



SLUDGE MASS CONTROL

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SLUDGE MASS CONTROL

- Why Do We Care?

- MCRT/SRT Control
- Sets The Proper Wasting Rate
- Defines The Microbial Population
- Affects Effluent Quality & Settling
- Can Wash Out Certain Filaments
- **Wasting Control Is The Most Common Process Control Error**

CAUTION:

Wasting is the Strongest
Process Control for Activated
Sludge and Should be Performed
Thoughtfully and Intentionally

COMMON MISTAKES

- Trying to maintain constant MLSS when organic load is not constant
 - Flow and Organics Change the MLSS
- Trying to maintain a specific F/M when organic load is not constant
 - Requires BOD Data: Too Slow
- Solution: Realize that MCRT is proportional to F/M and MLSS
 - MCRT takes into account variability in organic load and in microorganism growth rates

WHY MCRT?

Mean Cell Retention Time

- Can be targeted to meet actual conditions
- Higher BOD load produces more sludge
 - MCRT control dictates higher waste mass
- Lower BOD load produces less sludge
 - MCRT Control dictates lower waste mass

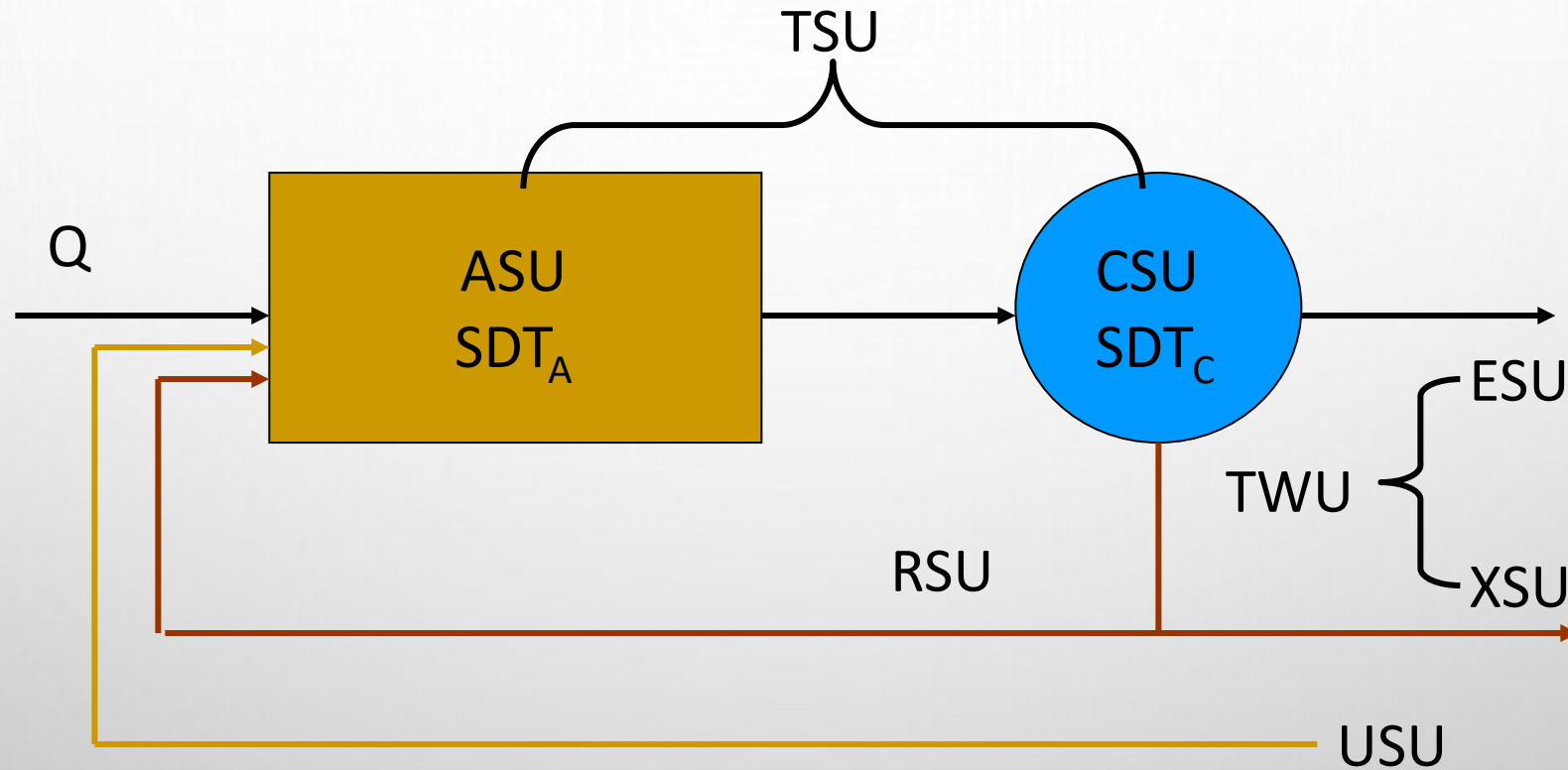
SLUDGE MASS CONTROL

Three Crucial Questions

1. How Many Microorganisms Are There?
2. Where Are They?
 - Aeration Tank
 - Clarifier
 - Effluent?
3. How Long Are They There?
 - Detention Times

HOW MANY BUGS ARE THERE?

MASS AND TIME



Units can be in pounds or any other defined mass

HOW MANY BUGS ARE THERE?

AERATOR SLUDGE UNITS

- Aerator Sludge Units (ASU)
 - Mass of microorganisms in the aeration basin

$$ASU = MLSS (mg / L) \times Vol_A (MG) \times 8.34$$

HOW MANY BUGS ARE THERE?

