Cross Drainage Works

Syllabus

- **Cross Drainage Works:** Types– selection of suitable type of CD works– aqueduct and Syphon

- **Aqueduct**– determination of maximum flood discharge and waterway for drain, fluming of canal– uplift pressure on underside of barrel roof and at the floor of the culvert– design of bank connections

What is Cross Drainage Works?

- In an Irrigation project, when the network of main canals, branch canals, distributaries, etc.. are provided, then these canals may have to cross the natural drainages like rivers, streams, nallahs, etc. at different points within the command area of the project. The crossing of the canals with such obstacle cannot be avoided. So, suitable structures must be constructed at the crossing point for the easy flow of water of the canal and drainage in the respective directions. These structures are known as cross–drainage works.

Cross Drainage Works

- Irrigational Canals while carrying water from headworks to crop field, have to cross few natural drainage streams, nallaha, etc.. To cross those drainages safely by the canals, some suitable structures are required to construct. Works required to construct, to cross the drainage are called Cross Drainage Works (CDWs). At the meeting point of canals and drainages, bed levels may not be same. Depending on their bed levels, different structures are constructed and accordingly they are designated by different names.

Necessity of Cross Drainage Works

- The water-shed canals do not cross natural drainages. But in actual orientation of the canal network, this ideal condition may not be available and the obstacles like natural drainages may be present across the canal. So, the cross drainage works must be provided for running the irrigation system.

- At the crossing point, the water of the canal and the drainage get intermixed. So, for the smooth running of the canal with its design discharge the cross drainage works are required.

- The site condition of the crossing point may be such that without any suitable structure, the water of the canal and drainage can not be diverted to their natural directions. So, the cross drainage works must be provided to maintain their natural direction of flow.

Necessity of Cross Drainage Works

Types of Cross Drainage Works

- **Type I (Irrigation canal passes over the drainage)**
- (a) Aqueduct
- (b) Siphon Aqueduct

- **Type II (Drainage passes over the irrigation canal)**
- (a) Super passage
- (b) Siphon super passage

- **Type III (Drainage and canal intersection each other of the same level)**
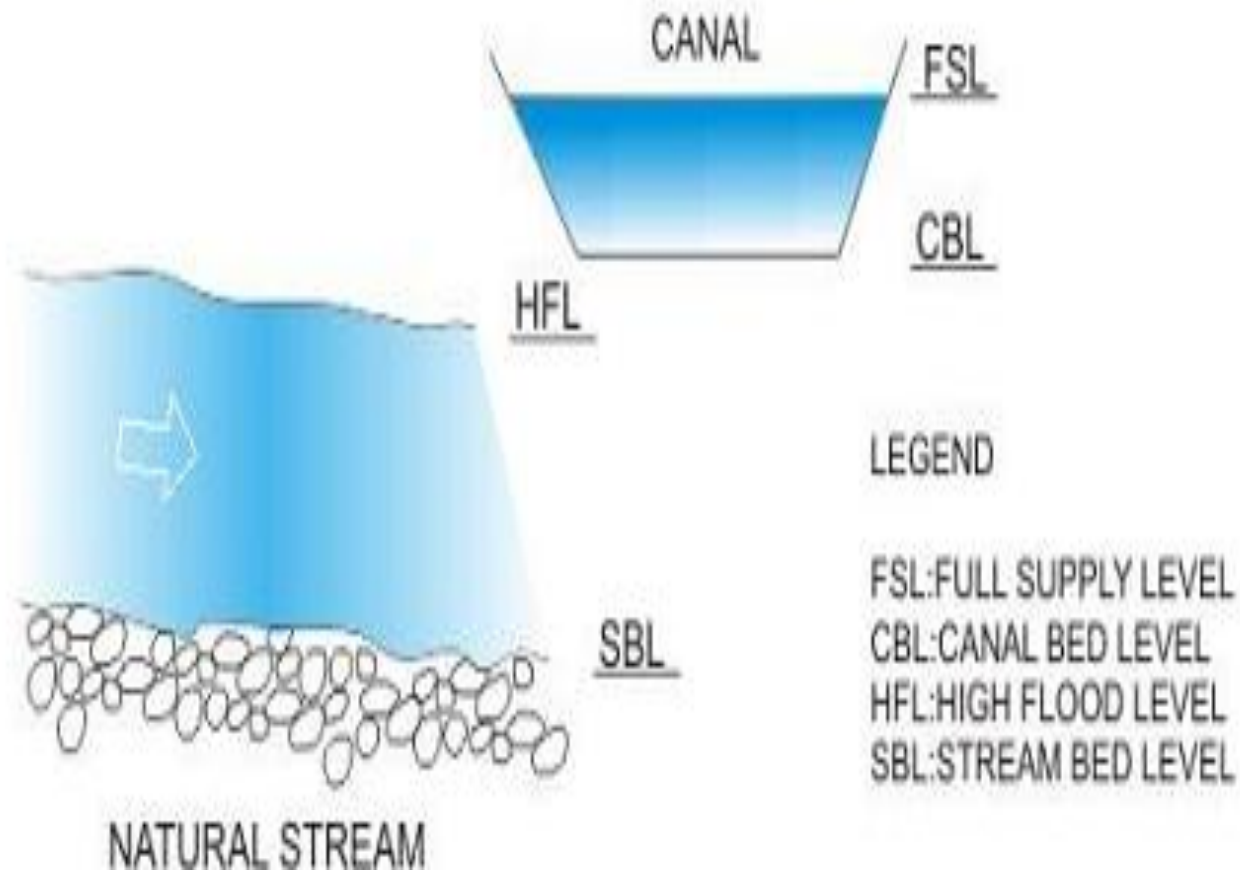- (a) Level crossing
- (b) Inlet and outlet

Selection of Type of Cross Drainage Works

- Relative bed levels
- Availability of suitable foundation
- Economical consideration
- Discharge of the drainage
- Construction problems

Types of Cross Drainage Works

- **Type-I Irrigation canal Passes over the Drainage:** This condition involves the construction of following:

- **Aqueduct**

- The hydraulic structure in which the irrigation canal is taken over the drainage (such as river, stream etc..) is known as aqueduct. This structure is suitable when bed level of canal is above the highest flood level of drainage. In this case, the drainage water passes clearly below the canal.

Aqueduct

CANAL

FSL

CBL

HFL

SBL

NATURAL STREAM

LEGEND

FSL:FULL SUPPLY LEVEL
CBL:CANAL BED LEVEL
HFL:HIGH FLOOD LEVEL
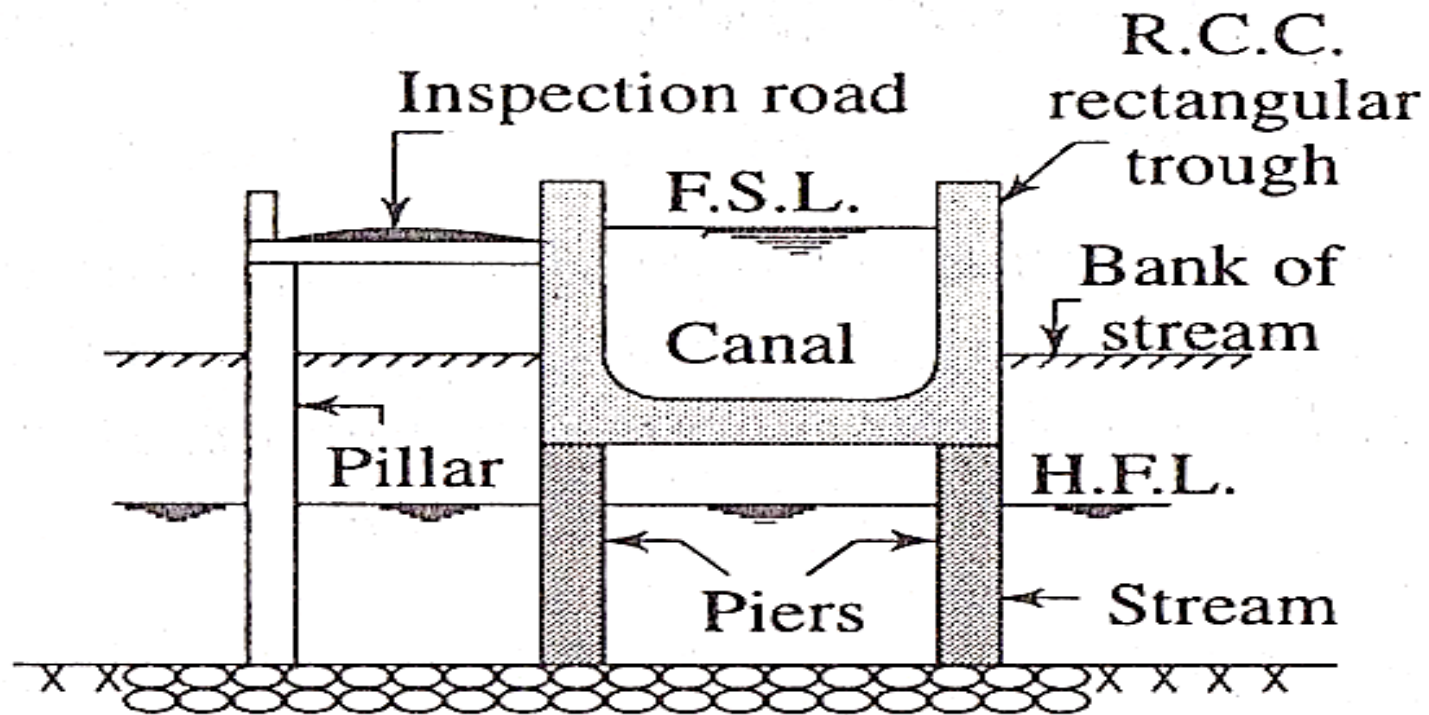SBL:STREAM BED LEVEL

Aqueduct

Fig: Aqueduct

Aqueduct

Siphon Aqueduct

- In a hydraulic structure where the canal is taken over the drainage, but the drainage water cannot pass clearly below the canal. It flows under siphonic action. So, it is known as siphon aqueduct. This structure is suitable when the bed level of canal is below the highest flood level.

