

# New Remedial Design Characterization (RDC) and In-Situ Treatment Injection Methods for Effective Site Closure *It's a Contact Sport!*



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**22<sup>nd</sup> International Petroleum  
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Grand Hyatt in Downtown Denver





# ***Vista*** ***GeoScience***

**EXPERT SUPPORT SERVICES FOR ENVIRONMENTAL  
SITE INVESTIGATION AND REMEDIATION**

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IPEC, Denver, Colorado, Nov 2015; Exhibitor Showcase

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# Key Staff

- **John Fontana** - PG, President/CEO
  - 35 Years of Experience
- **Mike Martin** - Operations Manager, HSO
  - 18 Years of Experience
- **TJ Haley** - Gulf Coast Regional Manager
  - 14 Years of Experience

# Outline



- **In Situ Treatment Technology Review**
- **The Need & Challenges?**
- **Remedial Design Characterization (RDC) Phase**
- **In-Situ Treatment Application Phase**
- **Recent Examples**
- **Summary & Conclusion**

# The In-Situ Treatment Revolution!

- Amendment Injections
  - In-Situ Chemical Oxidation (ISCO)
  - In-Situ Chemical Reduction (ISCR)
  - In-Situ (Enhanced) Bio-Remediation or Bio-Reduction (ISBR)
- Environmental Hydraulic Fracturing
  - Similar Amendments & Treatments
  - Enhanced Permeability
- *Too Often are Improperly Applied!*



# Why In-Situ Injection Installation of Treatments?

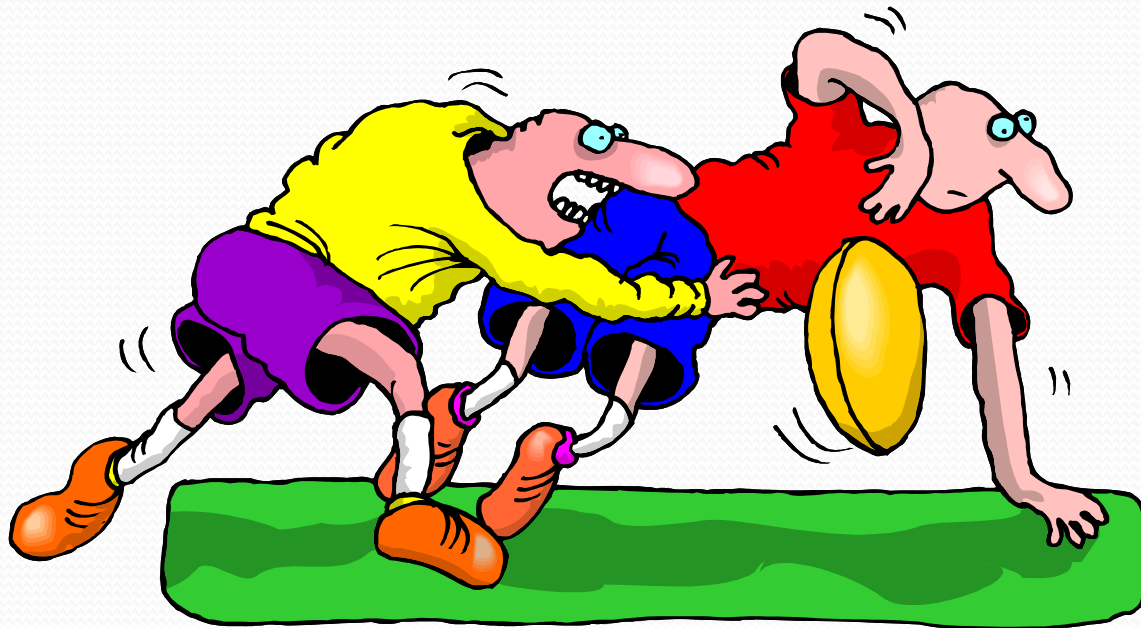
- **Direct Push Injection Advancements Allow Direct Injection of Treatments in In-Situ**
- **Limited or No Disposal Issues**
- **In Place Destruction of Contaminants**
- **Less Invasive - Works Around Infrastructure**
- **Many Work with Natural Environment**
- **Improved Understanding of Hydraulic-Fracturing**
- **Improved Monitoring Methods,**
- **So..... Seen as Faster, Cheaper *and it's*.....**

***Greener & Sustainable Technology!***



# In-Situ Remediation: *It's a Contact Sport!*

- **HOME TEAM:** Contaminated Soil & Ground Water
- **VISITING TEAM:** Treatment Reagents



# The Need?

*Better Results from In Situ Remediation Projects*

## *The How:*

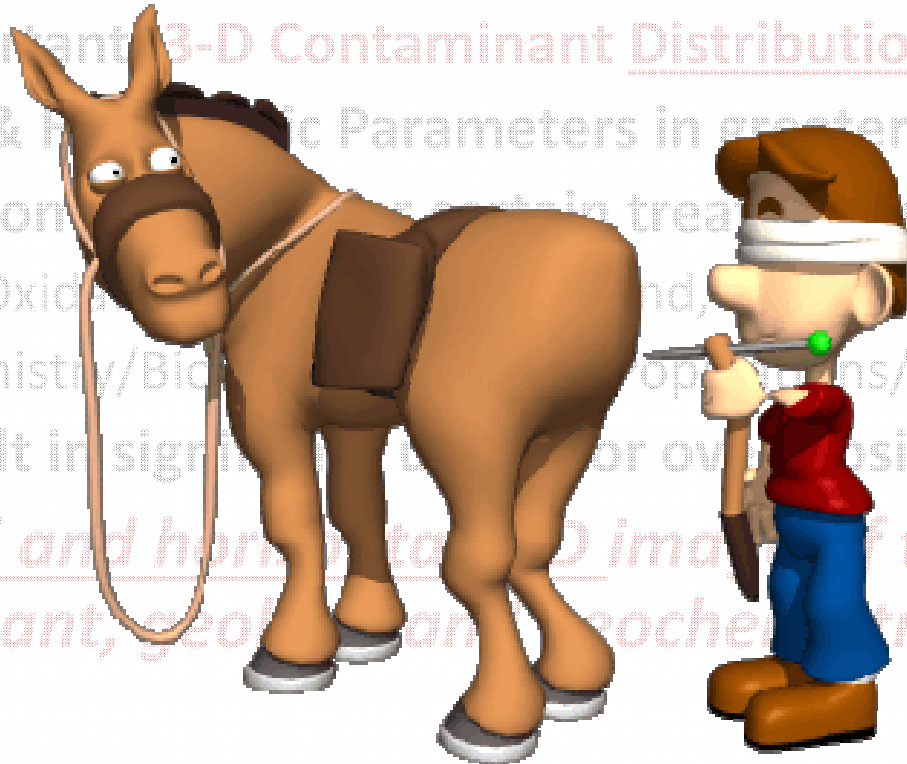
1. **Remedial Design Characterization (RDC): Develop & Refine the Conceptual Site Model by Collecting High Resolution Data, both Qualitative and Quantitative. (Cost is typically <10% of entire in-situ injection projects)**
2. **Apply In Situ Treatments Using High Resolutions Application Tools and Methods to Better Target Contaminants in Place.**



