Effective LNAPL and DNAPL Remediation Using Ivey-sol Surfactant Enhanced Remediation

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SESSION 6
LNAPL and Chlorinated Compounds Remediation
September 22, 2020

BAW
ENVIRONMENTAL ENGINEERING

REMTECH EXPO

IVEY-SOL®
Surfactant Technology
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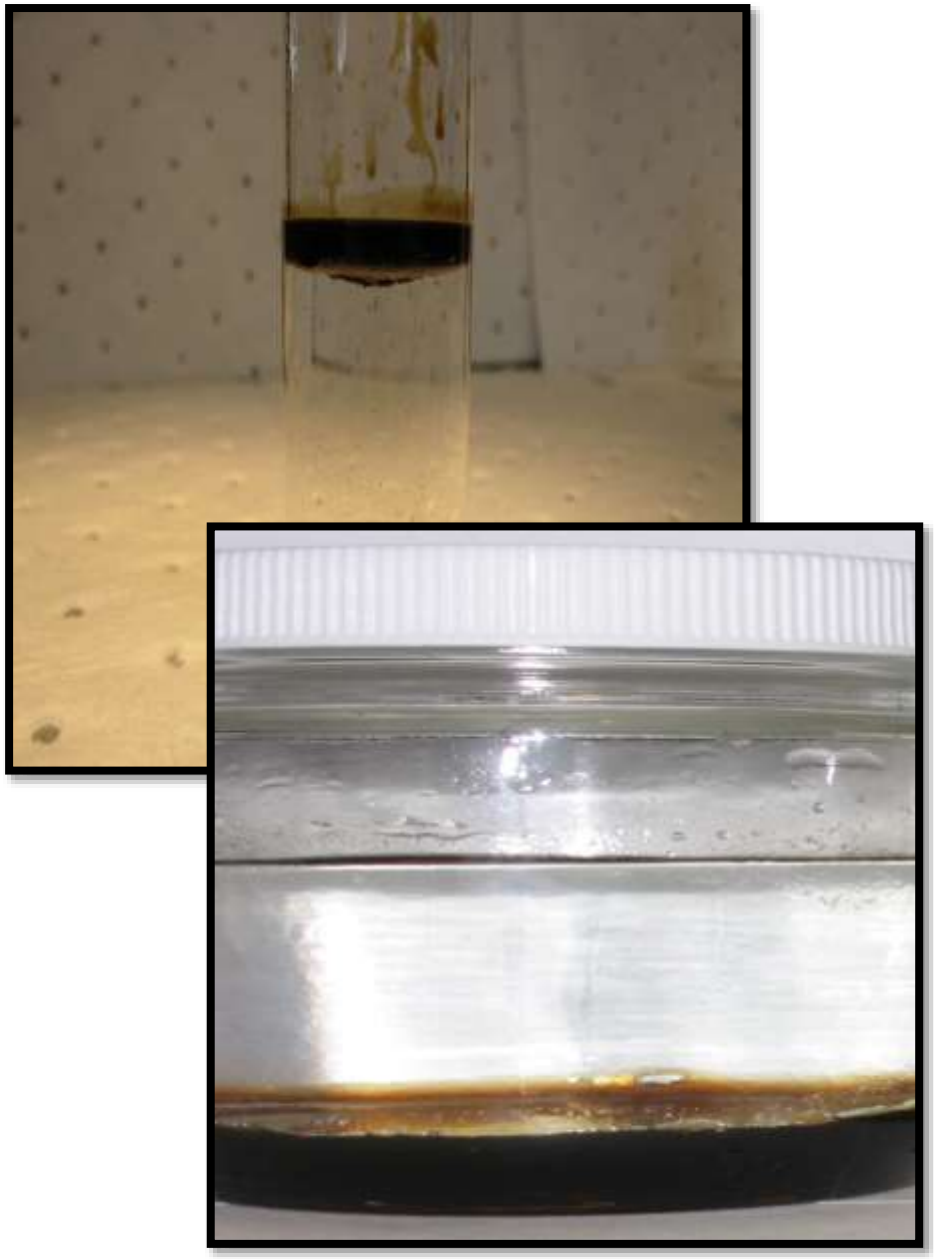
NAPL LNAPL DNAPL PSH Free Product

Non-aqueous phase liquids (NAPL) that do not dissolve in or mix with water (hydrophobic). Like gasoline and diesel petroleum products, and chlorinated solvents. NAPL contaminates soil, groundwater, and can generate vapor intrusion.

Light NAPL [LNAPL] have a lower density than water so they will tend to float on the groundwater table.

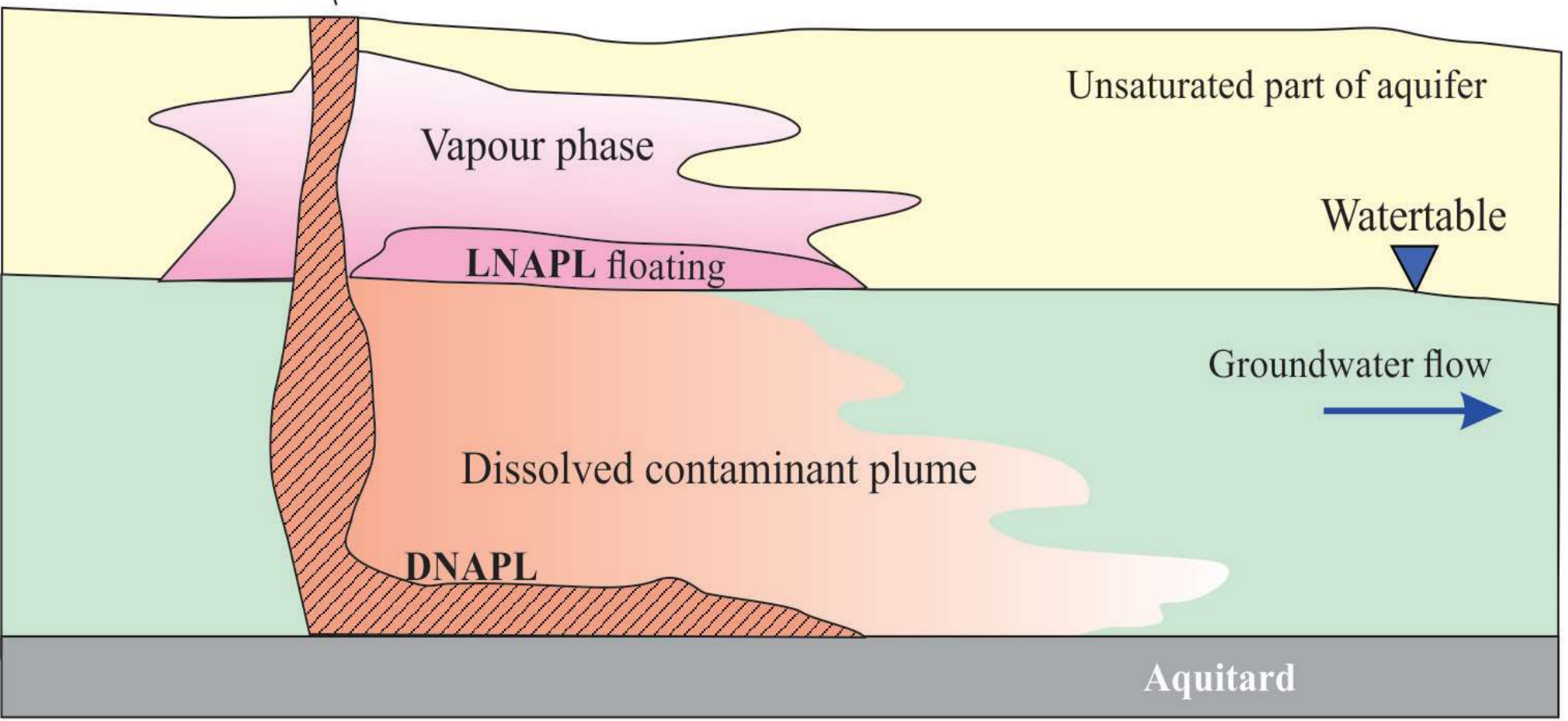
Dense NAPL [DNAPL] are denser than water so will tend to sink below groundwater table.

NAPLs are immiscible so do not dissolve in groundwater. They can become trapped in pore spaces (*interfacial tension → pathway interference*) and sorb to surfaces - limiting availability for physical, biological and chemical remediation.



