# It's a Contact Sport - Application of Highly Focused Injection Methods for Improve Results of In-Situ Treatments


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*Vista GeoScience*




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***Petroleum Environmental Issues & Solutions in Exploration * Production * Refining * Distribution***


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# What I Saw in Monterey

**Battelle Conference on Chlorinated Solvents:**

**Presentations & Posters on High Resolution Site Characterization (HRSC) Methods**

# What was Missing?

**Methods to Apply that Data to In Situ Treatments; i.e., High Resolution *Application* Methods**

# Outline

- In Situ Treatment Technology Review
- In-Situ Treatment Application Phase
  - Selecting the Right Tools and Methods for a Particular Treatment
  - Applying Higher Resolution Targeted Application Methods
- Problems with Early Injection Methods
- "Conventional" Injection Methods
- Hydraulic Fracture Emplacement Methods
- 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!***

# Sampling of the Many In-Situ Remediation Product Providers









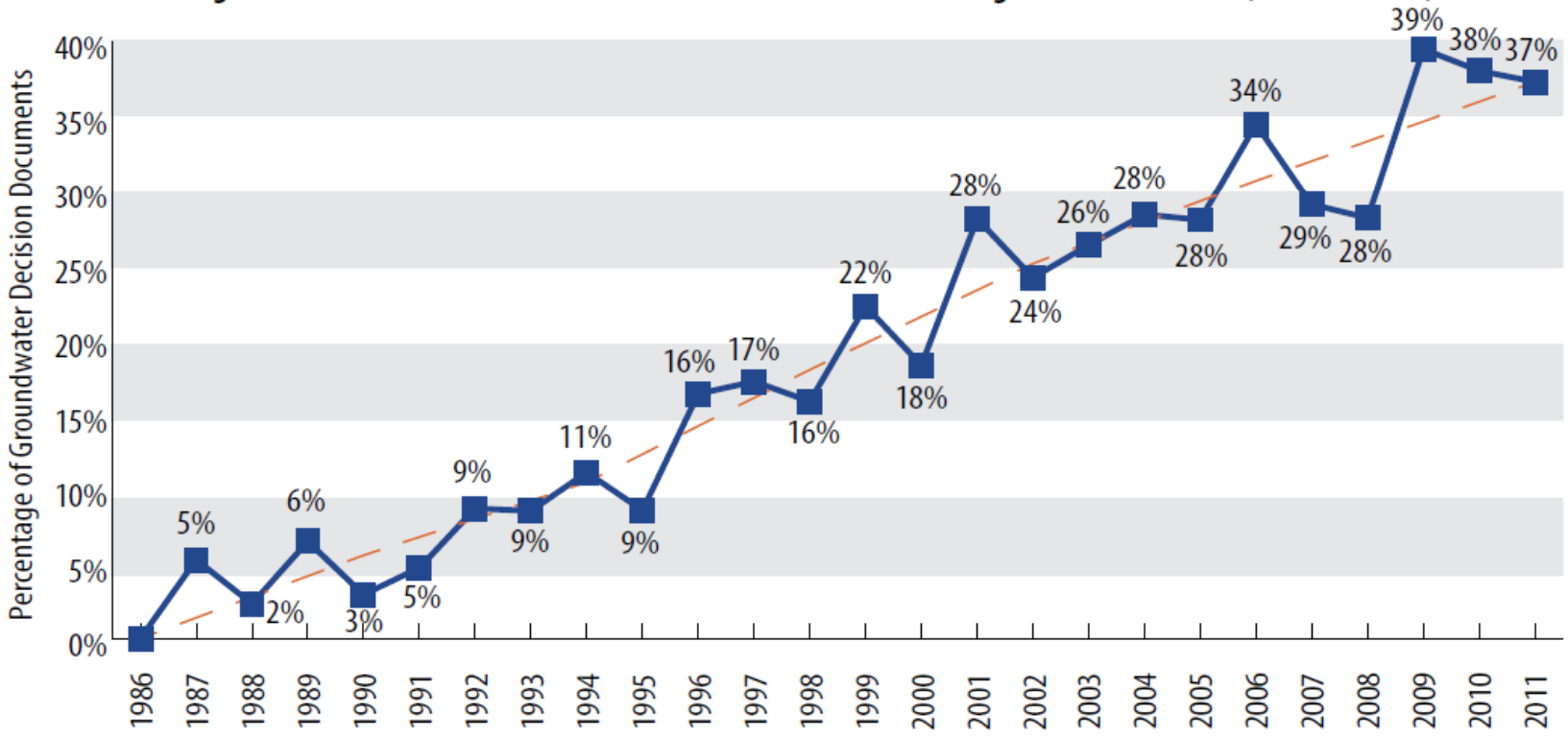



# Increased Use of In-Situ Technologies for Groundwater (1985 – 2011, NPL Sites)

EPA-Superfund Remedy Report (SRR) Fourteenth Edition (EPA 542-R-13-016), November 2013



**Figure 13: Trends in Groundwater Decision Documents Selecting In Situ Treatment (FY 1986-2011)**




• Number of groundwater decision documents = 1,919.

# Why In-Situ Injection Installation of Treatments?

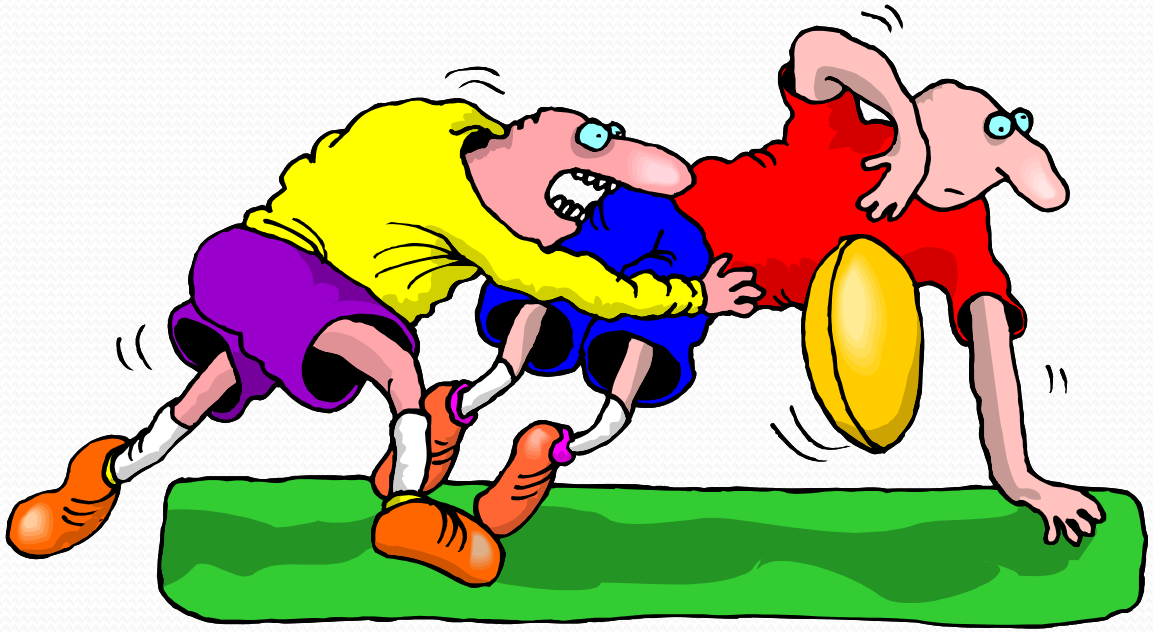
- **Limited or No Disposal Issues**
- **In Place Destruction of Contaminants**
- **Less Invasive - Works Around Infrastructure**
- **Many Work with Natural Environment**
- **Direct Push Injection Advancements**
- **Improved Understanding of Hydraulic-Fracturing**
- **Improved Monitoring Methods,**
-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

