

USING MULTIPLE TECHNIQUES TO MONITOR EFFECTIVENESS OF *IN-SITU* INJECTIONS

Eleventh International Conference
on Remediation of Chlorinated and
Recalcitrant Compounds

April 8 – April 12, 2018

Palm Springs, California



BATTELLE

R³

Presented by *Remediation Risk Reduction, LLC*

Agenda

R³

- Background
- Injection Challenges
 - Matrix Variation
 - Refusal (Now What?)
- Unintended Consequences
 - Hydraulic Push/Plume Spreading
 - Fugitive Emissions
- So, How Do You Monitor Effectiveness?
 - Sampling/ Electrical Conductivity
 - Gaging Hydraulic Head
 - Tracers
 - Surface Deflection
 - Forensic Drilling
- Lessons Learned



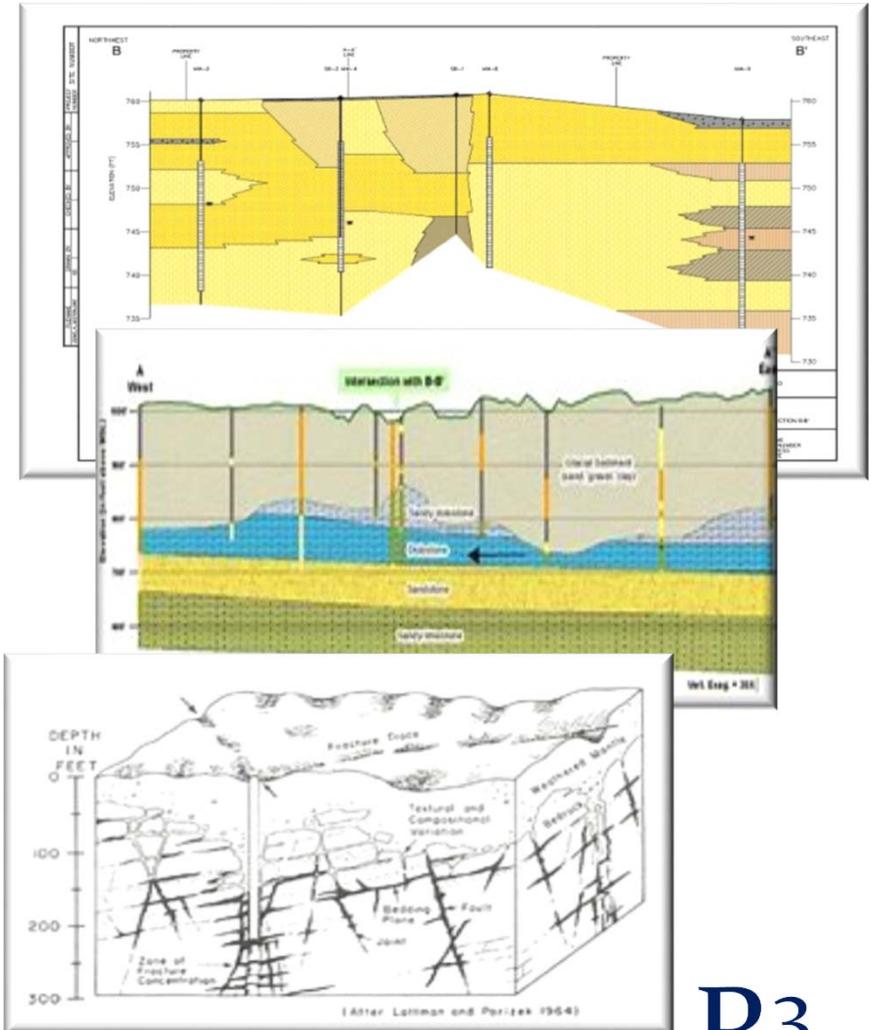
Background

- Challenges of injecting abiotic or biotic, reagents or amendments into the subsurface to remediate soil and groundwater can include unexpected treatment results and deleterious/catastrophic affects to solute transport
- “Everything’s good” right up until the moment when it’s not
- Better to know “sooner than later” if outcomes are different than expected – and why
- Success is riding on it, so multiple techniques have been developed and implemented to achieve project objectives

Injection Challenges

Matrix Variation – “it’s about the architecture”

- Granular Soil: grain size and density can cause deflection and dictate preferential flow
- Fine-grained Soil: high fracture pressure can prevent propagation and cause short-circuiting
- Bedrock: fracture aperture can prevent entry and lineaments can “pirate” injectate away from target



Injection Challenges

Refusal – “now what?”

