

*State of the Practice for Innovative  
and Optimized Delivery Methods for  
Liquid and Solid Amendments in a  
Variety of Lithologies*


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# This Morning's Outline

- What am I not going to talk about.
- What I am going to talk about:
  - Direct and indirect contact delivery approaches.
  - Where are we now?
  - What delivery challenges are we trying to overcome?
  - What innovation have we tried?
  - What's new, if anything?

# I'm Not Going To Talk About

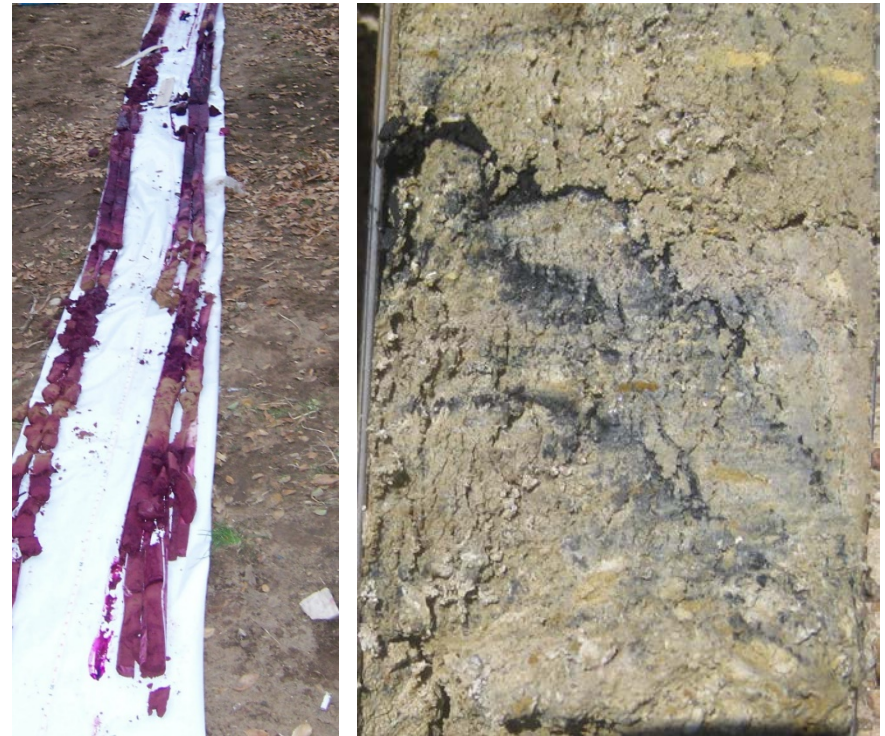
- Dosing for Matrix Back Diffusion
  - Radius of Influence
    - Residence Time
    - Seepage Velocity
    - % pore volume injected
  - Distribution verification
  - Optimizing contact through higher resolution site characterization
  - Soil Mixing
  - Regulatory restrictions
- 

# What I am Going To Talk About

- Direct and indirect contact delivery approaches.
- Where are we now with best practices?
- What delivery challenges are we trying to overcome?
- Innovation in our industry
- What's new, if anything?

# Delivery Contact Options

- **Direct Contact**
  - Injection liquids in permeable zones and relying on advection and/or recirculation for additional distribution.
- **Direct and Indirect Contact**
  - Same as above but in heterogeneous zones and relying on diffusion for additional contact in finer grained soils not contacted directly.
- **Indirect Contact**
  - Emplacement of liquids or solids into fine grained soils by creating new pathways that rely on diffusion and advection for contact.



