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Keys to Successful In-Situ Remedial Designs at Brownfield Sites

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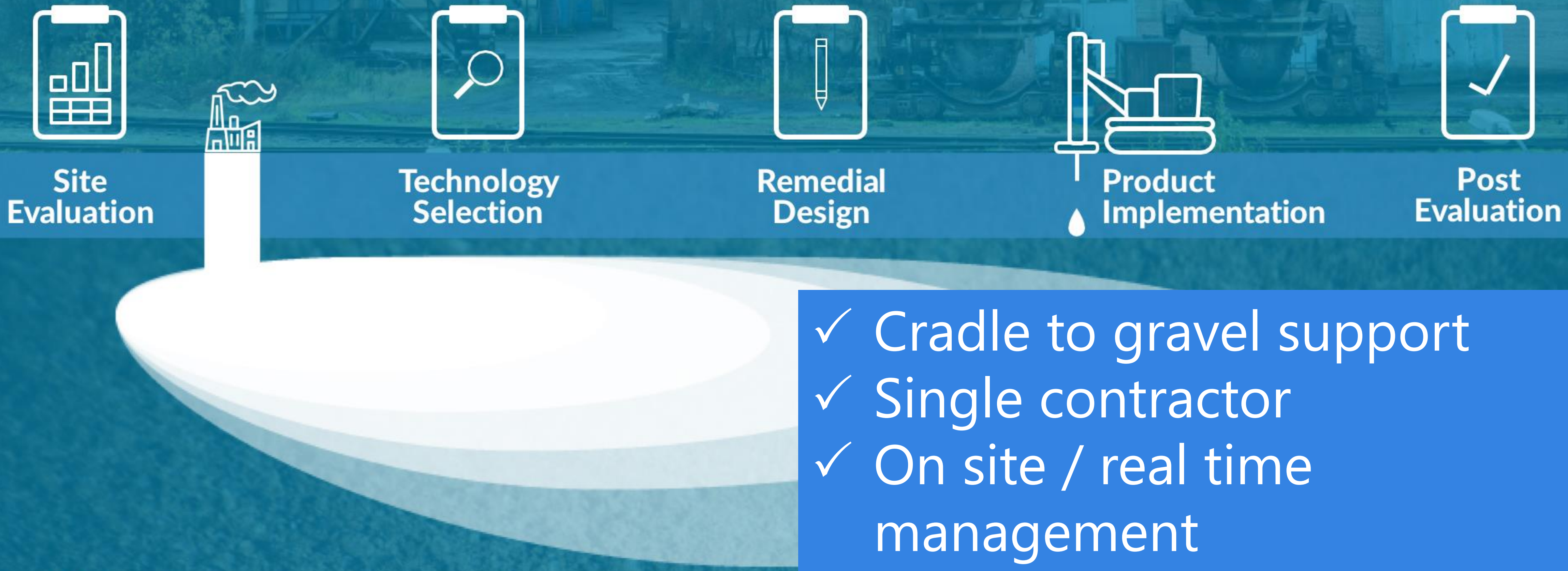
Roadmap

Discuss

- Technical Approach
- Keys to Successful Remedial Design
- Design Verification Testing
- Placement Validation
- Case study
- Questions

OUR PROCESS

We support you through all phases of the remediation project including:



- ✓ Cradle to gravel support
- ✓ Single contractor
- ✓ On site / real time management
- ✓ Assured its being done right

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The REGENESIS Process

FluxTracer
Flux Mapping Tool

DVT
Design Verification Testing

FluxTracer
Mass Flux Vertical Profiling

Design Revision
Placement Validation

Injection
Distribution Verification

Technical Review of Performance

Our Experience

800+
Applications Completed

100+
Applications Per Year

13,000,000+
Gallons Applied

15,000,000+
Pounds Applied

Success follows from:

The right amount of Reagent

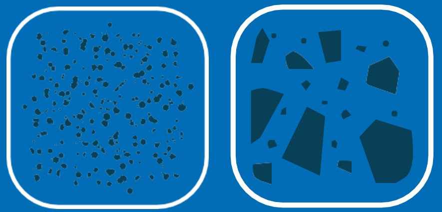
…in the right place

What are the engineering steps we follow to achieve this?

KEYS TO A SUCCESSFUL REMEDIAL DESIGN: BUILDING THE CSM

Contaminant Type and Distribution

Biogeochemistry



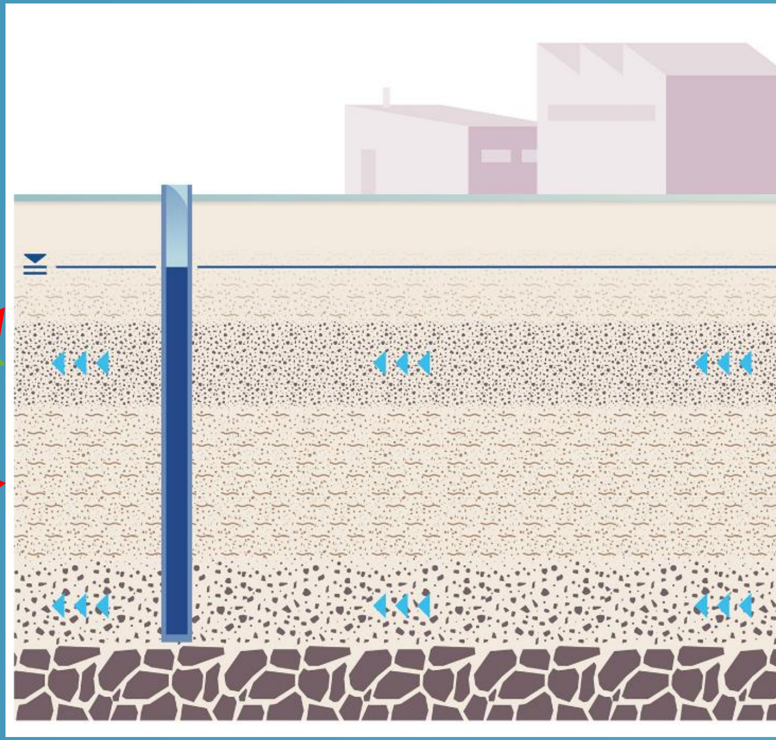
Site Geology and Hydrology

Fundamentals of Contaminant Distribution

- Vertical and Lateral relationships between fine- and coarse-grained units
  - Determination of vertical and lateral relationships between low and high Kh zones are critical
- Organization and Position of COC Storage Units and Transport Units
  - Fine grained units - storage
  - Coarse grained units – transport
- Sand Content "Plumbing"
  - How much
  - How well sorted
  - What is its positional orientation

Higher permeability zones
"Freeways"

Lower permeability zones
"Parking lots"



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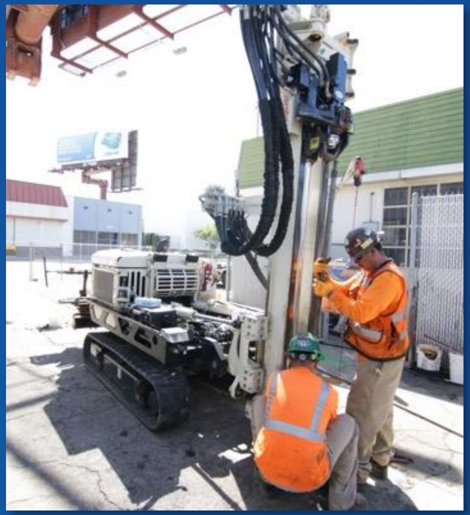
The right amount of Reagent
… in the right place

Design Verification Testing – What?

- Subsurface investigation specific to application requirements
- Separate mobilization ahead of the principal application
- Detailed stratigraphy, feasible flow rates, appropriate tooling, aquifer response to injection (clean water)
- Informs design refinement and placement optimization



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Design Verification Process – Why?

