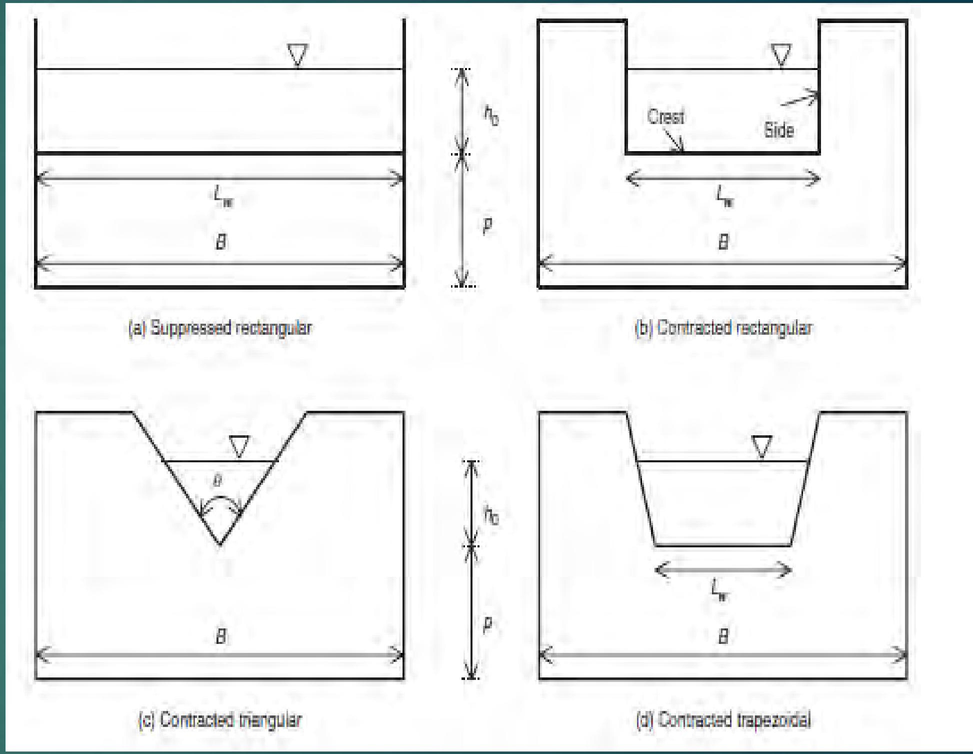
Hydraulic Structures

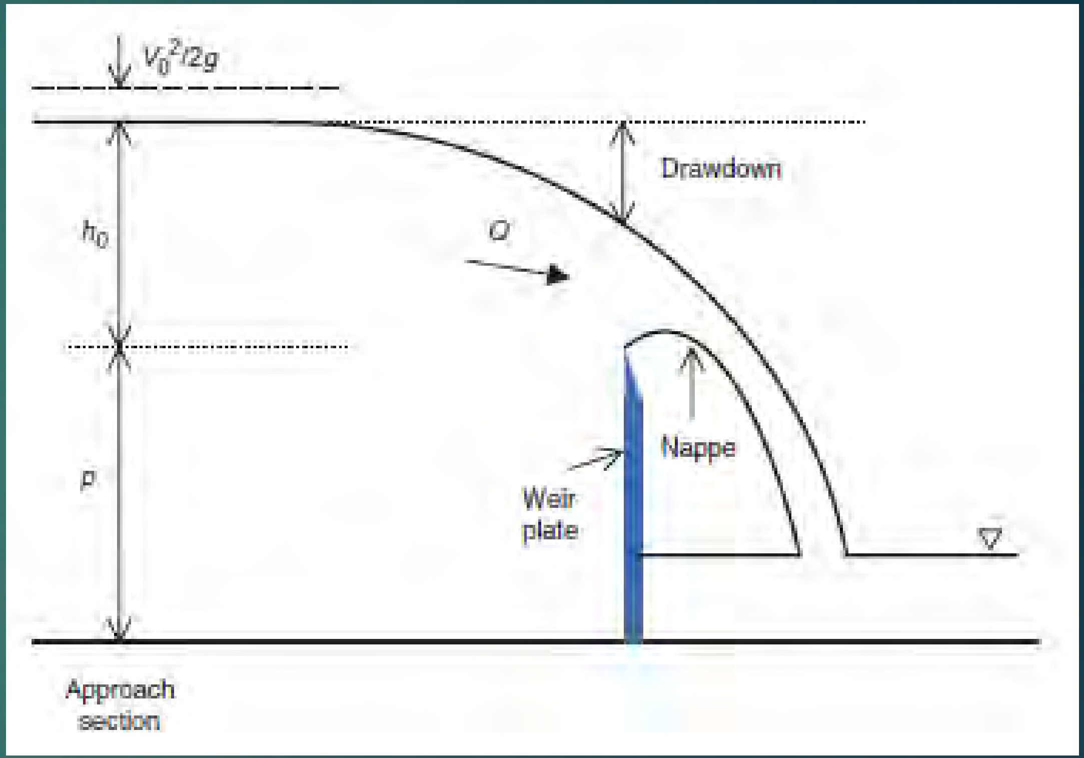
- Hydraulic structures are used to control and manage the flow of water in natural and built systems.
- They include flow measurement structures such as weirs, conveyance structures such as culverts, and flood control structures such as dams.
- Measurement of flow in open channels is essential for better management of limited supplies of water.



Hydraulic Structures

- Accurate measurement practices help provide equitable distribution of water between competing demands, and conserve the water supplies by minimizing waste due to excess delivery.

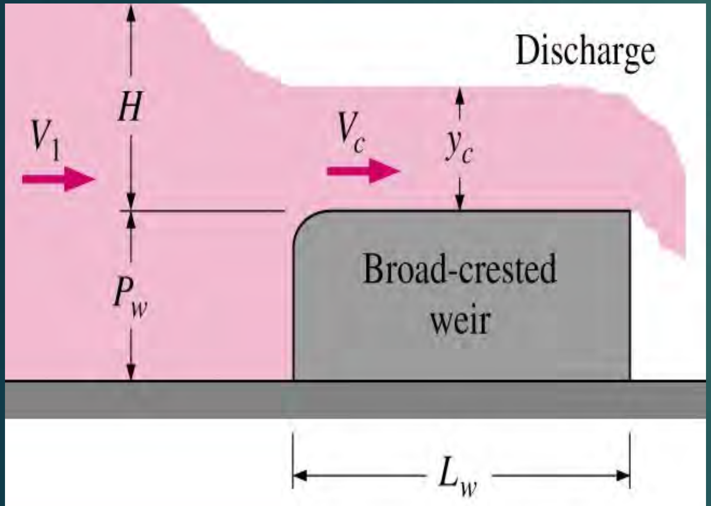
- Most flow measurement structures are emplaced in a channel. They are used to determine the discharge indirectly from measurements of the flow depth.



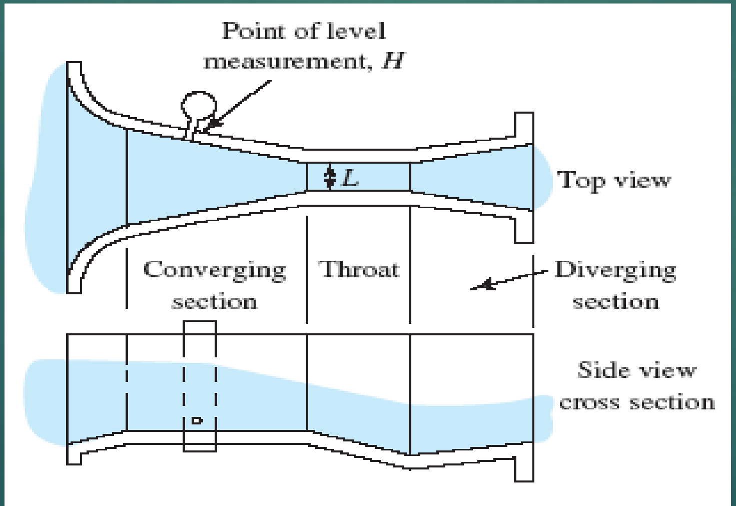
Hydraulic Structures

- In open channel flows, flow rate is controlled by partially blocking the channel.
- The way this works is, blocking the channel to change the shape and velocity of the flow (e.g., critical flow).