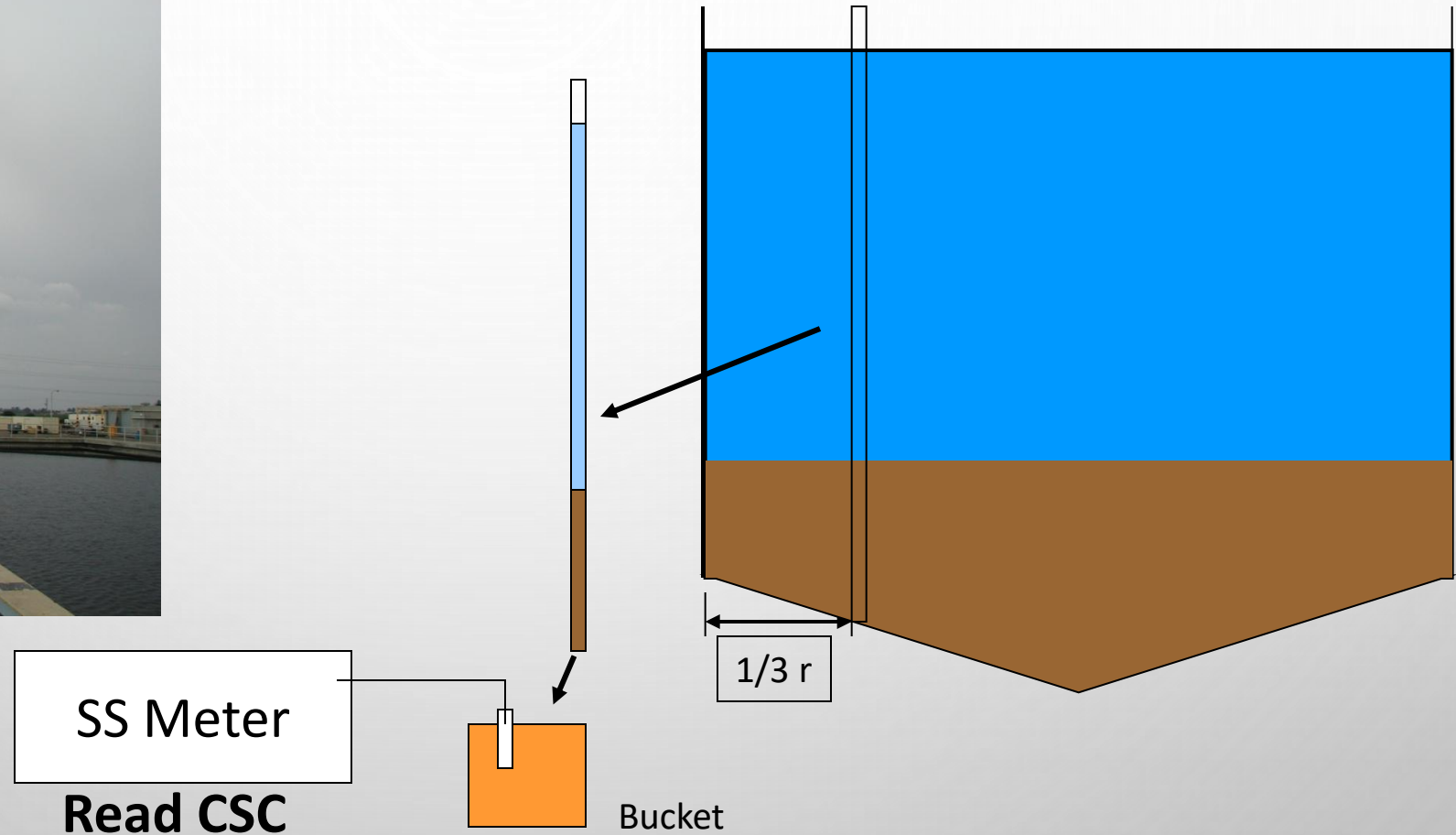
CLARIFIER SLUDGE UNITS

- Clarifier Sludge Units (CSU)
 - Mass of microorganisms in the clarifiers

$$CSU = CSC \text{ (mg / L)} \times Vol_c \text{ (MG)} \times 8.34$$

HOW MANY BUGS ARE THERE?

CLARIFIER SOLIDS CONCENTRATION



HOW MANY BUGS ARE THERE?

CLARIFIER SLUDGE UNITS

- Clarifier Sludge Units (CSU)
 - Mass of Microorganisms in the Clarifiers

$$CSU = CSC (mg / L) \times Vol_C (MG) \times 8.34$$

- The CSC is usually much smaller than the MLSS value
- If CSC and MLSS are close in value, it indicates excess sludge in the clarifier

HOW MANY BUGS ARE THERE?

TOTAL SLUDGE UNITS

- Total Sludge Units
 - All microorganisms available for treatment

$$TSU = ASU + CSU$$

HOW MANY BUGS ARE THERE?

WASTE SLUDGE UNITS

- Excess Sludge Units (Wasted Sludge)

$$XSU(lbs / d) = WSF (MGD) \times WSC (mg / L) \times 8.34$$

- Effluent Sludge Units

$$ESU(lbs / d) = Q (MGD) \times Eff\ TSS (mg / L) \times 8.34$$

- Uncaptured Sludge Units (recycle streams)

$$USU(lbs / d) = USF (MGD) \times USC (mg / L) \times 8.34$$

- Total Waste Units

$$TWU(lbs / d) = XSU + ESU - USU$$

WHERE ARE THEY?

