SiREM

Optimizing Bioremediation with Low pH Tolerant *Dhc*

Corey Scales

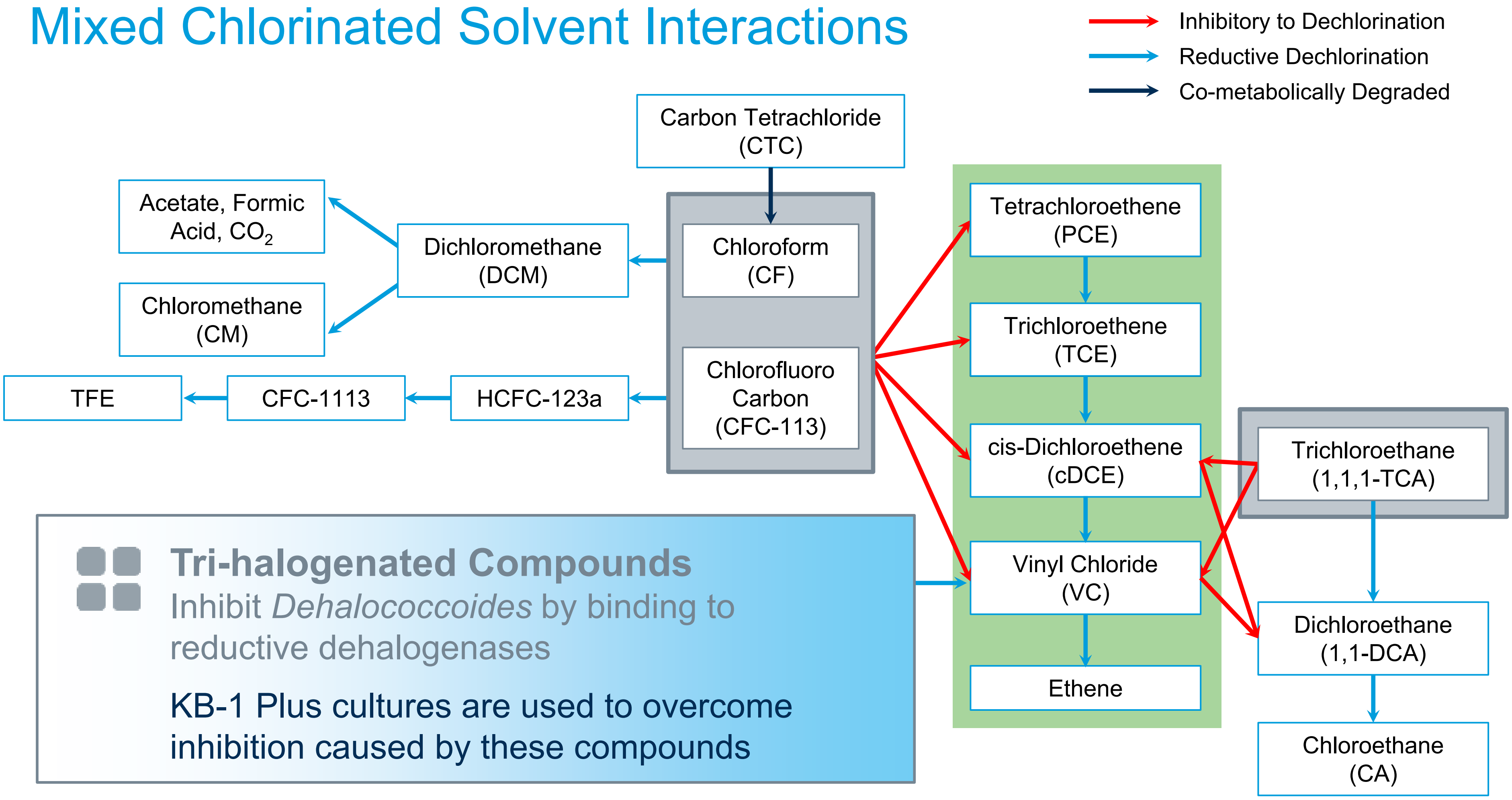
Jeff Roberts
Sandra Dworatzek
Phil Dennis

June 5, 2024

Let's Talk About…

1. Inhibitors to chlorinated ethene degradation
2. Effects of low pH on *Dehalococcoides* (*Dhc*)
3. Case Studies
4. Key Takeaways

Mixed Chlorinated Solvent Interactions



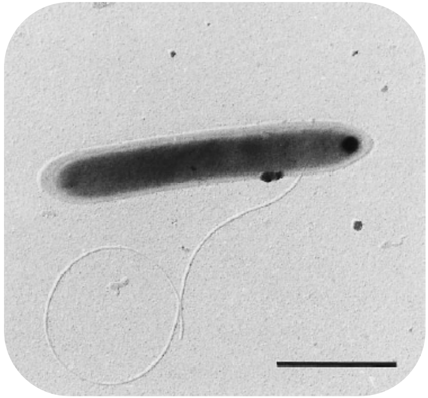
Tri-halogenated Compounds

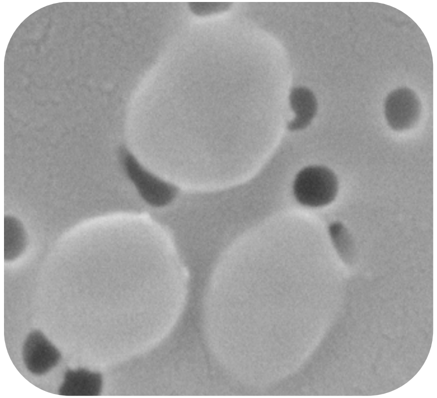
Inhibit *Dehalococcoides* by binding to reductive dehalogenases

KB-1 Plus cultures are used to overcome inhibition caused by these compounds

Dehalobacter (*Dhb*) & *Dehalogenimonas* (*Dhgm*)

Dehalobacter





Dehalogenimonas

1,1,1-TCA degradation to CA (*Dhb*)
(Grostern and Edwards, 2006)

Chloroform to Dichloromethane (*cfrA*)
(Grostern, Edwards, Duhamel and Dworatzek, 2010)

DCM to acetate
(Justicia-Leon et al., 2011)

1,1,2,2-TeCA to ethene (*Dhgm*)
(Manchester et al., 2012)

