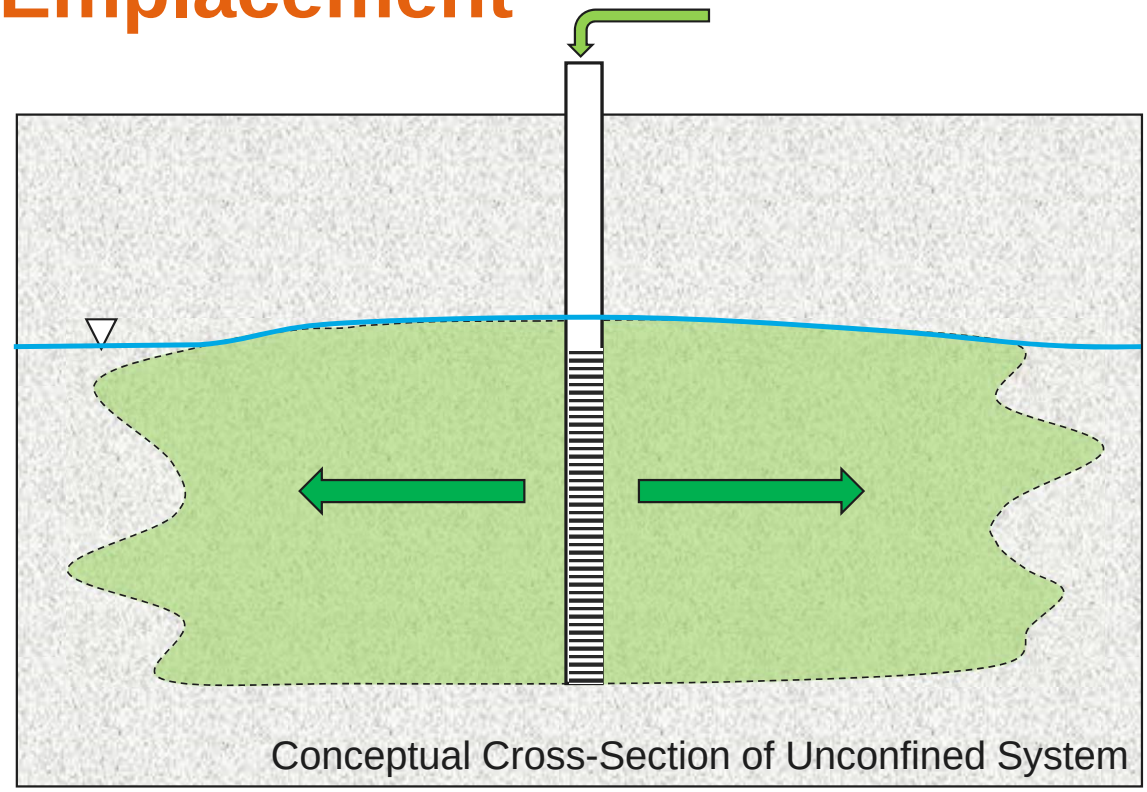
ARCADIS Design & Consultancy for natural and built assets

