

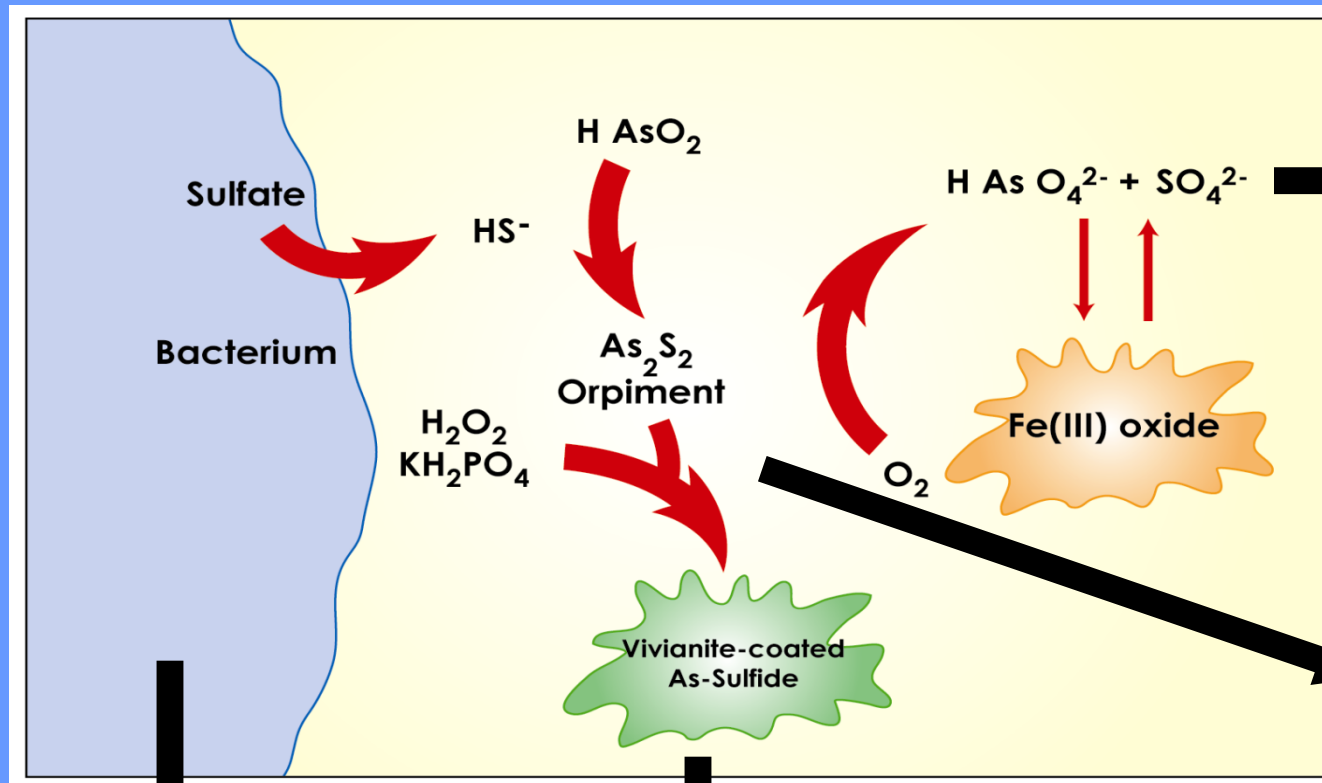


***In Situ* Biosequestration of Arsenic in Groundwater**

Mary DeFlaun, Ph.D.
Jackie Lanzon, P.E.
Michael Lodato, P.G.
Carl Elder, Ph.D., P.E.

Bench-scale Column Studies

Conducted at Princeton University
Collaborator Professor T.C. Onstott



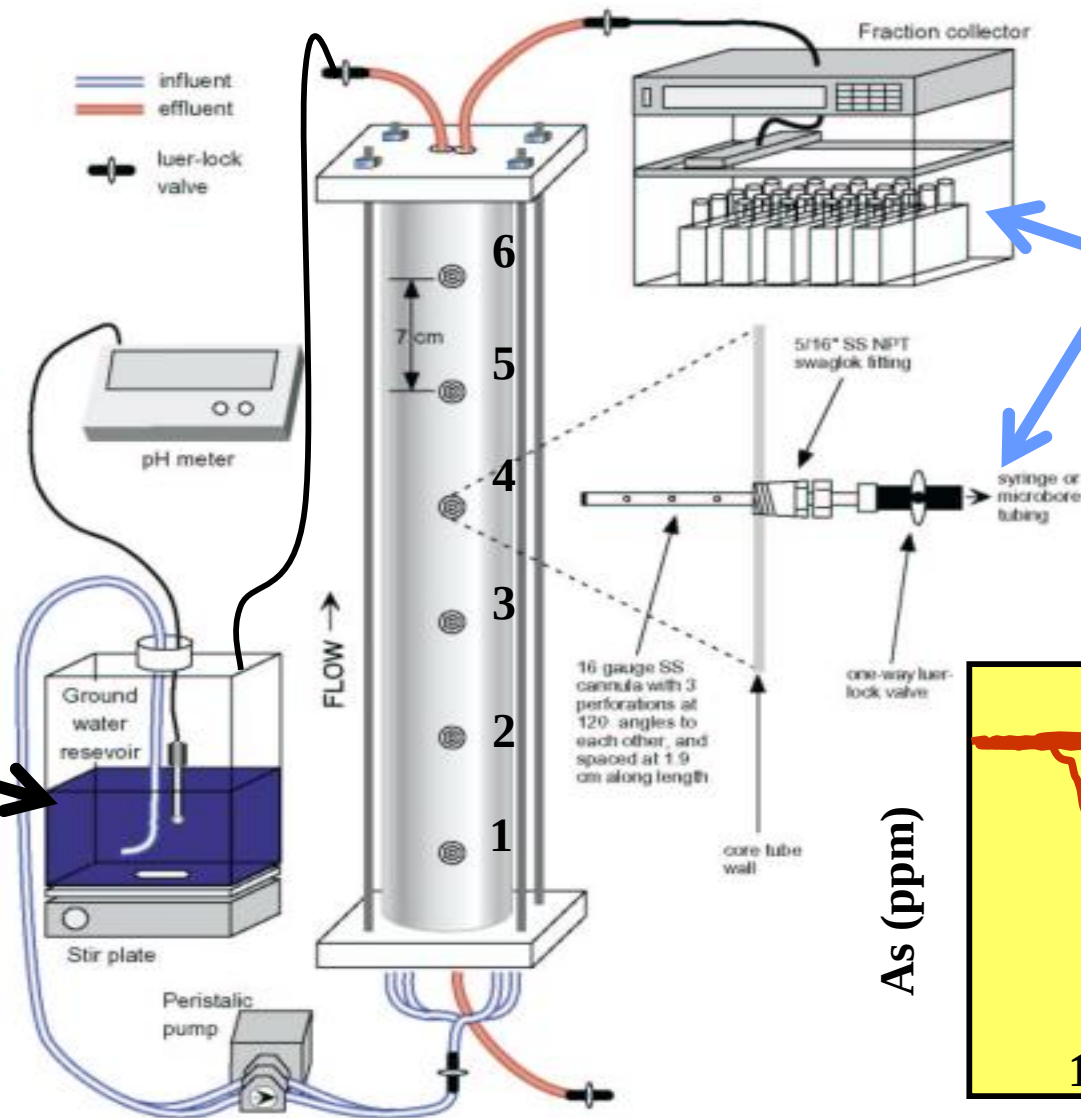
Sorption and
desorption of
arsenate on
oxyhydroxides

Uncoated:
Dissolution of
orpiment under
oxic conditions

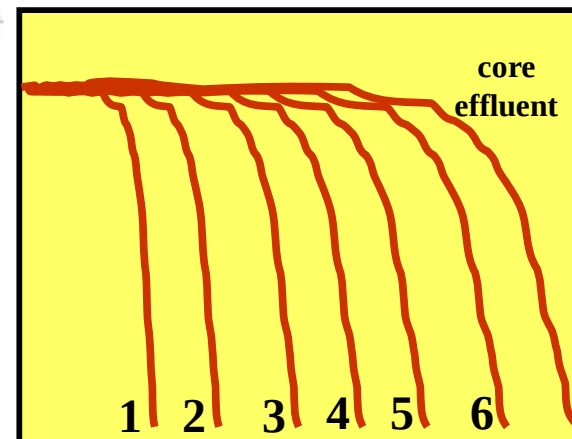
SRBs readily utilize
lactate and ethanol as
e-donors for sulfate
reduction

Coating: Stabilization of As-sulfide
could prevent re-mobilization under
oxic conditions

Arsenic-contaminated ground water + NaBr, Ethanol, lactate, sulfate, $(\text{NH}_4)_2\text{HPO}_4$ amendment solution, ^{35}S sulfate spike

