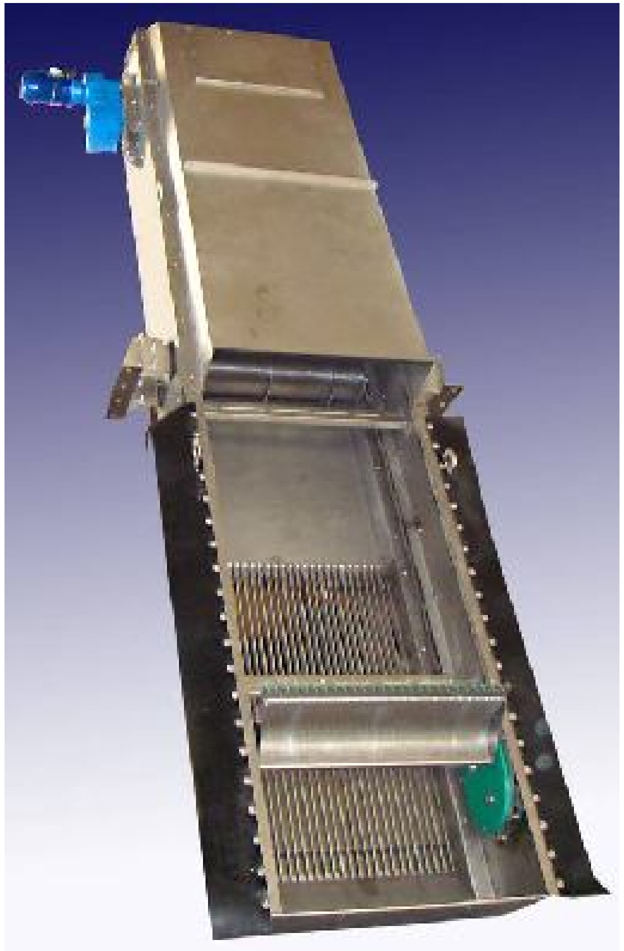
2. Preliminary Treatment

2.1 Bar screens

Manual Bar Screen



Mechanical Bar Screen

Bar screens

Screens are used in wastewater treatment for the removal of coarse solids. Screens are either manually or mechanical cleaned.

Characteristics of manual bar screen

- Bar spacing is in range of 2-5 cm
- The screen is mounted at an angle of 45-70 from horizontal
- Bars are usually 1 cm thick, 2.5 wide
- Minimum approach velocity in the bar screen channel is 0.45 m/s to prevent grit deposition.
- Maximum velocity between the bars is 0.9m/s to prevent washout of solids through the bars.

Characteristics of mechanical bar screen

- Bar spacing is in range of 1.5-4 cm
- The screen is mounted at an angle of 70- 90 from horizontal
- Bars are usually 1 cm thick, 2.5 wide
- Minimum approach velocity in the bar screen channel is 0.45 m/s to prevent grit deposition.
- Maximum velocity between the bars is 0.9 m/s to prevent washout of solids through the bars.

Design of the bar screen channel (Approach Channel)

The cross section of the bar screen channel is determined from the continuity equation:

$$Q_d = A_c V_a$$

$$A_c = \frac{Q_d}{V_a}$$

$$A_c = W \bullet d$$

Q_d = design flow, m^3/s

A_c = channel cross section, m^2

V_a = Velocity in the approach channel, m/s

W= channel width, m

d = water depth in the channel, m

Usually, rectangular channels are used, and the ratio between depth and width is taken as 1.5 to give the most efficient section:

$$\frac{d}{W} = 1.5$$

The head loss through the bar screen is given by the following equation:

$$H_l = \frac{(V^2_b - V^2_a)}{2g} \bullet \frac{1}{0.7}$$

H_l = head loss

V_a = approach velocity, m/s

V_b = Velocity through the openings, m/s

g = acceleration due to gravity, m/s^2

The cross section of the bar screen is given by the following equation:

$$As = \frac{Ac}{\sin\theta}$$

A_s = bar screen cross section, m^2

Θ = inclination angle of the screen

The net area of the bar screen available for flow is given by the following equation:

$$A_{net} = As \frac{S}{S + t_{bar}}$$

S = space between bars ,m

t_{bar}= thickness of the screen bars, m

The number of bars in the screen is given by the following equation:

$$n\ t_{bar} + (n-1)S = W$$

Example 1

A manual bar screen is to be used in an approach channel with a maximum velocity of 0.60 m/s, and a design flow of 300 L/s. the bars are 10 mm thick and openings are 3 cm wide, the angle of inclination is 50°. Determine:

The cross section of the channel, and the dimension needed
The velocity between bars
The head loss in meters
The number of bars in the screen

