
Pressure Pulse Technology: An Innovative Fluid Flow Technique and Remedial Tool

by

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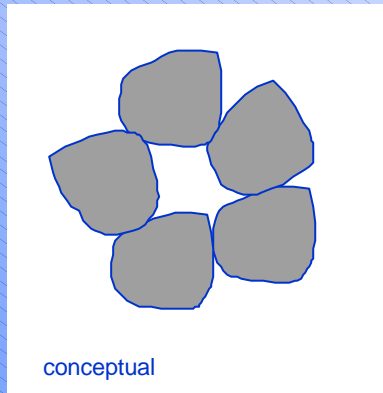
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Advanced Solutions for the Petroleum and Environmental Sectors

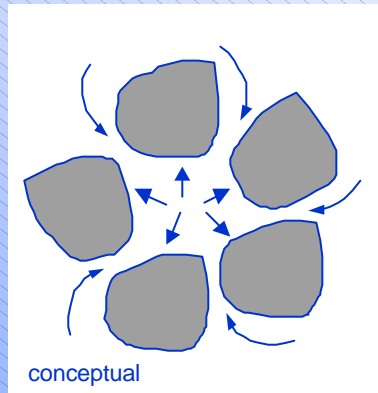


-
- A proven fundamental fluid-flow development.
 - A non-seismic wave propagation process in porous media.
 - PPT generates porosity dilation waves in porous media.
 - The porosity dilation wave is a slow body wave, predicted by theory, and verified in the laboratory and field.
 - PPT transmits dynamic (inertial) energy to the pore liquids.

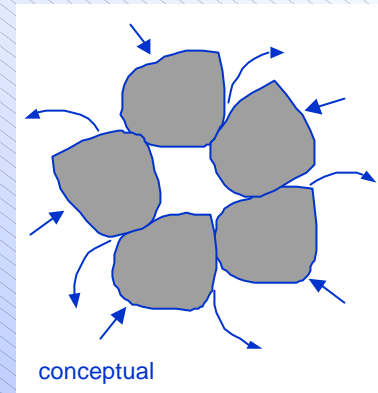
Pressure or Strain Perturbations



original state of
the porous media



response of porous media due
to a pressure or strain pulse

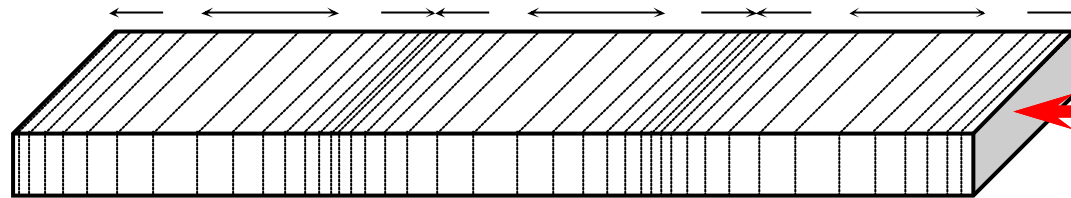


relaxation of porous media
after pulse has dissipated

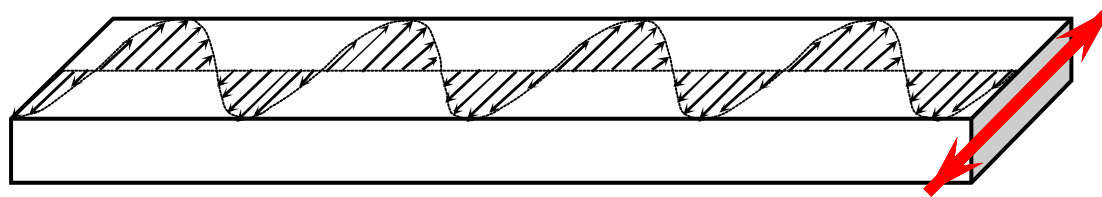
Repeating of this process yields a synergetic effect

Porosity Dilation Wave Mechanics

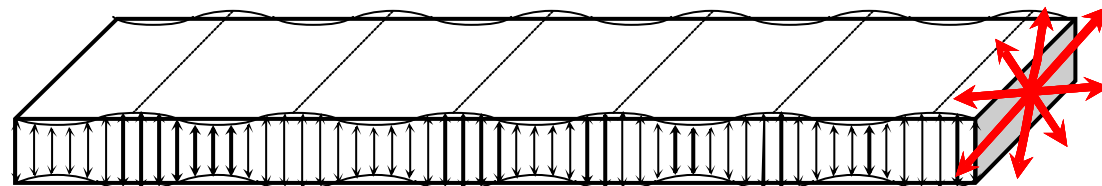
Type of Body Wave



Compressional
Wave, V_p



Shear Wave
 $V_s \sim 0.6V_p$



Porosity
Dilation Wave
 $V_D \sim 0.05-$
 $0.08V_p$

Why Should You Be Interested in PPT?

