Hydraulic structures
Weirs and Canal Intakes

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May 05,2016

CIVE 717

Hydraulic structures

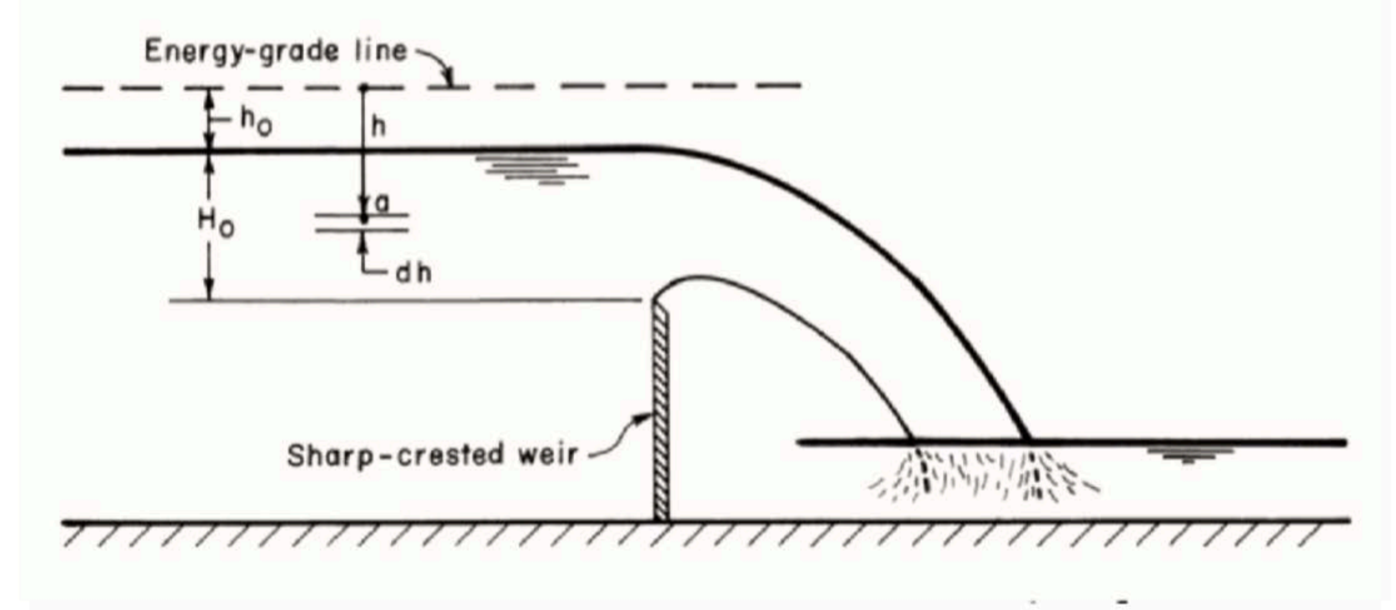
- A **hydraulic structure** is a structure submerged or partially submerged in any body of water, which disrupts the natural flow of water. They can be used to divert, disrupt or completely stop the flow. An example of a hydraulic structure would be a dam, which slows the normal flow rate of the river in order to power turbines. A hydraulic structure can be built in rivers, a sea, or any body of water where there is a need for a change in the natural flow of water.
- Hydraulic structures may also be used to measure the flow of water. When used to measure the flow of water, **hydraulic structures** are defined as a class of specially shaped, static devices over or through which water is directed in such a way that under free-flow conditions at a specified location (point of measurement) a known level to flow relationship exists.
- In this presentation, we mainly focus on weirs and canal intakes.

Principle of Weir design

- The occurrence of critical depth is put to good use in the design of open channel flow measuring devices. By creating an obstruction, critical depth is forced to occur and a unique relationship between depth and discharge results. This is the principle upon which weir design is based.

Main Types of Weir

1. Sharp-Crested weirs



A sharp-crested weir usually comprises of a thin plate mounted perpendicular to the flow direction. The top of the plate has a beveled, sharp edge which makes the nappe spring clear from the plate. If $y_1/l \geq 1.5$, we can call it sharp-crested weir. Where y_1 is the upstream flow depth above the weir, L is the weir length.