# Remedial Design Characterization - Critical for Success

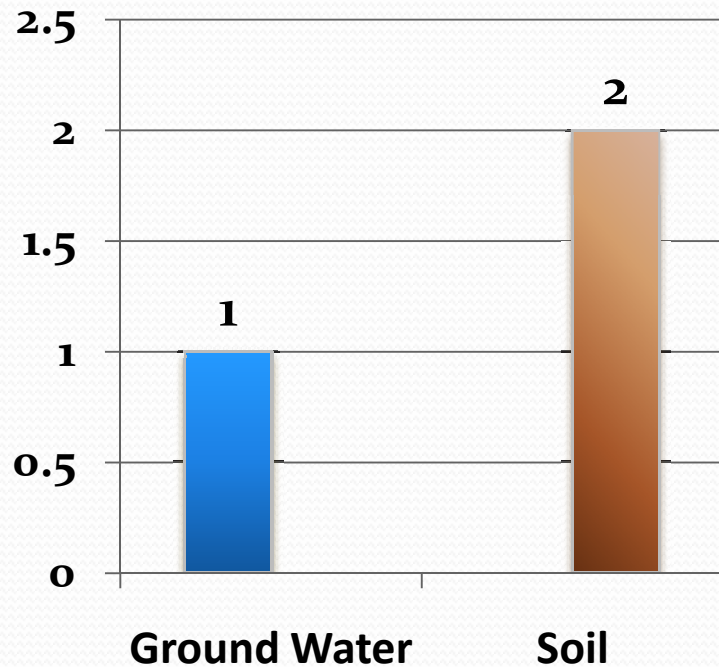
## Don't Be Blindfolded and Miss the Target

- Yes, in 2-D, but we need more data for the Remedial Design!
- **Most Important 3-D Contaminant Distribution and Mass**
- Lithologic & Hydraulic Parameters in greater detail
- Chemical Conditions for certain treatments is unknown
  - Natural Oxidation/Reduction, Donors & Acceptors
  - Geochemistry/Biochemistry for Operations/Nutrients
- Errors result in significant under or over dosing – or both!
- **A vertical and horizontal 3-D image of the site contaminant, geologic and geochemistry is required!**

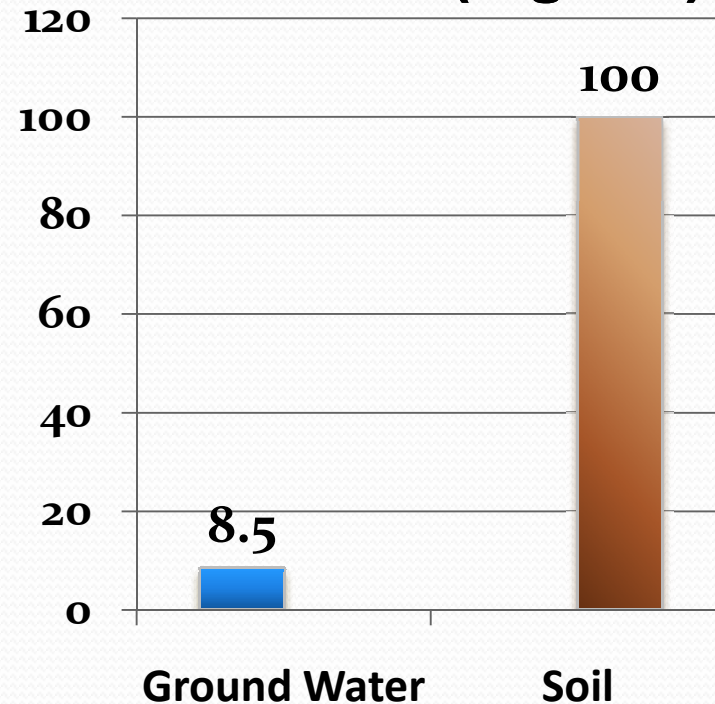


# Adsorbed Phase vs. Dissolved Phase Contaminant Loading

## Soil and Ground Water Concentrations (ppm)



## Contaminant Load by Volume (mg / ft<sup>3</sup>)



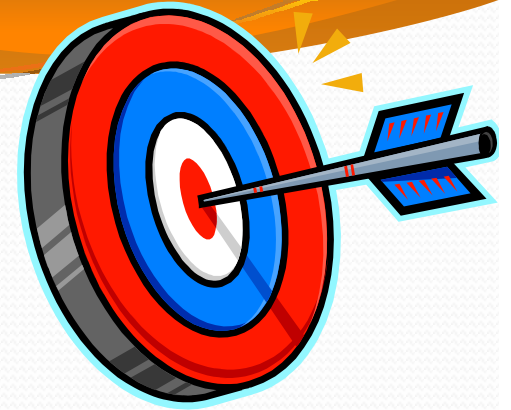
***If you design to only treat the dissolved phase contaminant, you get REBOUND***

# Back Diffusion from Clays = REBOUND (Consider Mass Flux Discharge in RDC)



Courtesy Tom Sale, PhD, Colorado State University (Go RAMS!)

# The Goals of a RDC




## *Determine:*

- Where the Contamination is Located
  - Vertical and Horizontal Distribution
- How Much Mass is There to Treat (Dosing)
- Physical, Chemical & Biological Parameters as Needed for Specific Treatments. (SOD, COD, etc.)
- If Back Diffusion Affects the Choice of Methods
- Soil/Rock Types & Heterogeneity for Delivery Methods

# Use High Resolution Data to Create “Decision Units” for Treatment Dosing

DEPTH

Injection Depth	<u>Area A</u> 500 sq. ft, 5 pts.	<u>Area B</u> 1,500 sq. ft, 15 pts	<u>Area C</u> 4,000 sq. ft. 40 pts.
12'	▼		
14'	10 lbs	25 lbs	10 lbs
16'	40 lbs	40 lbs	25 lbs
18'	25 lbs	25 lbs	25 lbs
20'	10 lbs	10 lbs	10 lbs
22'			10 lbs



# High Resolution Site Characterization (HRSC)

## Tools for Remedial Design Characterization

- ✓ **Direct Sensing Probing Tools**
  - ✓ MIP, HPT, LIF, EC, Cone Penetrometers, etc.
- ✓ **High Resolution Sampling Methods**
  - ✓ Discrete Soil Core and Discrete Ground Water Sampling
- ✓ **Determines the mass and 3-D distribution**
- ✓ **Other Investigation Tools/Methods**

