Better Plants
U.S. DEPARTMENT OF ENERGY

SESSION 6

OPTIMIZING RAS RATE, STATE POINT ANALYSIS, AND MORE ENERGY MATH

U.S. DEPARTMENT OF
ENERGY

Today's Agenda

- Welcome and Introductions
- Opportunity Register Report Outs
- Optimizing RAS Rate
- Statepoint Analysis
- Tools of the Trade – Part 2
- Closing Remarks

OPPORTUNITIES?

Report Outs

Opportunity Register

Energy Projects

Energy Project		VALUE MATRIX		Step 1	Identify					
Opportunity #	Opportunity Name	Savings (1-10)	Cost/Effort (1-10)		Opportunity Description	Location	System*	Date Submitted	Capital or O&M	Submitted By
1	Lower W3 Pressure	3	2							
2										
3										
4										
5										
6										
7										

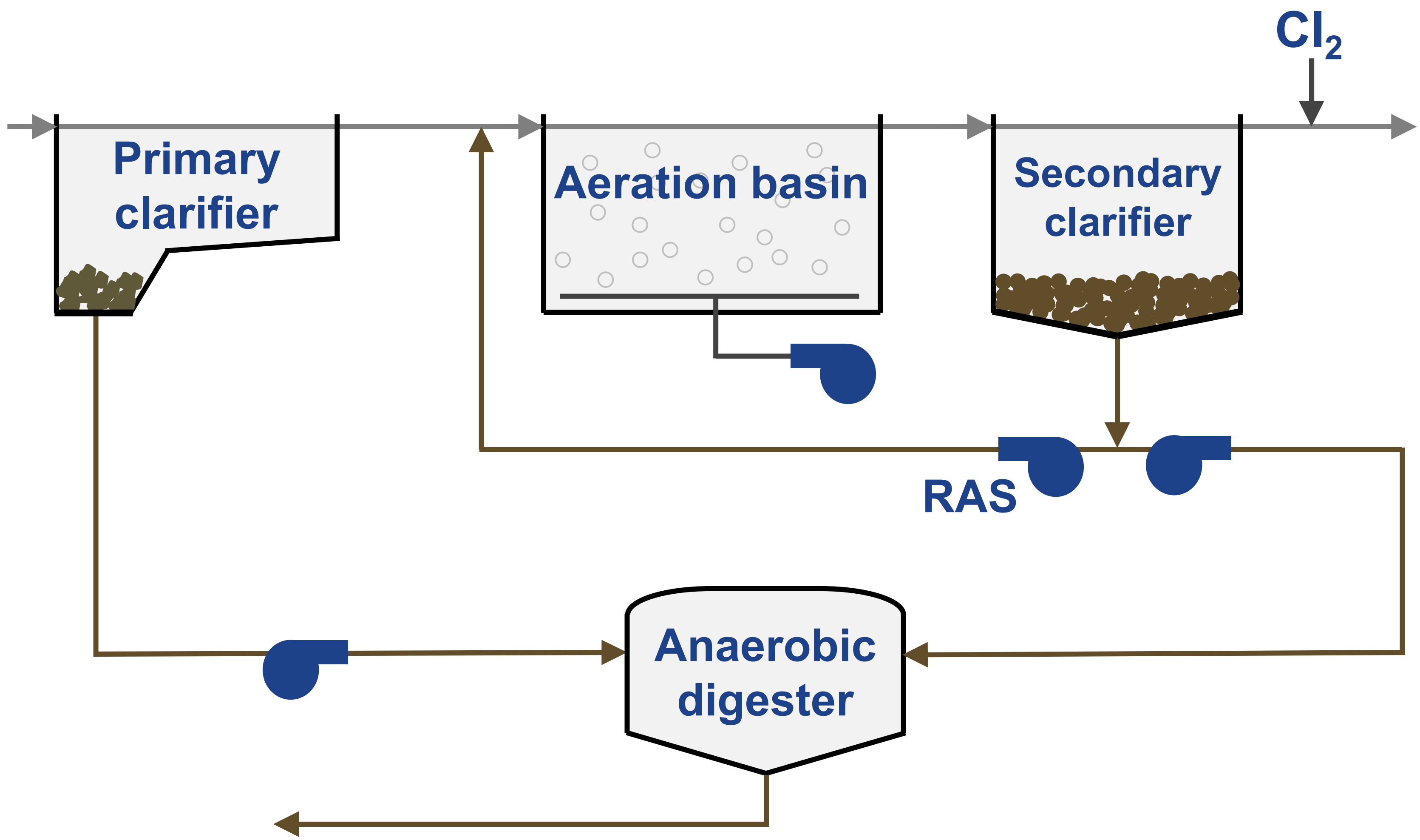
We Operate Multi-Million Dollar Facilities with Someone Else's Money

Let’s Cut to the Chase

“You can make good wine with good grapes, you can make bad wine with good grapes, but you can never make good wine with bad grapes.”

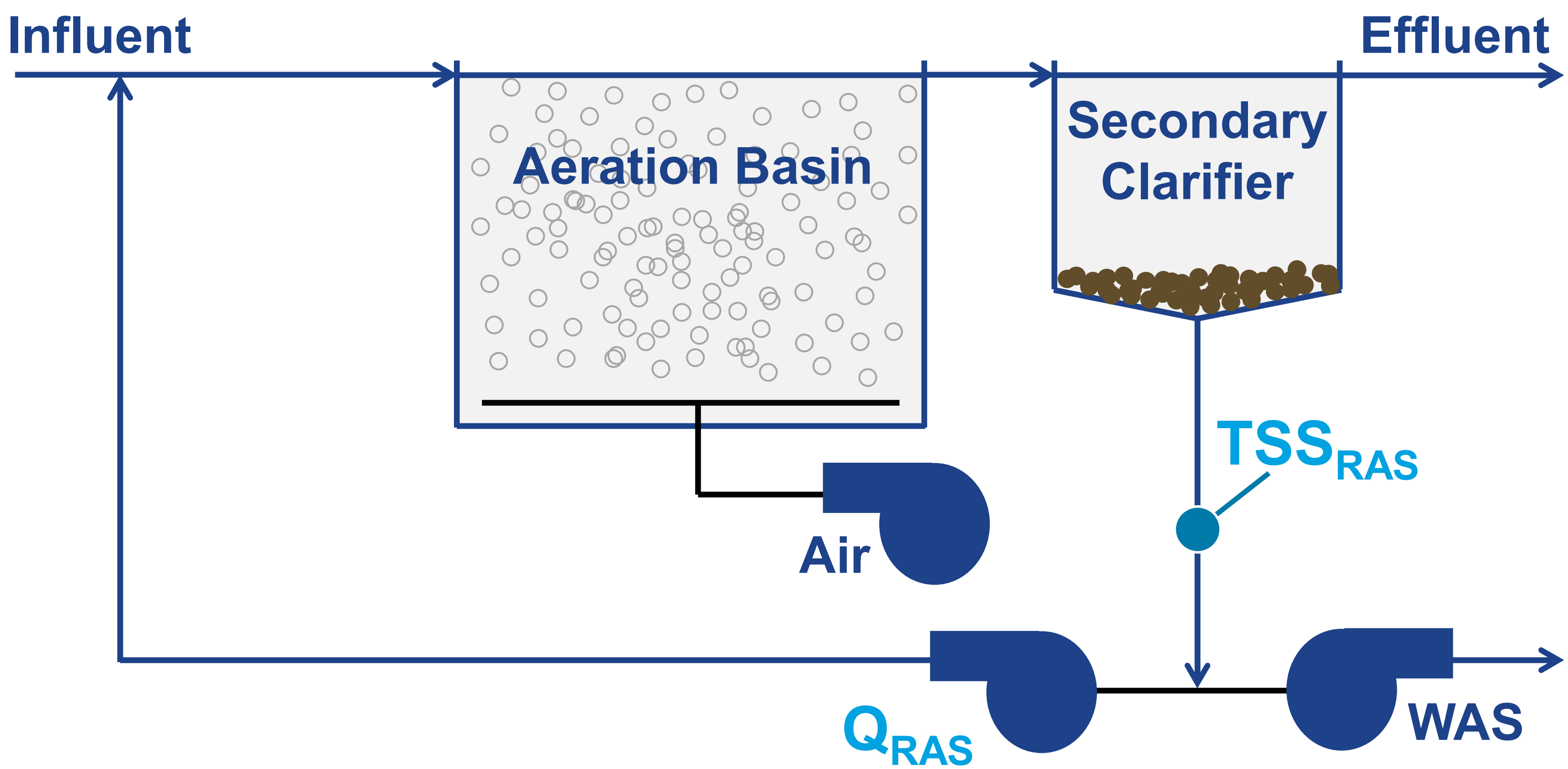
"You cannot have good effluent quality without good sludge quality."

To Talk About RAS Flow, We Need to Talk About the Secondary Clarifier



Why We Care: Low-Head-High-Flow RAS Pumps Require Big Electric Motors

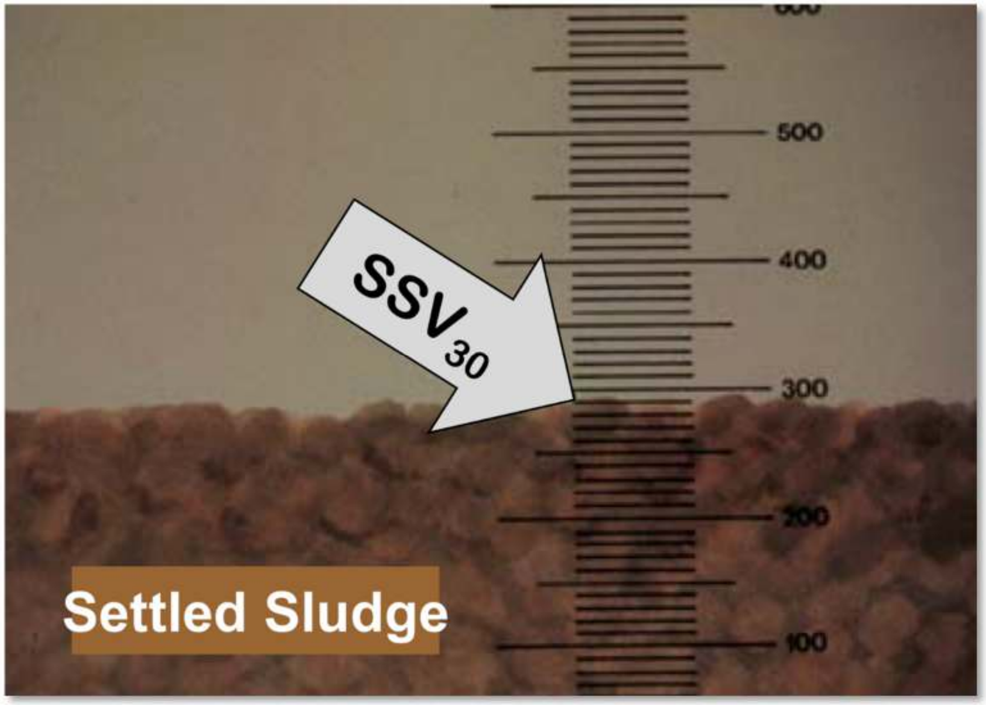
Two Reasons for Confusion Around RAS Flow (Q_{RAS}) and RAS TSS Concentration (TSS_{RAS})



1. Thickening is ***NOT*** a Process Objective of the Secondary Clarifier

To remove settleable solids (biomass).

