Optimizing LNAPL Remediation at a Fractured Bedrock Site Using Electrical Hydrogeology

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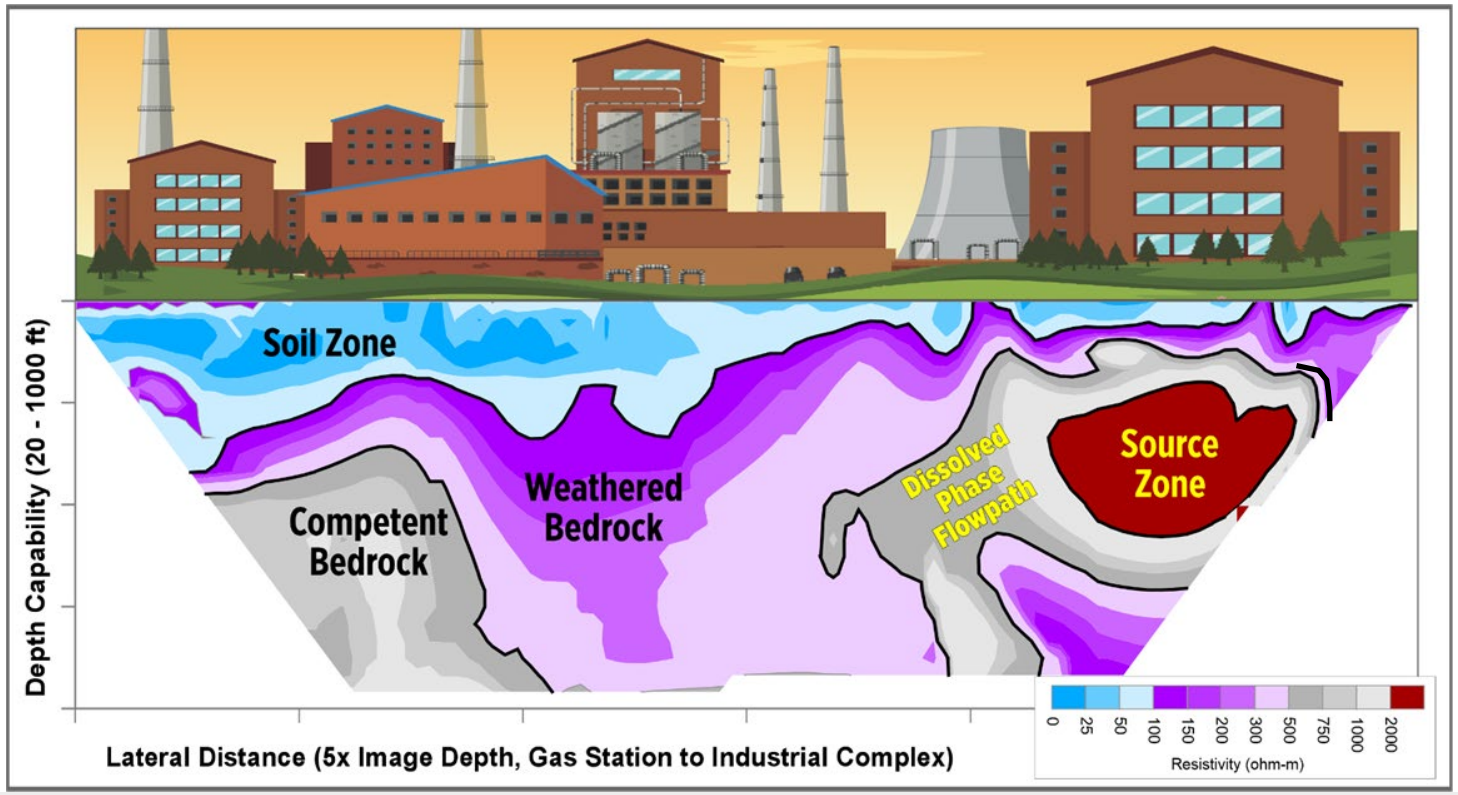
Aestus

DEQ
Montana Department of Environmental Quality
2026 Consultants Days

Today's Topics

1. Electrical Hydrogeology
   What, Why, How?
2. Case Study: Fractured Bedrock Site
3. The GeoTrax Survey™ Difference
4. Closing Remarks
5. Q&A



Ultra-HRSC – Continuous vertical images of subsurface

Electrical Hydrogeology™ Process:
Leveraging Scan First Approach & Integrated Data Sets

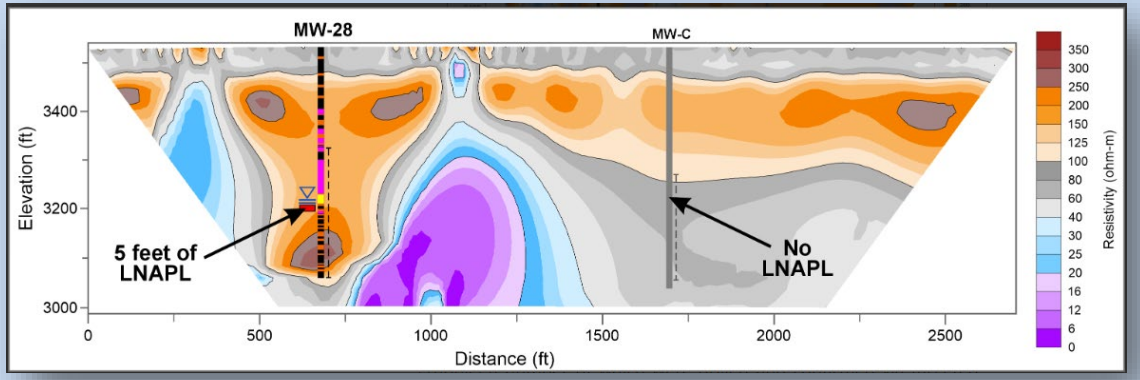
Electrical Hydrogeology =

Traditional Hydrogeology

- Potentiometric surface maps
- Lithology logs
- Stiff Diagrams
- Pipe Diagrams
- GW Chemistry
- GW Flow Models
- Geology Maps
- Aquifer Maps
- HPT/MIP Results
- Etc.

+

Electrical Imagery/Targeted Drilling/3D Modeling



Applications:

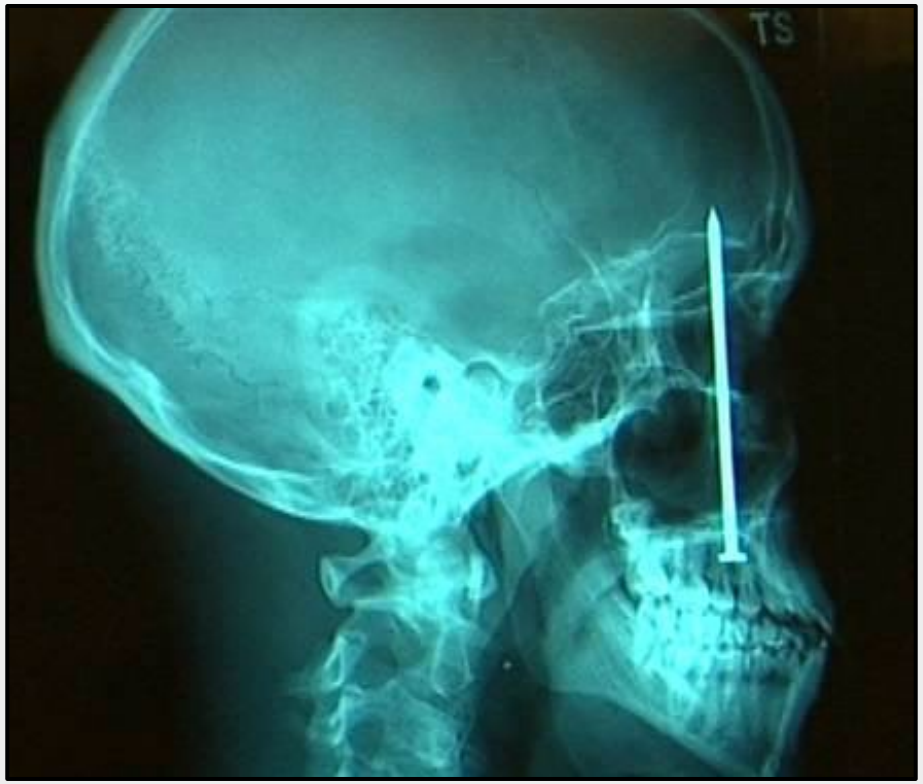
1. *Site Characterization (Static Imaging)*
2. *Site Monitoring (Temporal Imaging)*

Industry Challenge & Solution

Video found at https://www.youtube.com/watch?v=FqGjHWf08Io

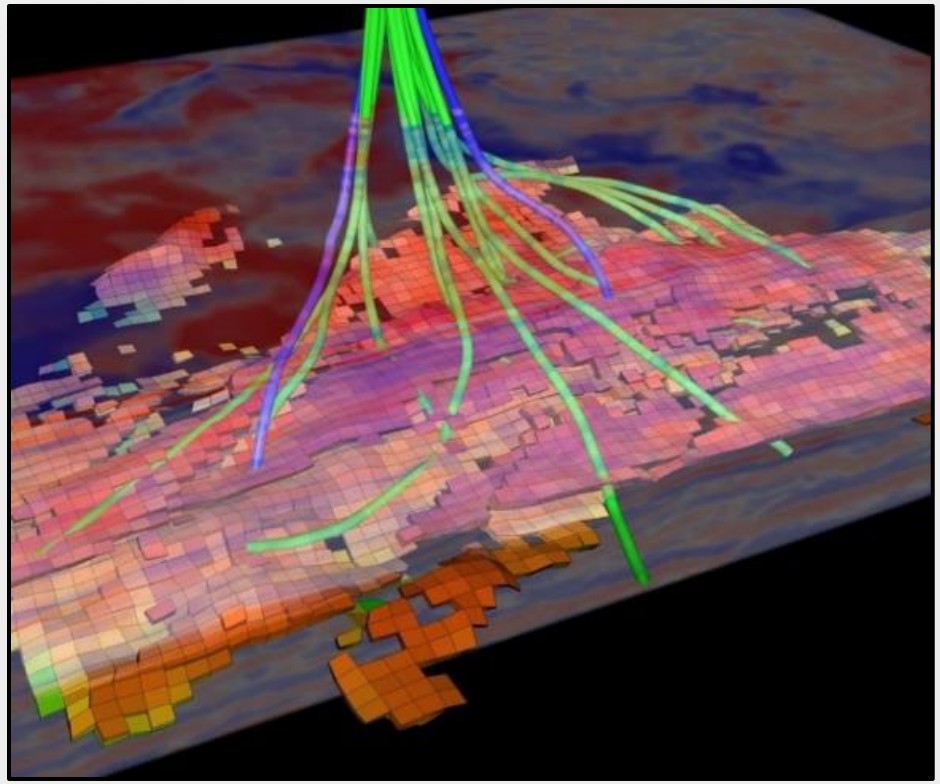
Scan then Target Approach: Aligning with Other Industries

