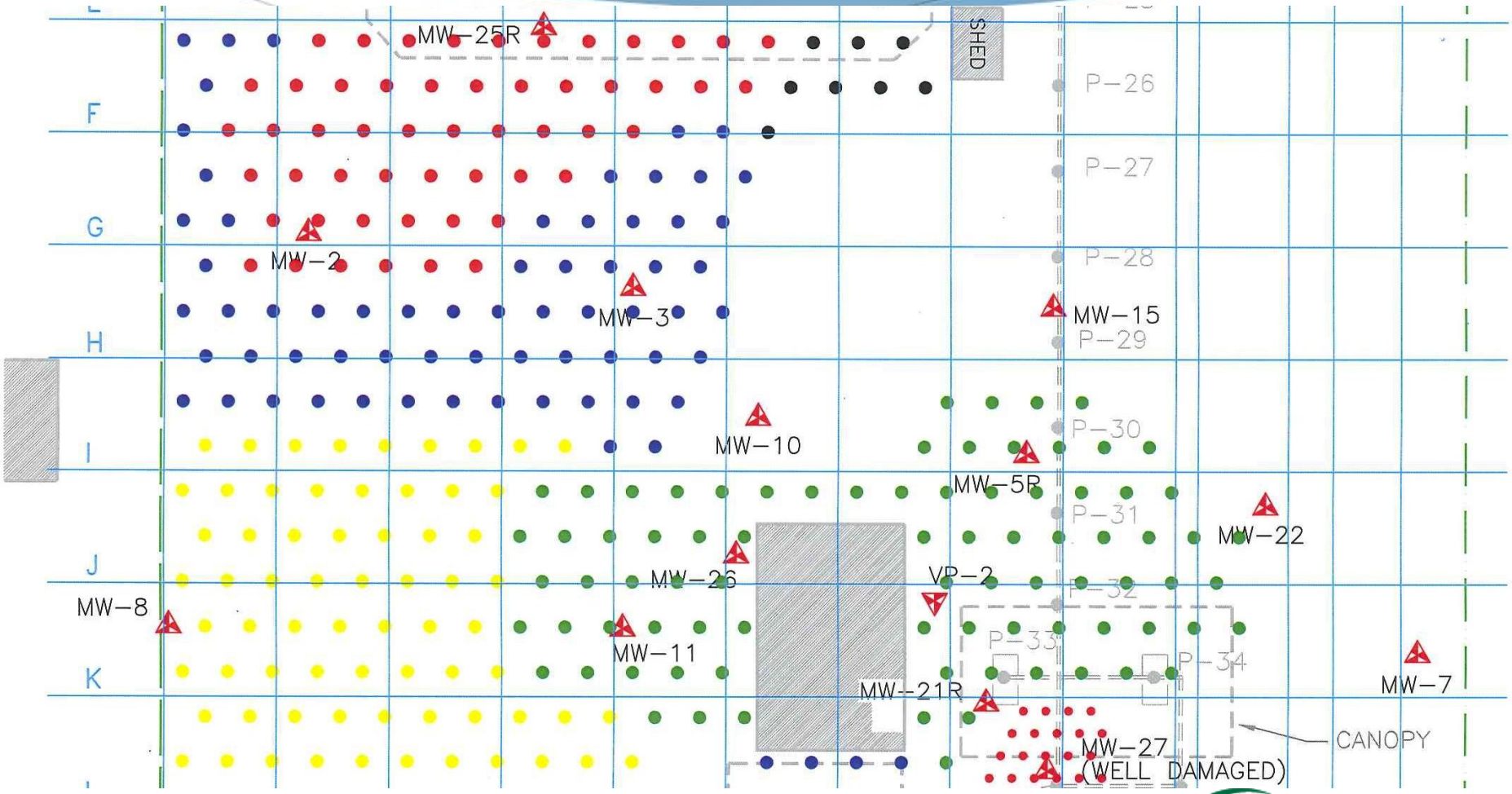

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Pueblo, CO Former UST Site

	MTBE	Benzene
MW-2 Before	10,000	Not Signif.
2 Mo After	ND (0.5)	
MW-3 Before	2,900	Not Signif.
2 Mo After	ND (0.5)	
MW-6R Before	1,900	3,300
2 Mo After	0.7	1.7
MW-27 Before	LNAPL	LNAPL
2 Mo After	ND (0.5)	1

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Three Most Important Things

- INJECTION CONTRACTOR
- Chosen Technology Matched to the Injection Technique
- High Resolution Injection Plan

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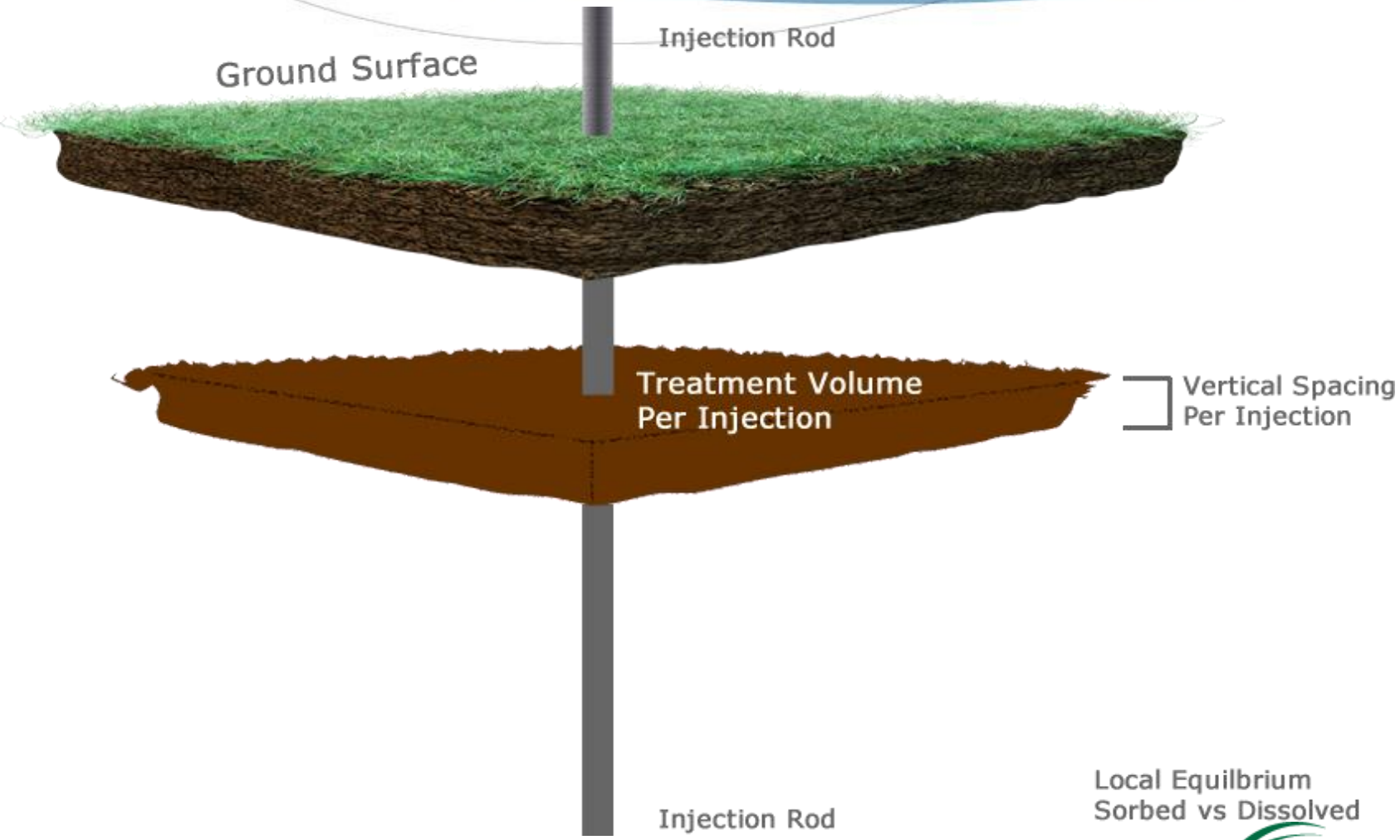
Injection – What's the Goal?



