UNIT-V					
10		Derive the expression for discharge in case of unconfined Aquifer with neat sketch.	L3	CO5	10 M
OR					
11	a)	Describe the Occurrence of ground water.	L2	CO5	5 M
	b)	Write the short notes on well construction and Open Well-Recuperation test.	L2	CO5	5 M

Code: 23CE3502

III B.Tech - I Semester - Regular Examinations - NOVEMBER 2025

ENGINEERING HYDROLOGY
(CIVIL ENGINEERING)

Duration: 3 hours   Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level   CO – Course Outcome

PART – A

		BL	CO
1.a)	Define Hydrologic cycle and write its applications.	L1	CO1
1.b)	List out different types of rain gauge networks.	L1	CO1
1.c)	Explain Evapotranspiration and controlling methods.	L1	CO2
1.d)	What is meant by infiltration capacity curve?	L1	CO2
1.e)	Explain the concept of Unit Hydrograph.	L1	CO3
1.f)	Define Synthetic Unit Hydrograph and Instantaneous Unit Hydrograph (IUH).	L1	CO3
1.g)	Define Standard Project Flood (SPF) and Probable Maximum Flood (PMF).	L1	CO4
1.h)	What are the flood control methods?	L1	CO4
1.i)	Differentiate between confined and unconfined aquifer.	L1	CO5
1.j)	List out the different types of wells.	L1	CO5

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Define the Hydrologic Cycle. Explain its components with a neat sketch.	L2	CO1	5 M
	b)	Explain the Non-Recording type of rain gauges and discuss their merits and demerits.	L2	CO1	5 M
		OR			
3	a)	The normal annual rainfall at stations A, B, C and D in a basin are 70.97, 57.59, 86.28 and 89.01 cm respectively. In the year 1995, the station D was inoperative and the stations A, B and C recorded annual precipitation of 81.11, 92.23 and 89.89 cm respectively. Estimate the rainfall at station D in that year.	L2	CO1	5 M
	b)	Differentiate between Intensity Duration Frequency (IDF) and Depth Area Duration (DAD) curves.	L2	CO1	5 M
		UNIT-II			
4	a)	Discuss the factors affecting evaporation and its control methods.	L2	CO2	5 M
	b)	Explain the initial abstraction and its importance in hydrological analysis.	L2	CO2	5 M
		OR			

5	a)	Explain the different infiltration indices such as φ-index and W-index.	L2	CO2	5 M
	b)	Determine the flood hydrograph from the unit hydrograph obtained due to a 3-hour storm. Total precipitation =20 cm, initial loss = 0.6, Ø-index=1cm/hr.	L3	CO2	5 M

Time (hr)	0	3	6	9	12	15	18	21	24	27	30
Discharge (cumecs)	4	9	12	18	20	16	20	10	8	6	4

		UNIT-III			
6	a)	Define Runoff and explain different factors effecting runoff.	L2	CO3	5 M
	b)	Explain the terms: i) Flow Mass Curve ii) Flow Duration Curve	L2	CO3	5 M
		OR			
7		Explain the different components of a unit hydrograph with a neat sketch and write its merits and demerits.	L3	CO3	10 M
		UNIT-IV			
8		Define floods. Explain the causes and effects of floods with controlling methods.	L3	CO4	10 M
		OR			
9		For a data of maximum recorded annual floods of a river the mean and standard deviation are 5200 m^3 and 2705 m^3 respectively. Using Gumbel's Extreme Value Distribution, estimate the return period of a design flood of 9700 m^3/s. Assume as infinite sample size.	L4	CO4	10 M

III B. Tech – I Semester – Regular Examinations

November 2025

ENGINEERING HYDROLOGY (23CE3502)

(CIVIL ENGINEERING)

Scheme of Evaluation

PART-A (10× 2 = 20 Marks)

1(a) Hydrologic Cycle – 2 Marks

1(b) Rain Gauge Networks – 2 Marks

1(c) Evapotranspiration – 2 Marks

1(d) Infiltration Capacity Curve – 2 Marks

1(e) Unit Hydrograph – 2 Marks

1(f) SUH & IUH – 2 Marks

1(g) SPF & PMF – 2 Marks

- SPF definition → 1 mark
- PMF definition → 1 mark

1(h) Flood Control Methods – 2 Marks

1(i) Confined vs Unconfined Aquifer – 2 Marks

- Confined aquifer explanation → 1 mark
- Unconfined aquifer explanation → 1 mark

1(j) Types of Wells - 2 Marks

PART – B (5× 10 = 50 Marks)

Q2 (a) Hydrologic Cycle – 5 Marks

Mark Distribution:

- Definition → 1 mark
- Sketch (even rough) → 1 mark
- Explanation of components (any 4–5) → 3 marks