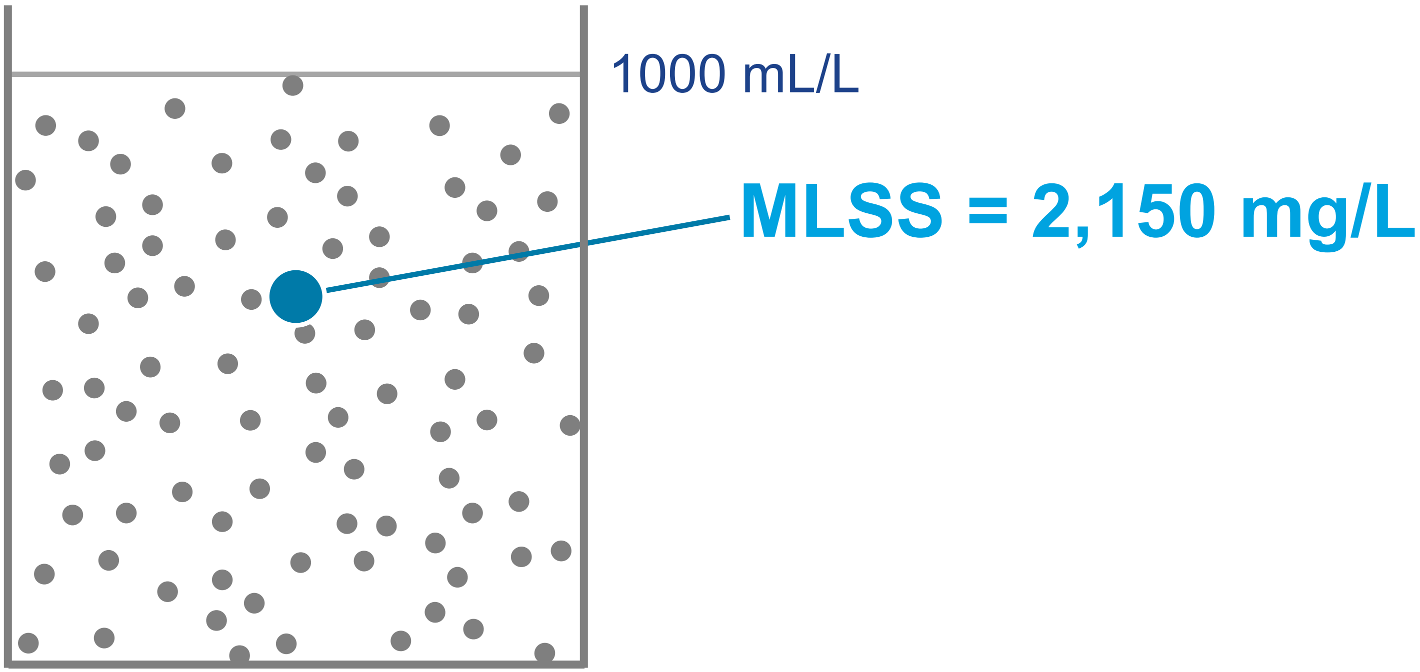
Activated Sludge Does Not **Appreciatively** Settle/Thicken/Compact More After 30 min



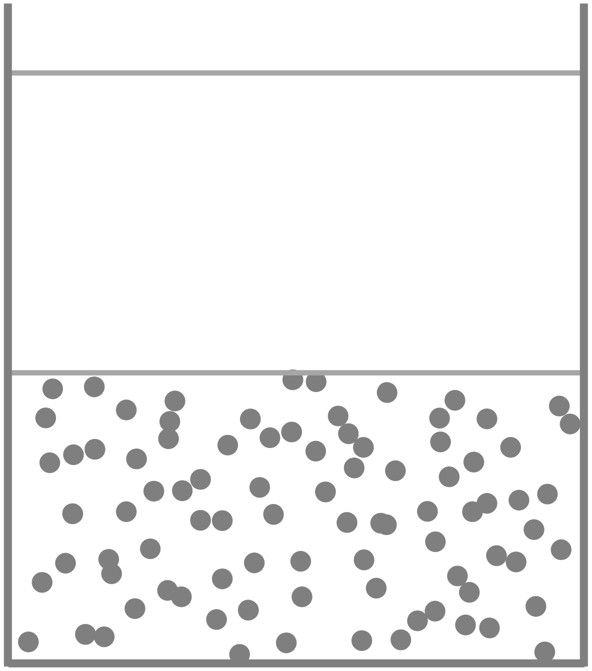
SSV_{30} = 290 mL/L

SSV_{60}, SSV_{120} not much different

Measure MLSS on Sample
Used In Settleometer Test

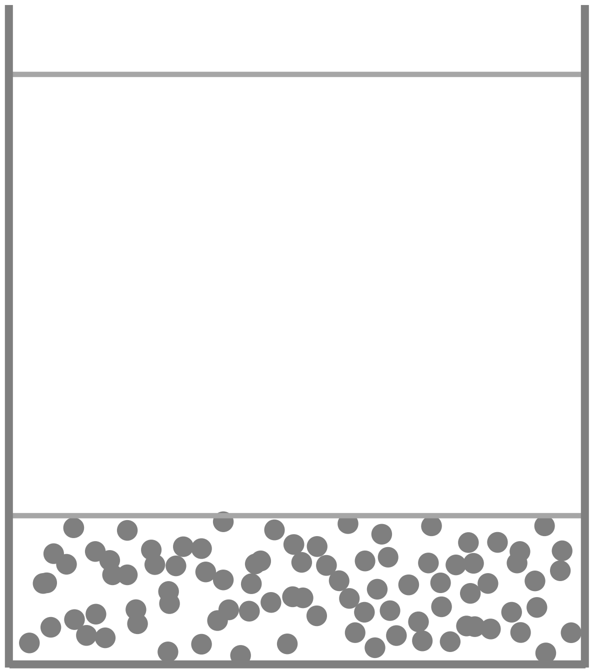


SSV_5



500 mL/L

SSV_{30}

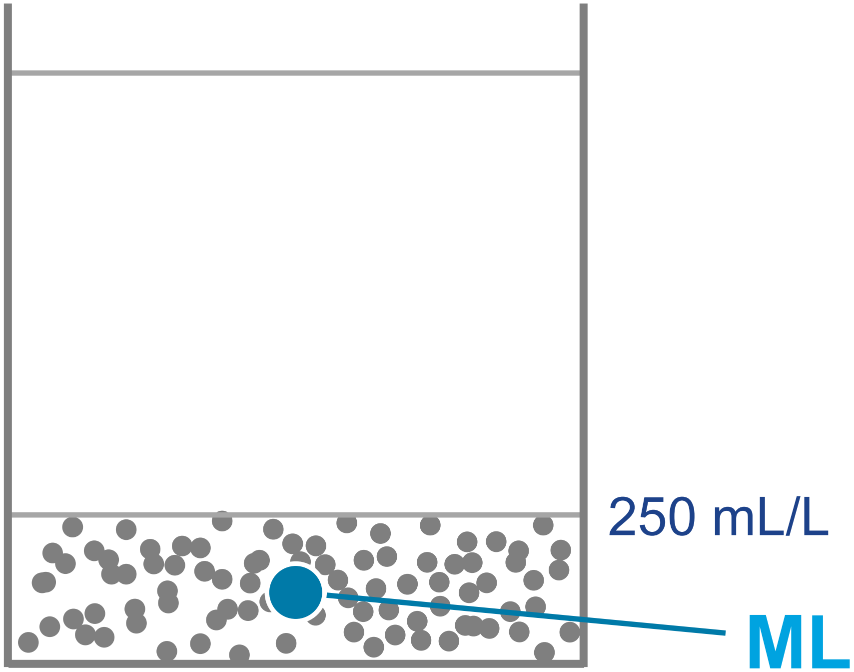


250 mL/L

$MLSS_{30}$ = Sludge Blanket TSS Concentration After 30 min In Settleometer

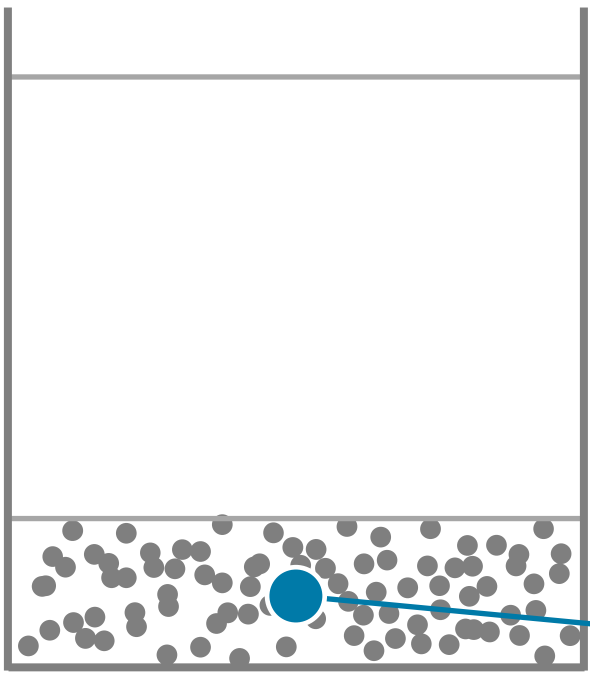
$$MLSS_{30} = \frac{MLSS \times 1{,}000}{SSV_{30}}$$

Calculate $MLSS_{30}$



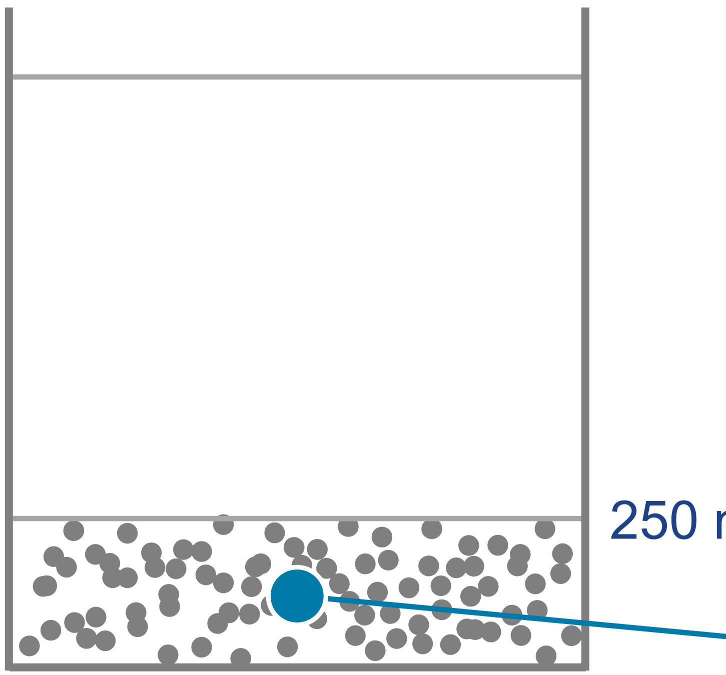
$MLSS_{30}$ = 8,600 mg/L

For All Intents and Purposes, $MLSS_{30}$ is Max Possible RAS Concentration (TSS_{RASmax})



TSS_{RASmax} = 8,600 mg/L

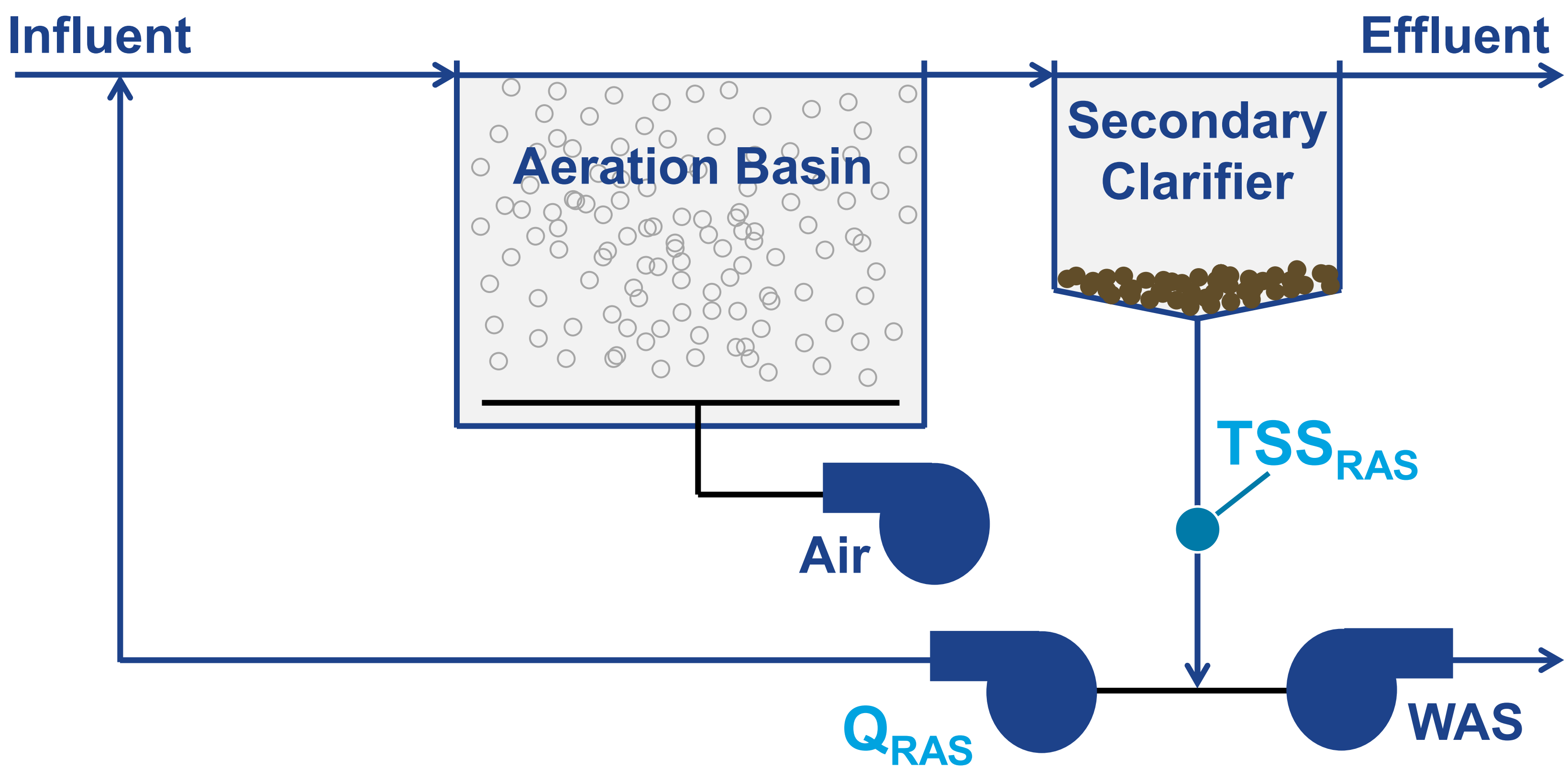
Thickening is ***NOT*** a Process Objective of the Secondary Clarifier



Compaction is a sludge quality characteristic, not a function of the secondary clarifier

TSS_{RASmax} = 8,600 mg/L

2. Q_{RAS} Controls TSS_{RAS} ***NOT*** the Other Way Around



Solids Mass Balance Around Secondary Clarifier Gives This Result

$$TSS_{RAS} \approx \left(1 + \frac{Q}{Q_{RAS}}\right) \times MLSS$$

A Mass Balance is ***FUNDAMENTAL*** it Must Be True; it is Non-Negotiable

Example

Q = 1.2 Mgal/d

$\mathbf{Q_{RAS}}$ = 375 gal/min = 0.54 Mgal/d

MLSS = 2,000 mg/L

$$TSS_{RAS} \approx \left(1 + \frac{1.2\ \cancel{Mgal/d}}{0.54\ \cancel{Mgal/d}}\right) \times (2{,}000\ mg/L)$$

$$\mathbf{TSS_{RAS} \approx 6{,}444\ mg/L}$$

Some Plants Have Proportional RAS Flow Control (r is Constant)

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

$$TSS_{RAS} \approx \left(1 + \frac{Q}{Q_{RAS}}\right) \times MLSS$$

TSS_{RAS} is a Fixed Multiple of MLSS and Does **NOT** Change with Q and Q_{RAS}

$$TSS_{RAS} \approx \left(1 + \frac{1}{r}\right) \times MLSS$$

A Mass Balance is ***FUNDAMENTAL*** it Must Be True; it is Non-Negotiable

Example

r = 85% = 0.85

MLSS = 3,500 mg/L

$$TSS_{RAS} \approx \left(1 + \frac{1}{0.85}\right) \times (3{,}500 \text{ mg/L})$$

$$TSS_{RAS} \approx 7{,}618 \text{ mg/L}$$

So, What Should My RAS Flow be

?

