Metropolitan Water Reclamation District of Greater Chicago

Welcome to the
October 25 Edition of the
2024 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- Remote attendees' audio lines have been muted to minimize background noise.
  For attendees in the auditorium, please silence your phones.
- A question and answer (Q/A) session will follow the presentation.
- For remote attendees, please use "**Chat**" only to type questions for the presenter. For other issues, please email Pam to SlabyP@mwrd.org.
  For attendees in the auditorium, please raise your hand and wait for the microphone to ask a verbal question.
- The presentation slides will be posted on the MWRD website after the seminar.
- This seminar is pending approval by the ISPE for one PDH and pending approval by the IEPA for one TCH. Certificates will be issued only to participants who attend the entire presentation.

Rudy A. Maltos

Staff Engineer, Technology and Innovation Division
Metro Water Recovery, Denver, Colorado

Rudy Maltos is an adventurous Ph.D. graduate from Colorado School of Mines. He applies his passion and excitement to the intricate world of process engineering at Metro Water Recovery. When he's not refining densification processes for activated sludge or optimizing phosphorus recovery techniques, you'll find him enthusiastically supporting the Denver Nuggets or navigating Colorado's whitewater rapids. Rudy's passion for applied research and zest for adventure make him a dynamic force in both his professional and personal pursuits.

METRO WATER RECOVERY®

Implementing a Full-Scale Activated Sludge Pilot to Improve Sludge Settleability

Rudy Maltos, PhD

November 22, 2024

Topics

- Metro Water Recovery
- Robert W. Hite Treatment Facility
- Technology and Innovation Department

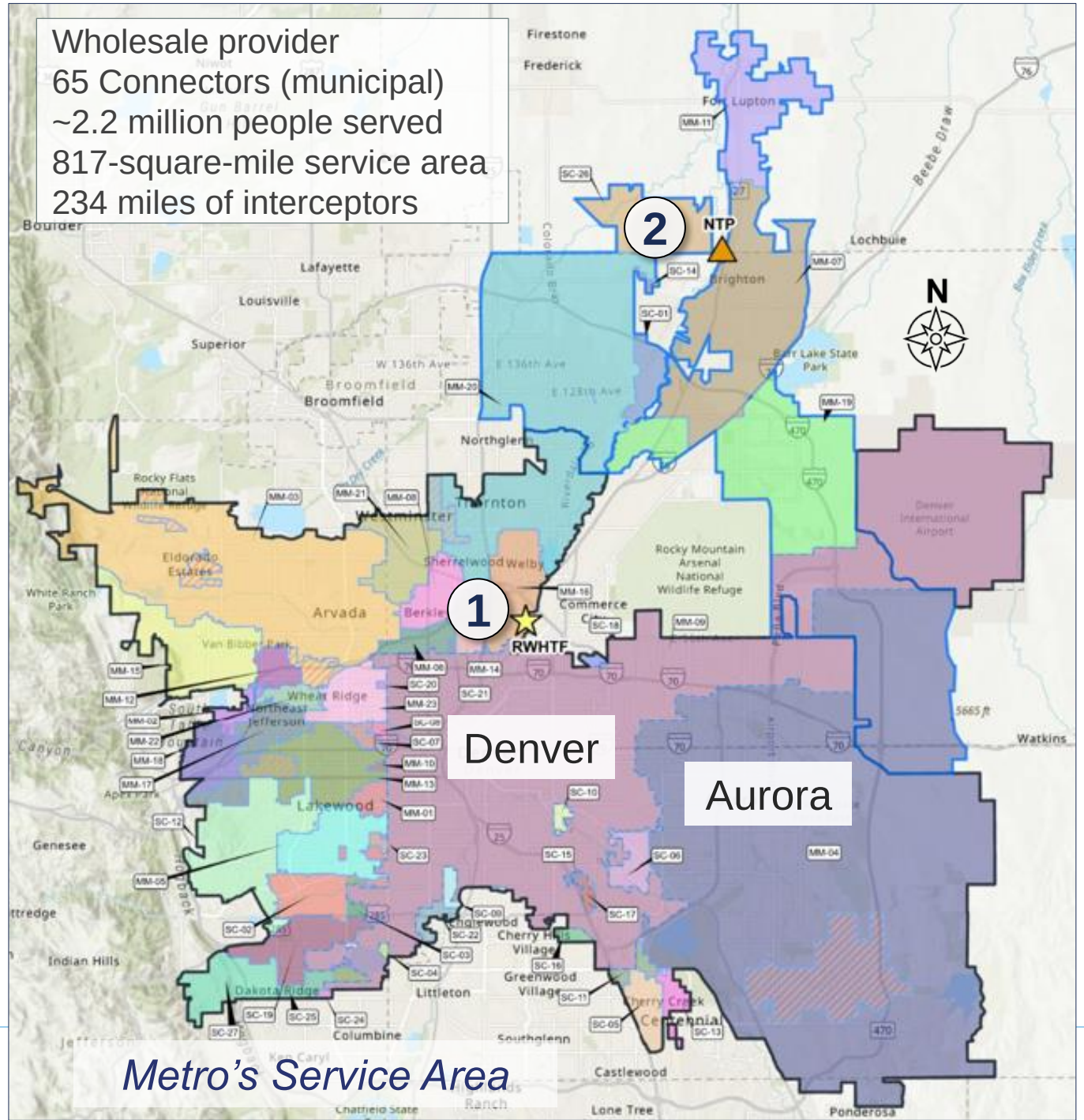
Densified Activated Sludge Pilot

- Biological Selection
- Physical Selection
- Evaluating the Impacts of Particle Size on Settleability
- Evaluating Floc and Granule Kinetics through Activity Testing

DAS Pilot Secondary Clarifier

Metro Water Recovery

- **Special District Formed in 1961 by Colorado statute**
  - Wholesale wastewater treatment services
  - Membership includes 60 local governments
  - 39-member Board of Directors
- **Largest wastewater treatment provider in the Rocky Mountain West**
  - Serving 2.2 million people in 7 major basins
  - 820-sq. mi. (2,120 sq. km.) service area
- **Facilities**
  - Robert W. Hite Treatment Facility 220 MGD (833 MLD)
  - Northern Treatment Plan 28.8 MGD (109 MLD)
  - METROGRO™ Farm 52,000 acres
- Publicly funded by its membership through annual charges and sewer connection fees



We Get Your Water… and We are the River

- Effluent dominated river, low dilution
- Increasingly challenged with meeting in-stream standards at our outfall

South Platte River through Downtown

South Platte at 64th Avenue (Upstream of Outfalls)

South Platte River at Outfalls


South Secondary Complex (SSEC)
North Secondary Complex (NSEC)
MLE+SAR
Densified activated sludge (DAS) pilot
RWHTF
• 130 million gallons/day (mgd)
• 220 mgd rated capacity

Technology & Innovation Department

METRO WATER RECOVERY®

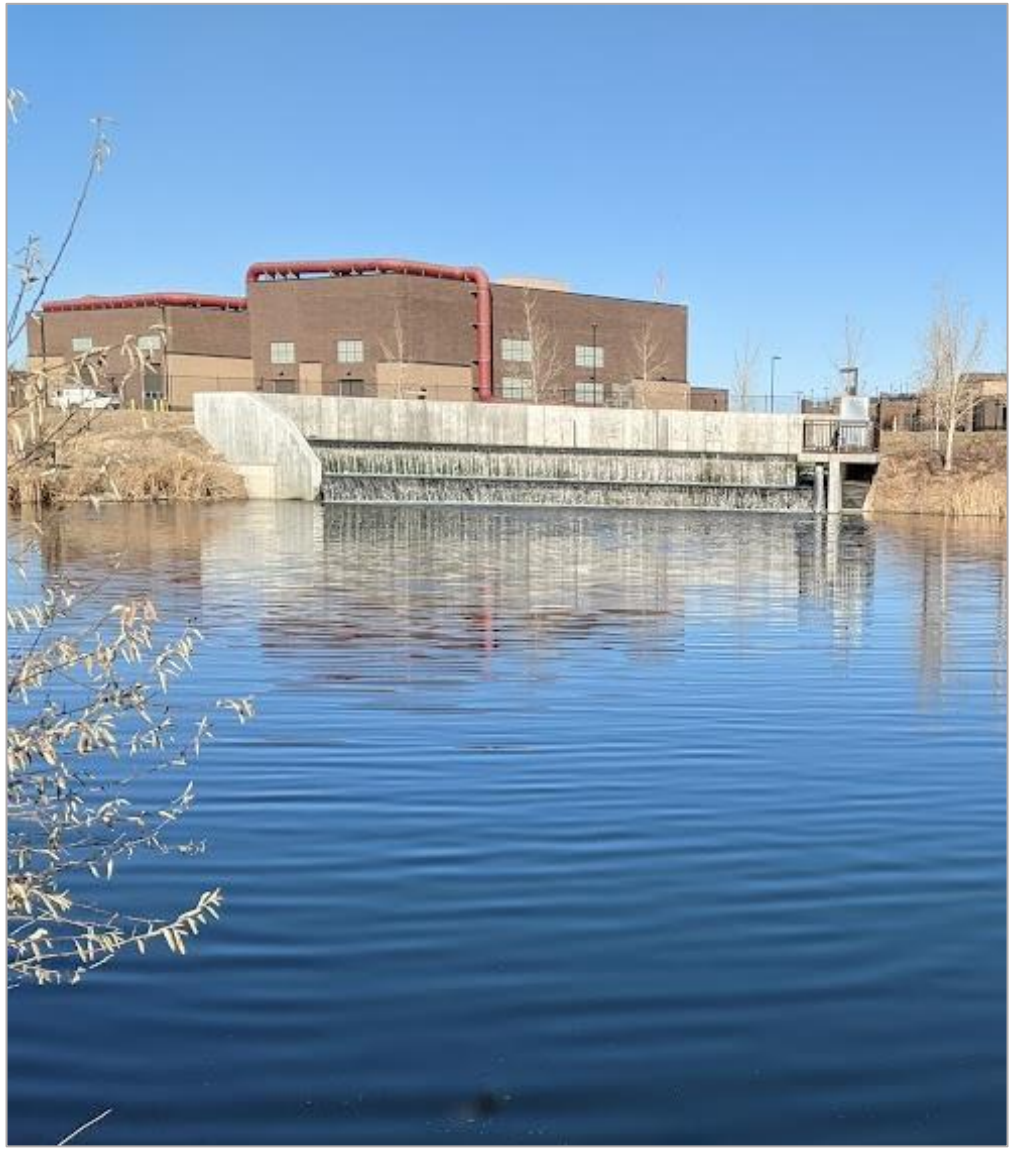
Why We Look To Innovate

- CAPex and OPex cost savings
- Process optimization
- New regulations
- Emerging processes and technologies
- Increasing flows and loads
- Aging infrastructure
- Site space constraints
- Piloting affords understanding of:
  - Efficacy and compatibility
  - Site-specific design criteria
- Reduces conservatism
- Each installation has unique challenges

Metro Applied Research Center (MARC)/ PAA testing

Technology and Innovation Department Support

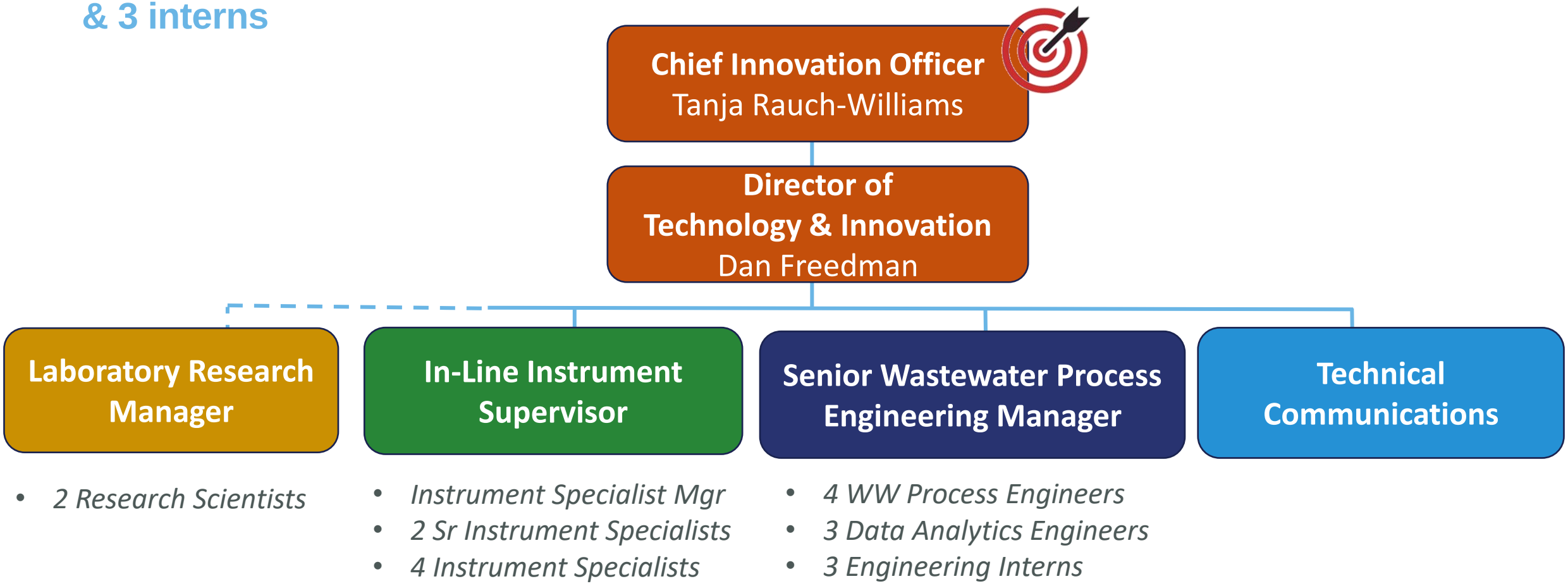
- Operational Support
- Process Optimization and Troubleshooting
- Data Utilization and Integration
- Technology Evaluations and Application
- Applied Research
- Legal and Regulatory Support
- Industry Engagement and Public Outreach



NTP re-aeration/ outfall

Technology and Innovation (& Friends)

21 permanent staff
& 3 interns



Ongoing and Near-term Pilot Studies

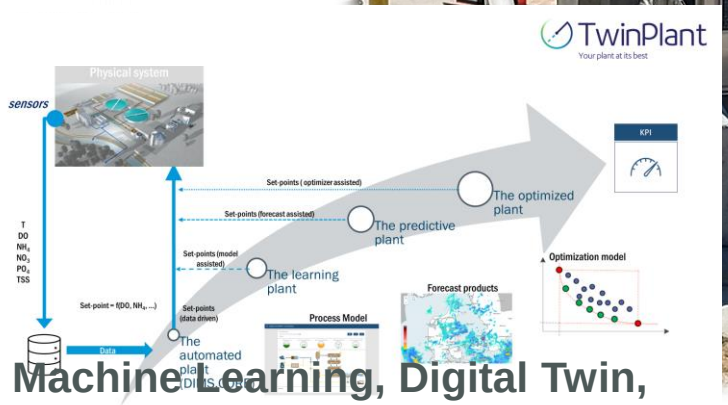
Temperature, Nutrients, Salinity, Process Optimization

Struvite Optimization

Advanced Tertiary Treatment (CBAT) for DON/DOP (2024-2026)

Densified Activated Sludge (DAS) (2018-2024)

SIX/XBAT Bench Testing for Salinity (2024-2025)



Machine Learning, Digital Twin, ABAC, & aSRT

NTP Effluent Cooling - Phase 1 Tertiary Demonstration (2023-2024)

