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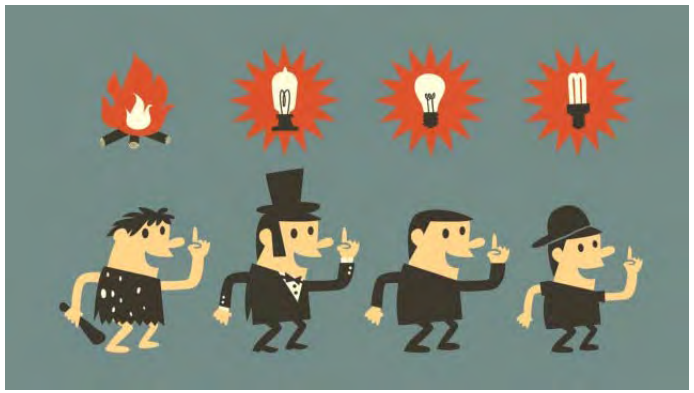
Formerly CB&I Federal Services, LLC

The Importance of Site Characterization and Understanding the CSM for Targeted Bioremediation in Fractured Bedrock

Case Study – Loring AFB

Introduction

- Conceptual Site Model (CSM)
  - Definition:
    - Identifies site-specific hydrogeologic components, potential migration pathways, and the nature and distribution of contamination.
  - Takeaway?
    - CSM is critical for characterizing your site and designing your remedy.
    - Complacency kills
    - Constantly evolving.



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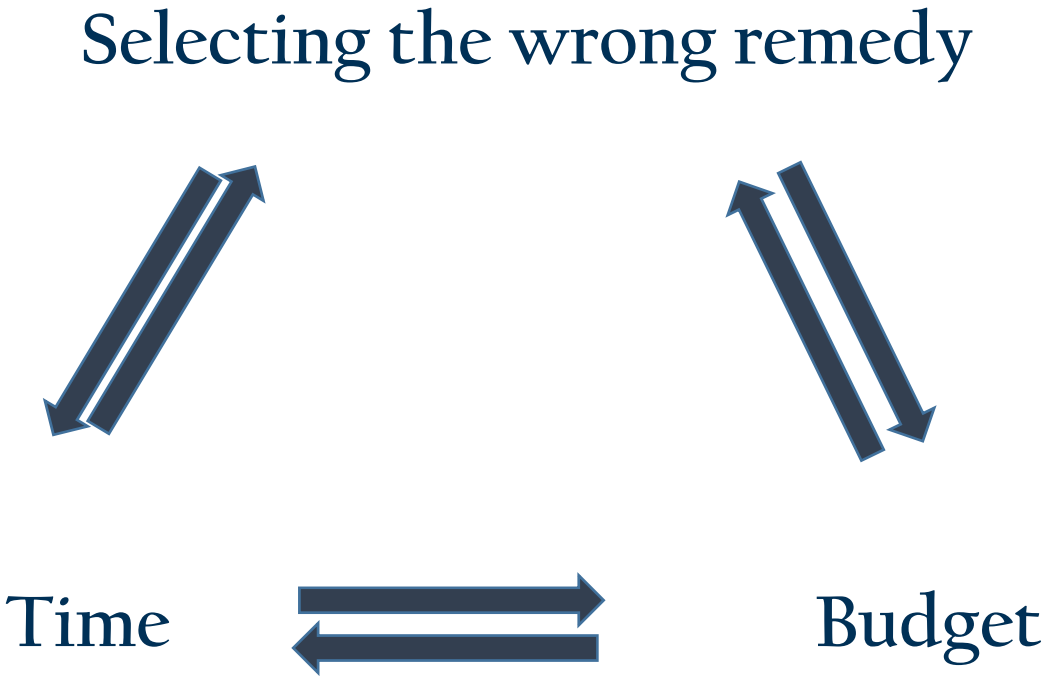
Conceptual Site Model



Introduction

- Filling Data Gaps
  - Where to begin?????
- Research
  - Look at your current CSM
  - Do you have all the data to support long-term scientific based decisions
- Geology and Hydrogeology 101
  - Don't ignore
  - Properly design your remedy

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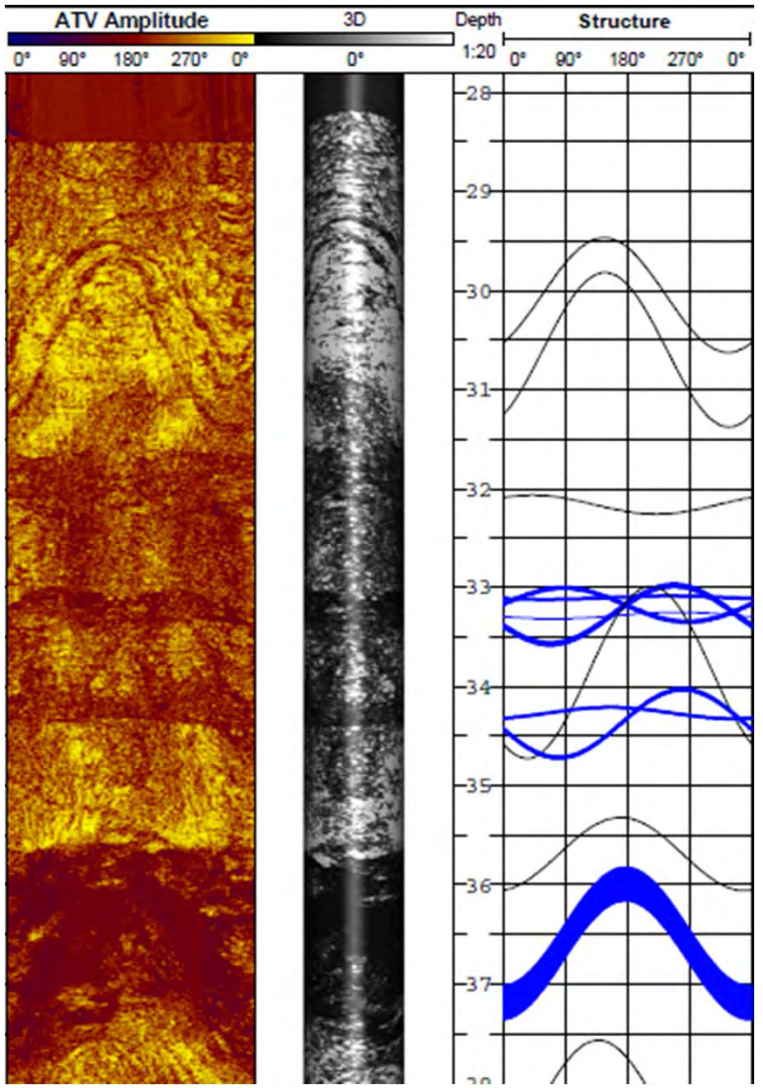
Site Characterization/Delineation

- Open Boreholes vs. Conventional MWs
  - Conventional
    - Advantages
      - Discrete Zone sampling
      - Relatively Inexpensive
    - Disadvantages
      - Once set, cannot go back
      - Limits in data collection
      - Regulators often don't allow injections into wells used for LTM
  - Open Borehole
    - Advantages
      - Perform Geophysics
        - Identify strike and dip of bedding/fracture zones
        - Identify transmissive zones
        - View rock quality



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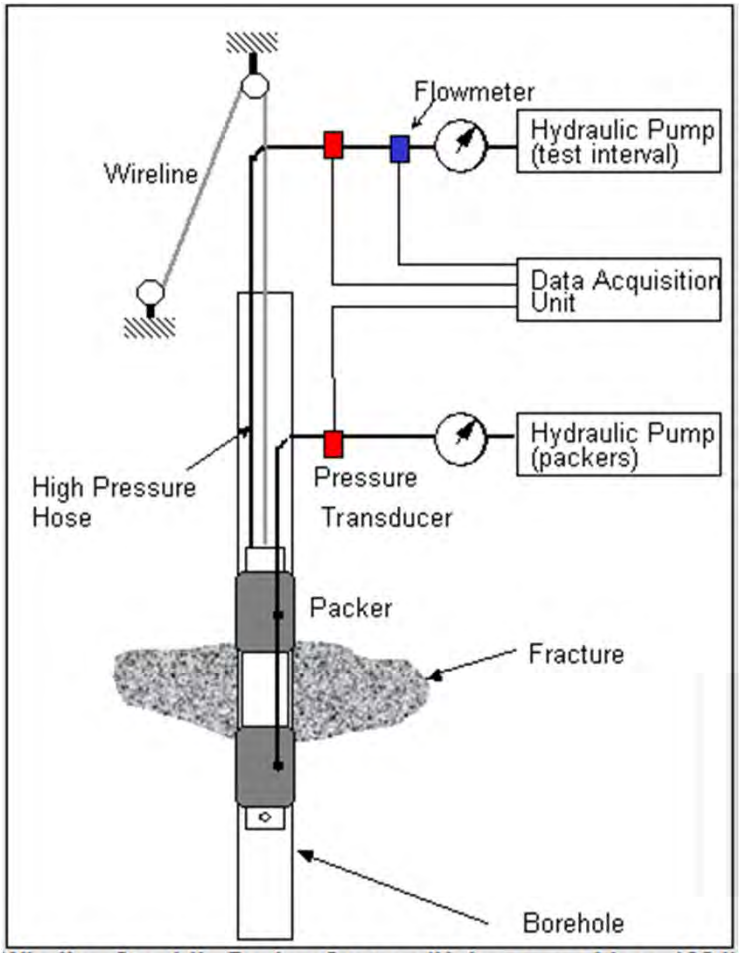
Site Characterization/Delineation

- Open Boreholes vs. Conventional MWs
  - Open Borehole (cont'd)
    - Advantages
      - Multiple Interval Sampling
        - Use of packers
        - Identify High Flux Zones
        - Target Treatment
    - Disadvantages
      - More expensive than conventional wells



Wireline Straddle Packer System (Haimson and Lee, 1984)

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Site Characterization

- Pump and or Dye Tests
  - Additional tools in the belt
    - Advantages
      - Use to evaluate and verify interconnectivity between wells
      - Calculate aquifer properties
        K, T, gw velocity
      - Determine injection rates and design
        - Do I need to build a re-circulation system?

