# Sustainable Remediation Case Study: Transitioning from Pump and Treat to ISS and ISBR to Address DNAPL and Dissolved-Phase VOCs

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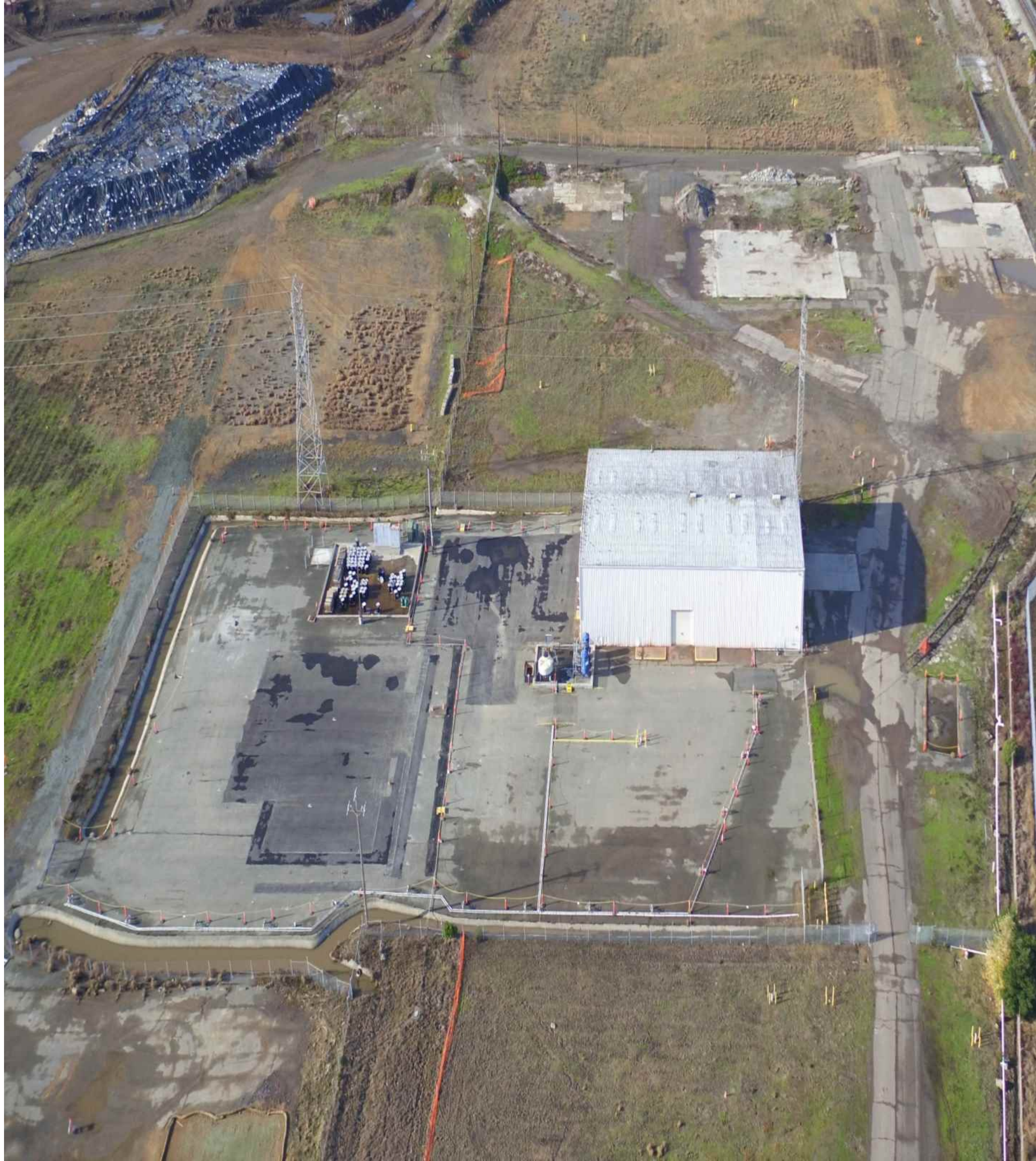
Sustainability is our business





# Agenda

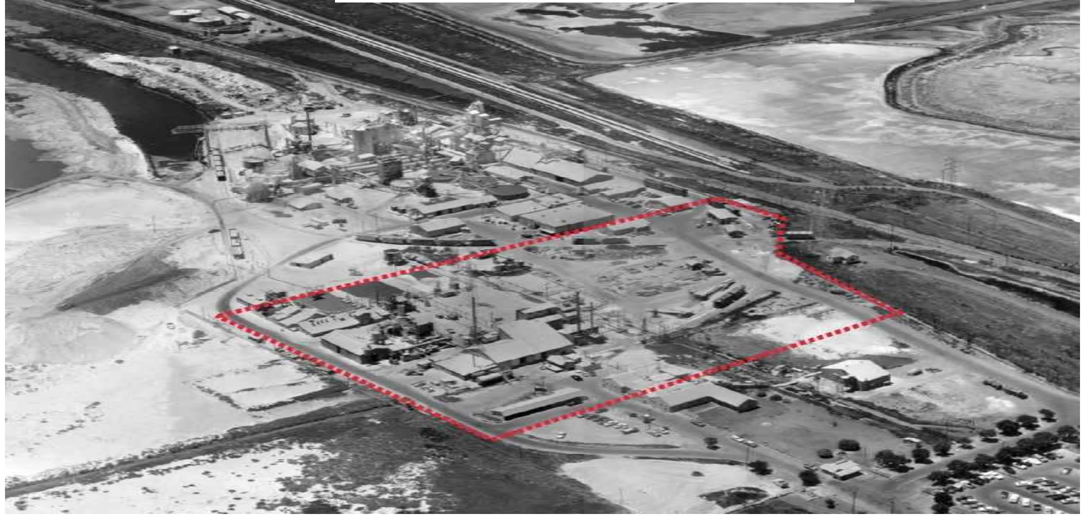
- Background
- Conceptual Site Model
- Bench and Field Pilot Studies
- Full-Scale Implementation
- Lessons Learned

