SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

SWIM-H2020 SM Regional Activities 14

Presented by:

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SWIM and Horizon 2020 SM REG-14: Refugee Emergency: Fast track project Design of wastewater

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SECONDARY CLARIFIERS

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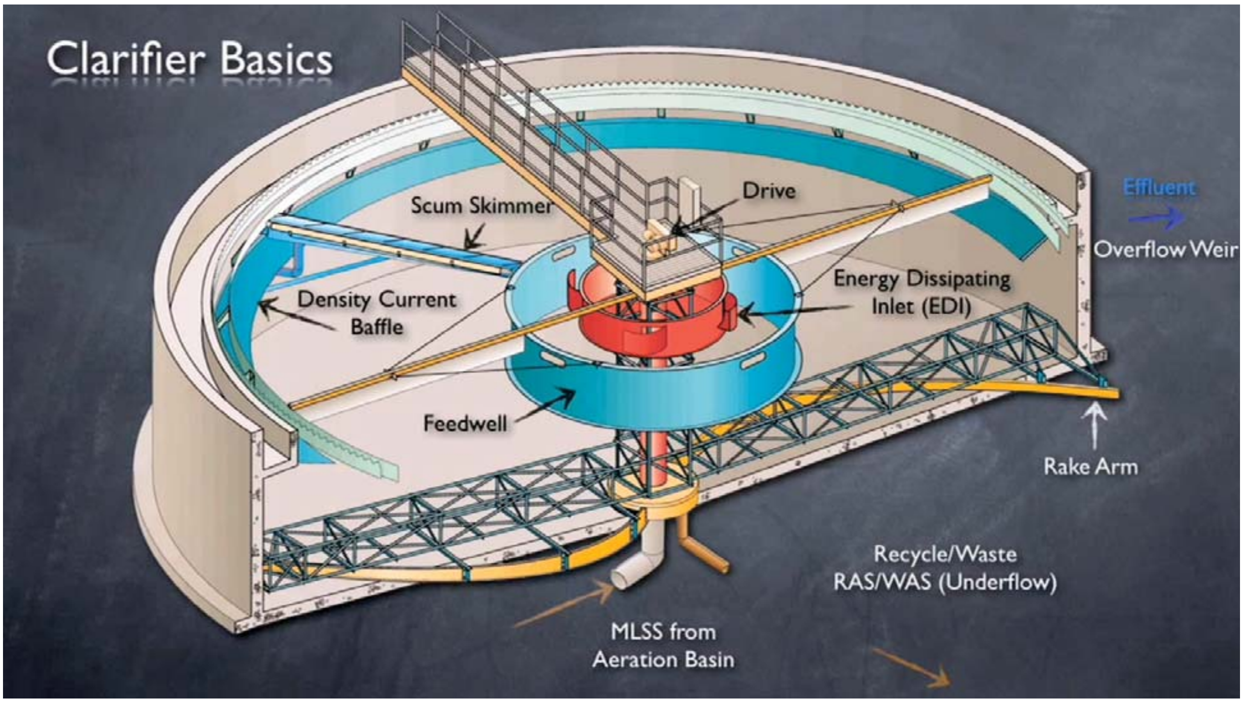
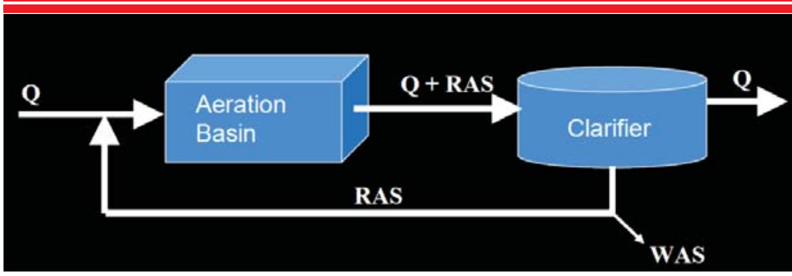
SECONDARY CLARIFIER

