LNAPL Treatment / Remediation Options in Support of Risk Assessment-Based Closures

October 16, 2024

RemTech Symposium

Kevin French, B.A.Sc., P.Eng.
VEI Contracting Inc.

Presentation

- VEI Overview
- LNAPL and Risk Assessments
- Technologies
  - LNAPL Characterization
  - LNAPL Destruction
  - LNAPL Immobilization
- Injection Approaches
- Case Study
- Closing Thoughts
- Questions

VEI Overview

Overview – VEI Contracting

VEI Contracting Inc.

- Founded in 2003 (formerly Vertex Environmental Inc.)
- Specialized Environmental Remediation Contracting (in-situ, ex-situ, systems, HRSC)
- Provides services across Canada

Kevin French, P.Eng

- Vice President, VEI Contracting
- B.A.Sc., Civil/Env. Eng., U. Waterloo
- Environmental engineering (consulting and remediation contracting) since 1988

LNAPL and Risk Assessments

Risk Assessment Challenges with LNAPL

Several Canadian jurisdictions allow RAs on PHCs:

- AB:
  - Control (non-mobile) or **actively remediate** (remove) to the **“extent practicable”** (mobile)
  - LNAPL source control: “stable” and “decreasing”
  - Exposure controls and risk management may be needed
- BC:
  - Must assess **whether LNAPL is mobile** or stable (1 yr monitoring needed)
  - LNAPL (>2 mm) in MWs and mobile LNAPL can trigger **“high-risk site”** classification
  - Must assess VI considerations

Risk Assessment Challenges with LNAPL

- ON:
  - Permitted (B/R) but not preferred (O/B)
  - Remove LNAPL to the **"extent practicable" (incl. films, sheen and >50% solubility)**
  - Must assess VI considerations
- QC:
  - Not allowed (not even for PHCs!)

Is there were a way to effectively destroy or immobilize LNAPL to allow easier RA approval?

Assist with reducing off-site risks & need for barrier walls; address GW to SW migration pathway; reduce vapour concerns; shorten length of monitoring programs, etc.

Technologies

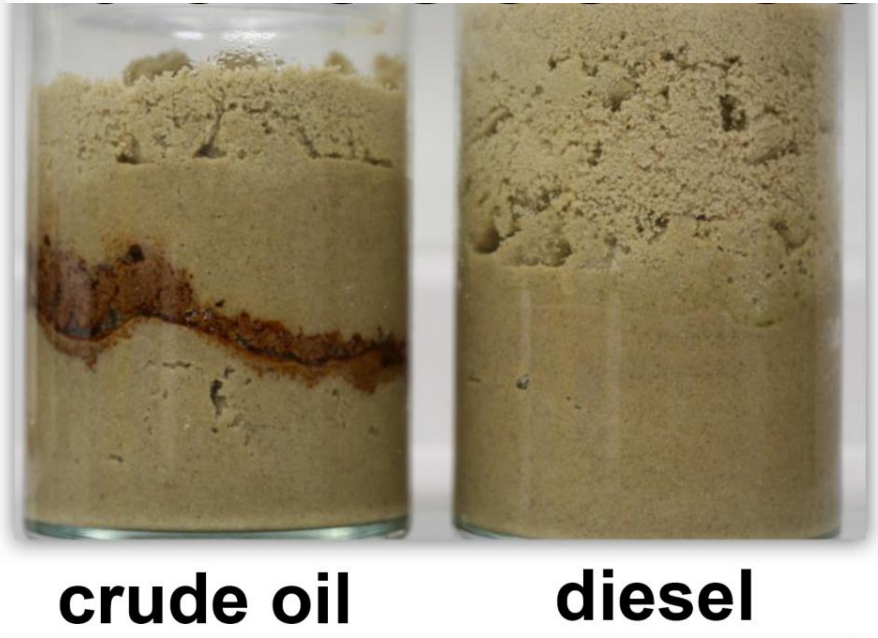
LNAPL Characterization

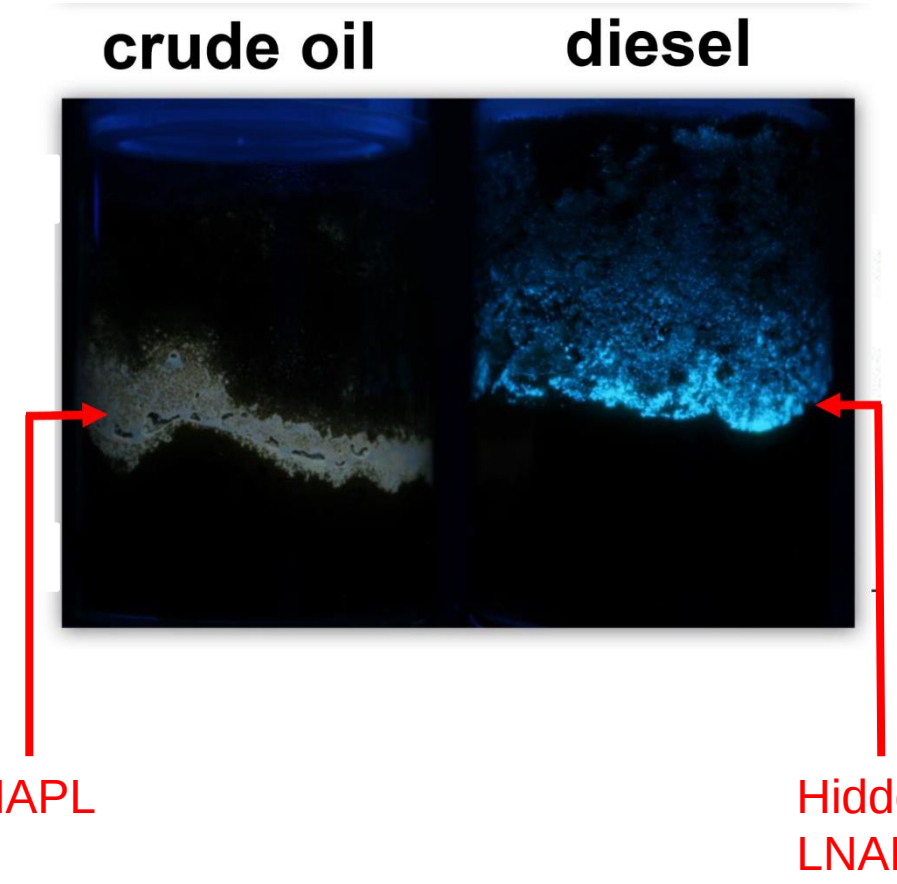
Laser Induced Fluorescence (LIF)

Free-Phased PHCs

- **Four UV Wavelengths of Laser:**
  - Excites PAHs to fluoresce
  - Fluorescence is detected
  - Semi-quantitative concentration (“response”)
- **Detection of Free-Phased PHCs:**
  - Mobile (flowing) or non-mobile (sorbed)
  - Above or below the water table
  - “Fingerprint” of PHC type and age
- **Soil Classification:**
  - Electrical conductivity

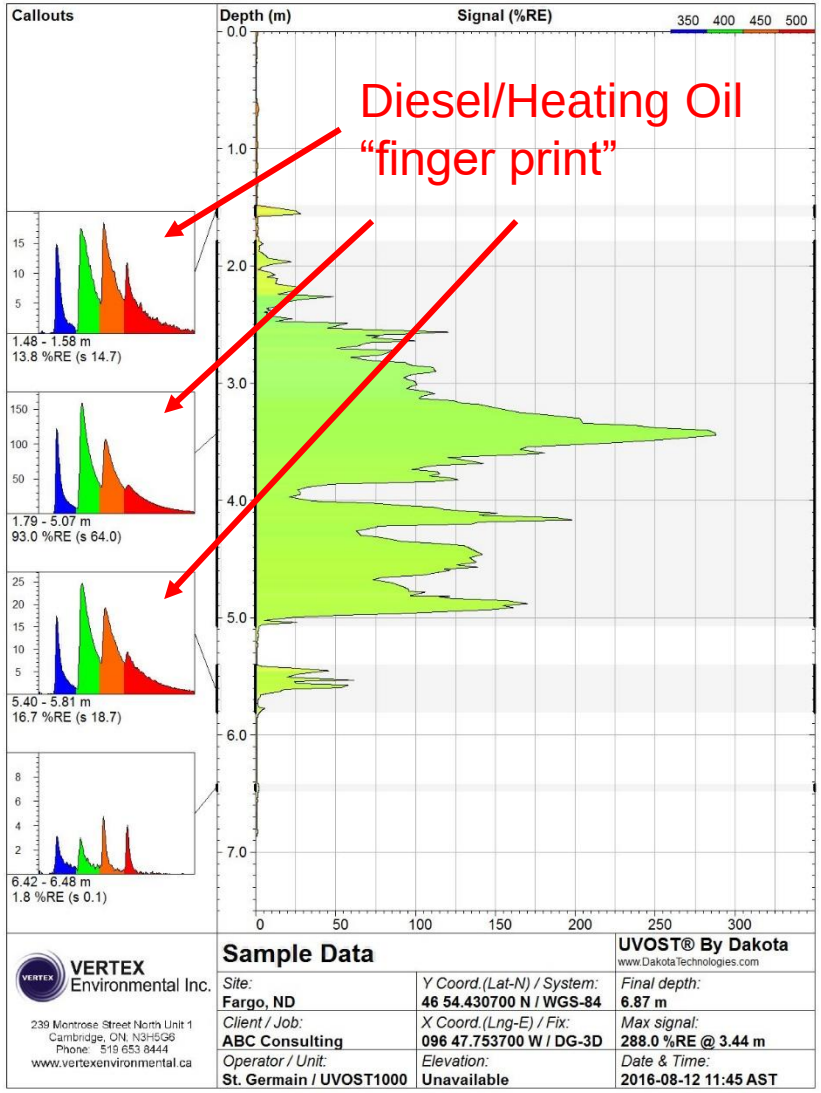
Laser Induced Fluorescence (LIF)

