Rajshahi University of Engineering & Technology

Course No.:CE 3221

Course Title:Hydrology

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- Introduction
- Precipitation
- Water Losses
- Run Off
- Stream Gauging
- Hydrograph
- Flood Routing
- Ground Water
- Well Hydraulics
- Problems

Rajshahi University of Engineering & Technology

Mithun chakrabartty
Roll no – 120013

course no: CE 3221

Title: Hydrology

Hydro – (3.2) (3+2)

Hydrology

2K11

Q. Define hydrology. Write down it's scope.

⇒ Hydrology:

Hydrology = Hydro + logos
↓ (water) ↓ (science)

So, hydrology is the science which is concerned with all water on earth, it's occurrence, distribution and circulation, it's physical and chemical properties, it's effects on the environment and on life of all forms.

Wisler and Brater — "The science that deals with process governing the depletion and replenishment of water resources of the land areas of the earth."

2K13

⇒ Scope of hydrology:

① Maximum probable flood (Raghunath-13)

② Yeilding of water from basin

③ Ground water development

④ Maximum intensity of strom and it's frequency.

⑤ Excessive erosion of catchment.

Q. What is hydrologic cycle? Explain the hydrologic cycle with diagram.

2K17

⇒ Hydrologic cycle:

The cycle which represents different paths through which the water in nature circulates and transformed is known as hydrologic cycle.

Hydrologic cycle is the water transfer cycle which occurs continously in nature; the three important phases of hydrologic cycle are:

ⓐ Evaporation and evapotranspiration

ⓑ Precipitation

and ⓒ run-off.

⇒ Explanation:

The cycle starts with the precipitation from the atmosphere. Precipitation may take place in liquid form and also in solid form while precipitation is taken place, a part of it may evaporate and reach back to the atmosphere. Some more precipitation is intercepted by trees and vegetation and rest of it only would reach the ground. The intercepted precipitation eventually evaporates into the atmosphere.

(Dig. – Reddi Page-4)

The precipitation reaching the ground surface is called "through fall". considerable portion of through fall gets infiltrated into the ground. The precipitation falling directly over the streams is called channel precipitation and it readily becomes run off without any delay.

Evaporation would also be taking place from stream surface. The infiltrated water may be distributed in different ways —

Ⓐ

Q. Write down the importance of hydrology.

→ Importance of hydrology: ↳ for water development.

① It gives an estimate of water resources potential of the water basin.

② It provides the idea about probability of flood occurrence, their pattern and magnitude.

③ The dependable yeilds for irrigation and hydro-electric power stations can be determined. (RIP FNF SED)

④ Spillway capacity, dam height, dam safety etc can be designed.

⑤ Formulation of flood control measures can be carried out.

⑥ It helps in improvement of navigations sediment carrying capacity.

⑦ It gives a guideline for erosion control.

⑧ Maximum expected flood discharge and it's volume entering a reservior can be determined.

→ For this, Hydrology is important for water development.

Q. Define precipitation. Write down the forms of precipitation.

⇒ <u>Precipitation:</u>

The fall of water in any form from the atmosphere, which is known as the precipitation.

⇒ <u>Forms of precipitation:</u>

① <u>Rain:</u> condensed water vapour of atmosphere falling in drops from the clouds.

② <u>Sleets:</u> (শিলা বৃষ্টি) frozen rain drops while falling through air at sub-freezing temperature.

③ <u>Snow:</u> Ice crystal resulting from sublimation.

④ <u>Snow flakes</u> (তুষার কণা): Ice crystal fused together.

⑤ <u>Drizzle:</u> Light steady rain in fine drops (0.5 mm) and intensity $< 1 \text{ mm hr}^{-1}$.

~~⑥ Moisture con~~

⑥ <u>Dew:</u> Moisture condensed from the atmosphere is small drops upon cool surfa[ce]

⑦ Glaze: freezing of drizzle or rain when they come in contact with cold objects.

⑧ Hail: small lumps of ice (> 5mm in dia.) from atmosphere in form by alternate freezing and melting.

Q. Explain the formation of precipitation.

⇒ Formation of precipitation:

The point are given below according to their functions—

① Evaporation:

First water is evaporated to the atmosphere and transfer into the water vapour. It is commonly occured at the river, lakes, or their water reservior.

② Cooling:

Then, condensation of liquid or water vapour occurs, before cooling.

③ Condensation:

By condensation small drops at first and then gradually big drops of rain will be formed from the clouds.

④ Growth of droplets:

The water drops become heavy and when the pressure of air on the drops is higher then the drops remain stable. When the weight of water drops exceeds the pressure of air on the drops, the rain will fall.

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

2x14

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

⇒ Required hydrologic data:

For the analysis and design of any hydrologic project and adequate data and length of records are necessary.

The basic hydrologic data required are :—

(i) climatologic 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 or piezometric heads

(vi) evaporation data.

(vii) Water quality data of surface streams and ground water.

(viii) Geomorphologic studies of the basin like area, shape and slope of the basin, mean and median elevation and ~~other~~ stream density and drainage density.

(ix) cropping pattern, crops and their consumptive use.

(x) Hydro-meteorological characteristics of the basin:

(a) long term precipitation

(b) Depth-area-duration (DAD) curves for critical storms.

(c) Isohyetal maps.

(d) cropping patterns - crops and their seasons.

Q. Explain the hydrologic equation.

2k14

⇒ **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 = out flow
ΔS = change in storage.

This equation states that during a given period, the total inflow into a given area must equal the total outflow from the area plus the change in storage.

While solving this equation, the ground water is considered as an integral part of the surface water and it is the sub-surface inflow and outflow that poses problems in the water balance studies of a basin.

Q. Explain, 'hydrology is Inter-disiplinary science'.

⇒ **Explaination:**

Hydrology is the combination of

(i) Physics
(ii) chemistry
(iii) Geology

(iv) Geo-morphology

(v) Geo-physics

(vi) mathematics

(vii) statistics etc.

Precipitation

Q. Define precipitation. Discuss different types of Precipitation.

→ Precipitation:

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

→ Different types of precipitation:

Four types of precipitation —

(i) conveetional precipitation:

This type of (घूर्णन) precipitations is in the form of local whirling thunder storms and is the typical of the tropics. The air close to the warm earth gets heated and rises due to its low density.

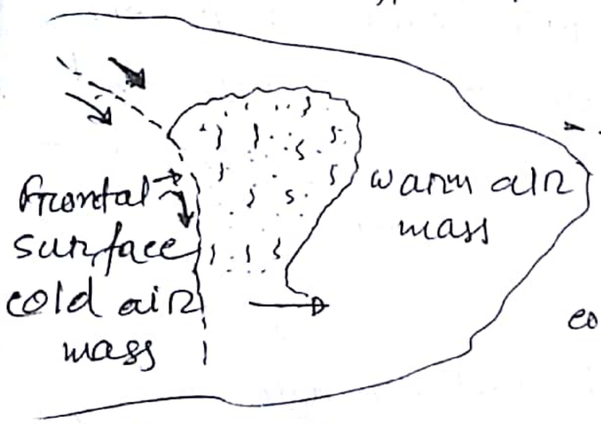
(ii) frontal precipitation (conflict betⁿ two air masses):

When two air masses due to contrasting tempetures and densities clash with each other, condensation and precipitation occur at the surface of contact. This surface of contact is called a 'front' or frontal surface.

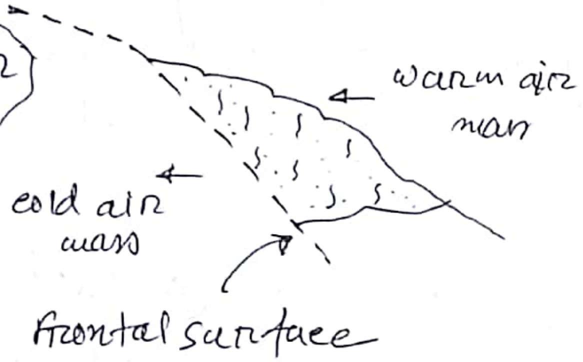
If cold air mass drives out a warm air mass is called "cold front" and if a warm air mass replaces the retreating cold air mass, it is called a "warm front".

On the other hand if the two air masses are drawn simultaneously towards a low pressure area, the front development is stationary and is called a "stationary front".

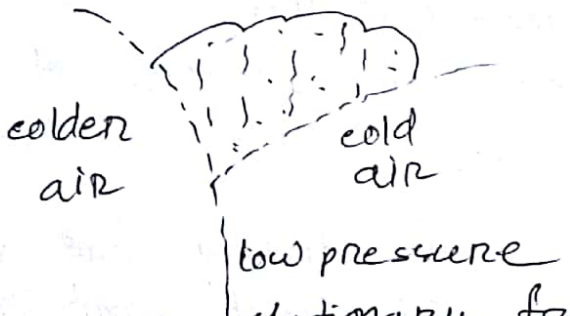
cold fronts move faster than warm fronts and usually overtake them, the frontal surfaces of cold and warm air sliding against each other. the phenomenon is called 'occlusion' and resulting frontal surface is called "occluded front'.



(a) cold front



(b) warm front



(c) stationary front.

(iii) Orographic lifting (orographic precipitation):

The mechanical lifting of moist air over mountain barriers, causes heavy precipitation on the windward side. Ex cherrapunji in the Himalayan range. ~~and Agumbe~~.

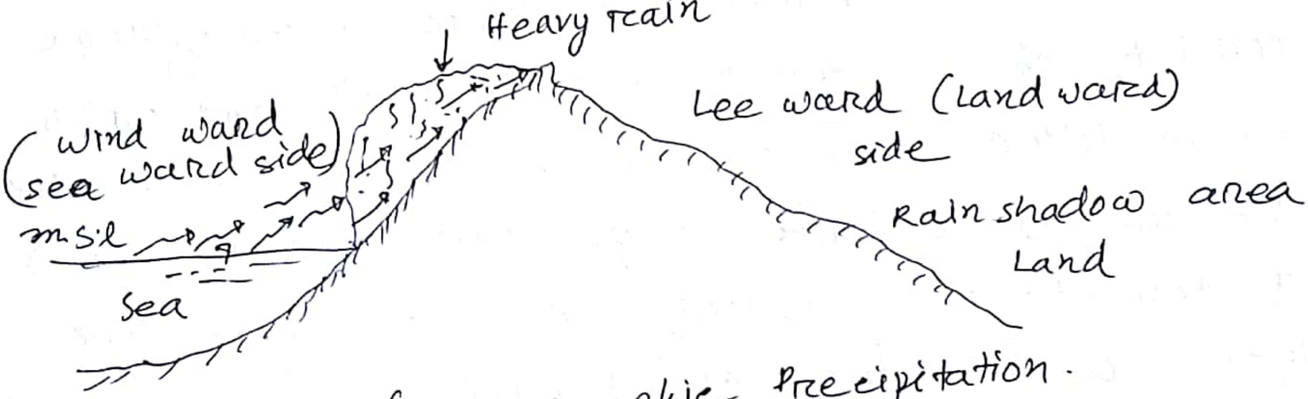


fig. orographic Precipitation.

(iv) cyclonic (cyclonic precipitation):

This type of precipitation is due to lifting of moist air converging into a low pressure belt. i.e due to the pressure differences created by the unequal heating of the earth's surface.

2. Explain the components of the non-recording rain-guage with it's working / U.S weather Bureau rainguage.

⇒ Components of U.S weather Bureau raingauge:

The U.S weather Bureau rainguage consists of a can B. 8" diameter and 24" in depth. It is fitted over a copper receiver A. whose top rim is a knife edge and bottom consists of a funnel. A measuring tube c under the funnel takes water from the funnel. A measuring stick 24" long, 3/8" wide and 1/8" thick completes the equipment. The cross-sectional area of the measuring stick is exactly one-tenth of the opening area of the Receiver.

Figure

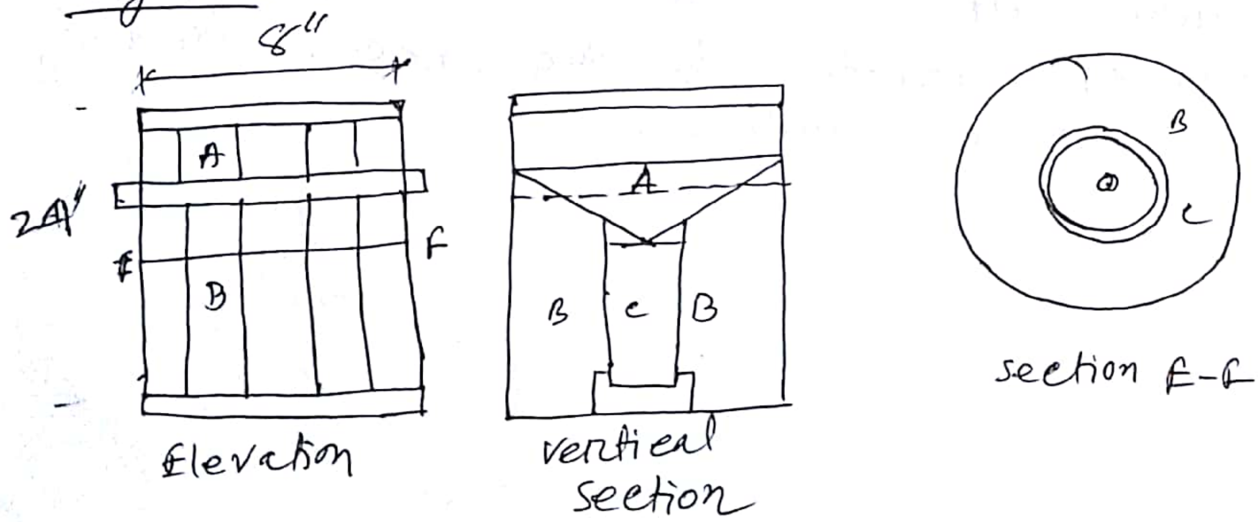


fig: Non-recording raingauge.

→ **Working:**

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

In non-recording type rainguage only takes the rainfall but can't measure the amount.

$$\text{Rainfall depth (cm)} = \frac{\text{Volume of water collected (cm}^3\text{)}}{\text{Aperture area of the guage (cm}^2\text{)}}$$

Q. Write short notes on recording type rain guage.

Ans: (Suresh → 27 Page)

Q. What are the advantages and disadvantages of recording type rainguage?

⇒ advantages:

① It provides a detail information about the rainfall such as rainfall depth and its duration.

② It automatically records the rainfall amount with respect to time.

③ It is the only means to record the rainfall data in hilly areas.

④ It provides the information about onset and cessation of rainfall.

⑤ Measuring capacity of recording type rain gauge is more to that of non-recording type of rainguage.

⑥ Duration and authentic result ~~the~~ are provided.

⇒ Disadvantages:

① It's cost is more than the non-recording type guage.

⑪ It requires a regular service for its proper working.

⑪ Its maintanance cost is comparaitively high.

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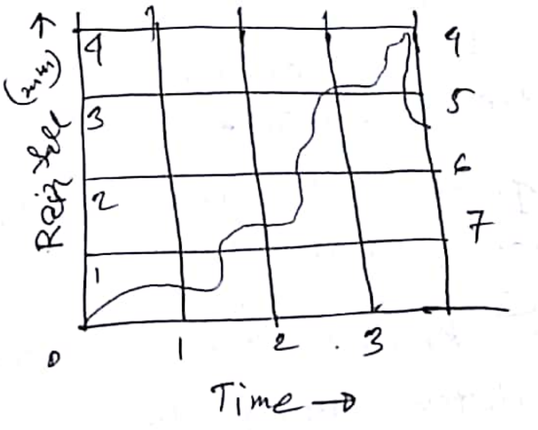
(iv) Additional precautions are required to operate this guage.

(v) Due to some mechanical faults the rain-fall data may be interrupted.

2K
5 Define : Mass curve of rainfall and also explain it.

⇒ Mass curve of rainfall :



The curve shows the relation betn 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. Distinguish betn recording and non-recording type rainguage.

⇒

Recording type rainguage	Non-recording type rainguage
① It records rainfall amount and it's duration simultaneously.	① It records only the depth of rainfall.
② Measuring capacity is high.	② Measuring capacity is low.
③ It provides more authentic result.	③ It provides less authentic result.
④ Maintenance cost is comparatively high.	④ Maintenance cost is comparatively low.
⑤ Recording of rainfall data may be interrupted by mechanical faults.	⑤ There is no possibility of mechanical faults.
⑥ Example: → Tipping bucket → Weighing type → Float type	⑥ Ex: Symon type rainguage

2×15
Q. What are the conditions to be provided for location of rainguage?

⇒ conditions:

① The site should be an open place.
② The site should be easily accessible.
③ The site should be away from the continuous wind forces.
④ The site should be represented the entire water shed.
⑤ The rainguage should be placed on a level ground.
⑥ Horizontal distance between the rainguage and nearest object should be twice the height of object.
⑦ The guage should be vertical.
⑧ The percent of total number of rainguage stations of any basin should be self-recording.
⑨ The observer must visit the site regularly to ensure it's proper readings for measurement.

2×14
Q. Define rainguage density.

⇒ Rainguage density:

The number of rain-guages to be elected in a given area is termed as the rainguage density.

Area	Rain-guage density
① plain	1 in 520 km²
⓪ Elevated regions	1 in 260–390 km²

③ Hilly and very heavy rainfall areas — 1 in 130 Km^2. preferably with 10% of the raingauge stations equipped with self recording type

⊛ In BD, given by BD metrology Department — 1 in 220-225 Km^2 for 35 stations.

2K15
Q. what is A.A.R? what are the factors on which A.A.R depends on? C.T

⇒ A.A.R:

The mean of yearly rainfall observed for a period of 35 consecutive years is called the average annual rainfall or A.A.R

⇒ Depends on:

(i) Distance from the ocean.
(ii) Direction of the prevailing winds.
(iii) Altitude of the place.
(iv) Topography of the place.
(v) Mean annual precipitation.

⊛ Index of wetness:

$$I.W \text{ (of any year)} = \frac{\text{Rainfall (that year)}}{A.A.R} \times 100\%$$

Q. Write a short notes on estimations of missing Raifall data.

⇒ Estimation of missing rainfall data:

When a rainfall data of a day is missing then it will be estimated by taking different methods. There are some of methods of estimation of missing rainfall data, are as given below,

(1) Arithmetic mean method
(2) Normal ratio method
(3) Graphical method
(4) Normal weather service method.
(5) Long term mean rainfall for a new station method.

Arithmetic mean method:

If the normal annual precepitations at the adjacent stations are within 10% of the normal rainfall of the station under consideration, then the missing rainfall data may be estimated as a simple arithmetic average of the rainfalls at the adjacent gueges. Thus if the missing precipitation at station X is P_x and $P_1, P_2 --- P_n$ are the rains falls at them surrounding raingueges. Then,

$$P_x = \frac{P_1 + P_2 + --- + P_m}{m} \quad \text{——— (1)}$$

where,

~~N_x = Normal annual rainfall at station X.~~

~~$N_1, N_2, \cdots N_m$ = Normal annual rainfall at the surrounding guages.~~

2X15 Q. Explain normal ratio method of estimating the missing rainfall data.

Normal ratio method:

If the normal annual rainfalls at the surrounding guages differ from the normal annual rainfall of the ~~same~~ station by more than 10%. the normal ratio method is preffered. In this method the rainfall value at the surrounding stations are weighed by the ratio of the normal annual rainfalls. That is —

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

where,

N_x = Normal annual rainfall at station X.

$N_1, N_2, \cdots N_m$ = normal annual rainfalls at the ~~stations~~ in surrounding guages.

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

⇒ Points are responsible for making the rainfall data inconsistent, as given below—

① Due to change in location of rainguage station. This is might be due to the shifting or rain guage to a new location.

② when neighbourhoods of the station have gone significantly changed.

③ Repetation of observational error from a certain period.

④ Due to change in exposure of station, caused by construction of new building, development of forest or occurence of land slides in hilly regions etc.

