WELCOME

TO THE MARCH EDITION

OF THE 2013

M&R SEMINAR SERIES

BEFORE WE BEGIN

- **SILENCE CELL PHONES & SMART PHONES**
- **QUESTION AND ANSWER SESSION WILL FOLLOW PRESENTATION**
- **PLEASE FILL EVALUATION FORM**
- **SEMINAR SLIDES WILL BE POSTED ON MWRD WEBSITE (www. MWRD.org: Home Page $\Rightarrow$ Reports $\Rightarrow$ M&D Data and Reports $\Rightarrow$ M&R Seminar Series $\Rightarrow$ 2012 Seminar Series)**
- **STREAM VEDIO WILL BE AVAILABLE ON MWRD WEBSITE (www.MWRD.org: Home Page $\Rightarrow$ MWRDGC RSS Feeds)**

Christine Voigt, PE

Current: Principal Engineer, Metropolitan Council Environmental Services, Minneapolis/St Paul, MN

Experience: More than 24 years of environmental engineering experience with Metropolitan Council Environmental Services

Research and development department (2 yrs)*:*

Support services business group (22 yrs)*:*

Enhanced Biological Phosphorus Removal Full-Scale Test and Retrofit

Track, analyze, trouble shoot and optimize treatment systems at all MCES treatment facilities.

Education : B.S. in Civil Engineering, University of Minnesota, Minneapolis, MN

Professional: Registered Professional Engineer in Minnesota

George Spouse, Ph.D., PE

Current: Manager of Process Engineering Group, Metropolitan Council Environmental Services (MCES) , Minneapolis/St Paul, MN

Experience: Manager of Process Engineering Group

Manage a group of 8 engineers and scientists whose mission is to track, analyze, trouble shoot and optimize treatment systems at all MCES treatment facilities.

Project Manager, Technical Services Group, MCES

Process Engineer, at MWH , Chicago, IL
Process Engineer, at Baxter and Woodman, Cristal Lake, IL

Education : B.S. & M.S. in Civil/Environmental Engineering, University of Illinois, Champaign-Urbana , IL

Ph.D. in Civil/Environmental Engineering, Northwestern University, Evanston, IL

Professional: Registered Professional Engineer in California, Illinois, Minnesota and Wisconsin

Implementation and Operation of Enhanced Biological Phosphorus Removal at the Metropolitan WWTP

Christine Voigt
George Sprouse

MWRDGC April 5, 2013

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Presentation Outline

- Brief background on Metropolitan Council Environmental Services (MCES)

- History of effluent phosphorus removal implementation at the Metropolitan WWTP (Metro)

- Enhanced biological phosphorus removal at Metro
  - Configuration and systems
  - Operational history
  - Lessons learned – Metro and other MCES P-removal plants

- The future

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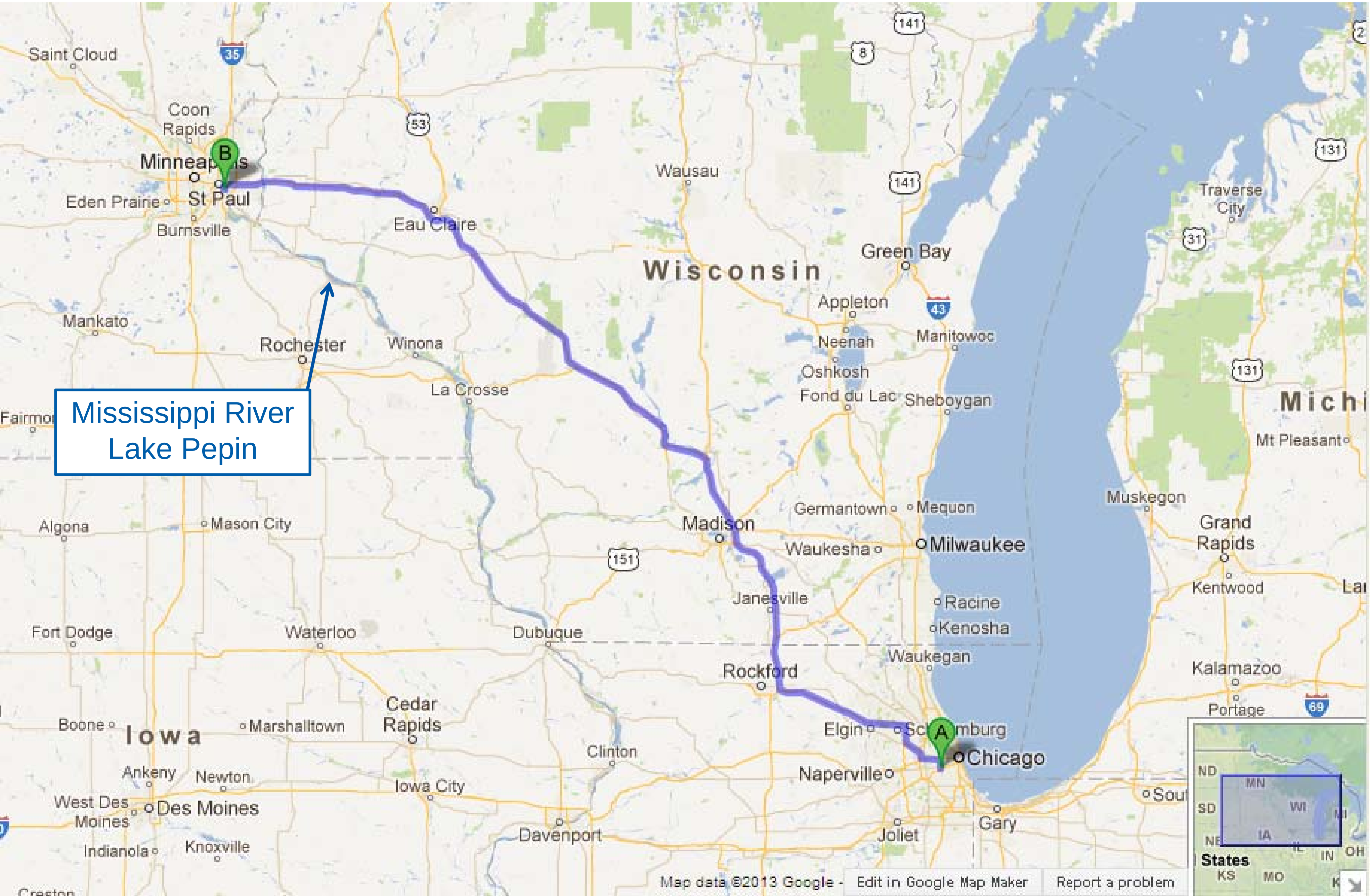
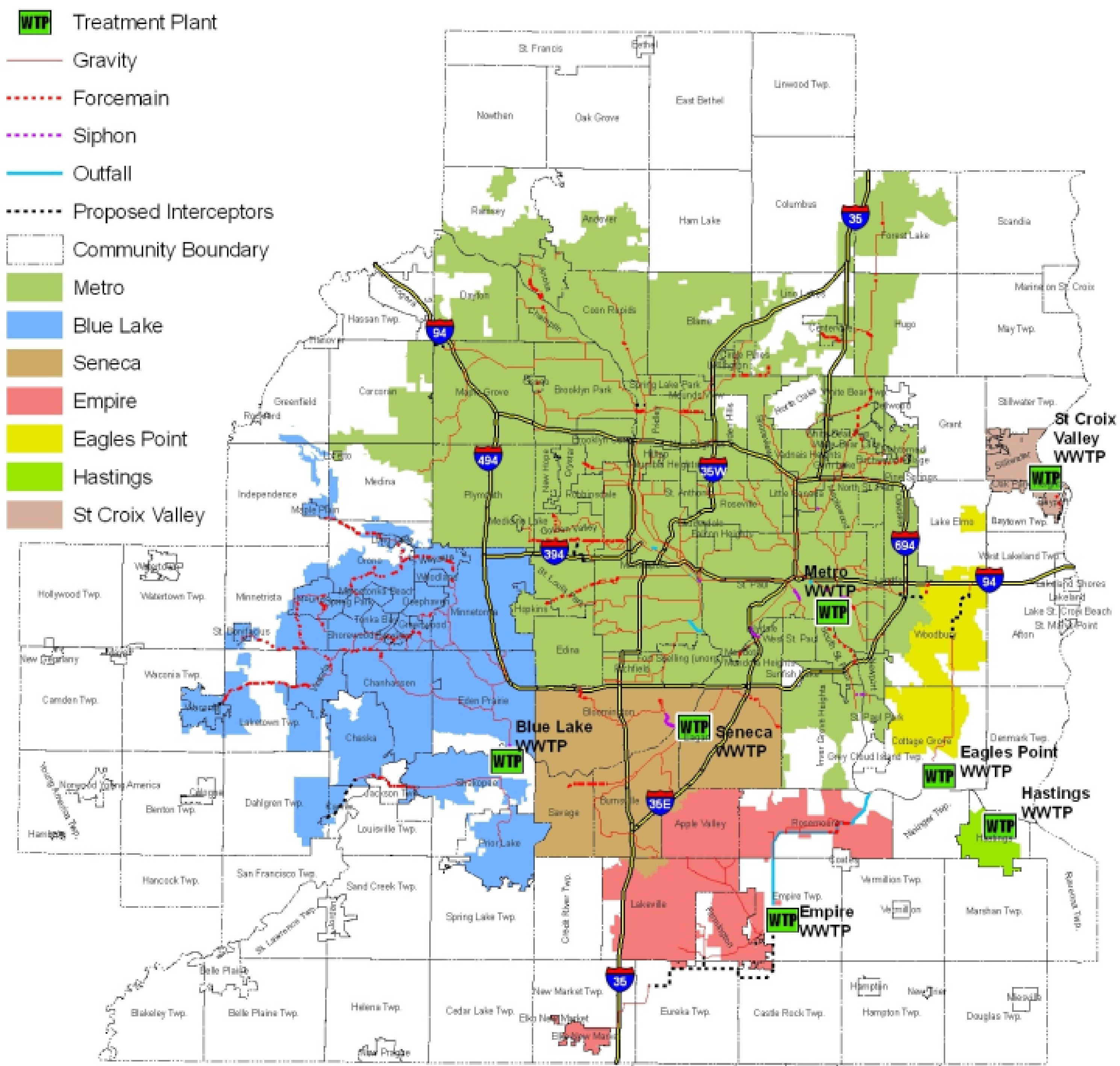
MCES



C O U N C I L

MCES Service Area



Metropolitan Council History

- Formed in 1967
- Seven county area - (3,000 square miles)
- 17 member board
- Operates regional wastewater, transit and parks system
- Coordinates regional planning and guides development

Phosphorus Removal at the Metro Plant

- **1988 drought provided the impetus**

- Phosphorus reduction efforts at the Metro Plant have their origins back in 1988. That's when the state suffered its worst drought in years and a massive algae explosion in Lake Pepin was blamed in large part on phosphorus discharged from the Metro Plant.

- As a result of negotiations with the Minnesota Pollution Control Agency (MPCA) and the U.S. Environmental Protection Agency, the Council began a series of studies in 1990. Among the goals were to determine both the contribution that the Metro Plant makes to phosphorus loads in the Mississippi River and the most effective way to reduce phosphorus discharged from the plant.

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Metropolitan Council Environmental Services

- Provides regional wastewater conveyance and treatment for the 7 county metropolitan area of the Twin Cities, MN
  - Provides service to 2.5 million people and 104 communities
- Owns and operates 7 wastewater treatment plants with 1 under construction:

Facility/ River	Permitted WW Flow	Phosphorus and Nutrient Effluent Limits/ Phosphorus Removal Systems
Metropolitan Mississippi	314 mgd	1.0 mgTP/l*; seasonal ammonia limits Enhanced biological phosphorus removal activated sludge system (EBPR) (2005)
Blue Lake Minnesota	42 mgd	1.0 mgTP/l*; seasonal ammonia limits EBPR (2008) with ferric chloride addition capabilities
Seneca Minnesota	38 mgd	1.0 mgTP/l*; seasonal ammonia limits EBPR (2008) with alum addition capabilities
Empire Mississippi	28.6 mgd	1.0 mgTP/l*; seasonal ammonia limits EBPR (2006)
Eagles Point Mississippi	11.9 mgd	1.0 mgTP/l*; seasonal ammonia limits EBPR (2003) with alum addition capabilities
St Croix Valley St Croix	5.8 mgd	0.8 mgP/l monthly TP Alum addition chemical system
Hasting Mississippi	2.7 mgd	Monitor only
East Bethel (under const.)	0.47 mgd	1.0 mgP/l monthly TP; 10.0 mgN/l monthly TN (TKN+nitrate, nitrite) MBR with EBPR and chemical addition capabilities

* 12 month moving average

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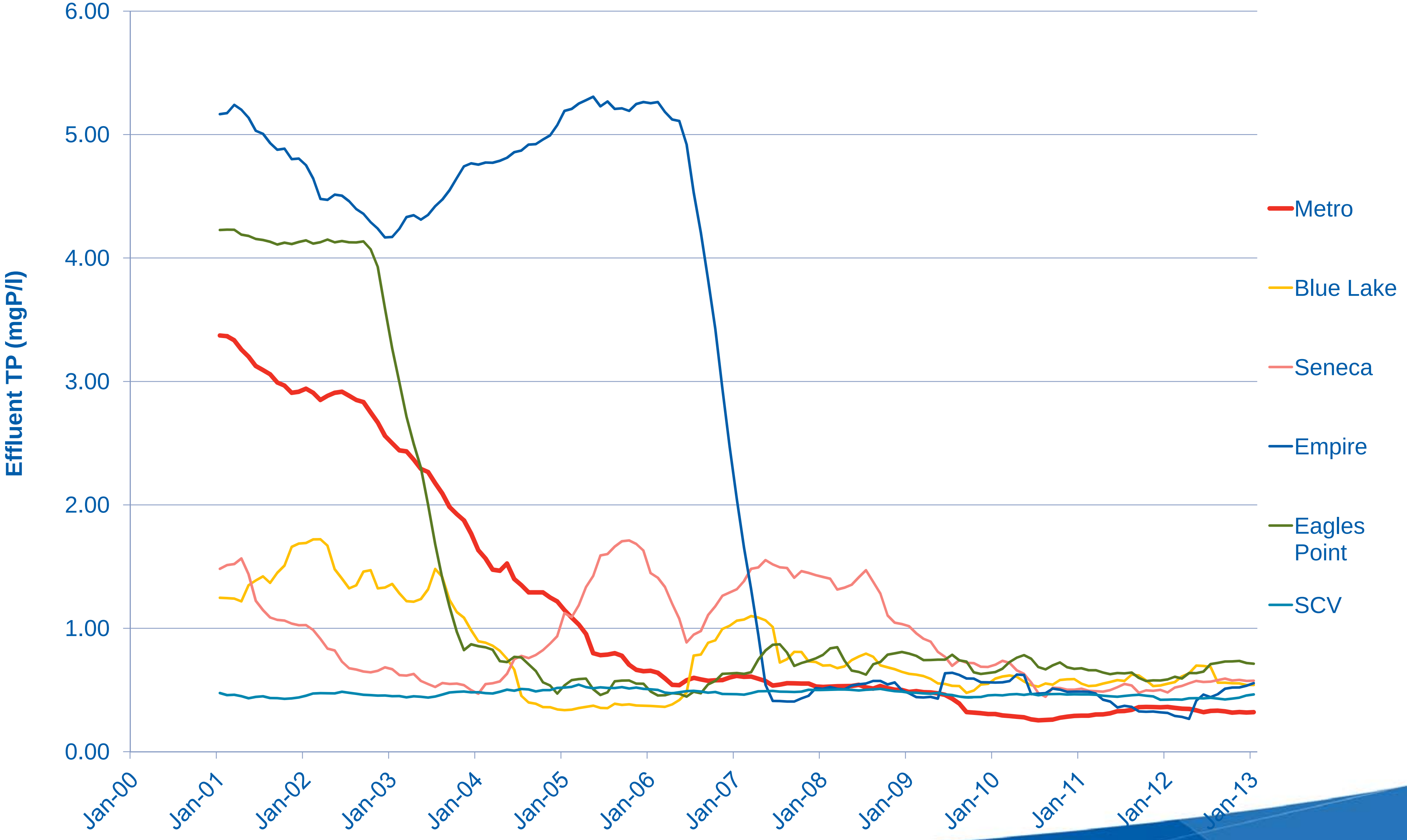
MCES 12-Month Moving Average Effluent TP from Permit Limited Plants



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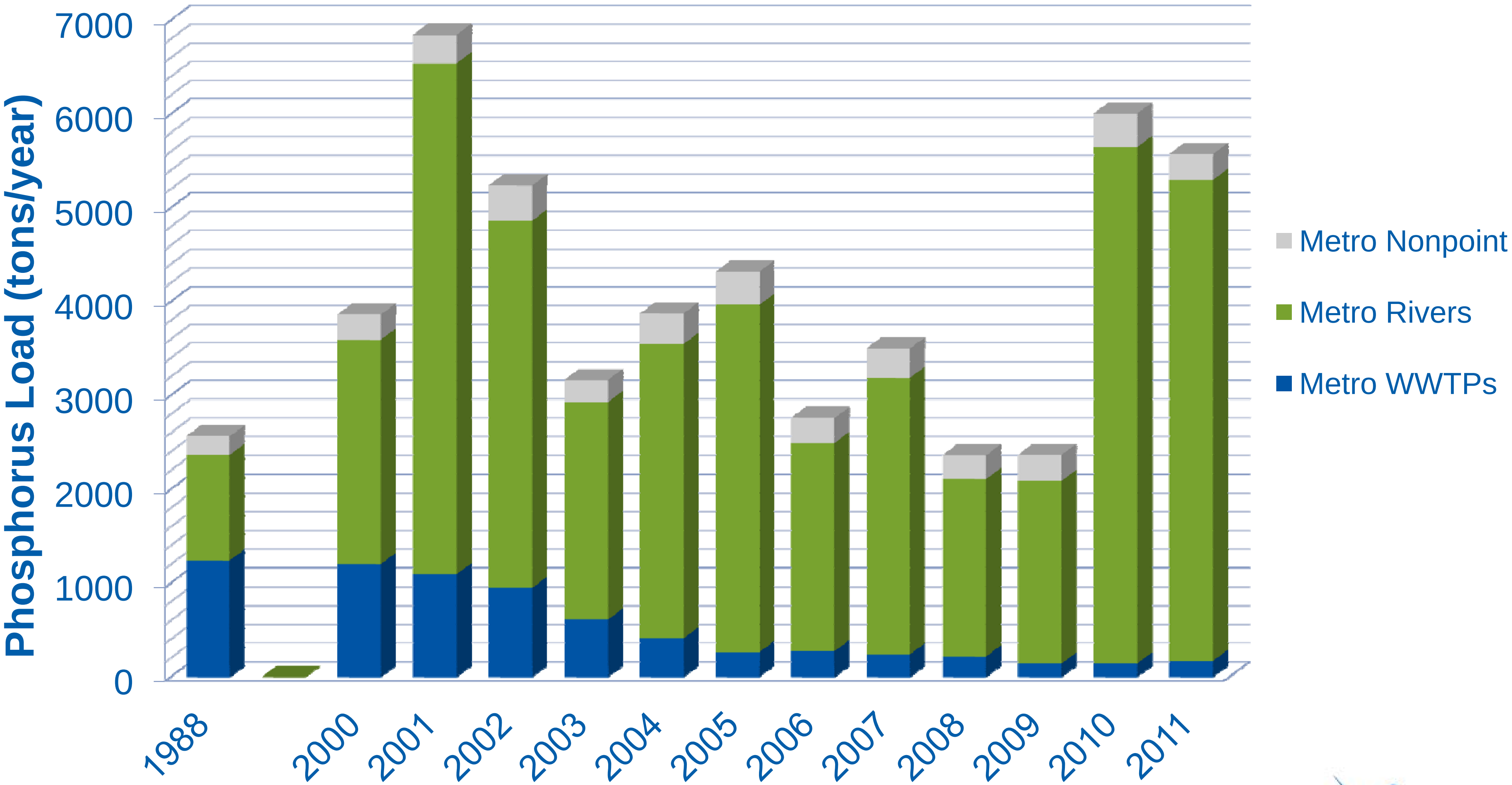
Phosphorous Load Contributions in the Metro Area



