Efficient Design Configurations for Biological Nutrient Removal

A Case Study: Upper Blackstone Water Pollution Abatement District

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UBWPAD Wastewater Treatment Facility

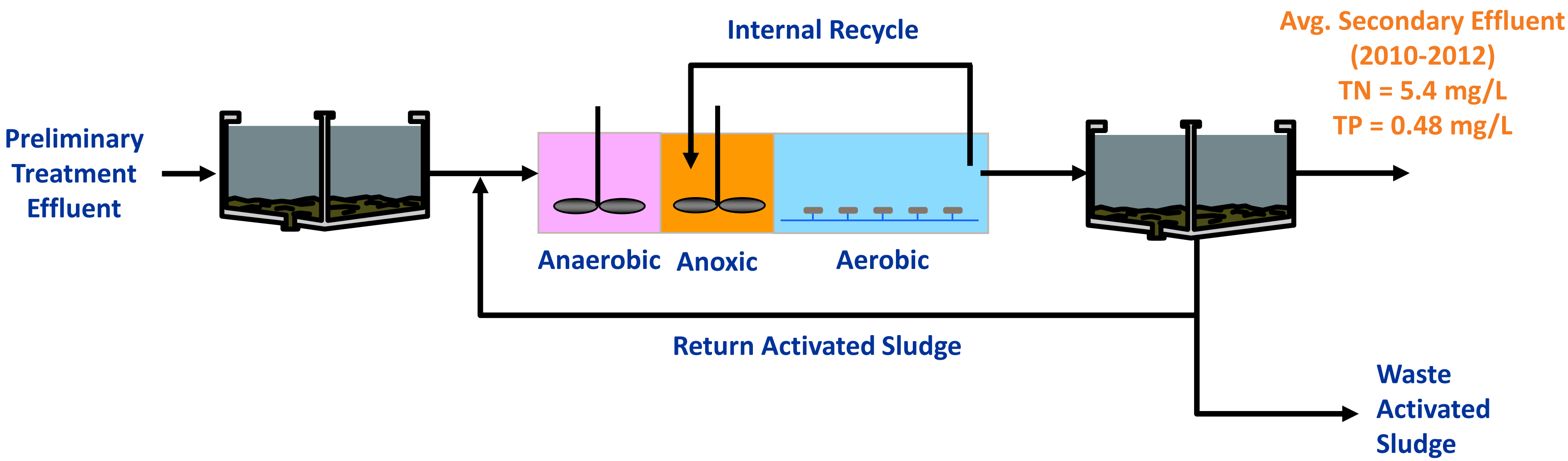
- Serves 250,000 people in greater Worcester, MA
- Regional biosolids facility
- Designed for 45 mgd ADF, 160 mgd peak hour

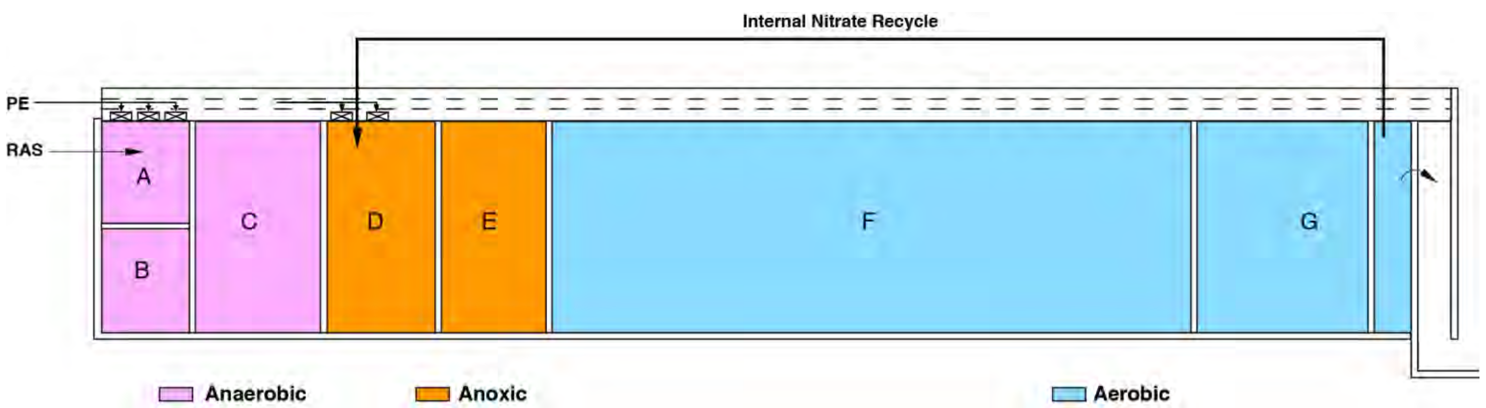
UBWPAD 2001 NPDES Permit Limits

Constituent	2001 Permit	
CBOD (mg/L)		
Nov – Apr	25	
Jun – Oct	10	
TSS (mg/L)		
Nov – Apr	30	
Jun – Oct	15	
Total Nitrogen (mg/L) – Monthly Average		
May – Oct	No Limit	
Nov – Apr	No Limit	
Total Phosphorus (mg/L) – 60-day Rolling Average		
Apr – Oct	0.75	
Nov – Mar	Report	

