High-Resolution Site Characterization Methods and Applications for Evaluating LNAPL and Dissolved-Phase Plume Stability

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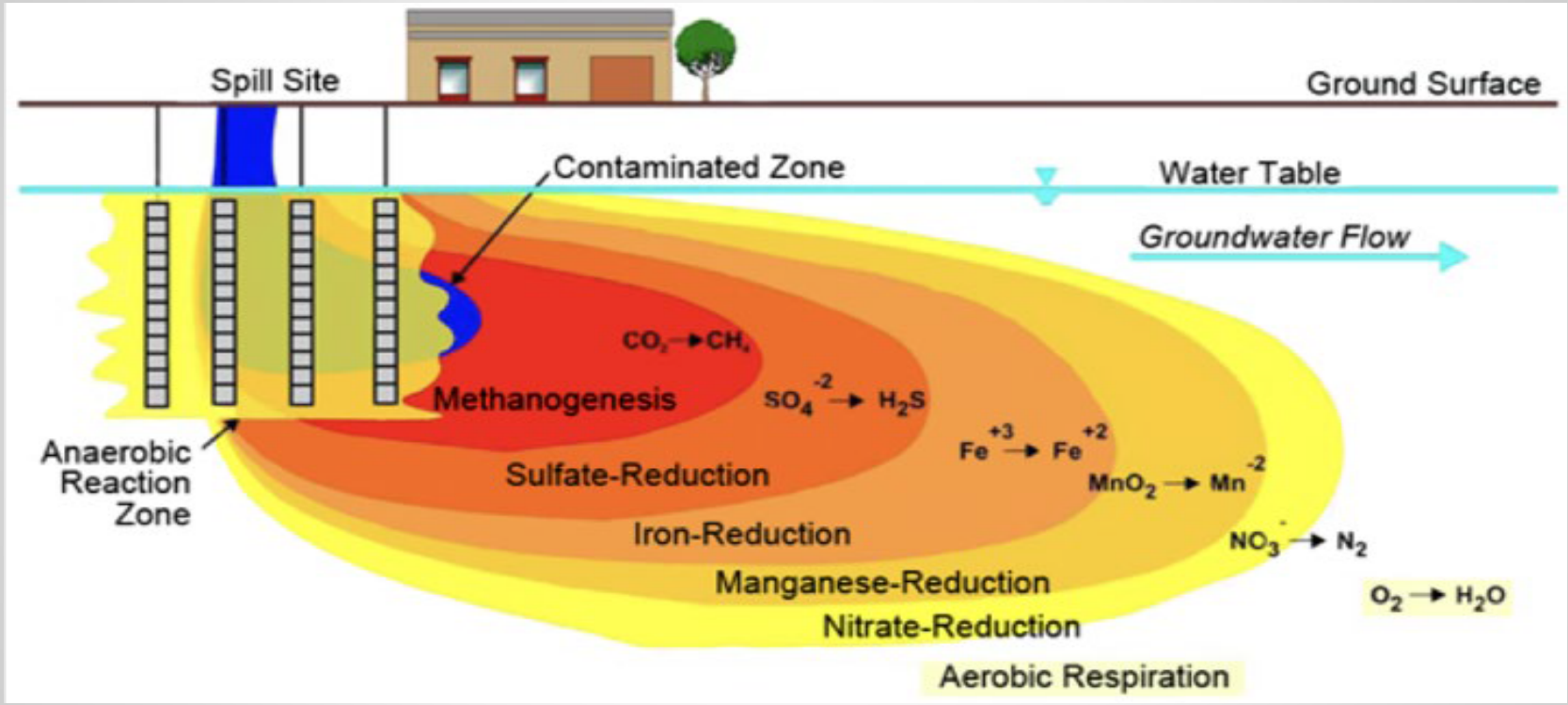
"Think and restore, *sustainably*"

THE PURPOSE

Highlight the role of methods & HRSC tools for evaluating LNAPL and dissolved-phase plume attenuation/stability



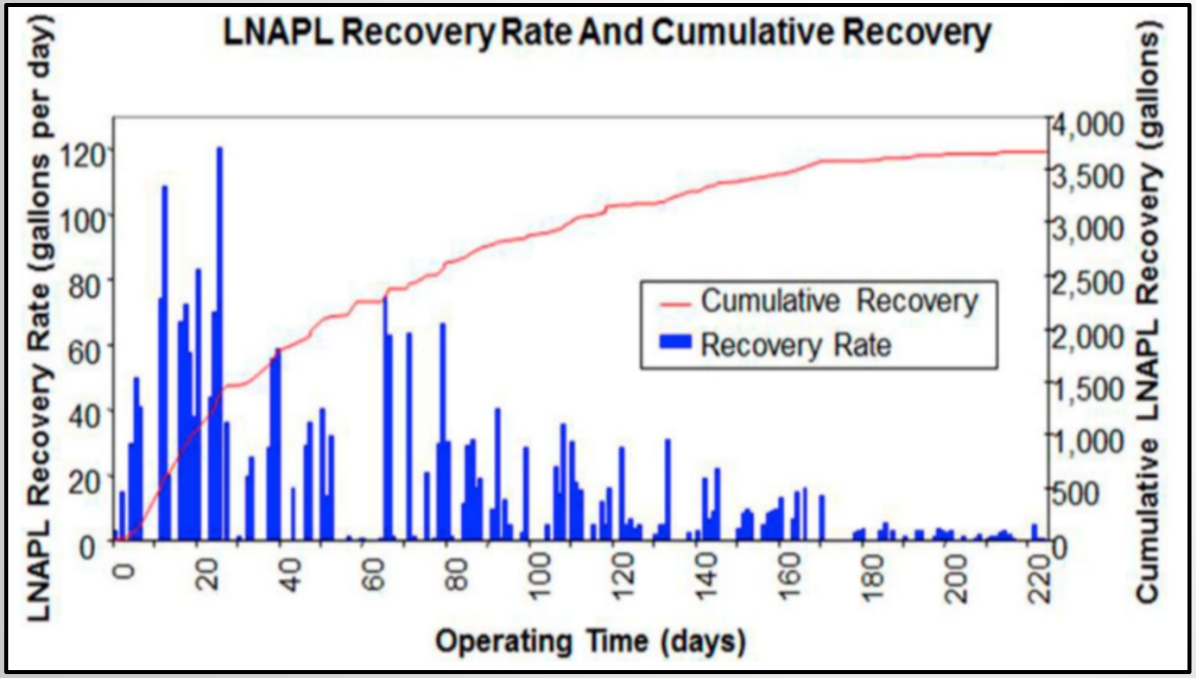
Natural LNAPL depletion in the subsurface has been greatly underestimated.

-John Wiley

THE PROBLEM

Remediation often goes on for decades with increasing costs and diminishing results.

1) Incomplete Site Characterization
2) Ineffective/Incomplete Remedial Strategies
3) Inconsistent performance monitoring



NATURAL MASS REDUCTION PROCESSES

- **DISSOLUTION -** LNAPL source material in the saturated zone dissolves into groundwater.
- **VOLATILIZATION -** Contaminants convert to a gas phase.
- **DIFFUSION -** Movement from areas of higher concentration to areas of lower concentration.
- **ADVECTION -** Movement from areas of high pressure to areas of low pressure
- **DISPERSION** - Spreading and mixing of chemical constituents in groundwater due to microscopic variations in velocities within and between interstices.

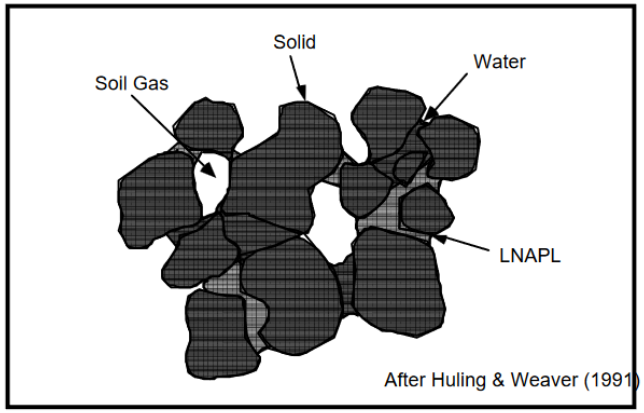


Figure 2. Contamination in the unsaturated zone may be present in four physical states: gas, sorbed to soil materials, dissolved in water, or immiscible liquid.

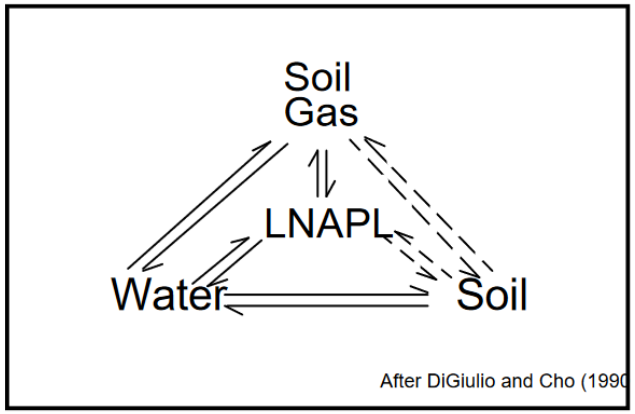
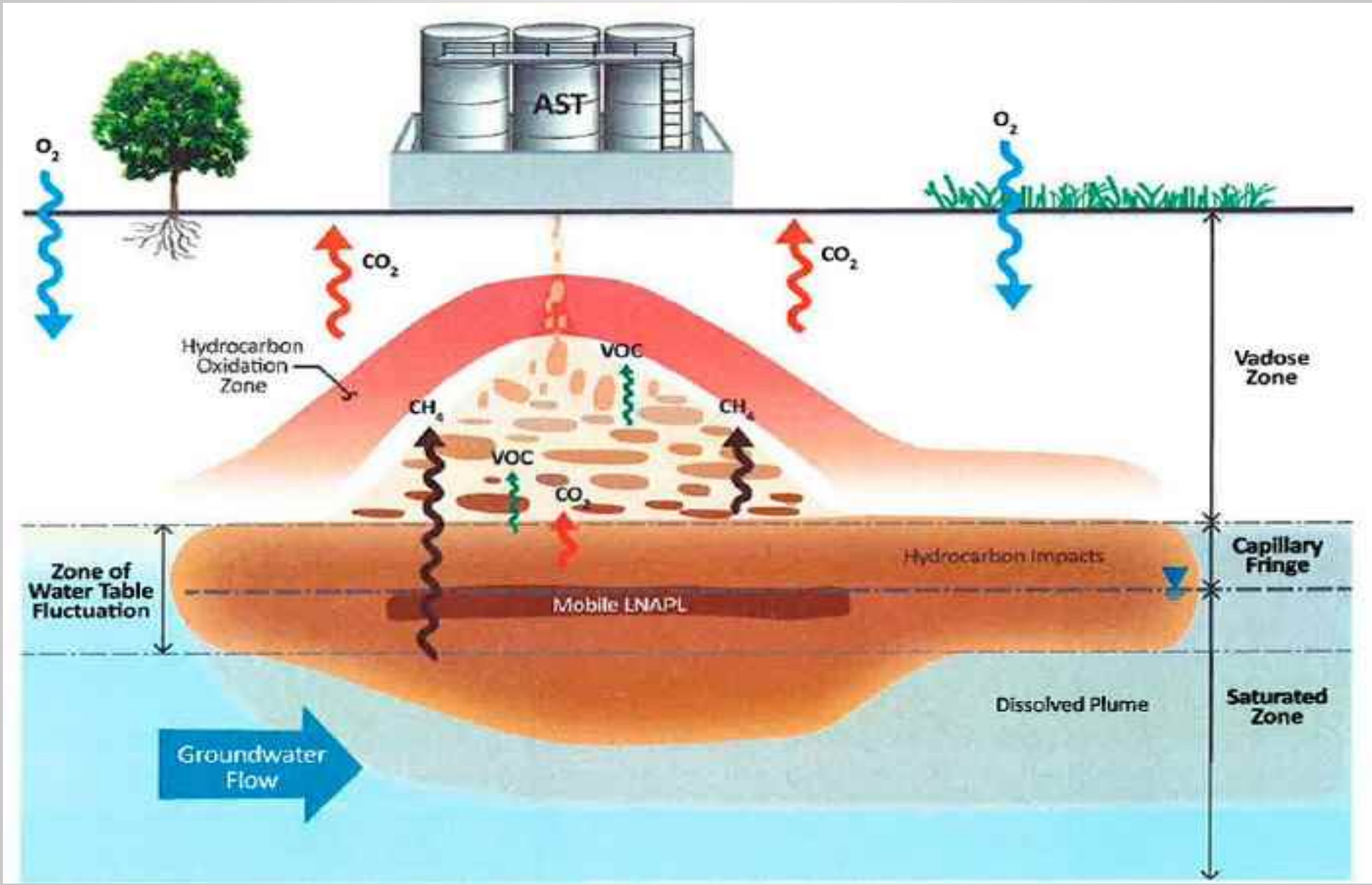