Siphon Aqueduct
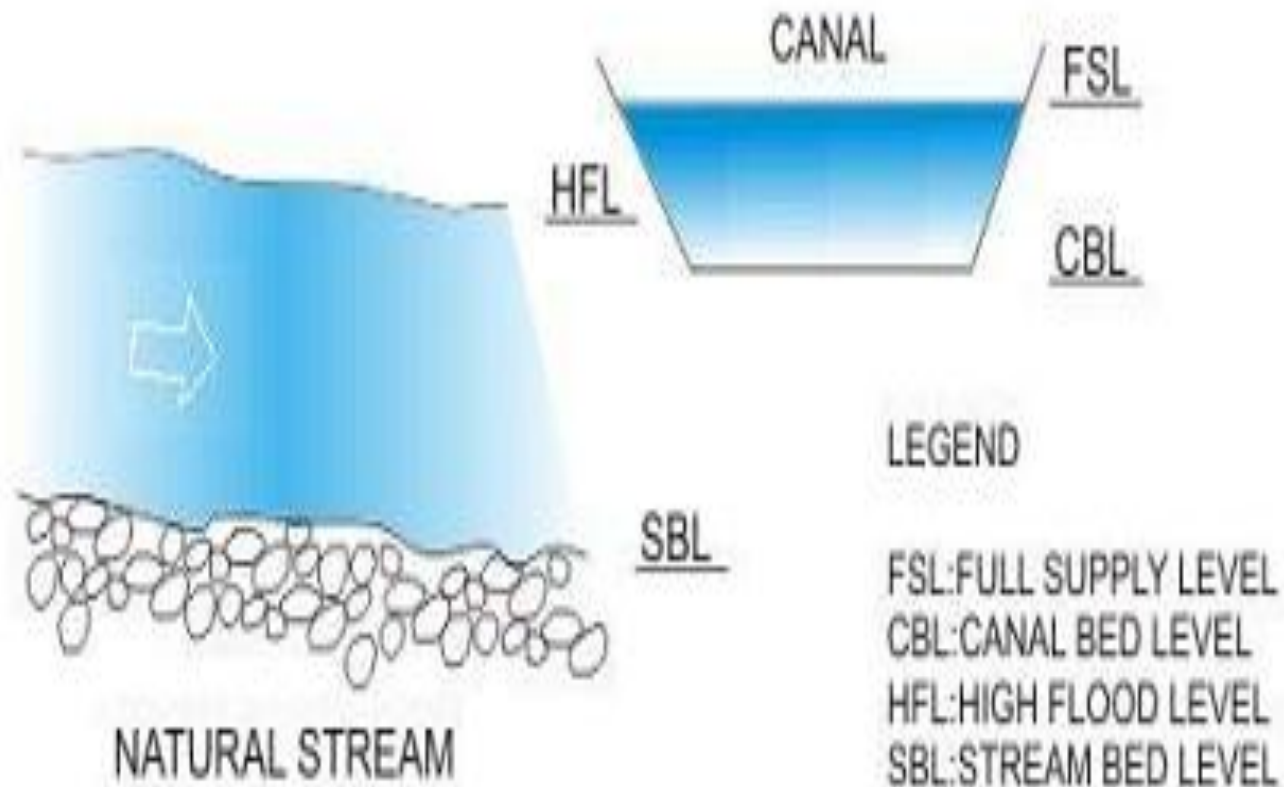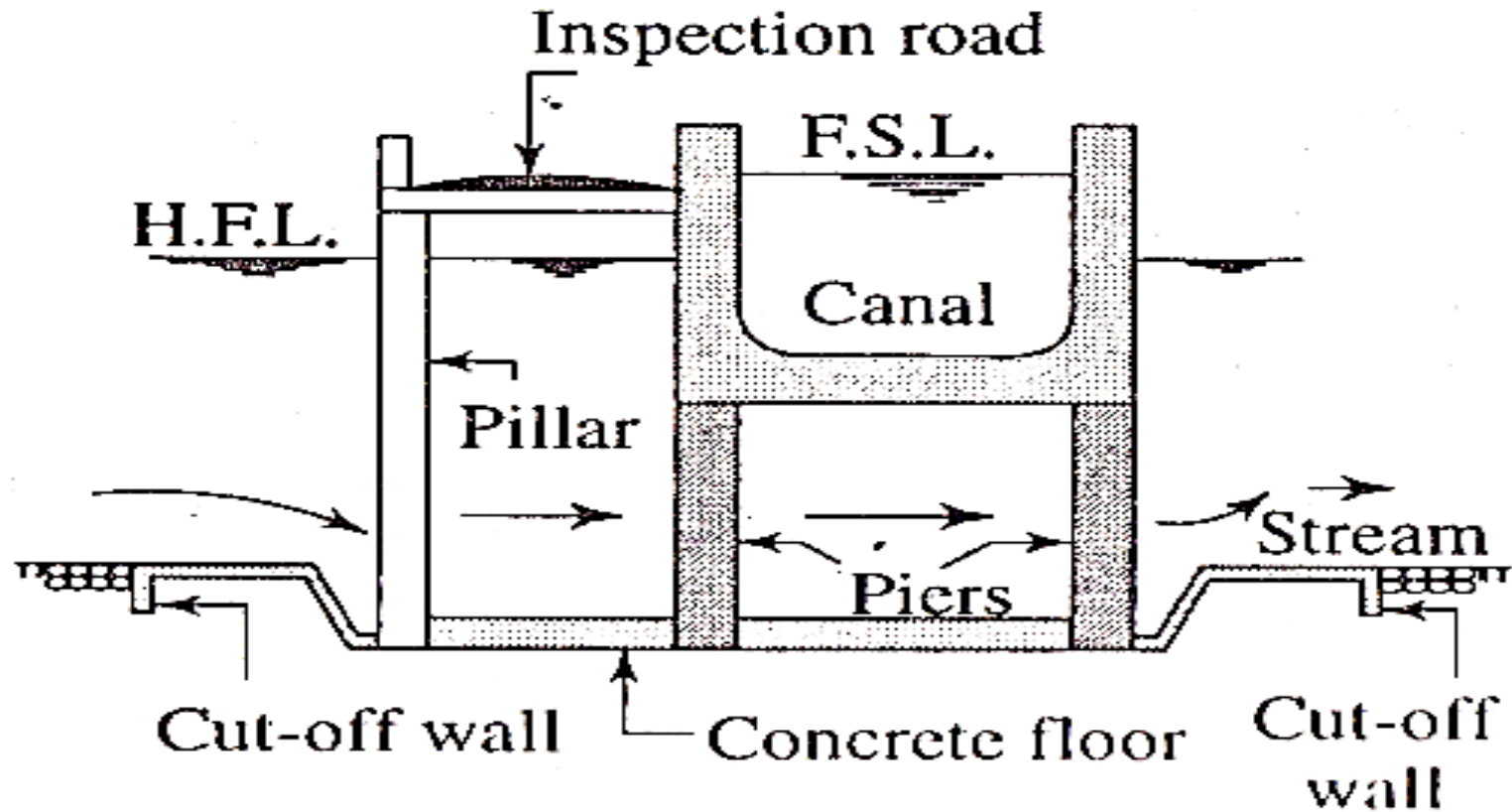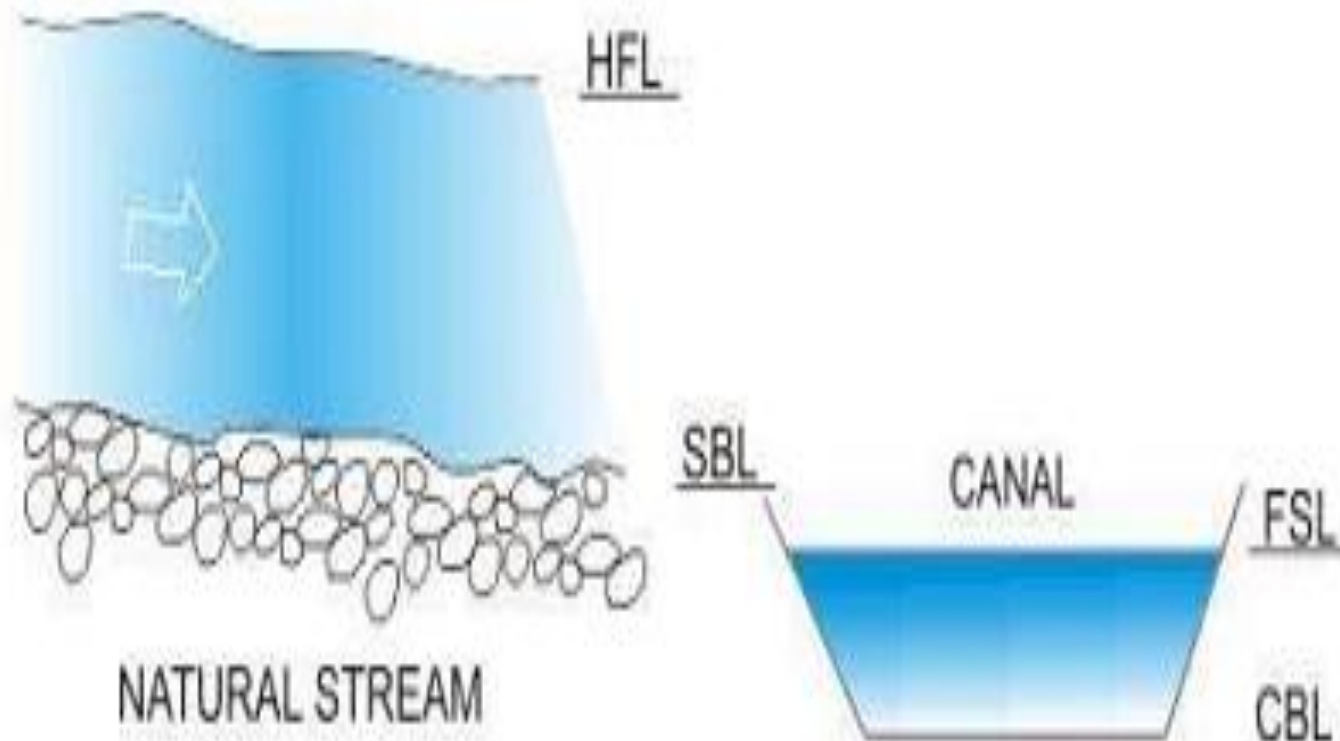
Siphon Aqueduct