# Indirect Contact



*F.E. Warren AFB,  
Zone C Remedial  
Action Update, In  
Situ Chemical  
Oxidation Using  
Potassium  
Permanganate  
and Hydraulic  
Fracturing, May  
23, 2006*

# Where Are We Now – Best Practices

Solids Vs. Depth, Pressure, Lithology	Direct Push		Sonic	Wells	Open or Cased Bore Holes
	Injection	Hydraulic Emplacement or Jetting	All	Injection	Hydraulic or Pneumatic Emplacement
Depth	< DPT	< DPT	> DPT	<> DPT	> DPT
Pressure	< Fracture	> Fracture	<>Fracture	< Fracture	> Fracture
Gravels					
Cobbles					
Sandy Soils (SM, SC, SP, SW)		x	x		
Silty Soils (ML, MH)		x	x		x
Clayey Soils (CL, CH, OH)		x	x		x
Weathered Bedrock		x	x		x
Bedrock			x		x


# Where Are We Now – Best Practices

- Pumps
  - Moving away from air diaphragm and progressive cavity pumps to centrifugal, positive displacement, and higher flow piston pumps
- Tooling
  - Switching to larger diameter tooling for solids to minimize pressure loss
  - Inner-Hose To maintain to eliminate pressure spikes
- Manifolding
  - Increasing # of simultaneous locations
- Flow rate monitoring
  - Converting to magnetic flow meters for solids





# Delivery Challenges

- Depth (Shallow or Deep)
  - Low K formations
  - Heterogeneity
  - Physical properties of reagents
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# Traditional DPT Refusal

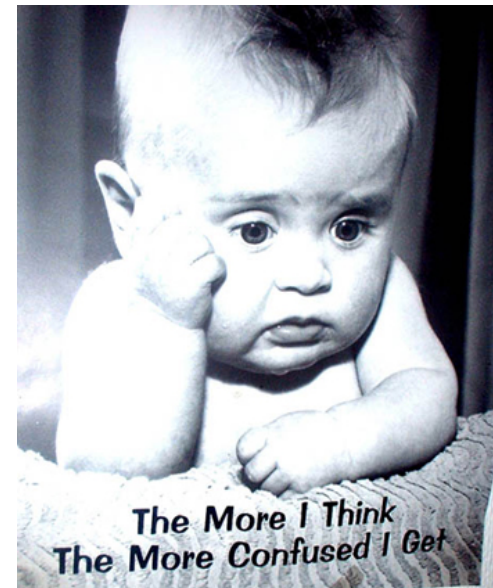
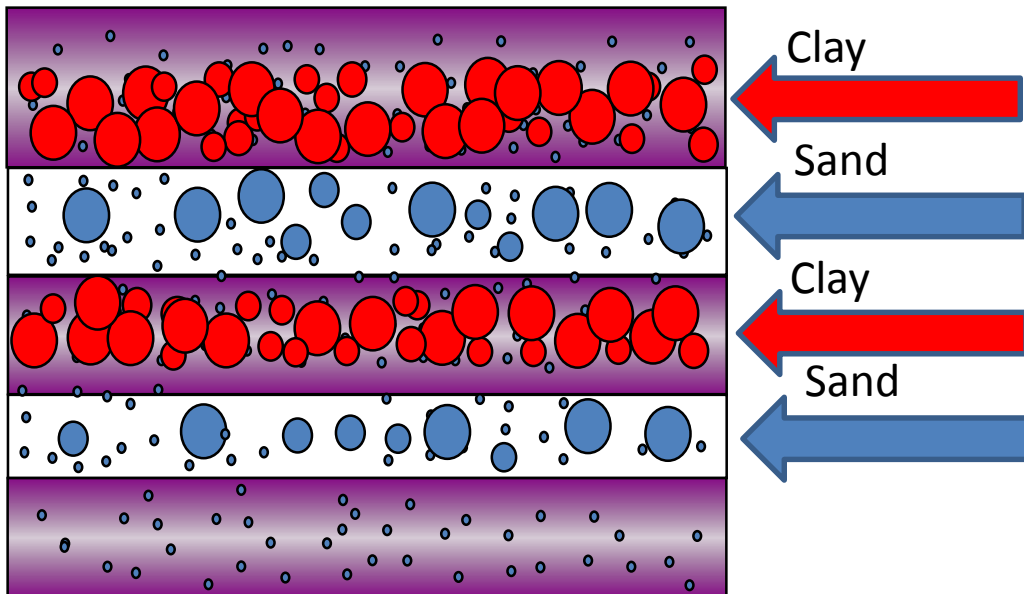
- 8040 Geoprobe
- Sonic



