Case Study: New Delivery Method to Inject Remedial Amendments into a Difficult Aquifer

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Premier Environmental Services Inc.

SMART Remediation
Toronto, ON | January 23, 2020

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SMART Toronto Presentation
January 23, 2020
Kevin French, P. Eng. – Vertex
Gerren Feeney, P. Geo$_{(Limited)}$ - Premier

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Introduction – Agenda

- **Introduction**
  - What is a Difficult Aquifer?
- **Site Background**
  - Data Review & Gap Analysis
  - Bench-Scale Treatability Testing
  - Historical Remediation Activities
- **Delivery Approach for Difficult Aquifer**
  - Pilot-Test Results
  - Full-Scale In-Situ Program
  - Performance Monitoring
- **Lessons Learned / Conclusions**

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Introduction – Presenters

- **Gerren Feeney, P. Geo$_{(Limited)}$**
  - Project Manager at Premier
  - University of Guelph, Ontario
  - 11+ years experience as environmental consultant

- **Kevin French, P.Eng.**
  - Environmental Engineer at Vertex
  - University of Waterloo, Ontario
  - 30+ years experience in environmental consulting and contractor

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What is a Difficult Aquifer for Injection?

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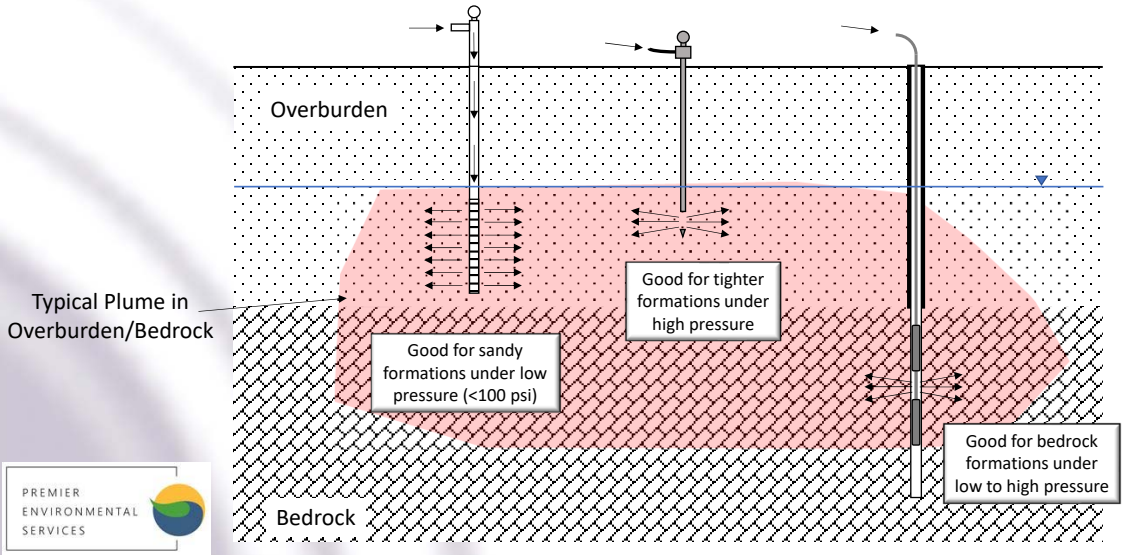
What is a Difficult Aquifer for Injection?

Three Standard Injection Methods:

1) Permanent Injection Well
2) Direct Push Injection Point
3) Open Borehole Packer Injection



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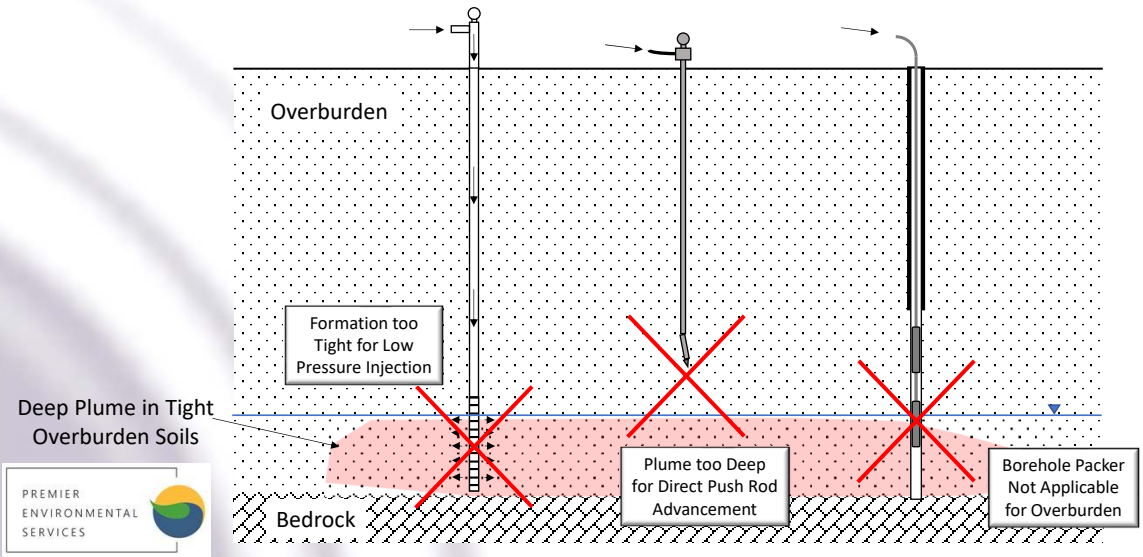

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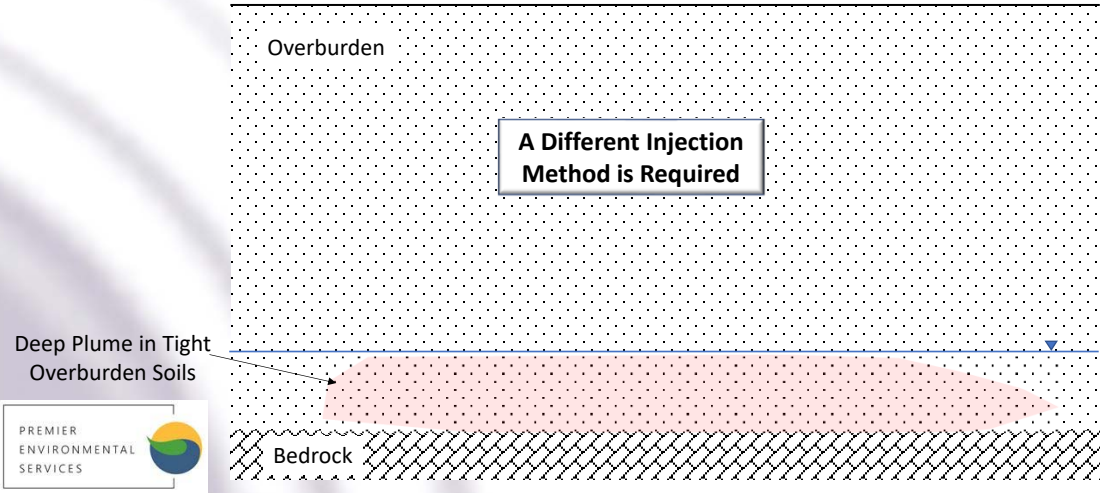

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Case Study

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Site Background – Site Location

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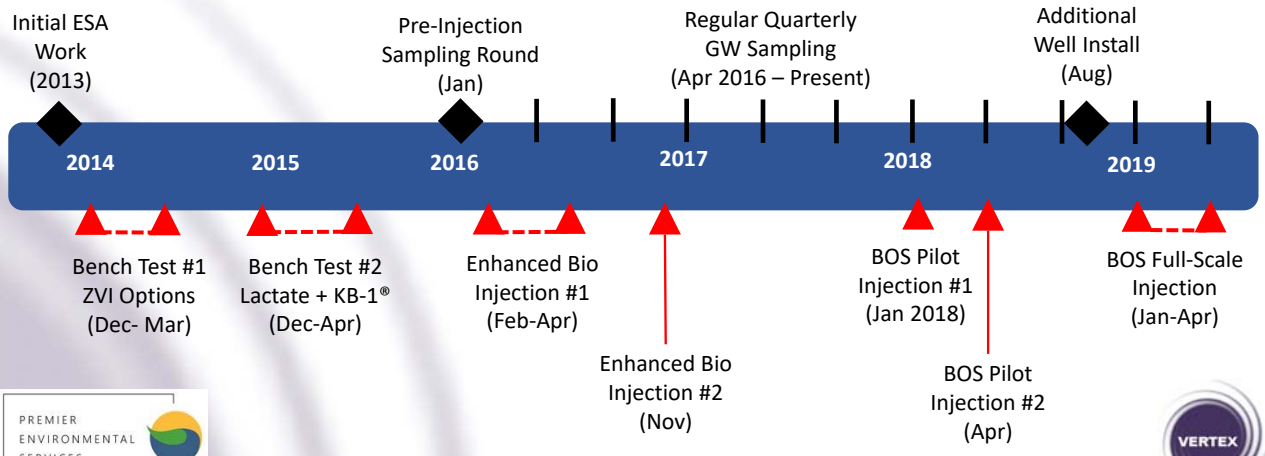
Timeline



