Battelle 2016 AECOM

Angled Injection

to Mitigate PCE Intrusion into a Stream at a Federal Superfund Site in the Piedmont Region of North Carolina

Caleb Krouse, PE

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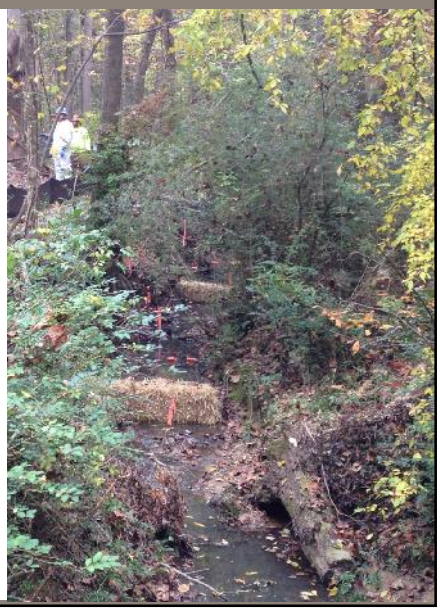
Agenda

- Background
- Investigation and Design (abridged)
- Injection Summary
- Streambed Porewater Results
- Surface Water Results
- Conclusion and Discussion



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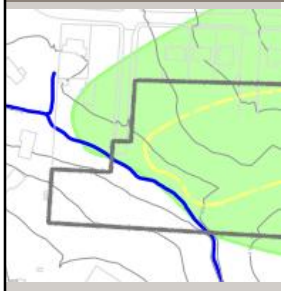
Background



- Small perennial stream impacted with PCE up to 20 µg/L
- PCE in porewater 2 ft (0.6 m) below stream as high as 270 µg/L
- NC Surface Water Standard of 3.3 µg/L
- Piedmont geology (Saprolite, Weathered Rock, Rock)
- Back diffusion investigated and is likely non-existent or negligible
- Wooded area, steep 5 ft (1.5 m) ravine
- Permeable Reactive Barrier (PRB) selected during feasibility study
- Pre-Design Investigation Performed

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Investigation and Design

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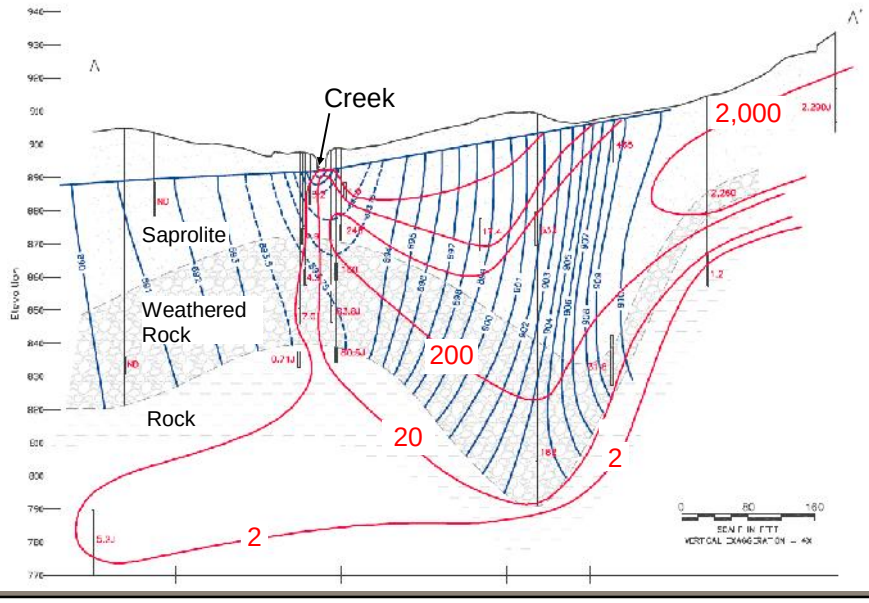
PCE Concentration Gradient Cross-Section



