Methodology and Lessons Learned Conducting In-Situ Bioremediation Using an Emulsified Vegetable Oil

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EPAZ Conference

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ADEQ Arizona Department of Environmental Quality

Presentation Purpose

- ADEQ Conducted In-Situ Bioremediation Injections at the 7th Avenue & Bethany Home Road WQARF Site in Phoenix, AZ
- Presentation Will Discuss:
  - Project Background
  - Project Technology & Design
  - Project Implementation
  - Performance Monitoring
  - Conclusions & Lessons Learned

Project Background

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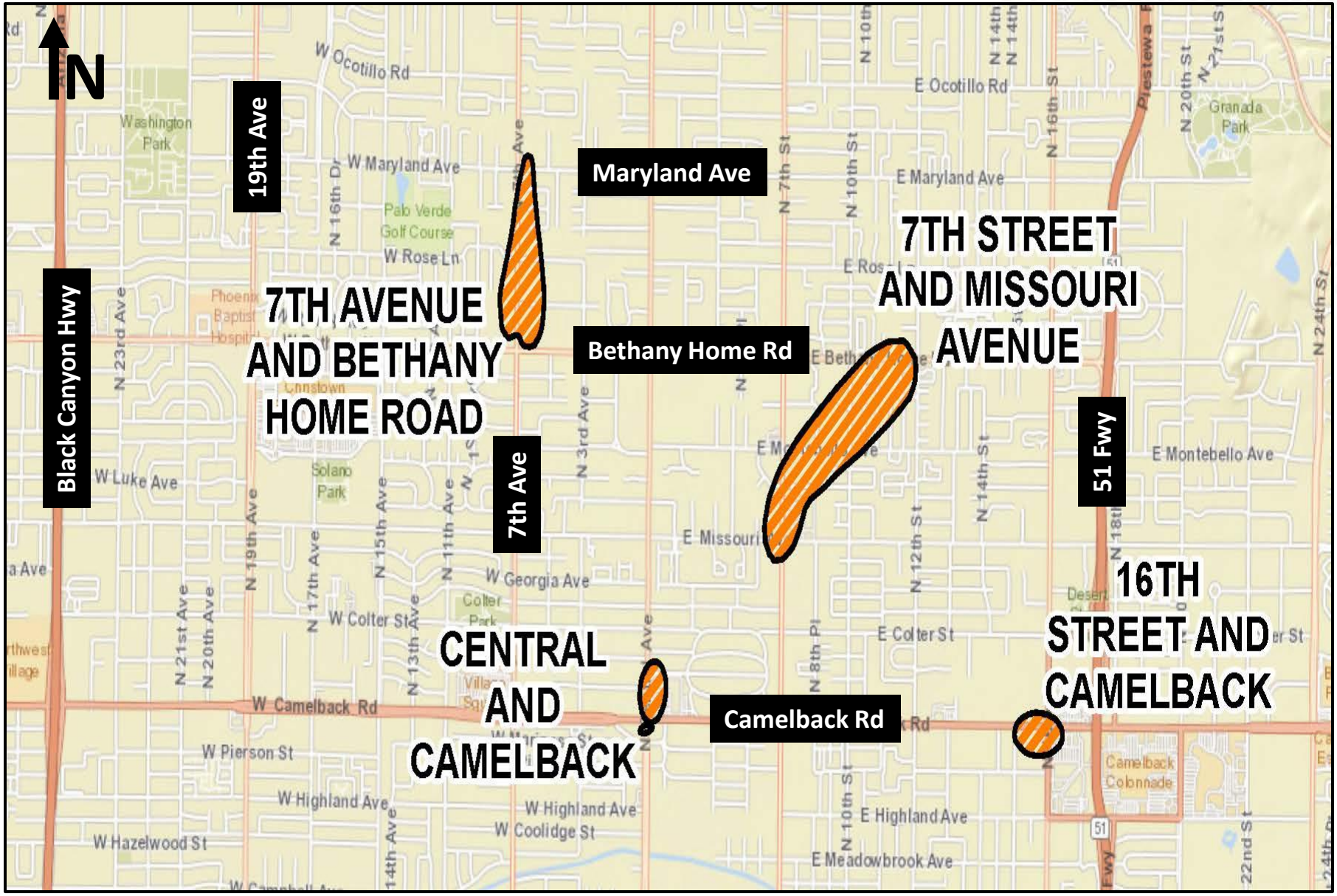
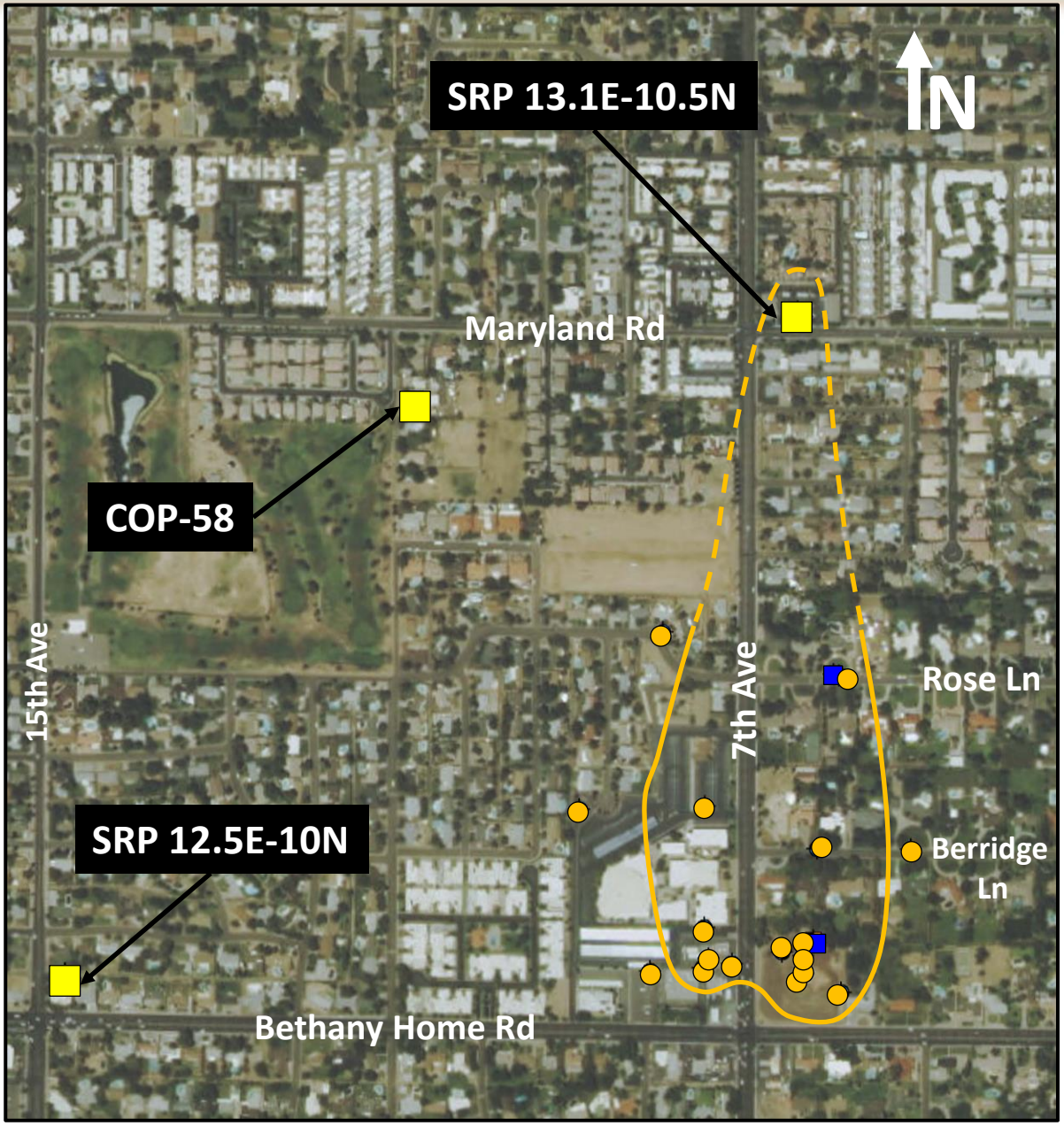
Site Location Map



