Case Studies: Overcoming Annoying Contaminant Rebound Using Adsorptive Technologies

RemTech – Banff, AB

October 11, 2018

Kevin French

Presenter

Kevin French, P.Eng

- Vice President, Vertex Environmental Inc.
- B.A.Sc., Civil/Environmental Engineering, University of Waterloo
- 30+ years environmental engineering; 25 in consulting and last 6 as a remedial contractor

Vertex Environmental Inc.

- Founded in 2003
- Bruce Tunnicliffe, M.A.Sc., P.Eng.
- Specialized Environmental Remediation Contracting
- High Resolution Site Characterization (HRSC)

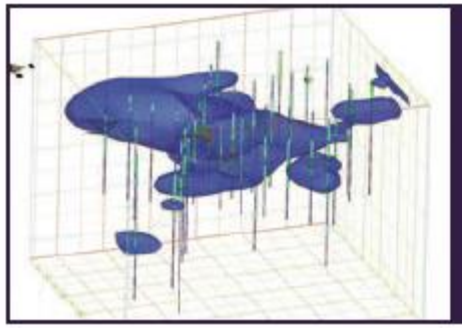
Vertex Environmental Inc.

In-Situ Remediation

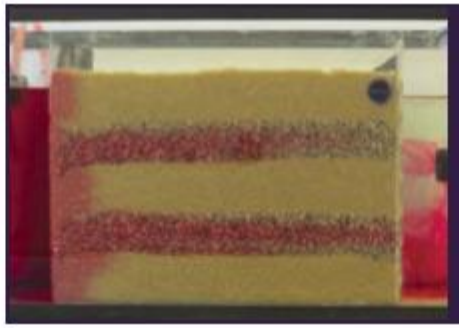
Ex-Situ Remediation

High Resolution Characterization

Treatment Systems



Remedial Design



Bench-Scale Testing

VERTEX

Presentation Overview

- Common Organic Contaminants
  - What They Are and How to Find Them
  - Why Are They a Problem?
  - Common Approaches to Remediation
- Case Studies
  - Neighbour to Former Dry Cleaner
  - Former Underground Storage Tank
  - Two More “Quickies”
- Closing Thoughts
- Questions

Common Organic Contaminants
What They Are
and How to Find Them

Common Organic Contaminants

LNAPL

Gasoline
0.75 g/cm^3

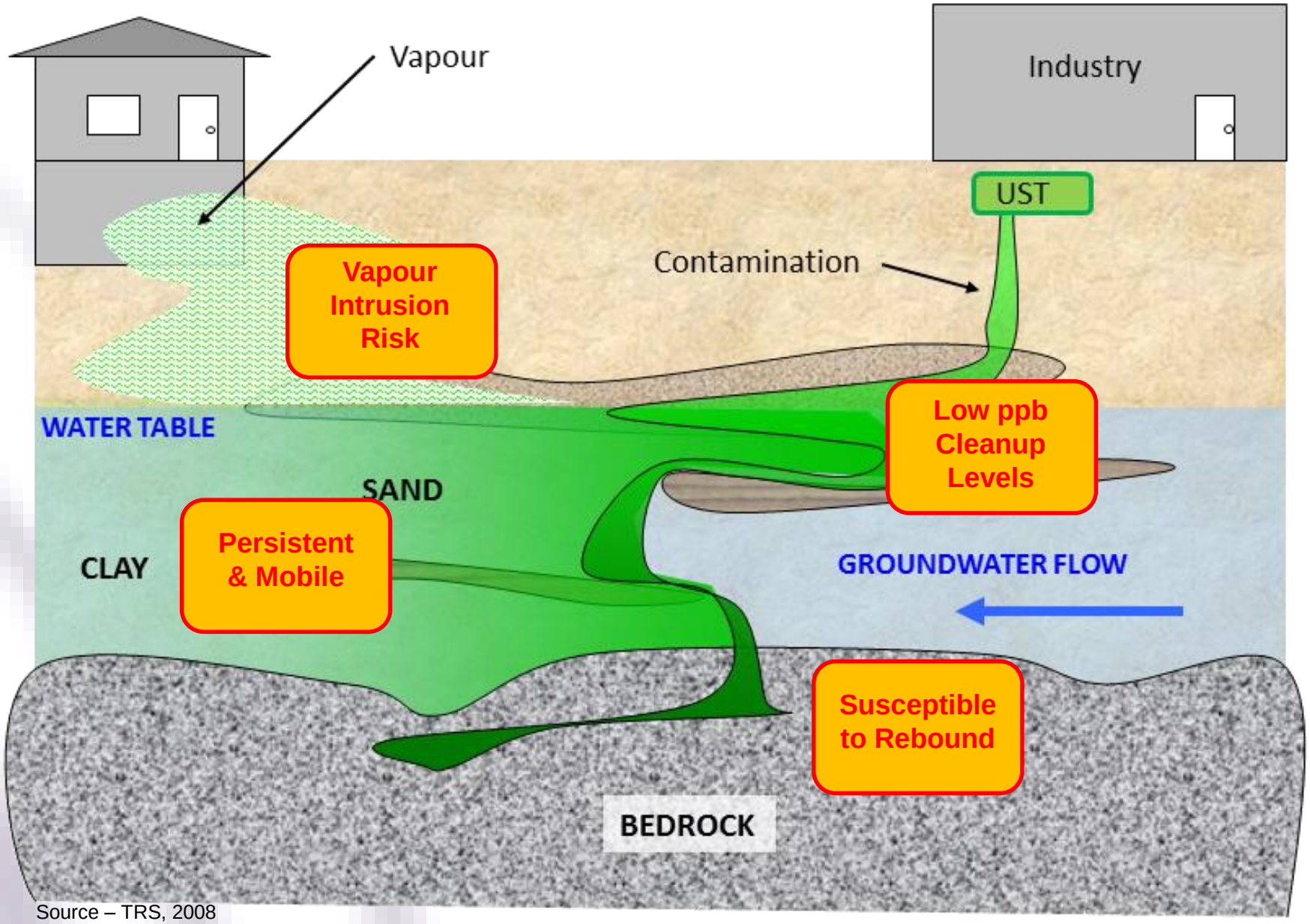
- **Petroleum Hydrocarbons (PHCs)**
  - Lighter than water (“floaters”, LNAPL)
  - Gasoline, diesel, motor oil, fuel oil, etc.

DNAPL

TCE
1.46 g/cm^3

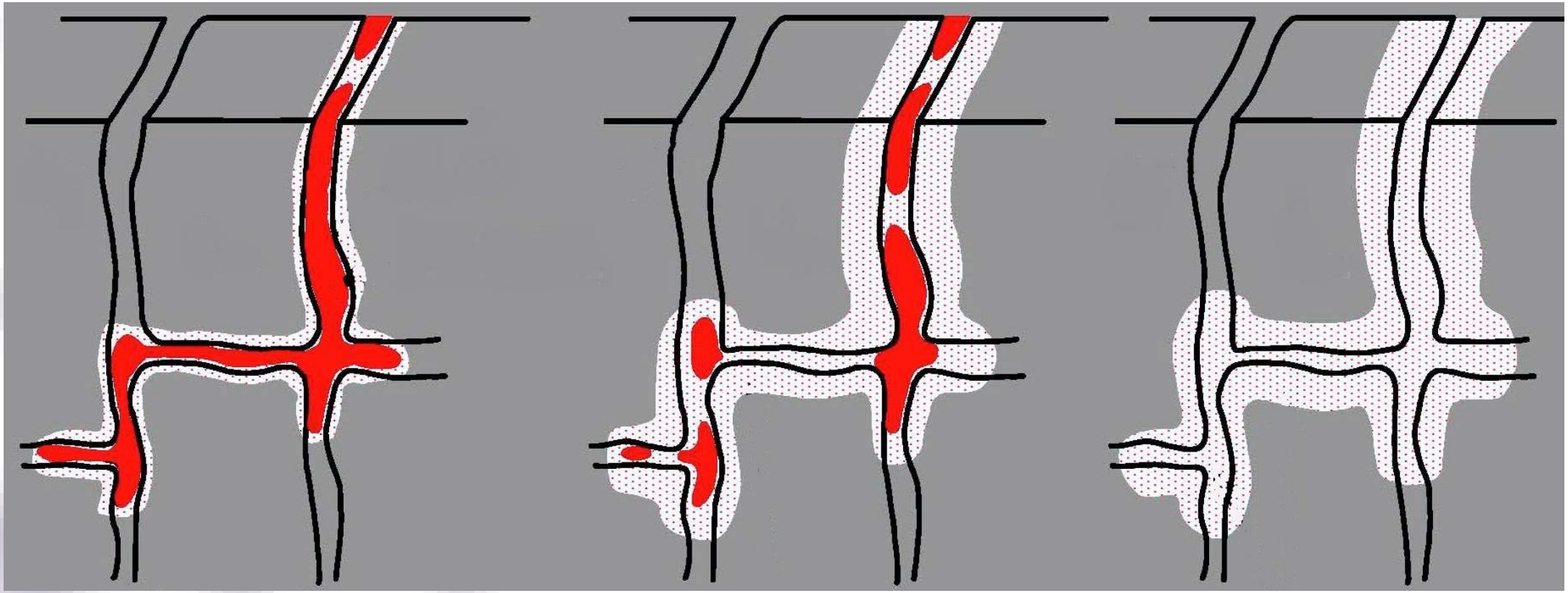
- **Chlorinated Solvents (cVOCs)**
  - Heavier than water (“sinkers”, DNAPL)
  - Tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1,1-trichloroethane (TCA), etc.
  - Were commonly used for dry cleaning, degreasing, etc.

Why They Can be so Problematic



Source – TRS, 2008

Why They Can be so Problematic



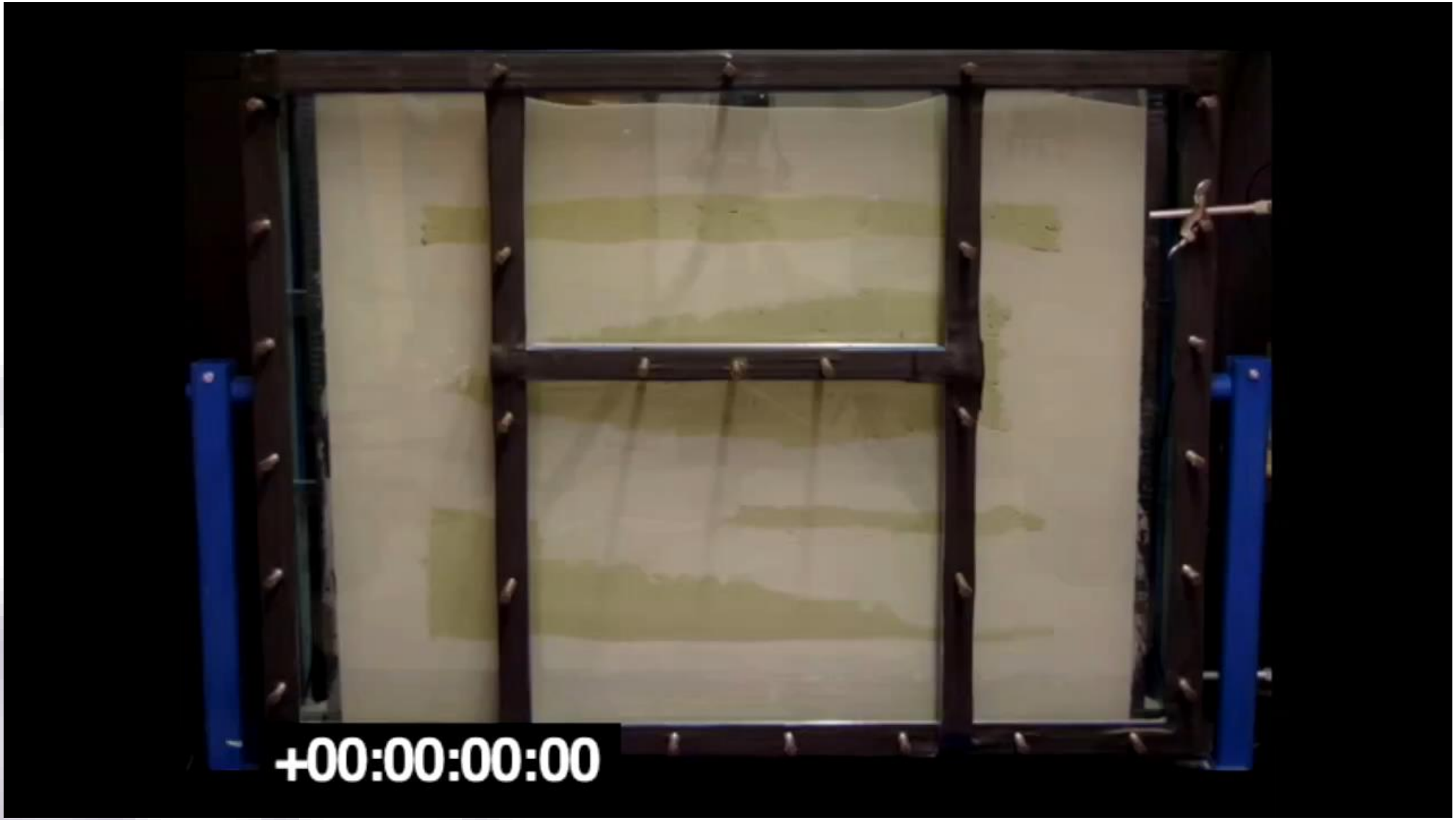
Early Time **Intermediate Time** **Late Time**