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Site Characterization

- Establishing good baseline conditions

  - Step 1
    - What state is your aquifer in?
      - Anaerobic vs Aerobic
        - Take a look at your field parameters (i.e. DO, ORP)
        - This will determine most effective remedial approach/design

  - Step 2
    - Review LTM data (if available)
      - Perform your own sampling
        - Need to establish baseline concentrations of contaminants of concern to look for trends throughout and following your treatment
        - Need to establish baseline general chemistry (i.e. follow your electron acceptors)
        - Need to establish baseline DHE and TOC
          - Biostimulate
          - Bioaugment

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Performance Monitoring

- What are your objectives/goals
  - Need to define
    - Concentration Reductions during a certain period
    - Mass flux/Mass Discharge reductions
- Use to Track Performance of Remedy
  - Sample parameters
    - Are we testing for the right analytes
    - DNA Testing

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Background

Former Loring Air Force Base

Located in Aroostook County in Northern Maine.

Constructed in 1947 operating to 1992 as part of the Strategic Air Command (SAC)/Air Combat Command(ACC)

Cold War – Most direct route over the Artic Circle

BRAC – Closed in 1994

RI/FS – 1997/1999

Background

Entomology Shop/Jet Engine Build Up Shop (ES/JEBS South Plume)

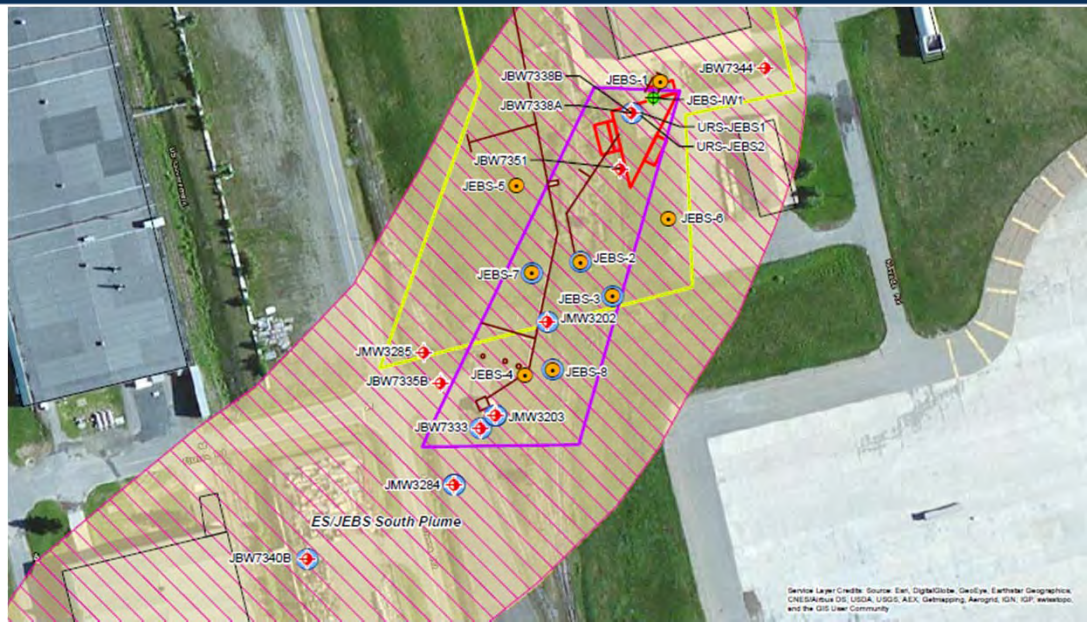
Active – 1952-1991

Former activities included draining, maintenance, repair, teardown, and modification of jet engines.

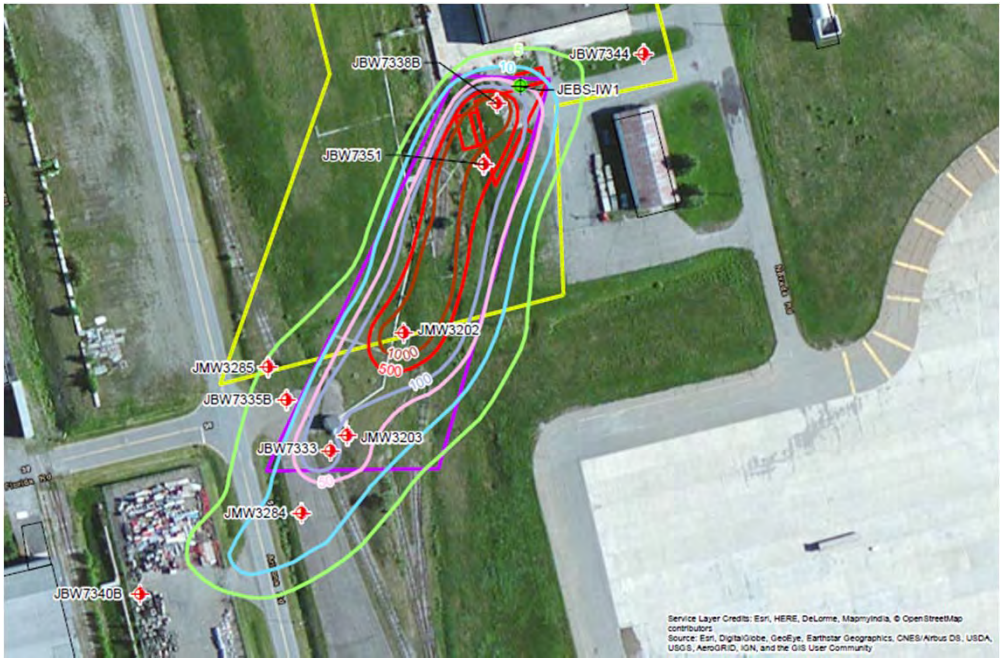
TCE plume

PCE/TCE-impacted soil above leaching criteria

FS - SVE and some limited excavation chosen as selected remedy (1996-2008)



Background



Entomology Shop/Jet Engine Build Up Shop (ES/JEBS South Plume)

2012 – Baseline Sampling
Plume size in 2012 = 2.35 acres and a maximum concentration of 1,800 ppb

2013 – Implemented soil excavation (October)

- Fall LTM

2013 – Implemented limited ISEB Injections to Bedrock Surface (November)

2014 – June/July Performance Monitoring Sampling

- Initial reductions followed by some rebound

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Pilot Study - 2015

- Purpose
  - Assess the effectiveness of in situ enhanced bioremediation in treating chlorinated VOCs in fractured bedrock
  - The goal of the pilot study is to demonstrate the feasibility of ISEB for the treatment of localized areas of groundwater contamination in fractured bedrock at the ES/JEBS South Plume
  - ISEB selected because of pre-established anaerobic conditions

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Pilot Study

- Pre-Design/Updating the CSM
  - Geology Characterization
    - Install open bore bedrock wells
      - Identified Karst geology
        - Highly weathered/calcite zones
    - Borehole Geophysics
      - Strike/Dip
      - Transmissive Fractures
  - Plume Delineation
    - Packer Sampling
      - Multiple zone interval sampling
      - Contaminant distribution
      - Set permanent packers

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Pilot Study

- Pre-Design/Additional Characterization
  - Hydrogeology Characterization
    - Dye Test
      - Updated previously known gw direction
    - Pump Test
      - Drawdowns of up to 1.94 ft
      - ROI up to 196 feet from pumping well
      - Identified IWs and injection rates
  - Additional Baseline Sampling May/August
    - 2.0 acres max concentration of 150 ppb.