SOLIDS DISTRIBUTION RATIO

- Solids Distribution Ratio = ASU/CSU

- Typical Values:

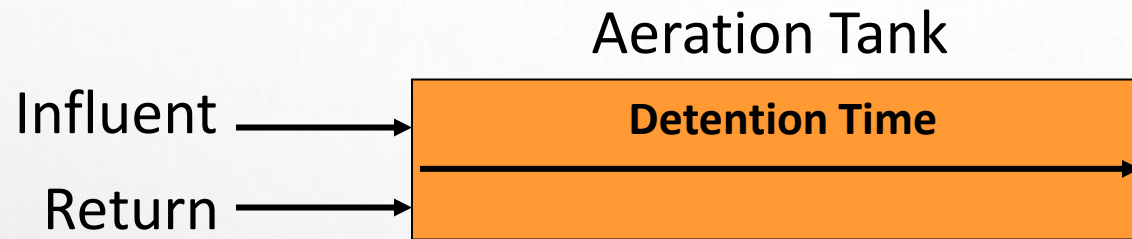
SDR	Typical Values
>10	Very good
6.5 – 10	Good
5.0 – 6.5	OK
3.0 – 5.0	Potential Problems Exist
< 3.0	Immediate/Pending Problems Exist

HOW LONG ARE THEY HERE? DETENTION TIMES

- How long in the Aeration Basins?
- How long in the Secondary Clarifiers?
- How long in the System?

HOW LONG ARE THEY HERE?

SOLIDS DETENTION TIME - AERATOR



Objective – organisms to clarifier should be in endogenous respiration

$$SDT_A = \frac{Vol_A (MG) \times 24}{Q (MGD) + RSF (MGD)}$$

SDT_A = time for a particle to travel from the aeration tank entrance to the exit

High RSF gives low SDT_A and high clarifier solids loading

HOW LONG ARE THEY HERE?

OXIDATION INDEX

- How can we use the SDT_A ?
- Oxidation Index:

$$OXI = SDT_A \times MLSS$$

- A certain number of microorganisms (MLSS) has a certain amount of time (SDT_A) in which to act
- Indicates amount of oxidative pressure applied
- Controlled by both return and wasting

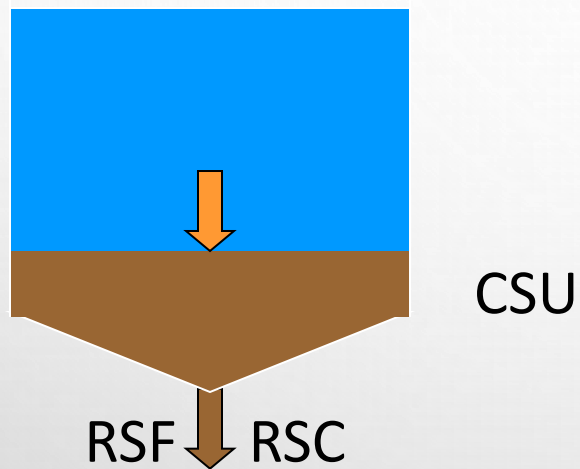
HOW LONG ARE THEY HERE?

OXIDATION INDEX

- Oxidation Index Hypothesis:
 - There is an OXI range that works best for a plant under defined feeding conditions
 - Adjust SDT_A or MLSS at the present temperature to provide the OXI that works best for your plant

HOW LONG ARE THEY HERE?

SOLIDS DETENTION TIME - CLARIFIER



SDT_C is the time for a particle to travel through the clarifier to the return/waste line

$$SDT_C = \frac{CSU (lb) \times 24}{RSF (MGD) \times RSC (mg / L) \times 8.34}$$

HOW LONG ARE THEY HERE?

DETENTION TIMES

- SDT_A and SDT_C not typical design parameters
- Important from operations perspective
- Industries may have waste-specific detention times required to metabolize certain waste components

HOW LONG ARE THEY HERE?

SOLIDS DETENTION TIME - SYSTEM

- Mean Cell Residence Time (MCRT)
 - Includes All Of The Solids
 - Critical For Settling, Filaments, BNR
- Solids Retention Time (SRT)
 - Only Aerator & Waste Solids
 - Critical For Nitrification

$$MCRT = \frac{TSU \text{ (lbs)}}{TWU \text{ (lbs/d)}}$$

$$SRT = \frac{ASU \text{ (lbs)}}{TWU \text{ (lbs/d)}}$$

HOW LONG ARE THEY HERE?