Diffusion into the Soil or Bedrock Matrix

During Remediation – Back Diffusion

Source: Beth Parker

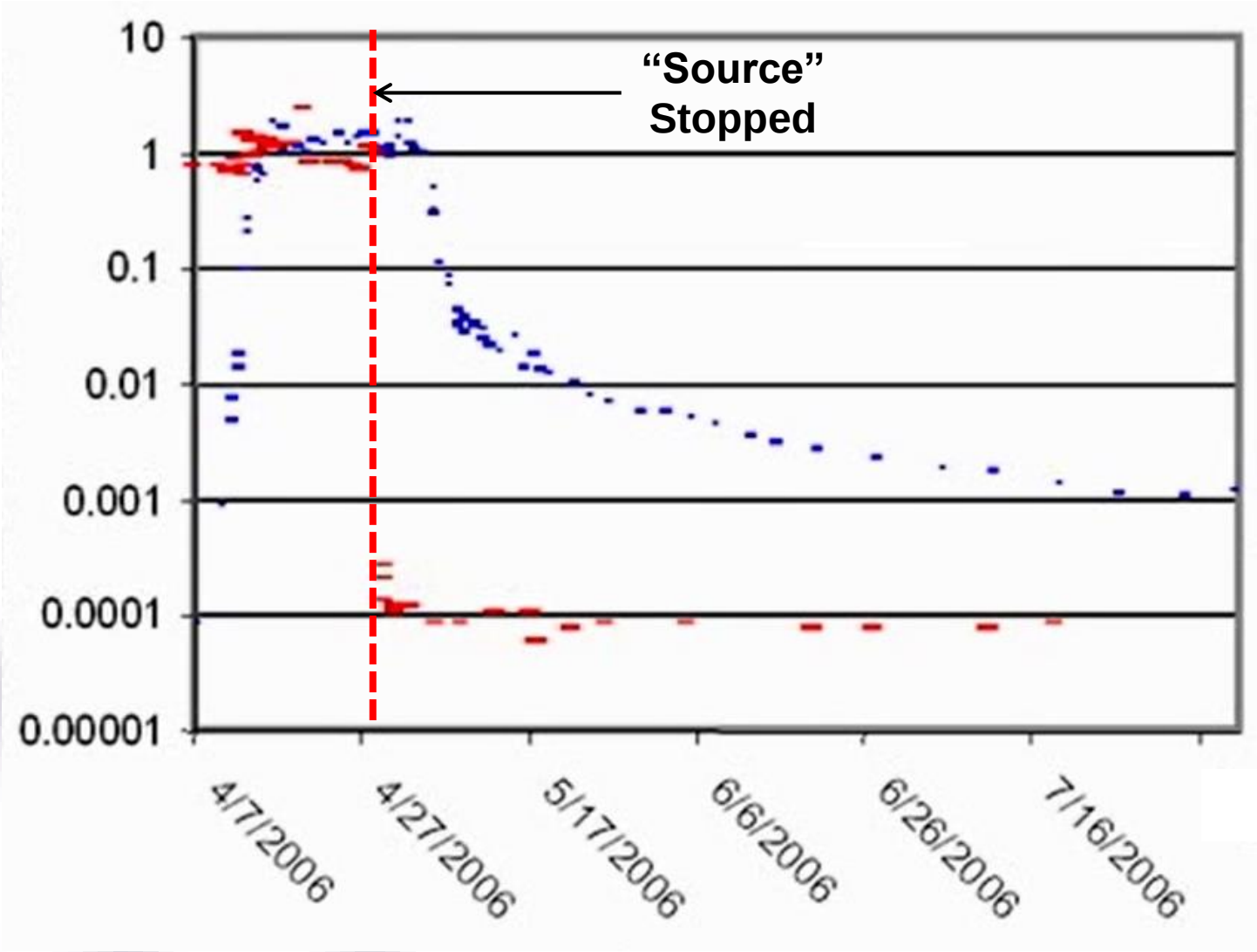
Why They Can be so Problematic



Contaminant Back Diffusion (cause of “rebound”)

Source – Colorado State University

Why They Can be so Problematic



Effluent

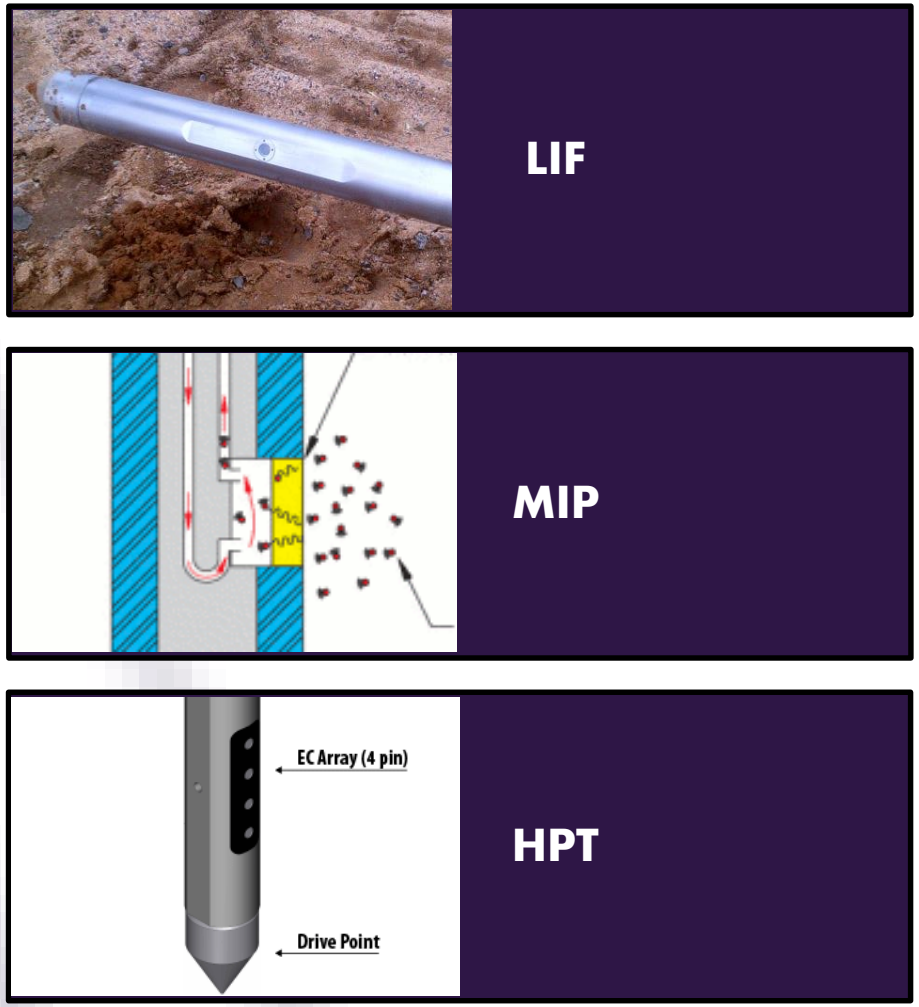
Influent

Difference caused by back-diffusion = "rebound"

Contaminant Back Diffusion (cause of "rebound")

Source – Colorado State University

High Resolution Methods to Find Organic Contaminants



Laser Induced Fluorescence (LIF)

- Free Phase PHCs / LNAPL

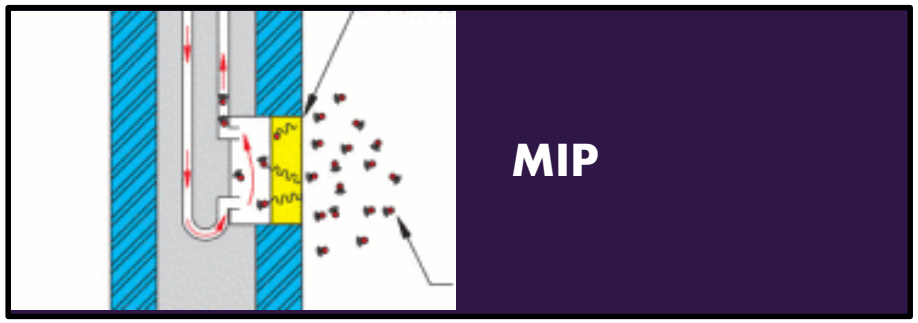
Membrane Interface Probe (MIP)

- Dissolved Phase PHCs and VOCs

Hydraulic Profiling Tool (HPT)

- Subsurface Permeability and Conductivity Est.

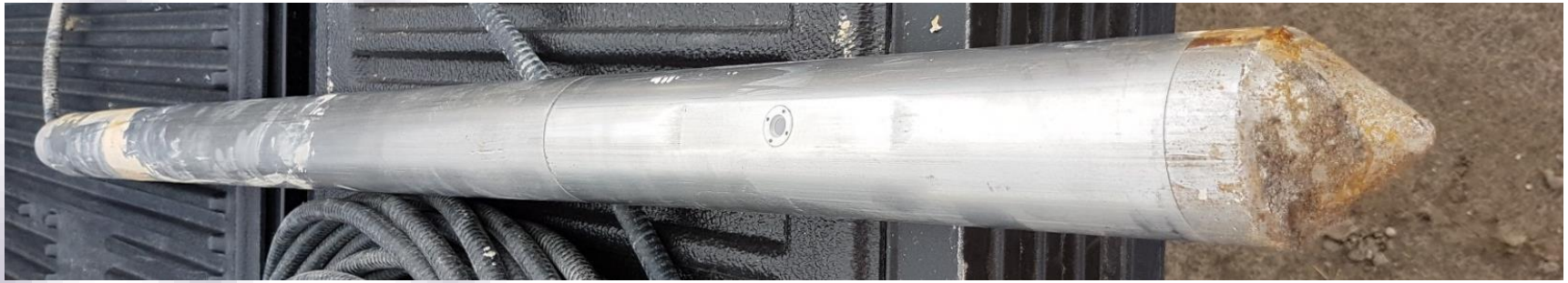
High Resolution Methods to Find Organic Contaminants



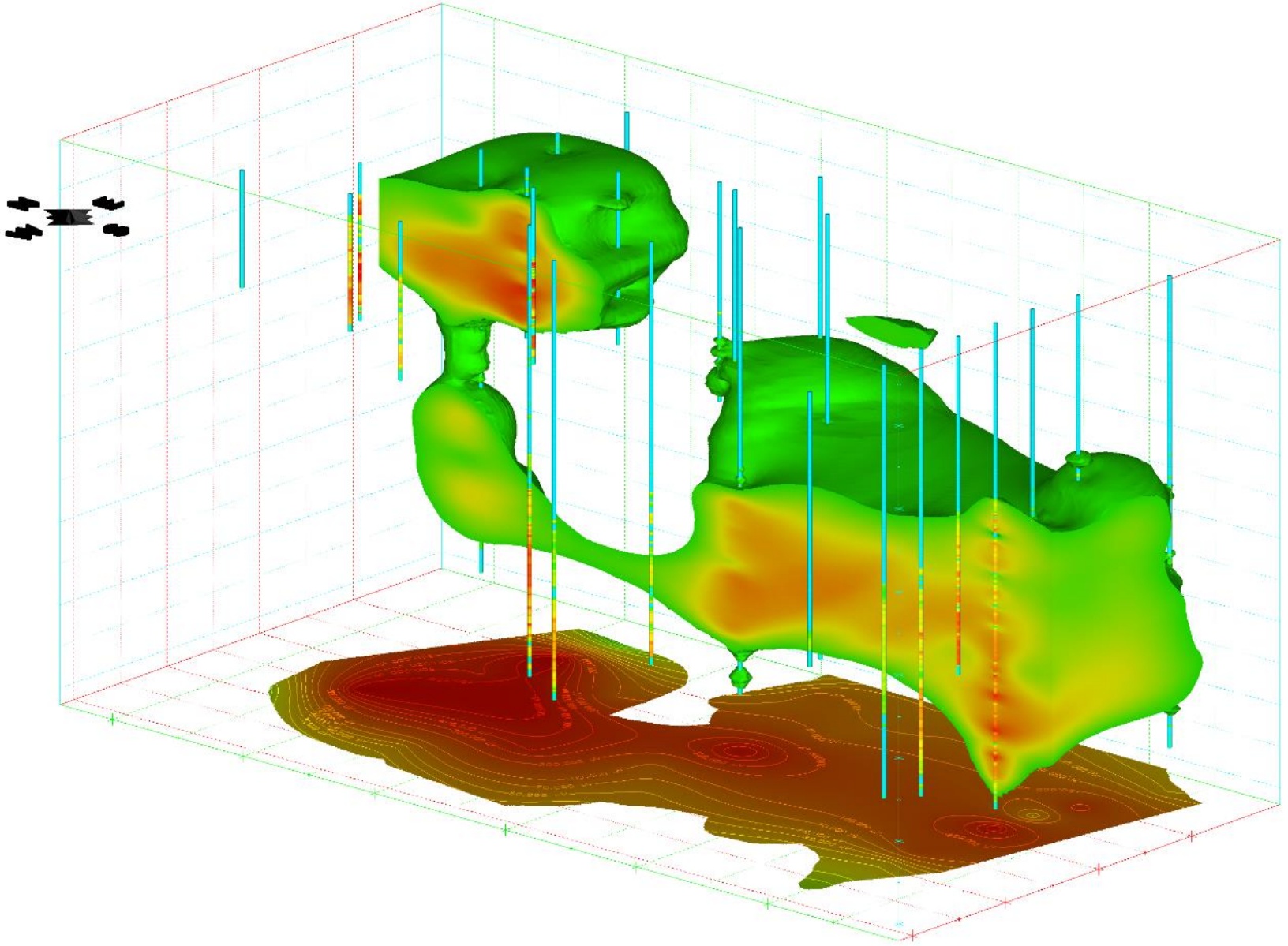
Membrane Interface Probe (MIP)

- Three detectors:
  - Photoionization Detector (PID) **PHCs** **cVOCs**
  - Flame Ionization Detector (FID) **PHCs**
  - Halogen Specific Detector (XSD) **cVOCs**
- Detection of VOCs:
  - Petroleum Hydrocarbons (BTEX, PHCs)
  - Chlorinated Solvents (TCE, PCE, TCA, etc.)
- Electrical Conductivity
  - Classify soil

