The process of artificially supplying water to soil for rising crops is called Irrigation.

a) Surface irrigation (or) Flow irrigation

water is supplied directly to soil surface from a channel located at higher elevation of field (i.e by gravity)

b) Lift irrigation:

By lifting water from the available at a lower level. (i.e by Machines).

Efficiencies:

a) Irrigation Efficiency = $\dfrac{\text{water actually utilised by growing crops}}{\text{water delivered from the source.}}$

$\dfrac{W_u}{W_s}$ = water use efficiency (η_u)

b) Water Conveyance/Transit Efficiency (η_c)

$\dfrac{W_f}{W_s} = \dfrac{\text{water delivered to the form}}{\text{water delivered from the source}}$

c) Water application efficiency (η_a)

$\dfrac{W_{sr}}{W_f} = \dfrac{\text{Water stored in the root zone}}{\text{water delivered to the form}}$

d) Water Storage Efficiency (η_s)

$\dfrac{W_{sr}}{W_{nr}} = \dfrac{\text{Water stored in the root zone during irrigation}}{\text{Water Needed in the root zone prior to irrigation}}$

(∵ water needed in the root zone prior to irrigation
W_{nr} = Field capacity − Available moisture)

Salts present in water are useful for cultivation purpose

a) Sodium carbonate b) potassium sulphate c) Calcium sulphate

Classification of Soil Water

1. Capillary water:

A part of water exists in the porous space of the soil by molecular attraction.

→ Useful water for the growth of plants.

2. Gravitational water: (or) Superflouous water:

A part of water move out of soil due to providing proper drainage.

→ Not useful for growth of plants & it cannot be absorbed by root zone.

3. Hydroscopic water:

At low rainfall, oven dried soil present in atmosphere, it absorbs that water. Hence

→ Growth of plants stopped and ultimately plants are dead.

Terms used in Irrigation:

1. Saturation Capacity (or) Total Capacity (or) Maximum holding Capacity

The amount of water required to fill up all pore spaces in soil particles.

2. Field Capacity

The moisture content of the soil, after free drainage has removed most of the gravity water (i.e. Max water absorbs by land without standing on land).

3. permanent wilting point

The water content present in soil (at rest or transit) at which plants can no longer extract sufficient water from soil for its growth.

→ It depends upon a) Depth of root zone & b) Water holding capacity of soil.

4. Available moisture:

The water content present in soil at which plants can extract water from soil for it's growth.

i.e. Available moisture = Field Capacity − Permanent wilting point.

5. Kor-watering:

The first watering given to the Crop, it helps it grown a few centimeters.

Optimum depth of kor-watering for Rise - 19 cm

Sugar cane - 16.5 cm

wheat - 13.5 cm

6. paleo (or) paleva

The first watering before Sowing (to seed) the crop.

7. overlap allowance:

(when the Crop is not fully matured at the end of season)

The extent of water supplied for maturing a particular crop from one season to another season.

8. Crop ratio:

$$= \frac{\text{Crop area in one Season (eg: kharif)}}{\text{Crop area in anothe Season (eg: Rabi)}}$$

Commanded Areas:

1. Gross Commanded Area

It is the total irrigated area without considering the limitations of water available.

2. Culturable Commanded Area:

Possible Area in which crop is grown at a particular time (or) crop Season.. per available water.

a) Culturable Cultivated Area:

Area of cultivation done

b) Culturable uncultivated Area:

Area of Cultivation is possible but not done due to some reasons. (like economical, political ... etc).

*) Intensity of irrigation

$$= \frac{\text{Cultivated land for a particular Crop}}{\text{Culturable Commanded Area.}}$$

Base period, Delta and Duty:

Sowing = put seed into the ground (విత్తు వేయటం)

Harvesting = ripened crops are gathered (పంట కోయటం)

1) **Crop period:**

Time from Sowing - Harvesting

2) **Base period (B)** (water given) (in days)

Time from preparation ground to last watering before (some days) harvesting.

