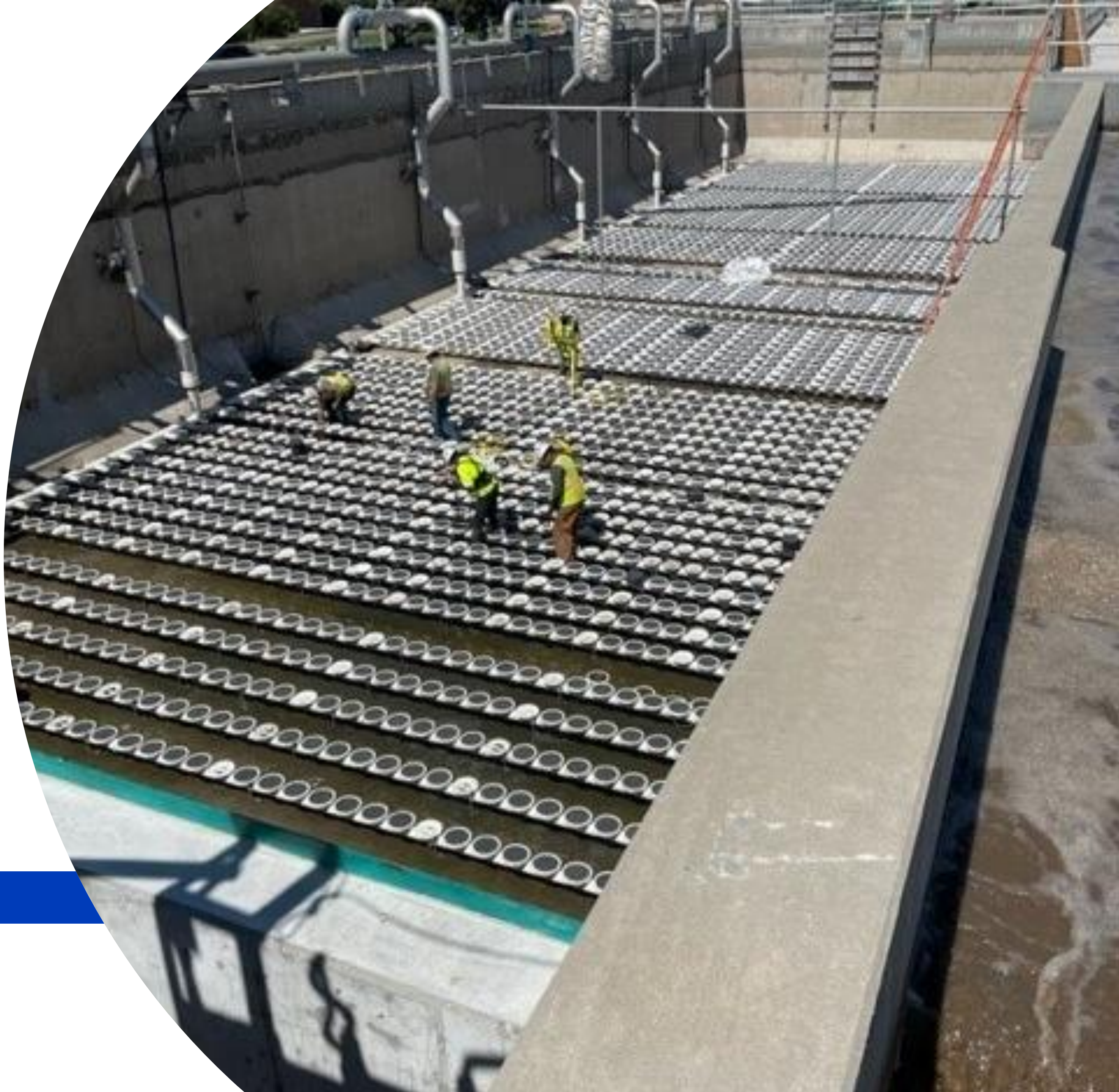
Minnesota R2E Group Meeting

How Low Can You Go? Demystifying Low DO/Suboxic Nutrient Removal

Michelle Young, Ph.D.

Innovation Lead – Low DO/SNR Operations

January 18, 2024



Safety Moment

Onsite Safety During New Construction

- New faces on site that are unfamiliar with the facility and operations
- Help new faces
  - » Understand operations and safety rules
  - » Stay in the right paths
  - » Provide feedback if you have concerns
- Safety should be first in everything we do

Learning Objectives

- Understand the role of low dissolved oxygen (DO) on activated sludge and nutrient removal
- Identify the impacts of low DO on process and energy efficiency
- Identify ways to implement low DO in existing WWRFs

01

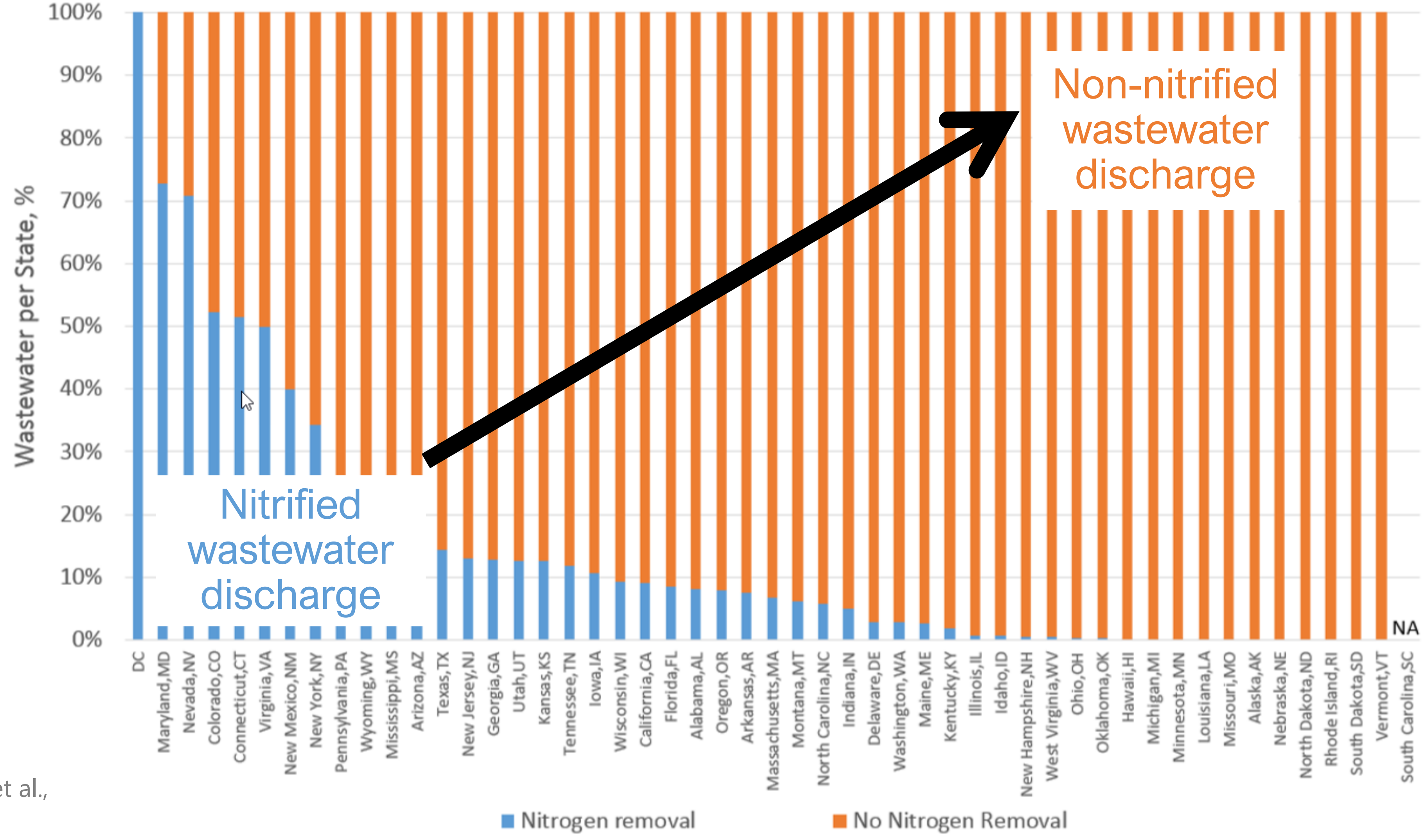
The Nutrients Problem and Suboxic Nutrient Removal

Optimizing Aeration will help meet DEP's Goals

- GHG emission reductions from 2006 baseline:
  - »40% by 2025
  - »50% by 2030
  - »80% by 2050
- Energy Neutral WRRFs by 2050
- Zero Waste by 2030
- 100 MW of solar PV by 2025

A growing number of WRRFs In the U.S. are required to nitrify

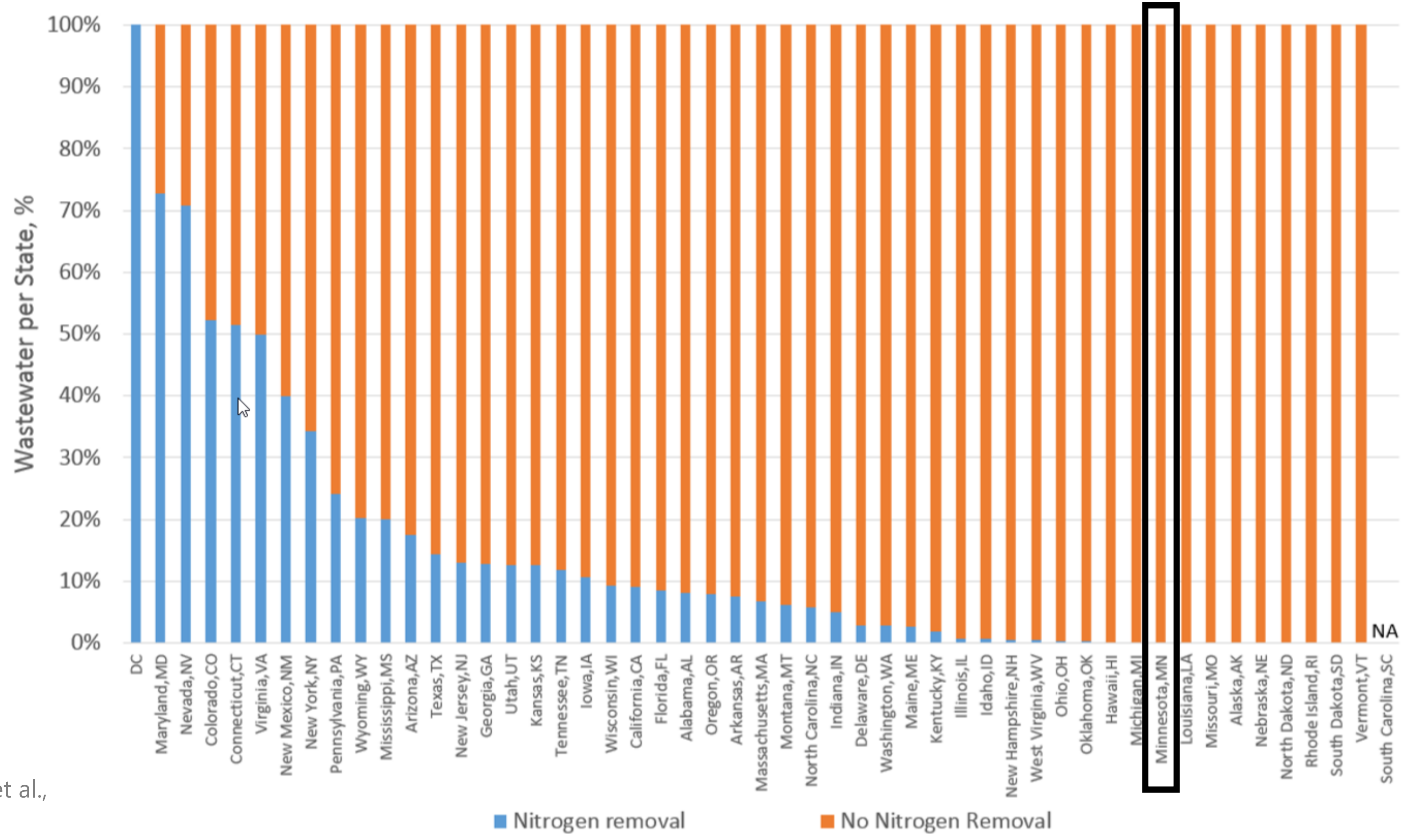
~40% of US water resource recovery facilities (WRRFs) are required to remove ammonia.



