Better Plants
U.S. DEPARTMENT OF ENERGY

## SESSION 6

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

U.S. DEPARTMENT OF ENERGY

# Chat question for the week

- ***JUST ANSWER YES OR NO: (We'll get the numbers later)***

- > Do you know your ***RAS recycle*** percentage?
  or
- > Do you know your ***plant and RAS flow rates***?

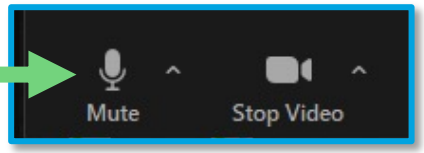
- > Do you know your ***MLSS concentration?***
- > Do you know your ***RAS TSS concentration****?*

# Using Zoom!

**Mute yourself!**

Have a question?
Use the chat feature.

*Controls accessed at the bottom*



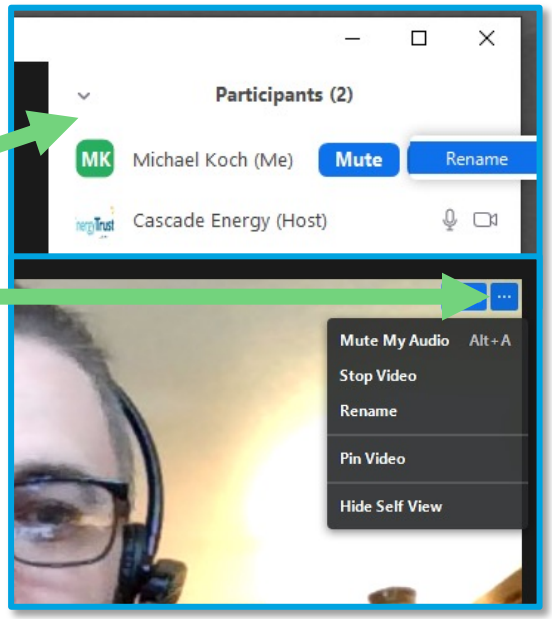

**Rename yourself**

"Name (Company)"

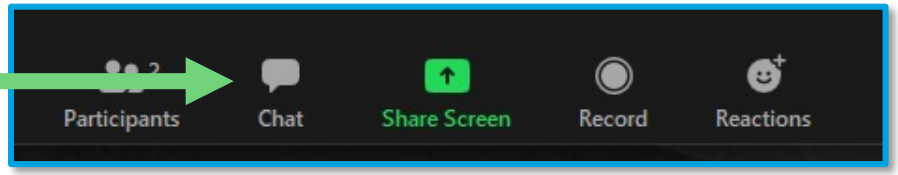
*Right click on your picture or 3 dots*

*OR*

*Controls accessed at the right after clicking 'Participants' at bottom.*



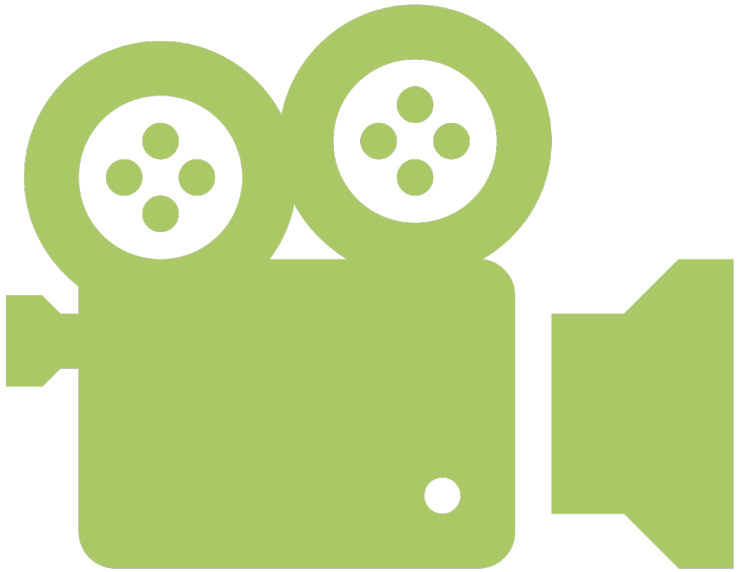

**Access Chat at the bottom**



# Recording

**This meeting is being recorded (both audio and video)**

*If you do not consent to being recorded, please let the meeting moderator know ASAP and we will facilitate your participation in another way or adjust our procedure.*



# Thank You!

## Sponsor

# Today's Agenda

- Welcome
- Opportunity Register Report Outs
- Optimizing RAS Rate
- Statepoint Analysis
- Tools of the Trade
- Closing Remarks

# Poller

- How many energy saving opportunities have you compiled in your Register?

- 0....My plant is already as efficient as it can be
- 0....I have no idea what you are talking about
- 0....Have not had time to list any
- 1 or 2
- 3 – 5
- > 5

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# Report Outs

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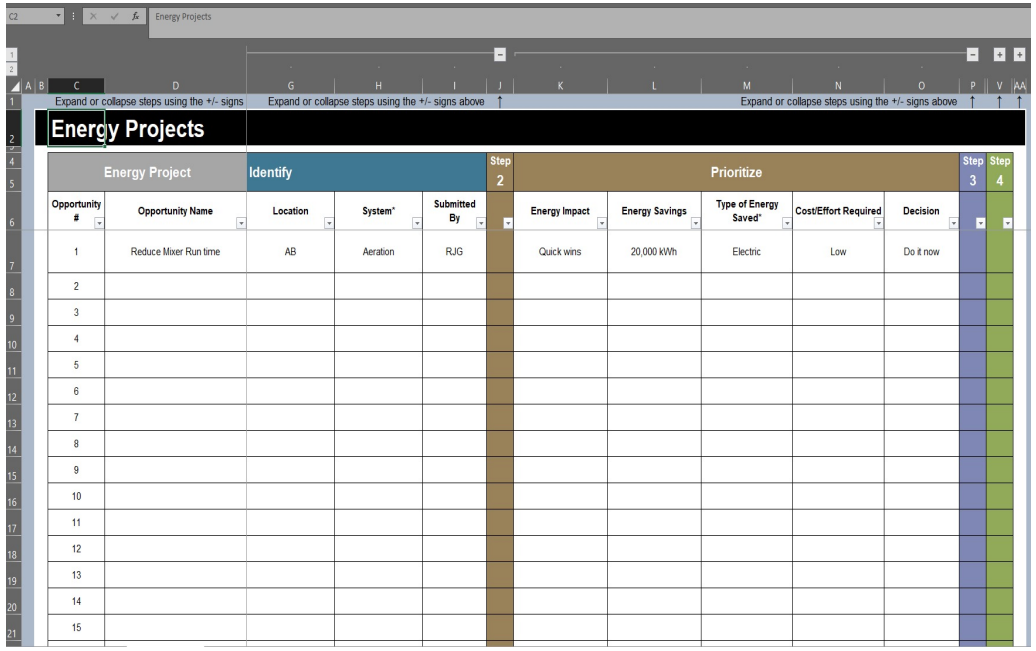
# Report outs!

- Who wants to tell us about some energy saving opportunities that they have discovered?
- Have you begun to populate your opportunity register?



Energy Projects

| Energy Project | | Identify | | | Step 2 | Prioritize | | | | | Step 3 | Step 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Opportunity # | Opportunity Name | Location | System* | Submitted By | | Energy Impact | Energy Savings | Type of Energy Saved* | Cost/Effort Required | Decision | | |
| 1 | Reduce Mixer Run time | AB | Aeration | RJG | | Quick wins | 20,000 kWh | Electric | Low | Do it now | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
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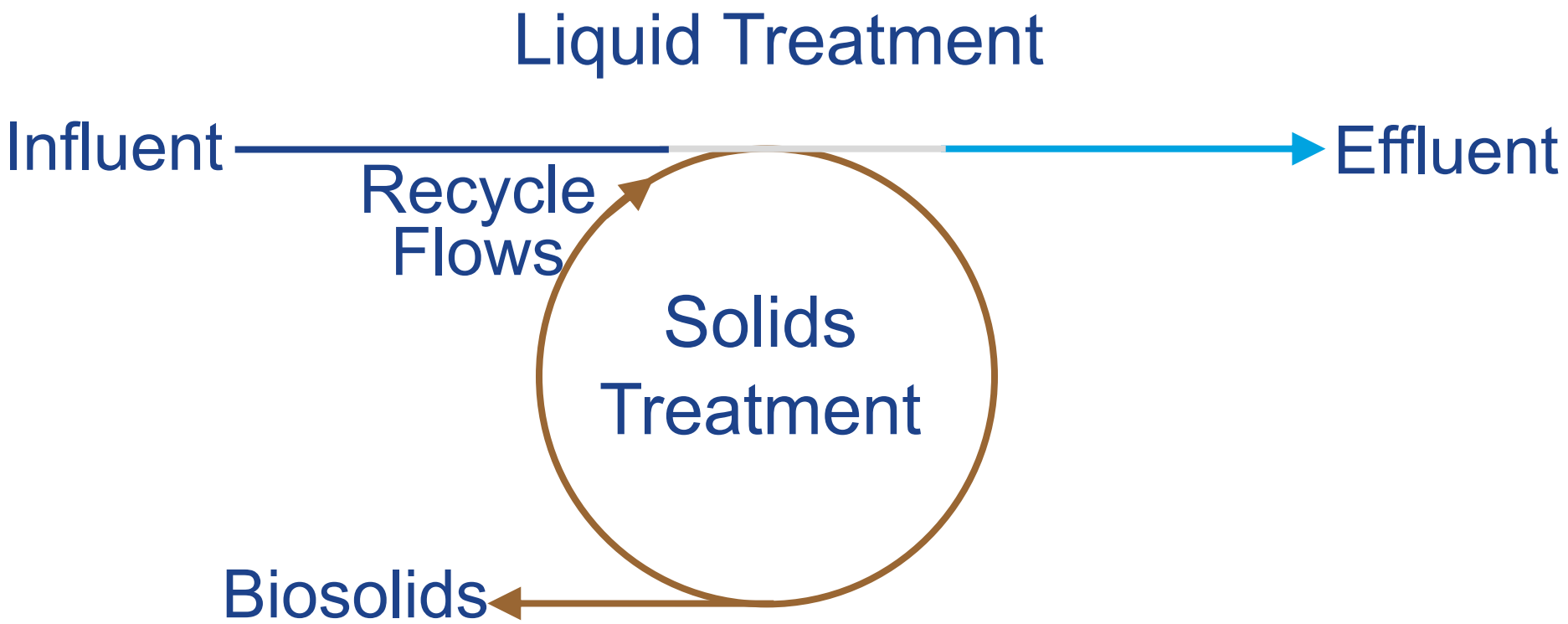
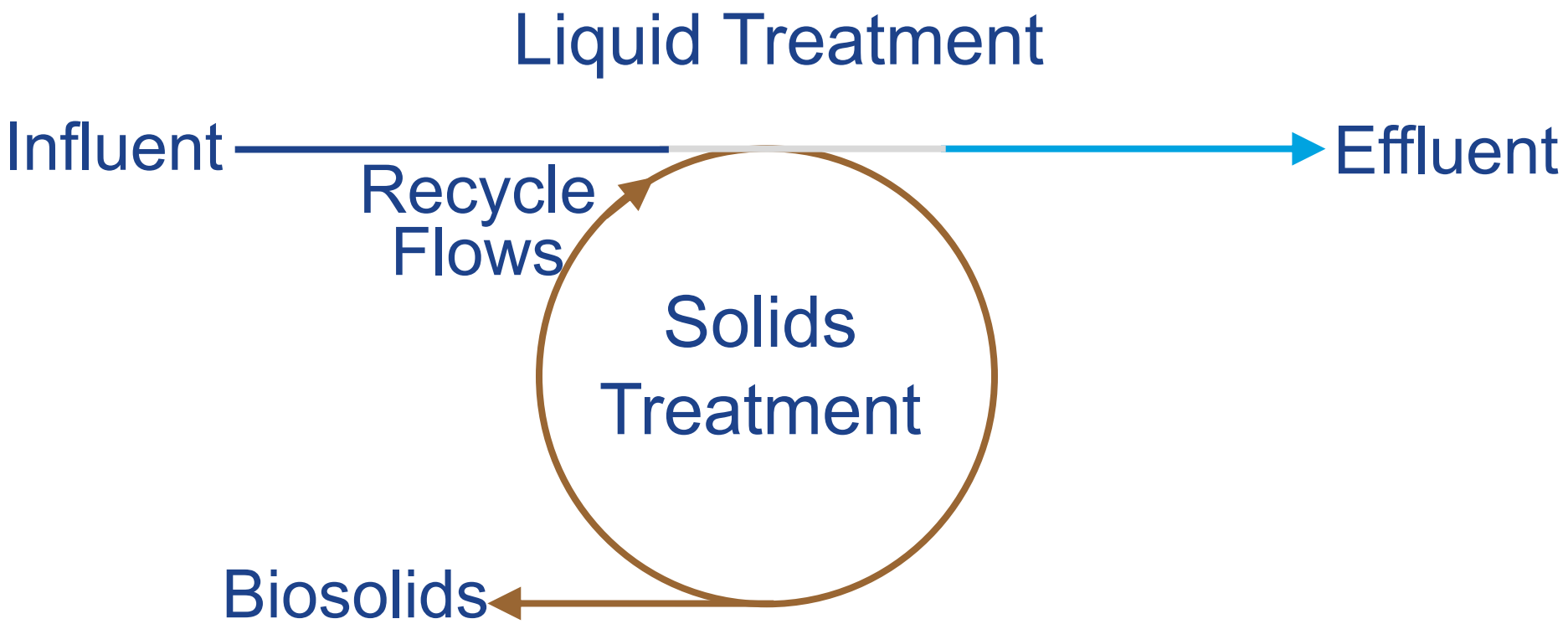
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |

