Phosphorous Reduction Demonstration Project at the John E. Egan Water Reclamation Plant

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Analytical Lab Staff

EM&R Laboratory technicians

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Background Info

-USEPA 2000 Nutrient Criteria Guidance

-Illinois Nutrient Standards Workgroup

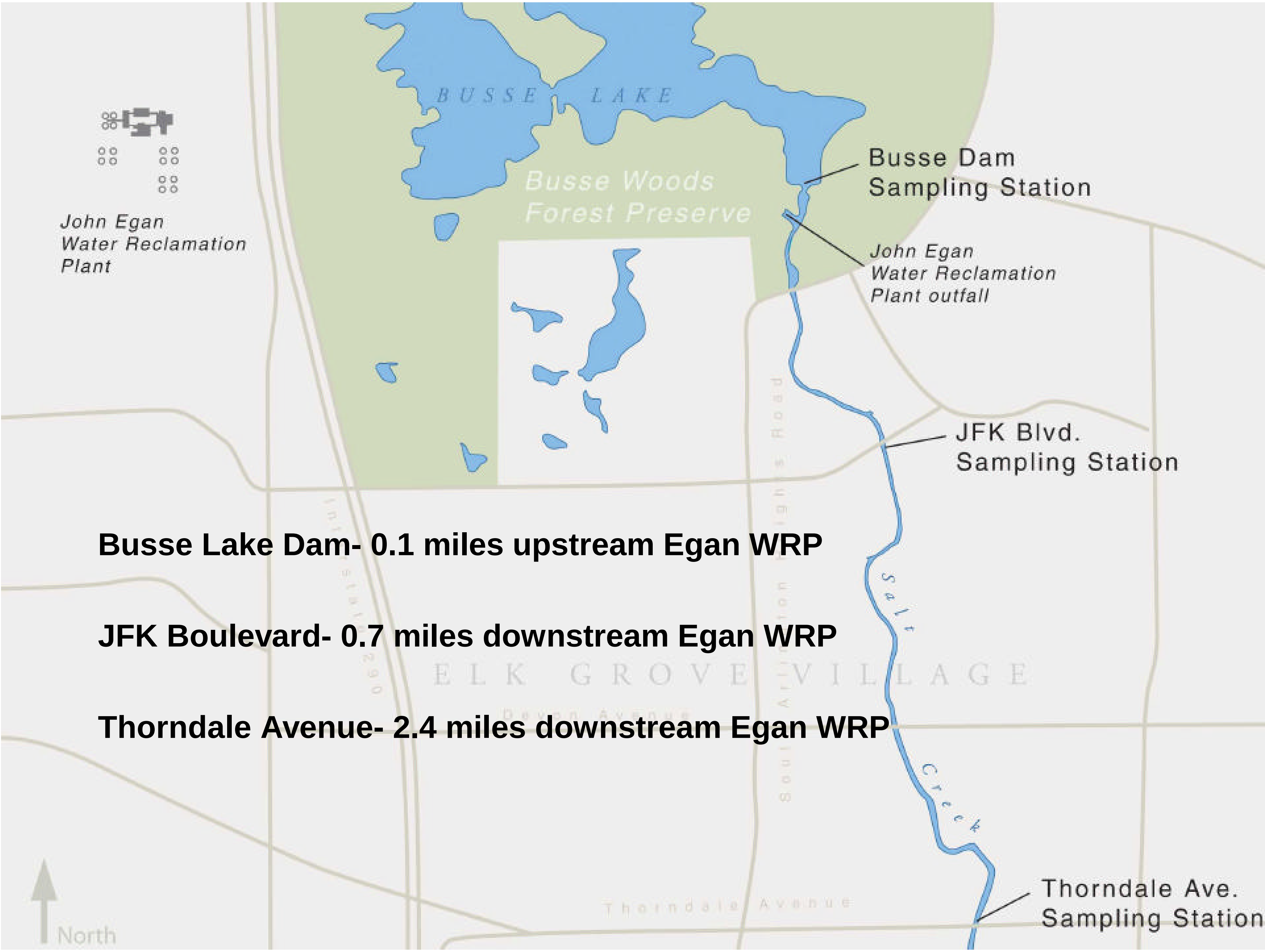
-Discussions with IEPA about Demonstration Project

-Goals to Observe Effects on Operations, Effluent, Biosolids, and Receiving Stream Quality

Stream Water Quality Objectives

- -Determine Effects of P-Removal from Egan WRP on Downstream Water Quality
- -Explore potential predictive relationships between nutrients and algae as urged by USEPA guidance in 2000
- -Determine Any Resulting Changes in the Paradigm:

  Nutrients → Algae → Dissolved Oxygen
- -Observe Any Subsequent Effects on Biota



Busse Lake Dam- 0.1 miles upstream Egan WRP

JFK Boulevard- 0.7 miles downstream Egan WRP

Thorndale Avenue- 2.4 miles downstream Egan WRP

P Reduction Demonstration Project Methodology

Chemical

- Continuous monitors for dissolved oxygen, temperature, pH, conductivity, and turbidity
- TP, Ortho-P, NH_4, NO_2, NO_3, TKN, BOD_5, $CBOD_5$, COD, TSS, VSS
- Sediment Chemistry

Biological

- Chlorophyll *a* (same frequency as chemical constituents)
- *Selanastrum* algal assay quarterly, then bimonthly
- Fish, benthic invertebrates, physical habitat characterization (once per year)

P Reduction Demonstration Project Methodology (continued)

Water Sampling Schedule

- December-March 1x/month
- April-November 2x/month
- 4 consecutive days after rain event (3-4 per year)

Sediment and Biological Sampling

- Once each summer

Sampling Years

- Pre- P reduction sampling during 2005-6
- ***Ferric Chloride dosing began February 7, 2007
- Post- P reduction sampling during 2007-8

P Reduction Demonstration Project Phosphorus Results

Upstream of Egan at Busse Dam

	2005	2006	2007	Jan-Sept. 2008
Mean P (mg/L)	0.25	0.18	0.11	0.11
Range P (mg/L)	<0.05-3.15	<0.05-0.87	0.06-0.36	0.04-0.35

Egan Effluent daily 24-hour composite samples

	2005	2006	2007	Jan-Sept. 2008
Mean P (mg/L)	3.26	3.72	0.35	0.43
Range P (mg/L)	0.98-5.87	0.92-8.22	0.06-1.77	0.13-1.38

P Reduction Demonstration Project Phosphorus Results (continued)

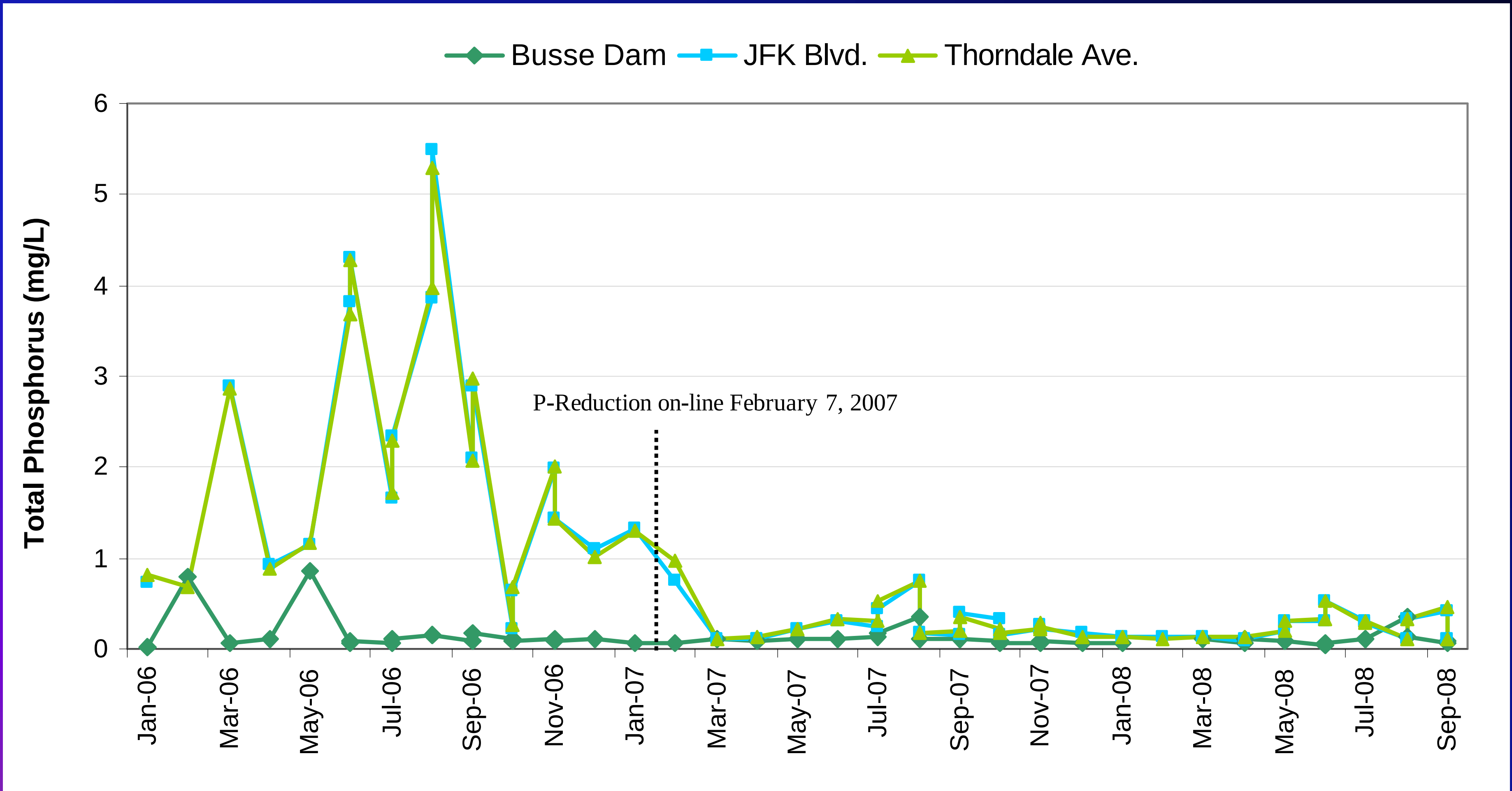
Downstream of Egan at JFK Blvd.

	2005	2006	2007	Jan-Sept. 2008
Mean P (mg/L)	2.76	2.20	0.29	0.23
Range P (mg/L)	0.88-4.64	0.22-5.49	0.10-0.76	0.09-0.52

Downstream of Egan at Thorndale Ave.

	2005	2006	2007	Jan-Sept. 2008
Mean P (mg/L)	2.51	2.12	0.30	0.24
Range P (mg/L)	<0.05-4.45	0.27-5.30	0.10-0.97	0.11-0.52

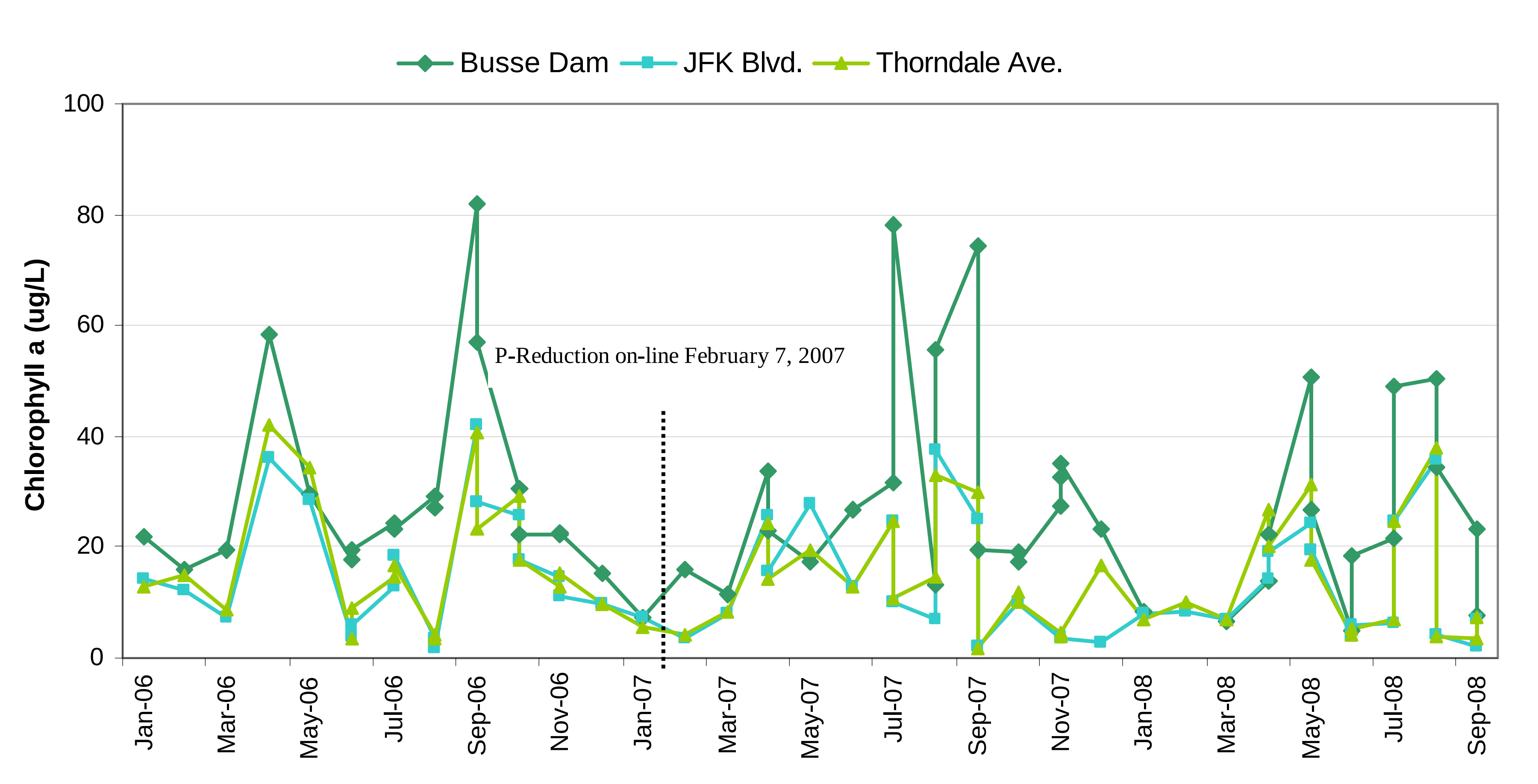
P Reduction Demonstration Project Phosphorus Results (continued)