Other industries requiring data "below the surface" evolve to scan first then go invasive



X-ray of Skull

nydailynews.com



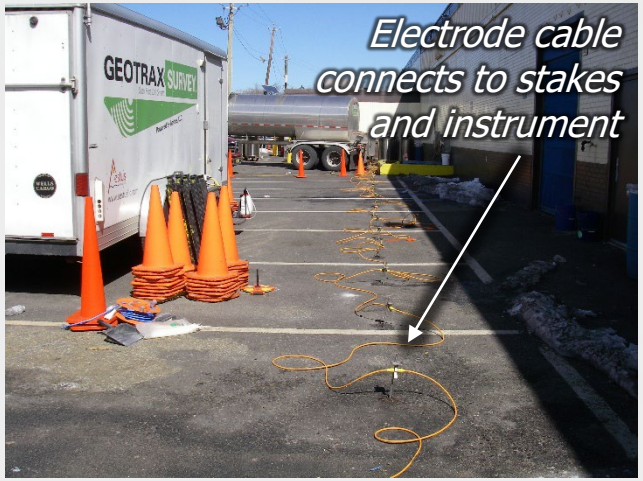
3-D Seismic North Sea

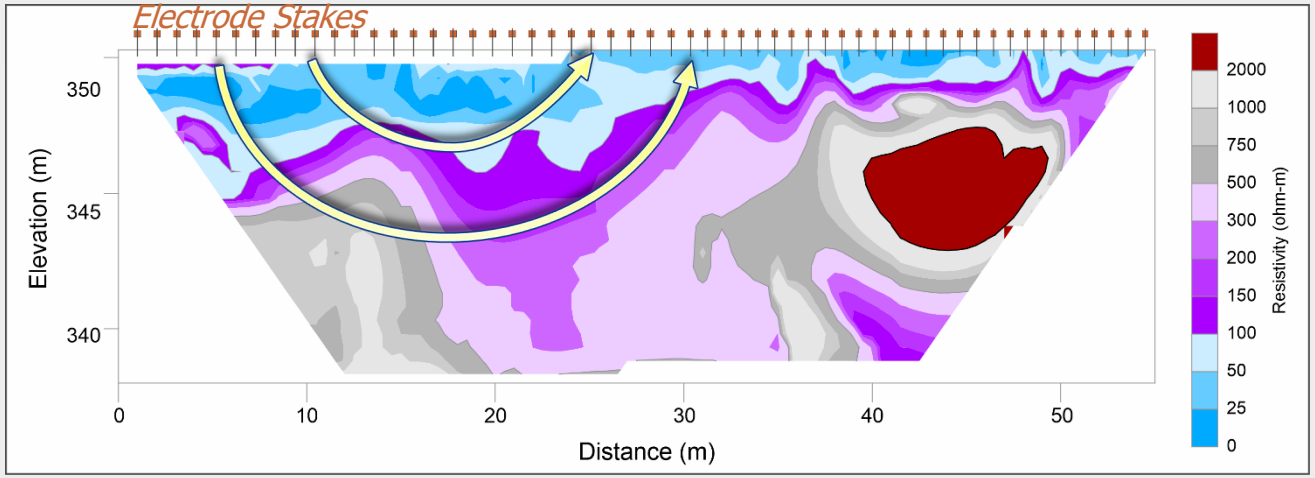
dgi.com

Field Deployment - Static Imaging

(single site characterization event, temporary installation)

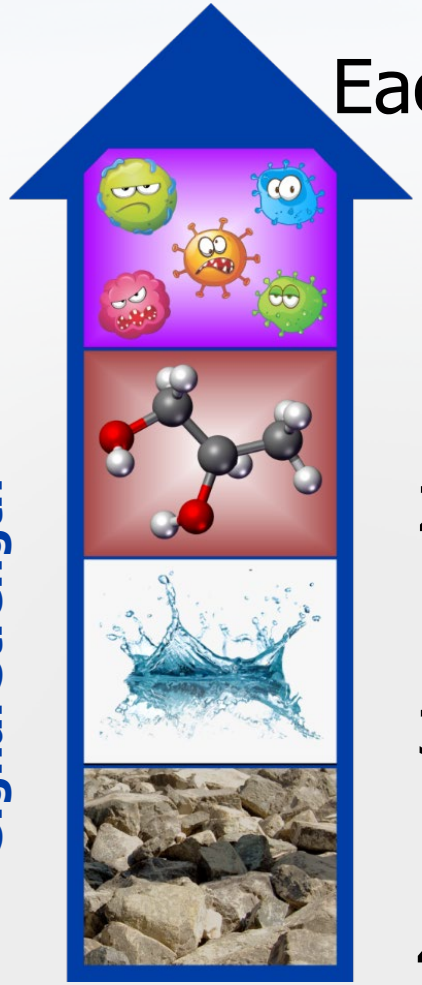
- Must be in a straight line
- Line length=5x imaging depth
- In place for ~3 to 5 hours





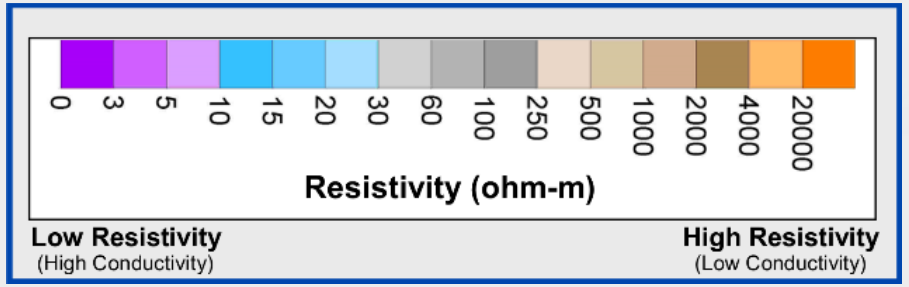
Electrical current flows between electrode pairs
Results in a vertical 2D continuous electrical image of the subsurface

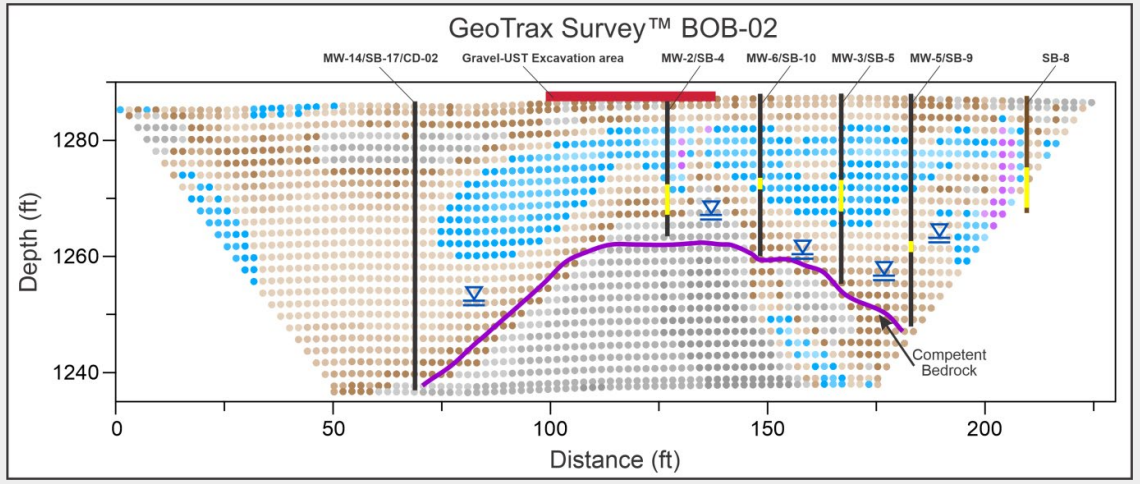
What Do Electrical Images See?



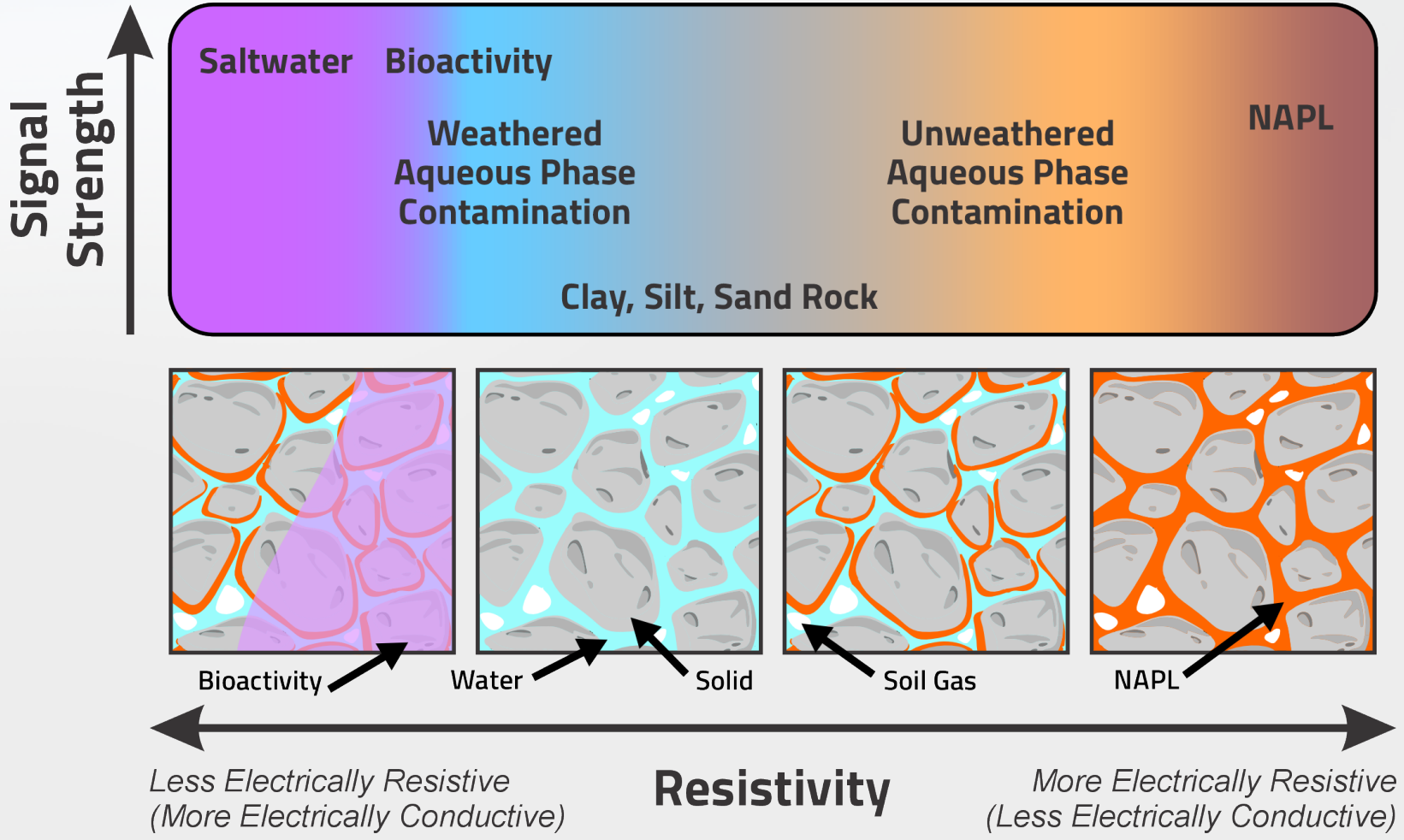
Each data point (pixel) equals the sum of:

1. Biological activity
2. Contamination/ Injectates/etc.
3. Groundwater/Fluids
4. Soil and rocks





Typical Electrical Properties



After Mowder, 2019

Proven Electrical Hydrogeology™ Process
Remedial Design Characterization

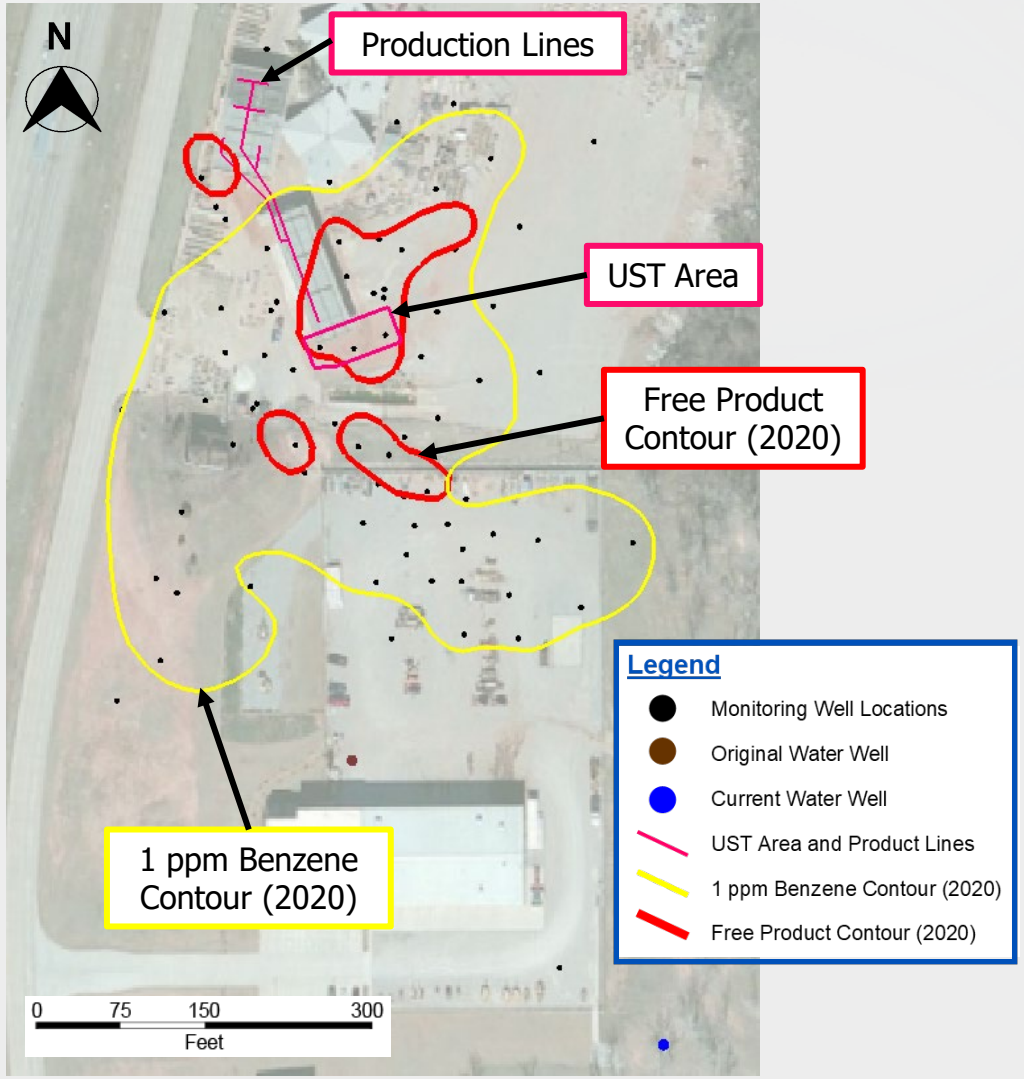
1	2	3	4	5
Site Data in 3D	**Subsurface Scan**	**Interim Report**	**Targeted Drilling**	**Final Report**
- Client sends existing site data to Aestus	- GeoTrax Survey™ field data aquisition	- Integrate scanning data in 2D & 3D (QC)	- Confirmation drilling & sampling by client	- Integrate confirmation drilling data (QC)
- Integrate data in 3D visualization model	- Use dynamic work strategy with QA/QC	- Interpret datasets; form hypotheses	- Test hypotheses from Interim Report	- Updated conceptual site model (CSM)
- Must occur prior to field work (Step 2)	- Yields high resolution 2D continuous images	- Select confirmation drilling locations	- Client sends final data package to Aestus	- Remedial design characterization report

Case Study Overview

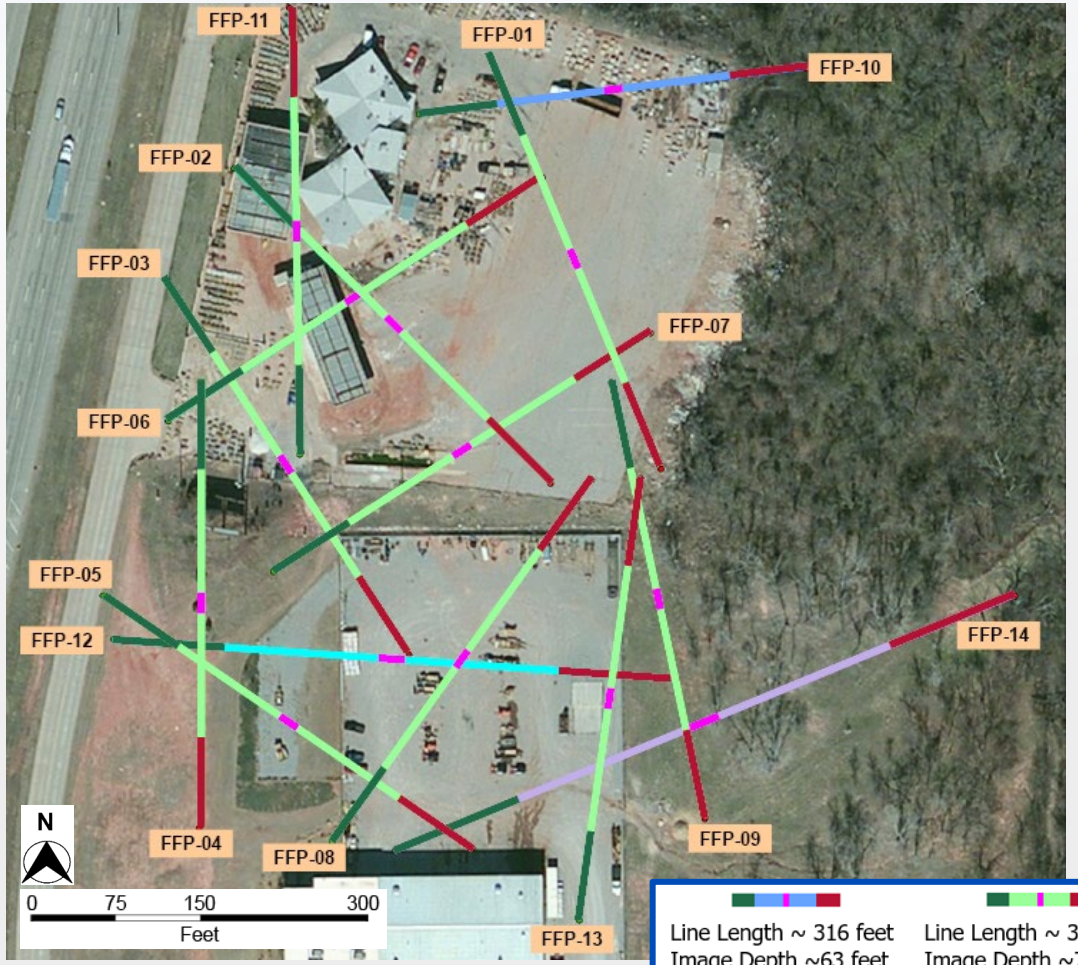
- Location: Oklahoma City, OK USA
- Geology:
  - Cross bedded, fine-grained sandstones with interbedded siltstones
  - Underlying fractured sandstone aquifer
- Source: LNAPL, dissolved benzene (former truck stop)
- Problem: preferential flowpaths controlling transport remain unknown

Site History

- Former truck stop with multiple recorded releases during the 1990s (up to ~2,100 gallons)
- Significant historical LNAPL plume (free product thickness ≥ 10 ft)
- Remediation strategies deployed between 2008 and 2017:
  - Free product recovery
  - Enhanced fluid recovery
  - Surfactant injections
- Free product in measurable amounts still present in 2020



Site Logistics & GeoTrax Survey™ Work



Instrument Location at Center of Pink Box

Full depth of trapezoidal shaped image exists in center zone; partial depth in green and red zones