Sources: Gu et al., 2017; Rauch-Williams et al., 2018; Rauch-Williams et al., 2019

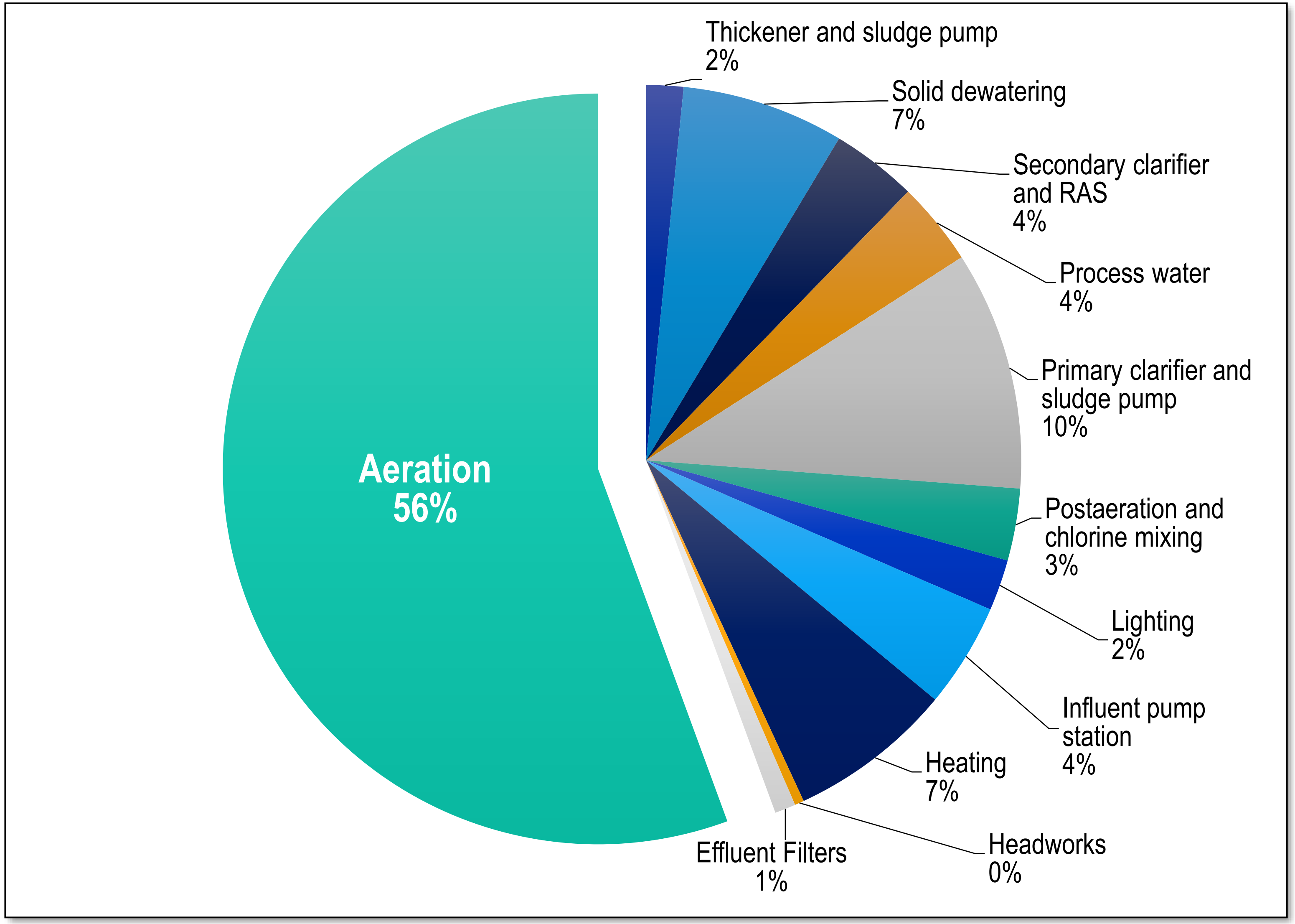
A growing number of WRRFs In the U.S. are required to nitrify

MN limits:
- MPCA considering N limits
- TP limits as low as 0.06 mg/L



Sources: Gu et al., 2017; Rauch-Williams et al., 2018; Rauch-Williams et al., 2019

While important for society, WRRFs are a significant energy consumer

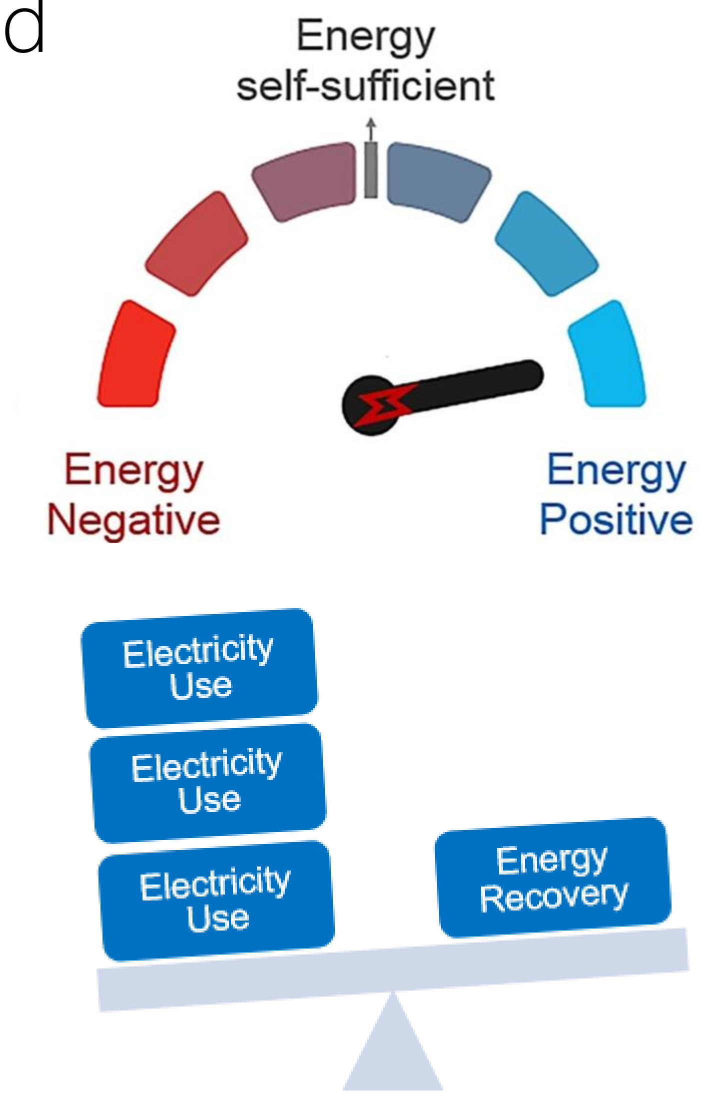


*Municipal water resource reclamation facilities (WRRFs) account for **3-4%** of US energy consumption*

Source: Metcalf and Eddy, 2003; Shen et al., 2015

Improving energy efficiency is a tremendous potential for reducing national energy demand

- DOE EERE funding opportunities to develop technology innovations that enable WRRFs to become **net energy positive**
- Based on typical wastewater characteristics:
  - » 10 times the amount of energy in wastewater than is required to treat it
- A key step: look at optimizing the most energy intensive process



U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

What is suboxic nutrient removal (SNR) and low dissolved oxygen (DO) operations?

