Targeted Remediation in Fractured Bedrock on a Remote Superfund Site Using Electrical Hydrogeology

Kyle Spears, MS

Stuart McDonald, P.E.

Samantha Frandsen, MSc

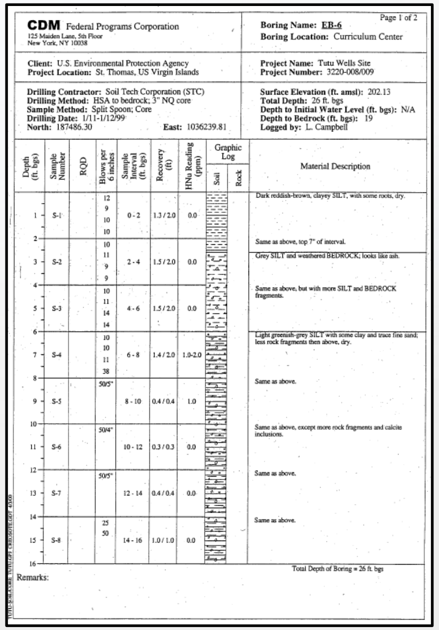
Aestus

RemTech 2024 Conference, Banff, Canada

Executive Summary

I. What is the Industry Standard for Data Density?
II. Increasing Data Density with Electrical Hydrogeology
III. Case Study: DNAPL in fractured rock
IV. Benefits of Electrical Hydrogeology

The Common Approach to CSM Development



Page 1 of 2

CDM Federal Programs Corporation
125 Maiden Lane, 5th Floor
New York, NY 10038

Boring Name: EB-6
Boring Location: Curriculum Center

Client: U.S. Environmental Protection Agency
Project Location: St. Thomas, US Virgin Islands

Project Name: Tutu Wells Site
Project Number: 3220-008/009

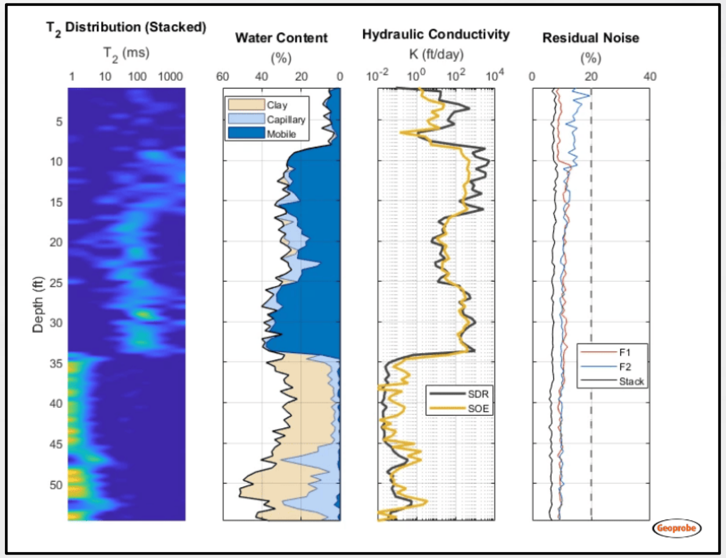
Drilling Contractor: Soil Tech Corporation (STC)
Drilling Method: HSA to bedrock; 3" NQ core
Sample Method: Split Spoon; Core
Drilling Date: 1/11-1/12/99
North: 187486.30 **East:** 1036239.81

