

**CH2MHILL**

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# **Results of a Pilot Fluidized Bed Reactor Selenium Treatment Demonstration**

***17<sup>th</sup> Annual British Columbia/ Canadian Mine  
Environment Neutral Drainage Program  
(MEND) Mining Leaching/Acid Rock Drainage  
Workshop***

December 2, 2010

Vancouver, British Columbia

**By Tom Sandy/CH2M HILL**

# Agenda

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- **Background**
- **Technology Overview**
- **Pilot Test Objectives**
- **Pilot Unit Design Configuration**
- **Key Design Criteria**
- **Water Quality**
- **Results**
- **Conclusions**

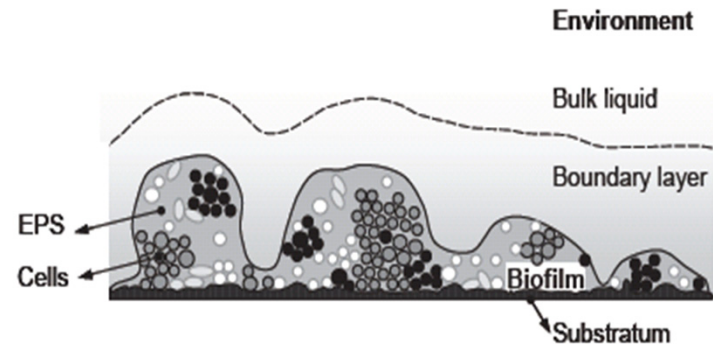
# Background

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- **Eastern US Appalachian mountain surface coal mine**
- **Compliance at 3 Outfalls of 4.7 µg/L average month 8.2 µg/L daily max**
- **One of many end of pipe treatment technologies evaluated**
  - ABMet®
  - Zero Valent Iron
  - Reverse Osmosis
  - VSEP®
- **Considered in conjunction with other in mine management alternatives**
- **Watershed hydrology and ecotoxicology studies**

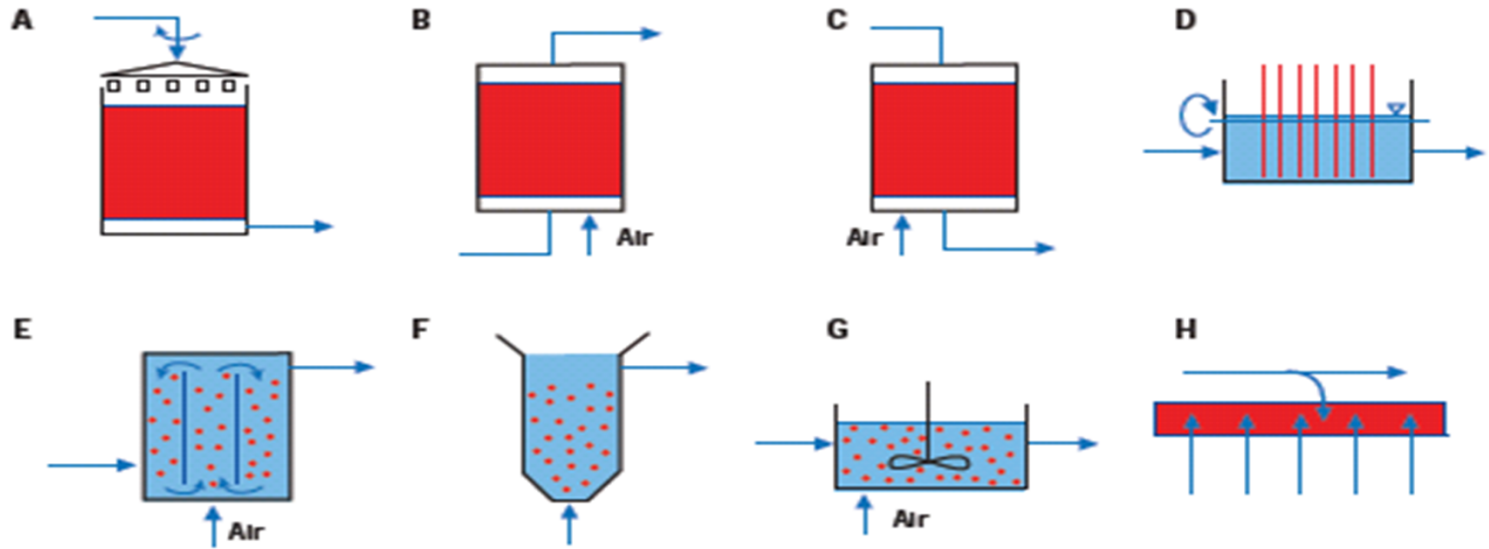
# Fluidized Bed Reactor (FBR) Technology Overview

- **Attached growth biological treatment**
- **Heterotrophic anaerobic biogrowth**
- **Configuration provides efficient mass transfer**
- **Continuous liquid solid separation**
- **Relatively Simple**



- **Uses sand, activated carbon or other solid media with similar characteristics**
- **Small footprint**
- **Lower capital cost**