Successes and Challenges of Metro TID's Pilot Program

Successes

- **Overall capital and O&M savings**
- Regulatory risk reduction
- Creative, excited workforce
- Change management
- Promotion of new, valuable technologies
- Resource sharing with other utilities
- Partnerships/collaborations

Challenges

- Balancing innovation and protocol
- Interdepartmental coordination
- Communication of activities and value
- Metrics
- Prioritization
- Resources

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Started from the Bottom, Now We're Here

Metro Applied Research Center

- TID formerly gathered testing samples and analyzed the data wherever space could be found – *even in storage closets!*

The MARC occupies approximately 1,000 square feet:

- ✓ The west portion of the space is a clean room and water quality lab
- ✓ The east portion is a high-bay area where TID may conduct, build, and scale pilots and other tests

Robert W. Hite Treatment Facility

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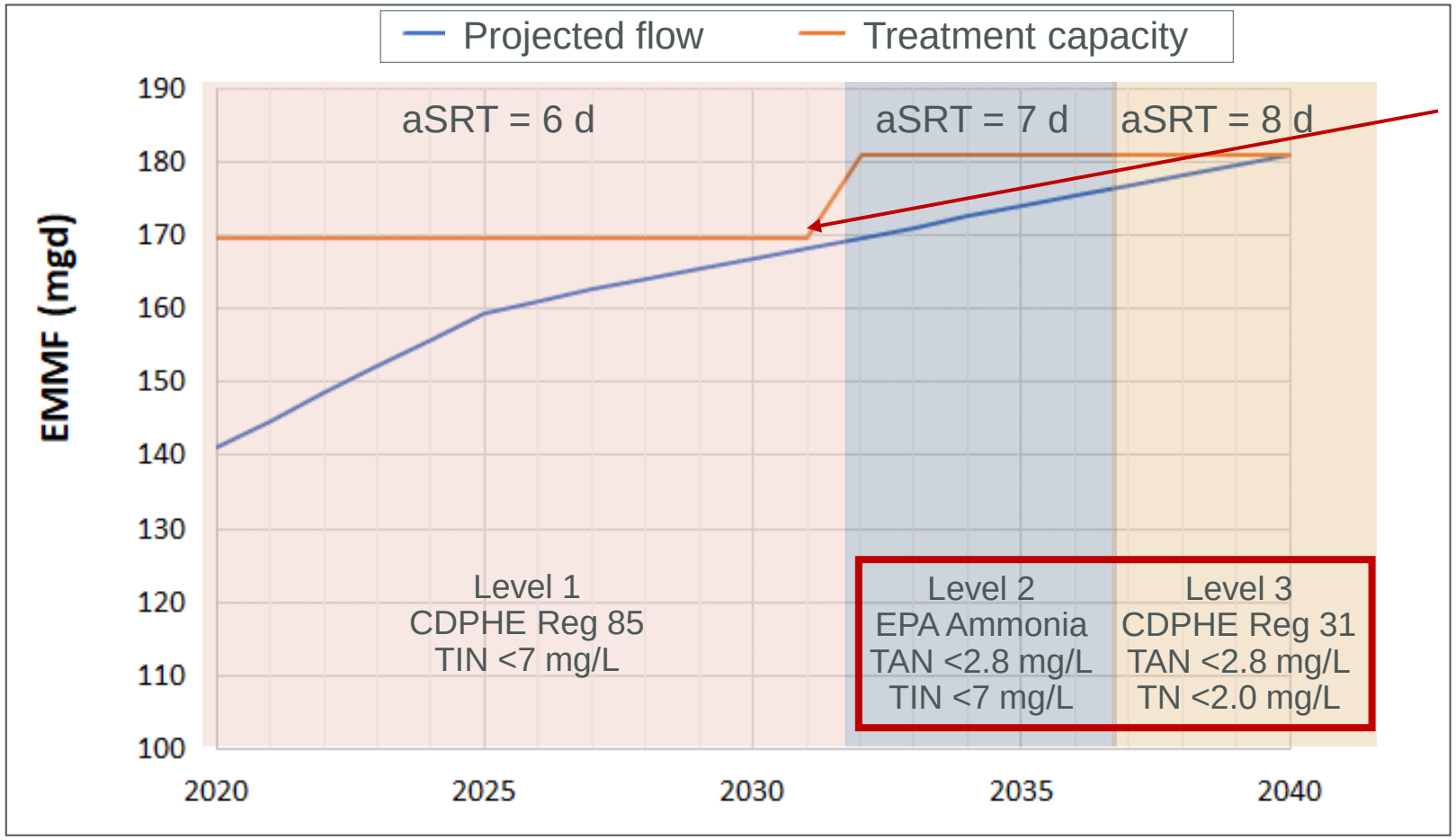
2018 Facility Plan: Higher aSRT for Nitrogen Removal

Degree of intensification determines aeration basin and clarifier expansion



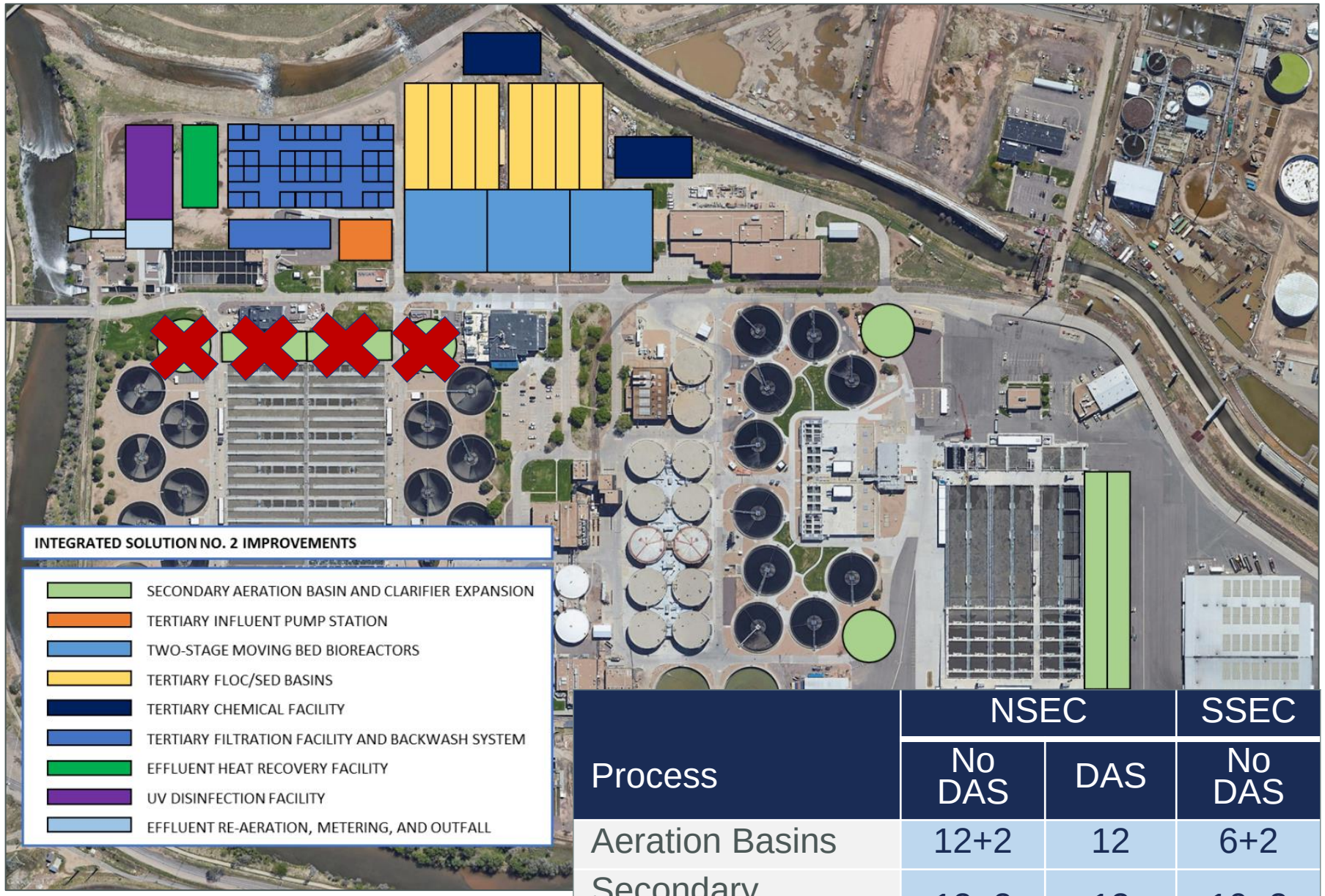
Secondary capacity limitation identified at 2032 with all basins in service at current settling conditions

Considerations to accommodate increased aerobic solids retention time (aSRT) and mixed liquor suspended solids (MLSS):

- Secondary expansion
- Intensification via sludge densification

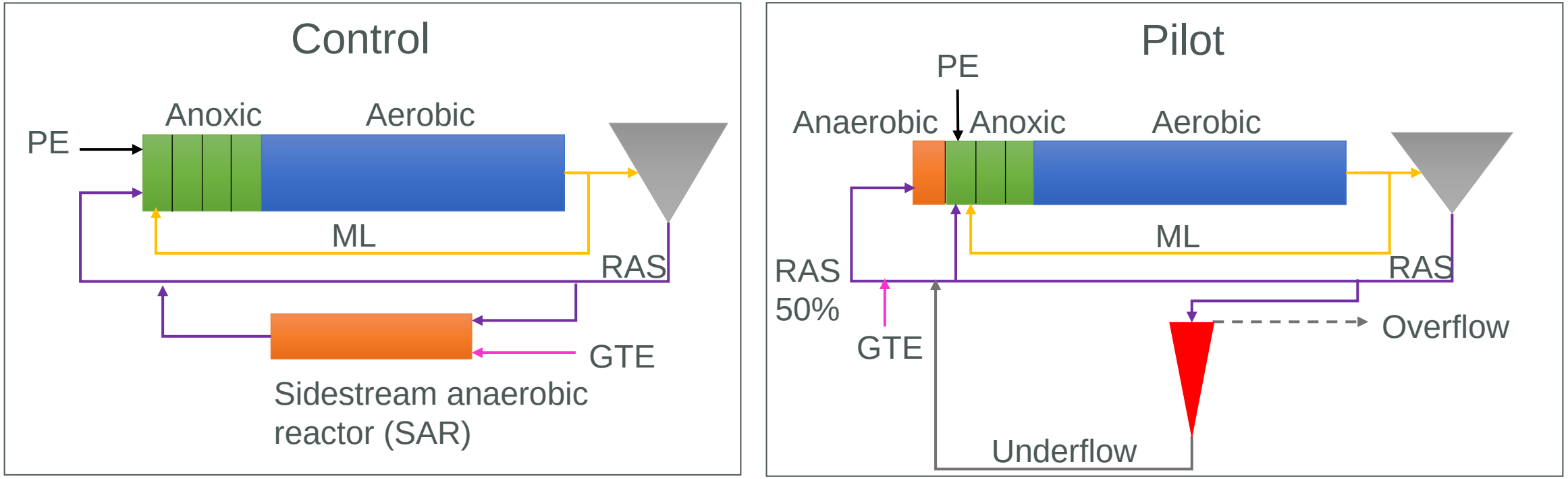
Intensified Biofarms Can Minimize Infrastructure Expansion

- DAS could avoid new basins and clarifiers in NSEC
- Up to $66 million in capital savings

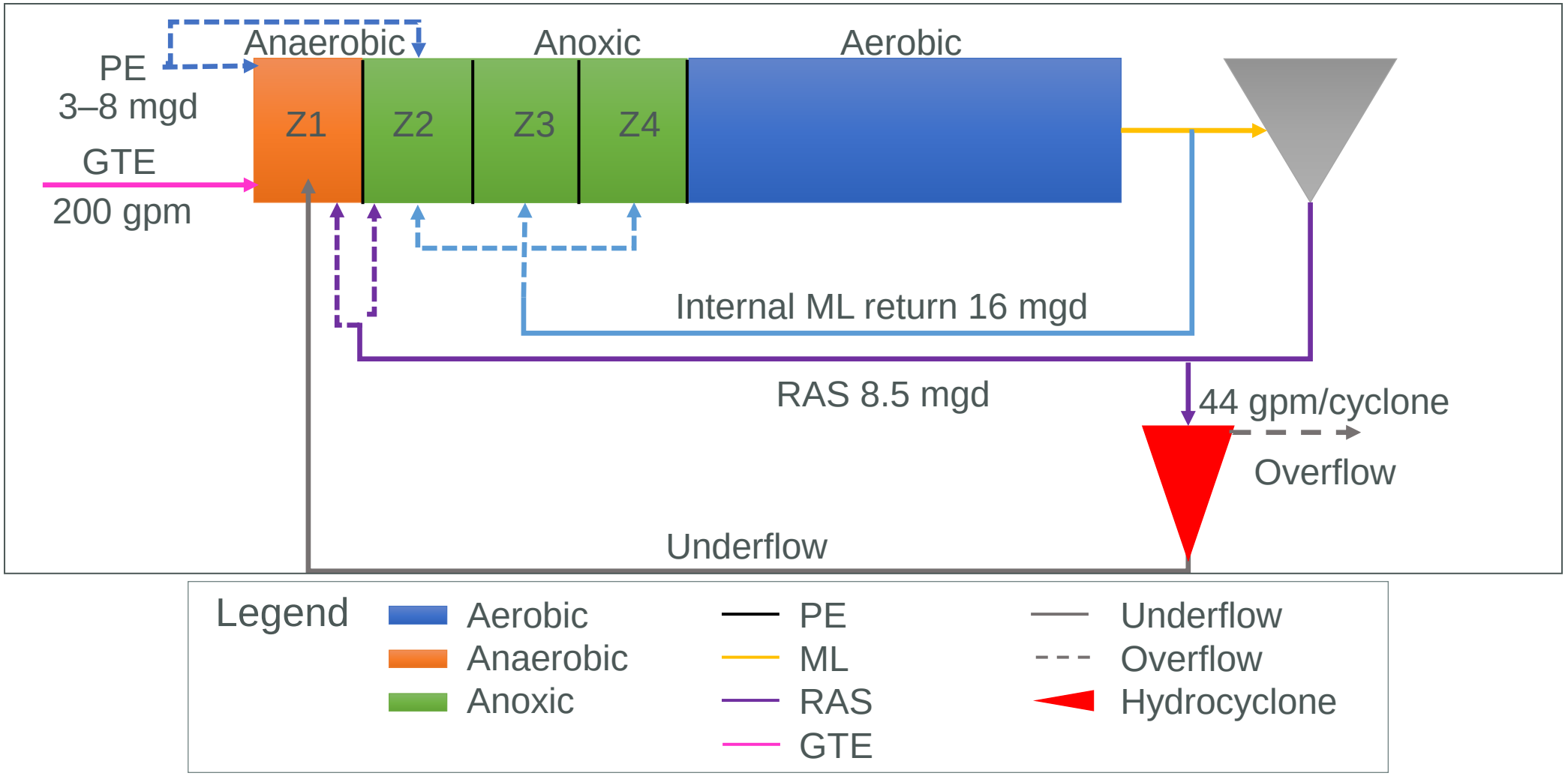


Process	NSEC		SSEC
	No DAS	DAS	No DAS
Aeration Basins	12+2	12	6+2
Secondary Clarifiers	12+2	12	10+2