Figure 3. Partitioning of LNAPL among the four phases potentially found in the unsaturated zone.

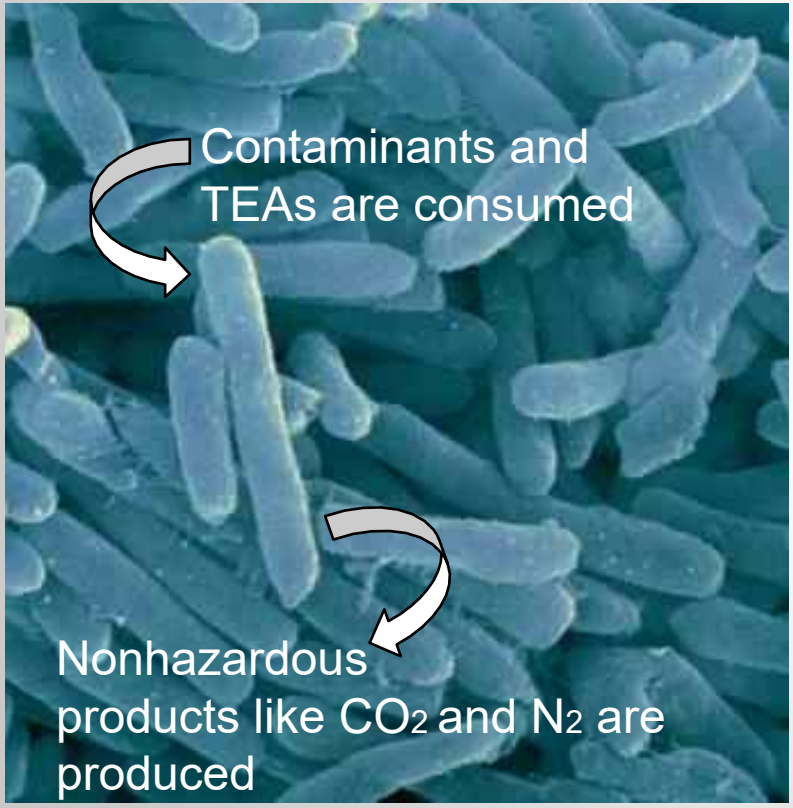
https://www.epa.gov/sites/default/files/2015-06/documents/lnapl.pdf

NATURAL MASS REDUCTION PROCESSES



BIOGEOCHEMICAL PRINCIPLES

Many microbes utilize LNAPL compounds as a source of energy. These biotic processes degrade petroleum products via metabolic processes.



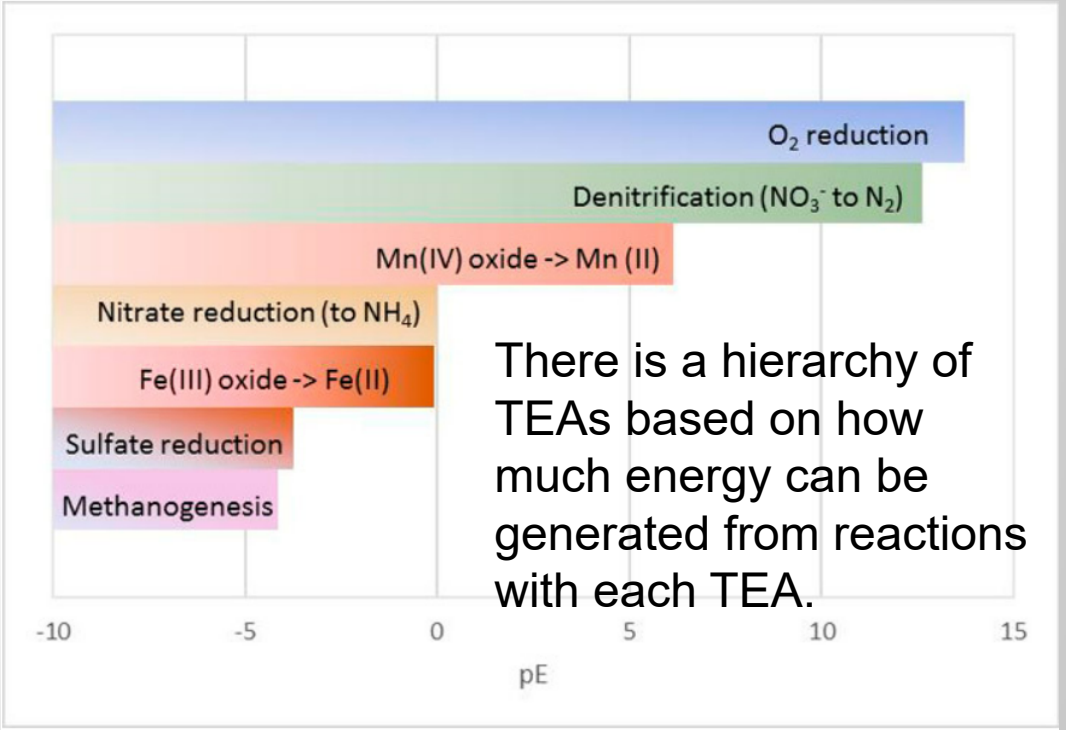


Figure NSZD-2. Electron acceptor ladder.

OVERVIEW

LNAPL Conceptual Site Model

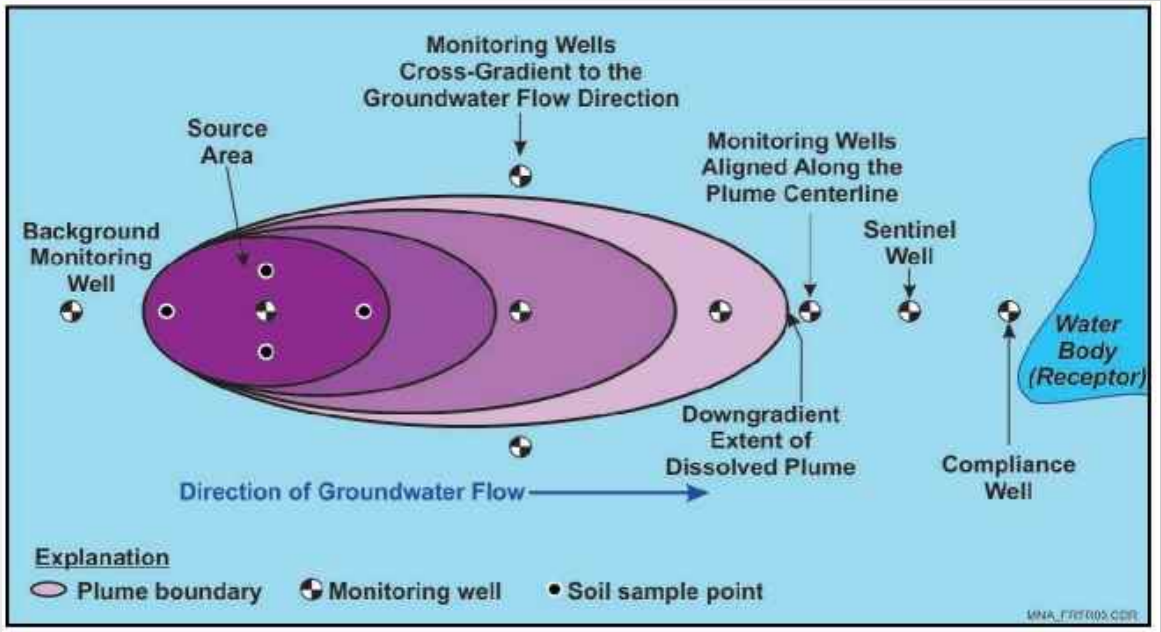
- ✓MiHpt, OiHpt, EC, and high-resolution sampling
- ✓Real-time data visualization & 3-D Visualization

