GPSC - CIVIL

Engineering Hydrology

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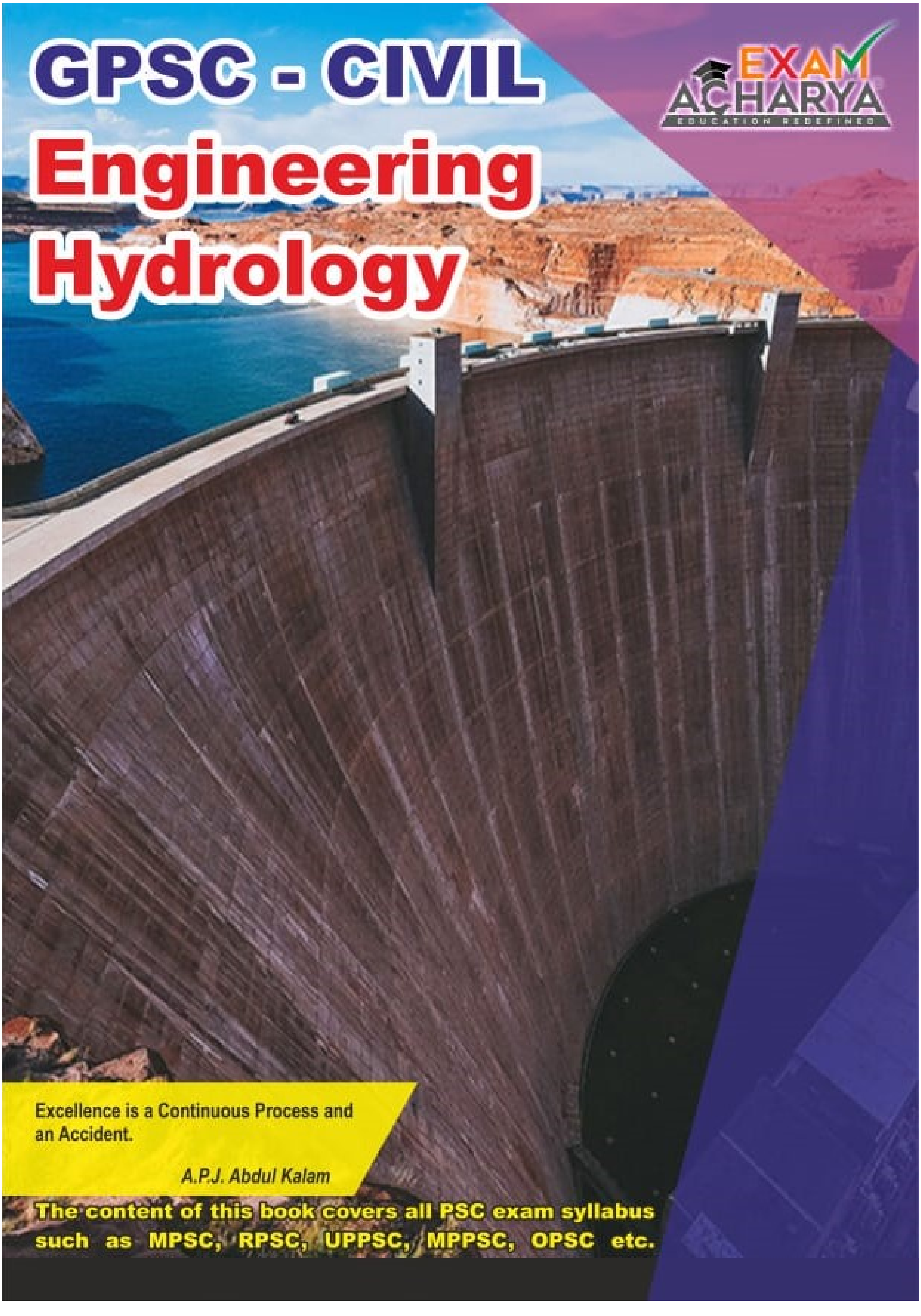
EDUCATION REDEFINED



Excellence is a Continuous Process and an Accident.

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

PREFACE

Engineering Hydrology, a comprehensive refresher for GPSC, is designed for aspirants who are targeting GPSC and definitely useful for other job oriented technical exams such as RPSC, MPSC, MPPSC, UPSC, RRB JE, SSC JE etc by Exam Acharya. This book provides knowledge of the field and also helpful hints to make the study and understanding easier to the aspirants. Each chapter in this book has been meticulously designed by the state PSC's toppers and experienced faculties with the idea of maximizing the potential of an individual in a limited time. Every chapter in the book is logically divided to various sections while ensuring that the content in the book is self-sufficient and requires no cross referencing. Extra efforts have been made to simplify and summarize the theoretical aspects of the subject. Over all the whole content of the book furnishes the students with the knowledge of the subject and paves a confident path for the aspirants to accomplish success in state PSC's.

Key Features:

- Conforms to the latest syllabus prescribed by GPSC.
- Presents each topic in a lucid manner for a quick recap.
- Facilitates quick revision of concepts.

Prepared by

Mukesh Rai

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CHAPTER – 1

INTRODUCTION HYDROLOGY

Hydrology means the science of water. Hydrology deals with the occurrence, circulation and distribution of water on the earth & atmosphere. Practical application of hydrology is required in the design and operation of hydraulic structure, water supply, irrigation, hydro power generation, flood control etc.

HYDROLOGICAL CYCLE

- Water occurs on the earth and atmosphere in all three states (liquid, gas, solid). There are endless circulations of water between the earth and atmosphere. This circulation is called hydrologic cycle.
- Water on the earth exists in a space called hydrosphere and it has boundary 15 km up into atmosphere and 1 km down into lithosphere.
- Sun and Coriolis force (due to this force, wind moves in different direction) play important role in completion of hydrologic cycle.
- Sun evaporates water and Coriolis force by controlling wind circulate the water vapour where precipitation occurs.

Components of Hydrological Cycle

(i) Evaporation

(ii) Precipitation

(iii) Runoff

(i) Evaporation

When water come into contact with heat radiation, it turns into vapour. It is called evaporation.

- In hydrologic cycle, evaporation mainly occur from ocean.

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Building Material and Construction

Dream is not that which you see while sleeping it is something that does not let you sleep.

A.P.J. Abdul Kalam

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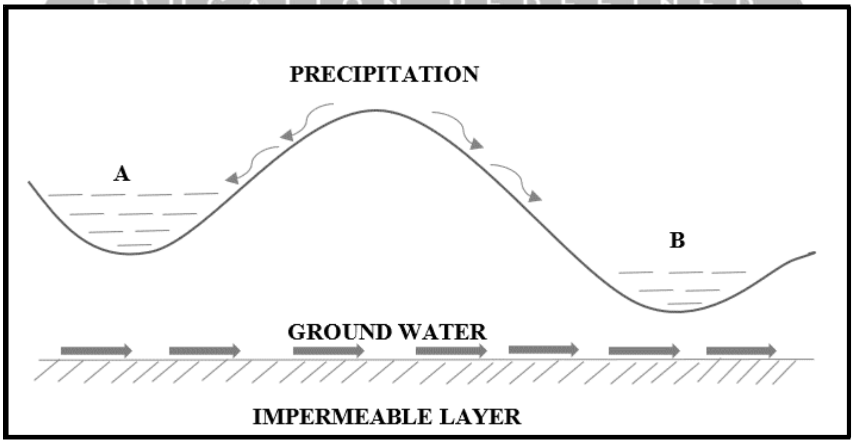
CATCHMENT AREA / DRAINAGE BASIN / DRAINAGE AREA / WATERSHED

The area of land from which the runoff comes into a stream is called the catchment area of that stream. A catchment area is separated from its neighbouring areas by a ridge called divide or watershed.

If the catchment has no outlet point than it is called a closed catchment. In closed catchment water converges to a single point inside the basin known as sink, which may be a permanent lake, or a point where surface water is lost underground.

Leakage of Catchment

We measure the runoff at the outlet of catchment area, sometimes it happens that runoff from nearby catchment also come, so due to this error will come in result. This generally occur due to subsurface water. Thus, the catchment leakage is said to occur. It is also said to occur when to topographic divide are not coincident with ground water divide.



HYDROLOGICAL EQUATION / WATER BUDGET EQUATION

The quantity of water going through various individual paths of the hydrological cycle in a given system can be described by the continuity principle known as Water Budget Equation or Hydrologic Equations. It is based on Conservation of Mass.

For a given catchment area in an interval of time Δt, the continuity equation of water is

Mass of water inflow - Mass of water outflow = Change in mass of water storage

Water Budget equation for a catchment for a particular time Δt

$$P - R - G - E - T = \Delta S$$

P = Precipitation

R = Surface runoff

G = Net ground water flow out of the catchment

E = Evaporation

T = Transpiration

ΔS = Change in Storage

Residence Time

The residence time is the average duration for a water molecule to pass through a subsystem of hydrological cycle.

Average time taken by water molecule to pass through a particular part of hydrological cycle is known as residence time of that part of hydrological cycle.

Residence time is calculated as

$$T_r = \frac{S}{Q}$$

S = Storage of water in that particular subsystem or part.

Q = Flow of water through that particular subsystem or part.

Scope of Hydrology

The study of hydrology helps us to know

(i) The maximum probable flood that may occur at a given site and its frequency, this is required for the safe design of drains and culverts, dams & reservoirs, channels & other flood control structures.

CLEAR YOUR CONCEPT

Qu.1. Water evaporated is carried with the air in form of vapour known as ______________

a) Cloud
b) Drizzle
c) Fog
d) Smoke

Qu.2. When does vapour turn into form of water or snow?

a) Cooled below Dew point
b) At Frost point
c) When cooled Freezing point
d) When there is rise in Humidity

Qu.3. What source of energy does evaporation and precipitation consists of?

a) Perennial energy
b) Gravitational energy
c) Thermal energy
d) Kinetic energy

Qu.4. Water on the ground surface entering the soil is called __________

a) Filtration
b) Transpiration
c) Infiltration
d) Precipitation

Qu.5. The energy input to the hydrological cycle is by _____________

a) Wind
b) Water
c) Sun
d) Head

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

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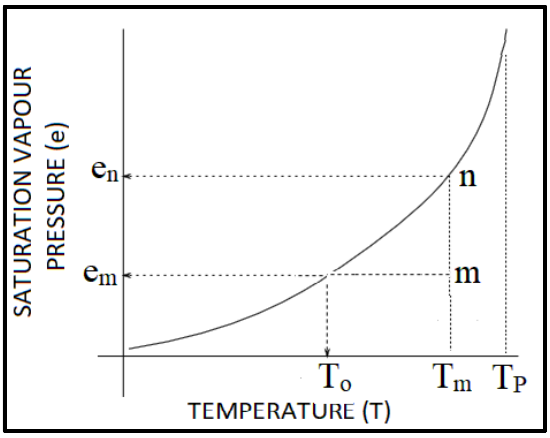

- If we decrease the temperature from T_m to T_o, the moisture will be at saturation level and precipitation will start.
- If we increase the temperature from T_m to T_p, saturation deficit increases and its moisture holding capacity increases.

Forms of Precipitation

(1) Drizzle - A fine sprinkle of numerous water droplets which have size less than 0.5mm and intensity less than 1mm/hr.

(2) Rain - The condensed water vapour of the atmosphere falling in drops (> 0.5mm - maximum size 6mm) from the clouds.

On the basis of intensity, rainfall is classified as

Type	Intensity (mm/hr)
Light rain	< 2.5 mm/hr
Moderate rain	2.5-7.5 mm/hr
Heavy rain	> 7.5 mm/hr

(3) Glaze - When the water droplet (rain or drizzle) come in contact with ground which have the temperature near about 0^0c or less than it, these water drops freeze and form ice coating on ground surface which is called glaze or freezing rain.

(4) Sleet: Frozen rain drops with transparent grains while falling through air at subfreezing temperature. It denotes both rain & snow.

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

(6) Snow Flakes: Snow is made up of ice crystals which usually combine to form flakes. When these flakes reach to earth's surface than snow fall occur.

Average density of snow is 0.1 g/cm^3

(7) Hail: Hail are large size of snow which have size greater than 8mm. They are in the form of irregular pellets or lumps of ice destructive in nature (destroy agriculture & are harmful for animal & human) (they occur when vertical current of wind is very strong)

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

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

(10) Fog: A thin cloud of varying size formed at the surface of the earth by condensation of atmospheric vapour (interfering with visibility)

(11) Mist: A very thin fog.

