

Water Resource Engineering (315314)

MSBTE K-Scheme · Model Question Paper — Set C · Model Answers

Q.1 Attempt any FIVE of the following:**10 M****a) State the classification of irrigation projects based on purpose (any four).**

2 M

Irrigation projects are classified on the basis of purpose as:

1. **Protective irrigation project** – provided to protect crops against failure of rainfall / famine in drought-prone areas; financial return is not the main aim.
2. **Productive irrigation project** – provided to increase production and give financial return (revenue) on the investment.
3. **Single-purpose project** – serves only one purpose, i.e. irrigation.
4. **Multipurpose project** – serves irrigation along with hydropower, water supply, flood control, navigation, fisheries, recreation etc.

Note: On the basis of culturable command area (CCA), projects are also classified as major (CCA > 10,000 ha), medium (2,000–10,000 ha) and minor (< 2,000 ha).

(Any four, ½ M each)

b) Define runoff. State any two factors affecting it.

2 M

Runoff: the part of precipitation which, after meeting losses, flows over the ground surface and through the soil and reaches streams and rivers.

Factors: (i) intensity and duration of rainfall; (ii) size, shape and slope of catchment (also soil type, vegetation).

(Definition 1 M, two factors 1 M)

c) Define: i) Base period ii) Delta.

2 M

Base period (B): The time period (in days) between the first watering of the land before sowing and the last watering before harvesting of the crop.

Delta (Δ): The total depth of water (in cm or m) required by a crop during its base period, assumed spread uniformly over the area irrigated.

(Each definition 1 M)

d) Name any four types of spillways.

2 M

Types of spillways:

1. Ogee (overflow) spillway
2. Chute (trough) spillway
3. Side channel spillway
4. Shaft (morning glory) spillway
5. Siphon spillway
6. Free overfall spillway

(Any four, ½ M each)

e) Define the terms heel and toe of a gravity dam.

2 M

Heel: The point (portion) of a dam where its upstream face meets the ground / foundation.

Toe: The point (portion) of a dam where its downstream face meets the ground / foundation (tail-water side).

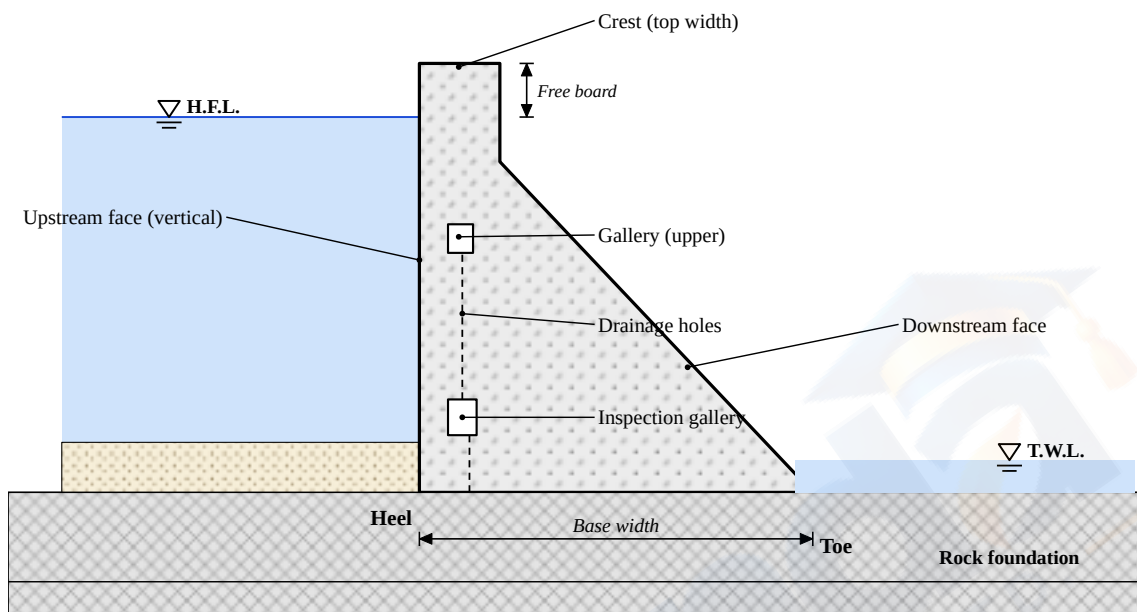


Fig.: Typical section of a gravity dam

(Each definition 1 M)

f) Define bandhara. State any two advantages of bandhara irrigation.

2 M

Bandhara: A bandhara is a small masonry (or concrete) weir constructed across a stream to raise the water level, from which water is diverted to the fields by a small canal called **pat**.

Advantages: (i) low cost and simple construction using local material; (ii) irrigates nearby land by gravity without pumping; also helps groundwater recharge.

(Definition 1 M, two advantages 1 M)

g) Define: i) Level crossing ii) Siphon aqueduct.

2 M

Level crossing: A CD work provided when the canal bed and drain bed are at about the same level; the drain water is allowed to enter and cross the canal at the same level, with regulators on the drain (inlet and outlet) and a cross regulator in the canal to control the flow.

Siphon aqueduct: A CD work in which the canal is taken over the drain, but the H.F.L. of the drain is above the canal bed, so the drain water passes under the canal through barrels under pressure.

(Each definition 1 M)

Q.2 Attempt any THREE of the following:

12 M

a) Explain with a neat sketch how rainfall is measured using Symon's rain gauge.