Local Equilbrium
Sorbed vs Dissolved

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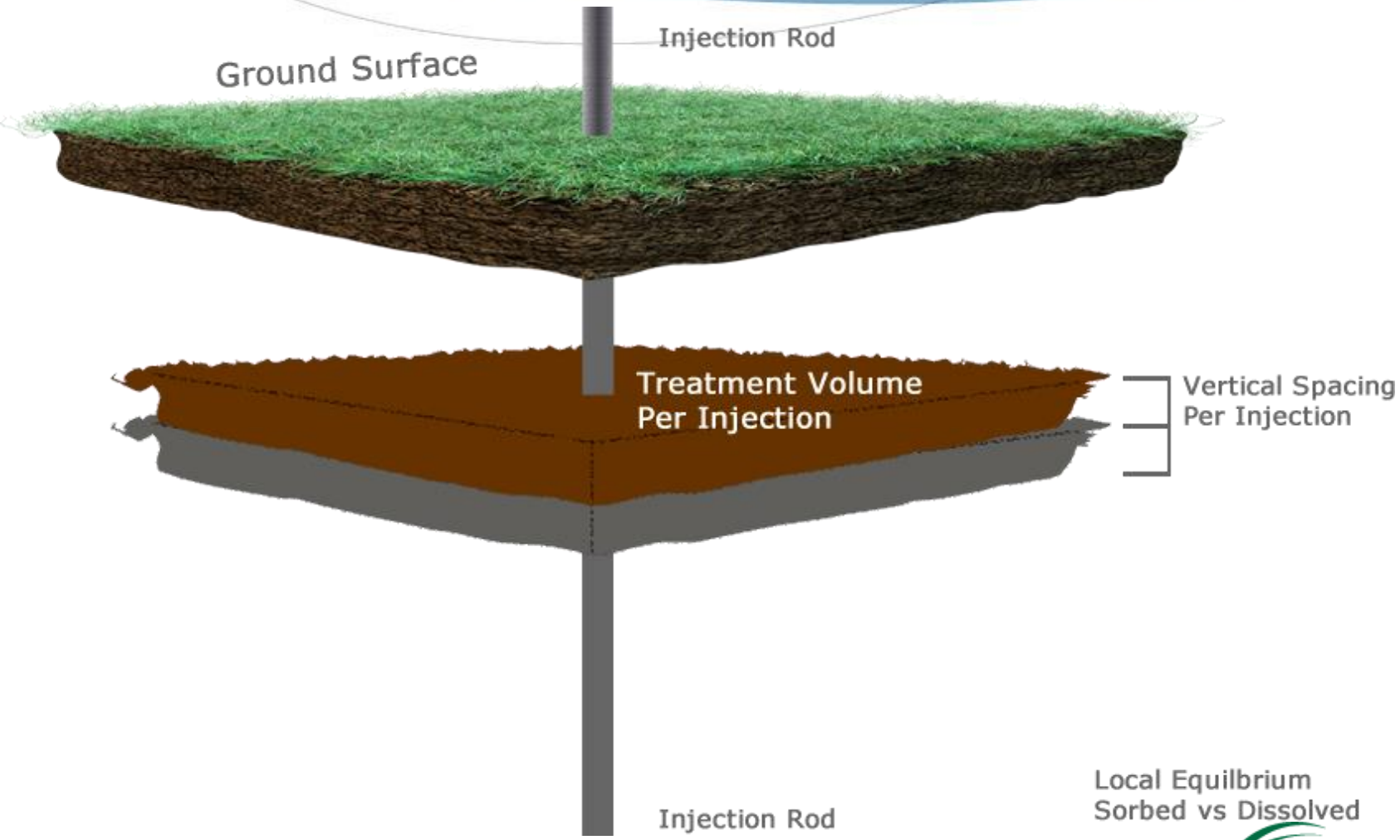
Injections vs Mass



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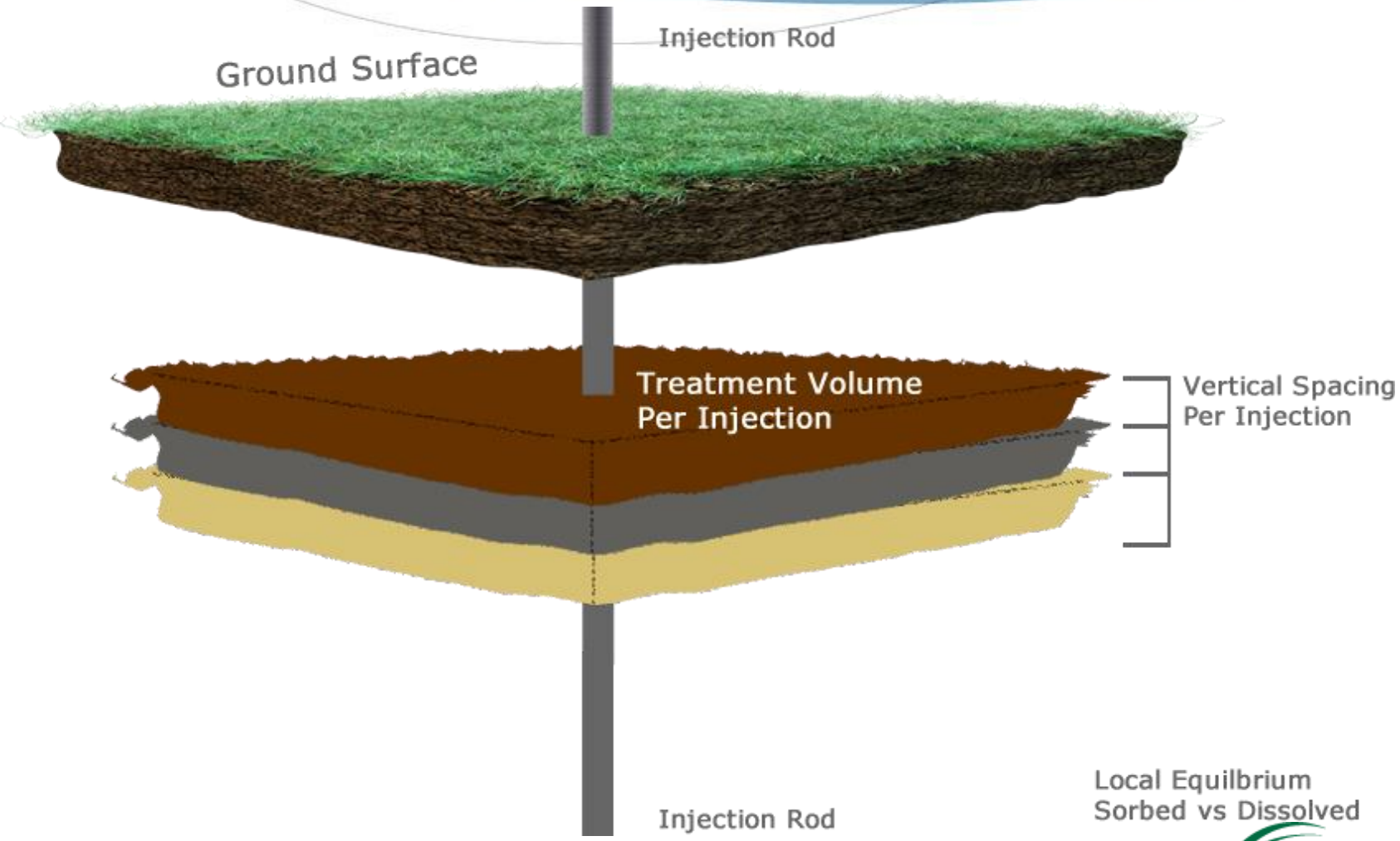

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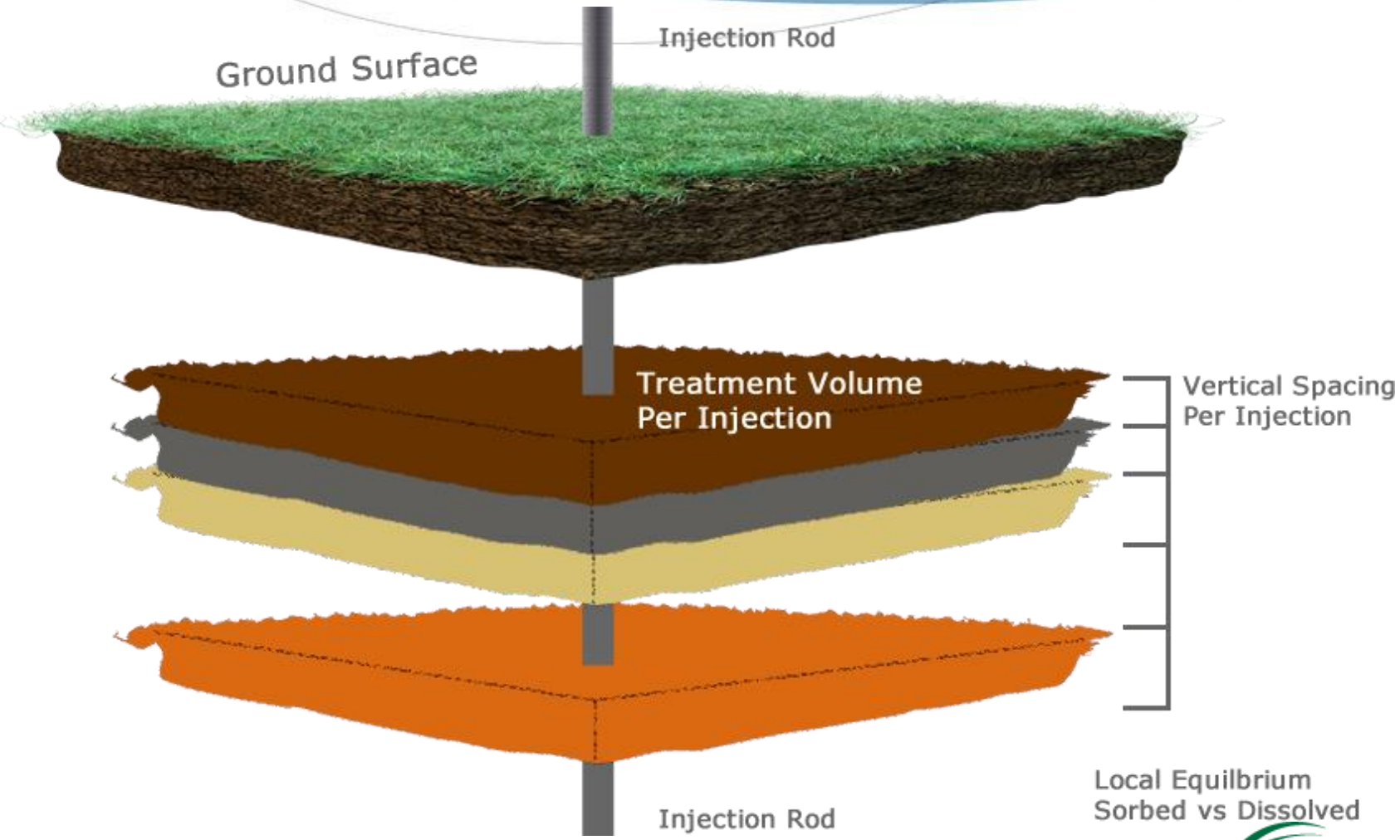