Line Length ~ 316 feet
Image Depth ~63 feet

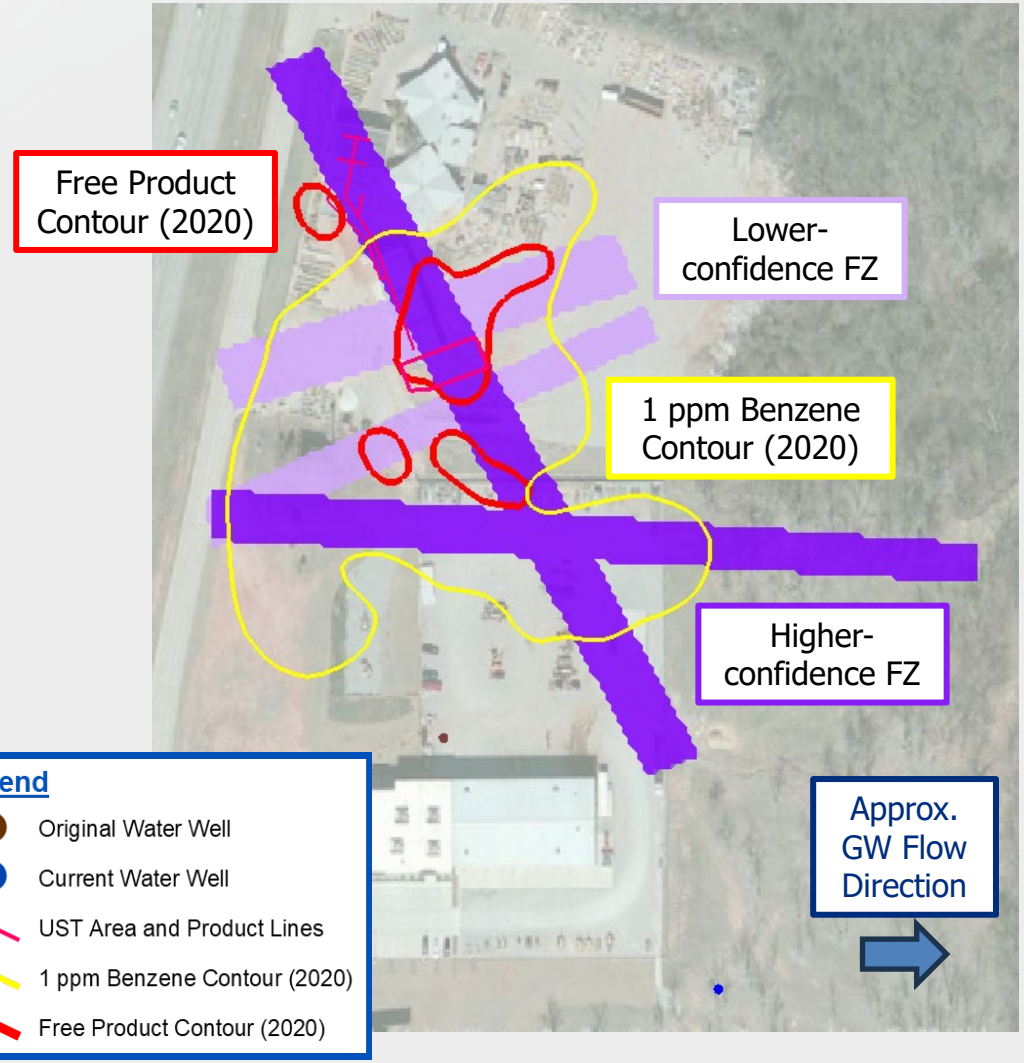
Line Length ~ 361 feet
Image Depth ~72 feet

Line Length ~ 451 feet
Image Depth ~90 feet

Line Length ~ 541 feet
Image Depth ~108 feet

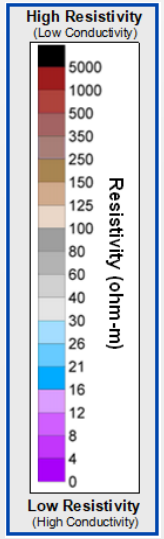
GeoTrax Survey™ Informed CSM Components

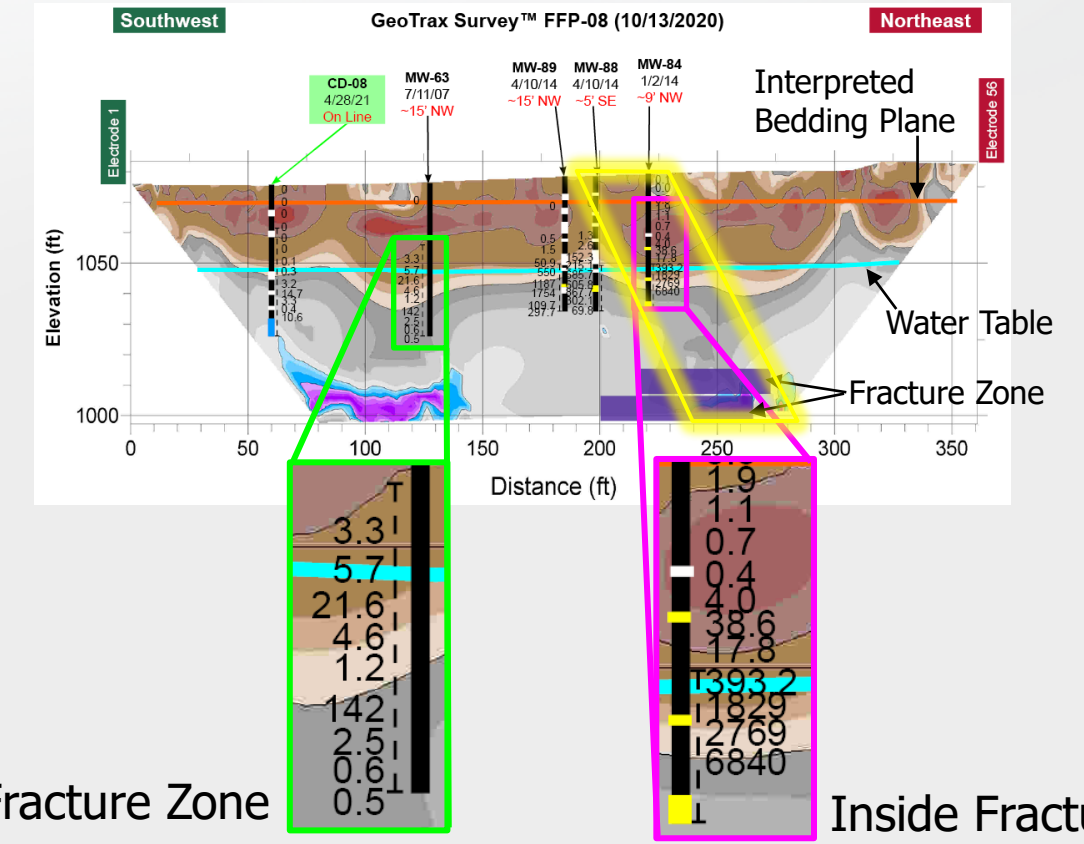
- Geology
  - 2 higher-confidence fracture zones (FZ)
  - 2 lower-confidence fracture zones
- Hydrogeology
  - GW flow on site is likely heavily influenced by fracture zones
- Contaminant
  - FP, highest PID values, and dissolved phase benzene plume closely follow fracture zones
- Bio
  - Biodegradation limited by lack of electron acceptors



Horizontal and Vertical Contaminant Extents

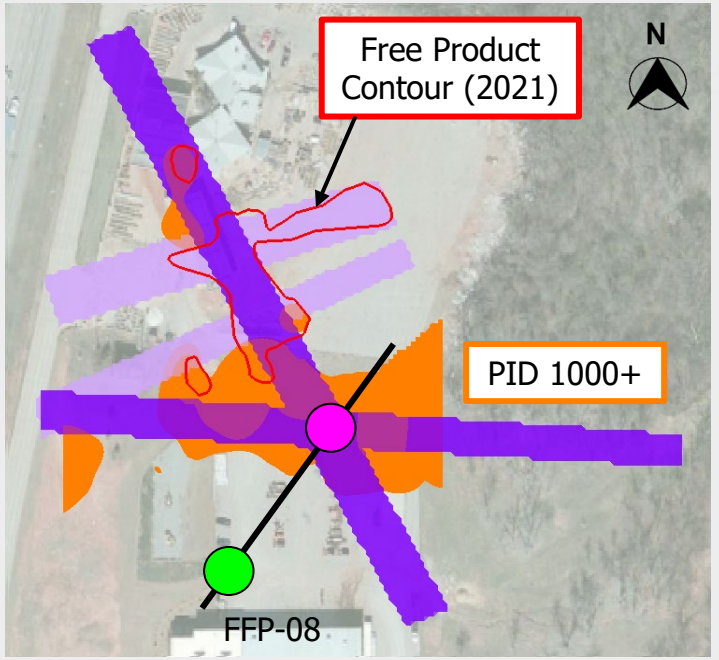
- PID values higher in fracture zone than outside fracture zone
- Plumes and PID closely follow fracture zone orientation

