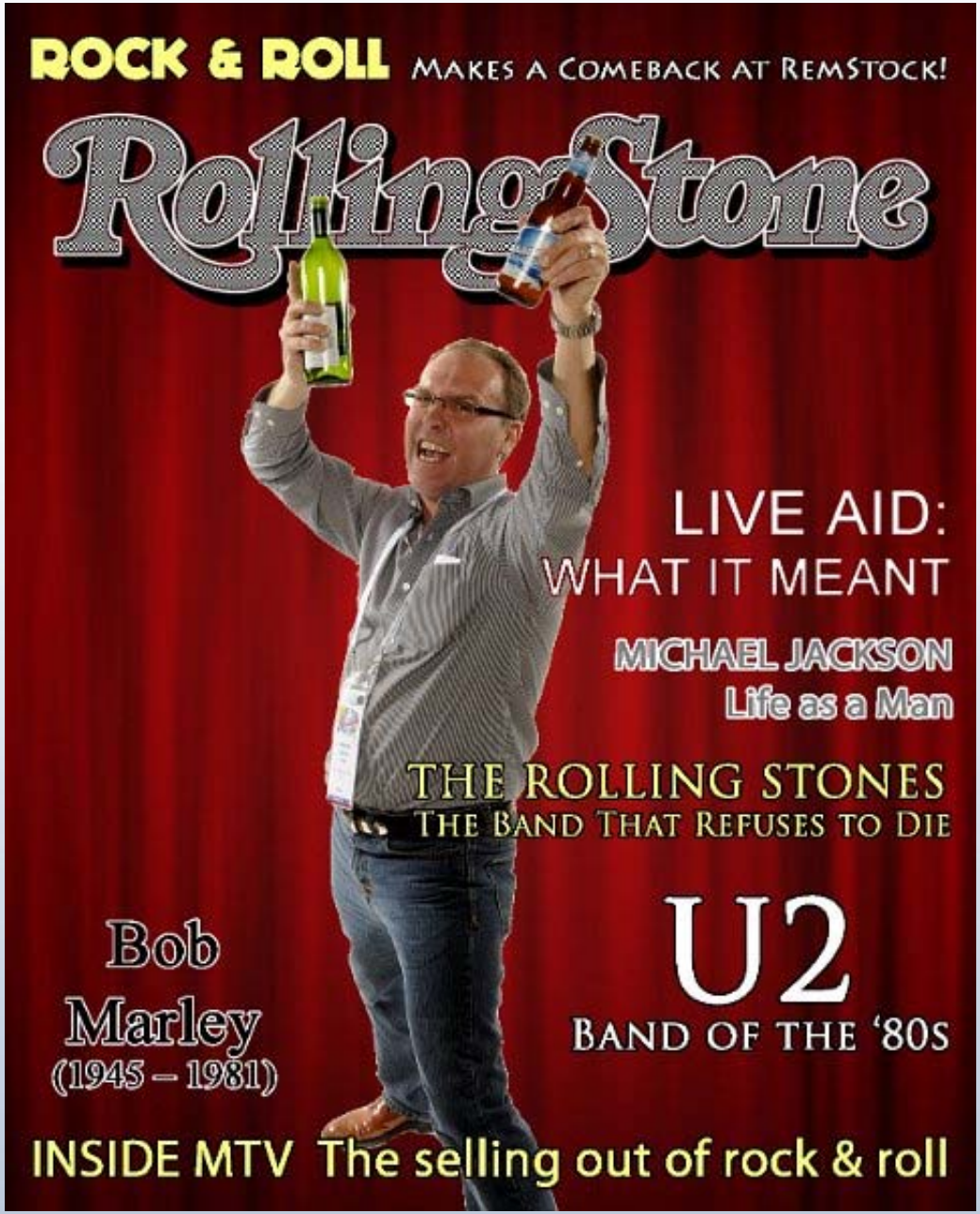
Surfactant Enhanced HVDPE Remediation of Petroleum Contaminated Soil, Bedrock, and Groundwater Northern California, USA

George A. Ivey, B.Sc., CES, CESA, P. Chem
Ivey International Inc., BC, Canada

Dr. Galen Kenoyer, PG & Chris D'Sa
RMT Inc., Los Angeles, California

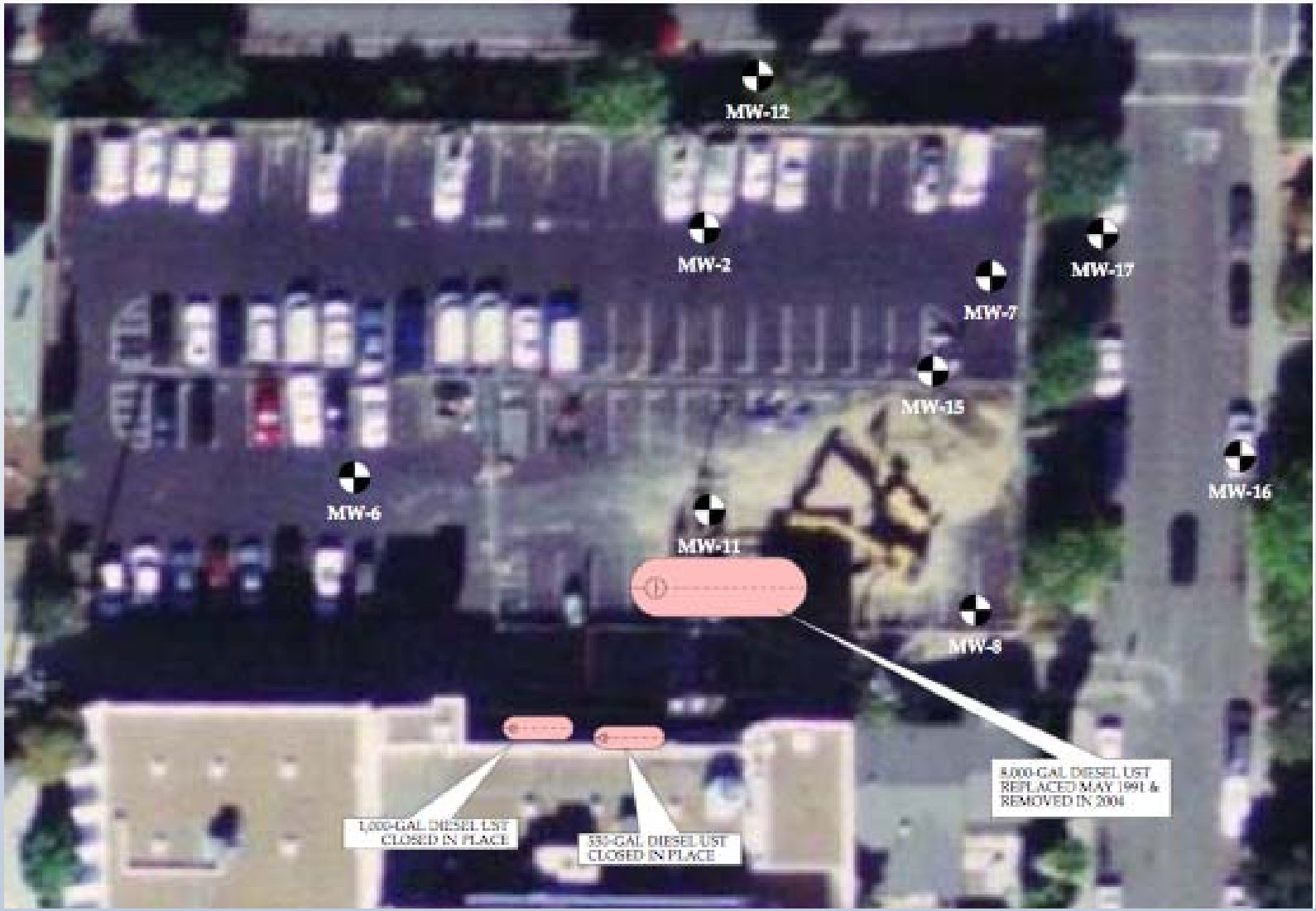
Presented by:
George (Bud) Ivey
Senior Remediation Specialist
Ivey International Inc.

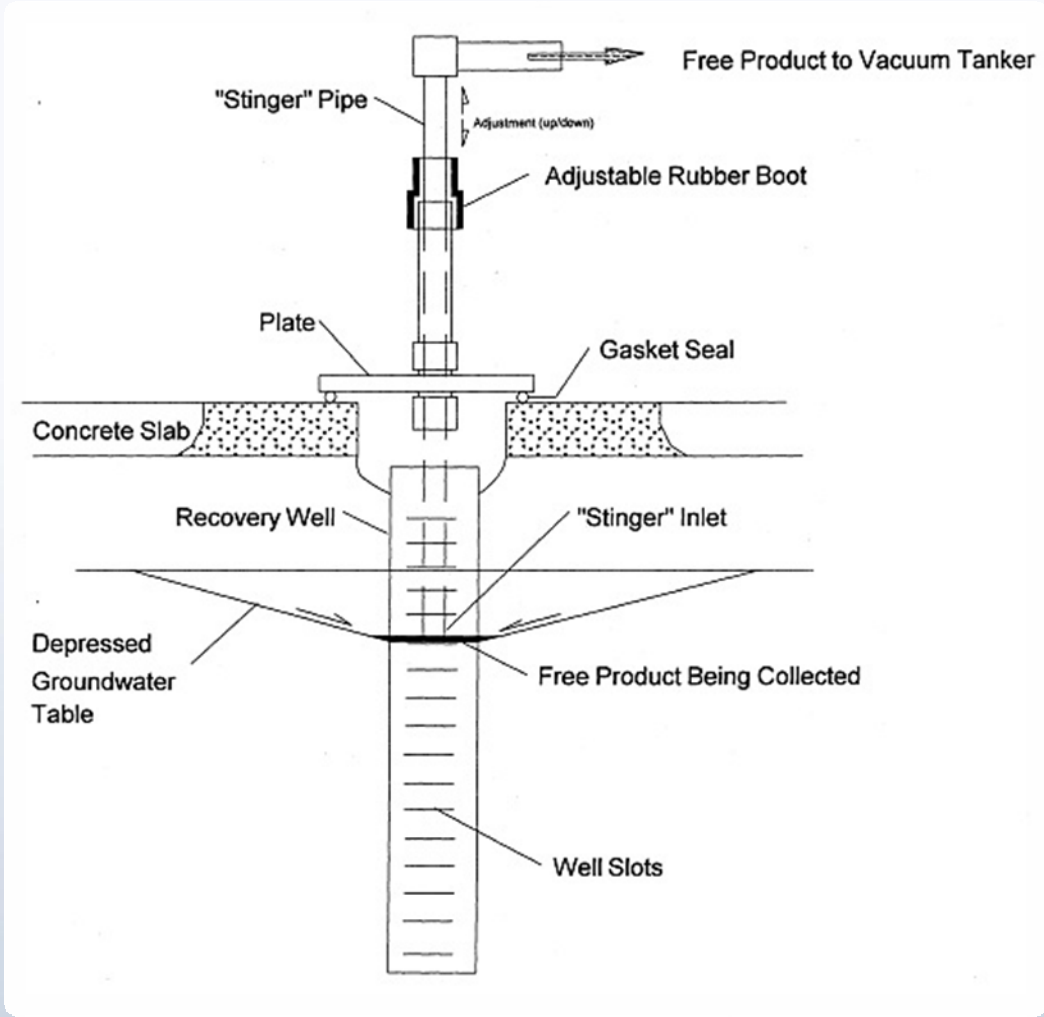


Presentation Outline

- High Vacuum Dual Phase Extraction
- Surfactant Chemistry
- Site Conditions & Pilot Test Approach
- Pilot Test Results
- Questions

The Site





HVDPE Extraction Well

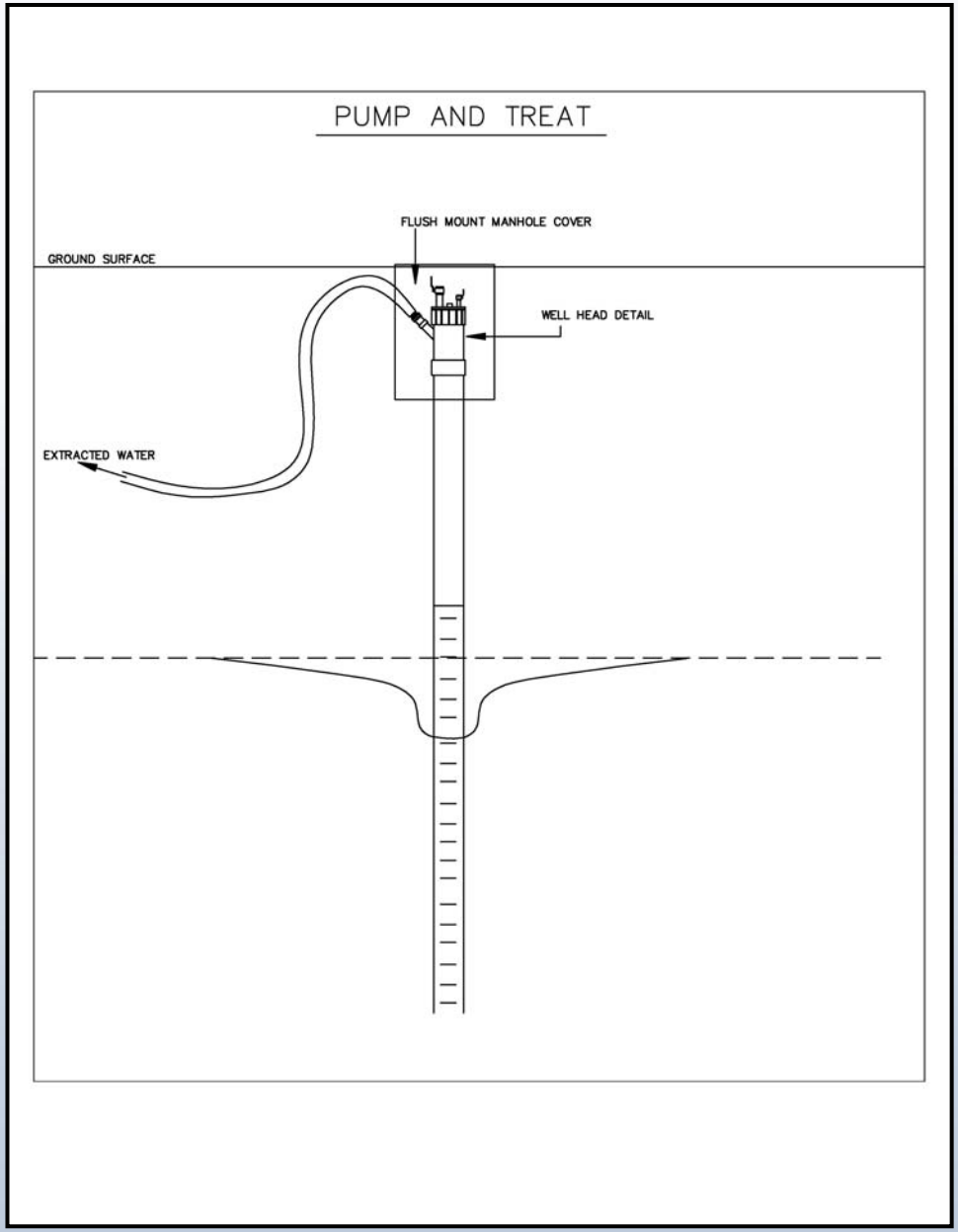
Diagram shows radius of influence and potential LNAPL collection

Standard Pump & Treatment drawdown.

