APPENDIX F

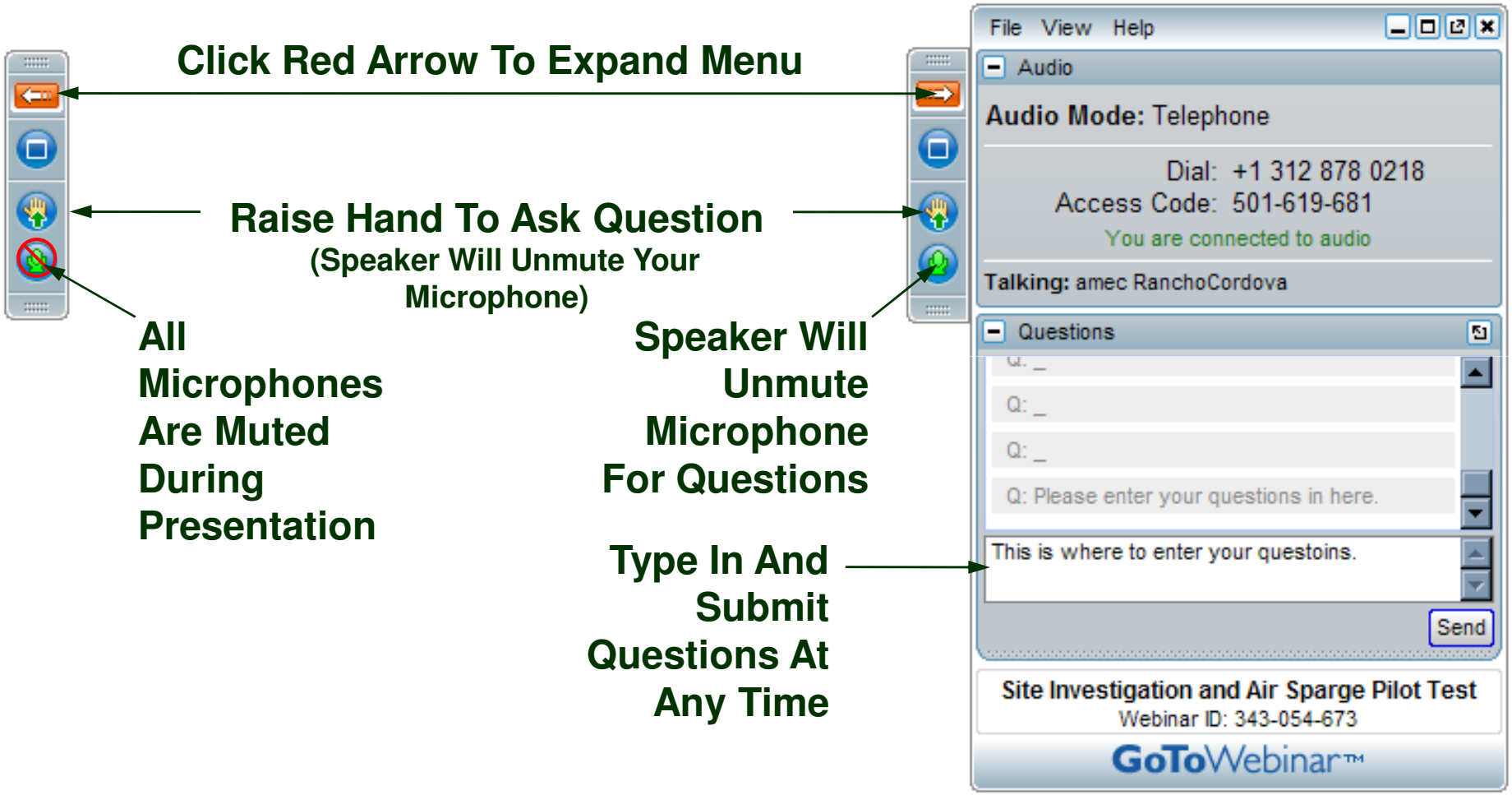
2010 Aspen Seep Bioreactor Performance Review Presentation Slides

Aspen Seep Bioreactor Treatment System Performance Review
Leviathan Mine Site
February 14, 2011

Atlantic Richfield Company

amec

Webinar Information



Agenda

- Bioreactor Overview
- Site and System Improvements
- System Operations
- System Performance
  - Indicator Parameters (ORP, DO, sulfate/sulfide)
  - Metals Removal
- System Optimization
  - Biocell Flow Reversal
  - Ethanol/Acetate analysis
- Sludge Management
  - Biocell Flushing and Sludge Removal
  - Sludge Drying Bed Pilot Test Results

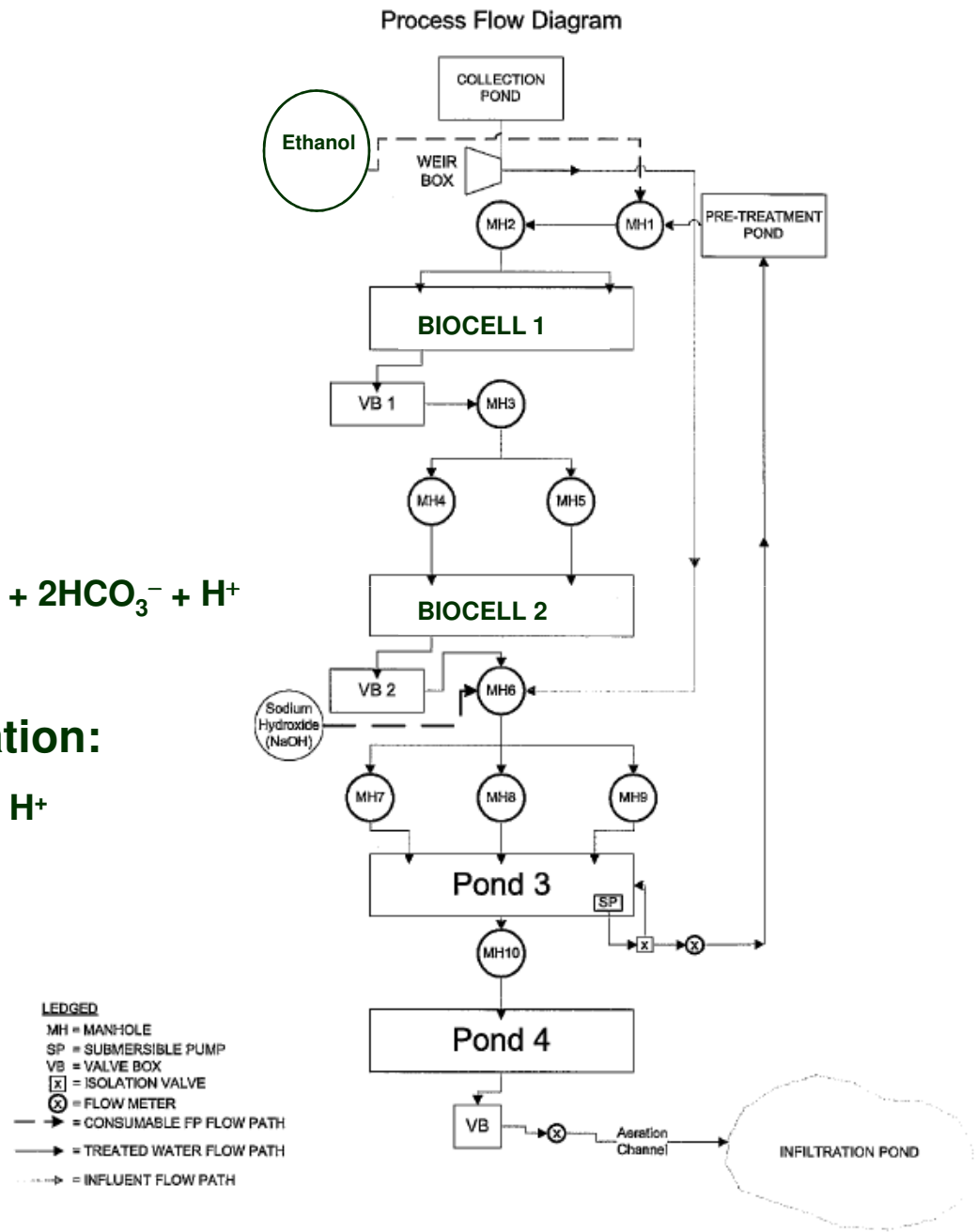
Bioreactor Overview

Sulfate Reduction:

$$2CH_2O + SO_4^{2-} \rightarrow HS^-_{(aq)} + 2HCO_3^- + H^+$$

Metal Sulfide Formation:

$$HS^-_{(aq)} + Me^{2+} \rightarrow MeS_{(s)} + H^+$$



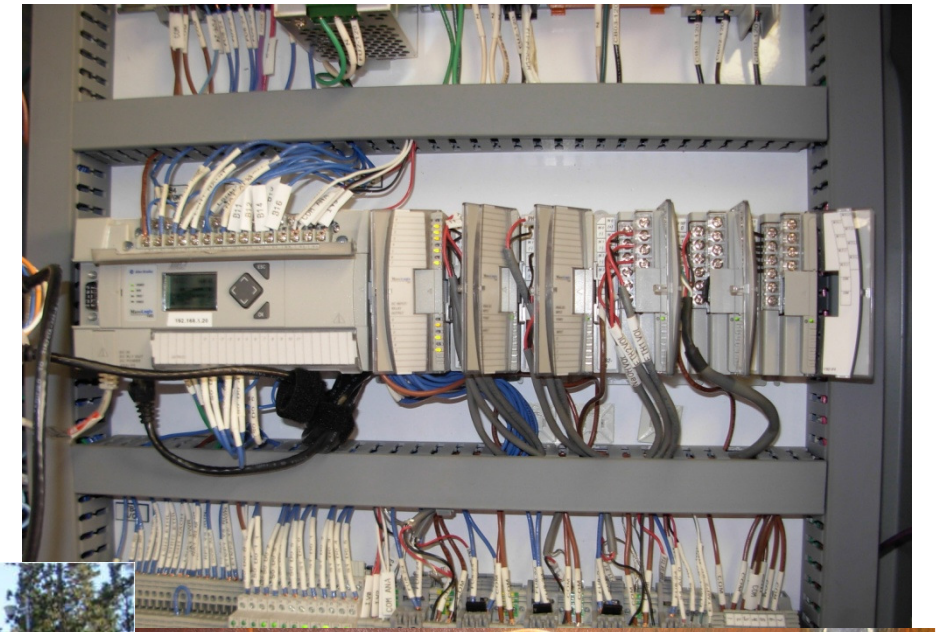
Bioreactor Overview

Bioreactor Overview

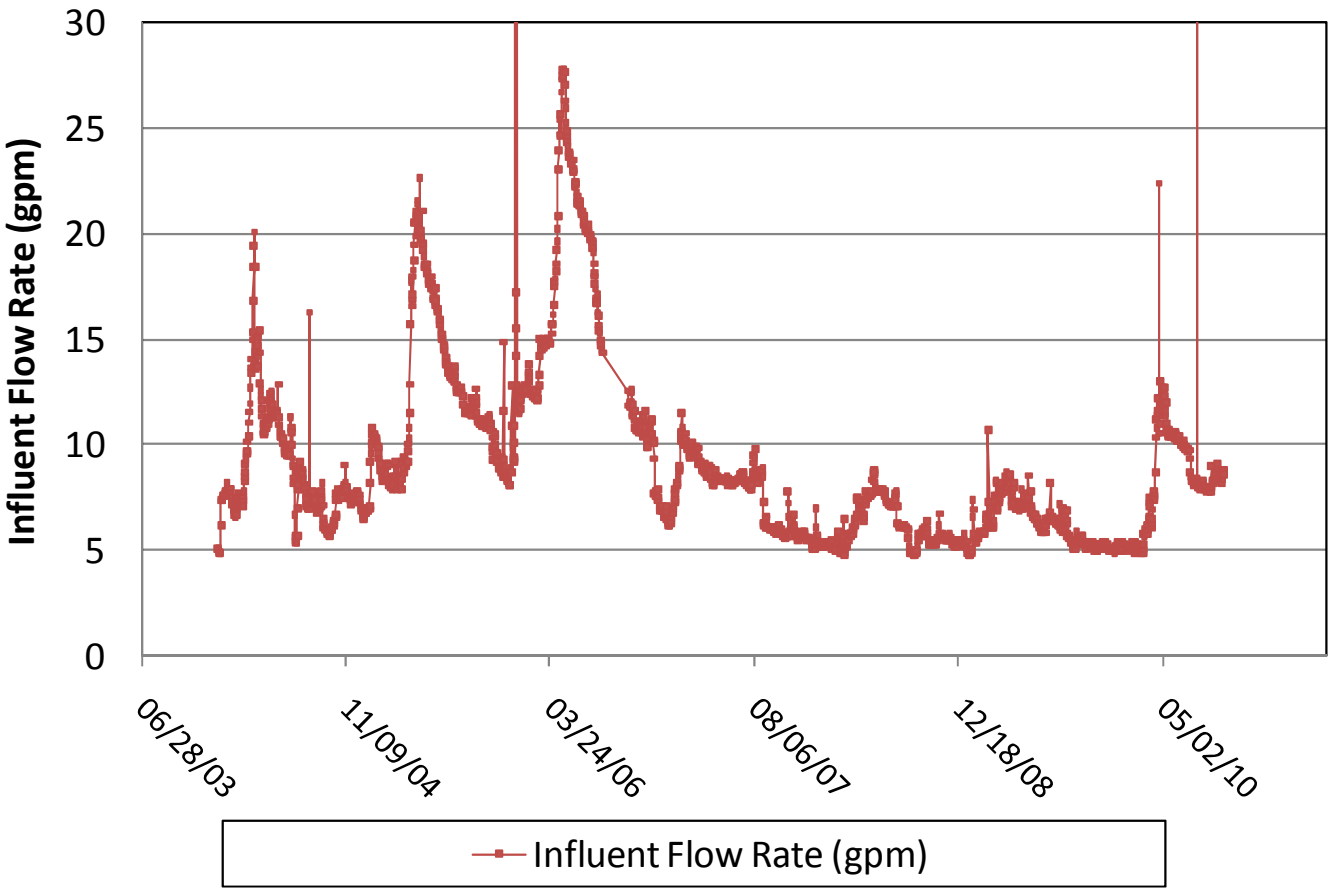
Bioreactor Overview

2010 – Site and System Improvements

- Hydrogen Sulfide Exposure Evaluation
- Year Round Safety Shower Installation
- Chemical Feed System Improvements
- PLC Replacement
- Power Generation System Evaluation
  - Battery Load Testing & Reconditioning
- Influent Line Replacement
- Secondary Influent and Recirculation Line Installation