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Metropolitan Wastewater Treatment Facility

- Current: 180 MGD
- Design Avg: 251 MGD
- Primary Treatment
- Activated Sludge
    - Nitrification
    - Biological Phosphorous Removal
- Disinfection
- Solids Dewatering
- Incineration

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Phosphorus Removal - Implementation

- 1990 -1991
  - Evaluate alternatives
- 1992 – 1993
  - Demonstration Projects
    - chemical removal
    - biological removal
- 1997 – 2001
  - Full scale demonstration of biological phosphorous
    - 25% of secondary treatment converted
    - Year+ data gathering and evaluations of bio-P system and settling tank improvements

Phosphorus Removal - Implementation

- 2001 - 2005
  - Remaining facility converted to biological phosphorous
- 2003
  - Permit limit 3 mg/l monthly
- 2005
  - Permit limit 1 mg/l annual
- 2002 – 2006
  - Solids systems upgrades including decommissioning of thermal conditioning
- 2005 -2012
  - Actual 0.6 – 0.4 mgTP/l

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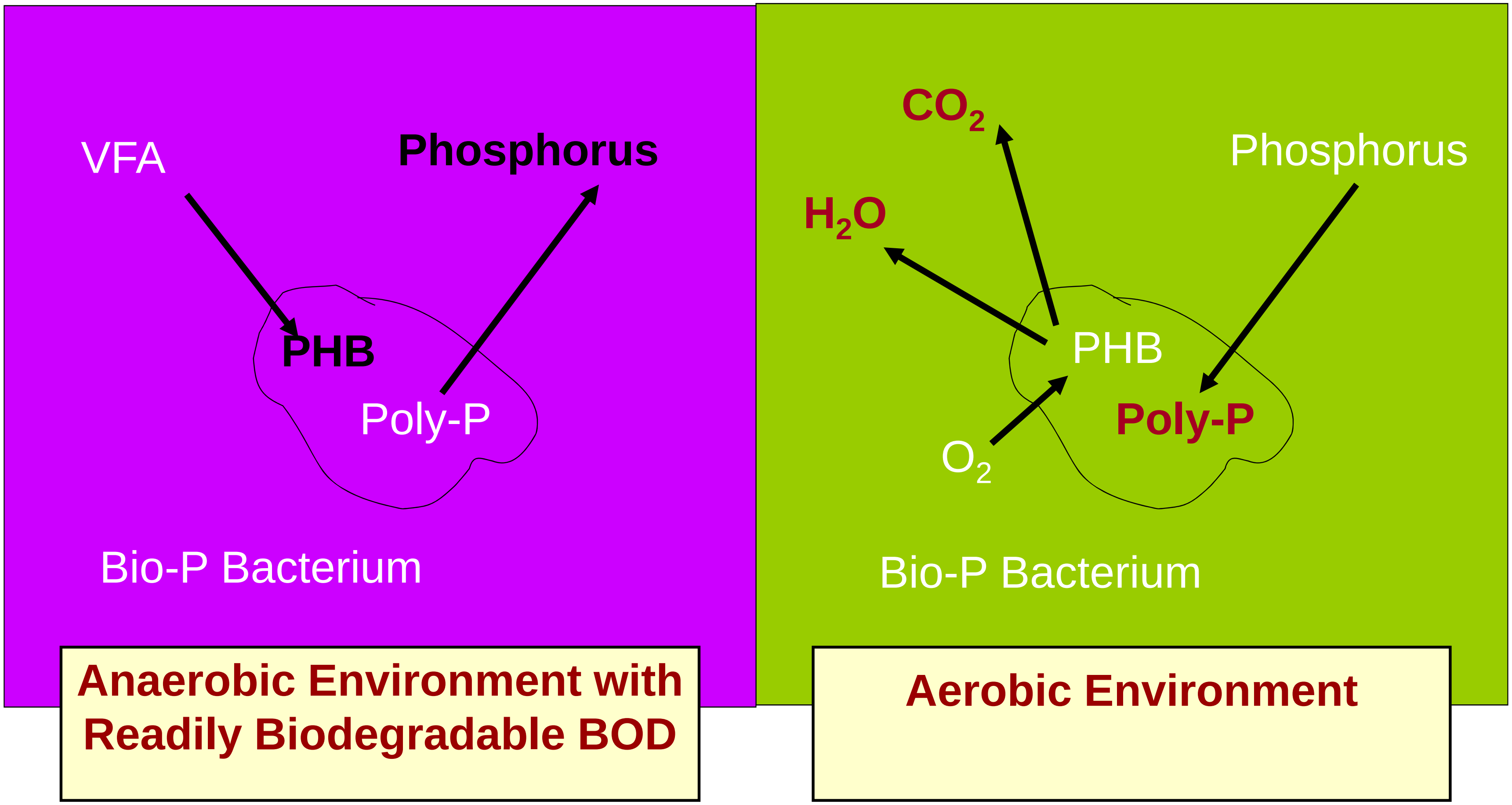
Enhanced Biological P Removal



Key items:

- Availability of VFAs
- Absence of Nitrates (nitrate allow other organisms to grow and compete with PAOs for VFAs)

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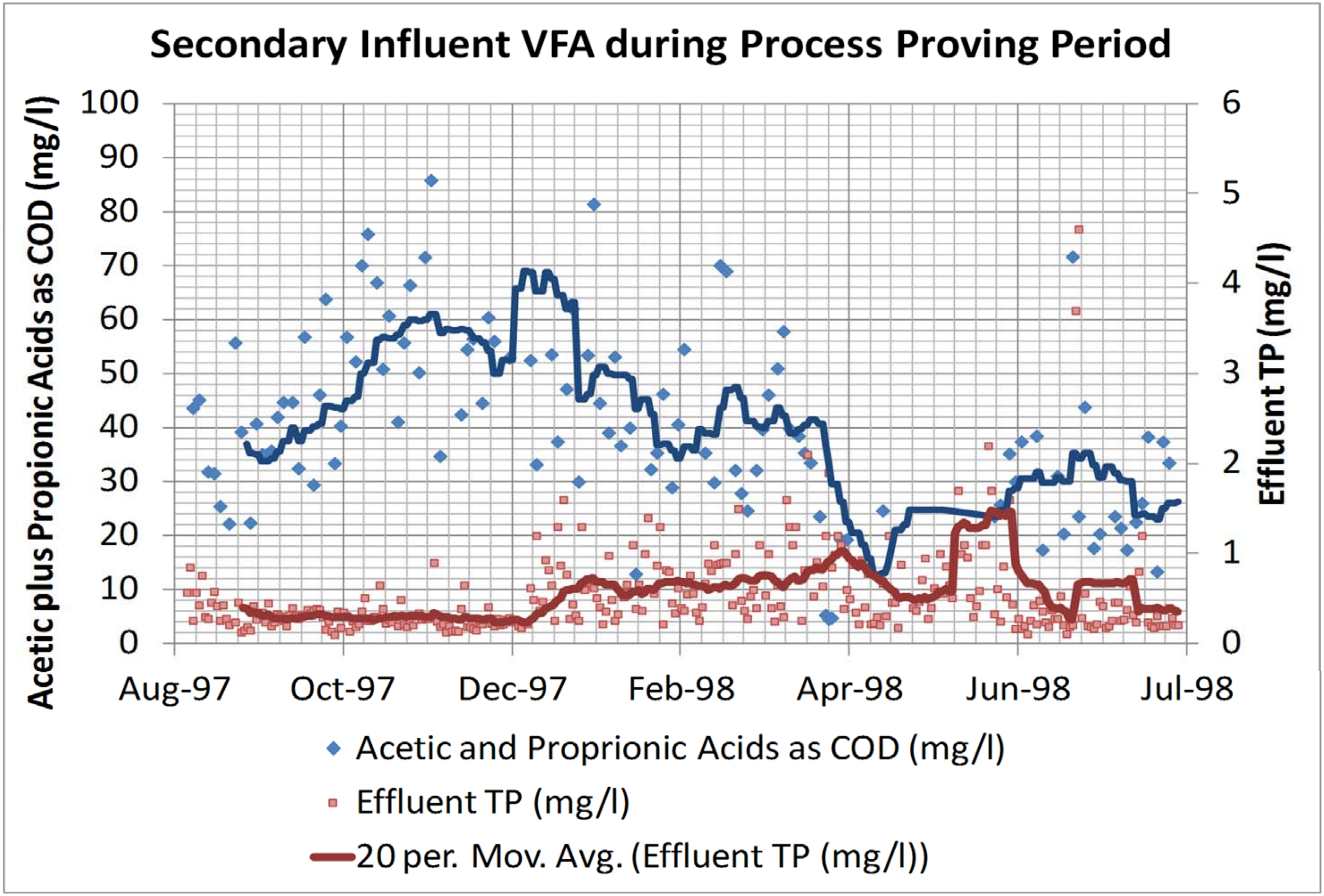
Initial (and on-going) Bio-P evaluations include monitoring VFA concentrations



Bio-P Major Modifications:

- Converted all aeration tanks to fine bubble diffusers

- Converted step feed aeration nitrifying activated sludge system to plug flow Bio-P configuration
  - Feed Pipe
  - Baffles and mixing
  - RAS splitter box

- Modified final settling tanks
  - Replaced cross collector with suction header
  - Implemented channel flocculating baffling
  - Implemented FST influent energy dissipation, flocculation baffling

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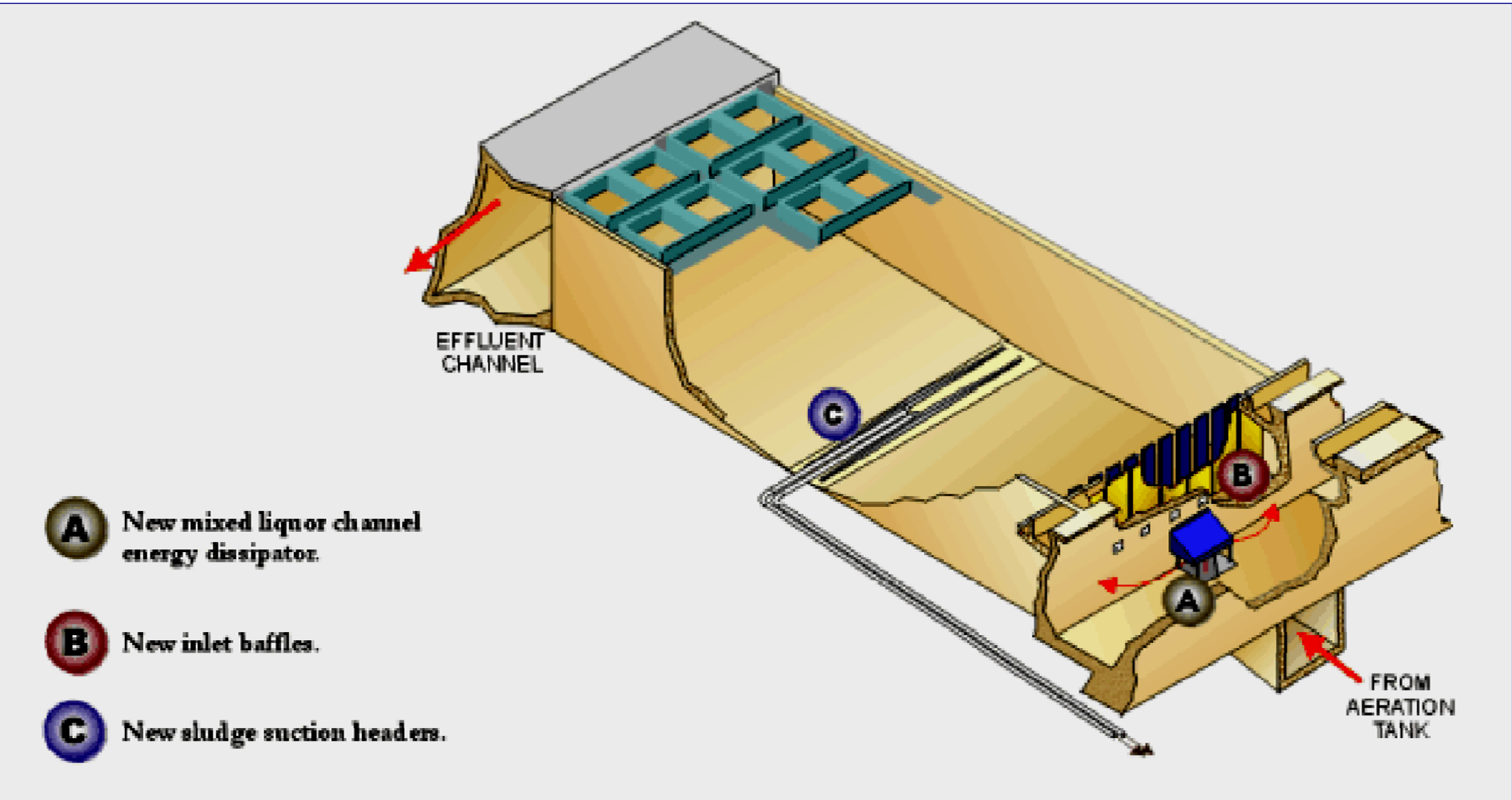
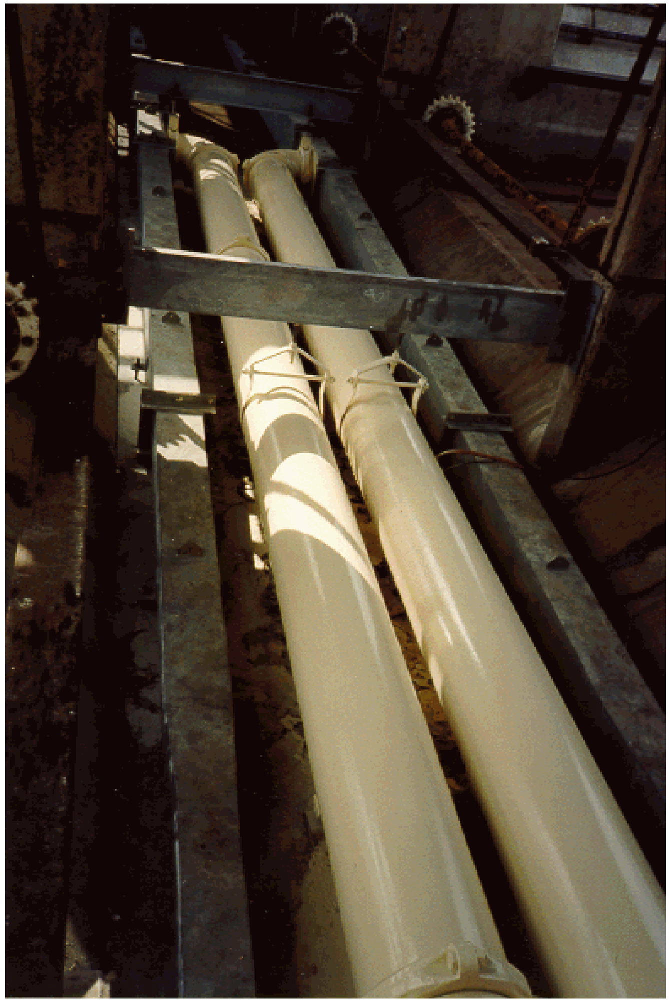
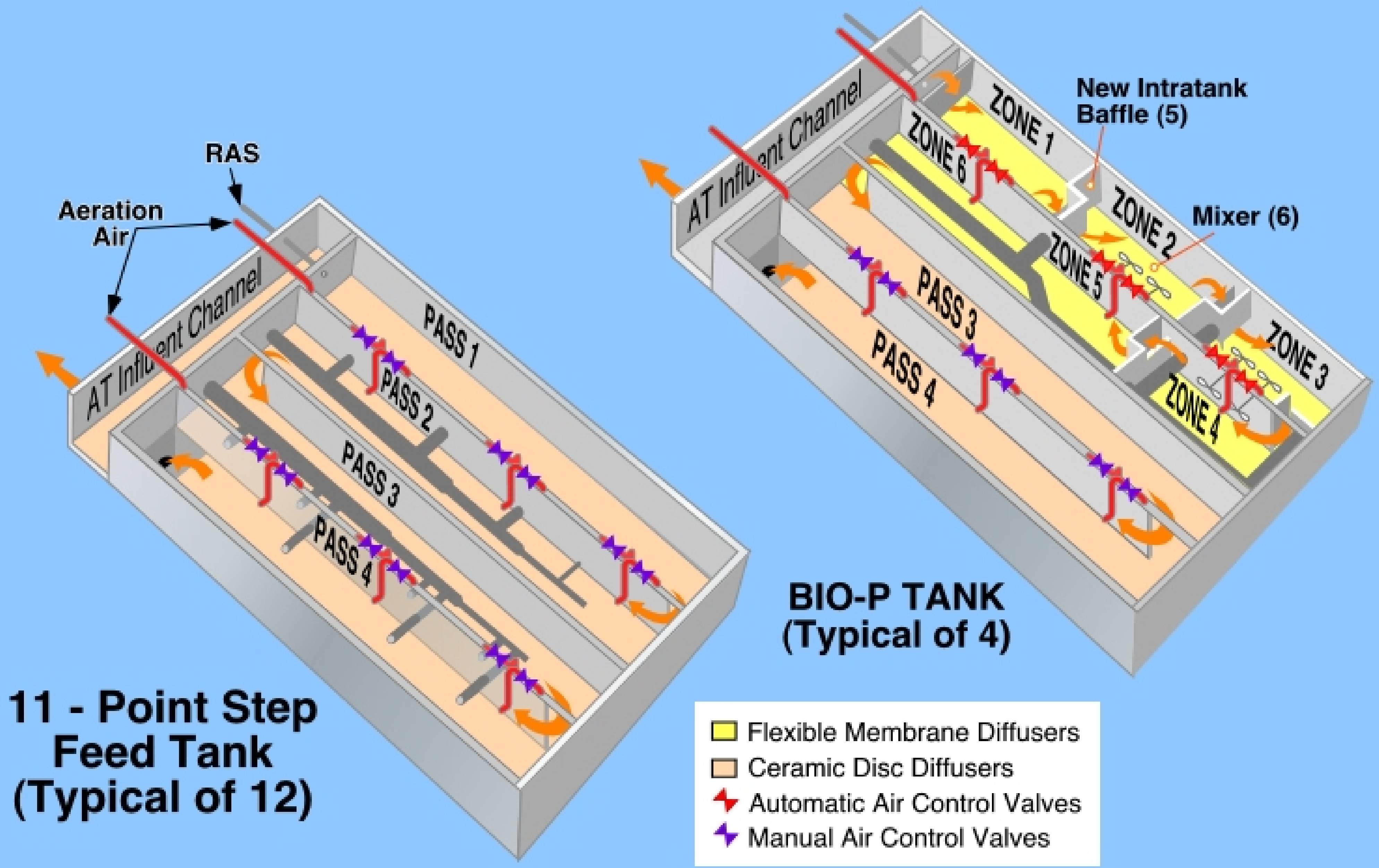
Final Settling Tanks

- Efficient removal of sludge from tank to eliminate potential for P release
- Limit is Total P and TSS will be >5% Phosphorus with Bio-P: excellent TSS capture and performance required at settling