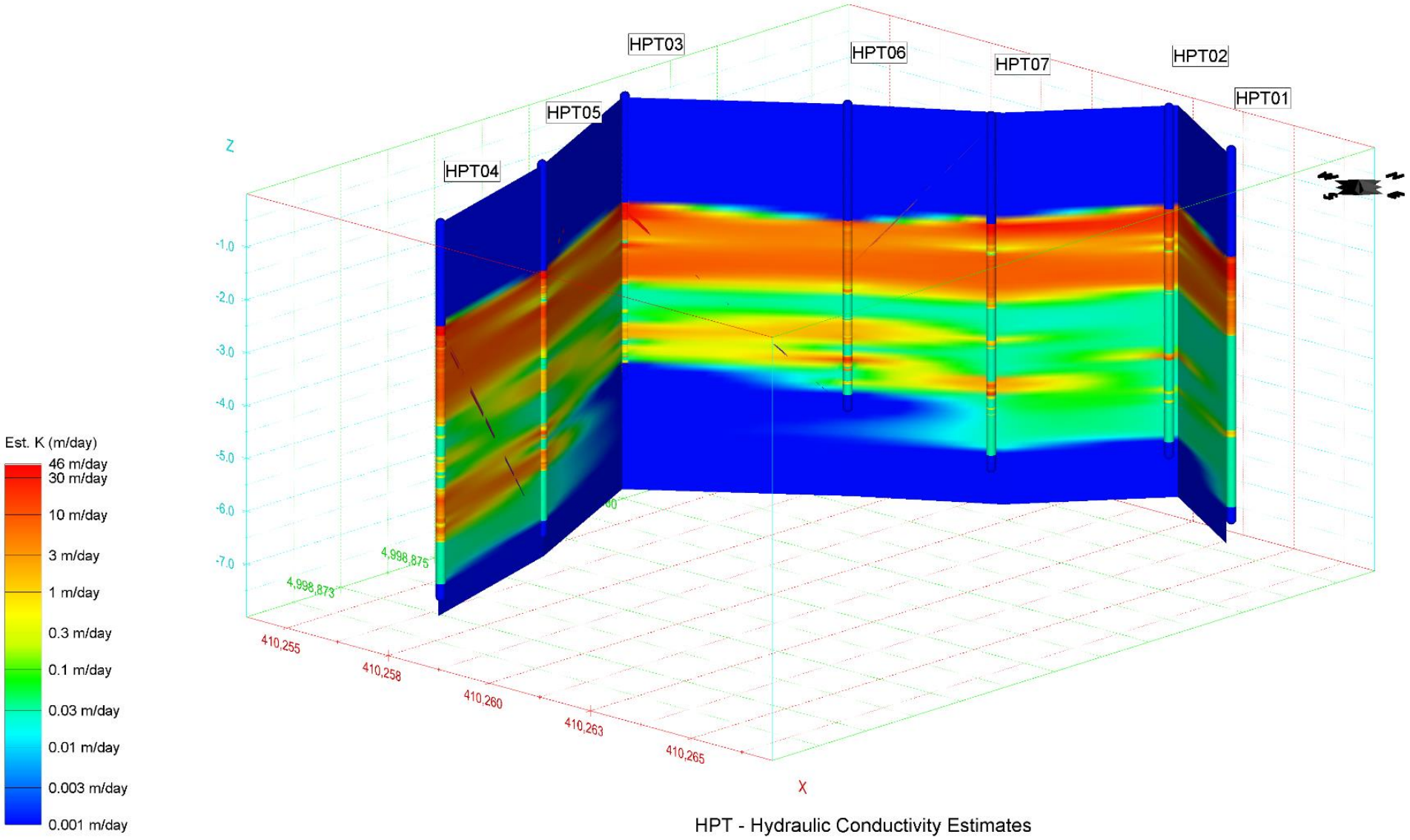
High Resolution Methods to Find Organic Contaminants – Field Work



High Resolution Methods to Find Organic Contaminants – Visualization



High Resolution Methods to Find Organic Contaminants – Visualization



HPT - Hydraulic Conductivity Estimates

Common Remediation Approaches

- “Do Nothing” / Monitored Natural Attenuation
- Excavation and Off-Site Disposal
- Chemical Oxidation & Reduction
- Permeable Reactive Barriers (PRBs)
- Adsorption-based (Trap & Treat®)
- Enhanced Bioremediation (aerobic & anaerobic)
- Systems Technologies & Phase Separation
- Sub-Slab Depressurization (vapour intrusion mitigation)
- Risk Assessment / Risk Management
- Combinations of the above

Trap & Treat® Technology

Remedial Amendments

- Trap & Treat® BOS 100® - for cVOCs
- Trap & Treat® BOS 200® - for PHCs
- Application using temporary points or by direct soil mixing
- Plume remediation or PRB applications

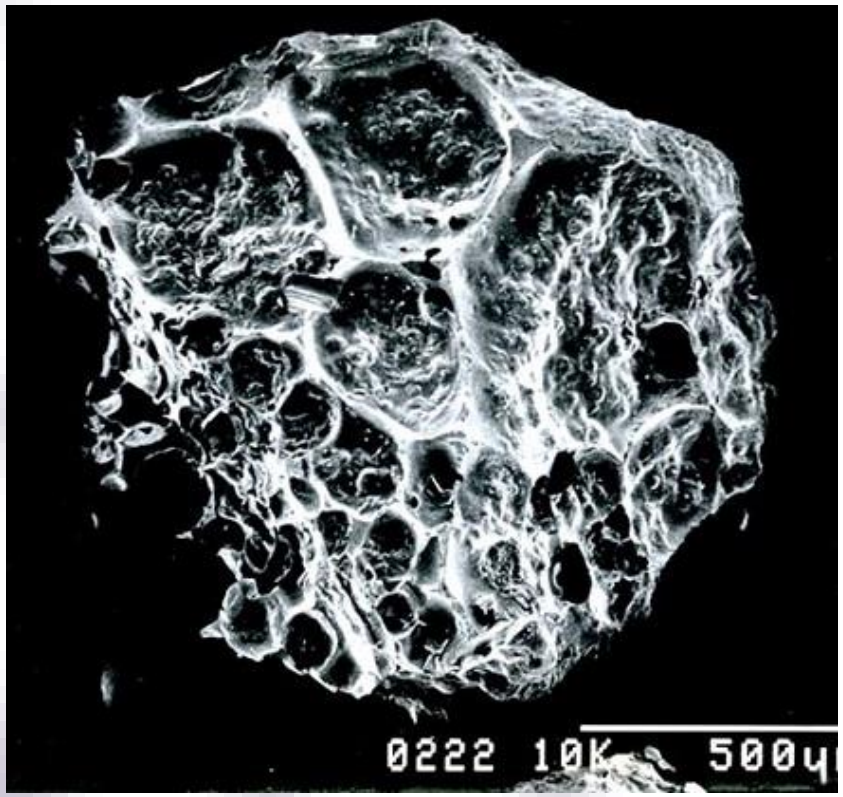
Mechanisms of BOS 100® and BOS 200®

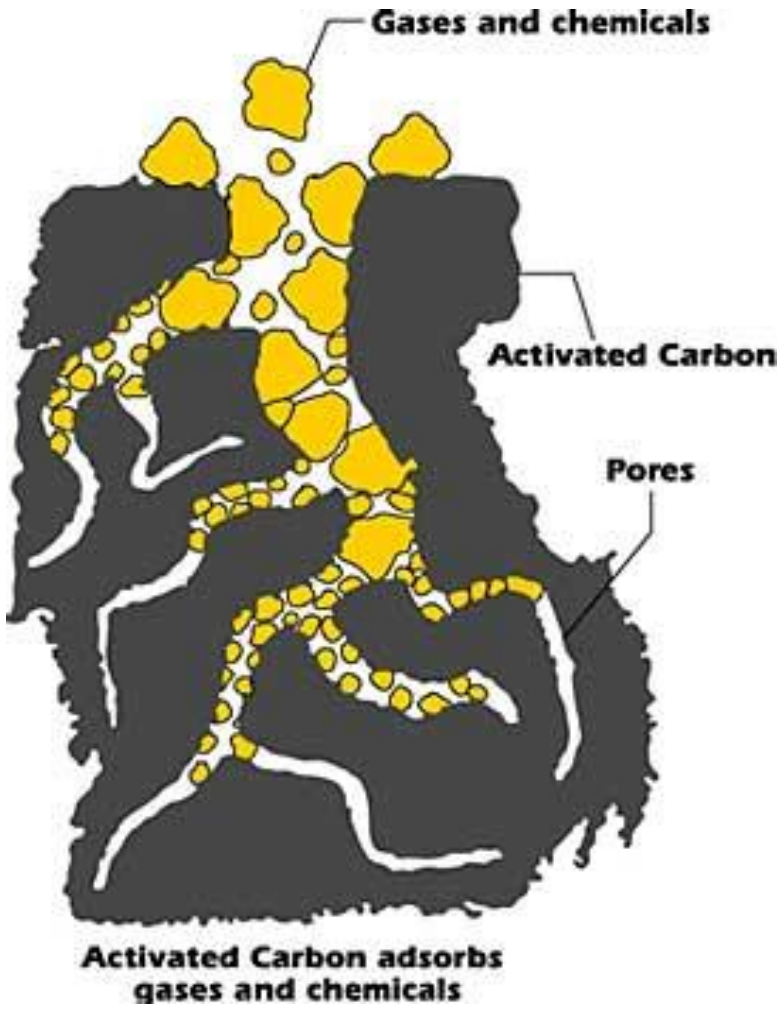
- **“Trap”** the contamination within the AC matrix
- **“Treat”** within the matrix using amendment

Benefits

- Usually Single Application
- Long-Term Solution
- **Back Diffusion Control = Prevents “Rebound”**