Problem : 3.1

A catchment area involves 5 rain guages. During rainy season the magnitudes of rainfall measured by these guages are 25 cm, 35 cm, 45 cm, 10 cm and 75 cm. respectively. Calculate the ~~main~~ mean aerial rainfall using arithmatic mean method?

Solⁿ Mean arial rainfall $(P) = \sum_{i=1}^{n} \frac{P_i}{N}$

$$= \frac{25+35+45+10+75}{5}$$

$= 38$ cm (Ans)

108 B Define : Isohyet.

⇒ Isohyet :
A line going the places having same A.A.R. is called isohyet.

Q. Discuss the selection of suitable Method for computing the Mean Areal Precipitation.

⇒ The selection of suitable method among arithmetic mean method, theissen polygone method and isohyetal method, for computing the mean aeral preecipitation, depends on the following three main factors—

① Rainguage network of the catchment
② catchment size and
③ Topographical feature of the catchment.

Discussion :

Rainguage network : It is expressed by the number of rainguage stations present in the catchment area. The rainguage network is categorized into two groups—
(i) The sufficient number of stations and (ii) limited number of stations.

The choice of accurate method based on this is given below—

① watershed with sufficient guages.
② water shed with Limited guages.
③ watershed with on raingauge.

catchment size:

The areal extent of catchment, affects greatly the choice of method to be used for computing the mean areal precipitation.

catchment area (sq.km)	suitable method
Less than 500	Arithmetic mean
500 - 5,000	theissen polygone
more than 5,000	Iso hyetal

Topography of the area:

Regarding selection of suitable methods for computing the mean areal precipitation, the topographical features of the area and suitable methods →

(i) Mountain - arithmatic mean method.
(ii) Plain land - theissen polygone method.
(iii) Hilly and rugged terrain - iso hyetal method.

2K10 Q. How optimum number of rainguage station can be calculated?

⇒ The aim of the optimum rain-guage network design is to obtain all quantitative data (averages and extremes) that define the statistical distribution of the hydrometeorological elements, with sufficient accuracy for practical purposes.

Procedure: The optimum number of rain-guage stations to be established in a given basin is given by—

$$N = \left(\frac{C_v}{P}\right)^2 \quad \text{—— (i)}$$

$$C_v = \frac{\sigma_{n-1}}{\bar{x}} \times 100 \quad \text{—— (ii)} \quad = \frac{S.D}{\bar{x}} \times 100$$

= co-efficient of variation of the rainfall of the existing rain guage stations.

$$\sigma_{n-1} = \sqrt{\frac{\Sigma (x_i - \bar{x})^2}{n-1}} \quad \text{—— (iii)}$$

P = desired degree of percentage error in estimated of the average depth of rainfall over the basin.

(1) where by collecting the depth of rain fall of each rainguage stations of given basin.

~~(2) Averages will be got by using formula and~~
~~... will be also got.~~

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② Average will be got of the depths of rain fall.

③ Then σ_{n-1} will be got by using formula and e_v will be also got.

④ And finally by using eqn ①, we can get actual N.

✱ Define: hyetograph.

⇒ <u>Hyetograph:</u> A hyetograph is a bar graph showing the intensity of rainfall with respect to time.

It is useful in determining the maximum intensities of rainfall during particular strom as is required in land drainage and design of culverts.

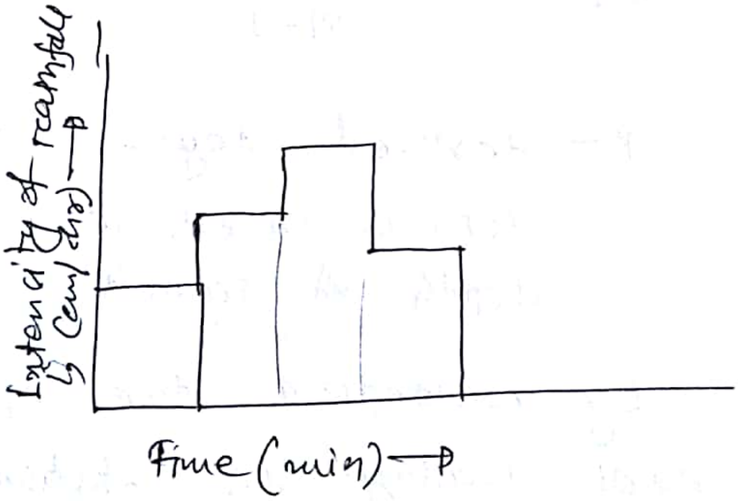


Fig. hyetograph.

Problem: For the following fig.

2*8 Q. Define. return period.

→ **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, $T = \frac{1}{p}$ —— (1)

Here, Return period = Recurrence interval
= frequency.

X Q. Define saturated Network design.

→ **Saturated Network Design:**

If the project is very important, the rainfall has to be estimated with great accuracy, then a network of rain-guage stations should be so set up that any addition of rain-guage stations will not appreciably alter the average depth of rainfall estimated.

Such network is refferred to as a saturated network.

Q. What do you mean by graphical representation of rainfall? Explain it.

→ **Graphical representation of rainfall:**

The variation of rainfall with

Respect to time may be shown in graphically by ____

① Hyetograph ⑪ Mass curve.

Q. What are the characteristics of a rain-strom?

⇒ characteristics:

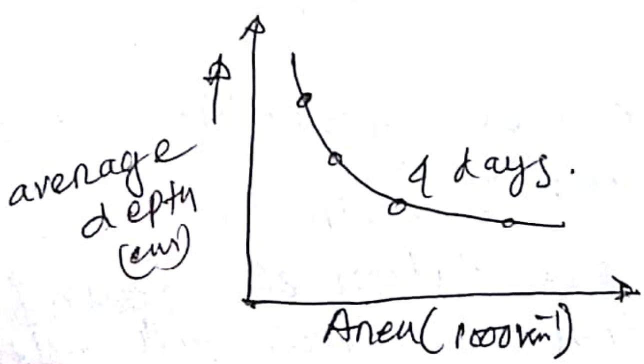
① Intensity (cm/hr)
② Duration (Min, hr, days)
③ frequency (Once in 5 years, once in 10, 20, 40, 60 or 100 years).
④ Areal extent (i.e area over which it is distributed.).

2K14 2K13

Q. Define DAD curve.

⇒ DAD curves:

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



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

Analysis of rainfall data:

Rainfall intensity can be obtained by—

(i) $i = \frac{a}{t+b}$: A.N. Tabot's formula

(ii) $i = \frac{K}{t^n}$

(iii) $i = K t^x$

where, t = duration of rainfall

a, b, K, n and x are constants

$i = K t^x$

$\Rightarrow \log i = \log K + x \log t$

if $t = 1$ then $\log i = \log K$

$\Rightarrow i = K$

Ex: 2.7, 2.8,

Q. Write a short notes on PMP. Describe the 2K9 methods of estimating PMP. What are it's design application.

⇒ **Probable Maximum Precipitation (PMP):**

PMP is defined as the estimated of the extreme maximum rainfall of a given duration that is physically possible over the basin under critical, hydrological and meteorological conditions.

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 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.

<u>meteorological approach:</u>
In meteorological approach, the strom is maximised by experience of the basin and taking all the storms of the basin and adjoining areas which are meteorologically homogeneous.

steps involved in obtaining PMP are—
ⓐ Depth and duration analysis of major stroms of the region.
ⓑ Maximisation of the strom.
ⓒ envoloping the maximised values of all the storms to obtain DAD curve of PMP.

Q. what do you mean by 75% dependable rainfall?
⇒ <u>75% dependable rainfall:</u>
It means that 75% of the average rainfall is considered for the design

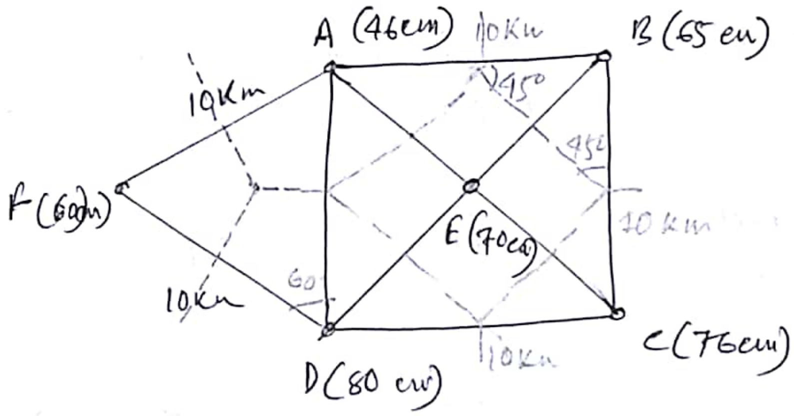
of any hydrological subject matter such as irrigation, flood level etc. which is known as the 75% dependable rainfall.

PRECIPITATION

Problems:

Ex(2.3a) (31 Page)

A square plus an equilateral triangular plot of side 10 km. The annual precipitations at the rain-guage stations located at the four corners and centre of the square plot and apex of the triangular plot are indicated in figure. Find the mean precipitation over the area by Thiessen polygon method, and compare with the arithmetic mean.



Soln The thiessen polygon is constructed by drawing perpendicular bisectors to the lines joining the rain-guage stations—

The weighted mean precipitation is computed in the following table—

Area of square plot = 10 * 10 = 100 Km^2

Area of inner square plot = $\frac{10}{\sqrt{2}} \times \frac{10}{\sqrt{2}} = 50 \text{ km}^2$

Difference = 100 − 50 = 50 km^2

Area of each corner triangle in the square plot = $\frac{50}{4} = 12.5 \text{ km}^2$.

$\frac{1}{3}$ area of equilateral triangular plot

$= \frac{1}{3} \times \left(\frac{1}{2} \times 10 \times 10 \sin 60°\right)$

$= 14.4 \text{ km}^2$.

Station	Area, A (km^2)	Precipitation P. (cm)	A × P.	Pave (cm)
A	12.5 + 14.4 = 26.9	46	1238	
B	12.5	65	813	$= \frac{\Sigma A.P}{\Sigma A}$
C	12.5	76	950	$= \frac{9517}{143.2}$
D	12.5 + 14.4 = 26.9	80	2152	= 66.3 cm
E	50	70	3500	
F	14.4	60	864	
n = 6	ΣA = 143.2	ΣP = 397	ΣA.P = 9517	

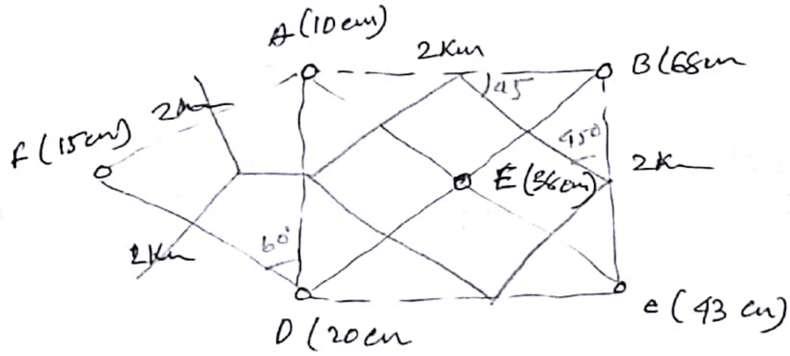
$\therefore$ arithmetic mean $= \frac{\Sigma P}{n}$

$= \frac{397}{6} = 66.17$.

which compares fairly with the weighted mean.

RK10

find the mean precipitation for the area shown in figure below by Thiessen polygon method. The area B computed of a square plus an equilateral triangular plot of side 2 km. Rainfall readings are in cm at the various stations indicated.



soln

area of square $= 2 \times 2 = 4$ Km²

" inner " $= \frac{2 \times 2}{\sqrt{2} \times \sqrt{2}} = 2$ Km².

" " triangle (each) $= \frac{4-2}{4} = 0.5$ Km²

Area of equilateral triangle

$= \frac{1}{2} \times 2 \times 2 \sin 60^\circ = 1.73$ Km²

$\therefore \frac{1}{3}$ of E.T.A $= \frac{1}{3} \times 1.73 = 0.58$ Km²

P.T.O

Station	A (km^2)	P (cm)	P×A
A	0.5+0.58 = 1.08	10	10.8
B	0.5	68	34
C	0.5	43	21.5
D	1.08	20	21.6
E	2	38	76
F	0.58	15	8.7
	$\Sigma A = 5.79$		$\Sigma PA = 172.6$

∴ Average depth of precipitation —

$$= \frac{\Sigma PA}{\Sigma A} = \frac{172.6}{5.79} = 30.06 \text{ cm. (Ans)}$$

Ex: 2.2 Rain-guage station D was inoperative for part of a month during which a strom occurred. The strom rainfall recorded in the three surrounding stations A, B and C were 8.5, 6.7 and 9.0 cm respectively. If the a.a.R for the stations are 75, 84, 70 and 90 cm. respectively. estimate the storm rainfall at the station D.

Soln

$$\frac{N_D - N_A}{N_D} \times 100 = \frac{90-75}{90} \times 100 = 16.67\% > 10\%$$

$$\frac{N_D - N_B}{N_D} \times 100 = \frac{90-84}{90} \times 100 = 6.67 < 10\%$$

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$$\frac{N_D - N_C}{N_D} = \frac{90-70}{90} \times 100 = 22.22 > 10\%$$

[(১) $\frac{N_D - N_A}{N_D} \times 100 < 10\%$ হলে — সেক্ষেত্রে arithmetic average → $P = \frac{P_A + P_B + P_C}{3}$]

[(২) কোন একটির 10% বেশি হলে Normal ratio method]

Here, $m = 3$

$P_A = 8.5$ cm ; $P_B = 6.7$ cm ; $P_C = 9$ cm ; $P_D = ?$

$N_A = 75$ cm ; $N_B = 84$ cm ; $N_C = 70$ cm ; $N_D = 90$ cm.

$$\therefore P_D = \frac{1}{m}\left[\frac{N_D}{N_A} \cdot P_A + \frac{N_D}{N_B} \times P_B + \frac{N_D}{N_C} \times P_C\right]$$

$$= \frac{1}{3}\left[\frac{90 \times 9.5}{75} + \frac{91 \times 6.7}{84} + \frac{90}{70} \times 9\right]$$

$= 9.65$ cm. (Ans)

2K14

\# Neighboring rain guage stations A, B, C, D, E and F have normal rainfalls of 610, 554, 468, 606, 563 and 382 mm respectively. During a strom stations A, B, C, E and F have reported rainfalls of 22, 29, 35, 13 and 25 mm respectively and station D did not report as it was inoperative. Estimate the missing storm rainfall at D by the arithmetic average and normal ratio method.

Soln.

① Arithmetic average —

$$P_D = \frac{P_A + P_B + P_C + P_E + P_F}{5}$$

$$= \frac{22 + 29 + 35 + 13 + 25}{5}$$

$$= 24.8 \text{ mm. (Ans)}$$

(II) Normal ratio method —

$N_A = 610$; $N_B = 559$; $N_C = 468$; $N_D = 606$;

$N_E = 563$; $N_F = 382$.

$$\therefore P_D = \frac{N_D}{m}\left[\frac{P_A}{N_A} + \frac{P_B}{N_B} + \frac{P_C}{N_C} + \frac{P_E}{N_E} + \frac{P_F}{N_F}\right]$$

$$= \frac{606}{5}\left[\frac{22}{610} + \frac{29}{559} + \frac{35}{468} + \frac{13}{563} + \frac{25}{382}\right]$$

$\Rightarrow P_D = 30.5$ cm. (Ans)

formula :

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

(ii) co-efficient of variation, $C_v = \frac{S.D}{mean} \times 100$

$\therefore C_v = \frac{\sigma}{\bar{x}} \times 100\%$

(iii) $\bar{x} = \frac{\Sigma x_i}{n}$

(iv) optimum number of rainguage, $N = \left(\frac{C_v}{P}\right)^2$

P = Percent Error.

2013

A catchment has six rainguage stations. In a year, the annual rainfall recorded by guages are as follows—

Station –	A	B	C	D	E	F
Rainfall – (cm)	82.6	102.9	180.3	110.3	98.8	136.7

For a 10% error in the estimation of the mean rainfall, calculate the optimum number of stations in the catchment.

soln

P.T.O

Station	Rainfall (cm) $P(x_i)$	$(x_i - \bar{x})$	$(x_i - \bar{x})^2$
A	82.6	-36	1296
B	102.9	-15.7	246.5
C	180.3	61.7	3806.9
D	110.3	-8.3	68.89
E	98.8	-19.8	392.04
F	136.7	18.1	327.61
$\Sigma n = 6$	$\Sigma x_i = 711.6$		$\Sigma (x_i - \bar{x})^2 = 6137.94$

$$\therefore \bar{x} = \frac{\Sigma x_i}{\Sigma n} = \frac{711.6}{n}$$

$$= 118.6$$

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

$$= \sqrt{\frac{6137.94}{6-1}} = 34.92$$

$$\therefore C_v = \frac{\sigma}{\bar{x}} = \frac{34.92}{118.6} = 0.294 = 29.4\%$$

$\therefore$ Number of stations — $P = 10\%$

$$N = \left(\frac{C_v}{P}\right)^2 = \left(\frac{29.4}{10}\right)^2 = 8.64 \simeq 9.$$

2K11

A watershed has a network of five rain guages. Annual rainfall record by these guages is given for a year as:

Rainguage	1	2	3	4	5
Annual rainfall	50	82	73	69	105

calculate the optimum number of rain-guages for this watershed for a 10% error in estimate of mean annual rainfall.

soln

station	A. Rainfall P_i (x_i) cm	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
1	50	-29.8	615.69
2	82	7.2	51.84
3	73	-1.8	3.24
4	69	-10.8	116.64
5	105	30.2	912.04
$\Sigma n = 5$	$\Sigma x_i = 379$		$\Sigma (x_i - \bar{x})^2 = 1698.8$

$\therefore \bar{x} = \frac{\Sigma x_i}{n} = \frac{379}{5}$

$\therefore \bar{x} = 79.8$

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

$= 20.6$

$\epsilon_v = \frac{20.6}{79.8} = 28\%$

$\therefore N = \left(\frac{28}{10}\right)^2 = 7.84 \simeq 8$

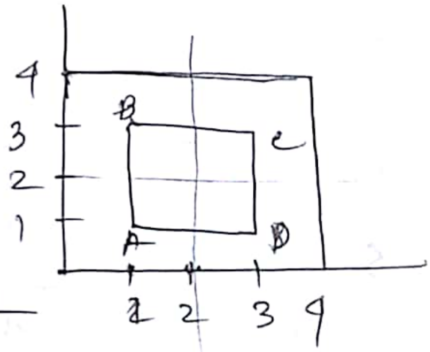
Problem :

consider a rectangular area whose (x, y) co-ordinates are (0,0), (4,0), (0,4) and (4,4). The area is 4 km wide and 4 km long. The area has 4 rain gauges. The location of the gauges and rainfall data are—

Rain gauge	(x, y)	Rainfall (cm)
A	(1,1)	5
B	(1,3)	10
C	(3,3)	8
D	(3,1)	12

Determine mean rainfall by Thissen polygon method.

Soln



Area of outer square

$= 4 \times 4 = 16\ km^2$

" " inner " $= 2 \times 2 = 4\ km^2$

Area of each corner square $= \frac{1}{4}(16-4) = 3\ km^2$

PTO

Station	A	P	AP
A	3	5	15
B	3	10	30
C	3	8	24
D	3	12	36
	$\Sigma A = 12$		$\Sigma PA = 105$

$$\therefore \text{Mean Rainfall} = \frac{\Sigma PA}{\Sigma A} = \frac{105}{12}$$

$$= 8.75 \text{ cm. (Ans)}$$

2K11

A major basin is divided into four sub-basins with areas of 920, 705, 1075 and 1665 Km^2. If the average annual rainfall on these sub-basins is 73, 85, 112 and 100 cm, respectively. What is the average annual rainfall for the basins as a whole?