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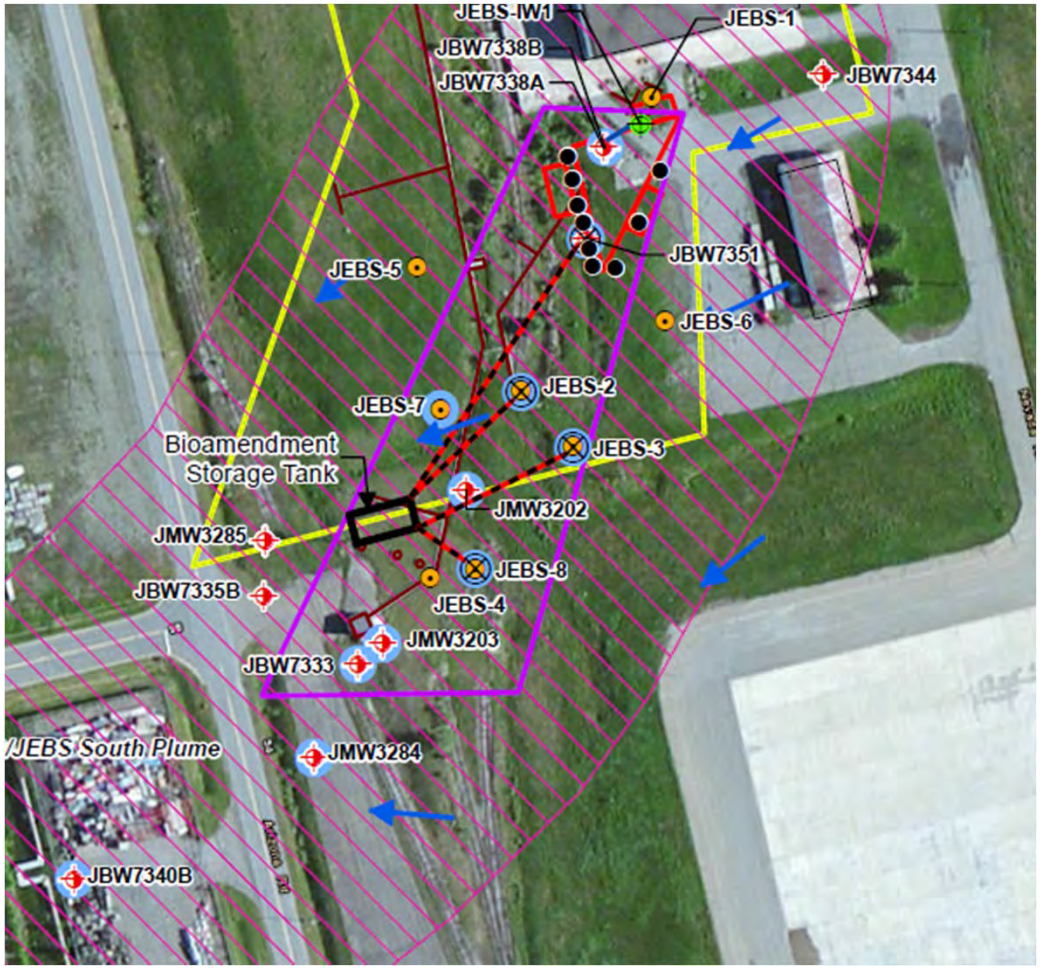
Pilot Study

- Design
  - Four IWs
    - Provide coverage in all portions of the plume
  - Area
    - 414 ft x 175 ft (72,450 ft^2)
    - Targeted bedrock treatment 30-63 feet bgs
  - Amendment
    - ~87k gallons
      - EDS-ER™
      - SDC-9
      - Accelerite
      - DAP



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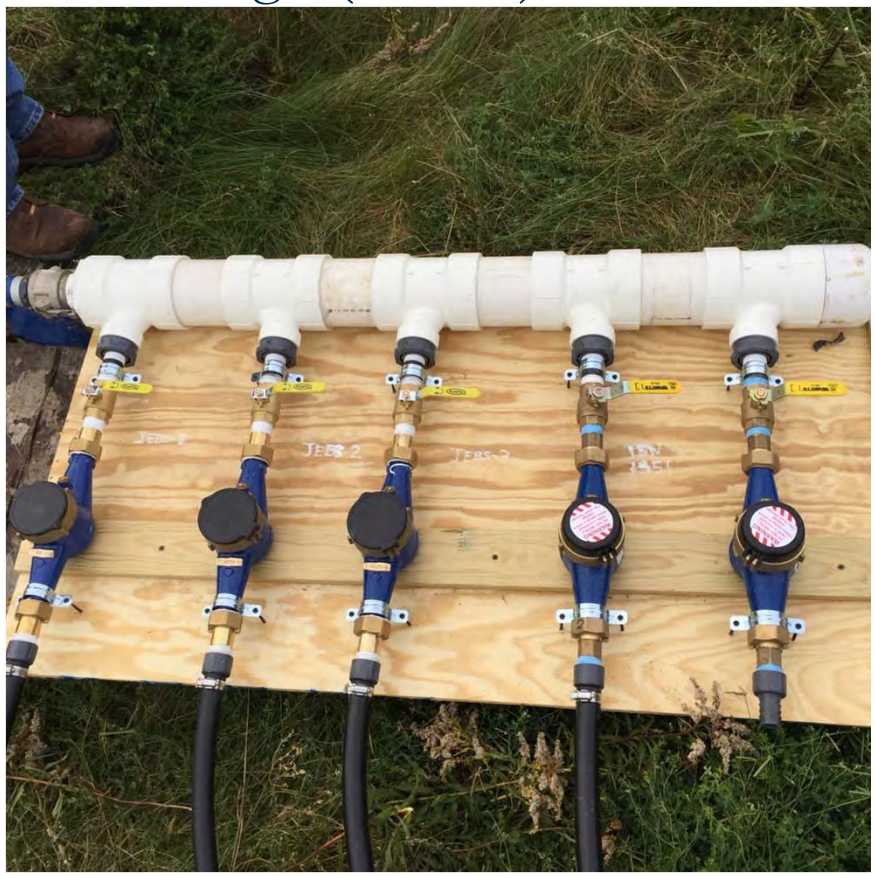
Pilot Study

- Design (cont'd)



Injection Manifold

Injection Layout

Pilot Study

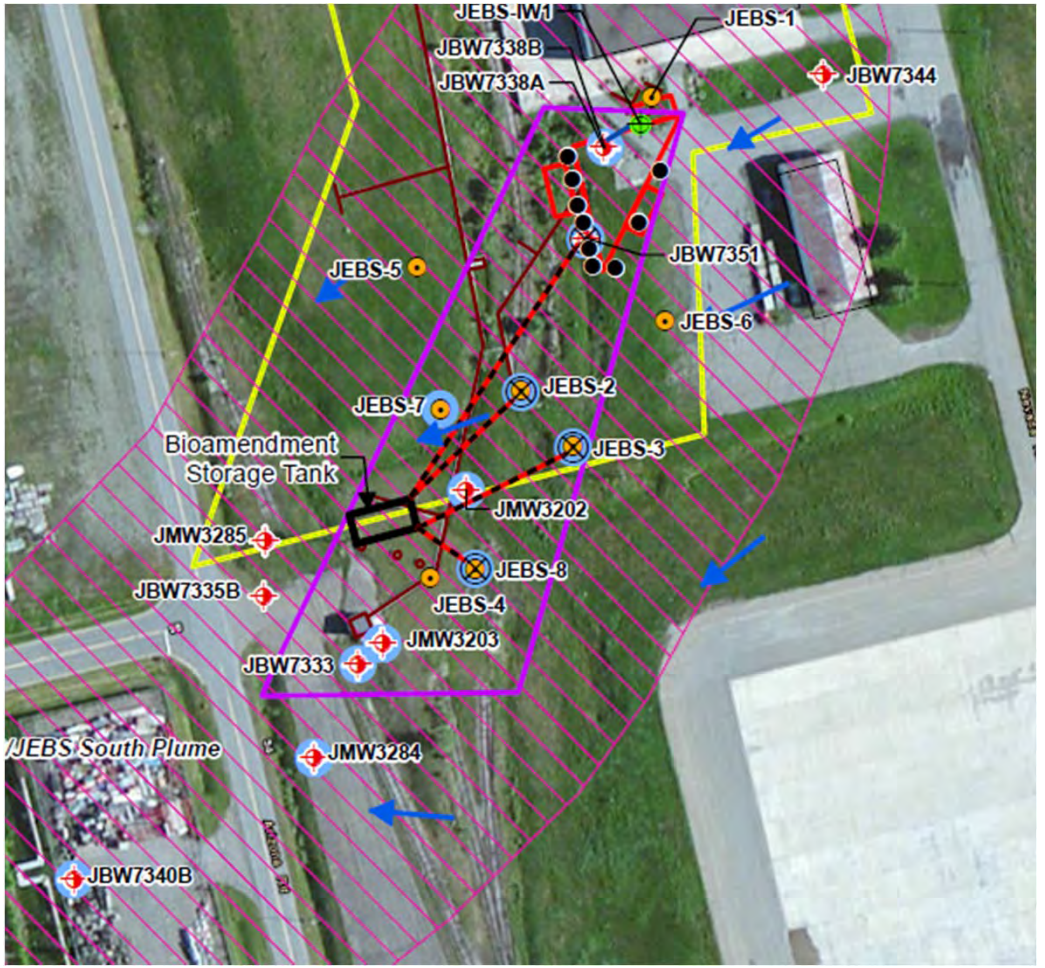
- Design (cont'd)

Relieve valve and well head assembly

Bioamendment in Tank

Pilot Study

- Performance Monitoring
  - Performance Wells
    - 11 MWs throughout treatment area
    - Representative Coverage
  - Analysis
    - COCs; MNA; general chem; metals; DHC-select DNA sampling
  - Study Period
    - 4 rounds of seasonal data (i.e. spring and fall)
    - First event (fall) 2.5 wks
    - Second event (spr.) (7-mos.)
    - Third event (fall) (12-mos.)
    - Fourth event (spr.) (20-mos.)



