Vertex Environmental Inc.

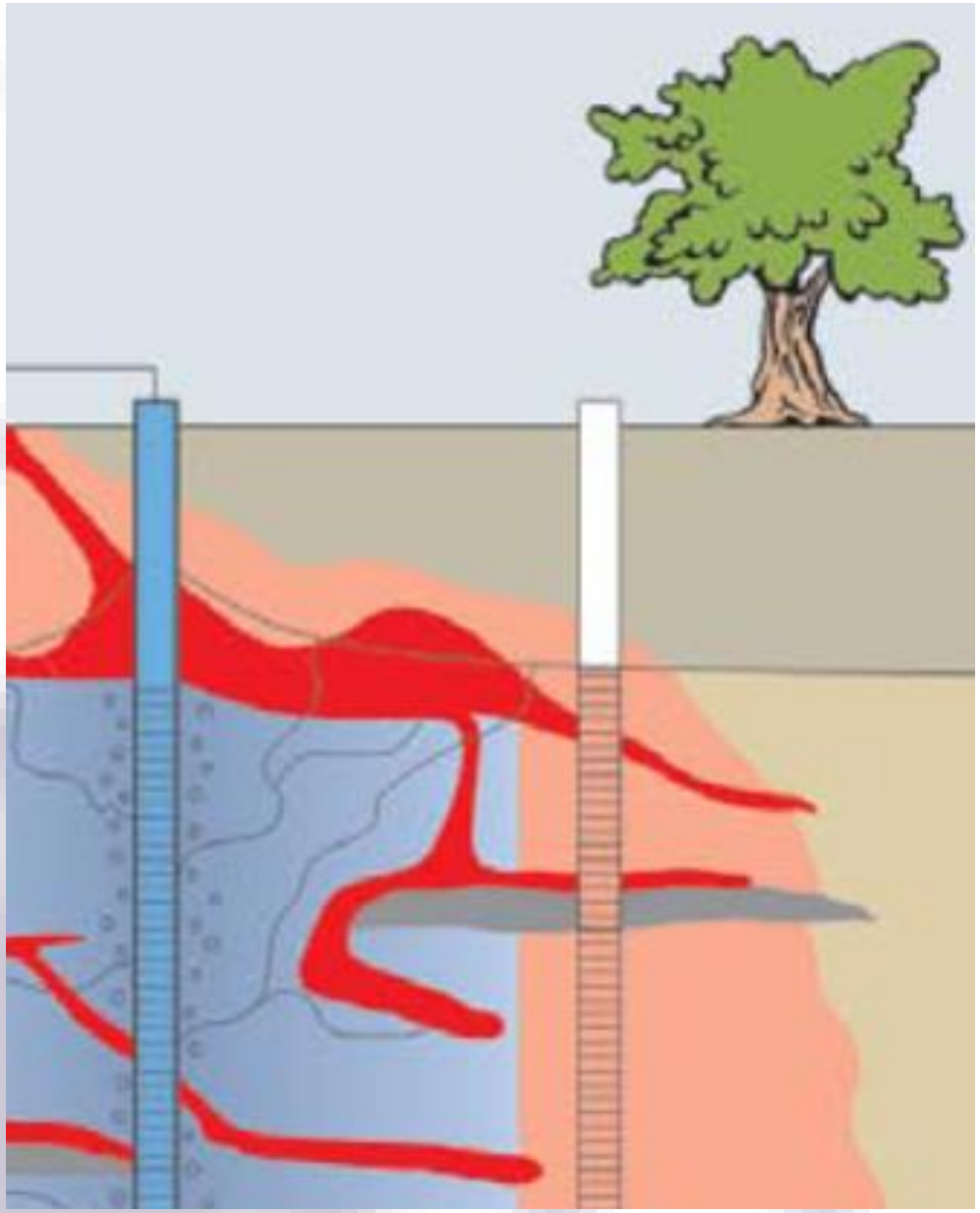
Novel In-Situ Adsorptive Method to Address Vinyl Chloride Risk

RemTech Presentation

October 13, 2017

Nathan Lichti

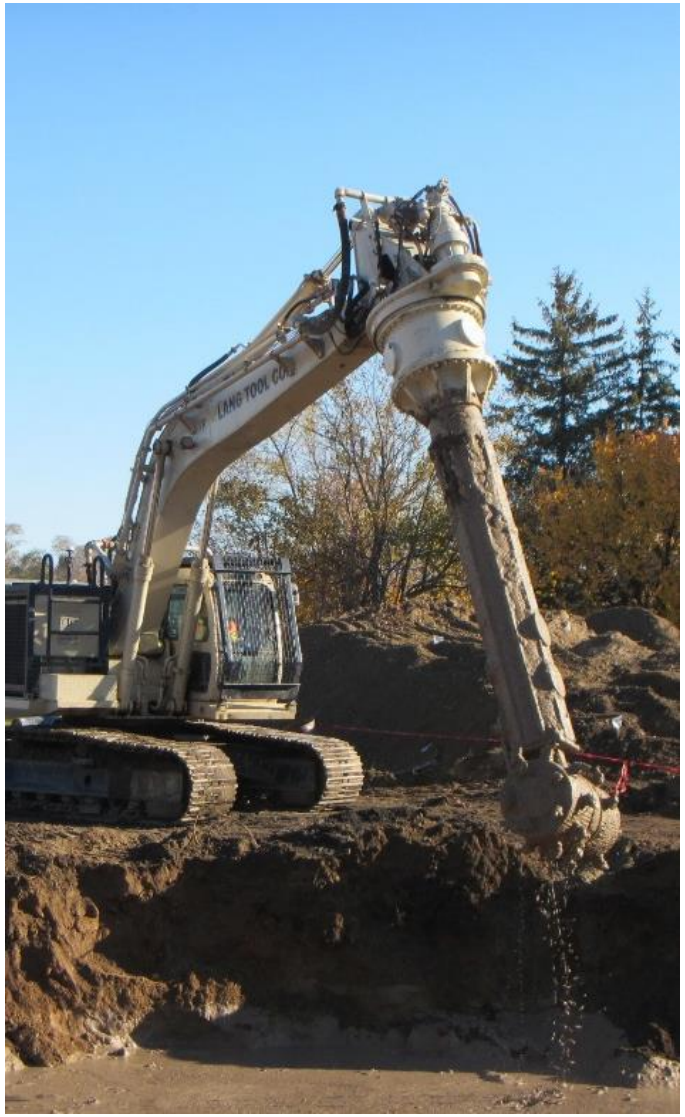
Overview



- Background
- Vinyl Chloride and cVOCs
- Remediation Technologies
  - Historical Approaches
  - New Adsorptive Approach
- Case Studies
  - Sewer Bed Remediation
  - Time Critical cVOC Plume
- Questions

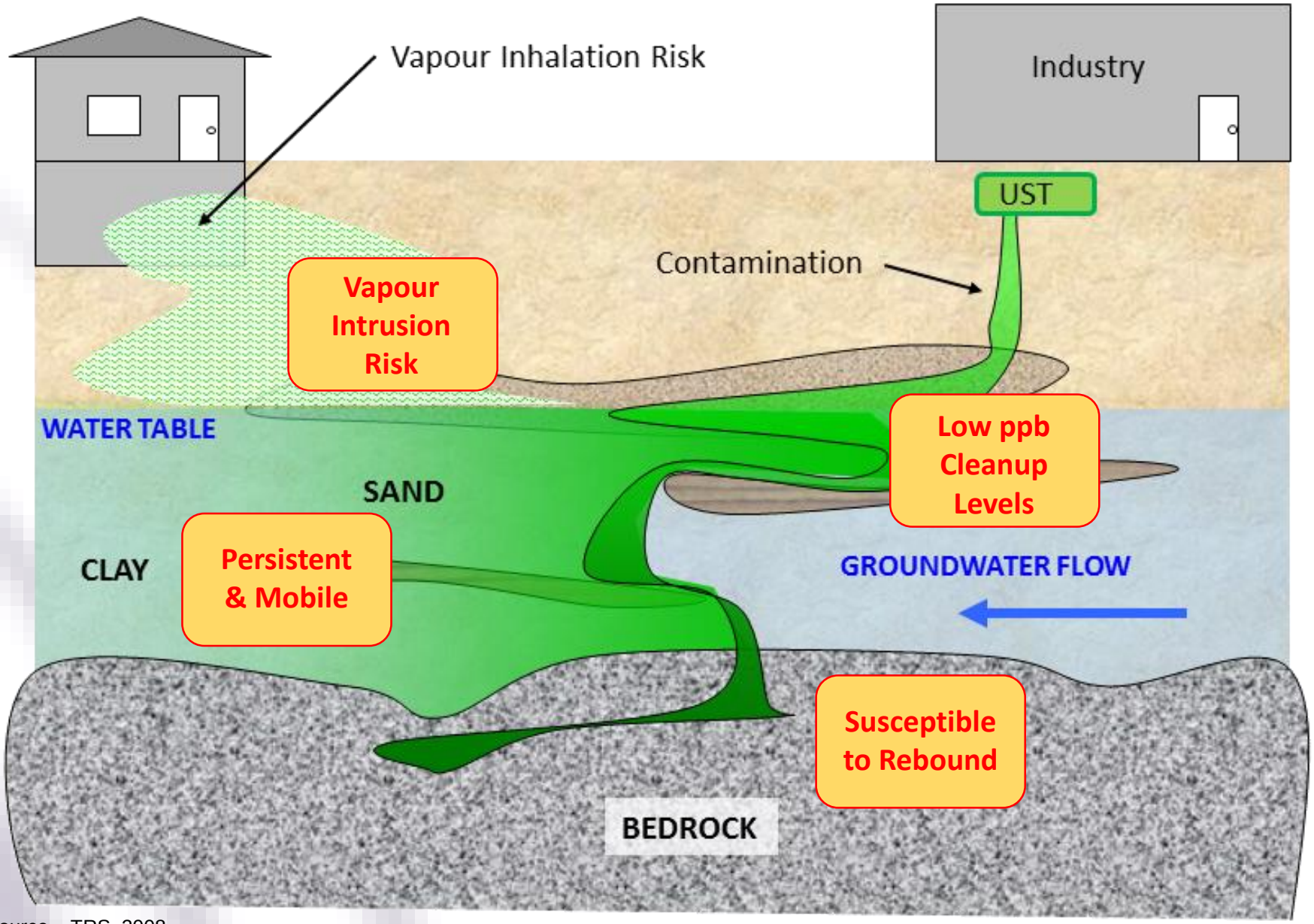
Vertex Background

- Nathan Lichti
  - Environmental Engineer
  - University of Waterloo
- Vertex Environmental Inc.
  - Environmental Contracting
  - In-Situ and Ex-Situ Remediation
    - Remedial Design
    - Implementation (bench, pilot, full-scale)
  - High Resolution Characterization (MIP, LIF, HPT)
  - Treatment Systems (SVE, MPE, P&T)