Soln

Average annual rainfall —

$$= \frac{73 \times 920 + 85 \times 705 + 112 \times 1075 + 1665 \times 100}{920 + 1075 + 1665 + 705}$$

$$= 94.89 \text{ cm} \quad \text{(Ans)}$$

2K12

During the construction period of 10 years of a reservior. a coffer dam is required to be constructed with a capacity to take care of 5 year floods. What is the probability that ——

(i) The flood will not occur at all

and (ii) It will occur twice during the construction period?

Soln

Here,

$n = 10$; $p = \frac{1}{5} = 0.2$

$q = 1 - p$

$= 0.8$

(i) will not occur at all → $r = 0$

$\therefore P(r=0) = {}^{n}C_{r} \cdot p^{r} \cdot q^{n-r}$

$= {}^{10}C_{0} \cdot (0.2)^{0} \cdot (0.8)^{10-0} = 0.107$ (Ans)

(ii) occurs twice, $r = 2$

$P(r=2) = {}^{10}C_{2} \cdot (0.2)^{2} \cdot (0.8)^{10-2}$

$= 0.302$ (Ans) #

Water Losses

The hydrologic eqn states that—

$$\text{Rainfall} - \text{Losses} = \text{Run off}.$$

Runoff: A part of precipitation flows over the land is called runoff. Runoff may defined as that portion of rainfall which makes it's way towards the rivers, streams, oceans etc.

$$\text{Run off} = \text{surface runoff} + \text{base flow}.$$

2K10

Q- Explain briefly various water losses / OR, water losses project.

⇒ Water losses:

(i) Interception loss :- due to surface vegetation i.e held by plant leaves. building

(ii) Evaporation :-

(a) from water surface. i.e reservoirs, lakes, ponds, rivers 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.

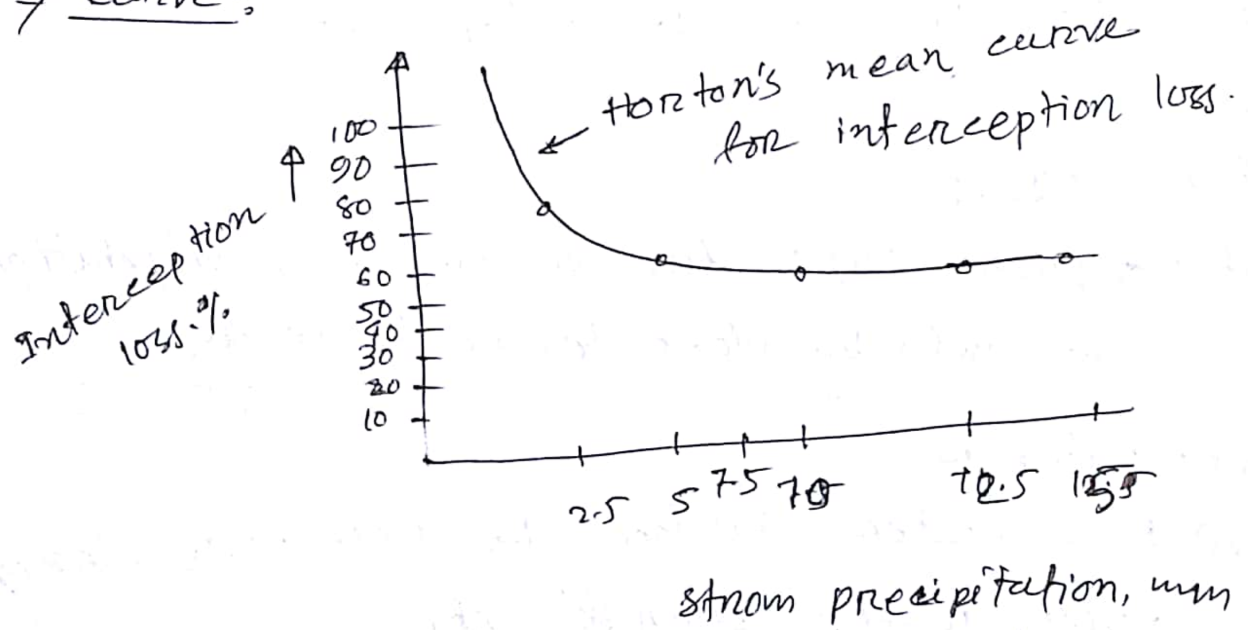
(v) Infiltration — into the soil at the ground surface.

(vi) Water shed leakage — Ground water movement from one basin to another or into the sea.

~~Q. What~~

Q. Draw curve of interception loss (Horton).

→ Curve:



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

Interception loss is high in the begining of stroms and gradually decreases.

Q. What are the factors that influence the process of evaporation?

⇒ Factors:

(I) Air
(II) Barometric pressure
(III) Expose surface area
(IV) Relative humidity
(V) salinity of the water
(VI) water temperature
(VII) Wind velocity.

2K.14

Q. Is consumptive use and Evapotranspiration same? Explain.

⇒ Explanation:

Yes

Here,

consumptive use = Evapotranspiration + Some water (losses)

This eqn shows that consumptive use is slightly greater than Evapotranspiration. But the quantity of water losses is little. ~~in quantity~~. so, It is assumed to be same.

7Q. what is pan co-efficient? why it is need to be corrected?

⇒ Pan co-efficient:
2K15

Pan co-efficient is defined by 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-efficients range from 0.67 to 0.82 with an average of 0.7.

why correction is done:

Evaporation pan data can not be applied to free water surfaces directly. They should be adjusted for their differences incurred due to climatological and physical factors.

The water body in the limited size of metallic pan contains little volume of water compared to the big water body or lake (larger and deeper). The small volume of water in the metallic pan is greatly affected by temperature fluctuations in the air or by solar radiations in contrast with large bodies of water (in reservoir) with little temperature fluctuations.

Thus the pan evaporation data have to be corrected to obtain the actual evaporation from water surfaces of lakes and reservoirs by multiplying the factors pan co-efficient.

Q. What are the methods to estimate Lake Evaporation?

Ans:

(i) The storage eqn —

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

where, P = precipitation ; I = surface inflow

[O_g = subsurface inflow or outflow

inflow + out flow −

E = evaporation ; O = surface outflow

S = change in surface water storage.

increase + ; decrease −

(ii) Auxiliary pans like land pan, floating pans, colorado sunken pans etc.

(iii) Evaporation formula like that Dalton's law

(iv) Humidity and wind velocity gradients.

(v) The energy budget
(vi) The water budget
(vii) combination of aerodynamic and energy balance eqns - Penman's eqn.

2×4
Q. Explain the difference among evaporation, transpiration, and evapotranspiration.

→ Difference:

Evaporation	Transpiration	Evaptranspiration
(i) The process by which water from liquid or solid state converts into vapour state and is diffused into atmosphere is called evaporation.	(i) The process by which water from liquid state converts into vapour state through plant metabolism is called transpiration.	(i) The process by which water is evaporated from wet surfaces and transpired by plants together is called the evapotranspiration
(ii) It is expressed as depth	(ii) It is expressed as transpiration ratio.	(ii) It is actually expressed as depth (cm, mm) over area

Lake evaporation method:

↳ storage eqn.

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

suresh: 4.1 Ex 2K14

calculate the amount of water lost by evaporation if:

(i) amount of precipitation = 12 mm (P)

(ii) Quantity of surface inflow = 120 mm (I)

(iii) Ground water flow amount = 75 mm (O_g)

(iv) surface outflow = 13 mm (O)

(v) storage decrease by 5 mm (S).

Soln

eqn Let O_g = out flow

$$P + I - O_g = E + O - S$$

$$\Rightarrow E = P + I - O_g - (O - S)$$

$$= 12 + 120 - 75 - (13 - 5)$$

$$= 49 \text{ mm} \quad \text{(Ans)}$$

O_g – Inflow

$$P + I + O_g = E + O - S$$

$$\Rightarrow E = 12 + 120 + 75 - (13 - 5)$$

$$= 199 \text{ mm.} \quad \text{Ans}$$

4.2 compute the value of pan co-efficient, if lake and pan evaporation are 25mm and 30 mm respectively.

soln

Lake evaporation (E_L) = 25 mm

Pan " (E_P) = 30 mm

Pan co-efficient $(P_c) = \frac{E_L}{E_P}$

$= \frac{25}{30}$

$\therefore P_c = 0.83$ (Ans)

Raghunath:

Ex 3.1 The following are the monthly pan evaporation data (Jan-Dec) at Krishnarajasagara in a certain year in cm.

Jan	Fe	Mar	April	May	June
16.7	14.3	17.8	25.0	28.6	21.4
16.7	16.7	16.7	21.4	16.7	16.7
July	Au	Sep	Oct	Nov	Dec.

The water spread area in a lake nearby in the begining of January in that year was 2.80 Km² and at the end of December it was measured as 2.55 Km². calculate the loss of water due to evaporation in that year. Assume a pan co-efficient of 0.7.

Sol^n

Mean water spread area of lake

$$A_{ave} = \frac{1}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)$$; cone formula

$$= \frac{1}{3} * \left(2.80 + 2.55 + \sqrt{2.80 \times 2.55}\right)$$

$$= 2.673 \text{ Km}^2 \text{ — (A)}.$$

Annual loss of water due to evaporation ~~(adding)~~

$$= (16.7 + 14.3 + 17.8 + 25.0 + 28.6 + 21.4)$$
$$+ (16.7 + 16.7 + 16.7 + 21.4 + 16.7 + 16.7)$$

$$= 228.7 \text{ cm } . (E_p).$$

Annual volume of water lost due to evaporation.—

$$= (2.673 \times 10^6) * \frac{228.7}{100} \times 0.7 \leftarrow (P_e)$$

m^2 ; for m

$$= 4.29 \times 10^6 \text{ m}^3$$

$$\simeq 4.29 \text{ M. m}^3 \quad \text{(Ans)}$$

Ex. 3.1(ii) Page 66

Sol^n Pan evaporation. E_p(mm) = Rainfall + water added on − water removed

Surface area = 640 ha; $P_e = 0.75$

Day:	1	2	3	4	5	6	7
E_p: (m)	14−5	6+3	12	8	7	5+4	6+3
	=9	=9	12	8	7	=9	=9

$\Sigma E_p = 63$ m

Pan evaporation in the week $= \sum_{1}^{7} E_p$

$= 63$ mm.

Now. $P_e = \frac{E_L}{E_p}$

$\Rightarrow E_L = P_e * E_p = 0.75 * 63 = 47.25$ mm.

∴ water lost from the lake −

$= A \cdot E_L$

$= 640 * \frac{47.25}{1000}$ ha.m.

$= 30.24$ ha.m

$= 0.3$ M.m³

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Ex: 3.1(b) The total observed runoff volume during a strom of 6-hr duration with a uniform intensity of 15 mm/hr is 21.6 M.m^3. If the area of the basin is 300 km^2, find the average infiltration rate and the run off co-effieient for the basin.

Soln

(i) Infiltration loss, F_p = Rainfall(P) − Run off(R)

$$= (15 \times 6)\,mm - \left(\frac{21.6 \times 10^6}{300 \times 10^6} \times 1000\right) mm$$

(runoff; basin area; for mm)

$$= (90 - 72)\,mm$$

$$= 18\,mm$$

Average infiltration —

$$f_{ave} = \frac{F_p}{t} = \frac{18\,mm}{6\,hr} = 3\,mm/hr.$$

(ii) Yeild = cAP

$$21.6 \times 10^6\,m^3 = c(300 \times 10^6\,m^2) \cdot \frac{15 \times 6}{1000}$$

$\Rightarrow c = 0.8$ (Run off co-efficient).

Q. What are the measures to reduce lake evaporation? 2KM

⇒ Measures: If the following thing can be done, then reduction of lake evaporation can be possible —

(1) Depth of reservoirs should be increased and surface area is less.

(2) Trees should be planted as the wind breakers.

(3) By spraying certain chemicals or fatty acid on the surface of water of reservoir or lake but which has not bad effect on the water.

(4) Water flow is need to keep the water cool.

(5) River should be straight which reduces the area.

(6) In small reservoir, using polythin evaporated water can be stored.

(7) Reservoir can be made as under the ground-surface.

(8) Many trees should be planted around the reservoirs.

2K10 (Reddy – 7.4) (231 Page)

During a daily routine observation, 10.8 liters of water was added to bring the water surface in the evaporation pan to the stipulated level and the nearby rain guage measured 3.6mm of rainfall. what was the evaporation recorded for the day if the diameter of the pan is 122 cm?

Soln Evaporation = $\frac{\text{Volume}}{\text{Area}}$

$= \frac{10.8 \times 10^{-3} \, m^3}{\frac{\pi}{4} \times (1.22)^2 \, m^2}$

$= 9.24 \times 10^{-3} \, m$

$= 9.24 \, mm.$

Total evaporation = $(3.6 + 9.24)$ mm = depth of water added + rainfall

$= 12.84$ mm. (A)

(Do. Problem from Reddy. 231 Page)

Reddy – (CT-13 series)

Ex: 7.5: what is evaporation, if 4.75 litres of water is removed from an evaporation pan of diameter 1.22 m and the simultaneous rainfall measurement is 8.8 mm?

Soln

Area of the pan = $\frac{\pi}{4} * (122)^2 = 11689.87 \text{ cm}^2$

Volume of water removed = 4.75 litres

= 4750 cm^3.

Depth of water removed = $\frac{4750}{11689.87}$

= 0.406 cm

= 4.06 mm.

Evaporation = rainfall − depth of water removed

= 8.80 − 4.06 = 4.74 mm

Q. What do you mean by soil evaporation?

⇒ Soil evaporation:

The evaporation from a a wet soil surface immediately after rain or escape of water molecules with more resistance when the water table lies within a metre from ground is called the soil evaporation.

This expressed as a percentage of evaporation from free water surface is called evaporation opportunity.

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

Q. Define transpiration and transpiration ratio.

⇒ Transpiration:

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

⇒ Transpiration ratio:

The ratio of the weight of water absorbed (through the root system), ~~conveyed~~ ~~through~~ ~~and~~ and the weight of dry matter produced called the transpiration ratio

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

Evapotranspiration:

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

2K11
Q. what are factors Affecting Evapo transpiration?

→ Factors:

(i) climatological factors like percentage sun shine hours, wind speed, mean monthly temperature and humidity.

(ii) crop factors like the type of crop and the percentage growing season.

(iii) The moisture level in the soil.

2K11
Q. what is infiltration? Draw the infiltration curve of horton. what are the factors that infiltration depends on?

Infiltration: water entering into the soil at the ground surface is called the infiltration.

Infiltration curve/Horton's curve:

on the basis of following eqn Horton prepared an infiltration curve, where—

$$f = f_c + (f_0 - f_c)\, e^{-kt} \quad \text{---- (1)}$$

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

where, f_o = initial rate of infiltration capacity

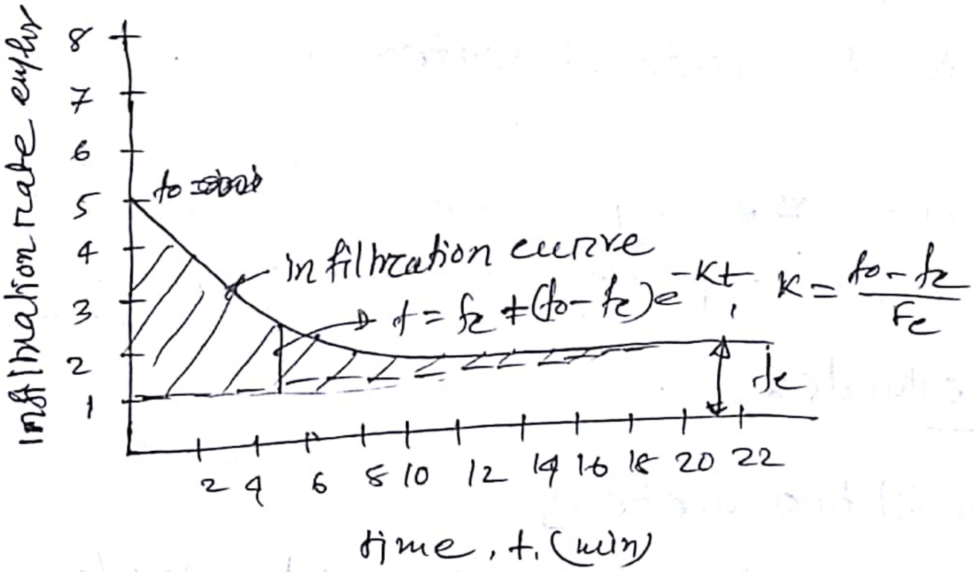
f_c = final constant rate of infiltration at saturation.

K = a constant depending primarily upon soil and vegetation.

e = base of the Napierian logarithm.

F_c = shaded area in fig. (Net infiltration)

t = time from begining of the storm



The infiltration takes place at capacity rates only when the intensity of rainfall equals or exceeds f_p; i.e $f = f_p$ when $i \geq f_p$; but when $i < f_p$, $f < f_p$ and the actual infiltration rates are approximately equal to the rainfall rates.

2K14

Q. Briefly describe the factors affecting infiltration rate

⇒ Infiltration depends on:

(i) Intensity and duration of rainfall.
(ii) Weather (temperature)
(iii) Soil characteristics
(iv) Vegetal cover
(v) land age
(vi) Initial soil moisture content
(vii) Entrapped air
(viii) Depth of ground water table.

Q. Explain ~~the~~ any method of determining infiltration capacity of soil surface.

⇒ Methods:

(i) Infiltrometers
(ii) Observation in pits and ponds
(iii) Placing a catch basin below a laboratory sample
(iv) Artificial rain simulators
(v) Hydrograph analysis.

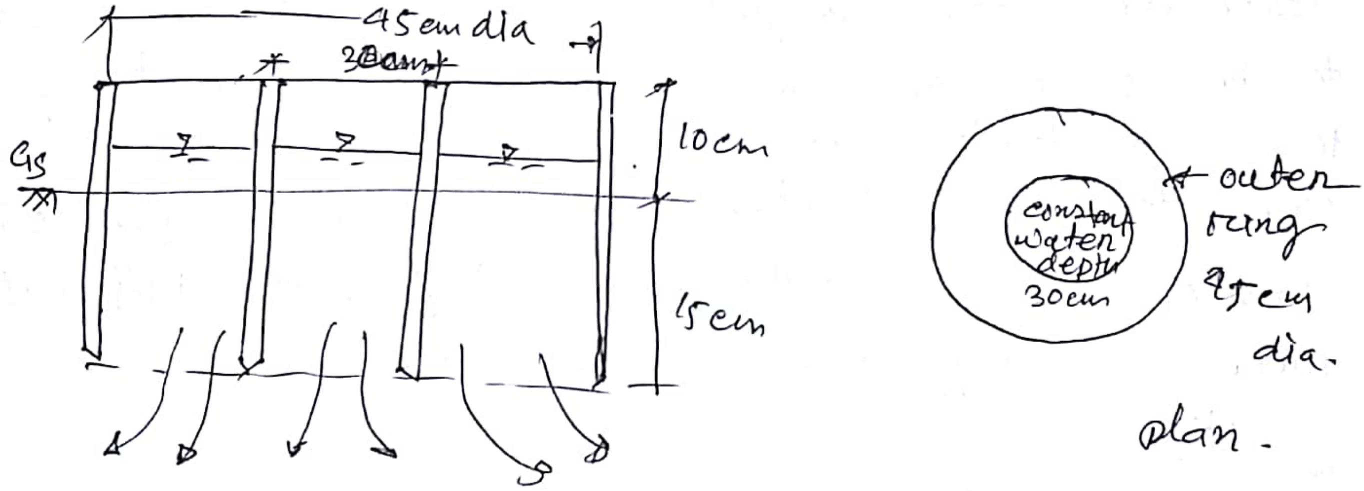
2K12 2K15

① **Double ring infiltrometer method:**

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

ⓑ The disturbed soil, if any, adjacent to the sides is tamped.

ⓒ Point gauge are fixed in the centre of the rings and in the annular space betn the two ring.



Section

Fig. double ring.

ⓓ water is poured into the ring to a desire depth.