- Required seasonal phosphorus limit of 0.75 mg/L to protect Blackstone River
- Moved from seasonal to year-round nitrification
- Facility upgraded to meet 2001 permit limits using the A^2/O process
- Process enabled denitrification to 8 -10 mg/L TN

A²/O Process Configuration





2012 UBWPAD NPDES Permit Limits

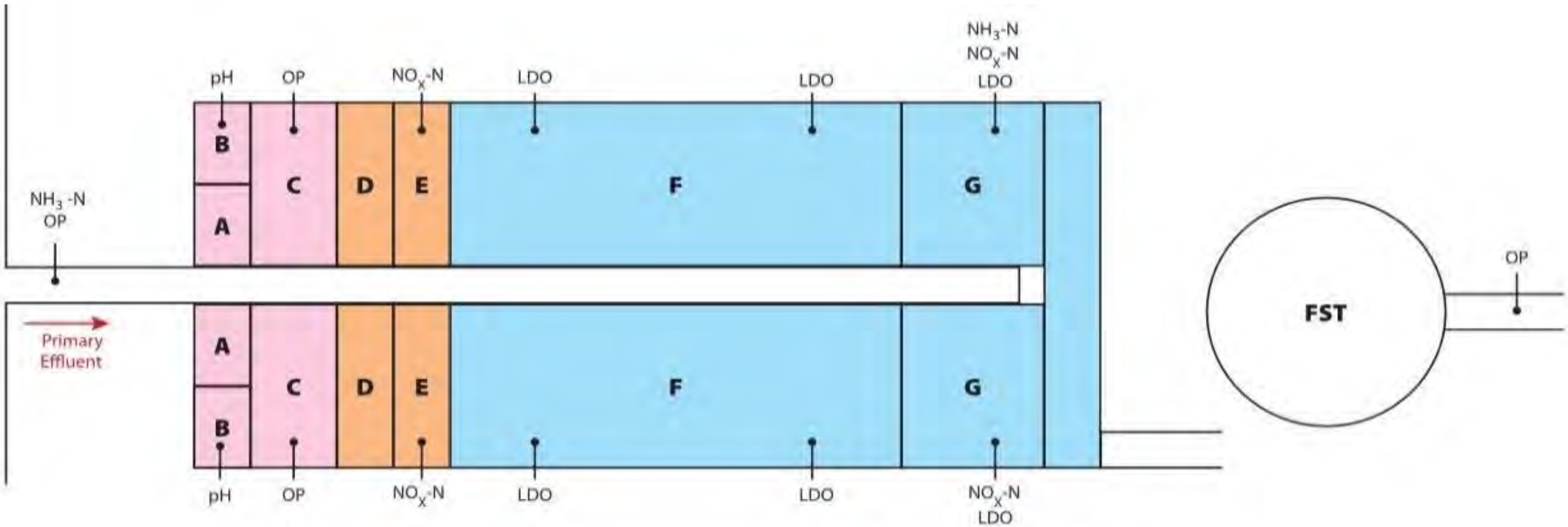
Constituent	2001 Permit	2012 Permit
CBOD (mg/L)		
Nov – Apr	25	25
Jun – Oct	10	10
TSS (mg/L)		
Nov – Apr	30	30
Jun – Oct	15	15
Total Nitrogen (mg/L) – Monthly Average		
May – Oct	No Limit	5
Nov – Apr	No Limit	No Limit
Total Phosphorus (mg/L) – 60-day Rolling Average		
Apr – Oct	0.75	0.1
Nov – Mar	Report	1.0

- During middle of construction (2008) EPA issued new draft permit
- 5 mg/L TN to protect Narragansett Bay
- 0.1 mg/L TP seasonally to protect Blackstone River
- Permit appealed but ultimately went into effect in 2012

How much better can A^2/O process perform?