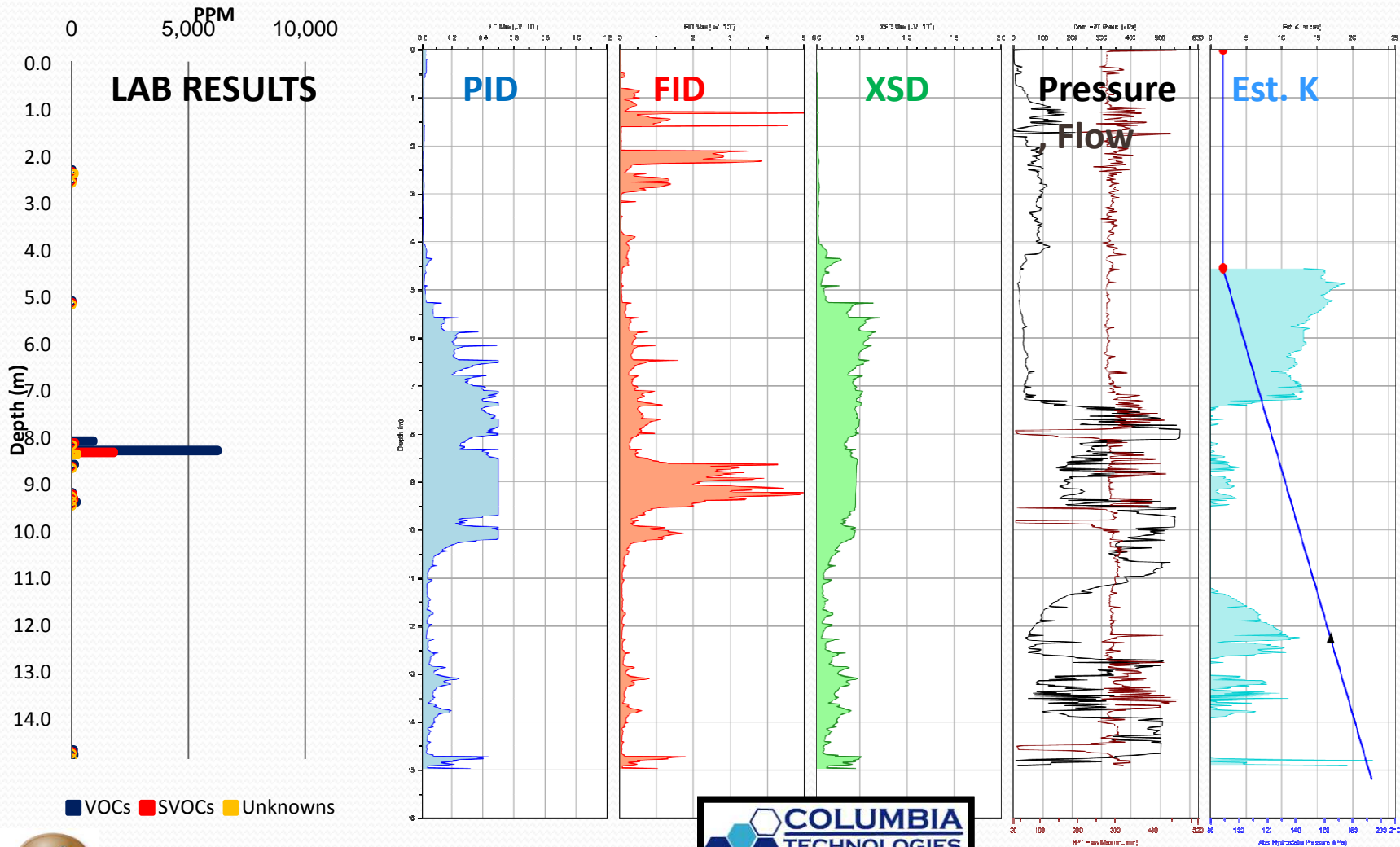
# High Resolution Direct Sensing Investigation Tools