PPT has been shown to:

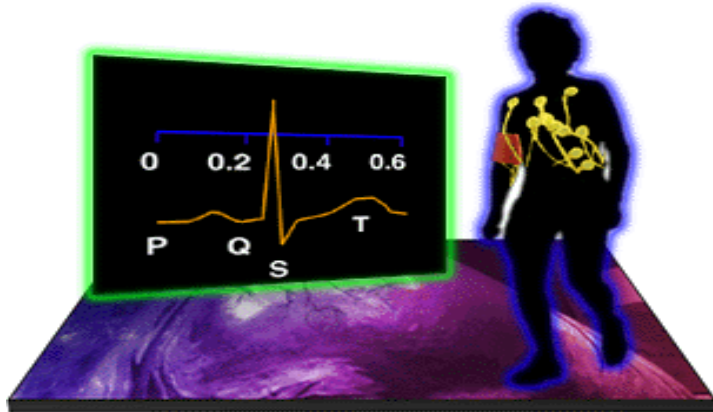
Significantly increase oil production rate, total production, and fluid injectivity. It is estimated that will yield an additional **7.5 billion barrels** of oil.

Significantly increase pore scale dispersion.

Mobilize ganglia of contaminants.

PPT is unique. **It will become the standard for enhanced fluid flow.**

Pressure Pulse Waves – The Heart and Wavefront Tooling



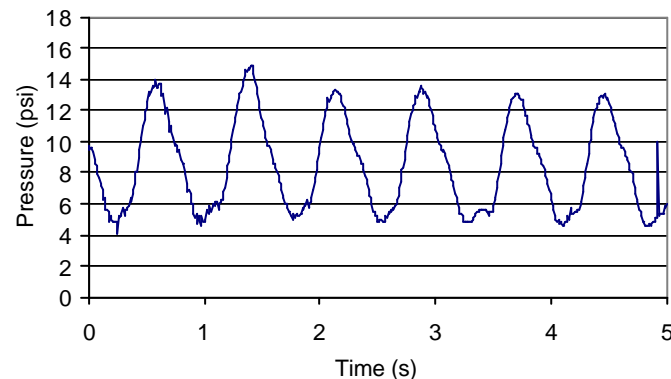
Stroke Volume = volume pumped/beat

Cardiac Output = stroke volume x heart rate

Vessel diameter critical to flow

With each beat of the heart:

- .diastole - relaxation, recharge
- .systole - contraction, discharge



Stroke Volume = volume affected/down stroke

Total Output = stroke volume x stroke frequency

Pore diameter critical to flow

With each PPT cycle:

- .diastole - up stroke of piston, cylinder recharge
- .systole - down stroke of piston, fluid expulsion

Scales of Interaction

Molecular (Micro) Scale - Diffusion

Diffusion is mixing at the molecular-scale and involves chemical reactions. It is independent of fluid flow.

Macro (Pore) Scale - Mixing

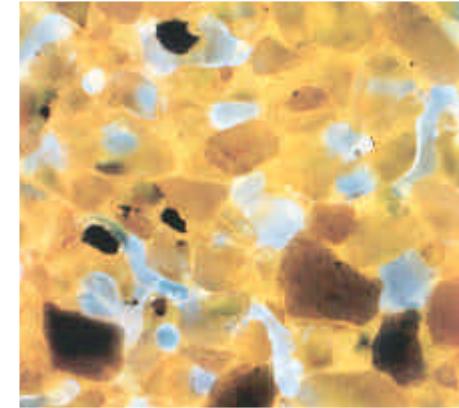
Involves mechanical mixing at the pore scale. It is dispersion and is greatly enhanced by PPT.

Mega (1000's of Pores) Scale - Mixing

"Fingering or viscous fingering" describes mega scale mixing. It is a quasi-static phenomena.

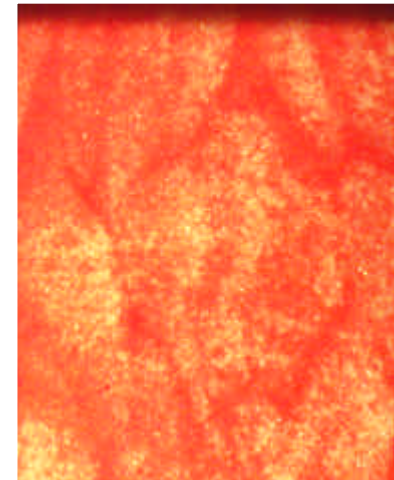
Properties of Porous Media

All porous media is heterogeneous at all scales.



The mobility of fluids in porous media is a function of interconnected pore scale pathways.

Rebound or contaminant persistence is related to poor mixing at the pore scale or the inability of fluids to flow in the mainstream.