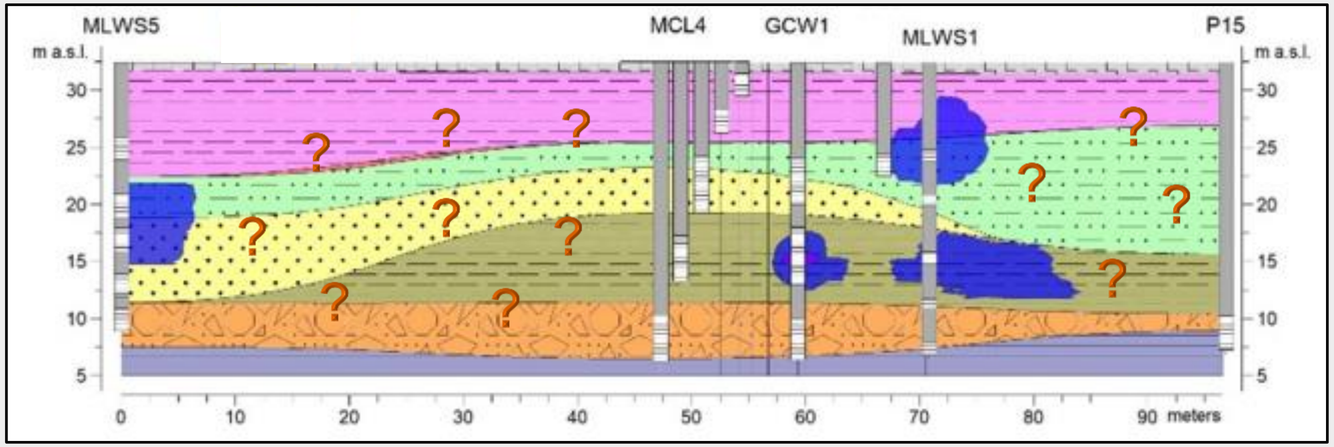
Surface Elevation (ft. amsl): 202.13
Total Depth: 26 ft. bgs
Depth to Initial Water Level (ft. bgs): N/A
Depth to Bedrock (ft. bgs): 19
Logged by: L. Campbell

Depth (ft. bgs)	Sample Number	RQD	Blows per 6 inches	Sample Interval (ft. bgs)	Recovery (ft)	HNu Reading (ppm)	Graphic Log Soil	Graphic Log Rock	Material Description
1	S-1		12 9 10 10	0 - 2	1.3 / 2.0	0.0			Dark reddish-brown, clayey SILT, with some roots, dry. Same as above, top 7" of interval.
3	S-2		10 11 9 9	2 - 4	1.5 / 2.0	0.0			Grey SILT and weathered BEDROCK; looks like ash.
5	S-3		10 11 14 14	4 - 6	1.5 / 2.0	0.0			Same as above, but with more SILT and BEDROCK fragments.
7	S-4		10 10 11 38	6 - 8	1.4 / 2.0	1.0-2.0			Light greenish-grey SILT with some clay and trace fine sand; less rock fragments then above, dry.
9	S-5		50/5"	8 - 10	0.4 / 0.4	1.0			Same as above.
11	S-6		50/4"	10 - 12	0.3 / 0.3	0.0			Same as above, except more rock fragments and calcite inclusions.
13	S-7		50/5"	12 - 14	0.4 / 0.4	0.0			Same as above.
15	S-8		25 50	14 - 16	1.0 / 1.0	0.0			Same as above.

Total Depth of Boring = 26 ft. bgs

Remarks:





Modified* After: *Ciampi et al, 3D dynamic model empowering the knowledge of the decontamination mechanisms and controlling the complex remediation strategy of a contaminated industrial site, Science of The Total Environment 793,2021*

**It is difficult for environmental professionals to gain enough certainty with CSMs as they are often hindered by lower data density from traditional 1-D drilling data*

