



Application of Injected ZVI PRB to Control Off-Site Migration of a VOC Plume at a Drycleaner Site in Quebec

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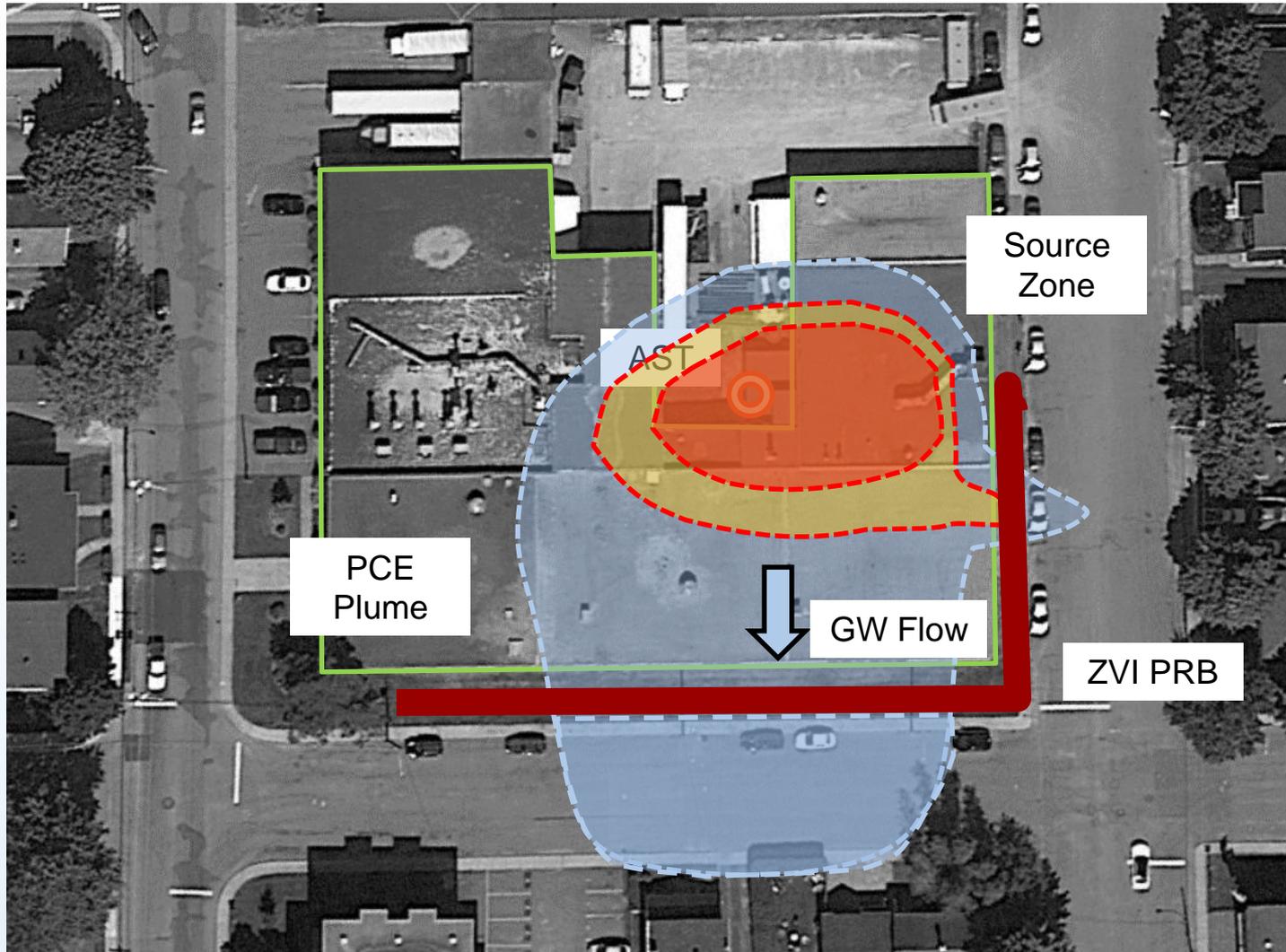
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Presentation Overview

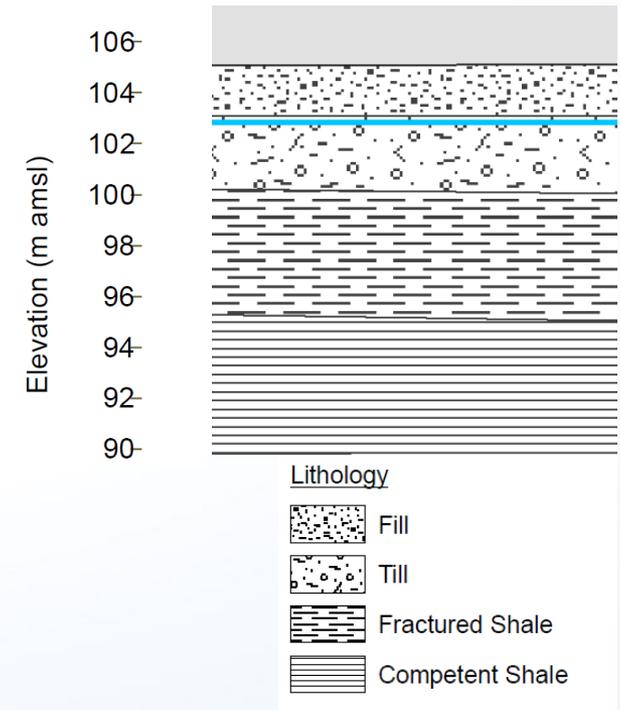
- Project Summary.
- Site Conditions
- ZVI PRB Design.
- PRB Installation.
- PRB Monitoring.
- Summary