***Greener & Sustainable Technology!***

# In-Situ Remediation:

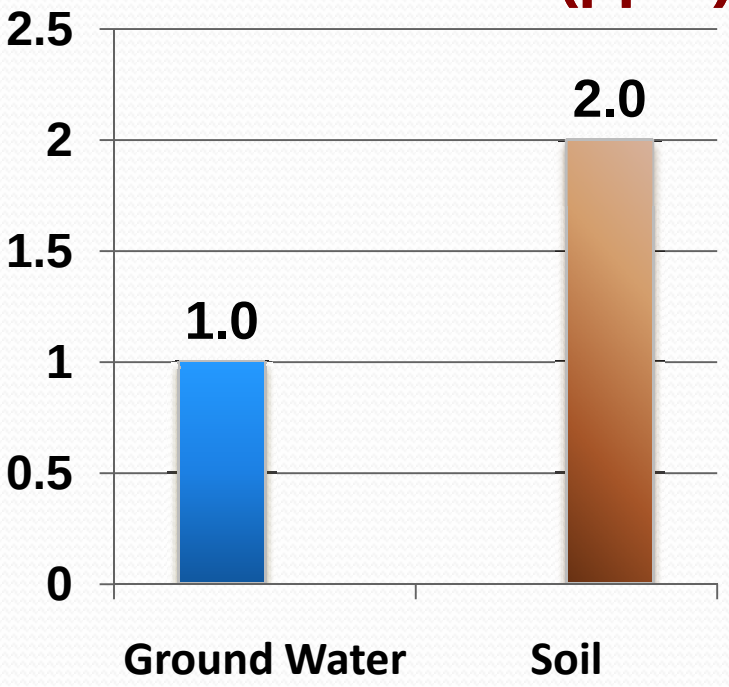
## *It's a Contact Sport!*

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

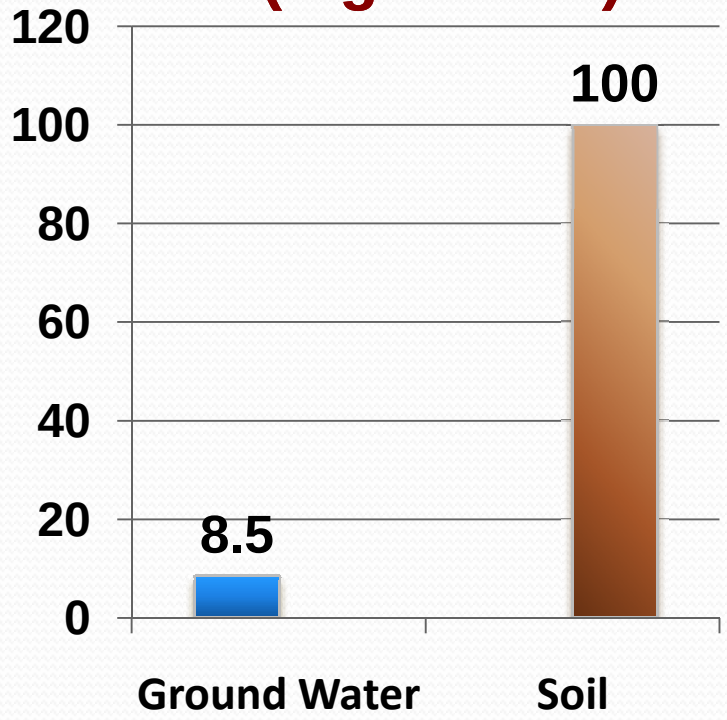


# Treatment Trivia 1: Adsorbed Phase vs. Dissolved Phase Contaminant Loading

## Soil and Ground Water Concentration (ppm)




## Contaminant Load (mg / cu. ft.)




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

# Treatment Trivia 2: Back Diffusion from Clays
## (Consider Mass Flux Discharge = Rebound)


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

# Applying Remedial Design Characterization (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

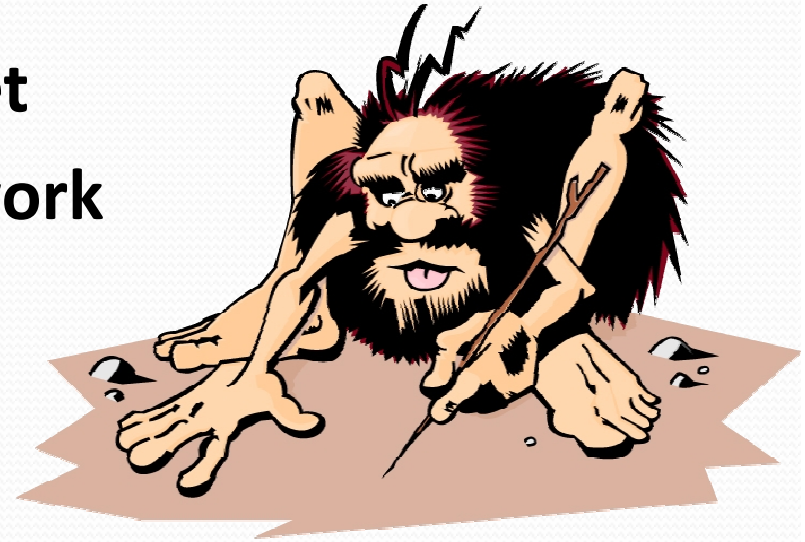
# Use High Resolution Data to Create "Decision Units" for Treatment Dosing

DEPTH

| Injection Depth | Area A<br>500 sq. ft, 5 pts. | Area B<br>1,500 sq. ft, 15 pts | Area C<br>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 |

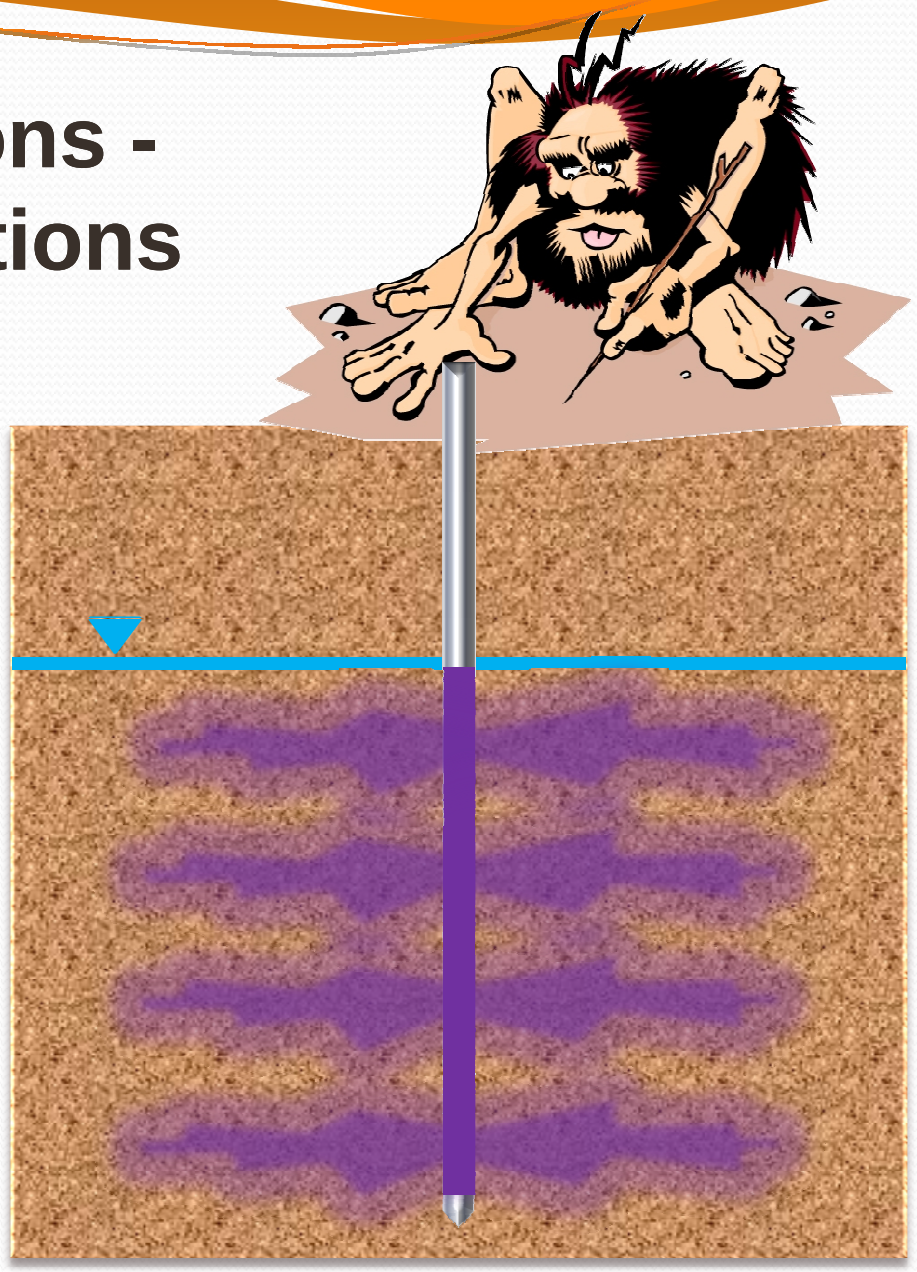
# “Early” In-Situ Injection Methods

- New Treatments on the Market
- Existing Monitoring Well Network
  - Socks
  - Gravity Feed
  - Injections in it’s Infancy
- Open Auger Bore Holes, Open Pits, Trenching
- Dedicated Injection Wells using HSA
- *We used what we had!*