Two Reasons to Run Q_{RAS} as Low as Possible

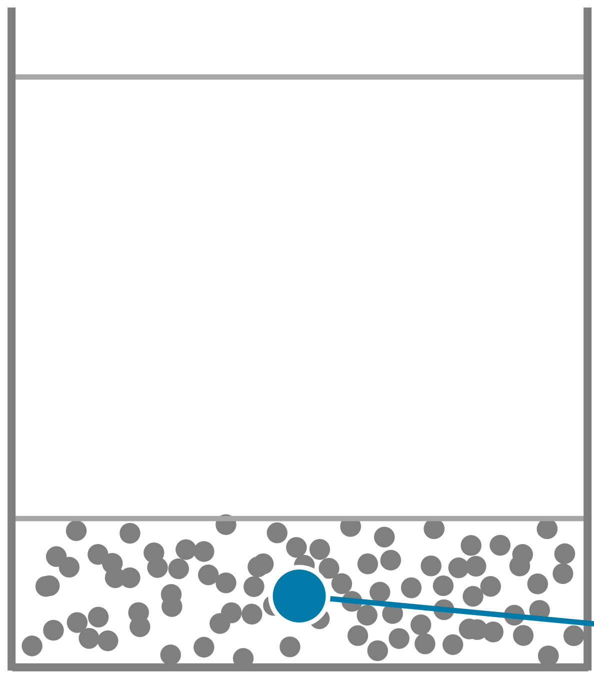
1. Higher RAS flows than necessary waste electricity (and ratepayer money)

2. Due to turbulence in the secondary clarifier, high RAS flows can deteriorate performance by increasing TSS_{SCE}

This Shows TSS_{RAS} Concentration Increases With Decreasing Q_{RAS}

$$TSS_{RAS} \approx \left(1 + \frac{Q}{Q_{RAS}}\right) \times MLSS$$

Suggested Here $TSS_{RASmax} = MLSS_{30}$, Calculated Using SSV_{30} from Settleometer



Compaction is a sludge quality characteristic, not a function of the secondary clarifier

TSS_{RASmax} = 8,600 mg/L

Resulting Equations
Set Eqns. 1 and 2 Equal, Solve for Q_{RASmin}

$$TSS_{RASmax} \approx \left(1 + \frac{Q}{Q_{RASmin}}\right) \times MLSS \quad \textit{(Eqn. 1)}$$

$$TSS_{RASmax} = \frac{MLSS \times 1{,}000}{SSV_{30}} \quad \textit{(Eqn. 2)}$$

Optimum RAS Flow (Q_{RASmin}) or Percentage (r_{min}) Fixed by Extent of Compaction

$$Q_{RASmin} = \frac{SSV_{30}}{1,000 - SSV_{30}} \times Q$$

$$r_{min} = \frac{SSV_{30}}{1,000 - SSV_{30}}$$

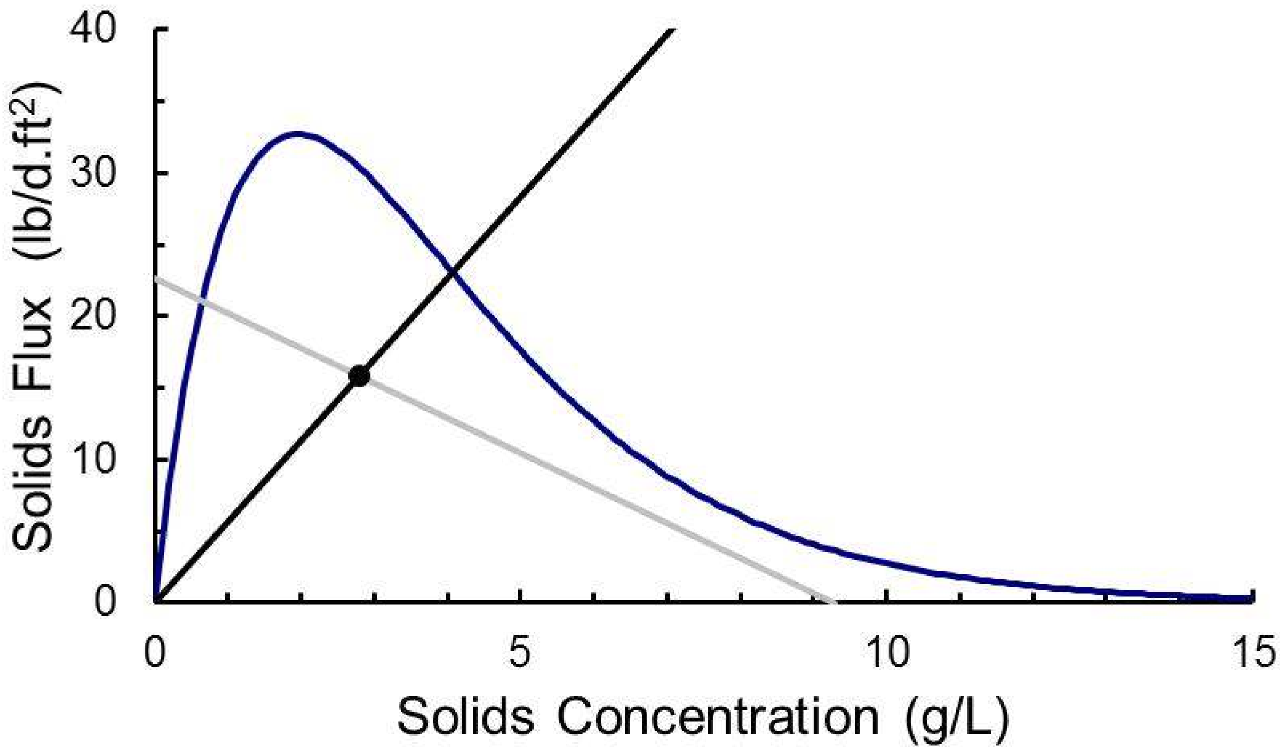
Good Sludge Quality Saves Ratepayer Money HUGE!