Crop period > Base period

3) **Duty (D):** (hectares/cumec)

Amount of water required/sec for the area of crop irrigated, during it's entire period of growth.

(i.e. n m^3/sec of discharge req for m hectary throughout base period)

4) **Delta (Δ)** (meters)

[∵ Quantity of water (m^3) = Area of land (m^2) × Depth of water (m)]

∴ Delta = Total depth of water required by a crop throughout Base period (i.e. Depth of water penetrate into the soil)

*) **Relation:**

(i) Δ (m) of water required for D (hectary) of land @ 1 cumec

$$= \Delta D \left(m \times \frac{hectary}{Cumec} \right) = \Delta D \left[m \times \frac{10^4 m^2}{m^3/sec} \right]$$

$$= \Delta D \times 10^4 \text{ sec's}$$

(ii) For the same B (days) of water required

$$= B\,(days) = B\,(24 \times 60 \times 60) \text{ Sec's}$$

$$\therefore \Delta D \times 10^4 = 24 \times 60 \times 60\, B$$

$$\Delta = \frac{24 \times 60 \times 60}{10^4} \times \frac{B}{D}$$

$$\therefore \boxed{\Delta = \frac{8.64\, B}{D}}$$

(∵ Δ in meters
D in hectary/cumec
B in days)

Methods of Distribution of Irrigation water

1. Free flooding irrigation:

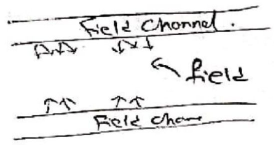
Water enters the field at higher end to lower end

→ Large quantity of water wasted

→ Field is divided into a small sized plots by field channels

→ Used in a) Inundation (high rainfall) irrigation system

b) where steep (high gradient) land is available.



2) Check flooding irrigation: →

Same as free flooding but field is divided into level plots surrounded by checks or levees (kdm).

→ Equally distributed in entire field

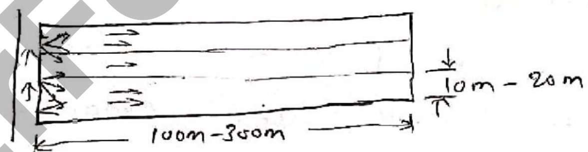
→ wastage of water is less

→ Suitable for permeable soil

→ used for crops which can "stand inundation of water for sometime"

(i.e after completely penetration of water again release)

3) Border flooding

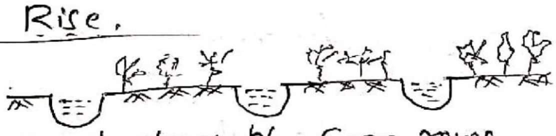


Field divided into No. of long parallel strips called Boarders.

→ Used for closed growing crops, such as wheat, fodder ... etc

But not for Rice.

4) Furrow irrigation:



Furrows (Trenches) are developed b/n crop rows

→ Suitable for irrigating crops planted in rows.

Potato,
Sugar cane,
Ground nut.

5) Sprinkler irrigation

Artificial rain created by perforated pipes

6) Drip irrigation:

water supplied through flexible pipe lines (water tubes)

7) Contour Farming:

In hilly areas having steep slopes with quickly falling contours.

Hydrology :

1) Hydrology = Science deals with occurrence, distribution & circulation of water

2) Hydrography = Science deals with physical features & conditions of water on the earth surface.

3) Hydrometry = Science deals with measurement of water.

4) Hydrological Cycle = Earth water circulating system (i.e from the stage of Evaporation from ocean to final return to ocean)

Precipitation = Evaporation + Run-off

$$P = E + R$$

a) precipitation :

Fall of moisture from the atmosphere to the earth surface in any form (like rain, snow, hail, sleet... etc).

→ precipitation is generally measured by Rain gauge

b) Runoff :

Amount of water which flows over the surface of earth after the all losses (i.e evaporation, plant usage .. etc)

Catchment Area : Area which contributes run-off.

c) Maximum Flood Discharge

Dicken formula $Q = CA^{3/4}$

Ryve's formula $Q = CA^{2/3}$

Fanning's formula $Q = CA^{5/6}$

Irrigation Canals

1) Type of Soil

alluvial Canal = Canals which pass through alluvial (transport by water) Soil.