ASB – Historic Influent Flow Rates (USGS)



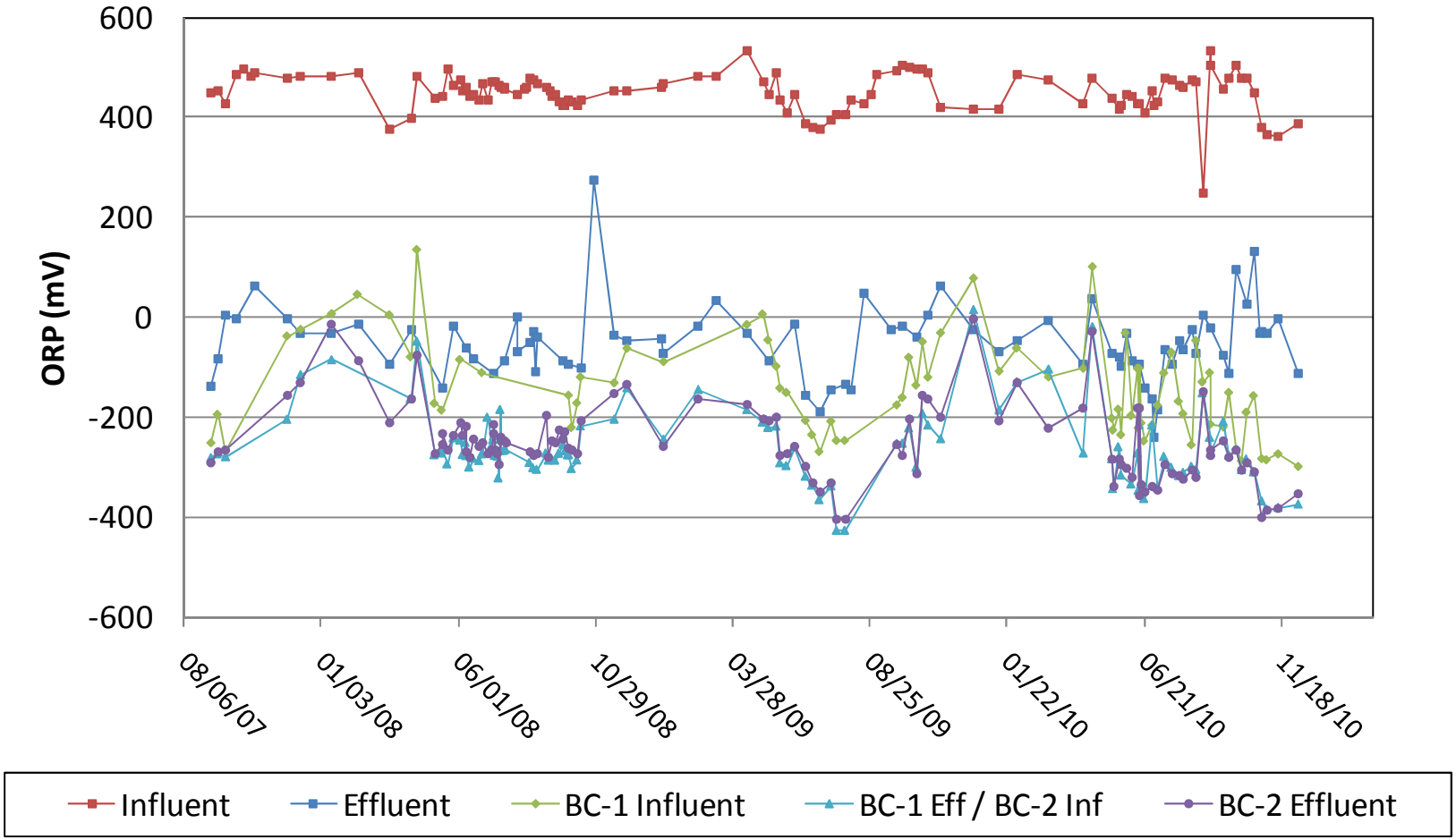
Note: Data is provisional for 9/30/09 through 9/30/10

- Successfully treated ~3.6 million gallons of acid drainage collected from the Aspen Seep from January 1 through December 31, 2010

2010 – System Performance

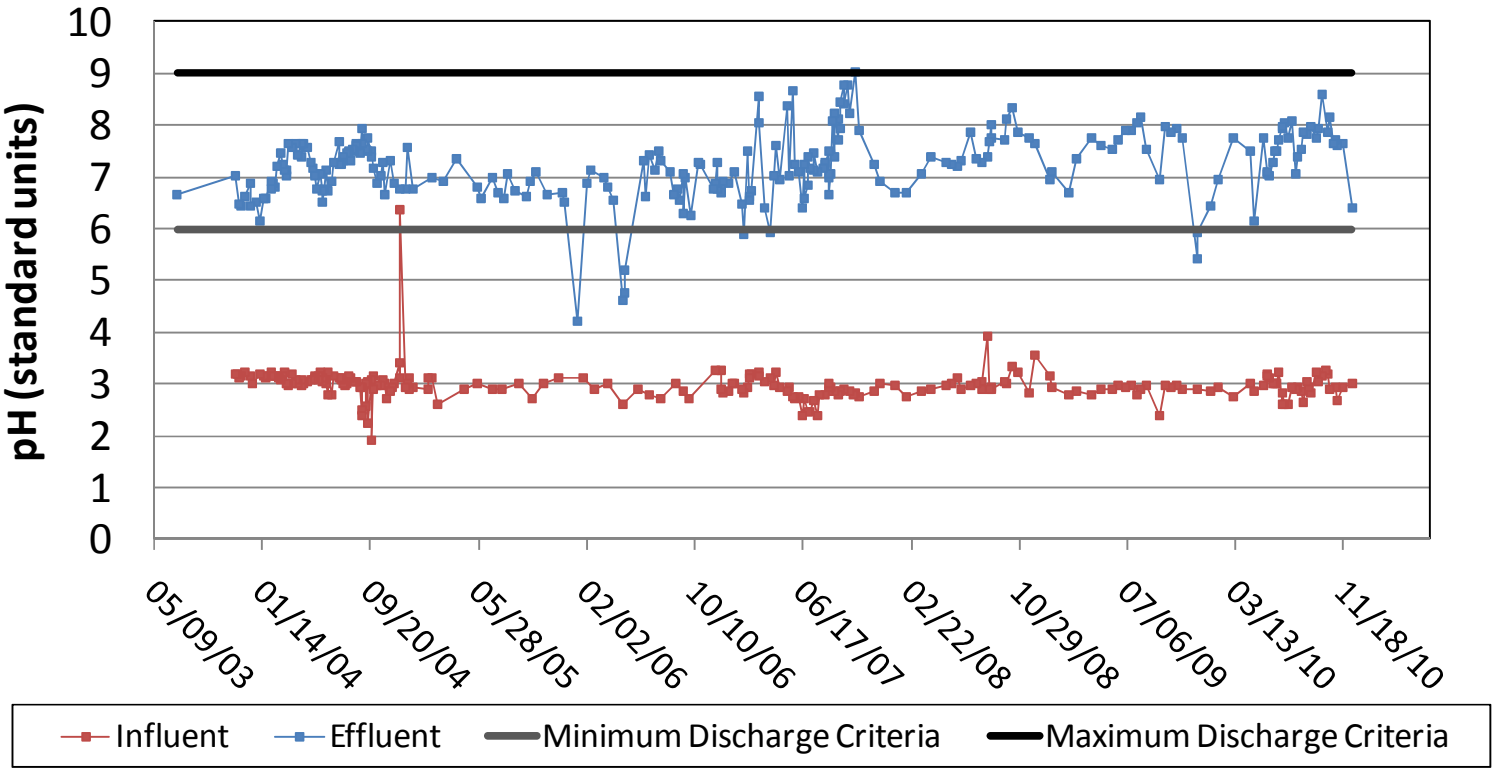
- Performance and achievement of discharge criteria demonstrated by:
  - Indicator parameters
    - ORP
    - pH
    - Sulfate removal
  - Metals removal

Oxidation/Reduction Potential



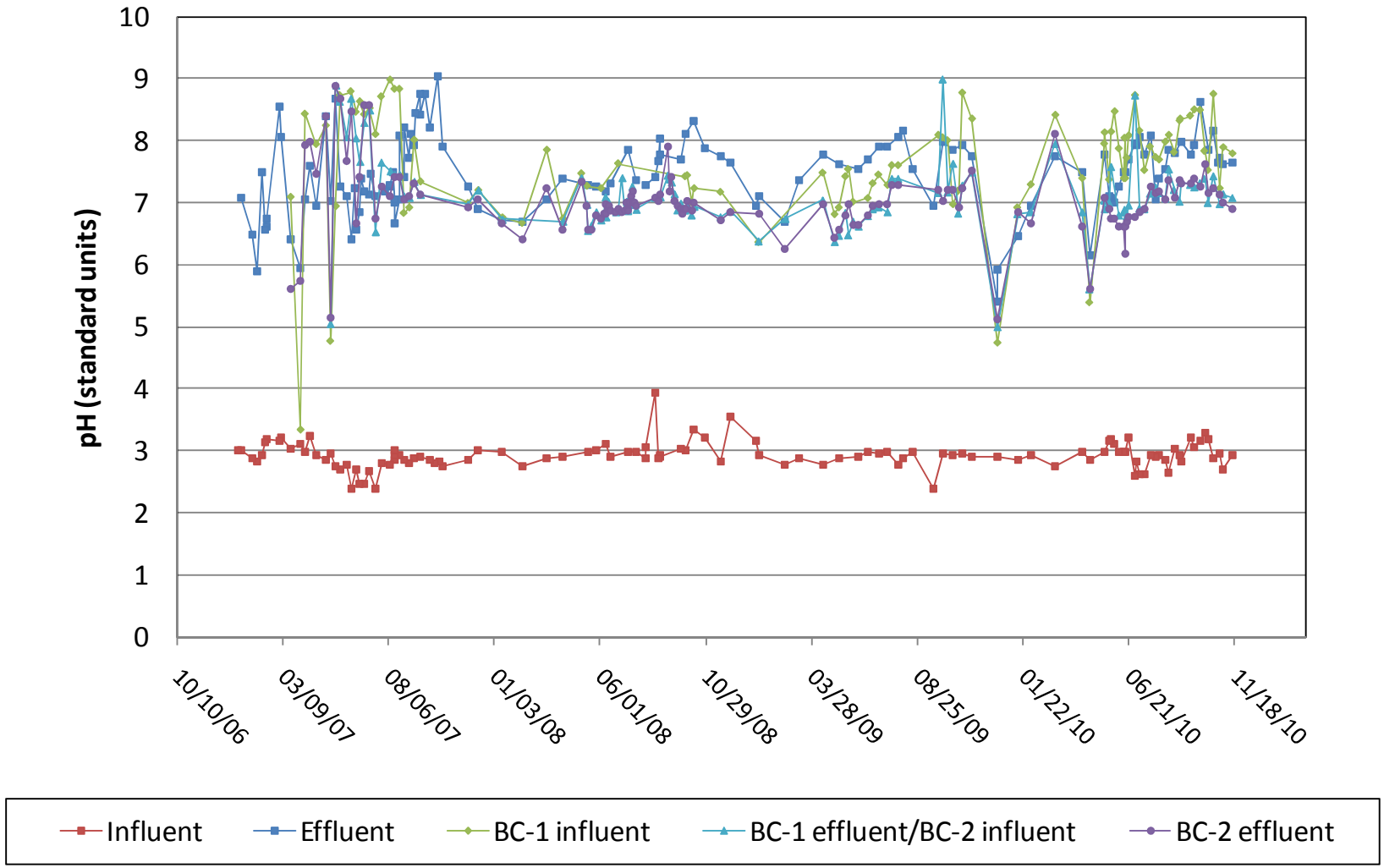
- 2010: Biocell 1 & 2 average effluent ORP of -278 mV
- 2010: Biocell 1 & 2 effluent ORP range of -19 to -403 mV

