In Situ Bioremediation of Chlorinated Solvents at a Low pH Site

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SUPPORTING [DOING] LEADING

Outline

- Site Overview
- Treatment Approach
  - Importance of pH
- Results
- Conclusions

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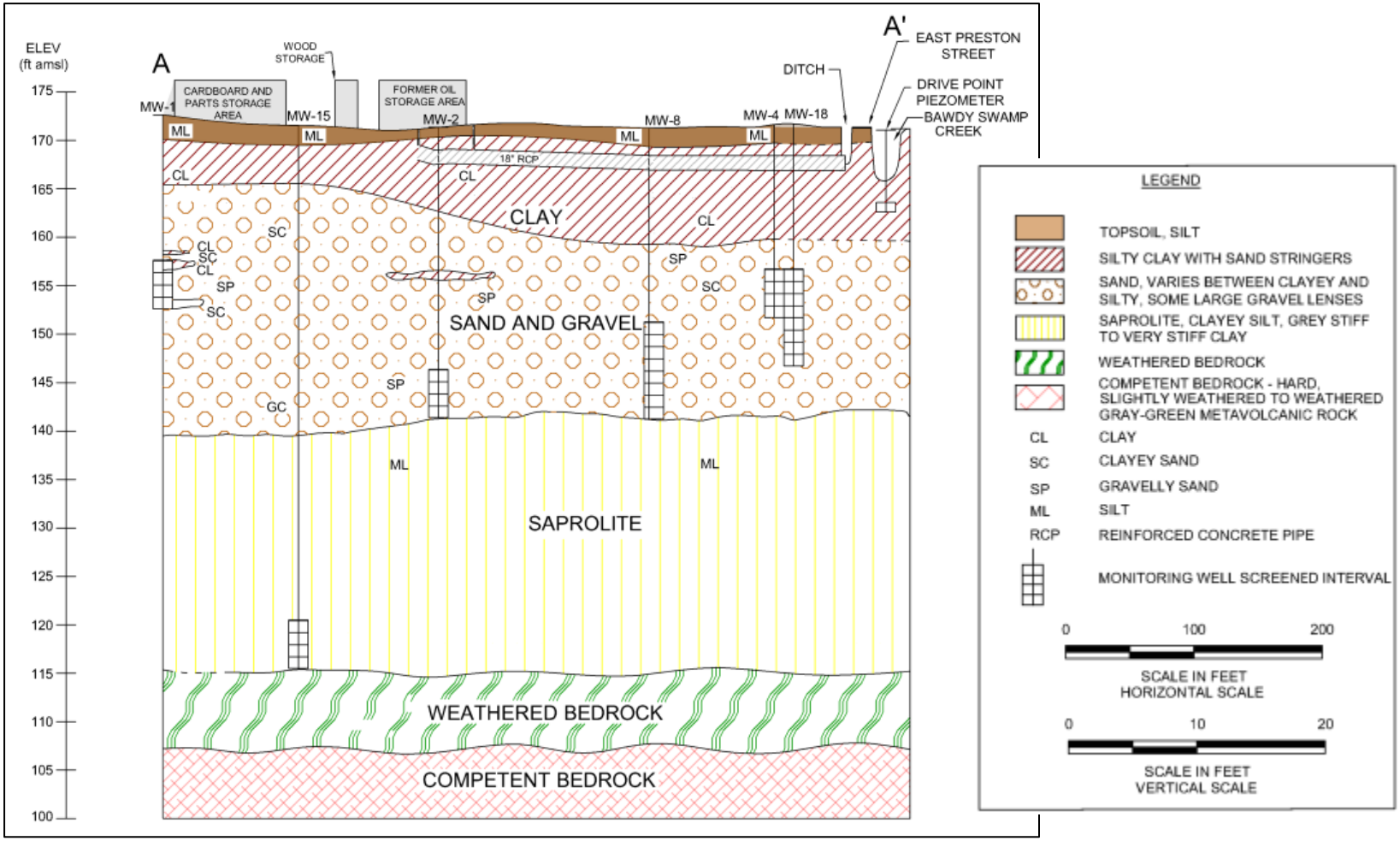
Site Overview

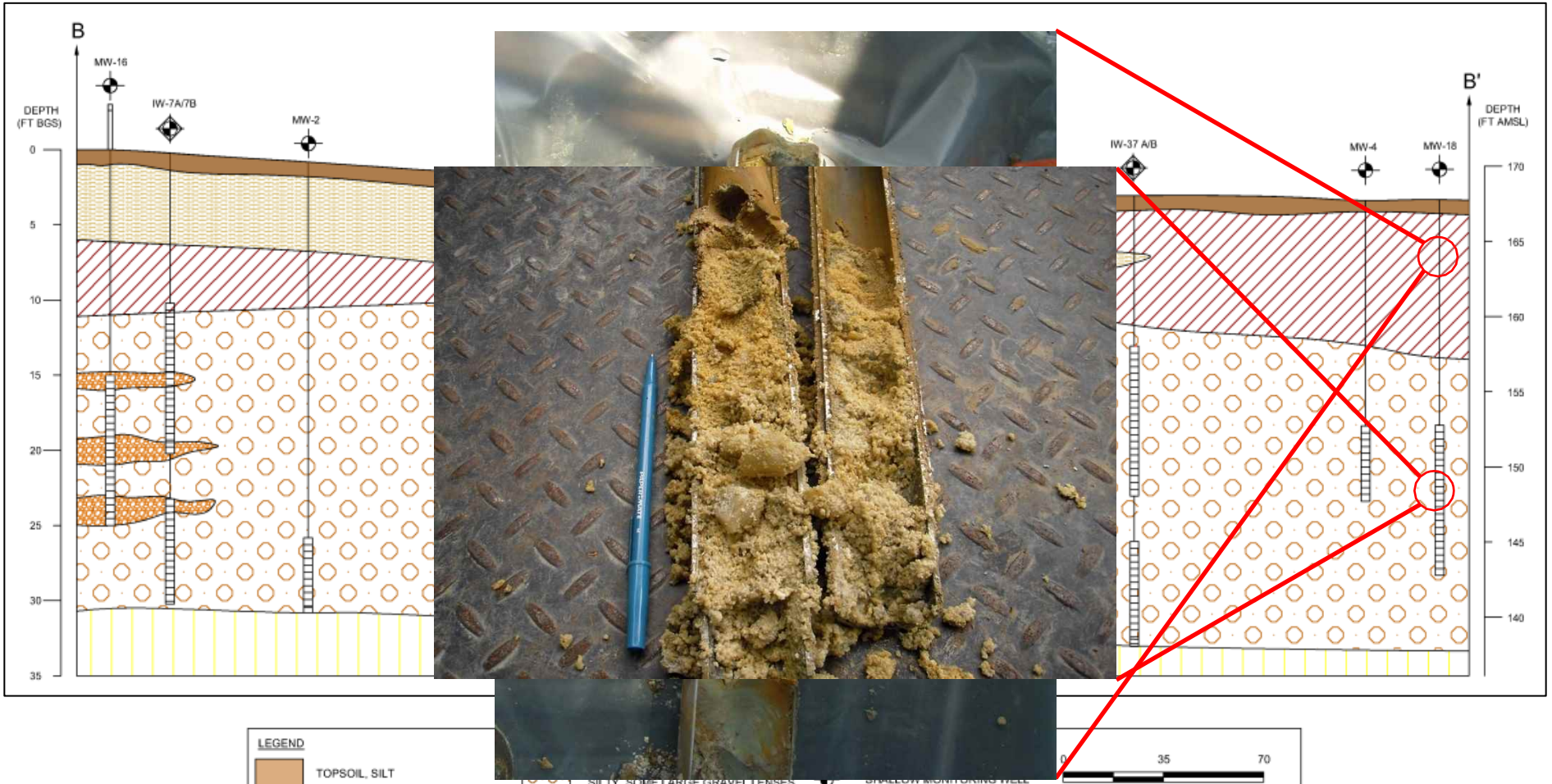
- Former industrial facility in eastern NC
- Contaminated soil and groundwater through inadvertent release of PCE to a storm sewer