**Membrane Interface Probe (MIP)  
at the Denver Federal Center**

# High Resolution = Millions of Data Points

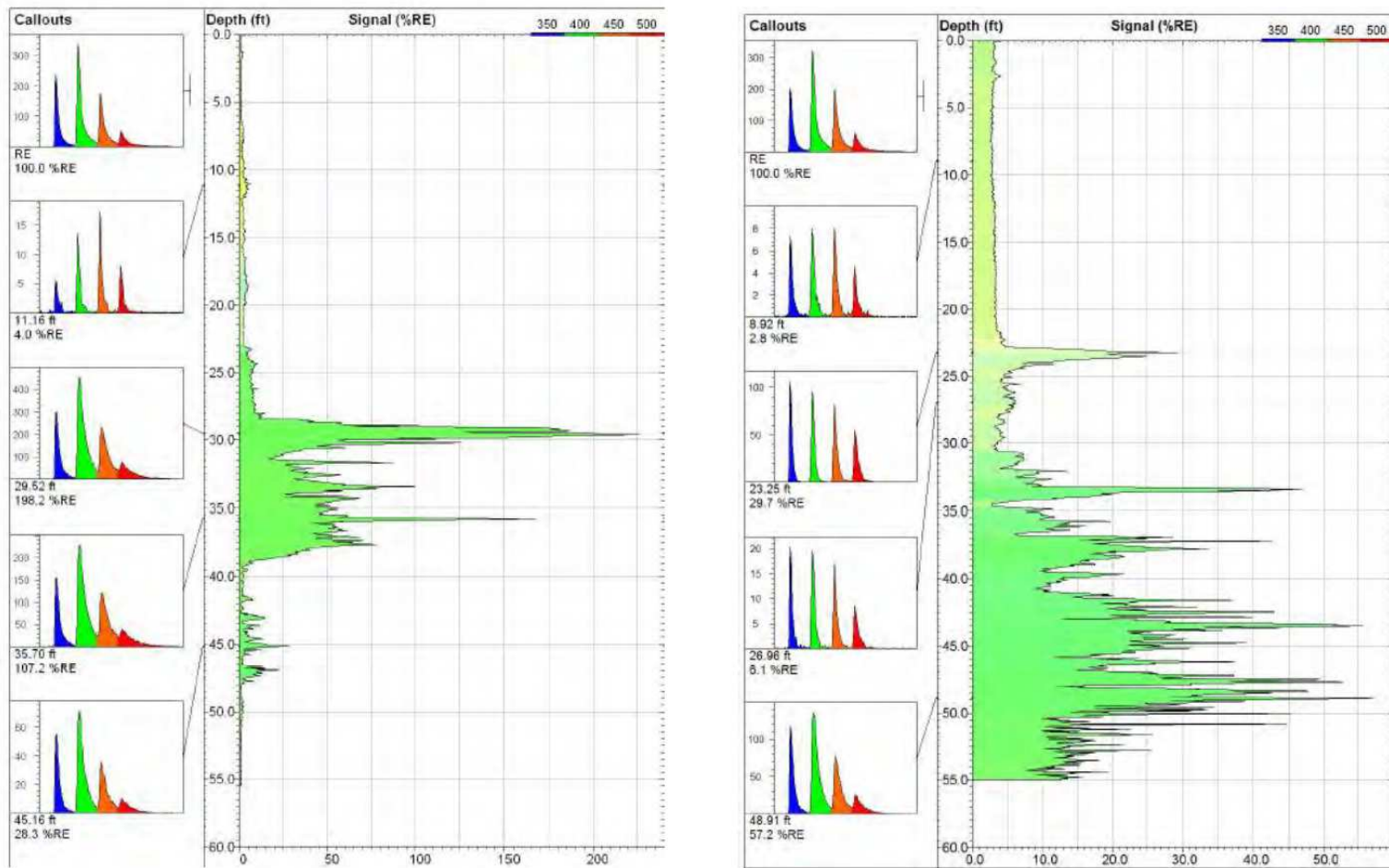
## MiHpt Log - Tracking SVOC DNAPL





# Laser Induced Fluorescence (LIF) Logs (Ultra Violet Optical Screening Tool – UVOST)

## LIF Logs

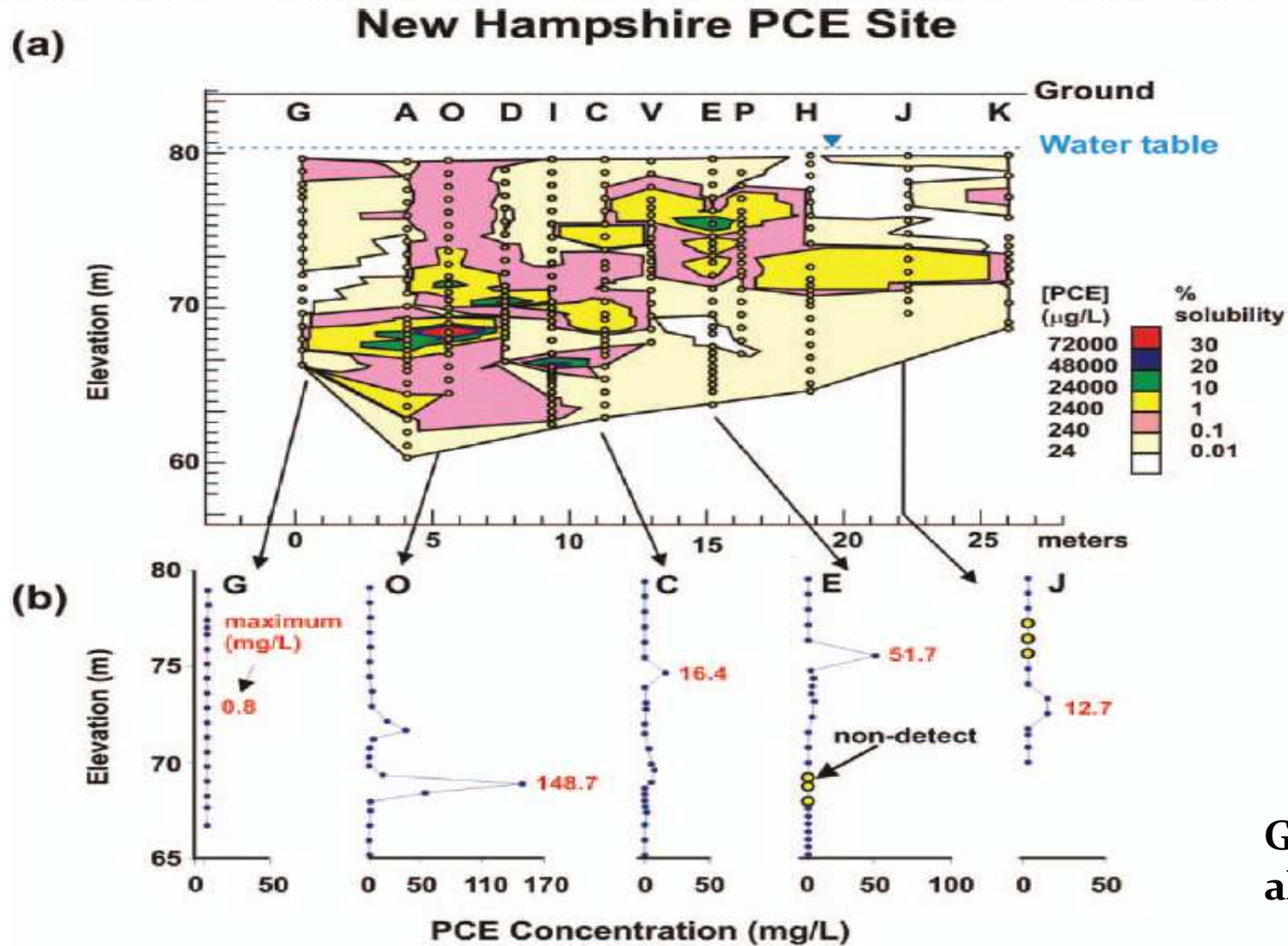


# High Resolution Sampling

Low Tech: Required for Quantitative  
Analysis of Mass Present

- **Dosing Calculations Require Quantitative  
Contaminant Mass in 3-D**

# High Resolution Soil Sampling



Guilbeault et al., 2005

# Representative Sampling from Continuous Soil Cores

(Remember: A saturated soil sample includes the pore water, and therefore the combined adsorbed and dissolved phase)

## Sub-Sampling Continuous Cores for VOCs Using Plugs



## Cutting a Composite “Wedge” from the Continuous Core



ITRC (Interstate Technology & Regulatory Council). 2012. *Incremental Sampling Methodology. ISM-1.* [www.itrcweb.org](http://www.itrcweb.org).

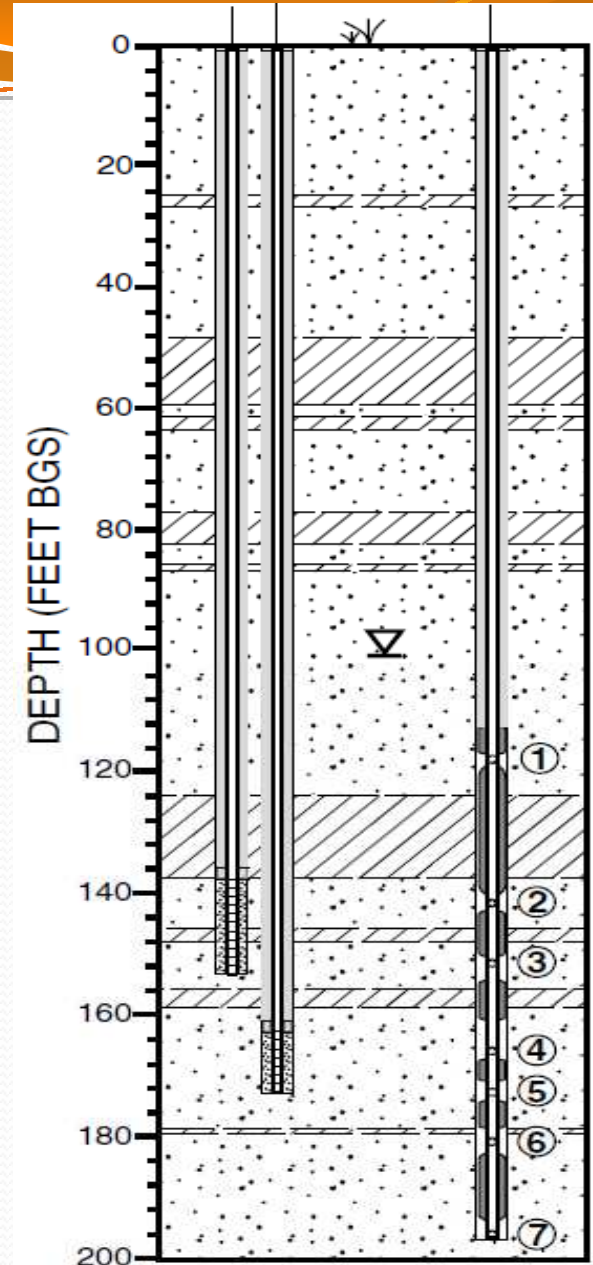
# Tools for Discrete Ground Water Samples

- Discrete GW Sampling Tools
- Multiple Wells with Discrete Screens
- Single Well with Multi-Level Ports
- ....BUT REMEMBER: 80-90% of the mass resides in the saturated soils.



Geoprobe® Screen-Point Sampler

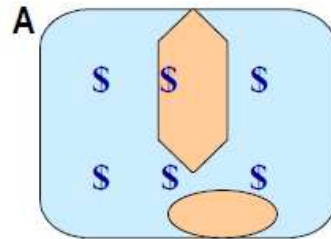
Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring, Second Edition, Ed. David M. Nielsen – CH 11, Multi-Level Ground Water Monitoring, Murray Einarson



*How much will all of that detailed analysis cost!?!?!?*

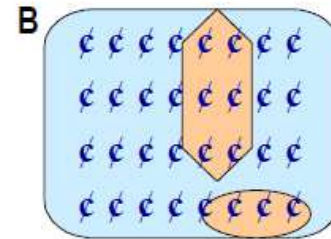
# Use Screening Data vs. Definitive Data to Reduce Cost and Increase Detail

## Data Quality vs. Information Value



Fewer “higher quality” data points leads to lower information value of the data set

Less likely



Many “lower quality” data points leads to higher information value of the data set

More likely

Goal: A defensible site decision that reflects the “true” site condition

2001, D. M Crumbling, EPA 542-R-01-013, Current Perspectives in Site Remediation and Monitoring