	DO Conc., mg/L
Conventional Aeration	1.5 – 4.0
Optimized Aeration	1.5 – 2.5
Low DO	0.7 – 1.5
Suboxic	0.2 – 0.7

DOE Project LOW DO/SNR Operations objectives

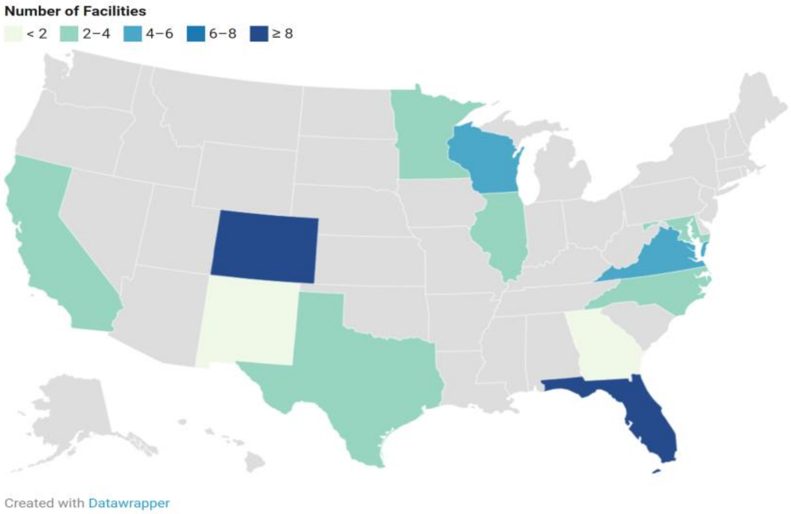
1 Scientific Process Understanding

1. Operational strategies for microbial acclimation
2. Kinetic and process limitations
3. Microbial populations and metabolic functions
4. Aeration control specifications
5. Process stability and resilience
6. Sludge settleability
7. Biological phosphorus removal
8. Greenhouse gas emissions
9. Organic carbon demand

2 Engineering Design & Operational Boundary Conditions

1. Modeling parameters
2. Oxygen transfer efficiencies
3. Design sludge volume indices (SVI)
4. Minimum sludge residence times (SRTs)
5. Volumetric loading rates
6. Minimum hydraulic residence time
7. SOPs for process transitioning/adaptation
8. Mixing
9. Aeration control system performance specifications
10. Suitable sensor technology

DOE project objectives met through collaboration and multiple efforts

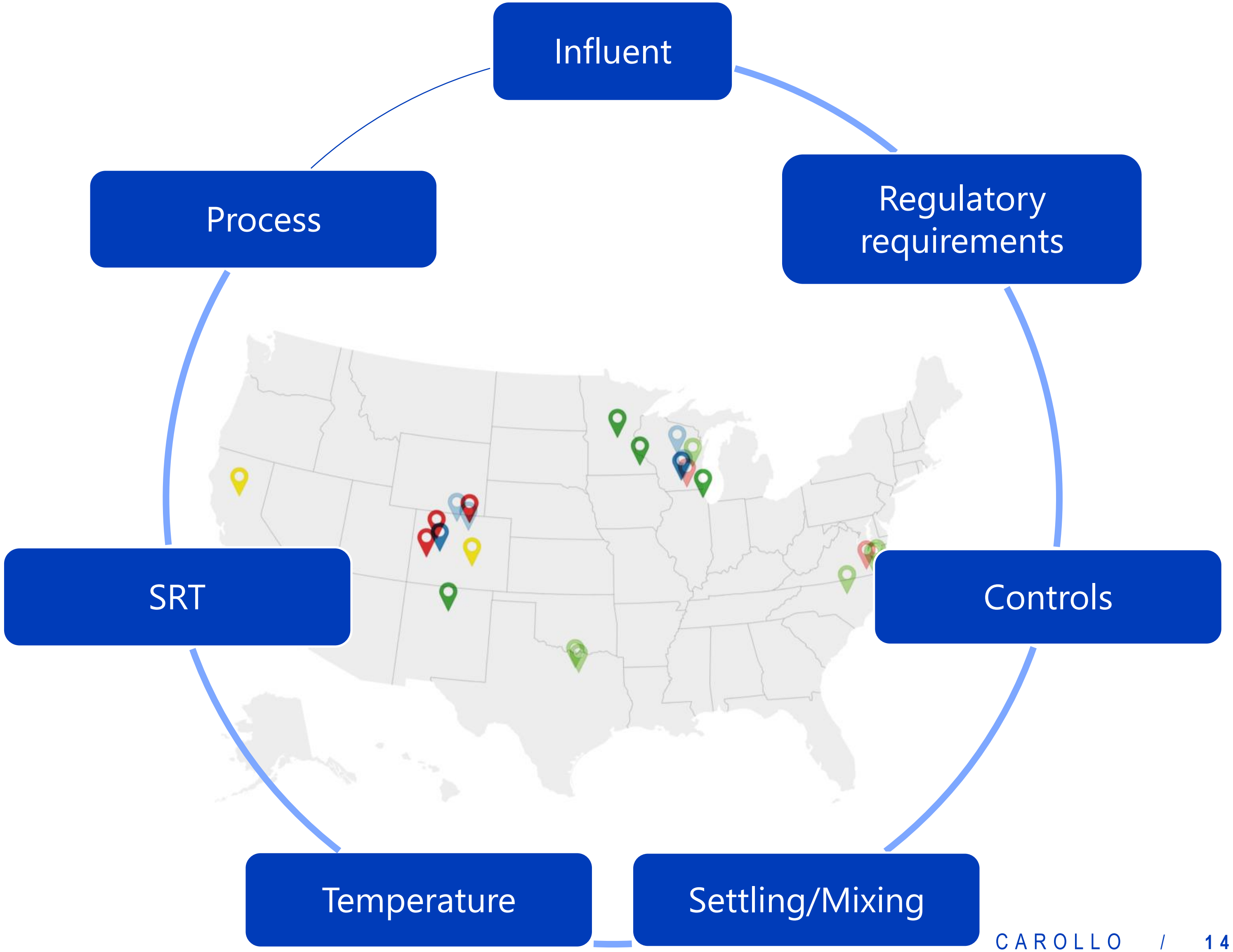


- **Demonstration Testing**
  - » Pilot (Hampton Roads Sanitation District)
  - » Full-scale (Los Angeles County Sanitation District, Pomona)
- **Three Workshops (Fall 2022)**
  - » Knowns and Unknowns
  - » Case Studies
  - » Design Concepts
- **National Survey**
  - » 24 participating utilities
  - » Data evaluation and comparisons

02 National Survey and Workshop Results

Operational and controls trends in low DO/SNR operations

- Understand low DO/suboxic treatment schemes in the U.S.
- Various aeration control approaches in use for operation



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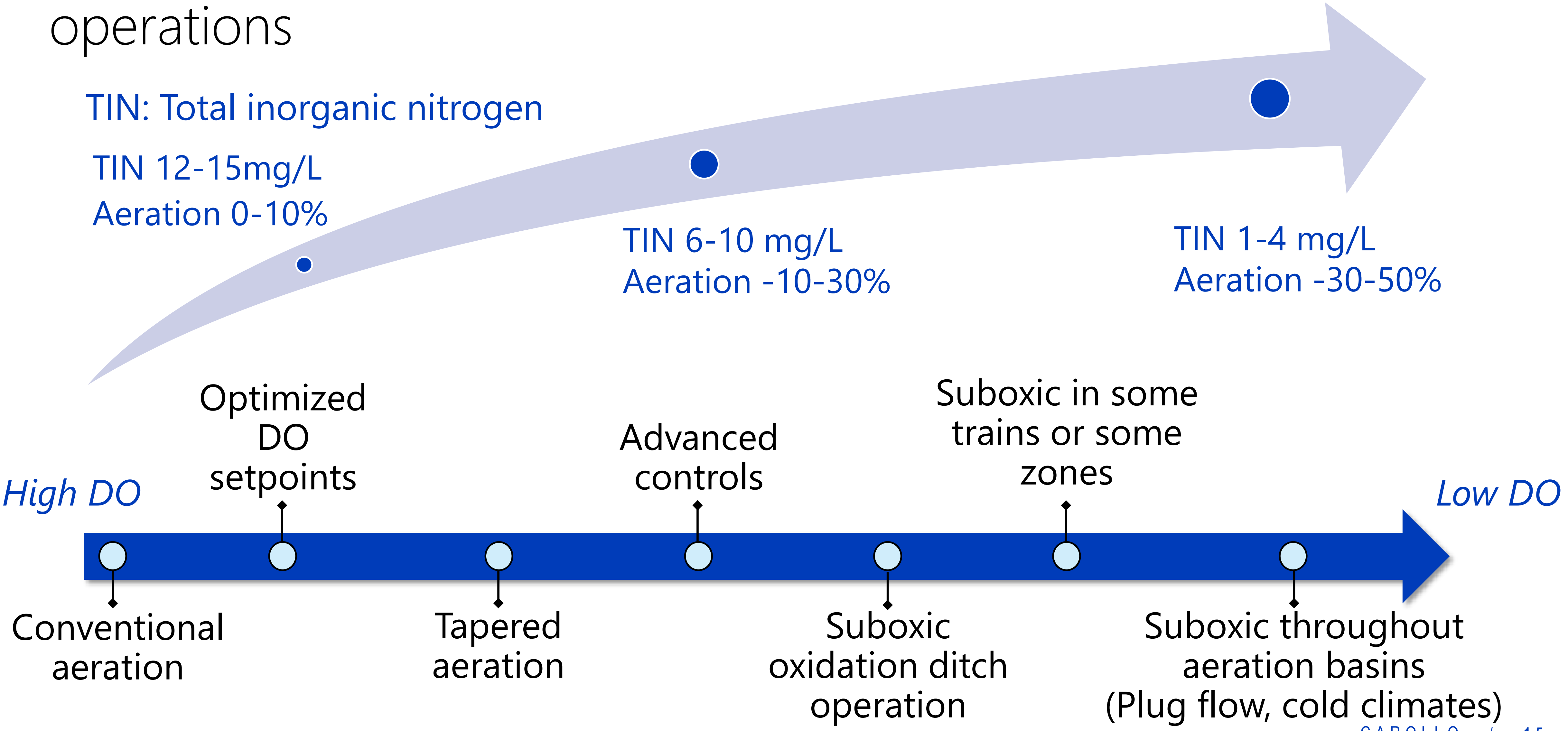
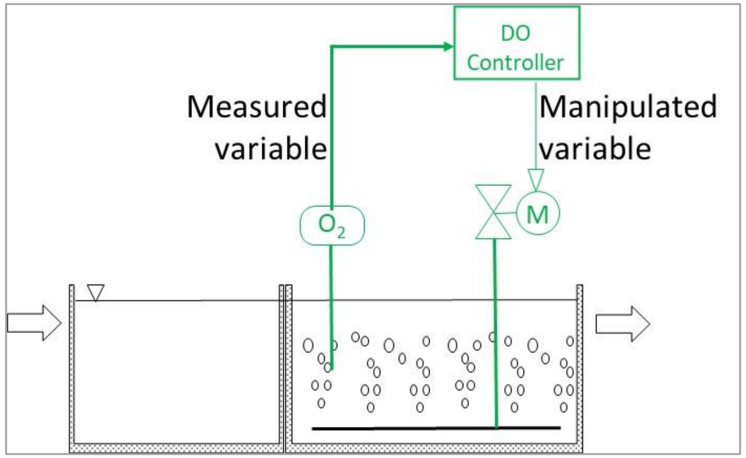
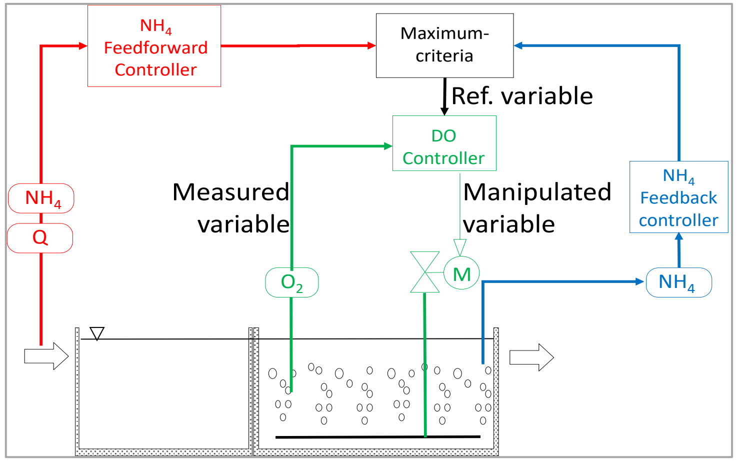