Don’t get caught off guard

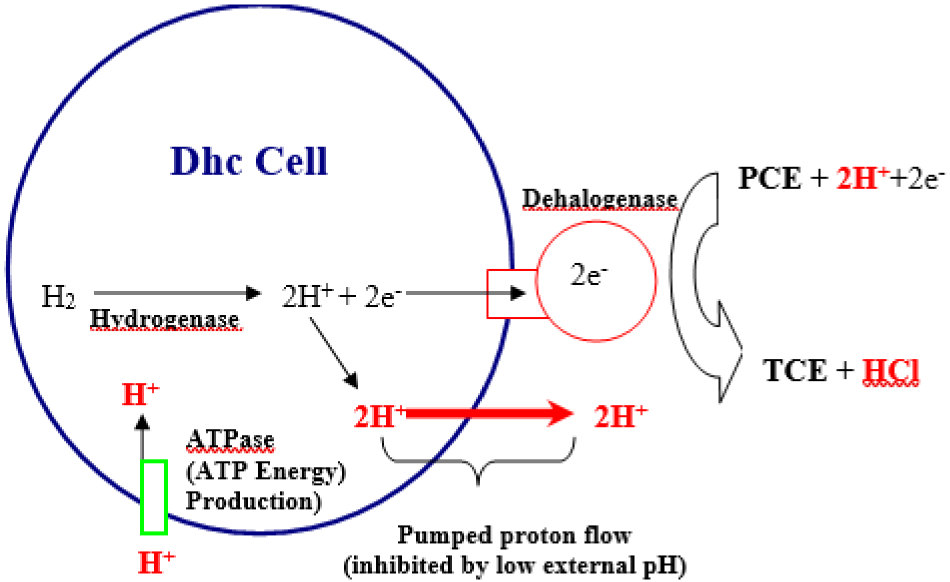
The Site

Low pH

pH Biological Perspective

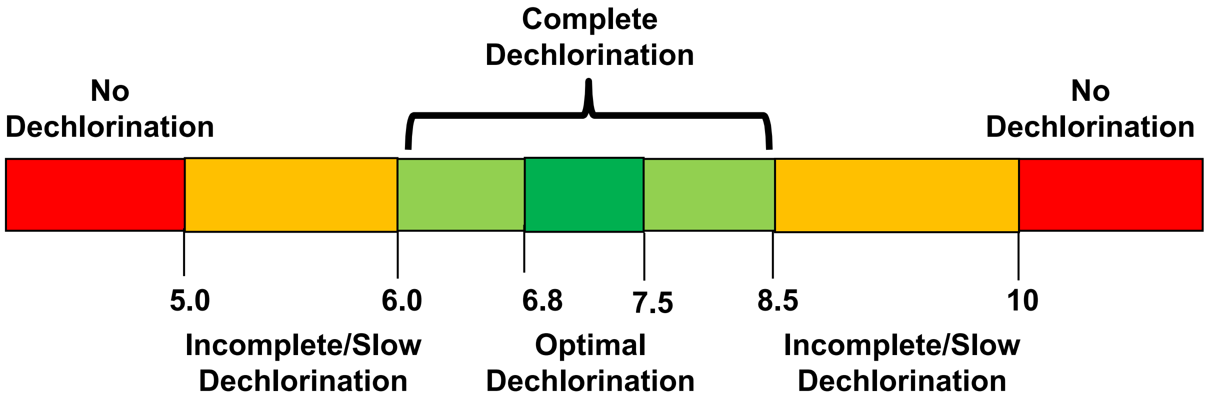
- pH = -log [H^+] - pH 6.0 is **10 times** more acidic (H^+) than pH 7.0,
- pH 5.7 is twice as acidic as pH 6.0
- What appear to be relatively small changes in pH can have significant biological impacts on microbial:
    - cell membranes
    - enzyme activity
    - DNA stability
    - energy metabolism

Impact of pH on Dechlorination



*Diaz, 2008

Impact of pH on Dechlorination

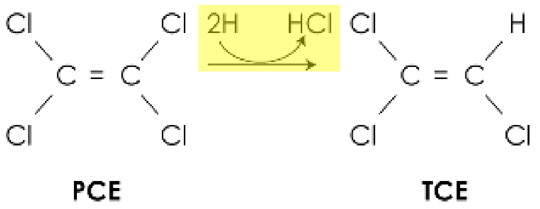


- pH of 6.0-8.5 is <u>generally</u> required for dechlorination to ethene*
- pH 6.8-7.5 is considered optimal range, 7.5 is best*
- Sites with low pH more likely to accumulate cDCE/VC

*Rowlands, 2004

Declines in pH during Bioremediation

(1) Reductive dechlorination produces hydrochloric acid



(2) Fermentation of many electron donors produce acidic byproducts such as acetic acid:

Glucose $\longrightarrow$ 4 H_2 + 2 Acetate + 2 CO_2

CO_2 dissolves in water forming carbonic acid

Acid Generation During Bioremediation

Aquifer pH Neutralization

pH neutralization using $NaHCO_3$, KOH, NaOH, and MgOH are used to buffer aquifers

Challenges include:

- Volume requirements/cost may be high
  -e.g. many tons of $NaHCO_3$
- Keeping pH elevated is often difficult
- Distribution challenges can lead to alkaline conditions at injection point, acidic further out