Site Assessments have different objectives than DVT

- Nature and Extent, Plume Boundaries
- Liability and Risk, Sensitive Receptors
- **Delineation for risk ≠ Delieation for Remediation**

DVT improves remedial outcome by increasing site resolution :

- Focusing on identifying position of COC mass and high flux zones
  -Emphasis on identification of principal impacted units
  -Provides greater reagent-COC contact = improved performance

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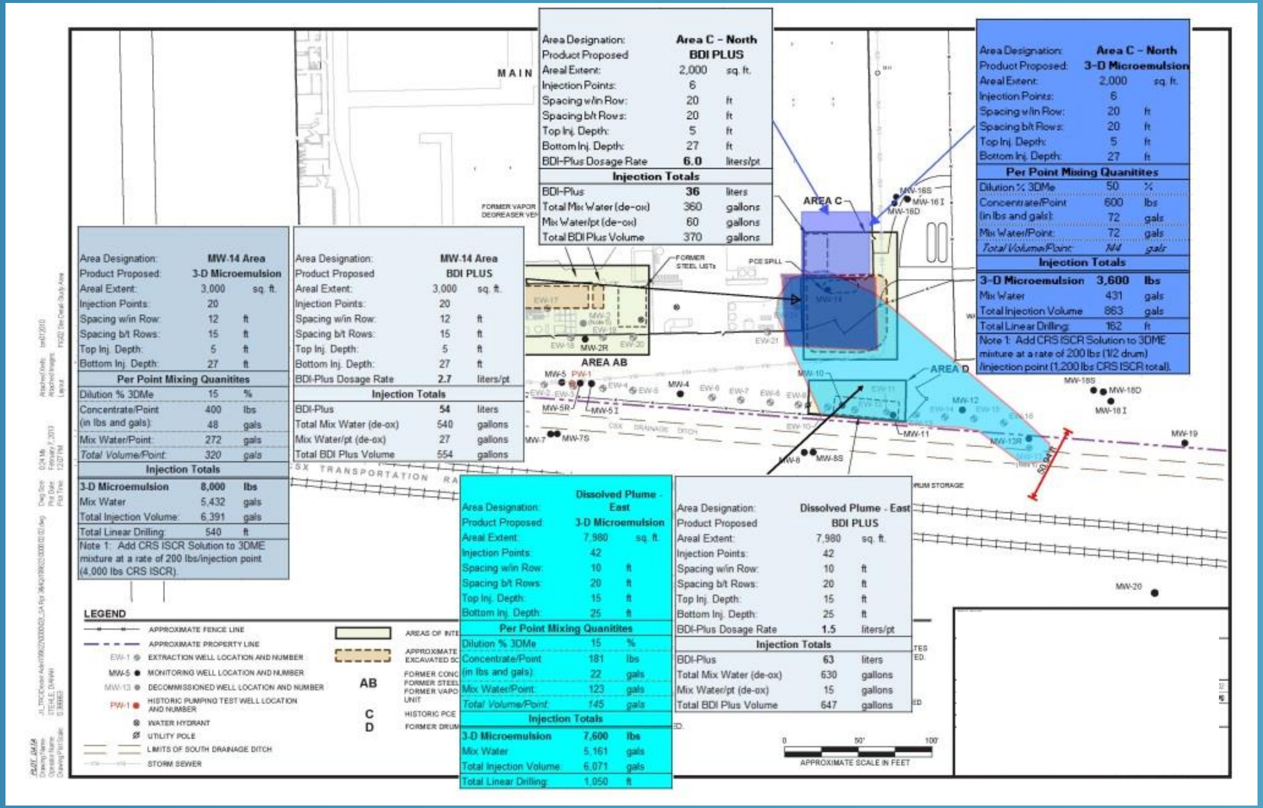
DESIGN VERIFICATION PROCESS - PURPOSE

Assists Designer in:

- ID Technical Blind Spots
  - Vertical Profiling
- Calibrate Reagent Design
  - Dose/Volume
- Calibrate Treatment Zones Accommodation Rates and Volumes
  - ID Hydraulic Limitations



Design Verification: Tools Box

- Continuous Soil Core Logging
- Soil Contaminant Analysis
- Settling Tubes
- Clear Water Injection
- FluxTracer

Continuous Core Logging

- Physical Characteristics
  - Moisture content
  - Contaminant: e.g. odor, staining, PID
- Grain Size:
  - % clay- silt-
  - % fine- medium- coarse- sand/gravel
- Gradation:
  - coarsening upward vs. fining upward
- Soil contaminant analysis:
  - Identify contaminant concentrations within flow pathways

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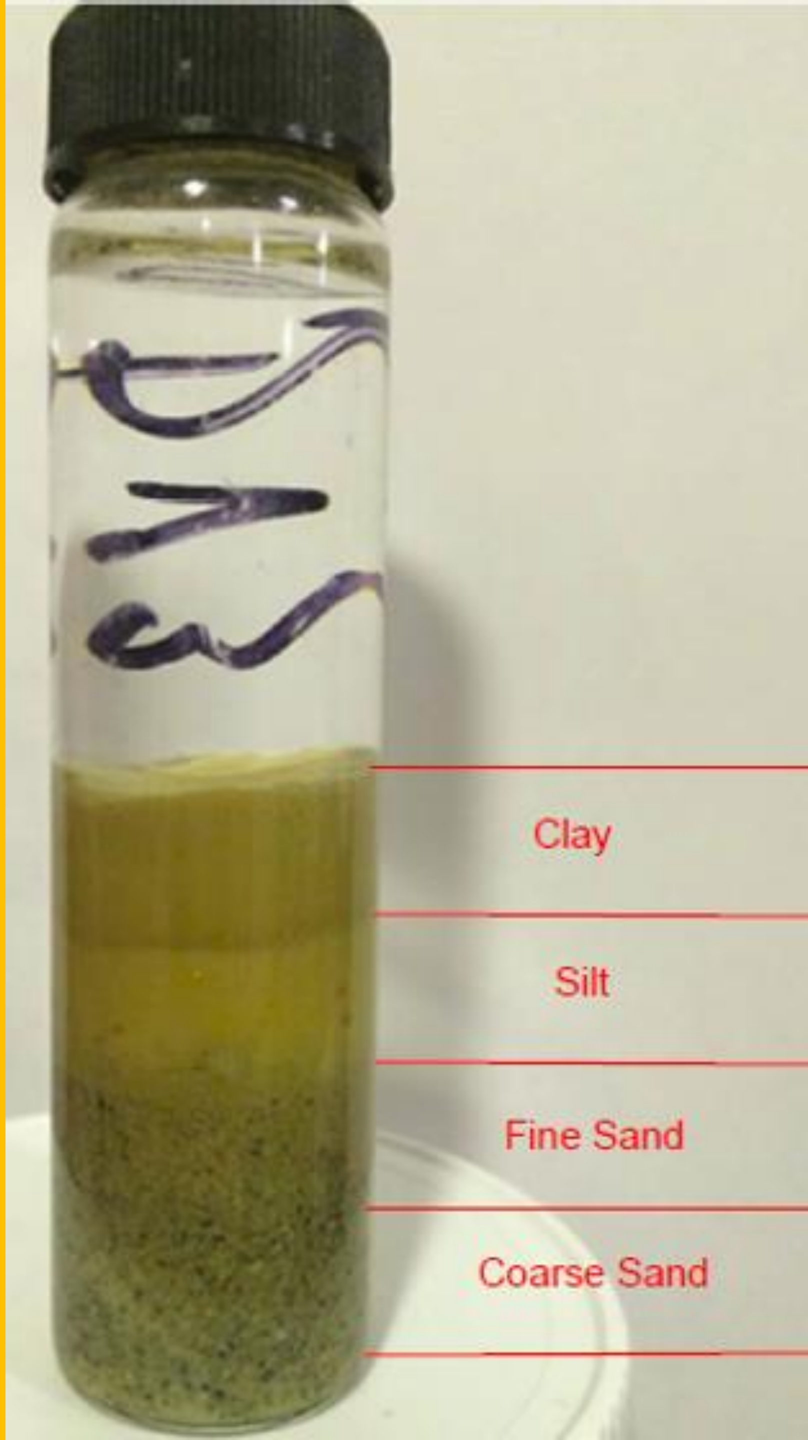
Design Verification: Soil Settling Tubes

- Field Technique provides semi-quantitative data to trained Field Geologist
- Visual Determination
  - Sand, Silt, Clay
  - Soil particle size %
  - Sand: grain size and sorting
- Simple Rapid Reliable
- Decreases Subjectivity
  - e.g. Silty sand silty clayey sand etc.
- High density, 1 foot vertical interval



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Design Verification: Clear water injection test

- Documents acceptance rates and volumes
  - Vertical TTZ's interval
- Assists in application decisions
  - Direct Push Injection
    - Top-down vs Bottom-up
  - Injection wells
    - Screened Intervals
- Data collected often differs greatly from the estimated K_h based volume