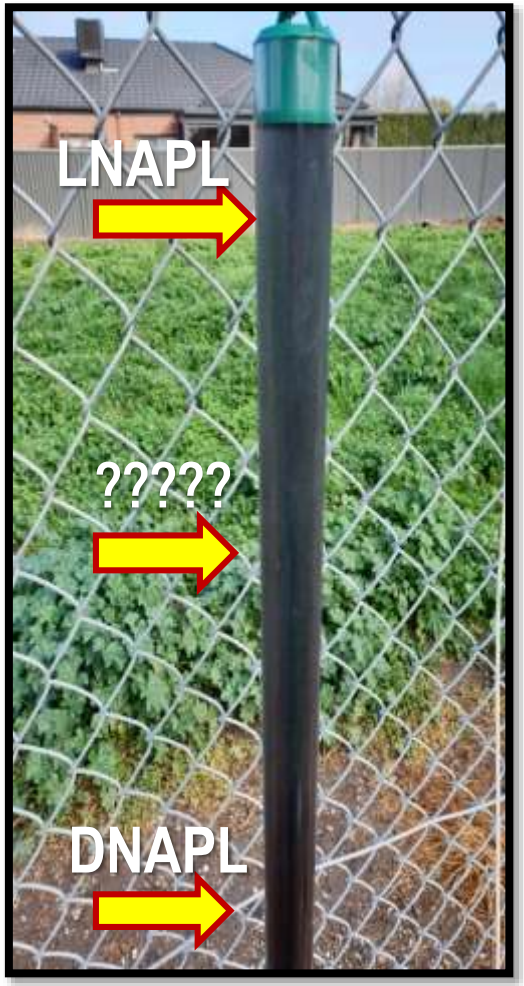
LNAPL = Light non-aqueous phase liquid (e.g. petroleum, benzene)
pronounced 'ell napple'

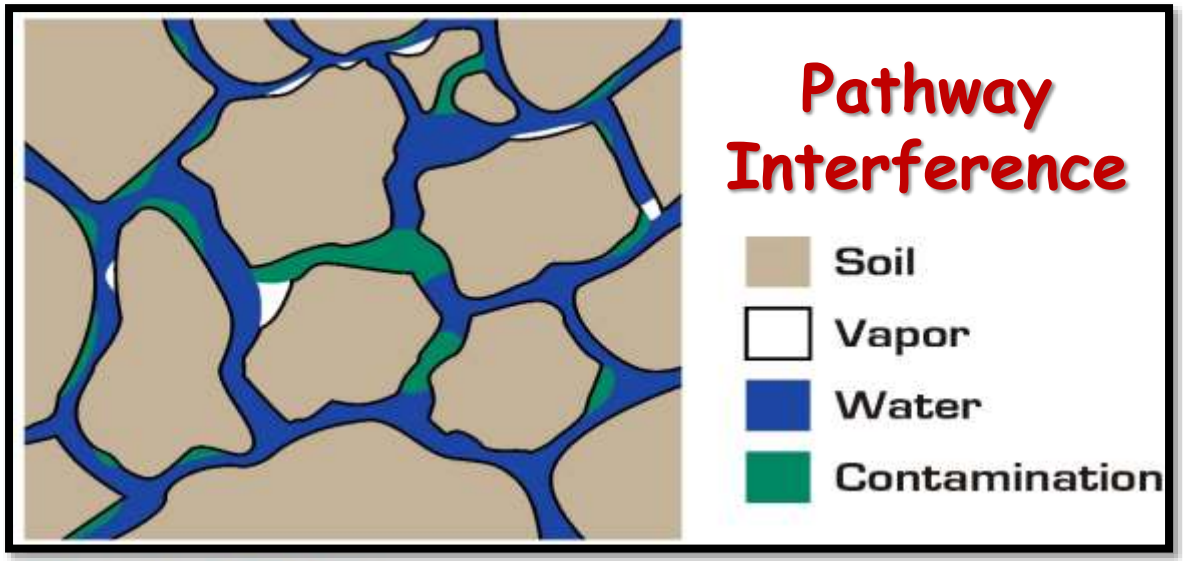
DNAPL = Dense non-aqueous phase liquid (e.g. coal tar, creosote
Trichlorethylene (solvent))
pronounced 'dee napple'

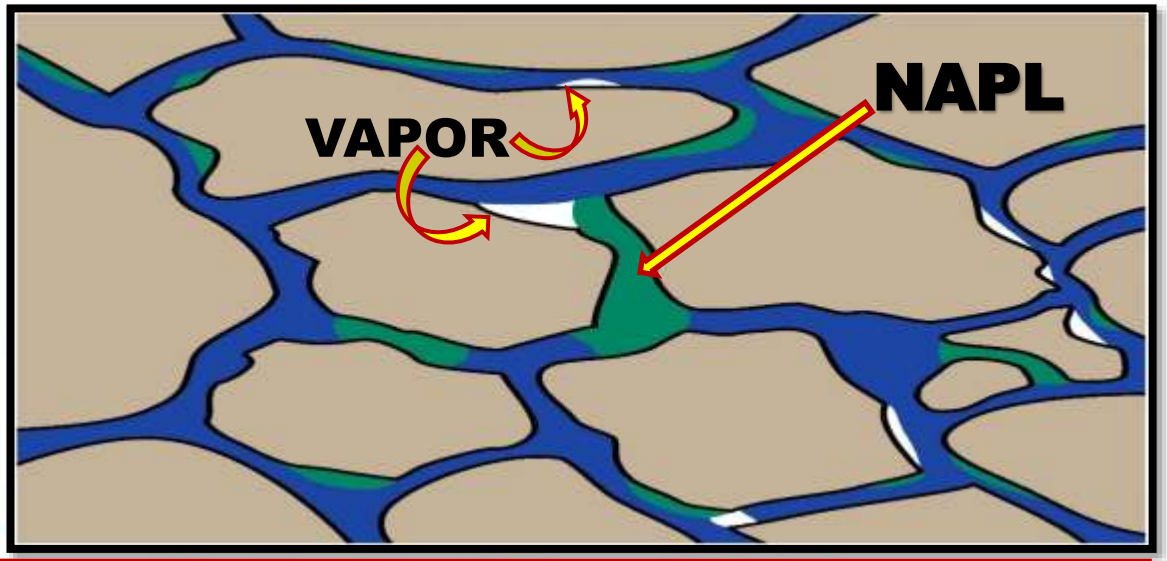


Organic contaminants, like petroleum fuels and solvents may be present as a free liquid, dissolved liquid (in water) and as vapour

Sources: UST, AST, Pipelines, Surface Spills, Truck Rollovers, Sabotage, Off-shore Spills, etc.







Mobile NAPL

NAPL body is continuous and its capillary pressure is high enough to exceed groundwater pore entry pressure, displace groundwater, and migrate through the subsurface.

Potentially Mobile NAPL

NAPL body is continuous, but its capillary pressure is not high enough to exceed groundwater pore entry pressure; under current conditions, it will not displace groundwater and migrate. If conditions change (for example, drilling through a potentially mobile DNAPL body, soil fracturing), potentially mobile DNAPL may mobilize and begin migrating.