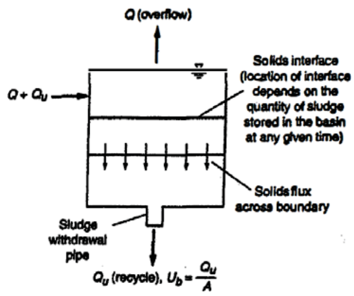


SECONDARY CLARIFIERS

- Functions
  - Clarification, separate solids from mixed liquor to produce a clarified effluent quality with low TSS.
  - Thickening, concentrate sludge to produce concentrated underflow(RAS) to maintain MLSS in aeration tank.
  - Conveyance, transferred sludge to aeration tanks or wasting.
  - Scum removal, remove scum/foam from the surface of the clarifier.
- Clarification Failure
  - Rise in effluent TSS, no sufficient time for solids settlement.
- Thickening Failure
  - Rise in sludge blanket depth, sludge removed slowly.
- Clarification & Thickening failure

SURFACE OVERFLOW RATE(SOR)



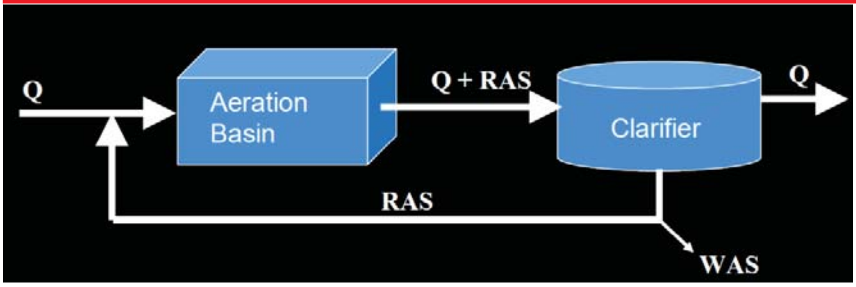


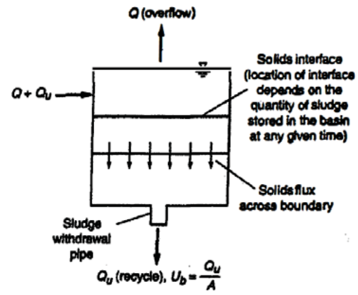
- Surface Overflow Rate(SOR)
  - The upward velocity of water.

$$SOR = \frac{Q}{A}$$

Q	= Influent flowrate, m3/day
A	= Clarifier Surface Area, m2
SOR	= Surface Overflow rate, m3/m2.day

SOLIDS LOADING RATE(SLR)





- Solids Loading Rate(SLR)
  - The mass of solids applied per unit area per time.

$$SLR = (Q + Q_R) \times \frac{X}{A}$$

Q		= Influent flowrate, m3/day
Q_R		= Return activated sludge flowrate, m3/day
A		= Clarifier Surface Area, m2
X		= MLSS entering the secondary clarifier, g/m3
SLR		= Solids loading rate, kg TSS/m2.day

$$SOR = \frac{Q}{A}$$

BASIC DESIGN PARAMETERS FOR SECONDARY CLARIFIERS

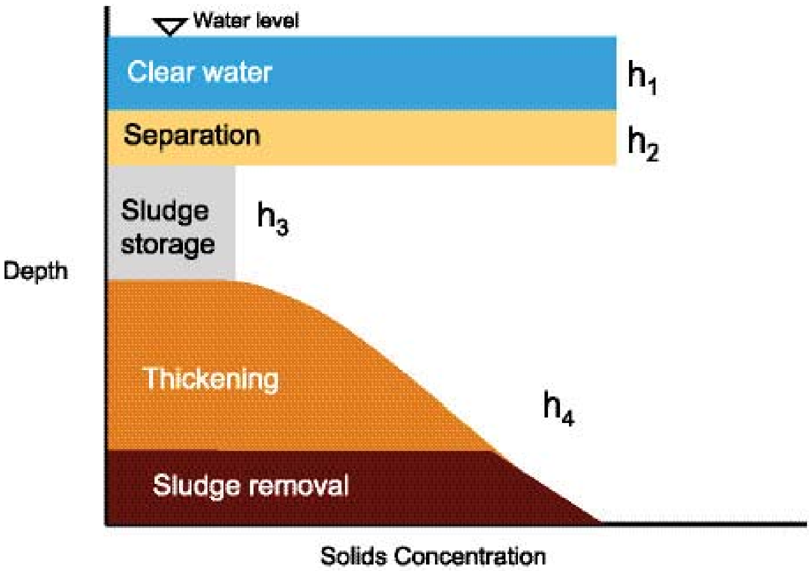
Item	Reference	Overflow Rate m3/m2.d		Solids Loading Rate (kg/m2.h)		Weir Loading Rate (m3/m.d)
		At Average Flow	At Peak Flow	At Average Flow	At Peak Flow	At Peak Flow
Settling following air activated sludge	Metcalf & Eddy	16-28	40-64	4-6	8	-
Settling following Extended Aeration	Metcalf & Eddy	8-16	24-32	1-5	7	-
Settling following Activated Sludge	MOP8	22.8	50	4.2-6.3	8.3-10	250-375