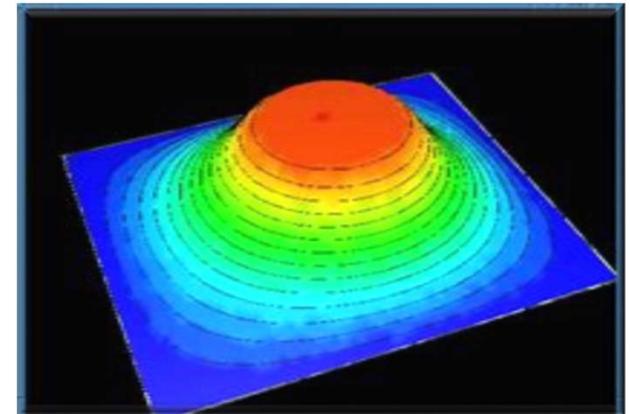
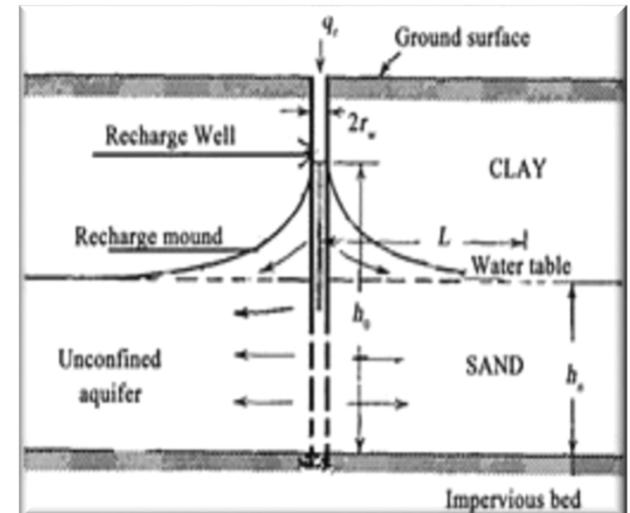
- **Direct Push:** Refusal is common
 - Use a bigger hammer
 - use auger rig drill to 1'-2' above interval, place bentonite seal, then DPT to target depth
 - use auger rig through interval, then use packers to isolate targets
- **Drilling:** switch methods, as needed (coring, rotary, sonic, etc.)



Unintended Consequences

Hydraulic Push

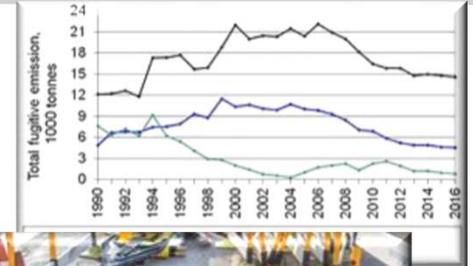
- **Mounding:** Compare total-fluid injection volume with estimated native matrix pore-water volume to evaluate displacement potential
 - hydrology assessment for more accuracy by installing transducers in wells at different radial distances from injection point to calculate hydraulic-head changes to evaluate temporary mounding and/or pressure pulsing
- **Plume Spreading:** Want to prevent the unintended consequence of extending plume geometry (dimension), especially offsite or under structures
 - can alter injection order to limit aggregate head buildup, i.e., move to different area each injection to “spread around” the total fluids dispensed in a day



Unintended Consequences

Fugitive Emissions

- Vapor plume expansion can be an unintended consequence of dissolved-phase plume expansion
 - off-gassing can cause fugitive vapors to permeate subsurface structures (basements, vaults, trenches) and create explosive atmospheres

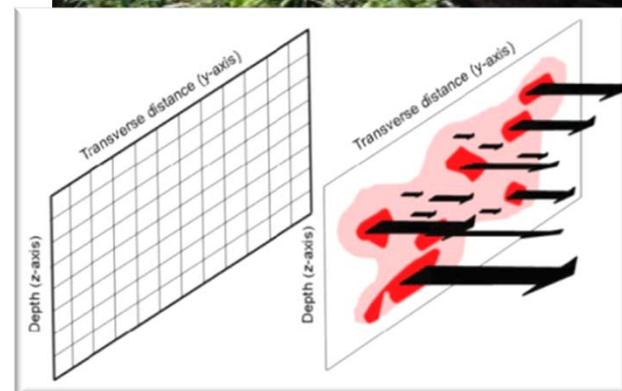


R³

Monitoring Effectiveness

Sampling

- **Soil & Groundwater:** Collect samples for chemical analysis before, during, and after injections
 - quick lab turn-around allows you to be “nimble” in making design and implementation adjustments in the field
 - may need to collect groundwater samples from intervening locations using discrete sampling methods, e.g., hydro-punch or “implants”
 - use results to calculate mass flux and mass discharge to track solute mass reduction