Fig: Siphon Aqueduct

Types of Cross Drainage Works

- **Type–II Drainage Passes Over the irrigation Canal.**

- **Super Passage**

- The hydraulic structure in which the drainage is taken over the irrigation canal is known as super passage. The structure is suitable when the bed level of drainage is above the full supply level of the canal. The water of the canal passes clearly below the drainage.
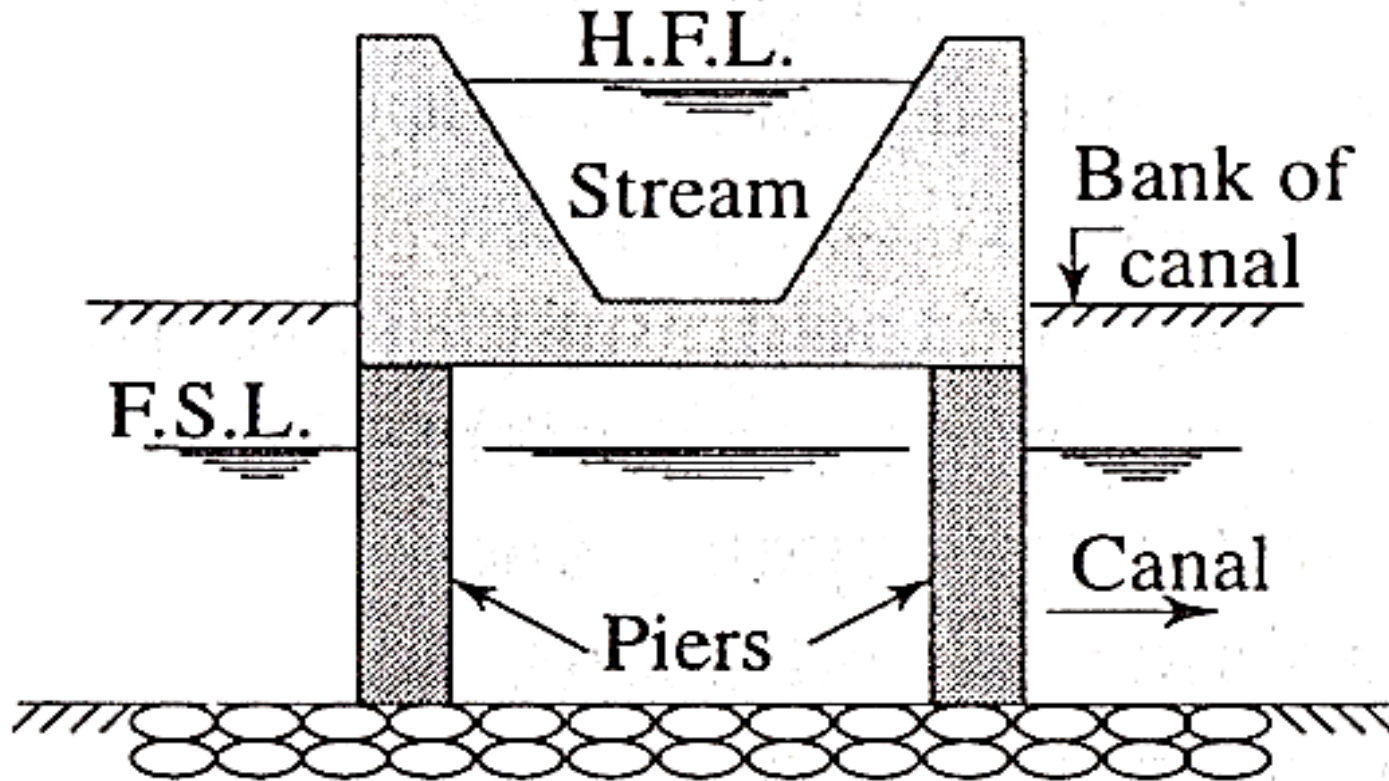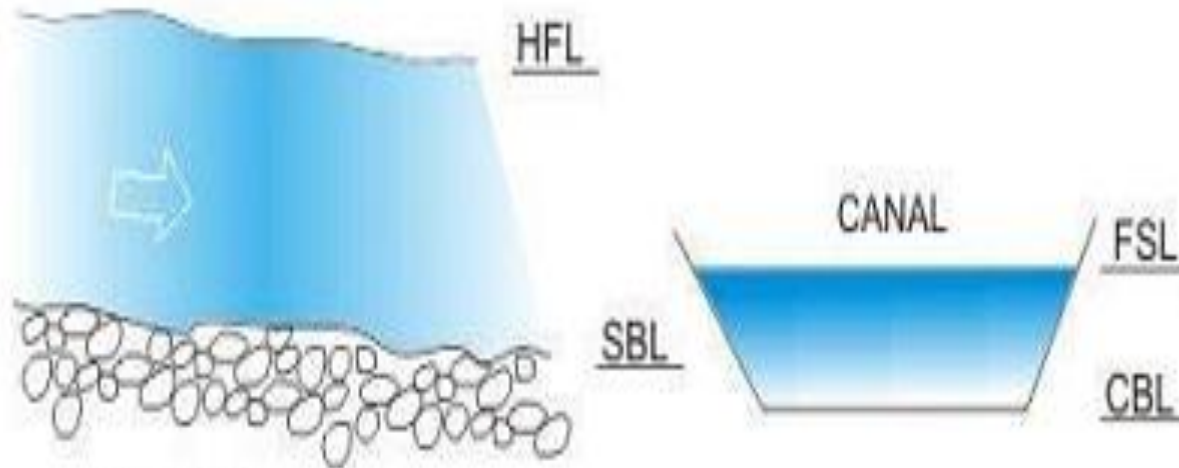
Super Passage

Super Passage

Fig: Super Passage

Siphon Super Passage

- The hydraulic structure in which the drainage is taken over the irrigation canal, but the canal water passes below the drainage under siphonic action is known as siphon super passage. This structure is suitable when the bed level of drainage is below the full supply level of the canal.

Siphon Super Passage

HFL

CANAL   FSL

SBL   CBL

NATURAL STREAM

LEGEND

FSL:FULL SUPPLY LEVEL
CBL:CANAL BED LEVEL
HFL:HIGH FLOOD LEVEL
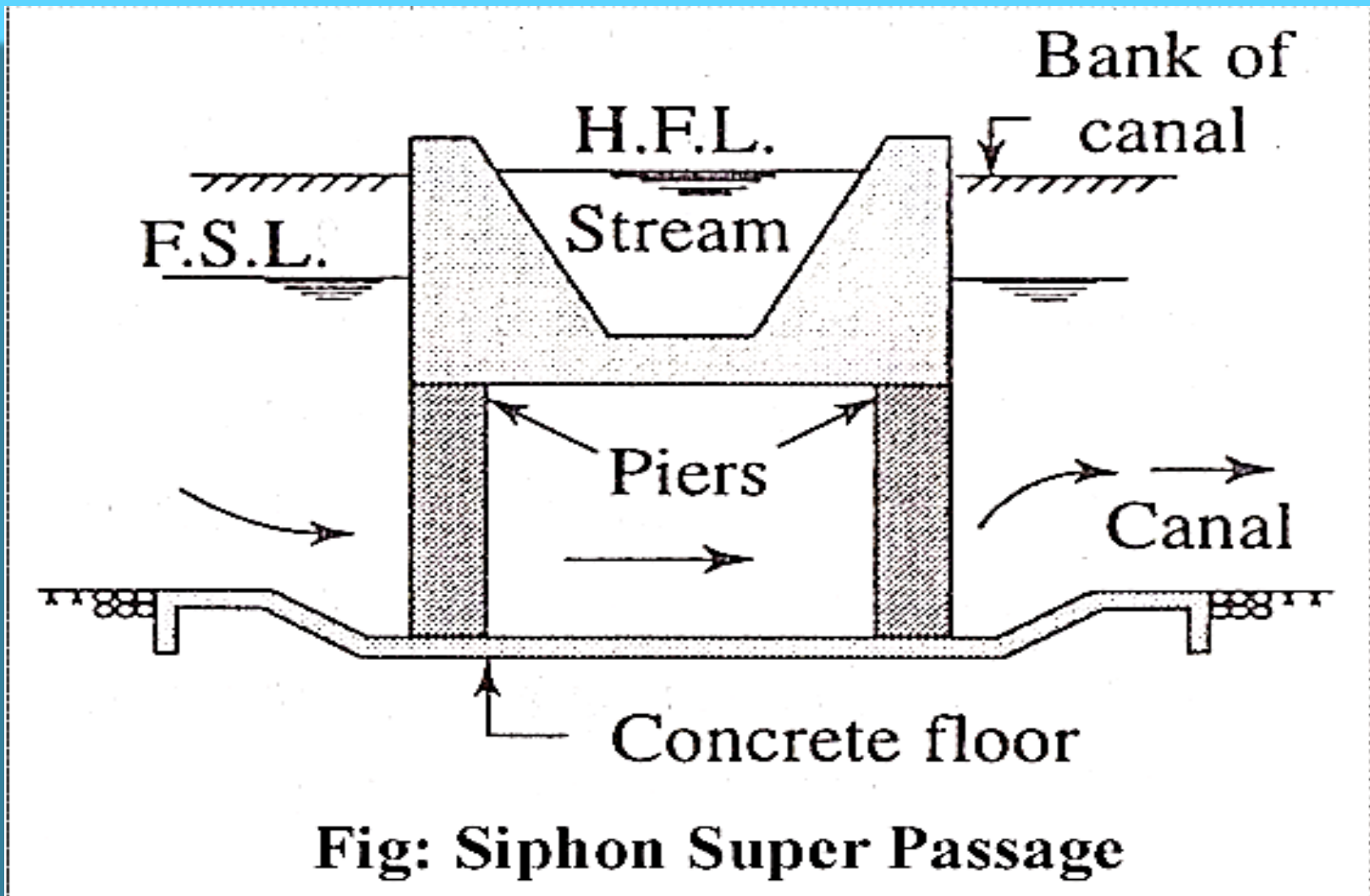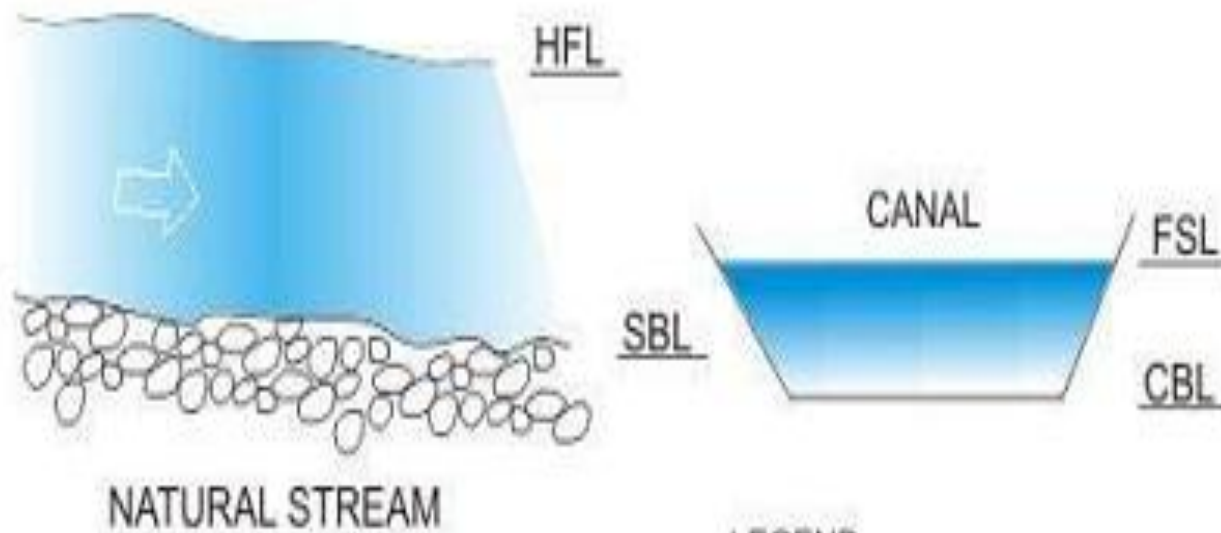SBL:STREAM BED LEVEL

Siphon Super Passage

Fig: Siphon Super Passage

Types of Cross Drainage Works

- Type III Drainage and Canal Intersect each other at the same level.