Parameters Effecting Fluid Flow

Porosity

Permeability

Phase saturations

Viscosity of fluids

Interfacial tension

Wettability

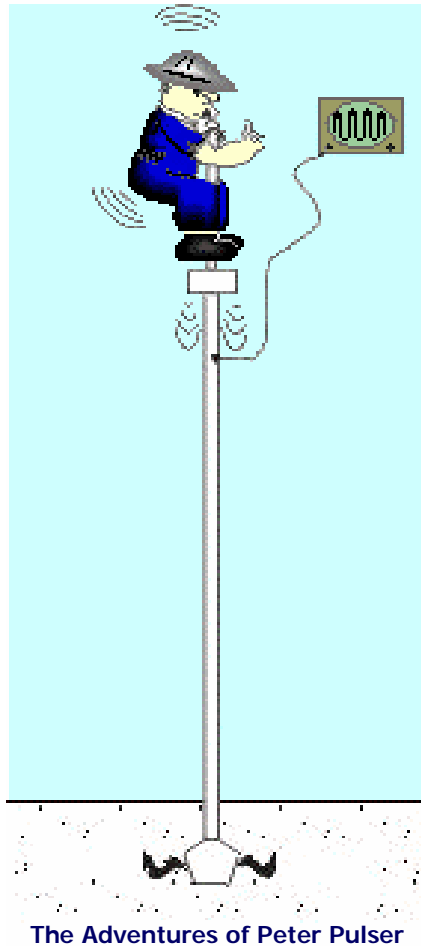
Pore throat diameter

Pulse Frequency

Environment – The Problem

- Natural flow processes inhibit the recovery of contaminants and the uniform distribution of injected remedial amendments.

A Tool to Address the Problem



Pressure Pulse Technology

Developed to increase ultimate oil recovery, accelerate contaminant extraction, and improve the distribution of *in-situ* treatment remedies for groundwater contaminants.

The bottom line in the ground...**PPT** results in **greater contact and distribution** of injected liquids, and the **accelerated** recovery of fluids.

What is to Gain in Using PPT?

1. Mixing and dispersion of amendments (biotic, or abiotic) at the pore scale.
2. Ability to increase radius of influence hence reducing the number of injection points.
3. Ability to influence distribution of remedial fluids in heterogeneous formations.
4. Ability to reach sensitive or difficult locations.
5. Ability to mobilize trapped ganglia. Optimizing pump-and-treat programs.

Comparison of Pressure and PPT Injection

Pressure Injection

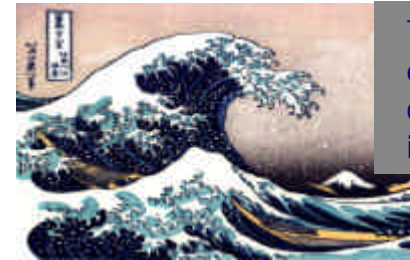
- .A quasi-static process.
- .Predominance to displacement: no control over dispersion.
- .Injected fluid tends to channel or finger
- .Injected fluids have tendency to propagate towards regions of low pressure: dominated by high permeability channels.
- .For a given porous media and fluid, injection rate governed by magnitude of injection pressure.

Pressure Pulse Technology

- .A dynamic process.
- .Tailored for displacement or dispersion.
- .Injected fluid tends to disperse or mix at the pore scale
- .Injected fluids have tendency to propagate towards regions of low pressure: less dominance by high permeability channels.
- .For a given porous media and fluid, injection rate governed by injection pressure, rate of change in pressure increase, and dilative capacity.

PPT and Fluid Displacement Waves

The pulsing tool generates a fluid displacement wave in the porous media.



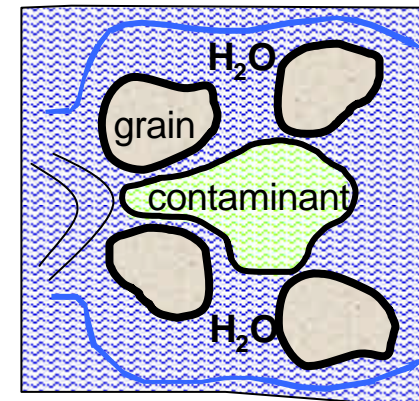
The best known example of a fluid displacement wave is the Tsunami.