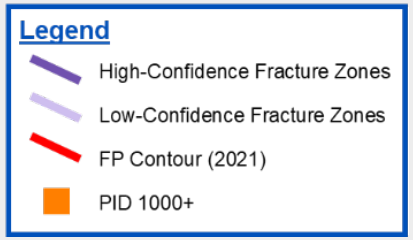




Outside Fracture Zone

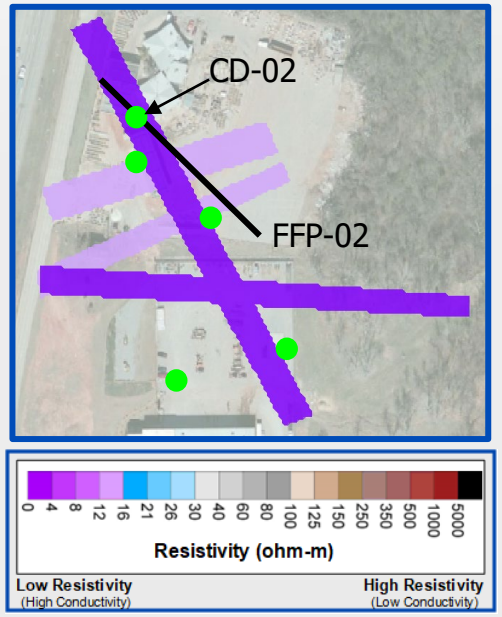
Inside Fracture Zone

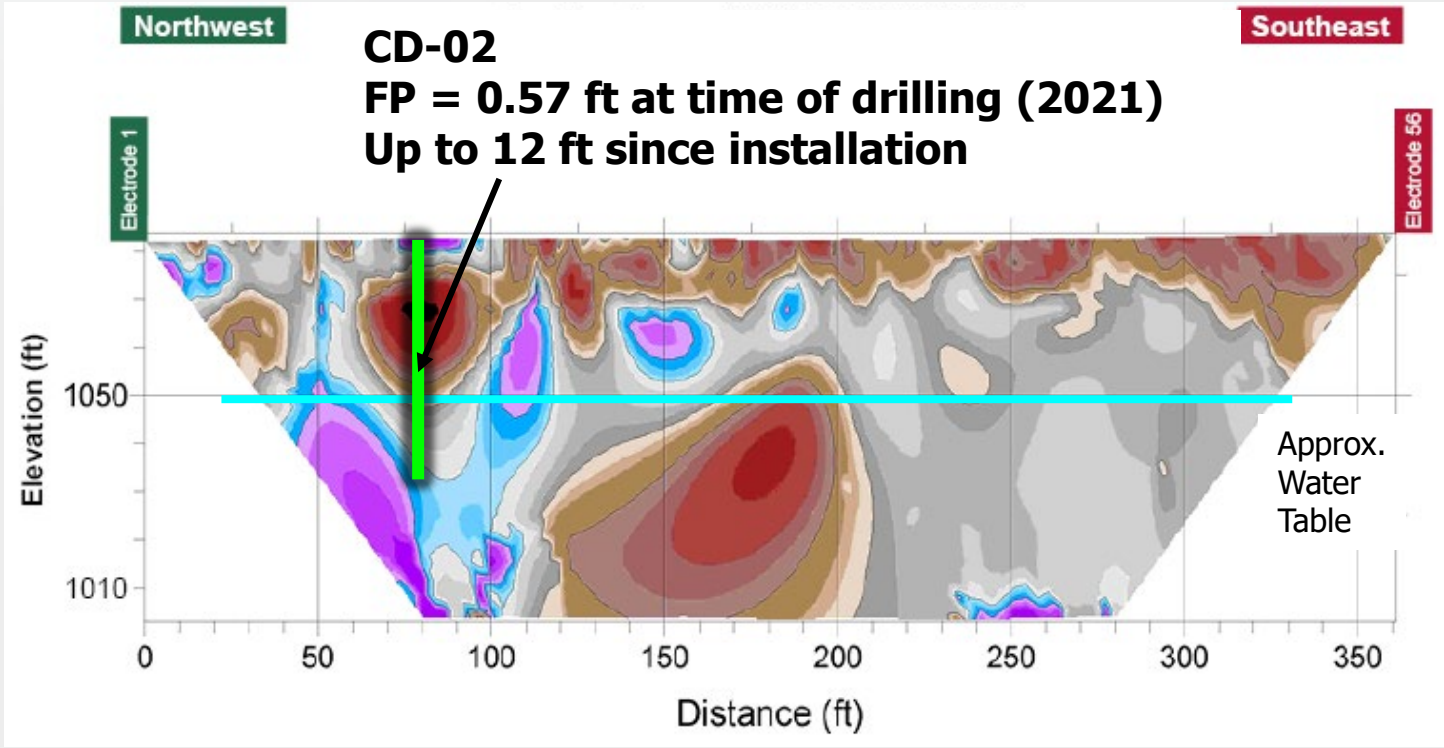




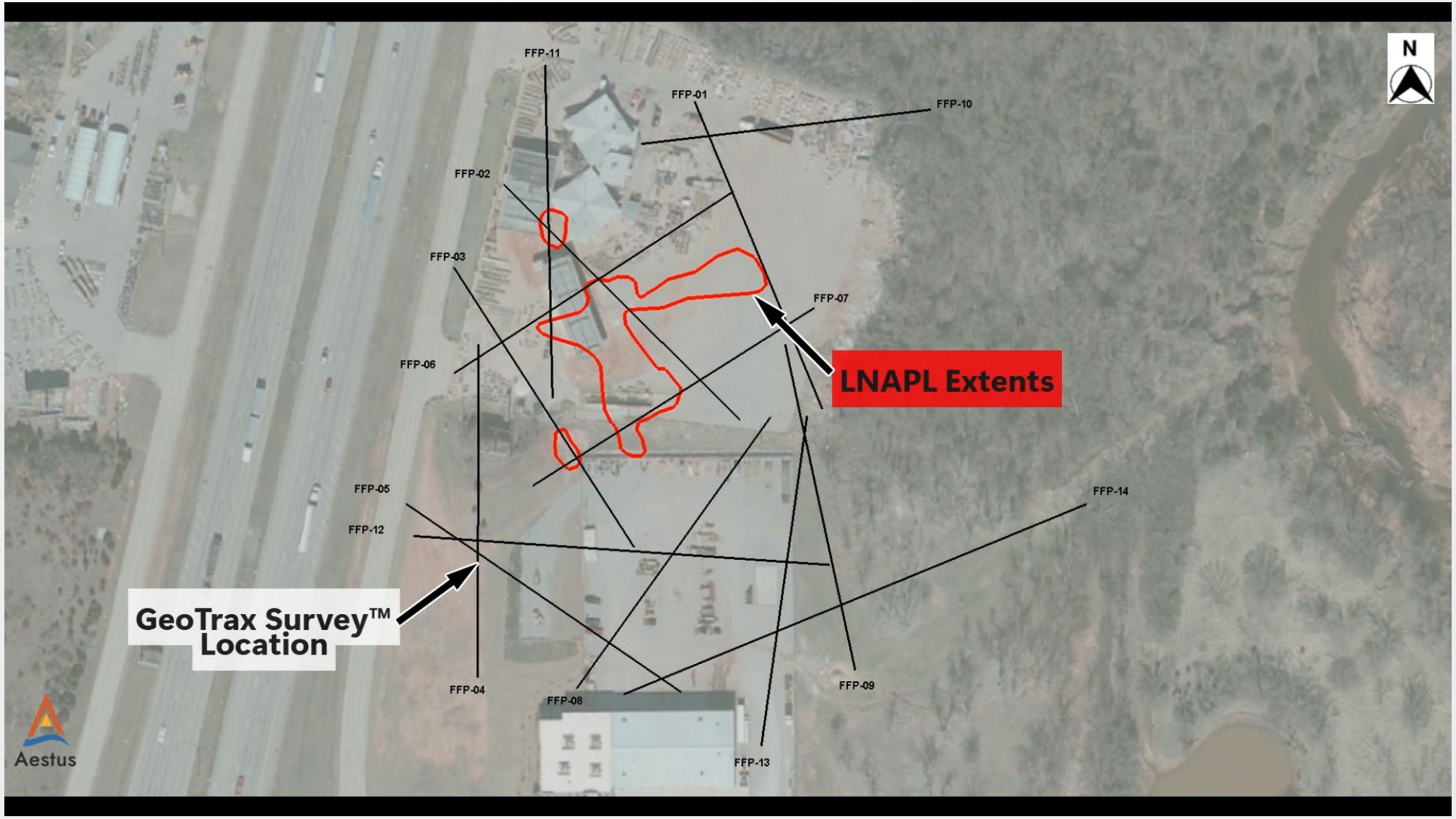
Confirmation Drilling Results

- 5 CDs targeted based on GeoTrax Survey™ data to investigate suspected fracture zones and inform contaminant extents
- 2 CD locations contained free product