Limited Datasets In 3D Are Still Limited

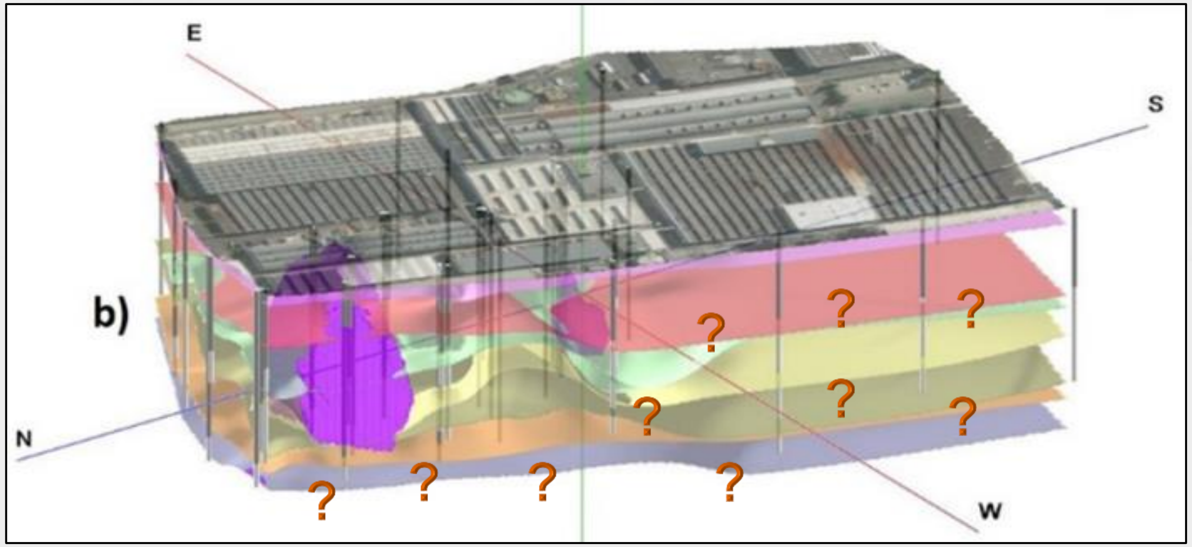
- Modelling software typically used for interpolating sparse data
- Does not solve low data density problem