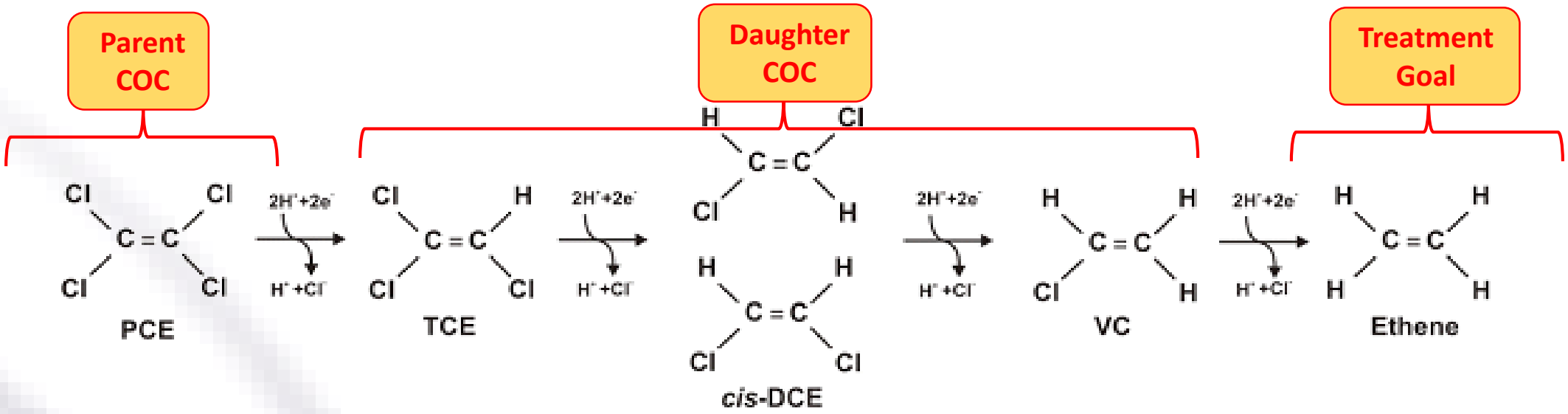
Vinyl Chloride and cVOCs

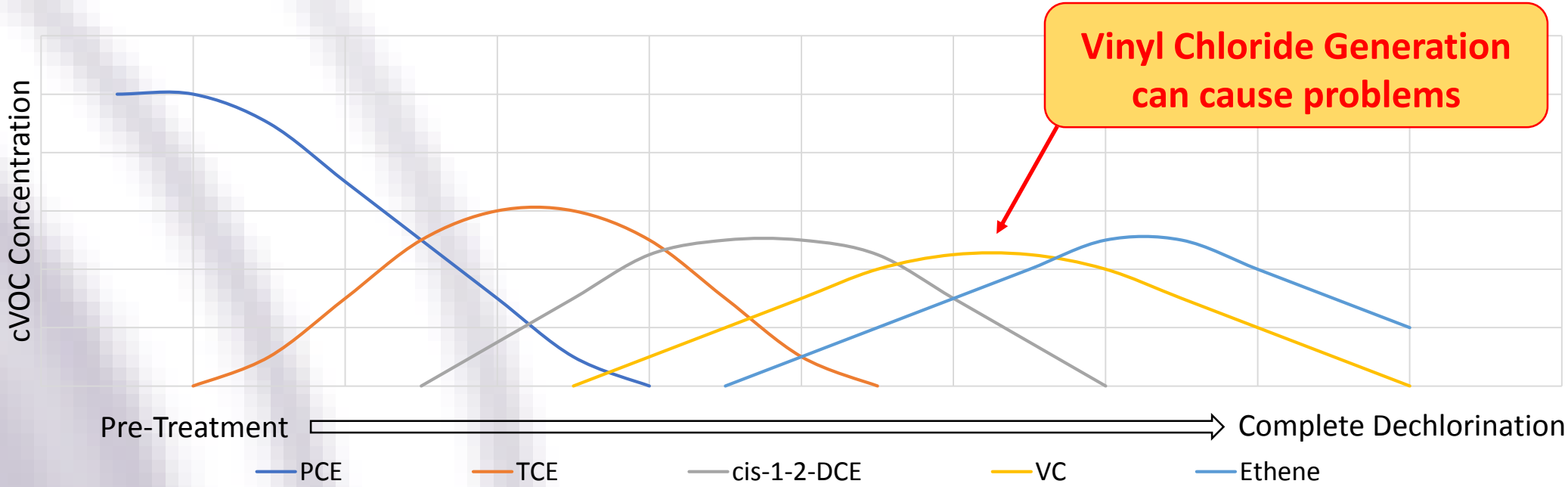
Why cVOCs are so problematic?



Source – TRS, 2008

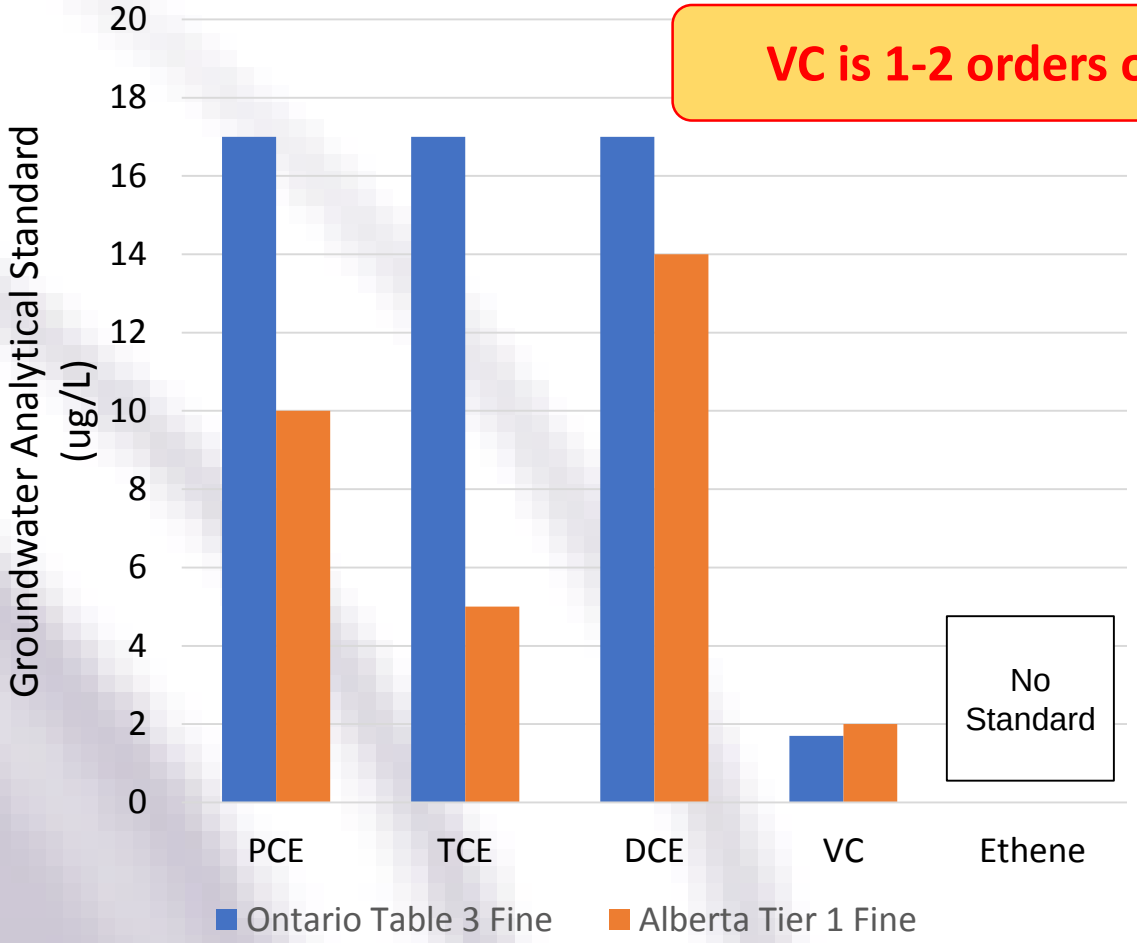
cVOCs Dechlorination





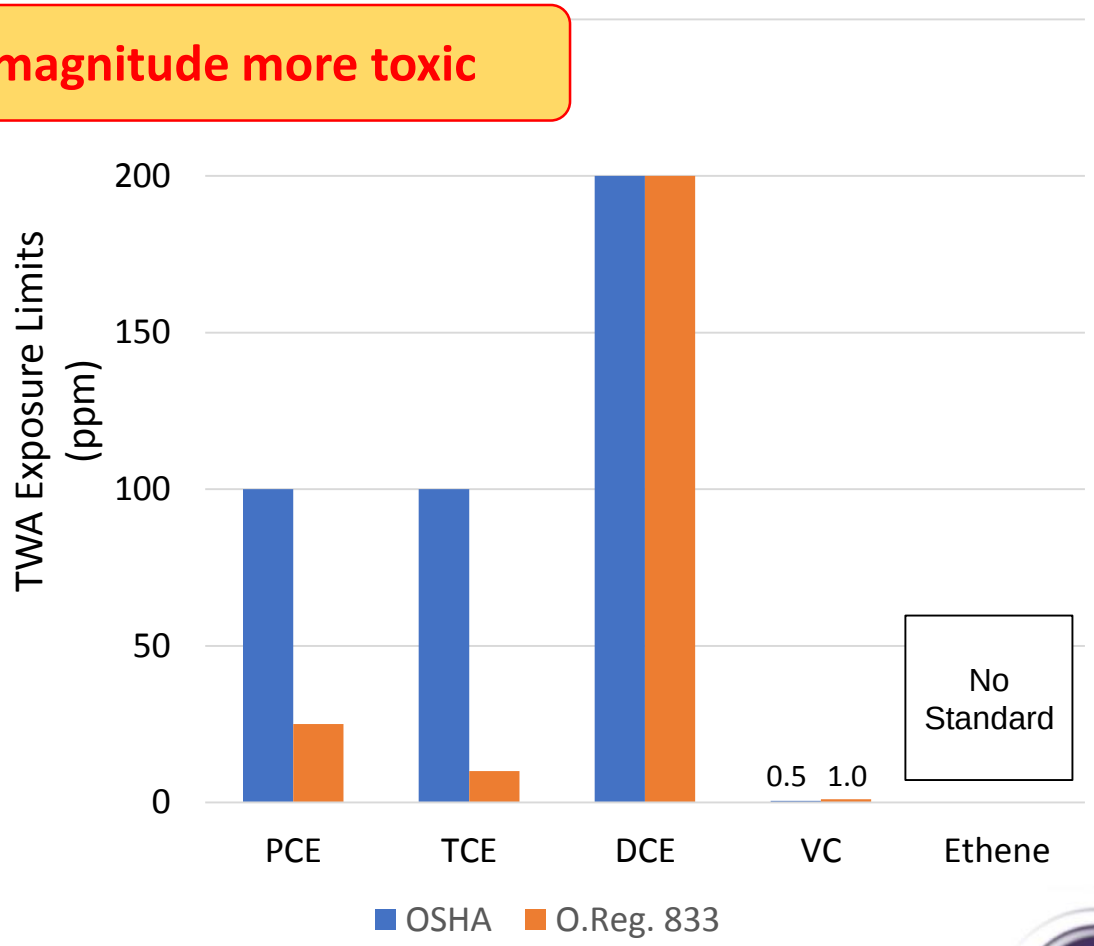
Vinyl Chloride Treatment Standards

Groundwater



VC is 1-2 orders of magnitude more toxic

Vapours

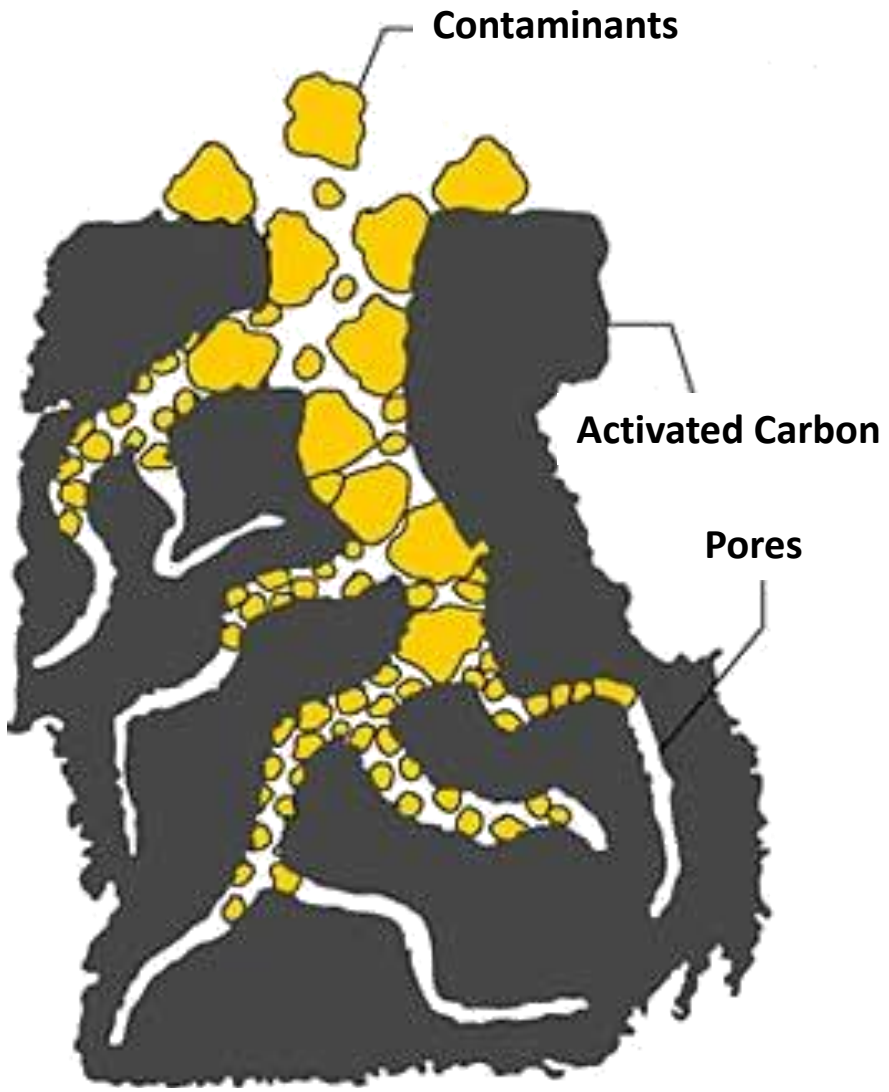


Enhanced Reductive Dechlorination

- Historical in-situ treatment approaches include:
  - Addition of Zero Valent Iron
  - Addition of Organic Substrates (ie. electron donors)
  - Bioaugmentation (ie. KB-1®)