Process Configuration Control and Full-Scale Pilot



Biological and Physical Selection Flexibility



Biological Selection Via Process Configuration

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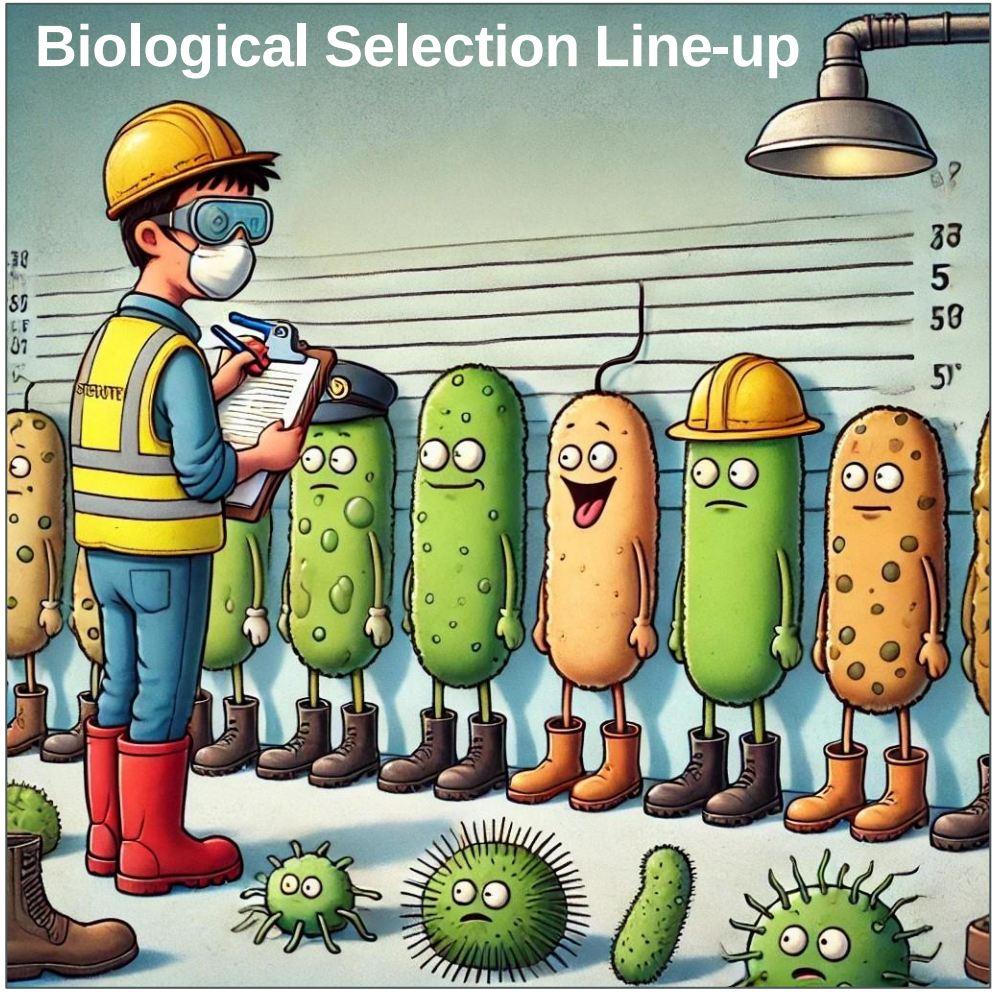
Biological Selection Definition

- Definition: Utilize substrate concentration and redox conditions to:
  1. Promote target organism growth (**feast**)
  2. Limit undesirable bacteria (**famine**)
- Measure: anaerobic food-to-microorganism ratio
- Control: process configuration



Pilot Process Configurations

AO configuration
High anaerobic feast achieved in Z1 and Z2 using combination of PE and GTE

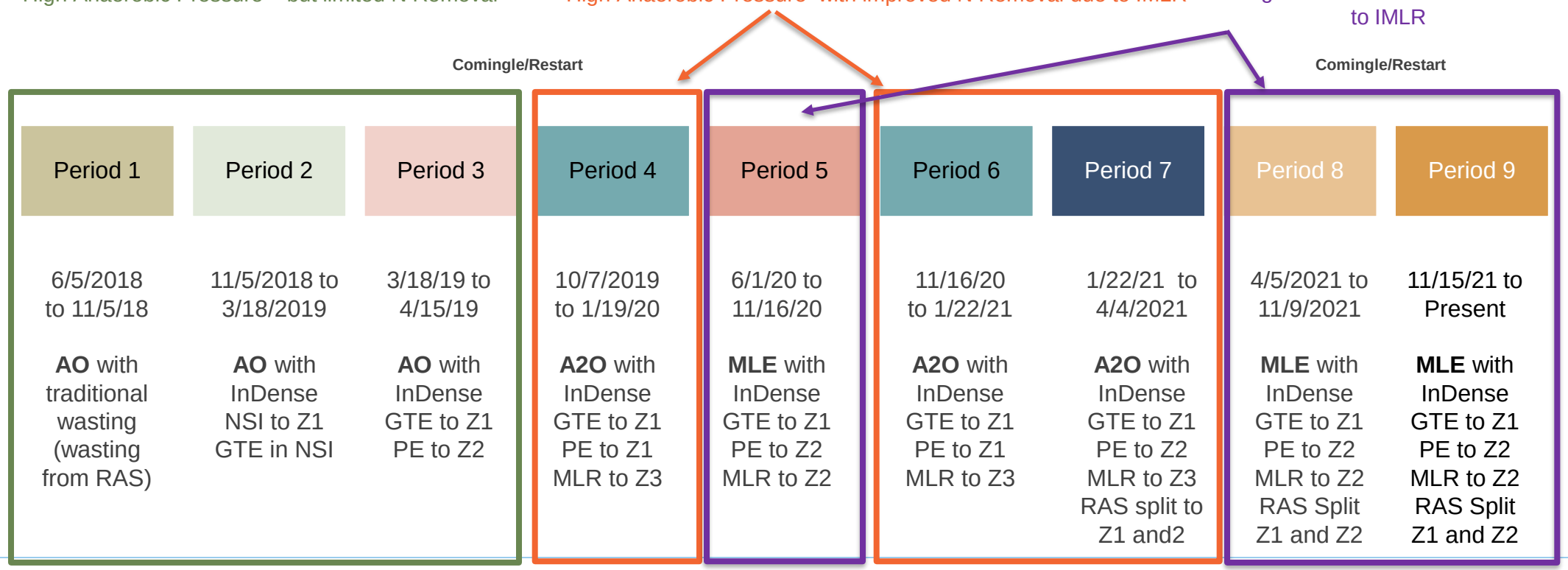
High Anaerobic Pressure – but limited N Removal

A2O
High anaerobic feast achieved in Z1 and Z2 using combination of PE and GTE

High Anaerobic Pressure with improved N Removal due to IMLR

SAR-MLE
Minimal anaerobic feast condition with GTE*

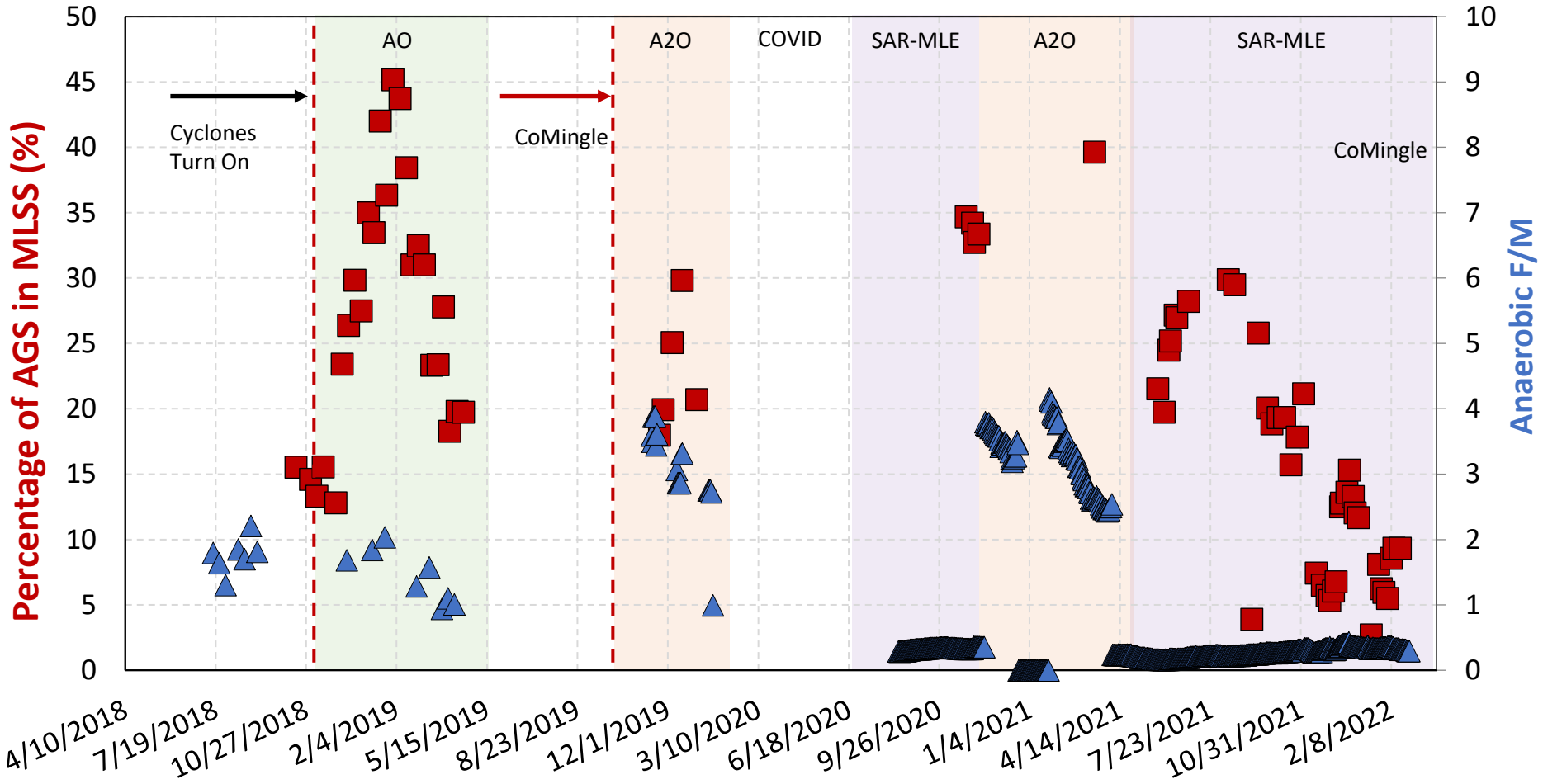
High anoxic feast* with PE due to IMLR



Granule Sludge and Anaerobic F/M

- AO Configuration
- A2O Configuration
- SAR-MLE Configuration

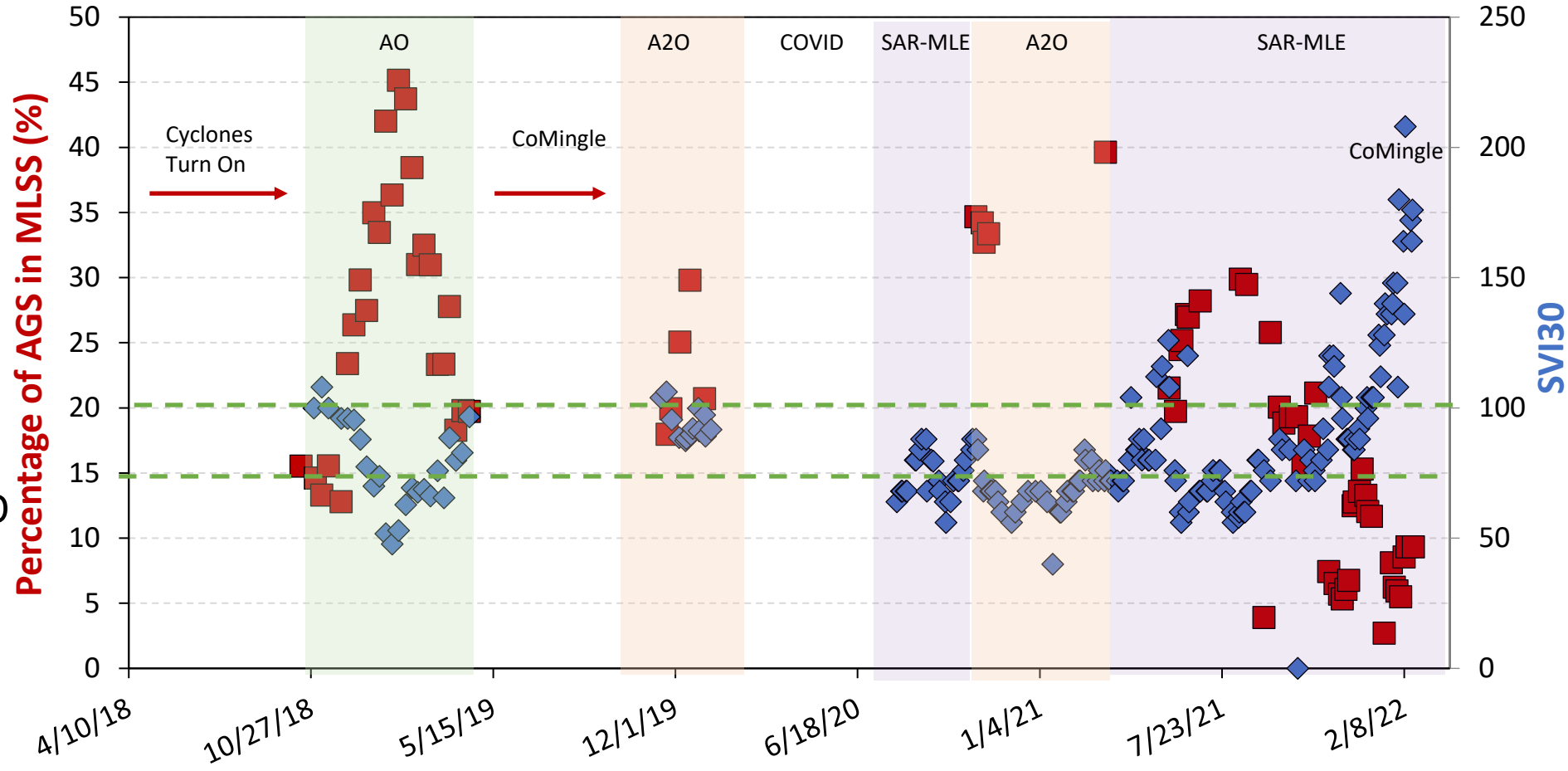
- High fraction of granules when Anaerobic F:M>1
- SAR-MLE configuration Anaerobic F:M<0.5



Granules and Sludge Compaction

- AO Configuration
- A2O Configuration
- SAR-MLE Configuration

- Desired SVI30 < 100 mL/g
- Require AGS% > 15
- Occurs during AO and A2O



Confirming Factors that Influence Stable DAS

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WRF 5130 Pilot Study

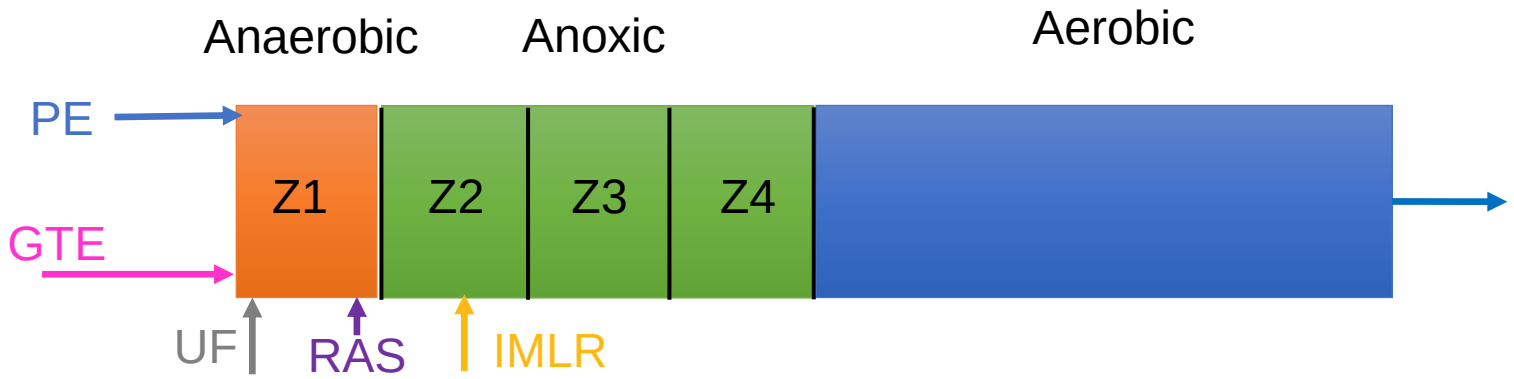
- Objectives: operate continuously for entire year