Non-alluvial Canal = canals pass through non-alluvial (i.e rock plain) Soils.

2) Nature of water Supply

Perennial (or) permant Canals = Flows throughout year

Non-perennial (or) inundation cals = Not flow throughout year

3) Funds available

protective Canals = In the interest of public without any revenue expect

productive Canals = which are constructed for revenue.

* Canal Alignment :

Alignment Should be such that

→ It can irrigate maximum area

→ To ensure minimum number of cross-drianage works.

a) Contour Canal :

→ Aligned parallel to the Contours of the Country

→ It can irrigate only one side of the canal, (i.e low value contour side)

→ Most Suitable in hilly areas.

b) Watershed (or) Ridge Canal :

→ Aligned along watershed (highest level) line

→ Can irrigate both sides of the Canal

→ Irrigation Canals are generally aligned along water-shed.

c) Side slope Canal

→ Aligned at Right-angles to the Contours of the Country

→ Runs approximately parallel to Natural drianage of Country

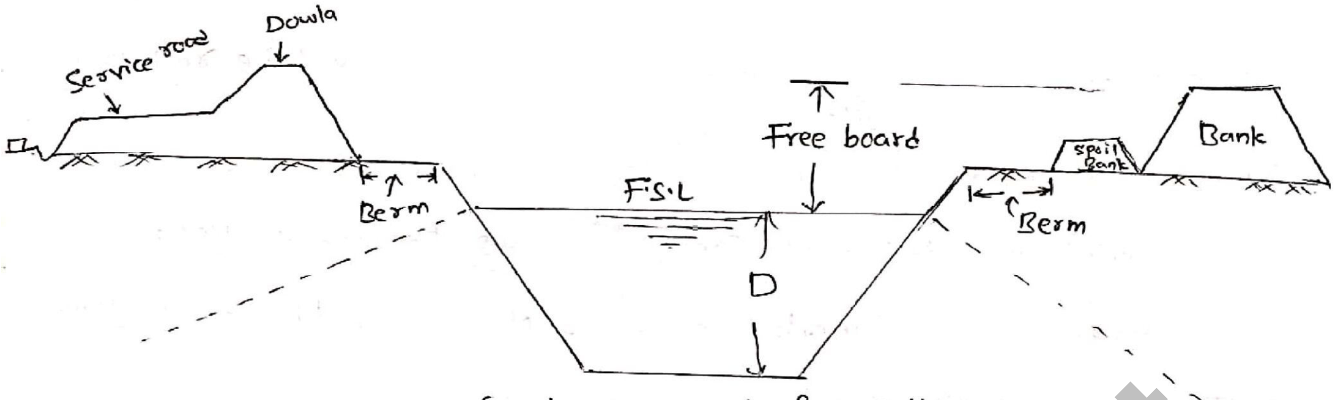
→ Cross-drianage works are Completely eliminated

*) Layout of Canal System

Main components or construction works in Canal System in Correct sequence are as follows.

Canal head works → Head regulator → Main Canal → Branch Canal → Distributory (Major & Minor) → Field channel (or) water courses.

Cross-Section of Irrigation Canal



Canal section in full cutting

1) Free board

F.S.L – Top of Bank (Unlined Canals)

F.S.L – Top of lining (Lined Canals)

Free board = $0.20 + 0.15\,Q^{1/3}$ (Lacey's recommendation)

2) Berm

Land left at the G.L between Inner toe of the bank and top edge of cutting.

→ To protect the bank from erosion because of wave action
→ Sometimes provide an additional inspection path
→ Scope for future widening of Canal
→ Bring the saturation line within embankment

Min Berm width = $0.5 + \frac{1}{4}$ (width of Combined slopes cut + fill)

Max Berm width = $0.5 + \frac{1}{2}$ (width of Combine Slopes)

*) Recommendations of IS: 7112-1973 for berm width

Berm width = 2D (Canal is cutting or partly cutting + filling)
= 3D (Canal is wholly filling) i.e. 