Assess/Quantify Natural Mass Reduction Processes

- ✓ Natural Source Zone Depletion
- ✓ Monitored Natural Attenuation

Performance Monitoring

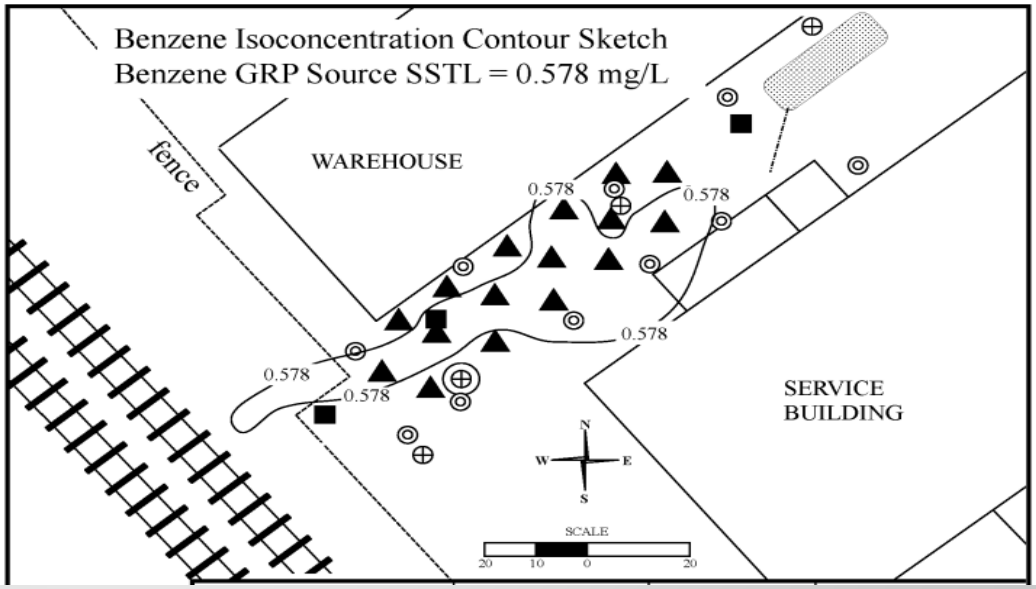
- ✓Plume Stability Evaluation
- ✓Assess the Potential for Exposure



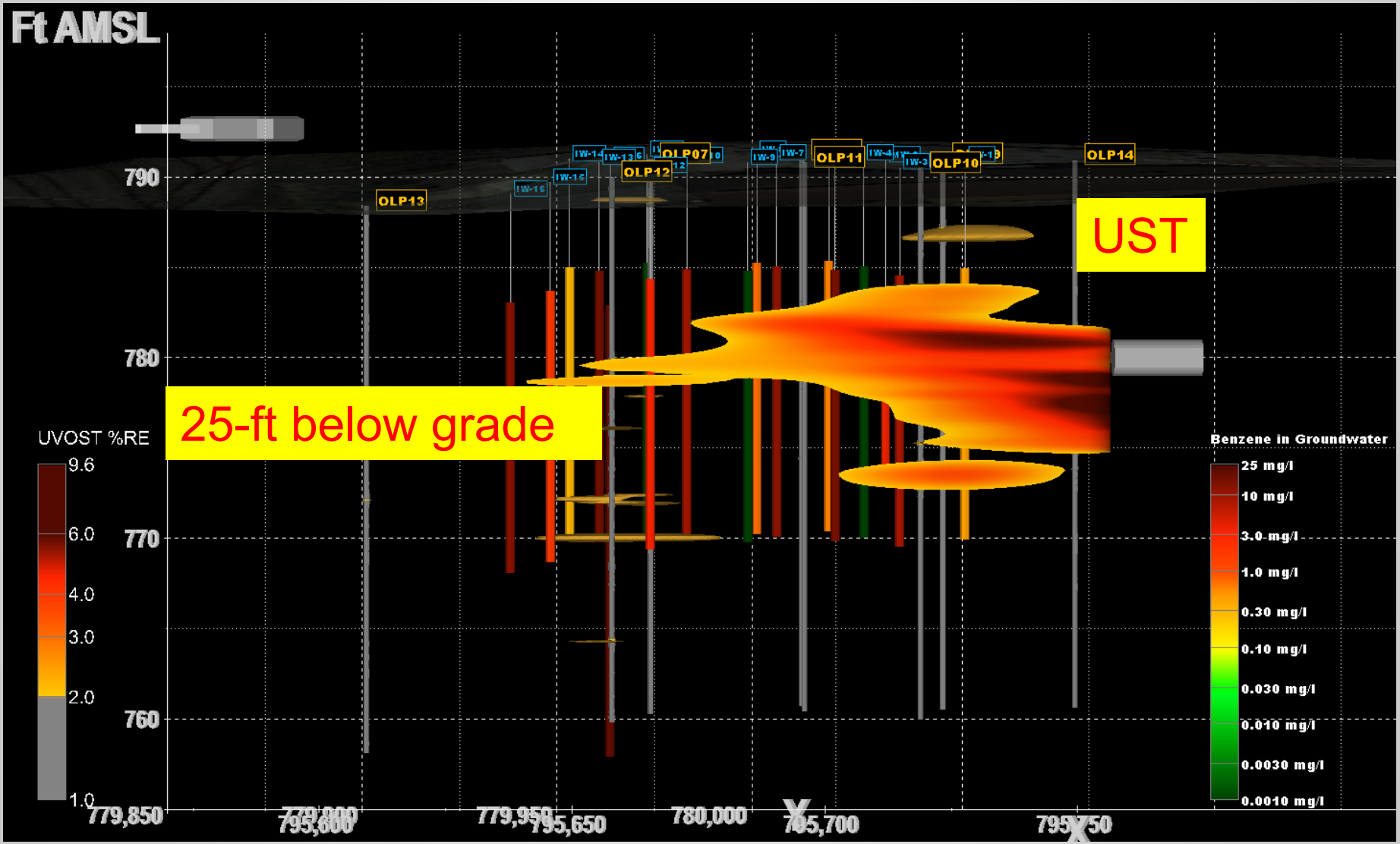
Federal Remediation Technologies Roundtable (https://frtr.gov/matrix/Monitored-Natural-Attenuation/)

CASE STUDY 1 - ALABAMA

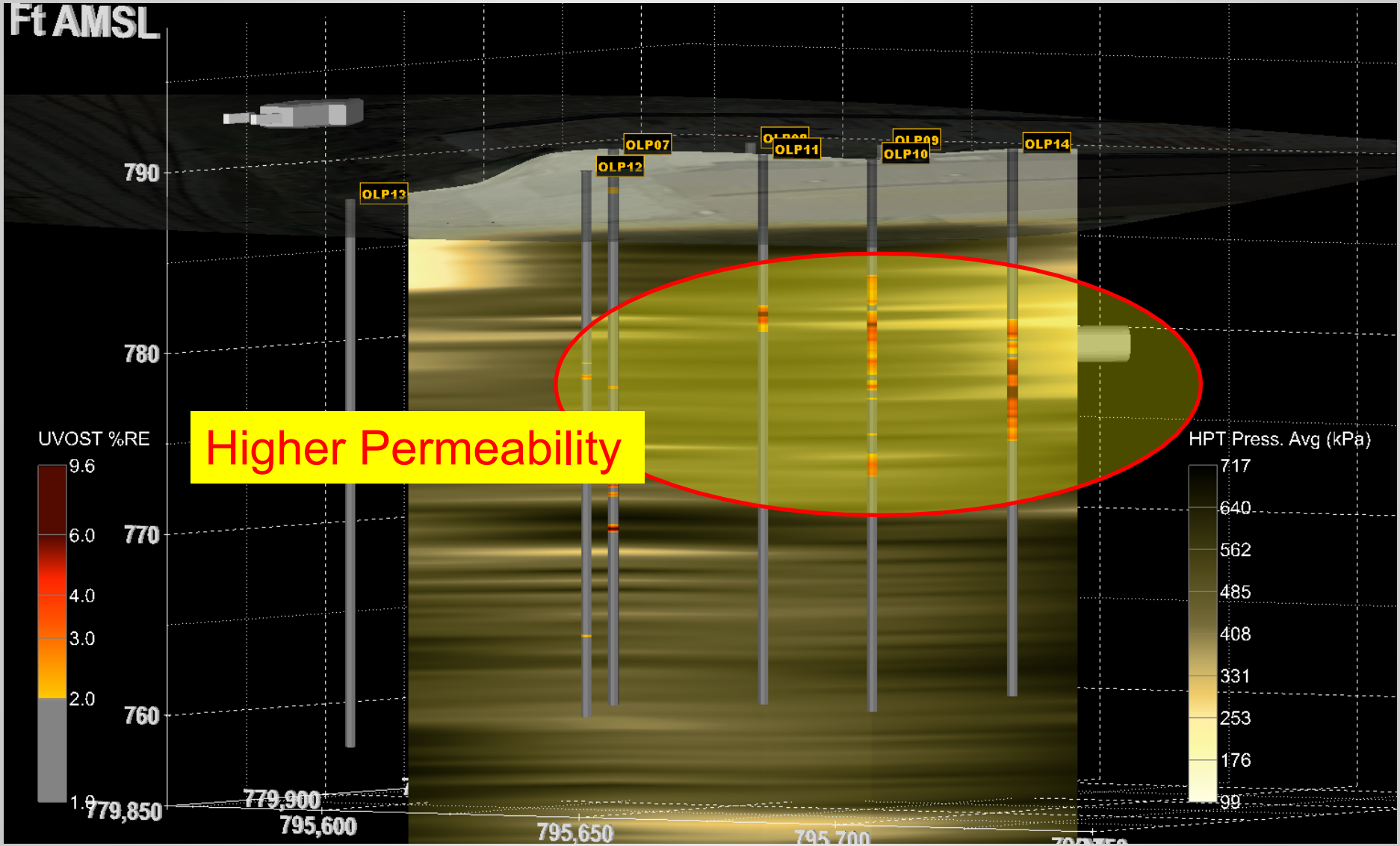
- ✓ Gasoline release discovered in 1992 during UST closure
- ✓ Soil - Saprolite derived from metamorphic rocks with layers of clay, silt, and sand