(capture winter performance)

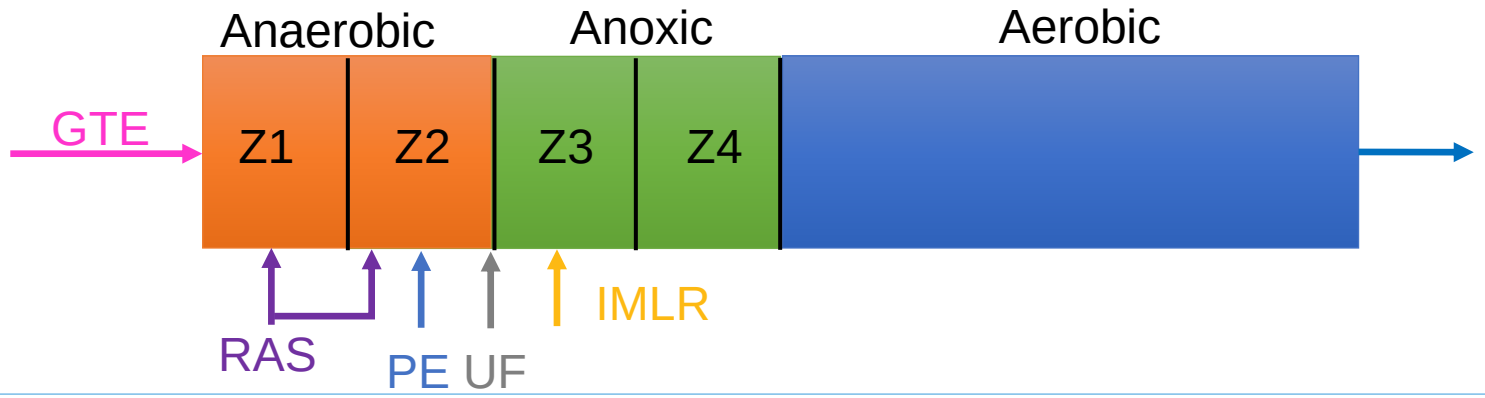
  - Confirm appropriate biological conditions
  - Evaluate secondary clarifier effluent water quality
  - Monitor physical selection
- Start date: 04/19/22 – Ongoing
- Feed: Primary effluent, mimics diurnal pattern of control basins
- Process Configuration: A2O
- Anaerobic F:M: 2-3 (g sCOD/g MLVSS d)
- DO operation: ABAC, max DO of 3 mg/L
- RAS: Constant flow, 1-2Q

Process Configurations

Dates:
05/23/22-11/17/22
(178 days)
06/28/23-Current
(92 days)



Dates:
11/17/22-06/28/23
(223 days)

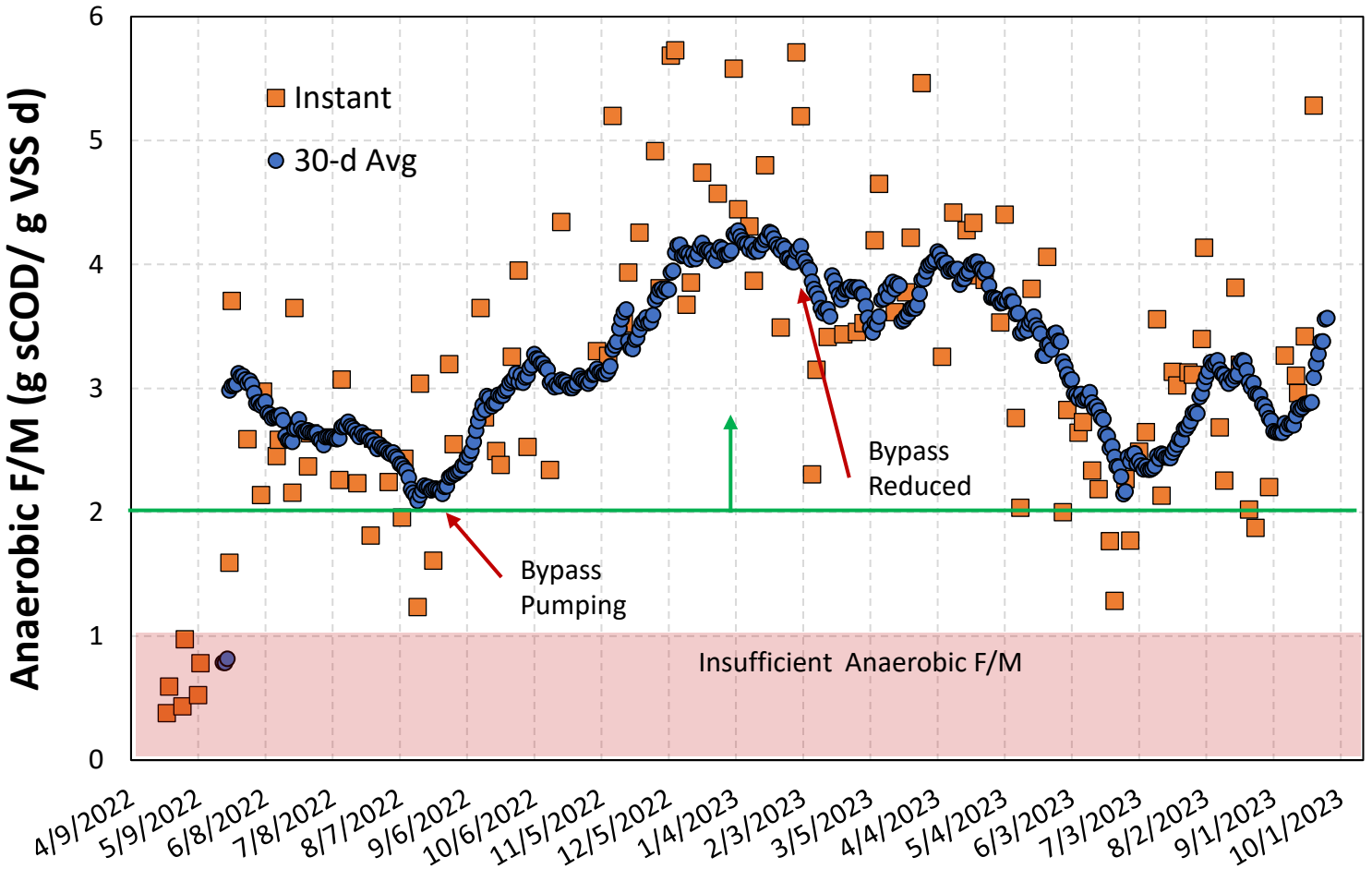


Legend:

- Aerobic
- Anaerobic
- Anoxic
- Hydrocyclone
- Primary Effluent
- Mixed Liquor (ML)
- Return Activated Sludge (RAS)
- Gravity Thickener Effluent (GTE)
- Underflow
- Overflow

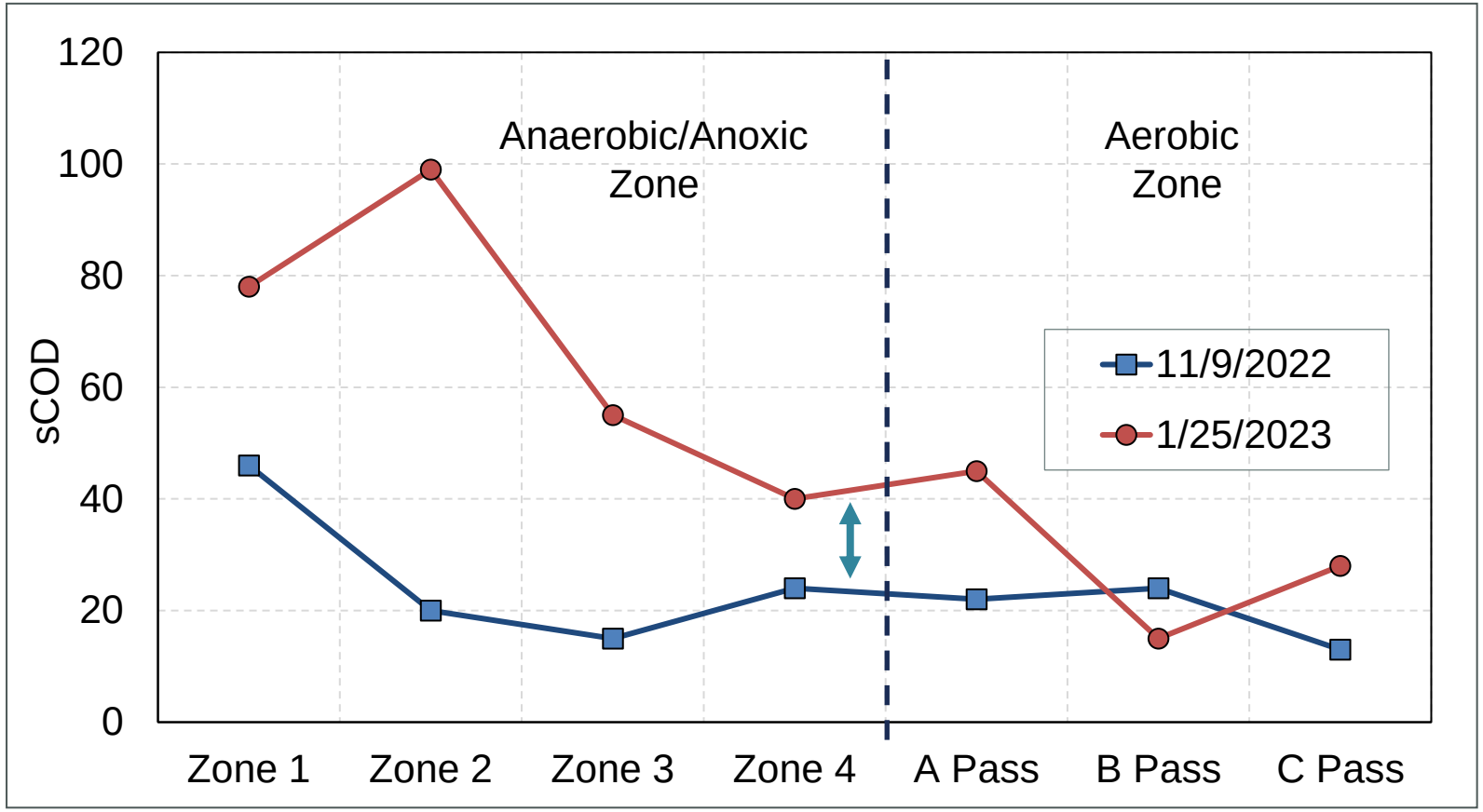
Anaerobic F/M

- Target >2 g sCOD/ g MLVSS
- Maintained for both process configuration
- Bypass pumping increases carbon load to DAS pilot
- Bypass pumping is reduced at the start of Feb 2023



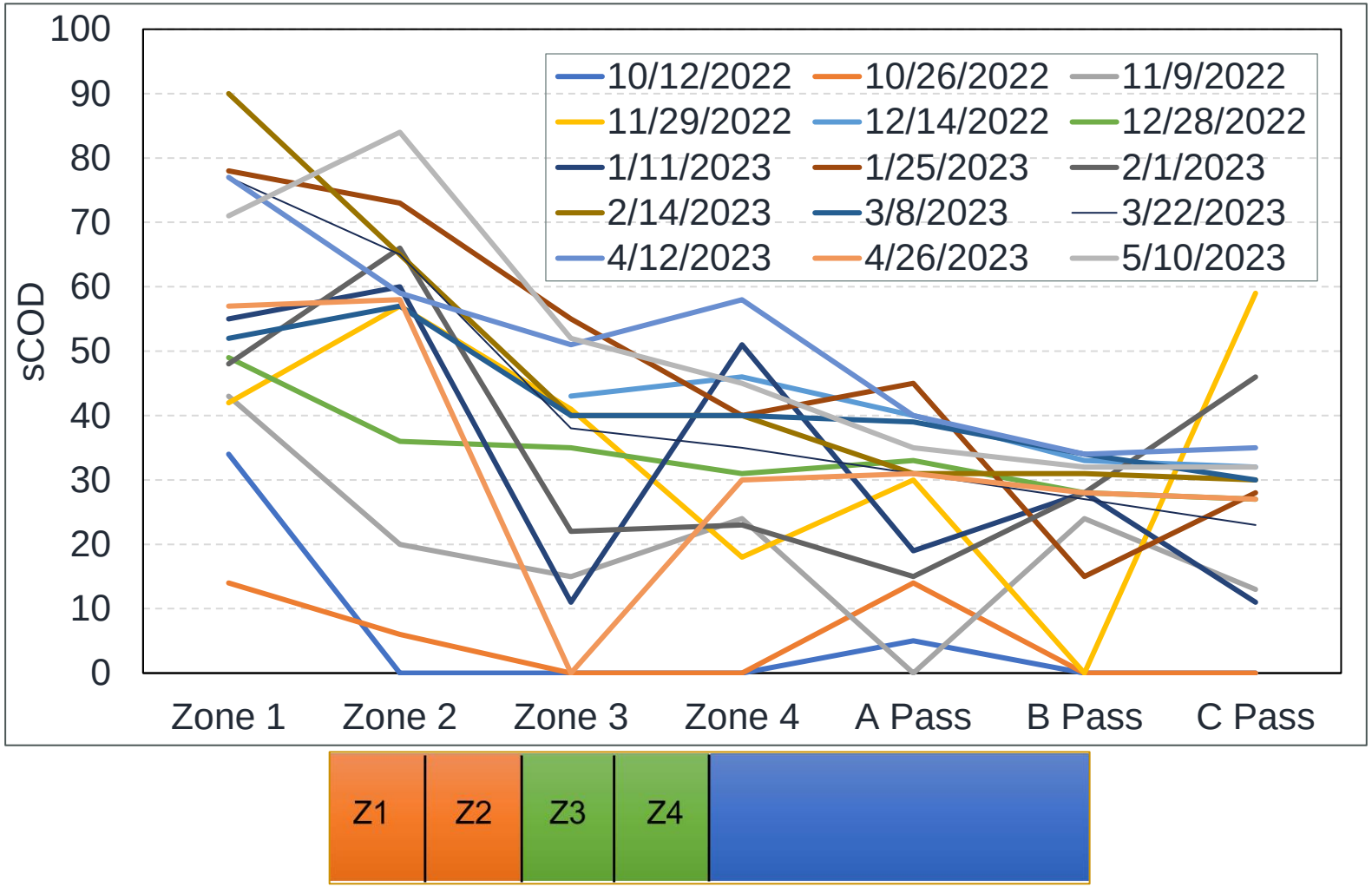
Famine Detection Carbon Profiles

- Conditions
  - All readily biodegradable chemical oxygen demand (rbCOD) must be consumed before the famine phase (anaerobic/aerobic)
- Purpose
  - Prevent filamentous growth
  - Metabolize stored carbon