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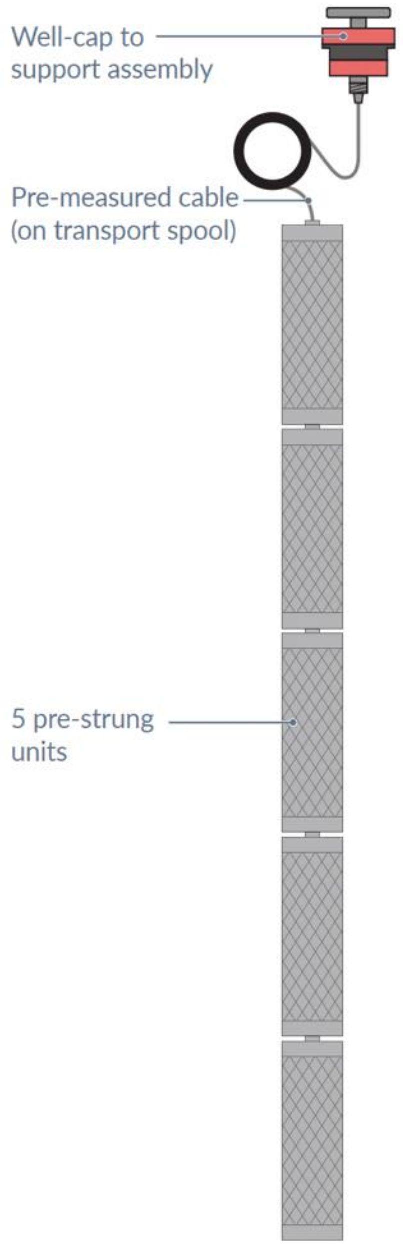
FluxTracer®
Flux Mapping Tool

Key Benefits:

- Collects information to aid in site characterization and remedial designs
- Vertically delineates contaminant mass flux and groundwater speed within an existing monitoring well
- Better site characterization and more specific design choices lead to better remedial outcomes
- Units for specific wells arrive pre-assembled and ready to deploy

How it Works:

- FluxTracer is deployed for two weeks and retrieved
- Alcohol tracers are washed out – contaminants are sorbed
- Device is sent back to REGENESIS for sample analysis
- Results are used to provide a report containing useful information such as contaminant mass flux and groundwater Darcy flux



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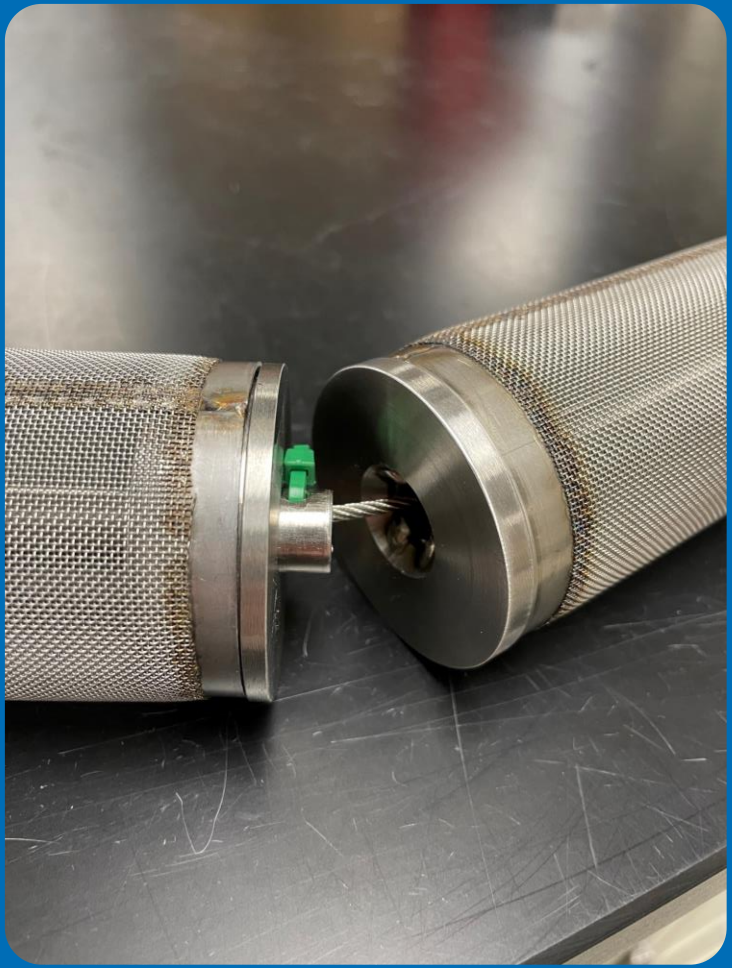
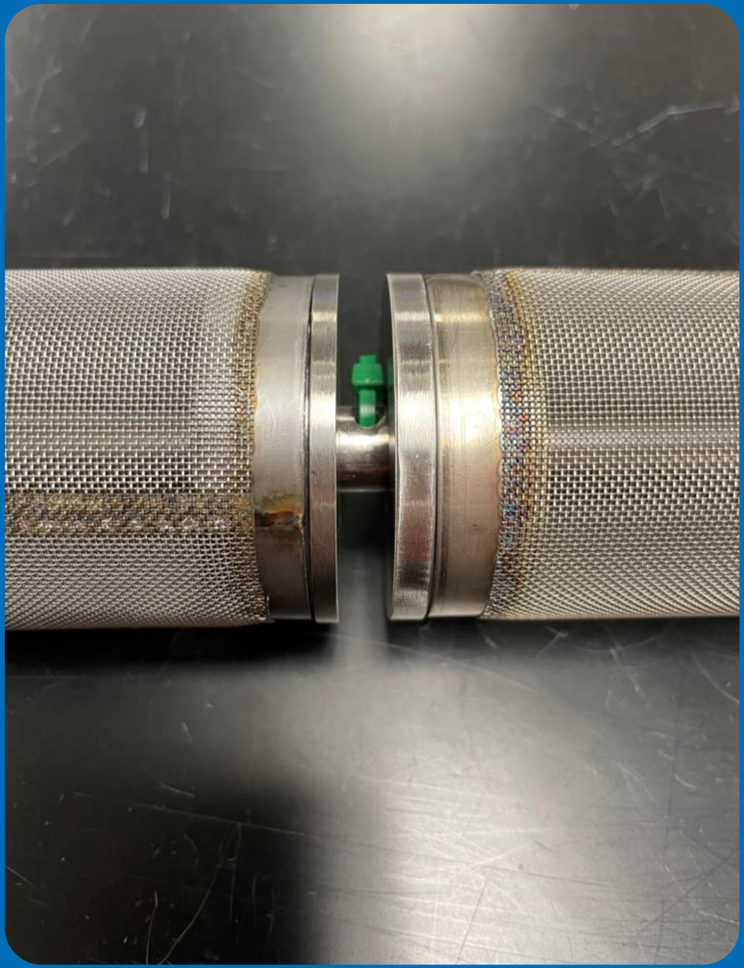
FluxTracer Construction

FluxTracer®
Flux Mapping Tool

- All stainless-steel construction
- Sealed and tamper-resistant
- Self-centering
- Junctions allow “train car” movement