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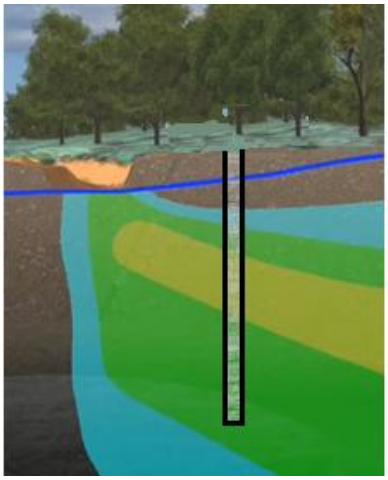
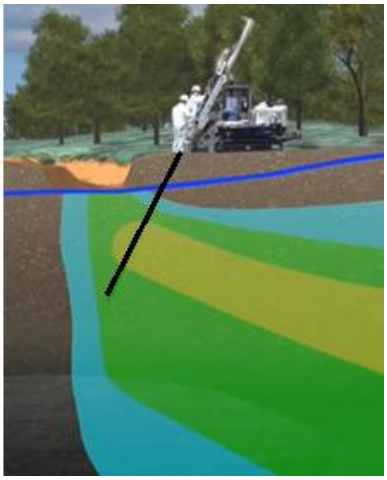
Alternative to Deep PRB In Weathered Rock?

Vertical PRB



Angled Injection



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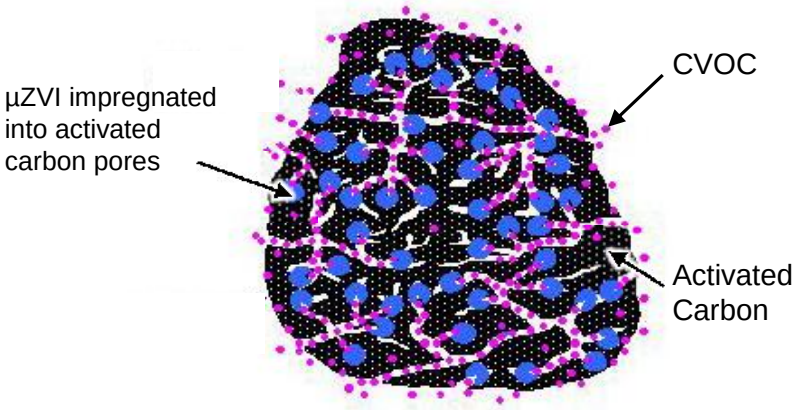
Injected PRB Treatment Media

BOS-100® (Trap and Treat)



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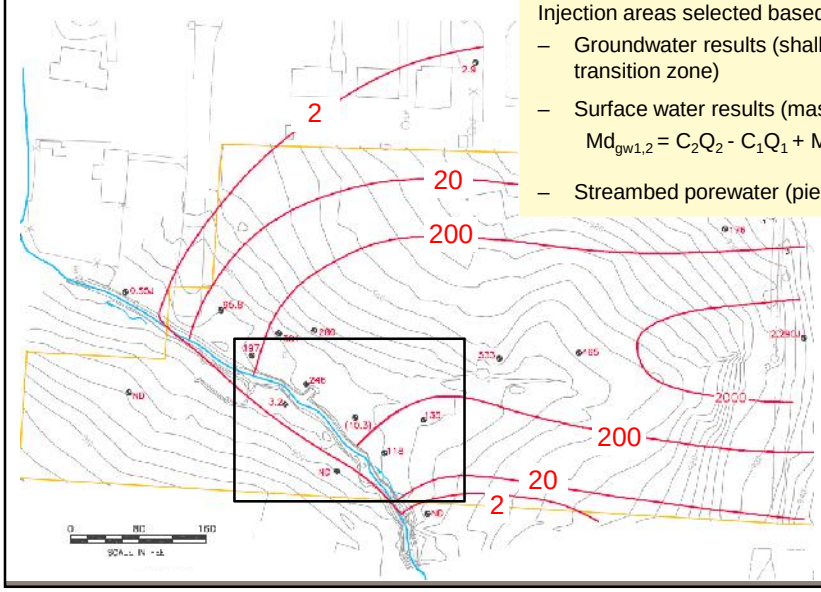
Injection Area Selection



Injection areas selected based on:

- Groundwater results (shallow and transition zone)
- Surface water results (mass discharge):
  $Md_{gw1,2} = C_2Q_2 - C_1Q_1 + Md_{loss1,2}$
- Streambed porewater (piezometers)

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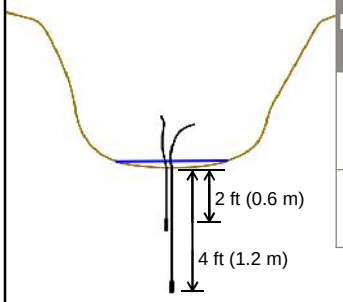
Streambed Piezometers



Location	PZ-101D	PZ-101S	PZ-102D	PZ-102S	PZ-103D	PZ-103S	PZ-104D	PZ-104S	PZ-105D	PZ-105S	PZ-106D	PZ-106S
Head (in(cm))	6.0 (15)	8.4 (21)	17 (43)	11 (28)	11 (28)	7.2 (18)	10 (25)	7.2 (18)	13 (33)	4.8 (12)	10 (25)	1.2 (3)
Inferred Flow	Up	Down	Up	Up	Up	Up	Up	Up	Up	Up	Up	Up

- Piezometers confirm vertical flow into gaining stream
- Baseline results used to design injections
- Baseline sampling results range from 50 µg/L and 270 µg/L
- Monitored to assess injection performance

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Injection Summary

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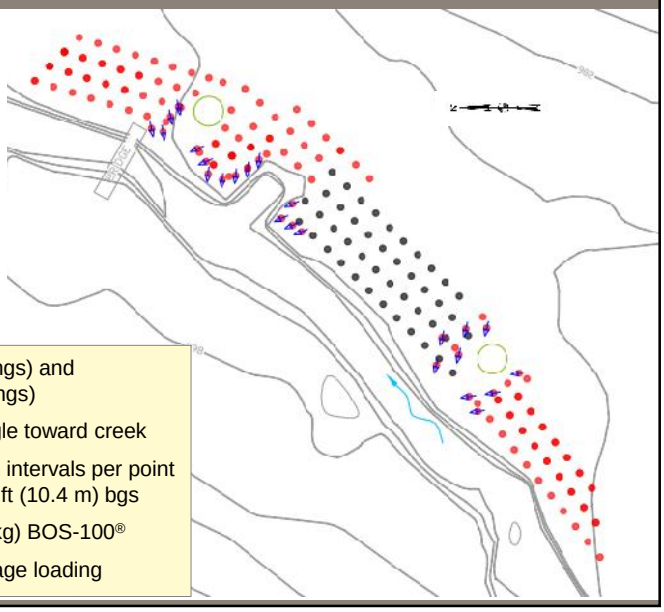
Injection Description

Map Legend

- Pilot Test Boring (2013)
- Phase 1 Injection Boring (2015)
- Boring Orientation (all other borings perpendicular to creek)



- Fall 2013 Pilot Test (43 borings) and Fall 2015 Phase 1 (116 borings)
- All borings at 25-degree angle toward creek
- Approximately 16.5 injection intervals per point between 6 ft (1.8 m) and 34 ft (10.4 m) bgs
- Total of 22,470 lbs (10,190 kg) BOS-100®
- 0.19 lbs/ft^3 (3.1 kg/m^3) average loading

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Injection Description – Photographs

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Injection Description – Photographs

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Injection Description – Photographs