LESSONS LEARNED FROM DIRECT-PUSH INJECTIONS OF IN-SITU REAGENTS

April 12th, 2018

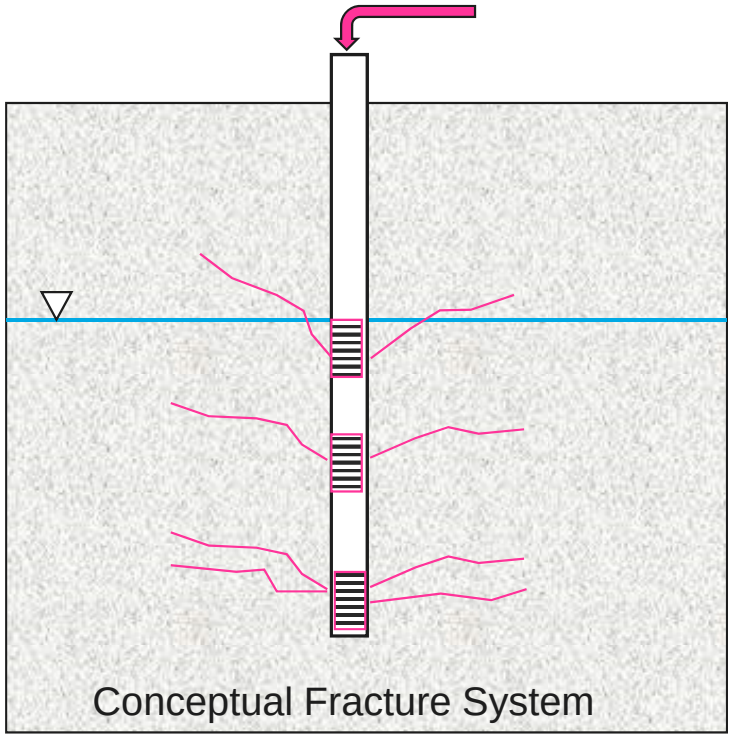
Low-Pressure Matrix Emplacement

- Relies on displacement of liquid either laterally or vertically to accommodate delivery through existing pore spaces
- Gravity feed or low pressure (<5 psi)
- Solution-based amendments only
- Typically accomplished using extendable screens

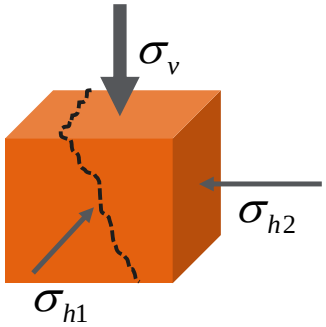


Conceptual Cross-Section of Unconfined System

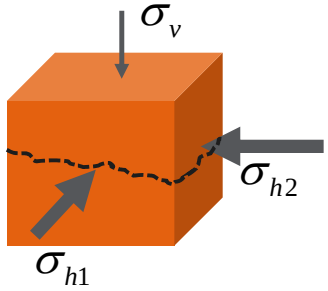
High-Pressure Fracture Emplacement



- Relies on deformation of subsurface to accommodate delivery through newly created porosity (fractures)
- Generally high pressure – fractures occur when injection pressure overcomes effective stress
- Typically used for injection of slurries



Normally Consolidated – subvertical fractures



Overconsolidated – subhorizontal fractures

Problem Statement

- Injection of remedial amendments using direct-push injection (DPI) frequently encounters issues (distribution, health and safety, remedial performance, surfacing)

Objectives

- Identify common “root causes” of issues
- Evaluate available guidance documents for solutions
- Develop lessons learned and suggestions as needed

Typical Practice vs Best Practice

Approach

- Survey via email/social media to create dataset of typical direct-push injection practices
- Review of guidance documents to develop best direct-push injection practices

Results

- 132 survey responses from consultants, drillers, responsible parties and regulators
- 3 primary guidance documents reviewed
  - NAVFAC (2013) - Best Practices for Injection and Distribution of Amendments
  - LA Region Water Quality Control Board (2009) - Technical Report: Subsurface Injection of In Situ Remedial Reagents Within the LARWQCB
  - Arcadis (2014) – Best Practices Document: Direct-Push Injection Approaches