# Bench Testing, Treatability, or Pilot Testing?



- **Bench Testing – Make Sure its Done Right.**
  - Mixing together of soil, ground water and treatment.
  - Generally, it has already has been done by someone!
  - Some “test tube” methods do not simulate real subsurface conditions.
  - We often already know which treatments work on what contaminants.
  - Difficult with anaerobic methods, requires zero-O<sub>2</sub> chambers.
  - **Proper applications requires mimicking field conditions.**
- **Treatability Studies**
  - Soil Oxidant Demand
  - Chemical Compatibility
  - In-Situ Treatability Testing (bio-remediation)
  - Bacteria Type & Health Testing
- **Pilot Testing**
  - **Best to test methods before going full scale.**



# Applying RDC Data to In Situ Remediation Treatments

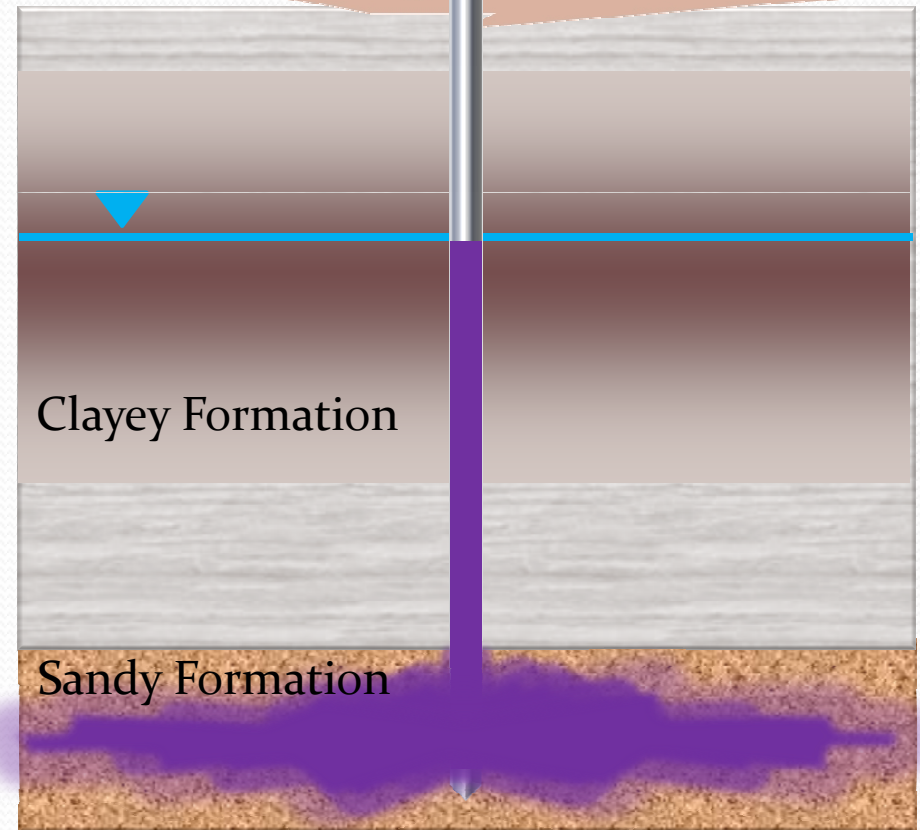
- Now we know where the contaminants are and how much is there, so now we need properly targeted & applied treatments.
- Old vs. New Application Methods
- Conventional Injections vs. Hydraulic Fracturing Methods



# Bottom Up Injections in *Non-Ideal* (Common) Conditions

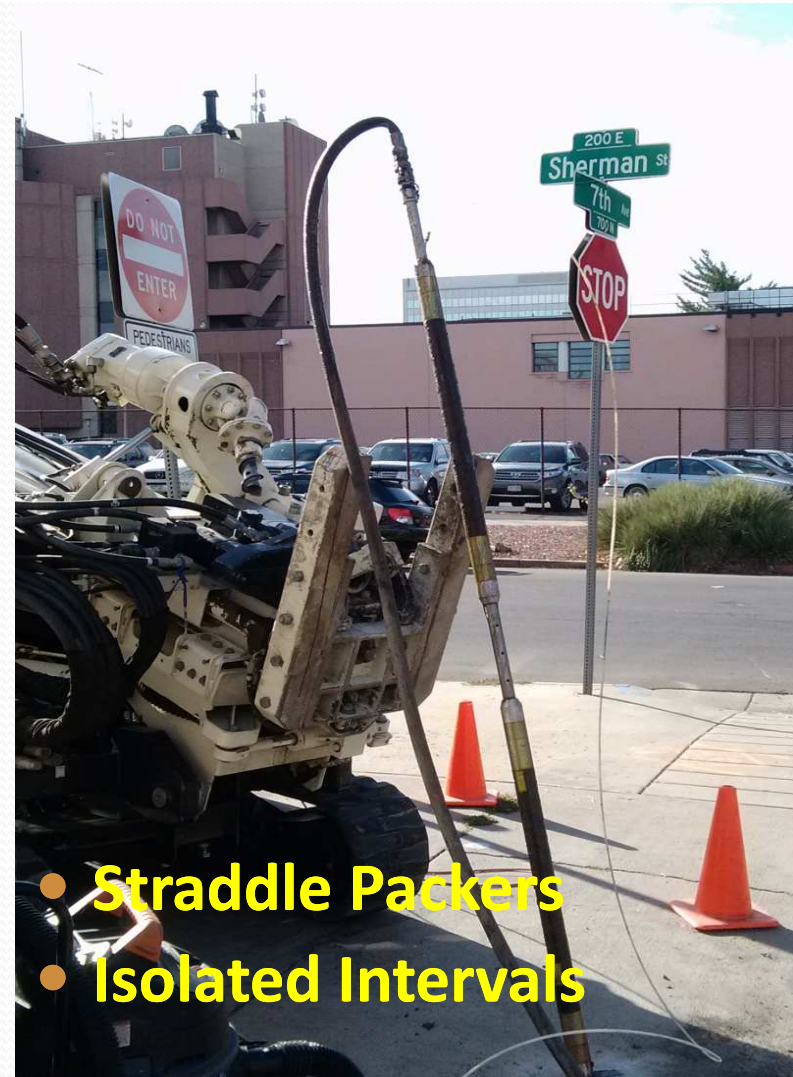
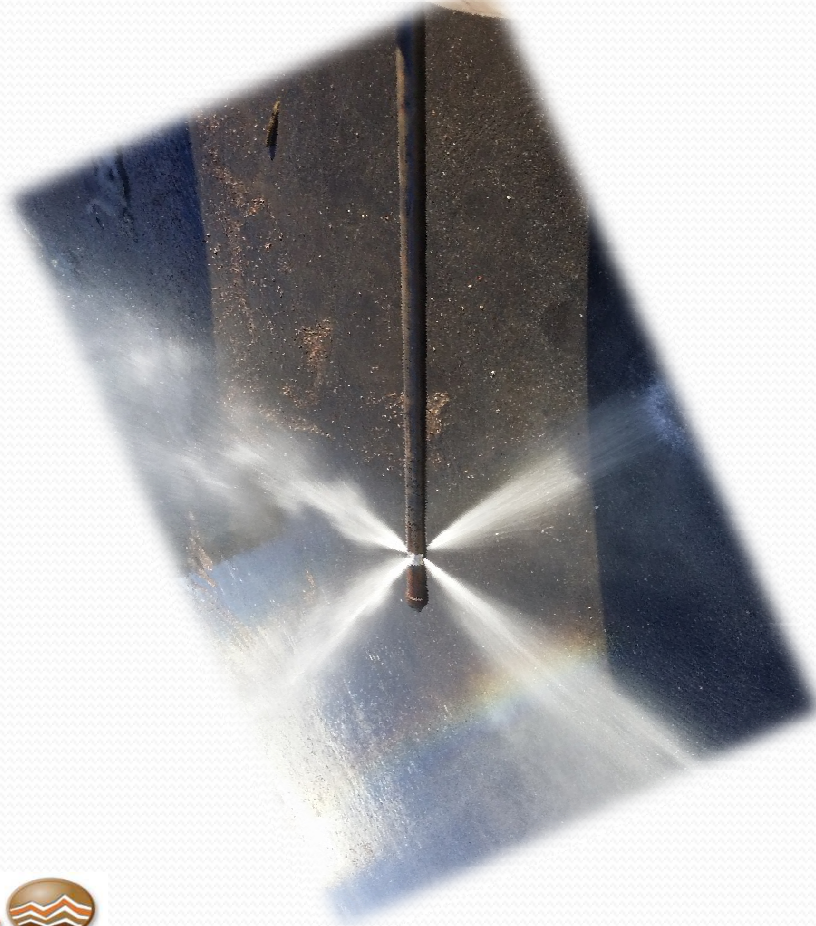