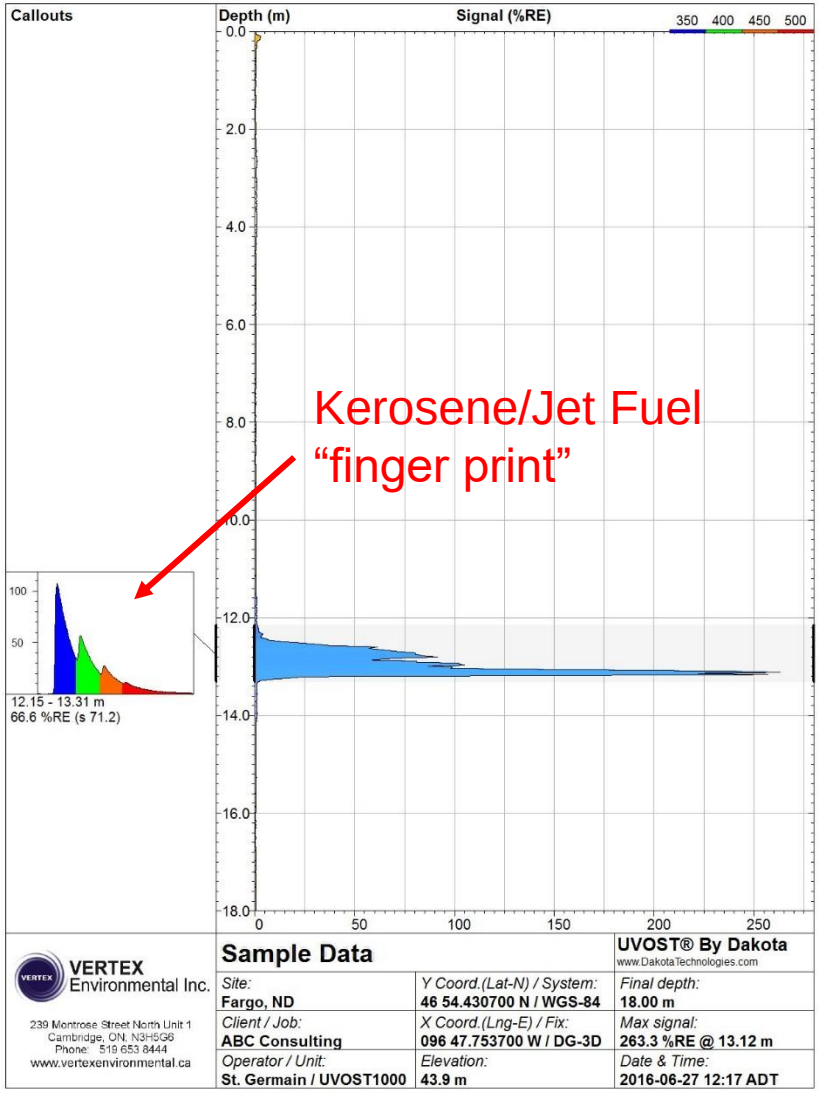




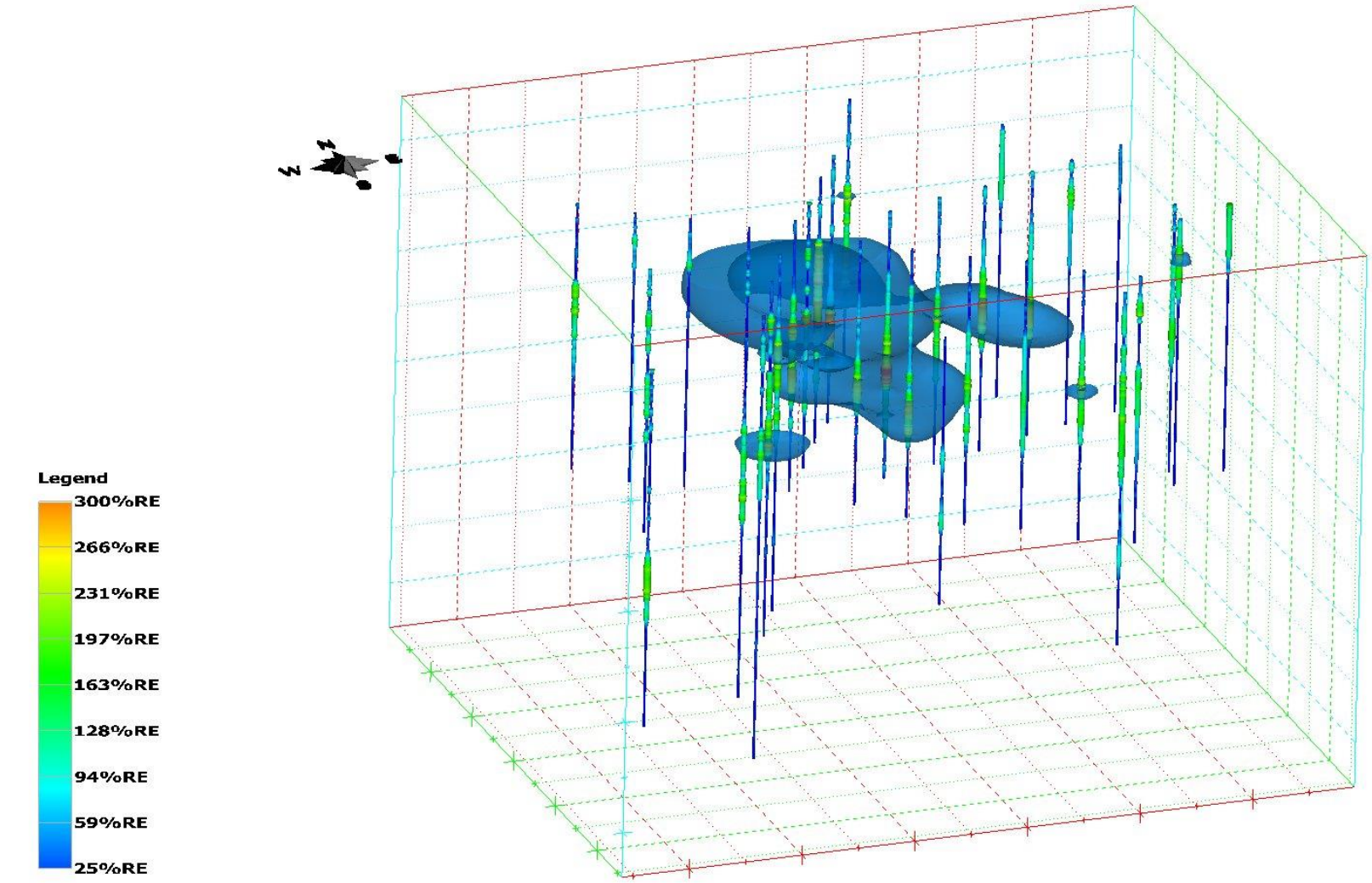
- Molecules absorb light (gain energy)
  and then emit light (lose energy = fluoresce)
- Aromatic molecules (PAHs) readily absorb and emit light

Laser Induced Fluorescence (LIF)