ⓥ To maintain constant depth, water is

added continuously and water requirement for regular time intervals is recorded up to a period of least 6 hours.

(vi) The results are plotted as infiltration rate cm/hr versus time in min.

Infiltration capacity is determined from f_{c} curve.

2K15

Ex 3.4(a)

For a small catchment, the infiltration rate at the begining of rain was observed to be 90 mm/hr and decreased exponentially to a constant rate of 8 mm/hr after $2\frac{1}{2}$ hr. The total infiltration during $2\frac{1}{2}$ hr was 50mm. Develop the Horton's equation for the infiltration rate at any times $t < 2\frac{1}{2}$ hr..

Solution

Net infiltration, $F_c = 50 - 8 \times 2.5 = 30$ mm.

$f_0 = 90$; $f_c = 8$

Now. $K = \dfrac{f_0 - f_c}{F_c} = \dfrac{90-8}{30} = 2.73\ hr^{-1}$

Horton's eqn — $f = f_c + (f_0 - f_c)e^{-Kt}$

$= 8 + (90-8).e^{-2.73t}$

$= 8 + 82\, e^{-2.73t}$ ∴ f in mm/hr, t in hr.

Ex 3.5 (82 page)

soln

Here, $A = 1.8\ km^2 = 1.8 \times 10^6\ m^2$

observed rainfall, $P = 10$ cm.

$f_0 = 1$ cm/hr.

$f_c = 0.3$ cm/hr.

$K = 5\ hr^{-1}$

Evaporation ⇒ $E_p = 0.6$: $P_e = 0.7$

Now.

infiltration capacity —

$$f_p = \int_0^{24} \left[f_c + (f_0 - f_c) e^{-kt} \right] dt$$

$$= \int_0^{24} \left[0.3 + (1.0 - 0.3) e^{-5t} \right] dt$$

$$= 0.3t + \frac{0.7}{-5e^{-5t}} \Big]_0^{24}$$

$$= \left(0.3 \times 24 + \frac{0.7}{5 \cdot e^{-5 \times 24}} \right) - \left(0 - \frac{0.7}{5 \cdot e^0} \right)$$

$= 7.34$ cm.

Runoff $= P - F_p - E$ $\qquad E = E_p + P_e$

$= 10 - 7.34 - (0.60 + 0.7)$

$= 2.24$ cm.

Scanned by CamScanner

volume of runoff from the catchment —

$= \underline{\text{Runoff} \times \text{Area}}$

$= \frac{2.24}{100} \times (1.8 \times 10^6)$

$= 40320 \, m^3$. (Ans)

Reddy 2K13

Ex 8.6 (269 page)

The cumulative depth of infiltration in an experiment on a tube infiltrometer is observed to follow the eqn $F = 0.165 \, t^{0.65}$. where, F is in cm and t is in minutes. Determine the equation for infiltration rate and the average infiltration rate.

Solution:

$F = 0.165 \, t^{0.65}$

Infiltration rate. $f = \frac{dF}{dt}$

$= 0.165 \times 0.65 \times t^{-0.35}$

$= 0.10725 \, t^{-0.35}$ cm/min.

$f = 6.435 \, t^{-0.35}$; t min

$= 6.435 (60 \times t)^{-0.35}$; t hr

$= 1.5353 \, t^{-0.35}$ ⇒ t hr.

$f = 6.435 \, t^{-0.35}$ cm/h ; t in minutes.

or, $f = 1.5353 \, t^{-0.35}$ cm/h, t in hours

average — $f_{av} = \frac{F}{t}$

$= 0.165 \, t^{-0.35}$ cm/minute

$= 9.9\, t^{-0.35}$ cm/hr; where t in minutes.

$= 2.362 \cdot t^{-0.35}$ cm/h ; t in hours.

(A)

2K15
Ex.8.7 (Reddy)

The Horton's infiltration equation for a basin is given by $f = 6 + 16 e^{-2t}$, where f is in mm/h and t is in hours. What are the values of f_0, f_c and K? If a storm occurs on this basin with an intensity of more than 22 mm/h determine the depth of infiltration for the first 45 minutes and the average infiltration rate for first 45 minutes.

Soln On comparison with the Horton's eqn in the standard form one can observe that

$f_c = 6$ mm/hr

$f_0 = 22$ mm/hr

and $\Rightarrow K = 2$/h

Since the rainfall intensity is more than f_0, the infiltration takes place at the capacity rate throughout the storm.

Hence the cumulative depth of infiltration for the first 45 minutes is given by

$$F = \int_0^{3/4} f \cdot dt$$

$$= \int_0^{0.75} (6 + 16e^{-2t})\,dt$$

$$= \left[6t - 8 \cdot e^{-2t}\right]_0^{0.75}$$

$$= (6 \times 0.75 - 8 \times e^{-1.5}) - (0 - 8)$$

$$= 12.5 - 8e^{-1.5}$$

$$= 12.5 - 1.785$$

$$= 10.715 \text{ m.m}$$

The cummulative depth of infiltration for the first 75 minutes is given by—

$$F = \int_0^{1.25} f \cdot dt = \left[6t - 8 \cdot e^{-2t}\right]_0^{1.25}$$

$$= \left[6 \times 1.25 - 8 \times e^{-2.5}\right] - (0 - 8)$$

$$= 15.5 - 0.657 = 14.843 \text{ mm.}$$

Average for infiltration rate for the 75 min —

$$f_{av} = \frac{F}{t}$$

$$= \frac{14.83}{1.25} = 11.879 \text{ mm/h}$$

Q. Explain infiltration indices.

→ **Infiltration indices:**

Three types —

(I) **ϕ - index:**

The ϕ index is ~~the~~ defined as that rate of rainfall, above which the rainfall volume equals to the run off volume.

So, ϕ - Index = $\frac{\text{basin recharge}}{\text{duration of rainfall}}$

2K14
Q. Distingush bet ϕ-index and w- index.

(II) **W- index:**

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

So, W index = $\frac{F_P}{t_R} = \frac{P-Q-S}{t_R}$

where, P = total rainfall

Q = surface runoff

S = effective surface retention

t_R = duration of storm during which is F_P

F_P = total infiltration.

(iii) Average index:

In this method, an average infiltration loss is assumed throughout the storm, for the period i > f.

2K7
Q. Write a short notes on watershed leakage and water balance:

⇒ Watershed leakage:

The rain water after infiltering into the ground may percolate through water, through the water bearing strata may flow into the adjacent basin or directly into the sea. This is called water shed leakage.

⇒ Water balance:

The input items into a basin are essentially precipitation (P) and sub-surface inflow (G_i) while the water losses are evaporation (E), evapotranspiration (E_t) and sub-surface out flow. The balance goes to recharge ground water (G_r) increase the soil moisture (SMA) and as surface run off (stream, R).

The water balance eqn—

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

21.06

Ex: 3.6 (Raghunath)

The rate of ~~fall~~ rainfall for the successive 30 min period of a 3-hour storm are: 1.6, 3.6, 5.0, 2.8, 2.2, 1.0 cm/hr. The corresponding surface run off is estimated to be 3.6 cm. Establish the ϕ index. Also determine the W-index.

soln

construct the hyetograph—

$$\Sigma (i - \phi) t = P_{net}$$

$$\Rightarrow \left[(3.6-\phi) + (5.0-\phi) + (2.8-\phi) + (2.2-\phi)\right] \frac{30}{60} = 3.6$$

$$\therefore \phi = 1.6 \text{ cm/hr.}$$

$\phi \geq 1.6$ ধরে কাজ হয়েছে। ⇒ যদি result এ ϕ এর মান 1.6 এর ছোট হয় তখন $(1.6-\phi)$ করে অর্থাৎ $\phi < 1.6$ ধরে trail দিতে হবে।

⇒ আবার last $(2.2-\phi)$ ধরা হয়েছে। যদি ϕ এর result 2.2 থেকে বেশি আসে তাহলে $(2.2-\phi)$ term বাদ দিয়ে trail দিতে হবে।

$$P = (1.6 + 3.6 + 5.0 + 2.8 + 2.2 + 1.0) \times \frac{30}{60}$$
$$= 8.1 \text{ cm.}$$

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w index $= \dfrac{P-Q}{t_R}$

$= \dfrac{8.1-3.6}{3} = 1.5$ cm/hr. (Ans)

2K19

Ex: 3.7 Hourly rainfalls of 2.5, 6 and 3 cm occur over a 20-ha area considering 4 ha of $\phi = 5$ cm/hr. 10 ha of $\phi = 3$ cm/hr. and 6 ha of $\phi = 1$ cm/hr. Derive hourly values of net rain.

Soln

1st hour: ($P = 2.5$ cm)

(2.5 − 5) → 2.5 হবে ওটা zero.

(2.5 − 3)

$P_{net\text{-}mean} = \dfrac{4(0) + 10(0) + 6(2.5-1)}{20} = 0.45$ cm

negative হলে 0.

$P_{net} = \dfrac{A_1(P_x - P_1) + A_2(P_x - P_2) + A_3(P_x - P_3)}{A}$

2nd hour: ($P = 6$ cm)

$P_{net\text{-}mean} = \dfrac{4(6-5) + 10(6-3) + 6(6-1)}{20} = 3.20$ cm.

3rd hour: ($P = 3$ cm)

$P_{net\text{-}mean} = \dfrac{4(0) + 10(0) + 6(3-1)}{20} = 0.60$ cm.

Total net rain for the 3-hour storm

$= 0.45 + 3.20 + 0.60$

$= 4.25$ cm (Ans)

Ex. 3-8 Raghunath 86 Page

2KKI

Q. Distinguish betn infiltration rate and infiltration capacity.

Difference:

Infiltration rate	Infiltration capacity
① The entering of water into the soil per unit time is called the infiltration rate.	① It is the maximum rate at which the soil can absorb the water for any given condition is called infiltration capacity.
② It is expressed by f.	② It is expressed by fp

Q. What is the probability that a 5-year flood will occur at least once during the next 3 years?

Soln

Here,

$p = \frac{1}{5} = 0.2$; $q = 1 - 0.2 = 0.8$

$n = 3$

P(X≥1)(x=0)

$P = P(r=1) + P(r=2) + P(r=3)$

$= {}^{n}C_{r} \cdot (p)^{r} \cdot (q)^{n-r} + \cdots$

$= {}^{3}C_{1} \cdot (0.2)^{1} \cdot (0.8)^{3-1} + {}^{3}C_{2} \cdot (0.2)^{2} \cdot (0.8)^{3-2}$

$+ {}^{3}C_{3} \cdot (0.2)^{3} \cdot (0.8)^{3-3}$

$= 0.487$ Ans.

Or,

$P = 1 - P(r=0)$

$= 1 - {}^{3}C_{0} \cdot (0.2)^{0} \cdot (0.8)^{3-0}$

$= 0.487$ (Ans)

or,

$P = 1 - (1 - \frac{1}{T})^{N}$

$= 1 - (1 - \frac{1}{5})^{3}$

$= 0.488$. Ans

calculate the probability of exceedance of flood having a return period of 15-yrs. And also what would be the probality of that flood, which occurs in the next 10 years and 5 years return period.

Soln

~~Relation~~. Probability. $P = \frac{1}{T}$

$= \frac{1}{15} \times 100$

$= 0.066$

Probability of exceedance $= 6.7\%$

(Ans)

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Probabity of ~~that~~ flood, that will not occur in 10 years return period.

$= (1 - 0.066)^{10} = 0.51 = 51\%$

the probability of flood which will be equal or greater than in 10 year return period.

$= 1 - 0.51 = 0.49 = 49\%$

similarly, the probability of not occur-

$= (1-0.066)^5 = 0.71 = 71\%$ Ans.

And, probability of flood which will be occured in 5 year

$= 1 - 0.71 = 0.29 = 29\%$. Ans

Run off

Q. Define Run off.

⇒ **Runoff:** The portion of precipitation which appears in the surface streams of either perennial or intermittent nature is called run-off.

It can express as follows—

Run off = surface run off + Sub surface run off + ground water run off / base flow.

Q. Discuss different types of run off.

⇒ **Types of run off:**

Broadly classified into following three types ~~which~~ —

1. Surface run off
2. sub surface run off / inter flow } Direct Runoff
3. Base flow

(i) **surface run off:** The portion of rain fall which enters the streams, channels etc immediately after occurring the rainfall is called surface run off.

(ii) **Sub surface run off:** It is the amount of rainfall which first reaches into the soil and then starts flowing laterally without joining the water table to the streams, river etc called as sub surface run off.

(iii) Base flow : It is the delayed flow, defined as that part of rainfall which after falling over the ground surface, percolates into the soil and meets to the water table. and finally joins with the streams, ocean etc.

Q. Define — Depression storage
Detension storage
Influent stream. ; Effluent stream.

⇒ Depression storage: when overland flow starts due to strom, some flowing water is held in paddles pits and small ponds. the stored water is called depression storage

⇒ Detension storage: In the overland flow, the volume of water in transit, which has not yet reached the stream channel, is called the detension storage.

2KR
⇒ Influent stream: If the G.W.T is below the bed of stream, then seepage from the stream feeds the ground water resulting in the build up of water mound. such

streams as known influent stream.

~~Q Define Bank storage with figure.~~

⇒ Effluent stream: If the G.W.T is above the water surface elevation of the stream, the ground water feeds the stream. such stream is called effluent stream.

ekB
Q. Define Bank storage with figure.

⇒ 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.

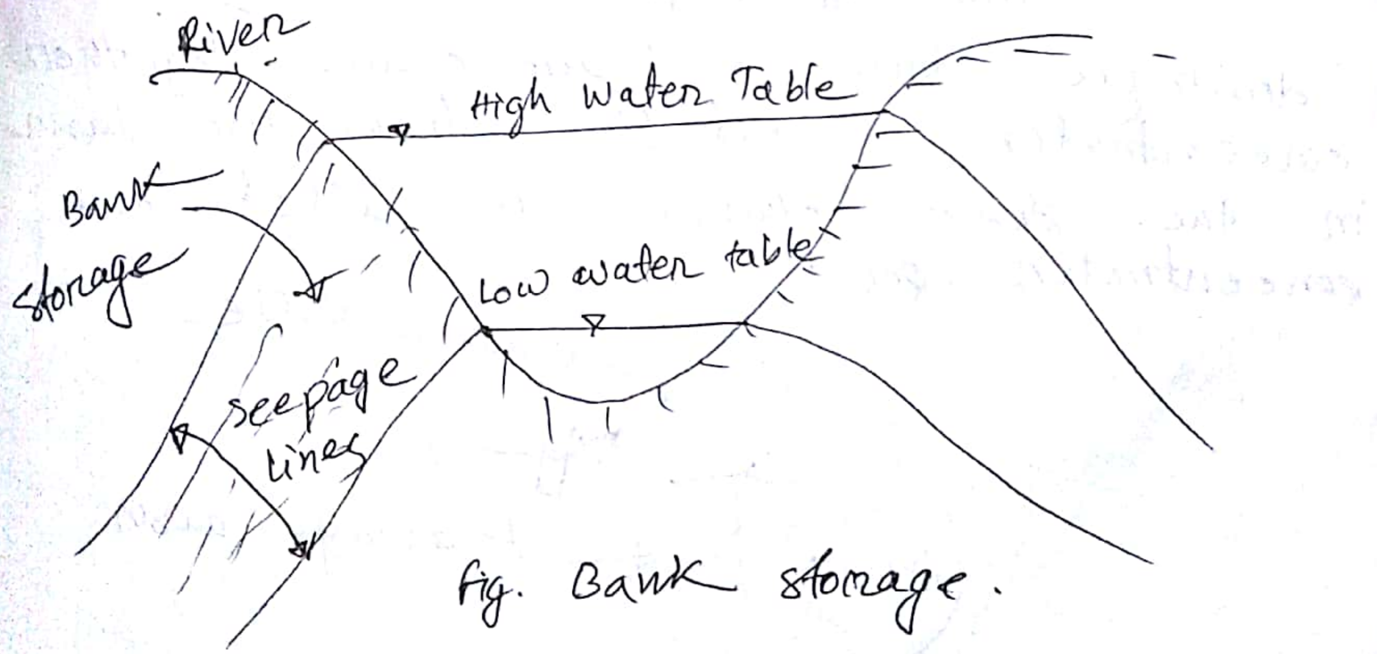


fig. Bank storage.

Q) Explain catchment characteristics.

⇒ catchment characteristics:

① Drainage basin or catchment area.

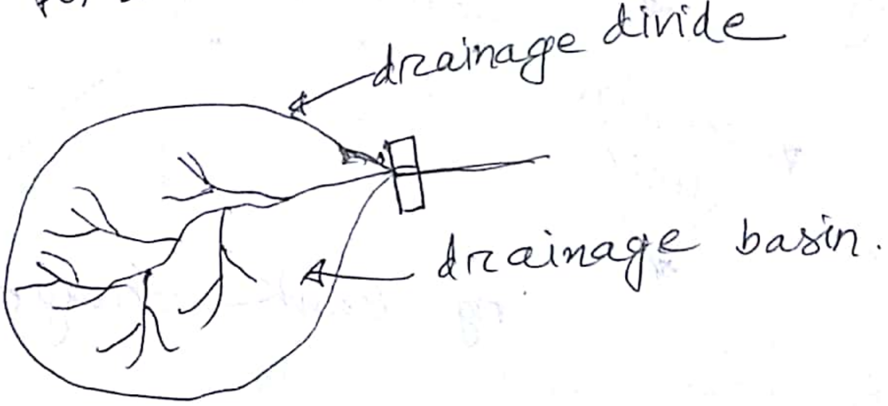
The entire area of river basin whose surface run off drains into the river in the basin is considered as a hydrologic unit and is called drainage basin, watershed or catchment area of river flowing.

② Drainage Divide

The boundary line along a topographic ridge, seperating two adjacent drainage basins is called drainage divide.

③ concentration point or measuring point.

The single point which all surface drainage from a basin comes together or concentrates as out flow from the basin in the stream channel is called the concentration point.



(4) 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 concentration time.

Q. Define distribution co-efficient.

⇒ Distribution co-efficient: The ratio of the maximum rainfall at a point to the mean rainfall of the concern catchment is called the distribution co-efficient.

It is expressed as Cd.

$$Cd = \frac{\text{Maximum rainfall amount}}{\text{Mean rainfall}}$$

Q. Define Form Factor.

⇒ Form factor: The ratio of the axial width of the basin to the axial length of basin is called the form factor.

$$\therefore \text{Form factor} = \frac{W_b}{L_b} \quad \text{--- (1)}$$

where, W_b = axial width of basin
L_b = " length " "

Here, co-efficient of shape of basin

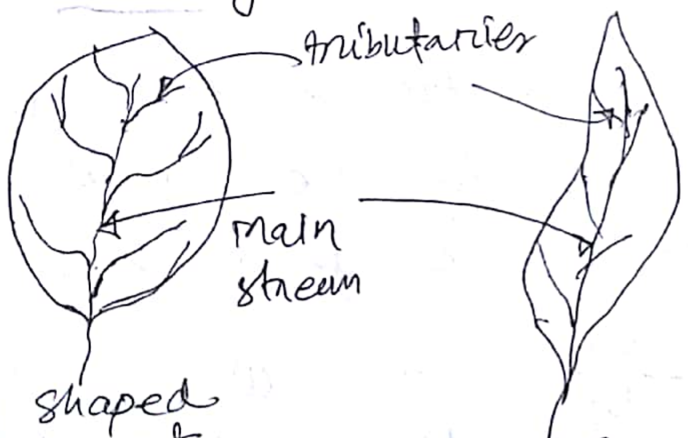
$$= \frac{1}{\text{form factor}}$$

v.v.I

Q. Explain, in Fern-shaped catchment the concentration time is more than that of fan shaped catchment.

⇒ Explanation: Since all the tributaries are nearly same length of the fan shaped catchment that produces greater flood intensity. Hence the concentration time is nearly the same and is less.

In case of fern shaped catchment the tributaries are of different length so the discharge is distributed over a long period of time as the concentration time is so high.



ⓐ fan shaped catchment

ⓑ Fern shaped catchment.