Site Overview

- Shallow silty-clay layer (0 to 10-18 ft bgs): Up to 3,000 mg/kg PCE and 149 mg/kg TCE
- Confined sand and gravel aquifer (15 to ~35 ft bgs): Up to 140 mg/L PCE and 36 mg/L TCE
- Piezometric surface varies from 1 to 10 ft bgs

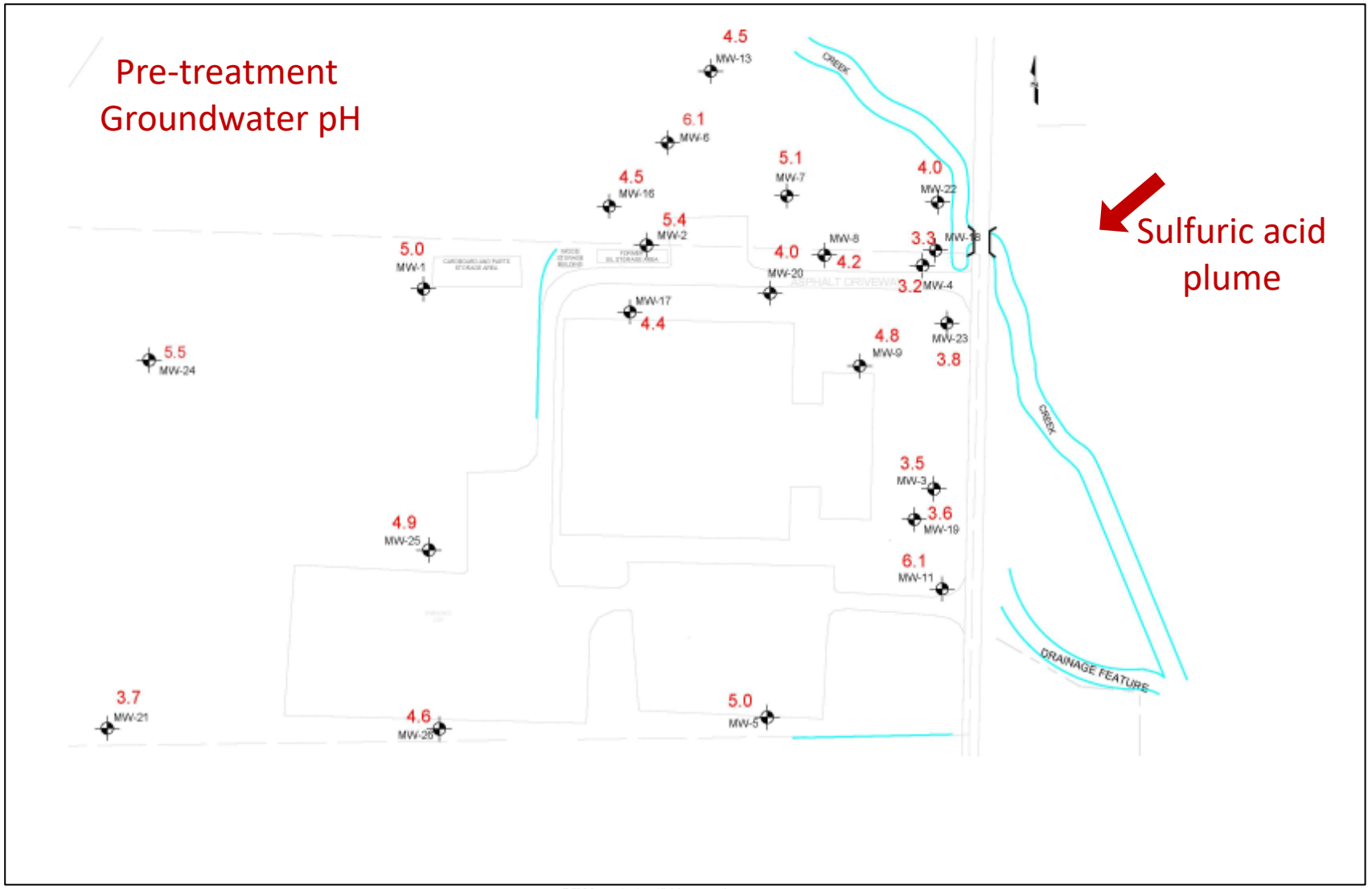


Site Overview



Site Overview

- Aquifer pH as low as 3.2 SU due to an off-site sulfuric acid plume

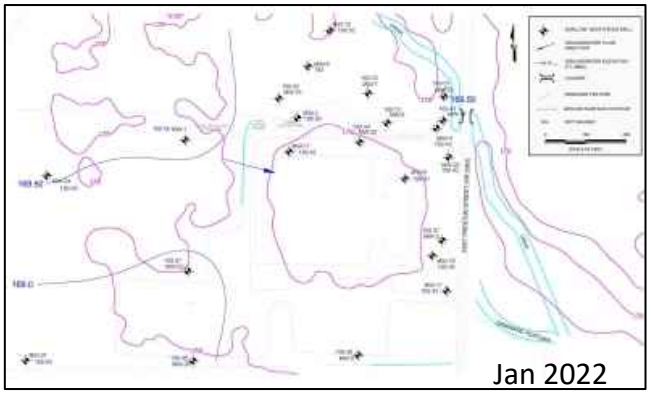


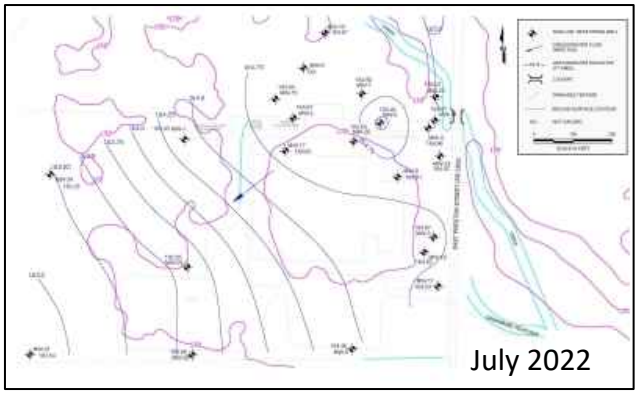
Treatment Approach

In-situ Bioremediation/Enhanced Reductive Dechlorination (ERD) to address GW contamination

Treatment Hurdles:

- Very high CVOC concentrations
- Low pH
- High sulfate concentrations
- Back diffusion from low permeability zones can result in a long-term slow-release source of contamination
- Low hydraulic gradient (0.001-0.002 ft/ft)
- Fluctuating GW direction