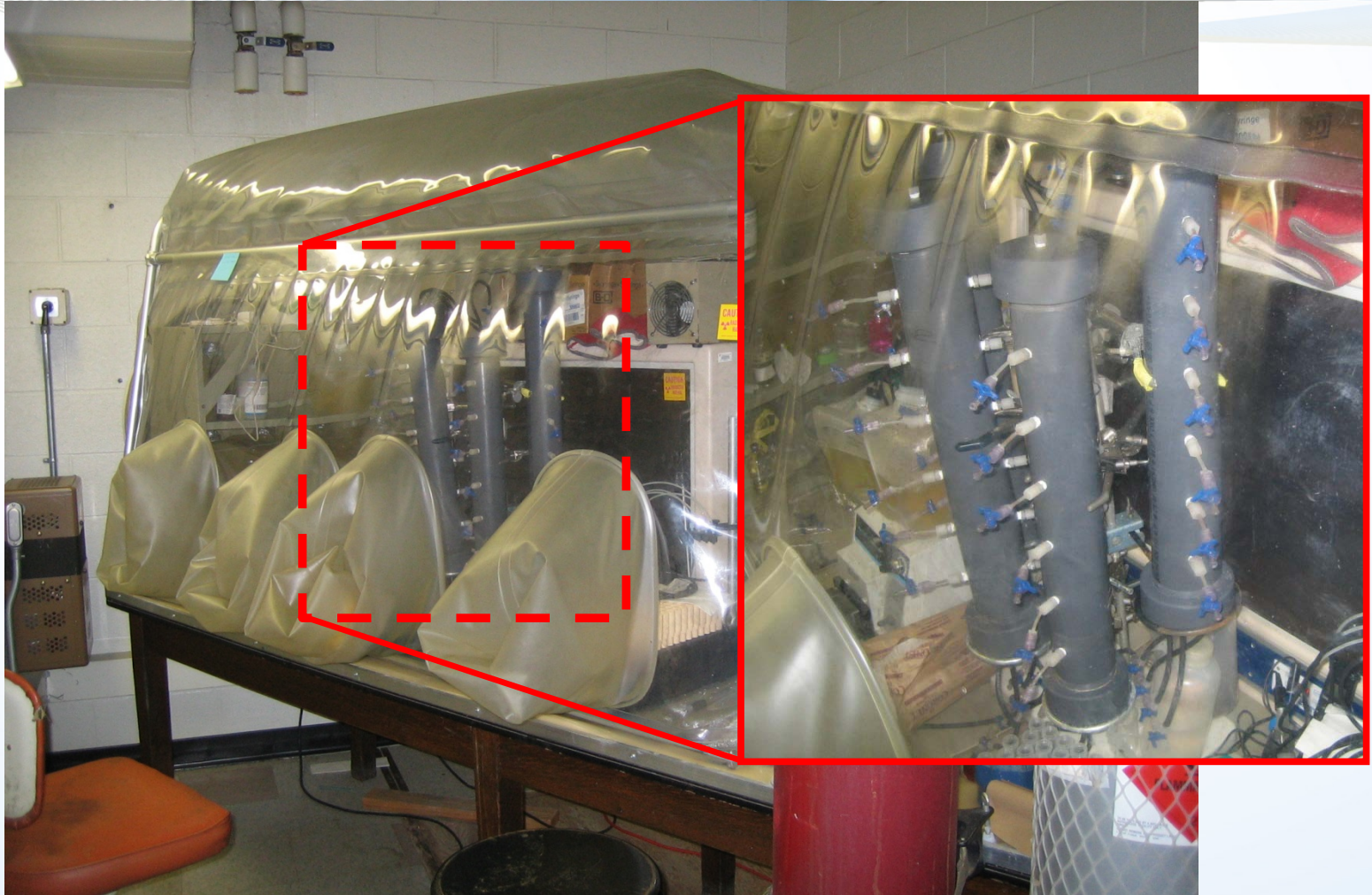


As (ppm)

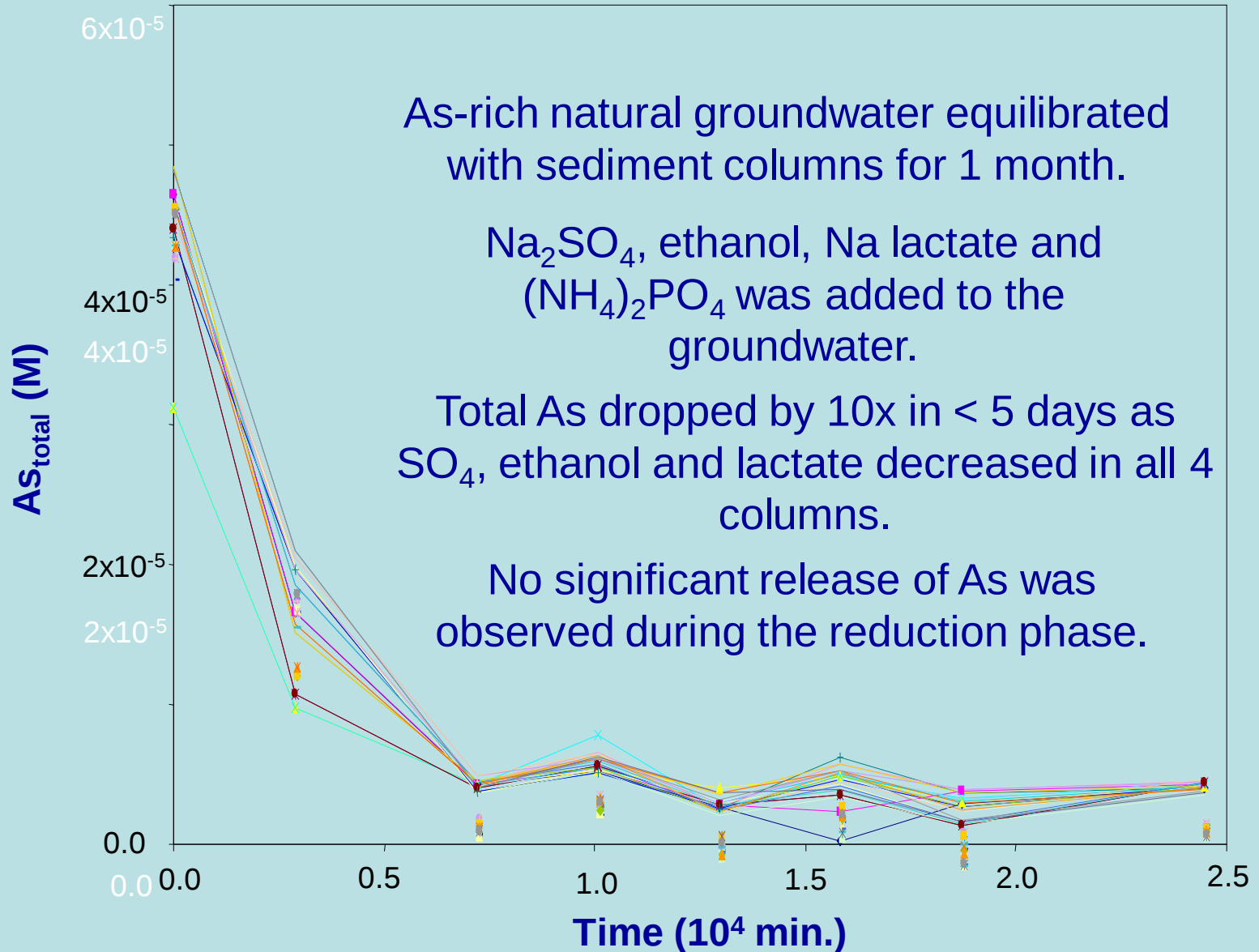


Time

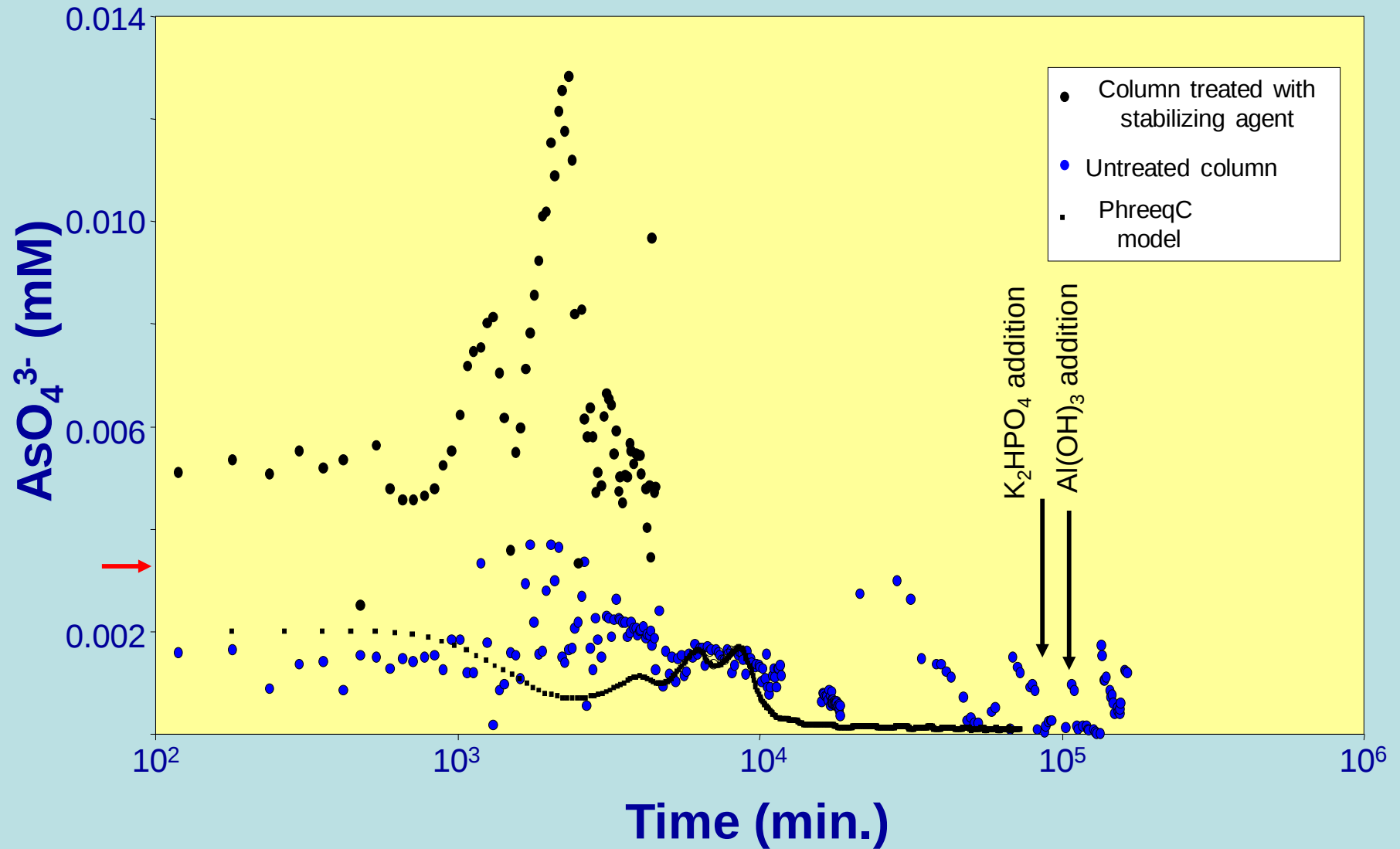
Anaerobic Chamber at Princeton University