Survey Topics

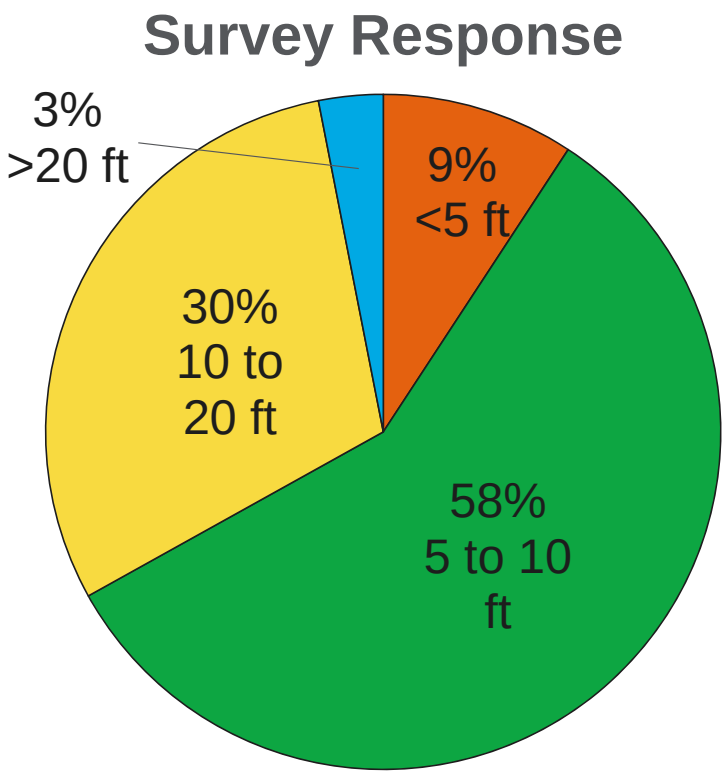
- Direct Push vs Injection Wells
- Applicable Amendments
- High Pressure (Fracture) vs Low Pressure (Matrix)
- Geology
- Injection Tooling
- Bottom-Up vs Top-Down
- Injection Point Spacing
- Injection Depth
- Remedial Endpoints
- Frequency/Type of Problems

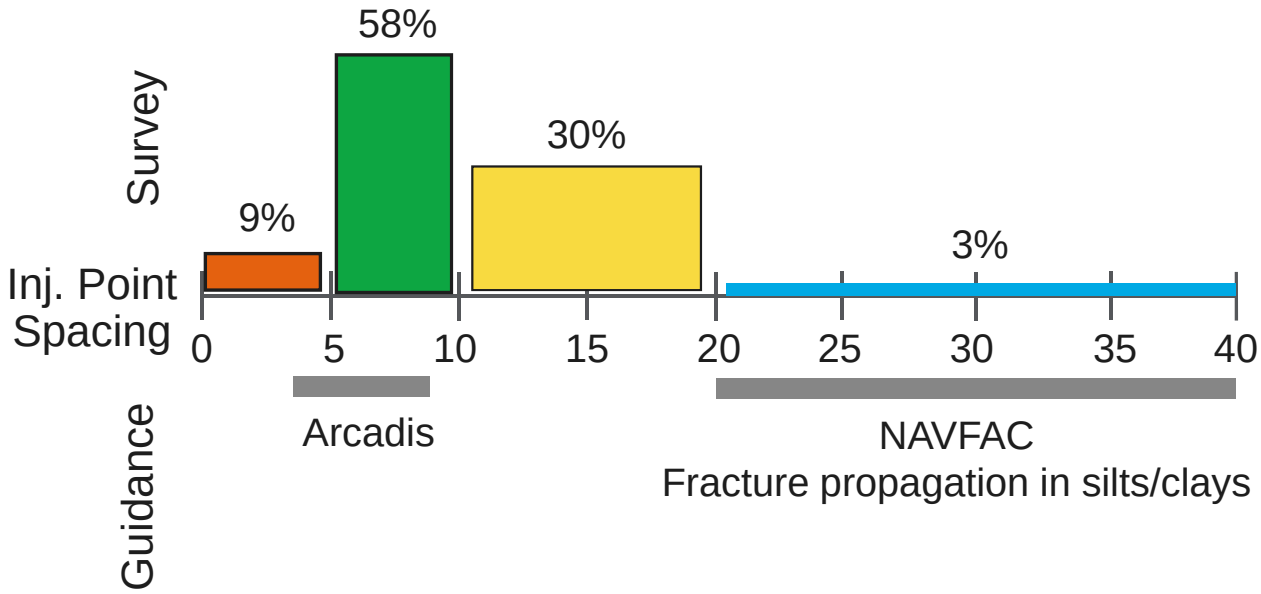
What is going right?

What is going wrong?