1. Sharp-Crested weirs

(a) For a flow over a rectangular weir, we have

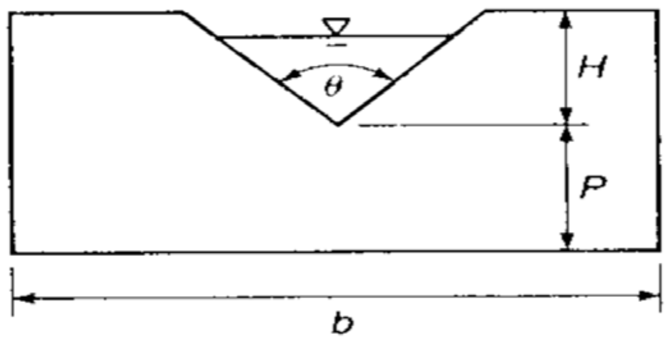
$$q = \frac{2}{3} C_d \sqrt{2g} {H_o}^{3/2}$$

Based on Rehbock's experimental results[Henderson 1966],

$$C_d = 0.611 + 0.08 \frac{H_0}{P}$$

in which P= height of the weir above the channel bottom. Measurements by Rouse[1950]indicate that this formula is valid for $\frac{H_o}{P} < 5$. It is approximate up to $\frac{H_o}{P} = 10$ when C_d is about 1.135[Henderson, 1966].For $\frac{H_o}{P} > 15$, the weir becomes a sill and the discharge may be computed from the critical flow equation assuming $y_c = H_o$.

1. Sharp-Crested weirs



(a) Definition Sketch

(b) For a flow over a triangular weir[Henderson,1966], we have

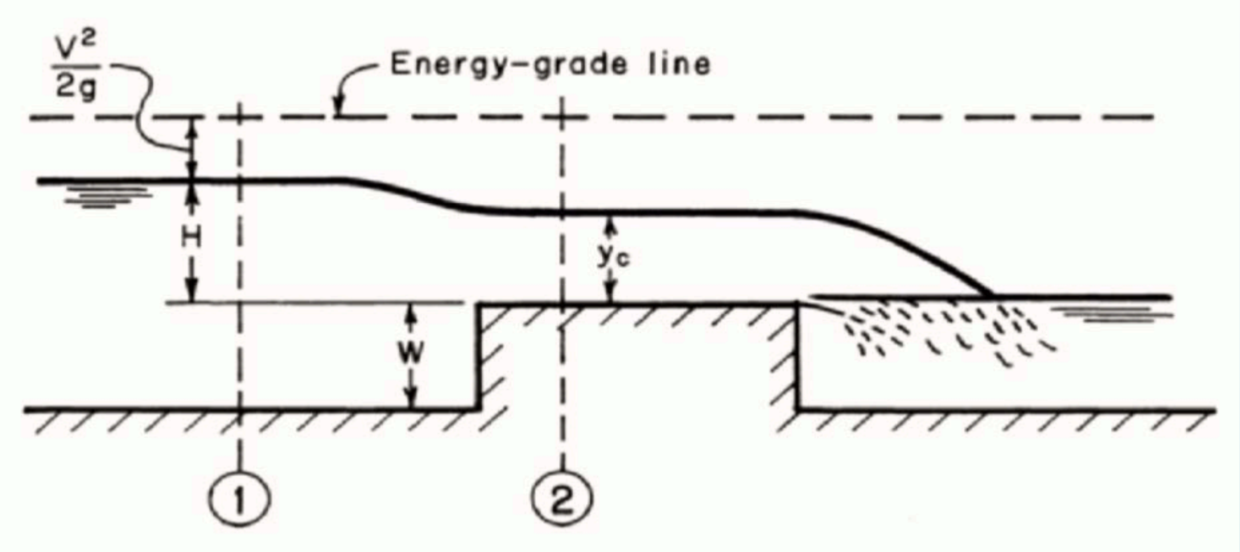
$$Q = \frac{8}{15} C_c \tan\frac{\alpha}{2} \sqrt{2g} H^{o\,5/2}$$

In which C_c =contraction coefficient and α = weir angle. The contraction coefficient for the most commonly used 90°-weir is approximately equal to 0.585.By substituting this value into the equation above, we obtain

$$Q = 2.5 H_o^{5/2}$$

Main Types of Weir

2. Broad-Crested Weirs



The broad-crested weir has a finite crest length parallel to the flow. When $0.07 \leq H_1/l \leq 0.7$, we can determine a broad-crested weir. Where H_1 is the upstream total energy above the weir, and l is the weir length.