VC: Mr Cognito

TYPES OF PRECIPITATION

(1) Orographic Precipitation

This type of precipitation occurs when moist air mass may get lifted up to higher altitude due to presence of mountain barriers because they cannot move forward. Due to rise, air undergo cooling, condensation and precipitation.

- In India, most of the precipitation occur due to orographic precipitation.
- The greatest amount of precipitation falls on the windward side & the leeward side has often very little precipitation.

(4) Frontal Precipitation

It is a type of cyclonic precipitation. When two contrasting air masses (cold polar air mass and warm westerly air mass) coming from opposite directions converge along a line, a front is formed. The warm wind is lifted upward along this front where as cold air being heavier settles downward.

Because the two types of form (warm and cold) have different temperature and density, frontal precipitation. occurs when they clash with each other.

TYPES OF CYCLONE

(1) **Tropical cyclone:** In it, isobars are closely spaced and winds are anticlockwise in northern hemisphere.

- Center of storm is called eye, which may have the size of about 10-50 km in diameter.
- The wind speed gradually decreases & the pressure increases towards outer edge of cyclone.

(2) **Anticyclone:** Wind circulation is clockwise in northern hemisphere.

- Weather is usually calm at center.
- Winds flow with moderate speed.

MEASUREMENT OF PRECIPITATION

- All forms of precipitation are measured as the vertical depth of water that would accumulate on a level surface, if entire precipitation remained where it falls.

- If 1 cm rainfall occur over an area of 1 km^2, then it represents that the total volume of water over that area is 10^4 m^3

Volume of Water = Rainfall depth X Area

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Construction, Planning and Management

"All Birds find shelter during a rain.
But Eagle avoids rain by flying above
the Clouds."

A.P.J. Abdul Kalam

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(2) Recording Type Rain gauges

- This type of rain gauge can give us a permanent automatic rainfall record. There is some mechanical arrangement by which rain fallen V_s time plot come on graph paper.
- These are sometimes called as Integrating rain gauges or Continuous rain gauges.
- They are of great use in hills and for opposite areas, where it is not practically feasible to daily visit the gauge station.

COMMONLY USED RAIN GAUGES

(A) Tipping Bucket Type

(B) Weighing Bucket Type

(C) Natural Syphon Type

(A) Tipping Bucket Type

- The catch from the funnel falls onto one of a part of small buckets. These buckets are so balanced that when 0.10mm - 0.25 mm of rainfall collects in one bucket, it tips and brings the other one in position. The tipping actuates an electrically driven pen to trace record on clockwork driven chart.
- The main advantage of this type of instrument is that it gives an electronic pulse output that can be recorded at a distance from the rain gauge.
- So, such gauges can be installed in hilly or inaccessible areas, from where they can supply. measurements directly into control room.

Note

➢ The record from the tipping bucket type of rain gauge gives the data of the intensity of rainfall.

- In a desert or a mountainous terrain, storage gauges are used to measure total seasonal precipitation. These gauges are read monthly, seasonally or whenever it is possible to inspect the stations.

RAIN GAUGE NETWORK

- Rainfall records is most important for hydrological investigations or a well distributed network of rain gauge station within the catchment is essential.
- The rain gauge should be evenly and uniformly distributed within a given catchment.
- Number of rain gauge in an area should neither be too many because it will increase the cost nor not be too low to give reliable result.
- The Indian standard (IS 4987-1968) recommends the following densities

  In plain areas - 1 station per 520 km

  In region of average elevation upto 1000m - 1 station per 260-390 km^2

  In predominantly hilly areas with heavy rainfall - 1 station per 130 km^2

- According to WMO at least ten percent of the rain gauge stations should be equipped with automatic (self-recording) rain gauges.

OPTIMAL NUMBER OF RAIN GAUGES (N)

- A certain number of rain gauge stations are necessary to give average rainfall with a certain percentage of error.
- If the allowable percentage error is more than lesser number of gauges would be required and vice-versa.
- For finding the optimum number of rain gauge in a particular catchment area with a certain percentage of error, following steps should be taken.

The 30-year normal rainfall is recomputed every decade to account for change in environment and land use, because these factor may affect the amount of rainfall on that area.

Preparation of Data

It is necessary to check the rainfall data for continuity and consistency of a station before using it. Continuity means availability of continuous record of previous rainfall and consistency means that rainfall data of previous years should be consistent with the present environmental and land use conditions (like if there is a jungle in a particular area which did not exist 15 years ago then previous records will not be consistent with current record).

ESTIMATION OF MISSING DATA

Sometimes a station has a break in record due to absence of observer or failure of instrument. It is then necessary to estimate the missing data. To estimate the data, three or more stations close to these stations are selected.

Following are the different methods of calculating missing data.

(i) Arithmetic Mean Method

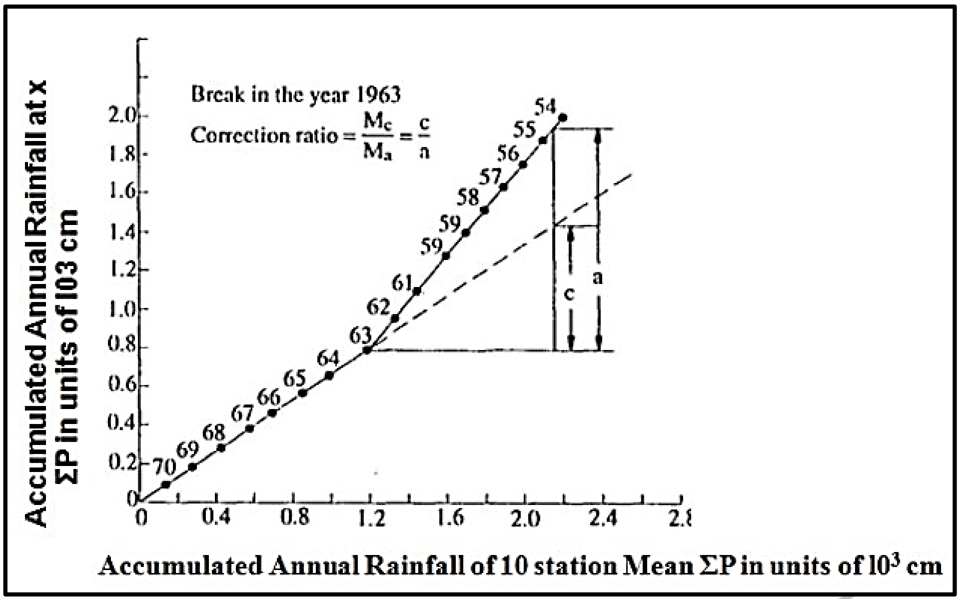
If the normal annual precipitation of the nearby stations is 10% of within the normal annual precipitation at station x, then use this method.

$$P_x = \frac{P_1 + P_2 + P_3 + \cdots + P_m}{m}$$

(ii) Normal Ratio Method

If the normal precipitation at any of these selected stations differ by more than 10% of selected station then we use normal ratio method.

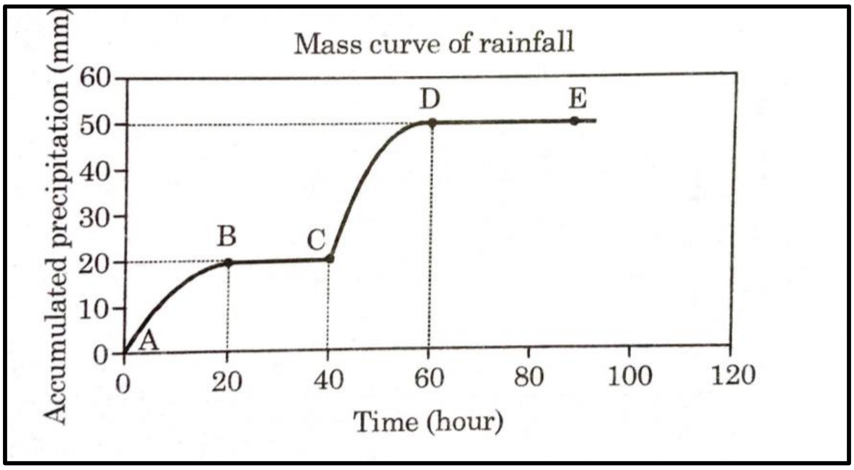
$$\frac{P_x}{N_x} = \frac{1}{m}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \cdots + \frac{P_m}{N_m}\right]$$



PRESENTATION OF RAINFALL DATA

(i) Mass Curve of Rainfall

- The mass curve of rainfall is a plot of the accumulated precipitation against time, plotted in chronological order. Records of float type and weighing bucket type gauges are of this form.
- Mass curves of rainfall are very useful in extracting the information on the direction and magnitude of a storm.
- Intensities at various time intervals in a storm can be obtained from the slope of the curve.



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(ii) Thiessen polygon method

(iii) Isohyetal method

(i) Arithmetic Mean Method

- This method gives equal weights to all the rain gauges.
- Apart from being quick & easy, it yields fairly accurate results of the rain gauges are uniformly distributed and are under homogeneous climate.
- Under normal condition, this method is least accurate method.
- This method doesn't take into account the rain gauge located outside the catchment.As per this method,

$$P_m = \frac{(P_1 + P_2 + \cdots + P_n)}{n}$$

P_m is average rainfall in the catchment

P_i is rainfall magnitude at i^{th} station inside catchment

n = number of rain gauges in the catchment.

(ii) Thiessen polygon method

- In this method, the rainfall recorded at each station is given a weightage on the basis of area closest to the station.
- In this method, the rain gauge outside the catchment is also considered.
- More accurate results compared to arithmetic mean method but less accurate method as compared to isohyetal method.
- This method is only reliable for plain areas, because it doesn't take into account elevation difference. In this method the whole catchment area is divided into smaller areas, on which we assume uniform rainfall.

Step 3 : The volume of rainfall is calculated between the isohyets by taking the average of isohyets multiplied by the area between the isohyets.

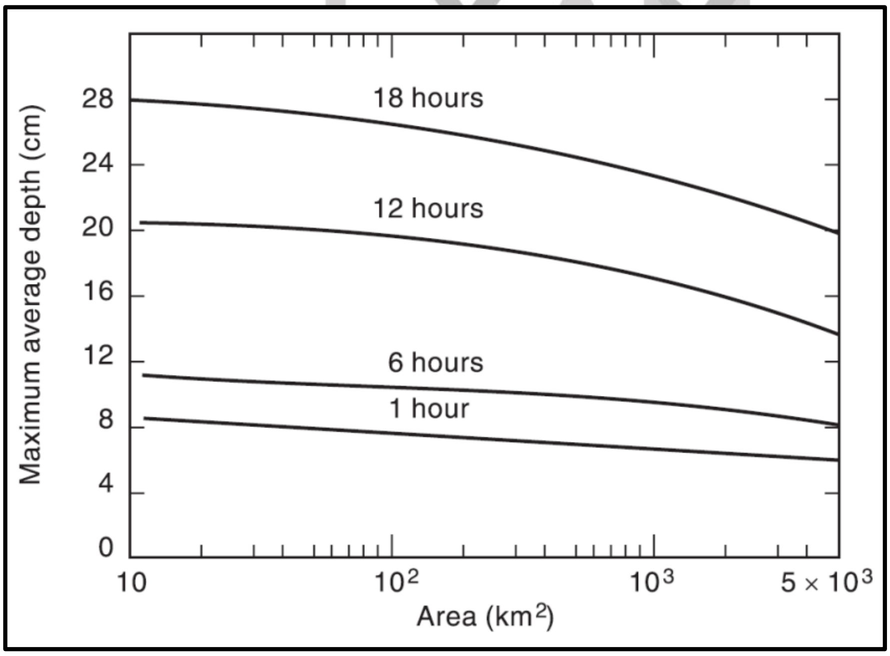
Step 4 : Calculate volume of rainfall of all area between the isohyets.

Step 5 : Calculate the cumulative volume & cumulative area.

Step 6 : This cumulative volume is divided by cumulative area and average depth of rainfall over the area for that storm is found out.

Step 7 : Same procedure is applied for other storm also

Step 8 : The graph between average depth and cumulative area is plotted. This is called depth area duration curve.



- DAD curve can also be obtained from empirical equation like

$$\bar{P} = P_o \bar{e}^{KA^n}$$

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

P_o = Highest amount of rainfall in catchment at the storm center.

