

# PERMEABLE REACTIVE TRANSECTS FOR TREATMENT OF HEXAVALENT CHROMIUM IN VARIED GEOLOGY

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# Site Setting

- Northeast U.S.
- Large hexavalent chromium plume
- Earlier remediation phases (T&D, P&T, etc.)
- Zones
  - Tight, silty sand
  - Silty sand with gravel
  - Glacial till
- Consistent Access?
  - Difficult to impossible
  - Depths up to 90 ft-bgs.
- Installation
  - Soil mixing?
  - Fracturing?
  - High energy radial mixing?
  - Contemporary modification to a PRB?



# **GeoTAP™**

## **(Geological Targeted Access Point)**

# Remediation & GeoTAP

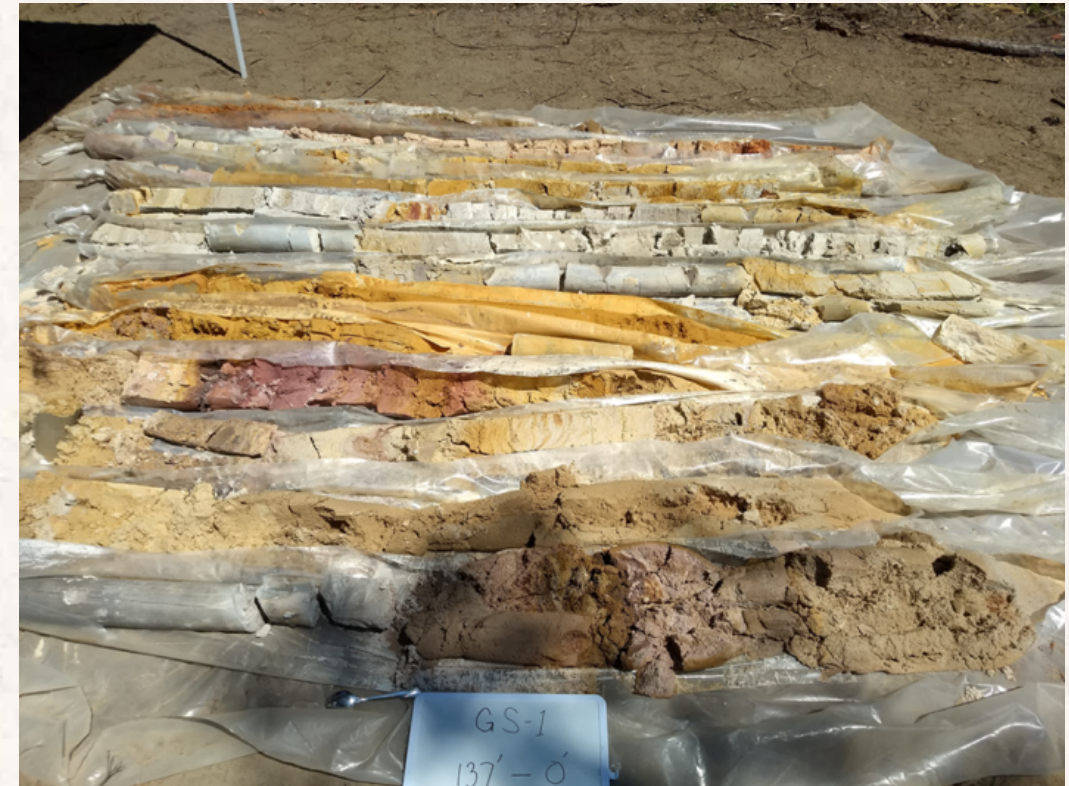
- In-situ remediation success requires proper reagent:
  - Longevity
  - Dosing
  - **Contact**
- DPT or straddle packers are not always options
- Injection well problems?
  - Mass location
  - Lithology
  - Injectate, e.g. slurry

- Refusal?
  - Gravel/cobble zones
  - Glacial till
  - Weathered bedrock/PWR/Saprolite
  - Historic fill, etc.
  - Clay
  - Flowing Sands
- Drill like BR; inject like OB