1. $A_c = Q_d/V_a = 0.3/0.60 = 0.5\ m^2$

$A_c = W \times 1.5W = 1.5\ W \times W$

W = 0.577 m, Depth (d) = 1.5 W = 0.866 m

Take W = 0.60 m, Depth (d) = 0.833 m, Ac = 0.50 m^2

$$As = \frac{Ac}{\sin\theta} = \frac{0.50}{\sin 50} = 0.653\ m^2$$

$$A_{net} = As\frac{S}{S + t_{bar}}$$ = 0.653(3/3+1) = 0.49 m^2

From continuity equation: $V_a A_c = V_b A_{net}$

$V_b = 0.60 \times 0.5/0.49 = 0.612$ m/s < 0.9 m/s ok

3. Head loss:

$$H_l = \frac{(V^2{}_b - V^2{}_a)}{2g} \bullet \frac{1}{0.7}$$

-For clean screen

$$H_l = \frac{(0.612^2 - 0.60^2)}{2 \bullet 9.81} \bullet \frac{1}{0.7}$$ = 0.0011 m

-For 45% clogged screen

$$(A_{net})^\backslash = 55\% A_{net}$$

V_b= 0.60x 0.5/(0.49*0.55) = 1.11 m/s

$$H_l = \frac{(1.11^2 - 0.60^2)}{2 \bullet 9.81} \bullet \frac{1}{0.7}$$ = 0.063 m

4. n t_{bar} + (n-1)S = W

n x 1 + (n-1) x 3= 56

n= 14.75 = 15

2.2 Grit Removal

Settling Theory

$$V_s = \sqrt{\frac{4g(\rho_s - \rho)d}{3C_D\rho}}$$

V_s = settling velocity of particles

ρ_s = density of particles

ρ = liquid density

d = particle diameter

C_D = drag coefficient

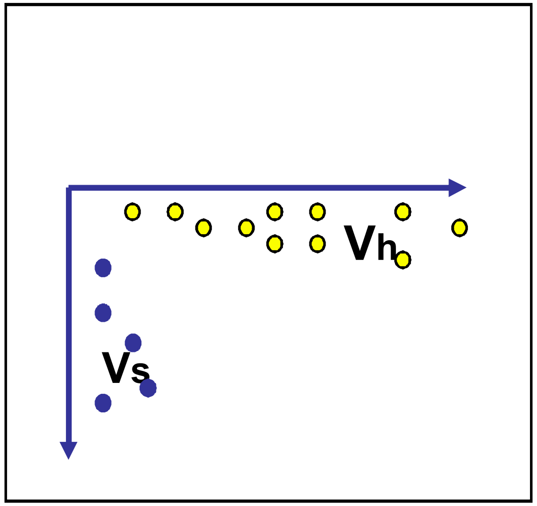
$$V_h = \sqrt{\frac{8\beta(\rho_s - \rho)gd}{f}}$$

V_h = scour velocity

β = Friction factor of particles

f = Darcy-weisbach friction factor

Particle Density (kg/m^3)	Settling Velocity (Vs) m/h	
	0.1 mm	0.2 mm
Sand 2650	**25**	**74**
Organic matter 1200	**3.0**	**12**
Organic matter 1020	**0.3**	**1.2**



Example 2

A suspension contains particles of grit with a diameter of 0.2 mm and specific gravity of 2.65. For particles of this size C_D= 10, f= 0.03, and β = 0.06. The suspension also contains organic solids of same size for which the specific gravity is 1.10 and β and f are unchanged. Determine the settling velocity of the grit and the scour velocity of grit and organic material.

Solution

$$V_s = \sqrt{\frac{4g(\rho_s - \rho)d}{3C_D\rho}} \qquad V_s = \sqrt{\frac{4x980(2.65-1)x0.02}{3x10x1}}$$ **= 2.1 cm/s**

$$V_h = \sqrt{\frac{8\beta(\rho_s - \rho)gd}{f}} \qquad V_h = \sqrt{\frac{8x0.06(2.65-1)x980x0.02}{0.03}}$$ **= 23 cm/s**

$$V_h = \sqrt{\frac{8x0.06(1.10-1)x980x0.02}{0.03}}$$ **= 5.6 cm/s**

Grit chamber control device design

- The horizontal velocity is very important to the proper function of the grit chamber
- The velocity can be held constant regardless of the flow, by proper combination of basin cross section and the control device.
- For a constant velocity, the basin cross section must be proportioned so that:

V_h = Constant

The condition of constant velocity is maintained, provided the width of the basin varies so that $Y^{n-1} = KX$. where n is the discharge coefficient of the control section.

- If the control section is rectangular in cross section (like a Parshall flume) n will be approximately 1.5, thus $Y = CX^2$ and the channel cross section must be parabolic.
- With a proportional flow weir , n= 1 and X=C. The channel cross section in this case is rectangular , which somewhat simplified construction.
- The actual proportions of the channel and weir must be selected together to provide the necessary conditions for grit removal.