K, n = Constant for a given region.

- This equation is applicable when the center of storm coincide with the rain gauge, but it is not possible at all for this we take the area of 25km^2 and find average depth over this area for the maximum storm.

> **Note**
> - In a typical depth area curve, depth decrease with increase in area. Similarly, analysis of rainfall of larger duration for a given area indicates that depth of rainfall increases as the duration increases.

Maximum Depth Area Duration Curve

- The severe most rainstorm are considered in the design because for the hydraulic structure design we should determine the design flood. This is found by maximum depth area duration curve.

- In area due to various storm find the depth area duration curve. Then area is plotted with respect to maximum depth of rainfall corresponding to the various storms. This is called Maximum DAD curve.

FREQUENCY OF POINT RAINFALL

When we design hydraulic structures, we design for a particular hydraulic structure also and design for a particular life span. If the flow value doesn't exceed from the design value in between the design life of hydraulic structure than our structure will be fine.

- We find the probability of occurrence of particular storm in particular time period by frequency analysis of point rainfall data.

Following steps are to be taken

(a) Arrange all the rainfall data in chronological order constituting a time series.

(b) Arrange the series in descending order of magnitude of rainfall and provide a number to each.

Number 1 to largest magnitude rainfall and N is given to least magnitude rainfall.

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Design of Steel Structures

"Shoot for the Moon. Even if you miss, you will land among the Stars."

Les Brown

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(c) Probability of the event not occuring at all in all 'n' successive years

$$= {}^nC_0 P^0 q^n = q^n = (1 - p)^n$$

(d) Probability of the event occurring at least once in 'n' successive years

$$= (1 - q^n) = 1 - (1 - p)^n$$

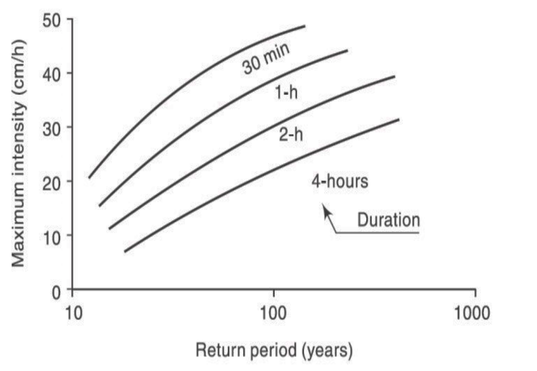
% dependable flow = **(100 x p) %**

INTENSITY DURATION FREQUENCY CURVES

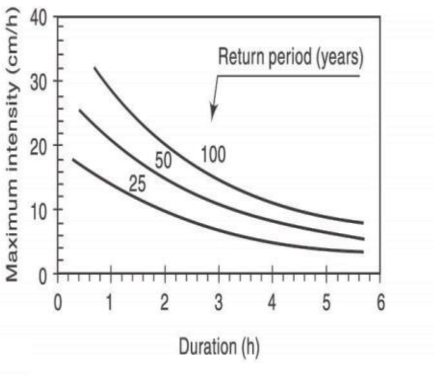
Intensity duration frequency curve estimates the rainfall intensities of different durations and recurrence interval.

These curves are used by engineers for risk assessment of dams, bridges, water drainage system, storm sewers, runoff canals etc.

They can also be used as a prediction tool to identify when a certain rainfall rate or a specific volume of flow will recur in the future that will create flooding havoc in an area.



Maximum Intensity-Return Period-Duration Curves



Maximum Intensity-Duration-Frequency Curves

Suppose one has to determine the design discharge of a storm sewer with a consideration that its return period is not less than 5 years i.e., the risk of storm sewer getting over flooded is acceptable once in 5 years.

- If the probability of occurrence of drought at an area is greater than 0.4 then such an area is called chronologically drought prone area.
- In India, about 33% area is drought prone

2. Hydrological drought

- Hydrological drought means, below average value of stream flow contents in lakes, ground water etc.
- It has 4 components:-

  (a) Magnitude (Amount of deficiency)

  (b) Duration

  (c) Severity (Cumulative amount of deficiency)

  (d) Frequency of occurrence

- In the studies on hydrological drought different techniques have to be adopted for study of

  (i) Surface water deficit

  (ii) Ground water deficit

3. Agricultural Drought

This is mainly characterized by deficiency of rainfall

It can be defined with the help of different indices for eg.

- Aridity Index
- Palmar Index
- Moisture Availability Index etc.

$$AI = \frac{PET - AET}{PET} \times 100$$

PET = Potential Evapotranspiration

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CLEAR YOUR CONCEPT:

Qu.1 The drum situated in recording type makes one rotation for how many hours?

a) 4 hours
b) 24 hours
c) 6 hours
d) 12 hours

Qu.2 Which gauge gives the permanent record of rainfall?

a) Recording gauge
b) Non-recoding gauge
c) Copper daily gauge
d) Plastic gauge

Qu.3 Where are funnel and receiver in Non-recording type placed?

a) Inside a Metal case
b) On top of the equipment
c) Below the base of equipment
d) In between the metal case

Qu.4 Movement and filtering of fluid from porous material is called as __________

a) Percolation
b) Infiltration
c) Transpiration
d) Precipitation

$$E_L = C\,(e_w - e_a) \qquad \textbf{Dalton's Law}$$

E_L = Rate of evaporation (mm/day)

C = constant

e_w = Saturation vapour pressure in mm of Hg

e_a= actual vapour pressure in mm of Hg

Evaporation will take place till $e_w \geq e_a$ and if $e_w < e_a$ then condensation takes place.

(ii) Temperature

By keeping other factors same, the rate of evaporation increases with an increase in the water temperature.

(iii) Wind

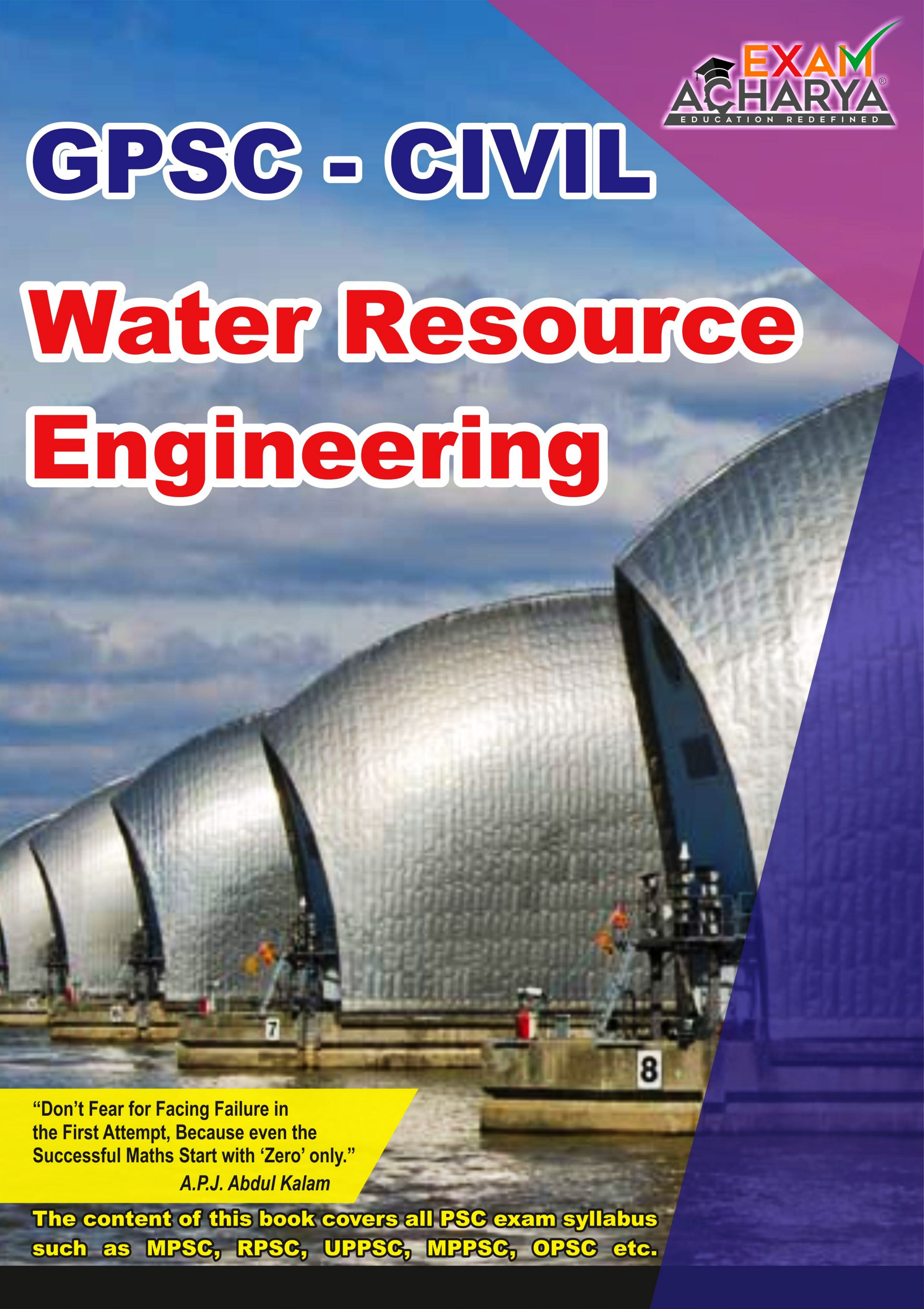
- Wind aids in removing the evaporated water vapour from the zone of evaporation hence increase in wind speed increases the scope of evaporation.
- However, if the wind velocity is large enough to remove all the evaporated water vapour (critical wind speed) any further increase in wind velocity does not influence the evaporation.
- This critical wind speed value is a function of the size of the water surface. For large water bodies high speed turbulent winds are needed to cause maximum rate of evaporation.

(iv) Atmospheric Pressure

Other factors like heat input remaining same, a decrease in the barometric pressure, as in high altitudes, increases evaporation.

(v) Water Quality

The rate of evaporation from water surfaces exposed to identical climatic conditions may vary according to the quality of water.



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Water Resource Engineering

"Don't Fear for Facing Failure in the First Attempt, Because even the Successful Maths Start with 'Zero' only."

A.P.J. Abdul Kalam

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FACTORS AFFECTING EVAPORATION FROM SOIL MOISTURE

(i) Soil Moisture Content

Experiments have shown that, the evaporation from saturated soil is more than the evaporation of same surface water body.

(ii) Soil Capillary Characteristics

Capillary supply water to surface so enhance evaporation.

(iii) Depth of Water Table

Higher the water table, higher is the evaporation.

(iv) Colour of Soil.

Soil colour also affects evaporation. A darker soil absorbs more heat and increase the temperature so enhances evaporation.

EVAPORATION MEASUREMENT

A. Evaporimeter data

B. Empirical evaporation equation

C Analytical method

Evaporimeters

Evaporimeters are water containing pans which are exposed to the atmosphere, and the loss of water by evaporation in them is measured at regular intervals.

(i) Class A Evaporation Pan.

Made up of unpainted galvanized iron sheet and monal metal is used where corrosion possess a problem.

If the wind velocity data would be available at an elevation other than that needed, then we find out the velocity by

$$U_h = C h^{\frac{1}{7}} \qquad \textbf{1/7}^{\textbf{th}} \textbf{ Power Law}$$

(ii) Rohwer's Formula

$$E_L = 0.771\,(1.465 - 0.000732\,P_a)\,(0.44 + 0.0733u_o)\,(e_w - e_a)$$

Analytical Methods

(a) Water budget method

(b) Energy Balance method

(c) Mass transfer method.

Water Budget Method

Simplest of the three analytical methods and least reliable.

Hydrological continuity equation.

$$P + V_{is} + V_{ig} = V_{os} + V_{og} + E_L + \Delta S + T_L$$

P = Daily Precipitation

V_{is} = Daily surface inflow into the lake.

V_{ig} = Daily groundwater inflow.

V_{os} = Daily surface outflow from the lake.

V_{og} = Daily seepage outflow

E_L = Daily lake evaporation

ΔS = Increase in lake storage in a day

T_L = Daily transpiration loss

- Evapotranspiration represents the most important aspect of water loss in the hydrologic cycle.
- The term consumptive use is also used to denote this loss by evapotranspiration.
- If sufficient moisture is always available to completely meet the needs of vegetation fully covering the area, the resulting evapotranspiration is called **Potential Evapotranspiration (PET).**
- Potential evapotranspiration does not depend on soil and plant factors but depends essentially on climatic factors.
- The real evapotranspiration occurring in prevailing / actual condition is called **Actual Evapotranspiration (AET).**
- If the soil moisture is at the field capacity AET = PET.
- If the water supply is less than PET, the soil dries out and the ratio AET/PET would then be less than unity.