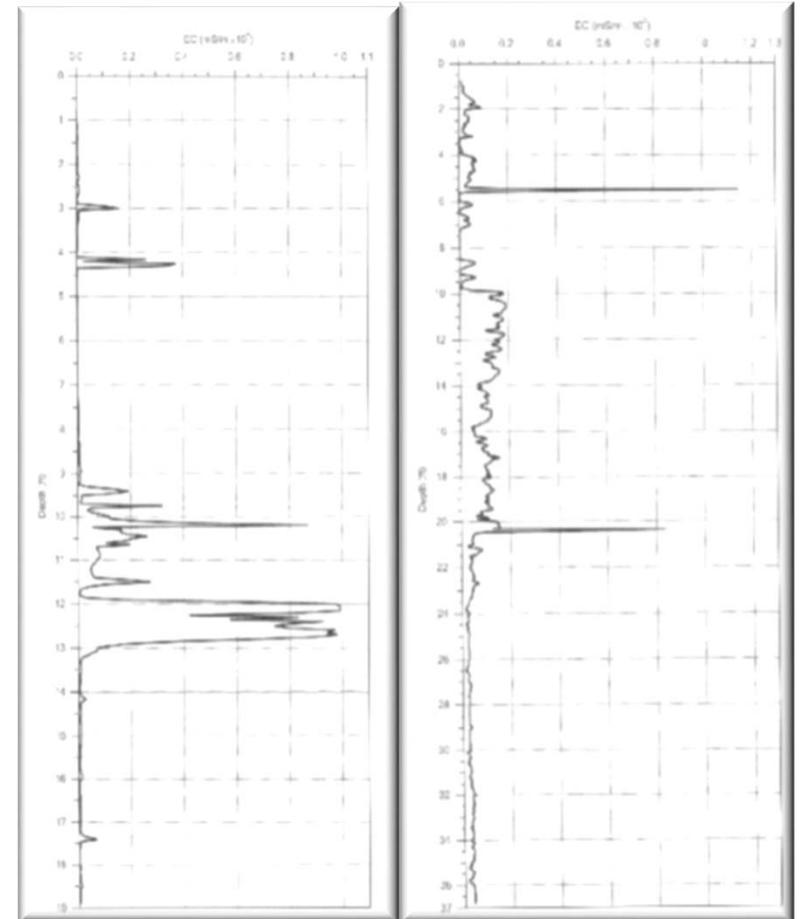


R³

Monitoring Effectiveness

Electrical Conductivity – Membrane Interface Probe

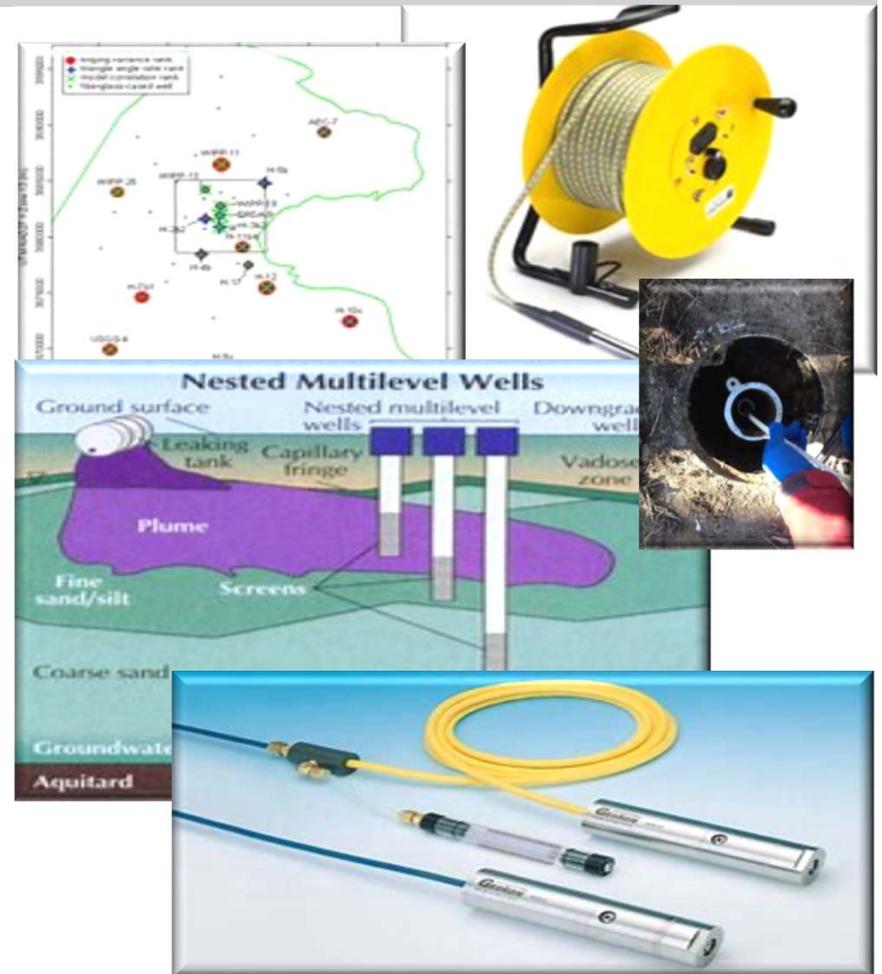
- EC in sandy soils is relatively low, whereas EC in metallic iron is relatively high
- **Example:** A site underlain by sandy soil was injected with ZVI and EZVI
 - EC logs were used to detect the seams of iron placed for treatment
 - the peaks correspond very closely to the injection depths



