Hydraulics Structures

Civil Engineering Department

Tikrit University

Wesam Sameer Mohammed-Ali

Ph.D., P.E., M.ASCE, M.AWRA

Hydraulics Structures

A hydraulic structure is a structure submerged or partially submerged in any water body, which disrupts water's natural flow. 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 river's regular flow rate to power turbines. A hydraulic structure can be built in rivers, a sea, or any water body where there is a need for a change in water's natural flow.

Types of the hydraulics structures

1. Control or Regulating structures …. Barrage and Regulator.
2. Conveyance structures …. Pipelines, siphon, Tunnels, and culverts
3. Measuring structures … weirs, and spillways
4. Protective structures …. Dams
5. Energy dissipation structures …. Stilling basin, drops, and hydraulics jumps.

Steps for design an irrigation or a hydraulics structures

1. Prepare the information for design
    - The purpose function of design.
    - Discharge (maximum and minimum discharge). Usually, 1.2Q is used for max. discharge and 0.7Q are used for min. discharge.
    - Head losses
    - Upstream (U/S) and Downstream (D/S) canal information.

2. Determine the best location of the structures.

3. The shape of approaches and the other components of the structure.

4. The waterway requirements.

5. Protection against scouring.

6. The best method of dissipation energy.

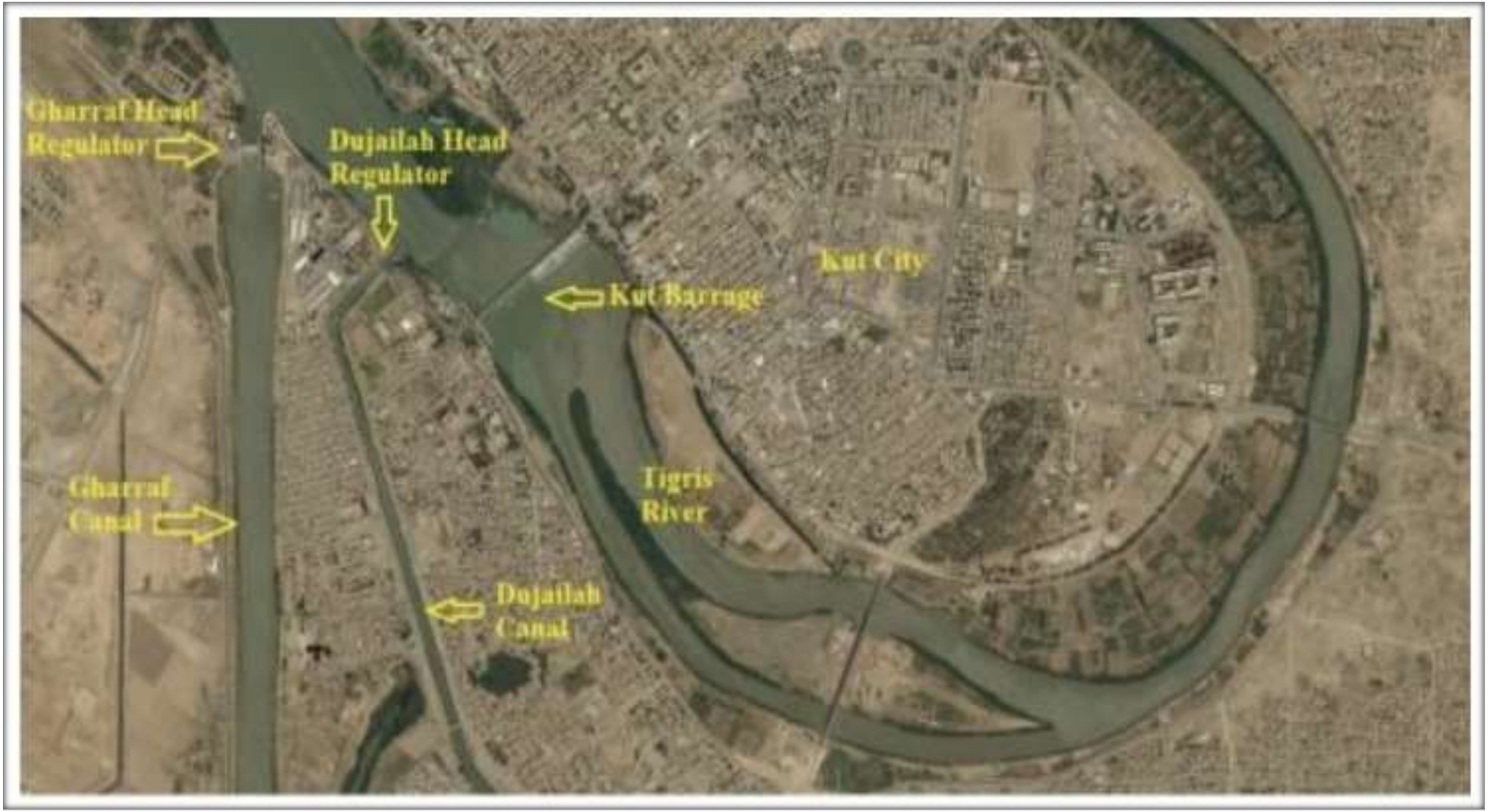
7. The forces are acting on various parts of all structures

- **<u>Regulators</u>**

A structure on a watercourse to regulate the amount of water discharge or its level.

Regulator

- River ….. it's named Barrage.
- Canal ….. it's named Cross Regulator.
- The Regulator at ahead of
- The main canal it's named Main Regulator.
- Other canal it's named Head Regulator.


Gharraf Head
Regulator
Dujailah Head
Regulator
Kut City
Kut Barrage
Tigris
River
Gharraf
Canal
Dujailah
Canal

The required data to design the Regulator

1. **River Data**

a. Low discharge

- The water level in the river.
- Bed level of the river.
- Depth of water in the river.

b. Flood discharge

- Depth of flow in the river
- The maximum water level of the river.