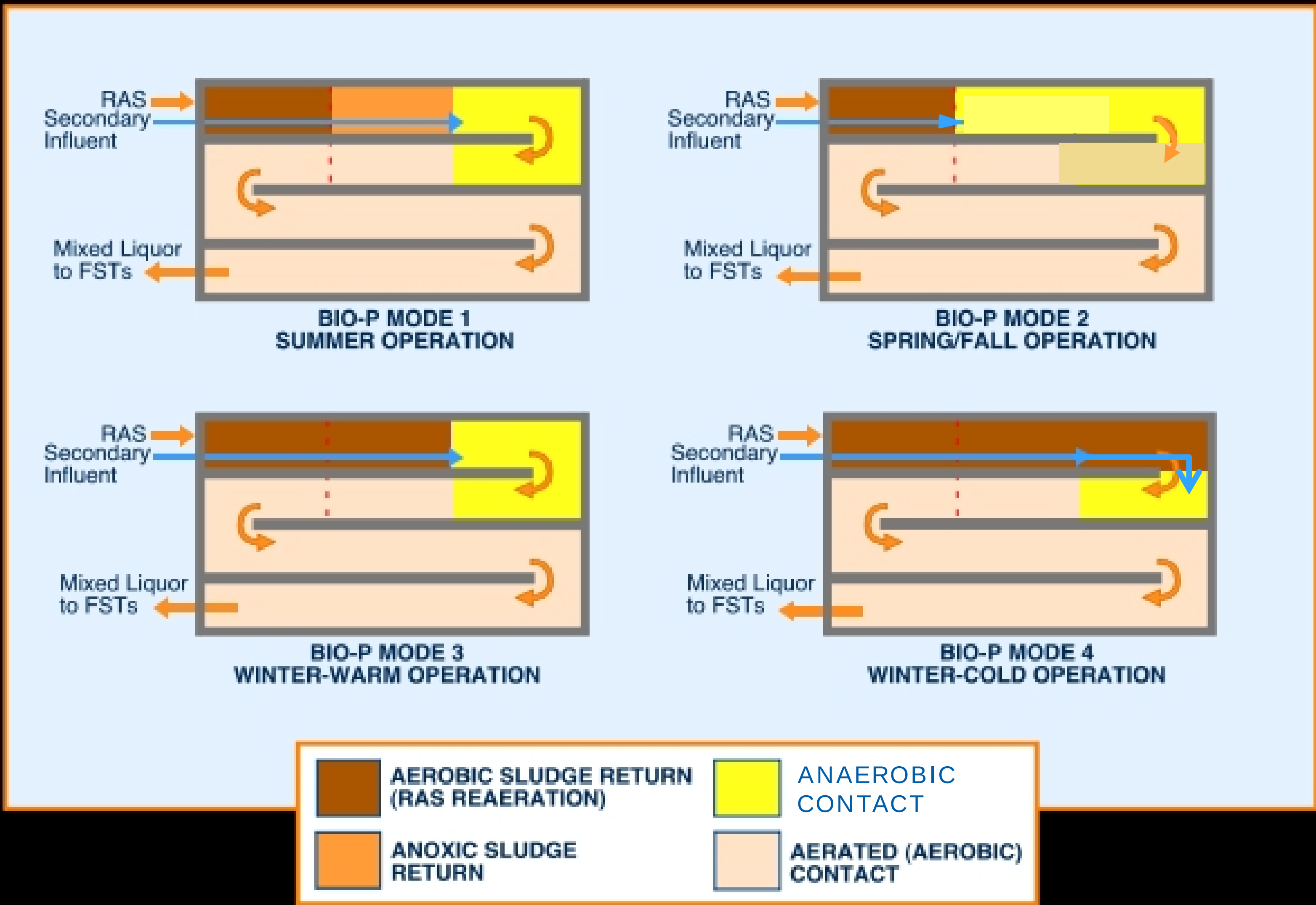




Aeration Tank Modifications

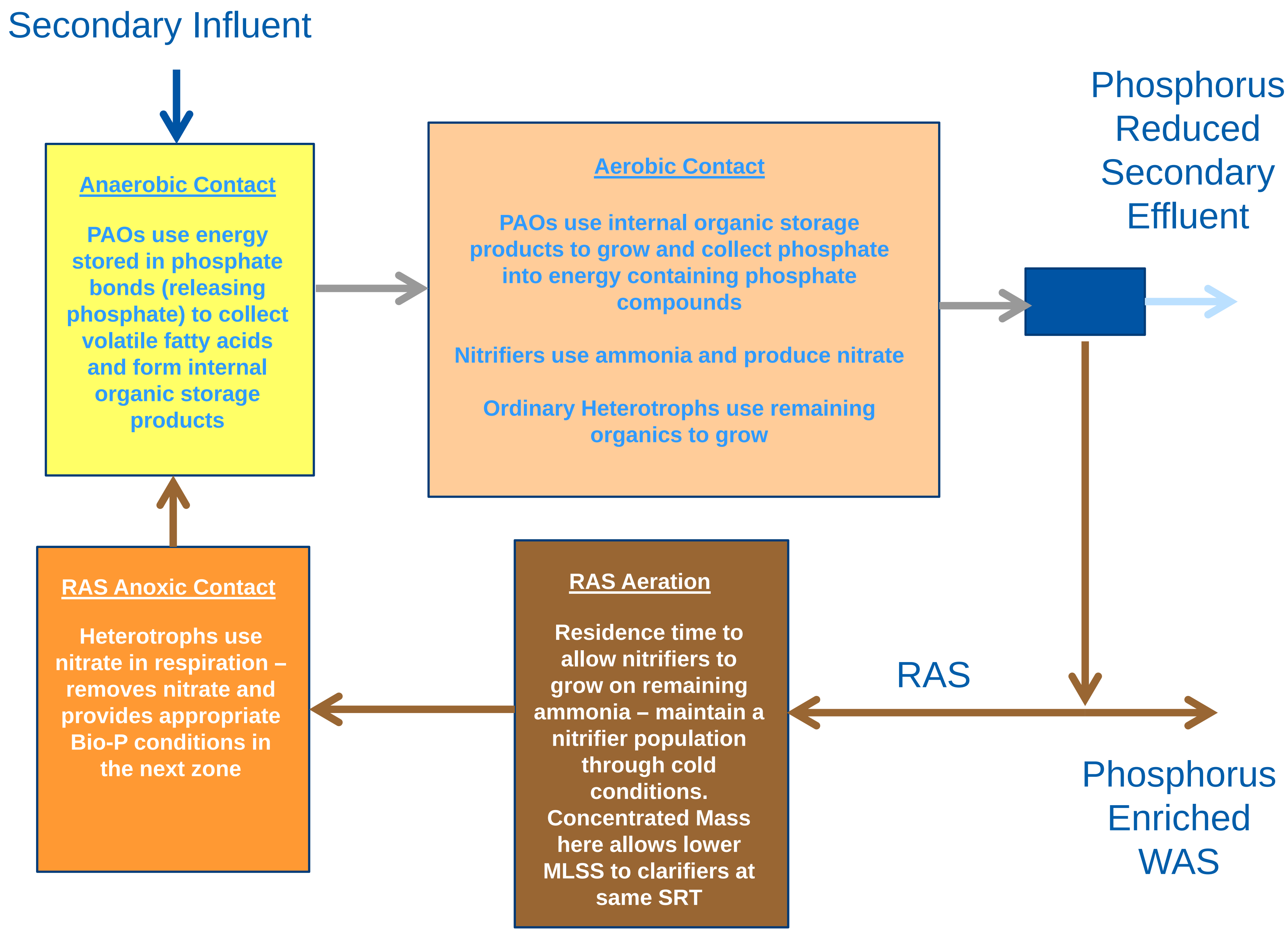


Bio-P Modes

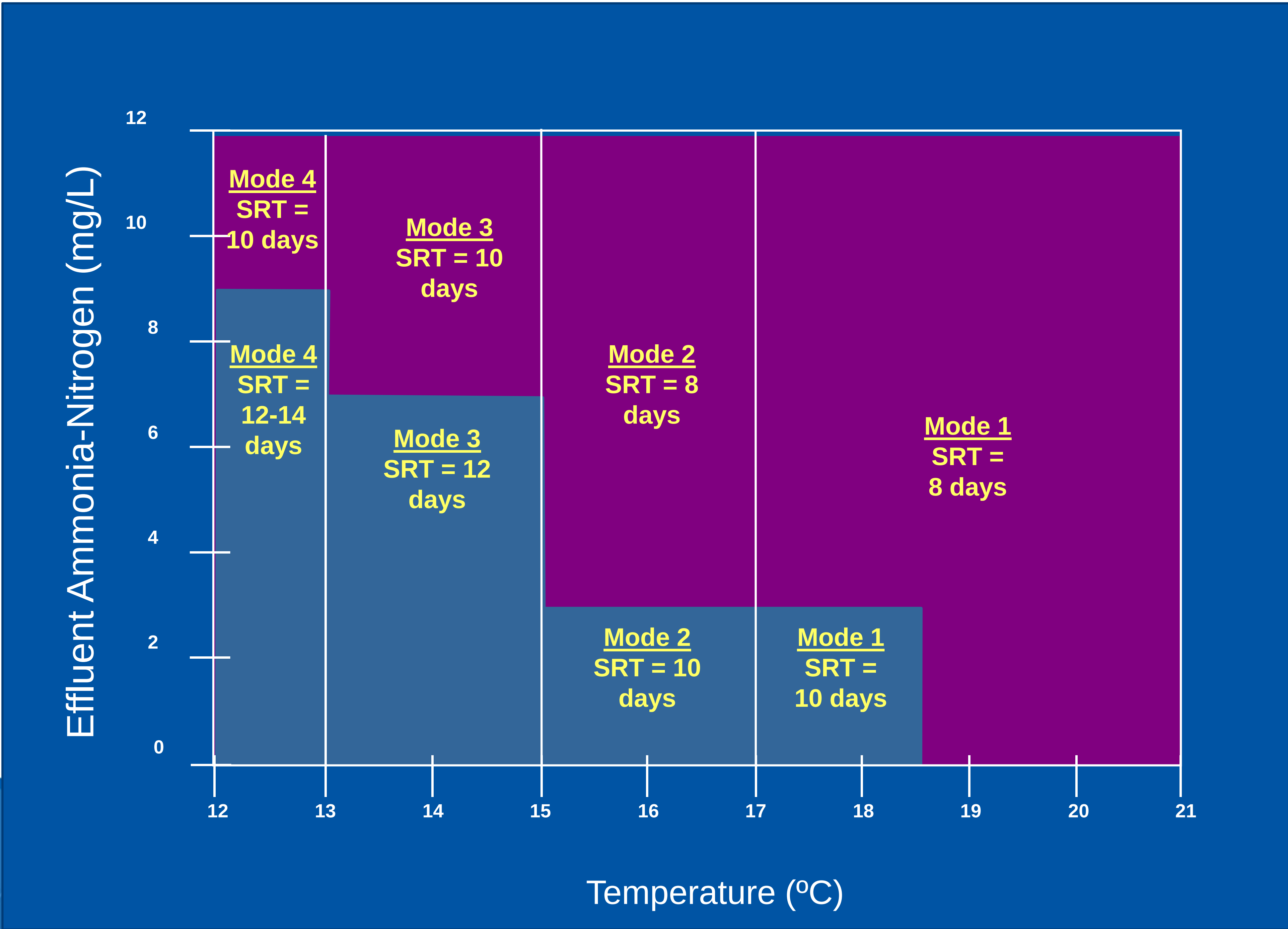


RAS
Secondary Influent
Mixed Liquor to FSTs
BIO-P MODE 1
SUMMER OPERATION
RAS
Secondary Influent
Mixed Liquor to FSTs
BIO-P MODE 2
SPRING/FALL OPERATION
RAS
Secondary Influent
Mixed Liquor to FSTs
BIO-P MODE 3
WINTER-WARM OPERATION
RAS
Secondary Influent
Mixed Liquor to FSTs
BIO-P MODE 4
WINTER-COLD OPERATION
AEROBIC SLUDGE RETURN (RAS REAERATION)
ANAEROBIC CONTACT
ANOXIC SLUDGE RETURN
AERATED (AEROBIC) CONTACT

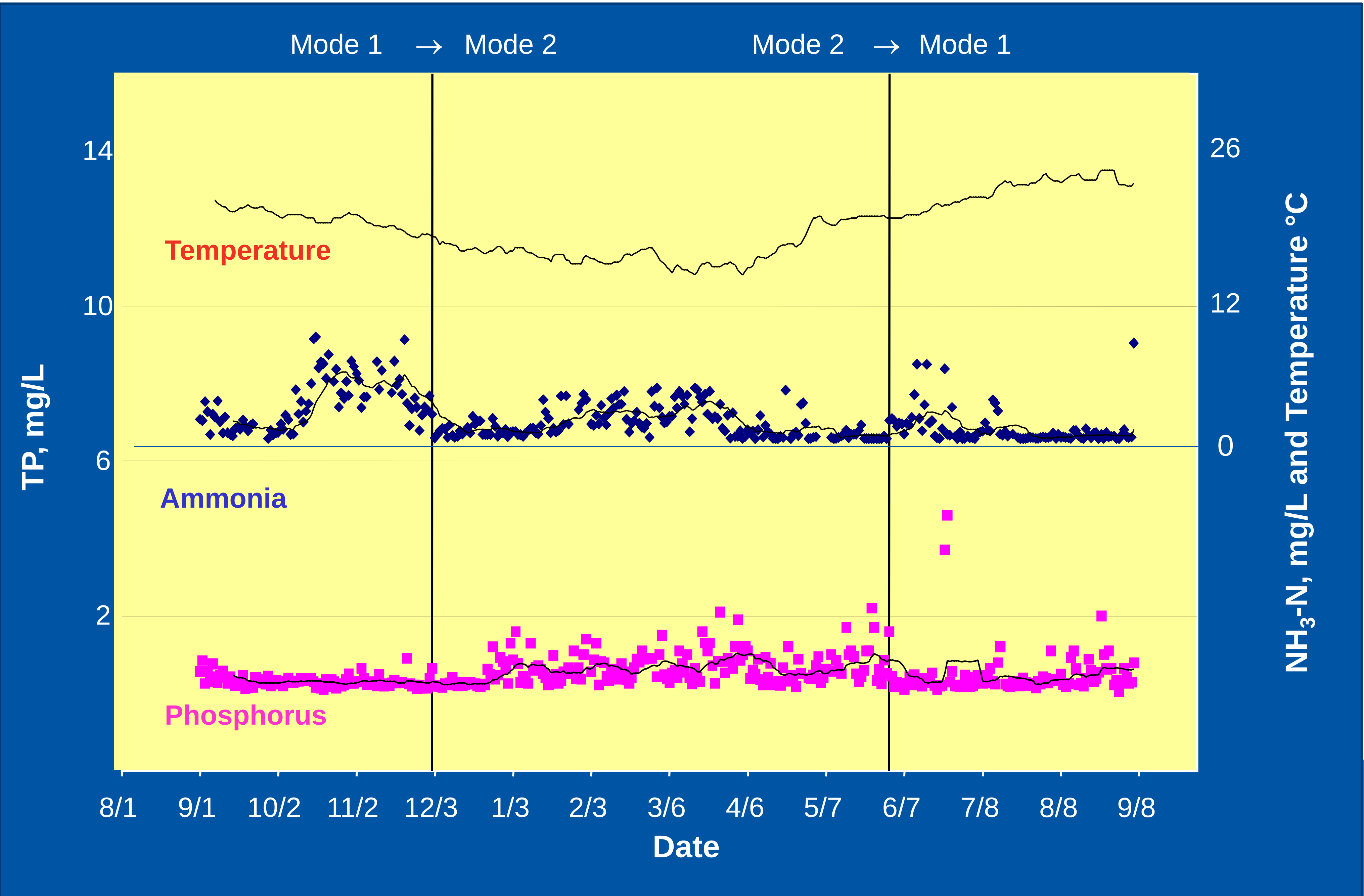
Bio-P Configuration Zones



Modes’ Design Concept



Metro made 2 mode changes during the period 9/97 through 9/98



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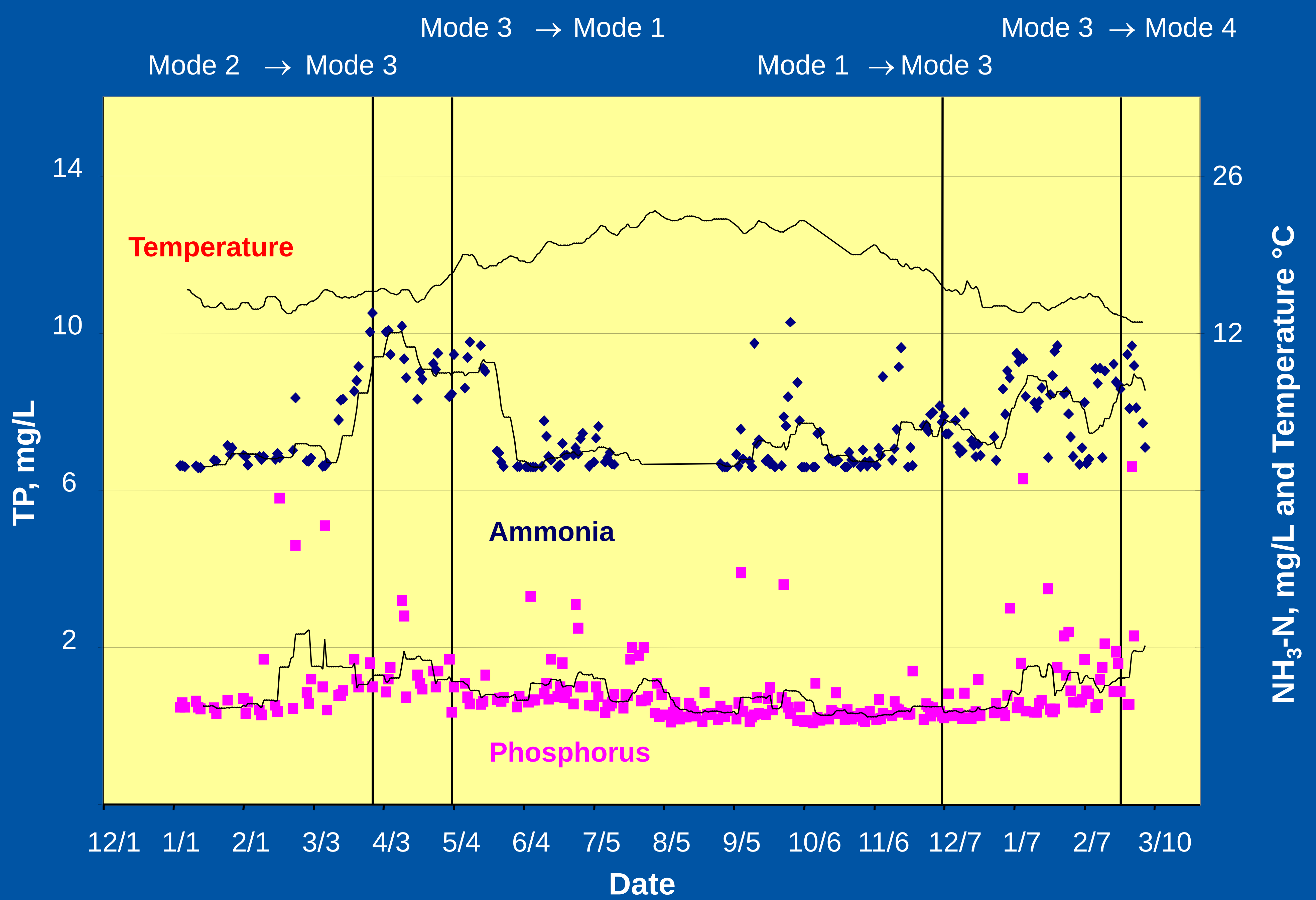
Metro made 4 mode changes during the period 1/00 through 3/01



Mode Operation

- For general operation since process proving, **Mode 1** has been used under all temperature conditions and has:
  - achieved phosphorus effluent requirements
  - maintained adequate nitrifying population to allow seasonal adjustments as needed to the level of nitrification

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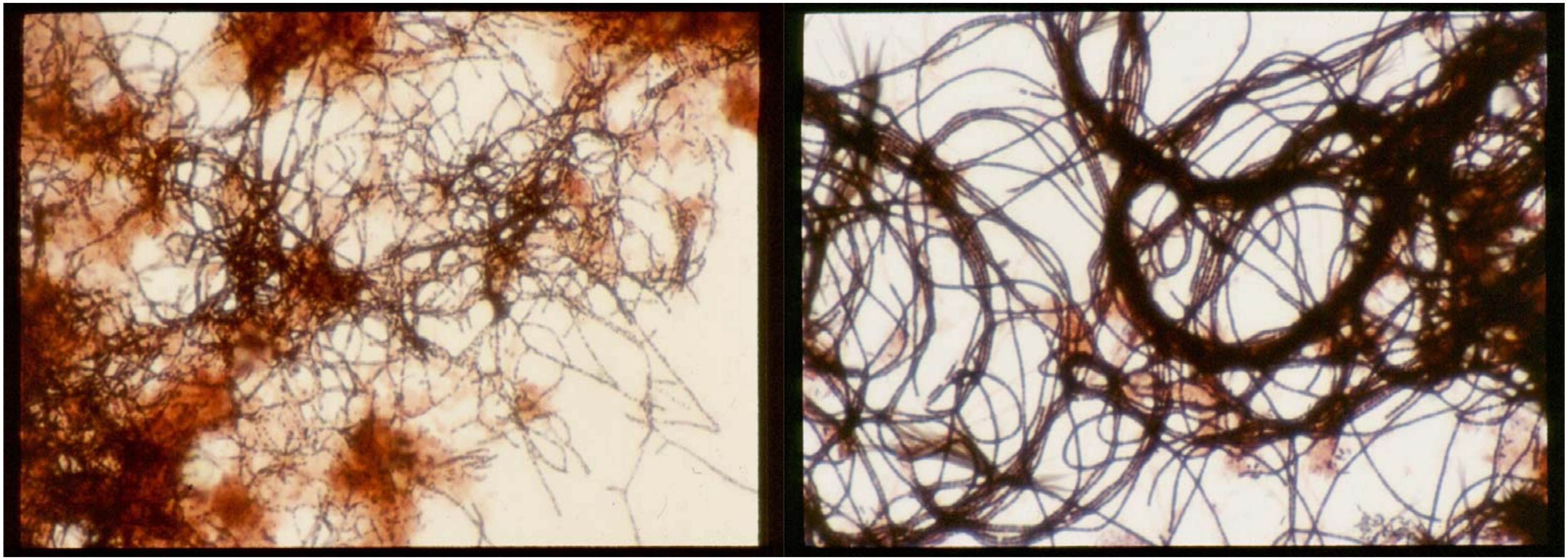
FOAM

Metro had 2 prevalent filamentous foaming organisms with the initial implementaiton of Bio-P, Norcardia & Microthrix Parvicella.