Creates an unsaturated zone.

Often requires higher pumping rates to affect and maintain roi..

The unsaturated zone can be a source of contaminant rebound

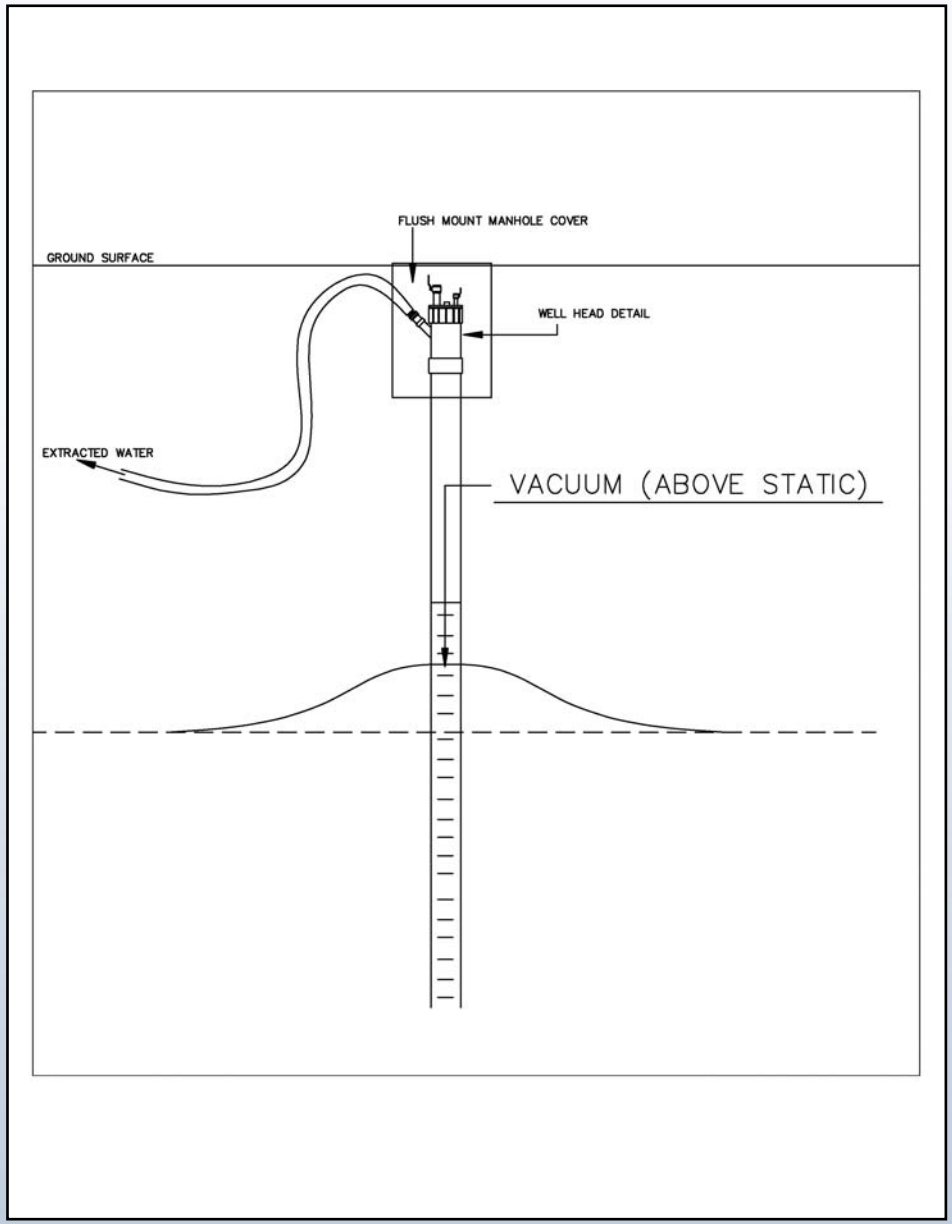


HVDPE
(Multi-Phase Extraction)

This targets the contaminants in both the saturated and unsaturated zone (Flexible)

The roi is controlled by the distribution of vacuum.

roi can be achieved with low flow rates.



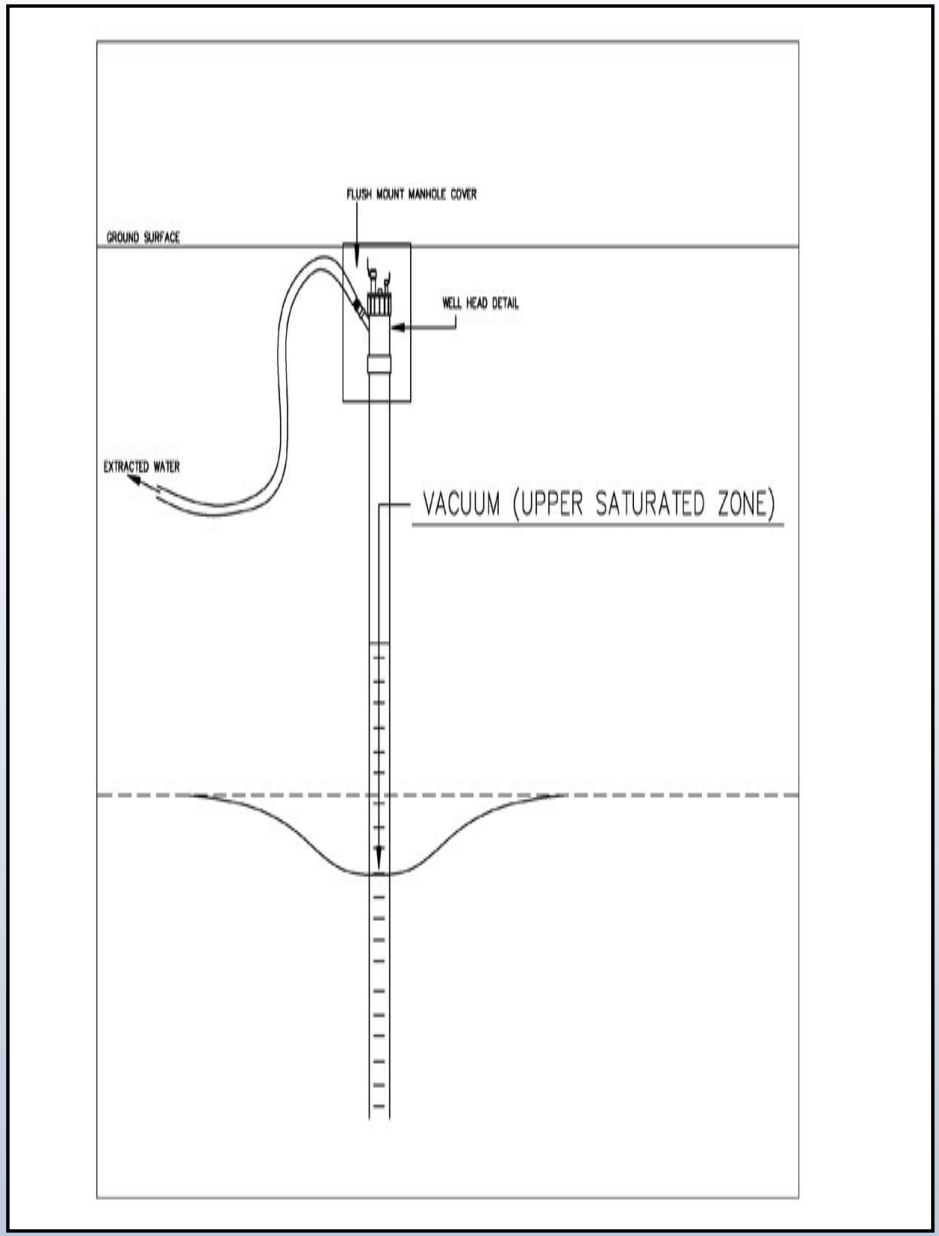
This represent HVDPE conditions.

roi is well maintained with low pumping rates.

HVDEP vacuum position allows flexibility in ensuring a saturated zone condition for Ivey-sol surfactant application.

The Ivey-sol surfactants desorb the sorbed phase under these condition for enhanced mass recovery.

This also resolved rebound issues.



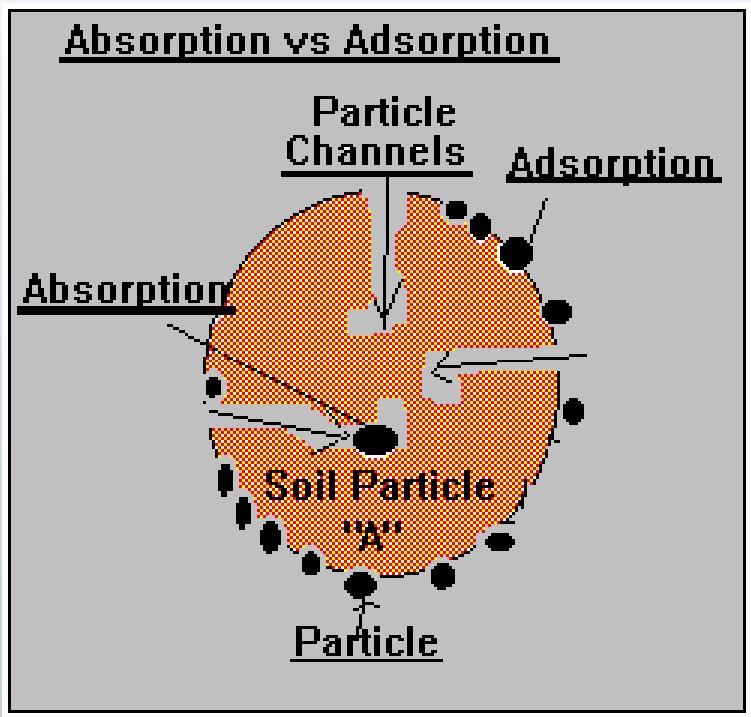
Practical Vacuum Effect on GW Extraction

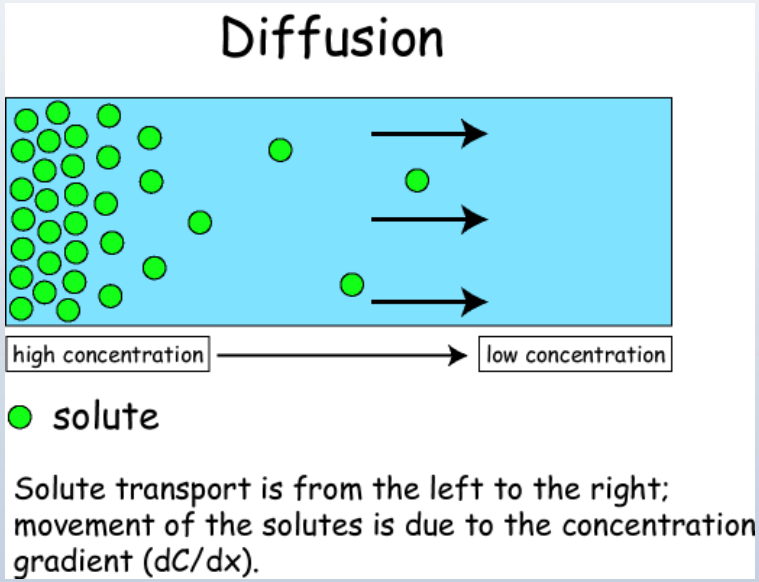
- Static Groundwater Level = 45 ft (13.7 m) MSL
- Dynamic Groundwater Level under pumping conditions = 50 ft (15.24 m) MSL
- Vacuum Effect on Groundwater Extraction raised water table approx. 5ft (1.52 m) in MW-6 and approx. 10 ft (3.05 m) in MW-7
- Flow-rate kept 0.24 gpm (0.91 lpm) throughout the pilot test.