EXAMPLE FOR CLARIFIER SIZING

SECONDARY CLARIFIERS SIZING					
	Unit	**ADF**	**ADMM**	**MD**	**PH**
Flow	m3/day	9,500	12,445	13,110	38,000
Design MLSS, X	mg/L	**4,200**			
Assumed solid loading rate @ Qav	kg/m2.day	**96**			
Return sludge ratio		1.00			
Total flow to clarifier	m3/day	**19001**			
Solids loading	kg/day	**79803**			
Calculated area based on SLR@Qav		**831**			
Number of Units	---	**2**			
Calculated area each unit		**416**			
Calculated diameter each unit		**23**			
Used Diameter	m	**25**			
Actual Area per unit	m2	491			
Area, total	m2	982			
Area, one unit out of service	m2	491			
Loadings		**ADF**	**ADMM**	**MD**	**PH**
HLR, all units in service	m3/d.m2	10	13	13	39
HLR, one unit out of service	m3/d.m2	19	25	27	77
SLR, all units in service	kg/day.m2	81.3	93.9	96.7	203.2
SLR, one unit out of service	kg/day.m2	162.6	187.8	193.5	406.4

Example for Clarifier Sizing

SECONDARY CLARIFIERS SOLIDS CONCENTRATION PROFILE



When SLR exceeds the limiting flux, the sludge storage zone expands. Continuous expansion will result in the sludge interface reaching the effluent weir, causing loss of solids.

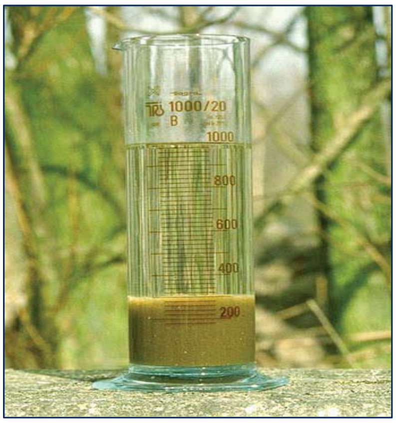
During normal operation , the storage zone expands and contracts in response to the diurnal fluctuation of solids loading; therefore sufficient clarifier depth should be provided to accommodate the routine expansion of the sludge blanket.

Sludge Volume Index (SVI)

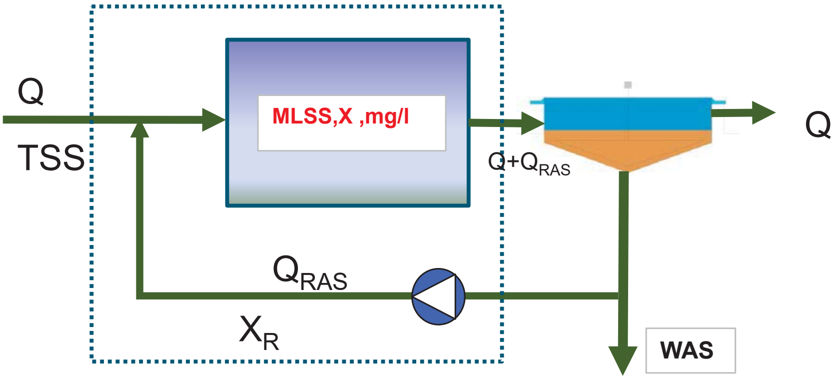
$$SVI = \frac{(Settled\_volume\_of\_sludge, ml/l) \times (1000 mg/g)}{(MLSS, mg/l)} = \frac{ml}{g}$$

$$SSVI = 4.1416 \times SVI^{0.621}$$

- The SVI is the volume of 1 g of sludge after 30 minutes of settling.
- SVI of 100 ml/g is considered good.
- SVI above 150 are typically associated with filamentous growth.
- Design for 125 mL/g
- Stirred SVI(SSVI)