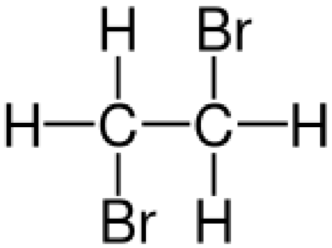
# Background

Site and Remediation History

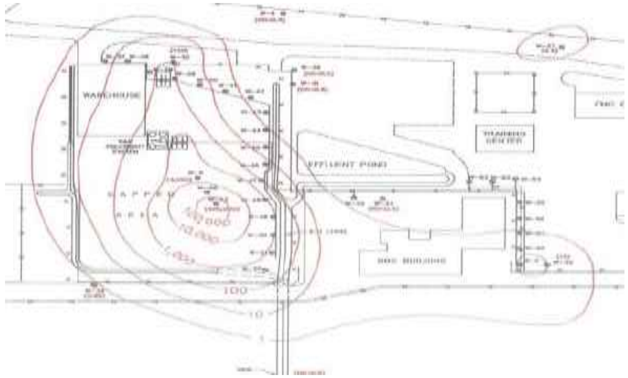
- Former ethylene dibromide (EDB) manufacturing plant in the San Francisco Bay Area
- EDB was manufactured primarily for agriculture use as a soil fumigant
- Release of approximately 8,000 gallons of EDB
- In the mid-1980s, a remedy consisting of an asphalt cap over the EDB release area and pump and treat (P&T) system was installed
- The existing remedy was not an effective, reliable, or sustainable long-term solution

**Historical Aerial Photo**





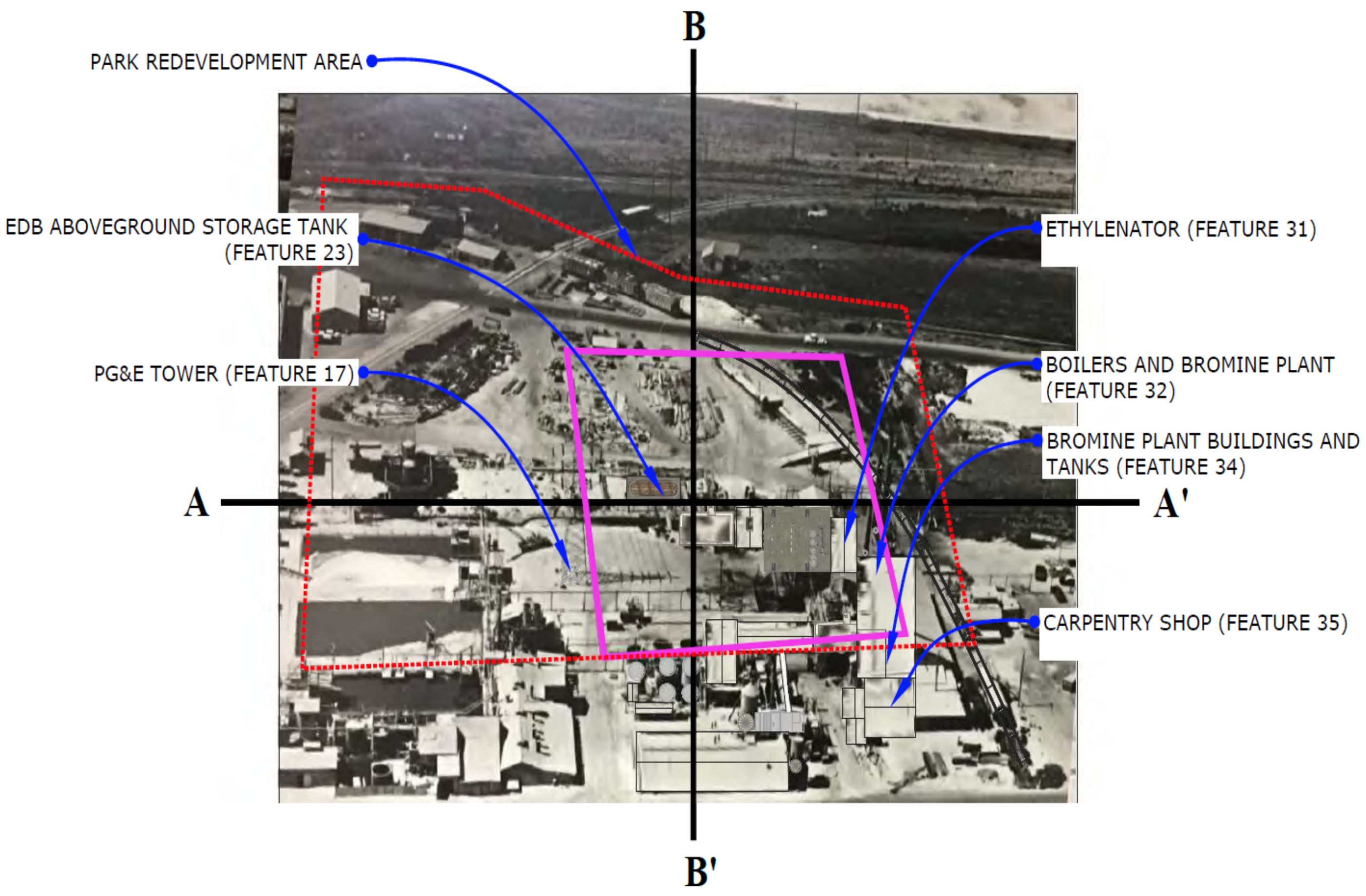

**Ethylene Dibromide**



**EDB Groundwater Plume**

# Background

## Site Redevelopment and Future Land Use





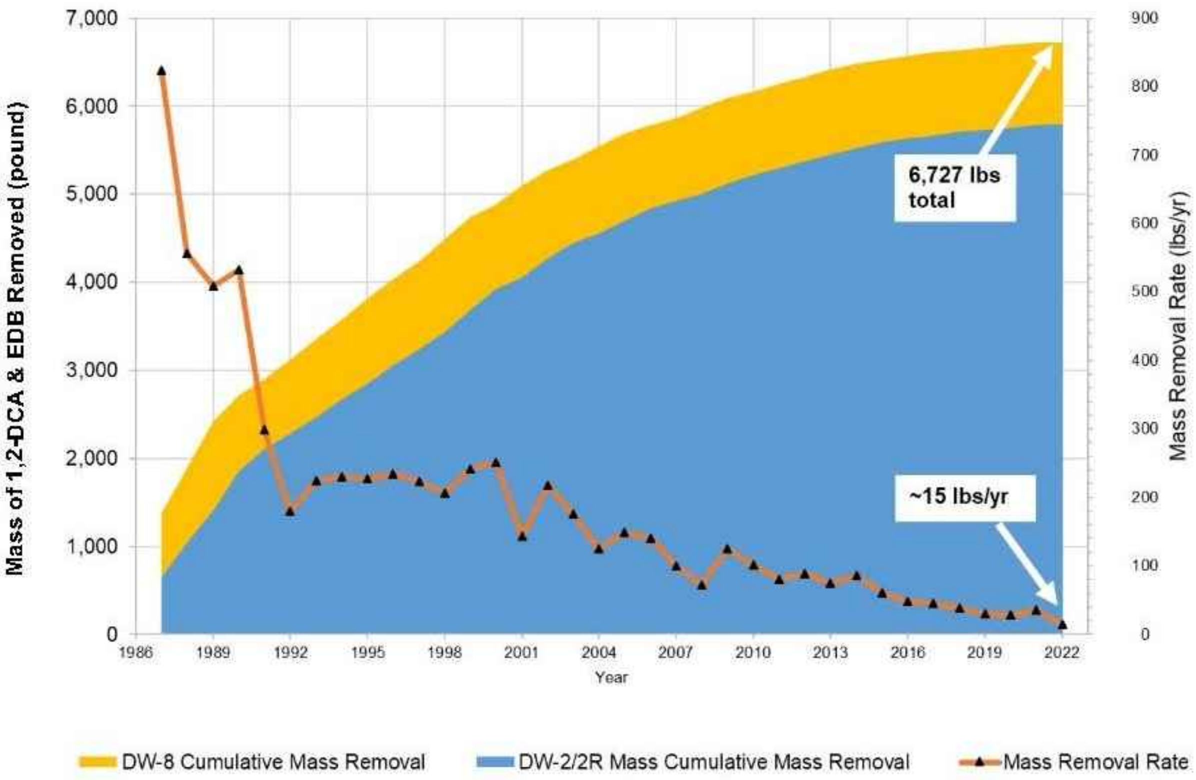
**Conceptual Park Plan (September 2018)**

