



# A MULTIDISCIPLINARY APPROACH TO REMEDiate TETRACHLOROETHYLENE IMPACTS BENEATH A BUILDING

REMTECH EAST 2022

Prepared by: Kerry-Anne Pumphrey,  
M.Sc., EP, P.Geo., QP<sub>ESA</sub>

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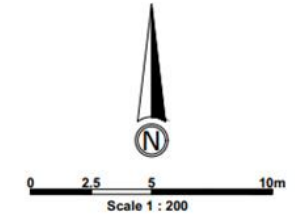
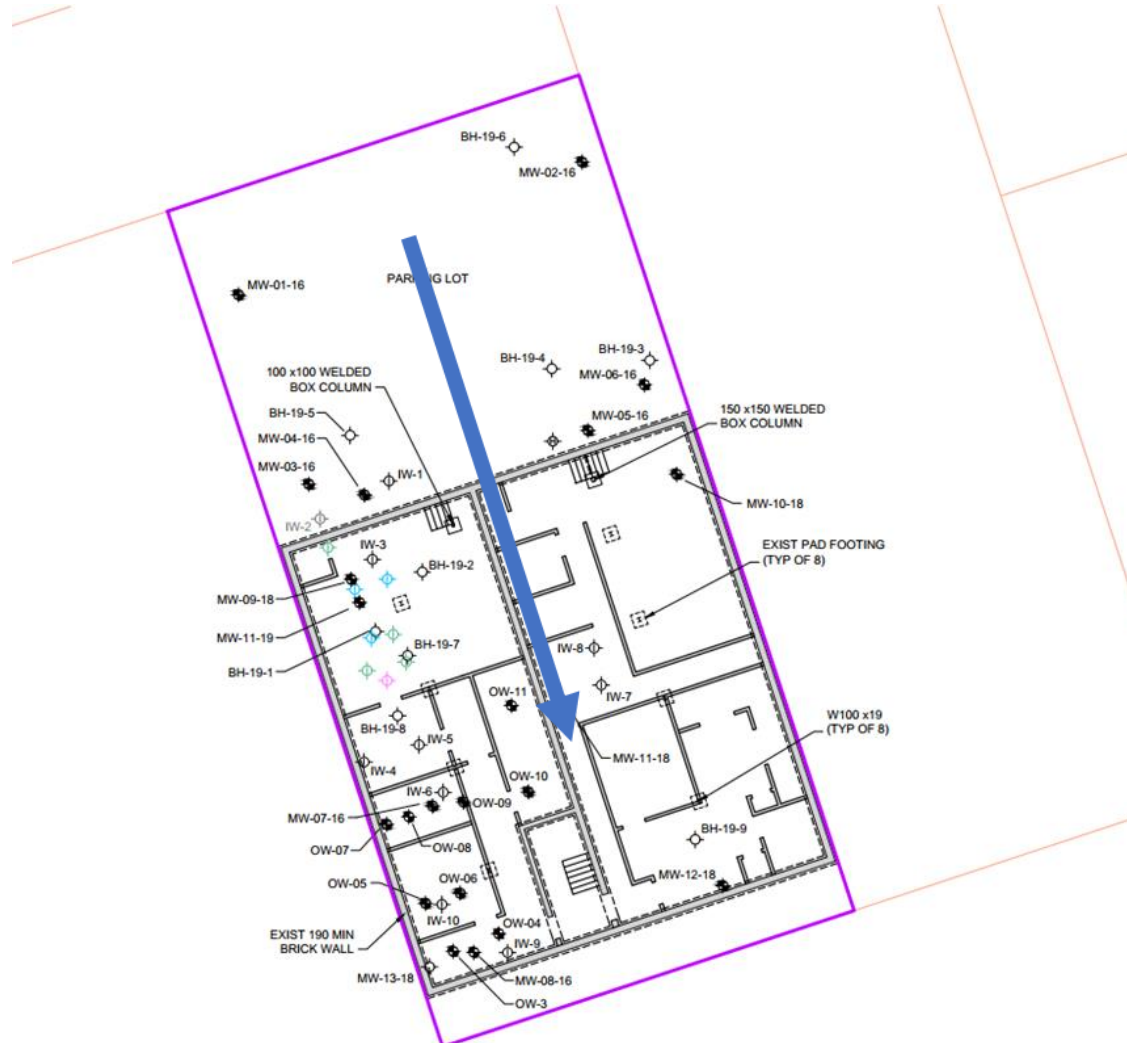


**BlueFrog**  
Environmental Consulting Inc.

# Introduction



# Site Location



## LEGEND

- SITE BOUNDARY
- EXISTING BUILDING FOOTPRINT
- PROPERTY BOUNDARY
- BOREHOLE
  - BH-19-1 TO BH-19-9 INSTALLED BY BLUEFROG (2019)
  - MW-13-18 (2018)
- OBSERVATION WELL
  - OW-3 TO OW-11 (NOT IN USE)
- MONITORING WELL
  - MW-07-18 TO MW-12-18 (2018)
  - MW-01-16 TO MW-06-16 (2016)
  - MW11-19 INSTALLED BY BLUEFROG (2019)
- INJECTION WELL
  - INSTALLED BY BLUEFROG (2019)
- INJECTION WELL (MISSING/DESTROYED)
- APPROXIMATE TEMPORARY ZVI INJECTION POINT
  - JULY 2019
  - AUGUST 2019
  - JULY & AUGUST 2019
- HORIZONTAL INJECTION WELL
  - INSTALLED BY BLUEFROG (2019)

## NOTES:

LOCATIONS ARE APPROXIMATE.

