Metropolitan Water Reclamation District of Greater Chicago

Welcome to the May Edition of the 2022 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- All attendees' audio lines have been muted to minimize background noise.
- A question and answer session will follow the presentation.
- Please use the "Chat" feature to ask a question via text to "All Panelists."
- 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 only be issued to participants who attend the entire presentation. However, the certificate will NOT be sent out until we receive the approval from ISPE.

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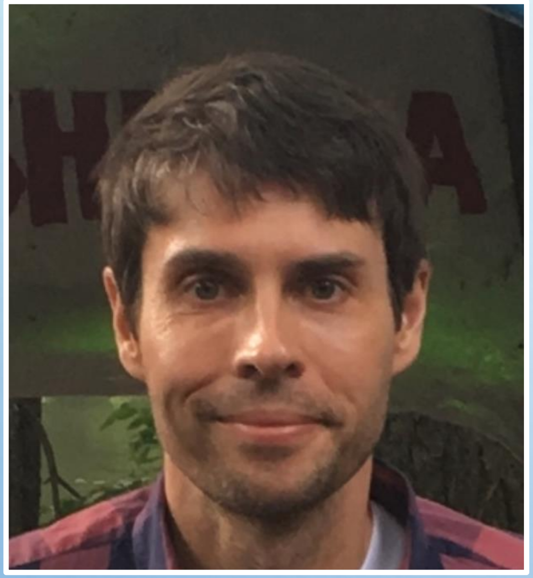
METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO



Dr. Joseph Kozak is a Principal Environmental Scientist for the Metropolitan Water Reclamation District of Greater Chicago. Dr. Kozak earned his Bachelor of Science in Geology from the University of Notre Dame, Master of Science in Environmental Geosciences from Michigan State University, and Ph.D. in Environmental Engineering from Northwestern University. He has over twenty years of experience in environmental, wastewater, and natural systems engineering. His current and past research interests include soil-plant system modeling, green infrastructure evaluation, sludge dewatering, biological nutrient removal, and greenhouse gas emissions from wastewater treatment.

JOSEPH G. CUMMINGS
OPERATIONS MANAGER
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Joseph Cummings is Operations Manager for the District's Stickney Water Reclamation Plant. He received a Bachelor of Science in Civil Engineering from the University of Illinois, Urbana-Champaign, Illinois and a Master of Science in Environmental Engineering from the Illinois Institute of Technology, Chicago, Illinois. He has over twenty years of experience in various roles at the District. He currently supervises treatment plant and mechanical operations at the Stickney Water Reclamation Plant, operations of the Racine Avenue Pump Station and TARP systems, including the Mainstream and Des Plaines Tunnels, Mainstream Pump Station and Reservoir, and railroad operations.

Metropolitan Water Reclamation District of Greater Chicago

Operating the Stickney Water Reclamation Plant to Meet the National Pollutant Discharge Elimination System Permit Limit for Total Phosphorus

Joseph Cummings
Joseph Kozak

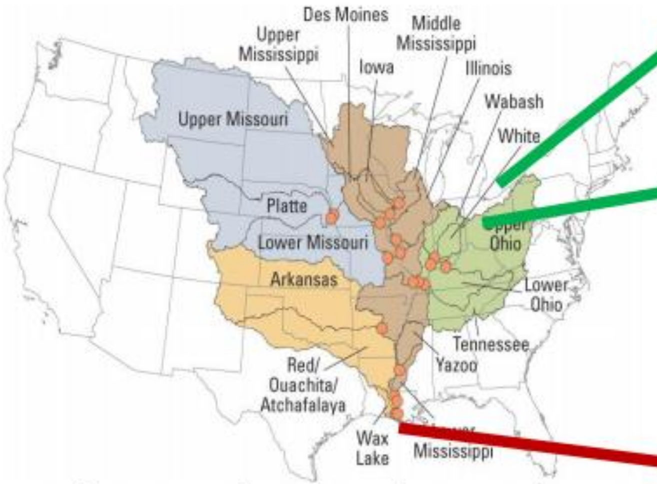
May 27, 2022

Outline

- **Why do we need to remove P?**
- **Current regulations and Stickney Roadmap**
- **How do we remove P?**
  - **Chemical Precipitation**
  - **Mainstream Biological Phosphorus Removal**
- Pilot Testing
- Full Plant conversion
- Ostara®
- Chem P implementation
- Operational Challenges
- Conclusions

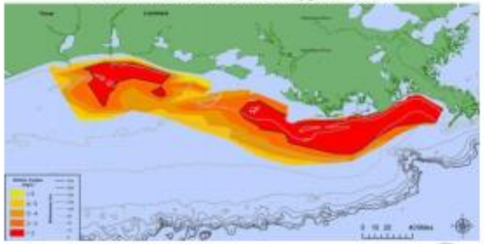
Why do we need to remove P (and N)?

Near and far.
Large and small.
Point and non-point.



http://water.usgs.gov/nasqan/images/nasqan_ms_web.jpg

Bottom-water Dissolved Oxygen – 2014



Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU
Funding sources: NOAA Center for Sponsored Coastal Ocean Research and U.S. EPA Gulf of Mexico Program

Phosphorus → freshwater harmful algal blooms (HAB)
Nitrogen → Estuary and marine eutrophication and hypoxia

Why do we need to remove P?

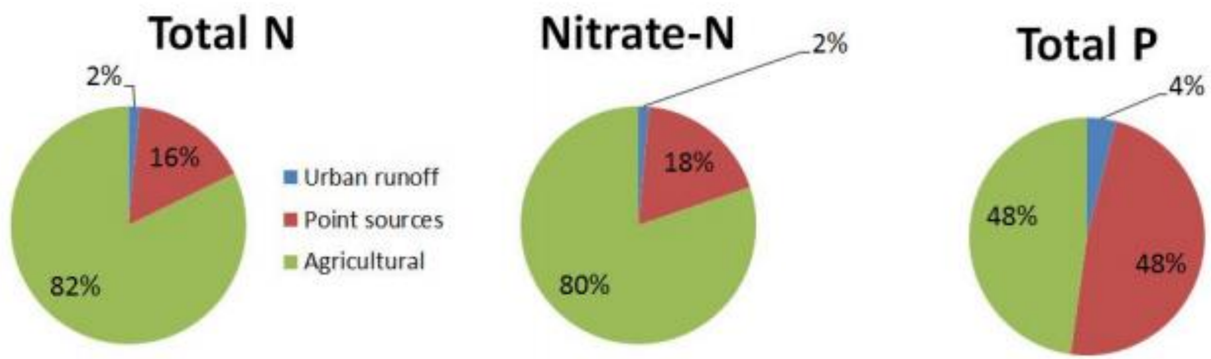


Figure 2.1. The proportion of nitrate and total phosphorus lost to the Mississippi River by source.

Table 3.1. Point source total phosphorus loads for the entire state and by major river basins. The category "all other basins" includes point sources outside the eight major basins.

	All 1,660 sources	Majors (263)
	million lb yr^{-1}	
Rock River	1.01	0.89
Green River	0.03	0.02
Illinois River	14.6	13.8
Kaskaskia River	0.52	0.4
Big Muddy	0.21	0.17
Little Wabash	0.16	0.14
Embarras River	0.1	0.08
Vermilion River	0.22	0.2
All other basins	1.12	0.94
State sum	18	16.6
State (David & Gentry, 2000)	14.7	

Total loading ~37 million lb/yr

State and Federal Nutrient Standards Development

1998
USEPA initiated nutrient criteria development

2000
IEPA requested to develop nutrient standards for the state

2000
USEPA finalized 14 ecoregional nutrient criteria recommendations for streams and rivers

2006
IEPA/IPCB promulgated the Interim P Rule

(1 mg/L TP as monthly average for new and expanding WWTPs)

2011
IEPA renewed its efforts to develop nutrient standards with 4 working groups

2015
IEPA finalized the Illinois Nutrient Loss Reduction Strategy

Stickney Nutrient Efforts – Strategic Plan for Resource Recovery and Sustainability

2011

Informed IEPA on steps:

- To biologically remove P *using existing infrastructure*
- Recover P where possible
- To work within District's long term strategic plan on resource recovery and sustainability

2012

Formed a District-wide Phosphorus Task Force to study and implement of EBPR

Full-scale test in one battery at the Stickney

2013

Converted all SWRP to EBPR configuration

2016

P recovery facility Ostara® I/S @ Stickney WRP

2017

New NPDES permits issued for Stickney

Stickney Nutrient Efforts – Strategic Plan for Resource Recovery and Sustainability

2019
P Feasibility Study (AECOM)
GCT fermenters I/S

2021
Mixers installed in 3 Batteries
Temporary chem P system

Aug 2021
Stickney permit goes live

Sept 2023
Chem P Polishing System I/S

2023
Mixers installed in final battery

Phosphorus removal in general

2005-2010 Stickney raw influent averaged 7.8 mg/L total phosphorus

Sedimentation

Primary treatment can remove a fraction of phosphorus→mostly particulate or sorbed reactive soluble

Assimilation in activated sludge

Bacteria need P as nutrient (~2% of biomass)

Removed via sludge wasting

Stickney average outfall was 1.1 mg/L (75th percentile at 1.6 mg/L)

But we need to get <1 mg/L

How to obtain additional P removal

Convert soluble P to insoluble P (chemically or biologically)

Capture insoluble P (in clarifier or some other solids removal system, e.g. filters)

Chemical P Removal

Use of metal salts (Alum, FeCl3, PAC)

Phosphate & metal combine to form insoluble precipitate

- Removed through sedimentation or filtration

Dosing

- Stoichiometrically 1 mole of a trivalent metal reacts with 1 mole P but often need much higher than that due to interference and to achieve lower levels