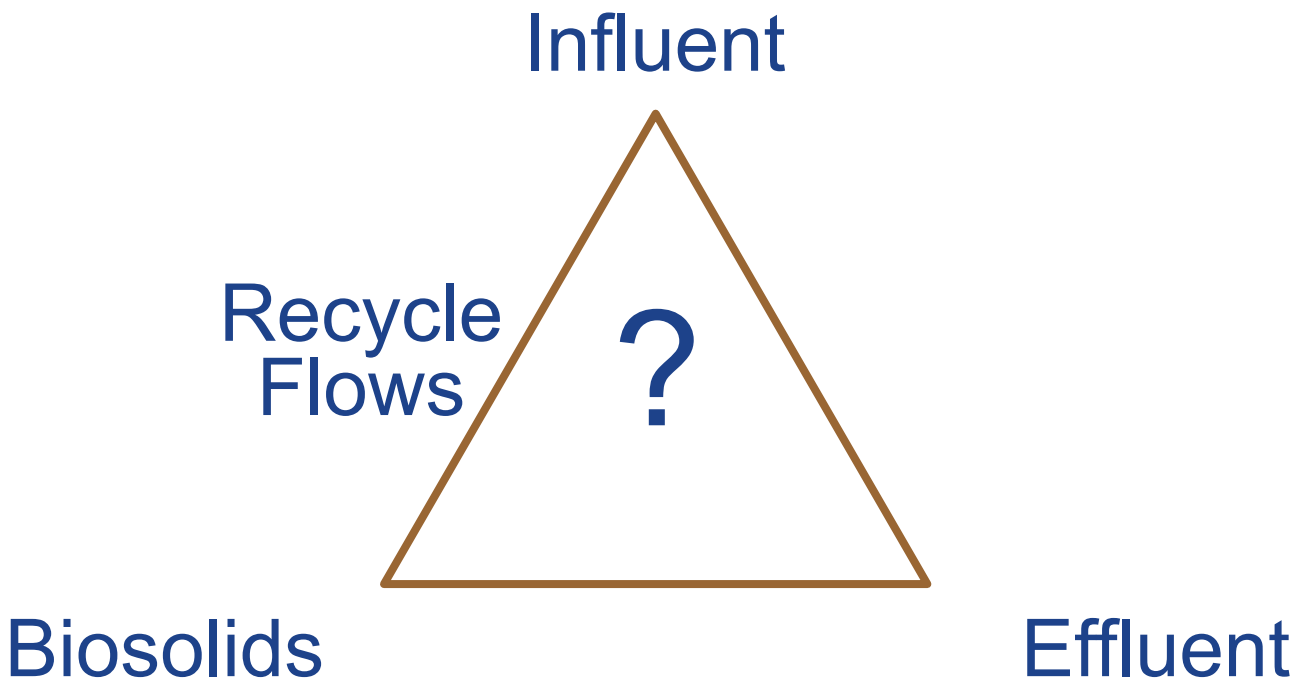
# A WWTP is like a manufacturing plant



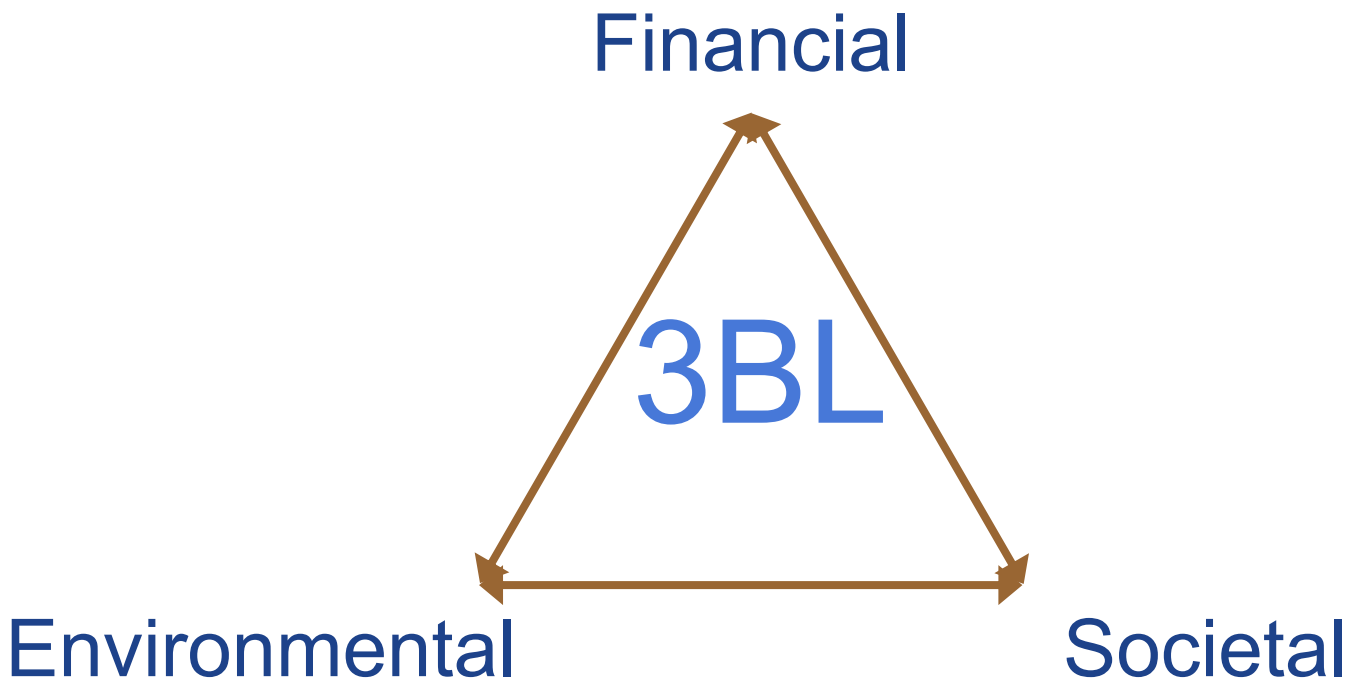
# But what is it we produce?



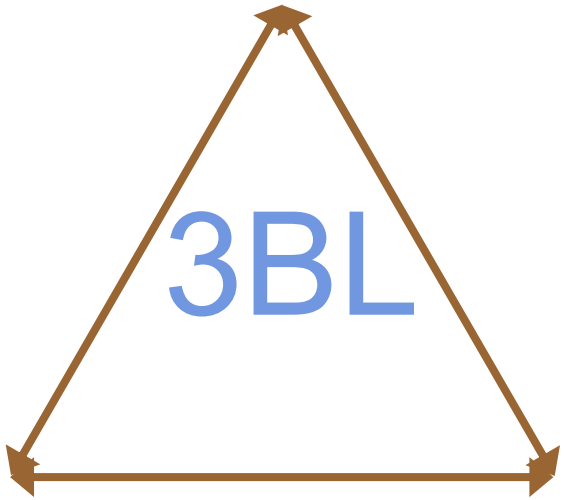
# What is it we do?



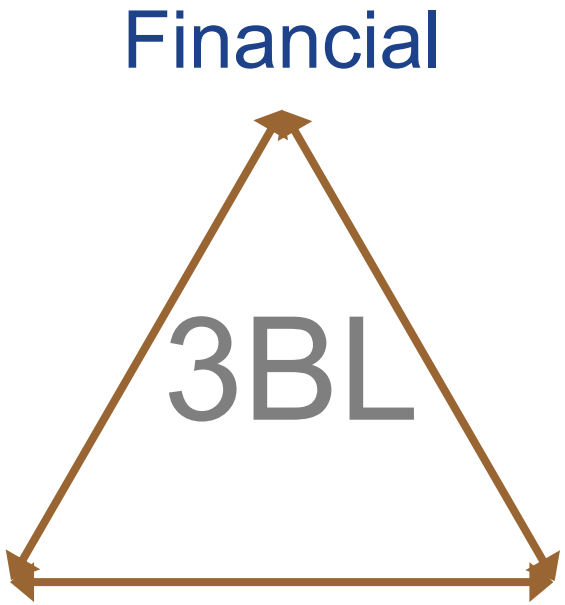
# As Operations Professionals we live the Triple Bottom Line (3BL) every day



# For society

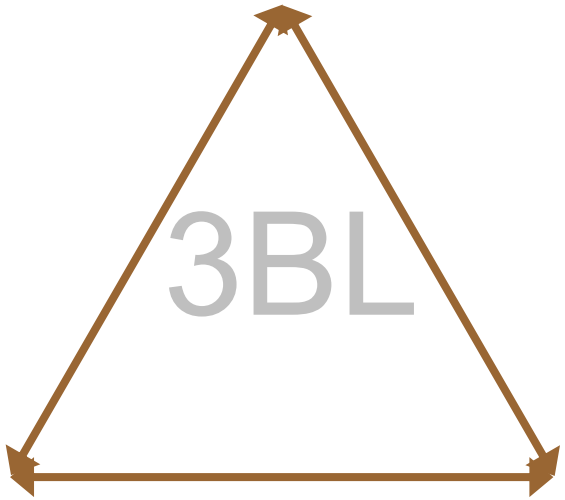


# For the environment



# For our ratepayers

Stewards of public monies

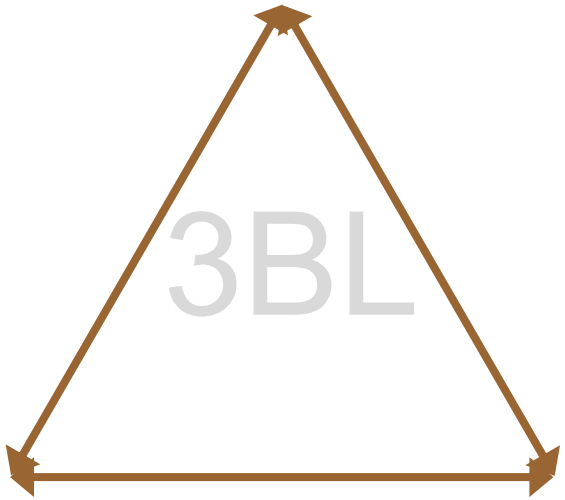



Protectors of environmental health

Protectors of public health

# Much, much more than “making permit”

Stewards of
public monies




Protectors of
environmental health

Protectors of
public health

# Professional operator credo:

To remove pollutants from the incoming water while complying with all permits—water, air, and land—and convert them to recyclable biosolids as sustainably and cost effectively as possible.

# As a profession, we have put a lot of emphasis here

To remove pollutants from the incoming water while complying with all permits—water, air, and land—and convert them to recyclable biosolids as sustainably and cost effectively as possible.

.....and

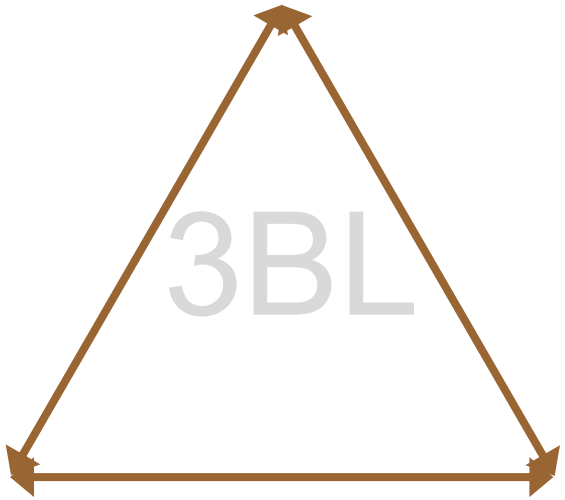
# Here…..

To remove pollutants from the incoming water while complying with all permits—water, air, and land—and **convert them to recyclable biosolids** as sustainably and cost effectively as possible.

**And you have done so quite successfully!**

# BUT REMEMEBER THE TRIPLE BOTTOM LINE:

**Stewards of public monies**




Protectors of environmental health

Protectors of public health

# …..Now is the time to focus on number three in the credo.

To remove pollutants from the incoming water while complying with all permits—water, air, and land—and convert them to recyclable biosolids **as sustainably and cost effectively as possible.**

# Again, Professional Operator Credo:

To remove pollutants from the incoming water while complying with all permits—water, air, and land—and convert them to recyclable biosolids as sustainably and cost effectively as possible.