SOLIDS DETENTION TIME - SYSTEM

Typical MCRT Values

Activated Sludge System	MCRT (days)
Conventional	3-10
Step-feed plug flow	3-10
Extended air	10-30+
Pure oxygen	1-4
Sequencing Batch Reactors	10-30

HOW LONG ARE THEY HERE?

WASTING CONTROL

- Wasting provides the largest system pressure
- Waste **pounds**, not gallons!!!!
- MCRT is your major process control parameter
- $F/M \sim MCRT \sim MLSS$
- Waste Sludge Concentration is Usually Wrong

HOW LONG ARE THEY HERE?

WASTING CONTROL

- Wasting pressures the system more than DO or RAS, and is probably equal to step-feed
- Wasting establishes the growth rate in the system for the given influent loading
- Wasting control is the most common process control error
 - Incorrect data
 - Inaction by operating staff

HOW LONG ARE THEY HERE?

MANUAL WASTING CONTROL

1. Calculate Present MCRT
2. Determine Pressure Required
3. Decide on Target MCRT
4. Calculate Required TWU for Target MCRT
5. Calculate WSF Based on Present WSC

HOW LONG ARE THEY HERE?

DETERMINE WASTE SLUDGE FLOW

- Determine Target MCRT

$$MCRT = \frac{TSU \text{ (lbs)}}{TWU \text{ (lbs / d)}}$$

- Calculate Target Total Waste Units (TWU) Necessary to Meet Target MCRT

$$\text{Target TWU (lbs / d)} = \frac{TSU \text{ (lbs)}}{\text{Target MCRT (d)}}$$

HOW LONG ARE THEY HERE?

DETERMINE WASTE SLUDGE FLOW

- Calculate Waste Sludge Flow (WSF) based on present Waste Sludge Concentration (WSC)

$$\text{Target TWU (lbs / d)} = \frac{\text{TSU (lbs)}}{\text{Target MCRT (d)}}$$

$$\text{Target TWU} = (\text{WSF}_{24} \times \text{WSC} \times 8.34) + \text{ESU} - \text{USU}$$

$$\text{WSF}_{24} = \frac{\text{TWU} - \text{ESU} + \text{USU}}{\text{WSC} \times 8.34}$$

WSF_{24} = waste sludge
flow rate over
24 hour period

HOW LONG ARE THEY HERE?

MANUALLY DETERMINE WASTE SLUDGE FLOW

- Small facilities may not waste 24 hrs/day
- Calculate actual WSF_{24} based on actual wasting period

$$\textit{Actual WSF} = WSF_{24} \times \frac{24}{\textit{Hours wasting per day}}$$

- If WSC changes, WSF must change!

HOW LONG ARE THEY HERE?

WASTING CONTROL: HOW OFTEN?

- 24 hours/day
 - Conventional AS facilities, say MCRT <7 days
 - Facilities with thickeners
 - Large chance for WSC variation
- 4-8 hours/d
 - MCRT 7-15 days
 - Medium chance for WSC variation
- Get it done! 2-3 hours
 - MCRT > 15 days
 - Least chance for WSC variation

HOW LONG ARE THEY HERE?

WASTING CONTROL: WSC VALUES

- Most often one sample for WSC is taken
- WSC varies throughout the day
 - Sludge settling changes
 - SLR changes
 - Pipe Hydraulics Change