SSV_{30} (mL/L)	r_{min} (%)
150	18
250	33
350	54
450	82
550	122
650	186
750	300

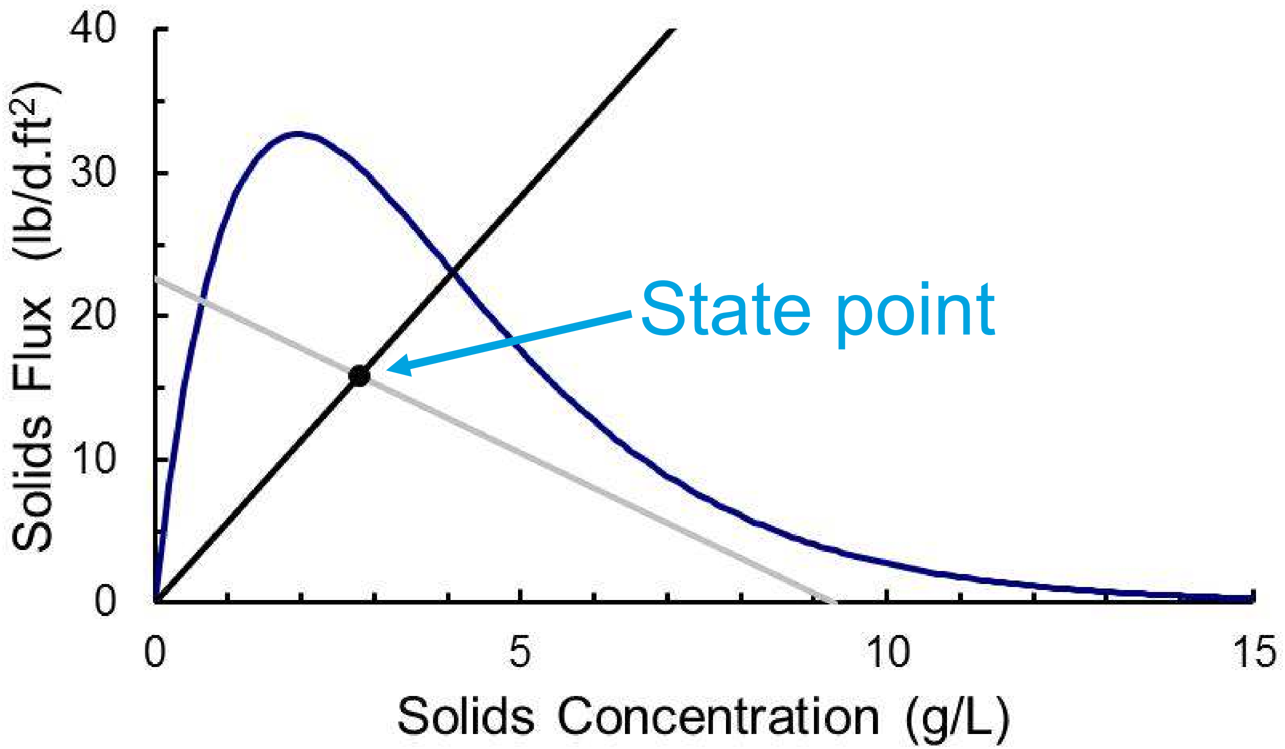
INTRODUCTION TO STATE POINT ANALYSIS

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

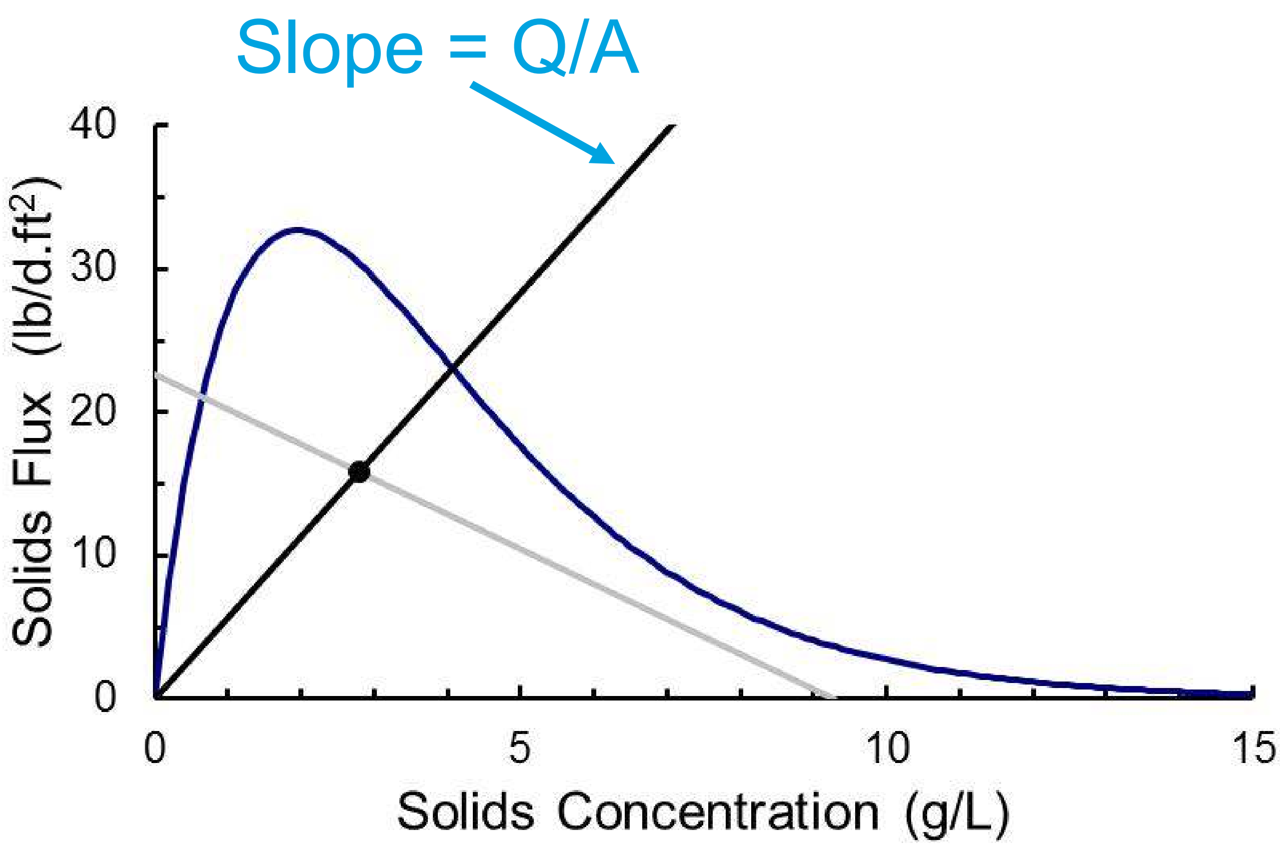
Introduction to State Point Analysis



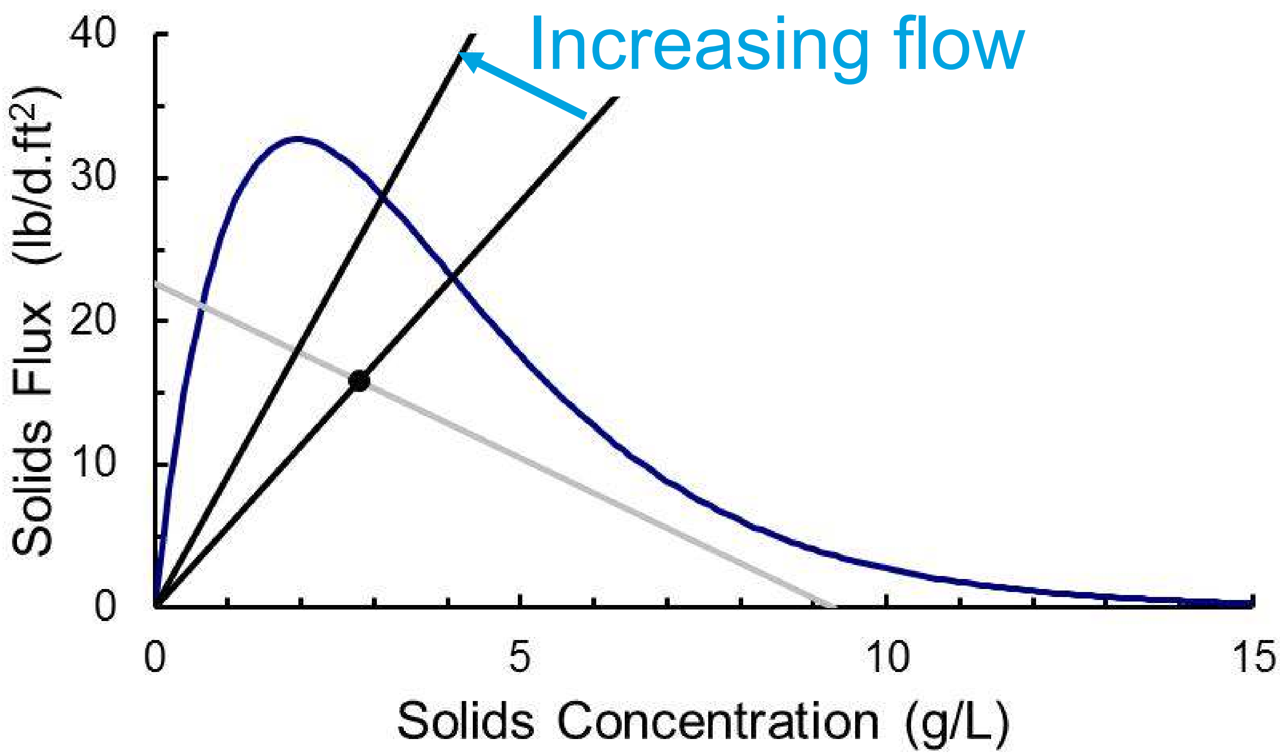
The State Point Is At the Intersection of the Two Operating Lines



The Line Going Up From Left to Right is the Overflow Rate Operating Line



The Slope Changes With Changes in Flow (Q) and Online Clarifiers (A)



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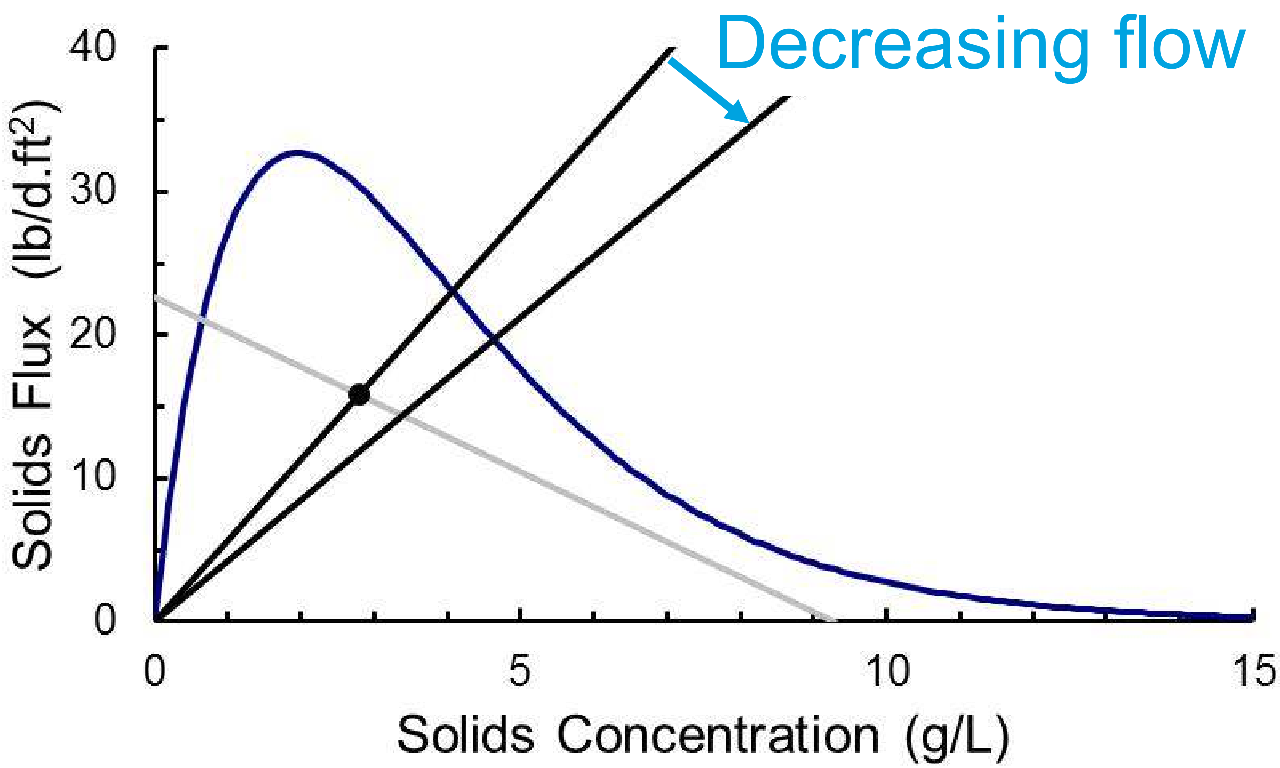

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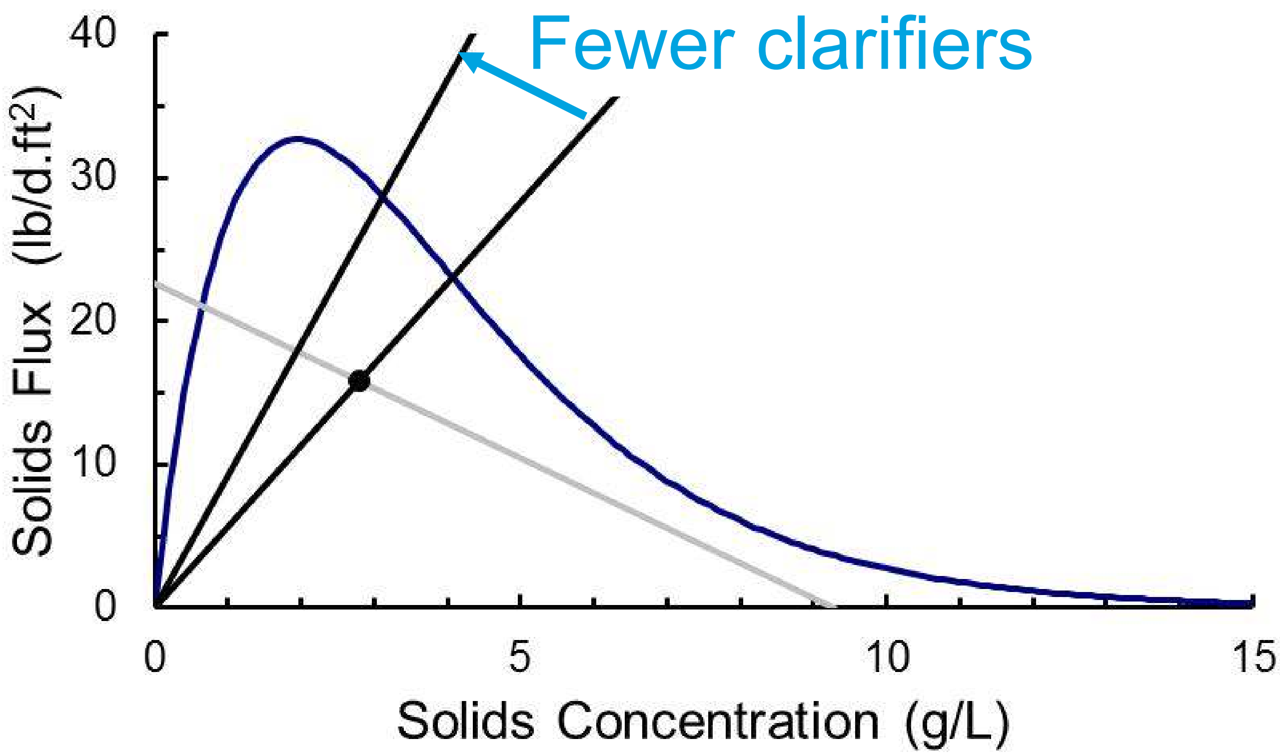

