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# Phosphorus Removal

Bench Scale and Full Scale Pilots that Result in Improved Phosphorus Removal

October 9, 2014

Wisconsin Wastewater Operators Association  
Annual Conference



Presented By:  
Troy A. Larson

**Strand Associates, Inc.**®

# ■ Today's Seminar Outline

- *Control Parameters That Impact Performance*
- *Jar Testing that Simulates Process Needs*
- *Full Scale Testing*
- *Automation and In-line Monitoring*

# ■ Presentation Will Not Focus on Emerging Technologies

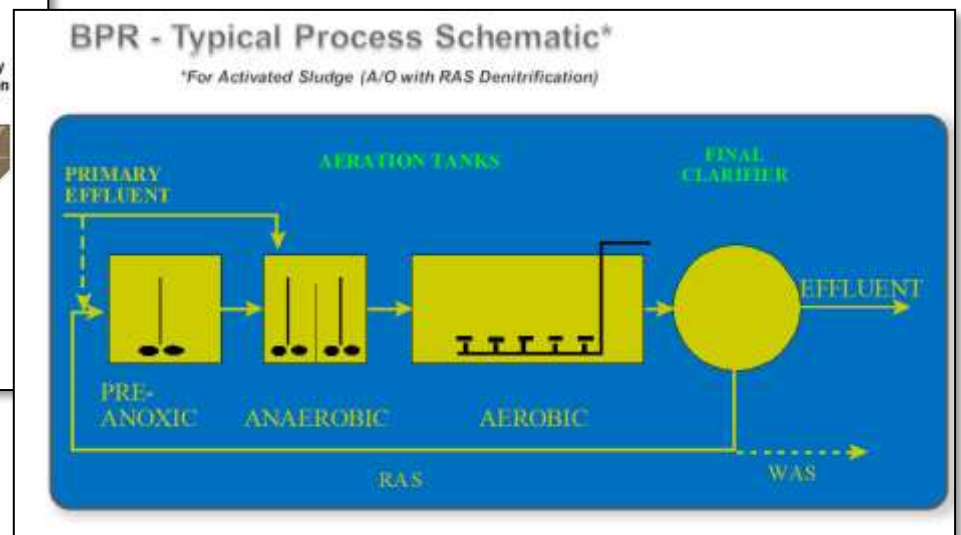
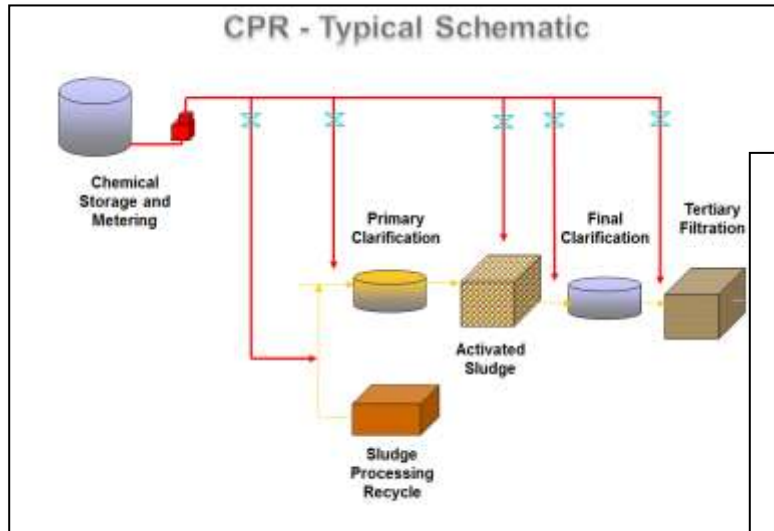


**Parkson Pilot - Manitowoc**



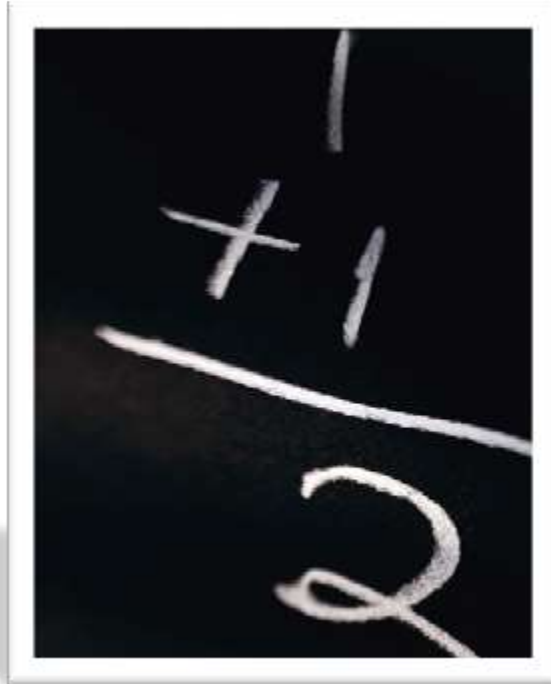
**CoMag Pilot – Fond du Lac**

# ■ Presentation Will Focus on Optimizing Current Technologies



Necessity... the mother of invention.  
Plato

# Phosphorus Removal Basics



# ■ Chemical P Removal - Principles

## Methods of Phosphorus Removal

- Chemical Phosphorus Removal
  - Add lime, iron, or aluminum salt
  - Precipitation/adsorption of soluble phosphorus
  - Relatively simple process
  - Higher sludge production
- Biological Phosphorus Removal
  - Facilitate growth of Phosphorus Accumulating Organisms (PAOs)
  - More complex/higher risk
  - Lower sludge production than with chemical addition

# Jar Testing Should Provide Lab Scale Simulations of Full Scale Considerations



# ■ Jar Testing in Proper Context Provides Value

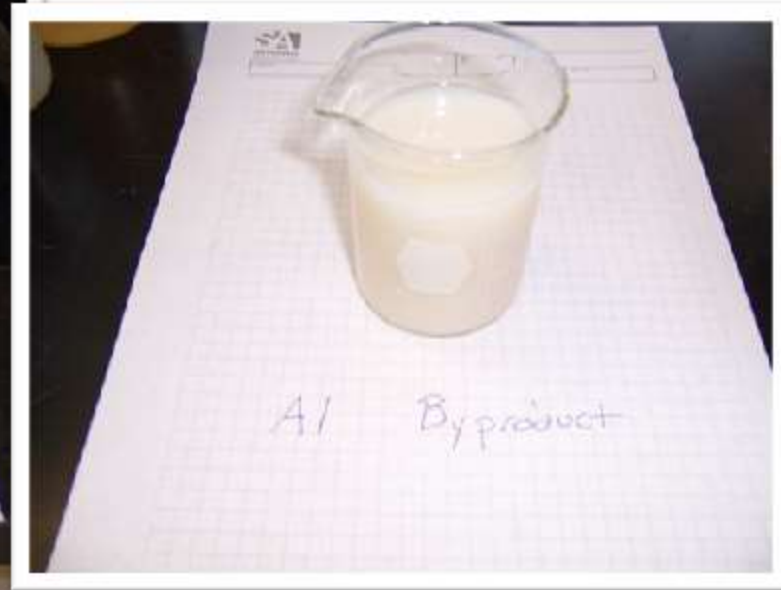
- Strengths of jar testing include:
  - Low cost
  - Easy comparison of many conditions
  - Provides proof of concept
  - Allows communication and training
- Limitations of jar testing include:
  - Jar tests do not always scale-up
  - Long term operation not always reflected
  - Full scale conditions can not always be mimicked

# ■ Bench Scale Testing for CPR Determines Key Parameters

- Precipitation/Adsorption Reactions
- Dose Rates and Costs
- Side Effects
  - pH Depression
  - Alkalinity Loss



# Jar Testing Allows Low Cost Comparisons



Aluminum Byproduct

Left to Right – Ferric Chloride, Alum, SorbX

# Jar Testing Provides Visual Comparisons



Impacts on Sludge Production

# ■ Jar Testing Provides Visual Comparisons



Impacts on Clarity

# Jar Testing Provides Visual Comparisons



Jar 1



Jar 2



Jar 3



Jar 4



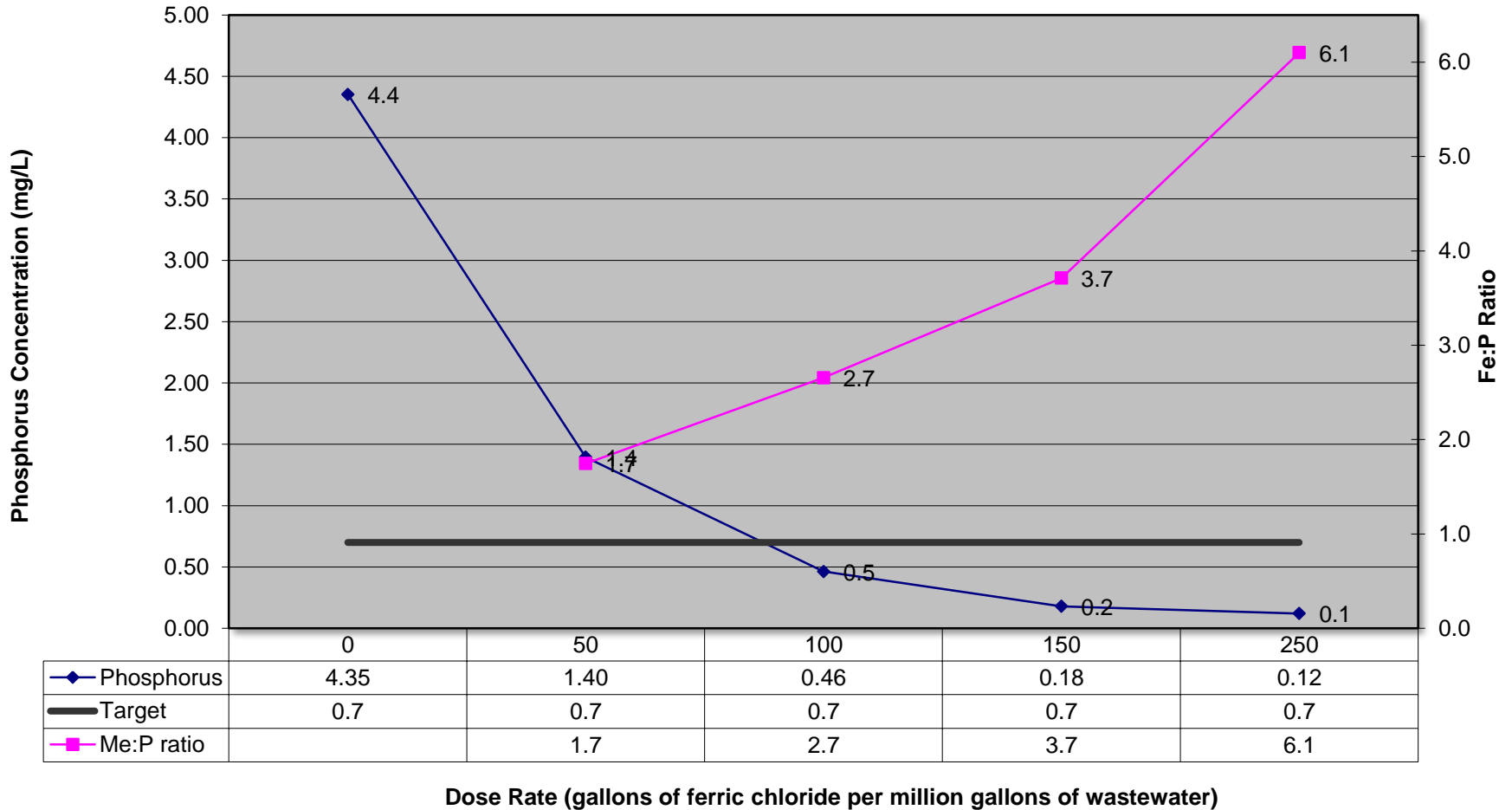
Jar 5

# ■ Jar Testing Provides Visual Comparisons



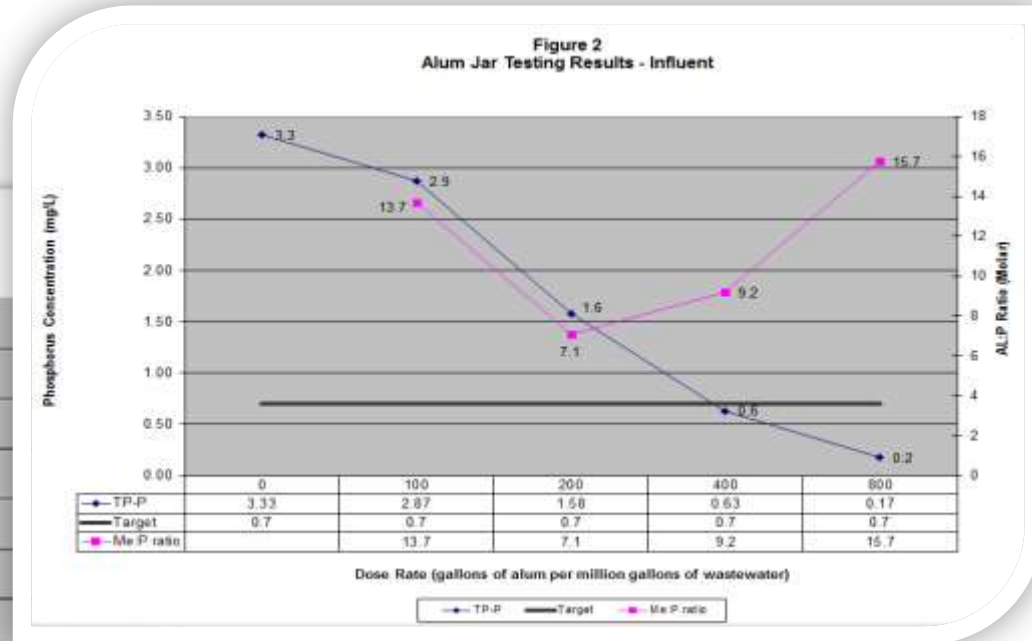
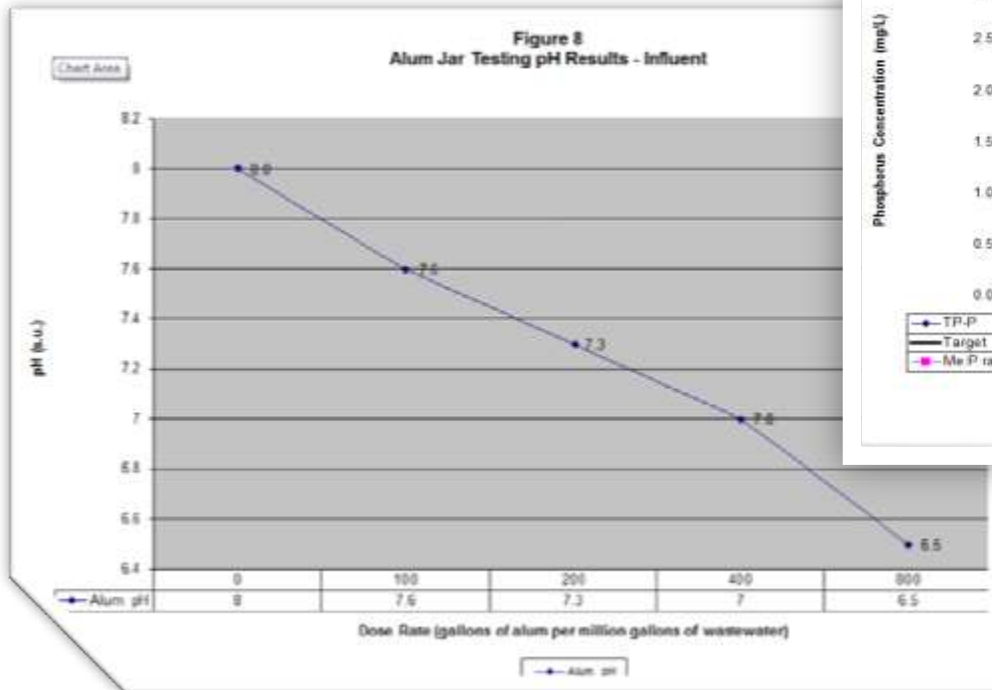
# Typical Jar Test Result