Various aeration control approaches in use for SNR operations

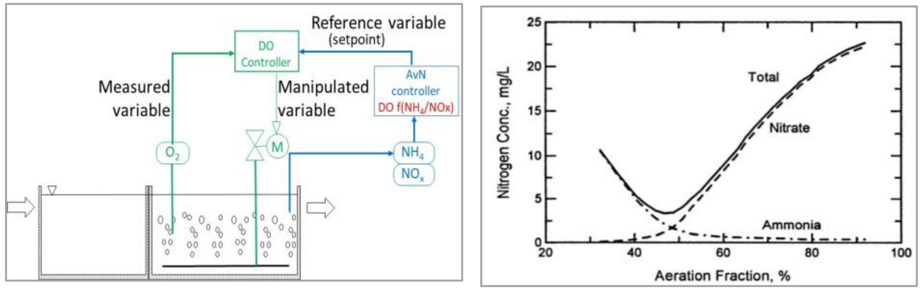
DO Setpoint Control



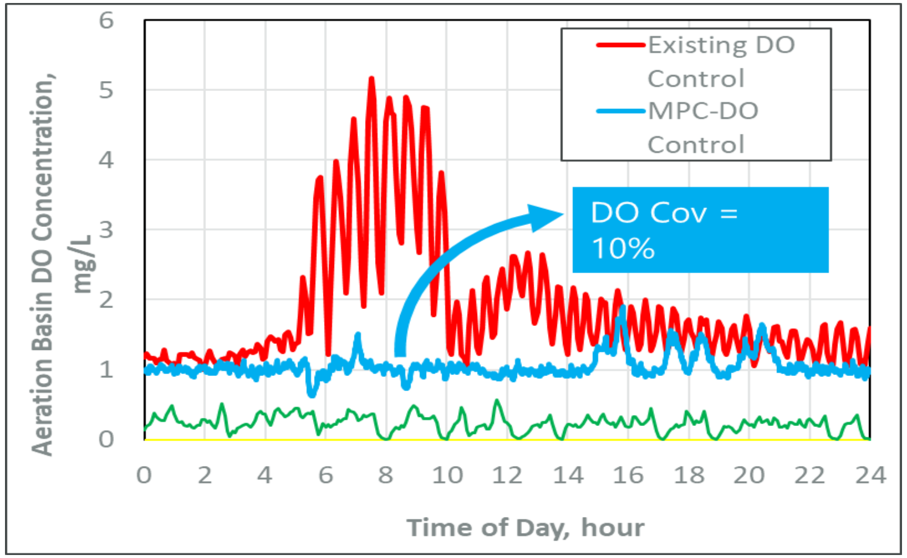
Ammonia Based Aeration Control (ABAC)



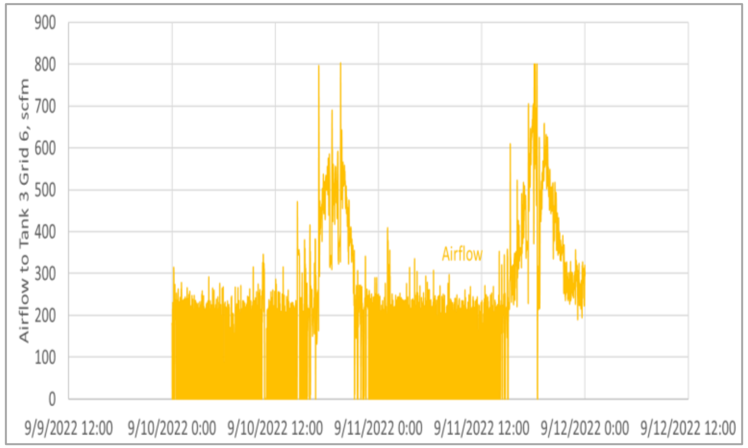
AvN Control



Model Predictive Aeration Control (MPAC)



Continuous vs. Intermittent Aeration



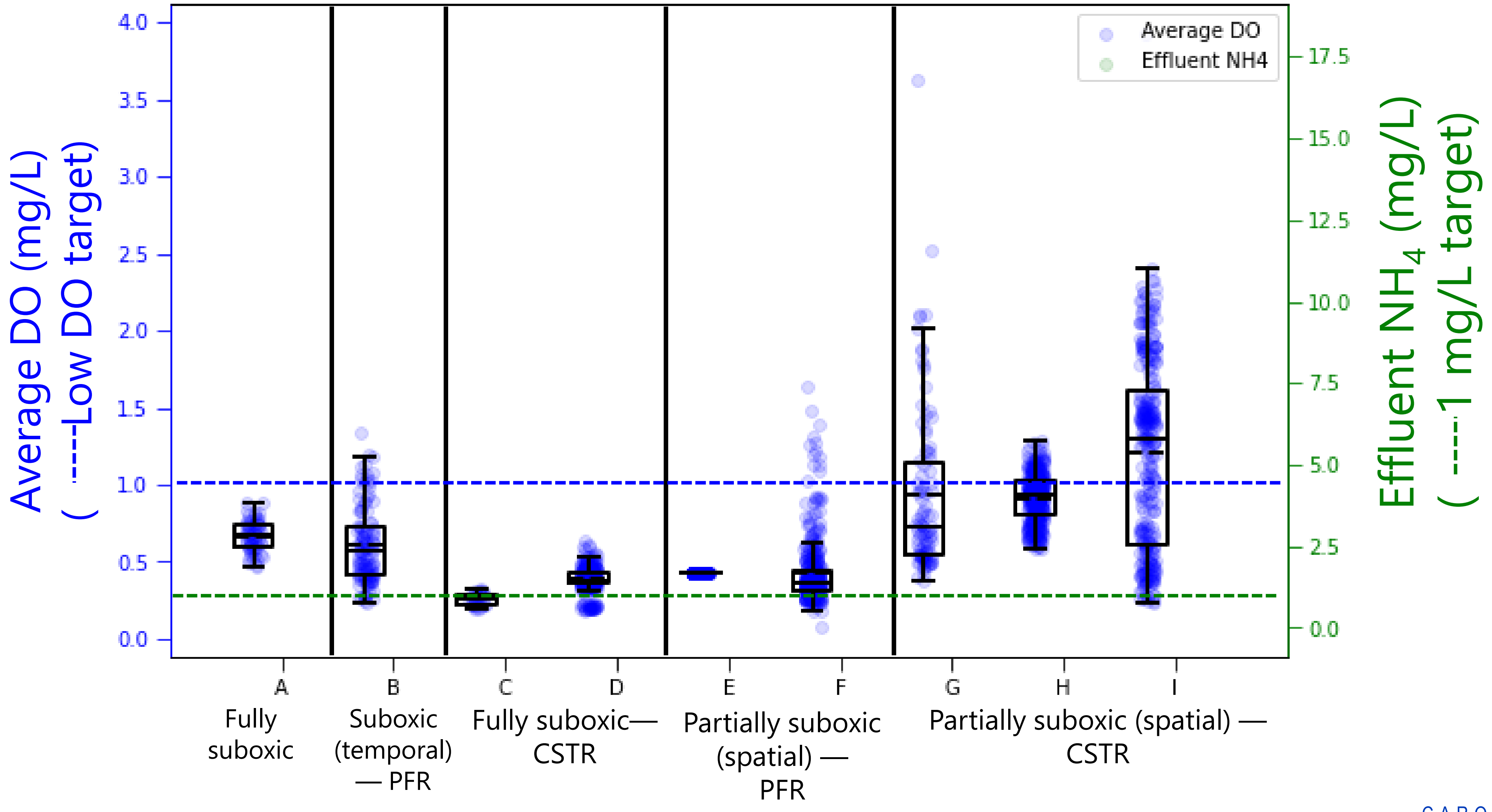
All approaches can result in low TIN effluent quality