LNAPL VERTICAL FOOTPRINT BY LIF-UVOST®



LNAPL VS SOIL PERMEABILITY

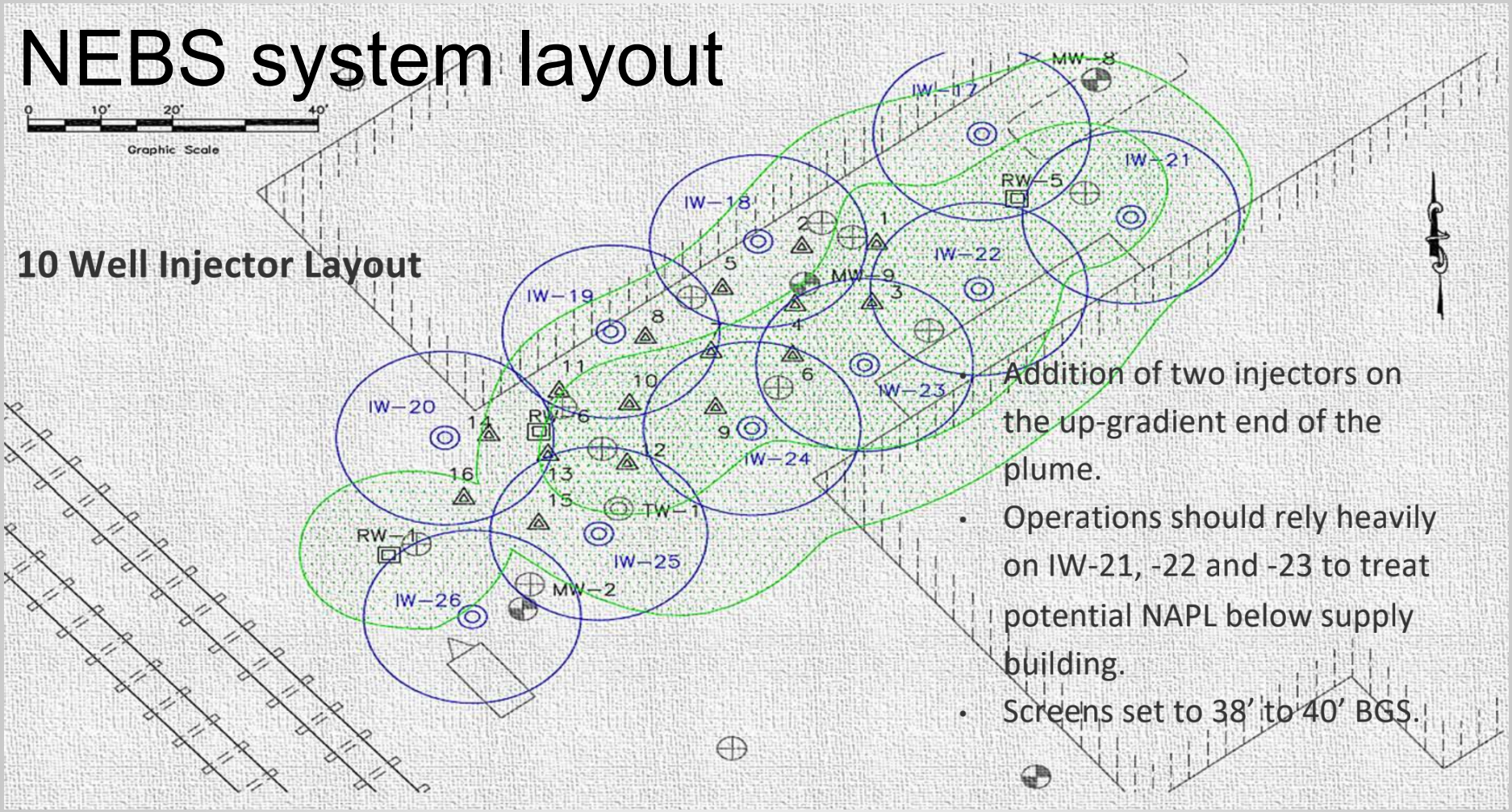


CONCLUSIONS FROM HRSC

- 4300 cu-ft of residual LNAPL mass identified (mass under the building not yet determined)
- LNAPL farther upgradient than originally thought
- LNAPL present as deep as 33-ft
- LNAPL trapped in and by low permeability soils

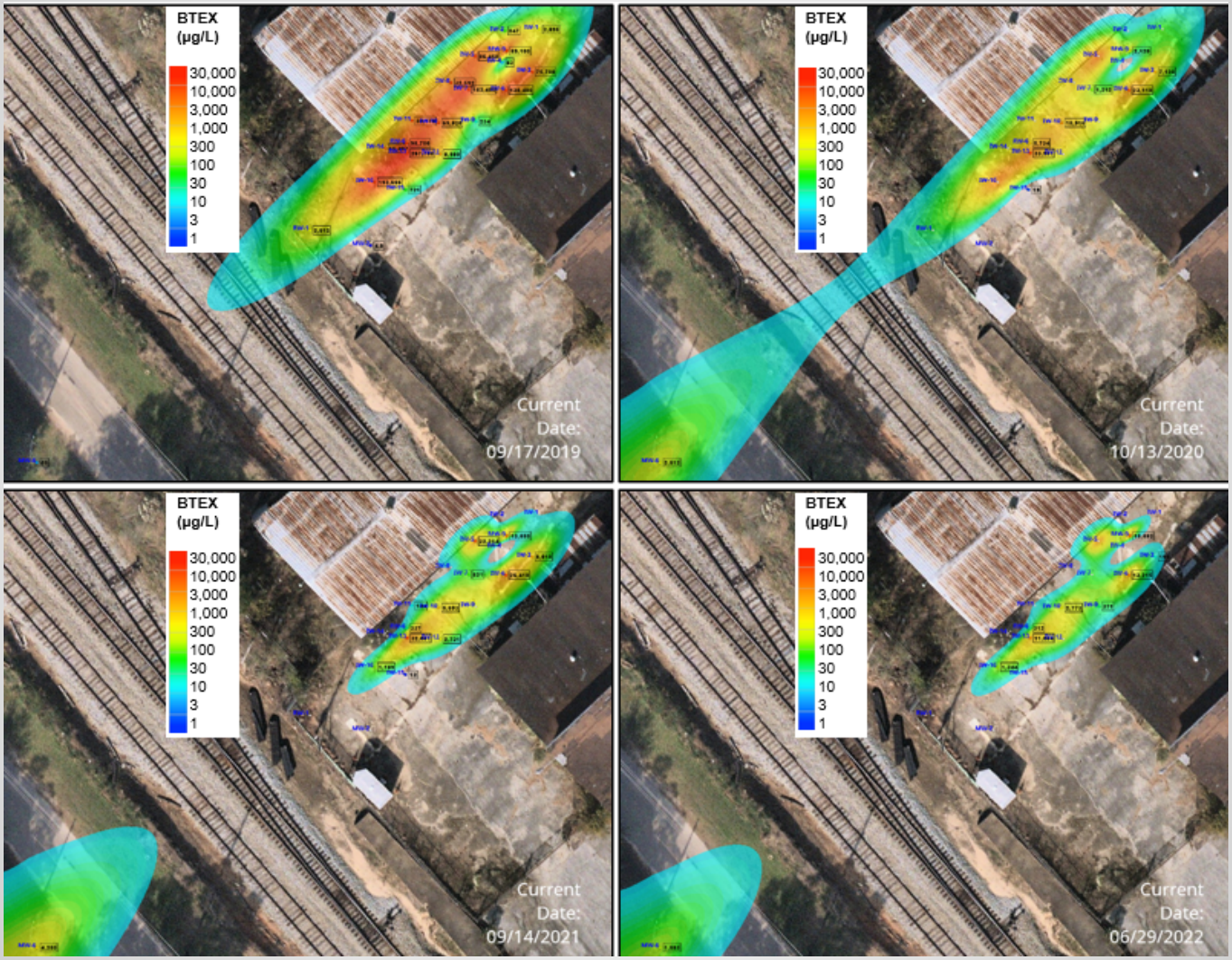
NUTRIENT ENHANCED BIO-STIMULATION

NEBS system layout

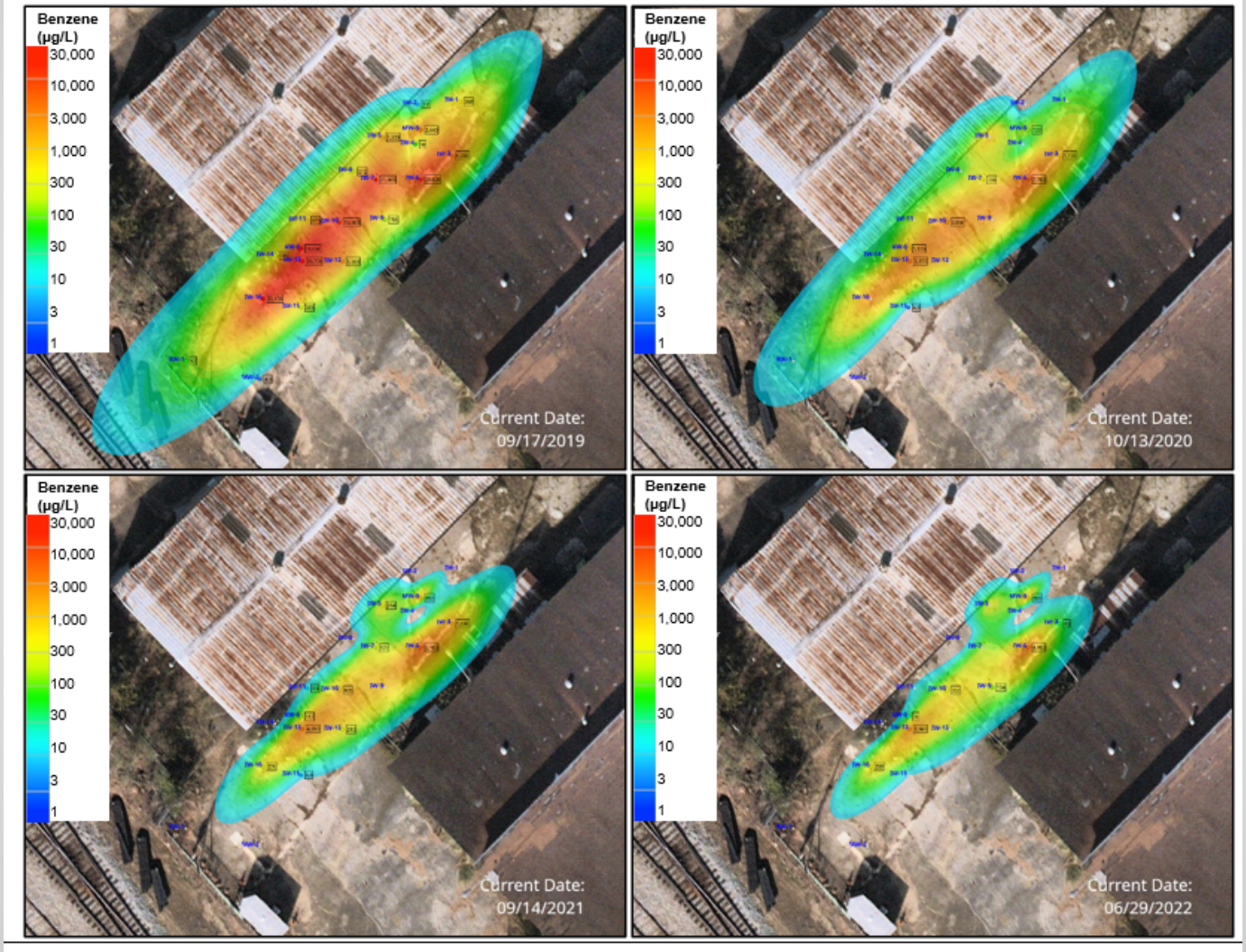


- Addition of two injectors on the up-gradient end of the plume.
- Operations should rely heavily on IW-21, -22 and -23 to treat potential NAPL below supply building.
- Screens set to 38’ to 40’ BGS.

