DESTRUCTION OF A SOURCE AREA THROUGH ESTABLISHMENT OF BIOBARRIERS AND OPTIMIZED DELIVERY OF EMULSIFIED SOYBEAN OIL

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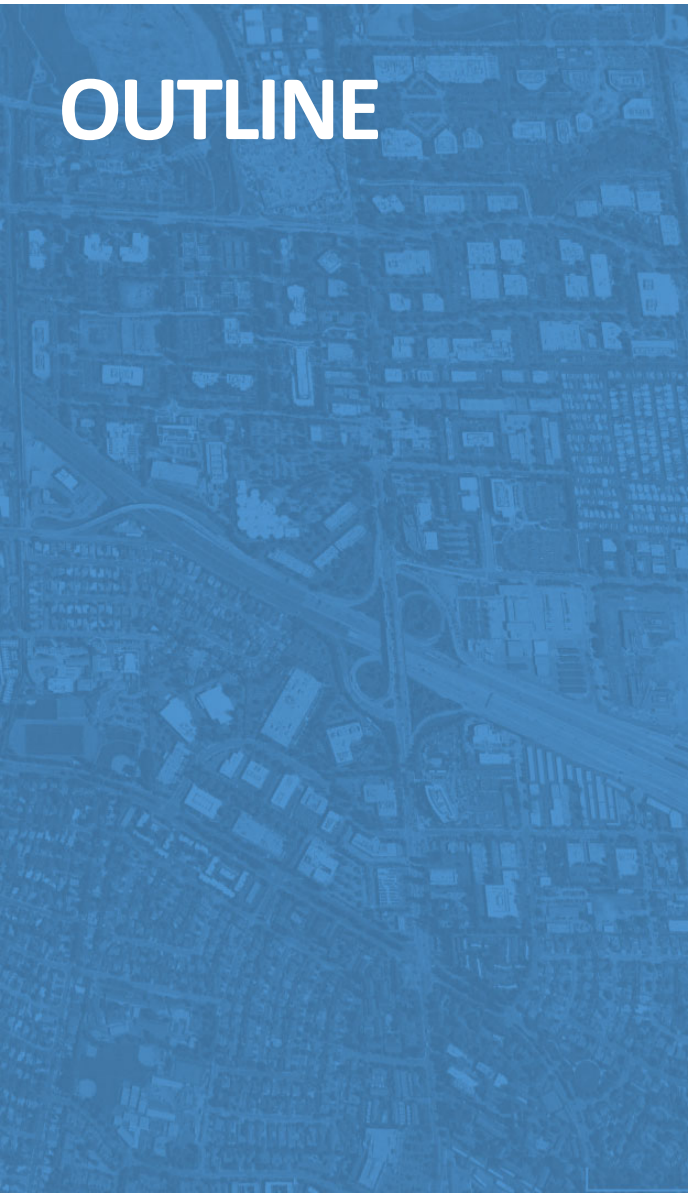
OUTLINE



- Background/History
- Site Hydrogeology
- Remedial Approach
- Characterization Findings
- ERD Injections
- Performance Monitoring Results
- Lessons Learned

BACKGROUND

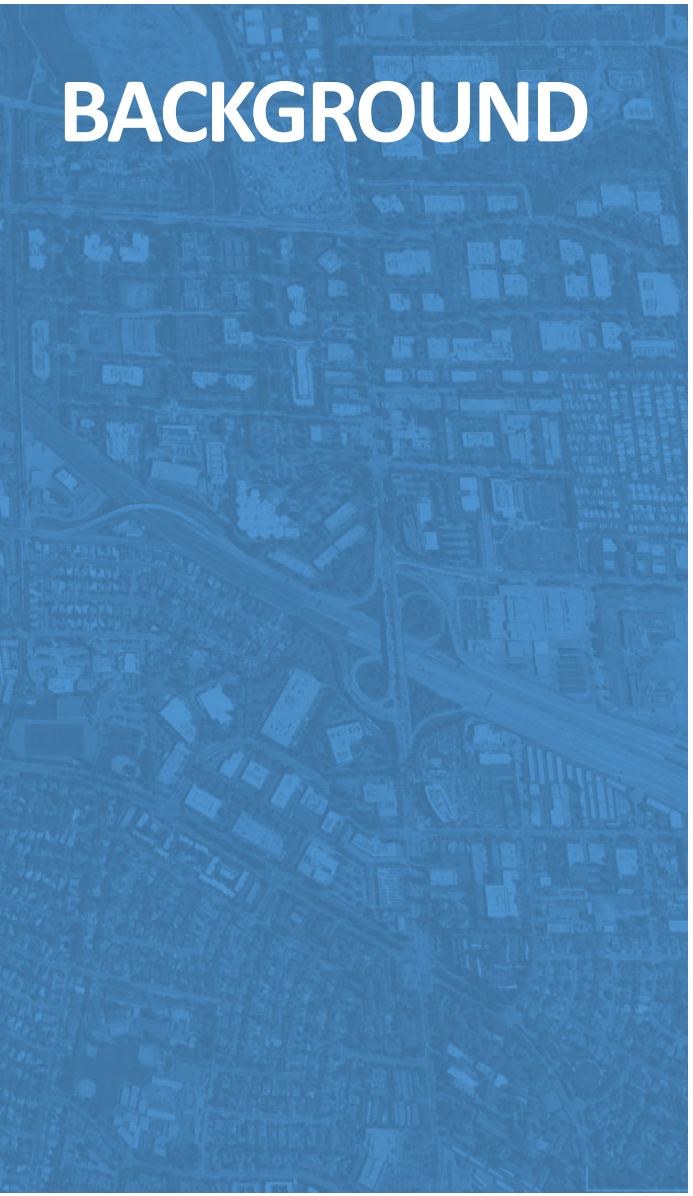
SITE LOCATION MAP

Former Teledyne Semiconductor/Spectra Physics Superfund Site

SITE LOCATION MAP

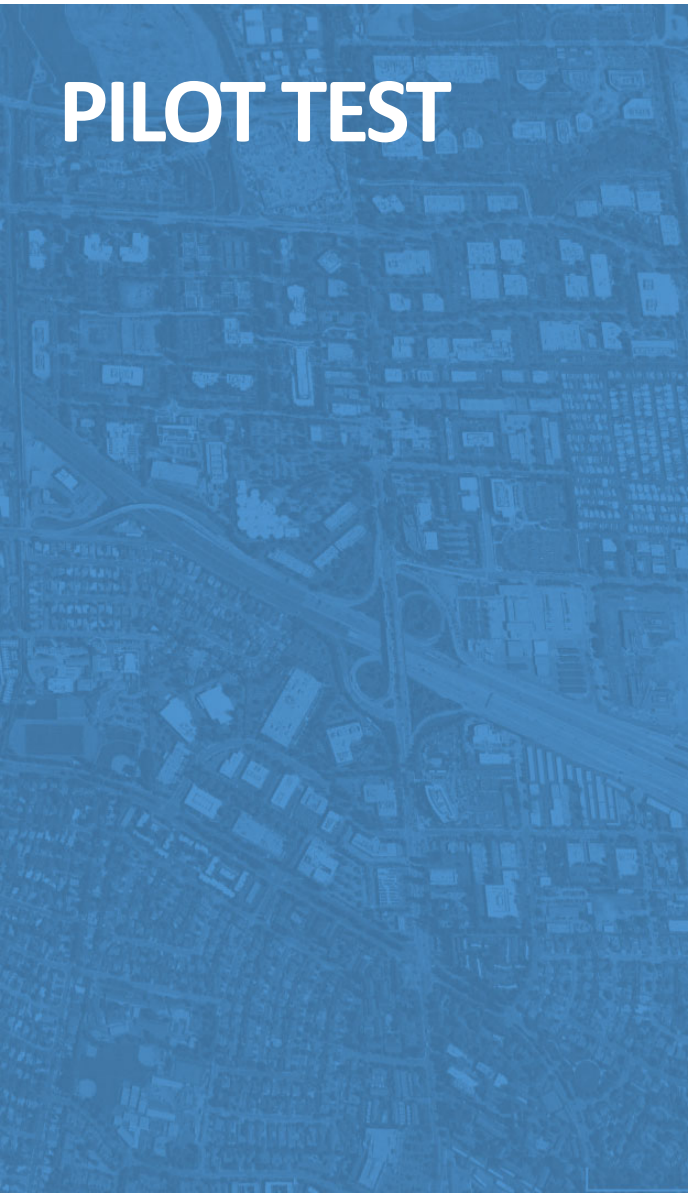
- Former Teledyne Semiconductor/Spectra Physics Superfund Site, Mountain View, California
- VOCs first detected in groundwater in 1982
- Groundwater extraction begins at Semiconductor property in 1986
- Primary chemical of concern was trichloroethene (TCE)

BACKGROUND



- The Semiconductor property extraction system was active for 20 years
- Extraction well performance data:
  - 1986: 1,300 µg/L TCE
  - 2006: 960 µg/L TCE
- October 2005 – Work Plan submitted for a pilot treatability study using anaerobic bioremediation (ERD)

PILOT TEST



- 2006 - 2008 pilot test implementation
- Reductions in TCE and generation of daughter products confirmed viability of ERD
- After discussions with regulatory agencies, decision to proceed to full-scale treatability study