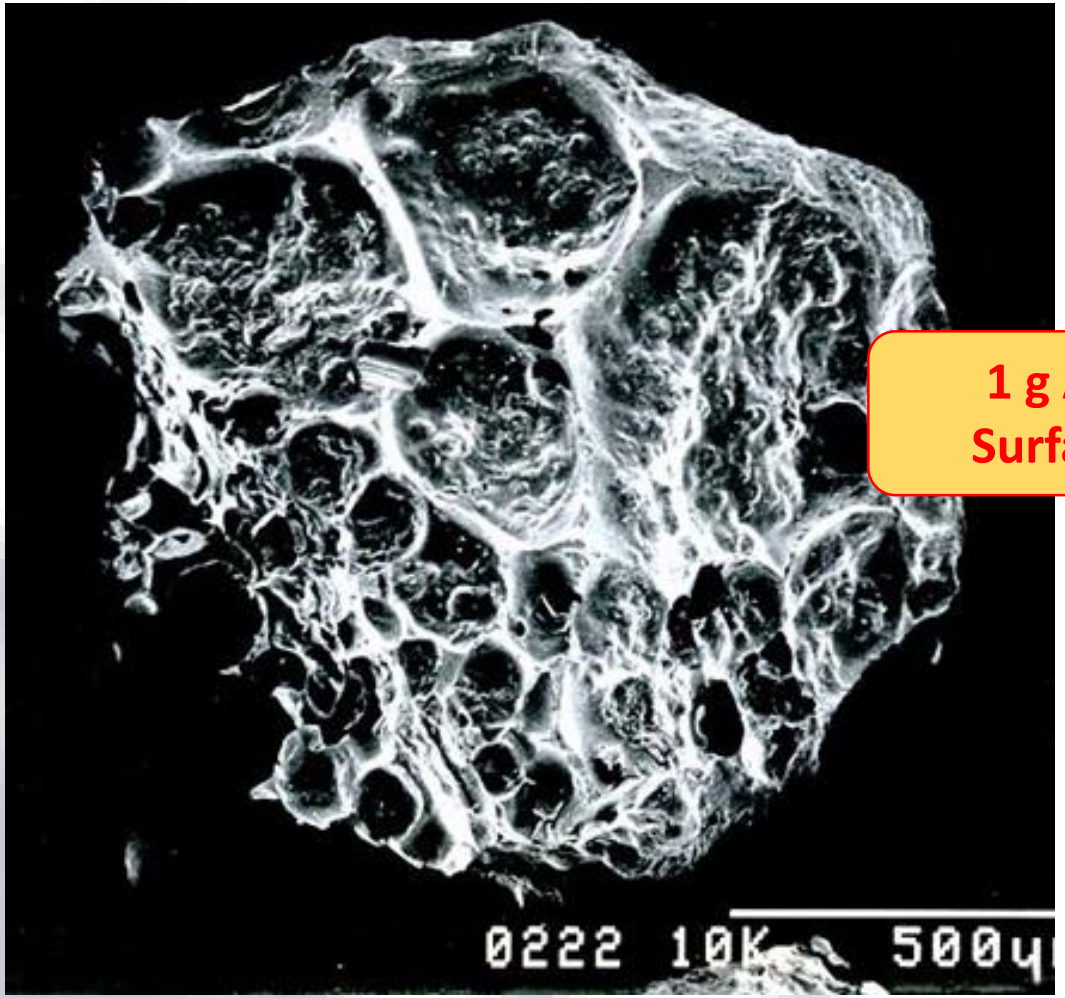
Enhanced Reductive Dechlorination

- Trap & Treat Amendments:
  - Introduced to Canada in 2015
  - BOS 100® for chlorinated solvent treatment
  - BOS 200® for petroleum hydrocarbon treatment
- Mechanisms:
  - **"Trap"** the contamination within the activated carbon matrix
  - **"Treat"** within the activated carbon matrix
- Trap:
  - Decrease groundwater mass immediately
  - Disrupt groundwater/soil mass equilibrium to drive desorption
- Treat:
  - Aerobic & Anaerobic Bioremediation
  - Chemical Reduction

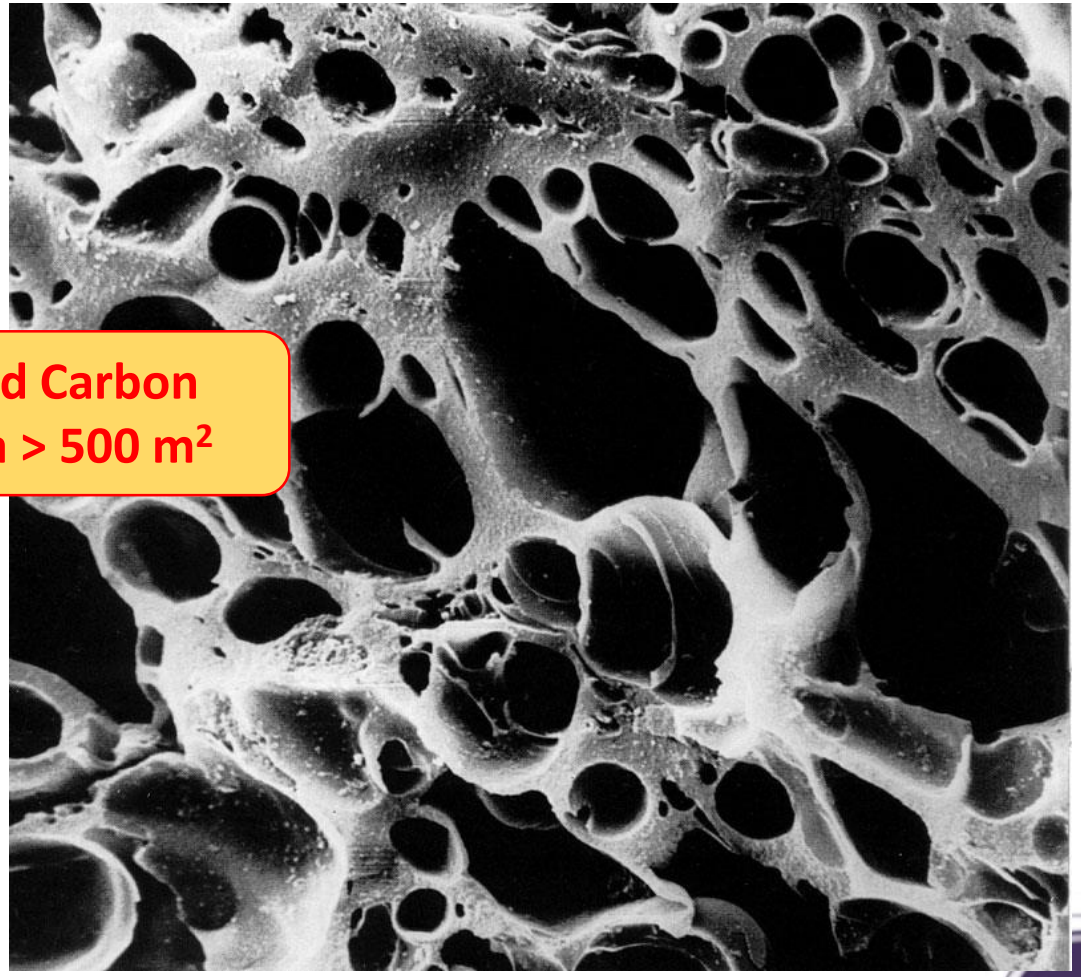


Activated Carbon adsorbs contaminants

Trap & Treat: Activated Carbon



1 g Activated Carbon
Surface Area > 500 m^2

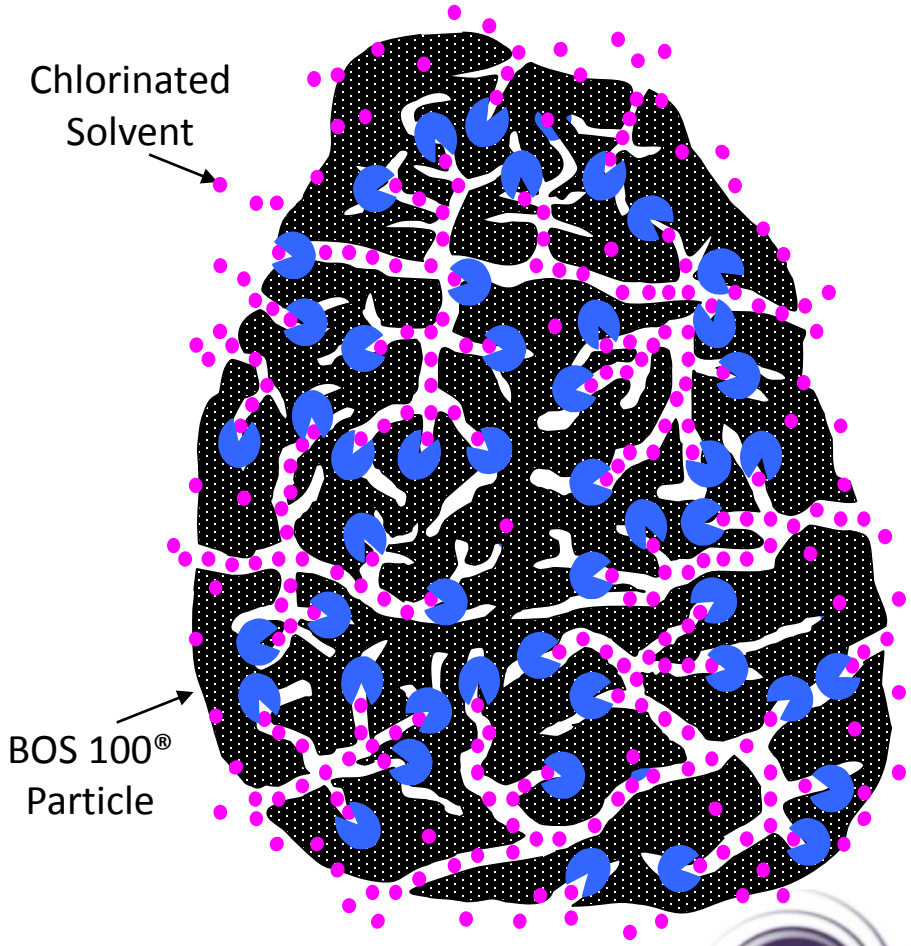


Trap & Treat: Activated Carbon

Trap & Treat: BOS 100®

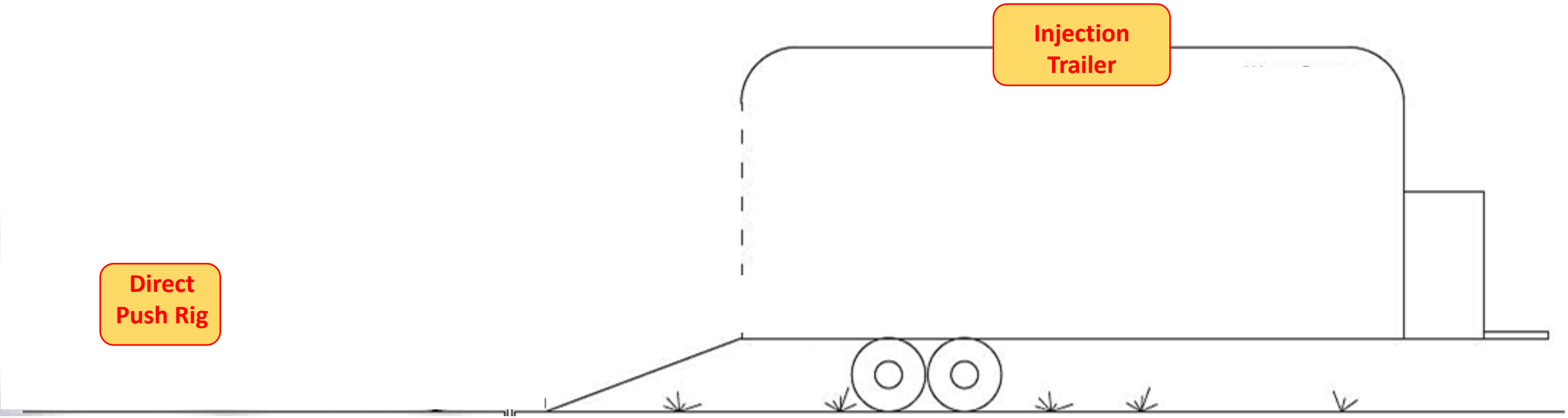
Mixing BOS 100® in the field

- BOS 100®
  - Consists of GAC impregnated with iron
- Mechanisms:
  - **"Trap"** the contamination within the GAC matrix
  - **"Treat"** the contamination via reductive dechlorination within the GAC matrix
- Applications:
  - Treatment of chlorinated solvents
  - Overburden or bedrock
  - Plume or barrier applications