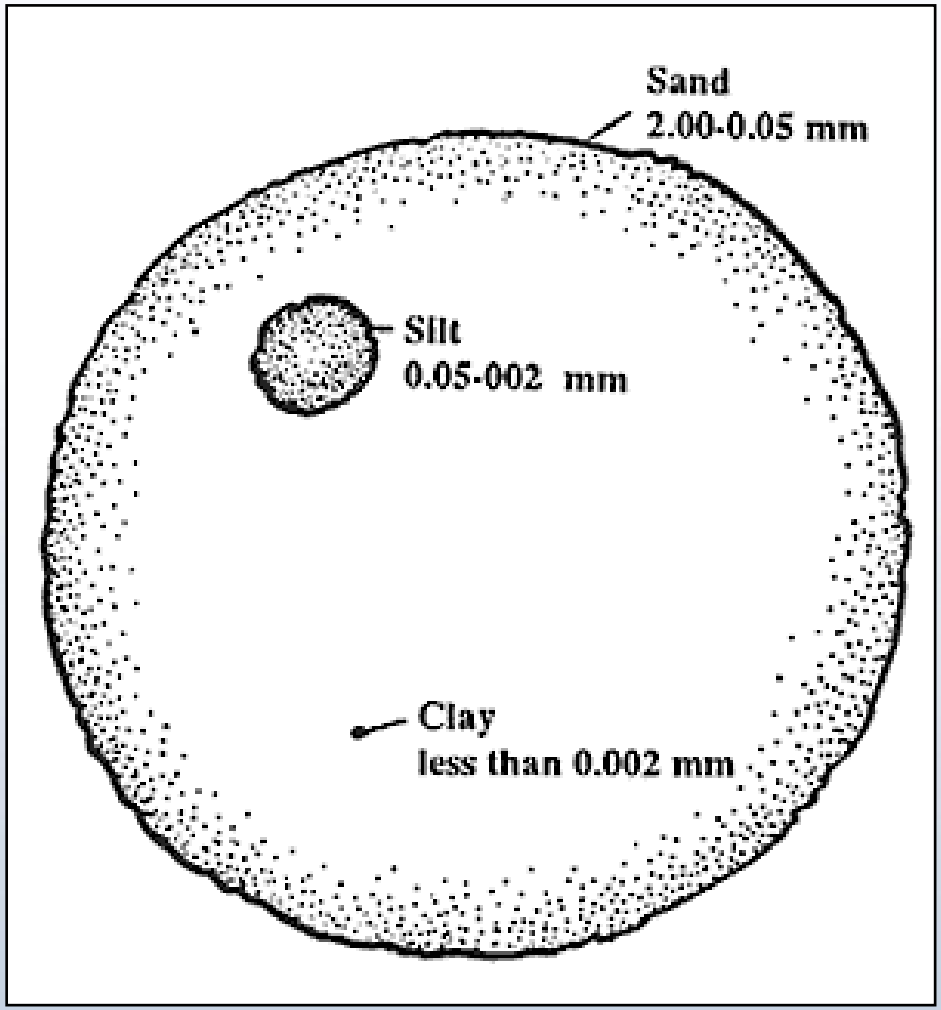
On-Site Photos

Remediation Challenge

Sorption >>> >>DeSorption or Diffusion







Did You Know ???

Surface Area For Sorption

Coarse Sand = 3 m^2

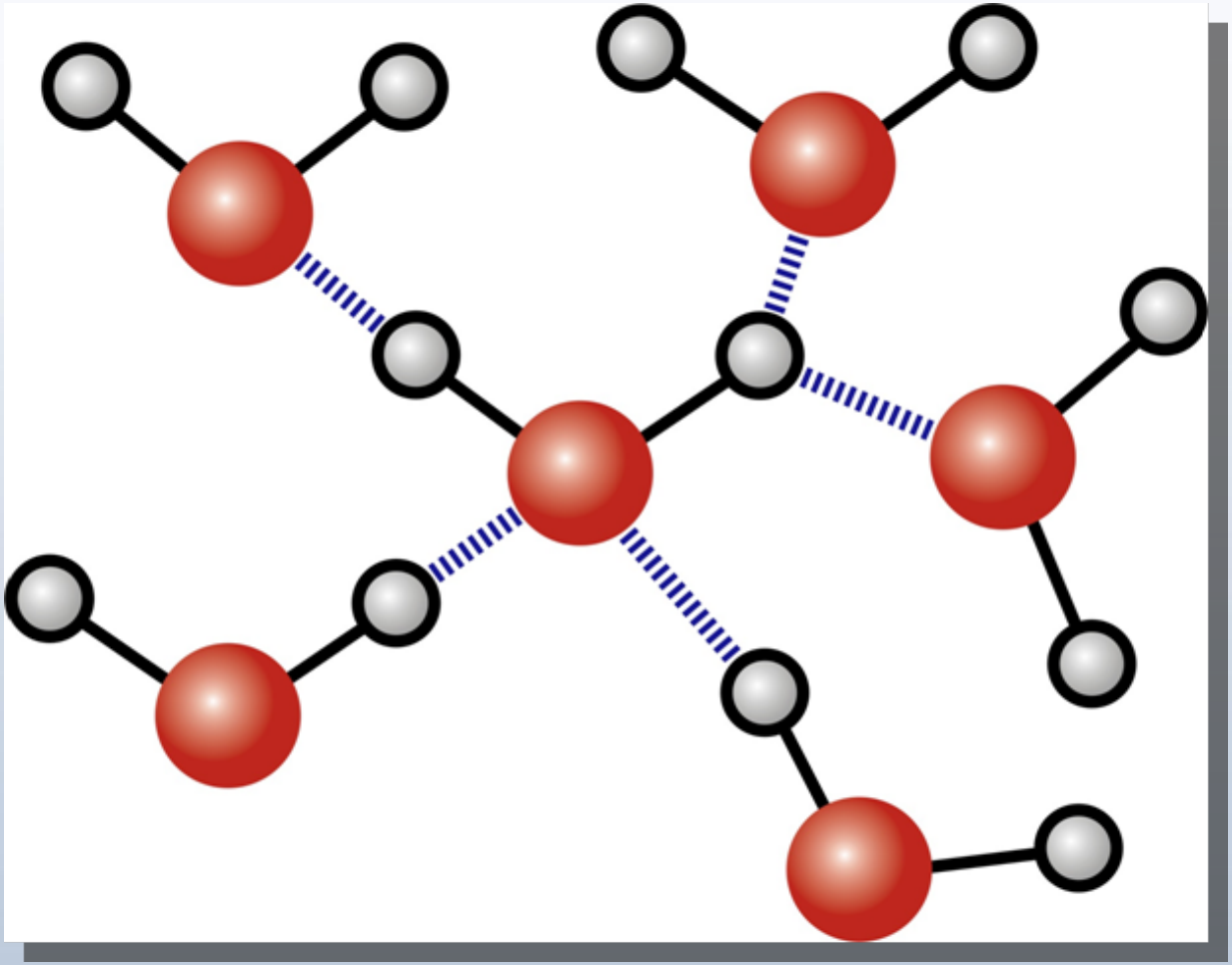
V. Fine Sand = 2.5 NHL Rinks

Coarse Clay = > CFL Field!

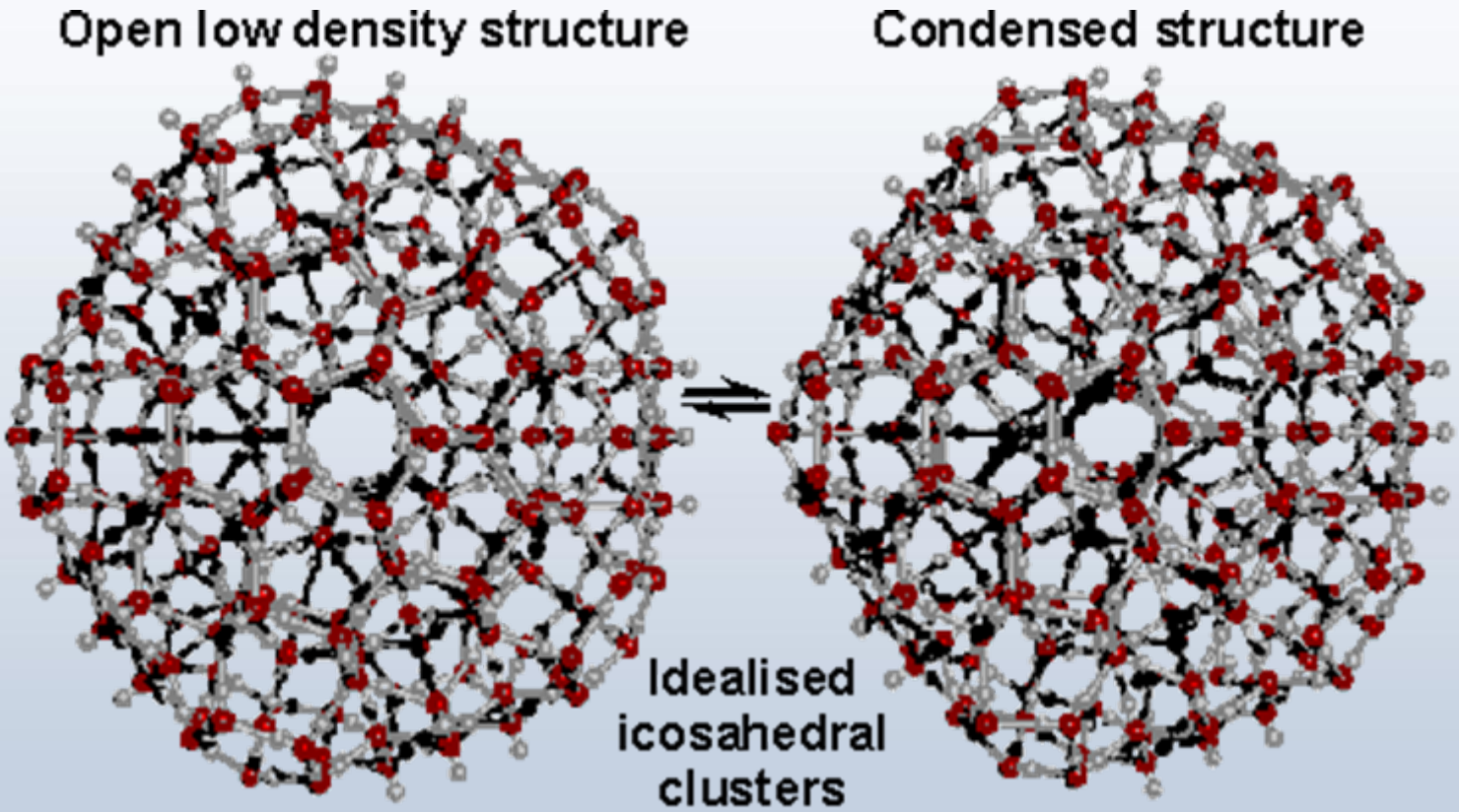
So finer soils have greater sorption potential!!!

Did You Know ???

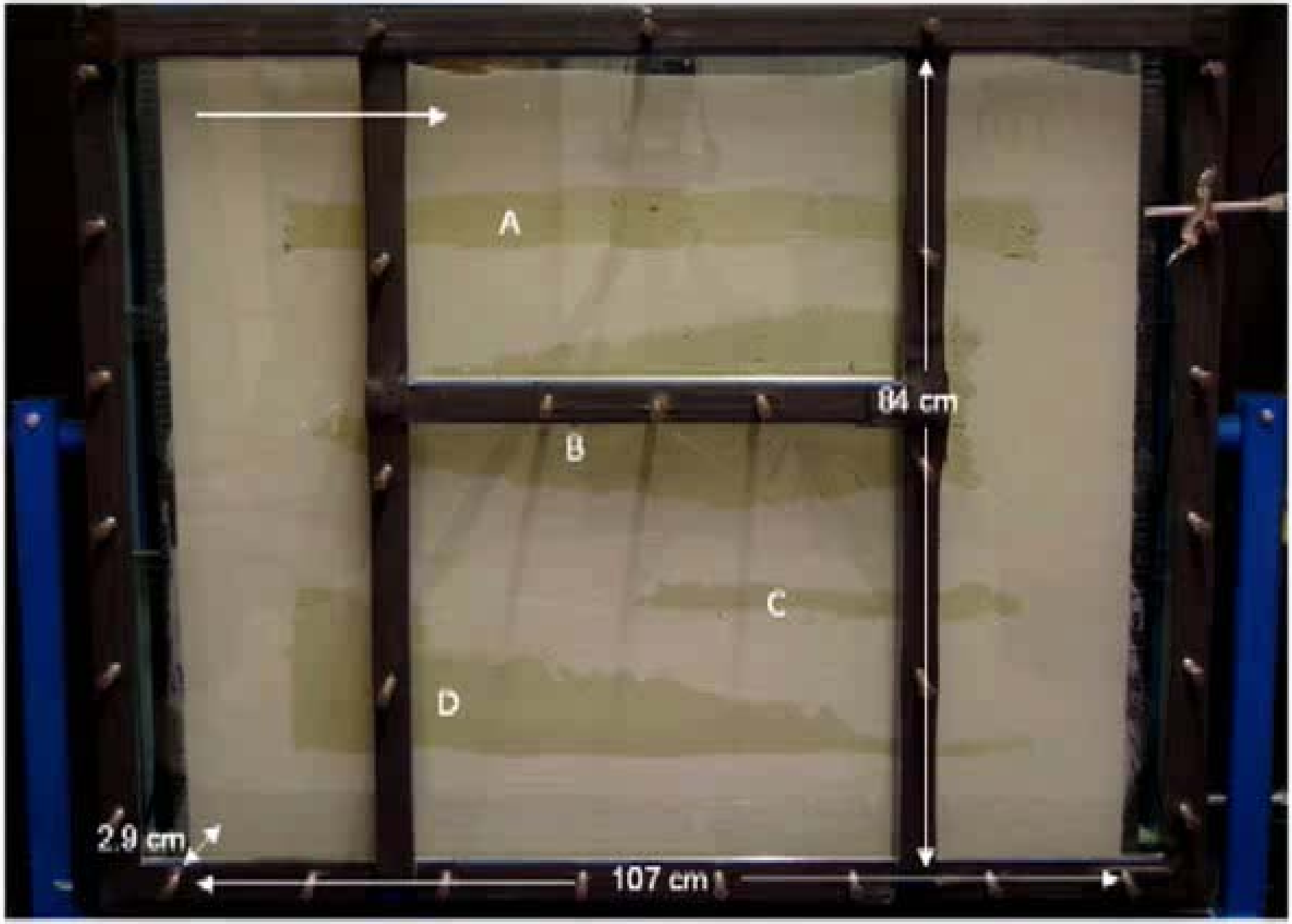
Water Is Not H_2O



Water Is Actually a Three Dimensional Cluster



Matrix Diffusion Video



Why a Surfactant?