4 M

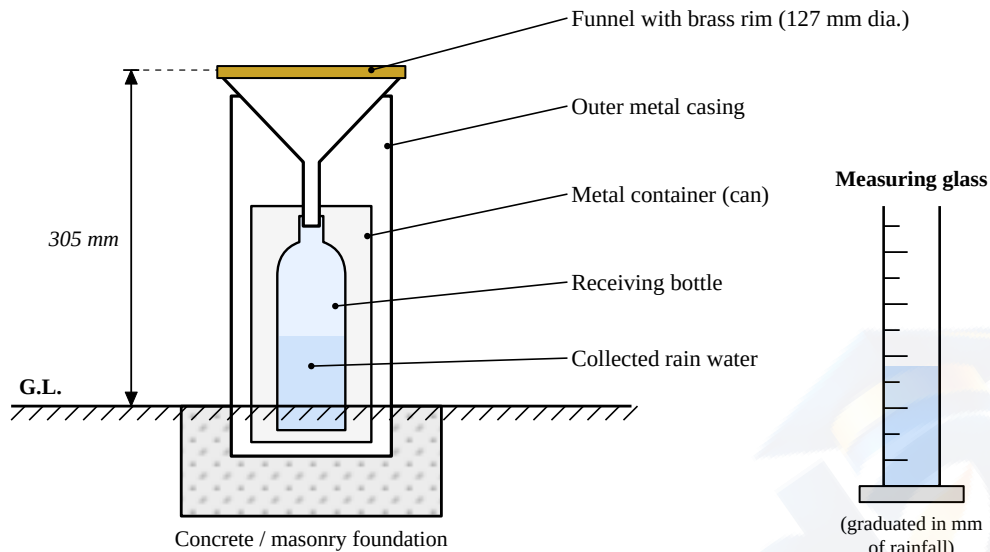


Fig.: Symon's (non-recording) rain gauge

Measurement of rainfall:

1. The gauge is installed on level open ground, at a distance of at least twice the height of any nearby obstruction (building, tree), with the funnel rim 305 mm above G.L.
2. Rain entering the 127 mm funnel is collected in the receiving bottle placed in the metal can.
3. Daily at 8:30 a.m. the bottle is taken out and the water is poured in the measuring glass, which is graduated directly in mm of rainfall (reading accurate to 0.1 mm).
4. Rainfall recorded is the total rainfall of the past 24 hours; if the bottle has overflowed, the water in the can is also measured and added.

(Sketch 2 M, procedure 2 M)

b) The Thiessen polygon areas and rainfall at four stations of a catchment are given below. Find the average rainfall by (i) arithmetic mean method and (ii) Thiessen polygon method.

Station	A	B	C	D
Polygon area (km ²)	320	313	258	260
Rainfall (mm)	82	104	121	96

4 M

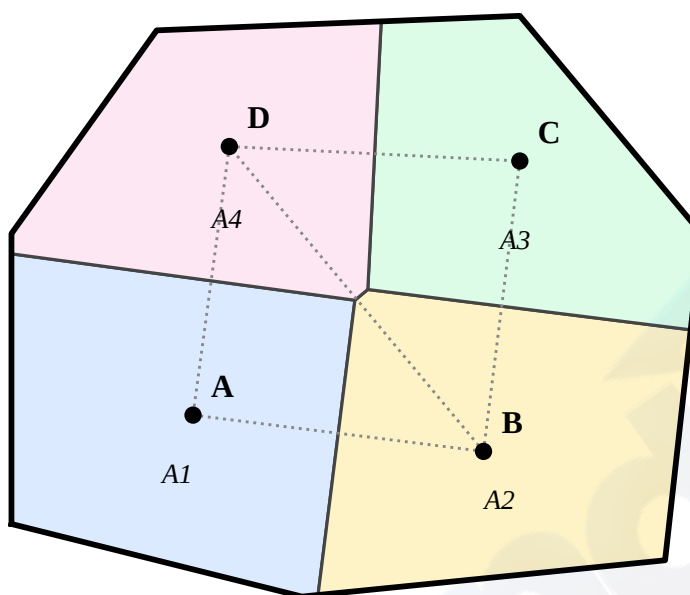


Fig.: Thiessen polygons for stations A–D (areas computed from the figure)

(i) Arithmetic mean method

Arithmetic mean method: $P_{av} = (P_1 + P_2 + \dots + P_n) / n$

$$P_{av} = (82 + 104 + 121 + 96) / 4 = 403 / 4 = \mathbf{100.75 \text{ mm}}$$

(ii) Thiessen polygon method

Thiessen polygon method: $P_{av} = \Sigma(A_i \times P_i) / \Sigma A_i$, where A_i = area of the polygon round station i.

Station	Polygon area A (km ²)	Rainfall P (mm)	A × P
A	320	82	26,240
B	313	104	32,552
C	258	121	31,218
D	260	96	24,960
Total	1,151		114,970

$$P_{av} = 114,970 / 1,151 = \mathbf{99.89 \text{ mm}}$$

The Thiessen value (99.89 mm) differs from the simple mean (100.75 mm) because it gives weight to the area represented by each station; it is more accurate when gauges are unevenly distributed.

(Arithmetic mean 1 M, Thiessen 3 M)

c) Explain the hydrological cycle with a neat sketch.

4 M

Hydrological cycle: It is the continuous circulation of water from the oceans to the atmosphere, from the atmosphere to the land and back to the oceans, driven by the heat of the sun.

