve difference (cumec) (4)-(5)	8-hr UGO (6) × $\frac{4}{8}$ (cumec)
1	2	3										4	5	6	7
0	0	–	–	–	–	–	–	–	–	–	–	0	–	0	0
4	24	0	–	–	–	–	–	–	–	–	–	24	–	24	12
8	82	24	0	–	–	–	–	–	–	–	–	106	0	106	53
12	159	82	24	0	–	–	–	–	–	–	–	265	24	241	120.5
16	184	159	82	24	0	–	–	–	–	–	–	449	106	343	171.5
20	151	184	159	82	24	0	–	–	–	–	–	600	265	335	167.5
24	103	151	184	159	82	24	0	–	–	–	–	703	449	254	127
28	64	103	151	184	159	82	24	0	–	–	–	767	600	167	83.5
32	36	64	103	151	184	159	82	24	0	–	–	803	703	100	50
36	17	36	64	103	151	184	159	82	24	0	–	820	767	53	26.5
40	6	17	36	64	103	151	184	159	82	24	0	826	803	23	11.5
44	0	6	17	36	64	103	151	184	159	82	24	826	820	6	3
48	–	[illegible]													

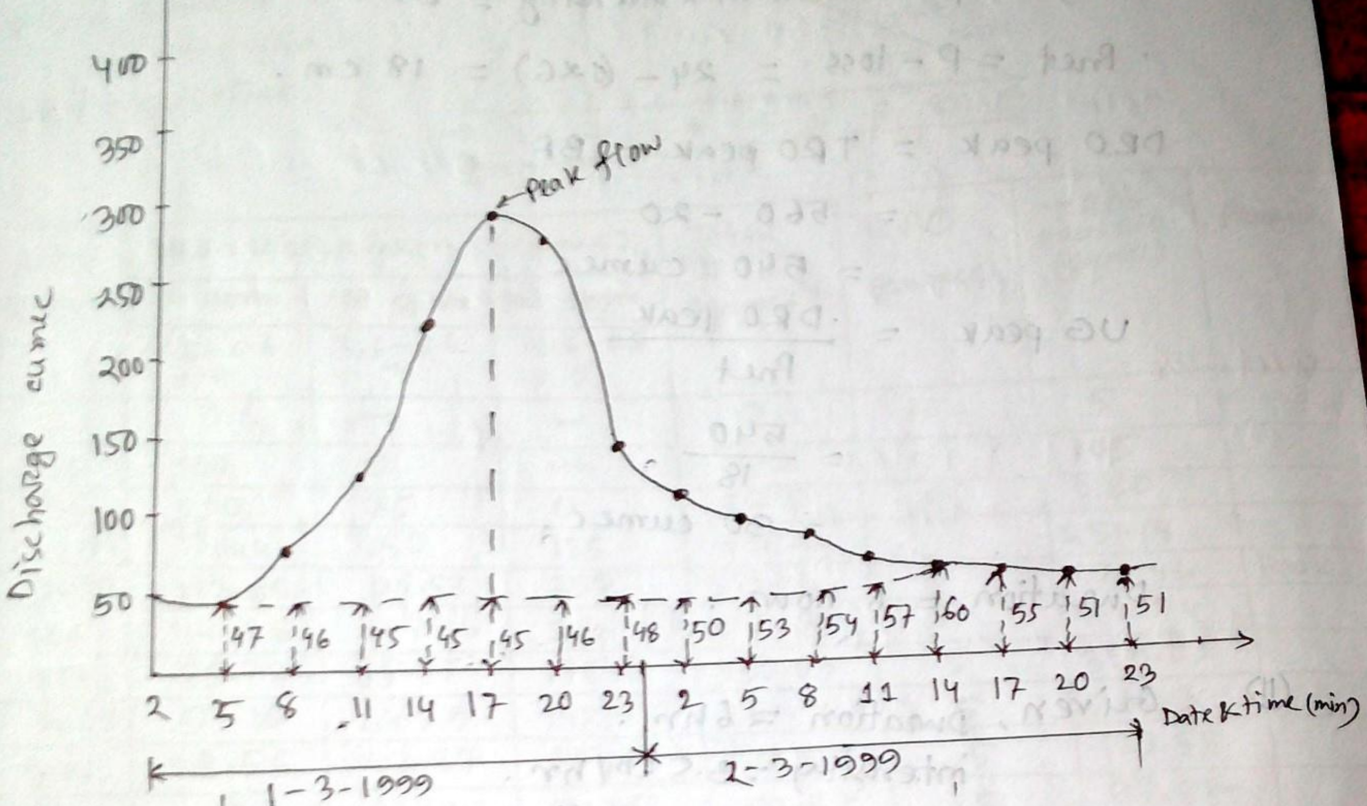
2008, 2011 → same Sheet-32, 33

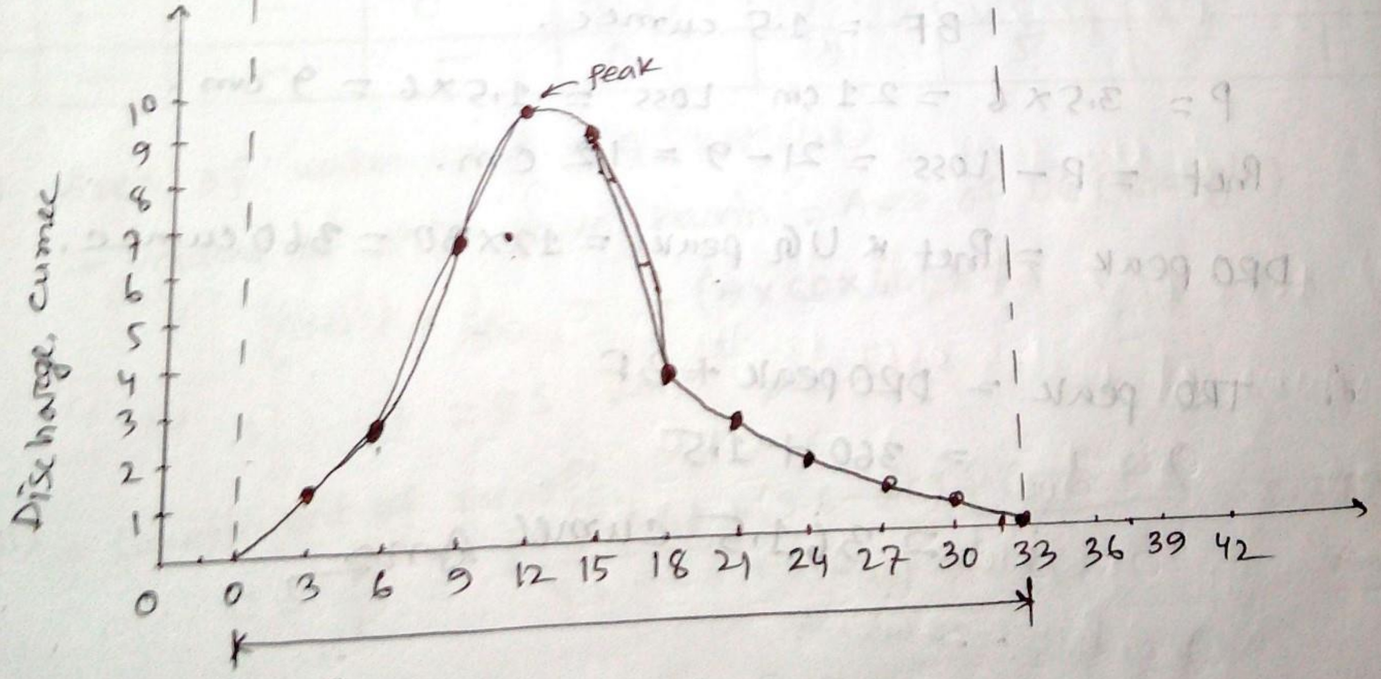
Derivation of the 3-hour unit hydrograph

Date	Time (min)	TRO cumec	BFO cumec	DRO (3)-(4) cumec	U.G.O (5) ÷ Pnet	Time from begining of surface run off (min)
1	2	3	4	(5)	6	7
1-3-1999	2	50	50	0	0	—
	5	47	47	0	0	0
	8	75	46	29	1.09	3
	11	120	45	75	2.82	6
	14	225	45	180	6.77	9
	17	290	45	245	9.21	12
	20	270	46	224	8.42	15
	23	145	48	97	3.65	18
2-3-1999	2	110	50	60	2.26	21
	5	90	53	37	1.39	24
	8	80	54	26	0.98	27
	11	70	57	13	0.49	30
	14	60	60	0	0	33
	17	55	55	0	0	36
	20	51	51	0	0	39
	23	51	51	0	0	42
				$\Sigma DRO = 986$		

$$P_{net} = \frac{\Sigma DRO.t}{A} = \frac{986 \times 3 \times 60 \times 60}{40 \times 10^6}$$

$$\therefore P_{net} = 0.266m = 26.6 \, cm$$





2008 Sheet-34

(I) Given, Duration = 6 hr. rate of loss = 1 cm/hr

TRO = 560 cumec, BF = 20 cumec . intensity = 4 cm/hr.

Rainfall, P = Duration x intensity = 6x4 = 24 cm.

∴ Pnet = P - loss = 24 - (1x6) = 18 cm.

DRO peak = TRO peak - BF

= 560 - 20

= 540 cumec.

UG peak = $\frac{\text{DRO peak}}{\text{Pnet}}$

= $\frac{540}{18}$

= 30 cumec.

Duration = 6 hour.

(II) Given, Duration = 6 hr.

intensity = 3.5 cm/hr.

loss rate = 1.5 cm/hr,

BF = 1.5 cumec.

P = 3.5 x 6 = 21 cm Loss = 1.5x6 = 9 cm.

Pnet = P - Loss = 21 - 9 = 12 cm.

DRO peak = Pnet * UG peak = 12x30 = 360 cumec.

∴ TRO peak = DRO peak + BF

= 360 + 1.5

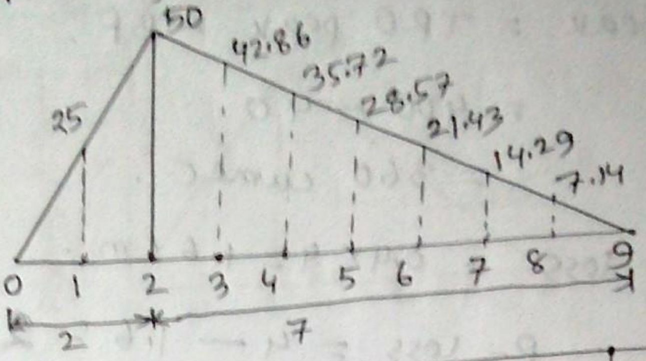
= 361.5 cumec Ans

Sheet-35
2007, 2003

The 1 hr UG can be approximated by a triangle of base of 9 hr with a peak of 50 cumec occuring after 2 hrs from the begining.

Loss = 6 mm/hr
= 0.6 cm/hr

DRO = UGO × Pnet.



Time hr	UGO (cumec)	DRO = UGO × Pnet (cumec)			Total DRO (cumec)	BFO (cumec)	TRO= DRO+BFO (cumec)	Remarks
		1st storm	2nd storm	3rd storm				
		4.6 − 0.6 = 4	3.6 − 0.6 = 3	5.6 − 0.6 = 5				
1	0	0	—	—	0	5	5	
2	25	100	0	—	100	5	105	
3	50	200	75	0	275	5	280	
4	42.86	171.44	150	125	446.44	5	451.44	
5	35.72	142.88	128.58	250	521.46	5	526.46	Peak.
6	28.57	114.28	107.16	214.3	435.74	5	440.74	
7	21.43	85.72	85.71	178.6	350.03	5	355.03	
8	14.29	57.16	64.29	142.85	264.3	5	269.3	
9	7.14	28.56	42.87	107.15	178.58	5	183.58	
10	0	0	21.42	71.45	92.87	5	97.87	
11	—	—	0	35.7	35.7	5	40.7	
12	—	—	—	0	0	5	5	

(ii) Area of water shed = A km² (let).

volume of water over basin = Area of UG (triangle)

$$\therefore (A \times 10^6) \times \frac{1}{100} = \frac{1}{2}(9 \times 60 \times 60) \times 50$$

$$\therefore A = 81 \text{ km}^2$$ Ans

(iii) co-efficient of runoff,

$$C = \frac{R}{P} = \frac{(4.6-0.6)+(3.6-0.6)+(5.6-0.6)}{4.6+3.6+5.6} = 0.87$$

Ans.

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eet-36
2005

DRO peak = TRO peak − BF.

$= 400 - 40$

$= 360$ cumec.

Total loss $= 0.4 \times 4 = 1.6$ cm.

Pnet $= P - \text{loss} = 4 - 1.6 = 2.4$ cm

UG peak $= \dfrac{\text{DRO peak}}{\text{Pnet}} = \dfrac{360}{2.4} = 150$ cumec Ans

Sheet-38

(I)

Pnet = P-loss

$= 5.9 - 0.9$

$= 5$ cm.

| P = 5.9 cm
| loss $= 0.3 \times 3 = 0.9$ cm
| TRO = 270 cumec
| BF = 20 cumec

DRO peak = TRO peak − BF

$= 270 - 20$

$= 250$ cumec.