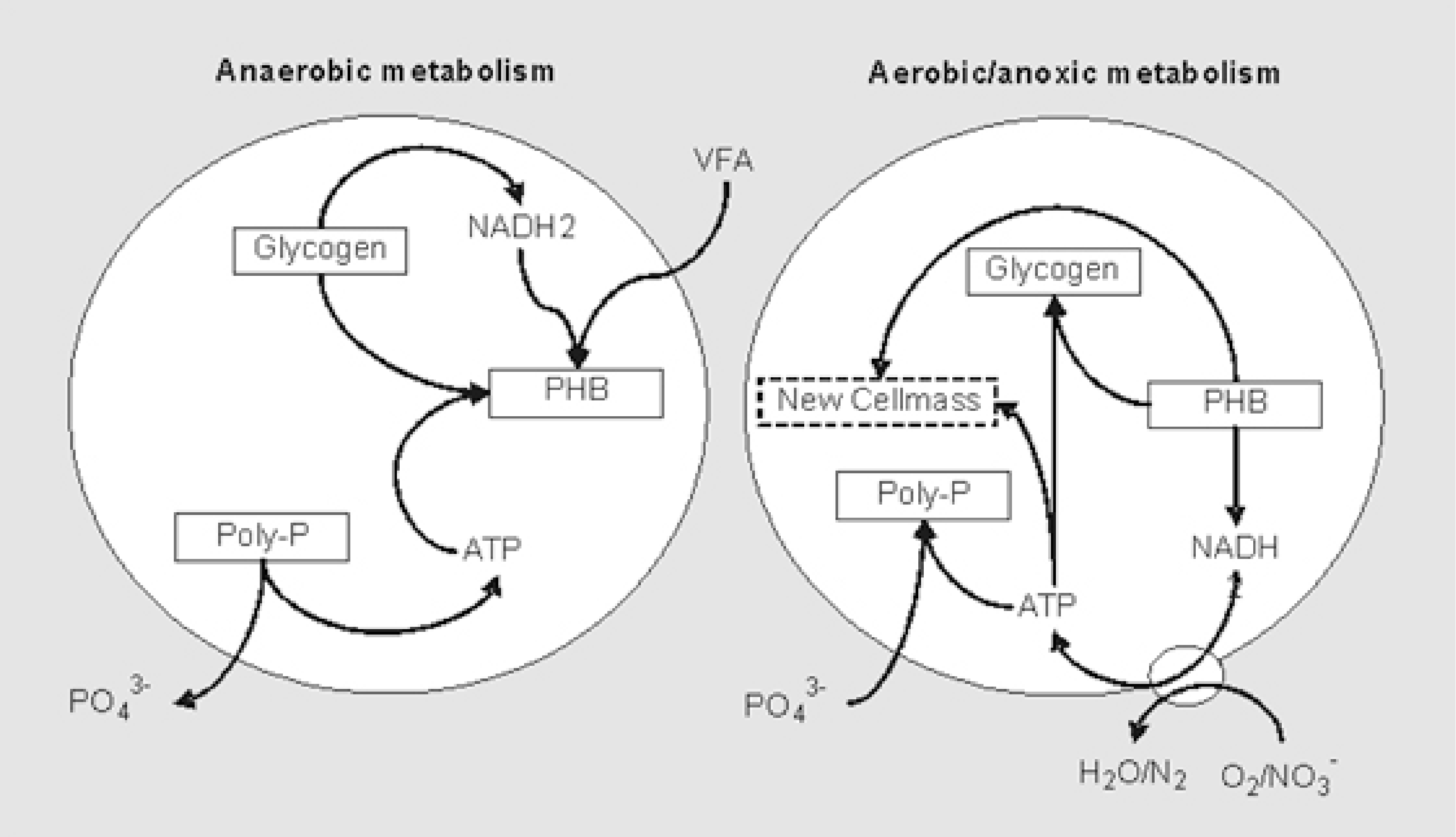
Potential dose points

- Before primaries, aeration tanks, secondaries, and tertiary treatment

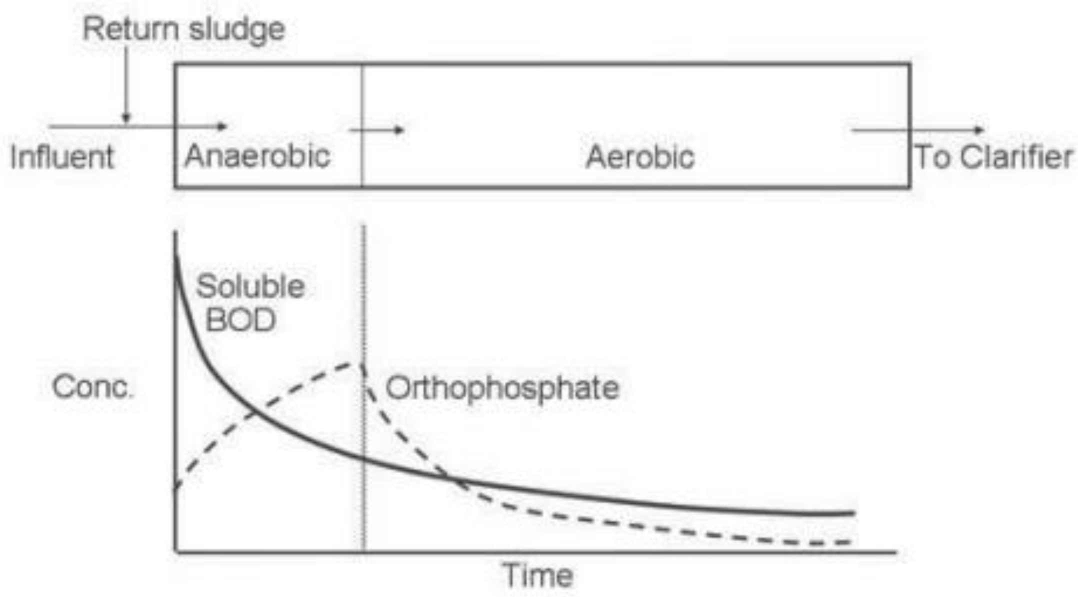
Chemical P Removal

BENEFITS	DISADVANTAGES	CAPITAL COSTS
• Easy to implement • Low capital costs • Reliable (no toxicity issues)	• Increased sludge production (up to 25%) • Unable to easily recover chemically bound P from sludge • Ongoing chemical costs • Occasionally difficult to dewater sludge • Consumed alkalinity negatively affecting nitrification • Increase MLSS • Vivianite formation ($Fe_3(PO_4)_2 \cdot 8(H_2O)$)	• Pumps • Piping • Chemical feed system • Storage tanks • Building (potentially) • Additional sludge handling (potentially)

Biological P Removal (Accumulabacter)

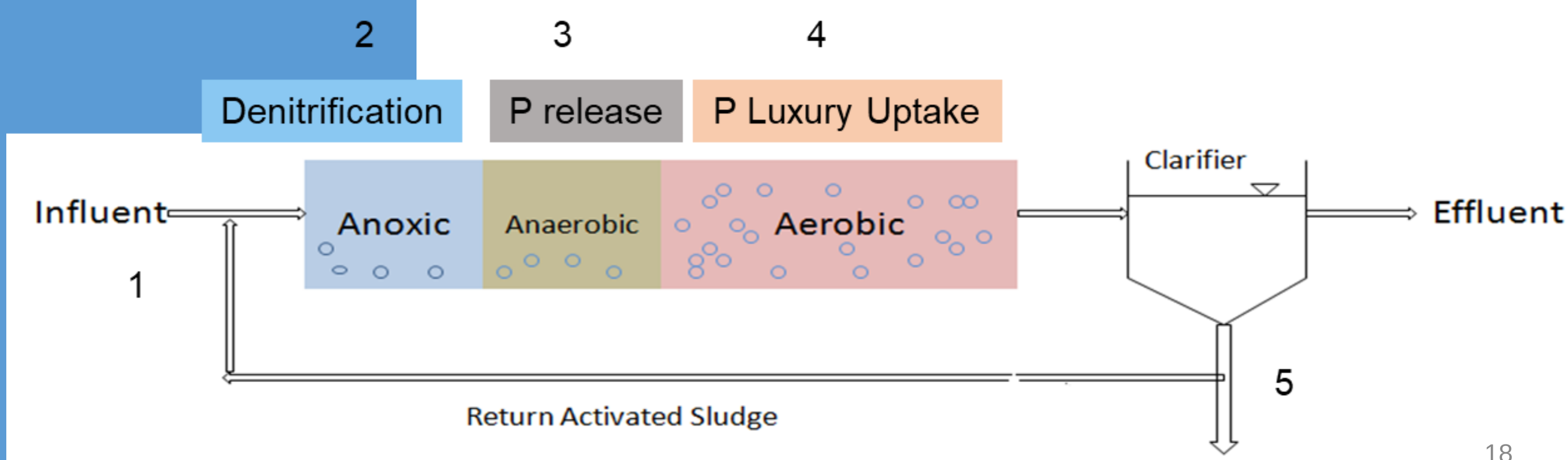


Mainstream Biological P Removal



Stickney Mainstream Bio P Configuration (AAnO)

1. PAOs and denitrifiers returned with RAS
2. Anoxic Zone-no oxygen➔Denitrification of NO_3 in RAS
3. Anaerobic Zone – no nitrate, no oxygen➔uptake VFA, form PHB and release P via the PAOs
4. Aerobic Zone – oxygen present➔luxury uptake P by PAOs, nitrification, and residual carbon removal
5. PAOs settle out w/ other biomass in secondary clarifiers and removed from system ➔ net removal from liquid stream



Mainstream Biological P Removal

DO

- DO=0 mg/L in anoxic and anaerobic zone; ORP<-50 mV
- DO>1 mg/L in aerobic zone: ORP>-50 mV

NOx-N

- NOx-N = 0 mg/L in anaerobic zone, ORP<-50 mV
- RAS:PE flow ratios < 0.7

Carbon

- Influent BOD:TP>25-30; COD:TP>40-50; rbCOD:TP>11-15

MLSS

- MLSS>3,000 mg/L

SRT

- Summer, 6 days; Winter, 10 days

Temp

- Not as critical, except high temps encourage GAOs (glycogen accumulating organisms)