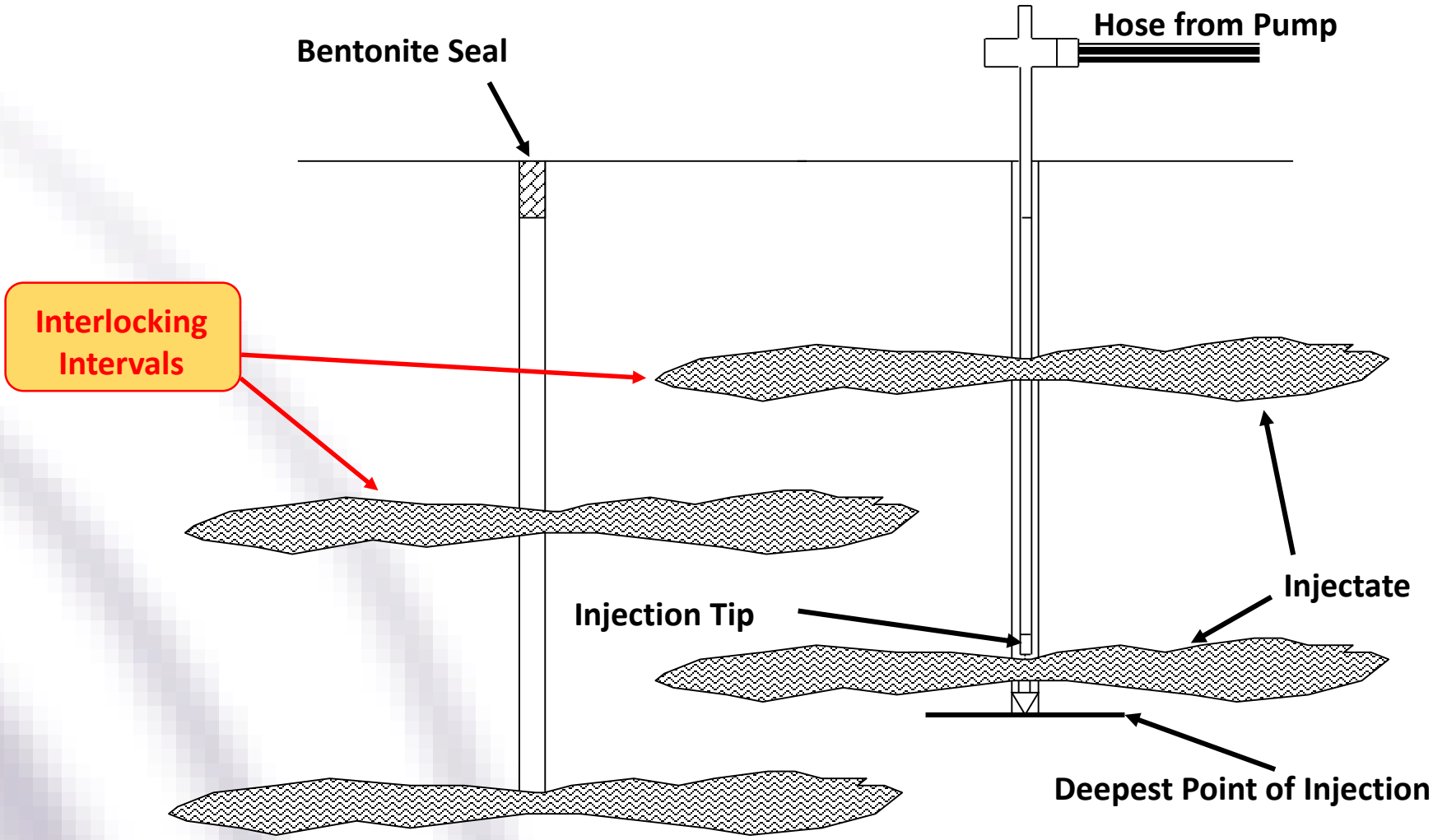


Activated Carbon & Iron

Trap & Treat: Amendment Delivery



Trap & Treat: Amendment Delivery



Injections using top-down approach

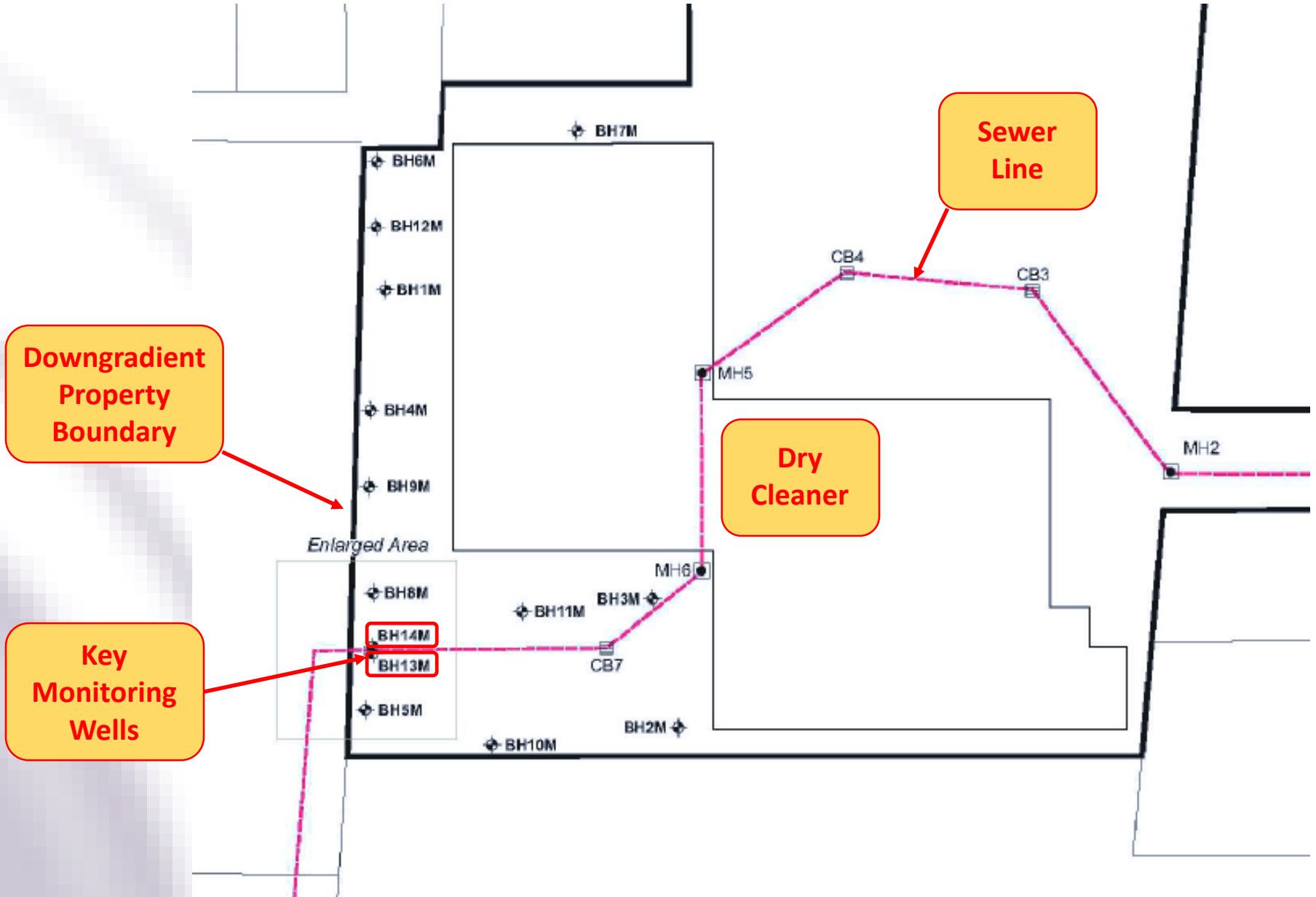
Trap & Treat® - Amendment Delivery

Case Studies

Case Study #1
Sewer Bed Remediation

Sewer Bed Remediation

Sewer Bed Remediation



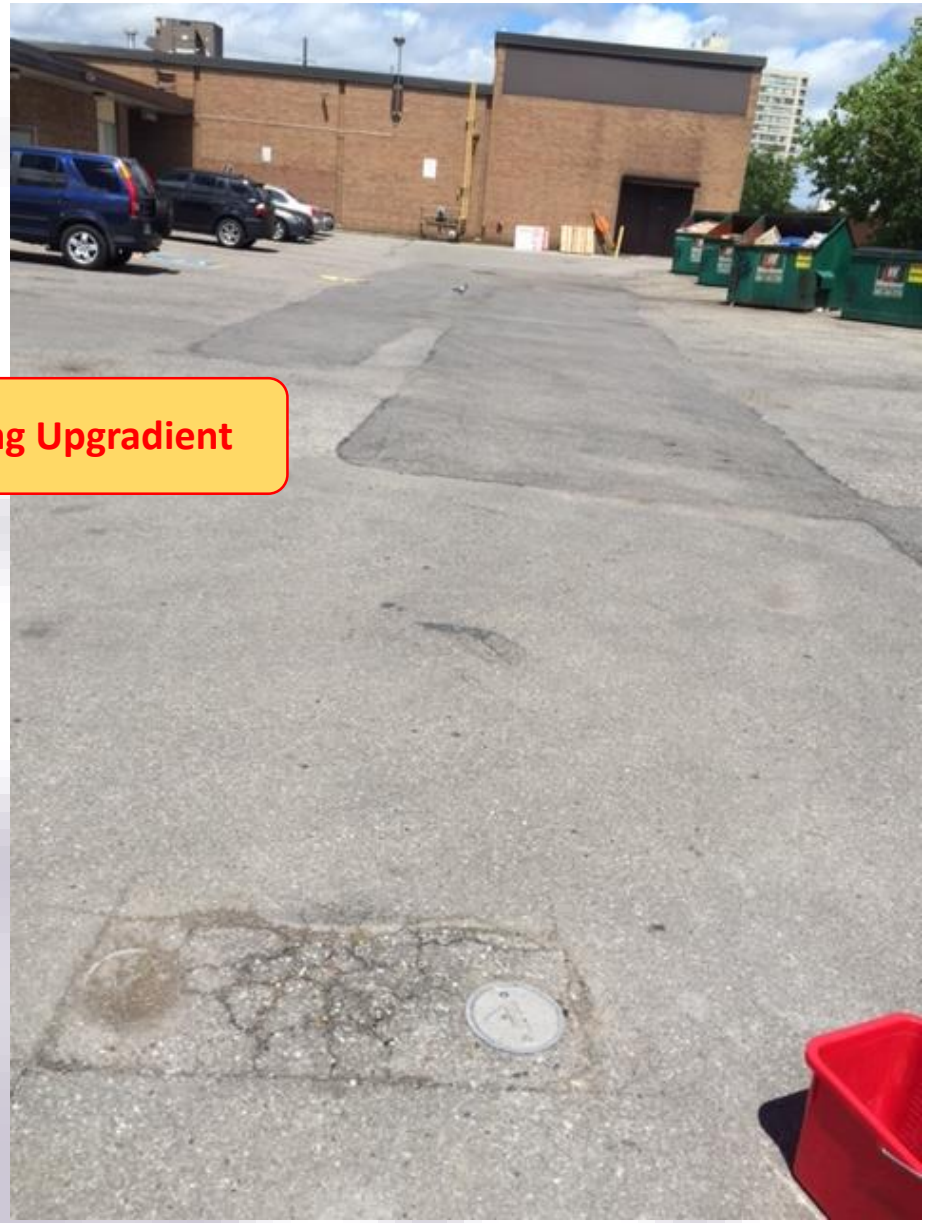
Sewer Bed Remediation

VOC Groundwater Analytical – Average Concentration

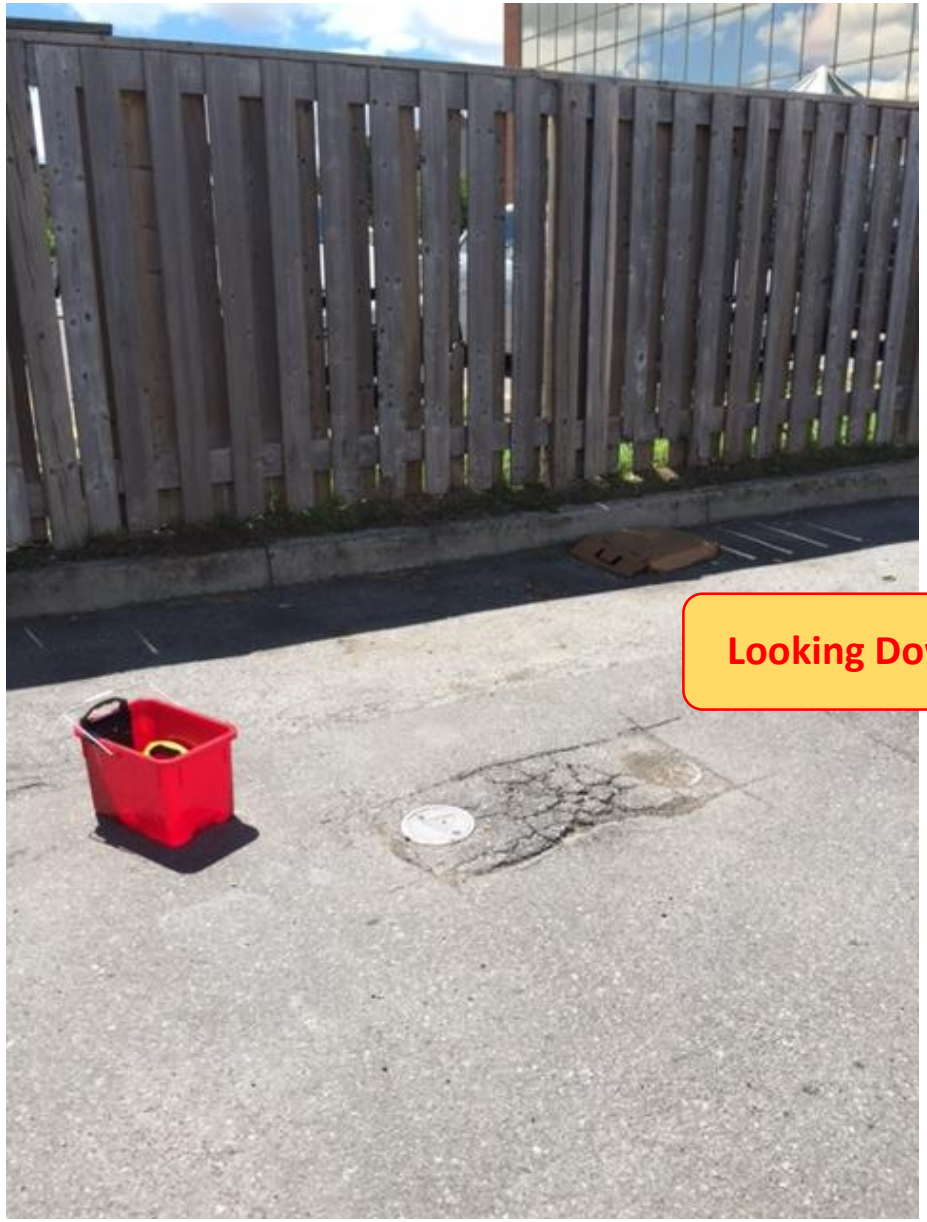
(ug/L)	MW13 Max Conc	MW14 Max Conc
PCE	4,680	3,410
TCE	4	5
DCE	<0.50	<0.50
VC	<0.20	<0.20
Total	4,680	3,415