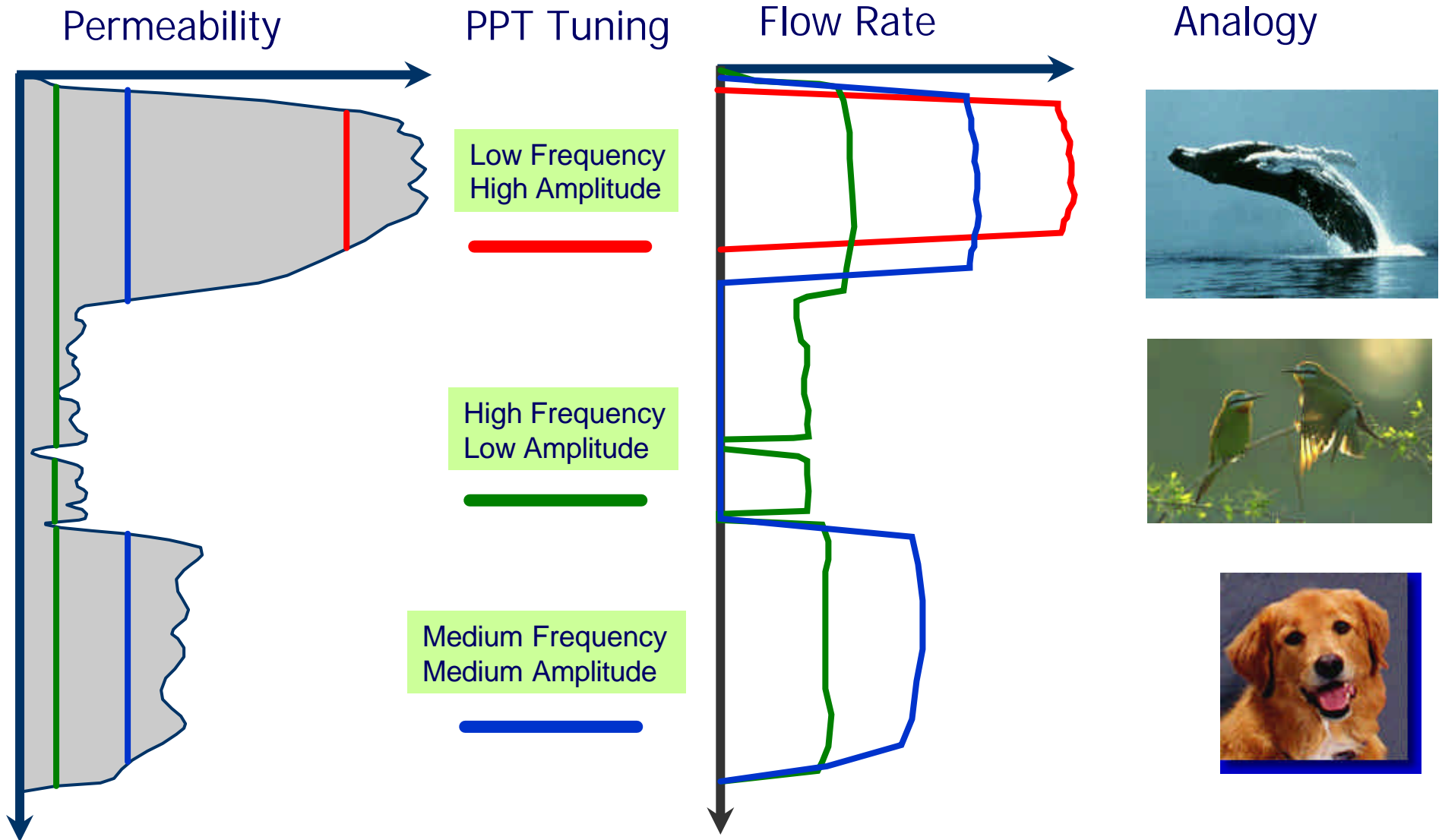
Akin to ripples from a stone thrown in a pond, the wave retains energy as it travels through the porous media.

These ripples generate high liquid acceleration through the pore throat, overcoming capillarity.

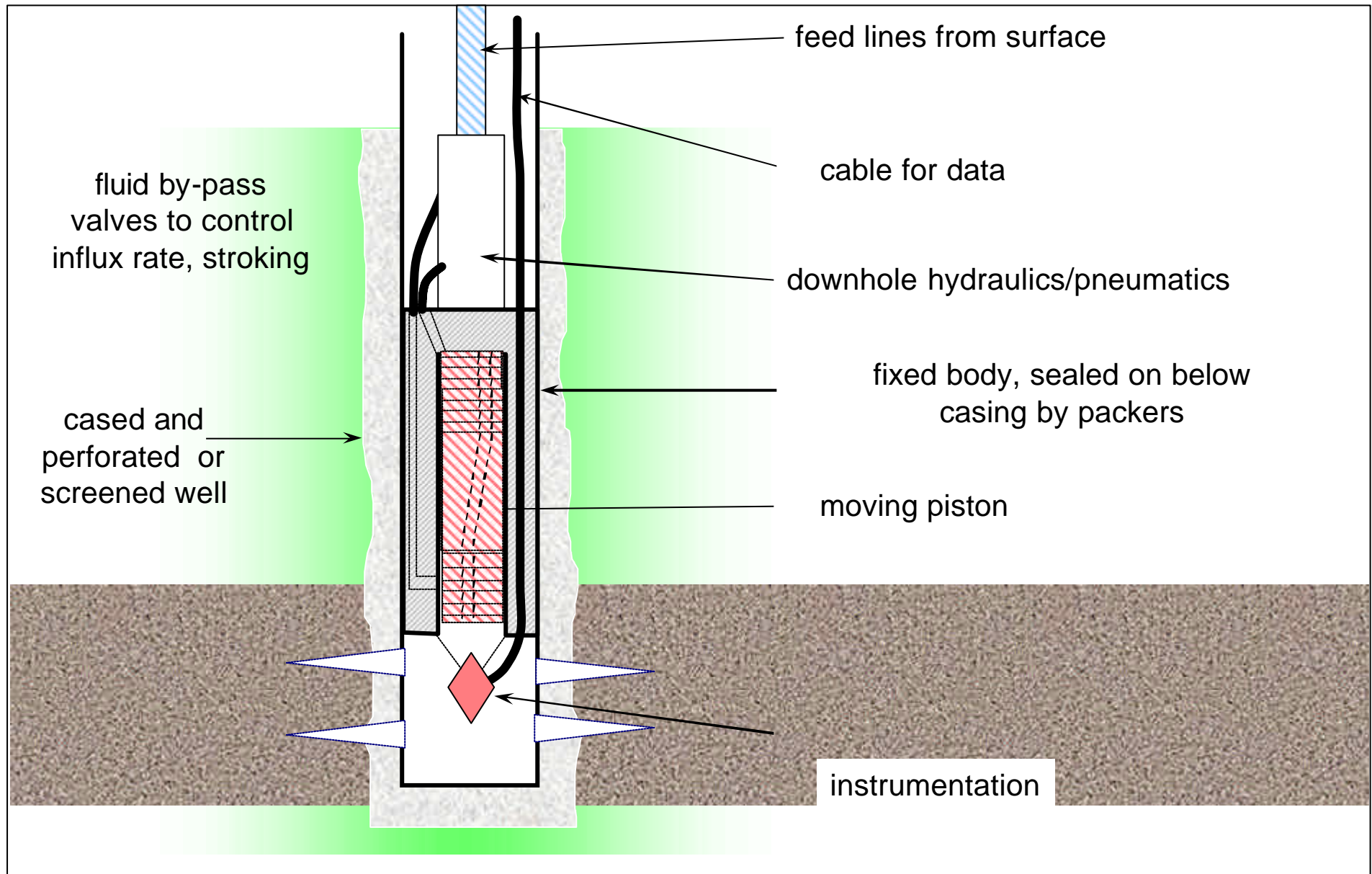
The critical factor for pressure pulse technology is generating the correct pulse shape at the optimum frequency.