Immobile Residual Phase NAPL

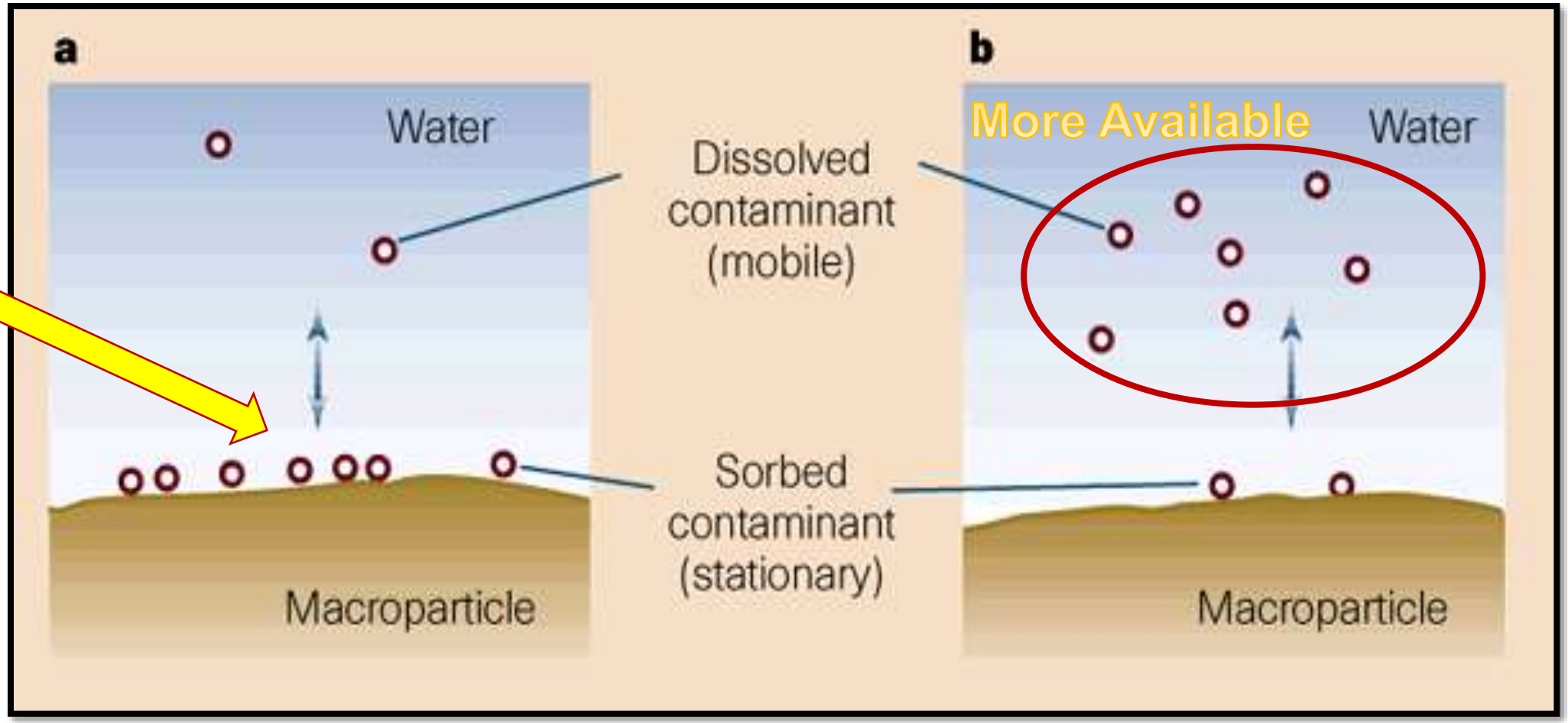
"Droplets" of NAPL called ganglia are present in the pore spaces but are not connected to other NAPL ganglia. They are immobile because they cannot exceed the capillary pressure and displace groundwater in the formation.

Interfacial Tension (dynes/cm) is the force that holds the surface of a particular phase together, and exists when two phases: gas/oil, oil/water, or gas/water come in contact. Interfacial tension can immobilize (trap) LNAPL and DNAPL within pore spaces → source of mass-flux = contamination rebound!

SORPTION

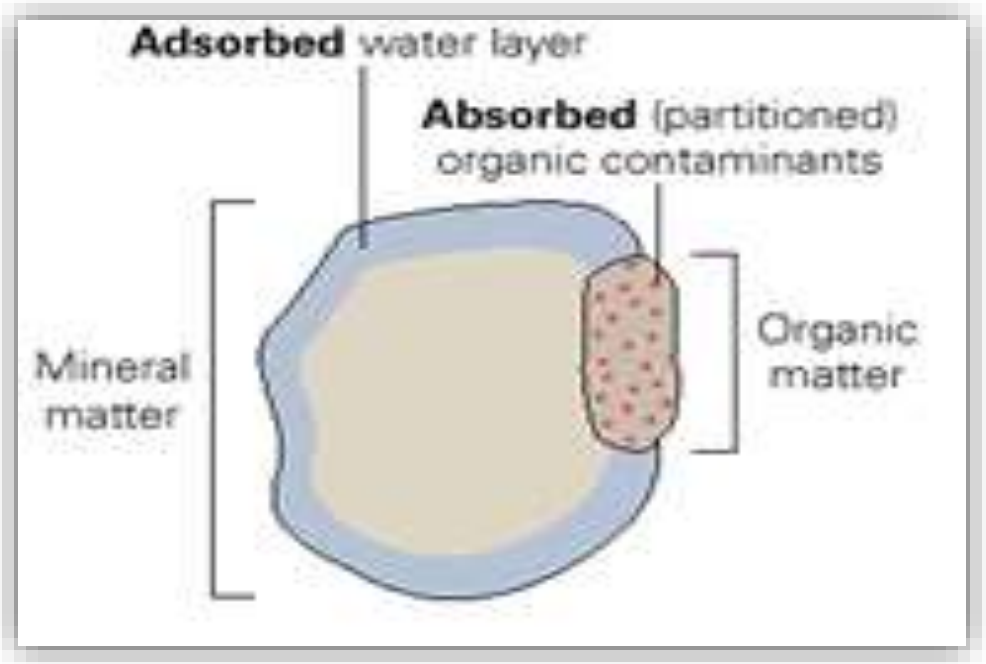
Hydrophobic organic chemicals exhibit limited solubility in groundwater. As a result the contaminants (Vapors, Dissolved, Sorbed, or NAPL) *Phase Partition* and sorb (i.e., absorb and adsorb) onto the soil surfaces or form NAPL (Globules or Layers). Contaminant Sorption & NAPL negatively effects Availability for Remediation.

Sorbed or NAPL Phase Globules With Limited Availability For Remediation



Sorption or NAPL Formation Limits Contamination Availability For All Forms of Remediation

Ivey-sol Overcomes This Limitation To Improve Their Remediation!



As a result, they are:

- **Less *'Physically Available'* for Multi-Phase Extraction (MPE), Pump & Treatment, and Soil Washing;**
- **Less *'Biologically Available'* for Bioremediation (Aerobic or Anaerobic), and**
- **Less *'Chemically Available'* for Chemical Oxidation or Reduction**

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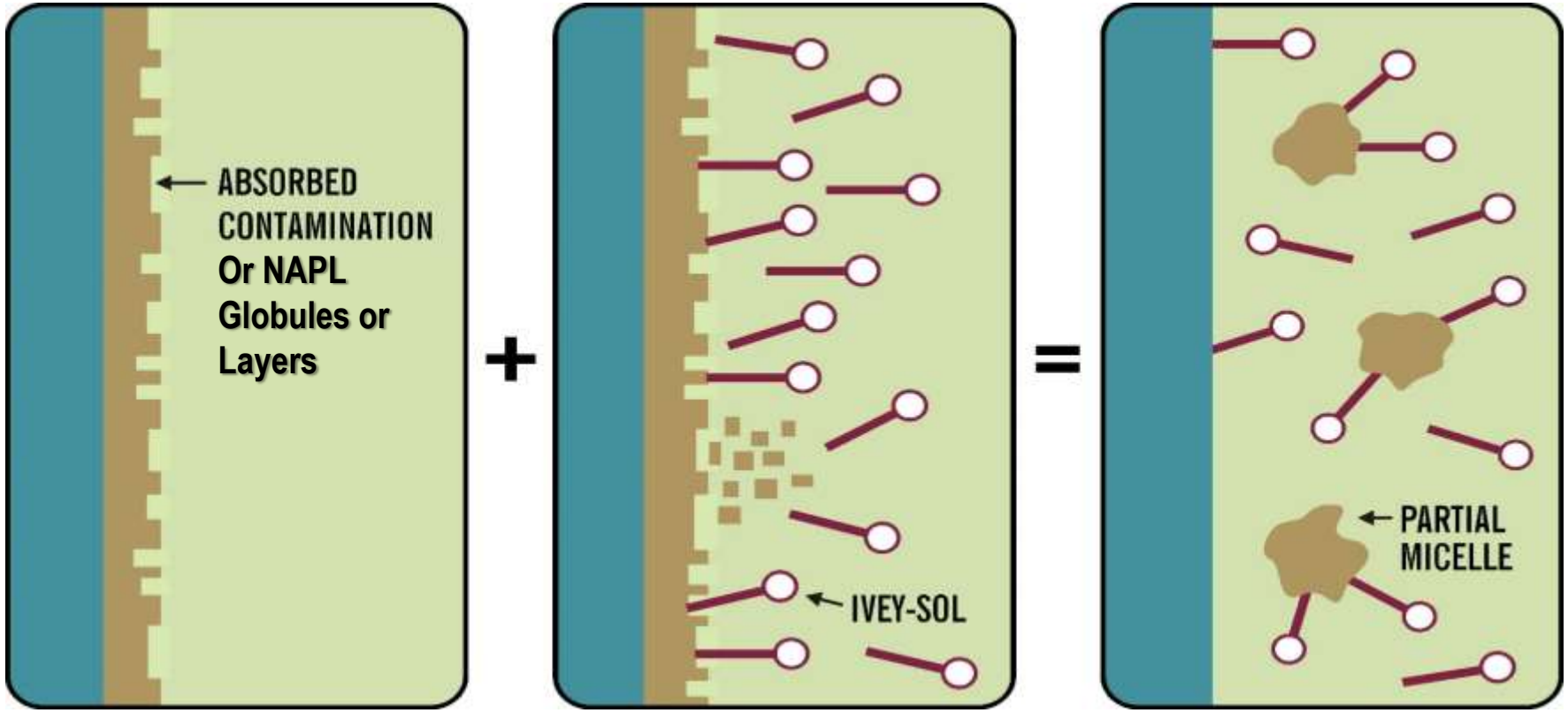
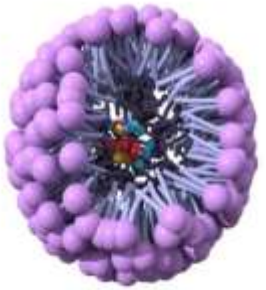