RETURN FLOW/RETURN SLUDGE CONCENTRATION AERATION TANK MASS-BALANCE



$$Q \times TSS + Q_{RAS} * X_R = (Q + Q_{RAS}) \times X$$

Influent solids are negligible compared to MLSS

$$X_R = \frac{(Q + Q_{RAS}) \times X - Q \times TSS}{Q_{RAS}}$$

$$Q_R = \frac{XQ}{X_R - X}$$

$$TSS = 0$$

$$X_R = \frac{X \times (1+R)}{R}$$

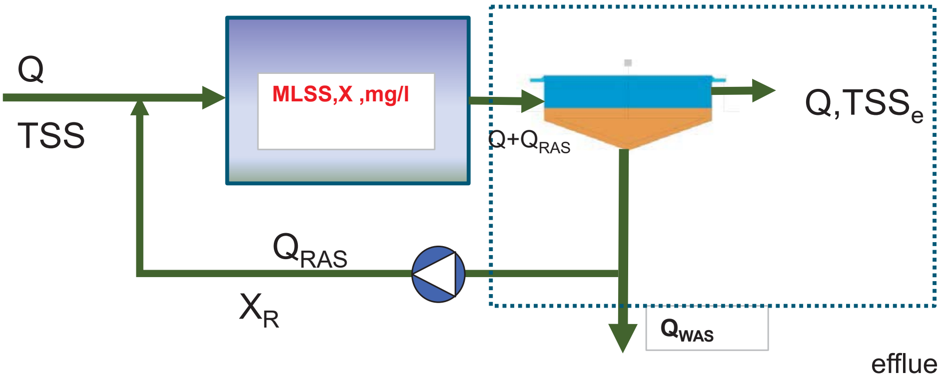
$$R = \frac{X}{X_R - X}$$

$$X = \frac{R \times X_R}{1+R}$$

$$R = \frac{Q_{RAS}}{Q}$$

Aeration Tank Mass Balance

RETURN FLOW/RETURN SLUDGE CONCENTRATION SECONDARY CLARIFIER MASS-BALANCE



effluent solids are negligible

$$(Q+Q_{RAS})\times X = Q_{RAS}\times X_R + Q_{WAS}\times X_R + Q\times TSS_e$$

X=MLSS

$$X_R = \frac{Q\times(1+R)\times X}{Q\times R + Q_{WAS}}$$

$$R = \frac{Q_{RAS}}{Q}$$

$$TSS_e = 0$$

$$R = \frac{1-\left[\frac{\tau}{SRT}\right]}{\left[\frac{X_R}{X}\right]-1}$$

$$Q_{RAS} = \frac{X\times Q - Q_{WAS}\times X_R}{X_R - X}$$

$$Q_{RAS} = \frac{X\times Q - \left[\frac{XV}{SRT}\right]}{X_R - X}$$

Clarifier Mass Balance

SETTLING MEASUREMENT

$$V_s = V_0 \times e^{-K\times MLSS}$$

Where:
Vs = Settling velocity of the sludge at MLSS concentration
V_0 = Vesiland velocity constant, m/d
K = hindered settling parameter constant, m3/kg
MLSS = mixed Liquor suspended solids, mg/l

- Settling column test is used to determine Vesiland constants. Proper settling column test data are not always available, therefore relationship between the constants and SVI have been developed as follows:
  - V_0 = 170 m/d.
  - K=0.1646+0.001586*SVI

$$K = 0.1646 + 0.001586\times SVI$$

- Should SVI data is not available it can be assumed as follows:
  - SVI=125 ml/g for designs with selectors
  - SVI=200 ml/g for aeration tanks without selectors.