Measurement of Actual Evapotranspiration

- Phytometer measures only transpiration.
- Lysimeter (evapotranspirometer)
  - Consists of a circular tank filled with soil and individual crops or natural vegetation for which the evapotranspiration is required.
  - It is buried so that its top is flush with the surrounding ground surface.
  - The sides of the lysimeter are impervious whereas the bottom is pervious. Water passing through the soil column is collected at the bottom and conducted through a small tube to a measuring gauge in an adjacent pit.

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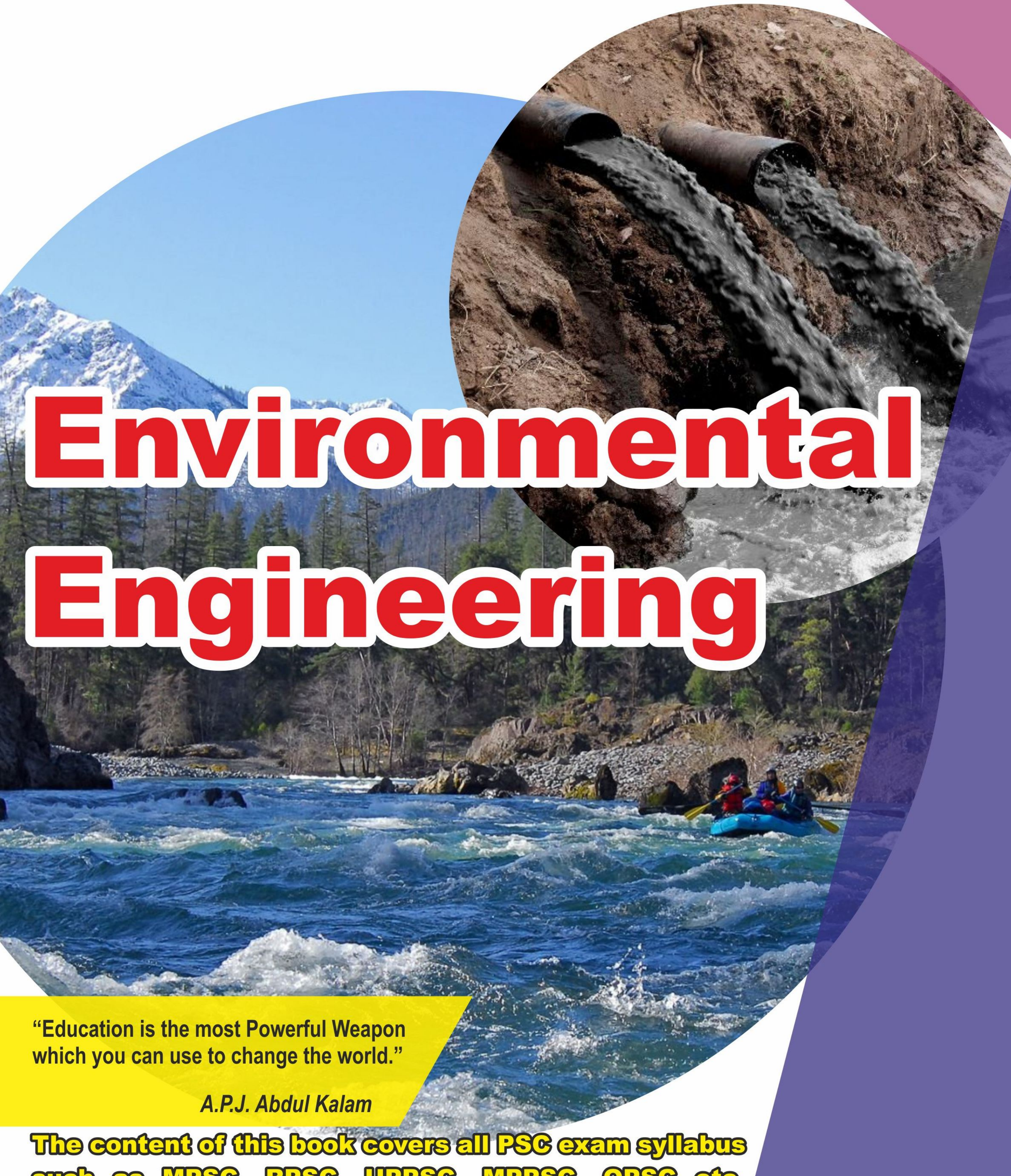

Environmental Engineering

"Education is the most Powerful Weapon which you can use to change the world."

A.P.J. Abdul Kalam

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Evapotranspiration is calculated as

$$AET = W_{si} + W_{ad} - W_c - W_{sf}$$

W_{si} = original weight of container + soil + plant + water moisture
W_{ad} = water added
W_c = water collected at bottom
W_{sf} = final weight of container content.

Field Experimental Plots

A plot is choosen and all the element like precipitation, irrigation input, surface runoff, soil moisture and percolation is measured.

$$ET = I - Q - \Delta S$$

ET = Evapotranspiration

I = Total inflow in mm including precipitation and irrigation water.

Q = Total surface runoff in mm

ΔS = Increase in soil moisture storage in mm

- As the measurement of percolation is a very difficult task in actual field problem so we keep the moisture level of soil at field capacity. This method provides fairly reliable result.

ESTIMATION OF POTENTIAL EVAPOTRANSPIRATION

(1) Penman's Equation

It is based on combination of the energy balance and mass transfer approach.

$$PET = \frac{A\,(H_n) + E_a\,\gamma}{A + \gamma}$$

PET = Daily potential evapotranspiration in mm per day
A = Slope of the saturation vapour pressure vs temperature curve at the mean air temperature in mm of mercury per $°C$

Main components of interception

(1) **Interception loss** – Water which is retained on a surface, as mentioned above, and which is later evaporated away.

(2) **Through fall** – Water which drips through, comes down from the leaves etc onto the ground surface.

(3) **Stem flow** – Water which trickles along the branches and finally down the main trunk onto the ground surface.

Note

- Interception losses solely due to evaporation and does not include transpiration, through fall or stem flow.
- **Transpiration Ratio** = $\frac{\textbf{Total mass of water transpired by plant during its full growth}}{\textit{Mass of any matter produced}}$

Factors Affecting Transpiration

(1) Atmospheric pressure

(2) Temperature

(3) Wind

(4) Light intensity

(5) Characteristic of plant

DEPRESSION STORAGE

When the precipitation of a storm reaches the ground, it must first fill up all depressions before it can flow over the surface. The volume of water trapped in these depression is called depression storage. (Initial Loss)

INFILTRATION

Infiltration is that process by which precipitation moves downward through the surface of the earth and replenishes soil moisture, recharges aquifers, and ultimately supports stream flows during dry periods.

Note

- Percolation is used to describe the downward flow of water through the zone of aeration towards the water table and Infiltration being restricted to the entry of water through the surface layers of the soil.

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

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Measurement of Infiltration

Infiltration characteristics of a soil at a given location can be estimated by

(a) *Flooding type infiltrometers*

This is a simple instrument consisting of a metal cylinder, open at both ends. This cylinder is driven into the ground and water is poured into it from top. As the infiltration proceeds water level goes down, to keep the water level at same initial point we add some water into it. As we know volume of water added, plot of infiltration capacity Vs time is obtained. This experiment takes nearly 2-3 hours for completion.

(b) *Rainfall Simulators*

In this experiment a small land of about 2m X 4m is provided with a series of nozzle on the longer side and arrangement is provided to collect & measure the surface runoff rate. The nozzles are specially designed to produce artificial rains of various intensities. By taking different combination of intensity & duration, surface runoff rate and volume are measured in each case.

Using the water budget equation the infiltration rate is also measured. If the artificial rainfall intensity is higher than the infiltration rate, we can calculate the infiltration capacity also.

Note

- Rainfall simulation type infiltrometer give lower values than flooding type infiltrometer. Because it takes the effect of rainfall impact and turbidity of the surface water present in the former.

(c) *Hydrograph Analysis*

Reasonable estimation of infiltration capacity of a small watershed can be obtained by analysis measured runoff hydrographs and corresponding rainfall records. If sufficiently good rainfall records and runoff hydrographs corresponding to isolated storms are available, water budget equation can be applied to estimate the abstraction by infiltration.

It gives good result for small watershed with fairly homogenous soil.

Empirical Infiltration Equations

Under given soil type and antecedent moisture conditions, there will be an initial infiltration rate f_o. This rate will decrease as more water gets infiltrated, finally achieving a constant rate f_c i.e., ultimate infiltration capacity.

This infiltration capacity rate prevails when the soil is saturated. The parameters f_o, f_c and the decay of infiltration capacity are functions of the soil moisture conditions, vegetation, rainfall, intensity and soil surface conditions.

Empirical Equations

(1) Green Ampt Model

(2) Horton Infiltration Equation

(3) Huggins Monka Equation

(4) Soil Conservation Service Practice

(5) Antecedent Precipitation Method

<u>Horton Infiltration Equation</u>

$$f_t = f_c + (f_o - f_c)\, e^{-\alpha t} \qquad \text{for } 0 < t < tc$$

f_t = Infiltration capacity at any time t from the start of rainfall

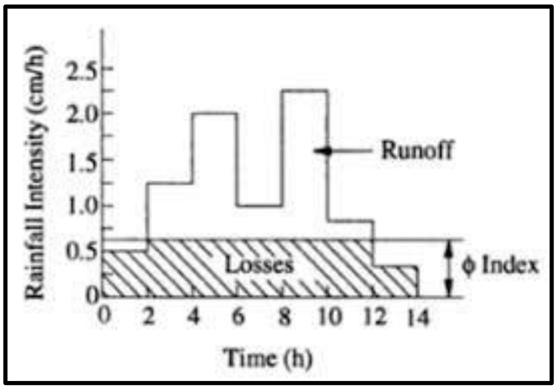
f_o = Initial infiltration capacity at t = 0

f_c = Ultimate infiltration capacity occurring at time $t = t_c$

α = Horton's decay coefficient which depends upon soil characteristics & vegetation cover.

Note

- This equation is applicable only when rainfall intensity is greater than or equal to f_t.



$$\phi \text{ index} = \frac{P-Q}{t_e}$$

P = Rainfall

Q = Runoff

t_e = time of rainfall excess

> **Note**
> In estimating the maximum floods for design purpose, in the absence of any other data, ϕ index value of 0.10 cm / hour is assumed.

(ii) W Index

The W- index is a refined version of ϕ index. It excludes the depression storage and interception from the total losses.

- It is the average infiltration rate during the time rainfall intensity exceeds the capacity rate.
- W - index is always less than ϕ index.

$$W = \frac{F}{t} = \frac{(P-Q-S)}{t}$$

Where,

F = Total infiltration

t = Time during which rainfall intensity exceeds infiltration capacity.

P = Total precipitation corresponding to t

Q = Total storm runoff

S = Volume of depression storage & interception.

Qu.5. Which method is time-consuming and expensive?

a) Tanks and Lysimeter
b) Vapour transfer method
c) Field plot method
d) Integration method

TEST YOUR SELF:

Qu.6. Which method is widely used in India for the computation of consumptive use?

a) Penman's equation
b) Hargreaves – Christiansen equation
c) Blaney-Criddle equation
d) Tanks and lysimeter

Qu.7. Which type of method is adopted for research studies on crops?

a) Phytometer Method
b) Lysimeter Method
c) Furrow Irrigation Method
d) Drip Irrigation Method

Answer:

1-(d), 2-(b), 3-(a), 4-(a), 5-(a), 6-(a), 7-(b)

GPSC - CIVIL

Fluid Mechanics and Hydraulic Machines

"Success Consists of going from Failure without Loss of Enthusiasm."

Winston Churchill

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

CHATER – 4

RUNOFF

RUNOFF

Runoff means the draining off of precipitation from a catchment area through the surface channel. It is expressed as volume per unit time i.e., Output from the catchment in a given unit of time.

Total Runoff can be Divided into Two Parts

(i) Direct Runoff or stream Runoff.