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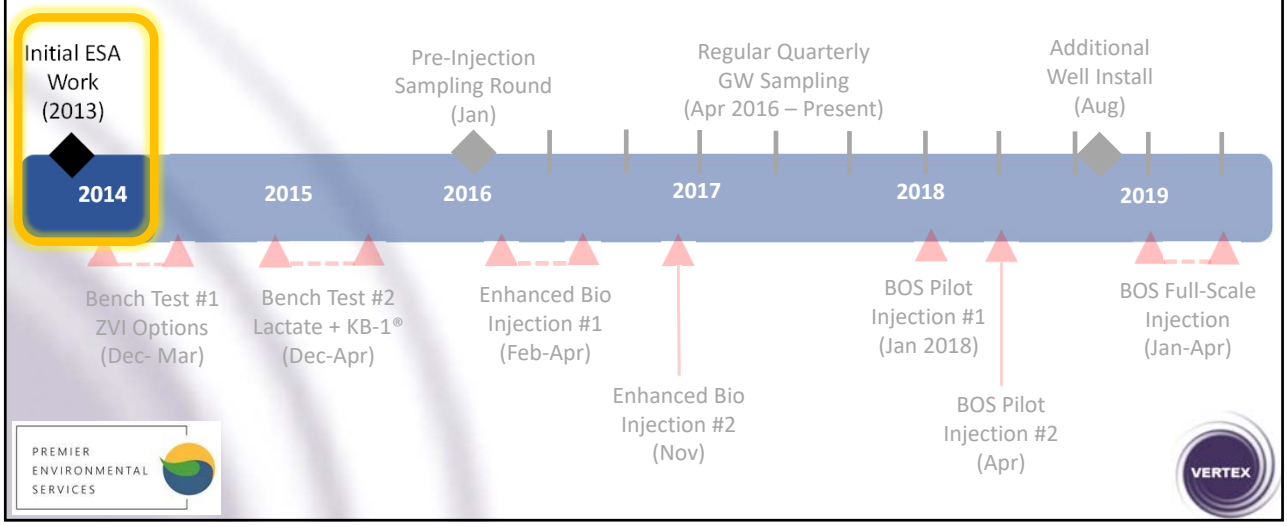
Timeline



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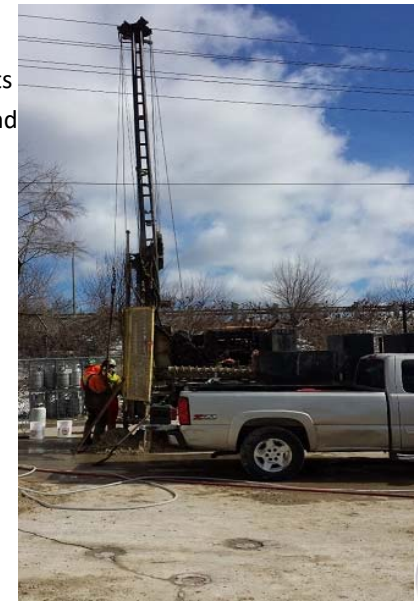
Site Background – ESA Approach - Site Characterization & Delineation

- Industrial manufacturing facility located in the GTA
- ESA site characterization work completed in 2013/2014
  - No soil concentrations > applicable Table 3 SCS limits
  - cVOC impacted groundwater (1,1,1-TCA, 1,1-DCE and 1,2-DCA) located in southeast corner
  - Laterally and vertically delineated
  - Unknown source!



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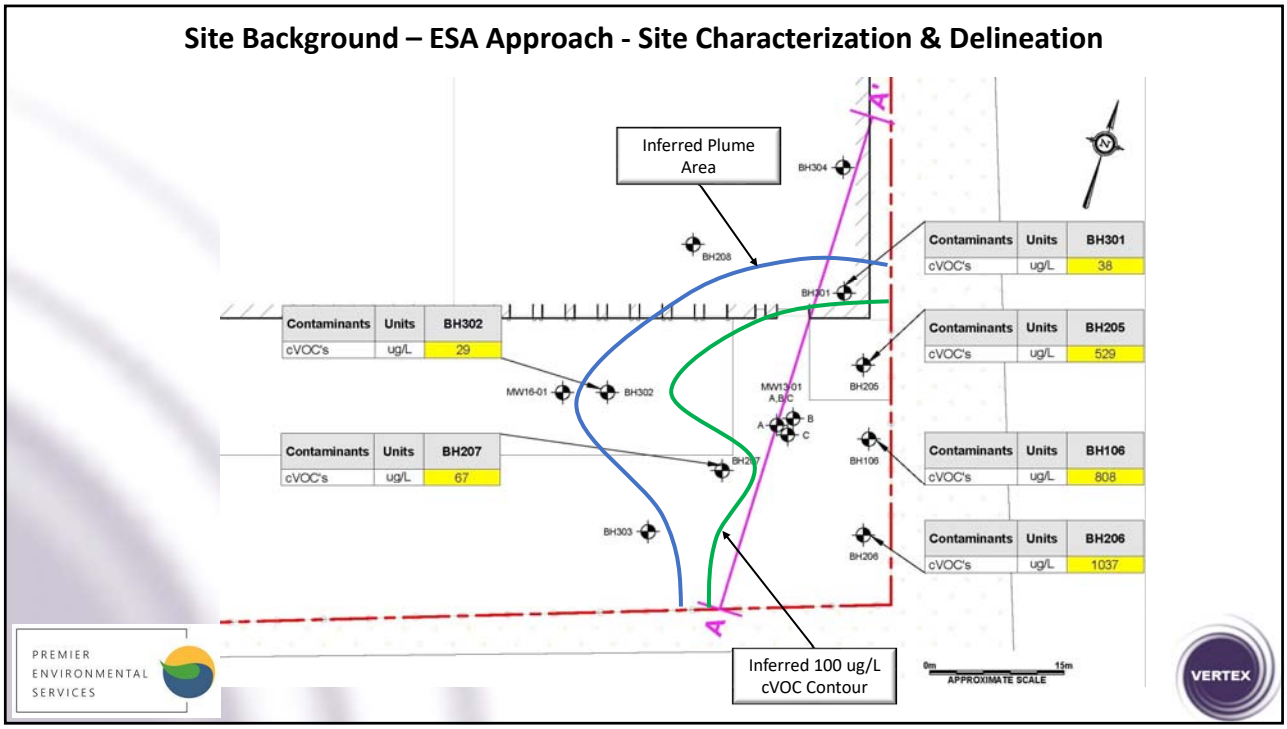
Site Background – ESA Approach - Site Characterization & Delineation