Nocardia is a branched filament that prevails during warm weather.

M. parvicella is an unbranched filament that prevails during cold weather.

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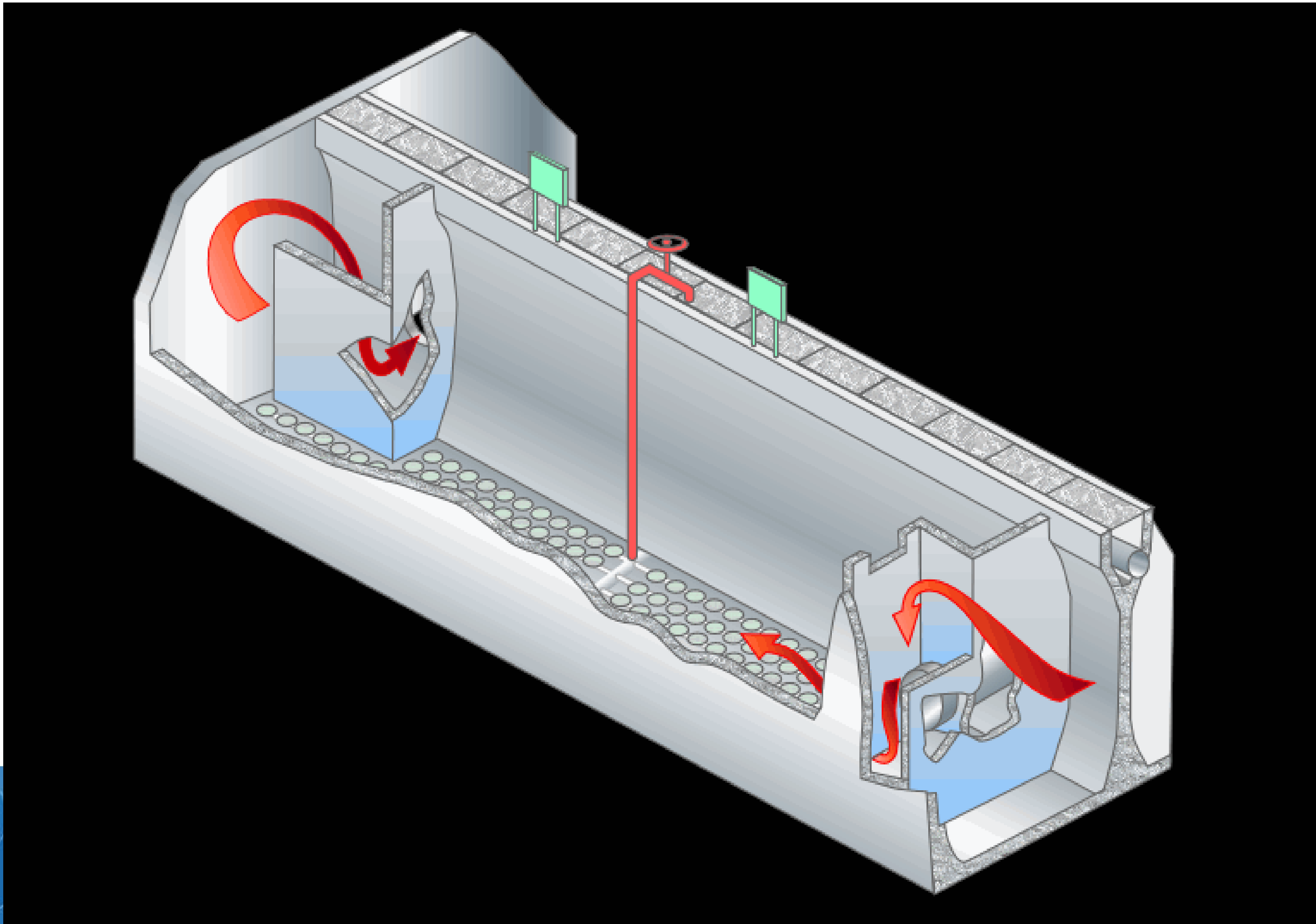
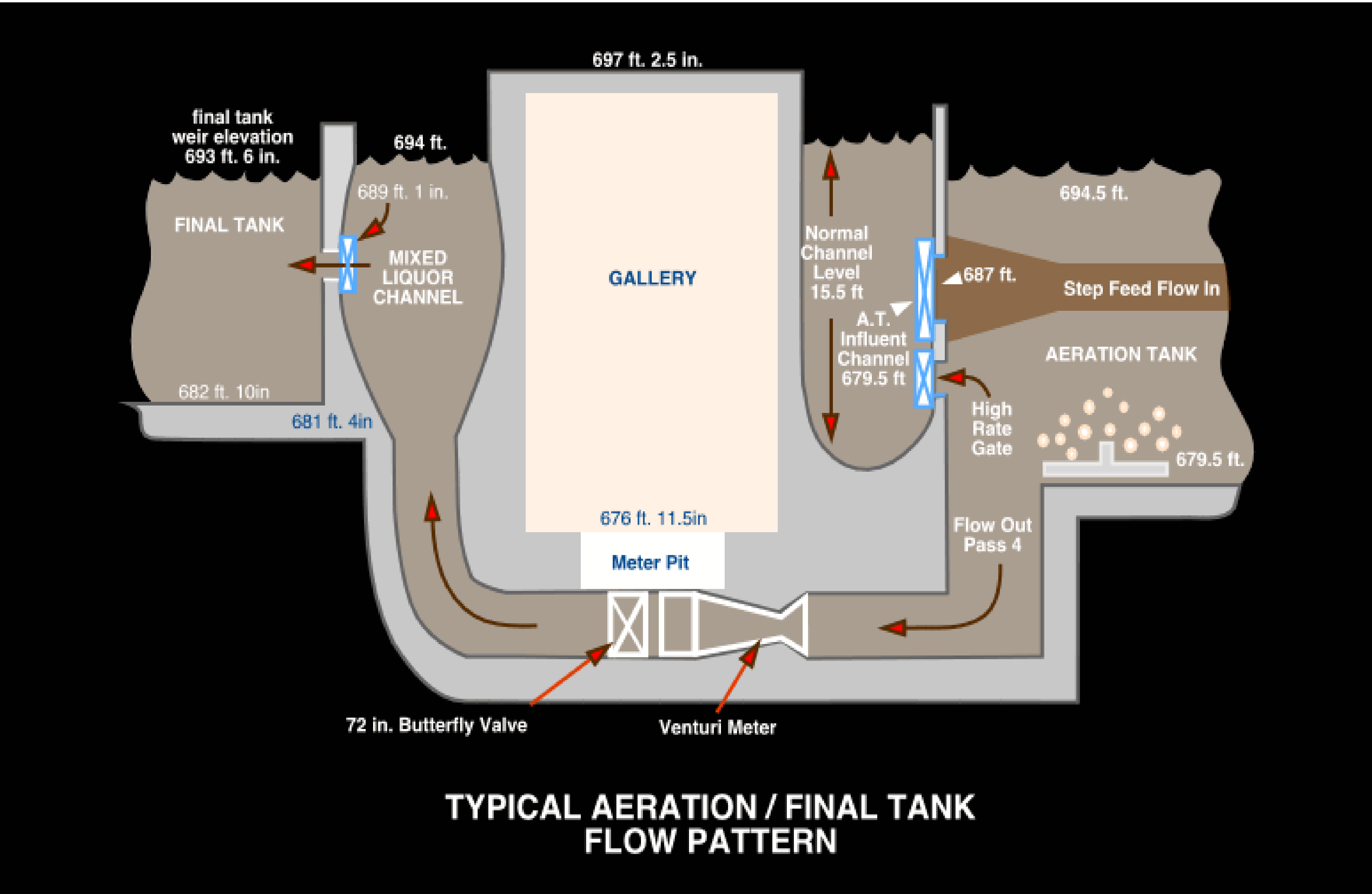
Foam is trapped at the end of each pass where mixed liquor goes under the Y-wall.



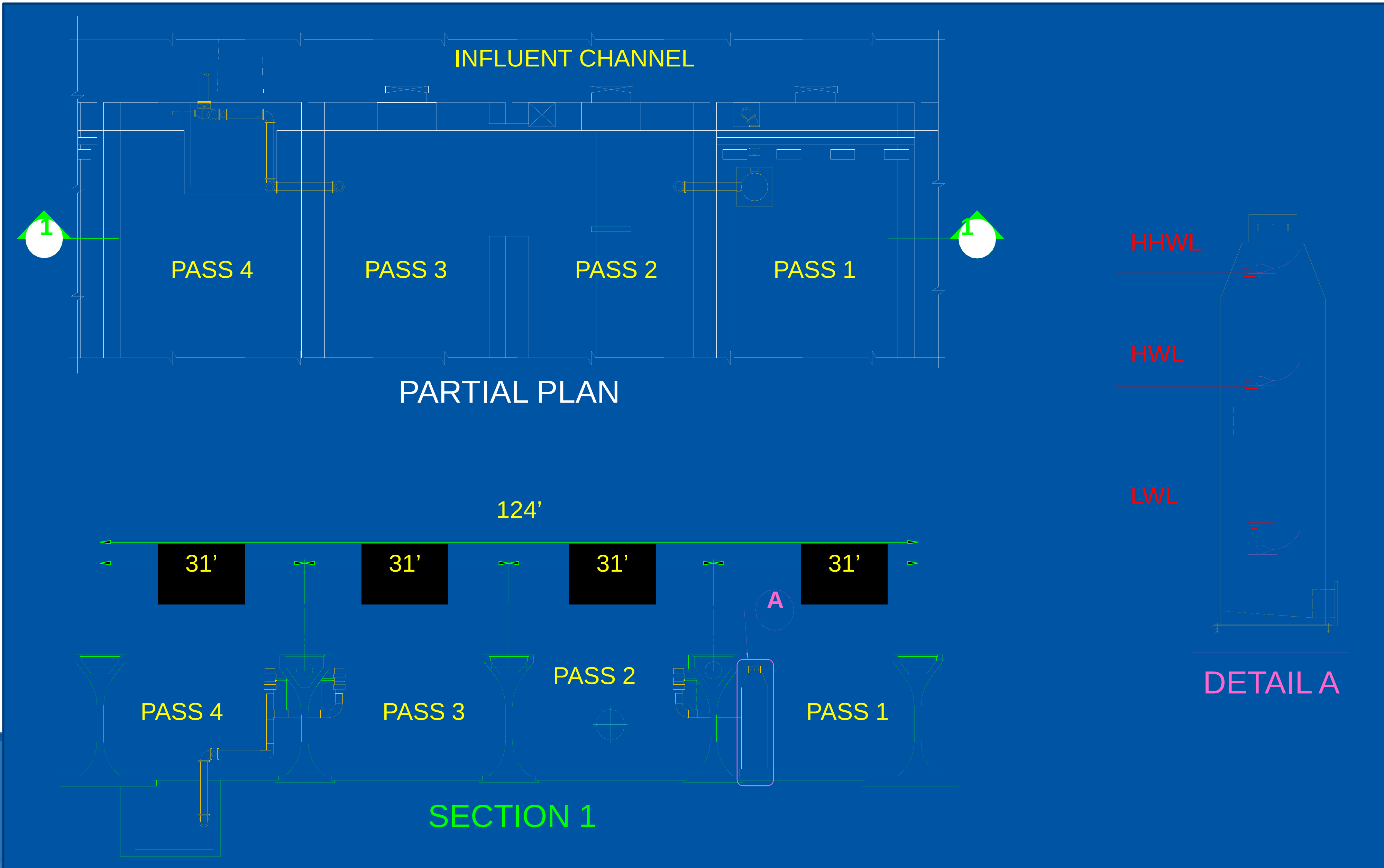
Foam is trapped at the tank outlet.



Metro controlled the foam by selective foam wasting in the RAS re-aeration zone, but design needed improvement.

- Foam is hard to pump
  - Rotary lobe pumps
- Did not remove foam in other passes
- Manual operation is difficult (16 tanks)

Improved foam wasting design provided 4 points for withdrawal & automatic foam level control



Foam and Filament Control at Metro

- Close observation of micro biology
- Operate at lower SRT, “Hydraulic” SRT for stable control of WAS rate
- Close observation of settleability parameters and conditions
  - SVI
  - Centrifuged volume
  - Blanket depth
- Selective use of RAS chlorination

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~Bio-P Costs 2002 to present

Facility	~Cost for Bio-P
Metro	$36M*
Blue Lake	$9M
Seneca	$8M
Empire	$2M
Eagles Point	$0.9M

*Earlier phase include conversion of ¼ of the tankage for Bio-P testing as well as other significant modifications, rehabilitations and improvements (e.g. diffuser replacement). Total earlier phase program cost was ~ $38M

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Observations and Lessons Learned

- Effluent TP variation – seasonal and weekly
- Impact of influent TP concentration
- Metro’s configuration and RAS aeration and non-aerated observations
- Bio-P response to extended reduction in wastage
- Importance of stable DO control (initial aerobic zones particularly)
- Recycle and load distribution between tanks
- Importance of influent soluble readily biodegradable COD
- Impact of RAS nitrates
- RAS chlorination impact on effluent P
- Dewaterability of anaerobically digested Bio-P sludge

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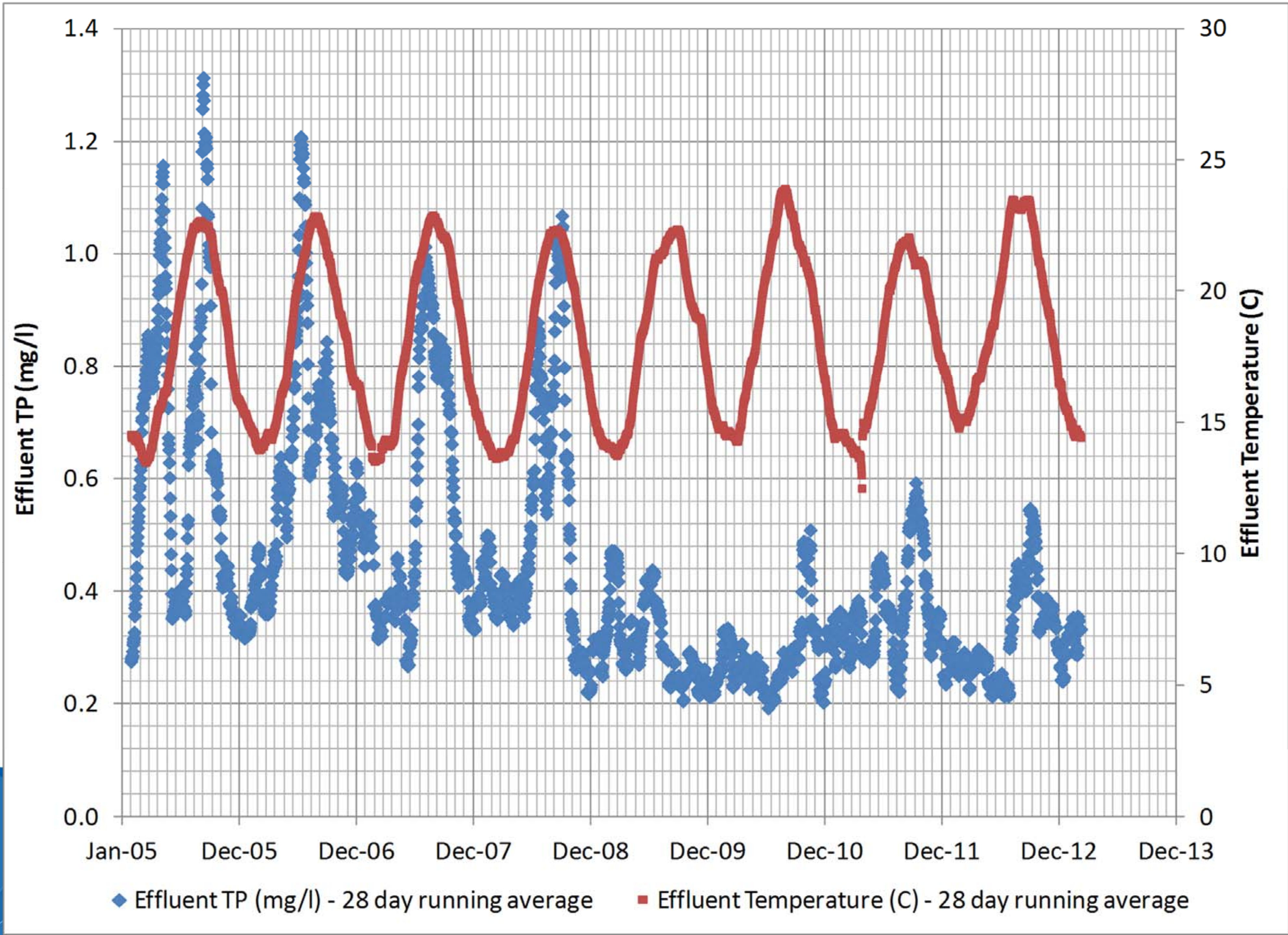
Effluent P Variations - Seasonal



Potential Causes for Seasonal TP Fluctuations

- Secondary influent characteristics
  - VFA and P concentrations
  - Recycle impacts
- Anaerobic Zone Effectiveness
  - VFA production, nitrate reduction
- DO Profile
  - P uptake and metabolism of intermediates
- P Release in FSTs
  - Solids retention
- Seasonal/Temperature impacts on micro-organisms