2. Broad-Crested Weirs

For a rectangular, borad-crested weir, we can solve for Q use

$$Q = C_v C_d \frac{2}{3} [\frac{2g}{3}]^{1/2} L H^{3/2}$$

In which the approach velocity coefficient $C_v = (H_e/H)^{2/3}$.This equation can be solved by assuming that $C_v = 1$.

$$C_d = 0.93 + 0.2(H/p_w)$$

Where H is the total energy upstream of the weir.

The weir is submerged if

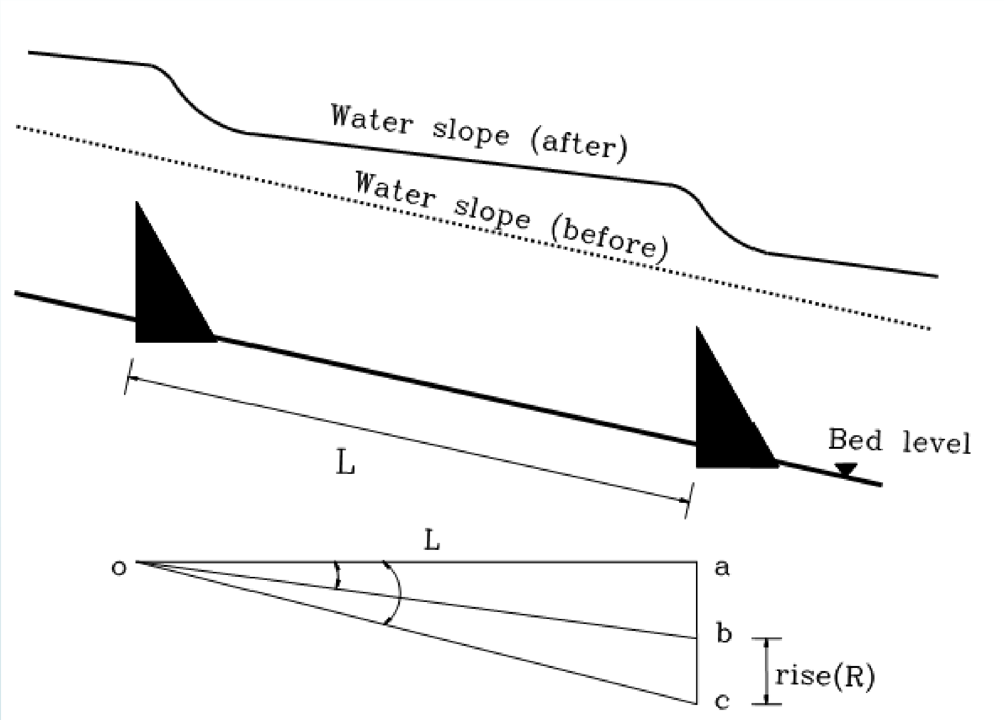
$$S = {}^{y_2}/_{y_1} \geq 0.65$$

Where y_2 is the difference between downstream water surface and the top of the weir. y_1 is the difference between upstream water surface and the top of the weir.

Drawbacks of weirs

- A weir will artificially reduce the upstream water velocity, which can lead to an increase in siltation (deposition of fine particles of silt and clay on the floor of a river).
- Weirs can also have an effect on local fauna.
- Even though the water around weirs can often appear relatively calm, they can be extremely dangerous places to boat, swim, or wade, as the circulation patterns on the downstream side—typically called a hydraulic jump— can submerge a person indefinitely.
- The weir can become a point where garbage and other debris accumulate.

Weirs for reducing water slope in steep landes



Where L is the distance between weirs.