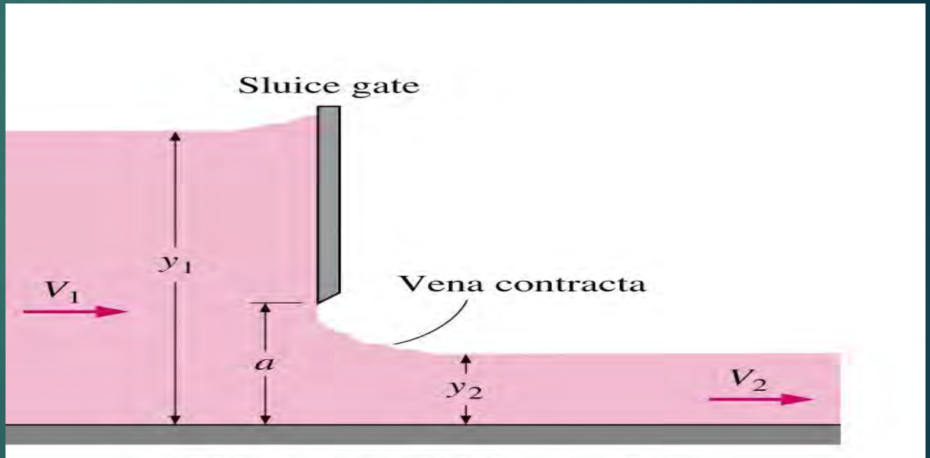
Weir : Flows over a device



Flume: Flows through a device



Underflow gate : Flows under a device



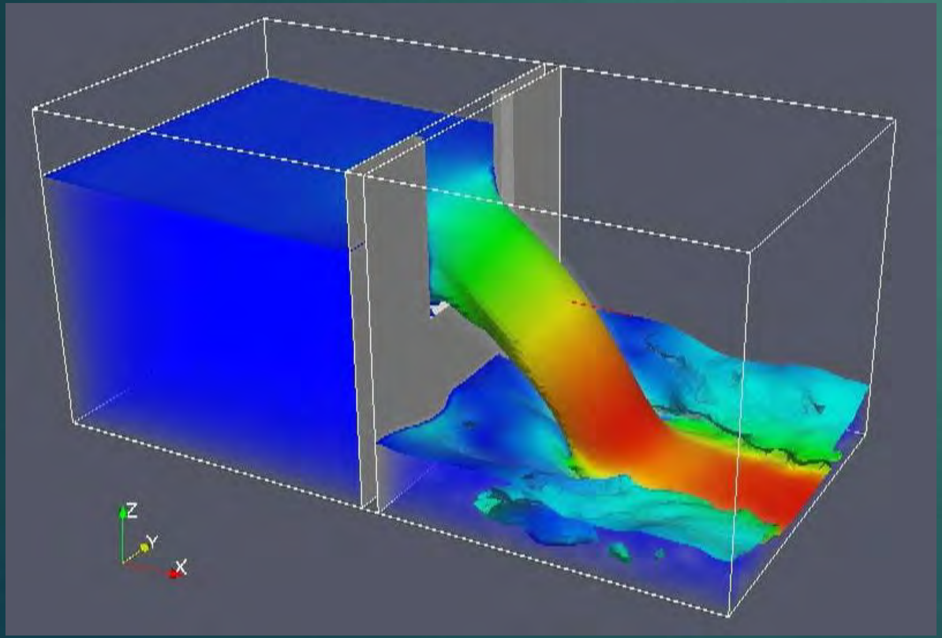
(a) Sluice gate with free outflow

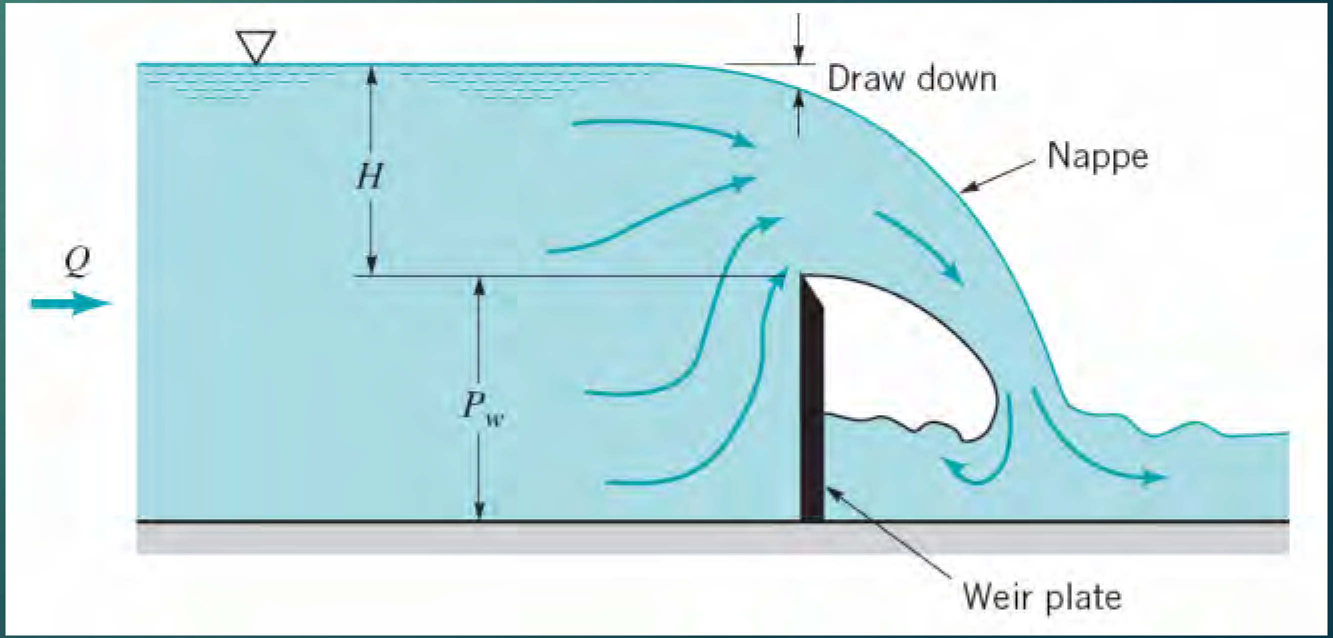
Flow Control and Measurement (weirs)

Weir provides a convenient method of determining the flowrate in an open channel in terms of a single depth measurement.

Flow Control and Measurement

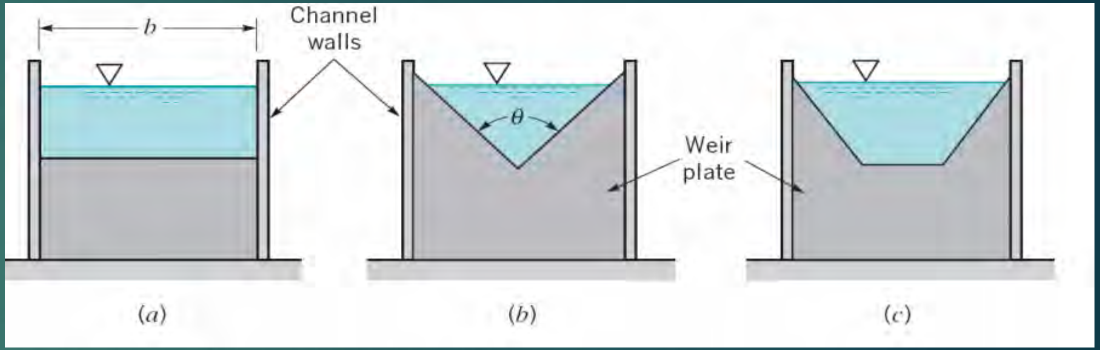
- A sharp-Crested weir is essentially a vertical-edged flat plate placed across the channel.
- The fluid must flow across the sharp edge and drop into the pool downstream of the weir plate.





Flow Control and Measurement

- Sharp-crested weir plate geometry: (a) rectangular, (b) triangular, (c) trapezoidal.

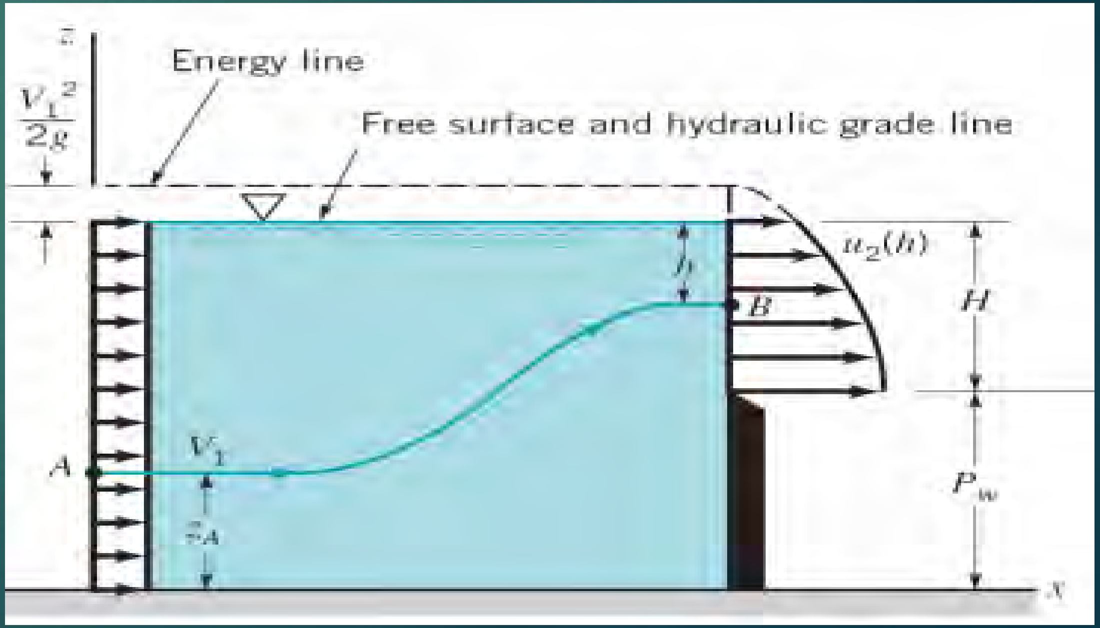


<u>Rectangular</u> sharp crested weir

$$Q = C_{wr} \frac{2}{3} \sqrt{2g} b H^{3/2}$$

$$C_{wr} = 0.611 + 0.075 \left(\frac{H}{P_W} \right)$$

C_{wr} is the rectangular weir coefficient.