$\therefore$ UG peak $= \dfrac{\text{DRO peak}}{\text{Pnet}} = \dfrac{250}{5}$

$\therefore$ UG peak = 50 cumec. Ans

(II) Let, Base of unit hydrograph = B.

volume of water over basin = Area of UG (triangle)

| $A = 567\ km^2 = 567 \times 10^6\ m^2$

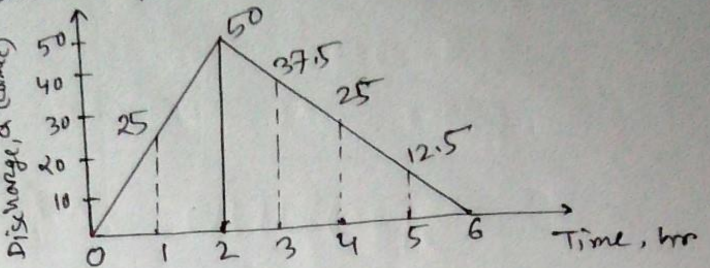
or, $A \times \frac{1}{100} = \frac{1}{2} \times B \times 50$

$567 \times 10^6 \times \frac{1}{100} = \frac{1}{2} \times B \times 50$

$\therefore B = 226800$ sec.

$\therefore B = 63$ hour. Ans

Sheet – 37
2013, 2015, 2005 The 1hr UG peak can be approximated by a triangle of base of 6 hr with a peak 50 cumec occurring after 2hr from the begining.



LOSS = 9 mm/hr
= 0.9 cm/hr

DRO = UGO × Pnet.

Pnet = P – Loss.

Time hr	UGO (cumec)	DRO = UGO×Pnet (cumec)		Total DRO (cumec)	BFO (cumec)	TRO = DRO+BFO (cumec)	Remarks.
		4.9–0.9=4 (cm)	3.9–0.9=3 (cm)				
0	0	0	–	0	10	10	
1	25	100	0	100	10	110	
2	50	200	75	275	10	285	
3	37.5	150	150	300	10	310	Peak flood.
4	25	100	112.5	212.5	10	222.5	
5	12.5	50	75	125	10	135	
6	0	0	37.5	37.5	10	47.5	
7	–	–	0	0	10	10	

(i) Let, Area of water shed = A km^2.

volume of water over basin = Area of UG (triangle)

$$(A \times 10^6) \times \frac{1}{100} = \frac{1}{2}(6 \times 60 \times 60) \times 50$$

$$\therefore \quad A = 54 \ km^2. \ \underline{Ans}$$

(ii) co-efficient of runoff.

$$C = \frac{R}{P} = \frac{(4.9-0.9)+(3.9-0.9)}{4.9+3.9} = 0.795$$

Ans

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রোল নং: ১৬০১১০

GROUND WATER

Formulla:

Porosity, $n = \frac{V_v}{V} = \frac{\text{Volume of void}}{\text{volume of formation}}$

Specific yield, $S_y = \frac{W_y}{V} = \frac{\text{water which drain freely}}{\text{Volume of the formation}}$

Specific Retention, $S_r = \frac{W_r}{V} = \frac{\text{Water retained volume}}{\text{Volume of formation}}$.

porosity, $n = S_r + S_y$.

Storage co-efficient, $S = \gamma_w \, n b \left(\frac{1}{K_w} + \frac{1}{n E_s} \right)$

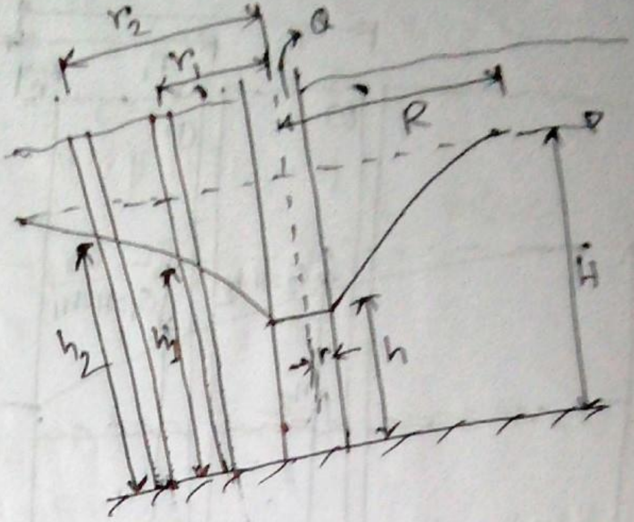
where, S = storage co-efficient.
γ_w = specific weight of water
n = porosity of soil.
b = thickness of the confined aquifer
K_w = bulk modulus of elasticity of water
E_s = modulus of compressibility.

Change in ground water storage = Area of aquifer X $\underset{\text{fluctuation}}{\text{drop}}$ in G.W.T *Specific yield.

$\Delta GWS = A_{aq} * \Delta G.W.T * S_y$. → unconfined

$\Delta GWS = A_{aq} * P.S * S$ → confined.

Steady radial flow unconfined aquifer :-



$$Q = \frac{\pi K (h_2^2 - h_1^2)}{\ln(\frac{r_2}{r_1})}$$

$$\text{or, } Q = \frac{\pi K (h_2^2 - h_1^2)}{2.303 \log(r_2/r_1)}$$

Now, $h_1 = h$, $h_2 = H$, $r_1 = r$, $r_2 = R$

For zero drawdown.

$$Q = \frac{\pi K (H^2 - h^2)}{2.303 \log(R/r)}$$

For very small drawdown, $H \sim h$, $H + h = 2H$.

$$H^2 - h^2 = (H+h)(H-h)$$

Transmitivity, $T = bK$
$= KH$

$$\therefore Q = \frac{2\pi KH (H-h)}{2.303 \log(R/r)}$$

$$\therefore Q = \frac{2.72\, T(H-h)}{\log(R/r)}$$

[K = permeability
unit m/day]

where, Q = Discharge,

T = transmitivity, [unit, $\frac{m^2}{day}$ or, $\frac{m^2}{sec}$]

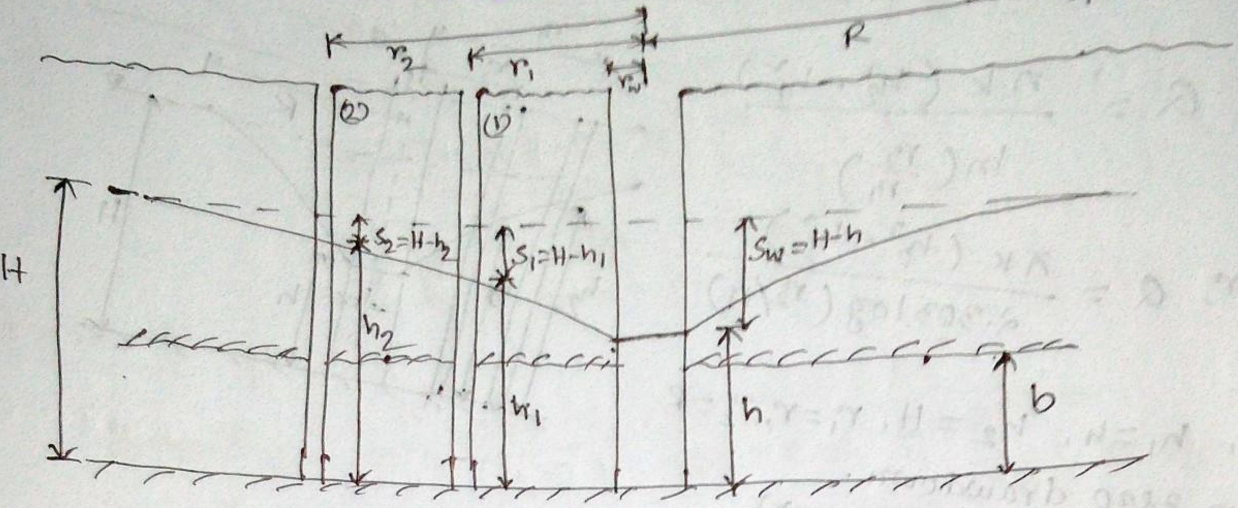
H = Height of water level at zero drawdown from base.

h = height of water level in the pipe or main well.

r = well radius.

R = radius of influence.

Steady state discharge at confined aquifer:



R = radius of influence, r_w = well radius.

h = water level in main well. b = thickness of confined aquifer.

H = Water level at zero drawdown.

$$Q = \frac{2\pi k b (h_2 - h_1)}{2.303 \log(r_2/r_1)}$$

$$Q = \frac{2\pi k b (S_1 - S_2)}{2.303 \log(r_2/r_1)} \quad [\because S_1 = H - h_1, S_2 = H - h_2)$$

For zero drawdown, $h_1 = h$, $r_1 = r$, $h_2 = H$, $r_2 = R$

Hence, $Q = \frac{2\pi k b (H - h)}{2.303 \log(R/r)}$

$$Q = \frac{2.72\ T (H - h)}{\log(R/r)}$$

$h = H - S_w$

$\therefore H - h = H - H + S_w$

$= S_w$.

$$Q = \frac{2.72\ T S_w}{\log(R/r)}$$

Sheet-39

2007,08,10

Given, $r_w = \frac{30}{2} = 15\ cm = 0.15 m.$

$b = 30\ m.$

$Q = 1200\ lpm = \frac{1200}{1000}\ \frac{m^3}{min} = \frac{1.2}{60}\ m^3/sec$

$\therefore Q = 0.02\ m^3/sec.$

$r_1 = 20\ m,\quad r_2 = 45\ m,$

$S_1 = 2.2m,\quad S_2 = 1.8\ m.$

transmitivity, $T = ?$ $\quad S_w = ?$

We know, $Q = \frac{2\pi kb(h_2-h_1)}{\ln(r_2/r_1)}$

$Q = \frac{2\pi kb(H-S_2-H+S_1)}{\ln(r_2/r_1)}$

$Q = \frac{2\pi kb(S_1-S_2)}{\ln(r_2/r_1)}$ $\quad [\because T = kb]$

$\therefore T = \frac{Q * \ln(r_2/r_1)}{2\pi(S_1-S_2)}$

$T = \frac{0.02 * \ln(45/20)}{2\pi(2.2-1.8)}$

$T = 6.45 \times 10^{-3}\ m^2/s.$

$\therefore T = 557.55\ m^2/day$ Ans.

যদি R দেওয়া না থাকে, Assume করতে হবে না,

Then,

$Q = \frac{2.72T(S_w-S_2)}{\log(r_2/r_w)}$

$\therefore S_w-S_2 = \frac{Q*\log(r_2/r_w)}{2.72*T}$

$S_w-S_2 = \frac{0.02*\log(45/0.15)}{2.72*6.45*10^{-3}}$

$\therefore S_w = 2.82+1.8$

$= 4.62 m$

Ans

Again, ~~$Q = \frac{2\pi kb(H-h)}{\ln(R/r_w)} = \frac{2\pi kb*S_w}{\ln(R/r_w)}$~~ $\quad$ | ~~Assume, $R = 300m.$~~

~~$\therefore S_w = \frac{Q*\ln(R/r_w)}{2\pi T} = \frac{0.02*\ln(300/0.15)}{2\pi*6.45\times10^{-3}}$~~

~~$\therefore S_w = 3.75\ m$~~ Ans

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eet-40
2006

Given,

$r_w = \frac{30}{2} = 15$ cm $= 0.15$ m.

$b = 50$ m,

$Q = 1800$ lpm $= \frac{1800}{1000 \times 60} = 0.03$ m^3/sec.

$r_1 = 15$ m, $r_2 = 45$ m,

$S_1 = 1.7$ m, $S_2 = 0.8$ m.

$T = ?$, $S_w = ?$

We know,

$$Q = \frac{2\pi K b (S_1 - S_2)}{\ln(r_2/r_1)}$$

$$\therefore \quad T = \frac{Q * \ln(r_2/r_1)}{2\pi (S_1 - S_2)} \quad [\because T = Kb]$$

$$= \frac{0.03 \times \ln(45/15)}{2\pi (1.7 - 0.8)}$$

$$= 5.83 \times 10^{-3} \text{ m}^2/\text{sec}.$$

$$= 503.57 \text{ m}^2/\text{day}.$$

Again,

$$Q = \frac{2\pi K b (S_w - S_2)}{\ln(r_2/r_w)}$$

~~Assume, R = 300~~ m

$[\because T = Kb]$

$$\therefore S_w = \frac{Q * \ln(r_2/r_w)}{2\pi T} + S_2$$

$$= \frac{0.03 \times \ln(\overset{45}{\cancel{300}}/0.15)}{2\pi * 5.83 \times 10^{-3}} + 0.8$$

= ~~6.22 m~~ ~~Ans~~

= 5.47 m Ans

Sheet-41
2011

Given, $r_w = \frac{25}{2} = 12.5\text{ cm} = 0.125\text{ m}$.

$H = 30\text{ m}$.

$Q = 1800\text{ lpm} = \frac{1800}{1000\times 60} = 0.03\text{ m}^3/\text{sec}$.

$r_1 = 13\text{ m}, \quad r_2 = 38\text{ m}$.

$s_1 = 1.2\text{ m}, \quad s_2 = 0.5\text{ m}$.

$\therefore h_1 = H - s_1 = 30 - 1.2 = 28.8\text{ m}$.

$h_2 = H - s_2 = 30 - 0.5 = 29.5\text{ m}$.

$R = 300\text{ m}$.

Transmitivity, $T = ?$, $S_w = ?$

we know, $$Q = \frac{\pi K(h_2^2 - h_1^2)}{\ln(r_2/r_1)}$$

$$\therefore K = \frac{Q * \ln(r_2/r_1)}{\pi(h_2^2 - h_1^2)}$$

$$= \frac{0.03 * \ln(38/13)}{\pi(29.5^2 - 28.8^2)}$$

$$= 2.51 * 10^{-4}\text{ m/sec}$$

(I) $\therefore$ Transmitivity, $T = KH = 2.51\times10^{-4}\times 30$

$\therefore T = 7.53 \times 10^{-3}\text{ m}^2/\text{sec}$.

$\therefore T = 650.57\text{ m}^2/\text{day}$.

$| \; H - h_w = S_w$

(II) Again, $$Q = \frac{2.72\, T(H - h_w)}{\log(R/r_w)}$$

$$\therefore S_w = \frac{Q * \log(R/r_w)}{2.73 * T}$$

$$= \frac{0.03 * \log(300/0.125)}{2.73 * 7.53\times10^{-3}}$$

$$= 4.93\text{ m}$$ Ans

Sheet-43
2009

Given, $r_w = 0.5\,m$. $H = 50\,m$.