# Low K – Hydraulic and Pneumatic Emplacement and Jetting



# Heterogeneity



# Physical Properties

- Off gassing
- Abrasives
- Corrosives
- Solubility



# Innovations

## Increasing Permeability

- Oil & Gas Production
  - Piezo Stimulation
  - Primawave
  - Downhole Fluidics Oscillator
- AirBurst®
- KAPSDIDS

## Heterogeneity

- Shear thinning fluids
- Electrokinetics

## Emplacement in Fine Grained Soils

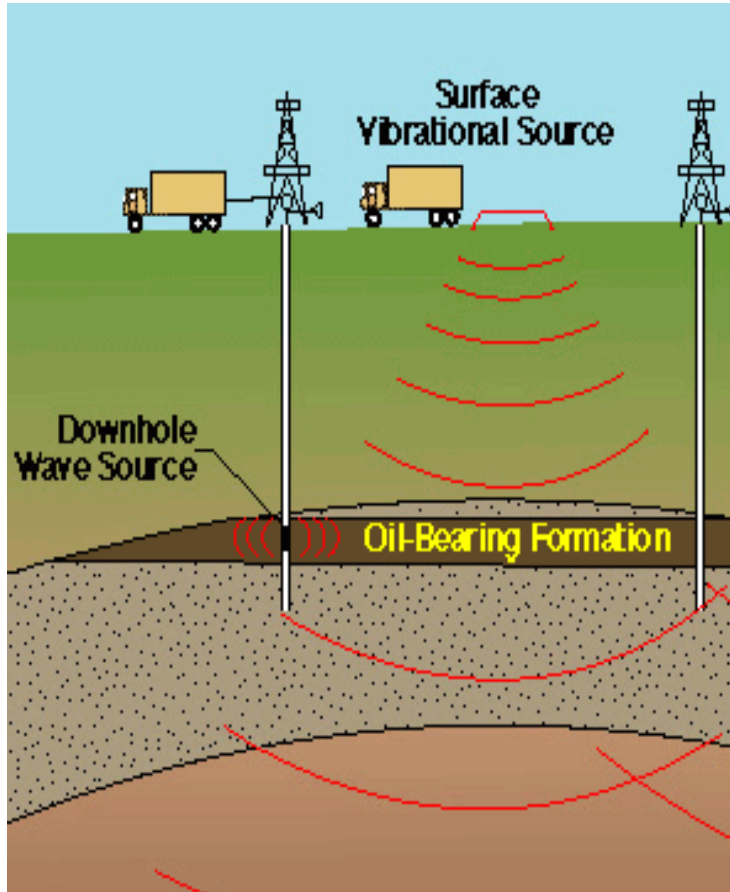
- Electrokinetics
- Constant Head
- BioJetting