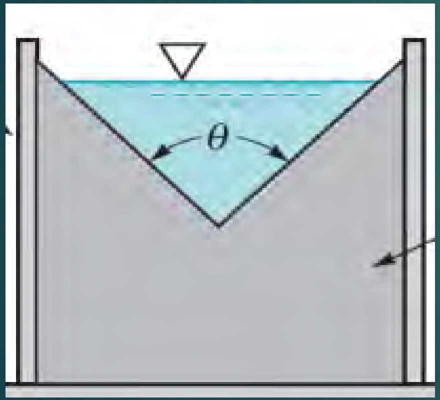


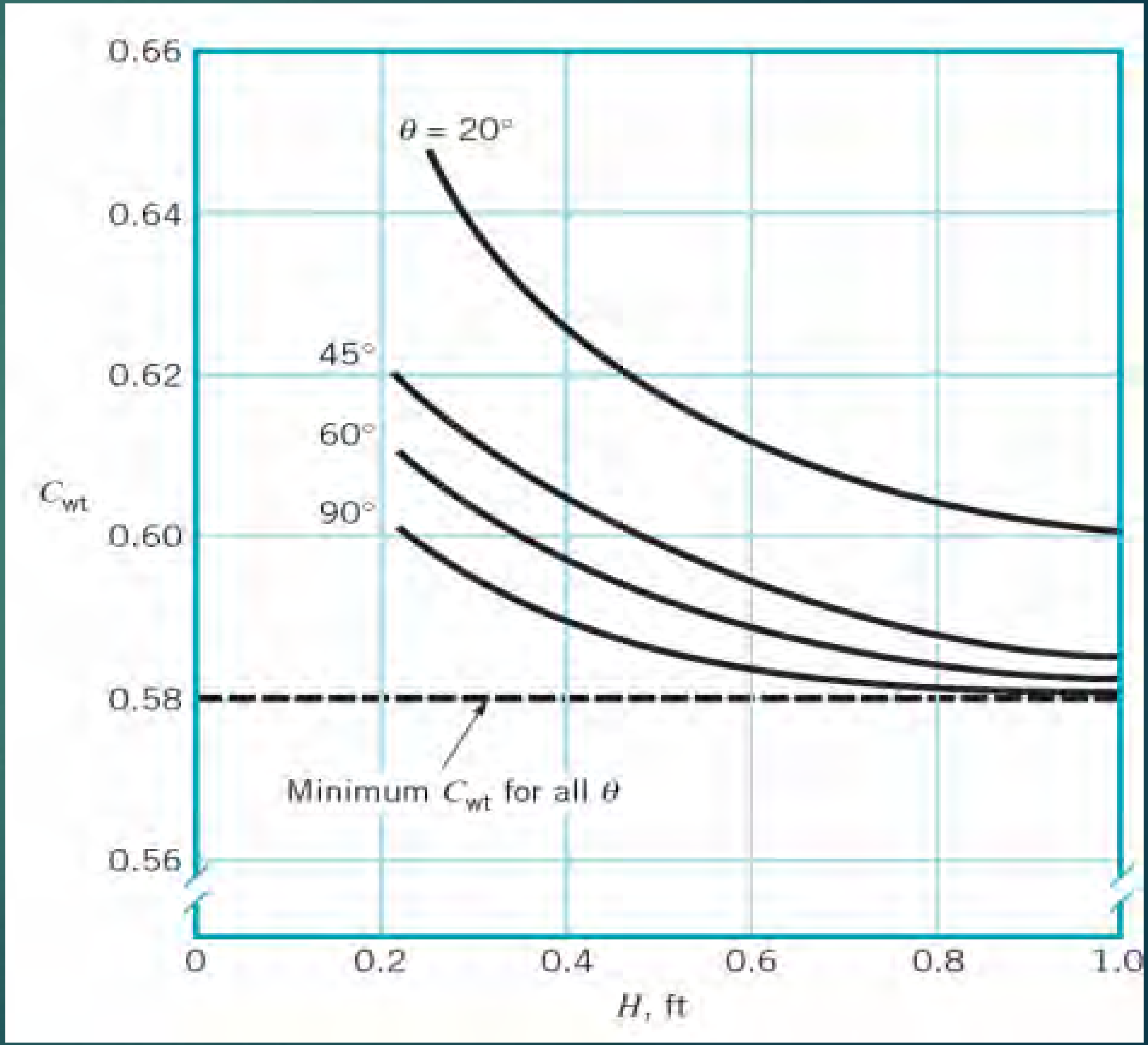
Flow Control and Measurement

Triangle sharp crested weir

$$Q = C_{wt}\frac{8}{15}Tan(\frac{\theta}{2})\sqrt{2g}bH^{5/2}$$

C_{wt} is the triangle weir coefficient.



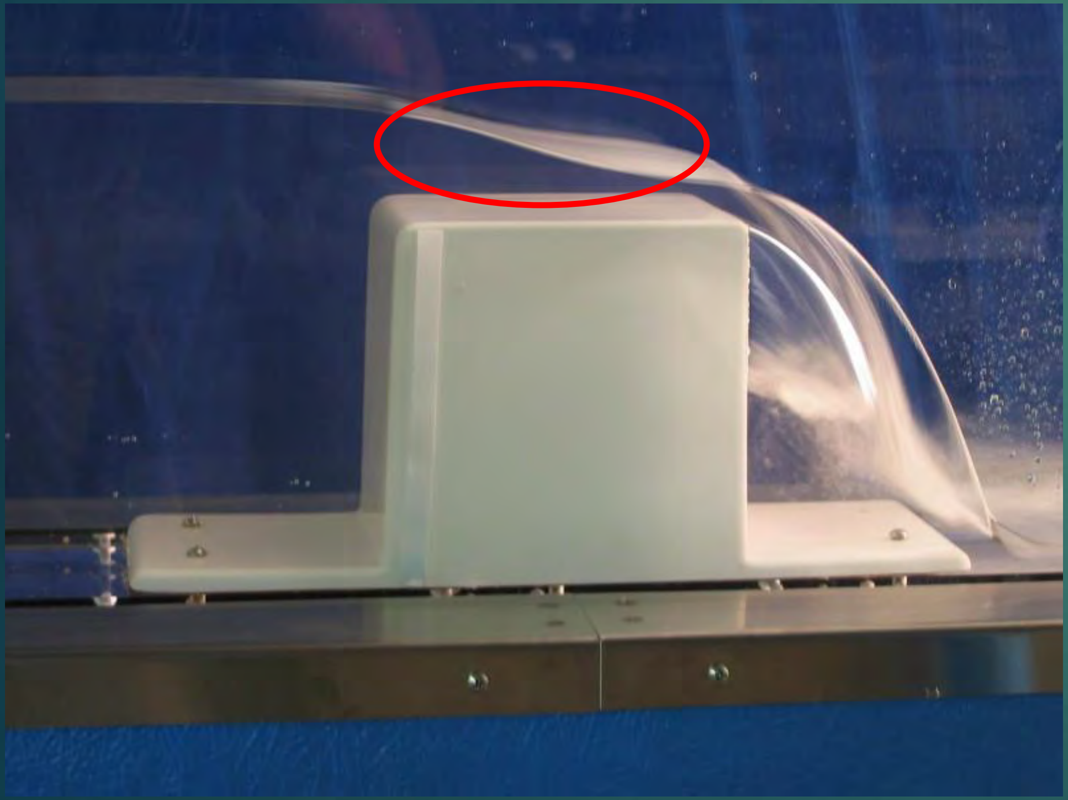


Flow Control and Measurement (Broad Crested weir)

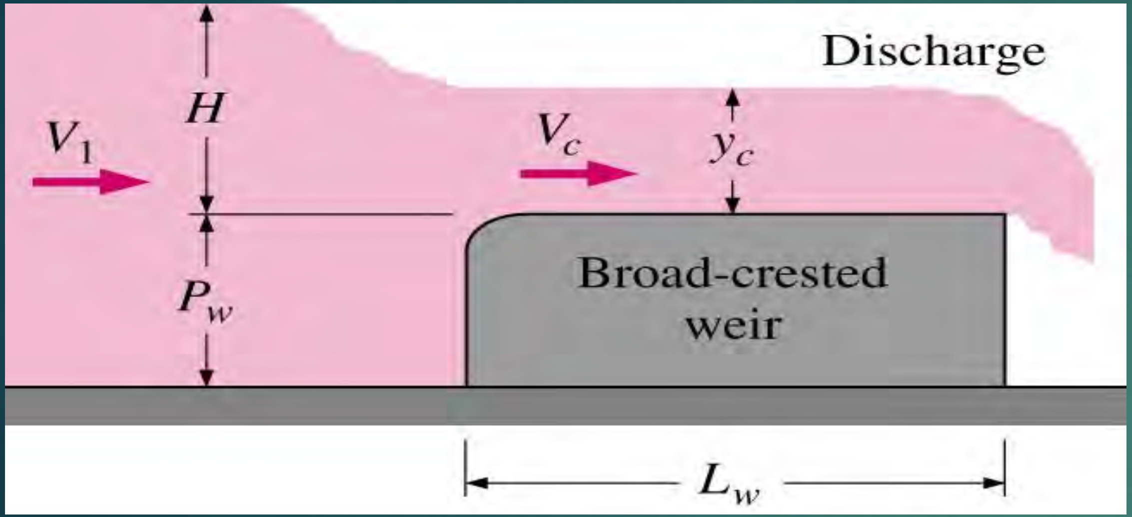
- This is the simplest device for flow measurement.
- The width of the weir is taken as the width of the waterway.

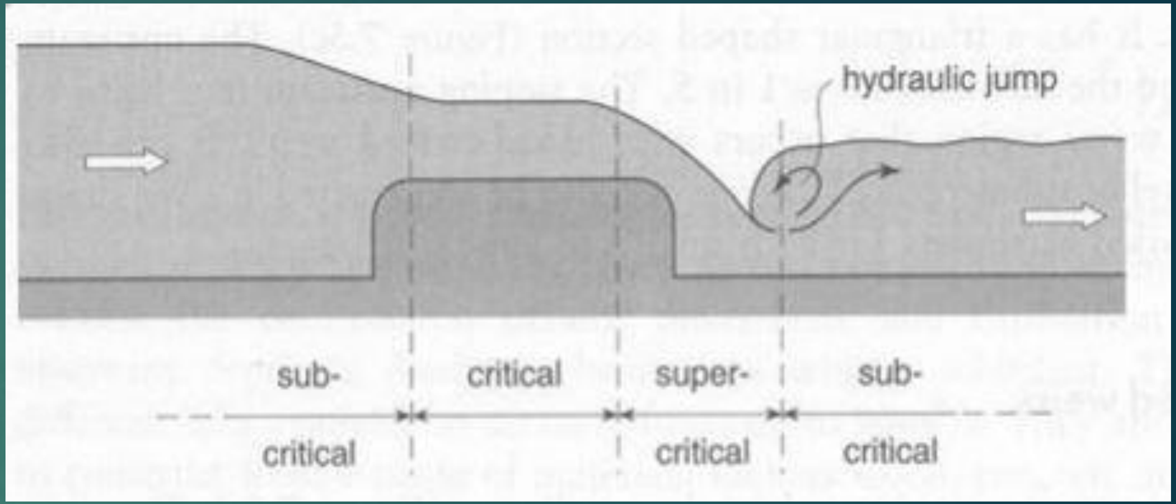
Flow Control and Measurement (Broad Crested weir)

- A key feature of a properly operating broad crested weir is critical flow over the weir crest.