# The Problem



# The Solution.....



- Impacts are predominantly beneath the building
- Client wanted flexibility in order to:
  - Manage timing of remediation activities to match business finances
  - Reduce disturbance to tenants
  - Address potential off-site impacts
- The Plan -> ISCR
  - Direct injection of ZVI around the source zone
  - EHC-L ,emulsified soy lecithin substrate and soluble organo-iron powder ( $\text{Fe}^{2+}$ ), injected into dedicated injection wells throughout the plume zone

# Remedial Injection Activities: ZVI Injection #1



Mixing ZVI Slurry



Geoprobe 420M Direct Injection



ZVI Daylighting

# Remedial Injection Activities: EHC- L Injection



- Injected EHC-L into the dedicated injection wells one week after first round of ZVI direct injections
- 50% of the intended quantity of EHC-L injected
- Challenges overcoming pressure head in the injection wells
- Seals above the well screens were not holding
- Well seals were reinforced

# Remedial Injection Activities: ZVI Injection #2



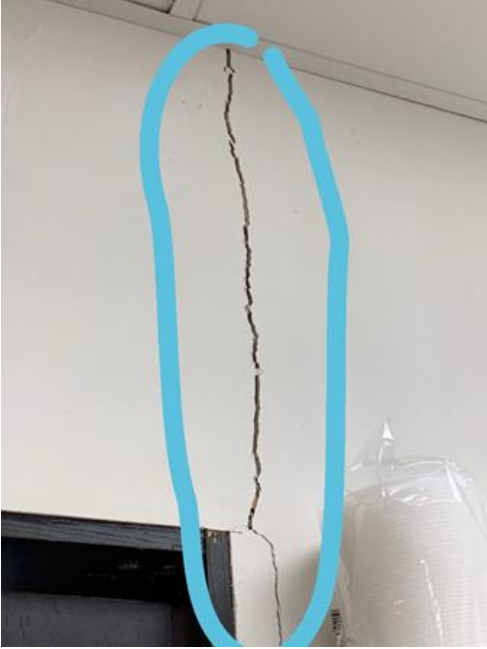
## Second Attempt to Inject ZVI

- Up to 41% of the total intended quantity was injected
- Slurry was denser than the first round to prevent daylighting
- Daylighting still occurred
- Cracks were observed in the drywall on the first floor above the injection area
- All work stopped and tenanted areas closed