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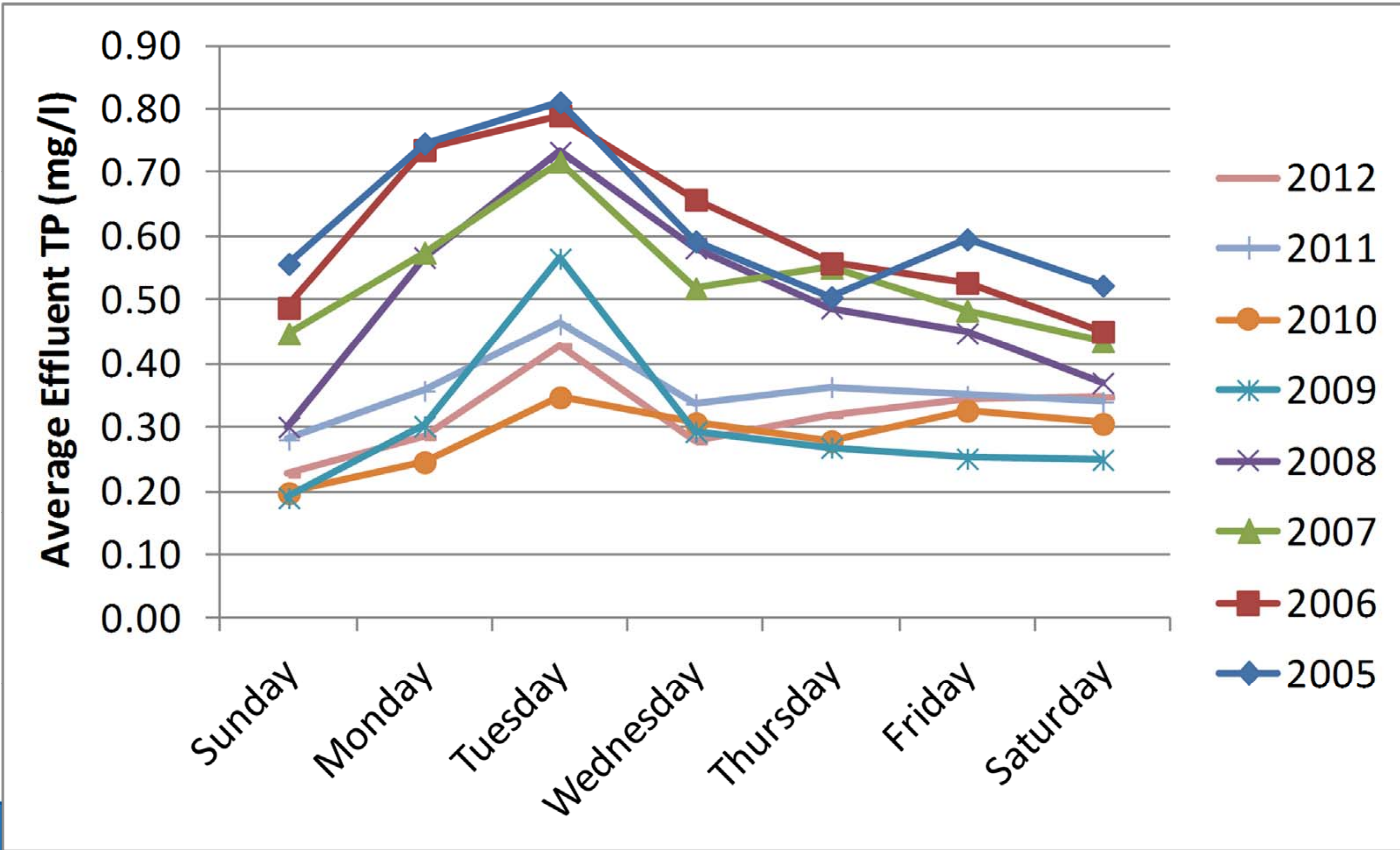
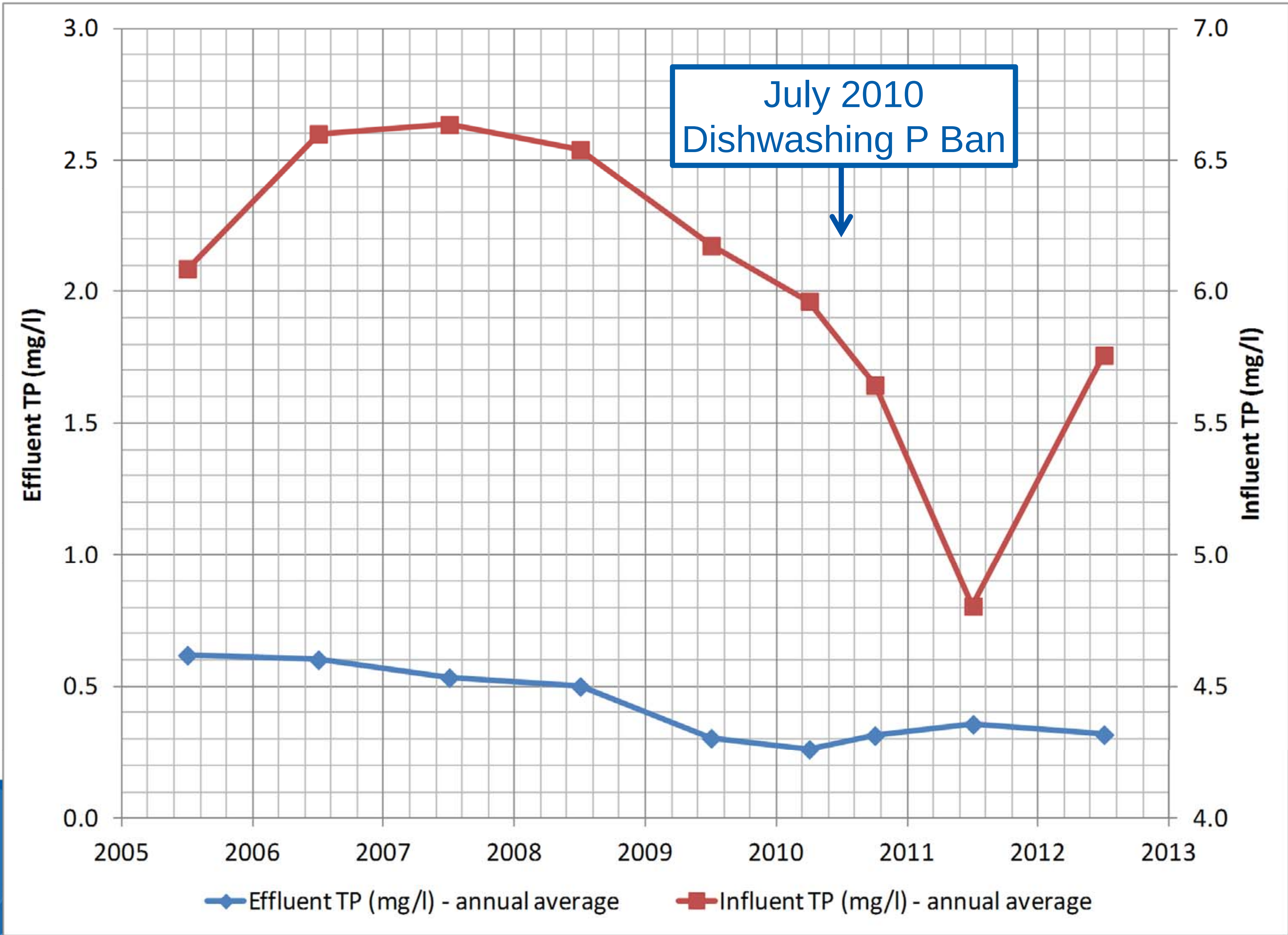
Effluent P Variations - Weekly



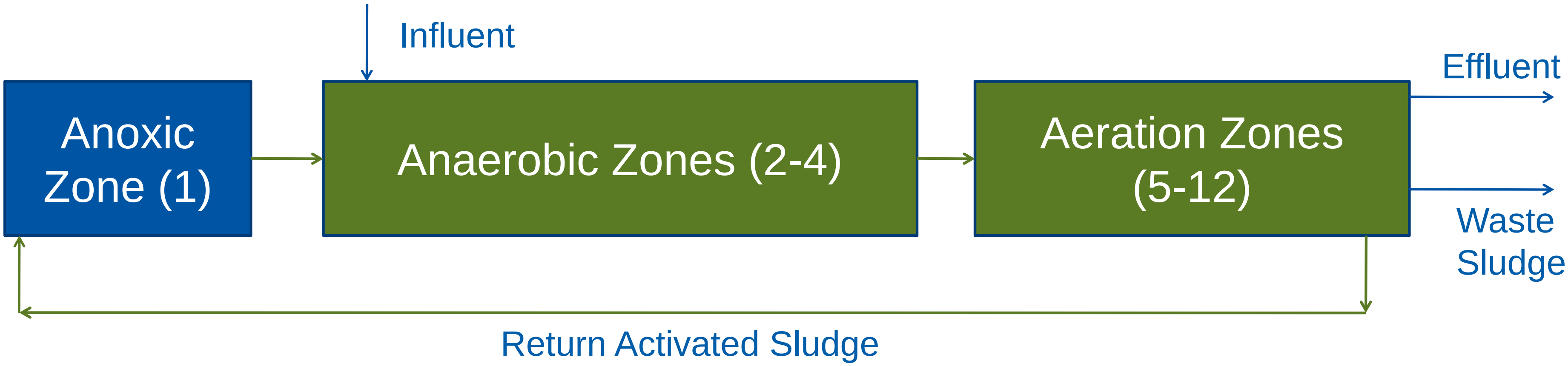
Weekly influent organic and/or nitrogen pattern impact/influence on Bio-P storage product cycle

Influent and Effluent TP

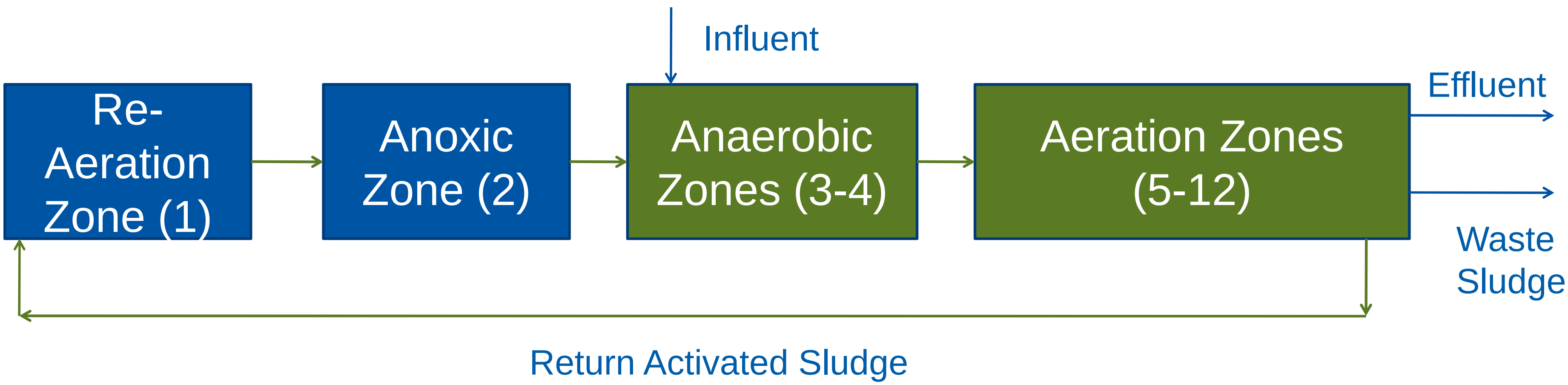


Period in NE Quad with No Aeration of Zone 1 – Low Air Mixing

NE Quadrant:

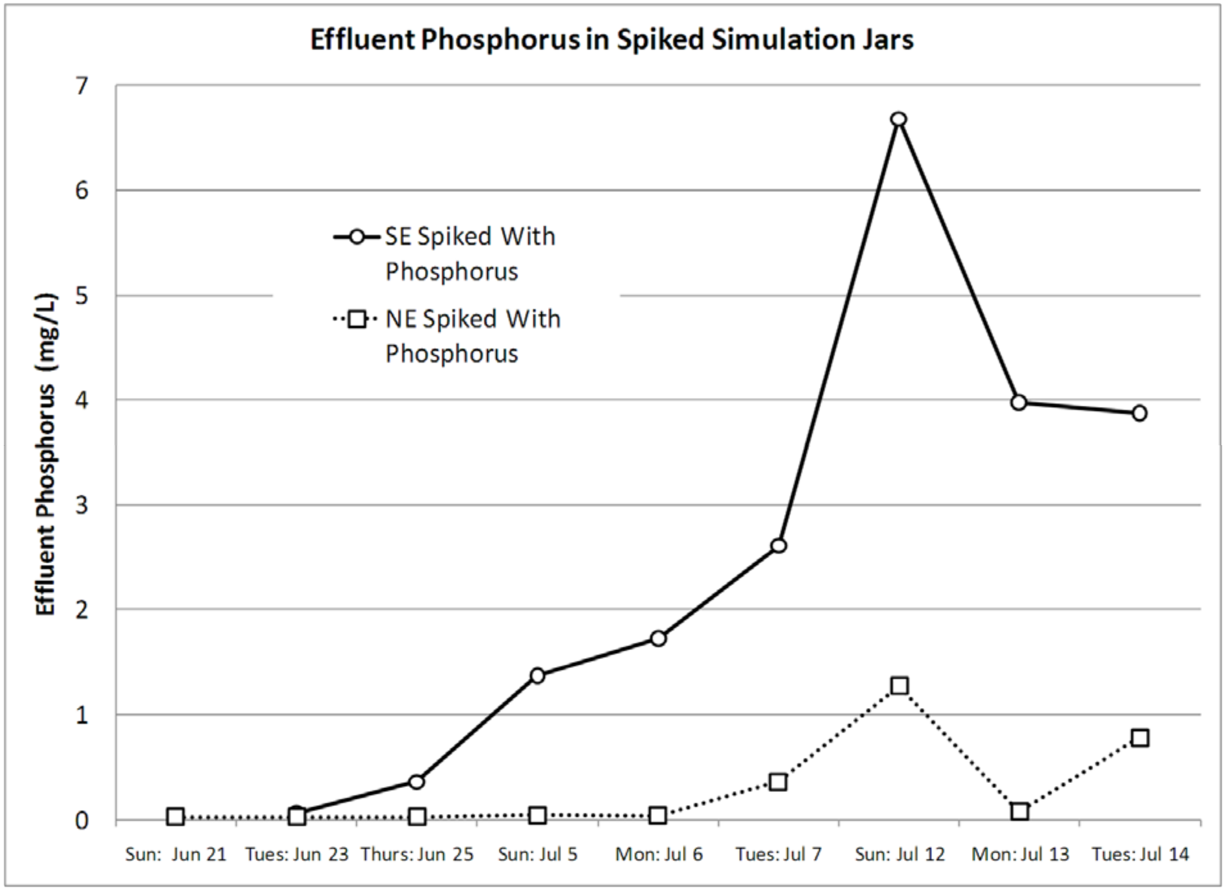


Other Quadrants (SE, NW, SW):



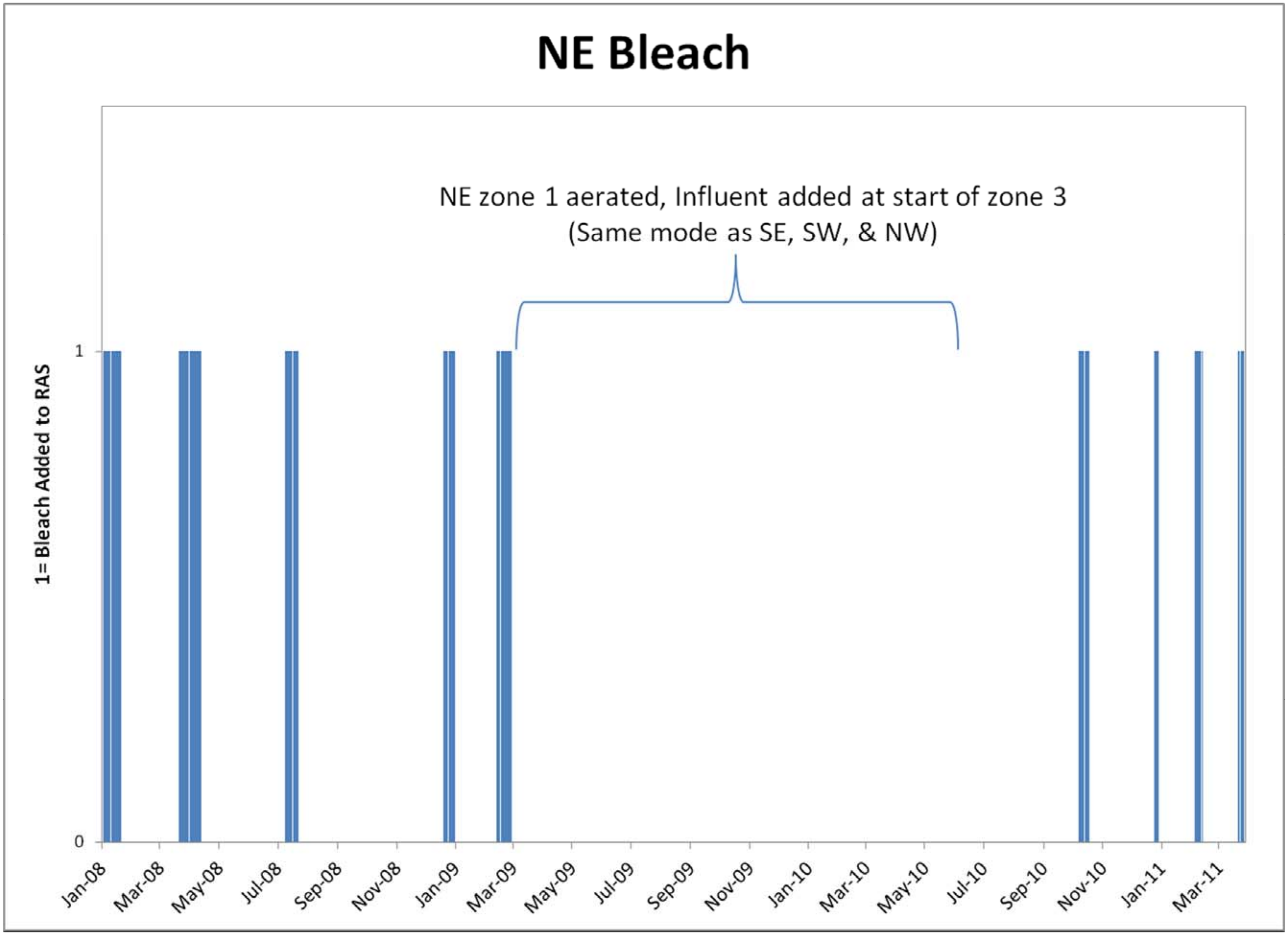
Period in NE Quad with No Aeration of Zone 1

- NE Quadrant – More consistent effluent phosphorus when exposed to increased phosphorus loads