3) Dowla or Dowel

Rised portion provided on the Canal side of Service road

→ Also act as bank
→ For safety of vehicles + they act as kerbs.
→ Heigh above road level = 30cm
Top width = 30 cm – 60cm

4) Spoil Bank :

Extra excavated earth deposited as additional banks.

→ provided on one side or both sides.

→ is parallel to main bank

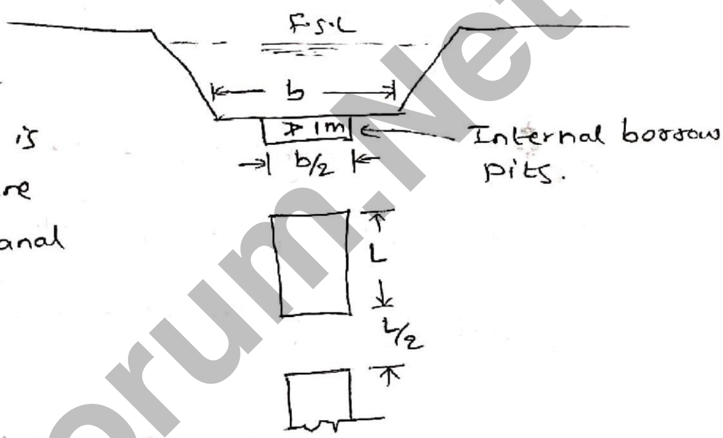
→ Should be discontinued at Cross-drainage works.

5) Balancing Depth or Economical depth

Quantity of excavated earth can be fully utilised by making the banks.

→ possible only when the Canal Section is partly cutting & partly filling i.e

6) Borrow pit :



Extra earth needed for filling banks. The earth is taken from pits which are inside or outside the canal

a) Inside borrow pits

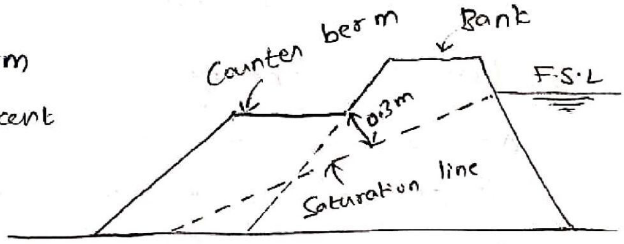
Depth ≯ 1m

width ≯ b/2

Gap of pits ≮ L/2

b) outside borrow pits (Depth ≯ 0.3m)

7) Back Berm or Counter Berm



Additional berm provide adjacent to bank to cover (protect) the saturation line.

Covered by 0.3m - 0.6m.

8) Service or Inspection road

Level of Service road = 0.4m - 0.8m higher than F.S.L

9) Canal Lining:

Laying of impervious layer to protects the bed and side slopes of the Canal.

→ To prevent erosion of bed

→ To increase velocity ⇒ Discharge

→ To retard growth of weeds

→ Most economical Section of lined canals

a) Triangular with Circular bottom (Small discharges)

b) Trapezoidal with rounded Corners (high discharges)

Silt Theories

1) Kennedy's Silt Theory :

Investigations on Upper Bari Doab canal system

→ According to kennedy

Regime channel is one which neither scours nor silts.

→ He made following observations

a) Silt sediment is suspension because of eddies generated from the roughness of bed only.

b) Side slopes do not have sufficient silt supporting power

→ He concluded that

Silt supporting power of channel ∝ Bed width of channel & not to it's wetted perimeter

Critical velocity $(V_0) = 0.55\, m\, D^{0.64}$

where, D = Depth of water over bed portion of channel

$$\text{Critical Velocity Ratio } (m) = \frac{\text{Critical velocity for any canal system}}{(\text{Critical velocity for upper Bari Doab canal system})}$$

→ kennedy did not give his own flow equation. He used "kutter's flow equation. to find (Depth (D) & width of canal) by Trail & error method

∵ kutter's flow equation $V = C\sqrt{RS}$

2) Lacey's Theory

According to him channel is said to be Regime state when

a) Flowing silt of same character that of transported material

b) silt grade & silt charge are constant

c) The discharge is constant.