Flow Control and Measurement (Broad Crested weir)





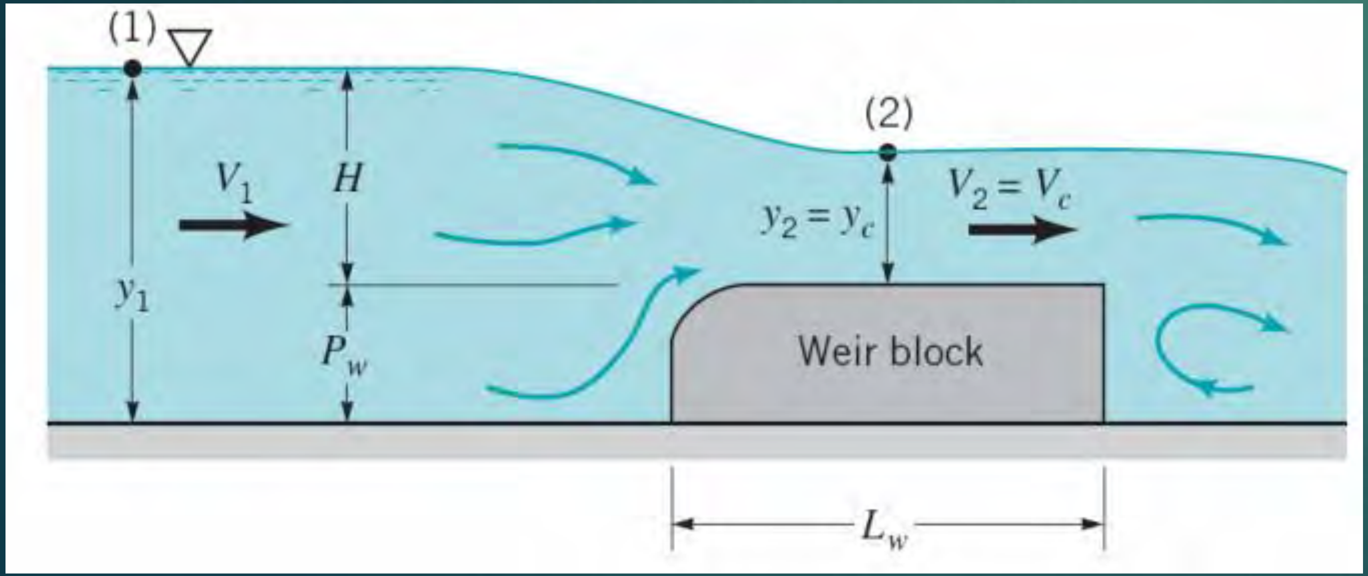
Advantages:

- Cost effective installation due to ease of design and construction.
- Relatively small head loss across the structure
- Capable of measuring discharge in small to medium channels

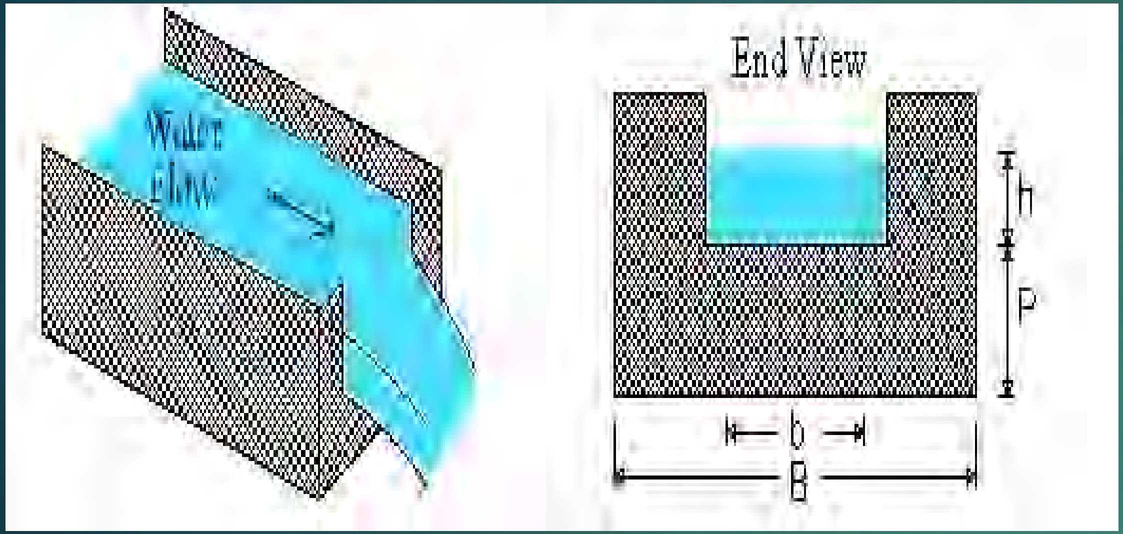
Flow Control and Measurement (Rectangular weir)

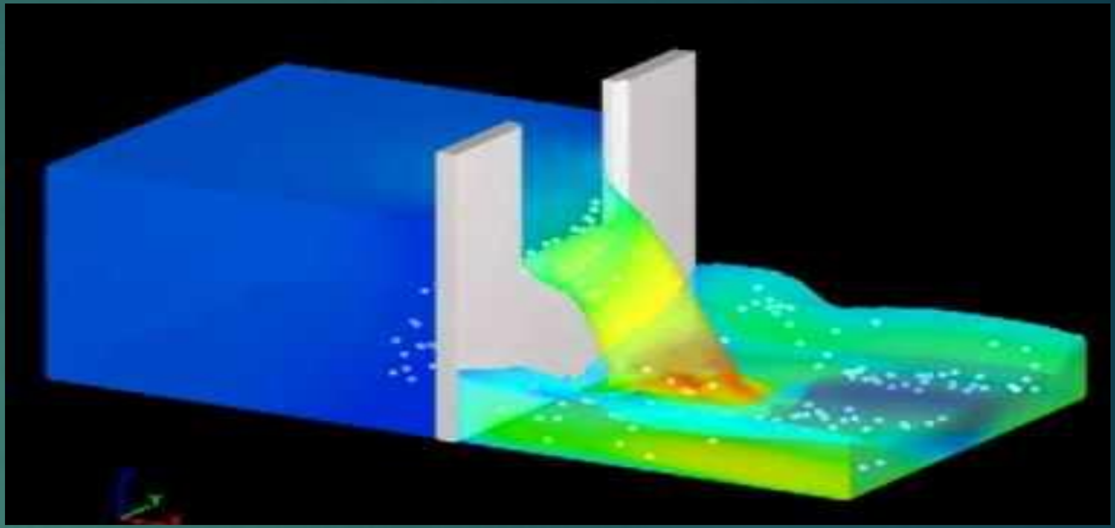
$$Q = C_{wb}\sqrt{2g}b\left(\frac{2}{3}\right)^{3/2} H^{3/2}$$

$$C_{wb} = \frac{0.65}{\left[1 + \frac{H}{P_w}\right]^{1/2}}$$

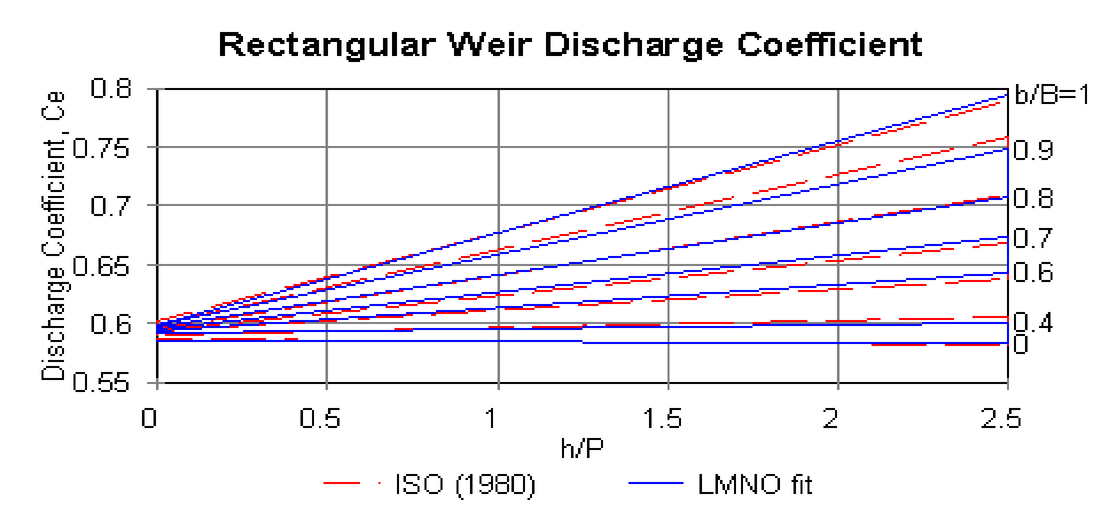


Flow Control and Measurement (Rectangular weir)