SITE HYDROGEOLOGY

REGIONAL SETTING

Site is located in the northern portion of the Santa Clara valley

Alluvial sediments comprised of sand, gravel, silt, and clay

Groundwater flow is to the north

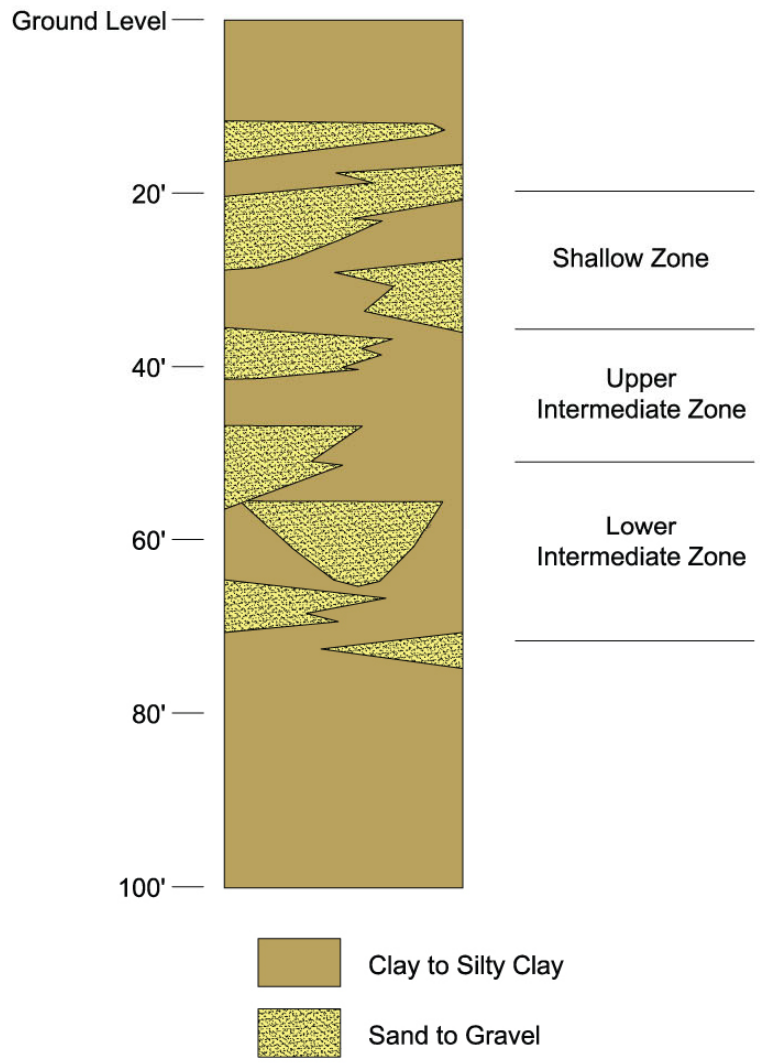
SITE STRATIGRAPHY

3 target treatment zones:

Shallow zone
(20 to 35 ft)

Upper intermediate
(35 to 50 ft)

Lower intermediate
(50 to 70 ft)



TECHNICAL APPROACH

PROJECT OBJECTIVES

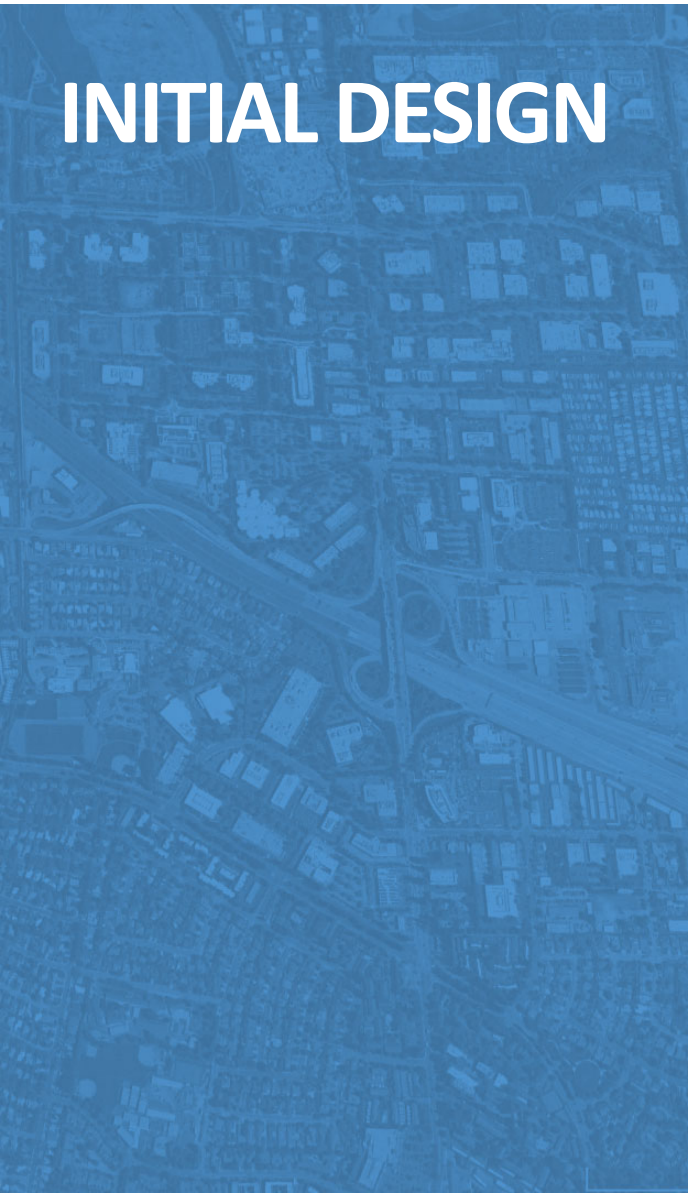
- The client issued an RFP in 2010 indicating they wanted a lump sum price to destroy the CVOC mass in the source area
- The performance requirement was to treat areas of the plume in excess of 500 µg/L total VOCs

FULL-SCALE TREATABILITY STUDY

Original Target Areas

- Shallow Zone
- Upper Intermediate Zone
- Lower Intermediate Zone

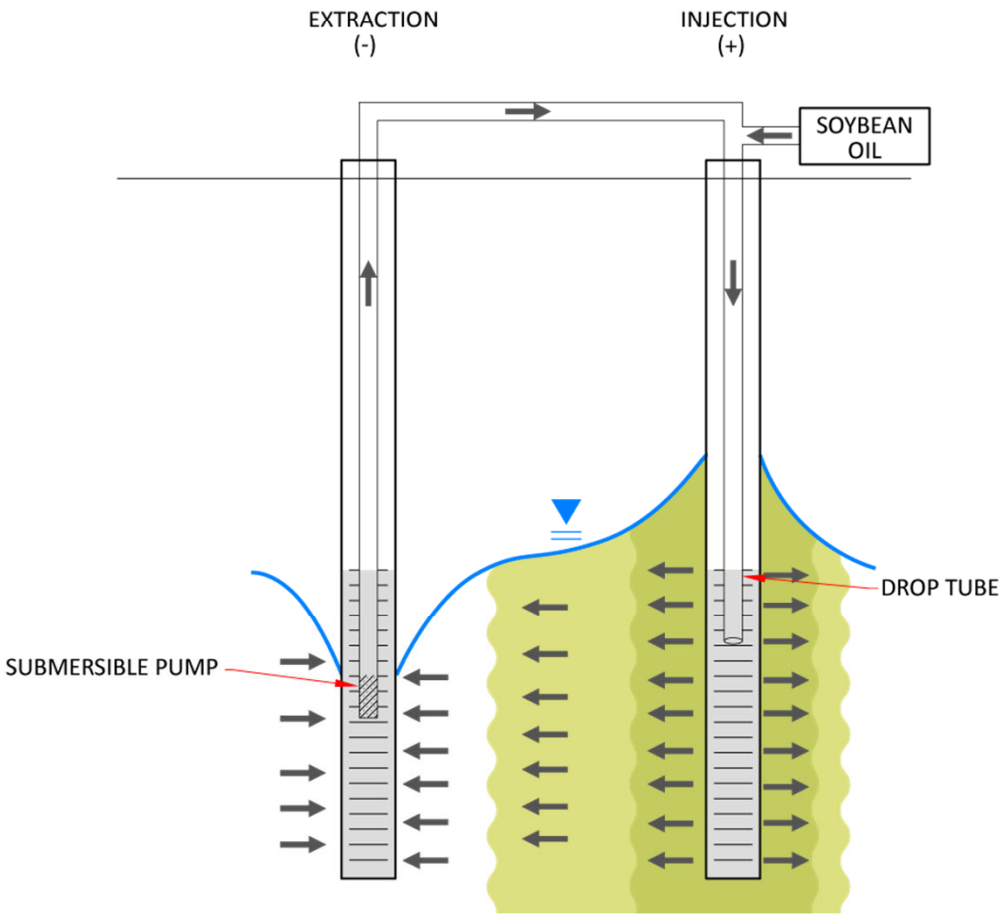
INITIAL DESIGN



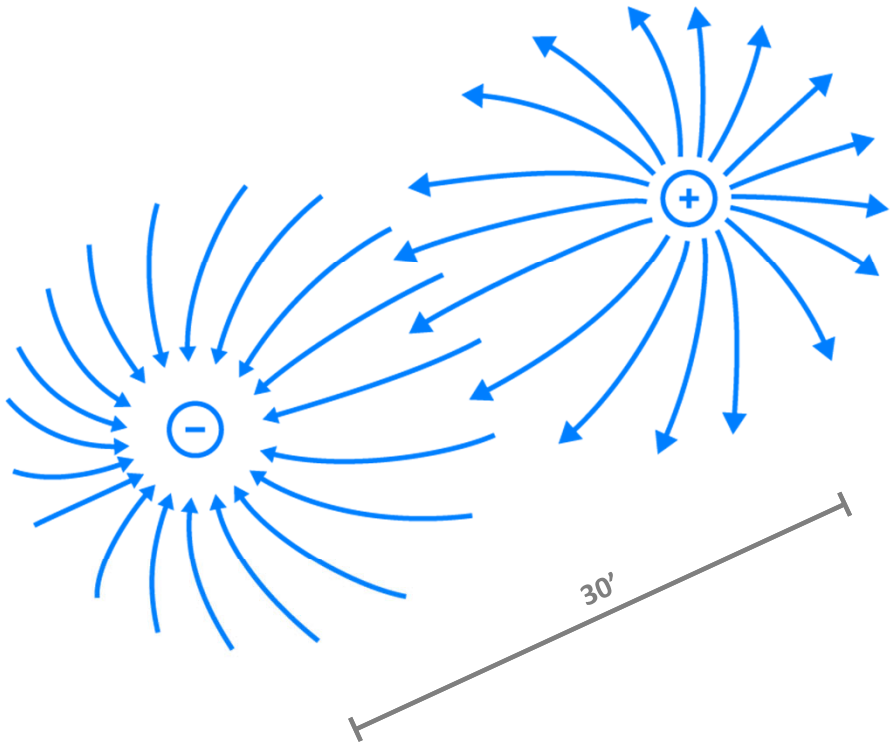
- Establish multiple biobarriers throughout the source area
- Five rows of injection wells would be installed, including 6 interior wells
- Biobarriers would be constructed by the delivery of emulsified vegetable oil (EVO) during simultaneous extraction/injection at adjacent well pairs, followed by a 24-hour recirculation
- Following completion of the recirculation period, the extraction and injection well pair would be reversed and the process repeated