Influent & Effluent pH



- 2010 average effluent pH of 7.6
- Target effluent pH of 7.2 to 8 to promote metals precipitation
- Low pH in December 2009 due to NaOH pump downtime
- Low pH in April 2010 likely due to 1 inch rain storm, snowmelt, and flow rate increase from 5 to 12 gpm

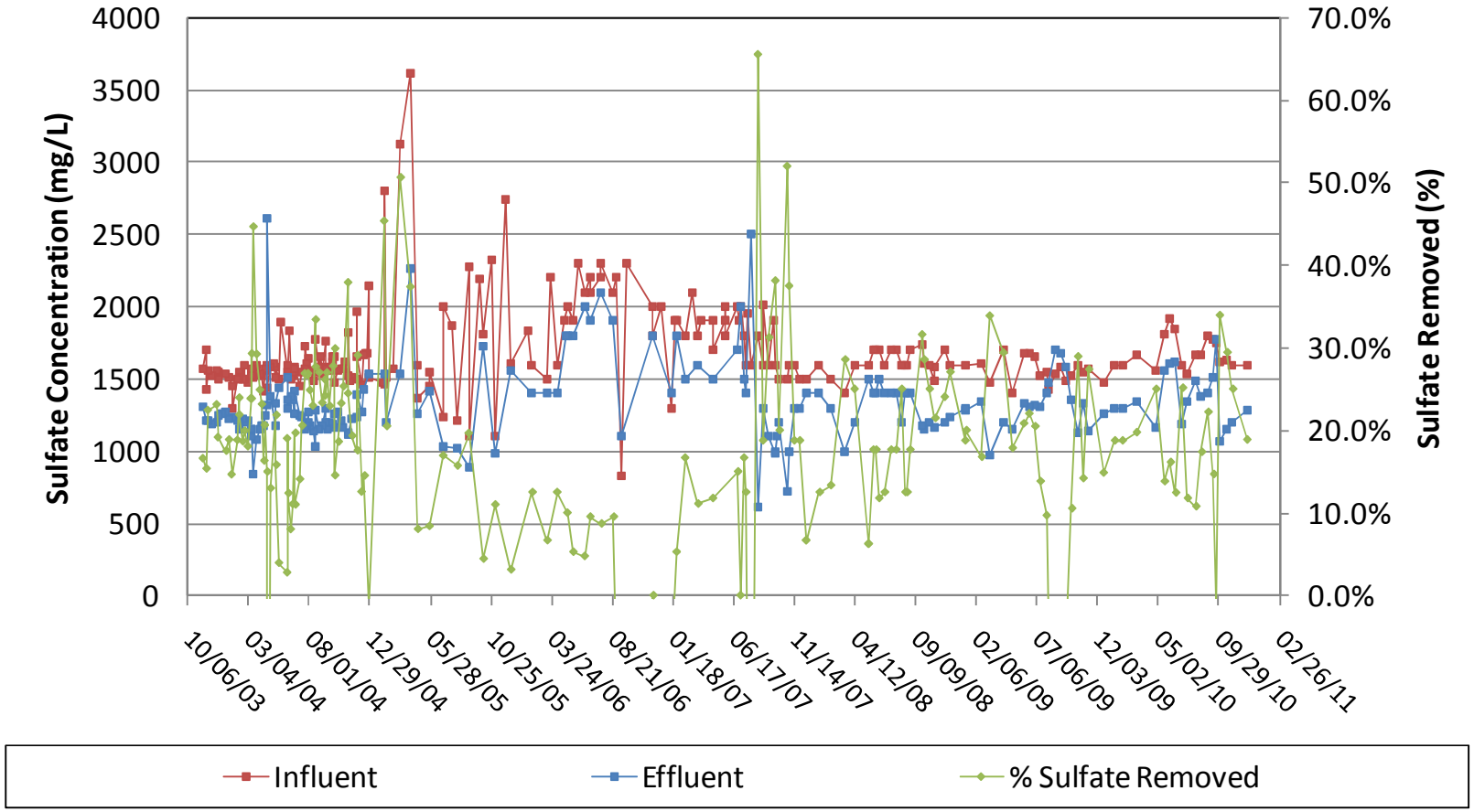
Biocell pH


pH (standard units)
10
9
8
7
6
5
4
3
2
1
0
10/10/06
03/09/07
08/06/07
01/03/08
06/01/08
10/29/08
03/28/09
08/25/09
01/22/10
06/21/10
11/18/10
Influent
Effluent
BC-1 influent
BC-1 effluent/BC-2 influent
BC-2 effluent

System Performance

Indicator	2006	2007	2008	2009	2010
Metals Removal (%)	90.4%	95.4%	99.2%	97.1%	98.0%
Sulfate Removal (%)	4%	16%	19%	15%	19.0%
Total Influent Metals (mg/L)	194	149	150	140	150
Influent sulfate (mg/L)	1,951	1,767	1,618	1,559	1,685

Sulfate Concentrations



- 2010: Typical removal of 28 lb/day (280 mg/L removed)
- Reduction of 190 mg/L sulfate required to precipitate all metals

System Operations

Unplanned Downtime

Year	Ethanol Pump	Sodium Hydroxide Pump	Recirculation Pump	Power Generation System
2009	4.6%	1.9%	3.8%	1.5%
2010	5.8%	4.0%	3.5%	3.4%

Metals Removal – Events Affecting Discharge Criteria Exceedance

- January 2010 (Iron, Nickel) –
  December 2009 NaOH pump failure (~2 weeks of pump downtime)

- February 2010 (Iron , Nickel) –
  System recovering from December 2009 NaOH pump failure

- April 2010 (Iron) –
  Increase in system influent flow rates from 5 to 12 gpm due to snowmelt and 1 inch of rain the week prior to sample collection

- September 2010 (Aluminum, Copper, Iron) –
  Centrifuge sludge dewatering

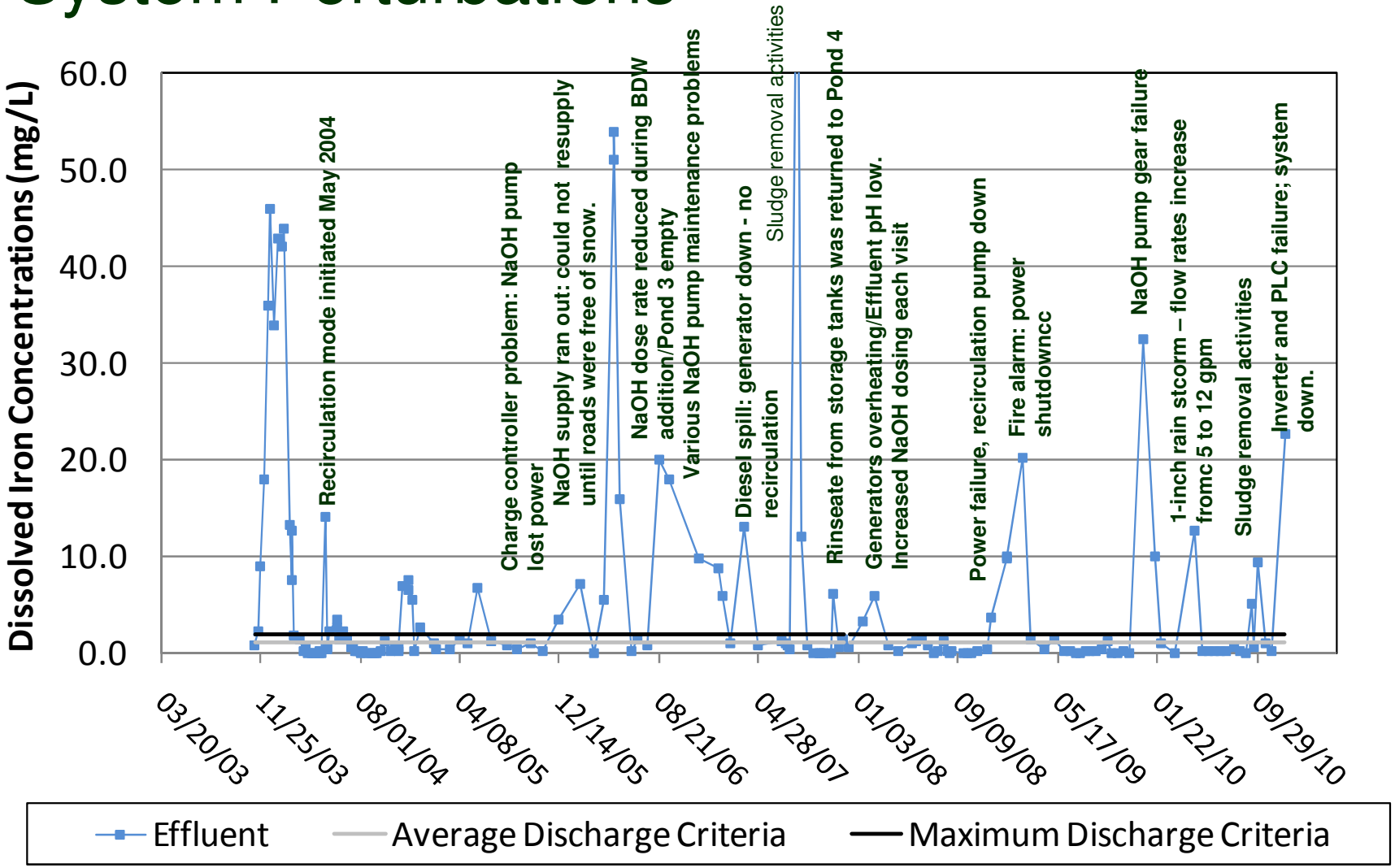
- December 2010 (Iron, Nickel) –
  Inverter and PLC failure caused a power outage and associated chemical dosing pump downtime and low system pH

Note: Arsenic, Cadmium, Chromium, Lead, and Selenium influent concentrations are typically below discharge criteria

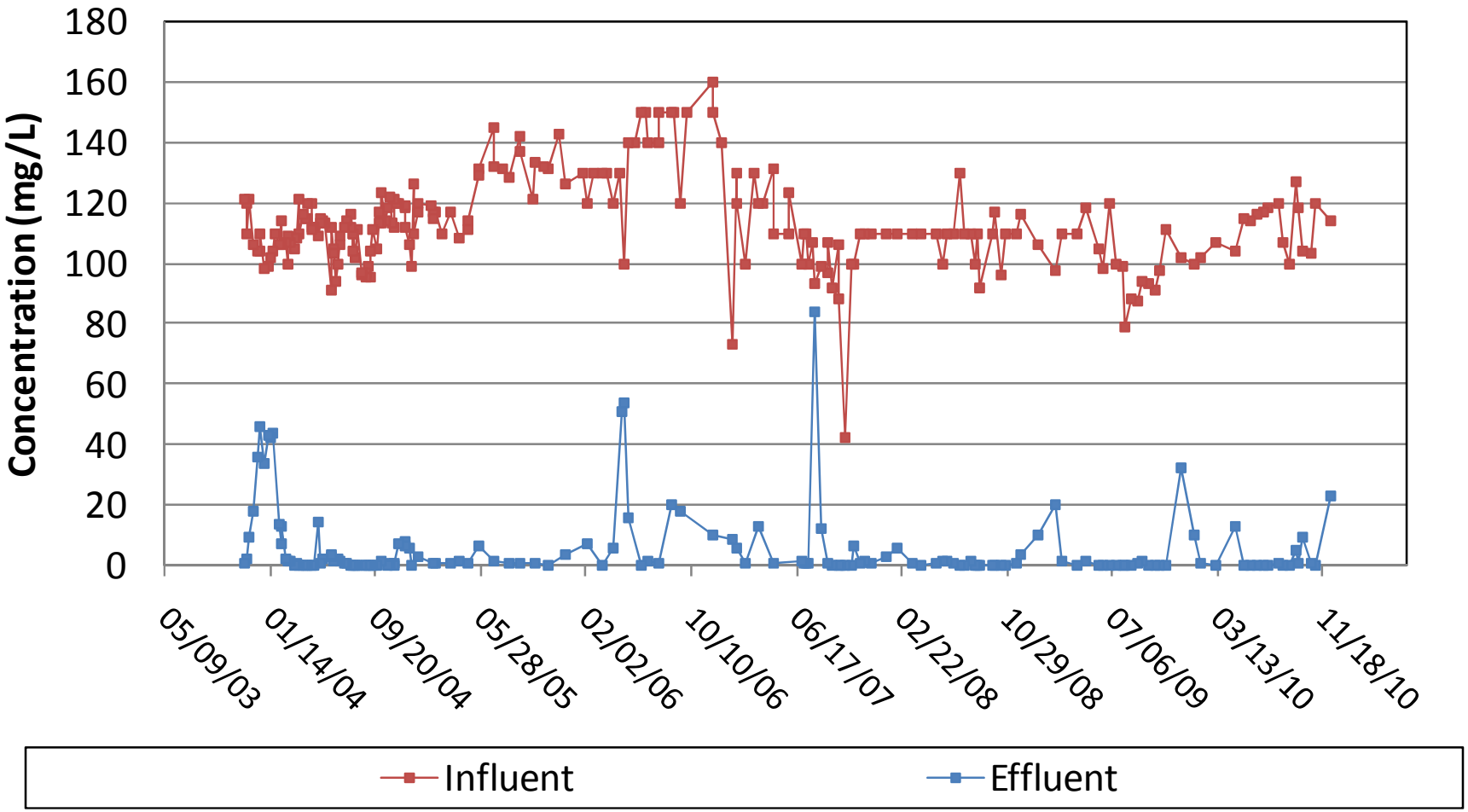
Iron Removal

- Most difficult to consistently achieve discharge criteria
- Highest metal concentration in influent (~100 mg/L)
- Sensitive to system upsets and low temperatures