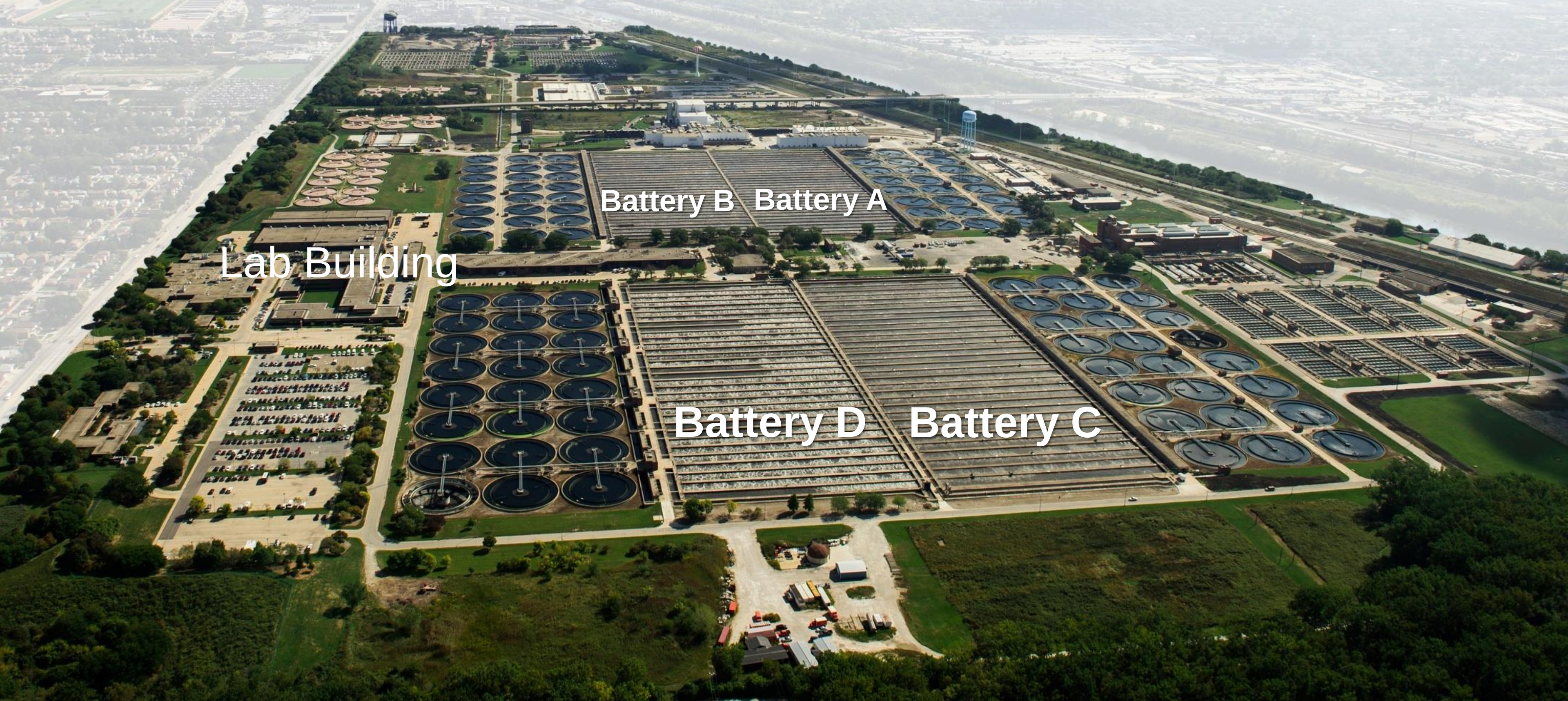
Bio P Removal

BENEFITS	DISADVANTAGES	CAPITAL COSTS
• Less sludge production • Less chem costs • Can recover P • Can be coupled w/ chem P • Lower operational costs	• More complex control • Toxicity upsets • Hard to dewater sludge • Takes up nitfrication capacity • Possible backmixing if no baffles • P will be released during anaerobic digestion • Downstream struvite formation	• Baffles • Pumps • Mixers • Instrumentation

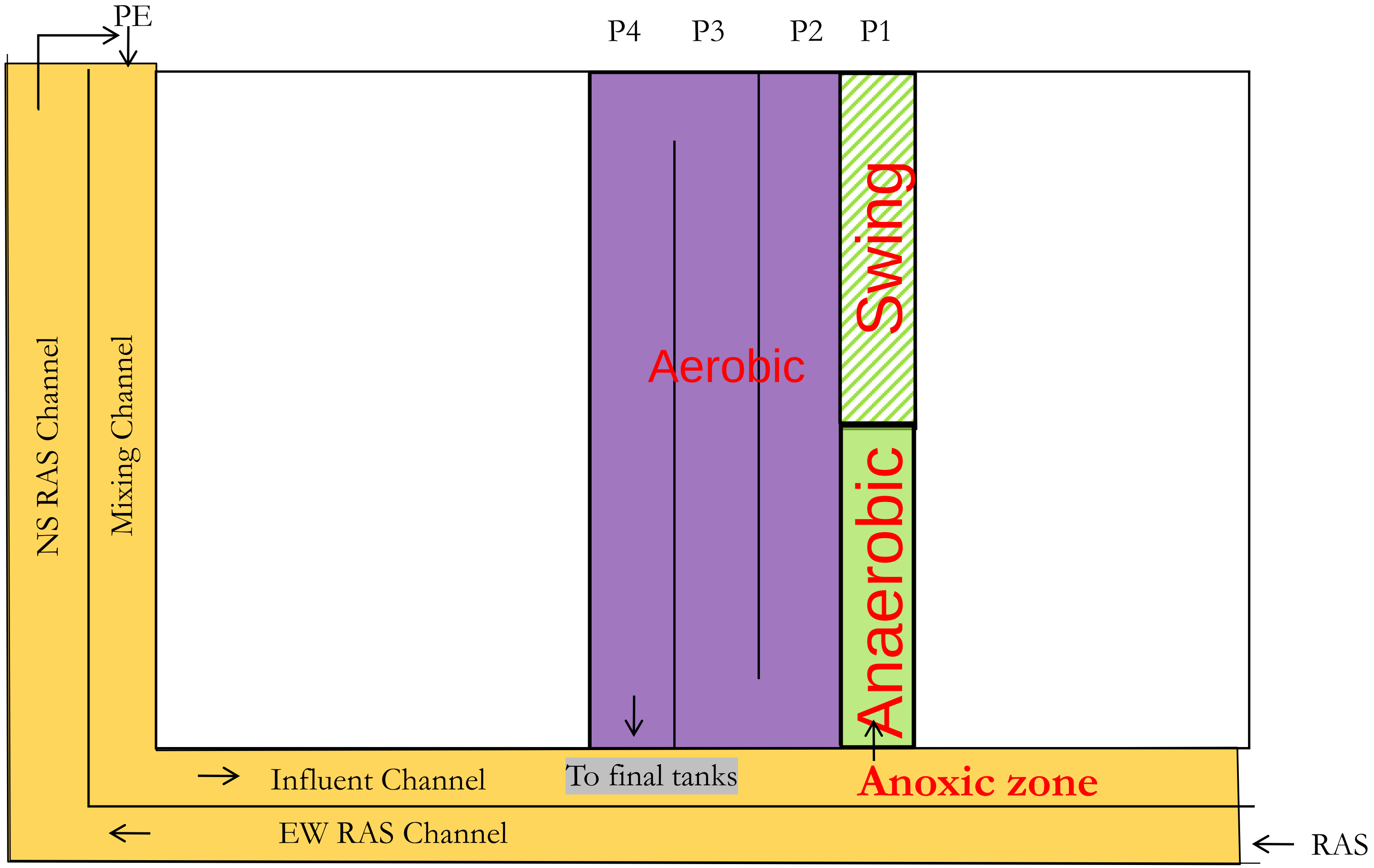
Stickney EBPR Pilot

Stickney Water Reclamation Plant

- Serves 2.38 million people
- Flows:
  - Avg Design Capacity: 1,200 MGD
  - Max Design Capacity: 1,440 MGD
- 4 aeration batteries
  - 8 tanks/battery
  - 4 passes/tank
  - 24 circular secondary clarifiers/battery



Aeration Battery Conversion to Bio P at Stickney WRP



- Using current air distribution system for mixing
- No baffles needed (high aspect ratio of 51)
- No recirculating pumps

Challenges to Establish Bio P at Stickney WRP

1. Create zero mg/L dissolved oxygen in A and An zones

- Limitations: Pseudo anaerobic zone using existing air system and no baffle walls

2. Reduce RAS return flow to lower “toxic” nitrate load

- Limitation: Limited dial back ability using airlifts

3. Optimize influent carbon

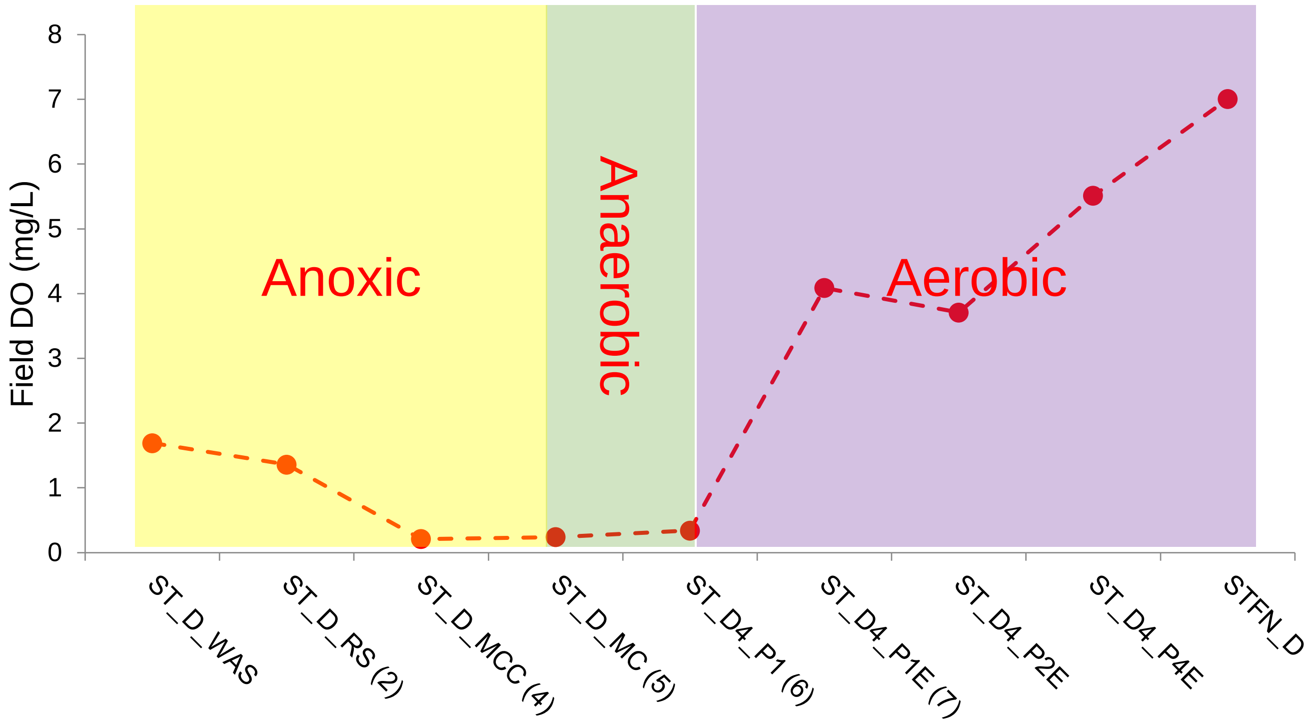
- Limitation: 50% of the time unfavorable influent for Bio P, especially during low flows

4. Reduce recycle stream loads

- Limitation: Manage four other WRP solids (O’Brien, Kirie, Egan, and Lemont)

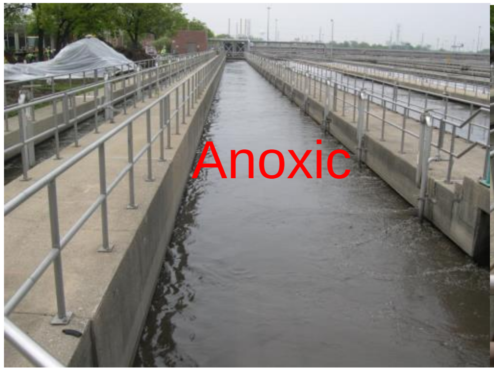
Step 1: Create Zones to Enrich PAOs

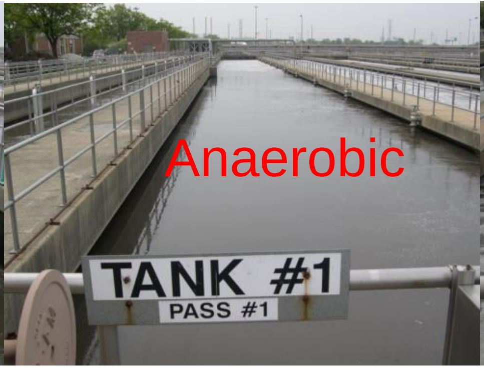
Closing air valves in RAS, influent and mixing channels and minimizing air in the first half of pass 1s.