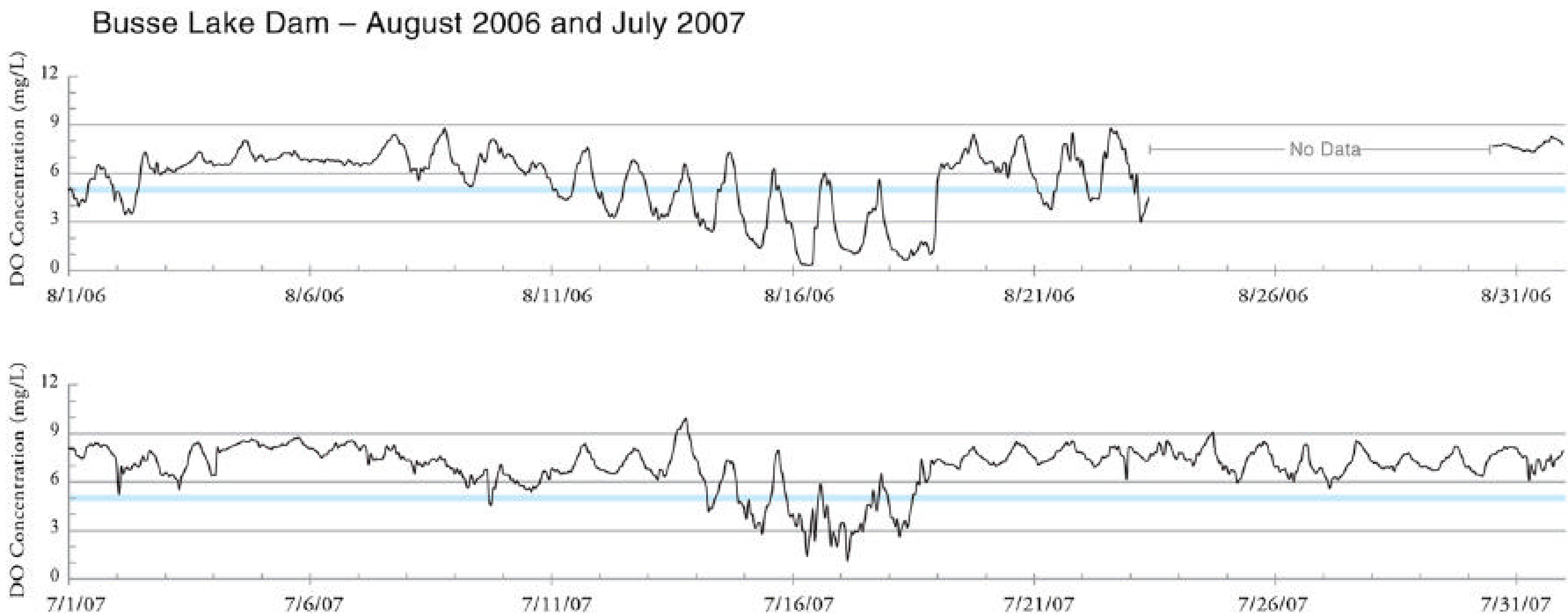
P Reduction Demonstration Project Chlorophyll *a* Results

Location		Chl. *a* (µg/L) 2005 (pre)	2006 (pre)	2007 (post)	2008 (post)
Busse Dam	Mean	29	30	31	24
	Range	7-63	15-82	11-78	5-51
JFK Blvd.	Mean	10	16	13	13
	Range	3-29	2-42	2-38	2-36
Thorndale	Mean	11	17	14	14
	Range	3-34	3-42	2-33	4-38

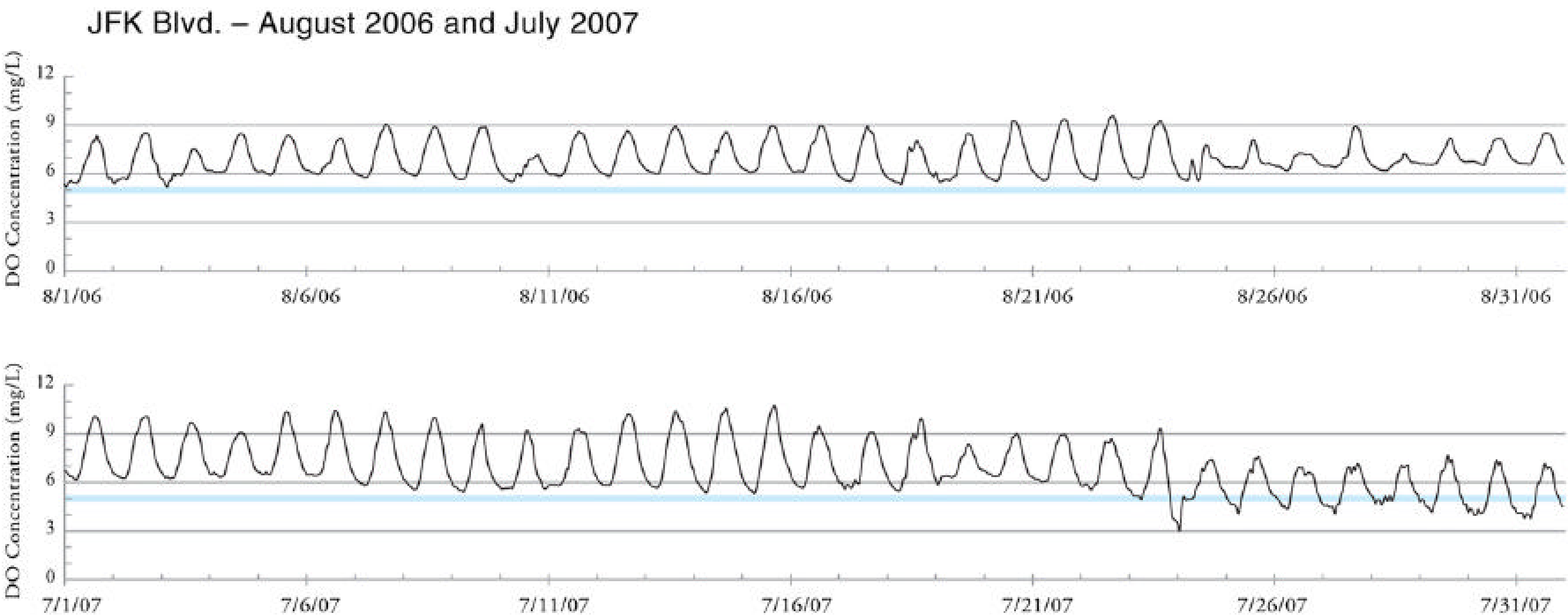
P Reduction Demonstration Project Chlorophyll *a* Results (continued)



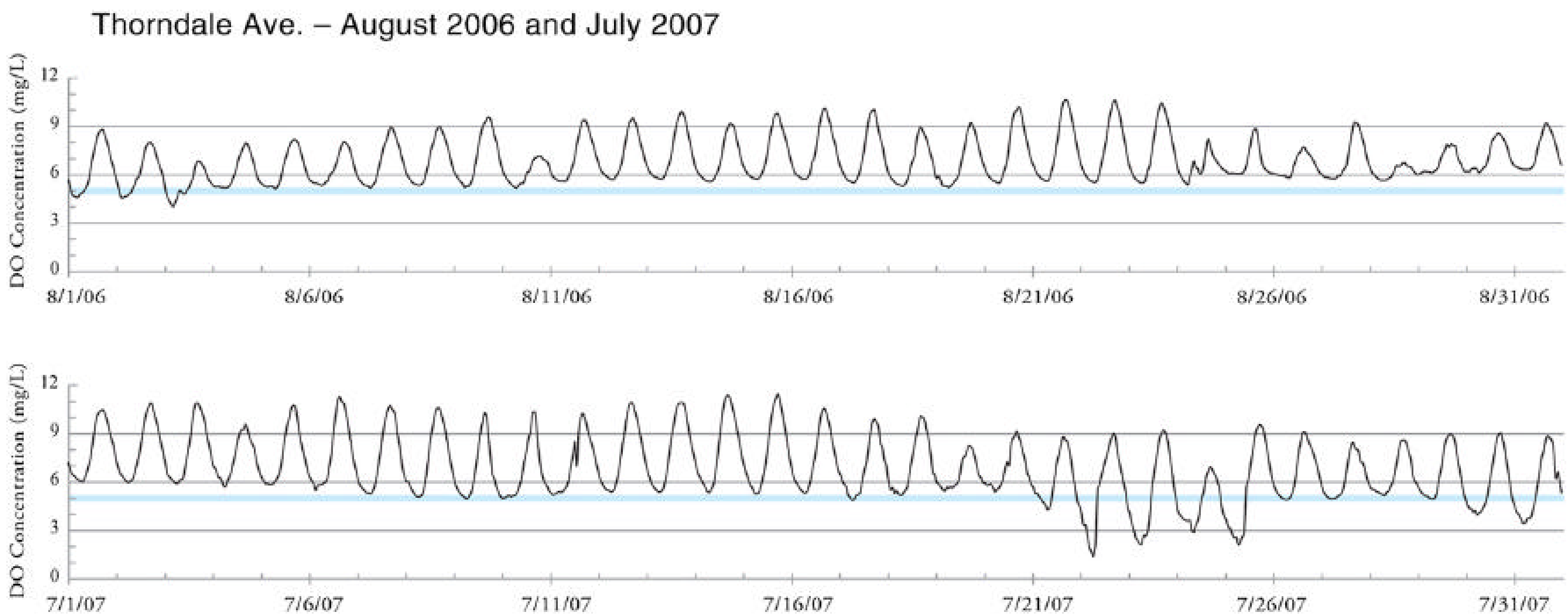
Continuous DO Comparison During Summer Month in 2006 (before) and 2007 (after) at Busse Lake Dam



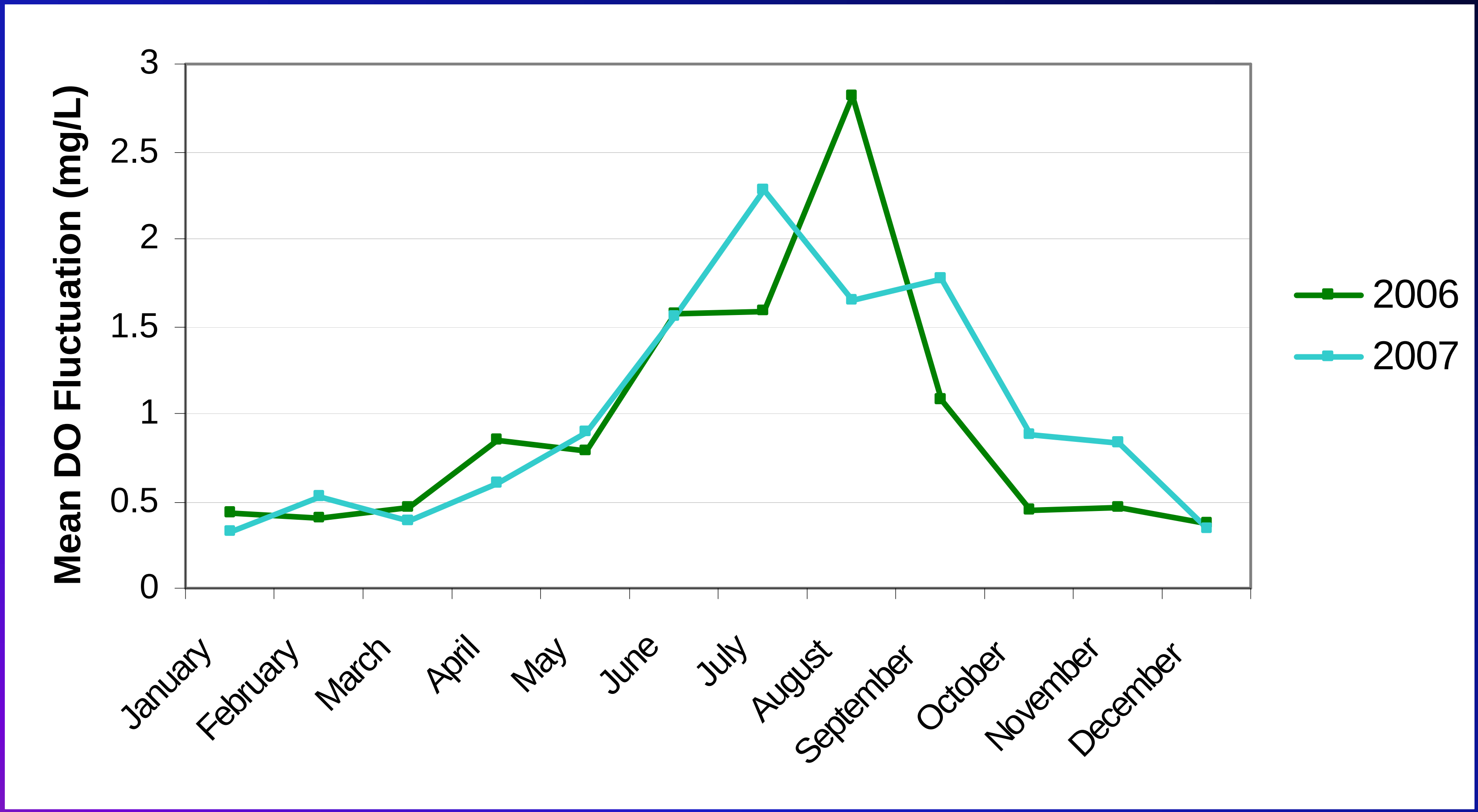
Continuous DO Comparison During Summer Month in 2006 (before) and 2007 (after) at JFK Blvd.



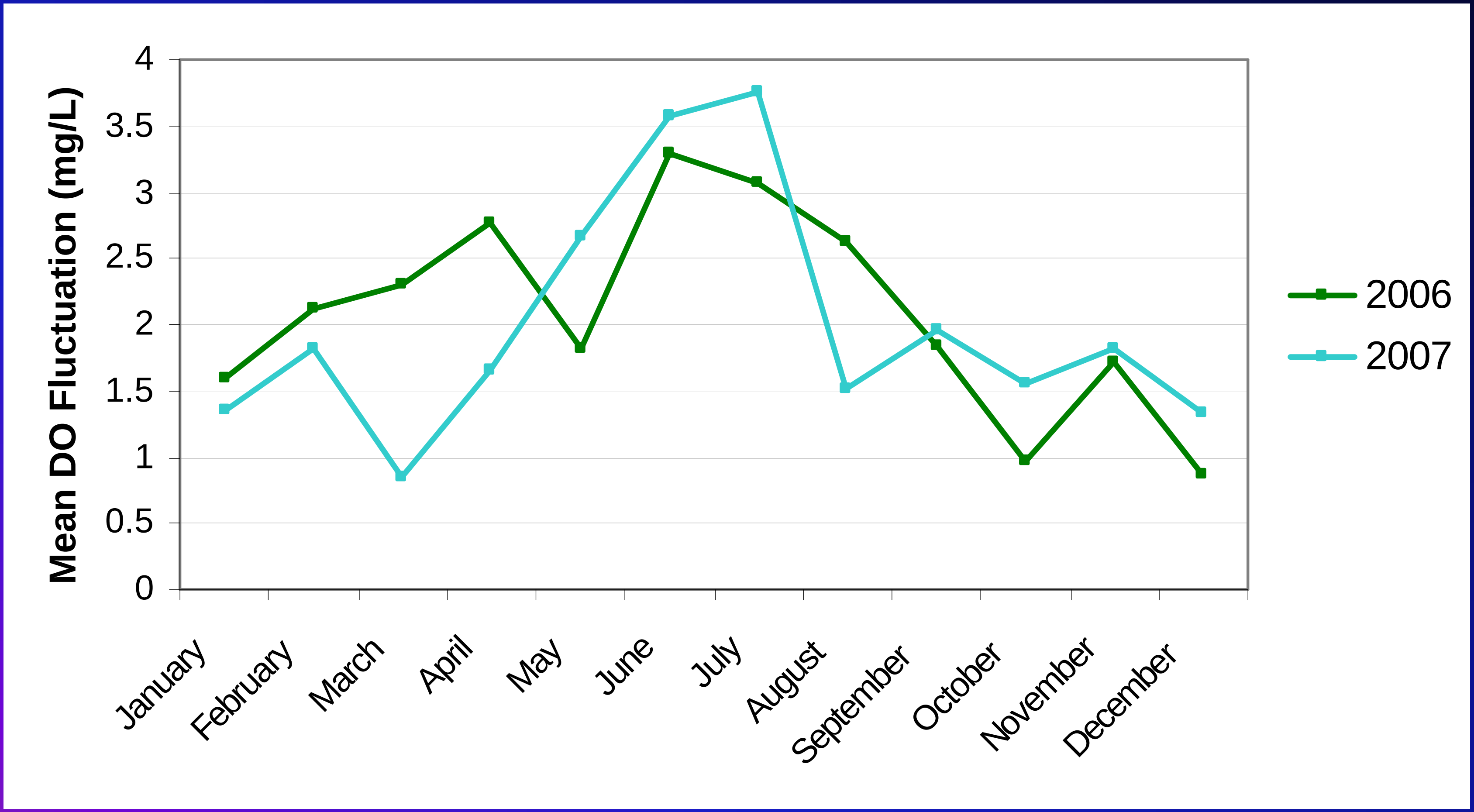
Continuous DO Comparison During Summer Month in 2006 (before) and 2007 (after) at Thorndale Avenue