WHAT IS SOLIDS FLUX(G)

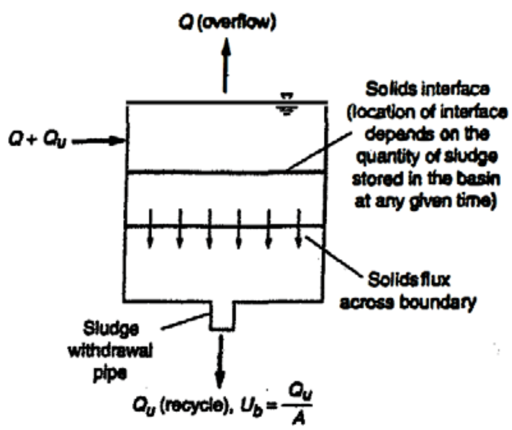
- Mass of solids passing to the clarifier in unit time per 1 m2 of clarifier area.
- It is measured in kg/m2.hr or kg/m2.day

Solids flux is the movement of solids through clarifier

Solids Flux = mass per unit area per unit time

SOLIDS FLUX ANALYSIS GRAVITY FLUX

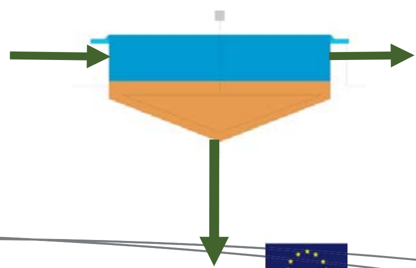
- Solids are transported to the bottom of a secondary clarifier by two mechanisms:
  - Gravity flux, differential settling because of density differences between solids and water.
  - Bulk flux, bulk transport from sludge withdrawal.
- Gravity Flux (G_s)