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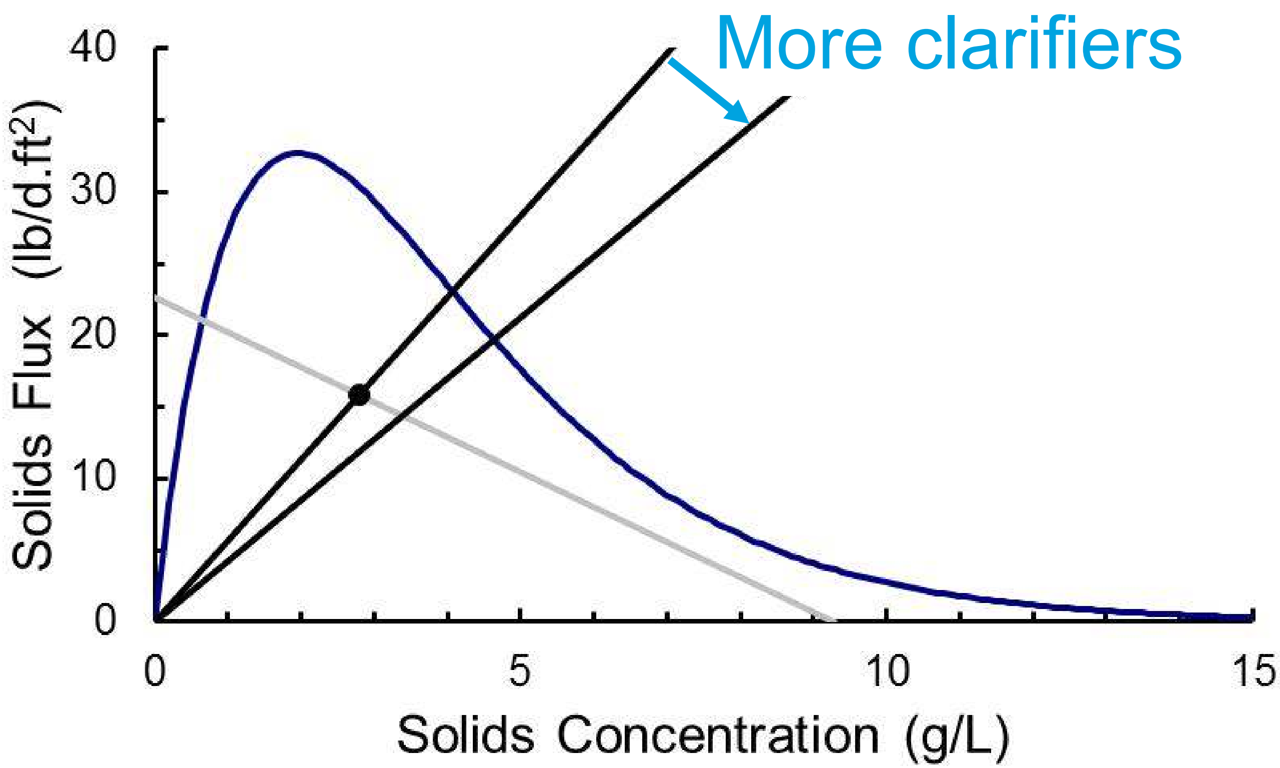
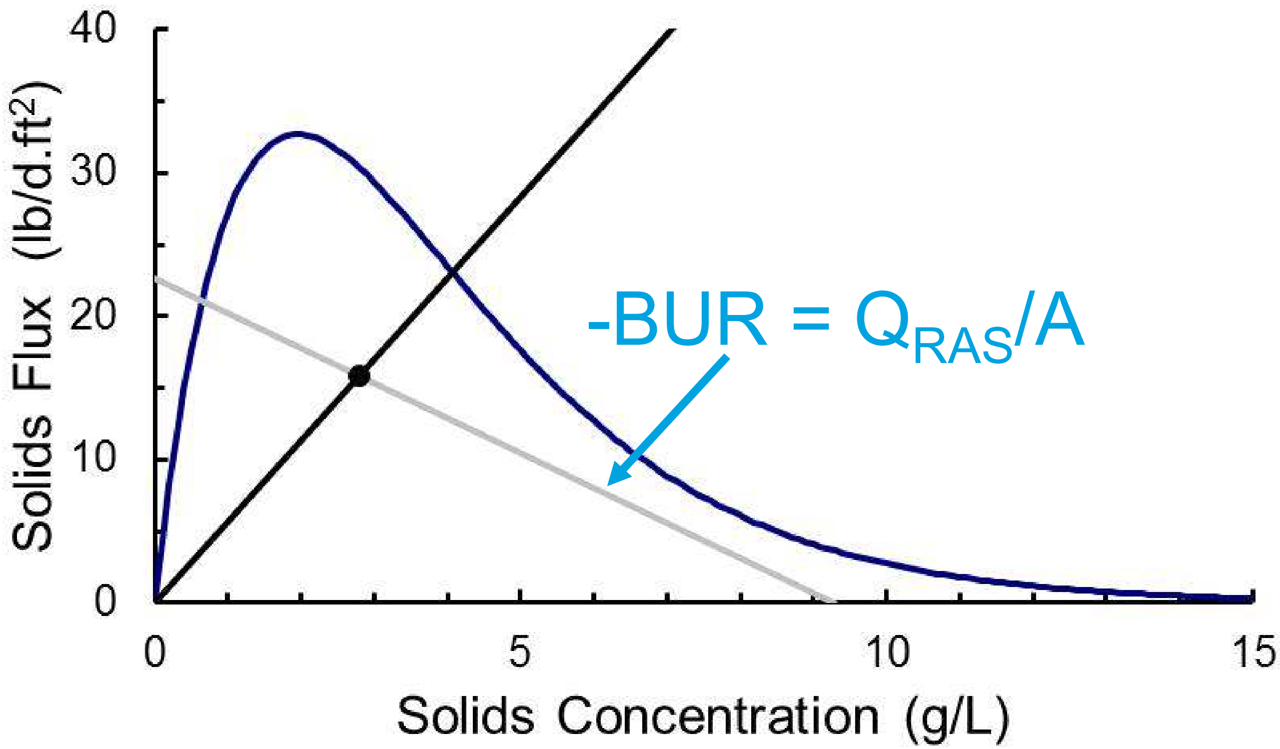
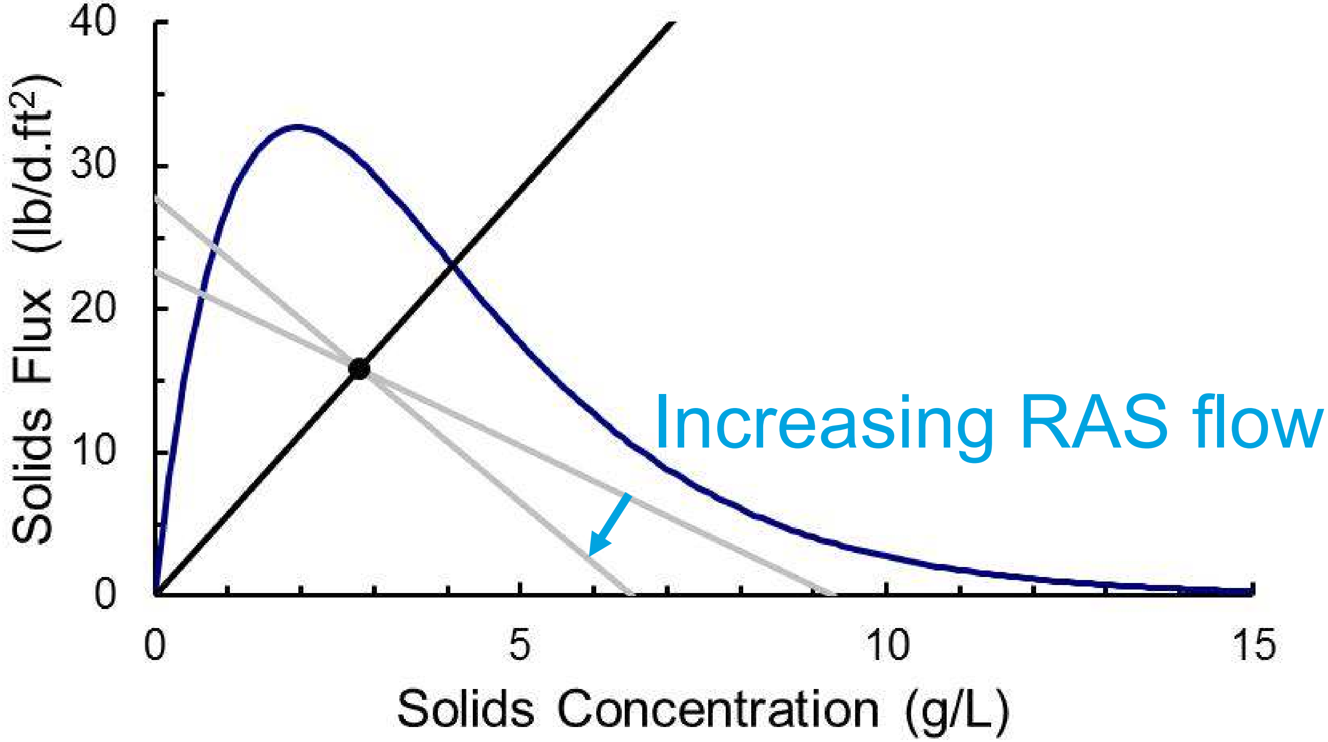


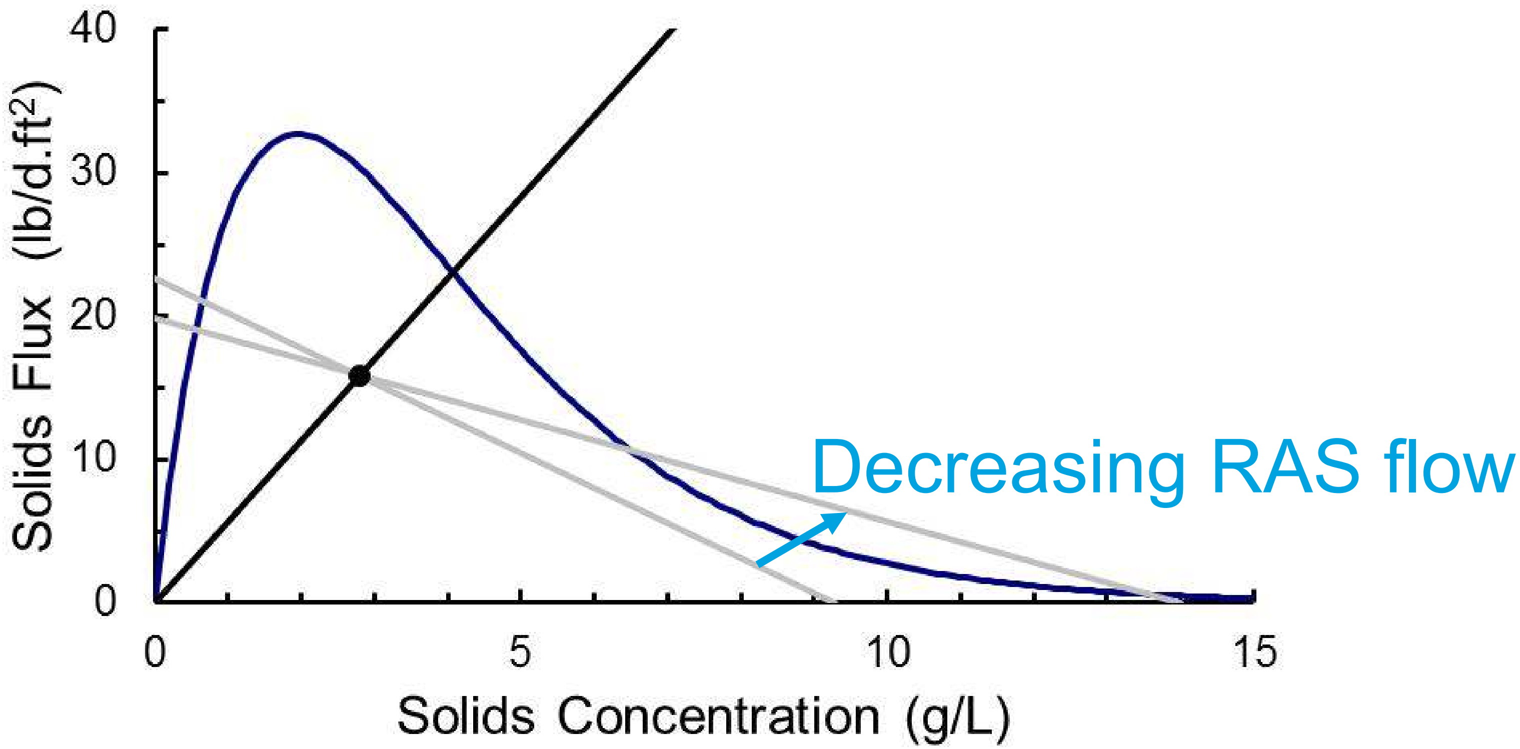
Line Going Down Left to Right is Bottom Underflow Rate Operating Line (BUR)



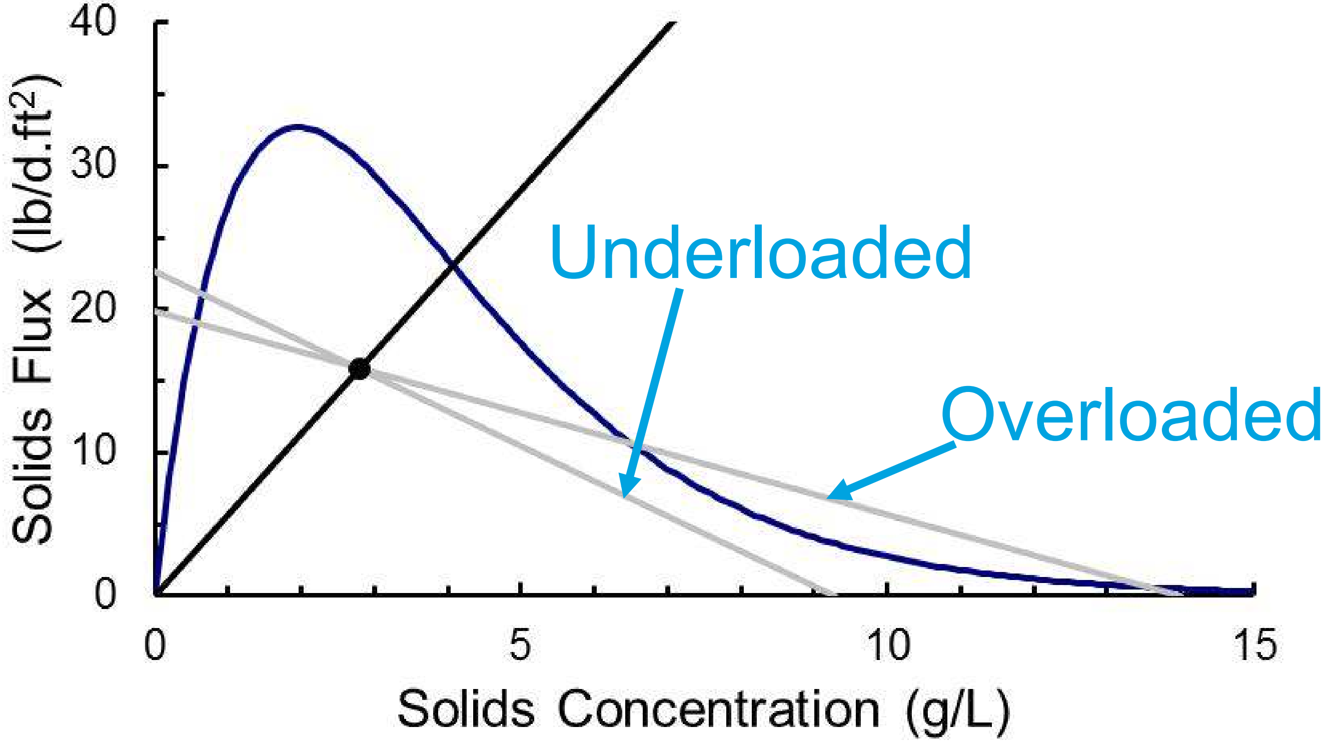
The Slope Changes With Changes in Q_{RAS}