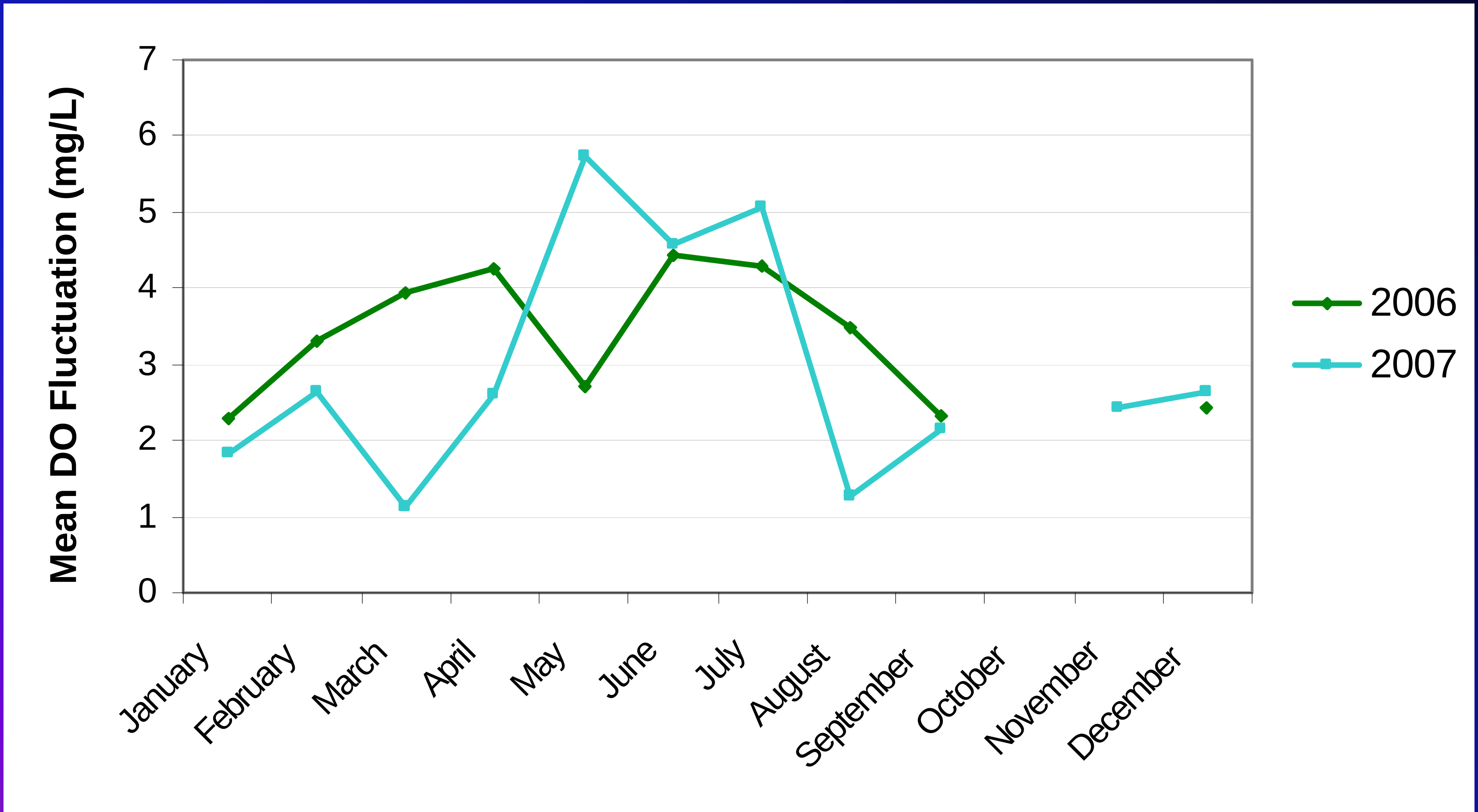
Mean Monthly DO Fluctuation at Busse Lake Dam During 2006 (before) and 2007 (after)



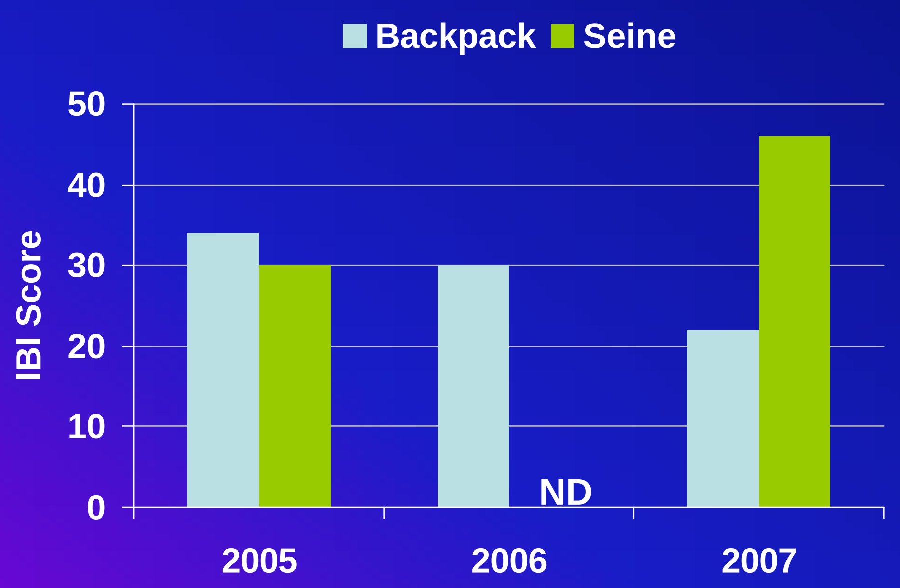
Mean Monthly DO Fluctuation at JFK Boulevard During 2006 (before) and 2007 (after)

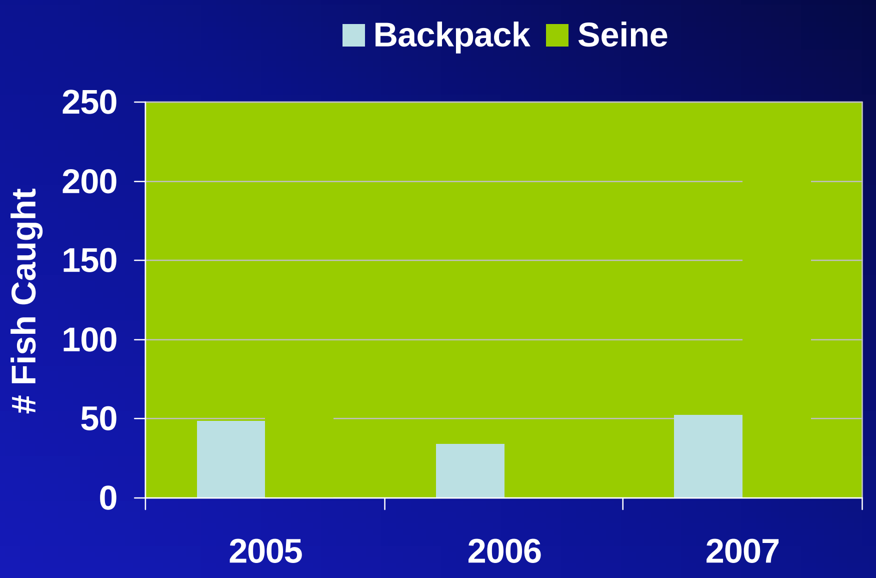


Mean Monthly DO Fluctuation at Thorndale Ave. During 2006 (before) and 2007 (after)

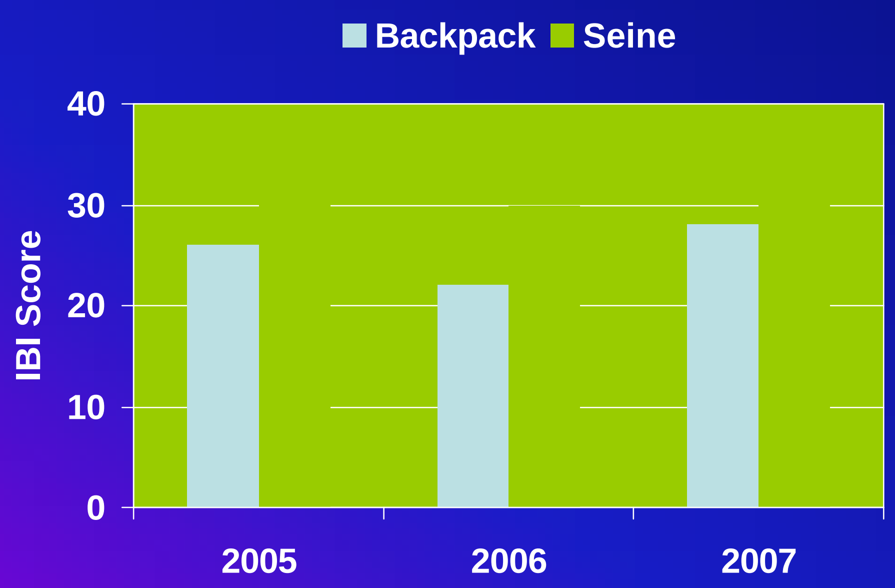


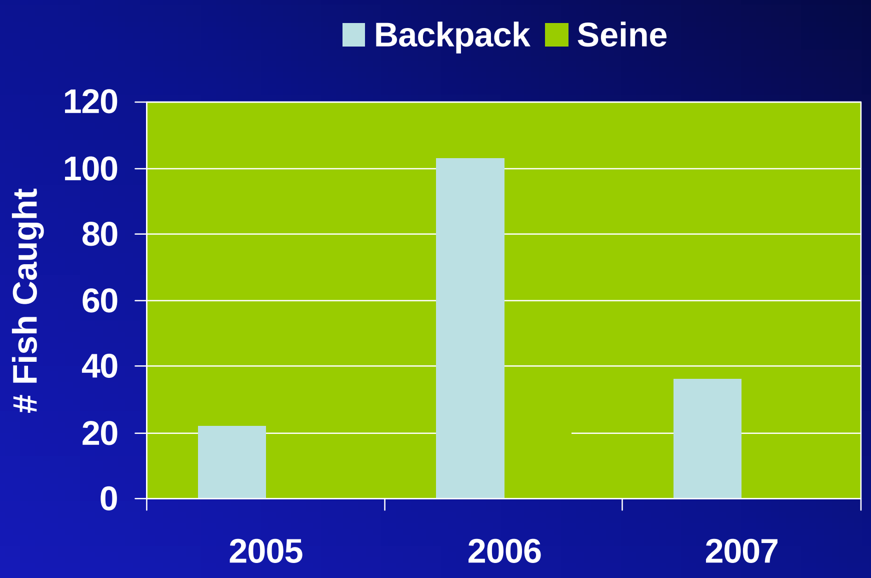
P Reduction Demonstration Project
Fish Results at Busse Lake Dam



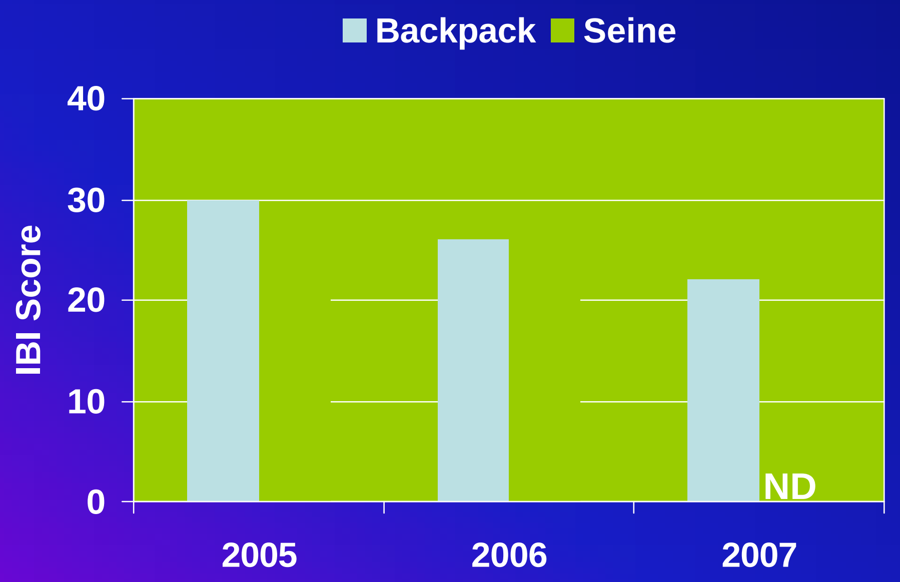


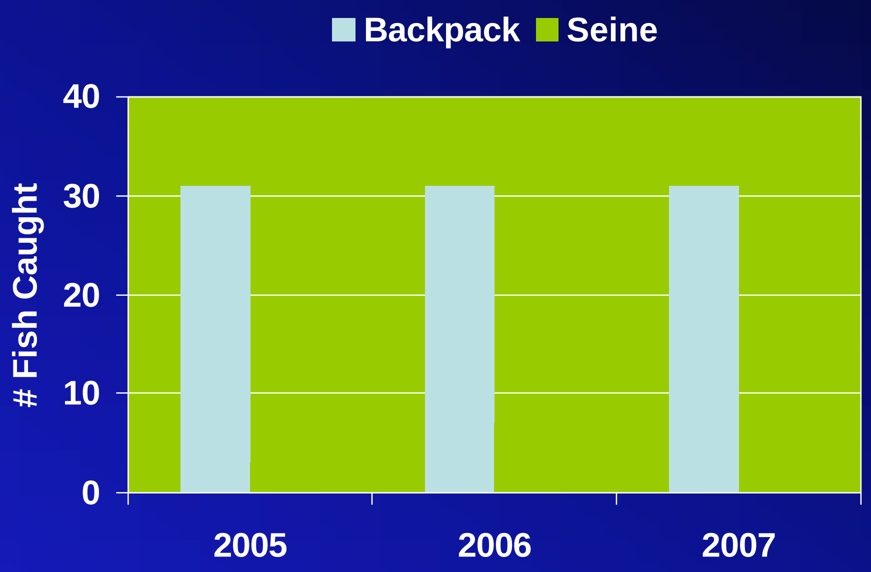
P Reduction Demonstration Project
Fish Results at JFK Boulevard