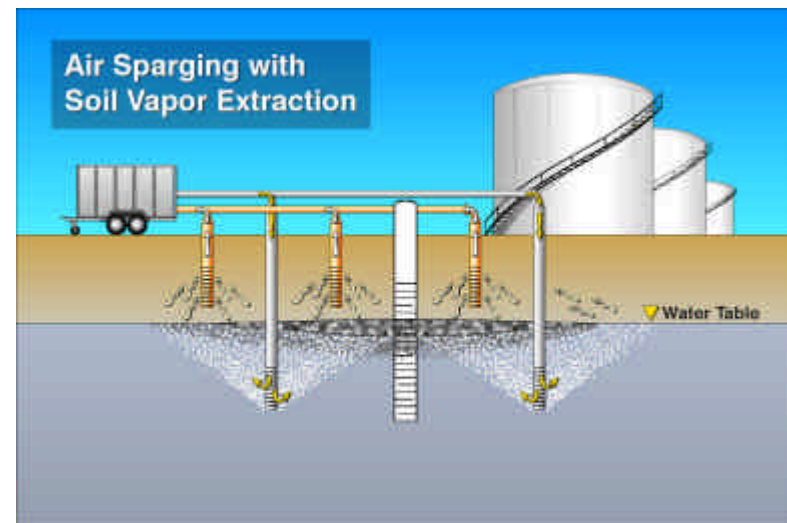
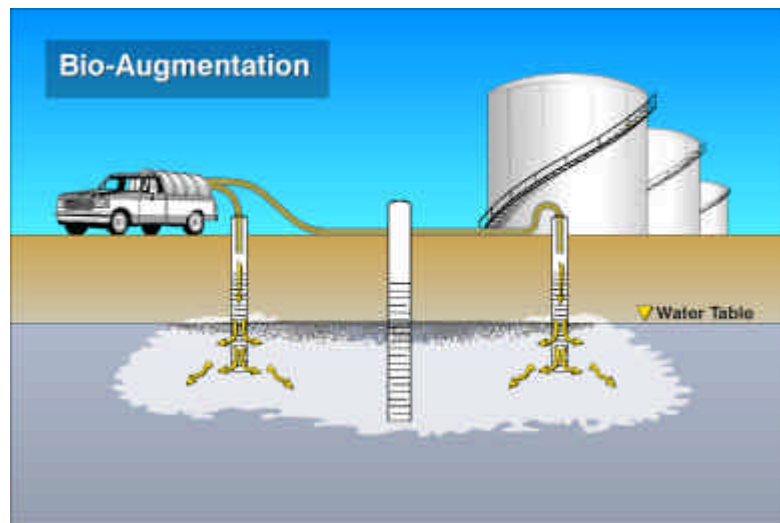
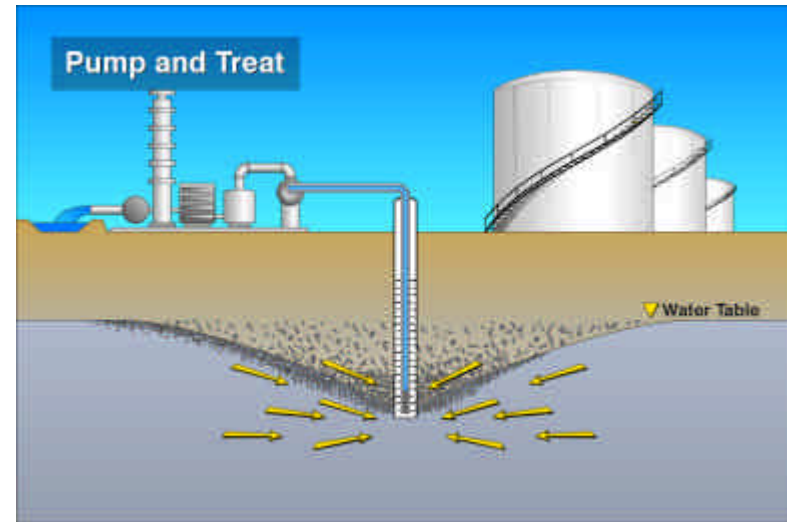
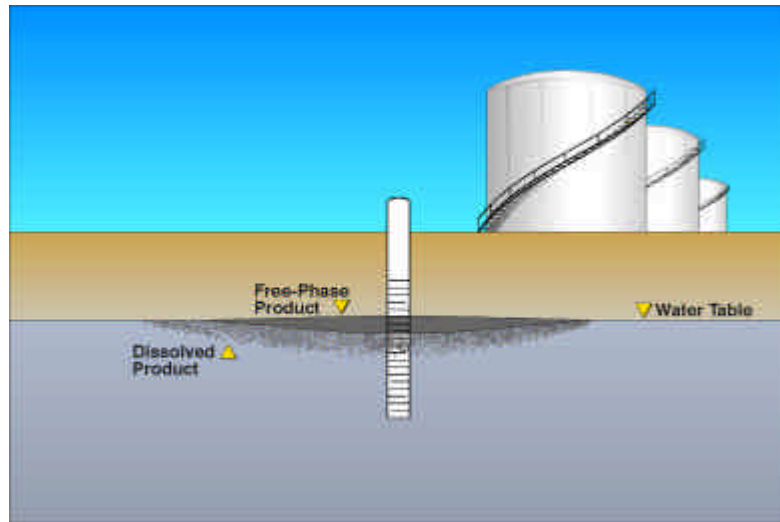
Permeability and PPT Relationship