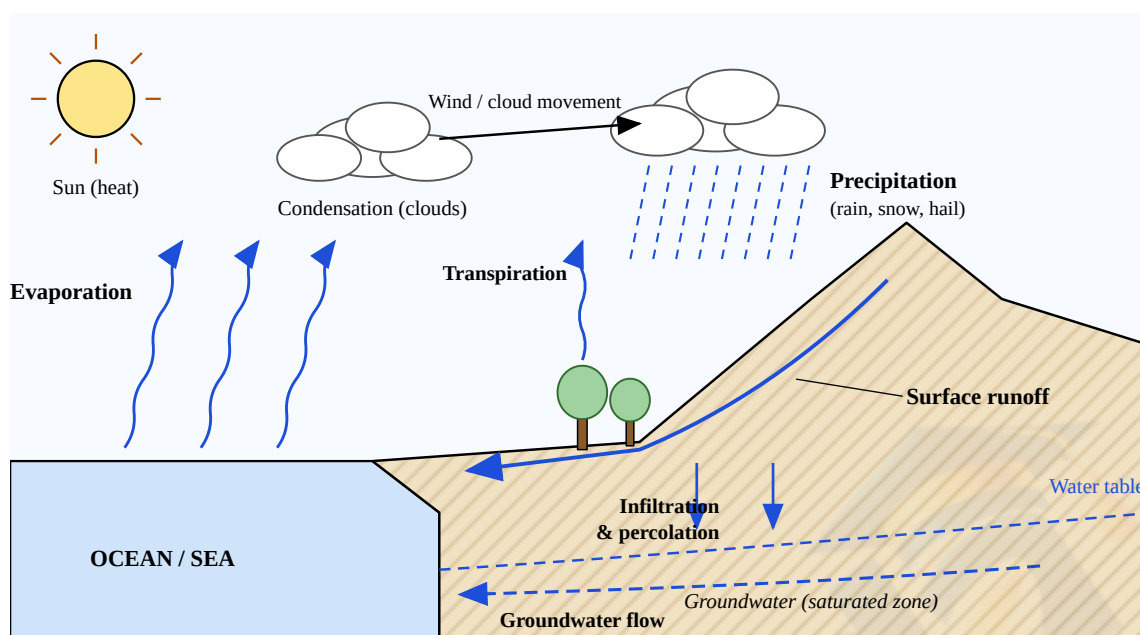


Fig.: Hydrological cycle

1. **Evaporation** – heat of the sun converts water of oceans, lakes and land surface into vapour; plants give out vapour by **transpiration**.
2. **Condensation** – the vapour rises, cools and condenses into clouds.
3. **Precipitation** – clouds moved by wind over land release water as rain, snow or hail.
4. **Infiltration and percolation** – part of precipitation enters the soil and moves down to the groundwater.
5. **Runoff** – the remaining water flows over the surface into streams and rivers; groundwater also flows slowly towards rivers and the sea, completing the cycle.

(Sketch 2 M, explanation 2 M)

d) Explain border strip, check basin and furrow methods of surface irrigation with sketches.

Surface irrigation methods (water applied by gravity over the field surface):

4 M

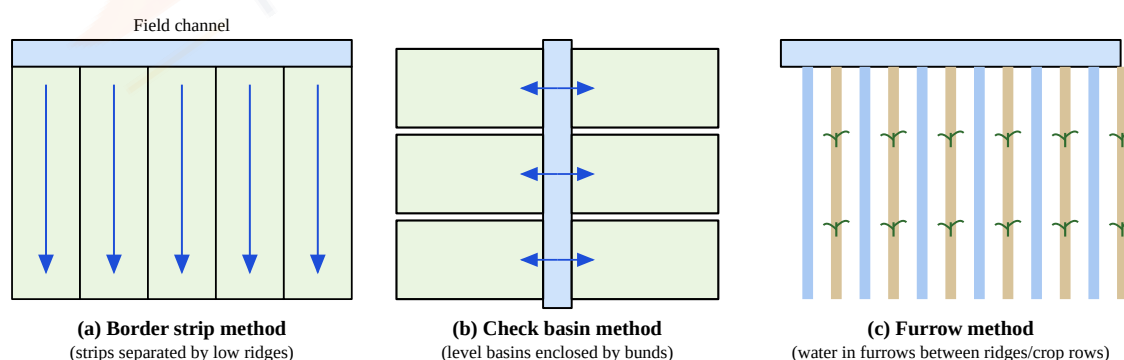


Fig.: Surface irrigation methods (plan)

1. **Border strip method:** the field is divided into long narrow strips (10–20 m wide) separated by low ridges (borders). Water from the field channel flows down each strip as a thin sheet.

Suitable for close-growing crops like wheat on gentle slopes.

2. **Check basin method:** the field is divided into level basins enclosed by bunds; water from the field channel is let into each basin and allowed to stand till it infiltrates. Suitable for rice, orchards and flat land.
3. **Furrow method:** water is run in small channels (furrows) between ridges on which row crops (sugarcane, cotton, vegetables) are grown; only part of the surface is wetted, so evaporation losses are less.

(Each method with sketch 1½ M)

Q.3 Attempt any THREE of the following:

12 M

- a) Explain the engineering surveys required for an irrigation project and enlist the data to be collected.

4 M

Engineering surveys for an irrigation project:

1. **Reconnaissance survey** – quick inspection of the area to study possible sites of dam / weir, command area and alternatives.
2. **Catchment survey** – area, shape, slope, land use and rainfall of the catchment to estimate yield and floods.
3. **Dam (headworks) site survey** – contour survey of the site, L-section and cross-sections of the river, and **reservoir survey** to prepare elevation–area–capacity curves and find submergence.
4. **Canal alignment and command area survey** – L-section and cross-sections along the proposed canal; contour map of the command.
5. **Geological and foundation survey** – trial pits / bore holes to study foundation rock, faults and permeability.
6. **Material survey** – availability of soil, sand, stone and metal near the site.

Data to be collected: rainfall and stream-flow (discharge) records, maximum flood discharge, sediment load; soil type and crops in command area, existing irrigation; land and property to be submerged (villages, roads, forest); communication and labour facilities; water rights of other users; cost of land; evaporation data.

(Surveys 2 M, data 2 M)

- b) Give any four points of difference between earthen dam and gravity dam.

4 M

Point	Earthen dam	Gravity dam
1. Section	Very wide base, flat side slopes (trapezoidal).	Narrow, nearly triangular section.
2. Stability	Stability depends on side slopes and shear strength of soil.	Resists forces by its own weight.
3. Maintenance	Maintenance cost is high.	Maintenance cost is low; life is long.
4. Overtopping	Fails if overtopped.	Can withstand some overtopping.

5. Foundation	Can be built on weak, soil or pervious foundations.	Needs strong, sound rock foundation.
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(Any four points, 1 M each)

c) Draw a neat labelled sketch of an ogee spillway and explain its parts.

4 M

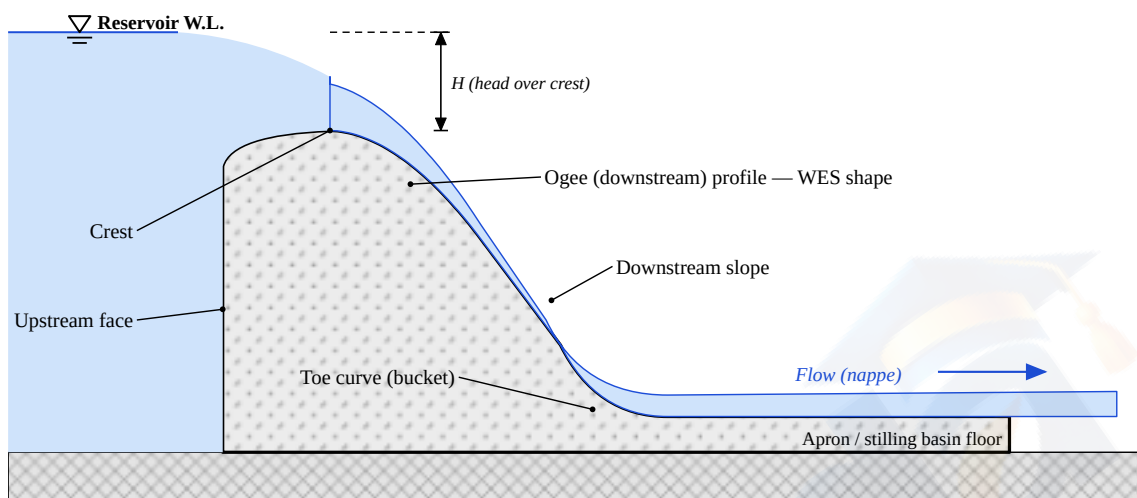


Fig.: Ogee spillway (section)

