Optimizing In-Situ Remediation

NEWMOA Workshops
March 22-24, 2016

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Today's Challenges For Remediation

- The remaining sites are complex
- Heterogeneity complicates remediation
- Understanding COC mass distribution versus geology and hydrogeology (e.g. K, seepage velocity) is a key to remedial success
- Traditional investigation methods do not meet the needs of today's challenging sites

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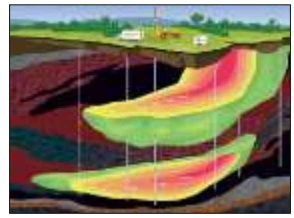
Remediation Toolbox Overview

- Site Characterization
  - MiHPT
  - UVOST (LNAPL)
  - Waterloo^{APS} / Mobile Lab
  - Core
- ISCO, ISCR, Bioremediation
  - Injection
  - Pneumatic and hydraulic emplacement
- Thermal Treatment
  - TCH/ISTD
  - Steam
  - ERH
- Combined Remedies
- S&D – Integration of site characterization and remediation



Technology fit versus mass/concentrations


NAPL pools


Mobile NAPL


Ganglia Droplets Adsorbed/dissolved


Trace

High Concentration Low

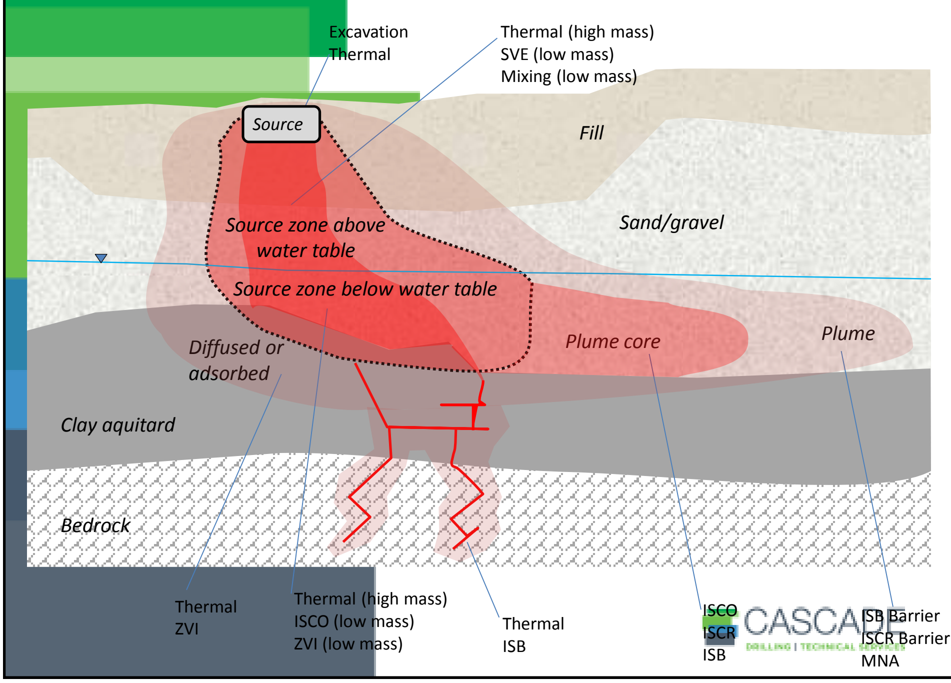
Thermal

ISCO/ISCR

ISB

MNA

Combined remedy -source and plume need different treatment



Risks of Faulty CSMs

- Remedies based on a flawed CSM may not perform as expected, increasing the time it takes to achieve remedial action objectives, and the overall cost
- Until the CSM reflects reality, investigation and cleanup will be costly