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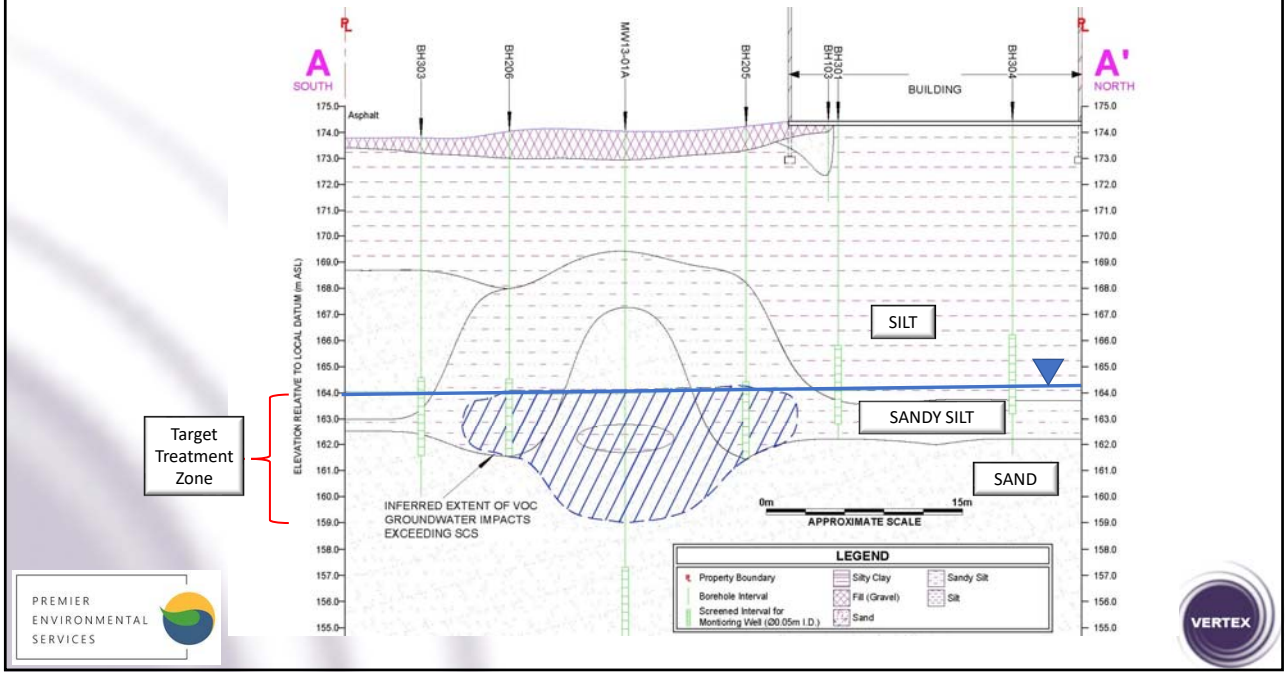
Site Background – ESA Approach - Site Characterization & Delineation



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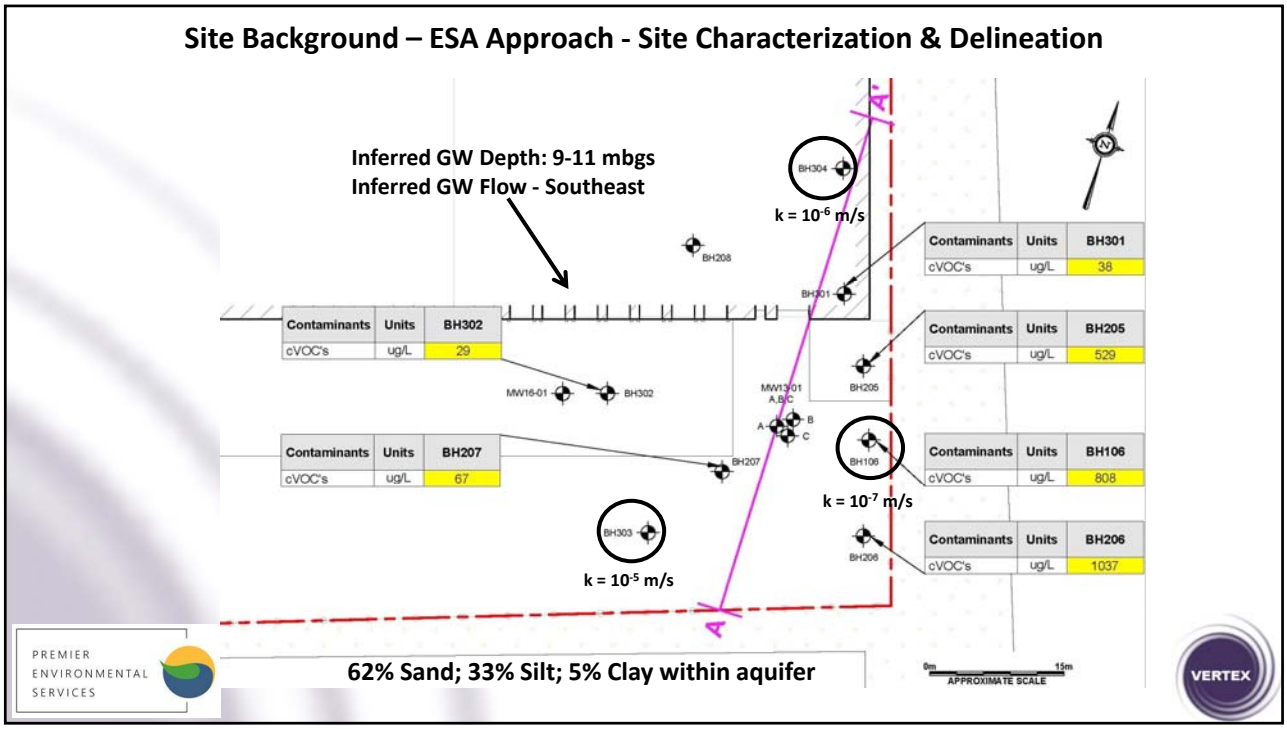

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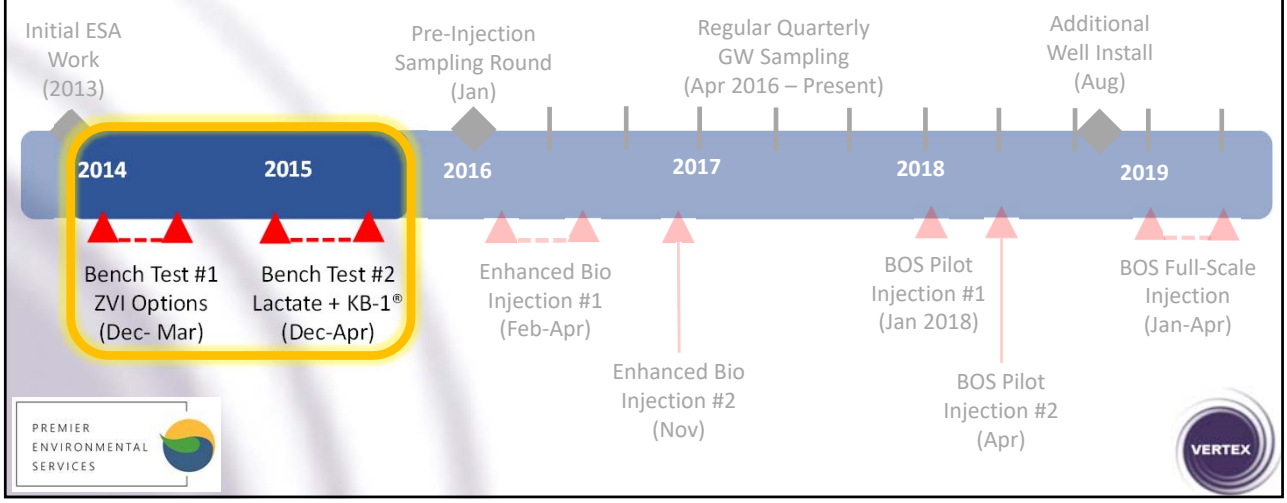
Timeline



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Site Background – Bench Test

Bench Test:

Vertex retained to conduct Bench Testing using soil and groundwater from the site to evaluate:

- Plume Treatment via Enhanced Bio
- Permeable Reactive Barrier with ZVI

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Site Background – Bench Test

Bench Test Results:

- Biostimulation (0.2% or 1.0% sodium lactate) was **not successful** in reducing cVOCs below the applicable SCS
- Biostimulation with bioaugmentation (KB-1®) **was successful** in reducing cVOCs below the applicable SCS
- 1.0% by weight ZVI mixture was **not successful** in reducing cVOCs below the applicable SCS
- 30% by weight ZVI mixture **was successful** in reducing cVOCs below the applicable SCS

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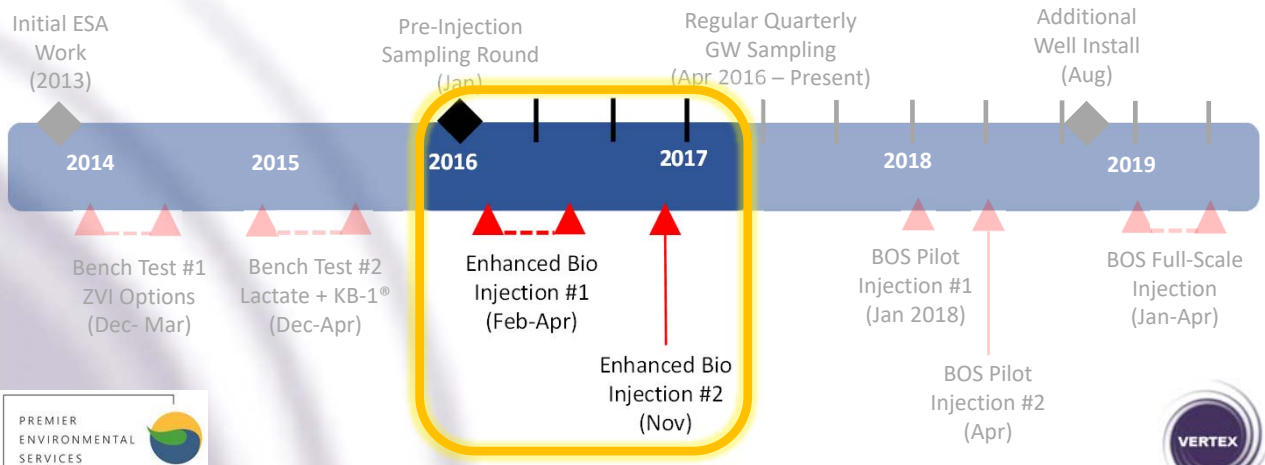
Timeline