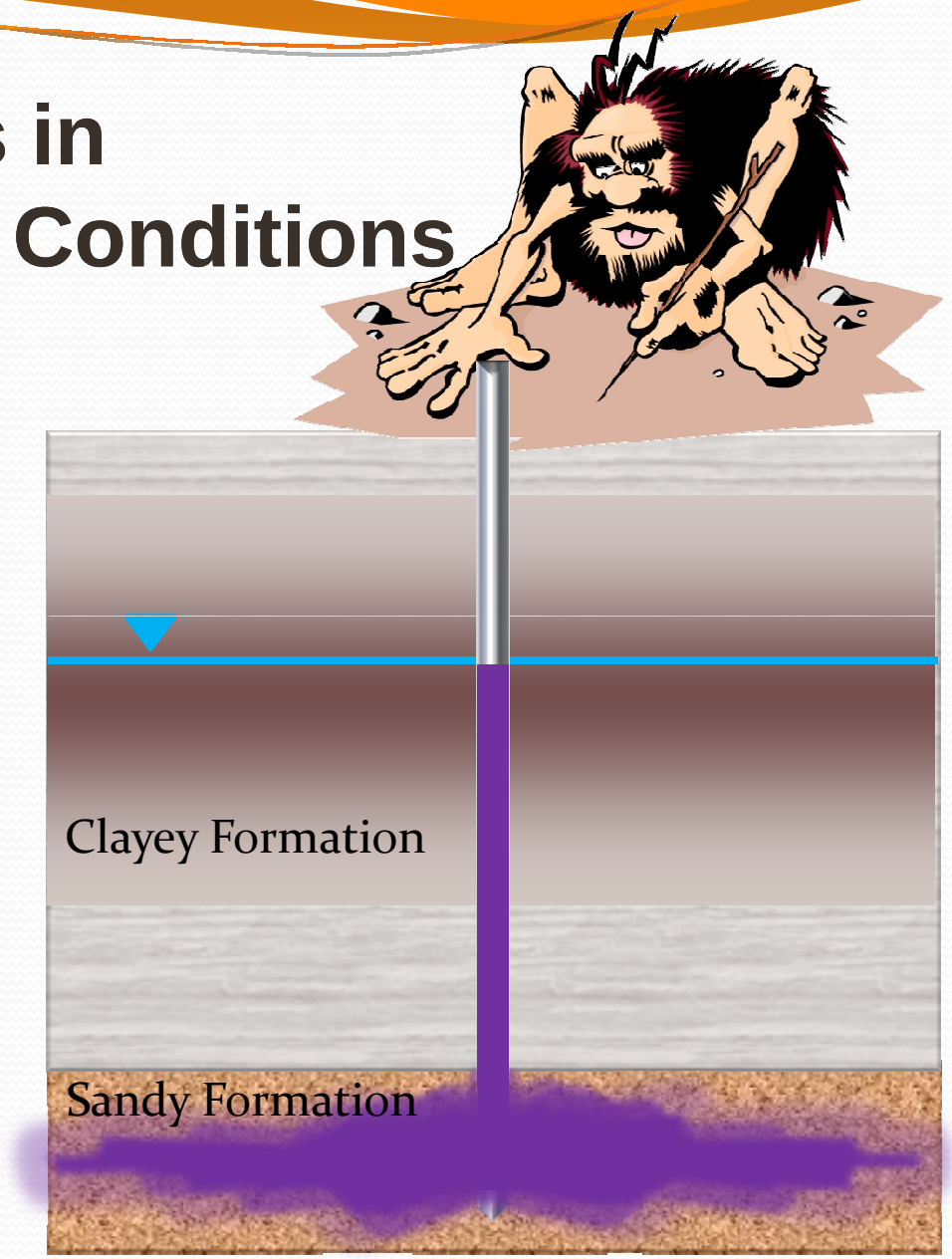
# Bottom Up Injections - Under *Ideal* Conditions

- Homogeneous
- Porous/Permeable
- No Preferential Bedding Planes
- Coarsening Upward
- Even Gravity Fed Wells are OK here!



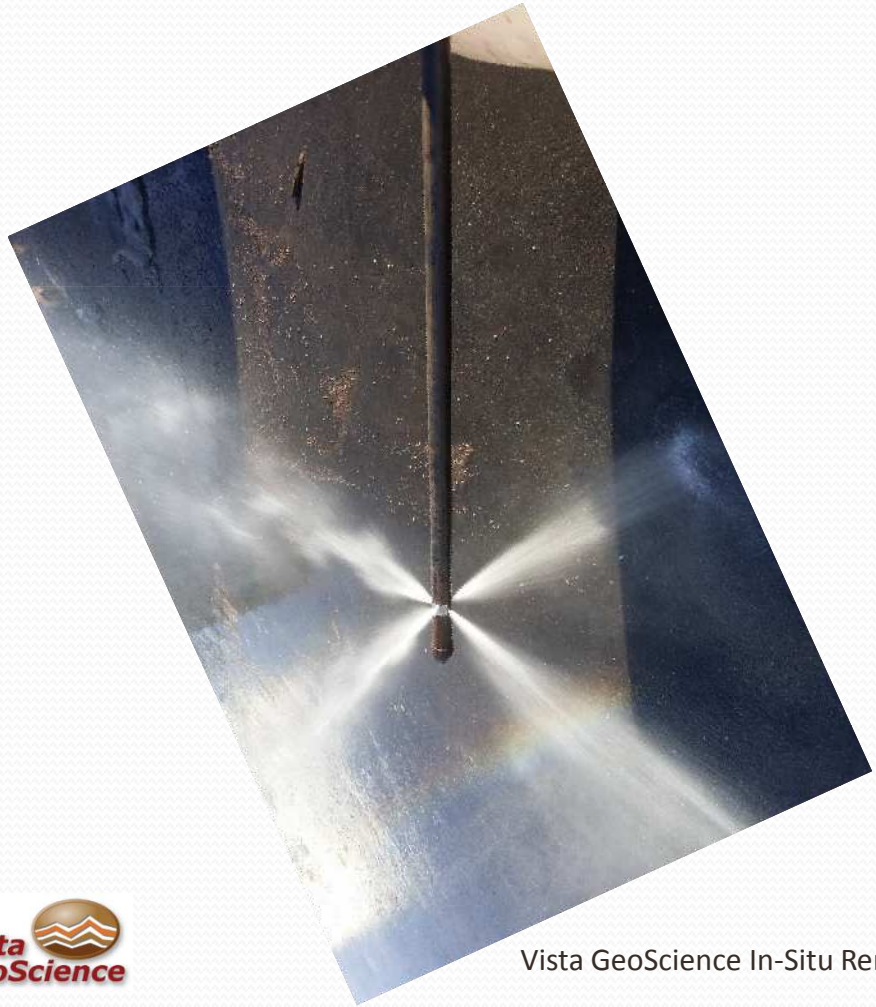
# Bottom Up Injections in *Non-Ideal* (Common) Conditions