PPT Tool Concept



The Importance of Dynamic Flow



June 2000 – First Environmental PPT

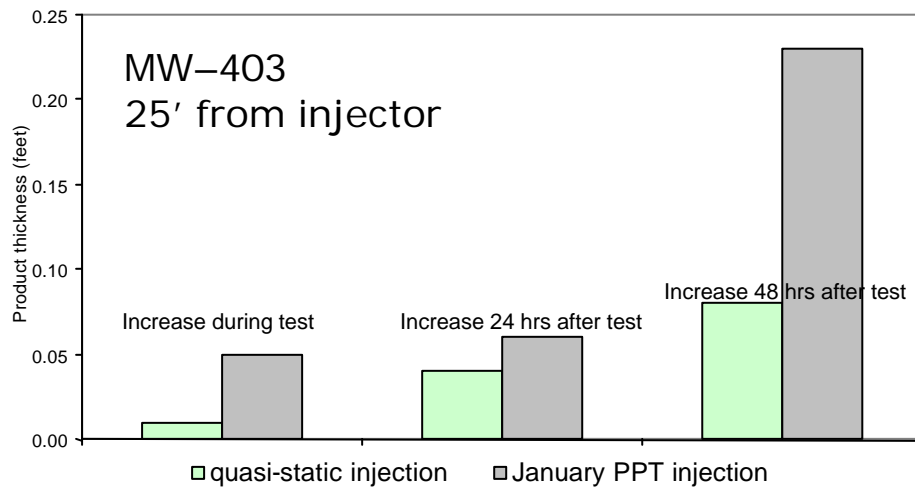
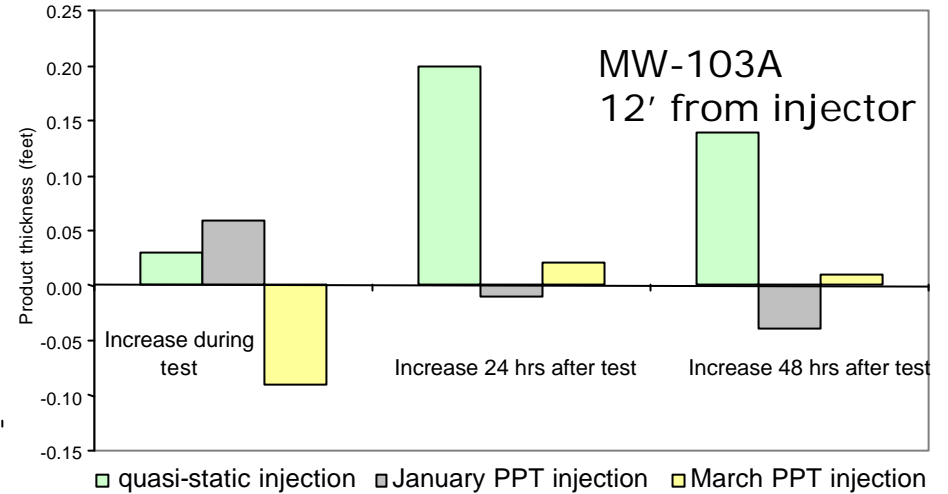
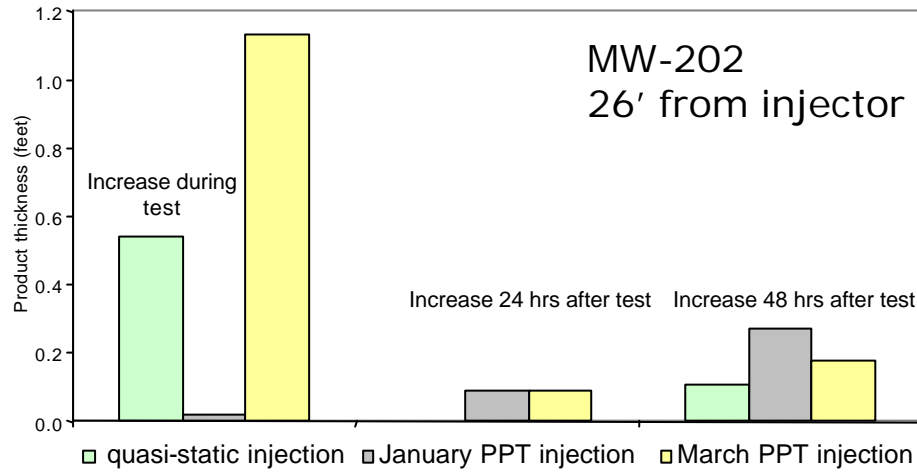