As-Sulfide Precipitation Experiments



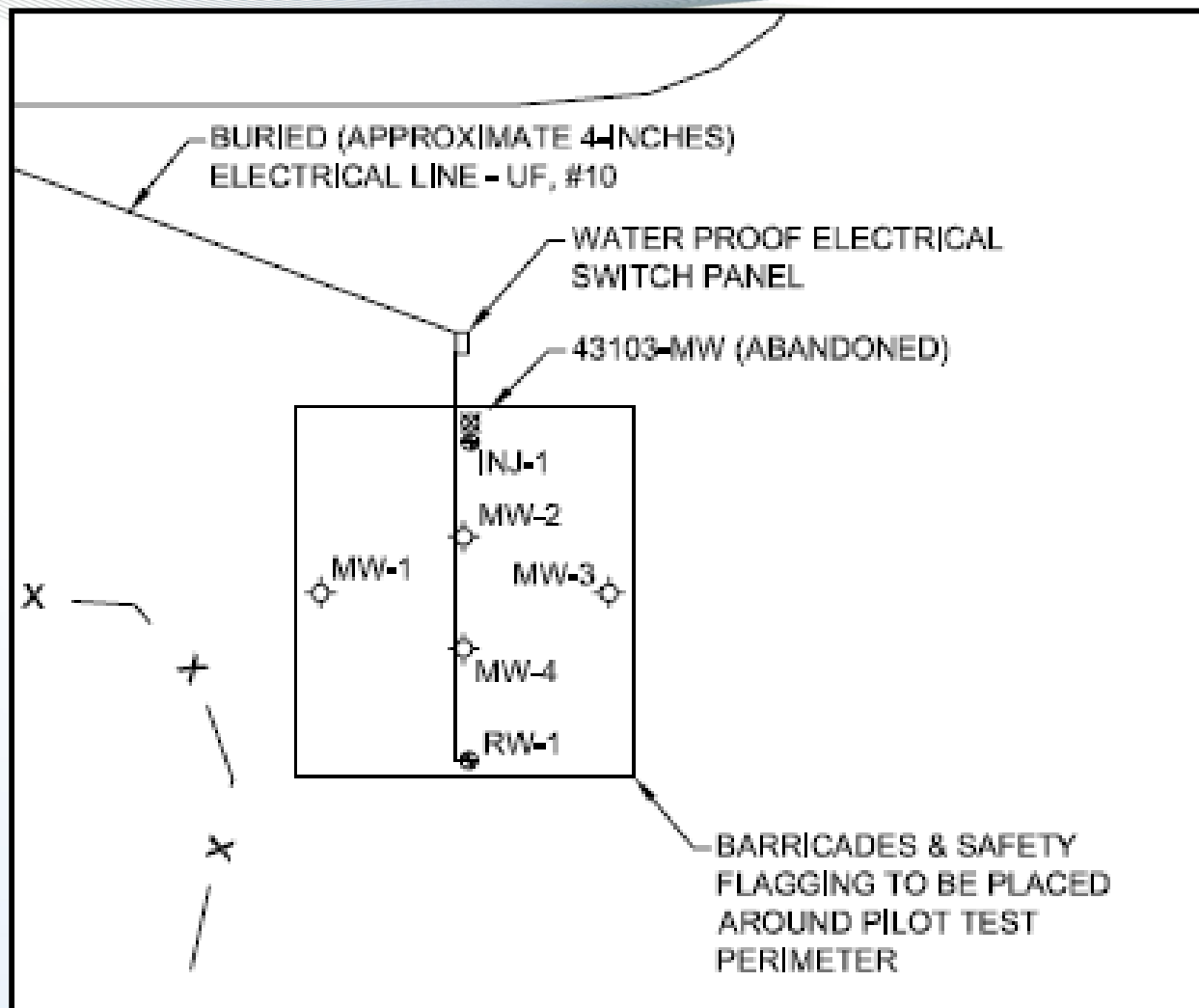
As-Sulfide Stability under Aerobic Conditions

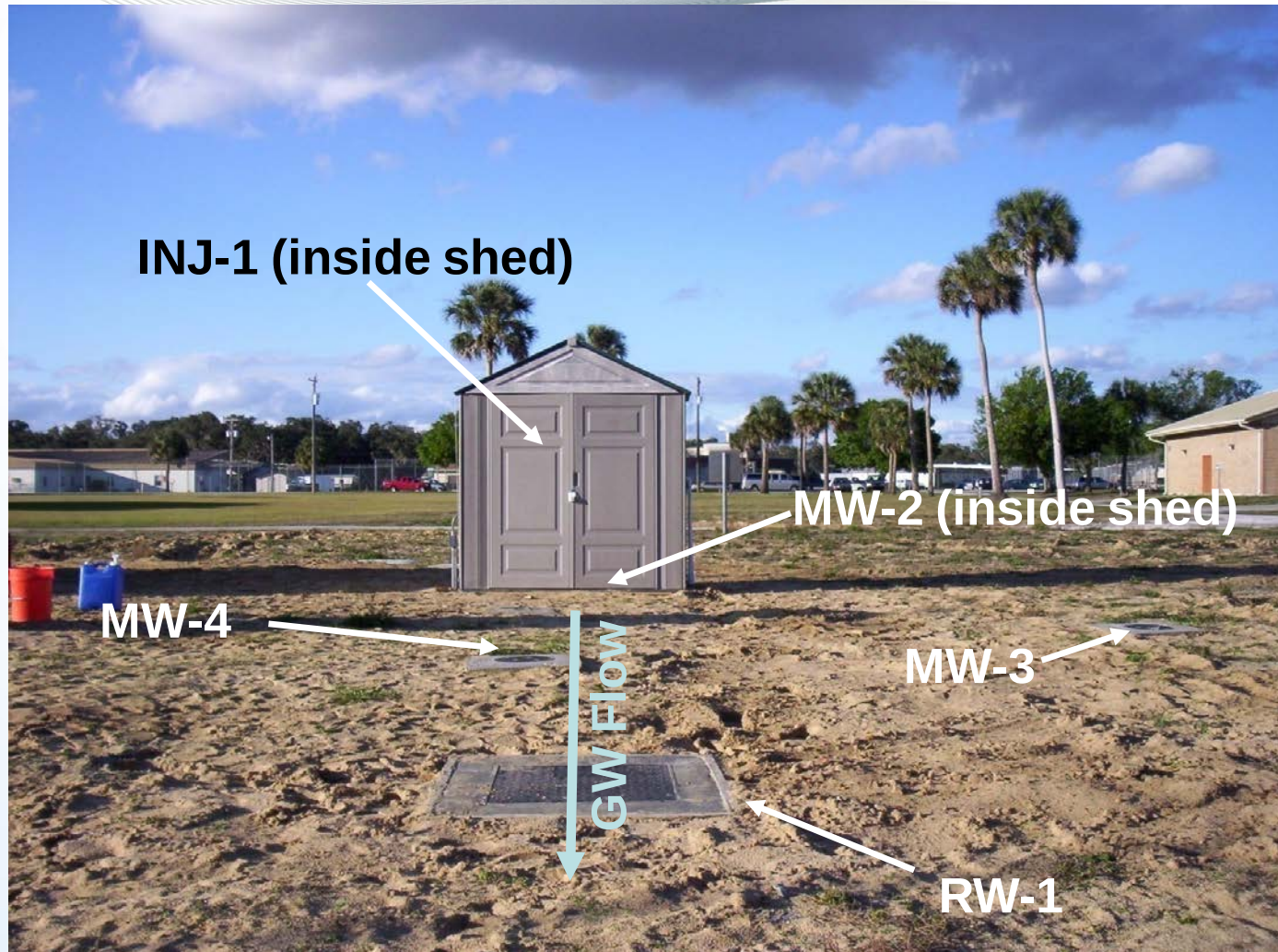


SERDP Field-Pilot

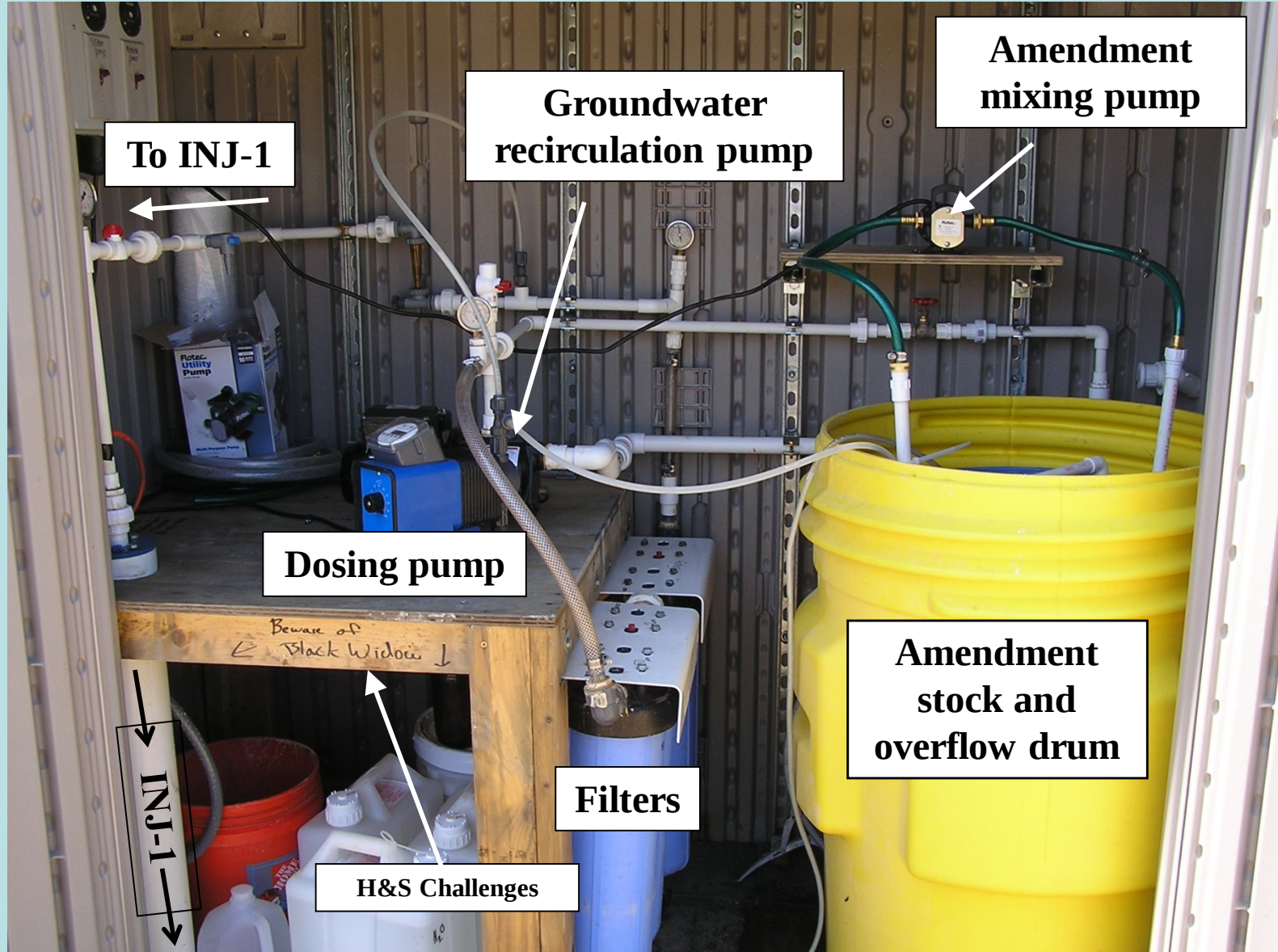
Avon Park AFR, Florida

Pilot Test Layout





Pilot Test System



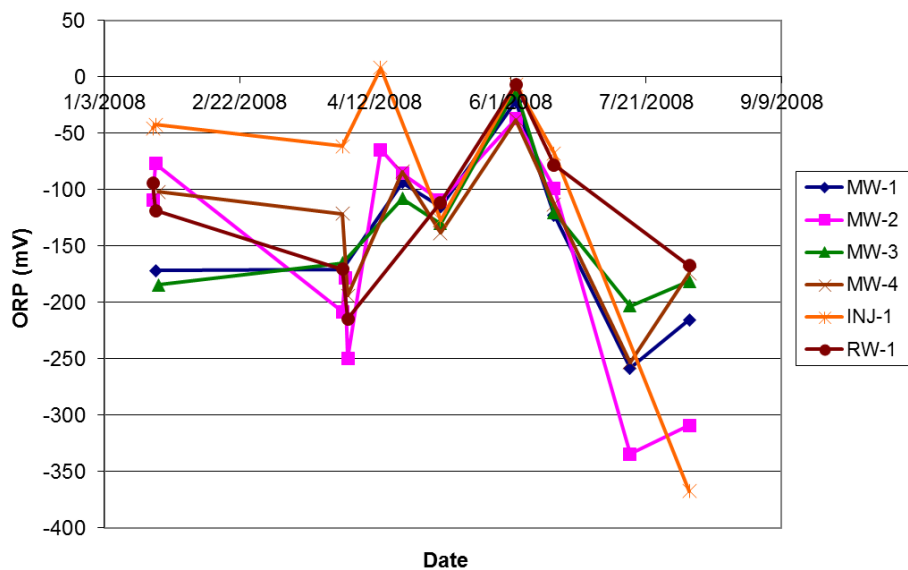
Amendment Composition

- Sodium lactate ($\text{NaC}_3\text{H}_5\text{O}_3$)
- Ethanol ($\text{C}_2\text{H}_5\text{OH}$)
 - Stopped injecting on 7/24/08
- Diammonium Phosphate ($(\text{NH}_4)_2\text{HPO}_4$)
- Sodium Sulfate (Na_2SO_4)