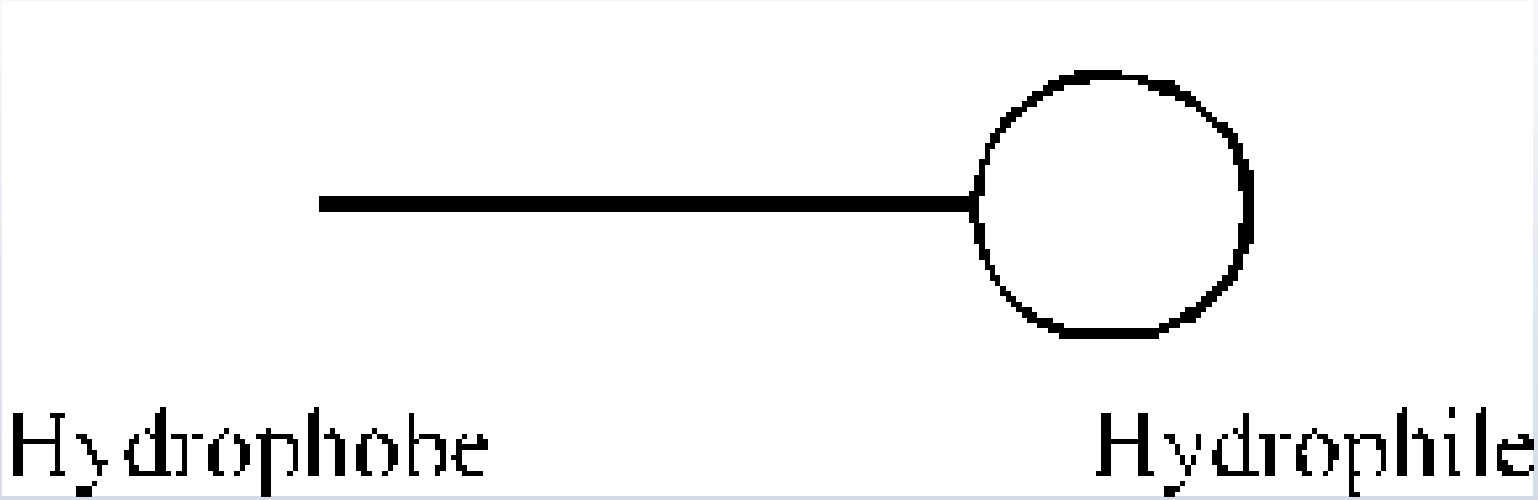
- **Improves desorption of target contaminants** from soil
- **Lowers the surface tension of water** improving both its wetting and associated permeability (K) properties
- Effective as a stand alone technology for soil washing
- Effective to improve other remediation techniques (i.e., P&T, Bioremediation, Chemical Oxidation, etc.)

It's all about contact…with the contaminant

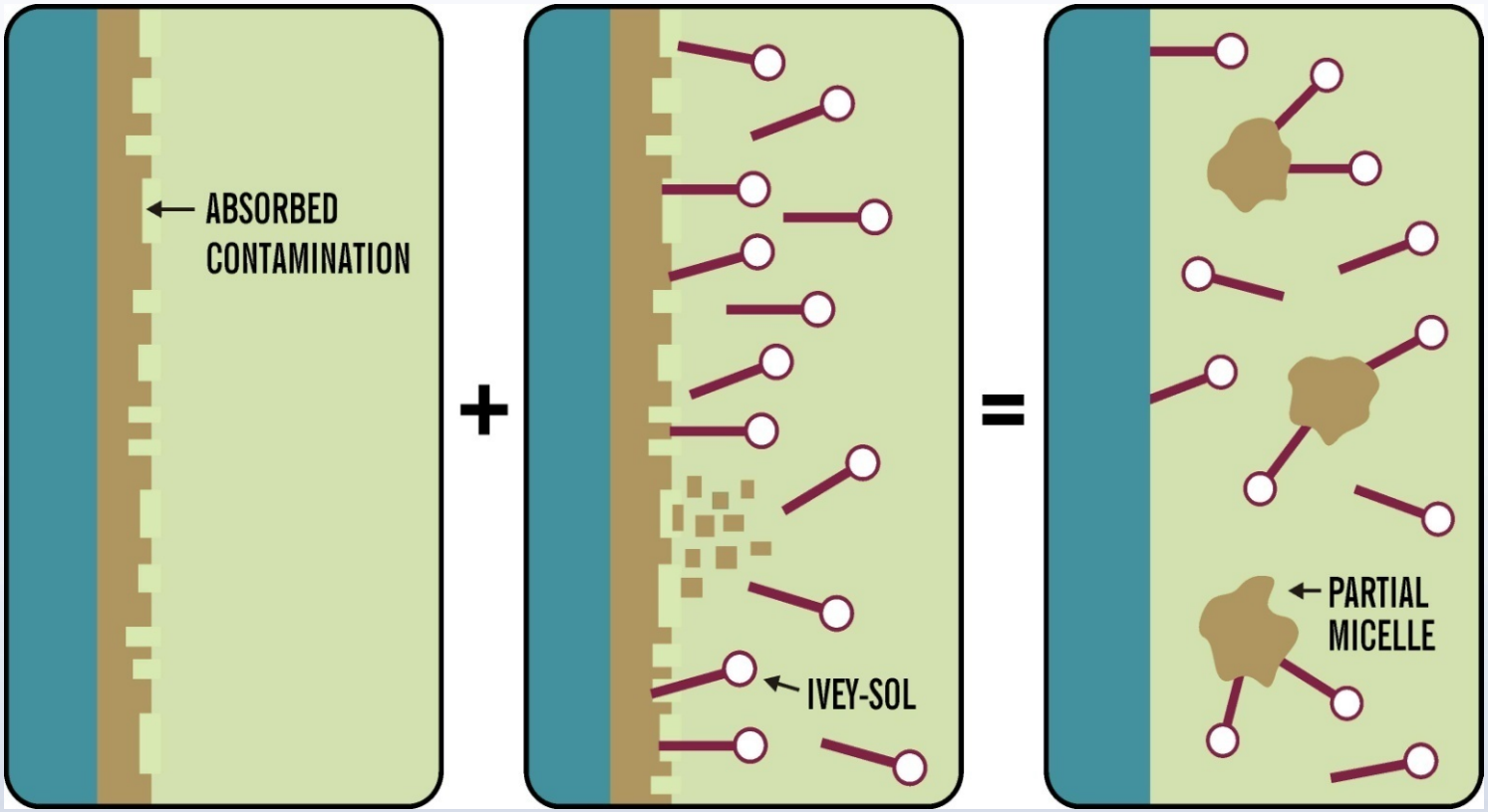
Classes of Surfactants

- Anionic: Have one or more negatively (-) charged groupings; commonly used in laundry detergent.
- Cationic: Have one or more positively (+) charged groupings; typically poor detergents but well suited for use as germicides, fabric softeners, and emulsifiers.
- Amphoteric: Contain both anionic and cationic groupings; prefer neutral pH and found in products such as hair shampoo, skin cleaners, and carpet shampoo.
  - *Ionic Surfactants make up >99% of the surfactant used around the world.*
- Non-ionic: Have no ionic constituents or groupings; largest single group of SAA and have a correspondingly wide range of chemical characteristics. Ivey-sol surfactant mixtures, are non-ionic and have the unique ability to selectively desorb contamination (LNAPL, DNAPL's, PAH, PCB, DCE, TCE, PCE), etc.

Surfactant Structure



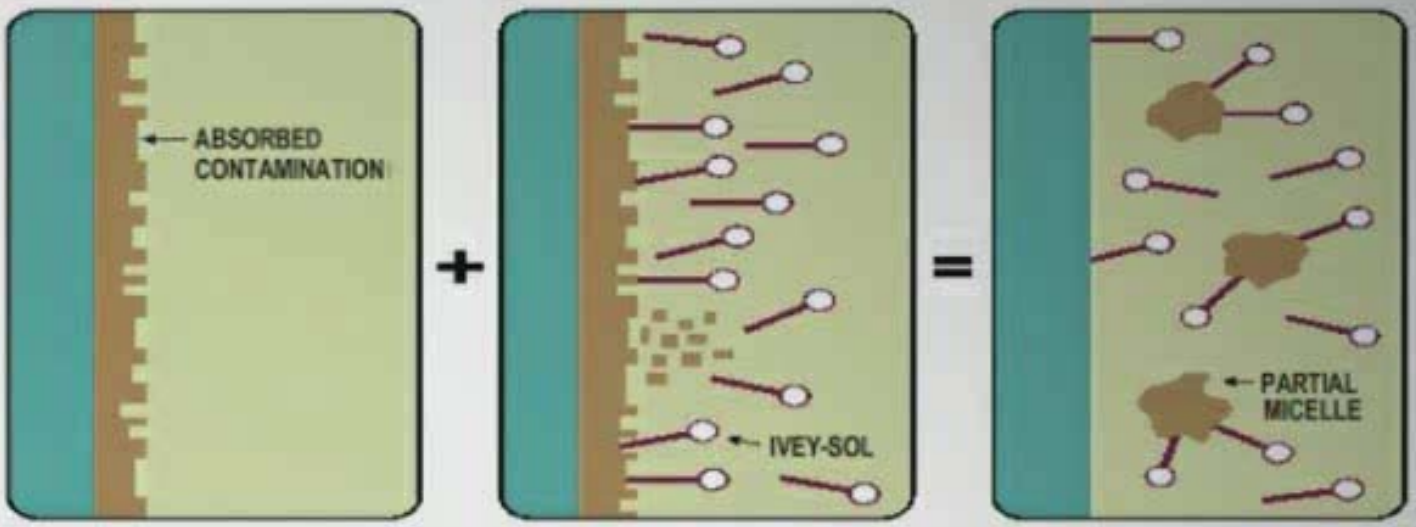
Hydrophilic (water loving) and Hydrophobic (water hating oil-liking) Groupings Allow For Surface Interaction With Many Contaminants



Surfactant Interaction with DNAPL. Helps dissolve DNAPL into pore space.