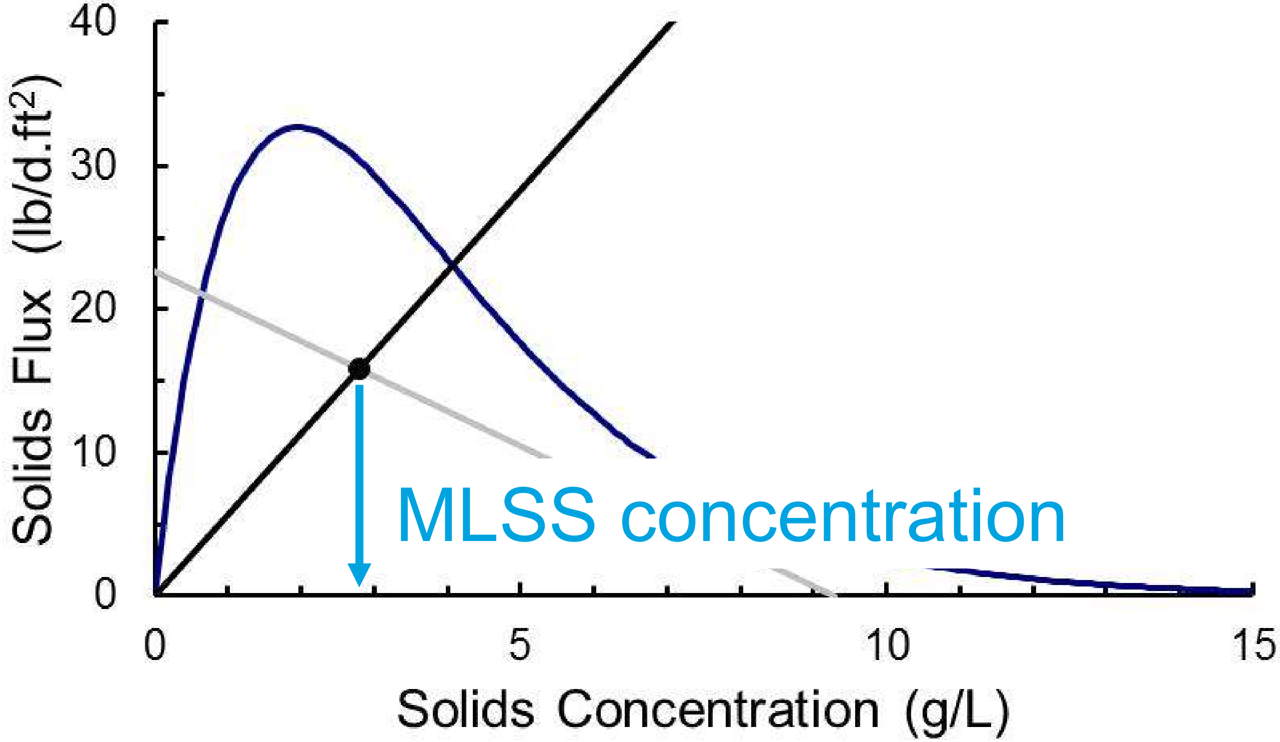
The Slope Changes With Changes in Q_{RAS}



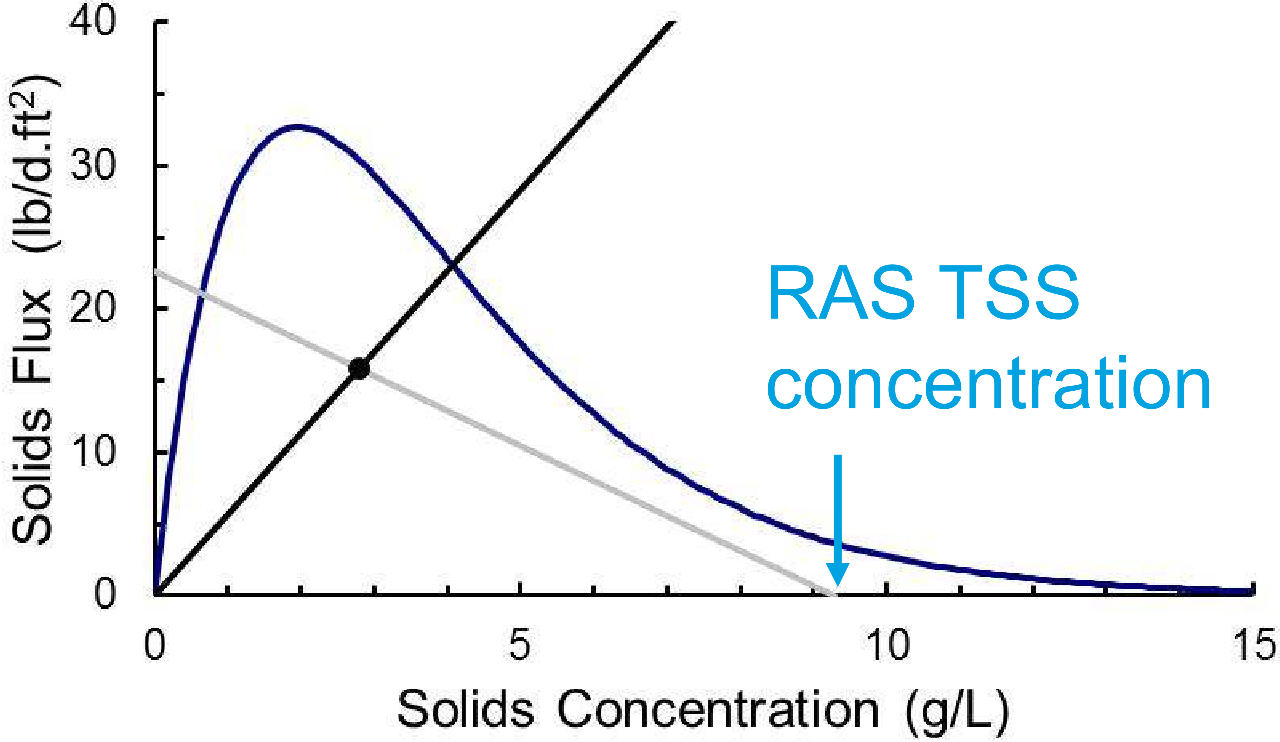
This is Important



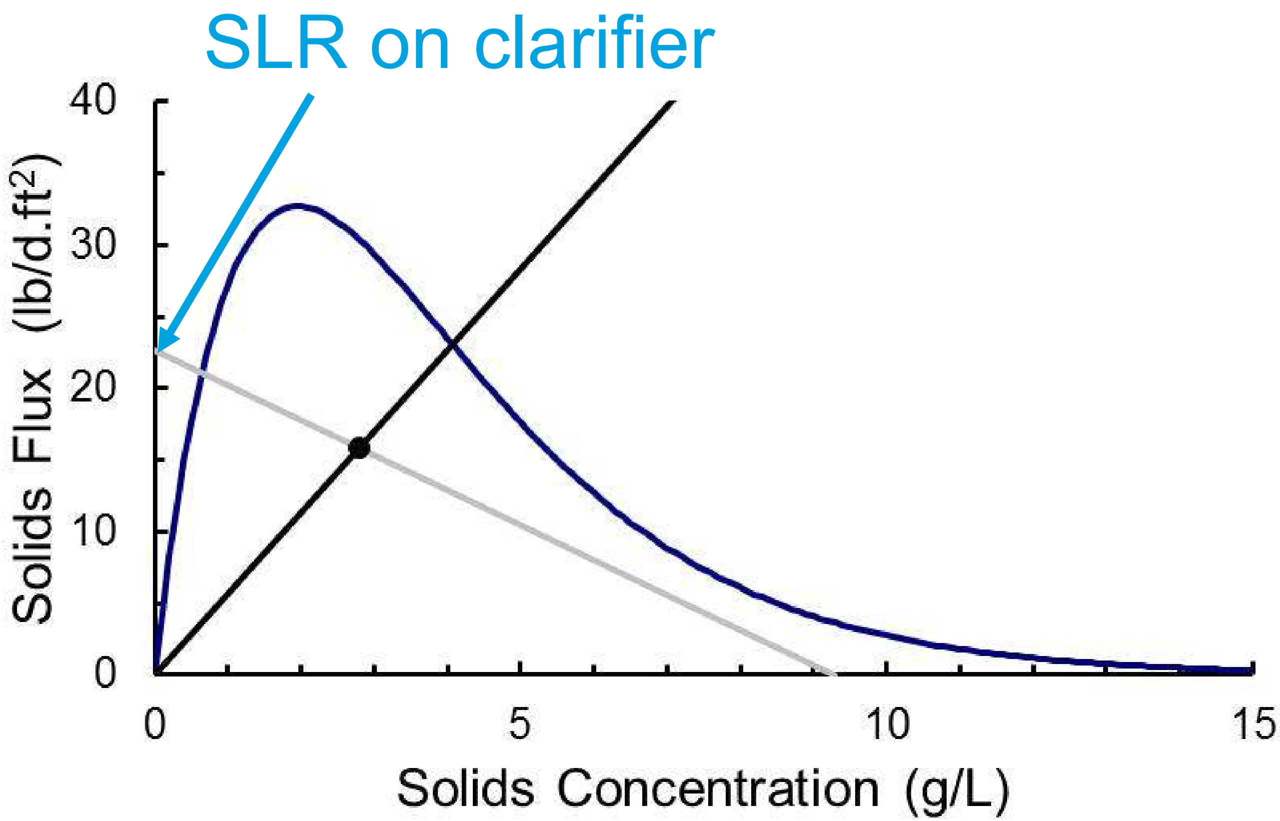
The Two Lines Intersect at the MLSS Concentration



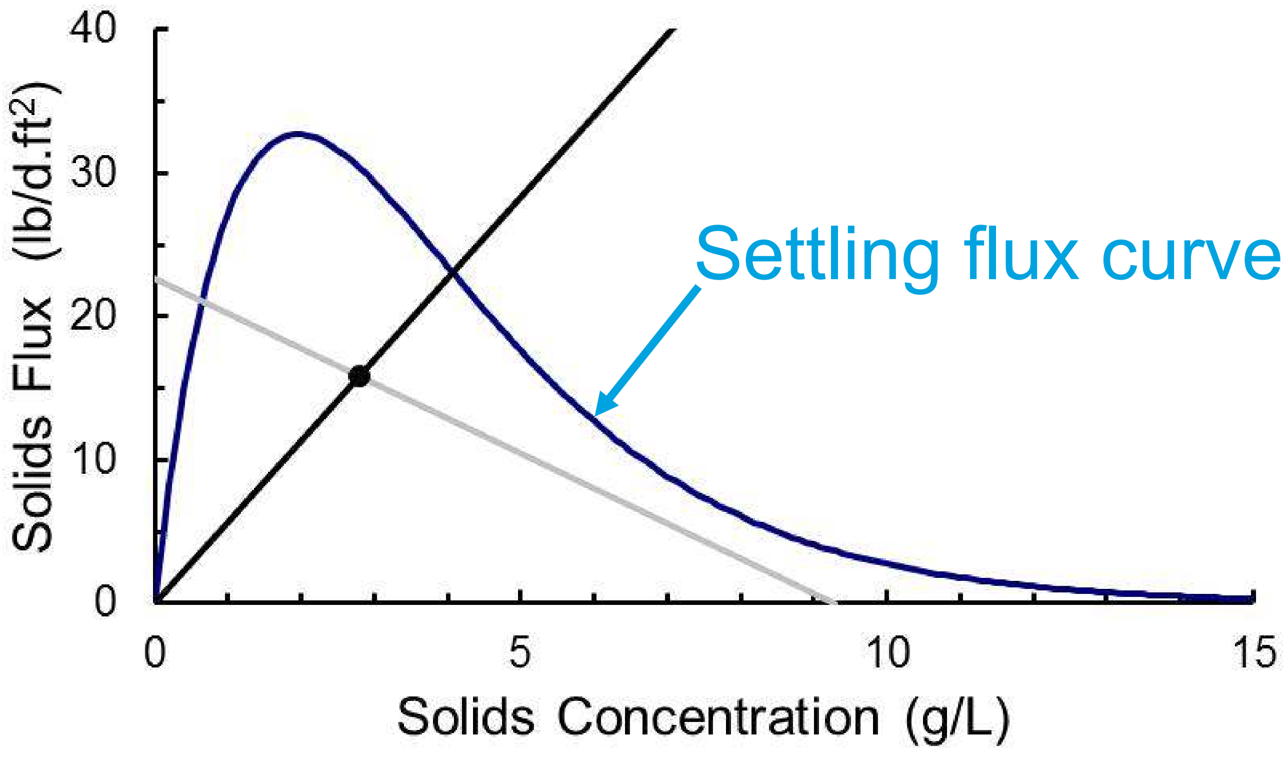
Underflow Rate Operating Line Intersects x-axis at TSS_{RAS} (when passing below curve)