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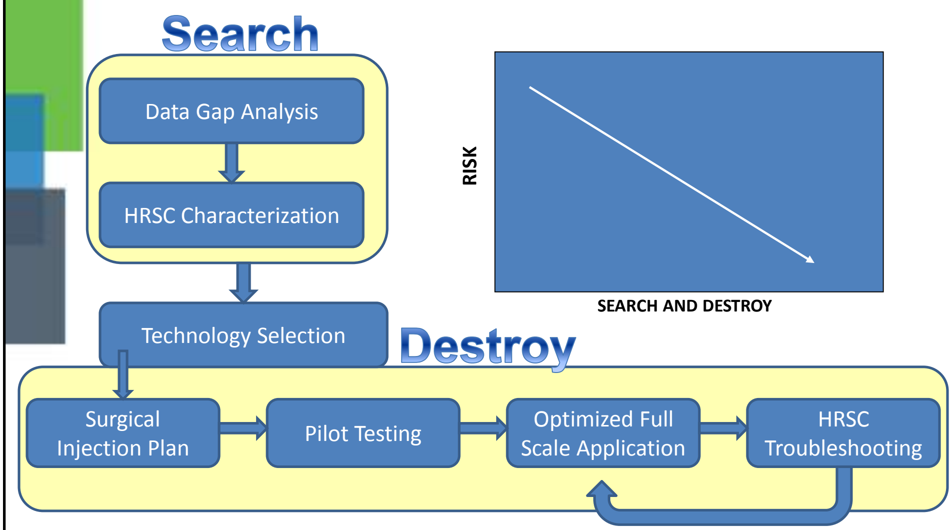
Search and Destroy™ Methodology



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Dispelling HRSC Myths

- "Too Expensive"

- Cost of an investigation that includes HRSC may be higher than a typical investigation initially, but the overall cost of the project will be lower due to:
- Reduced investigation phases
- More focused, appropriate, and cost effective remedy

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Dispelling HRSC Myths

- “Only for the most complex sites”
- All sites can benefit from HRSC; the complexity of most sites is not known until many mobilizations have occurred using traditional site characterization technologies

Moving On From Monitoring Wells

HRSC vs. MWs

- MWs yield depth-integrated, flow-weighted averaged data, with no vertical distribution of COCs in the screened interval
- MWs do not define the small scale heterogeneities controlling contaminant transport in groundwater
- MWs have high life cycle costs
- MW screens are often chosen based on limited data and do not intersect the real target interval

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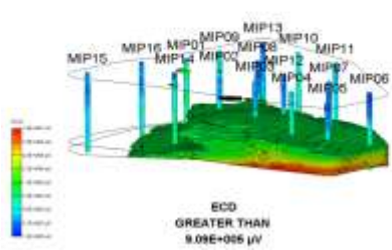
High Resolution Site Characterization (HRSC)

- Tools available to compile dense data sets and generate images to develop:
  - Conceptual Site Models
  - Pre-Design Investigation
    - NAPL, VOC, K and soil type profiling
    - Can be easily combined with pilot testing in same mobilization



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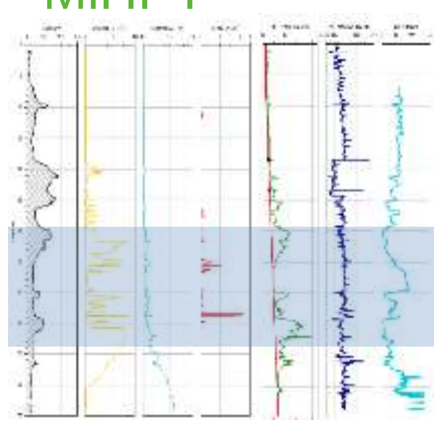
HRSC Technologies – What's in the Toolbox?

• Technology	Purpose
• Electrical Conductivity (EC)	Relative Grain Size
• Membrane Interface Probe (MIP)	VOC Delineation
• Hydraulic Profiling Tool (HPT)	Relative Hydraulic Conductivity
• MiHPT	Combined System
• Low Level MIP (LL MIP)	Lower Detection Limit
• Waterloo APS	Discreet GW Sampling and Hydrostratigraphic Logging
• UVOST	Fuel LNAPL Delineation
• Core DFN	Contaminant Mass in Fractured Bedrock
- On-site MobiLab	Rapid, Defensible Data

Next Generation Characterization Technologies - MiHPT

Can reduce remediation footprint and cost but more importantly increases probability of success with a more targeted remediation design.



Red = PID and HPT Dissipation Testing
Yellow = ECD
Light Blue = XSD and K
Black = Electrical conductivity
Green = Down Hole Pressure
Blue = Down Hole Flow

MiHPT – 3 Tools in One Boring

Providing the Whole Picture

- **Lithology**: Electrical Conductivity (EC)
- **VOC Mass**: Membrane Interface Probe (MIP)
- **Hydraulic Conductivity**: Hydraulic Profiling Tool (HPT)