- Level Crossings

- When the bed level of canal and the stream are approximately the same and quality of water in canal and stream is not much different, the cross drainage work constructed is called level crossing where water of canal and stream is allowed to mix. With the help of regulators both in canal and stream, water is disposed through canal and stream in required quantity. Level crossing consists of following components (i) crest wall (ii) Stream regulator (iii) Canal regulator.

Level Crossings

HFL

CANAL

FSL

SBL

CBL

NATURAL STREAM

LEGEND

FSL:FULL SUPPLY LEVEL
CBL:CANAL BED LEVEL
HFL:HIGH FLOOD LEVEL
SBL:STREAM BED LEVEL

Level Crossing
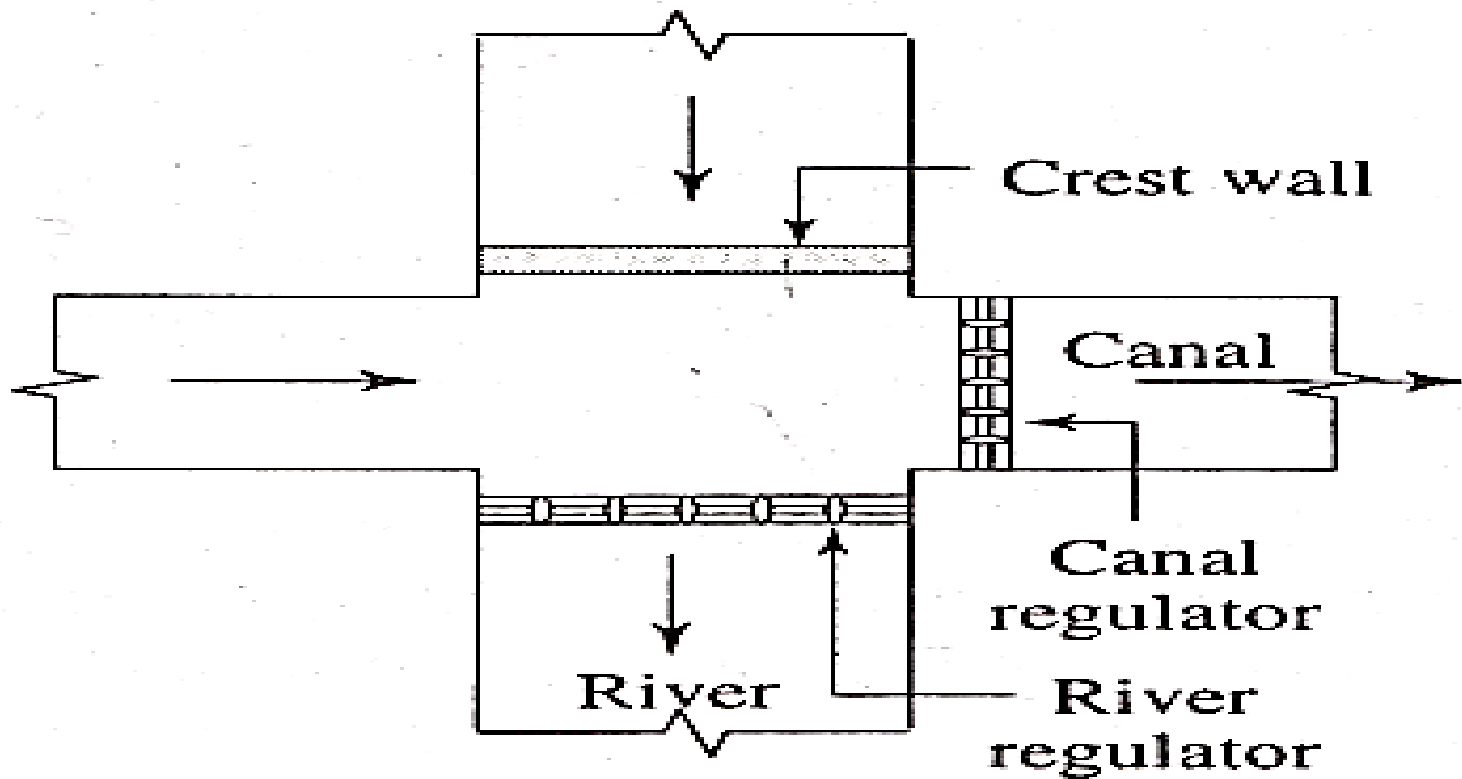
Fig: Level Crossing

Types of Cross Drainage Works

- ## Inlet and Outlet

- When irrigation canal meets a small stream or drain at same level, drain is allowed to enter the canal as in inlet. At some distance from this inlet point, a part of water is allowed to drain as outlet which eventually meets the original stream. Stone pitching is required at the inlet and outlet. The bed and banks between inlet and outlet are also protected by stone pitching. This type of CDW is called Inlet and Outlet.

Inlet and Outlet

Fig: Inlet and outlet

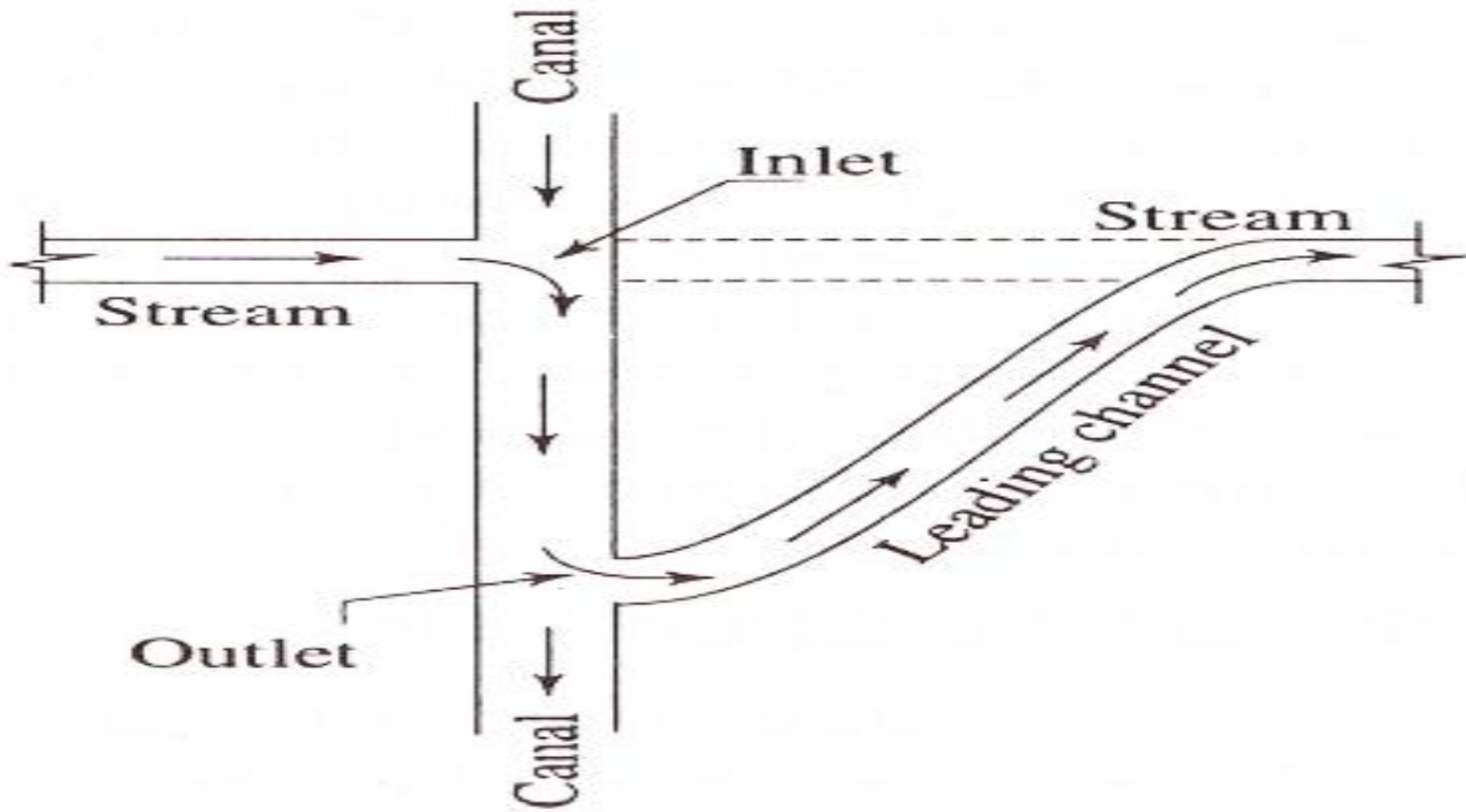# Selection of Type of Cross Drainage Work

- The following factors should be considered:
- **(i) Relative Bed Level**
- According to the relative bed levels of the canal and the river or drainage, the type of cross drainage work are generally selected which has been discussed earlier. But some problems may come at the crossing point
- **The following points should be remembered while recommending the type of work,**
- (a) The crossing should be at right angle to each other,
- (b) Well defined cross-section of the river or drainage should be available.
- (c) At the crossing point the drainage should be straight for a considerable length.
- (d) The width of the drainage should be narrow as far as possible.
- Considering the above points The C/s can be shifted to the downstream or upstream.

Selection of Type of Cross Drainage Work

Availability of Suitable Foundation

- For the construction of cross drainage works suitable foundation is required. By boring test, if suitable foundation is not available, then the type of cross drainage work should be selected to site Condition.

Selection of Type of Cross Drainage Work

Economic Consideration

- The cost of construction of cross drainage works should be justified with respect to the project cost and overall benefits of the project. So, the type of works should be selected considering the economical point of view.

Selection of Type of Cross Drainage Work

Discharge of the drainage

Practically the discharge of the drainage is very uncertain in rainy season. So, the structure should be carefully selected so that it may not be destroyed due to unexpected heavy discharge of the river or drainage.

Selection of Type of Cross Drainage Work

Construction of Problems

- Different types of constructional problems may arise at the site such as sub soil water, construction materials, communication, availability of land etc. So the type of works should be selected according to the site condition.

Determination of Maximum Flood Discharge

Determination of Maximum Flood Discharge

- The high flood discharge for smaller drain can be worked out by using empirical formulas; and for large drains other methods such as Hydrograph analysis, Rational formula, etc may be used.