Trap & Treat® Technology

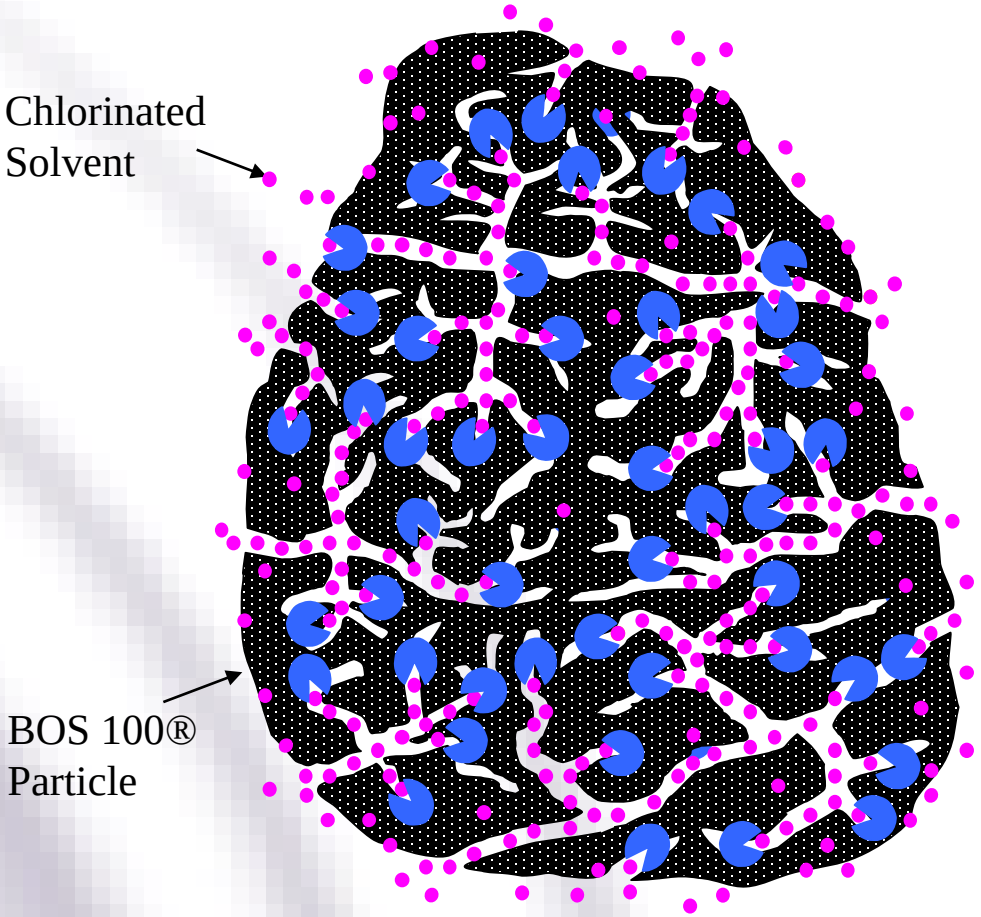




Activated Carbon Adsorption

Trap & Treat® Technology

BOS 100® - for cVOCs

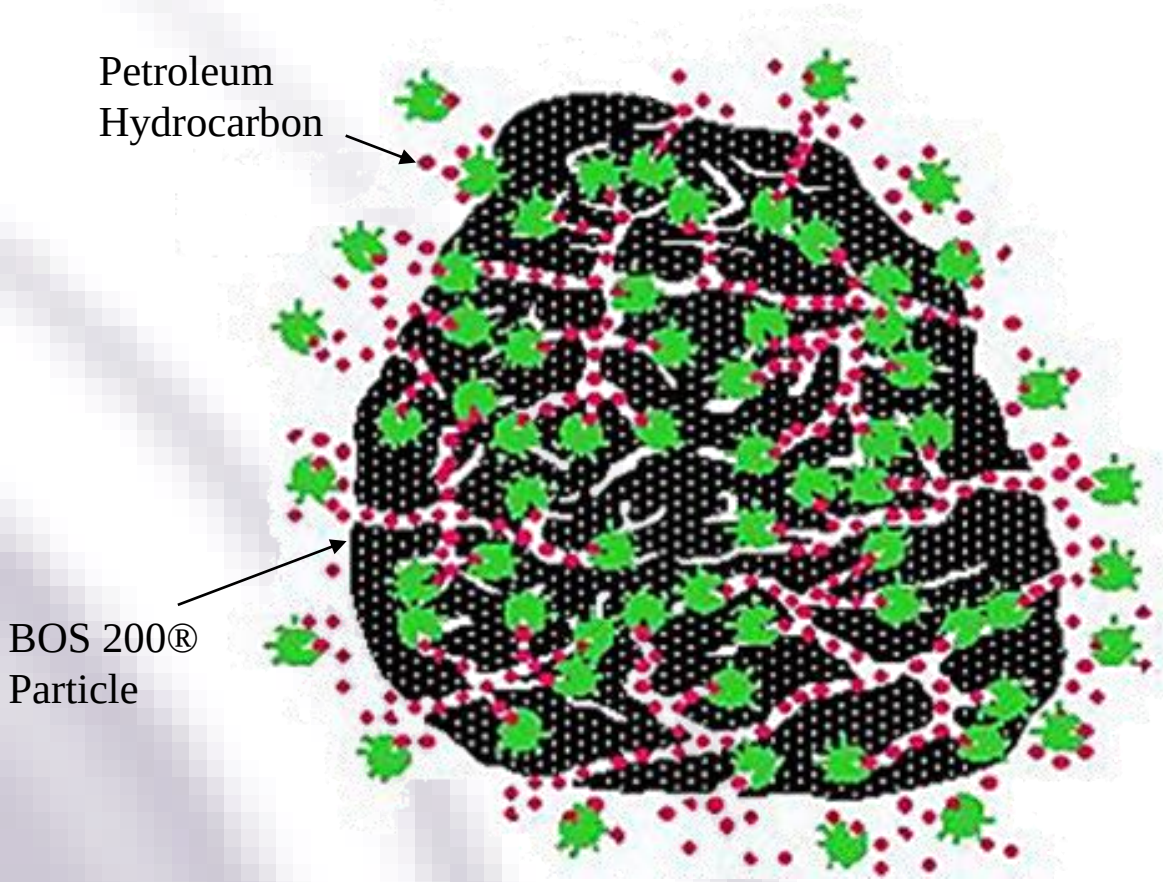


Activated Carbon & Iron

Source: AST Environmental

Trap & Treat® Technology

BOS 200® - for PHCs



Activated Carbon & Nutrients & Microbes

Source: AST Environmental

Case Studies

Case Study #1
Neighbour to Former Dry Cleaner

Case Study #1: Neighbour to Former Dry Cleaner

Site Background

- Site adjacent to former dry cleaner property
- **Full remediation required**

Contaminant Situation

- Plume of cVOCs flowing through the Site (entering and leaving)

Remedial Objective

- **Generic** groundwater standards

Obstacles

- **Minimize disruption to tenants** (only one injection event; therefore must prevent “rebound”)
- **Old (leaky?) sewer easement passes through Site** (non-mobile amendment needed)

Case Study #1: Neighbour to Former Dry Cleaner

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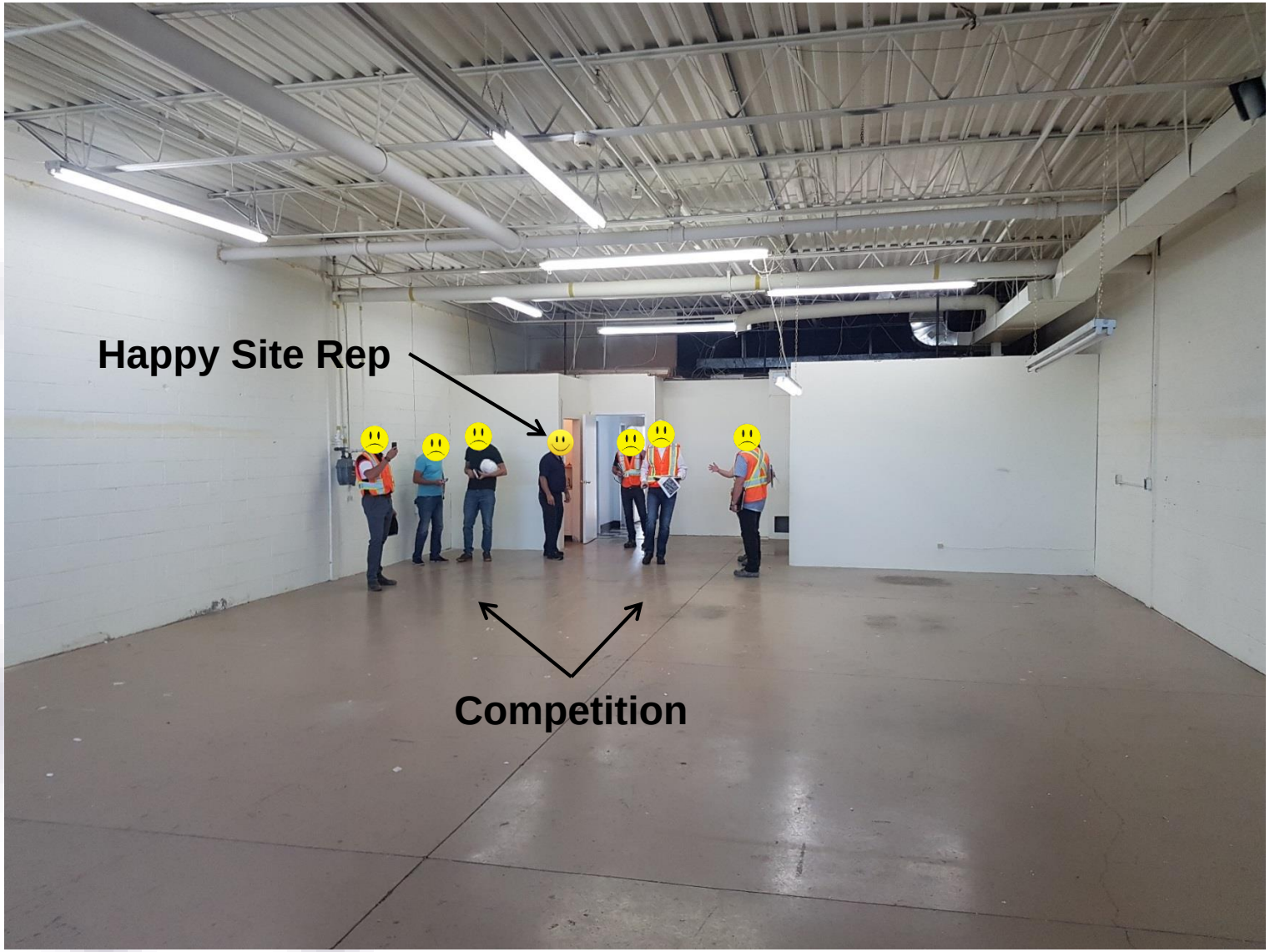

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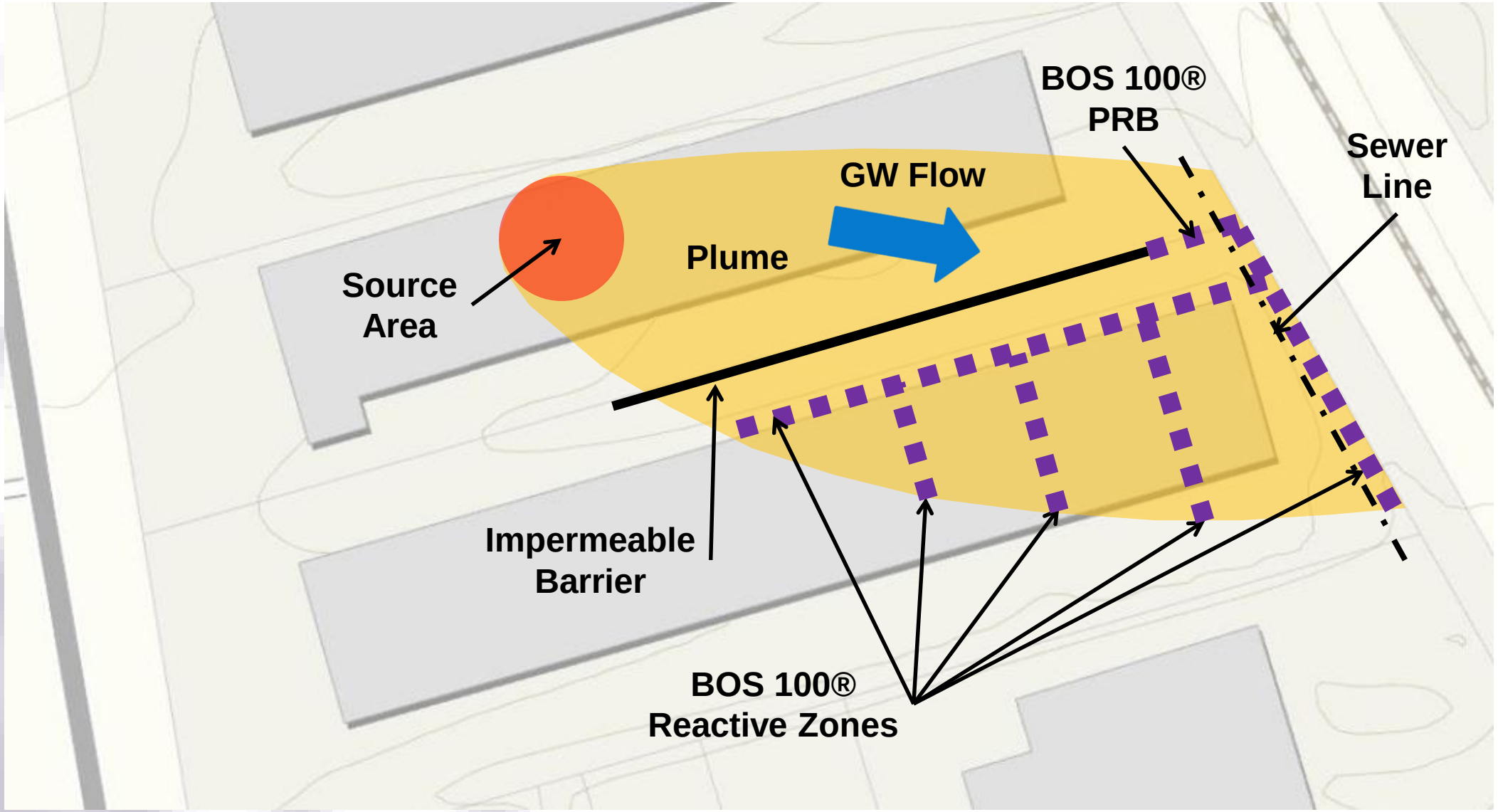
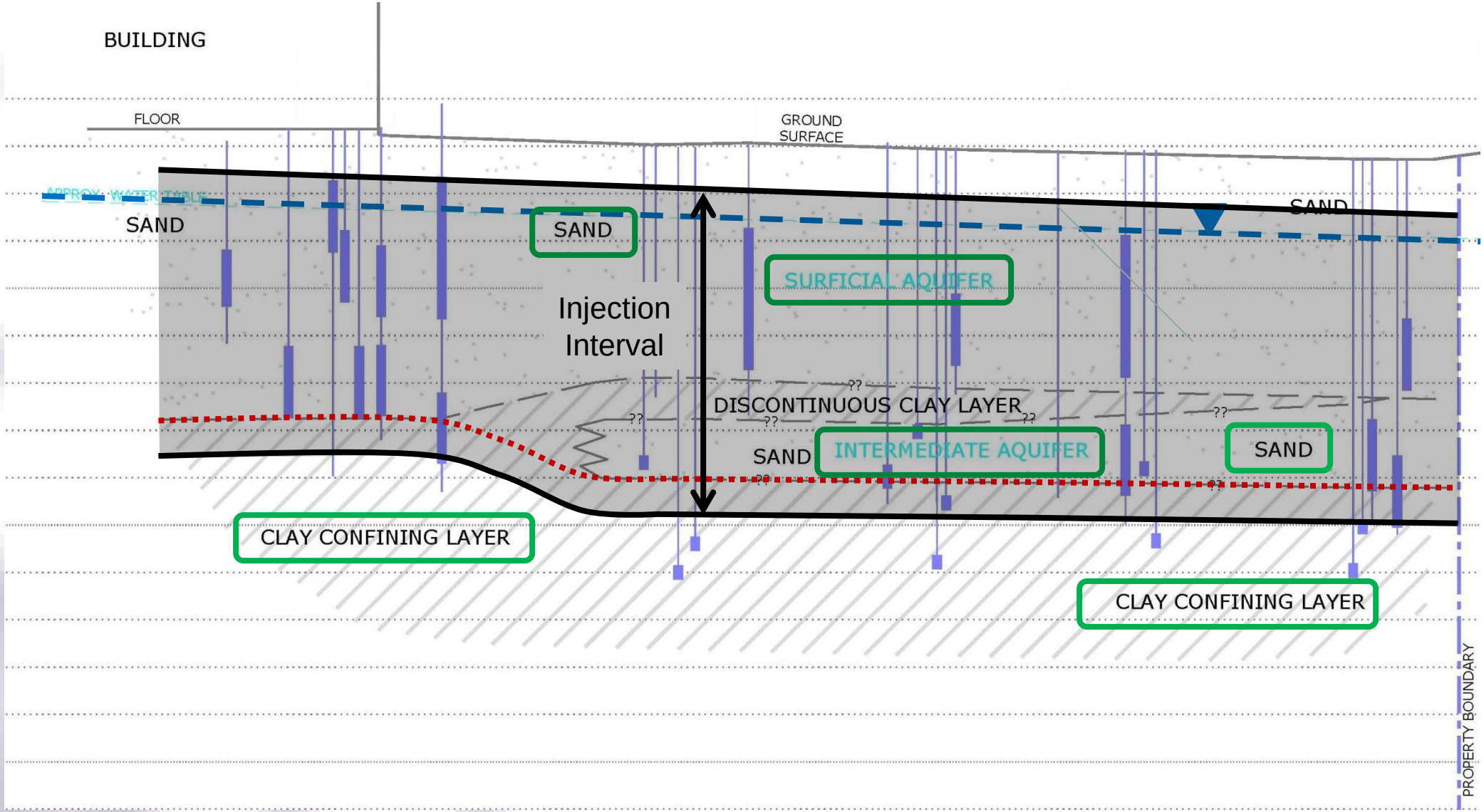