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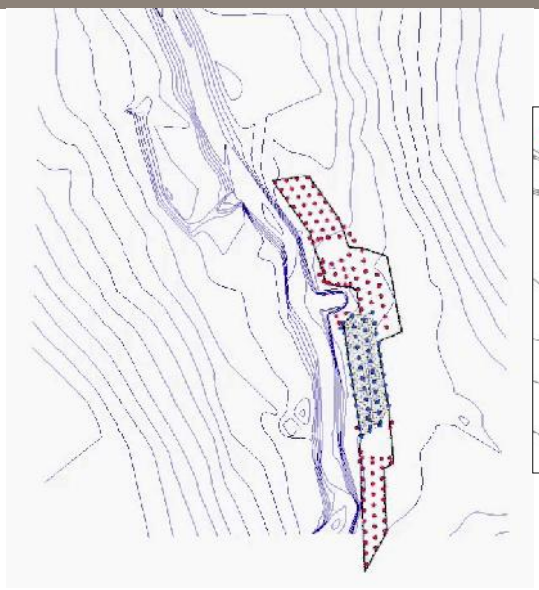
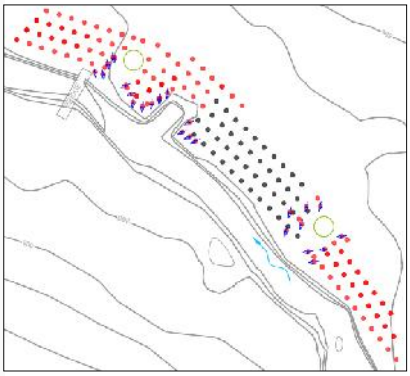
Injection Description – 3D Video





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Streambed Porewater Results

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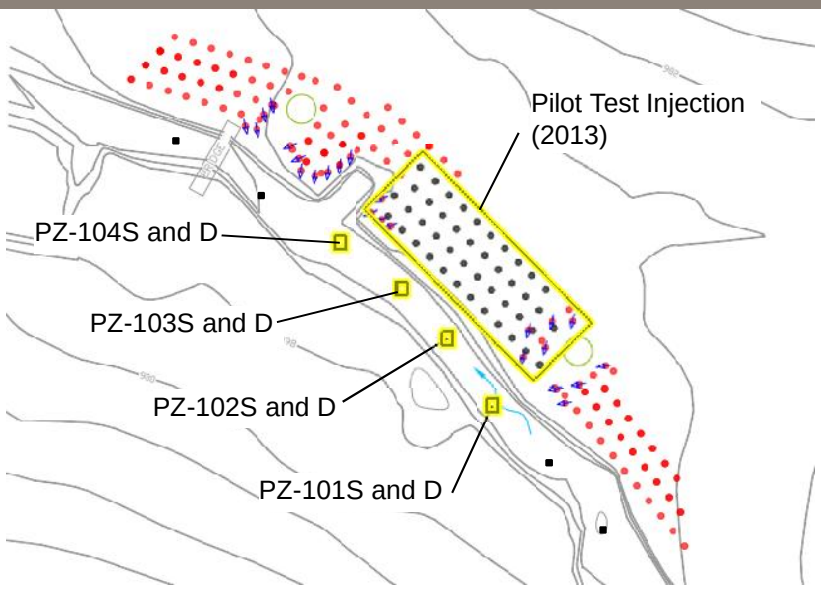
Piezometer Results – Pilot Test



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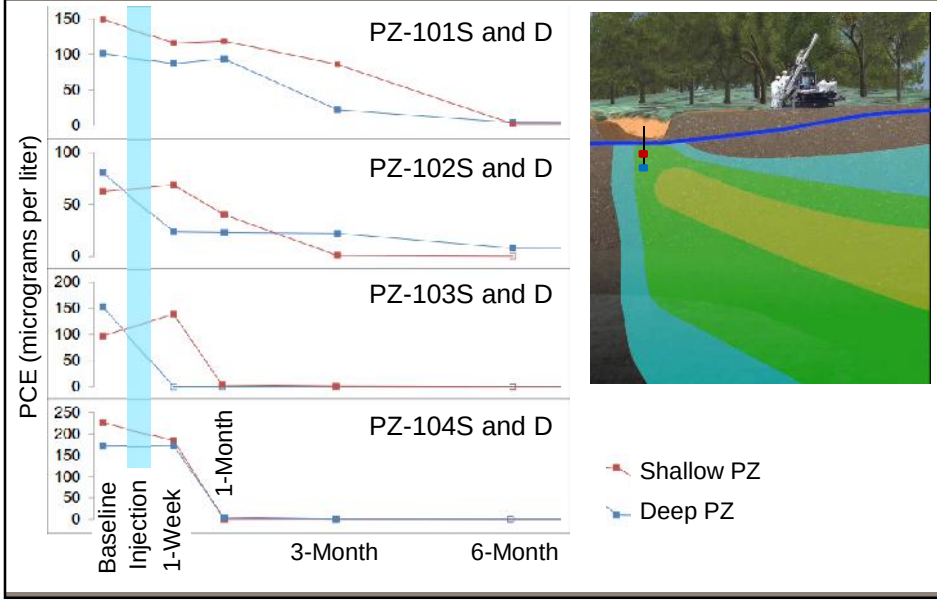
Piezometer Results – Pilot Test