Q2 (b) Non-Recording Rain Gauge – 5 Marks

- Definition & mention of Symons gauge → 1 mark

- Construction (any 3 parts) → 1 mark
- Working → 1 mark
- Merits (any 2) → 1 mark
- Demerits (any 2) → 1 mark

Q3 (a) Thiessen / Missing Station (Rainfall Estimation) – 5 Marks

Scheme:

- Formula identification → 1 mark
- Substitution of values → 2 marks
- Final computed rainfall at station D → 2 marks

Q3 (b) IDF vs DAD – 5 Marks

- IDF meaning + application → 2 marks
- DAD meaning + application → 2 marks
- Any 2 valid differences → 1 mark

Q4 (a) Factors Affecting Evaporation – 5 Marks

- Any 5 factors → 3 marks
- Any 2 control methods → 2 marks

Q4 (b) Initial Abstraction – 5 Marks

- Definition → 2 marks
- Components (interception, depression storage, etc.) → 1 mark
- Importance (any 2–3 points) → 2 marks

5 (a) Infiltration Indices (Φ-index, W-index, etc.) – 5 Marks

- Φ-index definition → 2 marks
- W-index definition → 2 marks
- Distinction / formula → 1 mark

Q5 (b) Flood Hydrograph from Unit Hydrograph – 5 Marks

- Tabulation of ER & UH ordinates → 2 marks
- steps → 2 marks
- Final DRH values → 1 mark

Q6 (a) Runoff & Factors Affecting Runoff – 5 Marks

- Definition of runoff → 1 mark

- Any 4–5 factors explained → 4 marks

6(b) Flow Mass Curve & Flow Duration Curve – 5 Marks

- Flow mass curve definition → 1 mark
- FMC merits + demerits → 1.5 marks
- Flow duration curve definition → 1 mark
- FDC merits + demerits → 1.5 marks

Q7 Unit Hydrograph (10 Marks)

- Definition → 1 mark
- Components (rising limb, peak, recession, lag) → 4 marks
- Sketch → 2 marks
- Merits → 1.5 marks
- Demerits → 1.5 marks

Q8 Floods – Causes, Effects, Control (10 Marks)

- Definition → 1 mark
- Causes (any 4–5) → 3 marks
- Effects (any 3–4) → 2 marks
- Structural methods → 2 marks
- Non-structural methods → 2 marks

Q9 Gumbel Distribution Problem (10 Marks)

- Identify formula (reduced variate, frequency factor) → 2 marks
- Calculation of y for given flood → 3 marks
- Return period (T) → 5 marks

Q10 Unconfined Aquifer Discharge (10 Marks)

- Sketch of unconfined aquifer → 2 marks
- Dupuit assumptions → 2 marks
- Derivation steps → 5 marks
- Final formula → 1 mark

Q11 (a) Occurrence of Groundwater – 5 Marks

- Vadose/saturated zone explanation → 2 marks
- Aquifers, aquitards, water table → 2 marks

- Confined/unconfined mention → 1 mark

Q11 (b) Well Construction & Recuperation Test – 5 Marks

- Construction steps/components → 2.5 marks
- Recuperation test procedure → 2.5 marks

PART – A : Answers (10 × 2 = 20 Marks)

1(a) Define the Hydrologic Cycle. (2M)
The hydrologic cycle is the continuous movement of water between the atmosphere, land, and oceans through processes such as evaporation, transpiration, condensation, precipitation, infiltration, and runoff.

1(b) List out different types of rain gauge networks. (2M)
The common rain gauge networks are:
1. **Non-Recording Rain Gauge Network**

Uses simple gauges that measure only the total rainfall over a period.
Gauges included

- Symons rain gauge

Recording Rain Gauge Network
Uses gauges that continuously record rainfall intensity versus time.
Gauges included

- Tipping bucket rain gauge
- Weighing type rain gauge
- Float-type recording gauge

1(c) Explain Evapotranspiration and its controlling methods. (2M)
Evapotranspiration (ET) is the combined loss of water from the earth's surface by evaporation and transpiration from plants.
Controlling methods: mulching, windbreaks, shading, reducing exposed water surface, and selecting low-water-demand vegetation.

1(d) What is meant by infiltration capacity curve? (2M)
It is a curve showing the variation of infiltration capacity with time during a storm. Infiltration capacity decreases rapidly at the beginning and then gradually becomes nearly constant.

1(e) Explain the concept of Unit Hydrograph. (2M)
A Unit Hydrograph (UH) is the direct runoff hydrograph produced by 1 cm of effective rainfall occurring uniformly over a catchment in a specific duration.

1(f) Define Synthetic Unit Hydrograph and Instantaneous Unit Hydrograph (IUH). (2M)
Synthetic Unit Hydrograph (SUH): A UH derived without using rainfall–runoff data, based on empirical relationships using basin characteristics.
Instantaneous Unit Hydrograph (IUH): The hydrograph produced by 1 unit of effective rainfall occurring instantaneously at a point in time (duration → zero).