# One of Many Attached Growth Reactors...But One of the More Efficient



**A) Trickling Filter**

**B) Upflow Draft**

**C) Downflow Draft**

**D) Rotating Biological  
Contactor**

**E) Suspended Biofilm**

**F) Fluidized Bed**

**G) Moving Bed**

**H) Membrane Attached  
Biofilm**

# Pilot Testing Overview

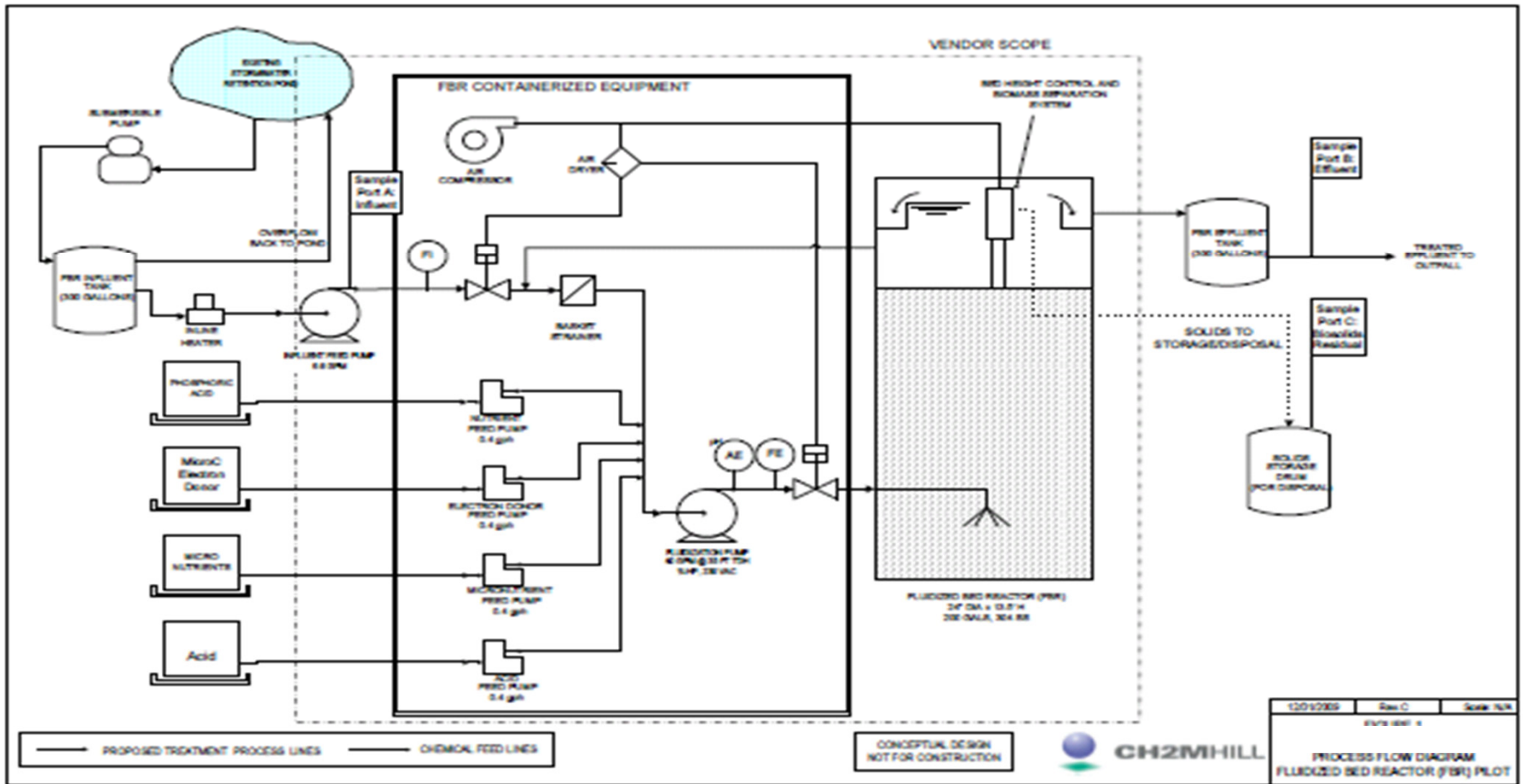
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- **Easily accessible outfall with similar water characteristics**
- **Proof of concept-16 weeks mid-February 2010 to end of May 2010**
- **Design testing-24 weeks mid-September 2010 to mid February 2011**
- **Parallel flow and water quality basis of design development during design testing both on-going.**