Example 3

Design a grit –removal system consisting of three identical channels for a plant which has a max flow of 65,000 m^3/day, an average flow of 50,000 m^3/day and a minimum flow of 20,000 m^3/day. Use parabolic channels. The design velocity (V_h) is 0.25 m/s.

Solution

The max flow per channel will be 65,000/3= 21666 m^3/day = 0.25 m^3/s

The average flow per channel will be 50,000/3= 16,666 m^3/day = 0.19 m^3/s.

The minimum flow per channel will be 20,000/3= 6,666 m^3/day = 0.077 m^3/s.

$A = Q/V$

$A_{max.} = 0.25/0.25 = 1.0\ m^2$

$A_{average} = 0.19/0.25 = 0.76\ m^2$

$A_{min} = 0.077/0.25 = 0.31\ m^2$

For parabolic channel A= 2/3* W*D

The channel in principal, can have any a appropriate combination of width and depth.

For width of 1.5 m at a maximum depth should equal:

$A_{max} = 1.0 = 2/3 * 1.5 * D_{max}.$

$D_{max} = 1.0$ m

The total energy head in the flume flow at Q_{max} is :

$V_h^2/2g + D = 1.0$ m $(V_h^2/2g)$ = small value

The control section will produce critical depth, thus, in the control $V_h = V_c$ and $d_c = V_c^2/g$.

The total energy head in the control is

$v_c^2/g + V_c^2/2g$.

If we assume the head loss in the control is 10% of the velocity head, then

$D = V_c^2/g + V_c^2/2g + 0.1\ V_c^2/2g = 3.1\ V_c^2/2g$

$D = 3.1\ V_c^2/2g$ $\quad V_c = (2\ g\ D/\ 3.1)^{0.5}$

At a maximum flow, with D = 1 m ,

$V_c = (2*9.8*\ 1/3.1)^{0.5} = 2.5$ m/s

$d_c = V_c^2/g$ $\quad d_c = 0.64$ m

And the width of control device section

$w = Q\ /\ (V_c\ *d_c) = 0.25\ /(2.5\ *\ 0.64) = 0.16$ m

For other flow conditions:

$d_c = (Q^2/w^2\ g)^{1/3}$

$D = (3.1/2)\ *\ d_c$

$W = 3/2\ *\ (A/D)$

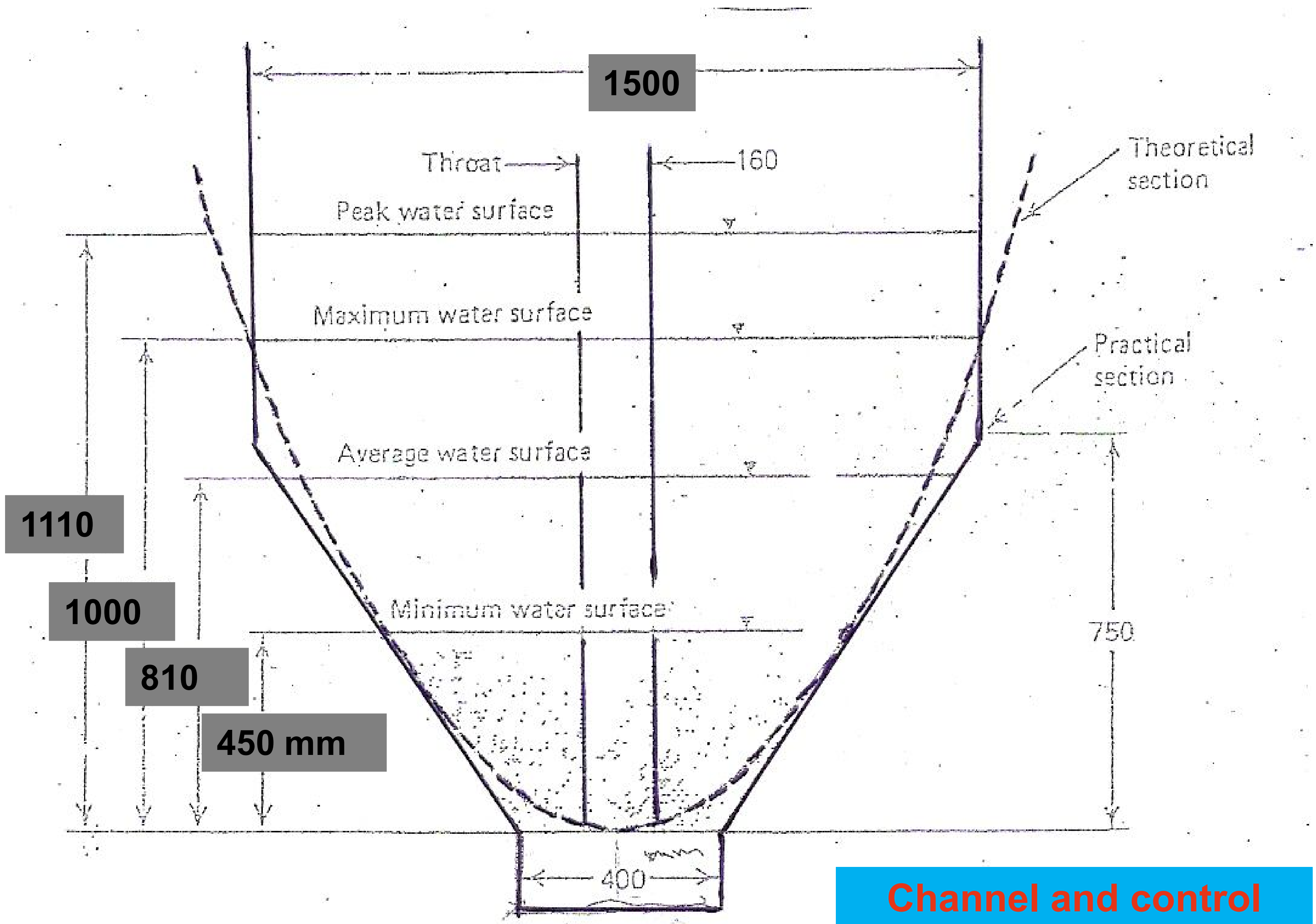
The length of the basin depends on the ratio of settling velocity and horizontal velocity.