Additional Insights

What is going right? Injection Point Spacing

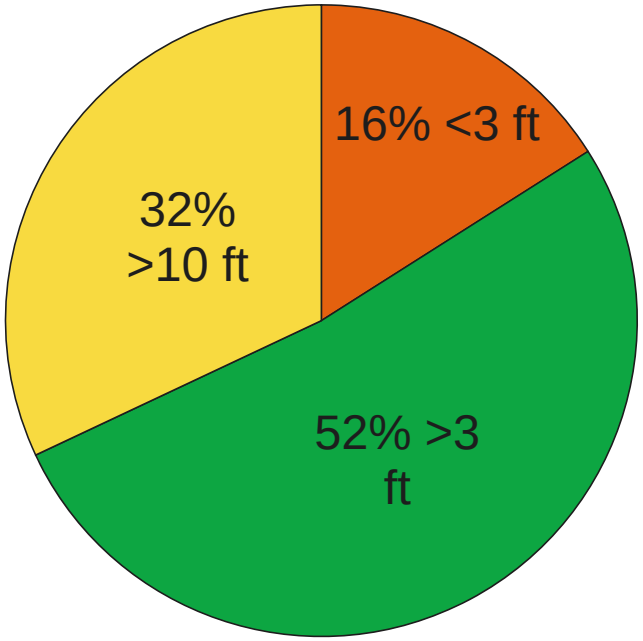




- NAVFAC – For low-pressure injection “In low permeability materials… the ROI may be limited”
- LARWQCB – “Radius of influence will depend on several factors”

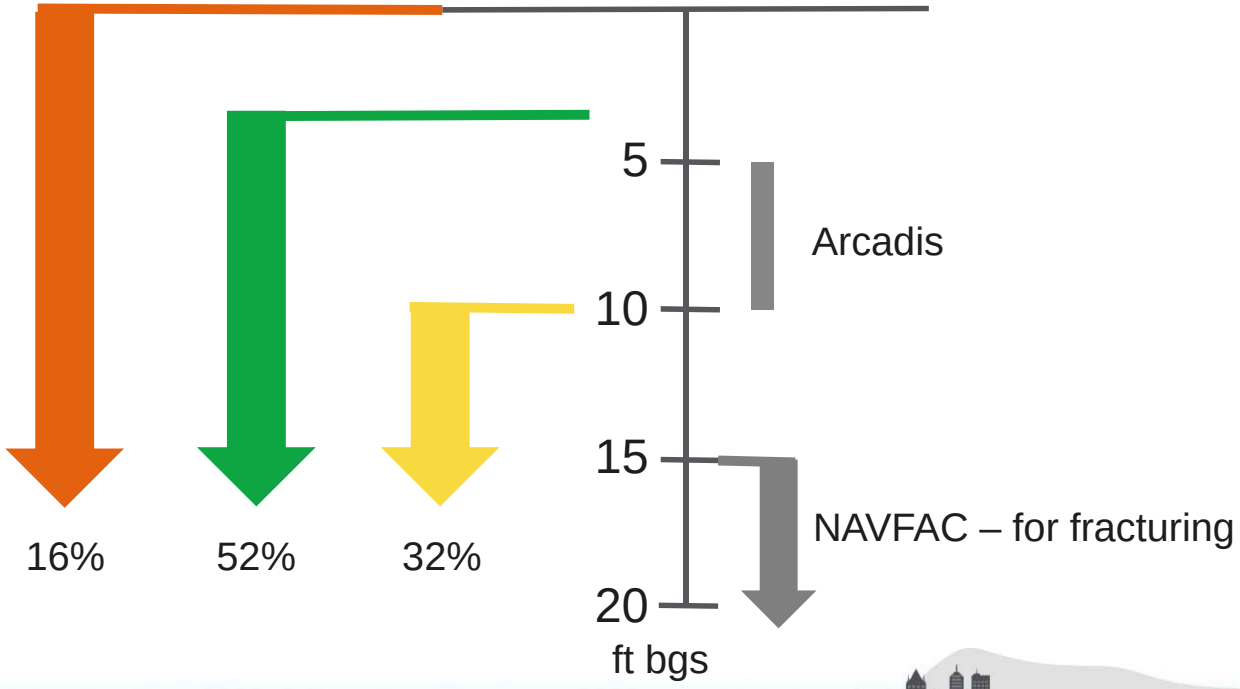
What is going right? Minimum Injection Depth