Ferric Jar Testing Results

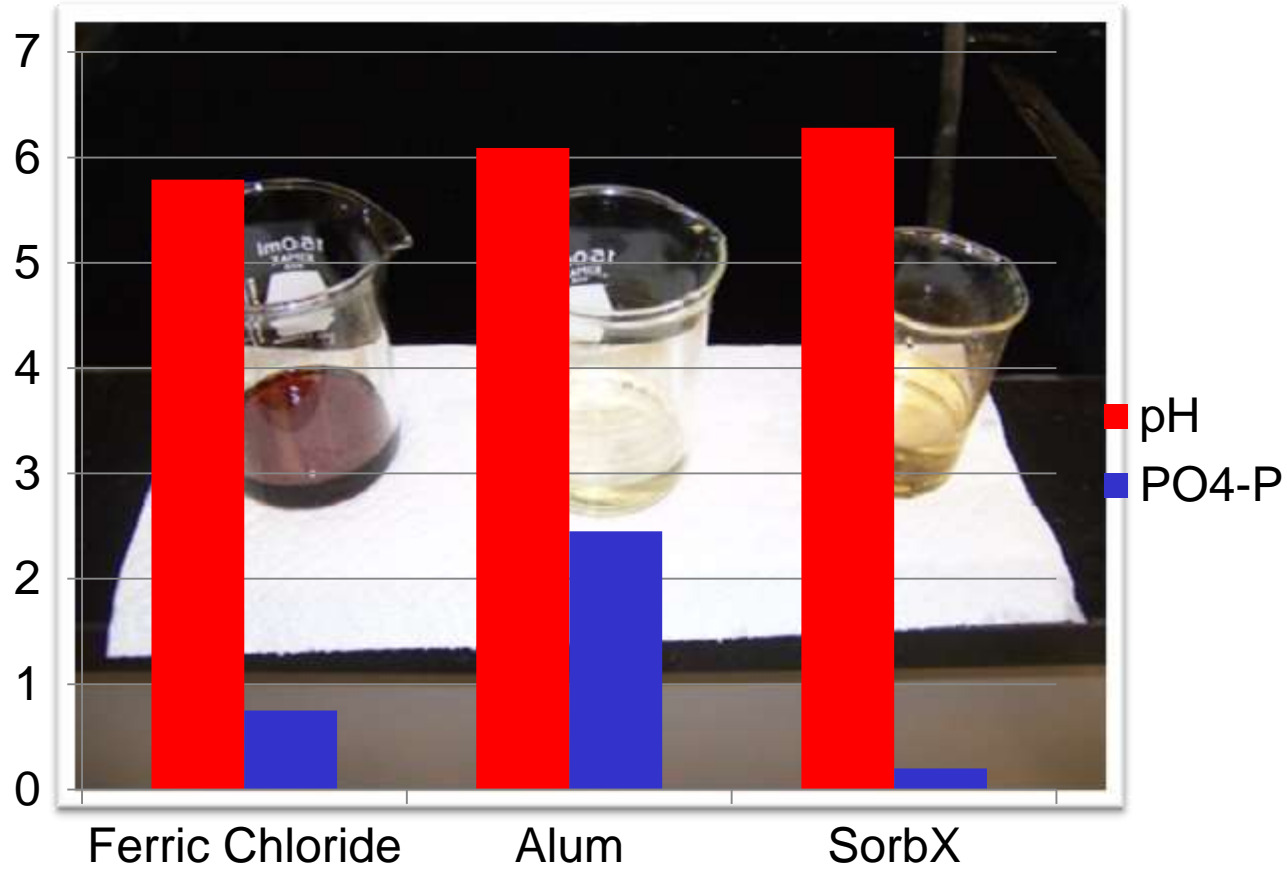


◆ Phosphorus — Target ■ Me:P ratio

# High pH Results in High Chemical Needs



# Emerging Chemical Performance Suggests Future Consideration Warranted

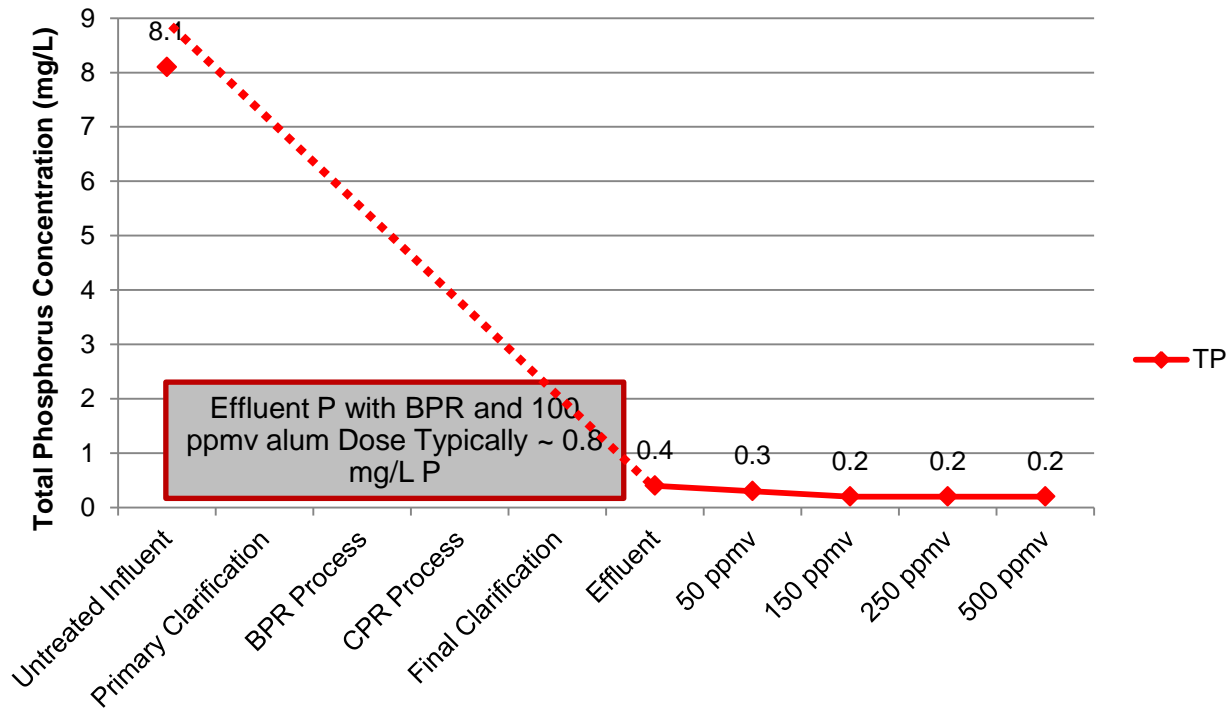


Results illustrate pH impacts and phosphorus results for comparing three chemicals at the same volumetric dose rate. SorbX removed the most phosphorus and had the lowest impact on pH

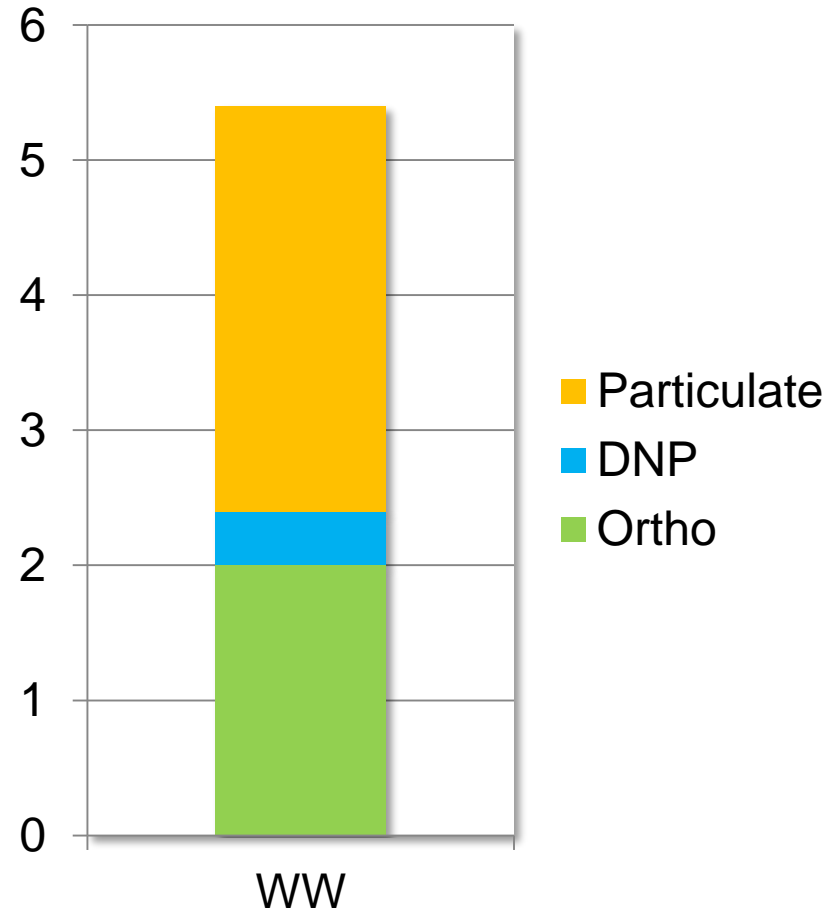
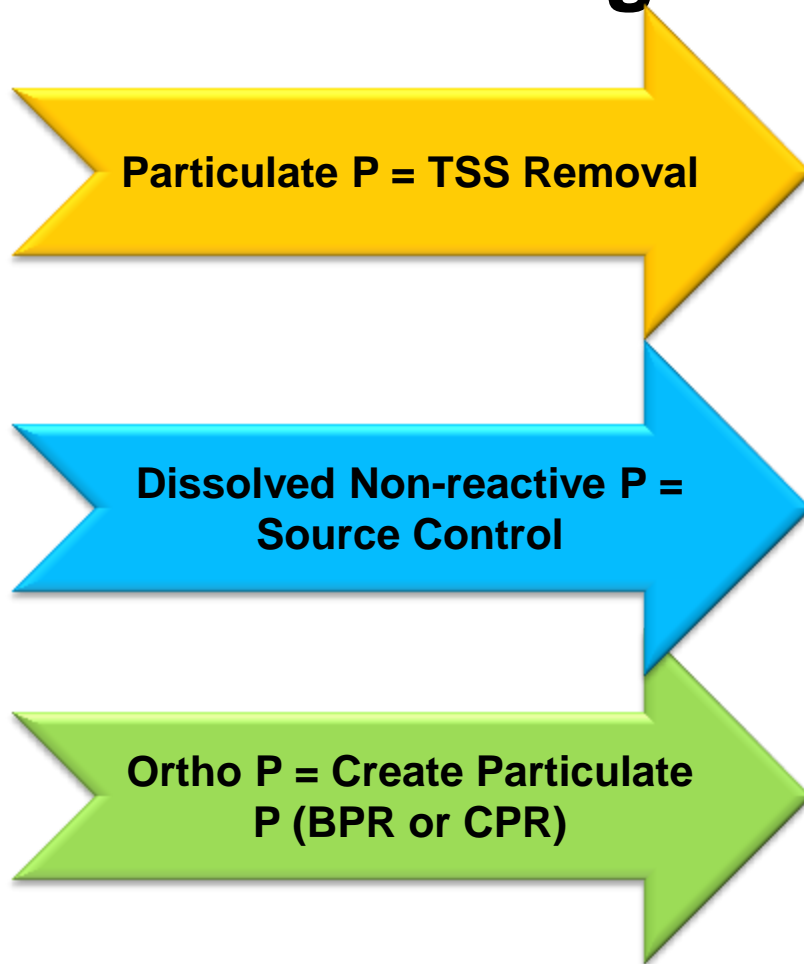
# Jar Stress Tests Can Isolate Performance