- Less Porous & Permeable Soils
- Preferential Bedding Planes
- Fracturing May Occur
- Coarsening Downward
- Path of Least Resistance



# SOLUTIONS: Surgical Injection Methods

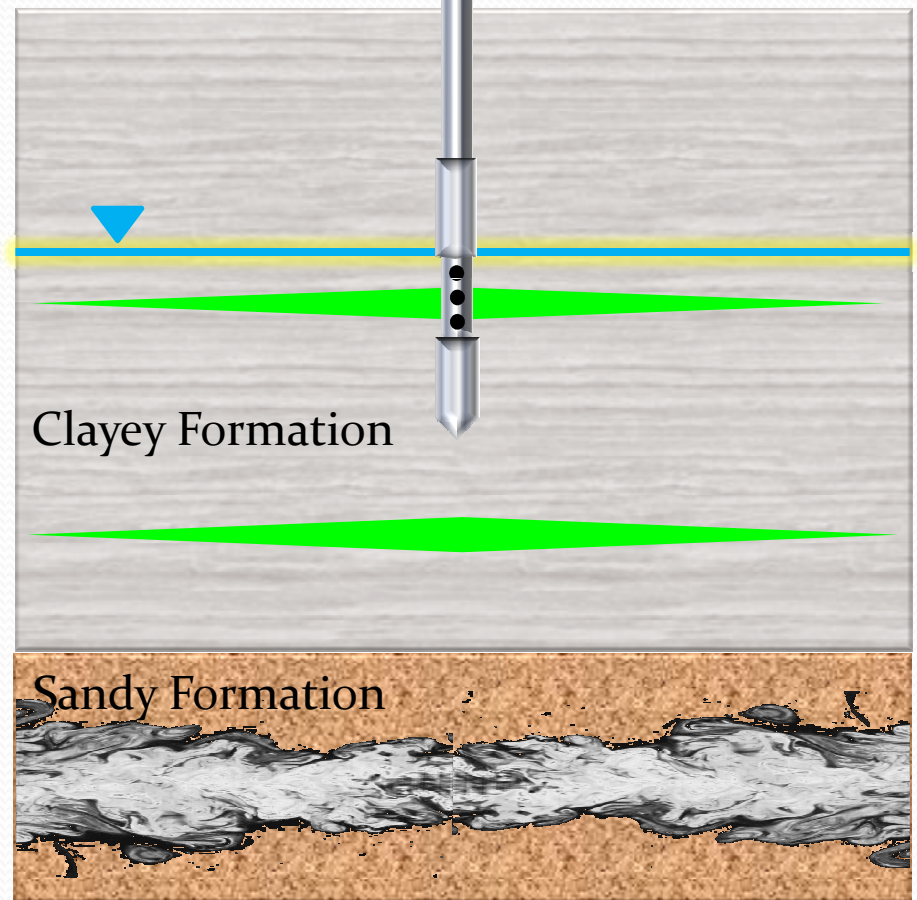
- Top-Down Injections Tools
- High Pressure, High Flow



- Straddle Packers
- Isolated Intervals

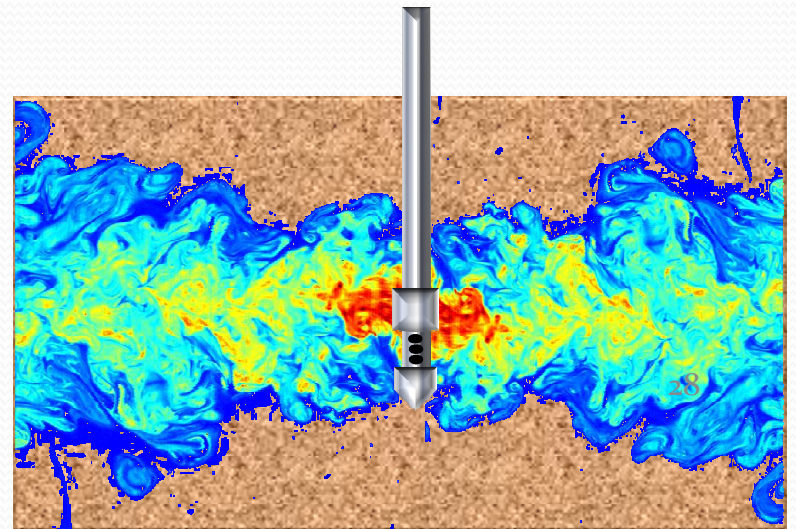
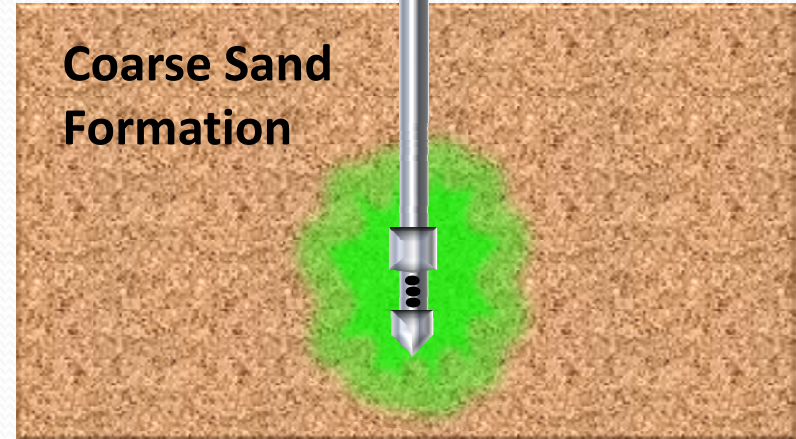
# SOLUTIONS: Improved Injection Methods

- Top Down Injections
- Lateral Inj. Ports or Packers
- High Pressure/Flow
- Precise Placement
- Low Perm will Fracture
- Permeable Zones will Fluidize
- = **BETTER CONTACT!**