Anoxic & Anaerobic zones:

DO<0.2 mg/L



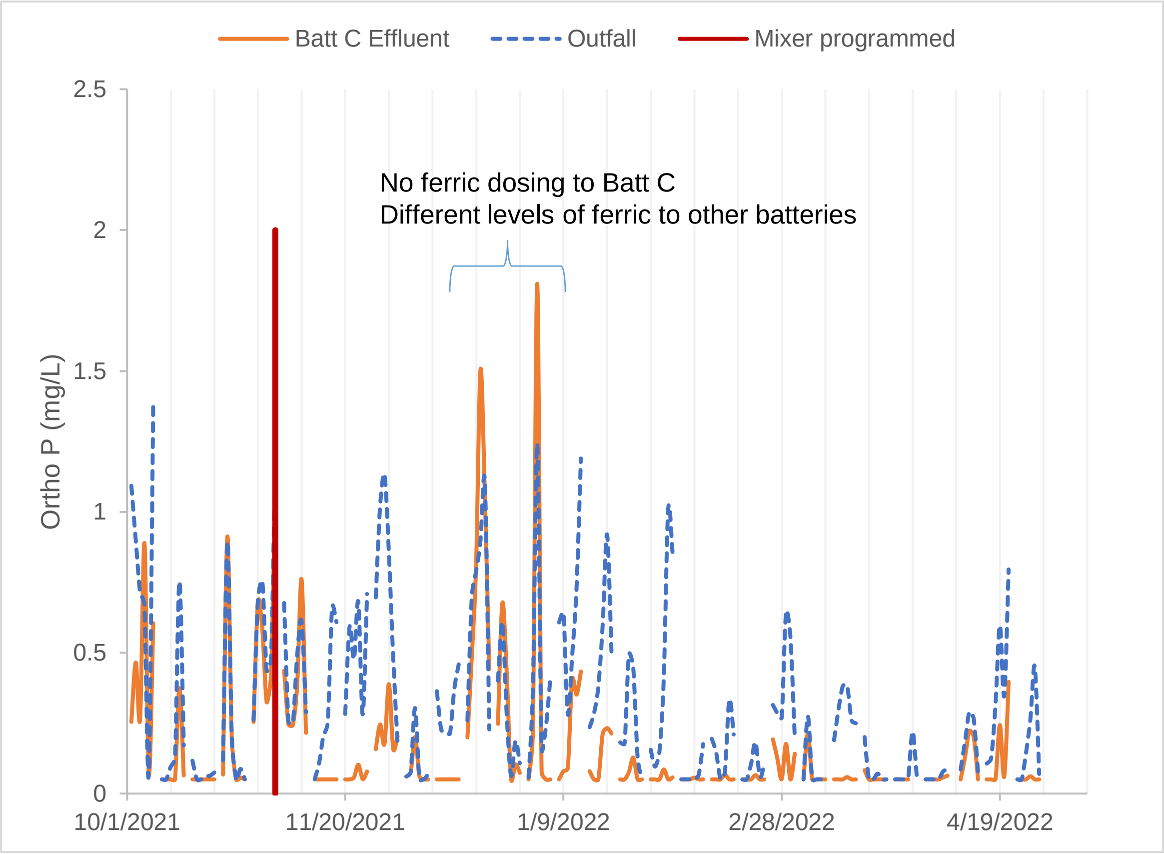


Challenges in Optimizing Selector Zones

- Pseudo anaerobic conditions make Bio P mechanism difficult to optimize
- Uncontrollable solids deposition in anaerobic zones

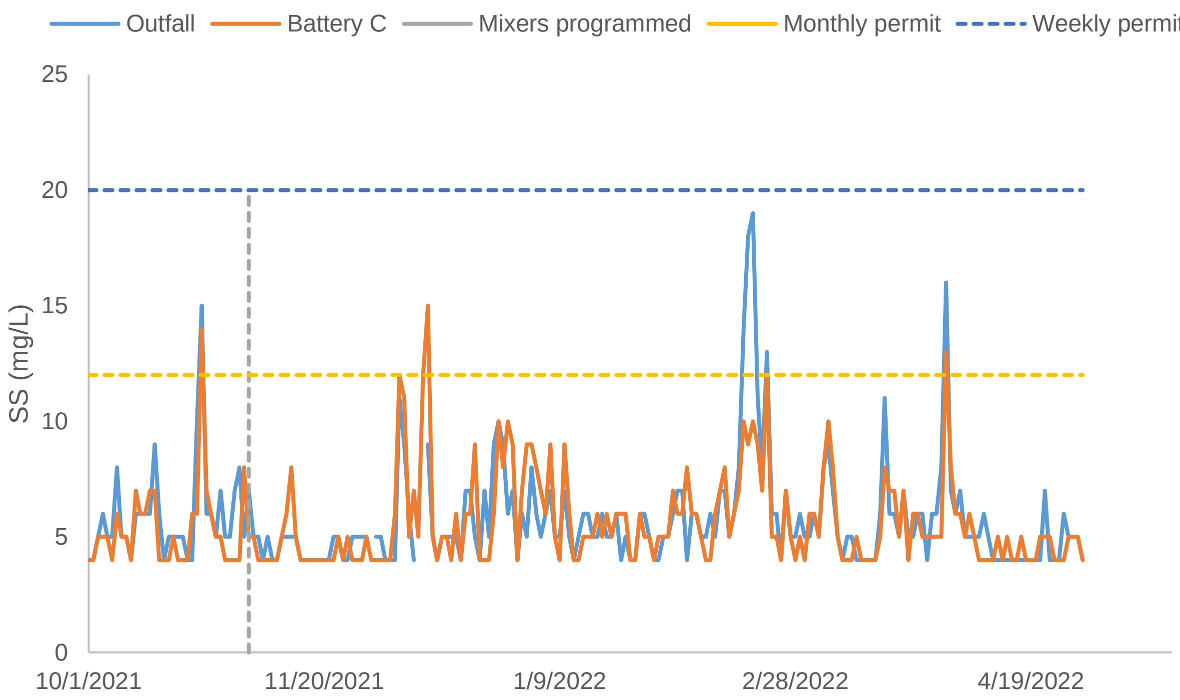
Install mechanical mixers
Four mixers each tank
(Batteries A,C&D installed; B to come in 2023)

Performance Improvement - Mixers



- Battery C mixers were programmed to 23 hours off and 1-hour daily bumping on 11/4/2021
- Battery C outperformed the outfall one week after mixer operational changes
- Ortho-P averages after 11/4/21:
  - Batt C – 0.152 mg/L
  - Outfall – 0.310 mg/L
- Battery C Ferric dosing on 1/3/21, 1/4/21, and 1/8/21

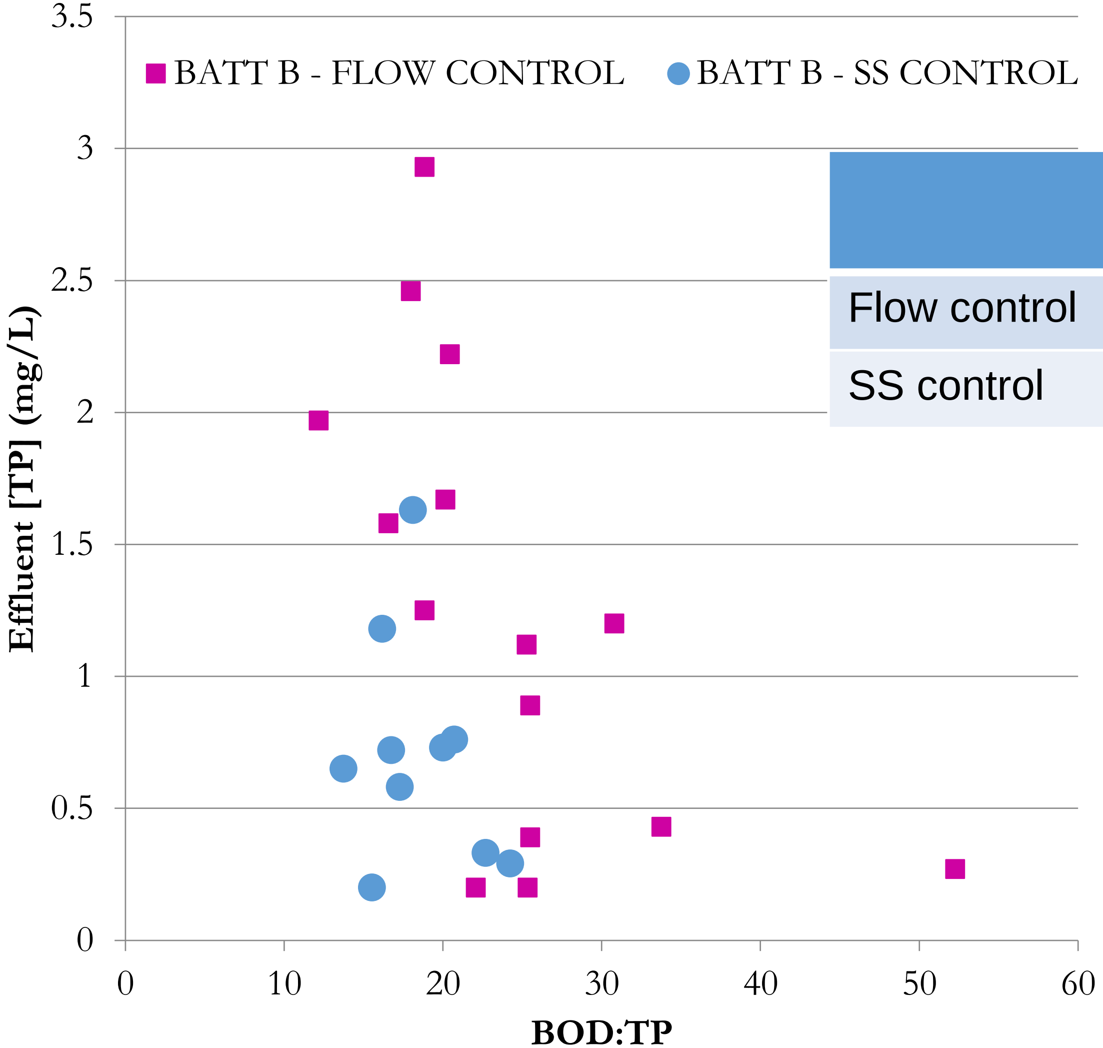
Impact on Effluent Suspended Solids



- No observed adverse impact on effluent SS thus far
- No observed elevated filaments thus far.
- Operational strategy is to bump the settled solids out prior to high flows with continuous mixing ahead of event
- Will continue to monitor settleability