- **In general the methods used in the estimation of the flood flow can be group as:**

- Physical Indications of past floods

- Empirical formulae and curves

- Overland flow hydrograph and unit hydrograph

Determination of Maximum Flood Discharge

- **Physical Indications of past floods- flood marks and local inquiry:**

- The maximum flood discharge may be approximately estimated by enquiring from the residents in the village situated on the banks of the river about the flood marks that the high flood in their memory in the past may have left on the river banks.

- By noting the high water marks along the banks of the river the cross-section area and wetted perimeter of the flow section as well as the water surface slope may be computed and using the manning's formulae, with suitable assumed value of the flood discharge may be determined.
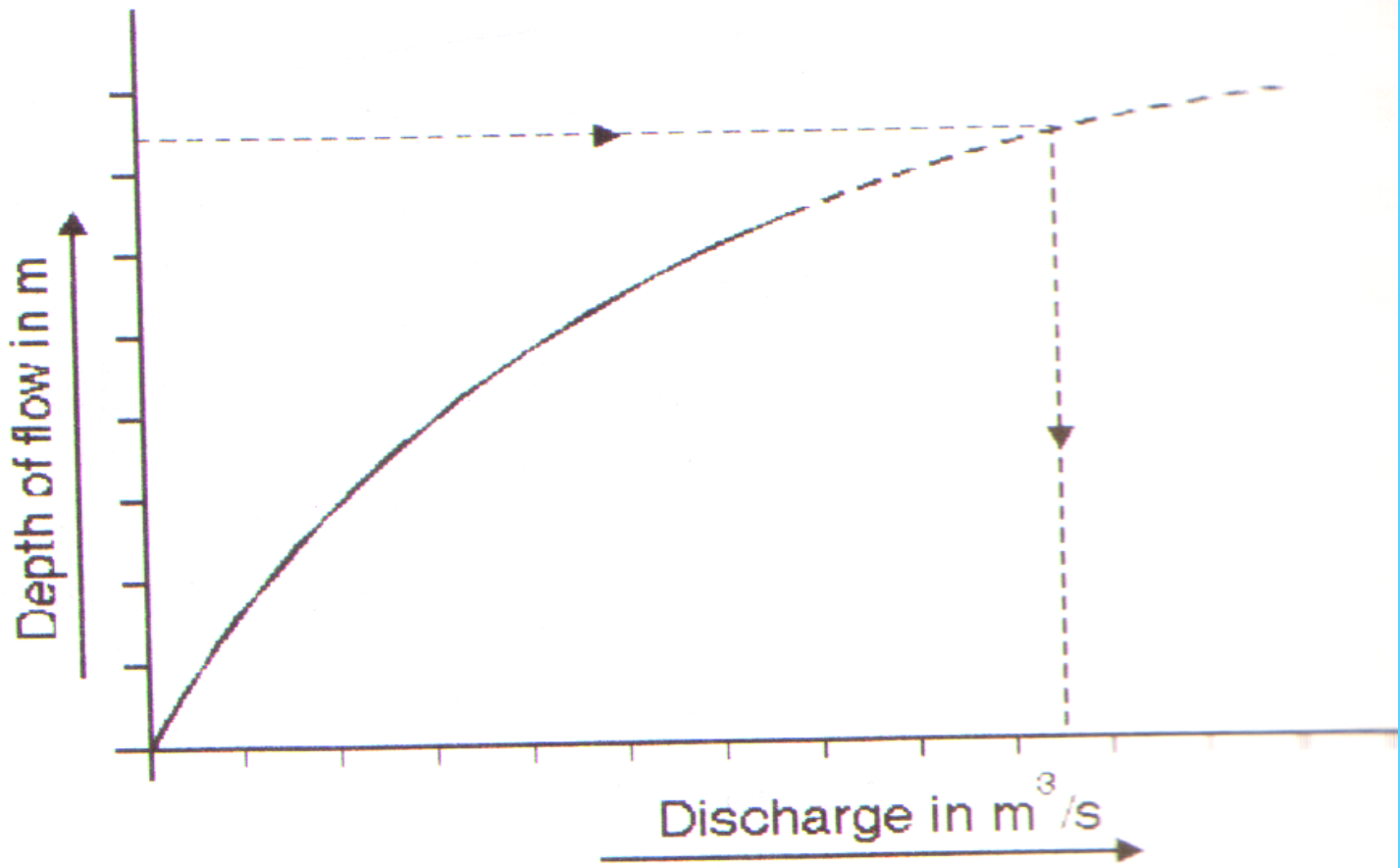
Determination of Maximum Flood Discharge

- Estimation of maximum flood discharge from rating curve: During the period of high flood, it is almost impossible to measure the discharge by making the use of markings of the high water marks on the banks of the river, the elevated water level, can be calculated. Making use of this values high water marks in meters the value of maximum flood discharge can be calculated, by extrapolation from the stage or rating discharge curve

- The above mentioned curve needs to be extended for the higher value of stage. It is done by using following methods.

- Simple Judgment

- Logarithmic method

- The above mentioned curve needs to be extended for the higher value of stage, it is done by using following methods.

- (a) Simple Judgment

- (b) Logarithmic Method

Determination of Maximum Flood Discharge

- **(a) Simple Judgment**

  The rating curve can be extended, by simple Judgment.

Determination of Maximum Flood Discharge

Simple Judgment method

Determination of Maximum Flood Discharge

- **(b) Logarithmic method:**

  The following equation can be used to extend the rating curve

  $$Q = K d^n$$

  Where,

  Q= Discharge (Cumecs)

  d= Stage in (m)

  K, n = Constants

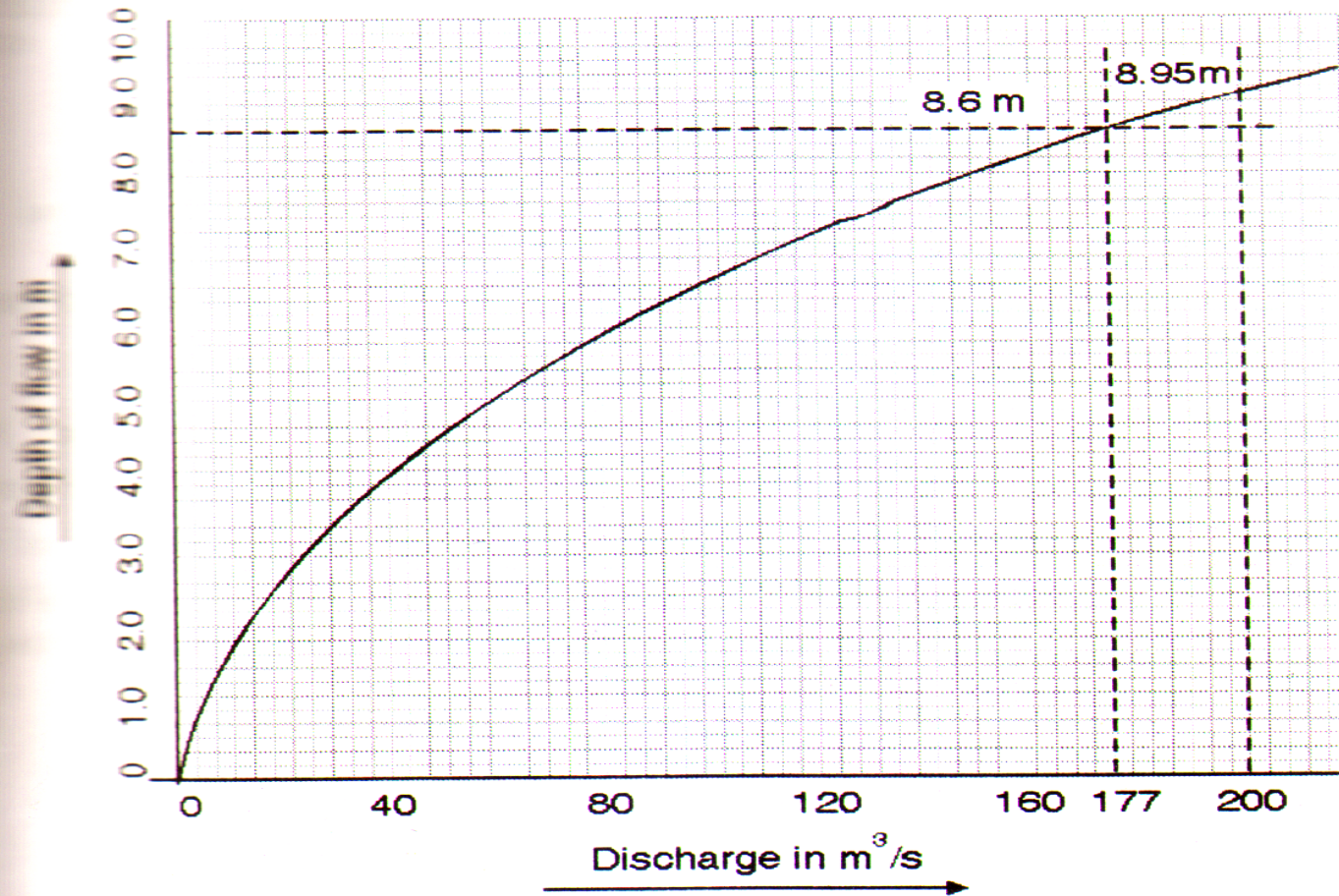 By taking logarithms of both sides, we get,

  Log Q= log k + n Log d

  If the available curve is plotted on a log-log paper, then it should be a straight line.

  This line can be extended to calculate the discharge at a higher stage.

Determination of Maximum Flood Discharge

Logarithmic method

Determination of Maximum Flood Discharge

Empirical Formulas

Several empirical formula have been developed for estimating the maximum or peak value of flood discharge. In these formulae the maximum flood discharge Q of a river is expressed as a function of the catchment area A. Most of these formulae may be written in a general form as:

- $Q = C A^n$

Where, C is coefficient and n is index, Both C and n depend upon various factor, such as

(i) Size ,shape and location of catchment ,

(ii) Topography of the catchment,

(iii) intensity and duration of rainfall and distribution pattern of the storm over catchment area.

Determination of Maximum Flood Discharge

- ## Dicken's formula:

Q = CA ¾

Where,

Q= Maximum flood Discharge in cumec.

A= Area of Catchment in sq. Km

C= coefficient depending upon the region

The maximum value of C= 35.

Region	Value of C
North India	11.4
Central India	13.9 to 19.5
Western Ghats	22.2 to 25

- ## Ryve's Formula:

Q= CA $^{2/3}$

Where, Q= discharge in cumec

A= Catchment Area in Sq. . Km

C= coefficient depending upon the region

Region	Value of C
1. Area within 24 km from the coast	6.75
2. Area between 24 km to 161 km from the coast	8.45
3. Limited areas near hills	10.00

Determination of Maximum Flood Discharge

Rational Method:

In this method it is assumed that the maximum flood flow is produced by a certain rainfall intensity which lasts for a time equal to or greater than the period of concentration time. When a storm continues beyond concentration time every part of the catchment would be contributing to the runoff at outlet and therefore it represents condition of peak runoff. The runoff corresponding to this condition is given by:

$Q = 2.78\, C\, I_c\, A$

Where, Q = Discharge in Cumec,

C= Coefficient which depends upon the characteristics of the catchment.