**Let's do this shall we !!??**

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

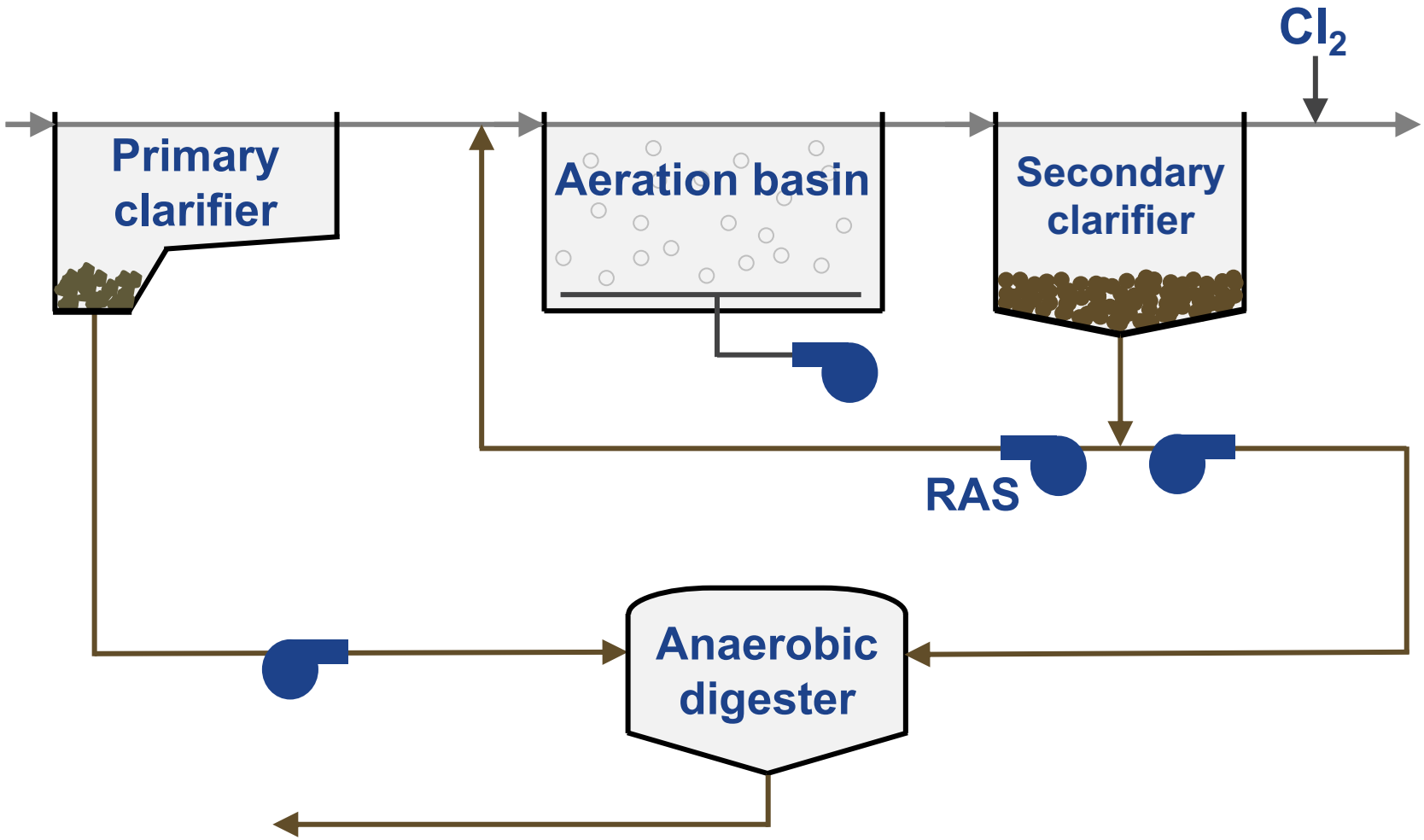
# Let's Cut to the Chase

**"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."**

# In the Business of Treating Wastewater with the Activated Sludge Process

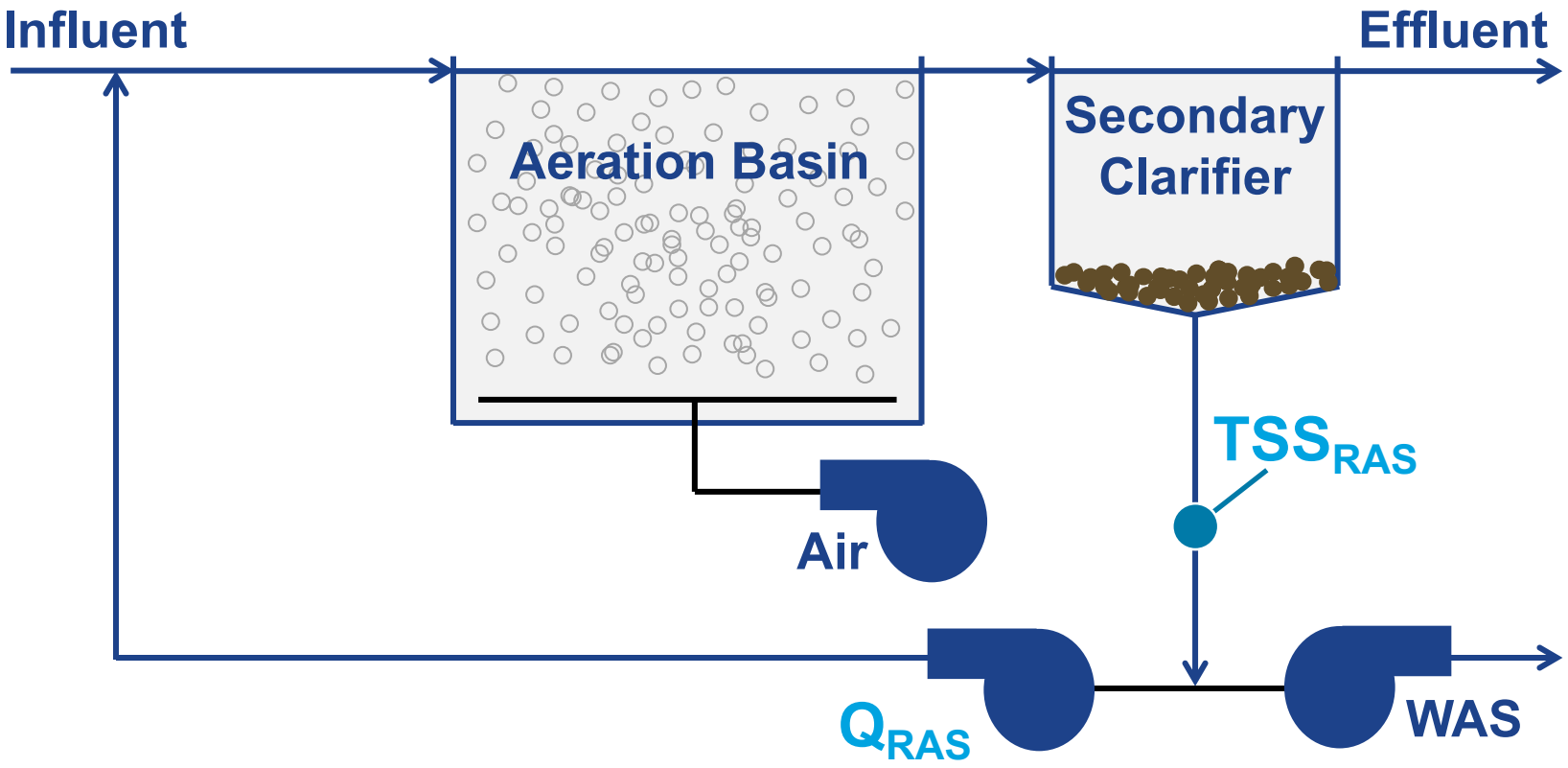
**“You cannot have good effluent quality without good sludge quality.”**

# 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

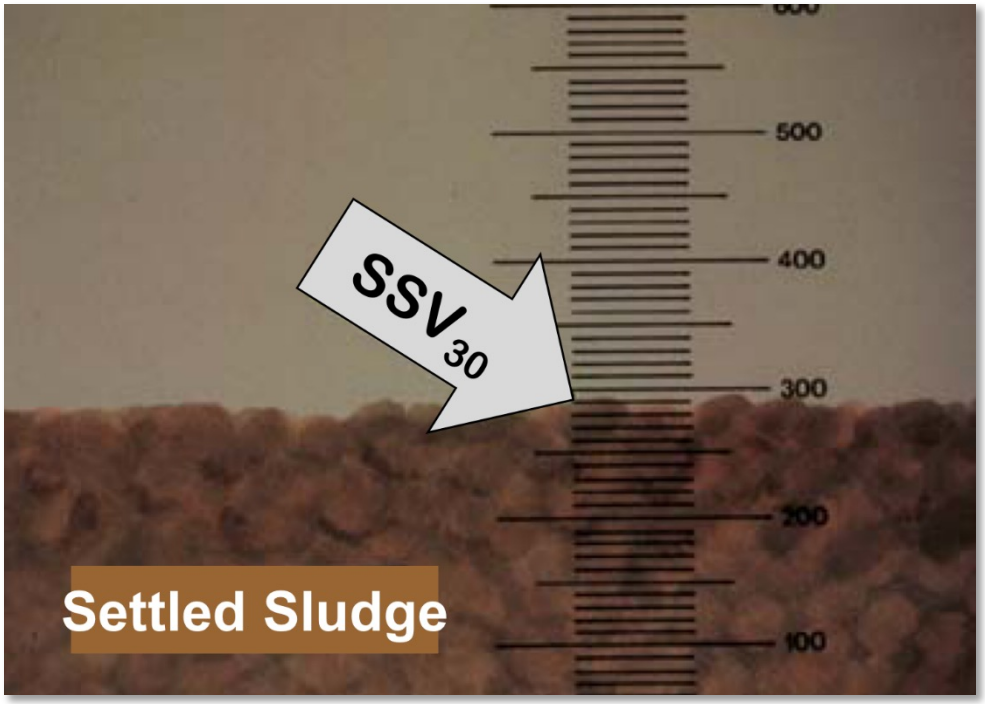
# Two Reasons for Confusion Around RAS Flow ($Q_{RAS}$) and RAS TSS Concentration ($TSS_{RAS}$)



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

**To remove settleable solids (biomass).**

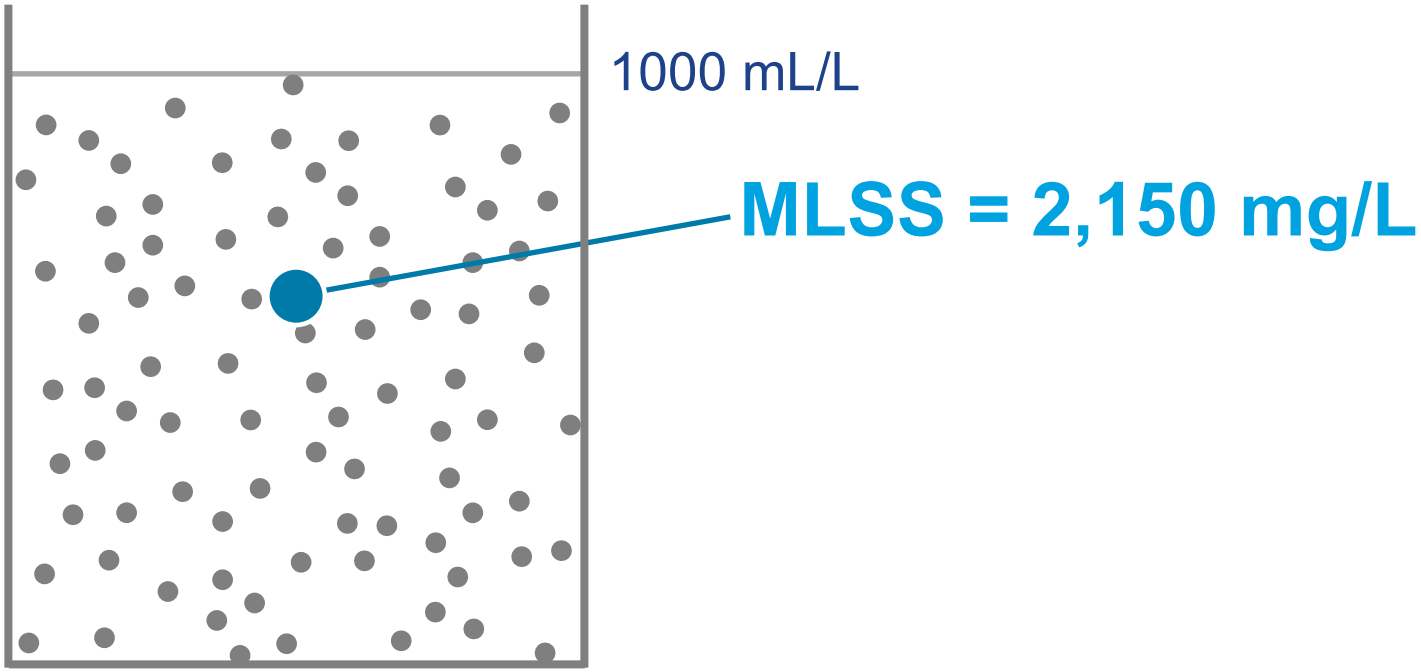
# Activated Sludge Does Not **Appreciatively** Settle/Thicken/Compact More After 30 min