# General Influent Water Quality

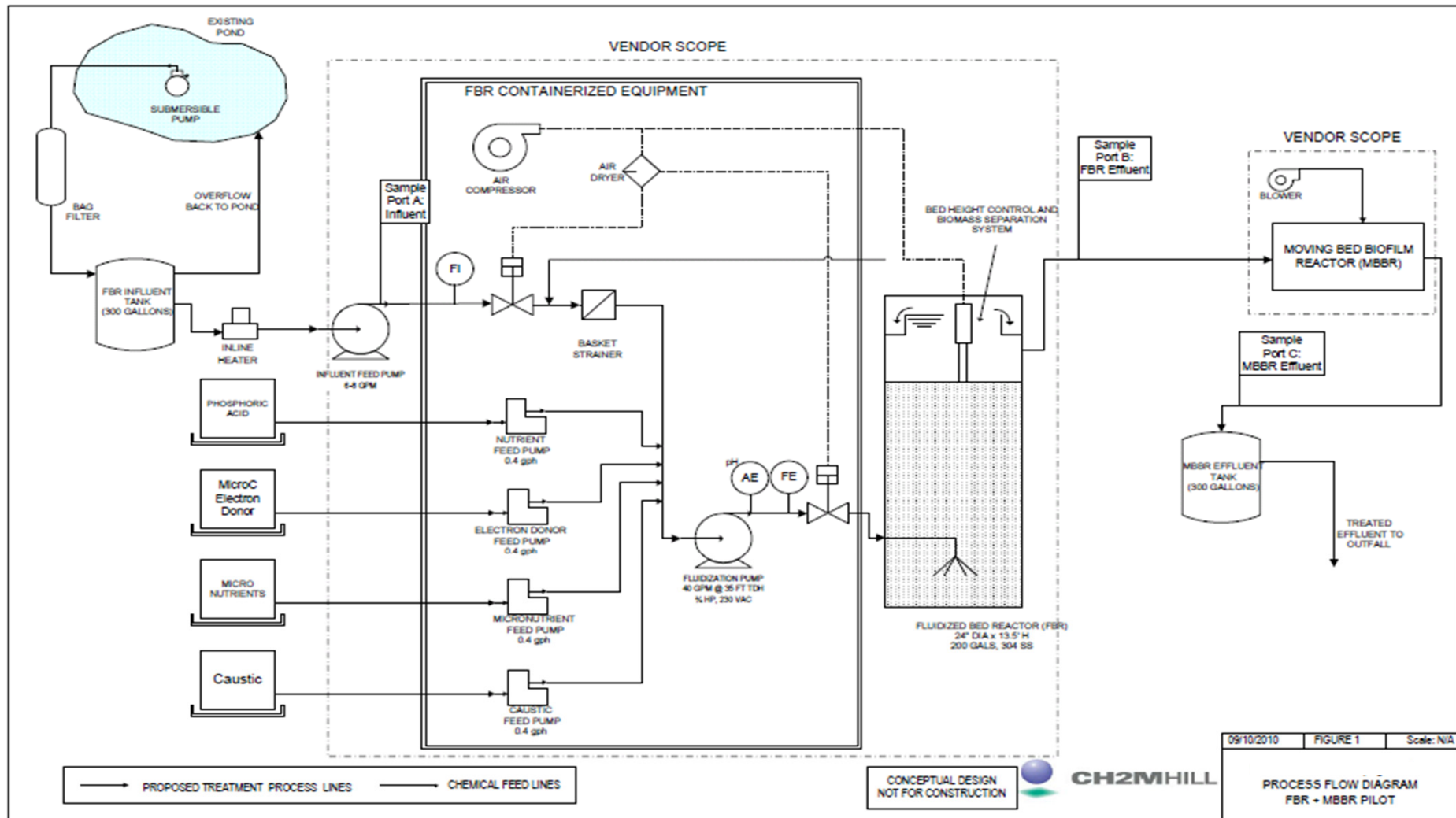
Parameter	Unit	Average	Std Dev.
TSS	mg/L	7	5
TDS	mg/L	2902	311
Total Solids	mg/L	2909	315
COD	mg/L	8.8	5
TOC	mg/L	2.6	1
Sodium	mg/L	14.7	0
Chloride	mg/L	9.5	0
Ammonia	mg/L	0.22	0
Sulfate	mg/L	1902	47
Strontium	mg/L	1.41	0
Total Phosphate	mg/L	0.96	0
Manganese	mg/L	0.03	0
Alkalinity	mg/L	278	8
Carbonate	mg/L	0	0
Bicarbonate	mg/L	290	14
Turbidity	ntu	11.28	12
Nitrate	mg/L	9.52	0
Calcium	mg/L	302	8
Magnesium	mg/L	377	10
Potassium	mg/L	29.9	2
Silica	mg/L	1.56	1
Hardness	mg/L	2169	35
Cyanide	mg/L	0.014	0
Orthophosphate	mg/L	<0.01	0
CBOD	mg/L	<1.0	0
Barium	mg/L	<0.10	0
Boron	mg/L	0.12	0
Fluoride	mg/L	0.17	0
TKN	mg/L	<0.10	0

# Proof of Concept Pilot Testing Setup & Configuration





# Design Pilot Testing Configuration



# Envirogen Pilot FBR



Pilot Exterior



Pilot Interior

# Pilot FBR



# Pilot FBR Configuration

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- **61 cm (2 ft) diameter by 4.3 m (14 ft) high stainless steel reactor**
- **38 lpm (10 gpm) and 151 lpm (40 gpm) maximum recycle flowrate**
- **Support equipment in 2.4 m (8 ft) by 3 m (10 ft) Conex Box**
- **163 Kg (360 lbs) of granular activated carbon (GAC) or 60% of active reactor volume**
- **Fluidized bed height 2 to 3 m (8 to 9.5 ft)**