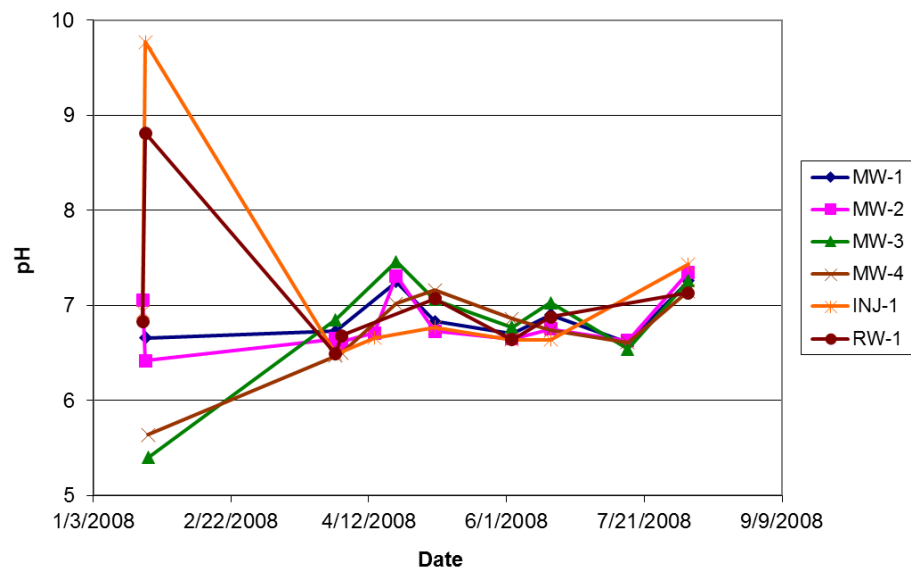


Results: Geochemical Parameters

ORP over time

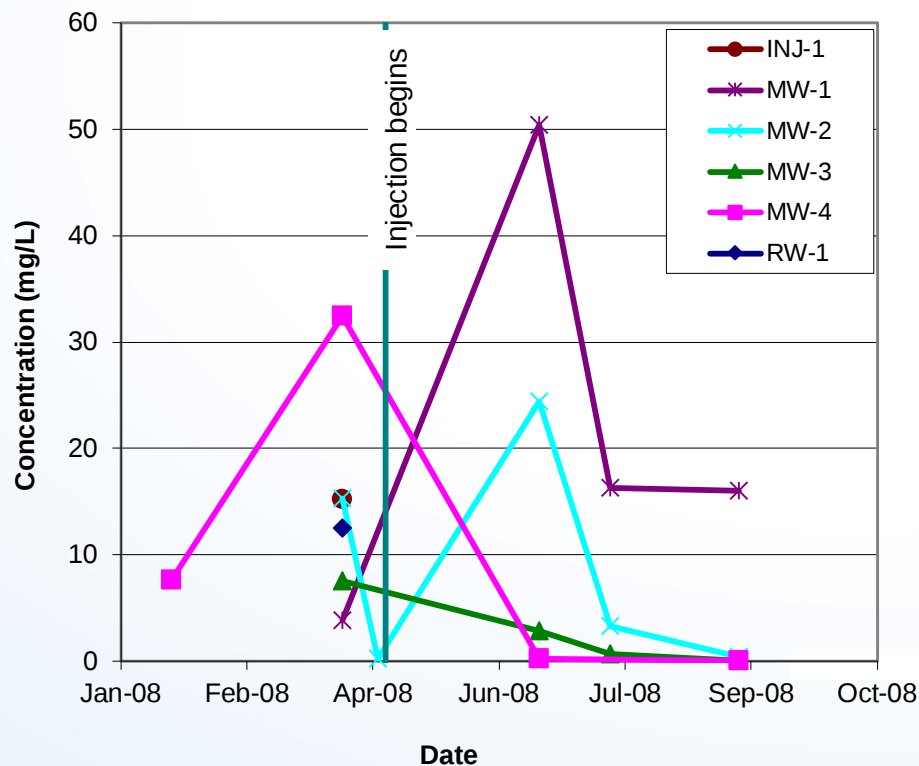


pH over time

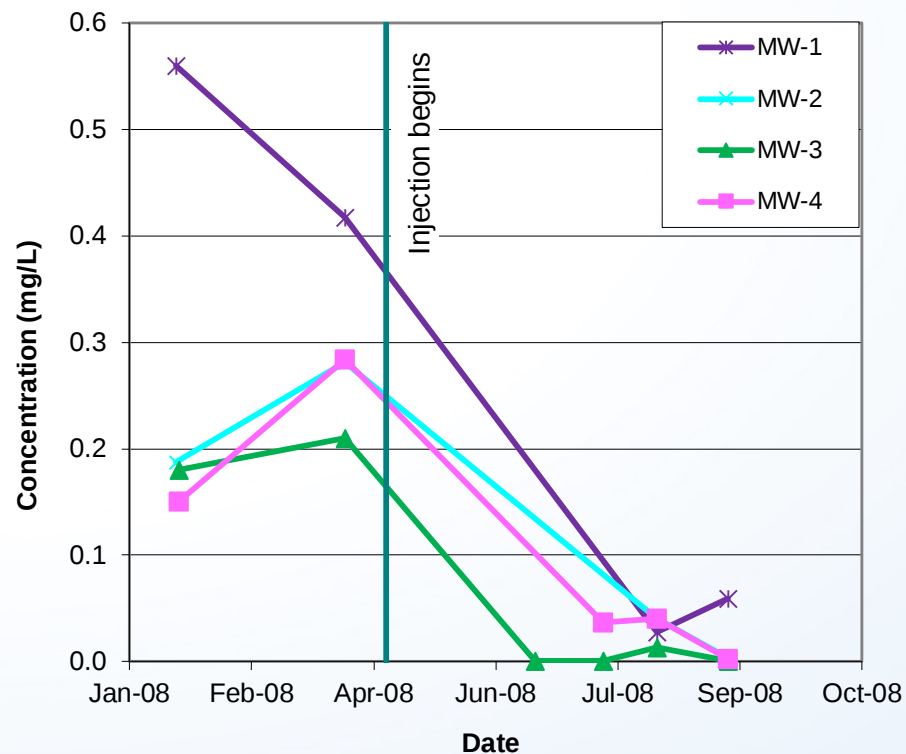


Results: As Precipitation

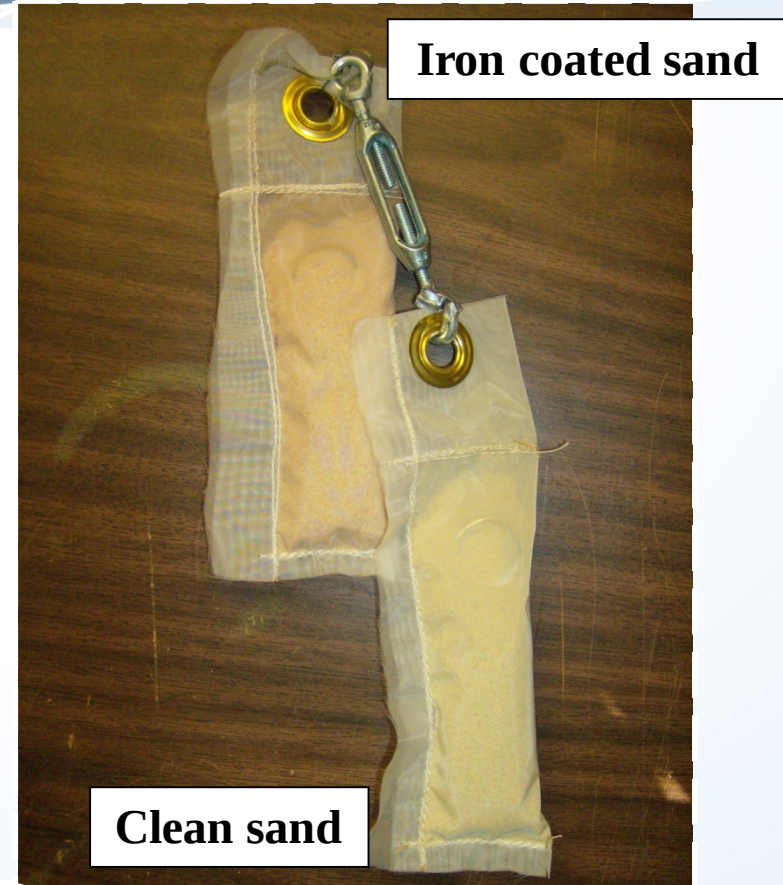
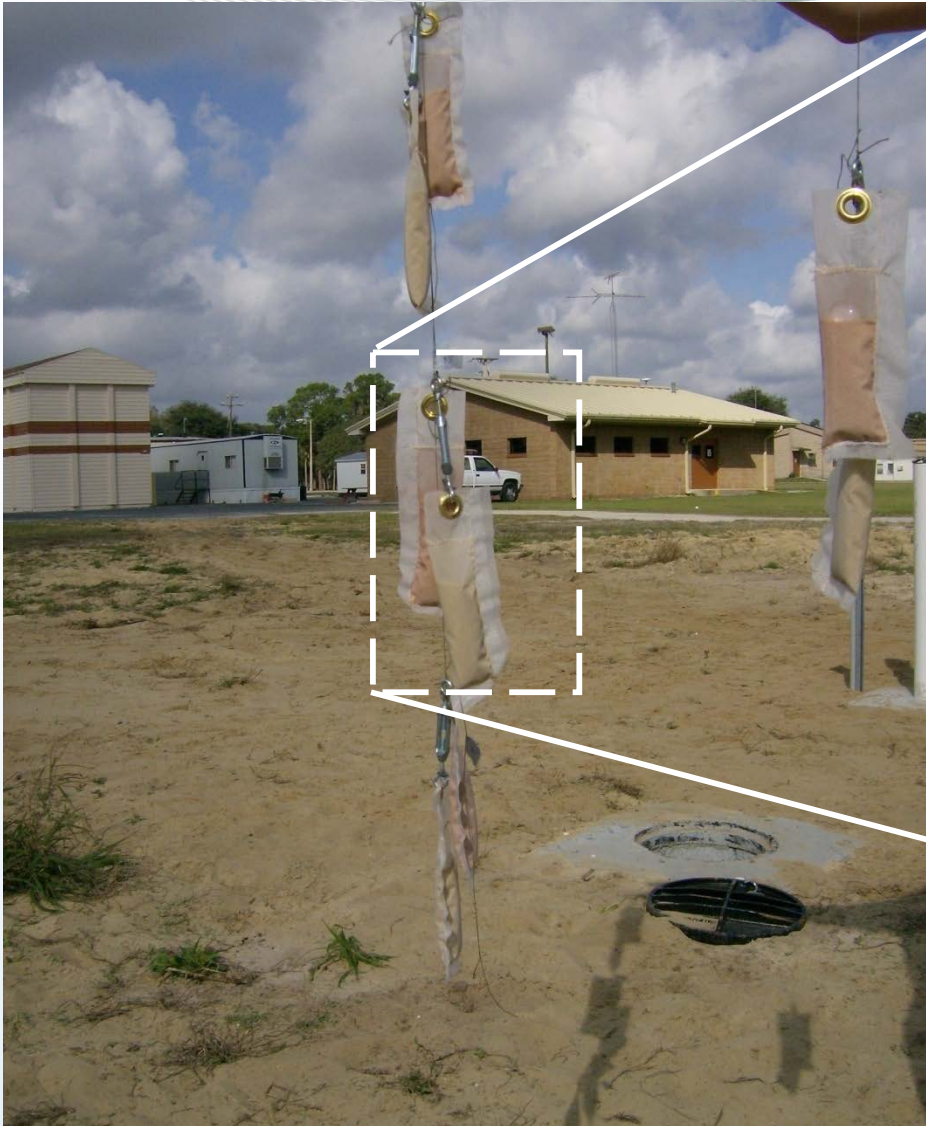
Total Sulfate