1(g) Define Standard Project Flood (SPF) and Probable Maximum Flood (PMF). (2M)
Standard Project Flood (SPF): A flood resulting from the Standard Project Storm, representing severe but reasonably possible conditions.
Probable Maximum Flood (PMF): The largest flood that could conceivably occur, derived from the Probable Maximum Precipitation (PMP).

1(h) What are the flood control methods? (2M)
Structural: dams, levees, floodwalls, diversion channels, channel improvement.
Non-structural: flood forecasting, zoning, evacuation planning, watershed management.

1(i) Differentiate between confined and unconfined aquifer. (2M)
Confined aquifer: Bounded above and below by impermeable layers; water is under pressure; piezometric head rises above aquifer.
Unconfined aquifer: Upper surface is the water table; not confined by an upper impermeable layer.

1(j) List out the different types of wells. (2M)
Common well types:
1. Open wells (dug wells)
2. Tube wells
3. Driven wells
4. Bored wells
5. Collector wells (radial wells)

PART-B QUESTIONS

Q2 (a) Define the Hydrologic Cycle. Explain its components with a neat sketch. (5 M)

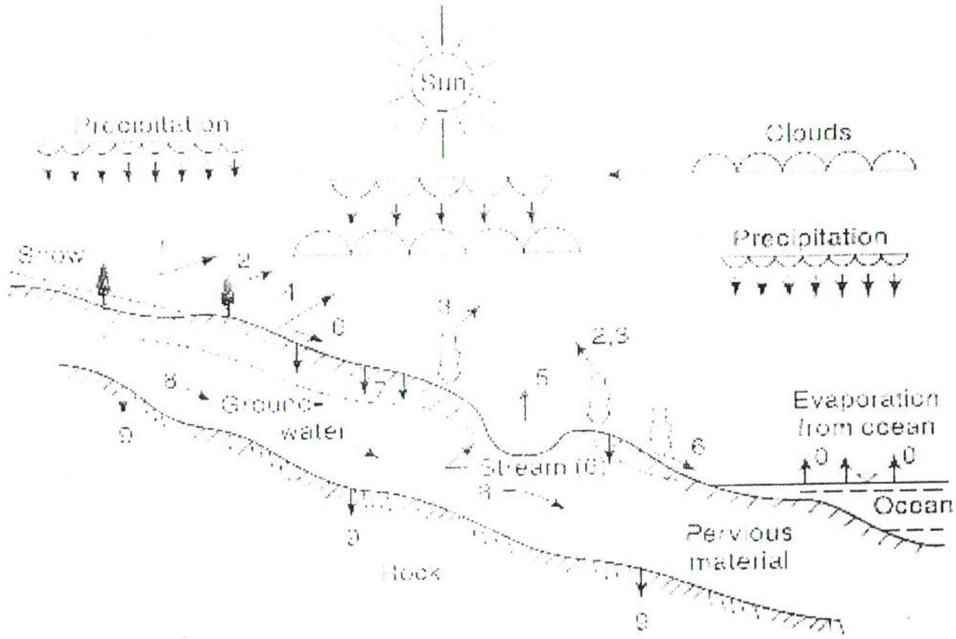
Definition: The hydrologic cycle (water cycle) is the continuous circulation of water in various phases (liquid, vapor, solid) between the atmosphere, land surface, and oceans through processes like evaporation, transpiration, condensation, precipitation, infiltration and runoff.

Major components and brief description (with sketch):

1. **Precipitation:** Water released from clouds in the form of rain, snow, sleet or hail; the primary input of moisture to the land surface.
2. **Interception:** Part of precipitation is intercepted by vegetation and other surfaces, and may evaporate back to the atmosphere.
3. **Infiltration:** Process by which precipitation enters the soil surface and becomes soil moisture or recharges groundwater. Varies with soil, vegetation, antecedent moisture.
4. **Percolation & Groundwater flow:** Movement from soil moisture to the saturated zone and lateral groundwater flow to rivers, lakes or oceans.
5. **Runoff / Overland flow:** Water that flows over land into channels when infiltration capacity is exceeded. Contributes to streamflow.

6. **Evaporation & Evapotranspiration:** Evaporation from water bodies and soil; transpiration from plants. Combined as evapotranspiration — major return to atmosphere.

7. **Storage (lakes, reservoirs, glaciers):** Temporary storages in the system and long–term storage in ice and groundwater



0 – Evaporation from ocean	5 – Evaporation from water bodies
1 – Raindrop evaporation	6 – Surface runoff
2 – Interception	7 – Infiltration
3 – Transpiration	8 – Groundwater
4 – Evaporation from land	9 – Deep percolation

Fig. 1.1 The Hydrologic Cycle

Q2 (b) Explain the Non-Recording type of rain gauges and discuss their merits and demerits. (5 M)

Answer

Non-Recording Type of Rain Gauges

A non-recording rain gauge is a type of instrument used to measure the total rainfall over a specific period, but it does not provide continuous records of rainfall intensity or variation with time. The most commonly used non-recording gauge in India is the Symons' Rain Gauge.