- Rate of LNAPL recovery significantly increased: greater than 250% quicker.
 - Environment and Industry Canada Technology Verification Certificate Received.
- Vugular Zones

PPT Waterflood – Queens, NY



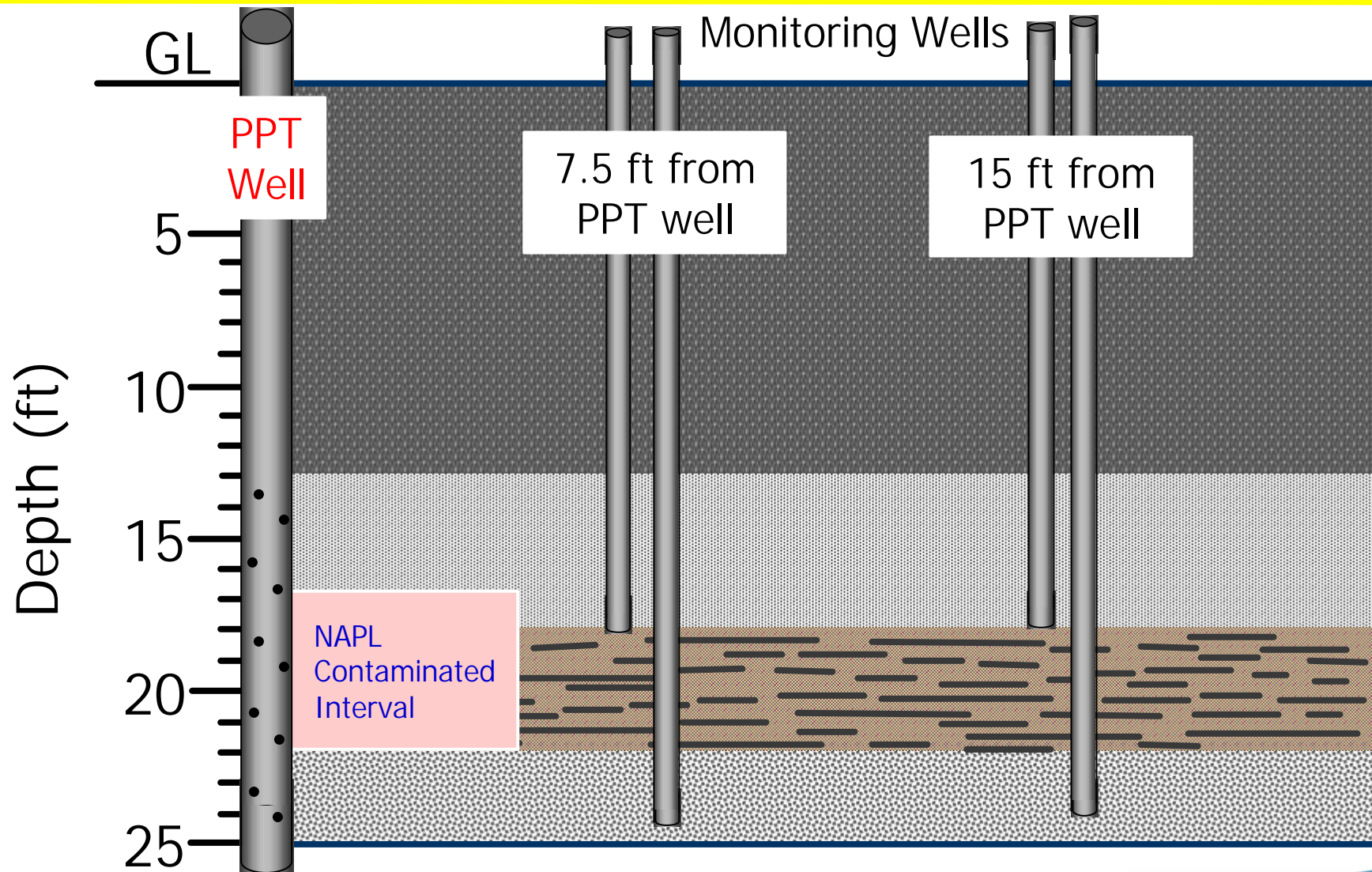
PPT Waterflood – Queens, NY



	Increase During Test (ft)	Injected Fluid (gal)	Product level Increase per Gallon (ft/gal)
Quasi-static injection	0.54	796.8	68×10^{-5}
January PPT injection	0.02	270.0	7.4×10^{-5}
March PPT injection	1.13	514.8	220×10^{-5}