Total As Over Time



Sediment Traps



Field Pilot

Fertilizer Manufacturing Facility

Direct Push Pilot Test

1) Source Area



2) Injection Point



3) Amendment Batch



5) Site Challenges!!



4) Injection



Amendment Composition

Compound Name	Volume added per 470 gallon batch	Concentration in Stock Solution	Diluted Concentration in Groundwater	Total amount injected during the study
Water	455 gallons			8190
Emulsified Soybean Oil	28 [14]	6% [3%]	1.2% [0.6%]	490 gallons
Calcium Carbonate (CaCO ₃)	10.3 kg	5620 mg/L	1124 mg/L	186 kg
Ferrous Sulfate (FeSO ₄)	4.75 kg	2626 mg/L	525 mg/L	86 kg

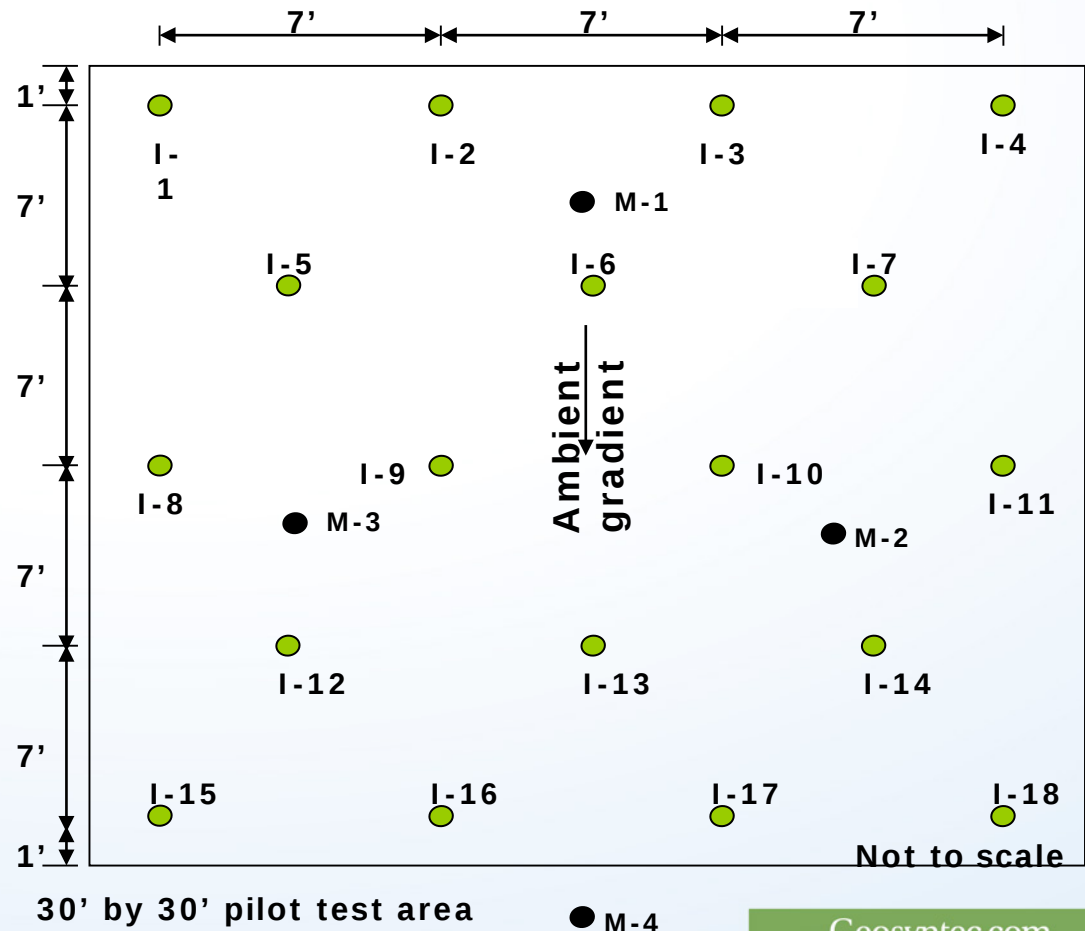
Injected at 2' intervals from 30 to 50' BGS

Design of Jet Injection

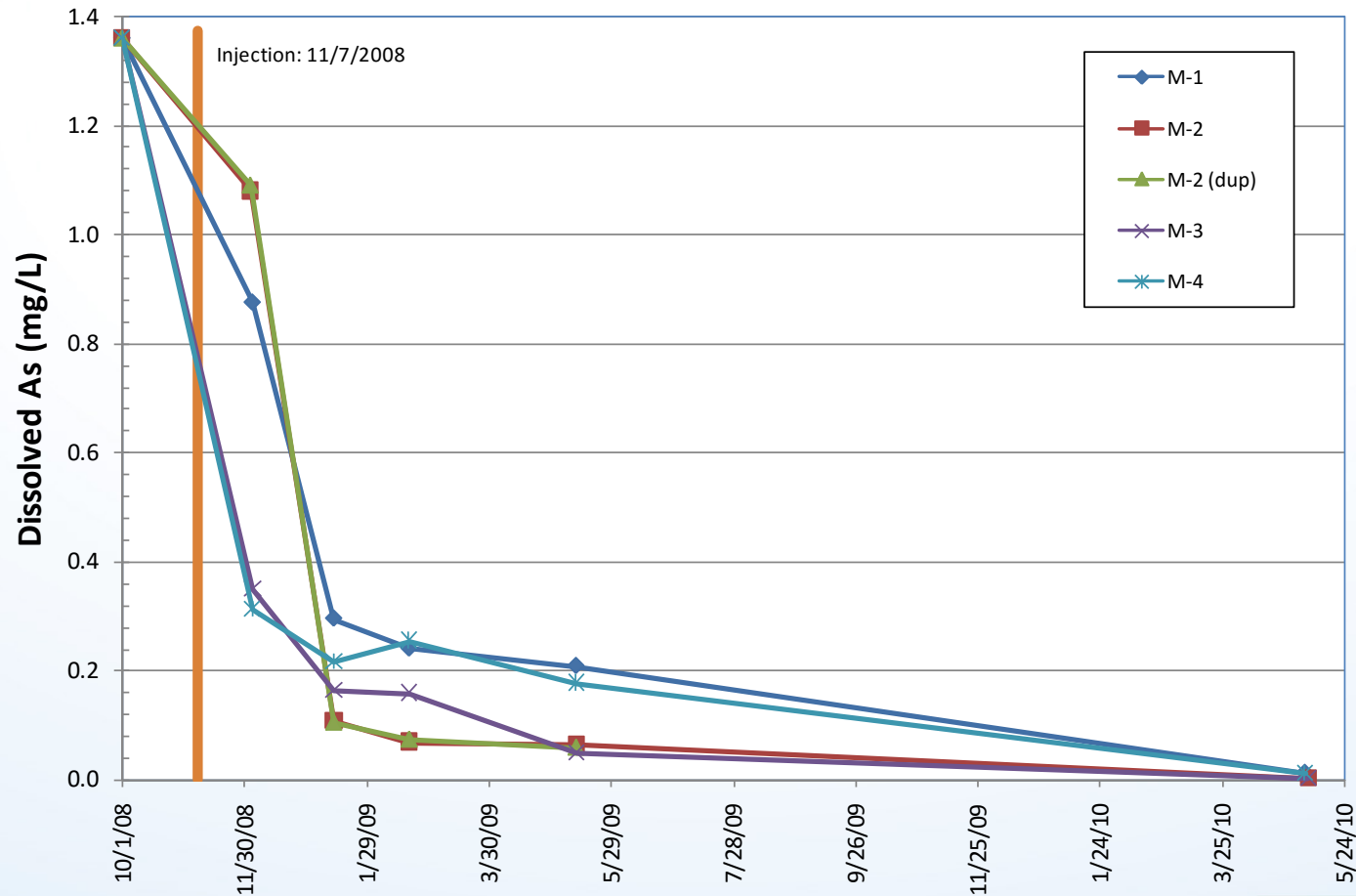
Layout of 18 Injection Points

Design Steps

- Calculate pore volume of treatment area.
- Calculate electron donor dose for pore volume.
- Estimate radius and volume for an injection point.
- Calculate number of injection points based on above.
- Adjust number of injection points based on cost limitations and site constraints (e.g., utilities).
- Divide volume of electron donor by number of points to obtain dosage per point.
- Layout injection locations (e.g., staggered grid).