Site Area: 120,000 m^2

56 boreholes/wells to ~30 m

106 piezometers

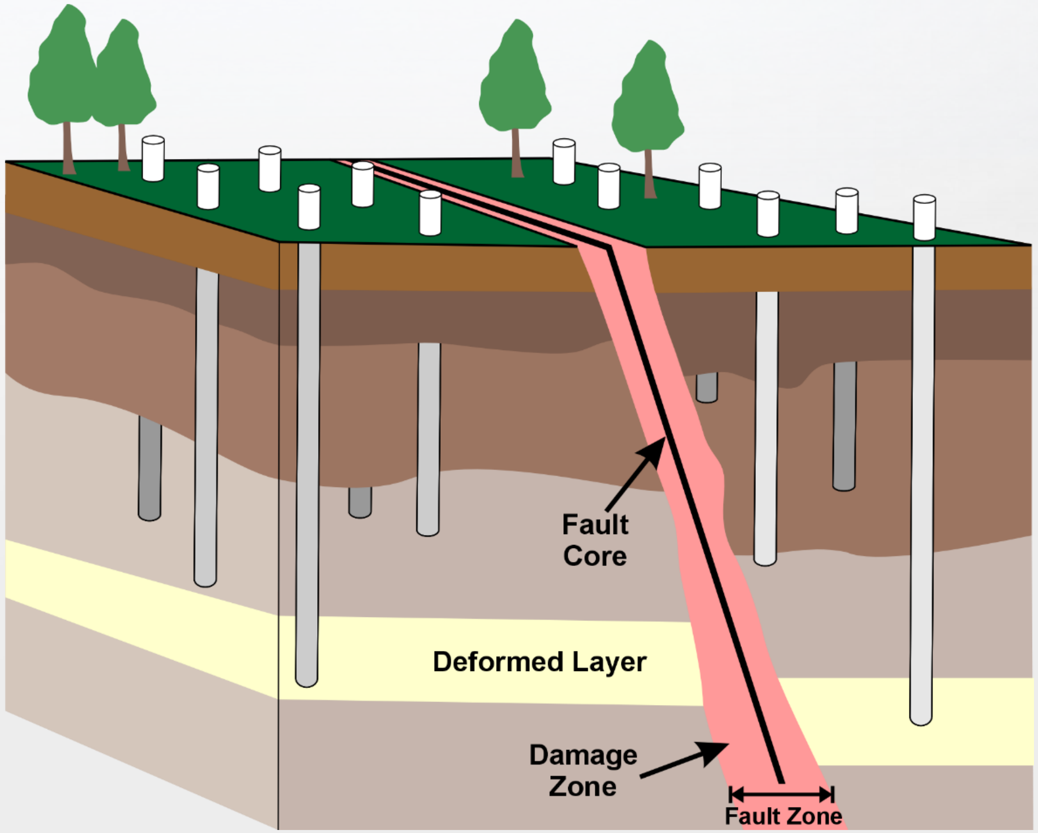
<1% of 3D domain is sampled



Modified* After: *Ciampi et al, 3D dynamic model empowering the knowledge of the decontamination mechanisms and controlling the complex remediation strategy of a contaminated industrial site, Science of The Total Environment, V 793,2021*

**It is difficult for environmental professionals to gain enough certainty with CSMs as they are often hindered by lower data density from traditional 1-D drilling data*

Vertical Data Inherently Limited



- "It is difficult to find vertical features w/ vertical tools (1-D drilling)"
- CSMs typically built from limited number of vertical wells
- Attempting to comprehend large volumes of the subsurface based on small discrete samples
- Limited information about subsurface conditions leads to failed remediation attempts