EVO INJECTION SCHEMATIC

CROSS-SECTIONAL VIEW



PLAN VIEW



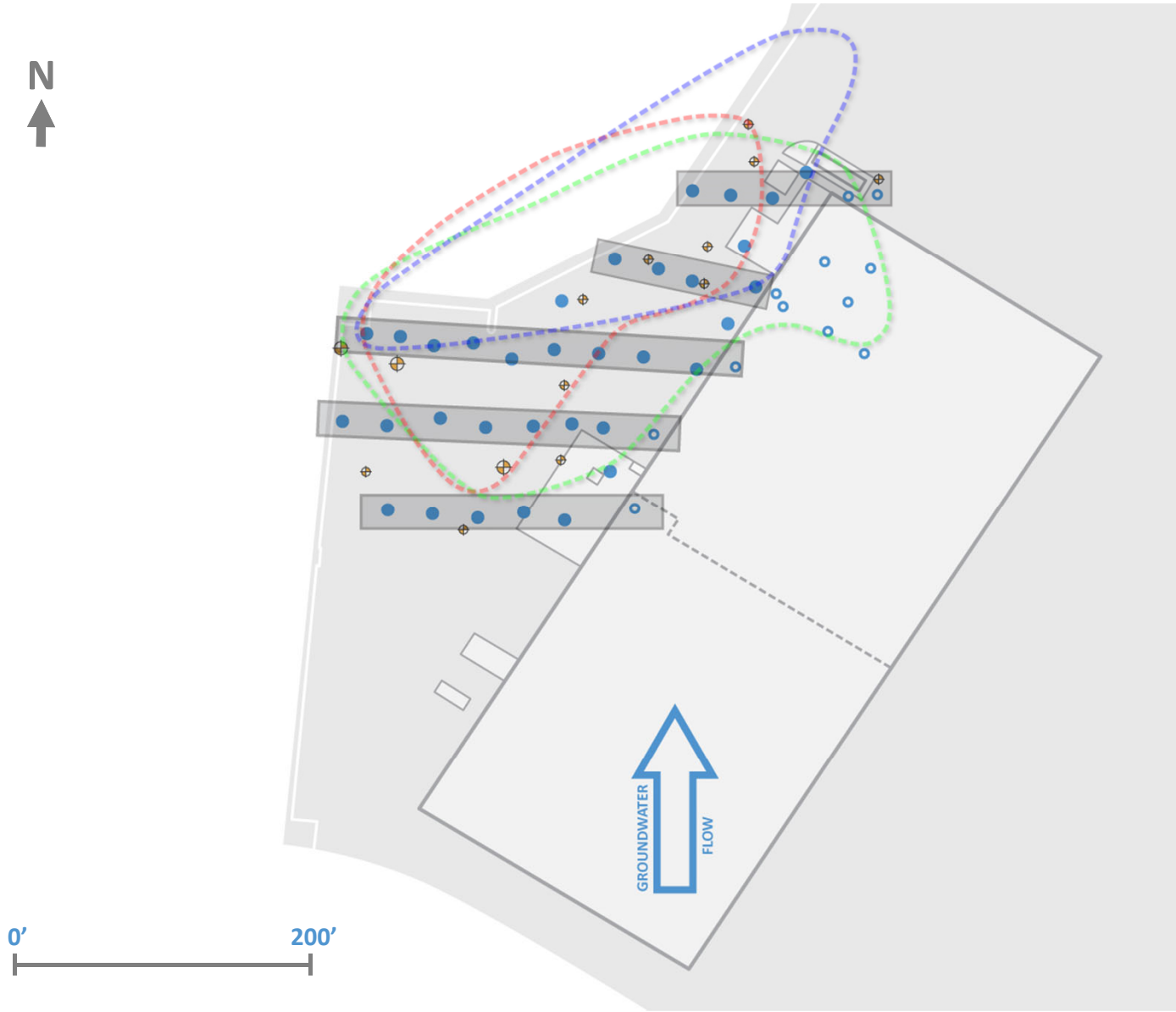
INITIAL DESIGN

- Based on the aquifer hydraulic parameters determined during the RI:
  - Injection well spacing = approximately 30 feet
  - Injection row spacing = 60 to 70 feet
- Most injection well locations consisted of a 3-well cluster with screened intervals corresponding to the 3 water-bearing zones
- 4-inch-diameter wells were installed where possible