Case Study #1: Neighbour to Former Dry Cleaner



Case Study #1: Neighbour to Former Dry Cleaner

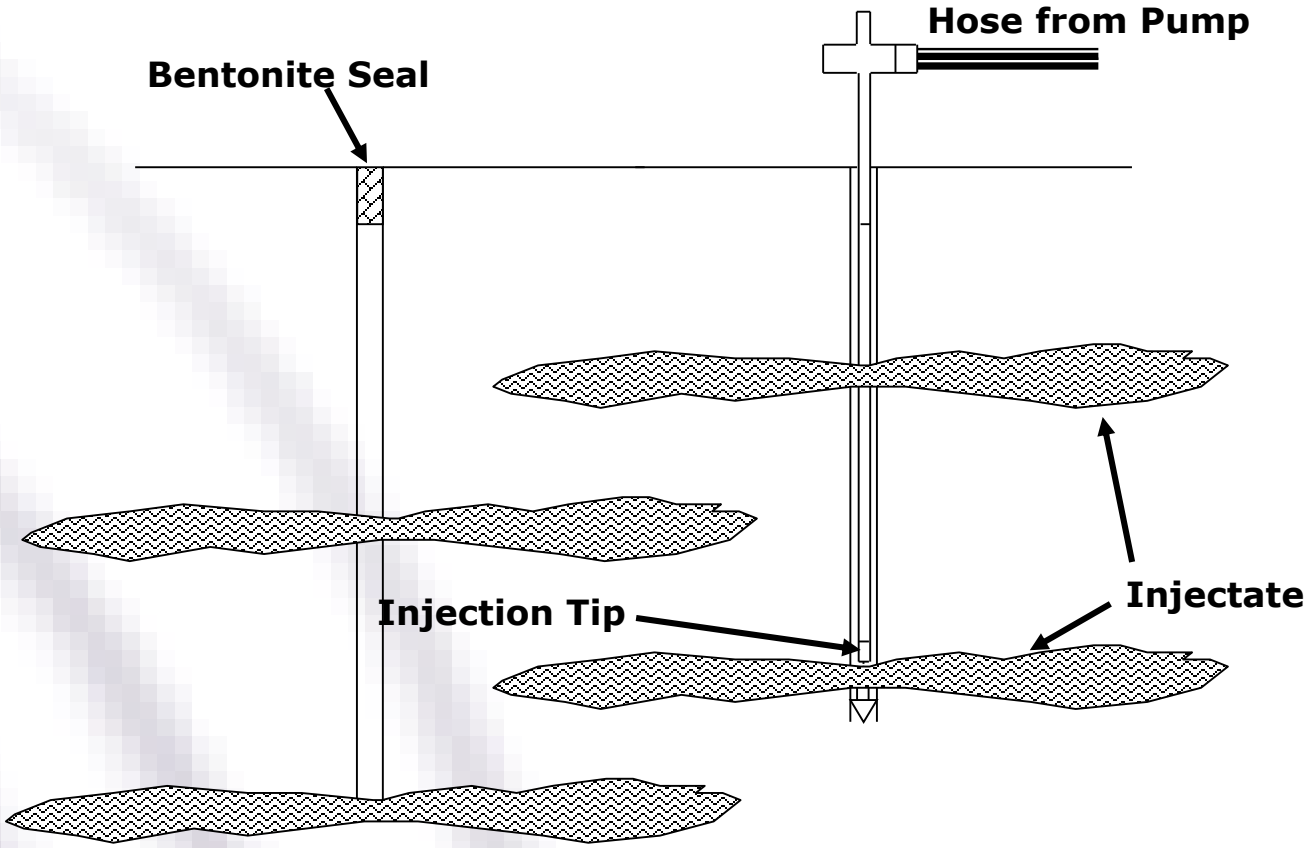
Remedial Approach

- **BOS 100® injection** program
  - Combined carbon adsorption and chemical reduction for cVOCs

Work Completed

- **Pilot-Scale Testing:**
  - Injected ~450 kg of BOS 100®
  - ~5,000 L suspension
  - Seventeen (17) temporary injection points
  - Completed over 2 working days (1 day in each test plot)

Case Study #1: Neighbour to Former Dry Cleaner

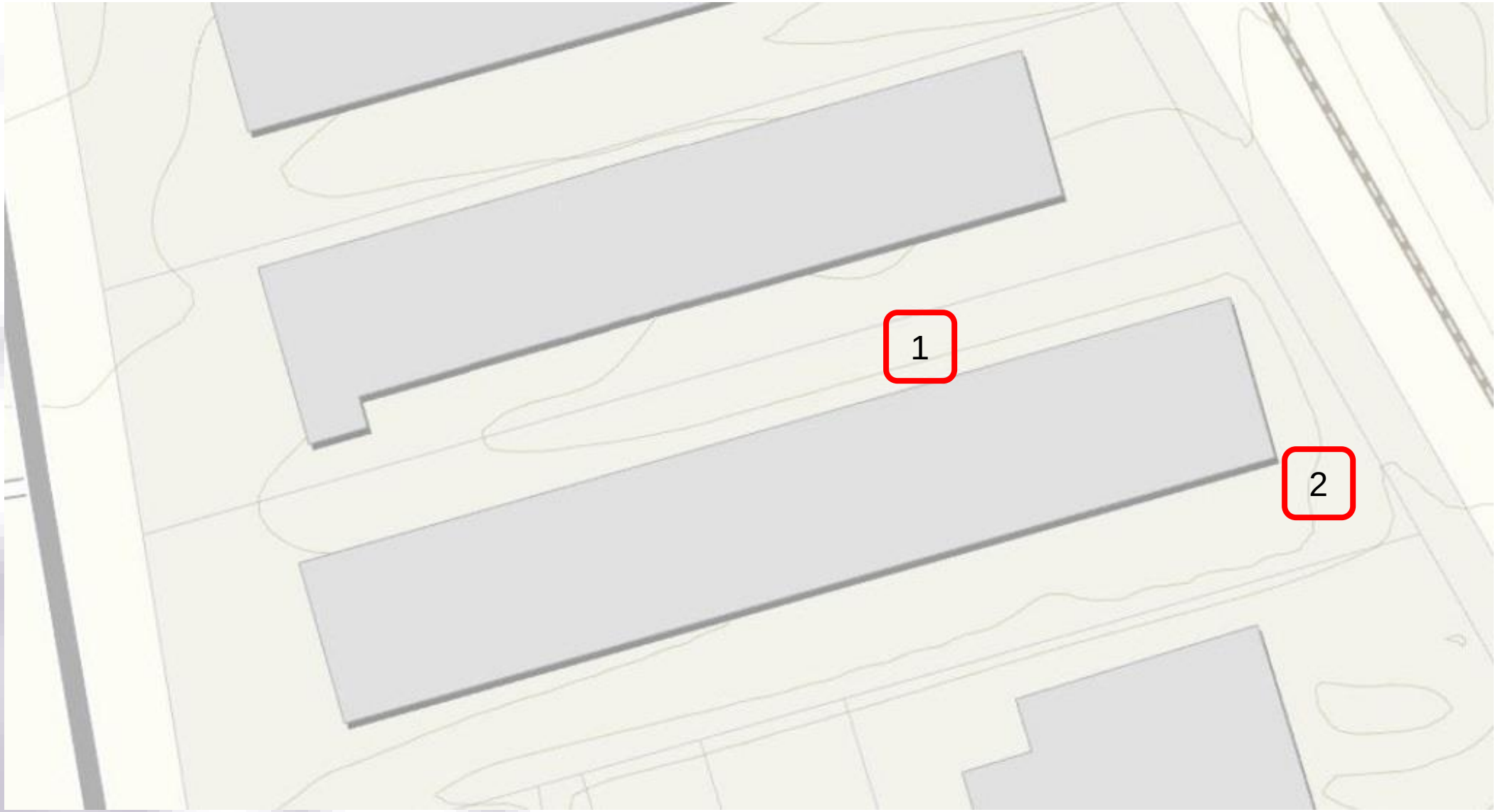


Injections using top-down approach

- Direct Push Injection
- Trap and Treat ® BOS 100®
- Top-Down Approach

Source: AST Environmental

Case Study #1: Neighbour to Former Dry Cleaner



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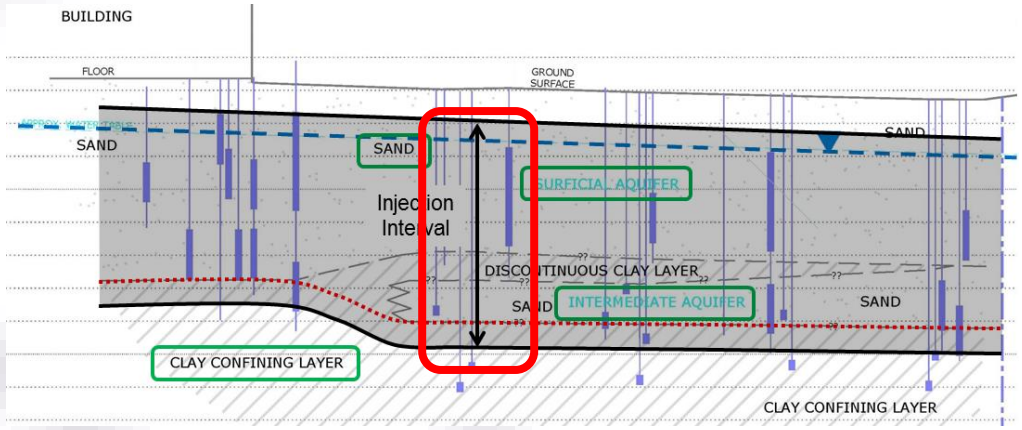
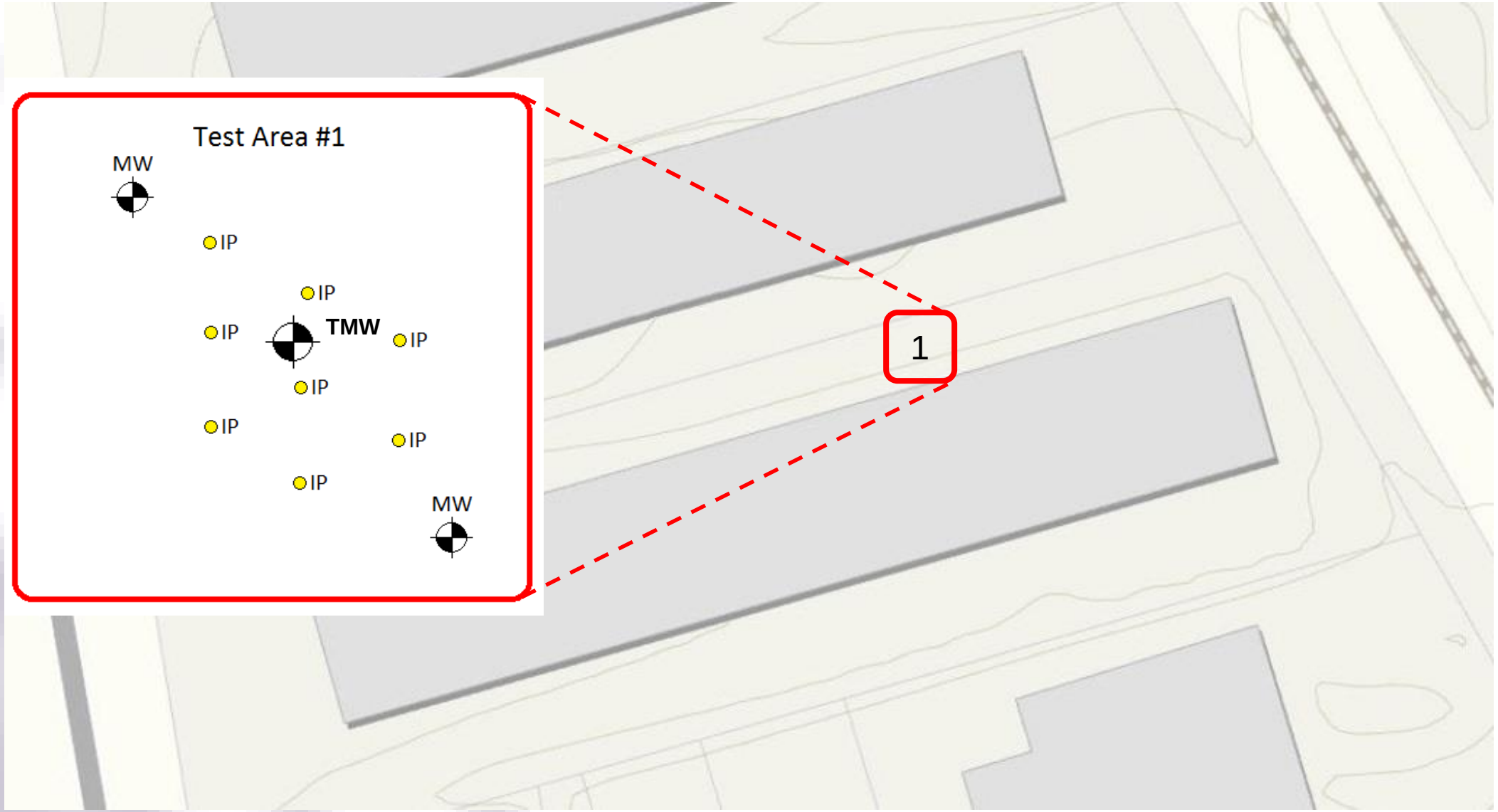