$G_s = MLSS \times V_s$

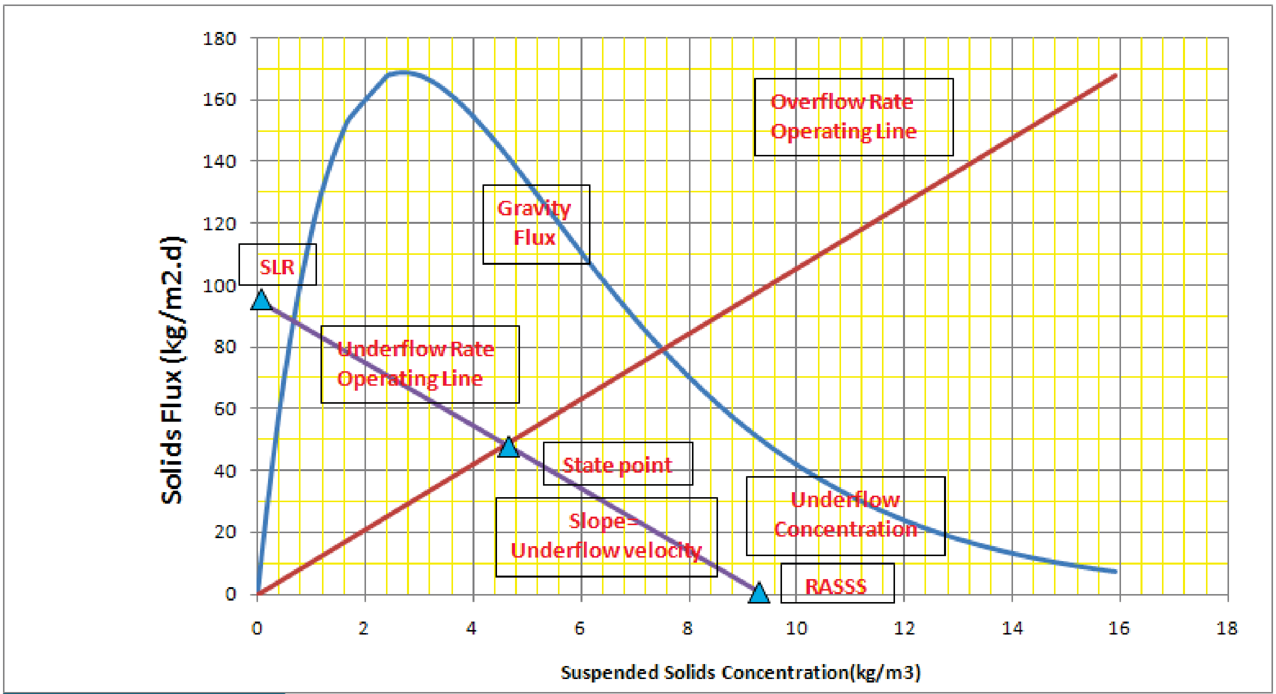
$V_s = V_0 \times e^{-K \times MLSS}$

$G_s = MLSS \times V_0 \times e^{-K \times MLSS}$



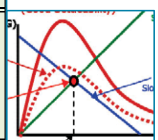
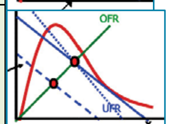
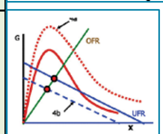
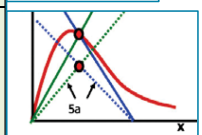
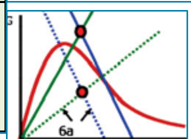
Settling Curve

STATE-POINT ANALYSIS

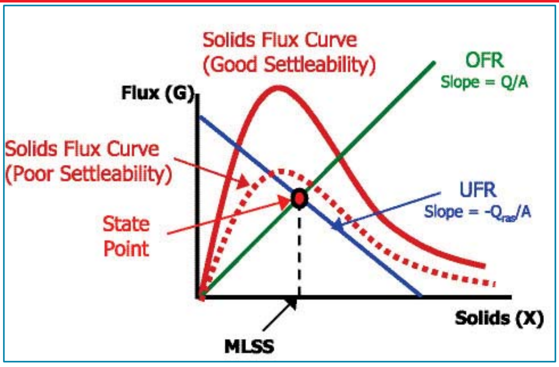


State Point Analysis

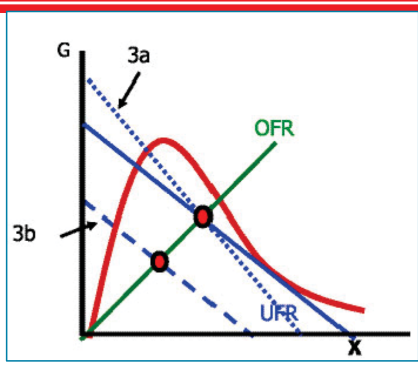
INTERPRETATION OF THE STATE POINT ANALYSIS

State Point	Underflow Rate (UFR) Line	Clarification	Thickening	Corrective Action	
Within the flux Curve	Below the descending limb of the flux curve	Underloaded	Underloaded	None	
Within the flux curve	tangent to the descending limb of the flux curve	Underloaded	Critically loaded	Increase RAS Rate Lower MLSS	
Within the flux curve	Intersects the descending limb of the flux curve	Underloaded	Overloaded	Improve SVI Lower MLSS	
On the flux curve	Below the descending limb of the flux curve	Critically loaded	Underloaded	Increase clarifiers area	
Outside the flux curve	Intersects the descending limb of the flux curve	Overloaded	Overloaded	Increase clarifiers area	

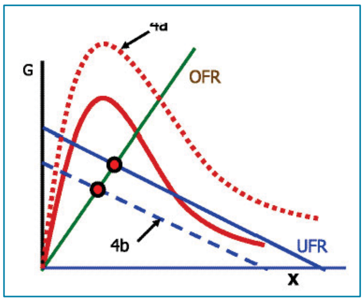
INTERPRETATION OF THE STATE POINT ANALYSIS