$k = 30$ m/day.

$h_w = 40\,m$.

$R = r = 500\,m$.

$Q = ?$

we know,

$$Q = \frac{\pi k (H^2 - h_w^2)}{\ln(r/r_w)}$$

$$= \frac{\pi \times 30 (50^2 - 40^2)}{\ln(\frac{500}{0.5})}$$

$$= 12279.38 \text{ m}^3/\text{day}.$$ Ans

Sheet -44
2008

$r_w = \frac{20}{2} = 10cm = ~~0.01 m~~ 0.1\,m$

$b = 25\,m$.

$Q = 200$ lit/min $= \frac{200}{1000 \times 60}$ m³/sec $= \frac{1}{300}$ m³/sec.

$r_1 = 10m$, $r_2 = 100\,m$

$s_1 = 3.5\,m$, $s_2 = 0.05\,m$.

$k = ?$, $T = ?$

$$Q = \frac{2\pi k b (s_1 - s_2)}{\ln(r_2/r_1)}$$

$$\therefore k = \frac{Q * \ln(r_2/r_1)}{2\pi * b (s_1 - s_2)}$$

$$\Rightarrow k = \frac{\frac{1}{300} \times \ln(100/10)}{2\pi \times 25 * (3.5-0.05)}$$

$\Rightarrow k = 1.42*10^{-5}$ m/sec. Ay

∴ Transmitivity, $T = Kb$

$= 1.42*10^{-5} \times 25$

$= 3.54*10^{-4}$ m²/sec Ay

$= 30.59$ m²/day Ay

Sheet-45+46
2006

we know,

$\Delta GWS = Aaq * \Delta$ piezo.surface * storage co-efficient (S)

Given,

$Aaq = 800$ km² $= 800 \times 10^6$ m²

$\Delta p. = 19 - 9 = 10$ m

$S = 0.0008$

∴ $\Delta GWS = 800*10^6 * 10*0.0008$

$= 6.4*10^6$ m²

$= 6.4$ Mm² Ay

$sy = 30$ m³/hr

$= 30 \times 24$ m³/day

∴ Annual draft = specific yield * pumping day

$= 30*24 * 200$

$= 0.144*10^6$ m²

$= 0.144$ Mm² Ay

∴ Number of wells that can be drilled in the area $= \frac{6.4}{0.144}$

$= 44.44$

= Say 44 wells

Ans. 44 wells Ay

Sheet-47

2005

Given, $A_{aq} = 120\ ha$ | ~~1ha = 10 m~~

1ha = 100 Km²

$= 120 \times 100 \times 10^6\ m^2$

$= 1.2 \times 10^{10}\ m^2$

$n = 28\%$ $S_r = 9\%$

$\Delta GWT = 5\ m$

Now, we know,

$n = S_r + S_y$

$\therefore S_y = n - S_r = 28 - 9 = 19\%$

$\therefore S_y = 0.19$

Again,

Change in Ground water storage,

$\Delta GWS = A_{aq} * \Delta GWT * S_y$

$= 1.2 \times 10^{10} * 5 \times 0.19$

$= 1.14 * 10^{10}\ m^3$ Ans

Sheet-48

2011, 14

Given, $n = 25\% = \frac{25}{100} = 0.25$

$K_w = 2.4 * 10^4\ kg/cm^2 = 2.4 \times 10^8\ kg/m^2$

$K_s = 2000\ kg/cm^2 = 2 \times 10^7\ kg/m^2$

$b = 30\ m$

$\gamma_w = 1000\ kg/m^3$

Storage co-efficient,

$$S = \gamma_w n b \left(\frac{1}{K_w} + \frac{1}{n K_s} \right)$$

$$= 1000 \times 0.25 \times 30 \left(\frac{1}{2.4 * 10^{8}} + \frac{1}{0.25 \times 10^{7} \times 2} \right)$$

$$= 1.53 * 10^{-3}$$

The fraction of storage ~~co-~~ attributable to the expansibility of water, as a percentage of S above,

$$\cancel{S_w = \gamma_w n b * \frac{1}{n K_s} = \frac{\gamma_w b}{K_s}}$$

$$\cancel{\therefore S_w = \frac{1000 * 30}{2 * 10^{7}} * 100}$$

$$\cancel{= \frac{1000 \times 0.25 \times 30 * \frac{1}{2.4 \times 10^{8}}}{1000 \times 0.25 \times 30 *}}$$

$$S_w = \gamma_w n b \frac{1}{K_w}$$

$$= 1000 \times 0.25 \times 30 \times \frac{1}{2.4 \times 10^{8}}$$

$$= 3.125 * 10^{-5}$$

$$\therefore S_w = \frac{3.125 * 10^{-5}}{1.153 * 10^{-3}} \text{ of } S$$

$$= 0.0204 \text{ of } S$$

$$= 2.04 \% \text{ of } S$$ (which is negligible)

Ans

Sheet-51
2015

Given,

$A_{aq} = 100$ ha

$= 100 \times 100$ km^2

$= 100 \times 100 \times 10^6$ m^2

$= 1 * 10^{10}$ m^2

1ha = 100 km^2

$\Delta GWT = 4.5$m, $n = 30\%$, $S_r = 10\%$, $S_y = ?$, $\Delta GWS = ?$

we know, $n = S_r + S_y$

$\therefore S_y = n - S_r = 30 - 10 = 20\%$

$\therefore S_y = 0.2$

Again,

$\Delta GWS = A_{aq} * \Delta GWT * S_y$

$= 1 \times 10^{10} * 4.5 * 0.2$

$= 9 * 10^9$ m^3 Ans

Sheet-53
2013

Given,

$r_w = 0.5$ m,

$b = 20$ m

$K = 8.2 * 10^{-4}$ m/s

$R = 200$ m

$S_w = 3$m.

$Q = ?$

we know that,

$$Q = \frac{2\pi K b (S_w)}{\ln(R/r_w)}$$

$$= \frac{2\pi \times 8.2 \times 10^{-4} \times 20 \times 3}{\ln(200/0.5)}$$

$= \sim\sim 515955.1804 \sim\sim$ m^3/sec

~~515955.1804~~

$= 0.05159$ m^3/sec

$= 51.59$ L/sec Ans

মো: রাবিউল ইসলাম
রাজশাহী প্রকৌশল ও প্রযুক্তি বিশ্ববিদ্যালয়
পুরকৌশল বিভাগ
রোল নং: ১৩০০১১০

FLood Routing

Sheet-54
2012

$$P = \frac{1}{5} = 0.2, \quad n = 10$$

$$q = 1 - P = 0.8$$

$P(r=0) = ?$ $\quad$ $P(r=2) = ?$

(i) $P(r=0) = {}^{n}C_{r}\, p^{r}\, q^{n-r}$

$$= {}^{10}C_0\, 0.2^{0}\, 0.8^{10-0}$$

$$= 0.107$$ Ans

(ii) $P(r=2) = {}^{10}C_2\, 0.2^{2}\, 0.8^{10-2}$

$$\simeq 0.302$$ Ans

$= 2.73\, hr^{-1}$

sheet -55

2010 Given,
For $n = 35$, $\bar{y}_n = 0.54034$ and $\sigma_n = 1.12847$

Using Gumbel's method,
$T_r = 50$ and 100

$y_T = -\ln\ln\left(\frac{T_r}{T_r-1}\right)$

$\therefore y_{50} = -\ln\ln\left(\frac{50}{50-1}\right)$

$y_{50} = 3.90194$

$K_T = \frac{y_T - \bar{y}_n}{\sigma_n}$

$\therefore K_{50} = \frac{3.90194 - \overset{0.54034}{0.54854}}{\underset{1.12847}{1.16066}} = \overset{2.98}{2.89}$

Again, $y_{100} = -\ln\ln\left(\frac{100}{100-1}\right) = 4.60$

$K_{100} = \frac{4.60 - \overset{0.54034}{0.56002}}{\underset{1.12847}{1.20649}} = \overset{3.60}{3.35}$

Now, $X_T = \bar{x} + K_T * S_x$

$X_{50} = \bar{x} + K_{50} * S_x$

$\therefore \bar{x} + \overset{2.98}{2.89} S_x$ —— ①

or, $660 = \bar{x} + K_{100} * S_x$

Again, $X_{100} = \bar{x} + \overset{3.60}{3.35} S_x$ —— (II)

or, $740 = \bar{x} +$

Solving ① & (II) we get, $\bar{x} = \overset{275.5}{157.4}$, $S_x = \overset{129.03}{173.9}$

$y_{200} = -\ln\ln\left(\frac{200}{200-1}\right) = 5.2958.$

Now, $K_{200} = \frac{5.2958 - 0.54034}{1.12847} = 4.21$

$\therefore X_{200} = 157.4 + 4.21 * 173.9 = 890$ m³/sec Ans

$X_{200} = 275.5 + 4.21 \times 129.03 = 819$ m³/sec Ans

Sheet -56

2009 4(c)

$P = 0.05$,

n = base period = 120 days.

$\therefore \lambda = pn = 0.05 \times 120 = 6$

$$\therefore P(r=1) = \frac{e^{-\lambda}\lambda^{r}}{\underline{|r}}$$

$$= \frac{e^{-6}\,6^{1}}{\underline{|1}}$$

$= 0.0149$

$= 1.49\%$ Ans.

$$P(r=4) = \frac{e^{-6}\,6^{4}}{\underline{|4}}$$

$= 0.134$

$= 13.4\%$ Ans

Sheet -57

2009 (1) Given, mean = 2264 m^3/sec

S.D, σ = 340 m^3/sec.

standond value of 3170, $z = \frac{3170-2264}{340}$

$= 2.66$.

$$P(z \geq 2.66) = \frac{1}{\sqrt{2\pi}}\int_0^{\infty} e^{-z^2/2}\,dz - \frac{1}{\sqrt{2\pi}}\int_0^{2.66} e^{-z^2/2}\,dz$$

$= 0.5 - 0.496$

$= 0.004$ Ans.

(11) $N = 25$ year. $x_T = 3170$, $S_x = 340$, $\bar{x} = 2264$

$$x_T = \bar{x} + K_T \cdot S_x$$

$$\therefore K_T = \frac{3170 - 2264}{340} = 2.66.$$

$$K_T = -0.45 - 0.7797 \ln\left\{\ln\left(\frac{T_r}{T_r - 1}\right)\right\}$$

$$\Rightarrow \frac{2.66 + 0.45}{0.7797} = -\ln\left\{\ln\left(\frac{T_r}{T_r - 1}\right)\right\}$$

$$= 0.98 = \frac{T_r}{T_r - 1}$$

$$\Rightarrow \therefore T_r = 54.48 \text{ year.}$$

$$\therefore P = 1 - \left(1 - \frac{1}{T_r}\right)^N = \left[1 - \left(1 - \frac{1}{54.48}\right)^{25}\right]$$

$$P = 0.37 \text{ Ans}$$

Sheet

58 (2009)

Year	Annual peak flood	Rearranging in descending order	Rank (m)	$F = \frac{m}{n+1} \times 100$
1961	3950	7660	1	5
1962	6190	7210	2	10
1963	7660	7050	3	15
1964	4220	6970	4	20
1965	2820	6860	5	25
1966	5600	6240	6	30
1967	7050	6190	7	35
1968	5280	5980	8	40
1969	5200	5890	9	45
1970	4360	5600	10	50
1971	6970	5280	11	55
1972	6240	5270	12	60
1973	4960	5200	13	65
1974	5890	4960	14	70
1975	5980	4360	15	75
1976	3950	4220	16	80
1977	6860	3950	17	85
1978	7210	3950	18	90
1979	5270	2820	19	95

Semi-log graph → plot করতে হবে।

Sheet-59,60 same

2007,13,15

Assuarance, = 95%

Risk, $R = 100 - 95 = 5\% = 0.05$

The Life period, $N = \cancel{30}\,50$ year.

we know, $R = 1 - \left(1 - \frac{1}{T_r}\right)^N$

$$0.05 = 1 - \left(1 - \frac{1}{T_r}\right)^{\cancel{30}\,50}$$

$$\therefore 1 - \frac{1}{T_r} = (1 - 0.05)^{1/50}$$

$$\therefore T_r = 975.286 \sim 975.30 \text{ year.}$$

Again,
we know,

$$y_T = -\ln\ln\left(\frac{T_r}{T_r - 1}\right)$$

$$\therefore y_T = -\ln\ln\left(\frac{975.3}{975.3 - 1}\right)$$

$$y_T = 6.88.$$

$$K_T = \frac{y_T - \bar{y}_n}{\sigma_n} = \frac{6.88 - 0.53622}{1.11238} = 5.70.$$

Now. Discharge, $x = \bar{x} + S_x * K_T$

$$= 1200 + 650 \times 5.70$$

$$= 4908 \text{ m}^3/\text{sec}$$ Ans

Sheet
63

2006

Relative humidity,

$$h = \frac{100\,e}{e_s}\,\% \text{ —— } ①$$

e = 19.873 mm of mercury

= 19.873 × 1.33 = 26.43 mb.

e_s = 37.796 mb for 28°C.

$$h = \frac{26.43}{37.796} \times 100\% = 69.93\%.$$

Dew point temperature, = 22°C ~~for~~

or e = 26.43.

$$\text{Density, } D = \frac{P}{RT}\left(1 - 0.375\,\frac{e}{P}\right]$$

$$= \frac{1005 \times 10^5}{287 \times 301}\left[1 - \frac{0.375 \times 26.43}{1005}\right]$$

$$= 1.152 \text{ kg m}^{-3}.$$

মো: রবিউল ইসলাম

Water loss

Sheet-1:

২০০৭,10,13

[illegible]

$F = 0.165\, t^{0.65}$ cm/min

We know

Infiltration rate, $f = \frac{dF}{dt}$

$= \frac{d}{dt}\, 0.165\, t^{0.65}$

$= 0.165 * 0.65\, t^{0.65-1}$

$= 0.10725\, t^{-0.35}$ cm/min

$= 6.435\, t^{-0.35}$ cm/hr. (t in hour)

Average infiltration, $f_{ave} = \frac{F}{t}$

$= \frac{0.165\, t^{0.65}}{t}$

$= 0.165\, t^{0.65-1}$

$= 0.165\, t^{-0.35}$ cm/min

$= 9.9\, t^{-0.35}$ cm/hr

Ans

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Sheet 2 05,06

we know that,
$$\Sigma(i-\phi)t = P_{net}$$
$$\Rightarrow [(1.6-\phi)+(3.6-\phi)+(5-\phi)+(2.8-\phi)+(2.2-\phi)]\frac{30}{60}=3.6$$
$$\Rightarrow \phi = 1.6 \text{ cm/hour}$$

$$\text{Rainfall} = (1.6+3.6+5+2.8+2.2+1)\times\frac{30}{60}$$
$$= 8.1 \text{ cm}$$

$$\text{W-index} = \frac{P-Q}{t_R} = \frac{8.1-3.6}{3} = 1.5 \text{ cm/hr.}$$

Sheet 3

$$\text{Evaporation} = \frac{\text{Volume}}{\text{Area}} = \frac{10.8\times10^{-3}}{\frac{\pi}{4}\left(\frac{122}{100}\right)^2} = 9.24*10^{-3} \text{ m}$$
$$= 9.24 \text{ mm.}$$

$$\therefore \text{Total evaporation} = 3.6+9.24 = 12.84 \text{ mm}$$ A

Sheet-4

$f_0 = 90$ mm/hr.