## Emplacement in Sands

- Fluidization



# Increase Permeability – Piezo Sona-Tool Stimulation



# Increase Permeability – Primawave

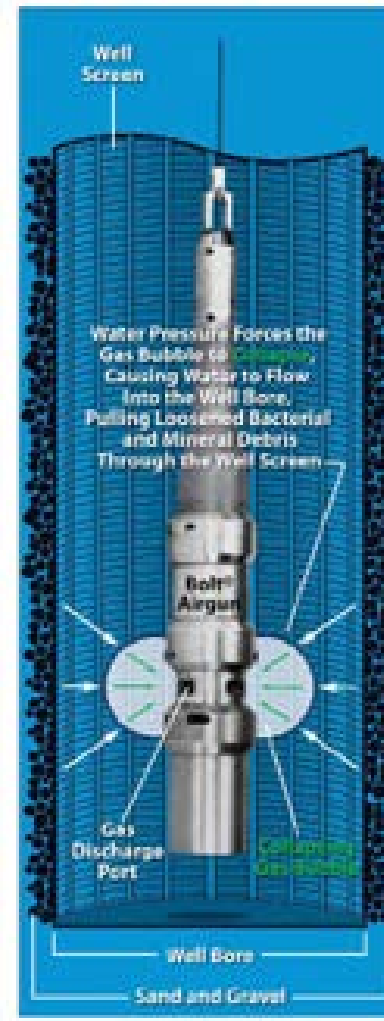
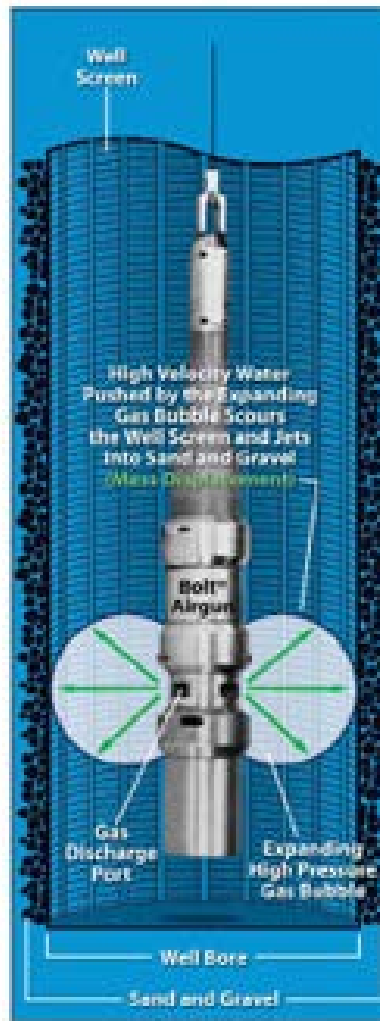