- Samples Filtered
- Lowest P level achievable

## Total Phosphorus - Bench Scale Stress Test



# ■ Proper Phosphorus Characterization Provides Targeted Actions



# Evaluation of Industrial Byproduct

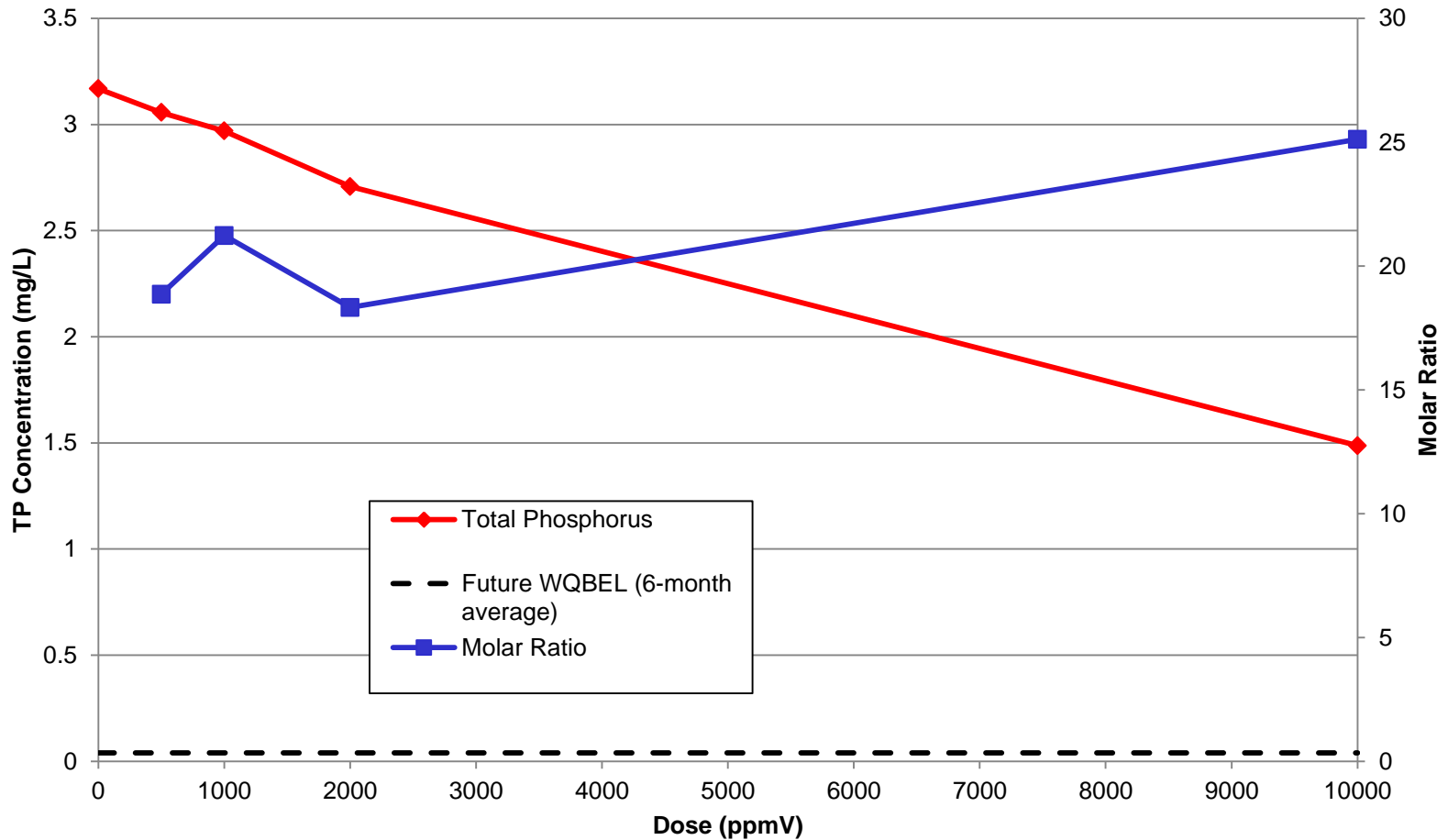
## Develops a Cost/Benefit Understanding

- Characterizations
  - Metals
  - Organics
  - pH
  - Other
- Negatives
  - Settles
  - Inconsistent
- Positives
  - Provides some P removal



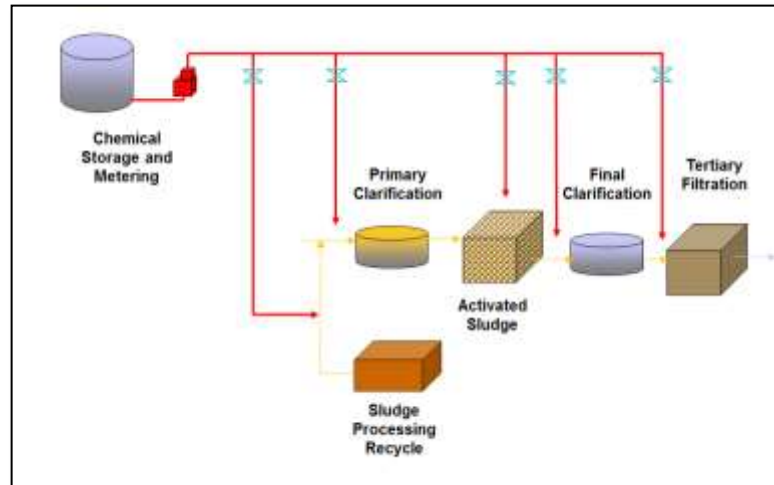
# Evaluation of Industrial Byproduct

## Primary Influent - Aluminum Byproduct



# ■ CPR Pilot – Multiple Application Points

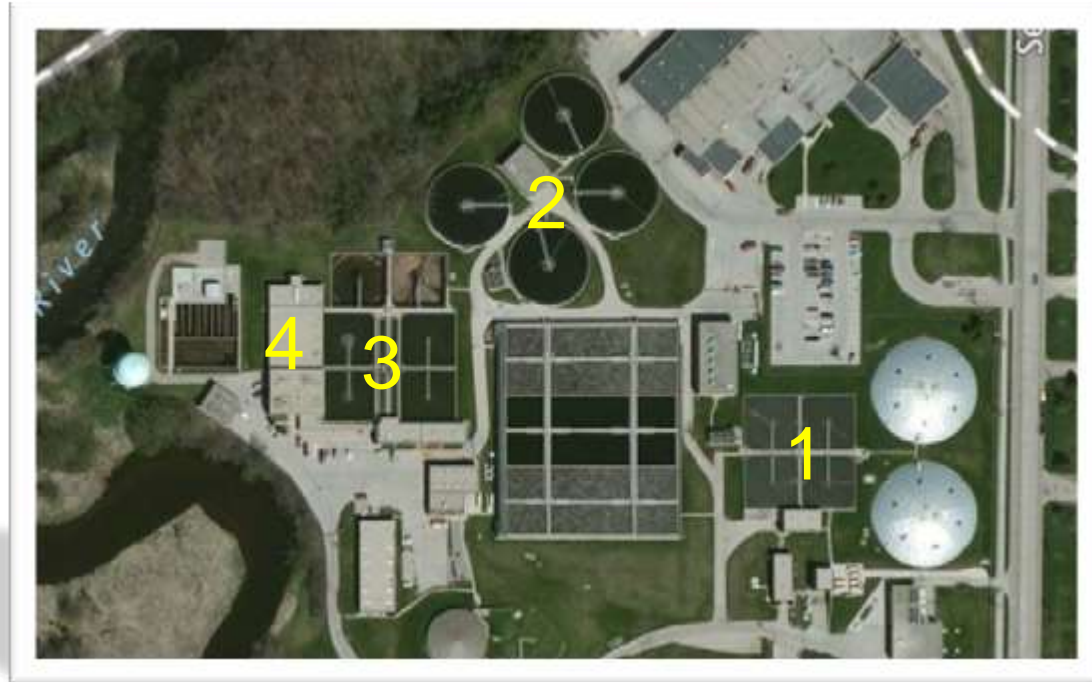
- Multiple Application Points
  - Reduce losses to competing reactions
  - Potentially develop residual value in multiple systems
  - Inherent redundancy



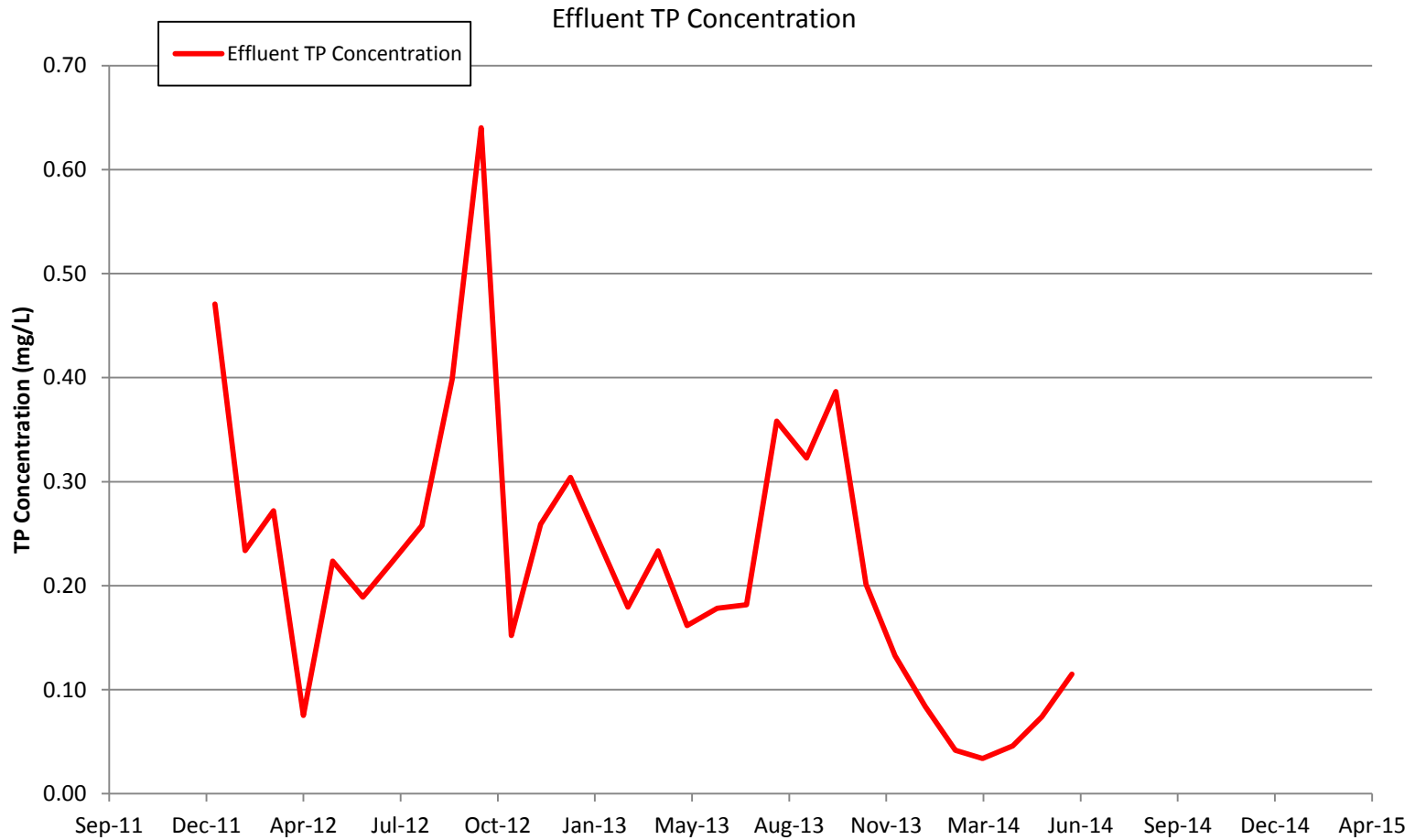
# ■ Each Facility Offers Unique Opportunities

Phosphorus is removed where solids are removed, such as:

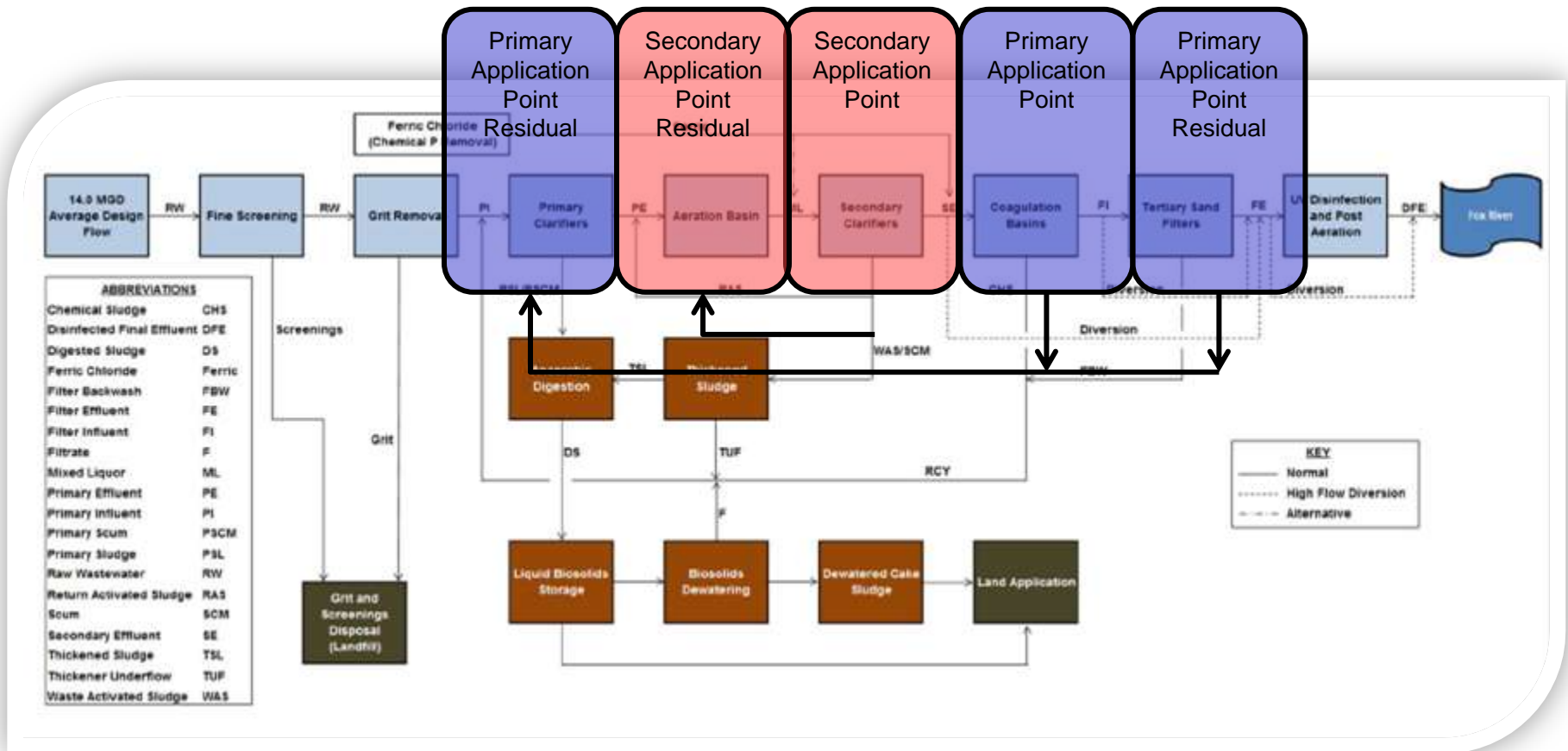
1. Primary clarifiers
2. Secondary clarifiers
3. Tertiary clarifiers
4. Filters