Balance between inline fermentation and mixing solids

Step 2: Reduce RAS Flow



	RAS/PE	BOD:TP	Effl TP (mg/L)
Flow control	0.9	25.7	1.04
SS control	0.7	18.1	1.00

- RAS/PE ratio was dropped via SS control in Battery B, especially compared to other batteries.
- Can operate at a lower BOD:TP ratio to get to the same TP with lower RAS/PE.

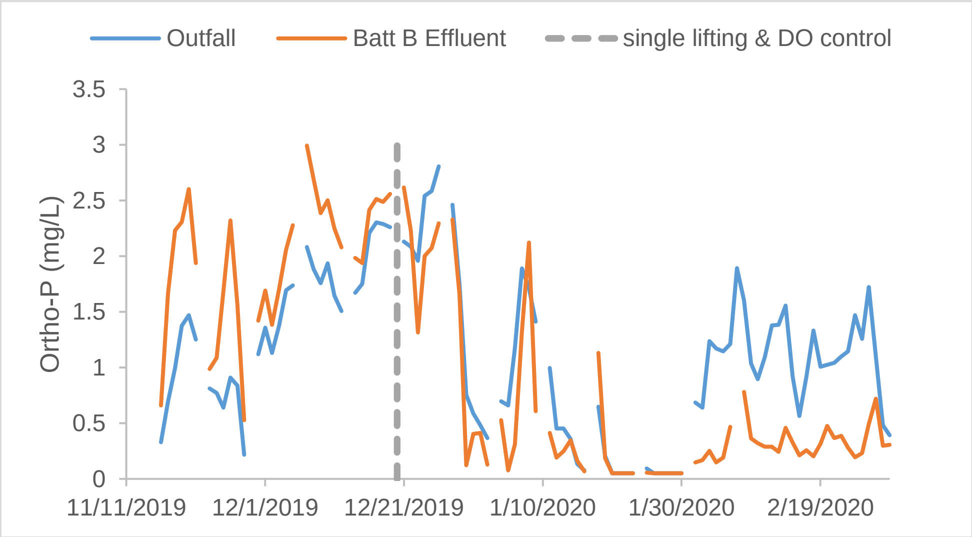
Challenges in Optimizing RAS Flows

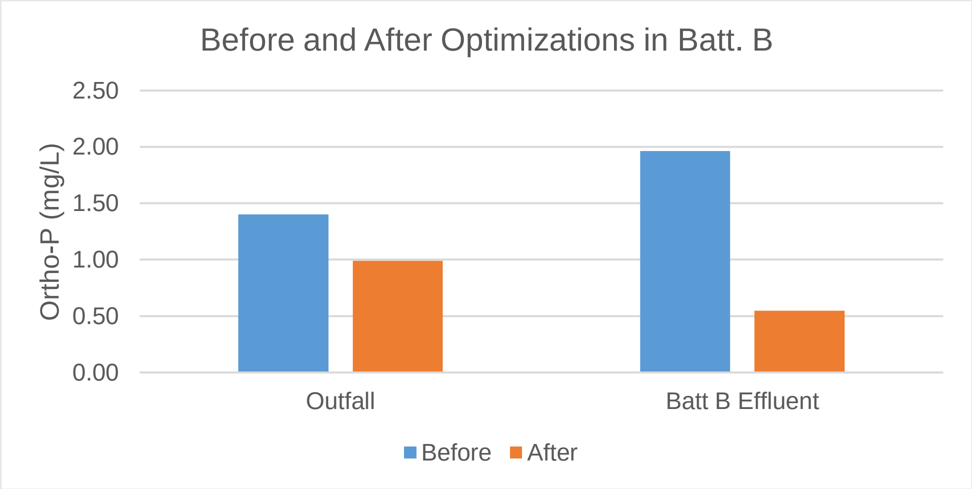
- Too many SS probes that need maintenance

- Malfunctioning probes

Utilize airlift settings –
High flows: Double lifting
Low flows: Single lifting

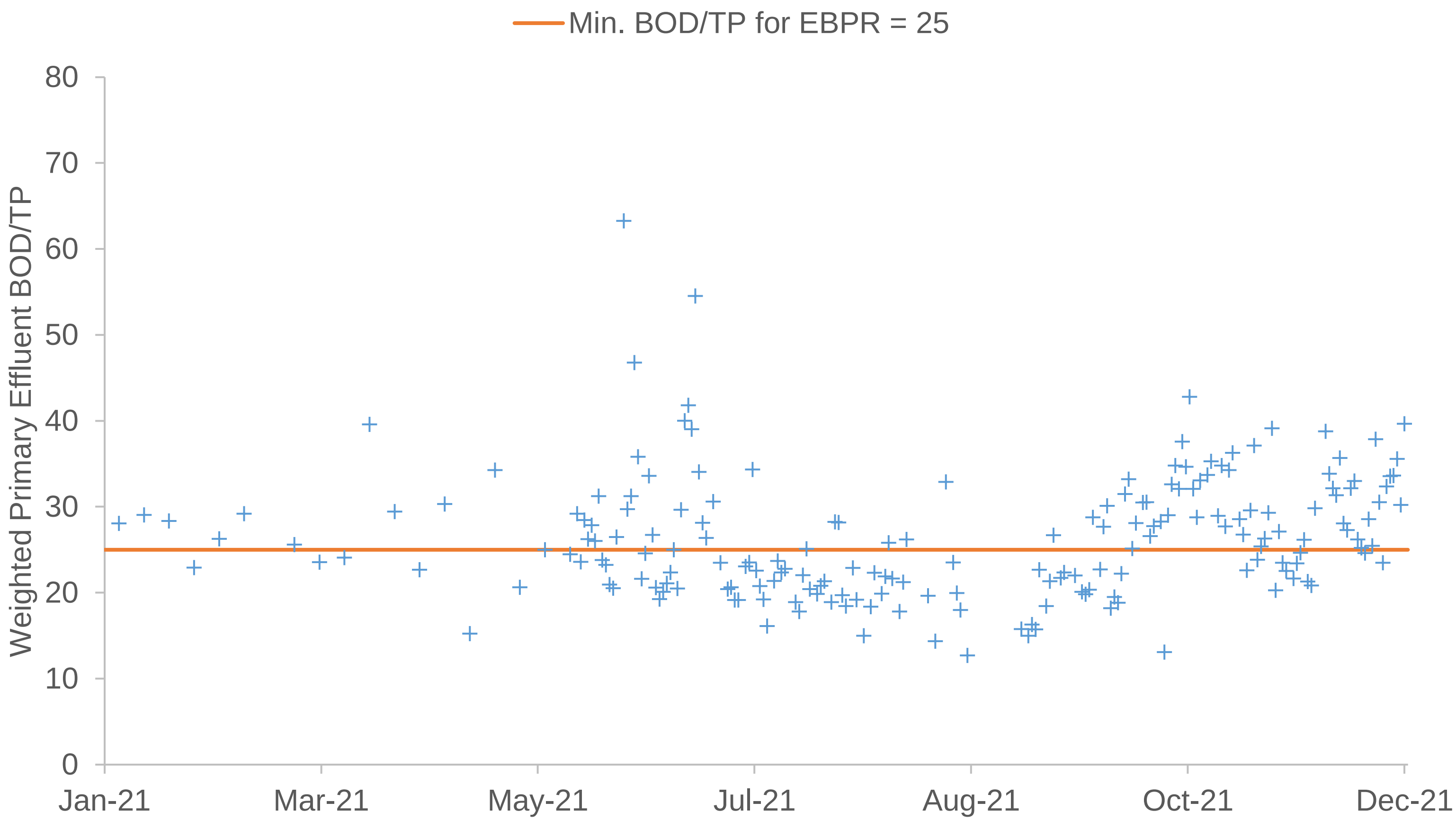
Performance Improvement – RAS Optimization





- Battery B anoxic/anaerobic zones were setup on 11/14/2019, however P removal performance was not seen better than other batteries for a month.
- Air and RAS flow optimization were in place on 12/20/2019.
- Battery B started outperforming the outfall right after the operational change and significantly better two weeks later.