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Reductive Dechlorination Pathways

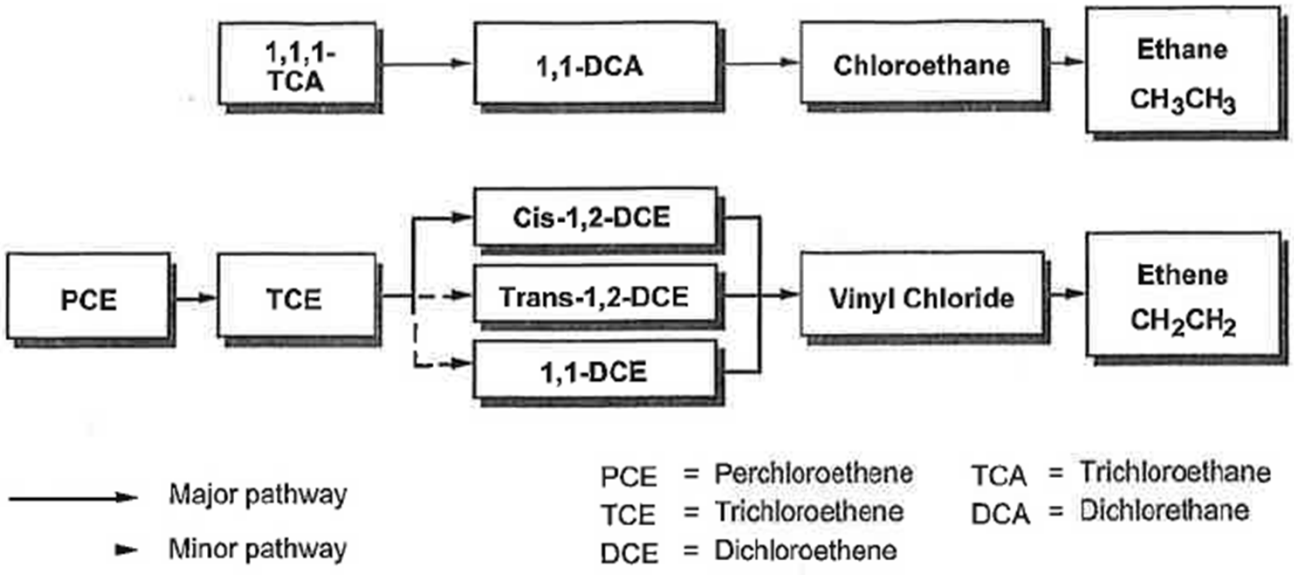
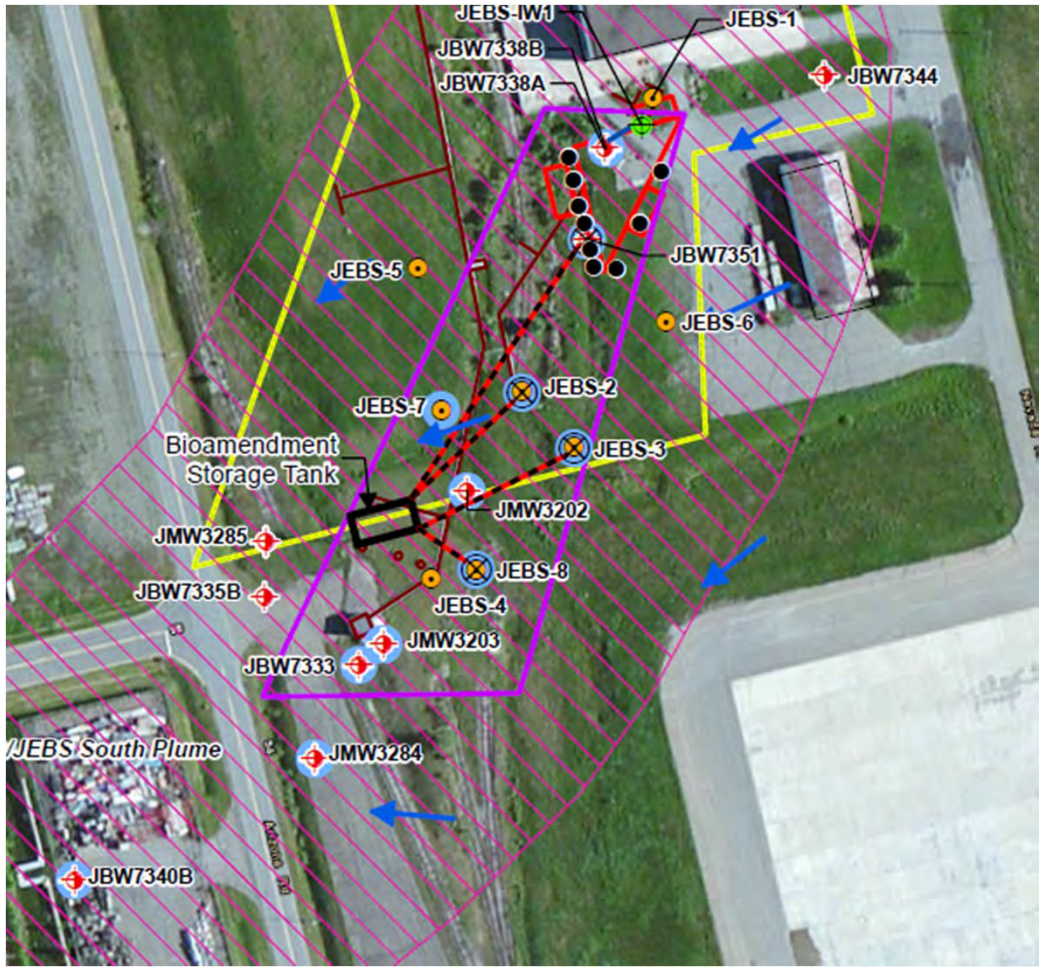


Figure 1. Reductive dechlorination pathways for common chlorinated aliphatic hydrocarbons (after Vogel and McCarty,1985; Vogel and McCarty,1987).

Pilot Study Results

- Performance Monitoring Evaluation
  - How do we review the data?
  - Geochemistry
    - pH, ORP, etc…
    - TOC
    - Gen. chem.
  - Chemical
    - COC concentration reductions
    - Daughter products
    - DHC/DNA
  - Physical
    - Amendment Distribution



