Hydraulic Structures (3-1-0) CR-04

7th Semester

Module- I

Water requirement of crops

For proper growth and maturity of the crops, water is of vital importance throughout the crop period. The water requirement may vary from crop to crop, from soil to soil and from period to period. Again, the total water requirement for a crop is not supplied at a time, but at a fixed interval so that the root zone of the crop may remain saturated throughout the crop period. Generally, the additional requirement is fulfilled by the irrigation system.

Factor affecting the water requirement

- Water Table
- Climate
- Ground Slope
- Intensity of Irrigation
- Type of Soil
- Method of Application of Water
- Method of Ploughing

Crop Season

The period during which some particular types of crops can be grown every year on the same land is known as crop season. The following are the main crop seasons.

a) Kharif Season
   This season ranges from June to October. The crops are sown in the very beginning of monsoon and harvested at the end of autumn.
   Ex- Rice, Maize

b) Rabi Season

this season ranges from October to March. The crops are sown in the very beginning of winter and harvested at the end of spring. Ex-Wheat, Gram etc.

Crop Period: The crop period is defined as the total period from the time of sowing a crop to the time of harvesting it. That means it is the period in which the crop remains in the field.

Base Period: When the base period is longer the water requirement will be more and the duty will be low and vice-versa. It defines that period from the first to the last watering of the crop just before its maturity.

Delta: Each crop requires certain amount of water per hectare for its maturity. If the total amount of water supplied to the crop is stored on the land without any loss, then there will be a thick layer of water standing on that land. This water layer depth is delta. Its unit is Cm.

Duty: The duty is defined as number of hectares that can be irrigated by constant supply of water at the rate of 1 cumec throughout the base period. Its unit is Hectare/cumec.

Consumptive Use of Water: It is defined as the total quantity of water used for the growth of the plants by transpiration and the amount lost by evaporation. It expressed in hectare-meter/hectare.

Frequency of Irrigation: The irrigation water is applied to the field to raise the moisture content of the soil up to its filed capacity. The application of water is then stopped. The water content also reduces gradually due to transpiration and evaporation. If the moisture content is dropped below the requisite amount, the growth of the plants gets disturbed. So the moisture content requires to be immediately replenished by irrigation and it should be raised to the field capacity.

Water logging: It is a form of natural flooding that occurs with over irrigation and water that rises from underground levels to the surface.

Causes:

- Inadequate drainage of the overland runoff increases the rate of percolation and in turn helps in raising the water table.
- The water from rivers may infiltrate into the soil.
- Seepage of water from earthen canals also adds significant quantity of water to the underground reservoir.
- Sometimes sub soil does not permit free flow of subsoil water which may accentuate the process of raising the water table.

Effects:

- Creation of anaerobic condition in the crop root zone.
- Growth of water loving wild plants.
- Impossibility of Tillage operations.
- Accumulation of Harmful salts.
- Lowering of soil temperature.
- Reduction in time of maturity.

Anti water-logging Measure:

- Lining of channels
- Provision of surface drain for drainage of rain water
- Implementation of Tube well projects both extensive and local.

Module-2

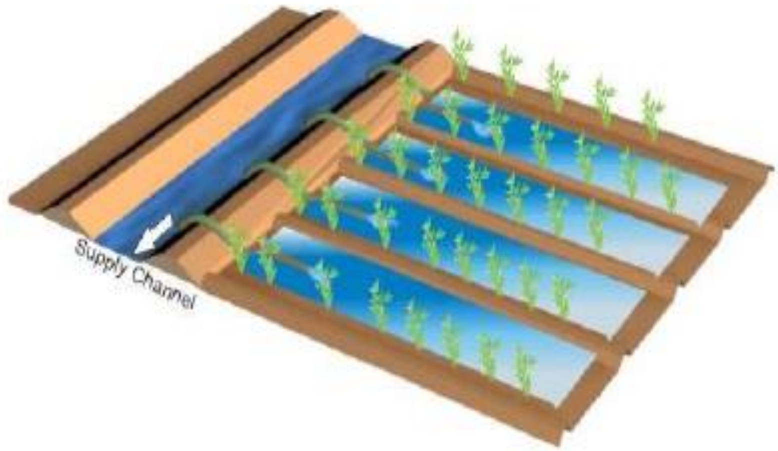
System of Irrigation:

Naturally it may be observed that a lot depends on the topography of the spreading to the low lying areas. The type of crop grown also immensely matter as some like rice, require standing water depths at almost all stages of its growth. An important parameter dictating the choice of the irrigation method is the type of soil. Sometimes water is applied not on the surface of the field but is used to moist the root zone of the plants from beneath the soil surface. Thus, in effective the type of irrigation methods can be broadly divided as under:

- **Surface irrigation method**

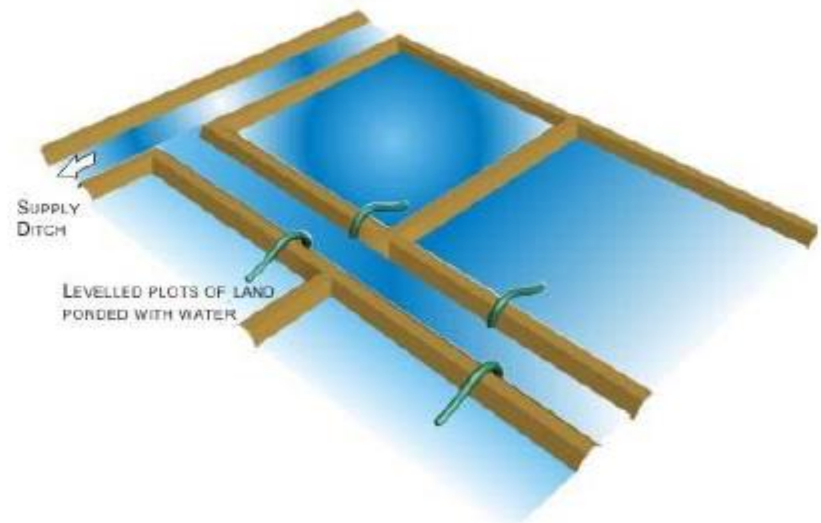
In this system of field water application the water is applied directly to the soil from a channel located at the upper reach of the field. It is essential in these methods to construct designed water distribution systems to provide adequate control of water to the fields and proper land preparation to permit uniform distribution of water over the field. One of the surface irrigation methods is flooding method where the water is allowed to cover the surface of land in a continuous sheet of water with the depth of applied water just sufficient to allow the field to absorb the right amount of water needed to raise the soil moisture up to field capacity,. A properly designed size of irrigation stream aims at proper balance against the intake rate of soil, the total depth of water to be stored in the root zone and the area to be covered giving a reasonably uniform saturation of soil over the entire field. ***Flooding method*** has been used in India for generations without any control what so ever and is called uncontrolled flooding. The water is made to enter the fields bordering rivers during folds. When the flood water inundates the flood plain areas, the water distribution is quite uneven, hence not very efficient, as a lot of water is likely to be wasted as well as soils of excessive slopes are prone to erosion. However the adaptation of this method doesn’t cost much. The flooding method applied in a controlled way is used in two types of irrigation methods as under:

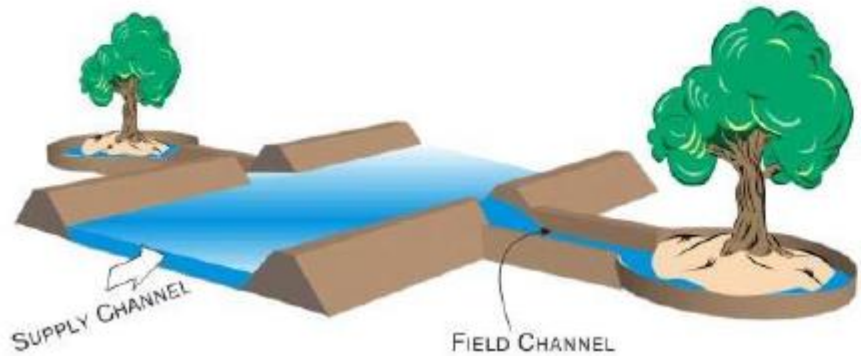
• ***Border irrigation method***



• ***Basin irrigation method***

As the names suggest the water applied to the fields by this inundates or floods the land, even if temporarily. On the other hand there are many crops which would try better if water is applied only near their root zone instead of inundating.



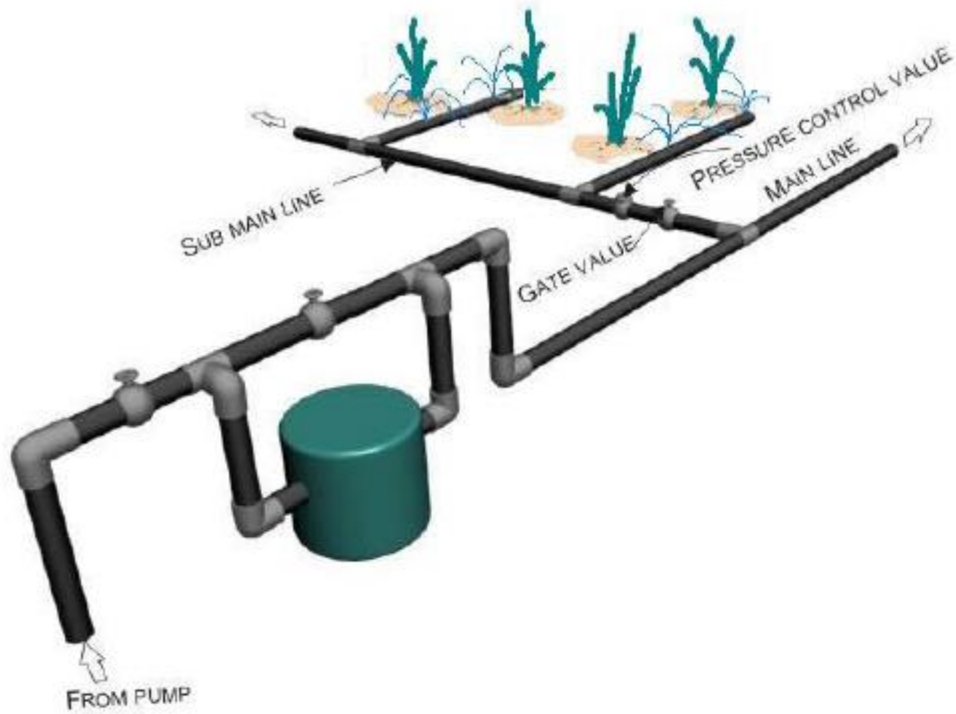


• **Subsurface irrigation method**

The application of water to fields in this type of irrigation system is below the ground surface so that it is supplied directly to the root zone of the plants. The main advantages of these types of irrigation is reduction of evaporation losses and less hindrance to cultivation works which takes place on the surface.

• **Sprinkler irrigation system**

Sprinkler irrigation is a method of applying water which is similar to natural rainfall but spread uniformly over the land surface just when needed and at a rate less than the infiltration rate of the soil so as to avoid surface runoff from irrigation. This is achieved by distributing water through a system of pipes usually by pumping which is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The system of irrigation is suitable for undulating lands, with poor water availability, sandy or shallow soils, or where uniform application of water is desired. No land leveling is required as with the surface irrigation methods. Sprinklers are, however, not suitable for soils which easily form a crust. The water that is pumped through the pump pipe sprinkler system must be free of suspended sediments. As otherwise there would be chances of blockage of the sprinkler nozzles



• Drip irrigation system

A typical drip irrigation system consists of the following components:

• Pump unit

• Control Head

• Main and sub main lines

• Laterals

• Emitters and drippers

Selection of Dam / barrage sites:

The canal head regulators (or head-works, as they are called) intending to divert water to a canal for irrigation has to be planned such that full command may be achieved by a barrage or weir of reasonable height. The combined cost of construction of head-works and that of the canal from the barrage up to the point where the water is first used for irrigation should be small.