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



# SOLUTIONS: Surgical Injection Methods

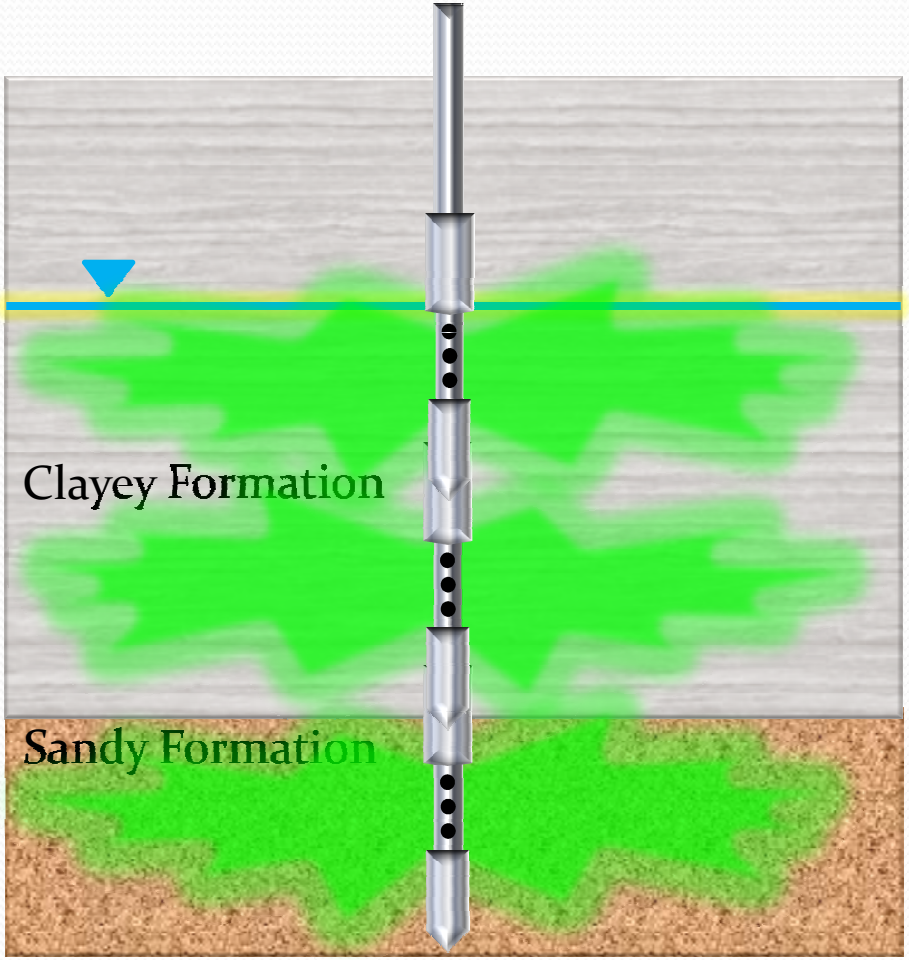
- Top-Down Injections Tools
- High Pressure, High Flow




- Straddle Packers
- Isolated Intervals

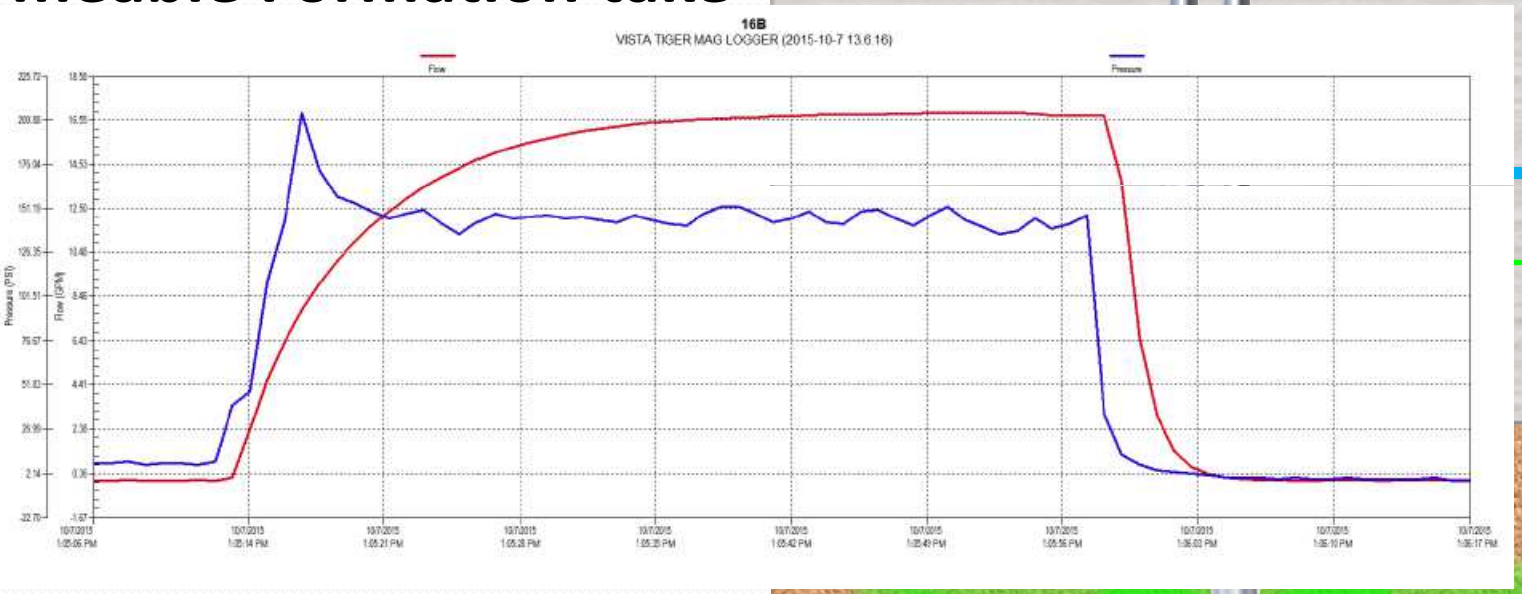
# SOLUTIONS: Improved Injection Methods

- Top Down Injection or Discrete Placement Tooling
- Seals Off Intervals
- Precise Placement
- Slower Application
- *= BETTER CONTACT!*



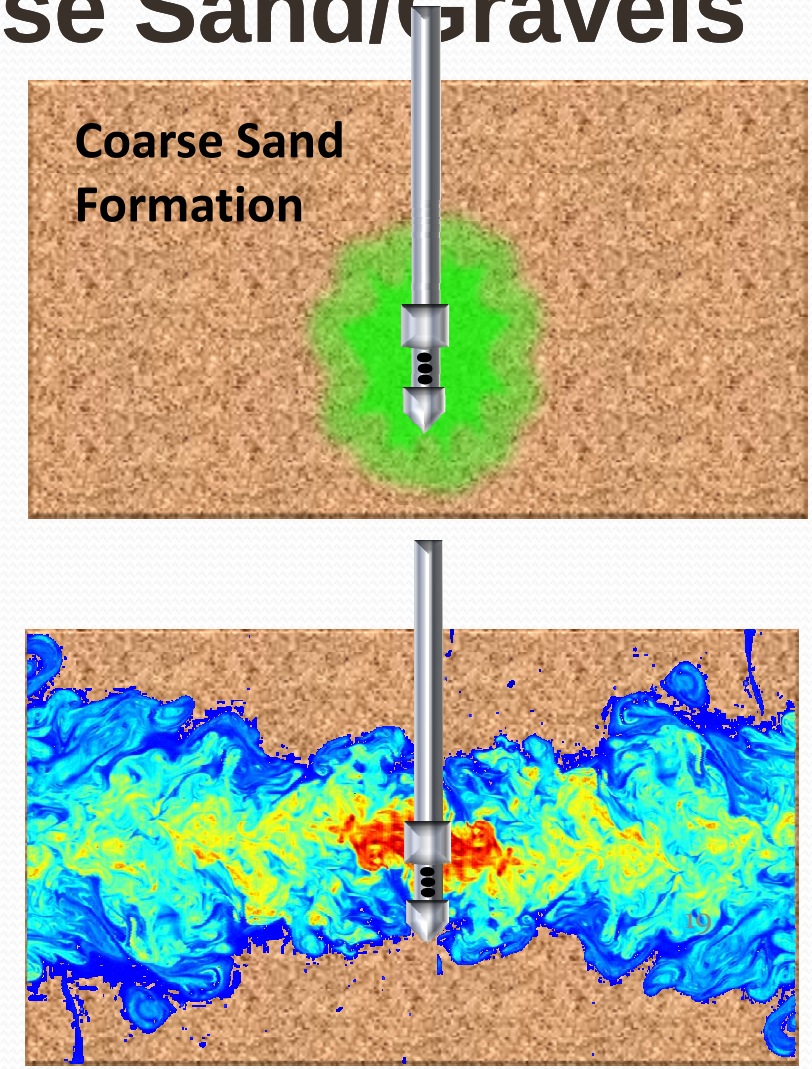
# Exceeding Overburden Pressures (Low Perm Formations / Bedrock)