Case studies evaluated

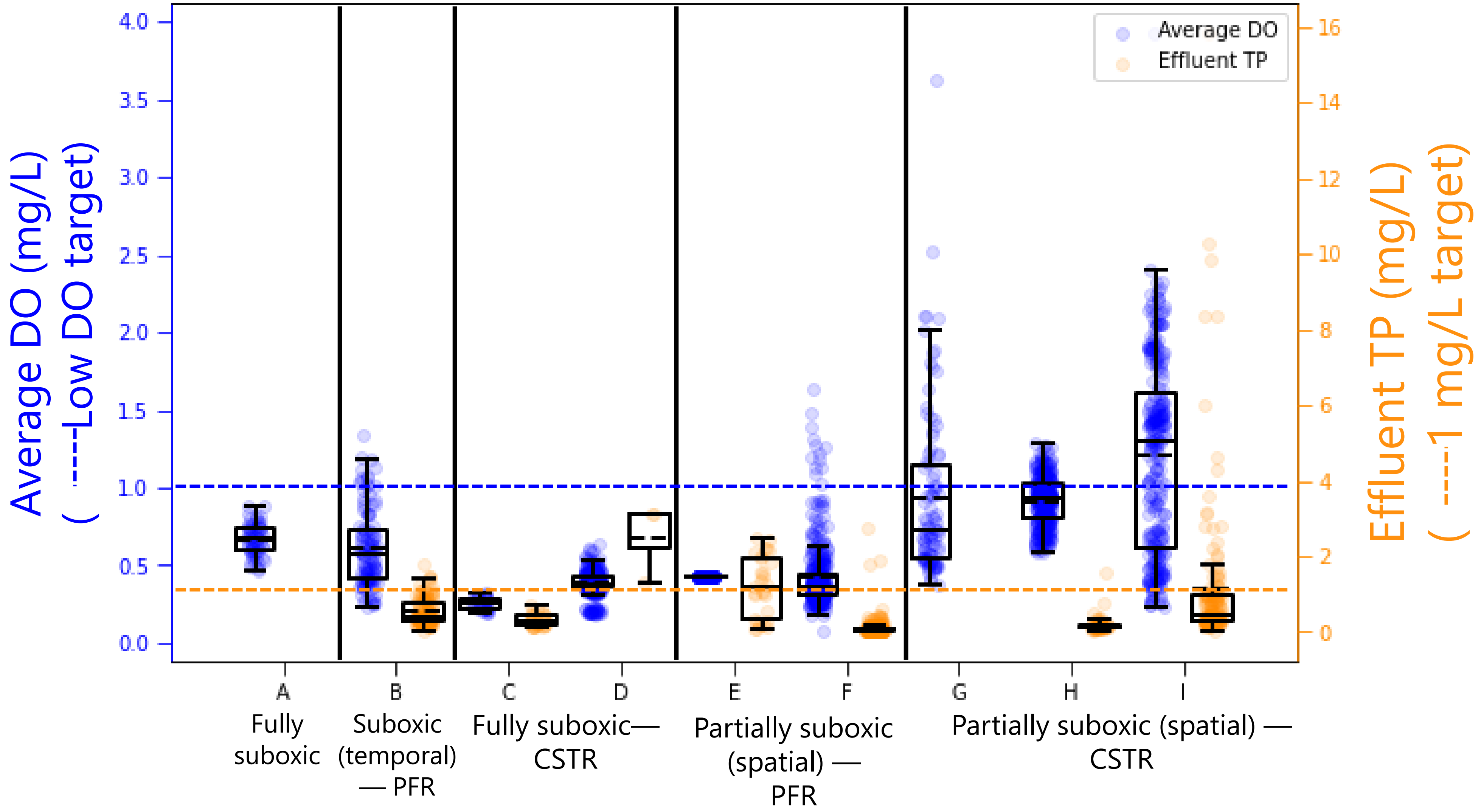
Facilities	BNR Process	Fully or Partially Suboxic	CSTR or Plug Flow (PFR)	Data Duration	Controls Scheme	Discharge limits
A	MLE	Fully suboxic	PFR	2 months	MPAC	NH_4
B	A2O	Temporally partially suboxic	CSTR	4 months	AvN	TIN, TP
C	Oxidation ditch	Fully suboxic	CSTR	6 months	DO setpoint	TIN, TP
D	Oxidation ditch	Fully suboxic	CSTR	11 months	DO setpoint	TIN, TP
E	A2O	Spatially partially suboxic	PFR	1 year	ABAC	NH_4
F	A2O	Spatially partially suboxic	PFR	1 year	Manual	TP, NH_4
G	Oxidation ditch	Spatially partially suboxic	CSTR	2 years	DO setpoint	N/A
H	Oxidation ditch	Spatially partially suboxic	CSTR	1 year	DO setpoint	NH_4
I	Oxidation ditch	Spatially partially suboxic	CSTR	5 years	DO setpoint	TN, TP

TIN = Total inorganic nitrogen, TN = Total nitrogen, TP = Total phosphorus

Plants achieve nitrification at SNR and low DO levels



SNR/Low DO operations also perform bio-P removal



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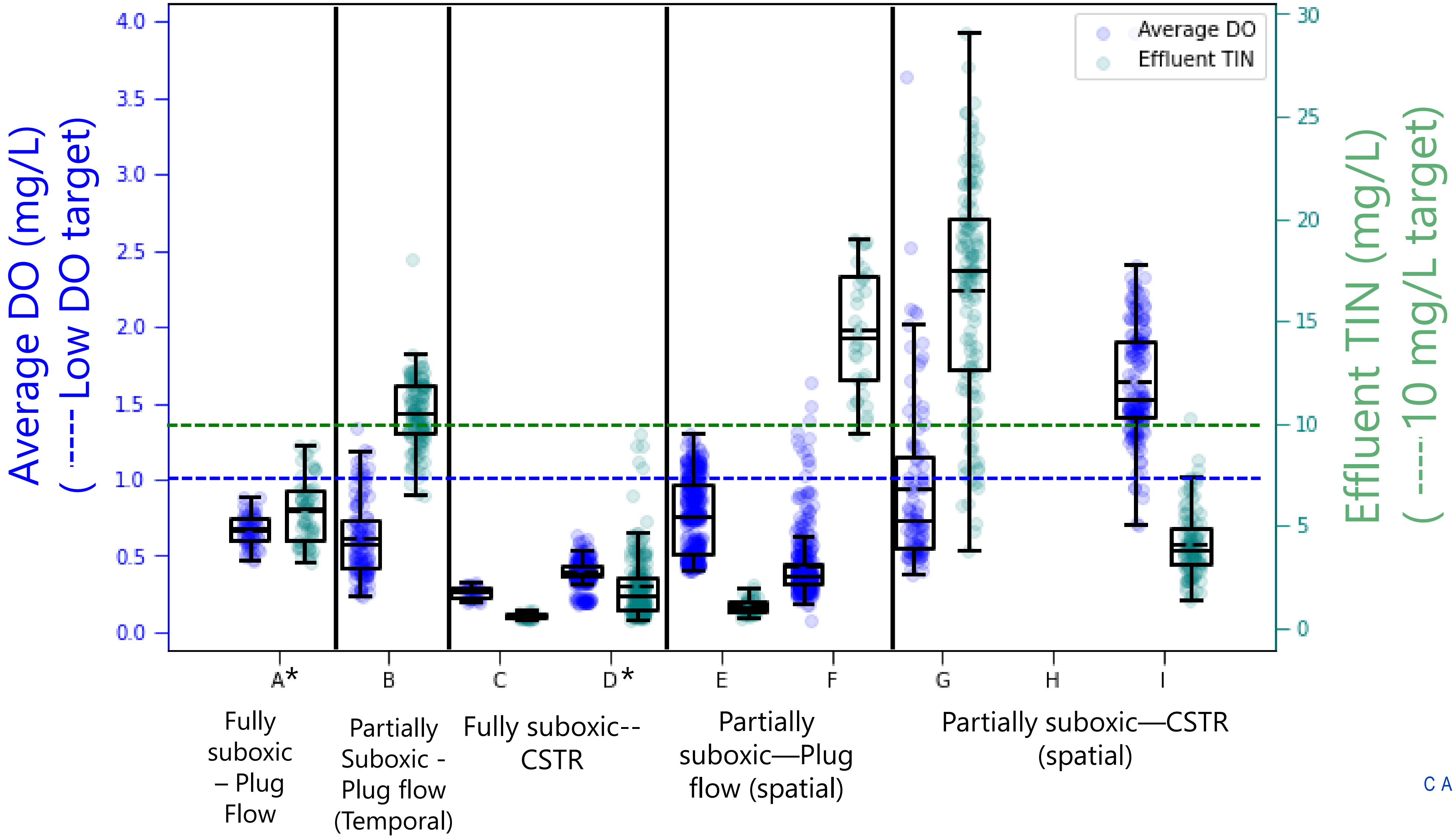
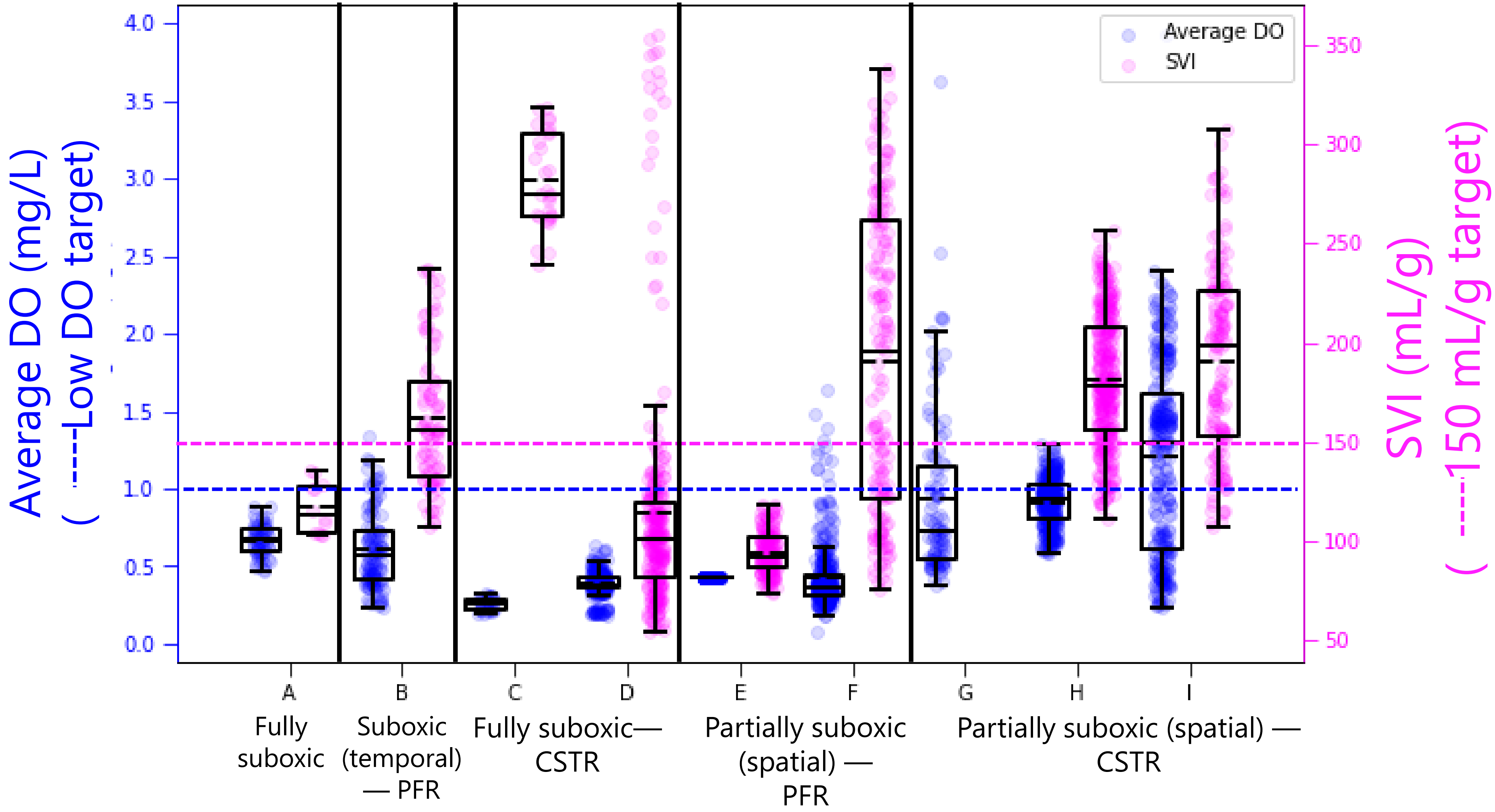
TIN = Total inorganic nitrogen, TN = Total nitrogen, TP = Total phosphorus