Monitoring Effectiveness

Gaging Hydraulic Head

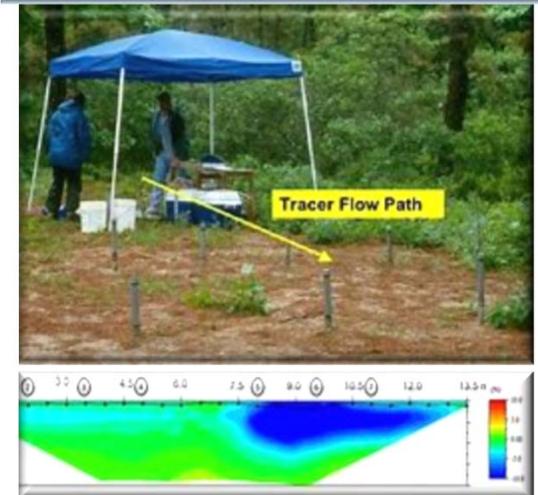
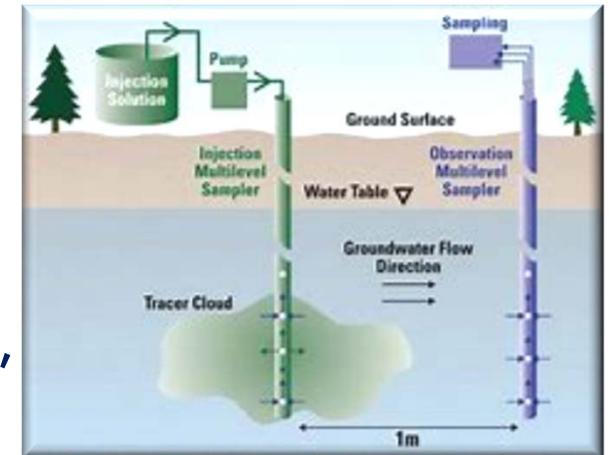
- Measuring water levels in nearby wells during injection can give you a sense of “the radius of injection”
- To gage multiple wells, data loggers (transducers) can collect more accurate information regarding pressure pulses



Monitoring Effectiveness

Tracers

- **Tracking Injectate:** A way to measure injection radius
 - some injectates are inherent tracers, e.g., potassium permanganate – “just look for the color purple”
 - when distribution is less obvious, conservative tracers, e.g., visible or fluorescent dyes, salts, or stable isotopes, can be added to the injectate and detected in nearby wells
- **Tracer Properties:** The chemical and physical behavior must be understood:
 - travel at same velocity and direction as groundwater
 - does not interact with solids
 - easily detected
 - present in concentrations well above background (if applicable)
 - should not modify hydraulic conductivity or other matrix properties



R³

Monitoring Effectiveness

Surface Deflection

- In unpaved areas, simple surveying equipment, e.g., transit level or theodolite, rod, and buckets, can be used to measure surface uplift caused when injectate displaces native matrix
 - a grid or crosshair array is used to “map” injectate-filled fractures



Monitoring Effectiveness

Forensic Drilling

- **Postmortem:** Confirmatory sampling to:
 - evaluate changes in solute mass via chemical analysis
 - evaluate “daughter products” and “wet chemistry” changes, e.g., cations and anions
 - observe for injectate, e.g., discoloration, injectate substance, etc.



Lessons Learned

- Conducting successful, *in-situ* injections is as much an art as it is a science
- It's not easy predicting or accounting for subtle nuances inherent to a target matrix
- Even if considered homogeneous, matrix architecture can result in failed injection efforts
- Gathering “effectiveness” data during or immediately following an injection program allows the practitioner to identify critical problems or expected outcomes
- Being “nimble” in the field can make the difference between failed and successful remediation treatment

Contact

Remediation Risk Reduction, LLC

138 Rudi Lane

Golden, Colorado 80403

303-642-9212



Tom Harp, PG, MSCE, MBA

tharp.rrrllc@gmail.com

303-903-4858

R3

“Remediation is only expensive when it doesn’t work”

Questions