These conditions are rarely (seldom) met. Hence he realized & state

Initial regime = Channel form section only but not longitudinal slope

Final regime = Channel form it's section and longitudinal slope

*) Lacey's silt factor $(f) = \dfrac{5V^2}{2R}$

$= 1.76\sqrt{m}$

[∵ V = mean regime velocity
R = Hydraulic mean depth $= \frac{A}{P}$
m = Mean particle dia (mm)]

*) Regime flow velocity $(V) = 10.8\, R^{2/3} S^{1/3}$

$= \left(\dfrac{Qf^2}{140}\right)^{1/6}$

*) wetted perimeter $(P) = 4.75\sqrt{Q}$

*) Scour Depth $= 0.47\left(\dfrac{Q}{f}\right)^{1/3}$

Water logging:

The air circulation is stopped in the root zone of the plant due to "Rise in water table".

→ It's effects productivity or fertility in plants

Depth of water table which affects growth of different crops.

Sugar Cane	- 0.3 m
Rise	- 0.6 m
wheat	- 0.9 to 1.2 m
Fooder Crop	- 1.2 m
Cotton	- 1.5 to 1.8 m
Luceine	- 2.1 m to 2.4 m

Canal Regulatory works.

The works (or) Structures constructed in (or) across the Canal in order to Control and regulate discharges, Velocity, depths.. etc. They are a) Regulators b) Escapes c) Falls d) outlets & Modules

a) Regulators

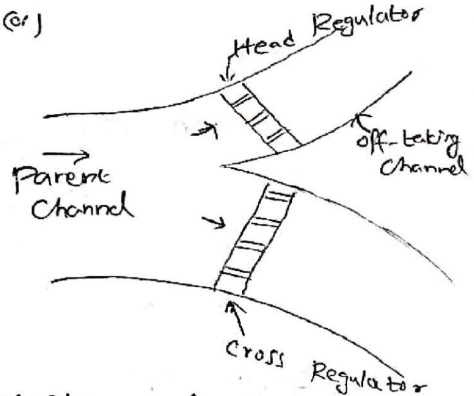
Constructed for regulating (i.e distributing the water at Specified time by lock gates) the supply of irrigation water

(i) Distributory head regulators

Constructed at the head of the off-taking (or) distributory (i.e Branch canal)

H.R are provided

→ To Control supplies to off-taking canal
→ To Control silt entry " "
→ To stop supply " "
→ To measure discharge " "



(ii) Cross-Regulators

Constructed in the main Canal (i.e Downstream of off-taking canal)

C.R are provided

→ To rise water level in case of low discharges
→ To absorb fluctuations in U/S
→ Also having the same functions as H.R

b) Escapes: (or) Safety Valves

Constructed for wasting excess water (in case of high rainfall) in to the Natural drainage.

(i.e Same as Branch Canal but it is not connected to Field Channel)

→ Minimum Capacity of escape should be provided = 50%.

C) Canal Falls:

Masonry Structure Constructed to provide design bed slope to fall/flow water from U/s to D/s @ Design speed

Canal falls are neccessary

→ When the Slope suddenly changes to steeper
→ Greater/less than permissible bed slope
→ More/less uniform bed slope
→ In Cross-drainage works F.S.L of Canal is above the bed level of drainage.