Need For Remediation

- Groundwater Impacted with Concentrations of Tetrachloroethene (PCE) Above the Aquifer Water Quality Standard (AWQS) of 5 Parts Per Billion (ppb)
- Source of Contamination is Two Former Dry Cleaners
- Groundwater Is Current Source of Irrigation Water and Future Source of Drinking Water

PCE Groundwater Concentrations (4/19)



- Water Supply Well
- Shallow Monitoring Well (70 to 110 ft bgs)
- Deep Monitoring Well (175 to 225 ft bgs)
- Concentration Contour (5 ppb)

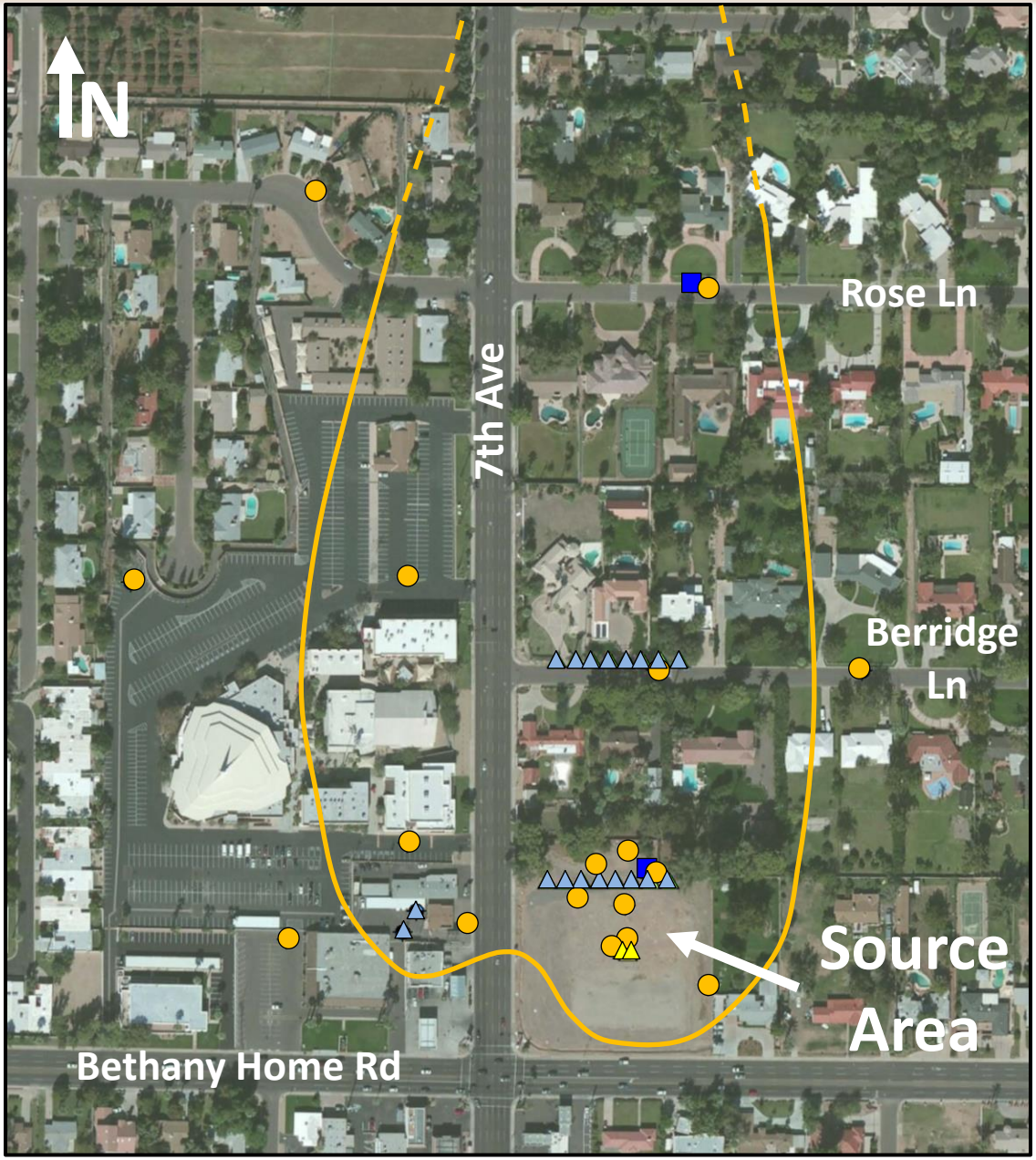
April 2019

PCE = <0.5 to 1,100 ppb

Depth to GW = 85 to 95 ft bgs

Flow Direction = North

Site Detail Map



- Existing Injection Well
- Shallow Monitoring Well
- Deep Monitoring Well
- Concentration Contour (5 ppb)

Groundwater Flow Direction is North

Project Technology and Design

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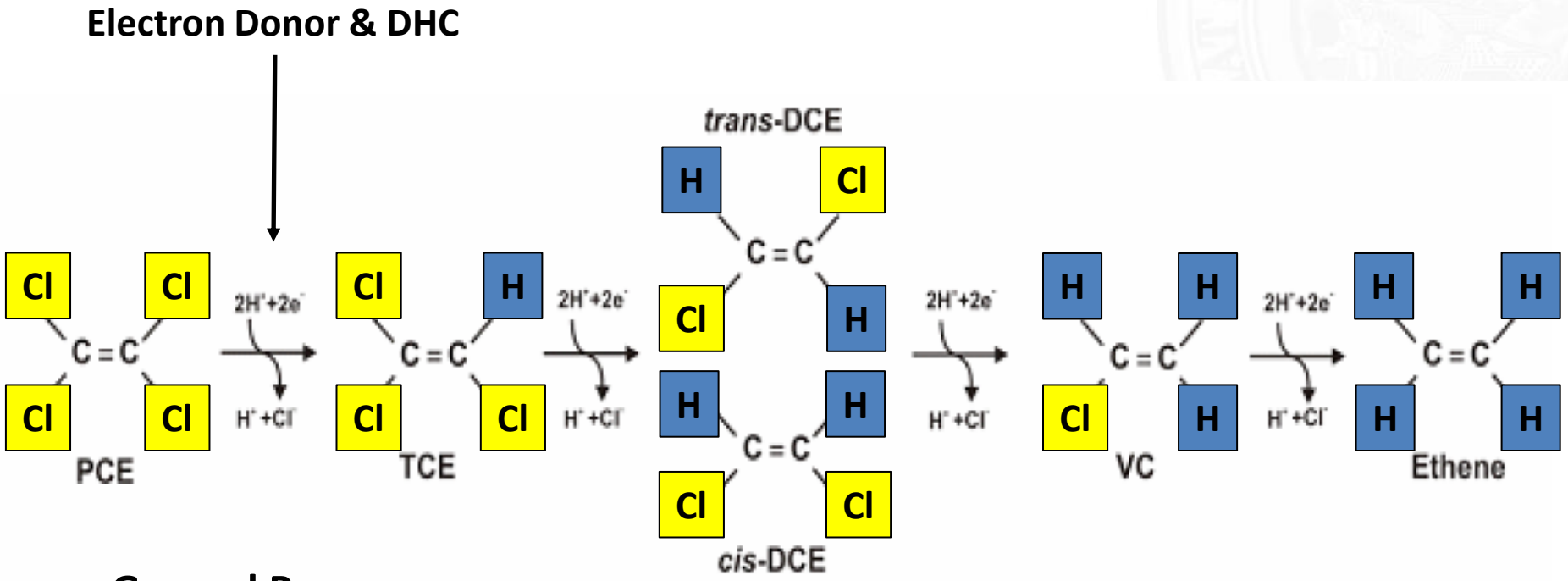
Reductive Dechlorination