~~$t = 2.5$~~

$f_c = 8$ mm/hr

Here,
$F_c = 50-(8\times2.5)$
$= 30$ mm

we know, that, $k = \frac{f_0-f_c}{F_c} = \frac{90-8}{30} = 2.73 \text{ hr}^{-1}$

Again, $f = f_c + (f_0-f_c)e^{-kt}$
$= 8 + 82e^{-2.73t}$, f in mm/hr, t in hr Ae

12,
Sheet 5

Given,

$$f_p = 3 + e^{-2t}.$$

we know, $f = f_c + (f_0 - f_c)\, e^{-kt}$

$f_c = 3$, cm/hr.

$f_0 - f_c = 1$

$f_0 = 4$ cm/hr

$k = \cdot 2$ hr^{-1}

(I) Fp at 1st 30 minutes,

$$F_p = \int_0^{30/60} f\,dt$$

$$= \int_0^{0.5} (3 + e^{-2t})\,dt$$

$$= 1.82 \text{ mm}.$$ A

(II) fp at 2nd 30 minutes,

$$F_p = \int_{30/60}^{60/60} f\,dt$$

$$= \int_{0.5}^{1} (3 + e^{-2t})\,dt$$

$$= 1.62 \text{ mm}$$ A

Sheet-6 14.15

Given, $f = 6 + 16 e^{-2t}$, f in mm/hr.

we know, $f = f_c + (f_0 - f_c) e^{-kt}$

$f_c = 6$, mm/hr

$f_0 - f_c = 16$ $\quad\Big|\quad k = 2\ hr^{-1}$

$f_0 = 22$ mm/hr

(I) For first 45 minutes,

$$F = \int_0^{45/60} f\,dt = \int_0^{0.75} (6 + 16 e^{-2t})\,dt$$

$$F = 10.71 \text{ mm}.$$

(II) For 2nd 75 minutes,

$$f = \int_{45/60}^{125/60} f\,dt = \int_{0.75}^{\overset{20}{\cancel{1.25}}} (6 + 16 e^{-2t})\,dt$$

$$F = \overset{9.14}{\cancel{4.12 \text{ mm}}}$$

$$\therefore f_{ave} = \frac{F}{t} = \frac{\overset{9.14}{\cancel{4.12}}}{1.25} = \overset{7.31 \text{ mm/hr}}{\cancel{3.296}} \text{ mm/hr}$$

Sheet 7 2014.

Given,

$P = 12mm$

$O_g =$ ~~120mm~~ 75

$O = 13mm$

$S = 5m$

$I = 120mm$

We know that,

$$P + I \pm O_g = E + O \pm S$$

$$\Rightarrow 12 + 120 - 75 = E + 13 - 5$$

$$\Rightarrow E = 49 \text{ mm}$$ Ans

Sheet 8 14

1st hour, $P = 2.5$ cm

$$P_{net\text{-}mean} = \frac{4(0) + 10(0) + 6(2.5-1)}{4+10+6} = 0.45 \text{ cm}$$

2nd hour, $P = 6$ cm

$$P_{net\text{-}mean} = \frac{4(6-5) + 10(6-3) + 6(6-1)}{4+10+6} = 3.2 \text{ cm}$$

3rd hour, $P = 3$ cm

$$P_{net\text{-}mean} = \frac{4(0) + 10(0) + 6(6-3)}{4+10+6} = 0.9 \text{ cm}.$$

∴ Total net rain for 3-hour storm $= 0.45 + 3.2 + 0.9$

$= 4.25$ cm

Run-off

sheet-9 11,10,07

Soln. Given, $A = 26560 \text{ km}^2$

$P_b = 965 \text{ Km}$

$L_b = 230 \text{ Km}$.

(I) Form factor, $F_c = \frac{A}{L_b^2} = \frac{26560}{230^2} = 0.502$

(II) Compactness co-efficient C_c,

$A = \pi R^2$ or, $R = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{26560}{3.14}} = 91.95$ km.

$C_c = \frac{P_b}{2\pi R} = \frac{965}{2\pi \times 91.95} = 1.67$

(III) Elongation ration, $E_r = \frac{2R}{L_b} = \frac{2 \times 91.95}{230}$

$\therefore E_r = 0.8$

(IV) Circularity ratio,

$P_b = 2\pi R' \Rightarrow R' = \frac{P_b}{2\pi} = \frac{965}{2\pi} = 153.58$ km.

$C_r = \frac{A}{\pi R'^2} = \frac{26560}{\pi (153.58)^2} = 0.358$

Sheet-10

Depth of runoff $= \frac{\text{volume}}{\text{Area}}$

$= \frac{5.68 \times 10^7 \text{ m}^3}{210 \times 10^6 \text{ m}^2}$

$= 27.04 \text{ cm}$

% of rainfall that became runoff

$= \frac{27.05}{65} * 100 = 41.61\%$

Area of crop that can be irrigated $= \frac{\text{volume}}{\text{depth}}$

$= \frac{5.68 \times 10^7 \text{ m}^3}{0.6 \text{ m}}$

$= 94.67 \text{ km}^2$

Az

Sheet-11

Soln. Infiltration loss, f_p = Rainfall − Runoff

$= (15 \times 6) - \frac{\text{volume}}{\text{area}}$

$= 90 - \frac{21.6 \times 10^6 \text{ m}^3}{300 \times 10^6 \text{ m}^2} * 1000$

$= (90 - 72) \text{ mm}$

$= 18 \text{ cm}$.

(i) $f_{ave} = \frac{F_p}{t} = \frac{18\,mm}{6\,hr} = 3\,mm/hr$

(ii) Again, $yield = CAP$

$$21.6 \times 10^6\ m^3 = C \times 300 \times 10^6 \times \frac{90}{1000}$$

$$C = 0.8$$

Sheet-12, 22

Total volume of flow $= 7 + 27 + 58 + 41 + 31 + 20 + 13$

$= 197\ m^3/day$

$= 197 \times 86400\ m^3$

$= 17020800\ m^3$ $[10^4\, m^3 = 1\, ha\text{-}m]$

$= 1702.08\ ha\text{-}m$

$=$

Runoff volume $= \frac{\text{Total flow volume}}{\text{Area}}$

$= \frac{17020800\ m^3}{100 \times 10^6\ m^2}$

$= 17.02\ cm$

Sheet-16

raingage Station	rainfall x_i	$x_i-\bar{x}$	$(x_i-\bar{x})^2$
1	50	-24.8	615.04
2	82	7.2	51.84
3	73	-1.8	3.24
4	64	-10.8	116.64
5	105	30.2	912.04

$n=5$ $\qquad \Sigma x_i = 374$ $\qquad \Sigma(x_i-\bar{x})^2 = 1698.8$

$$\bar{x} = \frac{\Sigma x_i}{n} = \frac{375}{5} \rightarrow 74.8$$

$$\sigma = \sqrt{\frac{\Sigma(x_i-\bar{x})^2}{n-1}} = \sqrt{\frac{1698.8}{5-1}} = 20.61$$

$$Cv = \frac{\sigma}{\bar{x}} = \frac{20.61}{74.8} = 0.28$$

$\therefore Cv = 28\%$

$Ep = 10\%$

$\therefore$ No of raingauge,

$$N = \left(\frac{Cv}{Ep}\right)^2 = \left(\frac{28}{10}\right)^2 = 7.84 \sim 8$$

Sheet -19

$r_1^2 = 10^2+15^2 = 325$

$r_2^2 = (-8)^2+5^2 = 89$

$r_3^2 = (-12)^2 + (-9)^2 = 225$

$r_4^2 = (5)^2 + (-15)^2 = 250$

$$P_x = \frac{[\frac{1}{r_1^2}P_1 + \frac{1}{r_2^2}P_2 + \frac{1}{r_3^2}P_3 + \frac{1}{r_4^2}P_4]}{[\frac{1}{r_1^2} + \frac{1}{r_2^2} + \frac{1}{r_3^2} + \frac{1}{r_4^2}]}$$

$$= \frac{[(\frac{1}{325}\times 73) + (\frac{1}{89}\times 89) + (\frac{1}{225}\times 68) + (\frac{1}{250}\times 57)]}{[\frac{1}{325} + \frac{1}{89} + \frac{1}{225} + \frac{1}{250}]}$$

$= 77.11$ mm Ans

Sheet-20

$$P_{ave} = \frac{\Sigma A \cdot P_\theta}{\Sigma A} = \frac{(920\times 73) + (705\times 85) + (1075\times 112) + (1665\times 100)}{920 + 705 + 1075 + 1665}$$

$\therefore P_{ave} =$ ~~60~~ 94.84 cm Ans

8 Sheet - 23

(a) Arithmetic average method,

$$P_D = \frac{P_A + P_B + P_C + P_E + P_F}{n} = \frac{22+29+35+13+25}{5}$$

$\therefore P_D = 24.8$ mm Ans

(b) Normal ratio method,

$$P_D = \frac{1}{m}\left[\frac{N_D}{N_A} * P_A + \frac{N_D}{N_B} * P_B + \frac{N_D}{N_C} * P_C + \frac{N_D}{N_E} * P_E + \frac{N_D}{N_F} * P_F\right]$$

$$= \frac{1}{5}\left[\left(\frac{606}{610} * 22\right) + \left(\frac{606}{554} * 29\right) + \left(\frac{606}{468} * 35\right) + \left(\frac{606}{563} * 13\right) + \left(\frac{606}{382} * 25\right)\right]$$

$= 30.50$ mm Ans

24 2015 1(c)

$$P_{EX} = 1-(1-F)^N$$

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

$= 46\%$

Ans

T = 20 year

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

$F = \frac{1}{20} = 0.05$

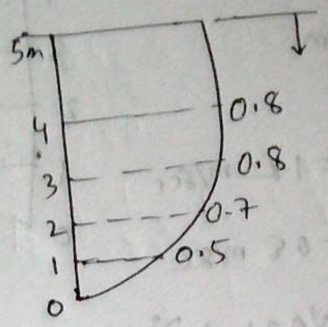
N = 12 year

Stream Gauging

25

$0.2d = 0.2 \times 5 = 1\ m$

$0.8d = 0.8 \times 5 = 4m$



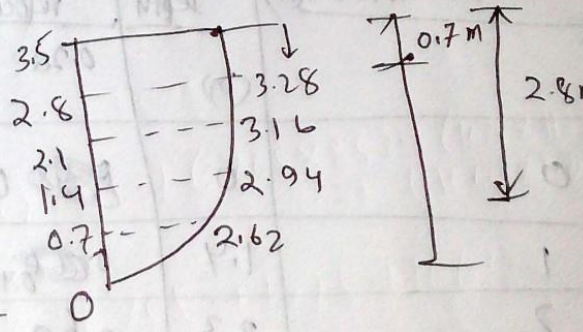
velocity at 0.2d, 0.8 m/sec

velocity at 0.8d, 0.5 m/sec.

$$\therefore v = \frac{v_{0.2d} + v_{0.8d}}{2} = \frac{0.8+0.5}{2} = 0.65$$

we know, $Q = bvd = 1 \times 0.65 \times 5 = 3.25\ m^3/sec$

26



$0.2d = 0.2 \times 3.5 = 0.7\ m$

$0.8d = 0.8 \times 3.5 = 2.8m$

velocity at. 0.2d, $v_{0.2d} = 3.28\ m/sec$

velocity at. 0.8d. $v_{0.8d} = 2.62\ m/sec.$

$$\therefore v = \frac{v_{0.2d} + v_{0.8d}}{2} = \frac{3.28+2.62}{2} = 2.95$$

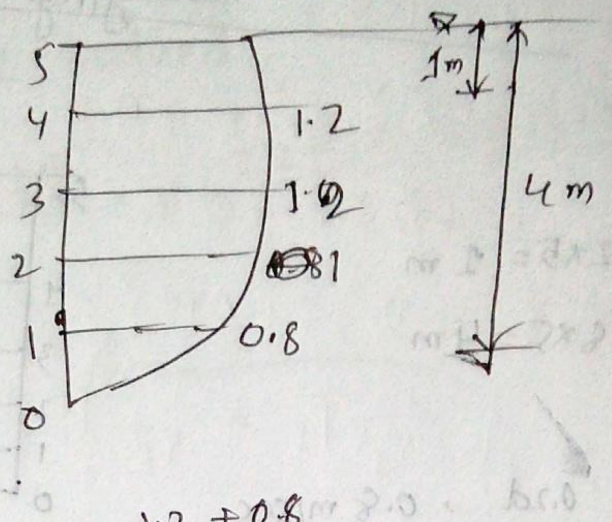
$\therefore Q = Av = bdv = 1 \times 3.5 \times 2.95 = 10.325\ m^3/sec$

