Low Pressure Injection of a Mixed Suspension of Colloidal ZVI and EVO into Fractured Clay at Niagara Falls Air Reserve Station

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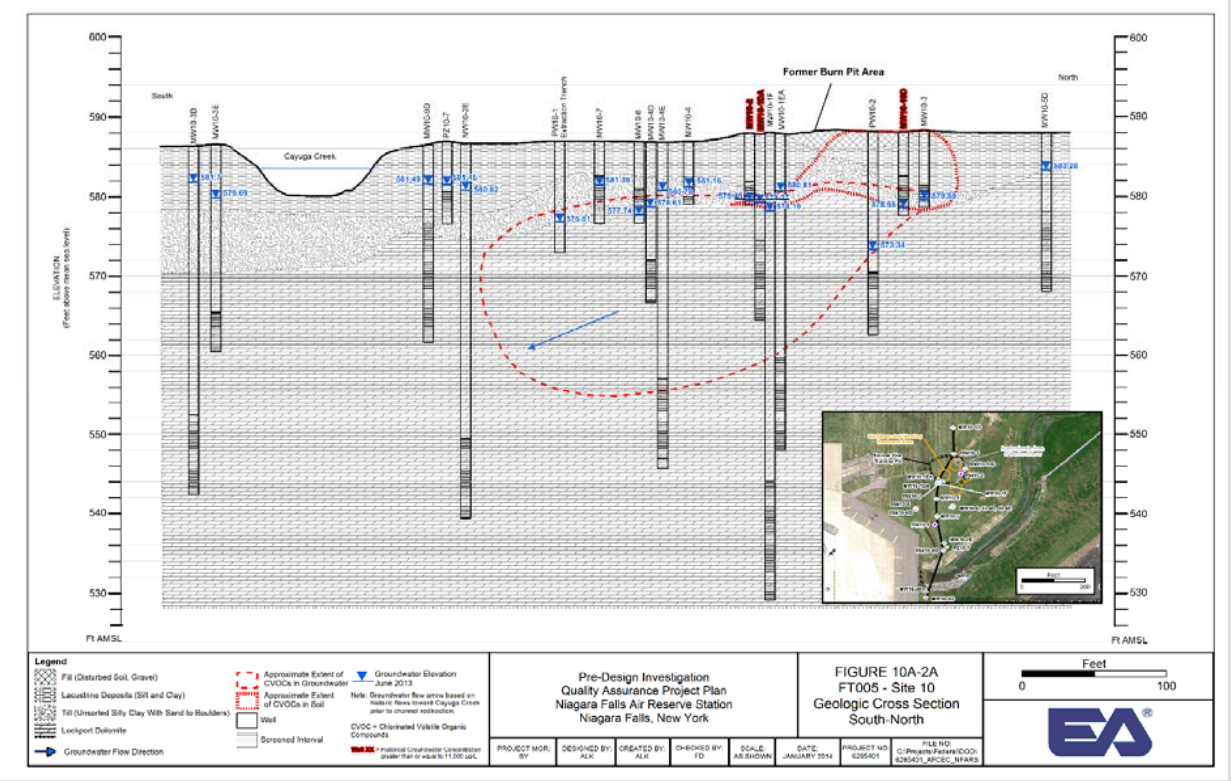
Discussions

- Objectives (target remaining residual source material)
- Understand the Geology/Hydrogeology
- Investigation Technologies - Fill Data Gaps
- Zero Valent Iron/emulsified vegetable oil (ZVI/EVO), effective both abiotic and biologic reductive de-chlorination
- Pilot Test – Additional Injection Understanding
- Injection – Challenges and considerations
- Success at overall reduction in chlorinated volatile organic compound (CVOC) concentrations

NFARS Geology

- Overburden (5 to 15 feet [ft] below ground surface [bgs])
  - Fine-grained clay and silt, fractured
- Shallow Bedrock (10 to 35 ft bgs)
  - Highly weathered and fractured
- Bedrock (25 ft+ bgs)
  - Dolostone, few fractures



Data Gap Investigation Approach

Overall CSM Understanding

- Original Source of Contamination
  - Chlorinated volatile organic compounds (CVOCs) associated with historic waste storage/fire training pit
- Historic and active remedial actions
- Contaminant Migration/GW Flow
  - Vertical and horizontal gradients, flow directions, preferred pathways, receptors
- Surface and subsurface structures/features
- Highest remaining concentrations
  - Overburden
  - Groundwater
  - Fractures