L = R/(nature slope – required slope)

ac=L*Slope(before)

bc=-L*Slope(after)

rise (R) = ac - ab = L{Slope(before)-Slope(after)}

A weir in Shields Bridge potion of the Cache La Poudre River in Fort Collins

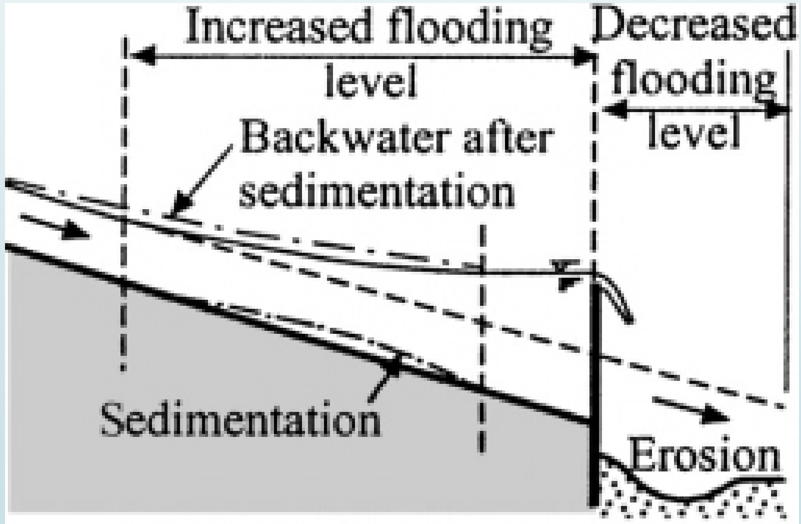
We went to this area, and saw a small weir which results in a sudden change of the slope is located in the middle of the river reach. It is estimated as1.5 meters high and 15meters wide. Because there is a lot of large boulders and branches that has been deposited both on and below the weir, we think it did not used for a long time. The downstream flow depth from the weir is about 2 or 3 ft. The upstream flow depth is deeper than the downstream flow.

Canal Headworks

- Canals deliver water from reservoirs or rivers for use as municipal drinking water or irrigation supply
- Types:
  - Lateral with damming
  - Lateral without damming
- Issues:
  - Maintain flow in canal
  - Control sediment intake
  - Facilitate fish passage