Jan 2022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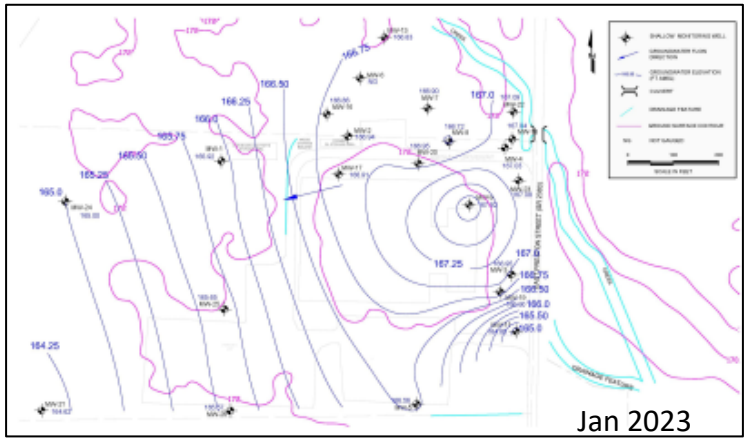
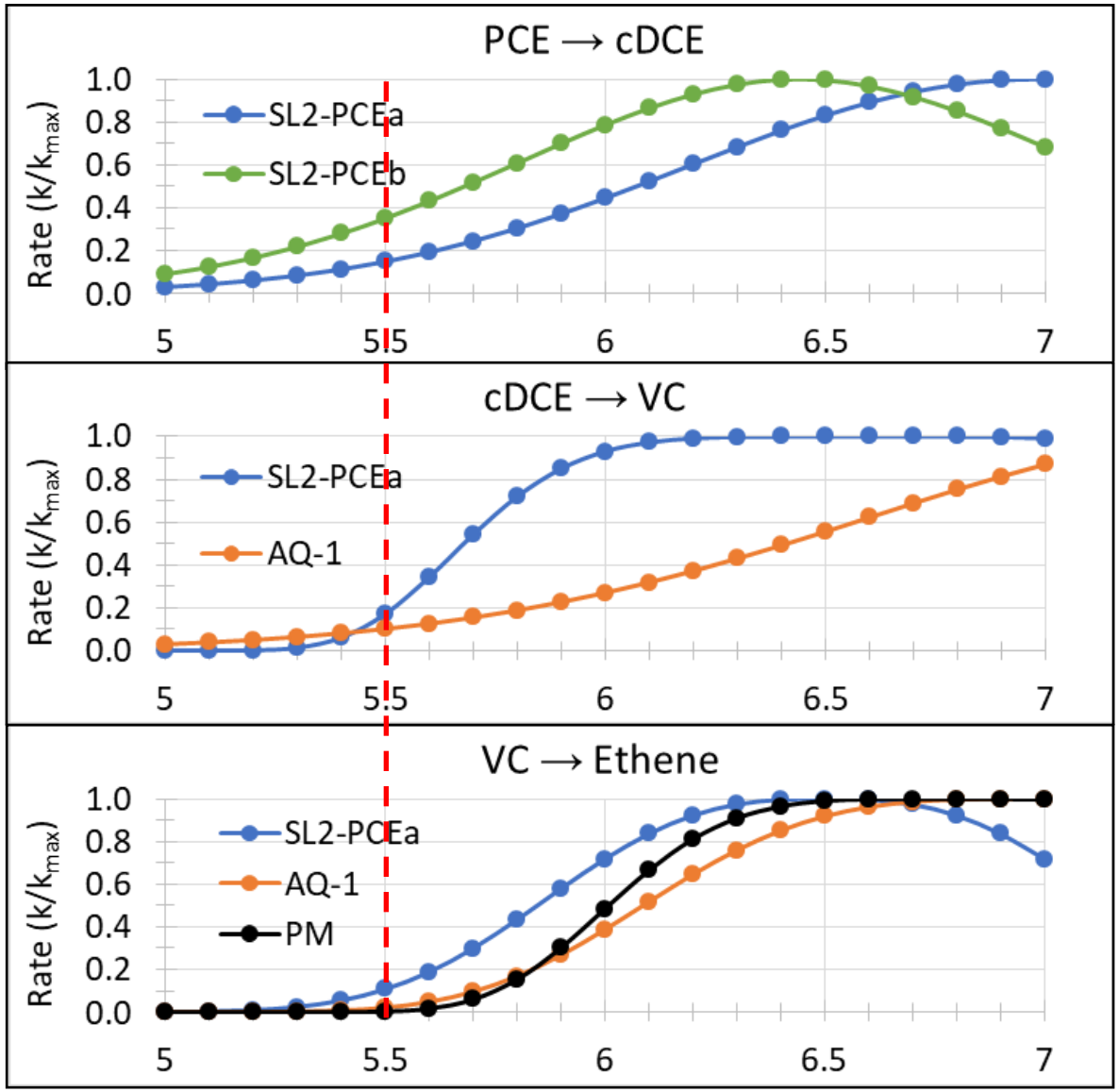

Jan 2023

Importance of pH



- Completed dechlorination to ethene is inhibited at pH below 5.5
- Dechlorination rates are highest at circumneutral pH

Lacroix et al.,
Appl. Environ. Micro,
July 2014

Importance of pH

Acidity from Fermentation of Substrate

Sodium Lactate ($NaC_3H_5O_3$)

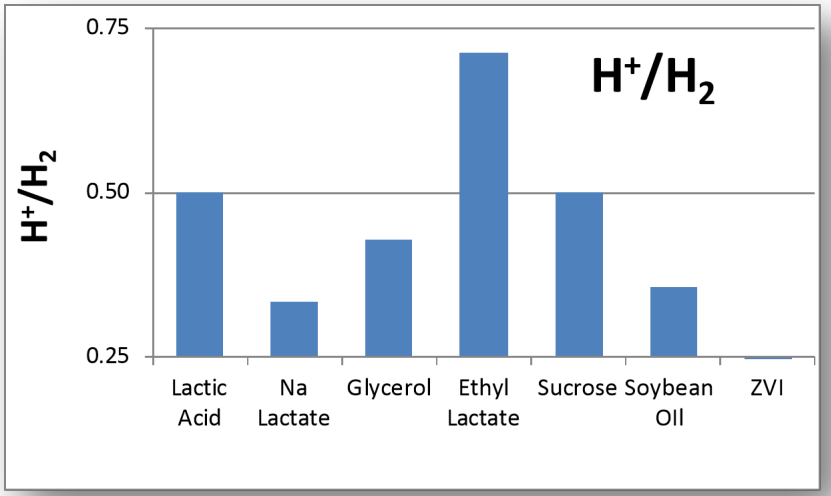
$NaC_3H_5O_3 + 6H_2O \rightarrow$

$\mathbf{6H_2} + 3HCO_3^- + Na^+ + \mathbf{2H^+}$

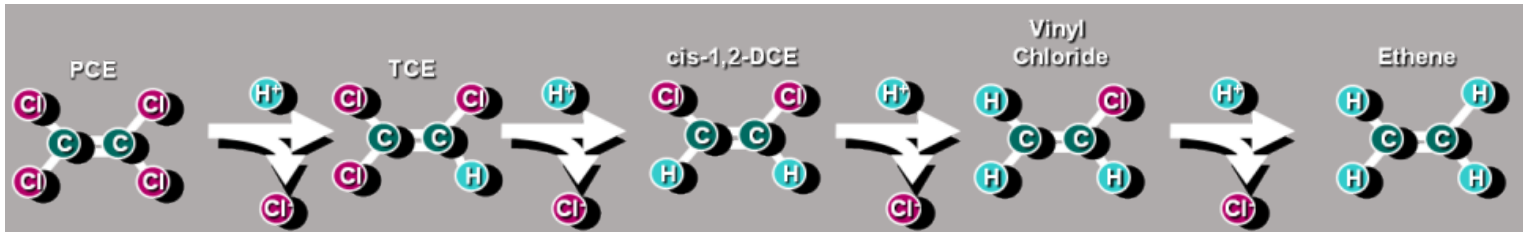
Soybean Oil ($C_{56}H_{100}O_6$)