• Sometimes, a favorable location for fixing the site for a barrage and canal head-works may have to be abandoned due to large quantities of rock excavation required.

•The river reach at the proposed location should be straight, as far as possible, so that velocities may be uniform and the sectional area of the river fairly constant. The banks should preferably be high, well defined and non-erodible. This will ensure a more or less straight flow to the barrage from the upstream. If such a site is available, it may need very small or practically no guide bunds. In case of high banks, the country side will not be submerged during high floods and a considerable saving in the cost of flood protection embankment may be effected.

•For barrages to be located in alluvial river reaches with meandering tendencies, the nodal points have to be ascertained. Nodal point is the portion of a meandering river which is more or less fixed in space. A nodal point may be decided by superimposing the survey maps or corresponding satellite imageries of the river for as many years as possible.

Canal Design:

The entire water conveyance system for irrigation, comprising of the main canal, branch canals, major and minor distributaries, field channels and water courses have to be properly designed. The design process comprises of finding out the longitudinal slope of the channels and fixing the cross sections. The channels themselves may be made up of different construction materials. For example, the main and branch canals may be lined and the smaller ones unlined. Even for the unlined canals, there could be some passing through soils which are erodible due to high water velocity, while some others may pass through stiff soils or rock, which may be relatively less prone to erosion. Further, the bank slopes of canals would be different for canals passing through loose or stiff soils or rock.

Design of Lined canals:

1. Select a suitable slope for the channel banks. These should be nearly equal to the angle of repose of the natural soil in the sub-grade so

that no pressure is exerted from behind on the lining. For example, for can passing through sandy soil, the slope may be kept as 2H: 1V where canals in firm clay may have bank slopes as 1.5H: 1V canals cut in rock may have almost vertical slopes, but slopes like 0.25 to 0.75H: 1V is preferred from practical considerations.

2. Decide on the freeboard, which is the depth allowance by which the banks are raised above the full supply level (FSL) of a canal.

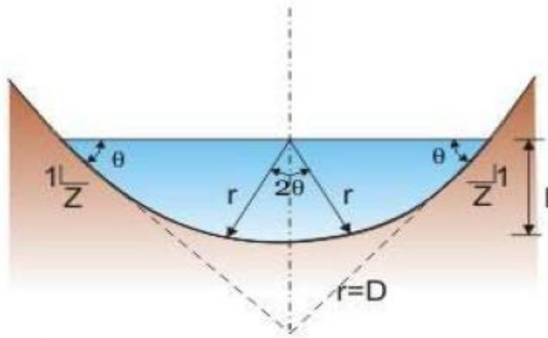


FIGURE 1 . Triangular channel section

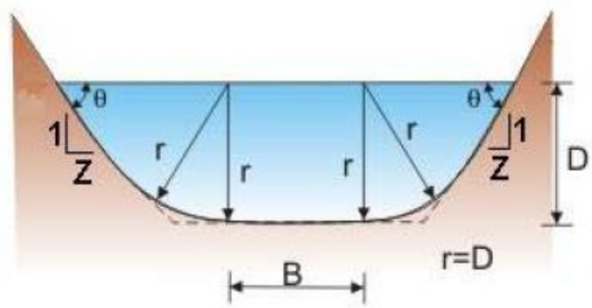


FIGURE 2. **Trapezoidal** channel section

3. Berms or horizontal strips of land provided at canal banks in deep cutting, have to be incorporated in the section.

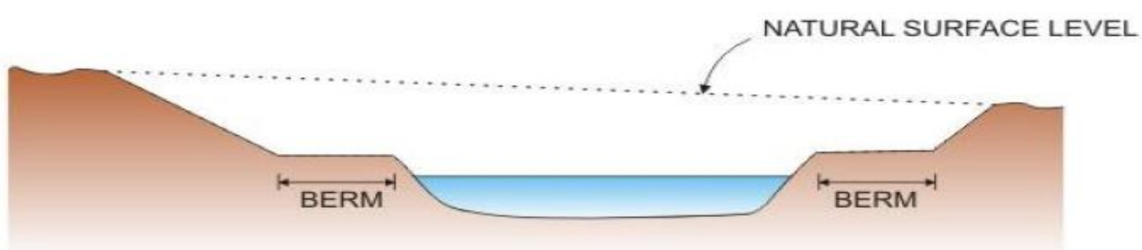


FIGURE 3. Berms for canal banks at deep cutting

The berms serve as a road for inspection vehicles and also help to absorb any soil or rock that may drop from the cut-face of soil or rock of the excavations. Berm width may be kept at least 2m. If vehicles are required to move, then a width of at least 5m may be provided.

4. For canal sections in filling, banks on either side have to be provided with sufficient top width for movement of men or vehicles.

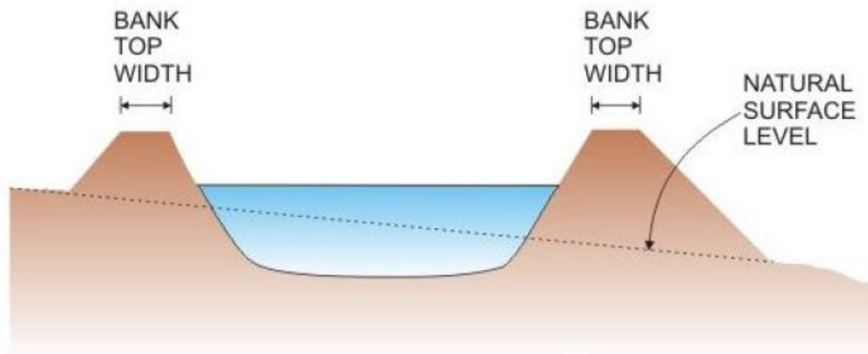


FIGURE 4. Canal section in filling

5. Assume a safe limiting velocity of flow, depending on the type of lining, as given below:
   • Cement concrete lining: 2.7 m/s
   • Brick tile lining or burnt tile lining: 1.8 m/s
   • Boulder lining: 1.5m/s
6. The longitudinal slope (S) of the canal may vary from reach to reach, depending upon the alignment. The slope of each reach has to be evaluated from the alignment of the canal drawn on the map of the region.
7. For the given discharge Q, permissible velocity V, longitudinal slope S, given side slope , and Manning' roughness coefficient, n, for the given canal section, find out the cross section parameters of the canal, that is bed width (B) and depth of flow (D).
   - Continuity equation: Q = A * V
   - Dynamic equation: V = $\frac{1}{n}(A\,R^{2/3}\,S^{1/2})$

Unlined Canal:

In 1895 Kennedy evolved an equation for V0, non-silting and non-scouring velocity and y depth of flow after studying dimensions of stable alluvial canals ranging over 30 sites in a strech of 144 km on upper Bari Doab Canal System in Punjab.

$$V_0 = 0.546y^{0.64} \quad (in\ mks)$$

Lindley's theory was further advanced by Lacey in 1929, but he adopted P, the wetted perimeter and R, the hydraulic mean radius, as the flow parameters instead of the surface width B, and the depth of flow, y, and in addition introduced a 'silt factor', f. Lacey's formulae in their final form is as follows,

$$P = 4.825\ Q^{1/2}\ \left(in\ mks\right)$$

$$R = 0.4725\ Q^{1/3} / f^{1/3}\ \text{(Same for both units)}$$

$$S = 0.0003015\, f^{5/3} / Q^{1/6}\ \left(in\ mks\right)$$

$$V = \frac{1}{N_a}\ R^{3/4}\ S_o^{1/2}\ \left(in\ mks\right)$$

$$N_a = 0.0225\, f^{1/4}\ \text{(Same for both units)}$$

Lacey's general flow equation is similar to that of Manning; but Na in Lacey's relation is an absolute rugosity coefficient which, in addition to boundary friction, allows for shock losses in the channel due to irregularities or bends. The silt factor f was correlated approximately to the silt grade m (in mm) by the relation, $f = 1.76\sqrt{m}$ on the implicit assumption of the 'regime charge' being carried by a channel in regime. Chitale analysed the data subsequently in 1966.

Cross Drainage Work: A cross drainage work is a structure carrying the discharge from a natural stream across a canal intercepting the stream. Canal comes across obstructions like rivers, natural drains and other canals. The various types of structures that are built to carry the canal water across the above mentioned obstructions or vice versa are called cross drainage works. It is generally a very costly item and should be avoided by diverting one stream into another. The changing the alignment of the canal so that it crosses below the junction of two streams.

Types of cross drainage works:

Depending upon levels and discharge, it may be of the following types, Cross drainage works carrying canal across the drainage the structures that fall under this type are:

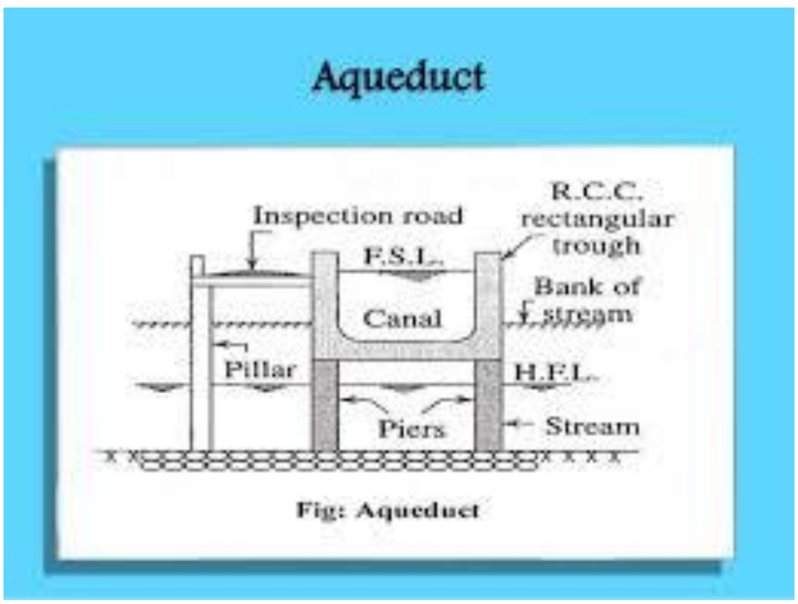
1. **An Aqueduct**

2. Siphon Aqueduct

Aqueduct:

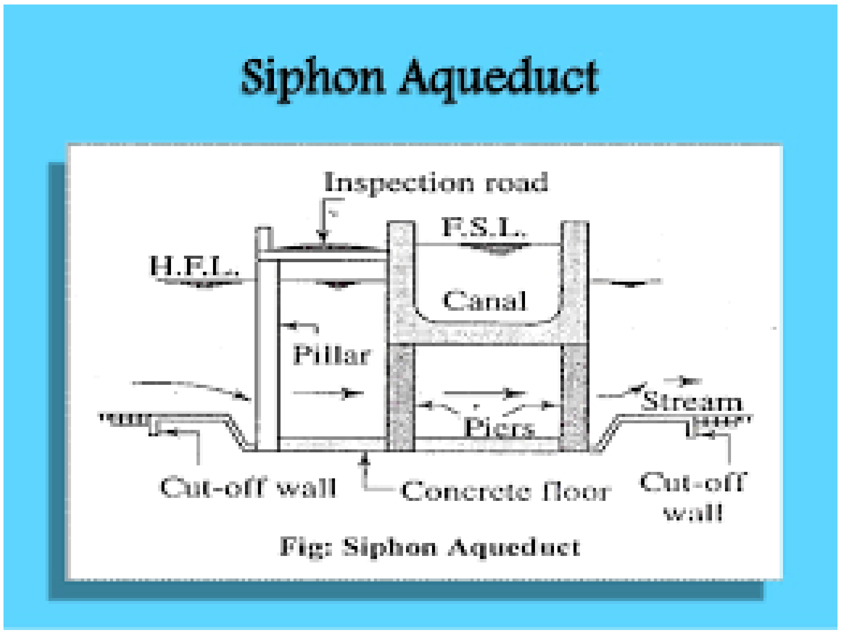
When the HFL of the drain is sufficiently below the bottom of the canal such that the drainage water flows freely under gravity, the structure is known as Aqueduct.