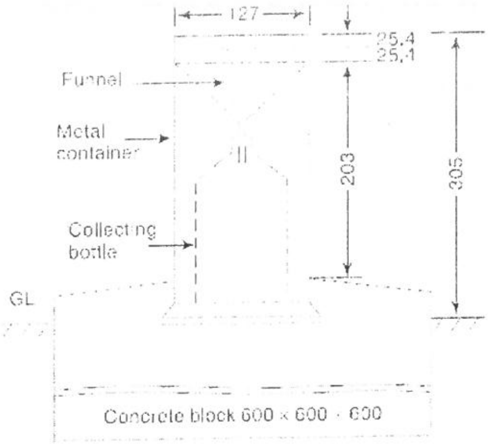


Fig. 2.5 Nonrecording Raingauge (Symons' Gauge)

Construction

A standard Symons' Rain Gauge consists of:

- A cylindrical collector with a diameter of 12.7 cm.
- A funnel that directs rainfall into a receiving bottle.
- The funnel rim is positioned 30.5 cm above ground level.
- A metal container houses the receiving bottle.
- Rainwater collected in the bottle is measured using a graduated measuring glass, with an accuracy of 0.1 mm.

Working

- Rainwater falling into the collector passes through the funnel and gets stored in the bottle.
- At a fixed time every day (in India at 8:30 AM IST), the collected rainfall is measured and recorded.
- The instrument only provides the total rainfall depth over the previous 24 hours.

Merits (Advantages)

1. Simple Construction
   - Easy to install, operate, and maintain.
2. Low Cost
   - More economical compared to recording gauges.
3. Reliable for Daily Rainfall Measurement
   - Provides accurate measurement of total rainfall with high precision (up to 0.1 mm).
4. Minimal Maintenance
   - No mechanical or electrical components that require servicing.
5. Suitable for Large Networks
   - Because of low cost, many gauges can be installed to achieve better spatial coverage.

Demerits (Disadvantages)

1. No Record of Rainfall Intensity
   - Cannot measure how rainfall varies with time during a storm (e.g., peaks, duration).
2. Not Useful for Hydrological Modelling

  - Lacks data for flood forecasting, runoff models, or intensity–duration–frequency (IDF) analysis.

3. Manual Observation Required
   - Needs a trained observer to take readings at fixed times.
4. Risk of Human Error
   - Mistakes during reading, emptying, or recording can affect data accuracy.
5. Not Suitable for Snowfall Without Modification
   - Snow measurement requires removing the funnel and manually melting snow.

Q3(A) Estimation by Thiessen or arithmetic — the question in paper: Estimate rainfall at an inoperative station D (data given). (5 M)

Normal Ratio Method Formula

$$P_D = \frac{1}{n}\sum\left(P_i \cdot \frac{N_D}{N_i}\right)$$

Where

- P_D = estimated rainfall at D
- P_i = precipitation at stations A, B, C
- N_i = normal precipitation at A, B, C
- N_D = normal precipitation at D = 89.01 cm
- $n = 3$

Calculations

For Station A

$$P_A \cdot \frac{N_D}{N_A} = 81.11 \cdot \frac{89.01}{70.97}$$

$$= 81.11 \cdot 1.2547 = 101.77$$

For Station B

$$P_B \cdot \frac{N_D}{N_B} = 92.23 \cdot \frac{89.01}{57.59}$$

$$= 92.23 \cdot 1.5457 = 142.55$$

For Station C

$$P_C \cdot \frac{N_D}{N_C} = 89.89 \cdot \frac{89.01}{86.28}$$

$$= 89.89 \cdot 1.0317 = 92.75$$

Average

$$P_B = \frac{101.77 + 112.55 + 92.75}{3}$$

$$P_B = \frac{337.07}{3} = 112.36 \text{ cm}$$

Q3 (B) Differentiate between Intensity–Duration–Frequency (IDF) curves and Depth–Area–Duration (DAD) curves. (5 M)

Answer

- **IDF curves:**
    - IDF gives rainfall intensity (I) as a function of storm duration (D) for a given return period (T) or frequency. Typically I = f(D, T).
    - Used for design of drainage, sewers, culverts, stormwater structures — need intensity for given duration.
- **DAD curves (Depth–Area–Duration):**
    - DAD shows how storm depth (or total rainfall) varies with area and duration for a given return period. It is useful when areal reduction or spatial extent matters, e.g., for large catchments or reservoir inflow.
    - DAD expresses depth as function of area and duration (and sometimes return period). Useful for regional analysis.