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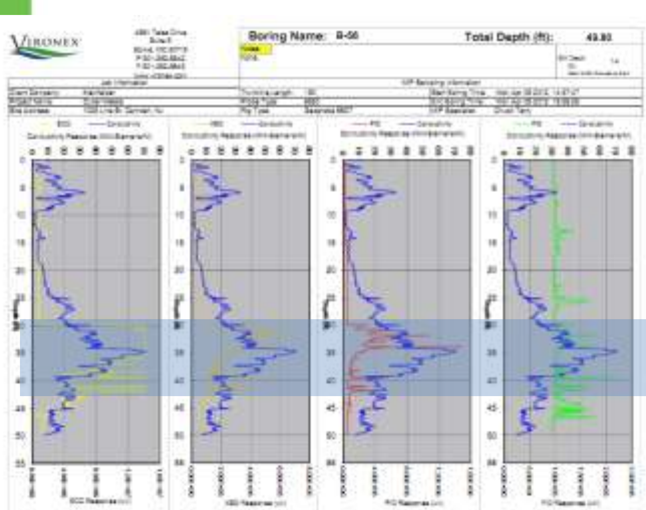
MIP: VOCs Versus Lithology



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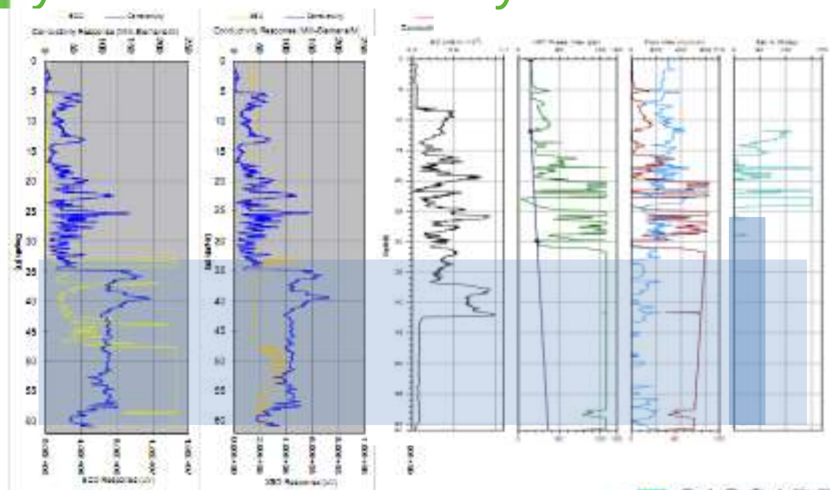
MiHPT: VOCs Vs Electrical and Hydraulic Conductivity



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Matrix Back Diffusion

VOC back diffusion from low permeability diffusion dominated units (typically silt or clay) into high permeability advection dominated units (typically sand or gravel).

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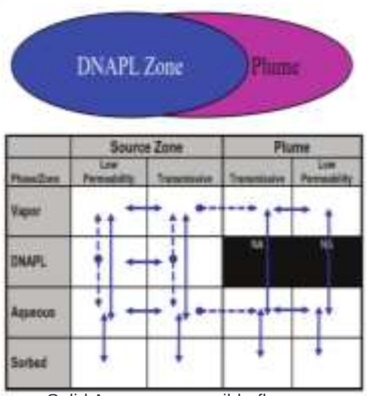
Source and Dissolved Plume With Common Contaminant Fluxes Between Compartments



- Solid Arrows = reversible fluxes
- Dashed Arrows = are irreversible fluxes

- DNAPL or dissolved phase contamination initially moves preferentially through the pathway with the greatest permeability. Initially little or no contamination in present in the lower permeability clay layers.
- Within time, dissolved phase contaminants migrate into the low permeability via diffusion and/or slow advection. Contaminants in the clay layers are stored in dissolved and sorbed phase.
- Most natural process and remediation technologies preferentially deplete chlorinated solves in transmissive zones. When this occurs contaminants are released from the low permeability zones via diffusion and slow advection.

Sale et. al., 2007

Measuring Mass Flux Through Vertical Transects - Waterloo^{APS}

- Useful for prioritizing sites, targeting remediation efforts, assessing remediation performance, and determining when to transition from aggressive treatment to more passive long term remediation strategies.
- Discharge and flux measurements provide credible assessments of performance an source status and lead to better decisions than relying on concentration data alone.
- Mass discharge can be linked directly to natural attenuation rates.