The required data to design the Regulator

2. Main Canal Data

a. Peak discharge

b. The water level in the main canal at the head regulator.

c. Bed level in the main canal.

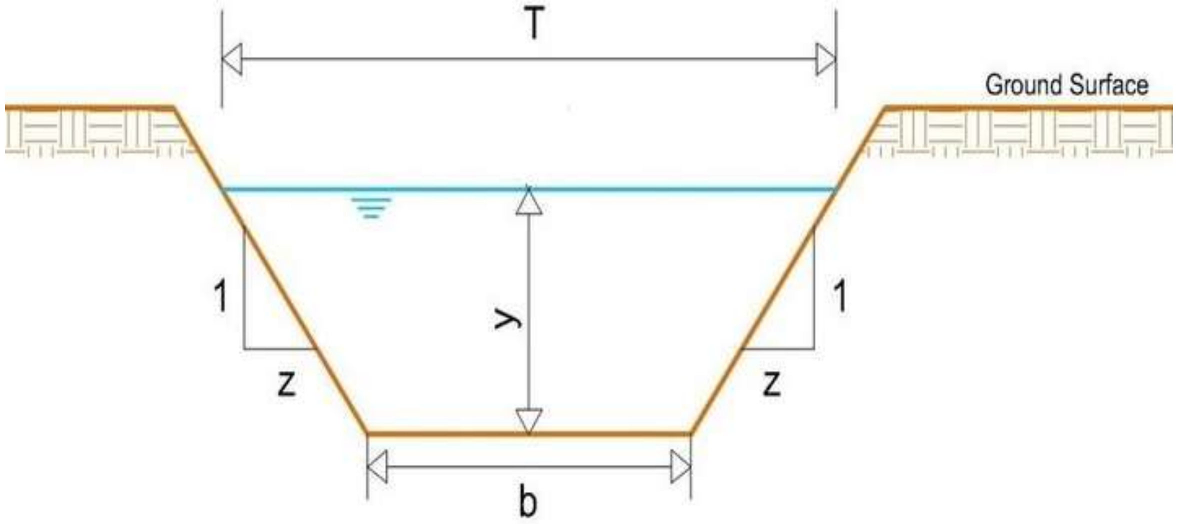
d. Depth of water in the main canal (y).

e. Side slope of the main canal (z).

f. Bed width of the main canal (b).

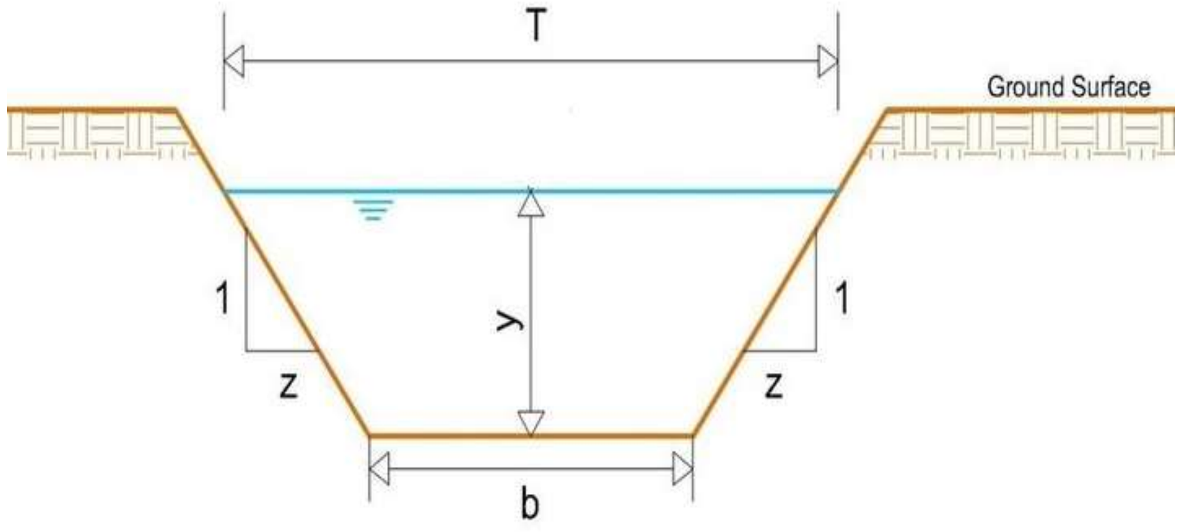
g. The longitudinal slope of the main canal (So).

h. Manning's coefficients of the main canal (n).



Manning's Equation …….

$$\boldsymbol{Q = \frac{1}{n}\ A\ R^{\frac{2}{3}}\ S_o^{\frac{1}{2}}}$$



- $A = by + zy^2$
- $P = b + 2y\sqrt{1 + z^2}$
- $R = \frac{A}{P}$

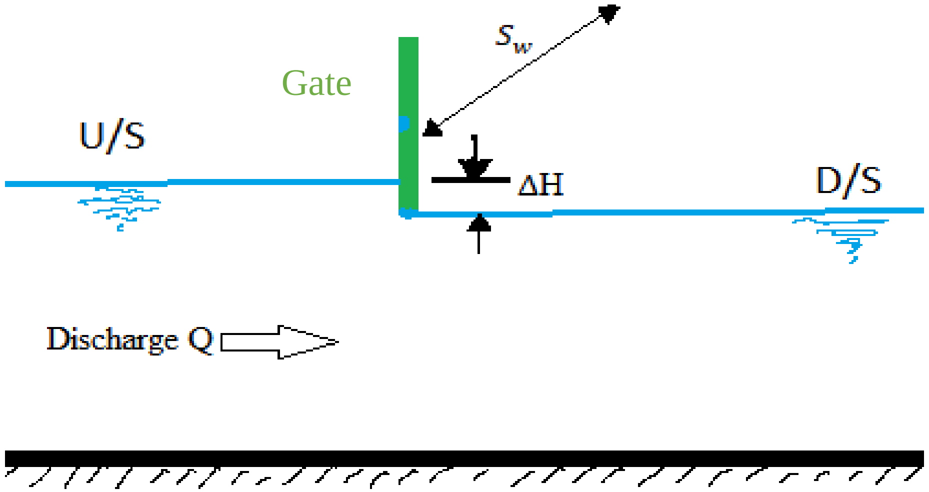
<u>Hydraulics of Regulator</u>

- Design Discharge (Q) is the flow during periods of maximum demand.