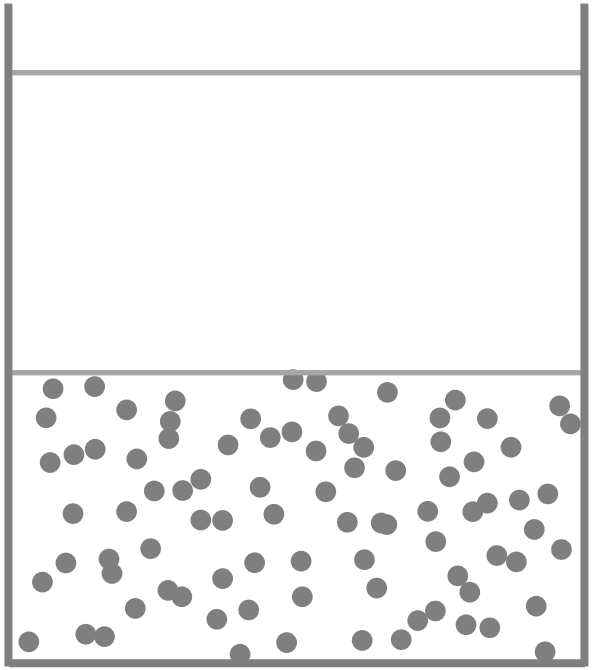

**$SSV_{30}$ = 290 mL/L**

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

# Measure MLSS on Sample
# **Used In Settleometer Test**

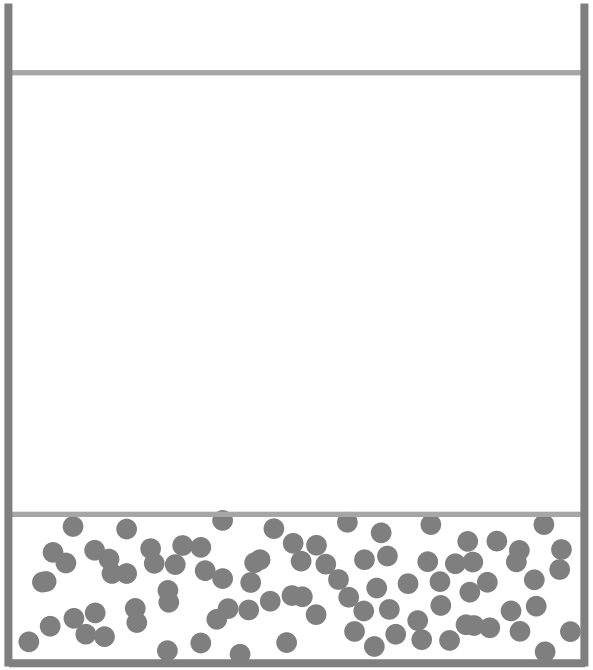


# $SSV_5$



500 mL/L

# $SSV_{30}$

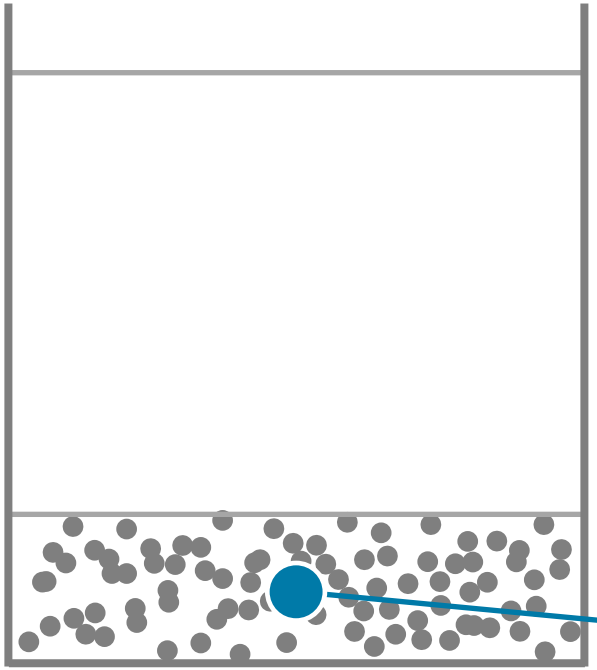


250 mL/L

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

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

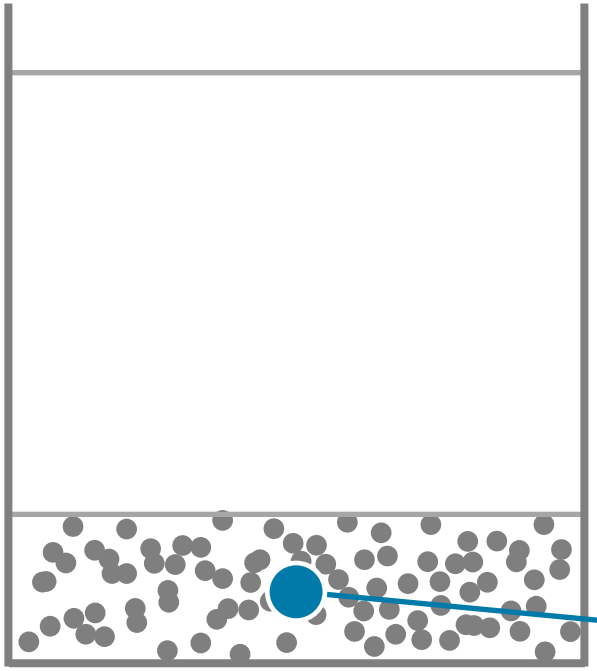
# Calculate $MLSS_{30}$



250 mL/L

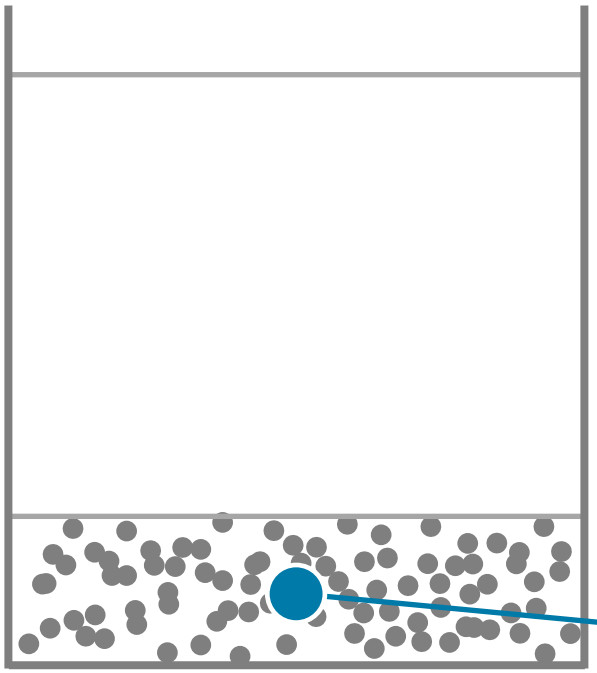
**$MLSS_{30}$ = 8,600 mg/L**

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




**$TSS_{RASmax}$ = 8,600 mg/L**

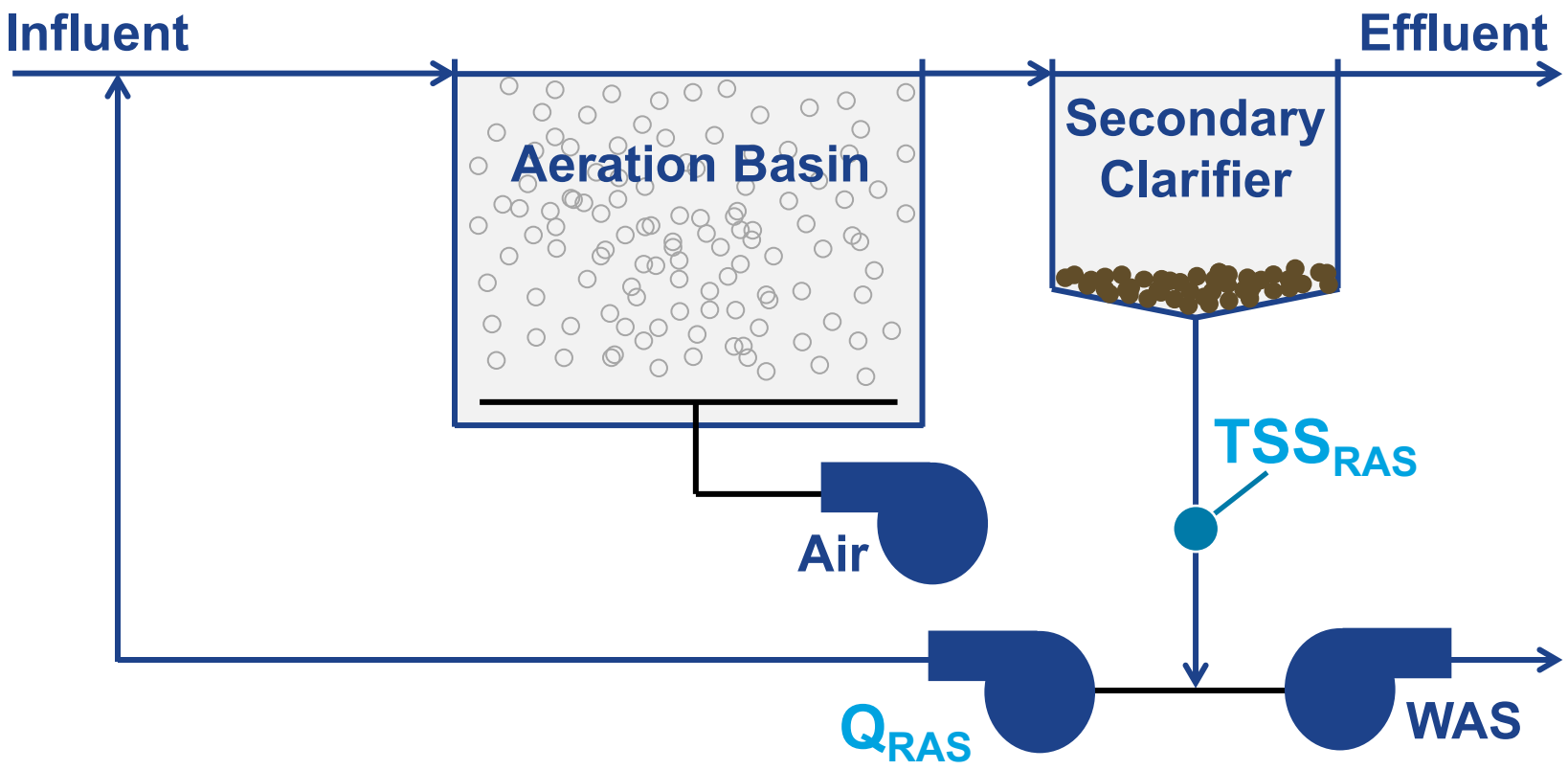
# Thickening is ***NOT*** a Process Objective of the Secondary Clarifier




**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

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

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

# So, What Should My RAS Flow be

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

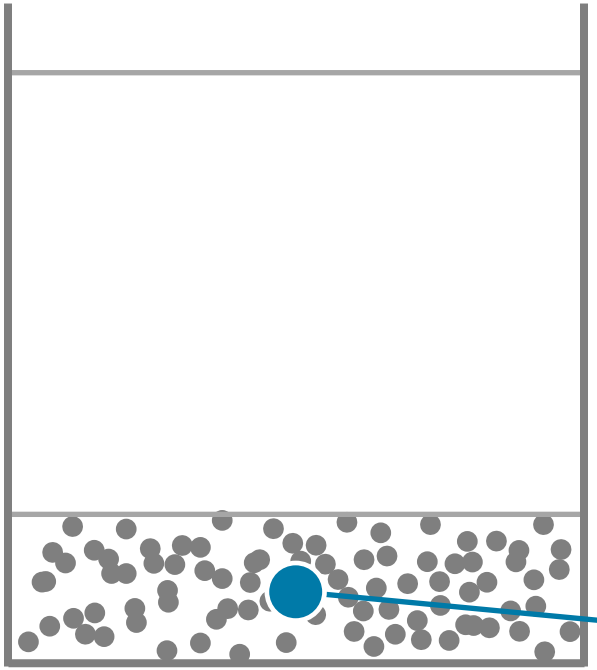
1. Higher RAS flows than necessary
   waste electricity (and ratepayer money)

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 |

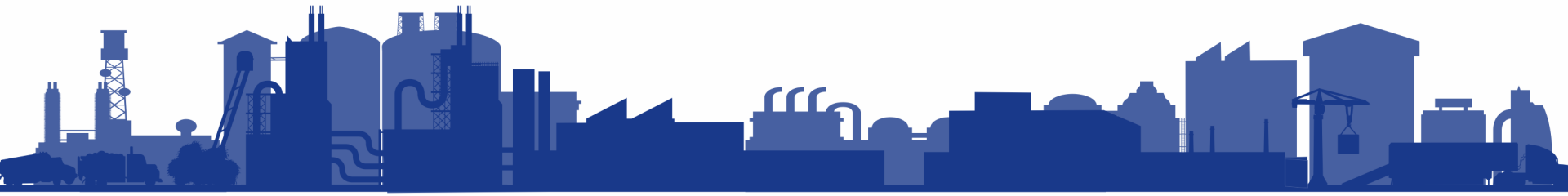
# Remember the chat question…….

- Who wants to volunteer and submit their plants numbers?

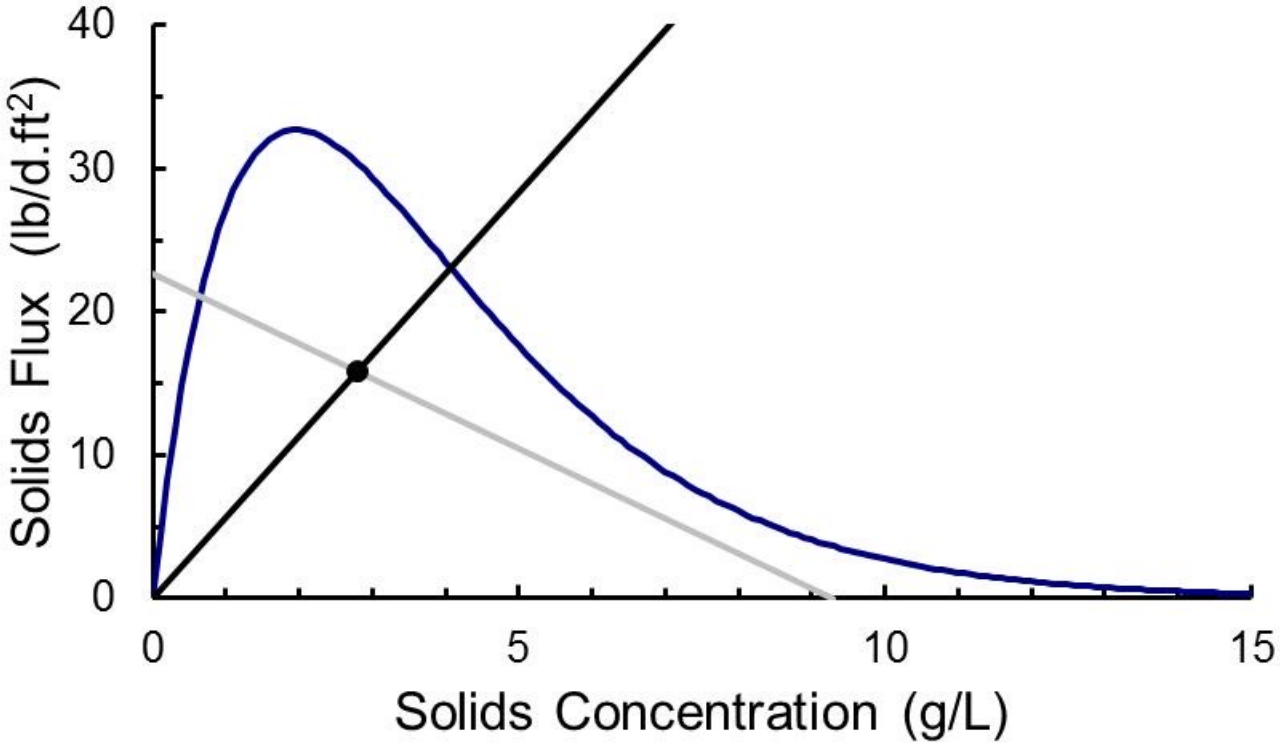
- RAS flow rate or percentage
- $MLSS_{30}$