Remediation Project Summary

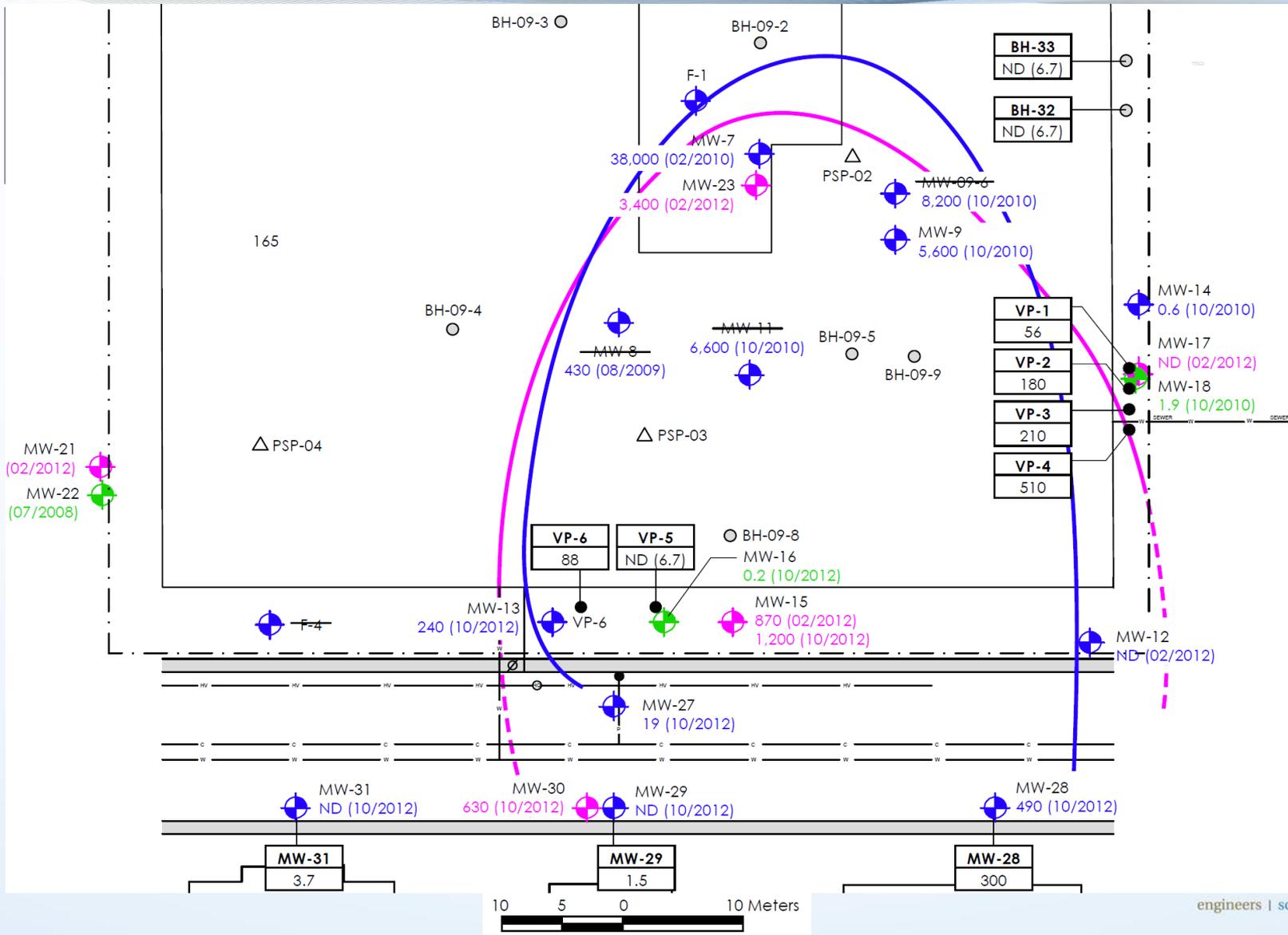


- Water table at 1.5 to 2.5 m bgs.
- Overburden saturated units:
 - Shallow glacial till.
 - Intermediate Fractured Shale.
- Competent shale (negligible GW flow).