2K12
Q. Discuss various factors that affecting the run off from a basin.

⇒ Factors affecting runoff:

① Strom characteristics
  (i) Types and season.
  (ii) Intensity
  (iii) Duration
  (iv) Frequency
  (v) Areal extent

② Meteorological characteristics.
  (i) Temperature
  (ii) Pressure variation
  (iii) Humidity
  (iv) Wind velocity

③ Basin characteristics
  (i) size
  ~~(ii) shape~~
  (ii) shape
  (iii) slope
  (iv) Altitude
  (v) Topography
  (vi) Geology
  (vii) Land use.

④ Storage characteristics
  (i) channels
  (ii) check dames
  (iii) Depression
  (iv) Flood plains
  (v) Ponds
  (vi) streams
  (vii) upstream reservoir.

Q. Define – Isochrones, Intermitten stream, perennial stream. 2×13

⇒ **Isochrones:** The lines joining all points in a basin of same key time elements in a stream such as beginning of precipitation are called Iso chones.

which are the time contours and represents lines of equal travel time and very helpful in driving hydrographs.

⇒ **Intermitten stream:**

The water remains only in a season at the stream.

⇒ **Perennial stream:** The water remains all the time at the stream.

Q. What are the methods of various runoff estimation? Explain the runoff estimation – ~~rotational~~ rational method.

⇒ **Run off estimation:**

Types —

(i) Empirical formulae, curves and tables.
(ii) Infiltration method
(iii) Rational method
(iv) Overflow – overland flow hydrograph.

(v) unit hydrograph method

etc.

Rational method:

A rational approach is to obtain the yeild of a catchment by assuming a suitable run off co-efficient.

$$Yeild = cAP \quad \text{—— (1)}$$

where. A = area of catchment
P = Precipitation
c = Run-off co-efficient.

The value of the c varies depending upon the soil type, vagetation, geology etc.

In this method ——

(i) Drainage area is divided into a number of sub-areas.

(ii) from the known concentration times for different areas, run off contribution from each area is calculated.

(iii) A suitable value of runoff co-efficient is choosen and runoff is calculated.

Q. Define maximum flood discharge. 2k7

⇒ Maximum Flood Discharge:

It is discharge in times of flooding of the catchment area i.e when the intensity of rainfall is greatest and the condition of the catchment regarding humidity is also favourable for an appriciable runoff.

Ex. 4.3 (Raghunath 112 Page)

A 4-hour rain of average intensity 1cm/hr falls over the fern leaf type catchment as shown in fig 4.10. The time of concentration from the lines AA, BB, CC and DD are 1, 2, 3 and 4 hours, respectively to the site O where the discharge measurement is made. The values of the runoff condition C are 0.5, 0.6 and 0.7 for the 1st, 2nd and 3rd hours of rainfall respectively and attains a constant value of 0.8 after 3 hours. Determine the discharge at site O.

S/n

P.T.O ⇒

Sub area (ha)	Time ~~of~~ from begining of strom, 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~~ at O from sub-areas–

$Q = \Sigma CAP$

(See book – 113)

e = 0.5	0.6	0.7	0.8	0.8	0.8	0.8
$0.5*(20*10^4)*\frac{1}{100}$	$0.6*(20*10^4)*\frac{1}{100}$	$(0.7*20*10^4)\frac{1}{100}$	$0.8*(20*10^4)*\frac{1}{100}$			
	$0.5*(30*10^4)*\frac{1}{100}$	$0.6*(30*10^4)\frac{1}{100}$	0.7*		0.8*	
		$0.5*(50*10^4)*\frac{1}{100}$	0.6	0.7	0.8	
			$0.5*(40*10^4)*\frac{1}{100}$			

Discharge at O Q. m^3/hr 1000 2700 5700 8700 8300 6800 3200 (m^3/hr)

(Ex. 4.4) (114 Page)

Ex 4.2 2k11

A basin has an area of 26560 km^2. Perimeter 965 km and length of thalweg 230 km. Determine (i) form factor (ii) Elongation ratio (iii) Circulating ratio (iv) compactness co-efficient.

Sol

Given,

Area; $A_b = 26560\ km^2$

Perimeter. $P_b = 965\ km$

Length. $L_b = 230 km$.

(i) Form factor $= \frac{W_b}{L_b} = \frac{W_b * L_b}{L_b^2} = \frac{A_b}{L_b^2}$

$= \frac{26560}{230^2} = 0.50$

(ii) Elongation ratio ⇒

$E_r = \frac{2R}{L_b}$

$A_b = \pi R^2$

$\Rightarrow 26560 = \pi * R^2$

$\Rightarrow R = 91.94\ km$

$= \frac{2*91.94}{230}$

$\therefore E_r = 0.80$

(iii) circularity ratio.

$$c_r = \frac{A_b}{\pi R'^2} \quad \text{——— (11)}$$

$$P_b = 2\pi R' \Rightarrow R' = \frac{P_b}{2\pi} = \frac{965}{2 * 3.14} = 153.58 \text{ km}$$

$$\therefore c_r = \frac{26560}{\pi * (153.58)^2} = 0.36$$

(iv) compactness co-efficient

$$c_c = \frac{P_b}{2\pi R}$$

$$= \frac{965}{2 * \pi * 91.94}$$

$$c_c = 1.67 \text{ Ans}$$

A drainage basin has an area 210 km². The average depth of rainfall received by it during a monsoon period is computed as 65 cm, while the runoff measured at its outlet during the same period is estimated to be $5.68 * 10^7$ m³. compute the depth of run off. what percentage of rainfall has become runoff? If all this runoff volume is stored and used to irrigate a crop which requires 60 cm of water. How many hectares can be irrigated?

P.T.O

Soln

Depth of runoff = $\frac{\text{volume of runoff}}{\text{Basin area}}$

$= \frac{5.68 \times 10^7}{210 \times 10^6}$

$= 0.2705$ m

$= 27.05$ cm

% of rainfall that become run off

$= \frac{27.05}{65} \times 100$

$= 41.62\ \%$ Ans

Area of crop that can be irrigated —

$= \frac{\text{volume of runoff}}{\text{Irrigation depth}}$

$= \frac{5.68 \times 10^7}{0.60}$

$= 9.467 \times 10^7$ m2 —

$= 94.67$ km2 —

$= 9467$ hectares Ans

Stream Gauging

2K15

Q. Define stream Gauging. What are the methods of stream gauging?

⇒ stream gauging: The most satisfactory determination of the runoff from a catchment is by measuring the discharge of the stream draining it, which is termed as stream gauging.

⇒ Methods:

1. Venturi flumes for small channel
2. Weirs
3. slope - area method
4. Contracted area method
5. sluice ways, spill ways
6. salt - concentration method
7. Area - velocity method.

2K15

Q. What are the factors that influence the selection of site for a stream gauging station?

⇒ factors influencing the selection of a site for stream guaging station:

① The section should be straight and uniform for a length of about 10 to 20 times the width of the stream.

② The bed and banks of stream should be firm and stable so as to ensure consistency of area-discharge relation.

③ There should be no longer overflow section at flood stage.

④ The best section is one with V-shape.

⑤ The stream gauging station should be easily accessible.

⑥ for the best consistency, the section should have good controll for down stream.

2K10

Q. Explain how a current meter rating curve is prepared.

⇒ Preparation of current meter rating curve:

The relationship betn the revolutions per second (N. rps) of the meter and velocity of flow past the melter (V. m/sec) has to be first established or if the rating eqn is given by the maker it has to be varifeed.

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This process of calibration of the meter is called the 'rating of current meter'.

The rating eqn —

$$V = aN + b \quad \text{——— (1)}$$

where, a, b are constant (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 constant a and b are determined by following fig —

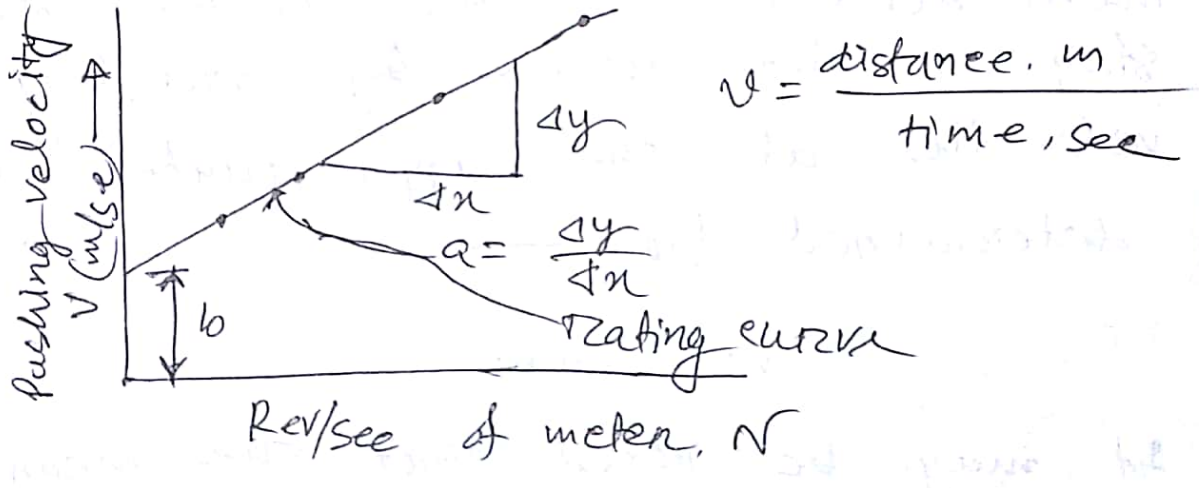


Fig. current meter rating curve.

Q 2K15 Write a short note on stage Discharge rating curve., use and neat sketch.

⇒ Stage-Discharge rating curve:/Flow rating curve

Once the rating eqn of the current meter is known, actual stream gauging can be done from bridge cradle, boat or launch. The cross section of the stream at the gauging site is divided into elements ~~stream~~ strips of equal width b and the current water is lowered to a depth of 0.6d below the water surface is the shallow depths ~~and~~ 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 is taken as that at 0.6d below the water surface in shallow depth of water (one point method) and as the average of the velocities at 0.2d and 0.8d below the water surface (two point methods).

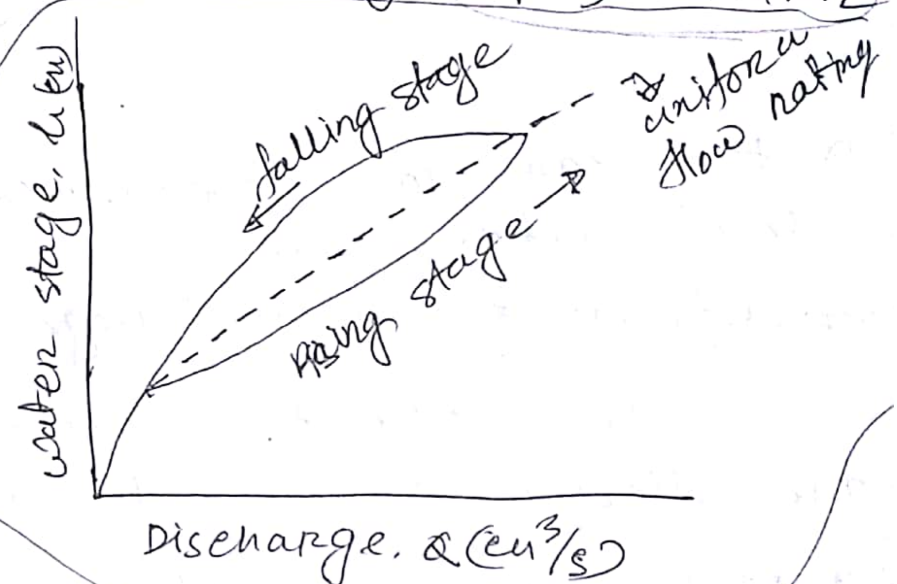
the discharge in each elemental strip is determined and the discharge in the stream is the sum of the discharge in all the elemental strip.

Q. Explain how the stage-discharge rating curve for a stream-gauging station is prepared.

Adjustment:

Due to rising and falling stages adjustment of rating curve is possible by loop formation.

And a dotted line is drawn a middle of loop which shows the uniform flow.



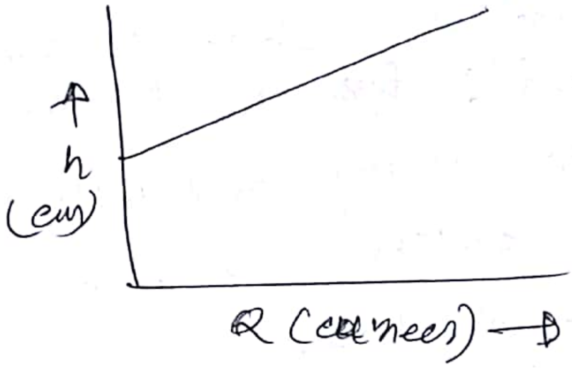
Correction:

During rising and falling stage in flood the correction is applied for Q_o discharge. Δh_o is the difference of gauge reading betn main and auxilary guage. For Q_a discharge Δh_a is reading.

So, $$\frac{Q_a}{Q_o} = \left(\frac{\Delta h_a}{\Delta h_o}\right)^n \quad \text{——— (1)}$$

where, $n = 0.5$

Typical stage-discharge rating curve is as following



Q. How can you determine the discharge in elemental strip.

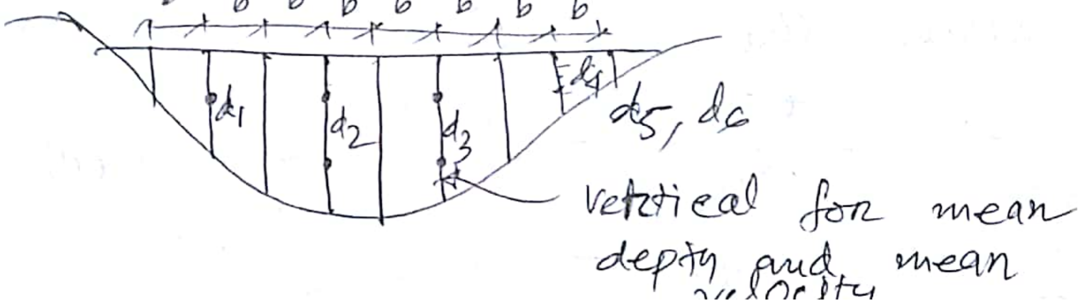
⇒ <u>Determination of discharge in elemental strip:</u>

There are two methods of determining the discharge in each catchment strip.

① <u>Mid-section method:</u>

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.

<u>Fig</u>



If b is the width of strip then the discharge in the elemental strip is given by —

$$\Delta Q = (bd) V_{0.6d} \text{ in shallow strips.}$$

$$\Delta Q = (bd) \frac{V_{0.2d} + V_{0.8d}}{2} \text{ in deep water strip}$$

Stream discharge. $Q = \Sigma \Delta Q$ —— (1)

② <u>Mean-section method:</u>

In this method the elemental strip is taken between the two verticals and the mean depth is taken as the average of the depths in the two verticals. The width of the strip is 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 points method). The discharge in the elemental strip is given by —

$$\Delta Q = b\left(\frac{d_1 + d_2}{2}\right)\left(\frac{V_1 + V_2}{2}\right) \text{ —— (1)}$$

V_1, V_2 determined as $V_{0.6d}$ for shallow water strip and $\frac{V_{0.2d} + V_{0.8d}}{2}$ in the deep water strip.

So stream discharge. $Q = \Sigma \Delta Q$.

Ex. 6.2 (Raghunath 197)

The stream discharges for various stages at a particular section were observed to be as follows. obtain an eqn for the stage-discharge Relationship and determine the discharge for a stage of 4.9m and 12m

Stage (m)	1.87	2.00	2.30	2.90	3.70	4.50	5.40	6.10	7.30	7.70	8.10
Discharge (m^3)	1.00	1.50	2.55	5.60	11.70	20.20	32.50	44.50	70.00	80.00	90.00

soln The relation betn stage (h) and discharge (Q) of the stream can be assumed of the form—

$$Q = K(h-a)^n \quad \text{——— (1)}$$

from graph—

The slope of this straight line gives the value of the exponent $n = 2.2$ and from the graph for $h-a = 1$; $Q = 1.2 = K$.

Now the constants are determined and the eqn for the stage-discharge relationship is-

$$Q = 1.2(h-0.9)^{2.2}$$

for, $h = 4.9m \Rightarrow Q = 25.3$ cumec

$h = 12\ m \Rightarrow Q = 240$ cumec.

AZ

Ex. 6.3 (Raghunath)

The following data were obtained by stream gauging of a river:

Main gauge staff reading (m)	12.00	12.00
Auxili gauge staff readings (m)	11.65	11.02
Discharge (cumec)	9.50	15.20

What should be the discharge when the main gauge read 12 m and the auxiliary gauge read 11.37 m?

Soln

$\Delta h_o = 12.00 - 11.65 = 0.35\,m$

$\Delta h_a = 12.00 - 11.02 = 0.98\,m.$

If Q_o is the discharge when Δh_o is the difference of gauge readings betn the main and auxiliary gauges during normal flow and Q_a is the discharge when Δh_a is the difference of the two gauges during a rising or falling stage then

$$\frac{Q_a}{Q_o} = \left(\frac{\Delta h_a}{\Delta h_o}\right)^n$$

$$\Rightarrow \frac{15.20}{9.50} = \left(\frac{0.98}{0.35}\right)^n$$

$$\Rightarrow n = 0.5125$$

Again, when the auxiliary gauge reads 11.37 m —

$$\Delta h_a = 12.00 - 11.37 = 0.63 \text{ m.}$$

$$\therefore \frac{Q_a}{9.50} = \left(\frac{0.63}{0.35}\right)^{0.5125}$$

$$\Rightarrow Q_a = 12.85 \text{ cumec. Ans}$$

HYDROGRAPH

2k11
Q. Define hydrograph. Draw a single peaked hydrograph with necessary components.

⇒ Hydrograph :
The variation of discharge w.r.to time is showing by in which path is called the hydrograph.