Ogee spillway is a gravity (overflow) spillway whose downstream profile is shaped like the lower surface of a freely falling nappe (S-shaped or “ogee” curve), so that water flows smoothly over it without separating and without negative pressure (cavitation).

- **Crest** – top of spillway over which water flows; head over crest = H.
- **Upstream face** – vertical (or slightly inclined) face of the spillway.
- **Ogee profile** – downstream curved profile following the nappe, then a straight slope.
- **Toe curve (bucket)** – concave curve at the bottom turning the flow horizontal.
- **Apron / stilling basin** – to dissipate energy before water joins the river.

(Neat labelled sketch 2 M, parts / explanation 2 M)

d) Explain the modes (causes) of failure of a gravity dam.

4 M

Modes (causes) of failure of a gravity dam:

1. **Overtopping** – about the toe, when the resultant of all forces passes outside the base (overturning moment > resisting moment). Safe when $F.S. = \Sigma M_R / \Sigma M_O \geq 1.5$.
2. **Sliding (shear failure)** – along the base or any horizontal joint, when horizontal forces exceed the frictional and shear resistance. Safe when $\mu \Sigma V / \Sigma H \geq 1$ (and shear friction factor is adequate).
3. **Compression (crushing)** – when the compressive stress at the toe exceeds the allowable stress of concrete / masonry or the foundation.
4. **Tension** – cracks develop at the heel when the resultant falls outside the middle third of the base; this increases uplift and leads to failure. Hence the resultant must lie within the middle third.

(Each mode 1 M)

Q.4 Attempt any THREE of the following:

12 M

a) Explain how a percolation tank differs from an irrigation tank.

4 M

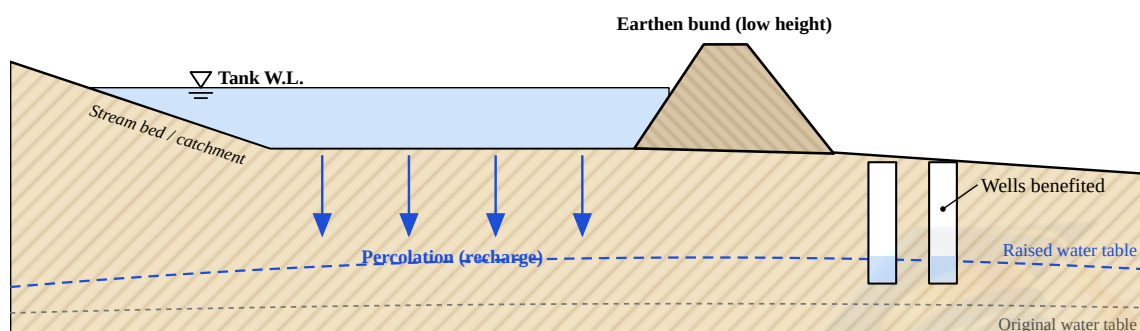


Fig.: Percolation tank (section) — water stored only to recharge groundwater

Point	Percolation tank	Irrigation (storage) tank
1. Purpose	To recharge groundwater by percolation.	To store water and supply it for irrigation.
2. Strata	Located on permeable strata.	Located on impervious strata (to avoid loss).
3. Outlet / canal	No outlet or canal is provided.	Outlet (sluice) and canal system are provided.
4. Use of water	Water is used indirectly from wells downstream.	Water is used directly through canals.
5. Seepage	Seepage is desirable.	Seepage is a loss and is reduced.

(Any four points, 1 M each)

b) Draw the layout of a sprinkler irrigation system. State its components and suitability.

4 M

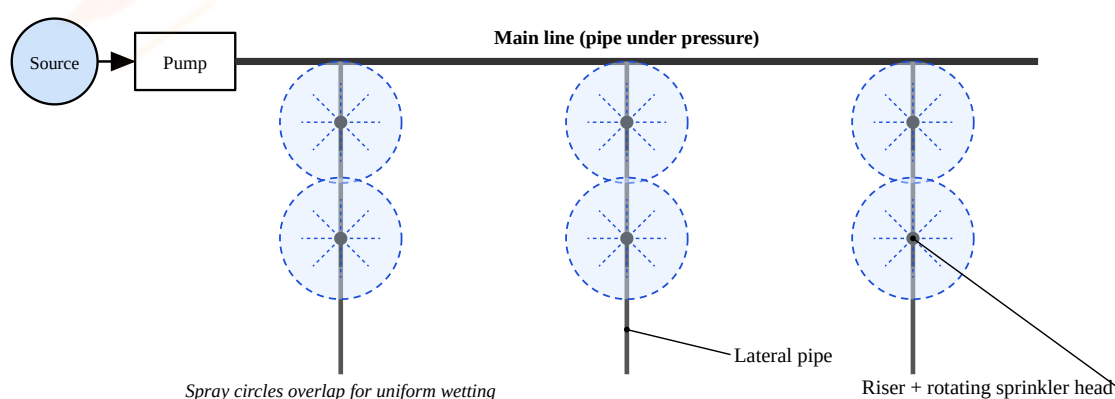


Fig.: Layout of sprinkler irrigation system

Sprinkler irrigation: water under pressure is sprayed into the air through nozzles and falls on the crop like natural rain.