# GeoTAP™ Technique

- Pre-drill each injection location to target depth
  - Augers (HSA, SSA)
  - **Sonic (log lithology)**
- Engineered bentonite backfill
  - Build in lifts
  - Sequential hydration
- DPT through bentonite column
- High energy injection
- Emplace reactant/reagent within native lithology
  - Geology still dictates injection tip, pressure, and flow
  - Radial mixing
  - Fracturing
- 60+ sites in various geologies/regions

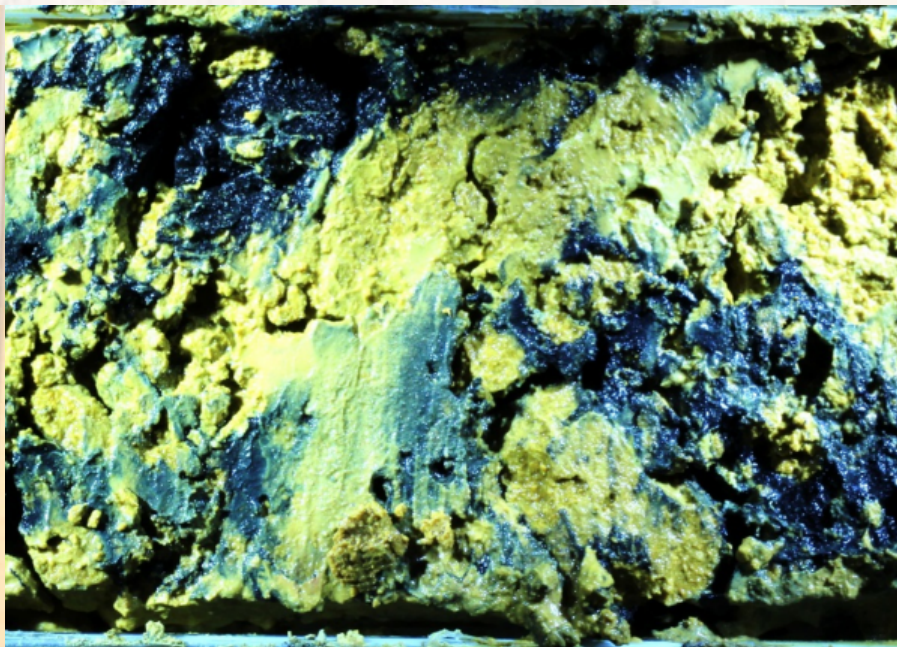
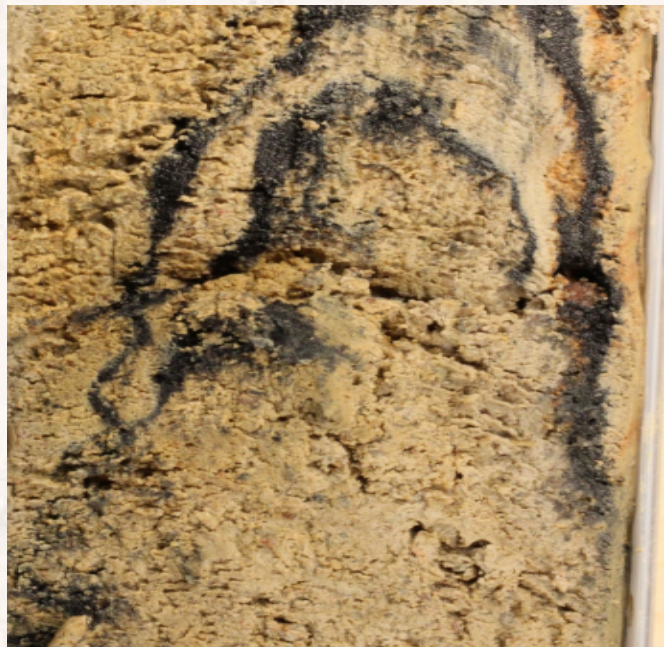