I_c= The critical Intensity of rainfall (cm/hr) corresponding to the time of Concentration (tc) of the catchment for a given recurrence interval obtained from the intensity of duration frequency curves.

A= Catchment Area in Km ^{2}

Determination of Maximum Flood Discharge

Rational Method:

$$I_C = \frac{P}{t_R} \left(\frac{t_R + 1}{t_C + 1} \right)$$

where P = the maximum precipitation (cm)

t_R = storm period (hours)

t_C = time of concentration (hours)

However, if the time of concentration t_C is not known then

$$t_C \approx \frac{P}{t_R}$$

Determination of Maximum Flood Discharge

Inglis formula:

- $$Q = \frac{124\ A}{\sqrt{A + 10.4}} = 124\ A^{\frac{1}{2}}$$

Where Q= discharge in cumec

A= area of catchment in Sq.. Km.

Inglish formula is derived by using the data of rivers of Mahashtra, where it is commonly used.

Ali Nawab Jang Bahadur formula:

$$Q = CA^{(0.993 - 1/14 \log A)}$$

Where, Q= Discharge in Cumec

A=area of catchment insq .km

C= Coefficient which varies from 48 to 60.
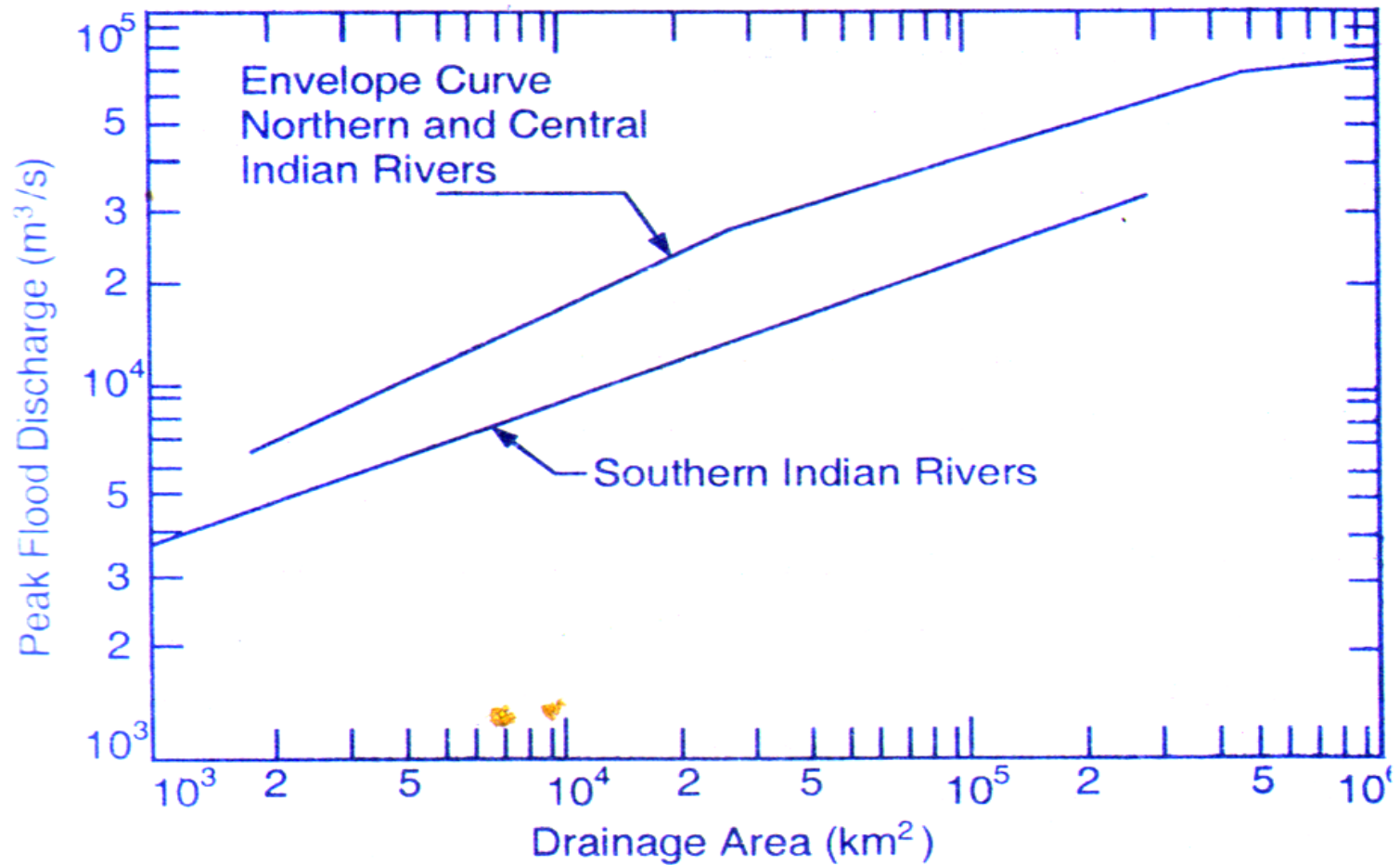
Determination of Maximum Flood Discharge

- **Myer's formula**
- Q= 175 $\sqrt{A}$
- Where,
- Q= Discharge in Cumec
- A= Area of Catchment in Sq.. Km.

Determination of Maximum Flood Discharge

Envelop Curves:

- Areas having similar topographical features and climatic conditions are grouped together. All Available data regarding discharges and flood formulae are compiled along their respective catchment areas. The maximum discharges are then plotted against the areas of the drainage basins and a curve is drawn to cover or envelop the highest plotted points, which is known as envelope curve. By using envelop curves the maximum flood discharge may be estimated if the area of the drainage basin is known.
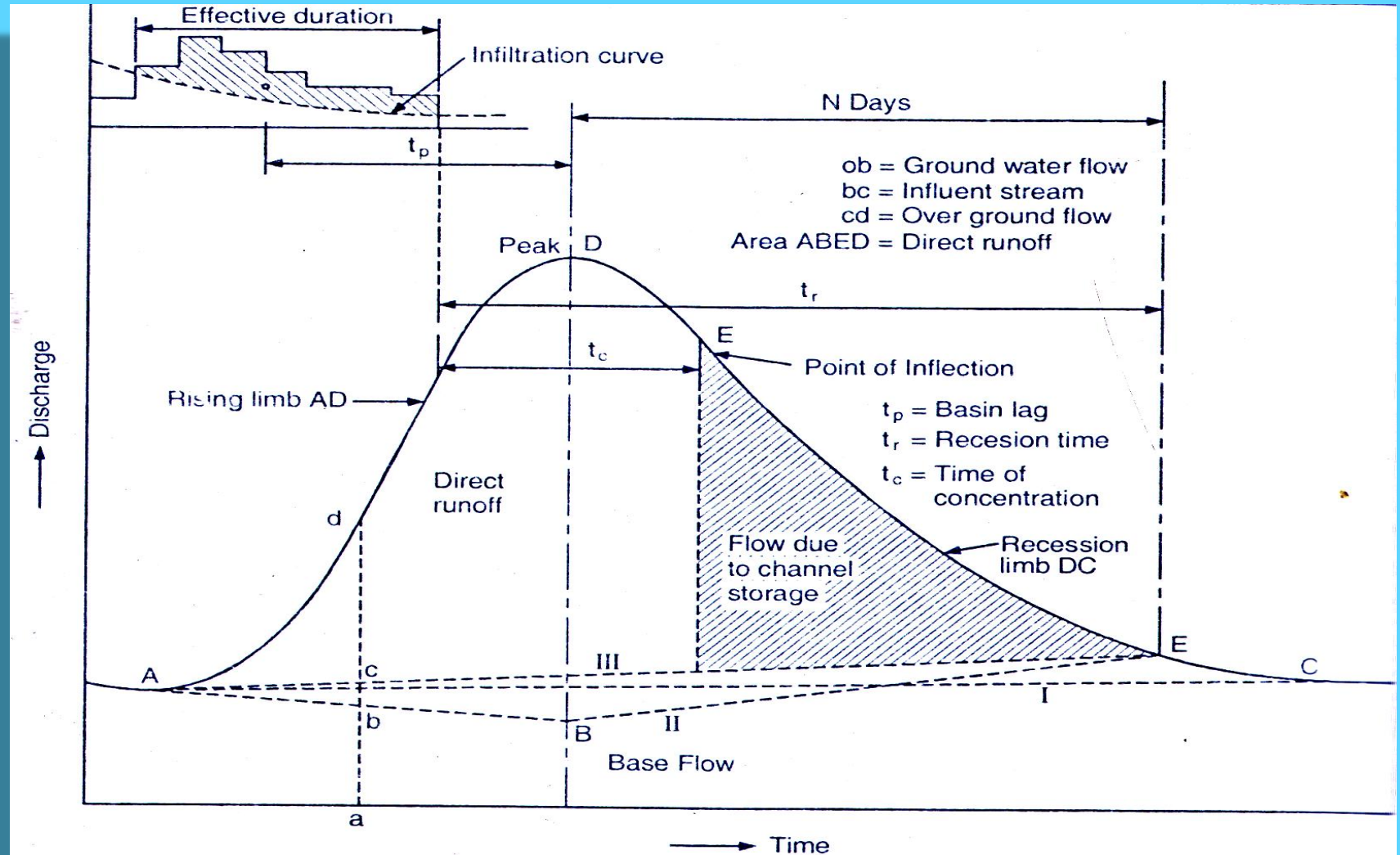
Determination of Maximum Flood Discharge

Determination of Maximum Flood Discharge

- **Overland flow Hydrograph and Unit Hydrograph:**
- A Hydrograph is a graphical plot of discharge of a natural stream or river versus time. It shows variation of discharge with time, at a particular point of a stream. It also shows the time distribution of total runoff at the point of measurement. Discharge is usually expressed in cumec or hectare-metre per day and time is expressed in hours, days or months. Discharge is plotted on Y-axis and the corresponding time is plotted on X-axis.

- **Unit Hydrograph:** A unit Hydrograph is a hydrograph representing 1 cm of runoff from a rainfall of some duration and specific areal distribution.
- Unit Hydrograph is defined as the hydrograph of surface runoff of a catchment area resulting from unit depth of rainfall excess or net rainfall occurring uniformly over the basin at uniform rate for a specified duration.

Hydrograph

Determination of Maximum Flood Discharge

- When a unit hydrograph is available for the catchment under consideration, it can be applied to the design storm to yield the design flood hydrograph from which peak flood value can be obtained.