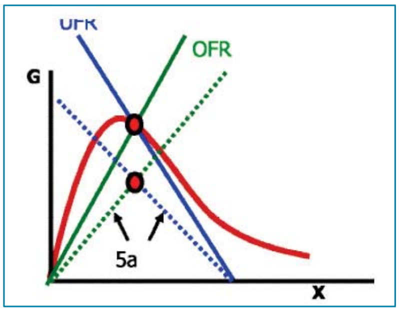
Elements of SPA



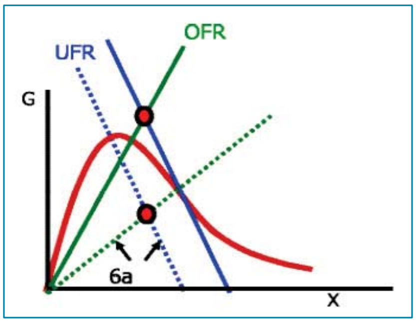
Critically Loaded-Thickening



Overloaded - Thickening



Critically Loaded-Clarification

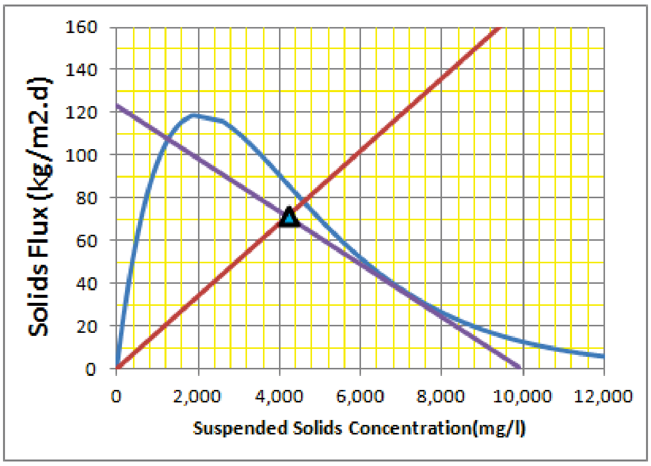


Overloaded – Clarification &Thickening

EXAMPLE-1 ON STATE POINT ANALYSIS

- Determine the minimum clarifier area required to accommodate the maximum day flow for treatment plant with the following design parameters:

V_0	156	m/d
SVI	200	ml/g
K	0.4818	m3/Kg
Q	13100	m3/day
Q_R	9500	m3/day
R	0.73	
Clarifier Area (A)	770	m2
V_u	12.34	m/d
V_o	17.01	m/d
X	4,200	mg/l
X_R	9,992	mg/l
SLR	123	kg/m2.d

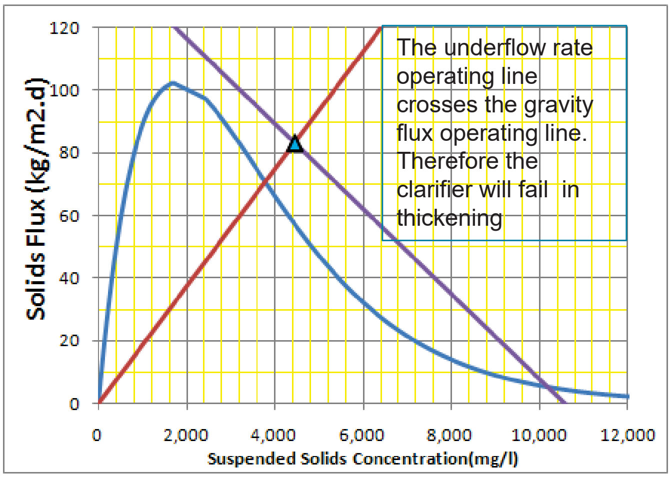


Example-1

EXAMPLE-2 ON STATE POINT ANALYSIS

- WWTP has a secondary clarifiers surface area of 700 m2 operating under max day flow of 13100 m3/day , return sludge =9500 m3/day and MLSS=4450mg/l. IF the SVI is 250 mg/l will the clarifiers operate properly.