Pilot Test Results

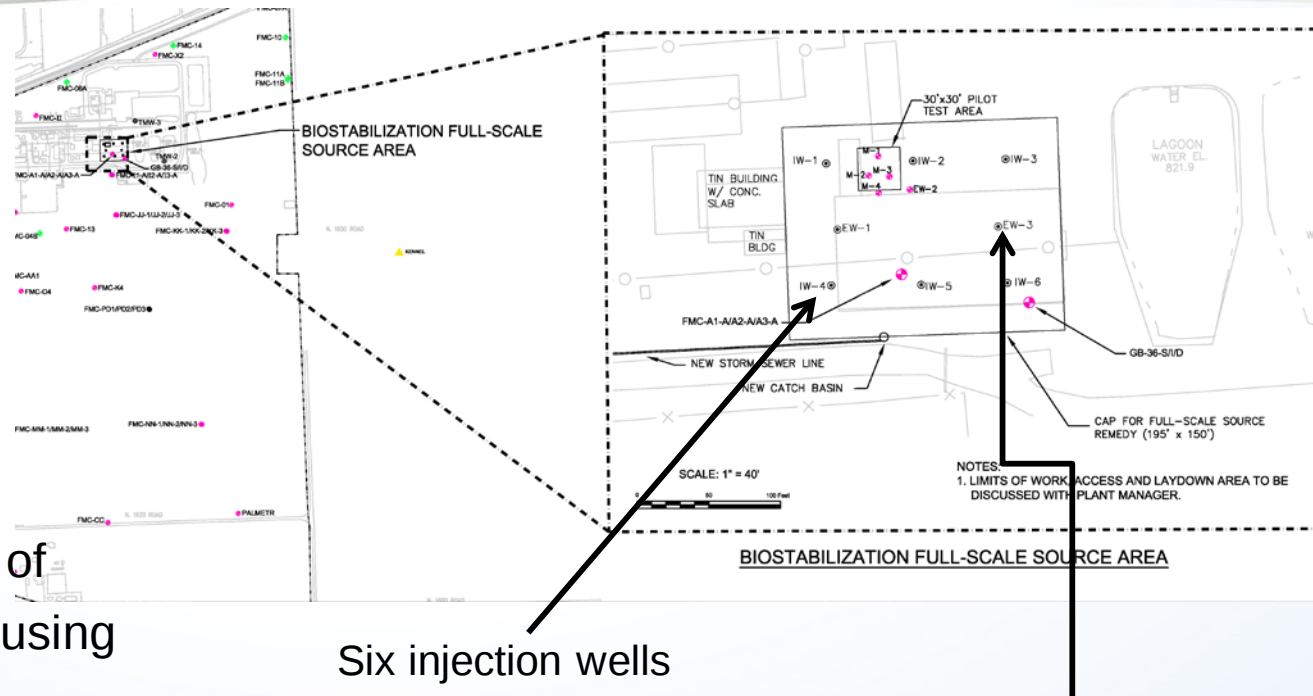


Full-Scale Remediation

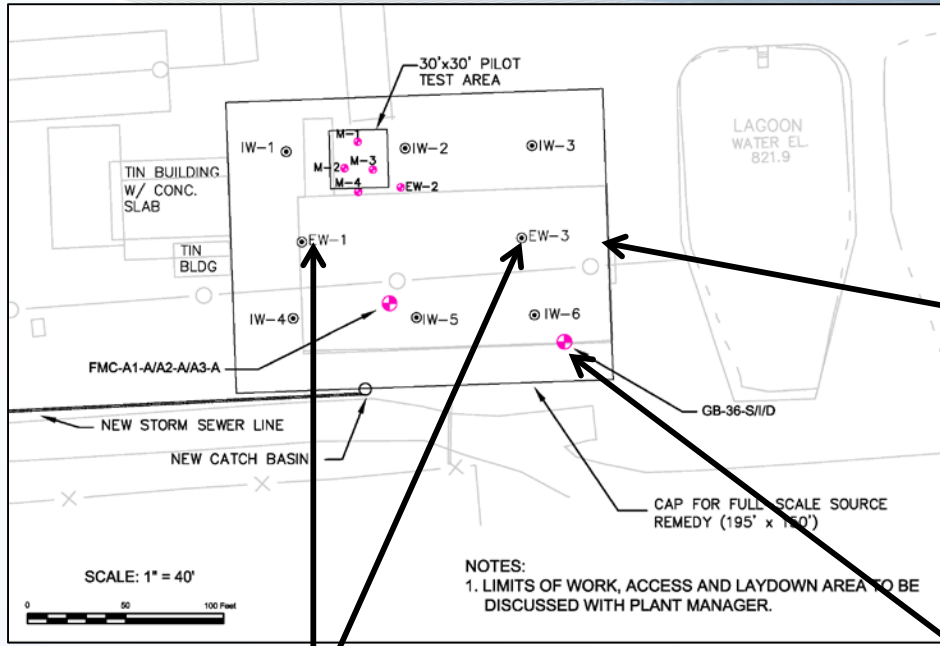
Fertilizer Manufacturing Facility

Source Area Design

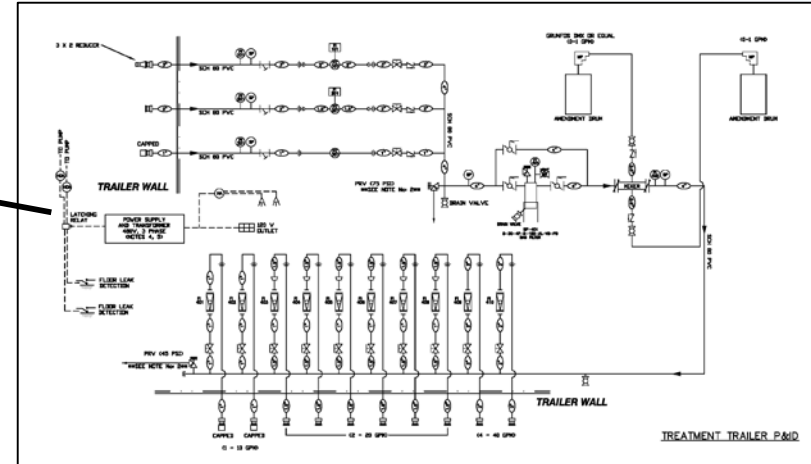
- Arsenic source area
- E-donor used to reduce sulfate in order to immobilize arsenic as arsenic-sulfide minerals.
- Semi-passive circulation of EVO and ferrous sulfate using
 - 2 extraction wells
 - 6 injection wells
 - Trailer-mounted system
- Construction in Summer 2014



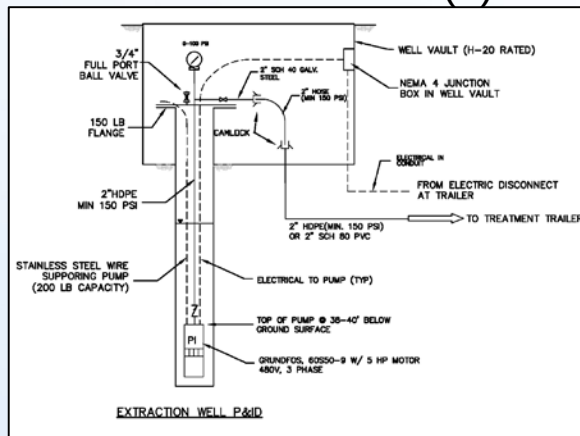
Components of the Groundwater System



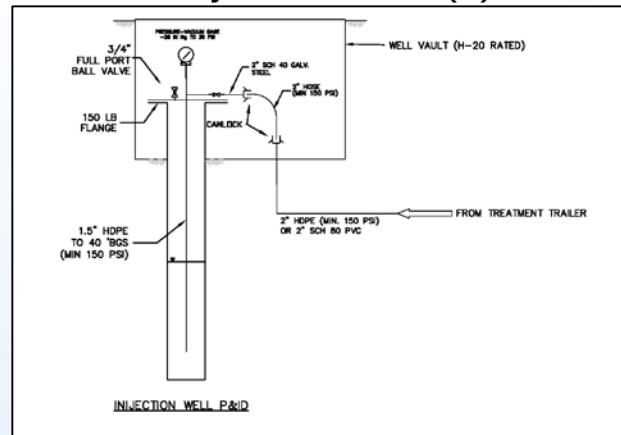
Treatment Trailer (temporary)



Extraction Wells (2)

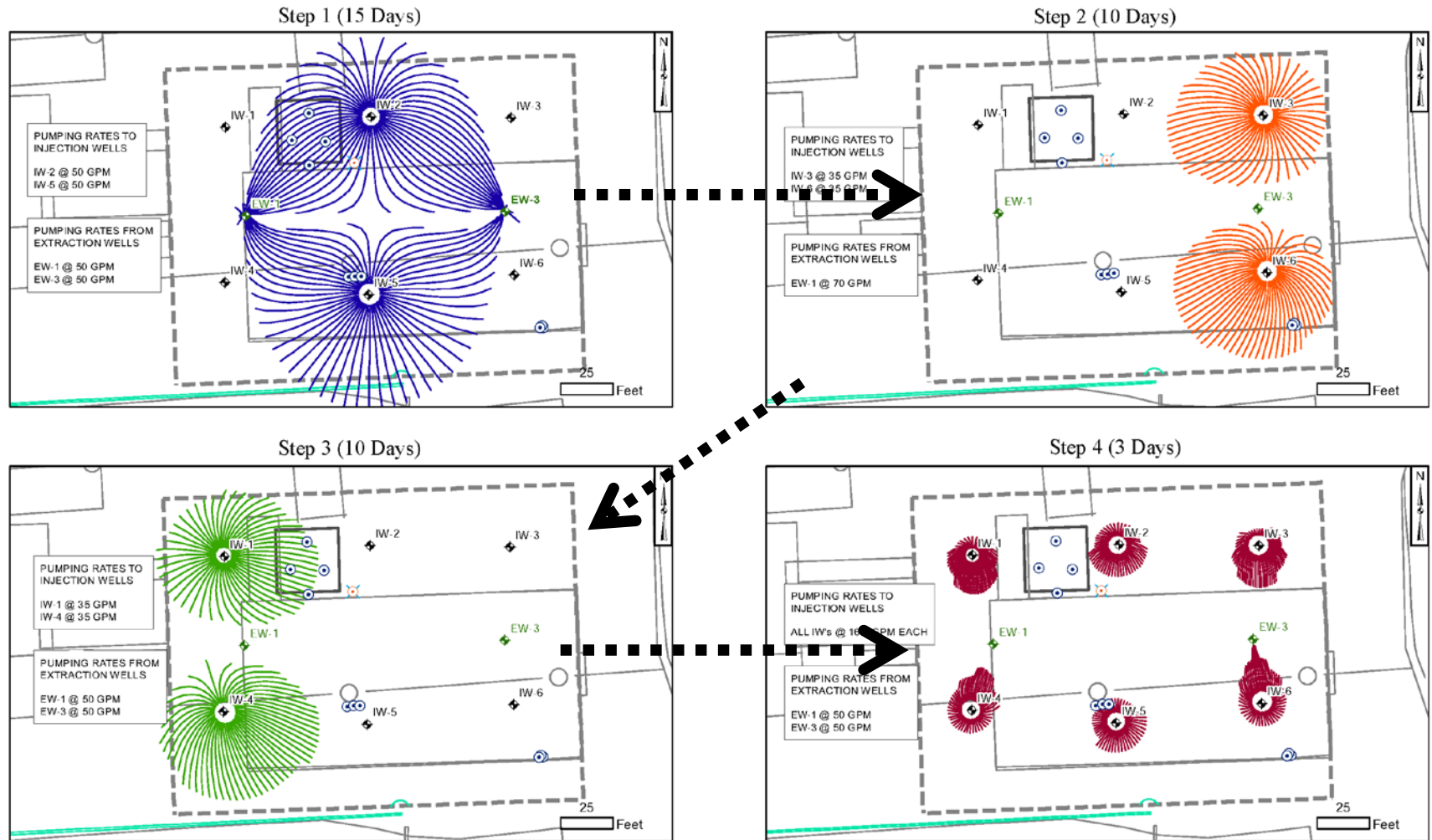


Injection Well (6)