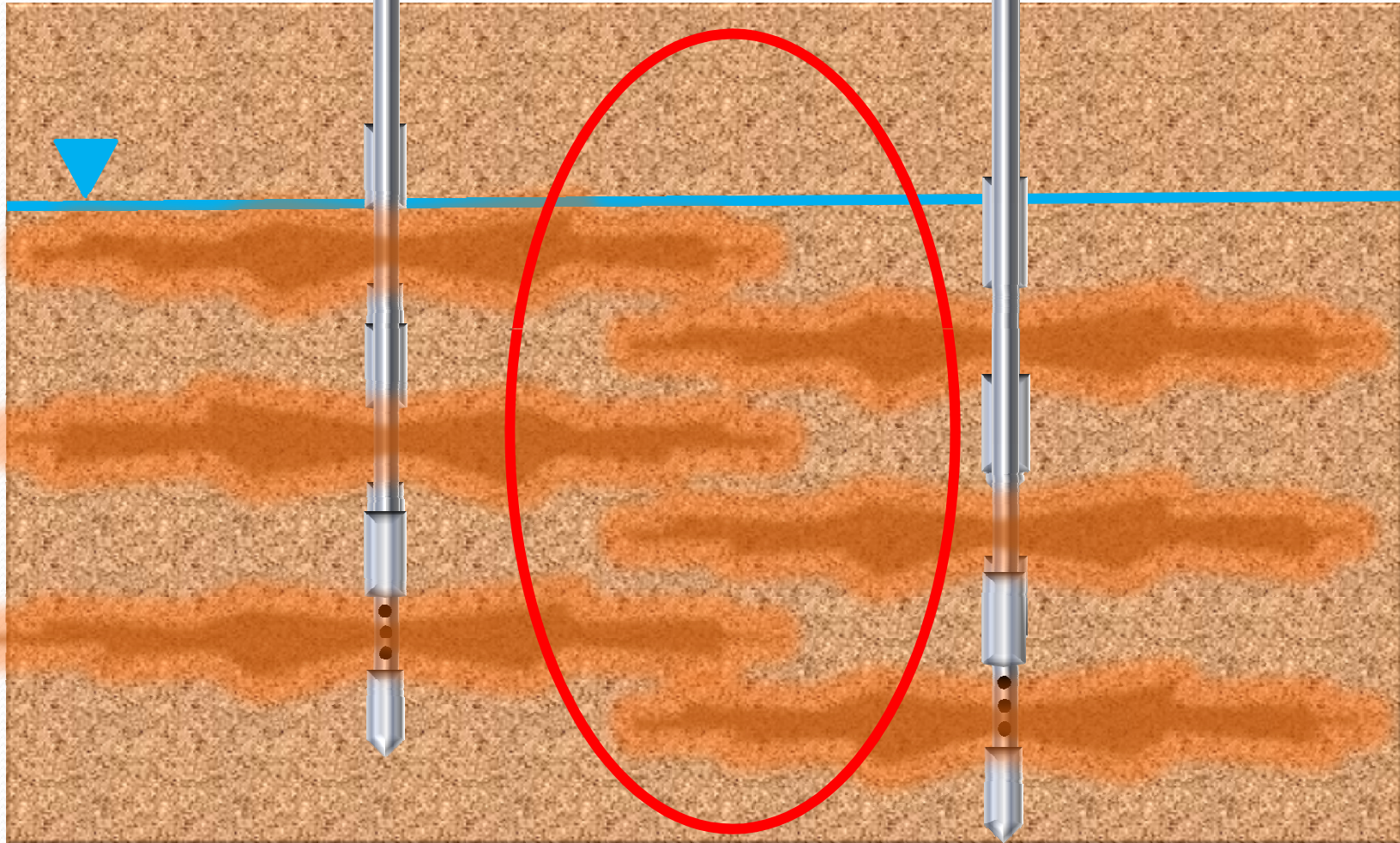


# Injection of Slurries (Solids) into Unconsolidated Coarse Sand/Gravels

- Liquids follow granular pore space paths.
- Slurries may filter out or “block off” porosity at low flow, solids drop out.
- High Velocity Injections can create additional mixing and extend ROI