Measuring Mass Flux Across Transect

High Resolution Investigation at a manufacturing plant

- MIP
- Waterloo^{APS}
- DPT Soil Coring
- On Site Laboratory

NGWA – "High Resolution Site Characterization Supporting Focused Combined Remedies," , Seth Pitkin, 5.23.14

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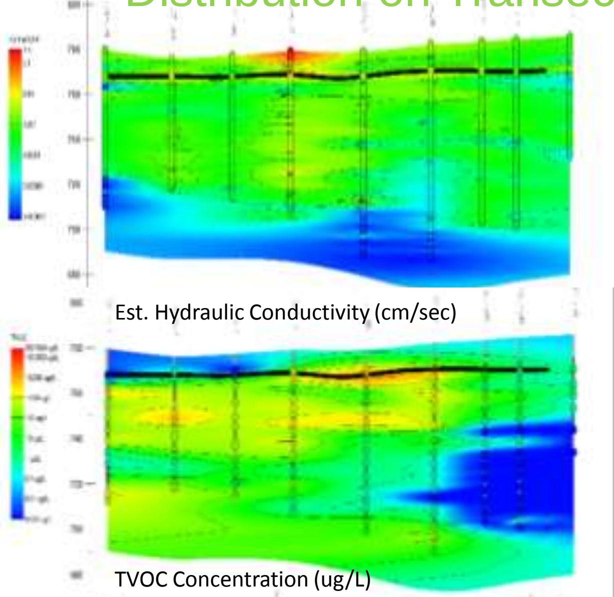
Estimated Mass Flux Distribution on Transect F



NGWA – "High Resolution Site Characterization Supporting Focused Combined Remedies," Seth Pitkin, 5.23.14

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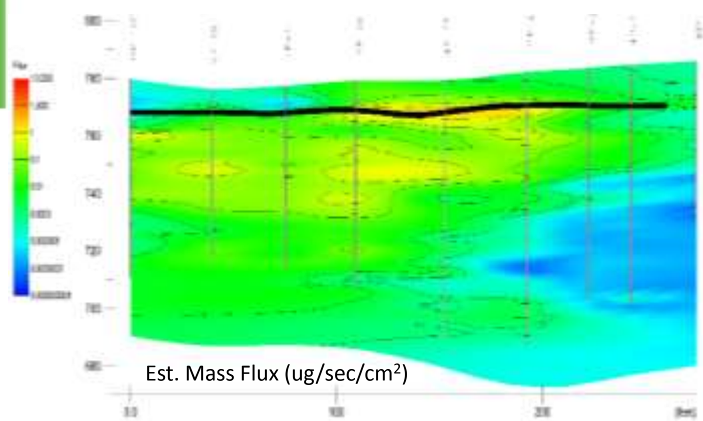
Simplified Mass Flux Estimate



NGWA – "High Resolution Site Characterization Supporting Focused Combined Remedies," Seth Pitkin, 5.23.14

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High Resolution Transect Benefits

- Typically mass discharge occurs over a small fraction of the total cross sectional area of the plume, suggesting that remediation can be targeted more effectively if high resolution sampling is conducted along one or more transects.
- Transects downgradient from the source can reveal locations within the source contributing the most to overall discharge or identify sources not found by soil borings or conventional monitoring wells.

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Making Contact

- Where is the mass located
- Physical distribution of the treatment technology to the mass
- Dosing for mass in NAPL, sorbed and dissolved phases.
- Achieving maximum residence time for treatment of sorbed mass as it back diffuses into dissolved phase.

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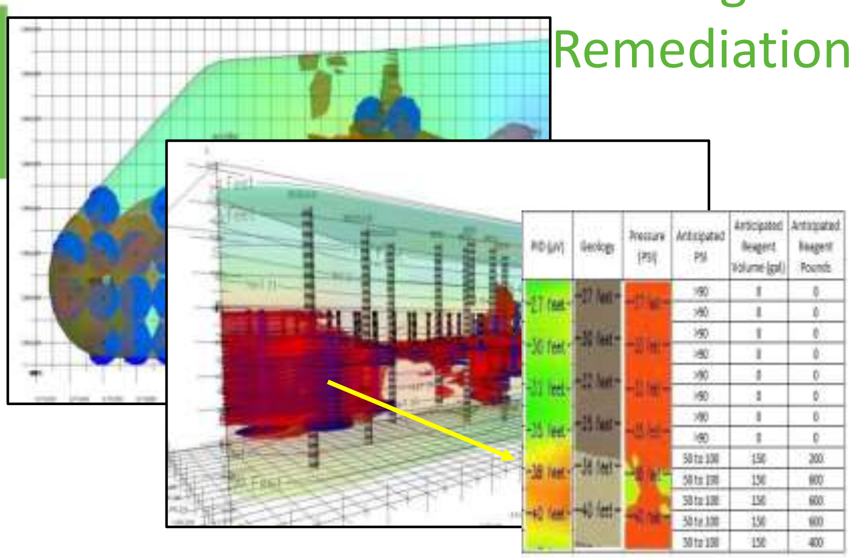
3D Imaged Remediation