27

Two point method:

$0.2d = 0.2 \times 5 = 1$ m

$0.8d = 0.8 \times 5 = 4$ m



At 0.2d velocity, $v_{0.2d} = 1.2$ m/sec

0.8d velocity $v_{0.8d} = 0.8$ m/sec

$$\therefore \quad V_{mean} = \frac{v_{0.2d} + v_{0.8d}}{2} = \frac{1.2 + 0.8}{2} = 1 \text{ m/sec}$$

$\therefore$ Discharge, $Q = bVd = 1 \times 1 \times 5 = 5$ m³/sec

28

Two point method:-

Depth from one end (m)	Depth (m)	velocity at 0.2d	velocity at 0.8d	mean velocity $V_m = \frac{v_{0.2d} + v_{0.8d}}{2}$	Discharge $Q = AV_m$ $= bdV_m$ $= 1 \times dV_m$ $= dV_m$
0	0	0	0	0	0
1	1.4	0.40	0.20	0.30	0.42
2	3.3	0.60	0.30	0.45	1.485
3	5.0	0.84	0.50	0.67	3.35
4	9.0	0.90	0.62	0.76	6.84
5	5.4	0.80	0.55	0.675	3.645
6	3.8	0.62	0.40	0.51	1.938
7	1.8	0.54	0.30	0.42	0.756

$\Sigma Q = 18.434$

মো: রবিউল ইসলাম
রাজশাহী প্রকৌশল ও প্রযুক্তি বিশ্ববিদ্যালয়
পুরকৌশল বিভাগ
রোল নং: ১৩০০১১০

Mathematical Problems On Hydrology

2015 1(b) A rainfall of certain high intensity is excepted to occur once in 20 years. what is the chance of occurance in any year? what is the probability that it may occur in the next 12 years?

Soln

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

$F = \frac{1}{20}$

$\doteq 0.05$

$T = 20$ years,

$N = 12$

Next 12 year occur,

$P_{Ex} = 1 - (1 - F)^N$

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

$= 46\%$

In any year.

$p = \frac{1}{T} = \frac{1}{20} = 0.05 = 5\%$ Ans

2011 3(c)
2015 2(c) Example 3.4(a) 82 page → Raghunath :

Soln Given that, $f_o = 90$ mm/hr

$f_c = 8$ mm/hr

$f = ?$

we know that, $k = \frac{f_o - f_c}{F_c} = \frac{90-8}{50 - 8\times 2.5} = 2.73\ hr^{-1}$

Horton's equation :, $f = f_c + (f_o - f_c)e^{-kt}$

$f = 8 + (90-8)e^{-2.73t}$

$\therefore f = 8 + 82e^{-2.73t}$, f in mm/hr, t in hr.

Ans.

2012 6(c)
2014 3(c)
2015 3(c) Example - 8.7, 269 page → Reddi

Soln Given equation,

$f = 6 + 16e^{-2t}$.

Here, $f_c = 6$ mm/hr.

$f_o - f_c = 16$

$\therefore f_o = 22$ mm/hr.

$k = 2\ hr^{-1}$

Since, the rainfall intensity is more than f_o, the infiltration takes place at the capacity rate throughout the storm. Hence the cumulative depth of infiltration for the first 45 minutes or $\frac{3}{4}$ hr is given by, $F = \int_0^{3/4} f.dt$

$$= \int_0^{0.75} (6 + 16e^{-2t})\, dt$$

$$= \left[6t - 8e^{-2t} \right]_0^{0.75}$$

$$= (6 \times 0.75 - 8 \times e^{-2 \times 0.75}) - (6 \times 0 - 8 e^{-2 \times 0})$$

$$= 10.715 \text{ mm.}$$

The cumulative depth of infiltration for the first 75 minutes or 1.25 hr is given by.

$$F = \int_0^{1.25} f\, df = \int_0^{1.25} (6 + 16\, e^{-2t})\, df$$

$$= \left[6t - 8e^{-2t} \right]_0^{1.25}$$

$$= (6 \times 1.25 - 8e^{-2 \times 1.25}) - (6 \times 0 - 8e^{-2 \times 0})$$

$$= 14.843 \text{ mm}$$

The average infiltration rate for the first 75 minutes is given by,

$$f_{ave} = \frac{F}{t} = \frac{14.843}{1.25} = 11.874 \text{ mm/hr}$$ Ans

2015 4(c) Example 6.6 → Page 198 — Reddy

Soln

Total volume of flow.

$= 7+27+58+41+31+20+13$

$= 197$ cumec-days.

$= 197 \times 86400\ m^3$

$= 17020800\ m^3$ [∵ 1 ha-m = 10000 meter^3]

$= 1702.08$ hectar-meter

Mean flow for the week $= \frac{197\ \cancel{m^3\text{-days}}\ \text{cumec-days}}{7\ \text{days}}$

$= 28.143\ m^3/sec$

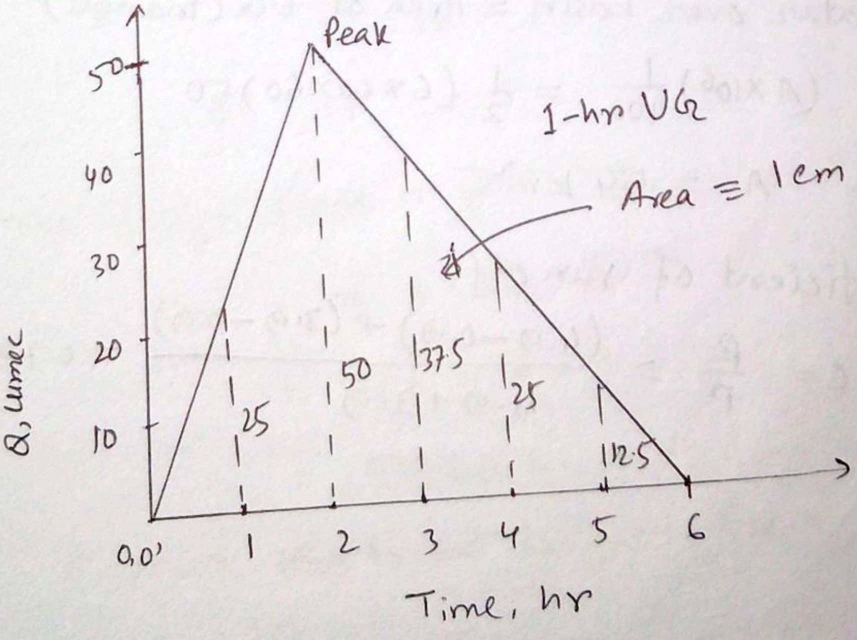
Depth of runoff $= \frac{\text{Volm of runoff}}{\text{Area of the basin}}$

$= \frac{17020800\ m^3}{100 \times 10^6\ m^2}$

$= 17.0208$ cm Ans

2015 5(c) Example-5.11, page-169, — Raghunath.

Soln



Computation of design flood hydrographs,

Time hrs	UGO cumec	DRO due to rainfall excess, cumec 4.9-0.9 = 4 cm	 3.9-0.9 = 3cm	Total cumec (DRO)	B.F cumec	TRO cumec TRO= DRO+BF	Remarks
1	0	0	—	0	10	10	
2	25	100	0	100	10	110	
3	50	200	75	275	10	285	
4	37.5	150	150	300	10	310	← Peak flood
5	25	100	112.5	212.5	10	222.5	
6	12.5	50	75	125	10	135	
7	0	0	37.5	37.5	10	47.5	
8	—	—	0	0	10	10	

(II) Area of water shed – to produce 1cm net rain over the entire water shed, (A km²)

volm of water over basin = Area of UG (triangle)

$$(A \times 10^6)\frac{1}{100} = \frac{1}{2}(6 \times 60 \times 60)50$$

$$\therefore A = 54 \text{ km}^2$$

(III) co-efficient of run off,

$$C = \frac{R}{P} = \frac{(4.9-0.9)+(3.9-0.9)}{4.9+3.9} = 0.795$$

Ans

2015 6 (d) Example 14.9 501 page Reddi

Soln Assurance $= 90\%$

Risk, $R = 100 - 90 = 10\%$

$\therefore R = 0.01$

The life period, $N = 50$ years.

we know,
$$R = 1 - \left(1 - \frac{1}{Tr}\right)^N$$
$$0.01 = 1 - \left(1 - \frac{1}{Tr}\right)^{50}$$
$$\therefore Tr = 4975.46 \text{ years.}$$

$$y_T = -\ln \ln \left(\frac{Tr}{Tr-1}\right)$$
$$= -\ln \ln \left(\frac{4975.46}{4975.46-1}\right)$$
$$= 8.51217$$

$$k_T = \frac{y_T - \bar{y}_n}{\sigma_n}$$
$$= \frac{8.51217 - 0.53622}{1.11238}$$
$$= 7.17$$

$\therefore$ The design flood is given by,
$$X_T = \bar{x} + k_T \times S_x$$
$$= 1200 + 7.17 \times 650$$
$$= 5860.61 \text{ m}^3/\text{s}.$$

$\therefore$ The structure has to be designed for a discharge of $5865 \text{ m}^3/\text{s}$ Ans

2015 7(c) Example 4.4 — 84 page ground water 2nd E. Raghunath.

In an area of 100 ha, the WT dropped by 4.5m. If the porosity is 30% and the specific retention is 10% determine.

(I) the specific yield of the aquifer.

(II) change in ground water storage.

Soln Given, $S_r = 10\%$, porosity $= 30\%$. $S_y = ?$

we know,

$$\text{Porosity} = S_y + S_r$$

$$\therefore 30\% = S_y + 10\%$$

$$\therefore S_y = 20\% \text{ or } 0.2$$

Change in ground water storage = Area of aquifer × drop in g.w.t × Sy

$$= 100 \times 4.5 \times 0.2$$

$$= 90 \text{ ha-m}$$

$$= 90 \times 10^4 \text{ m}^3$$ Ans

মো: রবিউল ইসলাম CE'130110

Introduction + Precipitation

Formula-01 [Missing Data] normal ratio method:

$$P_x = \frac{1}{m}\left[\frac{N_x}{N_a}P_a + \frac{N_x}{N_b}P_b + \frac{N_x}{N_c}P_c\right]$$

m = surrounding stations,

** $\frac{N_D - N_A}{N_D} * 100$ এটার যেকোন একটি যদি 10% এর বড় হয় তাহলে উপরের সূত্র use করতে হবে]
অন্যথায় $P = \frac{P_A + P_B + P_C}{3}$ এই সূত্রে হবে]

Q.2.1 Ragunath 25:

Given, A = 8.5, B = 6.7, C = 9.0 cm.
A.A.R, A = 75, B = 84, C = 70, D = 90.

Soln

$$\frac{N_D - N_A}{N_D} \times 100 = \frac{90-75}{90} \times 100 = 16.67 > 10\%$$

$$\frac{N_D - N_B}{N_D} \times 100 = \frac{90-84}{90} \times 100 = 6.67 < 10\%$$

$$\frac{N_D - N_C}{N_D} \times 100 = \frac{90-70}{90} \times 100 = 22.2 > 10\%$$

Here, m = 3, $P_A = 8.5$ cm, $P_B = 6.7$ cm, $P_C = 9$ cm.
$N_A = 75$ cm, $N_B = 84$ cm, $N_C = 70$ cm, $N_D = 90$ cm.

$$\therefore P_D = \frac{1}{m}\left[\frac{N_D}{N_A} \times P_A + \frac{N_D}{N_B} \times P_B + \frac{N_D}{N_C} \times P_C\right]$$

$$= \frac{1}{3}\left[\frac{90}{75} * 8.5 + \frac{90}{84} * 6.7 + \frac{90}{70} * 9\right] = 9.65 \text{ cm}$$

Ans

2014 1(c)

Given,

~~$P_A = 610$, $P_B = 554$, $P_C = 468$, P_D~~

$N_A = 610$, $N_B = 554$, $N_C = 468$, $N_D = 606$, $N_E = 563$,

$N_F = 382$.

$P_A = 22$, $P_B = 29$, $P_C = 35$, $P_E = 13$, $P_F = 25$

(All are mm).

Now, $\frac{-N_D + N_A}{N_D} \times 100 = \frac{-606+610}{606} \times 100 = 0.67\% < 10\%$

$\frac{N_D - N_B}{N_D} \times 100 = \frac{606-554}{606} \times 100 = 8.58\% < 10\%$

$\frac{N_D - N_C}{N_D} \times 100 = \frac{606-468}{606} \times 100 = 22.8\% > 10\%$

(b) $\therefore P_D = \frac{1}{m}\left[\frac{N_D}{N_A} \times P_A + \frac{N_D}{N_B} \times P_B + \frac{N_D}{N_C} \times P_C + \frac{N_D}{N_E} \times P_E + \frac{N_D}{N_F} \times P_F\right]$

$= \frac{1}{5}\left[\frac{606}{610} \times 22 + \frac{606}{554} \times 29 + \frac{606}{468} \times 35 + \frac{606}{563} \times 13 + \frac{606}{382} \times 25\right]$

$= 30.50$~~85~~ mm Ans

(a) Arithmatic average method,

$P_D = \frac{P_A + P_B + P_C + P_E + P_F}{n} = \frac{22+29+35+13+25}{5}$

$\therefore P_D = 24.8$ mm.