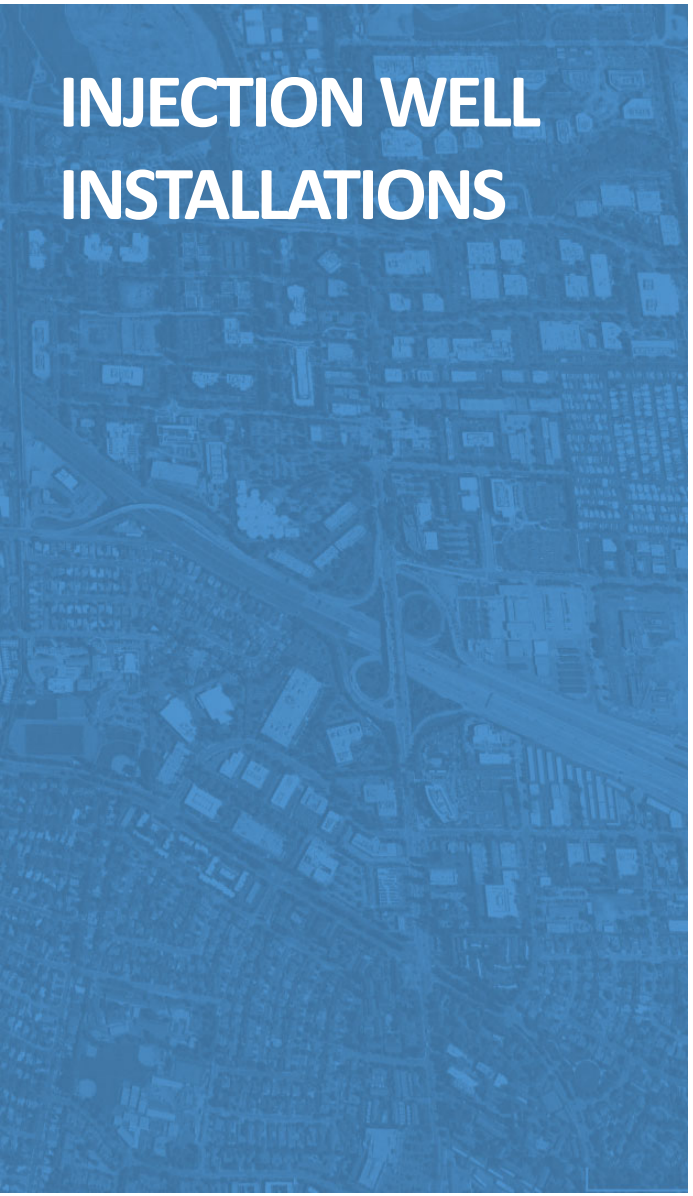
INITIAL INJECTION WELL NETWORK DESIGN

99 injection wells
9 new monitoring wells

- Multi-Injection Well Cluster
- Single Injection Well
- Monitoring Well



INJECTION WELL INSTALLATIONS

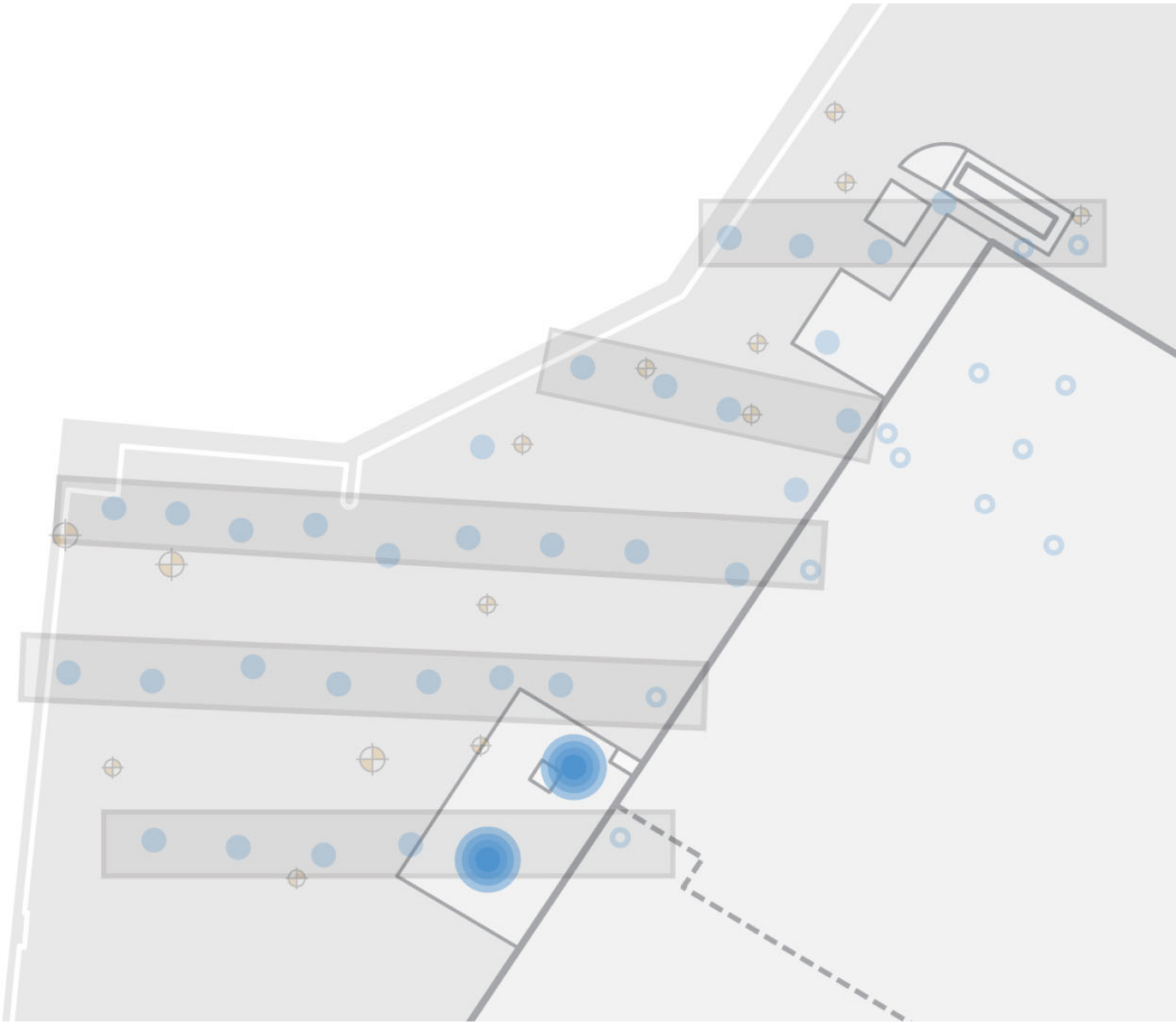


- At each injection location, the deepest well was continuously soil sampled to provide detailed characterization of the treatment zones
- PID readings were collected every foot
- The characterization data revealed the sand units were considerably more discontinuous and variable
- After all wells were installed and developed, a subset of injection wells and all monitoring wells were sampled to establish a ***baseline*** for performance monitoring

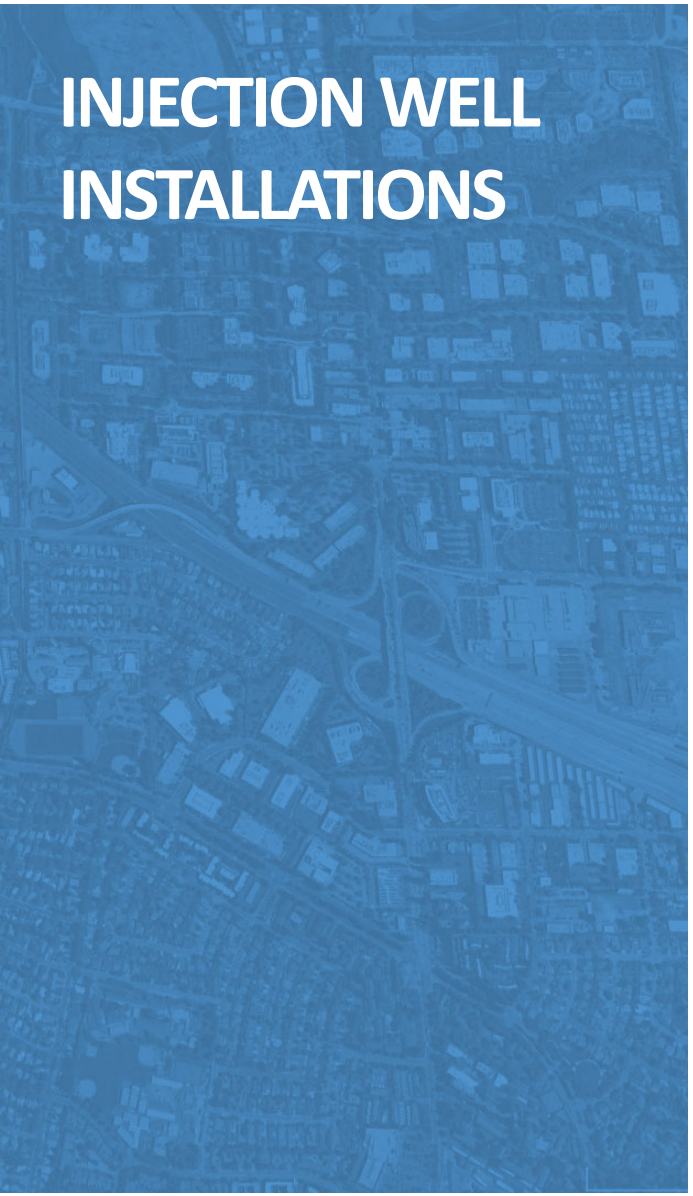
INJECTION WELL INSTALLATIONS

- Elevated PID readings were detected during installation of two wells in the upgradient injection row
- Groundwater samples from these wells:
  - B-5S – 49,000 µg/L TCE
  - B-6S – 17,000 µg/L TCE

A definite surprise, but no problem – we can add a few more upgradient injection wells



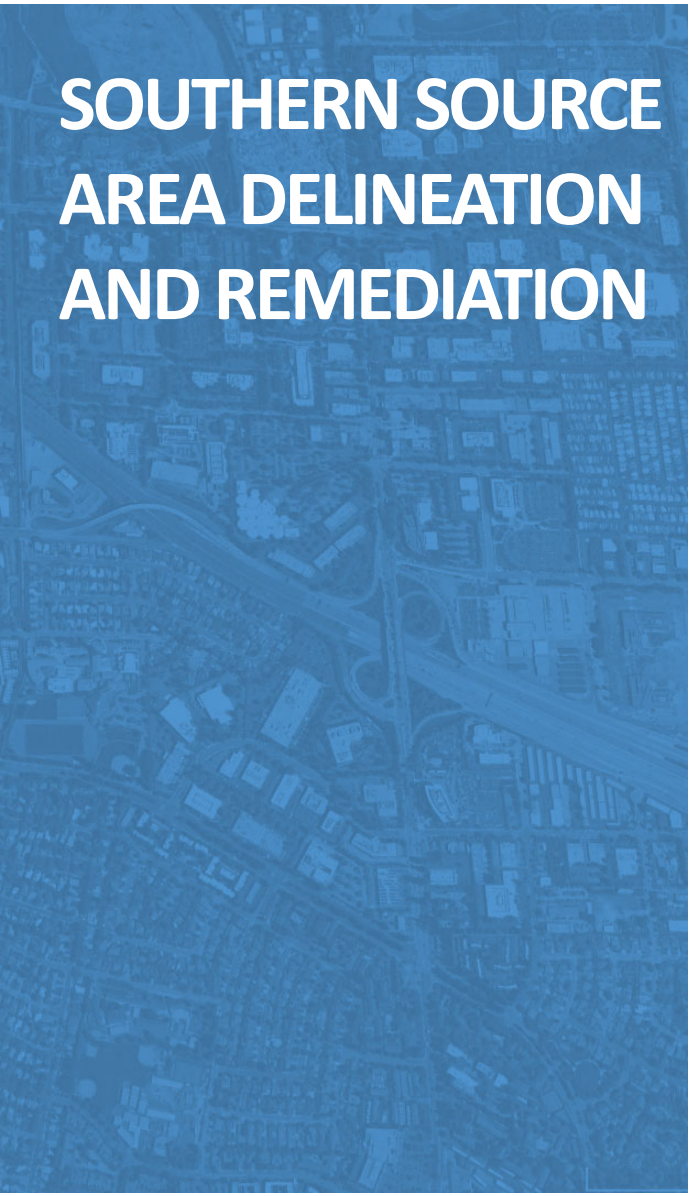
INJECTION WELL INSTALLATIONS



- We obtain permits, move upgradient (south), and drill 4 more wells
- This work is occurring while the original design injections have commenced
- More elevated PID readings observed and groundwater samples record TCE concentrations of 64,000 to 87,000 µg/L

Conclusion – There is a significant source area upgradient of the designed treatment area that needs to addressed for a successful project

SOUTHERN SOURCE AREA DELINEATION AND REMEDIATION



- The contamination extends beneath the building – access challenges
- Sand percentages diminish in upper and lower intermediate zones
- 52 additional injection wells and 3 performance monitoring wells are installed (May-November 2011)