How >99% of all other surfactants work by encapsulating the contaminants hindering their 'Availability' for remediation.

Ivey-sol® mechanism is selective and works below the CMC

Increasing Physical, Biological and Chemical Availability For Enhanced Remediation

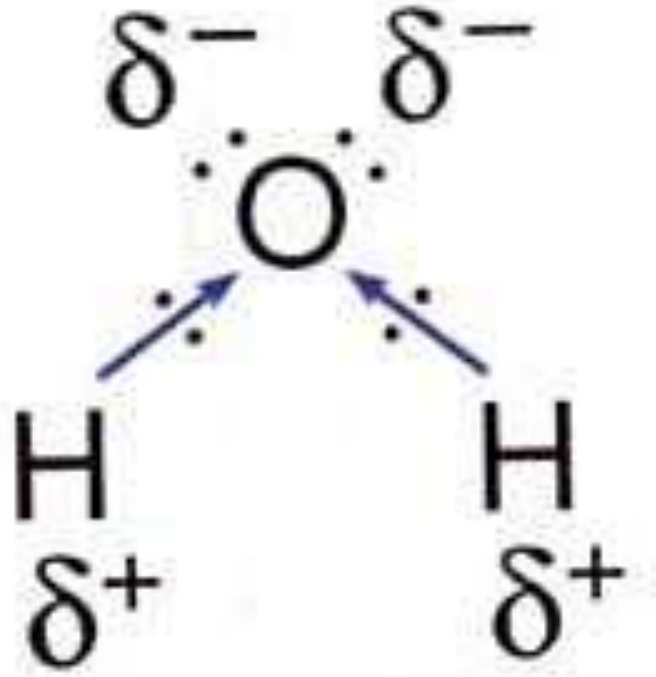
Biodegradable, pH Neutral, Non-toxic, Effective For Treating Broad Ranges of Contamination

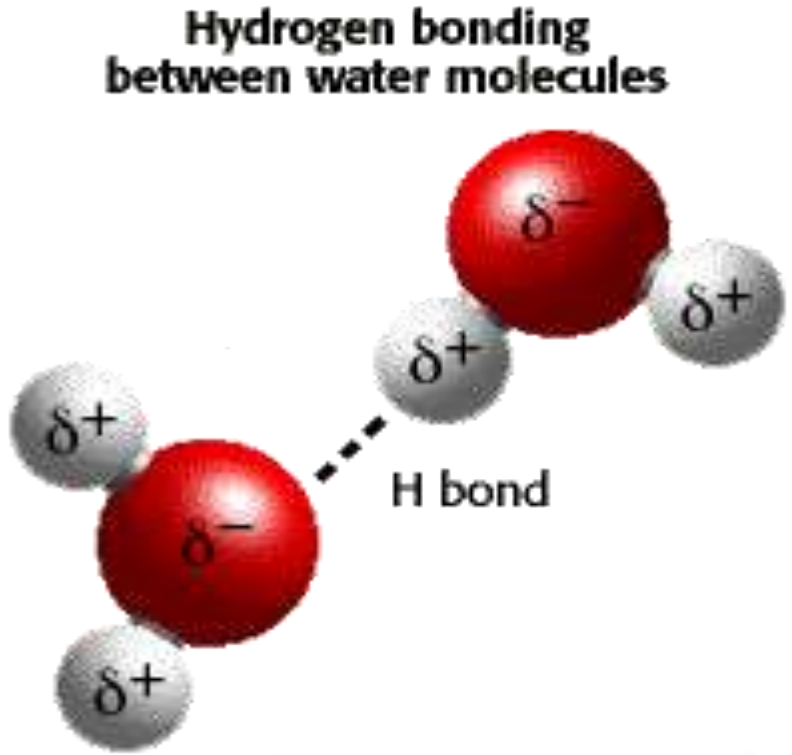
(Peer Reviewed Journal Paper Available On Request Available)

Water Beading On Fine Sand

Ivey-sol® Also Overcomes Surface Tension of Water

Hydrogen Bonding

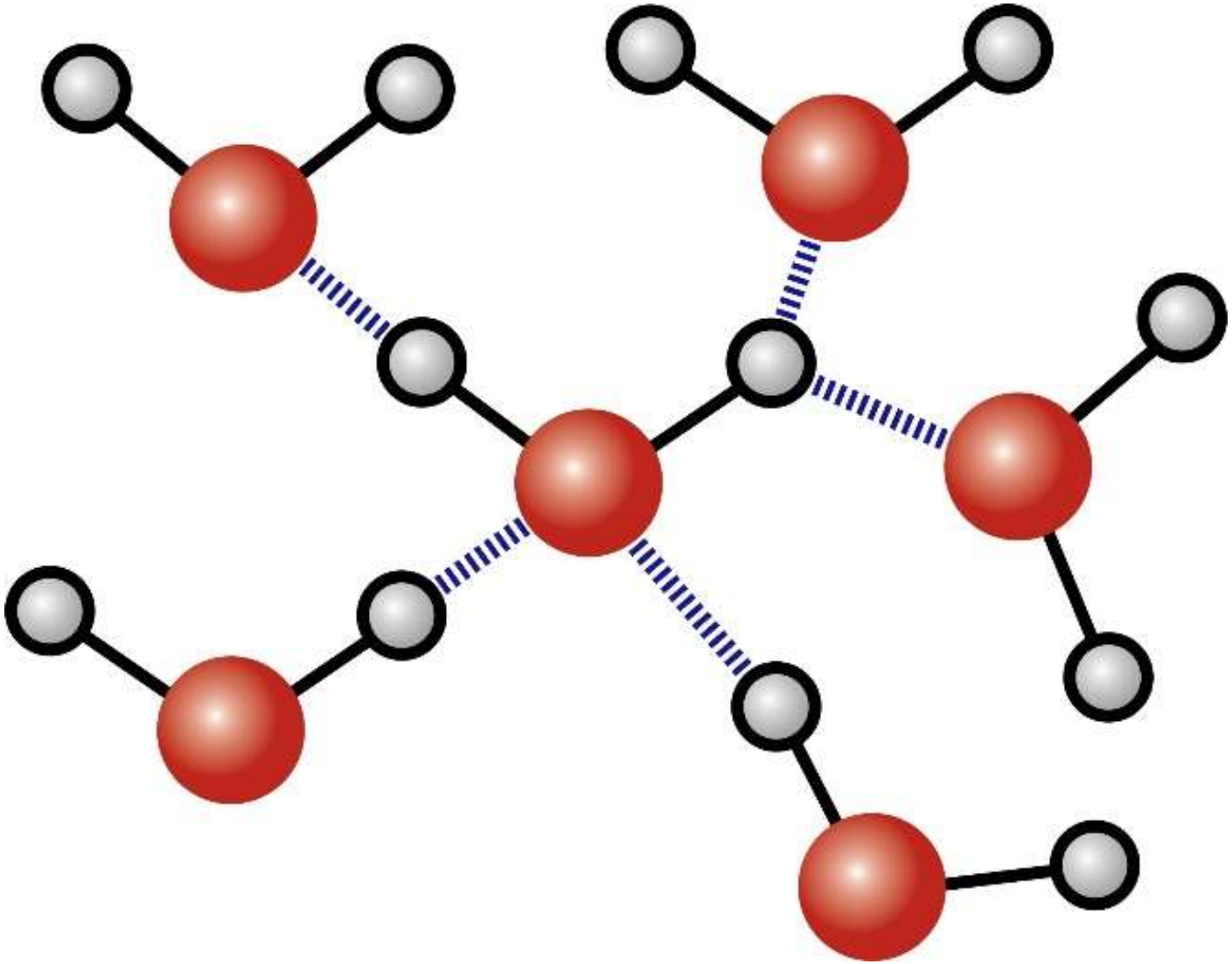




Oxygen (O) on one water molecule is attracted to Hydrogen (H) on neighboring water molecule - giving rise to *Hydrogen-Bonding.*

