ENVIRONMENTAL ENGINEERING -1

Lecture 15 – Sedimentation

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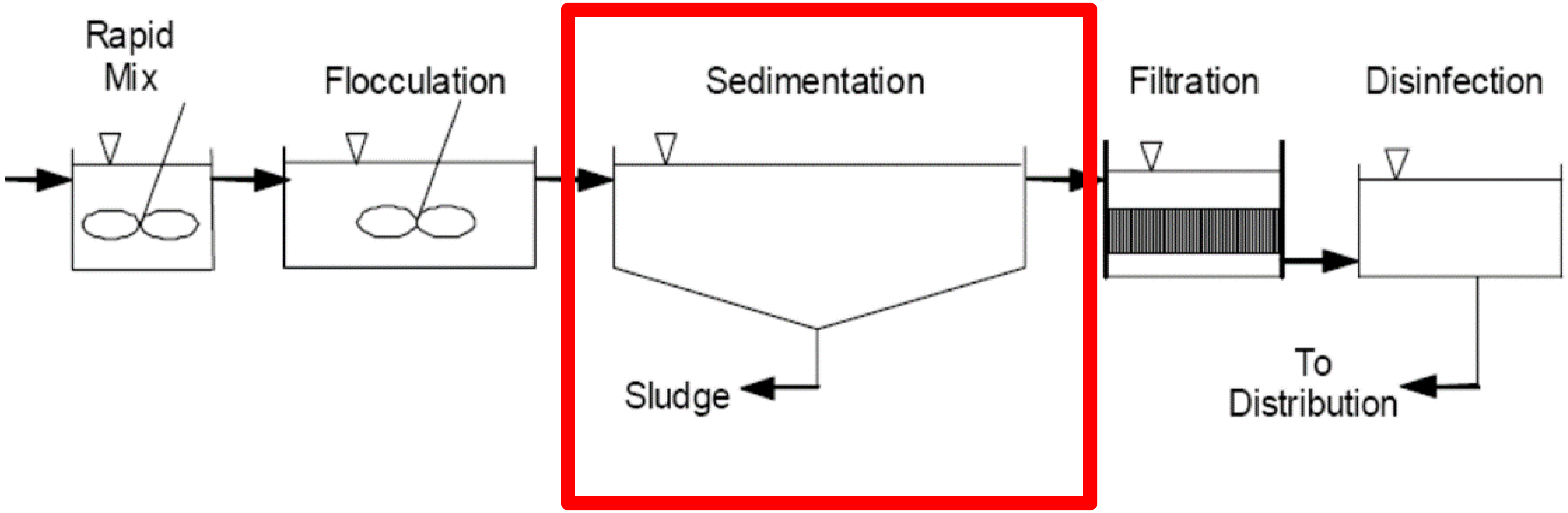

Rapid
Mix
Flocculation
Sedimentation
Filtration
Disinfection
Sludge
To
Distribution

Definition

It is a process of ***separation of unstable*** *and* ***destabilized suspended particles*** *from suspension by the* ***force of gravity****.*

Application in Water Treatment

1. Settling of coagulated and flocculated water prior to filtration
2. Settling of coagulated and flocculated water in a softening plant
3. Settling of treated waters in iron and manganese removal plant

Factors affecting Sedimentation

Settling of particles from suspension depends upon;

1. Characteristics of particles

2. Concentration of particles

Factors affecting Sedimentation

Characteristics of the Particles

DISCRETE PARTICLES

particles whose size, shape and specific gravity do not change with time.

FLOCCULATING PARTICLES

particles whose surface properties are such that they aggregate upon contact

Thus, changing in size, shape, and perhaps specific gravity with each contact

Concentration of Particles in Suspension

DILUTE SUSPENSIONS

suspensions in which the conc. of particles is not sufficient to cause significant displacement of water as they settle or in which the particles will not be close enough for velocity field interference to occur

CONCENTRATED SUSPENSIONS

suspensions in which the conc. of particles is too great to meet the conditions mentioned for dilute suspensions

3

Types of Settling

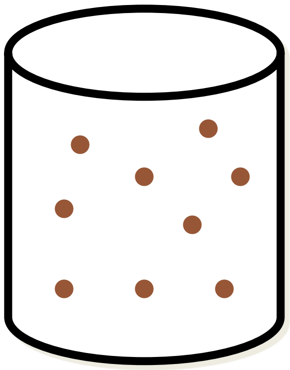
- Four basic classifications, depending on the nature of the solids present in suspension:

1. Discrete Settling
2. Flocculent Settling
3. Zone Settling
4. Compression Settling

Types of Settling

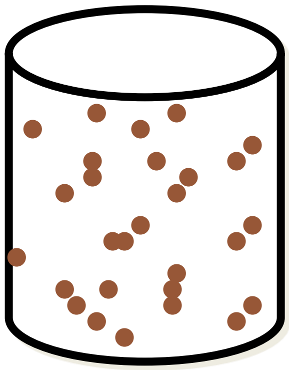
1. Discrete Settling(Type-1 settling)

- Low concentration
- Particles act independently
- No increase in size& shape
- Settle with constant velocity (discrete settling)