# Crack Investigation

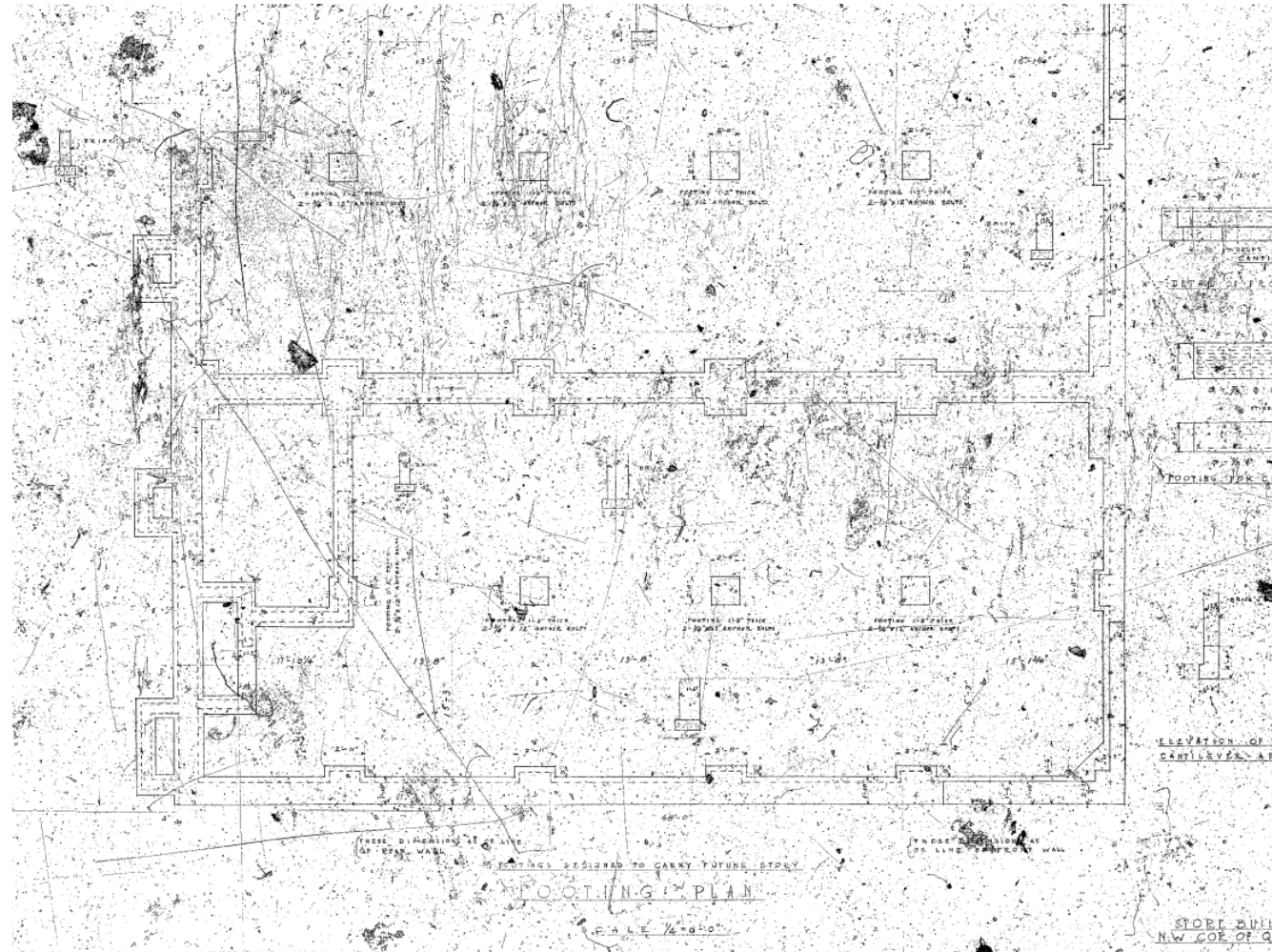


# Crack Investigation: Engineers and Building Plans (oh my)

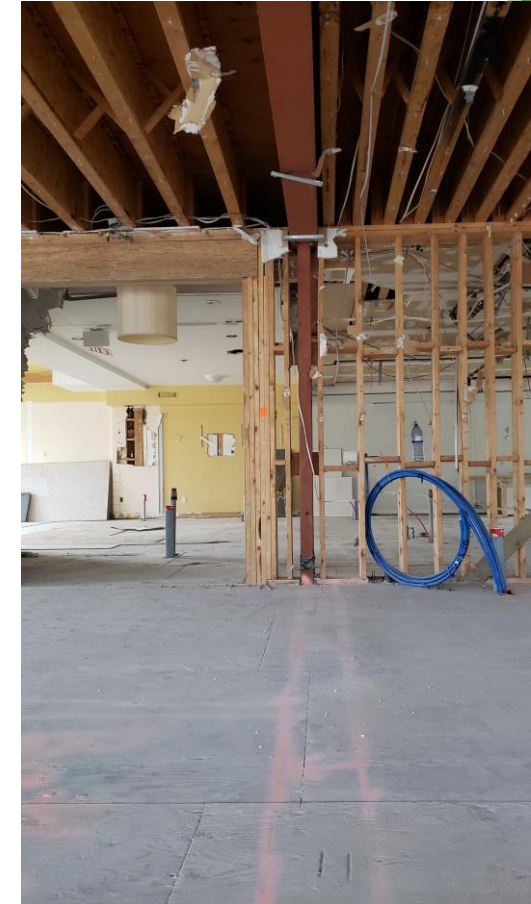


- Structural engineers assessed structural stability
  - Cracking was surficial (relief)
- Building plans were obtained from city archives
  - Foundations: Column and Strip Footings
  - Column above which dry wall cracking occurred was modified from its original design.