Key differences:

- IDF focuses on intensity for a point or small area vs DAD emphasizes total depth and its variation with catchment area. IDF used for urban drainage; DAD for hydrologic studies of larger basins.

Q4 (a) Discuss factors affecting evaporation and its control methods. (5 M)

Factors Affecting Evaporation

1. Temperature
    - Higher temperature increases the kinetic energy of water molecules, resulting in higher evaporation rates.
2. Wind Speed
    - Strong winds remove the saturated air above the water surface, enhancing evaporation.
3. Humidity

- High humidity reduces evaporation, while low humidity increases it due to greater vapor pressure difference.

4. Surface Area
    - Larger exposed surface area leads to more evaporation as more water molecules can escape.
5. Atmospheric Pressure
    - Lower pressure enhances evaporation, whereas high pressure suppresses it.
6. Water Quality
    - Presence of dissolved salts reduces evaporation (saline water evaporates slower than fresh water).
7. Solar Radiation
    - Higher solar radiation increases the heating of water and thus increases evaporation.

Control methods:

- Surface covers: Floating covers, shade, or oil films to reduce evaporation from reservoirs (note environmental concerns with oil).
- Windbreaks / shelterbelts: Reduce wind speed over water body.
- Reduce surface area: Use deeper, smaller-surface-area reservoirs where possible.
- Vegetation management: To control transpiration where desired.

Q4 (b) Explain the initial abstraction and its importance in hydrological analysis. (5 M)

Initial Abstraction (Ia)

Initial Abstraction refers to the initial losses that occur before runoff begins during a rainfall event. It includes all forms of water loss that take place prior to surface runoff, such as:

- Interception by vegetation
- Depression storage (water stored in small surface depressions)
- Infiltration during the early stages of rainfall
- Evaporation and wetting of the surface

Importance of Initial Abstraction in Hydrological Analysis

1. Determines Runoff Initiation
    - Runoff begins only after initial losses are satisfied. Therefore, Initial Abstraction controls when runoff starts during a rainfall event.
2. Affects Runoff Volume
    - Higher initial abstraction reduces effective rainfall, leading to lower runoff. Accurate estimation is essential for computing storm runoff.
3. Improves Flood Estimation
    - Initial abstraction plays a crucial role in hydrological modeling for flood forecasting and peak discharge calculations.
4. Essential in SCS-CN Method
    - It is a key parameter for computing effective rainfall (Pe) and directly influences watershed runoff predictions.
5. Reflects Watershed Conditions
    - Initial abstraction is influenced by land use, soil moisture, vegetation, and surface roughness. Understanding Initial Abstraction helps in assessing watershed behaviour before storm events.

Q5 (a) Explain the different infiltration indices such as p-index and W-index. (5 M)

Infiltration Indices – φ-Index and W-Index (5 Marks)

1) φ-Index (Phi-Index)

- The φ-index is defined as the *average constant rate of infiltration* during a storm such that the total rainfall above this value equals the total runoff.
- It is derived from the rainfall hyetograph together with the observed runoff volume.
- The initial losses (interception, depression storage, wetting) are treated as infiltration.
- If rainfall intensity is less than φ, all rainfall infiltrates.
- If rainfall intensity is greater than φ, the excess (rainfall − φ) becomes runoff.
- Rainfall excess calculated this way is also known as effective rainfall.

2) W-Index

- The W-index is the *average rate of infiltration during the periods when rainfall intensity exceeds infiltration capacity*, after excluding initial abstractions.
- It is more accurate than φ-index because initial losses are not included in the infiltration.

$$W\text{-index} = \frac{\text{Rainfall} - \text{Initial losses} - \text{Runoff}}{\text{Duration when } i > f}$$

Q5 (b) Determine the flood hydrograph from the unit hydrograph (5 M)

1. Compute continuing loss during storm (infiltration rate × duration):
   Φ-index (continuing loss) = 1 cm/hr, storm duration = 3 hr → continuing loss = 1 × 3 = 3.0 cm.
2. Effective rainfall (Peff):
   Peff = Total precipitation − initial loss − continuing loss
   Peff = 20.0 − 0.6 − 3.0 = 16.4 cm.

   (Interpretation: effective depth of rainfall that produces direct runoff = 16.4 cm.)

3. Unit hydrograph scaling: Unit hydrograph ordinates correspond to 1 cm (unit) of effective rainfall (assumption standard in UH problems). Multiply each UH ordinate by Peff (in cm) to obtain flood hydrograph ordinates in cumecs.
4. Compute flood hydrograph ordinates: (UH ordinate × 16.4)

Time (hr)	UH (cumec)	Flood hydrograph (cumec) = UH × 16.4
0	4	4 × 16.4 = 65.6
3	9	9 × 16.4 = 147.6
6	12	12 × 16.4 = 196.8
9	18	18 × 16.4 = 295.2
12	20	20 × 16.4 = 328.0
15	16	16 × 16.4 = 262.4
18	20	20 × 16.4 = 328.0
21	10	10 × 16.4 = 164.0
24	8	8 × 16.4 = 131.2
27	6	6 × 16.4 = 98.4
30	4	4 × 16.4 = 65.6

Q6 (a) Define Runoff and explain different factors affecting runoff. (5 M)

Runoff definition:

Runoff is the portion of precipitation that flows over the land surface or through subsurface to streams and rivers; it includes surface runoff, interflow and baseflow. Its magnitude is controlled by climatic inputs and catchment characteristics.