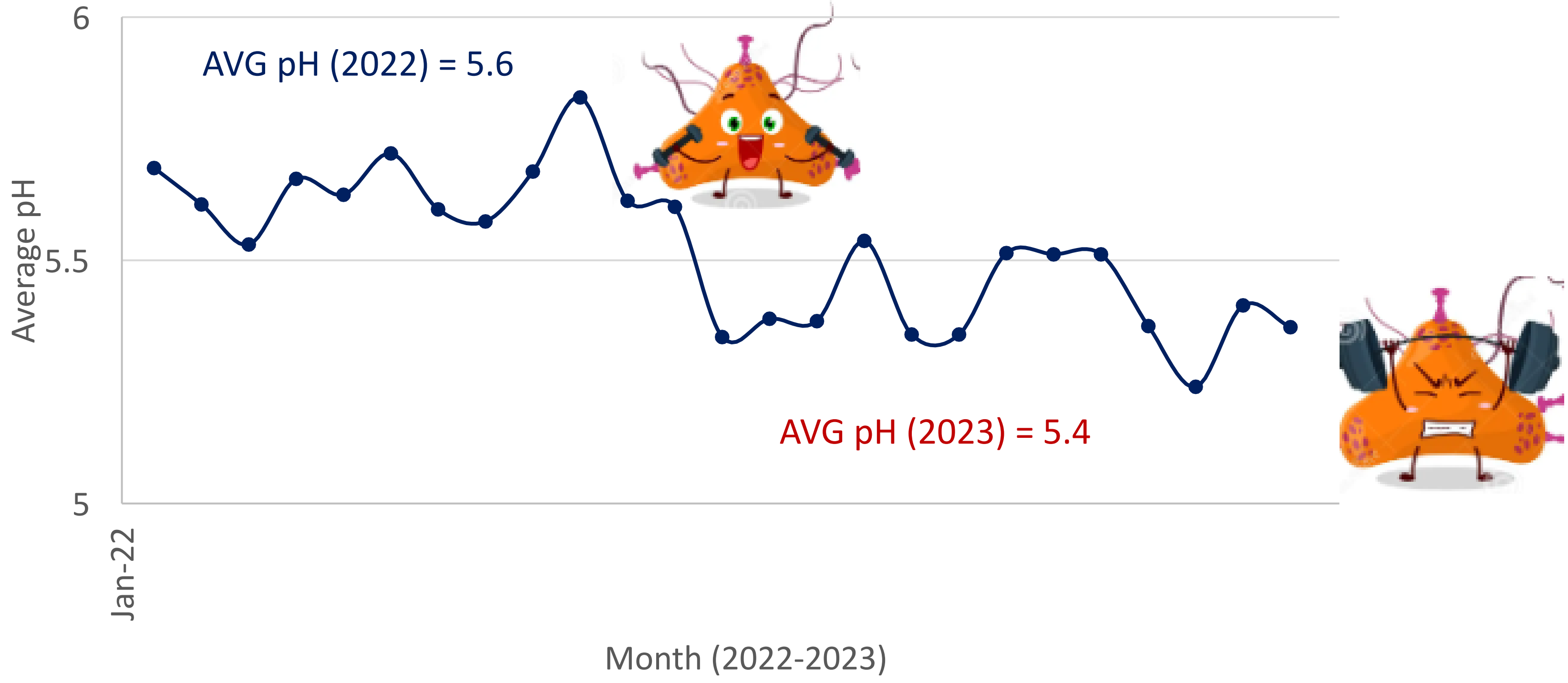
SiREM

LOW pH TOLERANT *DHC*

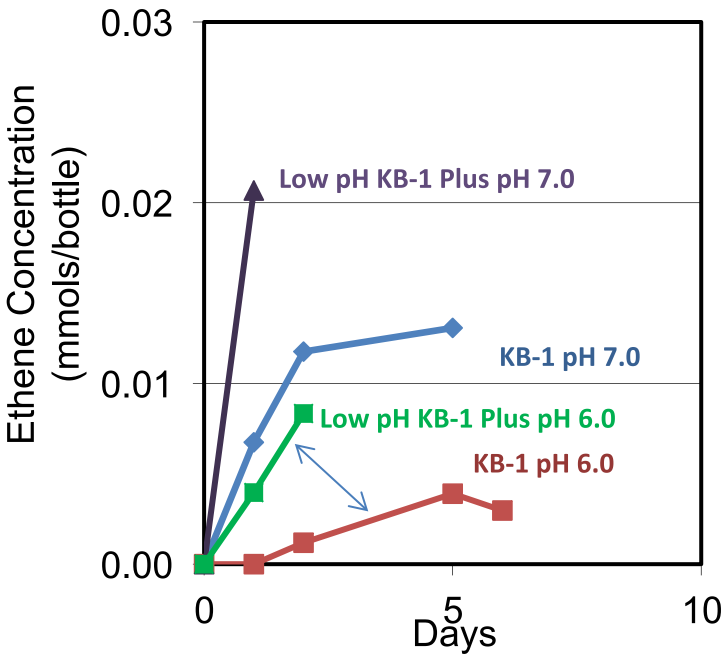
Low pH KB-1® Plus

- Anaerobic liquid bioaugmentation culture enriched from a wetland site with pH <5.0
- Grown on TCE at progressively lower pH over a >10-year period - started pH 6.5 currently at pH 5.5
- Applied at >50 sites to date in 13 states

Low pH KB-1 Plus Culture Growth



Ethene Production of KB-1® versus Low pH KB-1® Plus at pH 6.0



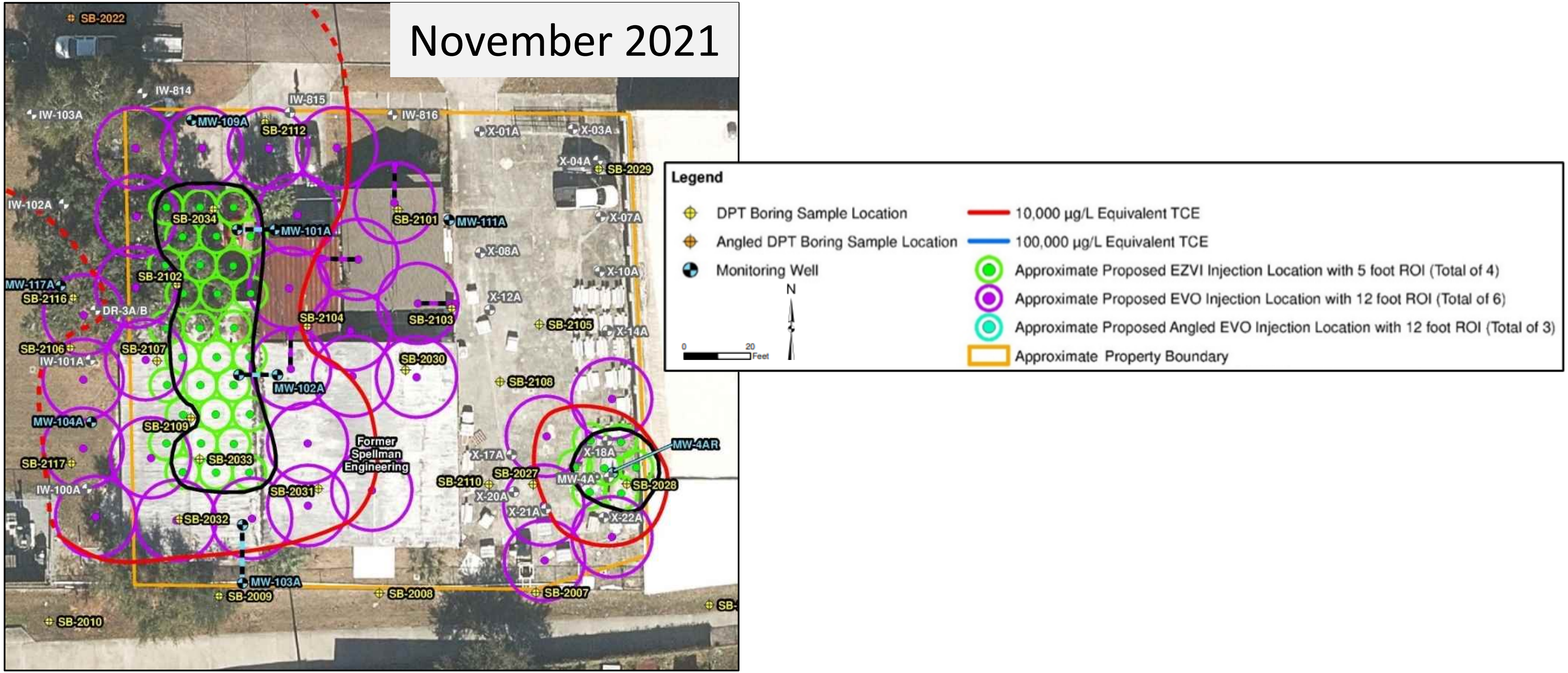
- Ethene production rate of low pH KB-1® Plus is 5X higher than standard KB-1® at pH 6.0