# Increase Permeability – Downhole Fluidics Oscillator



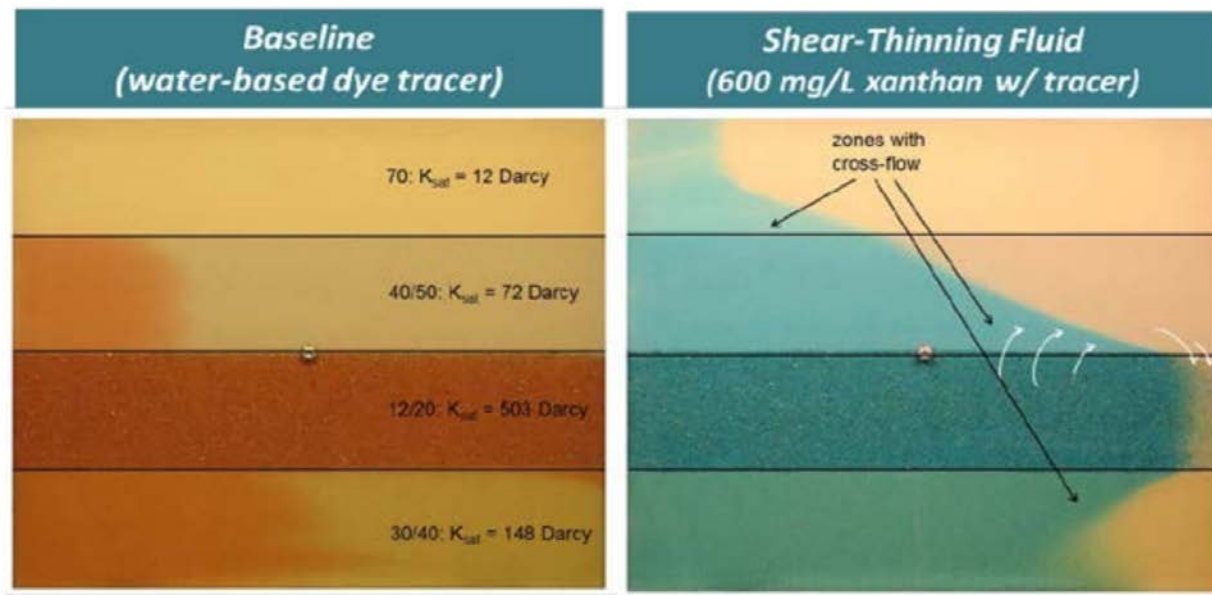
# Increase Permeability – AirBurst®



# Increase Permeability - Kinetically Adjustable Pore Space Dilation Injection Delivery System "KAPSDIDS"



# Heterogeneity – Shear Thinning Fluids



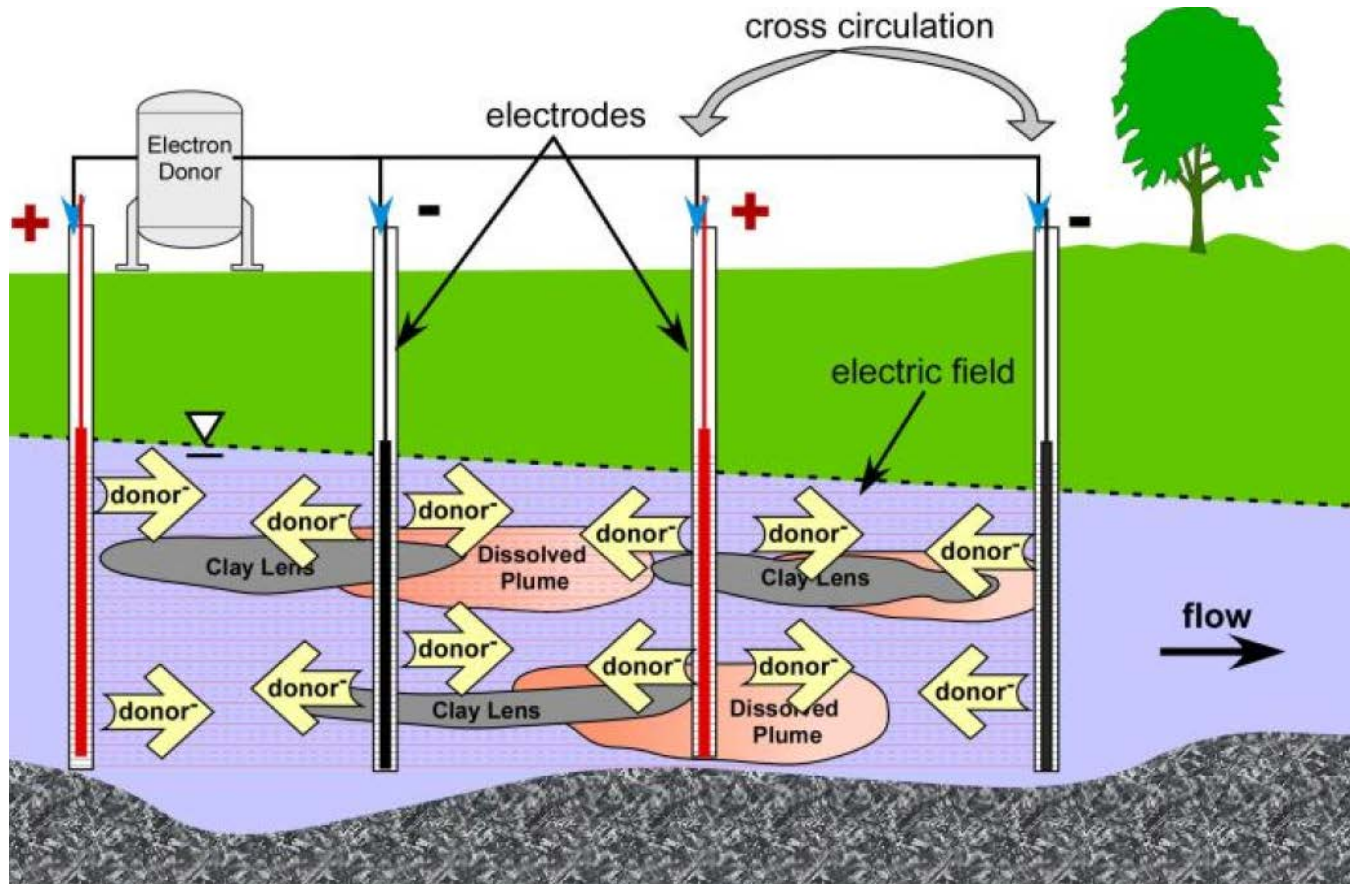
Flow cell showing improved distribution of tracer amended with a shear-thinning fluid in lower-k zones of a heterogeneous formation due to cross-flow