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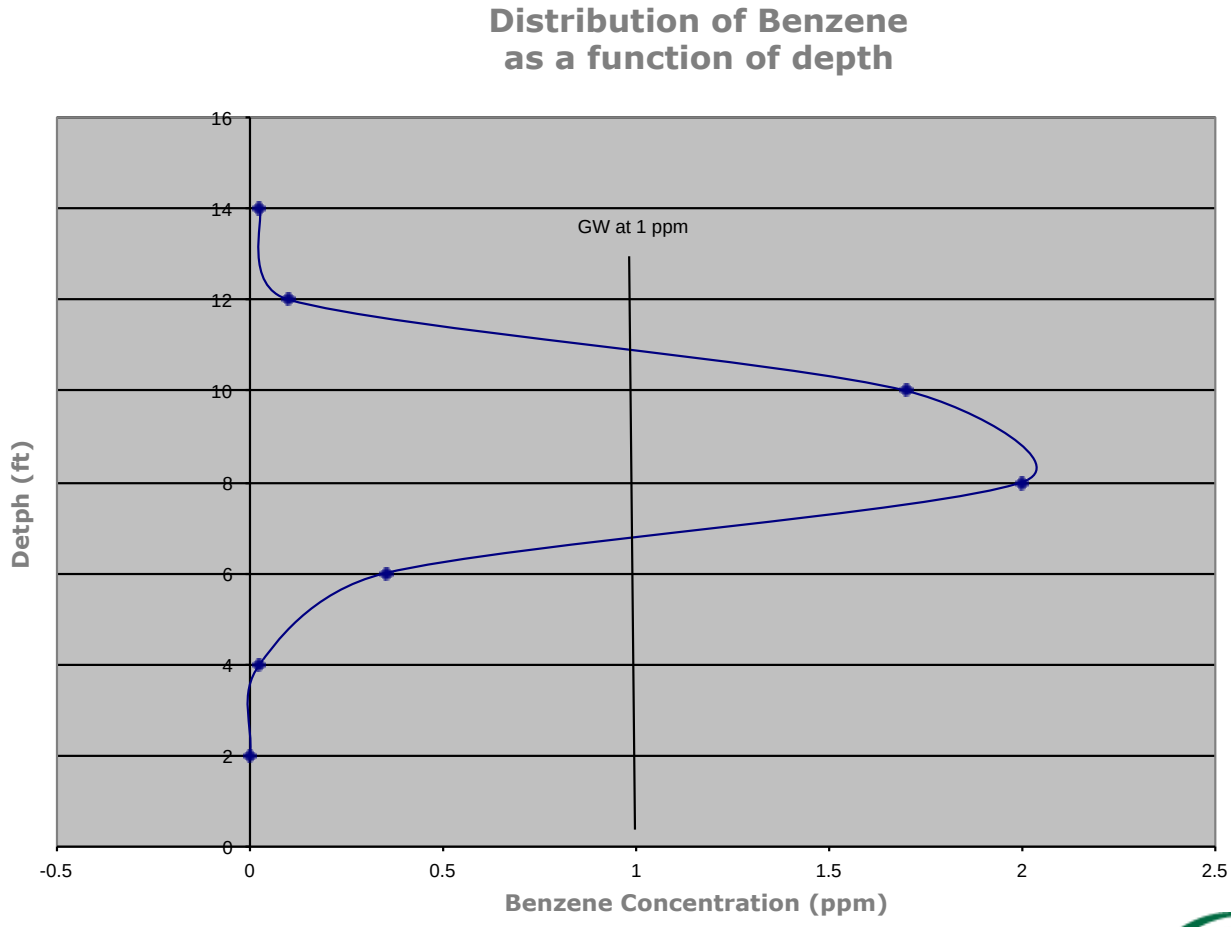
Vertical Profile at LUST Site



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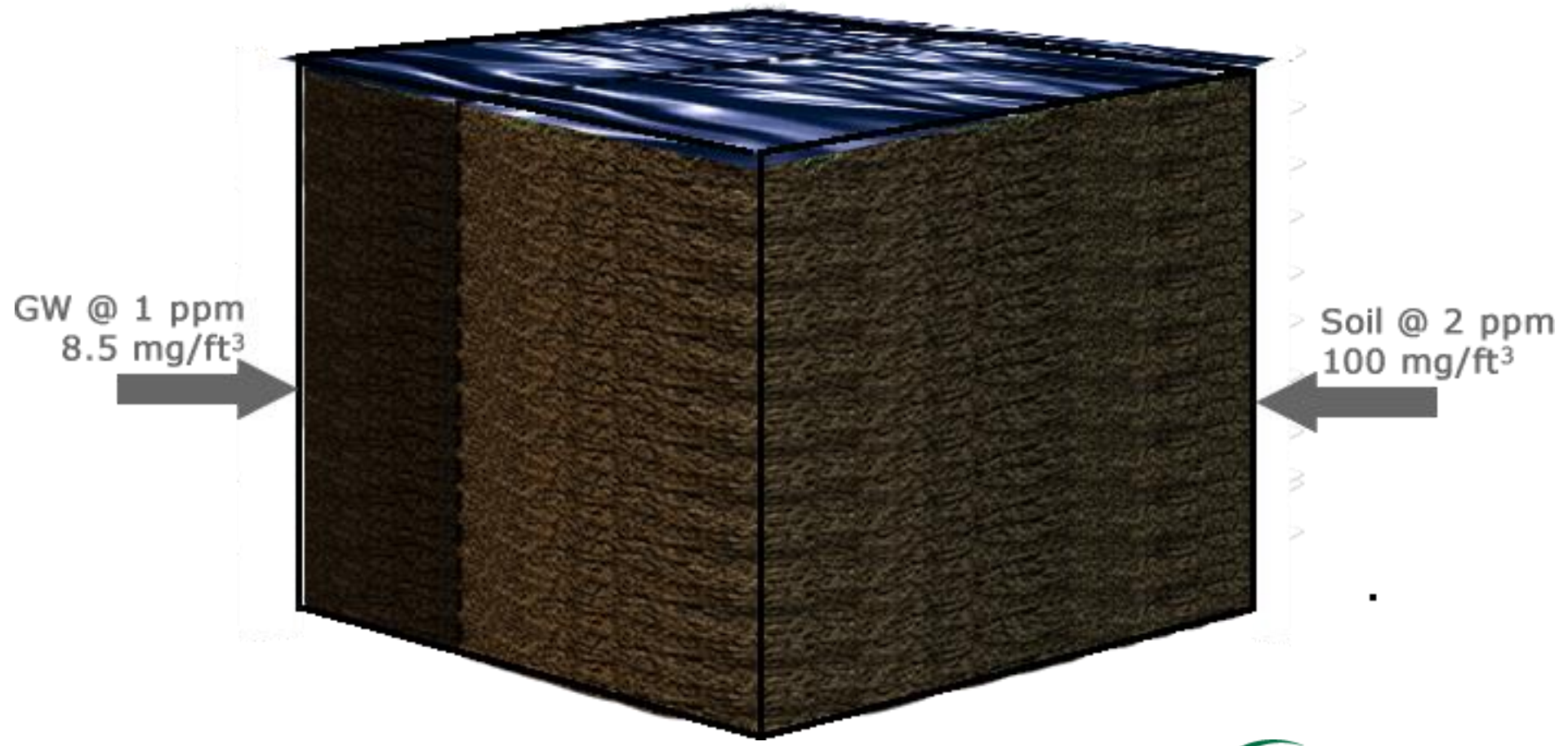
Why Saturated Soil Contamination Is Important



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Conceptual Site Model - Goals

Detailed Understanding of Vertical and Horizontal Distribution of Contamination

1. Lab analysis of soil to develop vertical profiles of contaminant mass – where impacts begin and where they end.
2. Use hydropunch or temp wells to define horizontal distribution of GW impacts.
3. Detailed Soil Boring Logs to Direct Future Injections