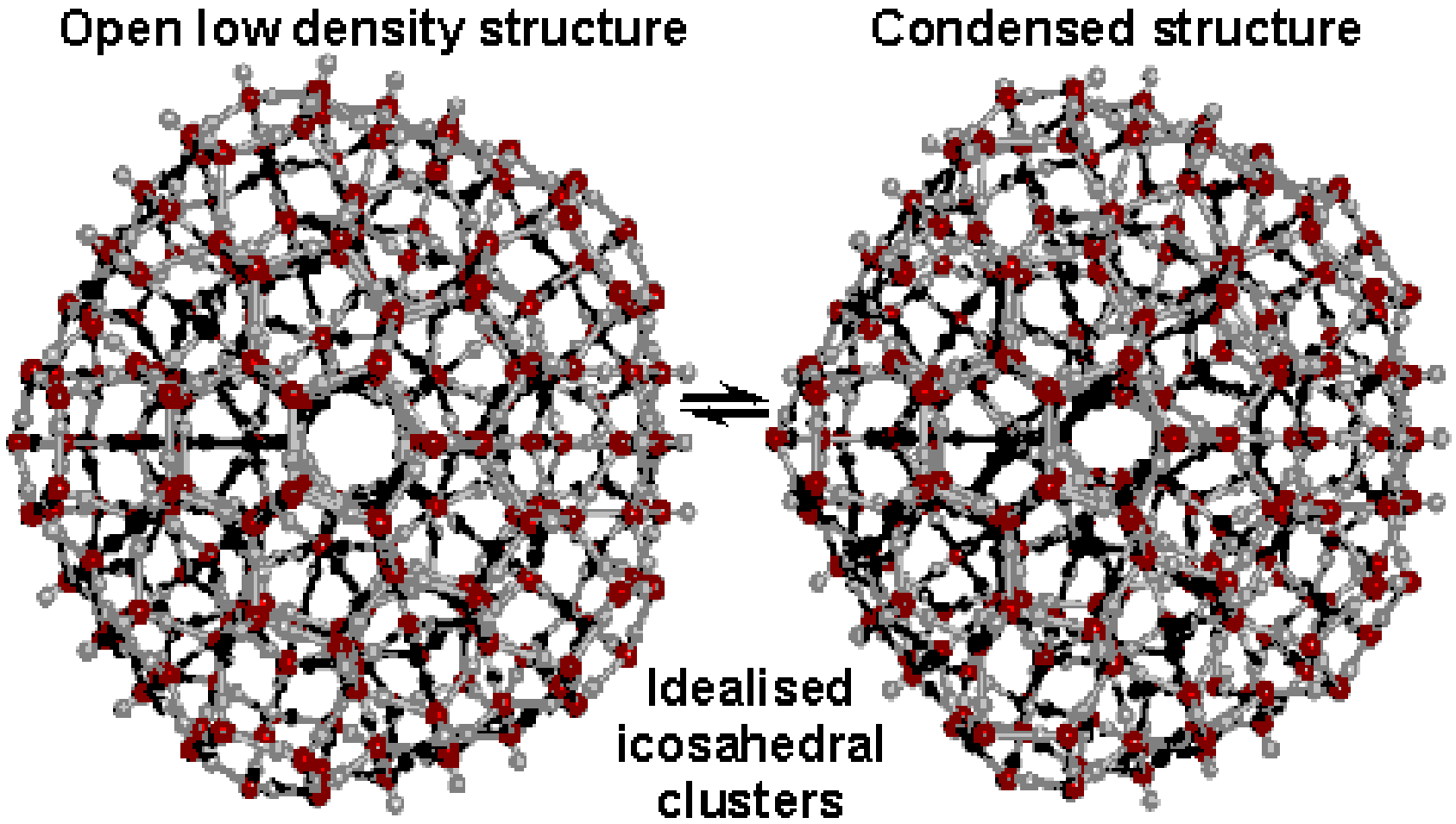
FACT: **Oxygen (O) is more electronegative than Hydrogen (H) Yielding its Polarity Analogous to behaving like magnets.**

Hydrogen Bonding Expanded



Water Is A 3-Dimensional '*Cluster*' - With Surface Tension of 73 Dynes
Water Cluster Size Limits (K) It's Ability To Move In Finer Texture Geology

Ivey-sol® Makes Water Clusters Smaller So Enter And Move More Easily Through Finer Grain Soils *(Lower Surface Tension < 30 Dynes)*

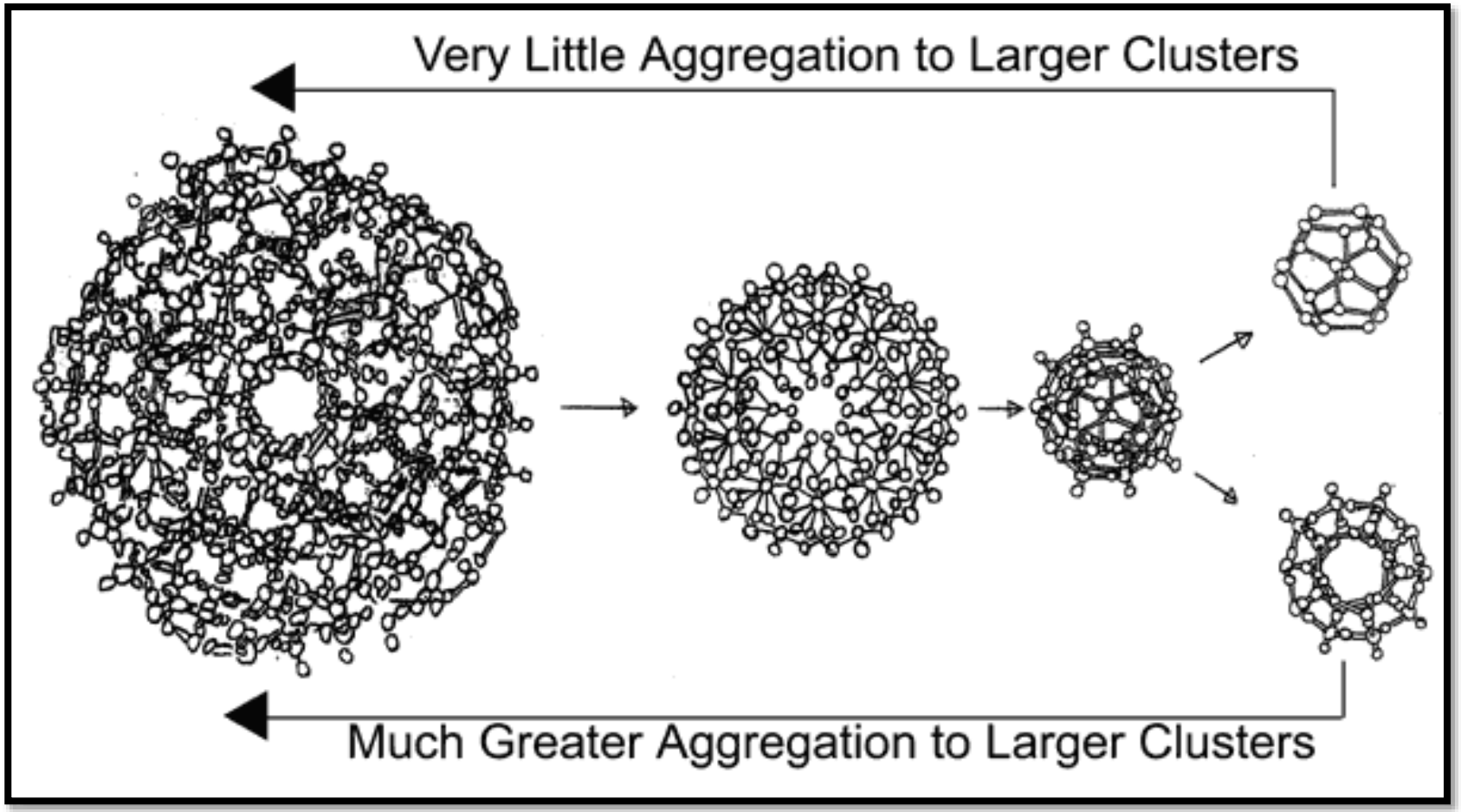


Ivey-sol Reduces The Size of Water Clusters

(Lower Surface Tension from 73 Dynes to < 30 dynes)