Factors affecting runoff:

- Rainfall amount, intensity and duration.
- Antecedent moisture conditions.
- Soil type, infiltration capacity, land use/vegetation cover.
- Slope and topography.
- Drainage network, channel conditions and human interventions (urbanization).

Q6 (b) Explain Flow Mass Curve and Flow Duration Curve (merits & demerits). (5 M)

Flow Mass Curve
Definition

A Flow Mass Curve is a plot of the cumulative discharge (or cumulative volume of flow) versus time.

It is obtained by continuously adding the flow volumes over time.

It shows:

- Water availability
- Storage requirements
- Reservoir capacity estimation

Uses

- Determining required reservoir storage to meet a constant draft.
- Reservoir operation studies.
- Comparing inflow with demand lines.

Merits

1. Simple and easy to construct.
2. Gives a clear picture of cumulative water availability.
3. Useful for determining minimum reservoir capacity.
4. Helps in analyzing deficit and surplus periods.

Demerits

1. Requires long-term continuous flow data.
2. Not suitable for short-duration or highly variable flows.
3. Does not show flow variability directly.
4. Difficult to interpret when inflow fluctuates widely.

Flow Duration Curve (FDC)

Definition

A Flow Duration Curve is a plot showing the percentage of time that a given discharge is equaled or exceeded in a stream. It is obtained by ranking the flows from highest to lowest and computing exceedance probability.

It shows:

- Reliability of flow
- Flow variability
- Power potential
- Minimum flows

Uses

- Hydropower studies.
- Planning water supply schemes.
- Estimating dependable discharge (e.g., 90% dependable flow).
- Assessing environmental flows.

Merits

1. Shows flow variability throughout the year.
2. Useful for hydropower and water supply design.
3. Helps estimate dependable flows.
4. Easy to interpret once data is arranged.

Demerits

1. Time sequence information is lost (does not show drought duration or flood timing).
2. Requires reliable long-term discharge data.
3. Cannot directly show storage requirements.
4. Sensitive to data quality and length of record.

7Q) Explain the different components of a unit hydrograph with a neat sketch and write its merits and demerits. (10 M)

Definition : A unit hydrograph (UH) is the direct runoff hydrograph resulting from one unit (commonly 1 cm or 1 in.) of effective rainfall uniformly distributed over the watershed for a specified duration (the unit duration).

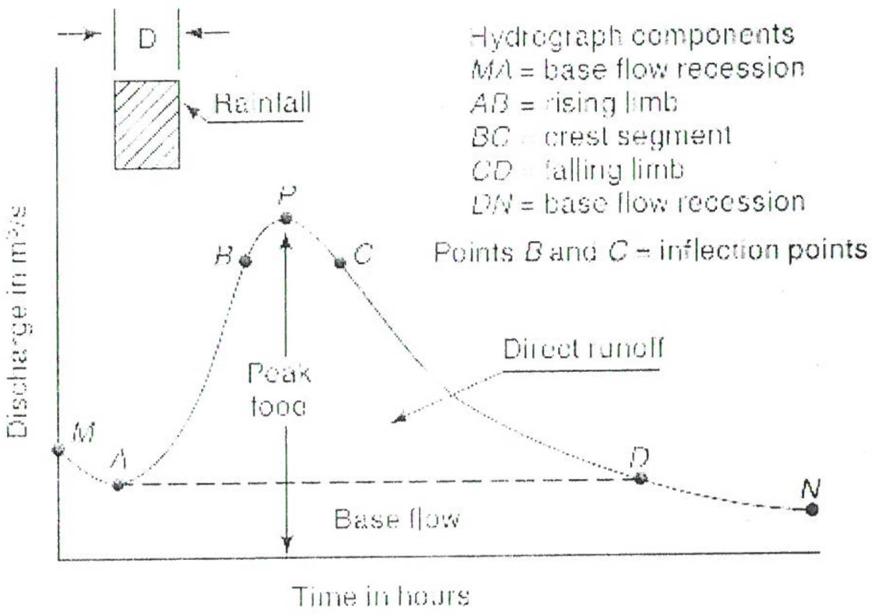


Fig. 6.1 Elements of a Flood Hydrograph

Components of a unit hydrograph (explain with sketch):

1. **Rising limb:** Represents the response of the catchment to the start of effective rainfall — controlled by quick flow and catchment travel times.
2. **Peak :** Maximum ordinate of the UH — depends on basin response, shape and duration of UH.
3. **Recession limb (falling limb):** Reflects the depletion of stored water and slower subsurface flow components — shape depends on storage and baseflow characteristics.
4. **Base/lag period:** Time from start of rainfall to peak (time to peak), and the total duration of hydrograph. **Time to peak** is important for flood routing.