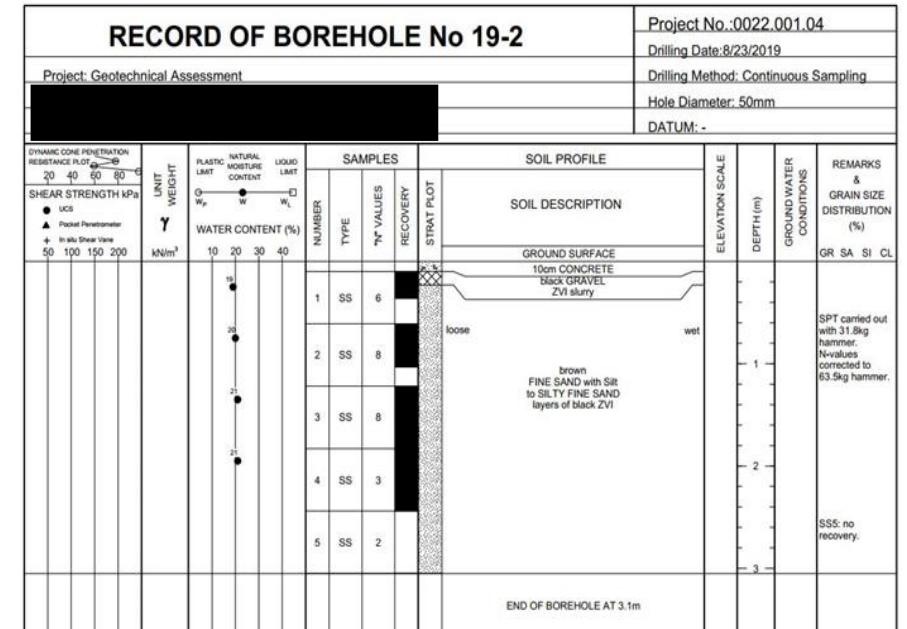
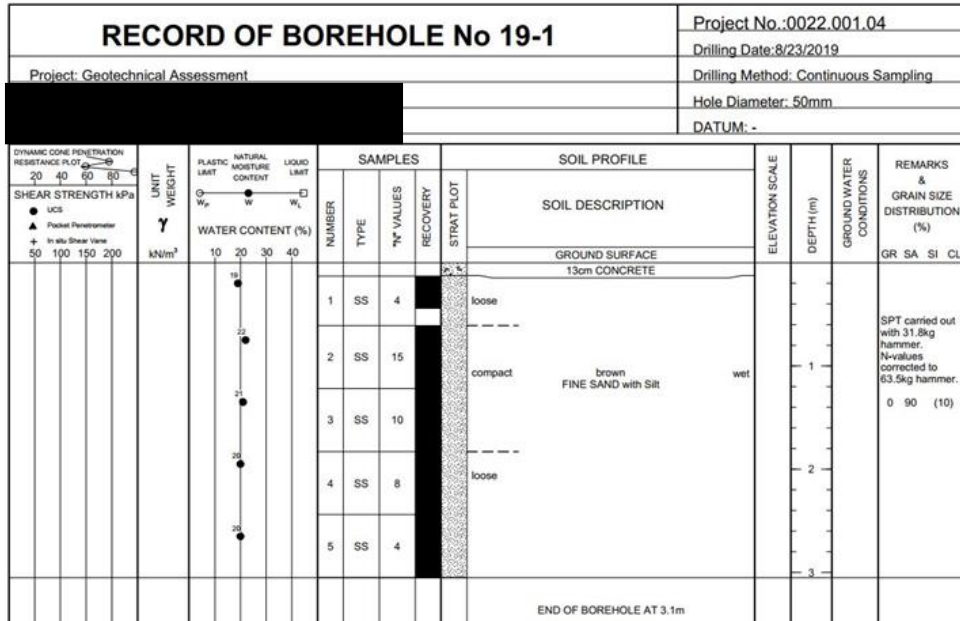
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# Geotechnical Assessment – HOW?



# Geotechnical Assessment Findings



- Depth to groundwater beneath the floor slab ranged: 0.3 to 0.6 m
- Poor drainage beneath the floor slab
- Soil compactness by SPT (no other equipment available would fit)
  - Loose soils ( $N < 10$ ) with some compact zones ( $N \leq 17$ ) between loose soils
- Soil has poor bearing capacity (factored ULS 70 to 115 kPa)
- Column and strip footings are 0.6 m wide
  - Footing beneath affected column is less than 0.2 m wide if present at all
- Shallow embedment of footings