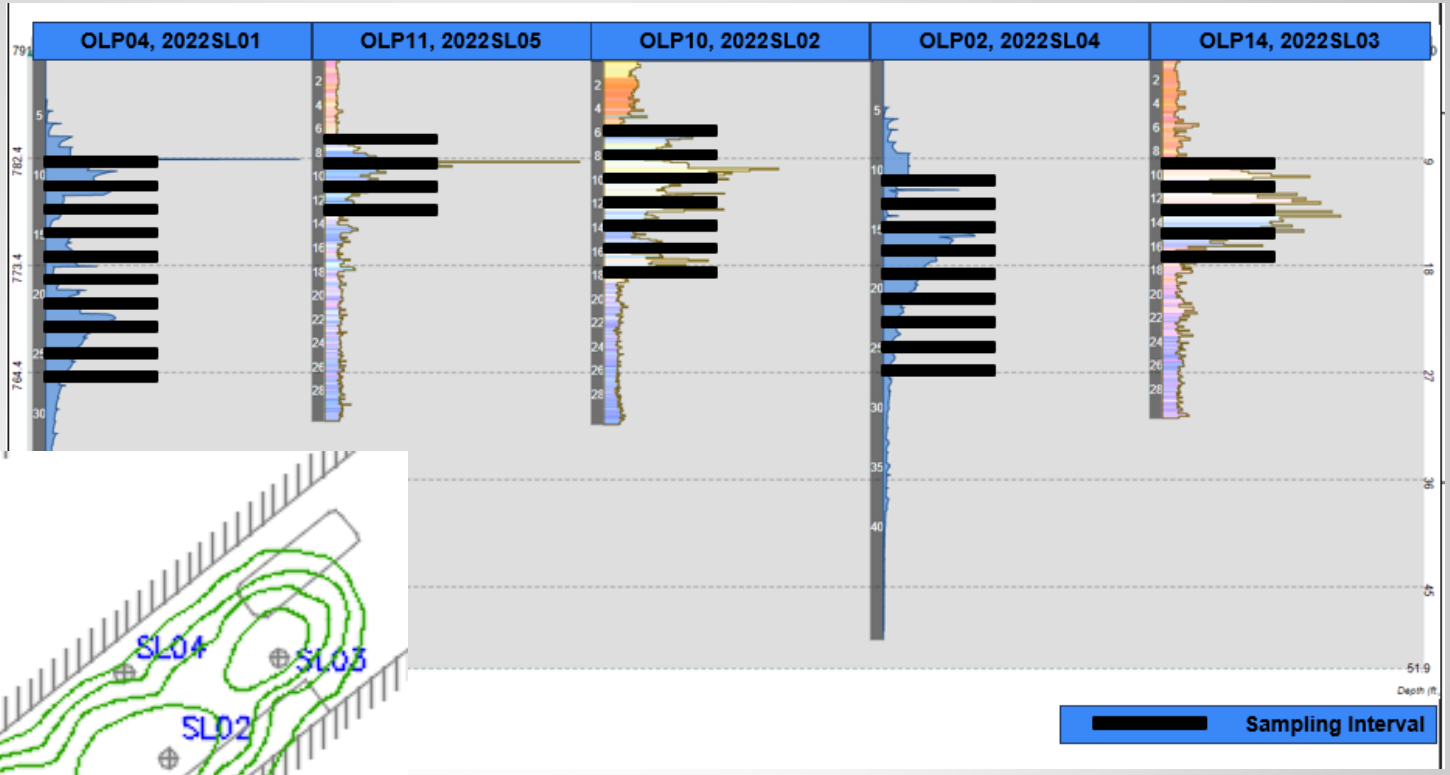
BTEX IN GROUNDWATER OVER TIME



BENZENE IN GROUNDWATER OVER TIME



HIGH RESOLUTION SOIL SAMPLING



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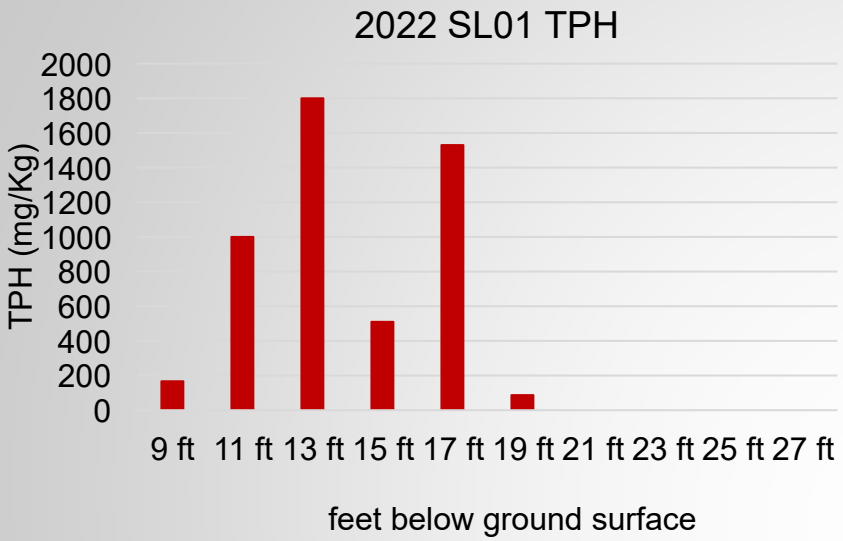
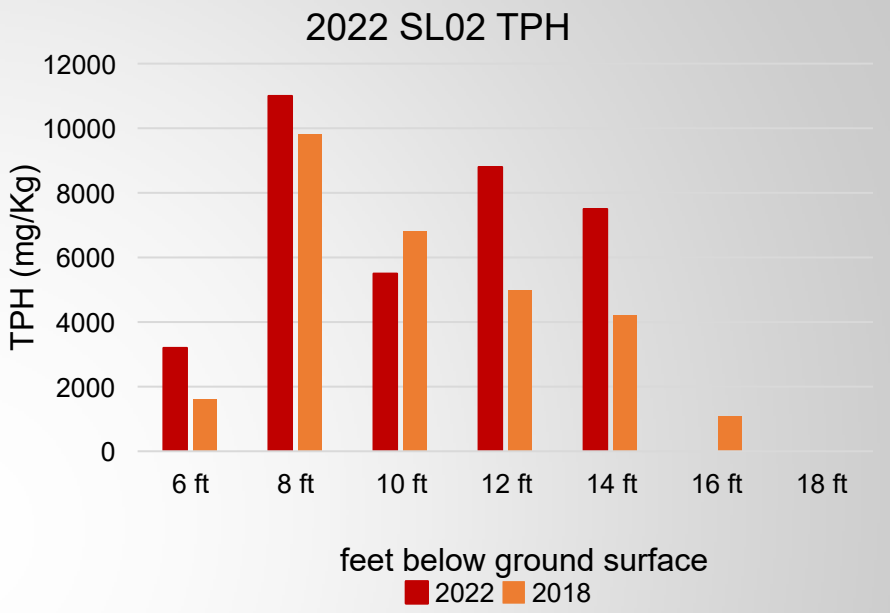
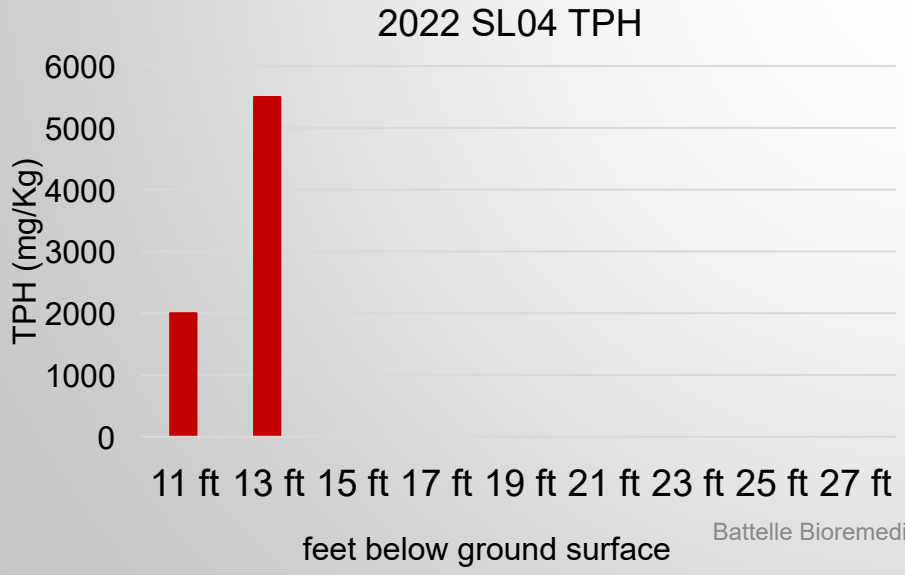
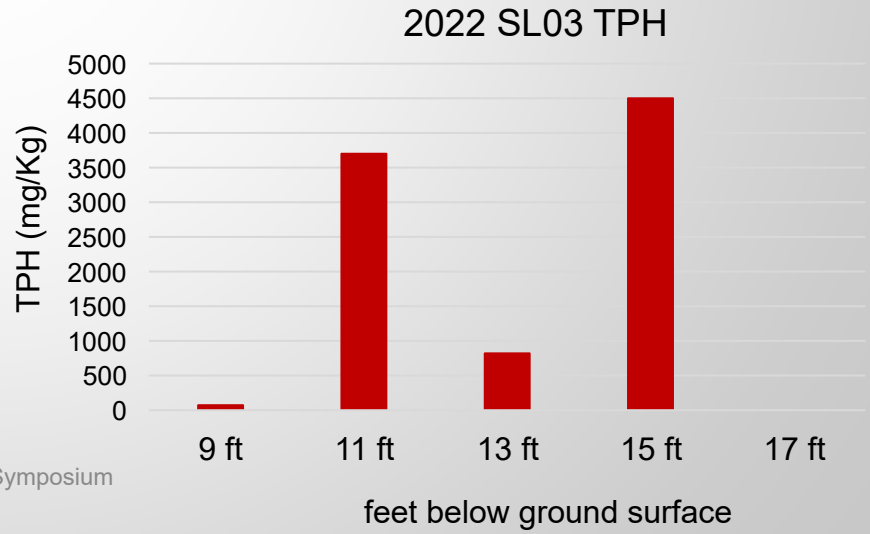