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2016 Injection Summary

Selected Approach: In-situ injection of sodium lactate biostimulant with KB-1® bioaugmentation

- Primary goal to reduce mass of contaminants
- Sodium lactate – electron donor
- KB-1® culture - metabolize contaminants

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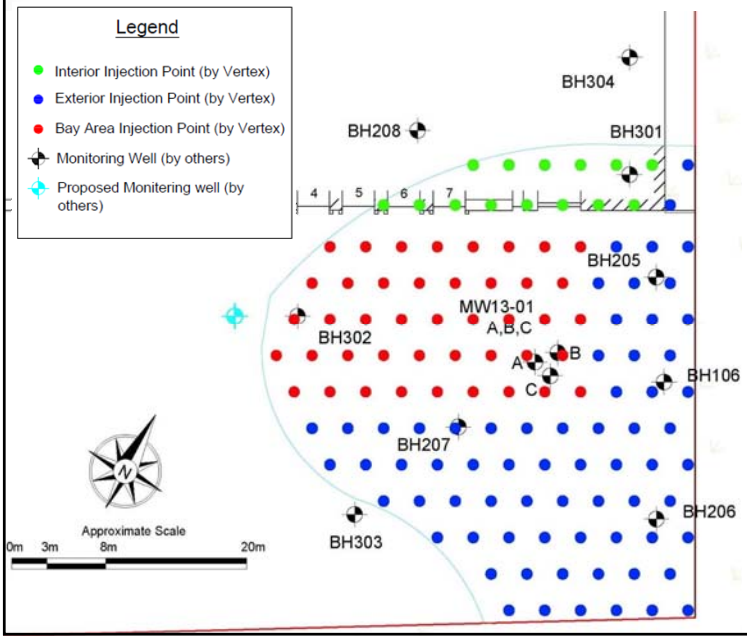
2016 Injection Summary



Injection Plan:

- Grid of 150 temporary injection points (over ~1,025 m^2 plume)
- Advance Injection Rods with Geoprobe to depth
- Inject Shallow Interval (10-13 m bgs) and Deep Interval (13-16.5 m bgs)

Injection Plan did not work…

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2016 Injection Summary – Delivery Issues

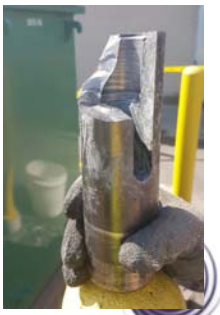
Delivery Issues

- Shallow Interval (10-13 m bgs):
  - Geoprobe could advance injection rods to depths
  - Rod breakage at 4 of 12 locations
  - The male thread snapped off inside the female thread due to extended hammering – stress on the rods

Decent Injection ROI but breakage at 1/3 of locations

- Deep Interval (13 – 16.5 m bgs):
  - Geoprobe could not advance rods to depth

Direct Push not Viable for deep interval



- Switched to Hollow Stem Augers (HSA) for Deep
  - HSA were able to advance to target depths
  - Attempted injection thru HSA didn't work
  - HSA very slow – Schedule Restraints

Temporary Point Injection not going to work

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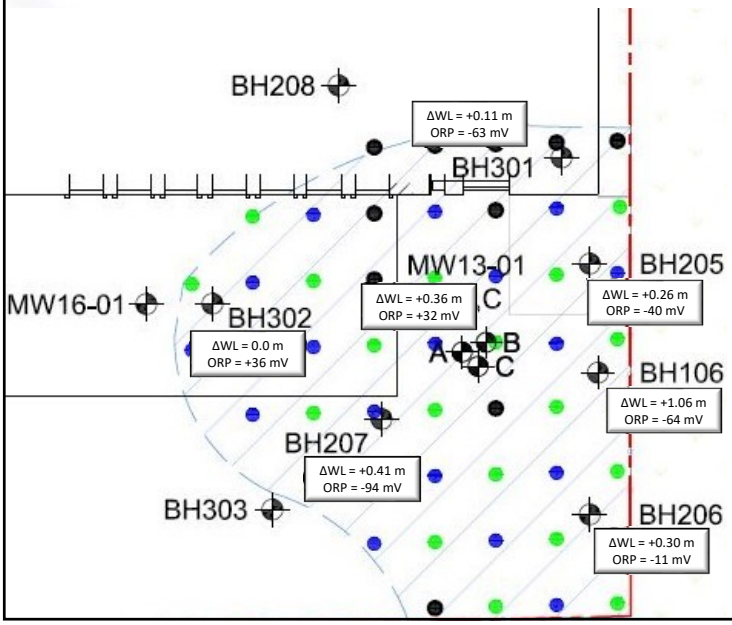
2016 Injection Summary – Delivery Issues



Revised Approach

- Finished Injection program with Permanent Injection Wells
  - 19x shallow wells (10-13 m bgs) (green)
  - 18x deep wells (13-16.5 m) (blue)
- Injected 20% Sodium Lactate Solution + KB-1®:
  - 18,550 L via temporary points (black)
  - 106,400 L via permanent wells
- Field Monitoring:
  - Average hydraulic influence of +0.36 m
  - Partial Geochem Shift
    - ORP_{AVG} = +38 mV (Pre-Inj)
    - ORP_{AVG} = -39 mV (Post-Inj)
    - KB-1 should have < -75 mV

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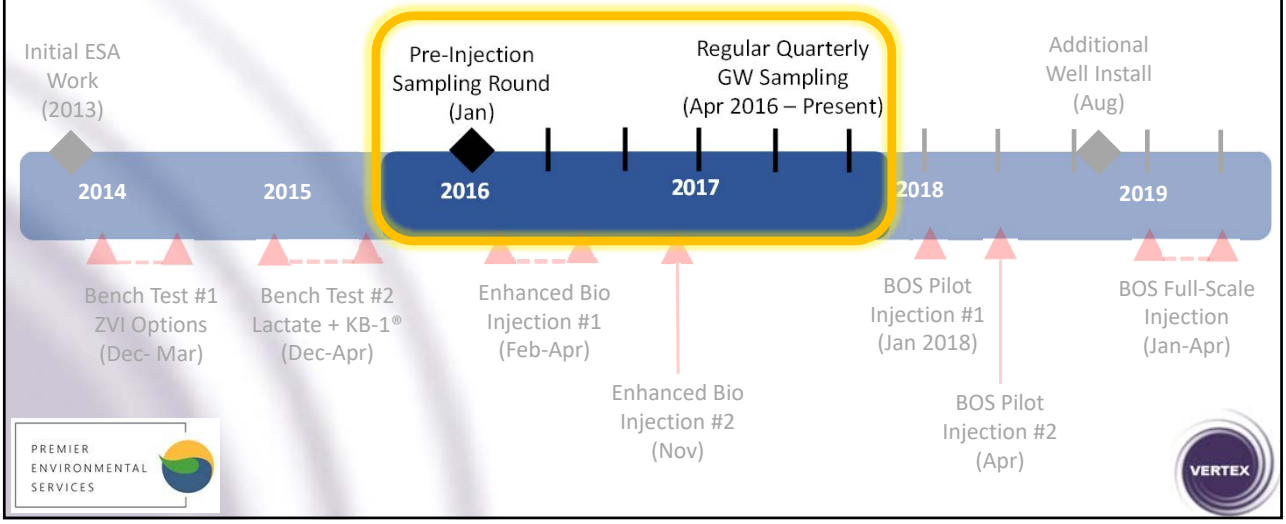
Timeline