Allowing Access & Regress within Finer Grain Soil Textures

Temporarily Improving K



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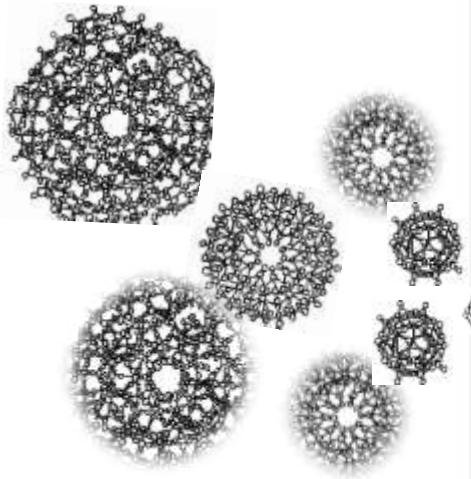
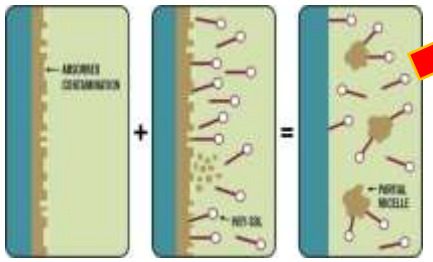
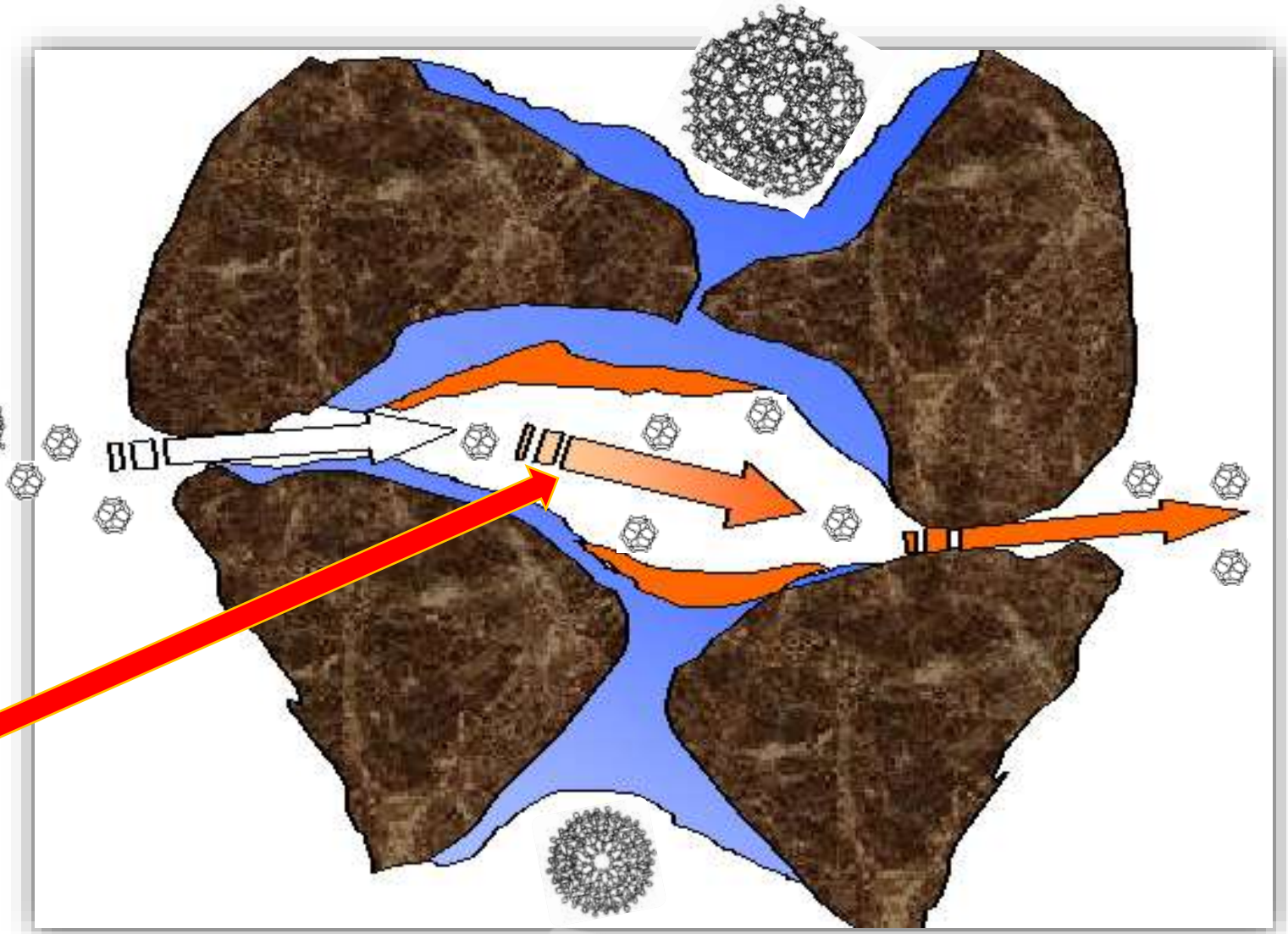
Ivey-sol Overcomes Low K and Retardation In Finer Grain Soil Improving Access, Regress, and Remediation

ACCESS







Interfacial Tension Will Effect NAPL Behaviors

More Available (Physio-Bio-Chem)

REGRESS

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3 Dimensional Animations

In-situ '*Push-Pull*' Ivey-sol® Application Options

Link For PDF Version To See Ivey-sol Animations:

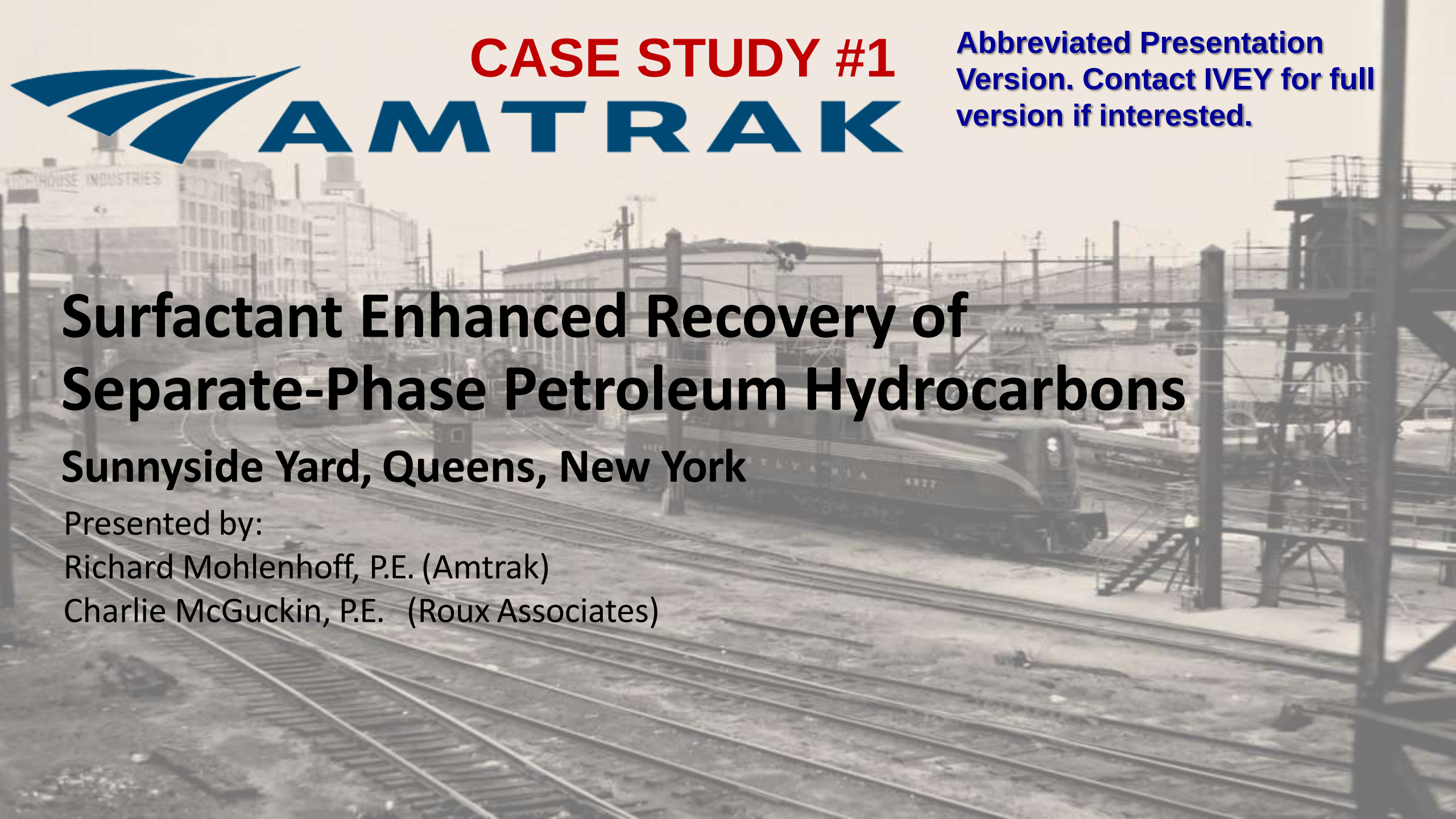
http://www.iveyinternational.com/videopresentation