- Whenever possible it is advisable to use the unit hydrograph method to obtain the peak flood. It gives not only the flood peak but also the complete flood hydrograph which is essentially required in determining effective storage of reservoir on flood peak through flood routing.

Unit Hydrograph
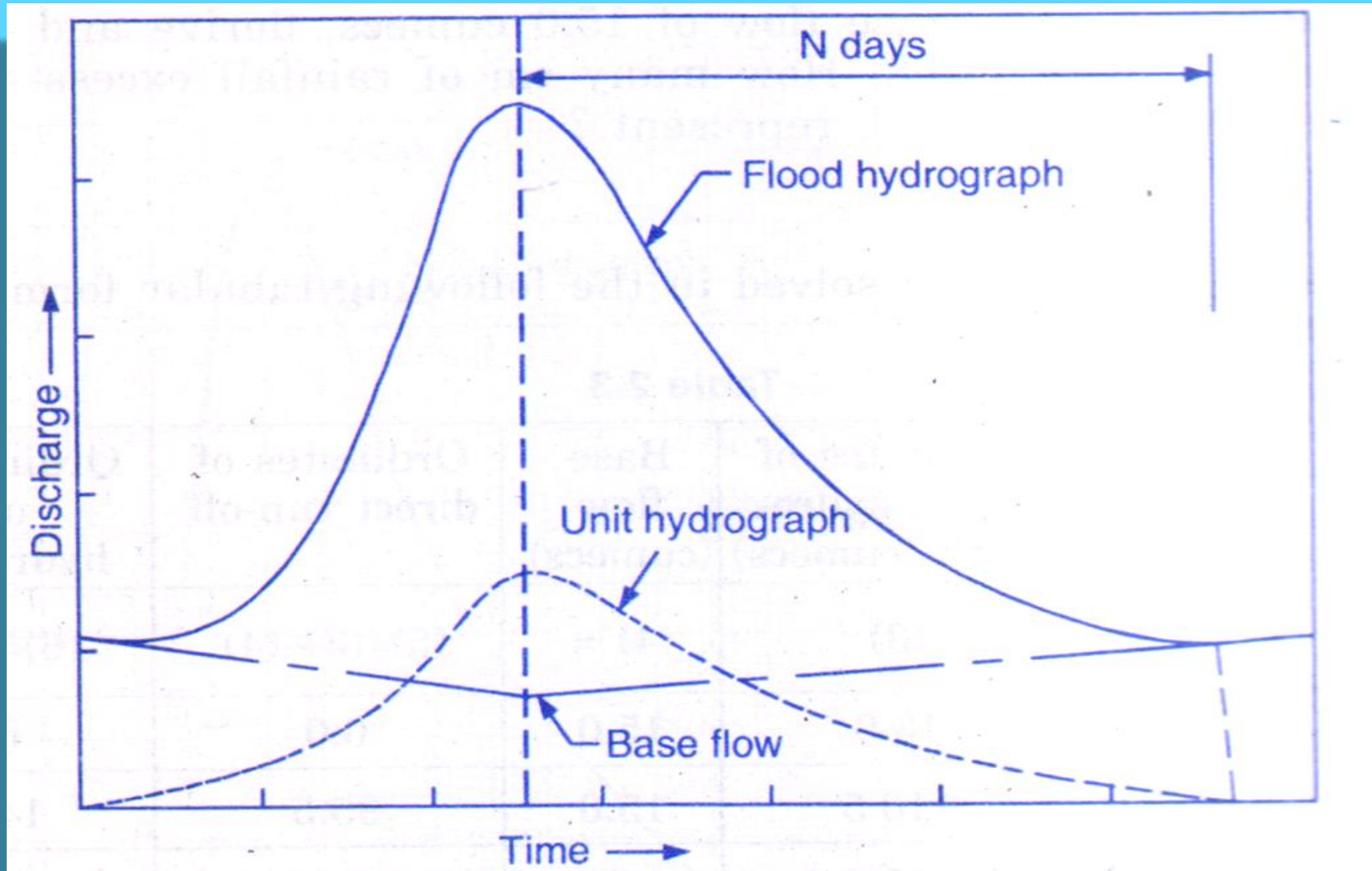
Fluming of Canal

- The Contraction in the waterway of the canal (i.e. fluming of canal) will reduce the length of barrels or the width of the aqueduct. This is likely to produce economy in many cases. The fluming of canal is generally not done when the canal section is in earthen banks.

- The maximum fluming is generally governed by the extent that the trough should remain subcritical, because if supercritical velocities are generated, then the transition back to the normal section on the downstream side of the work may involve the possibility of the formation of a hydraulic jump, This hydraulic jump, where not specially required and designed for, would lead to undue loss of head and large stresses on the work. The extent of fluming is further governed by economy and permissible loss of head. The greater is the fluming, the greater is the length of transition wings upstream as well as down stream. This extra cost of transition wings is balanced by the saving obtain due to reduction in the width of the aqueduct. Hence an economical balance has to be worked out for any proposed design.
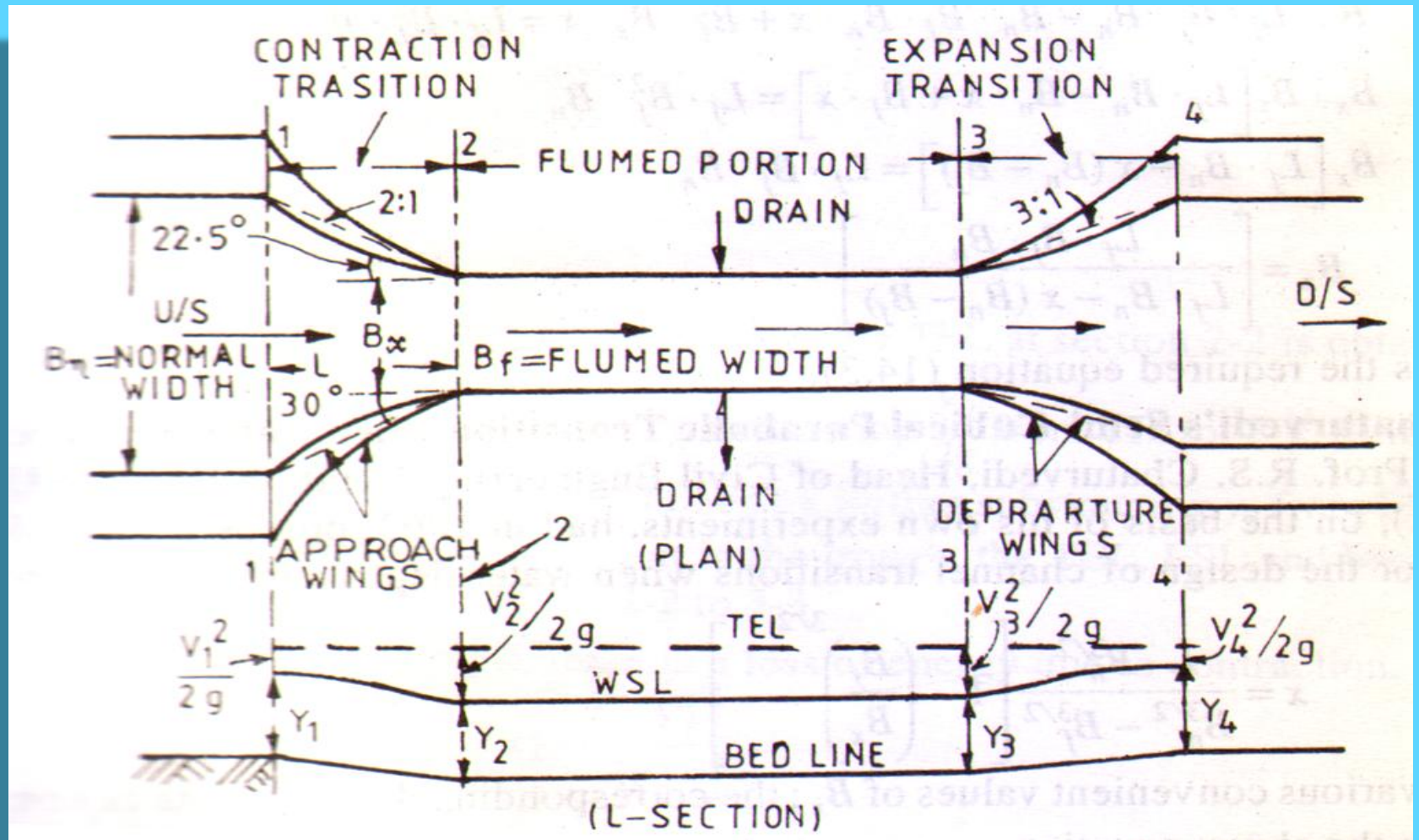
Fluming of Canal

- After deciding the normal canal section and the flumed canal section, the transition has to be designed so as to provide a smooth change from one stage to the other, so as to avoid sudden transitions and the formation of eddies, etc For this reason, the u/s or approach wings should not be steeper than 26.5 and the d/s or departure wings should not be steeper than 18.5. Generally the normal earthen canal is trapezoidal, while the flumed pucca canal section is rectangular. It is also not necessary to keep the same depth in the normal and flumed sections. Rather, it may sometimes be economical to increase the depth and still further reduce the channel width in cases where a channel encounters a reach of rocky terrain and has to be flumed to curtail rock excavation. But an increase in the water depth in the canal trough will certainly increase the uplift pressure on the roof as well as floor of the culvert, thus requiring larger roof and floor sections and lower foundations. Due to these reasons, no appreciable economy may be obtained by increasing depth.

Fluming of Canal

Fluming of Canal

Fluming of Canal

- The following methods may be used for designing the channel transitions:

- Mitra's method of design of transition (when water depth remains constant)

- Chaturvedi's method of design of transitions(when the depth remains constant)

- Hind's method of design of transitions (when water depth may or may not vary).

Fluming of Canal

- Mitras method of design Transition when water depth remains constant:

- Shri A.C. Mitra, Chief Engineer, U.P, Irrigation Department has proposed a hyperbolic transition for the design of channel transitions. According to him, the channel width at any section X–X, at a distance x from the flumed section is given by.

$$B_x = \frac{B_n \cdot B_f \cdot L_f}{L_f B_n - (B_n - B_f)\, x} \qquad \ldots(14.3)$$

where B_n = Bed width of the normal channel section.

B_f = Bed width of the flumed channel section.

B_x = Bed width at any distance x from the flumed section.

L_f = Length of transition.

Fluming of Canal

- Prof R.S Charturvedi, Head of Civil Engineering Dept, in Roorkee University, on the basis of his own experiments, had proposed the following equation for the design of channel transitions when water depth remains constant.

$$x = \frac{L \cdot B_n^{3/2}}{B_n^{3/2} - B_f^{3/2}} \left[1 - \left(\frac{B_f}{B_x} \right)^{3/2} \right] \quad \text{...(14.4)}$$

Choosing various convenient values of B_x; the corresponding distance x can be computed easily from the above equation.