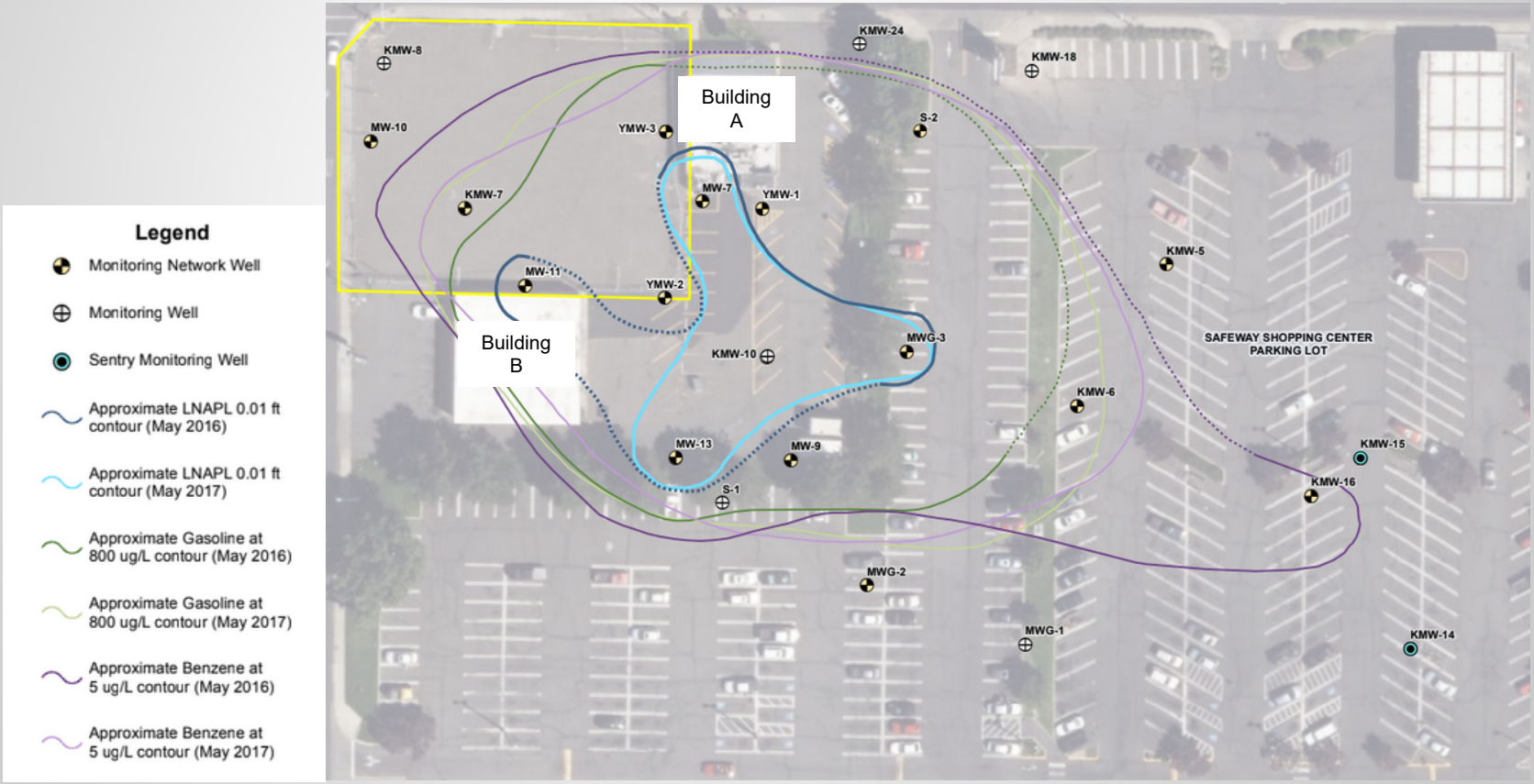
CASE STUDY 1 – ALABAMA CONCLUSIONS

- ✓ Comparing TPH data from 2018 and 2022 suggests that residual LNAPL is being degraded from the bottom up.
- ✓ Groundwater data suggests that the contaminant plume is also being degraded from the outside (lower concentration zones) in (higher concentration/ source areas).
- ✓ Soil and groundwater data suggest that benzene is being preferentially degraded.
- ✓ Continued operation of the NEBS system will likely result in the degradation of COCs below SSTLs

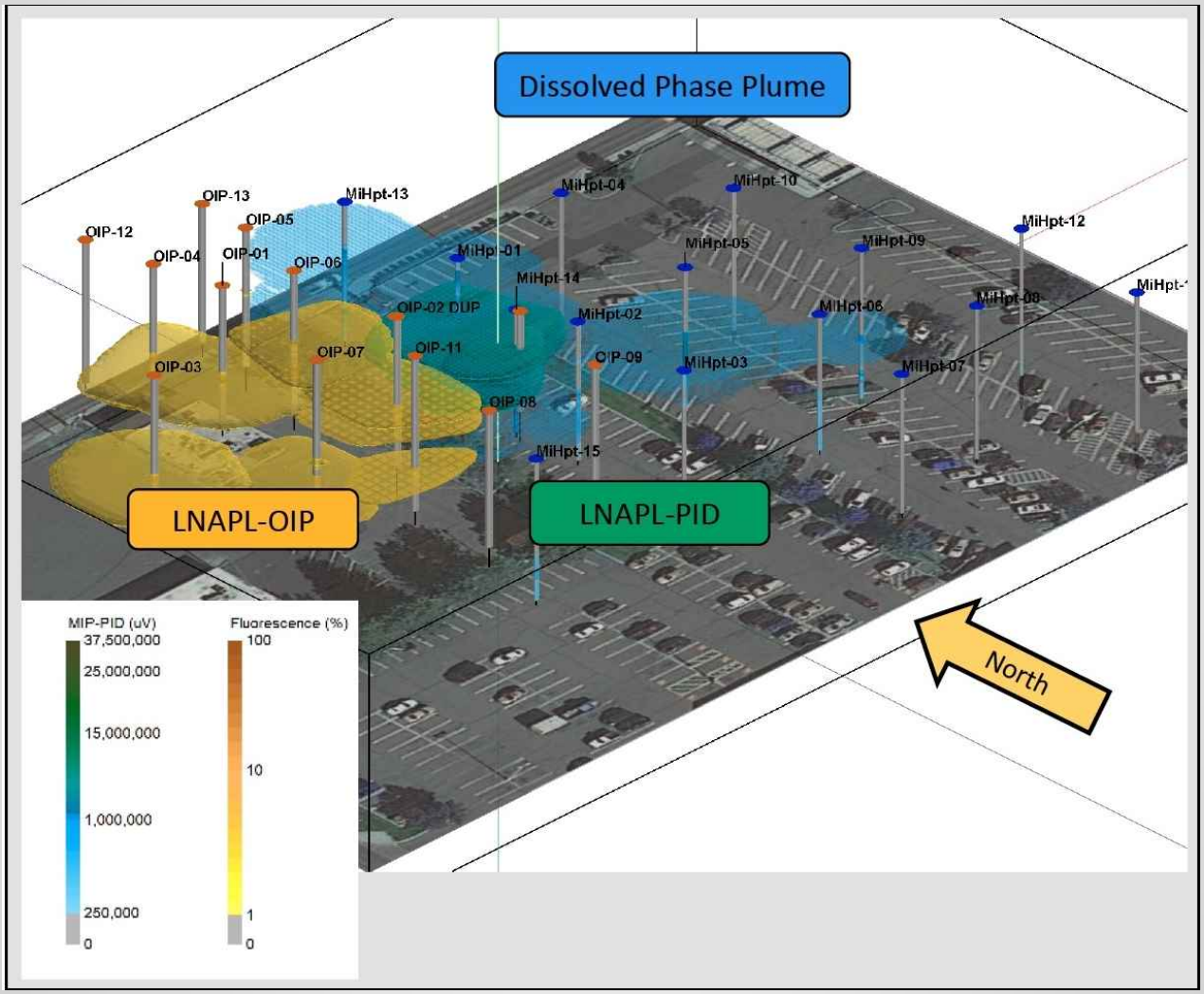
CASE STUDY 2 – WASHINGTON

The Property was a retail fuel station

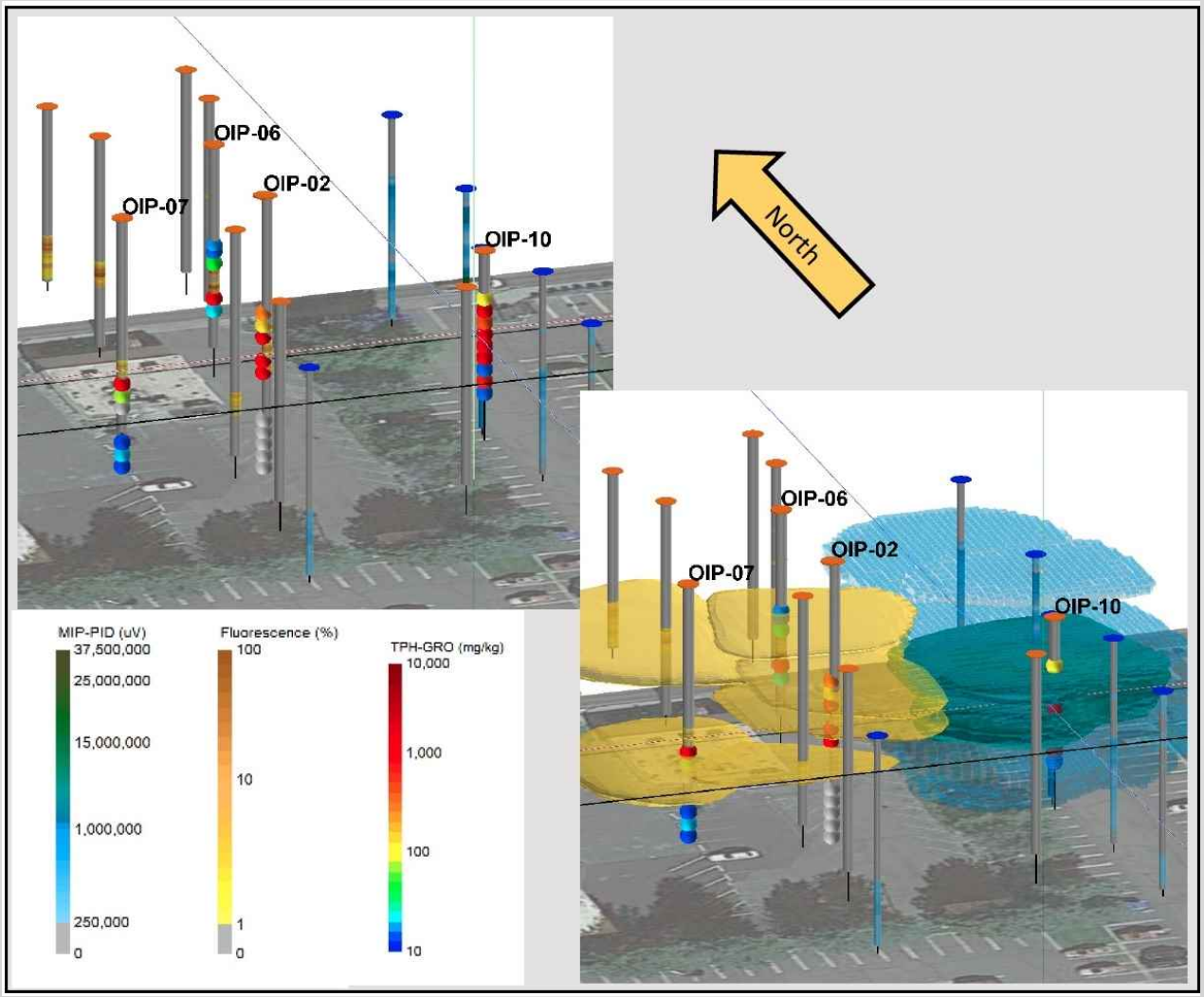
A leak in the product line of the UST system had impacted the surrounding soil and groundwater at the property and adjoining properties.