SOUTHERN SOURCE AREA –

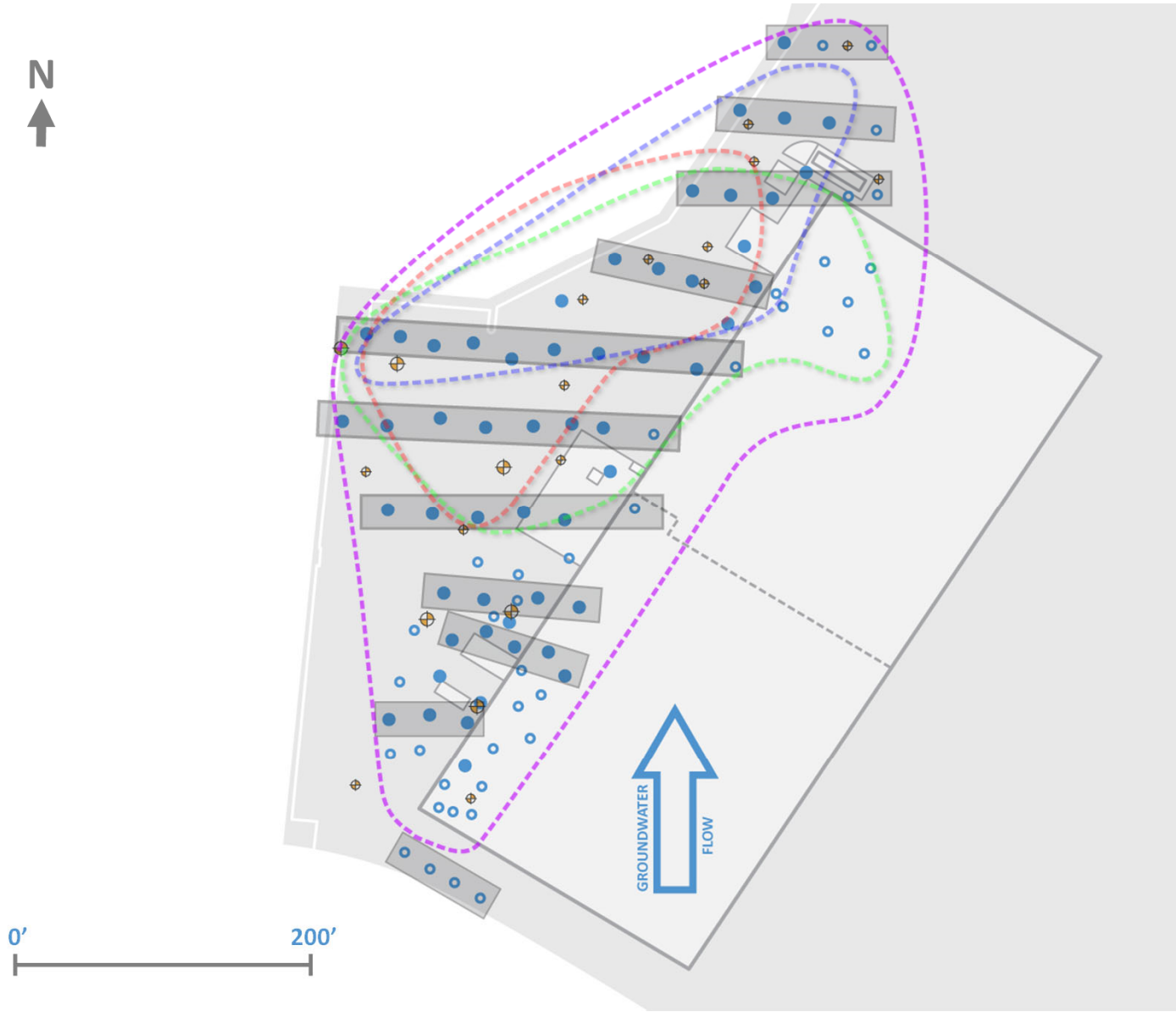
Restricted Work Space

In some areas we could use a low-clearance HSA rig

Removed walls (twice) to allow rig access

FINAL INJECTION WELL NETWORK

154 injection wells
12 new monitoring wells



Multi-Injection Well Cluster

Single Injection Well

Monitoring Well

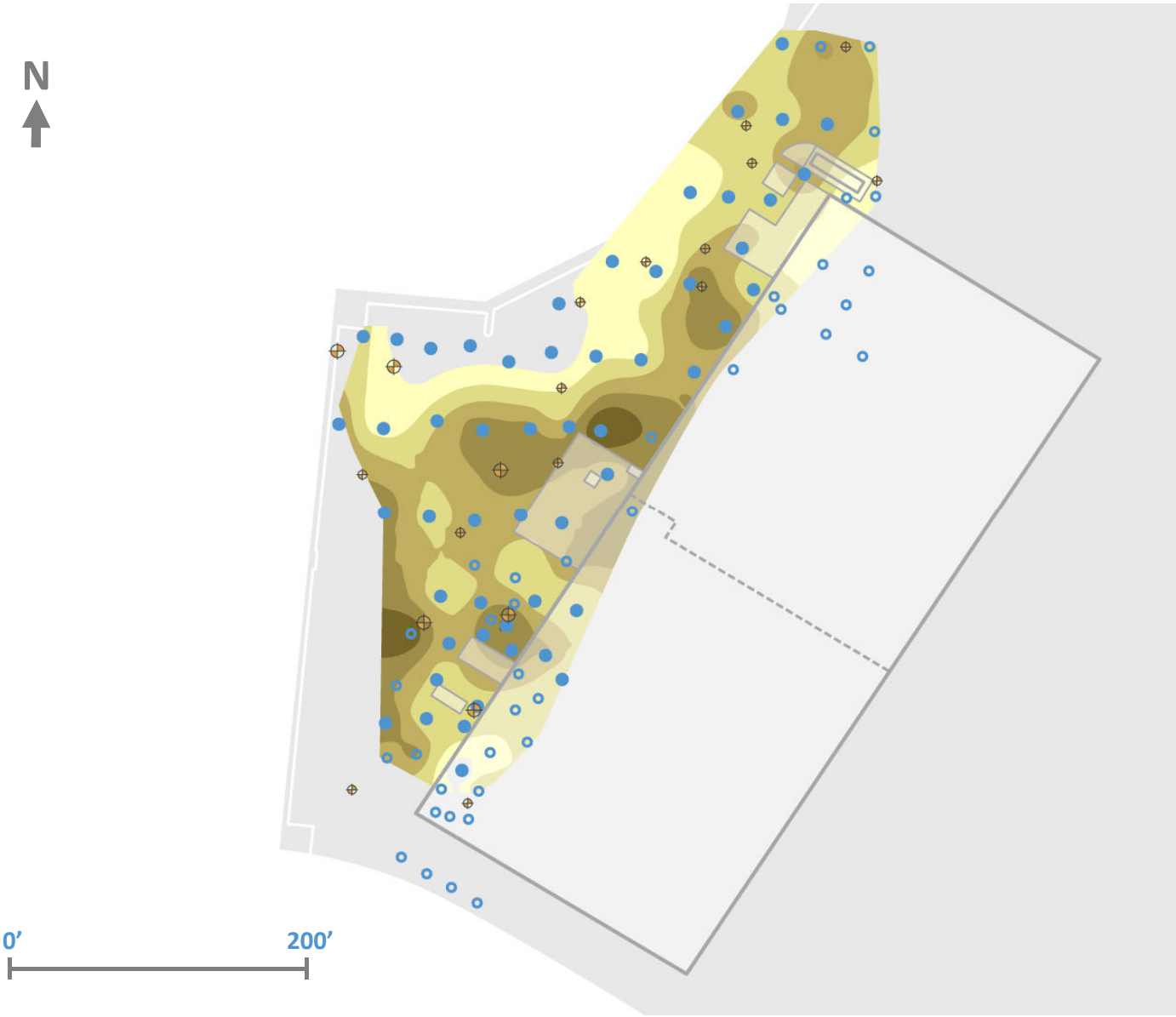
CHARACTERIZATION FINDINGS

NET SAND THICKNESS