P Reduction Demonstration Project
Fish Results at Thorndale Avenue





Conclusions - Stream Response

Following P Reduction at Egan, there was:

-Significant reduction in stream P concentrations at stations downstream of Egan

-No significant effect on sestonic algae in Salt Creek

Diurnal fluctuations of similar magnitude recorded both before and after P reduction

Fish data similar before and after P reduction

Next Steps

Analyze 2008 data

Identification/Enumeration of 2007-2008 Macroinvertebrates

Statistical analysis of 2005-2008 DO fluctuation data

- Account for stream discharge data

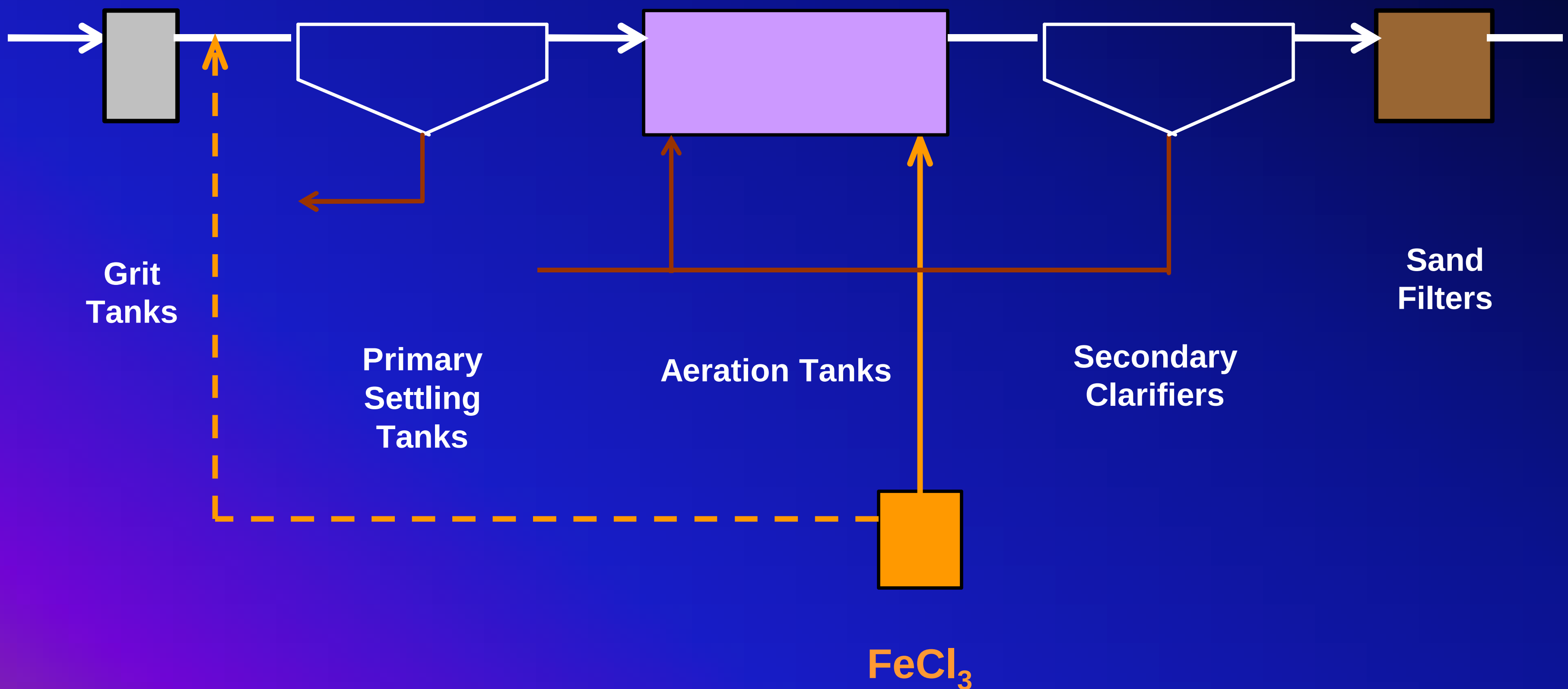
Final report including biological data as well as plant data on increased solids production and other issues, biosolids effects will be produced in spring of 2009

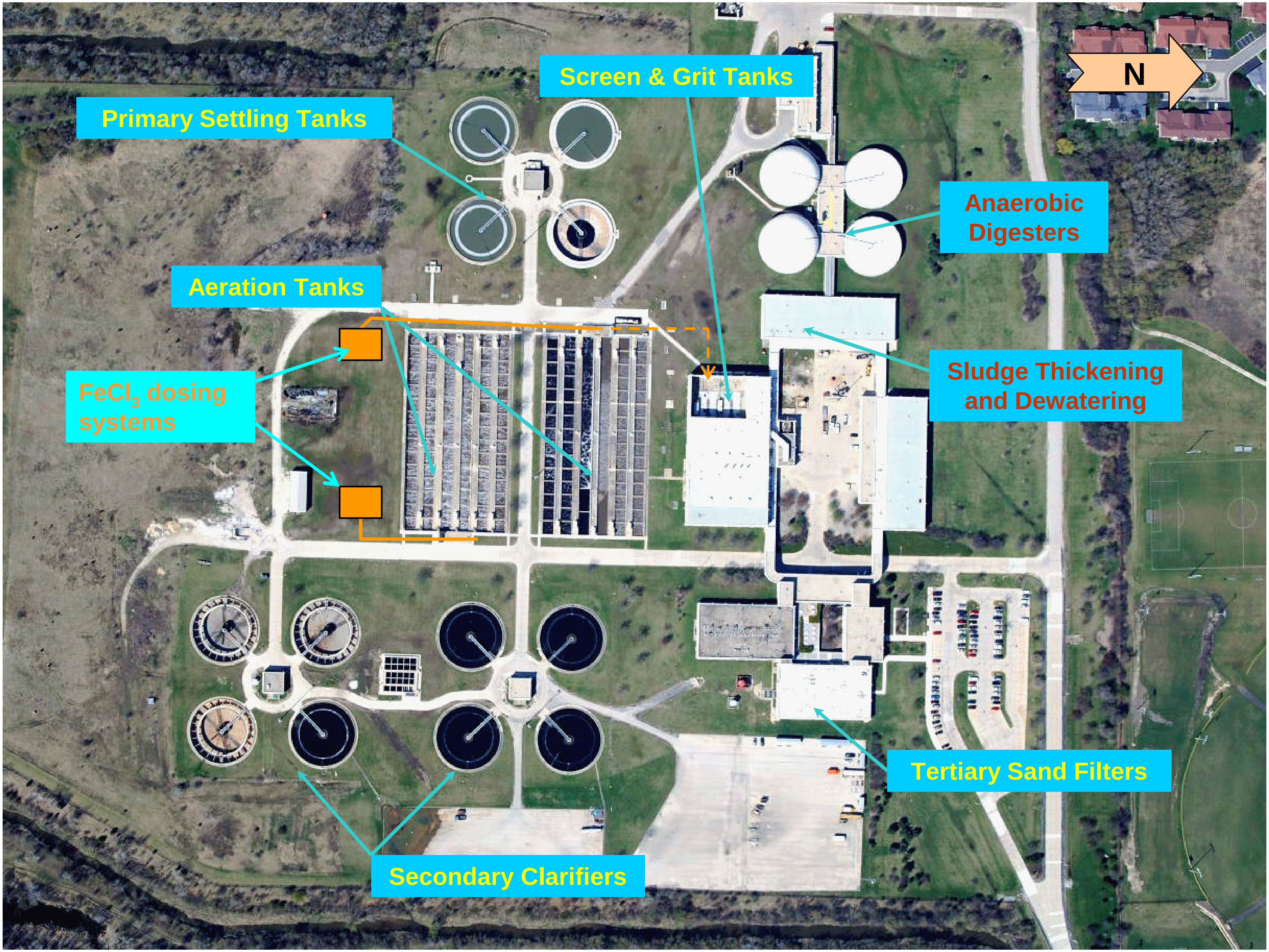
Outline for Plant Operations during P Removal

- Retrofit for chemical P removal at Egan
- Effluent P concentrations during P removal
- Chemical addition on effluent quality
- Impact on plant operations
- Chemical sludge yield estimation
- Other potential Impacts
- Conclusions

Retrofit for P Removal at Egan WRP

(Liquid process train at Egan WRP)




N
Screen & Grit Tanks
Primary Settling Tanks
Anaerobic Digesters
Aeration Tanks
Sludge Thickening and Dewatering
$FeCl_3$ dosing systems
Tertiary Sand Filters
Secondary Clarifiers

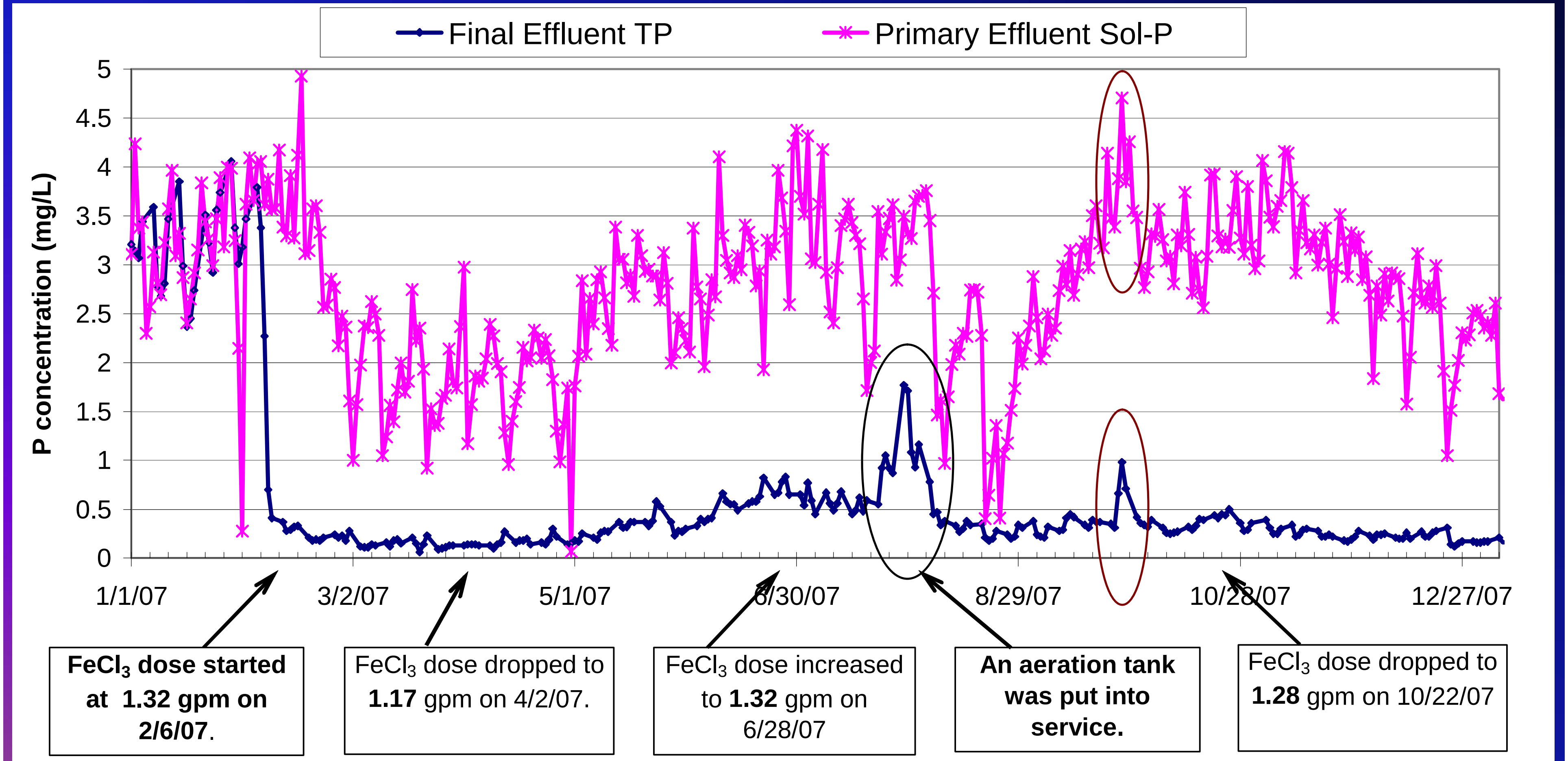
$FeCl_3$ Distribution System

At the end of Aeration Tanks

At the exit of Grit Tanks

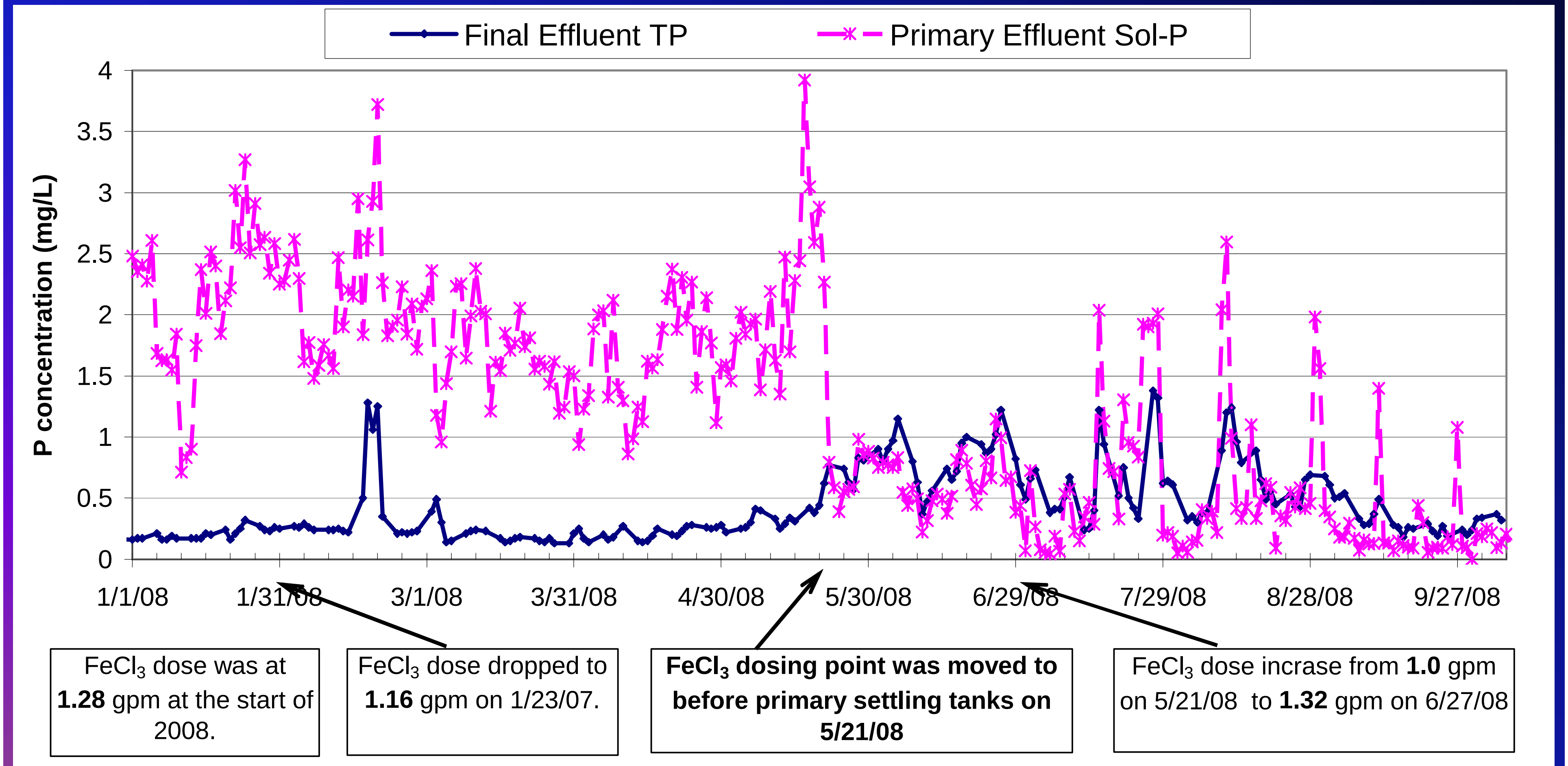
Effluent P Concentrations during P Removal

- $FeCl_3$ addition to mixed liquor started on 2/6/07 and through 2007. TP in the final effluent dropped immediately after $FeCl_3$ addition.