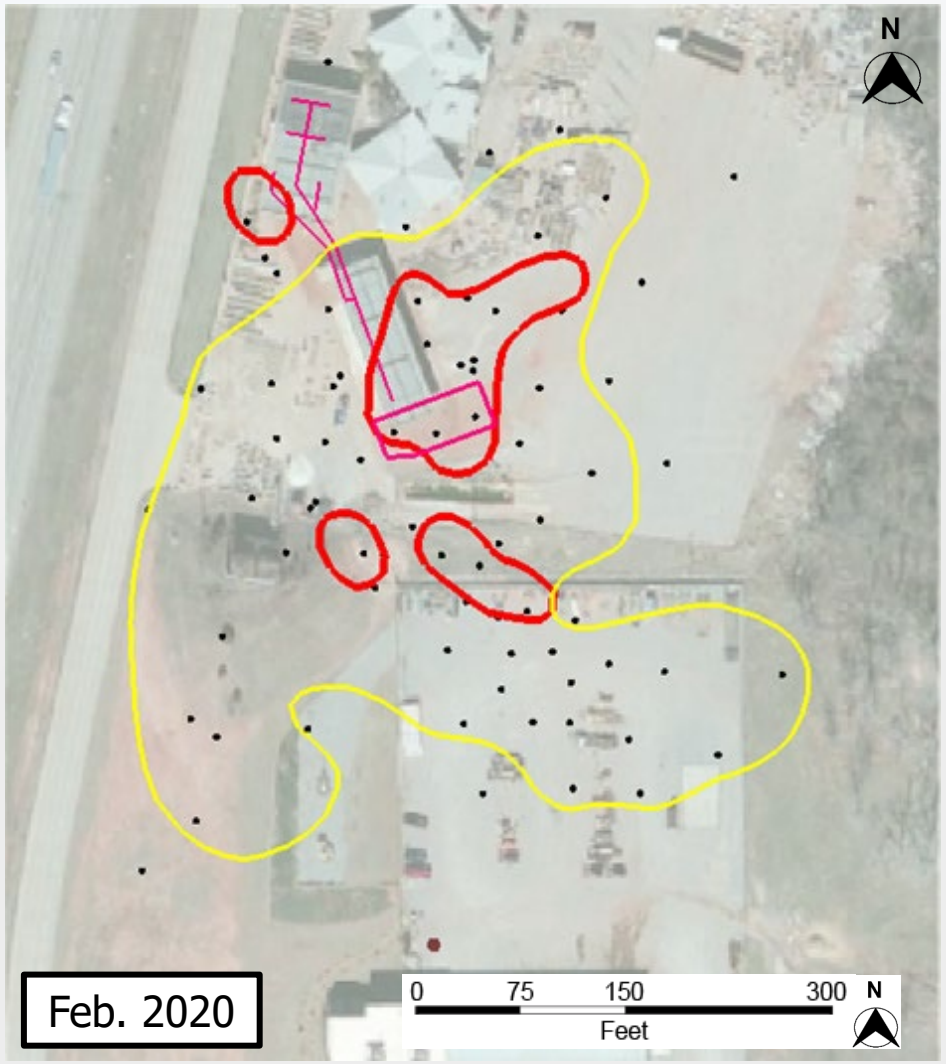


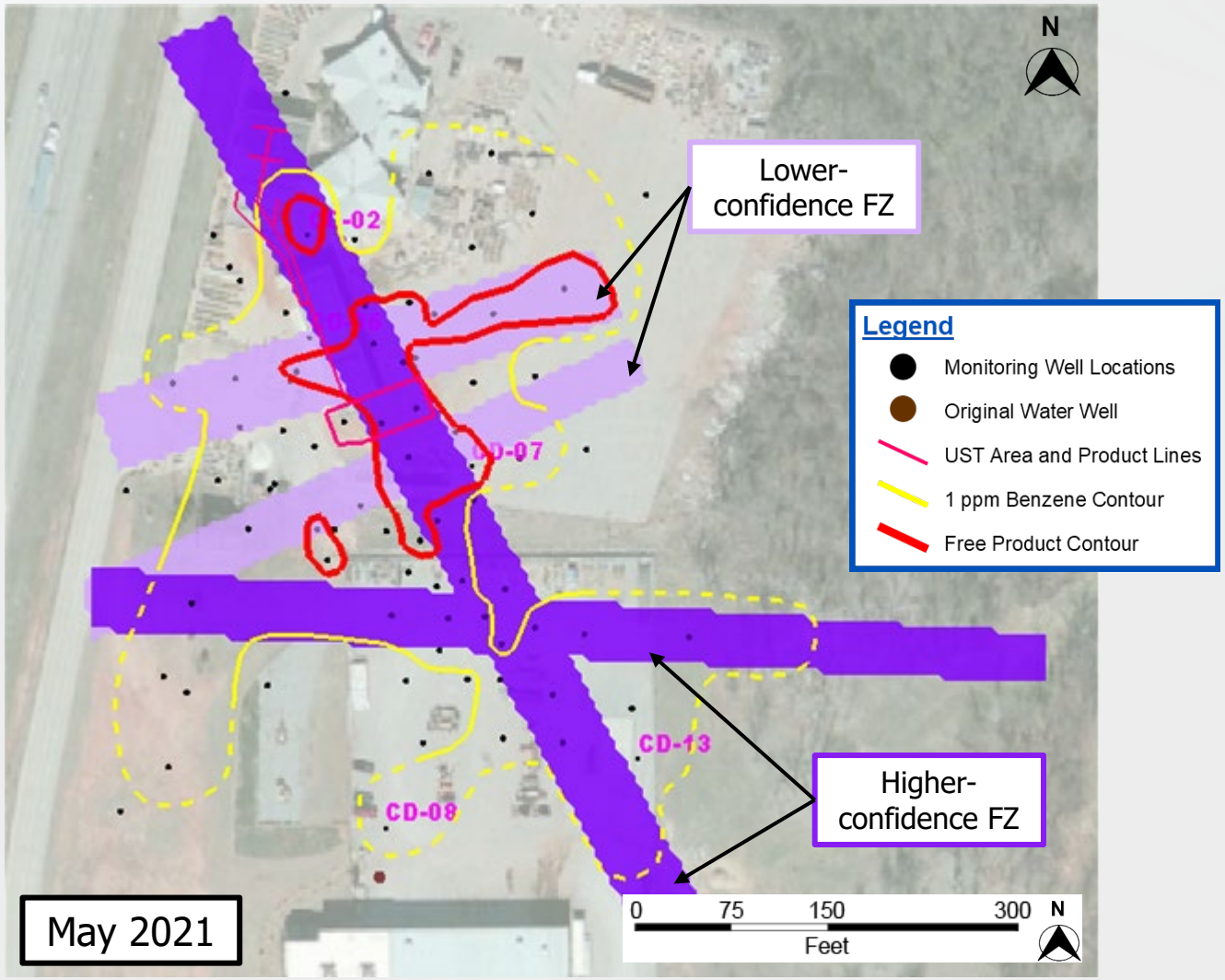


Final CSM – Calibrated Data

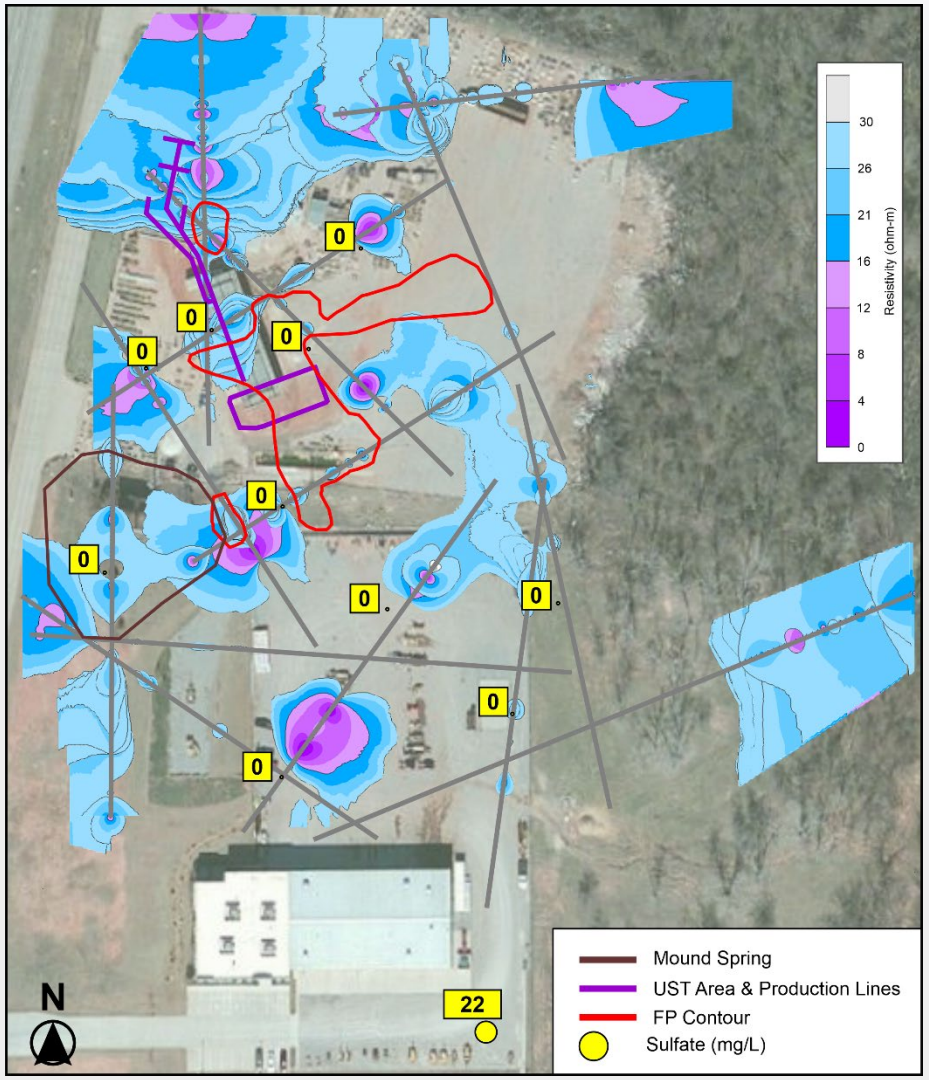


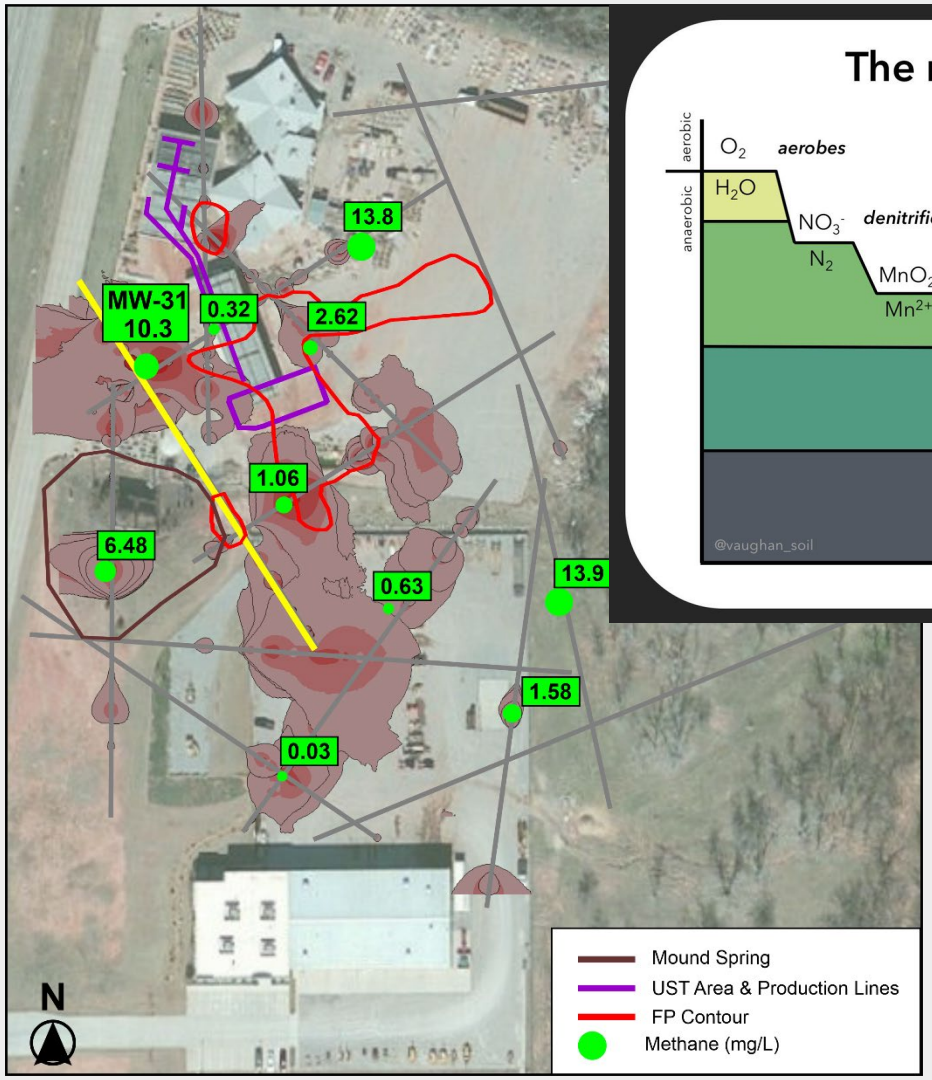
Final CSM Comparison

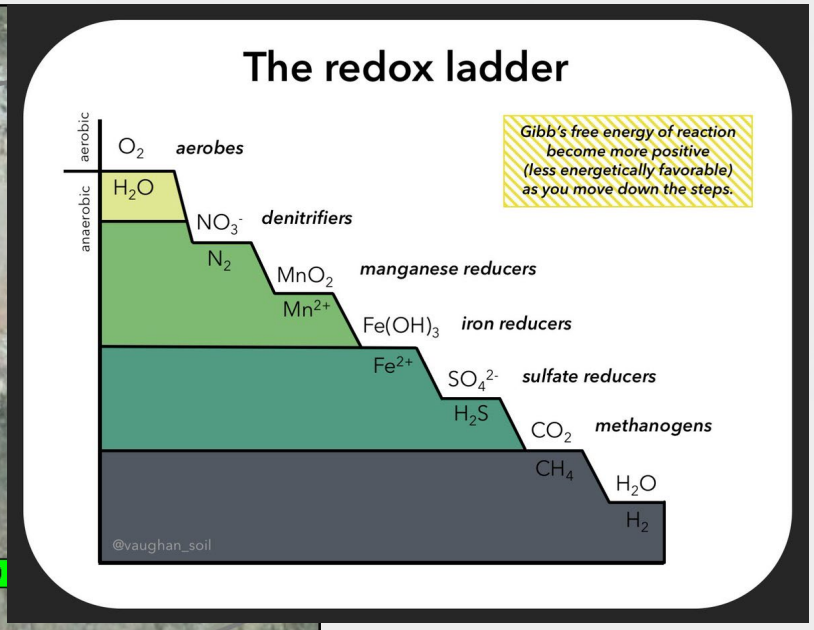