## FINAL REPORT

Enhanced Amendment Delivery to Low Permeability  
Zones for Chlorinated Solvent Source Area Bioremediation

ESTCP Project ER-200913

# Fine Grained Soils – Electrokinetics

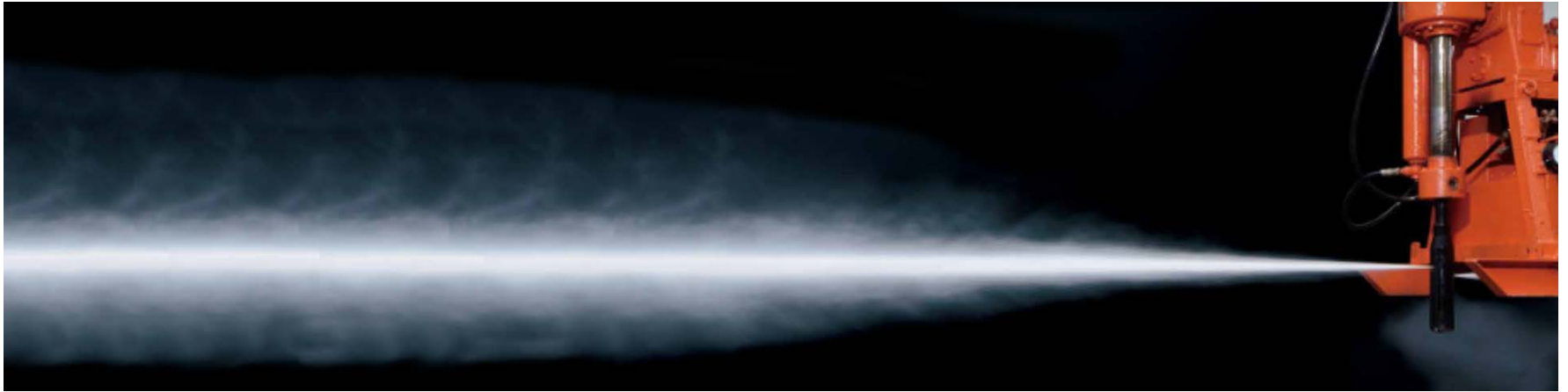


# Fine Grained Soils – Constant Head



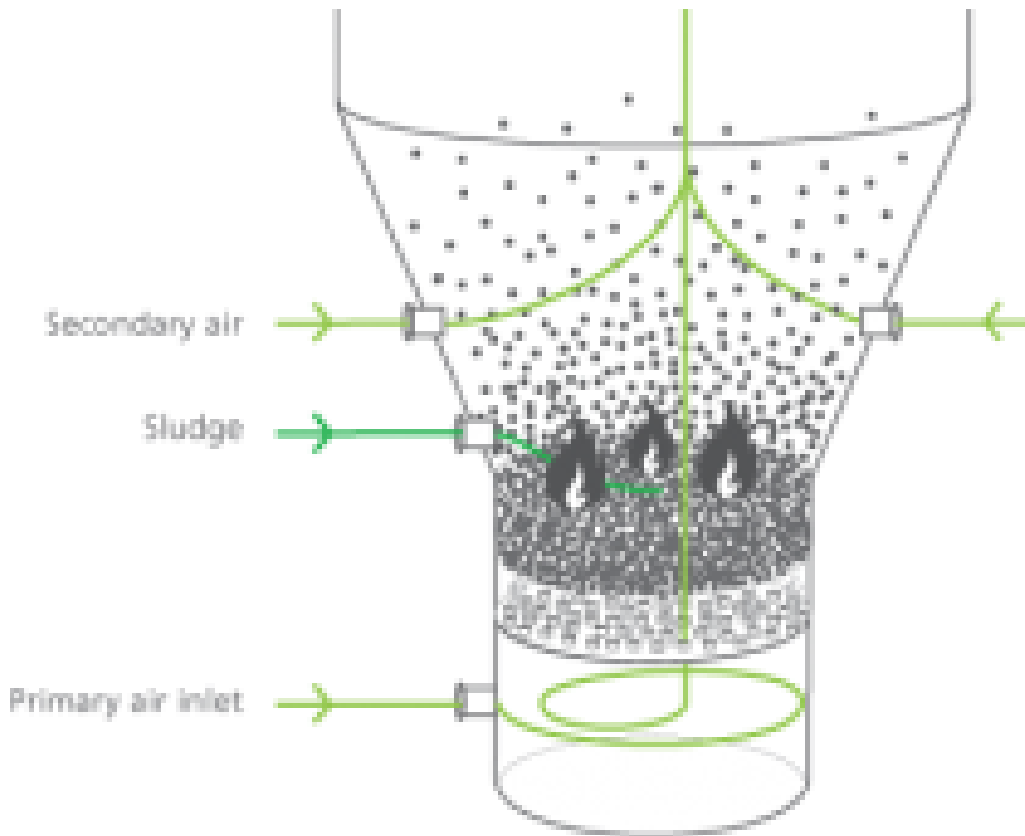
*“Constant Head  
Injection For Enhanced  
In Situ Chemical  
Oxidation” Timothy J.  
Pac, ERM,  
REMEDICATION 2014*