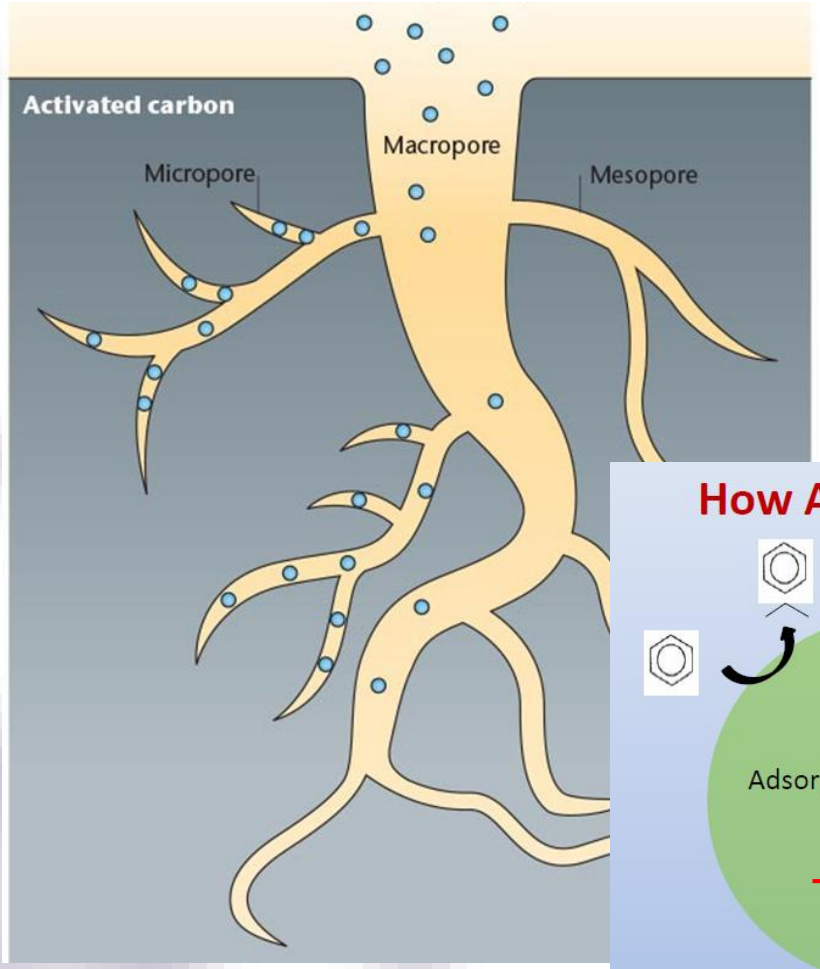


LIF Data – Visualization

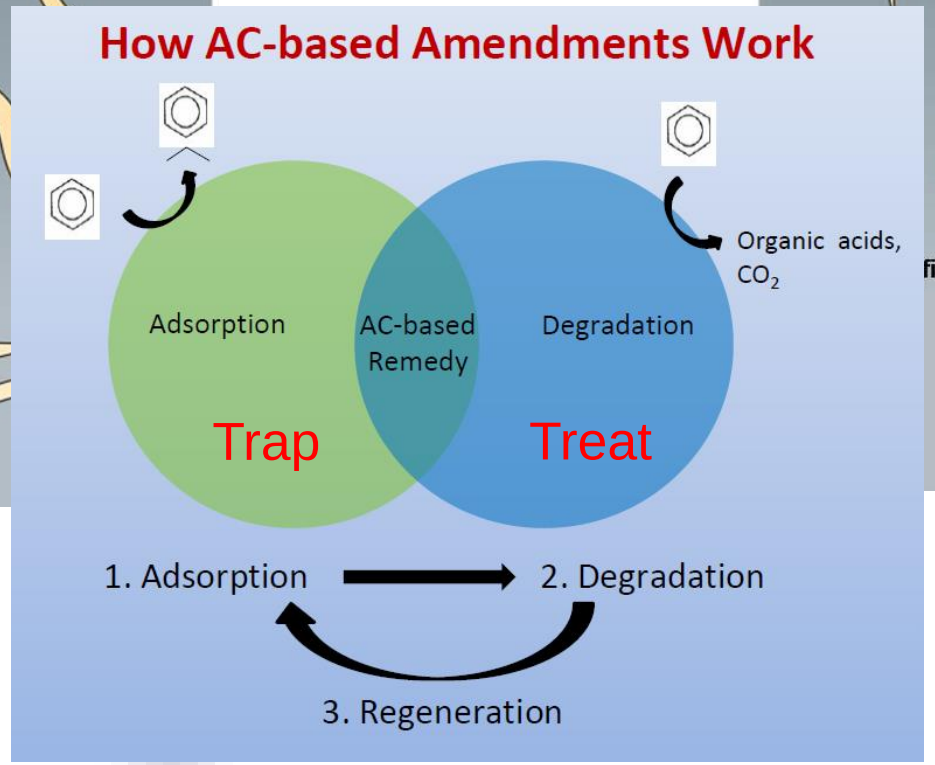


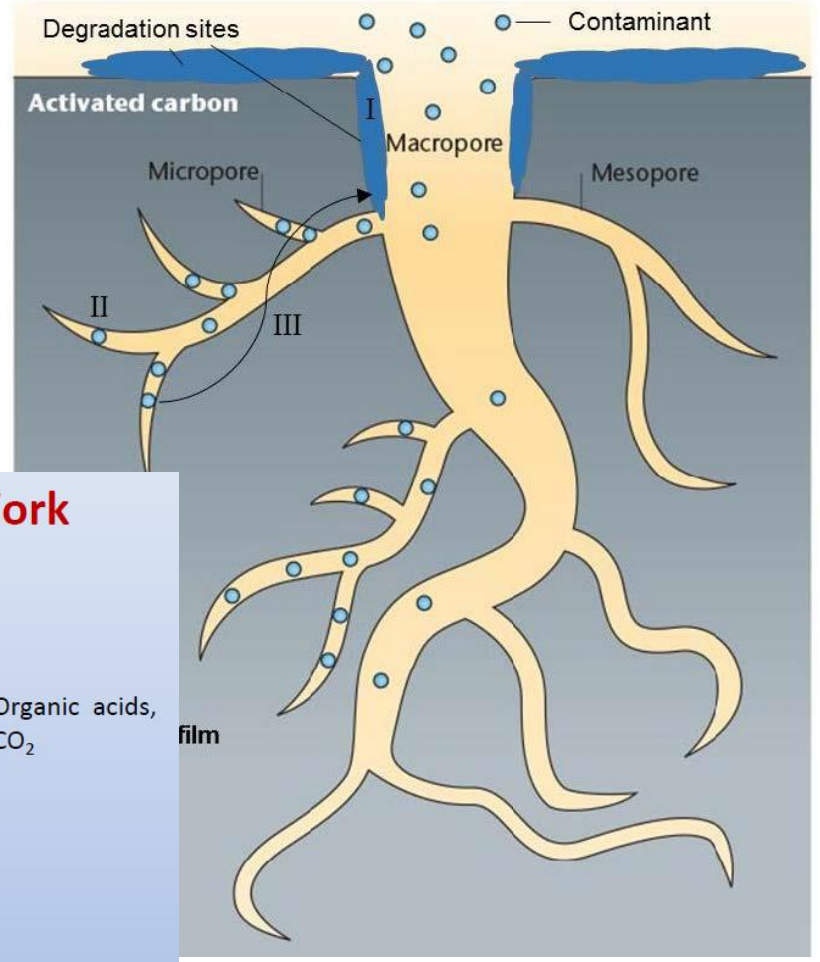
LNAPL Destruction

Trap & Treat® BOS 200+®



Trap





Treat

Trap & Treat® BOS 200+®

Treatment Mechanisms:

- BOS 200+® (PHCs) – carbon adsorption, enhanced anaerobic biodegradation and catalyzed biodegradation / co-metabolism
- Designed for LNAPL sites with high PHC soil concentrations and more recalcitrant compounds like heavier molecular weight PAHs

History:

- BOS 200+® used in the US since 2017; used in Canada since 2023

Applications:

- Source area / LNAPL remediation or PRB applications
- Placement via injection, backfilling or soil mixing

Benefits:

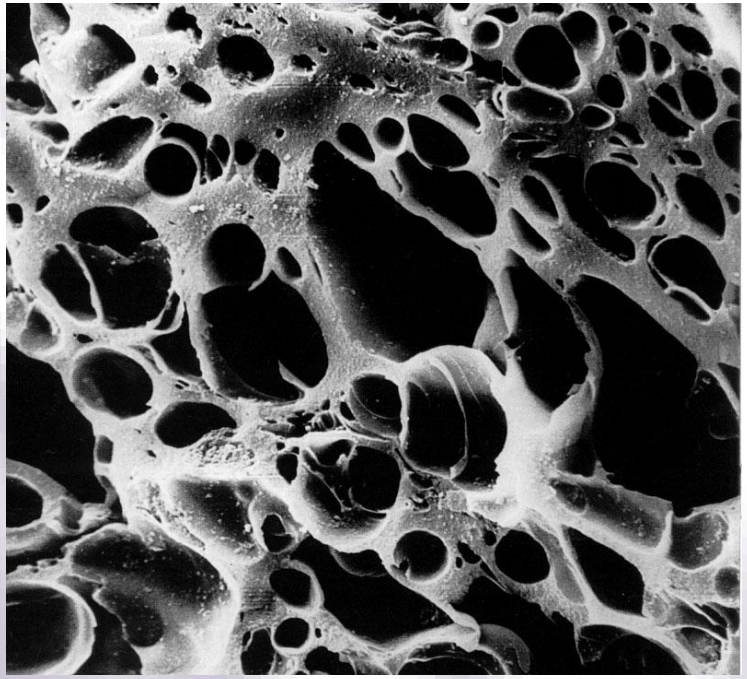
- Usually Single Application and Long-Term Solution
- Back Diffusion Control = Prevents “Rebound”
- **Overcomes contaminant mass limitations of PHCs in soil**

Trap & Treat® BOS 200+®

Do sorption limitations of AC prevent its application to LNAPL?

- The saturation adsorption capacity for PHCs on AC is widely considered to be 20 to 25% by wt.
- For BOS 200+® coal-based AC it has been **measured at 58% by wt.**
- Adsorbed PHCs, including gasoline and diesel range, are bioavailable even when located in the microporous structure of the AC.
- Biological **regeneration** of AC recovers substantial amounts **(i.e., over 90%)** of the original sorption capacity.

Trap & Treat® BOS 200+®



Do sorption limitations of AC prevent its application to LNAPL?

- Kinetic data for BOS 200+® suggests that **between 0.5 to 1 kg of PHC mass can be degraded per kg of AC per year**
- **There is no need to have enough AC in the ground to account for every kg of PHCs.**
- Biological regeneration of AC saturated with PHCs is a viable process.
- **BOS 200® coal-based AC amendment has the necessary properties coupled with a viable degradation mechanism to realistically address LNAPL impacted sites.**

LNAPL Immobilization

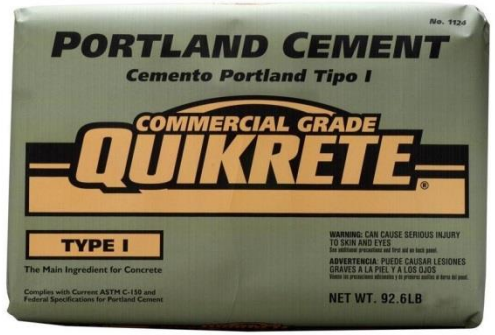
LNAPL Immobilization – Block & Adsorb©

Concept:

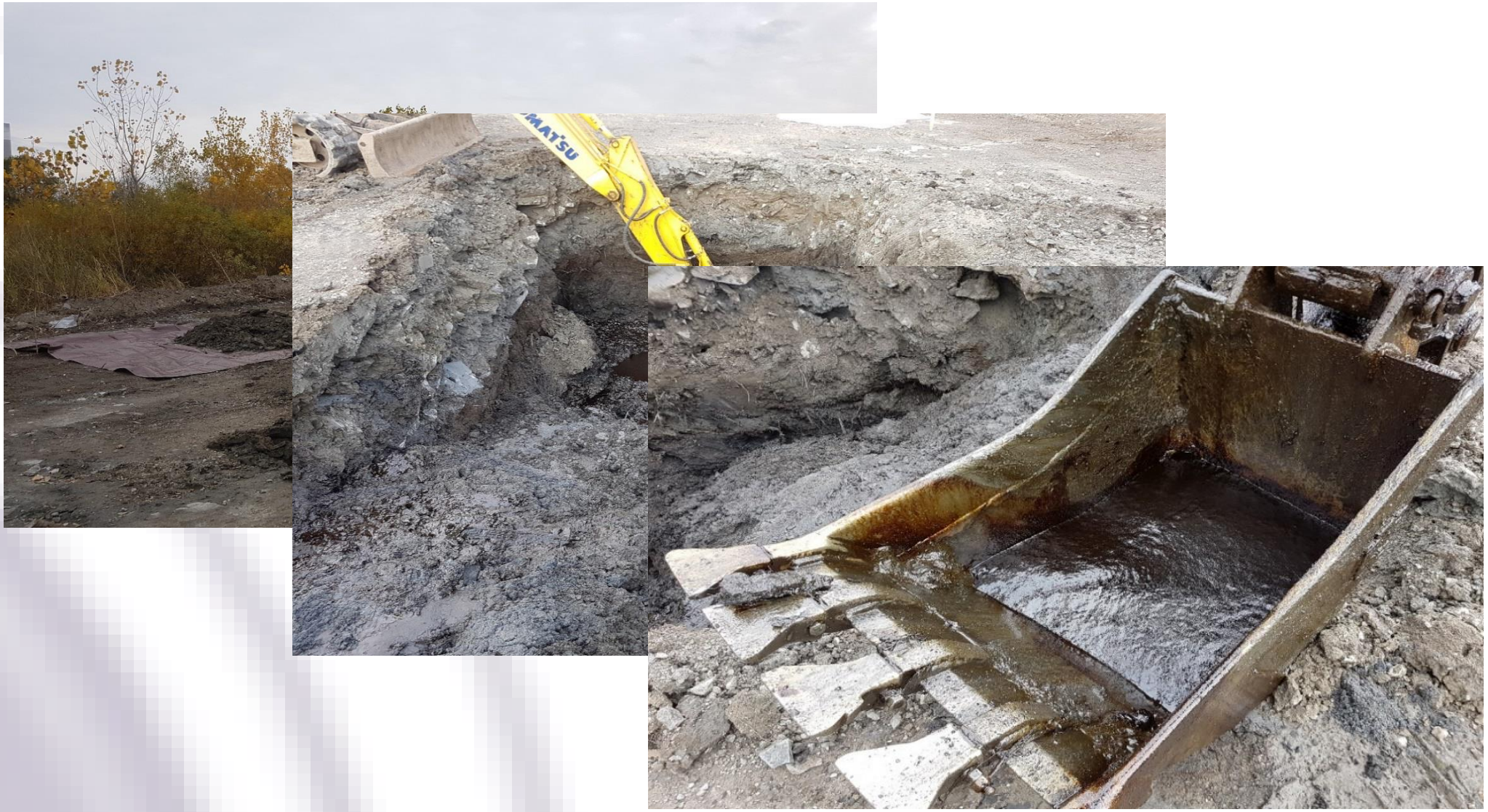
- Bind mobile LNAPL & high concentrations of PHCs in soil and groundwater
- Lower formation permeability

Block = Portland Cement (PC)

& Adsorb = Activated Carbon (GAC / PAC)