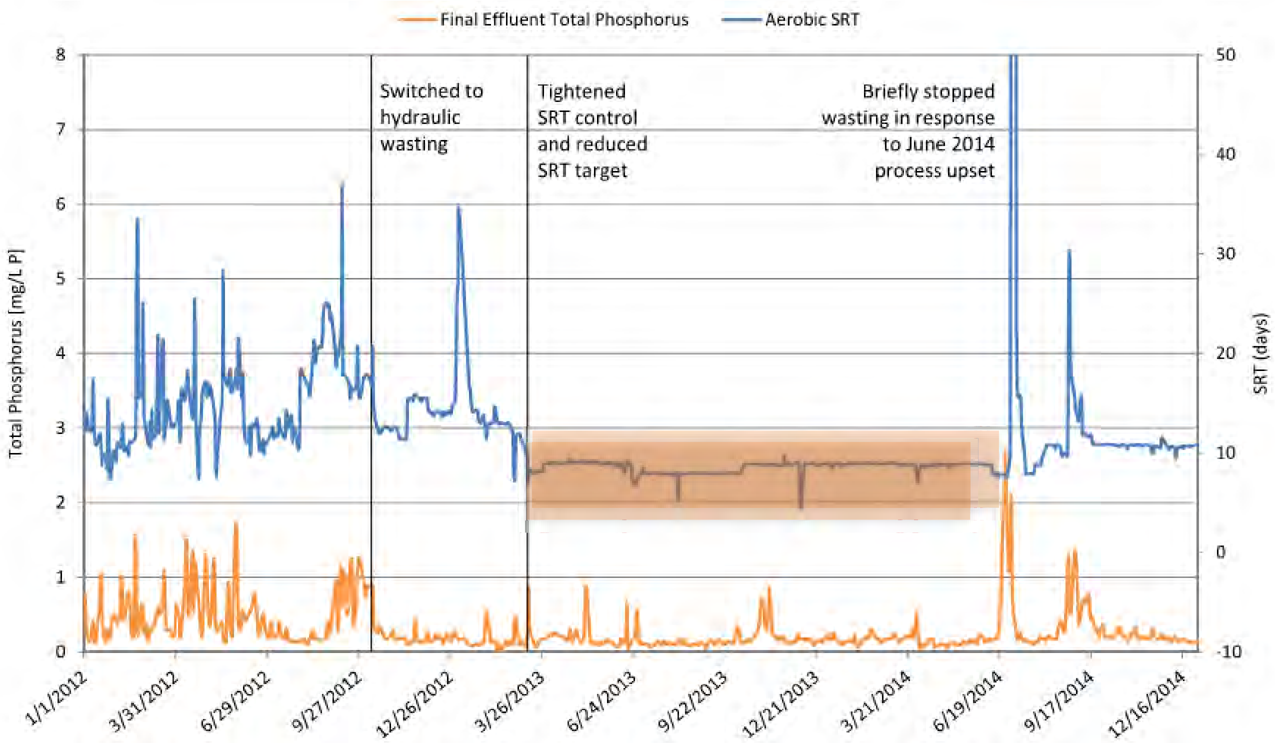
- Evaluated current operations
  - Suitable DO concentrations maintained
  - Nitrate recycle and RAS rates adjusted to optimize denitrification and EBPR
  - Number of operational aeration tanks adjusted based on season
  - High performing secondary clarifiers
- Reviewed historical data and identified new operational strategies to implement
- Modeled potential process modifications
- Tested operational strategies and process modifications over a 28-month period (March 2013 – June 2015) to develop additional tools District could utilize

Install Additional On-line Analyzers for Process Monitoring and Control



http://www.hach.com

Reduce and Stabilize SRT



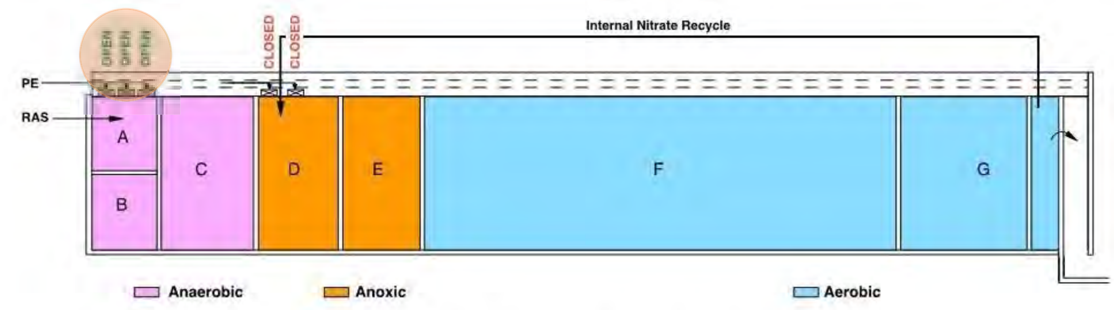
- Utilize hydraulic wasting of MLSS exclusively
- Find balance between nitrification and EBPR needs