# GeoTAP™ Design

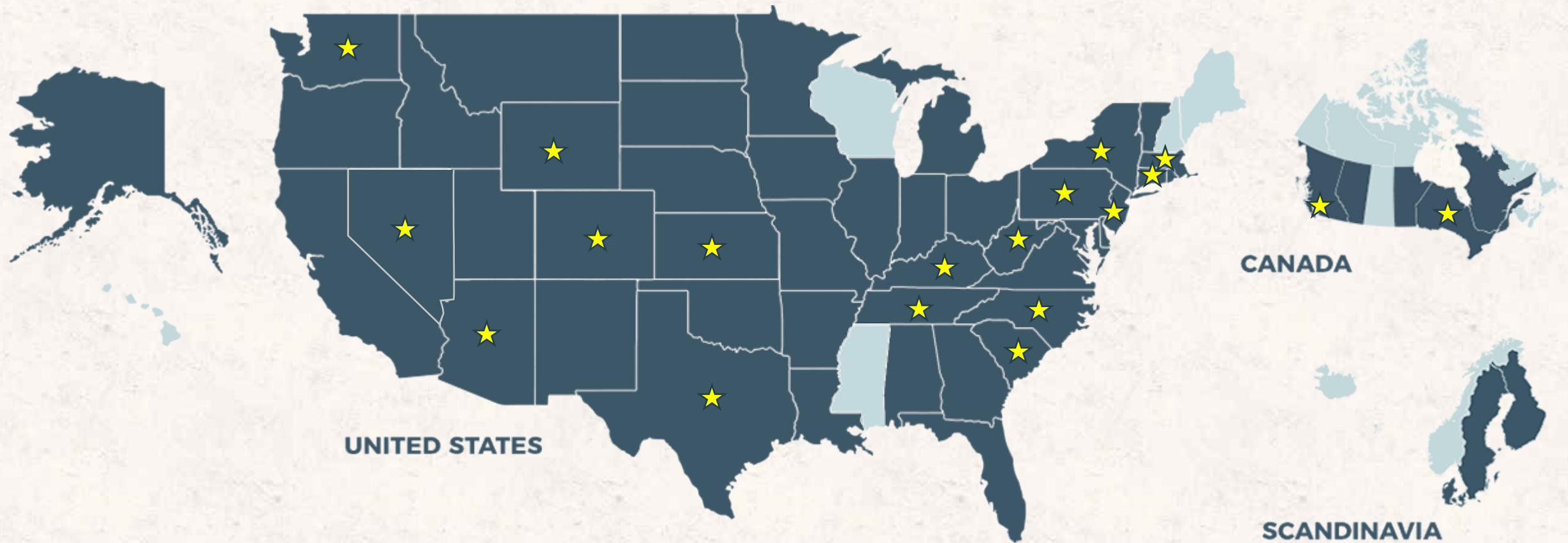
- Triangular grid pattern
- Spacing is a function of:
  - Depth
  - Lithology
  - Shot volume
- Adhere to injection spacing requirements
- Tied to OB or BR remedy?
  - Many times, yes
  - Spacing
  - Offsets



# Distribution Examples



# GeoTAP™ Applications





# Slurry Design Considerations

Plan for success

# Injectates

## SLURRIES (~10 to 300 um) ("pollen to sand")

- BOS 100<sup>®</sup>
- CAT 100
- BOS 200<sup>®</sup>/BOS 200+<sup>®</sup>
- Activated Carbon (GAC, PAC)
- FerroBlack<sup>®</sup>
- FluoroSorb<sup>®</sup>
- Organoclay<sup>®</sup>
- ZVI
- CaSO<sub>4</sub>
- Oxides