Pre-Remediation Concentrations at Property Boundary Wells

Sewer Bed Remediation

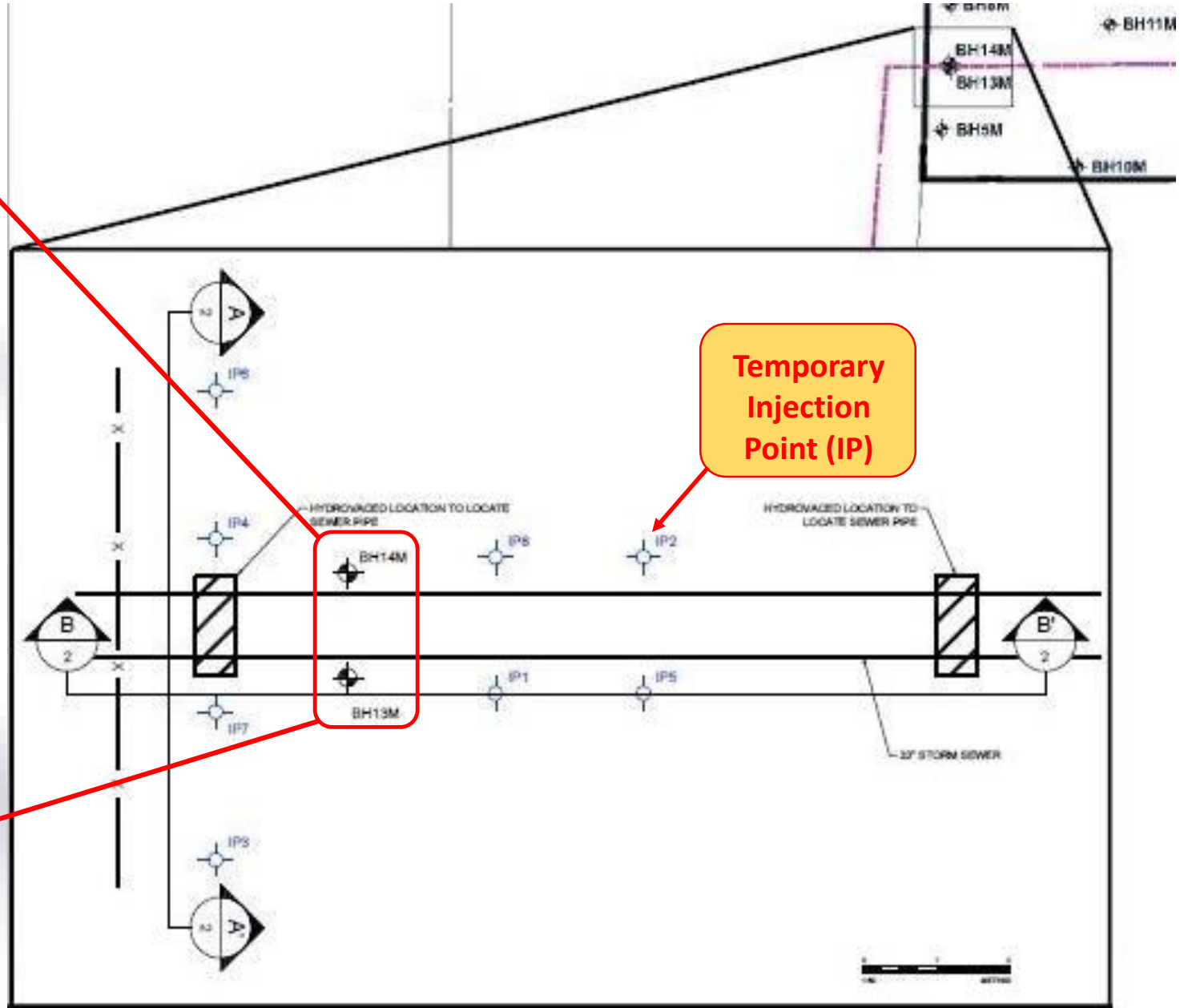


Looking Upgradient

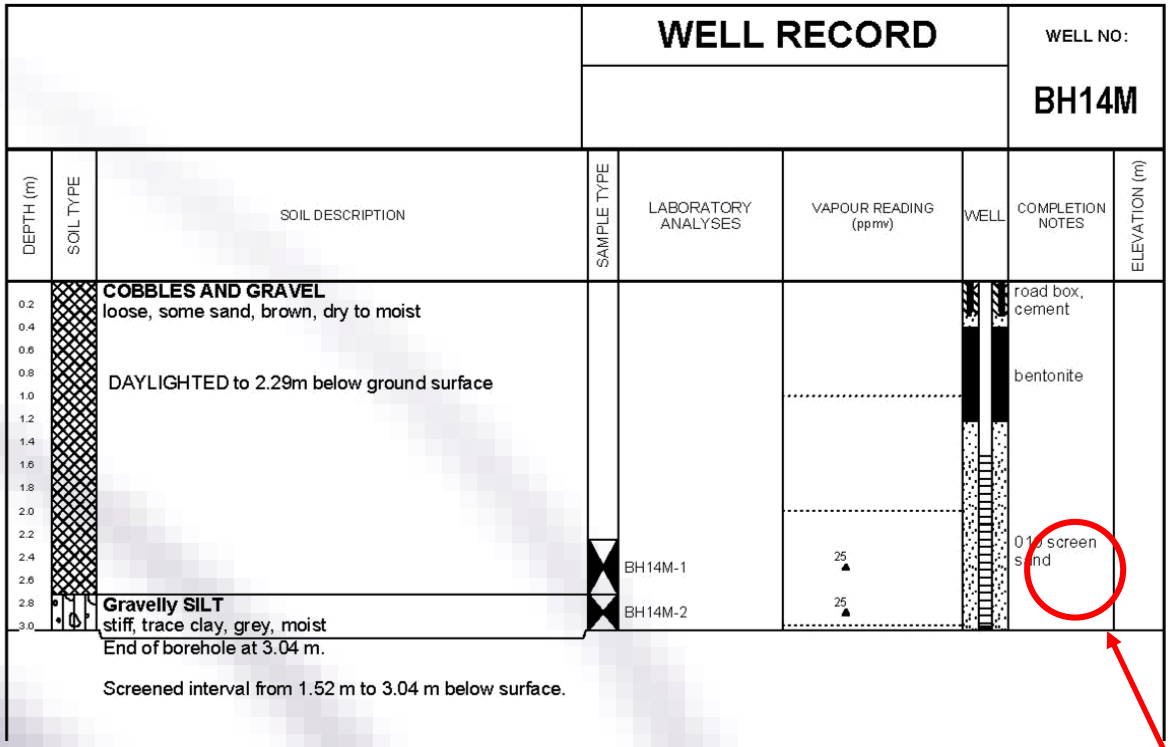


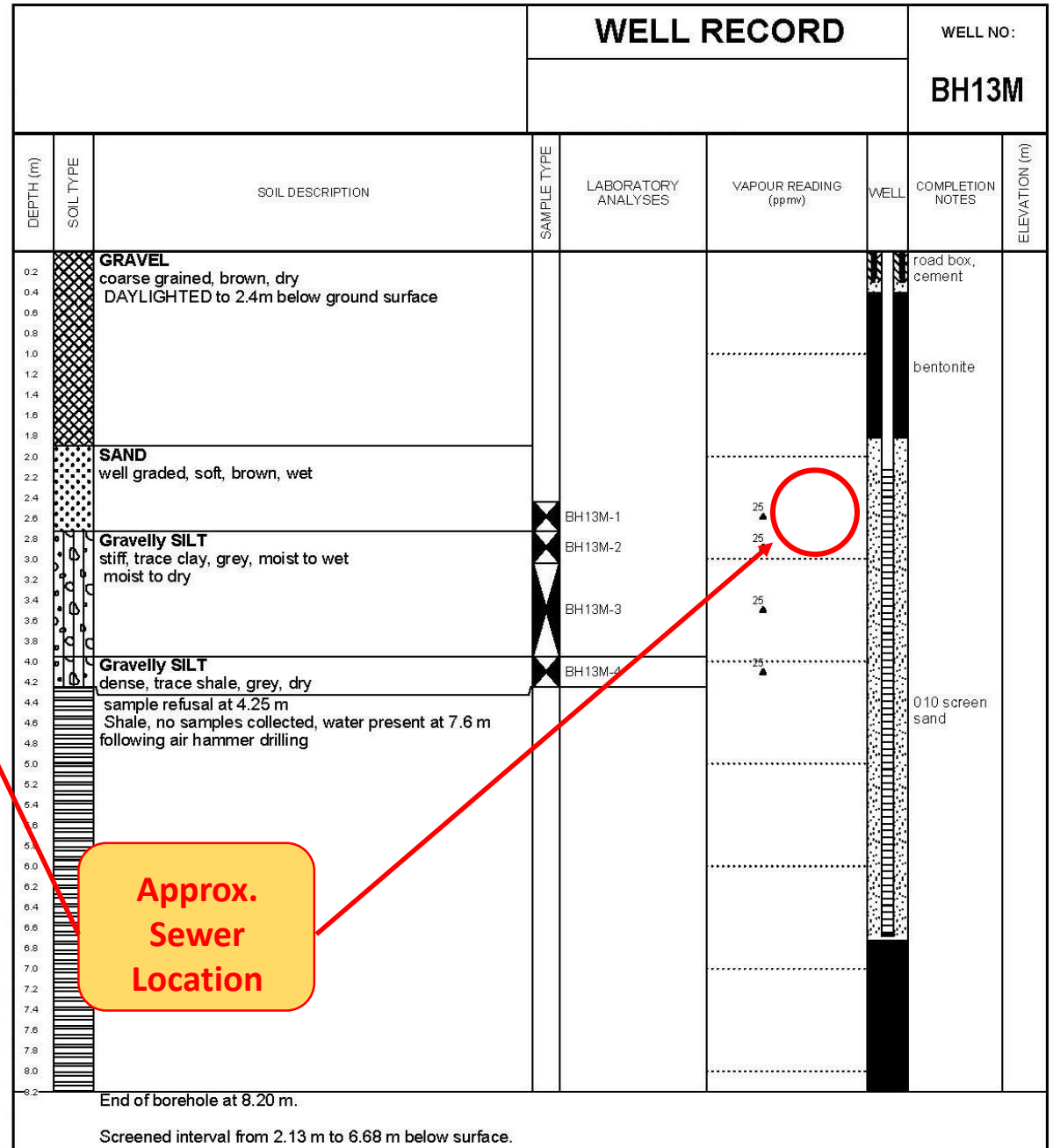
Looking Downgradient

Sewer Bed Remediation



Sewer Bed Remediation





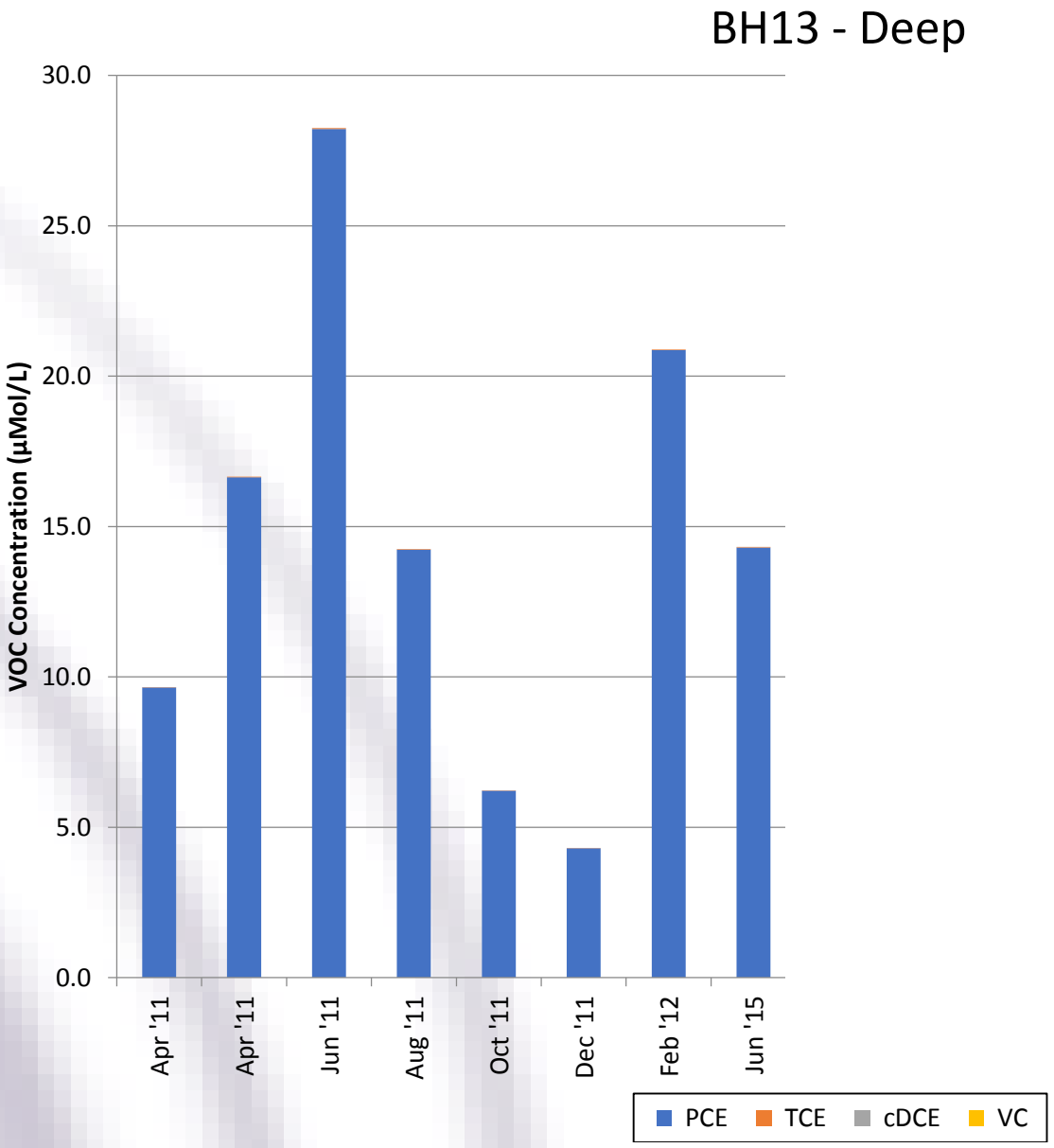
Sewer Bed Remediation

- Zero Valent Iron (ZVI) Injection
  - August 2015, 3 days
  - Vertical: 1.8 m to 4.6 m (shale)
  - 2,400 kg of ZVI, with guar gum
  - 7,000 L of slurry
  - 8 injection locations
- Trap & Treat® Injection
  - November 2016, 2 days
  - Vertical: 1.8 m to 4.6 m (shale)
  - 100 kg of Trap & Treat® BOS 100®
  - 1,500 L of slurry
  - 6 injection locations
  - Interlocking delivery over specific depth intervals
- Before Each Injection
  - Hydro-vac down to top of Sewer
  - Camera inside sewer at location of injection