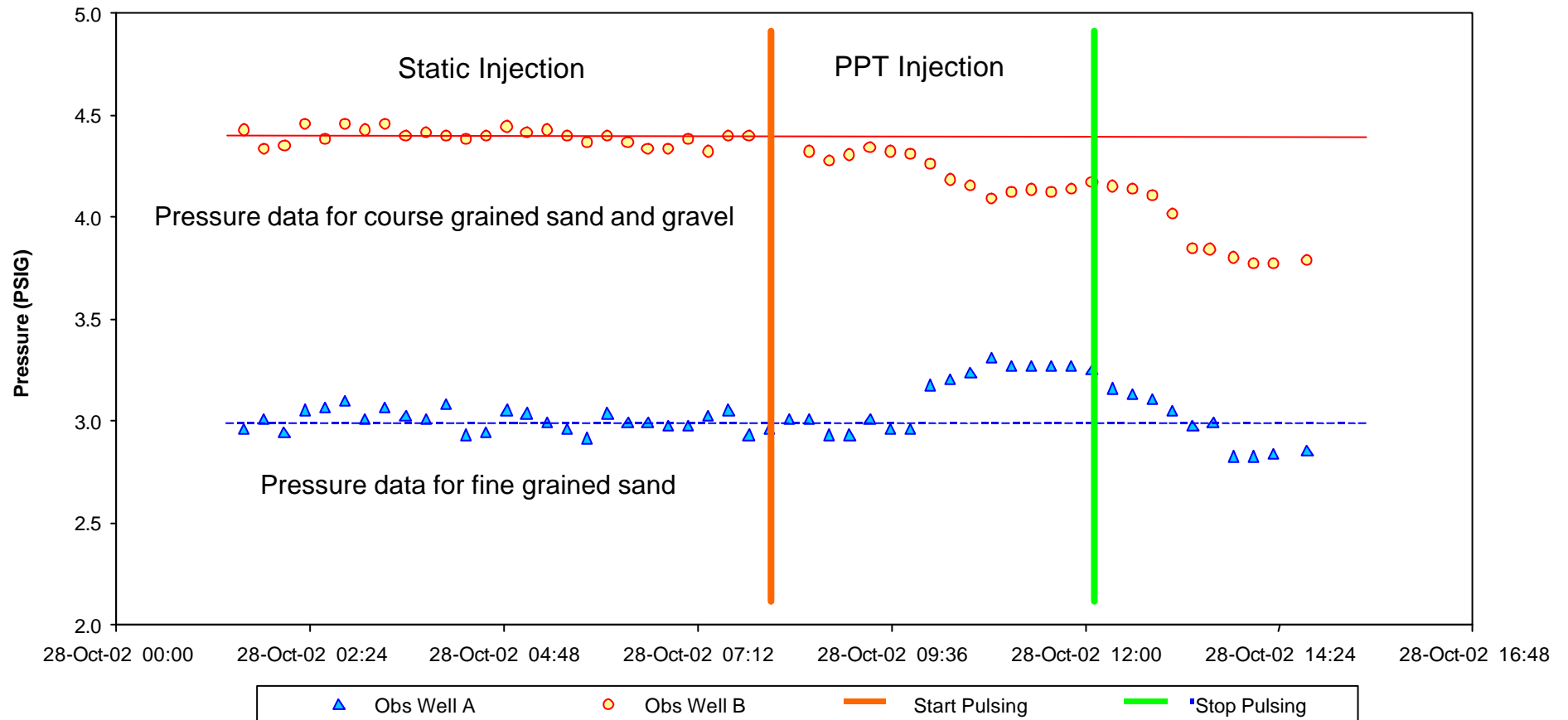
PPT increase over Quasi-static Injection by 3.2

Conformance in a Dual Permeability System



Injection Conformance

Formation Pressures 7.5 ft Away from Pulse Well



EZVI – NASA Pilot Program 2002



EZVI – NASA Pilot Program 2004



Bench Scale Creosote Treatability Study



- Initial creosote saturation for each test ~87%.
- Post PPT waterflood creosote saturation 38.9%.
- Post PPT surfactant flood creosote saturation reduced to <2%.

Summary of PPT

PPT represents a truly effective method for the mobilization and recovery of contaminants and a delivery mechanism for the dispersion of amendments at the pore scale. **It is unique.**

PPT is an enabling technology. It allows for better control Of fluid injection.

PPT is a tool in the overall strategy for the remediation of contaminated sites. Proper implementation will aid in reducing long-term liabilities and overall clean-up costs.