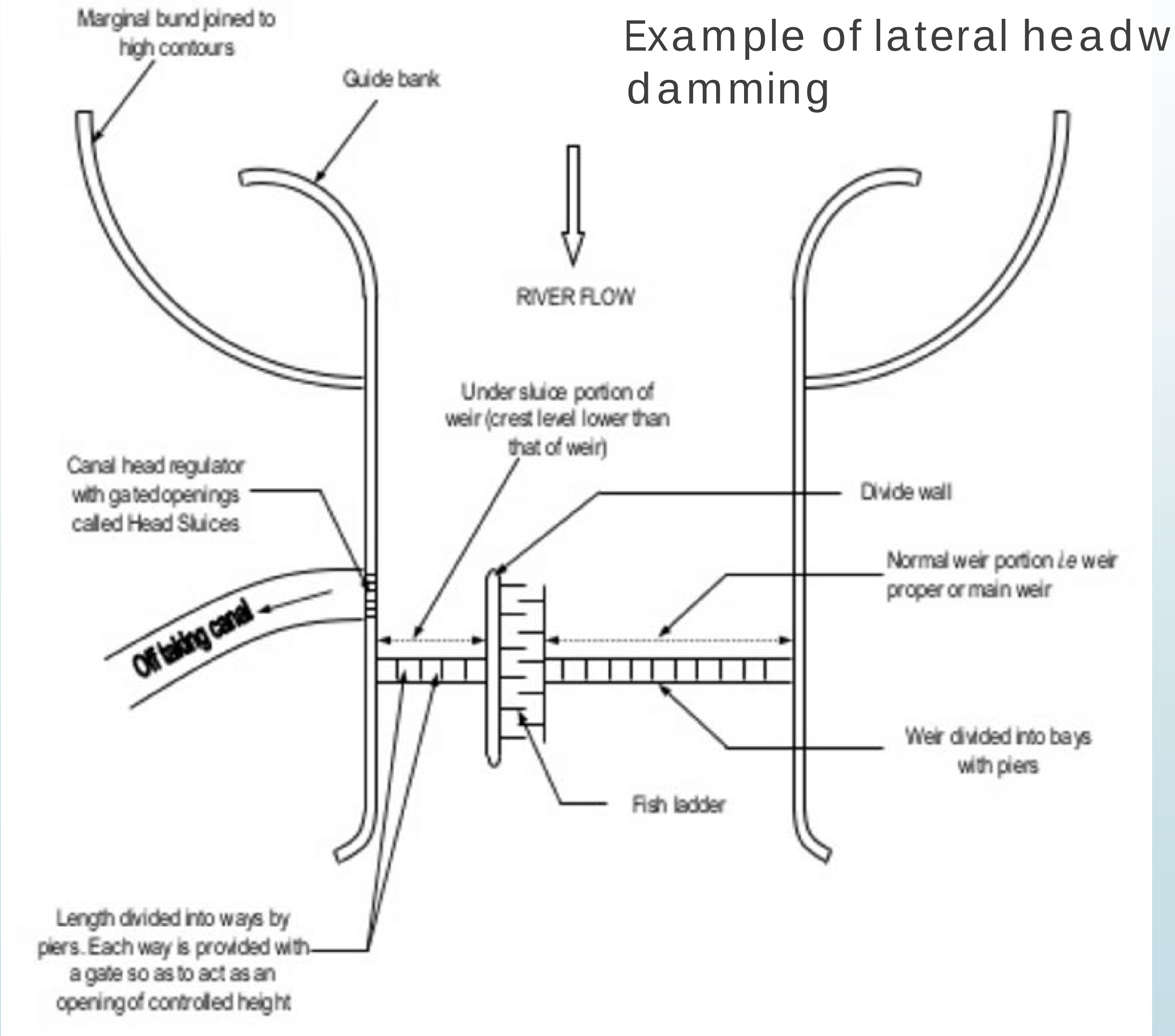
Canal Headworks

- Lateral Intake with Damming
  - Controls the water level using a weir or other hydraulic structure
  - Pros:
    - Reliable water supply during low flow
  - Cons:
    - More involved design process and high cost
    - Increased risk of flooding
    - High environmental impact (fish passage)
    - Downstream scour and upstream