$V_h/V_s = L/D$ **at peak flow**

$L = D\ (V_h/V_s)$

The length of the channel = 1.11 (0.25/0.02) = 13.2 m

Q (m^3/s)	Channel			Control device	
	A (m^2)	D (m)	W (m)	d_c (m)	w (m)
0.077	0.31	0.45	1.03	0.29	0.16
0.19	0.76	0.81	1.41	0.52	0.16
0.25	1.0	1.0	1.50	0.64	0.16
0.31	1.24	1.11	1.68	0.72	0.16



Channel and control device cross section

Example 5

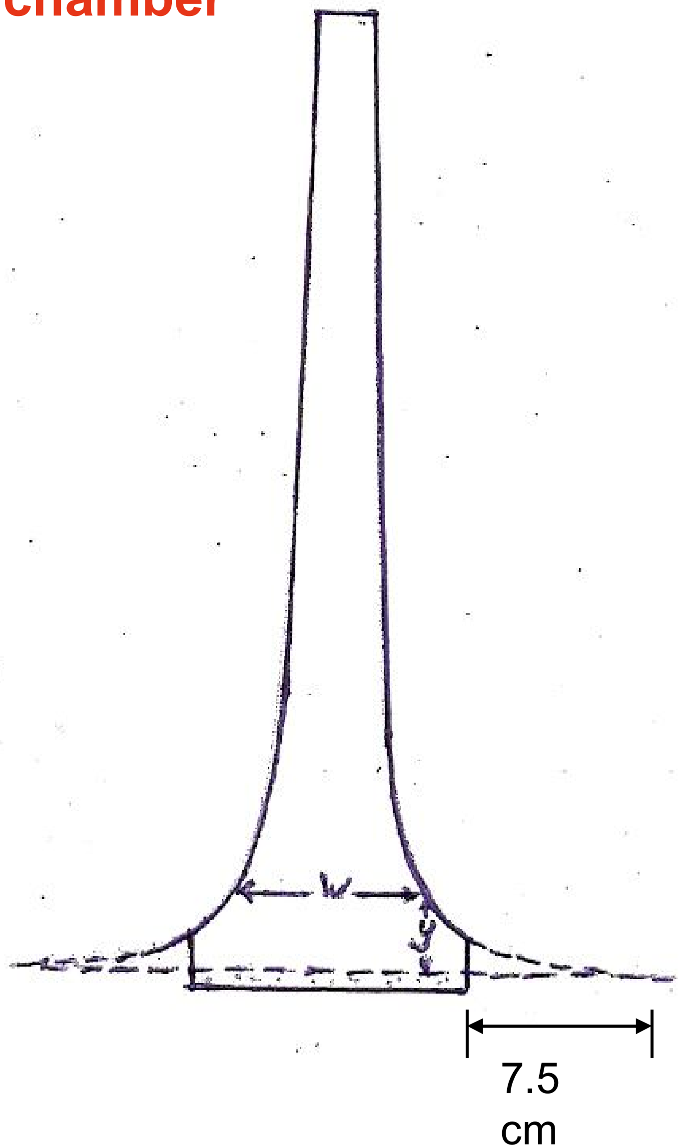
Design a set of rectangular grit basins with proportional flow weir for a plant which has a max flow of 65,000 m^3/day, an average flow of 50,000 m^3/day and a minimum flow of 20,000 m^3/day. Use three basins. Make the max depth equal to the width. The design velocity (V_h) is 0.25 m/s.