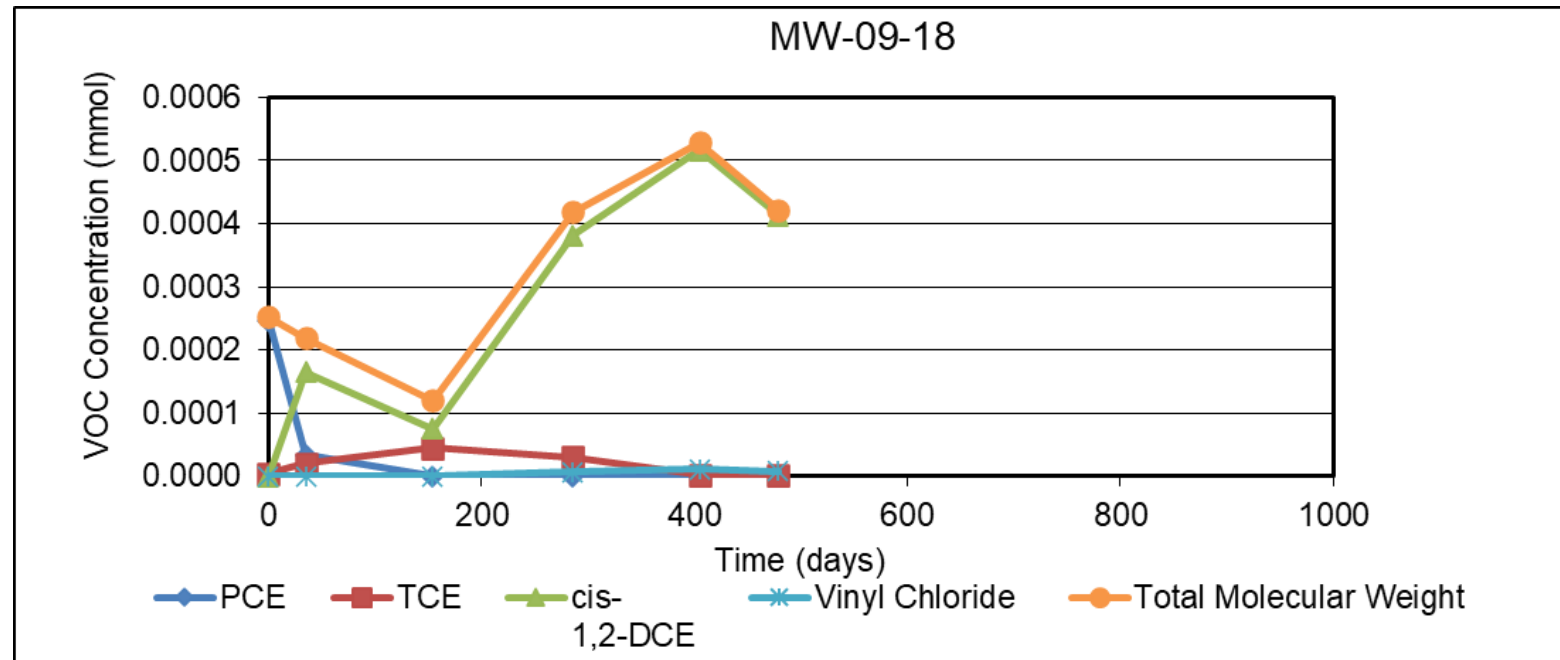
# The MIA Footing



# Plan to Move Forward



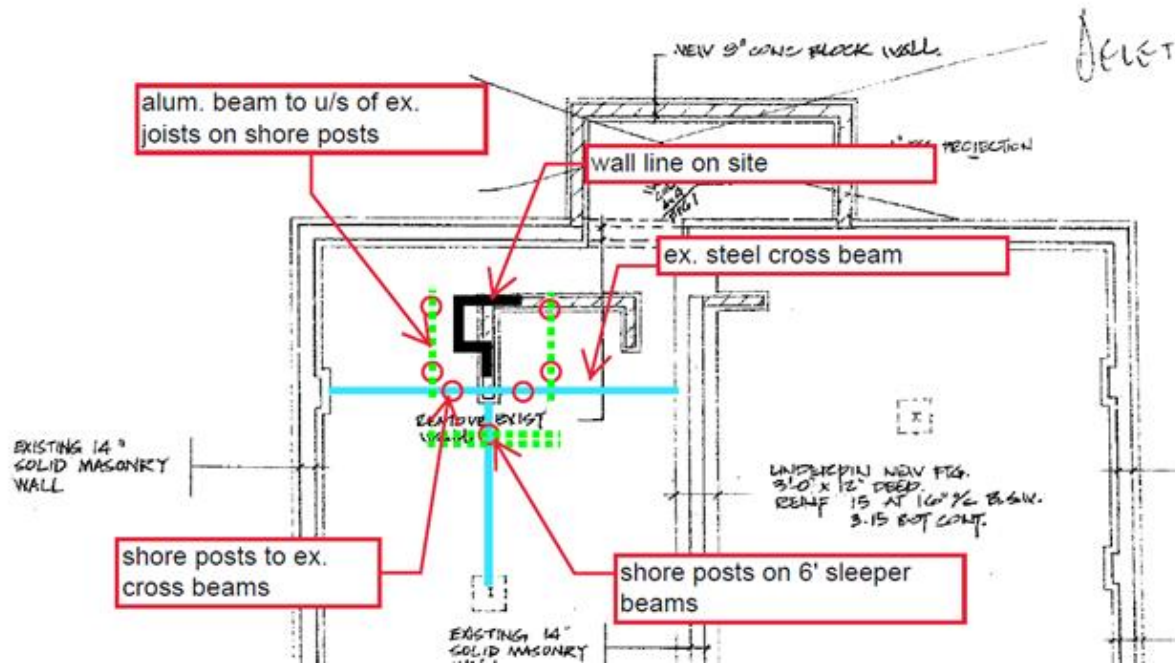
- Performance groundwater sampling indicated a reduction in concentrations



- Geotechnical engineer assisted us with modifying our injection method



# Plan to Move Forward: Structural Support



Structural Engineer Design



The Executed Design

# No Pressure/Gravity Feed EHC-L Injections



- EHC-L can be injected under gravity feed
- First attempt, two months after the ZVI injection was a success
- Subsequent attempt was not successful (not all of the EHC-L injected)
- Maple syrup method tried – got more EHC-L but not quite enough



# Can We Please Use Some Pressure?



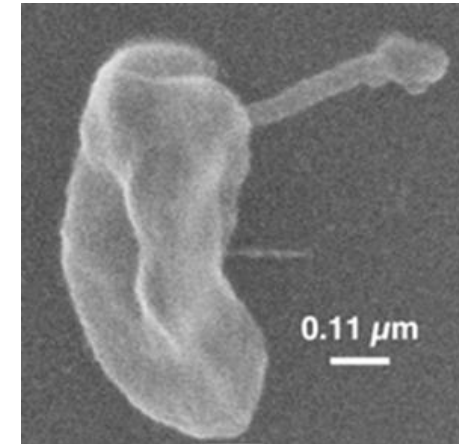
# Using Pressure – Install Crack Monitors