Parameter	Till	Fractured Shale
Groundwater Velocity (m/yr)	5 - 8	2 - 5

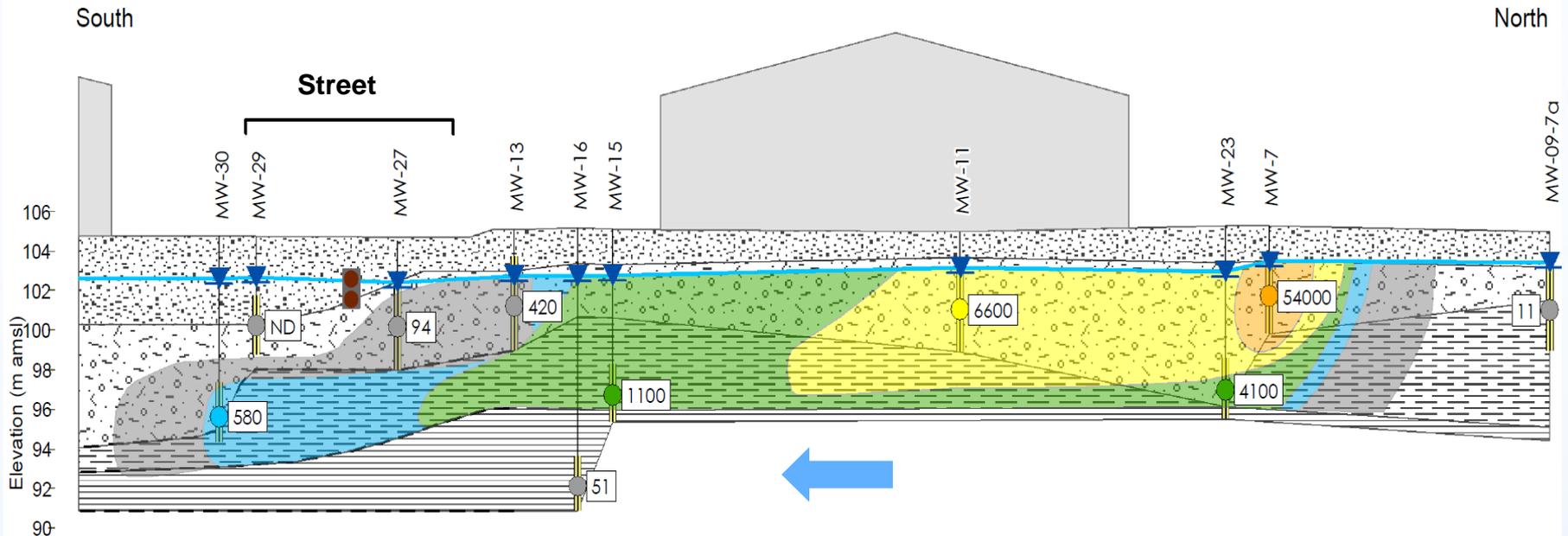


PCE in Groundwater in 2013 (Prior to PRB)



PCE Plume Distribution in 2013 (Prior to PRB Installation)

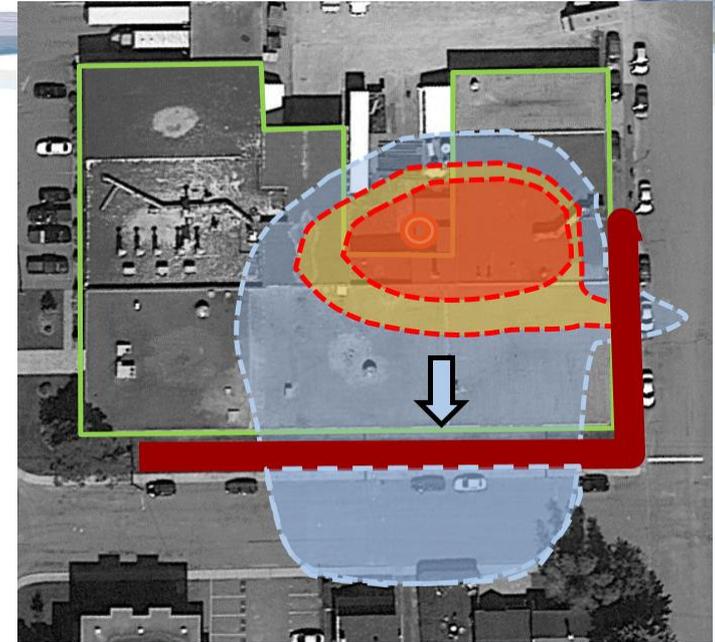
X-section along GW Flow Path



2013 (Prior to PRB Installation)

Lithology	PCE (ppb)
 Fill	● ≤500
 Till	● >500 - 1,000
 Fractured Shale	● >1,000 - 5,000
 Competent Shale	● >5,000 - 20,000
	● >20,000 - 50,000
	● >50,000

Remedial Feasibility Evaluation



- Remedial Objectives:
 - Source zone treatment infeasible (no VI issues);
 - Target preventing off-site migration of VOC plume.
- Approach to plume migration control:
 - ZVI PRB [complete treatment, superior longevity, no secondary products (e.g., gases CH_4 , VC, H_2S)].
- Methodology of ZVI PRB Installation:
 - Trenching and backfill impossible due to site setting (limited accessible area, high visibility, public safety concerns):
 - Direct injection selected to deliver ZVI (micro-scale) material to create the PRB.
 - Injection via hydraulic fracturing to assure overlapping of injection zones to create a continuous PRB in the site lithology (till and fractured shale).

Scale	Size Range	SSA (m ² /g)	Applications
Millimeter	0.1mm - 2mm	1 - 2	Trenched PRBs, Soil Mixing
Micrometer	20μm - 200μm 1μm - 20μm	3 - 5	Direct injections, Soil Mixing
Nanometer	20nm - 200nm	1 - 58	Direct injections, Injection Wells

SSA –specific surface area;