Design of Bank Connections

- Two sets of wings are required in aqueducts and syphon-aqueducts. These are:

- Canal wings or Land wings

- Drainage Wings or Water Wings

- **Canal Wings:** These wings provide a strong connection between masonary or concrete sides of a canal trough and earthen canal banks. These wings are generally warped in plan so as to change the canal section from trapezoidal to rectangular. They should be extended upto the end of splay. These wings may be designed as retaining walls for maximum differential earth pressure likely to come on them with no water in the canal. The foundations of these wings should not be left on filled earth. They should be taken deep enough to give safe creep length.

Design of Bank Connections

- **Drainage Wings or Water Wings or River Wings:** These wing walls retain and protect the earthen slopes of the canal, guide the drainage water entering and leaving the work, and join it to guide banks and also provide a vertical cut-off from the water seeping from the canal into drainage bed. The foundations of these wings wall should be capable of withstanding the maximum differential pressure likely to come on them.

- The layouts of these sets of wings depend on the extent of contraction of canal and drainage waterways, and the general arrangement of the work.

Uplift Pressure on the Underside of the trough or the Barrel Roof

- **Uplift Pressure on the Barrel Roof**
- The amount of the uplift pressure exerted by the drain water on the roof of the culvert can be evaluated by drawing the hydraulic Gradient line (H.G).
- The uplift pressure at any point under the roof of the culvert will be equal to the vertical ordinate between hydraulic gradient line and the underside of the canal trough at that point From the uplift diagram it is very evident that the maximum uplift occurs at the upstream end point near the entry. The slab thickness should be designed to withstand this maximum uplift.

Uplift Pressure on the Underside of the trough or the Barrel Roof
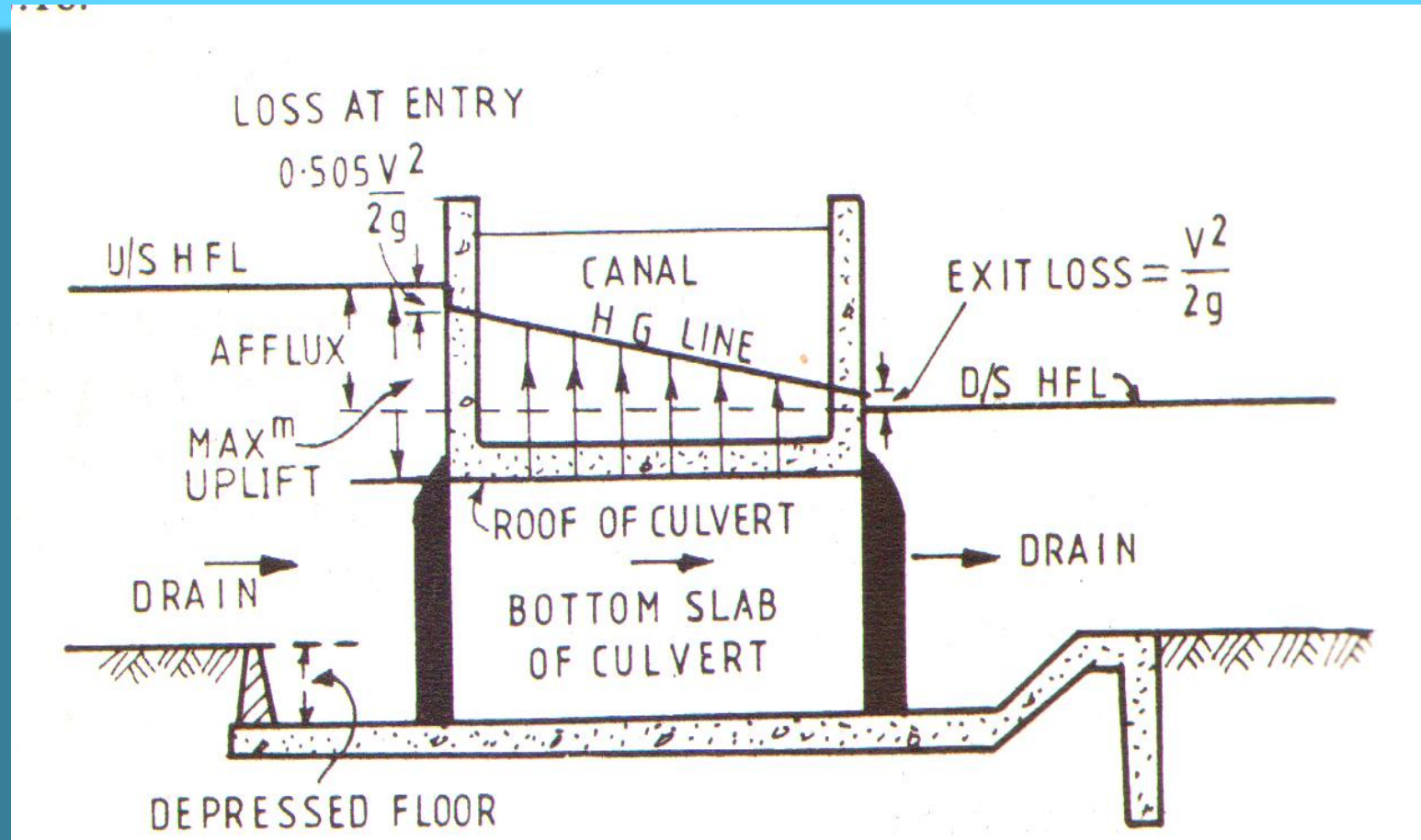
The uplift pressure exerted by the drain water on the roof of the culvert

Uplift Pressure on the Underside of the trough or the Barrel Roof

- The floor of the aqueduct or siphon is subjected to uplift due to two cases:

- **(a) Uplift due to Water-Table:** This force acts where the bottom floor is depressed below the drainage bed, especially in syphon aqueducts.

- The maximum uplift under the worst condition would occur when there is no water flowing in the drain and the watertable has risen up to the drainage bed. The maximum net uplift in such case would be equal to the difference in level between the drainage bed and the bottom of the floor.

Uplift Pressure on the Underside of the trough or the Barrel Roof

- **(b) Uplift Pressure due to Seepage of water from the canal to the drainage.**

- The maximum uplift due to this seepage occurs when the canal is running full and there is no water in the drain. The computation of this uplift due to this seepage occurs when the canal is running full and there is no water in the drain. The computation of this uplift, exerted by the water seeping from the canal on the bottom of the floor, is very complex and difficult, due to the fact that the flow takes place in three dimensional flow net. The flow cannot be approximated to a two dimensional flow, as there is no typical place across which the flow is practically two dimensional. Hence, for smaller works, Beligh's Creep theory may be used for assessing the seepage pressure, But for larger works, the uplift pressure must be checked by model studies.

Uplift Pressure on the Underside of the trough or the Barrel Roof
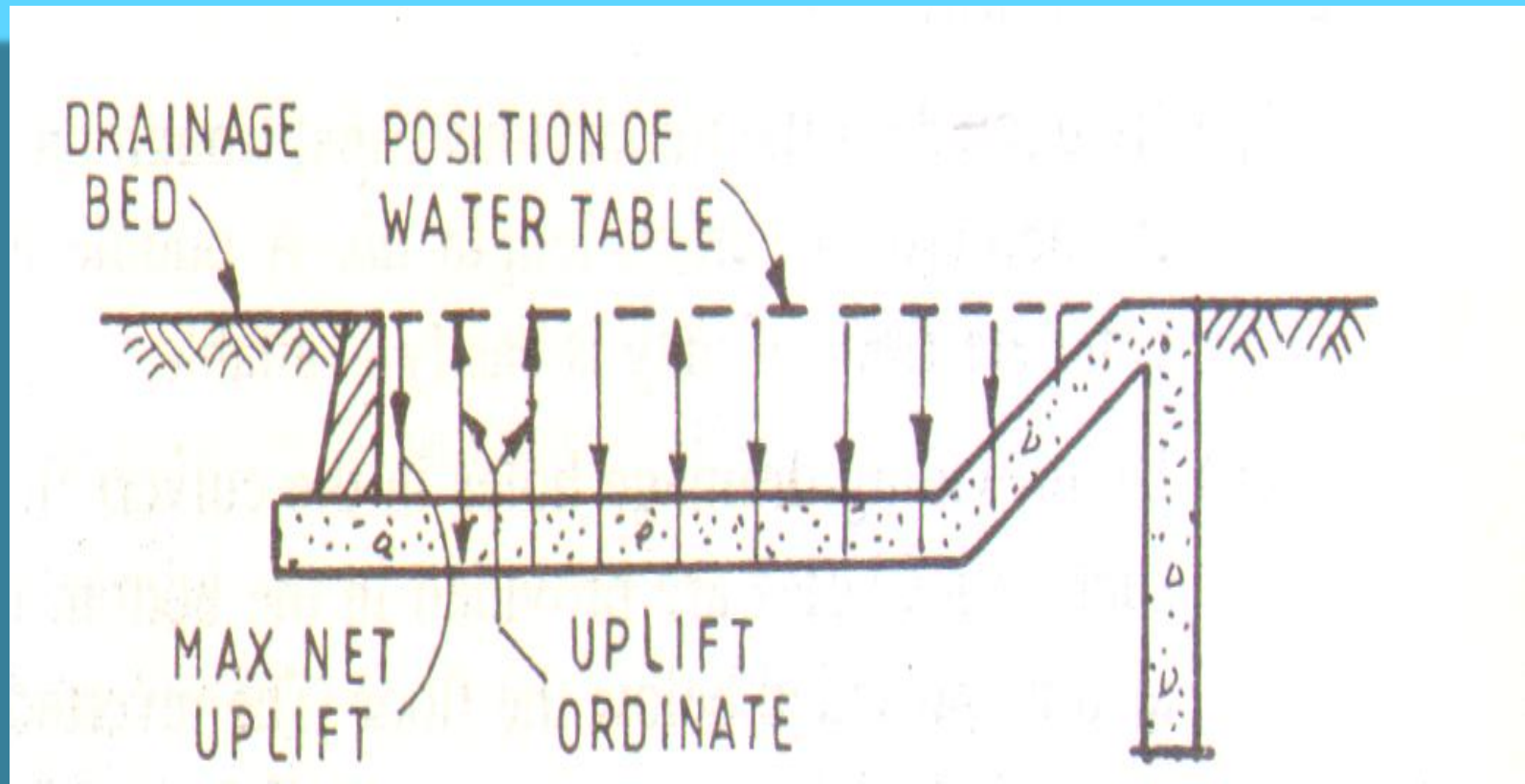
The floor of the aqueduct or siphon subjected to uplift