# Pilot FBR Operation-Proof of Concept

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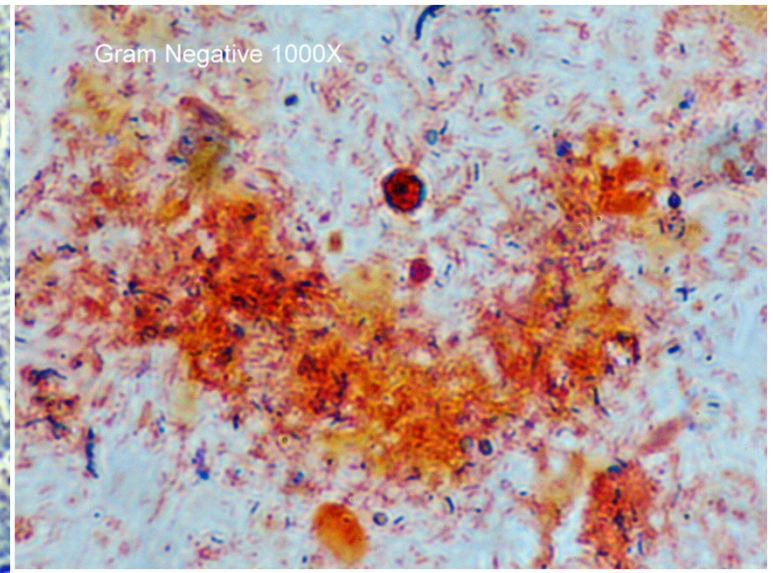
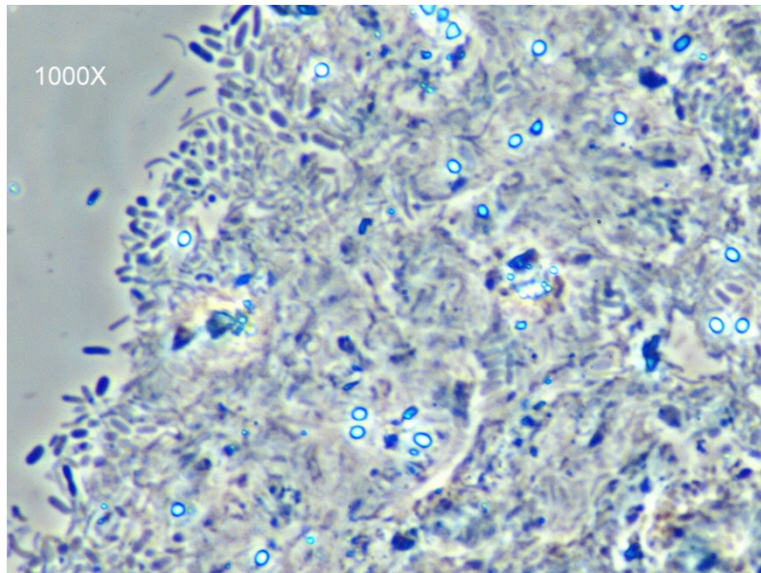
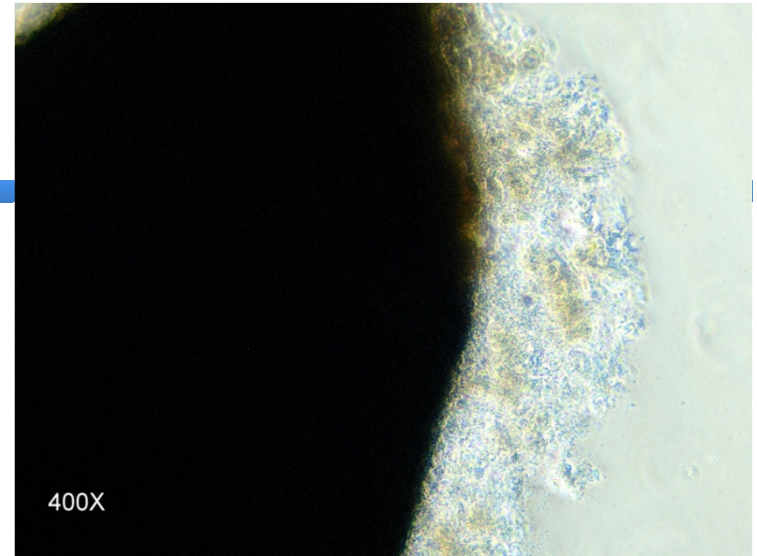
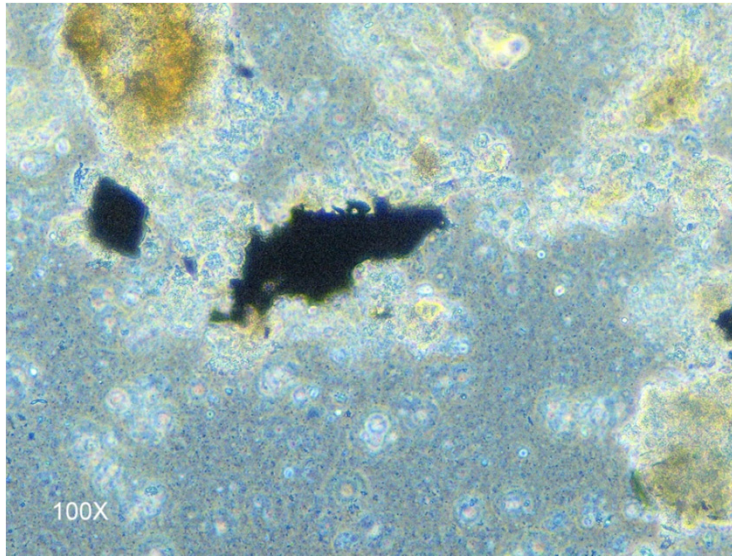
- **MicroCg carbon substrate feed**
- **Phosphoric acid, ammonium sulfate and micronutrients added**
- **30 lpm (8 gpm) forward feed**
- **132-151 lpm (35-40 gpm) recycle flowrate**
- **>3:1 recycle rate required for proper bed fluidization**
- **Hydraulic residence time (HRT) at 30 lpm (8 gpm) is approximately 28 minute in**