Example - 2.4 , Raghunath (33) → Same 2013 1(c), 2008 (1-c), 2011, 1(c)
2007 (1-c)

Q.

Soln

Station	Rainfall, cm (x_i)	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
A	82.6	−36	1296
B	102.9	−15.7	246.49
C	180.3	61.7	3806.89
D	110.3	−8.3	68.89
E	98.8	−19.8	392.04
F	136.7	18.1	327.61
$\Sigma n = 6$	$\Sigma x_i = 711.6$	0	6137.92

$$\therefore \bar{x} = \frac{\Sigma x_i}{\Sigma n} = \frac{711.6}{6}$$

$$\therefore \bar{x} = 118.6$$

$$\sigma = \sqrt{\frac{\Sigma (x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{6137.92}{6-1}} = 35.03$$

$$C_V = \frac{\sigma}{\bar{x}} = \frac{35.03}{118.6} \times 100\% = 29.54\%$$ Ans

$$N = \left(\frac{C_V}{E_p}\right)^2 = \left(\frac{29.54}{10}\right)^2 = 8.73 \sim 9$$

Example 2.4

Station	rainfall, cm x_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
A	88	−4.8	23.04
B	104	11.2	125.44
C	138	45.2	2043.04
D	78	−14.8	219.04
E	56	−36.8	1354.24
$\Sigma n = 5$	$\Sigma x_i = 464$	0	$\Sigma(x_i - \bar{x})^2 = 3764.8$

$$\bar{x} = \frac{464}{5} = 92.8$$

$$\sigma = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{3764.8}{5-1}} = 30.68.$$

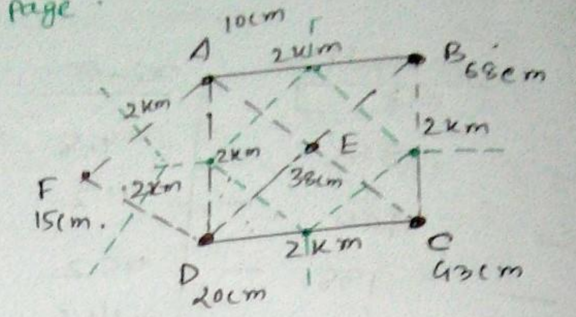
$$C_v = \frac{\sigma}{\bar{x}} = \frac{30.68}{92.8} \times 100\% = 33.06\,\%$$

$$\therefore N = \left(\frac{C_v}{E_p}\right)^2 = \left(\frac{33.06}{10}\right)^2 = 10.93 \sim 11.$$ Ans.

~~Station~~ Zone	I	II	III	IV	V	VI	total
Area, A km^2	410	900	2850	1750	720	550	7180
Area, as decimal, $\frac{A}{\Sigma A}$	0.06	0.125	0.4	0.24	0.1	0.076	
N × Area in decimal (N=11)	0.66	1.36	4.4	2.64	1.1	0.84	
Rounded as	1	1	4	3	1	1	11
Rain-gauges existing	1	1	1	1	1	0	5
Additional rain gauges	0	0	3	2		1	6

Scanned by CamScanner

2010 5(c) R→ 7 (b) — 56 page.



Area of square plot = 2×2 = 4 km^2

Area of inner square plot = $\frac{2\times2}{\sqrt{2}\times\sqrt{2}}$ = 2 km^2

Difference = 4 − 2 = 2 km^2.

Area of each corner trainage in the square plot = $\frac{2}{4}$ = 0.5 km^2

$\frac{1}{3}$ Area of equilateral traingular plot = $\frac{1}{3}[\frac{1}{2}\times2\times2\sin60)$

= 0.58 km^2

Station	Area A (km^2)	Precipitation P (cm)	A×P km^2.cm
A	0.5+0.58=1.08	10cm	10.8
B	0.5	68	34
C	0.5	43	21.5
D	0.5 + 0.58 = 1.08	20	21.6
E	2	38	76
F	0.58	15	8.7
	ΣA = 5.74		ΣAP = 172.6

∴ Average depth of precipitation = $\frac{\Sigma AP}{\Sigma A}$ = $\frac{172.6}{5.74}$ = 30.07 cm

Ans.

2012 1(c)

Given, $P = \frac{1}{5} = 0.2$, $n = 10$

$q = 1 - P = 1 - 0.2 = 0.8$

$P(r=0) = ?$ $P(r=2) = ?$

(1) $P(r=0) = {}^{n}C_{r}\, P^{r} q^{n-r}$

$= {}^{10}C_{0}\,(0.2)^{0}\,(0.8)^{10-0}$

$= 1 \times 1 \times 0.107$

$= 0.107$ Ans.

(11) $P(r=2) = {}^{10}C_{2}\,\cancel{0}\,(0.2)^{2}\,(0.8)^{10-2}$

$= 0.302$ Ans.

2011 2(c) Average annual rainfal.

$$P_{ave} = \frac{\Sigma A_a P_b}{\Sigma A}$$

$$= \frac{(920 \times 73) + (705 \times 85) + (1075 \times 112) + (1665 \times 100)}{920 + 705 + 1075 + 1665}$$

$= 94.84$ cm Ans.

Missing data → weighted Average of four station: → Reddi (141)

$$P_x = \frac{\left[\frac{1}{r_1^2} \times P_1 + \frac{1}{r_2^2} P_2 + \frac{1}{r_3^2} \times P_3 + \frac{1}{r_4^2} P_4\right]}{\left[\frac{1}{r_1^2} + \frac{1}{r_2^2} + \frac{1}{r_3^2} + \frac{1}{r_4^2}\right]}$$

r = quardant distance [suppose point (x, y), then, $r^2 = x^2 + y^2$]

2009 2c Reddi 141 (5.13)

Soln

Given, $P_1 = 73$, $P_2 = 89$, $P_3 = 68$, $P_4 = 57$ mm respectively.

Q. Quandatic points are, (10,15), (-8,5), (-12,-9), (5,-15).

Now, $r_1^2 = 10^2 + 15^2 = 325$

$r_2^2 = (-8)^2 + 5^2 = 89$

$r_3^2 = (-12)^2 + (-9)^2 = 225$

$r_4^2 = 5^2 + (-15)^2 = 250$

Missing rainfall at x,

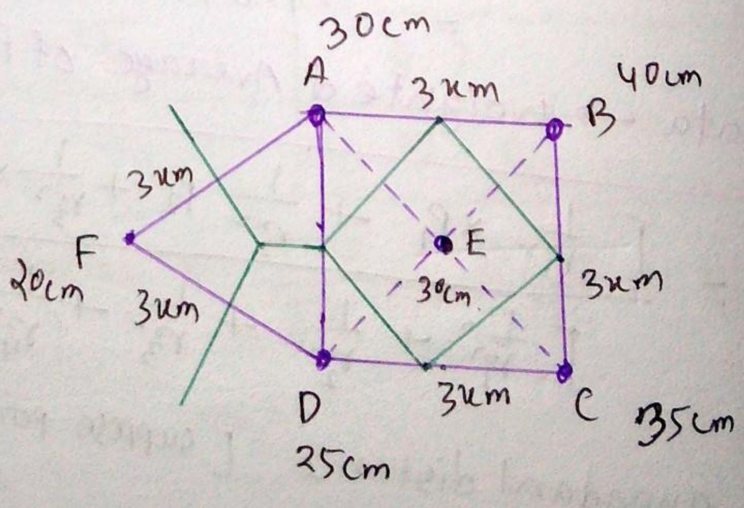
$$P_x = \frac{\frac{1}{r_1^2} \times P_1 + \frac{1}{r_2^2} \times P_2 + \frac{1}{r_3^2} \times P_3 + \frac{1}{r_4^2} \times P_4}{\frac{1}{r_1^2} + \frac{1}{r_2^2} + \frac{1}{r_3^2} + \frac{1}{r_4^2}}$$

$$= \frac{\frac{73}{325} + \frac{89}{89} + \frac{68}{225} + \frac{57}{250}}{\frac{1}{325} + \frac{1}{89} + \frac{1}{225} + \frac{1}{250}}$$

$= 77.11$ mm

Ans.

2009 7(c) 2006 1(c)



Area of square plot $= 3 \times 3 = 9\text{km}^2$

Area of inner square plot $= \frac{3}{\sqrt{2}} \times \frac{3}{\sqrt{2}} = \frac{9}{2} = 4.5\ \text{km}^2$

Difference $= 9 - 4.5 = 4.5\ \text{km}^2$

Area of each corner triangle in the square plot $= \frac{4.5}{4} = 1.125\ \text{km}^2$

$\frac{1}{3}$ area of equilateral traiangle plot $= \frac{1}{3}\left[\frac{1}{2} \times 3 \times 3 \sin 60^\circ\right)$

$= 1.3\ \text{km}^2$

Station	Area A (km^2)	Precipitation P (cm)	A×P km^2.cm
A	$1.125 + 1.3 = 2.425$	30	72.75
B	1.125	40	45
C	1.125	35	39.375
D	$1.125 + 1.3 = 2.425$	25	60.625
E	4.5	30	135
F	1.3	20	26
	$\Sigma A = 12.9$		$\Sigma AP = 378.75$

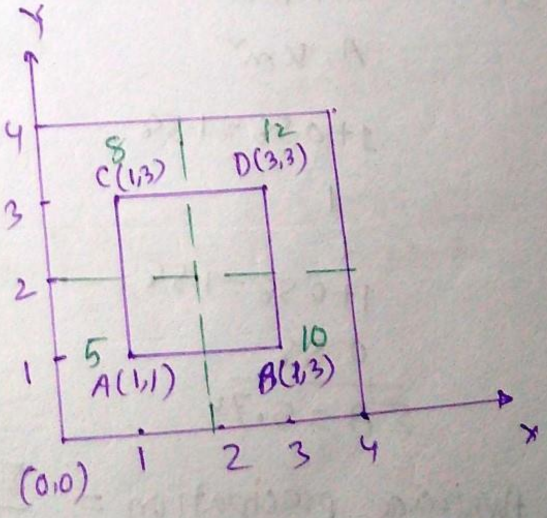
$\therefore$ Average precipation $= \frac{\Sigma PA}{\Sigma A} = \frac{378.75}{12.9} = 29.36$ cm

<u>2005</u> 1(c)

Area of square plot $= 4 \times 4 = 16\text{km}^2$

Area of each corner of square plot

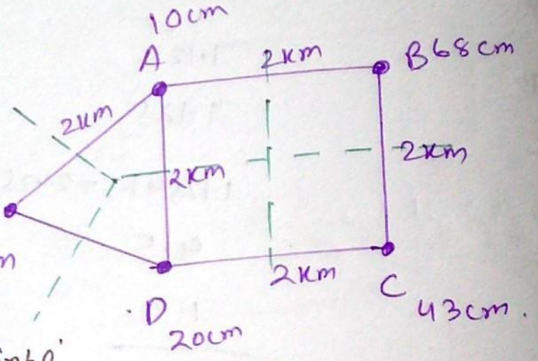
$= \frac{16}{4} = 4\ \text{km}^2$.



Station	Area A (km^2)	Precipitation P (cm)	PA km^2.cm
A	4	5	20
B	4	10	40
C	4	8	32
D	4	12	48
	$\Sigma A = 16$		$\Sigma PA = 140$

$\therefore$ Average precipitation, $P_{ave} = \frac{\Sigma PA}{\Sigma A} = \frac{140}{16} = 8.75$ cm Ans

2004 1(c)



Area of square plot $= 2\times2 = 4$ km^2

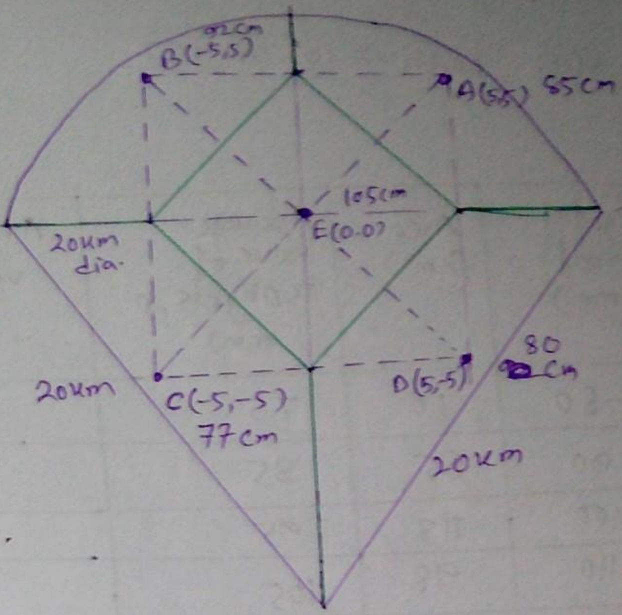
$\frac{1}{4}$ th area of square plot $= \frac{4}{4} = 1$ km^2

$\frac{1}{3}$ Area of equilateral triangle $= \frac{1}{3}\frac{1}{2}\times2\times2\sin60^\circ$
$= 0.58$ km^2

station	Area A, km^2	Precipitation P, (cm)	PA km^2.cm
A	$1+0.58=1.58$	10	15.8
B	1	68	68
C	1	43	43
D	$1+0.58=1.58$	20	31.6
E	0.58	15	8.7
	$\Sigma A = 5.74$		$\Sigma AP = 167.1$

$\therefore$ Average precipation $= \frac{\Sigma AP}{\Sigma n} = \frac{167.1}{5.74} = 29.11$ cm Ans.