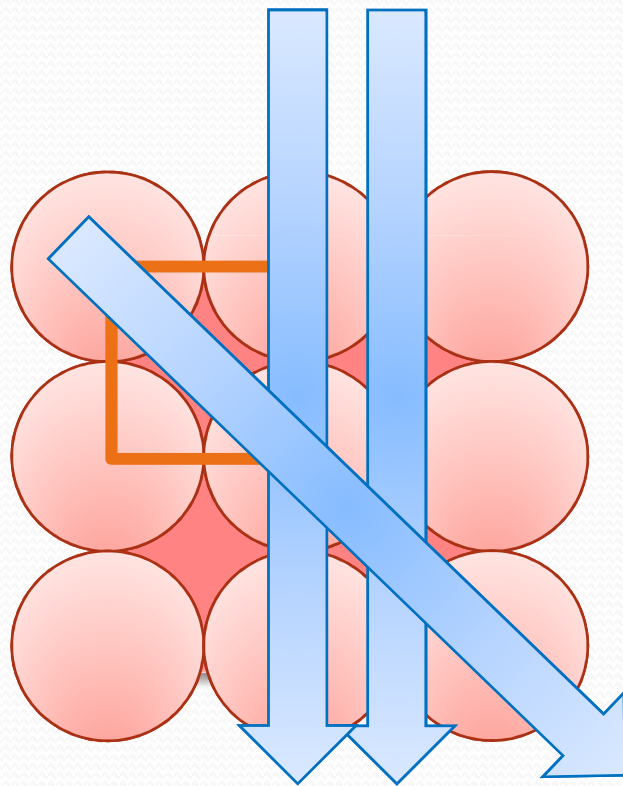


# Staggered Top-Down Injection Intervals

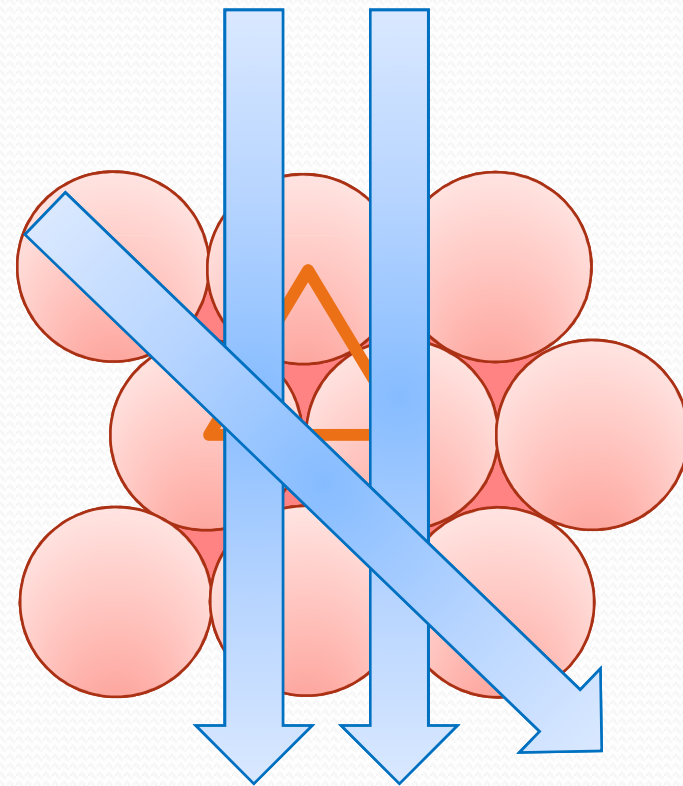


# Triangular vs. Square Injection Grids (Surface View)

- **Square Grid**

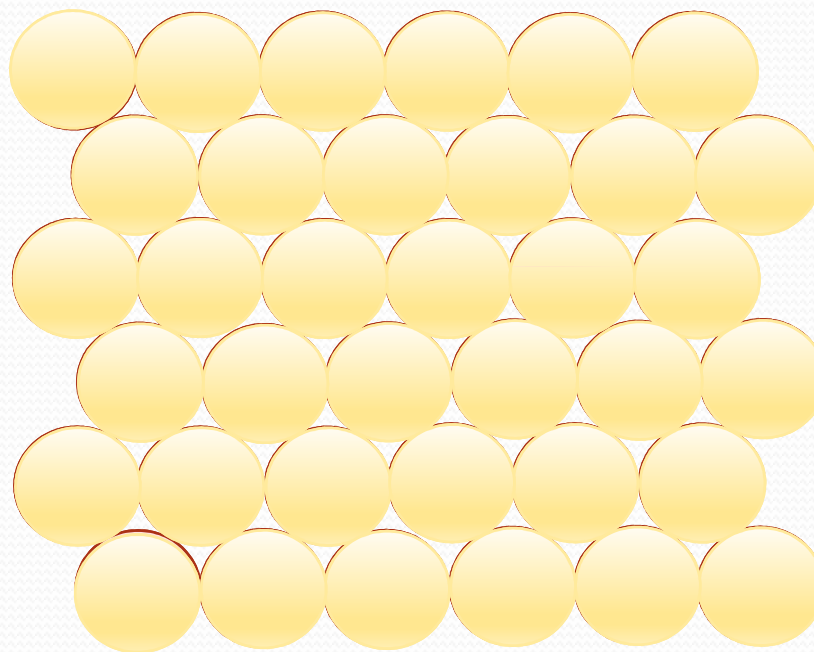


- **Triangular Grid**



# Will We Move Contaminants?

- **Yes, but not far from empirical evidence.**
- **Remember: Most of the mass is generally sorbed.**
- **Start injections from outer edge of plumes.**
- **Bounces around injection grids, do not move from one point to the next, or one side to the other.**
- **Possible Exceptions? High volume dilute injectates such as diluted emulsified vegetable oils. NAPL**



# Optimized Pumping & Mixing Systems

- *Use the right system for the right job!*
- High Pressure / Low Volume?
- Low Pressure / High Volume?
- High Pressure / High Volume
- Liquids vs. Slurries/Solids?
- Corrosive Chemicals
- In-Line Activator Mixing
- Many Pump Types (Progressive Cavity, Piston, Diaphragm, Centrifugal, to name a few)
- Experiment with flow rates and pressures to reduce surfacing of product.
- **Myth: High Flow = Surfacing**
- **Truth: Lower flows may INCREASE surfacing.**





# Safe Oxidant Mixing Systems

- Caustic/Acid Mixing
- In-Line Blending
- Spill Control Plans / Containment
- **Neutralizers on Site**



- Additional PPE
- Stainless or PVC Fittings
- Exothermic Reactions -  
Temperature Monitoring/Control

# Slurry (Powders & Solids) Specialized Mixing & Pumping Systems



# Simultaneous Injection Points for High Volume Applications



# Hydraulic Fracturing Installations

- **For Injection of Suspended Solids Treatments in Tighter Formations or Bedrock**
- **To Increase Permeability or Create Permeable Treatment Zones, Barriers or Cells.**

# Hydraulic Fracturing Remediation Applications

- **Air Sparge (AS) or Soil Vapor Extraction (SVE)**
  - Sand or Synthetic Proppant Support
- **Bio-Remediation Treatment Flow Cells**
  - Sand or High Surface Area Synthetic Proppants
  - Nutrient Additives, Organic Carbon,
  - Activated Carbon + Nutrients
- **Chemical Treatment Flow Cells**
  - Optional Proppant Fracture Support
  - Solid Chemical Slurry Injections

# Direct Push (DPT) or Auger/Rotary Hole + Packers for Hydraulic Fracture Installations



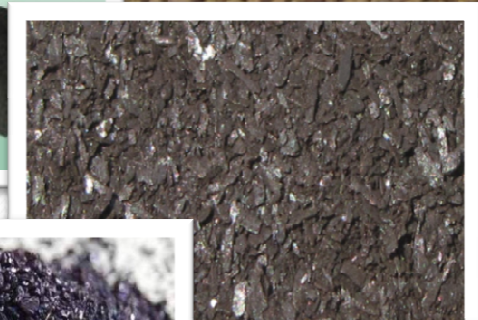
Single Packer



Straddle Packer

# Proppants

- *Inert or Reactive*
- Mixtures of:
  - Silica Sand
  - Porous Ceramic (Isolite™)
  - Activated Carbon +?
  - Zero Valent Iron
  - Potassium Permanganate
  - Chitin (Polysaccharide)
  - Bacteria Augmentation



# When Proppants are Used, Cross-Linked Guar-Gum is Used to Suspend the Proppant



Courtesy Foremost Inc.





# Performance Monitoring & Combined Methods

- Performance Monitoring **should** be part of the Game Plan. Can be done **on the fly** – Allowing for adjustments during the treatment phase on larger scale projects.
- Combined Methods or Phased Approach may be appropriate for some sites. One method may not be the silver bullet.

# Performance Monitoring Methods

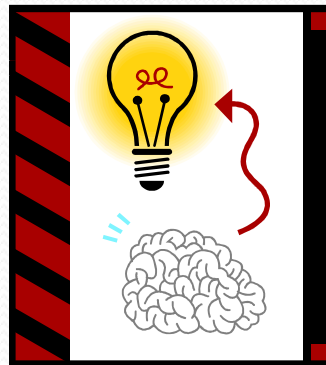
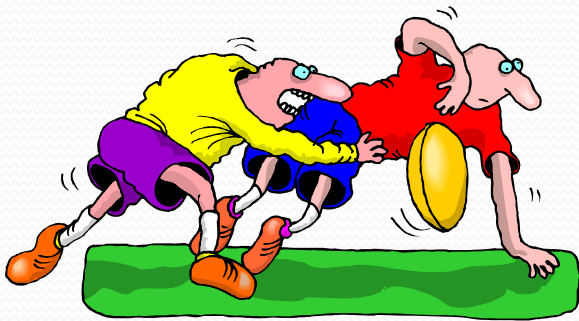
- **Monitor Well Level Fluctuation & Injectate Impacts**
- **Offset Continuous Cores Adjacent to Injection Points**
  - **Slurried Products That Can Be Seen in Cores Fractures, Pores**
  - **Dyed Added to Liquid Injectates**
- **Injectate Indicator Tests (specific to treatment product)**
- **Baseline and Post Injection Ground Water Sampling**
  - **COCs, Anions, Gases, Biologic Parameters.**
- **Some biologic treatments should be sampled more frequently than quarterly immediately following injections for biologic changes as well as COCs.**
- **Tilt Meters for Fracture ROI**

# Summary

- **In-Situ Treatment Success Rates are Significantly Improved by Performing a RDC phase to create a 3-D CSM by utilizing:**
  - **3-D Imaging and High Resolution Sampling Tools (Qualitative & Quantitative)**
  - **Advanced Targeting Injection Tools and Methods**
  - **Applying Treatments Using Decision Units -Targeted Dosing**
  - **Understanding ROI and Hydraulic Fracturing in Tighter Formations**
  - **Combined Method Approach May Be Appropriate**
  - **Utilizing Pilot Testing, Treatability, Performance Monitoring Tools, Monitoring Progress and Make Adjustments**
- **= The Goal of Clean Up & Closure – The First Time!**

# More Summary

- ***It's a Contact Sport, AND A TEAM SPORT !***



- ***Geology, Hydrology, Chemistry, Biology***
- ***Consultant + Driller + Installer + Supplier***





# Questions?



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