Show Them A Real Cool Ivey-sol Animation

Mechanism

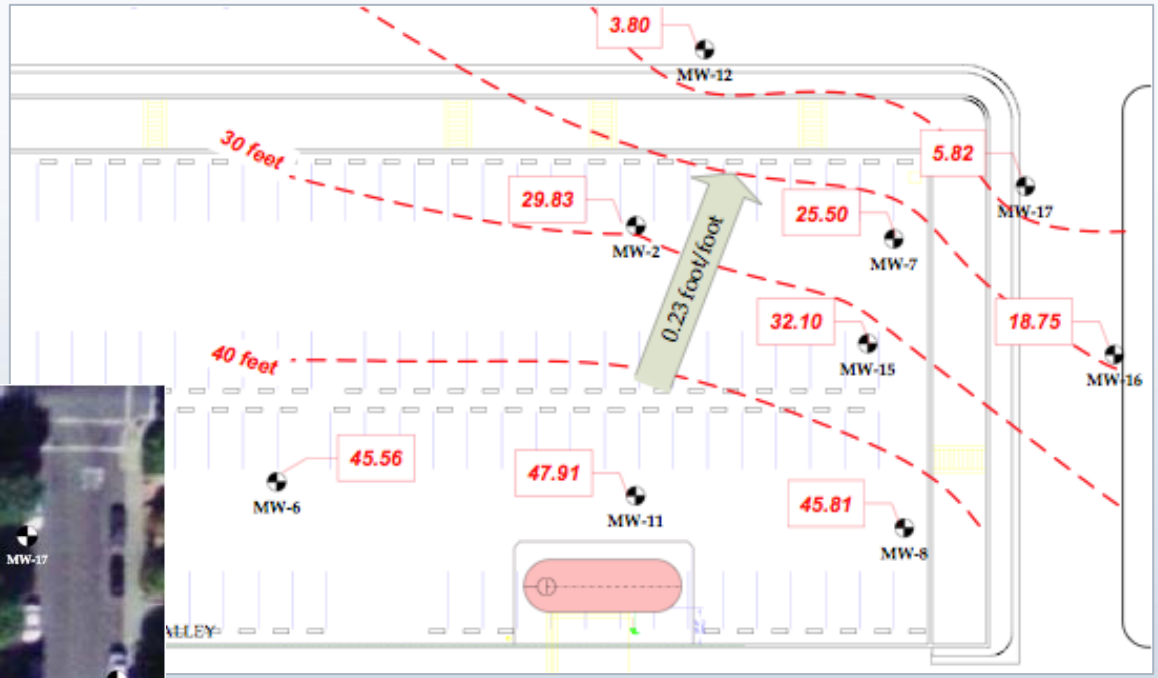


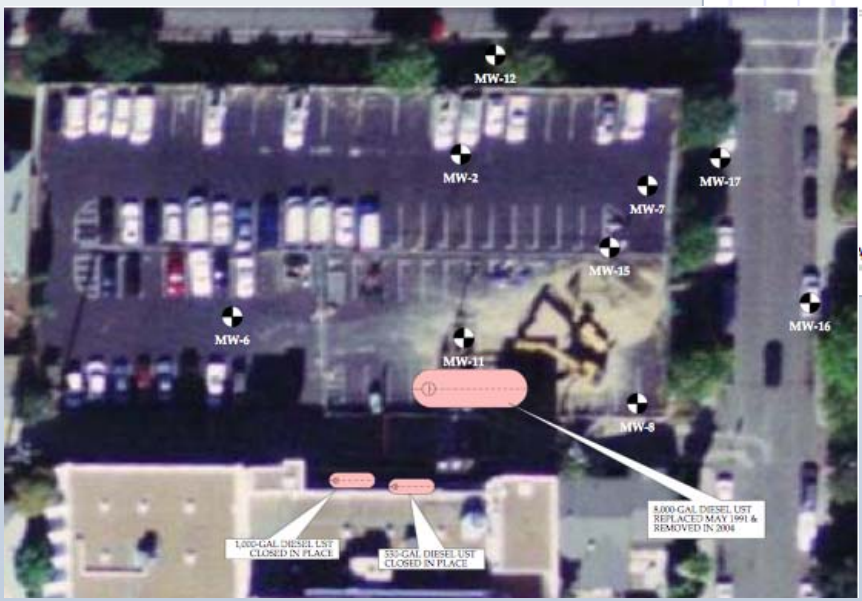
Ivey-sol® shown desorbing contamination off a surface. Once liberated the desorbed contaminants have increased 'Availability' for improving the associated in-situ or ex-situ remediation method being employed.

LNAPL
(Crude Oil)

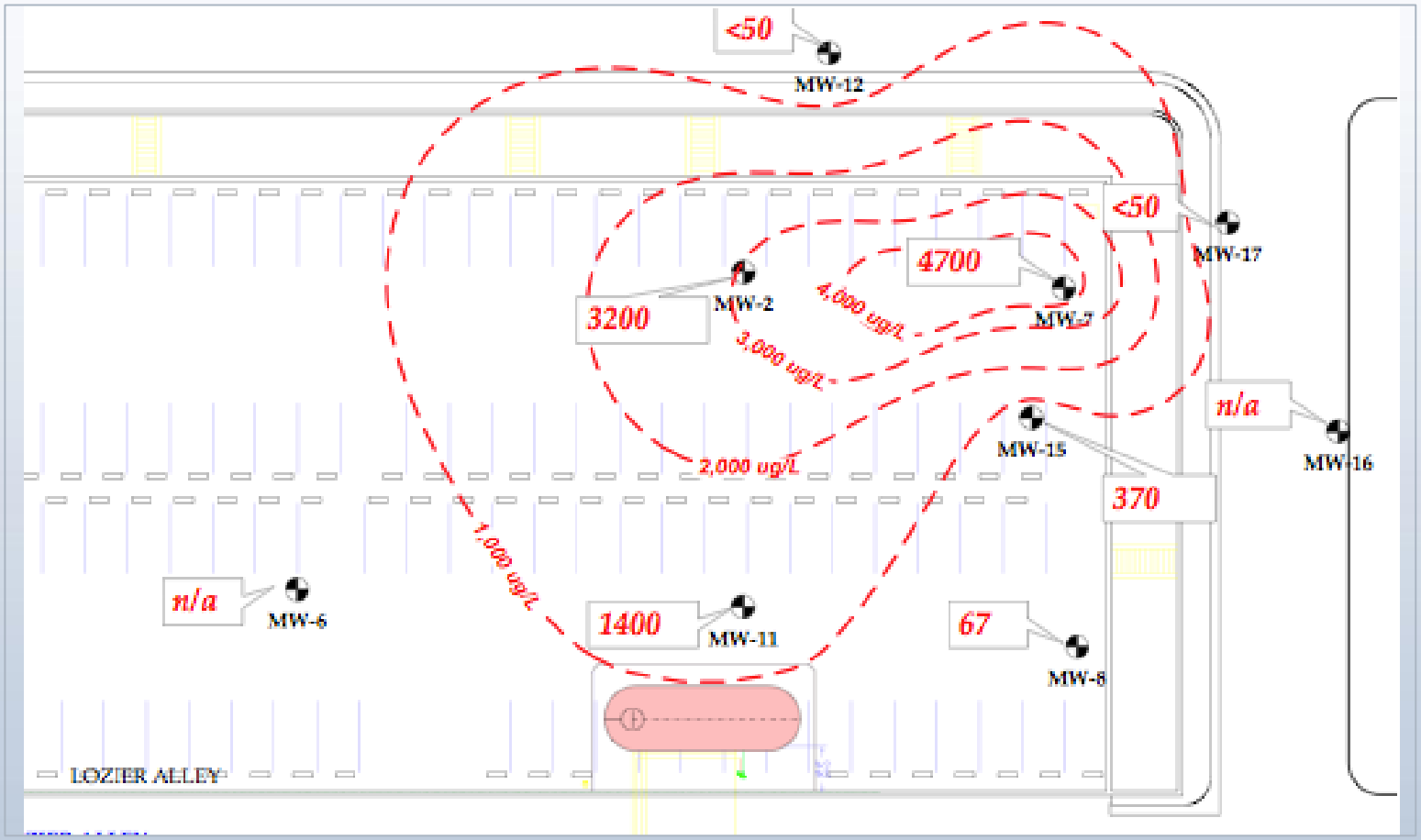
DNAPL (Dichlorbenzene, TCE, etc.) before and after Ivey-sol addition

Site GW Gradient





TPH-dIsoconcentration Map



Site Conditions

- Clayey shale with sandstone interbeds
- Depth to groundwater at approximately 50-70 feet below ground surface
- Impacted with diesel range petroleum hydrocarbons
- Former private use diesel fuel underground tanks for emergency generator
- Property owner operated HVDPE for multiple years without satisfactory results…. at considerable cost

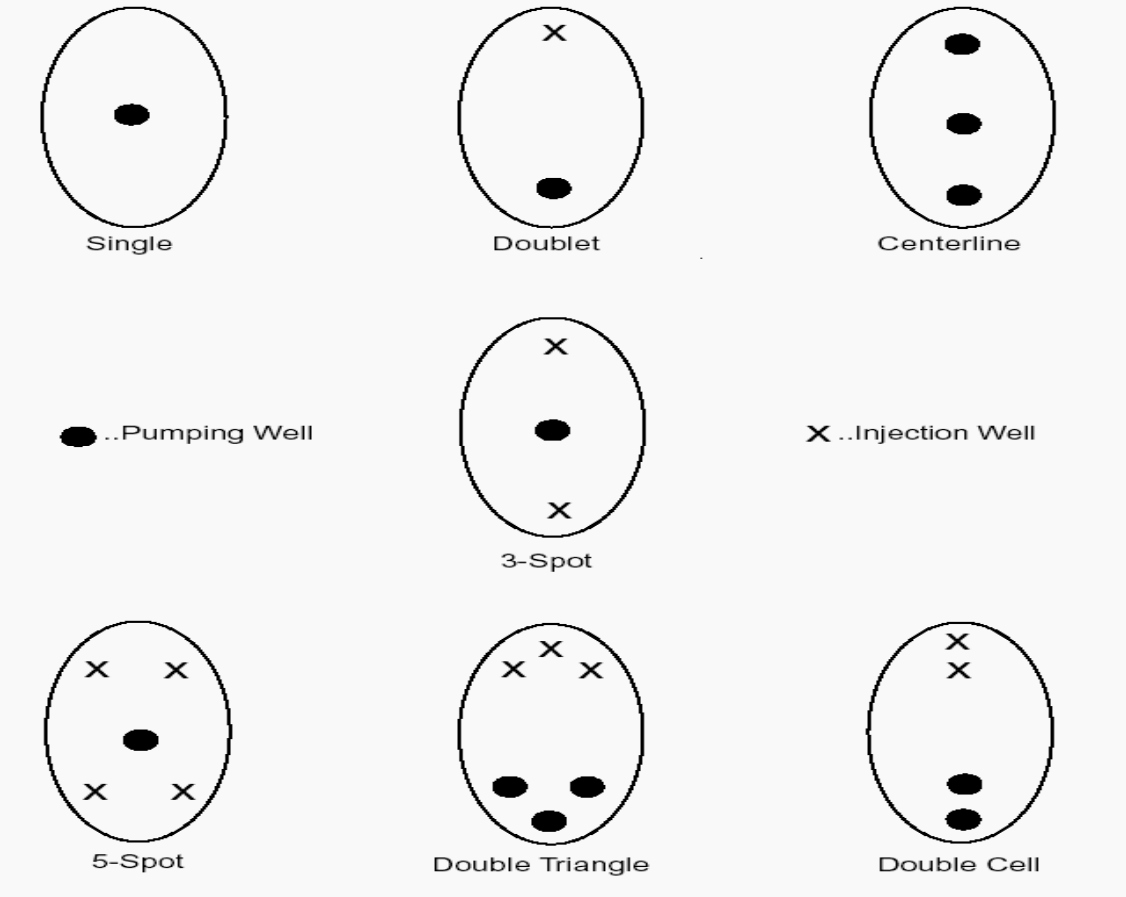
Pilot Test Objectives

- Maintainhydraulic control
- Achieve effective injection radius of influence
- Improve LNAPL recovery
- Assesspotential mass recoveryforfullscale design

Pilot Test Approach

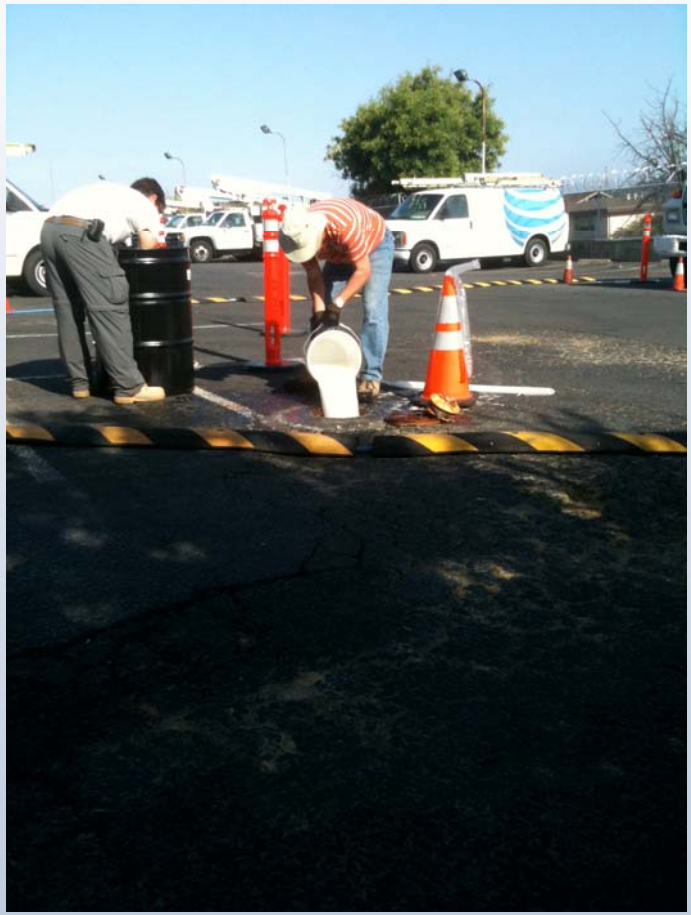
- Ivey-Sol 103 pilot scale injection program undertaken over 120 hours (5-days) in July 2009;
- Four injection events with one injection well
- Five surrounding recovery and monitoring wells
- Mobile HVDPE system capable of 28 inch Hg vacuum and 800 SCFM; and

Five & Single Spot Pattern Used



Major types of pumping/injection well patterns (Satkin and Bedient, 1988).