Effluent total inorganic nitrogen (TIN) versus average DO operation



Low DO/SNR processes can exhibit poor settleability

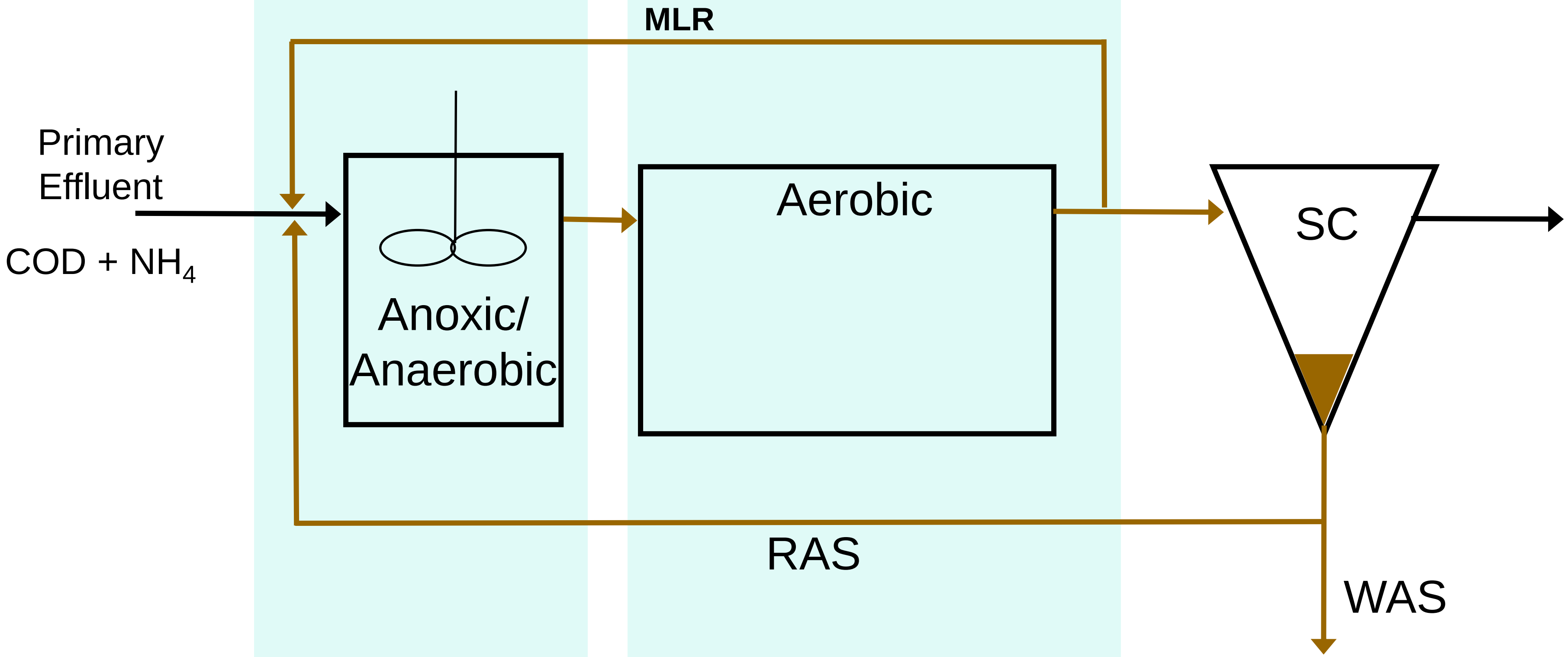


Mechanistic understanding of poor settleability

- Low DO filaments
  - » Type 1701
  - » *Sphaerotilus natans*
  - » *Haliscomenobacter hydrossis*
  - » *Microthrix parvicella*

•ORP stability
•Digestion stability

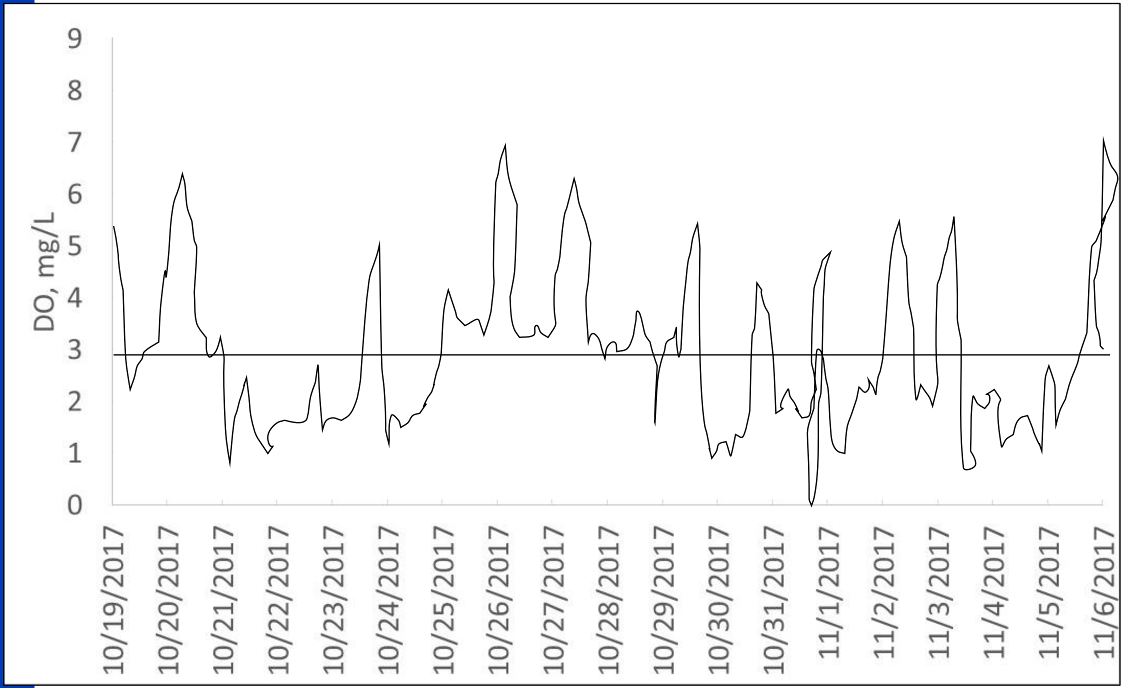
•sbCOD breakthrough
•Nitrate breakthrough
•DO variability
•SRT stability



02

How Accurate Do We Need to Be With Controls?

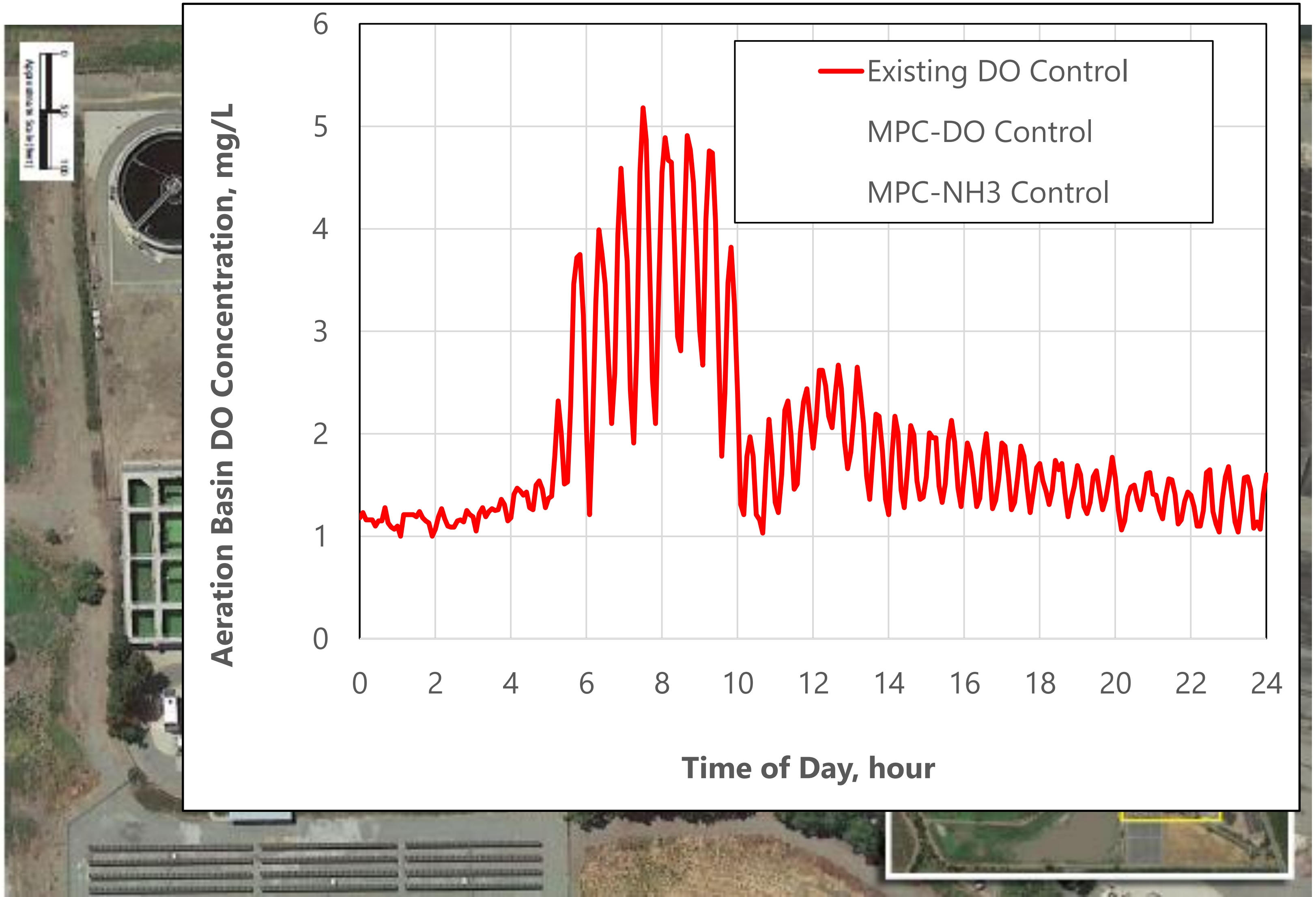
Aeration control accuracy



Aeration Control Approach	DO Variability of Setpoint (Covariance)	Estimated Energy Savings for Aeration
MPAC, accurately calibrated/trained	< 6%	30%-50%+ (with suboxic operation)
Advanced aeration control (ABAC, etc.)	<10%	20-30% (with suboxic operation)
DO control – PID based, well tuned	10-15%	10-15%
DO control – PID based, poorly tuned	20-30%	Baseline
Manual DO control	>35%	NA

City of Chico Water Pollution Control Plant's implementation of machine learning aeration control

- Chico, CA
- 3 - pass MLE process
- Use model predictive/machine learning aeration control
  - SVI 80-160 mL/g