- Observation of higher levels of filaments with the NE quadrant

- Not taxed in terms of nitrification during periods of operation in this mode



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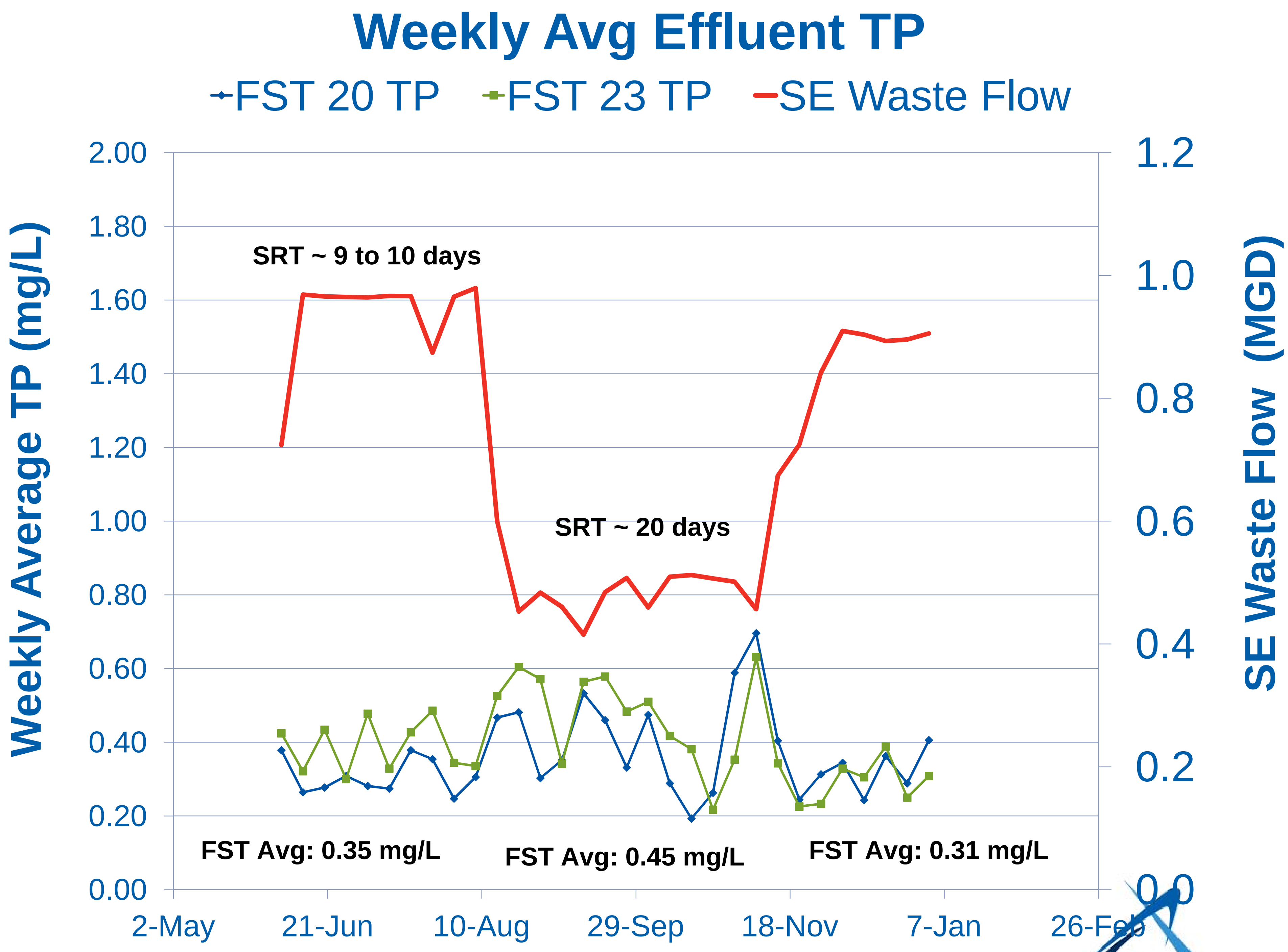
2010 Metro Test of Reduced Wastage

- Reduced wastage from one quarter of the plant to evaluate potential full plant impacts to accommodate future solids handling train projects
  - WAS was decreased from 1 mgd to 0.5 MGD for ~3 months in one quadrant of the plant



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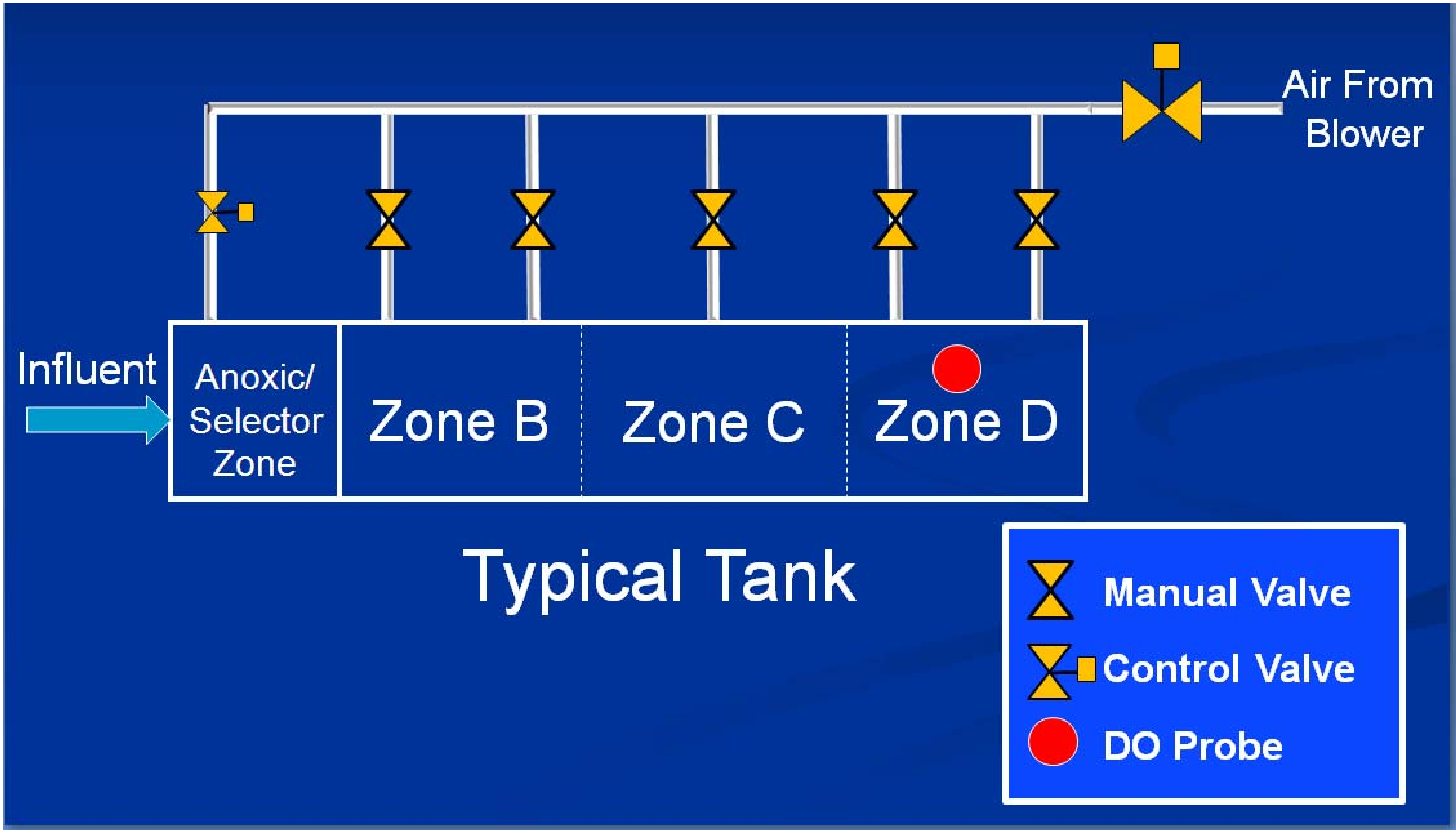
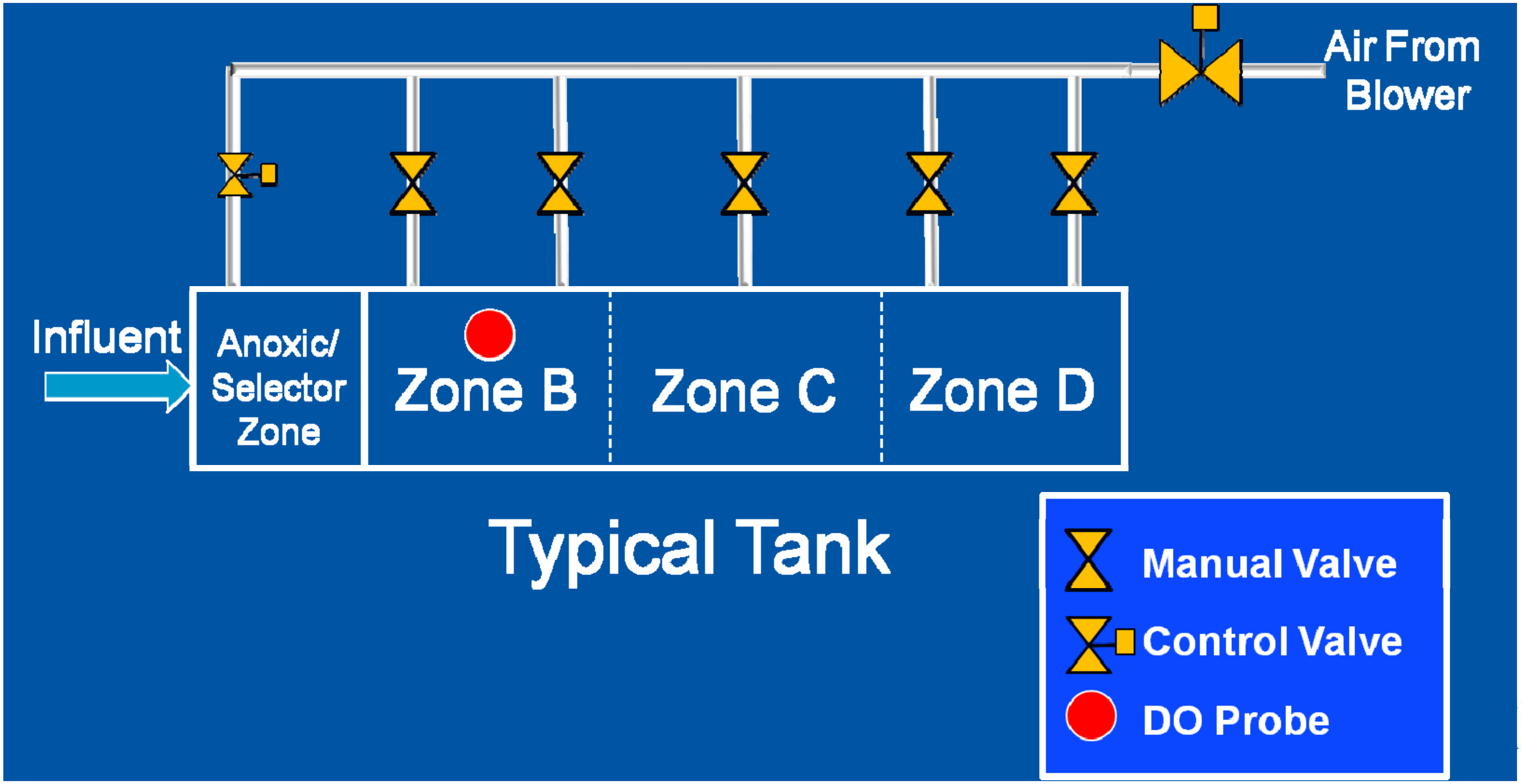
Seneca plant – Existing configuration

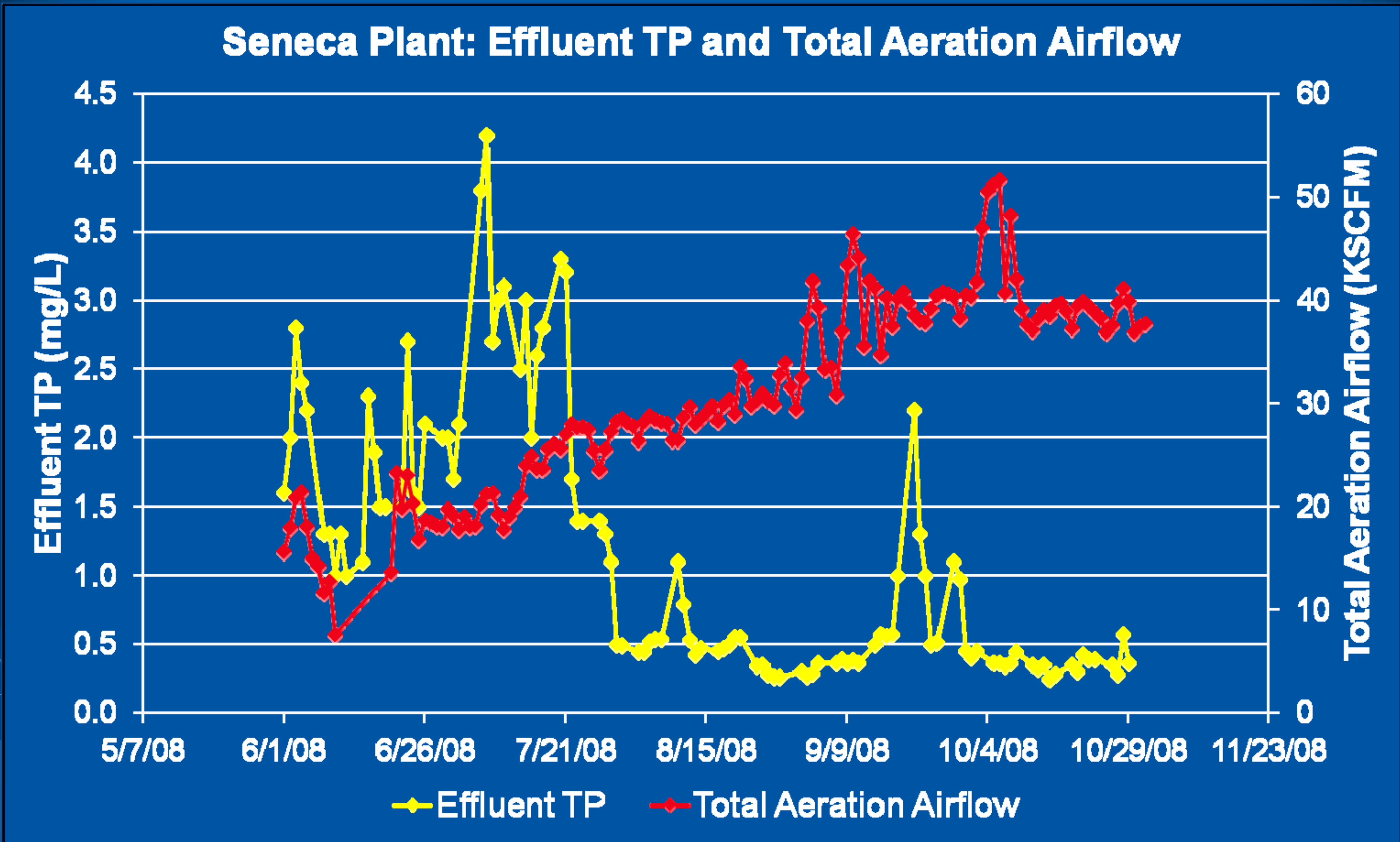


Stable DO Concentrations/Control (Seneca)

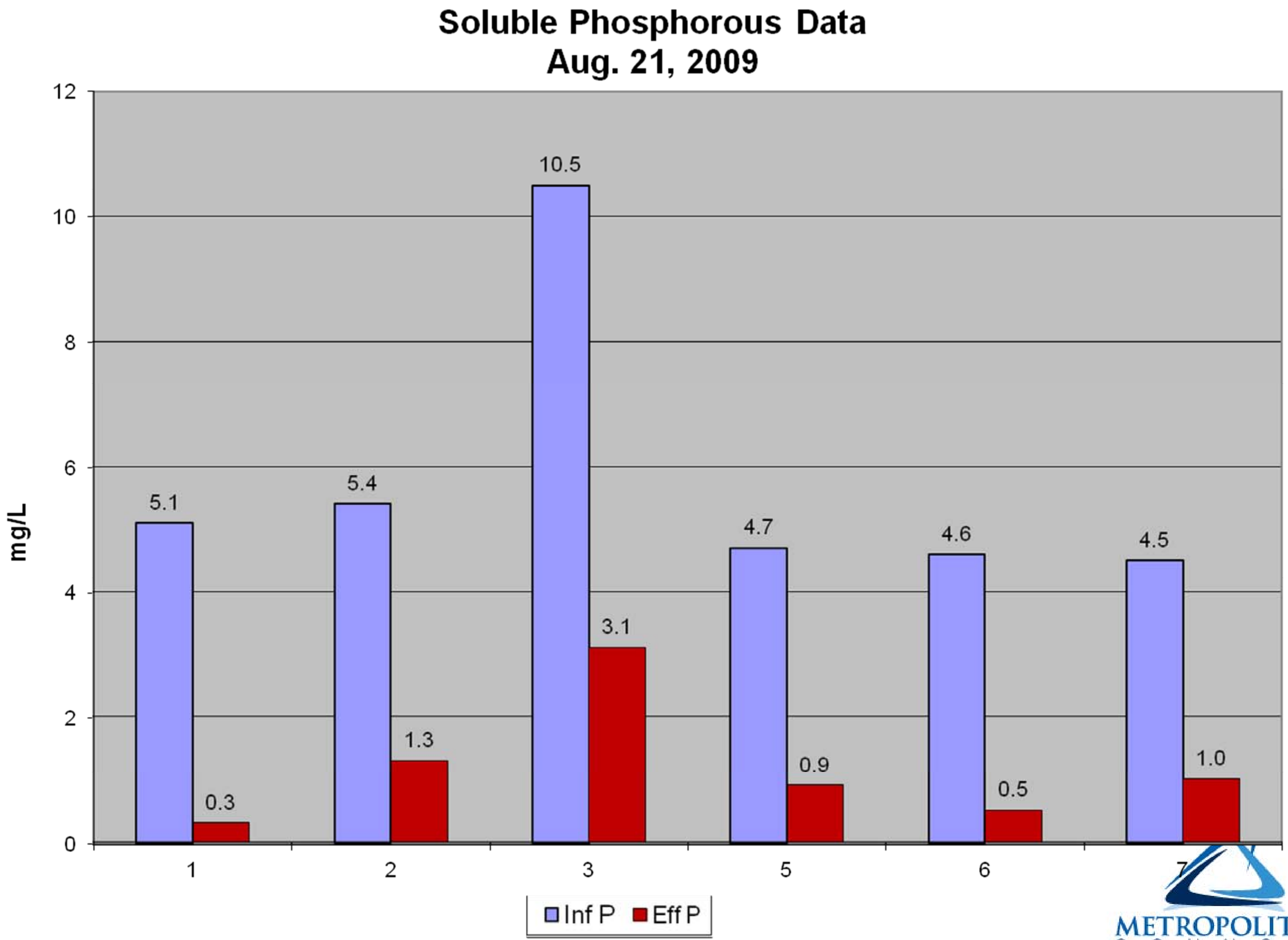
- One DO probe per tank at the end controls airflow to each tank
- Unable to provide sufficient air at front of tank for Bio-P