# break

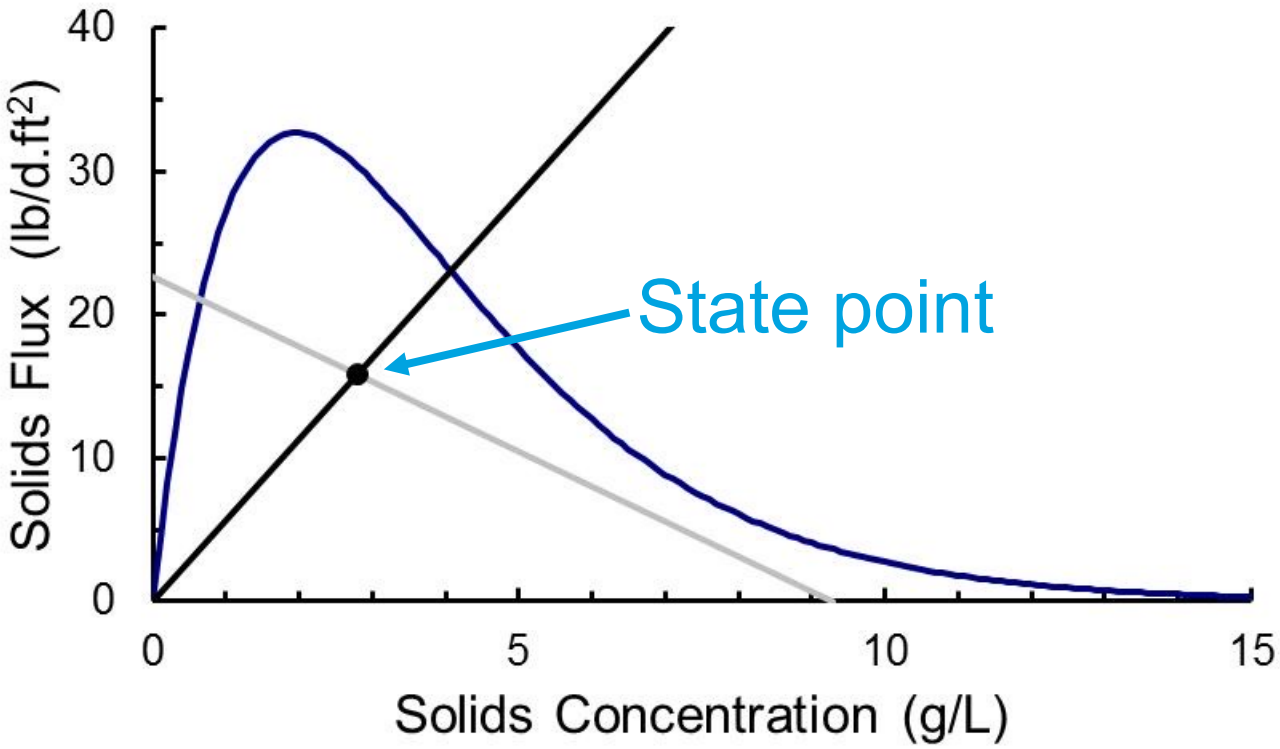
# INTRODUCTION TO STATE POINT ANALYSIS



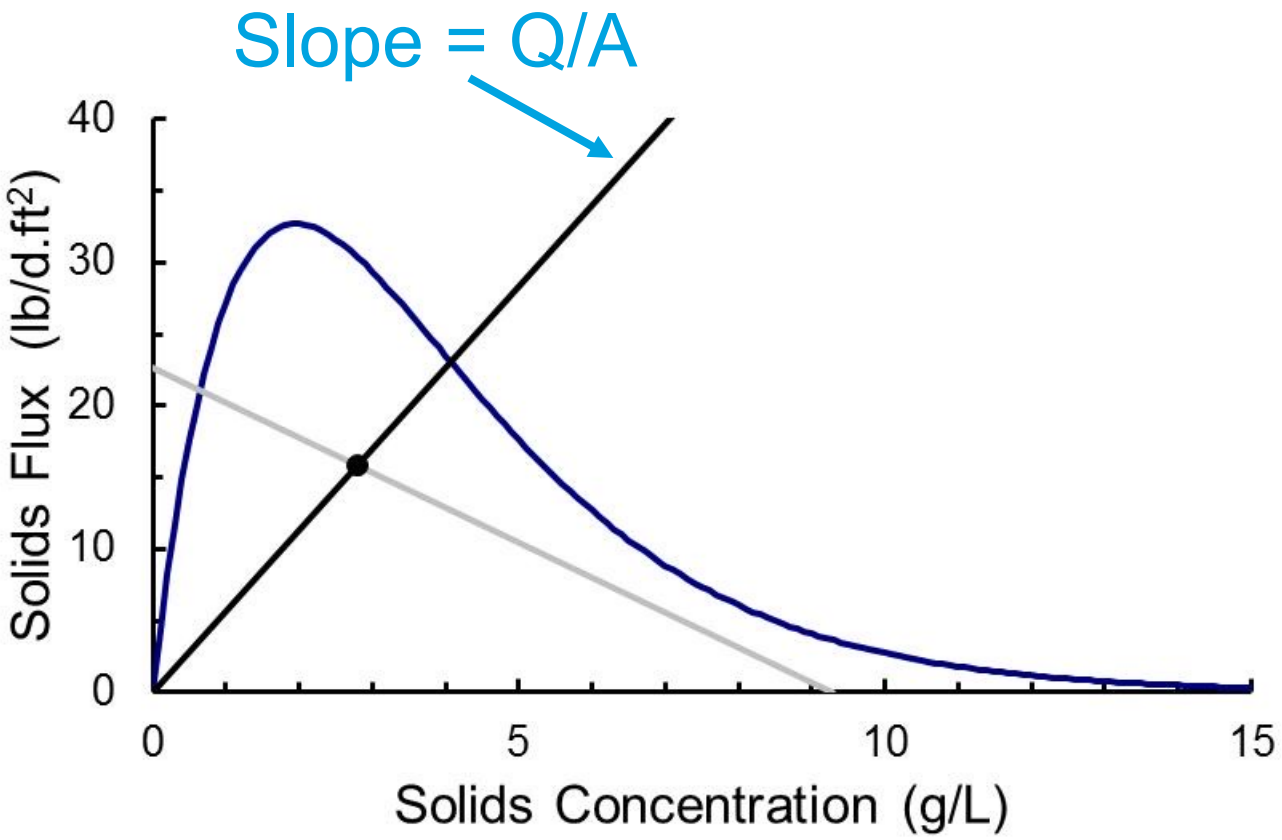
# Introduction to State Point Analysis



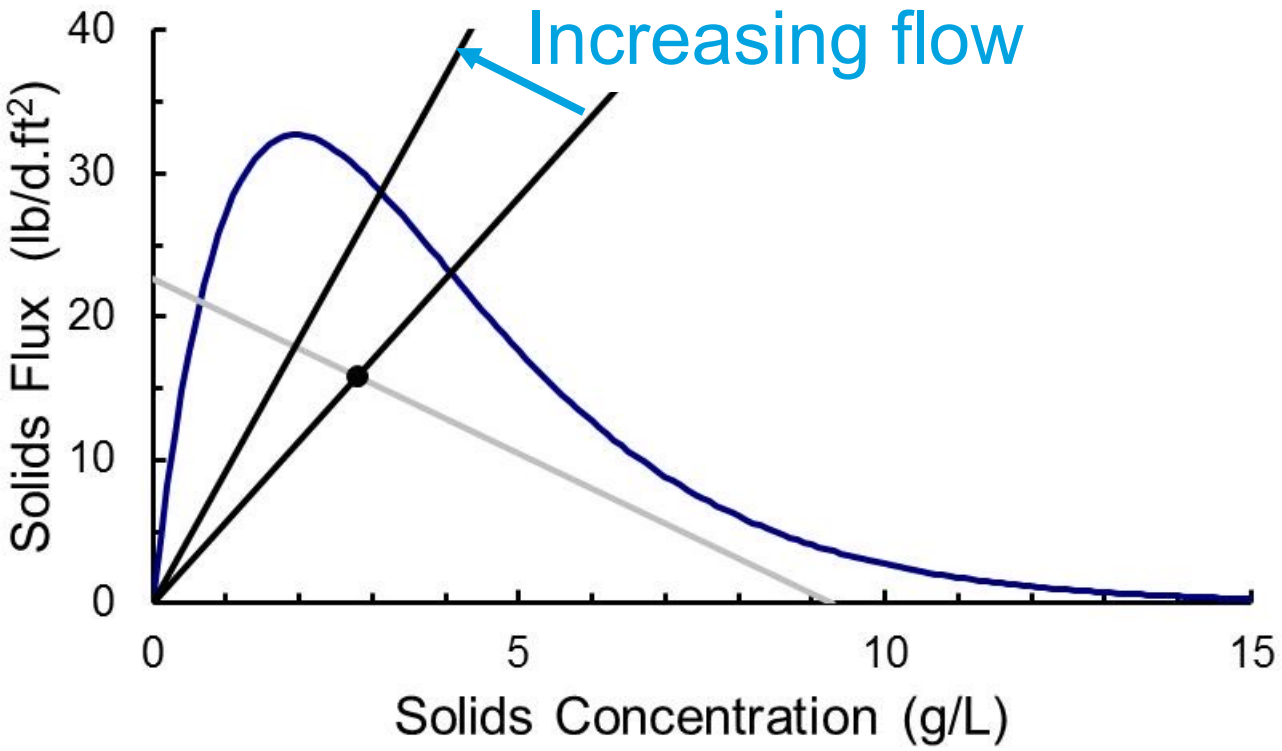
# The State Point Is At the Intersection of the Two Operating Lines



# 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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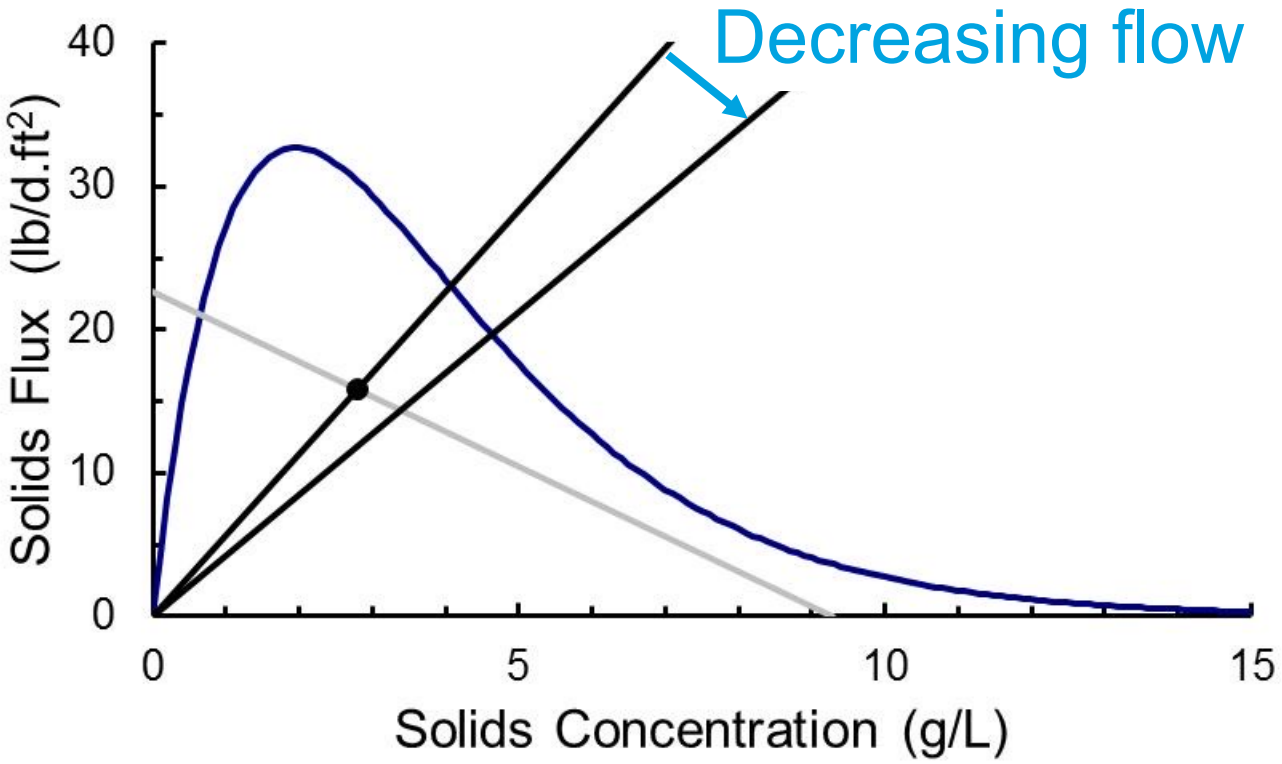

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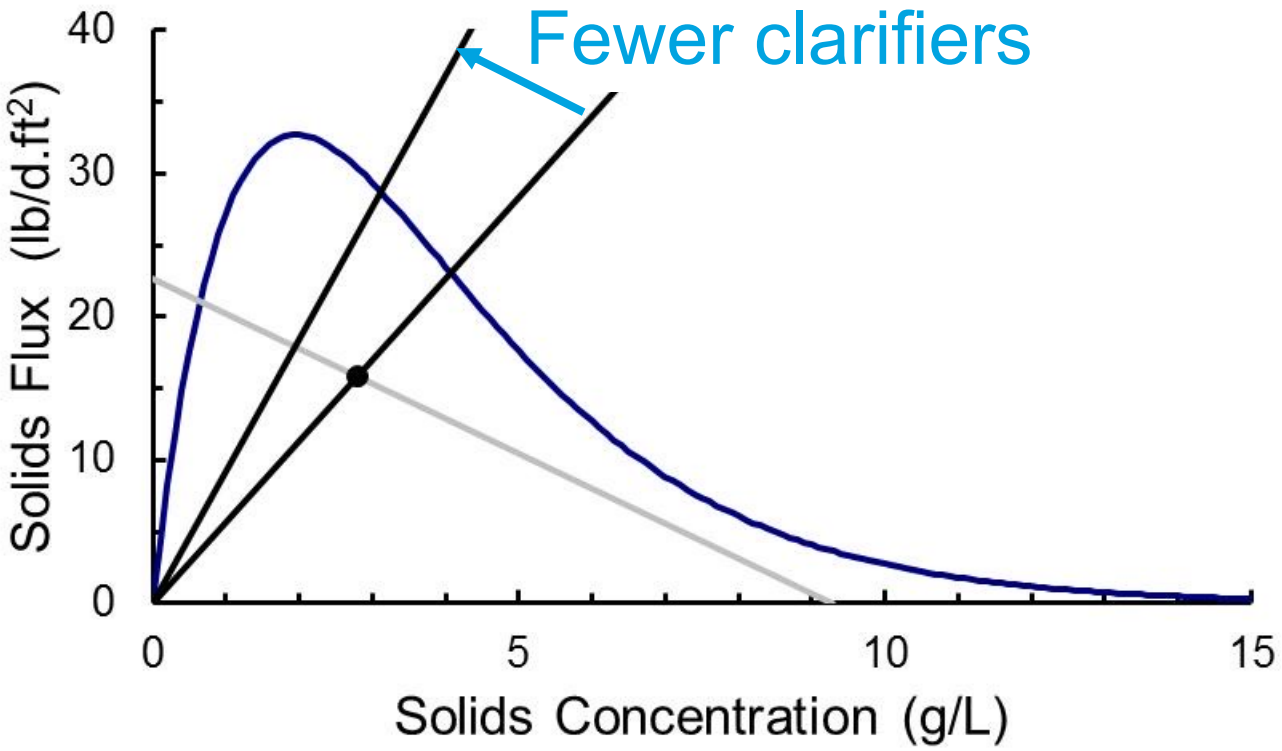