LNAPL Immobilization – Block & Adsorb©



LNAPL Immobilization – Block & Adsorb©

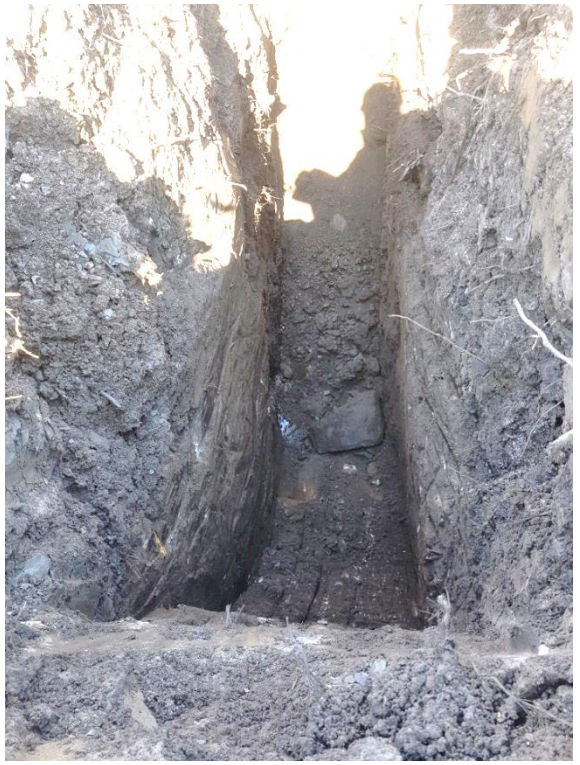
GAC addition and soil mixing

PC addition and soil mixing

LNAPL Immobilization – Block & Adsorb©

Groundwater Samples Collected: Control Plot vs Test Plot

Test Pit Excavated: Adjacent vs Within Treated Soil Mass

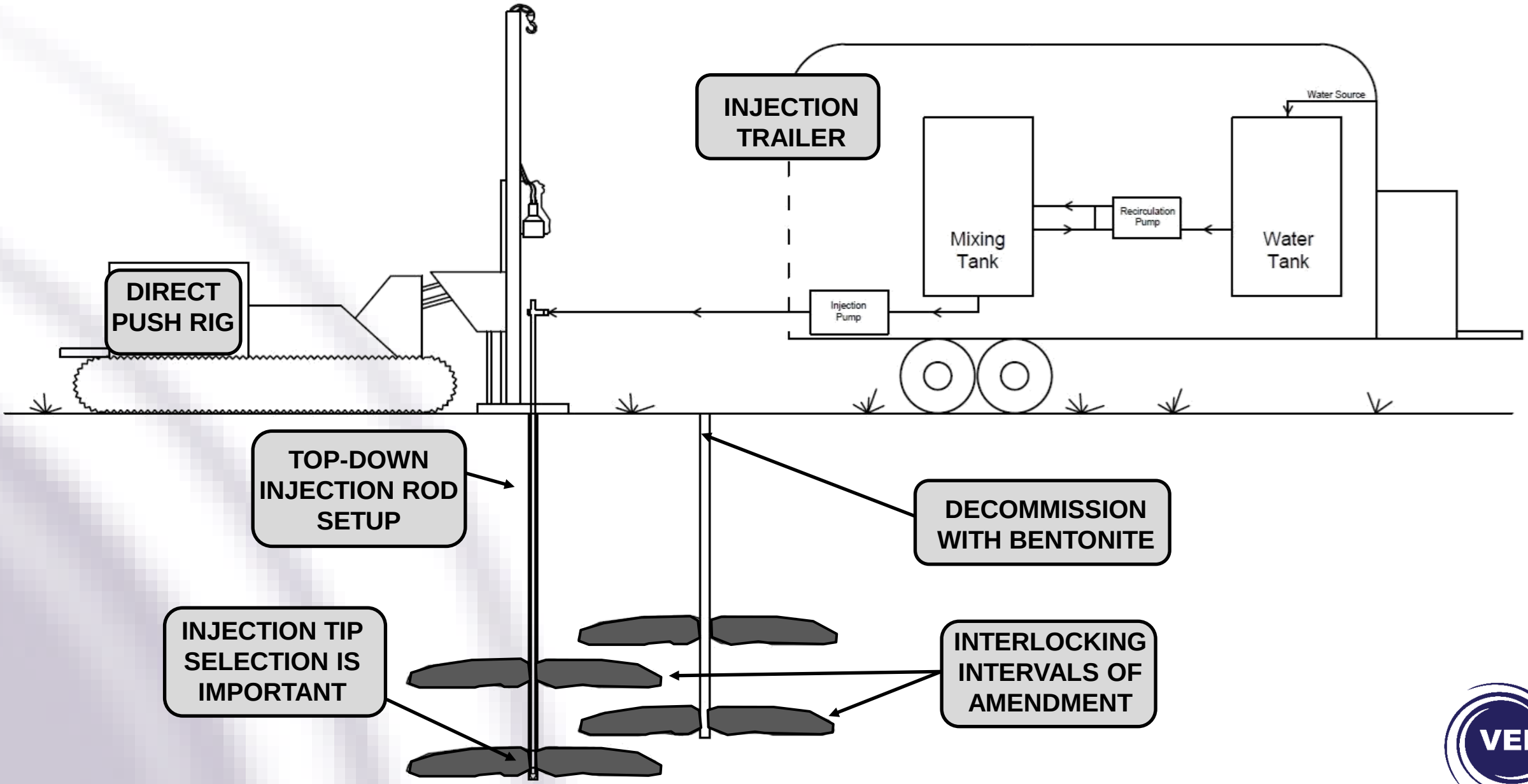


LNAPL Immobilization – Block & Adsorb©

- **Proven effective** at immobilizing LNAPL and sheens in soils in-situ
- **Combined PC and GAC is more effective than individually**
- Still “soil-like” with up to moderate concentrations of PC
- **Injection suitable** for deep soils and/or bedrock and areas not amenable to physical disturbance via direct soil mixing (e.g. under buildings)
- Also drastically reduces formation permeability and dissolved-phase PHC concentrations in groundwater
- **No excavation / extraction / wastes generated**
- **Sustainable**

Injection Approaches

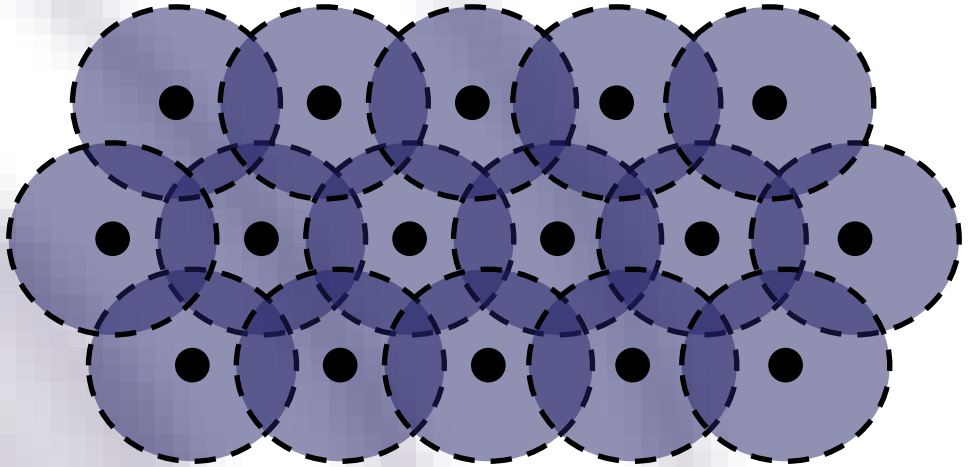
Injection Approaches – Trap & Treat®



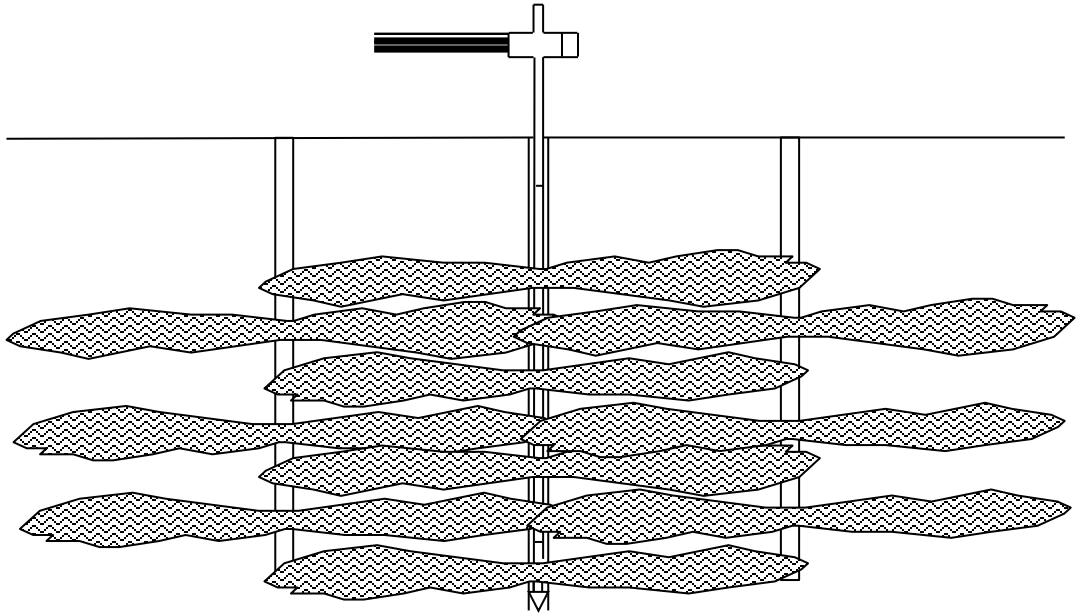
Injection Approaches – Trap & Treat®

The Goal:

- Uniform Distribution
- Intimate contact between remedial amendment and contaminants