- The waterway of the Regulator (S_w).

Discharge of Regulator with Fully Opening

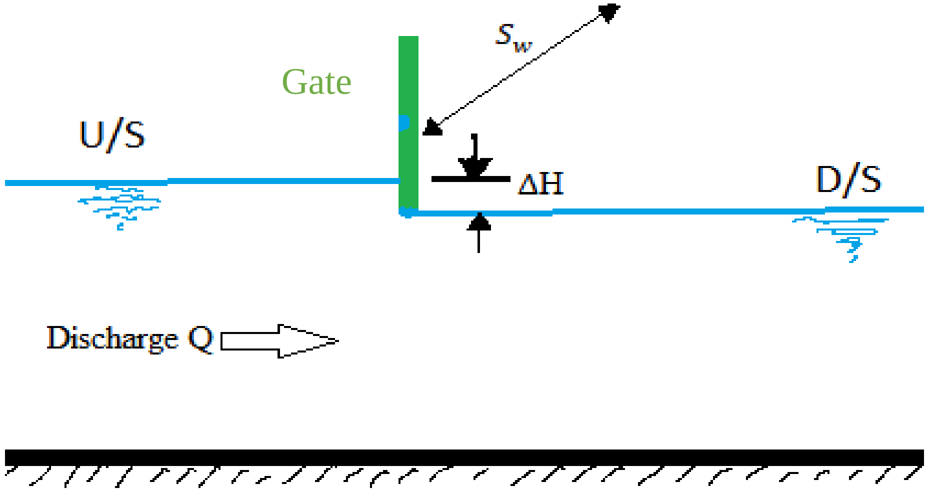
The gate dimensions are determined for the case when the gate has been *lifted completely* out of the water, and there are minimum head losses (ΔH) between the upstream and downstream regions of the flow

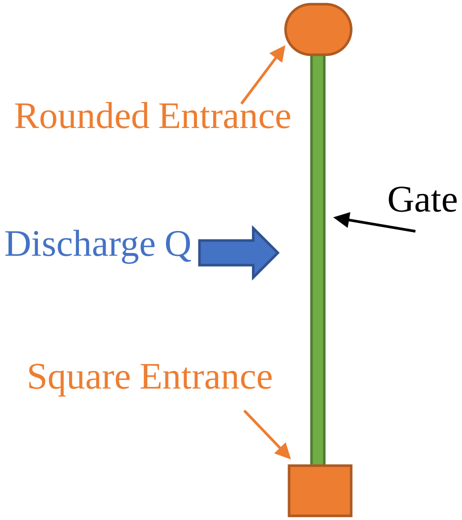


The following equation gives the discharge formula appropriated to this case: -

- $Q = C\,S_w\,y_t\sqrt{2gH_1}$

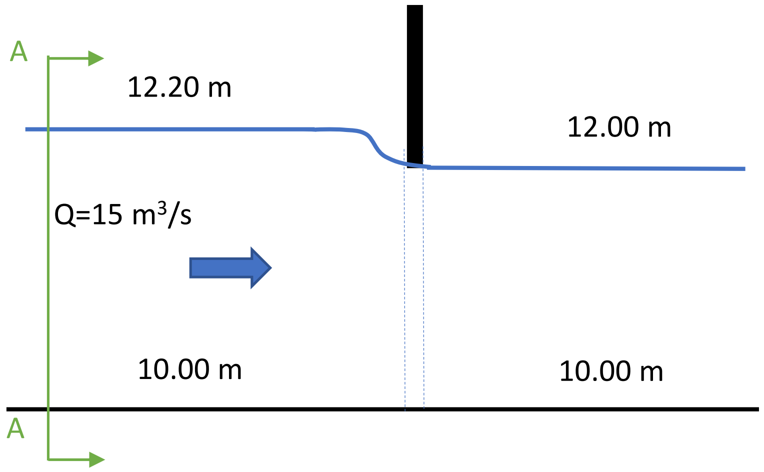
where,
Q… is the discharge
C… is equal to 0.82 for square entrance and 0.92 for rounded entrance.
Note: $C = 0.6 + 0.08S_w \leq 0.92$
y_t … is equal to D/S water level – Bed level under the gate.
H_1 … is equal to ΔH + h_v
ΔH … is equal to U/S water level – D/S water level.
h_v … is the approach velocity = $\frac{V^2}{2g}$

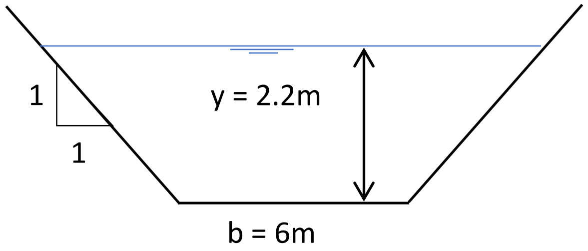




Example: Find ***the head of approach velocity (h_v)*** and the required ***regulator width (S_w)*** for the following irrigation regulator:

- U/S and D/S canal bed level =10 m.
- U/S canal water level = 12.20 m.
- D/S canal water level = 12.00 m.
- The side slope of the canal (z) = 1:1.
- The canal bed width (b) = 6 m.
- The design discharge = 15 m^3/sec .