Bioactivity Assessment

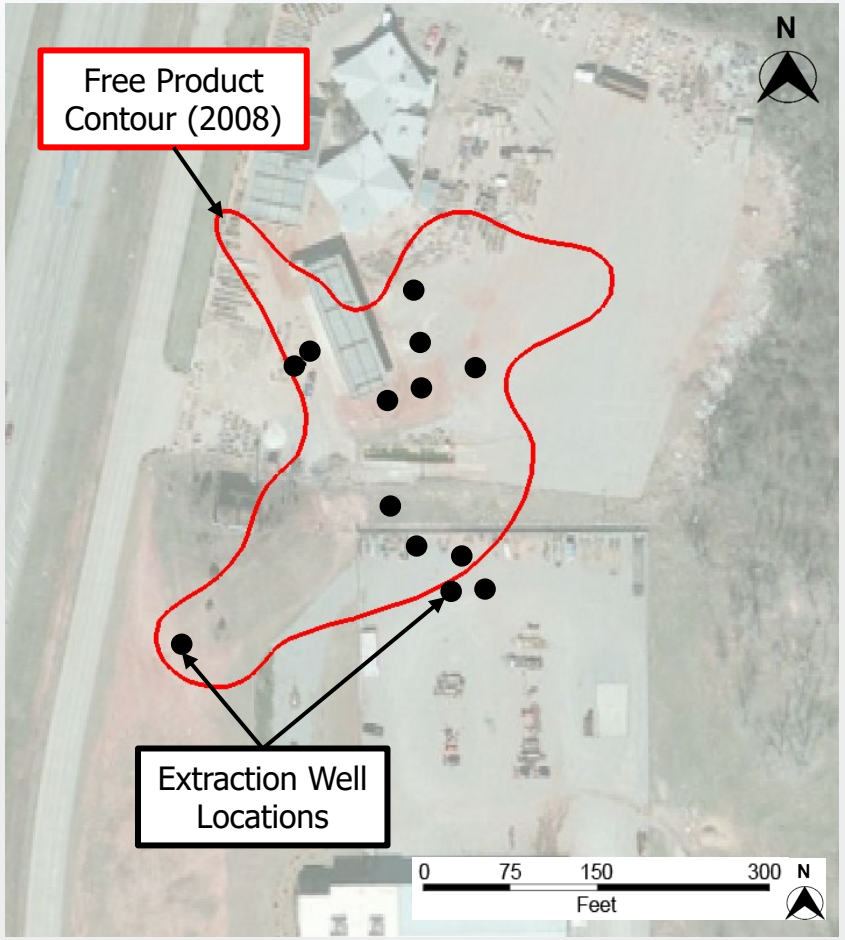




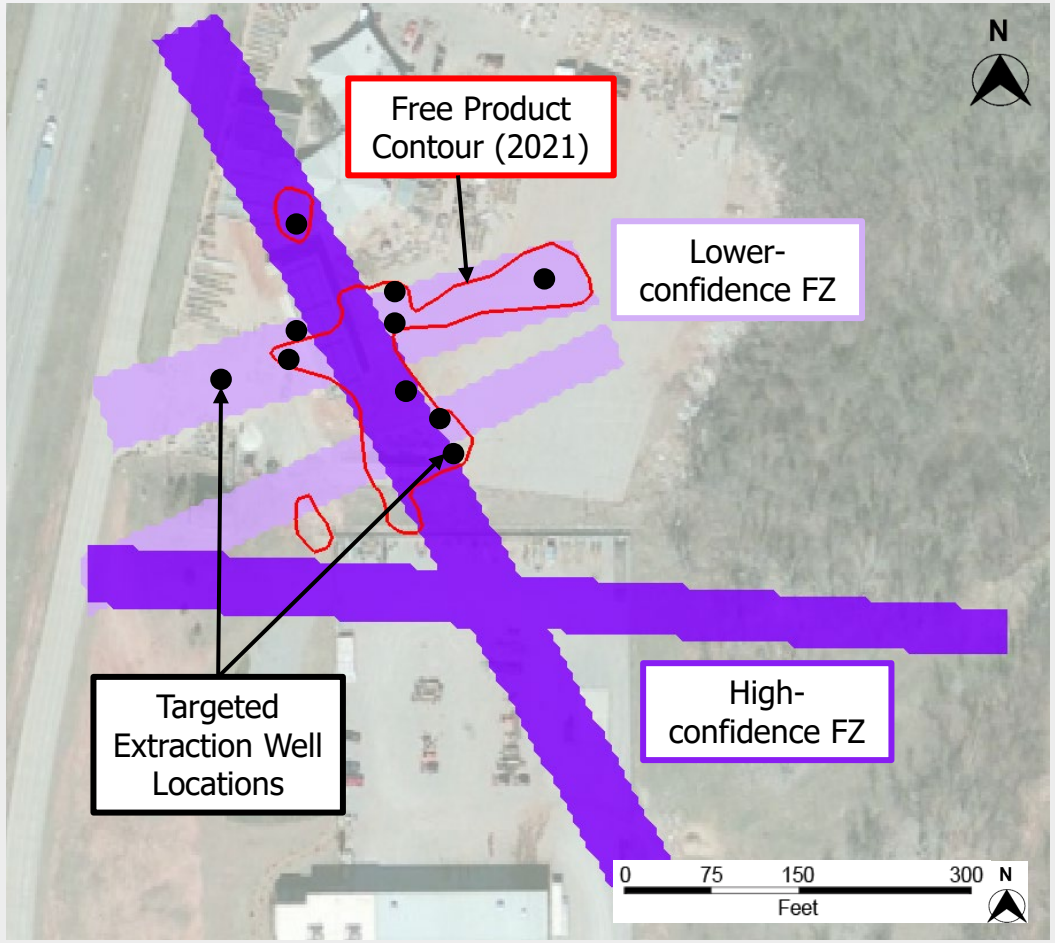


Remedial Design Characterization

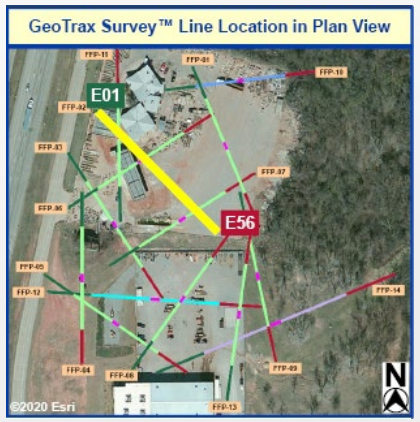
2013 High Vacuum Extraction:
212 gallons FP from 13 extraction wells