$C_{56}H_{100}O_6 + 162H_2O \rightarrow$

$\mathbf{156H_2} + 56HCO_3^- + \mathbf{56H^+}$



Acidity from Reductive Dechlorination

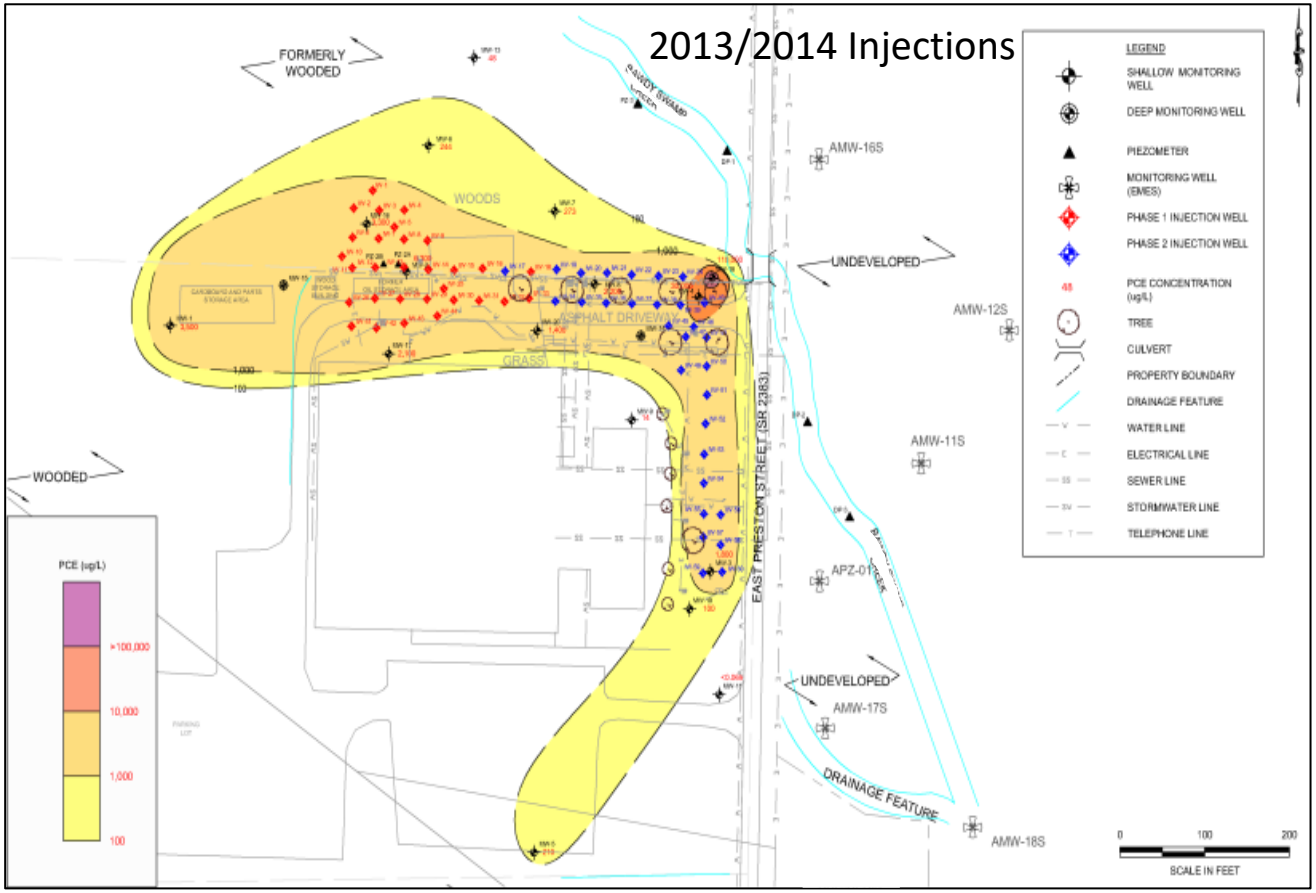


C_2Cl_4 (PCE) + $4H_2$ → C_2H_4 (ethene) + **4HCl**

Treatment Approach

In-situ Bioremediation/Enhanced Reductive Dechlorination (ERD) to address GW contamination

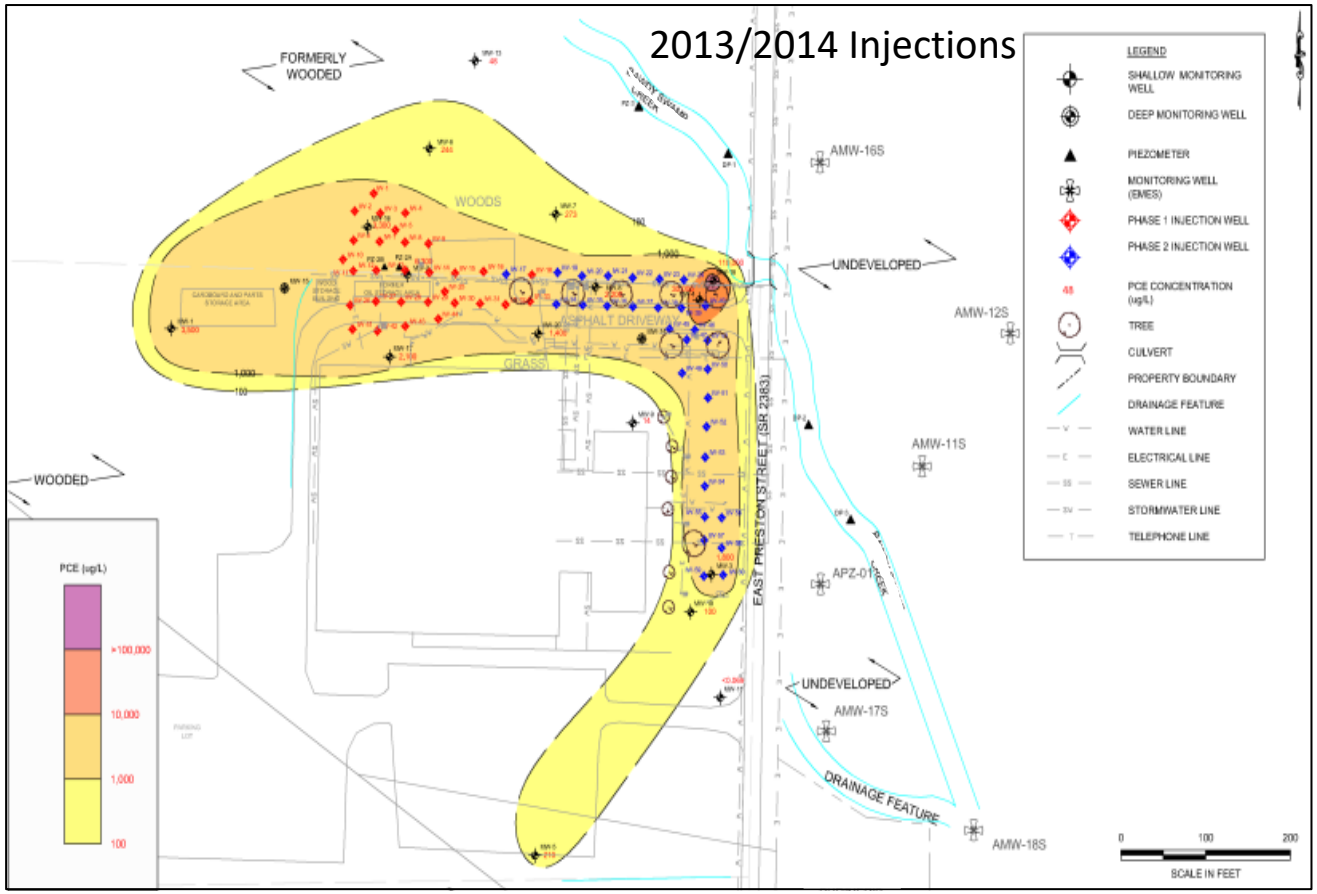
- 67,000 ft^2 injection area
- 120 injection wells
- 60 nested well locations
- Shallow (10-20 ft bgs) and deep screens (23-30 ft bgs)
- Injections in 2 phases