Neat sketch :

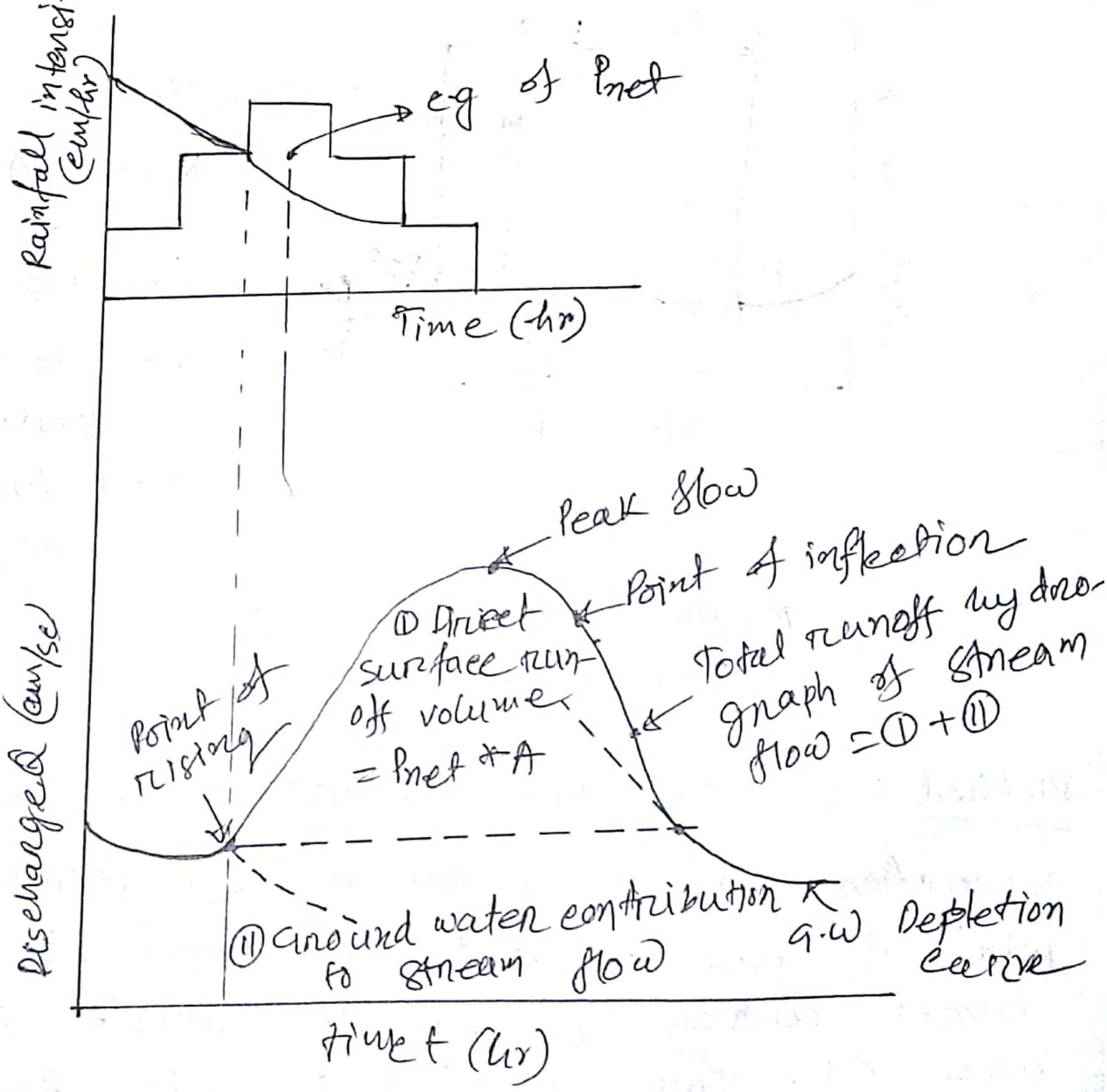


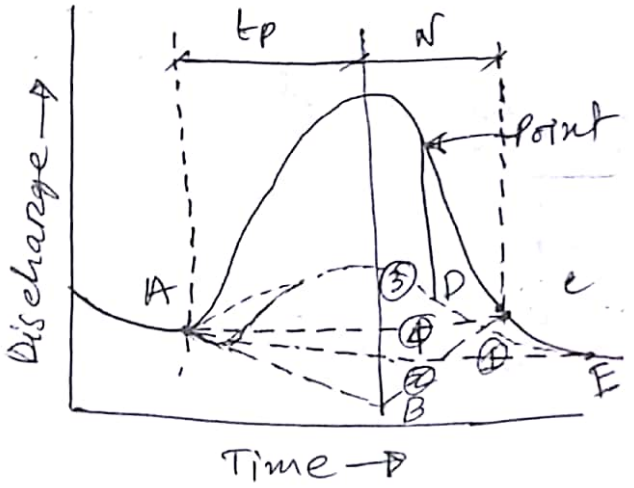
fig. single Peak hydrograph.

2V15. Describe with the help of net sketch any three methods of seperation of base flow from the hydrograph of runoff. / or from stream flow hydrograph.

⇒ **Description:**

The description of methods of seperation of base flow from hydrograph of the runoff are as following:

Fig



$N = 0.827 A^{0.2}$ Days

or

$N = a t_p$

a = 2 to 4 for small basin

a > 4 for basin large

fig. methods of base flow seperation.

Method 1: In this method the base flow seperation line is obtained by joining the point of rise (A) and the point of end of direct runoff (E) by a simple straight line AE. This method is also known as straight line method. It is simplist of all methods

Method-2: In this method (নিচের আগে অবস্থা) recession curve has existed before the point of rise is extended a point under peak of hydrograph (i.e AB) from the point of straight of line is drawn to the point of end of direct runoff. the line ABC the represent the baseflow seperation line. this is the most widely used seperation procedure:

Method-3:

In this method the base flow curve on the recession side of the hydrograph is extraplotted backwards to the time of ~~point~~ of the inflection on the recession limb and then it is connected to the point of rise by a smooth curve ADE. represents the baseflow seperation lines of this method.

2k12 Q. Define unit hydrograph. What are the properties of unit hydrograph.

⇒ Unit hydrograph:

The hydrograph of storm runoff resulting from an isolated rainfall of some unit duration occurring uniformly over the entire area of the catchment produce a unit volume of runoff is called the unit hydrograph.

Propositions of unit hydrograph:

① Same runoff duration:— For all unit storms of different intensities, the period of surface runoff (base period) is approximately same, although they produce different runoff volumes.

② Proportional ordinates:

For unit storms of different intensities, the ordinates of hydrograph at any given time are in same proportion as the rainfall intensities.

③ Principle of superposition:

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

④ <u>Same distribution Percentage</u>: If the total period of surface runoff is divided into equal time intervals the percentage of storms of surface runoff that occurs during each of this periods will be same for all unit storms of different intensities.

2K15
Q. what are the limitations of the unit hydrograph?

⇒ <u>Limitations</u>:

① The derivation of unit hydrograph assumes that rainfall is uniformly distributed throughout the water-shed and its duration but it is never satisfied.

② There is also an assumption that, rainfall intensity is constant for the duration of excess rainfall. In practice it is also not satisfied in the field.

③ Unit hydrograph can not be derived from a storm, which takes place in snow form i.e it is applicable only for rainfall.

④ Unit hydrograph of one-day storm can't be derived, particularly, where infiltration rate is greater than rainfall intensity.

⑤ For the area less than 25 Km^2 it is not applicable.

⑥ This method of estimating runoff requires a lot of observed rainfall data, for which it is essential to install the rainguage in large number thus involves additional investment of money.

Q. What are the assumptions of unit hydrograph?

⇒ Assumptions of unit hydrograph:

① The effective rainfall is uniformly distributed throughout the watershed area.

② The time base of hydrograph resulting from direct runoff caused by effective rainfall is constant.

③ The effective rainfall is uniformly distributed within it's duration.

④ The ordinates of direct runoff hydrograph of common time base are directly proportional to the direct runoff volume.

⑤ For a given watershed, the hydrograph for a specified rainfall duration reflects all physical characteristics of the watershed.

Q. Discuss the steps of derivation of unit hydrograph.

⇒ Derivation:

Step-1: Using the past records of several storms, an isolated storm should be selected which has some unit period of heavy rainfall.

Step-2: With the help of runoff data obtained from selected storm the hydrograph should be developed.

Step-3: Base flow should be seperated.

Step-4: The ordinate of direct runoff should be found.

fig

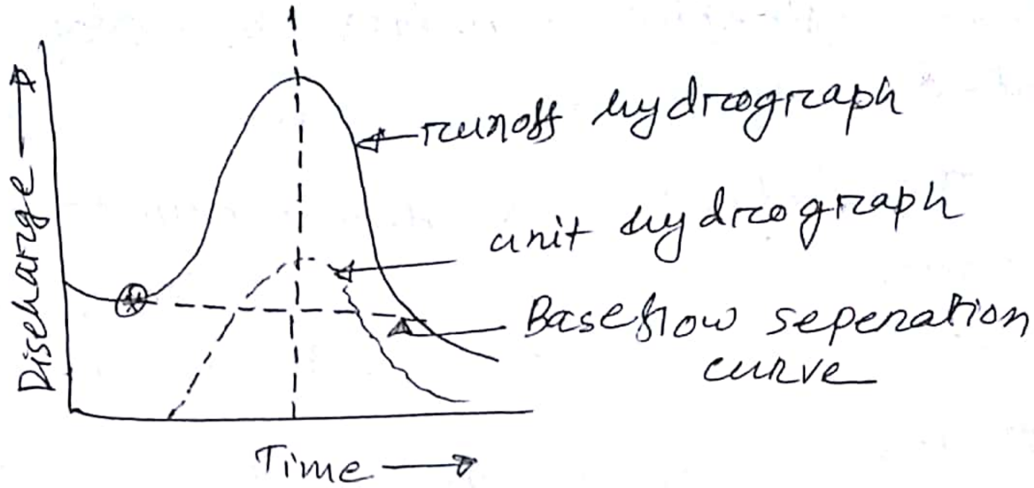


fig. Derivation of unit hydrograph.

Step-5 : ~~The to~~

Total depth of effective rainfall should be calculated. It may be obtained by using the following eqn.

Effective rainfall depth (cm)

$$= \frac{(\Sigma O).t}{A}$$

Here,

ΣO = Sum of all direct runoff ordinates of the hydrograph (m^3/sec).

t = Time interval betn successive ordinates (h)

A = watershed area (Km²)

Step-6 : The ordinates of unit hydrograph should be determined using the following relation.

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

<u>step-7:</u> 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.

Q. what is an Instantaneous Unit hydrograph (IUH)?

⇒ <u>Instantaneous Unit Hydrograph:</u>

The instantaneous unit hydrograph is a hydrograph of runoff resulting from the instantaneous application of 1 cm net rain on the drainage basin.

It was first proposed by clark in 1945. It can be developed either directly from the observed data or by adopting conceptual models.

4. What do you mean by 6-h unit hydrographs Discuss with diagram. 2013

→ <u>6-h unit hydrograph:</u>

It means the hydrograph of surface runoff resulting from an isolated rainfall of 6 hour unit duration occurring uniformly over the entire basin and producing a unit volumes of runoff. (i.e 1 cm depth).

<u>Discussion with diagram:</u>

Considering the following diagram, a storm of 6 hour unit duration which occurs uniformly over the basin and produces 1 cm net rain. If we plot discharge w.r. to time from begining of direct runoff. we will obtain a unit hydrograph which is a 6-h unit hydrograph.

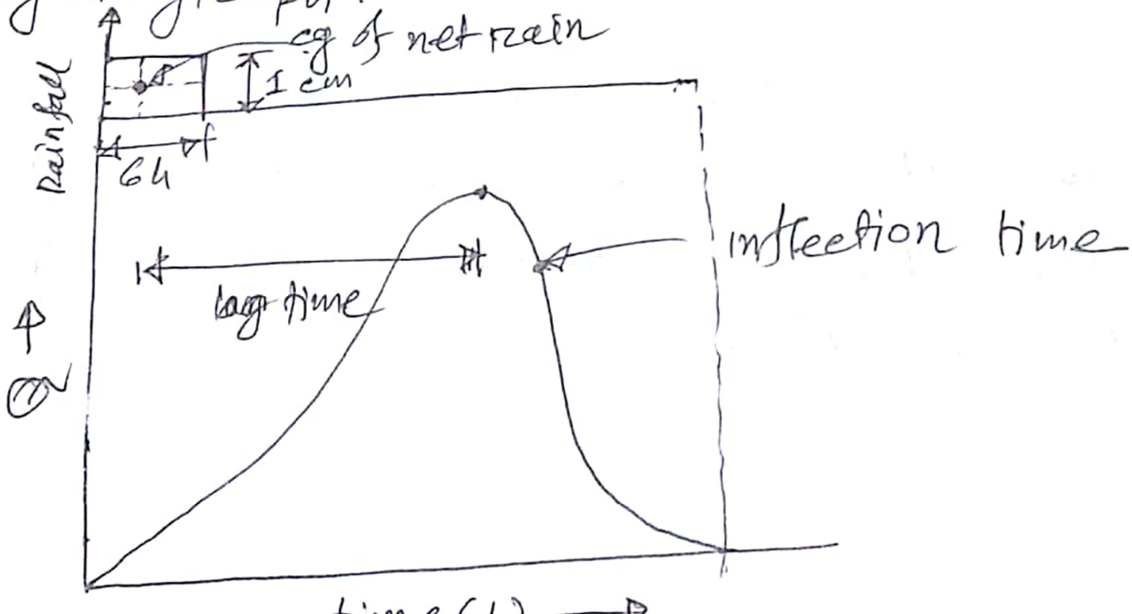


Fig. 6-h unit hydrograph.

Q. state the significance of the inflection point on the recession side of hydrograph.

⇒ significances:

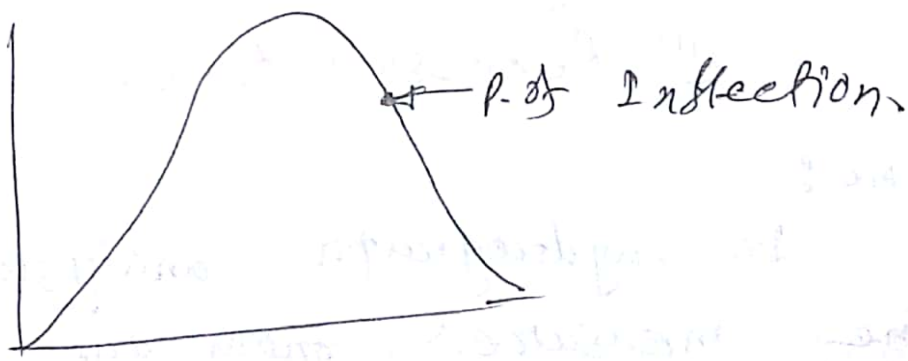
significances of point of inflections on the recession side of hydrograph are as given below —

① It indicates the end of surface inflow to the channel.

② It represents the condition of the maximum storage.

③ It is the point after which gradual withdrawl of catchment storage is started.

④ It is the point after which the hydrograph is independent of storm characteristics and dependent only on basin characteristics.



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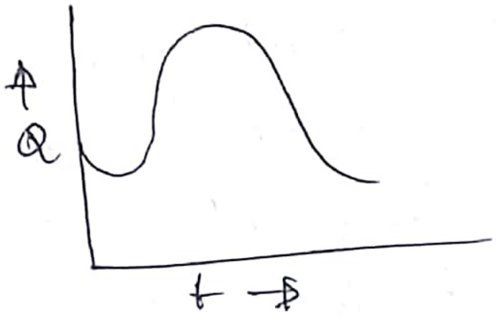
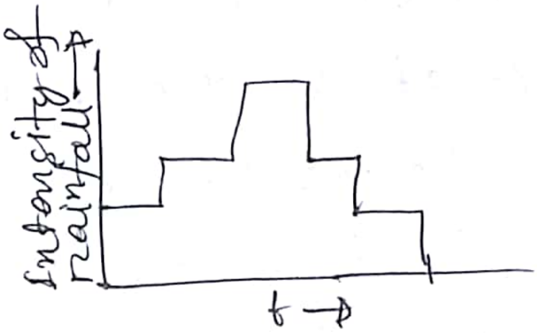
Q. What are the differences betn the hydrograph and ~~hydrogram~~ hyetograph?

⇒ **Differences:**

Hydrograph	Hyetograph
① The graph shows the variation of discharge w.r.to the time is called the hydrograph	① The graph showes the variation of intensity of rainfall w.r.to time is called hyetograph.
② Fig: 	② Fig: 

Q. Define— (i) Lag time
(ii) Recession time.

⇒ Lag time:

In hydrograph analysis lag time is the time measured from the centroid of the hyetograph of net rain to the point where hydrograph reaches it's peak value.

Recession time:

Recession time is the duration of direct surface run off after the end of net rainfall.

2K11
Q. What are the application of unit hydrograph?

→ **Application:**

① From this the design flood hydrograph can be obtained.

② A unit hydrograph of desired basin duration can be obtained from a unit hydrograph of known duration either by S-curve method or principle super-position.

2K8
Q. What do you mean by return period? Give some formulas to determine the return period.

→ **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.

3

Formulas:

① California formula —

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

$P(x_m)$ = Exceedence probability

② Hazen's formula

$$T_r = \frac{2n}{2m-1}$$

③ Weibul's formula

$$T_r = \frac{n+1}{m}$$

2k17

Q. What are the differences between the return period and exceedence probability?

⇒ Differences:

Return Period	Exceedence Probability
① It indicates average number of years within which a given event will be equalled or exceeded	① It is opposite of the return period.
② It is denoted by T_r	② It is denoted by $P(x_m)$

(3) Formula:

$$T_r = \frac{\eta}{m}$$

(3) Formula:

$$T_r = \frac{m}{\eta}$$

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Flood Routing

2KB

Q. Define flood routing? what are the uses of it?

⇒ Flood routing: It 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:

① It is establishing the height of a flood peak at a down stream location in short term flood forecasting.

② It is estimating the protection that would result from construction of reservior.

③ It is used for required level heights for flood protection.

④ It is used for ~~required level~~ ~~lei~~ determining the adequacy of spillways.

⑤ Predicting the behaviour of a river after a change in channel.

⑥ It is used for the derivation of the synthetic unit graphs.

2k7

Q. what are the differences betn the channel routing and reservoir routing?

Ans:

channel routing	Reservoir routing
① It analyzes the effect of storage of a specified channel reach on the flood hydrograph.	① It analyzes the effect of reservior storage on the flood hydrograph.
② It gives an information about flood occurrences in the river/streams.	② for this purpose information about storage vs elevation curve, inflow hydrograph are required
③ Some channel routing method are — ⓐ Muskingum method ⓑ Graphical	③ methods — ⓐ I.S.D method ⓑ Graphical

Q. What are the differences betn prism storage & wedge storage?

⇒ Differences:

Prism storage	Wedge storage
① It is formed by a volume of constant cross-section along the length of the prismatic channel.	① It is taken as the fraction of volume of the prism corresponding to (I−Q) I = inflow ; Q = outflow
② It depends on the outflow only.	② It depends on the differences bet I & Q or (I−Q)
③ Prism storage = KQ	③ Wedge storage = K·x(I−Q)

Q. Write down the two basic eqn of differential of hydraulic routing method and explain each term.

⇒ Basic two differential equations:

When there is no lateral inflow into the channel reach, the unsteady flow in the channel is described by the following two eqn which are known as saint-venant eqns —

$$\frac{\delta Q}{\partial x} + \frac{\delta A}{\delta t} = 0 \quad \text{—— (I)}$$

$$\frac{\partial v}{\delta t} + v\frac{\delta v}{\partial x} + g\left(\frac{\delta y}{\partial x} - S_o + S_f\right) = 0 \quad \text{—— (II)}$$

where,

x = The distance measured along the flow direction from same reference point to the section under consideration.

q = Discharge at the section.

A = Area of the flow at the section

t = the time available

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.

2k9

Q. Write down the procedure to estimate the design flood for any return period using Gumbel's eqn.

<u>Procedure:</u>

The procedure to estimate the

design flood for any return period using Gumbel's eqn are given below —

step-1:
from the given data on flood peaks for n years, the mean $\bar{x}$ and standard deviation S_n are computed.

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

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

step-2:
For the size sample n, the values of $\bar{y}_n$ and σ_n are obtained from the table.

step-3:
For the given return period T_p, the reduced value,

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

step-4:
Frequency factor is calculated from the above values. $K_T = \frac{y_T - \bar{y}_n}{\sigma_n}$

Step-5 :

The design flood, that can be obtained by following eqn —

$$x_T = \bar{x} + K_T \cdot S_x \quad \text{——} (*)$$

2k7

Q. What do you understand by frequency factor? How is it determined by Gumbel's eqn?

⇒ Frequency factor:

The magnitude of flood

$$x_T = \bar{x} + K_T \cdot S_x \quad \text{——} (1)$$

where,

$\bar{x}$ = mean ; S_x = standard deviation

K_T = Frequency factor

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

where, K_T is the frequency factor which depends on the type of the distribution and return period.

Determination:

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

2Y(E) Write short note on:

Standard project factor (S.P.F)

The estimation of flood likely to occur from the most severe combination of meteorological and hydrological condition but excluding extremely rare combination, is called SPF.

Maximum Probable flood: (MPF)

It includes the extremely rare and catastrophic flood and is usually confined to spillway design of very high dams.

Design flood:

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

causes of flood — Q. in BD 2K15

Surface run off is the primary causes of flood when in flow amount increases than the outflow of river or stream, then excess water tends to accumulate in river course and increases the water level. If this phenomena is continued for longer time period, the excess water also spread in the adjoining areas and thus resulting into occurrence of flood. The floods are generally affected by the characteristics of precipitation and water shed. for which precipitation characteristics have prime importance. The precipitation characteristics include type, form and it's intensity etc. The water shed characteristics are concerned, it involves soil type, texture, and structure, shape and size of water shed etc. affect the occurrence of flood.