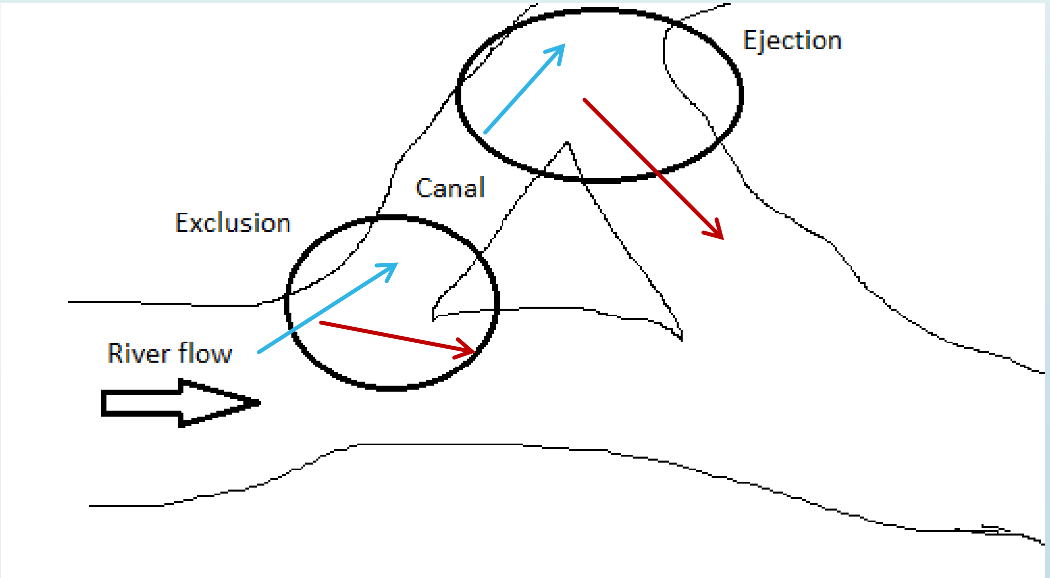
Canal Headworks

Example of lateral headworks with damming



Canal Headworks

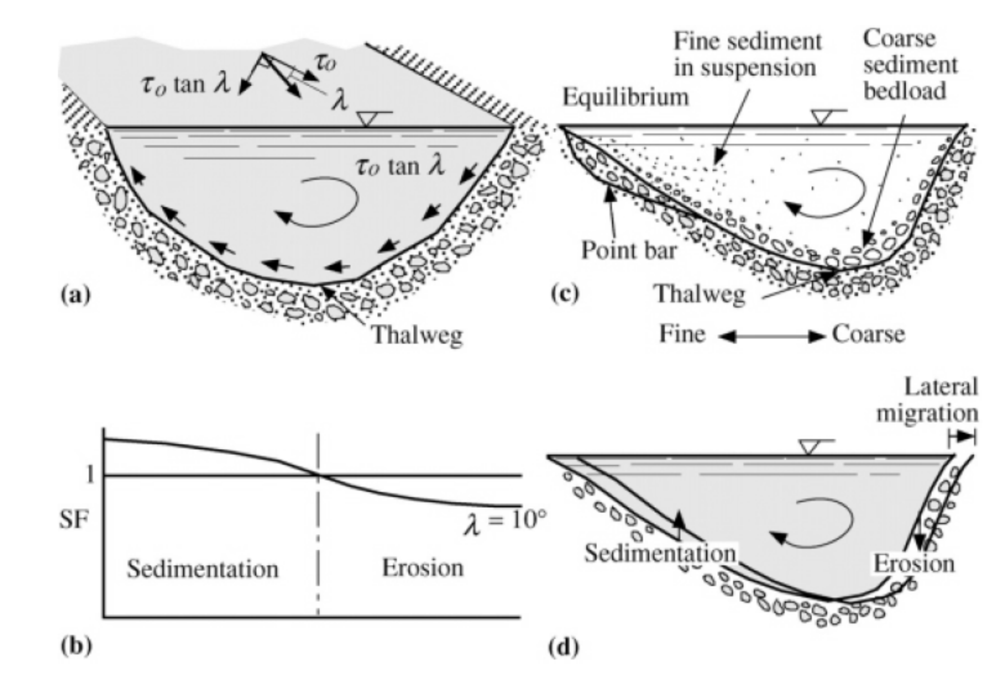
- **Sediment exclusion** – attempts to remove sediment before it enters canal
  - River curvature
  - Guide walls
  - Vanes
- **Sediment ejection** – usually used in conjunction with exclusion after the headgate
  - Tunnel ejector
  - Vortex tube
  - Settling basin