Ivey-sol® Injection and Diffusion Radius

CASE STUDY #1

AMTRAK

Abbreviated Presentation Version. Contact IVEY for full version if interested.



Surfactant Enhanced Recovery of Separate-Phase Petroleum Hydrocarbons

Sunnyside Yard, Queens, New York

Presented by:
Richard Mohlenhoff, P.E. (Amtrak)
Charlie McGuckin, P.E. (Roux Associates)

Site History

- Located in Sunnyside Yard, Queens, New York
- Over 100 years of service
- State Superfund Site
- Six Operable Units (OUs)
- 130 acre Site
- OU-3 LNAPL and PCB Plume

ROUX

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OU-3 Record of Decision

Cleanup Standards:

- PCBs < 25ppm {Bench Scale Testing Confirmed Ivey-sol Would Not Mobilize!}
- Lead < 3,900 ppm
- cPAHs < 25 ppm {Total of 7 compounds}
- SVOCs < 500 ppm
- LNAPL < 0.1 foot

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Dual Phase Vacuum Extraction (DPVE) ~ MPE System

June 2013

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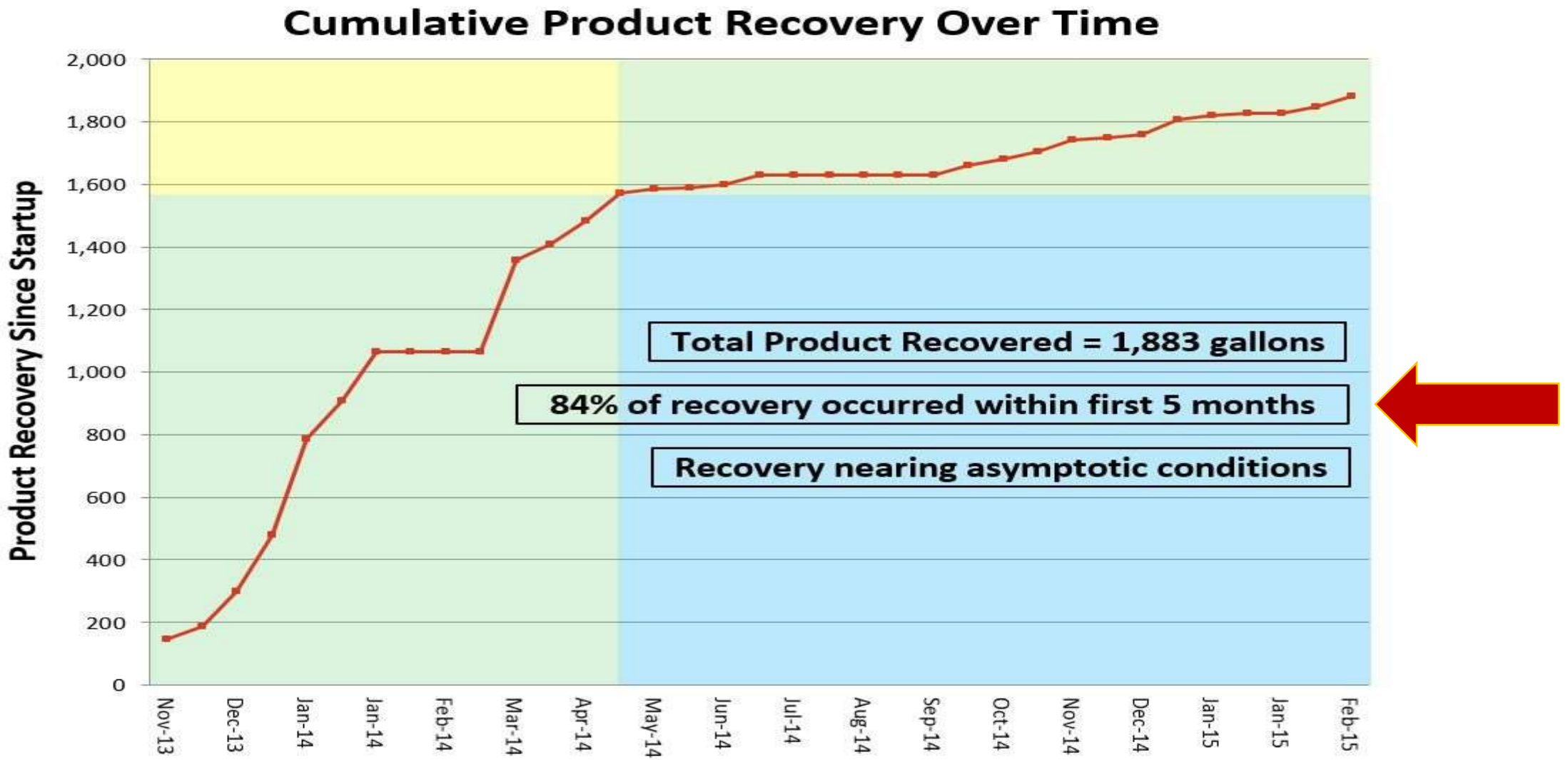
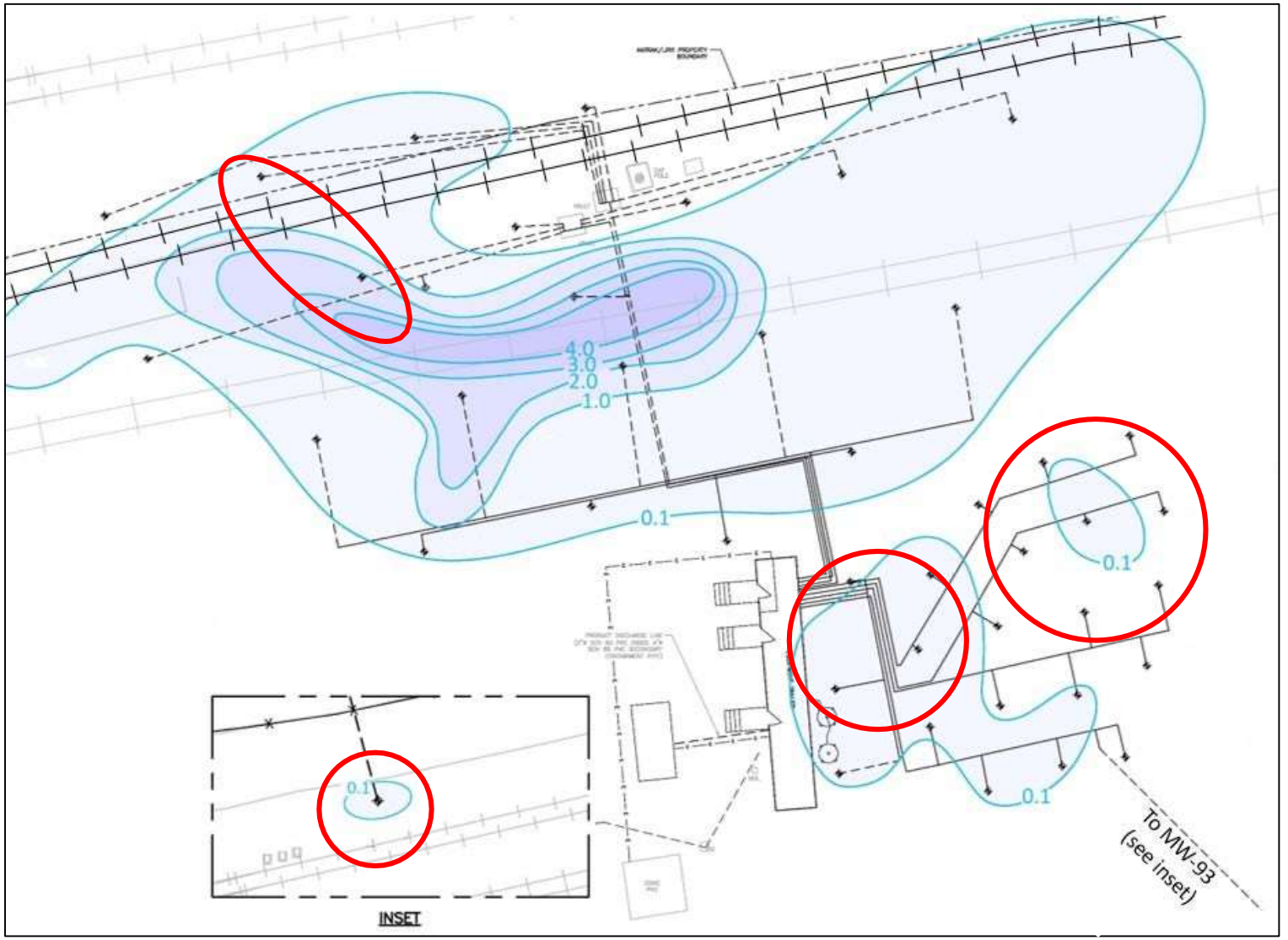
DPVE (MPE) System Performance