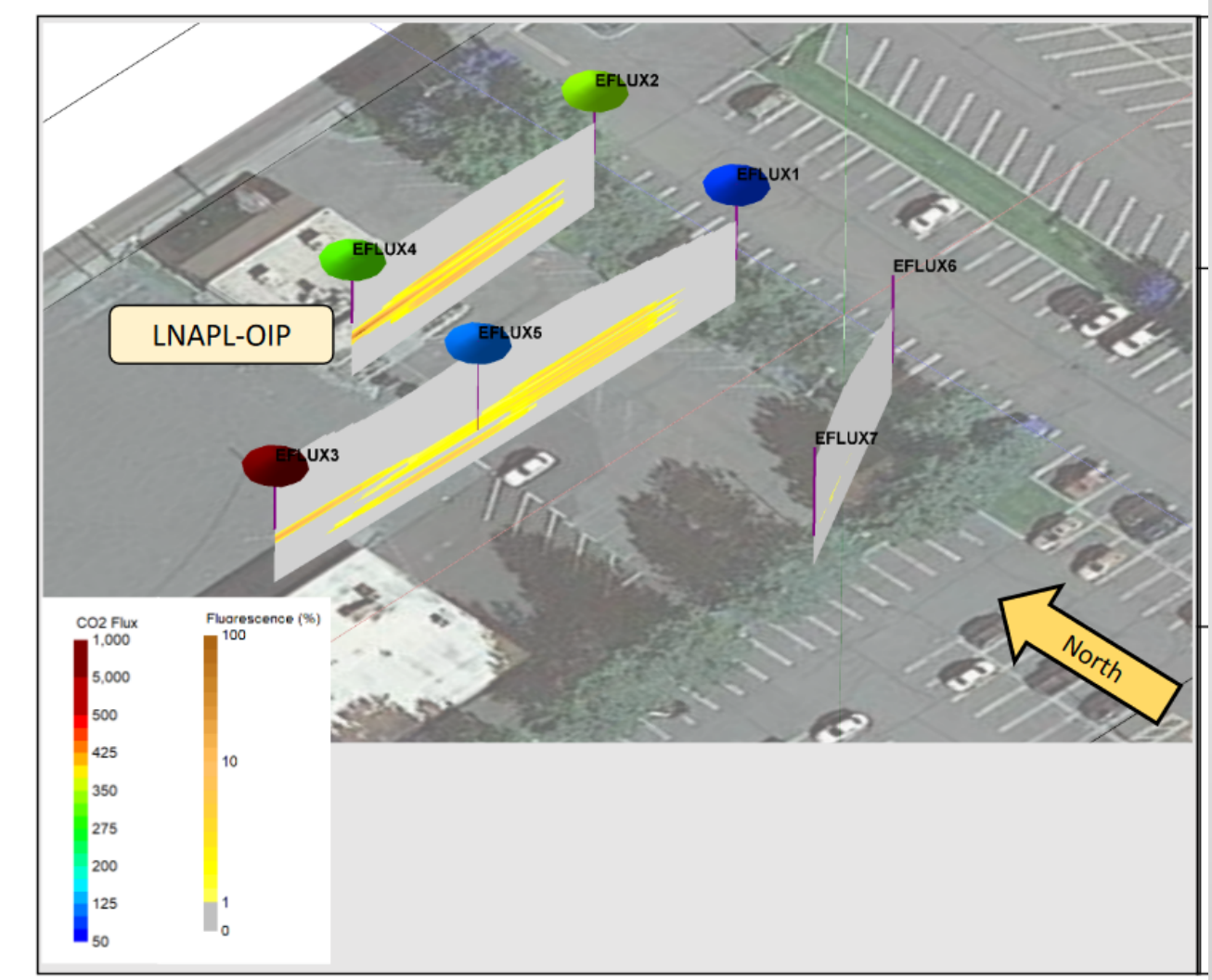
MIP AND OIP INVESTIGATION



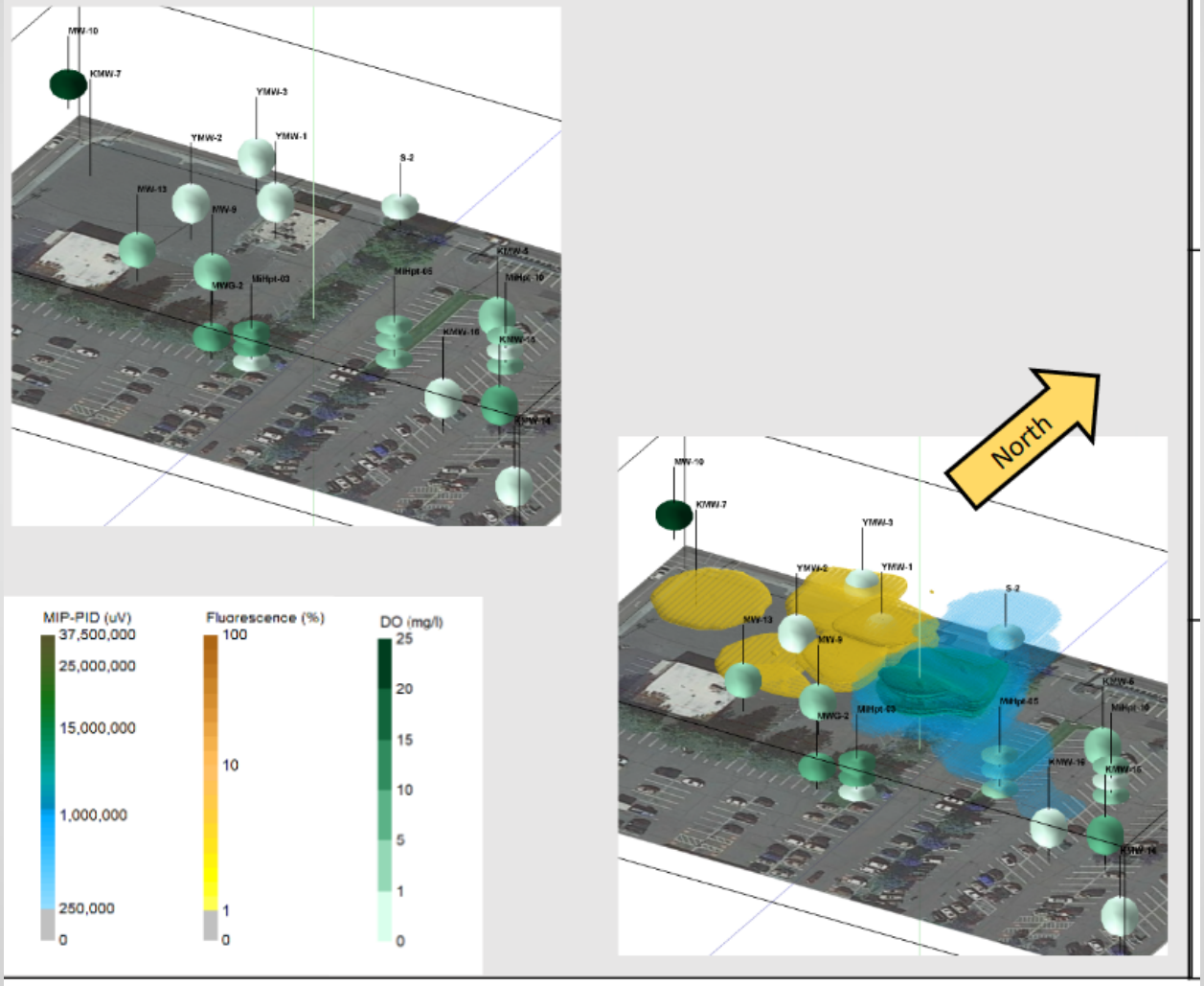
HIGH RESOLUTION SOIL SAMPLING



EFLUX CANISTERS TO MEASURE NSZD RATES



DISSOLVED OXYGEN MEASUREMENTS THROUGHOUT THE SITE



CASE STUDY 2 - WASHINGTON CONCLUSIONS

- ✓ Residual petroleum extends east and South of the site into the adjacent parking lots.
- ✓ TPH-GRO concentrations in the discrete soil samples indicate that the residual mass does not exceed the screening criteria for mobility and is therefore stable.
- ✓ CO2 Flux analysis indicates that Natural Source Zone Depletion is occurring within a range of 99 to 7743 Equivalent NSZD Rate with a median value of 476-gal/acre-yr in the summer as measured above the LNAPL body.
- ✓ Much of the residual LNAPL body is present in anaerobic conditions meaning the biologically-mediated processes are significantly compromised.

CONCLUSION

Incorporating multiple lines of HRSC data when evaluating LNAPL and dissolved-phase plume stability leads to stronger conceptual site models and better remediation outcomes