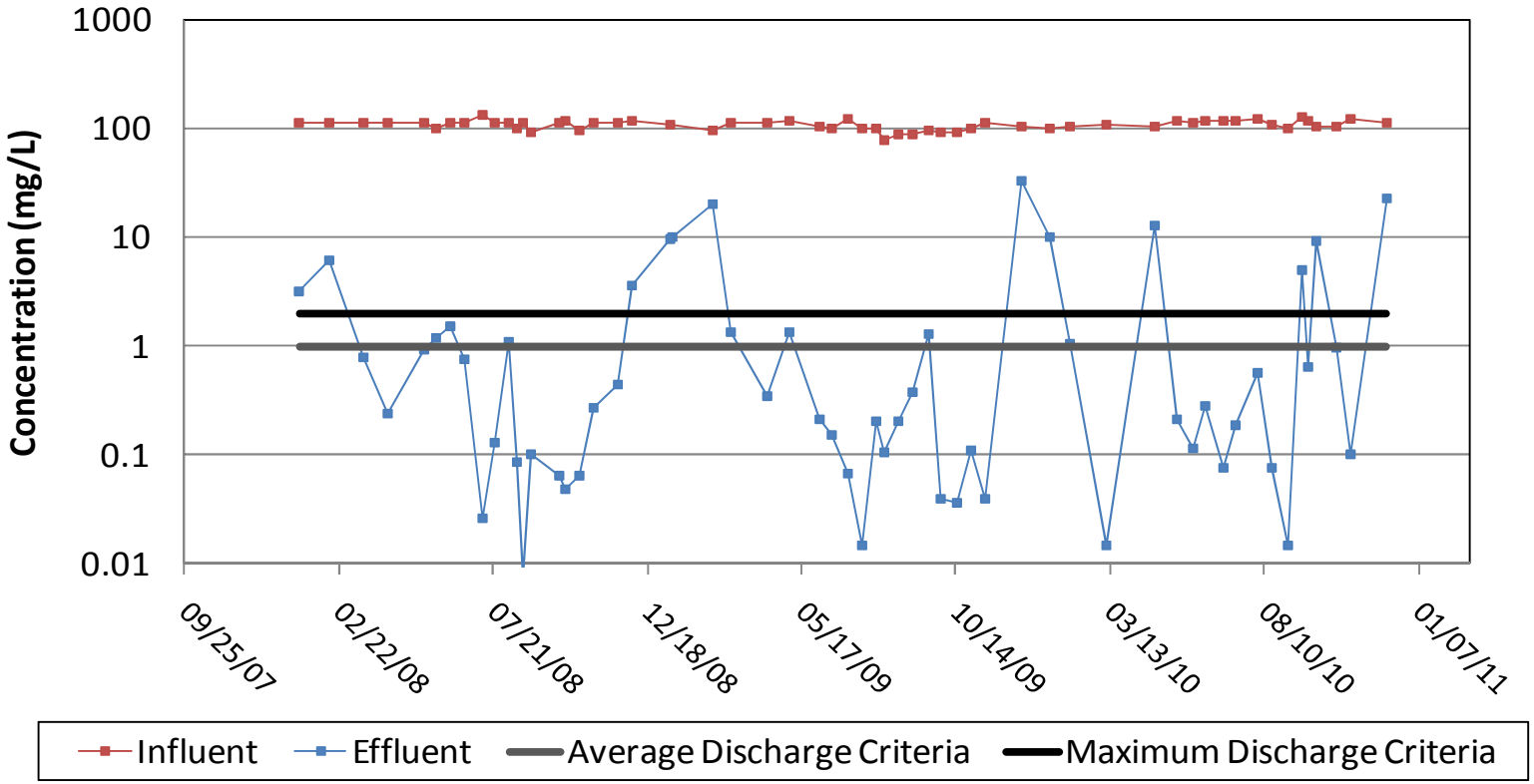
Dissolved Iron Concentrations– System Perturbations



Dissolved Iron Concentrations

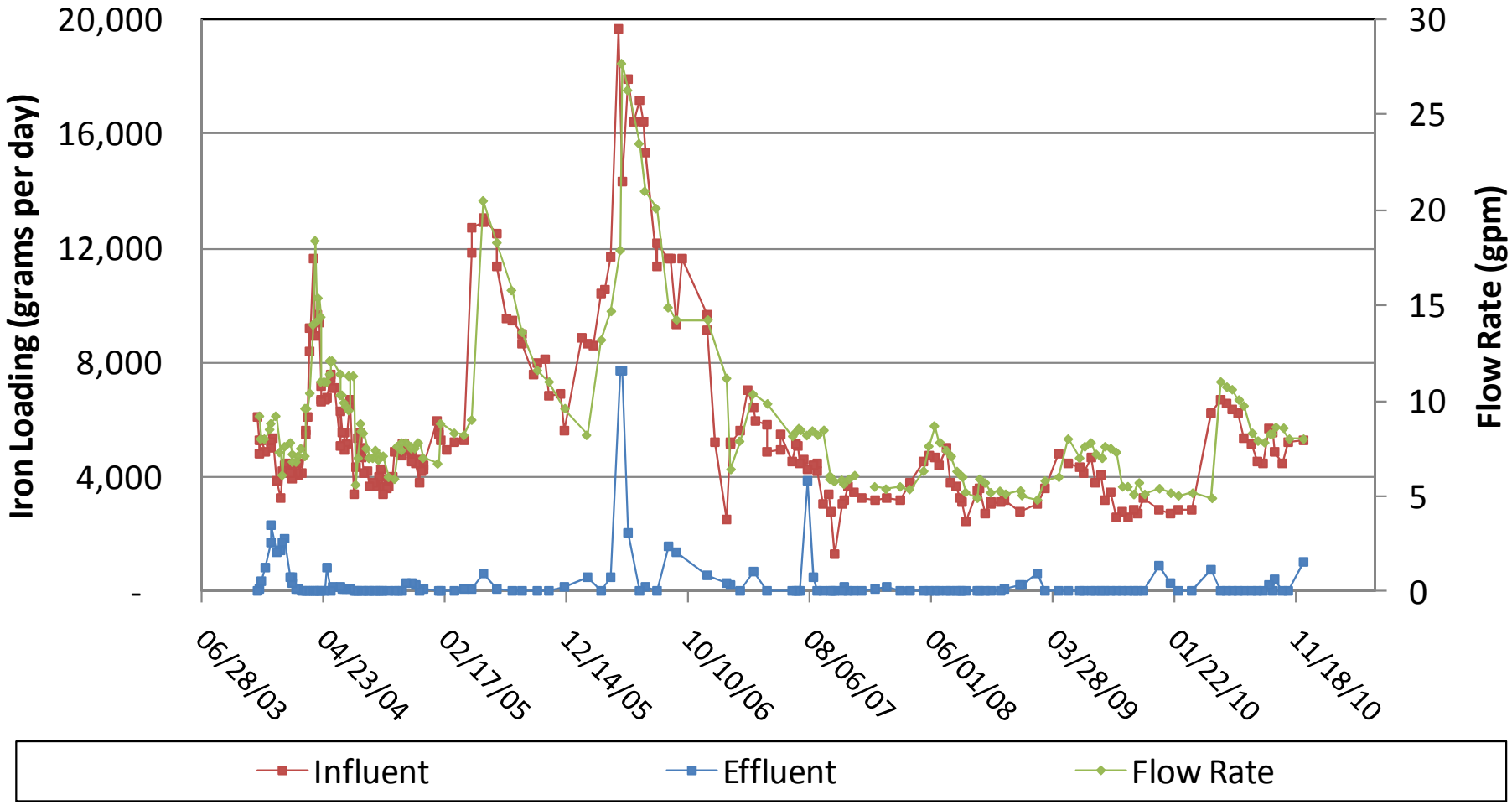


Dissolved Iron Concentrations



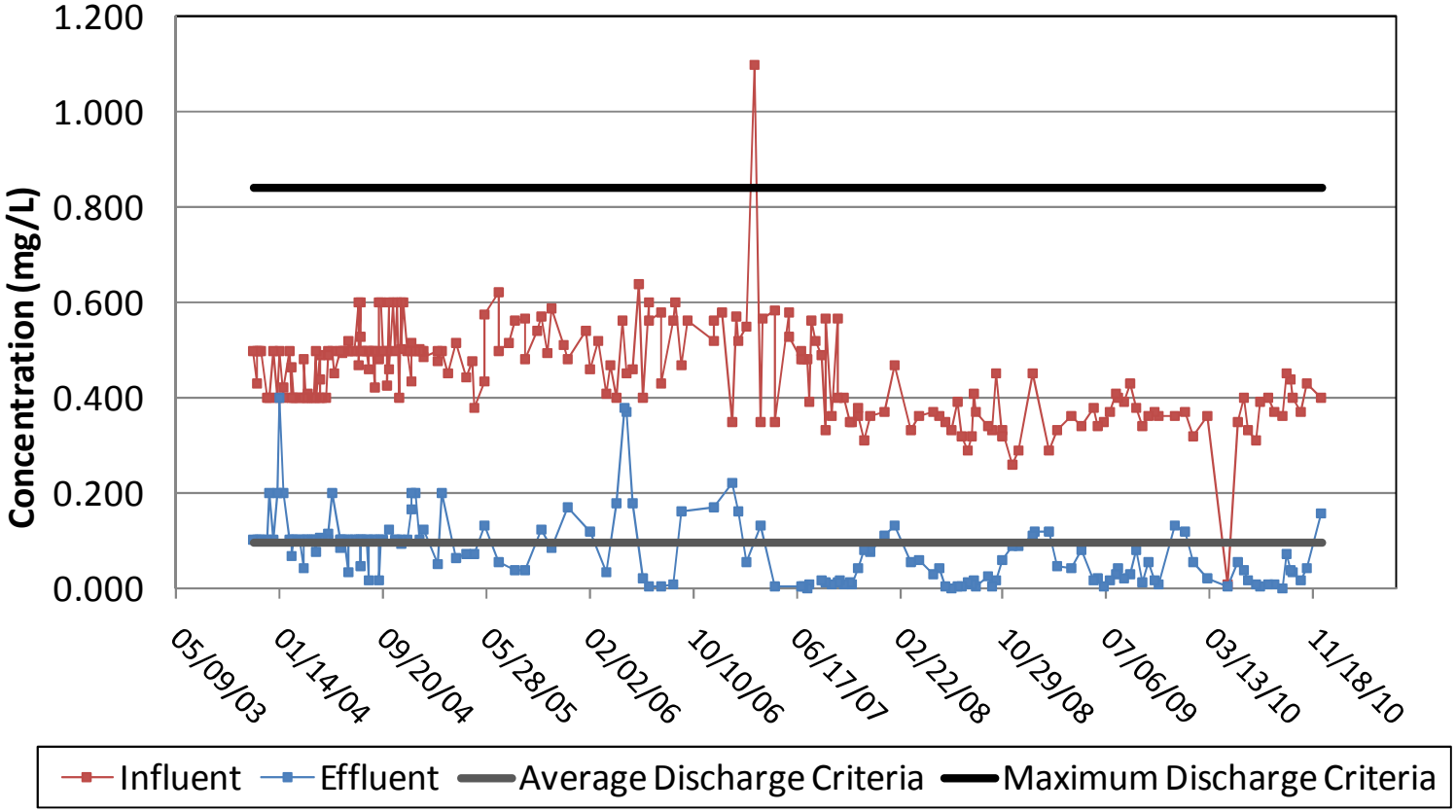
- January – exceedance following December NaOH pump failure (~2 weeks of pump downtime)
- February – exceedance following 0.6 inches of rain
- April – exceedance following 1 inch rain storm, snowmelt, and flow rate increase from 5 to 12 gpm
- September – exceedance during sludge dewatering
- December – exceedance following inverter failure