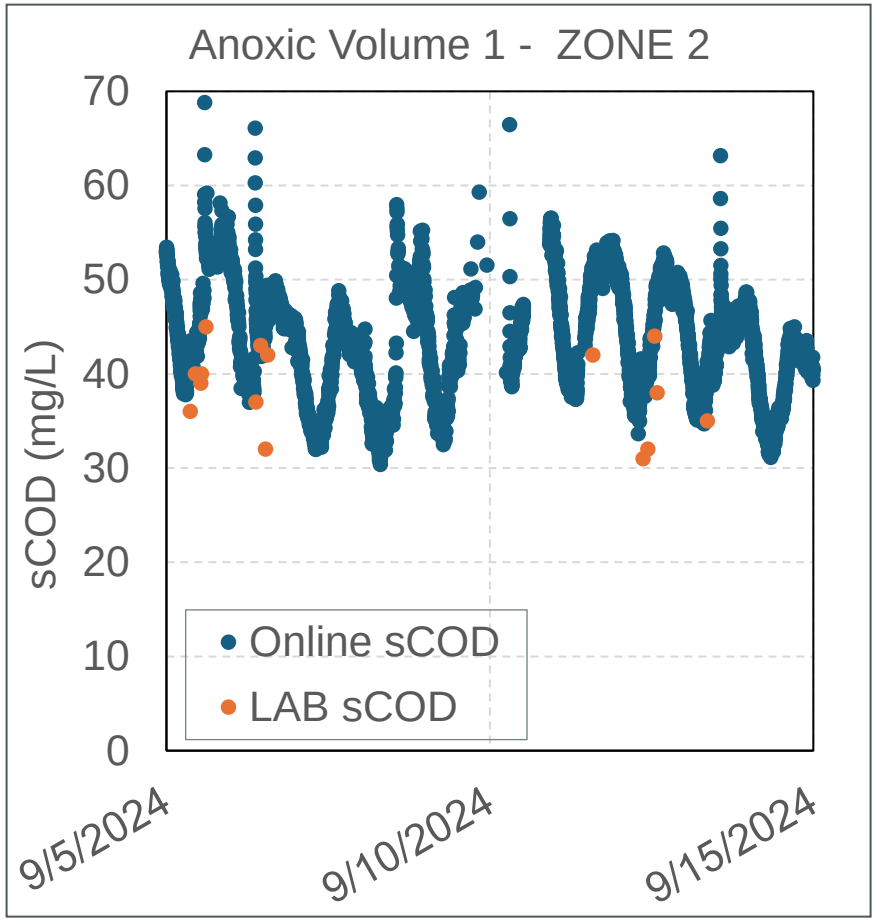
Famine Detection Carbon Profiles

- Conducted multiple soluble chemical oxygen demand (sCOD) profiles
- Difficult to relate sCOD profiles to filamentous development and poor settling
- Profiles taken during low flow conditions
- Online tracking of sCOD required



Online Famine Detection

- Installed June 2023
- Online filtration system
  - Dead-end microfiltration
- Instrument calibration
  - sCOD to UV-254
- Instrument moved from Zone 4 to Zone 2
  - Increased sCOD concentration
- Future testing
  - Increase PE flows
  - Vary RAS flows



Metro's instrument solutions

Tracking Sludge Settleability

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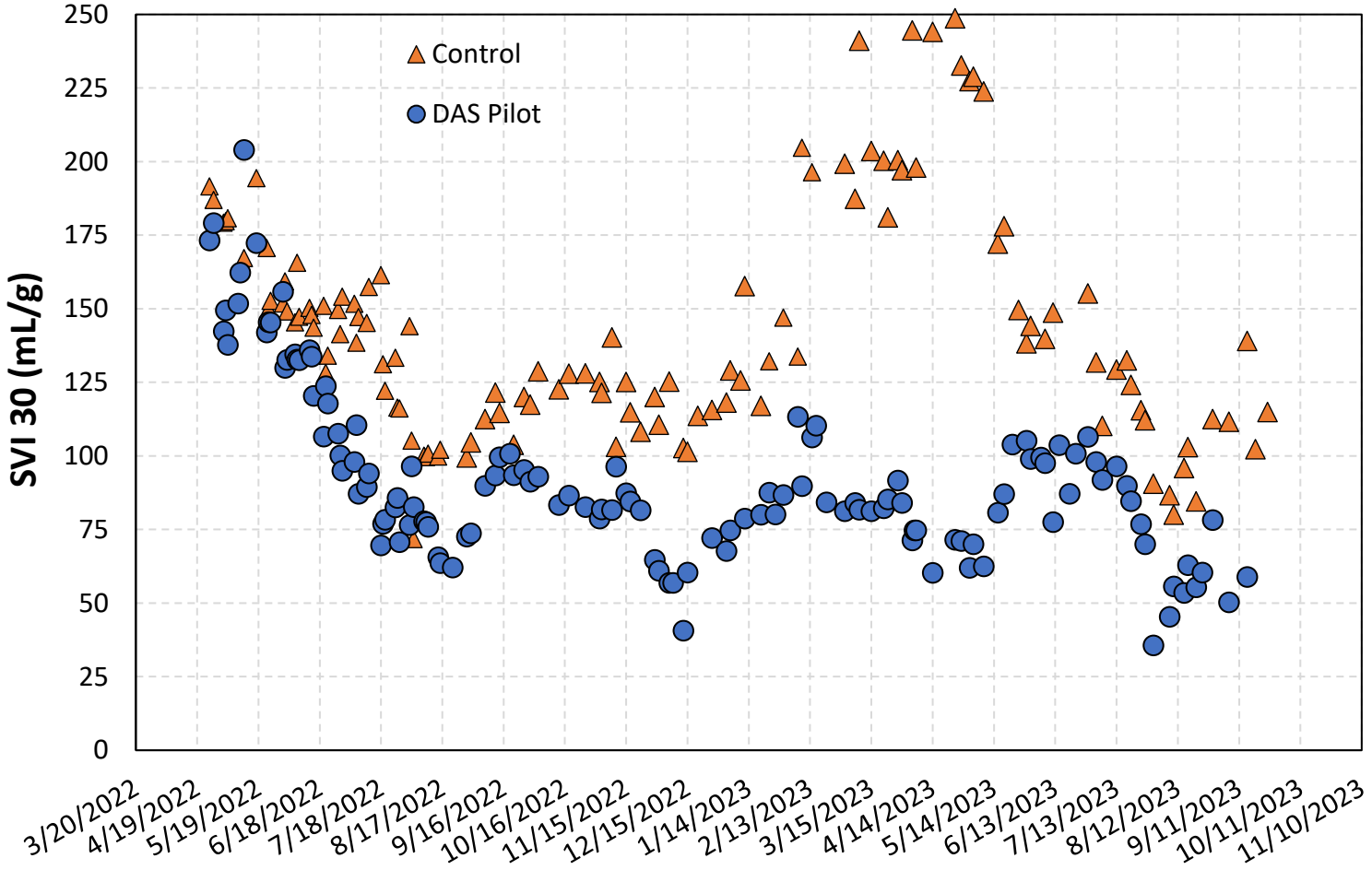
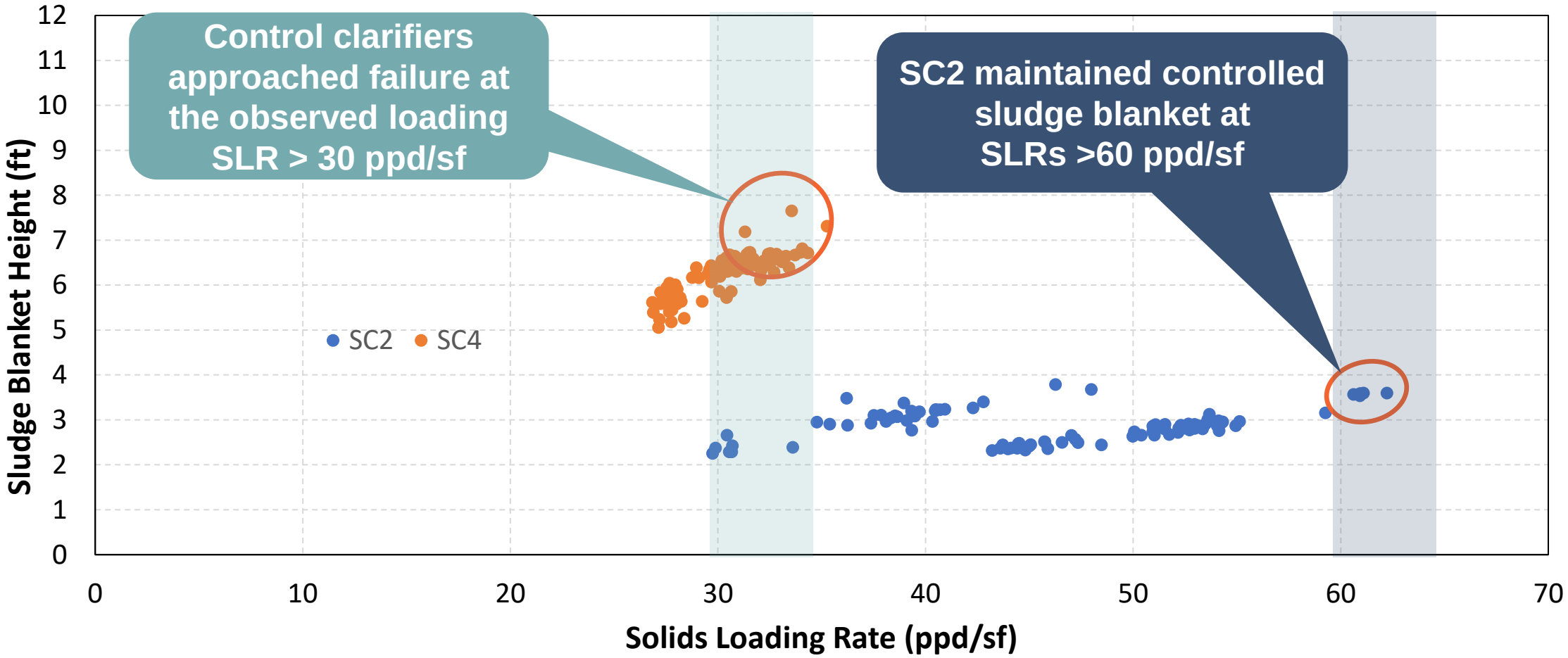
Sludge Settling Characteristics – DAS SVI

- Winter operation of DAS pilot accomplished
- February Temperature 57F/ 13.8C
- After 2.5 months of operation SVI30 ≤ 100 mg/L
- SVI30 lows ≈ 50 mL/g
- SVI30 and SVI5 are equal or nearly equal, is this this a function of granule fraction?



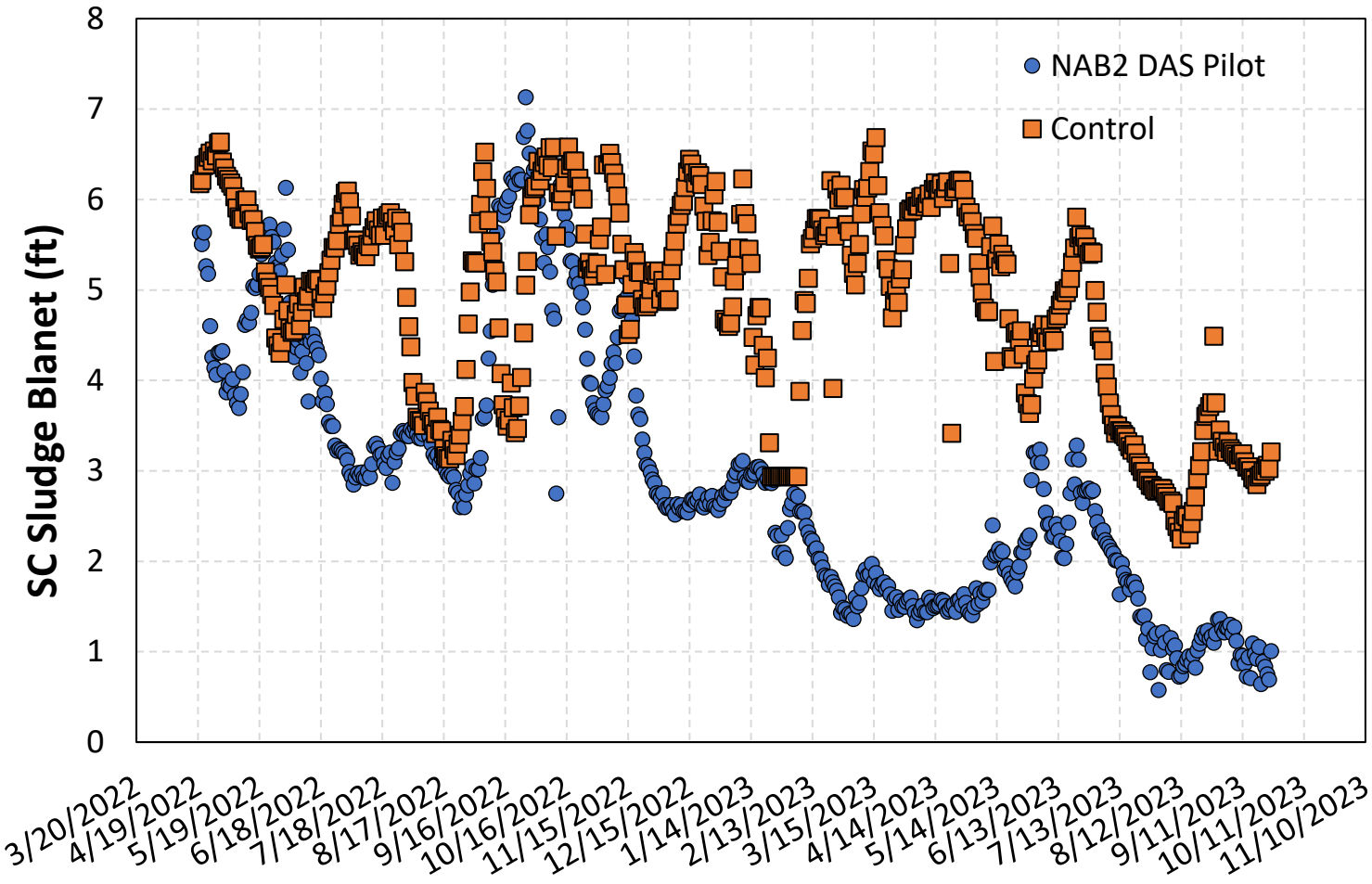
Clarifier Stress Testing



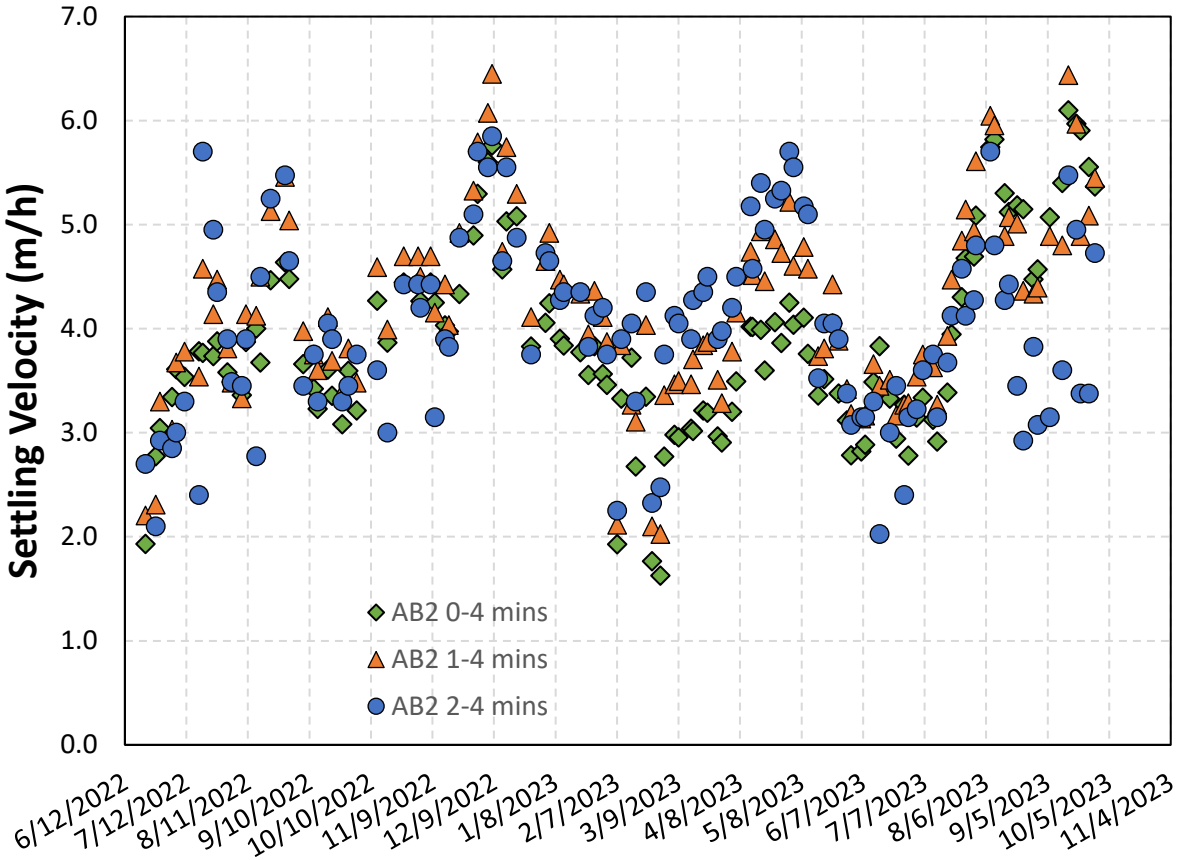
Sludge Settling Characteristics – DAS vs Control Sludge Blanket