# Background

## Alternative Remediation Strategy and Objectives

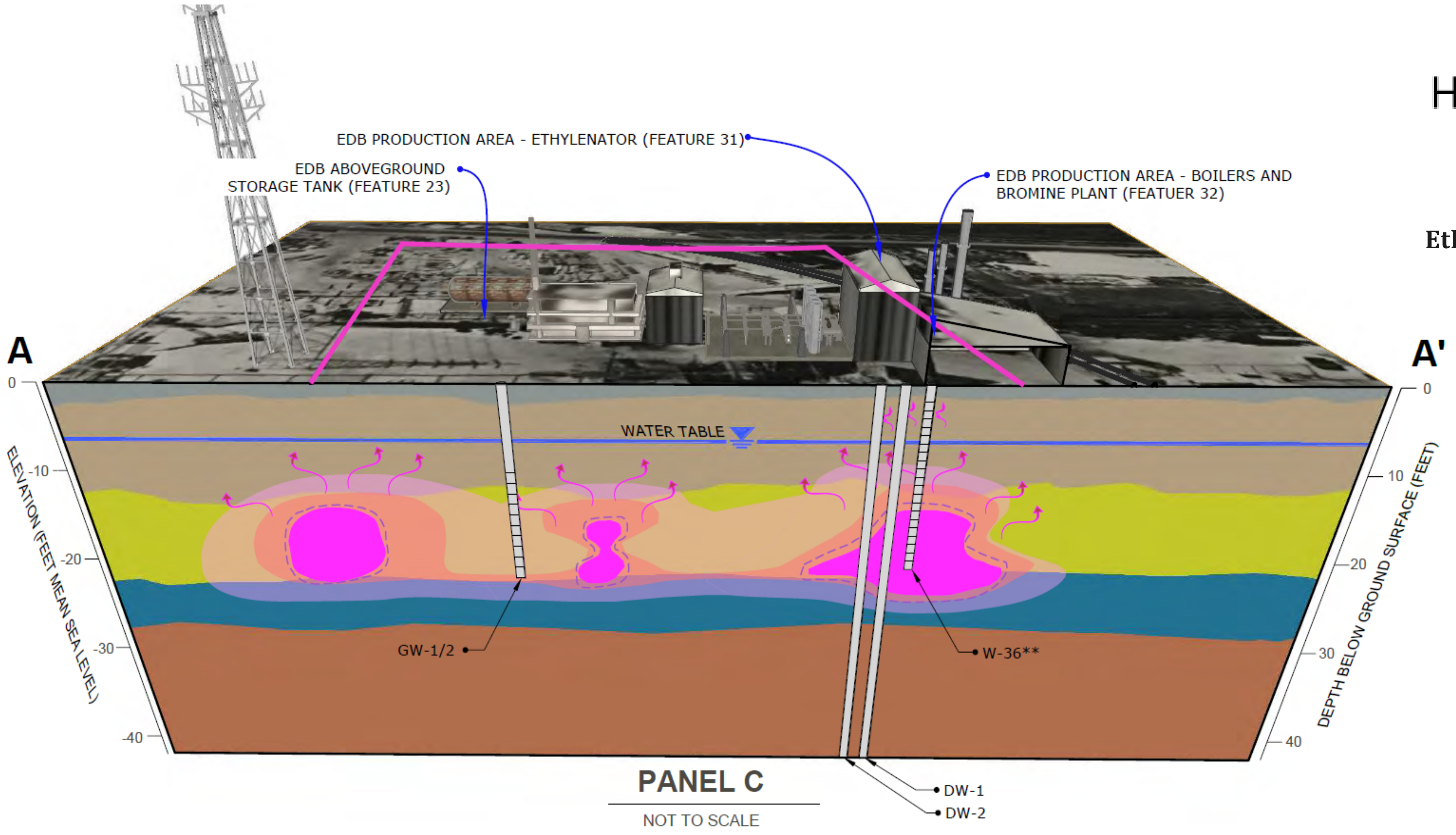
- Alternative remedy needed to address DNAPL/recalcitrant contaminants, be cost-effective and be compatible with the site redevelopment plans
- Selected ISS for DNAPL/source zone and ISBR for shallow groundwater and the deeper aquifer
- Shutdown of the existing P&T system
- Started with bench-scale treatability studies followed by ISS and ISBR field pilot studies
- Used a groundwater fate and transport model to evaluate several new remedial alternatives
- Full-scale implementation of ISS/ISBR remedy initiated in 2020 and completed in 2023.