1. **Pump unit** – takes water from source and develops pressure.
2. **Main line** – carries water from pump to the field.
3. **Sub-mains / laterals** – portable pipes (aluminium / HDPE) with quick couplers.
4. **Risers** – vertical pipes carrying the sprinkler heads above crop height.
5. **Sprinkler heads** – rotating nozzles which spray water in circles.

Suitability: undulating land, sandy soils with high infiltration, crops like wheat, groundnut, pulses, vegetables, tea; where water is scarce. Not suitable in very windy areas.

(Layout 2 M, components & suitability 2 M)

c) Explain open well and tube well with neat sketches.

4 M

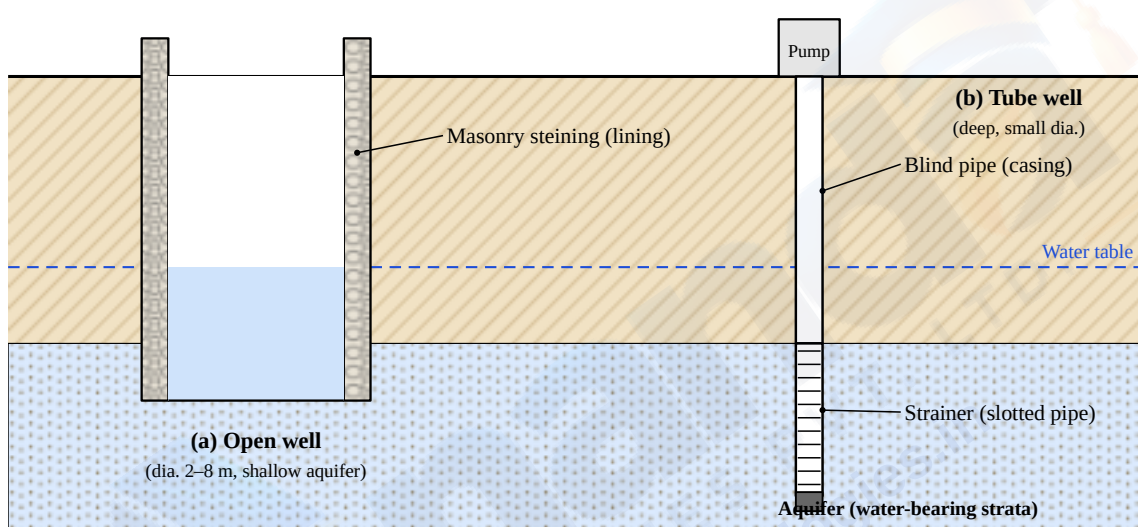


Fig.: Types of wells

1. **Open well:** large diameter (2–8 m) shallow well dug down into the water-bearing stratum; lined with masonry steining (or unlined in hard rock). Water is lifted by a pump (traditionally by mot or Rahat). Gives small discharge; suitable for small farms.
2. **Tube well:** small diameter (100–300 mm) deep well drilled into a deep aquifer. A blind pipe (casing) is provided in non-water-bearing strata and a **strainer** (slotted pipe) in the aquifer. Water is lifted by a submersible / turbine pump; gives large discharge.

(Each type with sketch 2 M)

d) Differentiate between weir and barrage (any four points).

4 M

Point	Weir	Barrage
1. Crest level	Crest is raised above river bed; water is ponded mainly by the crest.	Crest is at or near river bed level; pond level is kept by gates.
2. Gates	No gates or only small shutters on the crest.	Gates over the full height between piers.
3. Afflux	Afflux (rise of water level u/s during floods) is high.	Afflux is low because gates are opened during floods.

4. Cost	Less costly.	More costly.
5. Road bridge	Generally no road bridge.	Road bridge can be provided over the piers.

(Any four points, 1 M each)

e) State the necessity of canal lining and name any four lining materials.

4 M

Necessity of canal lining:

1. To minimise seepage losses (unlined canals may lose 25–50 % water) and save water.
2. To prevent water logging of adjoining lands.
3. To increase the command area with the same quantity of water.
4. To reduce maintenance (weed and silt clearance) and prevent breaches.

Lining materials: (1) cement concrete, (2) burnt bricks / tiles, (3) stone masonry / boulders, (4) soil-cement, (5) LDPE film covered with soil, (6) asphalt.

(Necessity 2 M, any four materials 2 M)

Q.5 Attempt any TWO of the following:

12 M

a) Fix the F.R.L., H.F.L. and top of bund level of a reservoir from the following data: D.S.L. (outlet sill level) = 320.00 m; effective storage required for crops = 13 Mm³; evaporation and other tank losses = 18 % of effective storage; maximum flood discharge = 420 m³/s; length of waste weir = 90 m ($Q = 1.84 L H^{3/2}$); free board = 1.5 m.

Contour R.L. (m)	318	320	322	324	326	328	330
Capacity (Mm ³)	1.2	2.4	4.6	7.9	12.3	17.8	24.6

Since D.S.L. is given, dead storage is read from the table and live storage is added to it. (No carry-over is given.)

6 M

1. Live (useful) storage = 13.00 (effective storage for crops) + 2.340 (tank losses 18 %) = **15.340 Mm³**

2. Dead storage at the given D.S.L. 320.00 m (from the table, interpolating if needed) = **2.400 Mm³**

3. Gross storage at F.R.L. = dead + live = 2.400 + 15.340 = **17.740 Mm³**

4. F.R.L. – gross storage 17.740 lies between 12.30 (R.L. 326.00) and 17.80 (R.L. 328.00):
 $F.R.L. = 326.00 + (2.00) \times (17.740 - 12.30) / (17.80 - 12.30) = \mathbf{327.98\ m}$

5. Flood lift (head over waste weir) by Francis formula $Q = 1.84 L H^{3/2}$:

$$420 = 1.84 \times 90 \times H^{3/2} \rightarrow H^{3/2} = 2.5362 \rightarrow H = (2.5362)^{2/3} = \mathbf{1.860\ m}$$

6. H.F.L. = F.R.L. + flood lift = 327.98 + 1.860 = **329.84 m**

7. T.B.L. (top of bund / dam level) = H.F.L. + free board = 329.84 + 1.50 = **331.34 m**

Control level	R.L. (m)
Dead storage level (D.S.L.)	320.00
Full reservoir level (F.R.L.)	327.98