# Baseline Data

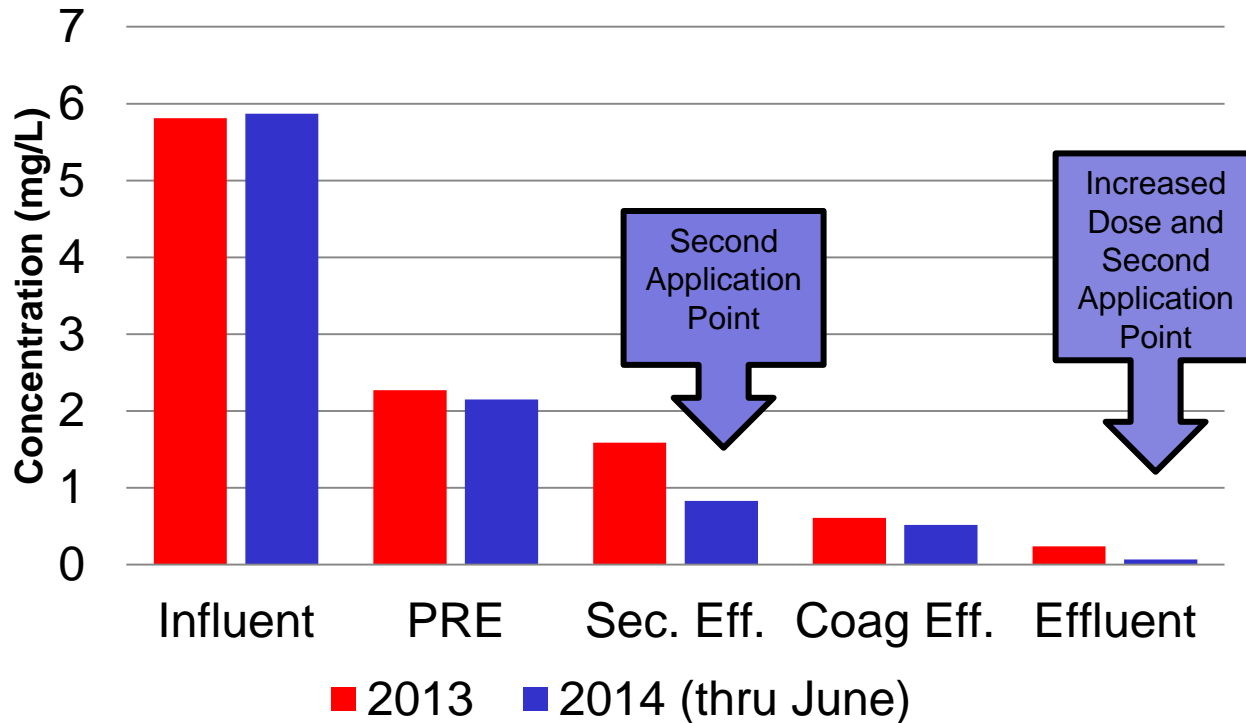


# Multiple Application Points Result in Multiple P Removal Mechanisms



# ■ Understanding Removal Mechanisms Improves Process Understanding

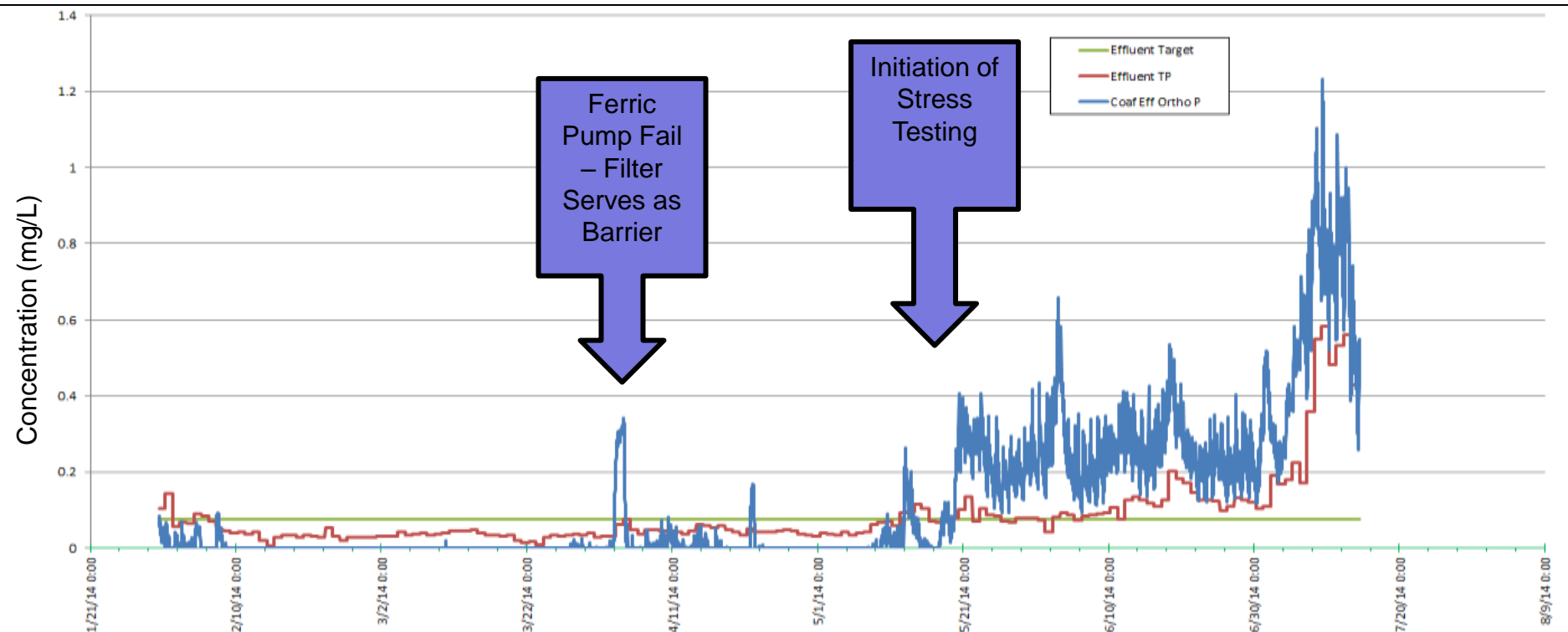
## Phosphorus Concentration



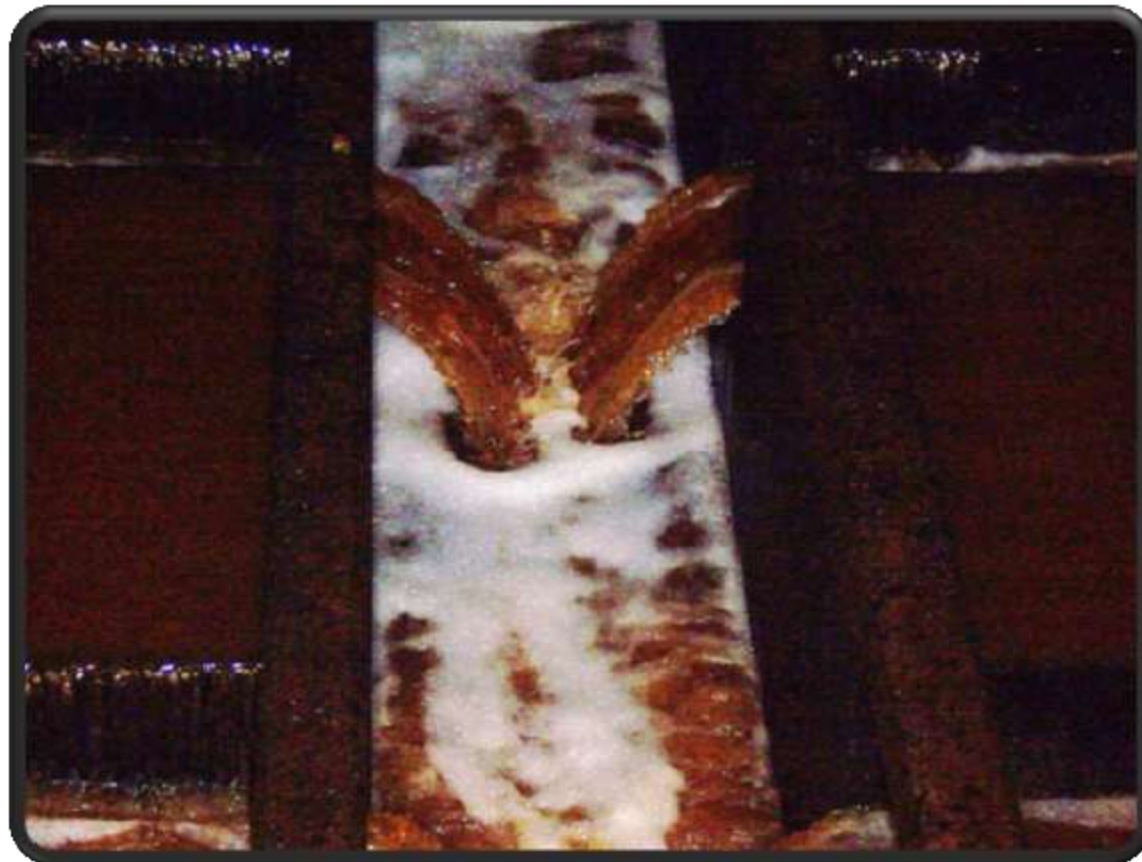
# ■ Waukesha – Monitoring: Upstream of Filter