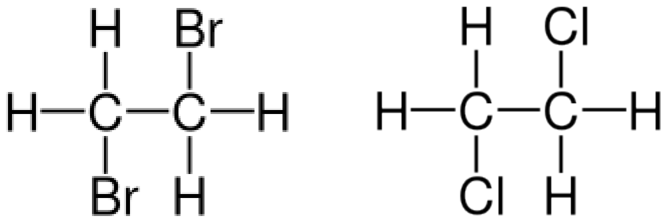
**Deeper Aquifer Mass Removal Graph**



# Conceptual Site Model

## Contaminant Fate and Transport Mechanisms

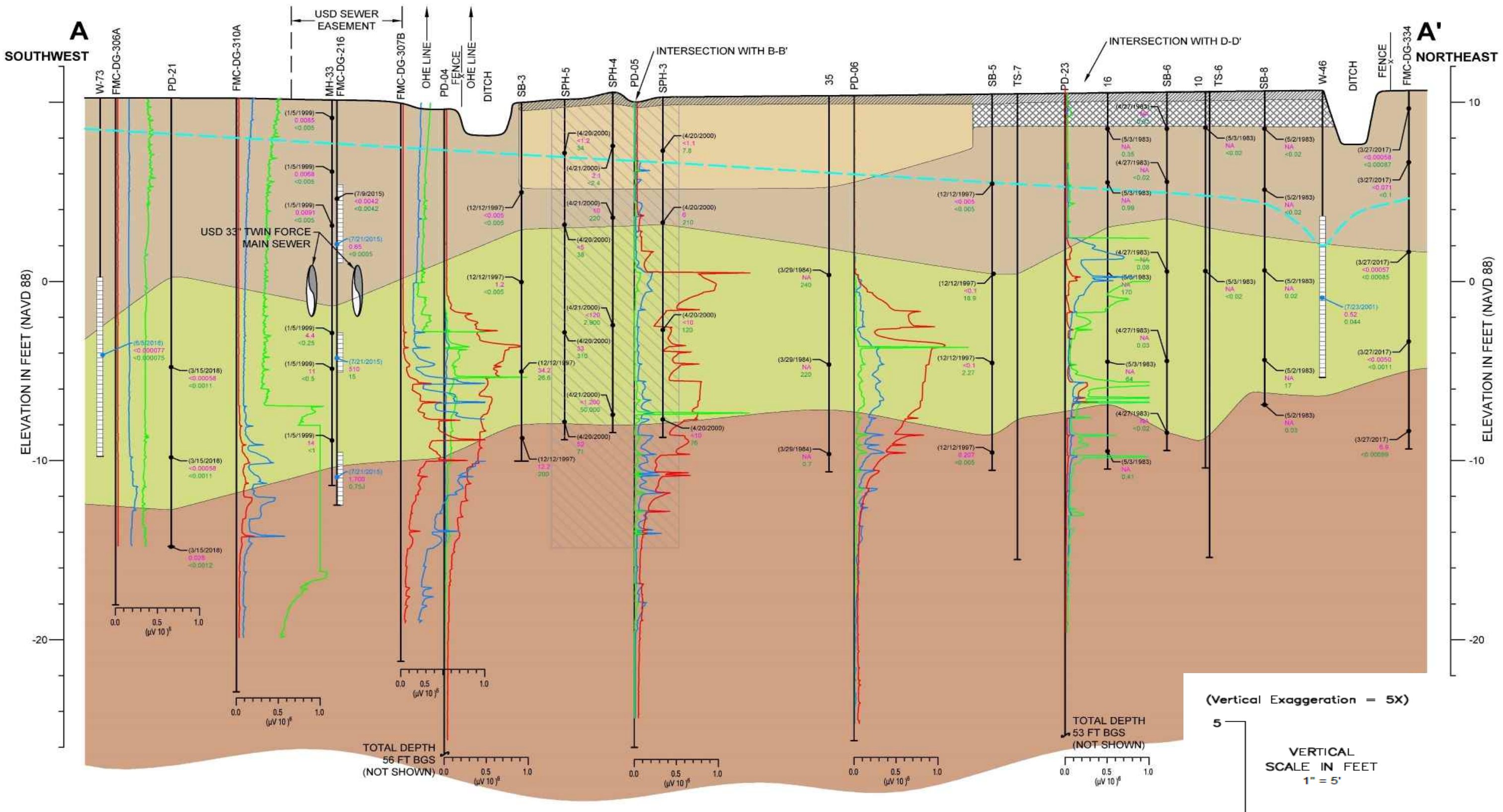


**Ethylene Dibromide** **1,2-Dichlorethane**

# Conceptual Site Model

## Remedial Predesign Investigation and Results

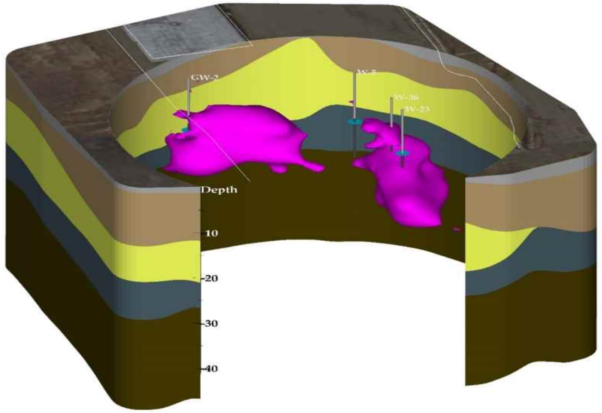



Refined EDB Cap Area Cross Section A-A’