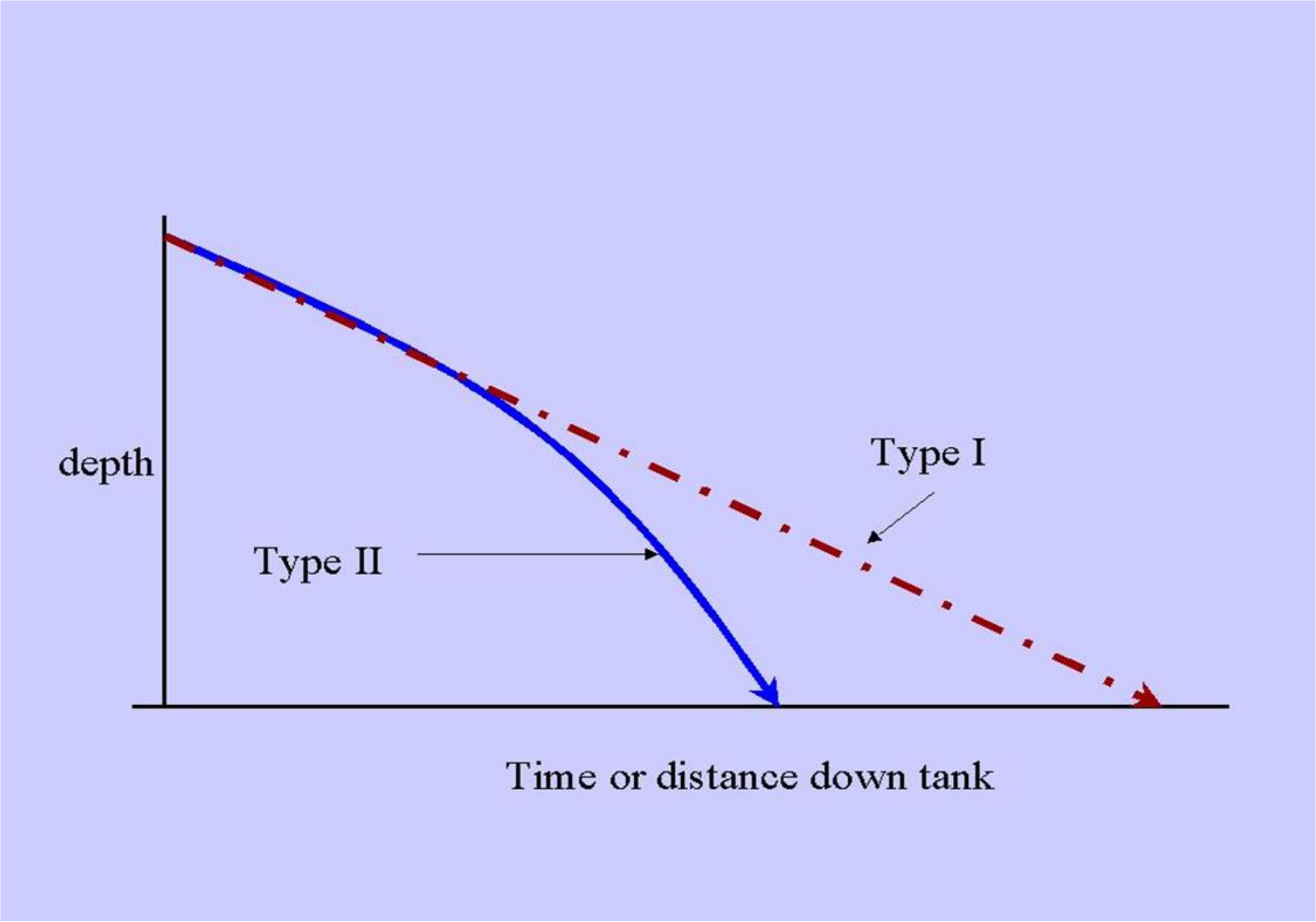


2. Floccuant Settling (Type-2 Settling)

- Particle-Particle interactions are significant.
- Particles may collide and stick together (form flocs) settling quickly
- Change in shape & size , done by coagulation



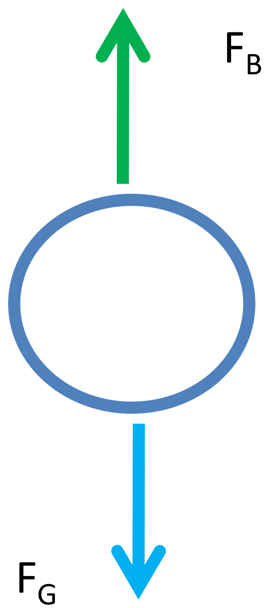
Comparison of Type I and II sedimentation



Settling of Discrete particles

Discrete particles are those particles which do not change their characteristics or properties i.e density or size.

- When a particle is suspended in water, it initially has 2 forces acting on it:



1. Force of gravity

$$F_G = \rho_p V_p g$$

2. Force of buoyance

$$F_B = \rho \ V_p g$$

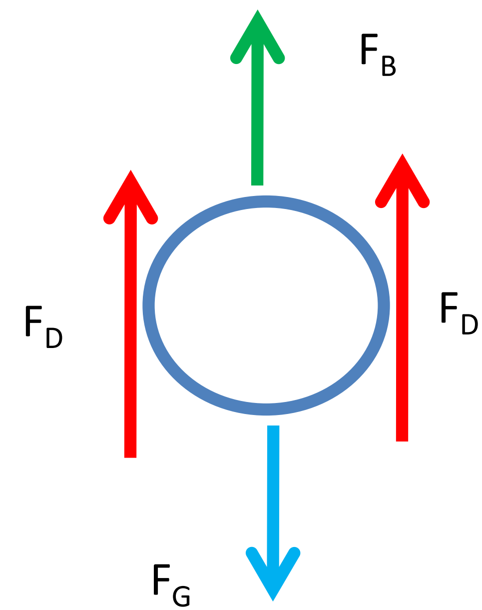
Once a motion has been initiated, 3rd force is created due to viscous friction:

3. Drag force

$$F_D = \frac{C_D A \rho V^2}{2}$$

Force balance for a discrete particles that is settling,

$$m_p \underbrace{\frac{d\vartheta_s}{dt}}_{\text{Downward acceleration of particle}} = F_G - F_B - F_D$$



- After an initial transient period, the acceleration dV_s/dt becomes zero and the settling velocity becomes constant

$$0 = \rho_p V_p g - \rho V_p g - \frac{C_D A \rho V^2}{2}$$

$$Vs = \sqrt{\frac{2g(\rho_p - \rho)V_p}{C_D A \rho}}$$

Settling Velocity of Discrete particles of any shape

- Settling velocity of spherical discrete particle:

$$V = \sqrt{\frac{4(\rho_p - \rho)gD}{3C_D\rho}}$$

- CD is the function of Reynold No., its value decreases as RN increases.
- RN< 1 Laminar flow
- RN > 1000 Turbulent flow

Stokes Law

- It is applicable for:

1. Spherical particle dia < 0.1mm
2. Laminar flow with $R_N < 1$

- Settling velocity can also be use interms of kinematic viscosity "V" in (cm^2/sec)

$$V_S = \frac{gd^2(s_S - s_f)}{18\nu} = \frac{gd^2(s_p - 1)}{18\nu}$$

s_S =specific gravity of particle

s=specific gravity of water

v= kinematic viscosity, cm^2/sec

Stokes Law

- Raynold Number (R_N)

$$R_N = \frac{V_s d\rho}{\mu} = \frac{V_s d}{v}$$

V_s = Settling velocity, cm/sec

ρ = Density of fluid. gm/cm^3

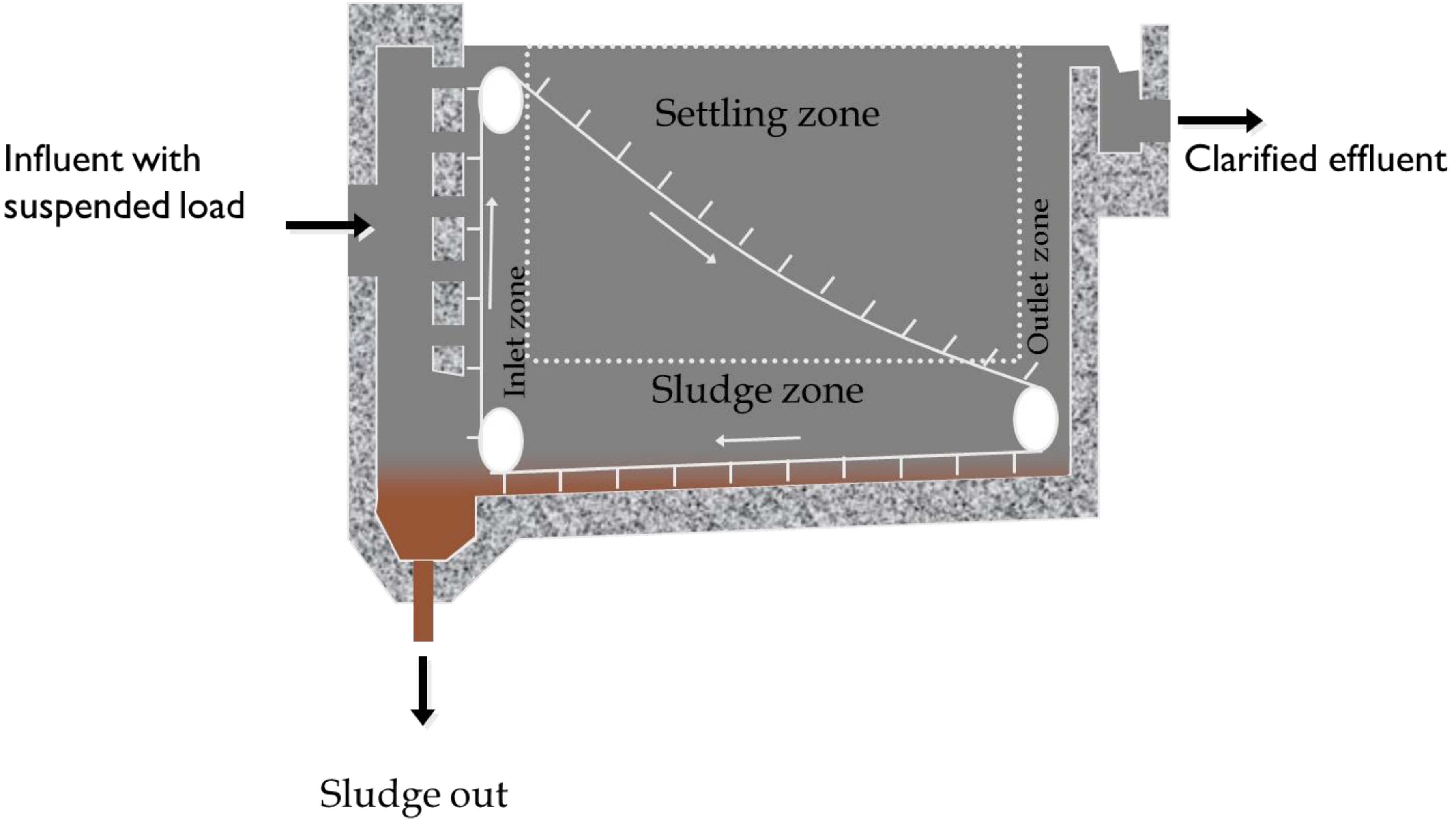
d = Dia of particle, cm

μ = Absolute viscosity, g/cm.sec

Numerical 1(Settling velocity)

- Calculate the settling velocity of a sand particle of 0.1 mm in size at 10°C.Take a specific gravity of sand as 2.65.Kinematic viscosity at 10°C is 1.3097 x 10^{-2} cm^2/sec.