(ii) Ground water flow or base flow

Direct Runoff

It is that part of runoff which enters the stream immediately after the precipitation. It includes surface runoff, prompt interflow and precipitation on the channel surface. It is sometimes termed as direct storm runoff or storm runoff.

Surface Runoff

It has two components

(a) Overland flow (flow of water over land before any open channel)

(b) Open channel flow

Over land flows are small and the flow is taken to be in laminar regime. Length of overland flow is generally small.

Open channel flow are in turbulent regime.

Factors Affecting the Distribution of Runoff in Time

❖ **Rainfall Characteristics**

(a) Types of Precipitation

Precipitation comes to earth surface as rainfall and snowfall. Rainfall contributes directly to runoff, while snowfall contribute to runoff after some time when it melts.

(b) Rainfall Intensity

If rainfall intensity > Infiltration capacity

- Rainfall immediately contributes to runoff

If Rainfall intensity < infiltration Capacity

- Delayed flow contribution.

(c) Rainfall Duration

Infiltration intensity decreases with time, so runoff will increase with time.

Also, if $T > T_c$ (time of concentration) → runoff maximum.

(d) Rainfall distribution

The time relationship between rainfall and runoff may be greatly affected by the distribution of rainfall over the catchment area. A uniformly distributed rainfall volume may lead to delayed runoff then the same volume falling over a localised part of catchment.

The first type of rainfall distribution will tend to result in an increased groundwater flow, and consequently a long-term increase in stream flow, while the latter type of distribution will tend to give large volumes of surface runoff and thus a more sudden, short lived increase in streamflow.

Note
- A long narrow catchment will yield a low value of the form factor and generally a lower peak runoff total than a similar sized area with a high form factor.

Compactness Coefficient is defined as

Compactness coefficient = $\frac{\textbf{Perimeter of the catchment}}{\textbf{Circumference of a circle whose area is equal to area of catchment}}$

- Theoretical minimum value of unity for a completely circular catchment.

Note
- The lower the value of the coefficient, the more rapidly is water likely to be discharged from the catchment area via the main streams.

A = area of catchment

P = Perimeter

r_c = radius of equivalent circle

$$A = \pi r_c^2$$

Circumference of equivalent circle

$$= 2\pi r_c = 2\pi\sqrt{\frac{A}{\pi}} = 2\sqrt{\pi A}$$

So, Compactness coefficient = $\frac{P}{2\sqrt{\pi A}}$

Stream Density

If in a catchment of area (A) there are N streams then

Stream Density = $\frac{No.of\ Stream}{Area} = \frac{N}{A}$

Here we only include perennial & intermittent river.

Human Factors

Manmade structure e.g. dam, diversion work affect runoff.

Antecedent Precipitation

New Batches are going to start.....

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If due to previous rain, soil is already saturated runoff will be more due to next rainfall. The previous rain is called Antecedent Precipitation.

Time of Concentration (TOC)

The time of concentration of a drainage area is the time required by the water to reach the outlet from most remote point of drainage area.

Travel Time or Time of flow

The time taken by the water to reach the catchment outlet, from the different points in the catchment, is called the travel time or time of flow.

Isochrone

The line joining the points of equal time of flow is called isochrone.

Water Year

In annual rainfall studies, a water year consider to begins from the time when the precipitation exceeds the average evapotranspiration losses. In a water year a complete cycle of climate change is expected so the water budget will have the least amount of carry over

Note

- In India, June 1st is beginning of the water year and it ends on May 31st of the following calendar year.

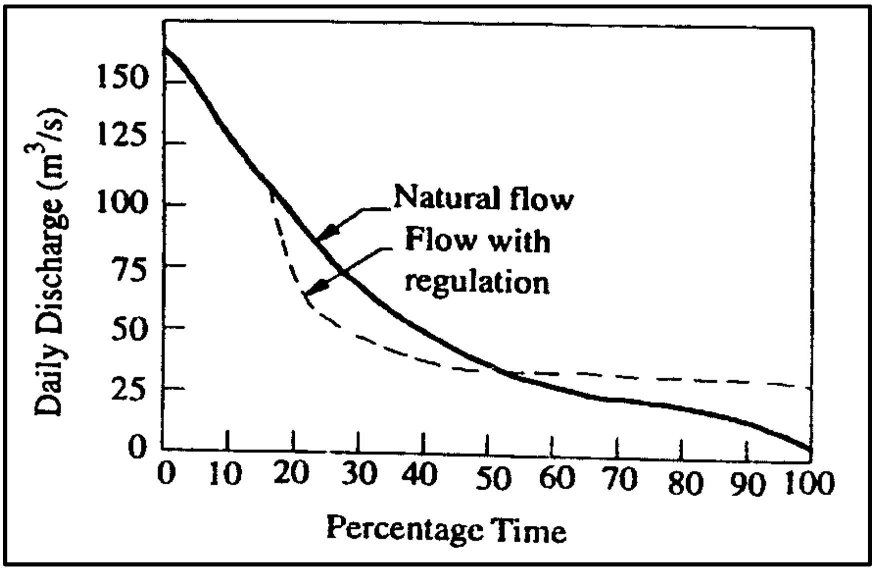
Yield

The total quantity of surface water that can be expected in a give period from a channel at the outlet of its catchment is shown as yield of catchment in that period.

Thus $\int_{t_1}^{t_2} Q \times dt$ provides the estimate of basin yield.

Therefore, yield from a basin is the summation of the continuous hydrograph of flow at its outlet over the specified time period.

- The ordinate Q_P at any percentage probability represents the flow magnitude in average year that can be expected to be equaled exceeded P_P percent of time and depend as P_P% dependable flow.
- In a perennial river Q_{100} = 100 % dependable flow is a finite value but in intermittent or ephemeral river the stream flow is zero for some part of year, so Q_{100} is zero.



Uses of Flow Duration Curve

(1) It is used for evaluating the characteristics of the hydropower potential of a river. In case of run-of-river-plant, with no storage facilities, the firm power is usually computed on the basis of flow available 90-97 percent of the time.

(2) If a sediment rating curve is available for the given stream the flow duration curve can be converted into cumulative sediment transport curve by multiplying each flow by its rate of sediment transport.

(3) It is used in the design of drainage system and in flood control studies.

(4) We get qualitative description of the runoff variability in the stream when drawn on log-log paper, steep slope indicates highly variable discharge which is common when flow is mainly from surface runoff. Flat slope indicates small

variability which shows that streams receiving both surface runoff and groundwater runoff.

(5) It can be used to estimate what minimum level of flow can be maintained through a reservoir so that minimum demand at all times can be met.

Note

- The serious drawback of flow duration curve is for a particular flow, it have same value of P_P, whether it occurred in January or June.

FLOW MASS CURVE

A graph of cumulative volume of runoff vs time is known as mass curve.

It is the integration of the hydrograph and therefore represents the area under the hydrograph from one time to another.

Mathematically mass curve is expressed as,

$$\mathbf{V(t) = \int_0^t Q(t)\, dt}$$

V (t) = Cumulative volume of flow up to time t from start of record,

Q (t) = Discharge as a function of time.

- Mass curve serves as a very useful tool to determine the required storage capacity for any uniform rate of demand.
- The rate of flow at any time is indicated by the slope of the tangent drawn to the mass curve at the corresponding time.

$$\frac{dv}{dt} = \mathbf{Q = Rate\ of\ flow}$$

- If the mass curve is horizontal, i.e., having zero slope, for a particular period of time it means that there is no discharge in the stream during that period.
- The rate of demand is the rate at which water is required for any use. A straight line having the slope equal to this rate is called demand line or draft line or use line.

EXAM ACHARYA
EDUCATION REDEFINED

GPSC - CIVIL

Geo-technical and Foundation Engineering

All of us do not have Equal talent.
But, all of us have an Equal Opportunity
to Develop our Talents.

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

CLEAR YOUR CONCEPT:

Qu.1 The runoff in cumec by the Rational method is defined by ______________

a) Q = K*A*I*R
b) Q = (K+A+I) *R
c) Q = (K+A) *R
d) Q = A*I*R

Qu.2 The value of the factor K in finding the storm water flow by Rational method is ____________

a) 100
b) 160
c) 1
d) 1/360

Qu.3 _______ is defined as the percentage of rain water in the form of runoff.

a) Storm water flow
b) Coefficient of permeability
c) Impermeability factor
d) Coefficient of consolidation

Qu.4 What do you call a graph which is plotted for discharge versus time?

a) Snow Graph
b) Hydrograph
c) Rain graph
d) Fluid graph

Qu.5 Choose the correct sentence about information available from hydrograph among the following options?

a) The mean annual runoff or mean runoff each week of the year
b) Total volume at that instant, as the area under hydrograph indicates the force of water during the duration
c) Rate of flow at any particular time during the duration period
d) Mean runoff for each month

TEST YOUR SELF:

Qu.6 A mean annual runoff of 1m^3/seconds from a catchment of area 10 km^2 represents an effective rainfall of

a) 100 cm
b) 315.4 cm
c) 31.54 cm
d) 10.0 cm

Qu.7 When the storm occurs once a year, the rainfall intensity R is ____________

a) $R = 300/t^{0.625}$
b) $R = 150/t^{0.625}$
c) $R = 150/t^2$
d) $R = 300/t^2$

Answer:

1-(a), 2-(d), 3-(c), 4-(b), 5-(d), 6-(b), 7-(b)

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A hydrograph consists of following components

(i) **Rising limb :** AB is the rising limb in fig.

- It is influenced by the storm characteristics.

(ii) **Falling limb:** DE is the falling limb or deflection limb or recession limb. The shape of it is mostly affected by catchment properties.

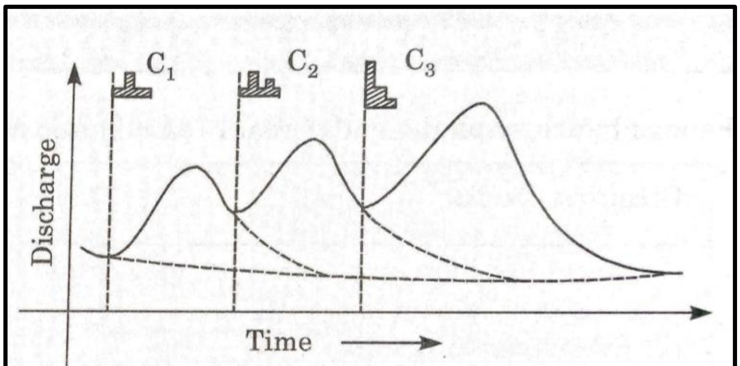
(iii)**Crest segment:** BCD portion is called crest segment.

(iv)**Inflection Point:** Point B & D is called inflection point. The contribution of the surface flow ceases after, the inflection points at the tail of recession limb, and the remaining flow represents withdrawal from the catchment storage.

(iv) **Crest:** Peak of hydrograph (that is C) is called Crest.

(vi) The area ABCDE shows the direct runoff.

- A_1 A E E_1 is the base flow contribution to total discharge.
- G_1 is center of mass of rainfall
- G_2 is center of mass of hydrograph
- T_L = lag time
- t_{pk} = time of peak from starting point 'A'.



(Three peaks due to three storm in succession)

Multi Peak hydrograph.

Factors Affecting Flood Hydrograph

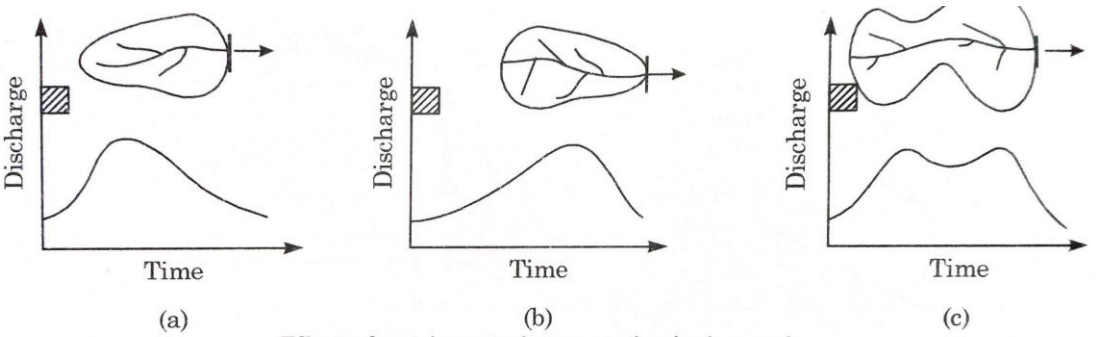
1) Physiographic factor 2) Climate Factor

PHYSIOGRAPHY FACTORS	CLIMATE FACTOR
1. Basin characteristics (a) Shape (b) size (c) slope (d) nature of valley (e) elevation (f) Drainage density	1. Storm Characteristics precipitation, intensity, duration, magnitude and movement of storm.
2. Infiltration characteristics (a) Land use & Cover (b) Soil type & geological conditions (c) Lakes, swamps & other storage	2. Initial Loss
3. Channel characteristics: Cross section, roughness & storage capacity	3. Evapotranspiration

Factors Affecting Shape of Hydrograph

(i) Shape of catchment

The shape of the catchment influences the time taken for water from the remote parts of the catchment to arrive at the outlet of catchment.