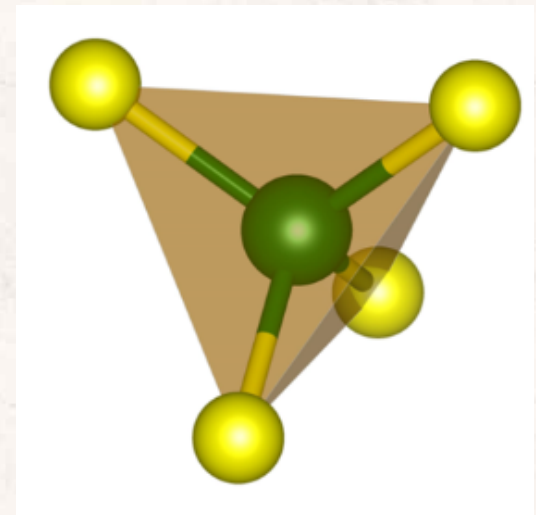
## AQUEOUS & COLLOIDAL (<10um) ("soot to red blood cells")

- MgSO<sub>4</sub>
- Persulfates
- Peroxides/MFR
- CaCO<sub>3</sub>
- Colloidal/Liquid Carbon (CAC, LAC)
- Drawbacks
  - Wash-out
  - Low rock matrix interaction
  - Inefficient (wt./vol.)
  - Multiple injection events



# Reactive Ferrous Sulfide (FeS)

- *Biotic or Abiotic Formation?*
- Not all iron sulfides are created equal, but generally:
  - Reduce  $\text{Cr}^6$
  - Bind with metal cations, especially +2
- Sulfate Reducing Microorganisms (SRM) + iron (biotic)
  - Phosphate reaction, reduce formation of FeS
  - Extracellular materials aggregate mackinawite
  - Create and maintain stable generation environment
- Synthesized (chemical reactor)
  - Adjust molar ratios of Fe, S, and Al
  - Polysulfide interlayer
  - No pyrite



# Reductant Technology

- FerroBlack®-H
  - Abiotic
  - Mackinawite-structured ferrous sulfides
    - Soluble sulfides
      - 1-2% wt.
      - Immediate treatment
    - Insoluble sulfides
      - 7-8% wt.
      - Long-term treatment
    - Multiple mechanisms
      - Reduction of hexavalent chromium
      - Trivalent precipitation
  - Viscous slurry (10.1 lb./gal)
    - pH ↑
    - ORP ↓





# Installation

Not your typical injection setup

# RDC

- Soil and groundwater samples
- Evaluate mass and mass flux
- 30-year lifespan
  - Requirement
  - Flow between transects
- Significant mass of reactant required
- Loading Calculations
  - lb./ft<sup>3</sup>
  - Transect specific
  - Depth specific
  - Dictated transect spacing (15 to 30 ft. centers)



# Equipment & Process

- Roto-sonic (“sonic”) drilling technology
  - Expeditious advancement
  - Logging soils
    - Complete vertical soil profile
    - Full transect span evaluation
    - Photographs
    - Succinct top and bottom intervals
  - Piezometer installation
    - 3 per transect
    - Distribution monitoring
- GeoTAP
- Schedule
  - Sonic drilling and backfill activities: 5 weeks
  - Conducted with a 4-week lead time

# Equipment (GeoTAP)



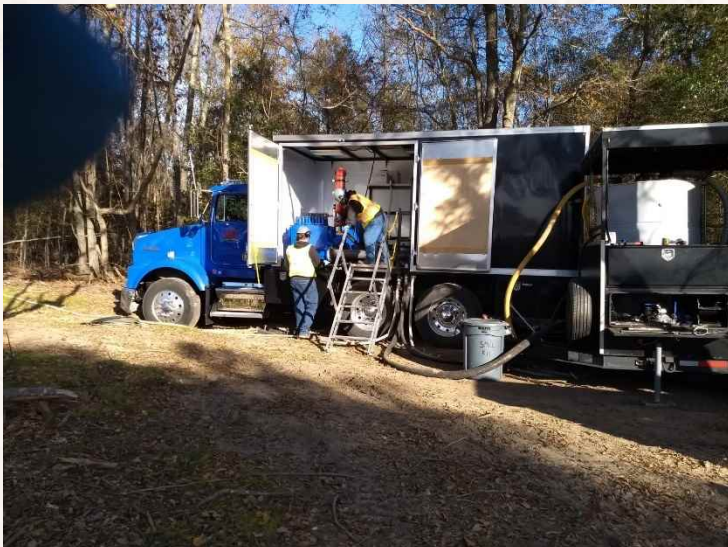
# Soil Logging (Transects)