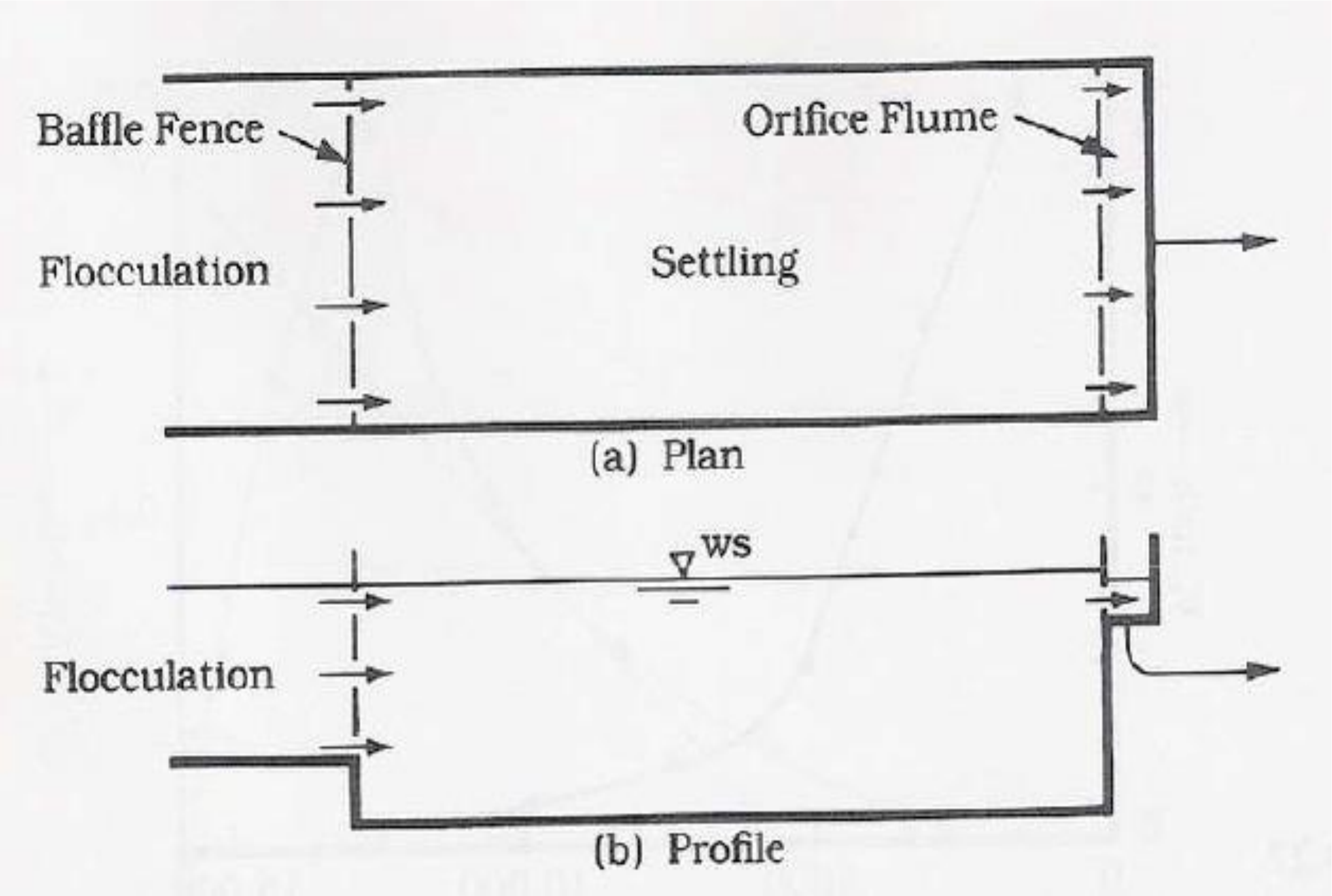
SEDIMENTATION BASIN ZONES

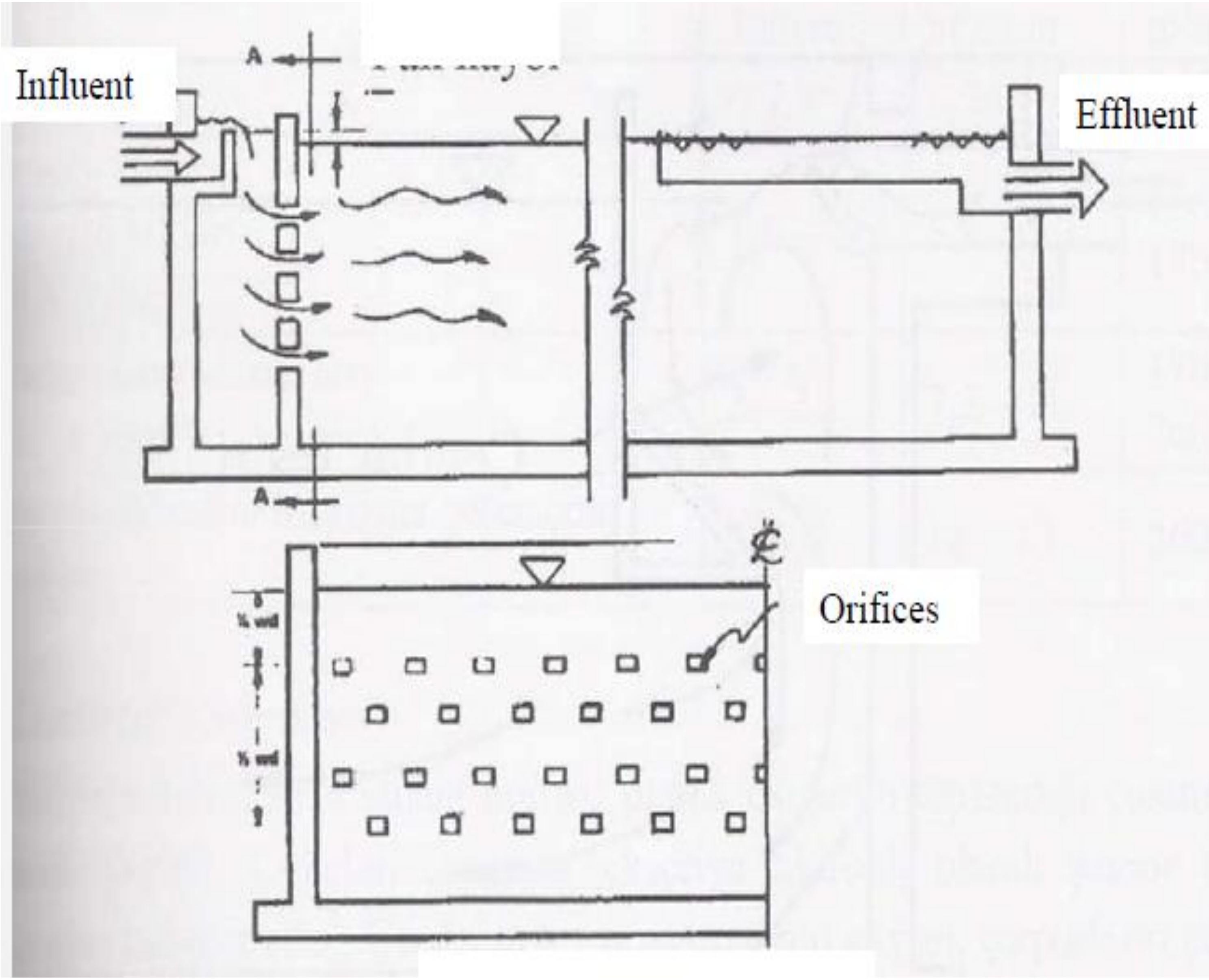


SEDIMENTATION BASIN ZONES

Inlet zone

- The inlet or influent zone should provide a smooth transition from the influent flow and should distribute the flow uniformly across the inlet to the tank.
- The normal design includes baffles that gently spread the flow across the total inlet of the tank and prevent short circuiting in the tank.
- The baffle could include a wall across the inlet, perforated with holes across the width of the tank.
- Basin inlets should be designed to minimize high flow velocities near the bottom of the tank.
- If high flow velocities are allowed to enter the sludge zone, the sludge could be swept up and out of the tank.
- Sludge is removed for further treatment from the sludge zone by scraper or vacuum devices which move along the bottom


Baffle Fence
Orifice Flume
Flocculation
Settling
(a) Plan
WS
Flocculation
(b) Profile


Influent
A
A
Effluent
Orifices

Settling Zone

- The settling zone is the largest portion of the sedimentation basin.
- This zone provides the calm area necessary for the suspended particles to settle.