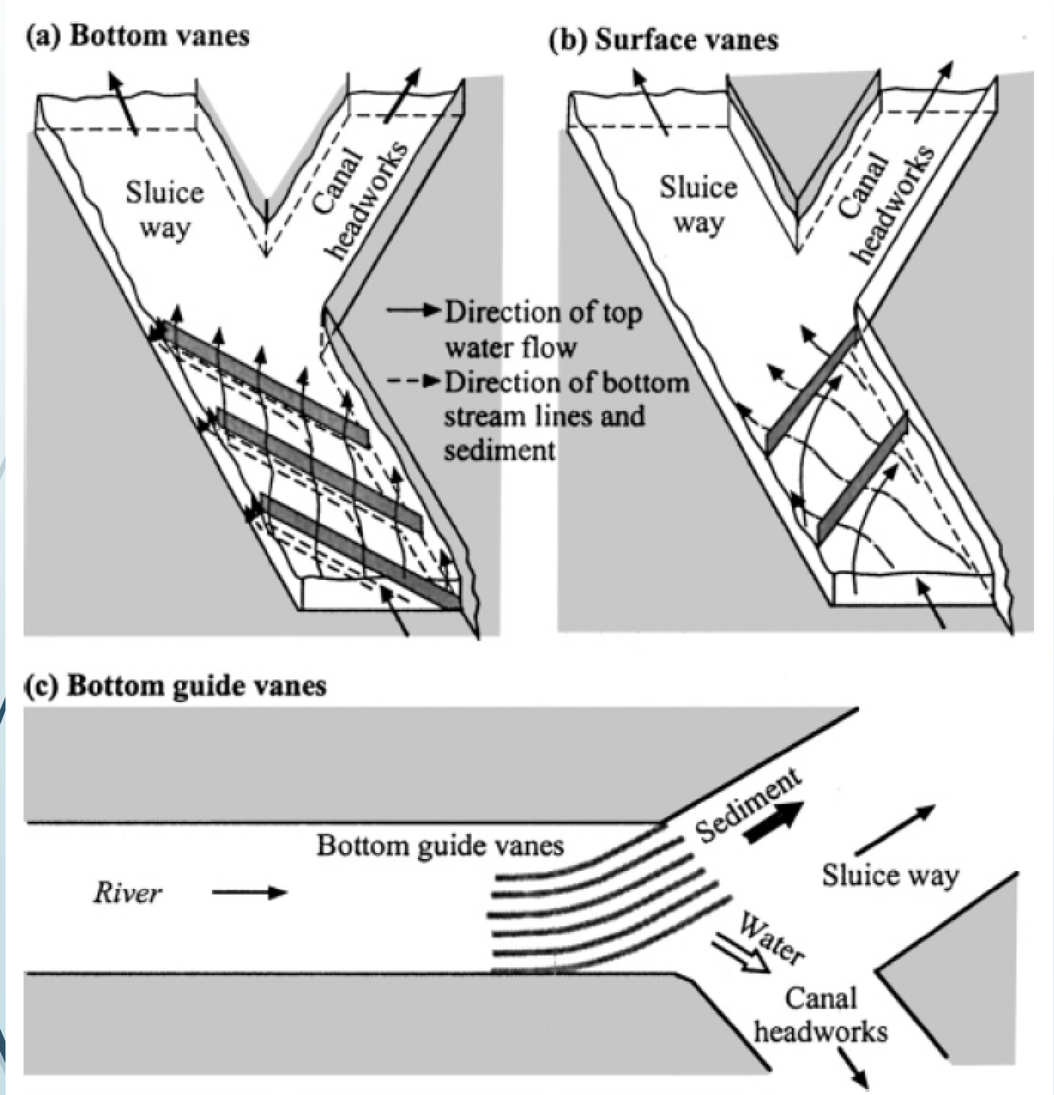
Canal Headworks

- **Sediment exclusion – river curvature**
  - Uses secondary flows to capture water with less sediment (see figure)
  - Located on the concave bank
  - River must be stable

    (no lateral migration)