Treatment Approach

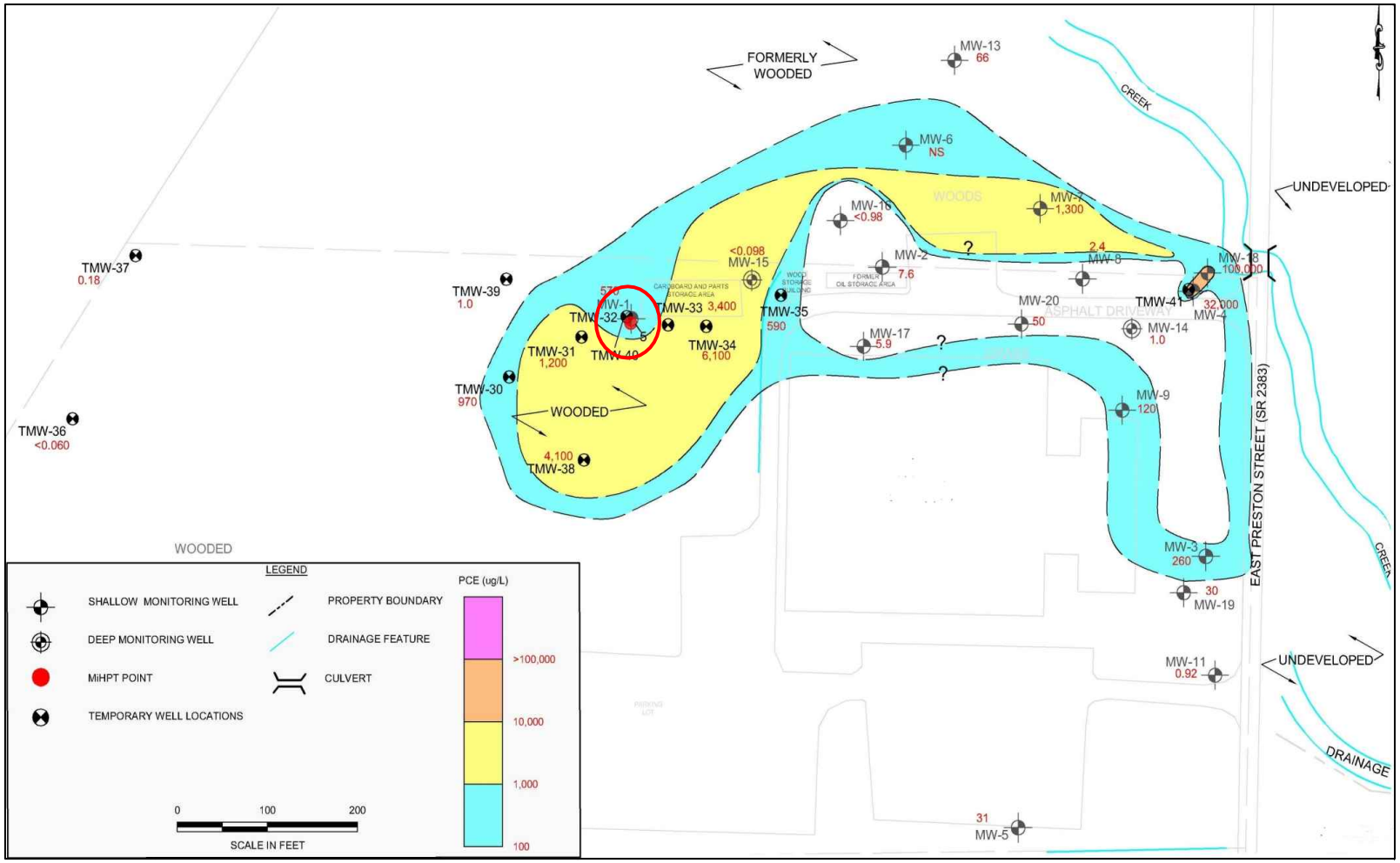
In-situ Bioremediation/Enhanced Reductive Dechlorination (ERD) to address GW contamination

- ~100,000 lbs Extended release EVO substrate (EOS XR; EOS Remediation)
- ~3,200 lbs Slow-release colloidal buffer (CoBupHMg™; EOS Remediation) to raise pH
- 120 L Bioaugmentation culture (BAC-9; EOS Remediation)
- Re-injections in 2016 (Phase 1) and 2020 (Phase 2) with nutrients and more buffer



Treatment Approach

- PCE and TCE concentrations in MW-1 remained elevated
- Additional site assessment/Plume delineation



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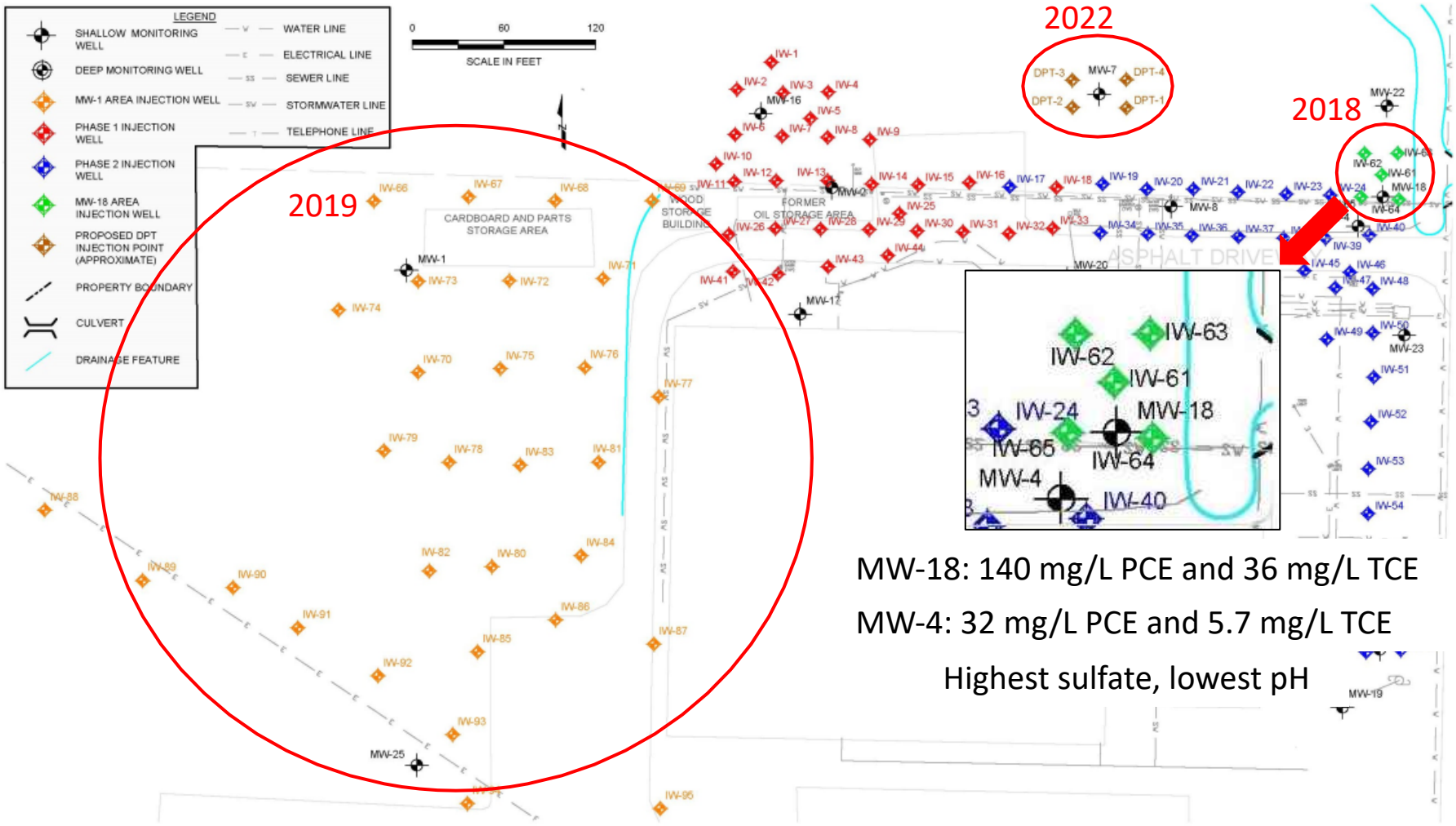


Treatment Approach

MW-18 Area :

- MW-18 was originally installed as a compliance monitoring well → revealed an area of elevated CVOCs separate from the original treatment area
- Very high CVOCs inhibit the biological activity
- Bioremediation not applicable without reducing CVOC concentration
- Potential approach
  - 'Saturate' high concentration area with vegetable oil
  - Oil acts as a sorbent reducing aqueous concentrations
  - Once CVOCs decline, oil will stimulate biodegradation