- Remedy also includes:
- 9" asphalt cap
 - storm water collection and conveyance
 - monitoring

Circulation Schedule



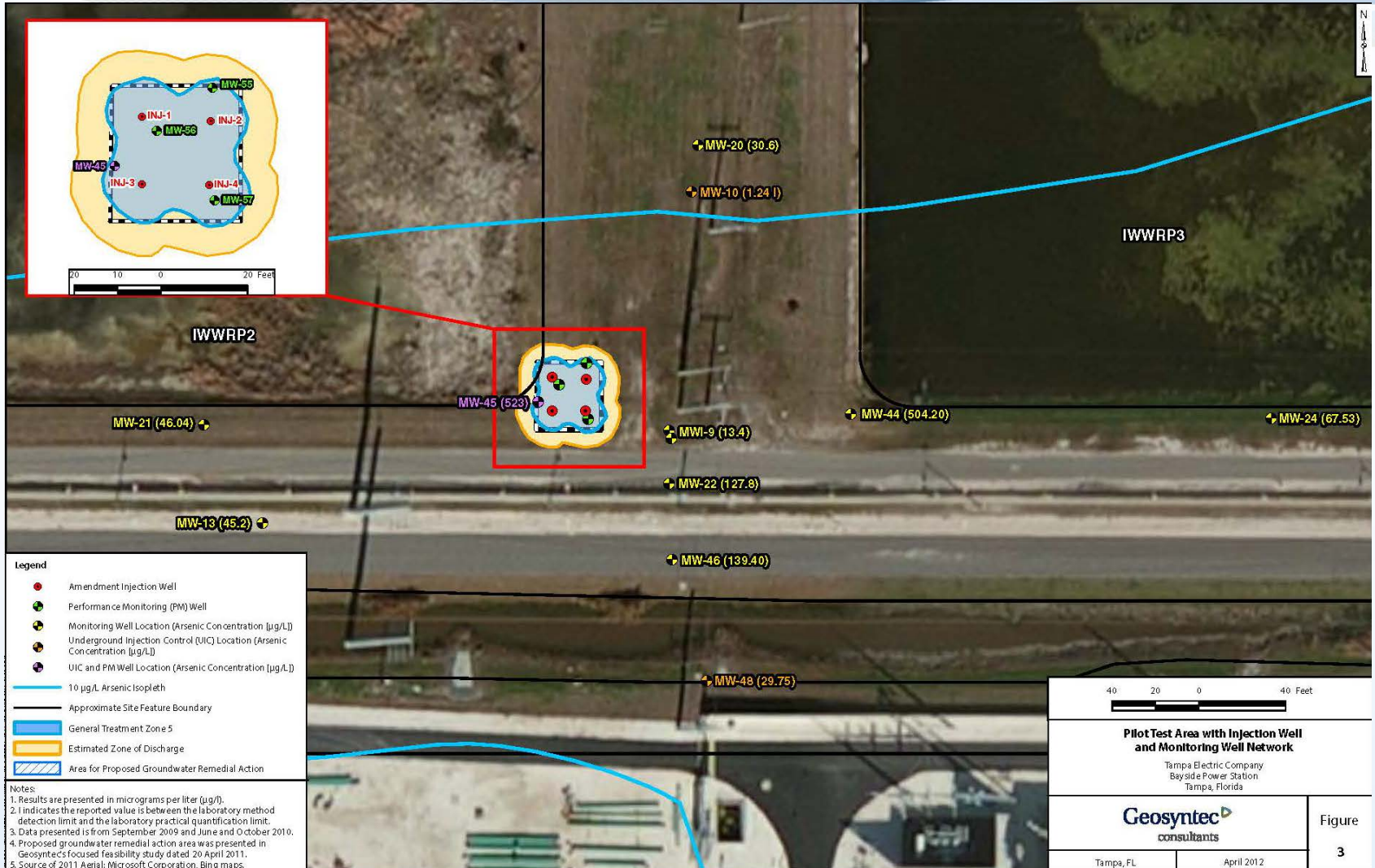
The pumping configuration is adjusted during groundwater recirculation to better distribute amendments

Source Area Design Summary

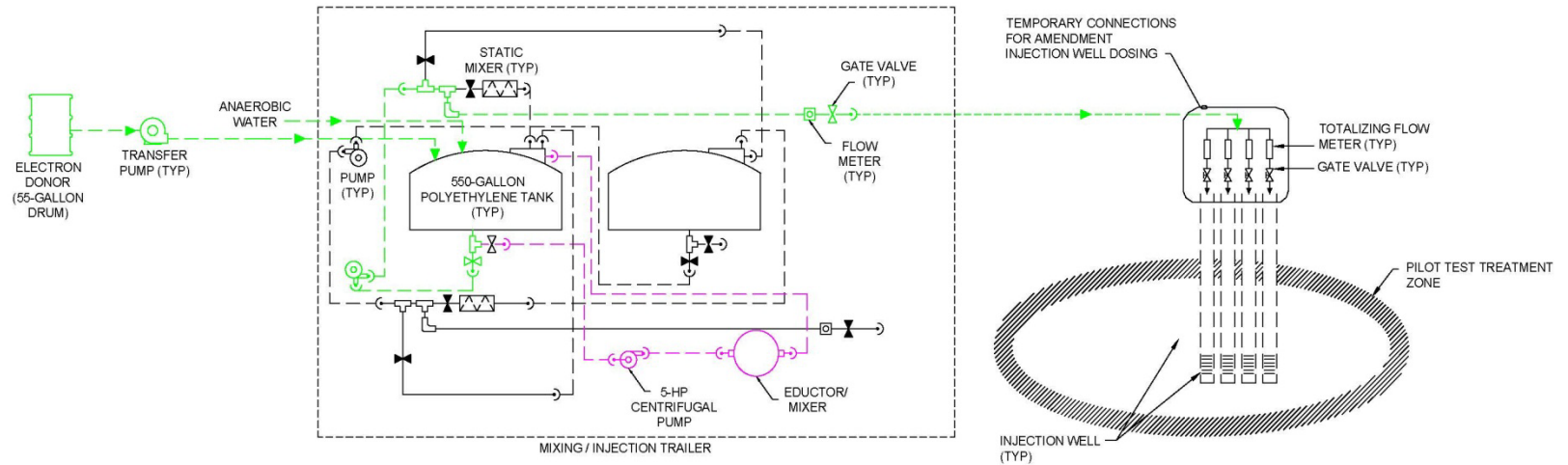
- Amendment distribution = one pore volume = 4M gallons of groundwater
- At 70 to 100 gpm total flow, delivery of amendments = 38 days
- After amendment delivery, piping and electrical will be disconnected and the treatment trailer demobilized
- Amendments are expected to last for ~2 years (perhaps more), so the expected O&M is a month of amendment delivery every other years
- Monitoring: semiannual for the initial 4 years, annually thereafter

Field Pilot Test

Florida Power Company



Process Flow Diagram



LEGEND

	CAM-LOCK FITTING
	PVC SUCTION LINE (FLEXIBLE)
	SCH 80 PVC TEE
	SCH 80 PVC ELBOW
	MAIN INJECTION PATH
	RECIRCULATION PATH
	NORMALLY OPEN GATE VALVE
	NORMALLY CLOSED GATE VALVE

AMENDMENT INJECTION
PROCESS FLOW DIAGRAM

TAMPA ELECTRIC COMPANY
BAYSIDE POWER STATION
TAMPA, FL

Geosyntec[®]
consultants

TAMPA, FL

DATE:	OCTOBER 2011	FILE NO.	FR1285.06F02
PROJECT NO.	FR1946	FIGURE NO.	7

Amendment Preparation:
Emulsified Soybean Oil and
Ferrous Sulfate

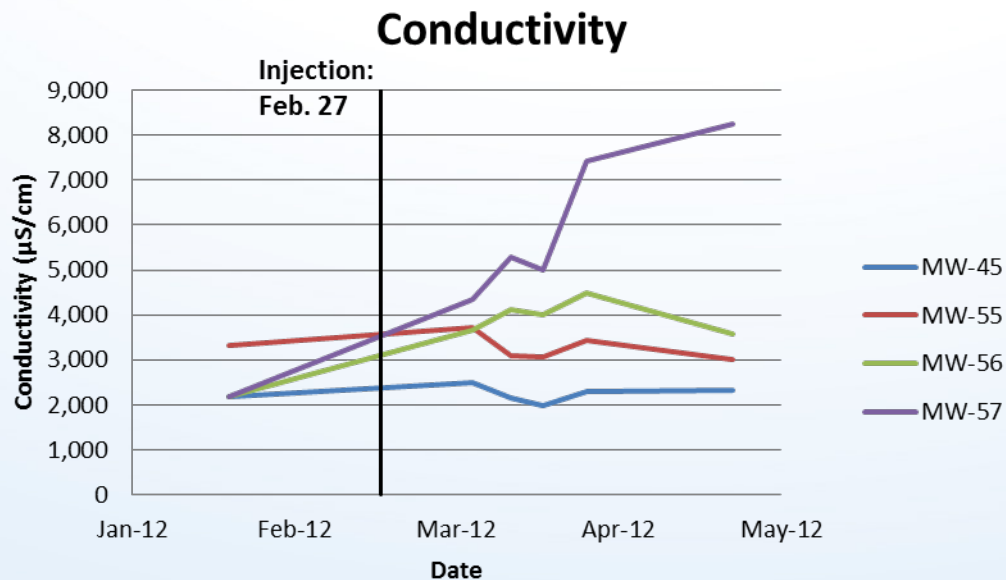
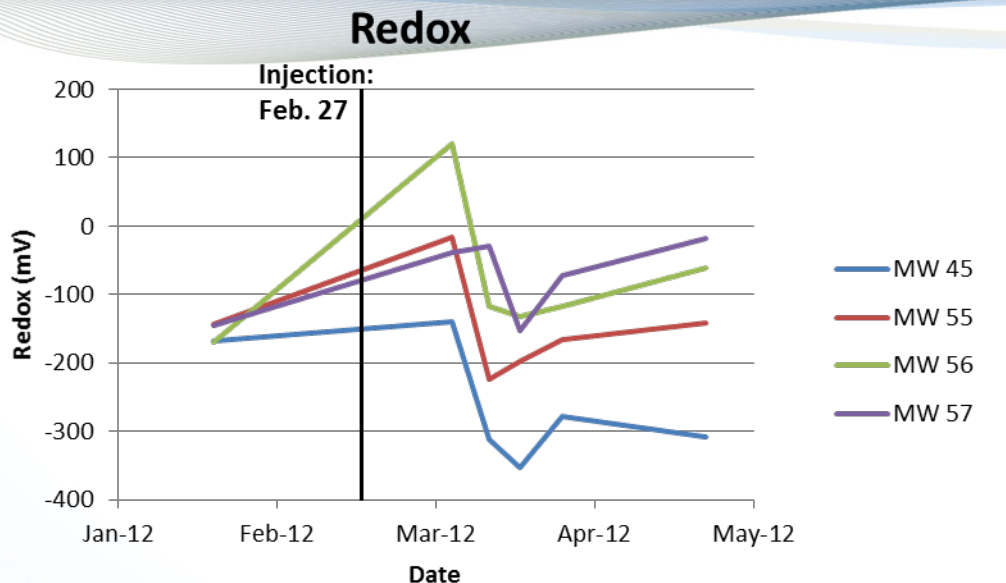