# Full Scale Test and Stress Test



## ■ Filter (Backwash)

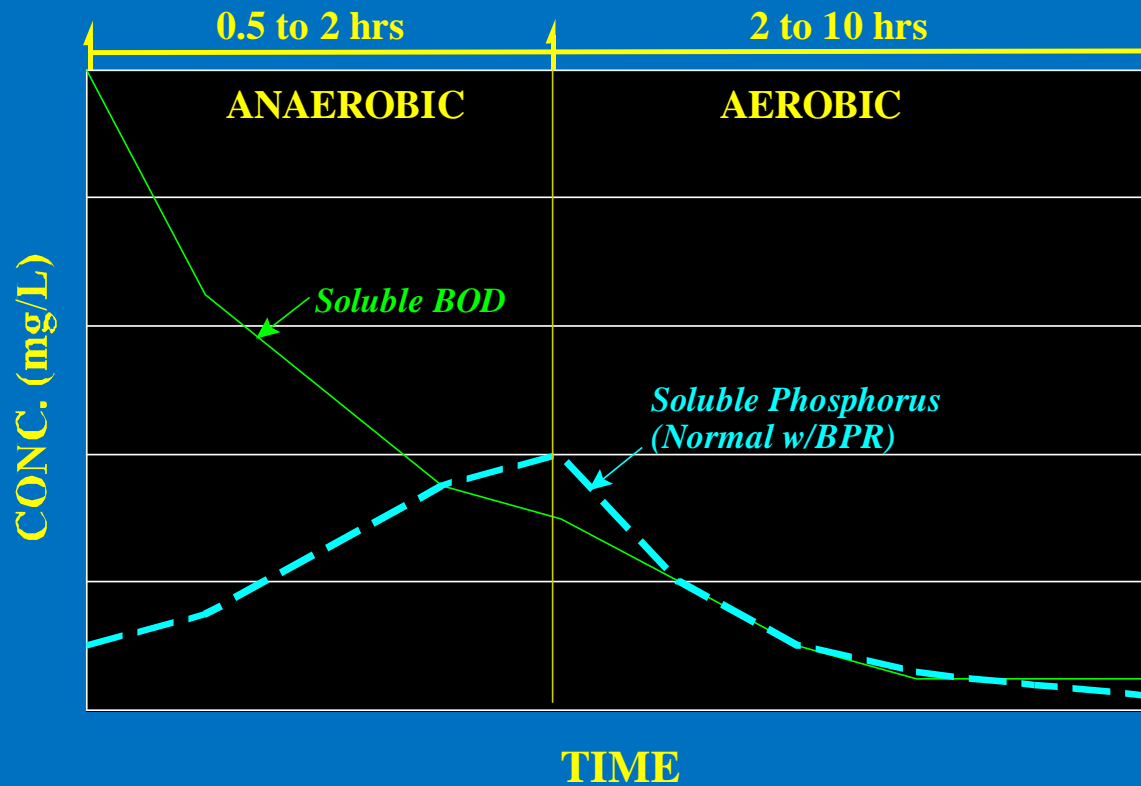


# BPR Pilot Tests Can Focus on Full Scale Trials With Little Capital Expenditure

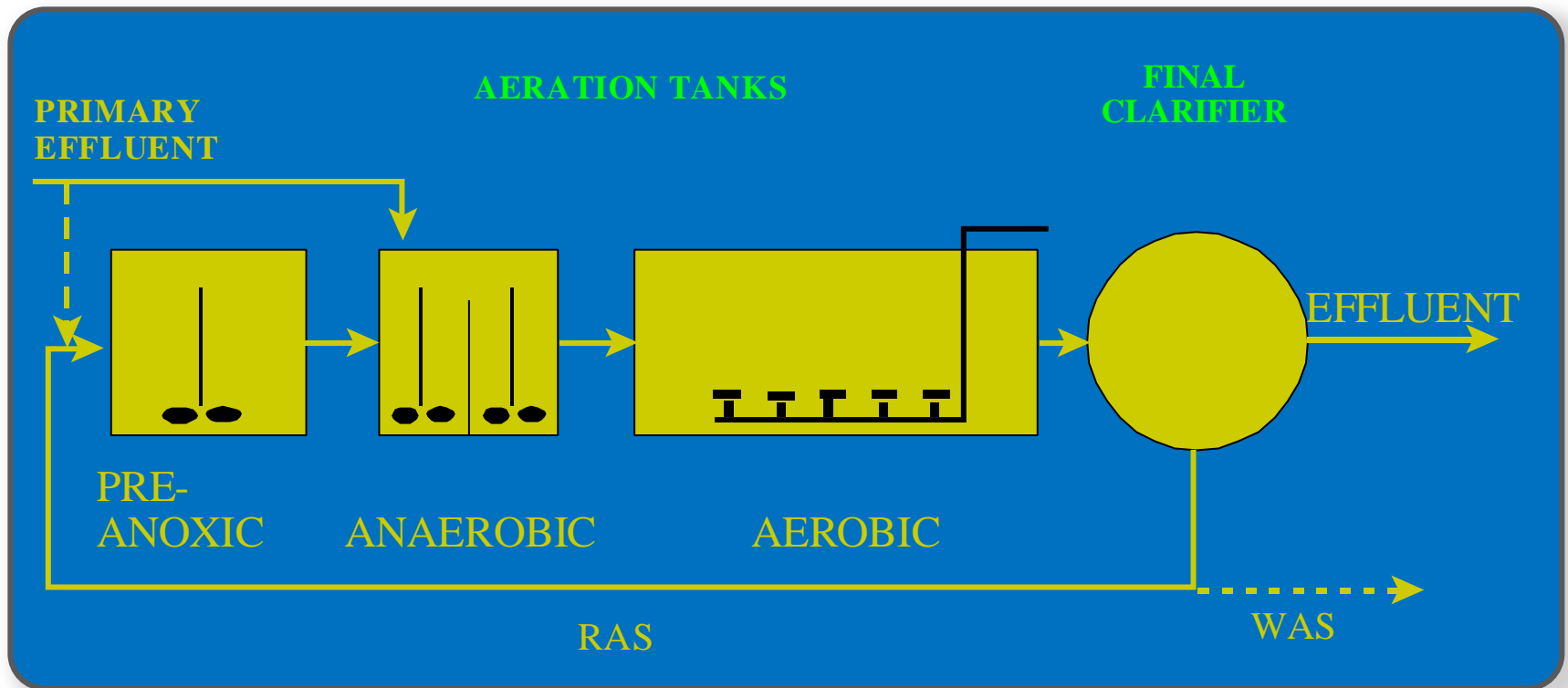


# ■ BPR Encourages Luxury P Uptake

Phosphorus cycle involves release in anaerobic zone, “luxury” uptake in aerobic zone



# ■ Typical BPR Process Schematic



*\*For Activated Sludge (A/O with RAS Denitrification)*

# ■ Pilot Considerations

- Cost Considerations
  - Consumables such as chemical
  - Engineering
  - Lab
  - Manpower
  - Utilities
  - Capitol Improvements
- Repeatability and/or Isolation
- Full Scale or Full Time Implementation
- Effluent Quality
  - Reliability
  - Termination Planning

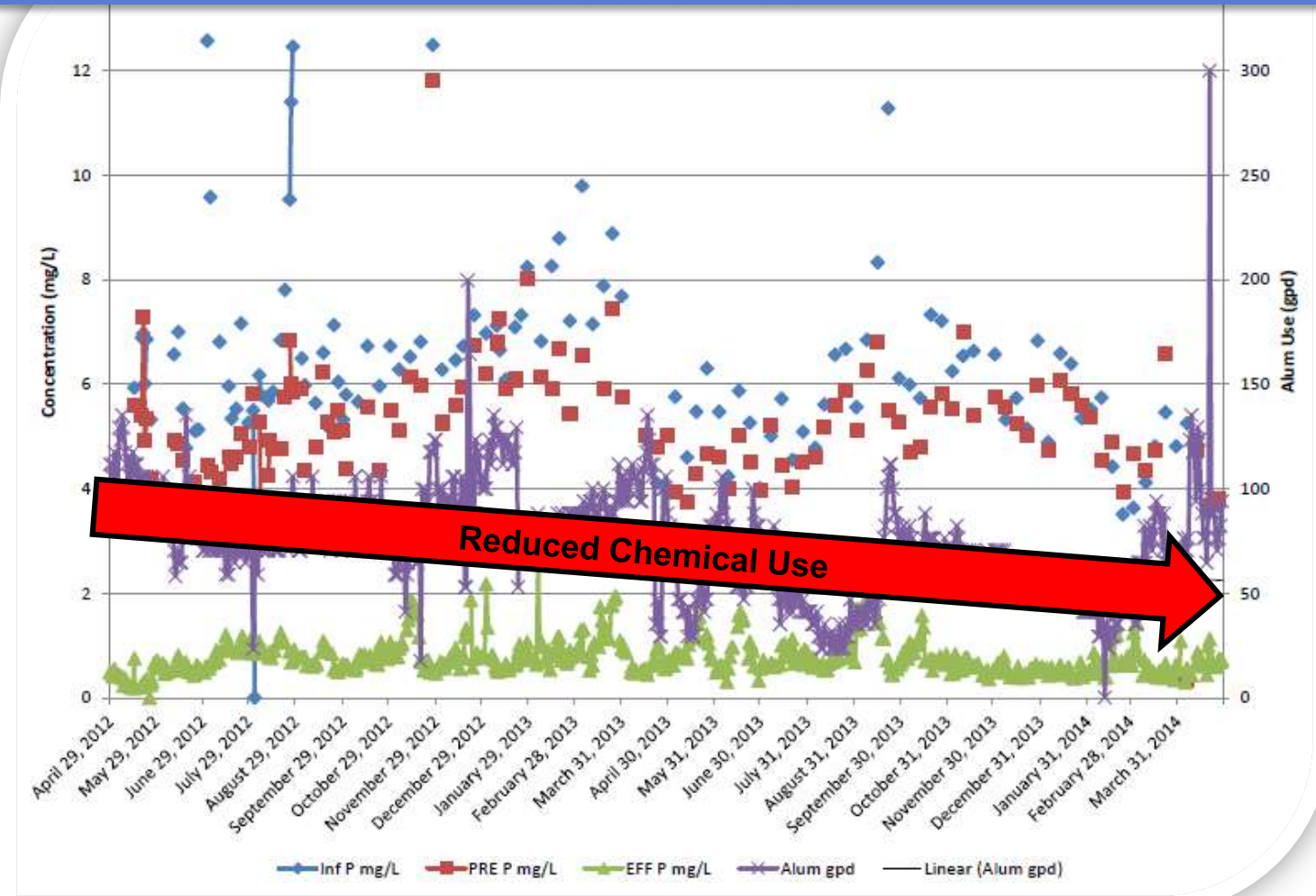
# ■ Full Scale Testing

## Full Scale BPR Testing in Conventional AS Plants

- Install cloth, wood, or block baffle walls and submersible mixers for ~2 zones; turn off air to zones
- Install temporary or permanent gates/piping as needed to route PRE/RAS where needed
- Measure SBOD, PO<sub>4</sub>, nitrate, and DO at various locations
- Monitor changes in sludge production and settleability/dewaterability