Effluent P Concentrations during P Removal (continued)

- $FeCl_3$ dosing location was moved from the end of aeration tanks to the end of grit tanks on 5/21/2008. Dosing rate started at 1.0 gpm and gradually increased to 1.32 gpm at the new location.



Chemical Addition on Effluent Quality

Average daily values of conventional parameters

Period	FLOW (MGD)	pH (unit)	BOD_5 (mg/L)	$CBOD_5$ (mg/L)	SS (mg/L)	TKN (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TP (mg/L)
2006	26.3	7.10	<2	<2	<2	1.3	0.08	15.05	3.72
2007*	26.1	7.00	<2	<2	<2	1.0	0.10	15.01	0.35
2008**	30.1	7.10	<2	<2	<2	1.0	0.08	15.49	0.43

Average daily values of other parameters of interest

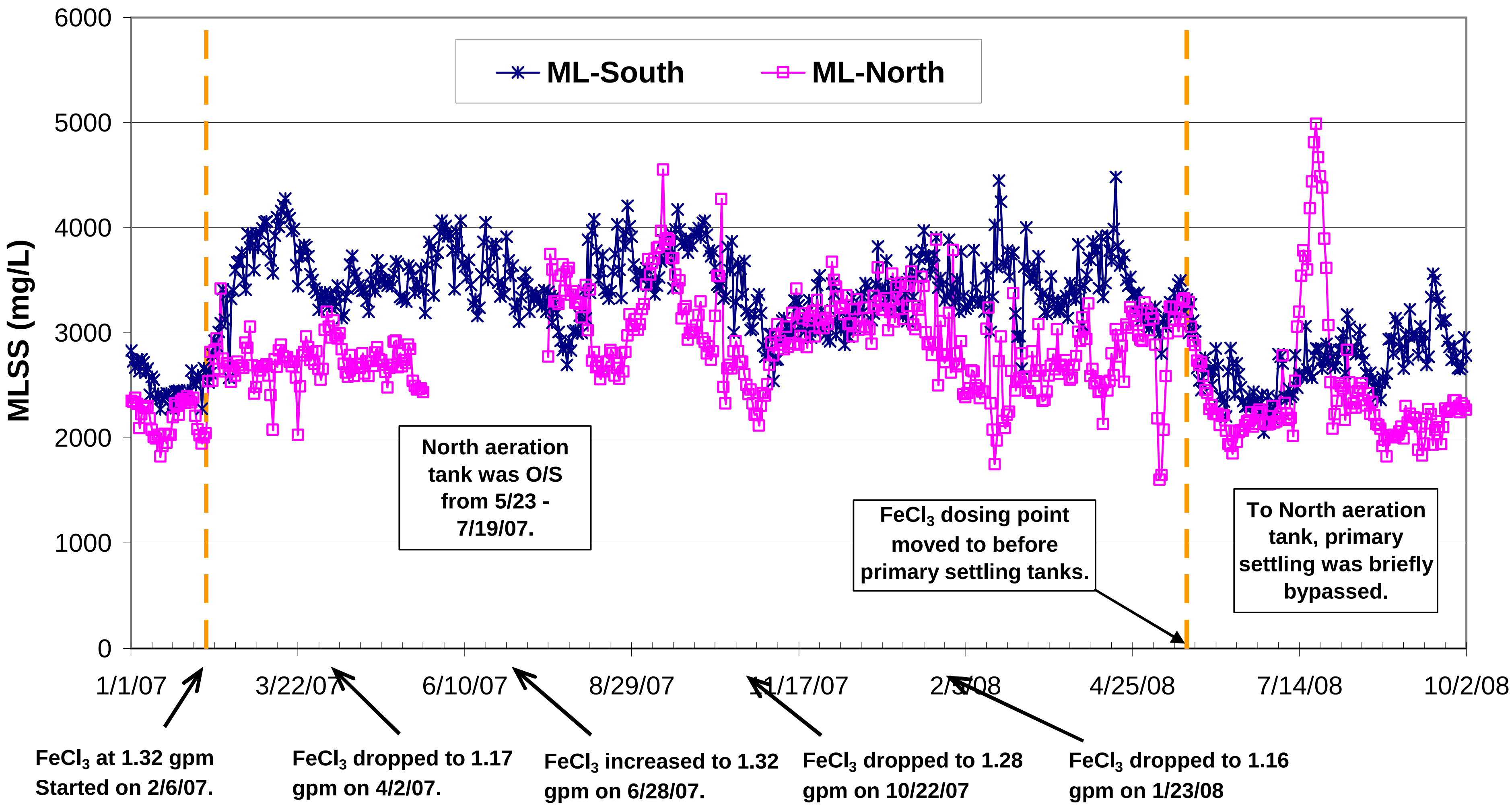
	Cl (mg/L)	SO_4 (mg/L)	As (mg/L)	Cu (mg/L)	Fe_Tot (mg/L)	Fe_Sol (mg/L)	Mn (mg/L)	Zn (mg/L)
2006	176	84.0	<0.013	0.008	<0.07	0.060	0.006	0.039
2007*	219	78.5	<0.016	0.006	0.150	0.067	0.106	0.024
2008**	250	78.7	<0.016	0.012	0.160	0.063	0.027	0.026

* 2007 data are averages for 2/7/07 through 12/31/07 after P removal started.

** 2008 data are averages for 1/1/08 through 9/30/08.

Impact on Plant Operations

- MLSS was about 30% higher while $FeCl_3$ was added to mixed liquor
- MLSS was lower while $FeCl_3$ was added before primary settling tanks



Impact on Plant Operations (continued)

- Impact of $FeCl_3$ addition on alkalinity and pH

Comparison of pH and alkalinity before and after $FeCl_3$ addition to ML

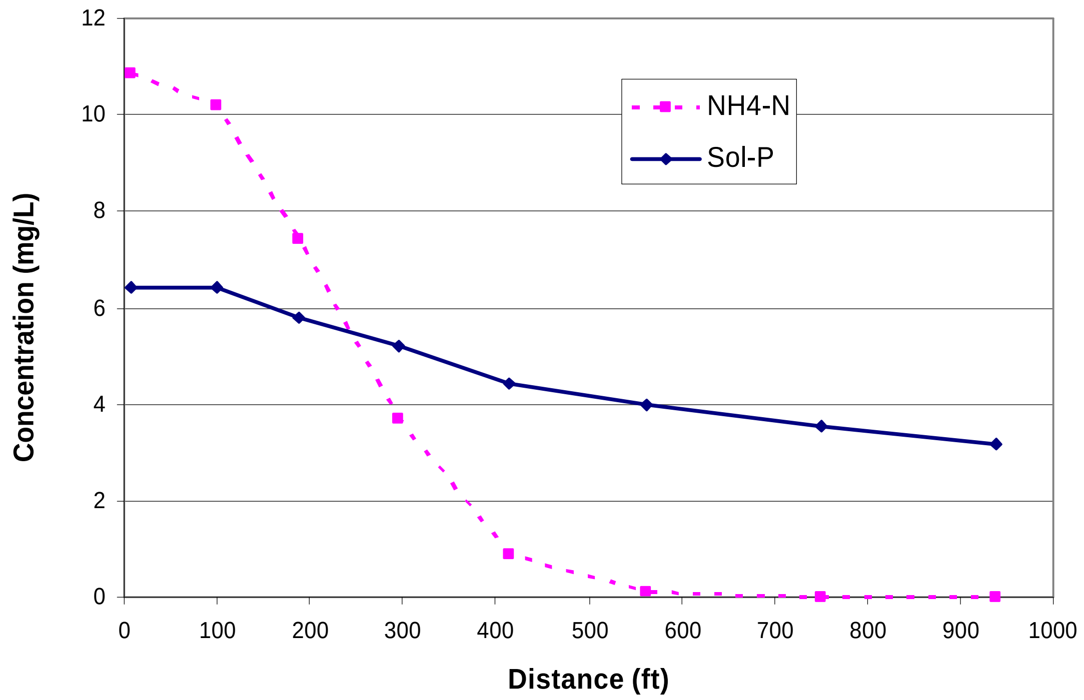
Time Period	Flow (mgd)	Primary Effluent Alkalinity	Primary Effluent pH	Secondary Effluent Alkalinity	Secondary Effluent pH
6/1 – 7/18/05	20.9	237 ± 14.5	7.62 ± 0.24	**123 ± 6.8**	**7.60 ± 0.1**
6/1 – 7/18/07	23.9	241 ± 16.4	7.50 ± 0.08	**80 ± 15.6**	**7.25 ± 0.18**

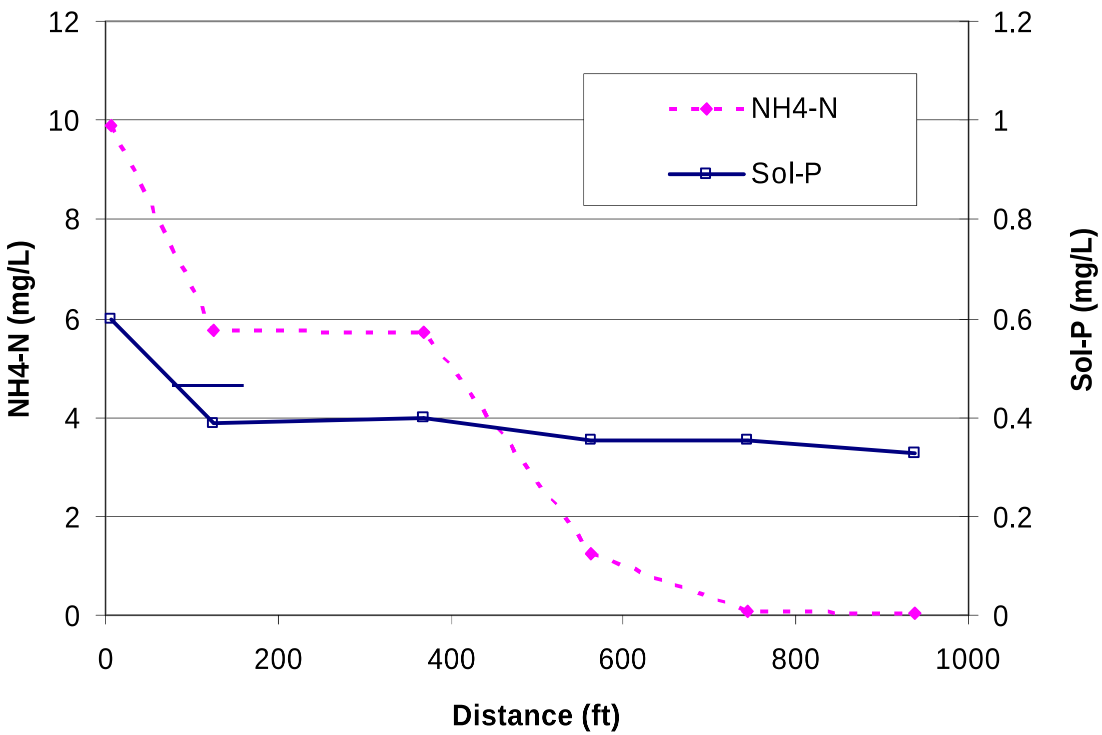
Comparison of pH and alkalinity between different $FeCl_3$ dosing points

Time Period	Flow (mgd)	Primary Effluent		Secondary Effluent	
		pH	ALK	pH	ALK
5/22 - 9/30/07	26.8	7.55 ± 0.15	243 ± 15.6	7.31 ± 0.28	101 ± 36.7
5/22 - 9/30/08	28.9	7.33 ± 0.21	222 ± 18.7	7.22 ± 0.30	111 ± 37.6

Impact on Plant Operations (continued)

- Much lower soluble P in mixed liquor was observed during P removal. At this level, it had no apparent adverse effect on nitrification and other bioactivity.