Effect of catchment shape on the hydrograph.

EXAM ACHARYA
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Reinforced Cement Concrete

Education's purpose is to
replace an empty mind with an open one.

Malcolm Forbes

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(v) Effect of rainfall

(a) Rainfall intensity

Peak & Volume of surface runoff is directly proportional to intensity of rainfall

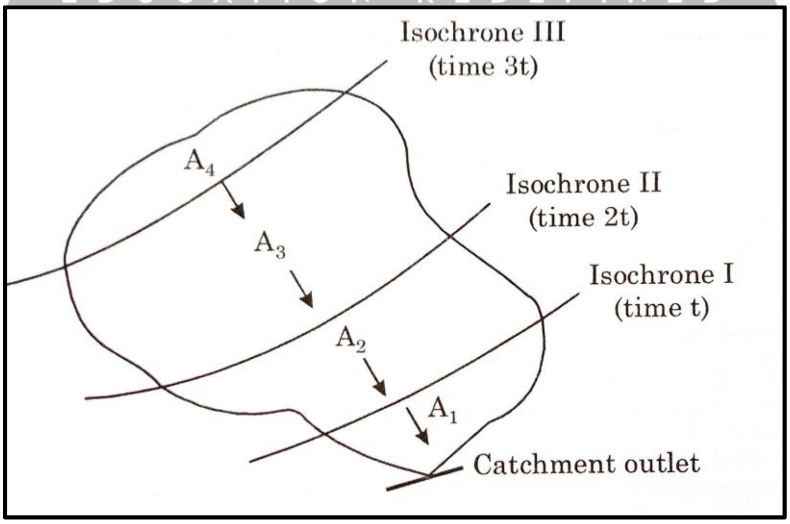
(b) Rainfall duration

If the rainfall intensity is constant, then the rainfall duration determines the peak flow and affects the rising limb.

(c) Direction of Rainfall

If the rainfall direction is in the direction of outlet then it gives left skewed hydrograph or if the rainfall direction is in the opposite direction of outlet then it gives right skewed hydrograph.

(d) Areal Distribution



If rainfall occur only in area A_1, then we immediately get peak because it is nearer to outlet and if rainfall occur in area A_4, we get peak later, because it is far from outlet.

(3) Simply by drawing a straight line AE, from the point of rise to the point E on the hydrograph, N days after the peak.

(4) Construct a line AFG by projecting backwards the ground water recession curve after the storm, to a point F directly under the inflection point of the falling limb & sketch an arbitrary rising limb from the point of rise of the hydrograph to connect with the projected base from recession.

RAINFALL EXCESS AND EFFECTIVE RAINFALL

Rainfall Excess

If the initial losses and infiltration losses are subtracted from the total rainfall, the remaining portion of rainfall is called rainfall excess (also called supra rain). Surface runoff occurs only when there is rainfall excess.

Rainfall excess = Total rainfall – ϕ t (i.e. infiltration loss)

$$\textbf{Runoff depth} = \frac{Total\ runoff - Baseflow}{Catchment\ area}$$

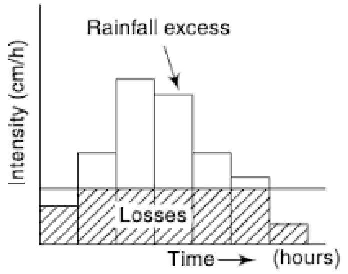
Effective Rainfall

It is that portion of the rainfall which causes direct runoff. As direct runoff includes both surface runoff and interflow, the effective rainfall is slightly greater than rainfall excess.

Effective rainfall can be obtained from direct runoff hydrograph

$$\textbf{Effective Rainfall} = \frac{Direct\ runoff\ volume}{Area\ of\ catchment}$$

If from the hyetograph of a storm, the initial loss and infiltration loss are subtracted, we get Effective Rainfall Hyetograph (ERH). It is also known as Excess Rainfall Hyetograph.



Effective Rainfall Hyetograph (ERH)

Q (a) The peak of flood hydrograph due to 3h duration isolated storm in a catchment is 270 m^3/s. The total depth of rainfall is 5.9cm. Assuming an average infiltration loss of 0.3 cm/h and a constant base flow of 20 m^3/s, estimate the peak of the 3h unit hydrograph (UH) of this catchment.

(b) If the area of the catchment is 567km^2, determine the base width of the 3 h unit hydrograph by assuming it to be triangular in shape.

Ans (a) Duration of rainfall excess = 3 hr

Total depth of rainfall = 5.9 cm

Loss @ 0.3 cm/hr for 3 hr = 0.9 cm

Rainfall excess = 5.9 – 0.9 = 5.0 cm

Peak of flood hydrograph = 270 m^3/s

Base flow = 20 m^3/s

Peak of DRH = 250 m^3/s

Peak of flood hydrograph = $\frac{\text{Peak of DRH}}{\text{Rainfall excess}} = \frac{250}{5.0} = 50m^3$

(b) Let B = base width of the 3 hr UH in hours.

Volume represented by the area of UH = volume of 1 cm depth over the catchment

= (Area of catchment x 1 cm)

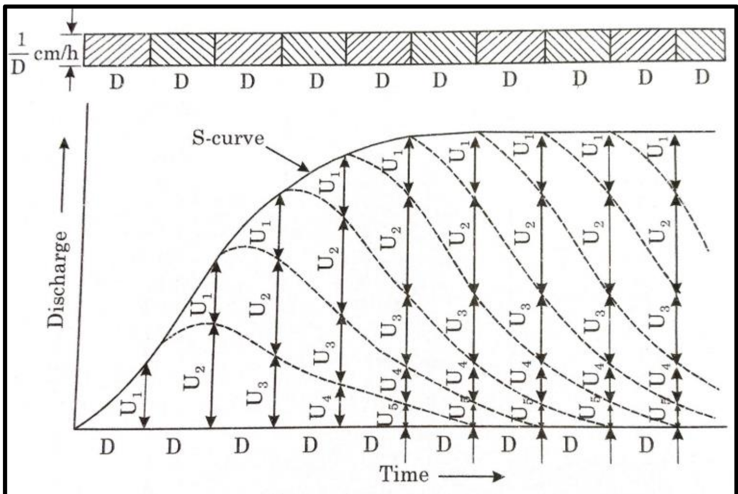
$$\frac{1}{2} \text{ x (B x 60 x 60) x 50} = 567 \text{ x } 10^6 \text{ x } \frac{1}{100}$$

$$B = \frac{567 \ x \ 10^4}{9 \ x \ 10^4} = 63 \text{ hours}$$

- As shown below, the S – curve is constructed by adding together a series of D h unit hydrograph, each lagged by D hr with respect to the previous one.

- The S - curve hydrograph attains a constant ordinate, called the equilibrium discharge denoted by Q_e, approximately at the end of the base period T_B of the UH.

- Thus the number of UHs needed to produce S curve is $\frac{T_B}{D}$



S-curve hydrograph.

- Since the rainfall rate is equal to the runoff rate at the equilibrium state it follows that.

$$\mathbf{Q = A\ \frac{1}{D}\, km^2 \text{ - cm/hr}}$$

$$\mathbf{Q = 2.778\ \frac{A}{D}\, m^3/s}$$

Where A is area of basin in km^2

D is duration of UH in hrs which is used in construction of S- curve

- Consider two D hr S- curves A & B displaced by T hour.

If the ordinates of B are subtracted from that of A, the resulting curve is a DRH produced by a rainfall excess of duration T hr and magnitude ($\frac{1}{D}$ x T) cm

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basins in the same hydrometerologically homogenous area from the known basin parameters. The UH thus obtained is known as Synthetic Unit Hydrograph

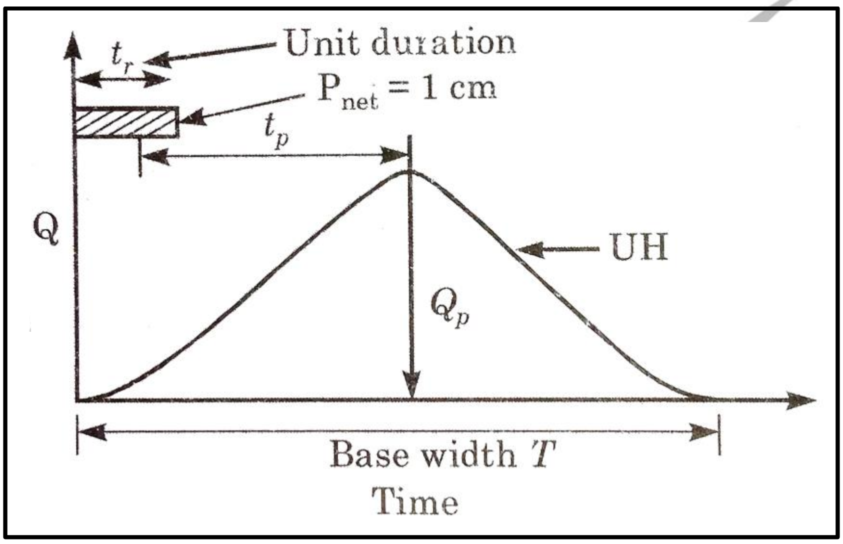
Synder selected three parameters for development of SUH

(i) Basin time width T

(ii) Peak discharge Q_P

(iii) Lag time i.e basin lag time t_P.

(Synder defined lag time as the time interval from mid-point of rainfall excess to peak of UH (instead of centroid)



He proposed following equations

Lag time $\mathbf{t_P = C_t (L\ L_{ca})^{0.3}}$

Base time width $\mathbf{T = (72 + 3t_P)}$

Peak discharge $\mathbf{Q_P = 2.78 \frac{C_P}{t_P} A}$

Tp is in hr

$C_t \rightarrow$ coefficient reflecting slope, land use & associated storage characteristics of basin.

Its value varies between 1.35 < C < 1.65 avg. = 1.5

L $\rightarrow$ basin length measured along the water course from the basin divide to the gauging station in km.

L_{ca} = Distance of centroid of catchment from the gauging point (in km).

T is in hr, Q_P is in the $\frac{m^3}{s}$, A catchment area in km^2.

$C_P \rightarrow$ regional constant having value blow 0.56 to 0.69

Also

$$W_{75} = \frac{W_{50}}{1.75}$$

Where,

W_{50} and W_{75} are the width of synthetic UH in hr at 50% and 75% of Q_P respectively, where Q_P is in m^3/s and A is area of catchment in Km^2.

INSTANTANEOUS UNIT HYDROGRAPH

The instantaneous unit hydrograph is a fictious, conceptual UH which represent the surface runoff from the catchment due to an instantaneous precipitation of the rainfall excess volume of 1 cm.

It occur when D $\rightarrow$ 0

- Obtained from S curve.
- It is single peaked hydrograph with a finite base width.
- For a given catchment IUH is independent of rainfall characteristics.
- Ordinate of instantaneous hydrograph is given by

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Solid Mechanics

"Education is the most Powerful Weapon which you can use to change the world."