# Pilot FBR Monitoring

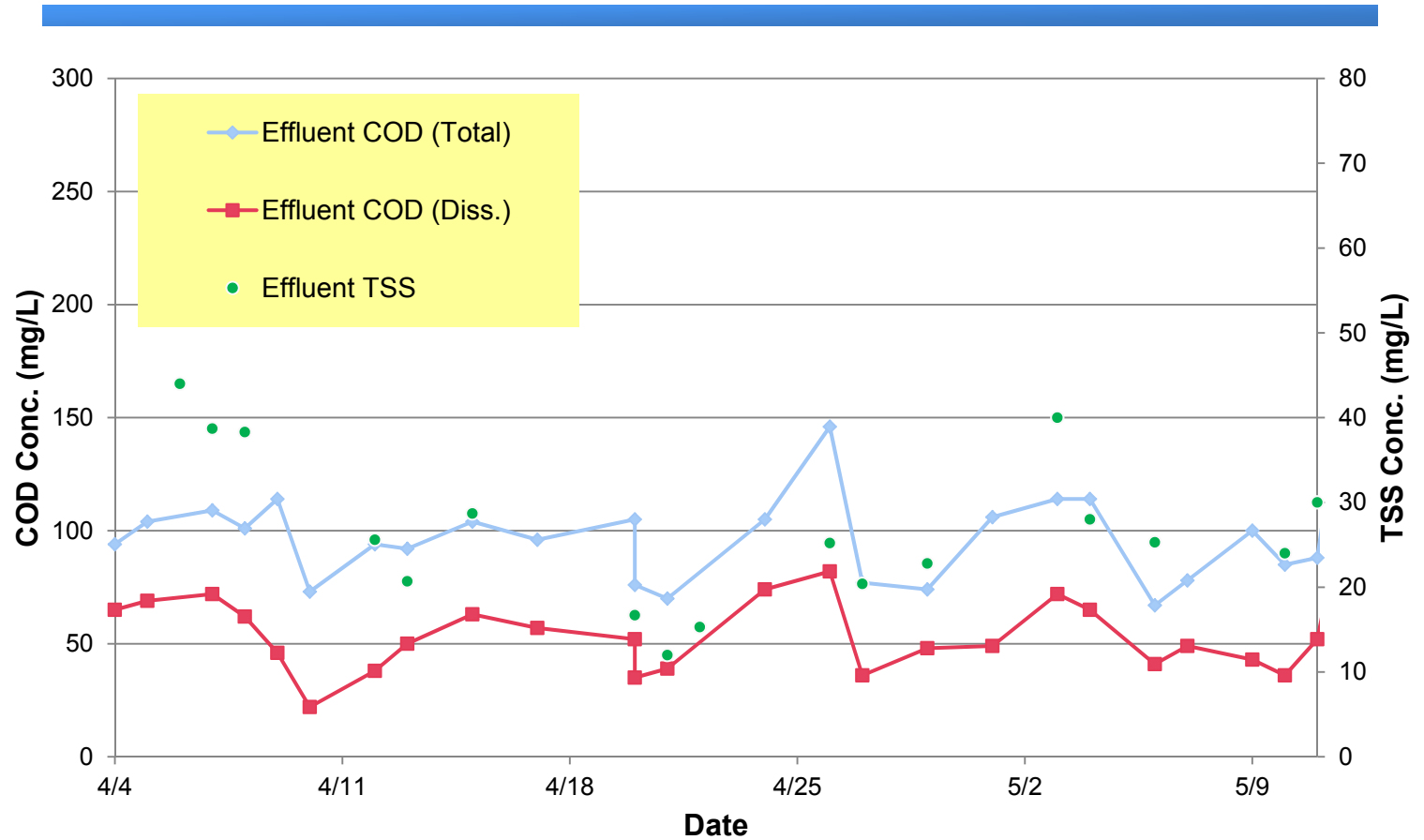
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- **Monitored a variety of parameters in influent and effluent**
  - pH, temperature, ORP, TSS, VSS, TDS, DO, COD, BOD, nitrate, sulfate, sulfide, phosphate, calcium, magnesium, selenium forms, micro exams,
- **Conducted Toxicity Characteristic Leach Procedure (TCLP) testing on solids in proof of concept**

# Microscopic Examination

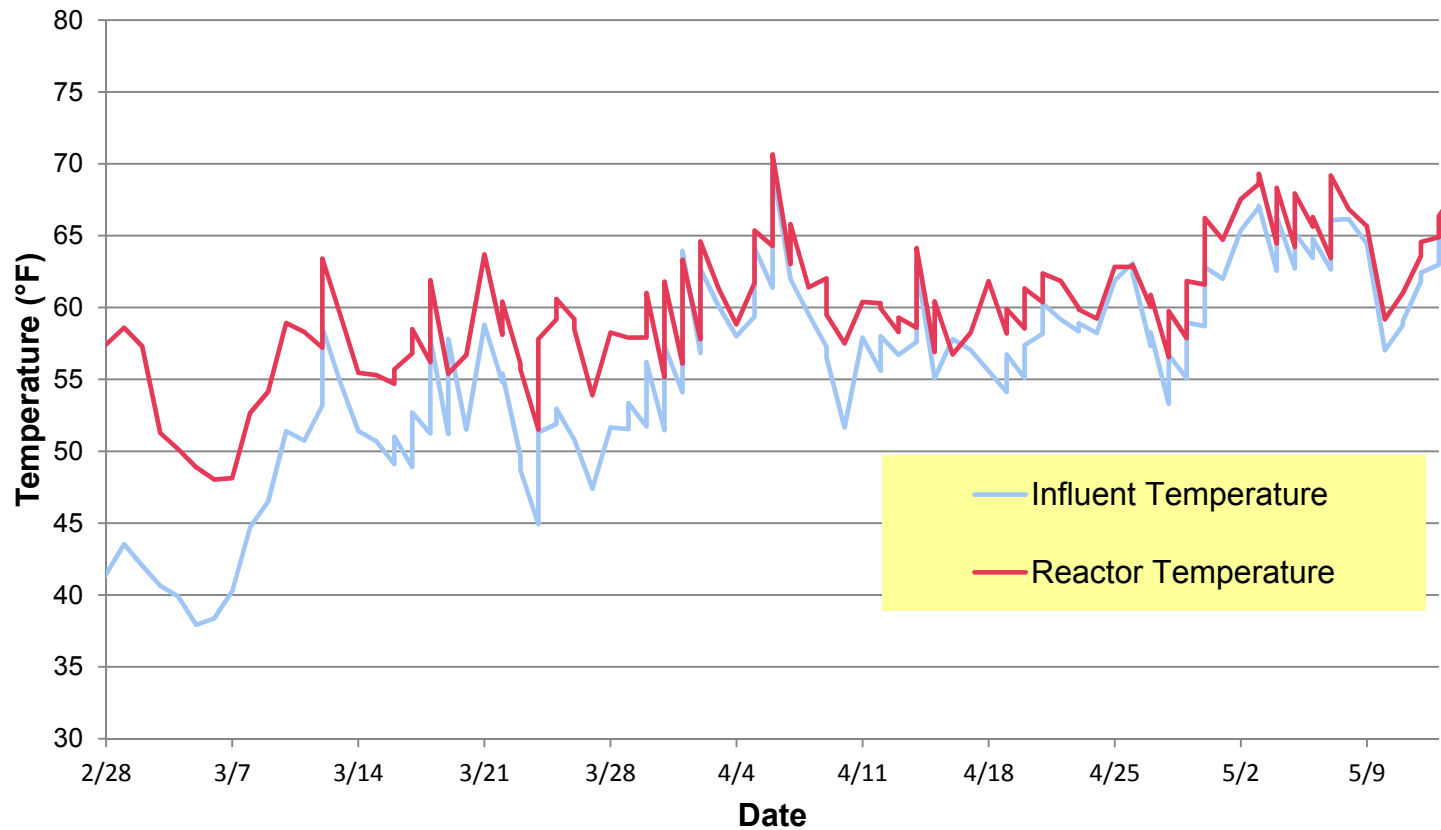


# Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS)

