Dam outlet works
a dam may be constructed to that height which is permissible within the given topography of the location or limited by the expenditure that may be possible for investment. The excess flood water, therefore, has to be removed from the reservoir before it overtops the dam. Passages constructed either within a dam or in the periphery of the reservoir to safely pass this excess of the river during flood flows are called Spillways.
Ordinarily, the excess water is drawn from the top of the reservoir created by the dam and conveyed through an artificially created waterway back to the river. In some cases, the water may be diverted to an adjacent river valley. In addition to providing sufficient capacity, the spillway must be hydraulically adequate and structurally safe and must be located in such a way that the out-falling discharges back into the river do not erode or undermine the downstream toe of the dam.

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.

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 outfalling water.
The spillway design depends primarily on the design flood, dam type and location, and reservoir size and operation. The design of bottom outlet works depends primarily on the purpose of the reservoir and the sediment inflow and deposition in the reservoir.

Spillways may be classified in several ways: according to function as (main) service, emergency and auxiliary spillways; according to mode of control as free (uncontrolled) or gated (controlled) spillways; according to hydraulic criteria, i.e. type, as overfall, side channel, chute, shaft, siphon and tunnel spillways.
Apart from economics, the main factors governing the choice of spillway for a given project are the reliability and accuracy of flood prediction, the duration and amount of spillage, seismicity of project site, topography and geology, and the dam type.

In the case of gated spillways the gates may be operated manually, by remote control, or automatically, depending on the level of water in the reservoir. Rigid control regulations are required for non-automatic operation in order to prevent an artificial major flood downstream and/or not to lose valuable water from the reservoir.

When controlling the reservoir outflow by spillway gates prior to or during a flood period, reliable flood forecasting methods have to be developed.
If the local conditions (e.g. **seismic activity, lack of confidence in maintenance and operating skills, or difficulties of access**) mean that there are doubts about the dependability of the gates, it might be better to opt for an **ungated** spillway. Regardless of how reliable gate operation may be, it is often stipulated that the spillway must be adequate to prevent the overtopping of the dam should one or more gates fail to open.
The selection of the **design flood** (reservoir inflow) hydrograph is one of the most important tasks in dam design; it depends on the dam location and the type of dam and the procedure for its determination.

The methods used for the calculation of floods developed from historical records of maximum observed floods, empirical and regional formulae, flood envelope curves and flood frequency analysis to modern methods based on rainfall analysis and conversion to runoff.
Free Overfall Spillway

the water freely drops down from the crest, as for an arch dam

In free falling water is ventilated sufficiently to prevent a pulsating, fluctuating jet.
It can also be provided for a decked over flow dam with a vertical or adverse inclined downstream face.
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. Occasionally, the crest is extended in the form of an overhanging lip to direct small discharges away from the face of the overfall section.
Where artificial protection is provided at the loose, the bottom may not scour but scour may occur for unprotected streambeds which will form deep plunge pool. The volume and the depth of the scour hole are related to the range of discharges, the height of the drop, and the depth of tail water. Where erosion cannot be tolerated an artificial pool can be created by constructing an auxiliary dam downstream of the main structure, or by excavating a basin which is then provided with a concrete apron or bucket.
Overflow Spillway

The overflow type spillway has a crest shaped in the form of an ogee or S-shape.

Hence, 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.
The upper curve of the ogee is made to conform closely to the profile of the lower nappe of a ventilated sheet of water falling from a sharp crested weir.

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.
Chute 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.
A side channel spillway is one in which the control weir is placed approximately parallel to the upper portion of the discharge channel.
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. The structure may be considered as being made up of three elements, namely, an overflow control weir, a vertical transition, and a closed discharge channel.

**Shaft Spillway**
When the inlet is funnel shaped, the structure is called a **Morning Glory Spillway**. The name is derived from the flower by the same name, which it closely resembles especially when fitted with anti-vortex piers. These **piers or guide vanes are often necessary to minimize vortex action in the reservoir**, if air is admitted to the shaft or bend it may cause troubles of explosive violence in the discharge tunnel-unless it is amply designed for free flow.
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.
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.
Selection of spillways

*Safety Considerations Consistent with Economy*

Spillway structures add substantially to the cost of a dam. In selecting a type of spillway for a dam, economy in cost should not be the only criterion. The cost of spillway must be weighed in the light of safety required below the dam.