Survey Responses

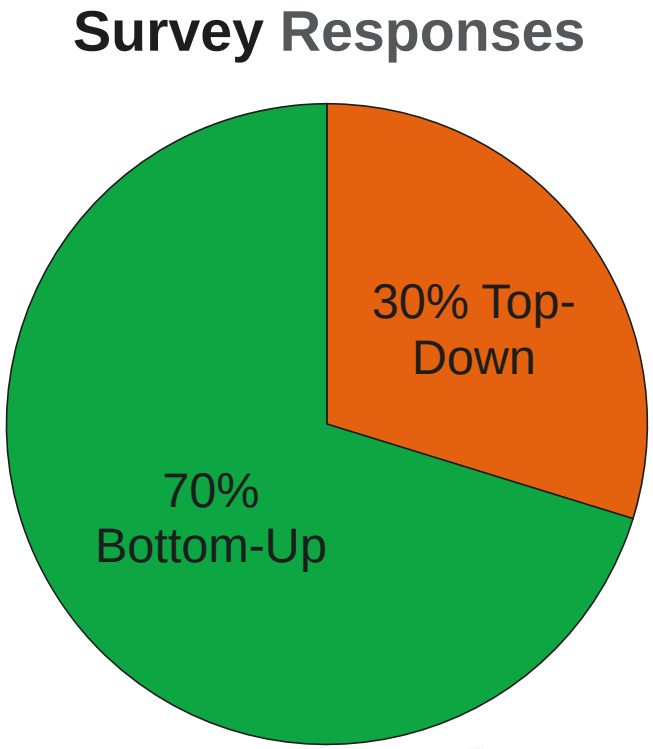


Survey Responses

Guidance



What is going wrong? Top-Down vs Bottom-Up



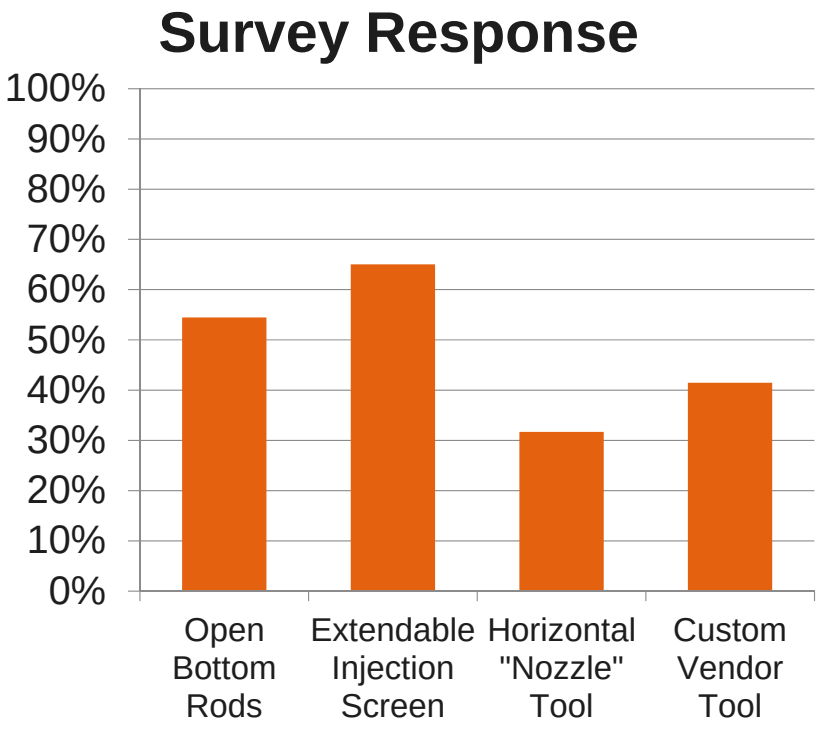
Survey

- 70% of survey respondents typically inject from bottom-up

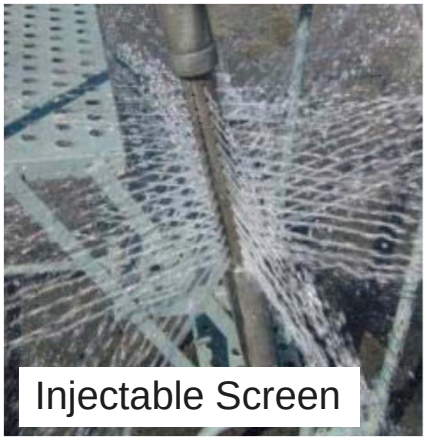
Guidance documents

- NAVFAC – "a top down approach results in more uniform distribution of reagent than a bottom up approach"