High flood level (H.F.L.)	329.84
Top of bund level (T.B.L.)	331.34

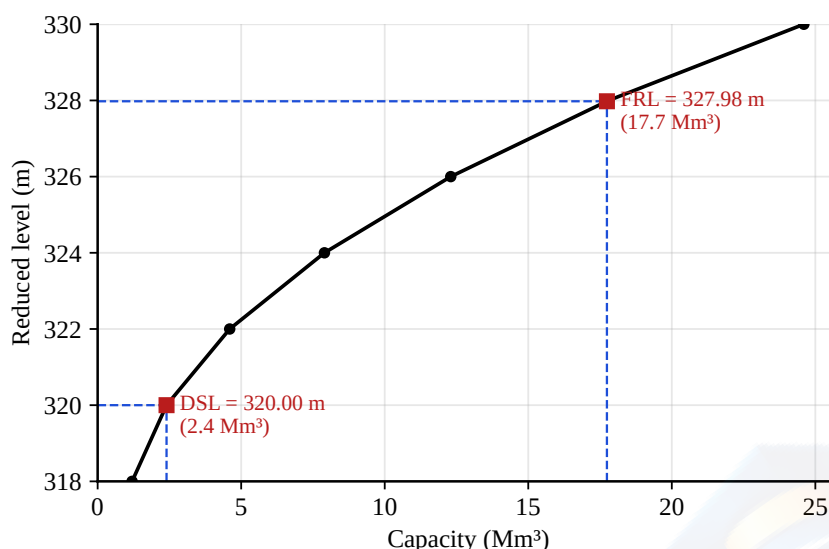


Fig.: Elevation–capacity curve (plotted from given data)

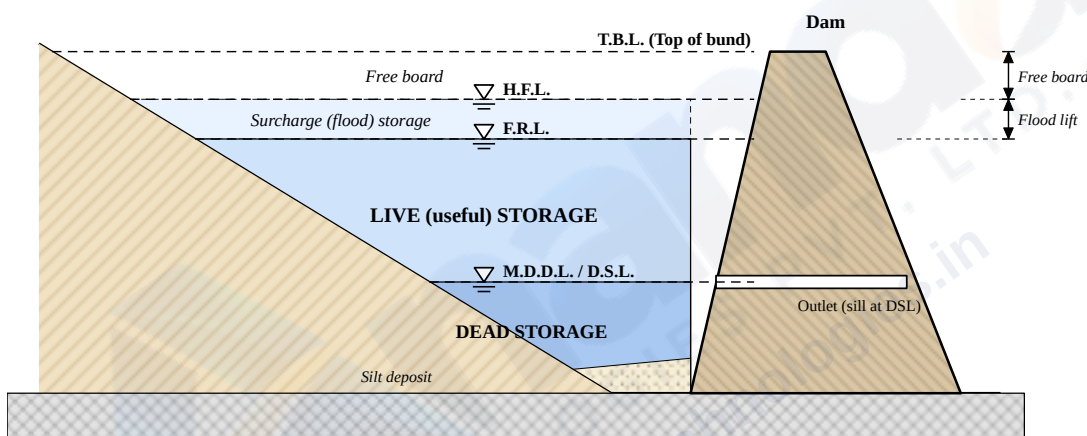


Fig.: Storage zones and control levels of a reservoir

(Dead & live storage 2 M, FRL 2 M, HFL 1 M, TBL 1 M)

b) The gross command area of a canal is 15,000 ha, of which 80 % is culturable. The intensity of irrigation and duty for the crops are given below. Find the discharge required at the head of the canal if transit losses are 20 % of the head discharge and the time factor is 0.8.

Crop	Season	Intensity of irrigation	Duty at field (ha/cumec)
Sugarcane	Perennial	10 %	730
Rice	Kharif	35 %	850
Wheat	Rabi	45 %	1750
Groundnut	Hot weather	8 %	900

CCA = $0.80 \times 15,000 = 12,000$ ha. Area under each crop = CCA $\times$ intensity:

6 M

- Sugarcane: $12,000 \times 0.10 = 1,200$ ha
- Rice: $12,000 \times 0.35 = 4,200$ ha

- Wheat: $12,000 \times 0.45 = 5,400$ ha
- Groundnut: $12,000 \times 0.08 = 960$ ha

Step 1 – Discharge at field (outlet) for each crop: $Q = A / D$

Crop	Season	Area A (ha)	Duty D (ha/cumec)	$Q = A/D$ (m ³ /s)
Sugarcane	Perennial	1,200	730	1.6438
Rice	Kharif	4,200	850	4.9412
Wheat	Rabi	5,400	1,750	3.0857
Groundnut	Hot weather	960	900	1.0667

Step 2 – Season-wise requirement (perennial crop needs water in every season):

- Kharif: $1.6438 + 4.9412 = 6.5850$ m³/s
- Rabi: $1.6438 + 3.0857 = 4.7295$ m³/s
- Hot weather: $1.6438 + 1.0667 = 2.7105$ m³/s

Maximum requirement is in the **Kharif** season: $Q_{\text{field}} = 6.5850$ m³/s

Step 3 – Allow for transit losses (20 % of the discharge at head): $Q_{\text{head}} = Q_{\text{field}} / (1 - 0.2) = 6.5850 / 0.80 = 8.231$ m³/s

Step 4 – Time factor = 0.8 (canal runs only 80 % of the days): design discharge = $Q_{\text{head}} / \text{time factor} = 8.231 / 0.8 = 10.289$ m³/s

(CCA & crop areas 1 M, discharges 2 M, season-wise 1 M, losses & time factor 2 M)

c) Explain the causes of seepage failure of an earthen dam and the measures to control seepage, with a neat sketch.

6 M

Seepage failure occurs when water seeping through the dam body or foundation emerges at the downstream face with high exit gradient and carries soil particles with it.

Causes:

- Phreatic line cutting the downstream slope (no drainage provided), causing sloughing of the toe.
- Piping through pervious foundation or along cracks, conduits and rat holes.
- Poor compaction, use of pervious soil, absence of core / cut-off.