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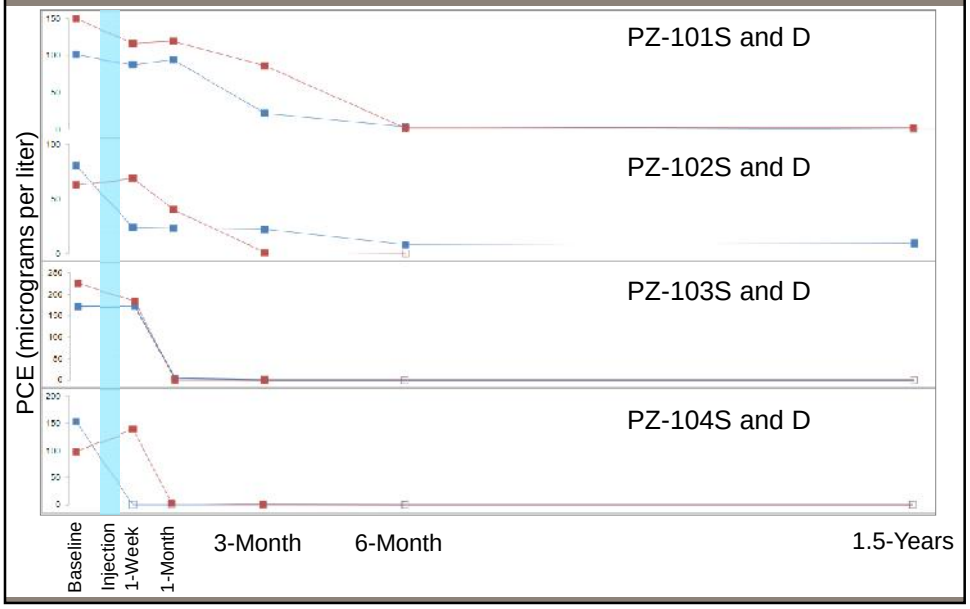
Piezometer Results – Pilot Test



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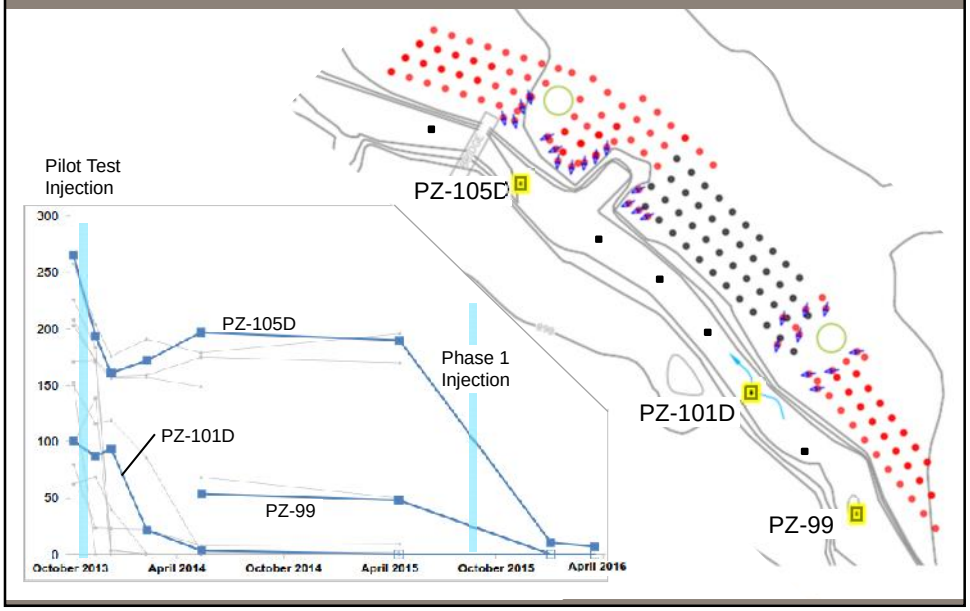
Piezometer Results – Full Scale