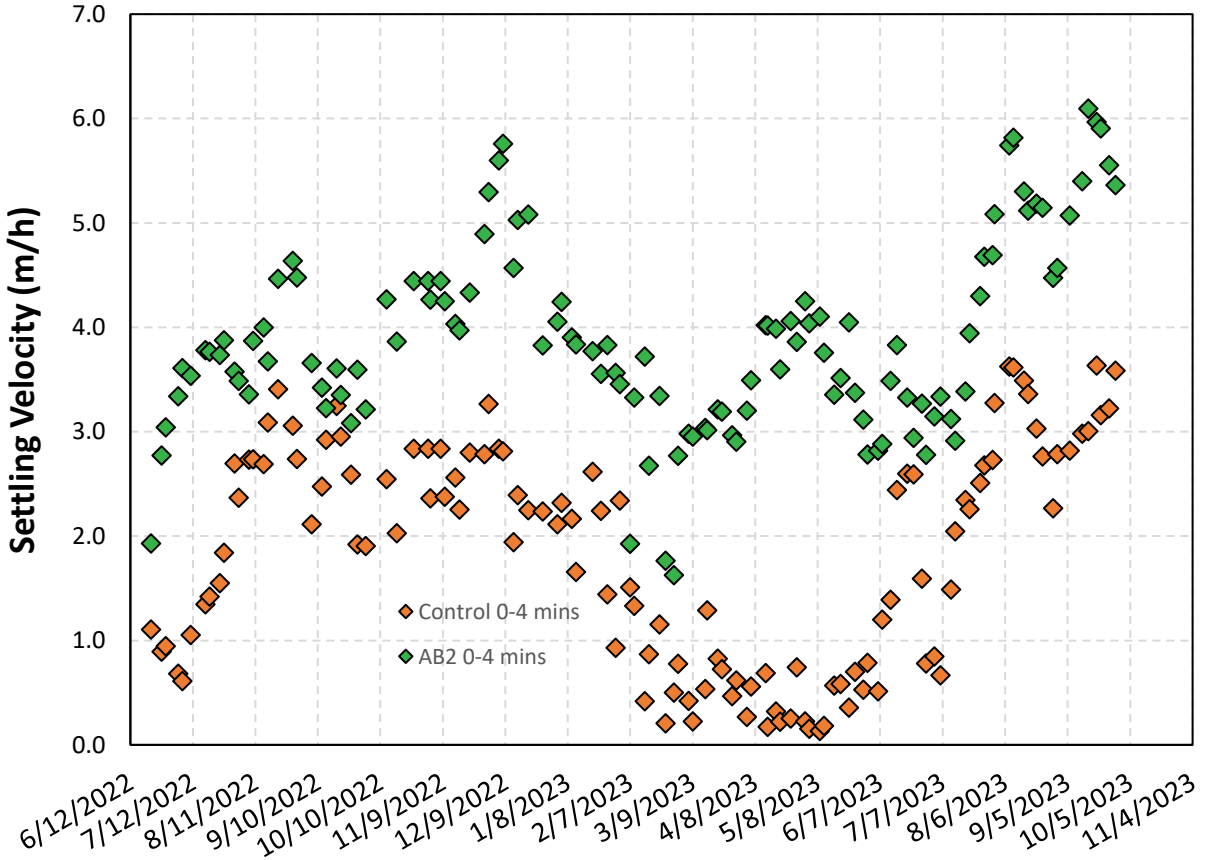
Factors to Consider

- Ras flow/SLR
- SVI/granule mass fraction



Sludge Settling Characteristics – Settling Velocities





Physical Selection – Particle Management via Hydrocyclone Operation

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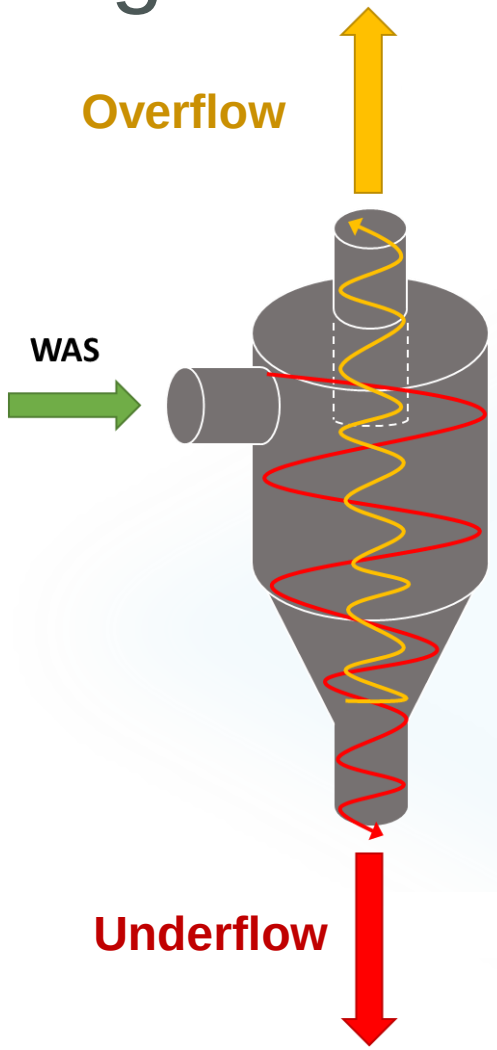
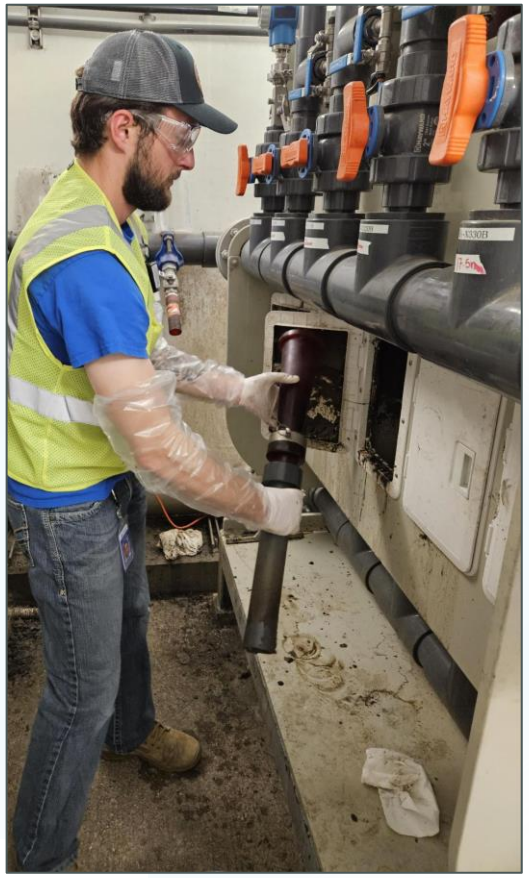
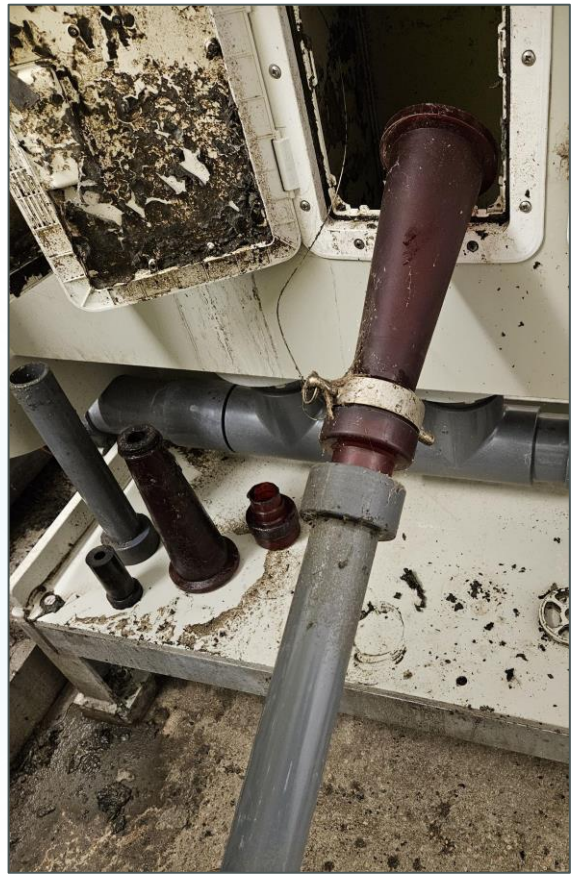
Hydrocyclone Management

- Feed (6 Hydrocyclones)
  - 44 gpm
  - 32–37 psig
- Hydraulic/mass split
  - Overflow (80%/65%)
  - Underflow (20%/35%)
- Controls
  - Hydrocyclone pressure
  - Nozzle size (18 mm)
- Solids retention time (SRT)
  - Floc SRT
  - Granule SRT







Will Peterson, Temporary Engineer

Physical Selection – Particle Separation

Physical sieving

- Labor intensive
- TSS test required
- Affordable

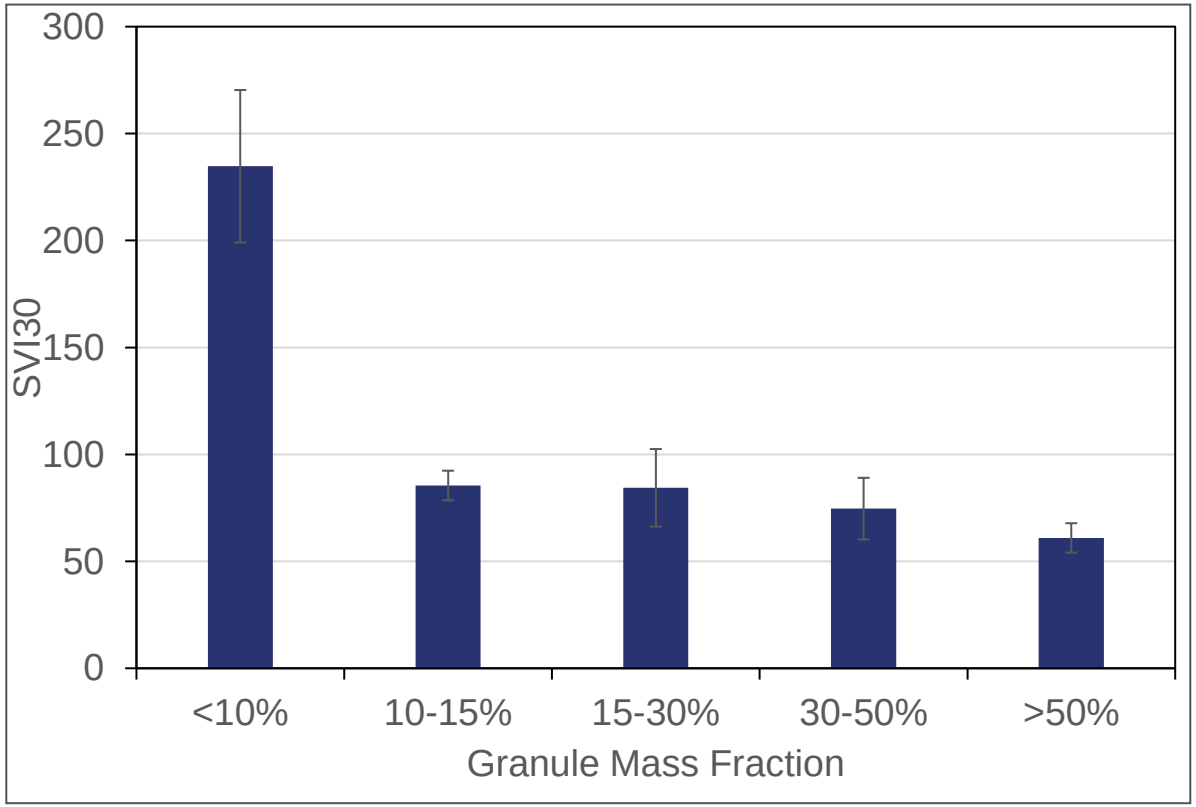
Particle size analyzer

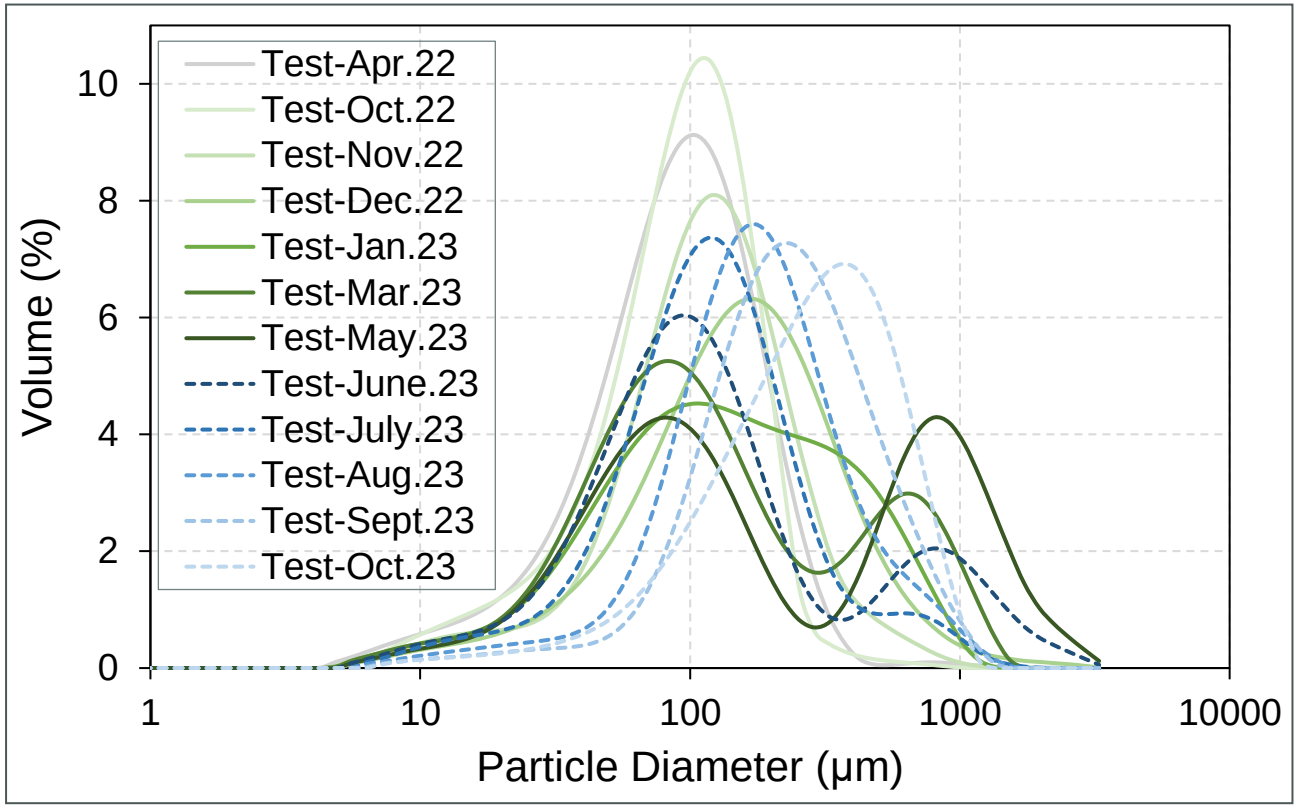
- Fast results
- More data
- Expensive

Particle size analyzer

- Floc passes through a laser chamber
- Light is scattered by the floc, an associated volume is calculated
- Volume-based cumulative distribution curve is developed