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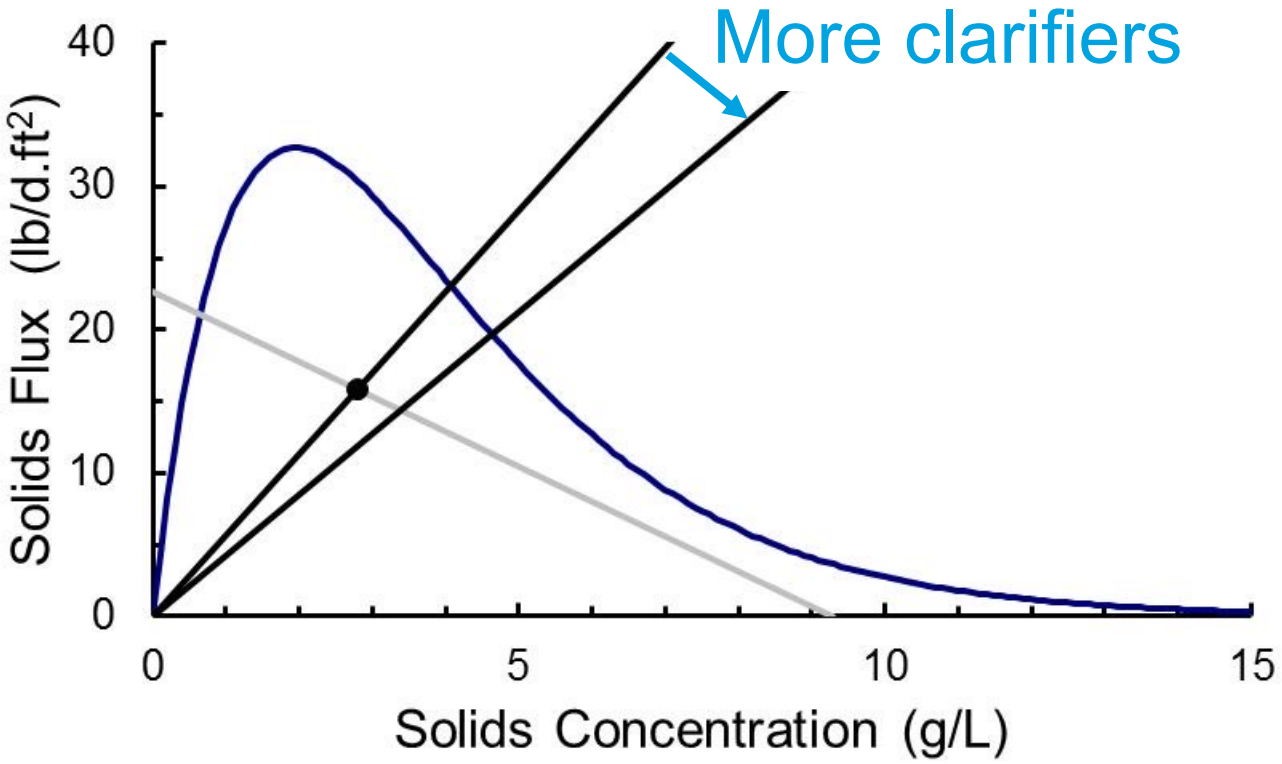
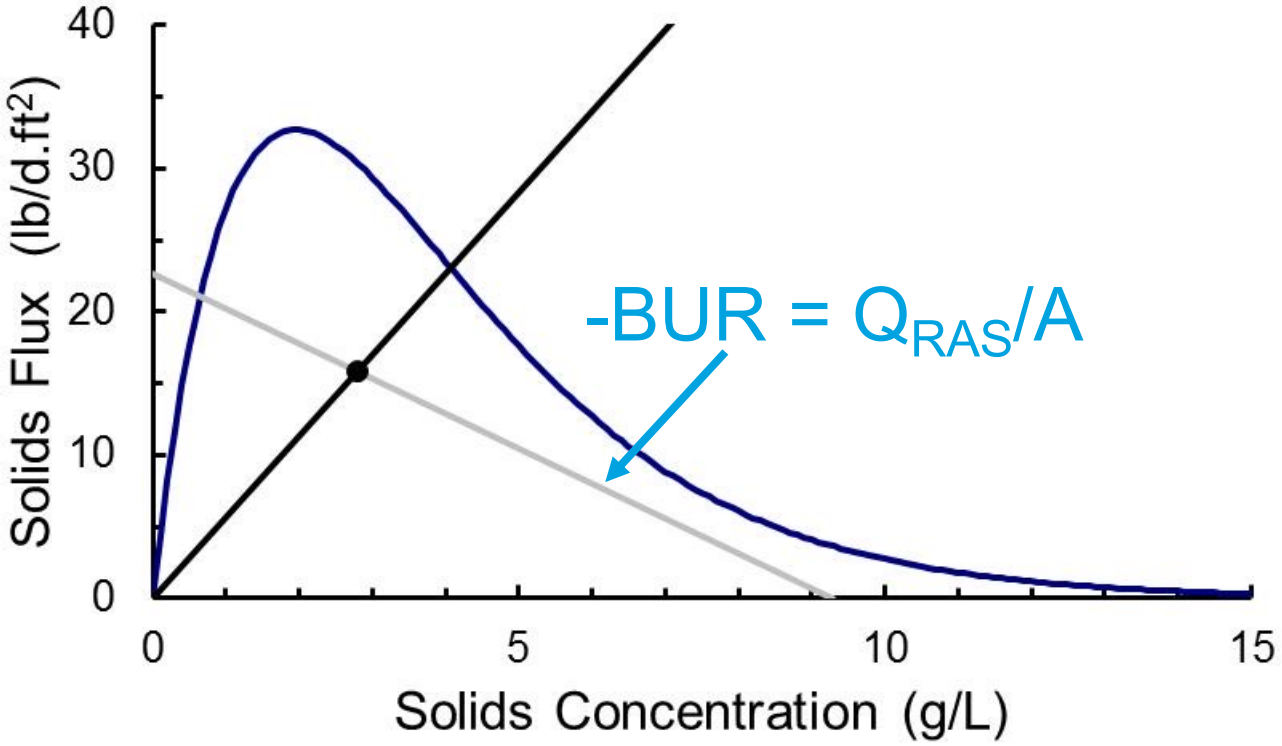
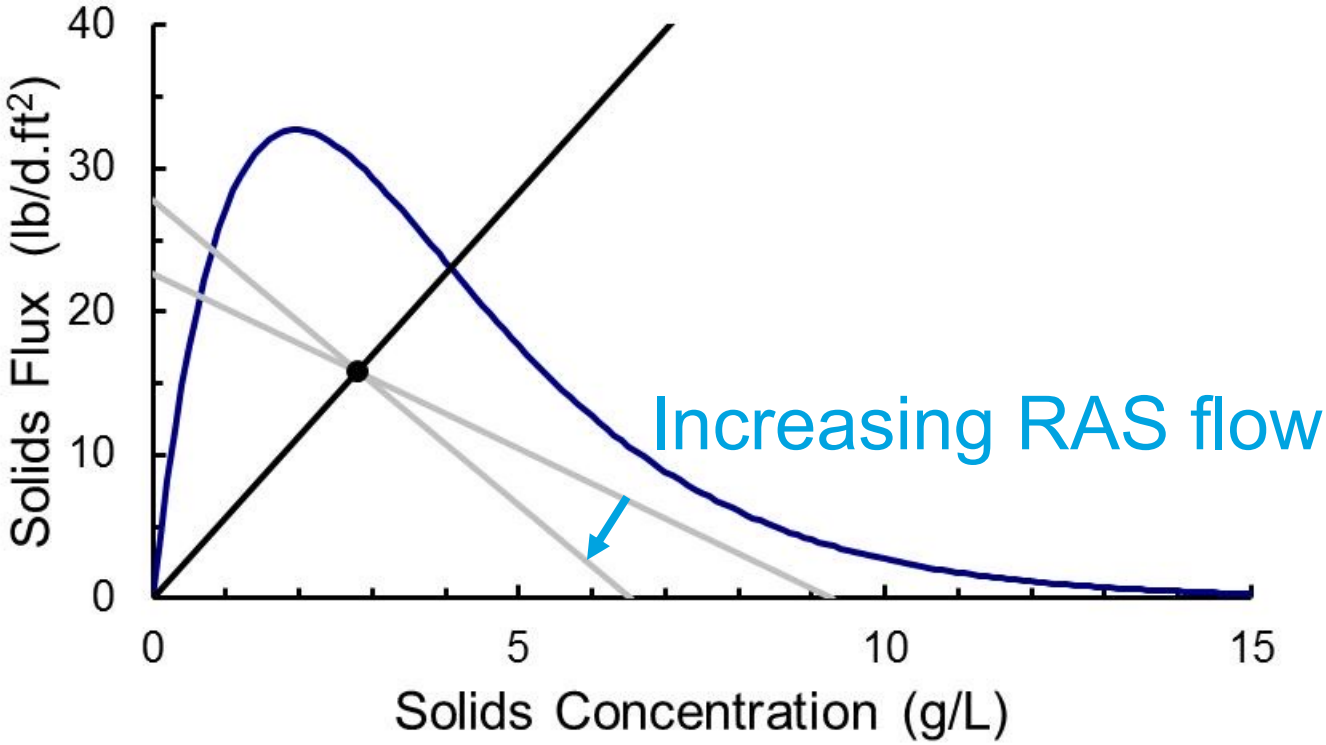


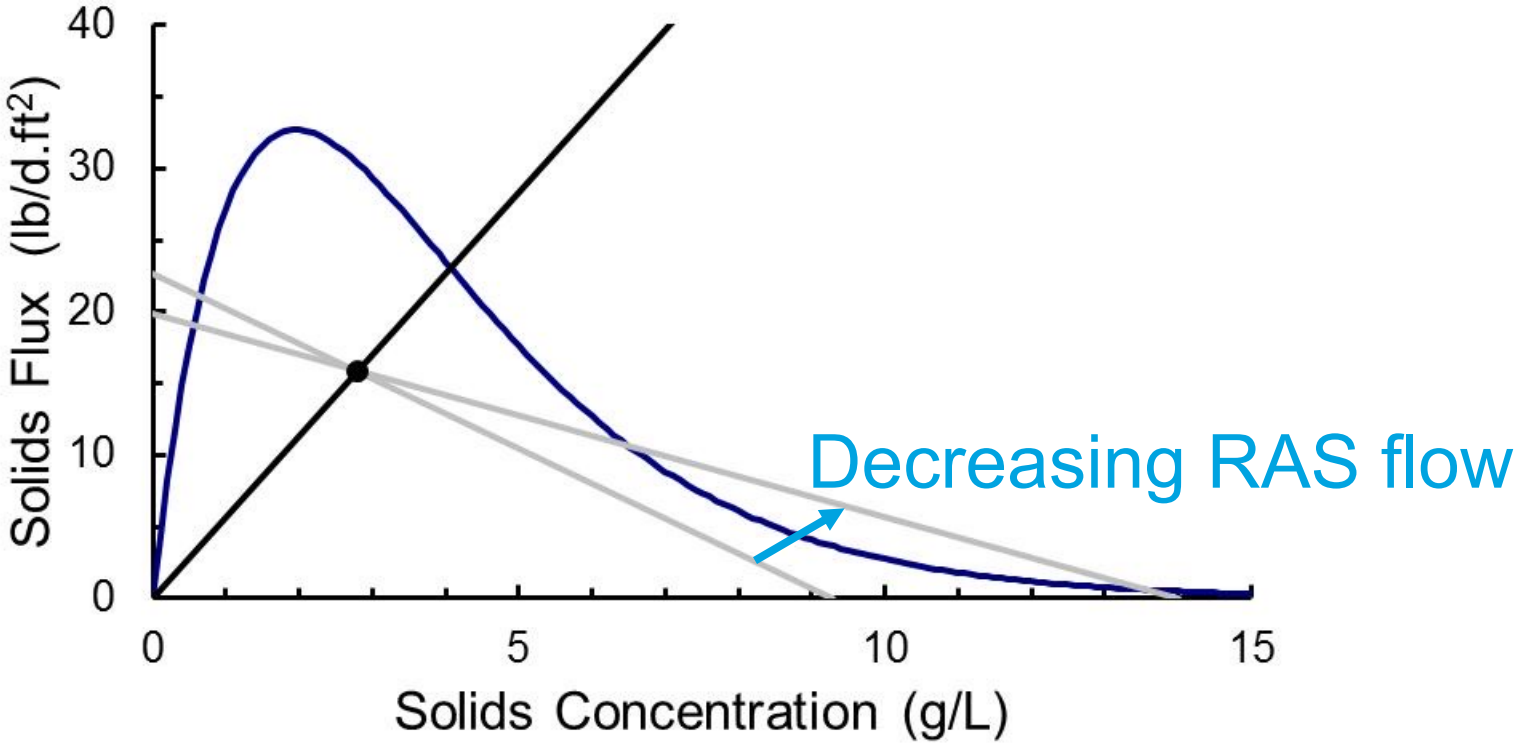
# Line Going Down Left to Right is Bottom Underflow Rate Operating Line (BUR)



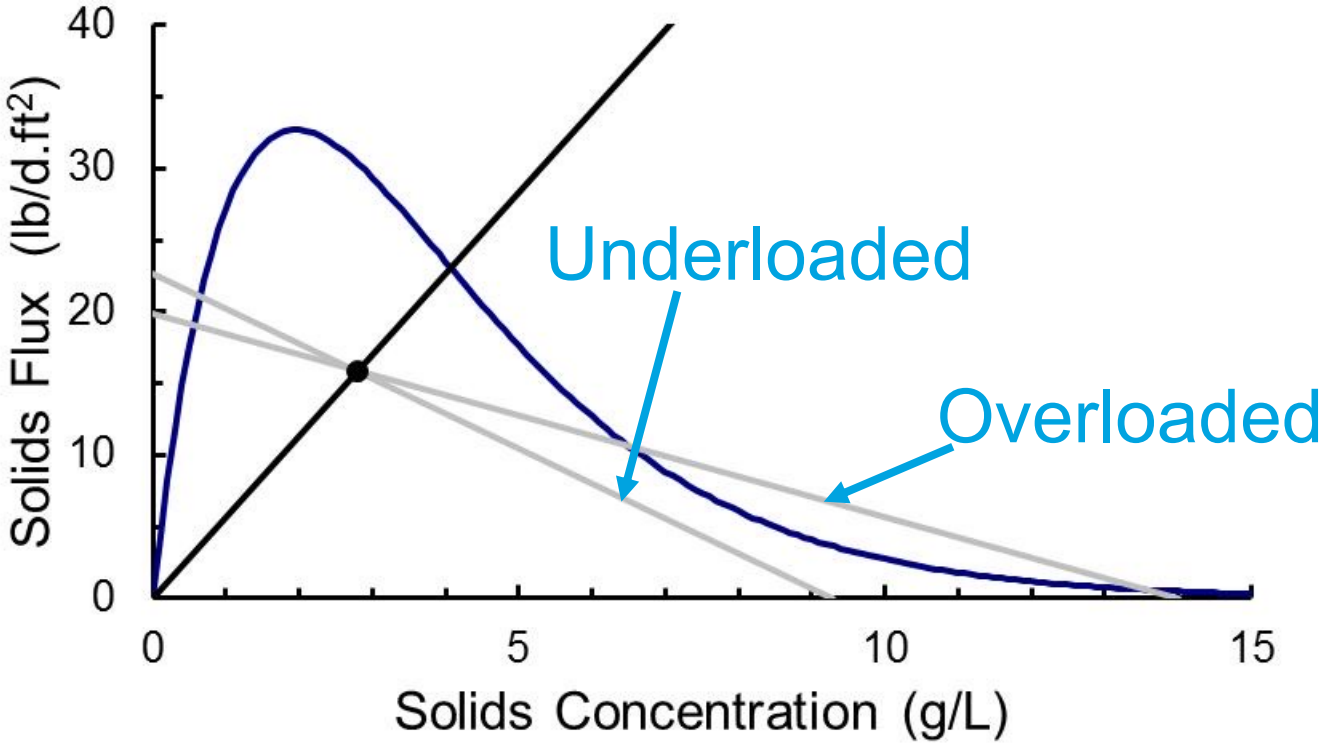
# The Slope Changes With Changes in $Q_{RAS}$



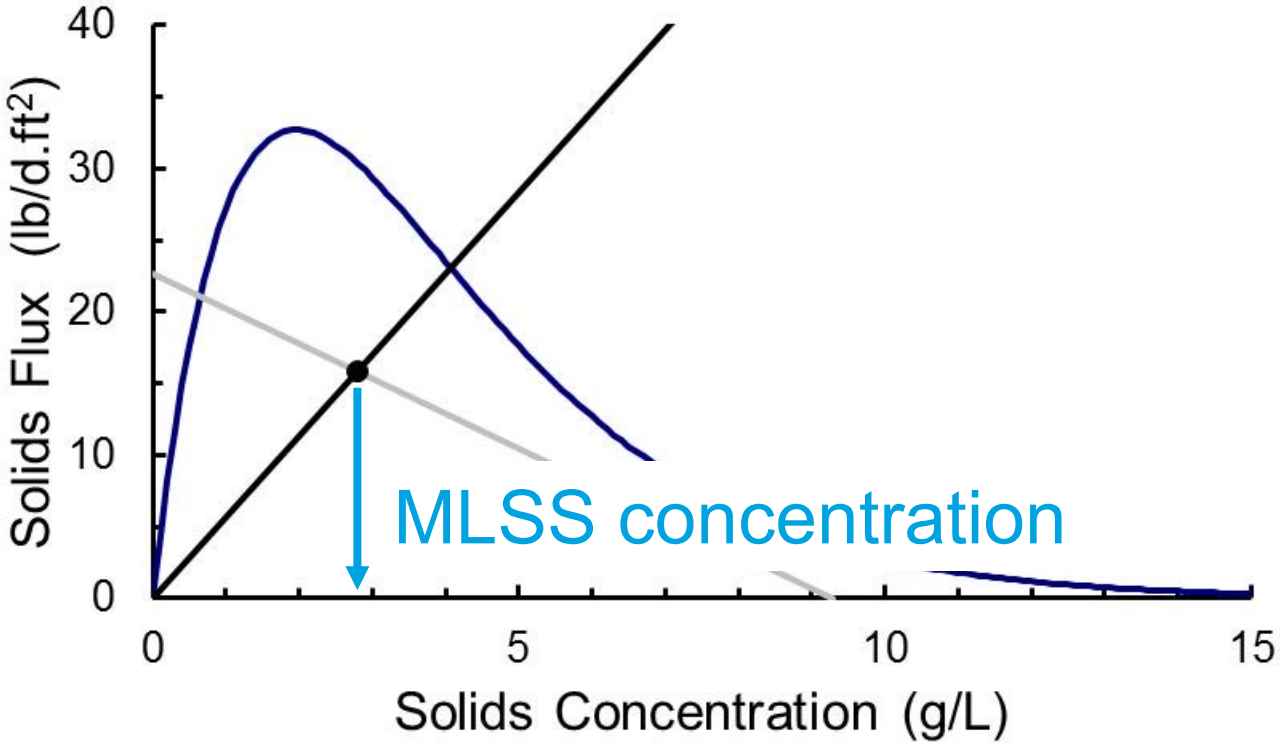
# The Slope Changes With Changes in $Q_{RAS}$