Credits: Ekster and Associates

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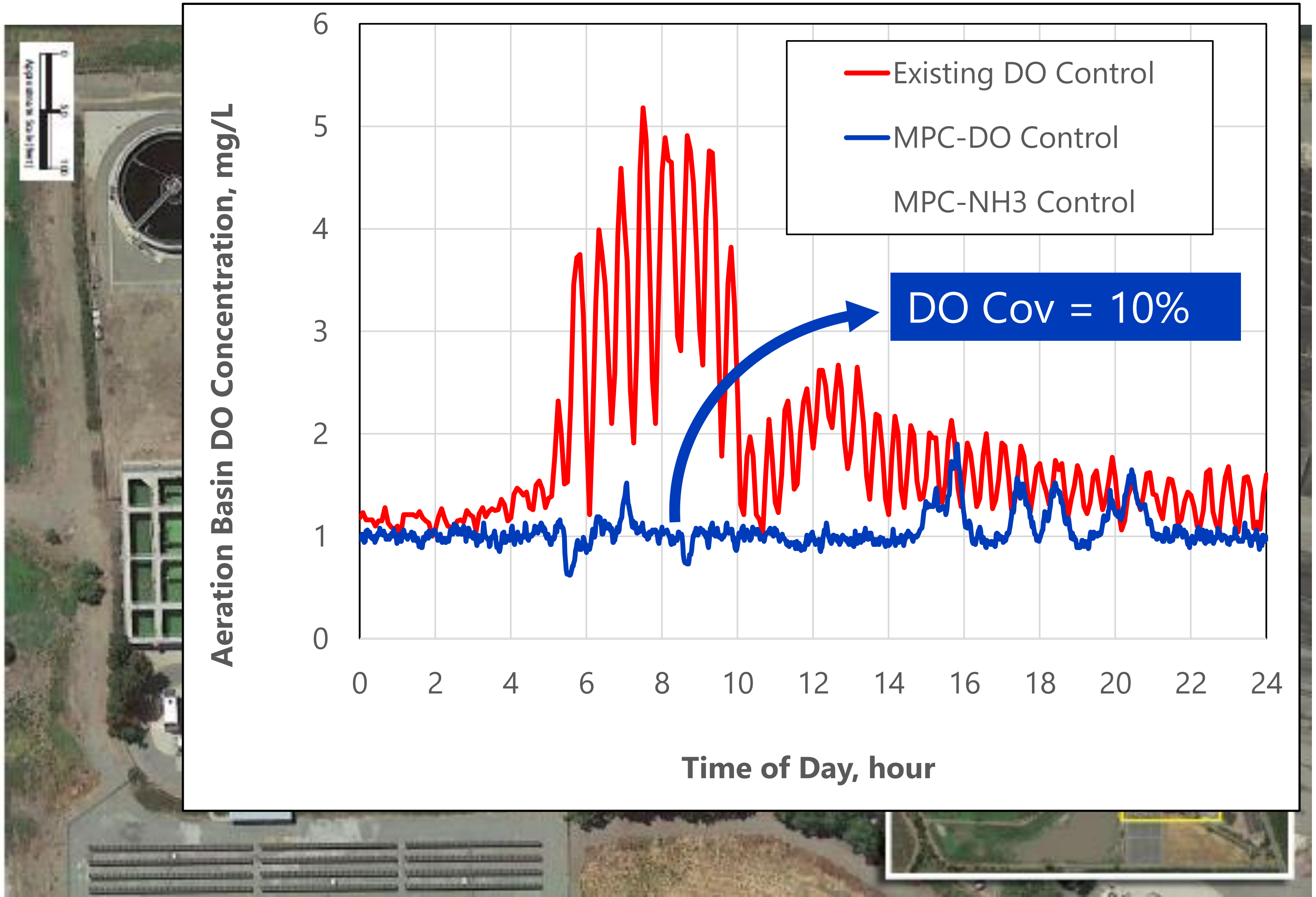

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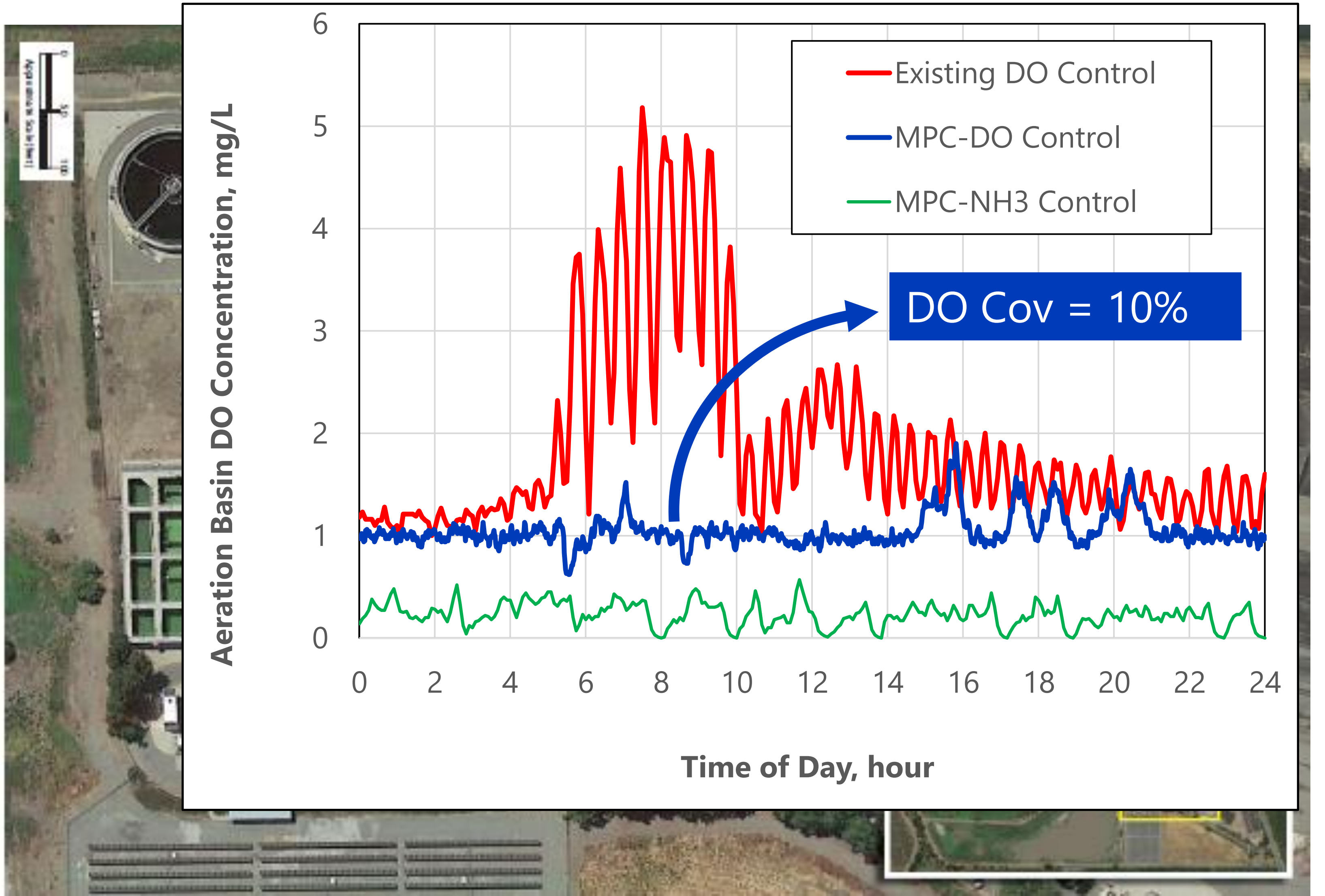
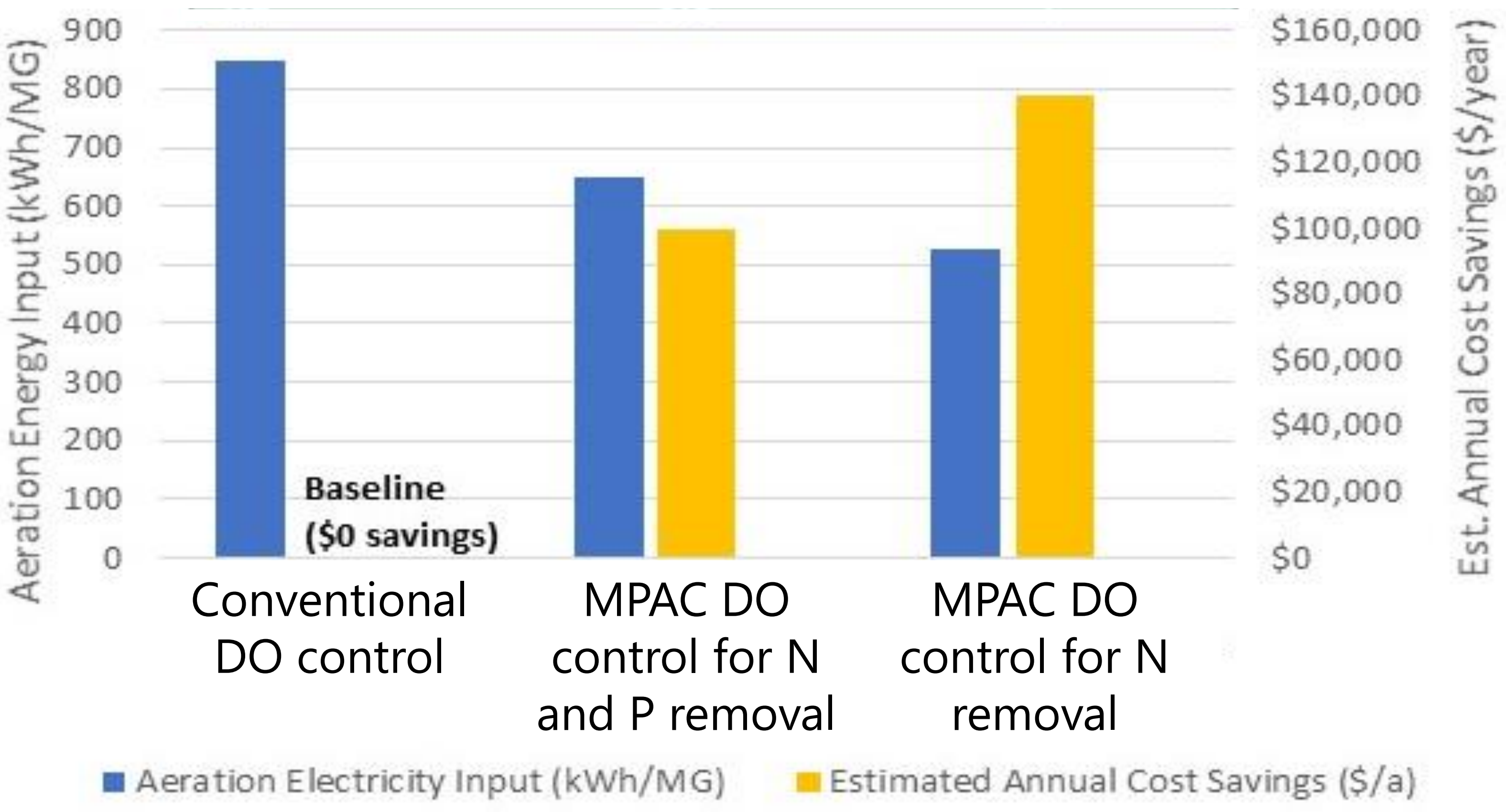