Solution

The max flow per channel is: 65,000/3= 21666 m3/day = 0.25 m3/s The average flow per channel is: 50,000/3= 16,666 m3/day = 0.19 m3/s. The minimum flow per channel is: 20,000/3= 6,666 m3/day = 0.077 m3/s. *A = Q/V A_{max} = 0.25/0.25 = 1.00 m2. *The depth D = W = 1.00 m . *The length of the channel = L L = D (Vh/Vs) L=1.00 (0.25/0.021) = 11.90 m	* The equation used to calculate y in the table to the right is: Y= Q/(Vh*W), for example Q= 0.077m3/s Y= 0.077/(0.25*1.0)= 0.308 m= 308 mm y = (2/3.1) *Y = (2/3.1) *308 = 198.7 mm *The weir must be shaped so that: $Q = 8.18 * 10^{-6} wy^{1.5}$ w= width of the proportional weir at depth (y). for example : y= 199 mm w= 106 mm

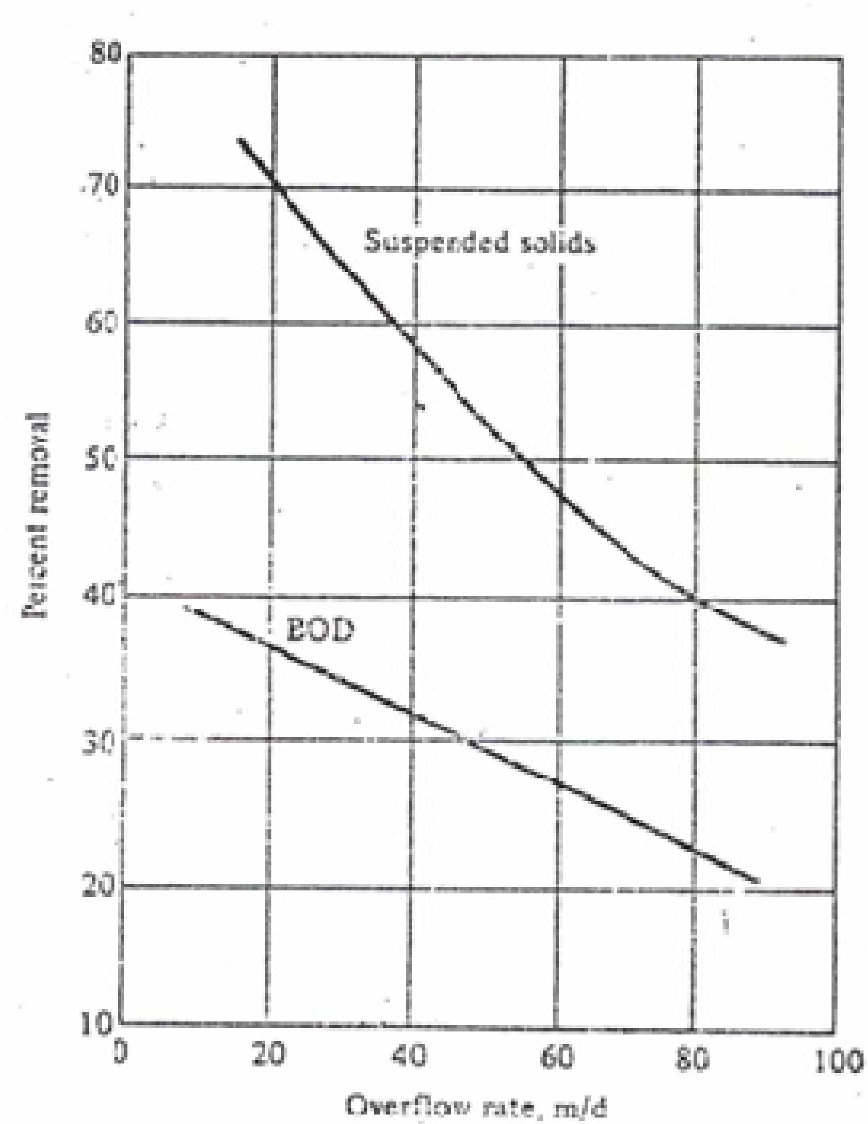
Q (m^3/s)	**Q (m^3/min)**	**Y (mm)**	**y (mm)**	**w (mm)**
0.0167	**1**	67	43	434
0.077	**4.62**	308	199	106
0.19	**11.4**	760	490	67
0.25	**15.0**	1000	645	58
0.33	**20**	1333	889	50