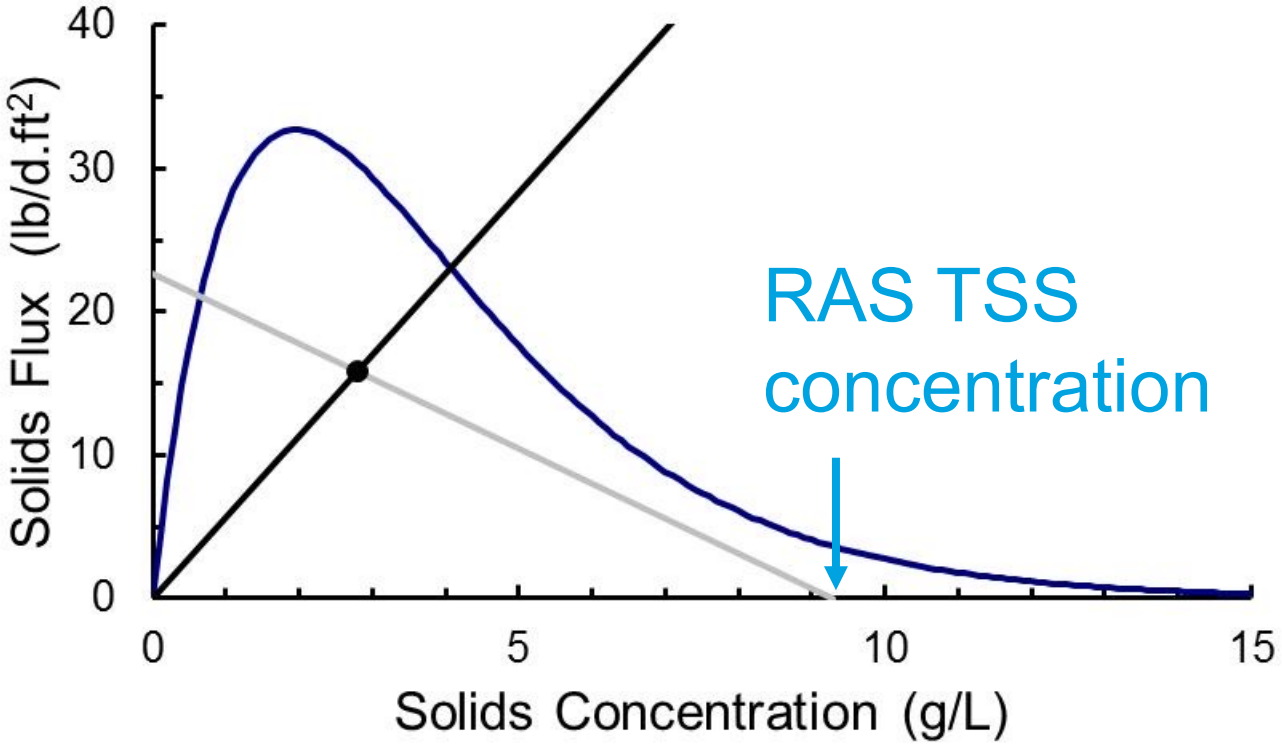
# This is Important



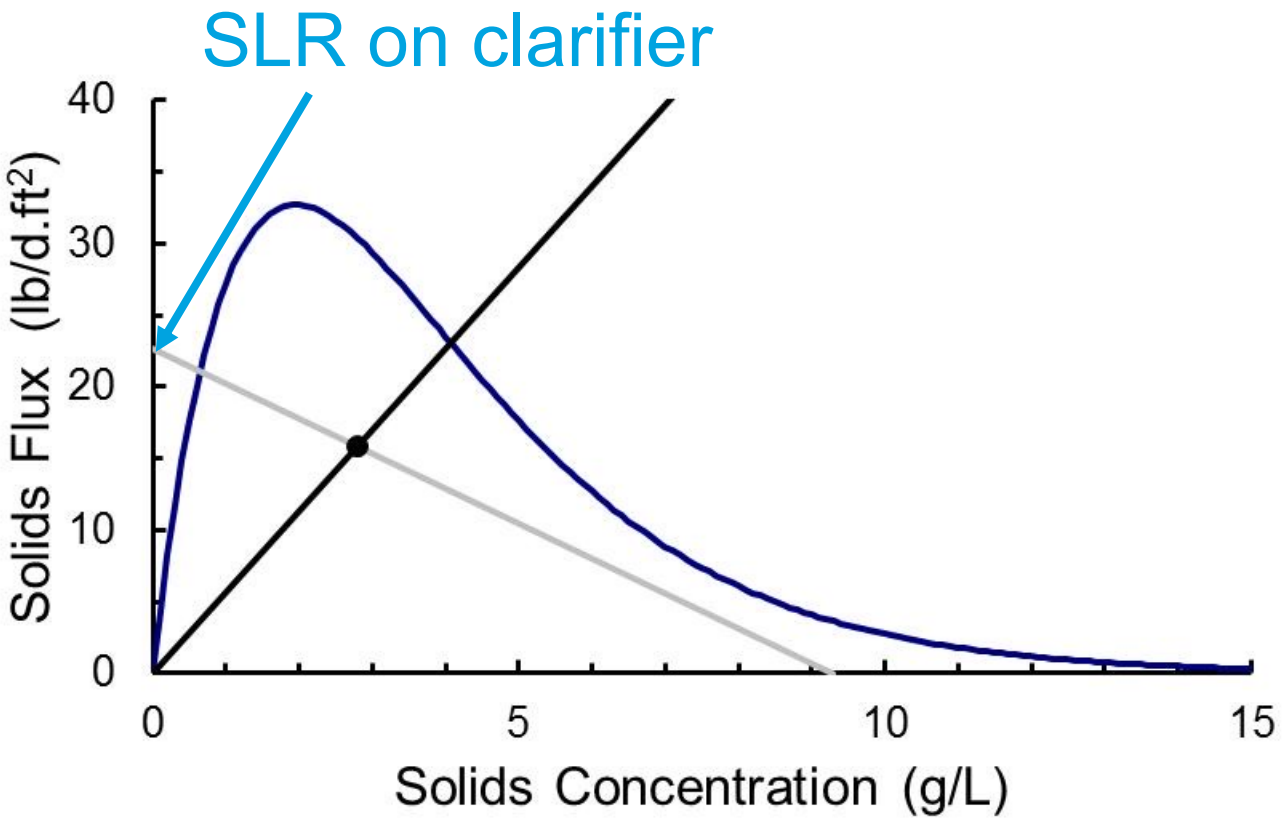
# The Two Lines Intersect at the MLSS Concentration



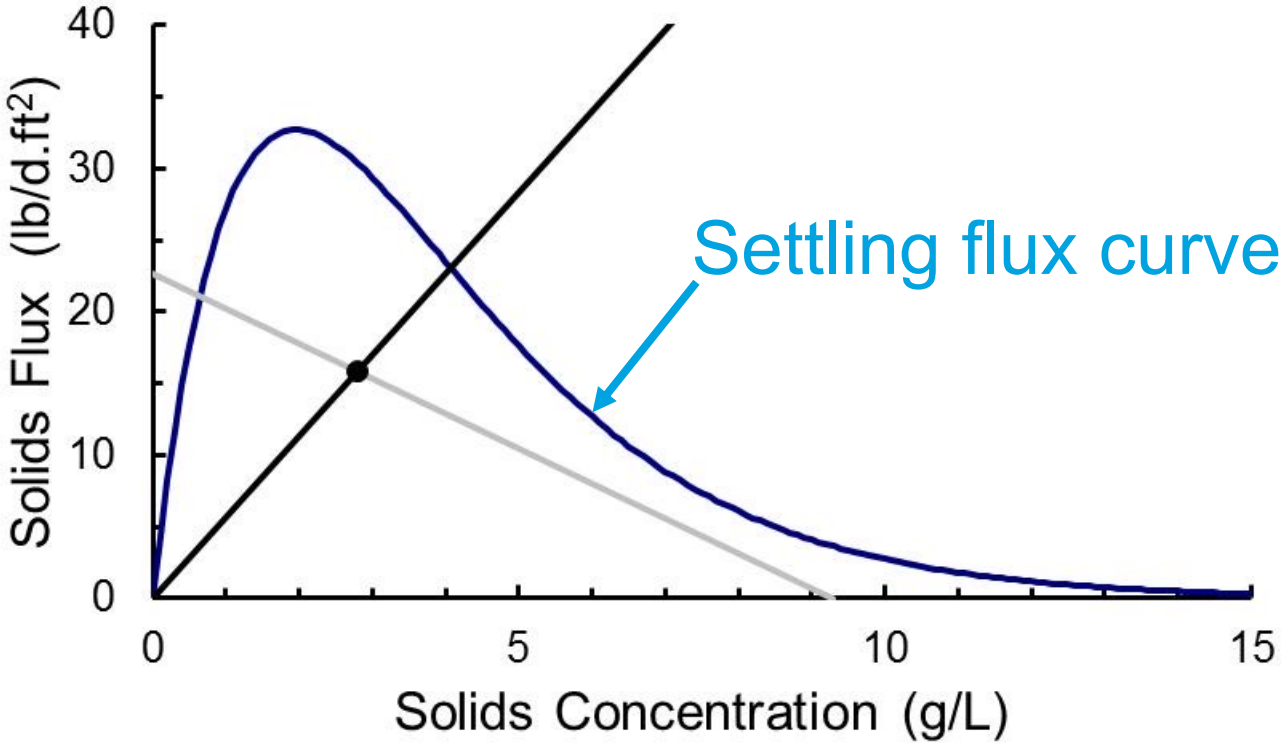
# Underflow Rate Operating Line Intersects x-axis at $TSS_{RAS}$ (when passing below curve)



# 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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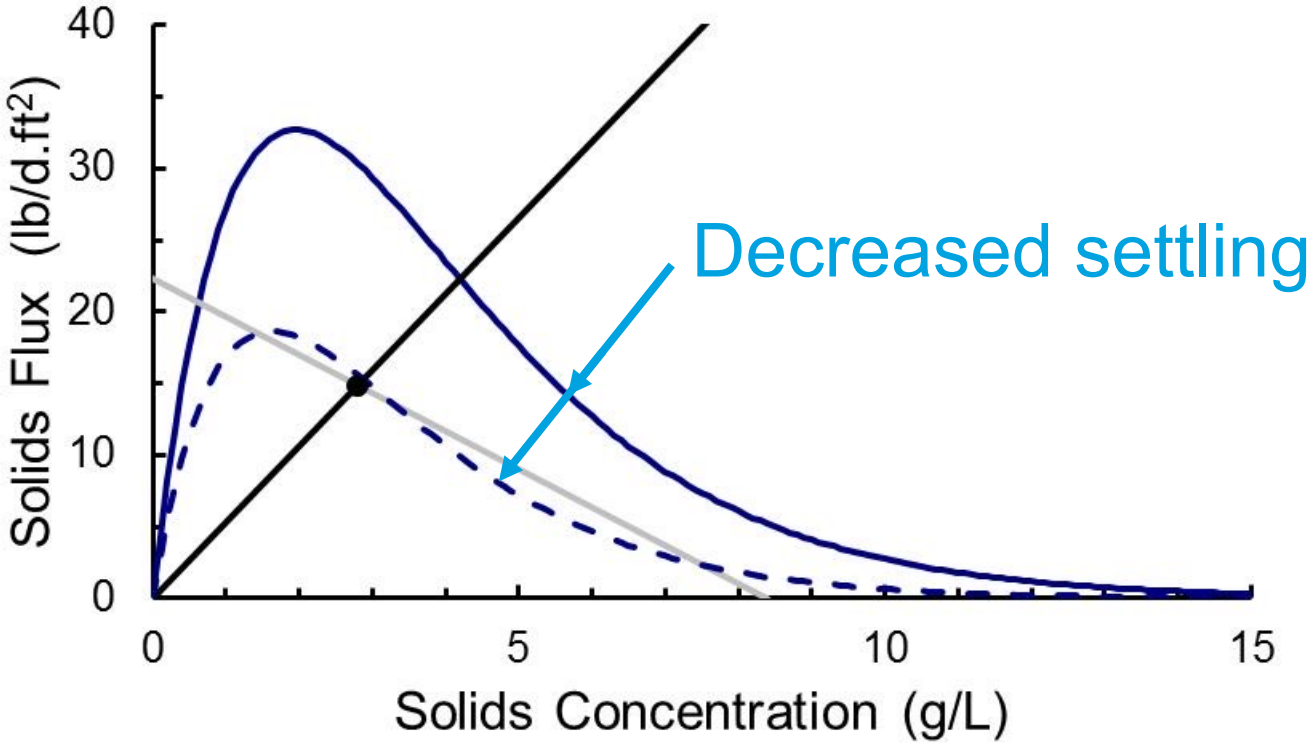
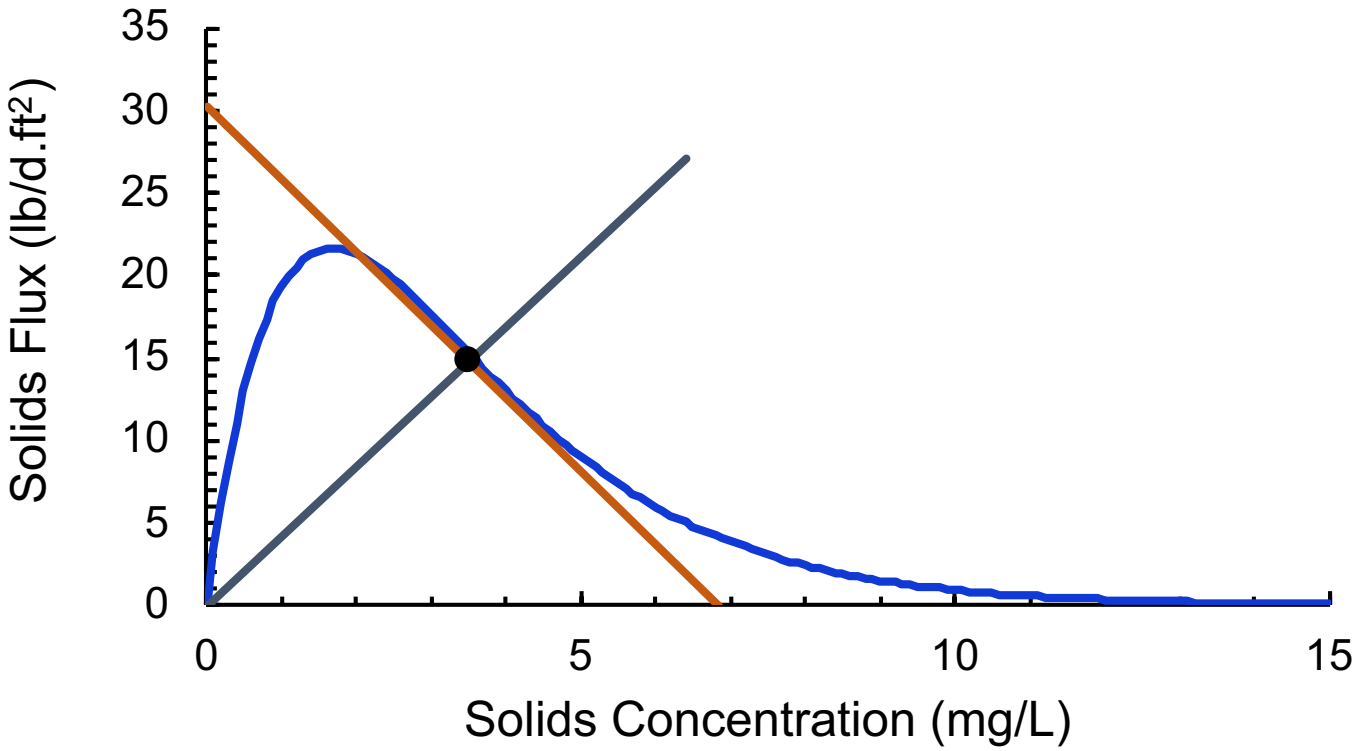
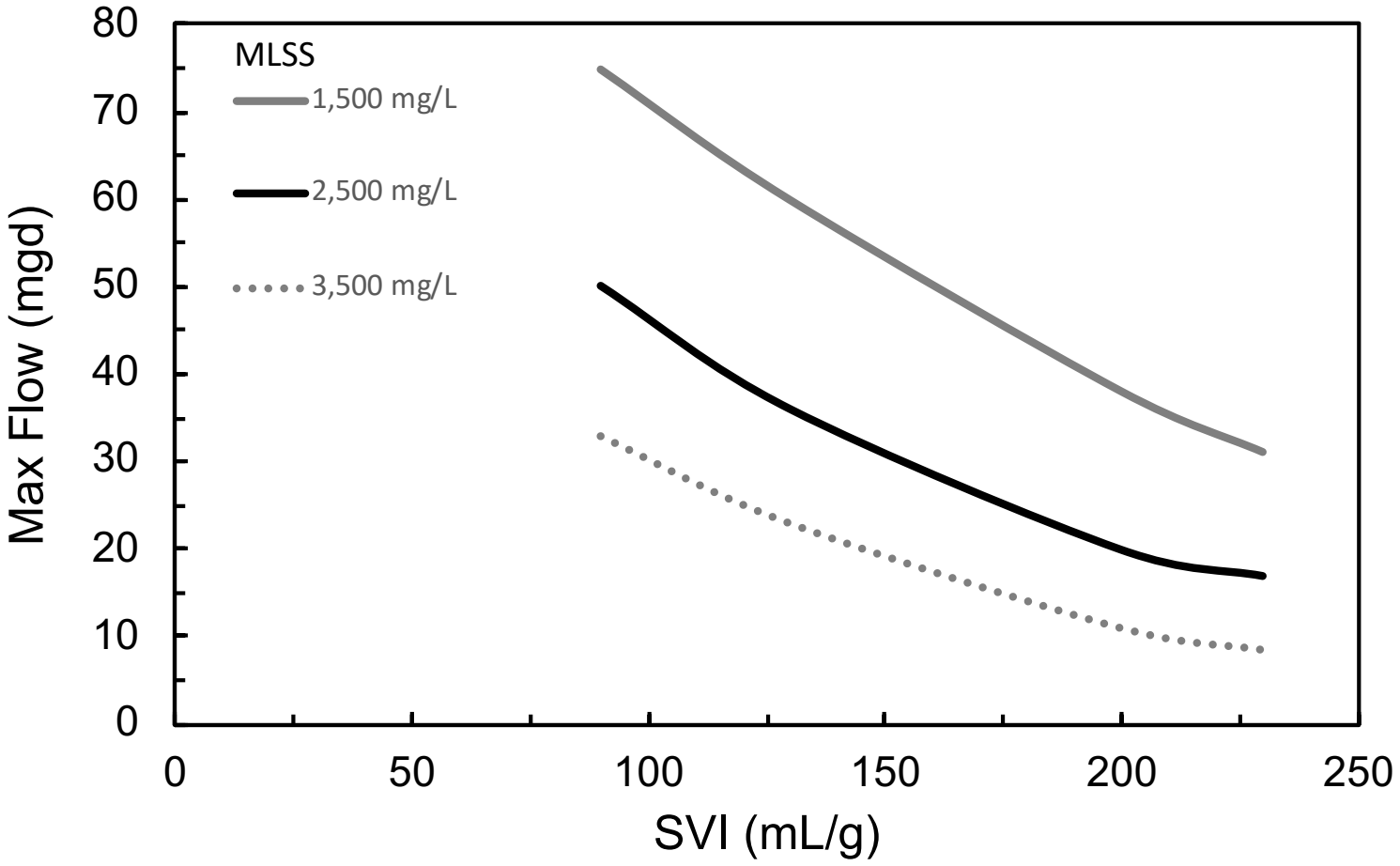