Three main cause of flood ⟶

① Occurrence of high intensity rainfall

over the small hilly catchment.

(2) Intense rainfall over large catchment for longer duration.

(3) Rainfall over accumulated snow.

24 # What are the methods to determine the maximum flood discharge? Describe rational method.

Ans: Methods:

(1) concentration time method
(2) Emperical formula and curves.
(3) Flood frequency studies
(4) Physical indication of past flood
(5) over land flow hydrograph.
(6) Unit hydrograph.
(7) Rational method.

Rational method:

(1) Rational method is based on the application of formula—

$$Q = ciA$$

Where, c = coefficient of runoff
A = catchment area.

② The intensity of rainfall i is equal to the design intensity 'or' critical intensity of rainfall i_c corresponding to the time of concentration t_c for the catchment for a given recurrence interval T.

③ The design intensity of rainfall $i (= i_c)$ can be found from intensity – duration frequency curves, for the catchment corresponding to t_c and T.

④ If the intensity-duration-frequency curves are not available, then the design intensity can be obtained from the eqn —

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

where, P = maximum Precipitation on the catchment (cm)

t_R = storm period

⑤ When the time of concentration t_c is not known then.

$$t_c = \frac{P}{t_R}$$

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Hydrology
MMM

2K14
Q. What are the importance of ground water?
or. Write down about the scope of ground-water study.

⇒ **Importance of ground water:**

(i) Ground water is free from pollution and usable in domestic use.

(ii) It can be made available at a small capital cost and in least possible time.

(iii) In arid regions, ground water is often the only reliable source of water for irrigation.

(iv) Ground water has been an important water resource throughout the ages, like any other natural resources.

(v) Ground water is also not unlimited. The must be wisely managed against undue explotation, pollutants and salt water.

2K13
Q. Classify the subsurface water. And also explain with neat sketch.

⇒ **Classification of subsurface water:**

Zone of aeration, water table, zone of saturation, soil water zone, capillary zone.

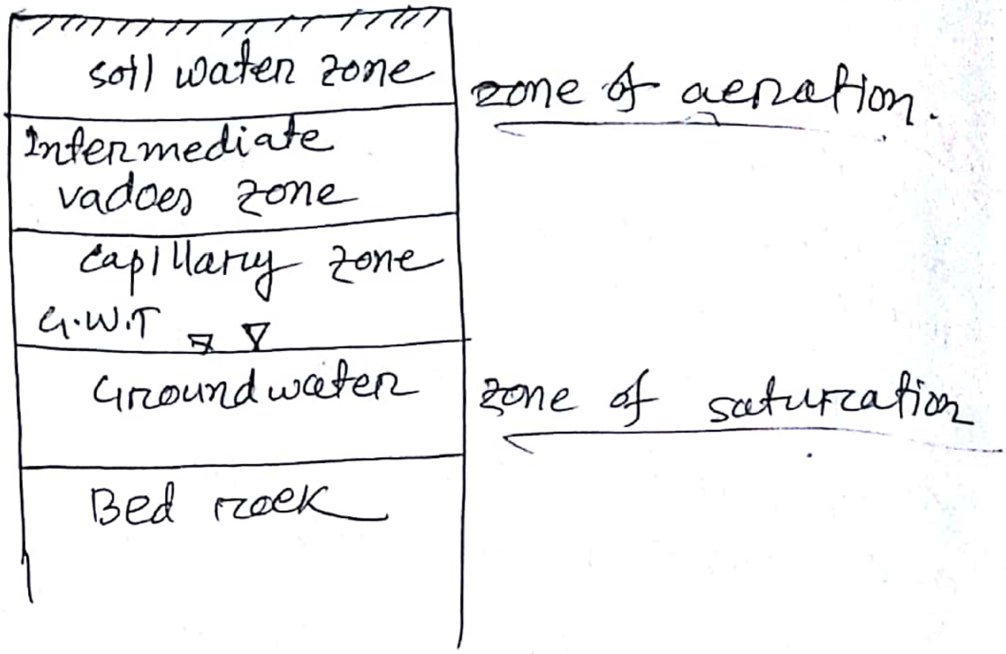


Fig. classification of sub-surface water

Q. Establish the relation, $n = S_y + S_r$.

⇒ <u>specific yeild:</u>

The volume of water, expressed as a percentage of total volume of the saturated aquifer, drained by gravity. It is expressed by S_y.

$$S_y = \frac{V_y}{V} \quad \text{——— (i)}$$

Here, V_y = volume of water drained by gravity
V = Total volume of the formation.

⇒ <u>specific retention:</u>

$$S_r = \frac{V_r}{V} \quad \text{——— (ii)}$$

V_r = volume of water retained

① + ⑪ ⇒

$$S_y + S_r = \frac{V_y}{V} + \frac{V_r}{V}$$

$$\Rightarrow S_y + S_r = \frac{V_y + V_r}{V}$$

$$\Rightarrow S_y + S_r = \frac{V_v}{V}$$

$$\Rightarrow \boxed{S_y + S_r = n}$$ [porosity, $n = \frac{V_v}{n}$]

Here the specific yeild is always less than the porosity.

Q. Differences

2K19 Zone of aeration	Zone of saturation
(i) Zone betn the water table and ground water surface	(ii) The lower zone of water table to the bed rock
(ii) Pressure is atmospheric. It is also called vadoes zone.	(ii) Pressure is greater than atmospheric
(iii) constituent: Air, or air or water.	(iii) constituent: Water. It is also called Phreatic zone

2K4

Aquifer	Aquiclude
① water can transmit from the aquifer.	① water cann't transmitted from aquiclude.
② It is sandy layer.	② It is clay layer.
③ Depending on porosity extraction of water can occur.	③ Extraction of water can't be possible.

2K13

confined aquifer	unconfined aquifer.
① An aquifer is sandwiched betn two impermeable layers.	① An aquifer starts from on imperable layer to the water layer.
② It is also called pressure aquifer or artesian aquifer.	② It is also called water table aquifer.
③ Sandy layer in betn the two clay layers.	③ clay layer to the water table.

Specific yeild	Specific retention
① The ratio of the volᵐ of water drained by gravity and total volᵐ of aquifer formation.	① The ratio of the volume of water retained due to molecular friction and surface tension and total volume of formation.
② expressed as S_y	② Expressed as S_r.
③ Mathematically – $S_y = \frac{V_y}{V}$	③ Mathematically – $S_r = \frac{V_r}{V}$

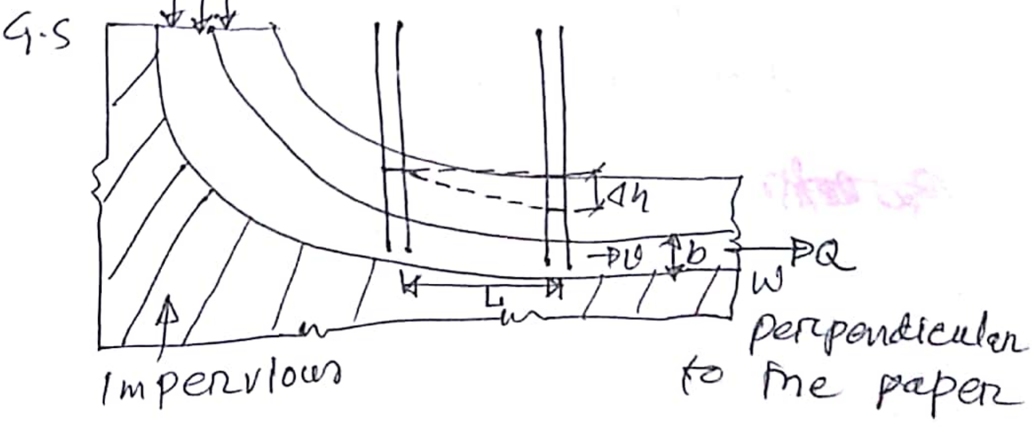
2K12 2K15

Q. Explain the Darcy's law with figure.

⇒ Darcy's law:

The velocity of flow in a porous medium is proportional to the hydraulic gradient.

Explanation:



where, water flows through aquifer and in v velocity and water is extracted by two way mathematically it is expressed by darcy's law —

$$V \propto i$$

$$\Rightarrow V = Ki$$

$$\Rightarrow V = K \cdot \frac{\Delta h}{L} \quad \text{—— (i)}$$

where,

K = coefficient of permeability or hydraulic conductivity

Δh = head loss

L = horizontal distan of head loss. occurance

Here discharge $Q = AV$

$$\Rightarrow Q = A \times Ki$$

$$\Rightarrow Q = Kibw \quad \text{—— (ii)}$$

b = saturated thickness of the aquife

w = width of the aquifer.

If $i = \frac{\Delta h}{L} = 1$ unit, $b = 1$ unit, $w = 1$ unit so,

from (ii) $Q = K$.

কাঁহাজি।

Well Hydraulics

2K14

Q. Define well hydraulics. Write down the conditions of well hydraulics.

⇒ Well hydraulics:

The theory of ground-water movement around well is known as well hydraulics.

There are two conditions to be considered in well hydraulics, as —

(i) Steady state flow

(ii) Unsteady state flow

Steady state flow: If the fluid characteristics (velocity, surface tension, density etc) are not changed with the change of time, then the state of flow of fluid is called steady state of flow.

Unsteady state flow:

If the fluid characteristics are changed with the change of time, then the state of flow of fluid is called the unsteady state flow.

Hydrology

Problems :—

Mithun chakrabartty

RUET ; CE'12001З

Run off

Ex- 4.1

(Problem— Raghunath 102 Page)

The contour map of a basin is sub divided into a number of square grids of equal size by drawing horizontal and vertical lines as shown in fig. P-4.1. The contour interval is 25m. The number of contour intersections by vertical lines is 75 and by horizontal lines 126. The total length of the vertical grid segments (after multiplying by the scale) is 53260m and of the horizontal grid segments 55250m. Determine the mean slope of the basin.

Sol^n

contour intersection by vertical lines/horizontal

Slope in the vertical direction

$$S_y = \frac{N_c * C.I}{\Sigma Y}$$ → contour interval

$$= \frac{75 * 25}{53260} = 0.0352 \; m/m$$

slope in the horizontal direction

$$S_x = \frac{N_c * CI}{\Sigma X} = \frac{126 * 25}{55 * 250} = 0.0570 \; m/m$$

∴ Mean slope of the basin

$$S = \frac{S_y + S_x}{2} = \frac{0.0352 + 0.0570}{2} = 0.0461 \; m/m \text{ OR, } 4.61\%$$

[P.T.O]

Also, from the Hortons eqn —

$$s = \frac{1.5(e.I)\,N_c}{\Sigma L}$$

$$= \frac{1.5 * 25(75+126)}{(53260+55260)} = 0.0695$$

$$= 6.95\%$$ (Ans)

Stream gauging

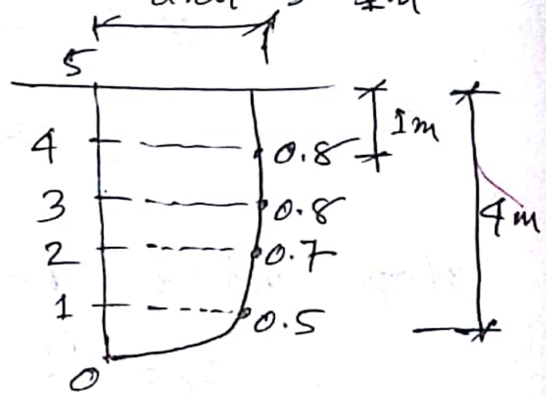
22/10 (Raghunath - 203 Page)

3(b) Following velocities were recorded in a stream with a current meter.

Depth above bed (m) :	0	1	2	3	4
velocity (m/sec) :	0	0.5	0.7	0.8	0.8

Find the discharge per unit width of stream near the point of measurement. Depth of flow at the point was 5m.

unit = b = 1m



soln

Here,

at 0.2d = 0.2 * 5 = 1m

velocity = 0.8 m/sec

at 0.8d = 0.8 * 5 = 4m

velocity = 0.5 m/sec

Now, $Q = AV$

$= bdV$

$= 1 * 5 * V$

$\therefore Q = 5V$ —— (1)

$$\therefore V = \frac{V_{0.2d} + V_{0.8d}}{2} = \frac{0.8 + 0.5}{2} = 0.65 \text{ m/sec.}$$

① ⇒

$$Q = 5V$$

$$\therefore Q = 5 * 0.65 = 3.25 \text{ m}^3/\text{sec}$$ (Ans)

Hydrograph

Ex. 5.4

The ordinates of a 4-hour unit hydrograph for a particular basin are given below. Derive the ordinates of (i) the S-curve hydrograph and, (ii) the 2-hour unit hydrograph and plot them. Area of the basin is 630 km².

Time (hr)	Discharge (cumec)	Time (hr)	Discharge (cumec)
0	0	14	70
2	25	16	30
4	100	18	20
6	160	20	6
8	190	22	1.5
10	170	24	0
12	110	–	–

Soln

(see 148 for formula)

Time (hr)	4 hr UGO (cumec)	S curve additions cumec — Unit storms after every 4 hr = tr					S curve ordinates (cumec) ② + ③	lagged S-curve (cumec)	S-curve difference (cumec) ④-⑤	2 hr UGO ⑥ × 4/2 (cumec)
1	2			3			4	5	6	7
0	0	-	-	-	-	-	0	-	0	0
2	25	-	-	-	-	-	25	0	25	50
4	100	0	-	-	-	-	100	25	75	150
6	160	25	-	-	-	-	185	100	85	170
8	190	100	0	-	-	-	290	185	105	210
10	170	160	25	-	-	-	335	290	65	130
12	110	190	100	0	-	-	400	335	45	90
14	70	170	160	25	-	-	425	400	25	50
16	30	110	190	100	0	-	430	425	5	10*
18	20	70	170	160	25	-	445	430	15	30
20	6	30	110	190	100	0	436	445	-9	-18*
22	1.5	20	70	170	160	25	446.5	436	10.5	21
24	0	6	30	110	190	100	436	446.5	-10.5	-21*

Ex- 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 stream flow at successive 3 hr interval.

Solution.

DRO peak = Flood peak − B.F
= 150 − 6
= 144 cumec.

$P_{net} = \frac{\text{DRO Peak}}{\text{UG peak}} = \frac{144}{36} = 4 \text{ cm}$

Depth of storm rainfall.

$P = P_{net} + \text{losses}$
$= 4 + 0.6 * 6 = 7.6 \text{ cm}$ (Ans)

DRO = UGO * P_{net} ; DRO + B.F = TRO

Hence multiplying the given UGO by 4 cm and adding 6 cumec, the stream flow ordinates at successive 3 hr intervals are; 6, 66, 150, 126, 76, 40, 18, 6 cumec respectively.

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Flood Estimation and control

Ex-8.1

Determine the peak discharge at the concentration point for a basin of 80 hectares having a time of concentration of 30 minutes due to a 5cm flash storm, if the duration of the storm is (i) 60 min (ii) 30 min, and (iii) 15 min. Assume a ϕ index of 2.5 cm/hr for the entire basin. When the storm duration is 15 minutes, only drainage from 60% of the area of the basin reaches the concentration point.

Soln

$Q = (i - \phi)A$; where i = Intensity of rain fall, cm/hr.

(i) $Q = (5 - 2.5)80 = 200$ ha cm $= 200 \times 0.028$
$= 5.6$ cumec

(ii) $Q = (\frac{5}{30} \times 60 - 2.5)80 = 600$ ha-cm $= 600 \times 0.028$
$= 16.8$ cumec

(iii) $Q = (\frac{5}{15} \times 60 - 2.5)(0.60 \times 80) = 840$ ha-cm
$= 840 \times 0.028$
$= 23.52$ cumec.

It is seen from (i) and (ii) that the peak discharge at the concentration point is maximum when the duration of storm is equal to the time of concentration

(a) gives the highest flood, since only 60% of the area drains, the concentration time becomes less and the intensity of rainfall is very high during this time..

(235 Page - V.V.S)

Ex-8.2 (234 Page)

For an area of 20 hectares of 20 minutes concentration time, determine the peak discharge corresponding to a storm of 25 years recurrence interval. Assume a runoff co-efficient of 0.6. From intensity-duration frequency curves for the area. for T = 25-yr, t = 20 min, i = 12 cm/hr.

soln for $t = t_c = 20$ min ; $T = 25$ yr ; $i = i_c = 12$ cm/hr

$$Q = CiA$$
$$= 0.6 * 12 * 60$$
$$= 144 \text{ ha-cm/hr} = 144 * 0.028$$
$$= 4 \text{ cumec}$$

[1 ha-cm/hr = $\frac{1}{36}$ cumec = 0.028 cumec]

Probability and stochastic method

Design flood

Reddi → 496 Page

Ex - 14.5

Ex - 14.6

Ex - 14.7 (499)

Ex - 14.8 (501)

Ex - 14.9

} next

Eqn

$$x_T = \bar{x} + \left(\frac{y_T - \bar{y}_n}{\sigma_n}\right) \cdot S_x$$

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

Flood Routing

Reddi —

Ex - 13.4 (461)

Ex - 13.5 (466)

Infiltration

Reddi →

Ex – 8.3 (265)

Ex – 8.4

Ex – 8.5

Ex – 8.6 (269)

Ex – 8.7

Design Flood

Reddi 496 → (14.5 Do (see))

2*10 Ex: 14.6 From the analysis of available data on annual flood peaks of a small stream for period of 35 years, the 50 year and 100 year flood have been estimated to be 660 m3/s and 740 m3/s using Gumbel's method. Estimate the 200 year flood for the stream.

Soln From table – 14.3 (494 page). for a record length of n = 35 years –

$$\bar{y}_n = 0.54034 \quad \text{and} \quad \sigma_n = 1.12847$$

using Gumbel's method –

$y_{50} = -\ln \ln\left(\frac{50}{49}\right) = 3.90194$

$K_{50} = \frac{3.90194 - 0.54034}{1.12847} = 2.9789$

$y_T = -\ln\left(\ln\left(\frac{T}{T-1}\right)\right)$

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

Similarly,

$y_{100} = -\ln \ln\left(\frac{100}{99}\right) = 4.60015$

$K_{100} = \frac{4.60015 - 0.54034}{1.12847} = 3.59762$

$x_{50} = \bar{x} + K_{50} \cdot S_x$

or, $660 = \bar{x} + 2.9789\, S_x$ —— (I)

again $x_{100} = \bar{x} + K_{100} \cdot S_x$

$\Rightarrow 740 = \bar{x} + 3.59762\, S_x$ —— (II)

solving (I) and (II) $\Rightarrow$

$\bar{x} = 279.83\ m^3/s$; and $S_x = 129.3\ m^3/s$

Now, $y_{200} = -\ln \ln\left(\frac{200}{199}\right) = 5.29581$

$K_{200} = \frac{5.29581 - 0.54034}{1.12847} = 4.2141$

$x_{200} = \bar{x} + K_{200} \cdot S_x$

$= 279.83 + 4.2141 \times 129.3 = 819.71\ m^3/s.$

$\therefore$ The 200 year flood for the stream would be $820\ m^3/s$. (Ans)

Ex 14.7 (499 → see)

Ex 14.8 ~~The analysis~~

A coffer dam is designed for a 25 year flood and constructed. If it takes 5 years to complete the construction of main dam, what is the risk that the coffer dam may fail before the end of the construction period? what return period in the design of coffer dam would have reduced the risk to 10%

Soln The risk of failure is given by

$$R = 1 - \left(1 - \frac{1}{T}\right)^N$$

Here, T = 25 years and N = 5 years.

Therefore

$$R = 1 - \left(1 - \frac{1}{25}\right)^5 = 0.1846 = 18.46\%$$

If the risk is to be reduced to 10%, we have —

$$0.1 = 1 - \left(1 - \frac{1}{T}\right)^5, \text{ which gives}$$

$$\Rightarrow T = 47.96 \text{ year} \simeq 50 \text{ years (Ans)}$$

2K15

Ex-14.9 The analysis of a 30 year flood data at a point on a river yeilded $\bar{x} = 1200\ m^3/s$ and $S_x = 680\ m^3/s$. For what discharge would you design the structure at this point to provide 95% assurance that the structure would not fail in the next 50 years?