- In this, canal water is carried across the drainage in a trough supported on piers.
- Bridge carrying water
- Provided when sufficient level difference is available between the canal and natural and canal bed is sufficiently higher than HFL.



Siphon Aqueduct:

In case of the siphon Aqueduct, the HFL of the drain is much higher above the canal bed, and water runs under siphonic action through the Aqueduct barrels. The drain bed is generally depressed and provided with pucca floors, on the upstream side, the drainage bed may be joined to the pucca floor either by a vertical drop or by glacis of 3:1. The downstream rising slope should not be steeper than 5:1. When the canal is passed over the drain, the canal remains open for inspection throughout and the damage caused by flood is rare. However during heavy floods, the foundations are susceptible to scour or the waterway of drain may get choked due to debris, tress etc.



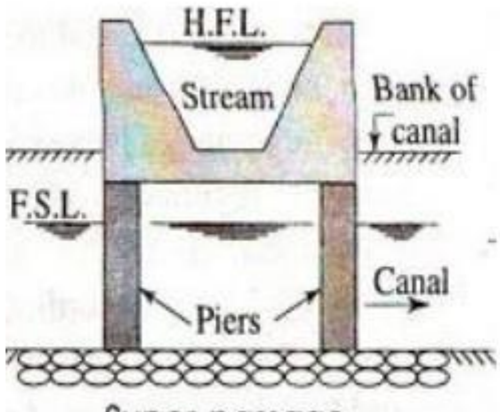
Cross drainage works carrying drainage over canal.

The structures that fall under this type are:

1. **Super passage**
2. **Canal siphon or siphon**

Super passage: The hydraulic structure in which the drainage is passing over the irrigation canal is known as super passage. This structure is suitable when the bed level of drainage is above the flood surface level of the canal. The water of the canal passes clearly below the drainage

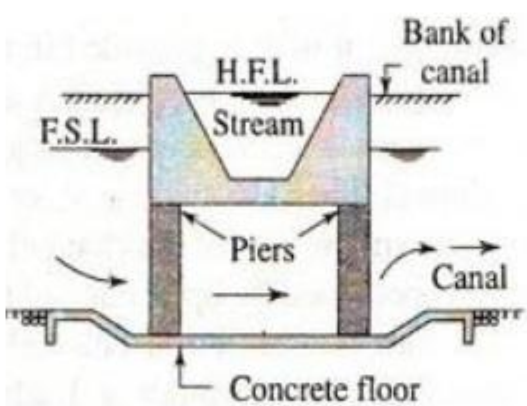
1. A super passage is similar to an aqueduct, except in this case the drain is over the canal.
2. The FSL of the canal is lower than the underside of the trough carrying drainage water. Thus, the canal water runs under the gravity.
3. Reverse of an aqueduct.



Super passage

Canal Syphon:

- If two canals cross each other and one of the canals is siphoned under the other, then the hydraulic structure at crossing is called “canal siphon”. For example, lower Jhelum canal is siphoned under the Rasul-Qadirabad (Punjab, Pakistan) link canal and the crossing structure is called “L.J.C siphon”
- In case of siphon the FSL of the canal is much above the bed level of the drainage trough, so that the canal runs under the siphonic action.
- The canal bed is lowered and a ramp is provided at the exit so that the trouble of silting is minimized.
- Reverse of an aqueduct siphon
- In the above two types, the inspection road cannot be provided along the canal and a separate bridge is required for roadway.



Siphon super passage

Module-3

In order to harness the water potential of a river optimally, it is necessary to construct two types of hydraulic structures

1. **Storage structure**: Usually a dam, which acts like a reservoir for storing excess runoff of a river during periods of high flows (as during the monsoons) and releasing it according to a regulated schedule.
2. **Diversion structure**: It may be a weir or a barrage that raises the water level of the river slightly, not for creating storage, but for allowing the water to get diverted through a canal situated at one or either of its banks. Since a diversion structure does not have enough storage, it is called a run-of-the river scheme. The diverted water passed through the canal may be used for irrigation, industry domestic water needs or power generation.

Weir: A low dam built across a river to raise the level of water upstream or regulate its flow.

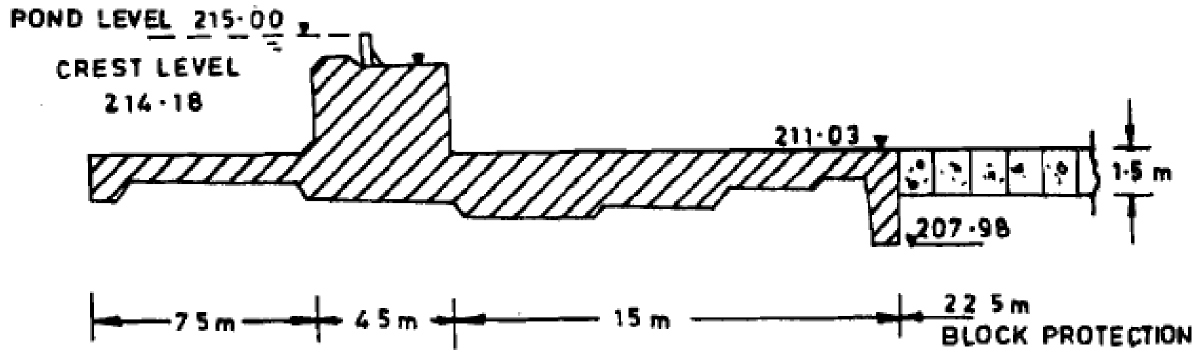
Barrage: An artificial barrier across a river or estuary to prevent flooding, aid irrigation or navigation, or to generate electricity by trial power.

Weir	Barrage
Low cost	High cost
Low control on flow	Relatively high control on flow and water levels by operation of gates
No provision for transport communication across the river	Usually, a road or a rail bridge can be conveniently and economically combined with a barrage wherever necessary
Chances of silting on the upstream is more	Silting may be controlled by judicial operation of gates
Afflux created is high due to relatively high weir crests	Due to low crest of the weirs (the ponding being done mostly by gate operation), the afflux during high floods is low. Since the gates may be lifted up fully, even above the high flood level.

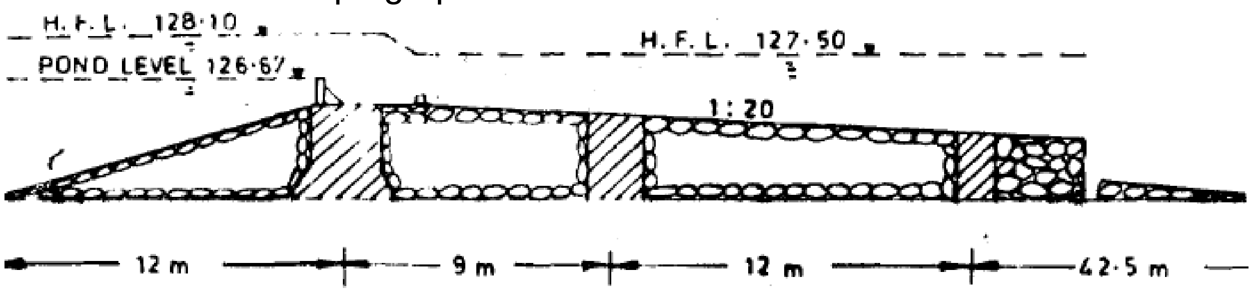
Classification of Weir:

There are mainly 3 types,

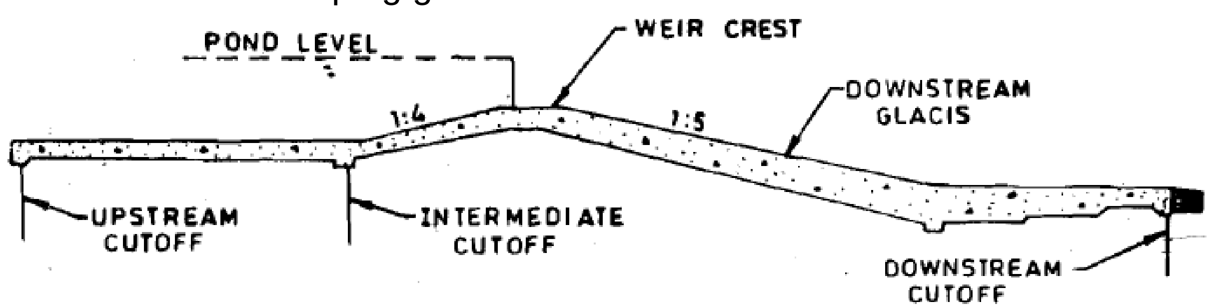
- Masonary wier with vertical drop



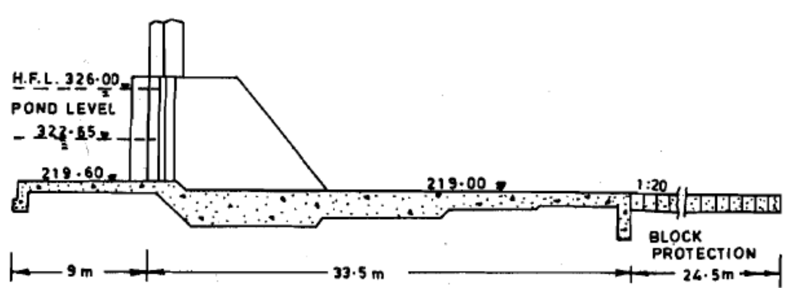
- Rockfill wier with sloping apron



- Concrete weir with sloping glacis downstream

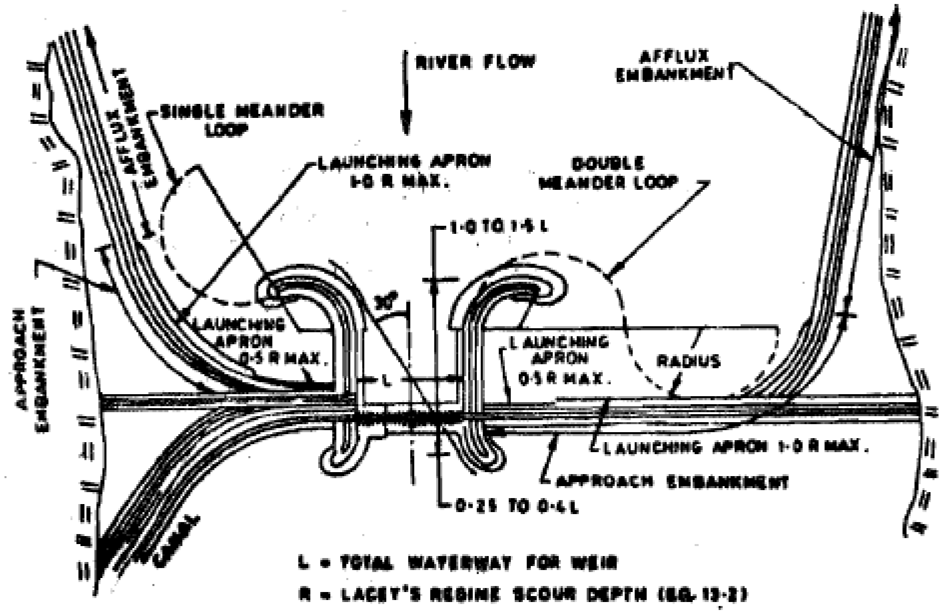


Barrage: (c/s of a barriage)



Components of Weir:

1. Weir /barrage divided into number of bays
2. Under sluices
3. Divide wall/groyne
4. Fish ladder
5. Canal head regulator
6. River training works



(Layout of canal head regulator with river training work)

<u>1.Spillway bays</u>:

This is the main body of the barrage for controlling the discharges and to raise the water level to the desired value to feed the canals. It is a reinforced concrete structure designed as a raft foundation supporting the weight of the gates, piers and the bridge above to prevent sinking into the sandy river bed foundation.