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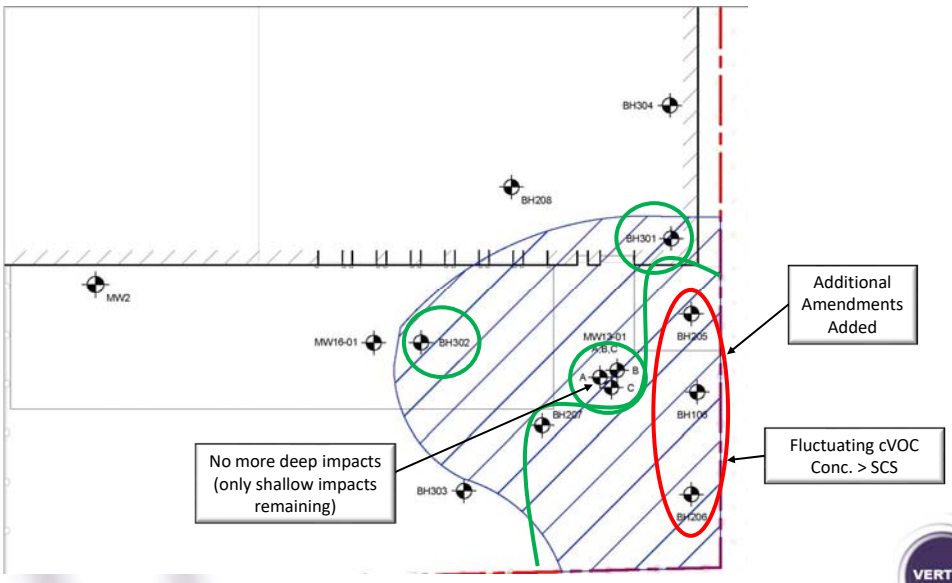
Site Background – Performance Monitoring



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Next Steps

Next Steps?

- Collected 2+ years of analytical and geochemistry data
- Completed additional Enhanced Bio injection, and well cleaning event
  - Enhanced Bio just not working for wells along property boundary

	Pros	Cons
Enhanced Bio (Sodium Lactate + KB-1®)	Lab proof of concept Some success at site	Delivery issues Could not maintain ORP < -75 mV KB-1® not thriving

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Next Steps

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	Pros	Cons
Enhanced Bio (Sodium Lactate + KB-1®)	Lab proof of concept Some success at site	Delivery issues Could not maintain ORP < -75 mV KB-1® not thriving
Trap and Treat® BOS 100®	Less dependent on geochemistry Persistent No maintenance or re-application	How to deliver a suspension?

Decided to undertake BOS 100® Pilot-Test to see if delivery was feasible

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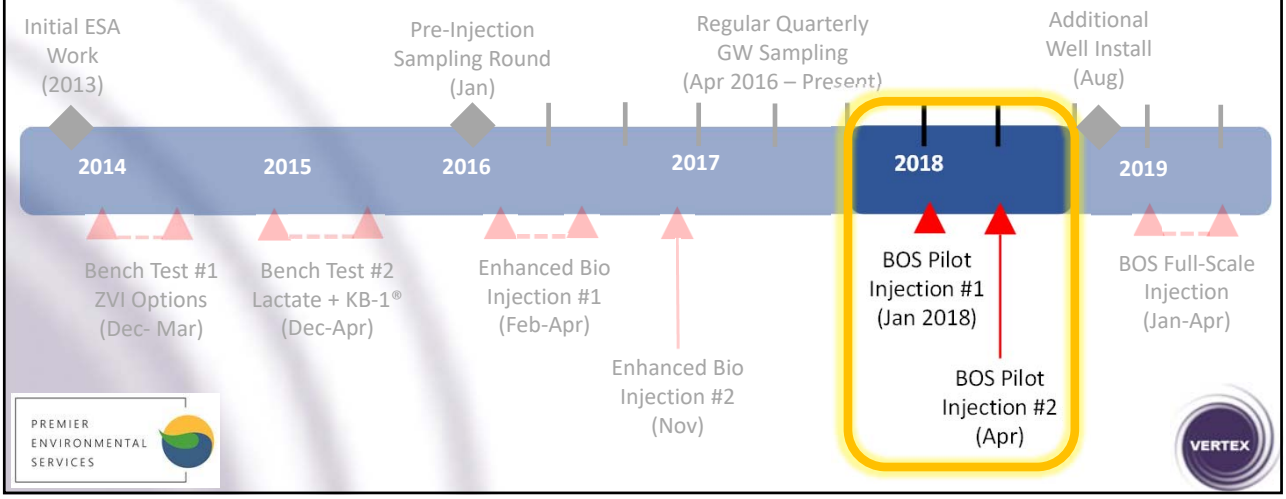
Timeline



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BOS 100® Pilot-Test – Delivery Attempt #1

What is BOS 100®?

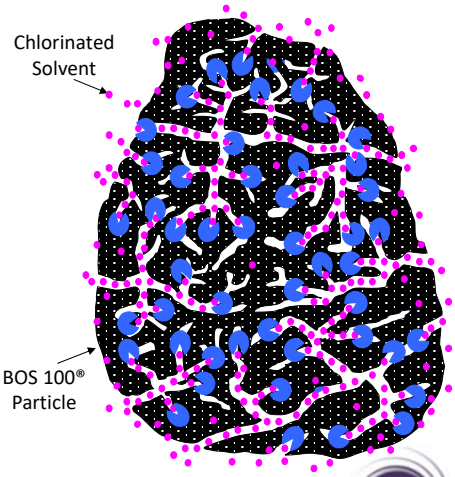
- Consists of GAC impregnated with elemental iron

Mechanisms:

- **"Trap"** the contamination within the GAC matrix
- **"Treat"** the contamination via chemical reduction via the iron within the GAC matrix

Injection Delivery:

- Mixed as a suspension
- Injected under high pressure
- Typically use Direct-Push rig with pre-strung 2.25" rods
- Suspension will not pass through a well screen



Activated Carbon & Iron

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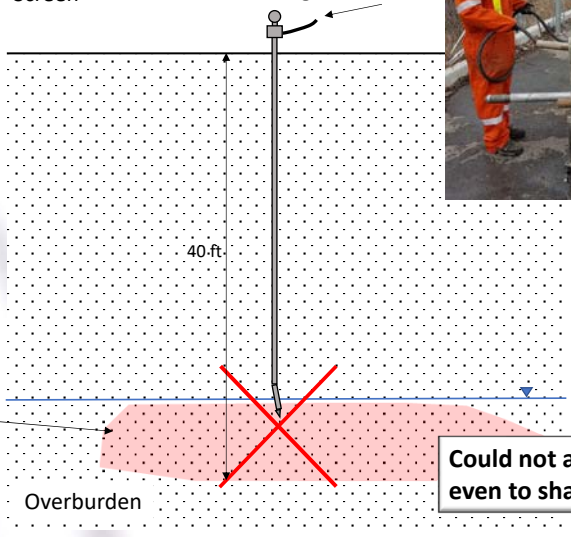
BOS 100® Pilot-Test – Delivery Attempt #1

BOS 100® is a suspension of AC & iron ⇨ Cannot Inject Through Well Screen ⇨ Attempted Injection via Pre-Strung Rods



Could not advance rods even to shallow interval

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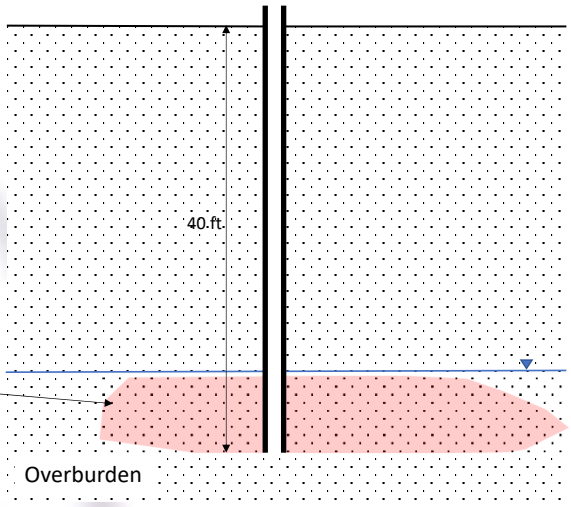
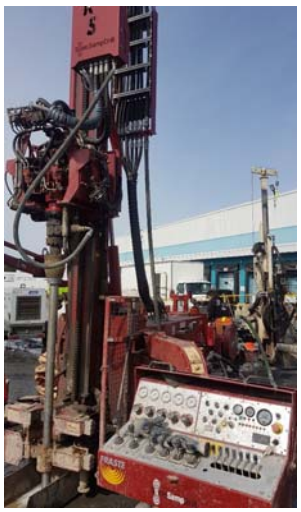
BOS 100® Pilot-Test – Delivery Attempt #2