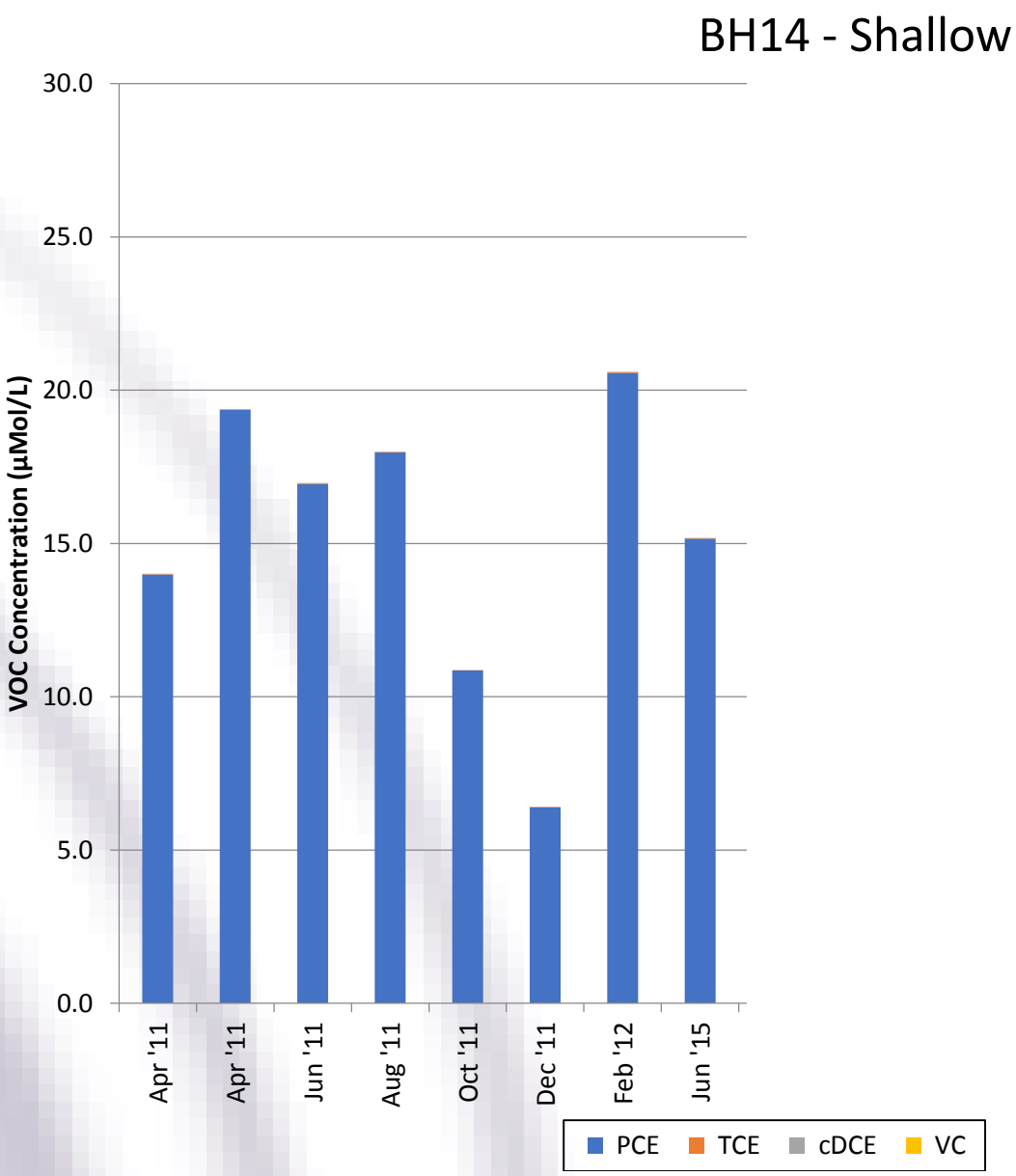
Sewer Bed Remediation

Hydro-vac’ing Top of Sewer

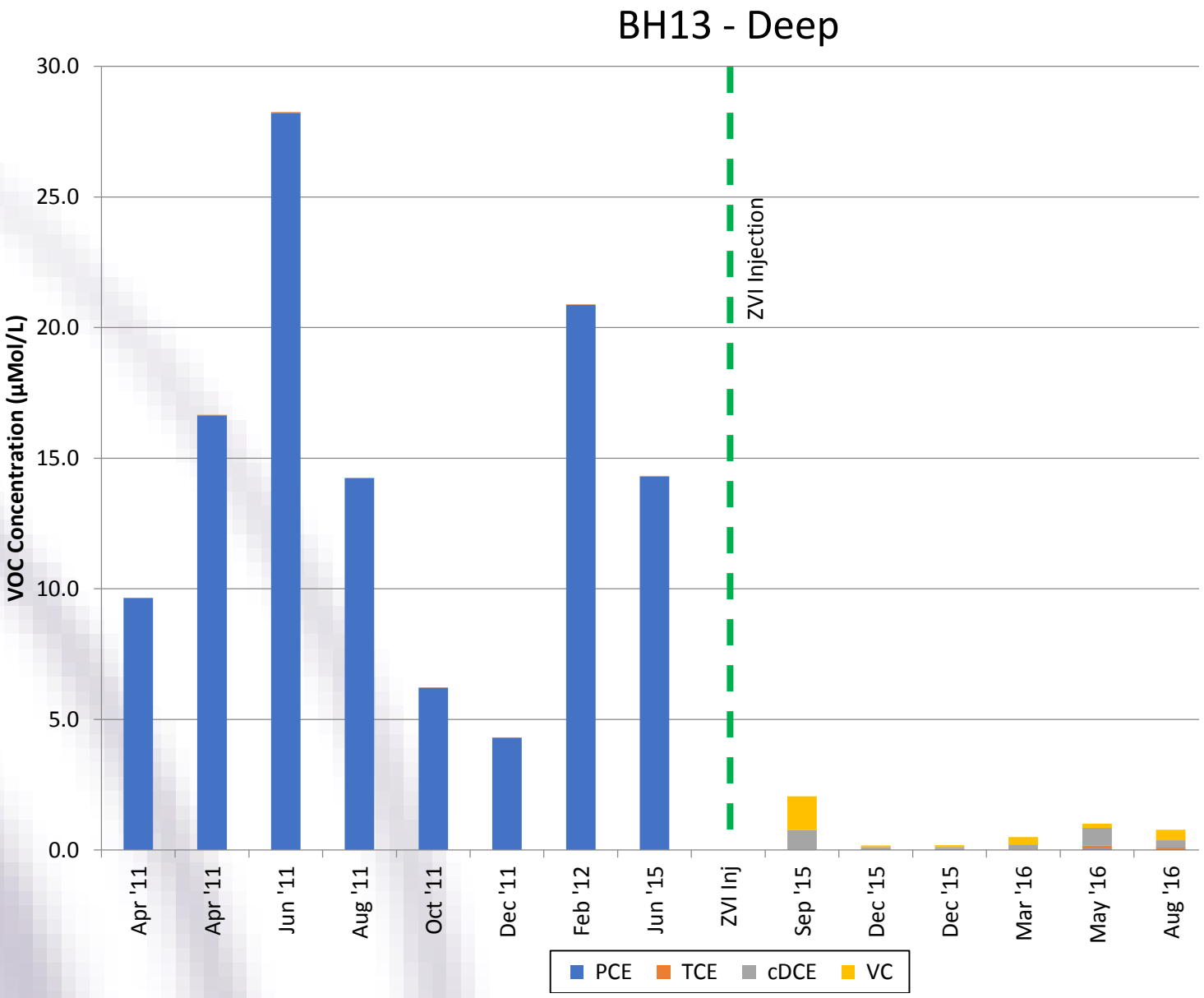
Sewer Bed Remediation



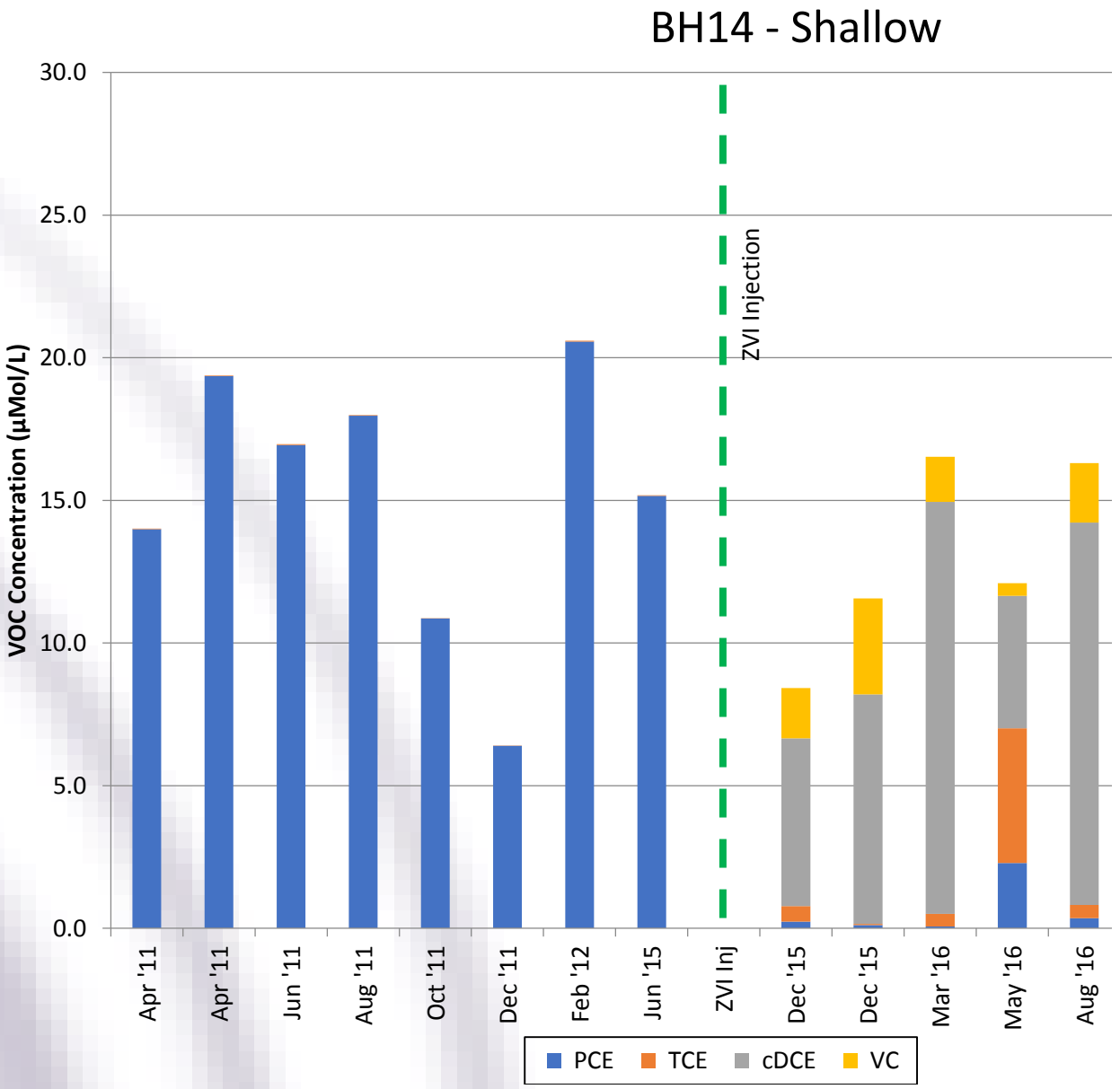
Sewer Bed Remediation



Sewer Bed Remediation



Sewer Bed Remediation



Sewer Bed Remediation

VOC Groundwater Analytical – BH13 (deep)

(ug/L)	Avg Conc Before Work	Avg Conc After ZVI	Avg Conc After BOS
PCE	2,370	4.5	1.8
TCE	2	4.6	0.7
DCE	<0.50	34	2.2
VC	<0.20	23	2.0
Total	2,372	66	6.7
% Reduction	-	97.2%	99.7%

Sewer Bed Remediation

VOC Groundwater Analytical – BH14 (shallow)

(ug/L)	Avg Conc Before Work	Avg Conc After ZVI	Avg Conc After BOS
PCE	2,510	101	16
TCE	3	163	5
DCE	<0.50	900	64
VC	<0.50	115	7
Total	2,513	1,279	92
% Reduction	-	49%	96.3%

Sewer Bed Remediation

Conclusions

- ZVI Injection
  - Very effective at remediating PCE
  - Yet daughter products remain (especially at the shallow MW)
  - Potential offsite migration of vinyl chloride made situation worse for the client
- BOS 100® Injection
  - Treatment of VC and cVOCs within the GAC matrix
  - Lowest cVOC groundwater concentrations recorded at those MWs
  - No more offsite migration of vinyl chloride above the standard