# Modified Injections

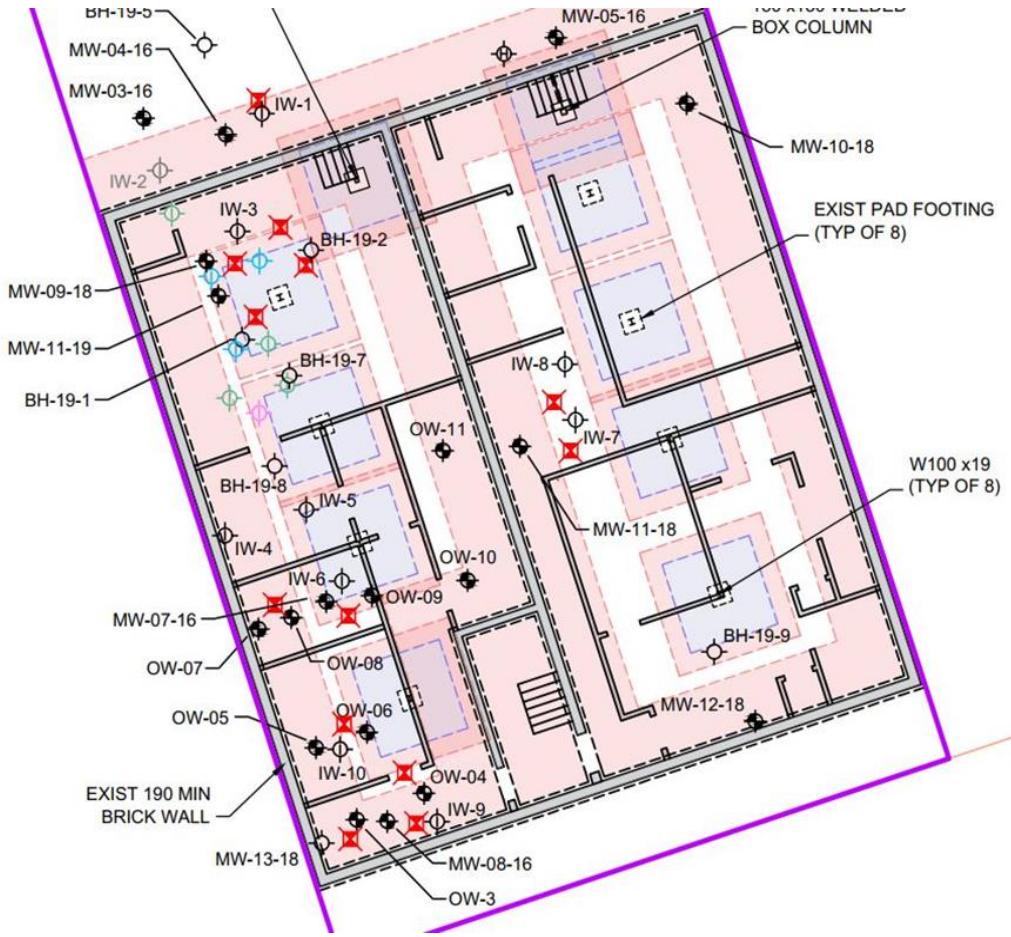


- EHC-L was doing okay
- Needed to give the dechlorination process a boost
- Bring in the bugs – *Dehalococcoides* sp. or DHC in the form of KB-1 (SiREM)
- Tried injecting into the wells, still difficult
- **Solution: direct injection into the ground starting at 3 m below the floor = SUCCESS**



SEM images by the late Dr. Robert P. Apkarian and Jeanette Taylor, at the Integrated Microscopy & Microanalytical Facility (IM&MF), Department of Chemistry, Emory University, Atlanta, GA