A.P.J. Abdul Kalam

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Solid Mechanics

CLEAR YOUR CONCEPT:

Qu 1 When is the Hydrograph called as a unit hydrograph?

a) When 1cm of runoff is resulted from a rain fall
b) When 3cm of runoff is resulted from rainfall
c) When 1mm of runoff is resulted from rainfall
d) When 3mm of runoff is resulted from rainfall

Qu 2 Unit hydrograph was explained by Sherman in which year?

a) 1925
b) 1928
c) 1932
d) 1945

Qu 3 What is unit hydrograph helpful in?

a) Estimating runoff from a basin
b) Estimating no of days of rain fall
c) Knowing the draught months in a year
d) In deciding the land for hydel power plant

Qu 4 What is the theoretical number of unit hydrographs for given basin?

a) 500
b) 2900
c) 36000
d) Infinite

Qu 5 Above which range should be the unit hydrographs be used?

a) Around 5000 sq km
b) Over 2500 sq km
c) Around 4000 sq km
d) Below 5000 sq km

TEST YOUR SELF:

Qu 6 **Determine the flow rate of water, if the catchment area of hydroelectric power is 2500 km^2, with an average rainfall of 160cm. the percolation and evaporation losses account for 19%?**

a) 9639.8 M^3/s

b) 42.8 M^3/s

c) 859.63 M^3/s

d) 2342 M^3/s

Qu 7 **What is the volume of rainfall in day sec-meters if 6.5cm rainfall occurs over an area of 2400 sq.km?**

a) 1805.56 day sec meter

b) 1225 day sec meter

c) 895 day sec meter

d) 1555.22 day sec meter

Answer:

1-(a), 2-(c), 3-(a), 4-(d), 5-(a), 6-(a), 7-(a)

Design Flood

It is the flood adopted for the design of hydraulic structures like spillways, bridge openings, flood banks etc.

The design flood is usually selected after making a cost benefit analysis the ratio of benefit to cost may be desired to be the maximum.

The methods used in the estimation of design flood can be grouped as under

(i) Physical indication of past flood

(ii) Envelop curves

(iii) Empirical flood formulae

(iv) Rational Method

(v) Unit Hydrograph application

(vi) Frequency analysis (or Statistical methods)

Guideline for Selecting Design floods (CWC, India)

S. NO	Structure	Recommended Design Flood
1.	Spillway for major & medium project with storage more than 60 Mm^3	a) PMF determined by UH and probable maximum precipitation (PMP) b) If (a) is not applicable or possible flood frequency method with T = 1000 years
2.	Permanent barrage and minor dams with capacity less than 60 Mm^3	a) SPF determined by UH and standard project storm (SPS) which is usually the largest recorded storm in the region. b) Flood with a return period of 100 years[(a) or (b) whichever is higher]
3.	Pickup weirs	Flood with a return period of 100 or 50 years depending on the importance of the project.
4.	Aqueducts a) Water way b) Foundations and free beard	Flood with T = 50 years Flood with T = 100 years
5.	Project with very scanty or inadequate data	Empirical formulae

METHODS

Physical Indication of Past Floods

By noting the flood marks (and by local enquiry), depths, affluxes (heading up of water near bridge opening, or similar obstructions to flow), the maximum flood discharge may be estimated.

Envelope Curve

Areas having similar topographical features and climatic conditions are grouped together. All available data regarding discharges are compiled along with their respective catchment areas. Peak flood discharges are then plotted against the drainage areas and a curve is drawn to cover on envelope the highest plotted points. Thus for any drainage area, peak flood can be read from the envelope curves.

- Gives rough estimate of peak flood
- We cannot assign any return period to the peak value.

Empirical Formula

<u>**Various Empirical Equations**</u>

Dicken's Formula

$$Q_p = C_D A^{3/4}$$

Q_p = maximum flood discharge (m^3/s)

A = catchment area (Km^2)

C_D = Dicken's constant with value between 6 to 30

- Used in Central and northern parts of the country (India).

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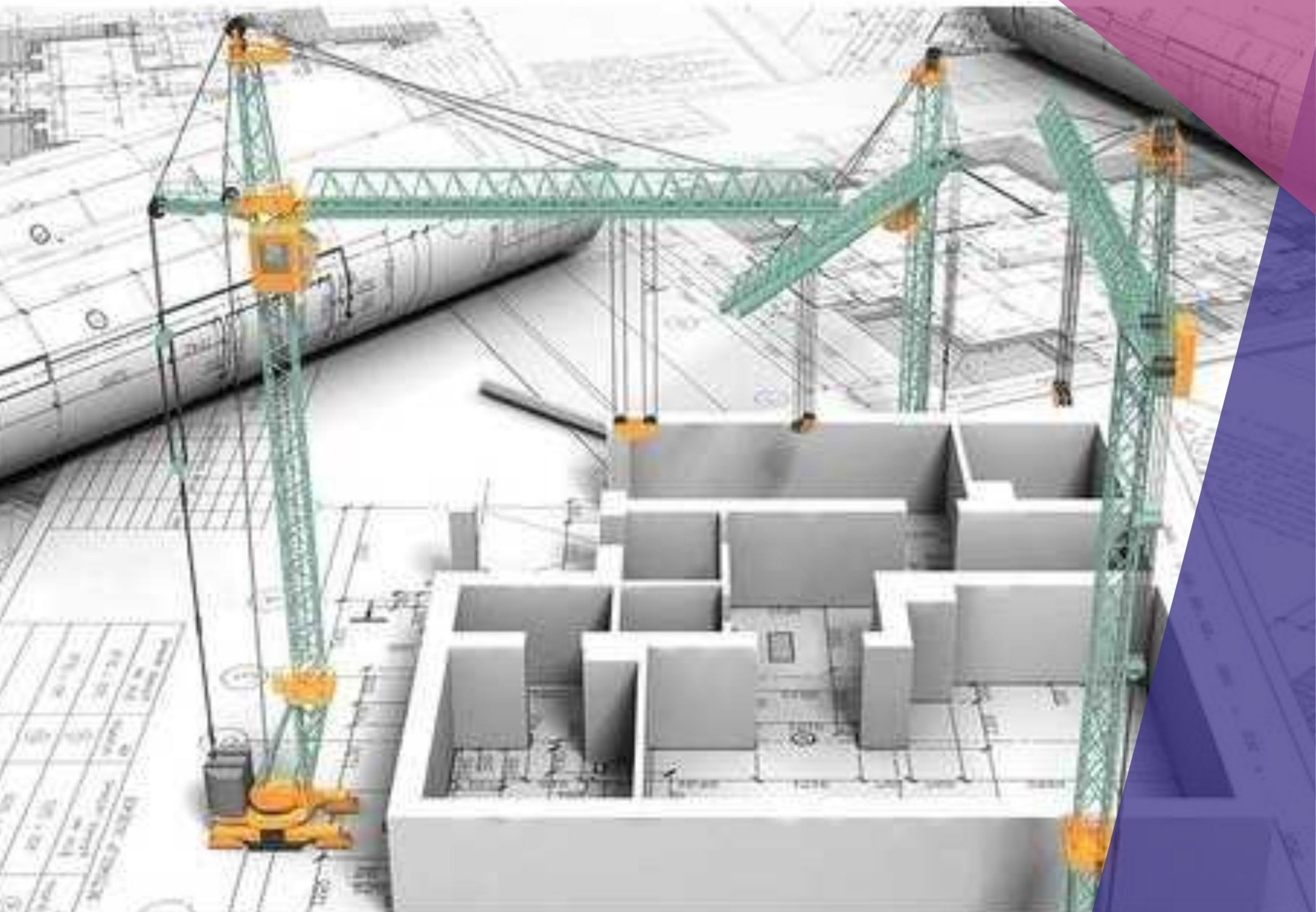

Structural Analysis

"All of us do not have Equal Talent.
But, all of us have an Equal Opportunity
to Develop our Talents."
A.P.J. Abdul Kalam

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The runoff rate corresponding to this condition in giving by

$$Q = C\ I\ A$$

A = area of catchment

I = Intensity of rainfall

C = Runoff Coefficient to account for abstraction from the rainfall

The intensity of rainfall should be corresponding to a duration equal to concentration time and desired return period as obtained from IDF curve.

(i.e. I = $i_{t_{c,p}}$ Rainfall intensity to a duration of time of concentration (t_c) and desired probability of exceedance P (return period T = 1/p))

$$i_{t_{c,p}} = \frac{KT^x}{(t_c + a)^m}$$

Where k, a, x, & m are constant.

Time of Concentration

- US practice

$$t_c = t_p = C_{tL}\left(\frac{LL_{ca}}{\sqrt{S}}\right)^n$$

- Kirpich equation (1940)

$$t_c = 0.01947\, L^{0.77}\ S^{-0.385}$$

t_c = Time of concentration

L = Maximum length of travel of water in m

S = Slope of catchment = ΔH/L in which

ΔH = Difference in elevation b/w the most remote point on the catchment & outlet.

Runoff Coefficient

Based on the field situation, aquifers are classified as

a) unconfined aquifer

b) confined aquifer

Unconfined Aquifer: Also known as 'water table aquifer'. It has a free surface, i.e. W. T exists

Confined Aquifer: It is also known as '**artesian aquifer'.** An aquifer confined between two impervious beds such as aquicludes or aquifuges. The water in the confined aquifer will be under pressure and hence the piezometric level will be much higher than the top level of the aquifer.

PERCHED WATER TABLE: The water table is retained locally in the impervious stratum

SPECIFIC YIELD (S_γ): It is the volume of water that can be extracted by the force of gravity. Expressed as percent of total volume of aquifer.

SPECIFIC RETENTION (S_R): It is the volume of water which is held in the aquifer against the gravity, expressed as percent of total volume of aquifer.

$$S_Y + S_R = n \qquad n = \text{porosity.}$$

STORAGE COEFFICIENT: It is the volume of water that an aquifer releases per unit surface area of aquifer per unit change in the component of head normal to that surface used to express water yielding capacity of confined aquifer. It is also called 'Storativity'.

COEFFICIENT OF TRANSMISSIBILITY (T)

It is the rate of flow of water through a vertical strip aquifer of unit width (1 meter) and extending to full saturation height under unit hydraulic gradient. It is also called "Coefficient of transmissivity".

Test Series Available..

Total weekly test	: 35
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Mock test	: 16
Total test	: 80

T = k X b for confined aquifer

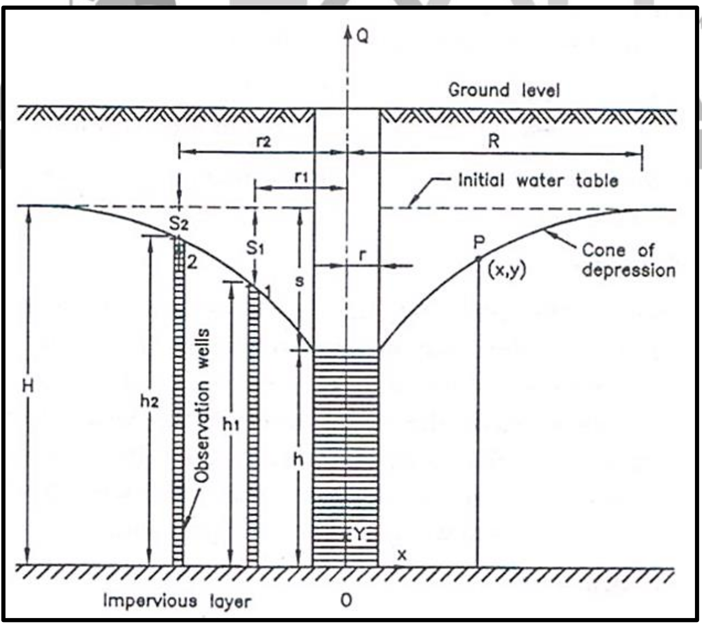
Where b = thickness of confined aquifer

T = k X H for unconfined aquifer

ASSUMPTIONS IN THE DUPIT'S THEORY

Velocity of flow is proportional to tangent of hydraulic gradient, flow is horizontal and uniform. Aquifer is homogeneous, isotropic, the well penetrates and receives water from the entire thickness of aquifer, the coefficient of transmissibility is constant, flow is laminar and Darcy's law is valid.

DUPIT'S THEORY FOR STEADY RADIAL FLOW TO A WELL: Fully penetrating well in unconfined aquifer:



r = Radius of well, R = Radius influence or Radius of zero draw down.

H = Thickness of the aquifer measured from impermeable layer to the initial level of W.T.

S = Draw down at the well.

h = Depth of water in the well measured above the impermeable layer.