*Hydrological and Site Conditions*

The type of spillway to be chosen shall depend on: a) Inflow flood; b) Availability of tail channel, its capacity and flow hydraulics; c) Power house, tail race and other structures downstream; and d) Topography

*Type of Dam*

This is one of the main factors in deciding the type of spillway. For earth and rockfill dams, chute and ogee spillways are commonly provided, whereas for an arch dam a free fall or morning glory or chute or tunnel spillway is more appropriate. Gravity dams are mostly provided with ogee spillways.

*Purpose of Dam and Operating Conditions*

The purpose of the dam mainly determines whether the dam is to be provided with a gated spillway or a non-gated one. A diversion dam can have a fixed level crest, that is, non-gated crest.
Conditions Downstream of a Dam

The rise in the downstream level in heavy floods and its consequences need careful consideration. Certain spillways alter greatly the shape of the hydrograph downstream a dam. The discharges from a siphon spillway may have surges and break-ups as priming and depriming occurs. This gives rise to the wave travelling downstream in the river, which may be detrimental to navigation and fishing and may also cause damage to population and developed areas downstream.

Nature and Amount of Solid Materials Brought by the River

Trees, floating debris, sediment in suspension, etc, affect the type of spillway to be provided. A siphon spillway cannot be successful if the inflow brings too much of floating materials. Where big trees come as floating materials, the chute or ogee spillway remains the common choice.

Apart from the above, each spillway can be shown as having certain specific advantages under particular site conditions. These are listed below which might be helpful to decide which spillway to choose for a particular project.
**Ogee Spillway**
It is most commonly used with gravity dams. However, it is also used with earth and rockfill dams with a separate gravity structure; the ogee crest can be used as control in almost all types of spillways; and it has got the advantage over other spillways for its high discharging efficiency.

**Chute Spillway**
a) It can be provided on any type of foundation, b) It is commonly used with the earth and rockfill dams, and c) It becomes economical if earth received from spillway excavation is used in dam construction.
The following factors limit its adaption: a) It should normally be avoided on embankments; b) Availability of space is essential for keeping the spillway basins away from the dam paving; and c) If it is necessary to provide too many bends in the chute because of the topography, its hydraulic performance can be adversely affected.

**Side Channel Spillways**
This type of spillway is preferred where a long overflow crest is desired in order to limit the intensity of discharge, It is useful where the abutments are steep, and it is useful where the control is desired by the narrow side channel.
The factor limiting its adoption is that this type of spillway is hydraulically less efficient.
Shaft Spillways (Morning Glory Spillway)

a) This can be adopted very advantageously in dam sites in narrow canyons, and b) Minimum discharging capacity is attained at relatively low heads. This characteristic makes the spillway ideal where the maximum spillway outflow is to be limited. This characteristic becomes undesirable where a discharge more than the design capacity is to be passed. So, it can be used as a service spillway in conjunction with an emergency spillway.

The factor limiting its adoption is the difficulty of air-entrainment in a shaft, which may escape in bursts causing an undesirable surging.
**Siphon Spillway**

Siphon spillways can be used to discharge full capacity discharges, at relatively low heads, and great advantage of this type of spillway is its positive and automatic operation without mechanical devices and moving parts.

The following factors limit the adoption of a siphon spillway:

- It is difficult to handle flows materially greater than designed capacity, even if the reservoir head exceeds the design level;
- Siphon spillways cannot pass debris, ice, etc;
- There is possibility of clogging of the siphon passage way and breaking of siphon vents with logs and debris;
- In cold climates, there can be freezing inside the inlet and air vents of the siphon;
- The structure is subject to heavy vibrations during its operation needing strong foundations; and Siphons cannot be normally used for vacuum heads higher than 8 m and there is danger of cavitation damage.
**Overfall or Free Fall Spillway**
This is suitable for arch dams or dams with downstream vertical faces; and this is suitable for small drops and for passing any occasional flood.

**Tunnel or Conduit Spillway**
This type is generally suitable for dams in narrow valleys, where overflow spillways cannot be located without risk and good sites are not available for a saddle spillway. In such cases, diversion tunnels used for construction can be modified to work as tunnel spillways. In case of embankment dams, diversion tunnels used during construction may usefully be adopted. Where there is danger to open channels from snow or rock slides, tunnel spillways are useful.