Shallow Zone

SAND THICKNESS

- > 19′
- 16′ – 19′
- 13′ – 16′
- 10′ – 13′
- 7′ – 10′
- < 7′

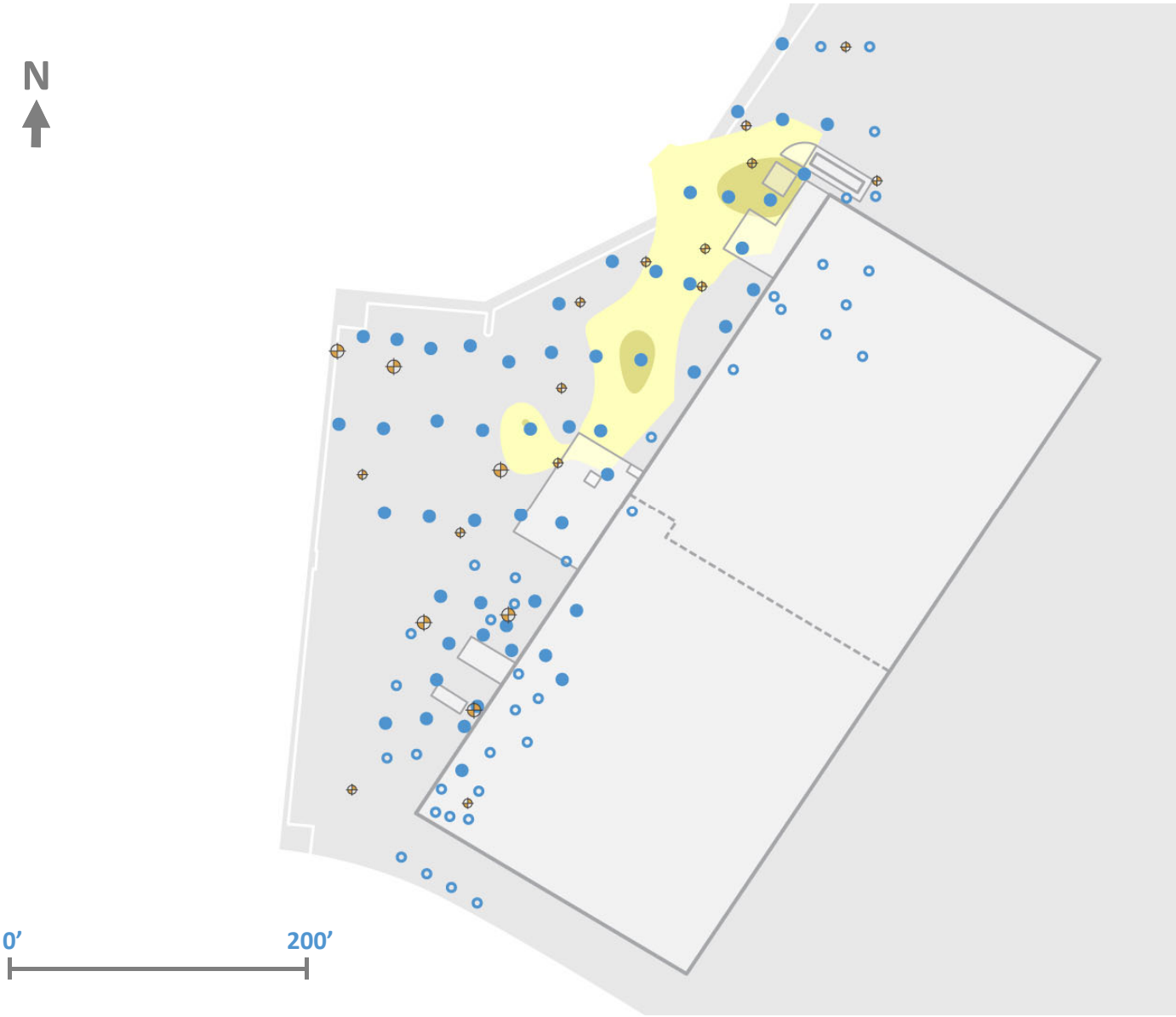


NET SAND THICKNESS

Upper Intermediate Zone

SAND THICKNESS

- 10′ – 13′
- 7′ – 10′
- < 7′

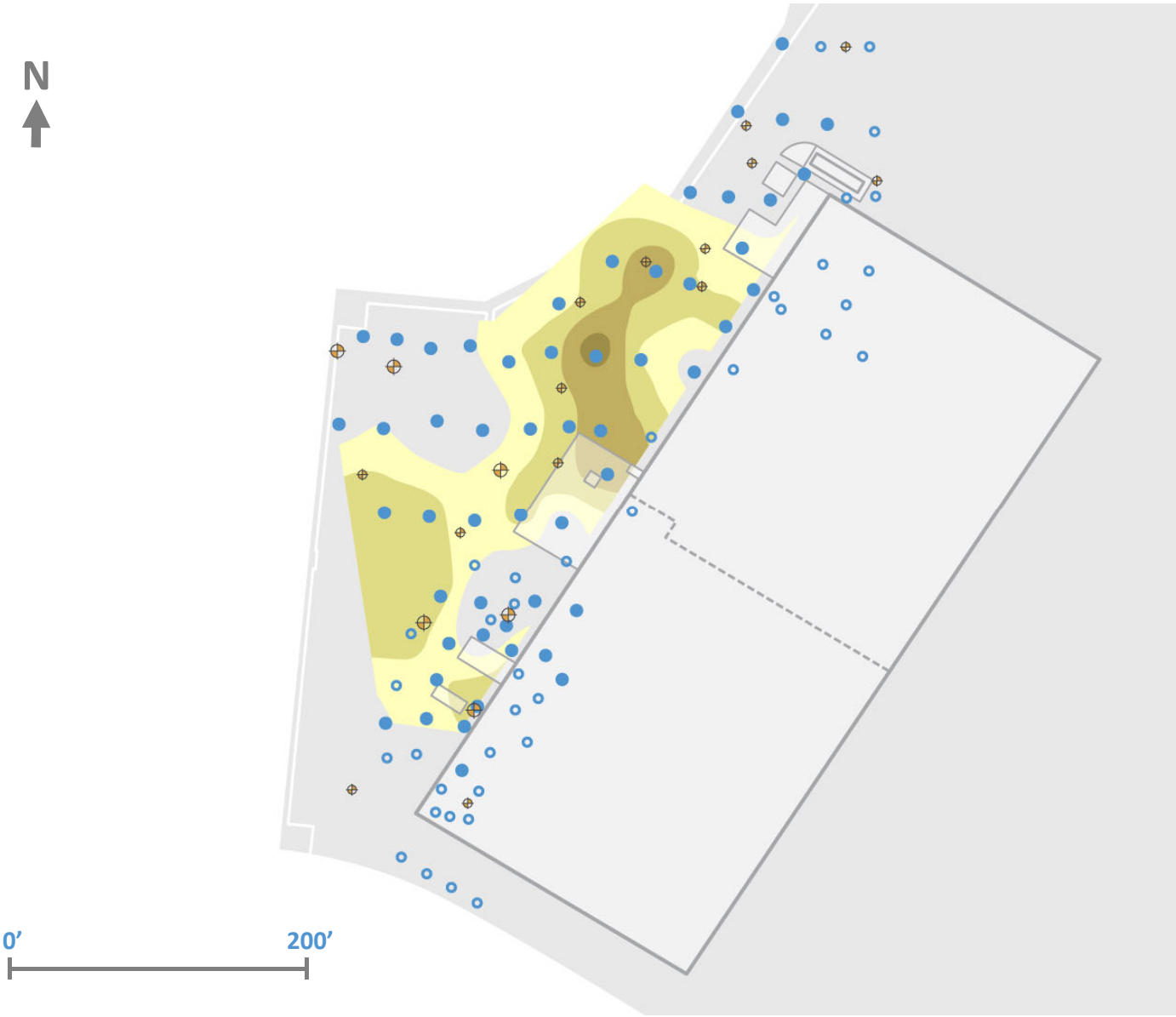


NET SAND THICKNESS

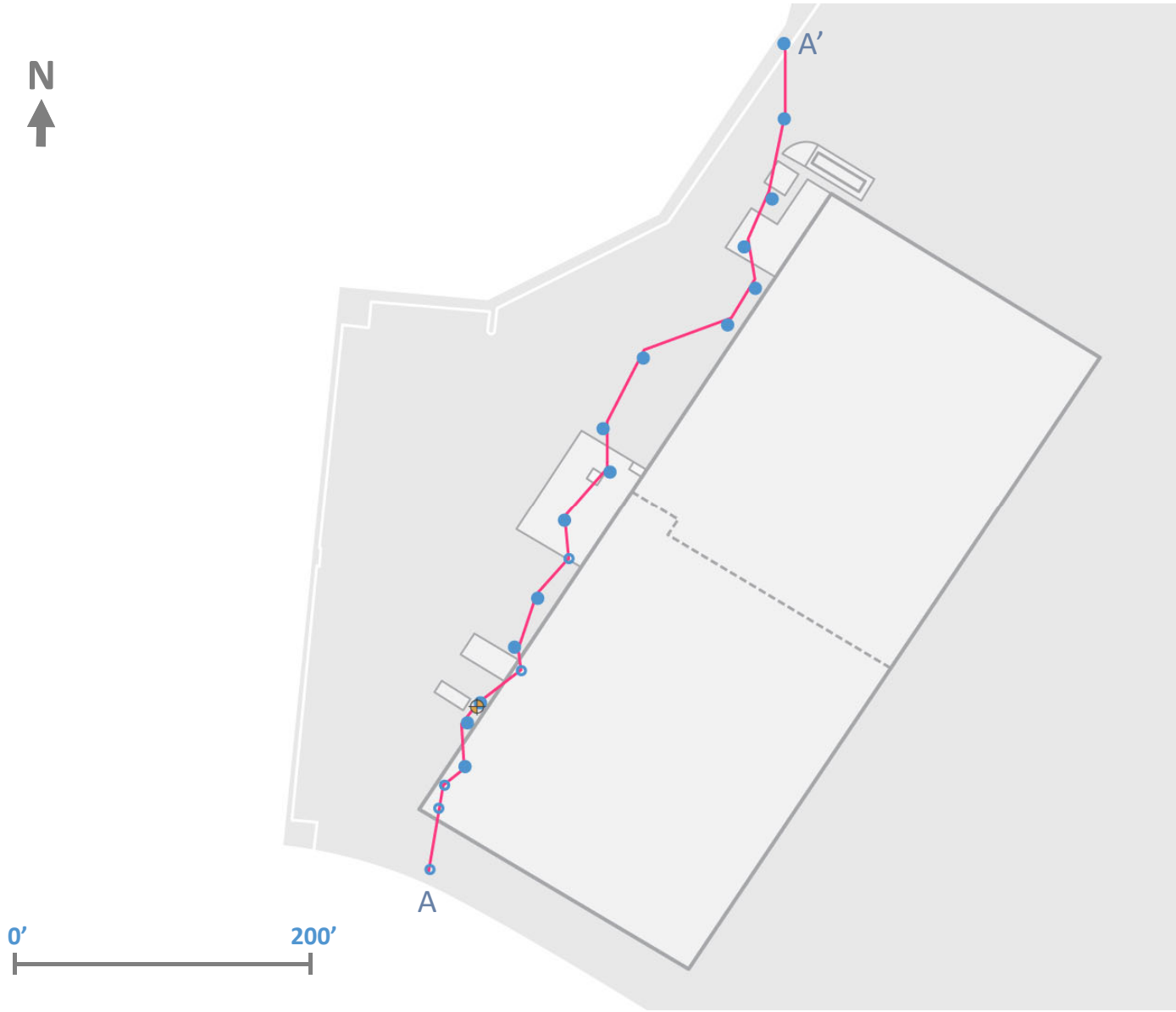
Lower Intermediate Zone

SAND THICKNESS

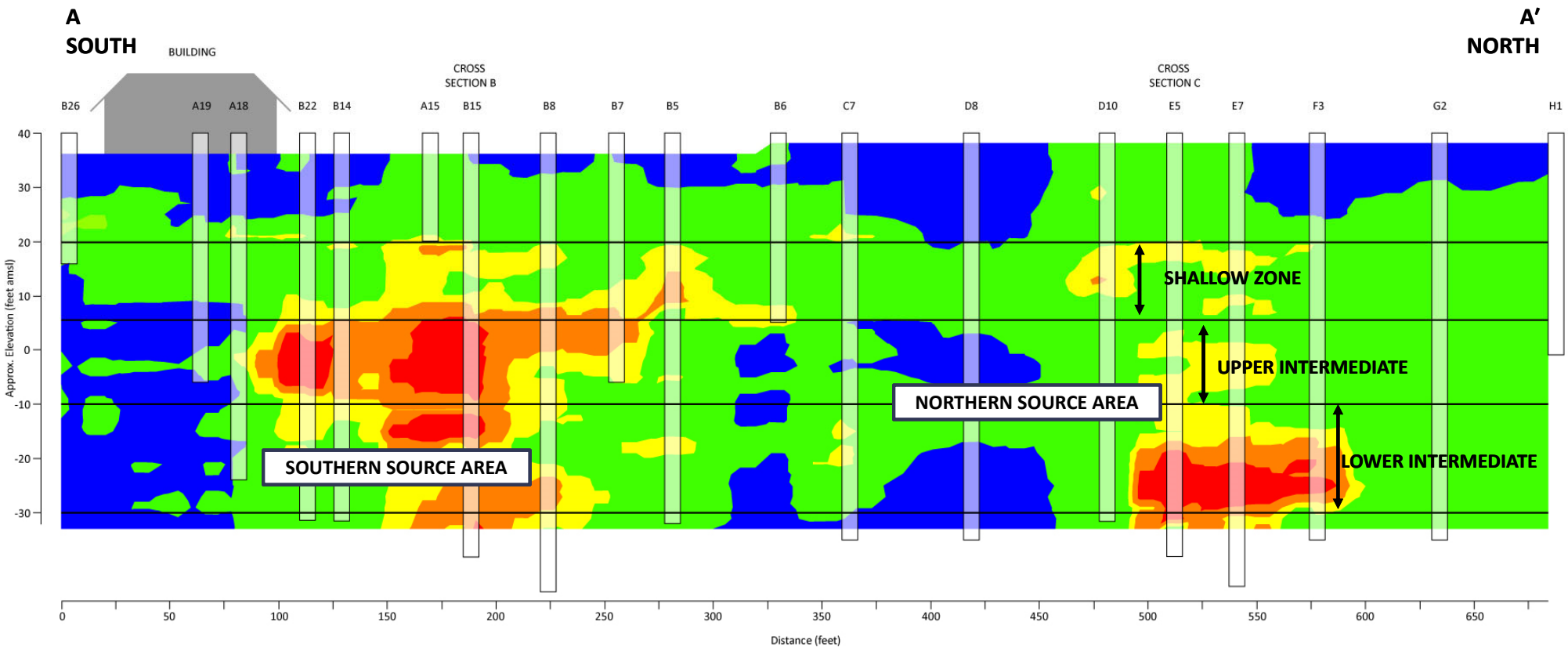