General Process:

- Carbon Substrate Addition (Food & Hydrogen) - "Electron Donor"
- Degradation/Fermentation Creates Anaerobic Conditions
- Specialized Anerobic Bacteria (DHCs) Replace Cl with H
- Chlorinated Ethenes Act as "Electron Acceptors"
- Competition: Other "Electron Acceptors" (CO_2, SO_4, Fe, Mn, NO_3, O_2)
- DHC Bacteria Added if Necessary - "Bioaugmentation"

Injection Design

Injection Well Vertical Interval (ft)	Target ROI (ft)	Assumed Mobile Porosity (%)	1 Pore Volume (gal)	Target Injection Pore Vol (%)	Injection Vol per Well @ 100% PV
ft	ft	%	gal	%	gal
15	15	25.0%	19,827	100%	19,827
screen interval length	*based on 30-ft spacing*	*based on Arcadis Pilot Study*		*based on Arcadis Pilot Study*	

# of screens	16	each	**Recommended EOS Remediation Product Amounts**		
EVO concentration	2%	%	**EOS Pro**	27 totes	7087.5 gals
Water requirement @ 100% Pore Vol[1]	310,145	gal	**BAC-9 (concentrated)**	152 Liters	40 gals
EOS Pro Vol	7,088	gal			
BAC-9 (concentrated) Vol	152	liters			
BAC-9 (concentrated) Vol	40.2	gals			
EOS Pro per well	443	gal/well			
Hydrogen per well	895	lbs H_2/well			
Fluid per well @ 100% Pore Vol	19,827	gal/well			

[1] Mix water Vol = 100% of Pore Vol minus EOS Pro Vol

ALL BELOW ASSUMES 100% OF PORE VOLUME REQUIREMENT

Water to EOS Pro Oil Ratio	EVO Concentration (%)	Mix Water per Well (gal)[1]	EOS Pro per Well (gal)	Total Fluid per Well (gal)	Total Fluid for 16 Wells (gal)
50:1	2%	19,384	443	19,827	317,232

[1]Using a series of frac tanks, "mix water" will be produced using MW-4 groundwater that is 1) treated to remove VOCs using granular actvated carbon; 2) made anoxic with sodium ascorbate; and 3) bio-augmented with the BAC-9 bacteria product. Groundwater from select injection wells is also planned to be used as source water for hydraulic control and to enchance distribution of ERD injectants between injection wells.

Project Implementation

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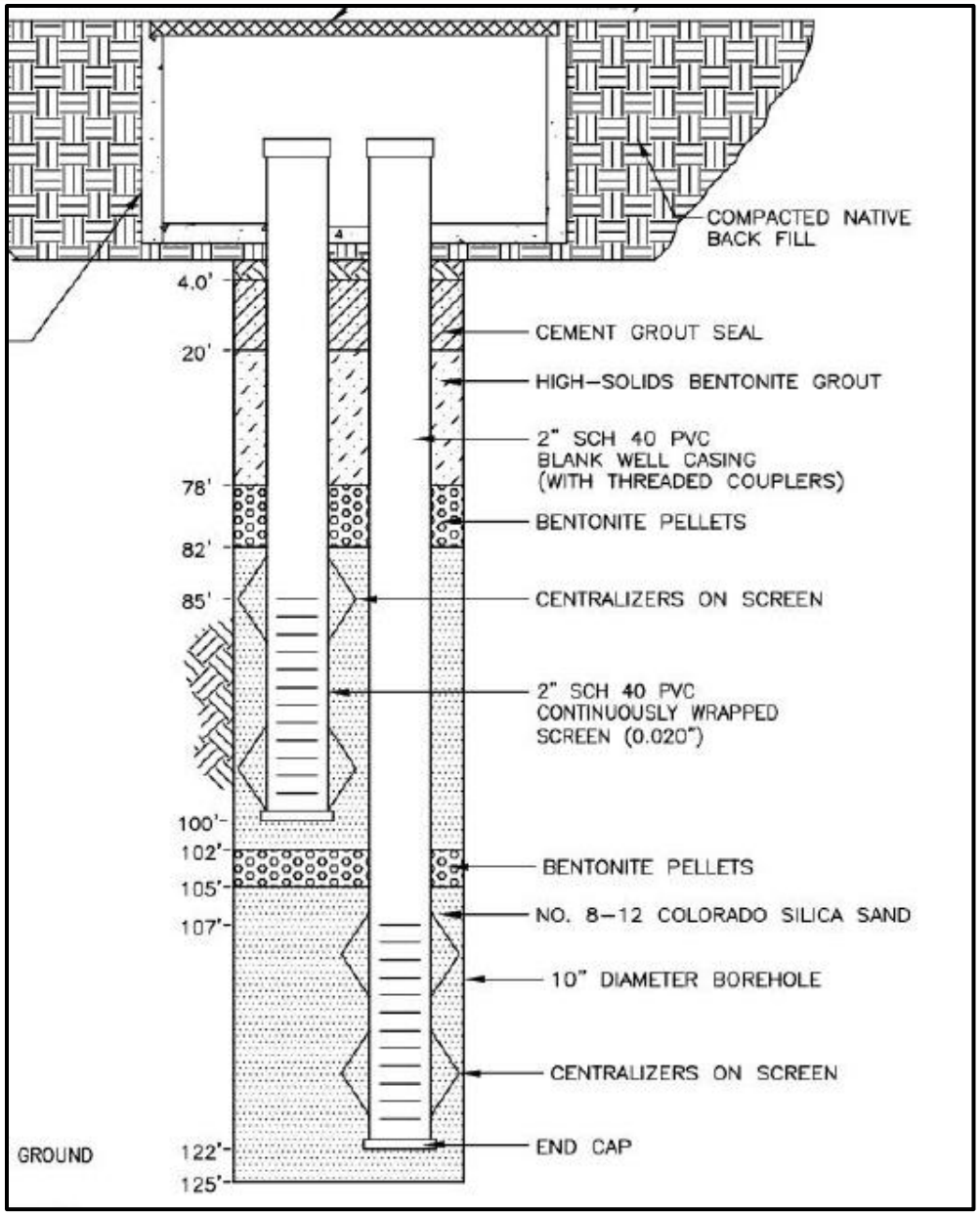
Injection Well Diagram



IW Screen Intervals:

- 85-100 ft bgs
- 107-122 ft bgs

Lithology:

- Sandy clay
- Sandy Silt
- Some silty sand

Hydraulic Conductivity:

- K = 25 to 75 ft/day

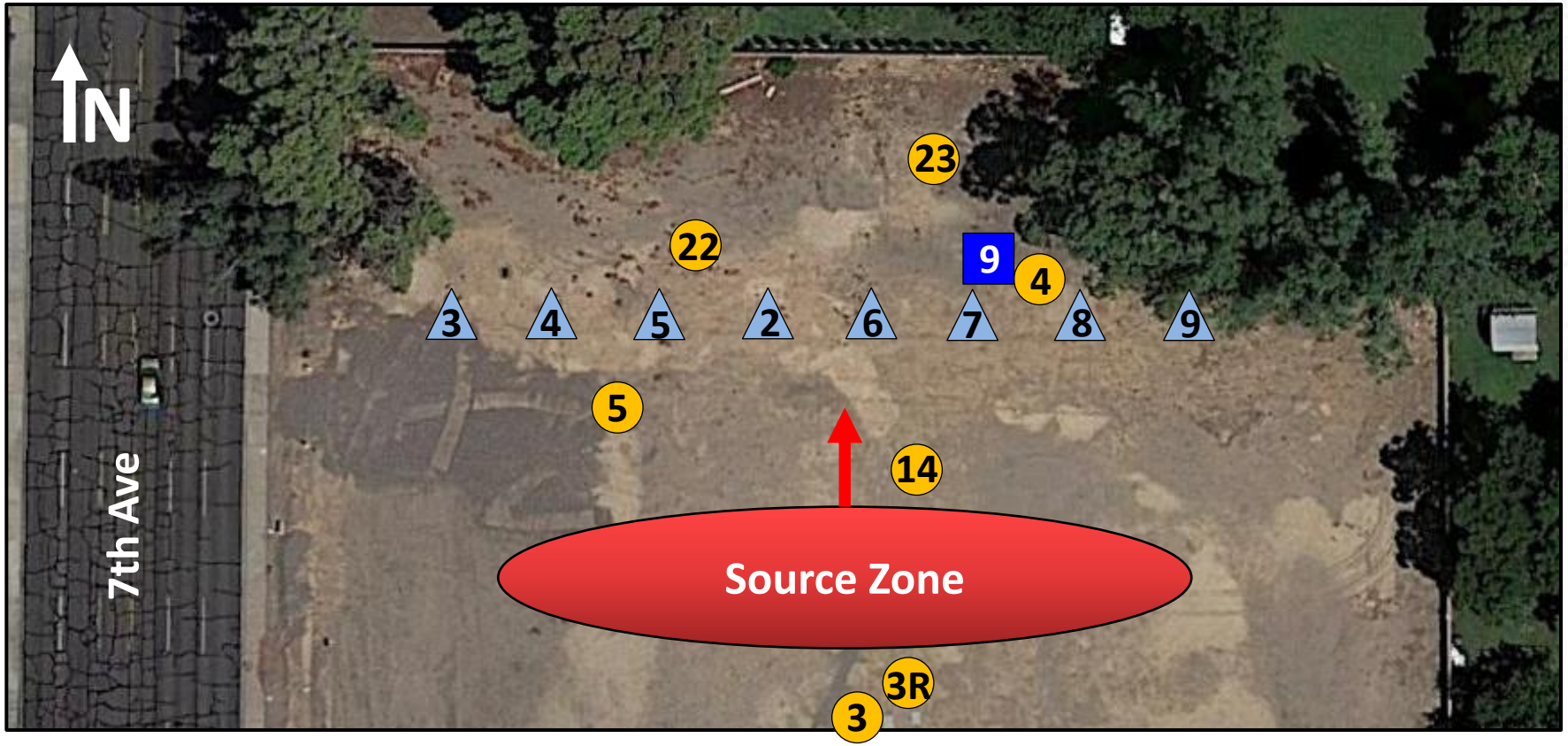
Groundwater Velocity:

- V = 0.35 to 1.05 ft/day

1 Year Travel Time:

- ~125 to 380 ft/yr

Source Area Detail Map



Injection Well (85 to 100 and 107 to 122 ft bgs) – 15 Foot ROI

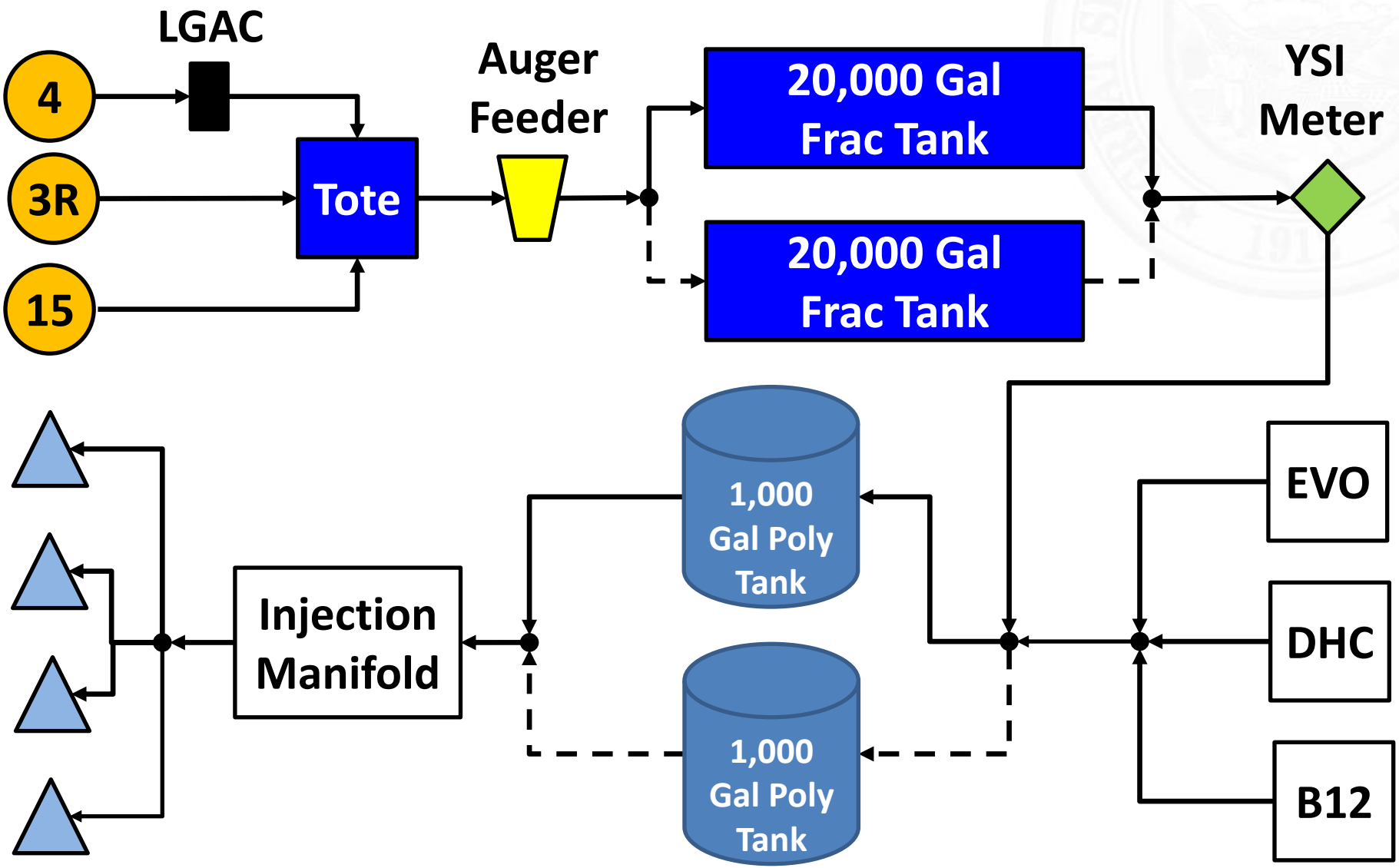
Shallow Monitoring Well (70 to 110 ft bgs)

Deep Monitoring Well (175 to 225 ft bgs)