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Surface Water Results

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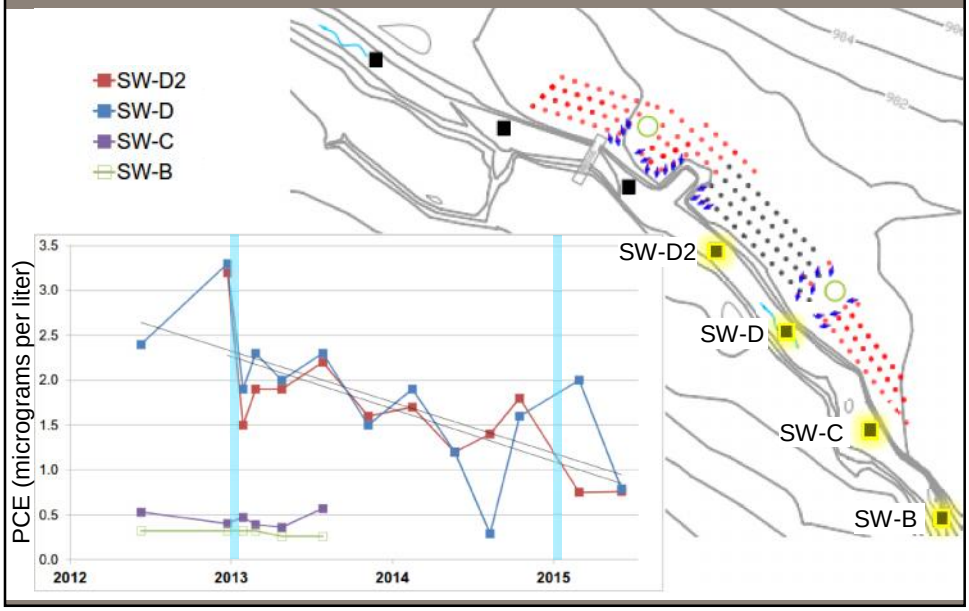
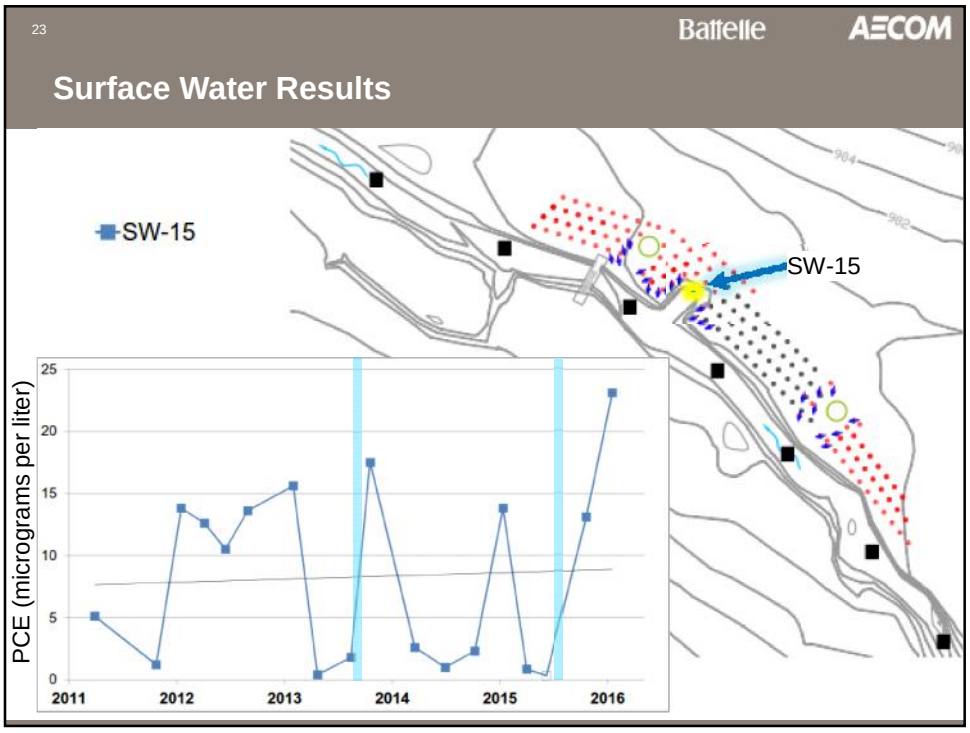
Surface Water Results