- 16′ – 19′
- 13′ – 16′
- 10′ – 13′
- 7′ – 10′
- < 7′



CROSS SECTION

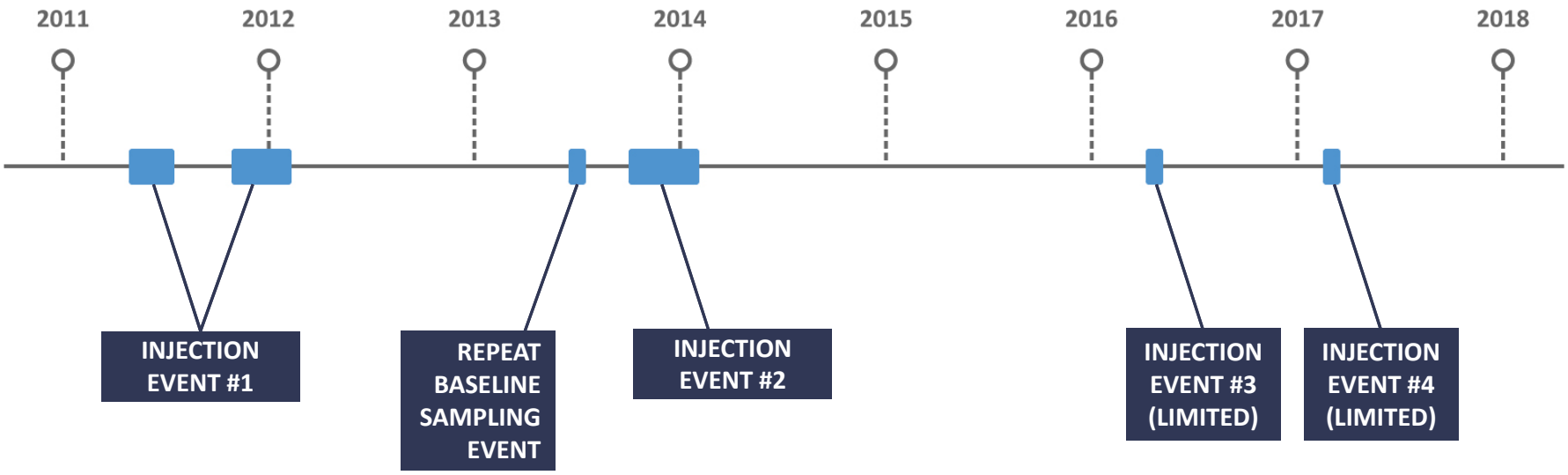


GEOLOGIC CROSS SECTION A-A’




ERD INJECTIONS

ERD INJECTION TIMELINE



ERD INJECTION SUMMARY

Event		EVO Mass (pounds)	Groundwater Injected/Recirculated (gallons)
1	May 2011 - Jan 2012	222,377	2,315,451
2	Nov 2013 - Feb 2014	56,549	1,867,981
3	Mar 2016	4,122	96,561
4	Feb 2017*	430	3,000