- Target injection interval originally identified as 1.5 to 6.7 mbgs
- Pilot-scale injection testing completed
- Boreholes advanced to collect forensic soil cores for QA/QC testing
- Evaluated BOS 100 distribution

Test Area	Test Hole	Target BOS 100® Injection Range			Apparent BOS 100® Presence Range			Percent Depth Coverage	
		Top (mbgs)	Base (mbgs)	Thick (m)	Top (mbgs)	Base (mbgs)	Thick (m)	%	Average %
1	1	1.5	6.7	5.2	1.2	4.1	2.9	56%	65%
	2	1.5	6.7	5.2	0.8	4.7	3.9	75%	
2	1	1.5	6.7	5.2	1.1	7.3	6.2	119%	102%
	2	1.5	6.7	5.2	2.3	6.7	4.4	85%	

Case Study #1: Neighbour to Former Dry Cleaner

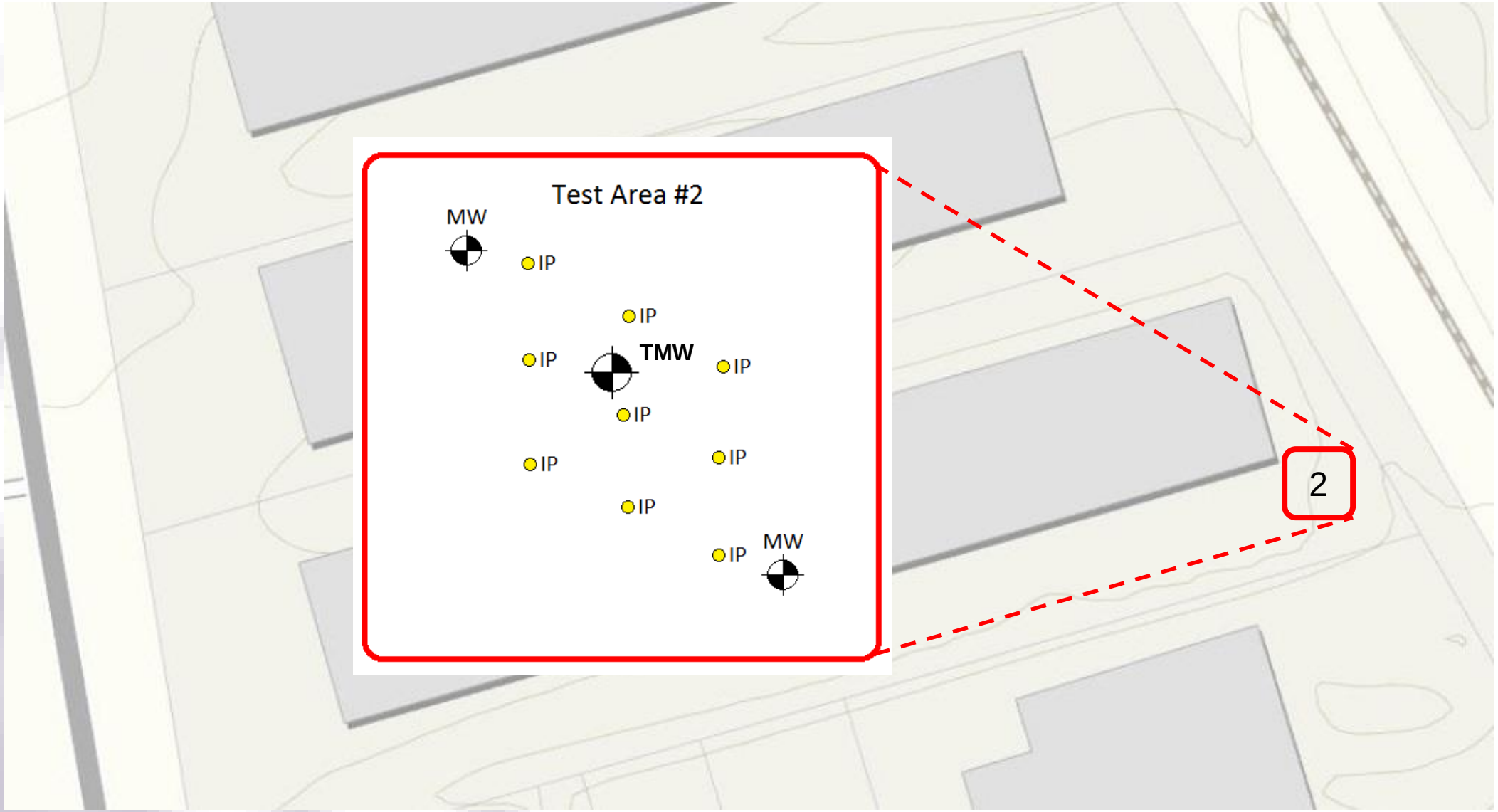


Case Study #1: Neighbour to Former Dry Cleaner

Test Area #1

Parameter	Standard	Pre-Injection	Post-Injection (1 month)	Post-Injection (2 months)	Post-Injection (3 months)
		MW Avg.	TMW Avg.	TMW Avg.	TMW Avg.
PCE	1.6	21.3	16.0	12.0	16.4
TCE	1.6	2.4	0.7	0.6	0.8
C12DCE	1.6	2.9	<0.20	<0.20	<0.20
VC	0.5	<0.17	<0.17	<0.17	<0.17
Totals	(ug/L)	26.6	16.7	12.5	17.1
Reductions	%	0.0%	37.1%	52.9%	35.6%

Case Study #1: Neighbour to Former Dry Cleaner

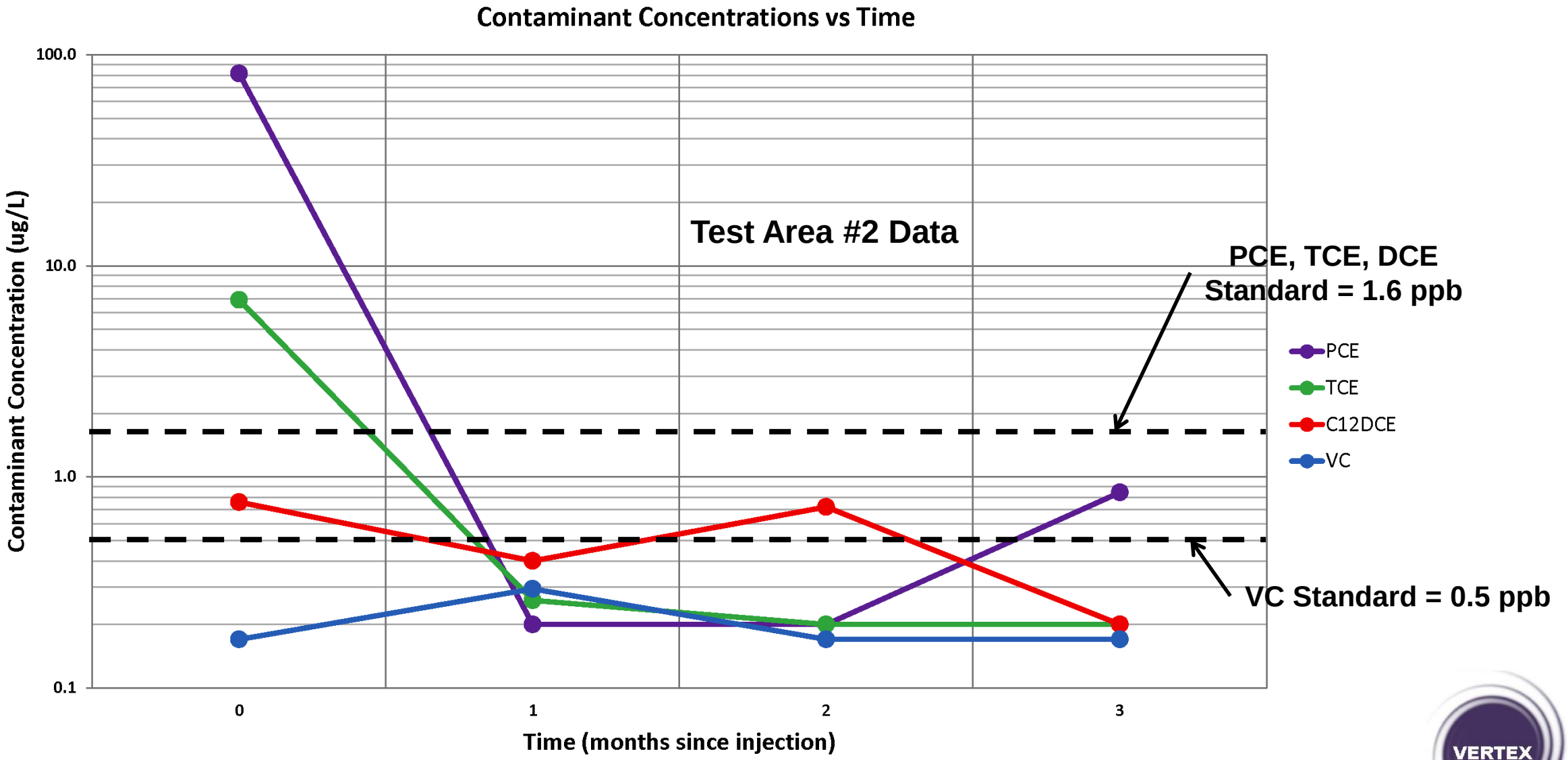


Case Study #1: Neighbour to Former Dry Cleaner

Test Area #2

Parameter	Standard	Pre-Injection	Post-Injection (1 month)	Post-Injection (2 months)	Post-Injection (3 months)
		MW Avg.	TMW Avg.	TMW Avg.	TMW Avg.
PCE	**1.6**	**81.5**	<0.20	<0.20	0.8
TCE	**1.6**	**6.9**	0.3	<0.20	<0.20
C12DCE	**1.6**	0.8	0.4	0.7	<0.20
VC	**0.5**	<0.17	0.3	<0.17	<0.17
Totals	**(ug/L)**	**89.2**	**1.0**	**0.7**	**0.8**
Reductions	%	**0.0%**	**98.9%**	**99.2%**	**99.1%**

Case Study #1: Neighbour to Former Dry Cleaner



Case Study #1: Neighbour to Former Dry Cleaner

Full-Scale Remediation Plan:

- Physical isolation of Site from source property by impermeable barrier
- **Trap & Treat® BOS 100® approach** selected for sewer easement PRB and plume using RZs
- Design work completed to calculate theoretical loading rate
- **Pilot-scale testing, interim monitoring & forensic soil cores completed**
- Demonstrated feasibility of approach in Test Area #2
- **Adjustments / refinements made** to full-scale BOS 100® approach
- Tighter control over vertical distribution of injections
- Full-scale site remediation about to start

Case Study #2
Former Underground Storage Tank

Case Study #2: Former UST

Site Background

- Tenant occupied light industrial site for over 25 years
- Former diesel fuel UST for truck fleet removed and soil / groundwater remediated in 1998
- **Lease expiring** and tenant vacating property

Contaminant Situation

- PHC impacts in soil and groundwater (vs current standards)
- Soils a mixture of granular fill, clayey silt, silty clay, silty sand, silt, sand

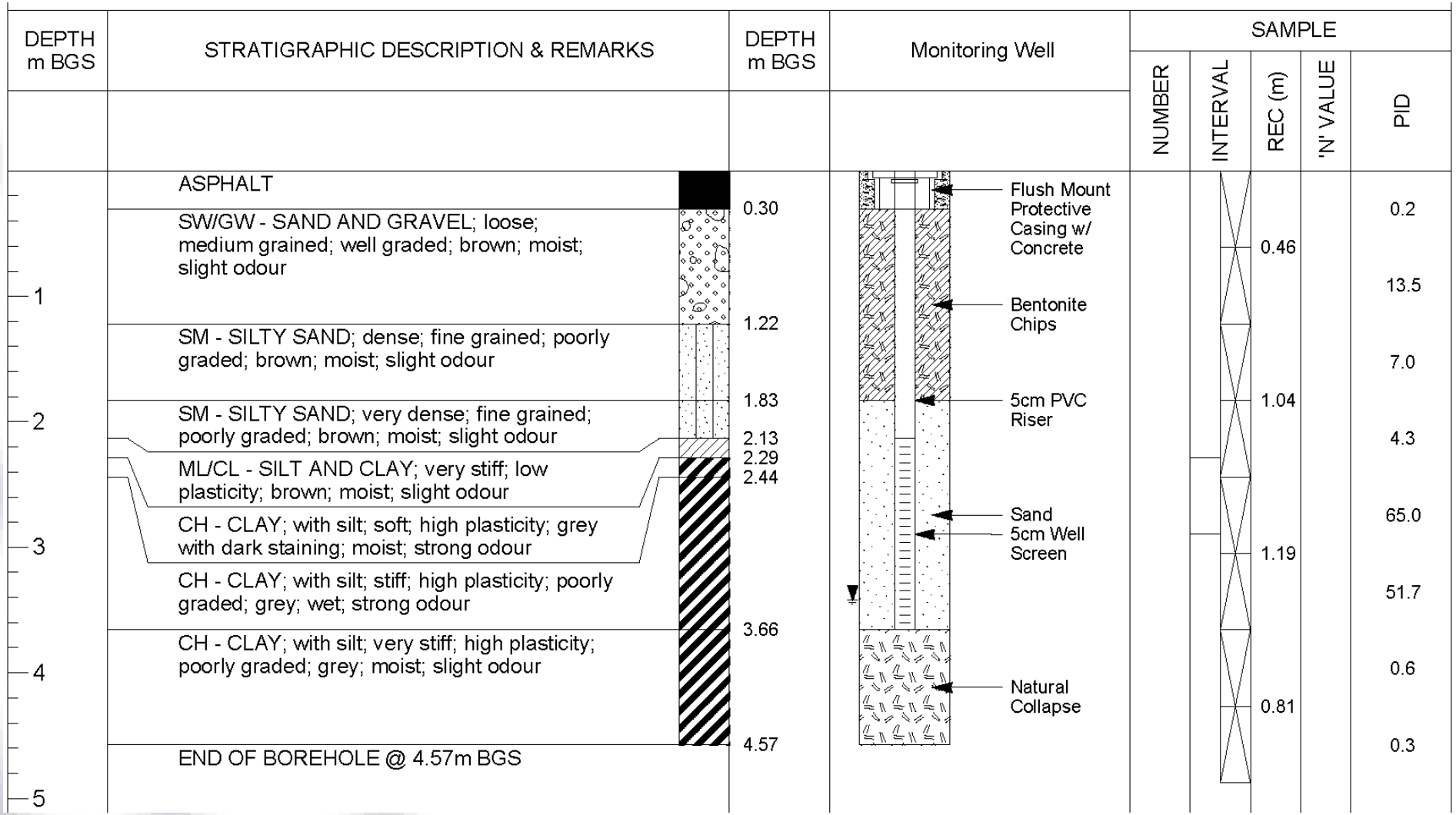
Remedial Objective

- Complete remediation of site prior to lease expiry
- Allow for “four quarters clean” verification sampling (therefore prevent “rebound”)
- **Generic regulatory standards**