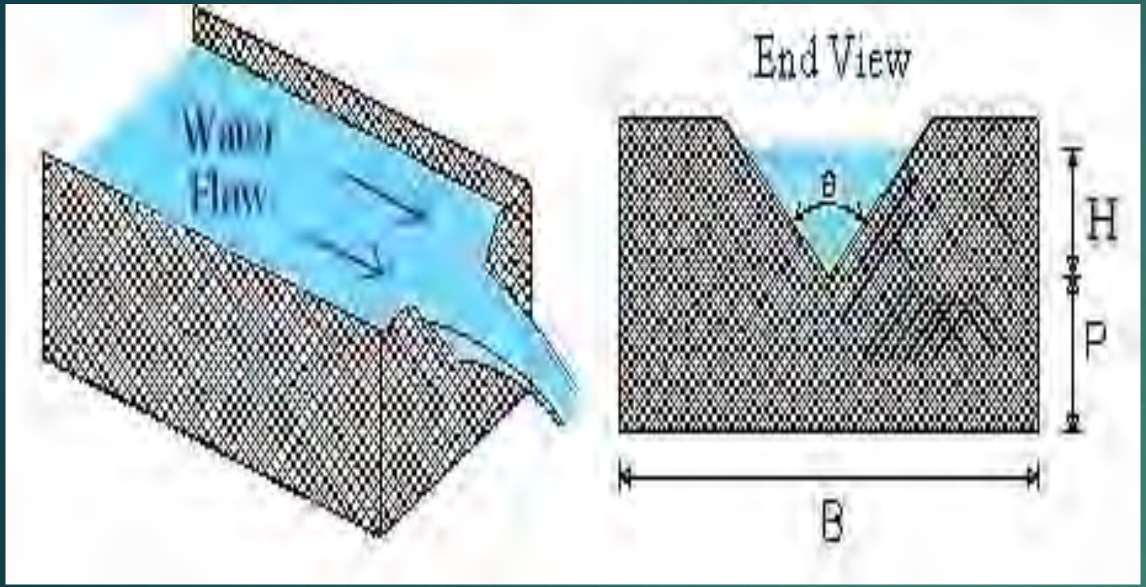


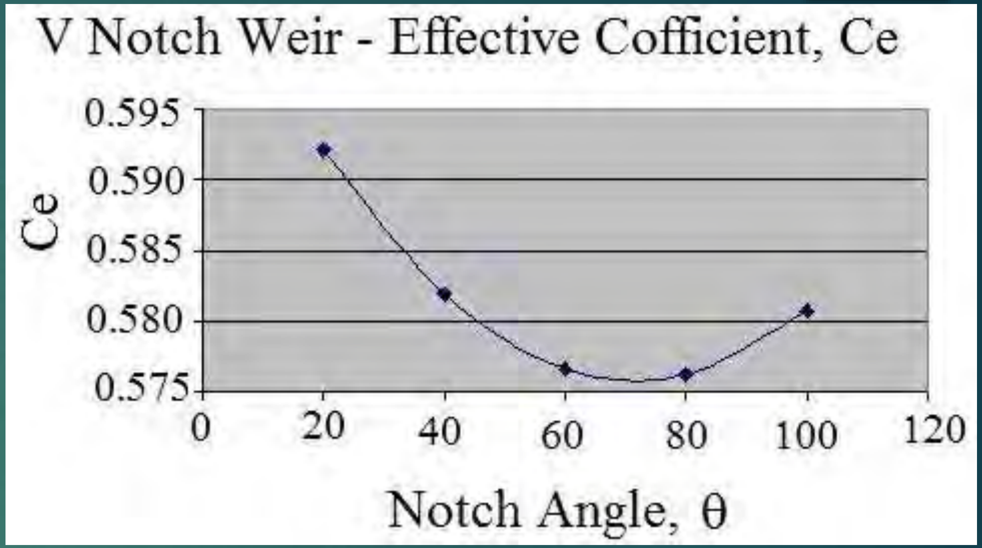


$$Q = \frac{2}{3} C_e \times b \times \sqrt{2g}\, h^{3/2}$$



Flow Control and Measurement (Triangular or V-notch weirs)





$$Q = \frac{8}{15} C_e \times Tan\frac{\theta}{2} \times \sqrt{2g} \times H^{5/2}$$

- One of the best for relatively small flows
- C_e is a function of θ

Flow Control and Measurement (Broad Crested weir)

Example 5-1

Water flows in a rectangular channel with the width of 2 m with H=0.5 m. This flow rate is to be measured by using a:

a. Rectangular sharp-crested weir

b. Triangular sharp-crested weir with $\theta = 90^\circ$

c. Broad crested-weir

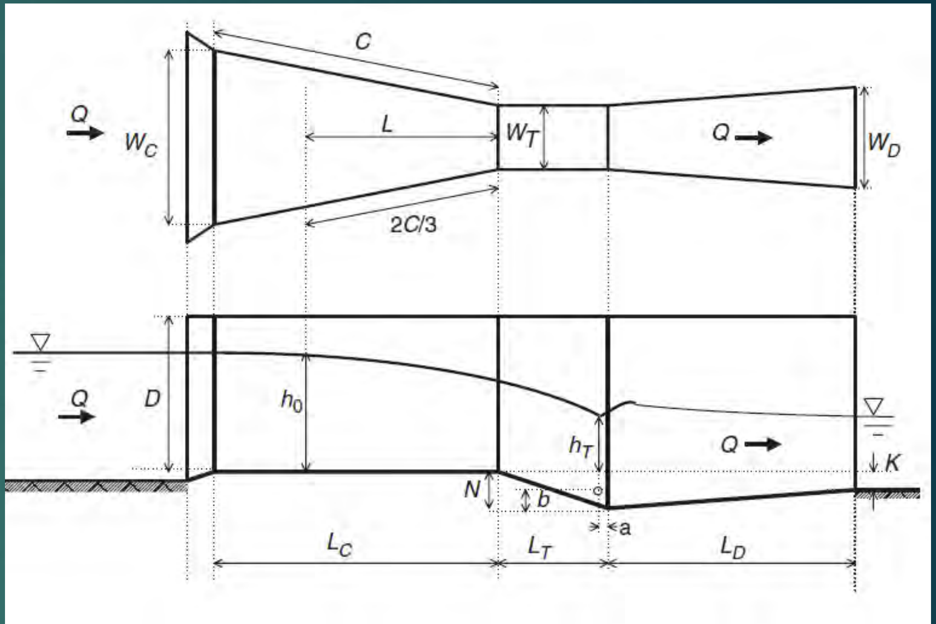
If the weir height is 1 m, calculate the flow rate.

Flow Control and Measurement (Flume)

Flow Control and Measurement (Flume)

A dimension of Parshall flume with the dimensions given in Table for various sizes.

Widths			Axial lengths			Vertical dimensions			Gage points				Free flow capacity	
W_T (ft)	W_C (ft)	W_D (ft)	L_C (ft)	L_T (ft)	L_D (ft)	D (ft)	N (ft)	K (ft)	C (ft)	L (ft)	a (ft)	b (ft)	Min. (cfs)	Max. (cfs)
1.0	2.77	2.00	4.41	2.0	3.0	3.0	0.75	0.25	4.50	3.00	0.167	0.25	0.11	16.1
1.5	3.36	2.50	4.66	2.0	3.0	3.0	0.75	0.25	4.75	3.17	0.167	0.25	0.15	24.6
2.0	3.96	3.00	4.91	2.0	3.0	3.0	0.75	0.25	5.00	3.33	0.167	0.25	0.42	33.1
3.0	5.16	4.00	5.40	2.0	3.0	3.0	0.75	0.25	5.50	3.67	0.167	0.25	0.61	50.4
4.0	6.35	5.00	5.88	2.0	3.0	3.0	0.75	0.25	6.00	4.00	0.167	0.25	1.30	67.9
5.0	7.55	6.00	6.38	2.0	3.0	3.0	0.75	0.25	6.50	4.33	0.167	0.25	1.60	85.6
6.0	8.75	7.00	6.86	2.0	3.0	3.0	0.75	0.25	7.00	4.67	0.167	0.25	2.60	103.5
7.0	9.95	8.00	7.35	2.0	3.0	3.0	0.75	0.25	7.50	5.00	0.167	0.25	3.00	121.4
8.0	11.15	9.00	7.84	2.0	3.0	3.0	0.75	0.25	8.00	5.33	0.167	0.25	3.50	139.5
10.0	15.60	12.00	14.00	3.0	6.0	4.0	1.12	0.50	9.00	6.00			6.0	300.0
12.0	18.40	14.67	16.0	3.0	8.0	5.0	1.12	0.50	10.00	6.67			8.0	520.0
15.0	25.00	18.33	25.00	4.0	10.0	6.0	1.50	0.75	11.50	7.67			8.0	900.0
20.0	30.00	24.00	25.00	6.0	12.0	7.0	2.25	1.00	14.00	9.33			10.0	1340.0
25.0	35.00	29.33	25.00	6.0	13.0	7.0	2.25	1.00	16.50	11.00			15.0	1660.0
30.0	40.40	34.67	26.00	6.0	14.0	7.0	2.25	1.00	19.00	12.67			15.0	1990.0
40.0	50.80	45.33	27.00	6.0	16.0	7.0	2.25	1.00	24.00	16.00			20.0	2640.0
50.0	60.80	56.67	27.00	6.0	20.0	7.0	2.25	1.00	29.00	19.33			25.0	3280.0

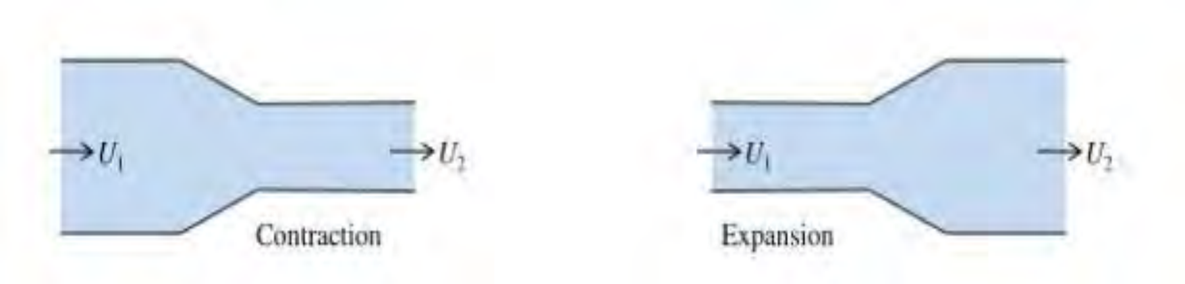


Channel Transition

- A structure designed to convey water smoothly from a conduit of one shape to one of different shape is called transition.
- A common transition for open channel flow is used between a canal of *trapezoidal* cross section and a flume of *rectangular* cross section.