Case Study #2
Time Critical cVOC Plume Treatment

Time Critical cVOC Plume Treatment

Site Background

- Historic on-site degreasing and waste storage activities
- Site being sold; full remediation required as condition of sale
- Timeline for remediation was inflexible

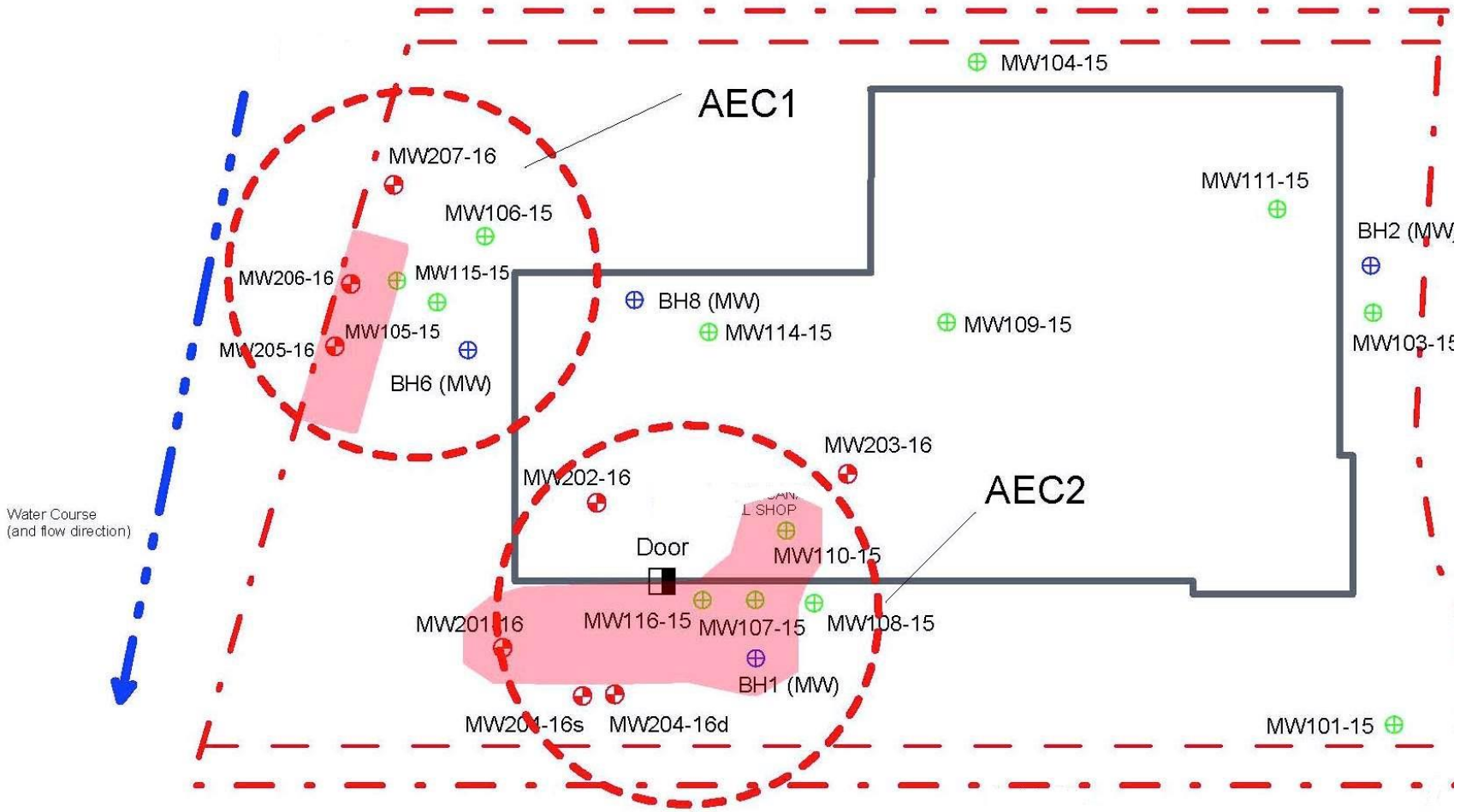
Contaminant Situation

- No remaining soil impacts
- Two separate plumes of cVOCs in groundwater
  - One primarily c-1,2-DCE (70 ppb) and 1,1,1-TCA (300 ppb)
  - Other primarily c-1,2-DCE (30 ppb) & VC (10 ppb)

Remedial Objective – Time

- Generic regulatory groundwater standards for commercial sites
- Must be completed by June 30, 2017

Time Critical cVOC Plume Treatment



Time Critical cVOC Plume Treatment

Remedial Approach

- Injection of Trap & Treat® BOS 100®
- Application using temporary points advanced via GeoProbe
  - Pilot-scale testing
    - Proof-of-concept for vendor
    - Confirmation of application rates
  - Full-scale injections

Obstacles

- Short timeframe for remediation (only 3 months)
- Mid-injection monitoring identified need for re-application in problematic area
- Creek adjacent to site – non-mobile amendment needed