On-Site Photos

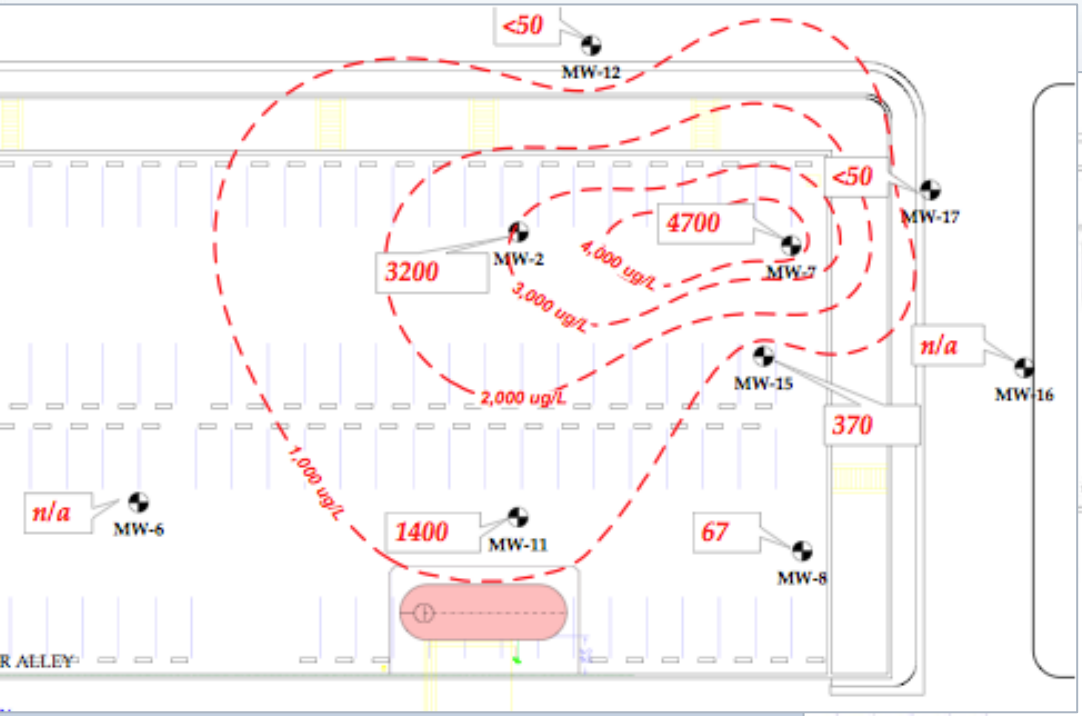


Outline

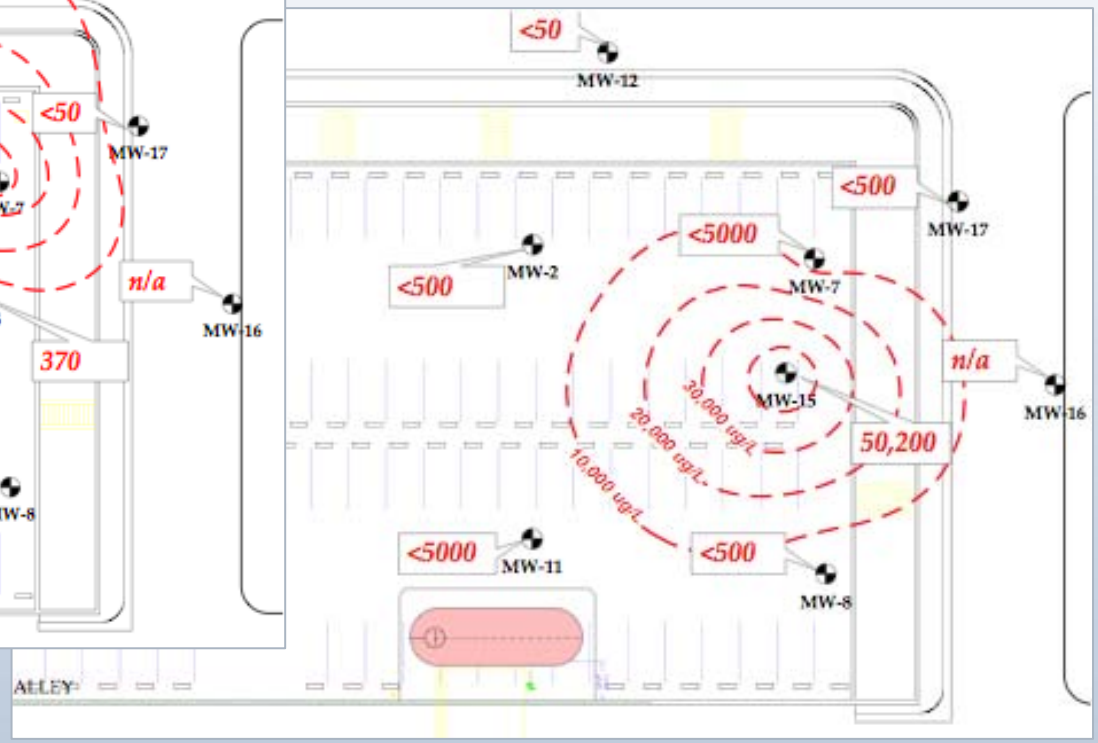
- High Vacuum Dual Phase Extraction
- Surfactant Chemistry
- Site Conditions and Pilot Test Approach
- Pilot Test Results
- Questions