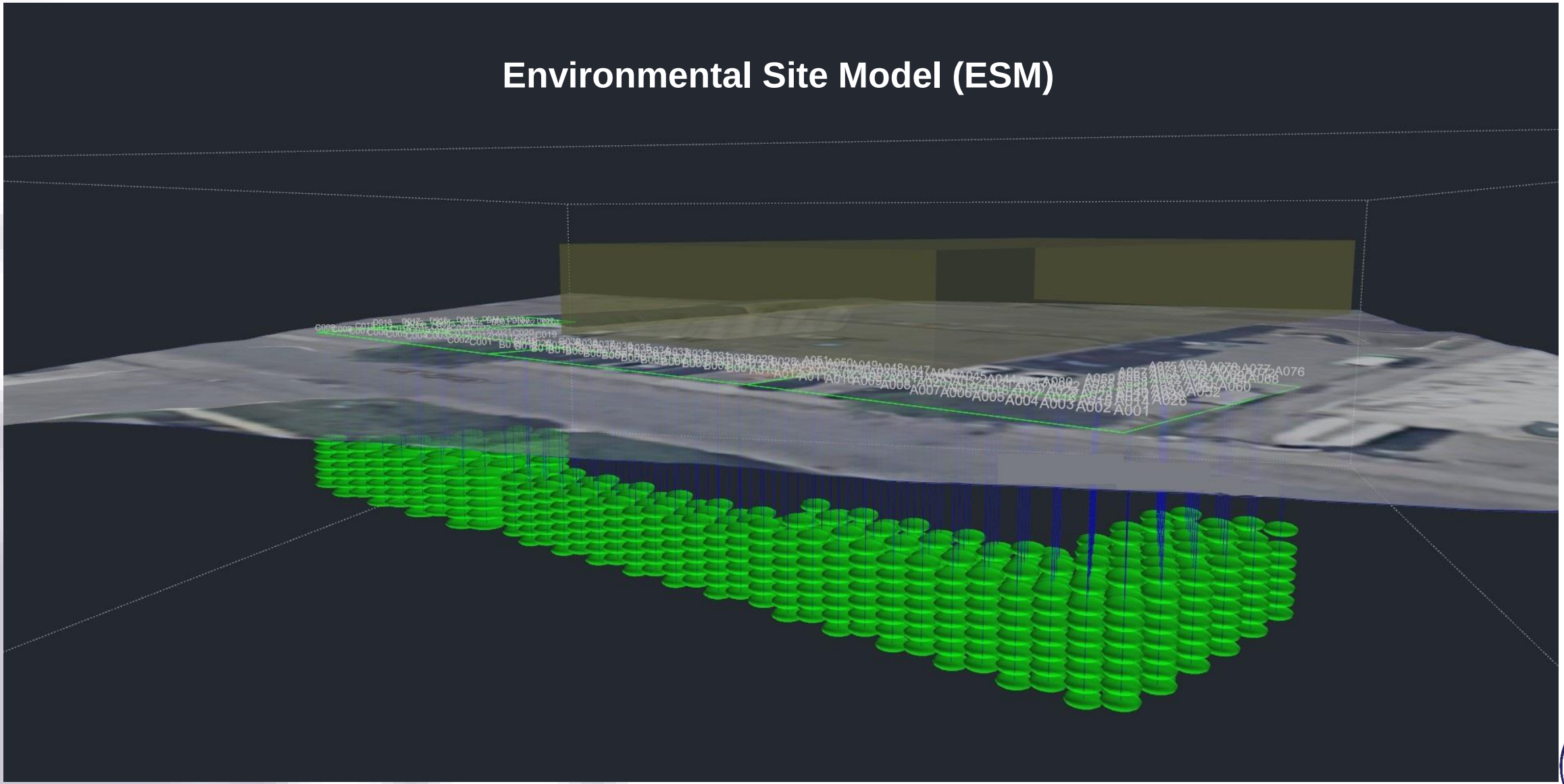


Plan View

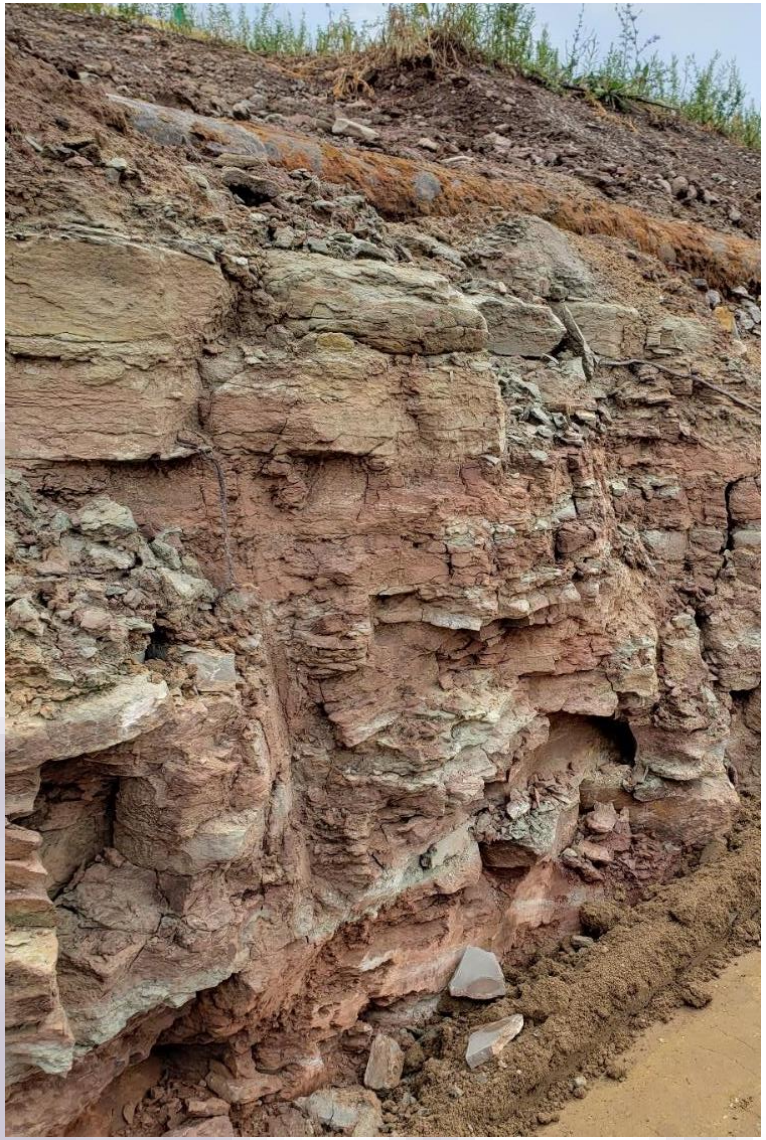


Profile View

Injection Approaches – Trap & Treat®

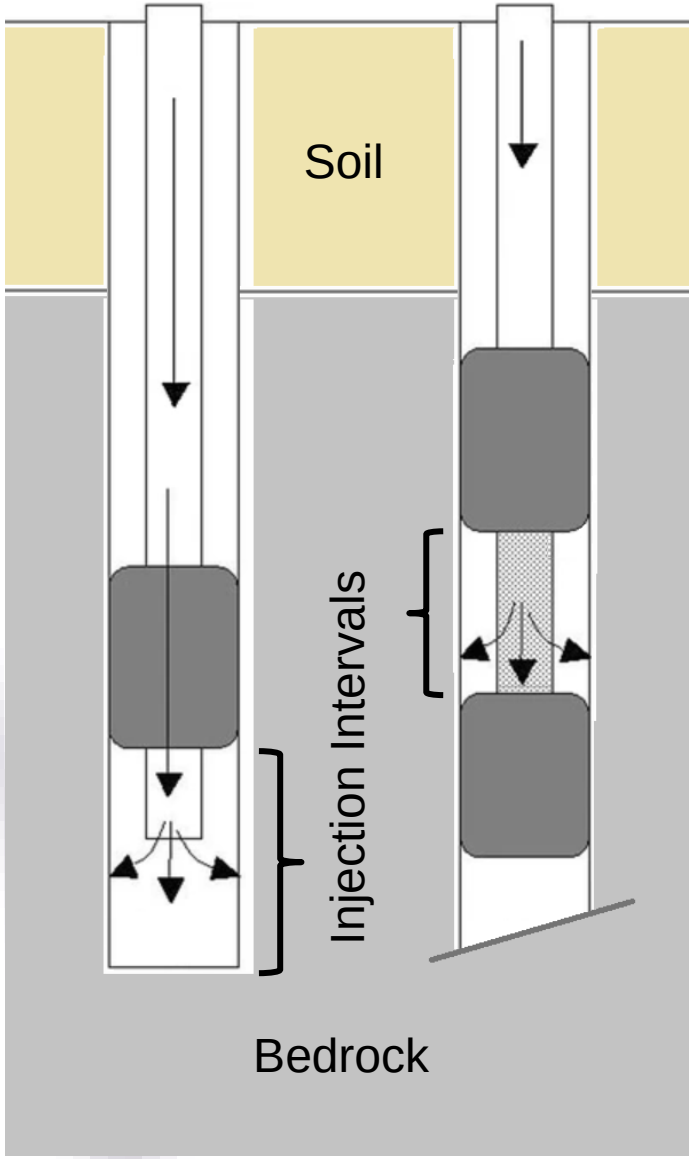


Injection Approaches – Bedrock



Bedrock injections pose special challenges for in-situ remediation

Injection Approaches – Bedrock

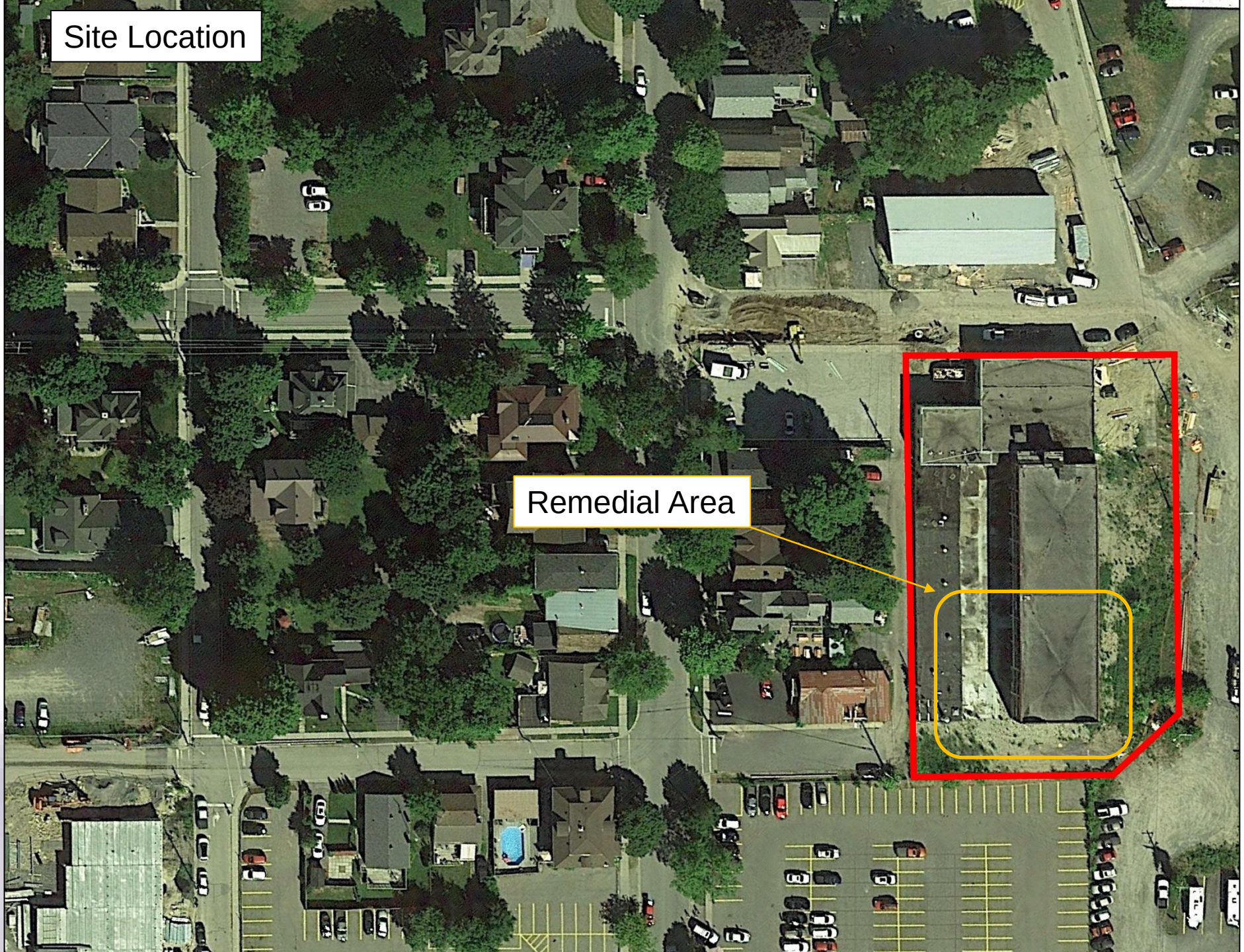


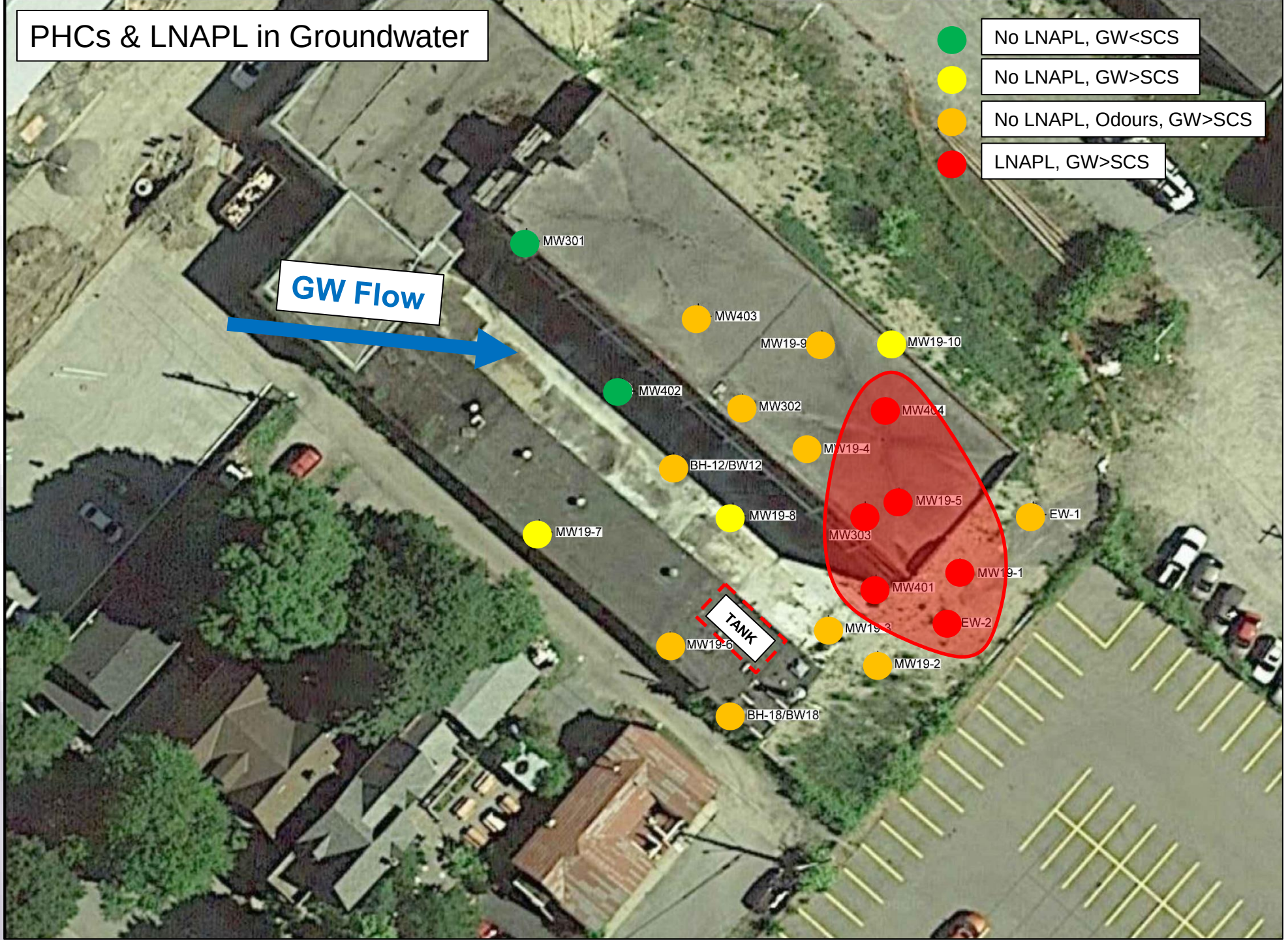
GeoTAP™ (Pre-Drill) Method

Case Study

Background – The Situation

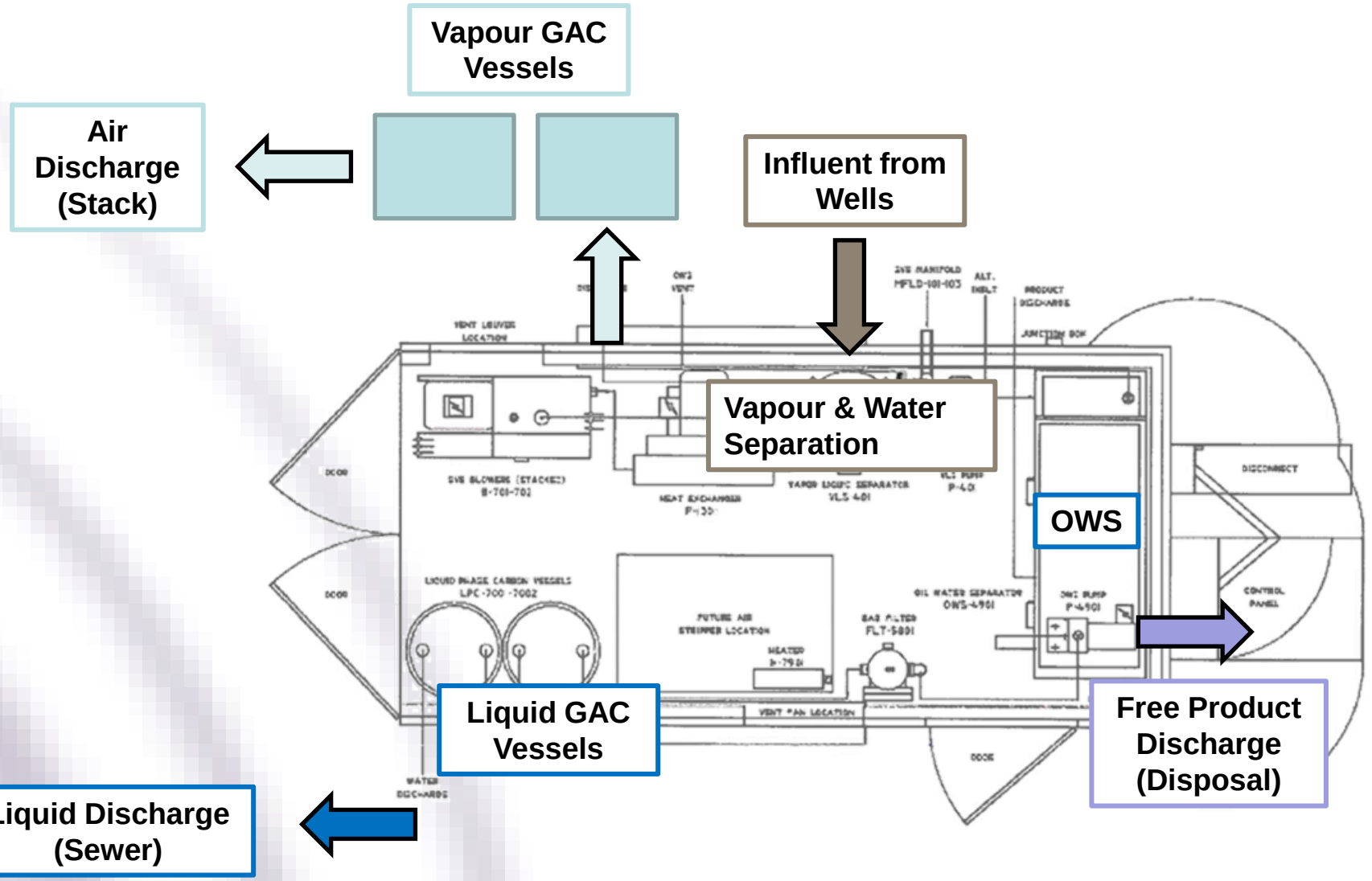
- Confidential site in Gananoque, ON
- Historical industrial operations:
  - Leaky fuel tank
  - PHCs and LNAPL primarily in bedrock groundwater
- Future redevelopment planned:
  - Residential redevelopment
  - RA and RSC process underway
  - Remediation required to address free product (LNAPL)
- Staged remedial approach:
  - Source Removal = Decommission fuel tank & removal of impacted soil
  - MPE System = Direct LNAPL removal
  - In-Situ Injection = Polishing step to address residual/remaining PHCs & LNAPL

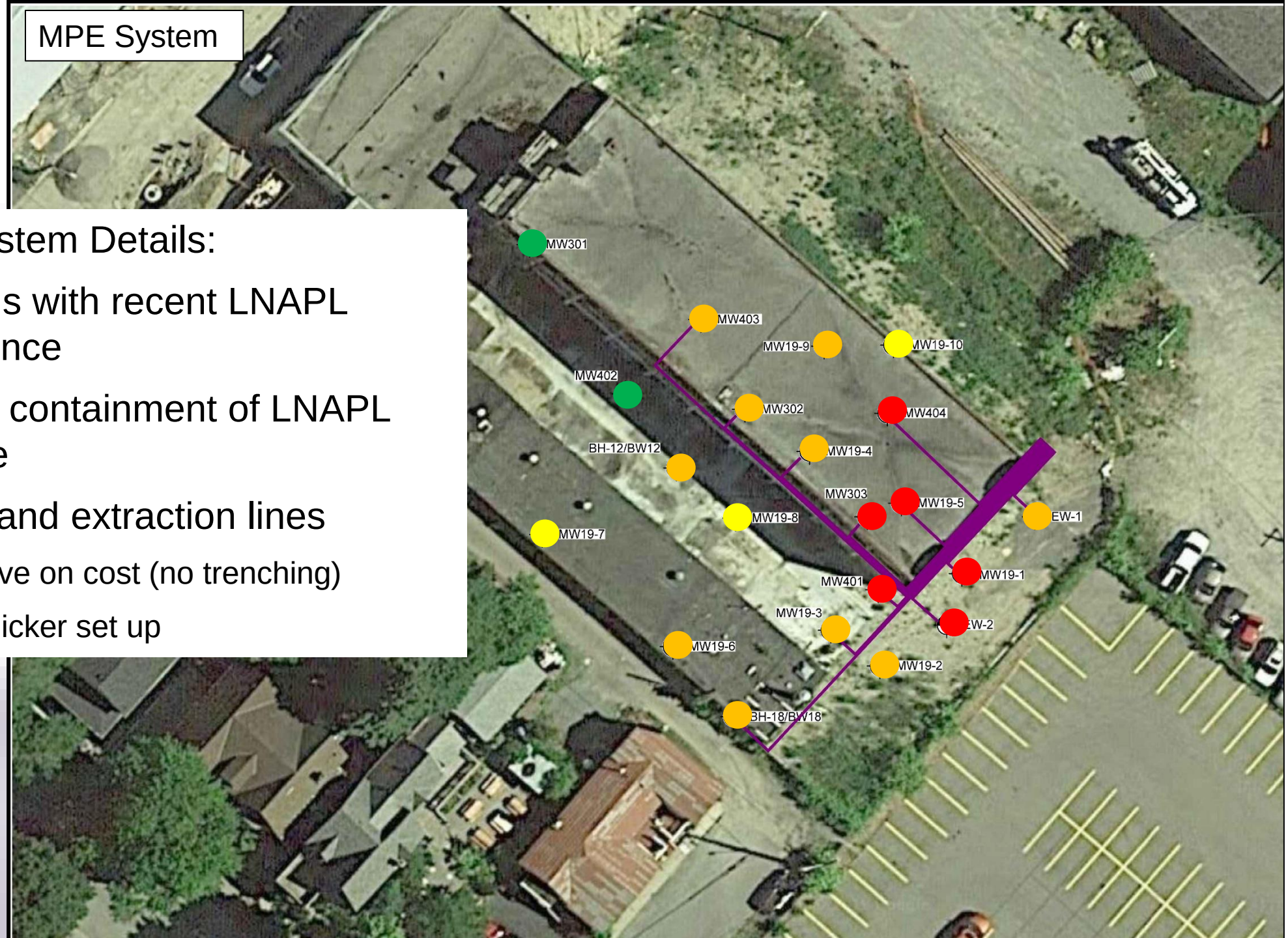

Site Location
Remedial Area


PHCs & LNAPL in Groundwater
No LNAPL, GW<SCS
No LNAPL, GW>SCS
No LNAPL, Odours, GW>SCS
LNAPL, GW>SCS
GW Flow
MW301
MW403
MW19-9
MW19-10
MW402
MW302
MW404
MW19-4
BH-12/BW12
MW19-5
MW19-8
EW-1
MW19-7
MW303
MW19-1
MW401
TANK
EW-2
MW19-3
MW19-6
MW19-2
BH-18/BW18