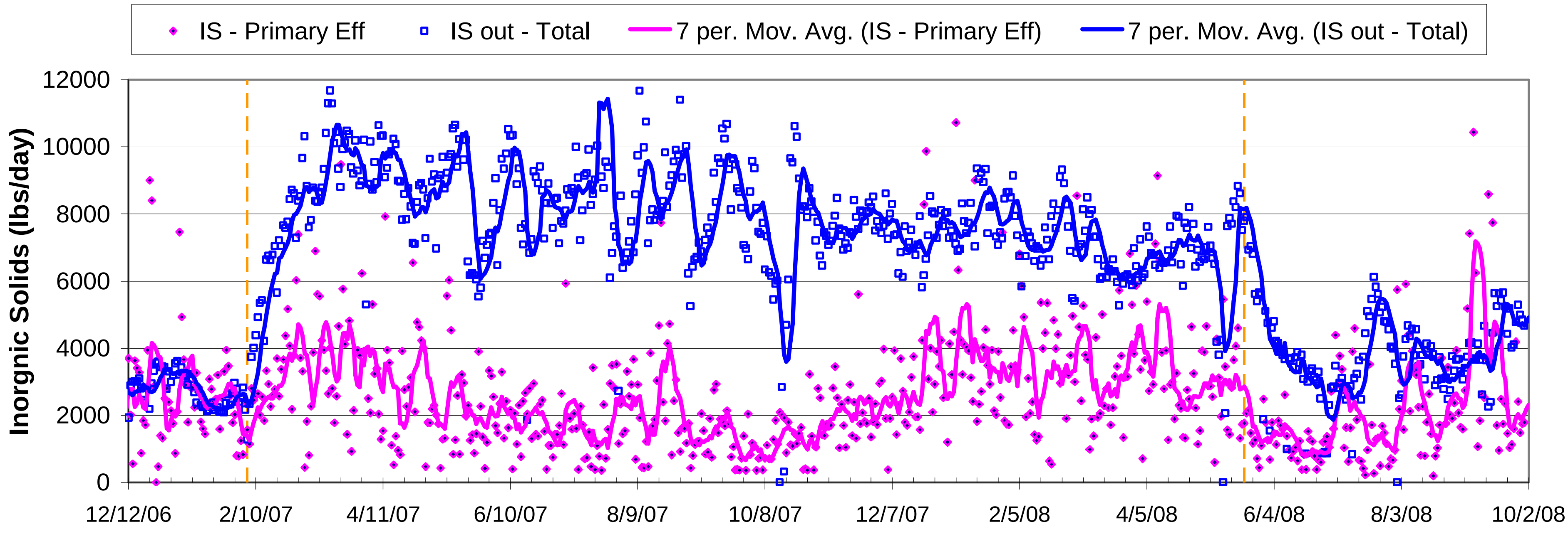


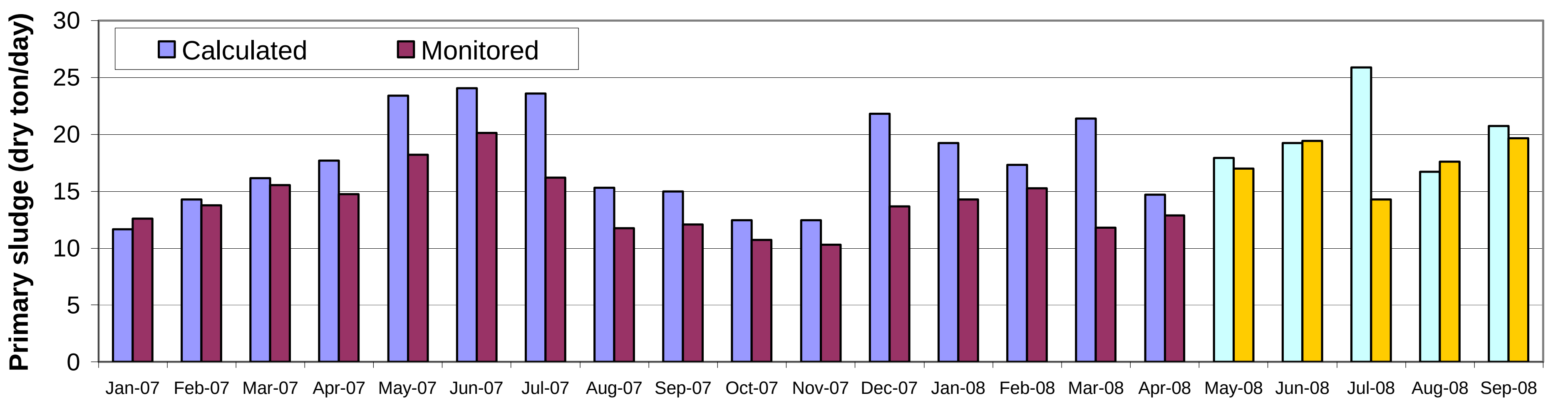
↑ Before $FeCl_3$ addition for P removal in 2005

After $FeCl_3$ addition for P removal in 2007

Chemical Sludge Yield Estimation

- Chemical sludge is estimated using mass balance approach





Chemical Sludge Yield Estimation (continued)

- Chemical sludge yield was estimated while $FeCl_3$ was added to the mixed liquor. The amount varied with the amounts of $FeCl_3$ added and P removed.

$PO_4^{3-} + Fe^{3+} = FePO_4\,(s)$ MW = 151

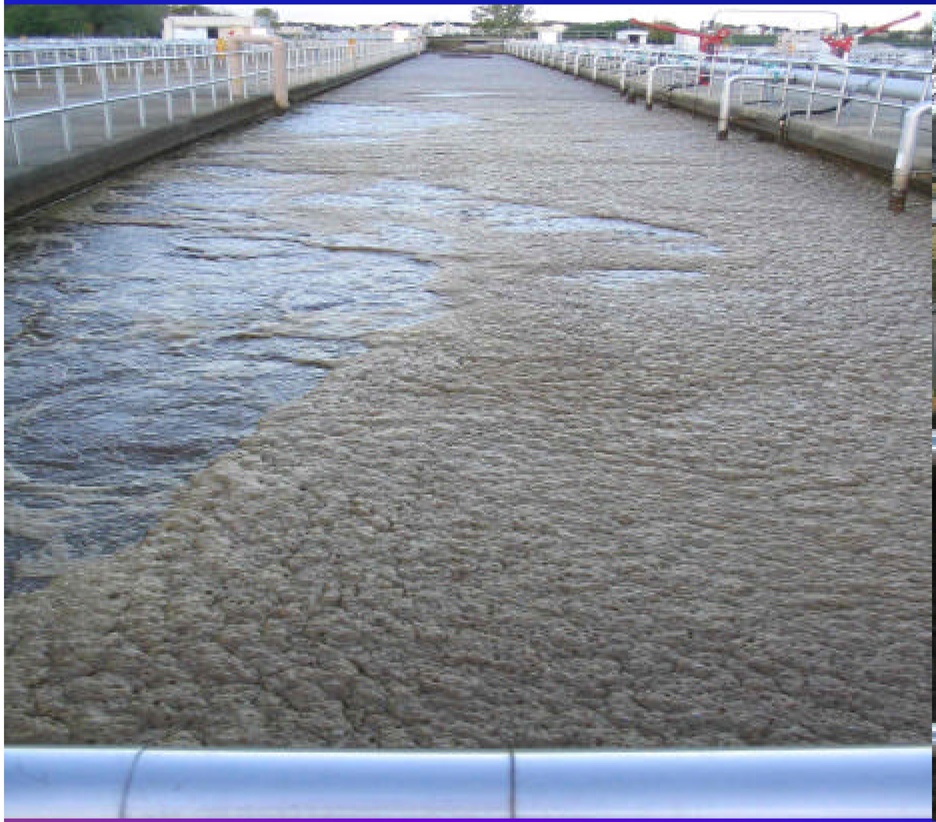
$3OH^{-} + Fe^{3+} = Fe(OH)_3\,(s)$ MW = 107

Time Period	TP Load (lb/d)	Sol-P Load (lb/d)	$FeCl_3$ Dose (gpm)	IS Produced (lb/d)	**IS Yield*** (lb IS/lb $FeCl_3$)
3/6 – 4/2/07	924	511	1.32	6470	**0.87**
4/3 - 6/29/07	951	552	1.17	6680	**1.01**
6/30 - 10/22/07	909	578	1.32	6890	**0.92**
10/23/07 -1/23/08	926	545	1.28	5460	**0.75**
1/23 -5/21/08	921	513	1.16	4470	**0.68**

*** IS stands for inorganic solids**

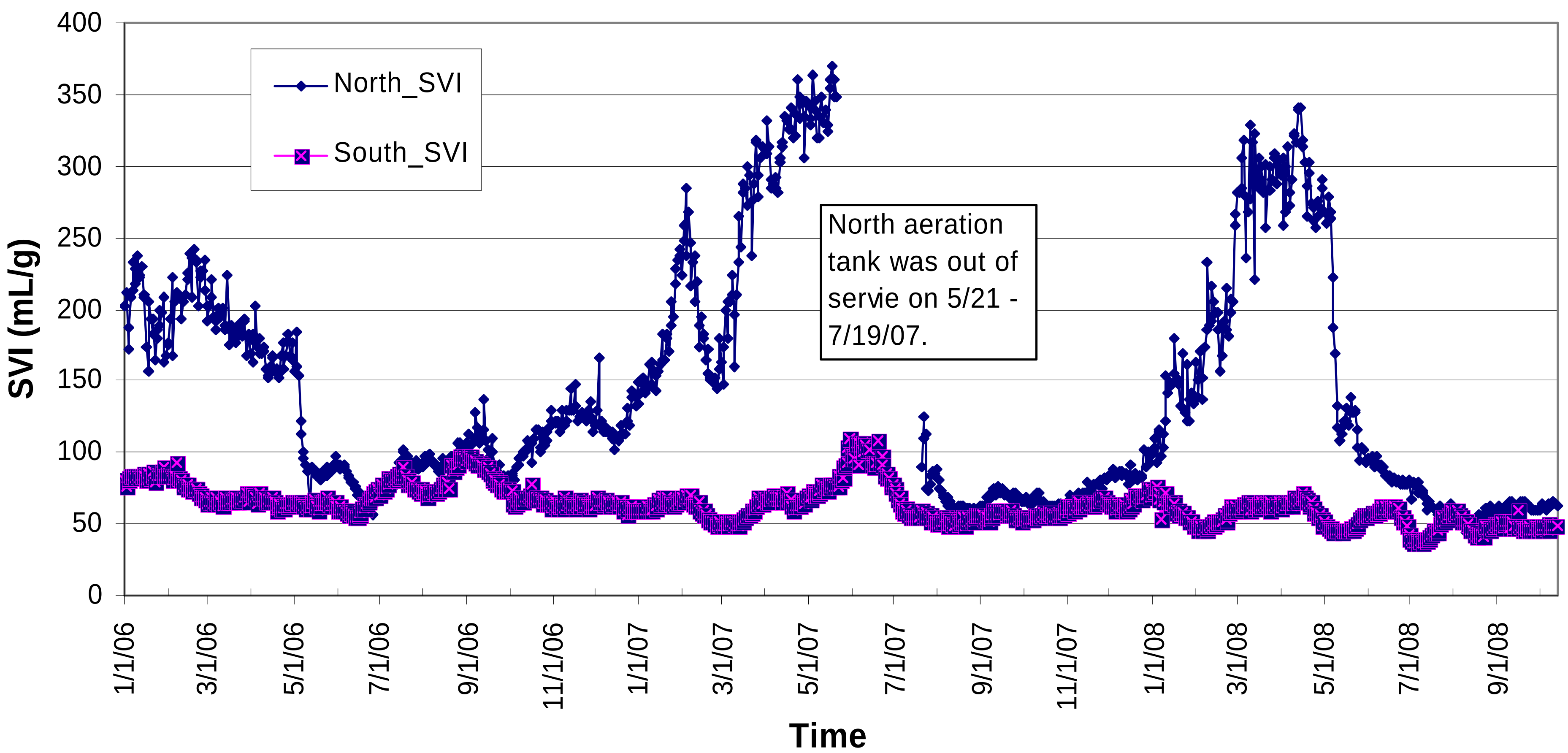
Other Potential Impacts

- Nocardia foaming developed in one of the aeration batteries during P removal. Lower pH in aeration tanks due to $FeCl_3$ addition might have been a major contributor.



Other Potential Impacts (continued)

- It appears that the mixed liquor settling characteristics in the north aeration battery was affected by the addition of $FeCl_3$ to the aeration tank. But, the same effect did not happen in the south aeration battery.



Conclusions – Plant Operations

P removal to 0.5 mg/L of TP in the effluent could be achieved by simply adding a chemical dosing system to the existing plant if the existing clarifiers have excess capacity with respect to solids loading.

$FeCl_3$ could be added, at a weight ratio ($FeCl_3$:Sol-P) of 12 to 14.8 or a molar ratio (Fe:Sol-P) of 2.3 to 2.8, either to the mixed liquor using secondary clarifiers or to primary influent using primary settling tanks for precipitating particulate P.

The addition of $FeCl_3$ has little impact on effluent quality. Alkalinity was reduced and pH dropped slightly. However, it may be a major contributing factor to the worsening of mixed liquor settling characteristics in one of the aeration batteries.

Inorganic content in MLSS increased from 16% to 37% after $FeCl_3$ was added to the aeration tanks. Approximately, 0.68 to 1.01 lb of chemical sludge per lb of $FeCl_3$ added was produced.

Why Monitor Solids Process Train?

- Poor GBT Performance During 2005 WERF Study (02-CTS-1), 30-45 mg/L $FeCl_3$ Dosed to ML to Achieve TP<0.5 mg/L for 6 Months
- Analogous Long-term Full-scale Demonstration Study To Evaluate the Effects of TP Reduction in the Receiving Stream During 2007-2008, TPOs Concerned
- As a Part of Future Nutrient Removal Strategy, $FeCl_3$ Based P-Removal Technology May be Considered
- GBTs Being Considered for Stickney and Calumet WRPs Under Master Plan

Objectives

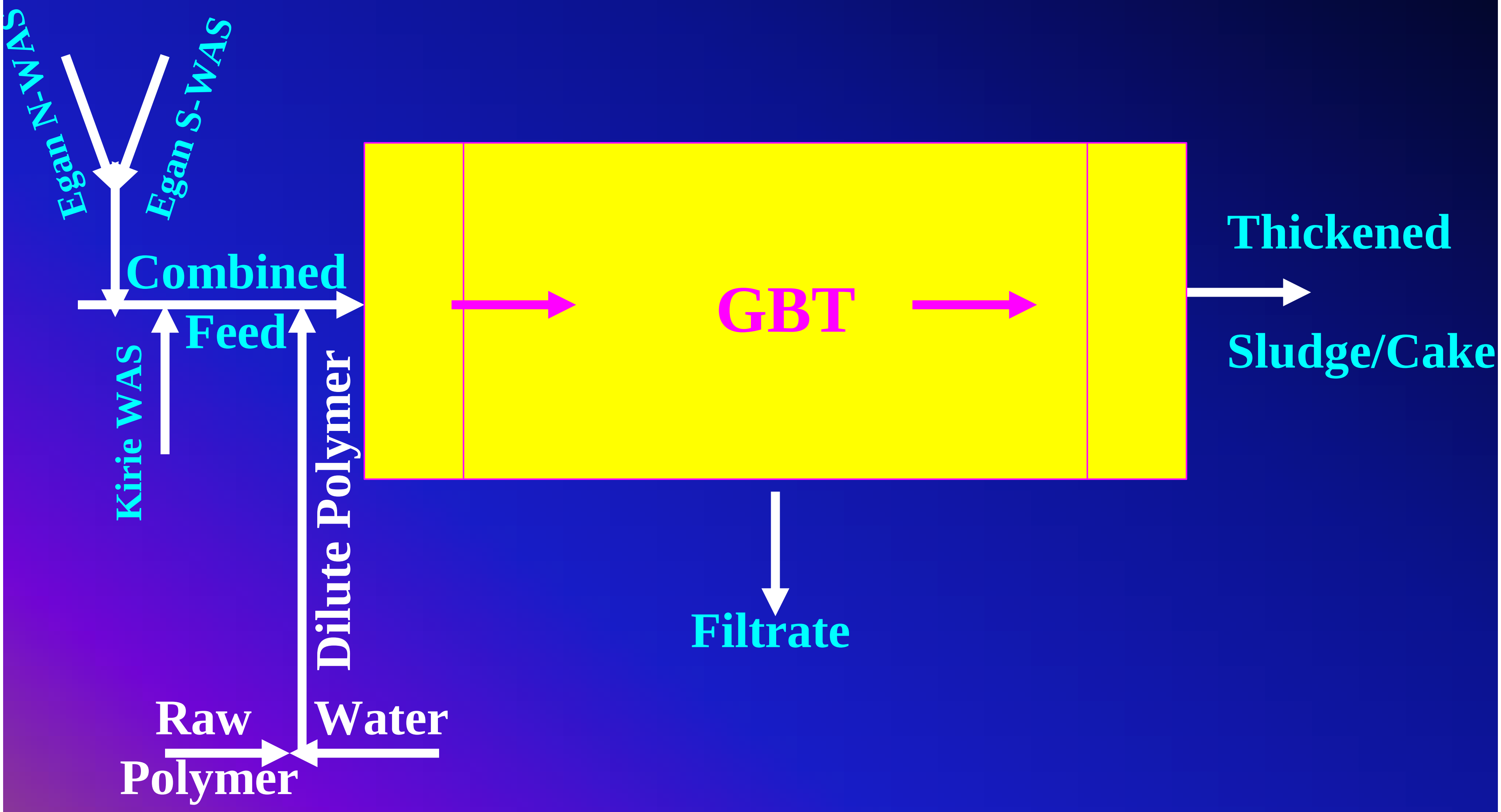
- To Evaluate the Effects of $FeCl_3$ Addition for Phosphorous Removal on Solids Processing Train - Includes GBTs, Anaerobic Digesters and Centrifuges for Dewatering