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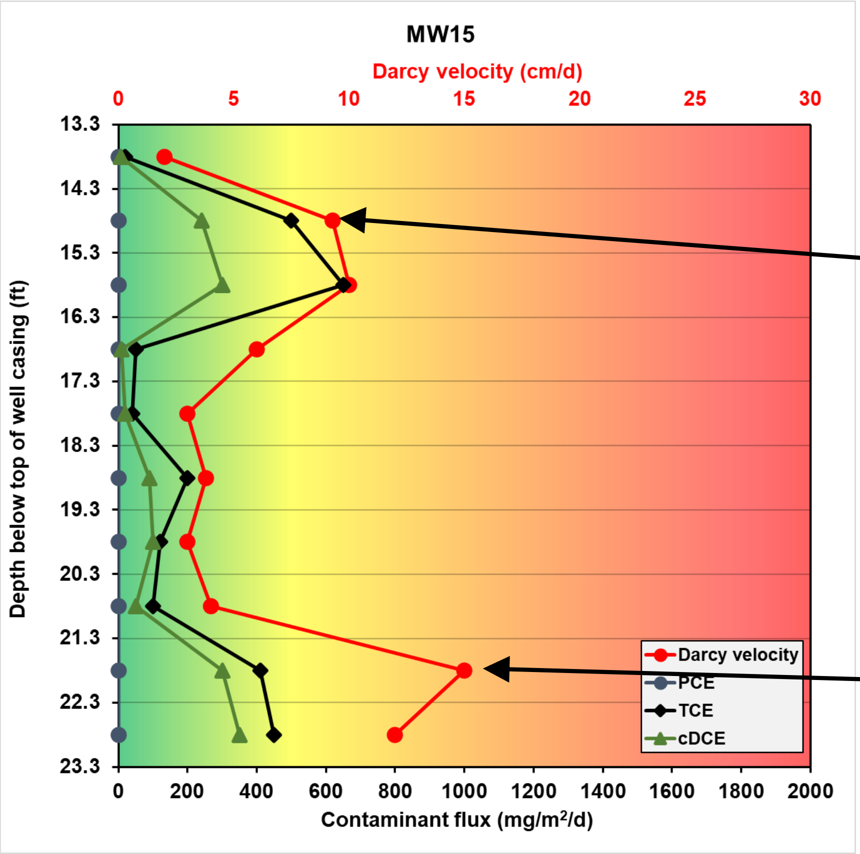
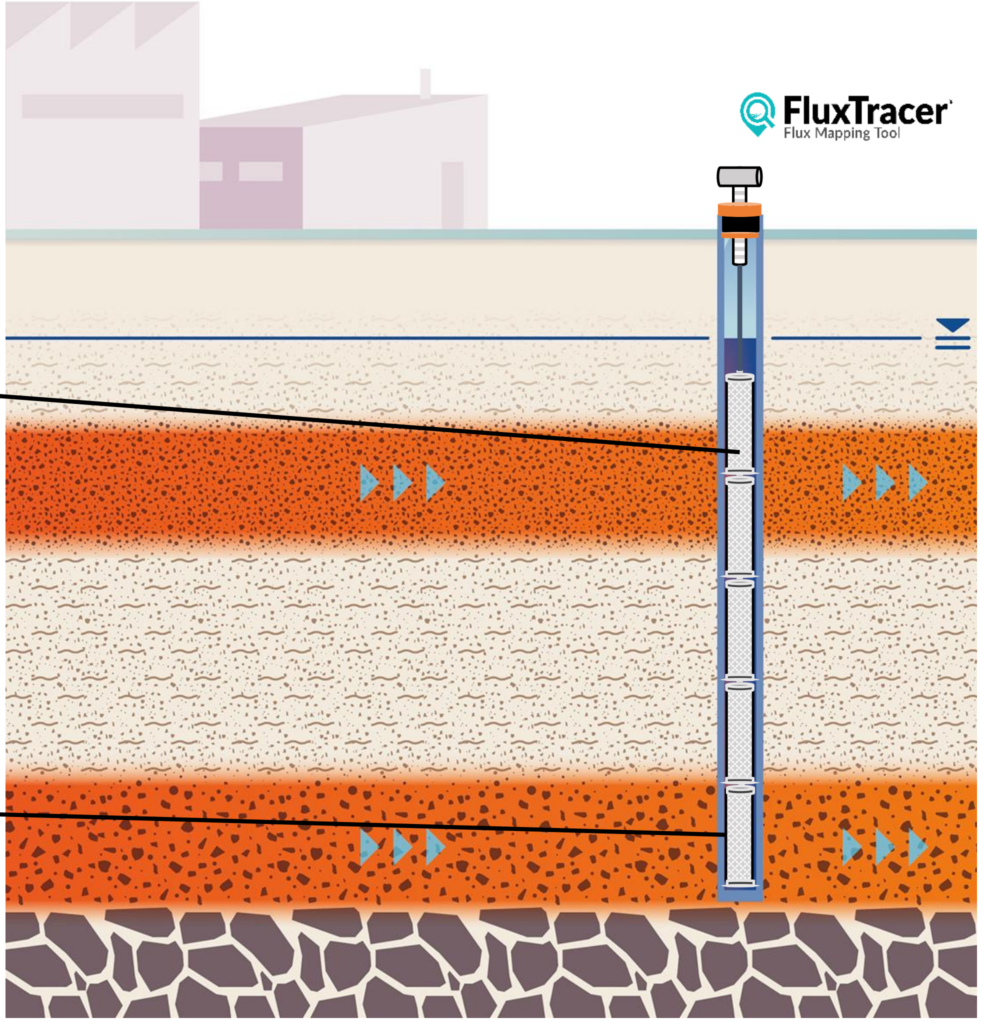
Shipping container with FluxTracer and tools
Pre-cut wire spool
FluxTracer unfolded
FluxTracer
Flux Mapping Tool

Flux Determination- Passive Methods

Resulting data identifies zones of varying flux





More permeable zone

Less permeable zone

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Data Reporting

Report elements

TABLE 1

Darcy velocity and contaminant fluxes

Depth below top of well casing (ft)	Darcy velocity (cm/day)	PCE (mg/m2/day)	TCE (mg/m2/day)	cDCE (mg/m2/day)
13.8	2.0	ND	20	8
14.8	9.3	ND	500	240
15.8	10.0	ND	650	300
16.8	6.0	ND	50	10
17.8	3.0	ND	40	20
18.8	3.8	ND	200	90
19.8	3.0	ND	120	100
20.8	4.0	ND	100	50
21.8	15.0	ND	410	300
22.8	12.0	ND	450	350

Flux Tracer Report

FluxTracer®
Flux Mapping Tool

Site Name	ABC Factory
Location	MW15
Client	REGENESIS
Contact	John S
Well ID	MW15
Report prepared by:	Josh Moreno
Deployment length (ft)	23.25
Date deployed	10/27/21 11:30
Date recovered	11/10/21 14:30

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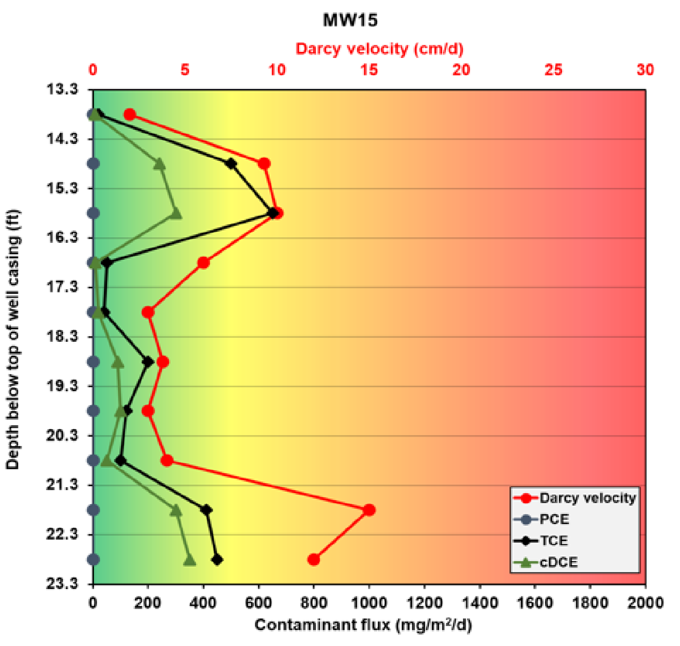
TABLE 2

Flux-derived concentrations

Depth below top of well casing (ft)	PCE (ug/L)	TCE (ug/L)	cDCE (ug/L)
13.8	N/A	1000	400
14.8	N/A	5380	2580
15.8	N/A	6500	3000
16.8	N/A	830	170
17.8	N/A	1330	670
18.8	N/A	5260	2370
19.8	N/A	4000	3330
20.8	N/A	2500	1250
21.8	N/A	2730	2000
22.8	N/A	3750	2920



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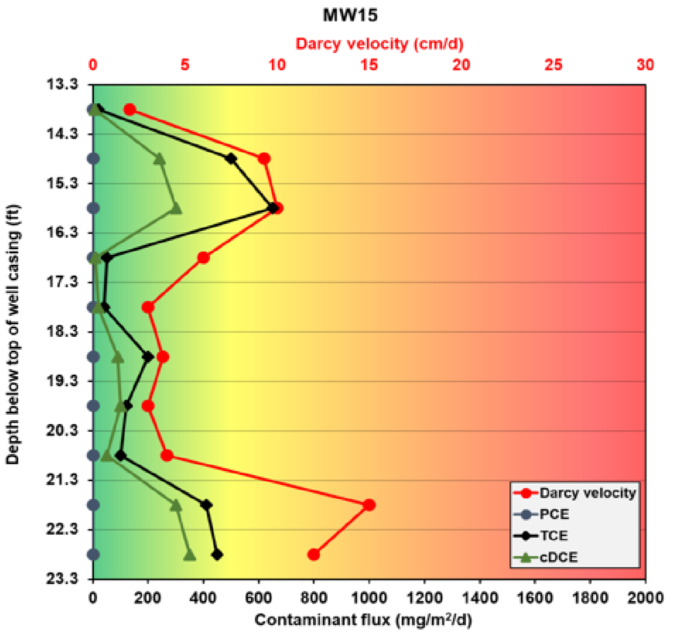

Brownfield's Redevelopment Site

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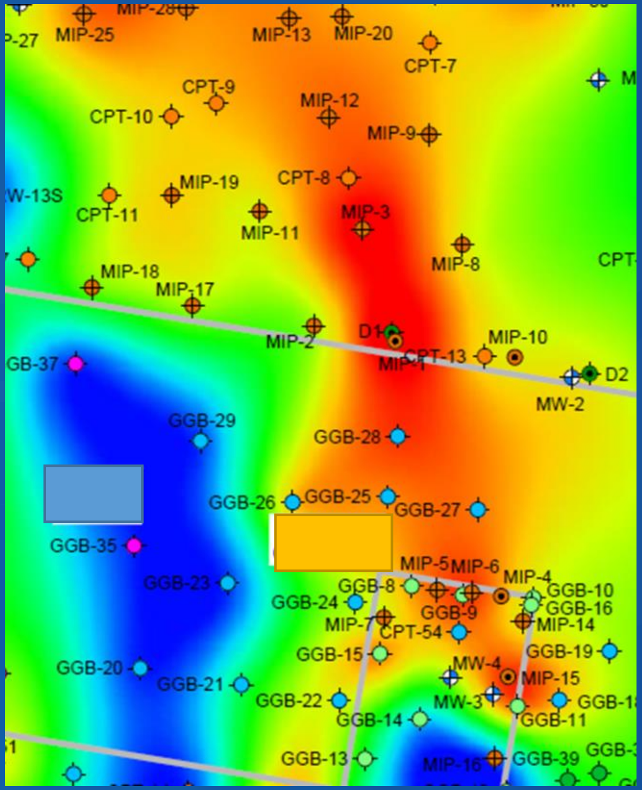
The Problem