Injection Areas (8 LNAPL Wells)

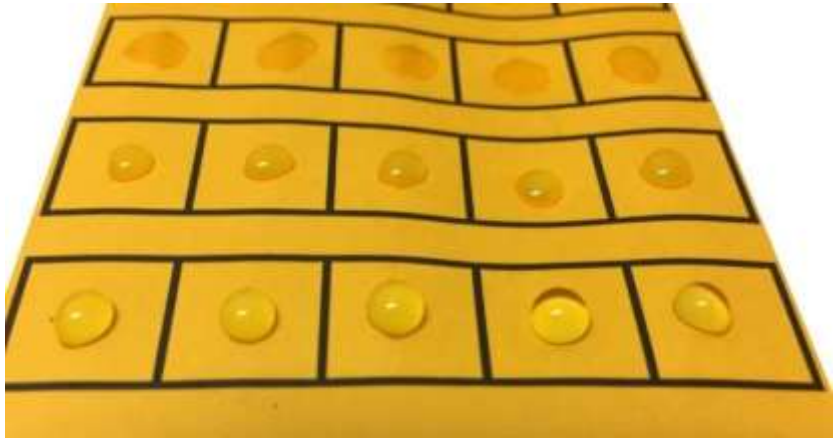


Pilot Study Methods

I. Injection (gravity feed/geoprobe)
   - ➢ Experimented with surfactant to water ratios (1:20-1:50)
   - ➢ Experimented with volumes of total mixture

II. Extraction (DPVE system)
   - ➢ Removed at least 1.5 to 3x the injection volume
   - ➢ Continued extraction until no surfactant was present

III. Extract from injection point (Push-Pull) or at a nearby extraction well (Sweep) Applications



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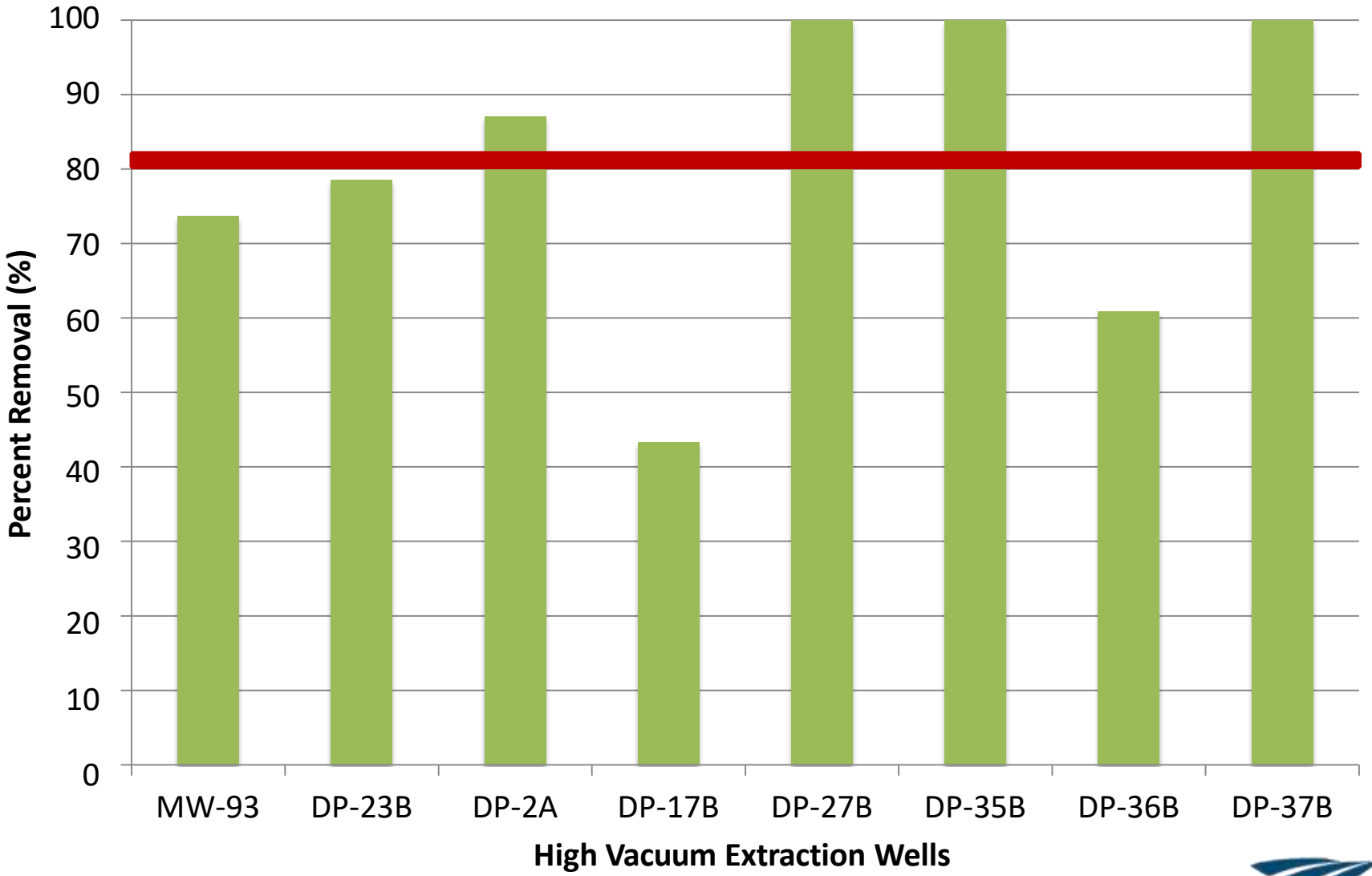
Free Product (LNAPL) Percent Removal
3 Applications in 1 week

81% Average LNAPL Mass Removal



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Conclusions

- LNAPL recovery was enhanced by the increase of SPH solubility
- Free product was not observed in the extracted groundwater
- Reduction of LNAPL thickness was usually observed within 24 hours of surfactant injection and persisted for several weeks or longer
- Low concentration ratios of surfactant (1:50) are effective and higher concentrations do not increase effectiveness
- Low injection volumes or injection rates were generally needed in OU-3 due to the low permeability soil conditions and high groundwater table

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The annual listing of 10 companies that are at the forefront of providing Environmental Technology solutions and transforming businesses

Ivey-sol Technology Representatives In Europe

CONTACT INFORMATION

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