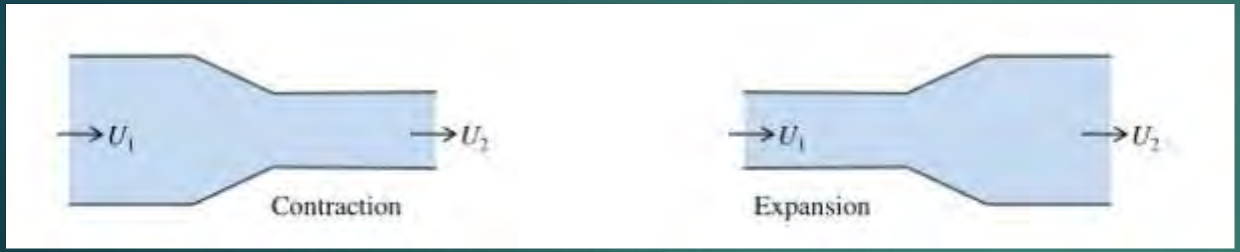
Channel Transition

- If the transition is from a conduit of large cross section to one of smaller cross section, it is an inlet transition or a contraction.
- If the transition is from an smaller one to a larger one, it is an expansion.

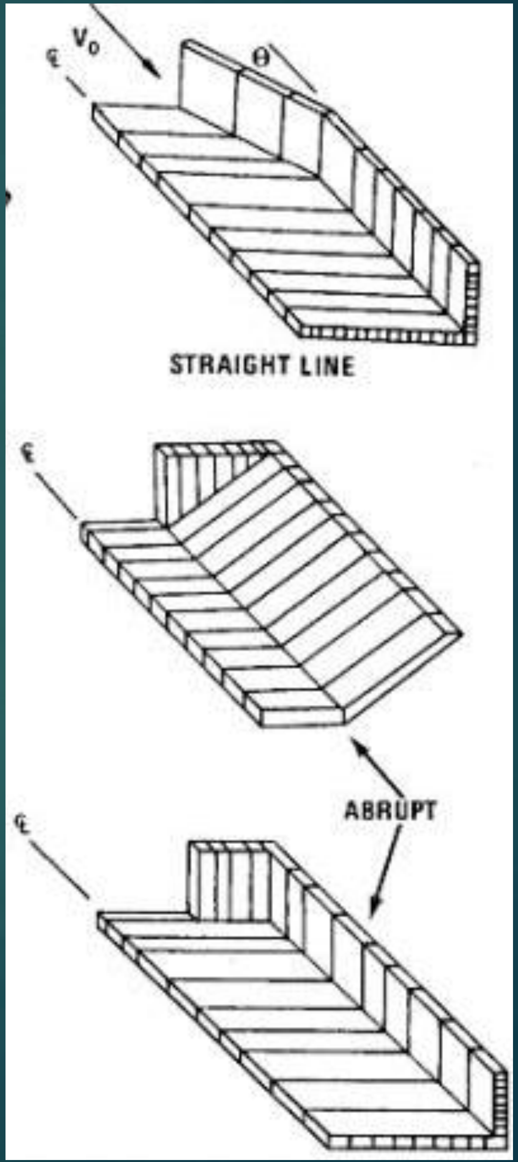


Channel Transition

- The simplest type of transition is a straight wall constructed normal to the flow direction.



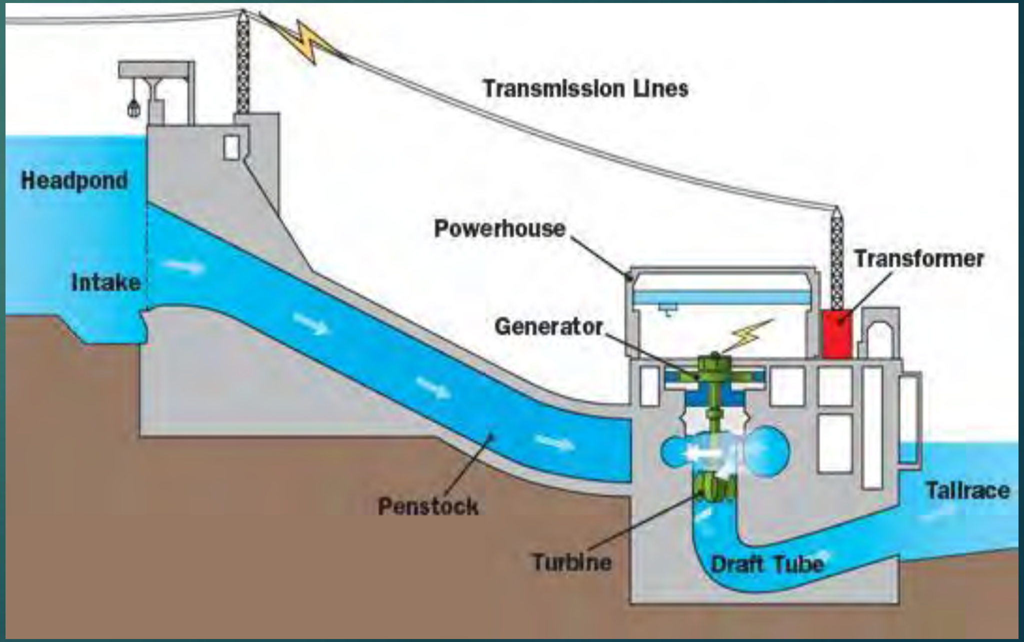
- This type of transition can work, but it will produce excessive head loss because of the abrupt change in cross section and ensuing separation that would occur.
- To prevent excessive head loss and to reduce the possibility of erosion in the case of an expansion to an erodible channel, a more gradual type of transition is usually used.



Spillways

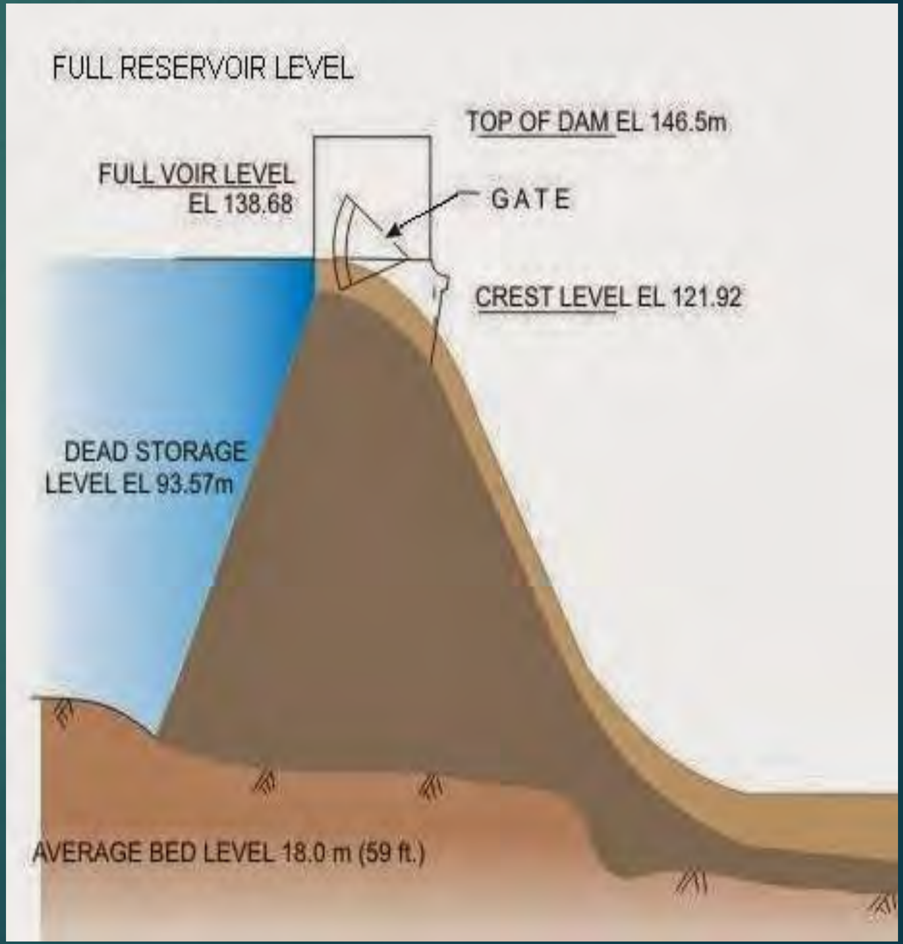
- A Spillway is nearly always required to pass flow by a dam.
- In the case hydropower dams, where large flows pass through hydraulic turbines, spillway maybe used infrequently to pass flood.

- The safe operation of spillways is the main objective in design, because the failure to perform its design function can lead to failure of a dam.
- As dams raise water level, spillways must be designed for high velocity flow.



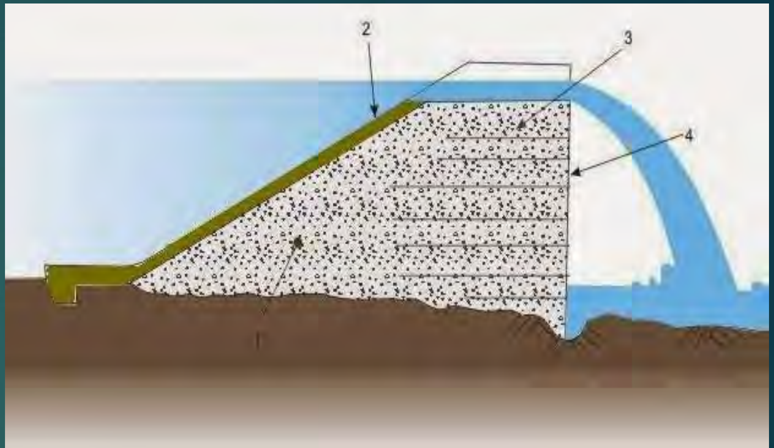
Spillways

<u>Controlled Spillways</u>: It has mechanical structure or gates to regulate the rate of flow of water from the reservoir.