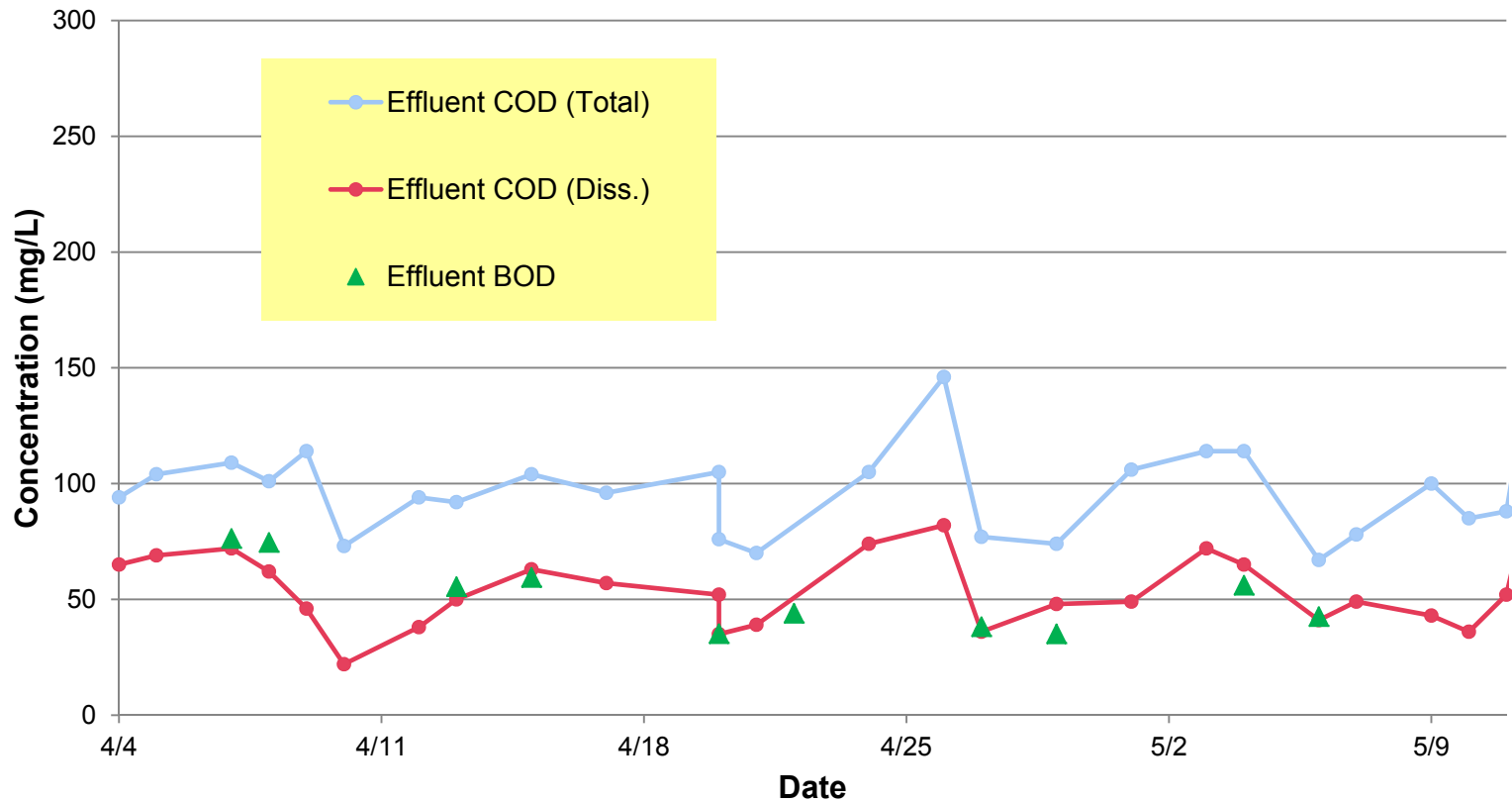




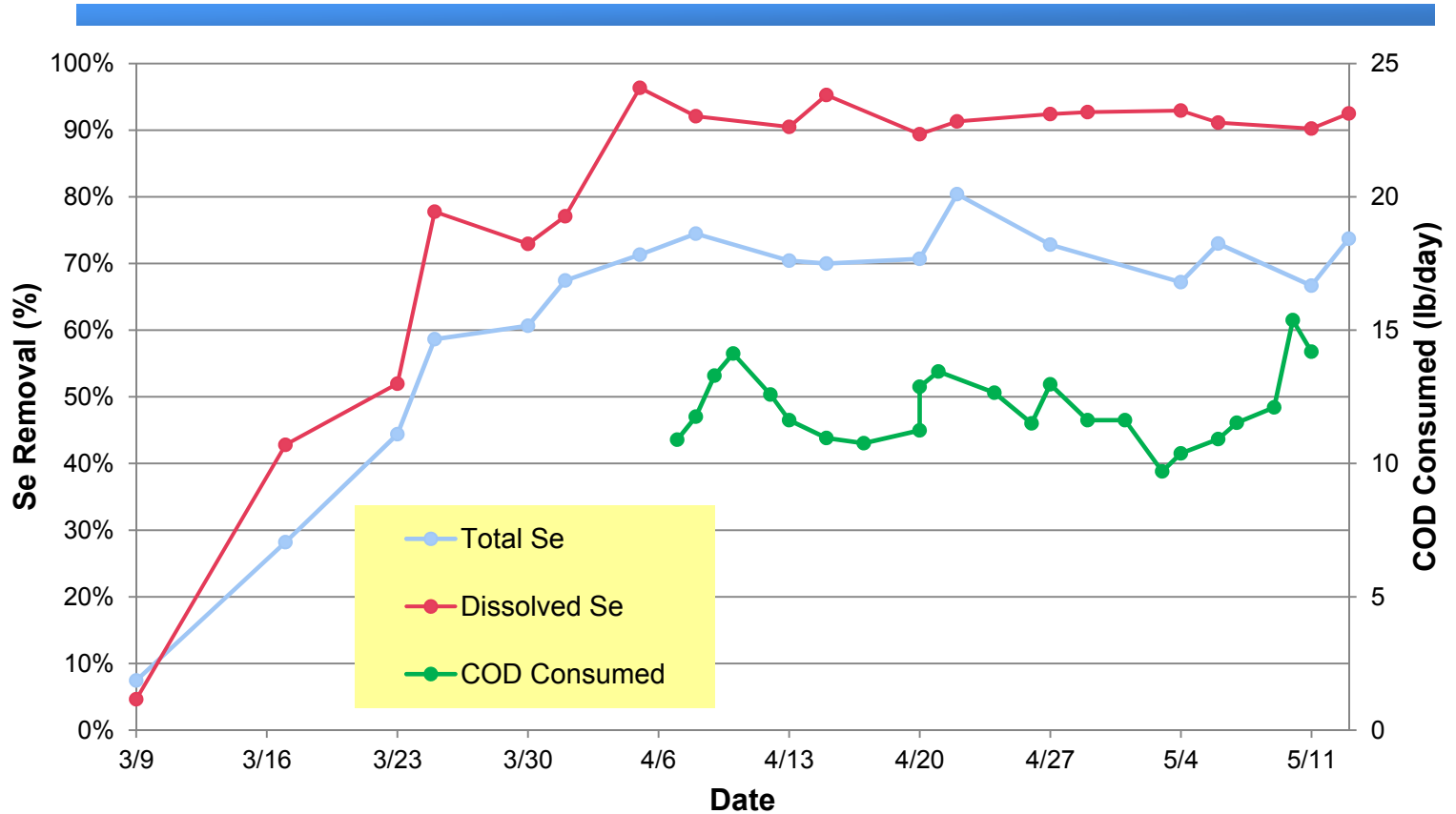
# Temperature