Iron Loading



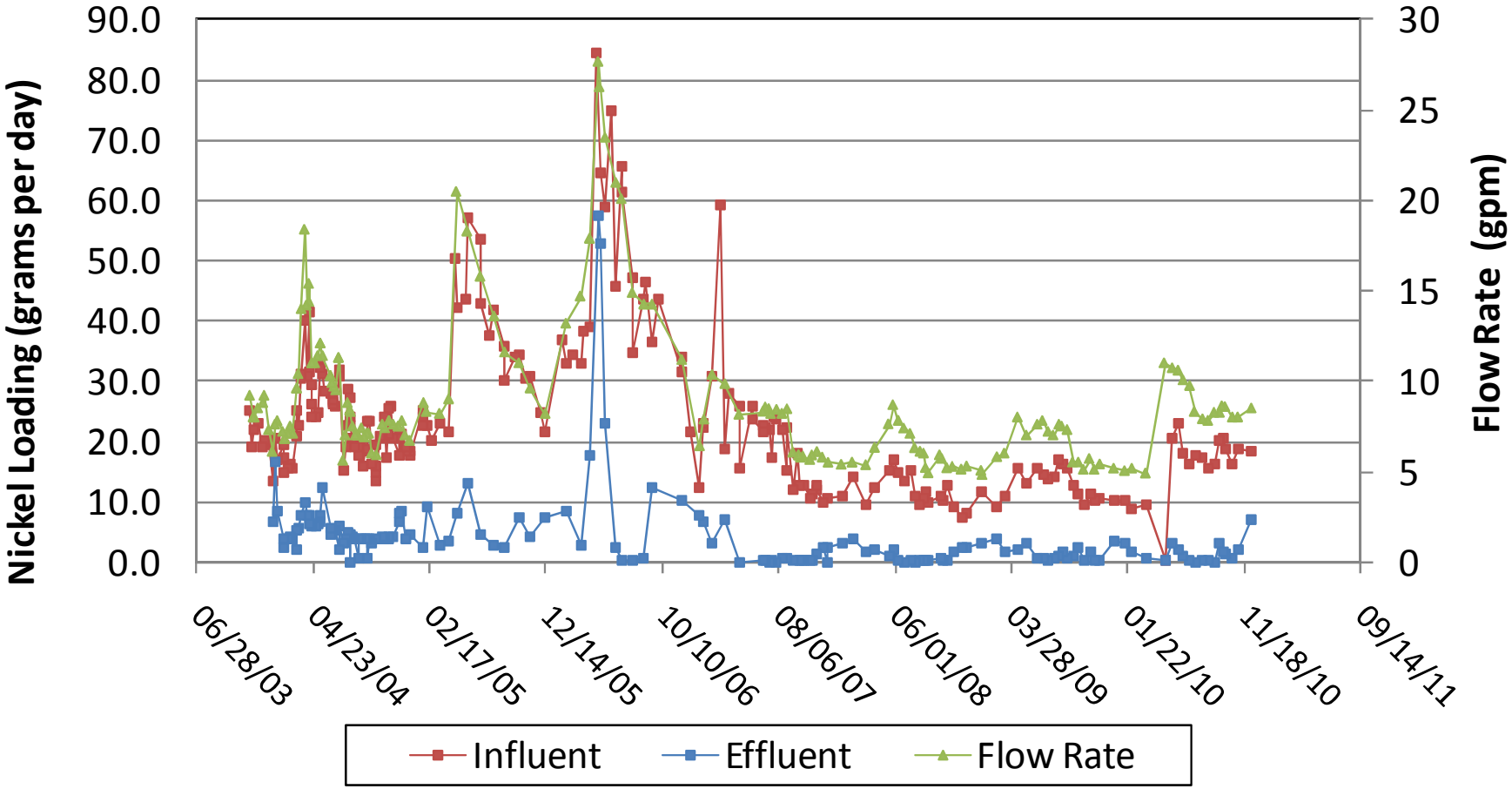
- Loading generally tracks influent flow
- 2010: Removed approximately 4,200 pounds of iron

Nickel Concentrations



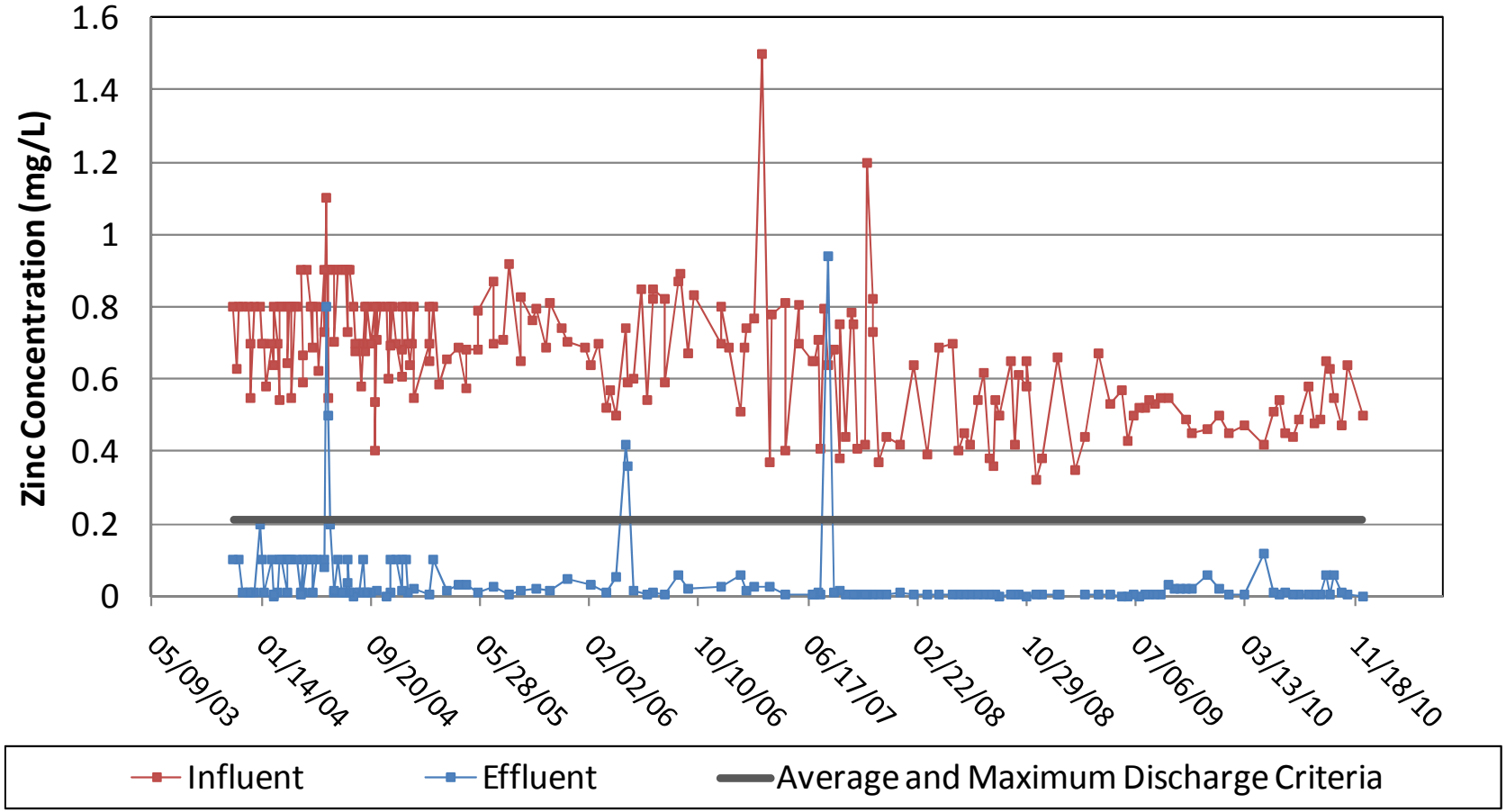
- January – exceedance following December NaOH pump failure (~2 weeks of pump downtime)
- February – exceedance following 0.6 inches of rain
- December – exceedance following inverter failure