Stabilize Mixed Liquor pH with Magnesium Hydroxide

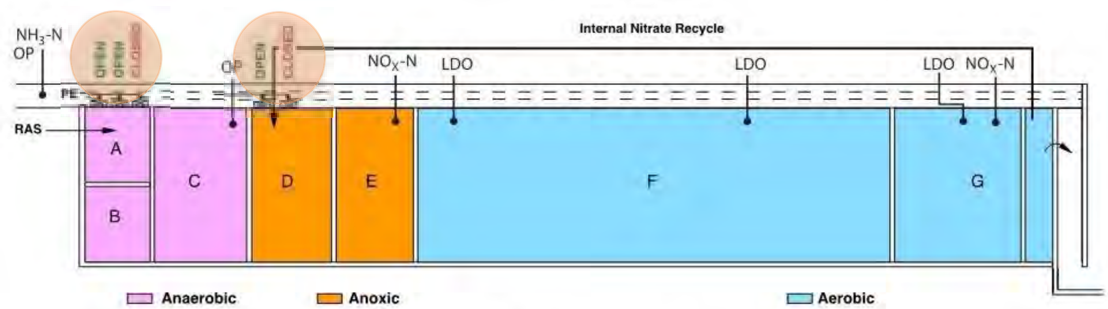
- Switched to magnesium hydroxide in September 2013
- Maintained pH set point of 6.9-7.0 with less fluctuation
- Reduced operator safety concerns

Process Modification
Step Feed Testing Summary

- Tested from February to September 2014
- Goal: Achieve 5 mg/L TN w/o impact on EBPR
- Quarter-scale test at start
- Increased to maximum three-quarter scale