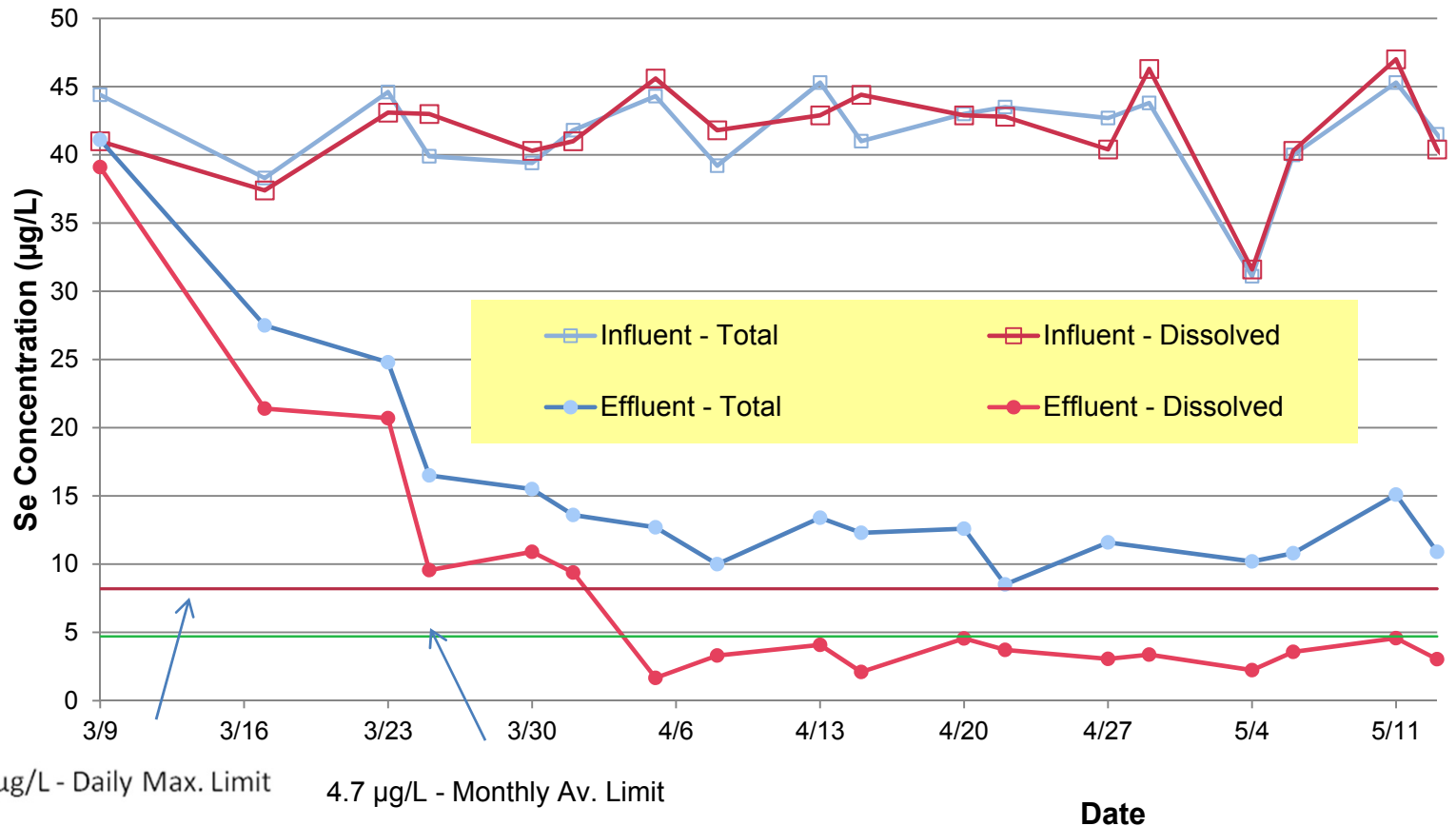
# Effluent COD and Biochemical Oxygen Demand (BOD<sub>5</sub>)