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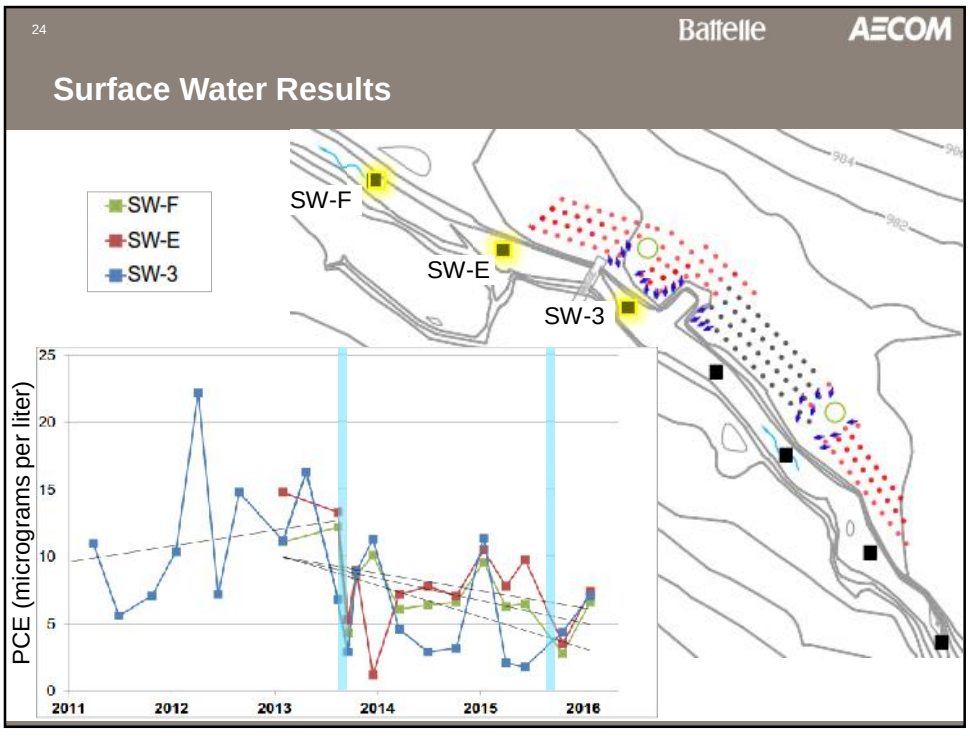
Surface Water Results
SW-15
SW-15
PCE (micrograms per liter)
25
20
15
10
5
0
2011
2012
2013
2014
2015
2016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Surface Water Results
SW-F
SW-E
SW-3
SW-F
SW-E
SW-3
PCE (micrograms per liter)
25
20
15
10
5
0
2011
2012
2013
2014
2015
2016

25

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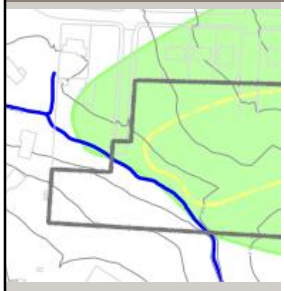
Conclusion and Discussion



- Drilling at 25-degree angle did not cause any significant problems (steeper angle feasible?)
- Daylighting due to roots; noteworthy but manageable
- Distribution assessed during pilot test
- Formation of PRB “net” evident based on streambed porewater results
- Porewater results show trend consistent with PRB dynamic and suggest good performance through 2.5-years post pilot test
- Surface water PCE concentrations illustrate decreasing trend despite untreated overland source

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Thank You!

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