Credits: Ekster and Associates

Results: City of Chico Water Pollution Control Plant, CA

- Effluent nitrate was reduced by 30%-40%
- Effluent TSS was reduced below 5 mg/l
- Electrical savings 47%
  - 1.3 M kWh/year
  - $200,000/year
  - 900 CO_2 metric tons/year
- Increased blower lives
- Nitrate removal could be independently controlled from P removal



05

Full-Scale SNR Implementation

Full-Scale demonstration testing At LACSD's Pomona Plant

LA County Sanitation District Pomona WRP Full-Scale Demonstration

Created with Datawrapper

Full-scale

- 12 mgd Modified Ludzack-Ettinger (MLE) process
- Experience with large system ugrades
- Kinetic testing/special sampling
- Additional case study for model-predictive aeration control and real-time SRT control

Blower improvements

- Demo/removal of existing blowers, piping, valves
- Electrical relocation/ new transformer
- Installation of new Turbo Blowers (APG-Neuros)
- New master control panel
- Power monitoring

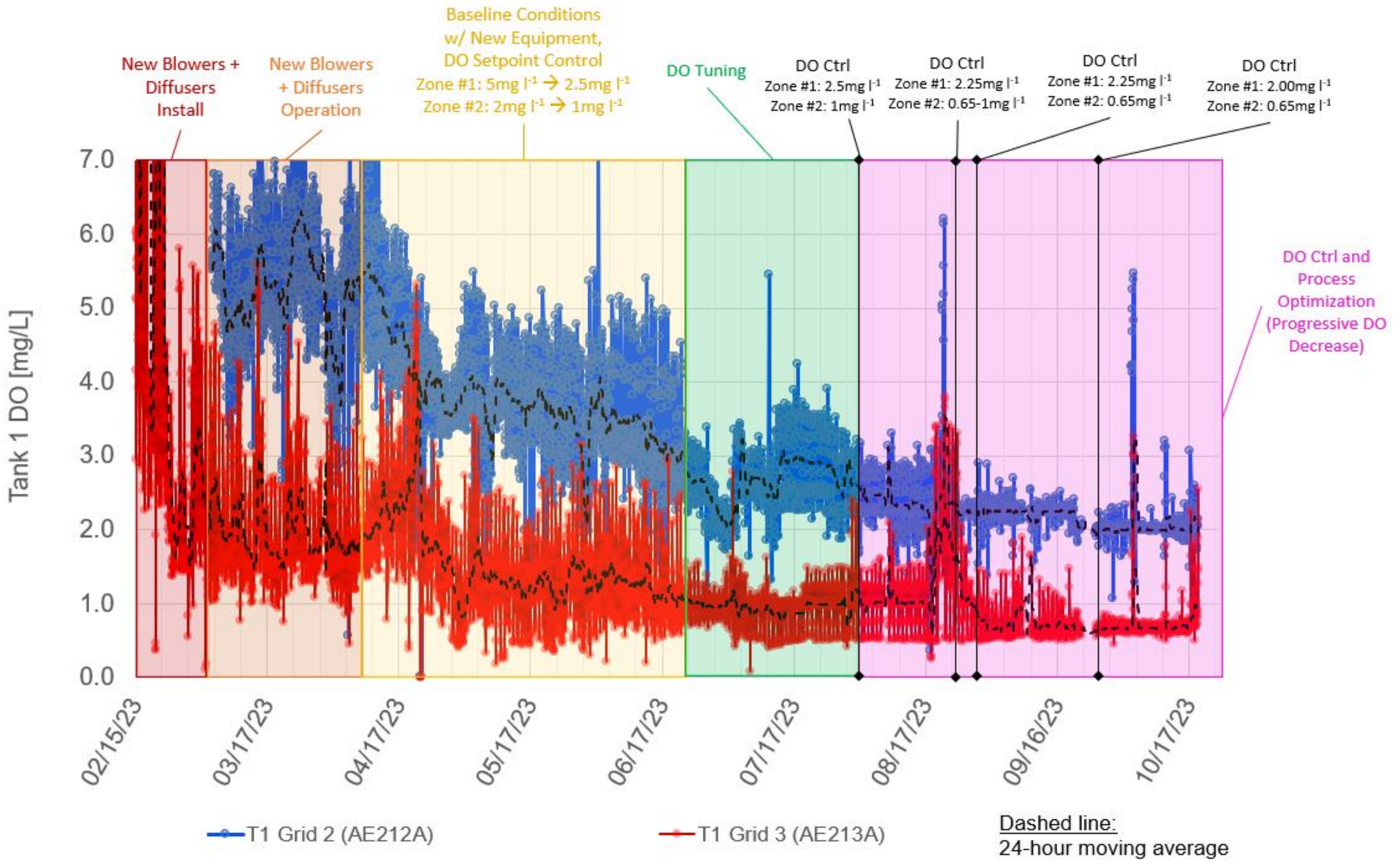
Original Blower Demolition

New APG Neuros Blower and Transformer

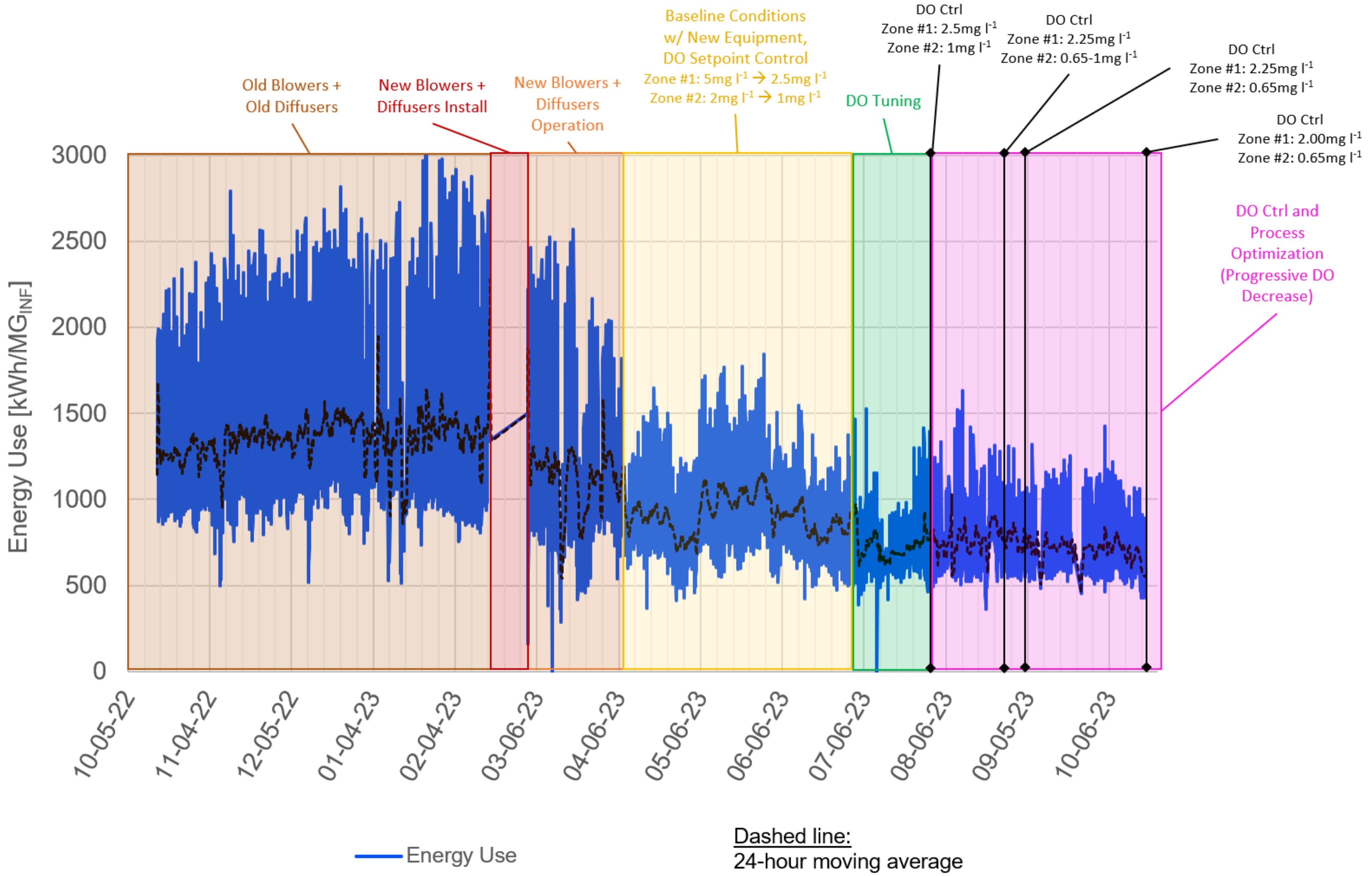
Aeration basin modification for SNR operations

- Aeration piping
  - New butterfly valves and electric actuators
  - Air flow meters
- Diffusers
  - Swapping ceramic discs with membrane
  - Plugging diffusers
- Instrumentation
  - DO, TSS, ammonia, nitrate

Accuracy improves with more sophisticated controls and blowers



Improved control has lowered energy consumption!



Dashed line:
24-hour moving average

06 | In Summary...

Summary

Summary

» What are the drivers for suboxic nutrient removal?
  - Better nutrient removal -> toward more stringent limits
  - Saves energy
  - Saves carbon

» Advanced aeration control
  - Critical for maintaining uniform, stable DO concentrations in plug flow systems and necessary for successful low DO operation

Outlook

» Continue to receive full-scale demonstration testing results and learning as we transition to low DO conditions

» Publish design, operational, and process control guidance and recommendations

Acknowledgements

Natalie Beach

nbeach@carollo.com

Michelle Young

myoung@carollo.com

Sam Reifsnyder

sreifsnyder@carollo.com

Tanja Rauch-Williams

trauch-williams@metrowaterrecovery.com

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Questions about Low DO/Suboxic Nutrient Removal?

Contact *Michelle Young* myoung@carollo.com
or *Brendan Wolohan* bwolohan@carollo.com