Merits of Unit Hydrograph method:

- Simple linear method to transform effective rainfall to direct runoff hydrograph — convolution principle.
- Good pedagogical and practical tool for small to medium catchments with linear behaviour.
- Useful for designing drainage and small catchment flood estimation.

Demerits / limitations:

- Assumes linearity and time invariance (real catchments can be non-linear).
- Valid only for same duration and spatial distribution assumptions; unit hydrograph derived for a particular basin and antecedent conditions; transfer between durations requires synthetic methods (Snyder, SCS. synthetic UH).
- Not suitable for very large basins or complicated antecedent conditions without modification.

Q8 Define floods. Explain the causes and effects of floods with controlling methods. (10 M)

Answer

Definition: Flood is an overflow of water onto normally dry land resulting from excessive runoff in a river or stream that exceeds channel capacity.

Causes: excessive precipitation (intensity/duration), snowmelt, lack of infiltration (saturated basin), land-use change (urbanization), dam breaks, deforestation, obstruction in channels, cyclones/storm surges (coastal flooding).

Effects :

- Loss Of Life/Property,
- Agricultural Damage,
- Erosion/Sedimentation,
- Infrastructure Damage,
- Pollution Issues And Long-Term Economic Impacts.

Control methods (structural & non-structural):

Structural:

- Reservoirs/Detention Basins,
- Levees/Embankments,
- Flood Channels/Diversions,
- Channel Improvements,
- Reforestation And Check Dams.

Non-structural:

- Flood Zoning,
- Early Warning Systems,
- Floodplain Management,
- Land-Use Planning,
- Disaster Preparedness.

Q9.For a data of maximum recorded annual floods of a river the mean and standard deviation are 5200 m^3/s and 2705 m^3/s respectively. Using Gumbel's Extreme Value Distribution, estimate the return period of a design flood of 9700 m^3/s. Assume infinite sample size. (10 M)

Solution:

Given: sample mean $\bar{x} = 5200\ \mathrm{m^3/s}$, standard deviation $s = 2705\ \mathrm{m^3/s}$. Design flood $x = 9700\ \mathrm{m^3/s}$.

For the Gumbel distribution

- mean $= \mu + \gamma\beta$ where $\gamma = 0.5772156649$ (Euler–Mascheroni),
- standard deviation $= \dfrac{\pi\beta}{\sqrt{6}}$.

Solve for scale β and location μ:

$$\beta = s\frac{\sqrt{6}}{\pi} = 2705 \cdot \frac{\sqrt{6}}{\pi} \approx 2109.08$$

$$\mu = \bar{x} - \gamma\beta = 5200 - 0.5772156649 \cdot 2109.08 \approx 3982.61$$

Gumbel CDF:

$$F(x) = \exp\left(-\exp\left(-\frac{x-\mu}{\beta}\right)\right)$$

Compute:

$$z = \frac{9700 - 3982.61}{2109.08} \approx 2.71085$$

$$F(9700) = \exp(-\exp(-2.71085)) \approx 0.93568$$

Annual exceedance probability $p = 1 - F \approx 0.06432$.

Return period $T = \dfrac{1}{p} \approx \dfrac{1}{0.06432} \approx 15.55$ years.

Answer: The return period of a 9700 m³/s flood ≈ 15.6 years (annual exceedance probability ≈ 0.0643).

Q10 Derive the expression for discharge in case of Unconfined Aquifer with neat sketch. (10 M)

Solution:

9.9.2 Unconfined Flow

Consider a steady flow from a well completely penetrating an unconfined aquifer. In this case, because of the presence of a curved free surface, the streamlines are not strictly radial straight lines. While a streamline at the free surface will be curved, the one at the bottom of the aquifer will be a horizontal line, both converging to the well. To obtain a simple solution *Dupit's assumptions* as indicated in Sec. 9.6 are made. In the present case these are the following:

- For small inclinations of the free surface, the streamlines can be assumed to be horizontal and the equipotentials are thus vertical.
- The hydraulic gradient is equal to the slope of the free surface and does not vary with depth. This assumption is satisfactory in most of the flow regions except in the immediate neighbourhood of the well.