Before and During Test

TPH-dIsocon Map before Pilot Test

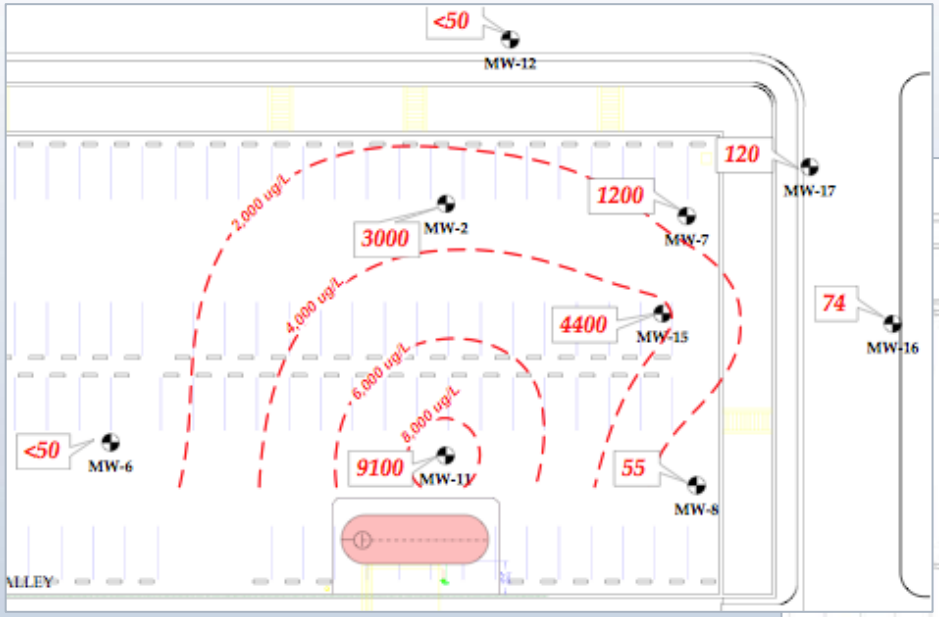


TPH-dIsocon Map 2 hrs after Pilot Test

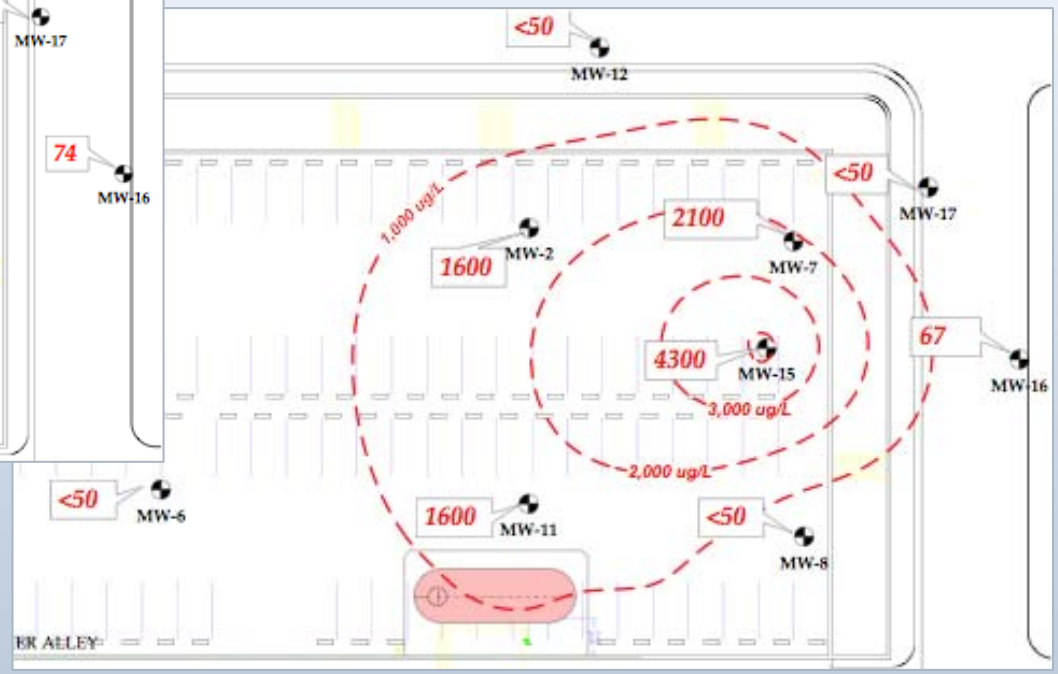


Post Pilot Test Results

TPH-d Isocon Map 1 Month after Pilot Test

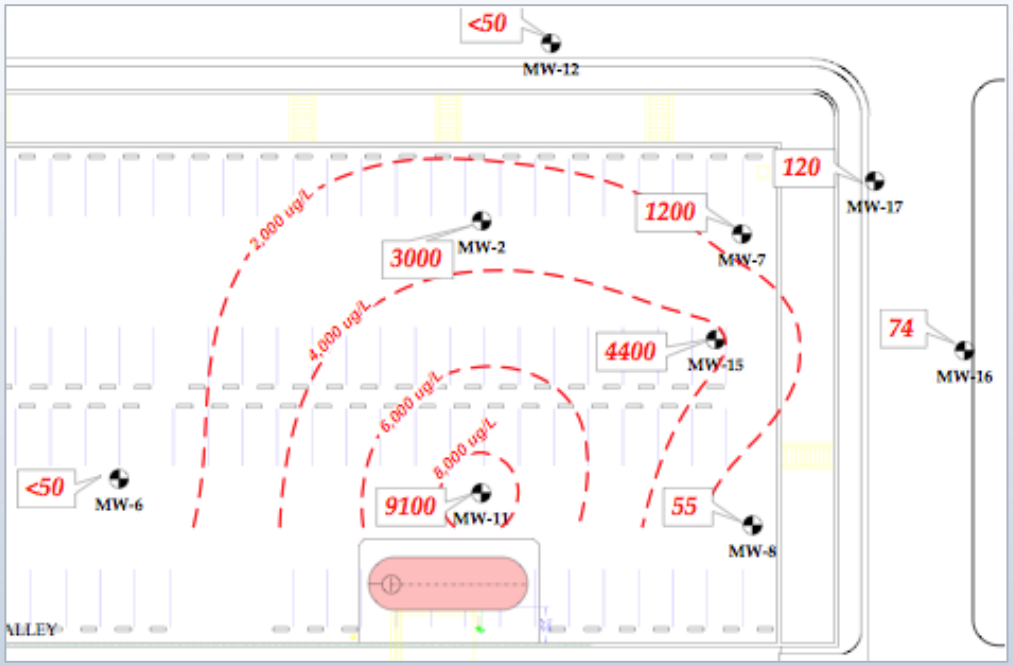


TPH-d Isocon Map 7 months after Pilot Test

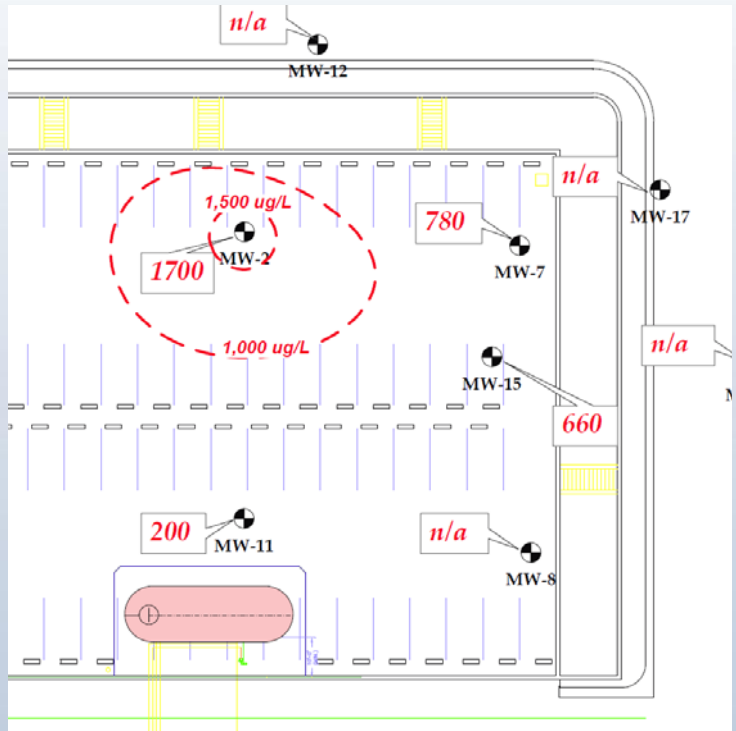


Post Pilot Test Results

TPH-d Isocon Map 1 Month after Pilot Test

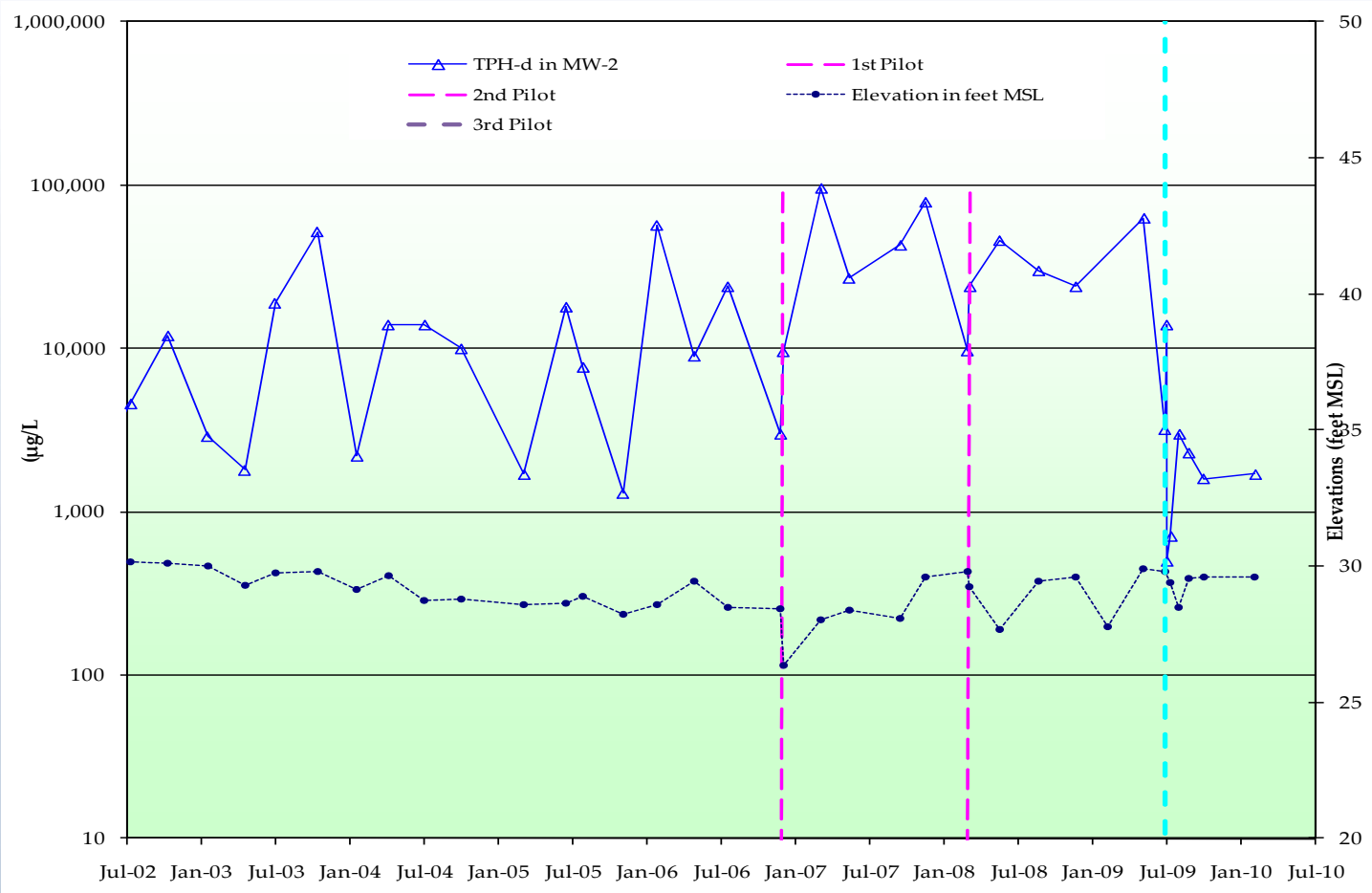


TPH-d Isocon Map 3 months after Pilot Test



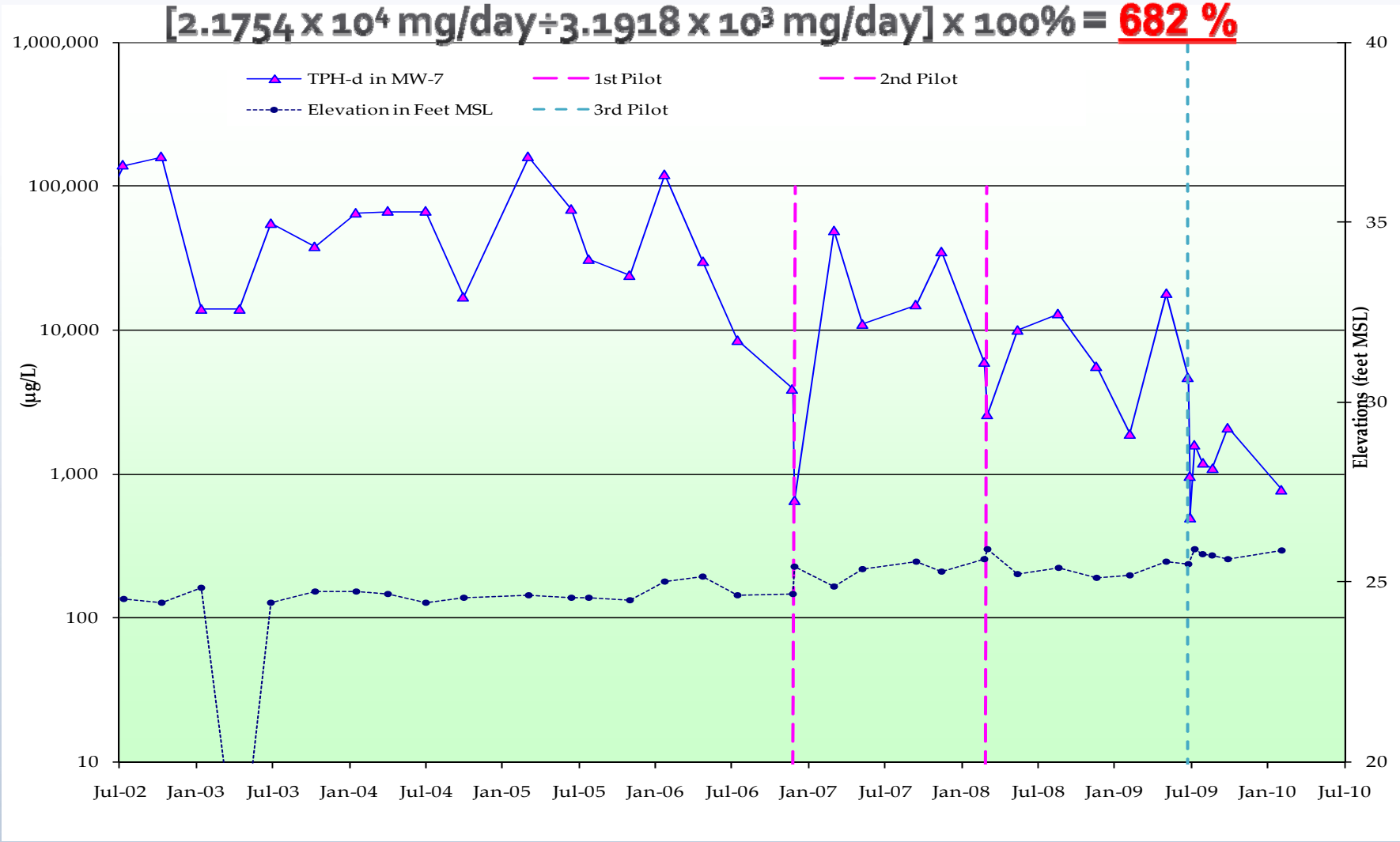
MW -2

$[9.169 \times 10^3 mg/day \div 1.5551 \times 10^3 mg/day] \times 100\% = \mathbf{590\ \%}$



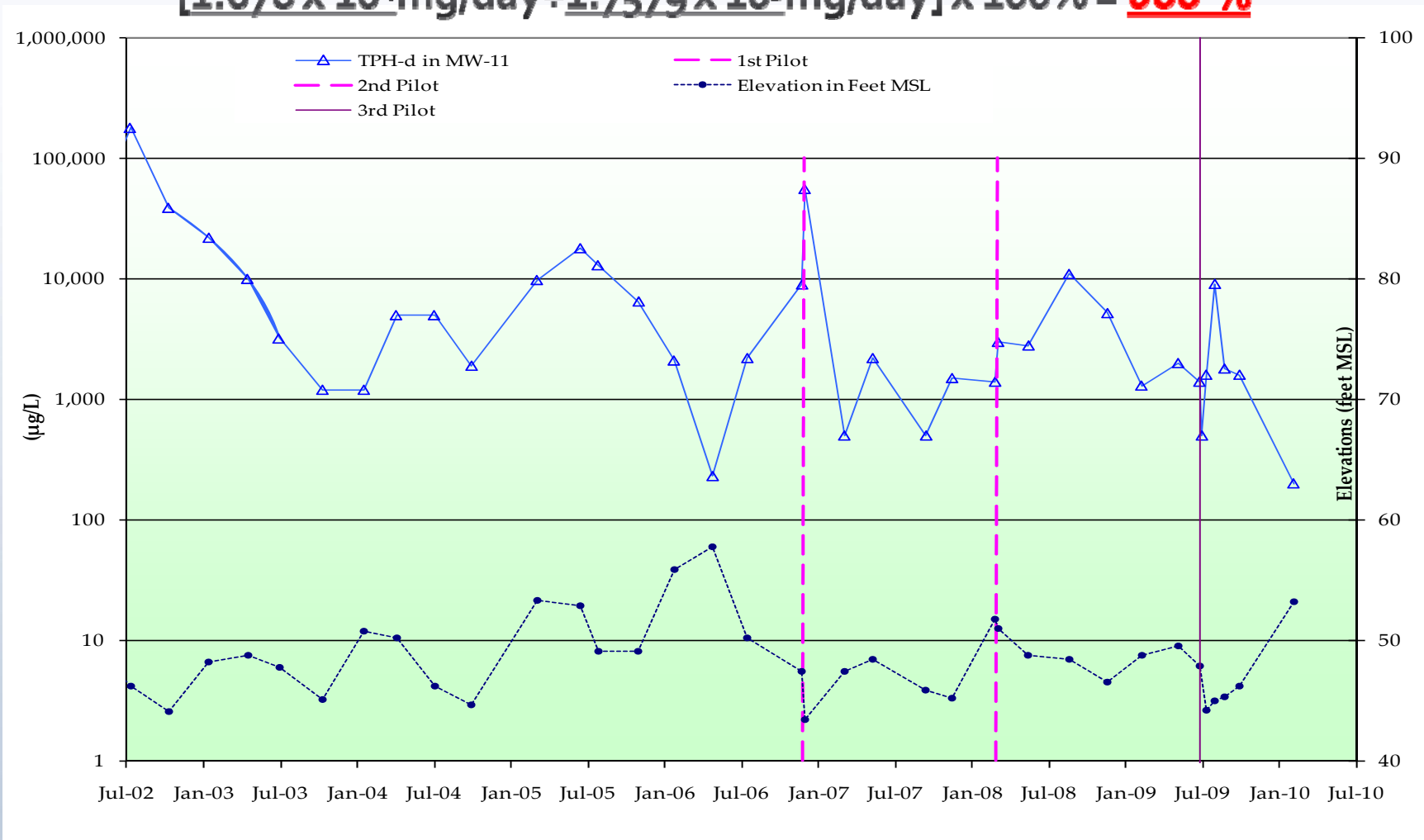
MW -7

$[2.1754 \times 10^4 \text{ mg/day} \div 3.1918 \times 10^3 \text{ mg/day}] \times 100\% = \underline{682\ \%}$



MW -11

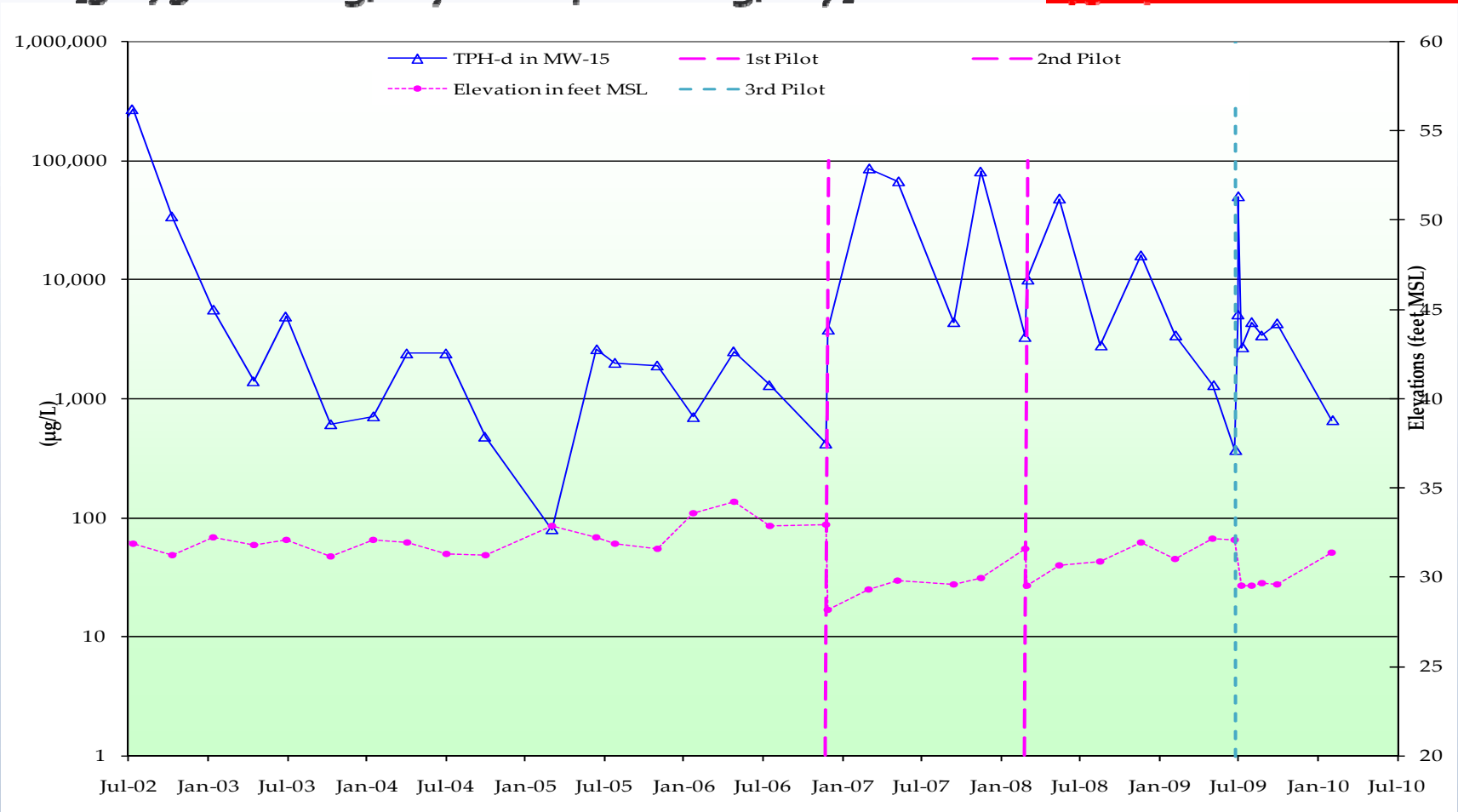
[1.678 x 10^4mg/day÷1.7579 x 10^3mg/day] x 100% = **955 %**