<u>2.Undersluice :</u> These low crested bays may be provided on only one flank or on both flanks of the river depending upon whether canals are taking-off from one or both sides. The width of theundersluice portion is determined on the basis of the following considerations.

•It should be capable of passing at least double the canal discharge to ensure good scouring capacity

•It should be capable of passing about 10 to 20 percent of the maximum flood discharge at high floods

•It should be wide enough to keep the approach velocities sufficiently lower than critical velocities to ensure maximum settling of suspended silt load.

3.Divide wall:

The divide wall is much like a pier and is provided between the sets of undersluice or river sluice or spill bays. The main functions of a divide wall:

• It separates the turbulent flood waters from the pocket in front of the canal head.

• It helps in checking parallel flow (to the axis of the barrage) which would be caused by the formation of deep channels leading from the river to the pocket in front of the sluices.

4.Fish pass/ladder:

Some barrages require providing special structures to allow migratory fishes to flow up and down the river through structures called Fish Passes or Fish Locks.

5.Canal Head Regulator:

The water that enters a canal is regulated through a Head Regulator. A typical cross section through a regulator is shown in Figure 9. As it is desirable to exclude silt as much as possible from the head regulator, the axis of the head regulator is laid out at 900-1100 an angle from to the barrage axis as recommended in Bureau of Indian Standards code IS : 6531(1972).

6.River training works :

The river training works for barrages are required to achieve the following;

1. Prevent out flanking of the structure

2. Minimize cross flows through the barrage

3. Prevent flooding by the river lands upstream

4. Provide favorable curvature of flow at the head regulator from the point of sediment entry into the canal, and

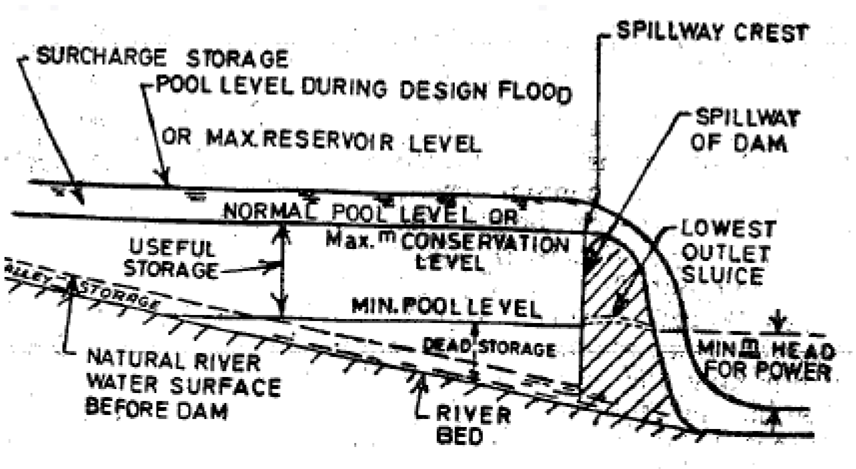
5. Guide the river to flow axially through the barrage or weir

Dams and Reservoirs:

The barrier constructed across a river in the form of dam, so that water gets stored in it on the upstream side of the barrier,forming a pool of water is called reservoir.

Depending upon purpose there are 3 types of reservoirs mainly found

- **Storage/ conservation type**
- **Flood control type**
- **Multipurpose type**



(Storage zone of a reservoir)

Dams constructed out of masonry or concrete and which rely solely on its self weight for stability fall under the nomenclature of gravity dams. Masonry dams have been in use in the past quite often but after independence, the last major masonry dam structure that was built was the Nagarjunsagar Dam on river Krishna which was built during 1958-69. Normally, coursed rubble masonry was used which was bonded together by lime concrete or cement concrete.

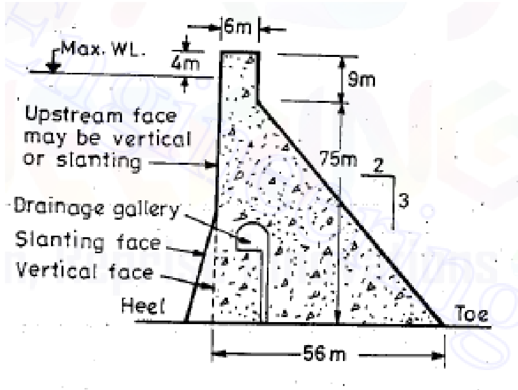


Fig. 19.1. A typical cross-section of a concrete gravity dam.

Forces acting on Gravity Dam:

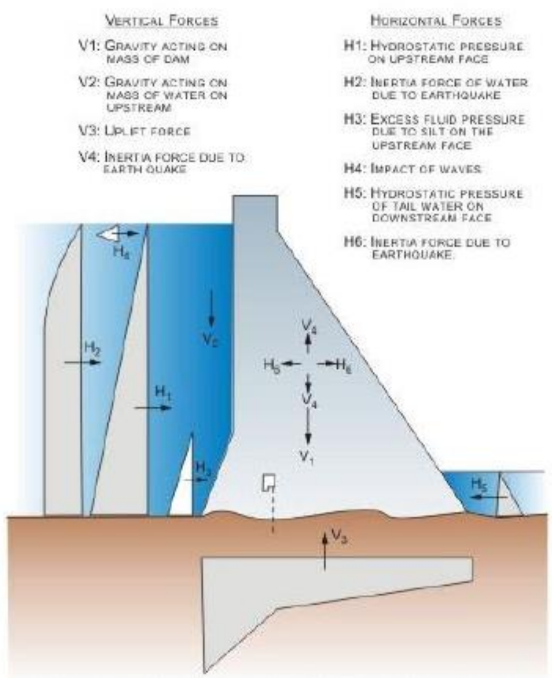
- Water pressure
- Uplift Pressure
- Silt pressure
- Earthquake pressure
- Wave pressure
- Ice pressure
- Stability of dam due to weight

The forces to be resisted by a gravity dam fall into two categories as given below:

1. Forces, such as weight of the dam and water pressure which are directly calculated from the unit weight of materials and properties of fluid pressure and
2. Forces such as uplift, earthquake loads , silt pressure and ice pressure which are assumed only on the basis of assumptions of varying degree of reliability. In fact to evaluate this category of forces, special care has to be taken and reliance placed on available data, experience and judgment.

The forces that give **stability** to the dam include:

1. Weight of the dam
2. Thrust of the tail water



(Forces acting on dam)

Stability Analysis of Gravity Dam:

The stability analysis of gravity dams may be carried out by various methods, of which the gravity method is described here. In this method, the dam is considered to be made up of a number of vertical cantilevers which act independently for each other. The resultant of all horizontal and vertical forces including uplift should be balanced by an equal and opposite reaction at the foundation consisting of the total vertical reaction and the total horizontal shear and friction at the base and the resisting shear and friction of the passive wedge, if any. For the dam to be in static equilibrium, the location of this force is such that the summation of moments is equal to zero. The distribution of the vertical reaction is assumed as trapezoidal for convenience only. Otherwise, the problem of determining the actual stress distribution at the base of a dam is complicated by the horizontal reaction, internal stress relations, and other theoretical considerations. Moreover, variation of foundation materials with depth, cracks and fissures which affect. stresses and foundation pressures should be computed both with and without uplift to determine the worst condition.

The stability analysis of a dam section is carried out to check the safety with regard to

1**. Rotation and overturning**

2. Translation and sliding

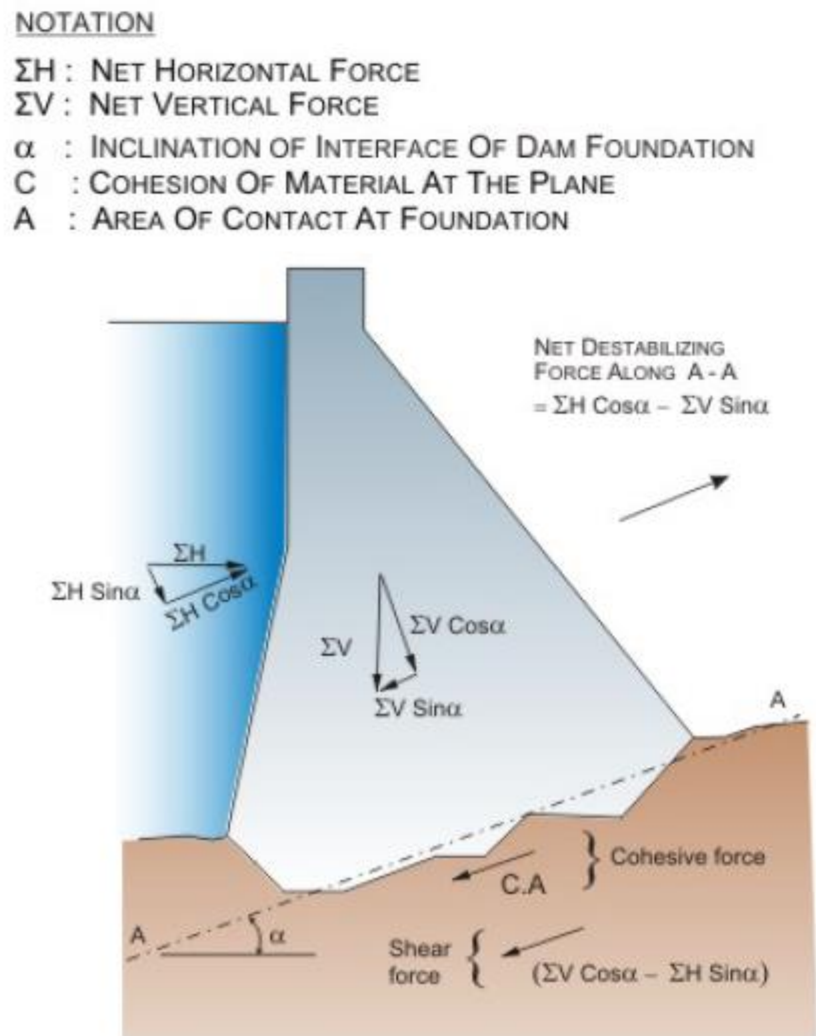
3. Overstress and material failure

Stability against overturning

Before a gravity dam can overturn physically, there may be other types of failures, such as cracking of the upstream material due to tension, increase in uplift, crushing of the toe material and sliding. However, the check against overturning is made to be sure that the total stabilizing moments weigh out the de-stabilizing moments. The factor of safety against overturning may be taken as 1.5. As such, a gravity dam is considered safe also from the point of view of overturning if there is no tension on the upstream face.