Mobilize Sonic Drill Rig

- Needed rig that could quickly pre-drill BHs to total depth

Step #1
Borehole Pre-Drill





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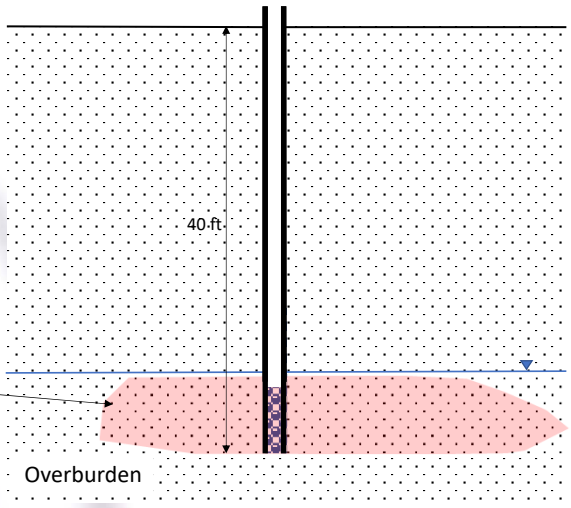
BOS 100® Pilot-Test – Delivery Attempt #2

Backfill Process:

- Add backfill in lifts

Step #2
Bentonite/Grout Backfill



Needed backfill material that can be drilled through while providing sufficient injection resistance and borehole sidewall stability?

Tested a variety of materials and mixtures

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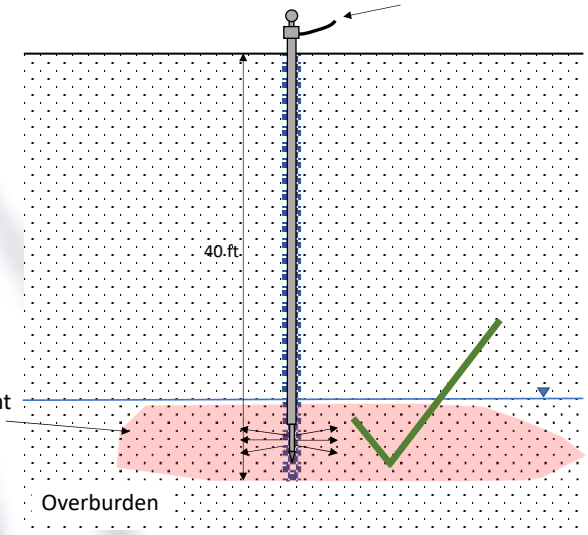
BOS 100® Pilot-Test – Delivery Attempt #2

Step #3
Injection Via Pre-Strung Rods

Injection Process:

- Mobilize direct push rig
- Advance 2.25" pre-strung rods down pre-drilled BH to top of injection interval



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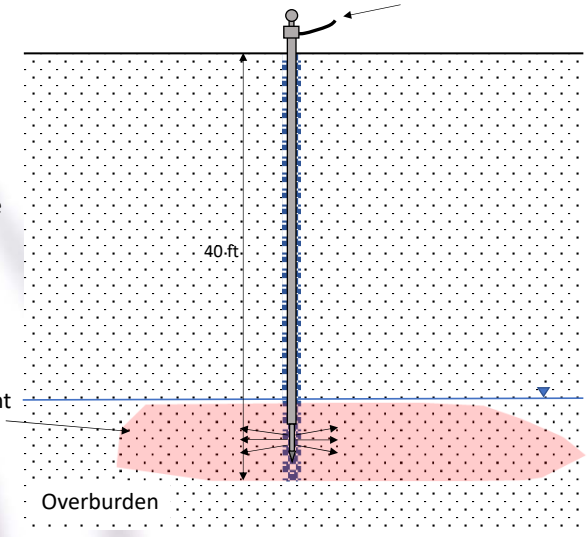
BOS 100® Pilot-Test – Delivery Attempt #2

Step #3
Injection Via Pre-Strung Rods

Results:

- Injected up to 500 L per IP
  - 100 L/depth interval
- Injection pump pressure ranged from 300-1,000 psi
- Observed Radius of Influence of 1.2 to 1.5 m



Results (cont'd.):

- Average analytical results at BH206 as follows:
  - 1,1-DCE: 47 ug/L to 0.7 ug/L
  - 1,1,1-TCA: 625 ug/L to 5.0 ug/L

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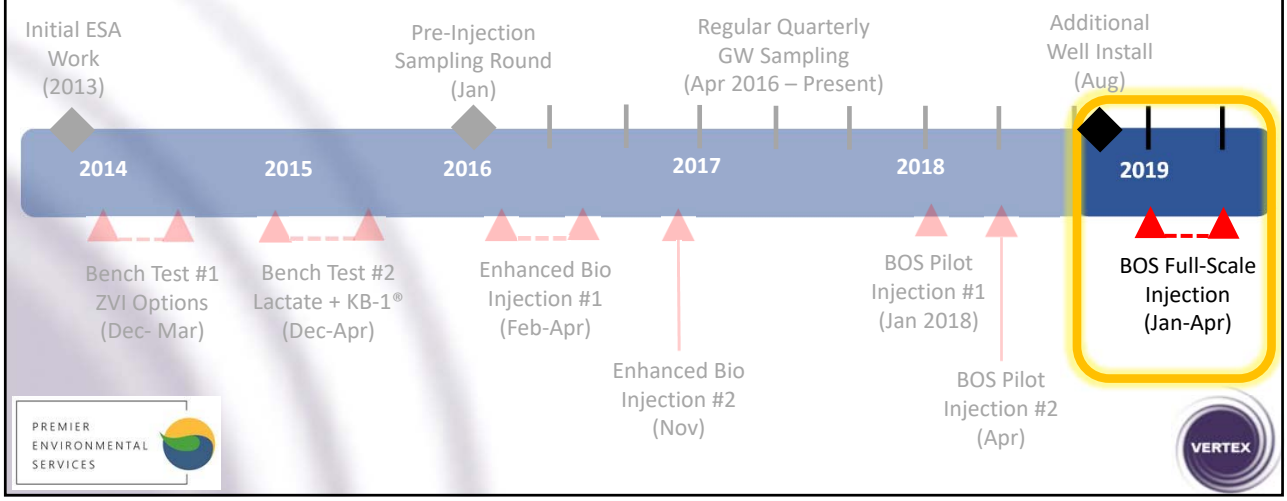
Timeline



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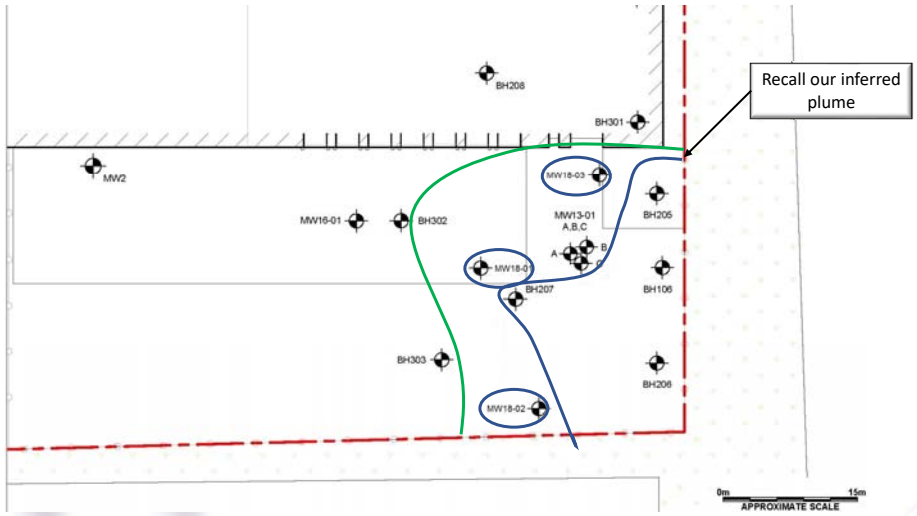
Additional Delineation