Nickel Loading

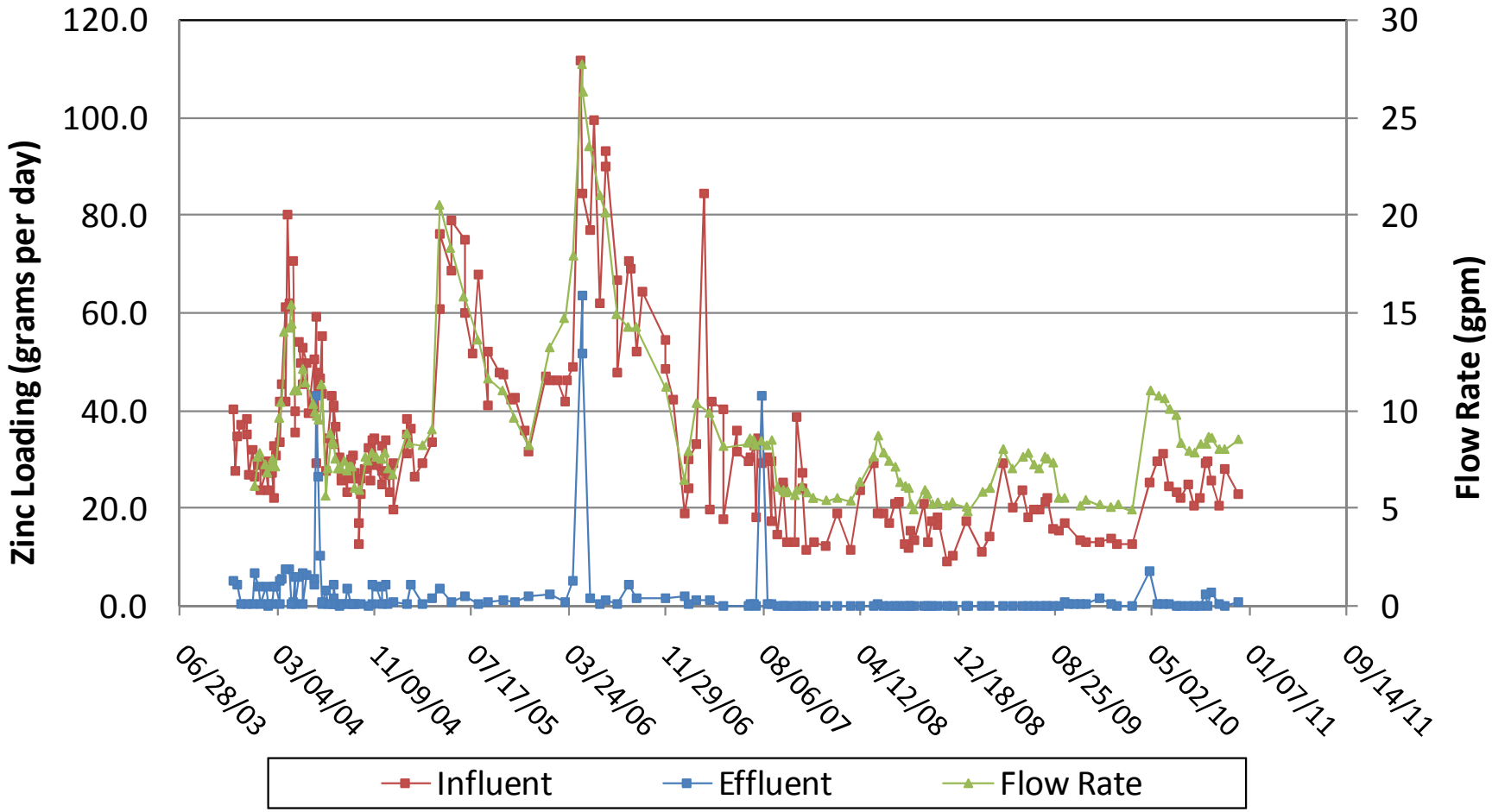


- 2010: Removed approximately 13 pounds of nickel

Zinc Concentrations

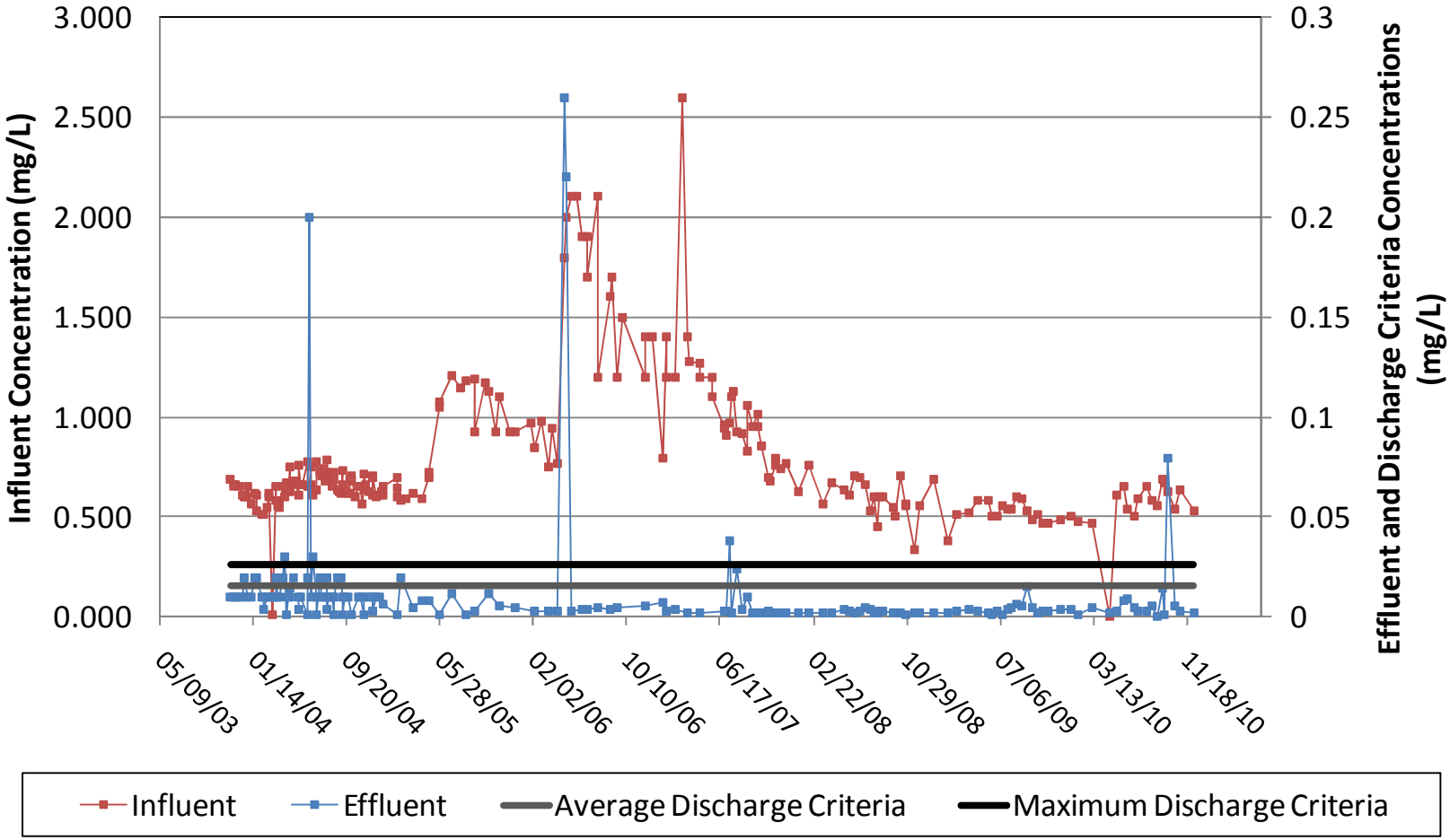


Zinc Loading



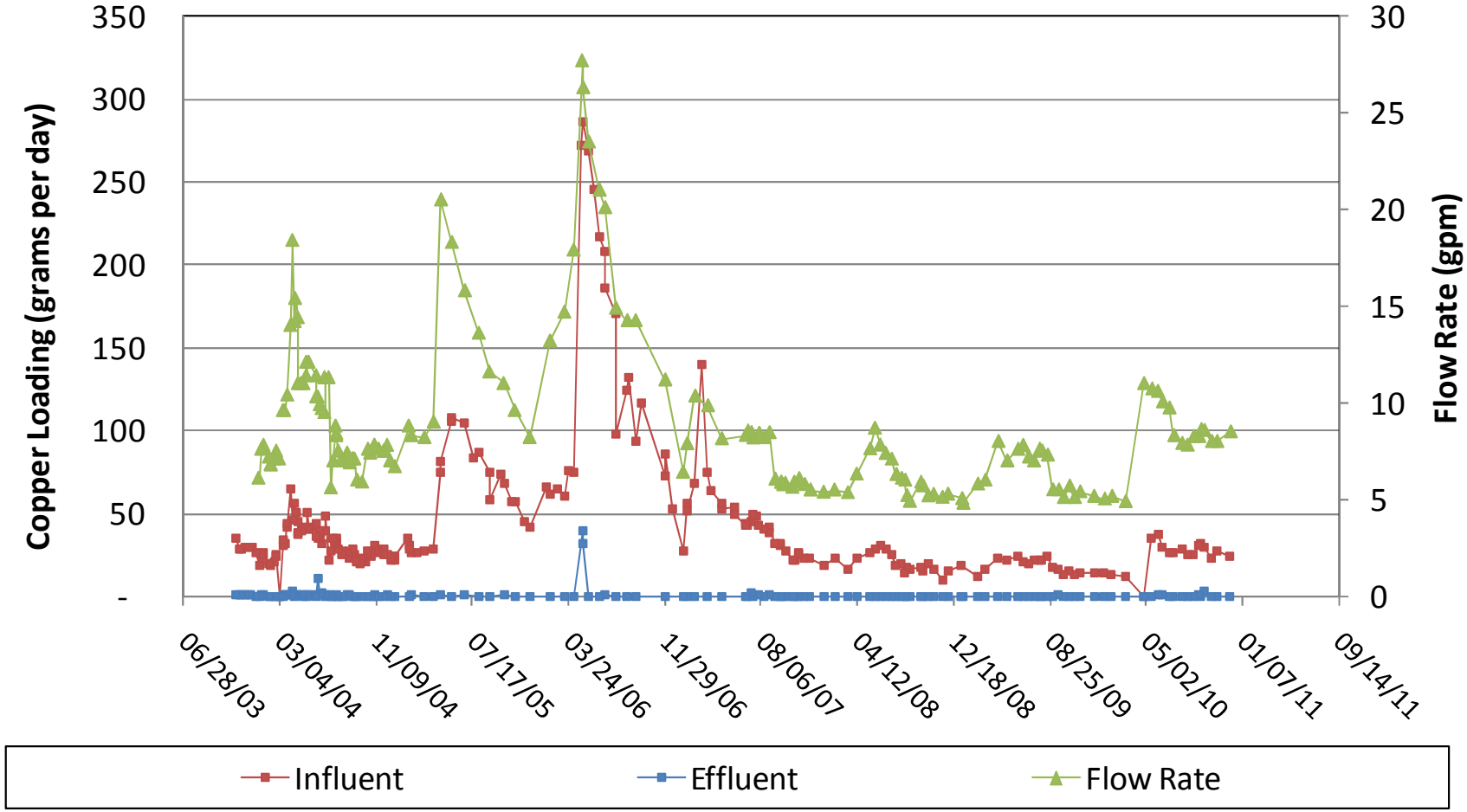
- 2010: Removed approximately 18 pounds of zinc