Millimeter



Micrometer



Colloidal



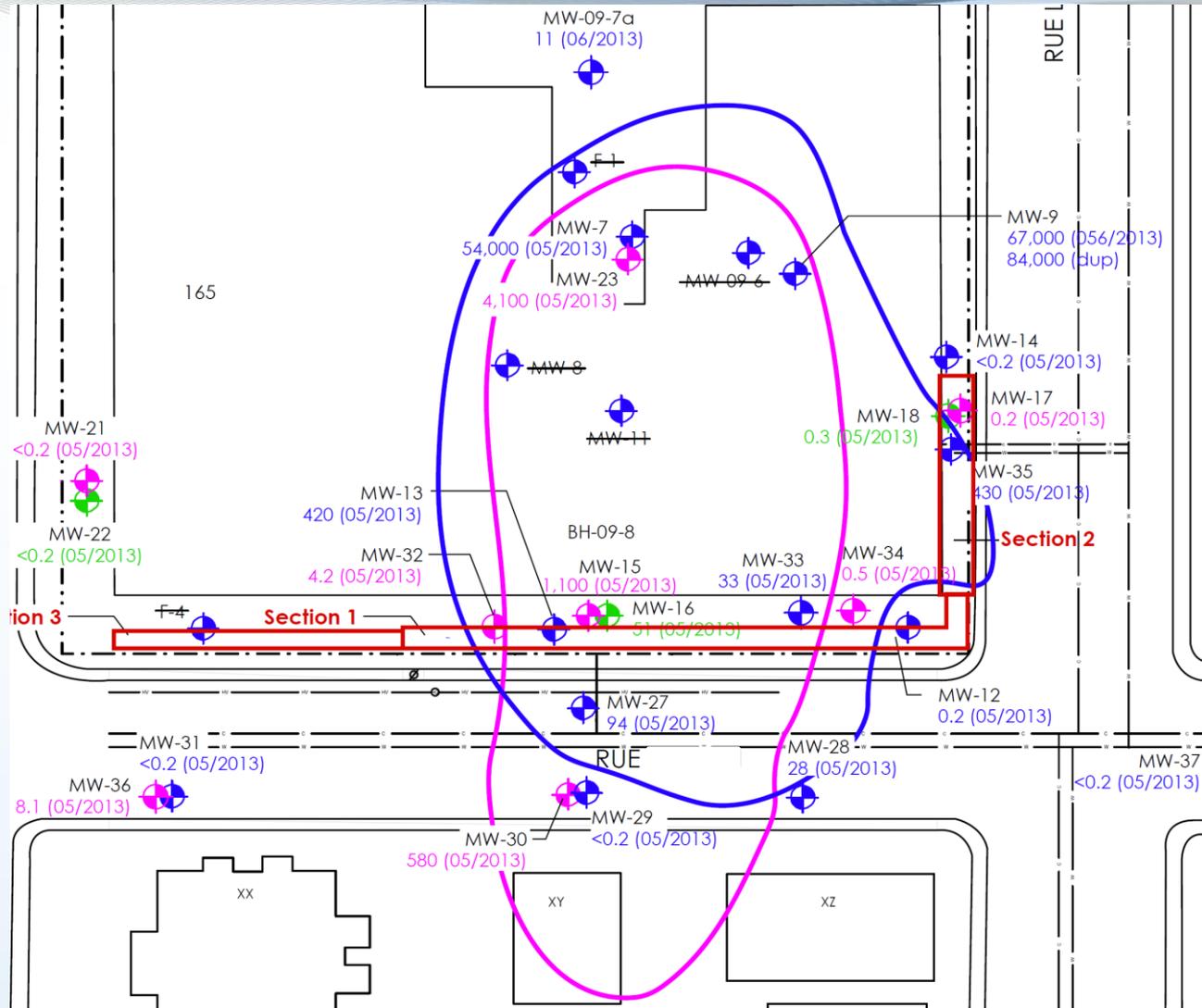
ZVI PRB Design

Design Consideration

Type, Concentrations, Standards for COCs

Location:		MW-13	MW-15	MW-33	MW-35
Top of Screen (m bgs)		1.5	6.8	1.6	1.3
Bottom of Screen (m bgs)		6.1	9.75	4.6	4.3
Standard					
Date Sampled:		30-May-13			
<i>VOCs (µg/L)</i>					
Tetrachloroethene	30	420	1,100	33	430
Trichloroethene	50	33	100	9.9	96
cis-1,2-Dichloroethene	50	7	41	10	170
Vinyl chloride	2	2 U	4 U	2.6	43

PRB Design Varying cVOC Concentrations along Alignment



Parameter	PRB Section 1		PRB Section 2		PRB Section 3	
	Till	Fract. Shale	Till	Fract. Shale	Till	Fract. Shale
Length of PRB Section (m)	55		20		25	
Depth Interval (m)	3	4	3	4	3	3
ZVI Volume (m ³)	5.7	3.5	3.3	1.1	1.8	0.7
Total ZVI Mass (tonnes)	53					



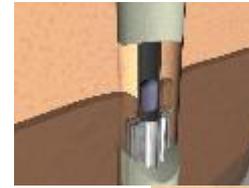
PRB Installation



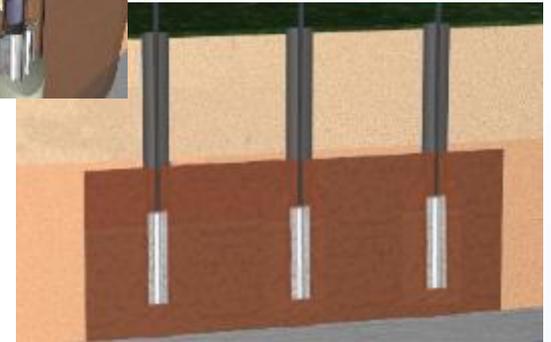
Direct injection
(30 ft, 9 m)



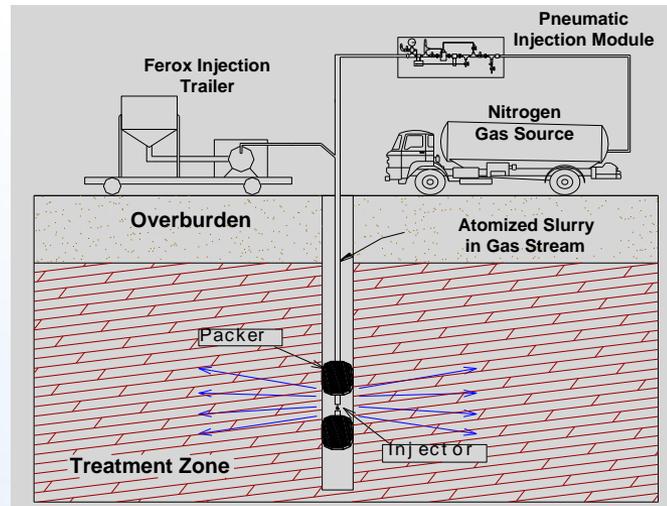
jetting techniques
(60 ft, 18 m)