Sludge Zone

- The sludge zone, located at the bottom of the tank, provides a storage area for the sludge before it is removed for additional treatment or disposal

Outlet Zone

- The basin outlet zone should provide a smooth transition from the sedimentation zone to the outlet from the tank.
- This area of the tank also controls the depth of water in the basin.
- Weirs set at the end of the tank control the overflow rate and prevent the solids from rising to the weirs and leaving the tank before they settle out

Outlet(rectangular basin)

Outlets(Circular basin)

Detention time

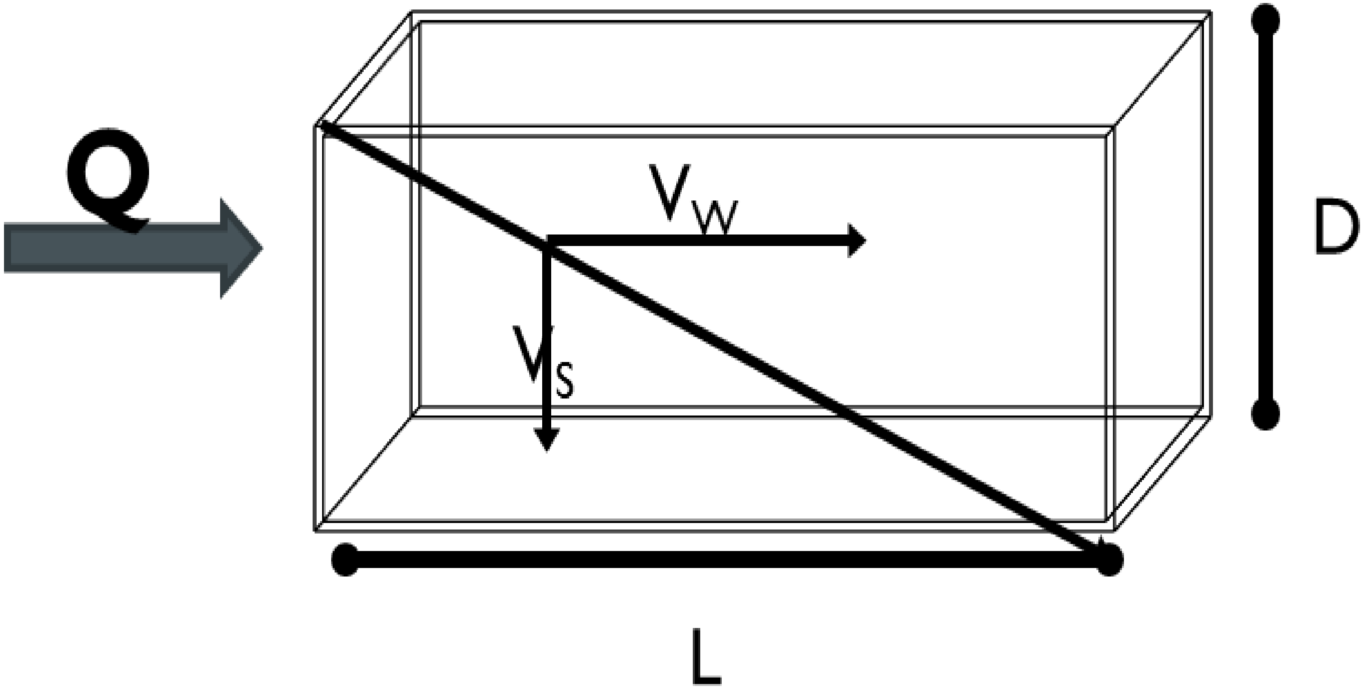
Theoretical time for which particle will stay in sedimentation tank

t_d=volume of tank/inflow rate=V/Q

Specified on basis of average flow rate

Actual time =flow through time

Ideal settling tank characteristics



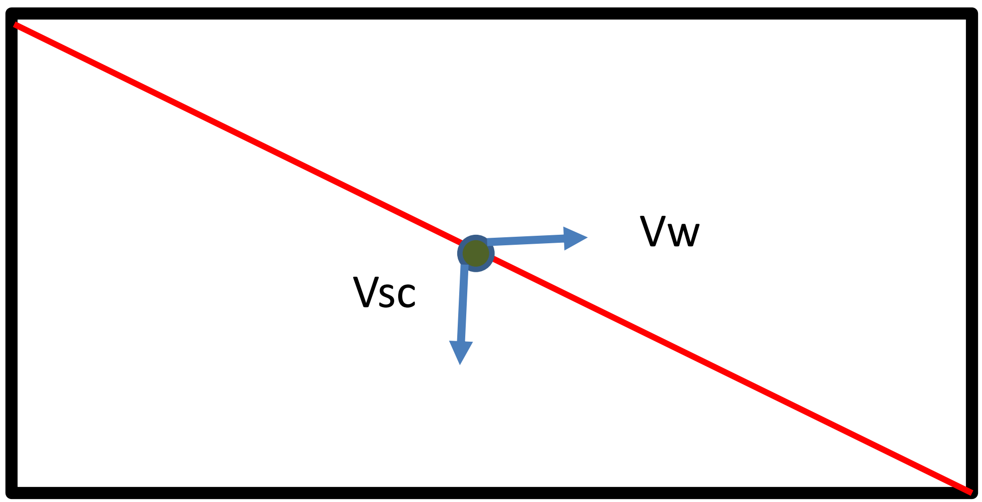
L=length of settling zone
D=depth of settling zone
W=width of settling zone
Vs=settling velocity of particle
Vw=horizontal velocity of water
Q=inflow to tank
V=volume of tank
As=surface are of tank