Contaminants	Concentrations	Treatment Area	Volume of Impacted Soil/GW
Chlorinated Solvents	27,000 µg/L	68,000 Square Feet	50,000 Cubic Yards

- **Additional Information:**
- **Very high contaminant concentrations**
- **Soil vapor issue contributing to contamination and cleanup criteria**
- **Two main treatment areas;**
  - **source and main plume body**



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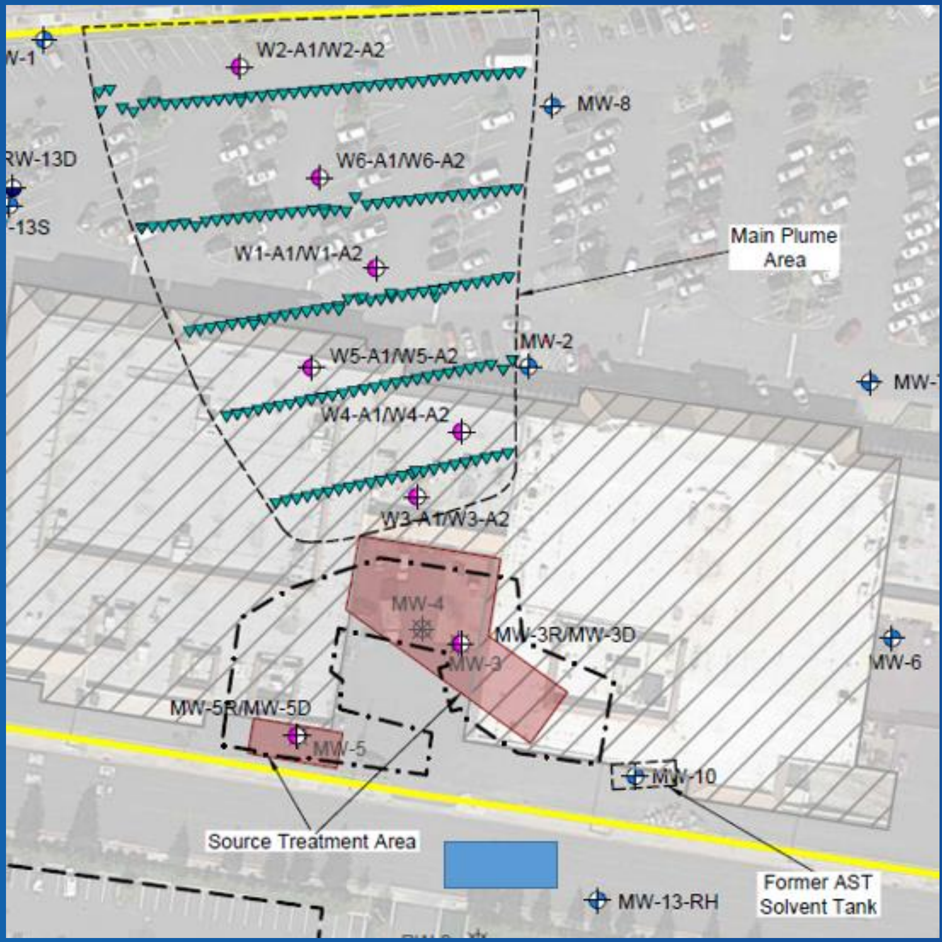
The Solution - Pre-DVT

Contaminants	Concentrations
PCE, TCE, DCE, VC	• Main Plume: up to 200 µg/L • Source Area: 1,400 – 27,000 µg/L
Soil	**Groundwater**
Heterogeneous sand and gravel aquifer	• Depth to GW: ~8-10 feet bgs. • Seepage Velocity: >1,000 feet per year (estimated prior to PFM deployment)
Source Area	**Plume Area**
Excavation, Injection of 3DME, SM-ZVI, and BDI	• Multi-Barrier PlumeStop and SM-ZVI



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Design Verification Program

DVT Item	Completed by	Purpose
Continuous Soil Cores/Soil Settling Tubes	REGENESIS	Identify transmissive zones through grain size analysis
Performance Monitoring Well Installation	PES	Track performance and demonstrate progress toward remedial goals
Passive Flux Study	PES Field Deployment and Collection REGENESIS Flux analysis and Predictive Models	Define contaminant flux to determine product dosing and optimize treatment row placement needed to meet remedial timeframes
Clear Water Injection Test	REGENESIS and PES	Assess optimal product injection radius, and define remediation injection timeframe

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Design Verification Program

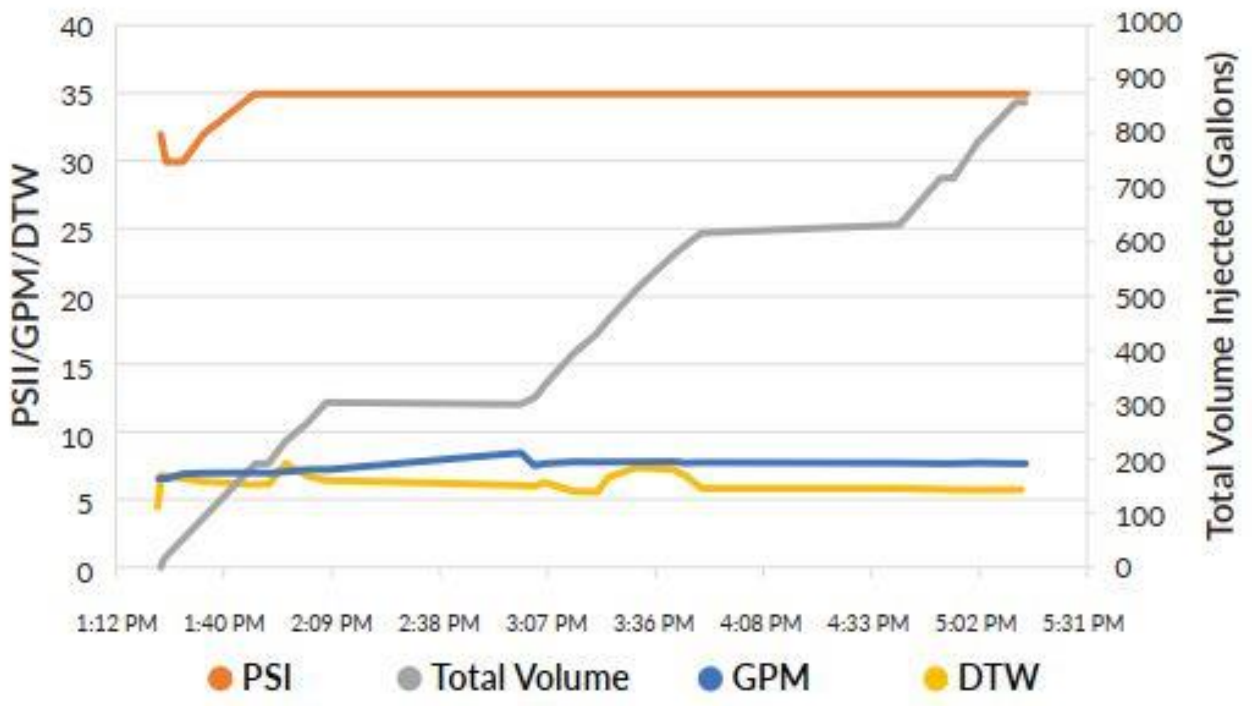

Chart showing pumping rate, injection pressures, depth to water and total volume injected.