A^2/O: Existing Process Mode



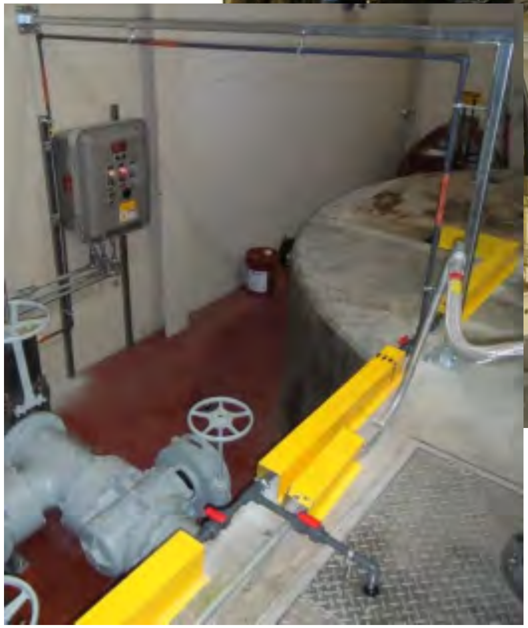
A^2/O: Step Feed Mode

Step Feed Testing Results

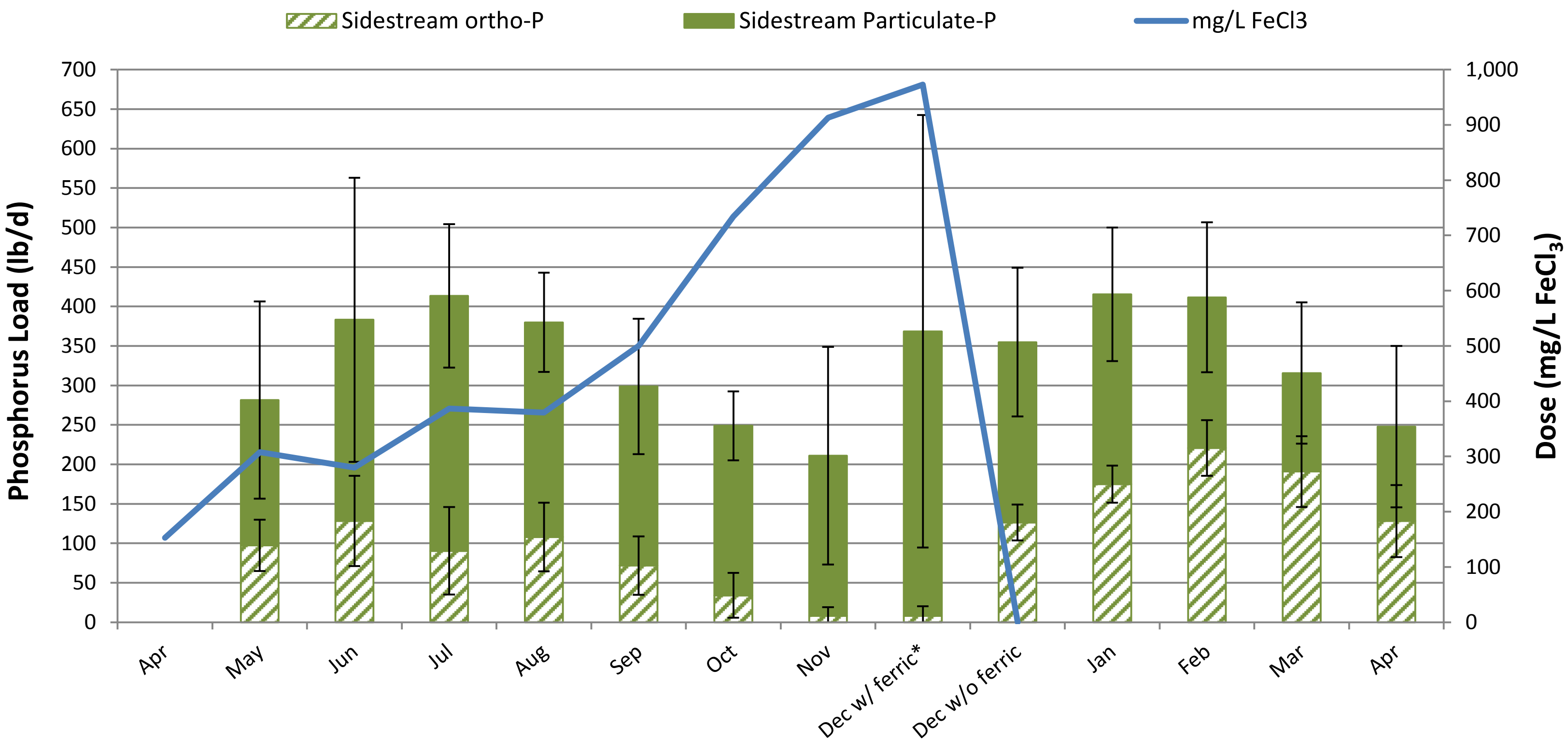
- Denitrification improved with lower and more stable effluent TN concentrations
  - NOx reduction of 0.5-1.5 mg/L
- Minimal impact on EBPR at first, but stability and robustness of EBPR was compromised over time
- Variable influent carbon confirmed as critical stressor on performance
- Beneficial tool for wet weather management

Process Modification
Ferric Chloride Addition Summary

- Tested from April to December 2014
- Add ferric chloride into belt filter press feed sludge
- Goal: Achieve reduction in TP load returned in sidestream w/o negative impact on sludge dewaterability or incineration
- Full-scale test

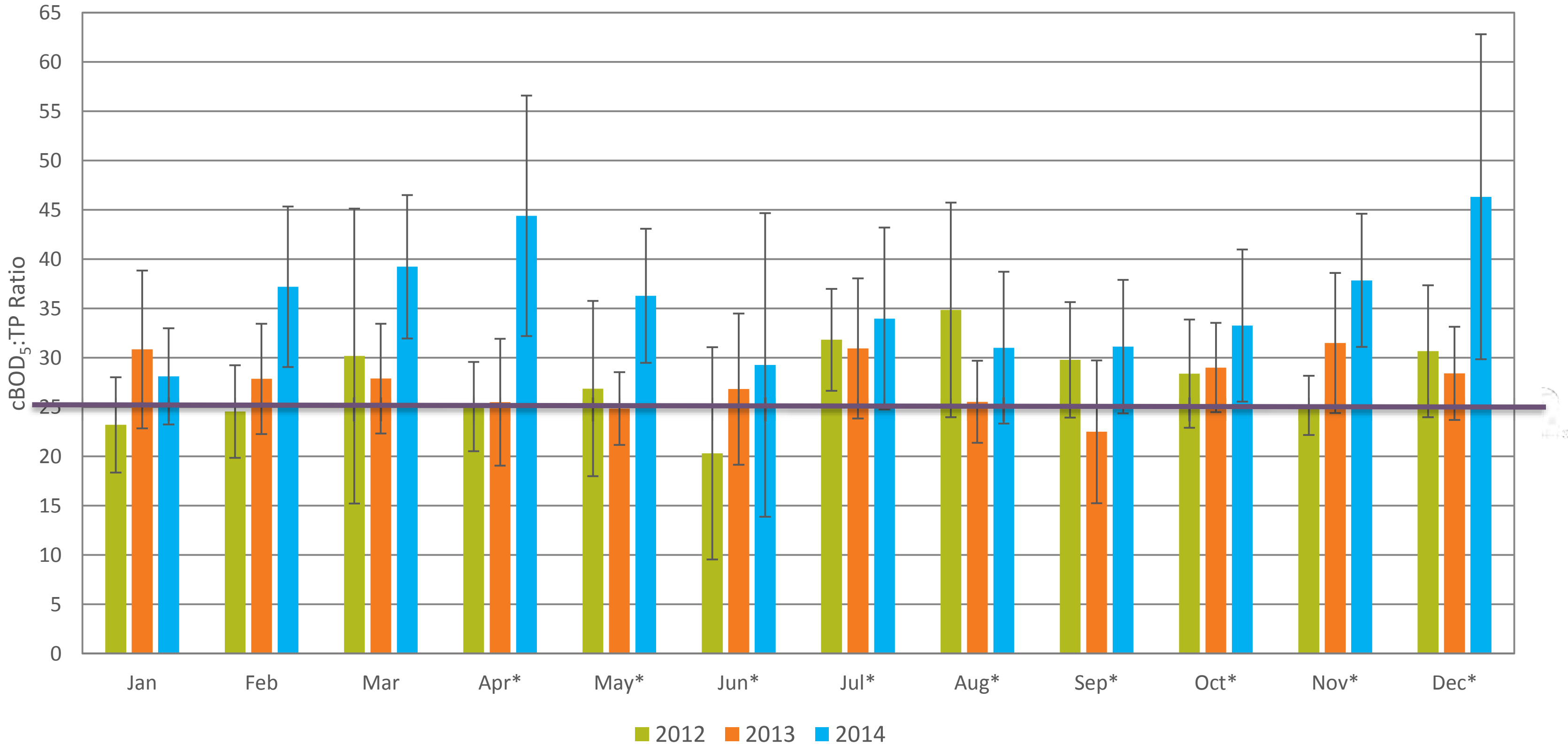
Phosphorus Loads in Sidestream Compared to Ferric Chloride Dosage