Section A-A

<u>Solution: -</u>

- ***Approach Velocity (h_v)***

$$h_v = \frac{V^2}{2g} \qquad V = \frac{Q}{A} \qquad A = by + zy^2$$

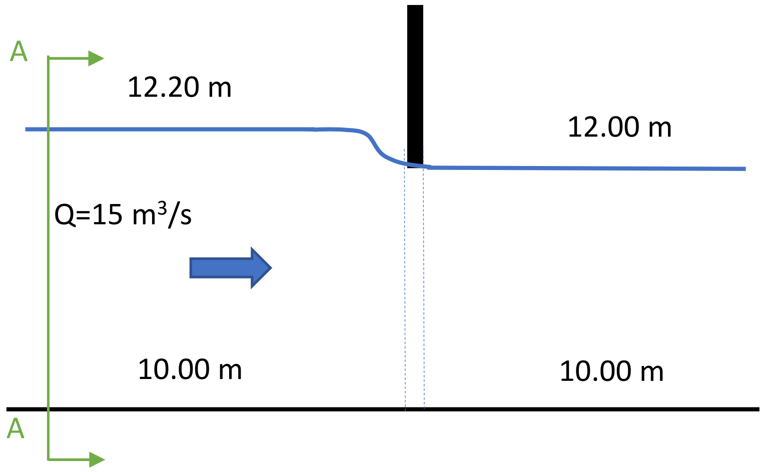
$$A = 6 * 2.2 + 1 * (2.2)^2 \quad \rightarrow \quad A = 18.04\, m^2$$

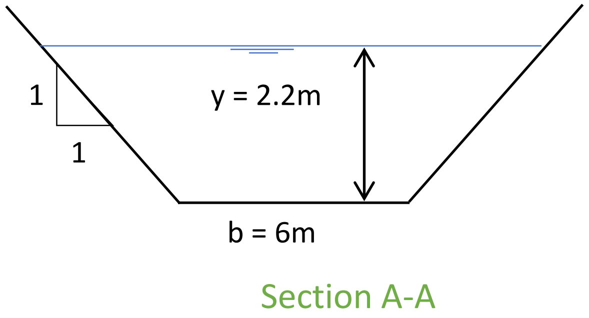
$$V = \frac{15}{18.04} = 0.831\, m/sec$$

$$h_v = \frac{(0.831)^2}{2*9.81} = 0.035\, m.$$

Example: Find ***the head of approach velocity (h_v)*** and the required ***regulator width (S_w)*** for the following irrigation regulator:

- U/S and D/S canal bed level =10 m.
- U/S canal water level = 12.20 m.
- D/S canal water level = 12.00 m.
- The side slope of the canal (z) = 1:1.
- The canal bed width (b) = 6 m.
- The design discharge = 15 m^3/sec .





- ***Regulator Width (S_w)***

$Q = C\, S_w\, y_t \sqrt{2gH_1}$ $\qquad C = 0.6 + 0.08S_w \le 0.92$

y_t = D/S water level – Bed level under the gate = 12-10 = 2 m.

$H_1 = \Delta H + h_v$, $\quad \Delta H$ = U/S water level – D/S water level = 12.2 -12= 0.2 m.

H_1 = 0.2 + 0.035 = 0.235 m.

$15 = (0.6 + 0.08S_w) * S_w * 2\sqrt{2 * 9.81 * 0.235} \quad \rightarrow \quad S_w = 3.9\ m.$

<u>Check (The Value of C):</u> ...

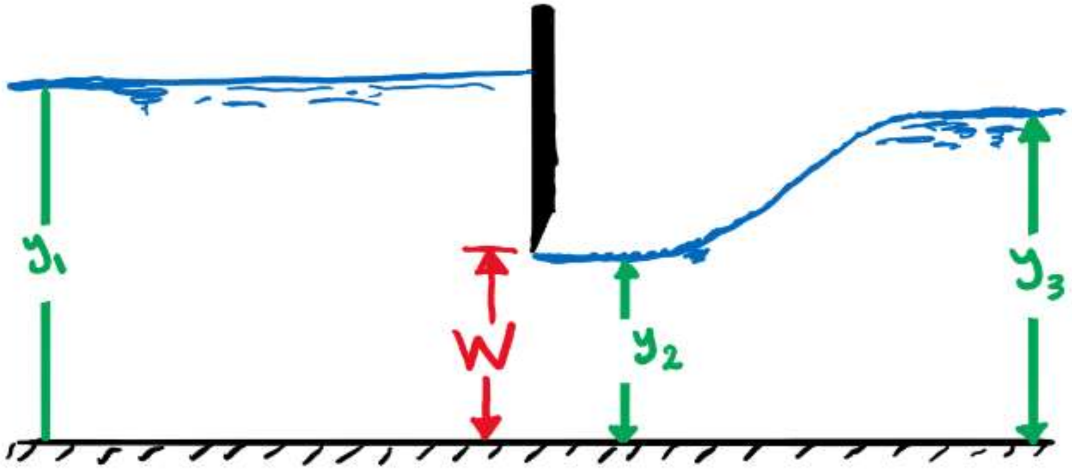
$C = 0.6 + 0.08S_w \le 0.92 \quad \rightarrow \quad 0.6 + 0.08 * (3.9) = 0.912 \le 0.92 \ldots\ldots O.K$

If C > 0.92 then use C=0.92 and find new S_w.