Case Study #2: Former UST

Case Study #2: Former UST

Mixed geology of sands, gravels, silts and clays



Case Study #2: Former UST

Locations	Date	Soil								
		Depth	B	T	E	X	F1	F2	F3	F4
MW07-2	07/2007	2.71-3.05	<0.02	<0.02	0.31	0.34	21	**330**	170	<10
		3.05-3.23	<0.02	<0.02	0.12	0.07	<10	220	89	<10
BH3	11/2012	2.5-3.6	<0.02	<0.05	0.45	<0.05	**61**	**800**	350	<50
BH4	11/2012	3.7-4.8	<0.02	<0.05	1.9	<0.05	**72**	**530**	160	<50
MW01-16	10/2016	2.29-2.90	<0.0068	<0.08	0.040	<0.05	6.9	**1120**	454	<50
MW02-16	10/2016	3.66-4.27	<0.0068	<0.08	0.203	0.297	**101**	66	56	<50
MOECC Standards (Table 3)		-	**0.32**	**68**	**9.5**	**26**	**55**	**230**	**1700**	**3300**

Locations	Date	Groundwater							
		B	T	E	X	F1	F2	F3	F4
MW07-2	08/2007	**83**	4.5	90	51	550	**530**	<100	<100
	11/2012	-	-	-	-	190	<100	<100	<100
	12/2016	5.49	<0.50	2.20	2.90	98	**310**	<250	<250
MW01-16	12/2016	1.39	<0.50	2.76	4.36	83	**210**	<250	<250
MW02-16	12/2016	1.60	<0.50	3.33	5.71	97	**180**	<250	<250
MOECC Standards (Table 3)		**44**	**18000**	**2300**	**4200**	**750**	**150**	**500**	**500**

Main Concern

Case Study #2: Former UST

Remedial Approach

- Full-scale **BOS 200® injection** program
  - Combined carbon adsorption and anaerobic biodegradation for PHCs

Obstacles

- **Excavation** approach (“cut & fill”) would require **shoring & dewatering**
- Relatively small work area with **lots of truck traffic**
- Limited disruption allowed = **no multiple injection events**
  - ISCO or bio alone would have required at least 2 to 3 injection events
- Client anxious to ensure site is remediated before end of lease
  - Therefore, **certainty in approach was a priority**

Case Study #2: Former UST

Case Study #2: Former UST

Work Completed

- Impacted area 100 m^2 by 2 m thick with soil and groundwater impacts
- 2,000 kg of BOS 200® , 800 kg gypsum & microbes in 10,000 L of slurry injected
- Approx. 40 temporary injection points advanced via Geoprobe
  - 1.5 m lateral spacing for points
  - Vertical injection intervals from 2.1 to 4.5 mbgs
- Completed over 3 working days on-Site

Case Study #2: Former UST

Locations	Date	Groundwater							
		B	T	E	X	F1	F2	F3	F4
MW07-2	08/2007	**83**	4.5	90	51	550	**530**	<100	<100
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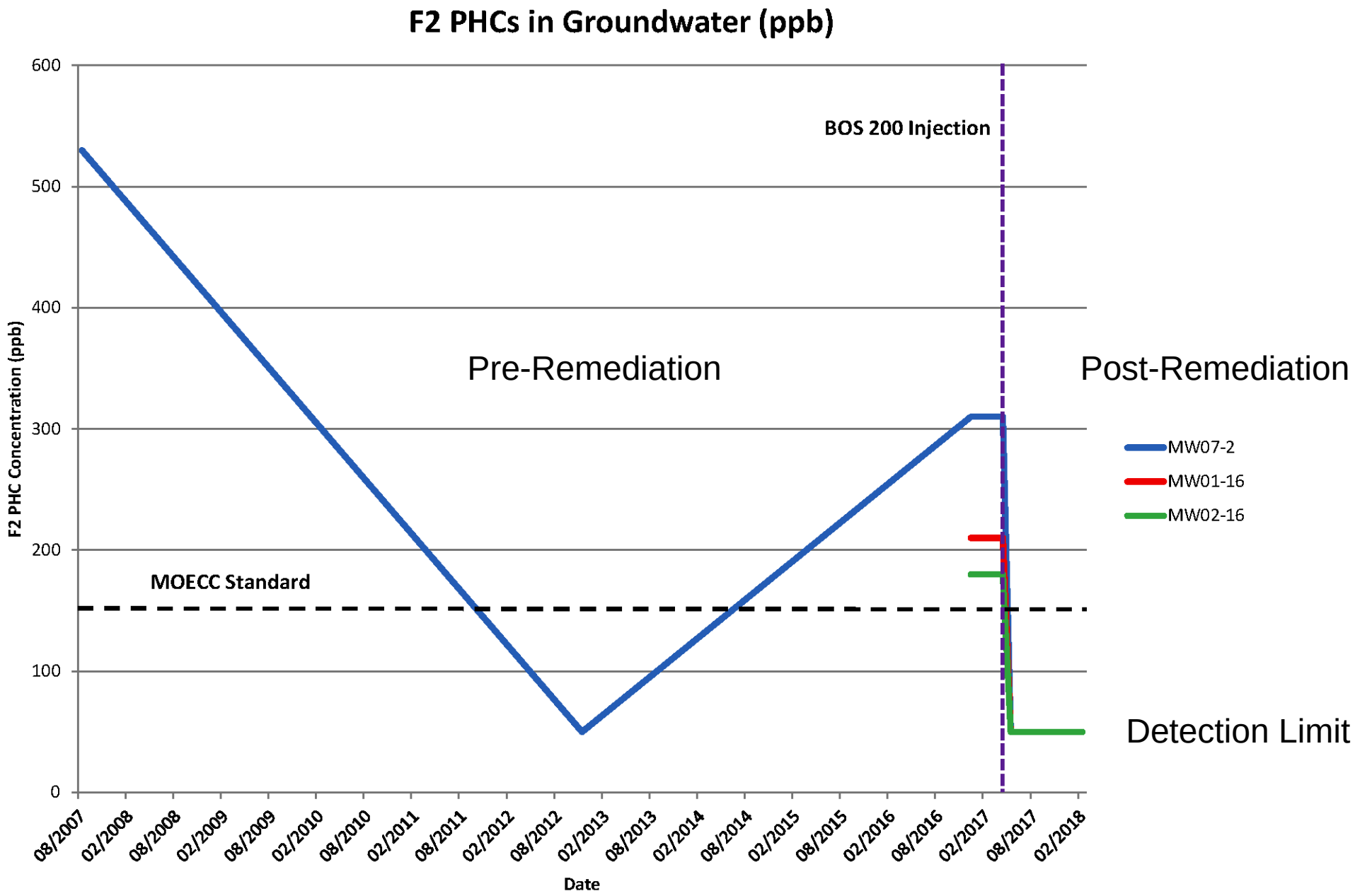
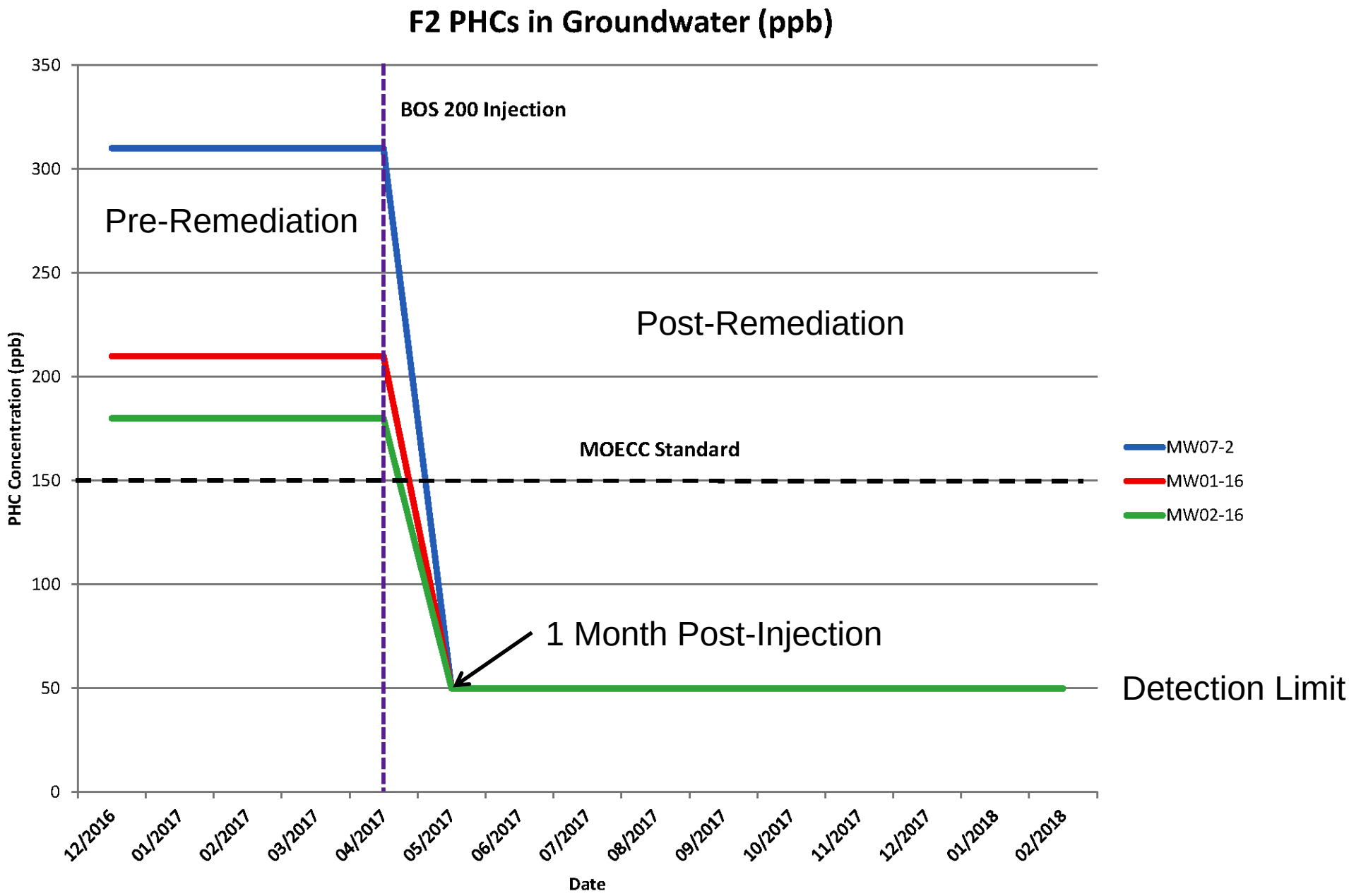
MW01-16	12/2016	1.39	<0.50	2.76	4.36	83	**210**	<250	<250
MW02-16	12/2016	1.60	<0.50	3.33	5.71	97	**180**	<250	<250
N/A	04/2017	**BOS 200® Injection Event**							
MW07-2	05/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	08/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	11/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	02/2018	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
MW01-16	05/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	08/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	11/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	02/2018	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
MW02-16	05/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	08/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	11/2017	<0.50	<0.50	<0.50	<0.50	44	<100	<250	<250
	02/2018	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
MW03-17	05/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	08/2017	1.13	<0.50	<0.50	<0.50	<25	<100	<250	<250
	11/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	02/2018	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
MOECC Standards (Table 3)		**44**	**18000**	**2300**	**4200**	**750**	**150**	**500**	**500**

Pre-injection groundwater analytical data

Four rounds of post-remediation groundwater analytical data


F2 PHCs in Groundwater (ppb)
F2 PHC Concentration (ppb)
600
500
400
300
200
100
0
BOS 200 Injection
Pre-Remediation
Post-Remediation
MOECC Standard
MW07-2
MW01-16
MW02-16
Detection Limit
08/2007
02/2008
08/2008
02/2009
08/2009
02/2010
08/2010
02/2011
08/2011
02/2012
08/2012
02/2013
08/2013
02/2014
08/2014
02/2015
08/2015
02/2016
08/2016
02/2017
08/2017
02/2018
Date