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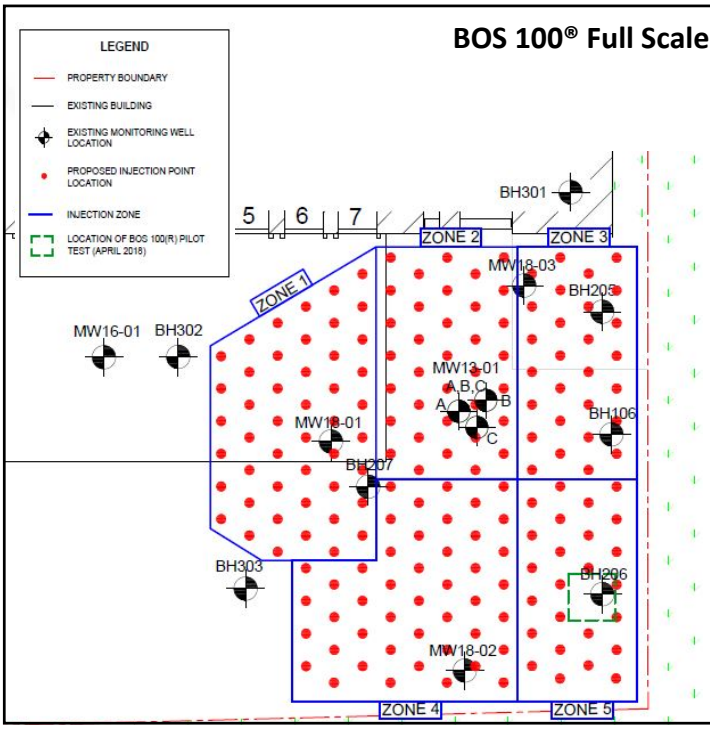
BOS 100® Full Scale Injection



Injection Details:

- Injection Grid of 180 locations on a 2.25 m grid spacing, split out over 5 zones
  - Active facility receiving deliveries
- Completed Injection over 3 months
  - Sonic 5 days per week (3-6 BHs/day)
  - Injection 50% of time (6-9/day)
- Totals:
  - 5,600 kg of BOS 100®
  - 83,500 L of suspension injected
  - Average Pump Pressure of 430 psi

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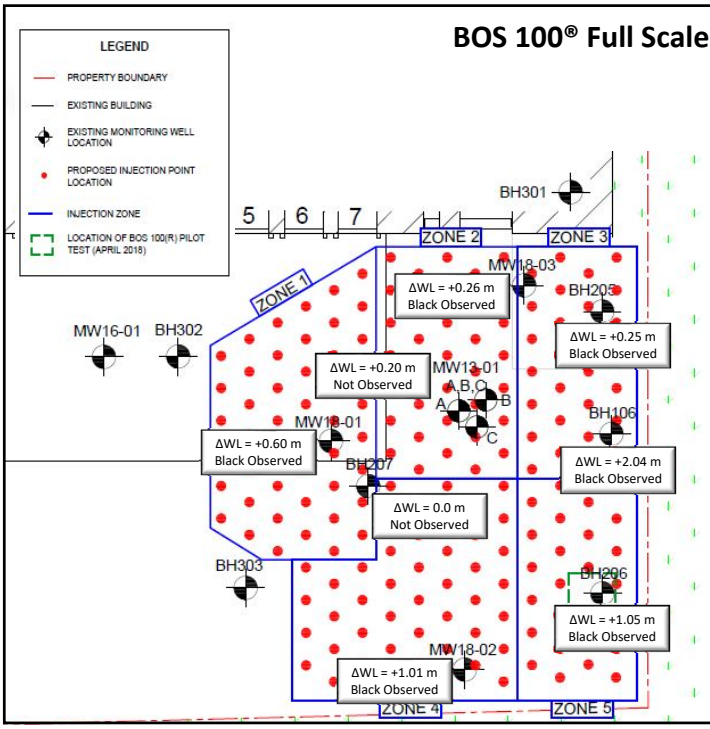
BOS 100® Full Scale Injection



Field Results:

- Field Monitoring:
  - Minimal daylighting
  - Good hydraulic influence ranging from +0.25 m to +2.04 m
  - Average hydraulic influence +0.70 m
- Visual Inspection
  - BOS 100® has black colour
  - Amendment can be visually observed as grey to black discolouration

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BOS 100® Full Scale Injection

Injection Delivery Challenges:

- Winter Weather
  - Shut-down for 4 days (temp < -20 °C)
  - 3 partial injection days due to line freezing issues
- Injection Tip Clogging
  - Problems with Bentonite Grout clogging injection tip while pushing down
  - Developed method of pulsing water as injection tip is advanced

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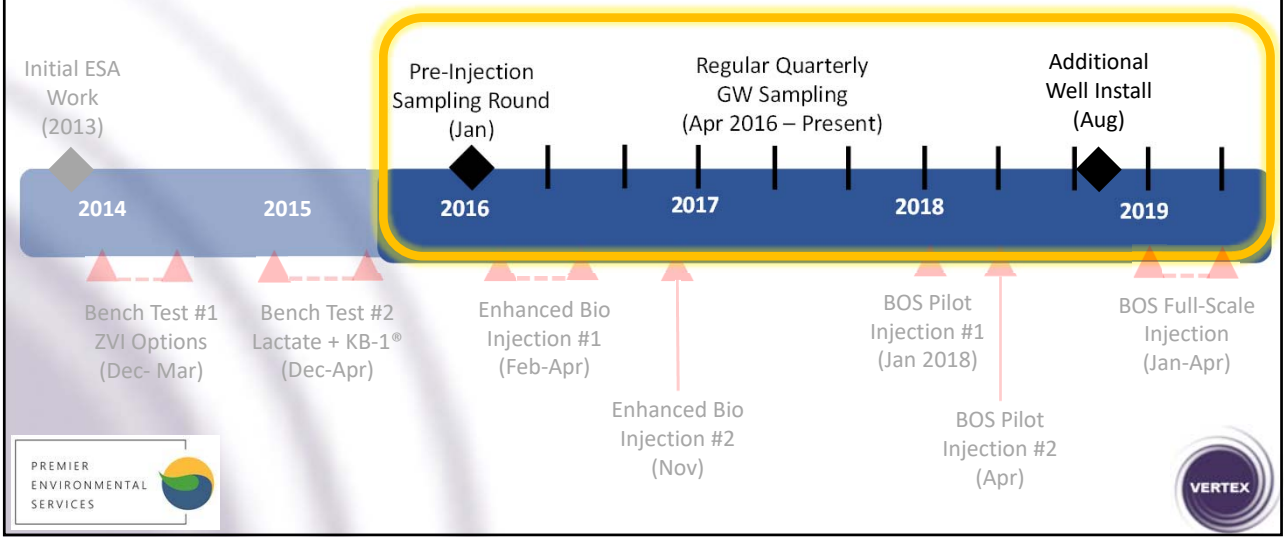
Timeline