- **Permeable Formation take**
  **hig**
  **pre**
- **Tig**
  **rec**
  **gai**
  **like**
  **fractures with a larger ROI.**



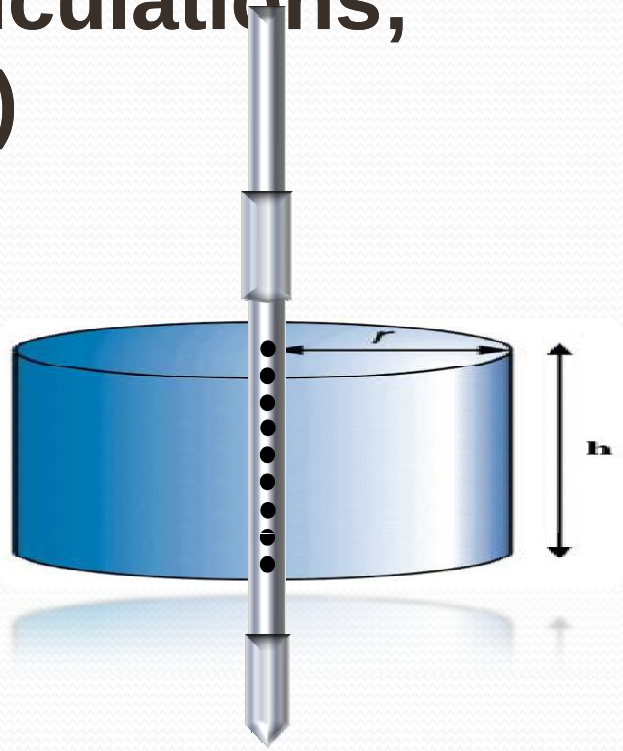
# Injection of Slurries (Solids) into Unconsolidated Coarse Sand/Gravels

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



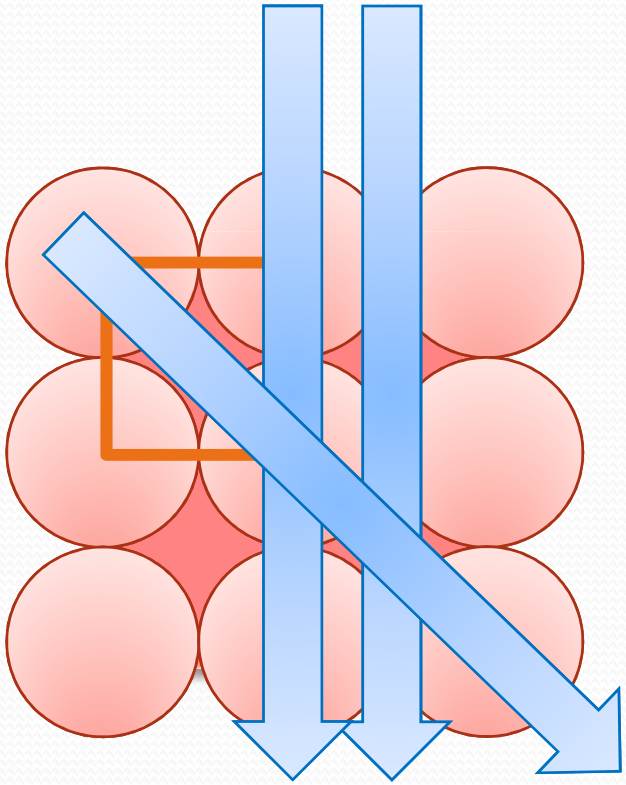
# Radius of Influence (ROI) Calculations; (Displacement vs. Pore Flow)

- 10’ Injection Grid:
  - Radius = r = 5’
  - Area = $\pi r^2$
  - Vertical Treatment Interval = h = 2’
  - Assuming *Effective* Porosity ≈ 20%
  - Volume conversion: 1 $ft^3$ = 7.48 gallons
- Therefore:
  - Volume = $\pi(5')^2$ x (2’) x (0.2) = 31.42 $ft^3$
  - Pore volume = 31.42 x 7.48 = 235 gallons
  - A 50 gallons injection = about 21% of pore volume.
- **HOWEVER: ROI is more a function of what % of the formation fractures during injection (displacement) vs. fluids that move through pore spaces.**