And the y-axis at Solids Loading Rate (regardless where it is relative to curve)



The Settling Flux Curve is Defined by Sludge Settleability



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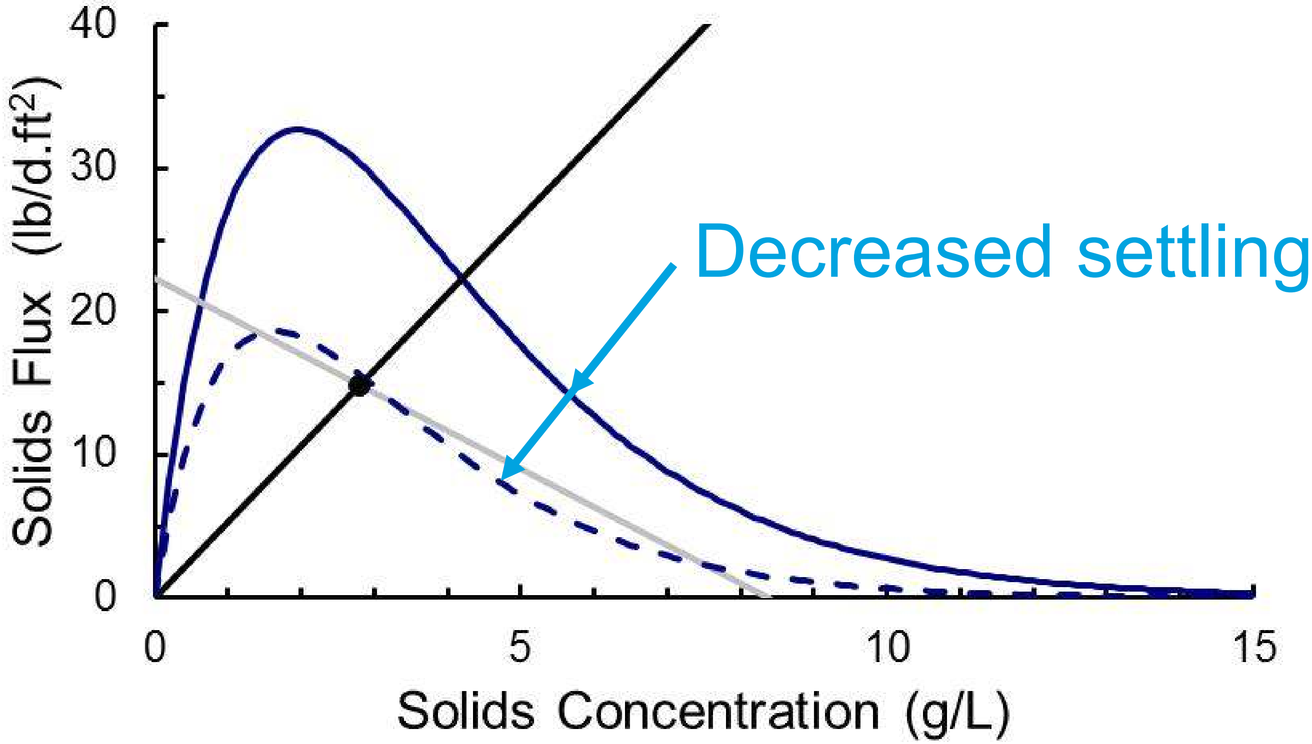
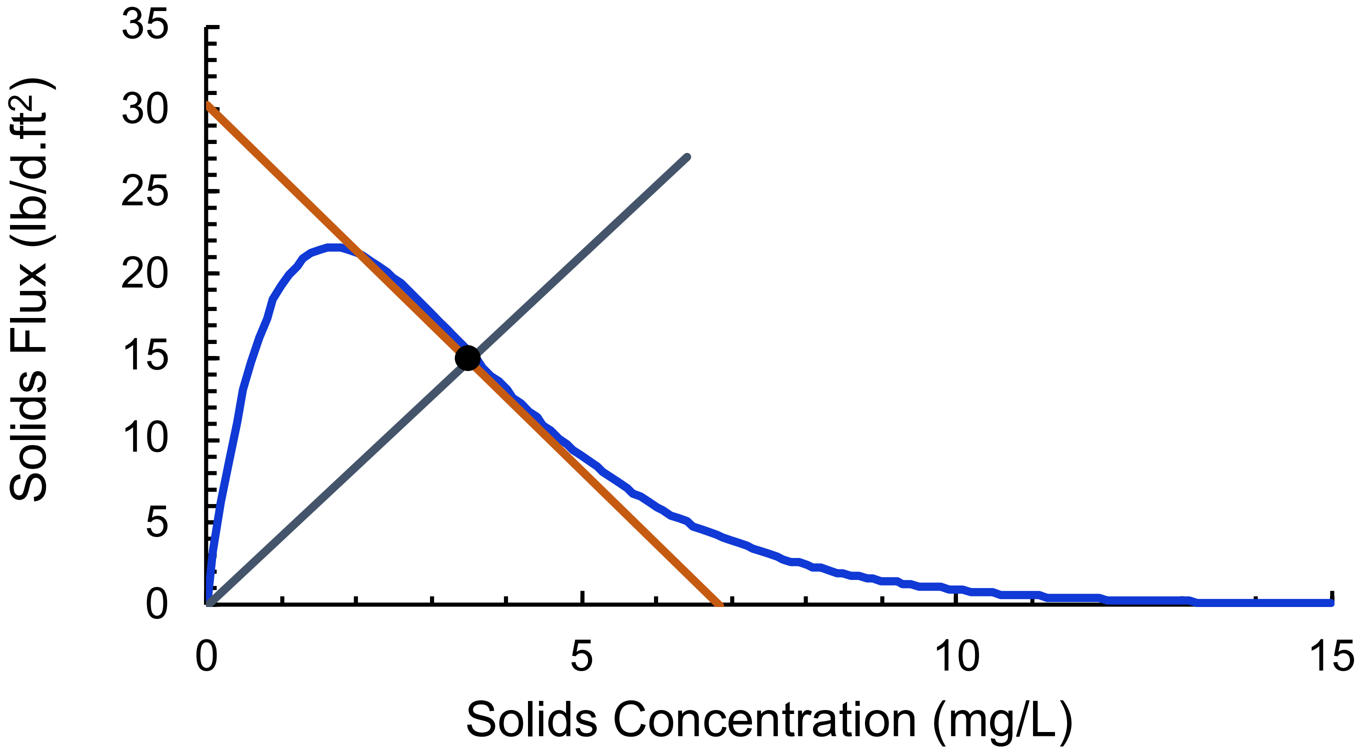
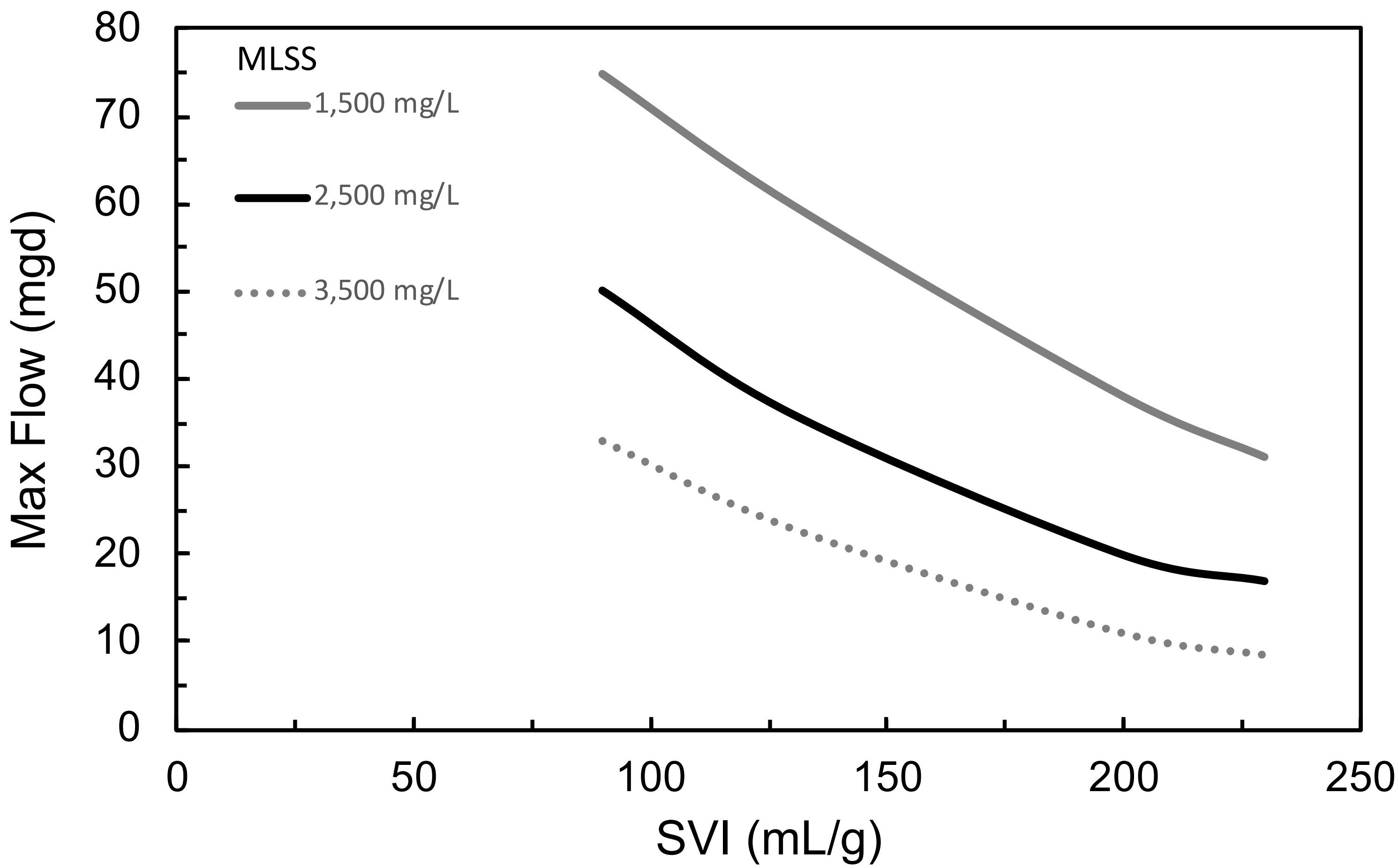


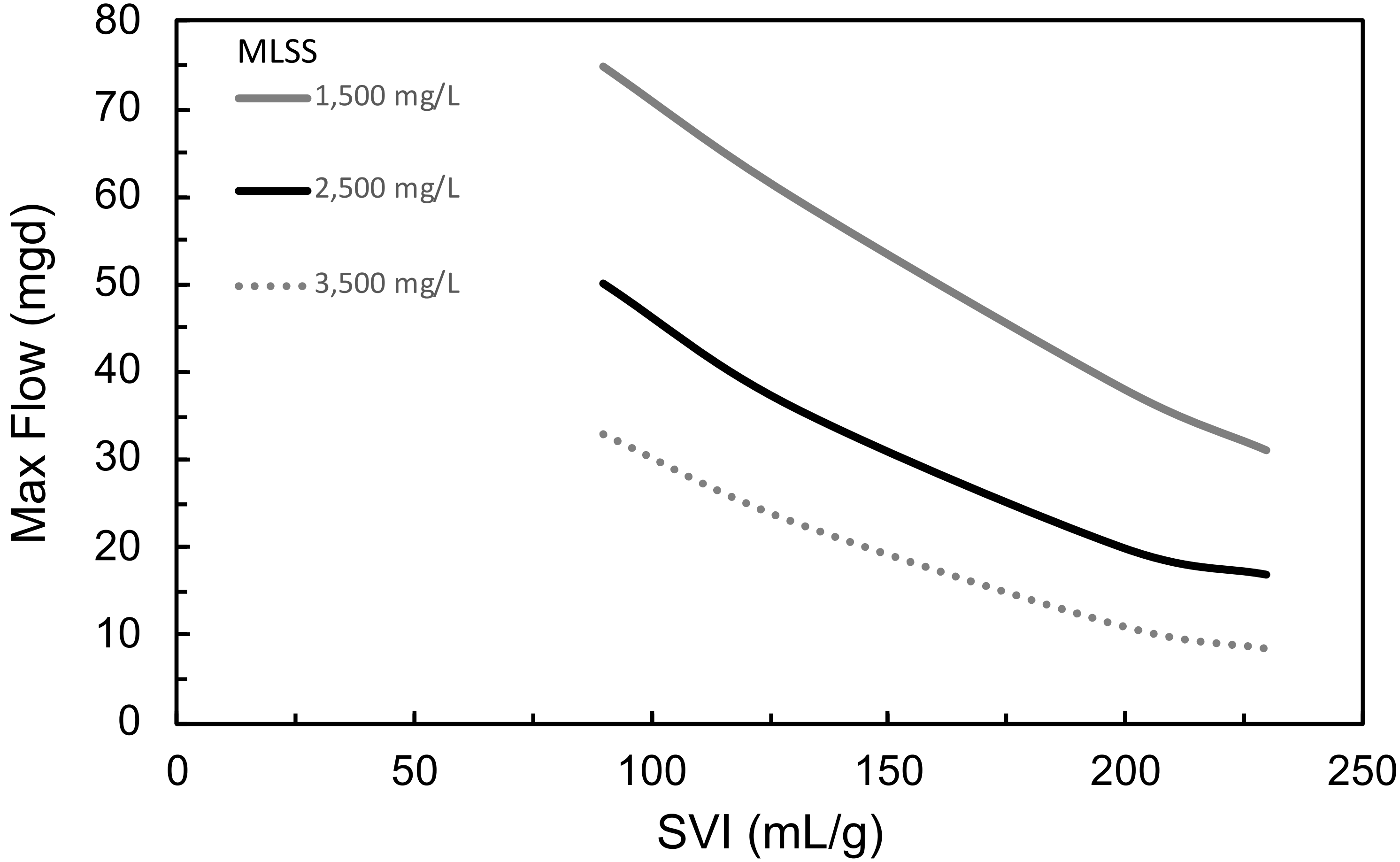
An Extremely Powerful Tool



Sludge Quantity (MLSS) and Quality (SVI) Have Huge Impact on Capacity



It's Elementary My Dear Watson: **Minimize Sludge Quantity, Maximize Sludge Quality**