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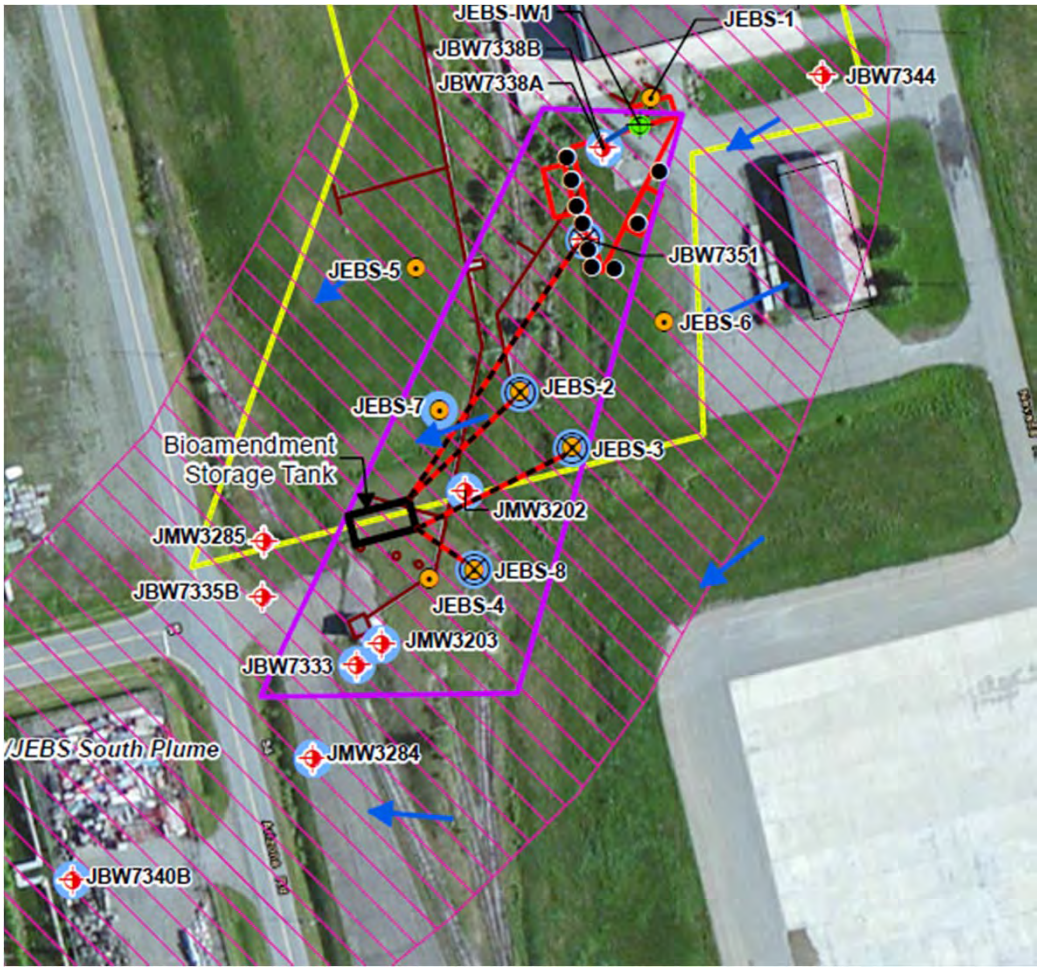
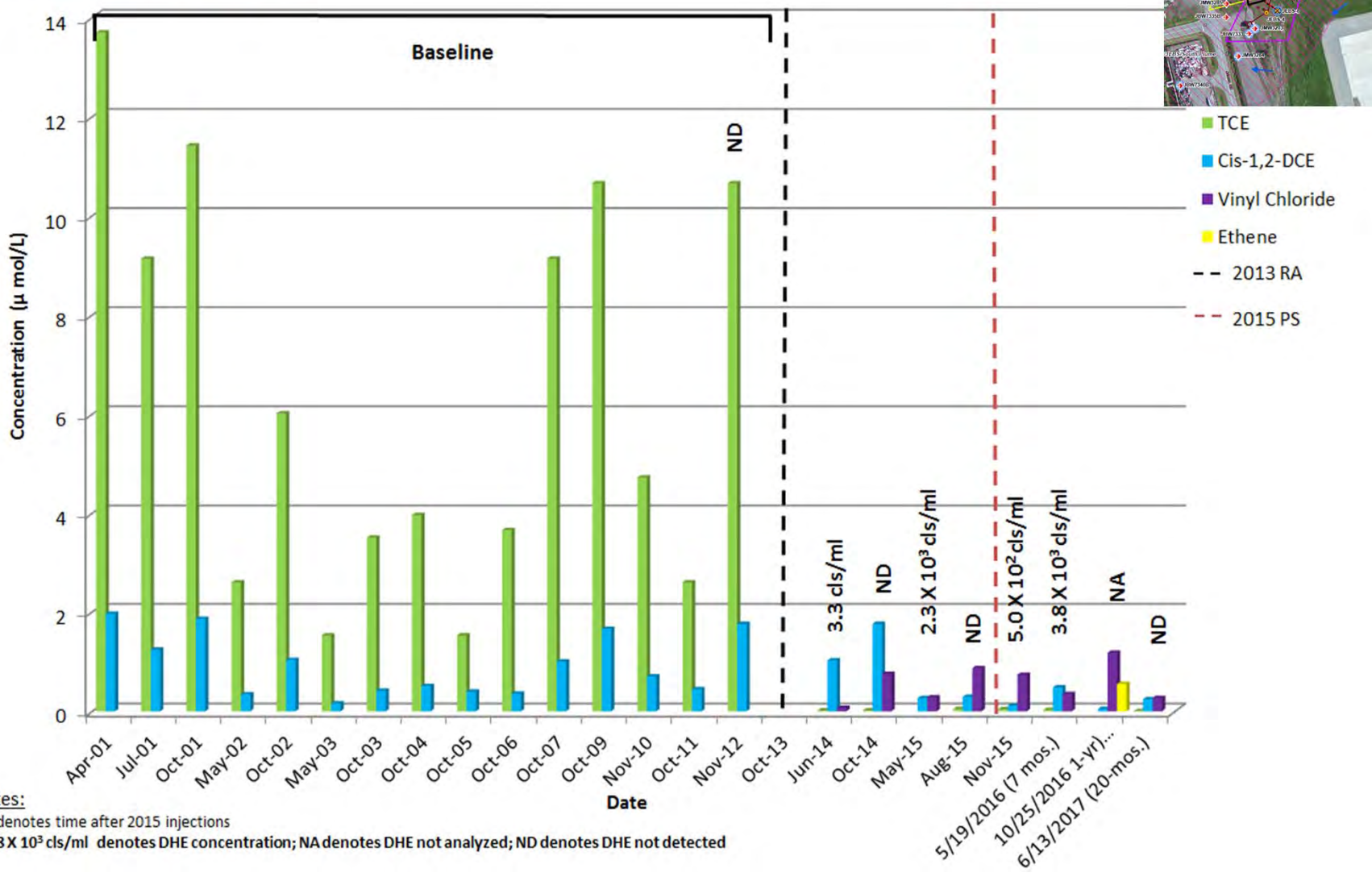
Pilot Study Results

- Favorable Geochemistry
  - pH
    - 5-9 (5.31 to 7.21)
  - ORP (< -50 mV)
  - TOC
    - >20 mg/L (42.7- 1,300 mg/L)
    - Highest in IWs, decreases further downgradient
  - Methane
    - Strongly anaerobic conditions exist.
    - Fermentation of carbon substrate
    - Available H+
  - TEAs
    - Mainly ND or low conc.



JBW7338B



Notes:

- () denotes time after 2015 injections
- **3.8 X 10^3 cls/ml denotes DHE concentration; NA denotes DHE not analyzed; ND denotes DHE not detected**

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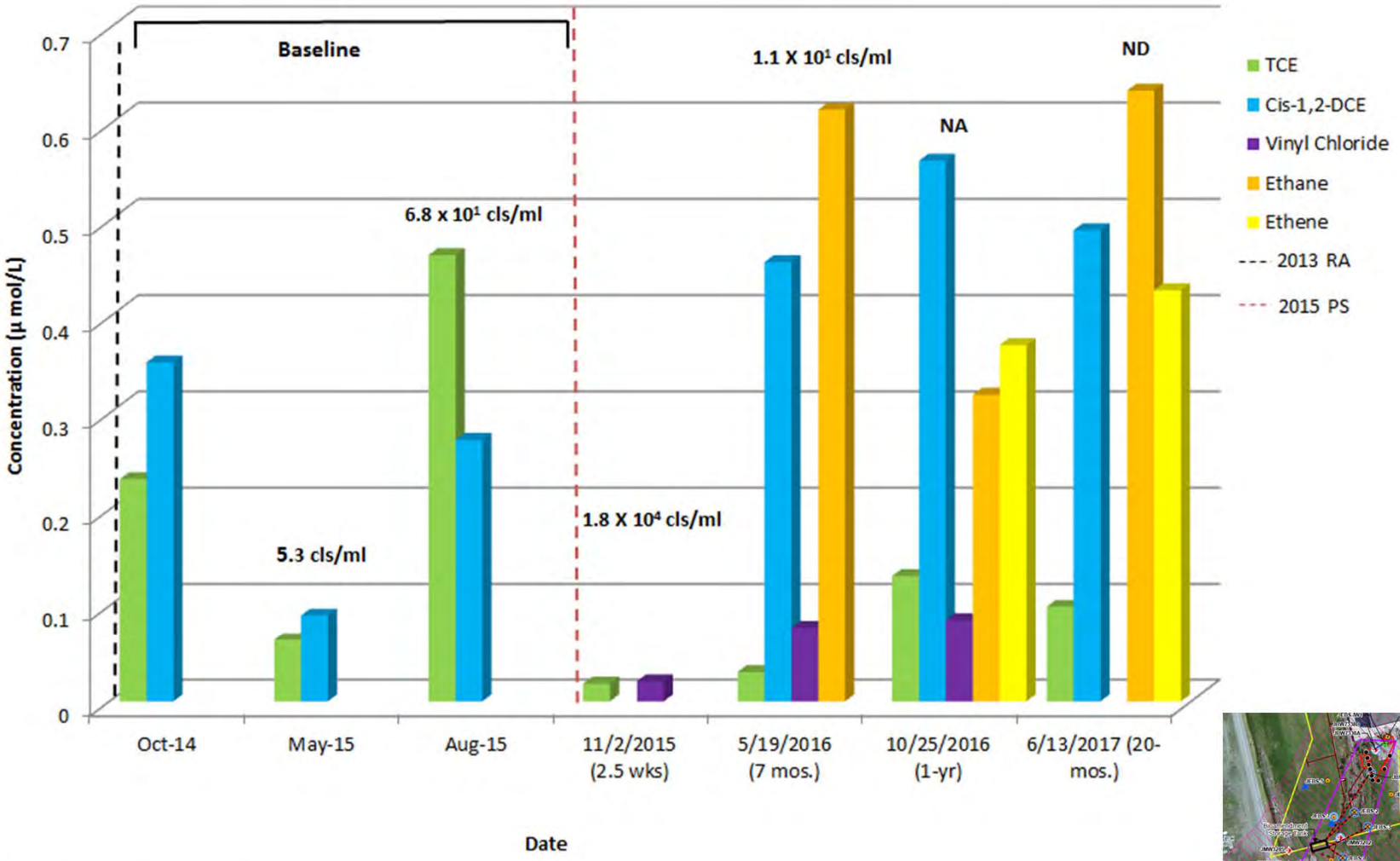
JEBS-2