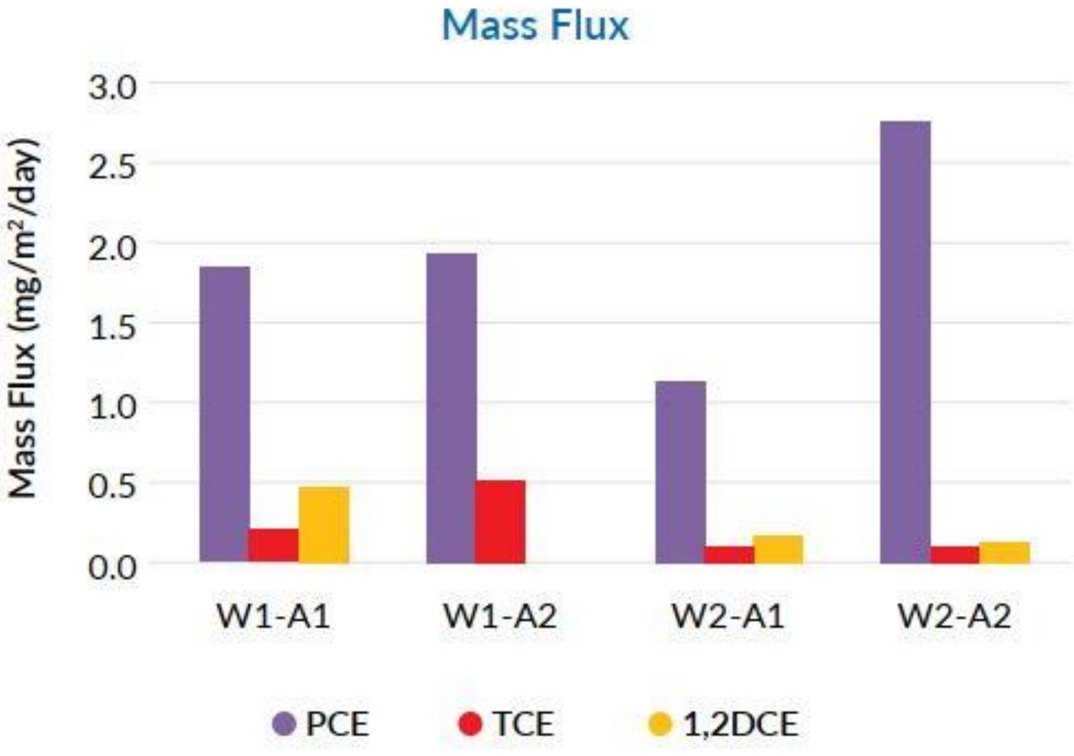

Chart Depicts CVOC Mass Flux at two well pairs, W1 and W2

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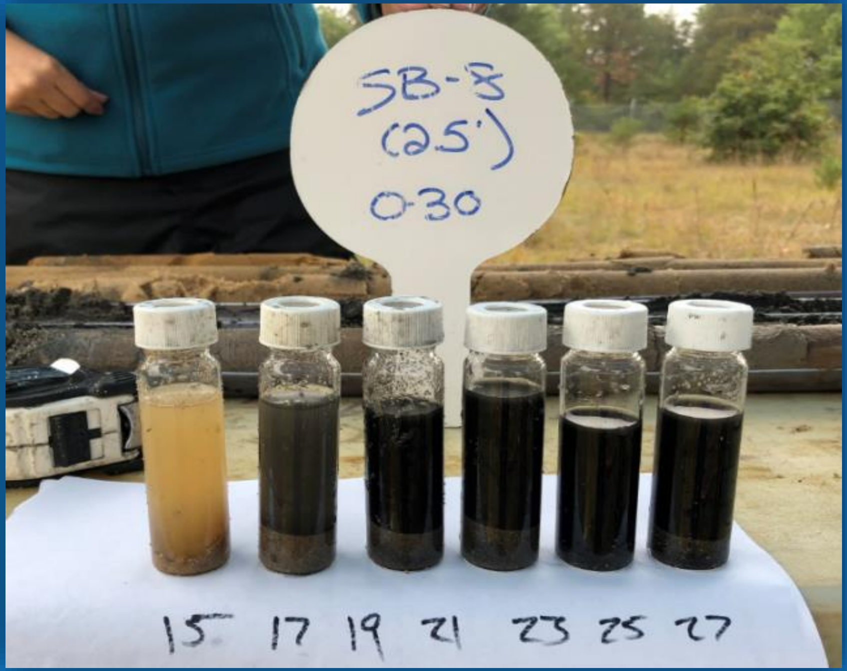
Post-DVT Design Changes

- Slightly tighter injection spacing for more robust barrier
- Decrease injection volume for desired ROI – less field time
- Ground water velocity from changed from ~1,000 to ~300 ft/yr
- Focused target zone from 8 to 30 ft vs. 10 to 30 ft – cost savings
- Reallocated PlumeStop to areas to target the faster mass flux
- Switch destruction product to SM-ZVI for greater longevity and performance

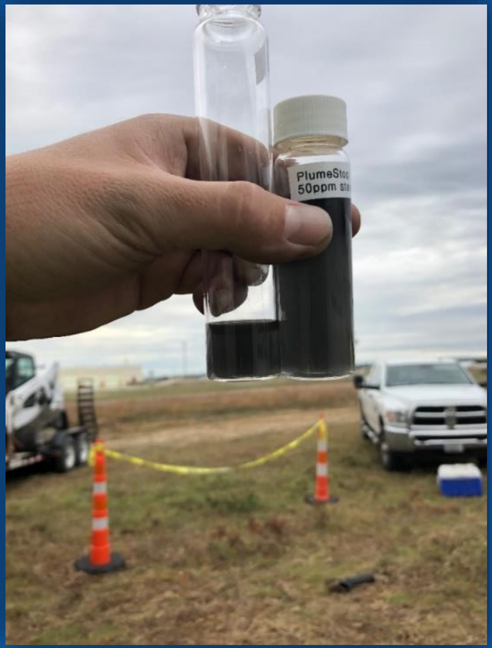
CAC-Distribution Confirmation

Distribution Confirmation



Soil Vial Shake Test

MW-29c



Field Test Kit

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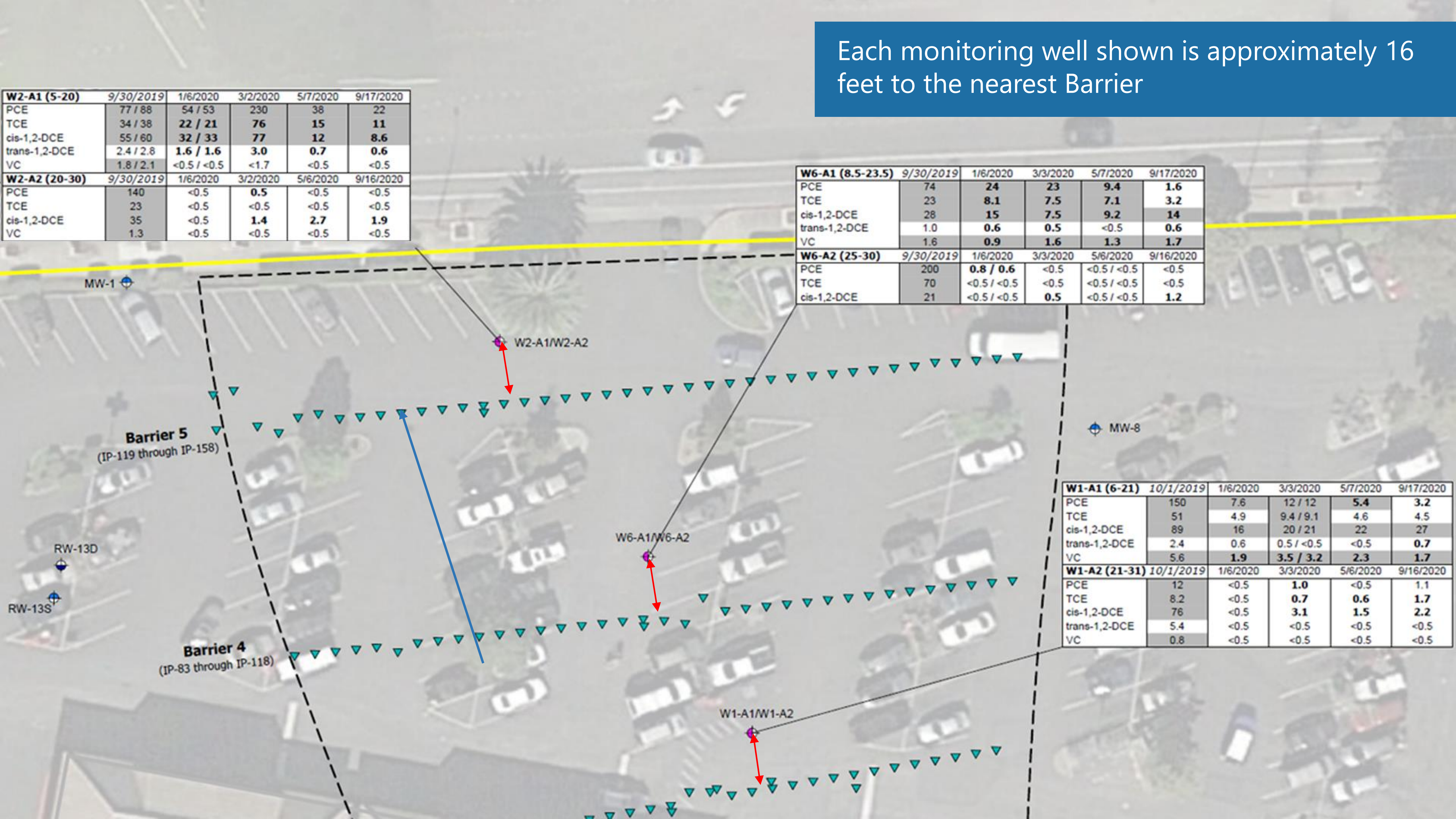
Application Plan