CASE STUDY 1: SITE IN SOUTHERN USA

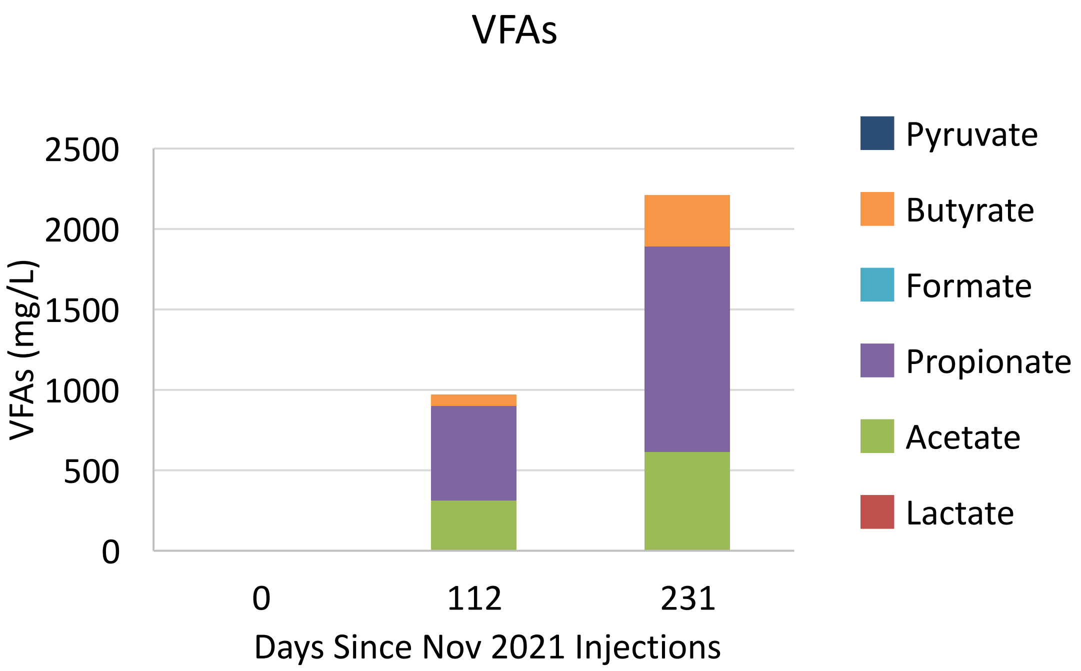
Background

- TCE discharge operated at the Site from 1963-1969
- TCE discharge was identified in 1992
- Impacts spanned 40-acres
- Located in an industrial area with adjacent residential areas
- Highest TCE Concentration of 759,000 µg/L prior to remedial activities
- Multiple remedial technologies were employed
- Average pH 5.8