- Assumptions

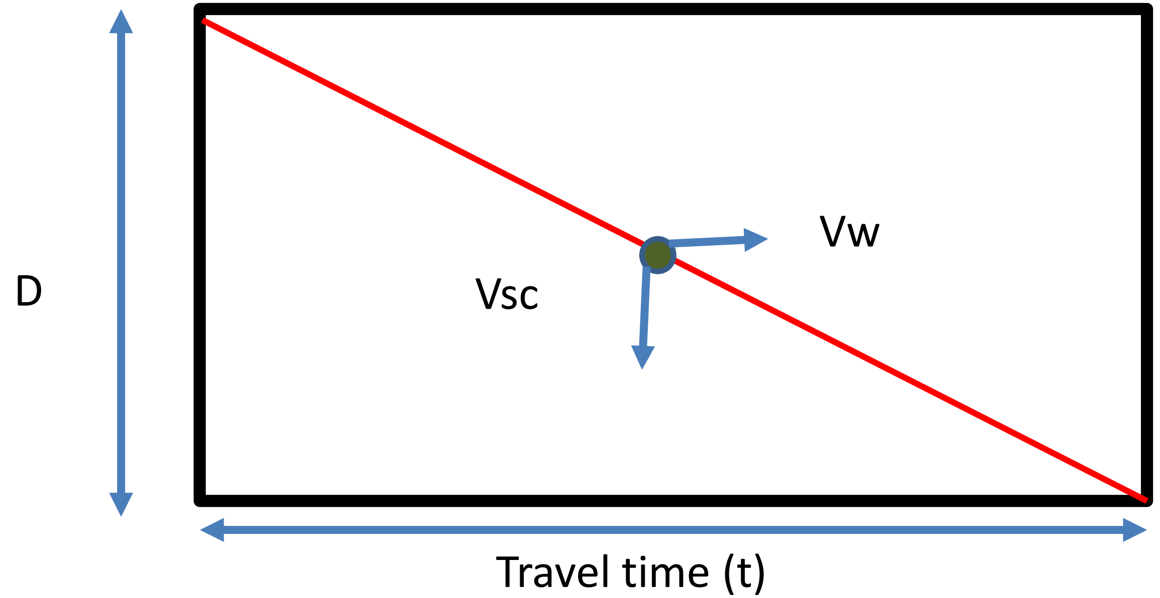
1. Plug flow conditions exists in tank
2. Uniform horizontal velocity in settling zone
3. Uniform concentration of all particles
4. Particles are removed once they reach the bottom of settling zone
5. Particles settle discretely without interference from other particles at any depth

For ideal discrete settling of particles in a rectangular tank :

1. Horizontal Velocity (Vw)=Constant
2. Terminal Settling Velocity (Vs)=different for particles with different size, shape and density.



Vsc=Critical settling Velocity or fixed settling velocity



Particle will settle down by travelling a vertical distance (D) in a time (t) with a settling velocity (Vsc):

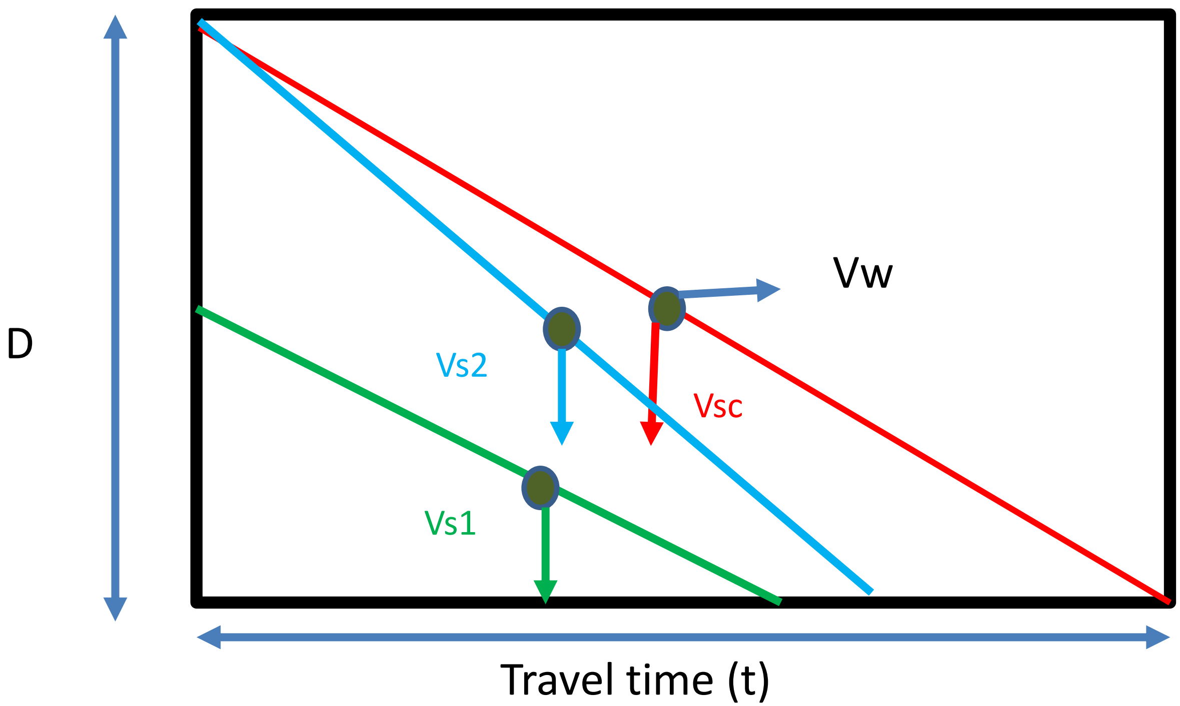
Vsc=Depth of tank/Detention time=D/td………(1)

where;