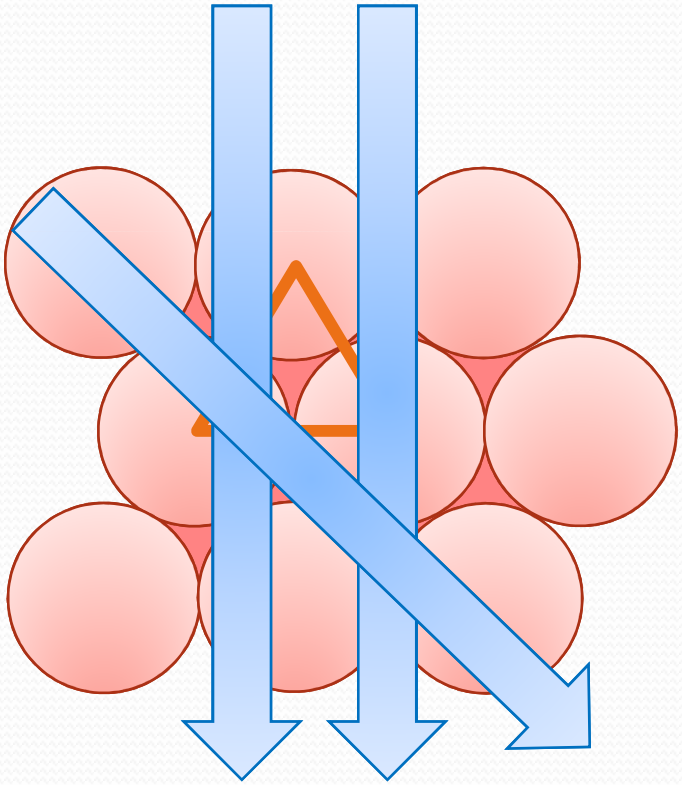


# Triangular vs. Square Injection Grids (Surface View)

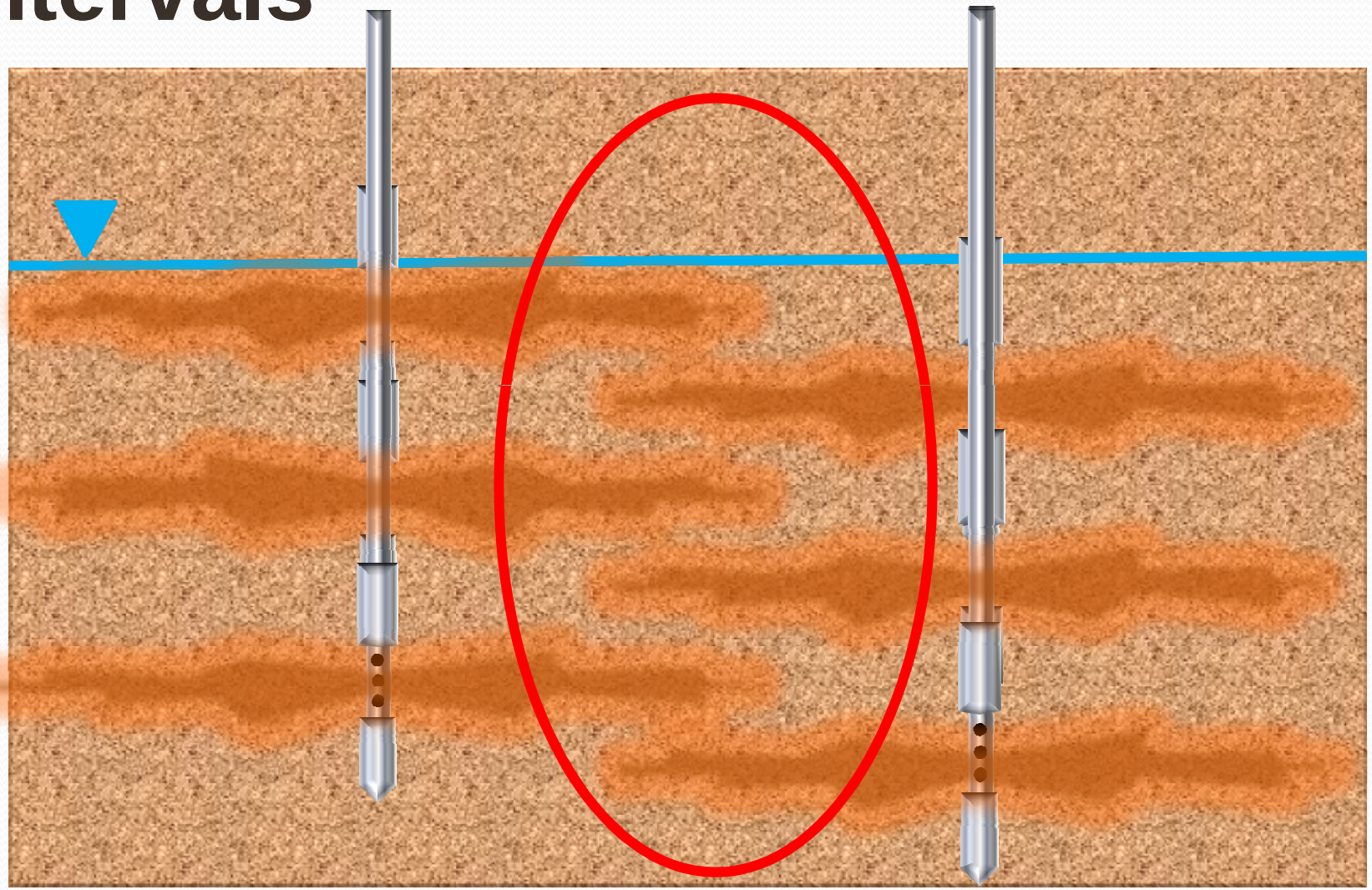
- **Square Grid**



- **Triangular Grid**

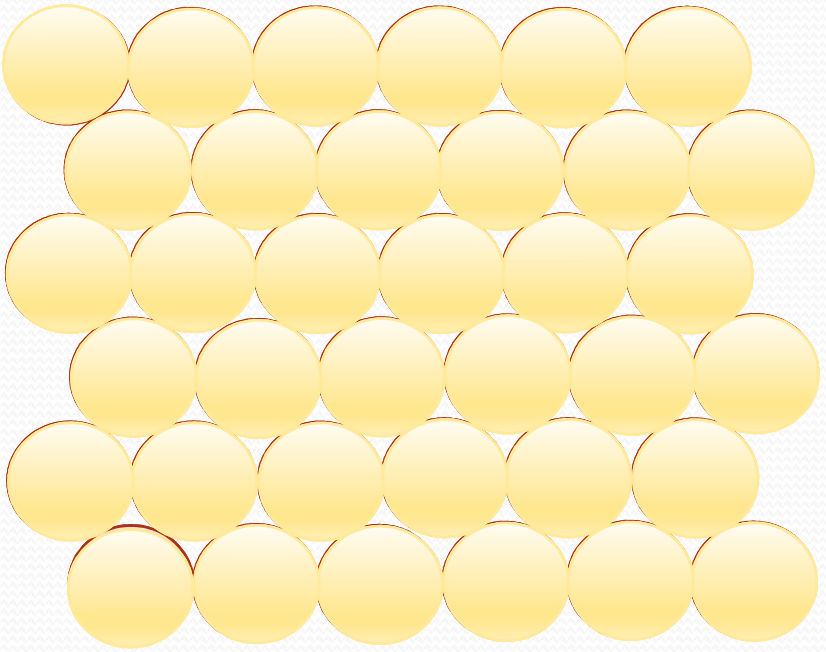


# Staggered Top-Down Injection Intervals



# 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?**
- **High-Volume/Low Pressure?**
- **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.**
- **Lower flows may INCREASE surfacing.**

# Slurry (Powders & Solids) Mixing & Pumping Systems


# 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

# 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

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

# In-Situ Slurry Injection/Fracture Pump Rigs

# 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

- **Another Section, Out of time, but…..**
- **Combined Methods or Phased Approach may be appropriate for some sites.**
- **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.**

# Ex. #1: 3400 York Street; Denver, Former Gas Station

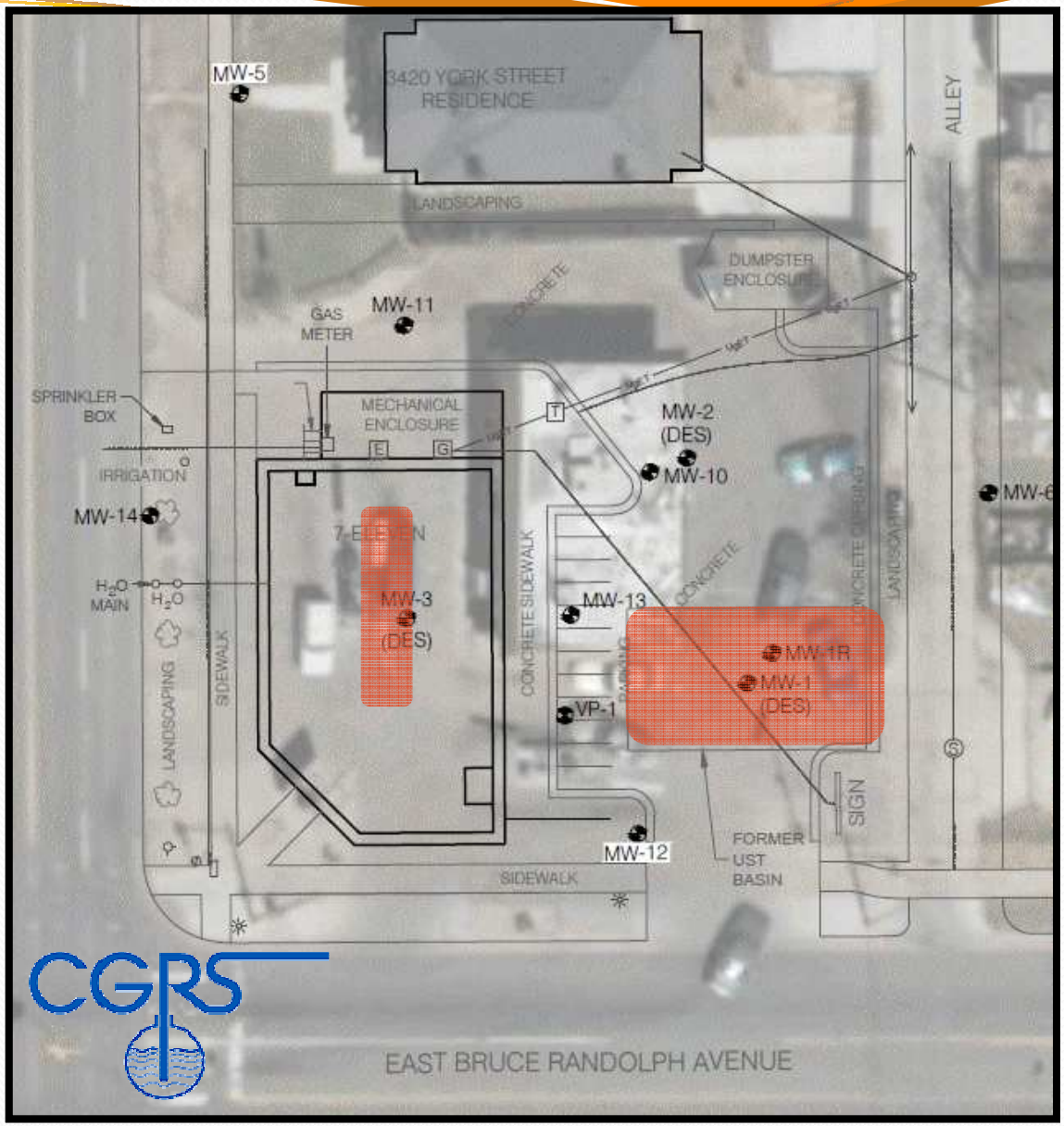
- CDLE-OPS Event No. 11494
- Release Discovered During Tank System Removal, August 2011
- 2nd Tank System Removed July 26, 2012; No Release Detected.
- Co-Mingled with PCE Plume from Upgradient Dry Cleaner Site
- New 7-Eleven Store Built Over Part of Plume Prior to Remediation
- Relatively Deep (Groundwater at ~45')
- Team Partners:

# 3400 York Street; Phases of Work

- **Site Developer: "NOT WAITING," New Building *Going In***
- **Chosen Remedy: Remediation Products BOS 200®**
  (Activated Carbon, Nutrients, Bacteria Augmentation)

1. **RDC Sampling & Treatment Design**
2. **Pilot Injection Test Conducted Near MW-1R, Former Tank Pit Area (May 2013)**
3. **Full Scale Site Injection on Balance of Site (Nov. 2013)**
4. **Post Injection Well Cleaning and Redevelopment**
5. **Post Injection Sampling & Monitoring**

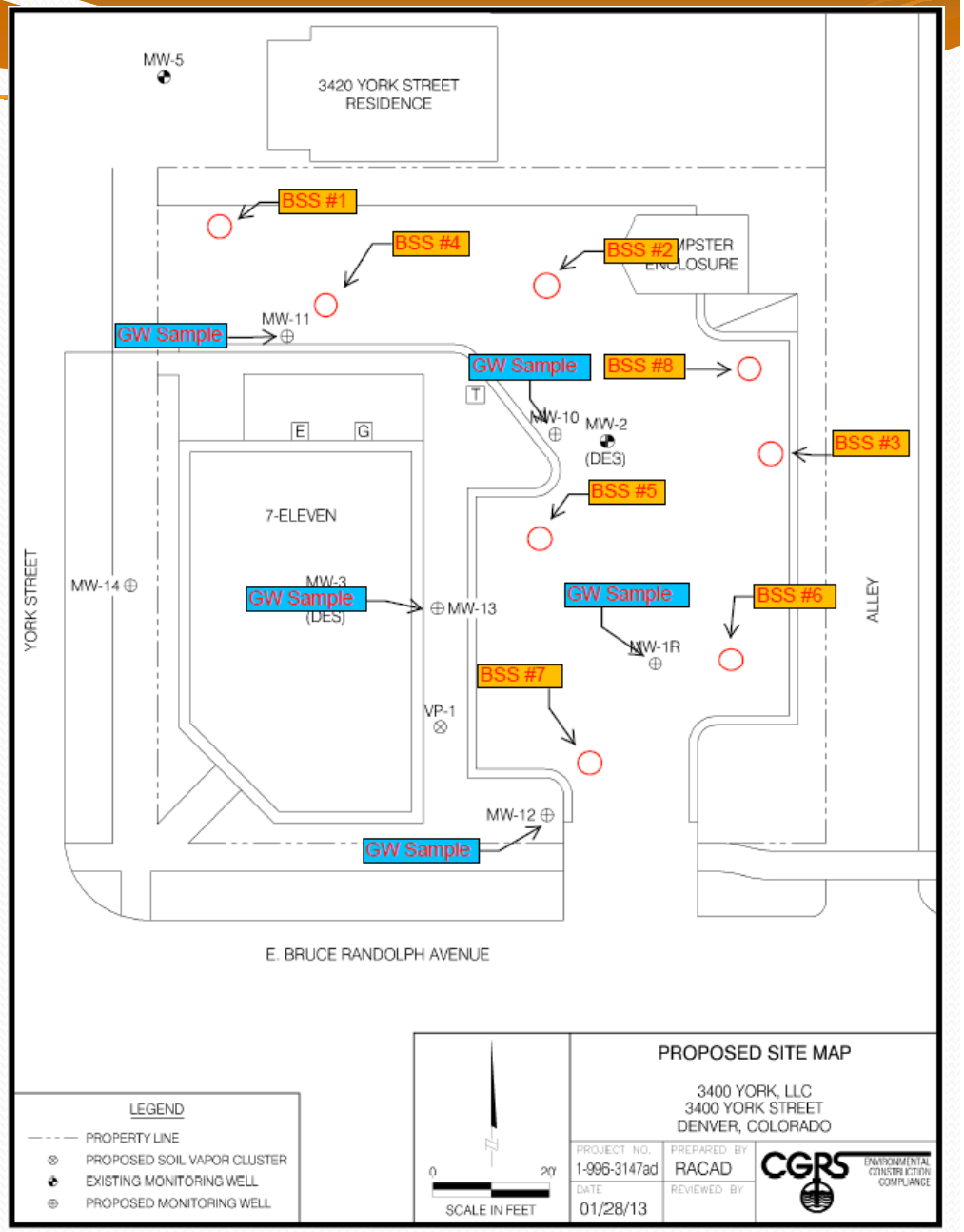
# Overlay of New Building Plan on Former Gas Station Site




**Courtesy CGRS Inc.**

# RDC Event

- **8 Continuous Soil Cores 5’ – 50’ in Treatment Area**
  - 56 soil samples collected at 2’ composite intervals.
- **5 Monitor Wells Sampled in Treatment Area.**
- **Analysis of 56 Soil & 5 Ground Water Samples:**
  - 8260 VOCs (BTEX, MTBE, TVPH, PCE & Daughters)
  - Sulfate, Chloride, Nitrate, Nitrite, Acetate (waters only)
- **Identified Shallow Vadose Contamination in Former Tank Pit Area.**