- Prime Objective is to Monitor Performance of GBT Operation

Gravity Belt Thickeners

Dilute Polymer Prep Tanks and Dilute Polymer Meters

Sampling Points at a Glance



Samples and Tests

Sample Stream	Sample Type, Frequency	Analytes
Egan N & S WAS	Composite,* daily	%TS, T-Fe, TP
Kirie WAS	Composite,* daily	%TS, T-Fe, TP
GBT Feed	Composite,* daily	%TS, T-Fe, TP
Cake	Composite,** daily	%TS, T-Fe, TP
Filtrate	Composite,** daily	%TS, T-Fe, TP
Dilute Polymer	1 Grab sample***, daily	% TS
Raw Polymer	1 Grab Sample, daily	% TS
Dilution Water	1 Grab Sample, daily	% TS, TDS

*Composite of 3 grab samples collected once per shift

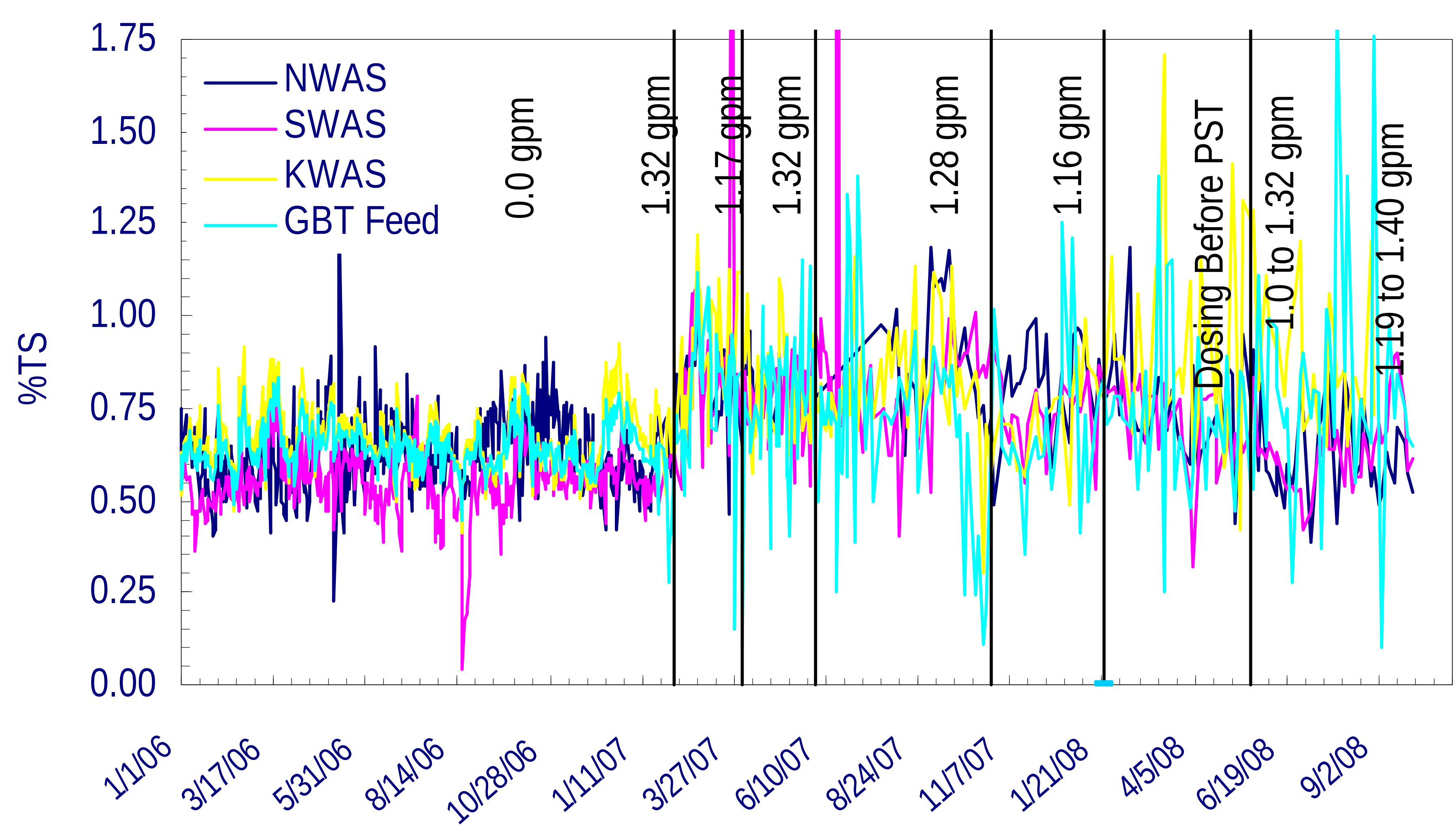
**Composite of 3 grab samples collected once per shift per machine

***Grab per shift per dilute polymer preparation tank

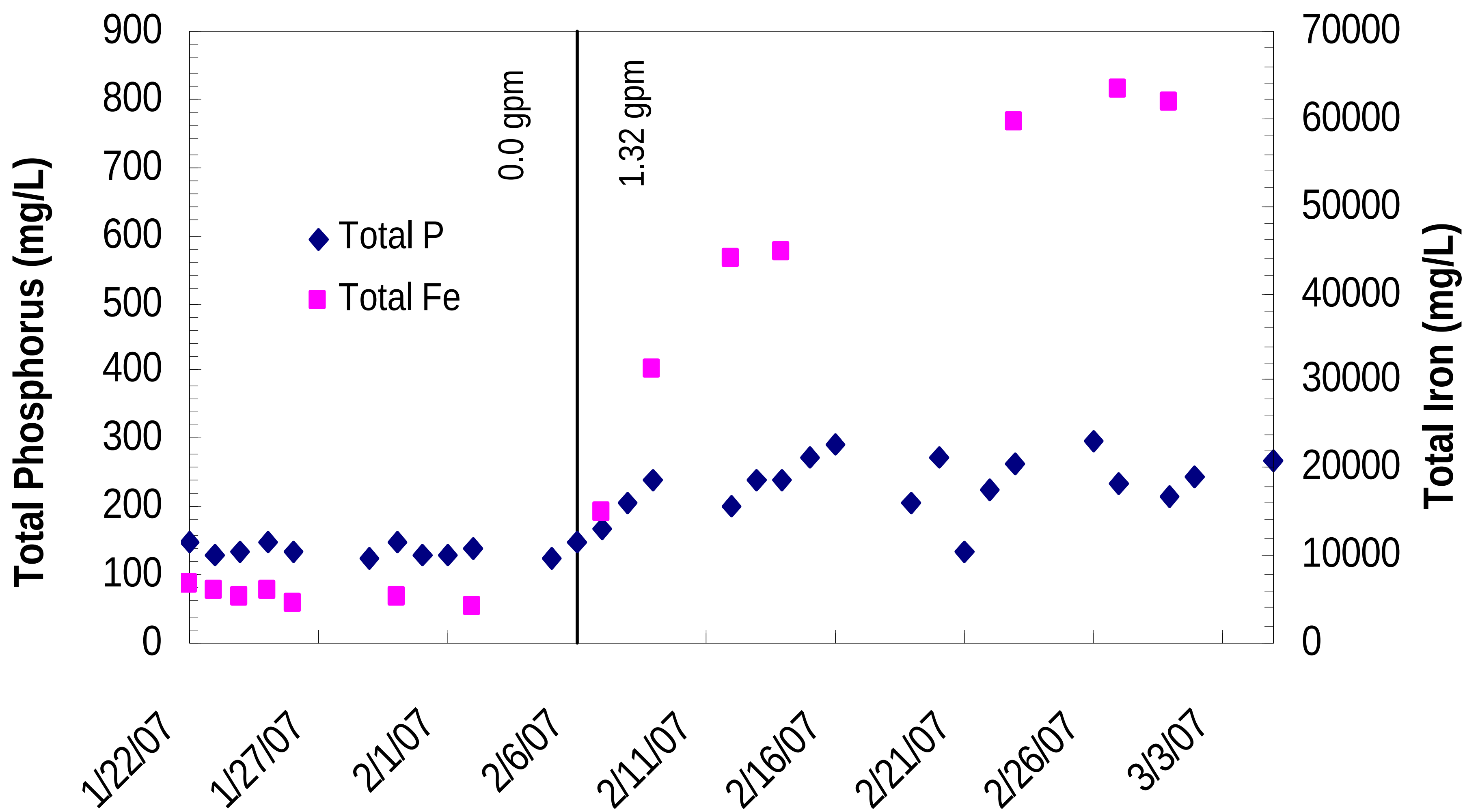
Results: Role of Polymer

- Individual Performance Evaluation Difficult When Both Polymer and $FeCl_3$ Applied to Same Sludge
- Polymer Addition Was Held Constant to Discern Effects of $FeCl_3$
- Consistent Raw Polymer Quality During Background and Testing Period (2/6/07- 9/30/08) (3.91, 3.71 %TS)
- Consistent Dilution Water Quality During Background, and Testing Period (2/6/07- 9/30/08) (684, 729 ppm TDS, City Water)
- Dilute Polymer Preparation During All Three Shifts in Both Tanks Remained Consistent and Comparable
- As a Result, Consistent Dilute Polymer Quality During Background, and Testing Period (2/6/07- 9/30/08) (8.08, 8.51 %TS)
- Polymer Dose Per Machine N/A Due To Lack of Polymer Flow Data

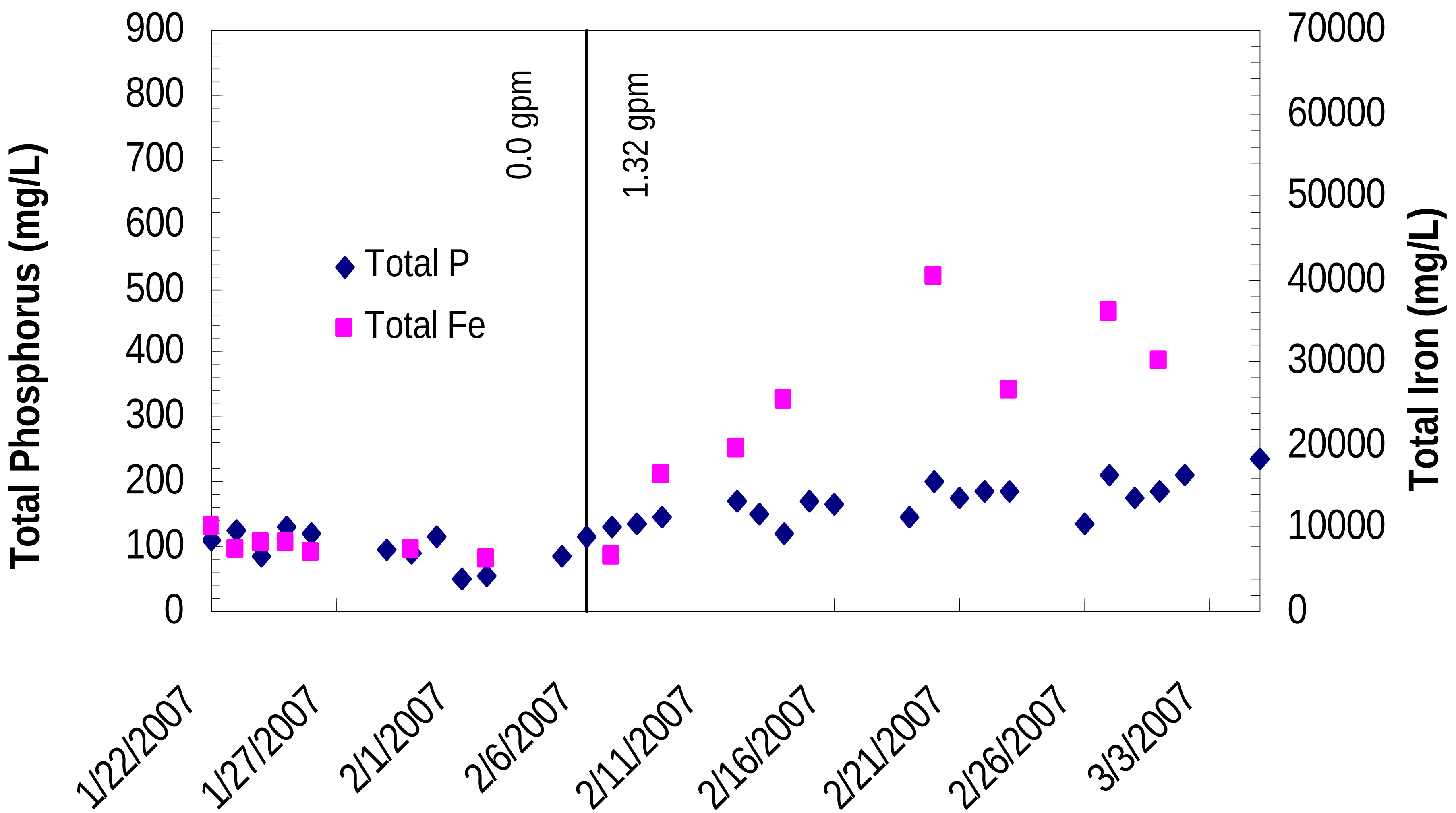
Impact on %TS in N-WAS, S-WAS, K-WAS and GBT Feed



Impact on Total Fe & TP – N WAS



Impact on Total Fe & TP - GBT Feed



Effects on Feed, Thickened Sludge & Filtrate

	TS, mg/kg			Total Fe, mg/kg			TP, mg/kg		
Stream	Background (1/22-2/5/07)	$FeCl_3$ Dose (2/6/07-9/30/08)	% Increase	Background (1/22-2/5/07)	$FeCl_3$ Dose (2/6/07-9/30/08)	% Increase	Background (1/22-2/5/07)	$FeCl_3$ Dose (2/6/07-9/30/08)	% Increase
N-WAS	6787	7646	13	5420	25237	366	135	246	82
S-WAS	5678	7804	37	6743	35236	423	113	256	127
K-WAS	6942	8403	21	8350	11831	42	125	150	20
GBT Feed	5337	7506	41	7902	21070	167	97	177	83
Avg Cake	64760	68737	6	7355	19053	159	1162	2064	78
Avg Filtrate	1235	1256	2	4	17	366	22	23	3

Filtrate Results are in mg/L

Impact on Anaerobic Digesters A & C

	Digester A			Digester C		
Parameter	No $FeCl_3$ Addition (1/22-2/5/07)	$FeCl_3$ Addition (2/6/07-9/30/08)	% Change	No $FeCl_3$ Addition (1/22-2/5/07)	$FeCl_3$ Addition (2/6/07-9/30/08)	% Change
Total Feed, MG	0.08	0.11	26	0.09	0.10	15
Digester Feed, DT	14.91	22.50	51	16.00	22.14	38
Dig Gas produced X1000 ft^3	253	221	-13	343	229	-33
%VS Destruction	57	45	-21	57	46	-20
Detention Time, days	32	25	-21	30	26	-13

	Digester A		Digester C	
Month	Detention Time, d	%VS Reduction	Detention Time, d	%VS Reduction
Oct-06	29.26	38.52	26.75	39.17
Mar-07	22.43	38.35	22.78	38.96

	Digester A		Digester C	
Month	Detention Time, d	%VS Reduction	Detention Time, d	%VS Reduction
Aug-07	27.60	35.60	27.66	36.11
Sep-08	26.13	37.10	26.13	38.06

Centrifugal Dewatering Operation

Impact on Centrifuge Dewatering Operations

Parameter	Background (1/22-2/5/07)	$FeCl_3$ Addition (2/6/07-9/30/08)	% Change
Sludge Feed, MG	0.24	0.23	-2
Sludge Feed, DT	20.70	23.86	15
Polymer Dose, lbs/DT	510	415	-19
Ferric Chloride Dose, lbs/DT	431	314	-27
Centrate SS, mg/L	2,498	2,893	16
Sludge Cake, %Total Solids	24	26	7

Preliminary Conclusions

- No Operational Problems for GBT, Digestion and Centrifugal Operations.
- The GBT Feed and Egan WAS Showed Appreciable Increase in TS, Fe and TP.
- The GBT Performance As Measured By %TS of Thickened Sludge Did Not Significantly Change by the $FeCl_3$ Addition.
- The $FeCl_3$ Fortified Thickened Solids Produced Less Volatile Solids Destruction in the Primary Digesters.
- Reduction in Gas Production May Be Associated With Less Volatile Solids Destruction Due to Shorter Detention Time wrt Before $FeCl_3$ Addition.
- No Significant Impact on Digester Performance Was Observed Due to $FeCl_3$ Addition.
- $FeCl_3$ and Polymer Demand Were Significantly Reduced for Centrifugal Dewatering Operation.
- Marginal Increase in Cake Solids and Centrate Solids Were Also Noted.