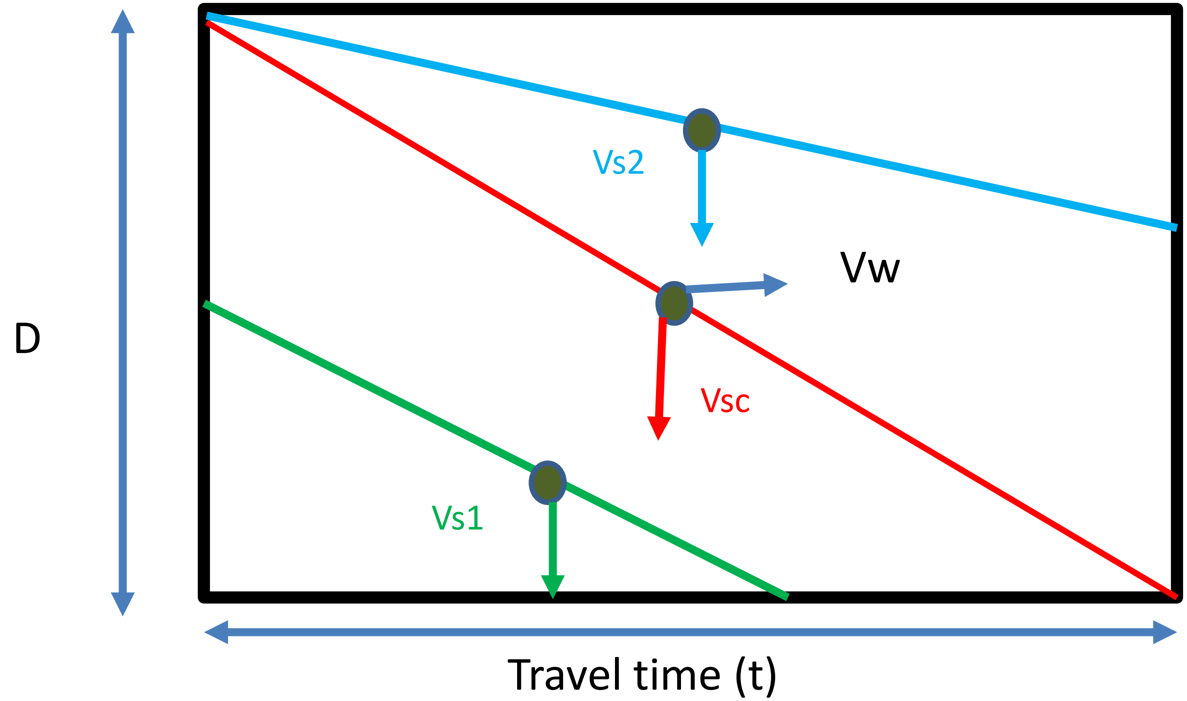
td=Volume of tank/flow=L*W*D/Q=As*D/Q

Put in equation 1 , we get;

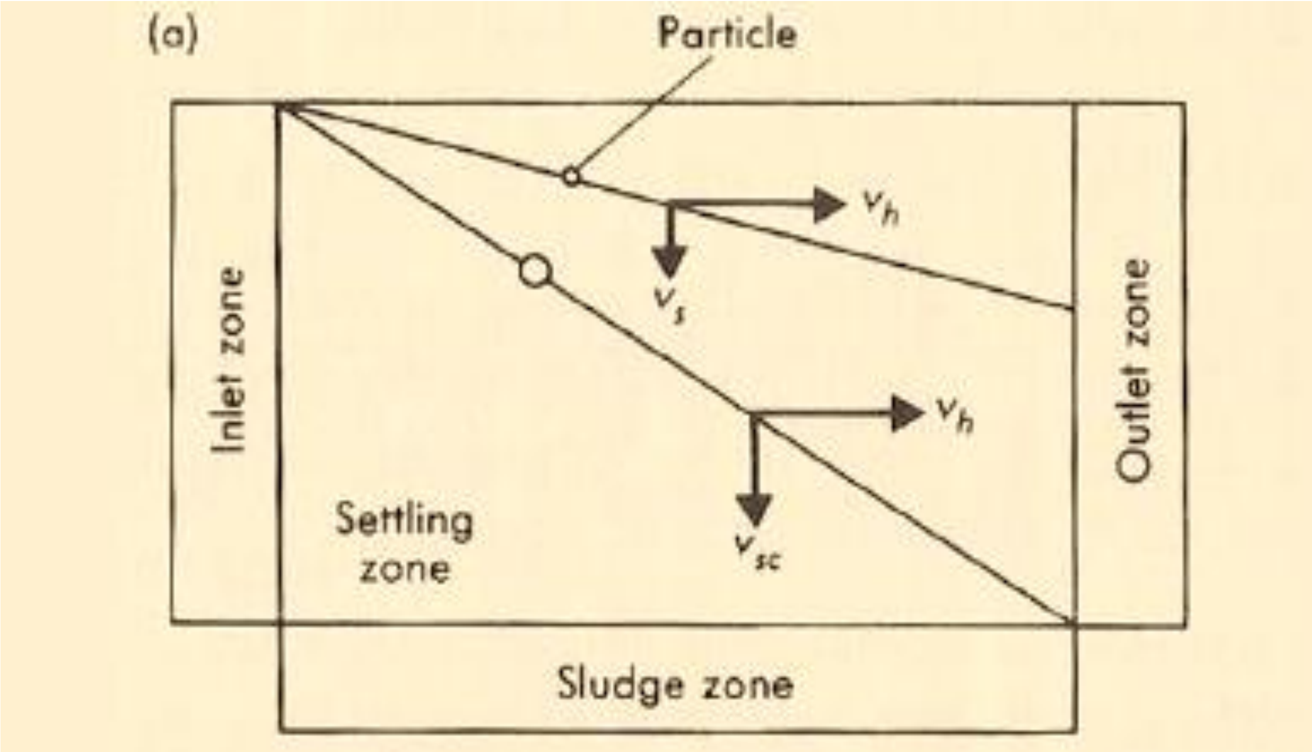
Vsc=D*Q/As*D=Q/A=Surface overflow rate=SOR



Particles having settling velocity (Vs) greater than Critical velocity (Vsc) will be removed 100% regardless of the position of particle at inlet



Particles having settling velocity (Vs)less than Critical velocity (Vsc) will be removed in the ratio of Vs/Vsc.May also depend on their position at inlet.



All particles with $V_S > V_C$ → will be completely settled.