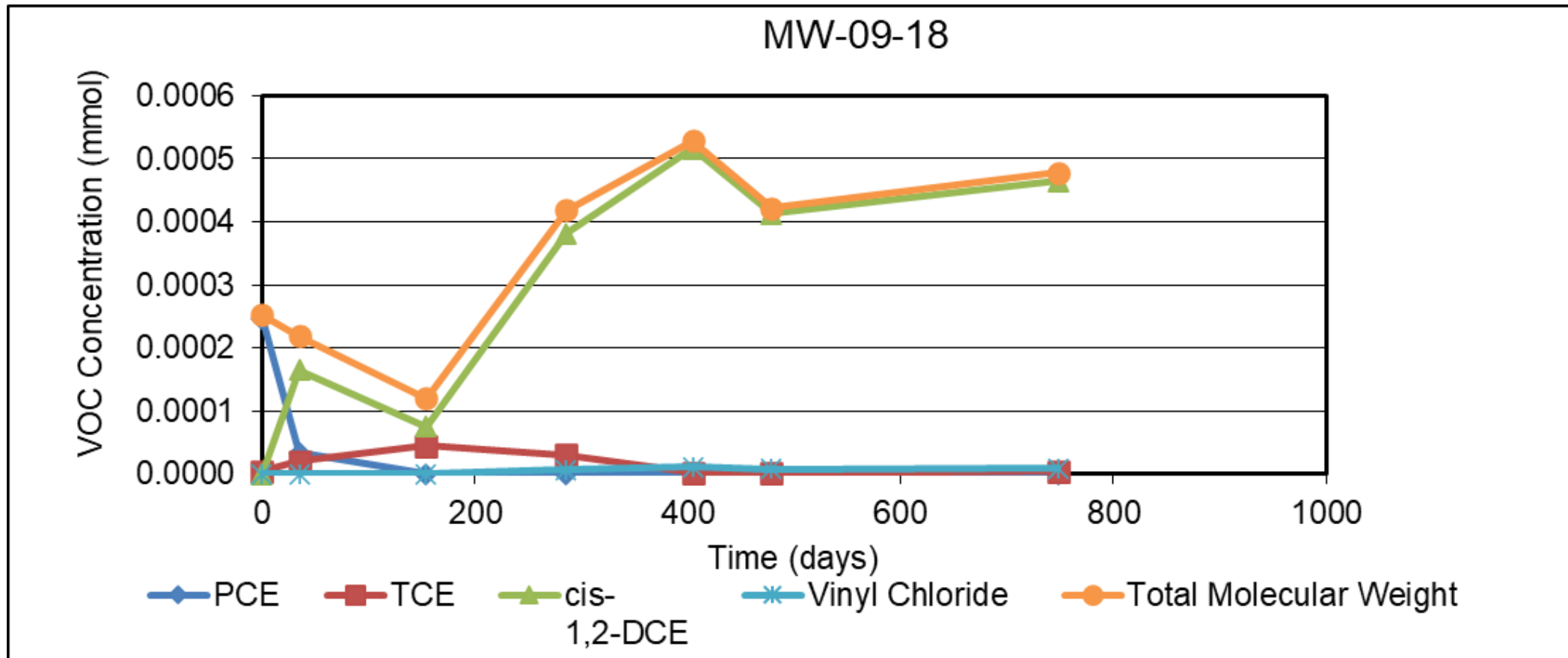
# Under (some) Pressure



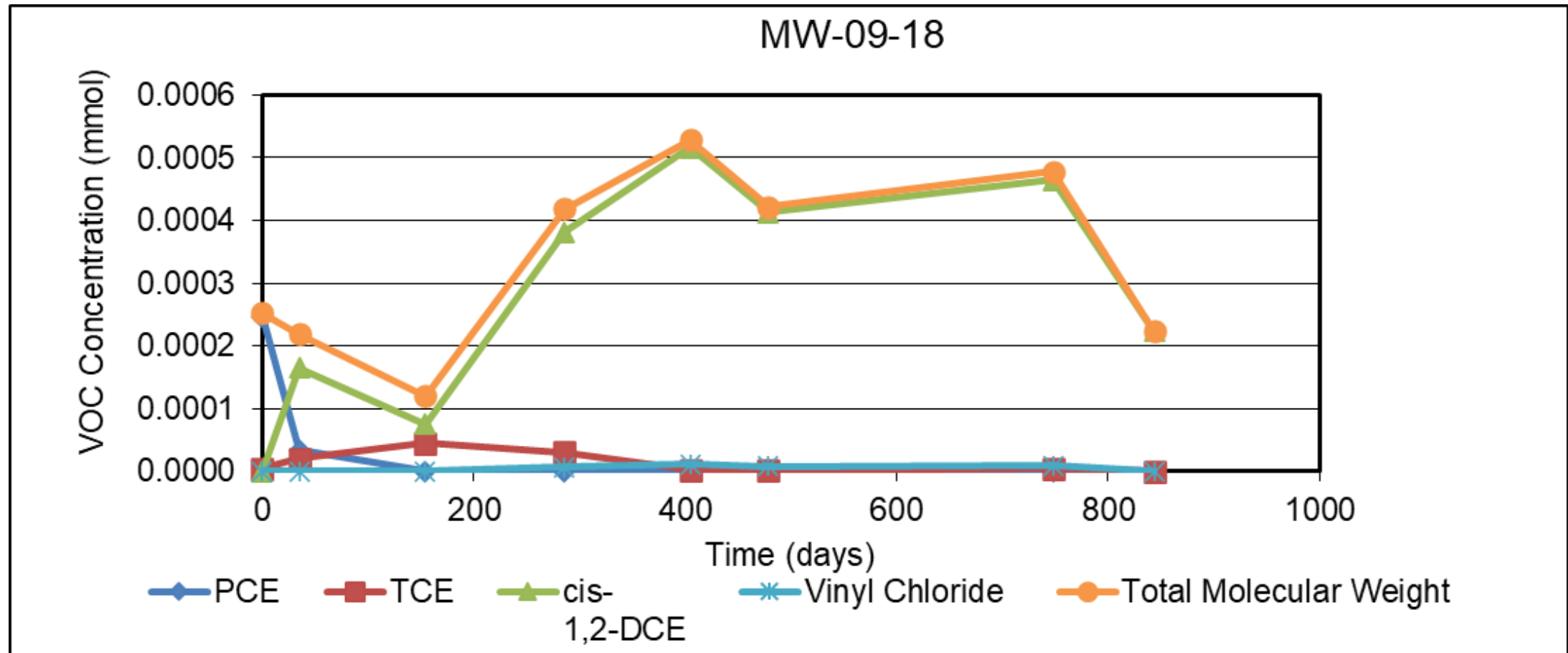
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- APPROXIMATE TEMPORARY ZV
- JULY 2019
  - AUGUST 2019
  - JULY & AUGUST 2019
- ⊕ HORIZONTAL INJECTION WELL
    - INSTALLED BY BLUEFROG
- 1 METRE RADIUS (5 psi)
  - 1.5 METRE RADIUS (10 psi)
  - WHITE SPACE (20 psi)
  - ⊕ DIRECT INJECTION LOCATIONS