Spillways

Uncontrolled Spillways: This doesn't have a gate and when the water raises above the crest of the spillway, start releasing from reservoir.

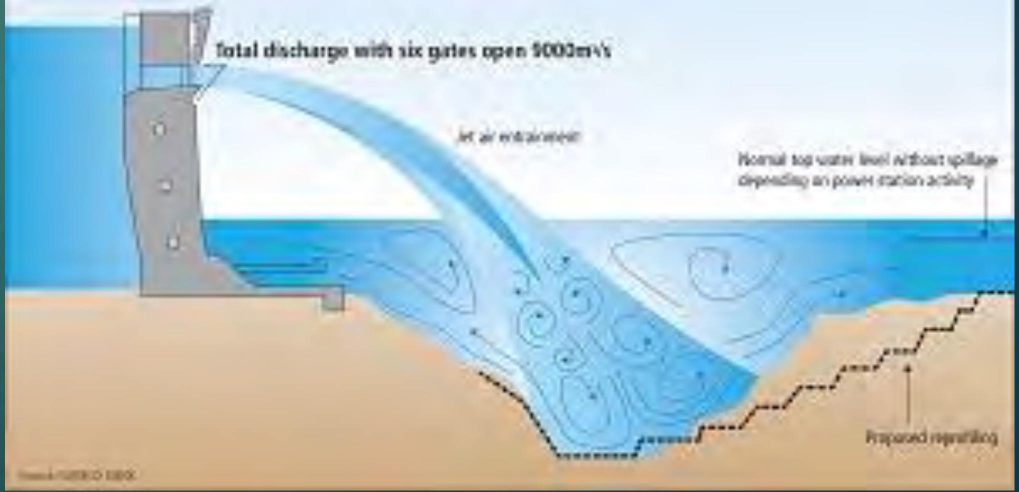


Spillways

Types of Spillway

<u>Type # 1: Free Over-Fall Spillway</u>

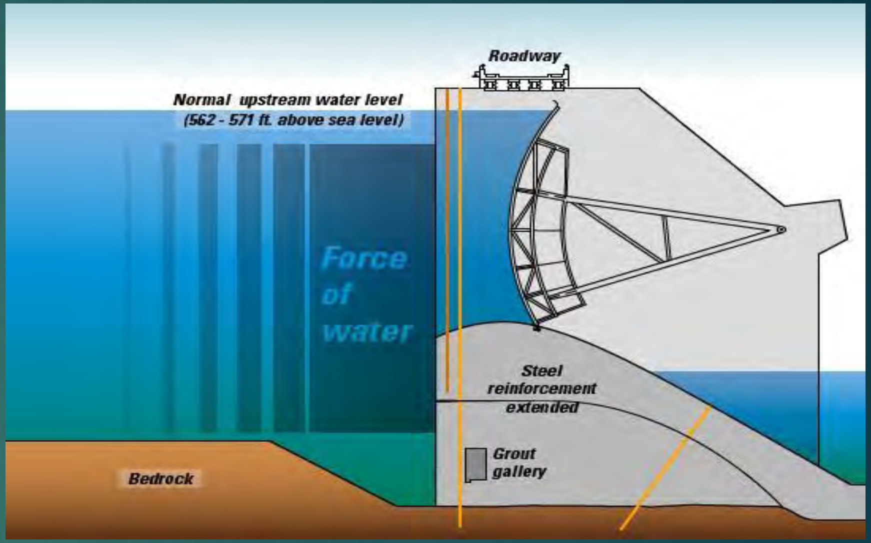
- As the name of the spillway indicates, the flow drops freely from the crest of a free over-fall spillway.
- Such a spillway is better suited for a thin arch dam whose downstream face is <u>nearly vertical</u>.
- In order to protect the stream bed from erosion, an artificial concrete pool is usually constructed which is called Plunge pool.



Spillways

Type # 2: Ogee Spillway

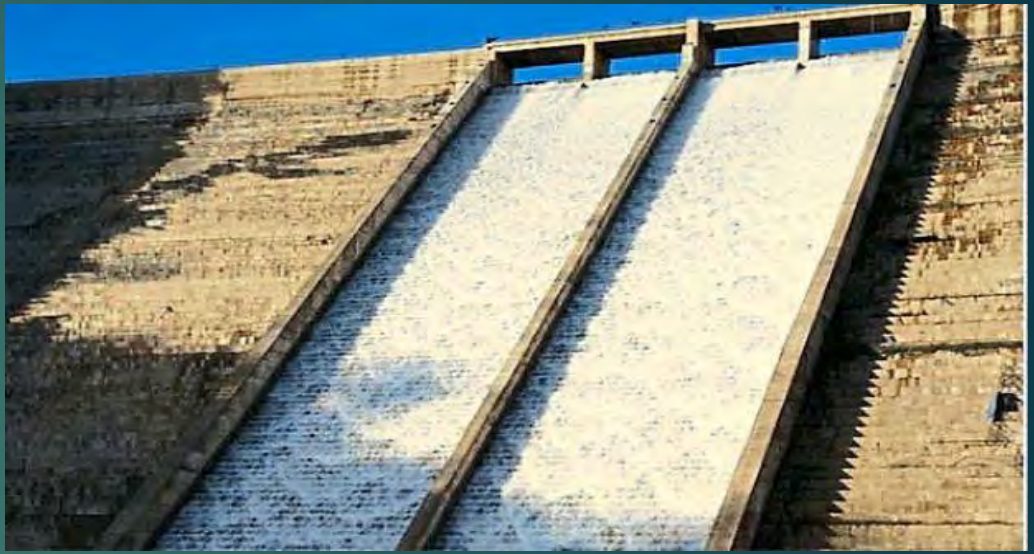
- The ogee or overflow spillway is the most common type of spillway.
- The structure divides naturally into three zones: the crest, the slope, and the toe.
- The nappe-shaped profile is an ideal profile because at the design head, the water flowing over the crest of the spillway always remains in contact with the surface of the spillway as it glides over it.



Spillways

Type # 3: Chute Spillway

- Chute spillways are common and basic in design.
- The spillway's slope and it's sides are lined with concrete.



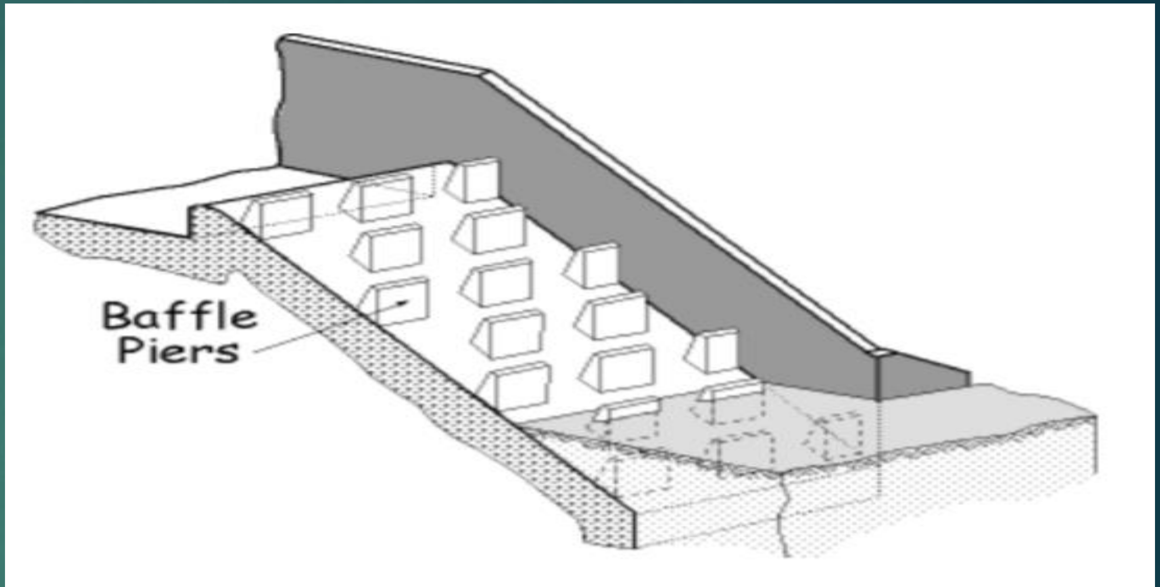
Advantages:

- The simplicity of their design and construction,
- Their adaptability to all types of foundation ranging from solid rock to soft clay.

Spillways

Baffled Chute Spillway

- A baffled chute spillway is composed of a chute that the surface is covered by a number of densely spaced baffle blocks.
- The baffle blocks dissipate the kinetic energy of the flowing water effectively.
- Special design is needed to maintain sufficiently small velocities at the entrance of a chute.