Copper Concentrations



- September – exceedance during Sludge dewatering

Copper Loading



- 2010: Removed approximately 21 pounds of copper

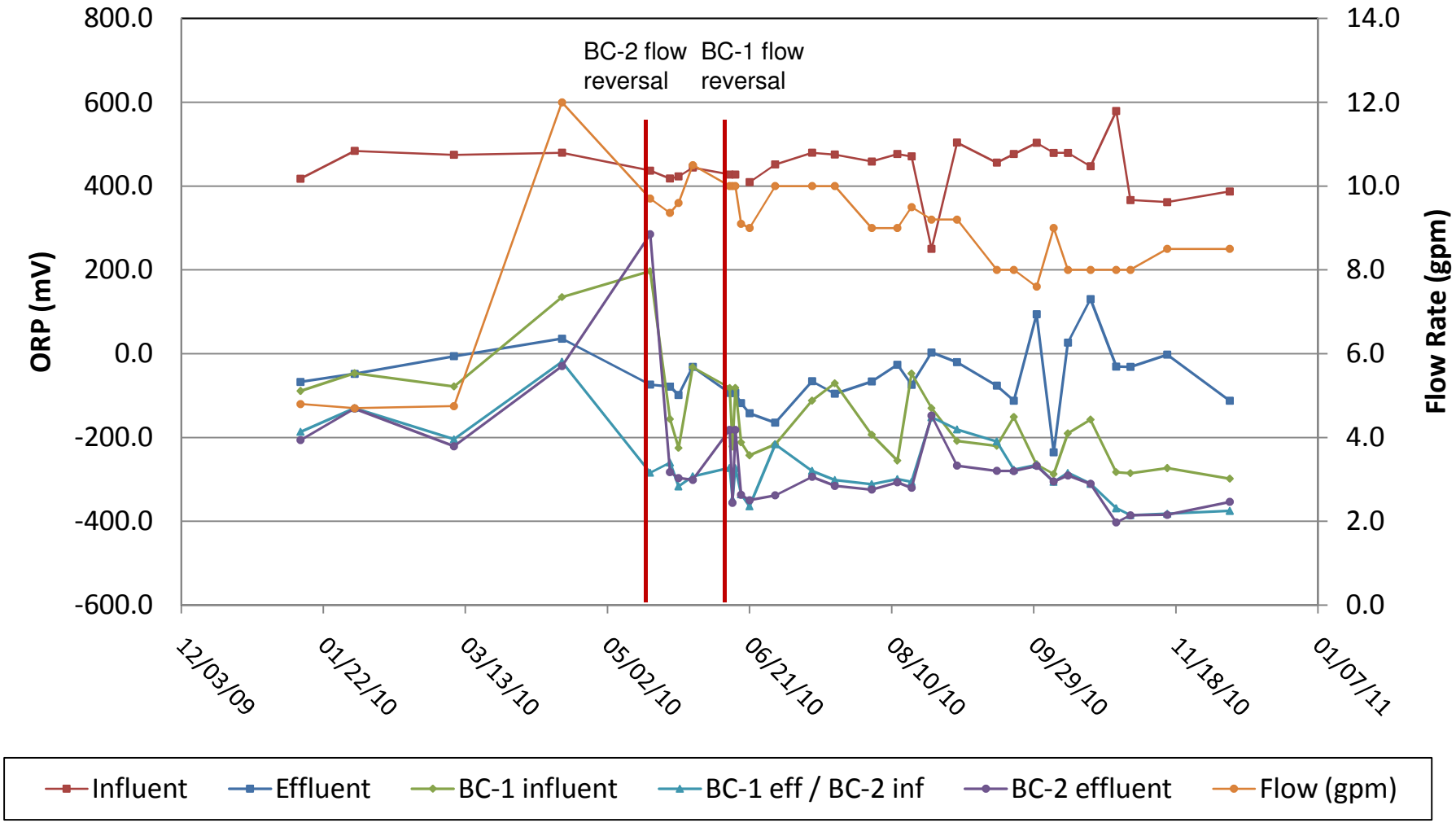
2010 – Optimization

- Bioreactor Flow Reversal

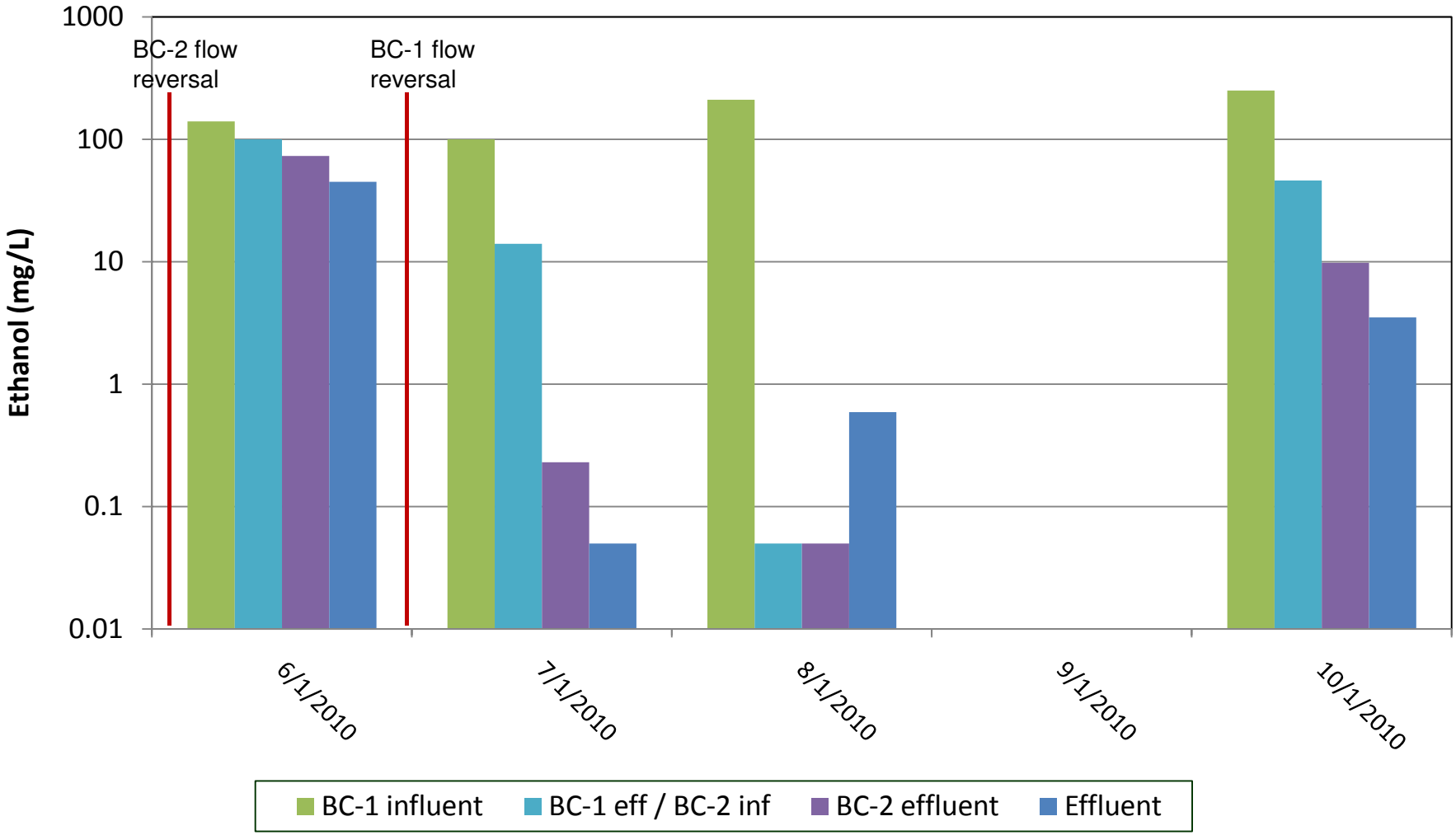
- Enhanced sampling analytes:
  - Sulfate
  - Sulfide
  - Ammonia
  - Phosphorus
  - Dissolved organic carbon
  - New analytes for 2010: ethanol & acetate

- Evaluate indicators of biological activity and further optimization of nutrient addition
  - Ethanol/acetate/DOC concentrations indicate ethanol oxidizes to acetate and no further
  - Effluent DOC has decreased more than 50% since 2008, while treatment system remains effective
  - Phosphorus and nitrogen concentrations remain low