# COD Stoichiometry and Selenium Removal Performance



# Selenium Removal Performance

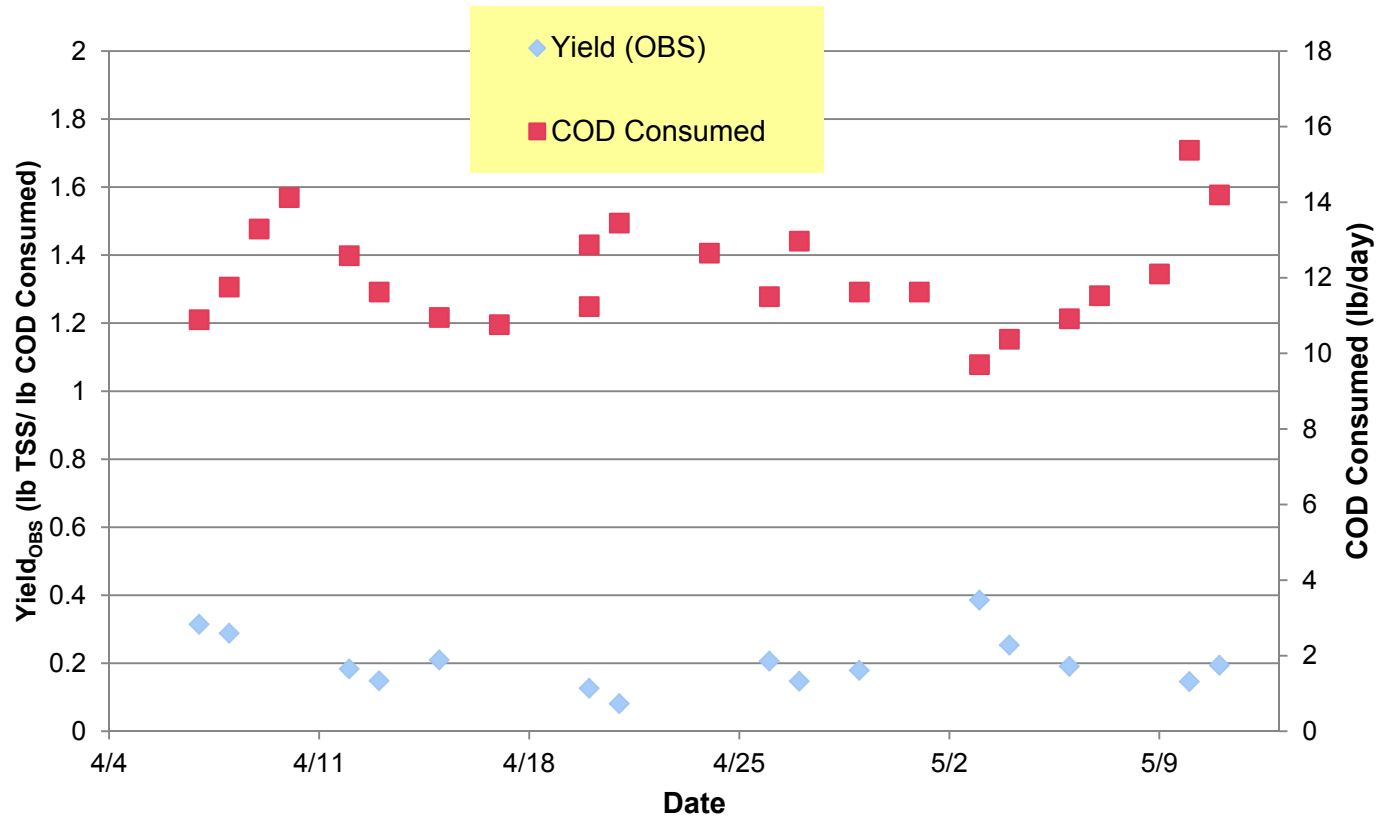


8.2 µg/L - Daily Max. Limit

4.7 µg/L - Monthly Av. Limit

Date

# Observed Yields



# Proof of Concept Conclusions

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- **Soluble selenium removal consistently below 4.6 µg/L**
- **Effluent TSS will require polishing to meet NPDES selenium requirements**
- **Effluent BOD will require aerobic treatment to meet expected NPDES requirements**
- **Residuals nonhazardous per EPA RCRA TCLP 1 mg/L Se**

# Design Testing Focus On-Going

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- **TSS removal evaluation: filtration and sedimentation**
- **BOD removal evaluation-aerobic attached growth bioreactor**
- **Maximum throughput design capacity**
- **Reliability and operability reviews**
- **Flow equalization/diversion requirements**

# Questions?

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