Multi-Phase Extraction (MPE) System

Multi-Phase Extraction (MPE) System

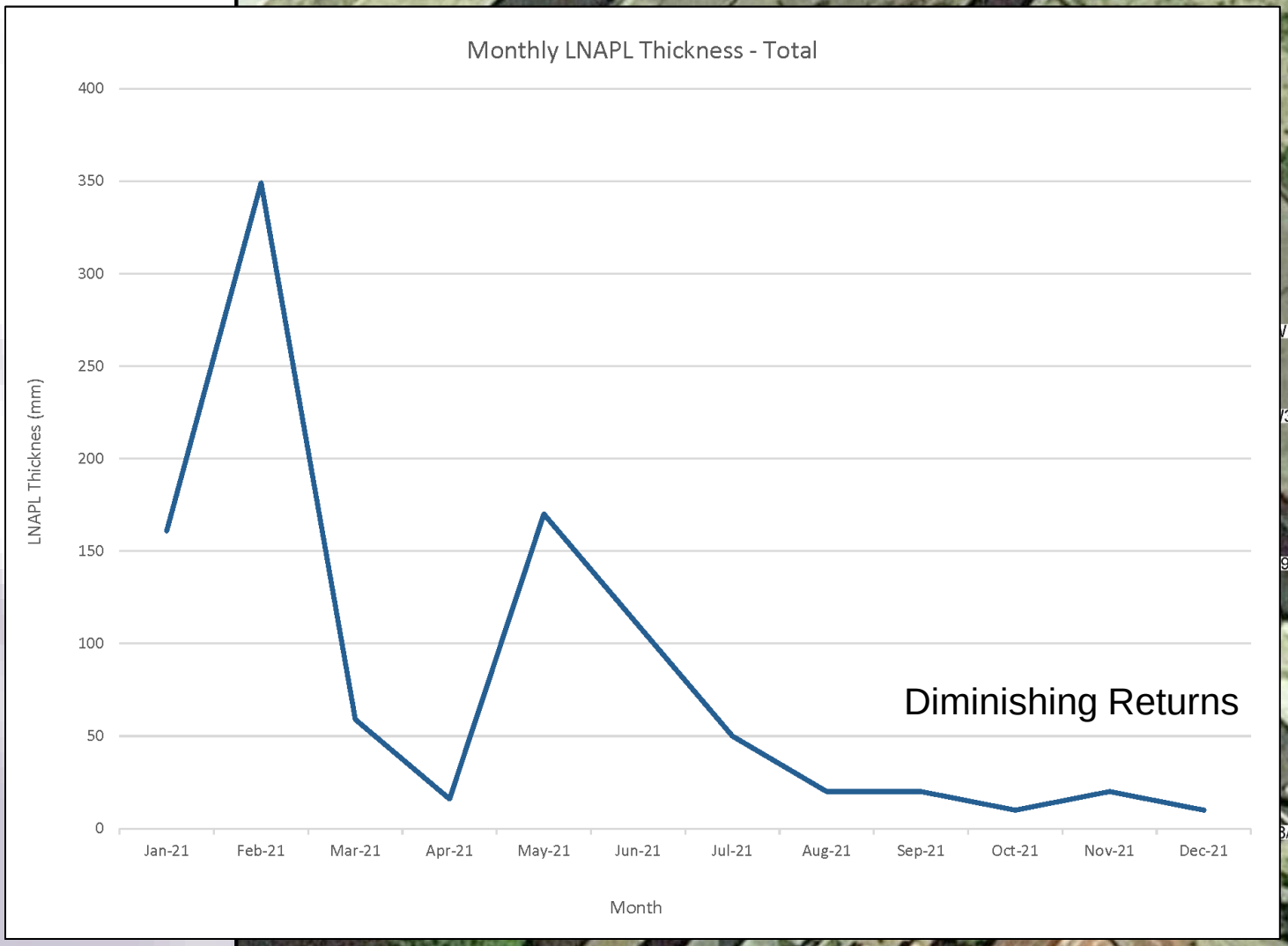




MPE System Details:

- 6 wells with recent LNAPL presence
- Good containment of LNAPL plume
- Overland extraction lines
  - Save on cost (no trenching)
  - Quicker set up

MPE System Results



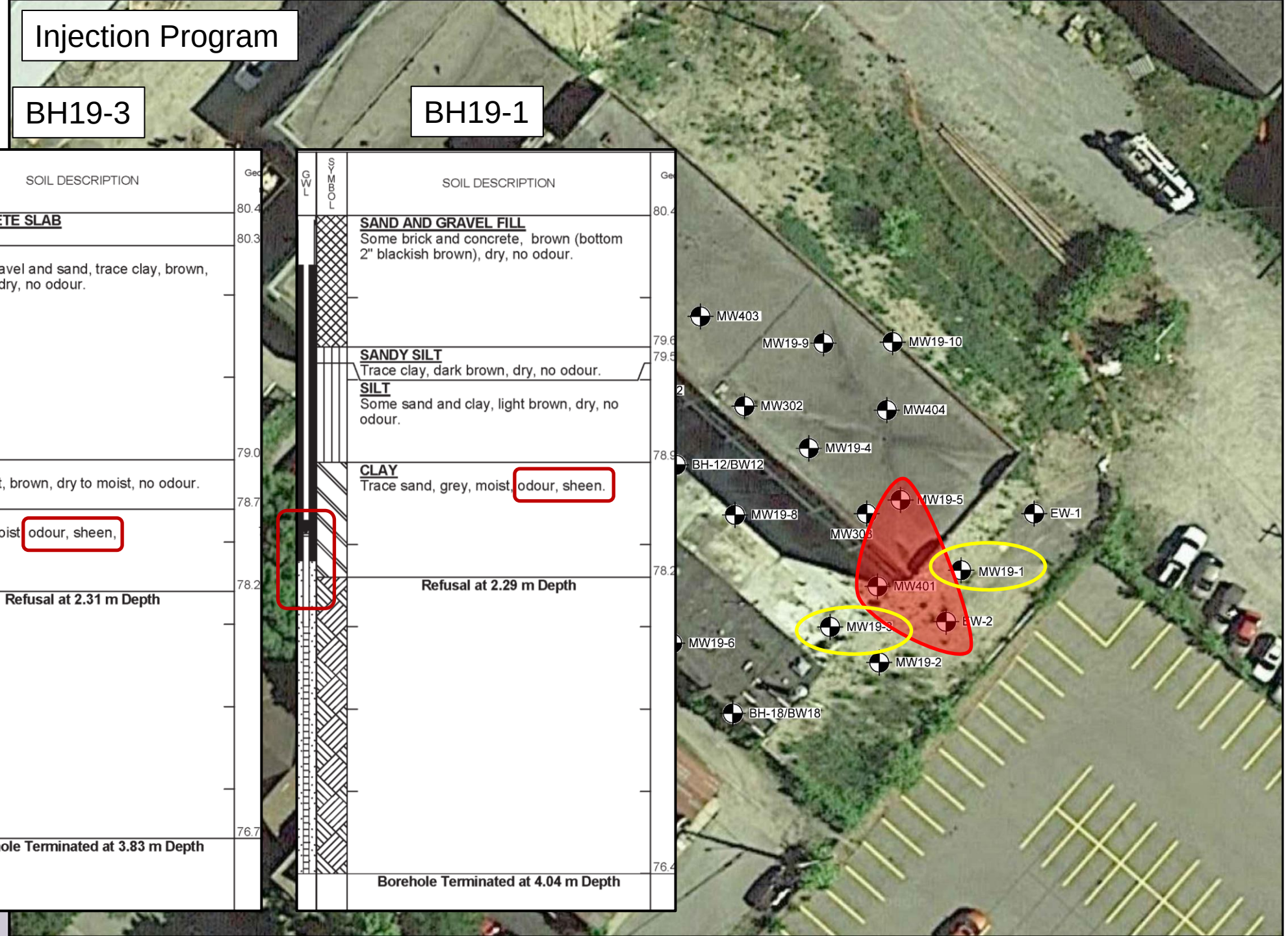
Injection Program

BH19-3

GWL	SYMBOL	SOIL DESCRIPTION	Ge
		CONCRETE SLAB	80.4
		SILT Some gravel and sand, trace clay, brown, moist to dry, no odour.	80.3
		CLAY Trace silt, brown, dry to moist, no odour.	79.0
		CLAY Grey, moist, odour, sheen,	78.7
		Refusal at 2.31 m Depth	78.2
		Borehole Terminated at 3.83 m Depth	76.7