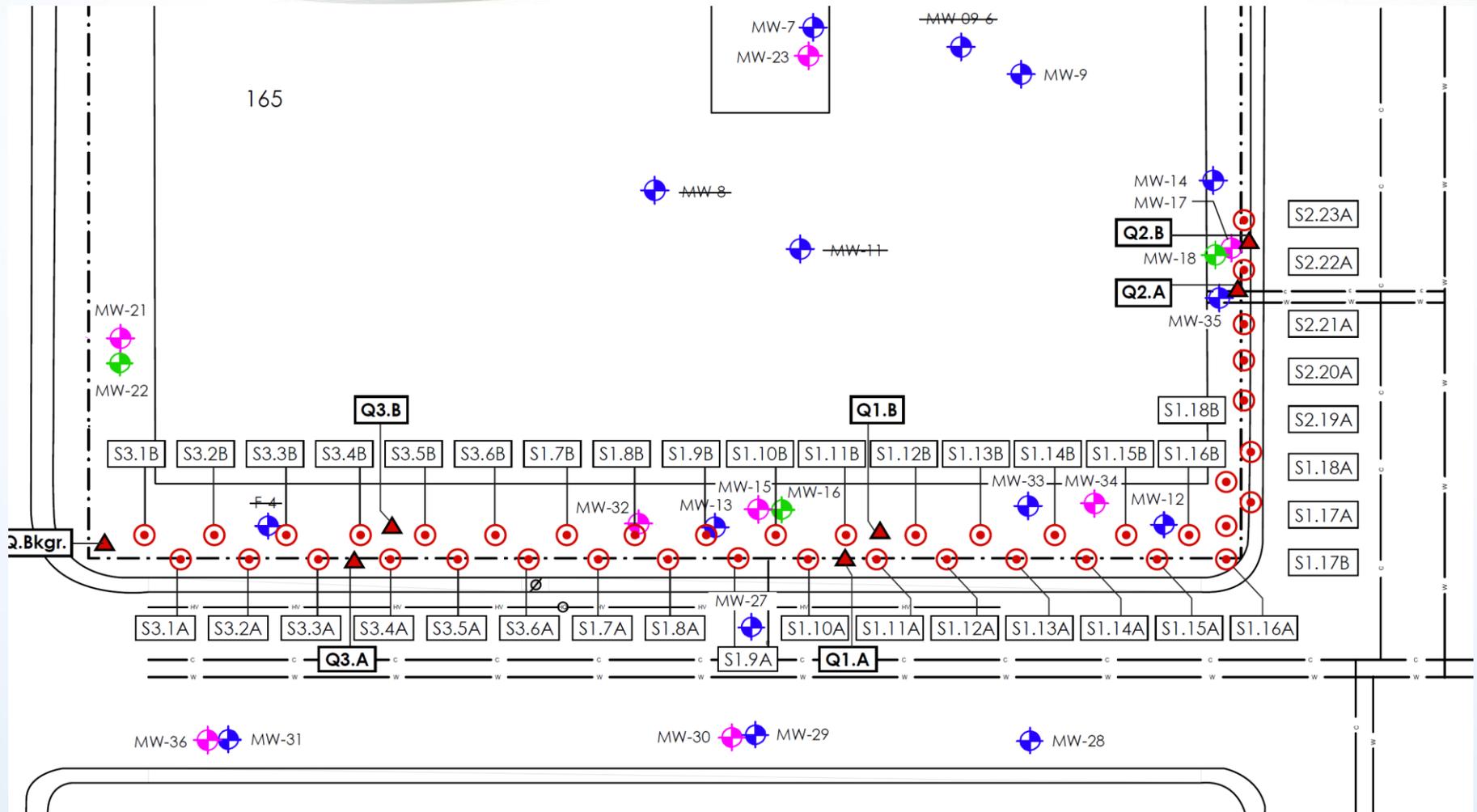


hydraulic fracturing/injection
(120 ft, 37 m)



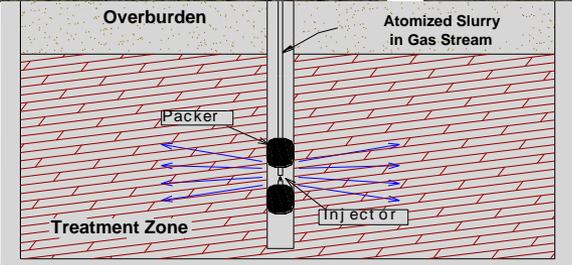
Pneumatic
fracturing
(90 ft, 27 m)