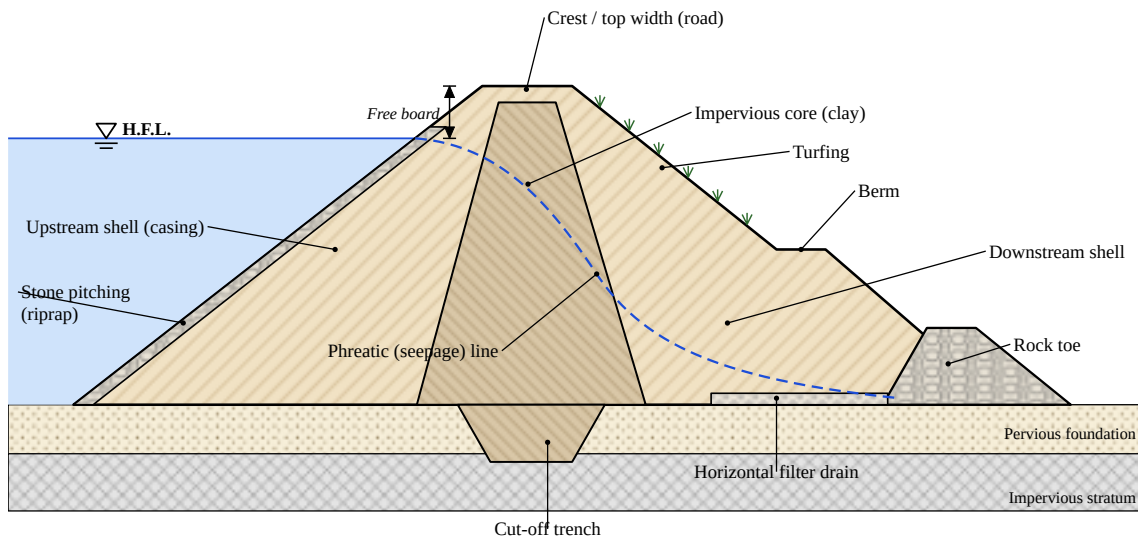


Fig.: Seepage control features in a zoned earthen dam

Measures to control seepage:

1. **Impervious core** of clay in the dam body to reduce seepage through the dam.
2. **Cut-off trench** filled with clay (or sheet piles / grout curtain) up to the impervious stratum to stop foundation seepage.
3. **Horizontal filter drain** and **rock toe with inverted filter** at the downstream to collect seepage and keep the phreatic line well inside the dam.
4. **Upstream impervious blanket** to lengthen the seepage path.
5. **Relief wells / toe drains** to relieve uplift pressure below the downstream toe.
6. Proper compaction of each layer at optimum moisture content.

(Causes 2 M, measures with sketch 4 M)

Q.6 Attempt any TWO of the following:

12 M

a) Explain with a neat sketch the various forces acting on a gravity dam.

6 M

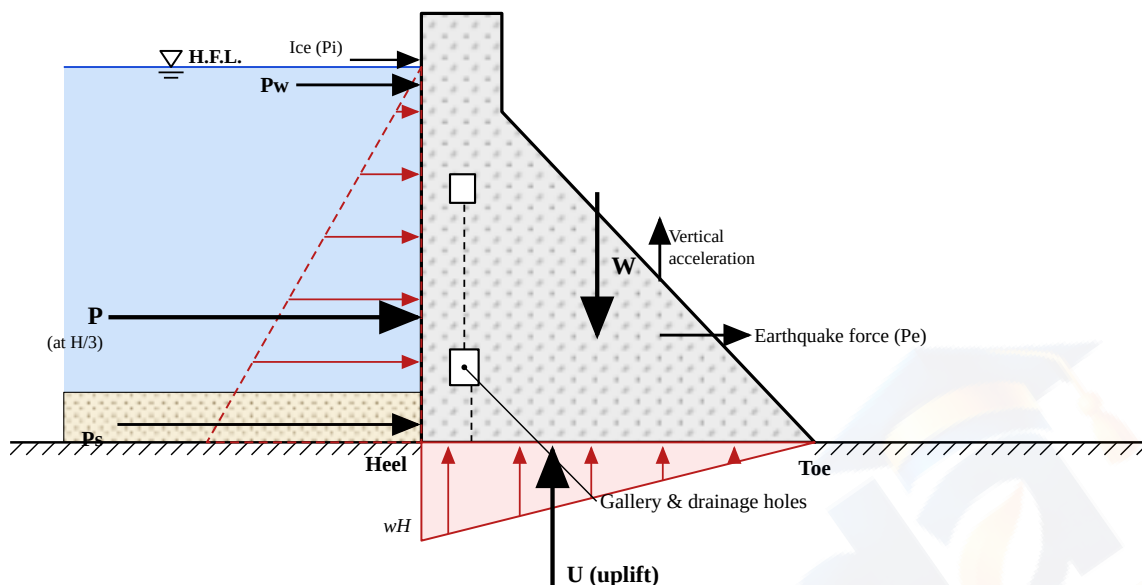


Fig.: Forces acting on a gravity dam

1. **Weight of dam (W)** – main stabilising force, acts vertically down through the centre of gravity of the section.
2. **Water pressure (P)** – horizontal pressure of reservoir water on the upstream face; $P = wH^2/2$ acting at $H/3$ above the base.
3. **Uplift pressure (U)** – upward pressure of water seeping under the base (and through pores); intensity wH at heel reducing to tail-water pressure at toe; reduced by drainage holes and gallery.
4. **Silt pressure (Ps)** – pressure of silt deposited against the upstream face.
5. **Wave pressure (Pw)** – pressure of waves generated by wind, acting near the top of the upstream face.
6. **Earthquake forces** – horizontal and vertical accelerations cause inertia forces on the dam and hydrodynamic pressure of water.
7. **Ice pressure (Pi)** – expansion of ice sheet in cold regions acting at the water surface.

Of these, the weight of the dam is the main **resisting (stabilising)** force; water pressure, uplift, silt, wave, ice and earthquake forces are **disturbing** forces. For stability the dam must be safe against overturning, sliding, crushing and tension.

(Sketch 2 M, explanation 4 M)

b) Draw a neat layout of diversion headworks and explain the functions of: i) Head regulator
ii) Divide wall iii) Fish ladder iv) Under-sluices.