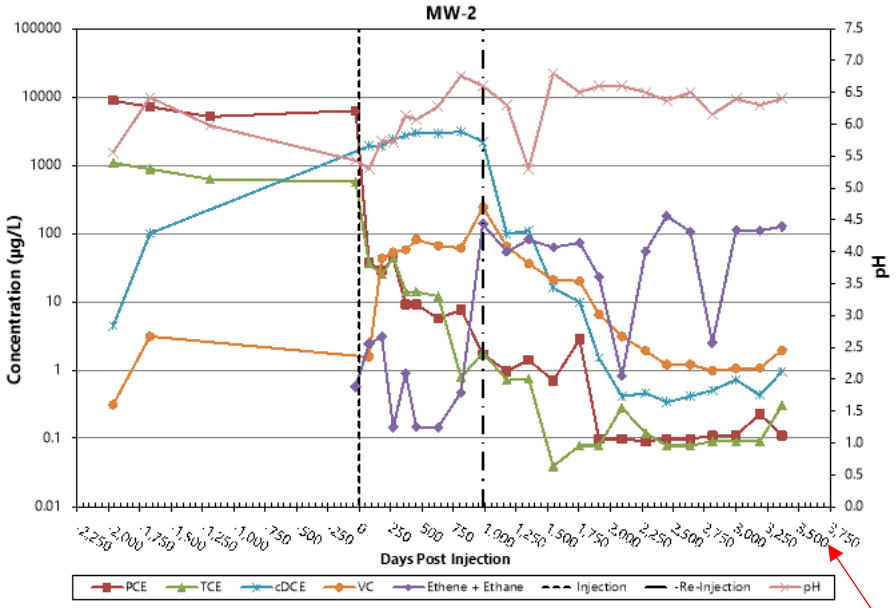
Injections:

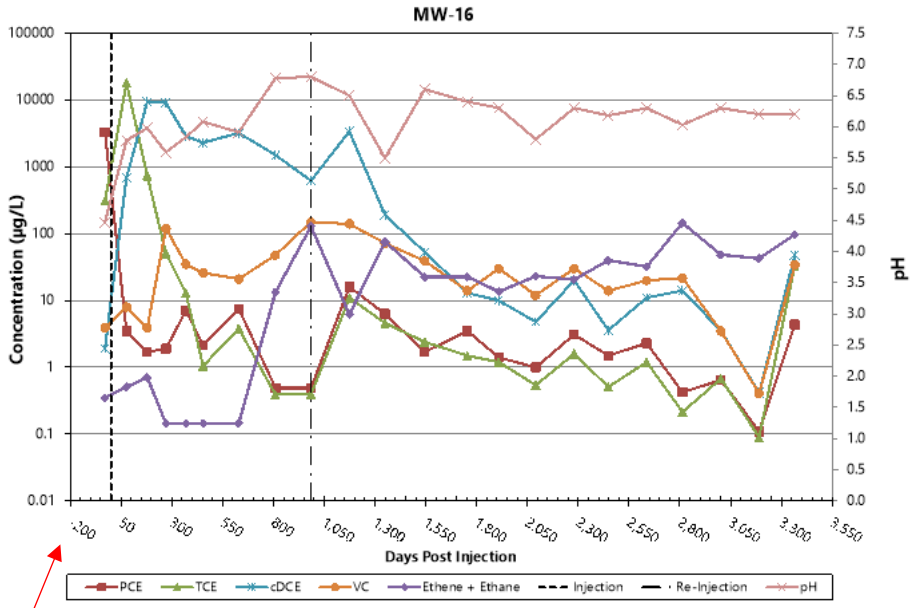
- 5,700 lbs glycerin (soluble substrate)
- 16,800 lbs EVO (EOS PRO) (long term substrate)
- 1,100 lbs Potassium bicarbonate (pH)
- 5,400 lbs CoBupHMg™ (pH)

Base Addition Design Tool (ESTCP project ER-20158)

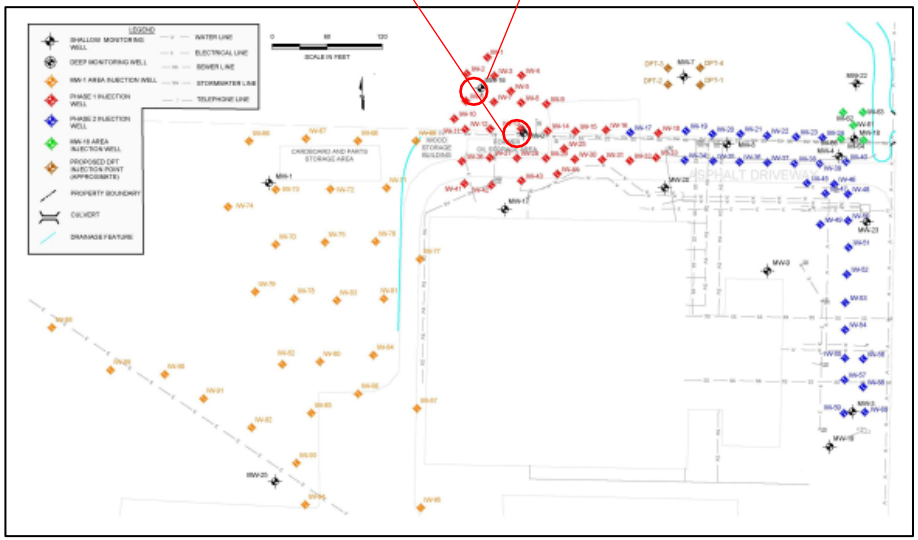
- 20 L BAC-9
- 300 lbs EOS ZVI (limited amount; abiotic degradation)