Why does P in biosolids matter?

Typical biosolids application rate: 22 Mg/ha

Biosolids generally contains: 2.5% P

Biosolids application increase soil P by: 550 kg/ha

Crop requirement for TSP: 40 kg/ha

R & D research indicates P availability:

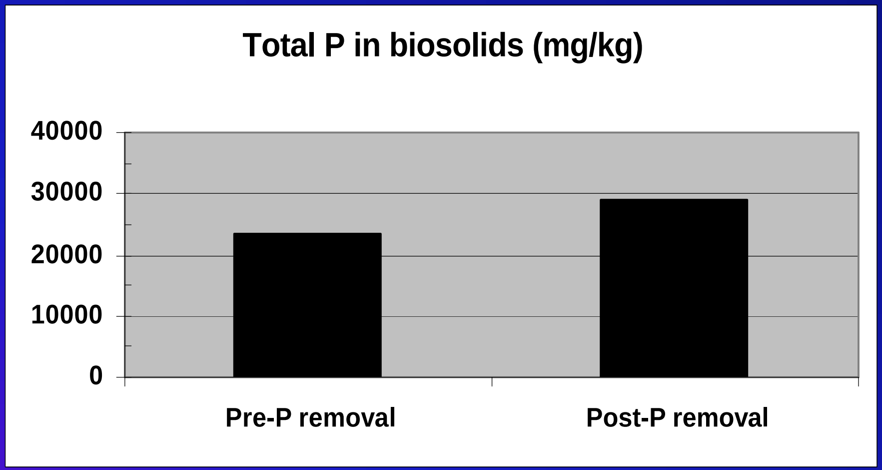
Biosolids P = 1/3 TSP

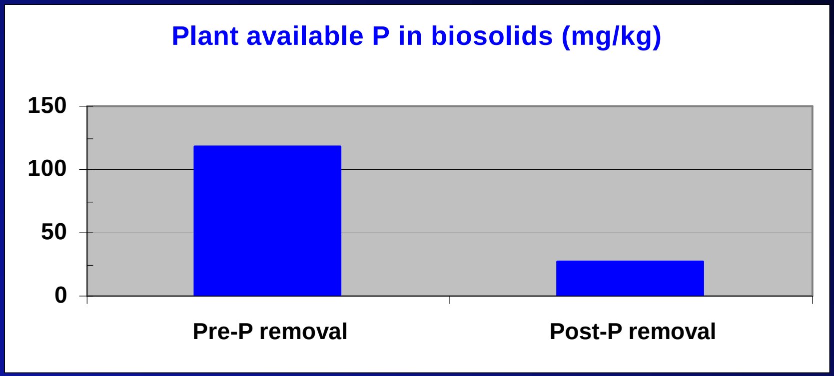
Even that: over application of P is still likely

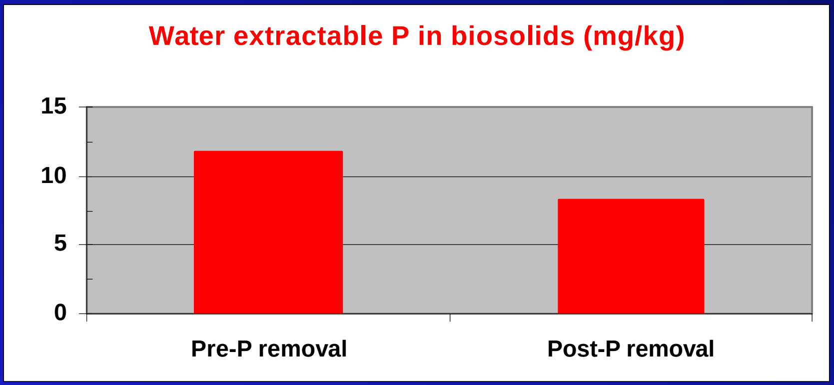
If P-based biosolids land application implemented in Illinois, biosolids application has to be reduced, resulting in high costs of operations.

P-removal in effluent changes P in biosolids, research is needed to find what impact of such change can cause to biosolids land application.

Effect of P removal on P in biosolids

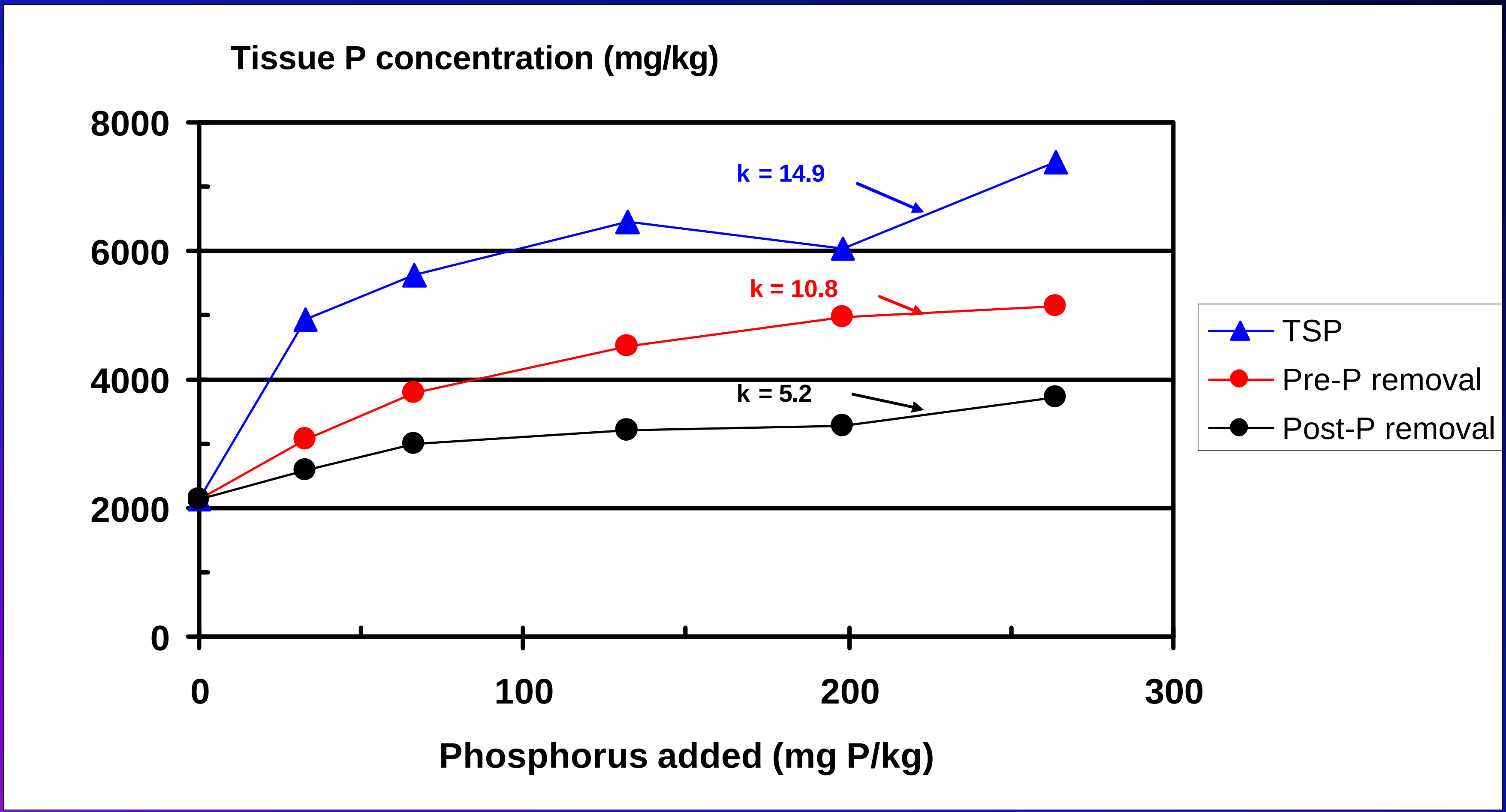






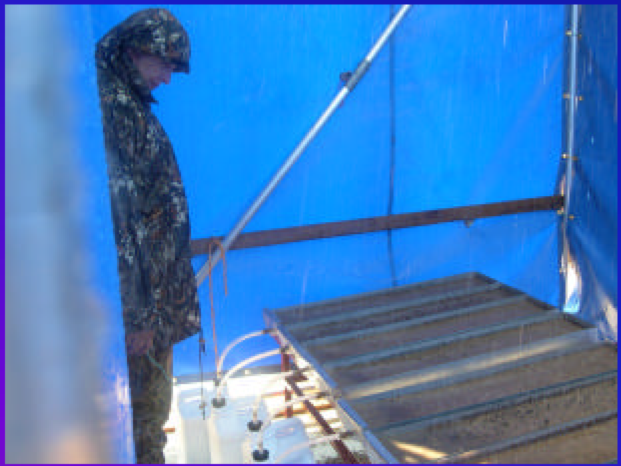
Greenhouse study

Availability: tissue P concentration

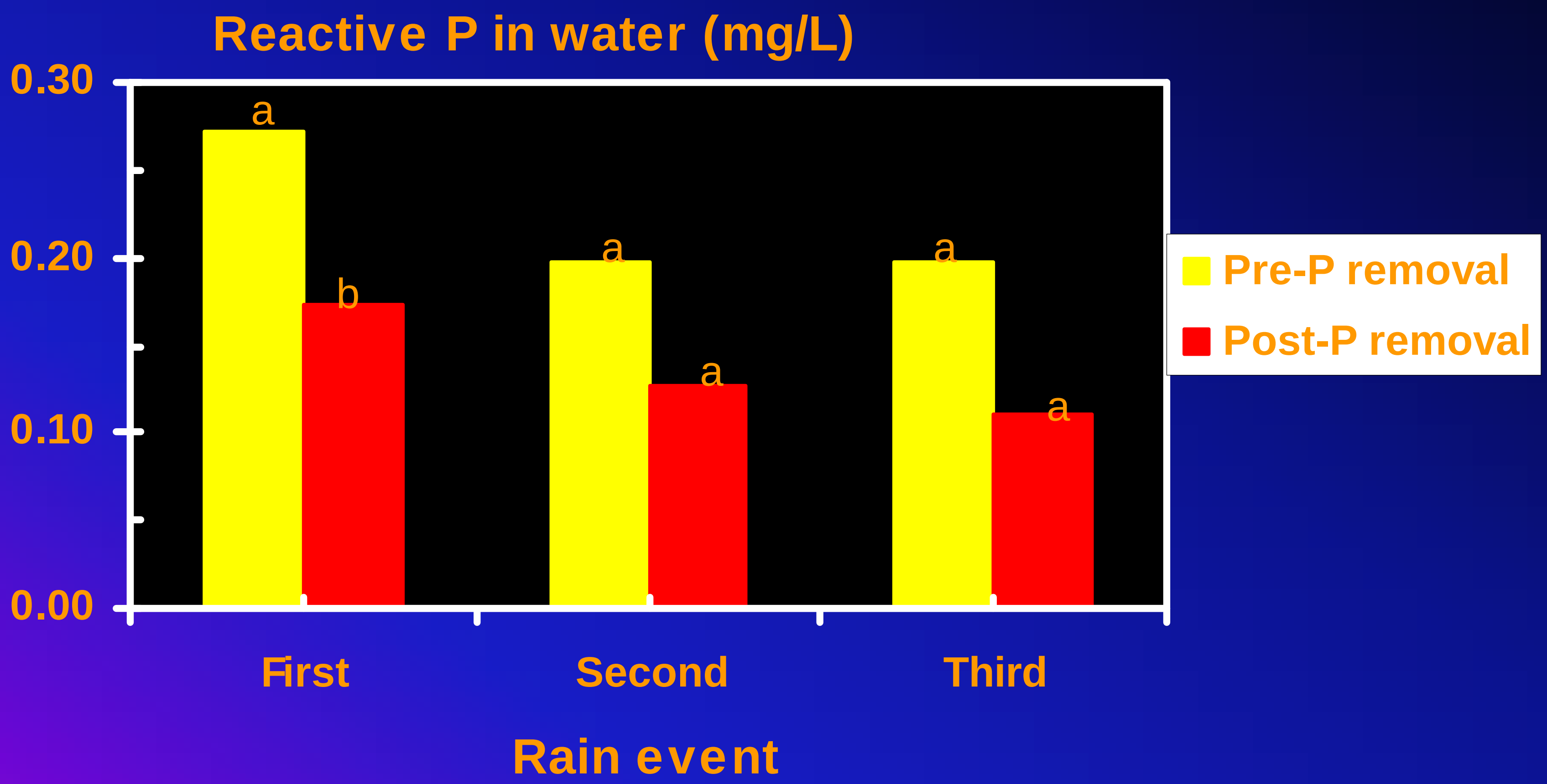


Environmental lability: P in runoff

- Soil mixed with biosolids
- Rainfall intensity: 100 mm hr^{-1}




Effect of P-removal on P in runoff



Conclusions - biosolids

This study indicates that

- chemical P removal process
  - slightly increases total P content of biosolids
  - greatly decreases the P agronomical availability and environmental lability of the biosolids.

The P-removal biosolids can be applied at a rate similar to or greater than conventional biosolids.