2003 3(c) Reddi(5.9) 131



Area of semicircle $= \frac{\pi r^2}{2}$

$$= \frac{\pi \times (\frac{20}{2})^2}{2}$$

$$= 157 \text{ km}^2$$

Area of equilateral triangle.

$$= \frac{1}{2} \times 20 \times 20 \sin 60^\circ$$

$$= 173.2 \text{ km}^2.$$

Area of inner square plot.

$$= \frac{10}{\sqrt{2}} \times \frac{10}{\sqrt{2}}$$

$$= 50 \text{ km}^2$$

$\frac{1}{4}$ th of inner square $= \frac{50}{4} = 12.5 \text{ km}^2$

Station	Area A (km^2)	Precipitation P (cm)	PA
A	$\frac{1}{2} \times 157 - 12.5$ $= 66$	85	5610
B	$\frac{1}{2} \times 157 - 12.5$ $= 66$	92	6072
C	$\frac{1}{2} \times 173.2 - 12.5 = 74.1$	77	5705.7 ~~5082~~
D	$\frac{1}{2} \times 173.2 - 12.5 = 74.1$	80	5928
E	50	105	5250
	$\Sigma A = 330.2$		$\Sigma AP = 28565.7$

$\therefore$ Average precipitation, $P_{ave} = \frac{\Sigma AP}{\Sigma A} = \frac{28565.7}{330.2} = 86.5$ cm.

Ans

2004 8(c) Reddi (5.10) — 132

Soln

Isohyetal interval (mm)	Area (km^2)	Average value of isohyets, P (mm)	Area × Average Isohyetal value, ($km^2 \cdot mm$) AP
70-80	10	75	750
80-90	85	85	7225
90-100	113	95	10735
100-110	98	105	10290
110-120	136	115	15640
120-130	67	125	8375
$\Sigma A = 509$			$\Sigma AP = 53015$

∴ Average depth of rainfall, $= \frac{53015}{509} = 104.16$ cm

Water loss

2014 2(c) Suresh 4.1 93 page

Soln we know that.

the storage equation,

$$P + I \pm O_g = E + O \pm S.$$

P = precipitation = 12 mm

I = surface inflow = 120 mm

O = surfack outflow = 13 mm.

S = storage decrease = 5 mm

O_g = ground water flow = 75 mm.

E = evaporation = ?

$$12 + 120 - 75 = E + 13 - 5$$

$$\therefore E = 49 \text{ mm}$$ Ans.

2012 6(c)

2014 3(c) → 2015 3(c) → Example − 3.7 → R. (85)

2014 4(c)

1st hour, P = 2.5 cm,

$$P_{net-mean} = \frac{4(0) + 10(0) + 6(2.5-1)}{4+10+6} = 0.45 \text{ cm}.$$

2nd hour, P = 6 cm,

$$P_{net-mean} = \frac{4(6-5) + 10(6-3) + 6(6-1)}{4+10+6} = 3.20 \text{ cm}.$$

3rd hour,

$P = 3cm$, $P_{net-mean} = \frac{4(0) + 10(0) + 6(3-1)}{4+10+6} = 0.60$ cm.

Total net rain for the 3-hour storm $= 4.25$ cm Ans

2014 3(b) What is the probability that a 5-year flood will occur at least once during the next 3 years.

Soln $p = \frac{1}{5} = 0.2$, $n = 3$,

$q = 1 - p = 0.8$.

$\therefore P(r = \text{at least once}) = 1 - P(r=0)$

$= 1 - {}^{n}C_{r}\, p^{r} q^{n-r}$

$= 1 - {}^{3}C_{0}\, (0.2)^{0} (0.8)^{3-0}$

$= 1 -$

$= 1 - 0.512$

$= 0.488$ Ans

009 3(c)
010 6(e)
2013 2(e)

$F = 0.165 t^{0.65} \rightarrow$ cm/min, find, $f = ?$ $f_{ave} = ?$

Soln

$f = \frac{dF}{dt} = 0.165 \times 0.65 t^{0.65-1}$

$= 0.107 t^{-0.35}$, t in minutes.

$\therefore f = 6.42 t^{-0.35}$ cm/hour, t in hour.

$\therefore f =$

$\frac{F}{t} = \frac{0.165 t^{0.65}}{t} = 0.165 t^{0.65-1} = 0.165 t^{-0.35}$. (t in min)

$\therefore f_{ave} = \frac{F}{t}$

$\therefore f_{ave} = 9.9 t^{-0.35}$ cm/hour. (t in hour)

Ans.

মো: রবিউল ইসলাম

WATER LOSS

2014 2(e) Given, $P = 12$ mm, $O_g = -75$ mm.

$I = 120$ mm, $O = 13$ mm

$S = -5$ mm.

we know that,

$$P + I \pm O_g = E + O \pm S$$

$$\Rightarrow 12 + 120 \overset{-}{\cancel{+}} 75 = E + 13 - 5$$

$$\therefore E = 49 \text{ mm}$$ Ans.

Roghnath 3.1 66

Given, $A_1 = 2.80$ km², $A_2 = 2.55$ km²

$A_{ave} = \frac{1}{3}(A_1 + A_2 + \sqrt{A_1 A_2})$, cone formula.

$= \frac{1}{3}(2.80 + 2.55 + \sqrt{2.8 \times 2.55})$

$= 2.673$ km²

Annual loss of water due to evaporation

$= 16.7 + 14.3 + 17.8 + 25.0 + 28.6 + 21.4 + 16.7 + 16.7$
$+ 16.7 + 21.4 + 16.7 + 16.7$

$= 228.7$ cm.

Annual volm of water lost due to evaporation $= A_{ave} \times A_{LE} \times$ Pan coff.

$= 2.673 \times 10^6 \times \frac{228.7}{100} \times 0.7$

$= 4.29 \times 10^6$ m³ Ans

$= 4.29$ M.m³ Ans

3.1 (a) 66

Pan evaporation, Ep, mm = Rainfall + water added or − water removed

Day :	1	2	3	4	5	6	7
EP :	14−5 = 9	6+3 = 9	12	8	7	5+4 = 9	6+3 = 9

Pan evaporation in the week $= \sum_{1}^{7} Ep = 63$ mm.

Pan coefficient, $0.75 = \frac{E_L}{E_p}$.

∴ Lake evaporation during the week E_L, = 47.25 mm.

$= 63 \times 0.75 = 47.25$

water lost from the lake $= A \cdot E_L = 640 \times \frac{47.25}{1000} = 30.24$ ha.m.

~ 0.3 M.m³ Ans

3.1 (b)

(I) Infiltration loss. F_p = Rainfall (P) − Runoff (R)

$= (15 \times 6) - \frac{vol^m}{Area}$

$= 90 - \frac{31.6 \times 10^6 m^3}{300 \times 10^6 m^2} \times 1000$

$= (90 - 72)$ mm

= 18 mm Ans

$f_{ave} = \frac{F_p}{t} = \frac{18 mm}{6 hr} = 3$ mm/hr.

(II) Yield = CAP ⇒ $21.6 \times 10^6 m^3 = C(300 \times 10^6 m^2) \times \frac{90}{1000}$

∴ C = 0.8 Ans

2012 6(c) Given, $f_p = 3.0 + e^{-2t}$, cm/hour. $F_p = 30$ min (1st)
$F_p = 30$ min (2nd)

Soln

$f =$ ~~6+1~~ $3 + e^{-2t}$

$f = f_c + (f_0 - f_c) e^{-kt}$

$f_c = 3$ cm/hour.

$f_0 - f_c = 1$.

$\therefore f_0 = 1 + 3 = 4$ cm/hour.

$k = -2$ /hr.

(i) depth, $F_p = \int_0^{30/60} f\,dt = \int_0^{0.5} (3 + e^{-2t})\,dt$

$= 1.82$ cm Ans.

(ii) depth, $F_p = \int_{30/60}^{60/60} f\,dt = \int_{0.5}^{1} (3 + e^{-2t})\,dt$,

$\therefore F_p = 1.62$ cm Ans.

2010 2(b) Given, 10.8 Liter water add,
rain gauge 3.6 mm. dia of span 122 cm.
calculate evaporation.

Soln Evaporation $= \frac{\text{Volume}}{\text{Area}} = \frac{10.8 \times 10^{-3}\ m^3}{\frac{\pi}{4}\left(\frac{122}{100}\right)^2 m^2} = 9.24 \times 10^{-3}$ m

$\therefore$ Evaporation $= 9.24$ mm

$\therefore$ Total evaporation $= 3.6 + 9.24 = 12.84$ mm Ans.

3.6 (b) R − 84 2006, 7(c), 2005, 5(c)

Runoff দিয়ে estimate করতে হবে।

We know that,

$$\Sigma (i - \varphi) t = \overset{\text{Runoff}}{P_{net}}$$

$$[((1.6 - \varphi) + (3.6 - \varphi) + (5 - \varphi) + (2.8 - \varphi) + (2.2 - \varphi)] \frac{30}{60} = 3.6$$

$$\therefore \varphi = 1.6 \text{ cm/hr}.$$

$$\therefore P = (1.6 + 3.6 + 5 + 2.8 + 2.2 + 1) \times \frac{30}{60} = 8.1 \text{ cm}.$$

$$\therefore W\text{-index} = \frac{P - \overset{\text{Runoff}}{Q}}{t_R} = \frac{8.1 - 3.6}{3} = 1.5 \text{ cm/hr}.$$

Example 3.5 − R − 82 :-

$$f = f_c + (f_0 - f_c) e^{-kt}$$

Soln

$$f = f_c + (1 - 0.3) e^{-5t}.$$

$$f = 0.3 + (1 - 0.3) e^{-5t}$$

$$\therefore F_P = \int_0^{24} f \, dt = \int_0^{24} (0.3 + 0.7 e^{-5t}) dt$$

$$\therefore F_P = 7.34 \text{ cm}.$$

$$\text{Runoff} = \text{precipitation} - F_P - \text{Evaporation}.$$

$$= 10 - 7.34 - (E_P \times \overset{0.7}{\text{Pan co-efficient}})$$

$$= 2.66 - (0.6 \times 0.7)$$

$$= 2.24 \text{ cm},$$

$\therefore$ Volume of runoff from the catchment.

$$= \text{Runoff} \times \text{Area}.$$

$$= \frac{2.24}{100} \times 1.8 (1000)^2$$

$$= 40320 \text{ m}^3$$

Reddi 8.8 271

Q. A 500 km^2 watershed received a 8 hr storm which
produced hourly intensities of 6, 9, 20, 16, 4, 14, 12 and 2 mm/hr
If the initial abstractions are estimated to be 15mm and
φ index is 5mm/hr. what would be the runoff volume
produced by the storm?

soln we know, $P_{net} = \Sigma (i-\varphi)t$

The rainfall occurring in the first two hours is 15mm
which is same as the initial abstraction. therefore
no runoff is produced in this period. In the remaining
6 hour period the rainfall excess is given by.

$$P_{net} = \{(20-5) + ((16-5) + 0 + (14-5) + (12-5) + 0\} 1$$

$$= 42 \text{ mm} \quad \text{Ans}$$

$$\therefore \text{Volume} = \frac{42}{100} \times 500 \times (100)^2$$

$$= 21 \times 10^6 m^3$$

$$= 21 \text{ Mm}^3 \quad \text{Ans}$$

CT-13 series: Reddi 7.5 (231) what is the evaporation, if 4.75 litre
of water is removed from an evaporation pan of dia 1.22 m and
the simultaneous rainfall measurement is 8.8 mm?

soln Area of pan $= \frac{\pi}{4} D^2 = \frac{\pi}{4} \times (122)^2 = 11689.87 \text{ cm}^2$

volm of water removed = 4.75 litre = 4750 cm^3

Depth of water removed $= \frac{\text{volm}}{\text{Area}} = \frac{4750}{11689.87} = 0.406$ mm.

$\therefore$ Evaporation = rainfall − depth of water removed = 8.80 − 4.06 = 4.74 mm

মো: রবিউল ইসলাম CE'130110

2010 3(c)
2011 4(c)

Runoff

Example 4.2 R(103) A basin has an area 26560 km^2, perimeter 965 km length of the thalweg 230 km. Determine. . . .

Soln

where,
$A = 26560 \text{ km}^2$
$L_b = 230 \text{ km}$

(I) Form factor, $F_f = \frac{A}{L_b^2}$

$$= \frac{26560}{(230)^2}$$

$$\therefore F_f = 0.502$$

(II) Compactness co-efficient C_c.

Radius of R of an equivalent circular area is given by.

$A = \pi R^2 \Rightarrow R = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{26560}{\pi}} = 91.95$ km.

$$\therefore C_c = \frac{P_b}{2\pi R} = \frac{965}{2\times\pi\times 91.95} = 1.67.$$

(III) Elongation ratio, $E_r = \frac{2R}{L_b} = \frac{2\times 91.95}{230} = 0.8$

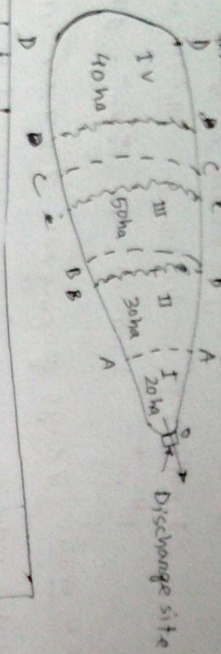
(IV) Circularity ratio, C_r,

Radius R' of a circle of an equivalent perimeter as the basin is given by, $P_b = 2\pi R' \Rightarrow R' = \frac{P_b}{2\pi} = \frac{965}{2\pi} = 153.58$ km.

$$\therefore C_r = \frac{A}{\pi R'^2} = \frac{26560}{\pi \times (153.58)^2} = 0.358$$

Example 4.3 Page 112

A 4hr rain of average intensity 1cm/hr



Soln

Sub area (zone) contibuting runoff, ha	Time for begining of storm, hr							
	1	2	3	4	5	6	7	8
I	20	20	20	20				
II		30	30	30	30			
III			50	50	50	50		
IV				40	40	40	40	–
Discharge at o from sub-areas, $Q = \Sigma CAP$ (m^3/hr) $P = 1cm/hr$ $= \frac{1}{100} m/hr$	$0.5 \times (20 \times 10^4) \frac{1}{100}$	$0.6 \times 20 \times 10^4 \times \frac{1}{100}$ $0.5 \times 30 \times 10^4 \times \frac{1}{100}$	$0.7 \times 20 \times 10^4 \times \frac{1}{100}$ $0.6 \times 30 \times 10^4 \times \frac{1}{100}$ $0.5 \times 50 \times 10^4 \times \frac{1}{100}$	$0.8 \times 20 \times 10^4 \times \frac{1}{100}$ $0.7 \times 30 \times 10^4 \times \frac{1}{100}$ $0.6 \times 50 \times 10^4 \times \frac{1}{100}$ $0.5 \times 40 \times 10^4 \times \frac{1}{100}$	– $0.8 \times 30 \times 10^4 \times \frac{1}{100}$ $0.7 \times 50 \times 10^4 \times \frac{1}{100}$ $0.6 \times 40 \times 10^4 \times \frac{1}{100}$	$0.8 \times 50 \times 10^4 \times \frac{1}{100}$ $0.7 \times 40 \times 10^4 \times \frac{1}{100}$	$0.8 \times 40 \times 10^4 \times \frac{1}{100}$	
Discharge at o. $Q, m^3/hr$	1000	2700	5700	8700	8300	6800	3200	

Stream flow measurement

1 cumec-day $= 86400\ m^3$

1 million $m^3 = 100$ ha-m $= 11.574$ cumec days.