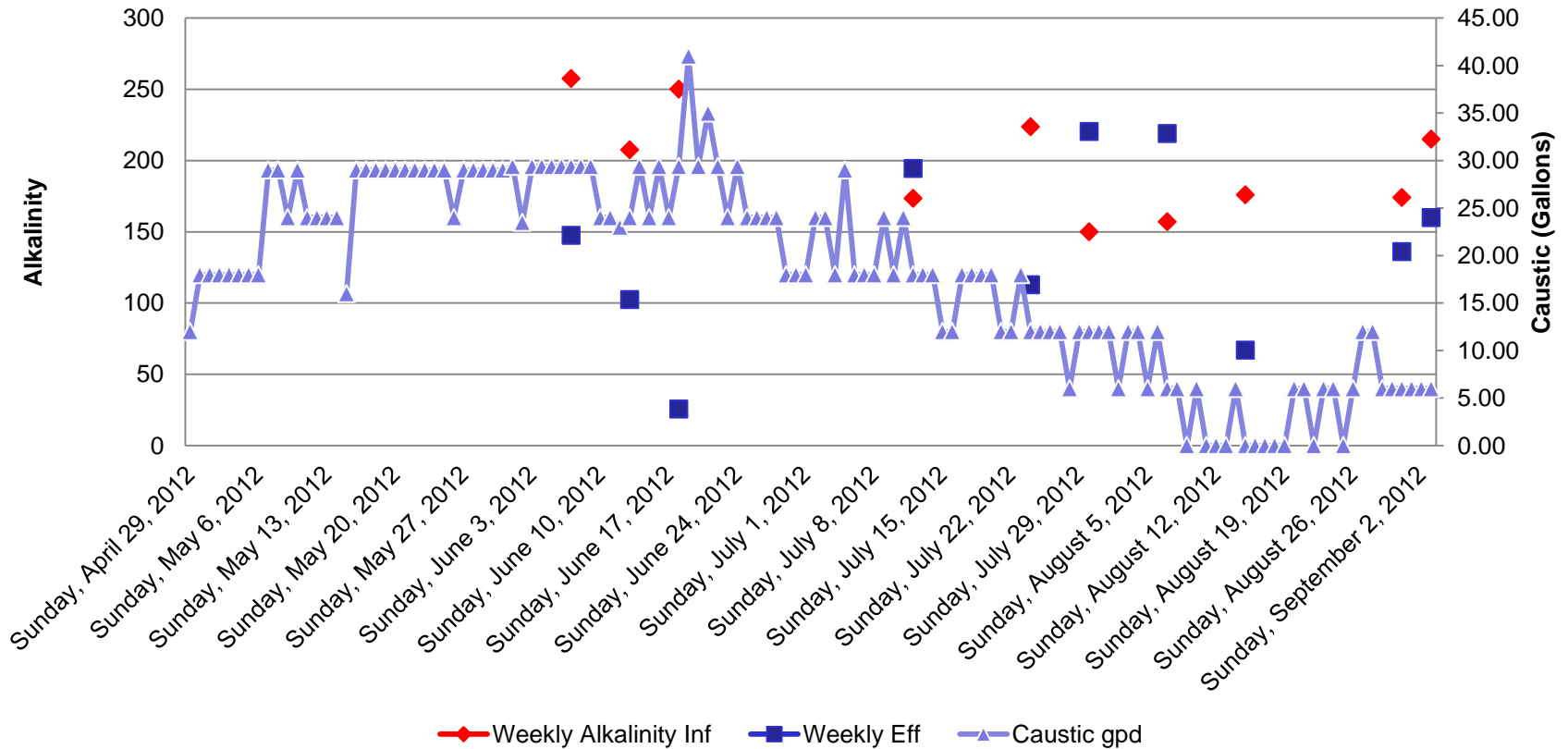


# Pilot Provides Long Term Treatment Benefits

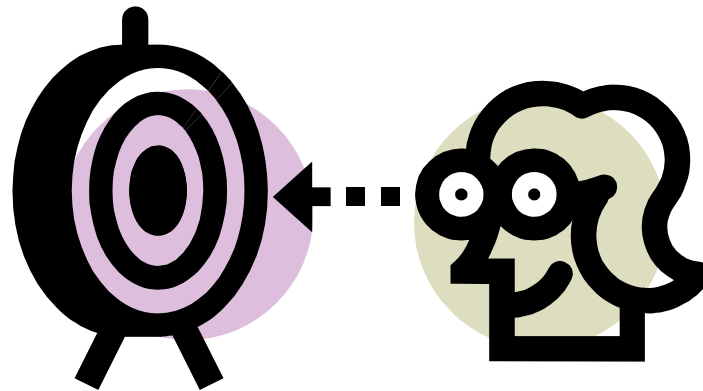


# Pilots Can Illustrate Ancillary Benefits

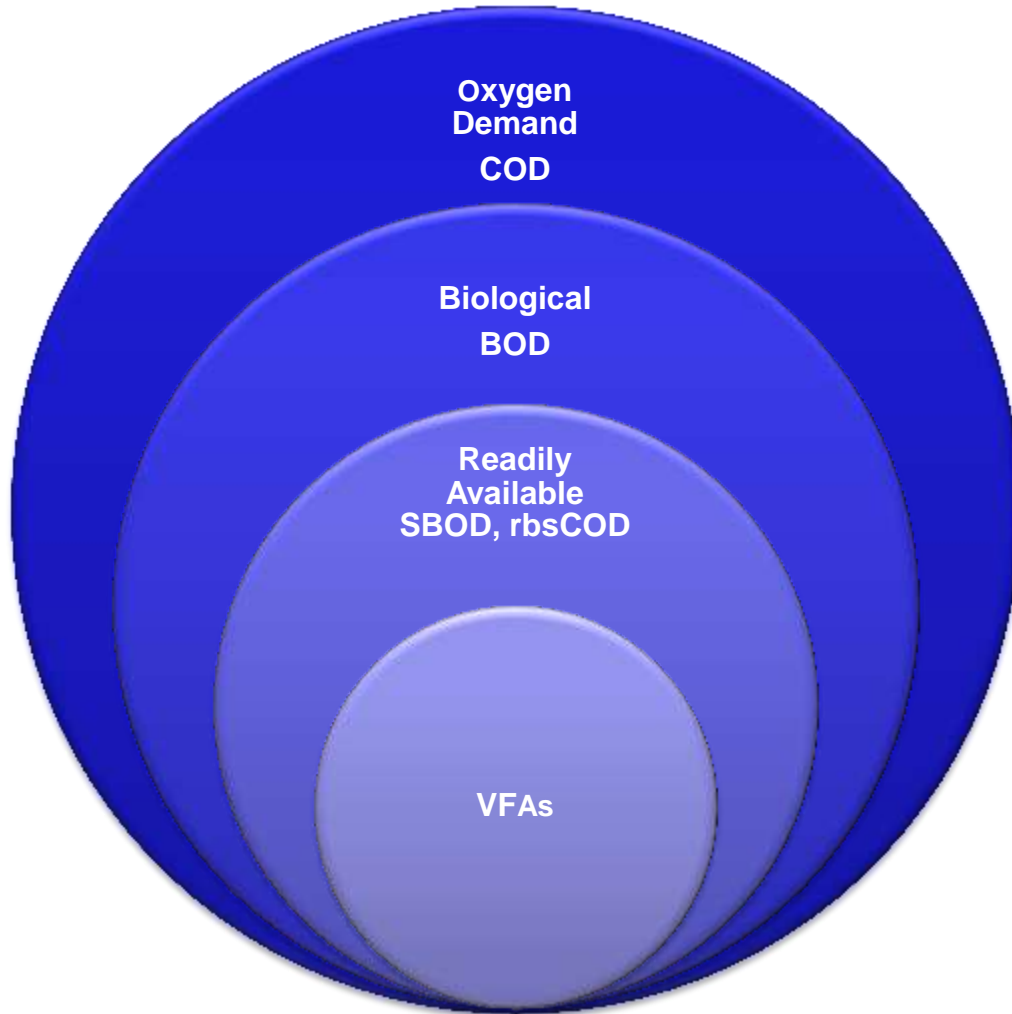
## Alkalinity



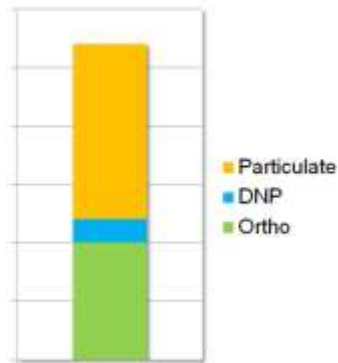
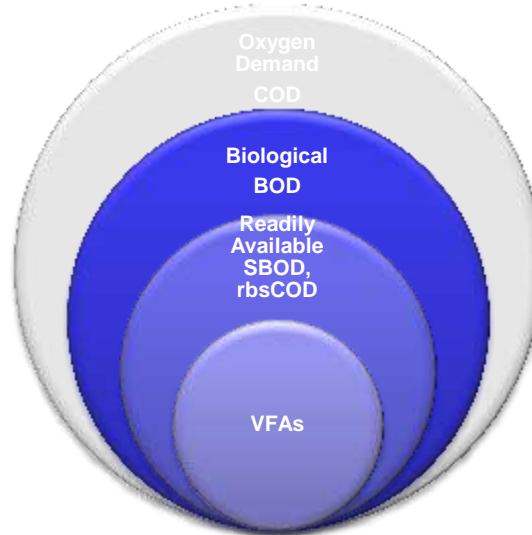
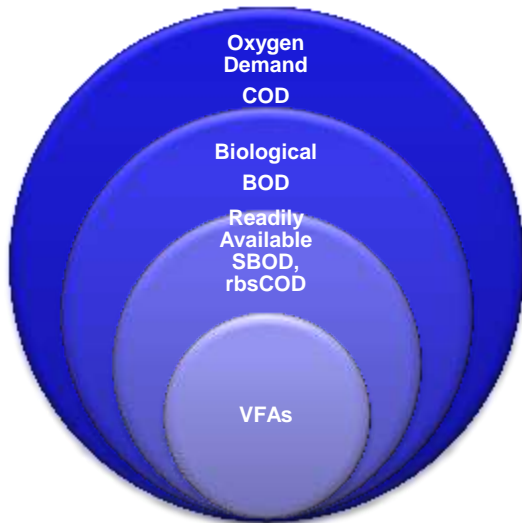
# Target Key Process Mechanisms by Piloting Operational Adjustments



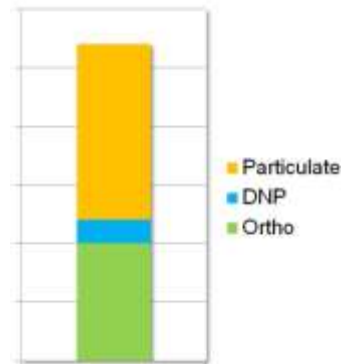
# ■ BPR Requires Proper Substrate to Support a Specific “Habitat”



# Organic Load Impacts Process Reliability



**COD:TP > 45**



**TBOD:TP > 20**

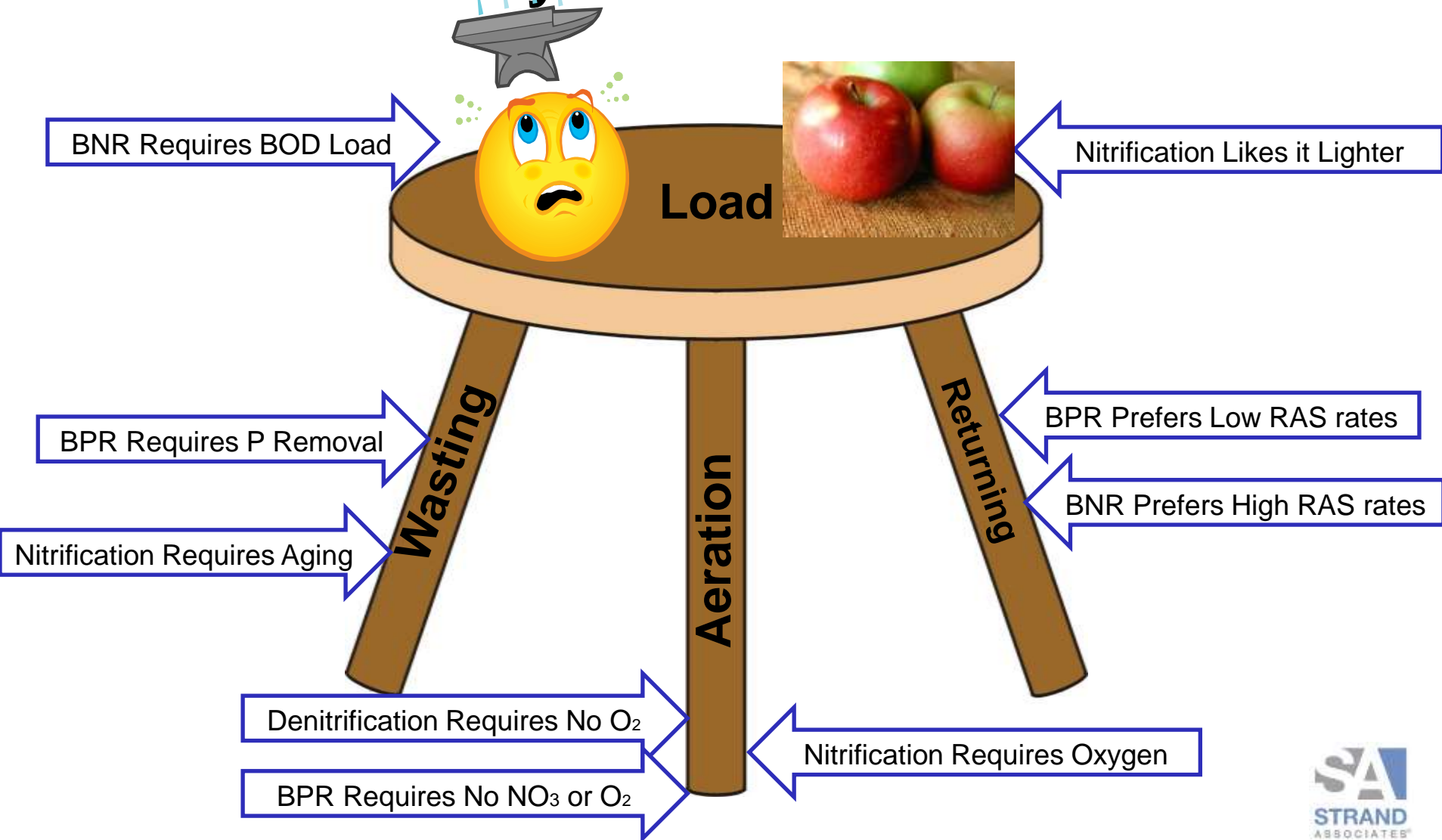
Because of the preference of the substrate VFA concentrations ultimately determine potential success.

7 to 9 mg of VFA required to remove each mg P.<sup>(1)</sup>

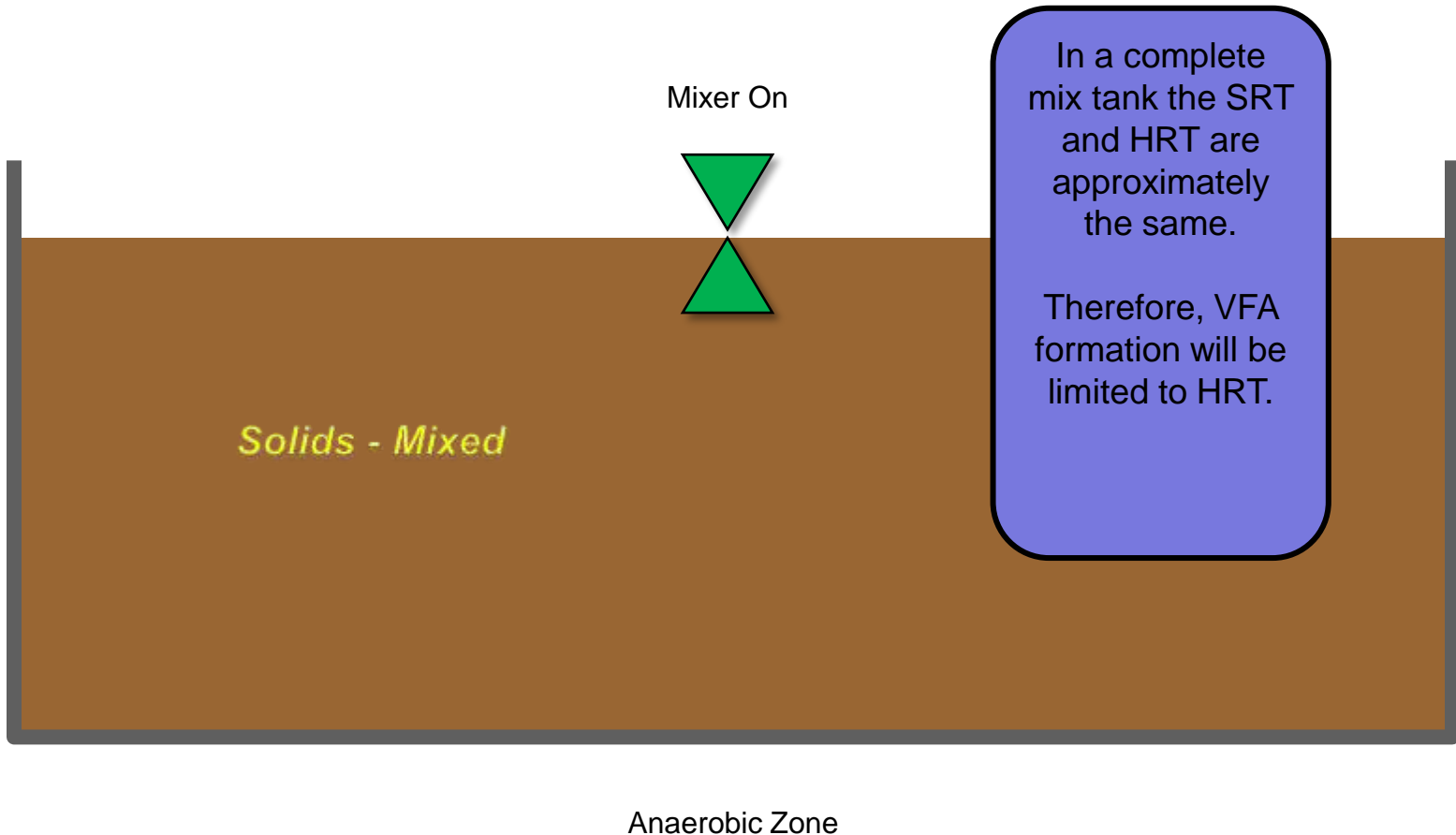
VFA losses to competing reactions need to be considered.

(1) Barnard

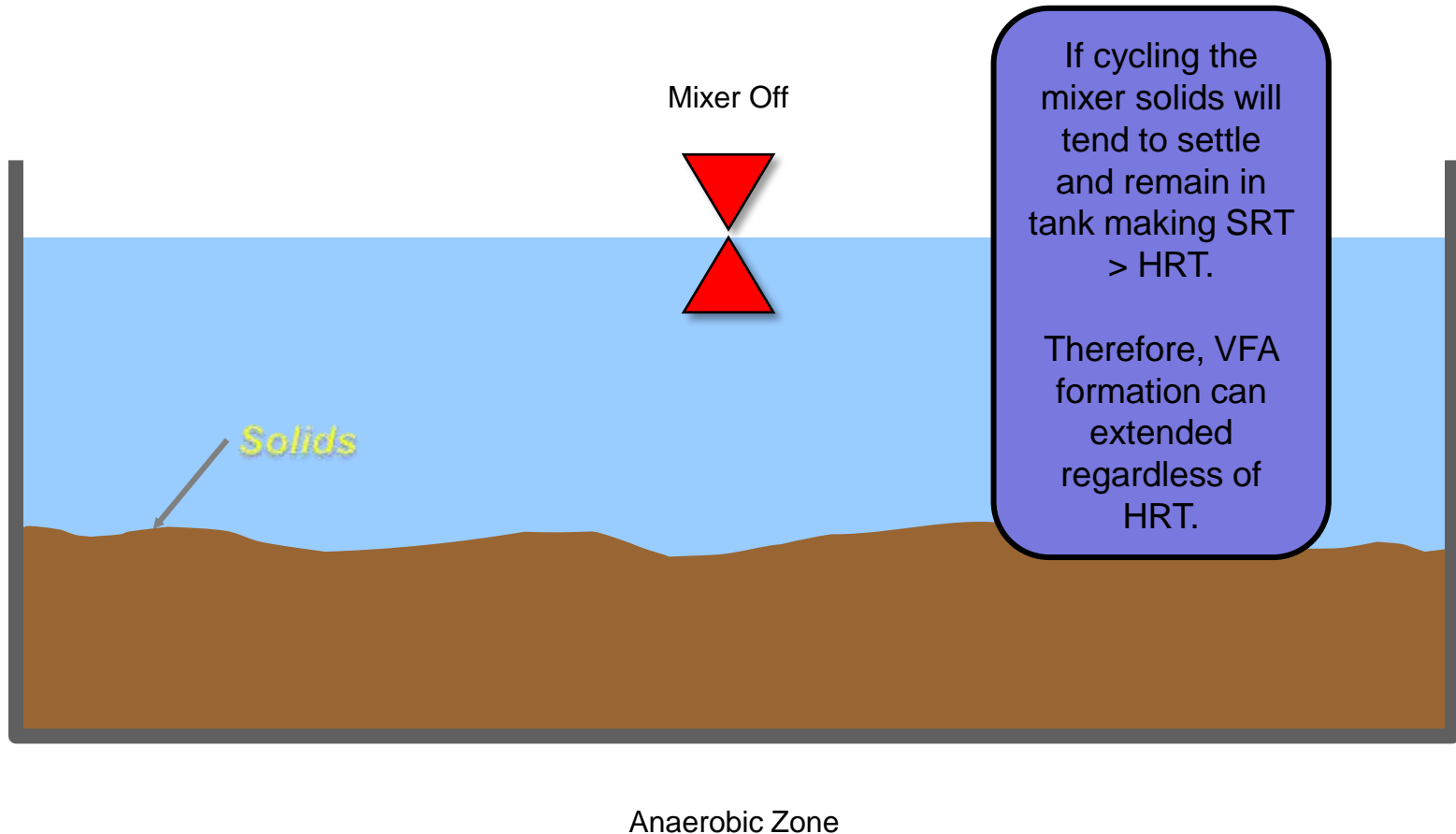
# Treatment Objectives Define Balance for Each Facility



# ■ BPR Pilot Element – Mixer Cycling



# ■ BPR Pilot Element – RAS Rate Control



# Case Study – Fond du Lac: *Ongoing*

Goal – Identify if the anoxic zones can be operated differently promoting anaerobic conditions resulting in BPR.