Discharge, Q

$$= \frac{2\pi kb(H-h)}{\log_e(R/r)} = \frac{2\pi kb(h_2-h_1)}{\log_e(r_2/r_1)}$$

$$= 2\pi kb\,\frac{(H-h_1)}{\log_e(R/r_1)} = 2\pi kb\,\frac{(h_1-h)}{\log_e(r_1/r)}$$

This is known as Thiem's equation.

$$Q = \frac{2\pi T(h_2-h_1)}{\log_e(r_2/r_1)}$$

Darcy's Law

$$V = K \times i$$

V = Apparent velocity of seepage = Q/A;

i = hydraulic gradient;

K = permeability

The above law is applicable for laminar flow conditions. Flow in soils can be taken as laminar when the Reynolds's number is ≤ 1

Coefficient of Permeability

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

$$K = k_0\frac{\gamma}{\mu}$$

k_0 = **intrinsic permeability,** which is a function of medium only, it has dimensions cm^2 or m^2 or in darcy's, where 1 darcy = 9.87 x $10^{-13}\ m^2$

- The ratio of water level change to atmospheric pressure head change is called barometric efficiency.
- In a pumping artesian well, the total draw down at the well (S) is made up of two parts

  (i) formation loss (ii) well loss

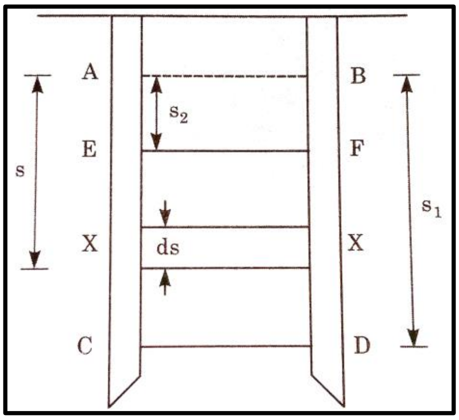
  Formation loss: It is the head drop required to cause the laminar porous media flow.

  Well loss: It is the total head drop required to sustain turbulent flow nearest to the well and head loss through the well screen and casing.

Specific Capacity: It is the discharge per unit draw down at the well (Q/S). It is a measure of the performance of the well.

Open Well Recuperation Test

Discharge is only from bottom of the well. The well sides are made of impermeable material.



h_1 = depression head when pumping stopped.

h_2 = depression head at a time 'T' after pumping stopped.

K = a constant

Specific yield or specific capacity of an open

Well (k/A) = C

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Surveying

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The best Brains of the Nation may be found on the last Benches of the Classroom.

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CLEAR YOUR CONCEPT:

Qu 1 An _________ is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well.

a) Aquitard
b) Aqifuge
c) Aquiclude
d) Aquifer

Qu 2 A commercially manufactured, vermin-proof _________ is the only type of cap designed to keep animals, insects and contaminants from entering your well.

a) Animal cap
b) Security cap
c) Danger cap
d) Well cap

Qu 3 There are two primary methods of drilling cable tool and ________

a) Rotary
b) Rotatory
c) Penetrating
d) Insertion

Qu 4 The specific retention S_R is given by _______

a) $(V_{wR}+V)*100$
b) $(V_{wR}-V)*100$
c) $(V_{wR}/V)*100$
d) $(V_{wR}*V)*100$

Qu 5 **The relation between porosity n, specific retention S_R, specific yield S_γ is __________**

a) $n= S_R-S_\gamma$

b) $n= S_R+S_\gamma$

c) $n= S_R*S_\gamma$

d) $n= S_R/S_\gamma$

TEST YOUR SELF:

Qu 6 **In the storage coefficient, the unit change in the component of the head is measured in _________ to the surface.**

a) Normal
b) Tangential
c) Radial
d) Inclined at 30°

Qu 7 **If b is the aquifer thickness, the relationship between coefficient of transmissibility T and coefficient of permeability is ________**

a) T=bk
b) T=b/k
c) T=b+k
d) T=b-k

Answer:

1-(d), 2-(d), 3-(a), 4-(c), 5-(b), 6-(a) – 7-(a)

The Sub-Surface Float Method

The sub-surface float is a hollow metal cylinder which is attached by a cord to the surface float. The sub surface float remains submerged in water. The movement of the surface float is guided by the movement of the sub-surface float.

The Velocity Rod Method

The velocity rod is made of hollow metal tube or wood. A weight is provided at the bottom of the rod to keep it vertical. The velocity gives the required mean velocity directly and need not be multiplied by any coefficient.

The Current Meter Method

The price current meter is commonly used for measuring the velocity of flow of the river. The number of revolutions per second is counted by the observer with the help of a stop watch. The velocity can be ascertained from the rating table corresponding to the number of rotations.

The price current meter and Gurley current meter are typical instruments under the vertical axis type current meters. The normal range of velocities is from 0.15 to 4.0 m/s.

A current meter is so designed that its rotation speed varies linearly with the stream velocity V at the location of the instrument.

The velocity of flow is calculated using the following equation.

$$\mathbf{V = a \times N_s + b}$$

Where V stream velocity at the instrument location in m/s.

N_s = revolutions per second of the meter and a, b are constants of the meter.

In shallow streams of depth upto about 3.0 m, the velocity measured at 0.6 times the depth of flow below the water surface is taken as the average velocity. This procedure is known as the single - point observation method.

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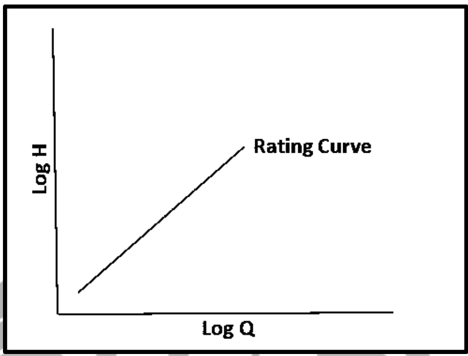
In moderately deep streams the velocity is observed at two points (two point method) and their average is taken i.e. at 0.2 and at 0.8 times the depth of flow below the free surface the velocities are measured and the average velocity is taken.

Stage – Discharge – Rating Curve

A curve drawn between stream discharge (Q) and gauge height 'h' is called "stage-discharge rating curve".



Gauge Well: Here water level is not subject to fluctuations caused by wind or waves. Gauge post is installed in the well.

Relation between Stream Discharge (Q) and Gauge height

$$Q = C_r\ [H - h_0]^n$$

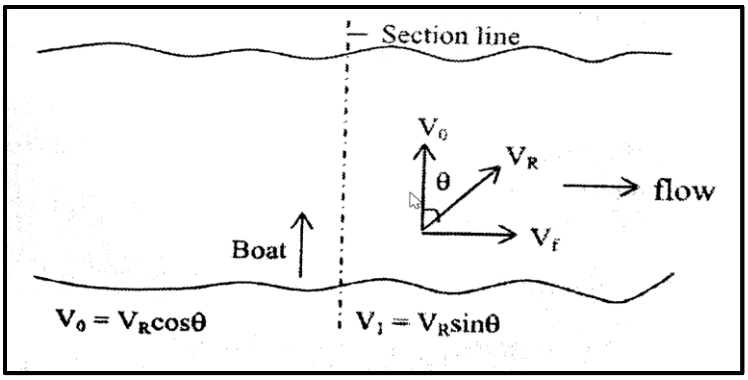
C_r and n are rating curve constants for a given stream gauging section.

H = gauge height (stage)

Stage is the water surface elevation with respect to some datum.

h_0 = a constant which represents gauge reading corresponding to zero discharge.

Measurement of discharge by **'Salt- Concentration method' or 'Chemical method' or 'Dilution method'.**



CLEAR YOUR CONCEPT:

Qu 1 River gauge is used to measure ______

a) Still level
b) Water level
c) Turbulence
d) Current

Qu 2 Which of the following instrument uses a rating curve?

a) River gauge
b) Rain gauge
c) Tipping bucket
d) Marine gauge

Qu 3 Rating curve can be used for __________

a) Reflecting signal
b) Determining strength of signal
c) Stage measurements
d) Polarization of signal

Qu 4 Which of the following constructions are used in the case of the application of river gauge?

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Transportation Engineering

END is not the end if fact E.N.D. means
" Effort Never dies"

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a) Culverts
b) Bridges
c) Dams
d) Weirs and notches

Qu 5 Which of the following equipment is used in stream gauge?

a) Stilling well
b) Ultrasonic device
c) Par shall fume
d) Stage encoder

<u>TEST YOUR SELF:</u>

Qu 6 A 1 hour rainfall of 10 cm has return period of 50 year. The 1 hour of rainfall 10 cm or more will occur in each of two successive year is

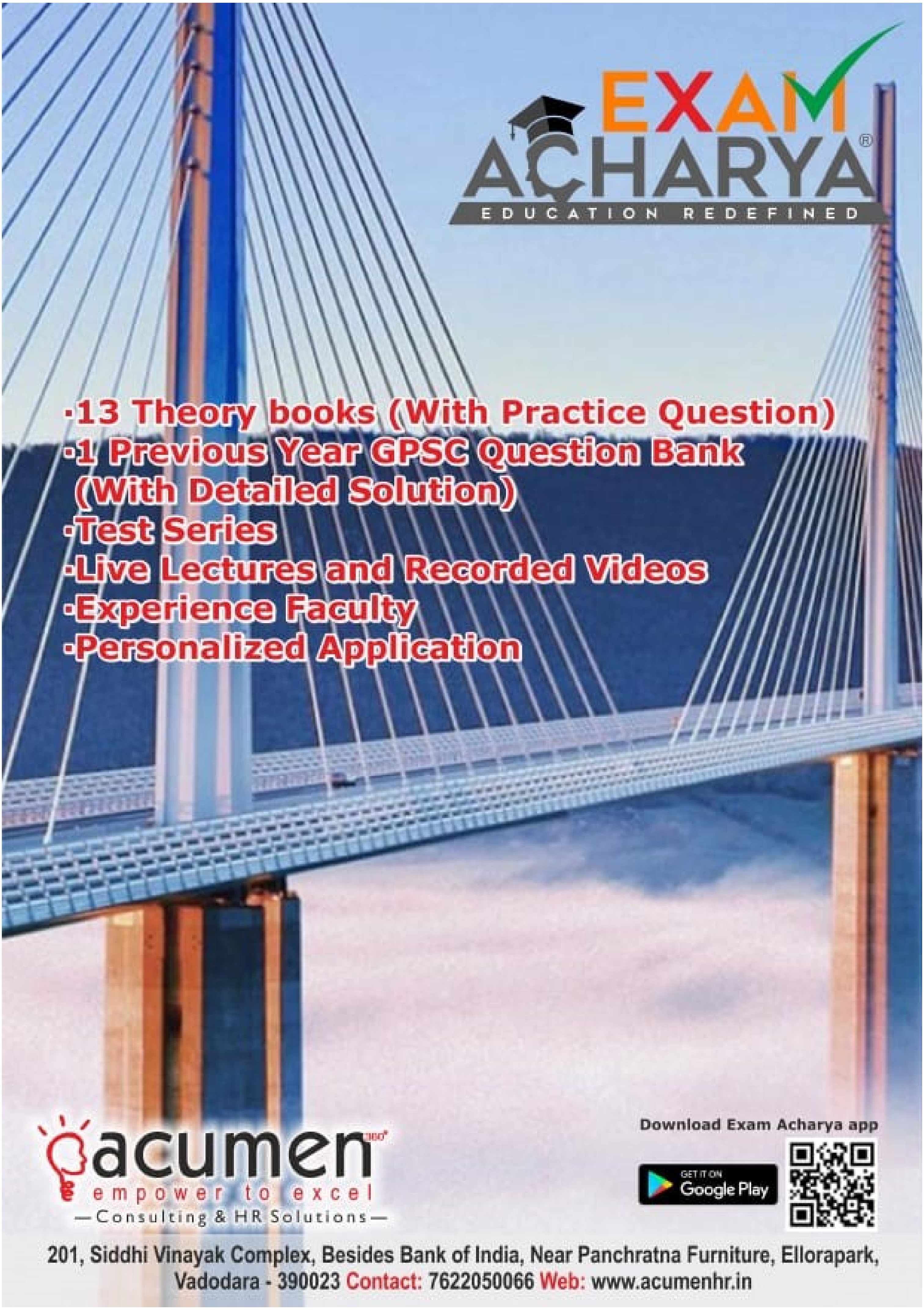
(a) 0.04
(b) 0.2
(c) 0.02
(d) 0.0004

Qu 7 What is the volume of rainfall in day sec-meters if 6.5cm rainfall occurs over an area of 2400 sq.km?

a) 1805.56 day sec meter
b) 1225 day sec meter
c) 895 day sec meter
d) 1555.22 day sec meter

Answer:

1-(b), 2-(a), 3-(c), 4-(d), 5-(a), 6-(d), 7-(a)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