Injection Equipment:

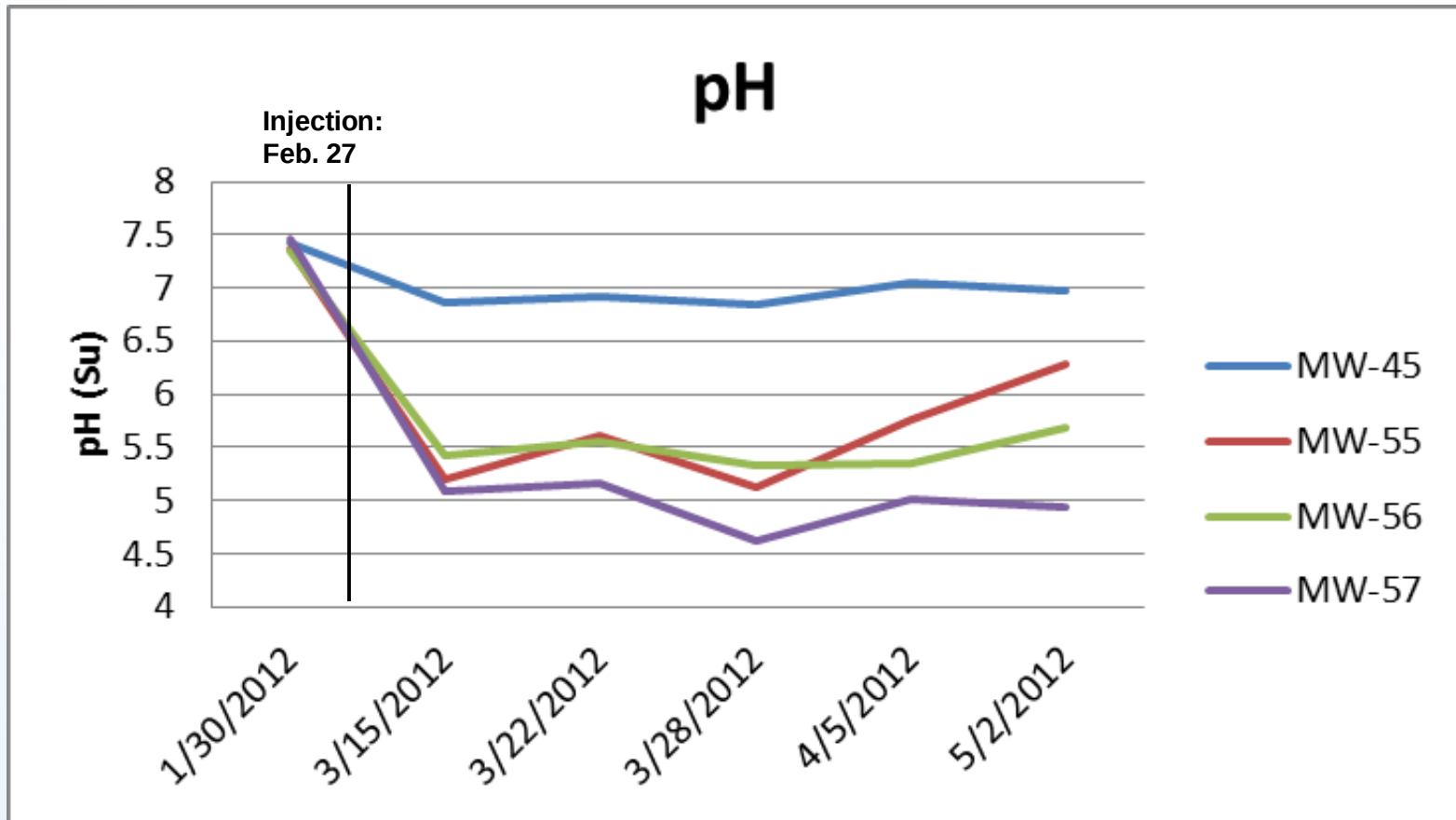
Two 550 gallon poly tanks for
amendment mixing and storage,
20,000 gallon frac tank for storage
of anaerobic water, injection
manifold, hosing, and pumps.



Pilot Test Results

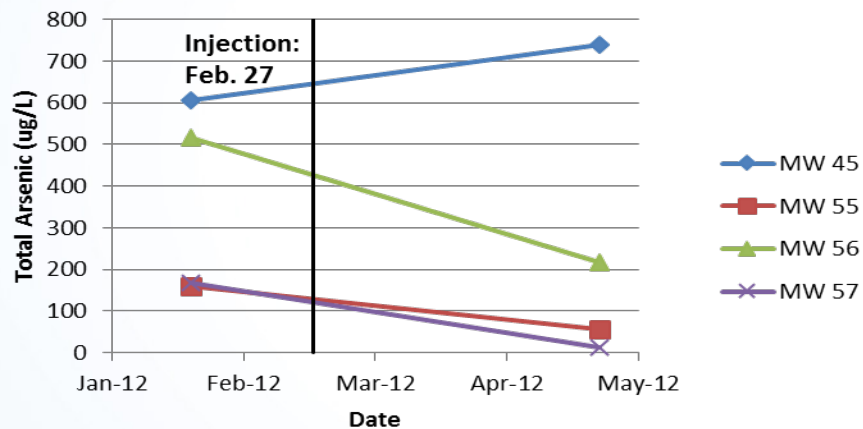


Pilot Test Results

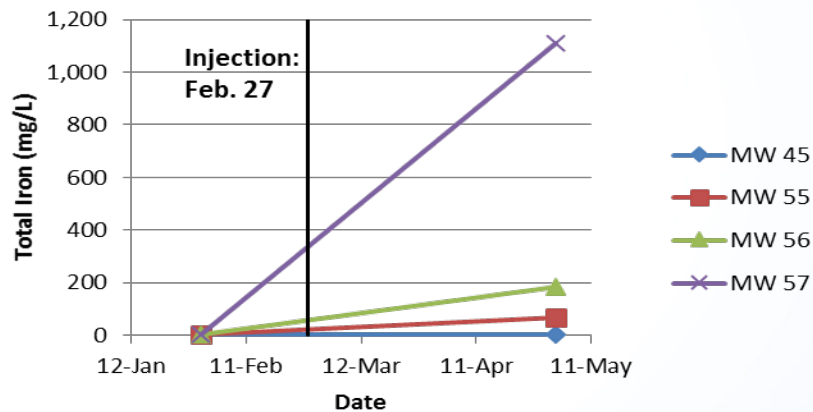


Pilot Test Results

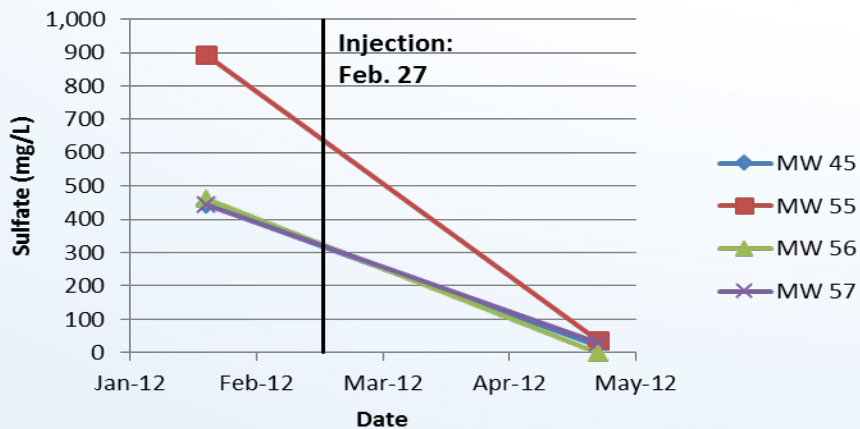
Total Arsenic



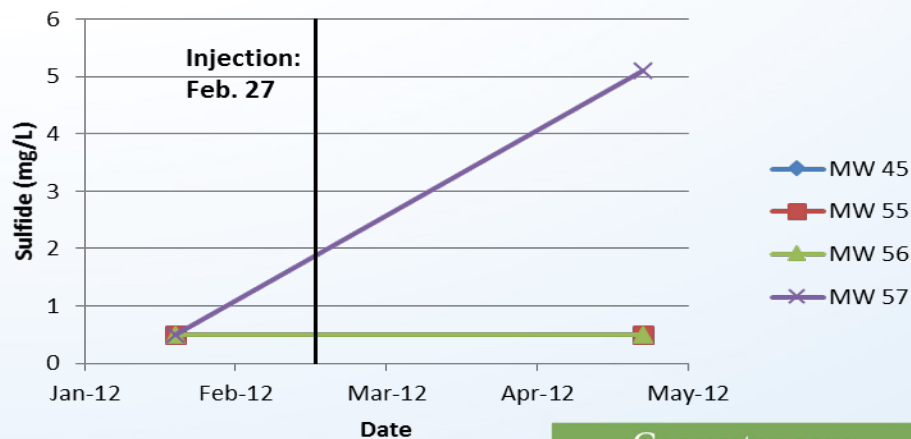
Total Iron



Sulfate



Sulfide





Questions?