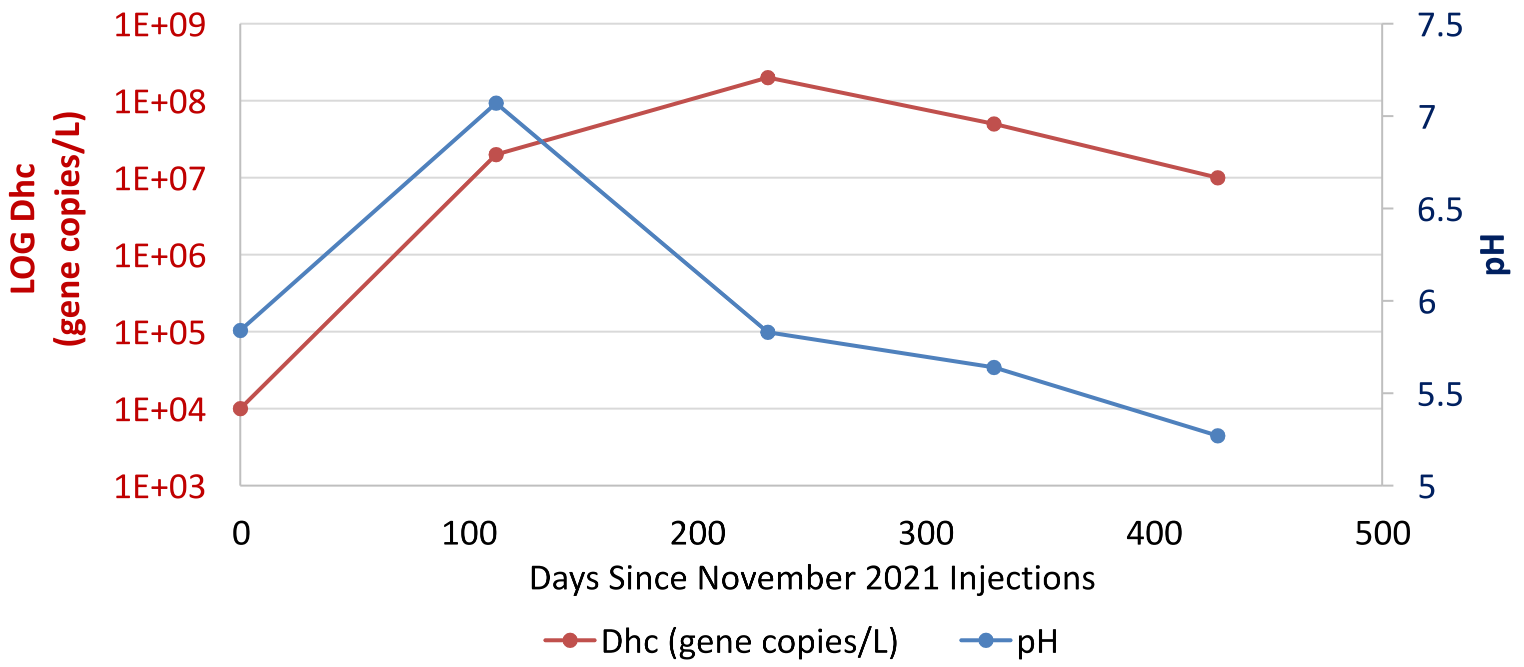
Case Study – Southern USA



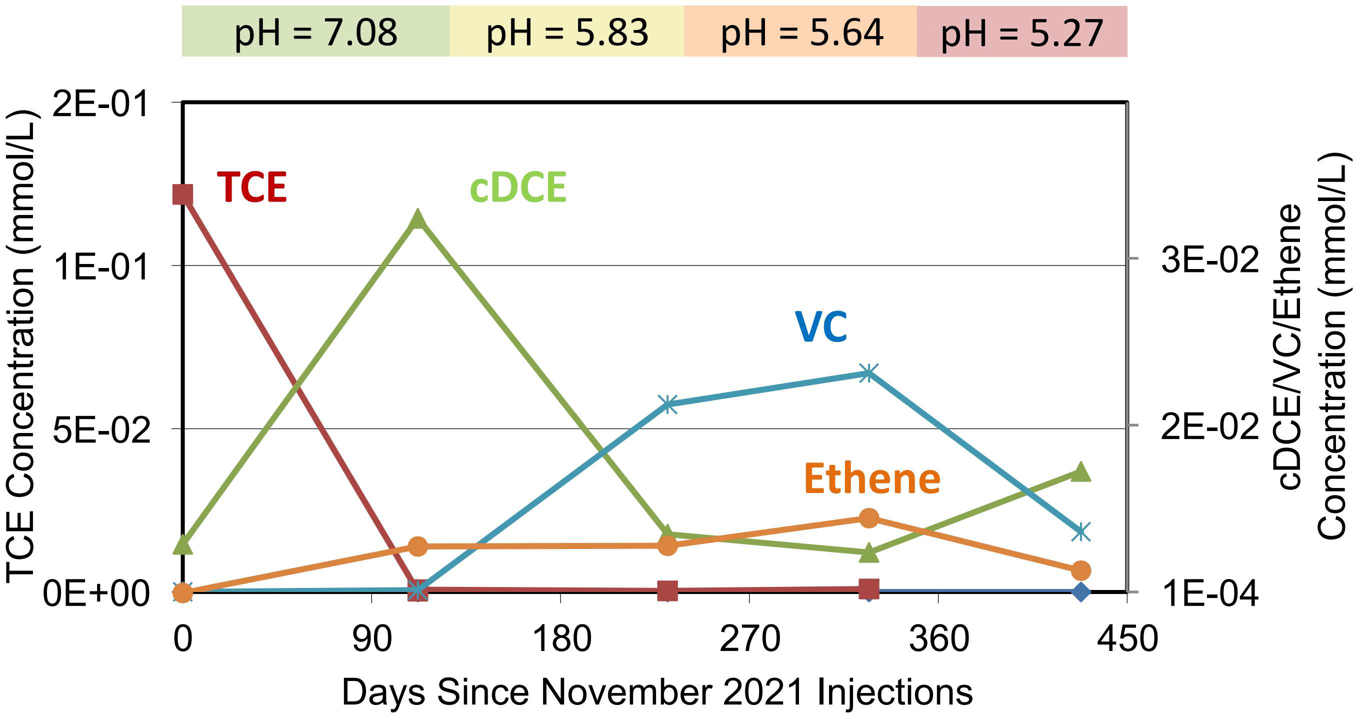
Volatile Fatty Acids (VFAs)



Site pH Trend & *Dhc* Growth



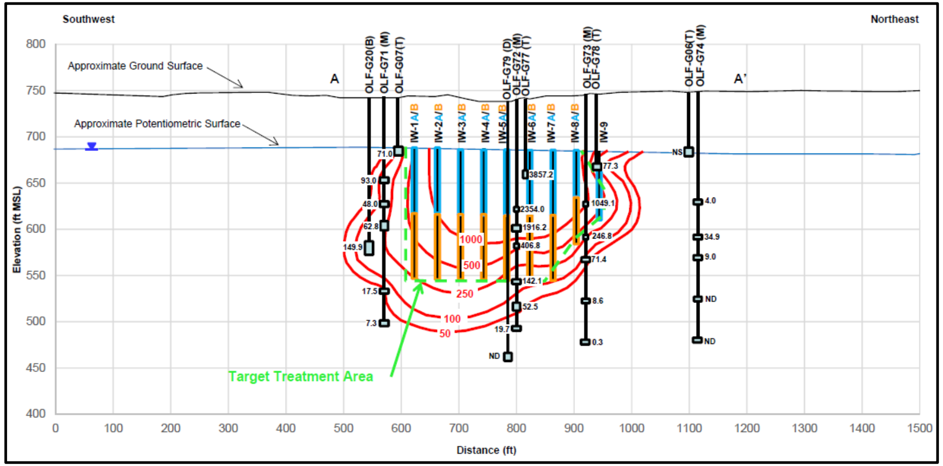
Degradation Results

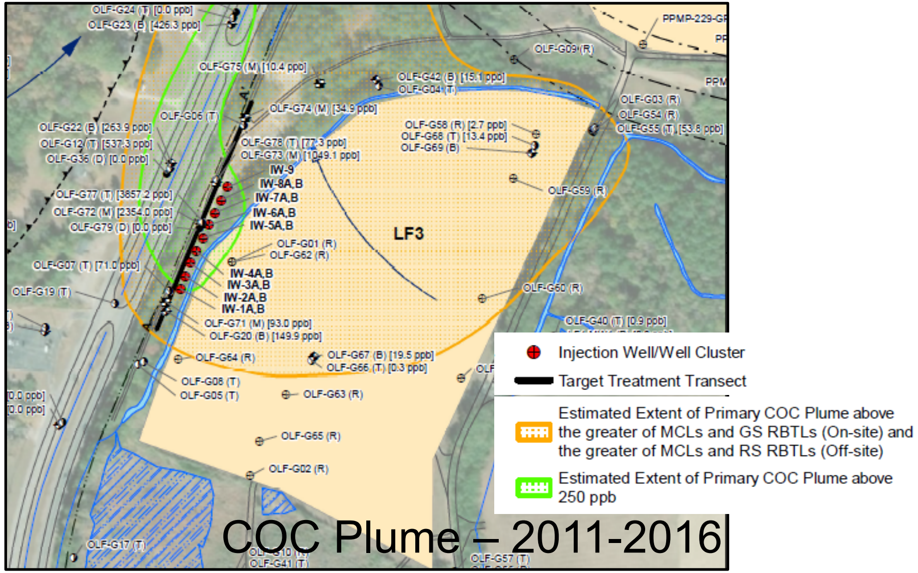


CASE STUDY 2: ALABAMA SITE

Background

- **Chlorinated ethenes and chlorinated ethanes**
- **Goal to reduce mass flux of cVOCs**
- **Bench-scale treatability study**
- **Bio-barrier injection implemented in May 2017**