V_0	156	m/d
SVI	250	ml/g
K	0.5611	m3/Kg
Q	13100	m3/day
Q_R	9500	m3/day
R	0.73	
Clarifier Area (A)	700	m2
V_u	13.57	m/d
V_o	18.71	m/d
X	4,450	mg/l
X_R	10,586	mg/l
SLR	144	kg/m2.d

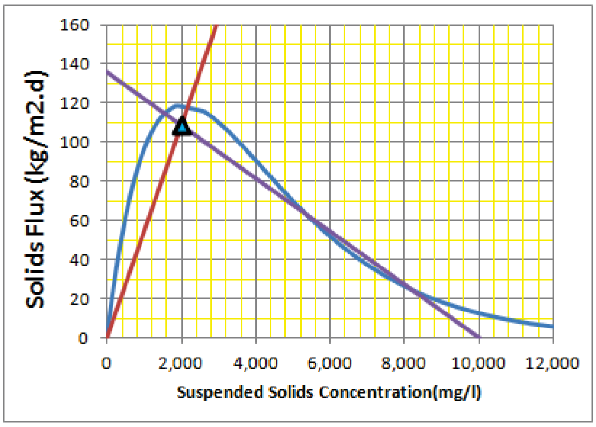


Example 2
High SVI

EXAMPLE-3 ON STATE POINT ANALYSIS

- Would the clarifier area given in Example 1 function properly at PHF of 38,000 m3/day.

V_0	156	m/d
SVI	200	ml/g
K	0.4818	m3/Kg
Q	38000	m3/day
Q_R	9500	m3/day
R	0.25	
Clarifier Area (A)	700	m2
V_u	13.57	m/d
V_o	54.29	m/d
X	2,000	mg/l
X_R	10,000	mg/l
SLR	136	kg/m2.d



Example-3

MINIMUM REQUIRED AREA FOR THICKENING

- Solids load/Applied flux to clarifier

$$SLR = (Q + Q_{RAS}) \times \frac{MLSS}{Clarifier\_Area}$$

$$R = \frac{Q_{RAS}}{Q}$$

$$X_R = \frac{MLSS \times (1 + R)}{R}$$

$$SLR(Ga) = \frac{Q \times MLSS * (R + 1)}{A}$$

By setting SLR equal to the limiting flux, the minimum clarifier area required for thickening can be solved

UNDER FLOW RATE FLUX

$$UFR(U_F) = \frac{-Q \times R \times (X - X_R)}{A}$$

SECONDERY CLARIFIERS DETAILS

- Diameters
  - 9 to 42 m.
- Side water depth
  - 4.25 m for diameters less than 20 m.
  - 5 m for diameters between 20 and 38 m.
  - 5.5 m for diameters greater than 38 m.
- Bottom Slopes
  - Clarifiers with hydraulic suction type mechanism , max 1 in 12 bottom slope.
  - Clarifiers with scraper type mechanisms, preferable 1 in 10 bottom slope.

RETURN ACTIVATED SLUDGE

- ❑ RAS = Return Activated Sludge.
- ❑ Purpose of RAS line is to keep MLSS in the aeration tank
- ❑ RAS rate must be sufficient to prevent accumulation of MLSS in the Secondary Clarifier
- ❑ RAS rate must be less than critical underflow rate, otherwise there is a risk of solids overload.

SURPLUS ACTIVATED SLUDGE (WAS,SAS)

- **Purpose**
  - Control a desired MLSS level
  - Control a desired sludge age.
- **Quantity**
  - BOD x Y_{obs} (kg/d)
  - Typical concentration 5000 – 8000 mg/L
- **Control**
  - SAS flow meter, volume control
  - Adjust volume to maintain the target MLSS level

RAS/WAS PUMPING

- Continuous sludge withdrawal should be provided.
- It is preferable to have a dedicated pump per clarifier with flow measurement and control.
- Three pumps(2 duty,1 standby) should be provided for every two clarifiers. The pumps can be connected by a common header, but valves should be arranged so that one clarifier can be isolated.
- Variable speed pumps should be provided to discharge variable quantities of sludge depending on process requirements.
- The rate of RAS pumping is a function of the recycle ratios required to maintain the design MLSS. It ranges between 20% to 100% for conventional activated plants and 30% to 150% for extended aeration.
- Sludge piping should be at least 100 mm dia with a minimum velocity of 0.6 m/s.
- Means for measurement of flow, taking samples, draining and flushing lines should be considered in the design.

SWIM-H2020 SM

For further information

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SWIM and Horizon 2020 Support Mechanism

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