$10^4\ m^3 =$ 1 ha-m. , $10^8\ km^2 = 1$ ha.

Example 6.6 Reddi (198) 7 days gauging are. 7, 27, 58, 41, 31, 20, 13 m^3/day

Find. total volume, mean volume, Depth of runoff when area 100 km².

soln

Total volume of flow.

$= 7+27+58+41+31+20+13$

$= 197$ cumec-days.

$= 197 \times 86400\ m^3$

$= 17020800\ m^3$ $[\because 10^4\ m^3 = 1\ ha\text{-}m]$

$= 1702.08$ ha-m

Mean flow for the week, $= \dfrac{197 \text{ cumec days}}{7 \text{ days}}$.

$= 28.14\ m^3/s$

Depth of runoff $= \dfrac{\text{Volm}}{\text{Area}} = \dfrac{17020800}{100 \times 10^6} = 0.1702\ m$

$\therefore$ Depth of runoff $= 17.02$ cm Ans

Reddi 6.7 Find Volm, 57 mm = runoff depth, 3300 km² = Area.

Soln

volume of runoff = basin area × depth of runoff

$= (3300 \times 10^6) \times 57 \times 10^{-3}$

$= 1881 \times 10^5\ m^3$

$= 188.1$ million $m^3 = 18810$ ha-m

$= 2177.08$ cumec-days Ans.

2008 2(c) 6.8 (198) Peddi Area 210 km² Agdepth 65cm. volume 5.68×10^7 m³ compute depth of runoff, % rainfall, find area irrigated. irrigated depth 60 cm.

soln

$$\text{Depth of runoff} = \frac{\text{volume}}{\text{Area}}$$

$$= \frac{5.68 \times 10^7}{210 \times 10^6}$$

$$= 0.2705 \text{ m}$$

$$= 27.05 \text{cm}$$

$$\text{\% of rainfall that became runoff} = \frac{27.05}{65} \times 100 = 41.62\%$$

$$\text{Area of crop that can be irrigated} = \frac{\text{volume}}{\text{depth}}$$

$$= \frac{5.68 \times 10^7}{0.6}$$

$$= 9.467 \times 10^7 \text{ m}^2$$

$$= 94.67 \text{ km}^2$$

$$= 9467 \text{ hectares}$$

Stream gauging

v.v.I 2014 5(c) A surface float took 10 sec to travel a straight run of a stream of 20 m. what is the appropriate mean velocity of the stream? If a velocity rod had been used what time it would have taken to travel the same run?

soln: For surface float, t = 10 sec, L = 20 m.

$$V_s = \frac{L}{t} = \frac{20}{10} = 2 \text{ m/sec}.$$

$$\therefore V = 0.85 V_s = 0.85 \times 2 = 1.7 \text{ m/sec}.$$

For velocity rod, v = 1.7 m/sec, L = 20 m.

$$t = \frac{L}{v} = \frac{20}{1.7} = 11.77 \text{ sec}.$$

* $\frac{Q_a}{Q_0} = \left(\frac{\Delta h_a}{\Delta h_0}\right)^n$

* $Q = K(h - h_0)^n$

* Two point method, $V_m = \frac{0.2d + 0.8d}{2}$

* Three point method, $V_m = \frac{0.2d + 0.6d + 0.8d}{3}$

* $v = aN + b$

Suresh 7.2 $a = 0.3$, $b = 0.05$, $N = 50$ rps, V = flow velocity?

Soln $V = aN + b = 0.3 \times 50 + 0.05 = 15.05$ m/sec Ans

2010
Raghunath 3(b)(203) Find the discharge point 5m.

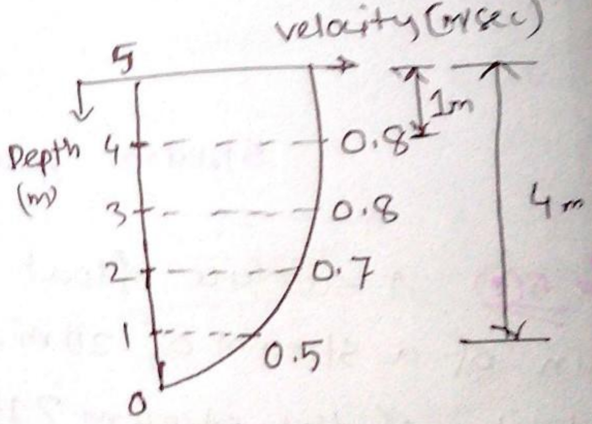
Soln

$Q = Av$

$Q = bdV$

$Q = 1 \times dV$

$Q = 5V$ ①



For two point method,

$V = \frac{V_{0.2d} + V_{0.8d}}{2}$

$= \frac{0.8 + 0.5}{2}$

$V = 0.65$ m/s

$\therefore Q = 5 \times 0.65 = 3.25$ m^3/sec Ans

At, $0.2d = 0.2 \times 5 = 1$ m

velocity, $V = 0.8$ m/s.

At $0.8d = 0.2 \times 5 = 4$ m.

velocity, $V = 0.5$ m/s.

Suresh 7.4 Find the mean velocity, $a = 0.4$, $b = 0.6$

stream depth,	0.2d	0.6d	0.8d
Revolution,	40	15	30
Time :	58	50	54

Soln

$V = aN + b$.

$V_{0.2d} = 0.4 \times \frac{40}{58} + 0.6 = 0.34$ m/sec

$V_{0.6d} = 0.4 \times \frac{15}{50} + 0.6 = 0.18$ m/sec.

$V_{0.8d} = 0.4 \times \frac{30}{54} + 0.6 = 0.28$ m/sec

$\therefore V_{mean} = \frac{1}{3}(V_{0.2d} + V_{0.6d} + V_{0.8d})$

$= \frac{(0.34 + 0.18 + 0.28)}{3}$

$= 0.27$ m/sec Ans

2008 4(c) By two point method, $V_m = \frac{V_{0.2d} + V_{0.8d}}{2}$

Depth from one end	Depth d	velocity (m/s) 0.2d	0.8d	mean velocity Vm (m/s)	Dischare $Q = AV_m$ $= bdV$ $b = 1m$
0	0	0	0	0.	0
1	1.4	0.40	0.20	0.3	0.42
2	3.3	0.60	0.30	0.45	1.485
3	5	0.84	0.50	0.67	3.35
4	9	0.90	0.62	0.76	6.84
5	5.4	0.80	0.55	0.675	3.445
6	3.8	0.62	0.4	0.51	1.938
7	1.8	0.54	0.3	0.42	0.76
					$\Sigma Q = 18.438$

$\therefore$ Discharge = 18.438 cumec Ans

6.3 (198) Ragunath

The following data

Main gauge staff reading (m)	12.	12
Auxiliary gauge staff reading (m)	11.65	11.02
Discharge (cumec)	9.50	15.20

what should be the discharge when the main gauge reads 12m and auxiliary gauge reads 11.37m?

Soln

$$\Delta h_o = 12 - 11.65 = 0.35\ m$$

$$\Delta h_a = 12 - 11.02 = 0.98\ m.$$

$$\frac{Q_a}{Q_o} = \left(\frac{\Delta h_a}{\Delta h_o}\right)^n$$

$$\Rightarrow \frac{15.20}{9.50} = \left(\frac{0.98}{0.35}\right)^n$$

$\therefore$ n = ~~0.5125~~ 0.456 (By calculator)

Again, $\Delta h_a = 12 - 11.37 = 0.63\ m$, $Q_a = ?$

$$\frac{Q_a}{Q_o} = \left(\frac{\Delta h_a}{\Delta h_o}\right)^n$$

$$\therefore Q_a = 9.50\left(\frac{0.63}{0.35}\right)^{0.456}$$

$$\therefore Q_a = 12.42\ \text{cumec}$$

HYDROGRAPH

Formula

$$P_{net} = \frac{\text{DRO peak}}{\text{UG peak}}$$

$$\text{DRO peak} = \text{TRO peak} - BF$$

$$P = P_{net} + \text{losses}$$

$$\text{Duration} = \frac{P_{net}}{\text{Intensity}}$$

$$\text{Run-off co-efficient} = \frac{\text{Runoff}}{\text{Rainfall}}$$

Volume of water over basin = Area of UG triangle.

where,

P = total rainfall

P_{net} = net precipitation or direct runoff as equivalent depth over the basin

Losses = due to infiltration (F_p) etc.

A = Area of drainage basin

Q_d, DRO = direct runoff ordinate.

TRO = total runoff ordinate.

t = time interval between successive direct runoff ordinates.

BFO = base flow ordinate.

Problem 1: Compute peak of 4hr UG. Given flood hydrograph peak was 400 cumec, Base Flow = 40 cumec, average loss = 0.4 cm/hr, Average watershed rainfall = 4cm.

Soln

DRO peak = TRO peak − BF

= 400 − 40 = 360 cumec.

Total loss = 0.4×4 = 1.6 cm.

Pnet = Rainfall − Loss = 4 − 1.6 = 2.4 cm.

$$\text{Pnet} = \frac{\text{DRO peak}}{\text{UG peak}}.$$

$$\therefore \text{UG. peak} = \frac{\text{DRO peak}}{\text{Pnet}} = \frac{360}{2.4} = 150 \text{ cumec}$$

Ans

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Problem2:

DRO peak = TRO peak − BF

= 560 − 20

= 540

Total loss = 1×6 = 6 cm.

P = Duration × intensity = 6×4 = 24 cm.

Pnet = P − Loss = 24 − 6 = 18

$$\therefore \text{UG peak} \; \frac{\text{DRO peak}}{\text{Pnet}} = \frac{540}{24-6} = \frac{540}{18} = 30 \text{ cumec}$$

Ans

$$\text{Duration} \; ~~6\text{ hour}~~ = \frac{\text{Pnet}}{\text{intensity}} = \frac{18}{4} = 4.5 \text{ hr}.$$

Loss = 1.5×6 = 9 cm

P = 6 × 3.5 = 21 cm Pnet = P − Loss = 21 − 9 = 12 cm.

DRO peak = Pnet × UG peak = 12 × 30 = 360.

∴ TRO peak = DRO peak + BF = 360 + 15 = 375 cumec

Ans

5.13 The successive three hourly ordinates of a 6-hr UG. for a particular basin are 0, 15, 36, 30, 17.5, 8.5, 3, 0 cumec respectively. The flood peak observed due to a 6 hr storm was 150 cumec. Assuming a constant base flow of 6 cumec and an average storm loss of 6 mm/hr, determine the depth of storm rainfall and the streamflow at successive 3hr interval.

U.G. peak

Given,
Flood peak = 150 cumec
Base flow = 6 cumec
UG peak = 36 cumec

Soln

$$\text{DRO peak} = \text{Flood peak} - \text{BF}$$
$$= 150 - 6$$
$$= 144 \text{ cumec.}$$

$$P_{net} = \frac{\text{DRO peak}}{\text{UG peak}} = \frac{144}{36} = 4 \text{ cm}$$

Depth of storm rainfall,

$$P = P_{net} + \text{losses}.$$
$$= 4 + 0.6 \times 6$$
$$= 4 + 3.6$$
$$= 7.6 \text{ cm}.$$

Given,

UGO (cumec):	0	15	36	30	17.5	8.5	3	0
DRO = UGO×Pnet:	0	60	144	120	70	34	12	0
TRO = DRO+BF:	6	66	150	126	76	40	18	6

2005 7(c) Peak flood due to a 3-h duration storm was 270 cumec. Total rainfall depth 5.9 cm. loss = 0.3 cm/h, and BF = 20 cumec. Estimate (i) peak of 3-h UH (ii) Base width of 3-hr UG is. basin are 567 km^2 and the UH is triangular.

Soln (i) Pnet = P − loss = 5.9 − (0.3×3) = 5 cm.

DRO peak = TRO peak − BF

= 270 − 20

= 250 cumec.

$$\text{Pnet} = \frac{\text{DRO peak}}{\text{UG peak}}.$$

$$\therefore \text{UG peak} = \frac{\text{DRO peak}}{\text{Pnet}} = \frac{250}{5} = 50 \text{ cumec.}$$

(ii) let, Base of unit hydrograph = b.

volume of water over basin = Area of UG triangle.

$$\text{Area} \times \frac{1}{100} = \frac{1}{2} \times b \times 50$$

$$\therefore 567 \times 10^6 \times \frac{1}{100} = \frac{1}{2} \times b \times 50$$

b = 226800 sec

$\therefore$ b = 63 hour

Ans