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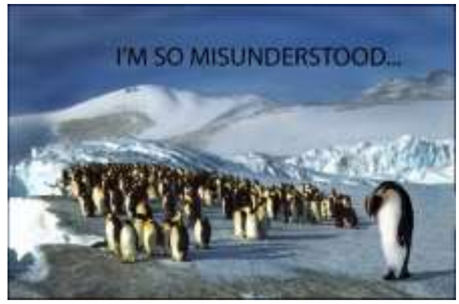
Radius Of Influence – So Misunderstood

- Injection point spacing rules of thumb for sands to clays?
- Distance where chemistry or reaction products shows up in MWs?
- Dependent on:
  - Chemistry dilution and volumes? Yes
  - Chemistry persistence? Yes
  - Seepage velocity and residence time? Yes



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ROI Conundrums

- Low Seepage Velocity versus High Pore Volume For Contact
- High Seepage Velocity Resulting in Low Residence Time

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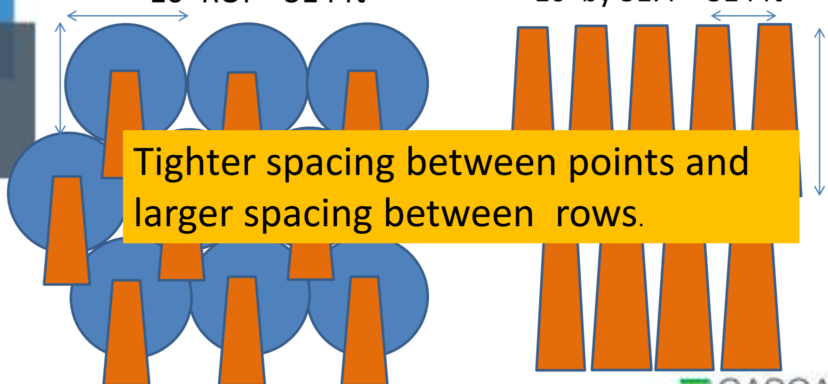
It's Not Always About Circles

Traditional Spacing,
20% Pore Volume
10' ROI = 314 ft^2

Advection Driven
20% Pore Volume
10' by 31.4 = 314 ft^2



Is ROI This Simple?

- Heterogeneous
- % Injectable
- Non-soluble chemistries
- Low Seepage Velocity = Emplacement of high volumes but regulatory concerns of plume dilution and spreading
- High Seepage Velocity = Low residence times
- Low K = Mass sorbed to soil matrix / higher residence times

- Homogeneous Sand
- Soluble chemistries
- Moderate Seepage Velocity

High Resolution Injection Tool (HRIT)

- Do you need to fracture?
- Max flow/pressure without fracturing to enhance Performance
- Real-Time High Resolution Injection Data:
  - Flow
  - Up-Hole Pressure
  - Down-Hole Pressure

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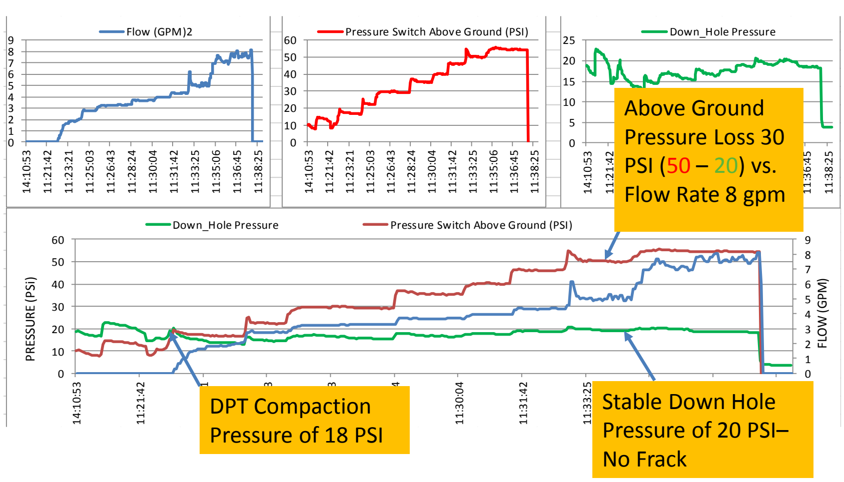
HRIT Logging – Direct Push