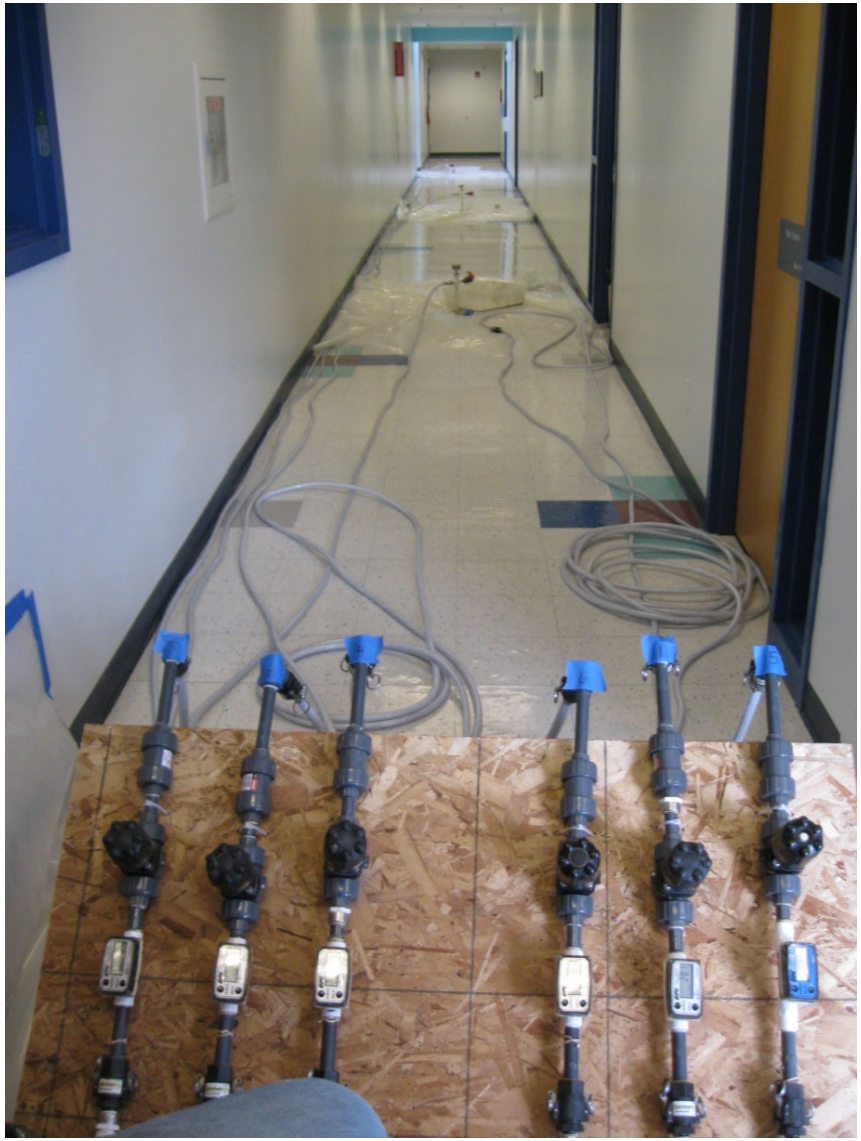
* direct injection delivery

PORTABLE POWER DISTRIBUTION UNIT

EXTRACTION WELL SETUP

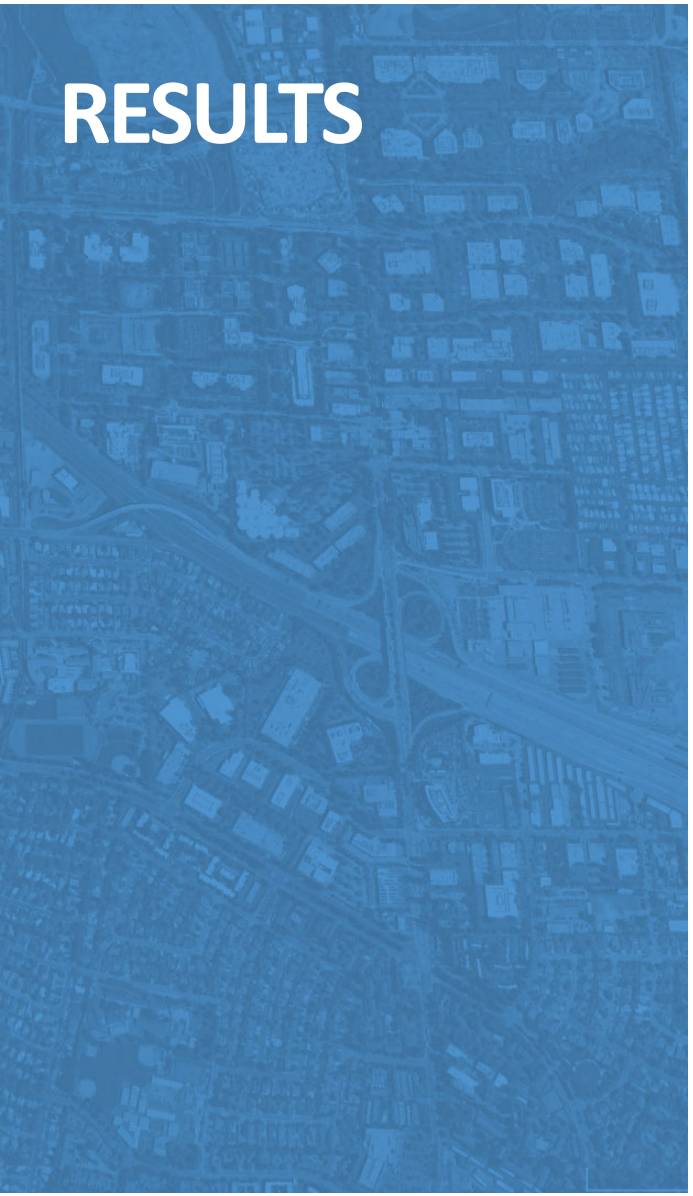
RECORD KEEPING

INTERIOR INJECTIONS



PERFORMANCE MONITORING RESULTS

RESULTS



- Rebound of VOCs has been minor since the second injection event
- Overall the reduction of CVOCs has been highly successful
- Two areas of poor response were addressed by limited additional injections

Cleanup objective changes

"Irrational exuberance"

COMPARISON OF TCE DISTRIBUTION

Shallow Groundwater Zone
Concentrations in µg/L

- ≥ 5,000
- ≥ 500 to < 5,000
- ≥ 50 to < 500
- ≥ 5 to < 50

Pre-ERD (2011)

Post-ERD (2018)

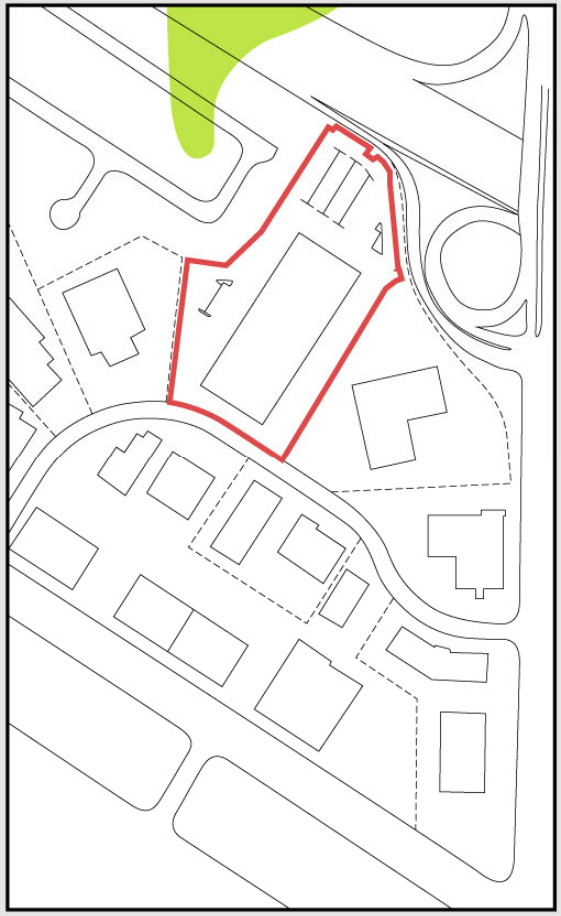
COMPARISON OF TCE DISTRIBUTION

Upper-Intermediate Groundwater Zone
Concentrations in µg/L

- ≥ 500
- ≥ 50 to < 500
- ≥ 5 to < 50

Pre-ERD (2011)

Post-ERD (2018)



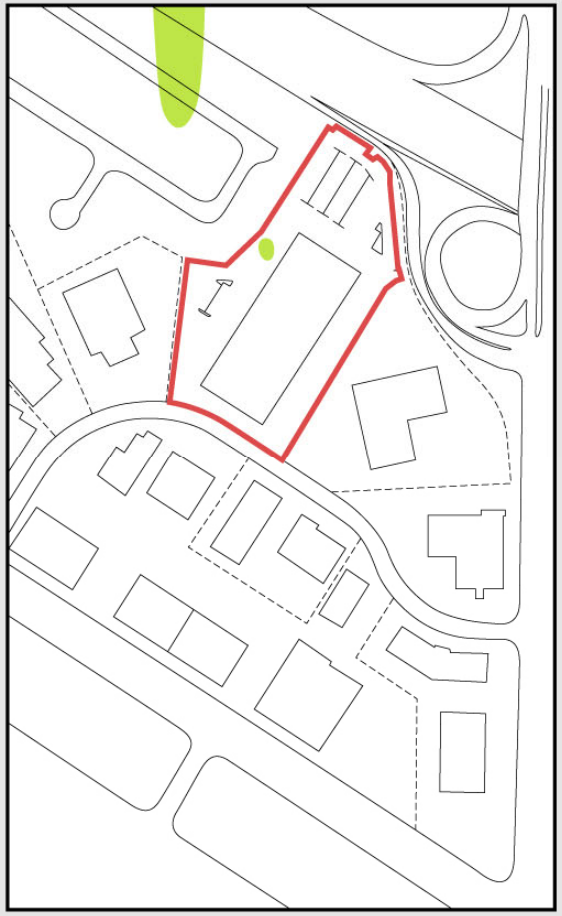
COMPARISON OF TCE DISTRIBUTION

Lower-Intermediate Groundwater Zone
Concentrations in µg/L

- ≥ 500
- ≥ 50 to < 500
- ≥ 5 to < 50

Pre-ERD (2011)

Post-ERD (2018)



LESSONS LEARNED

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1. Original CSM was incorrect due to insufficient site characterization
2. Lithologic information gained during well installation allowed a 30% reduction in the original EVO dose
3. Additional characterization enabled identification of the second source area
4. The injection/recirculation approach successfully distributed the EVO to allow creation of a highly robust ERD system throughout the source area

LESSONS LEARNED

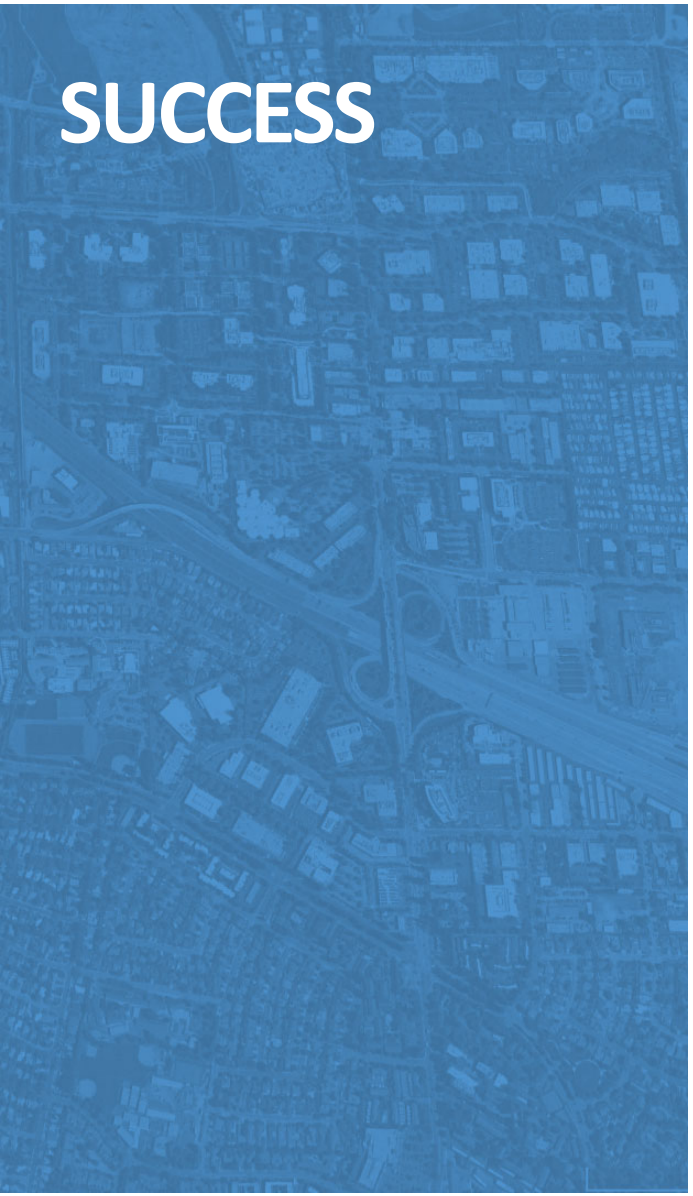
5. The permanent wells enabled a thorough assessment of the ERD system after 2 years of *in situ* remediation, which provided the data for a targeted 2nd injection event

6. The in-place well infrastructure made the 2nd and 3rd injection events less intrusive to the site occupants

7. Bio-fouling and decreased well hydraulics were encountered, but the problem was not widespread

8. Use of permanent wells is not the right approach for all sites, but in this case, it facilitated optimal construction of the biobarriers

SUCCESS



- In May 2018, the USEPA issued a fact sheet for public comment to change the site remedy to “Source Area ERD and MNA with Vapor Mitigation Controls”
- The pump-and-treat system has been completely shutdown and mostly decommissioned

THANK YOU AND ACKNOWLEDGMENT

- Co-authors:
  - Mike Apgar – lead field engineer for implementation
  - Peter Lepczyk – lead field geologist and technical contributor
  - Ken Chiang – teaming partner, technical and field support
- Client – TDY Industries, LLC
- Jerry Lisiecki, PhD – key contributor to our conceptual design

QUESTIONS?

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