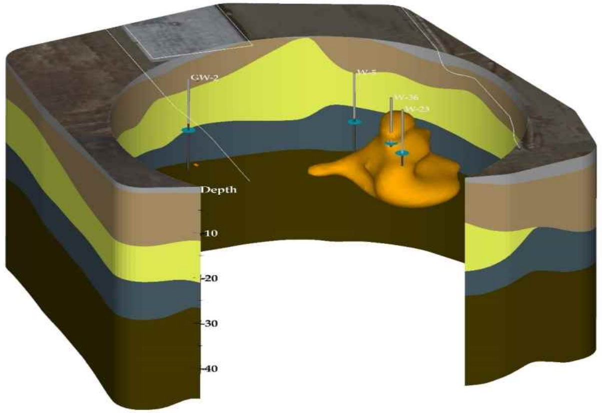

# Conceptual Site Model

## 3D Modeling

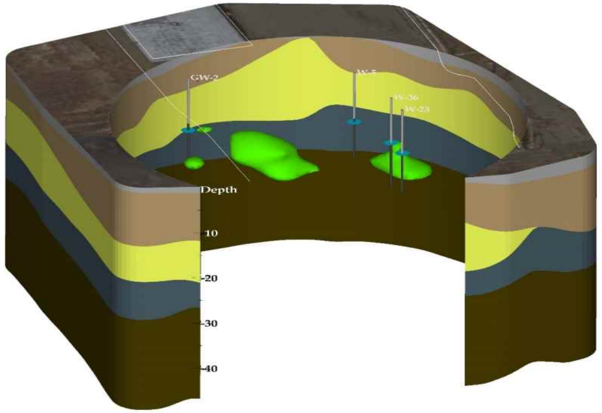
**Ethylene dibromide (EDB)**



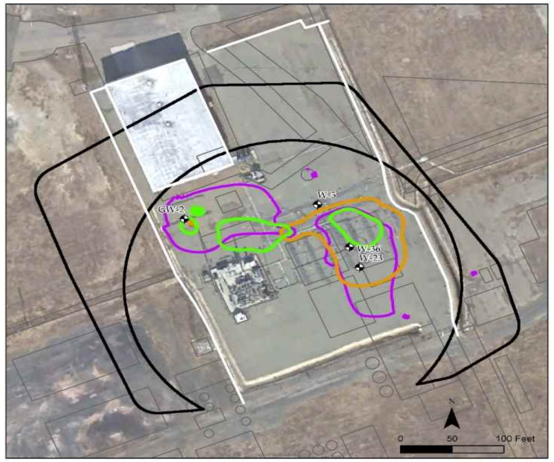

**Bromoform**




**1,2-Dichloroethane (1,2-DCA)**




**3D Model Extent and Source Zone Footprint**




**Boring Locations**


### Legend

- Ethylene dibromide (EDB) > 100 mg/kg
- Bromoform > 100 mg/kg
- 1,2-Dichloroethane (1,2-DCA) > 100 mg/kg
- Fill
- Silty-Clay
- Silty-Sand
- Blue-Gray Clayey-Silt } Aquitard
- Brown Silty-Clay } Aquitard

# Treatability Studies

Objectives, Design, and Results

## Objectives

- Evaluate other potential remedial technologies that had not been previously attempted

## Design

- Slurry Wall, ISS, and ISS combined with ISCO (persulfate) for the DNAPL/source zone
- ISBR, ISCR, and ISCO (persulfate) for shallow groundwater

## Results

- ISS was effective for DNAPL/source zone soils
- Although some mass destruction was documented, combining ISS with ISCO wasn't necessary
- ISBR was most effective for shallow groundwater

**Soil Logging/Sample Collection**

**Hydraulic Conductivity Testing**

**Bulk Soil Sample**

**Monolith Leachability Testing**

# ISS Field Pilot Study

Design and Results

## Design

- Installed ISS columns in two identified DNAPL/source areas
- Reagents were Portland cement and ground granulated blast furnace slag, also know as “slag” cement

## Results

- Met strength and hydraulic conductivity goals
- Leachability testing demonstrated significant reduction in mass flux of EDB and 1,2-DCA
- Demonstrated effective control of odors and VOC vapor emissions using a shroud and foam
- Post-ISS vapor flux chamber study showed no significant outdoor air risk to future park users

**ISS Pilot Study Layout**

**ISS Treatment in Area A**



**ISS Swell Survey**

**Post-ISS Vapor Flux Study**

# ISCR/ISBR Field Pilot Study

Objectives, Design, and Results

## Objectives

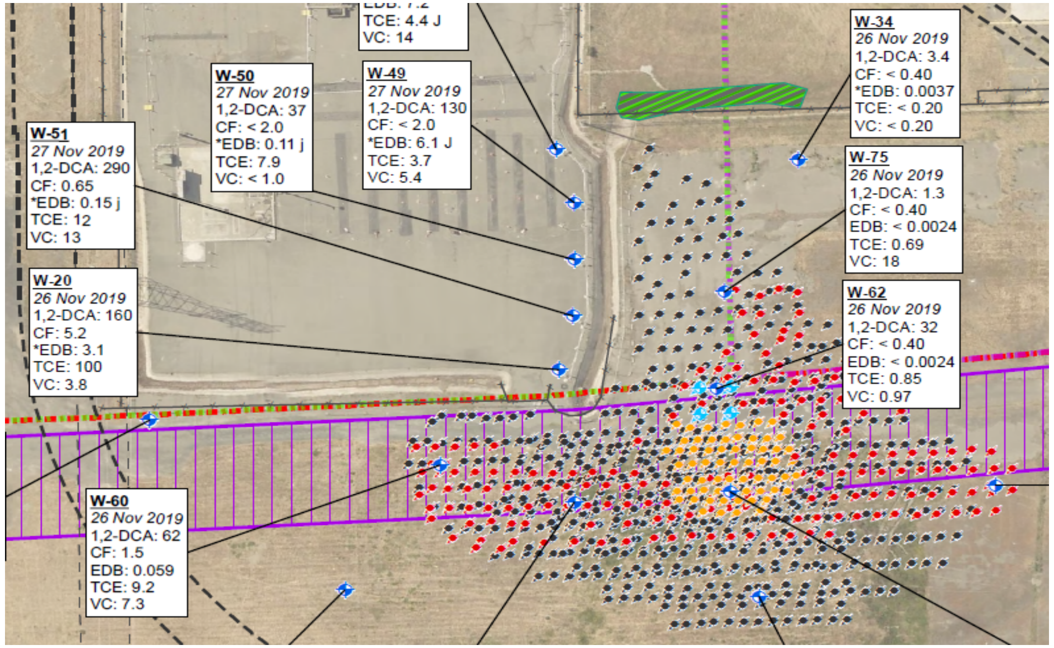
- Target 1,2-DCA and TCE in shallow groundwater
- Control source(s) to limit migration and future potential vapor intrusion risk in the residential development areas

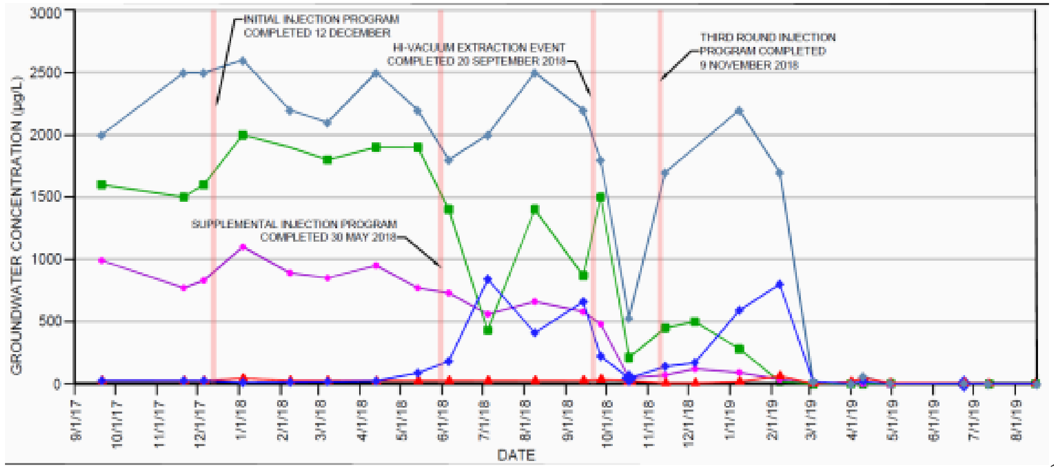
## Design

- Zero-valent iron, ferrous iron, carbon substrate, and microbial inoculates
- Four rounds of injections and 921 injection points total
- 25 post-injection groundwater monitoring events