MW -15

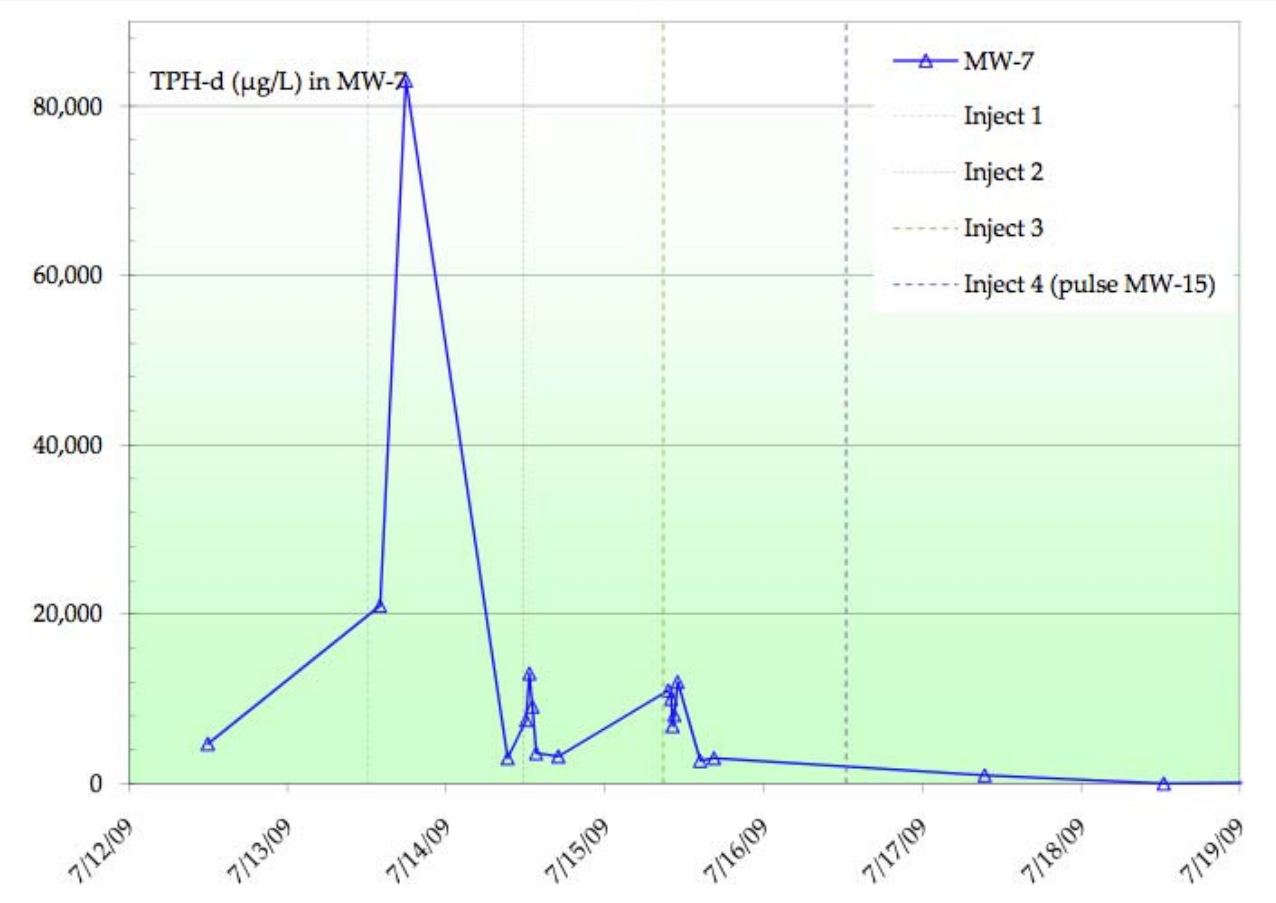
$[4.4107 \times 10^4 \text{ mg/day} \div 2.7603 \times 10^3 \text{ mg/day}] \times 100\% =$ **1,598 %** **Standard Pilot**

$[3.875 \times 10^4 \text{ mg/day} \div 2.014 \times 10^3 \text{ mg/day}] \times 100\% =$ **1,924 %** **Push-Pull** .

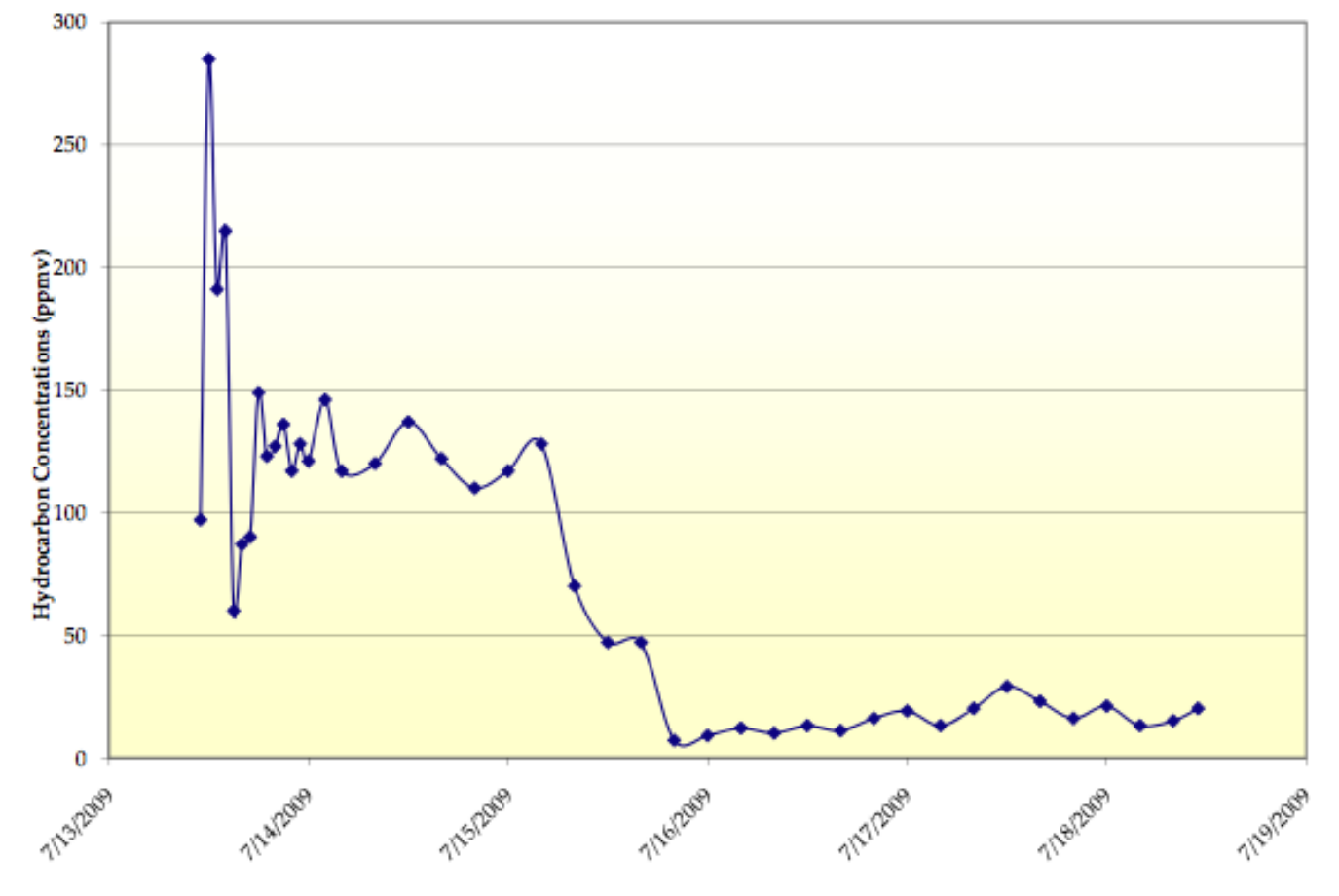


Radius of Influence

Response in MW-7 from injections in MW-15

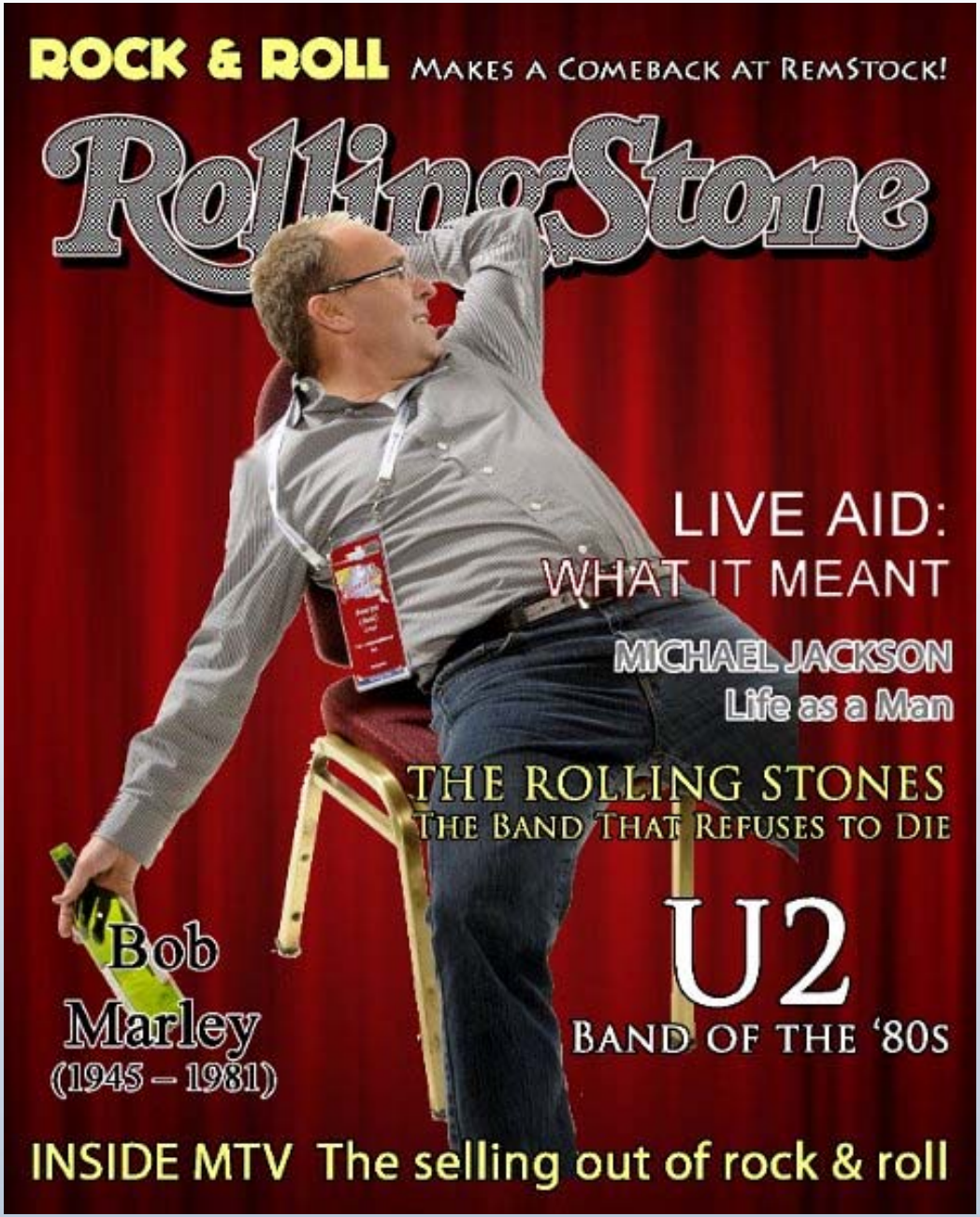


HVDPE Vapor Concentrations



Pilot Test Results Summary

- Hydraulic Control Achieved
- Increased TPH_d Recovery 590 to 924%!!!
  - **MW2** **590%**
  - **MW7** **682%**
  - **MW11** **955%**
  - **MW15** **1,598 to 1,924%**
- Obtained information for full scale design



Ivey International Inc.

"Today's Environmental Solutions For A Better Tomorrow"

George (Bud) Ivey, B.Sc, CES, CESA, P.Chem.
Senior Remediation Specialist

Direct:	**1.250.923.6326**
Toll Free:	**1.800.246.2744**
Email:	**budivey@iveyinternational.com**
WEB:	**www.iveyinternational.com**

Dr. Galen Kenoyer
Senior Hydrogeologist
RMT

Mobile:	**1.213.700.8704**
Email:	**Galen.Kenoyer@rmtinc.com**
Web:	**www.rmtinc.com**