Investigation Techniques

Different Sites Require Different Methods

- Site 10 – Overburden, overburden/fractured rock interface
  - Direct-push technology to Bedrock interface
  - Utilize membrane interface probe (MIP)
  - Use Hydraulic Profile Tool (HPT)
  - Collect confirmation soil/GW samples
- Site 5 – Limited overburden, fractured bedrock
  - Install core holes into fractured rock
  - Map fractures and fracture patterns in rock
  - Isolate fracture zones –
  - sample soil and groundwater
  - Sample groundwater from specific fractures

Injection Challenges/Considerations

- Difficult delivery in heterogeneous soils
  - Use smaller particle size ZVI – Colloidal ZVI 3 microns
- Shallow injections – daylighting in tight soils
  - Low pressure injections - ~3 psi
- Varying surface features – pavement, grass, drainage swales, fencing,
- Subsurface structures
  - Large missile pads
  - Stormwater culverts, pipes
  - Heterogeneous soils

Why Use Zero Valent Iron?

- Injected colloidal iron mixed with EVO and diluted with water provides fast and slow-release electron donor to stimulate reductive dechlorination.
- Under anaerobic conditions, adding dehalococcoides bacteria can use chlorinated ethenes (PCE, TCE, DCE, and VC) as electron acceptors to enhance the reductive dechlorination process.
- End result is non-toxic ethene and ethane, which volatilize or can be further metabolized.
- Can address chlorinated contamination through either chemical reduction and/or enhanced bioremediation.*
- In situ remediation technologies are attractive because they do not involve excavation or permanent system installation.*
- ZVI/EVO is persistent for over 2 years (typically 3+ years)

*Provided by REGENESIS

NFARS Test Injection

Pilot Test

- Performed prior to injections
  - Centered around existing well cluster
  - Installed DPT to refusal approximately 10 ft bgs
  - Direct-push technology points were installed 7, 10, and 12.5 ft from wells at 120-degree radial spacing
  - Injected suspension into well at low pressure approximately 3 psi
  - Looked for evidence of EZVI in DPT points

Distribution

- Identified EVO/ZVI in all DPT points within minutes
- Estimated reach of interest (ROI) at 10 ft from well for injections
- Utilized ROI for all sites – similar geology