DAS Pilot – Granule Mass Fraction





- Once granule mass fraction >10%, substantial improvements in sludge volume index (SVI) are observed

- MLSS particle size distribution (PSD) shifts to bimodal distribution over time
- Loss of granules shifted PSD back to a normal distribution

Evaluating the Impacts of Particle Size on Settleability

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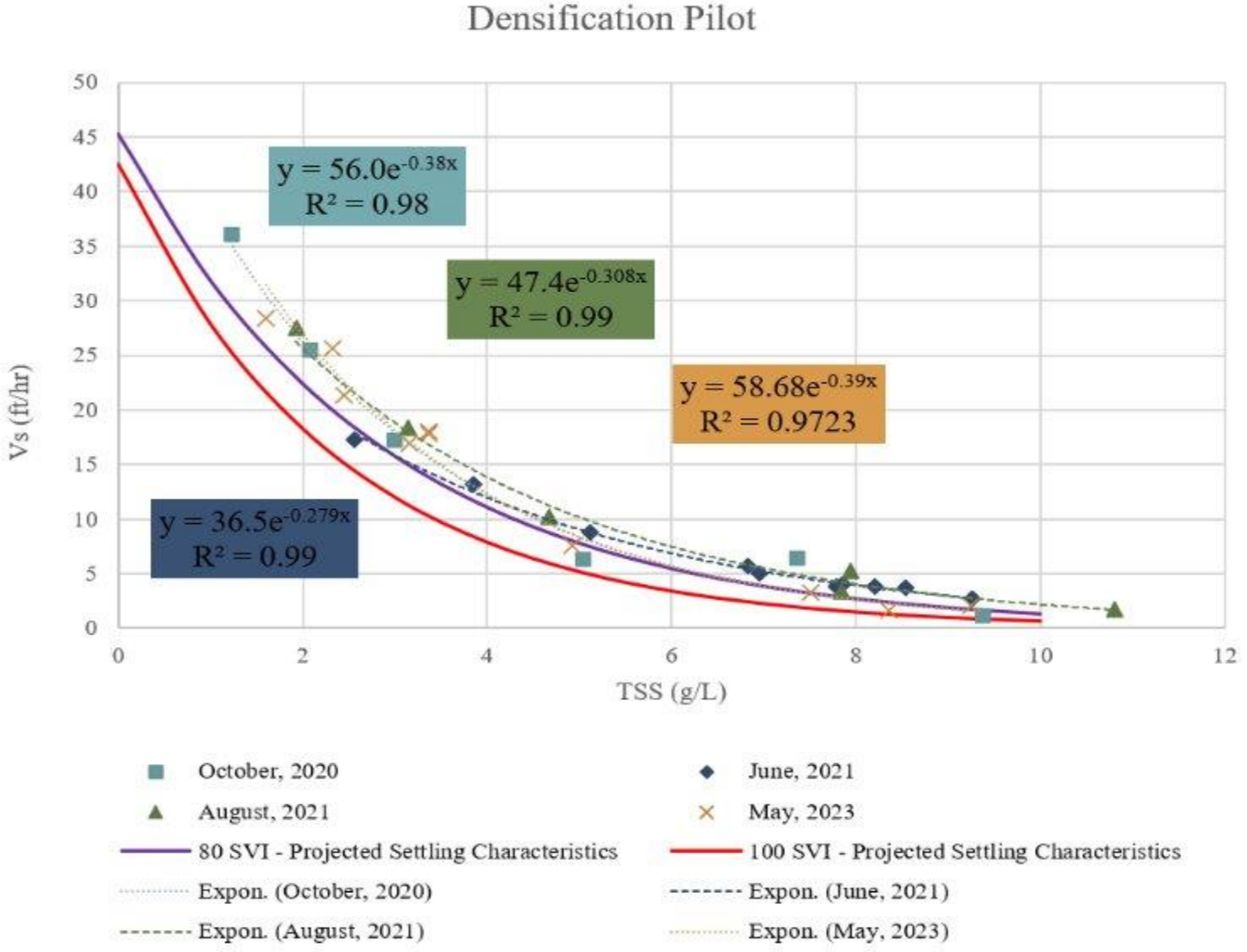
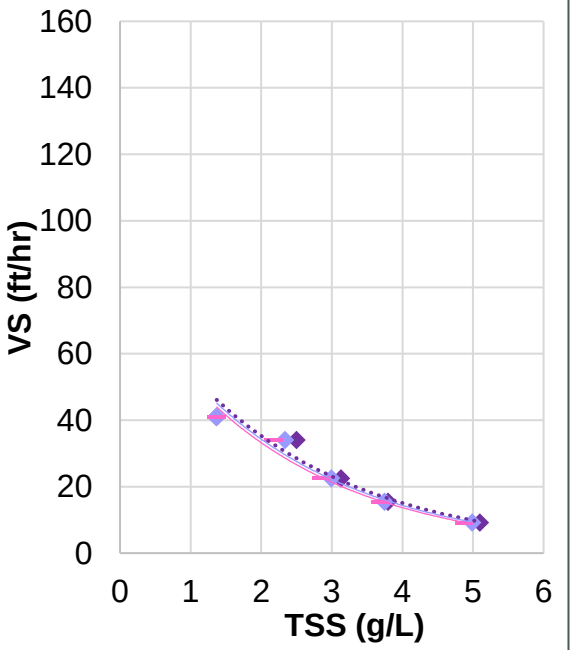
Field Testing: MLSS and RAS Settling Properties



Settling Properties of Biomass Fractions

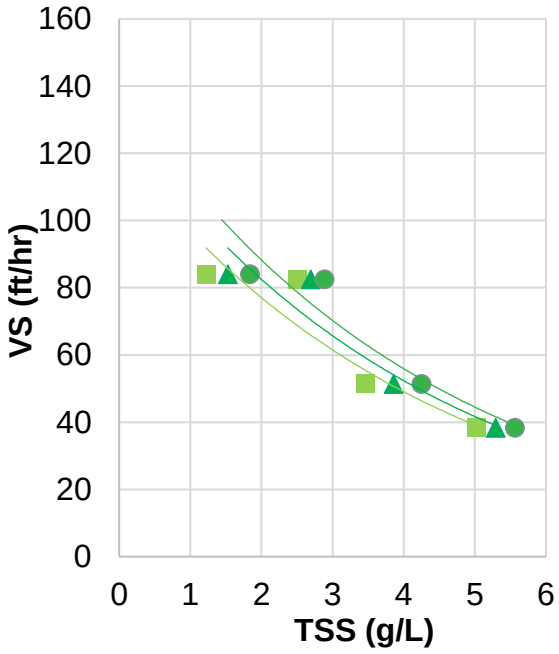
Biomass Fractions: Distinctly Different Settling



<200 µm

$y = 81.886e^{-0.435x}$

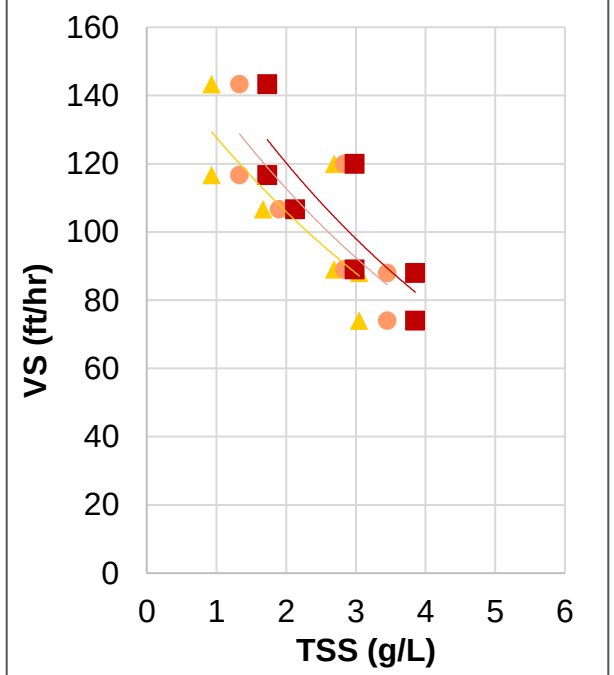
$R^2 = 0.9519$



200–600 µm

$y = 130.04e^{-0.228x}$

$R^2 = 0.8667$



>600 µm

$y = 167.66e^{-0.198x}$

$R^2 = 0.6439$

Settling Testing Insights

Key Takeaways

- Larger particles are associated with improved settling (velocity and compaction).
- While SVI is a great proxy for settleability, column testing offers unique insights into the settling characteristics of different particle fractions.

Knowledge Gaps

- What is the impact of PSD on effluent quality (i.e., TSS)?
- What is the potential for predictive settling using other performance metrics (e.g., PSD, zeta-potential/charge, filament count)?

Evaluating Floc and Granule Kinetics through Activity Testing

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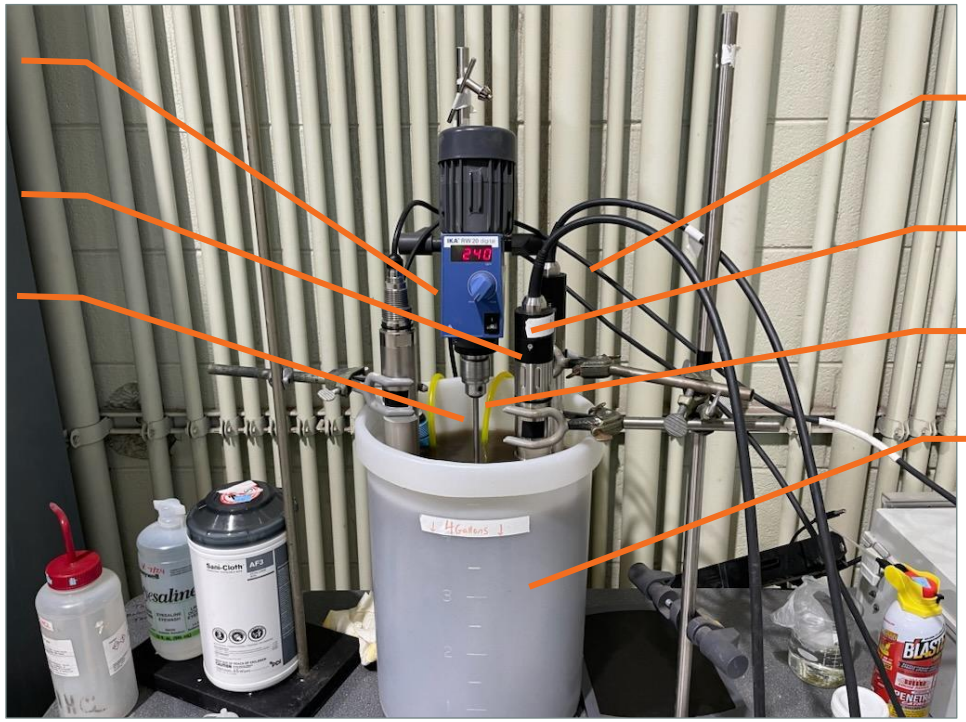
Activity Test Setup

NO3 Analyzer

Overhead Mixer

pH Analyzer



Dissolved Oxygen (DO) Analyzer

NH4 Analyzer

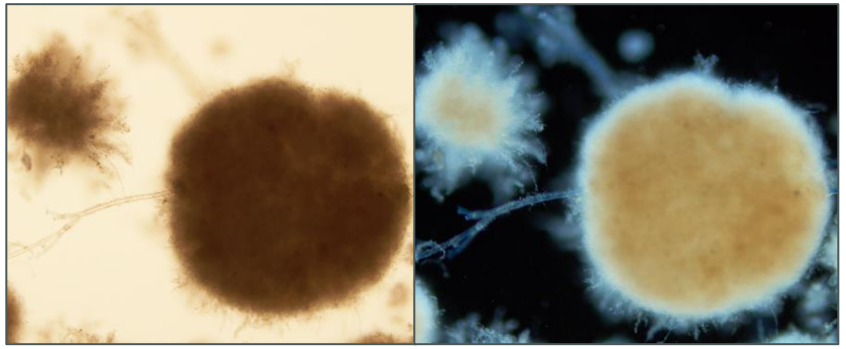
O2 Diffuser

4-Gallon Reactor

Other Materials

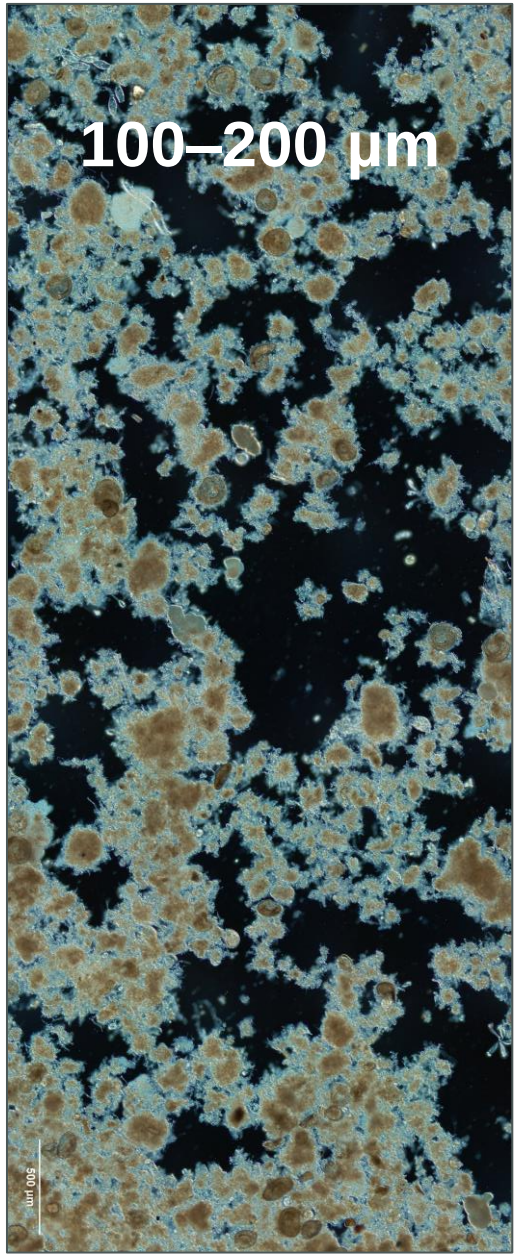
- Stock NO3, COD, and NH4 solutions
- Prefilters and 0.45-µm filters for sampling
- Hach TNT kits for measuring analyte concentrations
- Air compressor for O2 diffusers