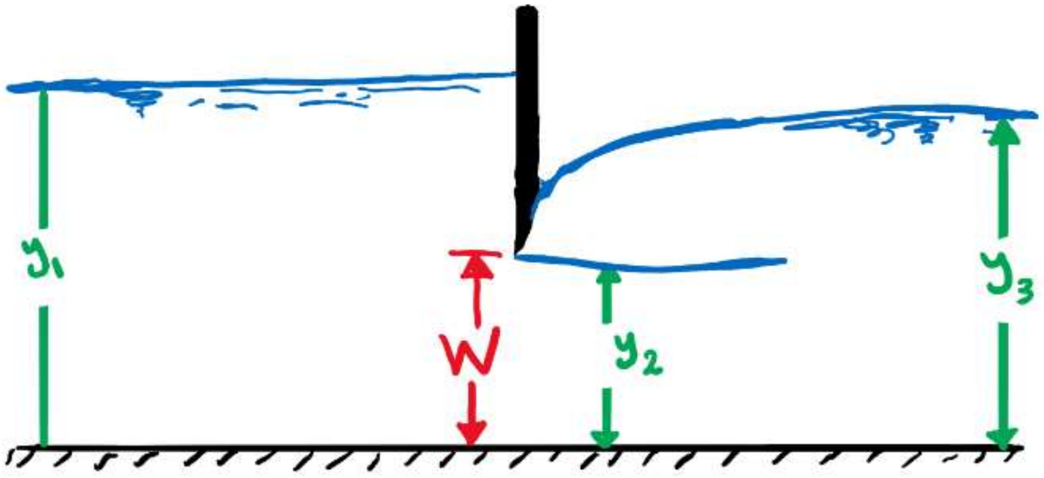
<u>**Hydraulics of Regulator**</u>

Discharge of Regulator with Partial Opening

There are two cases of flow under the gate:



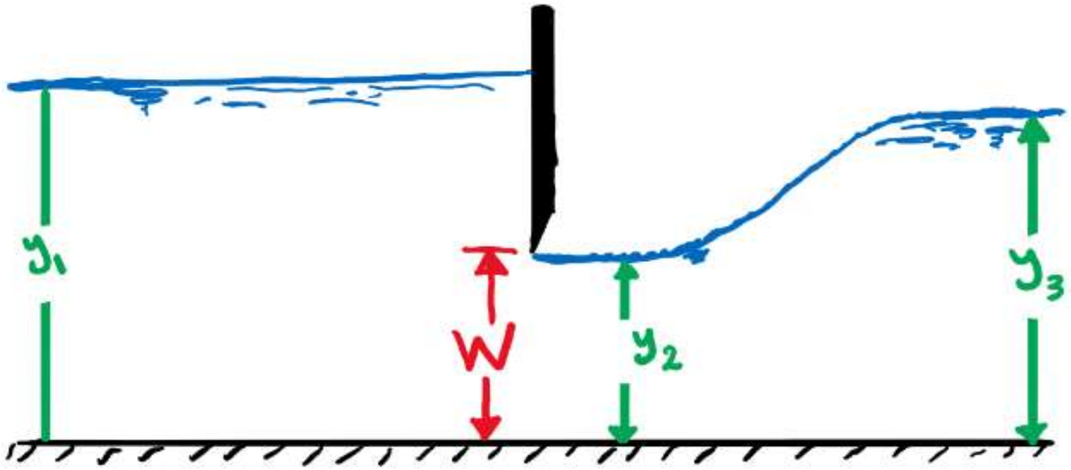
Free Flow



Submerged Flow

- ***<u>Free Flow</u>***

The *<u>Free Flow</u>* condition under the vertical gate occurs when the tailwater y_t is sufficiently low to allow a hydraulic jump to occur downstream of the gate. The discharge formula, in this case, is given by:



$$Q = C_d * S_w * W * \sqrt{2gy_1}$$

where:

Q: Design discharge

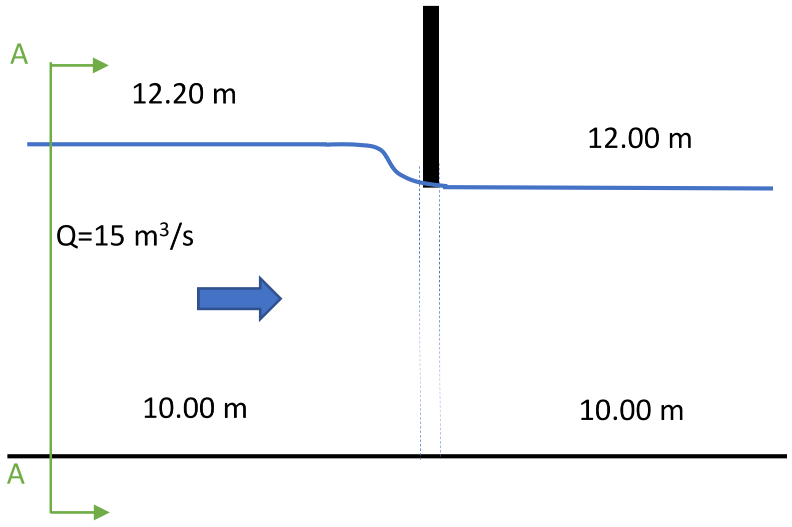
S_w: Waterway width

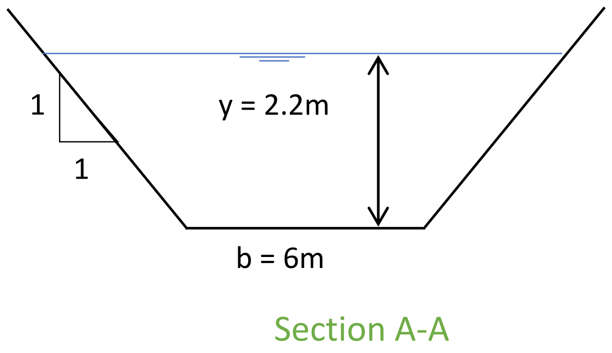
W: Vertical gate opening

y_1: U/S water depth with flood condition

$$C_d = \frac{0.61}{(1 + 0.61\,\frac{W}{y_1})^{1/2}}$$

Example: (1) For the previous example, if the floodwater level is 15m. Find W, which needed to pass the same discharge ($15\ m^3/sec$). (2) With normal U/S water level, find W which needed to pass discharge equal to ($5\ m^3/sec$)