* Average particulate P would have been 254 lb/d if exclude high data point on Dec 7

- Nearly complete elimination of Ortho-P load at high doses
- Reduction in Particulate P load of 50-100 lb/d
- Some reduction in sidestream variability but not eliminated

$cBOD_5$ to TP Ratio in A^2/O Influent With and Without Ferric Chloride Addition



* indicates ferric addition in 2014

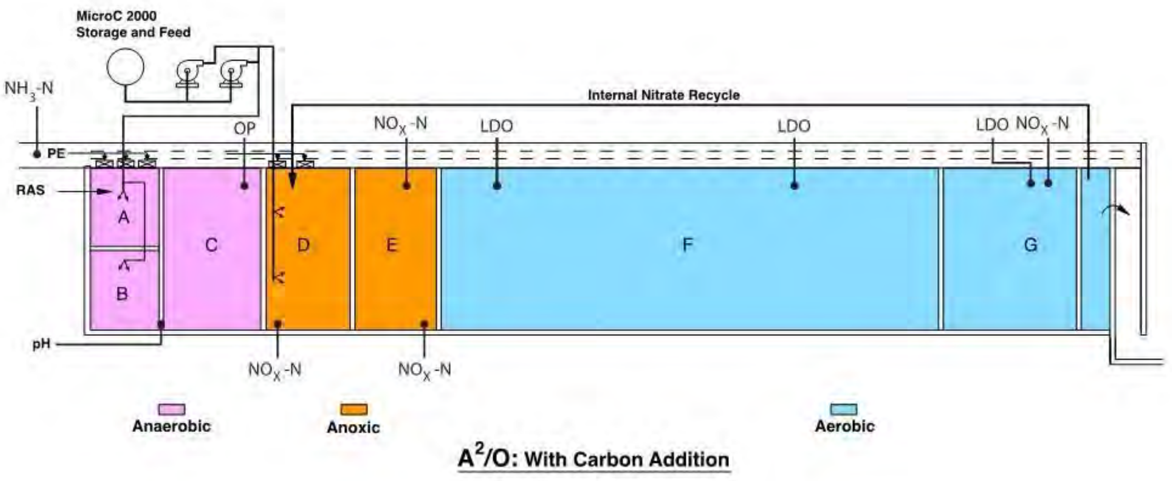
- Reduction in A^2/O Influent Ortho-P load of 100-150 lb/d
- Higher ratios attributable to ferric chloride in May through December

Ferric Chloride Testing Results

- No negative impact on sludge dewaterability with ferric doses up to 1,170 mg/L (or 590 gpd)
- Phosphorus reduction during testing
  - Over 90% in Ortho-P in filtrate
  - Up to 90% in Ortho-P in sidestream
  - Noticeable impact on A^2/O Influent Ortho-P loads
- Favorable A^2/O Influent conditions for EBPR due to higher $cBOD_5$ to TP ratio
- Favorable conditions for denitrification due to increased carbon availability in anoxic zones