ZVI Mixing and Borehole Installation



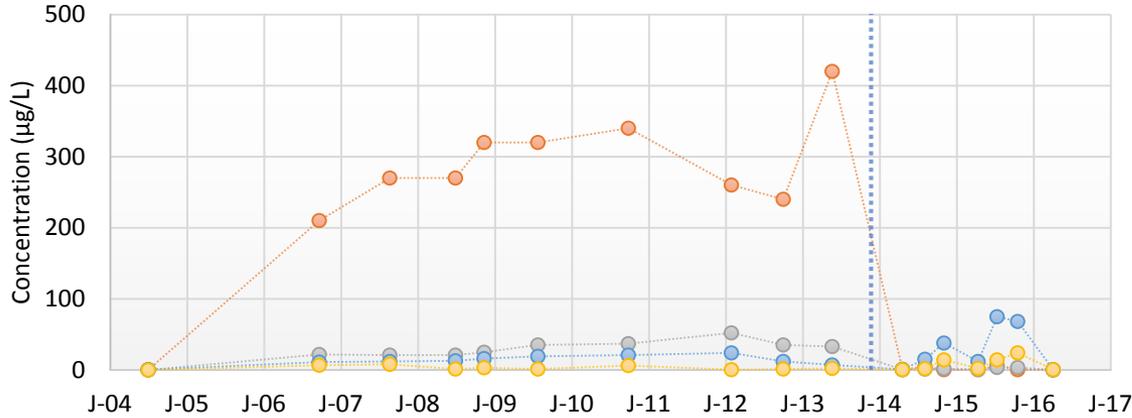




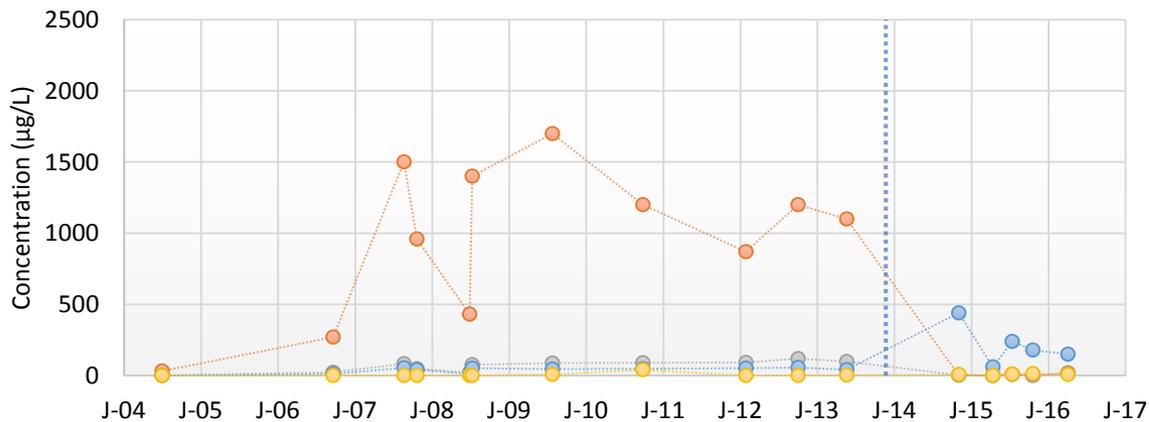
PRB Monitoring

Monitoring Wells – Upgradient of PRB

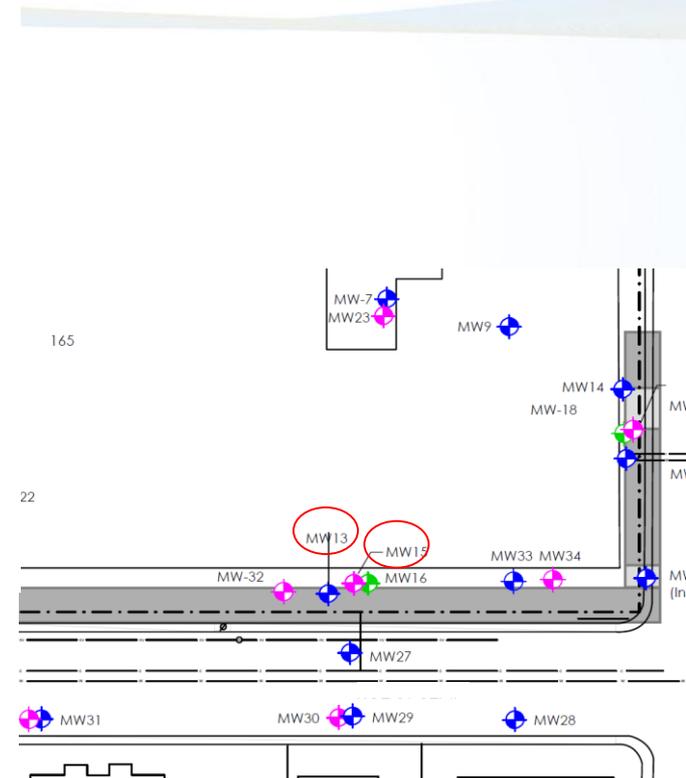
MW-13 (Till)



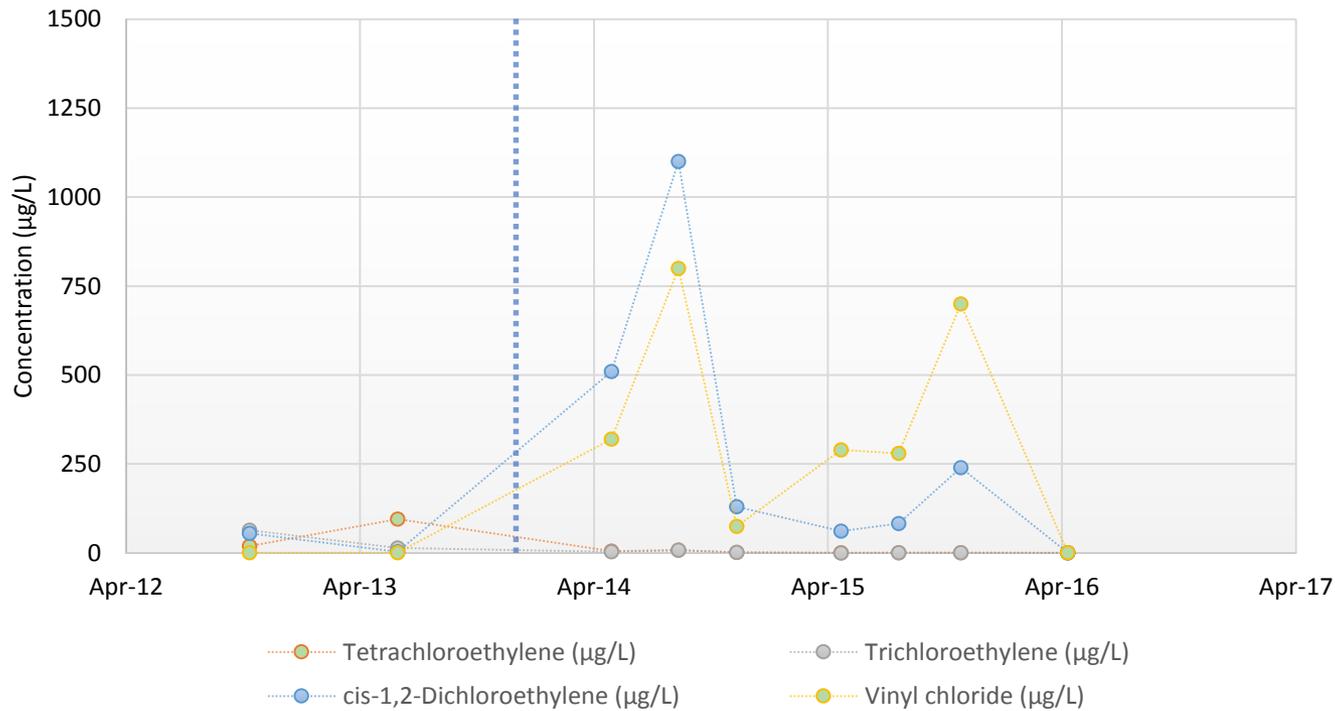
MW-15 (Fractured Shale)