NFARS Injection

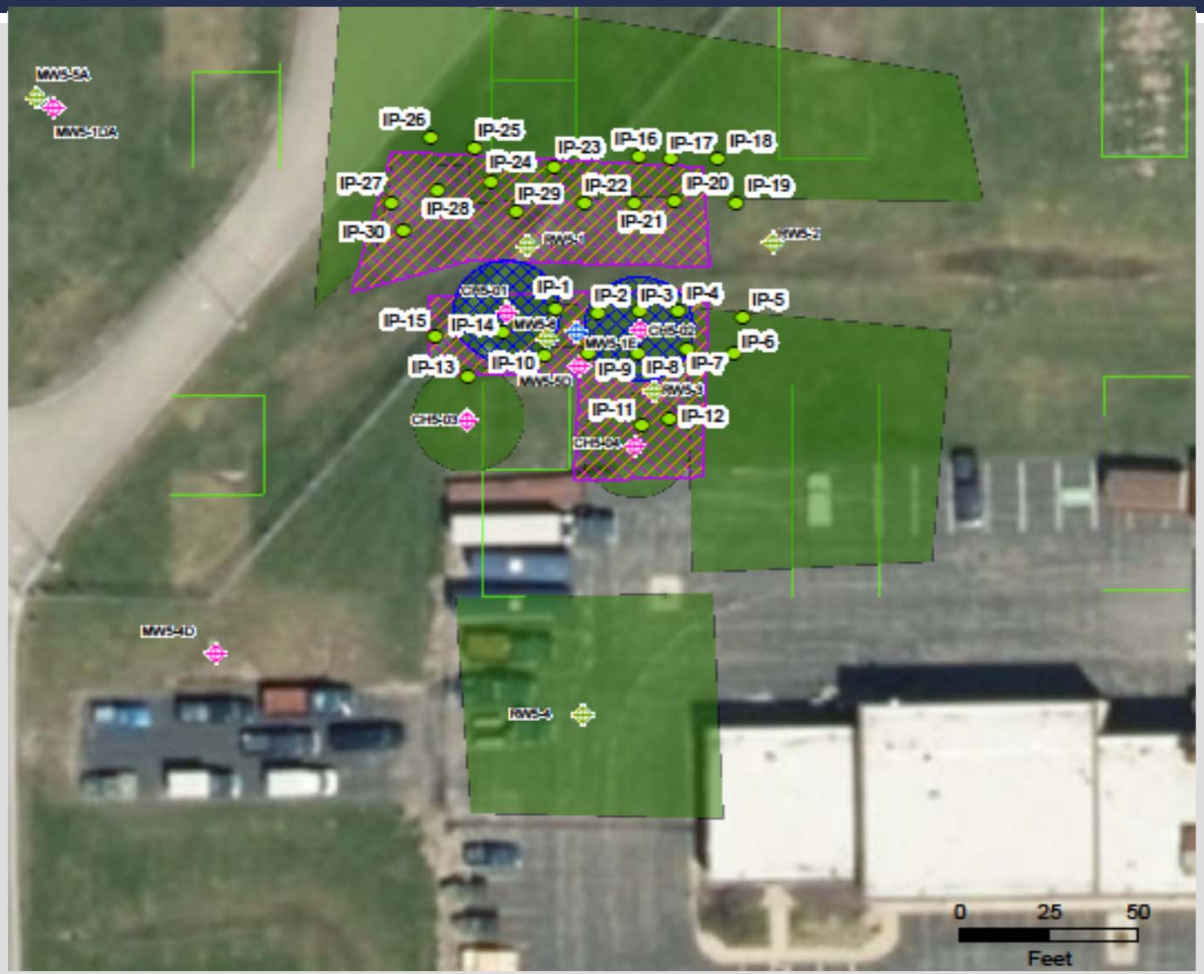
Site 5

- Injection locations/spacing
  - Rectangular grid spaced approximately 12-15 ft apart
- Process
  - 2-4 points installed at a time
  - 100 points
- Mixing
  - 0.2 lb of ZVI and 0.6 lb of EVO per gal of injectate mixed with municipal water on site
- Injection volumes/pressure
  - Each point received approximately 200 to 600 gallons
  - Total volume of 33,137 gallons
  - 600 gallons in fractures of 4 bedrock core holes

Site 10

- Injection locations/spacing
  - Rectangular grid spaced approximately 12 ft apart
- Process
  - 2-4 points installed at a time
  - 33 points
- Mixing
  - 0.2 lb of ZVI and 0.6 lb of EVO per gal of injectate mixed with municipal water on site
- Injection volumes/pressure
  - Each point received approximately 200 to 600 gallons
  - Total volume of 11,820 gallons

NFARS SITE 5 INJECTIONS



NFARS Site 10 Injections

SITE 5 RESULTS

Performance Monitoring Results – Total CVOCs (DS004 – Site 5) Niagara Falls Air Reserve Station, New York			
Performance Monitoring Well	Pre-Injection Total CVOCs[(a)] (µg/L) September 2015	Post-Injection Total CVOCs[(a)] (µg/L) October 2019	% Change Pre (September 2015) to Post (October 2019) Injection
MW5-5D	7374	2701	-63%
RW5-1	3873	12	-99%
RW5-2	6	22	+266%
RW5-4	132	4	-97%
AVERAGE	2846	685	-76%

(a) Includes trichloroethene (TCE), trans- and cis-1,2 Dichloroethene (DCE), and vinyl chloride (VC).

SITE 10 Results

Performance Monitoring Results (2015-2019) – Total CVOCs (FT005 – Site 10) Niagara Falls Air Reserve Station, New York			
Performance Monitoring Well	Pre-Injection Total CVOCs[(a)] (µg/L) September 2015	Post-Injection Total CVOCs[(a)] (µg/L) June 2019	% Change Pre- (September 2015) to Post- (June 2019) Injection
MW10-1DA	941.5	3.1	-99.7 %
MW10-2	1716.4	7.5	-99.6 %
MW10-10D	4650.8	1130.4	-75.7 %
PW10-2	994.5	0.0	-100.0 %
AVERAGE	2075.8	285.3	-93.7 %

(a) Includes trichloroethene (TCE), trans- and cis-1,2, Dichloroethene (DCE), and vinyl chloride (VC)

Summary

- Understand the geology/Hydrogeology of the site
- Use site-specific investigation techniques to fill data gaps – identify specific remaining source material
- Understand challenges/features of each site – plan ahead
- Colloidal ZVI/EVO amendments improved distribution, can create both abiotic and biologic reductive de-chlorination and are persistent for 3+ years
- Targeting specific residual source areas greatly reduces contaminant mass and cocentrations
- Overall % reduction in CVOC Concentrations at Niagara Falls ARS
  - 76.0% (Site 5) and 93.7% (Site 10)

Questions/Contact Information

- Questions/Comments?

- Contact Information
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