## Results

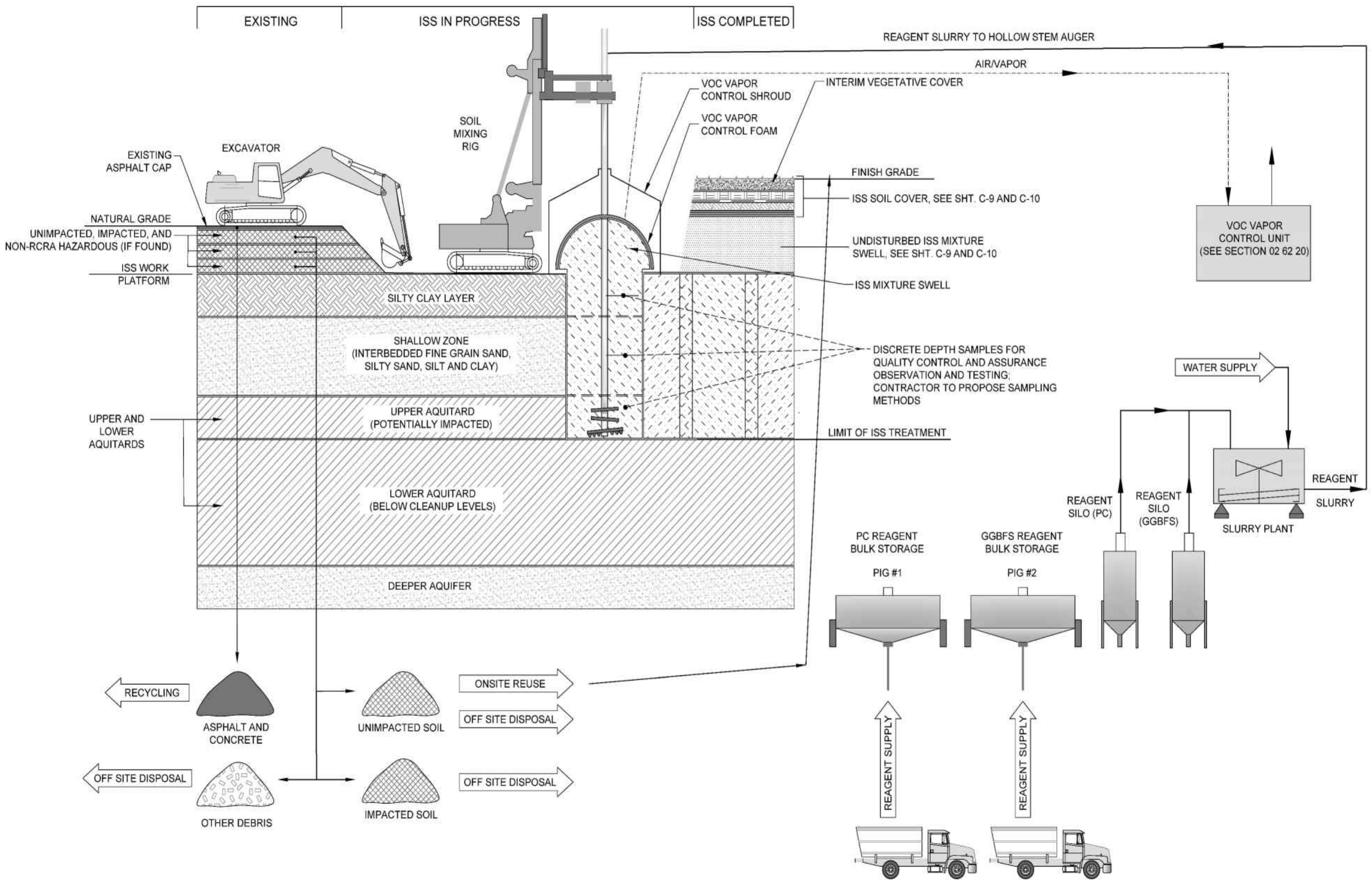
- Achieved >99% reduction of 1,2-DCA and TCE
- All COCs were reduced to below their respective risk-based cleanup levels
- Received No Further Action for shallow groundwater



# Full-Scale ISS

## ISS Treatment Process Flow Diagram



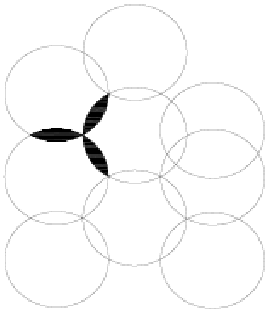

# Full-Scale ISS

## ISS Mix Design and Treatment Areas

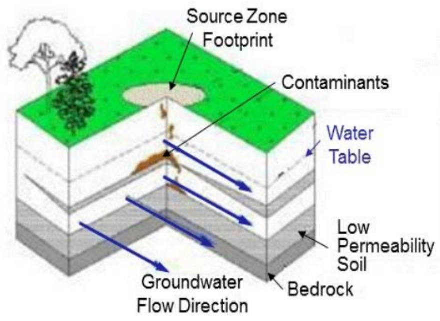
- ISS work was completed in two phases due to the presence of twin force sewer mains in the ISS treatment area
- Total ISS treatment volume was 45,000 cubic yards over 1.5 acres
- Reagent mix design was 4% Portland cement and 4% slag cement
- ISS keyed into aquitard to prevent further migration of DNAPL into deeper aquifer
- Soil cover system integrated with passive vapor barrier and collection system

| Phase 1 ISS Stats | Phase 2 ISS Stats |
|---|---|
| 2020 | 2022 |
| 57,000 sf | 11,000 sf |
| 36,000 cy | 9,000 cy |
| 25–30 ft bgs | 25–30 ft bgs |
| 10-foot | 6-foot |
| 908 ISS column | 493 ISS columns |
| 198 QC samples | 38 QC samples |

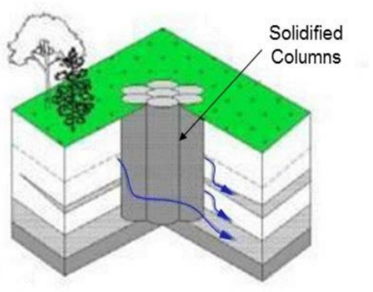
Notes: sf = square foot; cy = cubic yard; bgs = below ground surface; QC = quality control