NOTES:

# 90 Days Post EHC-L/KB-1 Injection Results



# 120 Days Post EHC-L/KB-1 Injection





# GeneTrac Analysis



Sample ID	VC Reductase ( <i>vcrA</i> )		BAV1 VC Reductase ( <i>bvcA</i> )		TCE Reductase ( <i>tceA</i> )	
	Percent <i>vcrA</i> <sup>(3)</sup>	Gene Copies/Liter	Percent <i>bvcA</i> <sup>(3)</sup>	Gene Copies/Liter	Percent <i>tceA</i> <sup>(3)</sup>	Gene Copies/Liter
MW-09-18	NA	1 x 10 <sup>4</sup> U	NA	1 x 10 <sup>4</sup> U	0.007 - 0.02 %	2 x 10 <sup>5</sup>
MW-08-16	0.0001 - 0.0004 %	2 x 10 <sup>5</sup>	0.0006 - 0.0002 %	9 x 10 <sup>4</sup>	0.0001 - 0.0004 %	2 x 10 <sup>5</sup>

# VFA Analysis

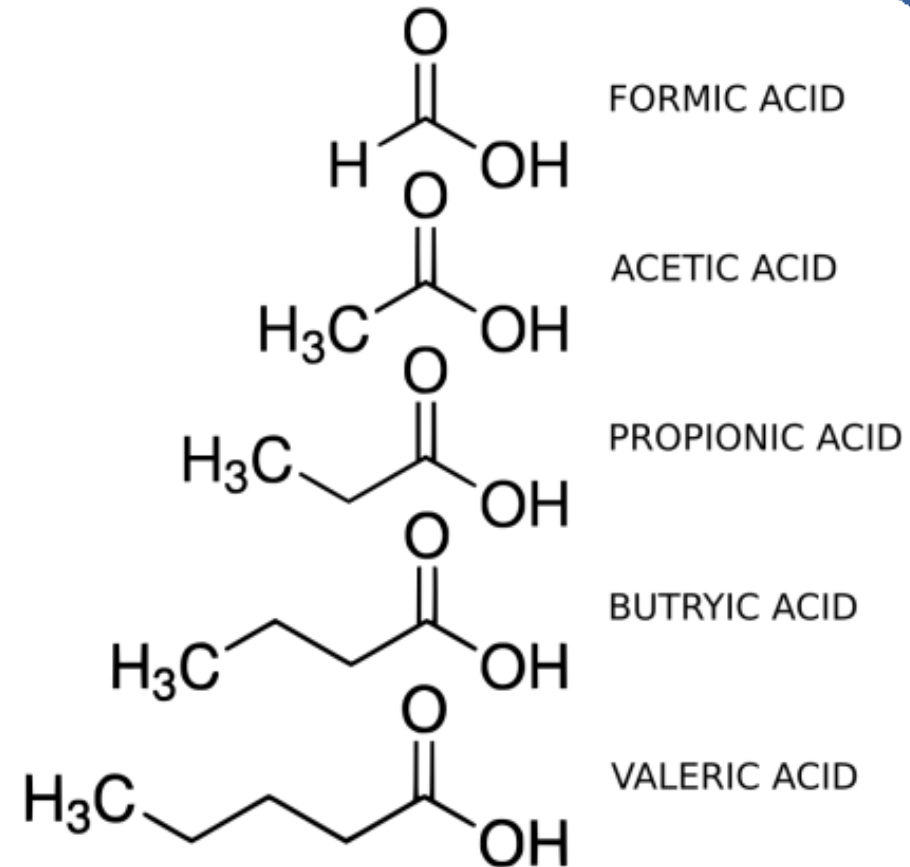


VFAs contribute the hydrogen and carbon that is required by DHC to grow and breakdown chlorinated compounds

## Analytical Results:

<10 mg/L VFA

DHC needs 100 mg/L VFA



Krzyżowski, Michał et al. "1 Repellent Effect of Volatile Fatty Acids on Lesser 2 Mealworm ( *Alphitobius diaperinus* ) 3." (2018).

# What Next?



- In March 2022 we:
- Added more VFAs that will last longer -> EDS-ER
- Increase *Dehalococcoides sp.* population by adding more KB-1
- Direct injected as per prescribed pressures

And now we are waiting until 90 days have passed before our next round of performance monitoring and sampling.

# What Did We Learn?



- Request and Review As Built Drawings of Building Foundations
- Complete a Pre-Injection Building Condition Assessment
- Request and Review Previous Geotechnical Assessments (soil bearing capacity)
- Document Soil Geotechnical Data When Conducting a Phase II/Two ESA
- **COLLABORATE** and **COMMUNICATE** with Your Project Team (contractor, technical specialists, client, colleagues etc.)
- Think Outside the Box and be Persistent



# Acknowledgements



***DownUnder Geotechnical***



**Strata Drilling Group**

1.866.7.STRATA (1.866.778.7282) [www.stratadrillinggroup.com](http://www.stratadrillinggroup.com)