Particle with $V_s < V_c$ → will be removed in the ratio V_p / V_c

Removal efficiency of settling tank

- **Surface over flow rate(SOR)** is a critical design parameter.
- SOR is independent of **depth** and **detention time**
- **Surface area of tank** is a significant parameter.by changing surface area ,**removal efficiency of tank can be enhanced**

RECTANGULAR BASINS

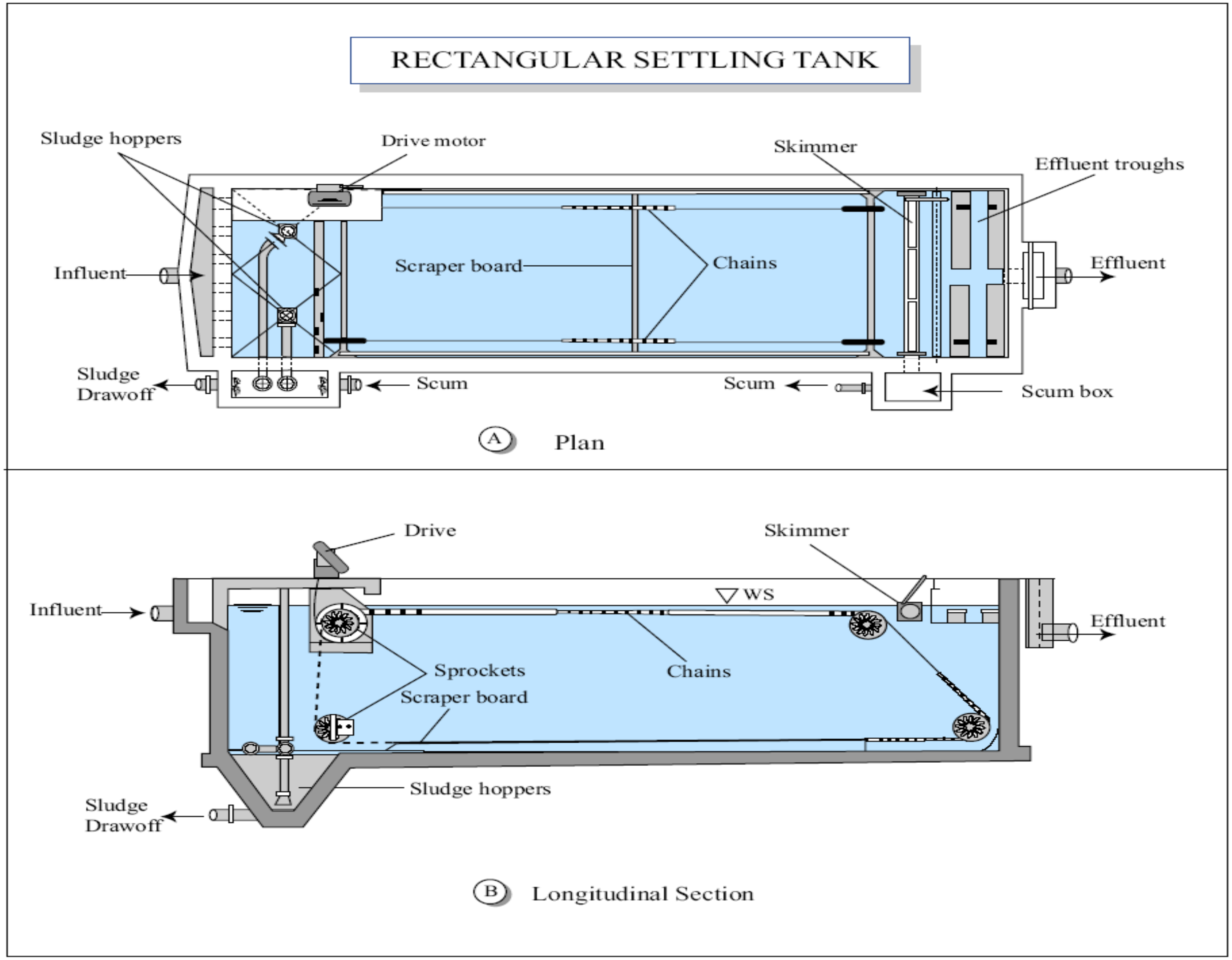


Figure by MIT OCW.

Adapted from: Reynolds, T. D., and P. A. Richards. *Unit Operations and Processes in Environmental Engineering*. 2nd ed. Boston, MA: PWS Publishing Company, 1996, p. 249. ISBN: 0534948847.

Design Criteria of Sedimentation Tank

Min. # of tanks	Two
Water depth	3-5m (2m or deep tanks 6.5m also used)
Detention time	2~8hrs
Overflow rate	20~33m^3/m^2/day
weir loading rate	≤250m^3/m/day
Sludge storage	20% extra volume required

Design Criteria Rectangular Sedimentation Tank

Length	30m
Width	10m(13m max)
L:W	$\leq$ 4:1(2:1 generally)
Bottom slope	1-2%(w/o scrapers)

Design Criteria circular Sedimentation Tank

Dia	30m(max)
Depth	3-5m
Bottom slope	8%(hopper bottom + scrapers)

Numericals

1. Design a sedimentation tank to treat a flow of 25000m^3/day; Surface Overflow rate (SOR)=25m/day; D.t=2hrs;sludge storage capacity 20% of effective volume. Under ideal conditions what particle size will be removed if ν=1.2 x10^{-2} cm^2/sec ; S_S=2.65

2. Determine the number and size of sedimentation tank to treat a water flow of 20000 m3/day using an overflow rate of 24 m/d and detention time of 4 hrs. Under ideal condition what size of particles will be completely removed, if ν=1.2 x10^{-2} cm^2/sec ; S_S=2.65

Numericals

3. Design a sedimentation tank to serve a population of 15,000 persons with an average water consumption of 350 lpcd.

4. Sedimentation tanks are to be provided to deal a flow of 6000m^3/day of water at a temperature of 20 C with kinematic viscosity of 1.01x 10^{-2} cm^2/sec .It is desired to remove all particles greater than 0.04mm in diameter. With specific gravity of 1.15.Assuming ideal condition and detention time of 3 hrs. Calculate the dimension of sedimentation tank to satisfy these conditions.