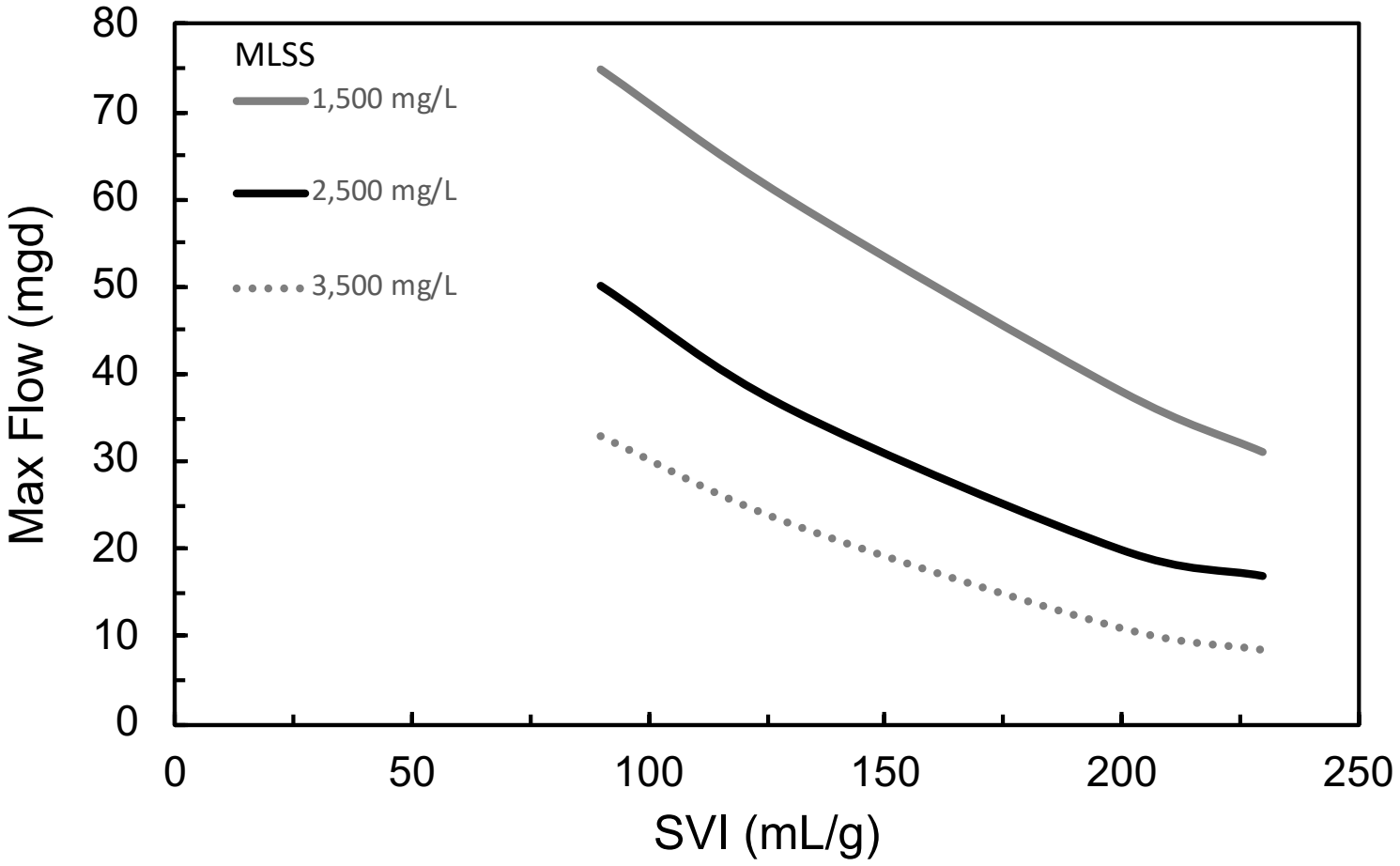
# An Extremely Powerful Tool



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



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



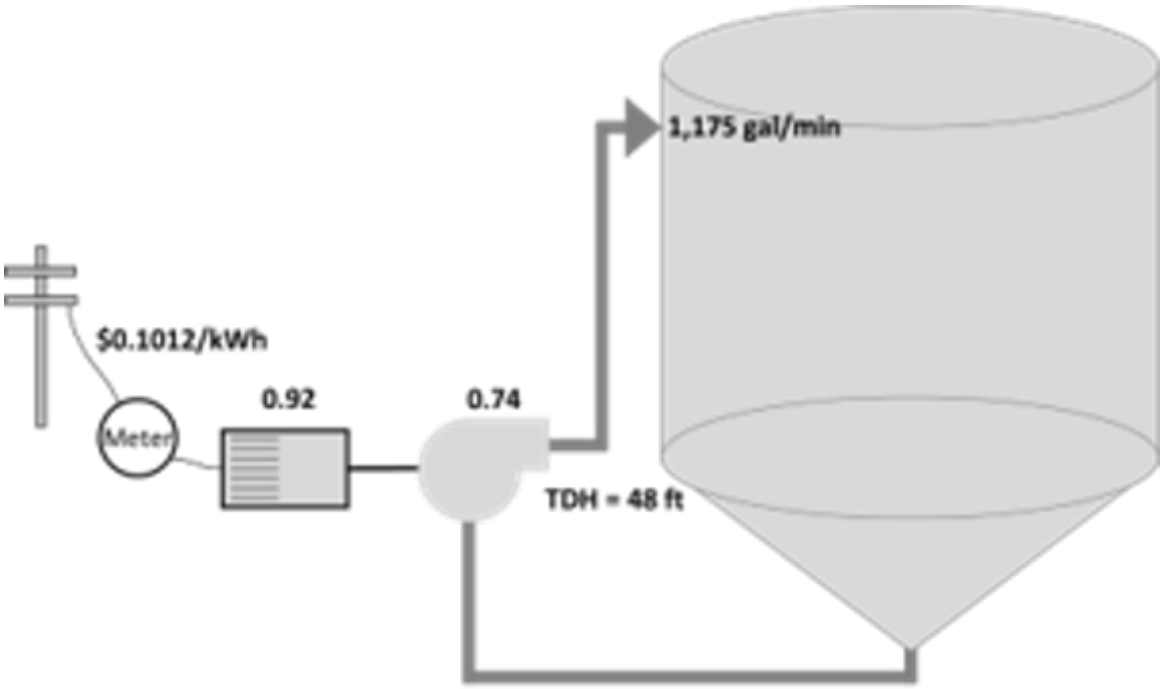
# Final Takeaways to Save Energy in the Liquid Treatment Train

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

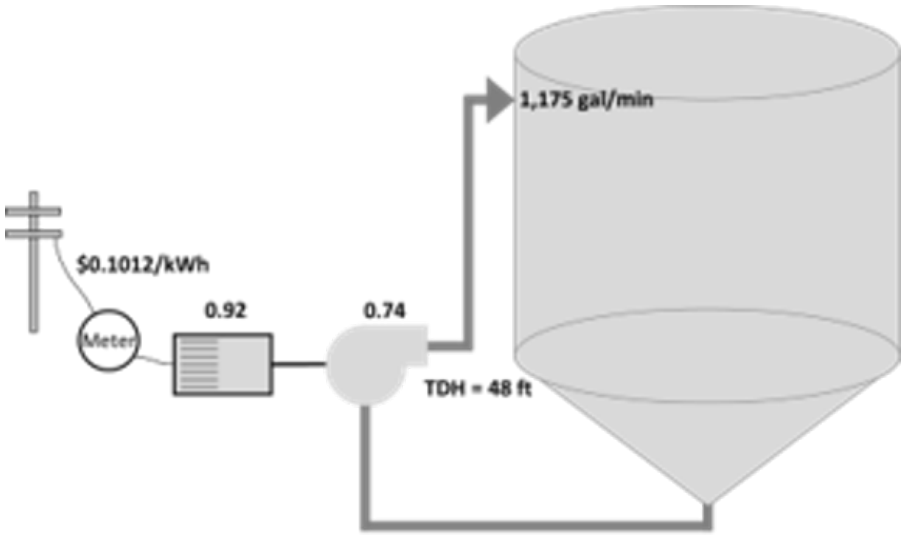
# A Sample Opportunity……..

4. The anaerobic digester mix pump continuously pumps 1,175 gal/min against a total dynamic head of 48 ft. From the manufacturer's literature, the pump is 74% efficient and the motor is 92% efficient. The average cost of electricity is $0.1012/kWh. The CPO conducted a study that found no deterioration in performance—measured in terms of VSR, gas production and gas composition—when turning the mix pump off for 20 minutes every 30 minutes (i.e., 10 min on, 20 min off). Calculate the annual electrical cost savings realized with this new operation, ignoring demand charges.

**Given**:
Pumping rate, Q = 1,175 gal/min
TDH = 48 ft
Motor efficiency = 92% = 0.92
Pump efficiency = 74% = 0.74
Old operation = 24 h/d
New operation = 10 min/30 min
Cost of electricity = $0.1012/kWh



# Answer:

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New operation = 10 min/30 min
Cost of electricity = $0.1012/kWh

1. **Estimate kW:**

$kW = BHP * 0.746$

$BHP = (Q * TDH)/(3960 * Eff_{Pump})$

$BHP = (1,175 * 48)/(3960 * 0.74)$

**= 19.25 HP**

$kW = (BHP * 0.746)/Eff_{motor}$

$kW = (19.25 * 0.746)/.92 =$ **15.6 kW**

2. **Estimate Hours of operation**

Old = **8760 hours/year**

New =10min/30min = 1/3 of the time

= 8760/3 = **2,920 hours/year**

3. **Estimate Savings:**

kWh/year = kW * hours/year

$Savings = kWh_{old} - kWh_{new}$

$kWh_{old} = 8760 * 15.6 = 136,737$ kWh/year

$kWh_{new} = 2920 * 15.6 = 45,552$ kWh/year

kWh Savings = 136,737 – 45,552 = 91,185 kWh/year

**$$ Savings = 91,185 kWh/year * $0.1012/kWh**

**= $9,227.92**

# 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

# Header Pressure – Remember?

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

| | | |
|---|---|---|
| 1. How much energy is saved if a 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 | % |

| | | |
|---|---|---|
| 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?<br>What is the approximate temperature of your plant's mixed liquor?<br>What is the DO residual setpoint at your plant? | hp<br>°F<br>mg/L |
| 6. | How much total money is saved if your plant reduces DO residual to 1 mg/L? | $ /year |

# Acknowledgments

Thanks to the following partners for their support in developing this curriculum

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U.S. DEPARTMENT OF ENERGY

Cascade Energy

WWTT
WasteWater Technology
TRAINERS