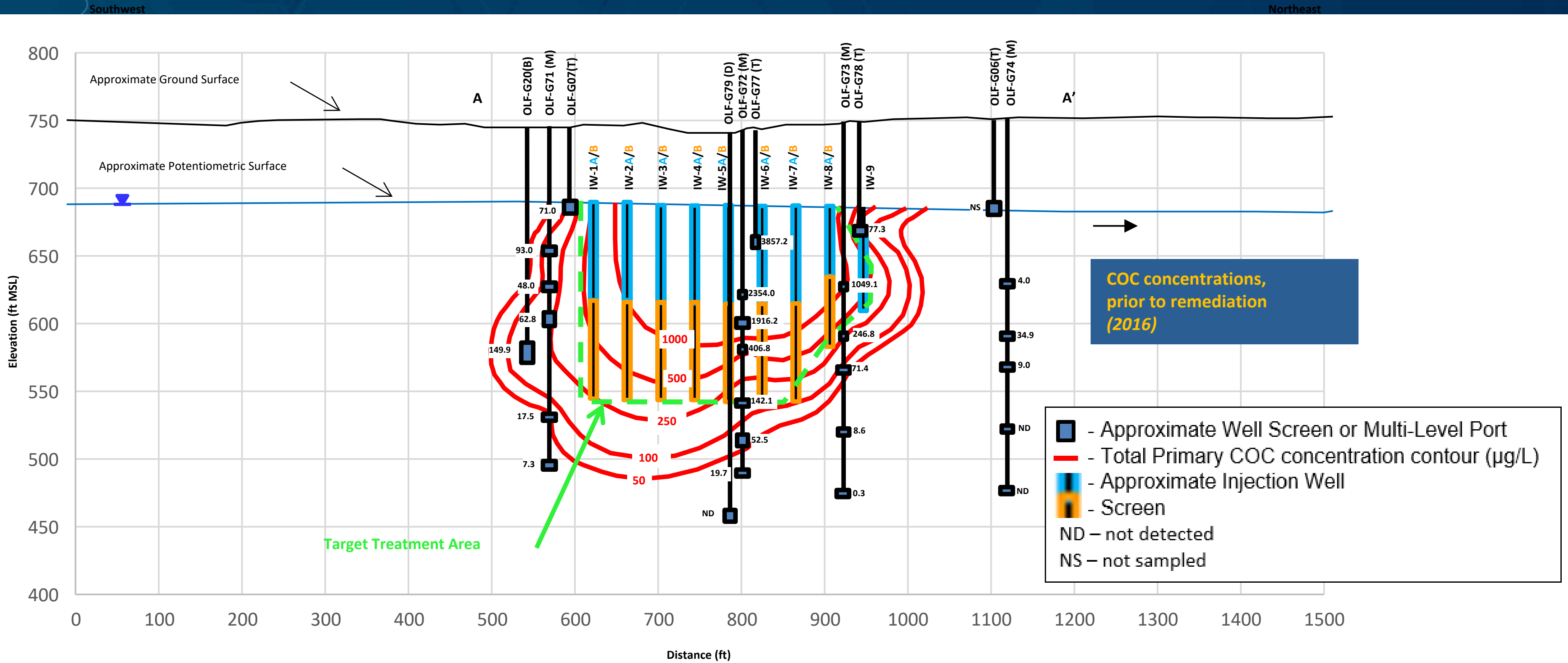


COC Plume – 2011-2016

Remedy Design

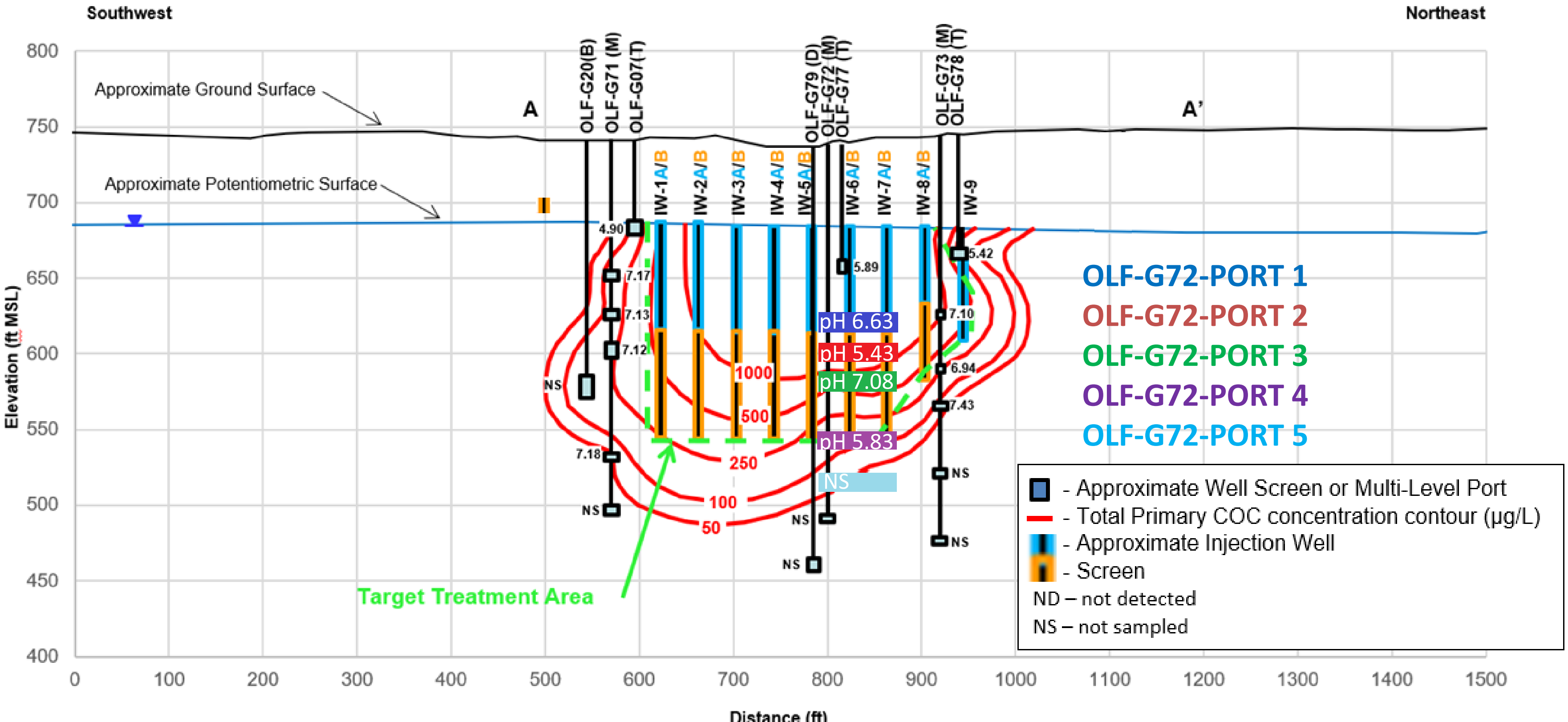
- Bio-barrier→ Targeting 250 ppb of total COCs
  - 9 well clusters, 17 wells total
  - Screen lengths between 50-75 feet,
    - deepest wells 275-ft bgs.
    - Target treatment area 150-ft thick
  - Target 20-ft ROI
- Amendment mix
  - EVO
  - Low pH KB-1® Plus
  - Anaerobic water = Water + totes with residual EVO + hot sun