Proportional flow weir for use with rectangular grit chamber

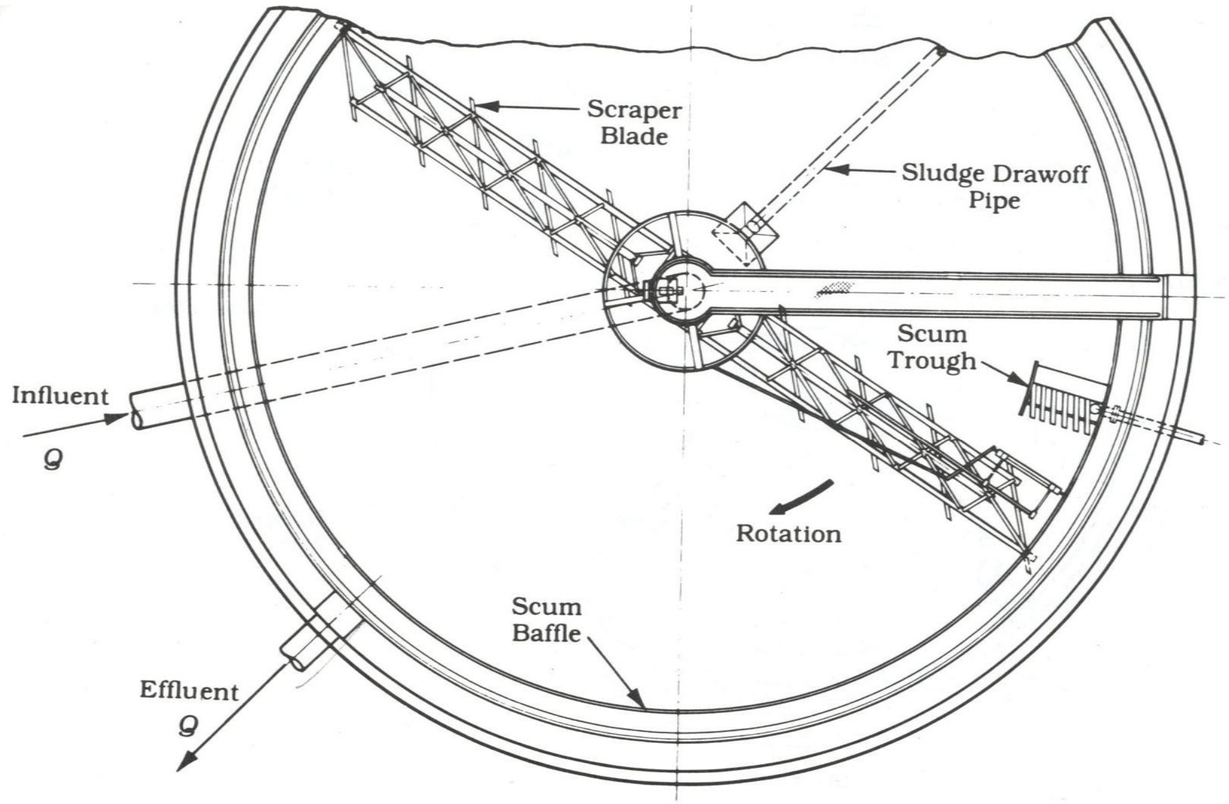


3. Primary Treatment

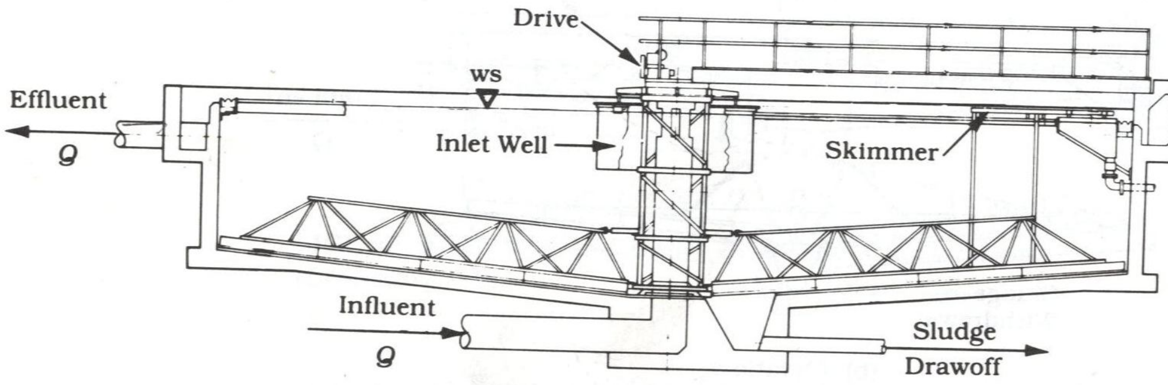
- **The main primary treatment unit is the primary sedimentation tank. It is used to separate (remove) settleable suspended solids.**
- **These tanks maybe circular or rectangular.**
- **The tanks are designed on the bases of overflow rate or the hydraulic surface loading rate (H_L) expressed as : Q/A ($m^3/m^2.d$), where A is the surface area of the tank. The overflow rate affects the efficiency of the tank as shown in the figure below. The range of (H_L) is 30-50 $m^3/m^2.d$ at the average design flow.**
- **Another important parameter is the weir loading rate expressed as W_L = Q/L ($m^3/m.d$), where L is the effluent weir length. The maximum allowable W_L = is 186 $m^3/m.d$ at the average design flow.**
- **The hydraulic detention time should not be less than 1.5 hrs based on the average flow. The hydraulic detention time is defined as $\Theta = V/Q$.**
- **The diameter of circular tanks is in the range of 3 to 60 m, and their depth is in the range of 3 to 6 m.**
- **The length of rectangular tanks is in the range of 10 to 100m, and the depth is in the range of 2.5 to 5 m. The width of the tank is in the range of 3 to 24 m. The ratio of length to width is in the range of 1.0 to 7.50. The ratio of length to depth is in the range of 4.2 to 25.**