Process Modification
A^2/O with Carbon Addition Summary

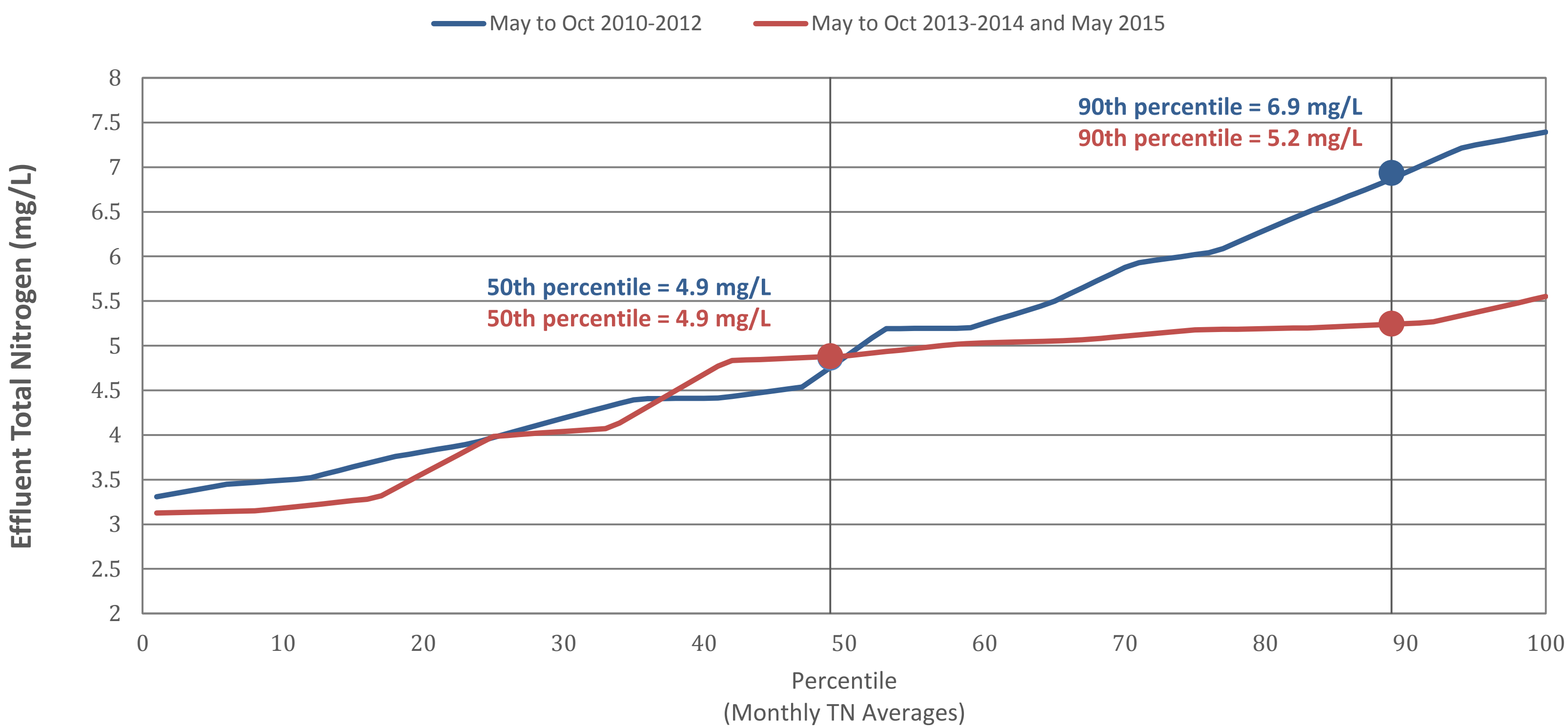
- Tested from March to July 2015
- Add MicroC 2000™ to anoxic zone and/or anaerobic zone
- Goals: (1) Maximize denitrification in existing process, (2) achieve 5 mg/L TN, (3) improve EBPR performance
- Quarter-scale test at start
- Increased to full-scale