Pre-Injection (2016) Plume – COC Concentrations



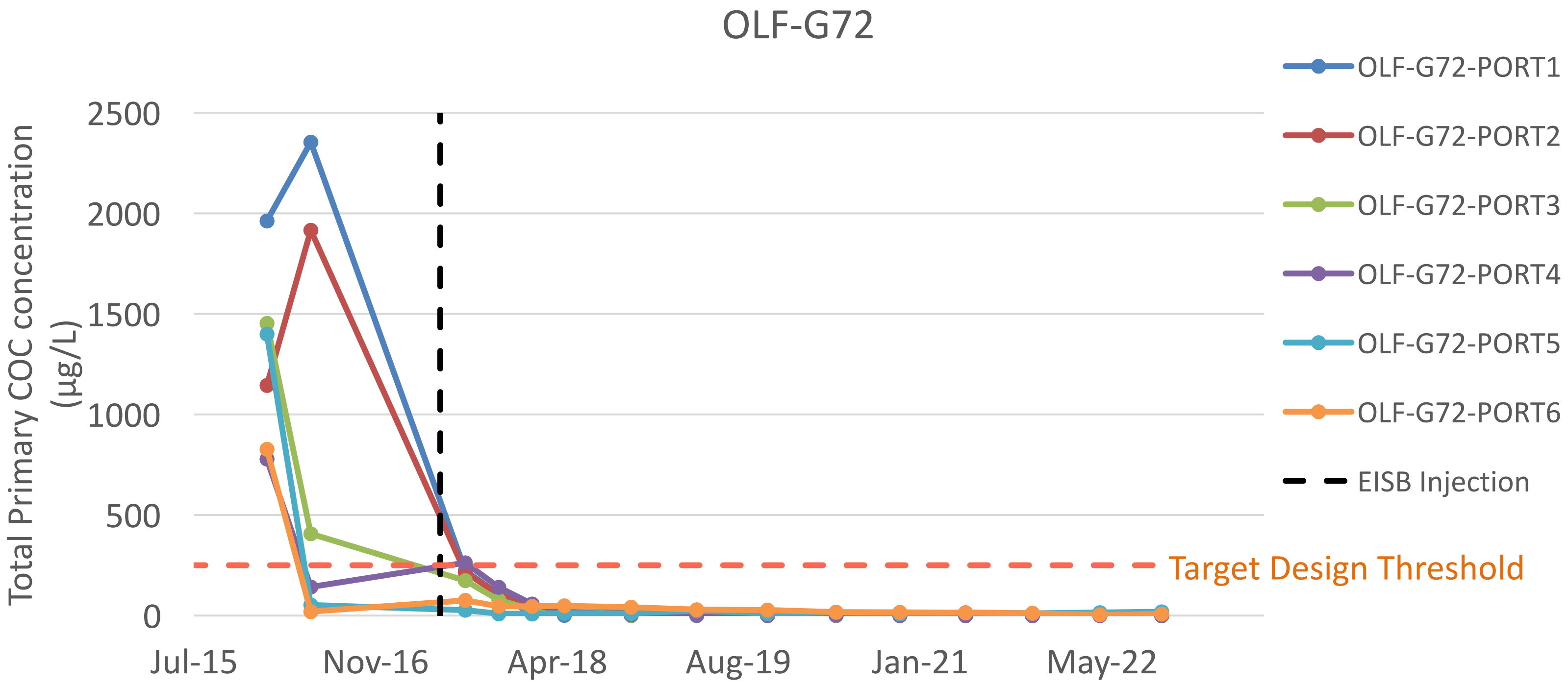
In-situ Bioremediation Target Treatment Area Cross-Section