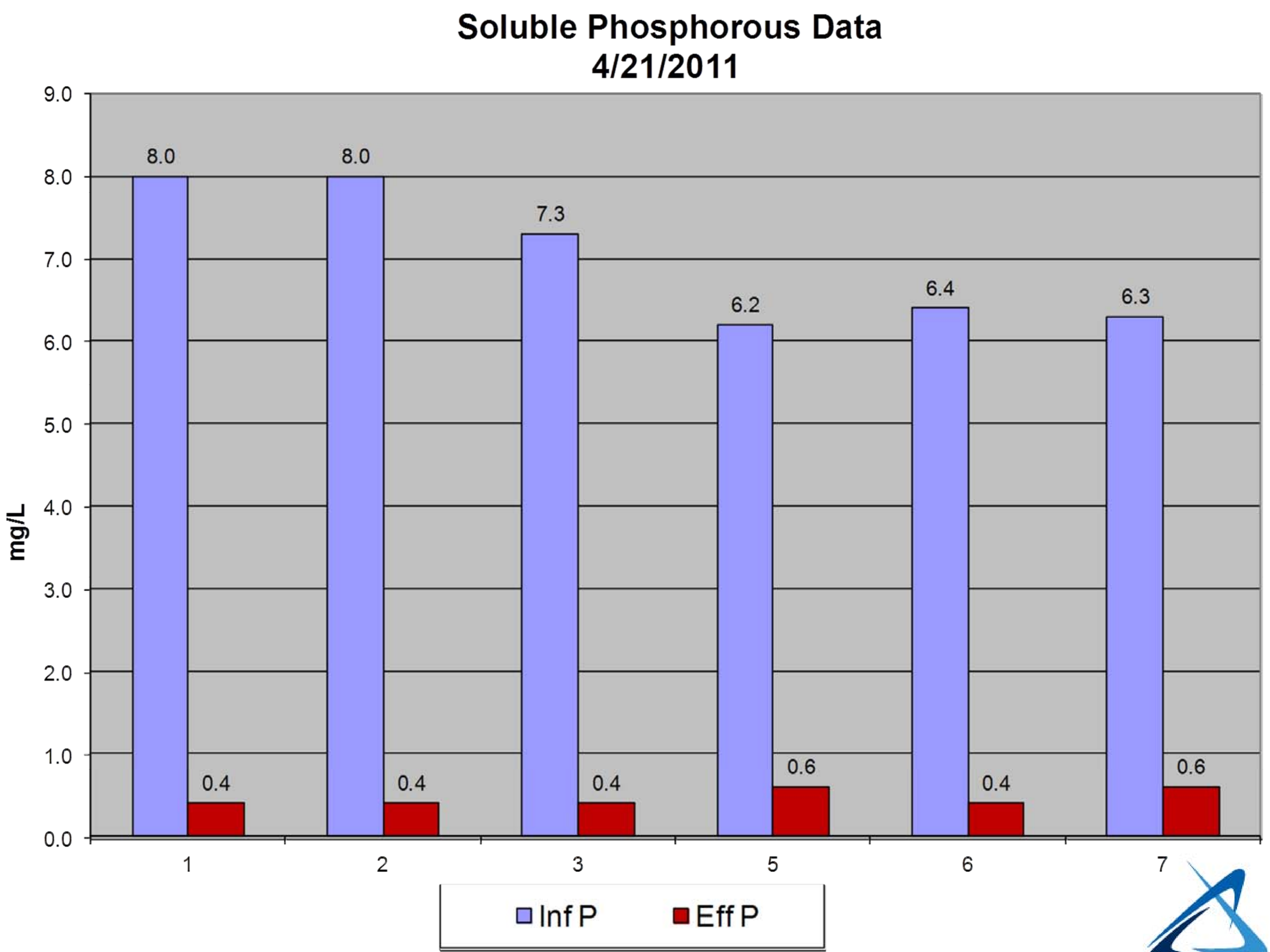


Stable DO Concentrations/Control (Seneca)



Recycle and load distribution





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Soluble Readily Biodegradable Organics

- Eagles Point – difficult to maintain Bio-P and alum was used
  - Interceptor includes drop structures that may aerate the sewage and limit production of fermentation products
  - Plant includes a primary sludge gravity thickener/fermenter
    - Thickener/fermenter recently has been successful in producing and returning sufficient soluble readily biodegradable organics – required implementation of elutriation flow

- Empire
  - Receives 100 mgCOD/l soluble readily biodegradable in the influent from an industry
  - For a period this industrial contribution was diverted and the impact was apparent

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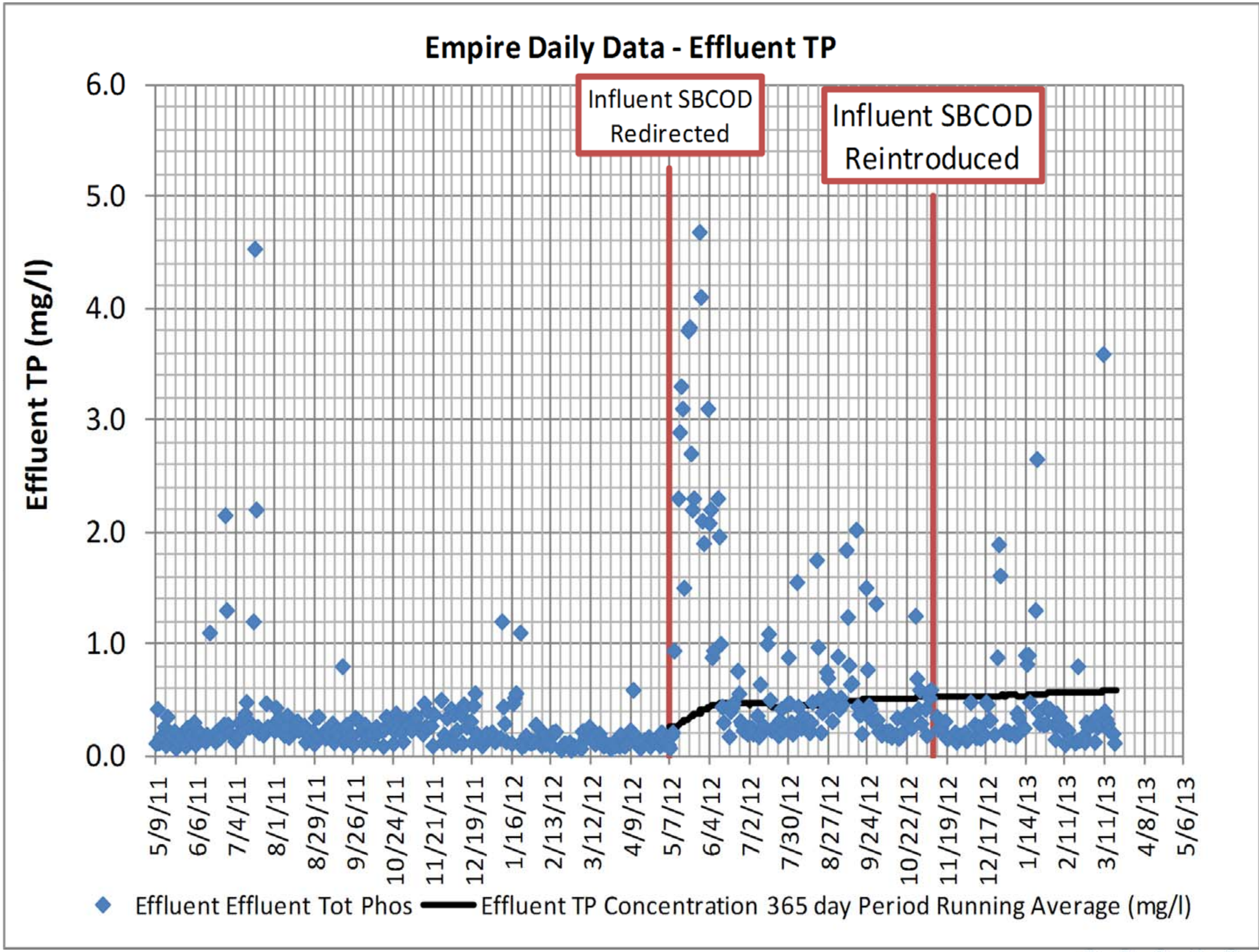
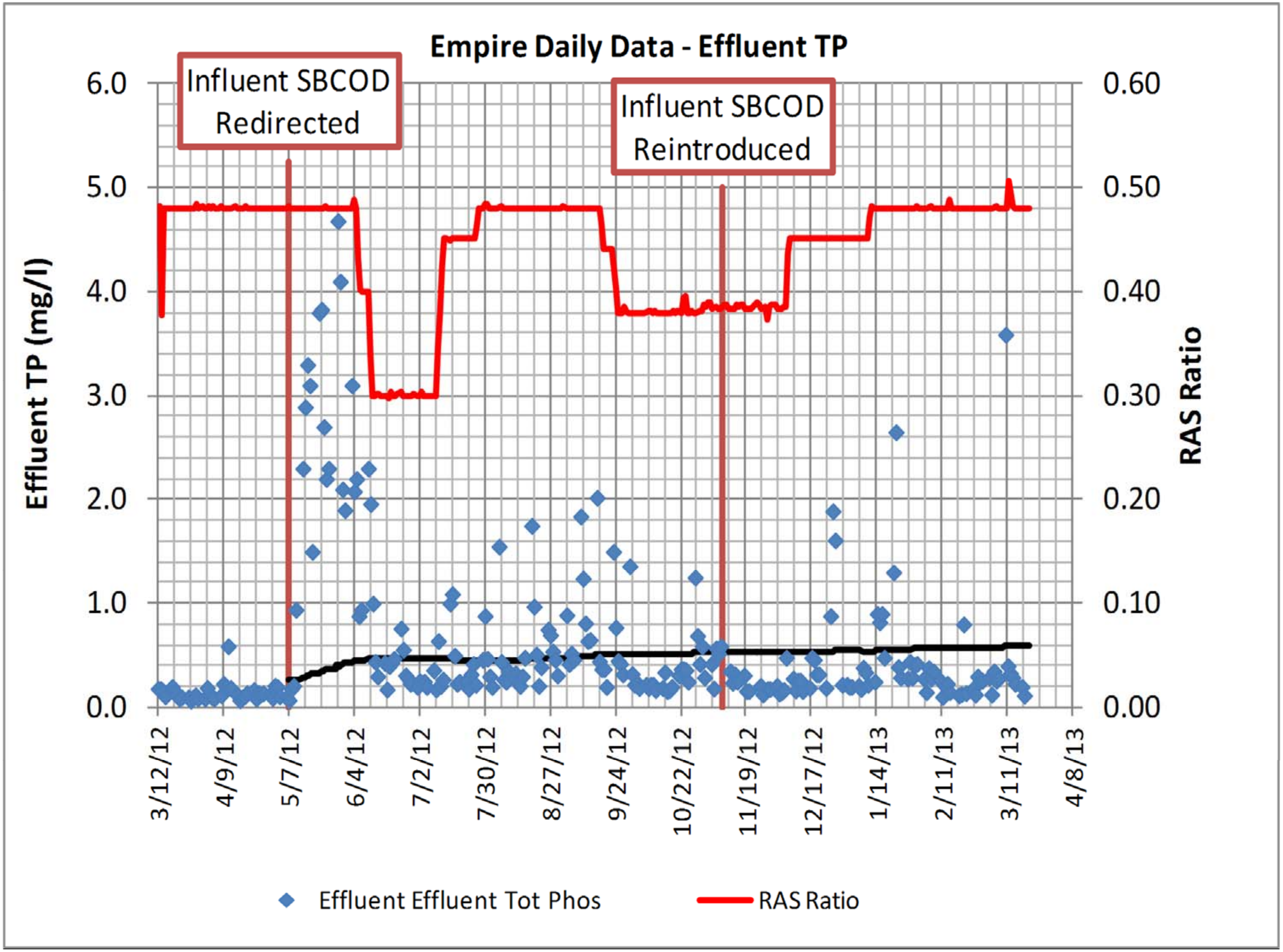
Soluble Readily Biodegradable Organics

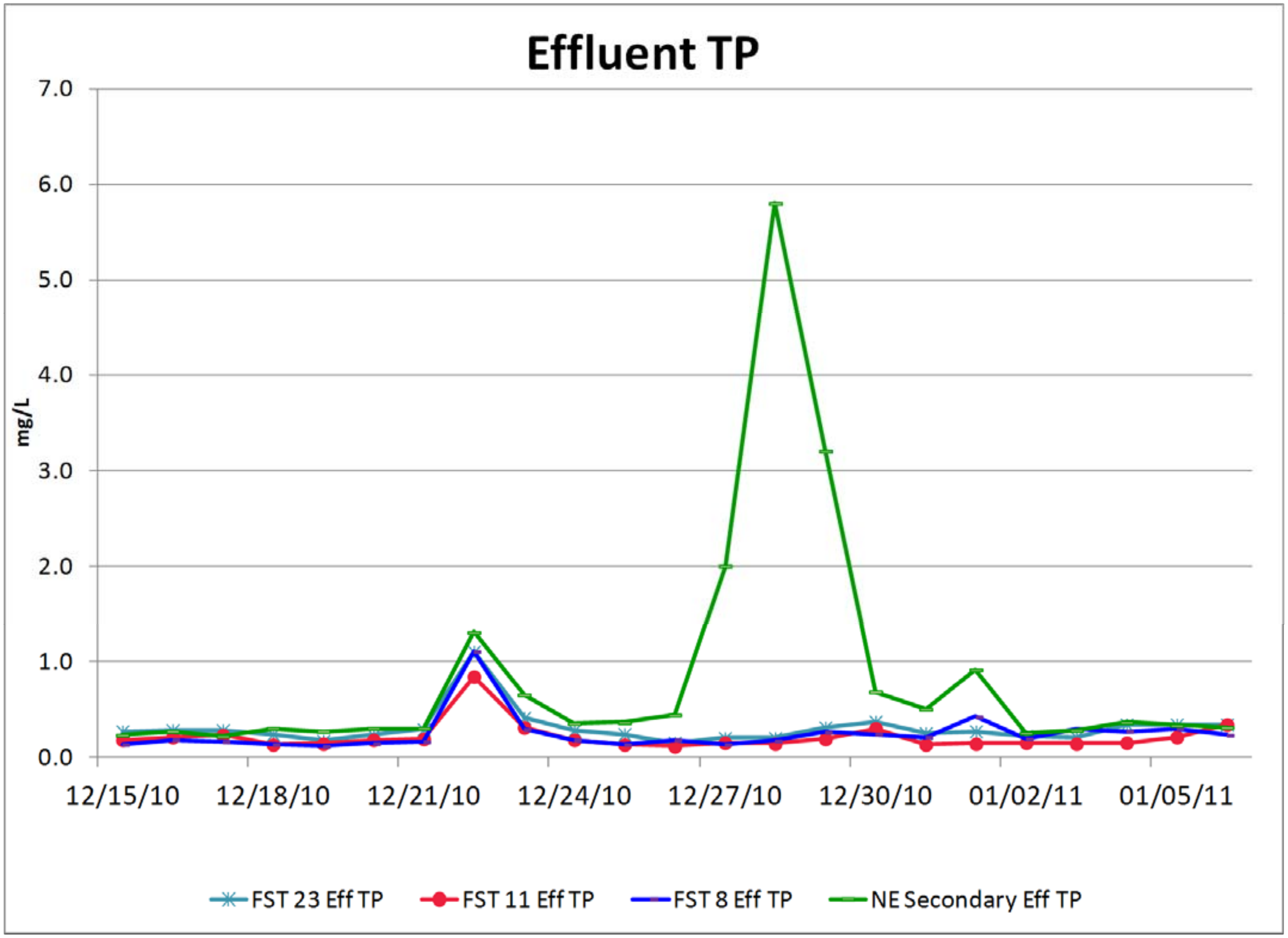


Response: Reduced RAS and the Nitrate Return



Experience with Bio-P and RAS Chlorination for Filament Control

- Effluent phosphorus increases when RAS is dosed with chlorine for filament control



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Possible Relationship between Anaerobic Digestion of Bio-P Sludge and Dewaterability

Empire – Belt Press Dewatering	
Condition	**Average Cake Solids $\pm$ 1 Std Dev (%)**
Before: 2 Sludge (HR+Nit) with no Bio-P (2005)	16.8 $\pm$ 1.4
After: 1 Sludge with Bio-P (2009) After: 1 Sludge with Bio-P (2012)	12.0 $\pm$ 0.8 12.5 $\pm$ 0.9

Blue Lake – Centrifuge Dewatering	
Condition	**Average Cake Solids $\pm$ 1 Std Dev (%)**
Before Anaerobic Digestion (2009) Before Anaerobic Digestion (2010)	29.4 $\pm$ 1.5 27.8 $\pm$ 1.3
After Anaerobic Digestion (2nd Half 2012, 2013 to date)	20.1 $\pm$ 1.6

Please note: There is a project on this subject underway by Charles Bott of Hampton Roads Sanitation District, Matt Higgins of Bucknell University, and others

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The Future

- Potential for lower total phosphorus limits
- Potential for nitrate and/or total nitrogen limits

The Future

- Evaluating in-situ ammonium, nitrate probes
  - Further optimize aeration control and power use
  - Nitrate monitoring in possible future nitrate, TN limit configurations
- Pursuing further reduction of return phosphorus load
  - Management of thickened sludge storage to reduce release
  - Chemical treatment of dewatering, side stream
- Planning to determine/confirm important rates and parameters for next phases
  - nitrification rates, denitrification rates, phosphorus uptake
- Pilot digestion investigations of dewatering performance
- Real time monitoring of oxygen transfer efficiency
  - currently in place
  - Determine best use of information
- Evaluation of luminescent, fluorescent dissolved oxygen instruments