Notes:

- () denotes time after 2015 injections
- 1.8 X 10⁴ cls/ml denotes DHE concentration; NA denotes DHE not analyzed; ND denotes DHE not detected

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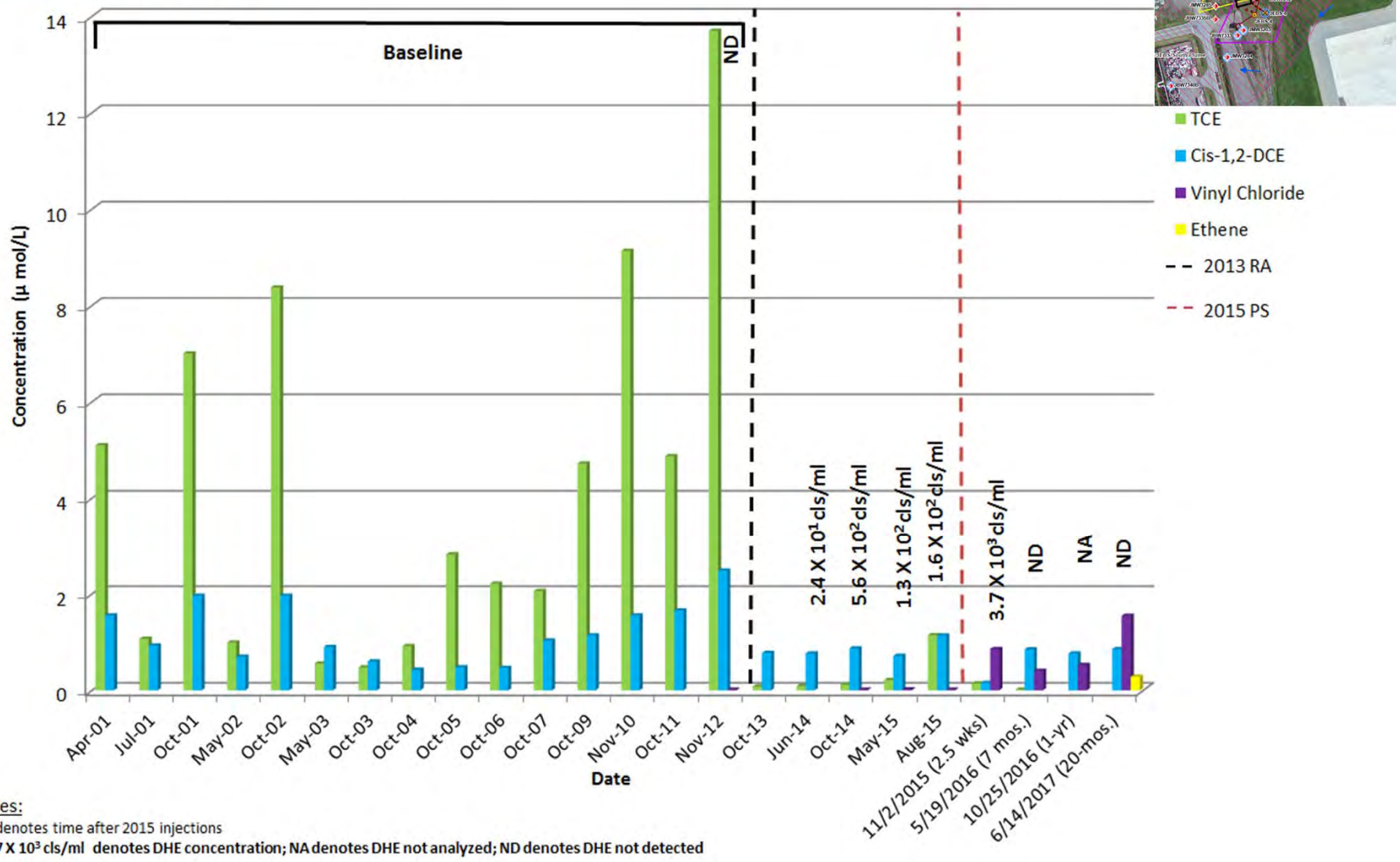
JMW3202



Notes:

- () denotes time after 2015 injections
- **3.7 X 10^3 cls/ml denotes DHE concentration; NA denotes DHE not analyzed; ND denotes DHE not detected**

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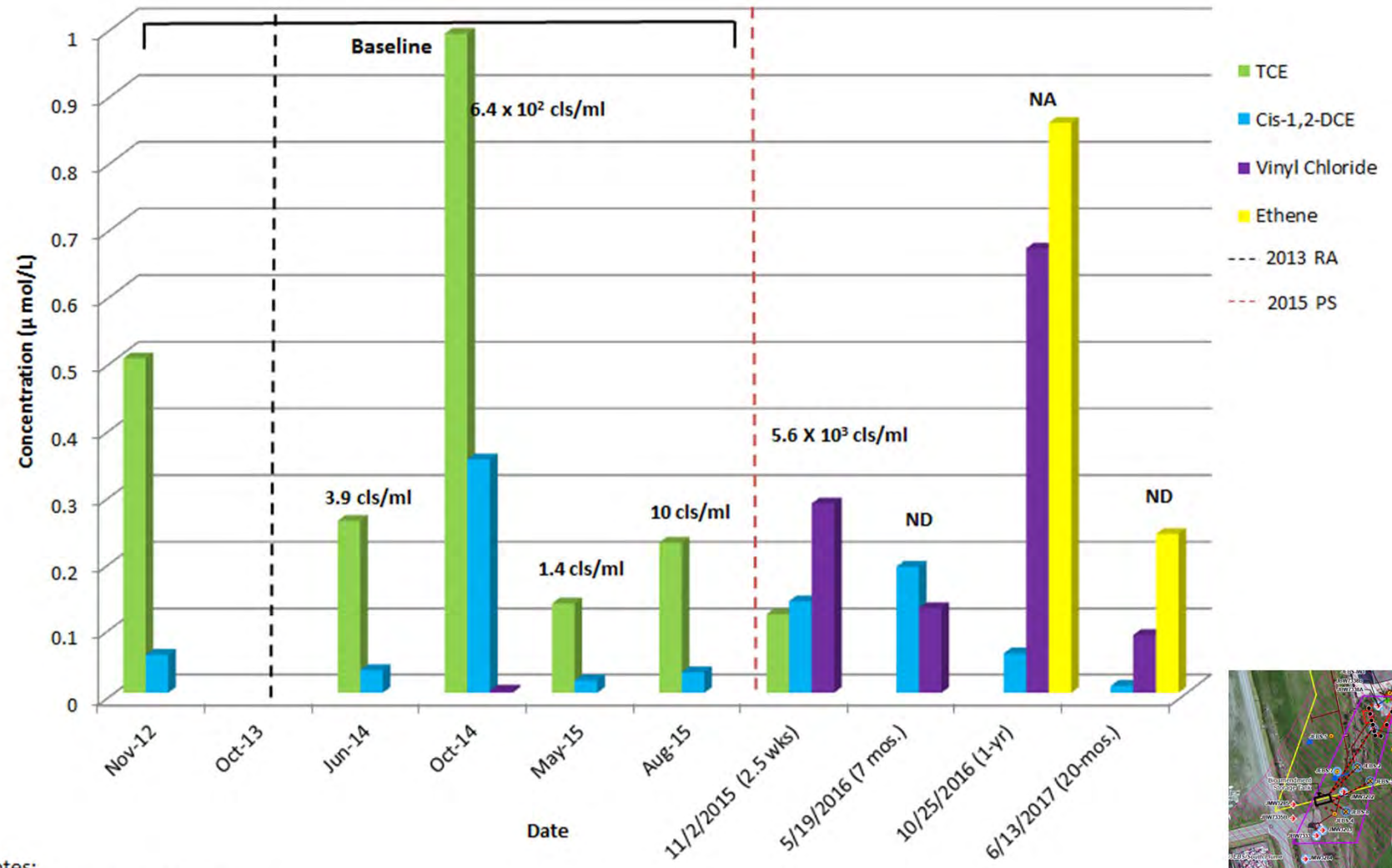
JMW3203