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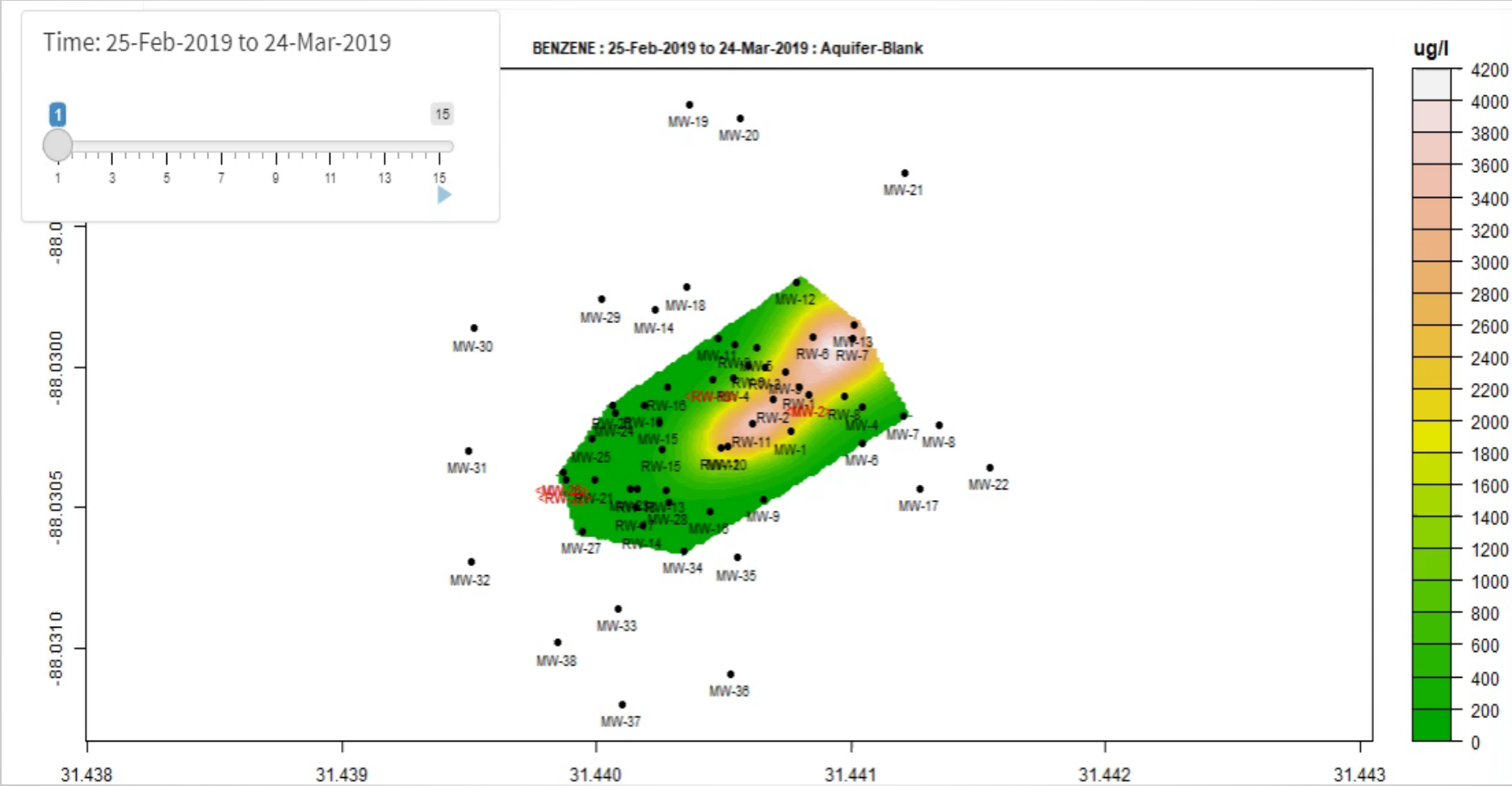
CASE STUDY 3 GWS DAT



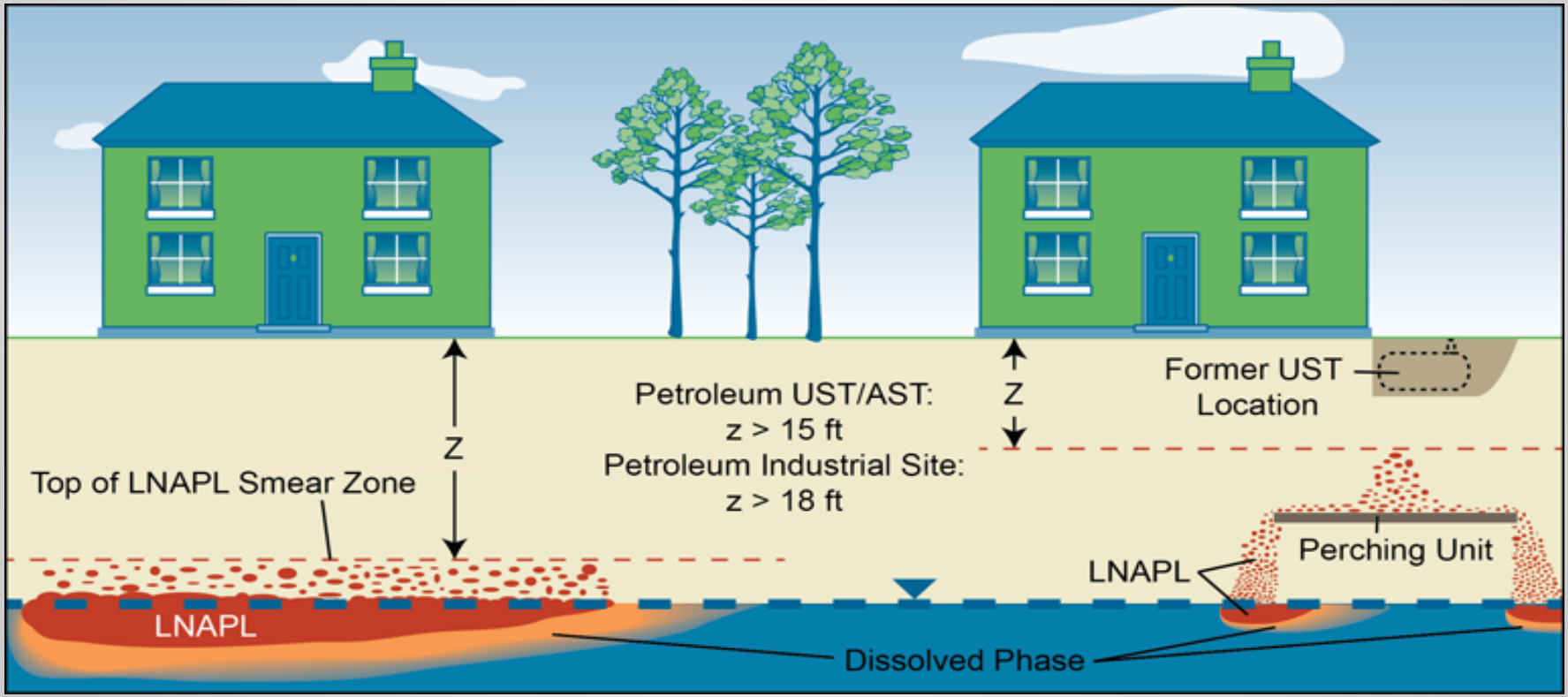
SITE CLOSURE STRATEGY

- Stakeholder communication-understanding-support regarding:
  - Reasonable, protective site closure goals
  - Conceptual Site Model (including updates)
- Team with stakeholders to generate a collaborative scope of work.
- Implement the plan, update the CSM, and assess plume-stability & exposure risk. ***Is site ready for closure?***
- If “no”, collaborate on site remedy technology(s), deployment strategy, and path-forward sampling plan to:
  - ✓ Evaluate remedial action performance metrics
  - ✓ Assess exposure risk
  - ✓ Build a case for site closure, as appropriate (repeat as necessary)

MULTIPLE LINES OF EVIDENCE #3

Petroleum Vapor Intrusion

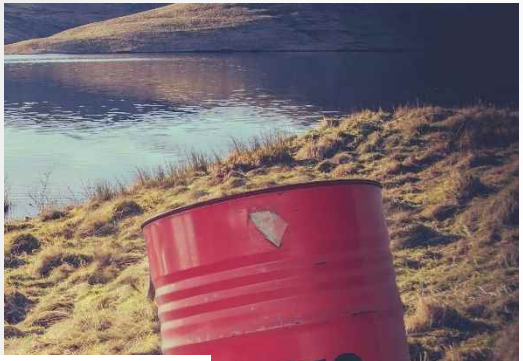
- Sub-Slab Sampling
- Indoor Air Sampling
- Screen Vertical & Horizontal Separation Distance

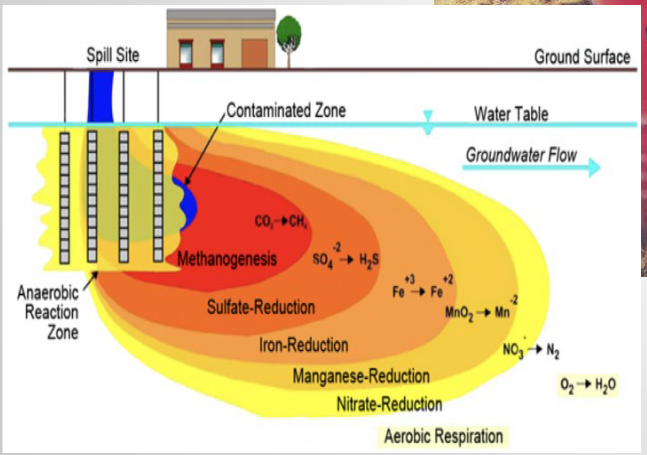


- Interstate Technology and Regulatory Council (ITRC) LNAPL-3 for LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies

Will can include a full include a full reference slide if deemed helpful

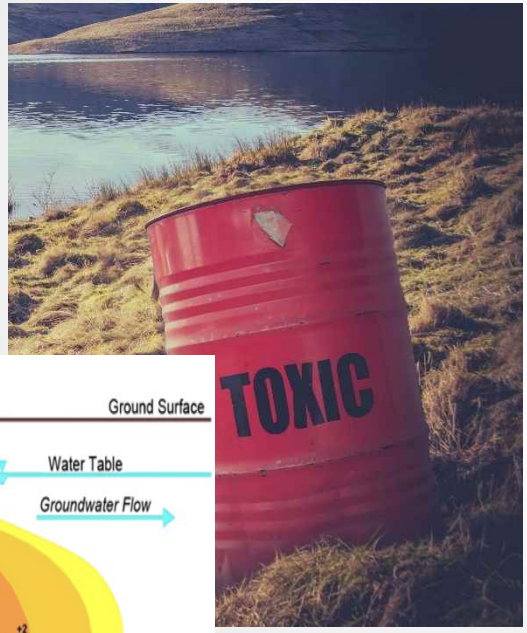
Natural LNAPL depletion in the subsurface has been greatly underestimated. *The key piece missing in traditional electron acceptor-driven mass balance models was a complete understanding of LNAPL depletion in the vadose zone and the role of methanogenesis.*

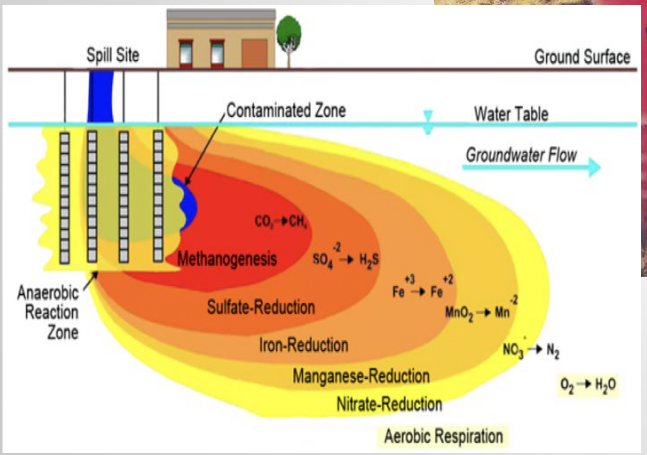




Microbes transform petroleum products by:

- ✓ Coupling the oxidation of petroleum with
- ✓ Reduction reactions of terminal electron acceptors (TEAs).





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- ✓ Coupling the oxidation of petroleum with
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Other tools not discussed in this talk

Compound Specific Isotope Analysis (CSIA)

- ✓ Temperature Profiles