Time Critical cVOC Plume Treatment

AEC-1

Time Critical cVOC Plume Treatment

AEC-2

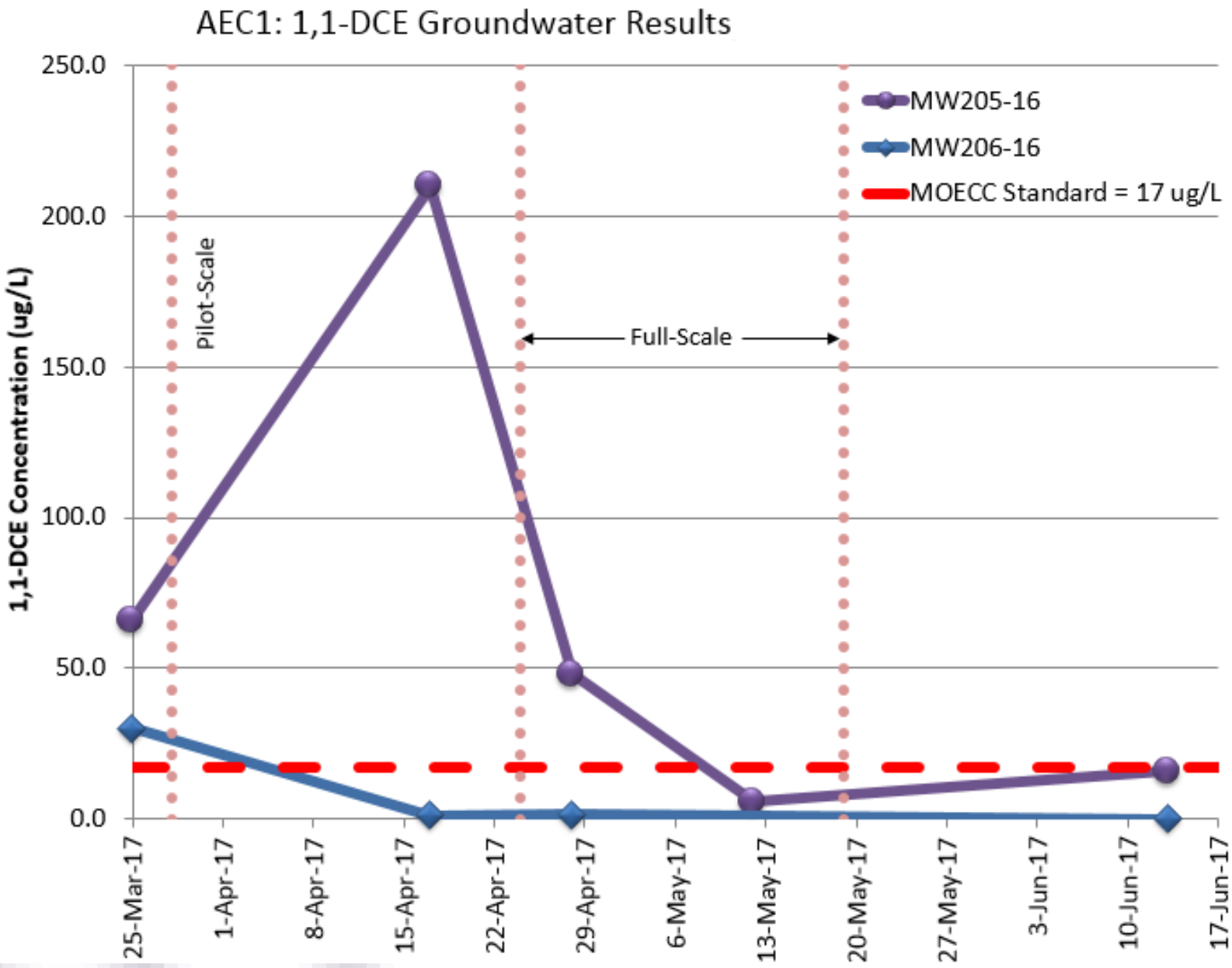
Time Critical cVOC Plume Treatment

Work Completed

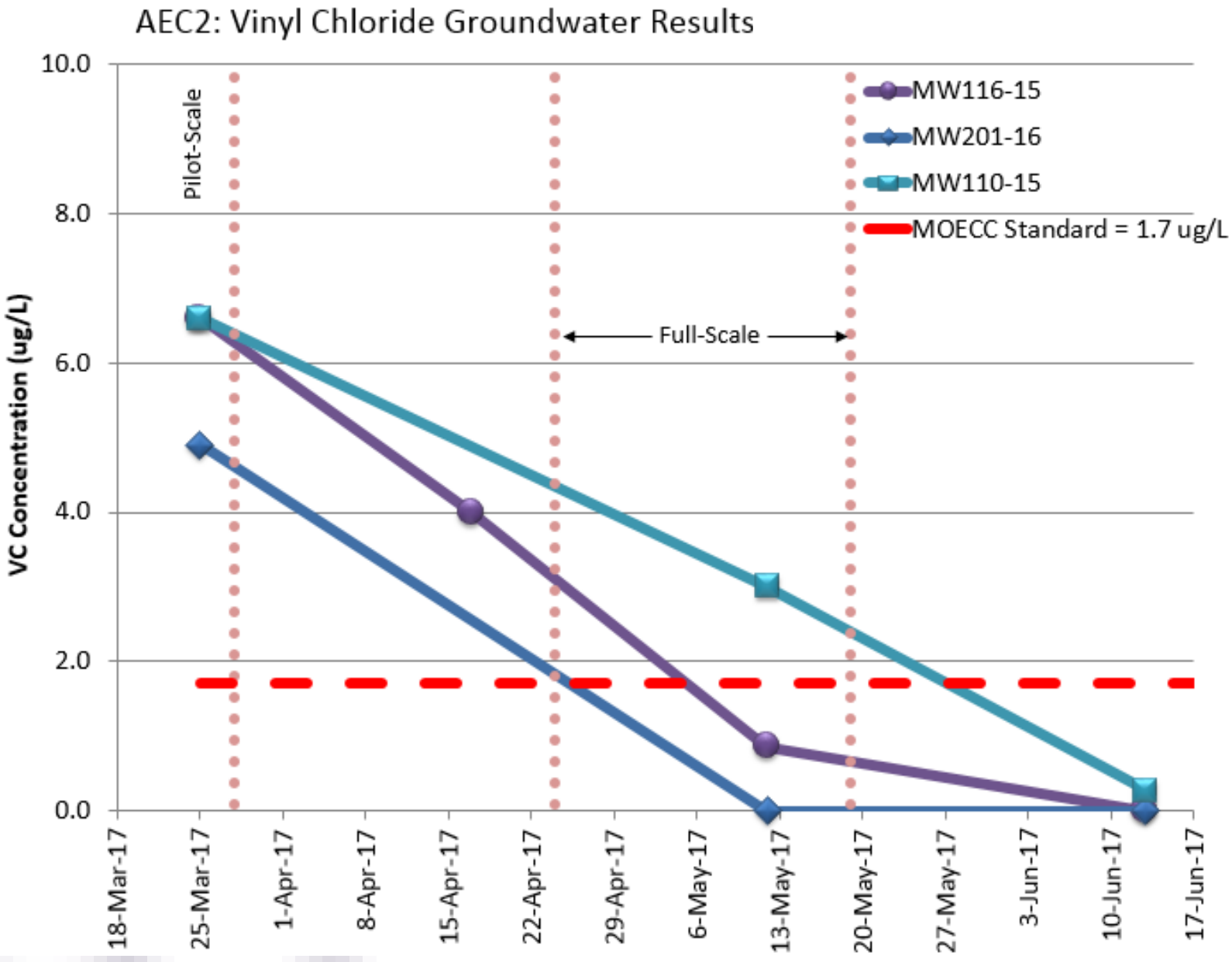
- Pilot-Scale Testing
  - Injected ~300 kg of BOS 100®
  - ~4,500 L slurry
  - 20 temporary injection points
  - Completed over 2 working days (1 day in each AEC)
- Full-Scale Injection
  - Injected ~2,200 kg of BOS 100®
  - ~36,000 L slurry
  - 115 temporary injection points
  - Completed over 12 working days

Outcome

Time Critical cVOC Plume Treatment



Time Critical cVOC Plume Treatment



Time Critical cVOC Plume Treatment

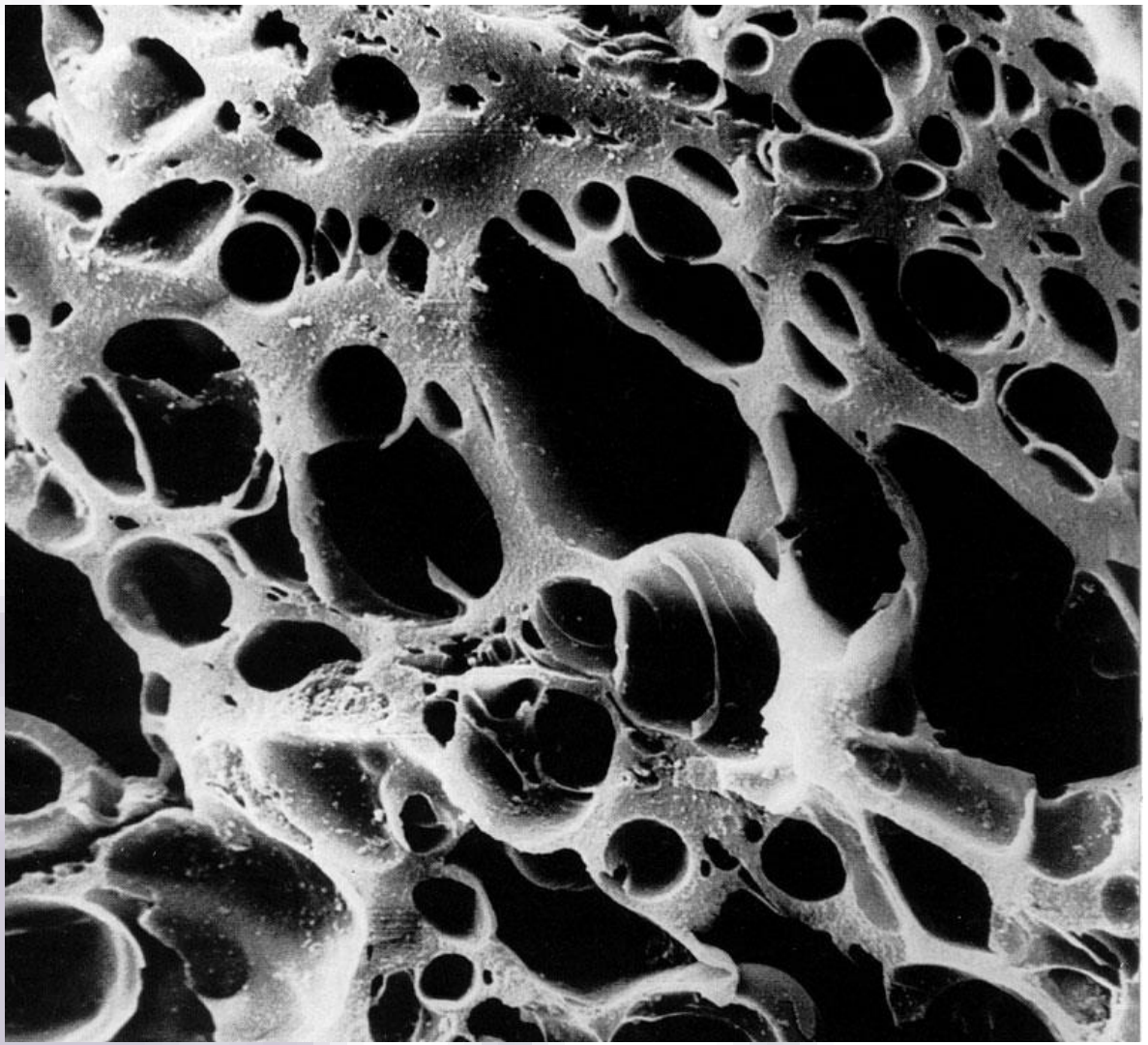
Project Summary

- cVOC plume and vinyl chloride was most challenging (1.7 ug/L standard)
- Client very sensitive to timeline (fixed deadline)
- Selected fast-acting approach where treatment happens with carbon matrix
- Completed pilot-scale testing to refine full-scale design
- Interim monitoring by consultant identified need to adjust amendment application in the field to meet remedial objectives
- Remediation was completed on time to Generic Standards

Closing Thoughts

Historical Challenges with Vinyl Chloride and cVOCs Treatment	New Adsorptive Carbon Based Treatment via BOS 100®
Remedial targets are often very low ppb levels of cVOCs	Properly applied = dramatic cVOC concentrations reductions to low ppb levels
Risk assessments can take years and leave stigma affecting property value	In-situ remediation can meet generic regulatory standards eliminating the need for risk assessments
Historical cVOCs treatment approaches can lead to increased vinyl chloride concentrations	New adsorptive carbon-based treatment can trap vinyl chloride in adsorptive carbon and treat within carbon matrix
Back diffusion or “rebound” of contamination after remediation can drag out remediation timelines and lead to numerous injection events	Single application of adsorptive carbon-based amendments can remediate plumes and reach remedial goals within shorter timeframes

Questions



Thank You for Your Time

Nathan Lichti

Vertex Environmental Inc.

(519) 591-4543 mobile

nathanl@vertexenvironmental.ca

www.vertexenvironmental.ca