Notes:

- () denotes time after 2015 injections
- 5.6 X 10^3 cls/ml denotes DHE concentration; NA denotes DHE not analyzed; ND denotes DHE not detected

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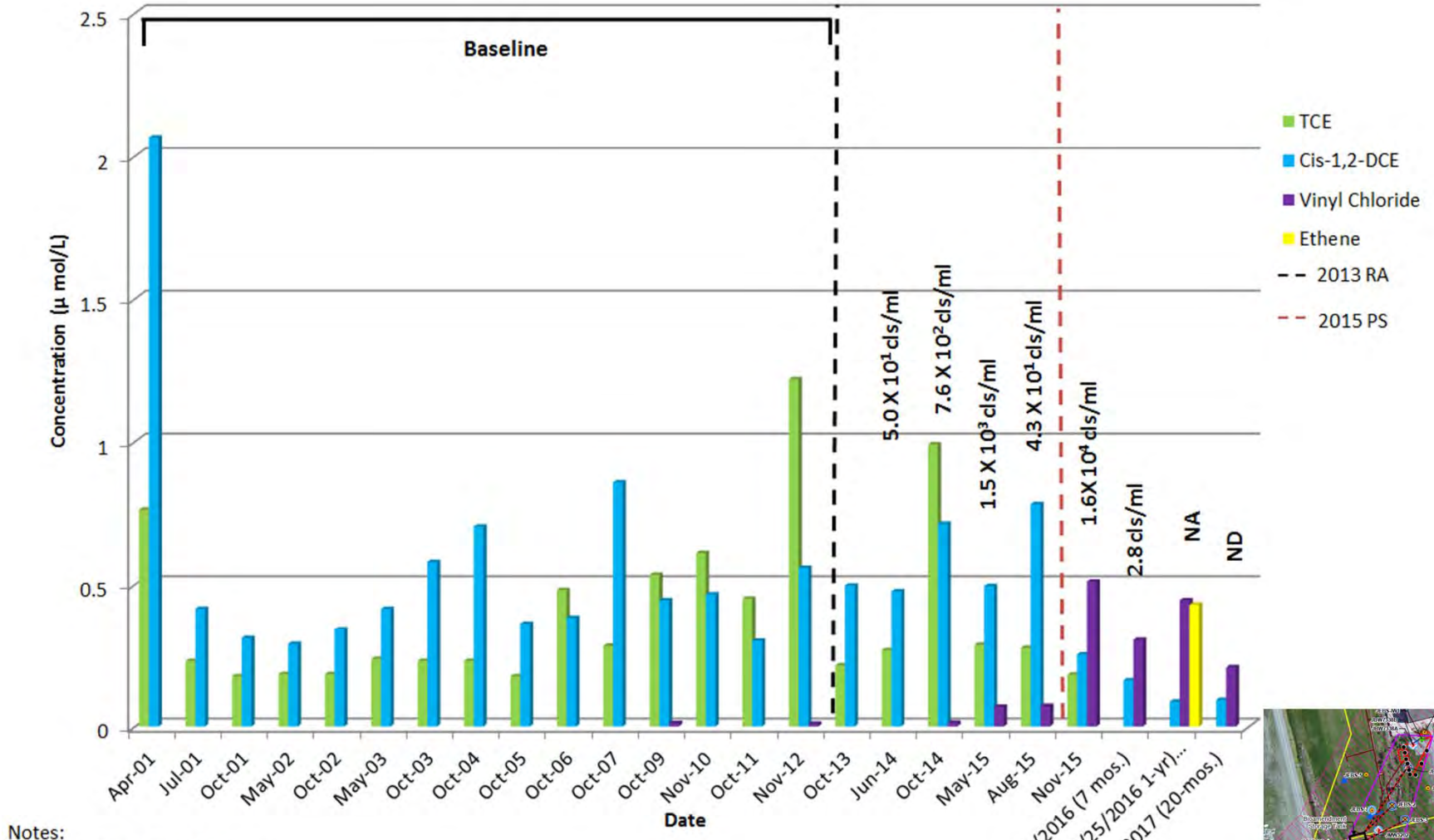
JBW7333



Notes:

- () denotes time after 2015 injections
- **1.6 X 10^4 cls/ml denotes DHE concentration; NA denotes DHE not analyzed; ND denotes DHE not detected**

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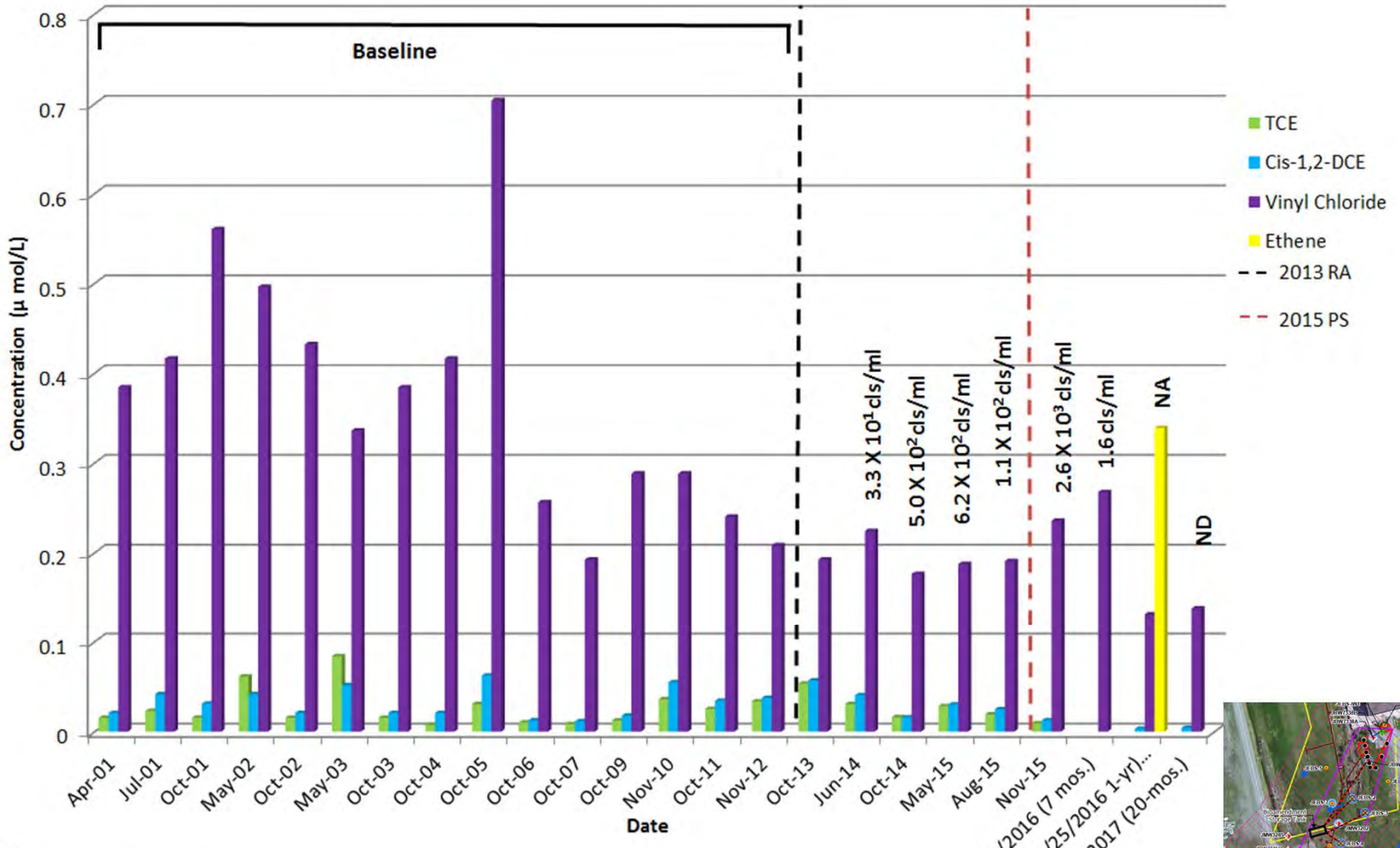
JBW7340B



Notes:

- () denotes time after 2015 injections
- 2.6 X 10^3 cls/ml denotes DHE concentration; NA denotes DHE not analyzed; ND denotes DHE not detected