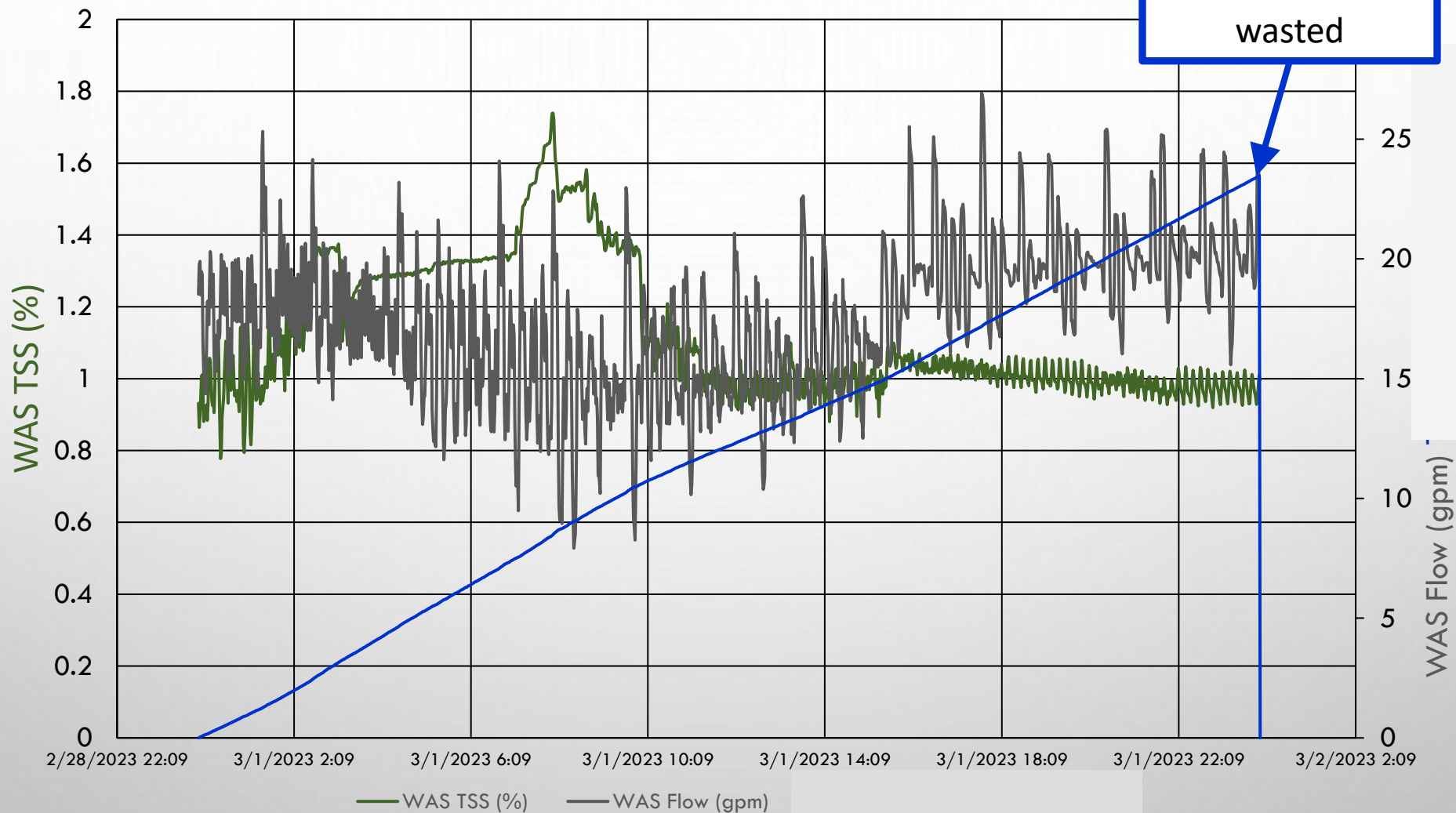
HOW LONG ARE THEY HERE?

WASTING CONTROL: WSC VALUES

- EXAMPLE: Based wasting on one sample taken at 11:00 a.m. showing 4,390 mg/L
- Actual WSC sample results over next 24 hr period
 - 4,150
 - 3,050
 - 3,170
 - 4,450
 - Average = 3,705
 - 16% less sludge wasted than intended

Wait, what?

Better!



MASS BALANCE SUMMARY

Three Important Questions

- How Many Bugs Are There?
- Where Are They?
- How Long Are They Here?

MCRT Control

- Recognize Your WSC Will Change
- TOTALIZE YOUR WAS MASS



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