3. Carbon Optimization



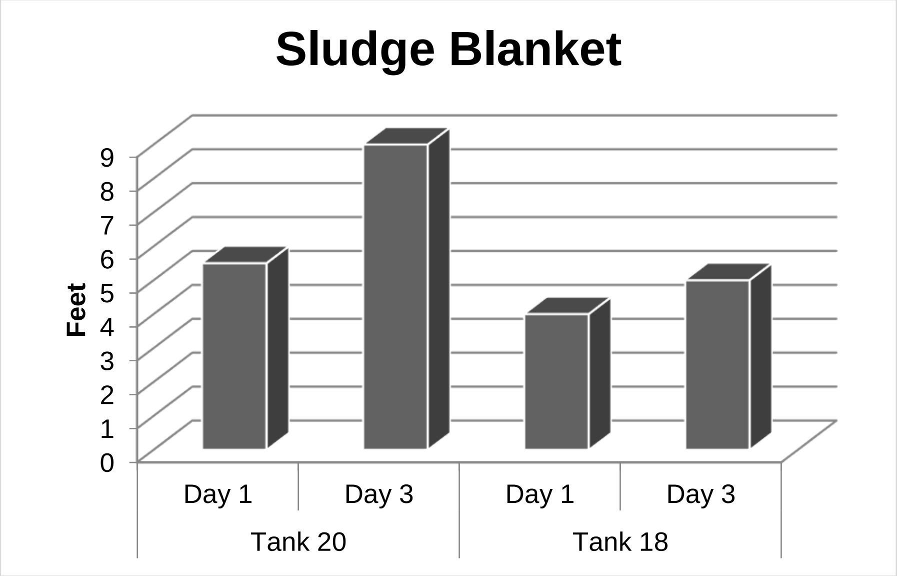
- 47% weighted primary effluent BOD:TP < 25
- Daily sampling started on 5/13/21

Step 3: Carbon Optimization

What we have tried	Challenges
Holding primary sludge to generate VFA in preliminary settling tanks	Caused downstream sludge transfer issue
Use less preliminary tanks to send more BOD to secondary	No correlation was found in improving P removal
Resource Recovery Ordinance to bring high strength organic material in	Not enough material
Inline mixed liquor fermentation	Inconclusive b/c not entire battery
Rotating preliminary settling tanks and bypass	Promising results

Rotating Preliminary Tanks

- Three tanks isolated each day; rotated every 48 hours
- After 48 hours isolating preliminary tanks, carbon concentrations of primary effluent from tanks increased:
  - COD by 17% to 224%
  - solCOD by -10 to 161%
  - and VFA by 207% to 683%
- Sludge blanket in isolated prel tanks increased after 48 hours
- Recognized odor, septicity etc.



Step 4: Recycle Stream Optimization

Recycle streams high in nutrients (N & P) and low in carbon

Recycle streams to the headworks hurt Bio P, especially in low flow

LASMA recycles – equalization

- Sending back in continuous and small streams to avoid shock load

Resource Recovery of post centrate

P recovery

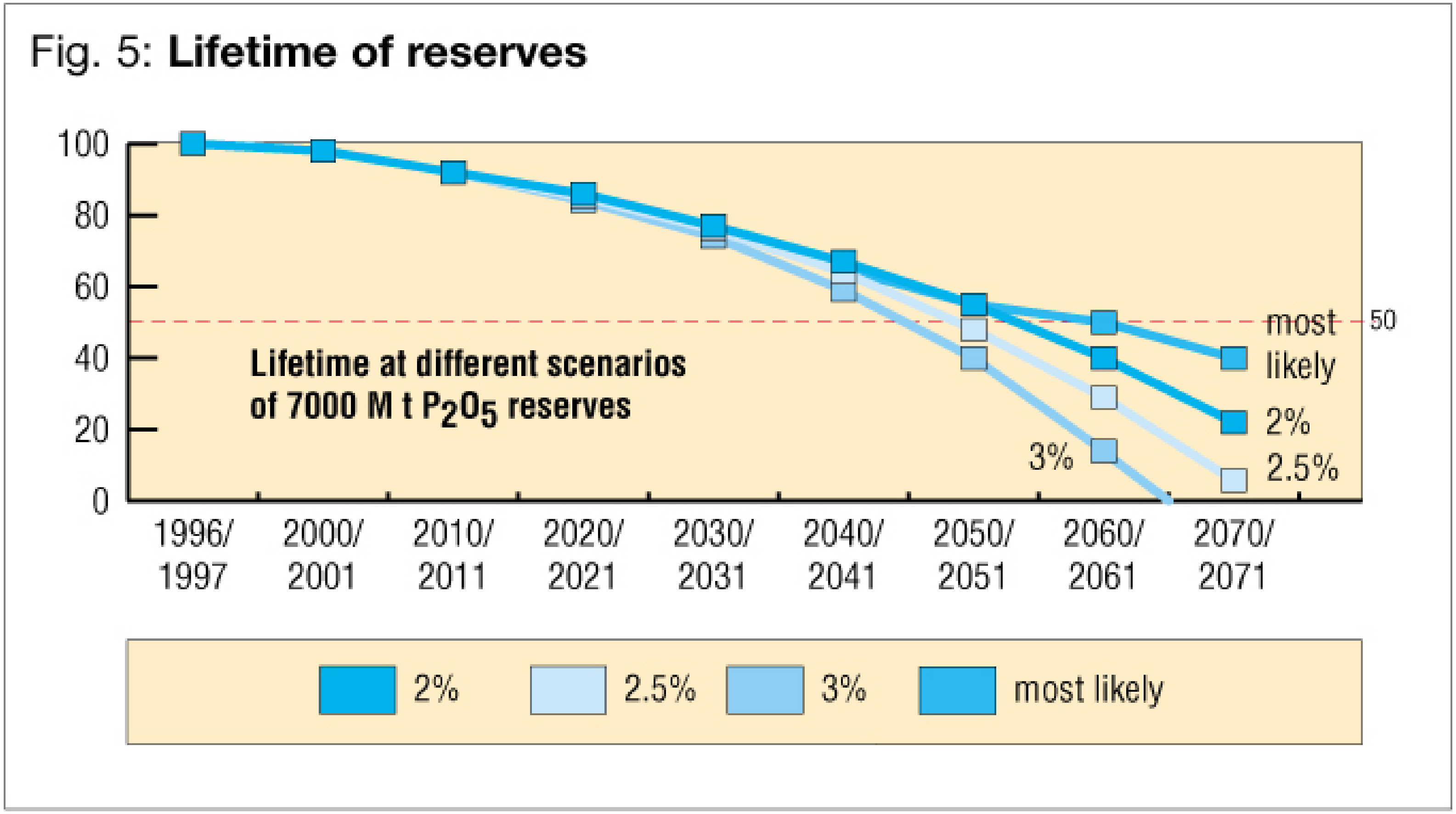
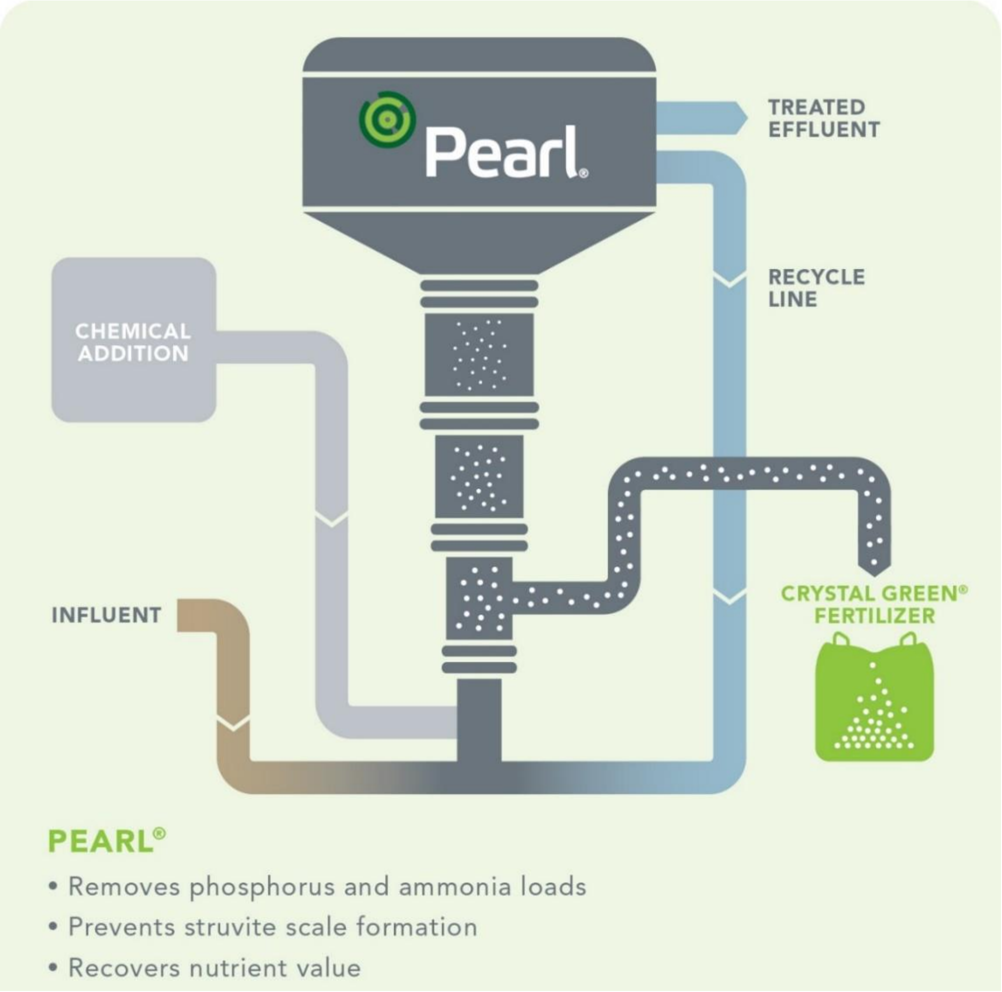