## Step 1 Develop Plan

A	B	C	L	M	N	O	R	S	T	U				
1	Fond du Lac	Schedule	Activity	BI-Week	BI-Week	Calc	Weekly	Weekly	Weekly	Typical	Typical	Typical	Typical	Typical
2	WPCF		* Grab	SBOD	Soi - P	SBOD:SP	NH3	NO3		Flow	Flow	Flow	Flow	Flow
3	BPR Pilot		#Filtered	PRE**	PRE**	PRE	Eff	Eff**	RAS**	Inf	Eff	RAS	WAS	Inf
4				mg/L	mg/L	Ratio	mg/L	mg/L	mg/L	mgd	mgd	mgd	kgal	mg/L
5	Start Date	Monday, April 07, 2014	Monday, April 07, 2014											
22	Start Date	Monday, April 07, 2014	Mixing Trial- turn off first of two mixers in each anoxic/anaerobic zone except for "bumping" these mixers once a day for ~3 minutes on (subject to adjustment).			#DIV/0!	0.05			6.388	7.840	5.96	431	210
23		Tuesday, April 08, 2014				#DIV/0!	0.05			6.193	7.585	5.96	431	306
24		Wednesday, April 09, 2014				#DIV/0!	0.06			6.324	7.305	5.98	431	222
25	Week 1	Thursday, April 10, 2014				57.989049	0.06	7	9	6.128	7.122	5.97	462	473
26		Friday, April 11, 2014				#DIV/0!	0.13			5.966	7.046	6.02	462	244
27		Saturday, April 12, 2014				#DIV/0!	0.06			16.893	10.626	6.00	529	174
28		Sunday, April 13, 2014				#DIV/0!	1.37			37.818	0.100	6.06	577	62
29		Monday, April 14, 2014				#DIV/0!	0.17			36.418	2.224	8.05	600	93
30		Tuesday, April 15, 2014				#DIV/0!	<0.02			19.748	8.208	8.35	600	74
31	Week 2	Wednesday, April 16, 2014				14.194	15.464			14.194	15.464	8.35	600	114
32		Thursday, April 17, 2014				71.130	15.440	8		11.310	15.440	8.35	600	130
33		Friday, April 18, 2014				9.648	11.558			9.648	11.558	6.06	460	175
34		Saturday, April 19, 2014				#DIV/0!	<0.02			8.422	10.064	6.06	460	144
35		Sunday, April 20, 2014				#DIV/0!	<0.02			6.996	9.070	6.06	461	231
36	Week 3	Monday, April 21, 2014				#DIV/0!	0.05			10.148	9.636	6.09	473	234
37		Tuesday, April 22, 2014				#DIV/0!	0.04			8.176	8.810	6.07	462	168
38		Wednesday, April 23, 2014				#DIV/0!	0.04			7.385	8.004	6.06	461	170
39		Thursday, April 24, 2014				35.156595	<0.02	8.0	7.2	9.348	9.642	6.08	461	171
40		Friday, April 25, 2014				#DIV/0!	0.04			8.159	8.488	6.07	461	205
41		Saturday, April 26, 2014				#DIV/0!				6.658	7.588	6.07	461	182
42		Sunday, April 27, 2014				#DIV/0!	0.04			6.528	7.206	6.06	461	179
43	Week 4	Monday, April 28, 2014				#DIV/0!	0.03			8.400	8.672	6.09	462	191
44		Tuesday, April 29, 2014				#DIV/0!	0.05			12.804	13.070	6.11	600	116
45		Wednesday, April 30, 2014				#DIV/0!	0.08			10.357	11.090	6.06	461	249
46		Thursday, May 01, 2014				57	1.67	34.070532	0.04	10.9	9.303	9.690	6.09	461
47		Friday, May 02, 2014				#DIV/0!	0.04			8.810	10.214	6.10	463	151
48		Saturday, May 03, 2014				#DIV/0!	0.03			8.228	9.792	6.06	461	195
49		Sunday, May 04, 2014				#DIV/0!	0.04			8.171	9.030	6.05	461	142

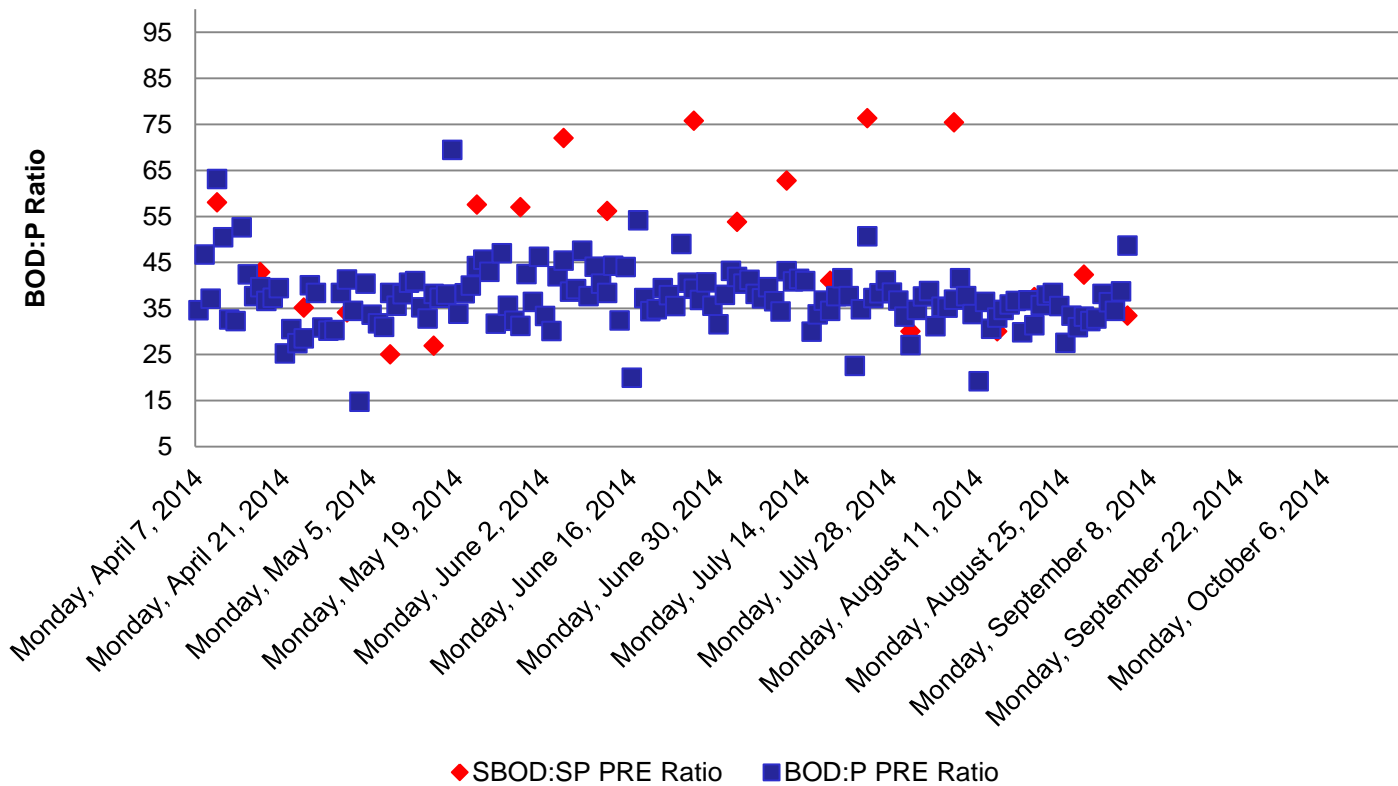
Identify, isolate, and prioritize test activities

Determine additional monitoring and indices.

Organize all information.

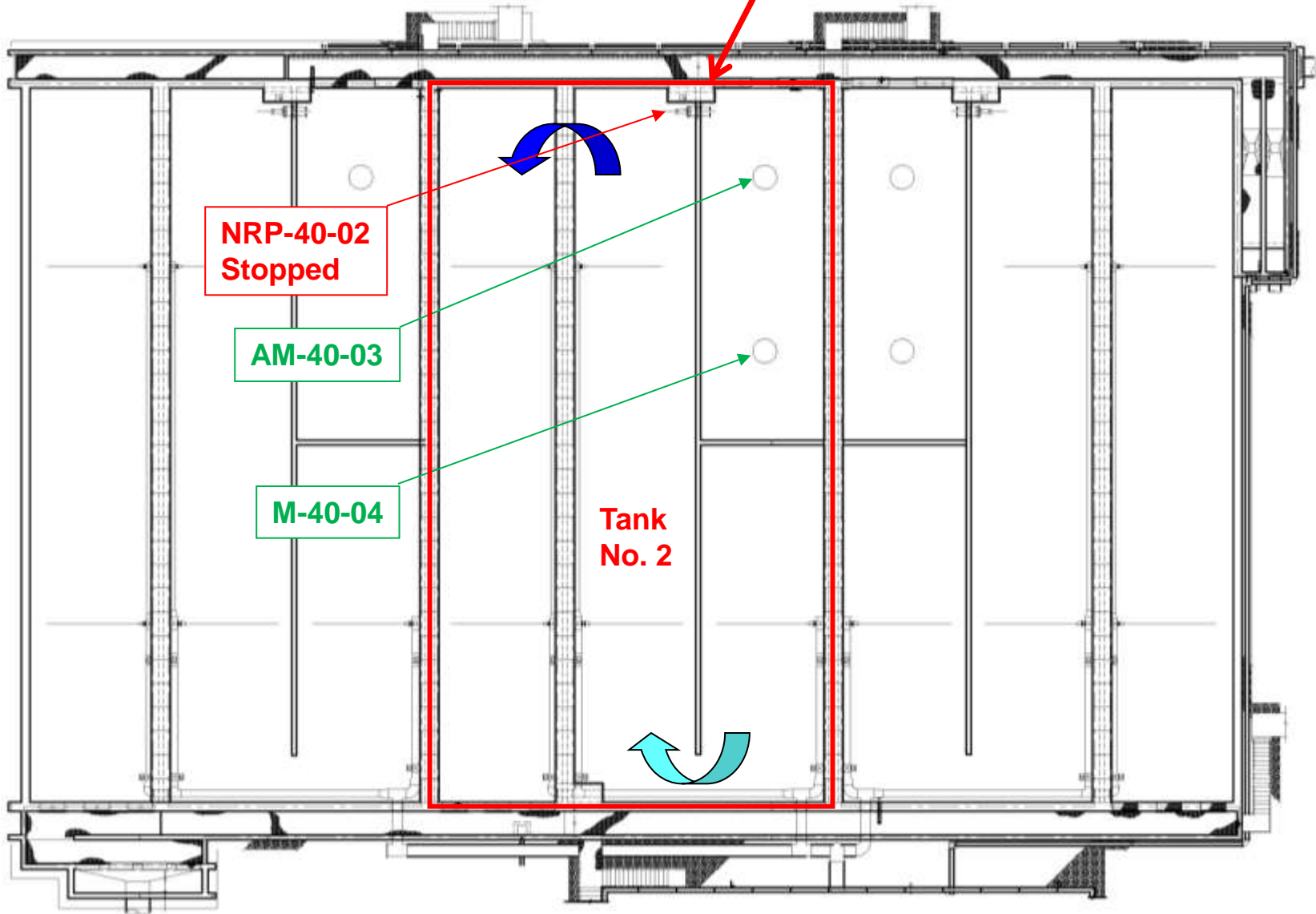
# Industrial Loadings Provide Promise of BPR