Results



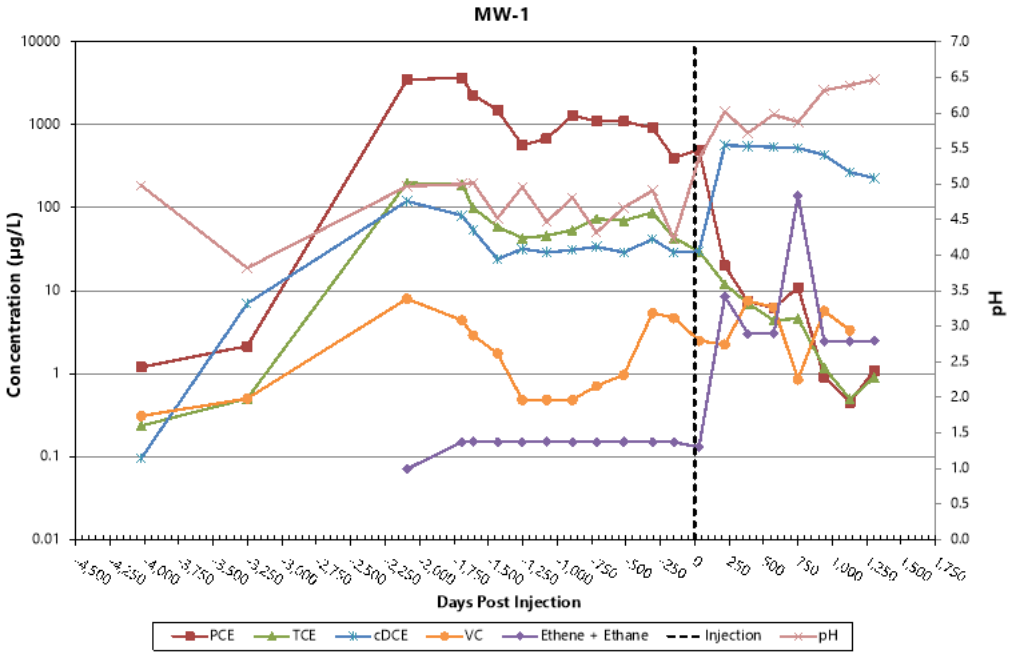


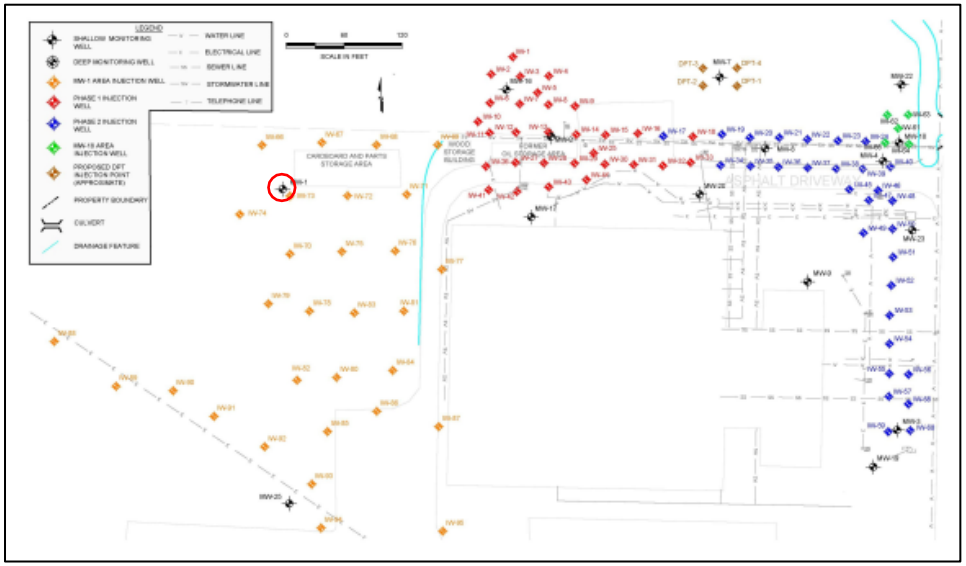
- >99% decrease in PCE and TCE
- Increase in pH
- Significant increase in DHC population
- Increase and decrease in cis-DCE and VC
- Ethene + Ethane production



Results

- >99% decrease in PCE and TCE
- Increase in pH
- Some increase in DHC population
- Increase in cis-DCE and VC
- Low Ethene + Ethane concentrations





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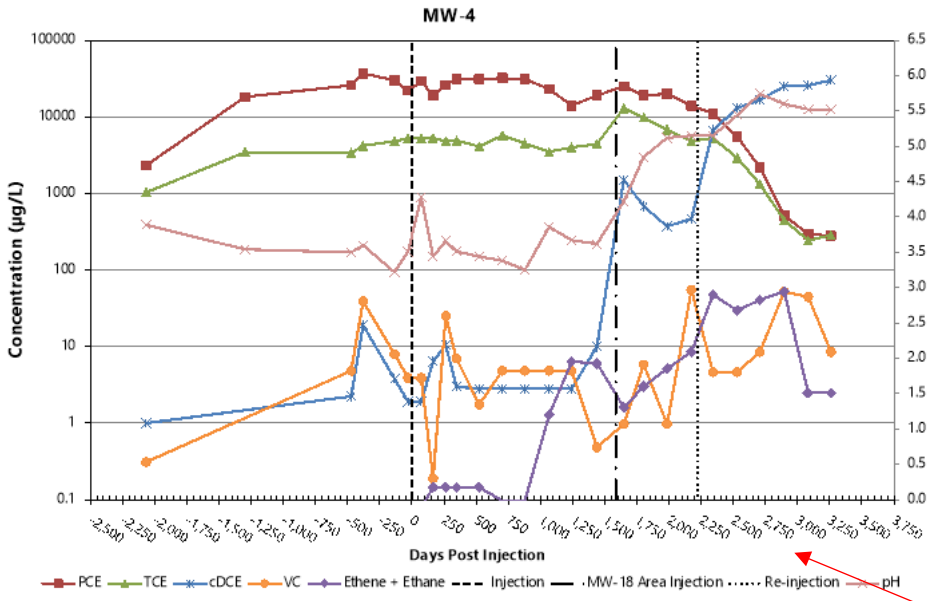
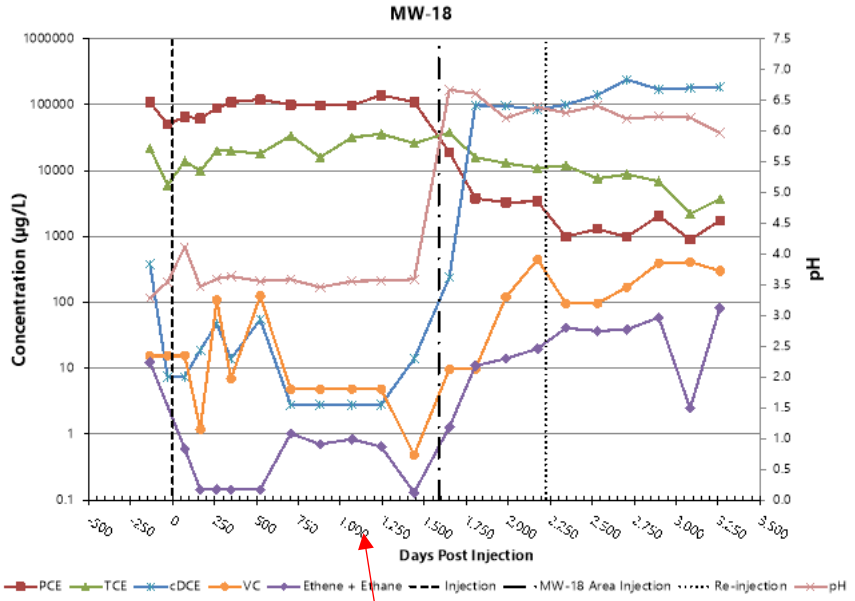
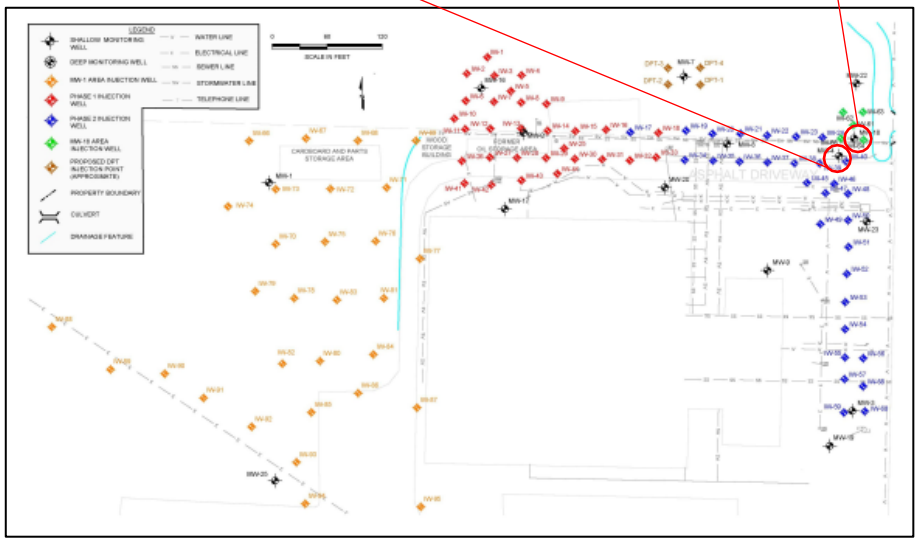