- LARWQCB – "Use tooling to improve vertical distribution that allows for top-down injections"

What is going wrong? Typical Injection Equipment



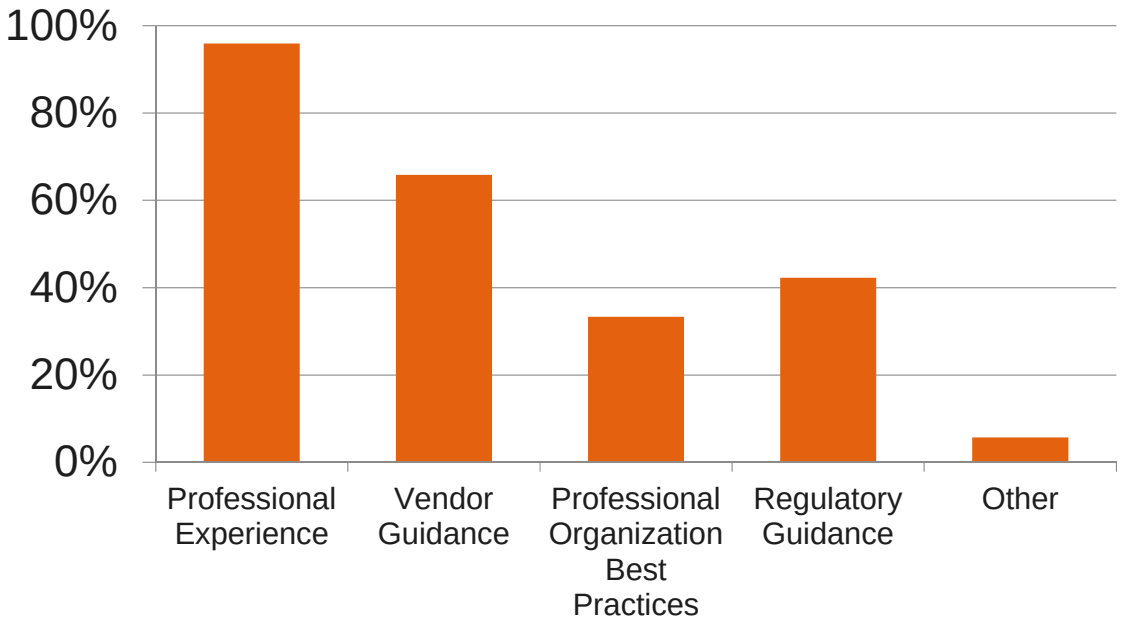
- Survey
  - No consistent preference, >50% use open bottom rods
- Guidance documents
  - NAVFAC – Extendable screens and custom vendor tools
  - LARWQCB – “Horizontal injection tool enhances the *outward* injection of the reagent”