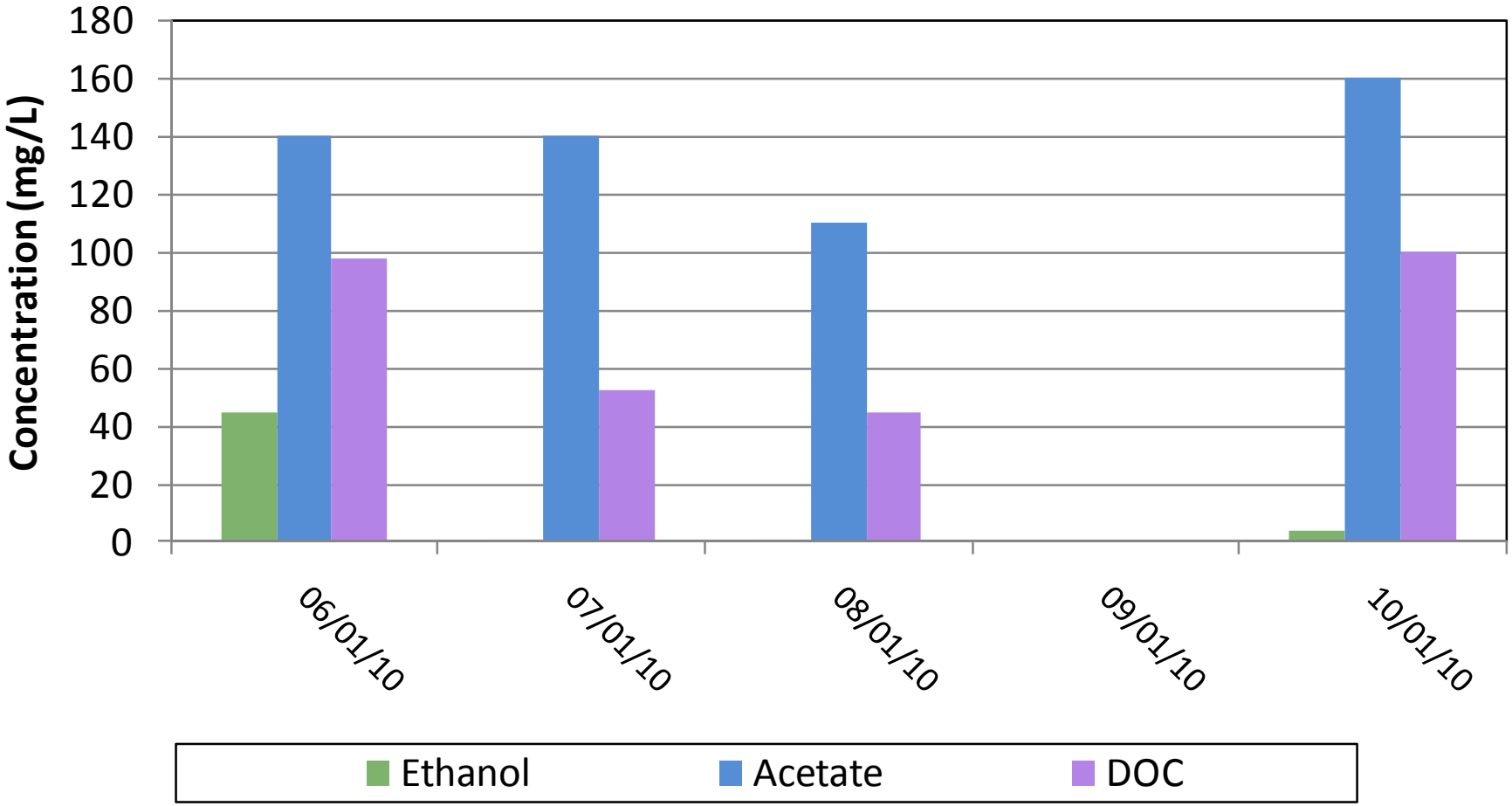
Bioreactor Flow Reversal - ORP



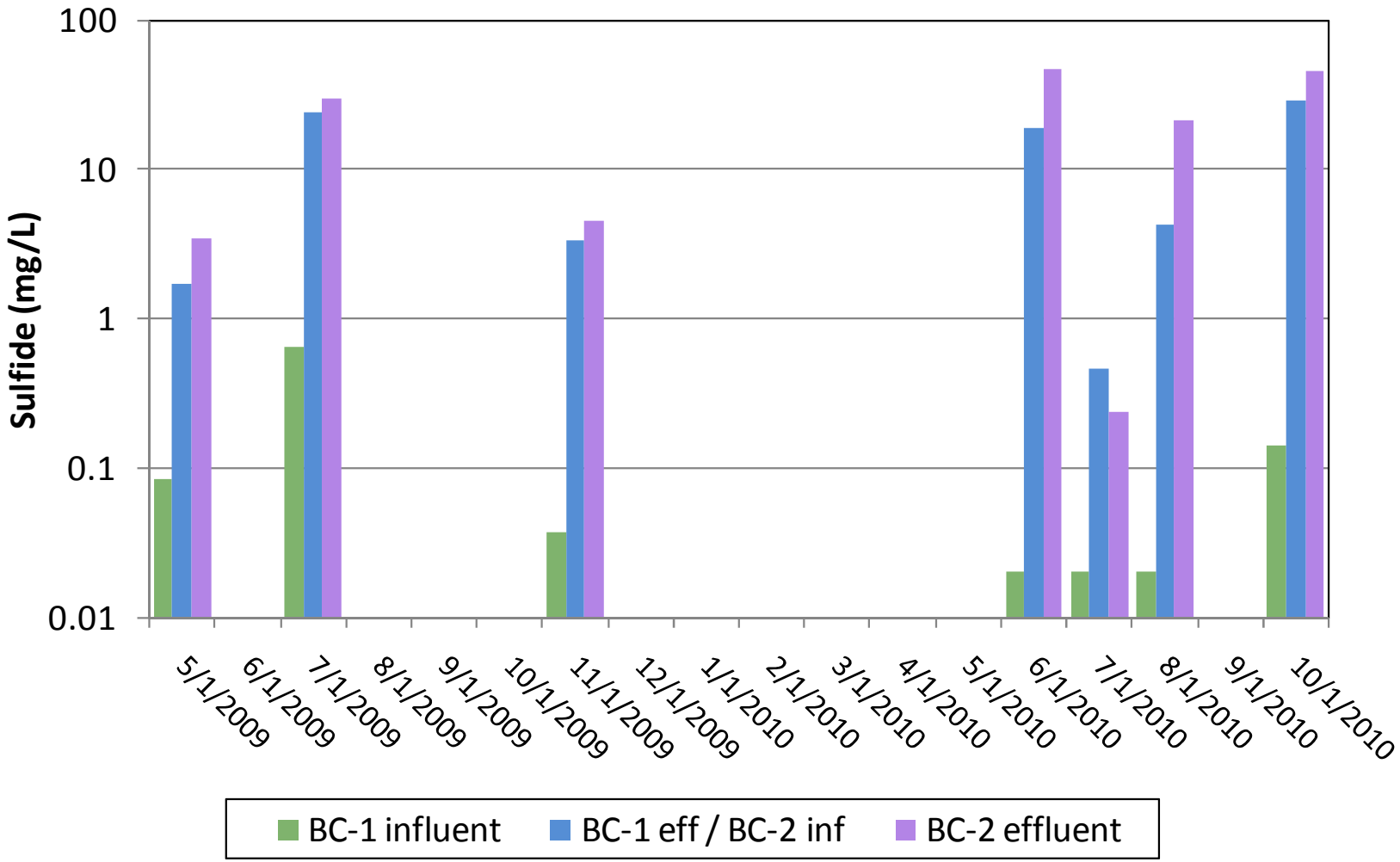
Ethanol Utilization



Effluent Substrate Concentrations



Biocell Sulfide Concentrations



Phosphorus and Nitrogen Utilization

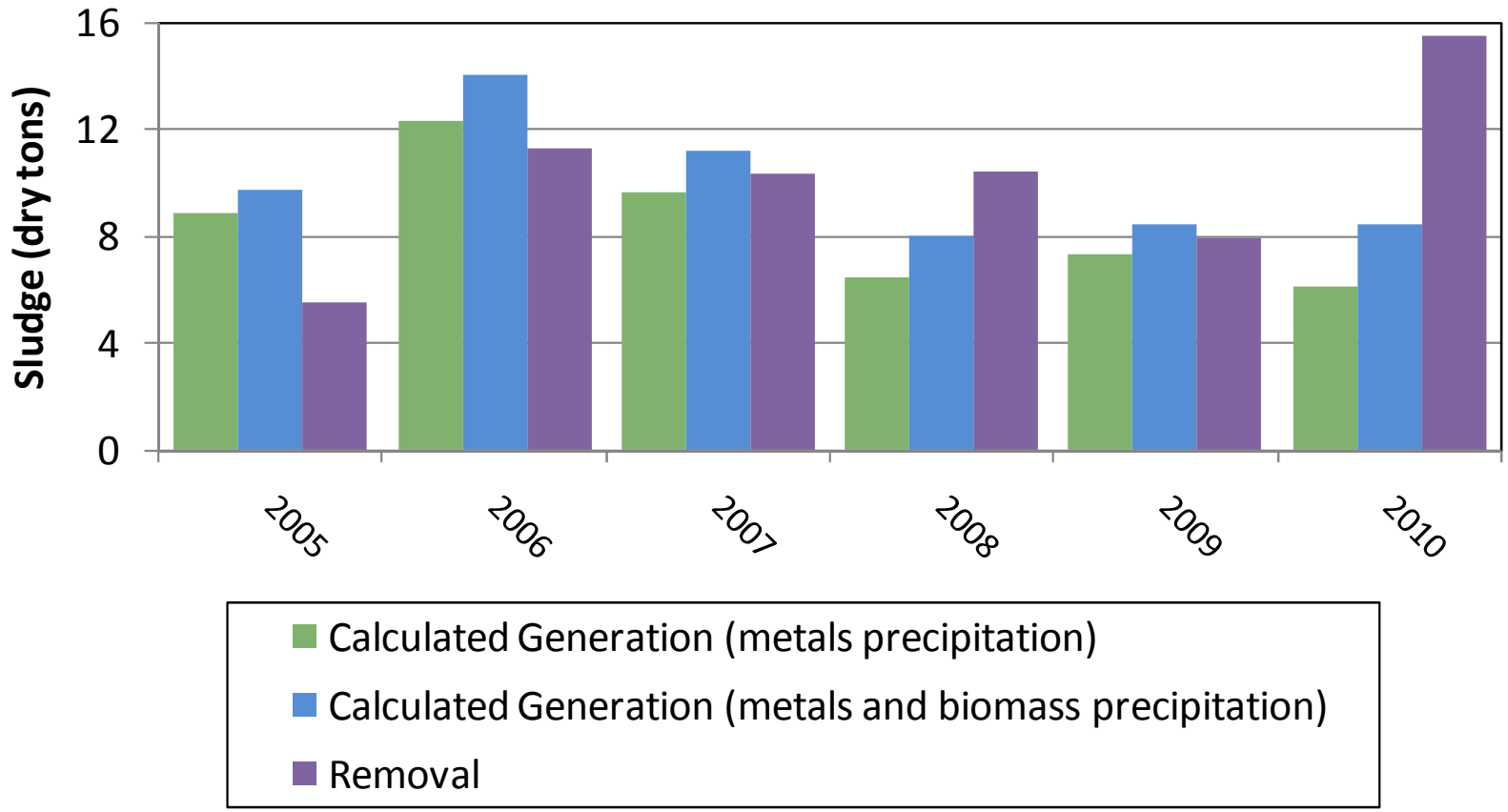
- 2009:
  - Started monthly addition of mono-sodium phosphate addition (with urea addition) in November
- 2010:
  - Phosphorus was not detected in enhanced samples
  - Nitrate/nitrite are not detected in enhanced samples
  - Ammonia detected in the biocells at a median concentration of 0.1 mg/L
- 2011:
  - Propose change in phosphate source to tri-sodium phosphate (TSP). TSP is more affordable with better availability.
  - Consider phosphorus dose increase
  - Maintain urea dose rate

2010 – ASB Sludge Management

- Biocell Flushing
  - Flushed Biocells 1 & 2 and biocell feed lines
  - Work included focused flush technique using a nozzle

- Sludge Removal
- Sludge Dewatering by Centrifuge
- Completion of Sludge Drying Bed Treatability Study

Estimated Historic Sludge Generation and Removal



2005-2010:

- Total calculated sludge generated (with biomass) – 60-62 dry tons
- Total calculated sludge removed – 61 dry tons

Sludge Drying Bed (SDB) Treatability Study

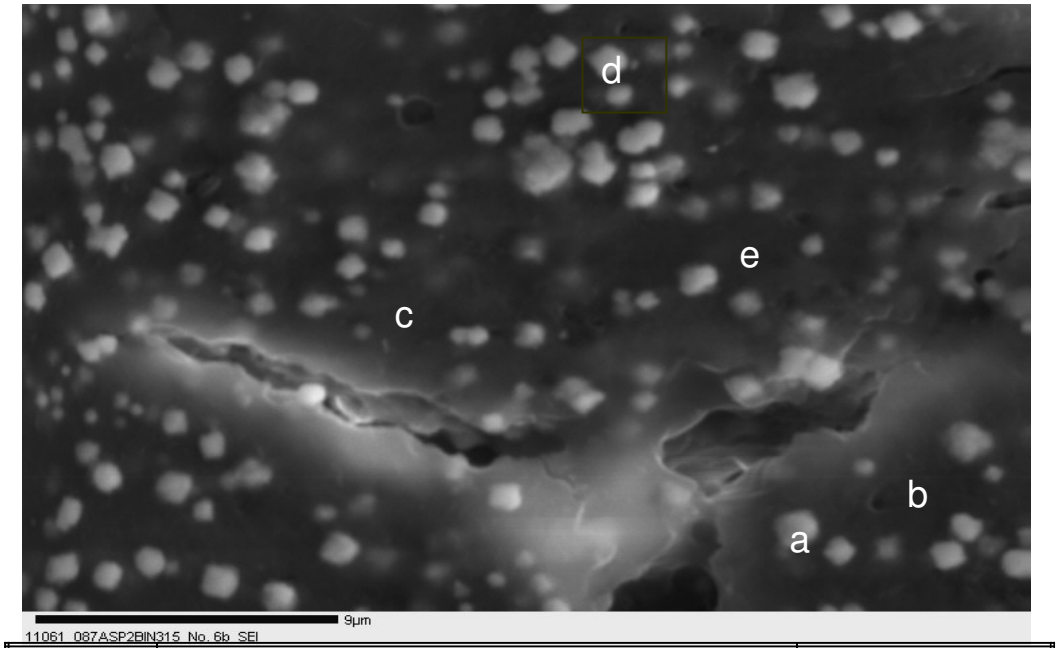
- Sludge previously dewatered by belt press (2007 & 2008) and centrifuge (2009 & 2010)
- Treatability study designed to:
  - Evaluate the effectiveness and potential cost savings of passive drying bed technology
  - Characterize and evaluate long term stability of sludge
- Two tests
  - Trial 1: evaporation, filtration & decanting
  - Trial 2: evaporation
  - Analyzed sludge and filtrate throughout study
- Study duration: October 26, 2009 through July 20, 2010

SDB Results – Sludge Analytical Summary

Parameter	Date	% Solids (weight basis)	TOC (as %)	Paste pH
Bulk Sludge	10/26/2009	5.5	6.2	7.9
Trial 1	10/26/2009	5.4	6.9	7.9
	11/17 & 11/19/09	20.8	---	7.9
	6/8/2010	35	3.3	6.7
	6/22/2010	32	8	6.6
Trial 2	10/26/2009	5.6	7.4	7.9
	11/17 & 11/19/09	7.2	---	8.0
	6/8/2010	26	5.6	7.8
	7/20/2010	97.3	10	7.1
	7/20/2010- duplicate	97.9	9.5	7.2

- Dewatering by centrifuge yields sludge with 17-20% solids

Sludge Characterization



	---------- Weight % ----------					Atom Ratio
Location	Fe	Ca	Al	Si	S	S / Fe
a	39		2.1	0.7	44	1.99
b	10.6	0.8	12.4	4.2	10.5	1.73
c	5	0.9	12.8	5.3	4	1.37
d	35	0.3	3.9	1.4	37	1.89
e	11.2	0.7	9.7	3.8	12.3	1.92

- Acid-Base Accounting results:
  - Acid-base potential: -218 and -305 t CaCO3/Kt for Trials 1 and 2, respectively
  - Sulfur pyritic sulfide: 6.51 and 5.9 % for Trials 1 and 2, respectively

Sludge Waste Characterization

- Sludge waste characterization testing included:
  - Total metals
  - STLC
  - TCLP
  - SPLP
  - DI-WET
- Sludge was characterized as non-hazardous waste (samples collected on April 26 & June 22)
- ABA and leachate results indicate that sludge management is critical

SDB Results – Filtrate Analytical Summary

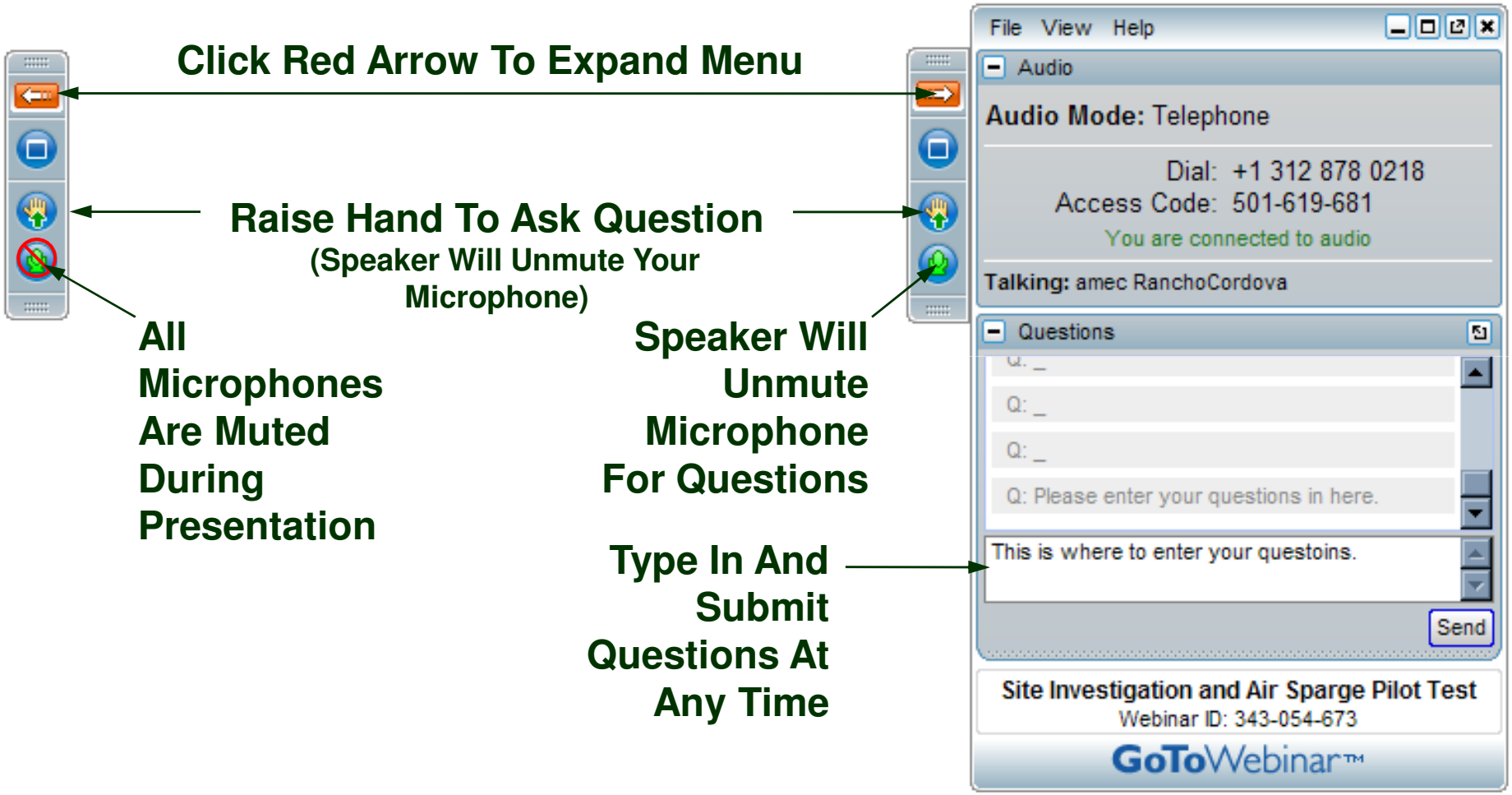
Parameter	Basis	Average Concentration (October 28 - November 19, 2009) (mg/L)	Average Concentration (February 2 - June 22, 2010) (mg/L)	ASB Discharge Criteria	
				Maximum Discharge Criteria (mg/L)	Average Discharge Criteria (mg/L)
pH[1]	Field	8.4	**3.2**	---	6.0 - 9.0 [2]
Al	Dissolved	0.025	**18.8**	4	2
Cd	Dissolved	0.0001	**0.004**	0.009	0.004
Cu	Dissolved	0.004	**0.1**	0.026	0.016
Fe	Dissolved	0.0167	**14.6**	2	1
Pb	Dissolved	0.0002	**0.006**	0.136	0.005
Ni	Dissolved	0.0	**0.4**	0.84	0.094
Zn	Dissolved	0.00	**0.6**	0.21	0.21
Se	Total	0.002	0.003	NP	0.005

- For Trial 1, filtrate pH declined and metals concentrations increased during the second half of the test

SDB – Results and Conclusions

- Sludge material:
  - Is acid-generating and contains pyrite likely formed in the treatment system
  - Trial 1 dewatered sludge to 79% moisture in 24 days
  - Achieves classification as a non-hazardous waste
- Trial 1 filtrate:
  - Found to be acidic during the second half of the study
  - Exceeded discharge criteria for several metals during the second half of the study
  - Could potentially be captured by the treatment system
- Topics for future evaluation:
  - ASB area is located in the Leviathan Creek Basin landslide; further construction is not desirable at this location
  - Location will effect feasibility (sludge and filtrate handling) and cost analysis
  - Sludge handling timing issues

Questions?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Raise Hand To Ask Question
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