# Fine Grained Soils - BioJetting



*Hayward Baker Forms Strategic Alliance  
with EOS Remediation and Chemical  
Grouting Company” DIGITAL JOURNAL,  
June 25, 2014*

# Fluidization – Emplacement of Solids In Sand



**Fluidization** is a process whereby a granular material, e.g. Sand, is converted from a static solid-like state to a dynamic fluid-like state.



# What's New? – Liquid Injection



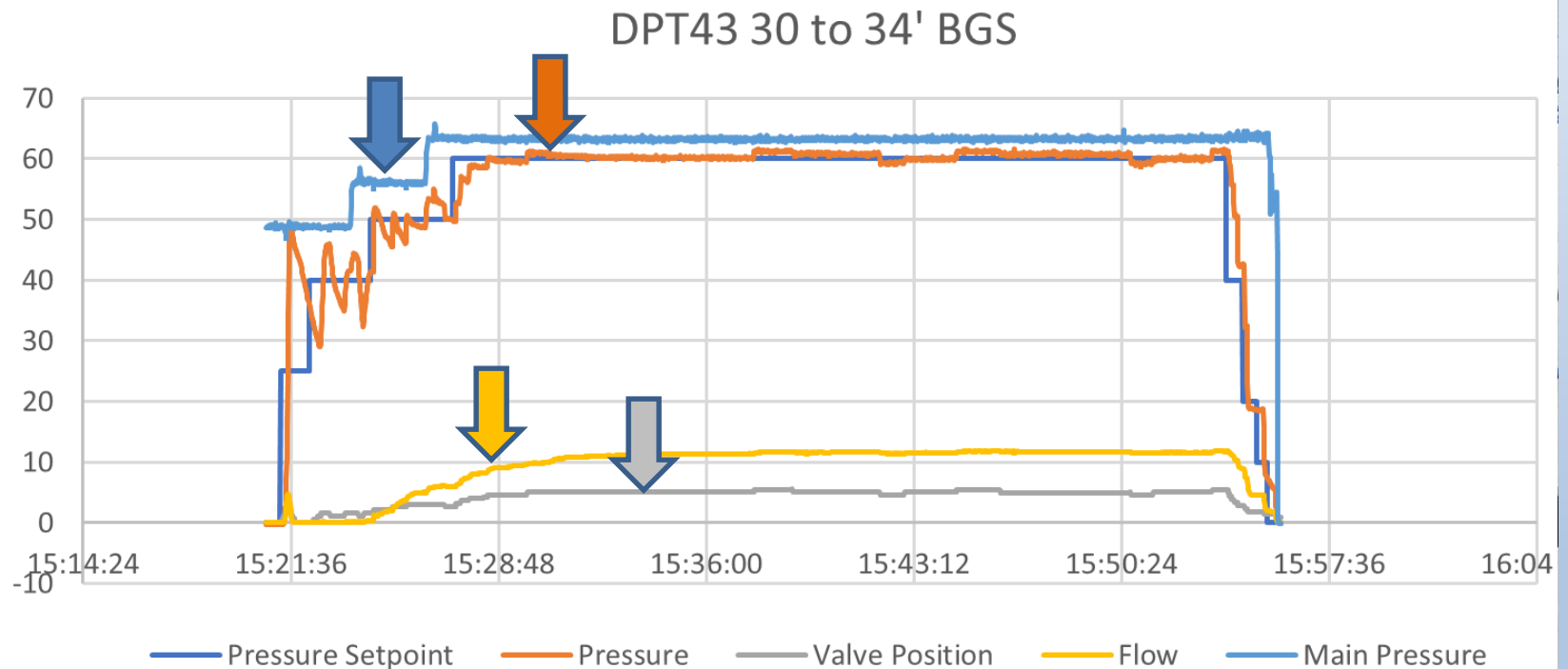
# Current Best Practice – Manual Control and Reporting