**Courtesy CGRS Inc.**

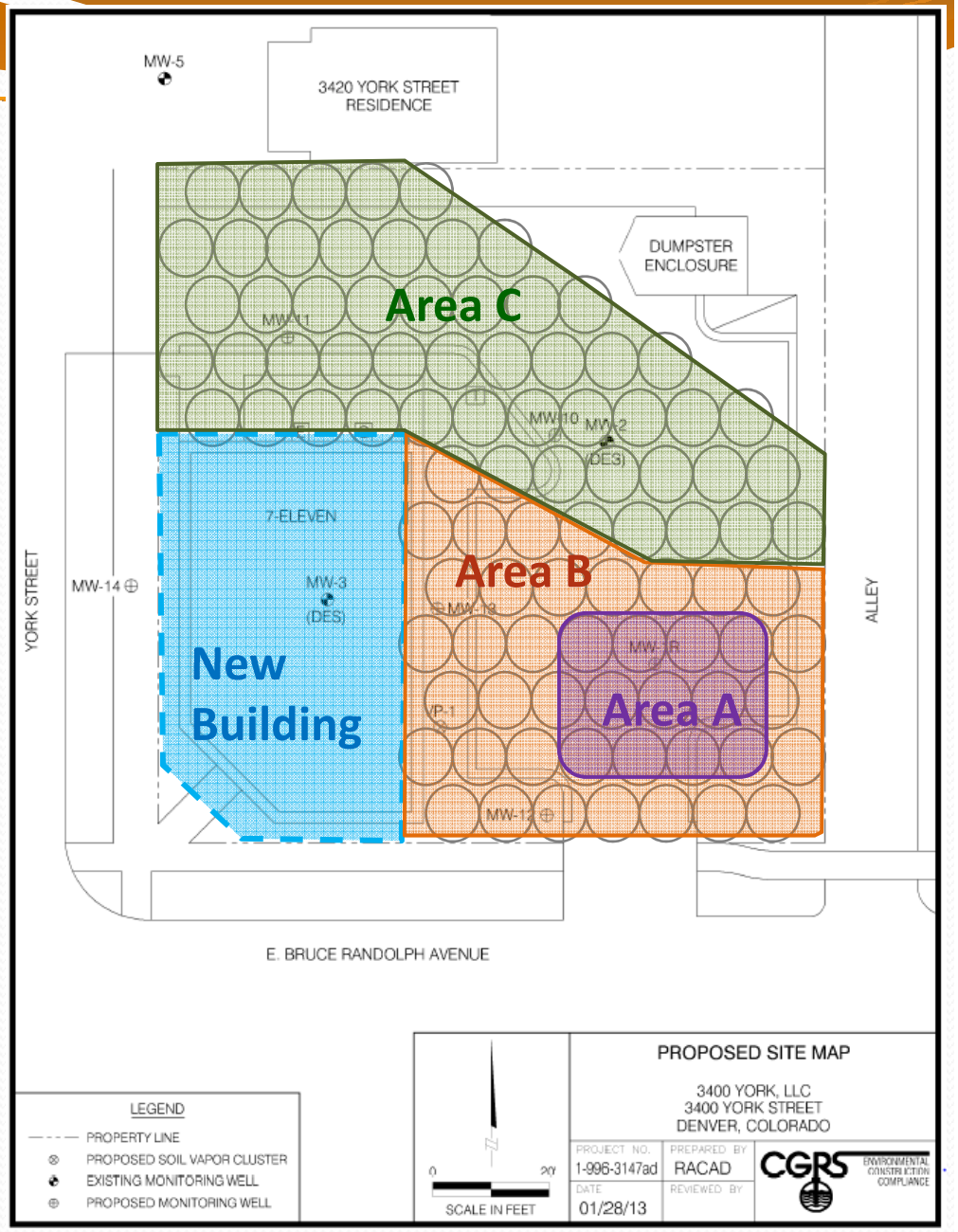
# Injection Design

**PILOT TEST: (May 2013)**

- **Area A:** MW-1R, former tank pit/source area; 12 pts, 15lbs/ft. 40'-50'
- **Total** 1,800 lbs BOS200

**FULL SCALE: (Nov 2013)**

- **Area B1:** 15pts, 10 lbs/ft, 40'-50'
- **Area B2:** 16 pts, 7.5 lbs/ft, 40-50'
- **Area C**: 42 pts, 5 lbs/ft, 40-50'
- **Total** 4,650 lbs BOS200




**Courtesy CGRS Inc.**

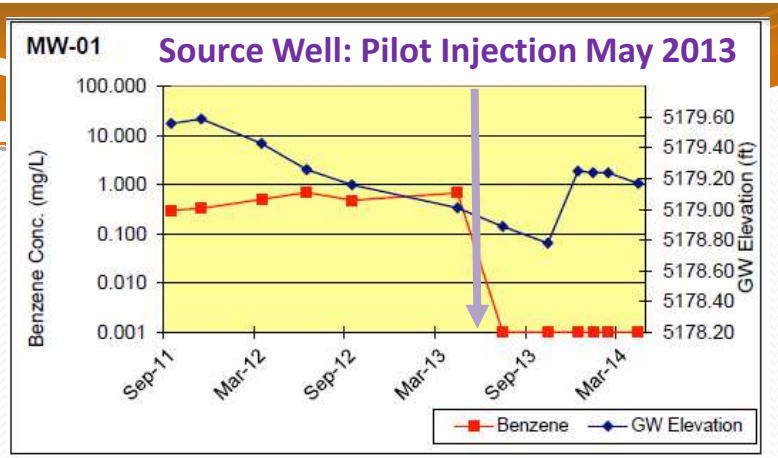
# **Results** (Benzene ppb)

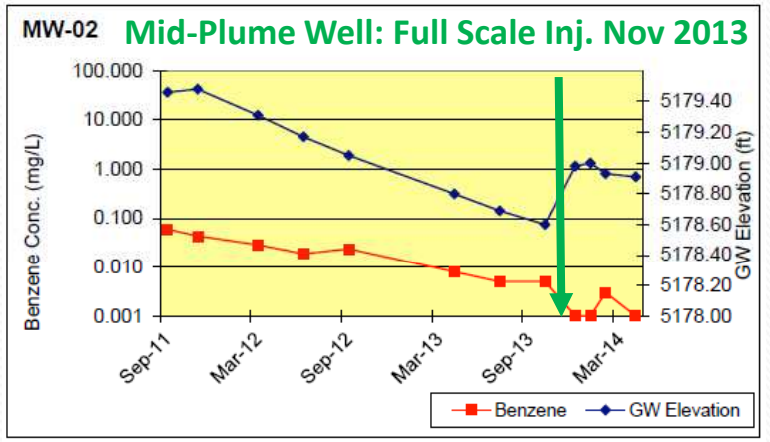
## SOURCE

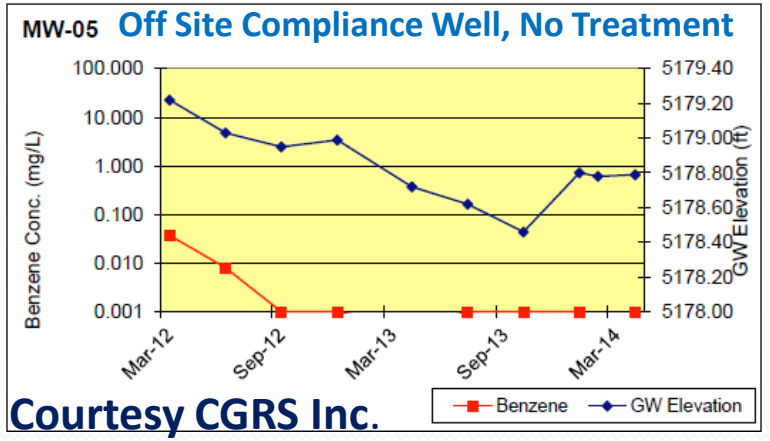
- **MW-1R:** 310-688 ➔ ND
  - (PCE: 3330 ➔ ND)

## MIDPLUME

- **MW-10/2:** 8-60 ➔ ND-3
  - (PCE: 6270 ➔1830)
- **MW-11:** 2-3 ➔ ND
  - (PCE: 2710 ➔ 11)
- **MW-12:** 5-12 ➔ ND-3
  - (PCE: 13900 ➔12900)
- **MW-13**: 23-47 ➔ 3-6
  - (PCE: 595 ➔ 1080)
- ***NFA*** *achieved in 2015 after post injection monitoring requirements*




**Courtesy CGRS Inc.**

# Cost to Our Client (Labor & Materials)

| | |
|---|---|
| • RDC Sampling | • $5,000 |
| • Pilot Test | • $16,000 |
| • Full Scale | • $57,000 |
| • **TOTAL:** | • **$78,000** |

**= Cost Effective Cleanup – The First Time!!**

# Performance Monitoring & Combined Methods

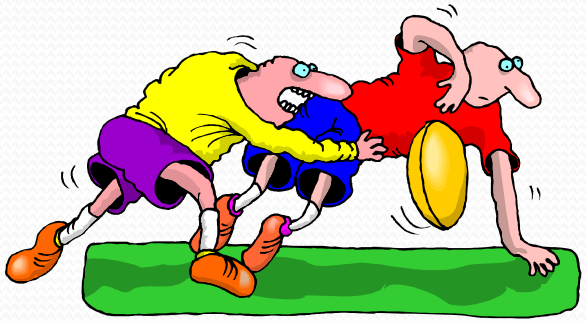
- **Where did my injection go?**
  - **Monitor wells, offset cores, post injection sampling, & HRSC tools will tell.**
- **Performance Monitoring *should* be part of the Game Plan.**
- **Can be done *on the fly* – Allowing for adjustments during the treatment phase on larger scale projects.**
- **Combined Methods or Phased Approach may be appropriate for some sites.**

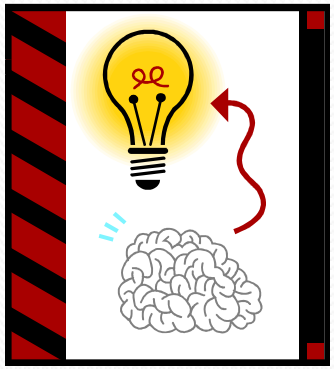
# Summary

- **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 - - *MAKING CONTACT!***
- **Performance Monitoring Tools and Methods to Monitor Progress and Make Adjustments**
- **= Goal of Clean Up the First Time, Fast!**

# More Summary

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





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

# Questions?

## It's a Contact Sport - Application of Highly Focused Injection Methods for Improve Results of In-Situ Treatments

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