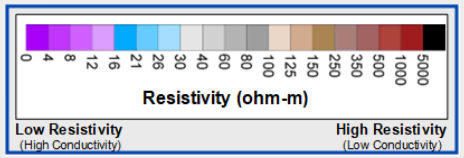


2024 Targeted High Vacuum Extraction:
152 gallons FP from 10 extraction wells
ROI of up to ~40 feet

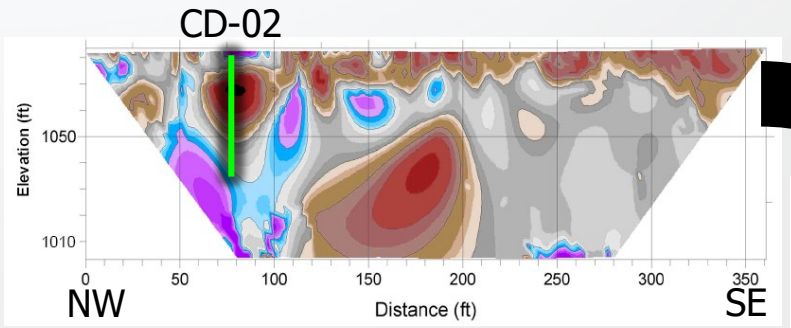


Monitoring Site Conditions in Source Area with Temporal Data Sets

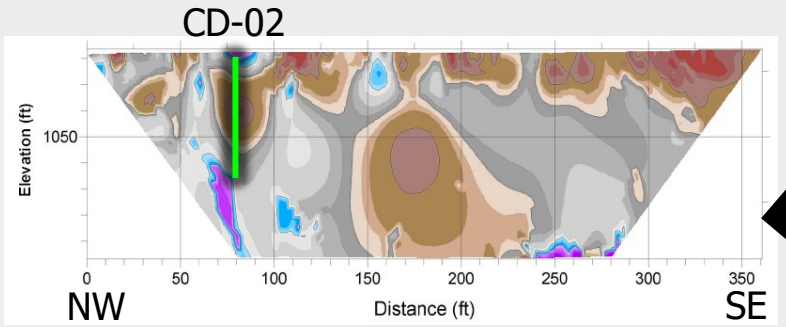




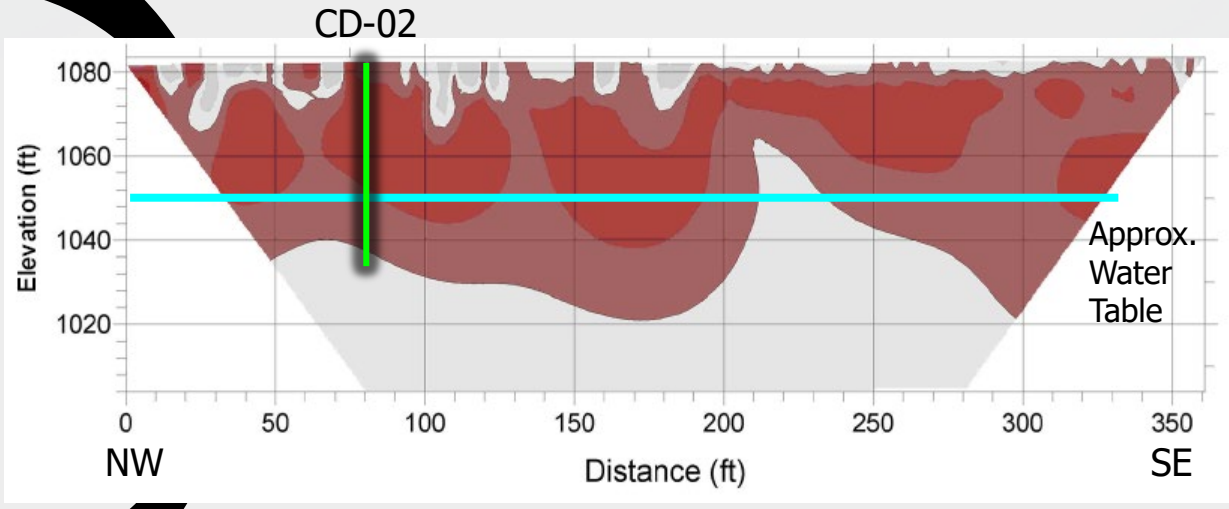
2020 GeoTrax Survey™ Static Image

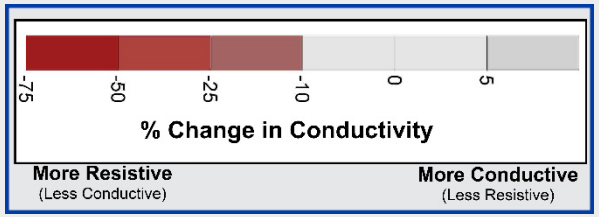


2025 GeoTrax Survey™ Static Image



Temporal GeoTrax Monitoring™ Image
ΔT = 5 Years





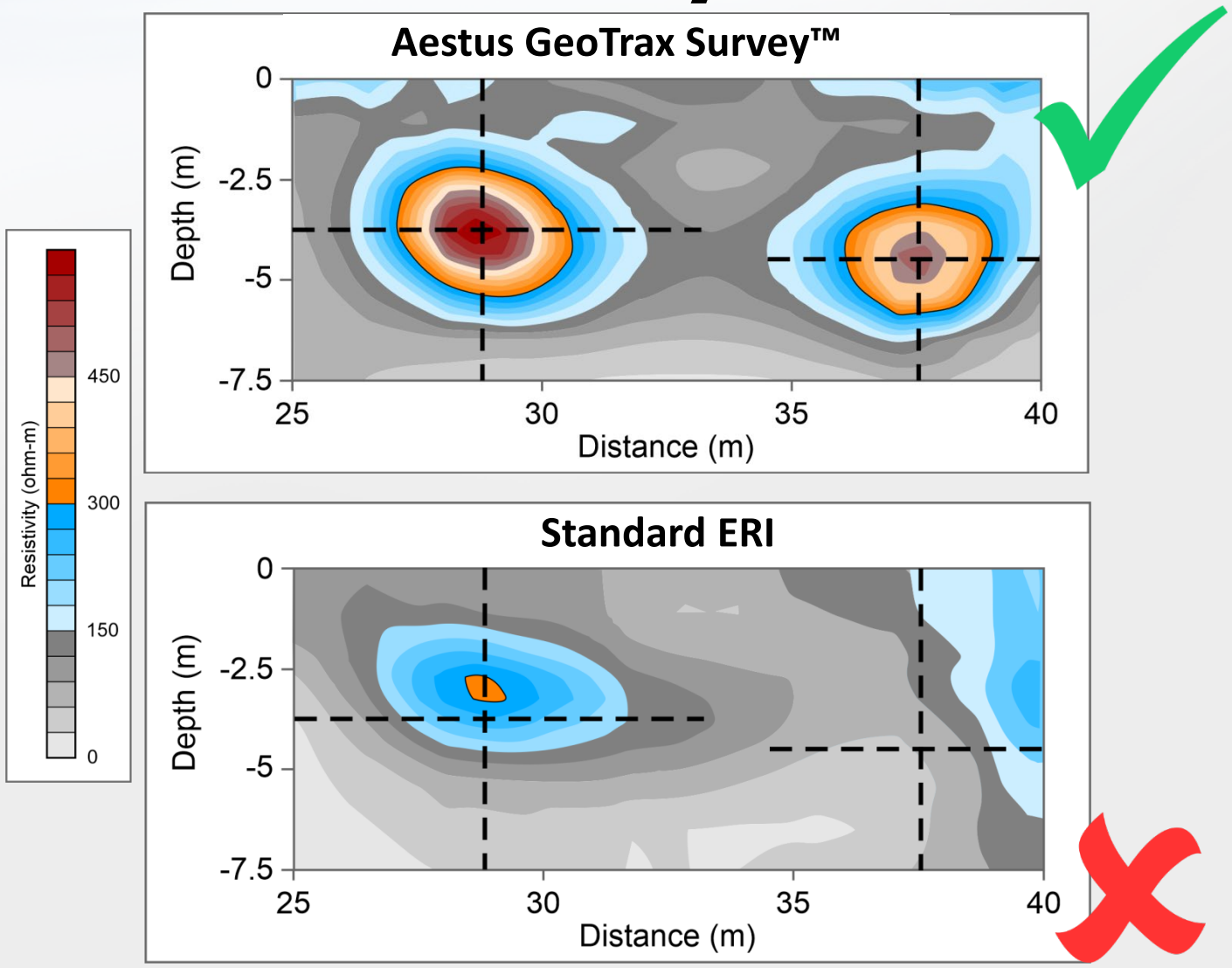
Project Summary: Client Feedback

"GeoTrax Survey™ electrical resistivity survey proved instrumental in understanding hydrocarbon migration patterns within our fractured aquifer system. Their expertise provided crucial insights that traditional methods simply couldn't deliver, allowing us to:

- ✓ **Accurately map the extent and movement of the hydrocarbon plume, even within the complex network of fractures.**
- ✓ **Identify the preferential pathways of migration, which was essential for targeting remediation efforts effectively.**
- ✓ **Make informed decisions about drilling and remediation strategies, saving us time and resources."**

-Kathy Lippert, Greystone Environmental Services, Inc.

GeoTrax Survey™ vs Standard ERI



Drillable Image

- ✓ *Designed for Environmental Contaminants*
- ✓ *Higher Sensitivity*
- ✓ *Better Quality Image*
- ✓ *Strong QA/QC Protocols*
- ✓ *Confirmed by EPA Ada Lab*

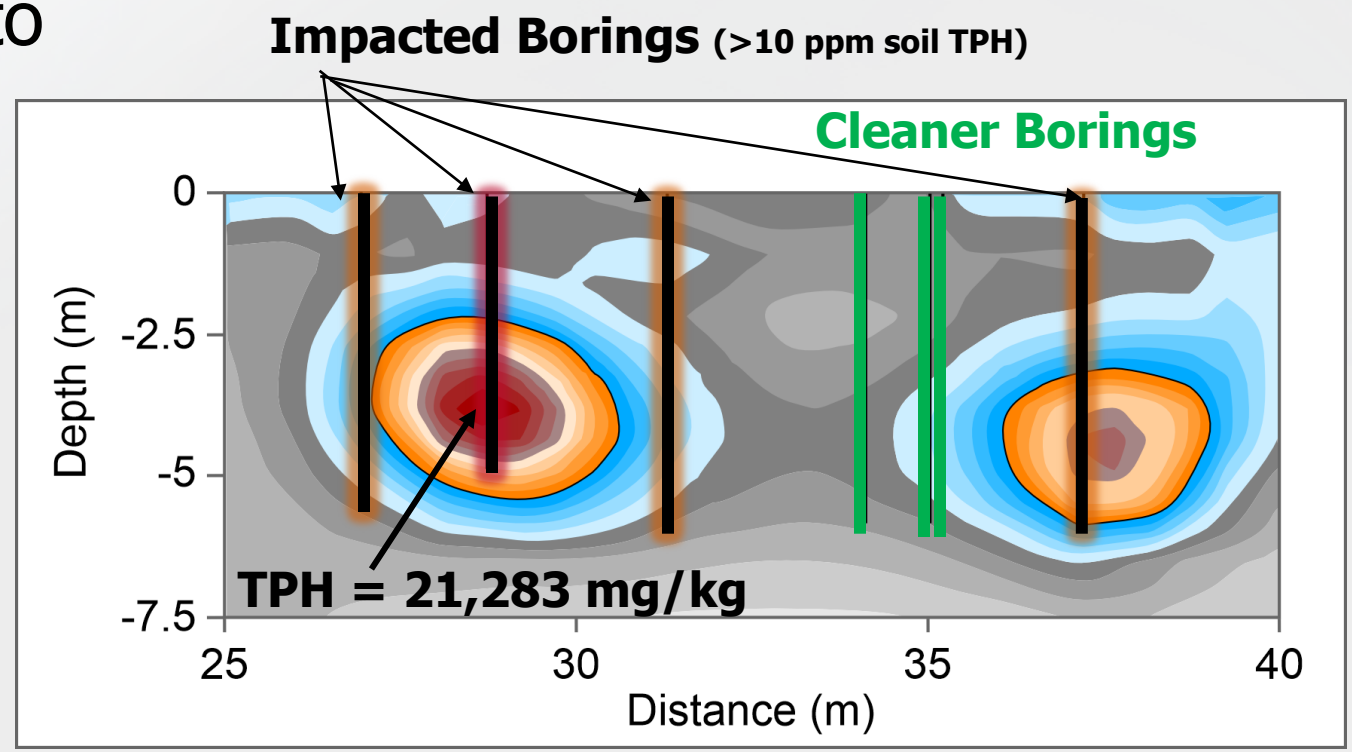
from Halihan et al, 2005

Same equipment

Same transect line

GeoTrax Survey™ vs Standard ERI

- GeoTrax Survey™ designed to accurately see contaminants via higher sensitivity image
- "Drillable" datasets (discrete targets for drilling)



Post-remediation evaluation of a LNAPL site using electrical resistivity imaging

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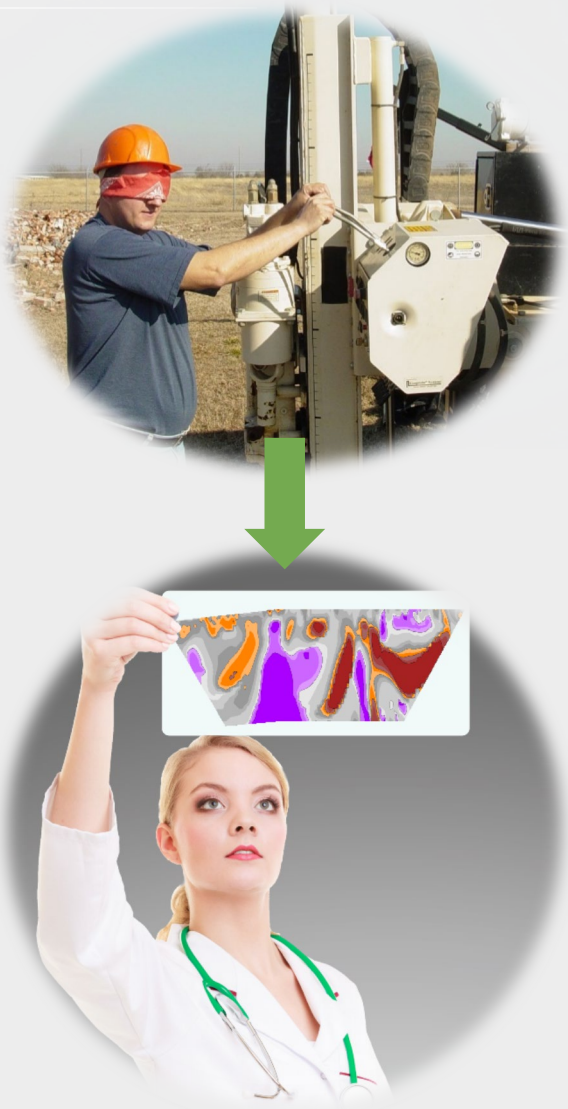
Key Takeaways

- Electrical hydrogeology process can be successfully applied at any time in a project
- Following the 5-step process ensures
  1. All site data integrated in figures and robust 3D model
  2. High-resolution GeoTrax Survey™ images infill any existing data gaps
  3. CSM components informed: geology, hydrogeology, contaminant, bioactivity
  4. Targeted drilling locations in critical site locations
  5. Updated, data-dense CSM for future decision-making
- Electrical monitoring of sites provides greater certainty



Better Data, Better Decisions

QUESTIONS?

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