Final Takeaways to Save Energy in the Liquid Treatment Train

1. Remove as much as possible in the primaries
2. Implement SRT control following guidelines given (best sludge quality!)
3. Optimize, by minimizing, RAS flow
4. Know the statistical accuracy of all data used to make process control decisions

State Point Exercise

This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	0	mL/g
Number of clarifiers	0	
Area of each clarifier	0	ft^2
MLSS	0	g/L
Influent flow	0	mgd
RAS flow	0	mgd

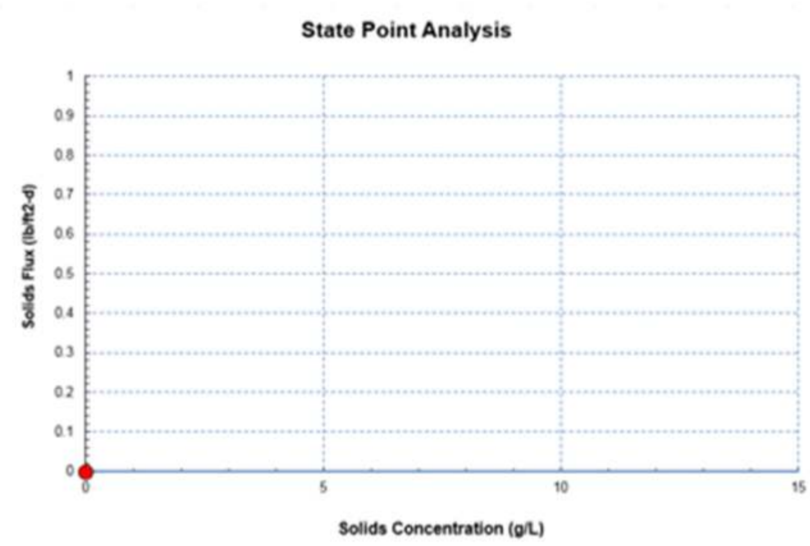
Alternate influent flow	0	mgd
Alternate RAS flow	0	mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

kg/m^2h	0
kg/m^2d	0
lb/ft^2d	0

Influent flow	0	gpm
	0	mgd
Combined RAS flow	0	gpm
	0	mgd

2-L Settleometer without stirring - Typically use this graph



Questions about your bill: Call toll free

BILLING DATE: **Mar 26, 2010** ACCOUNT NUMBER: DATE DUE: **Apr 13, 2010** AMOUNT DUE: **$23,005.02**

ITEM 5 - ELECTRIC SERVICE

METER NUMBER	SERVICE PERIOD From	To	ELAPSED DAYS	METER READINGS Previous	Current	METER MULTIPLIER	AMOUNT USED THIS MONTH
28819932	Feb 24, 2010	Mar 25, 2010	29	10344	10669	1,200.0	390,000 kwh
28819932	Demand	Mar 25, 2010			0.615	1,200.0	738 kw
28819932	Reactive	Mar 25, 2010			0.413	1,200.0	496 kvar

Next scheduled read date: 04-23. Date may vary due to scheduling or weather.

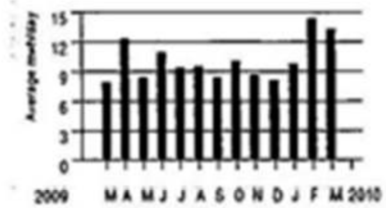
NEW CHARGES - 03/10	UNITS	COST PER UNIT	CHARGE
Basic Charge - 3P Pri Delivery	842 kw	0.6000000	782.20
Demand Charge Pri - Min 100 Kw	738 kw	3.8900000	2,870.82
Base Supply Demand Charge	738 kw	1.0000000	738.00
Delivery Charge Primary	390,000 kwh	0.0012200	475.80
Oregon Tax Charge	390,000 kwh	0.0014200	553.80
Reactive Power Charge Pri	201 kvar	0.6000000	120.60
Supply Enrgy Pri 1st 20000 Kwh	20,000 kwh	0.0455400	910.80
Supply Enrgy Pri > 20000 Kwh	370,000 kwh	0.0404500	14,966.50
Public Purpose		0.0300000	642.56
Energy Conservation Charge	390,000 kwh	0.0015700	612.30
Low Income Assistance	390,000 kwh	0.0005000	195.00
Jc Boyle Dam Removal Surcharge for 8 day(s)	107,586 kwh	0.0003200	34.43
Copco/Iron Gate Dams Remv Schg for 8 day(s)	107,586 kwh	0.0009500	102.21
Total New Charges			23,005.02

Total rate: $0.04516/kWh

Demand Charge

Reactive Charge

Historical Data - *ITEM 5*



Your Average Daily kwh Usage by Month

PERIOD ENDING	MAR 2010	MAR 2009
Avg Daily Temp	47	45
Total kwh	390000	231600
Avg kwh per Day	13448	7986
Cost per Day	$793.28	$517.00

Header Pressure

Distance from diffuser to water surface in feet divided by 2.31 = minimum header pressure in PSIG to form a bubble.

Aeration Savings & the Fact Sheet

3 IMPACT OF BLOWER PRESSURE ON ENERGY

Disch. pressure	Reduction in pressure of ___ psig				
	-0.2	-0.4	-0.6	-0.8	-1.0
12	1.3%	2.7%	4.0%	5.4%	6.7%
11	1.5%	2.9%	4.4%	5.9%	7.4%
10	1.6%	3.3%	4.9%	6.6%	8.3%
9	1.8%	3.7%	5.5%	7.4%	9.3%
8	2.1%	4.2%	6.3%	8.4%	10.6%
7	2.4%	4.8%	7.3%	9.7%	12.2%

*Assumes 70% blower eff & 92% motor/drive eff

Reduce pressure across blower by

- Clean inlet air filter
- Clean the aeration basin diffusers (which also improves OTE = reduces air demand)
- Use most open valve control strategies
- Reduce or eliminate throttling
- Hold return stream flows (e.g. centrate) until low load conditions at night (lower airflow lowers friction losses)

PSIG	IN H_2O
0.1	2.8
0.2	5.5
0.3	8.3
0.4	11.1
0.5	13.8
0.6	16.6
0.7	19.4
0.8	22.1
0.9	24.9

1 PSI = 2.31 feet of water
1 foot of water = 0.43 PSI

2 IMPACT OF DO LEVELS ON ENERGY

Saturated DO
DO in basin = driving force for oxygen transfer
Driving force UP means Energy goes DOWN

DO rule of thumb
0.5 mg/l reduction creates ~ 6% energy savings

DO calibration & cleaning
A probe that reads 10% low (e.g. 2.0 when actual is 2.2) is costing you 2.4% at the blower.

DO level increases
As mixed liquor temp increases, the impact of elevated DO levels increases.

IMPACT OF AVERAGE DO LEVEL ON BLOWER ENERGY

Mixed liquor temp		DO sat	Energy savings potential if DO reduced from __ to 2.0 mg/l			
°C	°F	mg/l	2.5	3	4	5
0	32	14.6	4.0%	7.9%	15.9%	23.8%
2	36	13.8	4.2%	8.5%	16.9%	25.4%
5	41	12.8	4.6%	9.3%	18.5%	27.8%
10	50	11.3	5.4%	10.8%	21.5%	32.3%
15	59	10.1	6.2%	12.3%	24.7%	37.0%
20	68	9.1	7.0%	14.1%	28.2%	42.3%
25	77	8.2	8.1%	16.1%	32.3%	48.4%

NOTE Higher impact as elevation increases

Exercise - Aeration Pressure

C) Impact of Blower Pressure on Energy

Impact of Discharge Pressure Reduction on Blower Energy

Discharge Pressure	Reduction in pressure of ___ psig.				
	-0.5	-1	-1.5	-2	-4
12	3.3%	6.7%	10.1%	13.4%	26.9%
11	3.7%	7.4%	11.1%	14.8%	29.6%
10	4.1%	8.3%	12.4%	16.5%	32.9%
9	4.6%	9.3%	13.9%	18.5%	37.0%
8	5.2%	10.6%	15.8%	21.0%	42.1%
7	6.1%	12.2%	18.3%	24.3%	48.6%

Example: 12 psig discharge lowered by 2 psig saves 13.4% at blower. (Assumes 70% blower eff. & 92% drive eff.)

psig	inches of H_2O
0.1	2.8
0.5	13.8
1	27.7
1.5	41.5
2	55.4
2.5	69.2
3	83.0
3.5	96.9
4	110.7

1 psi = 2.31 feet of water; 1 foot of water = 0.43 psi

What is the savings potential from lowering blower discharge pressure?

250	hp, blower
10	psig, discharge pressure
-0.5	pressure reduction
4.1%	%, potential energy savings
50,974	kWh annual energy savings
$3,058	annual cost savings @ $0.06/kWh

1. How much energy is saved if this 50 hp blower's discharge pressure is reduced from 7 psig to 5.5 psig?	**kWh/year**	
2. What if it's a 150 hp blower, and the pressure is lowered from 10 psig to 9.5 psig. What percentage of energy is saved?	**%**	
3. If a 75 hp blower is turned down from 11 psig to 9 psig, how much money is saved (if energy costs 6¢ per kWh)?	**$ /year**	
4. If a 40 hp blower is turned down from 8 psig to 7 psig, how much energy is saved, and what percentage does that represent?	**kWh/year**	**%**

DO Residual Aeration Tool

B) Impact of DO Levels on Energy

Saturated DO minus DO in basin = driving force for oxygen transfer; Driving force UP means Energy goes DOWN

Impact of Average DO Level on Blower Energy

Mixed Liquor Temp		DO Sat	Energy Savings Potential if DO Reduced from ___ to 1.0 mg/l			
°C	°F	mg/l	2	3	4	5
0	32	14.6	7.4%	14.7%	22.1%	29.4%
2	36	13.8	7.8%	15.6%	23.4%	31.3%
5	41	12.8	8.5%	16.9%	25.4%	33.9%
10	50	11.3	9.7%	19.4%	29.1%	38.8%
15	59	10.1	11.0%	22.0%	33.0%	44.0%
20	68	9.1	12.3%	24.7%	37.0%	49.4%
25	77	8.2	13.9%	27.8%	41.7%	55.6%

Note: *Higher impact as elevation increases.*

How much could my plant benefit from reducing DO to 1.0 mg/l?

100	hp, blower
68	°F, mixed liquor temp
9.1	mg/l, DO Sat
4	current DO level
37.0%	%, potential energy savings
212,779	kWh annual energy savings
$12,767	annual cost savings @ $0.06/kWh

1. What percentage of energy could be saved if an aeration basin holding 25°C mixed liquor lowered its DO residual from 2 mg/L to 1 mg/L?	**%**
2. If a plant is running 200 hp of blowers, and it has 59 °F mixed liquor, how many kWh/y of energy might it save by lowering its DO from 3 mg/L to 1 mg/L?	**kWh/year**
3. In b) how much cost is saved (at $0.06/kWh)?	**$ /year**
4. How much total money can be saved if a plant running 100 hp of blowers in 20 °C mixed liquor reduces their DO residual from 5 mg/L to 1 mg/L?	**kWh/year**
5. Your plant runs (on average) what total horsepower of blower? What is the approximate temperature of your plant's mixed liquor? What is the DO residual setpoint at your plant?	**hp** **°F** **mg/L**
6. How much total money is saved if your plant reduces DO residual to 1 mg/L?	**$ /year**

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