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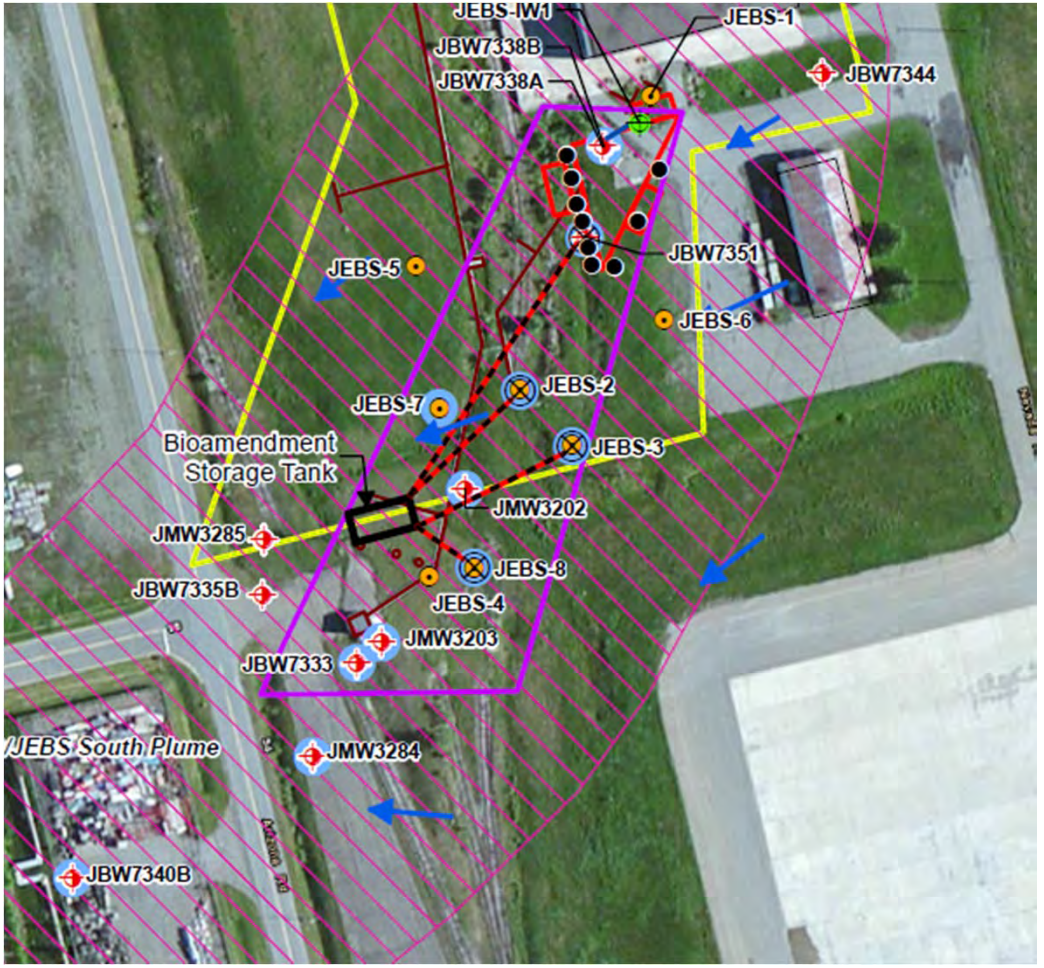
Pilot Study Results

- Physical
  - Amendment Distribution
    - Injection Wells (fa.15 – sp.17)
    - JEBS-7 (fa.15 – sp.17)
    - JMW3202 (fa.15 – sp.17)
    - JMW3203 (fa.15)
    - JBW7333 (fa. 15)
    - JBW7340B (fa.15 – fa.16)



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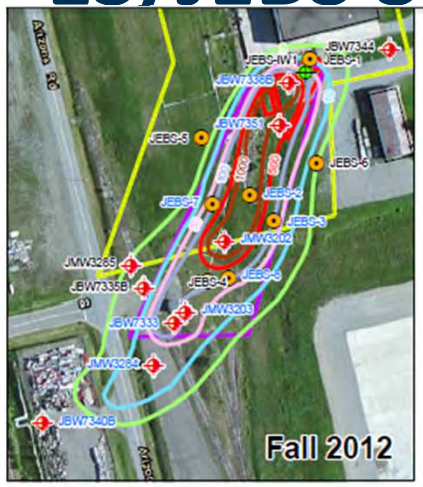
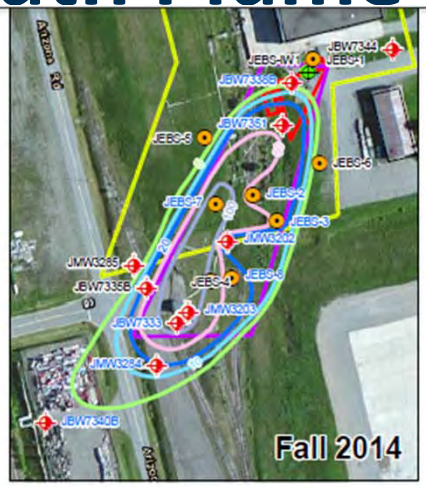
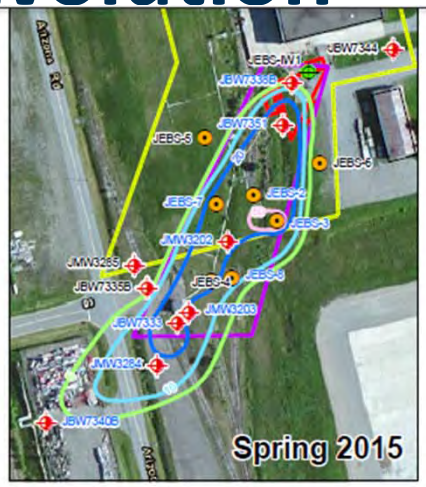
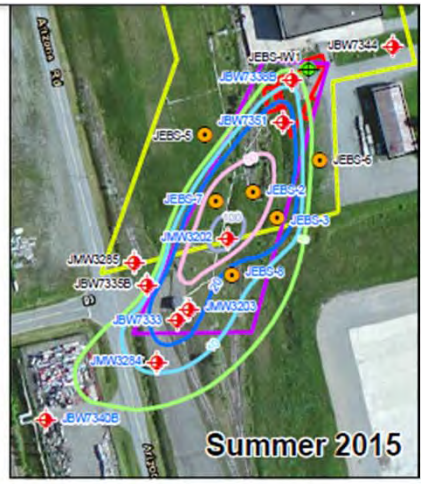
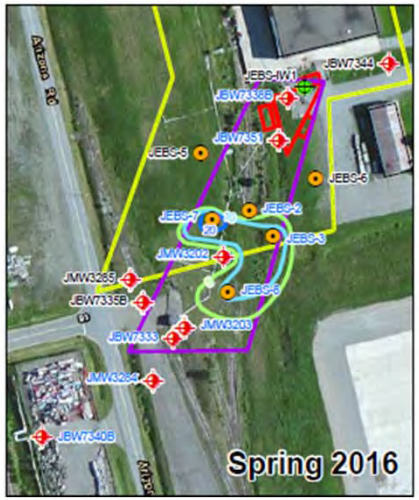
ES/JEBS South Plume Evolution











Legend

- Horizontal Injection Well Riser Pipe
- Bedrock Monitoring Wells
- 2014 Bedrock Borehole
- 2013 Soil Excavation Area
- Compliance Boundary
- ES/JEBS Treatment Area
- JBW7333 Performance Monitoring Well
- 5 ppb TCE Concentration Contour
- 10 ppb TCE Concentration Contour
- 50 ppb TCE Concentration Contour
- 100 ppb TCE Concentration Contour
- 500 ppb TCE Concentration Contour
- 1000 ppb TCE Concentration Contour

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ES/JEBS South Plume Results Summary

- Reductions of TCE across the site
  - Impacts measured 335 feet downgradient
- Several wells ND for the first time in sampling history
  - JMW3203; JBW7333; JBW7340B; (3 - consecutive rounds)
  - JMW3202; JMW3284 (2- consecutive rounds)
  - JBW7351 (fall 2016)
  - JEBS-7 (spr. 2017)
  - JEBS-8 (spr. 2017)
- Ethene Production for first time in sampling history
  - 8 of 11 wells
  - Complete dechlorination of TCE
  - Biofilms may still explain reductive dechlorination
- Residual source material may still be present
  - JEBS-2, JEBS-3

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ES/JEBS South Plume Results Summary

- Overall Plume Reduction
  - 2013 RAs reduced plume from 2.35 acres (2012) and max. conc. of 1,800 ppb to 1.92 acres (2014) and max. conc. of 130 ppb.
  - 2015 ISEB PS reduced plume from 2.0 acres (rebound from 2014) and max. conc. of 150 ppb to 0.24 acres (2017) and a max. conc. of 13 ppb.
- Overall Concentration Reduction
  - 94-99% concentration reductions
    - 9 out of 11 wells

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Conclusions

- Take the time and characterize your site
- Know your site conditions
- Data, Data, Data
- Draw in experience

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Closing and Thank you!

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