Low pH Conditions

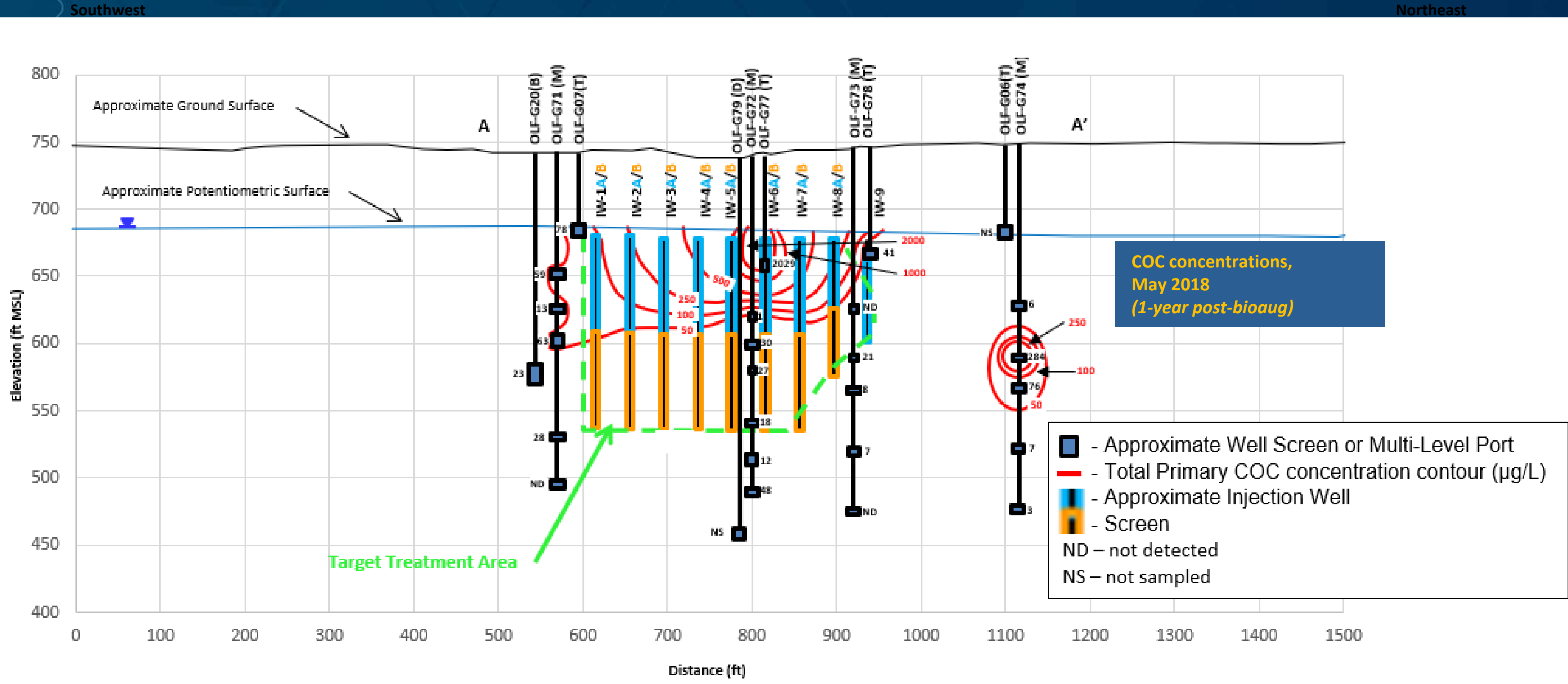


Values from 5/19/2017 sampling date

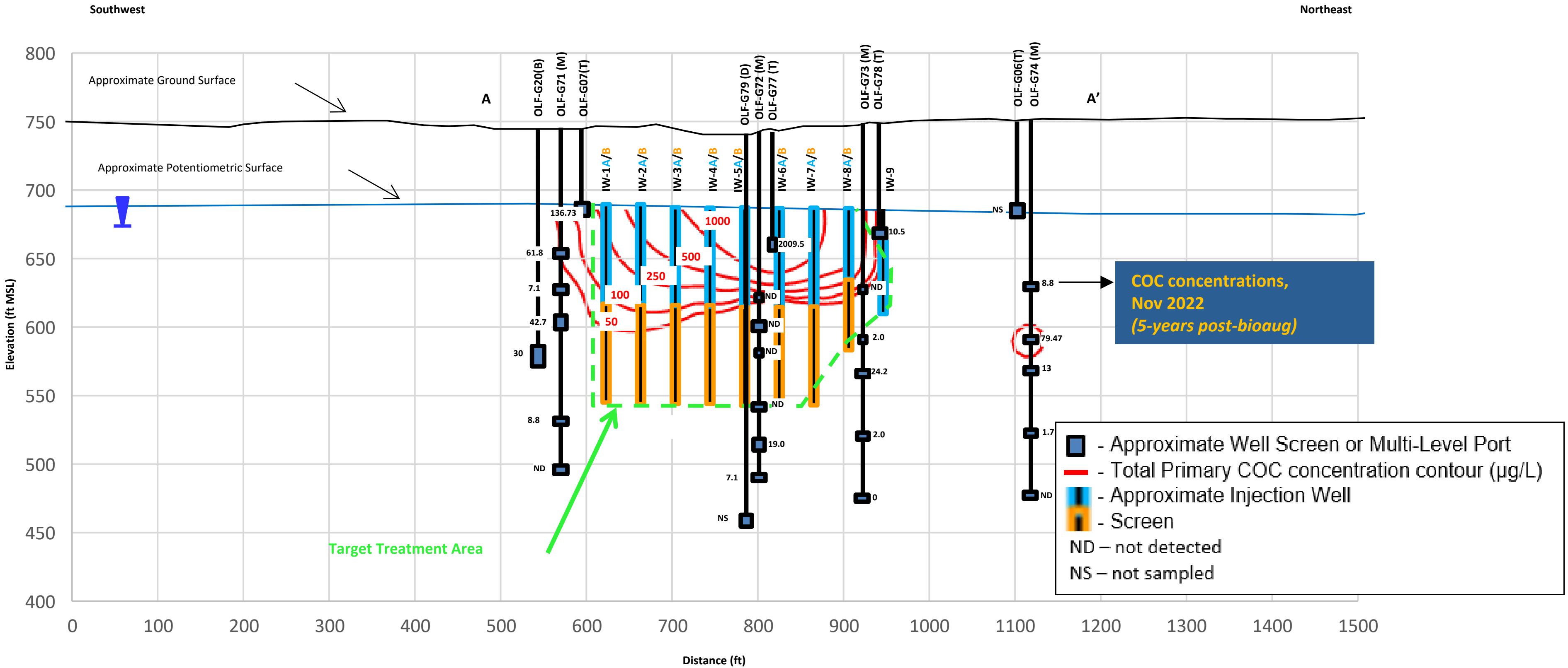
Results – Source Area Monitoring Well



POST-INJECTION, MAY 2018



Post-Injection (Nov 2022) Plume – COC Concentrations



Key Takeaways

- Reductive dechlorination and fermentation of electron donors produce acidic by-products
- Some sites may have low buffering capacity, or naturally low pH
- Overcome low pH conditions by;
  - Adding a buffering agent to increase the pH into the optimal range
  - Using a low pH acclimated bioaugmentation culture (low pH KB-1 Plus)

Questions?

siremlab.com

Corey Scales
Bioaugmentation Coordinator
cscales@siremlab.com
519-515-0848