A^2/O with Carbon Addition Testing Results

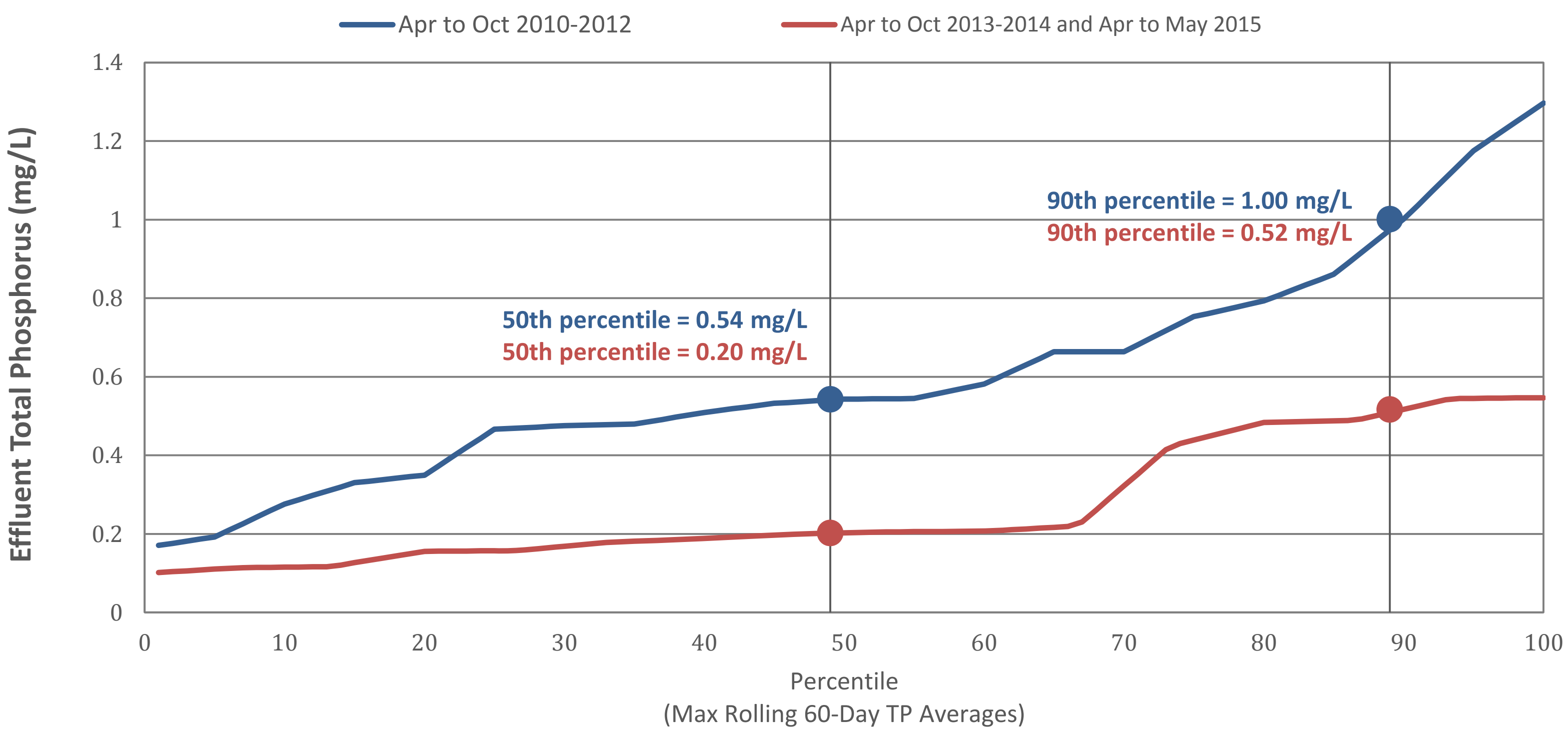
- Denitrification improved with MicroC™ addition
  - NOx reduction of 0.5 to 2 mg/L
- Carbon utilization efficiency for denitrification in typical range for MicroC™
- Beneficial tool to manage carbon variability
- Phosphorus release improved with MicroC™ addition likely due to fermentation not dPAO
  - 10 to 15% higher consistently; 20% maximum

Improved Nitrogen Removal due to Optimization Efforts



- 25% reduction in 90th percentile monthly average concentration
- Daily effluent concentrations below 5 mg/L TN 67% of the time

Improved Phosphorus Removal due to Optimization Efforts



- 63% reduction in 50th percentile 60-day rolling average concentration
- 48% reduction in 90th percentile 60-day rolling average concentration

District Now has Tools to Respond to Variable Conditions and Manage Stressors on BNR System

- Online analyzers to assess process performance and make necessary adjustments
- Operate at reduced and stable aerobic SRT optimized for EBPR and nitrification
- Utilize magnesium hydroxide to stabilize pH and alkalinity conditions
- Implement step feed A^2/O for short durations to maintain solids during periods of high flow
- Add ferric chloride to the BFP feed sludge as needed to reduce sidestream phosphorus loads
- Add MicroC to overcome periodic shortfalls in carbon loading or carbon-to-phosphorus ratios

Questions

CDM Smith