F2 PHCs in Groundwater (ppb)
350
300
250
200
150
100
50
0
PHC Concentration (ppb)
BOS 200 Injection
Pre-Remediation
Post-Remediation
MOECC Standard
1 Month Post-Injection
Detection Limit
MW07-2
MW01-16
MW02-16
12/2016
01/2017
02/2017
03/2017
04/2017
05/2017
06/2017
07/2017
08/2017
09/2017
10/2017
11/2017
12/2017
01/2018
02/2018
Date

Case Study #2: Former UST

Project Summary:

- Client **required certainty** prior to end of lease
- Trap & Treat® BOS 200® approach selected
- **Design work was essential**
  - Calculation of carbon and sulphate demand
  - Designed lateral and vertical injection spacing to ensure uniform distribution in the subsurface
- Full-scale application completed as planned
- Remedial objective achieved – **below Generic Standard**
- **PHCs remain low (mostly ND) one year after injection event!**

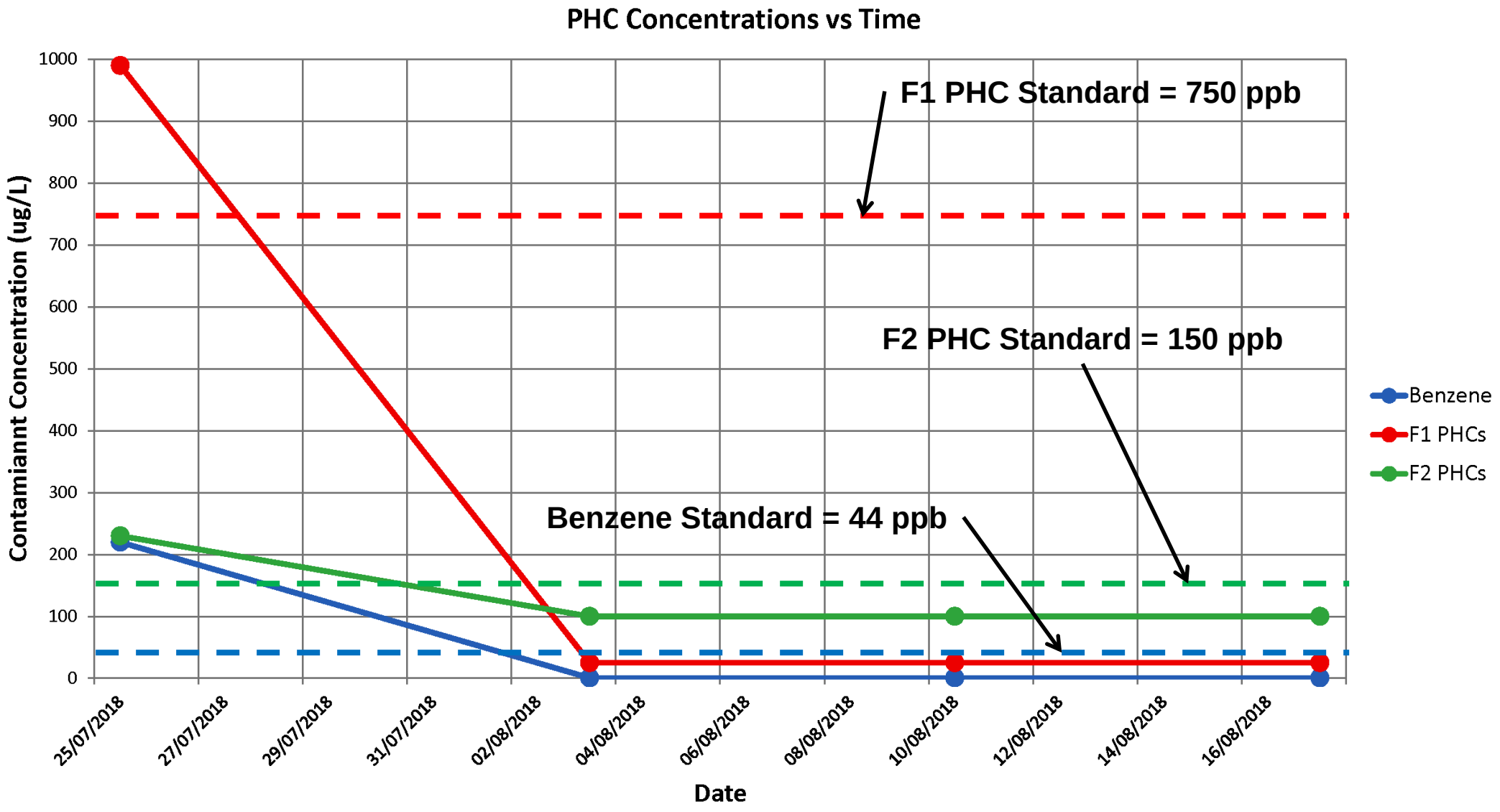
Case Study “Quickies”

“Quickie” Case Study #1 – Former On-Site RFO

Project Summary:

- Commercial property with former on-Site RFO from 1970s-1990s
- Excavation completed in May 2018 to remove PHC impacted soils
- Backfilled soils were sand and gravel fill
- Post-remediation groundwater quality failed at 1 of 3 MWs in backfill
- Trap & Treat® BOS 200® approach selected for fast and sustained remediation and to prevent “rebound”
- One day injection completed in July 2018
  - 216 kg BOS 200® plus microbial amendment
  - 1,800 L over six temporary injection points
- Remedial objective achieved – **below Generic Standard**
- **PHCs were all ND starting 9 days after injection event!**

“Quickie” Case Study #1 – Former On-Site RFO

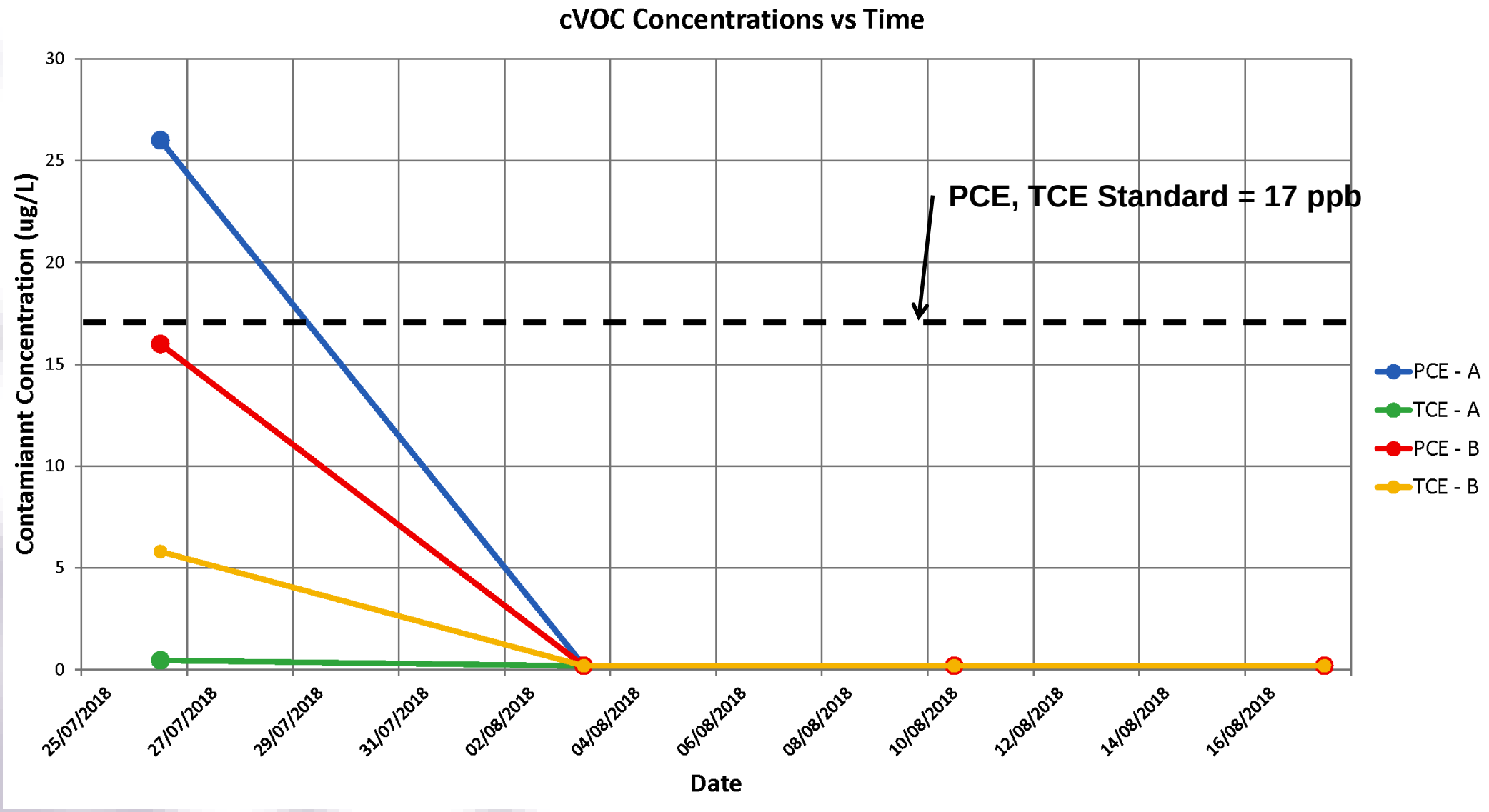


“Quickie” Case Study #2 – Former On-Site Dry Cleaner

Project Summary:

- Commercial property with former on-Site dry cleaner from 1960s-1980s
- No cVOC impacted soils identified
- Soils were primarily fine grained silts and clays with sand interbeds
- Groundwater quality failed at 1 MW in vicinity of former dry cleaner and just barely passed in a second MW nearby
- Trap & Treat® BOS 100® approach selected for fast and sustained remediation and to prevent “rebound”
- One day injection completed in July 2018
  - 182 kg BOS 100®
  - 2,800 L over ten temporary injection points
- Remedial objective achieved – **below Generic Standard**
- **cVOCs were all ND starting 8 days after injection event!**

“Quickie” Case Study #2 – Former On-Site Dry Cleaner



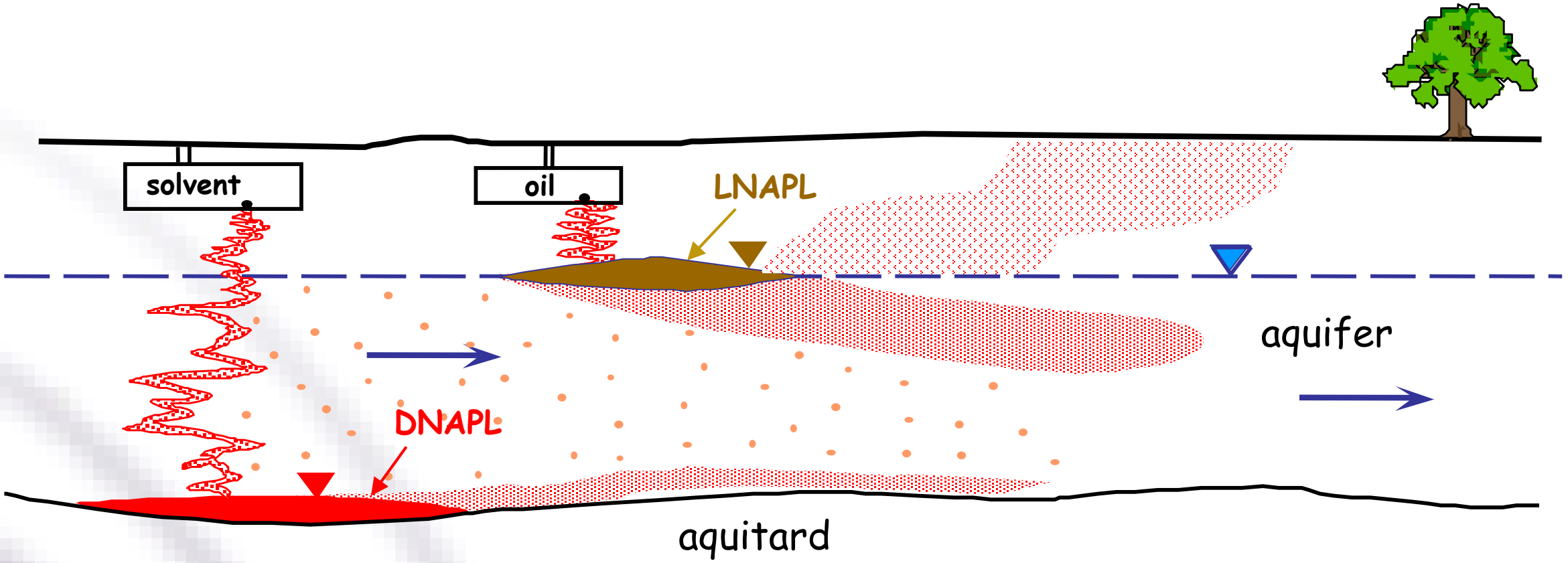
Closing Thoughts

Keys to Remediating cVOCs and PHCs
(or anything else for that matter)

- Adequately understand Site conditions (the “problem”)
- Collect additional site characterization data, if needed
  - Traditional Phase II ESA work, and/or
  - High Resolution Site Characterization and 3D modelling
- Use bench-scale and/or pilot-scale testing
  - Proof-of-concept
  - Refine full-scale design based on actual Site conditions

Keys to Remediating cVOCs and PHCs
(or anything else for that matter)

- Select the right remedial amendment and apply it properly
  - The right amounts in the right places to ensure contact
  - Use adsorptive technologies if “rebound” is a concern
- Monitor and re-evaluate as remediation progresses
  - Interim QA/QC (groundwater sampling, forensic soil cores)
  - Be flexible to adjust approach, if needed
- Use a qualified environmental remediation contractor!



Questions?

Thank You for Your Time

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