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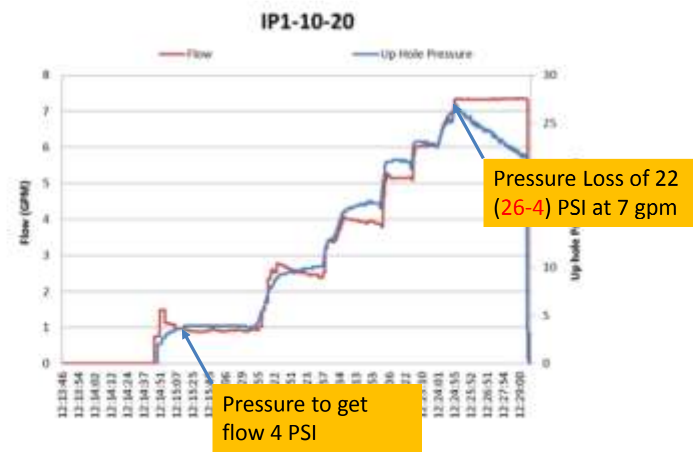
HRIT Logging – Injection Well



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DPT Best Practices For Maintaining Consistent Pressures

- Injection with inner-hose to maintain pressure on the injection tooling to avoid plugging and inadvertent fracturing as tools are advanced or retracted
- Use pressure relief on pumps to avoid flow rate spikes

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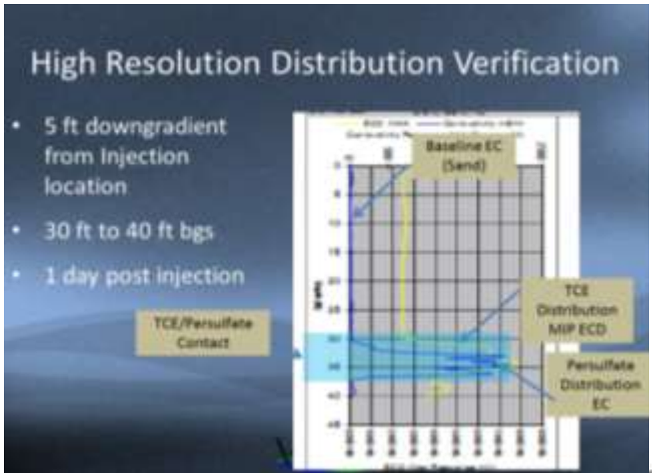
Design Optimization Testing – Distribution of Caustic Persulfate



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Key Takeaways

- Traditional soil sampling / well data is not enough to design for successful remediation.
- HRSC can be used to locate mass, understand soil stratigraphy/hydraulic conductivity and assist with successful remedial design.
- Must have a sound design basis for ROI
  - Injection volume
  - Site hydraulics
  - Reagent persistence and residence time
- Chemistries must be delivered for vertical contact and at the appropriated pressures to achieve lateral distribution

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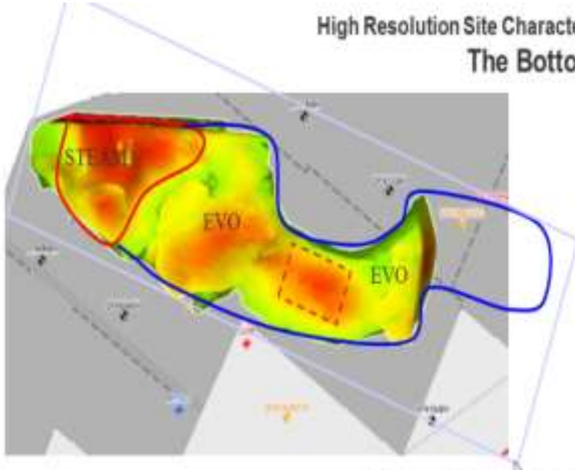
High Resolution Site Characterization:
The Bottom Line



"...instead of treating a more conventional rectangle, the density and quality of the data allowed for us to isolate the contaminant zones to a smaller and more irregular shaped region of the site."

"We were able to confidently reduce the treatment area by about 40%"

"The result was a more focused and more efficient remediation strategy."

James Baldock – ERM UK