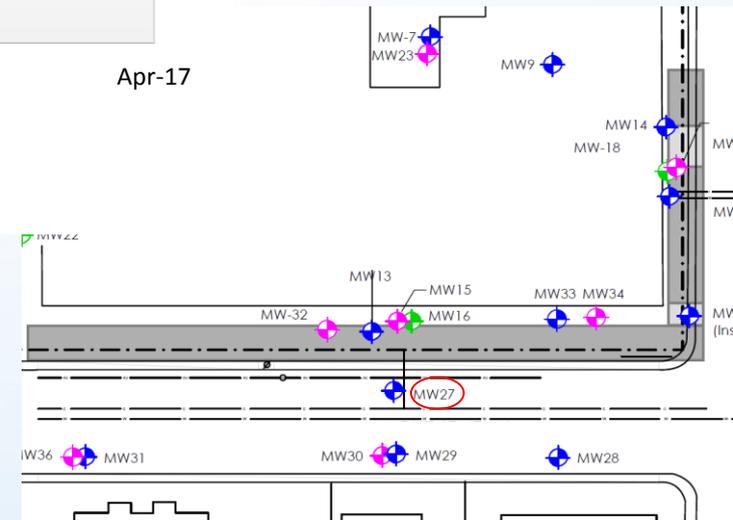
- Tetrachloroethylene (µg/L)
- Trichloroethylene (µg/L)
- cis-1,2-Dichloroethylene (µg/L)
- Vinyl chloride (µg/L)



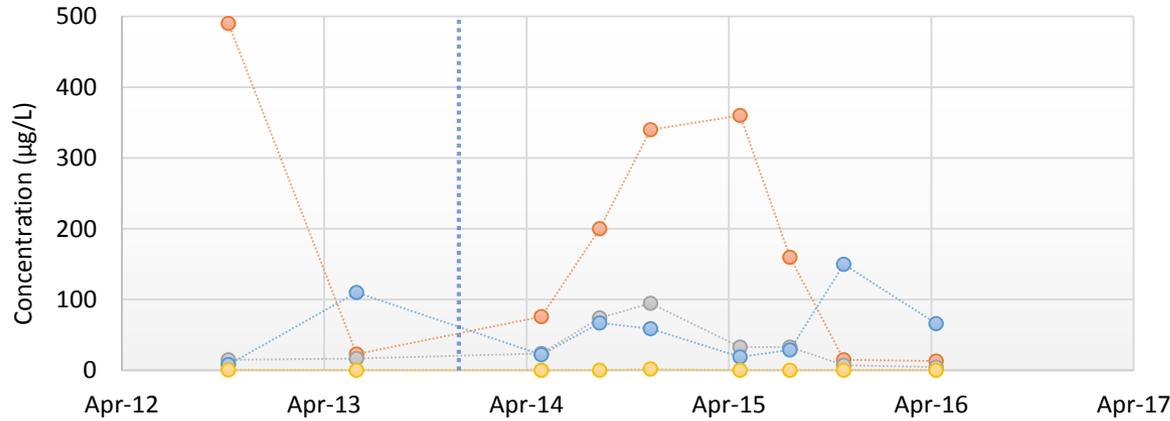
MW-27 (Till)