Stability against sliding

Many of the loads on the dam act horizontally, like water pressure, horizontal earthquake forces, etc. These forces have to be resisted by frictional or shearing forces along horizontal or nearly-horizontal seams in foundation. The stability of a dam against sliding is evaluated by comparing the minimum total available resistance along the critical path of sliding (that is, along that plane or combination of plans which mobilizes the least resistance to sliding) to the total magnitude of the forces tending to induce sliding.



(Stability against sliding on good rock)

Failure against overstressing:

A dam may fail if any of its part is overstressed and hence the stresses in any part of the dam must not exceed the allowable working stress of concrete. In order to ensure the safety of a concrete gravity dam against this sort of failure, the strength of concrete shall be such that it is more than the stresses anticipated in the structure by a safe margin. The maximum compressive stresses occur at heel (mostly during reservoir empty condition) or at toe (at reservoir full condition) and on planes normal to the face of the dam. The strength of concrete and masonry varies with age, the kind of cement and other ingredients and their proportions in the work can be determined only by experiment.

Earth Dams:

Earthen dams are still cheaper as they utilize the locally available materials and les skilled labor is required for them, as they build with the natural materials with a minimum processing and primitive equipments.

Types of Earthen Dams:

- **Homogeneous embankment type**
- **Zoned embankment type**
- **Diaphragm type**

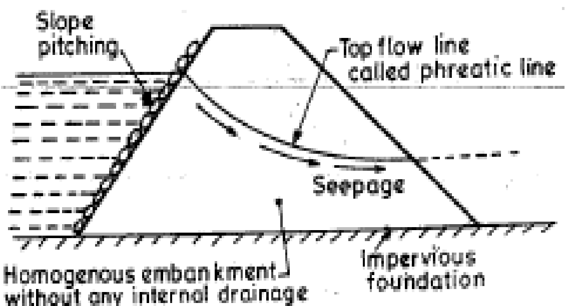


Fig. 20.1 (*a*). Homogeneous type embankment.

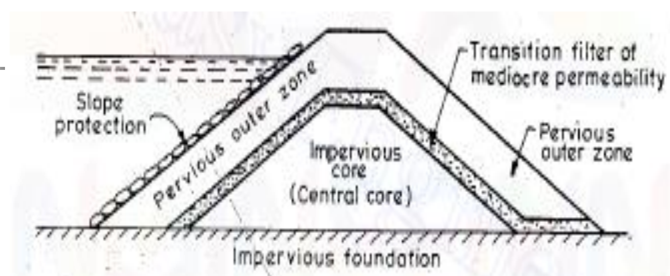


Fig. 20.2. Zoned type embankment.

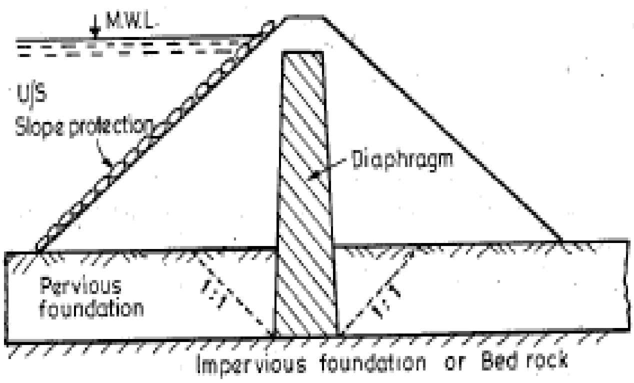


Fig. 20.3. Diaphragm type embankment.

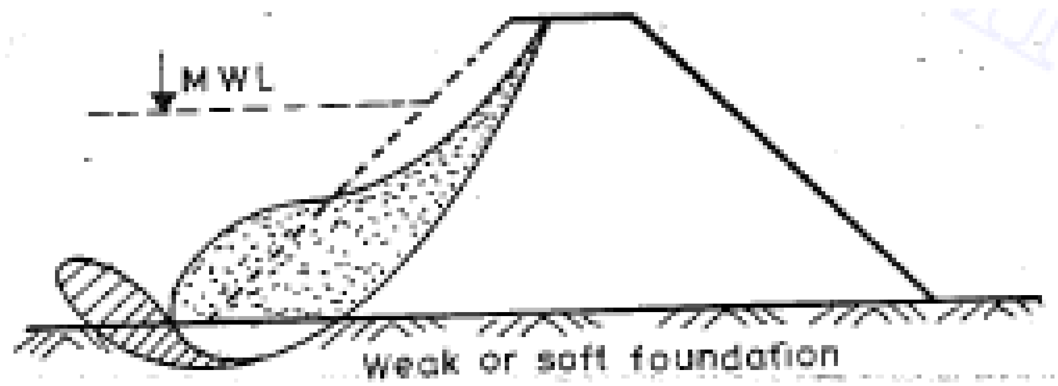
Causes of Failure of Earthen Dams:

Earth dams are less rigid and hence more susceptible to failure.

1. **Hydraulic Failures**
    - By over topping
    - Erosion of upstream face
    - Cracking due to frost action
    - Erosion of downstream face by gully formation

- Erosion of the downstream toe.

2. **Seepage Failures**
   - Piping through foundations
   - Piping through the dam body
   - Sloughing of downstream toe
3. **Structural Failures**
   - Foundation slide



- Slide in embankment:

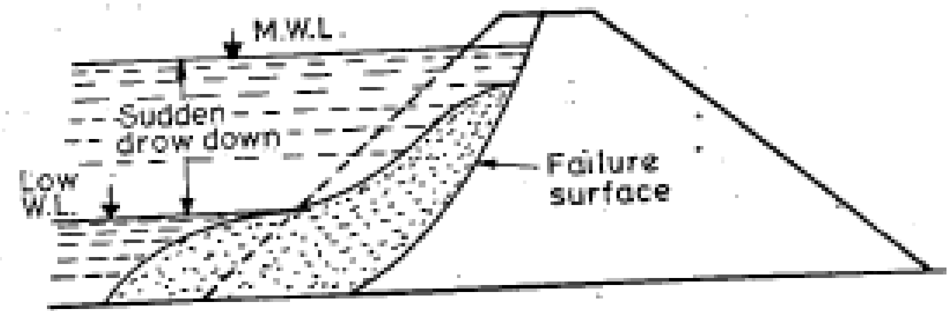


Fig. 20.9. U/S slope slide due to sudden draw-down.

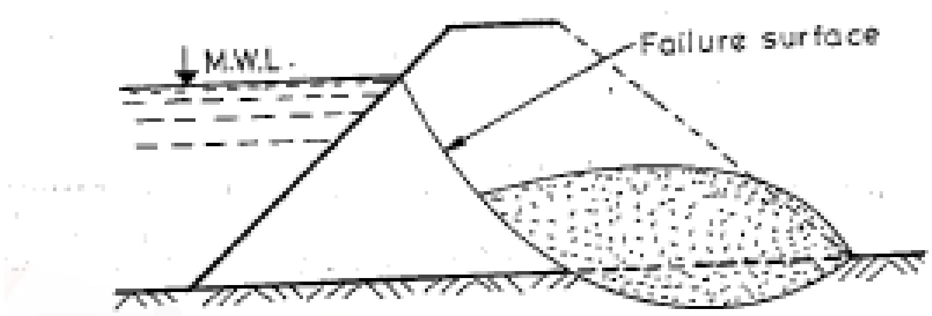


Fig. 20.10. D/S. slope slide during full reservoir condition.

Module – IV:

Spillways: Types Of spillways, Spillway gates, Types of Hydraulic Jump, Energy Dissipaters, River training works.

Spillways:

A *spillway* is a passage constructed either within a dam or in the periphery of the reservoir to safely pass the excess of the flood water during flood flows effectively from upstream to downstream. Depending upon the inflow rate, water will start rising above the normal pool level, at same water release by the spillways also. If water level increases over the maximum flood level, it ultimately overtopped the dam by causing failure of dam. So, spillway is an essential for safety concern.

The surface of the spillway should also be such that it is able to withstand erosion or scouring due to the very high velocities generated during the passage of a flood through the spillway. At the bottom of the channel, where the water rushes out to meet the natural river, is usually provided with an *energy dissipation device* that kills most of the energy of the flowing water. These devices, commonly called as *Energy Dissipators*, are required to prevent the river surface from getting dangerously scoured by the impact of the out falling water.

Usually, spillways are provided with gates, which provide a better control on the discharges passing through. The capacity of a spillway is usually worked out on the basis of a flood routing study and depends on following major factors,

- The inflow flood
- The volume of storage provided by the reservoir
- Crest height of the spillway
- Gated or ungated

Types of spillways:

1. Free Overfall (Straight Drop) Spillway

2. Overflow (Ogee) Spillway

3. Chute (Open Channel/Trough) Spillway

4. Side Channel Spillway

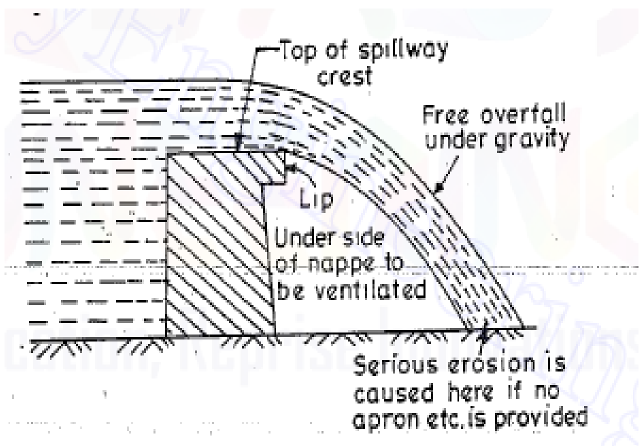
5. Shaft (Drop Inlet/Morning Glory) spillway

6. Tunnel (Conduit) spillway

7. Siphon spillway

1-<u>Free Overfall / Straight drop Spillway</u>:

In this type of spillway, the water freely drops down from the crest, as for an arch dam (Figure 1) also for a decked over flow dam with a vertical or adverse inclined downstream face (Figure 2). Flows may be free discharging, as will be the case with a sharp-crested weir or they may be supported along a narrow section of the crest. Water freely falls from crest under *the action of gravity*. Since vacuum is created in the under-side portion of the falling jet, sufficient ventilation of nappe is required in order to avoid *pulsating and fluctuating effects of the jet*.