TYPICAL DRILL PATTERN
N.T.S




**Groundwater Contact Scenario Before ISS**



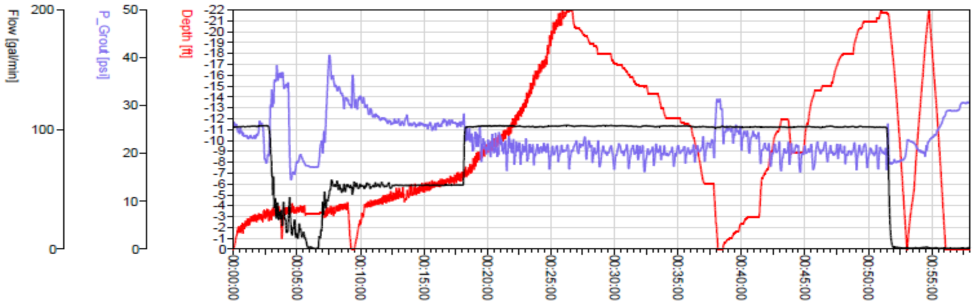

**Groundwater Contact Scenario After ISS**

Source: Interstate Technology and Regulatory Council, 2011. *"Development of Performance Specification for Solidification/Stabilization".* July.

# Full-Scale ISS

## Phase 1 and 2 ISS As-Builts


### Example “GUHMA Log” with ISS Drilling Parameters




Phase 1 ISS Drilling Rig (taller mast, more torque, larger-diameter augers)

Phase 2 ISS Drilling Rig (shorter mast, less torque, smaller–diameter augers)

# Deeper Aquifer ISBR Pilot

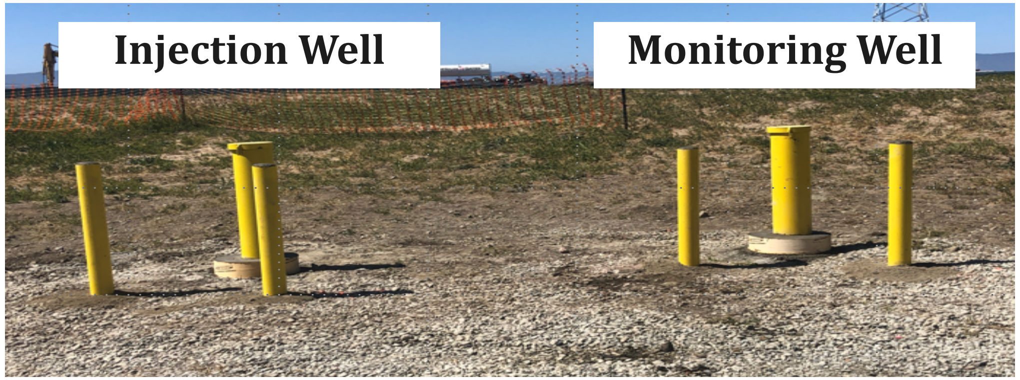
Pilot Study Objectives and Design

## Objectives

- Elevate viability of ISBR to remediate EDB and 1,2-DCA in saline groundwater conditions
- Shut down P&T system permanently

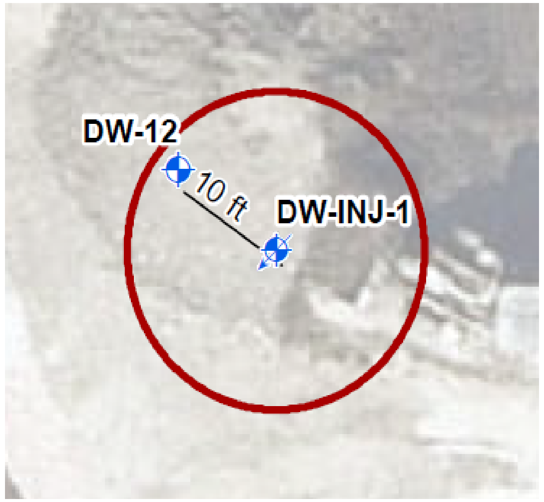
## Design

- Considered a bench study, but opted for field pilot study
- Installed injection and monitoring wells 10 feet apart
- Verified pilot test area represented groundwater plume conditions in deeper aquifer