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THANK YOU

Questions/Discussion

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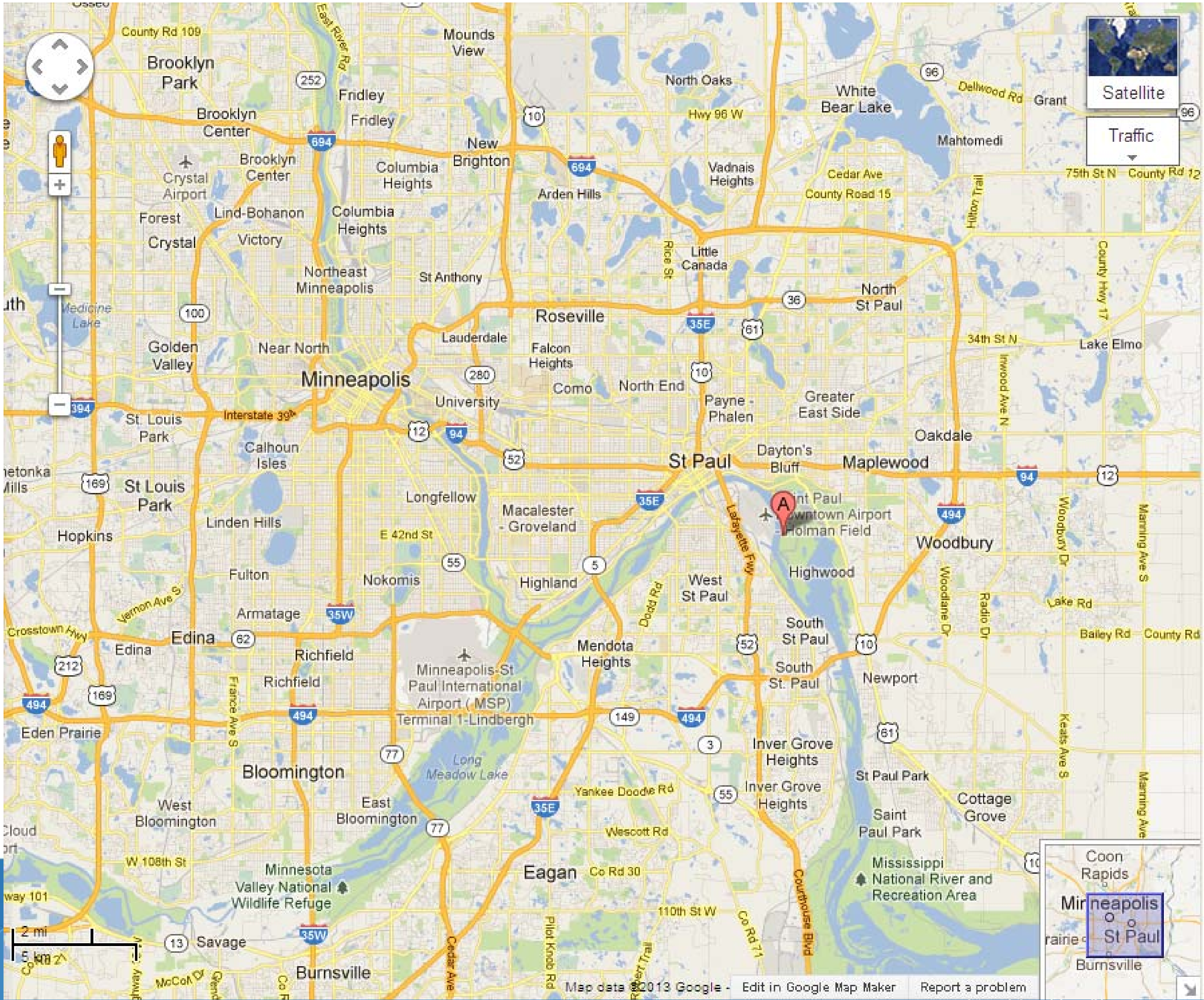
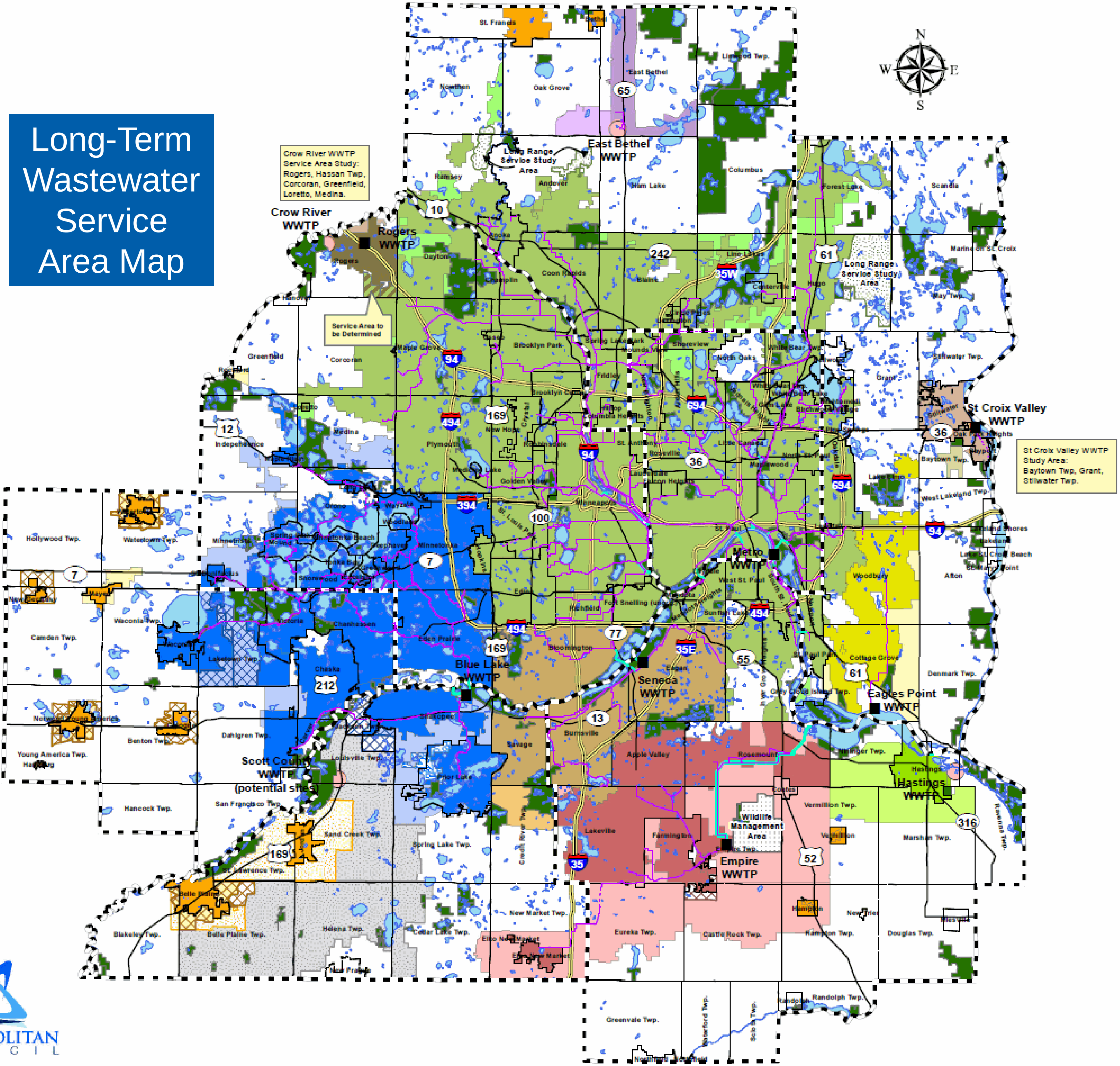
Other slides

The Metro Plant



Long-Term Wastewater Service Area Map



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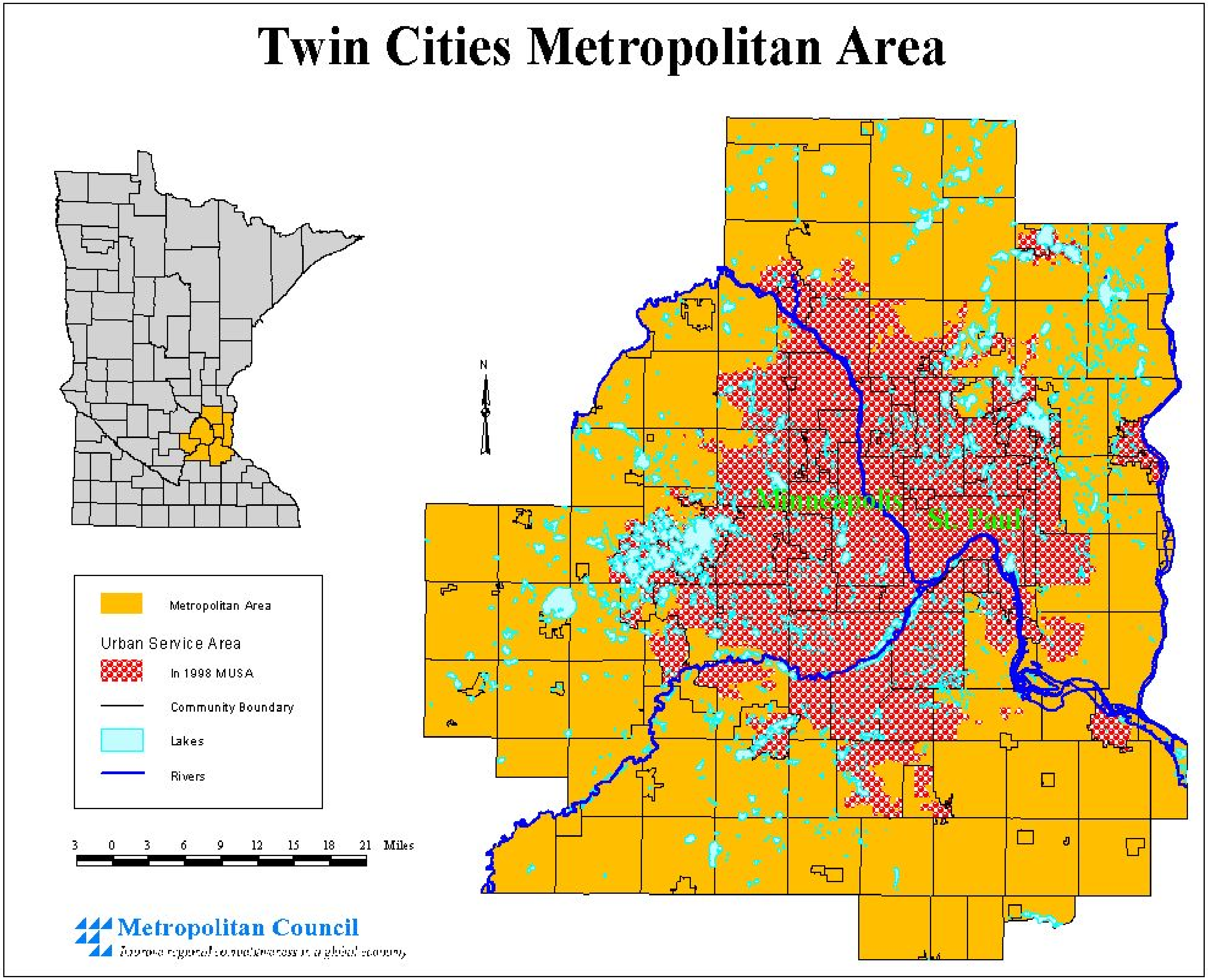
Metropolitan Council History



- Formed in 1967
- Seven county area - (3,000 square miles)
- 17 member board
- Operates regional wastewater, transit and parks system
- Coordinates regional planning and guides development

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The Metro Plant

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Some Milestones in Metro P removal 1

Date	Item
August 1990	NPDES permit issued. Required two-phase study of assessing P removal
June 1991	Completed Phase I Evaluation
Jan to Nov 1992	Plant Demonstration Testing of Chemical Removal (Ph II) 3 Full Scale Primary Sed Tanks with 3 Control
July 92 to Aug 1993	Plant Demonstration Testing of EBPR (Ph II) 2 Full Scale Test Aeration Basin and 3 Sed Tanks. A/O.
Nov 1993	NPDES permit issued. Achieve 4 mgTP/l; Design and construct SS treatment. Master Plan for 1 mgTP/l required before July 1997
Dec 1994	Final Facilities Plan Seven side stream treatment alternatives evaluated

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1994 Facility Plan

Table ES.1 Side stream treatment alternatives.

Alternative	Description	Treatment type
1	Physical/chemical side stream treatment using dedicated flotation thickeners	Physical/chemical
2a	Co-thickening in flotation thickeners with side streams and chemical addition	Physical/chemical
2b	Co-thickening in flotation thickeners	Physical
3	Physical chemical side stream treatment using dedicated flocculation/sedimentation tanks	Physical/chemical
4	Physical/chemical side stream treatment using primary sedimentation	Physical/chemical
5a and 5b	Side stream biological phosphorus treatment	Biological P-reduction
5c	Liquid stream biological phosphorus treatment	Biological P-reduction
6	Side stream load equalization	Equalization
7	Physical side stream treatment in flotation thickeners with waste activated sludge	Physical

Alt	Eff TP reduction (mgTP/l)	25-yr annualized cost (10^6 \$/yr)
1	1.2 – 1.4	3.5 – 6.3
2a	0.7 – 1.0	screened out
2b	0.2 – 0.4	screened out
3	1.0 – 1.2	3.5 – 7.4
4	0.1 – 0.3	screened out
5a and 5b	0.5 – 0.7	14.3 – 14.6
5c	**0.3 – 0.5**	**1.1**
7	0.2 – 0.4	na

Brown and Caldwell (1994) Side Stream Treatment Phosphorus Reduction Metropolitan Wastewater Treatment Plant: Final Facilities Plan

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Some Milestones in Metro P removal 2

Date	Item
End of 1995	Completed design/initiated construction phase of Bio-P process proving facilities (STIP I) - converted ¼ aeration tanks to of the plant to Bio-P and implemented test improvements to some final settling tanks
Sept 97 to Sept 98	Accomplished full scale Bio-P removal and final settling tanks process proving programs
July 1999	Completed and Submitted Facility Plan for Phase II Secondary Treatment Improvements with plans for and goals of meeting NPDES requirements of: - Commence operation of Bio-P removal and meet 3.0 mgTP/l limit by Dec 2003 - Meet 1.0 mgTP/l annual average by Dec 2005
2003	Completed construction phase of Bio-P process systems in full plant liquid stream (STIP II)
March 2005	Metro Plant 12-monthly rolling average effluent TP < 1.0 mg/l
2002 - 2006	Conversion to centrifuge dewatering, conversion from multiple hearth to fluidized bed incineration, thermal heat treatment systems decommissioned

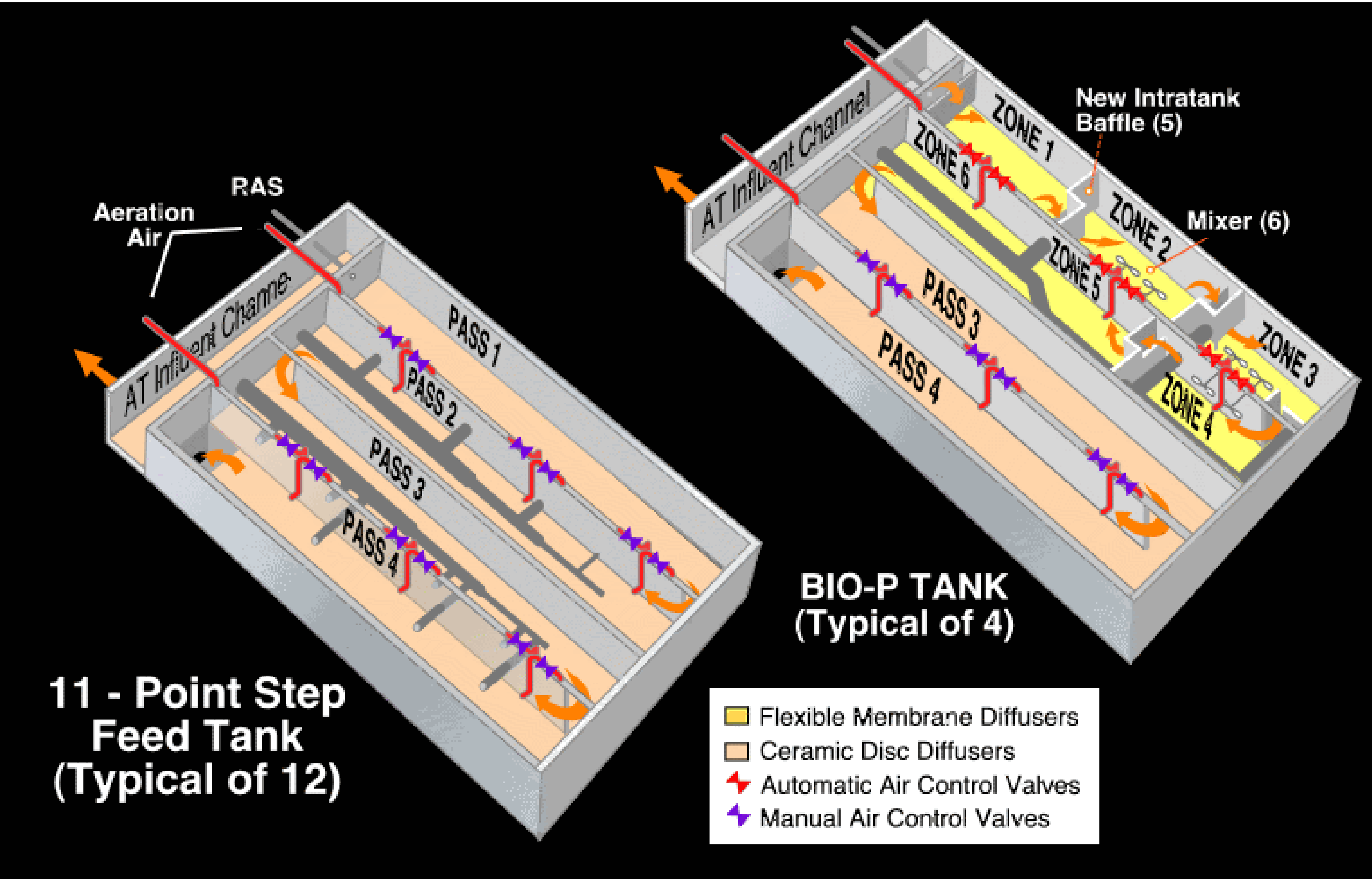
Enhanced Biological P Removal

- Sequence the conditions such that a certain type of organisms (PAO – phosphate accumulating organisms) have a competitive advantage and proliferate within the system

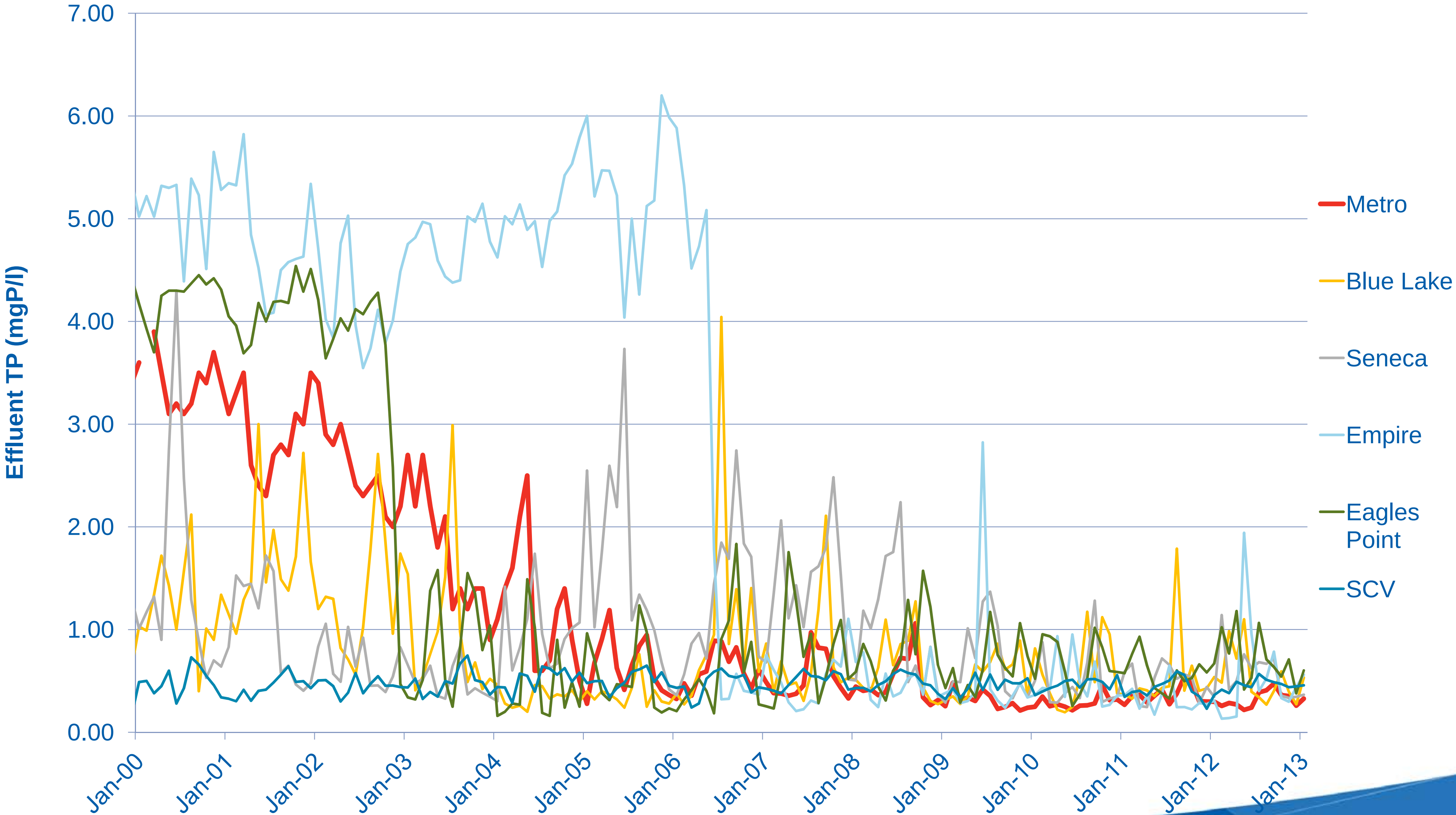
- In aerobic conditions (O_2) – PAOs use internal stored organics to grow and accumulate phosphate in internal poly-phosphate compounds
  - Removing these organisms from the system at this point (with the WAS), reduces the concentration of phosphate in the liquid stream

- In anaerobic conditions (no O_2 or NO_3^-) - PAOs use the energy stored in the poly-phosphate compounds, releasing phosphate to the liquid stream, gather readily biodegradable soluble organics (volatile fatty acids, VFAs) and generate the internal stored organics from the VFAs
  - Key items:
    - Availability of VFAs
    - Absence of Nitrates (nitrate allow other organisms to grow and compete with PAOs for VFAs)

Aeration Tank Modifications



MCES Monthly Effluent TP from Permit Limited Plants



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Influent and Effluent TP