PLUME STOP
Liquid Activated Carbon

S-Micro ZVI
Sulfidated Zero-Valent Iron

28	208,560	158	10-30
Field Days	Gallons of PlumeStop and SM-ZVI Applied	Direct-Push Injection Points (Spaced 6′ Apart)	Feet Below Ground Surface Total Treatment Zone (Narrowed as a result of DVT)

Each monitoring well shown is approximately 16 feet to the nearest Barrier

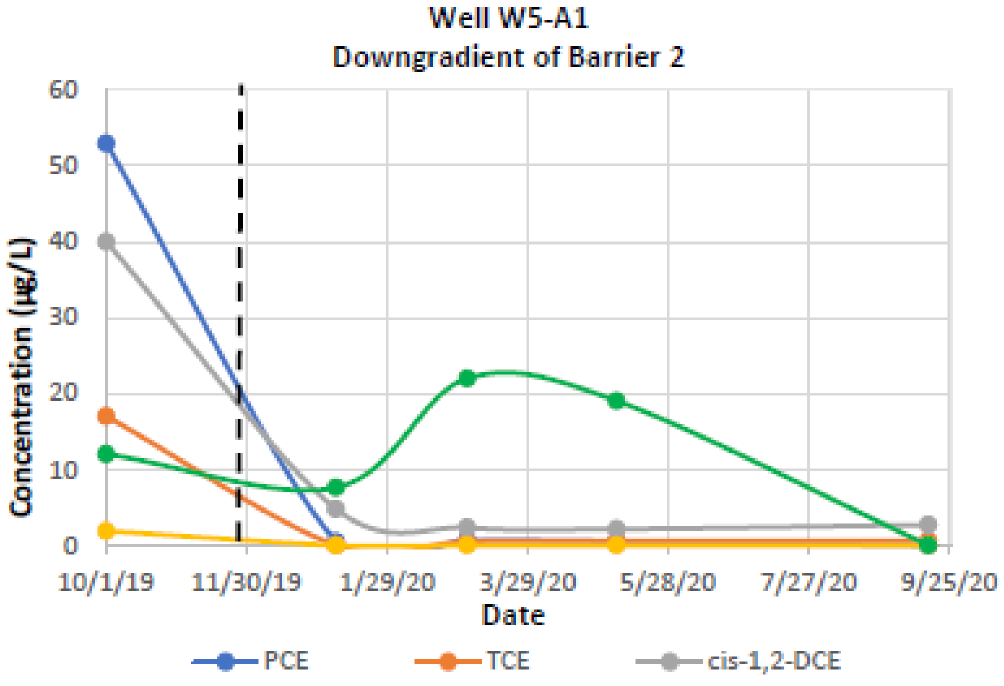


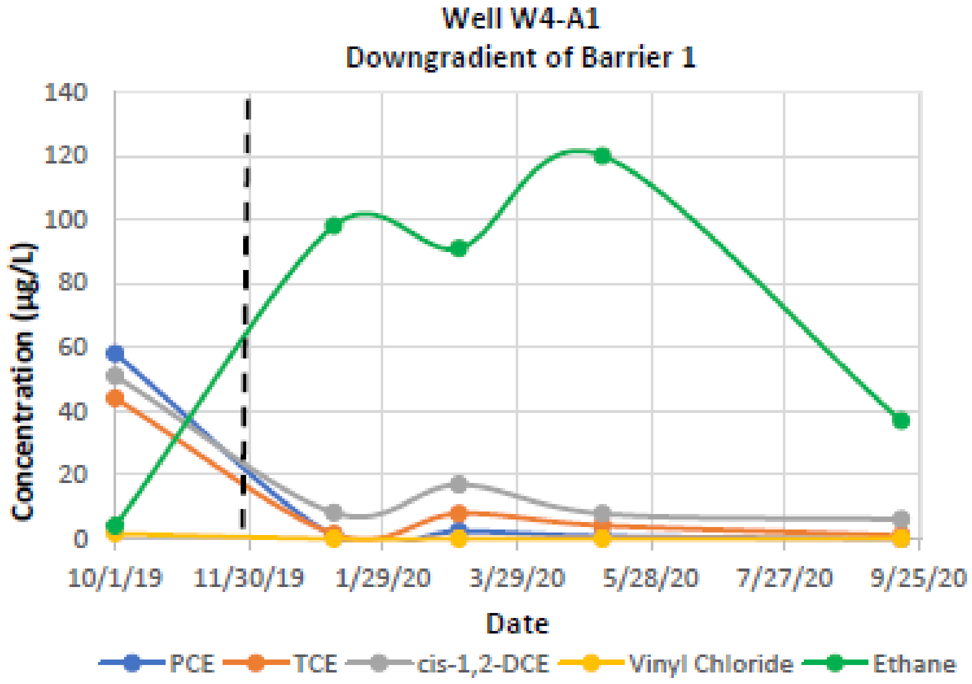
W2-A1 (5-20)	*9/30/2019*	1/6/2020	3/2/2020	5/7/2020	9/17/2020
PCE	77 / 88	54 / 53	230	38	22
TCE	34 / 38	**22 / 21**	**76**	**15**	**11**
cis-1,2-DCE	55 / 60	**32 / 33**	**77**	**12**	**8.6**
trans-1,2-DCE	2.4 / 2.8	**1.6 / 1.6**	**3.0**	**0.7**	**0.6**
VC	1.8 / 2.1	<0.5 / <0.5	<1.7	<0.5	<0.5
W2-A2 (20-30)	*9/30/2019*	1/6/2020	3/2/2020	5/6/2020	9/16/2020
PCE	140	<0.5	**0.5**	<0.5	<0.5
TCE	23	<0.5	<0.5	<0.5	<0.5
cis-1,2-DCE	35	<0.5	**1.4**	**2.7**	**1.9**
VC	1.3	<0.5	<0.5	<0.5	<0.5

W6-A1 (8.5-23.5)	*9/30/2019*	1/6/2020	3/3/2020	5/7/2020	9/17/2020
PCE	74	**24**	**23**	**9.4**	**1.6**
TCE	23	**8.1**	**7.5**	**7.1**	**3.2**
cis-1,2-DCE	28	**15**	**7.5**	**9.2**	**14**
trans-1,2-DCE	1.0	**0.6**	**0.5**	<0.5	**0.6**
VC	1.6	**0.9**	**1.6**	**1.3**	**1.7**
W6-A2 (25-30)	*9/30/2019*	1/6/2020	3/3/2020	5/6/2020	9/16/2020
PCE	200	**0.8 / 0.6**	<0.5	<0.5 / <0.5	<0.5
TCE	70	<0.5 / <0.5	<0.5	<0.5 / <0.5	<0.5
cis-1,2-DCE	21	<0.5 / <0.5	**0.5**	<0.5 / <0.5	**1.2**

W1-A1 (6-21)	*10/1/2019*	1/6/2020	3/3/2020	5/7/2020	9/17/2020
PCE	150	7.6	12 / 12	**5.4**	**3.2**
TCE	51	4.9	9.4 / 9.1	4.6	4.5
cis-1,2-DCE	89	16	20 / 21	22	27
trans-1,2-DCE	2.4	0.6	0.5 / <0.5	<0.5	**0.7**
VC	5.6	**1.9**	**3.5 / 3.2**	**2.3**	**1.7**
W1-A2 (21-31)	*10/1/2019*	1/6/2020	3/3/2020	5/6/2020	9/16/2020
PCE	12	<0.5	**1.0**	<0.5	1.1
TCE	8.2	<0.5	**0.7**	**0.6**	**1.7**
cis-1,2-DCE	76	<0.5	**3.1**	**1.5**	**2.2**
trans-1,2-DCE	5.4	<0.5	<0.5	<0.5	<0.5
VC	0.8	<0.5	<0.5	<0.5	<0.5