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Injection Dynamics Part 1

- Hydraulic Fracturing
- High Pressure – High Flow
- Injection in Clays/Silts, Sands & Gravel
- Radius of Influence

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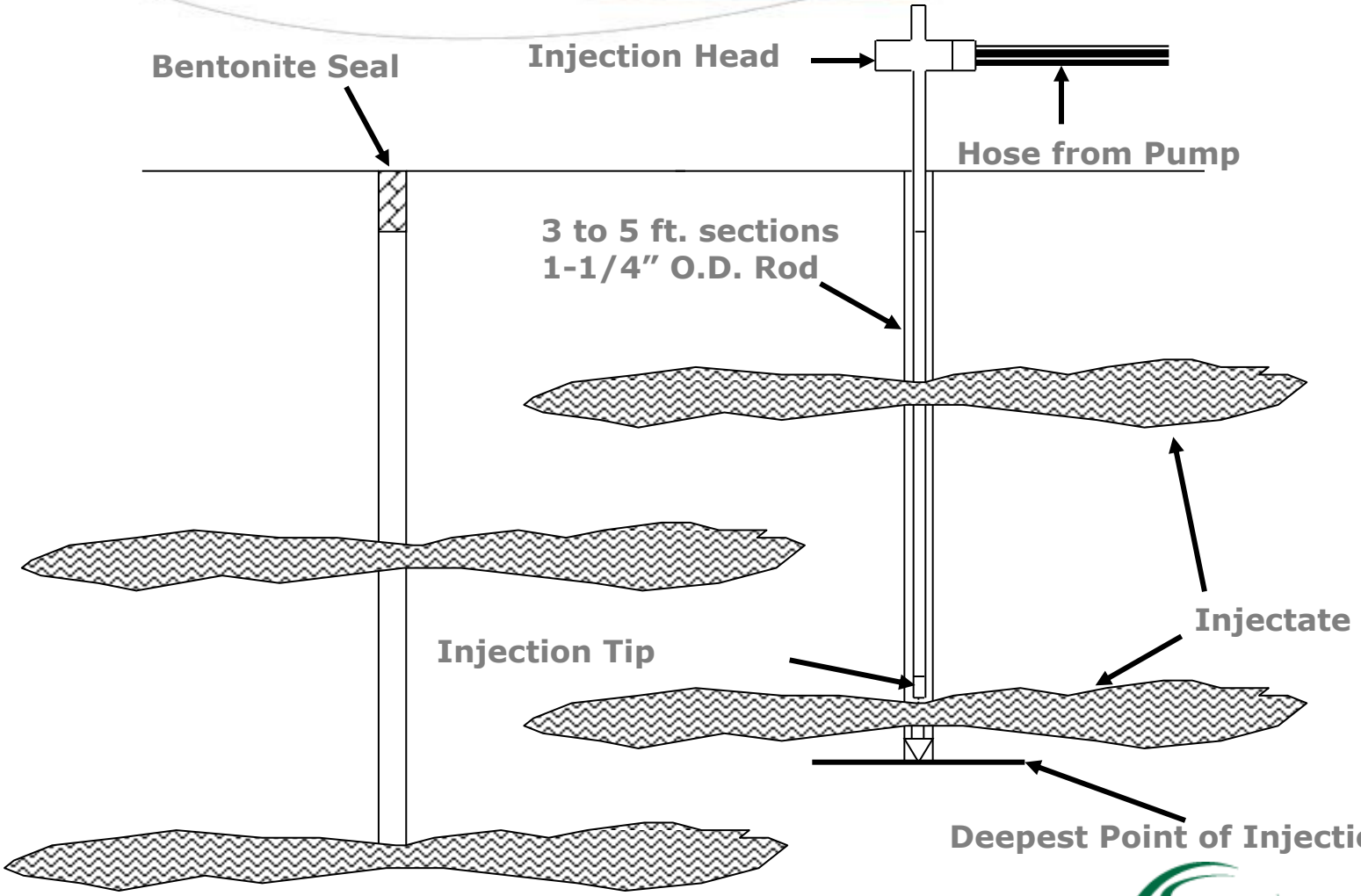
Typical "Top-Down" Injection for Clay Soils



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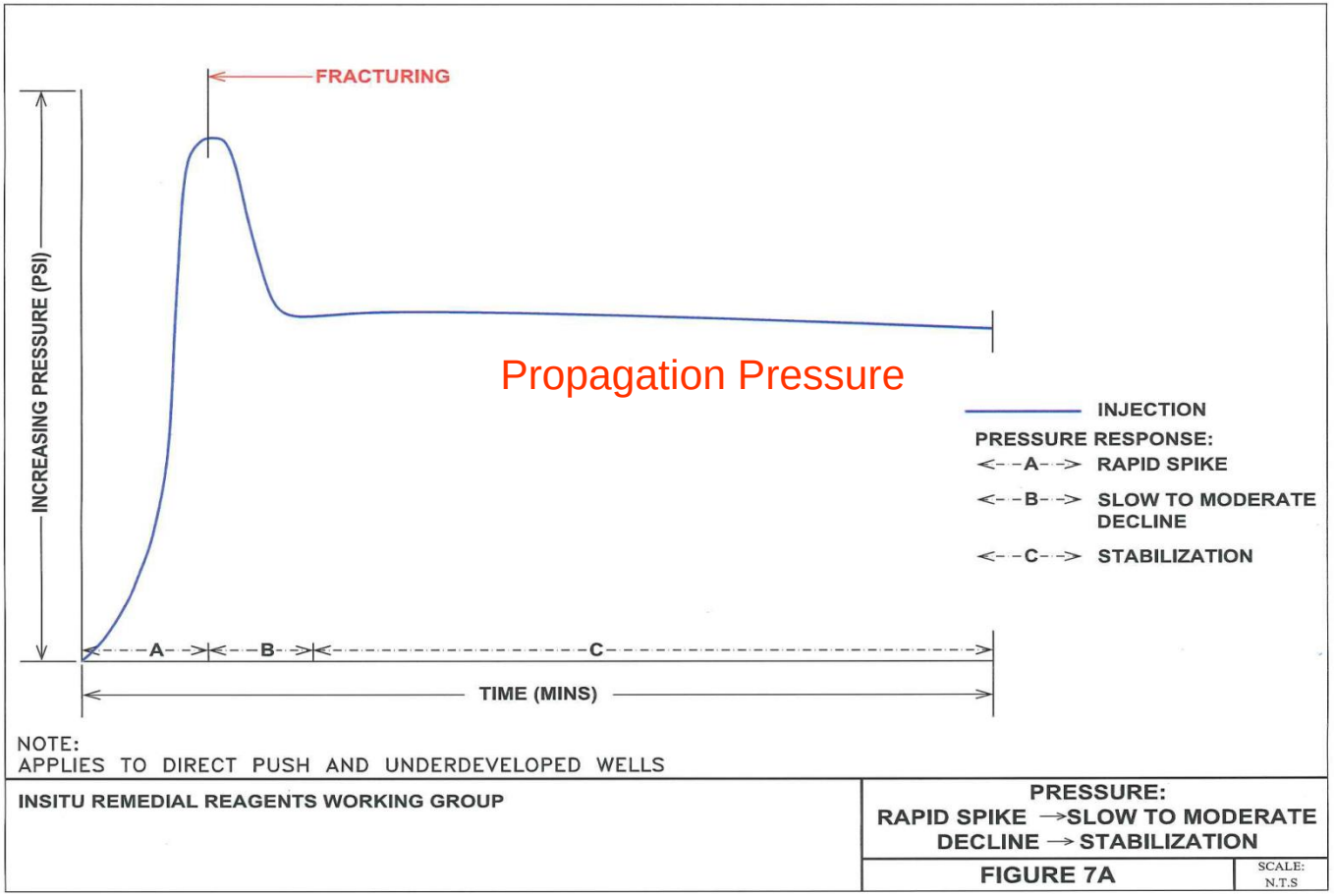
Hydro-Frac Signature