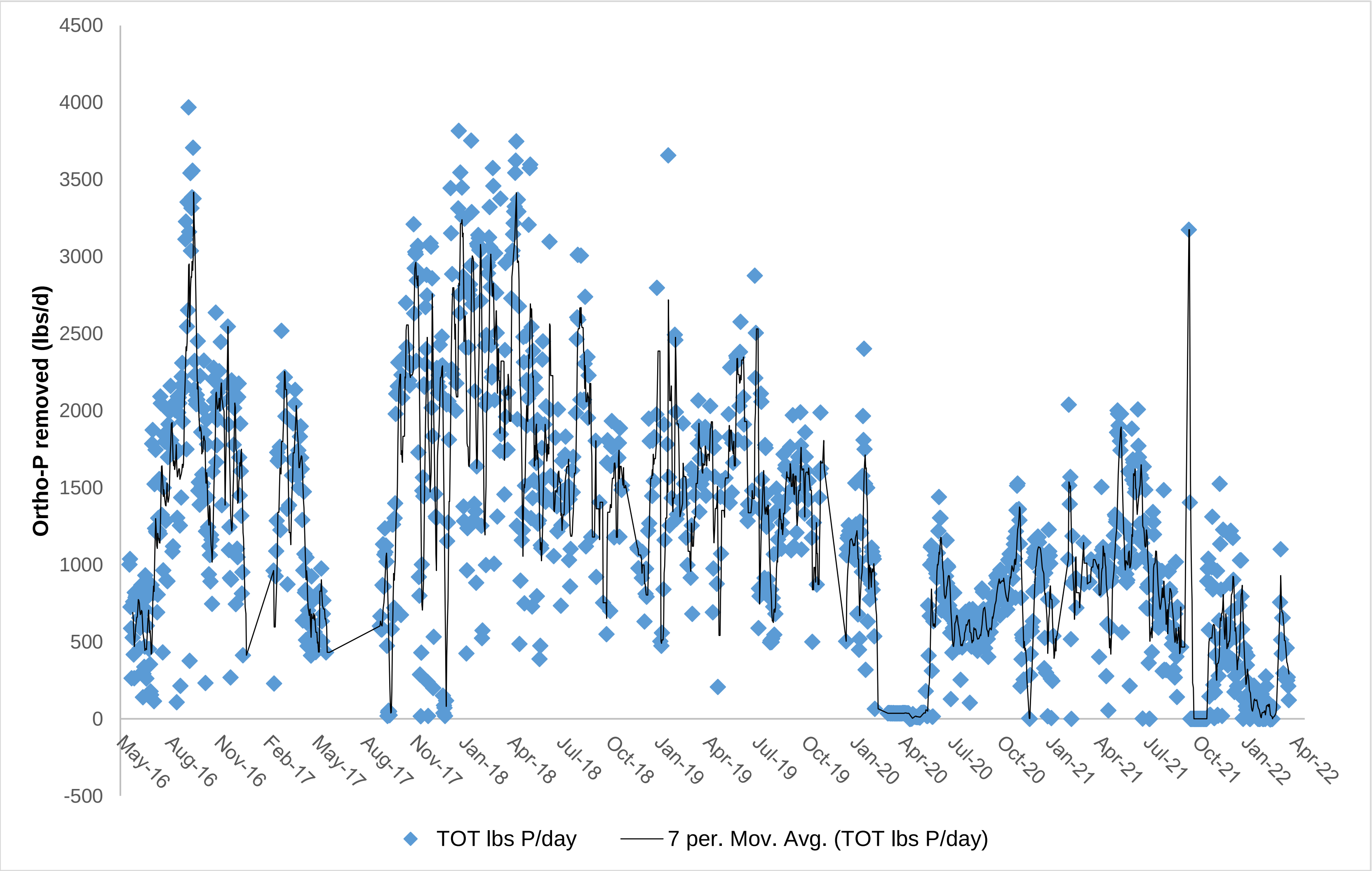
Fig. 5: Lifetime of reserves
100
80
60
40
20
0
Lifetime at different scenarios
of 7000 M t P_2O_5 reserves
50
most
likely
2%
2.5%
3%
1996/ 1997
2000/ 2001
2010/ 2011
2020/ 2021
2030/ 2031
2040/ 2041
2050/ 2051
2060/ 2061
2070/ 2071
2%
2.5%
3%
most likely

Ostara® post-centrate treatment

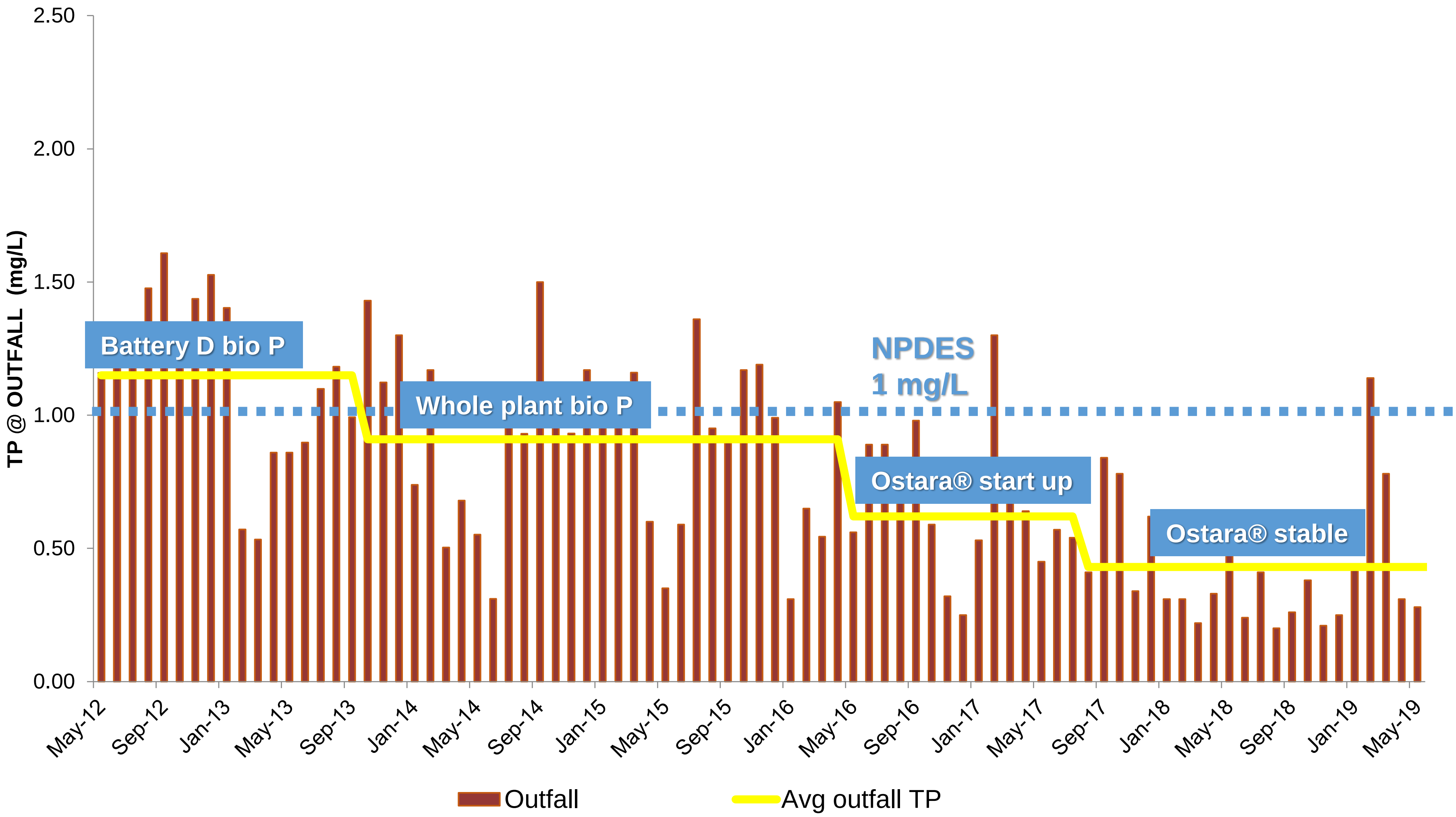
- Influent and recycle flow pumped upward through the bottom of the fluidized bed reactor
- Supersaturation conditions (driving force)
  - Inject NaOH to raise pH to 7.7/7.8
  - Reactor operating pH can range from low 7s to low 8s depending on water quality and characteristics.
  - Inject $MgCl_2$ at a molar ratio of 1.1 to 1 (Mg to P)
  - Spontaneous crystal nucleation occurs
- As chemical driving force reduces, deposition on surface of crystals occurs
  - Thermodynamically favorable as surfaces reduce chemical energy needed for precipitation
- Struvite crystals grow through this deposition to pellets