6 M

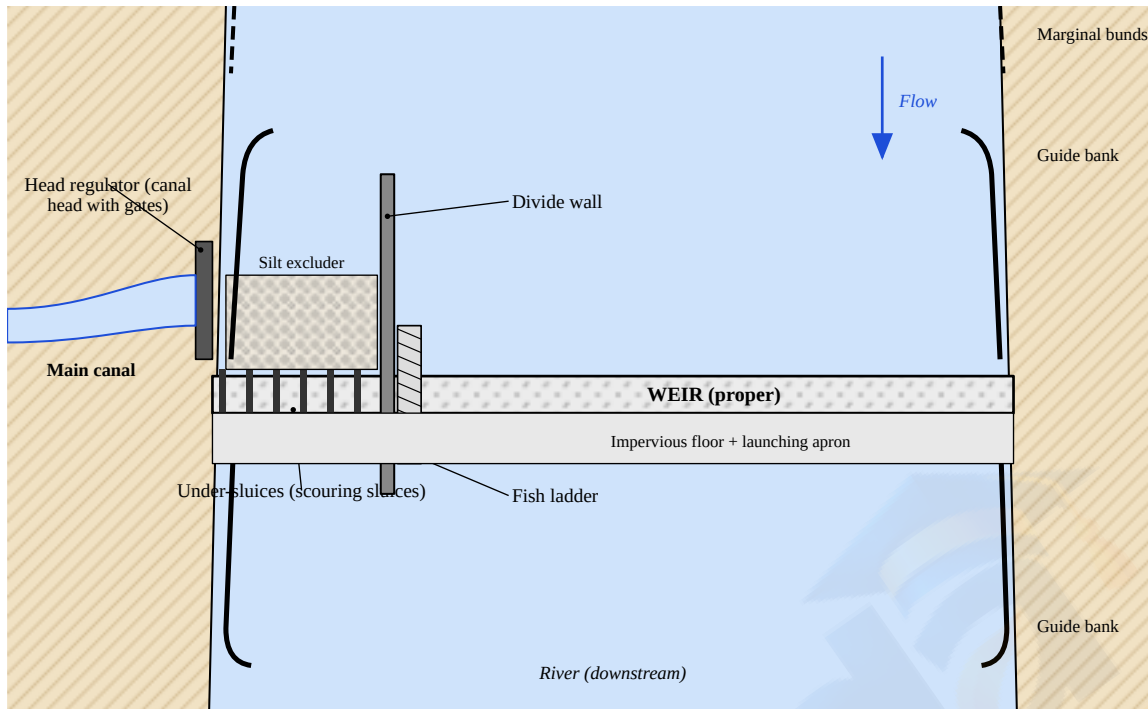


Fig.: Layout (plan) of diversion headworks

1. **Head regulator (canal head regulator)** – gated structure at the head of the canal which regulates the supply of water into the canal and checks entry of silt.
2. **Divide wall** – a wall at right angles to the weir separating the under-sluices from the weir proper; it creates a still pocket in front of the head regulator so that silt settles there and is scoured by the under-sluices, and prevents cross flow.
3. **Fish ladder** – a sloping passage with baffles near the divide wall which allows migratory fish to move upstream / downstream across the weir.
4. **Under-sluices (scouring sluices)** – gated openings near the canal head with floor lower than the weir crest; they scour silt deposited in front of the head regulator and keep a clear deep channel.

(Layout 2 M, functions 4 M)

c) Explain the classification of canals according to alignment. Draw a typical cross-section of a canal in partial cutting and partial filling.

6 M

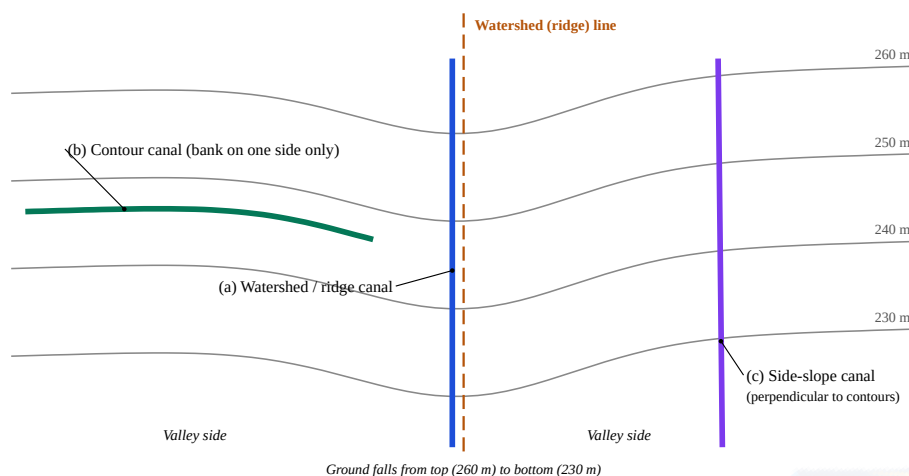


Fig.: Classification of canals according to alignment (plan with contours)

Classification of canals according to alignment:

1. **Watershed (ridge) canal:** aligned along the ridge (watershed) line of the area. It can irrigate land on both sides and does not cross any major drain, so cross drainage works are avoided. Most canals in plains are of this type.
2. **Contour canal:** aligned roughly parallel to the contours of the area (in hilly regions). It has a bank only on the valley side and irrigates land on one side only; it crosses many drains, so many CD works are needed.
3. **Side slope canal:** aligned at right angles to the contours (along the side slope, roughly parallel to drains). It does not cross drains, but its bed slope is steep so falls are needed; it irrigates on one side.

(Each type with explanation 1½ M (sketch for illustration))

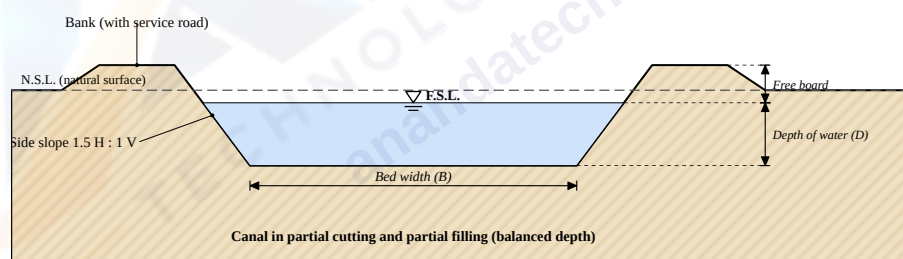


Fig.: Typical canal cross-section

(Classification 4 M, cross-section 2 M)

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