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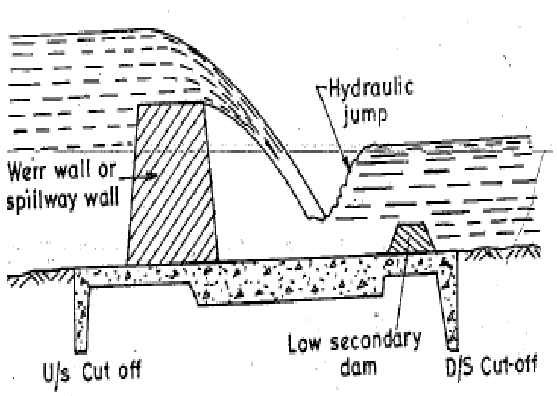

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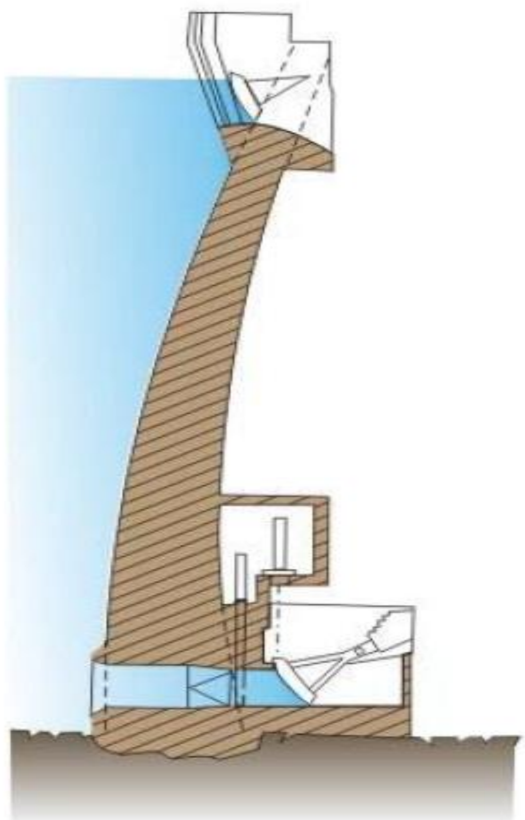
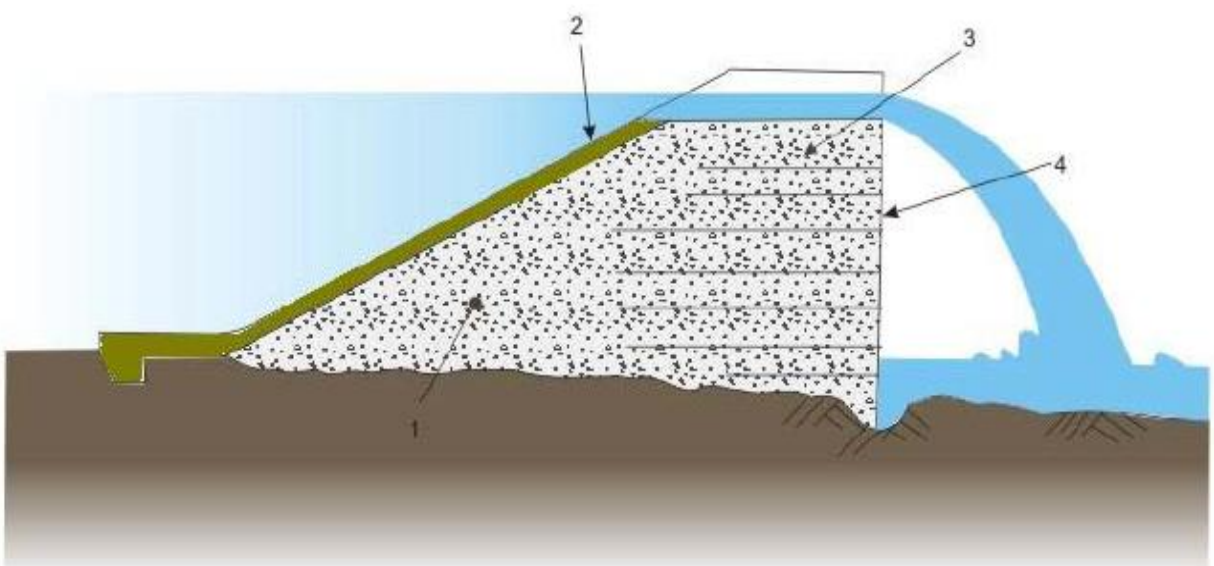


FIGURE 1. Free over fall spillway for an arch dam



LEGEND

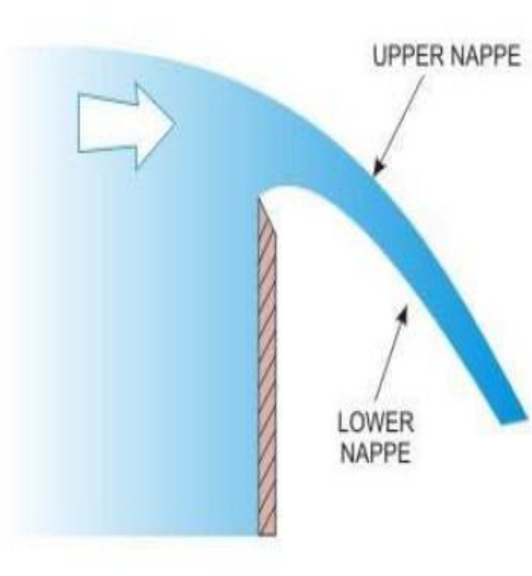
1. RANDOM FILL 2. WATERTIGHT MEMBRANE 3. STEEL TENDONS 4. CONCRETE SLABS (1.5 M X 1.5 M).

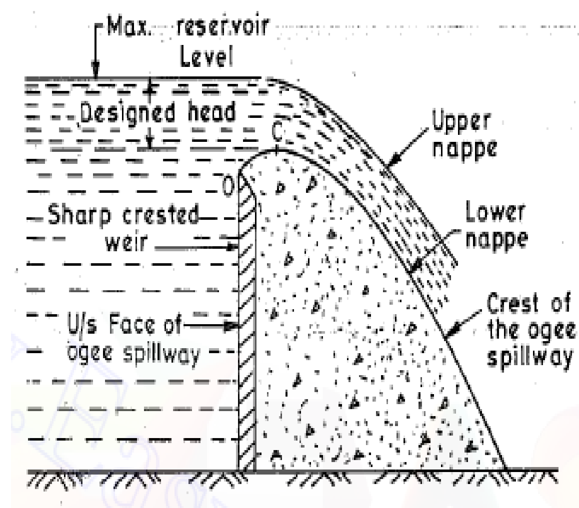
FIGURE 2. Free over fall spillway for a decked embankment dam

2- Overflow (Ogee) Spillway:

This type of spillway is the most common type adopted in the field. It divides naturally into three zones i.e. Crest, spillway face and the toe. The concept evolves from replacing the lower nappy of the flow over thin plate weir by solid boundary. The overflow type spillway has a crest shaped in the form of *an ogee or S-shape*. The upper curve of the ogee is made to conform closely to the profile of the lower nappy of a ventilated sheet of water falling from a sharp crested weir (figure 3). Flow over the crest of an overflow spillway is made to adhere to the face of the profile by preventing access of air to the underside of the sheet of flowing water.

Naturally, the shape of the overflow spillway is designed according to the shape of the lower nappe of a free flowing weir conveying the discharge flood any discharge higher than the design flood passing through the overflow spillway would try to shoot forward and get detached from the spillway surface, which reduces the efficiency of the spillway due to the presence of negative pressure between the sheet of water and spillway surface. For discharges at designed head, the spillway attains near-maximum efficiency.



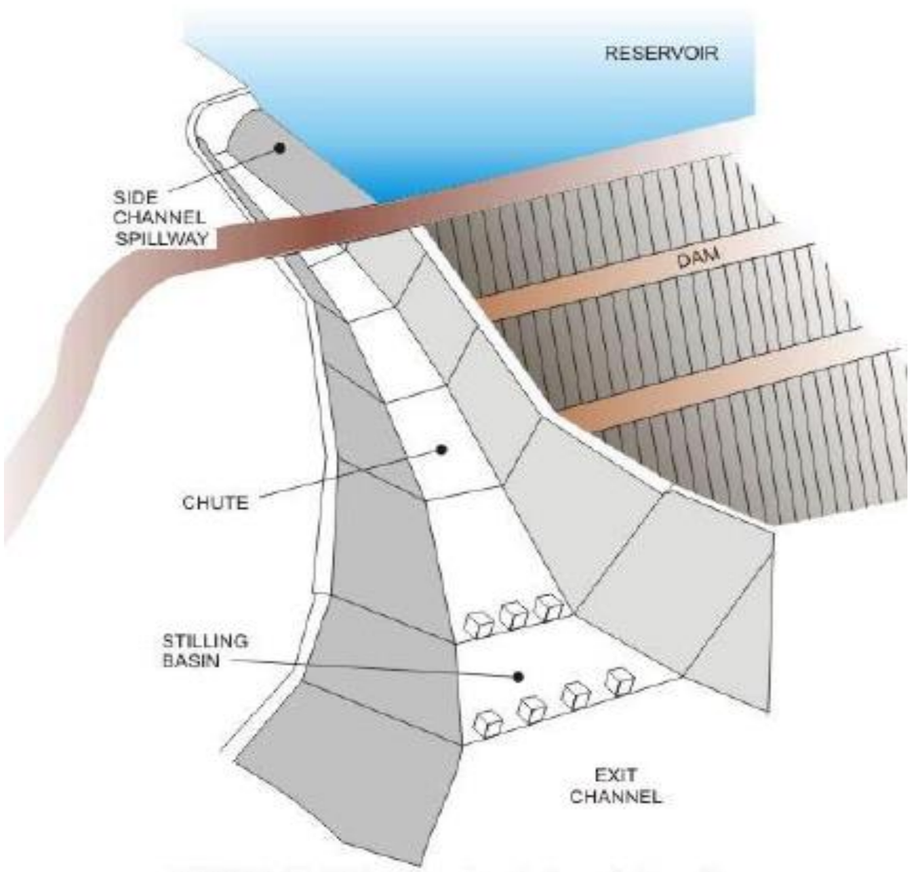


(Fig-3 Outflow from a freely falling weir, properly ventilated from below)

(Fig -4 Section of an Ogee spillway with vertical u/s face)

3. Chute (Open Channel/Trough) Spillway:

A chute spillway, variously called as open channel or trough spillway, is one whose discharge is conveyed from the reservoir to the downstream river level through an open channel, placed either along a dam abutment or through a saddle. The control structure for the chute spillway need not necessarily be an overflow crest, and may be of the side-channel type, as has been shown in Figure 5. Generally, the chute spillway has been mostly used in conjunction with embankment dams, like the Tehri dam. Chute spillways are simple to design and construct and have been constructed successfully on all types of foundation materials, ranging from solid rock to soft clay. Chute spillways ordinarily consist of an entrance channel, a control structure, a discharge channel, a terminal structure, and an outlet channel.

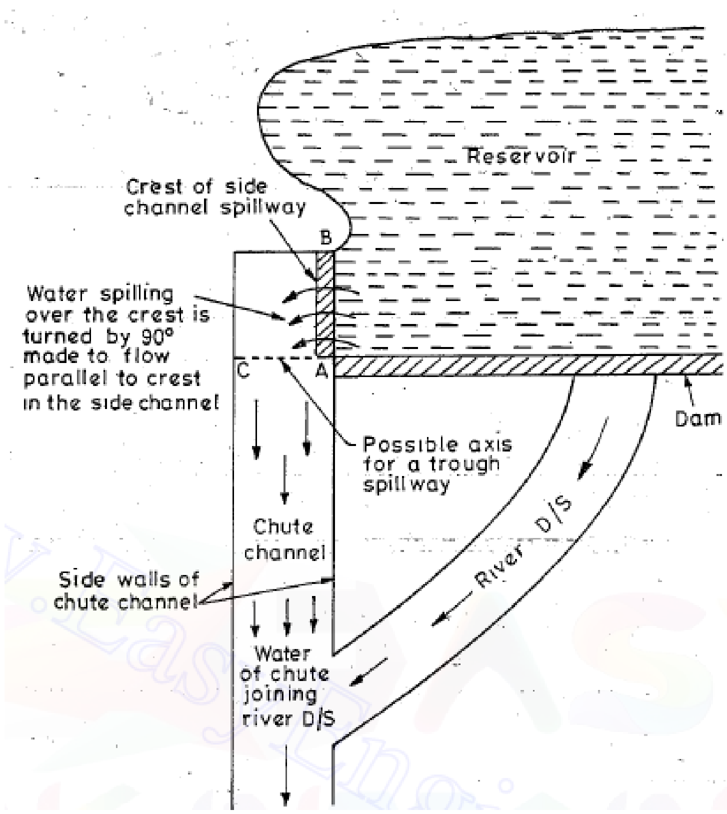


(Fig-5 side channel entry to a Chute spillway)

4. Side Channel Spillway:

A side channel spillway is one in which the control weir is placed approximately parallel to the upper portion of the discharge channel, as may be seen in fig 6. The flow over the crest falls into a narrow trough opposite to the weir, turns an approximate right angle, and then continues into the main discharge channel. The side channel design is concerned only with the hydraulic action in the upstream reach of the discharge channel and is more or less independent of the details selected for the other spillway components.