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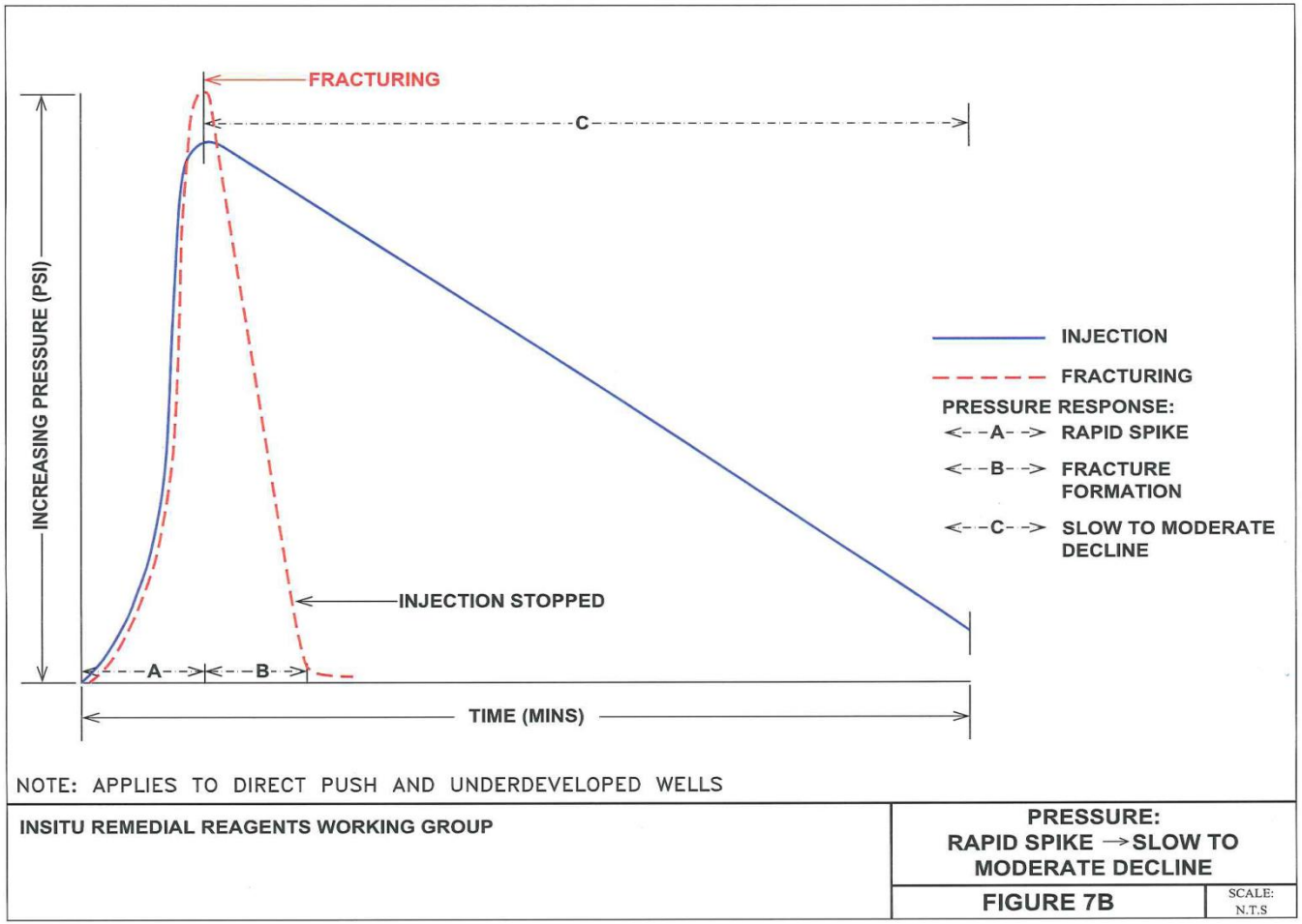
Overburden Pressure



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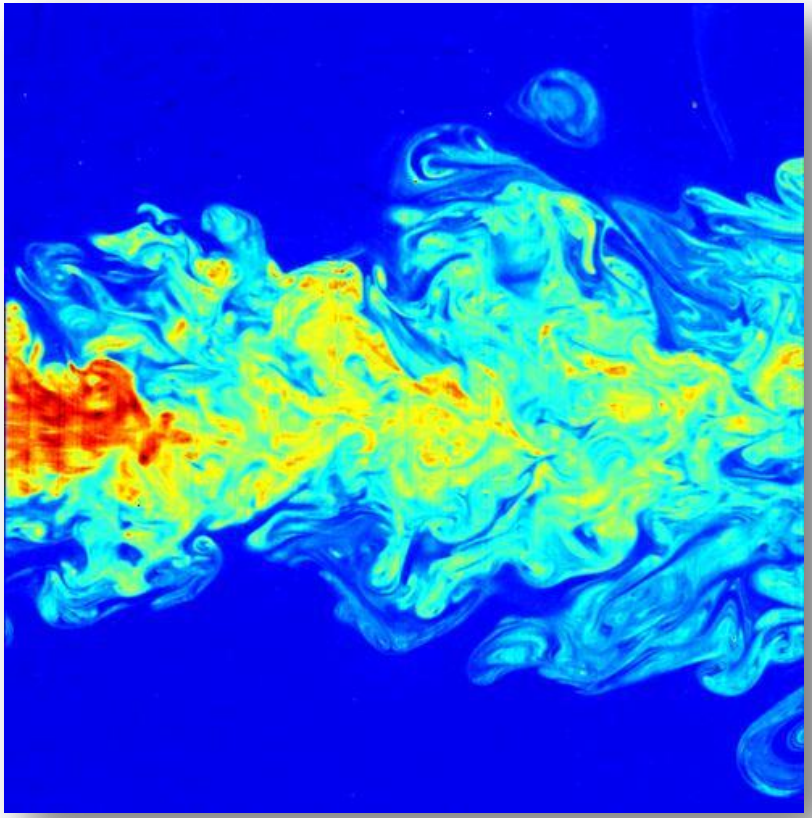
Injection In Sands



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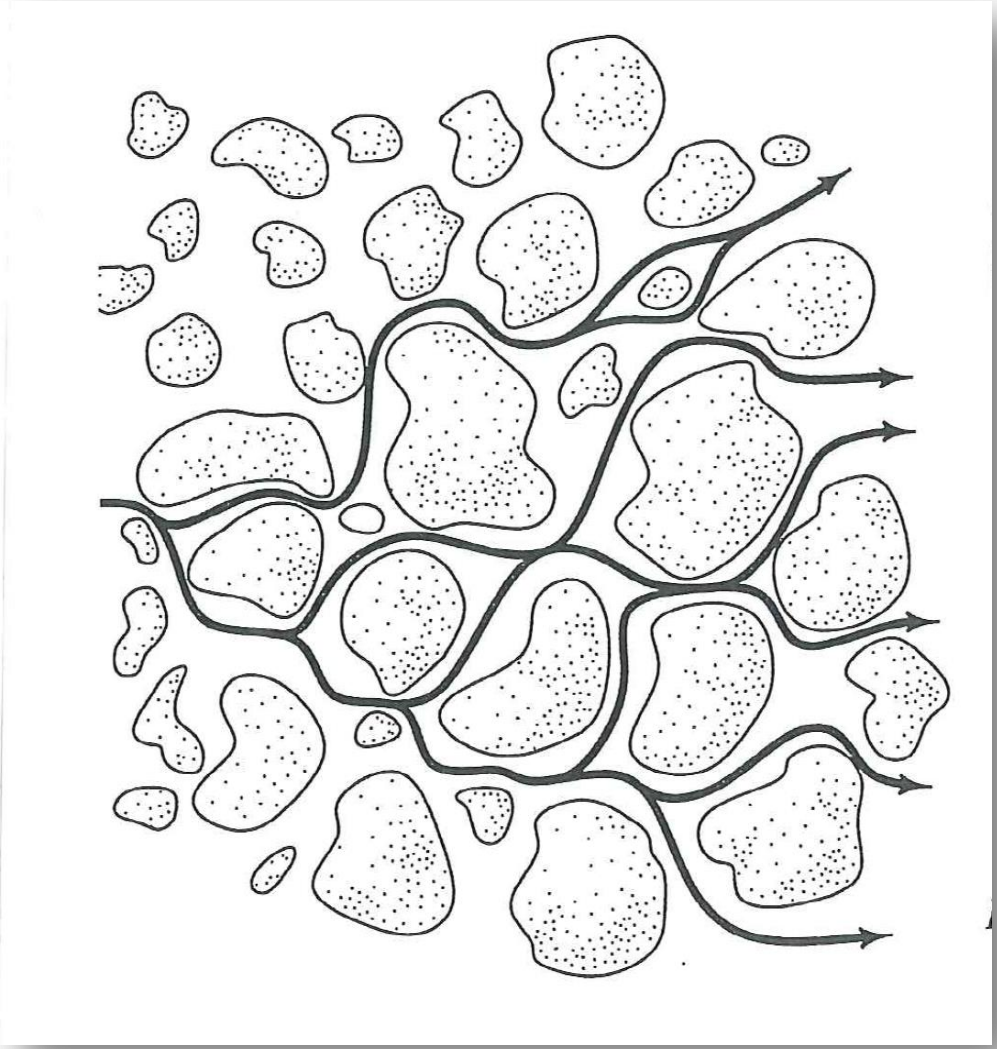
Injection In Gravel