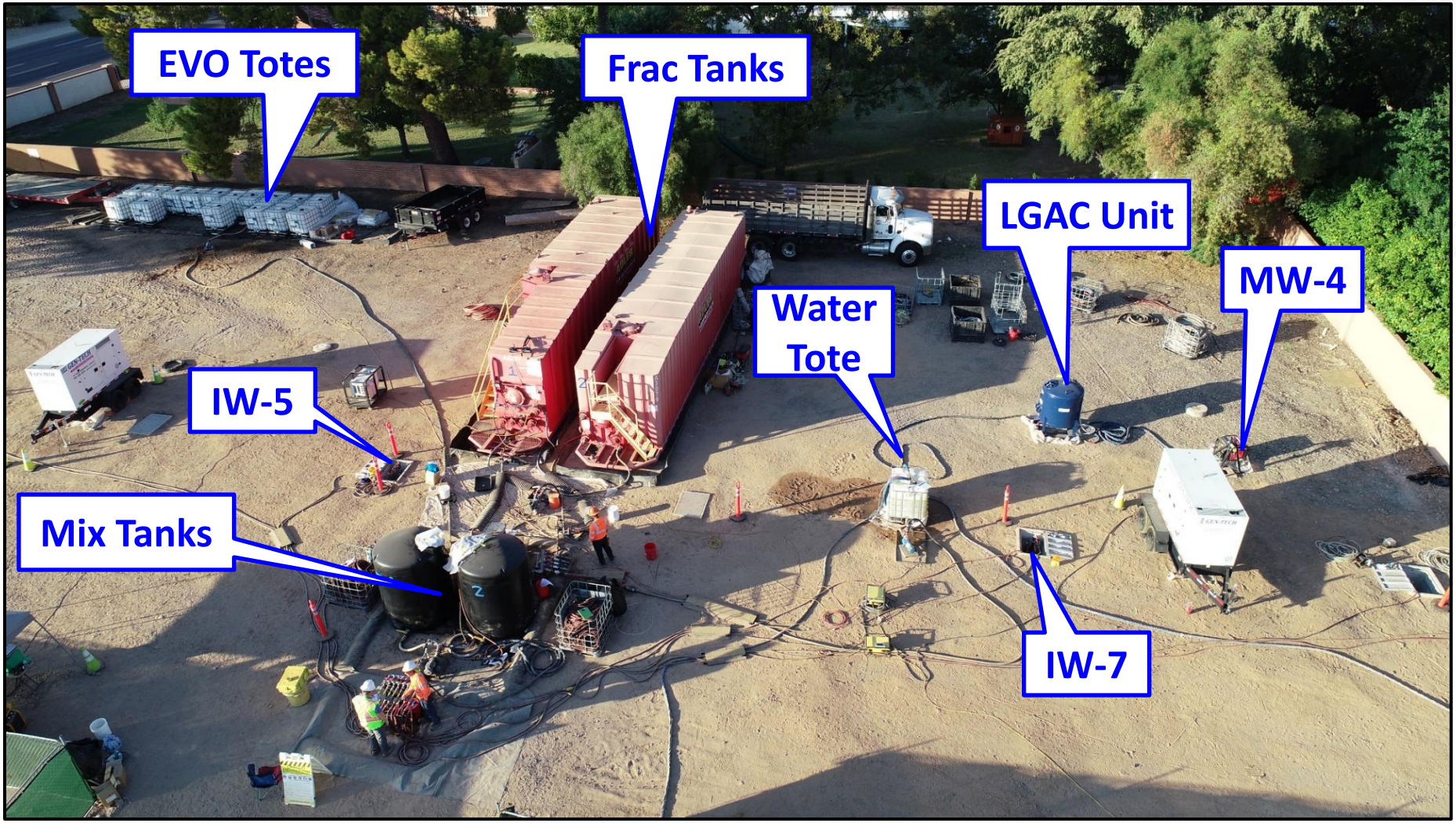
Field Process Summary

- Step 1 = Extract Site Groundwater, Treat for VOCs, Make Anoxic, and Store in Frac Tanks
- Step 2 = Prepare Batch Injection Fluid
  - Meter Anoxic Water to Mix Tanks
  - Meter EVO, DHC, & B12 to Mix Tanks
- Step 3 = Injection via Manifold
  - Phase 1 = Even Wells
  - Phase 2 = Odd Wells
- Step 4 = Performance Monitoring