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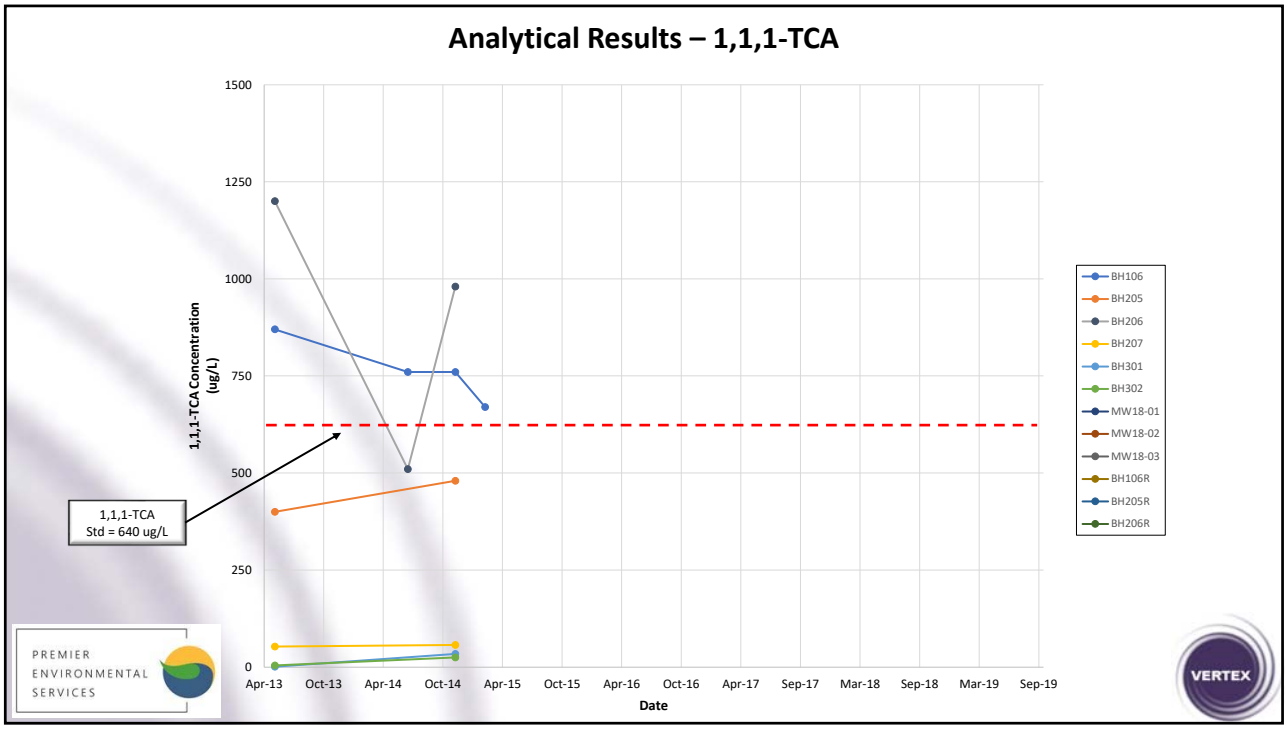
Analytical Results – 1,1,1-TCA
1,1,1-TCA Concentration (ug/L)
1500
1250
1000
750
500
250
0
Apr-13
Oct-13
Apr-14
Oct-14
Apr-15
Oct-15
Apr-16
Oct-16
Apr-17
Sep-17
Mar-18
Sep-18
Mar-19
Sep-19
Date
1,1,1-TCA
Std = 640 ug/L
BH106
BH205
BH206
BH207
BH301
BH302
MW18-01
MW18-02
MW18-03
BH106R
BH205R
BH206R
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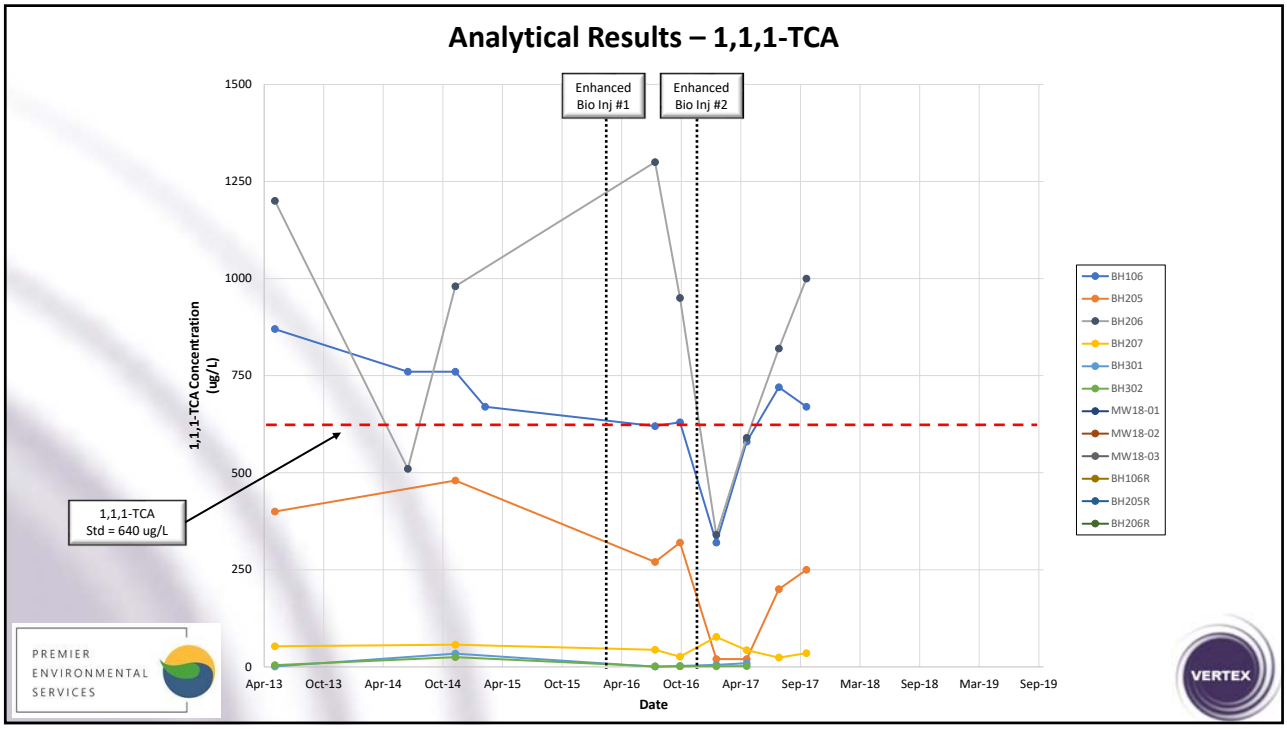
Analytical Results – 1,1,1-TCA
Enhanced Bio Inj #1
Enhanced Bio Inj #2
1,1,1-TCA Concentration (ug/L)
1500
1250
1000
750
500
250
0
Apr-13
Oct-13
Apr-14
Oct-14
Apr-15
Oct-15
Apr-16
Oct-16
Apr-17
Sep-17
Mar-18
Sep-18
Mar-19
Sep-19
Date
1,1,1-TCA
Std = 640 ug/L
BH106
BH205
BH206
BH207
BH301
BH302
MW18-01
MW18-02
MW18-03
BH106R
BH205R
BH206R
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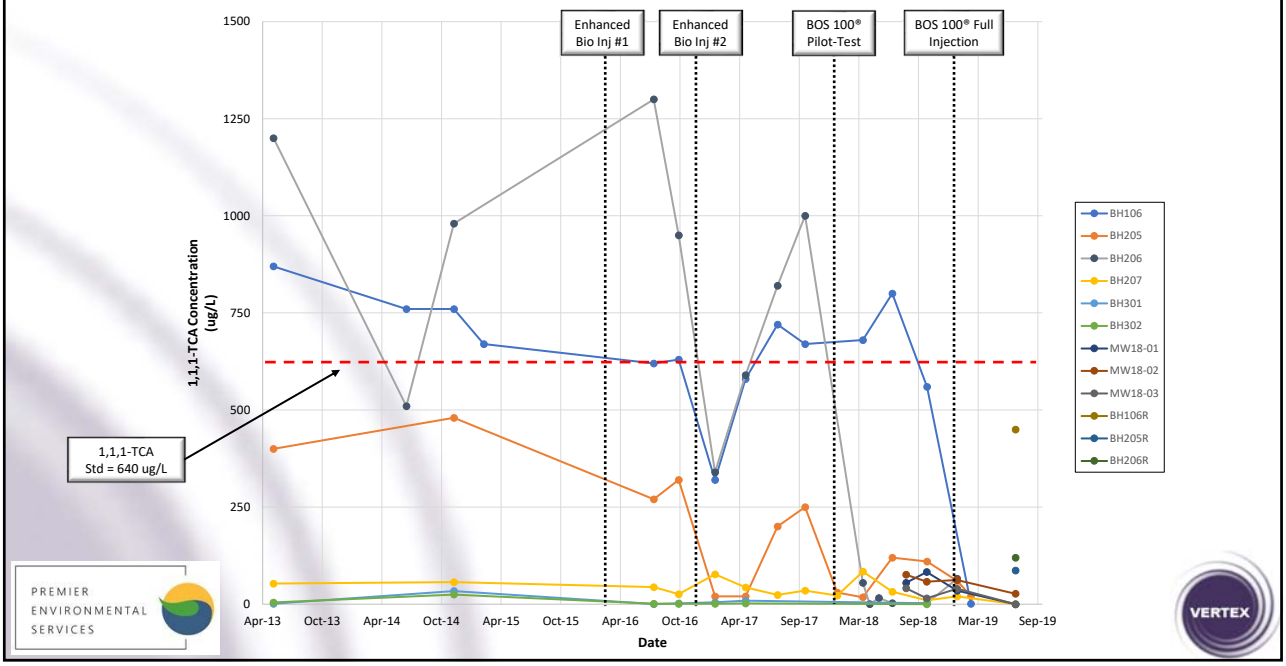
Analytical Results – 1,1,1-TCA



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Lessons Learned / Conclusions

Lessons Learned:

- Deep plumes in tight overburden soils are very "Difficult Aquifers" to treat via convention injection methods
- Bench-scale & Pilot-scale Testing is critical!
- The Sonic Pre-Drilling Approach provides an Injection Method to treat otherwise inaccessible "Difficult Aquifers"
- R&D for new liquid Injection Methods should not be completed in the winter!

Conclusions:

- Injection Approach has now been validated at this site (and others)
- Effective in-situ remediation is now possible at more site with (so-called) "Difficult Aquifers"

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Questions?

Thank You for Your Time!

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