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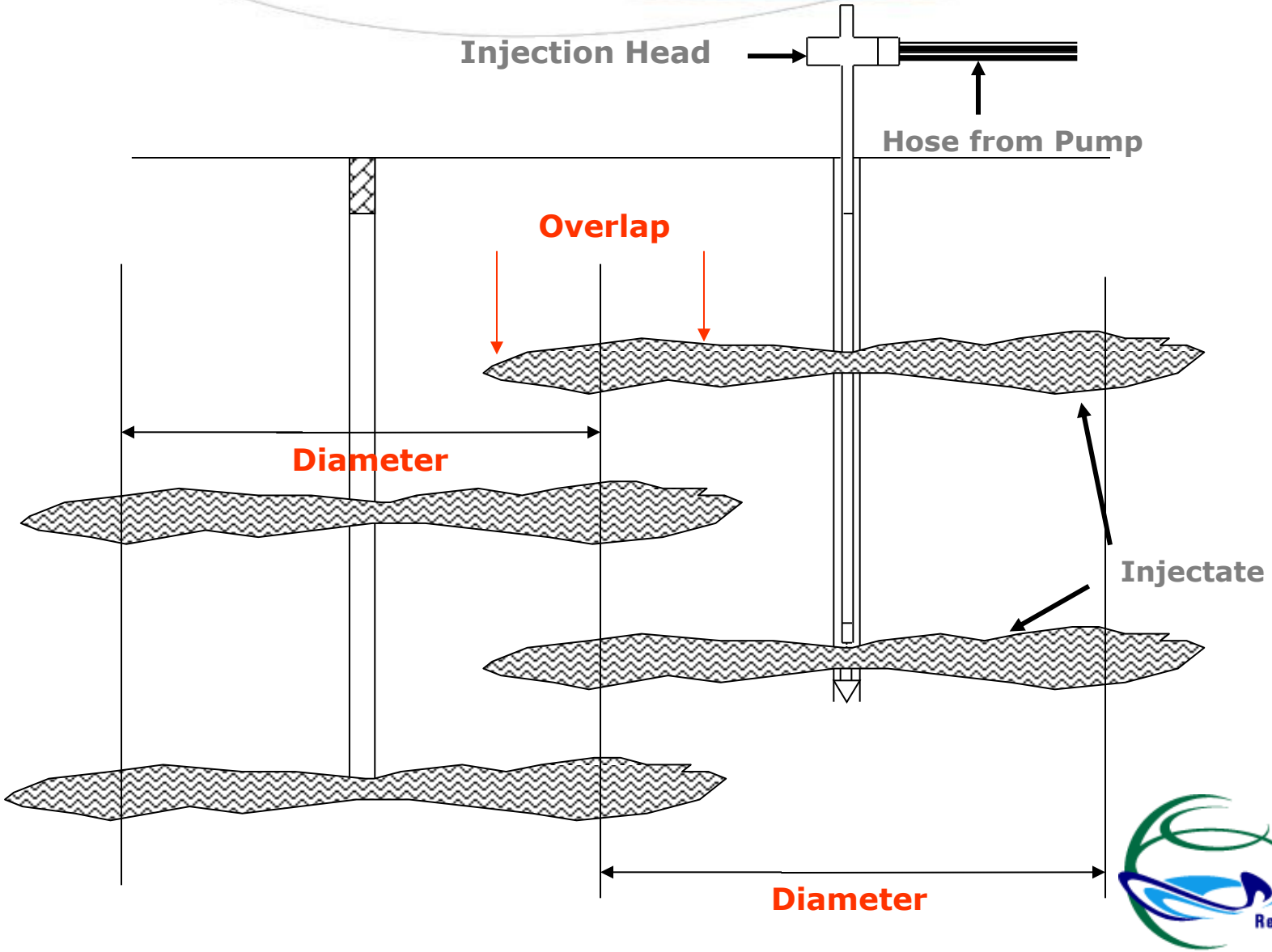
Effective Radius of Influence



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Effective Radius of Influence

Rules of Thumb – 10’ Grid

Silt/Clay – 40 to 50 gallons
Sands and Gravel – 50 to 70 gallons

Vertical Spacing
1.5’ to 2’ Typical
Up To 3’ in Fine to MG Sand

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Injection Dynamics Part 2

- Infiltration Galleries – "Gravity Feed"
- Low Flow in Low Pressure or High Pressure Conditions:
  - When is it a Good Idea?
  - Injection Wells and Use of Packers

Low flow at low pressure is the new industry "mantra "

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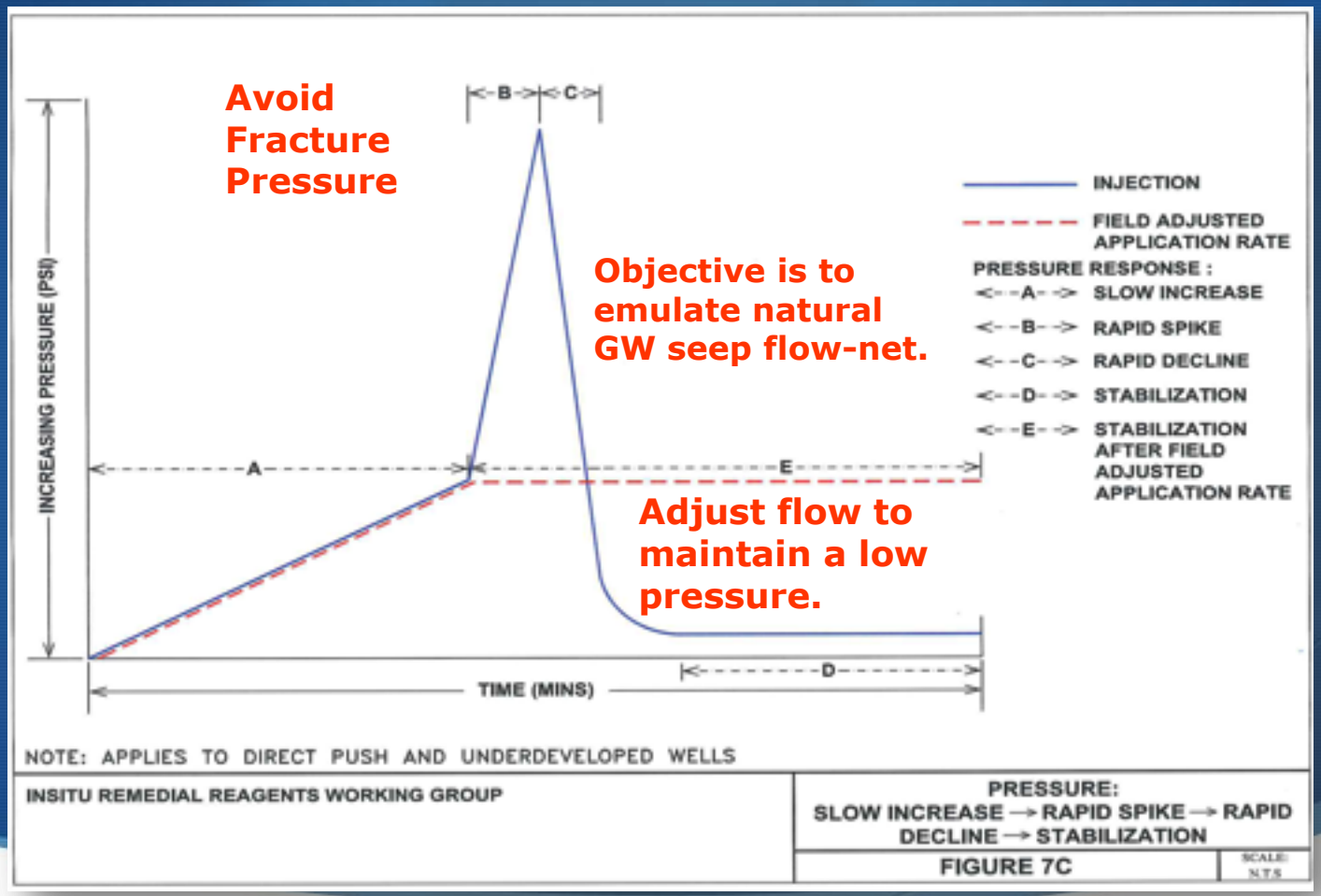
Low Flow Signature