Discharge characteristics of a side channel spillway are similar to those of an ordinary overflow spillway and are dependent on the selected profile of the weir crest. Although the side channel is not hydraulically efficient, nor inexpensive, it has advantages which make it adoptable to spillways where a long overflow crest is required in order to limit the afflux (surcharge held to cause flow) and the abutments are steep and precipitous.

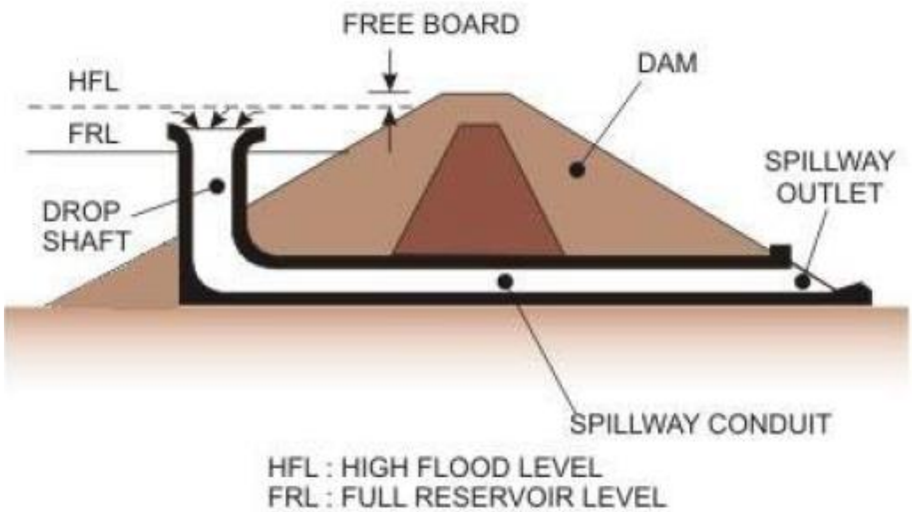


(Fig-6 sketch of a side-channel spillway)

5. Shaft (Drop Inlet/Morning Glory) spillway:

A Shaft Spillway is one where water enters over a horizontally positioned lip, drops through a vertical or sloping shaft, and then flows to the downstream river channel through a horizontal or nearly horizontal conduit or tunnel. A drop inlet spillway can be used advantageously at dam sites that are located in narrow gorges where the abutments rise steeply.

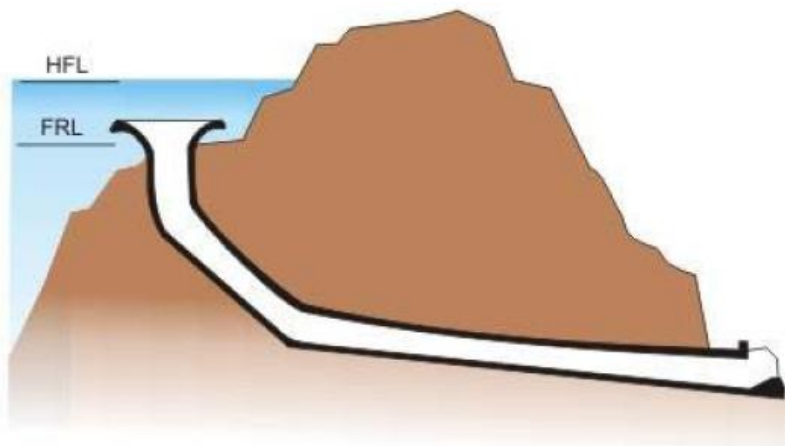
Discharge characteristics of the drop inlet spillway may vary with the range of head. The head increases, the flow pattern would change from the initial weir flow over crest to tube flow and then finally to pipe flow in the tunnel. This type of spillway attains maximum discharging capacity at relatively low heads. However, there is little increase in capacity beyond the designed head, should a flood larger than the selected inflow design flood occur.



(Fig-7 Section through a shaft spillway)

6. Tunnel (Conduit) spillway:

Where a closed channel is used to convey the discharge around a dam through the adjoining hill sides, the spillway is often called a tunnel or conduit spillway. The closed channel may take the form of a vertical or inclined shaft, a horizontal tunnel through earth or rock, or a conduit constructed in open cut and backfilled with earth materials. Most forms of control structures, including overflow crests, vertical or inclined orifice entrances, drop inlet entrances, and side channel crests, can be used with tunnel spillways. Tunnel spillways are advantageous for dam sites in narrow gorges with steep abutments or at sites where there is danger to open channels from rock slides from the hills adjoining the reservoir. Conduit spillways are generally most suited to dams in wide valleys as in such cases the use of this types of spillway would enable the spillway to be located under the dam very close to the stream bed.

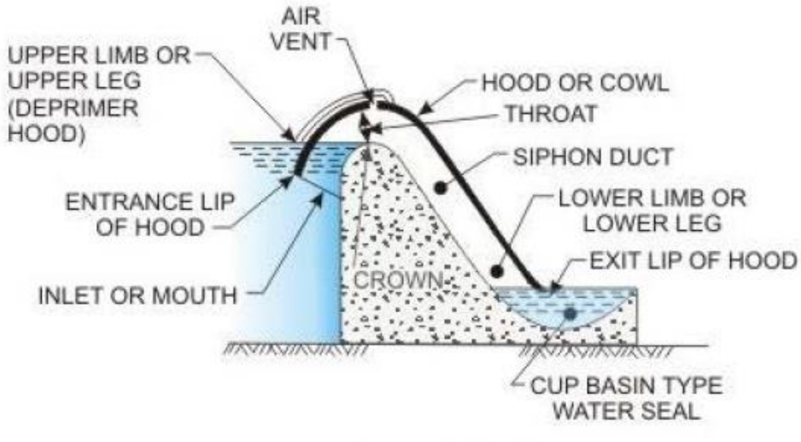


(Fig-8 Tunnel spillway with a morning glory entrance)

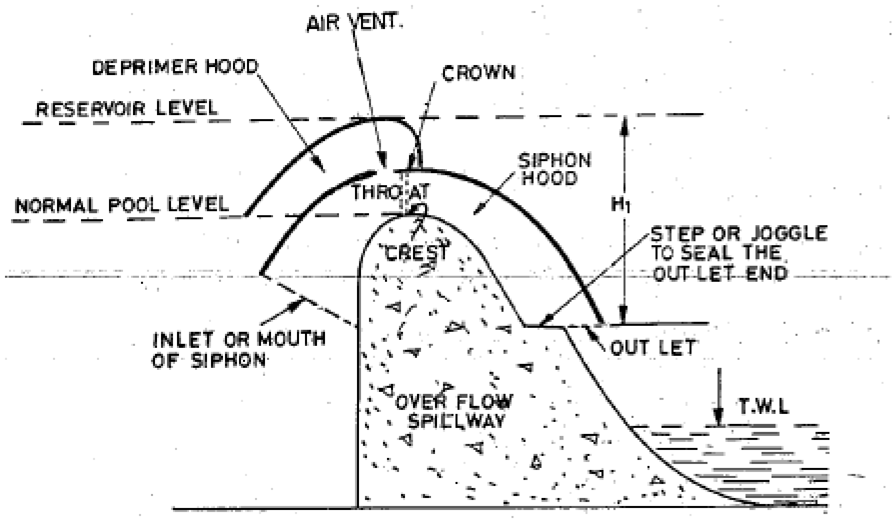
7. Siphon spillway:

A siphon spillway is a closed conduit system formed in the shape of an inverted U, positioned so that the inside of the bend of the upper passageway is at normal reservoir storage level. This type of siphon is also called a Saddle siphon spillway. The initial discharges of the spillway, as the reservoir level rises above normal, are similar to flow over a weir. Siphonic action takes place after the air in the bend over the crest has been exhausted. Continuous flow is maintained by the suction effect due to the gravity pull of the water in the lower leg of the siphon.

Siphon spillways comprise usually of five components, which include an inlet, an upper leg, a throat or control section, a lower leg and an outlet. Another type is hooded type of siphone spillway in which reinforced concrete hood is constructed over an ordinary overflow section of a gravity dam. The inlet of this hood is kept submerged so as to prevent entry of debris and ice. A small depriving hood is kept above the main hood and both these hoods are connected by air vent and head of the depriver hood is kept at normal pool level.



(Fig-9 Saddle Siphon)



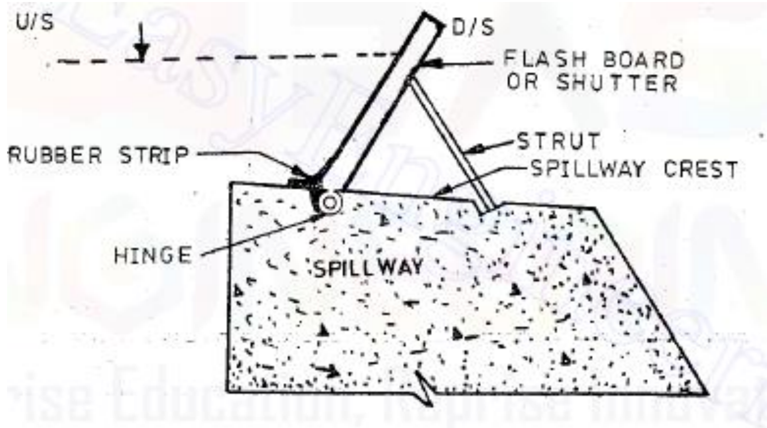
(Fig-10 Siphon installed over the overflow spillway)

Spillway gates:

The temporary barrier installed over the permanent raised crest of a spillway, so that additional water is stored between the spillway crest and top of the barrier during end of rainy season. In case of large dams regular gates may be installed over the permanent crest. Gates can provide in all types of spillway except siphon spillway.

Types of Gates:

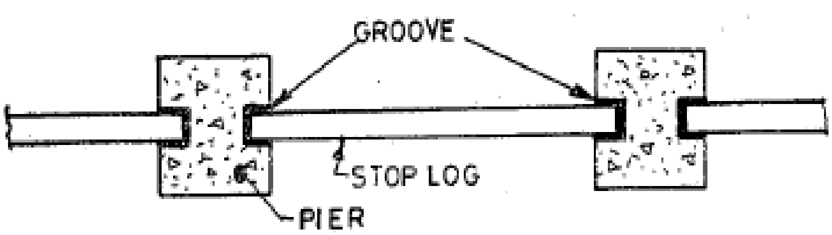
1- **Permanent Flash / Dropping shutters gate:** they consist of wooden panel of 1-1.25 m high. They hinged at the bottom and supported against the water pressure by shruts and not suitable for curved crests.