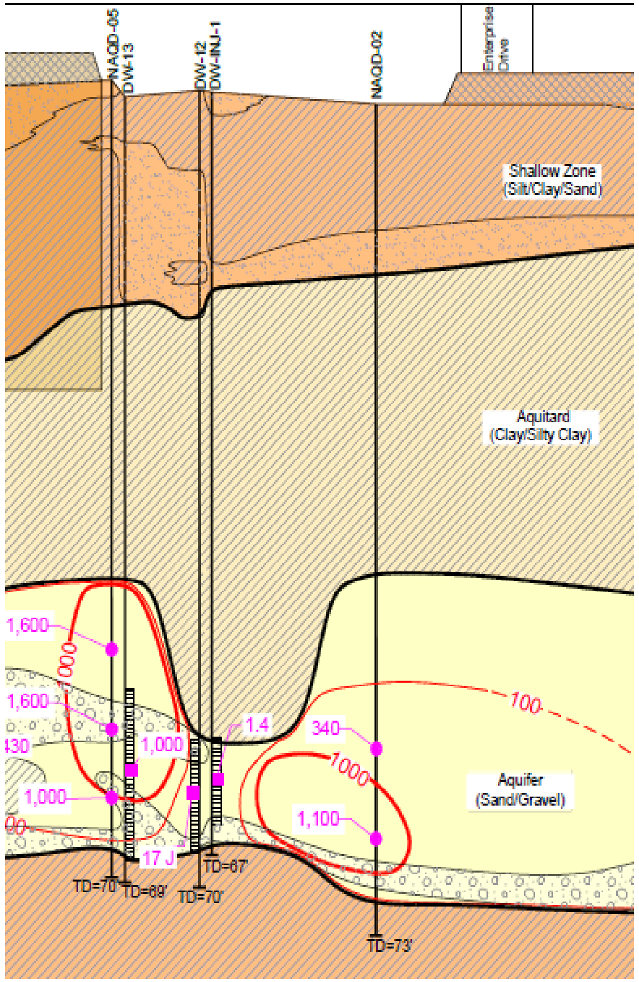




Deeper Aquifer Soil Type




Injection Well Spacing




Deeper Aquifer ISBR Pilot Cross-Section

# Deeper Aquifer ISBR Pilot

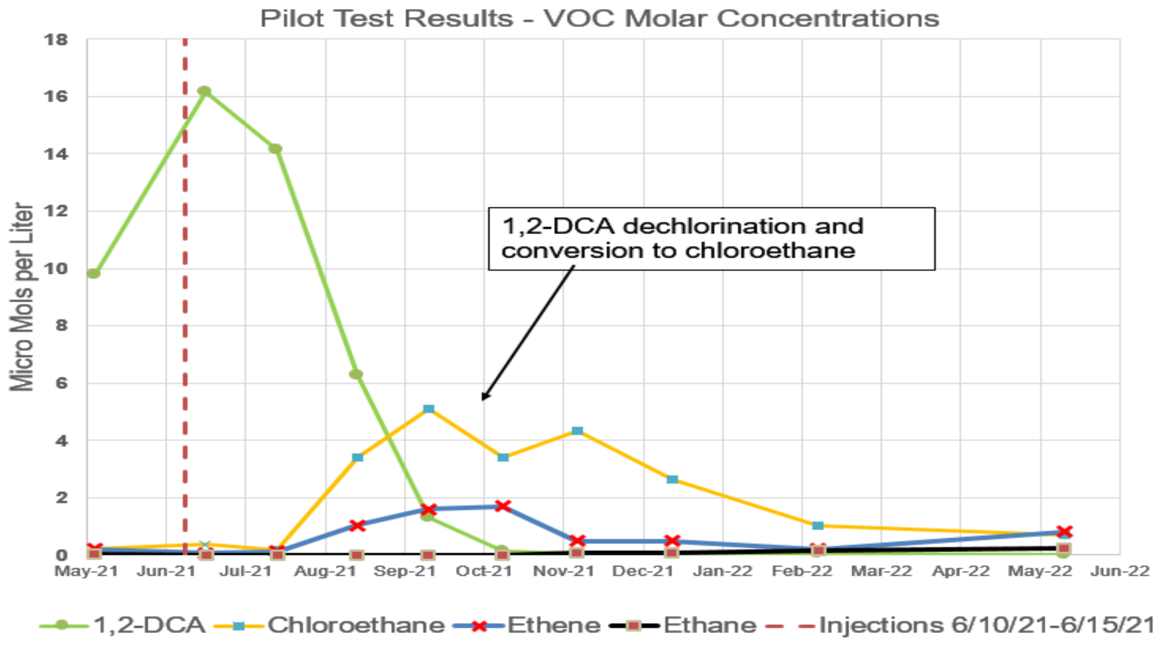
Pilot Study Implementation and Results

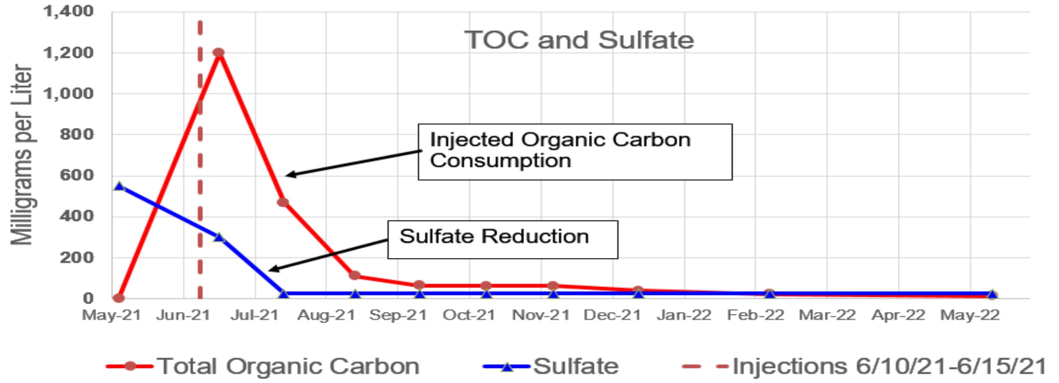
## Implementation

- Phase 1 injected 4,900 gallons of mixed ELS®/EHC® reagents with KB-1 Plus® and MDB-1 ® microbes
- Phase 2 injected 67,500 gallons of ELS® reagent with SCD-9 ® with MDB-1 ® microbes

## Results

- Achieved >99% reduction of 1,2-DCA and no rebound 1 year after injections
- Observed rapid onset of sulfate-reducing conditions
- No significant generation of vinyl chloride
- Remediation of 1,2-DCA was feasible under saline groundwater conditions



# Deeper Aquifer ISBR

Full-Scale ISBR Design and Implementation

- Source was located under the ISS treatment area
- Needed a solution that avoided drilling through the ISS monolith
- Selected a groundwater recirculation system for distributing the ISBR reagents
- Recirculation system consisted of 14 injection/extraction wells
- Supplemented with 40 direct-push injection points
- Started direct-push injections 10 days prior to starting the recirculation wells

# Deeper Aquifer ISBR

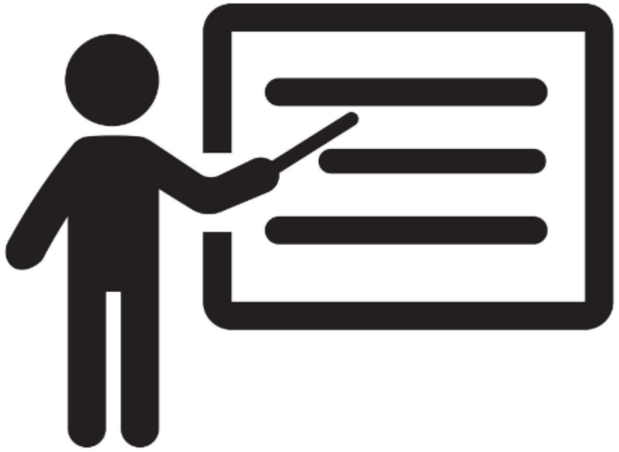
## Full-Scale ISBR Results

- Delivered gallons 2,000,000 gallons of mixed ISBR reagents
- Direct-push injection radius of influence (ROI) ranged from 5–90 feet
- Documented recirculation ROI under ISS treatment area of at least 60 feet
- Achieved >99% reduction of EDB and 1,2-DCA
- Officially shut down the P&T system in September 2023!

# Lessons Learned

What did we learn?

- Portland cement combined with slag cement is more effective than Portland cement-only mix designs when DNAPLs are present.
- Consider field pilot tests to evaluate implementability and constructability issues before proceeding with full-scale.
- Multiple rounds of injections were often required to achieve remedial objectives but also provided an opportunity to tweak the ISBR amendments, dosing rates, and microbial cultures.
- Using a diverse suite of microbes is a good best practice for remediation in difficult geochemical environments, such as saline groundwater conditions.



# Thank you

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