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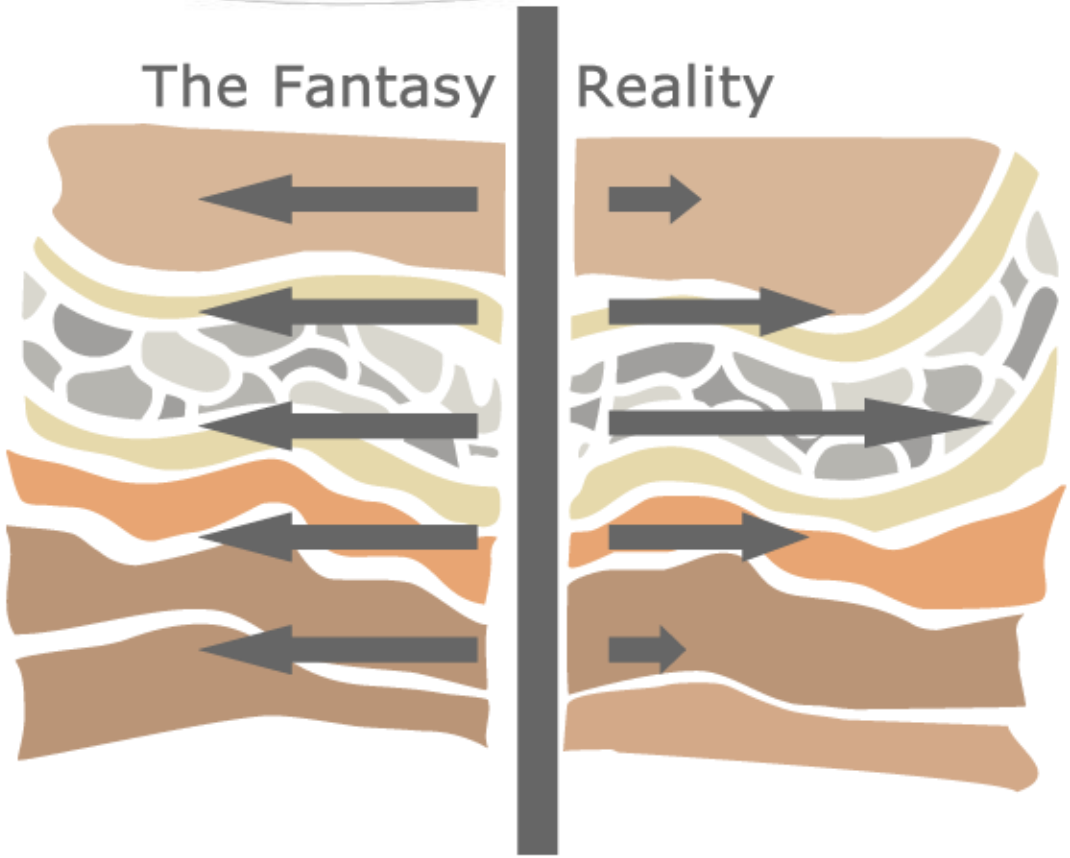
LF/LP Injection



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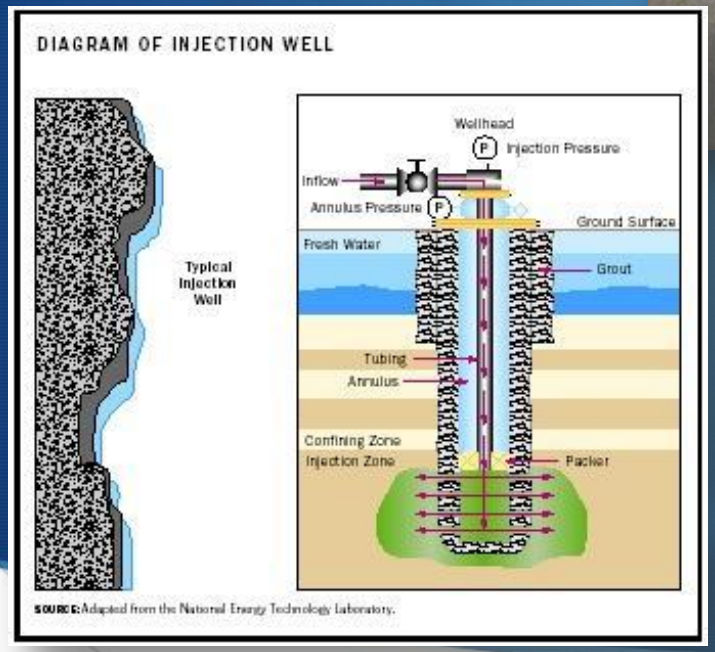
Injection Wells:

Open Screen vs. Packers



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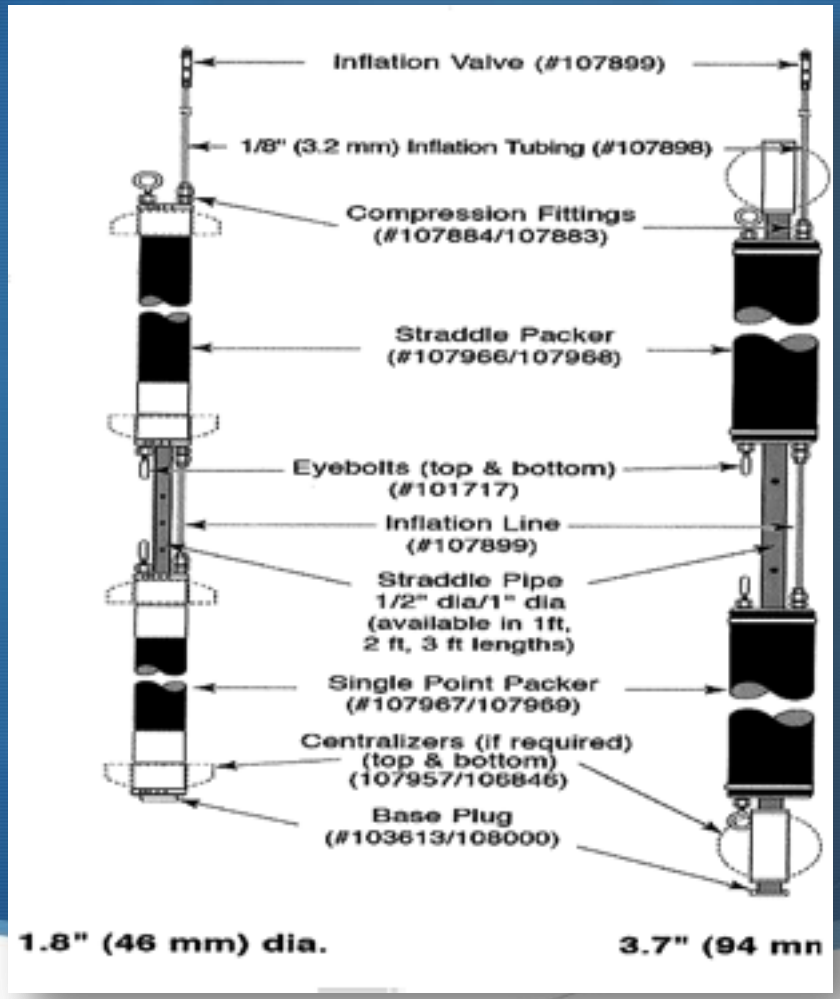
Straddle Packer



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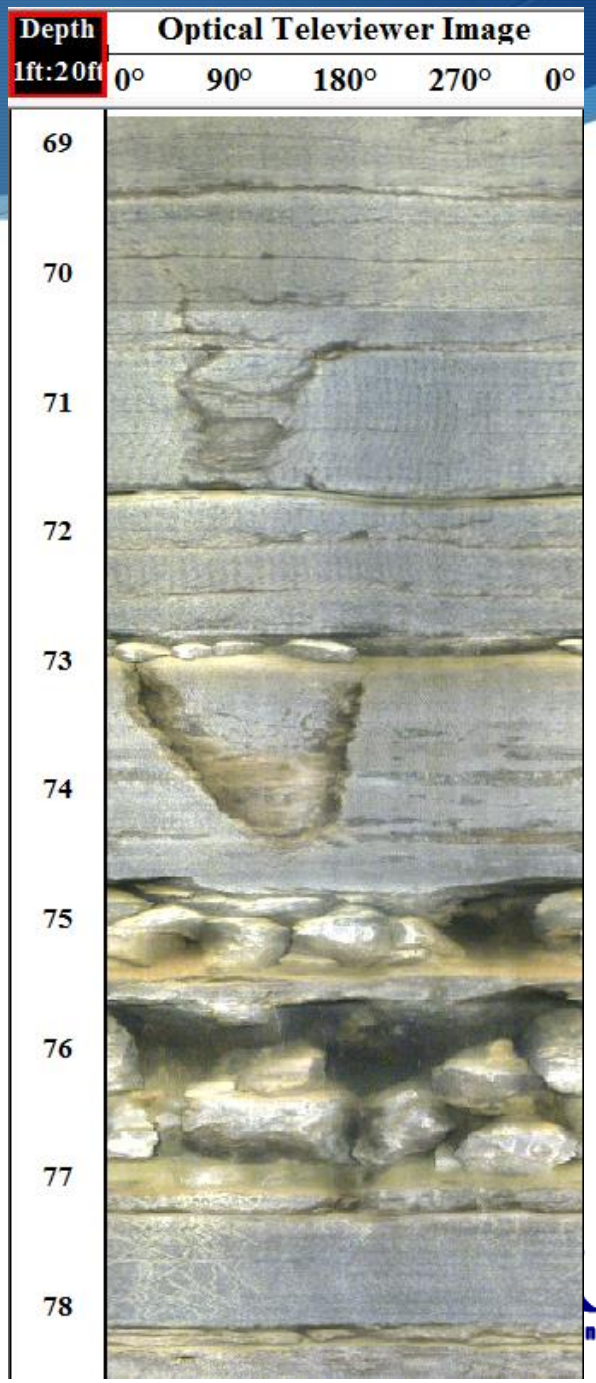
- This optical televiewer image illustrates the condensed nature of fracture networks.
- The need for a very small packer interval with accurate depth placement is critical for precision, controlled placement of product.
- Hydrophysics proved most, if not all, fractures present carried water.
- This is from Redstone Arsenal, a USACE site.
- Fractured limestone.