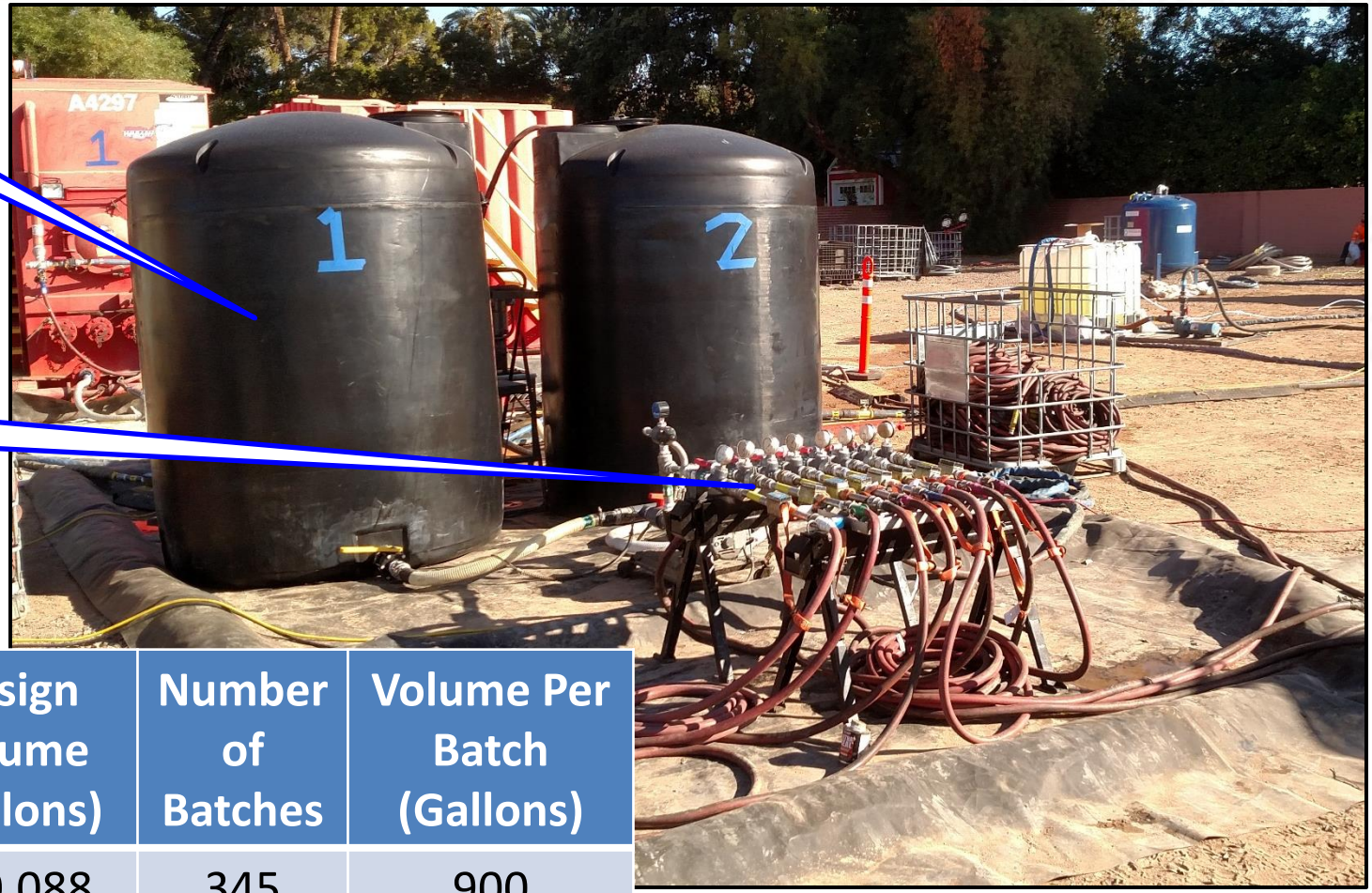
Simplified Process Flow Diagram



Equipment Set-Up

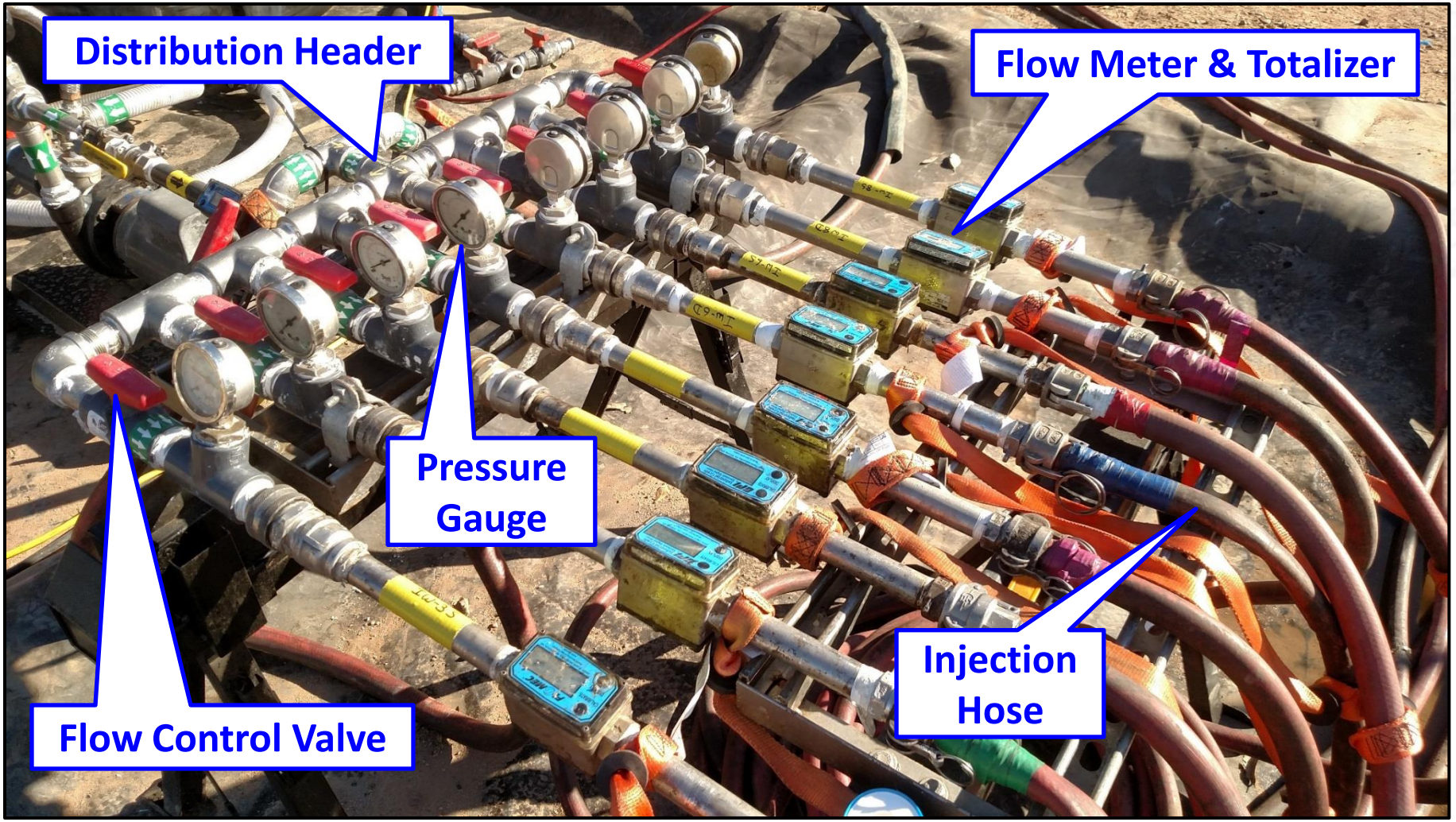


Mix Tanks & Injection Manifold



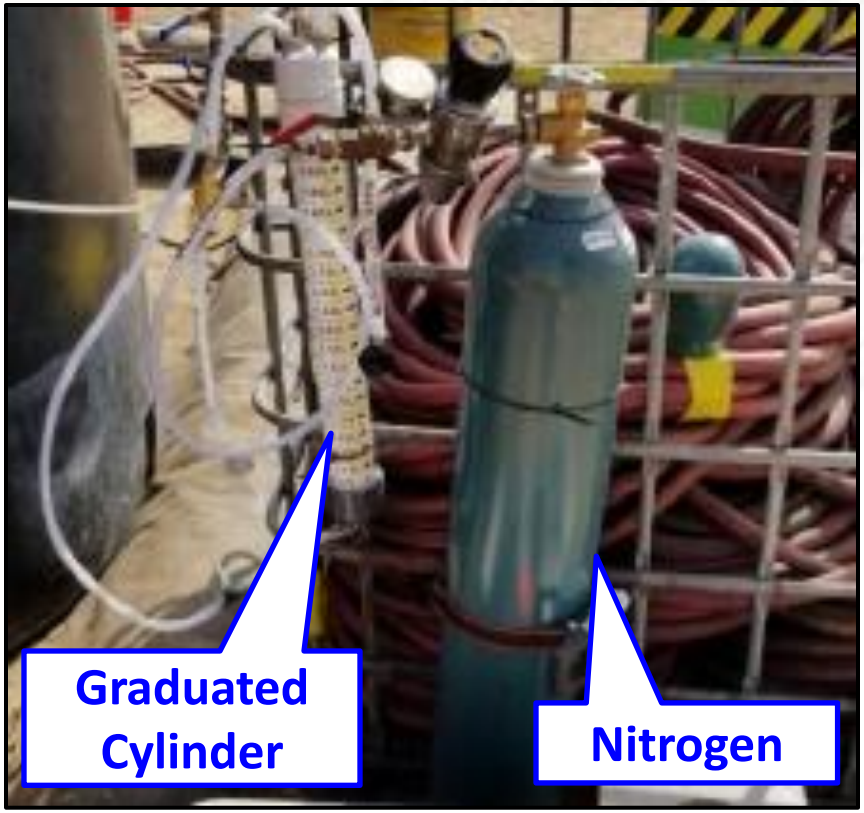
Ingredient	Design Volume (Gallons)	Number of Batches	Volume Per Batch (Gallons)
Water	310,088	345	900
EVO	7,088	345	20.5
DHC	10	345	110 mL
B12	1,120 oz	345	6 oz

Injection Manifold



Transfer Pump, Feed Auger & Hoses

Bioaugmentation



DHC Dosage

DHC @ 110 mL/Batch

Performance Monitoring

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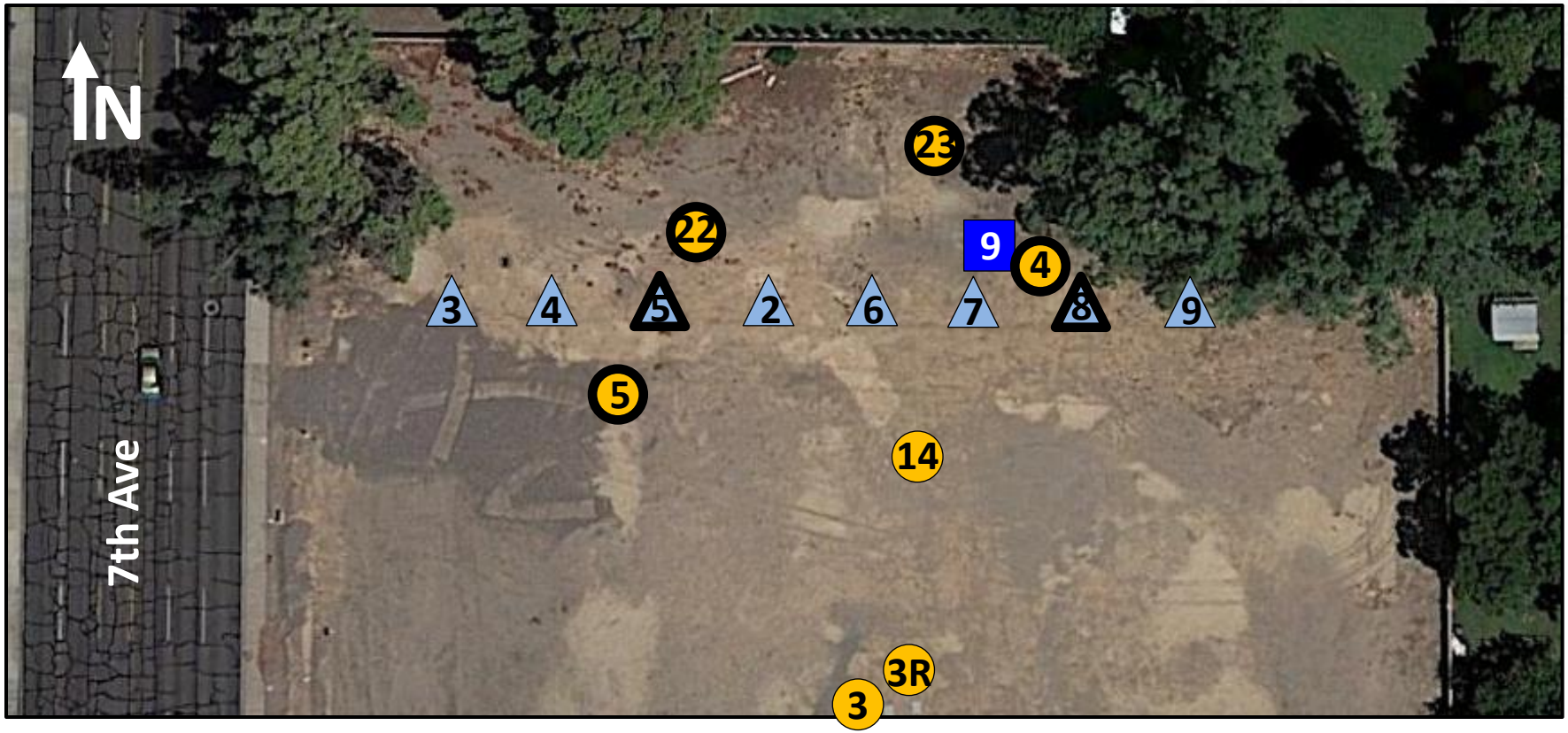
Sampling Plan