Canal Headworks

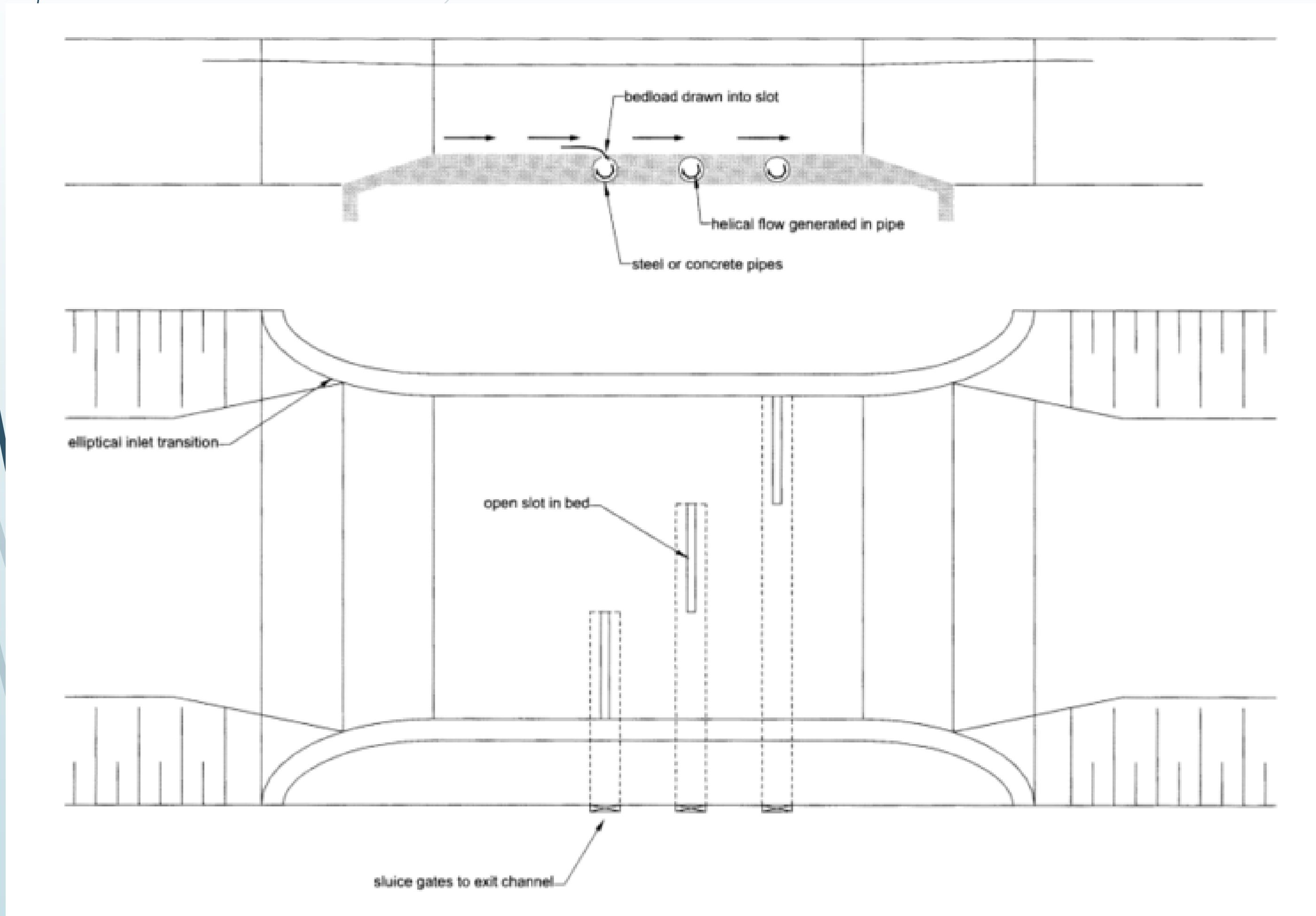


- **Sediment exclusion – guide vanes**
  - Utilize secondary flows to guide sediment away from the canal headgate
    - Bottom vanes
    - Surface vanes

Canal Headworks

- **Sediment Ejection – tunnel ejector**
  - Utilizes gravity to collect larger bedload particles in tunnels
  - A roof is placed over the tunnels to minimize turbulence
  - The tunnels guide the larger sediment back into the main channel

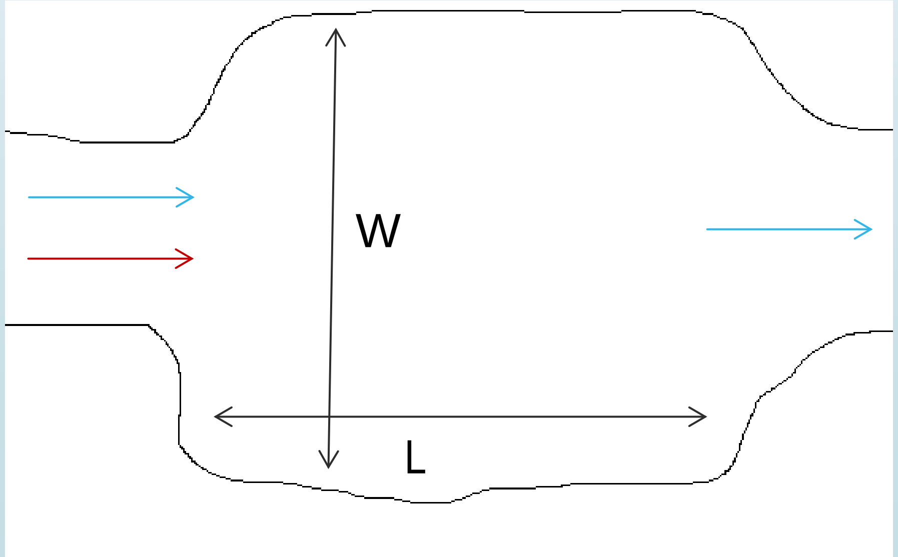
Canal Headworks



- **Sediment ejection – vortex tube**
- Effective at removing coarse bedload gravel
- Sediment enters tube slit and vortex caused by water flow flushes the tube

Canal Headworks

- **Sediment ejection – settling basin**
- Effective for both suspended and bed load
- Widens channel to decrease flow velocity and induce settling
- Must be maintained
- Requires large area
- Efficiency depends on the surface area of settling basin:



$$T_E = 1 - e^{-\frac{\omega W L}{Q}}$$

Canal Headworks

- Weirs can cut-off migrating fish routes
- Important, especially for salmonids
- Fish passage structures
  - Fish ladders create dynamic flow conditions that facilitate fish passage

Example of fish passage at diversion dam

Conclusions

- Both weirs and canal intakes can help maintain a uniform flow rate.
- They are used in conjunction to convey water
- Weirs are useful to measure the flow rate

Questions?