Soln

Assurance = 95 %

therefore risk; $R = 100 - 95 = 5\%$

$\Rightarrow R = 0.05$

The life period $N = 50$ years

eqn $\Rightarrow 0.05 = (1 - (1 - \frac{1}{T_r})^{50}$

$\Rightarrow T_r = 975.3$ years.

Now, Gumbel's method is used to estimate the flood with a return period of 975.3 years.

From Table 14.3 for $n = 30$; we obtain

$\bar{y}_n = 0.53622$ and $\sigma_n = 1.11238$ —

$\therefore y_T = -\ln \ln \left(\frac{975.3}{974.3}\right) = 6.88223$

again. $K_T = \frac{6.88223 - 0.53622}{1.11238} = 5.706$

from eqn the design flood is given by —

$x_T = 1200 + 5.705 \times 650$

$= 4908.25 \; m^3/s$.

the structure has to be designed for a ~~design~~ discharge of 4910 m^3/s.

~~Flood Routing~~

Infiltration

Ex. 8.3

The total observed runoff volume during a 6h storm with a uniform intensity of 15 cm/h is 21.6×10^6 m^3. If the area of the basin is 300 km^2, find the average infiltration rate for the basin.

$21.6 Mm^3$

Soln Total rainfall = Intensity of rainfall × Duration

$= 1.5 \times 6 = 9$ cm

Volume of runoff $= 21.6 \times 10^6$ m

Area of the basin = 300 km^2 $= 300 \times 10^6$ m^2

Depth of runoff $= \dfrac{\text{Vol. of runoff}}{\text{Area of the basin}}$

$= \dfrac{21.6 \times 10^6}{300 \times 10^6} = 0.072 m = 7.2$ cm

Total infiltration $= 9 - 7.2 = 1.8$ cm

Average infiltration rate $= \dfrac{1.8}{6}$

$= 0.3$ cm/h

$= 3$ mm/h.

Ex- 8.4 A 6 h storm produced rainfall intensities of 7, 18, 25, 12, 10 and 3 mm/h in successive one hour intervals over a basin of 800 sq.Km, The resulting runoff is observed to be 2640 hectare - metres. Determine ϕ-index for the basin.

soln Total volm of runoff = 2640 hectare-metres

$= 2640 \times 10000$

$= 264 \times 10^5 \, m^3$.

Area of basin $= 800 \, Km^2 = 800 \times 10^6 \, m^2$

$\therefore$ Depth of runoff $= \frac{Vol^n}{Area} = \frac{264 \times 10^5}{800 \times 10^6} = 0.033 \, m$

$= 33 \, mm$

The given rainfall hyetograph is shown —

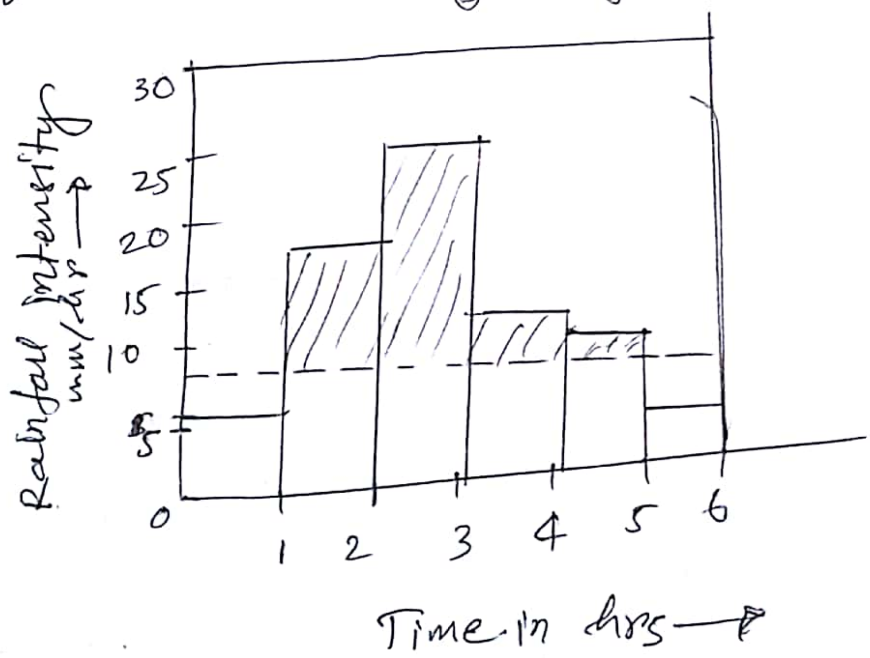

Fig. ϕ-index of ex 8.4

By trial and error if ϕ-index is choose to be 8 mm/h, the rainfall volume above the ϕ-index line is equal to ——

$\Rightarrow 0 + (18-8) + (25-8) + (12-8) + (10-8) + 0$

$= 33$ mm

This is exactly equal to the observed runoff. Therefore $\phi = 8$ mm/h.

<u>EX - 8.5</u> 286 page

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2K12

P→5

Sheet solution

Water losses

The infiltration capacity in a basin is represented by Horton's eqn as $f_p = 3.0 + e^{-2t}$, where f_p is in cm/h and t is in hours. Assuming the infiltration to take place at capacity rates in a storm of 60 minutes duration, estimate the depth of infiltration in (i) the first 30 mins and the second 30 minutes of the storm.

Soln

(i) the first 30 minutes —

30 min = 0.5 hr

$$F = \int_0^{t_1} f \cdot dt$$

$$= \int_0^{0.5} (3 + e^{-2t})\, dt$$

$$= \left[3t + \frac{e^{-2t}}{-2}\right]_0^{0.5}$$

$$= \left[3t - 0.5 * e^{-2t}\right]_0^{0.5}$$

$$= \left[3 * 0.5 - 0.5 * e^{-2*0.5}\right] - \left[-0.5 * e^{-2*0}\right]$$

$= 1.82$ cm. (Ans)

(ii) for second 30 min —

$$F = \int_{t_1}^{t_2} f\, dt$$

$$= \int_{0.5}^{1} (3 + e^{-2t})\, dt$$

$$= \left[3t - 0.5 * e^{-2t}\right]_{0.5}^{1}$$

$$= \left[3 - 0.5 * e^{-2}\right] - \left[3 * 0.5 - 0.5 * e^{-2*0.5}\right]$$

$$= 1.62 \text{ cm}$$

A Precipitation

Ex-5.12 (Reddi)

Rainguage station X did not function for a part of a month during which a storm occurred. The storm produced rainfalls of 84, 70 and 96 mm at three surrounding stations A, B and C respectively. The normal annual rainfalls at the stations X, A, B and C are respectively 770, 882, 736 and 944 mm. Estimate the missing storm rainfall at station X.

Soln

The missing rainfall is given by —

$$P_x = \frac{1}{3}\left[\frac{N_x}{N_a} P_a + \frac{N_x}{N_b} P_b + \frac{N_x}{N_c} \cdot P_c\right]$$

Here,

$N_x = 770$ mm
$N_a = 882$ mm
$N_b = 736$ mm
$N_c = 944$ mm

and

$P_a = 84$ mm
$P_b = 70$ mm
$P_c = 96$ mm

$$\therefore P_x = \frac{1}{3}\left[\frac{770}{882} * 84 + \frac{770}{736} * 70 + \frac{770}{944} * 96\right]$$

$= 74.957$ mm

≈ 75 mm

The missing storm rainfall at raingauge station X may be taken as 75 mm.

Pro → 14

Ex-5.13 : Station X failed to report the rainfall recorded during a storm. With respect to east-west and north-south axes set up at station X, the coordinates of 4 surrounding gauges, which are the nearest to station X in the respective quadrants, are (10,15), (-8,5), (-12,-9) and (5,-15) Km respectively. Determine the missing rainfall at X, if the storm rainfalls at the four surrounding gauges are 73, 89, 68 and 57 mm respectively.

soln $P_1 = 73$ mm ; $P_2 = 89$ mm ; $P_3 = 68$ mm ; $P_4 = 57$ mm

Let, r_1 be the distance betn the station in the first quadrant and the station X. Then we have

$$r_1^2 = 10^2 + 15^2$$

$$\Rightarrow r_1^2 = 325$$

The weightage factor for this station $= \frac{1}{r_1^2}$

$$= \frac{1}{325}$$

$$= 0.00308$$

Similarly we obtain,

$$r_2^2 = (-8)^2 + 5^2 = 89 \; ; \; \frac{1}{r_2^2} = 0.01124$$

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$r_3^2 = (-12)^2 + (-9)^2 = 225$; $\frac{1}{r_3^2} = 0.00444$

$r_4 = (5)^2 + (-15)^2 = 250$; $\frac{1}{r_4^2} = 0.004$

Now

$$P_x = \frac{\left[\frac{1}{r_1^2} * P_1 + \frac{1}{r_2^2} * P_2 + \frac{1}{r_3^2} * P_3 + \frac{1}{r_4^2} * P_4\right]}{\left[\frac{1}{r_1^2} + \frac{1}{r_2^2} + \frac{1}{r_3^2} + \frac{1}{r_4^2}\right]}$$

$$\therefore P_x = \frac{0.00308 * 73 + 0.01124 * 89 + 0.00444 * 68 + 0.004 * 57}{0.00308 + 0.01124 + 0.00444 + 0.004}$$

$$= \frac{1.75512}{0.02276}$$

$$= 77.11 \text{ mm}$$

The missing rainfall at X may be taken as 77.11 mm (A)

S→ 17

Ex-2.4 (Raghu) (33 Page)

S→19 (Ex-5.1 Reddy; 111)
[5.3]

The annual rainfalls in mm recorded at a rainfall station for a period of 19 years from 1970 to 1988 are given below:

520, 615, 420, 270, 305, 380, 705, 600, 350, 550, 560, 400, 520, 435, 395, 290, 430, 1020 and 900.

Construct the frequency curve and hence find the 75% and 50% dependable rainfall. What is the probability that a rainfall 800mm or more occurs in any year?

Soln

Year	Annual rainfall	Reading in decending order	Rank (m)	$P = \frac{m}{n+1} \times 100$ (%)
1970	520	1020	1	5
1971	615	900	2	10
72	420	705	3	15
73	270	615	4	20
74	305	600	5	25
75	380	560	6	30
76	705	550	7	35
77	600	520	8	45
78	350	520	9	50
79	550	435	10	55
80	560	430	11	60
81	400	420	12	65
82	520	400	13	70
83	435	395	14	75
84	395	380	15	80
85	290	350	16	85
86	430	305	17	90
87	1020	290	18	95
88	900	270	19	

$n = 19$

(Ex– 5.15 Reddi)

The average annual rainfall in cm at 4 existing raingauge stations in a basin are 105, 79, 70 and 66. If the average depth of rainfall over the basin is to be estimated within 10% error. determine the additional number of guages needed.

soln

Mean of the rainfalls at the existing guages is given by—

$$\bar{x} = \frac{1}{m} \sum x_i = \frac{105+79+70+66}{4}$$

$$= \frac{320}{4} = 80 \text{ cm.}$$

The standard deviation of the rainfalls is given by—

$$S_x^2 = \frac{\sum (x_i - \bar{x})^2}{(m-1)}$$

$$\therefore S_x^2 = \frac{(105-80)^2 + (79-80)^2 + (70-80)^2 + (66-80)^2}{(4-1)}$$

$$= \frac{922}{3} = 307.33$$

or, $S_x = \sqrt{307.33} = 17.53$ cm

$$C_v = \frac{S_x}{\bar{x}} * 100 = \frac{17.53}{80} * 100 = 21.91$$

$P = 10\%$

$$\therefore N = \left[\frac{C_v}{P}\right]^2 = \left(\frac{21.91}{10}\right)^2 = 4.80$$

Additional gauges required $= N - n$
$= 4.8 - 4$
$= 0.8$ say 1.

100 ha = 1 Km² ; 1 ha = 10000 m²

Stream flow Measurement : (Reddy) (107 Page)

- 1 cumec-day = 86400 m^3 = 8.64 ha-m
- 1 cumec-month = 2592000 m^3 = 259.2 ha-m
- 1 million m^3 = 100 ha-m = 11.574 cumec-days
- 1 cumec-year = 31536000 m^3 = 31.536 million m^3 = 3153.6 ha-m
- 1 ha-m = 1 sq.km-cm = 10000 m^3 = 0.01 million m^3.

2K15 (Reddi - 198)

Ex. 6.6 The mean daily flows at a gauging station for a period of 7 days are 7, 27, 58, 41, 31, 20 and 13 m^3/s respectively. What is the total volume of stream flow at the site in cumec-days? and in hectare-metres? What is the mean flow rate for the week. If the drainage area at the site in 100 km², what is the runoff volume in cm?

Soln

Total volume of flow (7 days).

= 7+27+58+41+31+20+13 = 197 cumec-day

= 197 * 86400 = 17020800 m³.

= 1702.08 ha-m.

Mean flow for the week = $\frac{197 \text{ cumec-days}}{7 \text{ days}}$

= 28.143 m³/s.

Depth of runoff = $\frac{\text{Volume of runoff}}{\text{Area of the basin}}$

$= \frac{17020800}{100 \times 10^6}$

= 0.170208 m

= 17.021 cm (Ans)

Ex-6.7 what volume is represented by 57 mm of runoff depth from a basin of area 3300 km²? Give the answer in m³. cumec-days ha-m and million cubic metres.

Sol^n

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

$= \frac{1881 \times 10^5}{10000} = 18810$ ha-m

$= \frac{1881 \times 10^5}{86400} = 2177.08$ cumec-day

Stream gauging

S-27 Followings velocities are recorded in a station with a current meter.

Depth above bed (m)	0	1	2	3	4
Velocity (m/sec)	0	0.8	1.0	1.2	1.2

Find the discharge per unit width of stream near the point of measurement. Depth of flow at the point was 5.0 m.

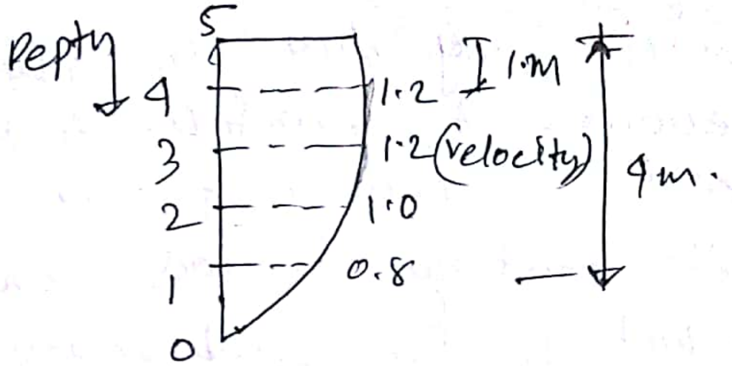
Sol^n

$Q = AV$

$= b \times d \times V$

$= 1 \times 5 \times V$

$\Rightarrow Q = 5V$ —— ①



At $0.2d = 0.2 * 5 = 1\ m$.

velocity $= 1.2\ m/se$

At $0.8d = 0.8 * 5 = 4\ m$:

velocity $= 0.8\ m/se.$

$\therefore V = \frac{V_{0.2d} + V_{0.8d}}{2} = \frac{1.2 + 0.8}{2} = 1\ m/se.$

$\therefore Q = 5 * 1\ m^3/se$,

(5-28) (2K8)

~~For~~ any day in July there is 20% chance of rainfall. A building slab is to be cast which requires no rainfall during it's casting period extending over 5 days. What is the probability of having no rainfall during this days and one rainy day during the period.

Patna book

Soln

Probability of having no rainfall

$r = 0$; $n = 5$; $p = 0.2$; $q = 0.8$

$P(r=0) = {}^nC_r \cdot p^r \cdot q^{n-r}$

$= {}^5C_0 * (0.2)^0 * (0.8)^{5-0} = 0.328$

Probability of having 1 rainy day

$r = 1$; $p = 0.2$; $q = 0.8$; $n = 5$

$P(r=1) = {}^nC_r \cdot p^r \cdot q^{n-r}$

$= {}^5C_1 * (0.2)^1 * (0.8)^{5-1} = 0.41$

Rainfall records of 80 years were scanned and it was found that the probability of precipitation of 300 mm in a day is 0.02. Find the probability of three precipitation of one day

magnitude exceeding 300mm in the next 10 years.

Soln

Given: $P = 0.02$; $n = 10$

$\lambda = np = 10 \times 0.02 = 0.2$

$r = 3$

$$P(r=3) = \frac{e^{-\lambda} \cdot \lambda^r}{r!}$$

$$= \frac{e^{-0.2} \times 0.2^3}{3!} = 0.0011 = 0.11\%$$

Ans

For design of a project, if an engineer is allowed to take 5% risk in the life span (40 years) of the project, then what is the return period?

Soln $n = 40$

Probability of occurrence = risk = 0.05

So, if T is the return period

$$0.05 = \left\{1 - \left(1 - \frac{1}{T}\right)^n\right\}$$

$$\Rightarrow 0.05 = 1 - \left(1 - \frac{1}{T}\right)^{40}$$

$\Rightarrow T = 780.33$ yrs (Ans)

Probability of occurrence of rain fall on any day from June to october is 0.20. what is the probability that 5 out of 20 days in the month of July will remain dry?

Soln $p = 0.2$; $q = 0.8$; $n = 20$; $r = 5$

$$P(r=5) = {}^{20}C_5 \cdot (0.2)^5 \cdot (0.8)^{20-5} = 17.46\%$$

2K9

~~# A rivers is dry for 5% days in a years.~~

2K15

A rainfall of certain high intensity is expected to occur once in 20 years. what ~~chance~~ is the chance of occurrance in any year? what is the probability that it may occur in the next 12 year?

Soln chance of occurrence in any year. $P = \frac{1}{T} = \frac{1}{20} = 0.05$ or 5%. Ans

The probability that it may occur in next 15 yr $N = 15$ yr

$\therefore P = 1 - (1 - \frac{1}{T})^N \Rightarrow P = 1 - (1 - \frac{1}{20})^{15} = 0.5367$ or, 53.67% Ans

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S-D28

$Q = AV$

$= bd * V_m$

$Q = d * V_m$ —— ①

$V_m = \frac{V_{0.2d} + V_{0.8d}}{2}$

for ~~each~~ 1st strip ; $d = 1.4$; $V_m = \frac{0.4 + 0.20}{2} = 0.30$

$\therefore Q_1 = 1.4 * 0.30 = 0.42 \ m^3/s$.

$Q = Q_1 + Q_2 \ldots \ldots$

(Do (নিজে))

S-D61

$n = 16$

$\Sigma x_i = 22 + 35 + 78 + 262 + 332 + 278 + 230 + 188 + 152 + 123 + 100 + 80 + 69 + 58 + 51 + 46$

$= 2104$

$\bar{x} = \frac{\Sigma x_i}{n} = \frac{2104}{16} = 131.5$

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$\Sigma(x_i-\bar{x})^2$ ~~= (131.5 - 22)~~

$= (22-131.5)^2 + (35-131.5)^2 + (78-131.5)^2$
$+ (262-131.5)^2 + (332-131.5)^2 + (278-131.5)^2$
$+ (230-131.5)^2 + (188-131.5)^2 + (152-131.5)^2$
$(123-131.5)^2 + (160-131.5)^2 + (80-131.5)^2$
$+ (69-131.5)^2 + (58-131.5)^2 + (51-131.5)^2$
$(46-131.5)^2$

$= 142988$

$\therefore s = \sqrt{\dfrac{\Sigma(x_i-\bar{x})^2}{n-1}}$

$= \sqrt{\dfrac{142988}{16-1}} = 97.63$

$\therefore \bar{x}_n = 131.5 \;;\; s_n = 97.63$

(Do them)