Relation between Overflow rate and efficiency of primary sedimentation tanks

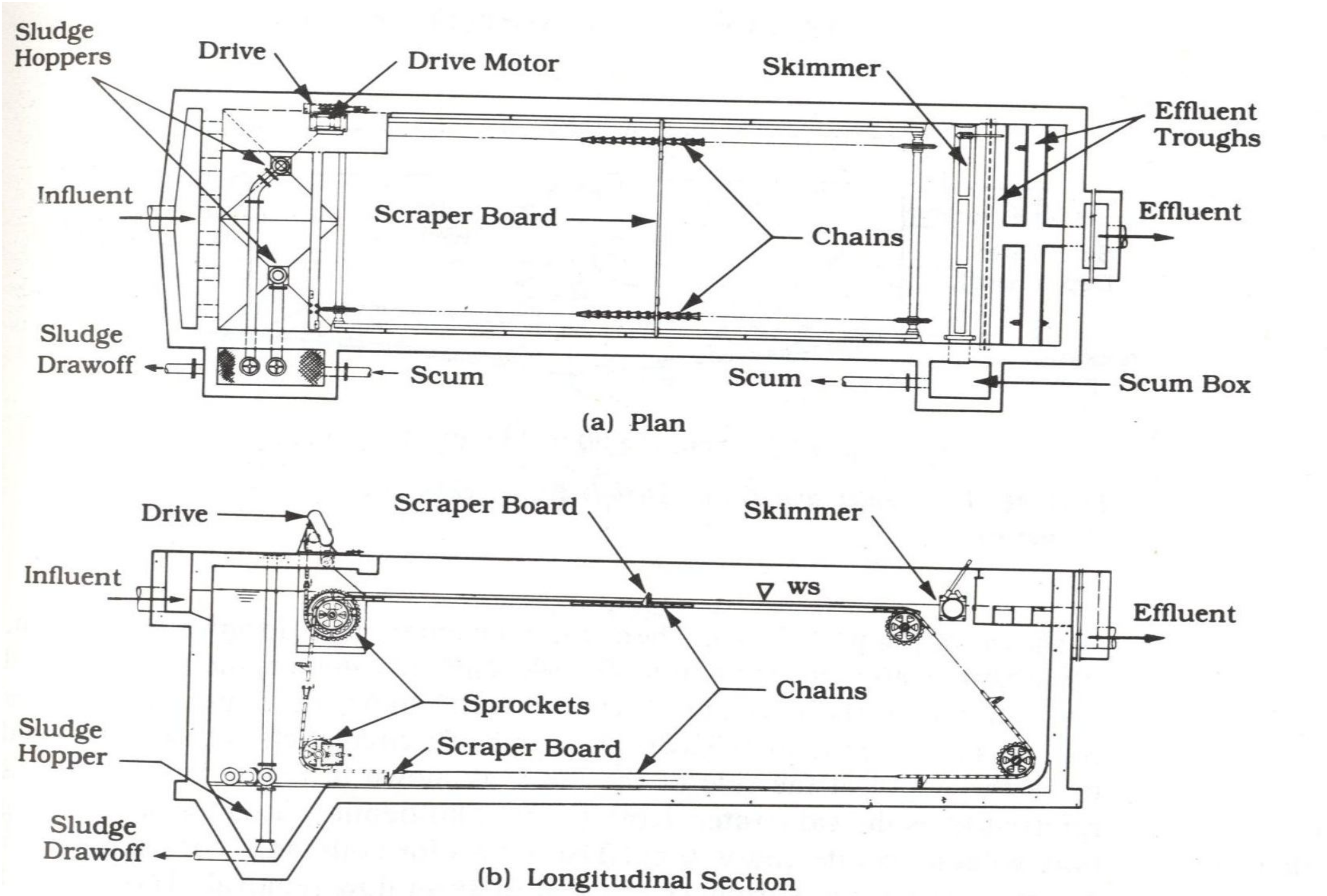


(a) Plan

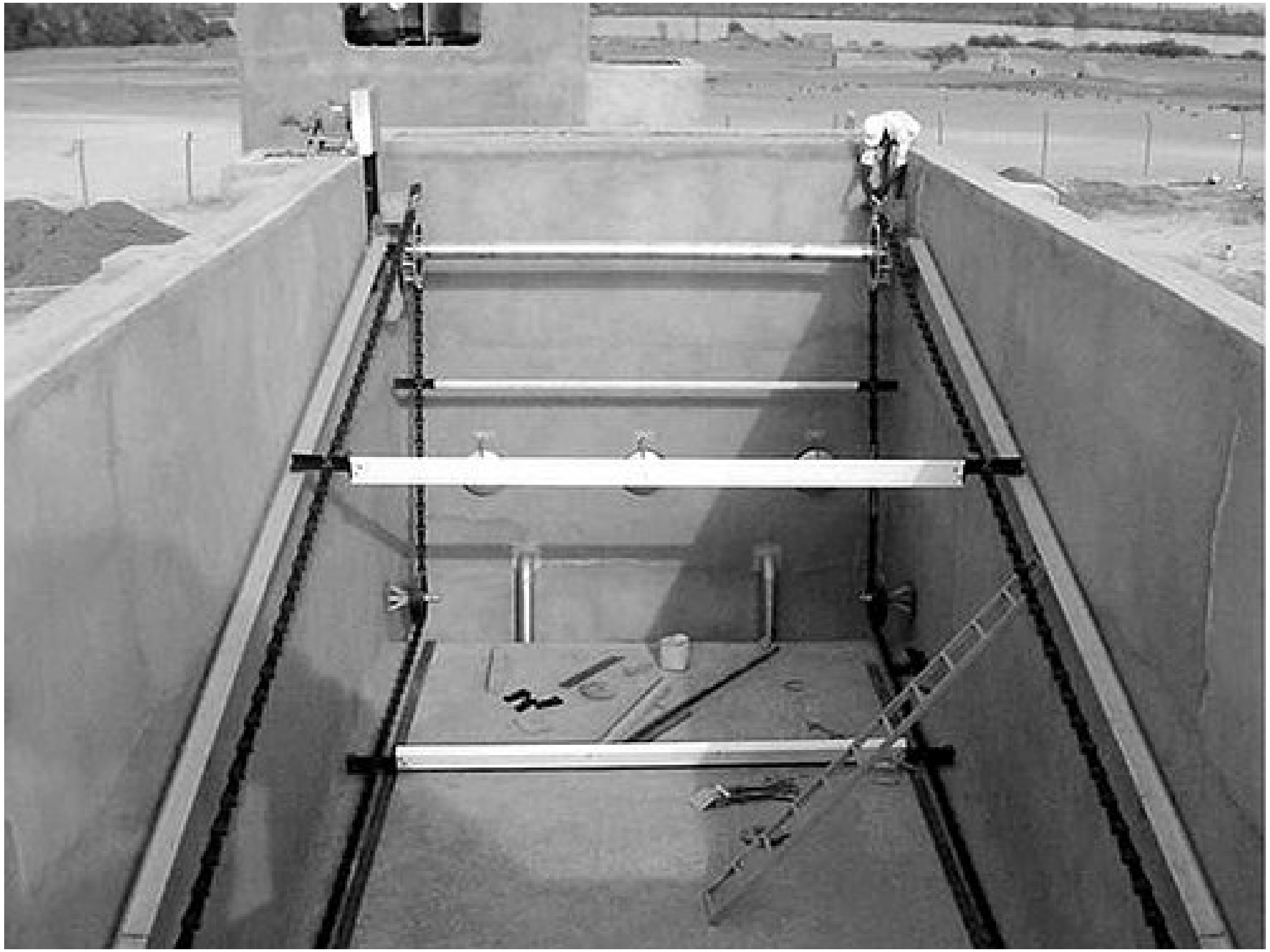


(b) Elevation

Circular primary sedimentation tank



Rectangular primary sedimentation tank



Example:

A circular primary sedimentation tank for a municipal wastewater treatment plant is to be designed for an average flow of 7570 m^3/d. The minimum side wall depth is 3 m. Assume The overflow rate (H_L) as 36.7 $m^3/m^2.d$ and the maximum allowable WL = is 186 m3/m.d at the average design flow. Determine:

1. The diameter of the tank.
2. The depth of the tank
3. Check the weir loading rate.

Solution:

1. $A = Q/ H_L = 7570/36.7 = 206.3\ m^2$

   $D = (4A/\pi)^{0.5} = ((4*206.3)/3.14)^{0.50} = 16.20\ m$

2. Select the minimum depth d =3 m and check for Θ :

   Volume of the tank (V) = $Ad = 206.3*3 = 618.9\ m^3$

   $\Theta = V/Q = 618.9/7570 = 0.08176$ day = 1.96 hrs > 1.50 OK

3. The circumference of the tank : $L = \pi*D = 3.14*16.2 = 50.868\ m$

   $WL = Q/L = 7570/50.868 = 148.82\ m^3/m.d < 186$ Ok