(Fig-11 Dropping shutters)

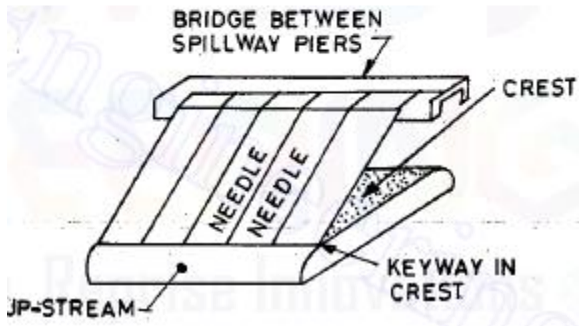
The automatic shutters work on the principle of counter weights against the water pressure and if they interfered by floating debris they don't function well.

2-Stop Logs and Needles: stop logs consist of wooden beam /planks placed one upon other and spanning in the grooves between the spillway piers. They can place either by hand or holistic mechanism. Leakage between the logs is also a big problem so, it used in minor works purpose.



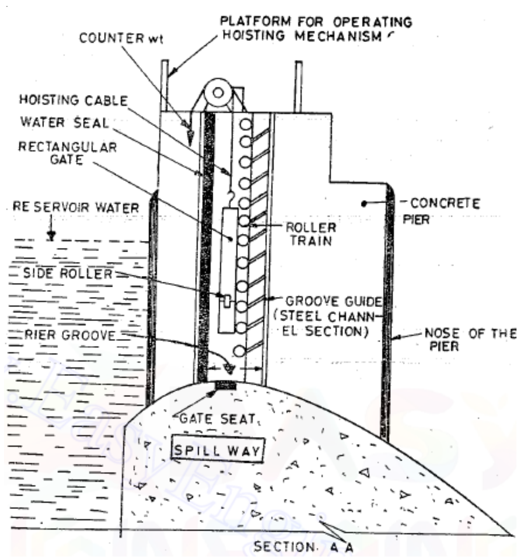
(Fig- 12 Plan view of stop logs)

Needles are the wooden logs kept side by side with their lower ends resting in a keyway on the spillway and upper ends supported by a bridge.



3-Vertical Lift Gates: Those gates are spanning horizontally between the grooves made in the supporting piers. These gates can move between the groove guides. These gates are often made of steels, wood and concrete.

Hydrostatic force generated as upstream water standing, so large friction is developed in case of vertical gate. In case of sliding gate, large holistic capacity is required to operate the gate because the sliding friction to overcome.



(Fig- 13 Vertical lift gate)

Frictional problem can overcome by placing cylindrical rollers between the bearing surface and the guide grooves.

4- Radial Gates: It consists of curved water made of steel. The pins are anchored in the downstream portion of spillway. The radial gates can be used for smaller lifting forces and for smaller works.

5-Drum gates:

They are used for longer spans of order 40m or medium heights say 10m.The drum gate consists of a segment of cylinder, which may be raised above the spillway crest.

Types of Hydraulic Jumps:

A hydraulic jump occurs when the flow goes from supercritical flow (Fr > 1) to subcritical flow (Fr < 1) or from an unstable flow to a stable flow.

Types :

I. Weak (Undular) Jump
   - Low energy dissipation rate
   - Smooth downstream water surface

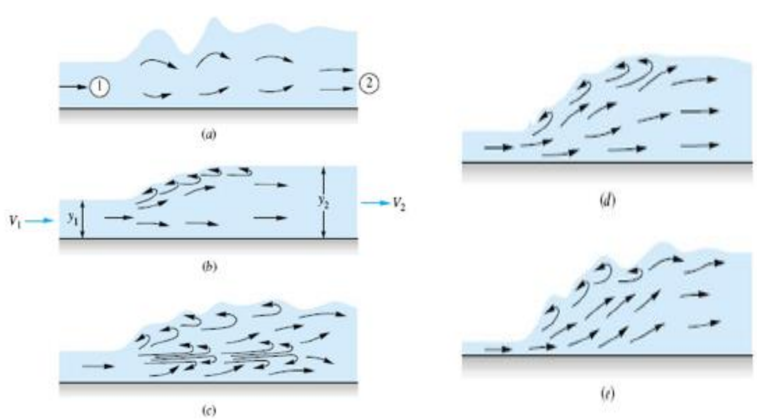
II. Oscillating Jump
   - Irregular fluctuations of flow
   - Causes turbulence downstream

III Steady Jump

   - Jump forms steadily at same location and is well balanced
   - Turbulence is confined within the jump

IV Strong Jump

   - Large change in depth of the water surface
   - High energy dissipation rate

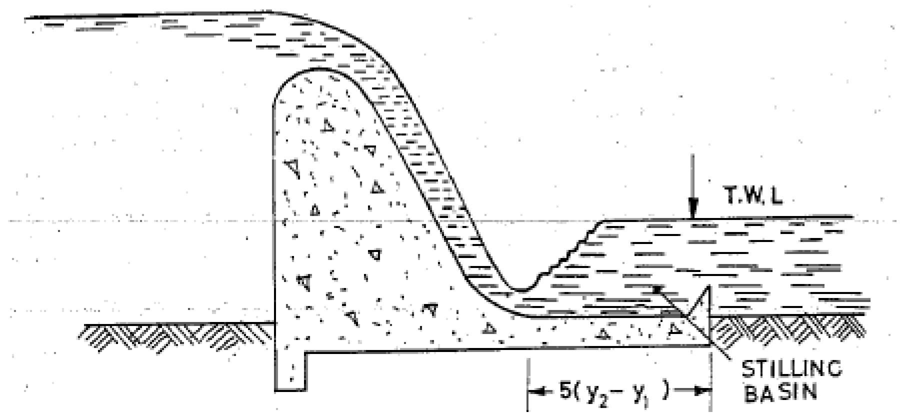


Classification of hydraulic jumps: (a) Fr =1.0 to 1.7: undular jumps; (b) Fr =1.7 to 2.5: weak jump; (c) Fr =2.5 to 4.5: oscillating jump; (d) Fr =4.5 to 9.0: steady jump; (e) Fr =9.0: strong jump.

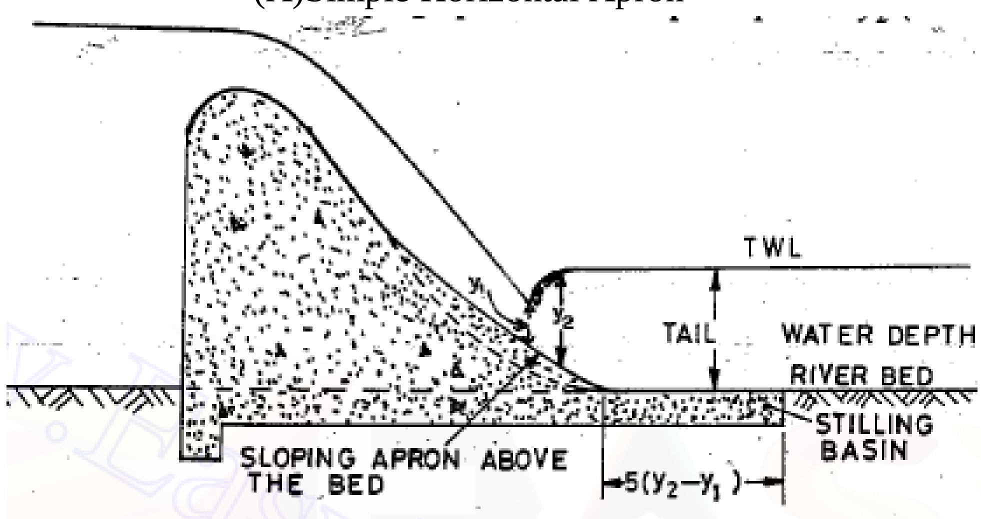
Energy Dissipaters:

The flood water discharging through the spillway has to flow down from a higher elevation at the reservoir surface level to a lower elevation at the natural river level on the downstream through a passage, which is also considered a part of the spillway. At the bottom of the channel, where the water rushes out to meet the natural river, is usually provided with an energy dissipation device that kills most of the energy of the flowing water. These devices, commonly called as Energy Dissipators, are required to prevent the river surface from getting dangerously scoured by the impact of the out falling water.

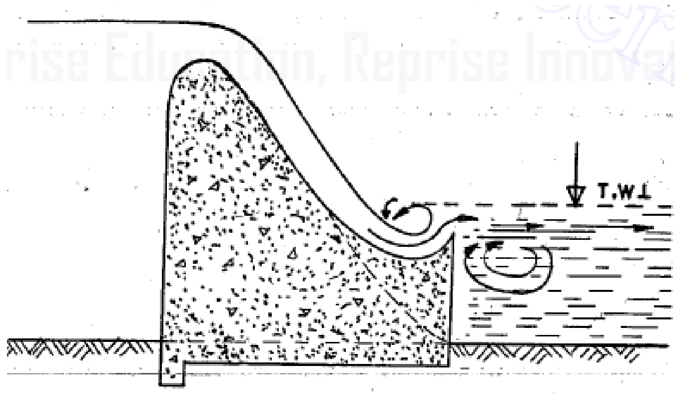
Types as per cases



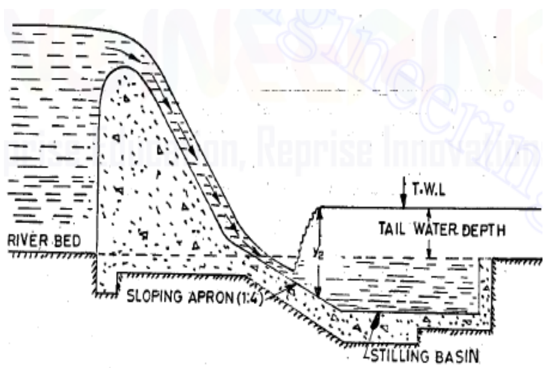
(A)Simple Horizontal Apron

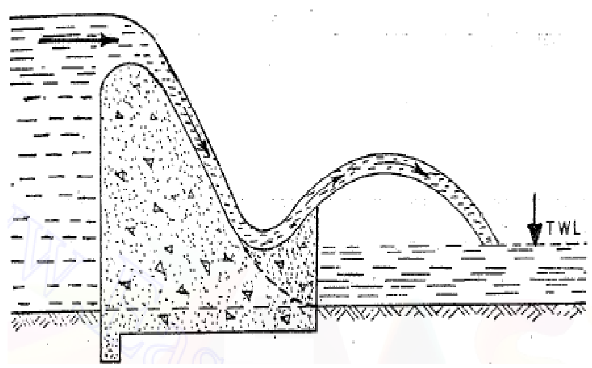


(B)Sloping Apron above the bed



(C)Roller Bucket Types





River Training Works:

Water is most important natural resources for existence of humanity/The prosperity of a nature depends primarily upon exploration of this sources as it is the primary wealth. Rivers classified on the basis of the topography of river basin i.e. Rivers in hilly regions, alluvial regions and flood plains. Also rivers classified on basis of flood hydrographs as flashy and virgin rivers.

Methods of River Training:

The chief aim is to achieve ultimate stability of the river. It is fill and final development of alluvial river. The following are adopted for training of rivers

- Marginal embankments or Levees
- Guide banks
- Groynes or Spars
- Artificial cut-offs
- Pitching of Banks and provision of launching aprons
- Pitching Islands

Objectives of Controls of River Training:

- To prevent the river from changing its course and to avoid out flanking of bridges, weirs like structure.
- To prevent flooding of the surroundings countries by providing a safe passage
- To protect the river banks by deflecting the river.
- To ensure effective disposal of sediment loads.
- To provide minimum water depth required for navigation.