## Biochemical Oxygen Demand



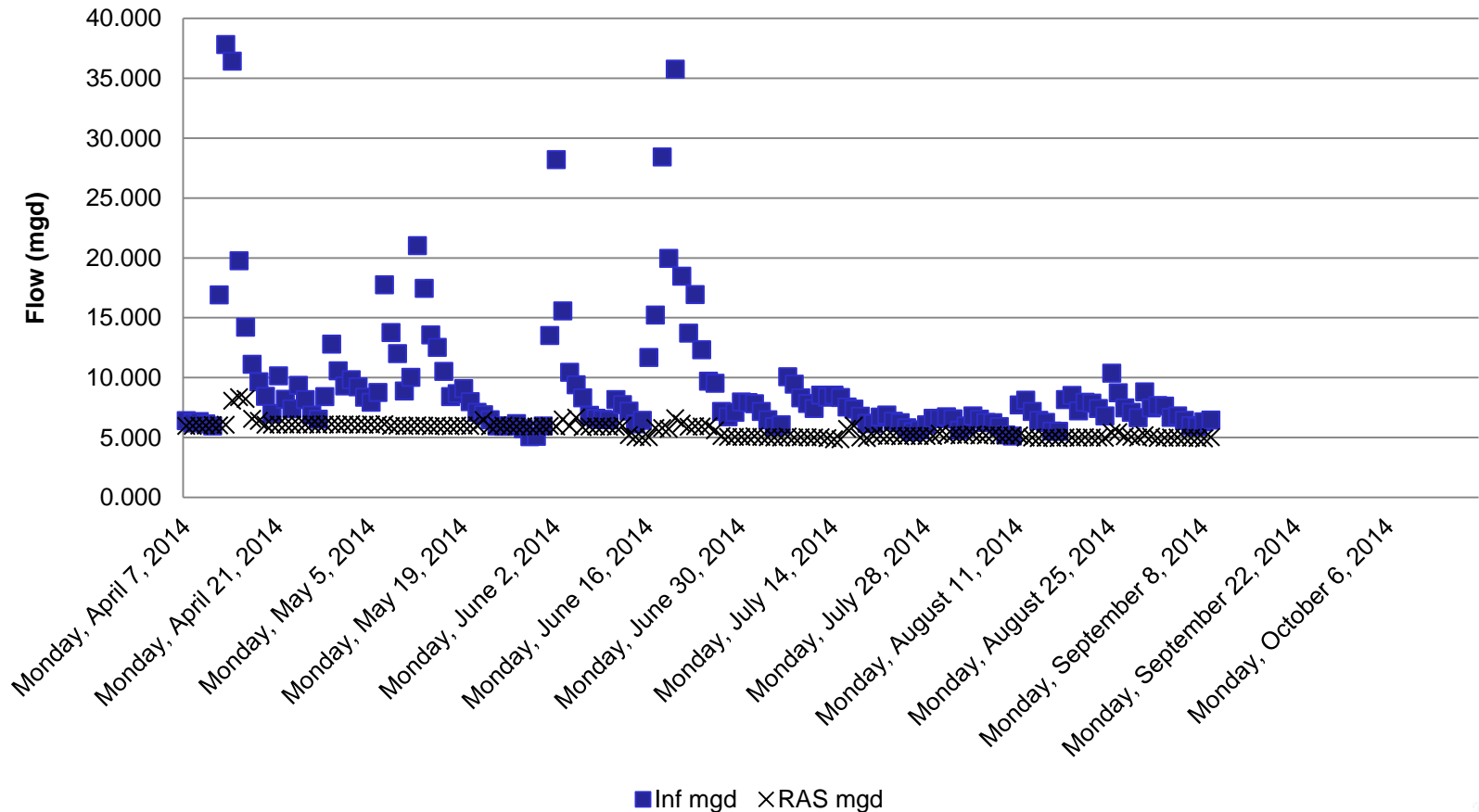
# Full Scale Example

AO Process Initiated (BPR)



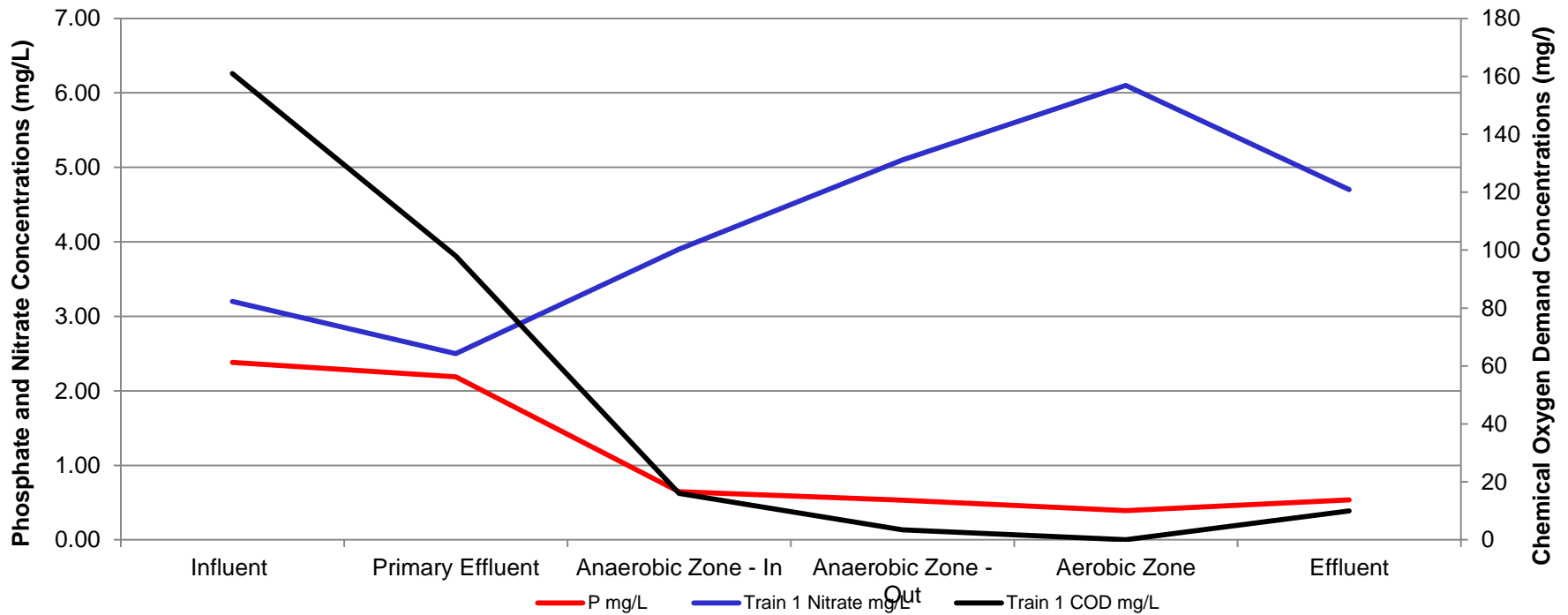
# ■ Early Efforts Were Impacted By Wet Weather

## Influent and RAS Flow

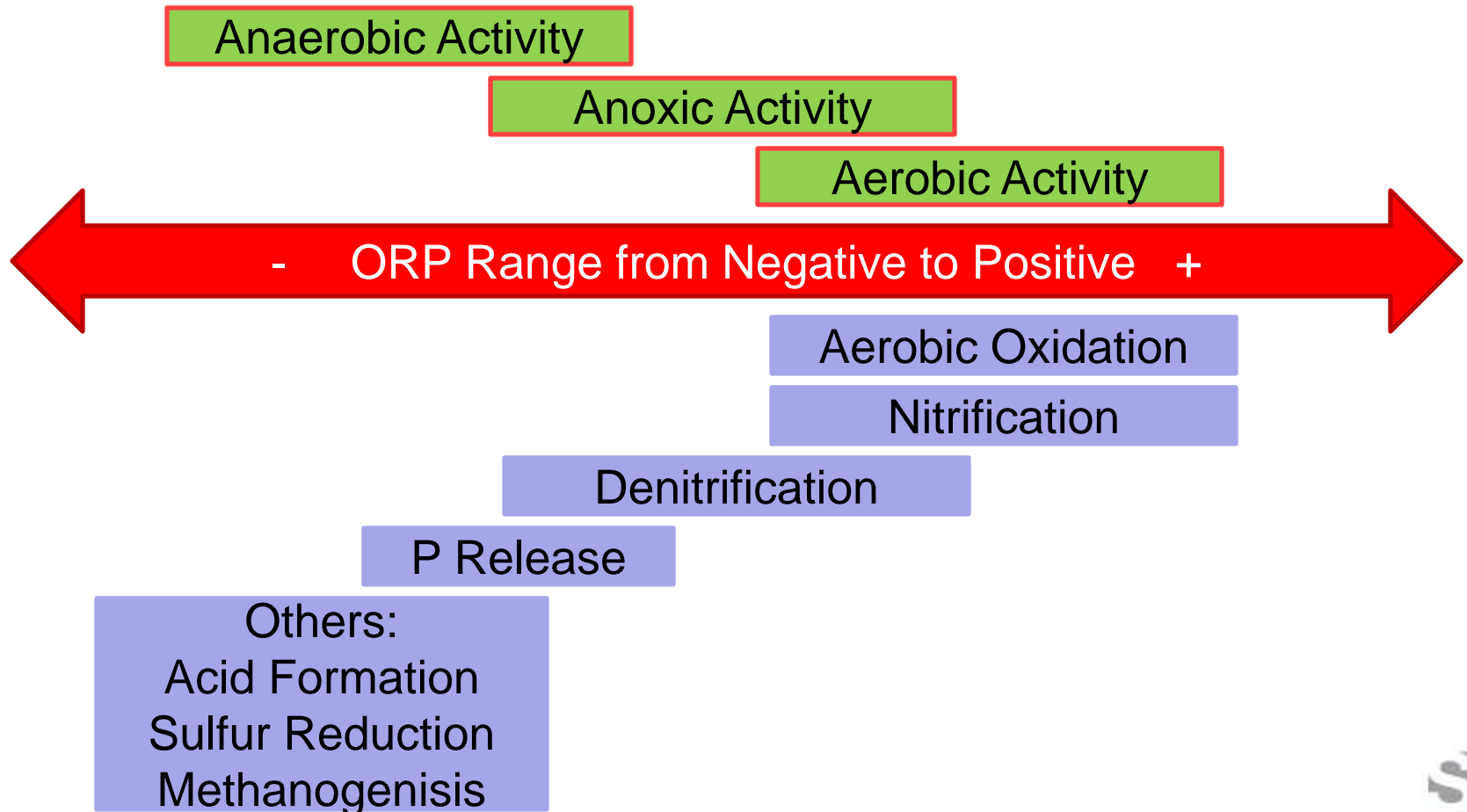


# Currently Nitrate Interference is Being Addressed

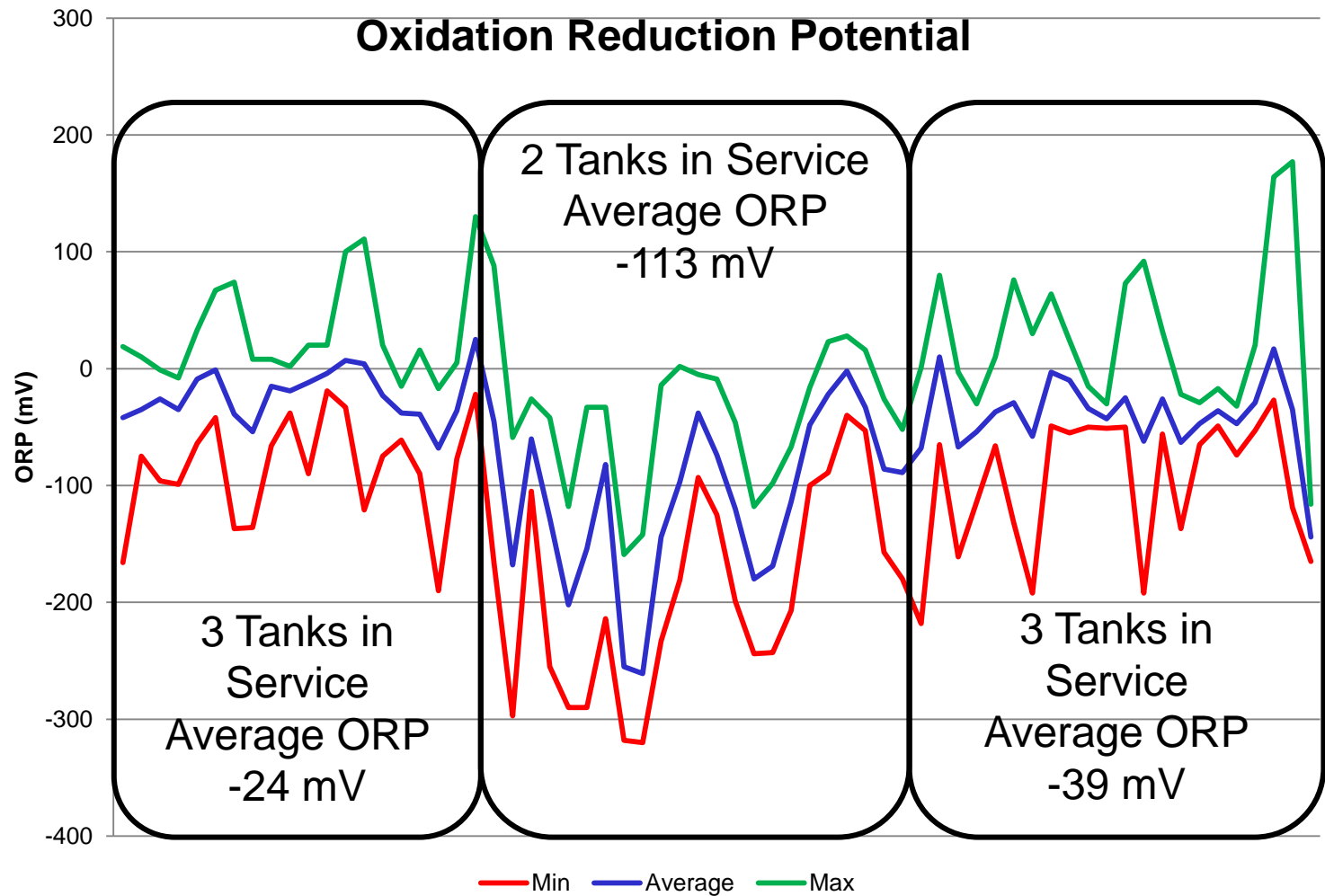
## Train 1 - BPR Profile



# ■ ORP Provides a Spectrum of Biological Activity



# Capacity Impacts Environments



# ■ Fond du Lac Interim Understanding

- Industrial loads provide unique dichotomy
  - Heavy BOD could drive process
  - Tendency to slug loads limits aeration tank configurations
    - Other processes can be upset if optimum BPR tankage were implemented
  - Cleaning chemical changes from phosphorus based chemicals to nitric acid based chemicals may have created too much nitrate
- Wet weather impacts add to the difficulty
- Attempts to create an environment to support BPR have not been successful
- Efforts to better understand the system have been successful

# ■ Summary

- Piloting operational changes can provide greater understanding of facility and improved performance.
- Jar scale testing can aid in training and proof of concept analysis.
- Impending phosphorus limits has contributed to improvements and increased knowledge base...
- ...you wont know if you don't try.

# ■ Acknowledgements

- Fond du Lac
  - Jeremy Cramer
  - Dave Carlson
  - Autumn Fisher
- Waukesha
  - Randy Thater
  - Jeff Harenda
  - Nate Tillis
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- Brooklyn
  - Leif Spilde
- Marathon City
  - Ken Bloom
- Merrill
  - Terry Vanden Heuvel
- Strand
  - Jane Carlson
  - Rachel Lee
  - Jeremy Brill



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