a) Ogee fall

A Combination of Convex & Concave curve

b) Rapid fall

1 in 15 to 1 in 20

Very satisfactory but expensive, (Ground surface is even & long)

c) Sharda fall (or) vertical drop fall

(i) When discharge is < 14 cumecs

→ Rectangular crest used

→ width = $0.55\sqrt{d}$

$$Discharge (Q) = 1.835\, L H^{3/2} \left(\frac{H}{B}\right)^{1/6}$$

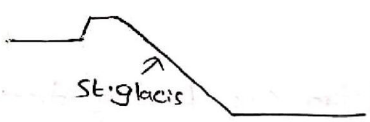
(ii) when discharge > 14 cumecs

→ Trapezoidal Crest used

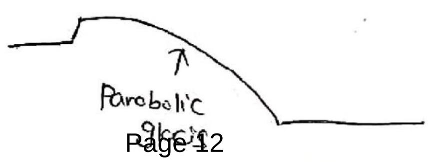
→ width = $0.55\sqrt{H+d}$

$$Discharge (Q) = 1.99\, L H^{3/2} \left(\frac{H}{B}\right)^{1/6}$$

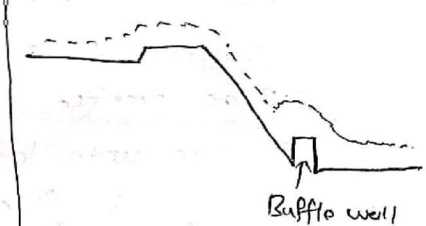
d) Glacis fall



e) Montage fall



f) Inglis (or) Baffle fall



Suitable for

→ all discharges

→ Drops ≯ 1.5 m

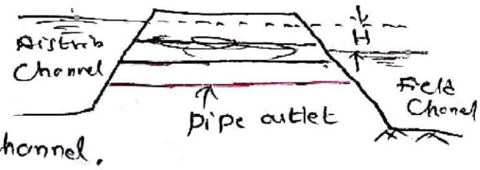
d) Canal outlets (or) Modules

(outlets = way of passage, Generally pipes)

An outlet is a small structure which admits water from distributing channel to field channel.

→ Should be design that the farmer can easily operate

a) Non Modular outlet



Discharge depends upon difference in water levels (H) in distributing & field channel.

eg: Submerged pipe outlet (most famous)

b) Semi-modular (or) Flexible outlet

Discharge depends ~~upon~~ only on the water level in distributory channel.

eg: pipe outlet, kennedy's gauge outlet, open flume, orifice semi-module

c) Rigid Module (or) Modular outlet

Discharge does not depends upon water levels in - - - .

eg: Gibbs Module.

Weir (or) Barrage

Weir: Constructed accross the river to rise water level & divert water into canals (only obstruction, no gates)

Barrage: To adjust water levels to different levels in different times (obstruction with gates)

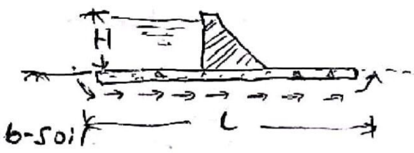
*) Weir or Barrage may fail due to

→ Rupture of floor due to uplift

→ Rupture of floor due to suction causes by standing wave

→ Scour on the upstream & downstream of the weir.

Bligh's Creep Theory



Percolating water creeps (permeable passage) along the base profile of the apron with sub-soil

Creep length: length of creep passage

→ Hydraulic gradient or percolation coefficient

$$C = \frac{H}{L}$$

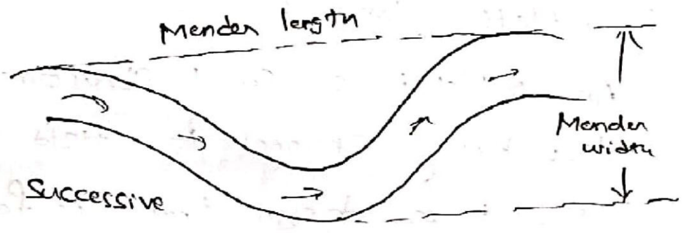
→ Bligh's Creep Coefficient

$$\frac{1}{C} = \frac{L}{H}$$

River Training works (Generally Required for Meandering type rivers)

Alluvial rivers are Classified as

a) Meandering:



Meander length

= Tangential distance b/w Successive points of meander

Meander width or belt

= Transverse distance b/n apex of one curve to successive Reverse curve

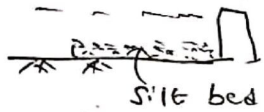
$$\text{Sinuosity} = \frac{\text{Curved length}}{\text{Straight axial distance}}$$

$$\text{Tortuosity} = \frac{\text{Curved length along the river}}{\text{Straight axial distance along the river}}$$

b) Aggrading type river

built up it's bed by laying down of sedimentation

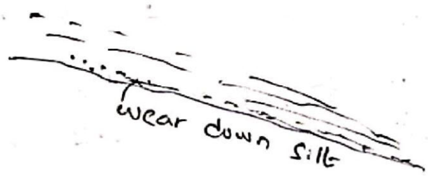
(Due to obstructed by weir, barrage, dam..etc)



c) Degrading type river

wear down it's bed Constantly

(Due to No obstruction)

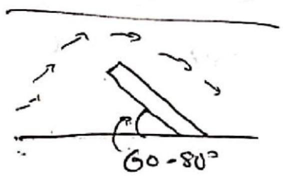


Groynes

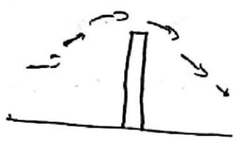
Structure Constructed from bank to river upto certain limit to transverse the river flow.

→ protect river bank, by keeping away river bank

→ Silt up the area in vicinity (They remove after)

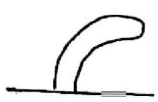


Repelling Groyne
(pointing towards U/S)

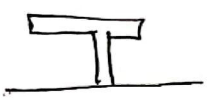


Deflecting Groyne

Attracting Groyne
(Pointing towards D/S)



Hockey groyne

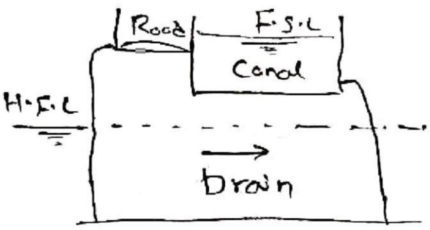


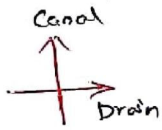
T-Shaped Denehy's groynes.

Cross-Drainage works

Works constructed at the crossing points of canal & drainage

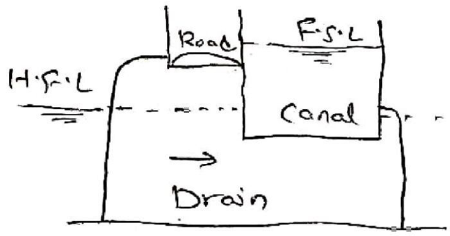
a) Aqueduct





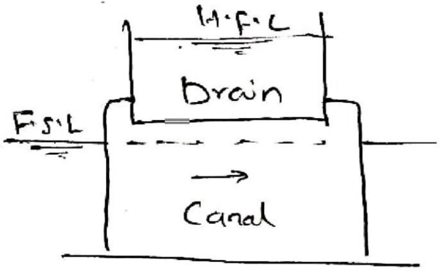
→ Bed level of canal is higher than H.F.L of drain

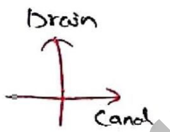
b) Syphon aqueduct



→ Bed level of canal is below the H.F.L of drain

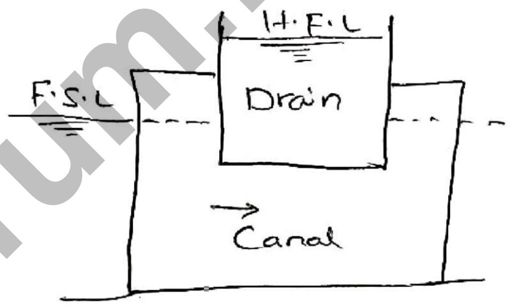
c) Super passage





→ Bed level of drain is higher than F.S.L of canal

d) Canal syphon



→ Bed level of drain is below the F.S.L of canal