Consider the well of radius r_w penetrating completely an extensive unconfined horizontal aquifer as shown in Fig. 9.17. The well is pumping a discharge Q. At any radial distance r, the velocity of radial flow into the well is

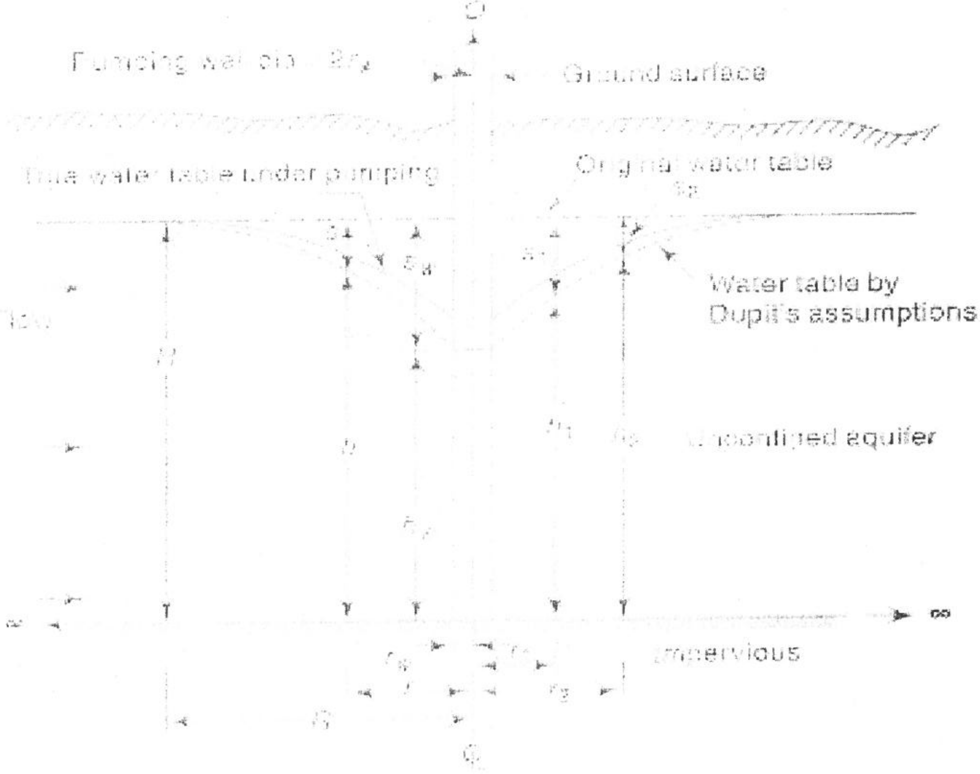


Fig. 9.17 *Radial Flow to a Well in an Unconfined Aquifer*

$$V_r = K \frac{dh}{dr}$$

where h is the height of the water table above the aquifer bed at that location. For steady flow, by continuity

$$Q = (2 \pi r h) V_r = 2 \pi r K h \frac{dh}{dr}$$

or
$$\frac{Q}{2 \pi K} \frac{dr}{r} = h\, dh$$

Integrating between limits r_1 and r_2 where the water table depths are h_1 and h_2 respectively and on rearranging

$$Q = \frac{\pi K (h_2^2 - h_1^2)}{\ln \frac{r_2}{r_1}} \tag{9.49}$$

This is the equilibrium equation for a well in an unconfined aquifer. As at the edge of the zone of influence of radius R, H =saturated thickness of the aquifer, Eq. (9.49) can be written as

$$Q = \frac{\pi K (H^2 - h_w^2)}{\ln \frac{R}{r_w}} \tag{9.50}$$

where h_w = depth of water in the pumping well of radius r_w.

Q11 (a) Describe the occurrence of ground water. (5M)

Answer :

Occurrence of groundwater:

- Groundwater occurs in the subsurface in the saturated zone occupying the pore spaces and fractures of geologic formations.
- The upper surface of this saturated zone is the water table.
- Zones above it are unsaturated (vadose). Subsurface storage depends on geology (porosity, permeability), stratification (aquifers vs aquitards), and recharge mechanisms (infiltration, percolation).
- Confined aquifers occur where impermeable layers overlie saturated layers, creating potentiometric surfaces.

Q11 (b) Write short notes on well construction and open-well recuperation test. (5 M)

Well construction (short notes):

Types: Dug wells (open wells), bored wells, driven wells, drilled wells (boreholes).

Components & steps:

- Site selection, casing, screen/slotted pipe (for intake), grouting/packing, wellhead construction, pump installation.
- Open (dug) wells are typically shallow and excavated with sloping sides, with stone/bricks lining.
- Boreholes are cased and screened to control entry of water and prevent collapse.
- Proper sanitary protection, slotted screen design, and gravel pack are important for performance.

Open-well recuperation (recovery) test:

A recovery test measures how quickly the groundwater level recovers after pumping (or after a drawdown) to estimate aquifer properties (transmissivity, storage).

Procedure:

- pump at a constant rate to drawdown.

- stop pumping.
- record water level recovery vs time.
- Analysis (Cooper-Jacob or Theis type methods adapted) yields hydraulic parameters.