Parameter	Purpose	Sample Schedule
Volatile Organic Compounds	Contaminant Reduction	<u>Pre-Injection</u> Baseline <u>Post Injection</u> 30 Days 60 Days 120 Days 6 Months 12 Months **18 Months** 24 Months
Iron, Manganese, Nitrate, Sulfate, Dissolved Oxygen, & Oxidation Reduction Potential	Reducing Conditions	
Total Organic Carbon	Radius of Influence & Amendment Duration	
Methane, Ethene, & Ethane	Full Dechlorination	
pH	Toxicity for Bacteria	
DHC & Functional Groups	Bacteria Concentration	

Performance Well Network



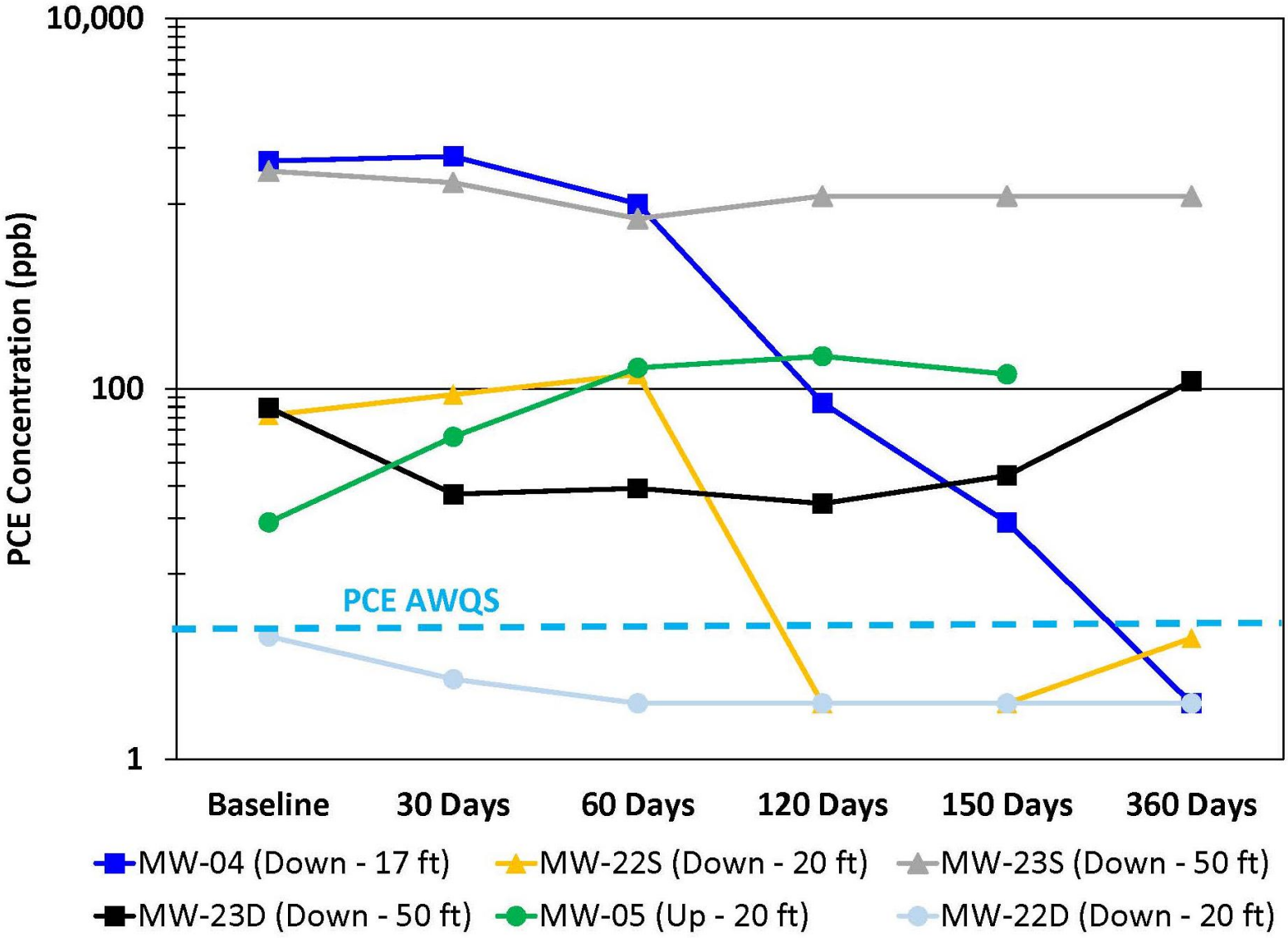
Injection Well

Shallow Monitoring Well

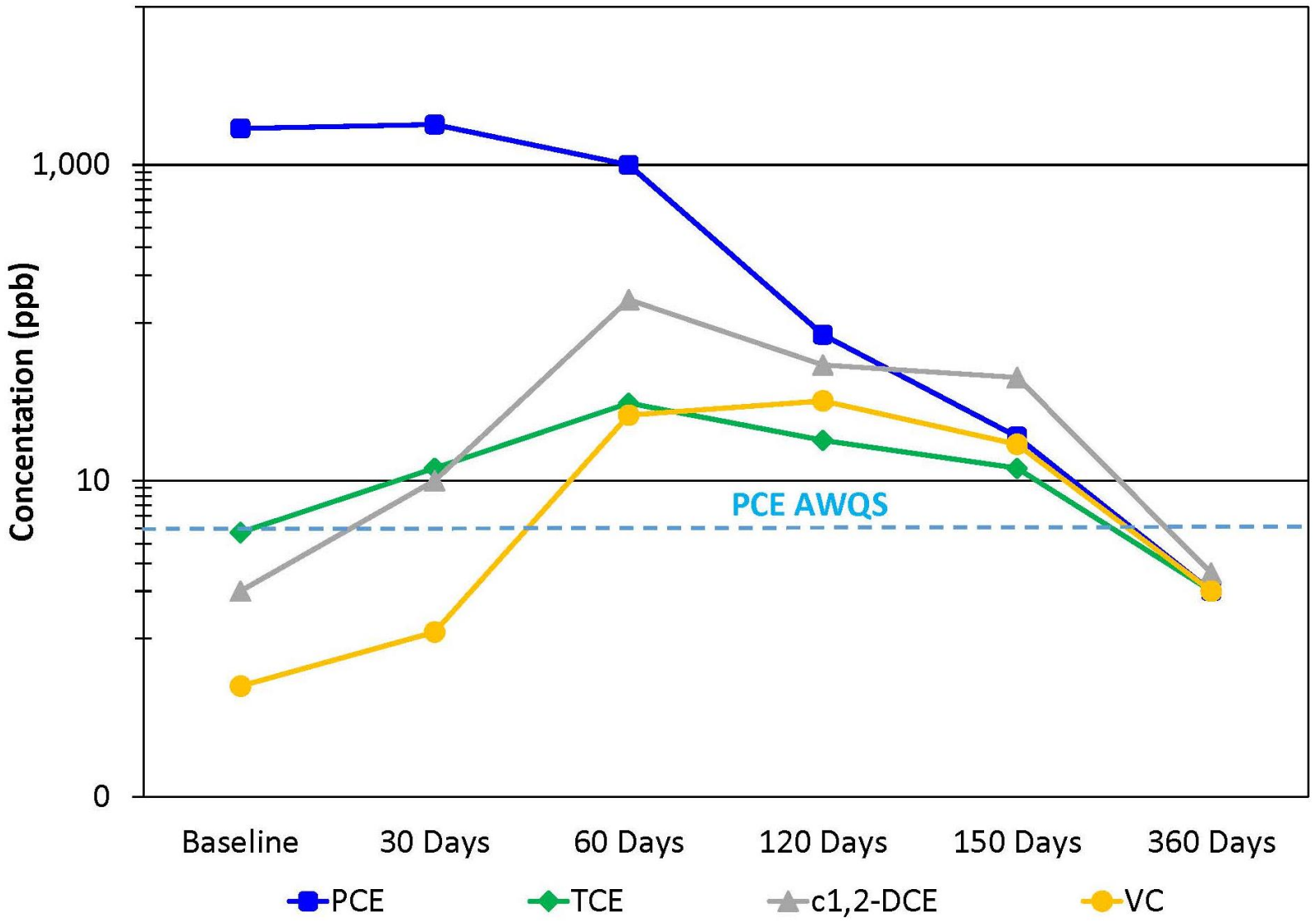
Deep Monitoring Well

*Performance Monitoring Wells Have **BOLD** Outline

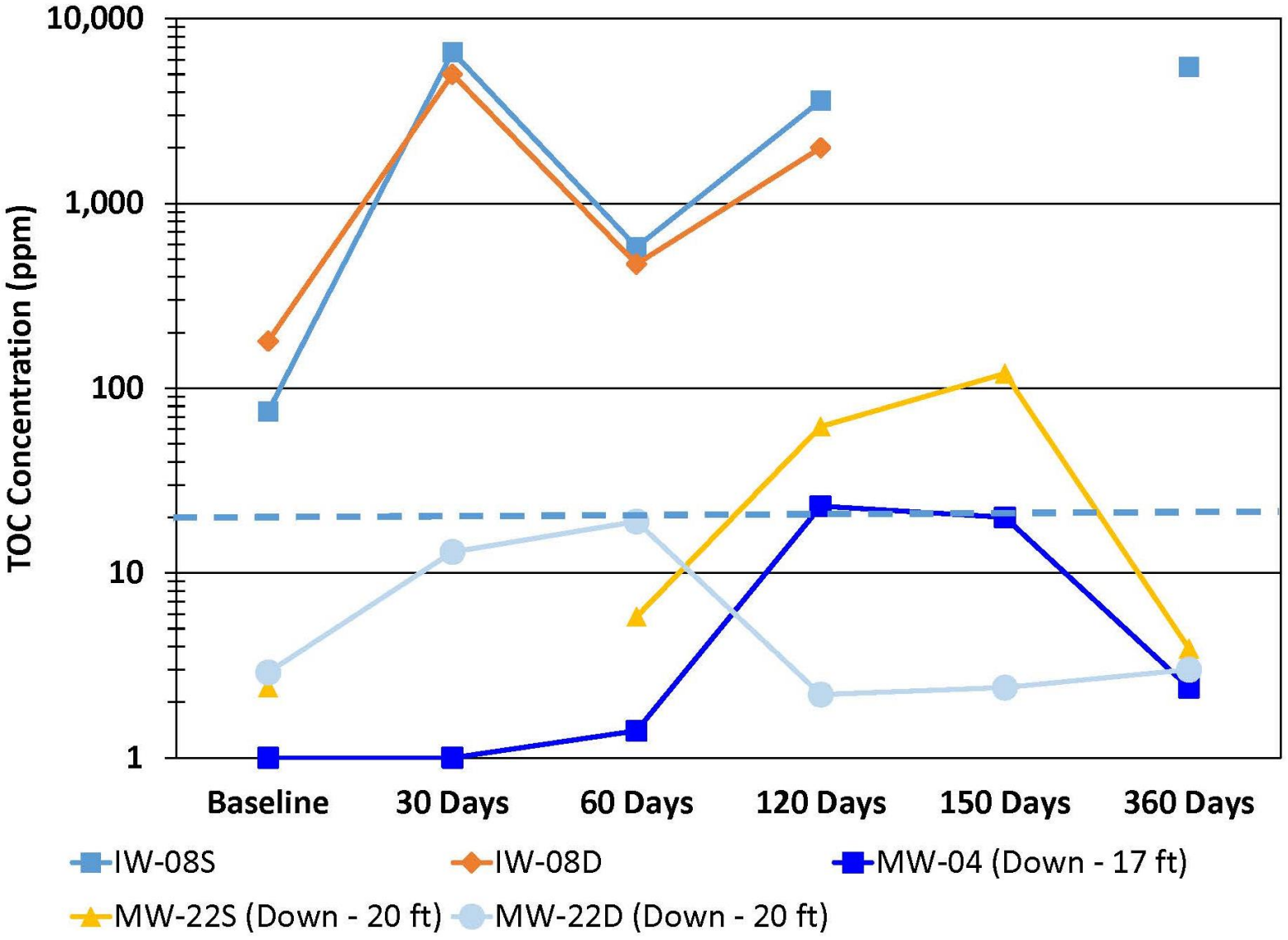
PCE Concentration Trend



MW-04 – VOC Concentration Trend



TOC Concentration Trend



Performance Monitoring Summary

Component	MW-04	MW-22S	MW-23S
Location	Down-Gradient	Down-Gradient	Down-Gradient
Distance	17 feet	20 feet	50 feet
PCE Trend	1,700 to <2 ppb	72 to 4.5 ppb	79 to 110 ppb
Daughter Products	TCE, c1,2-DCE, & VC	TCE, c1,2-DCE, & VC	TCE & c1,2-DCE
Reducing Conditions	Yes	Yes	Slight
Amendment @ Well	Yes	Yes	No
DHC (cells/mL)	Good (>10E04)	Low (~7.0E-01)	OK (8.5E02)
pH Range*	6.94 to 7.31	6.31 to 7.08	6.91 to 7.25