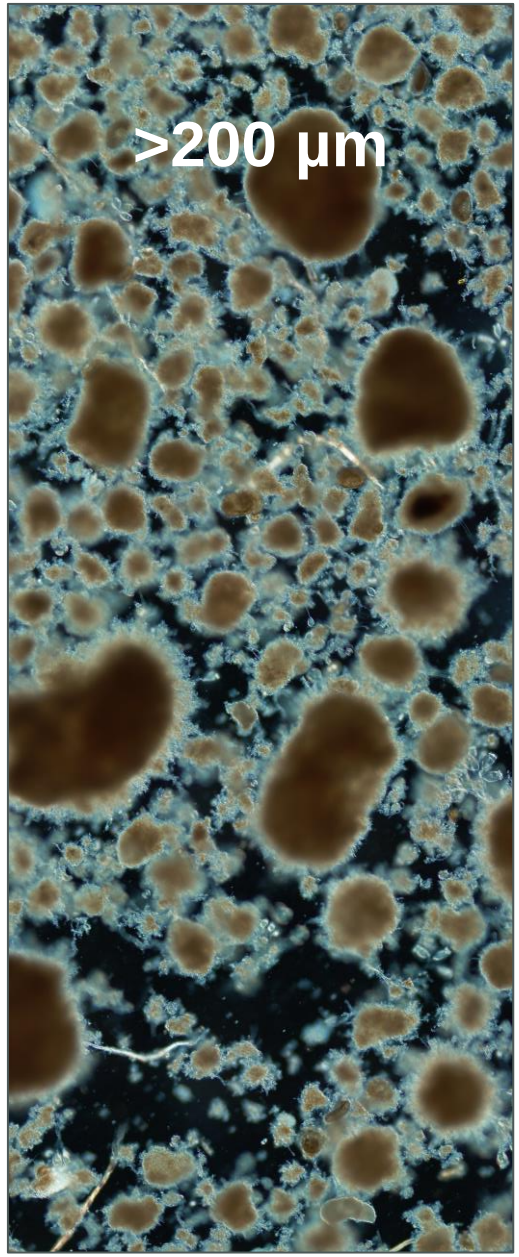
New Particle Categories?



Bright Field Dark Field

Differential Interference Contrast

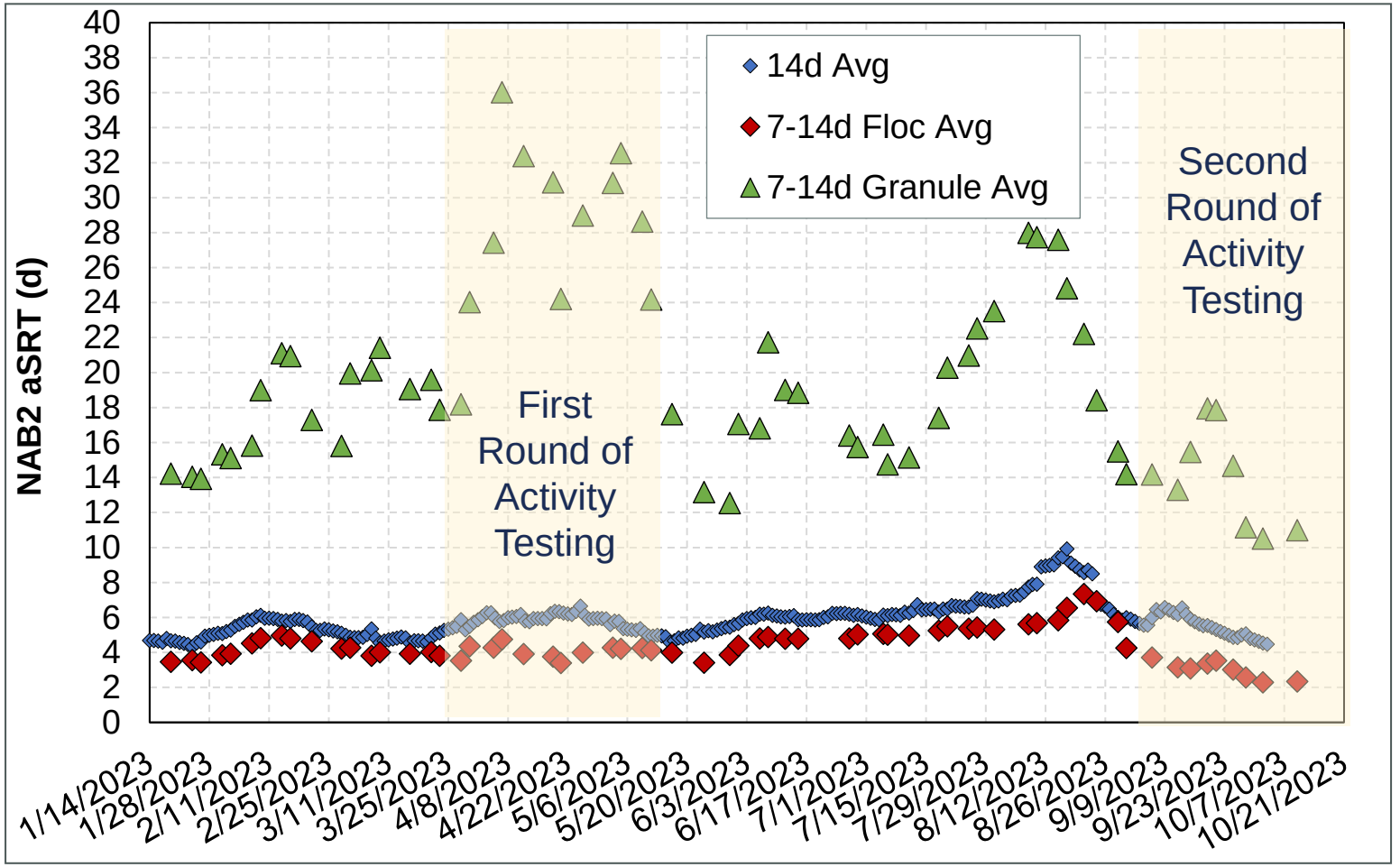




Reducing aSRT and Impacts on Particle Kinetics

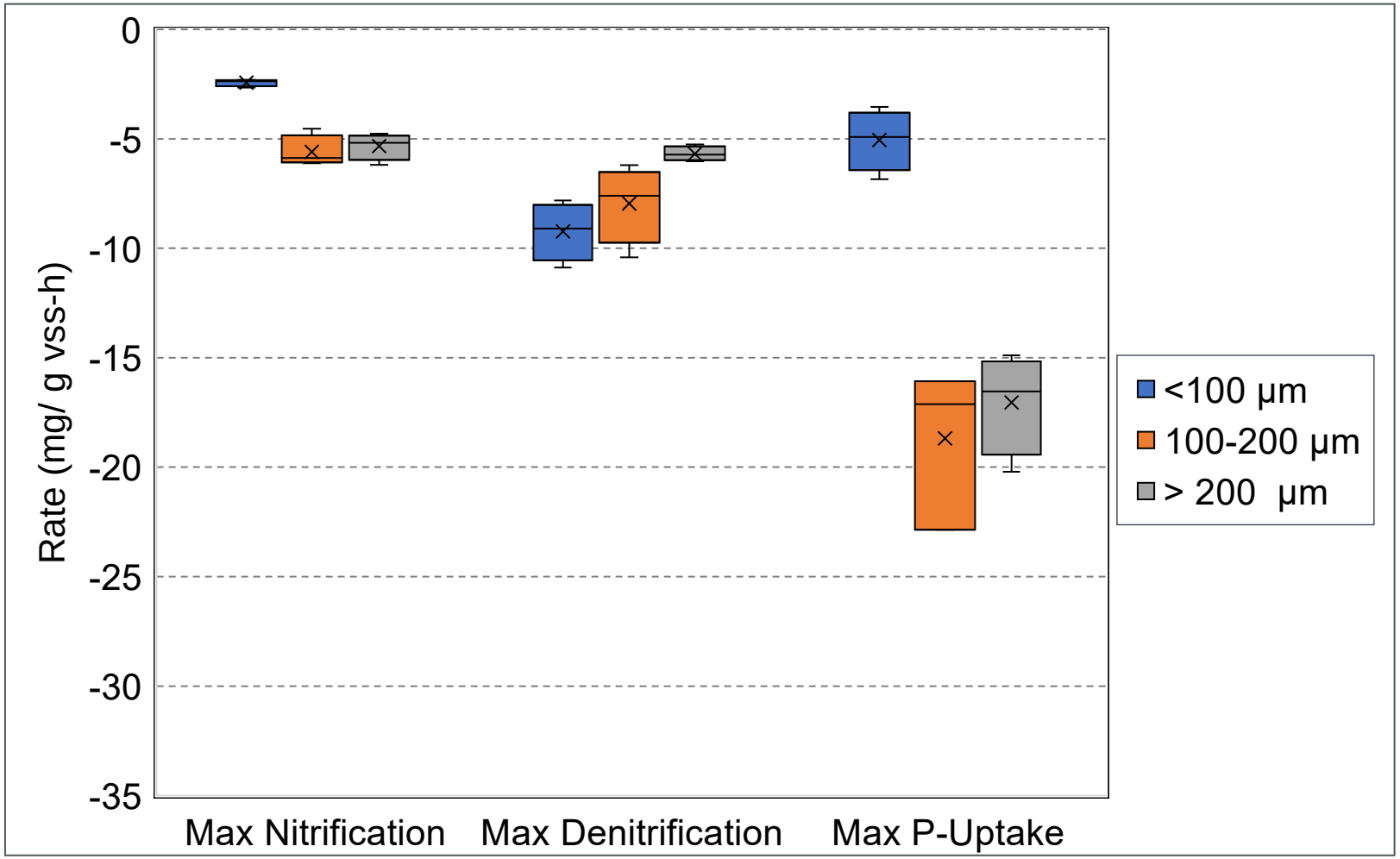
Time Frame	Granule Fraction (%)	Particle 90th Percentile (µm)
Apr–May 2023	42	1,082
Sep–Oct 2023	59	572

Time Frame	7d Avg aSRT (d)	Floc aSRT (d)	Granule aSRT (d)
Apr–May 2023	6.1	4.08	28.5
Sep–Oct 2023	5.4	2.91	14.0



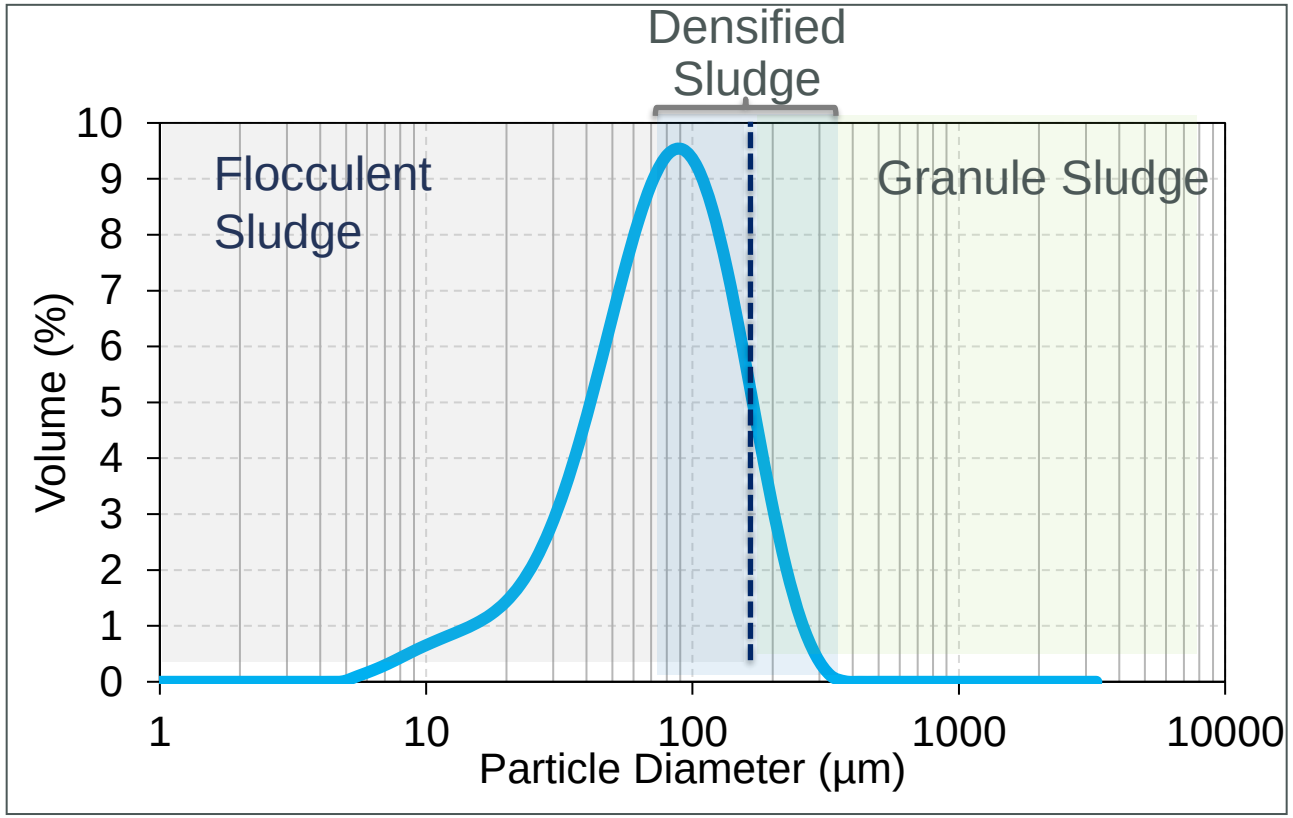
Reducing aSRT and Impacts on Particle Kinetics

- Low floc aSRT forced ammonia-oxidizing bacteria community onto granules
  - Floc aSRT: 2.91
  - Granule aSRT: 14.0
- Pseudo granules and granules obtained similar nitrification rate as floc
- A physical selector has the ability to control particle kinetics



Physical Selection and Particle Kinetic Takeaways

- The granule mass fraction makes a cyclone selection process dynamic
  - Number of online cyclones will vary
- The nitrification/denitrification kinetics of larger particles are less favorable compared to floc
  - Recent activity test showed highest nutrient removal rates in the 100–200 µm range
- Combined wasting approaches may provide PSD control



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Greetings from Technology and Innovation

Thank you.

Rudy Maltos
RMaltos@MetroWaterRecovery.com

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- Other presentations

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Making Waves

Making waves: Riding the densification wave from current understanding to advancement

Kayla Bauhs [a 1], Maxwell Armenta [a 1], Rudy Maltos [b], Belinda Sturm [c], Pusker Regmi [a]

Take-Aways for Other Utilities in the Rocky Mountain Region

- Track data and costs of optimization – justification for decision makers / influencers
- Pilot new technologies to save money and lower future risk
  - Plan funds in capital improvement budget
- Consider compiling a voluntary peer expert panel to help assess innovative technologies for your facility
- Take advantage of knowledge and resource sharing among facilities
- Visit ongoing pilots at other facilities
  - IWT organizing several tours in Colorado throughout year!

Rudy leading university students on a tour of the RWHTF