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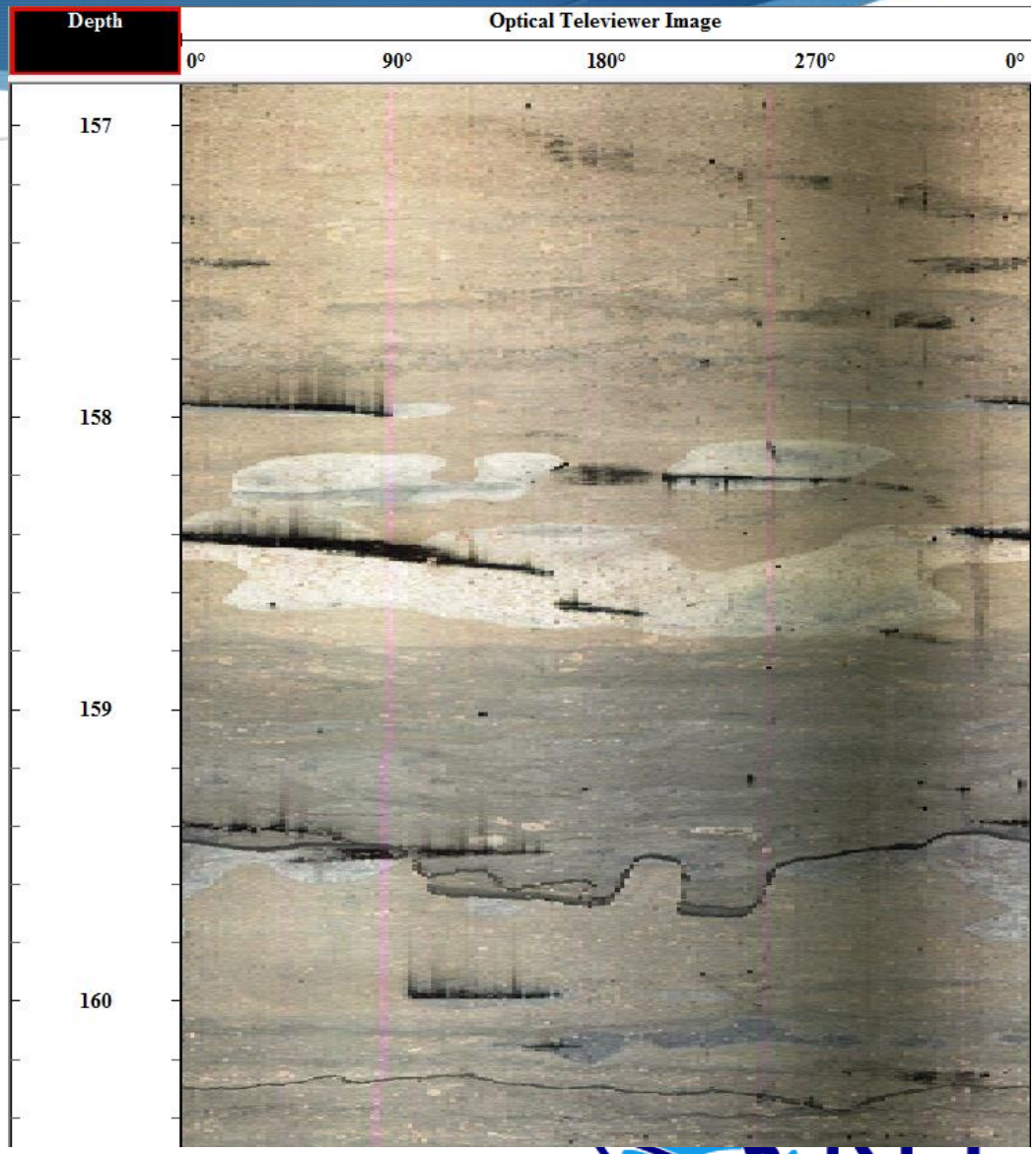
- This optical televiewer image naturally-occurring petroleum product oozing from discrete fractures.
- The product is lighter than water and is observed to float upward.
- This is from Redstone Arsenal, a USACE site.
- Fractured limestone.



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Importance of the Injected Product

- Water Soluble Reagents
- Solid Suspensions – Slurries
- Highly Reactive Agents

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Water Soluble Reagents

- The Most Versatile
- Compatible with Many Installation Techniques

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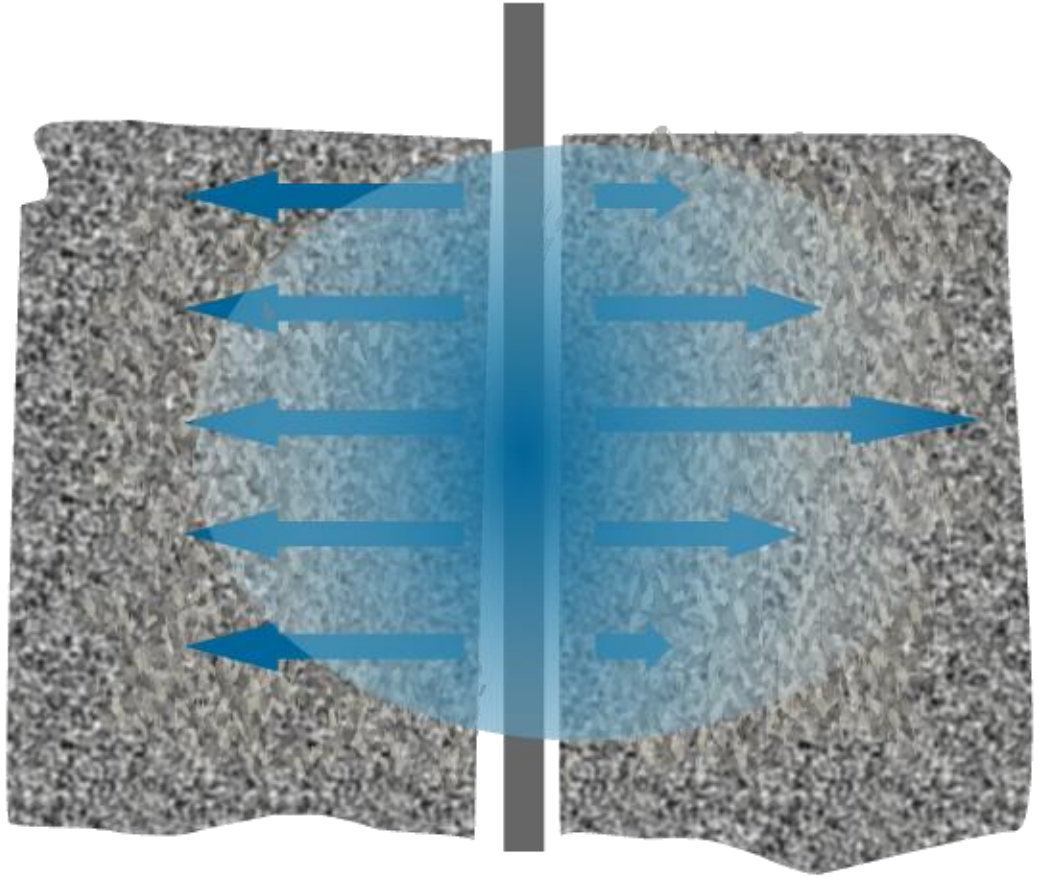
LF/LP Slurry Injection

Incompatible with Slurries

Formation Acts Like
Filter
Strains Out
Suspended Solids
Minimal ROI



Blob-like Installations

Virtually No Distribution
Out From Injection Tip.

Water Bleed-off
Leaving Solids Behind

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Highly Reactive Agents

- Hydrogen Peroxide/Fenton
- Activated Persulfate
- Very Short Lived

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Daylighting

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Daylighting – What are the Causes

- Loose Seal Around Injection Rod
- Worn Injection Rods
- Come up Old Bore Hole
- Seep from Monitor Well
- Intersect Pathway to Surface
- Excessive Injectate Volume

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Daylighting – Field Adjustments

- Off-set Injection Point
- Carefully Plug Old Bore Holes
- Replace Worn Injection Rods
- Cap Monitor Wells
- Reduce Injection Volume
- Alter Grid Spacing
- Revise Sequence of Installation – Scatter the Injections
- Reducing the Flow Rate will probably NOT HELP

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Hydraulic Effects

- Injecting Fluid: Where does it go?
- Mobilization of Sorbed Solute
- Displacement of LNAPL
- Ways to Mitigate Potential Displacement

"Do injections push contamination."

Common Question from Regulators and Clients

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Mobilization of Contamination

- Mounding causes a increase in hydraulic gradient
- Hydraulic push is likely minimal because total fluid volume is a small fraction of one pore volume
- Drainage results in temporal effect of short duration
- “Pressure pulses” can also transport solute, but effects are temporary and recover

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Ways to Mitigate/Monitor Potential Displacement

- Reduce slurry water volume
- The sequence order in which points are injected can be adjusted to minimize cumulative mounding effects
- Inject Areas of Low Concentration First – The Work Toward Source Areas
- Use of Sentinel Wells

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Summary

- Identify High Quality Injection Contractors
- Develop Robust Conceptual Site Model
- Vertical Distribution of Contamination Critical
- Utilize High Resolution Sampling Strategies
- Ensure Injection Technique is Compatible with the Technology Selected

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