Results Upper Zone





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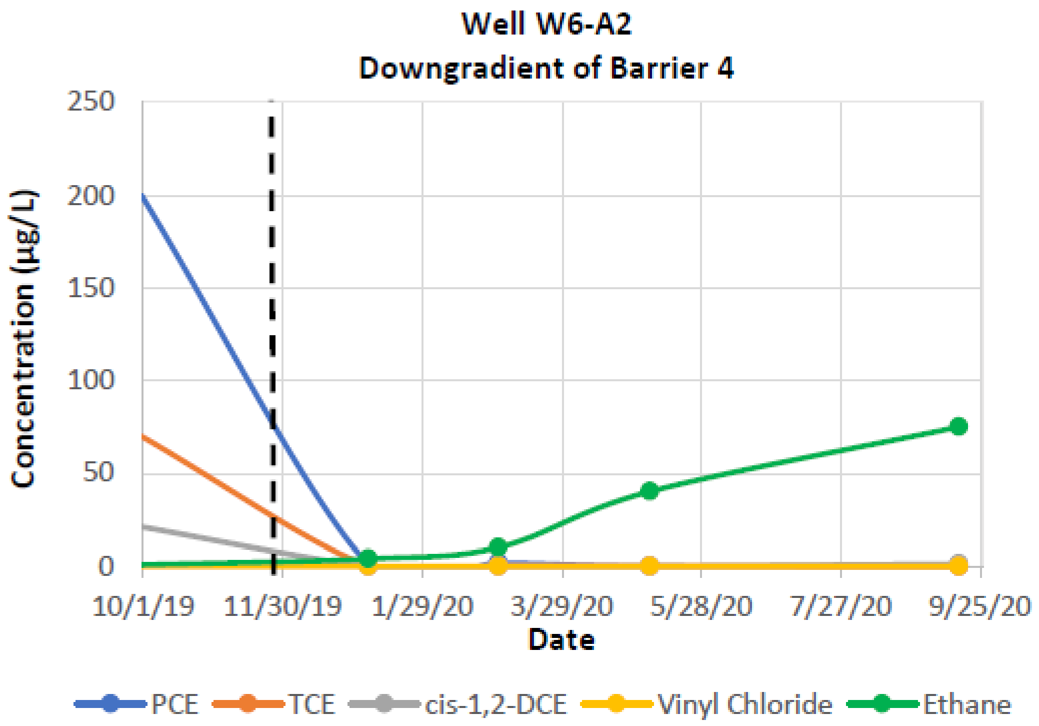
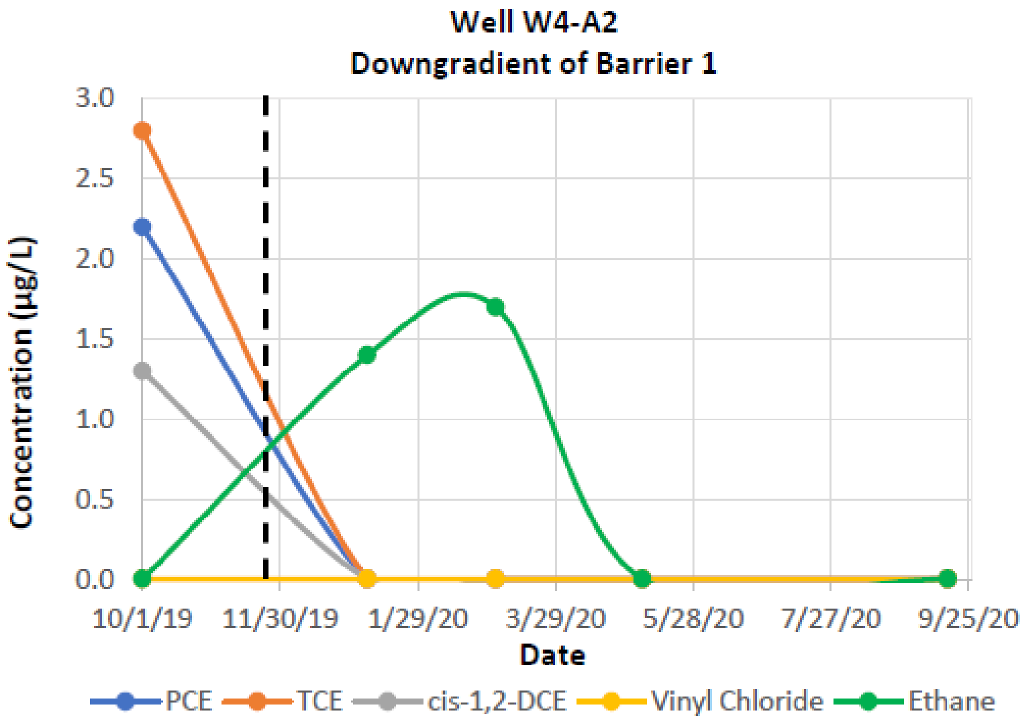
Results Lower Zone





So What Have We Learned?

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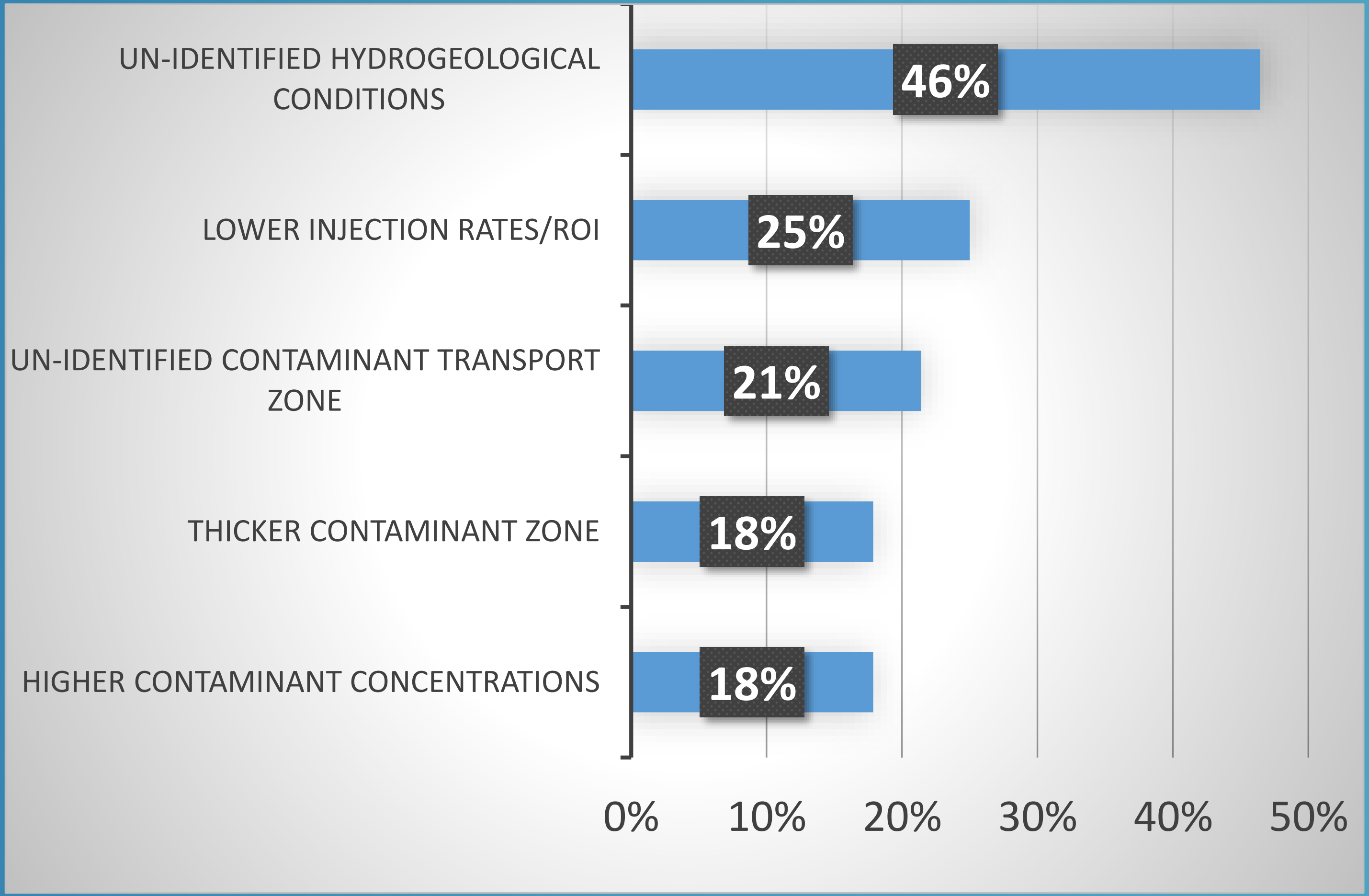
Design Verification Testing

What's the outcome?

- Analysis of 43 DVT investigations
- ~80% of tests found unanticipated results (technical blind spots)
- 62% of preliminary designs were modified / refined
- **Most changes were cost-neutral**



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Success follows from:

The right amount of Reagent

…in the right place

good tools + good processes → engineering control

because success isn't random

Thank You!

Elliot Maker, MSc.
Northeast Technical Manager
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