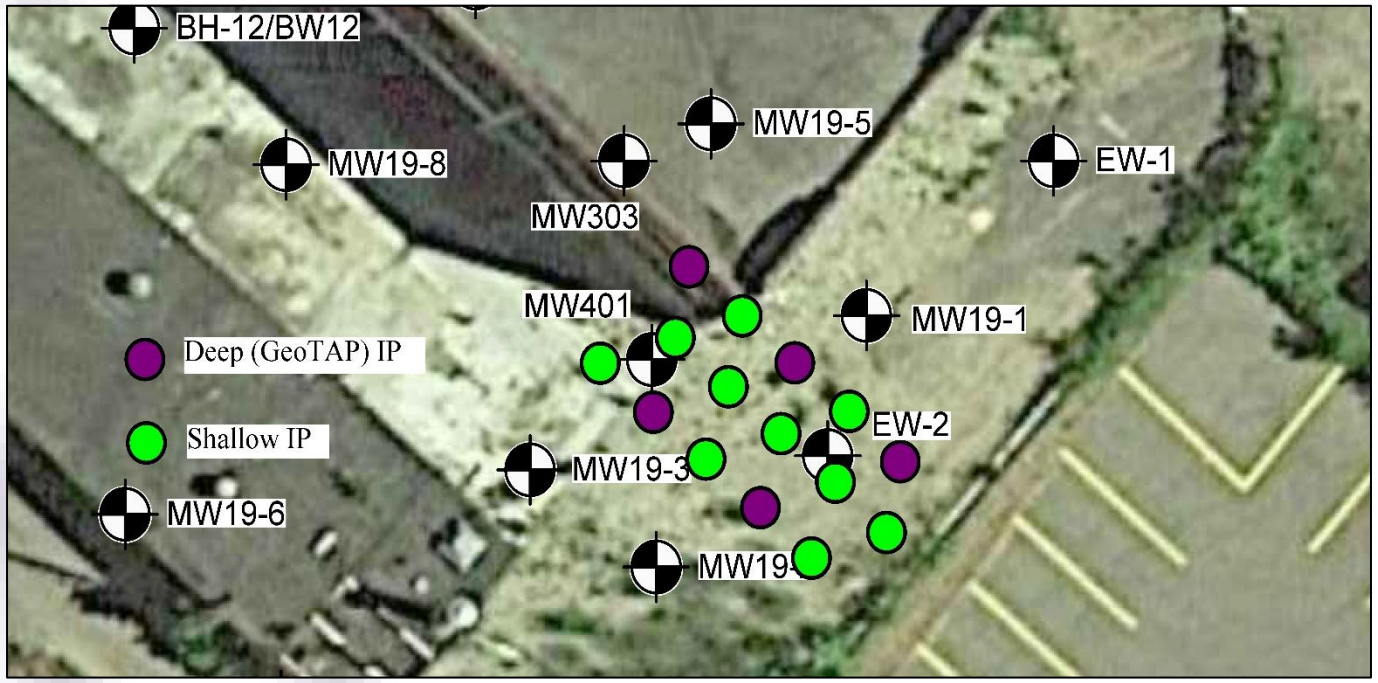
BH19-1

GWL	SYMBOL	SOIL DESCRIPTION	Ge
		SAND AND GRAVEL FILL Some brick and concrete, brown (bottom 2" blackish brown), dry, no odour.	80.4
		SANDY SILT Trace clay, dark brown, dry, no odour.	79.6 79.5
		SILT Some sand and clay, light brown, dry, no odour.	78.9
		CLAY Trace sand, grey, moist, odour, sheen.	78.2
		Refusal at 2.29 m Depth	
		Borehole Terminated at 4.04 m Depth	76.4

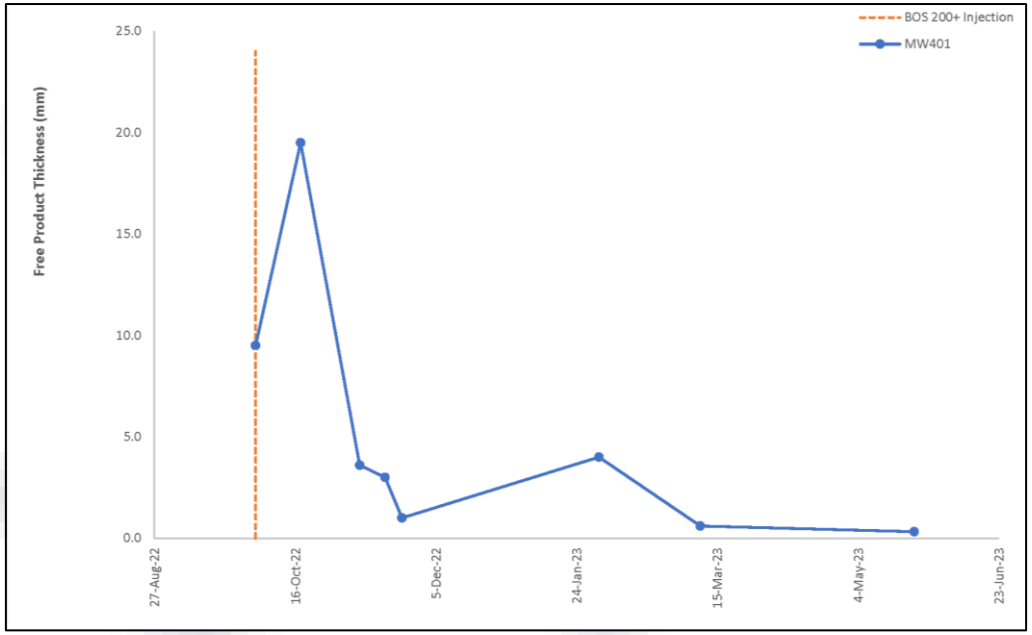


Injection Summary

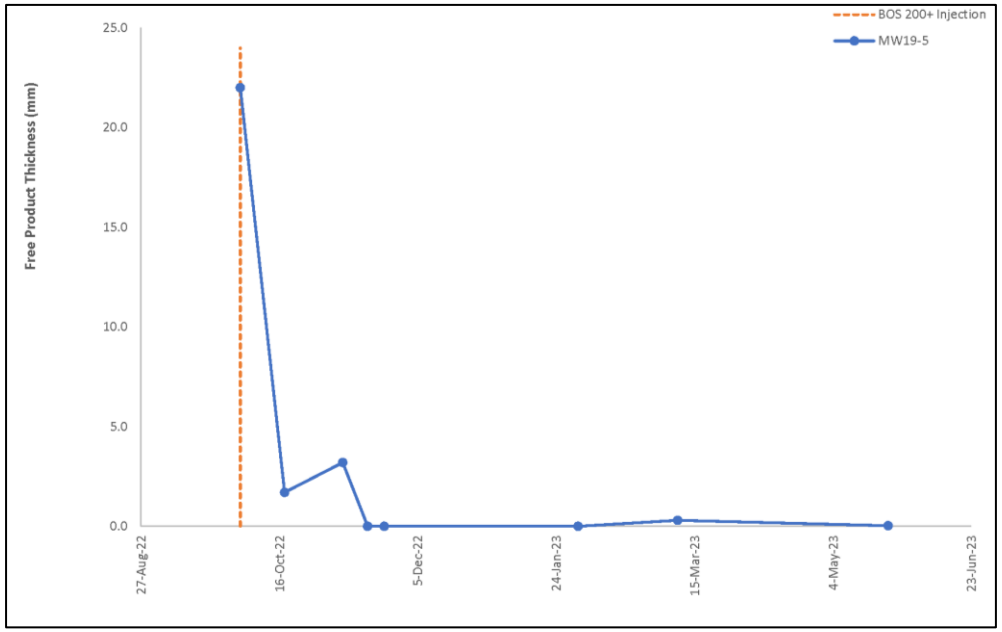
- Completed over 2 days in Fall 2022
- 5 bedrock GeoTAP™ injection points (IPs)
- 10 overburden direct-push IPs
- 15 IPs in total to target “Hot Spot” area
- Injected 2,200 kg BOS 200+® in 4,000 L



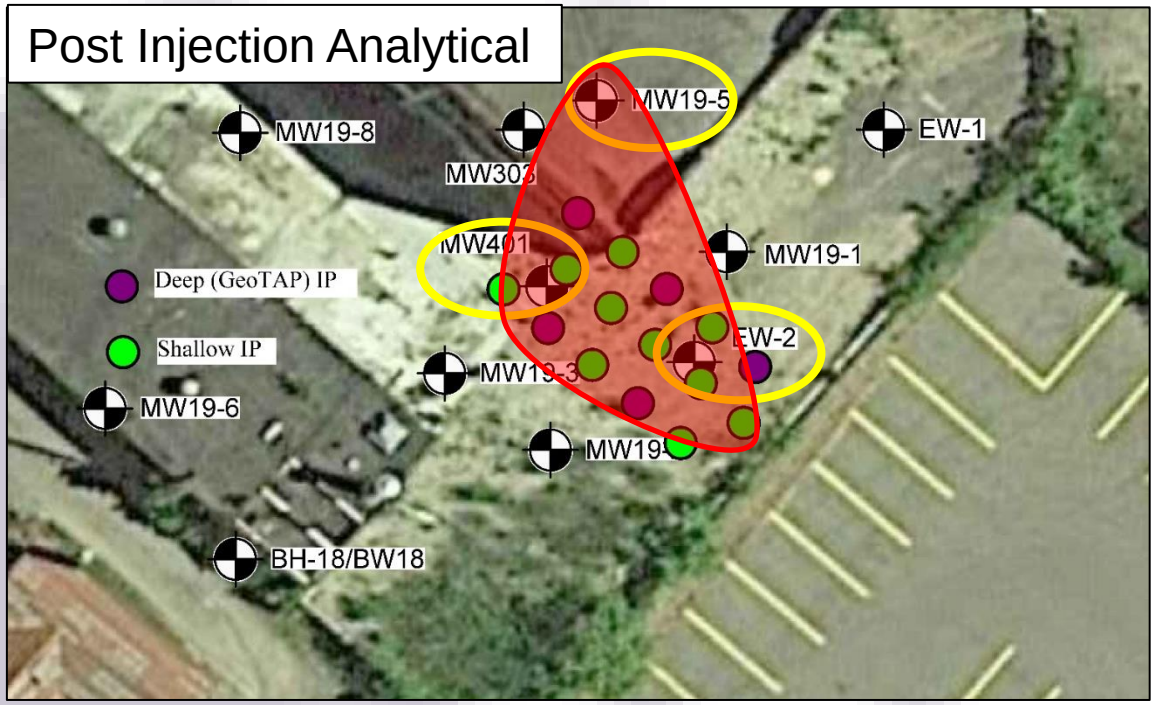
MW401



MW19-5



Post Injection Analytical



EW-2

Success!
8 months
after Injection

Case Study Wrap-Up

Remediation of Bedrock with LNAPL:

- UST Removal:
  - Source removal of leaky UST
- MPE System:
  - Implemented for a period of 12 months
  - Removal of majority (~75%) of the LNAPL volume
- Trap & Treat® BOS 200+® Injection:
  - Implemented GeoTAP™ method to allow in-situ injection into fractured bedrock and overburden bedrock interface
  - Amendment selected to destroy LNAPL, control migration and prevent back diffusion of PHCs
  - Sustained treatment in LNAPL

Closing Thoughts

Closing Thoughts

- **Successful RMMs for LNAPL sites start with a comprehensive CSM**
  - LIF can assist in providing more detail delineation of plume
  - RDC sampling and pro bono lab testing for Trap & Treat® BOS 200+®
- **LNAPL Destruction:**
  - Trap & Treat® BOS 200+® overcomes mass limitations of AC sorption alone
  - Kinetic treatment (degradation) of 0.5 to 1.0 kg of PHCs per kg of AC per year
- **LNAPL Immobilization:**
  - Block & Adsorb©: combined PC and GAC more effective than either individually
  - Proven effective at immobilizing LNAPL and sheens in soils in-situ
- **Injection Approaches:**
  - Application methods available for overburden, bedrock and transition zones
- **There are ways to effectively degrade &/or immobilize LNAPL in-situ to allow easier approval of RAs**

Questions?

Thank You for
Your Time!

Kevin French

VEI Contracting Inc.

(519) 404-5442

kevinf@vei.ca

www.vei.ca &
www.vertexenvironmental.ca