# Injections (DPT)

- DPT rig (7822DT)
- 2.25" injection rods, pre-strung hose (AST design)
- Geology-specific injection tip (AST design)
- Depth: 40 to 90 ft-bgs. (range)
- High-flow/high-energy Triplex injection system
  - Flow rates up to 280 gpm
  - Sustained injection pressures up to 2,000 psig.
  - Controlled distribution power – not a sledgehammer!

# Triplex Injection System



- 165 HP Triplex pump
- 8 gpm to 250 gpm
- Max press. - 2,500 psi
- Two 1,000-gallon slurry tanks

# Equipment (Triplex & DPT)



# Injection - Triplex (Varied Flow Rates)

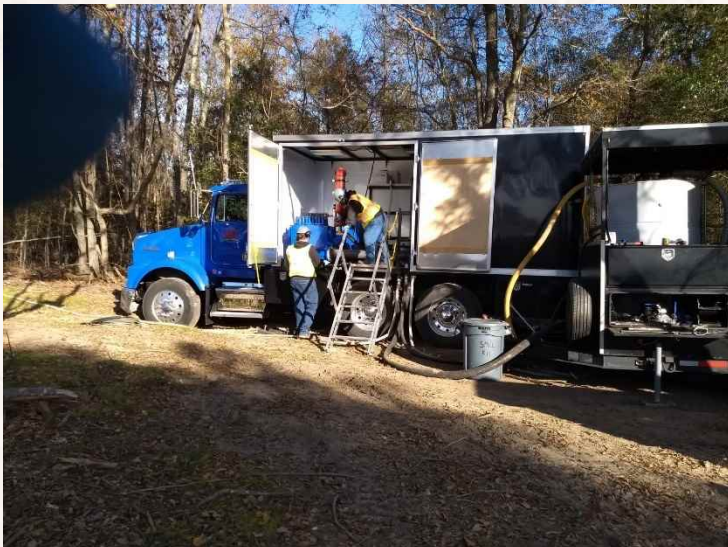


Various Flow Rates

20 gpm, 60 gpm

120 gpm, 250 gpm

# Triplex Injection System



- 165 HP Triplex pump
- 8 gpm to 250 gpm
- Max press. - 2,500 psi
- Two 1,000-gallon slurry tanks



# Lessons Learned

Optimization rooted in experience but adjusted real-time.

# Flow Rate

- Initial design
  - Based on previous experience
  - Depths up to ~180 ft-bgs.
  - 15 to 25 ft. centers
- In Field
  - Distribution at moderate energy?
  - Triplex vs. other pumps?
    - Energy
    - Duration
    - Preferential pathways- planning and management
      - Former sheet pile
      - Former wells
      - Former investigatory borings
      - Former canal



# Installation Summary

- ~34,600 gal of FerroBlack
- Five transects, totaling 2,340 linear ft (lf)
- 4 weeks of injection activities.
- Injectate distribution assessment
  - Transducers in existing monitoring wells and piezometers
  - Monitoring
    - Changes in groundwater geochemistry
    - Changes in water table
    - Colorimetric evaluation
  - Visual confirmation

# Optimization

- Deep
  - 50 to 200 psig
  - One 300-gallon shot
- Shallow
  - 50 to 80 psig
  - Sequential shots of 200 and 100 gallons.
- Groundwater monitoring continues at the site to evaluate performance



# Thank You

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