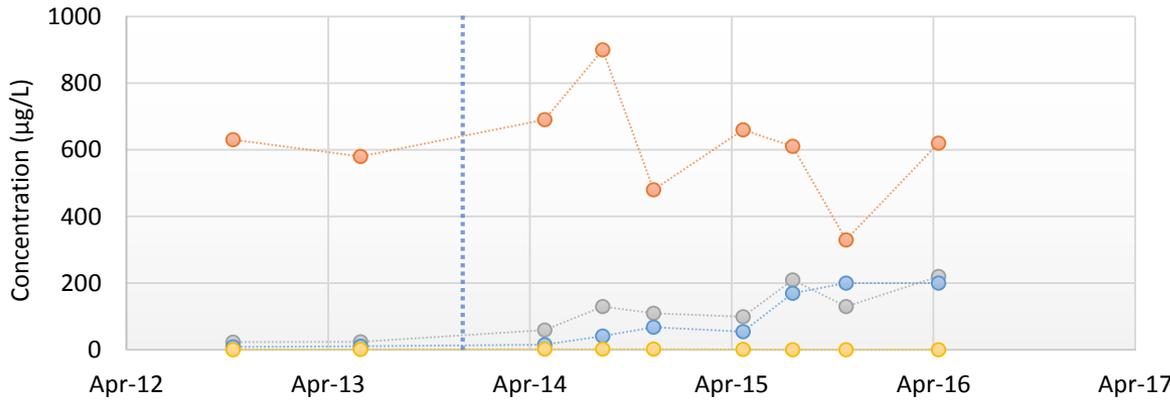
GW velocity till = 5 - 8 m/yr



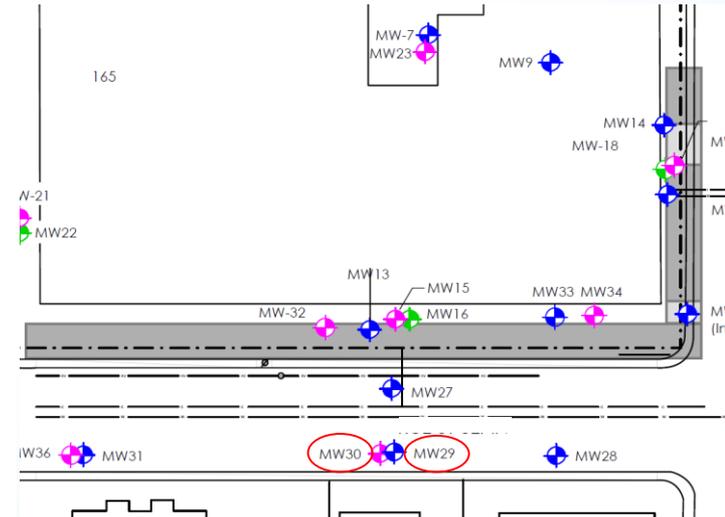
MW-29 (Till)



MW-30 (Fractured Shale)

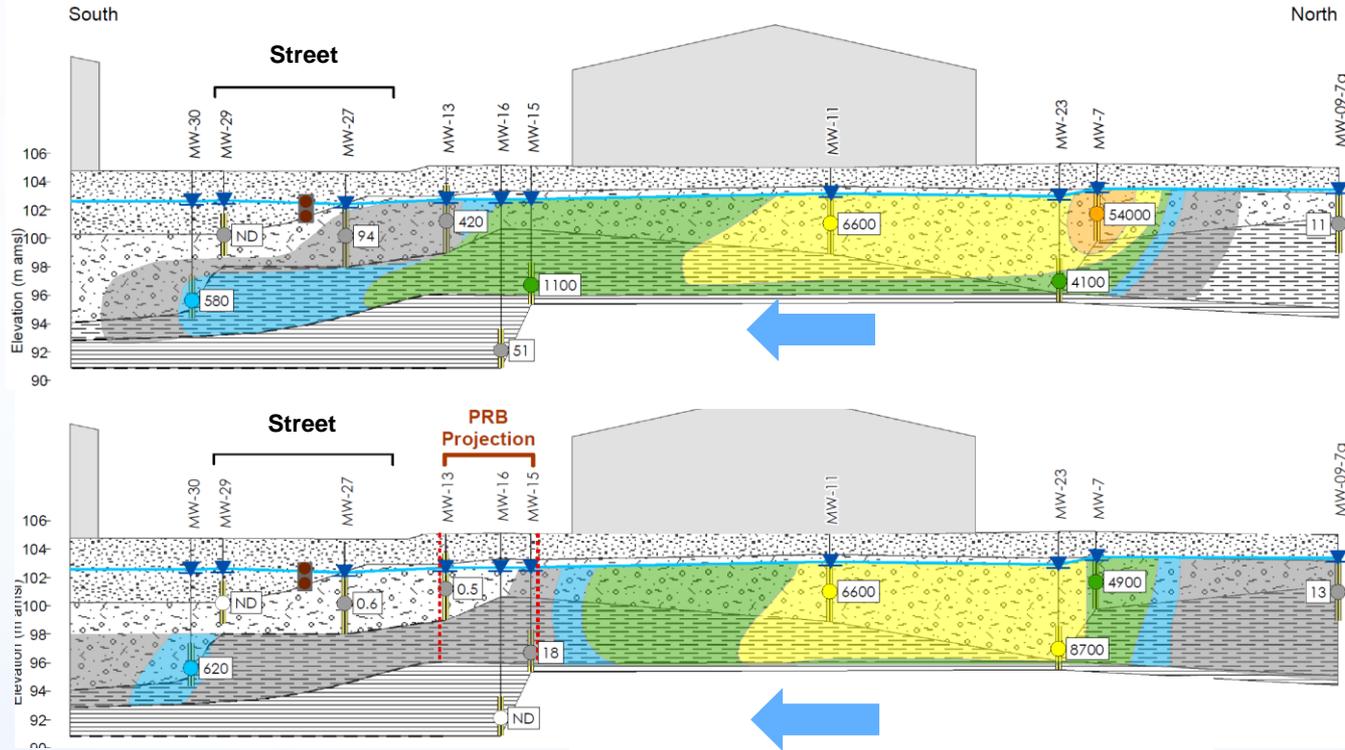


- Tetrachloroethylene (µg/L)
- Trichloroethylene (µg/L)
- cis-1,2-Dichloroethylene (µg/L)
- Vinyl chloride (µg/L)



GW velocity till = 5 - 8 m/yr
 GW velocity shale = 2 - 5 m/yr

Downgradient PCE Plume Attenuation (28 Month Monitoring)



2013 (Prior to PRB Installation)

2016 (28 months after PRB installation)

Lithology

-  Fill
-  Till
-  Fractured Shale
-  Competent Shale

PCE (ppb)

-  ≤500
-  >500 - 1,000
-  >1,000 - 5,000
-  >5,000 - 20,000
-  >20,000 - 50,000
-  > 50,000

- ZVI PRB installed to control off-site migration of PCE plume originating at a dry cleaner facility;
- Hydraulic fracturing used to install micro-scale ZVI along downgradient site boundary in shallow till zone and intermediate fractured shale units.
- PRB monitoring (2.3 yrs) showed:
 - Complete degradation of cVOCs (PCE and related compounds) within and near PRB footprint;
 - Gradual cleanup of cVOC plume in shallow downgradient zone within 5 m of PRB;
 - Slower cleanup of cVOC plume further downgradient zone within 15 m of PRB, especially in the intermediate zone with lower permeability.