Injectable Screen

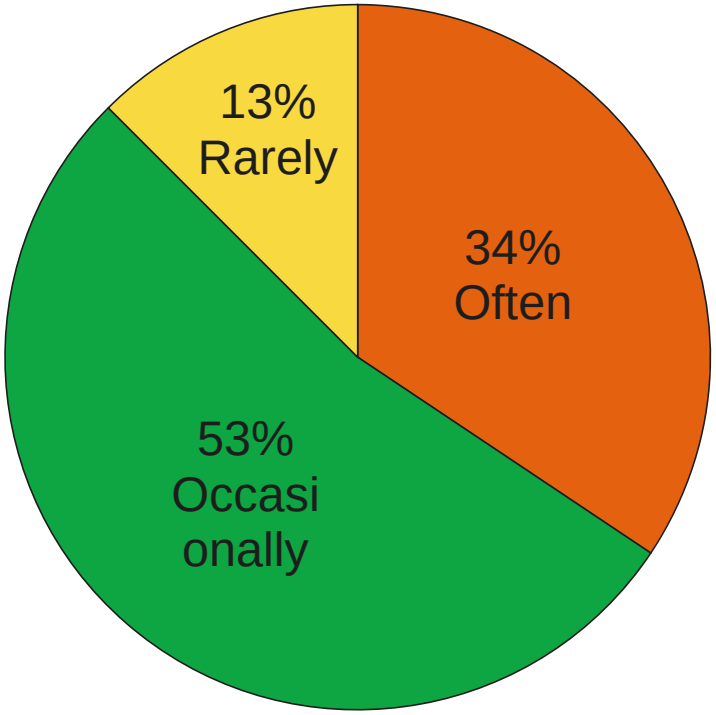

Nozzle Tool

Additional Survey Insights

Technical Resources

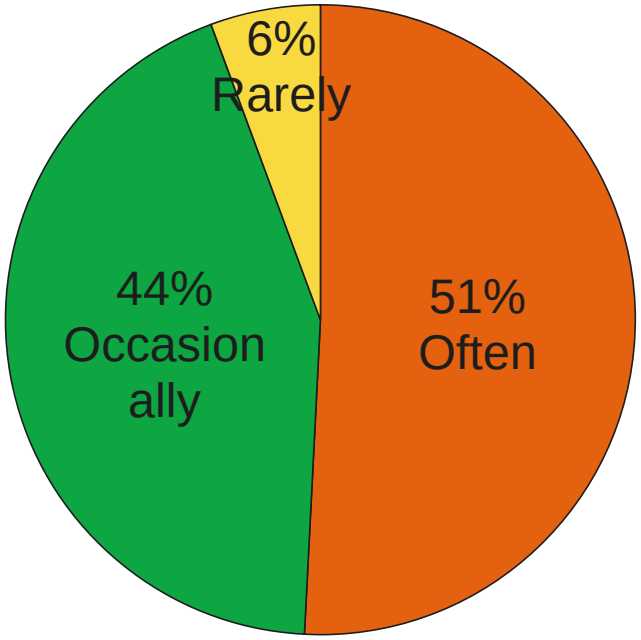


Implementation Issues

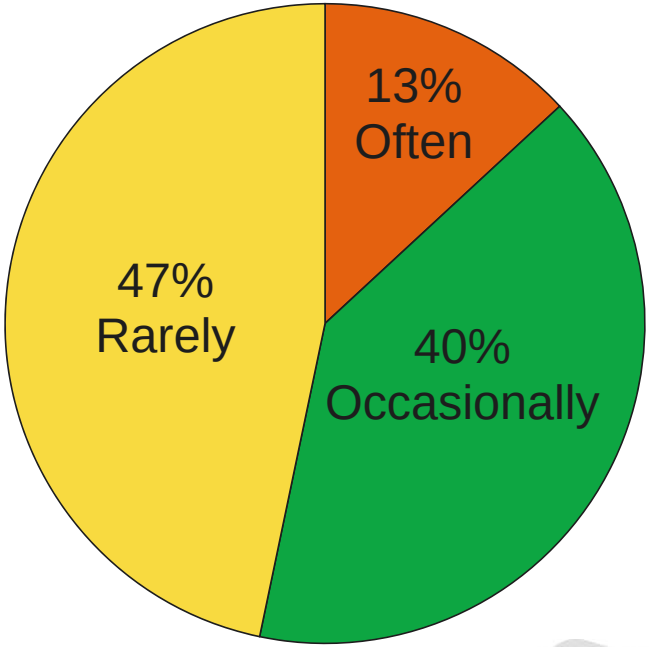


Additional Survey Insights

Order of Magnitude Reductions



Drinking Water Standards



Lessons Learned

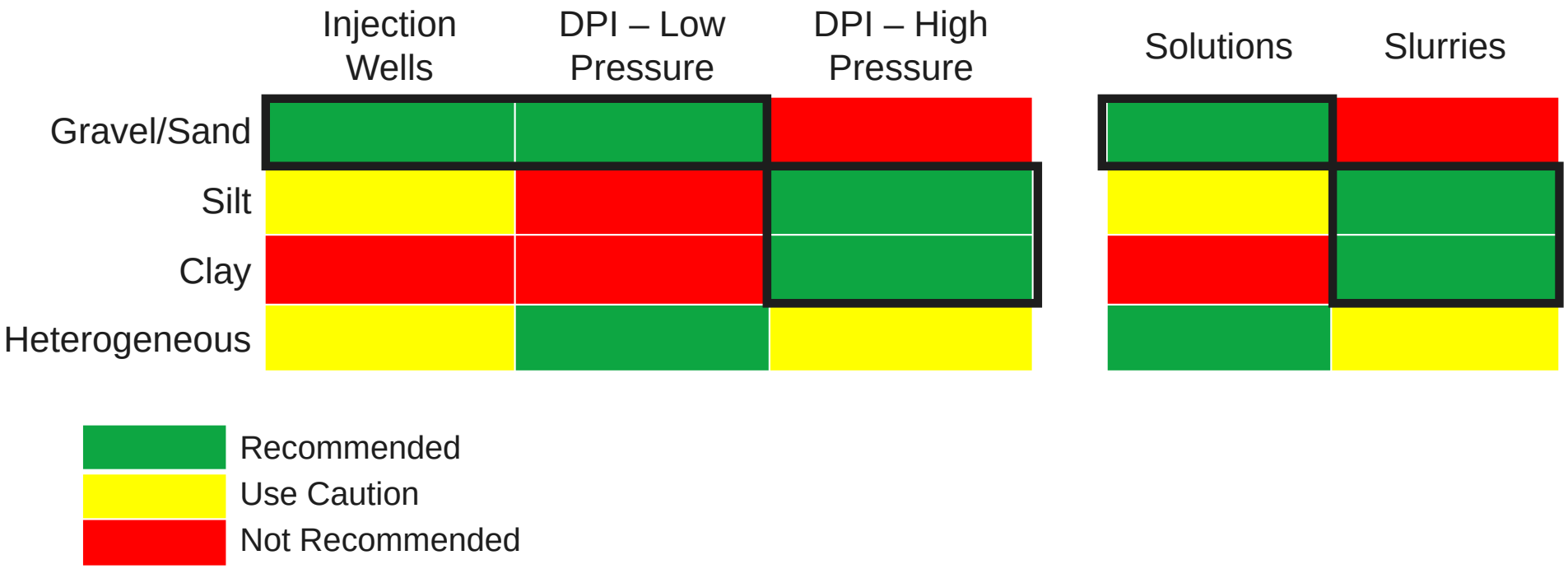
Very limited technical guidance available

- Don’t address all subjects
- Limited specific recommendations
- Reflects lack of one-size fits all approach

Direct-push injections are still the wild wild west of remediation

Lessons Learned

Let the CSM dictate the strategy, not the other way around



Lessons Learned

Account for heterogeneous distribution with a conservative design

- DPI amendment injection, particularly fracturing, is prone to uneven distribution
  - Tighter injection point spacing
  - Additional injection events
  - Offset downgradient transects
  - Understand likely fracture propagation direction

Path Forward

ITRC working group for *Optimizing In-Situ Remediation Performance and Injection Strategies* is developing a guidance document and on-line training. Scheduled for external release in 2020.

Your Presenter

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