Solution: -

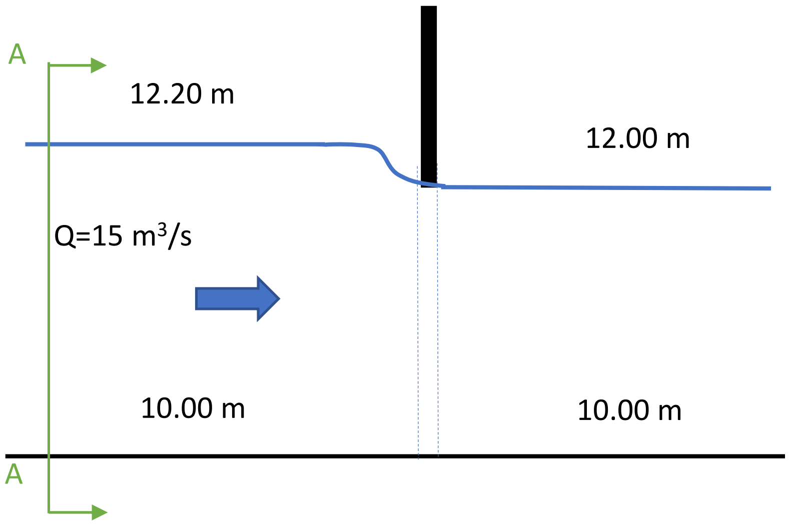
When the floodwater level is 15m and Q = 15 m³/sec

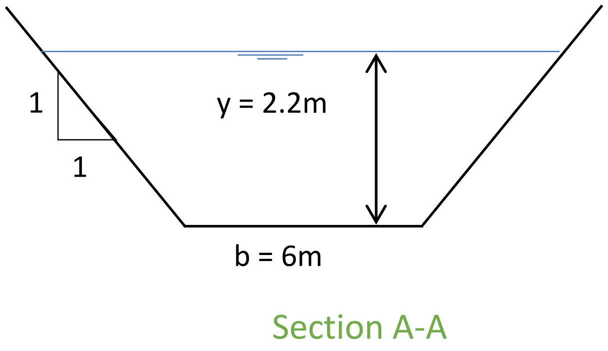
$$Q = C_d * S_w * W * \sqrt{2gy_1} \quad , \qquad y_1 = 15 - 10 = 5m$$

$$15 = \frac{0.61}{(1+0.61\frac{W}{5})^{1/2}} * 3.9 * W * \sqrt{2 * 9.81 * 5}$$

W= 0.66 m

Example: (1) For the previous example, if the floodwater level is 15m. Find W, which needed to pass the same discharge (15 m^3/sec). (2) With normal U/S water level, find W which needed to pass discharge equal to (5 m^3/sec)





When the flow at normal level 12.2m and Q = 5 m^3/sec

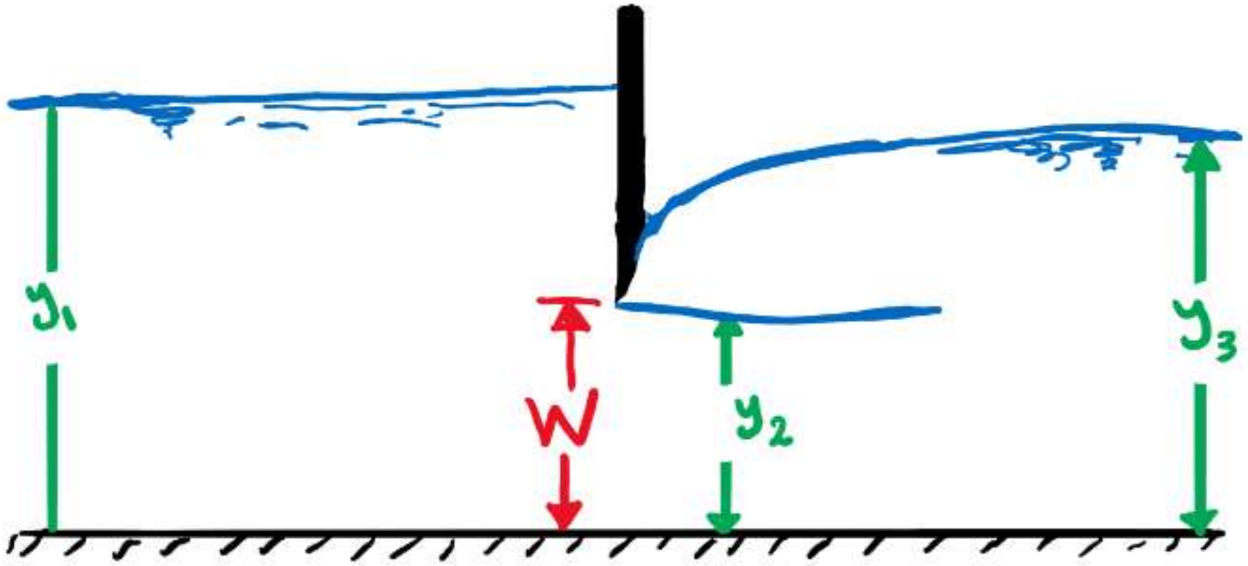
Q = 5 m^3/sec , $y_1 = 12.2 - 10 = 2.2\ m$

$$5 = \frac{0.61}{(1+0.61\frac{W}{2.2})^{1/2}} * 3.9 * W * \sqrt{2 * 9.81 * 2.2}$$

W= 0.33 m

- ***<u>Submerged Flow</u>***

When tail water y_t raise, the jump is downstream, and flow is submerged, affecting the discharge coefficient C_d. The easy method adopted to use the curve, which is plotted from energy and moment equations.