*pH Drop Observed Injection Wells From Background (~6.8) to Low (4.53 to 5.0)

Conclusions & Lessons Learned

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Conclusions - Successes

- PCE Concentrations Reduced in Shallow Zone Monitoring Wells
- Reducing Environment Established
- ROI = 20 feet
- Full Dechlorination at MW-04

Conclusions - Concerns

- Long Field Duration (Oct 22 to Nov 20, 2018)
- Low Injection Flow Rates (<1.5 gpm) at Some Injection Wells
- Amendment Observed in Injection Well Casing = Some Amendment Not Injected into Formation
- High TOC at Injection Wells and Low TOC at Monitoring Wells
- Low pH (4.53 to 5.0) Observed in Injection Wells = Bad for DHC

Lessons Learned / Optimization

- Redevelop Injection Wells Prior To Conducting Injection Event
- Modify Injection Method = 25% Envelope; 65% EVO, DHC, Etc.; and 10% Chase Water vs 99% Fluid and <1% Chase Water
- Consider Pore Volume Target of 50% to 75% vs 100%
- Consider a Soluble Amendment (Corn Syrup or Molasses) or Modify EVO Recipe with Greater % Soluble Components
- Re-evaluate Buffer Amount / Supplemental Buffer Injection

Questions

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Questions?

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