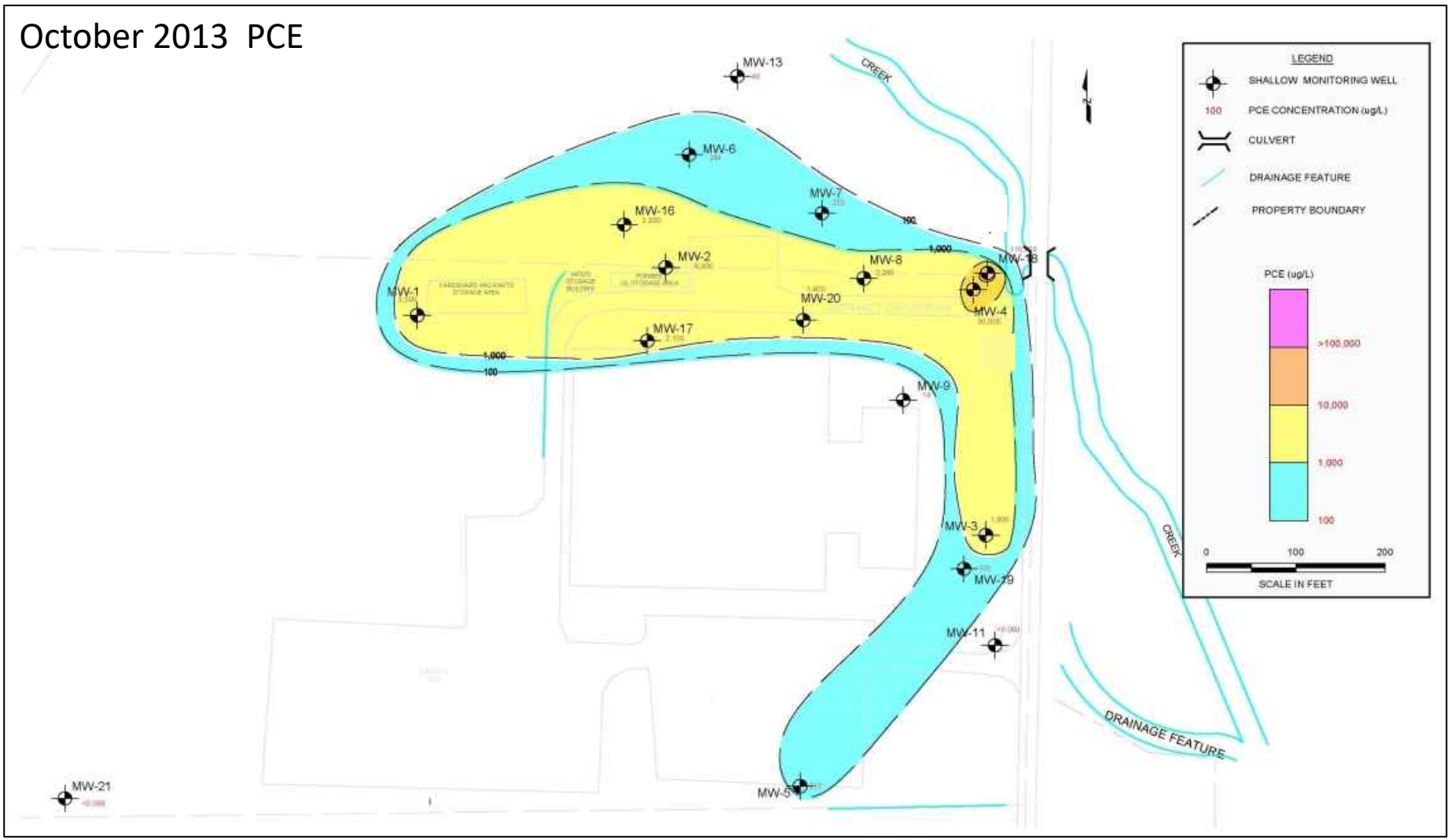


- >95% decrease in PCE and TCE
- Increase in pH
- Some increase in DHC population
- Increase in cis-DCE and VC
- Some Ethene + Ethane production
- Decrease in Sulfate 3,200 mg/L ⟶ 14.7mg/L in MW-18



Results

October 2013 PCE



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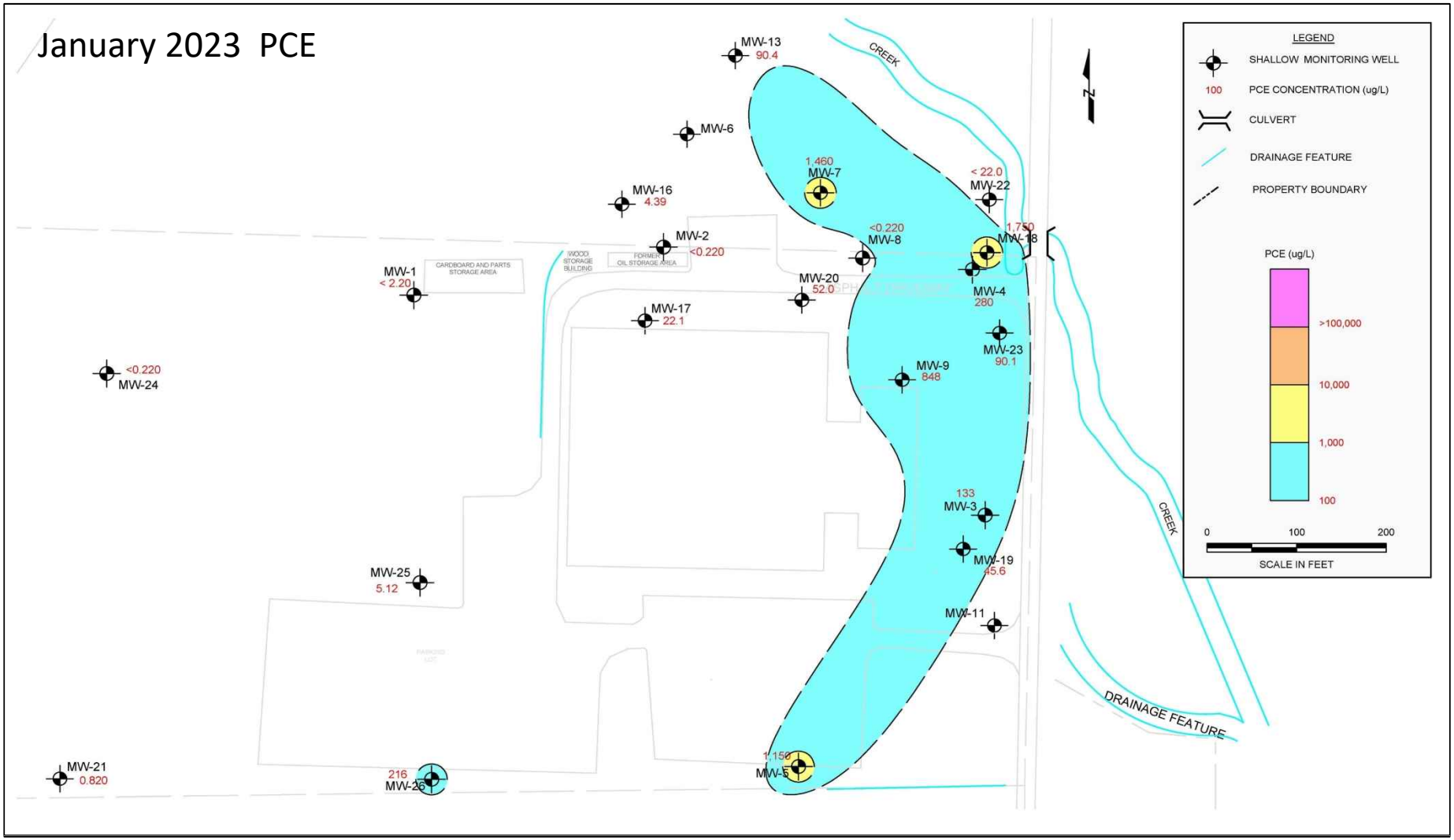

Conclusions

- In situ bioremediation has thus far been effective in reducing PCE and TCE concentrations by over 99% in some areas
- Complete dechlorination of cis-DCE and VC to non-toxic end-products ethene and ethane is still ongoing
  - Recently, injection of additional nutrients (nitrogen, phosphorus, amino acids, and vitamin B12) were injected into the areas where the accumulation of toxic intermediates observed
- Even when the conditions do not initially seem favorable for bioremediation (such as low pH and high contaminant concentrations) in situ bioremediation with proper pH adjustment/control can be a viable option to treat chlorinated solvents in an efficient and affordable way
- You may need high amounts of base for pH adjustment/control

Thanks!

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