Ostara® Daily Mass Removal

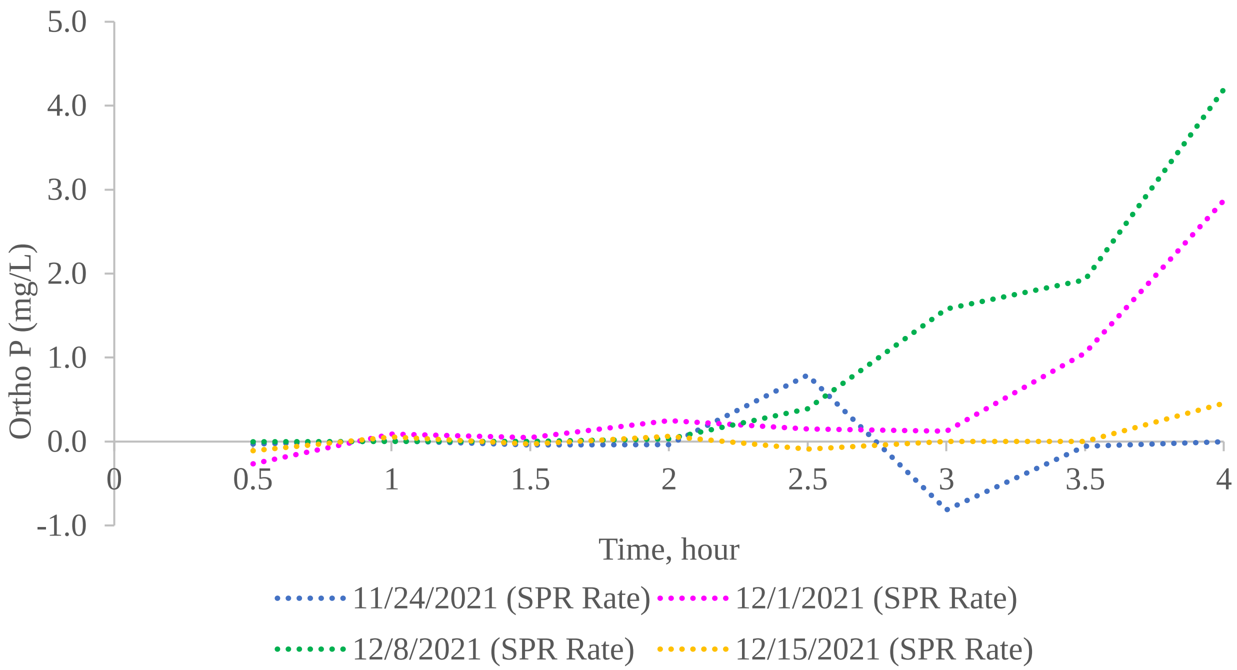


Sidestream Recovery Improved Effluent P

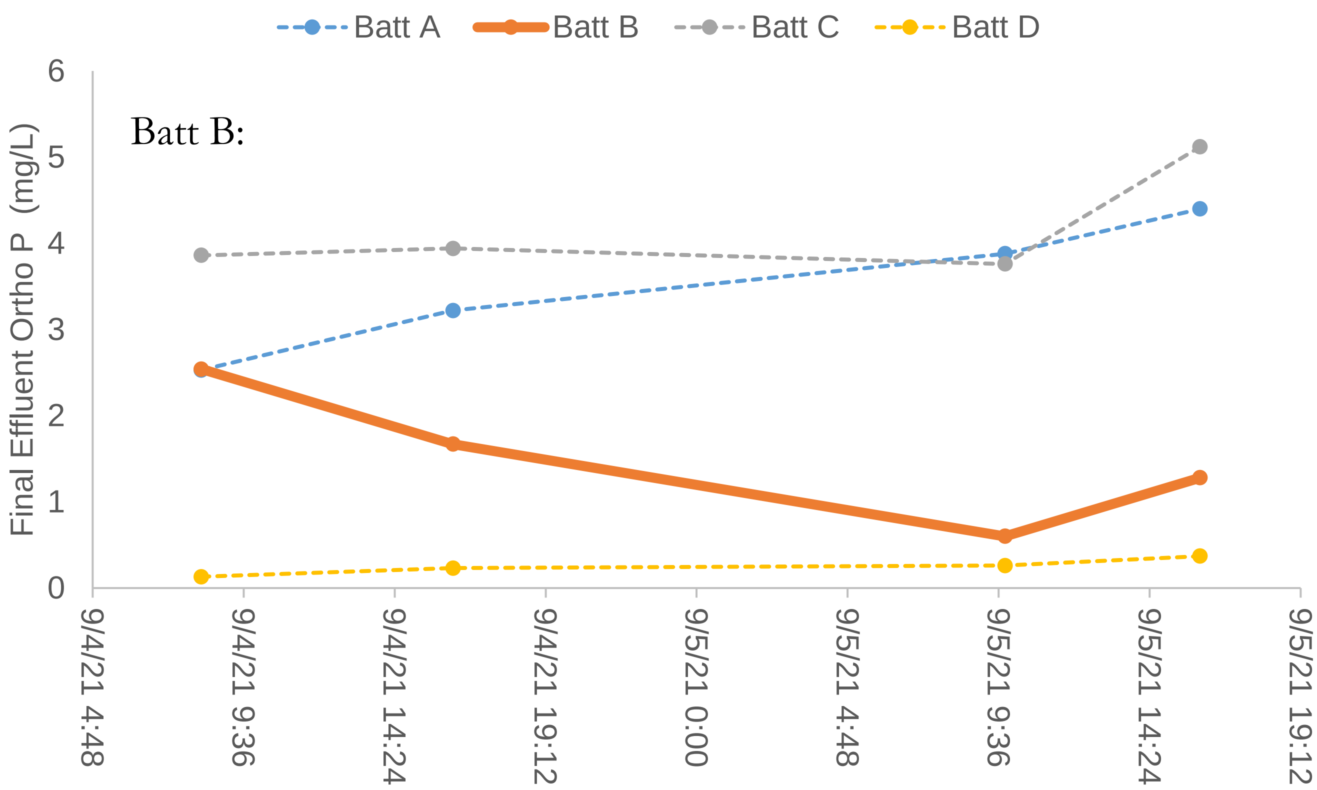


Other Optimizations

1. Secondary release during low flows
   - Idle final tanks to lower retention times
   - Pumping McCook and TARP in a “controllable” way
   - FT retention time < 2.2 hours preferred (800 MGD)
   - FT retention time 3 - 3.7 hours too long (400 MGD)



Reduce Secondary Release - Final Tanks Isolation



Easy to implement, however it takes a few shifts to put tanks back I/S.

Other Optimizations – Cont.

2. Seasonal Anaerobic zone setups
   - Longer Anaerobic zone in summer to promote inline fermentation and PAO conditioning
   - Shorter Anaerobic zone in winter to aid nitrification during cold weather

3. Ferric dosing
   - To help reliably meet the permit when Bio P not performing well

4. Elevated NH3-N led to better Bio P due to limited NO3-N return
   - Being a responsible environmental facility, we did not adopt this strategy

Temporary Chemical P System

To ensure Stickney WRP reliably meet the permit, a temporary ferric dosing system was constructed.

Two 6,500-gallon storage tanks

Dose to all four batteries, mixing channel

Contract 19-159-3P: Chemical P Facility

- 5x16,600-gallon fiberglass tanks
- 5-day storage
- Dose to all 4 batteries
- Dose to the effluent ML
- Expected completion by August 2023

Multivariable Operations

Influent Flows
(Avoid secondary release & negative impact from recycle stream @ low flows)

Recycle Streams
(Ostara)

Influent characteristics
(Bio P C:P requirement)

Others
(Seasonal)

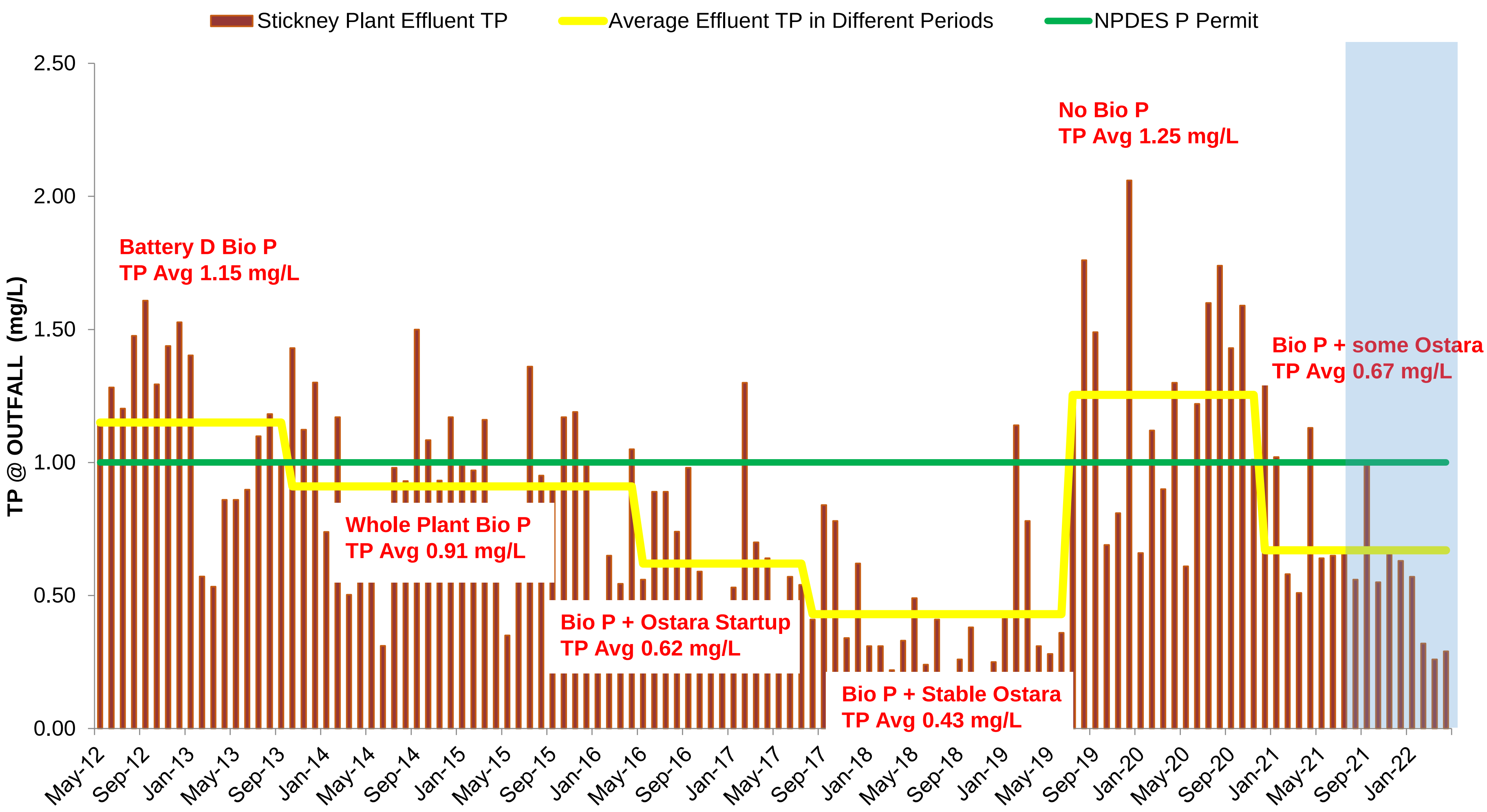
Optimized Bio P Performance and SS Removal
(Low effluent ortho P and SS)

Chemical Polishing When Necessary
(Meet the TP Permit)

Collaborations and Team Works

- Weekly Interdepartmental meetings to discuss
  - Plant performance
  - Proactive plans
  - Progresses of ongoing capital projects

Stickney Outfall Monthly Average TPs



Ongoing Operational Challenges

- Biology takes time to acclimate to the operational changes
  - Be patient and be proactive
  - Ability to cross-seed batteries

- Ostara® not staying online consistently can cause unstable Bio P performance

- Low flows, especially in Summer and Fall when influent unfavorable to Bio P, and during pandemic
  - Although we have implemented many measures to address the issue, we are still struggling under these conditions

Ongoing Operational Challenges – Cont.

- Solids settled in the unmixed channels and scums floats on top of the unaerated channels
  - Routine bumping – weekly

- First flush DO sags caused effluent NH3-N and P spikes
  - Additional air prior to rain which could mitigate the spikes, however, can not eliminate spikes

- Temporary chemical dosing system – unstable pumping rates
  - Maintain minimum pump rates to keep primed
    - Pump 1 minimum 4 GPM; Pump 2 minimum 0.5 GPM
  - TPOs check on pump status frequently

- P analyzer Issues
  - More Hach kits tests to avoid flying blindly

Ongoing Operational Challenges – Cont.

- Winter solids
  - Loss of nitrification capacity due to anaerobic zone
  - Recommendation to increase MLSS to accommodate nitrification needs
  - High solids make us more prone to SS washout
  - SWRP solids exhibit great settling characteristics (SVIs in the high 50s) but not when we go from 400 MGD to 1,440 MGD, poorer settling observed

- New processes would require new operational strategies
  - West Side primary settling tanks
  - McCook Phase 2 Reservoir (6.5 MG) online in 2029

Conclusions

- Stickney WRP met the NPDES P permit
  - Capital improvements
  - Operational improvements

- However,
  - Still lots of ongoing operational challenges to be addressed
  - Ongoing optimization to achieve stable Bio P performance

Acknowledgements

M&O Staff

- Management-guidance and consultation in converting Stickney to bio P
- TPOs – making the field adjustments
- Trades – installing monitoring equipment

Engineering Department

- Overseeing construction of Ostara®, mixers, fermenter, and permanent mainstream chem P facility

ALD Staff

- Analyzing the countless samples

M&R Staff

- EM&RD Technicians – running all bench scale experiments & collecting countless field samples
- Microbiology – many, many, many PAO analyses

Thank you!

Questions?

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