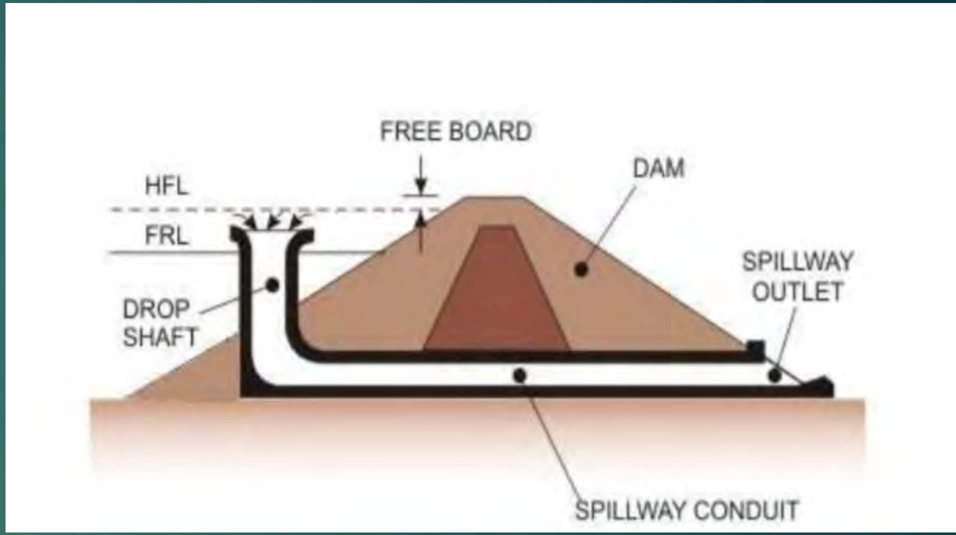


Spillways

Spillways

Type # 4: Shaft Spillway

- In a shaft spillway, water enters a horizontal crest, drops through a vertical or sloping shaft and then flows through a horizontal (or nearly horizontal) tunnel.
- The horizontal or the conduit may be taken either through the body of dam or through the underground.
- This spillway is not suitable for large capacity and deep reservoirs because of stability problems.
- Repair and maintenance of shaft spillways are difficult.

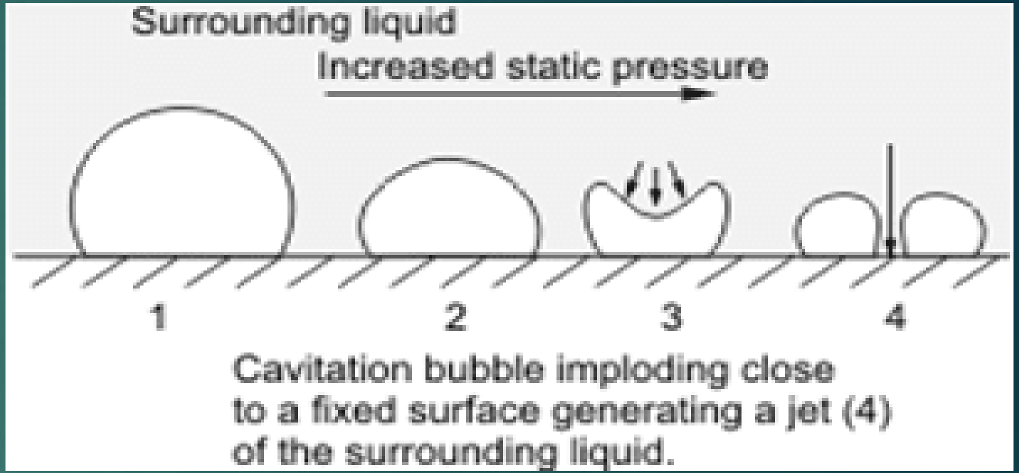


Shaft Spillway (uncontrolled)

Cavitation

Cavitation in Spillways

- Spillways of high dams produce high velocities that combined with the roughness that can be resulted in cavitation.
- Cavitation damage occurs on concrete surface when discontinuity is encountered in the path of high velocity water flow.
- This discontinuity in the flow path cause the water to lift off the flow surface, creating negative pressure zones and resulting bubbles of water vapor.



- These bubbles travel downstream and collapse.

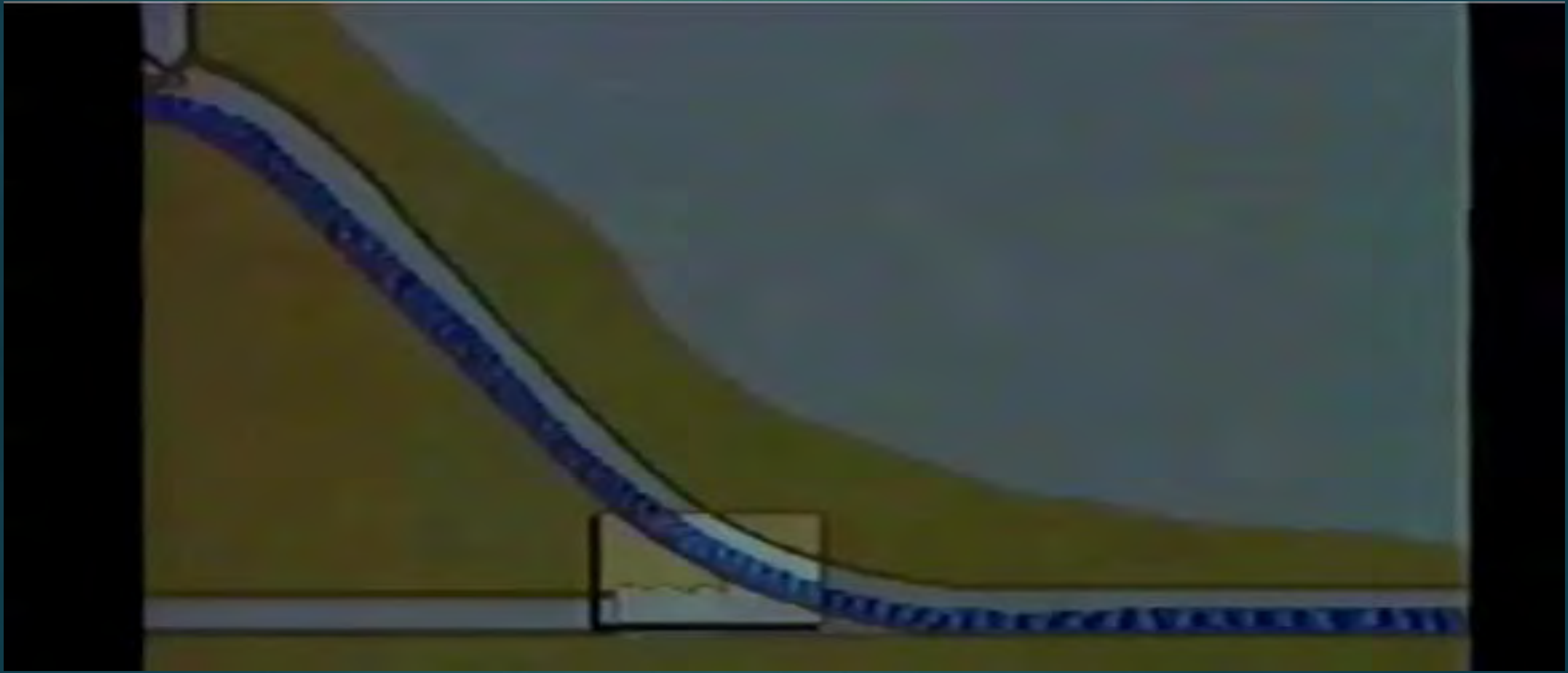
Cavitation

Cavitation in Spillways

- If the bubbles collapse against a concrete surface, it sends a very high pressure impact over an infinitely small area of the surface.
- Such high pressure impacts can remove particles of concrete, forming another discontinuity which then create more extensive cavitation damage.
- To date, no material, including stainless steel and cast iron, has been found capable of withstanding fully developed instances of cavitation.

Cavitation

Spillway Cavitation



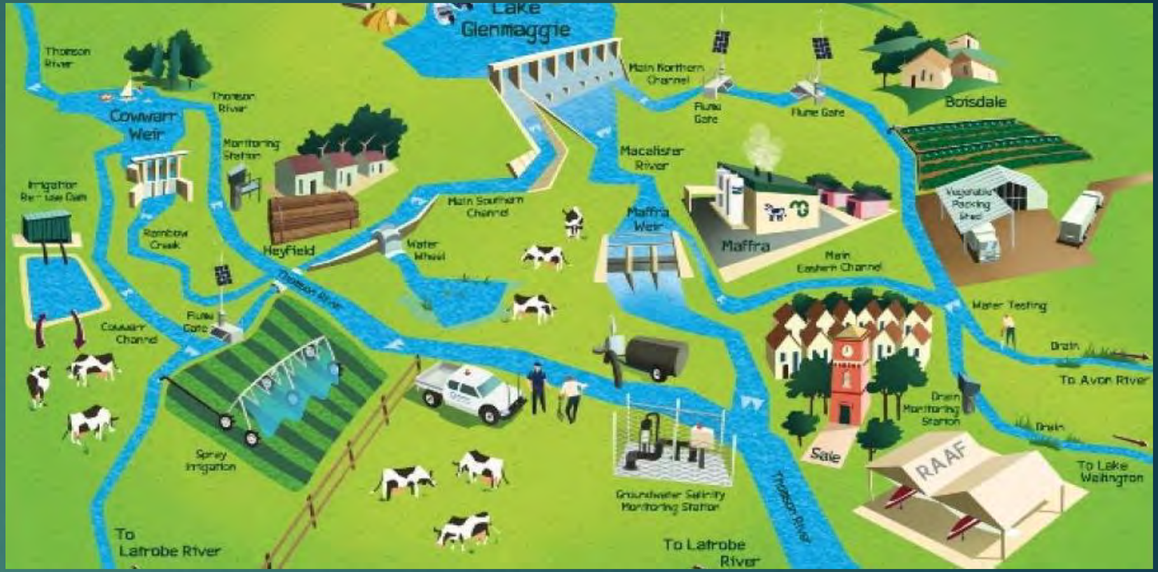
Dams and Reservoirs | Introduction

- Rivers are sources of water supply for drinking, industrial and agricultural uses and source of energy in the form of hydroelectric power.

- Rivers maybe serve as transportation arteries and sources of recreation.

- Rivers are also often used for sewage disposal.

- However, flooded rivers causing property damage and loss of life.



Dams and Reservoirs | Introduction

- As rivers have played an important and life-sustaining role in human societies, we need to control them to our advantages.
- Building structures such as dams is a way to control rivers.
- The most important items that must be considered in the planning and design of a *dam* and *reservoir* are:

1. Hydrological Data
2. Geologic Data
3. Reservoir Data
4. Environmental Data