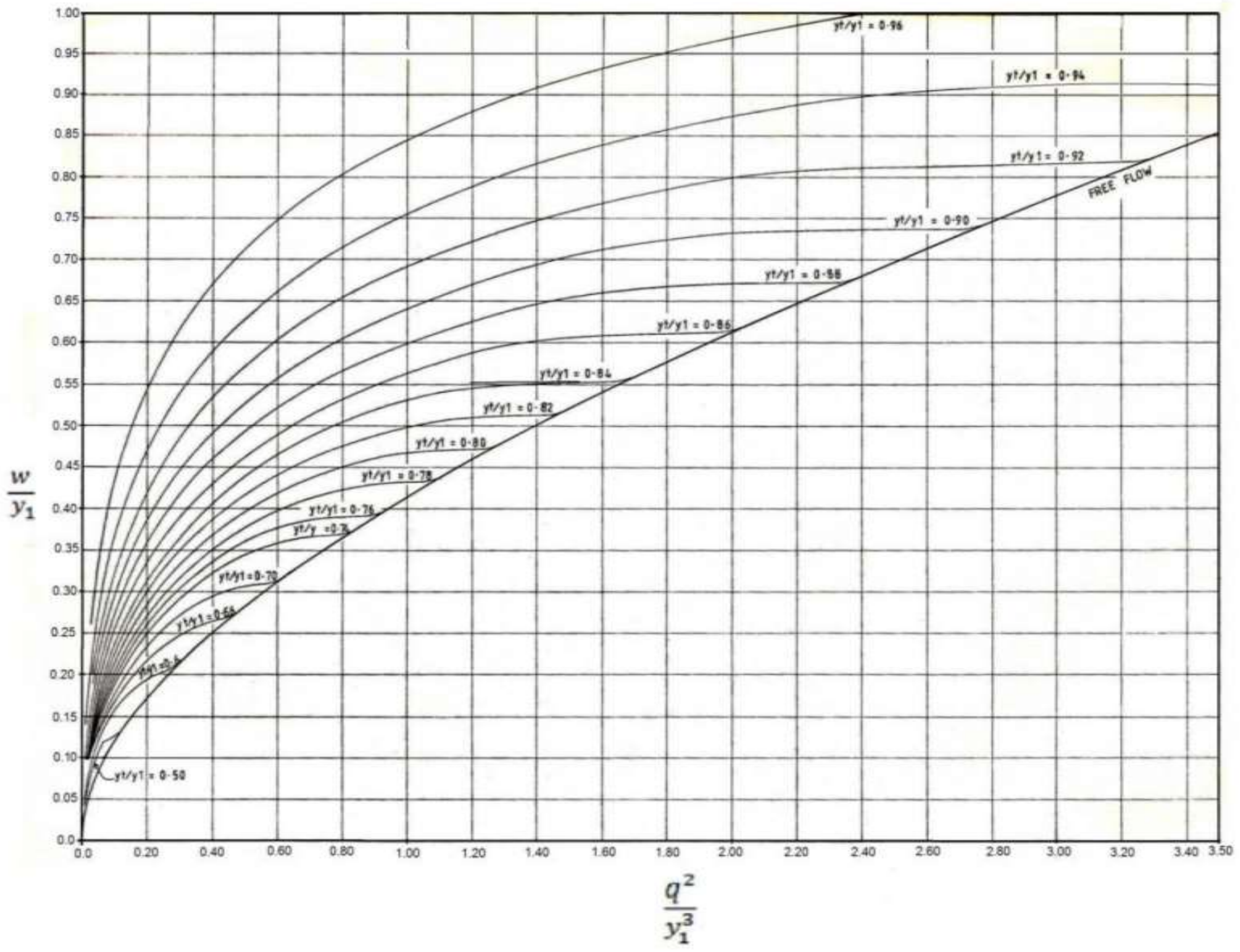
- ***Submerged Flow***

$$q = \frac{Q}{S_w} \text{ m}^3\text{/sec/m} \longrightarrow \frac{q^2}{{y_1}^3}$$

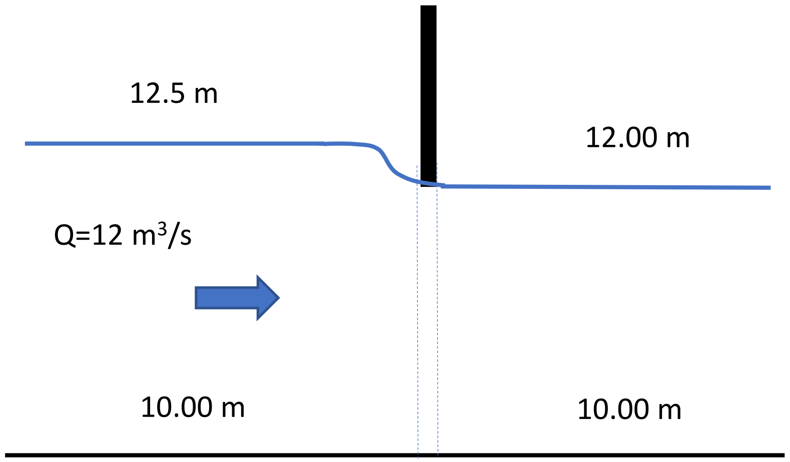
y_t = D/S Water Level – Bed Level Under the Gate

y_1: U/S water depth with flood condition

$$\frac{y_t}{y_1}$$



Example: For the previous example. Find the gate opening W when the flood level at U/S water level equal 12.5m and the discharge equal to 12m^3/sec. *Assume Submerged Flow*.



Solution:

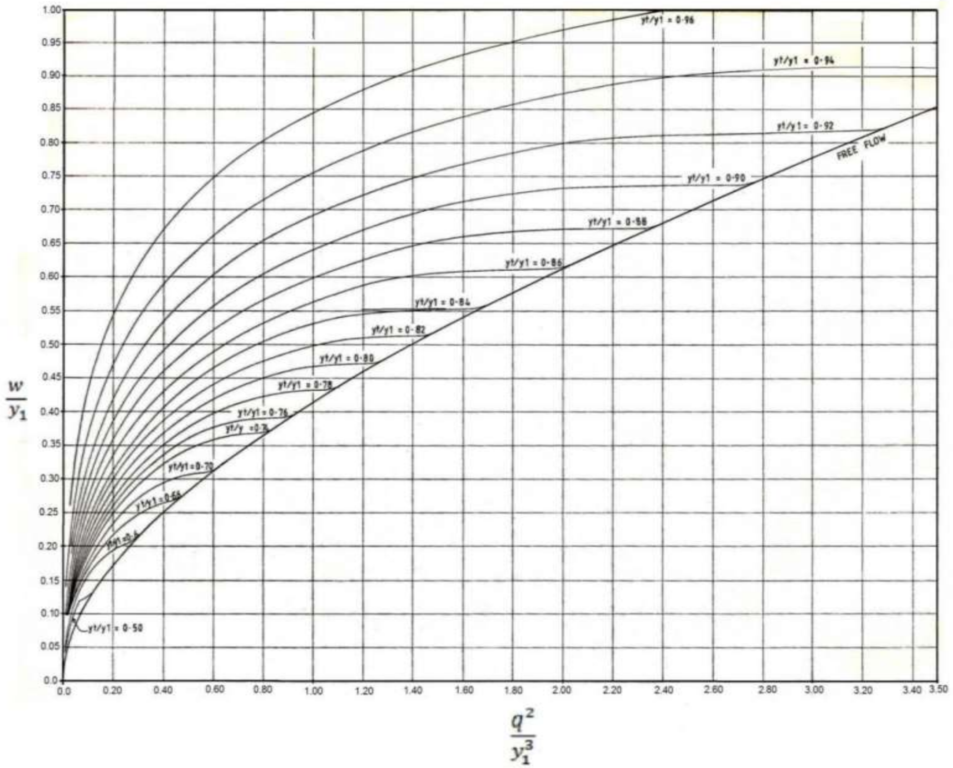
$$q = \frac{Q}{S_w} = \frac{12}{3.9} = 3.076\, m^3/sec\,/m \qquad y_1 = 12.5 - 10 = 2.5m$$

$$\frac{q^2}{{y_1}^3} = \frac{3.076^2}{2.5^3} = 0.605 \qquad \frac{y_t}{y_1} = \frac{2}{2.5} = 0.8$$

$$\frac{W}{y_1} = 0.42 \qquad W = 0.42 * y_1$$

$$W = 0.42 * 2.5$$

$$W = 1.05\, m$$



Discharge of Regulator with Fully Opening

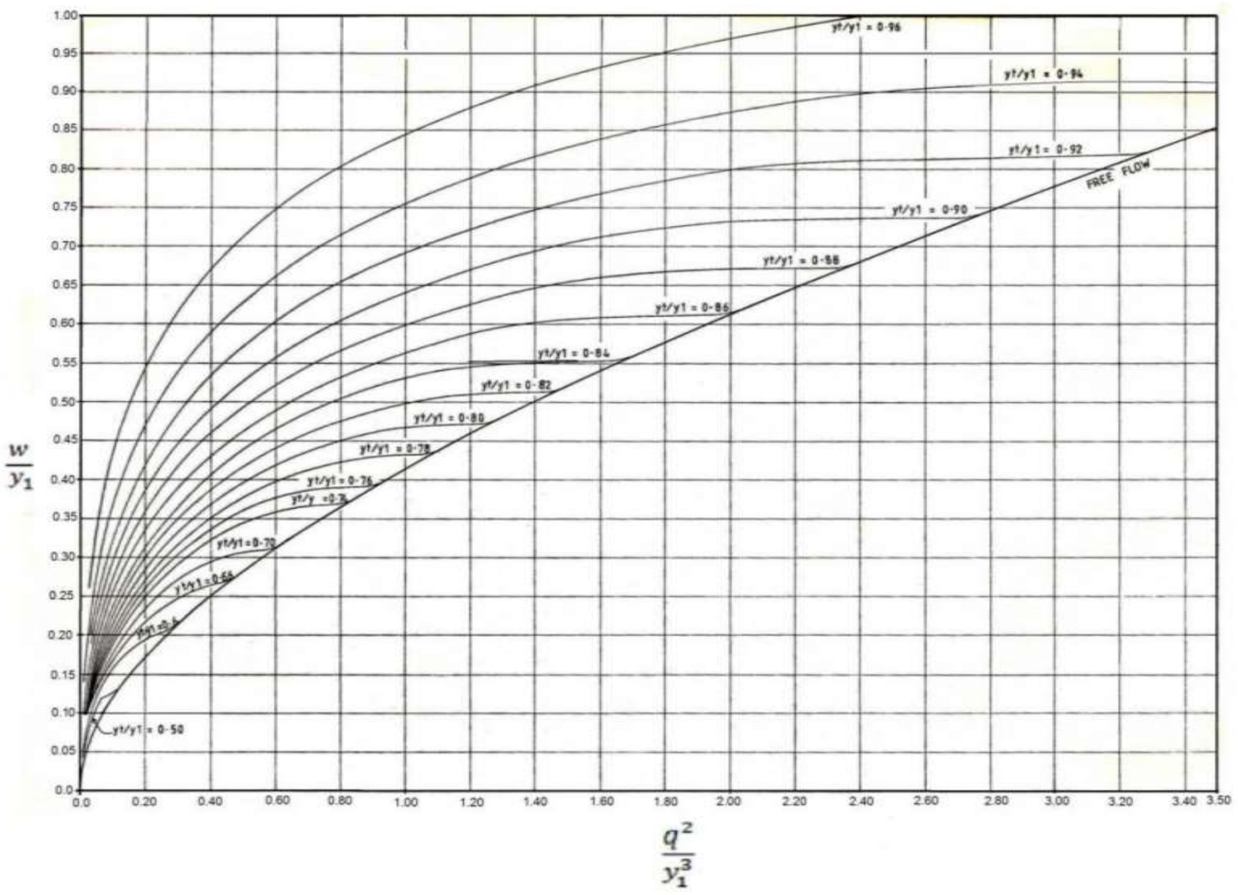
$$Q = C\, S_w\, y_t \sqrt{2gH_1}$$

Discharge of Regulator with Partial Opening

- ***Free Flow***

$$Q = C_d * S_w * W * \sqrt{2gy_1}$$

- ***Submerged Flow***



Hydraulics Structures

Civil Engineering Department

Tikrit University

Wesam Sameer Mohammed-Ali

Ph.D., P.E., M.ASCE, M.AWRA