Injection Point ID	Group	Subset	Start Date	Start Time	End Date	End Time	Depth (ft)	Tool Length (ft)	Gal per Interval	Average PSI	Average Flow Rate	EVO Injected (gal)	Bicarb Injected (lbs)	H2O Injected (gal)	Amended Total (gal)	Notes
IP-	10						7 - 12	5.0	1,343.0			0.00	0.00	0.0		
Design Volume												0.00	0.00	0.0		
2686.00												0.00	0.00	0.0		
Upper Volume												0.00	0.00	0.0		
0.00												0.00	0.00	0.0		
Upper Balance												0.00	0.00	0.0		
1343.00												0.00	0.00	0.0		
Lower Volume												0.00	0.00	0.0		
0.00												0.00	0.00	0.0		
Lower Balance							7 - 12	5.0	1,343.0			0.00	0.00	0.0		
1343.00												0.00	0.00	0.0		
% Complete												0.00	0.00	0.0		
0.00%												0.00	0.00	0.0		
=B21												0.00	0.00	0.0		
Total Balance												0.00	0.00	0.0		
2686.0												0.00	0.00	0.0		
IP-												0.00	0.00	0.0		
Total Volume												0.00	0.00	0.0		
0.0												0.00	0.00	0.0		

## Current Injection Best Practice:

- Manual Ball Valve Flow Control
- Pressure regulation through pressure relief valves
- Manual recording of injection parameters

# Advanced Injection Manifold



Full Shut Down

Clear

Main Pressure

58.6

Main Pressure SP

#####.#

### Injection 1

Pressure Setpoint (psi) 50.0

Pressure (psi) 51.8

Average Pressure (psi) 57.7

Max Pressure (psi) 70.3

Flow (gpm) 8.1

Injection Total (gal) 365.1

Inj Stop Total (gal) 641

Valve Position (0-10) 3.4

Injection File Name

IP 27 41-45

Summary File Name

Inj A Sum Log 180308

Stop Summary

File Name

Trigger

Stop

Pressure SP

Vol Stop SP

Clear Avg P

Clear Max P

Clear Inj Total

Clear

All

12.000

9.600

7.200

4.800

2.400

0.000

12:16:0

03/08/20



100.000

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“If you always do what you always did,  
you will always get what you always got”

– Albert Einstein

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