Brief Overview of Scan First Approach

Defined Process to Integrate Data Sets

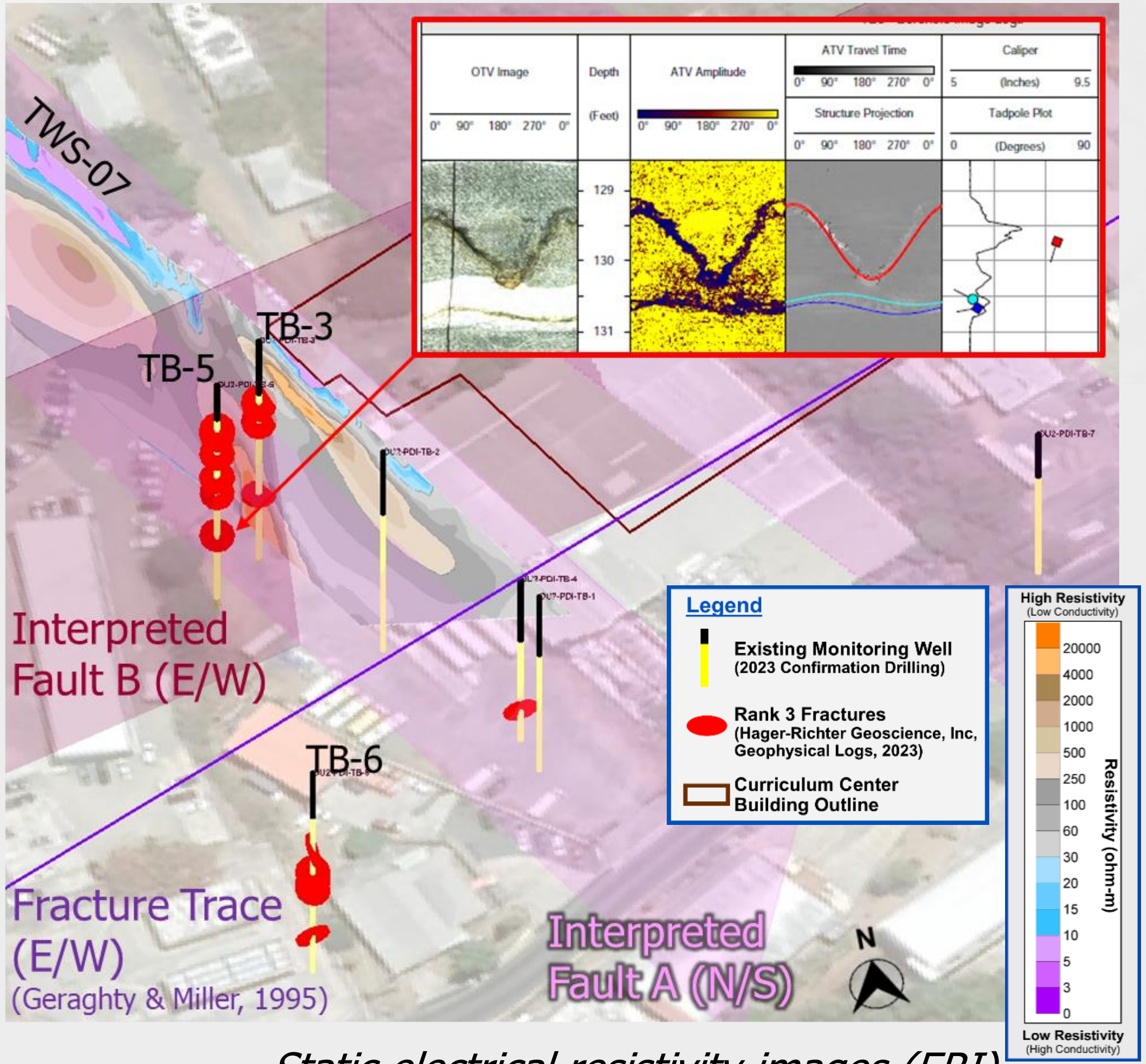
Traditional Hydrogeology

+

Electrical Imagery/Visualization/
Targeted Drilling

=

Electrical Hydrogeology



Static electrical resistivity images (ERI)

Electrical Hydrogeology Process

1 Visualize Existing Site Data in 3D

- Client sends existing site data to Aestus
- Must occur prior to fieldwork (Step 2)

2 Ultra-High Resolution Scan

- Acquire *GeoTrax Survey™* 2D Imagery
- Use Dynamic work strategy with QA/QC

3 Interim Report (w/Hypotheses)

- Integrate data sets in 2D & 3D (*GeoTrax Viz™*)
- Select confirmation drilling locations

4 Confirmation Drilling (by Client)

- Perform targeted drilling/sampling to test CSM
- Client sends final confirmation data to Aestus

5 Final CSM+ Report

- Integrate confirmation data (*GeoTrax Viz™*)
- Updated conceptual site model (CSM) for remedial design input

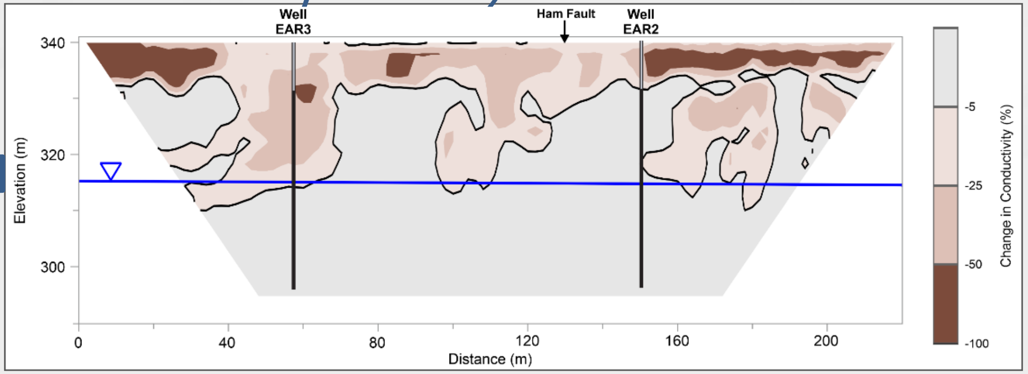
Monitoring Sites with “Planes” Instead of “Lines”

Monitor with a well
(<1 m of subsurface laterally)

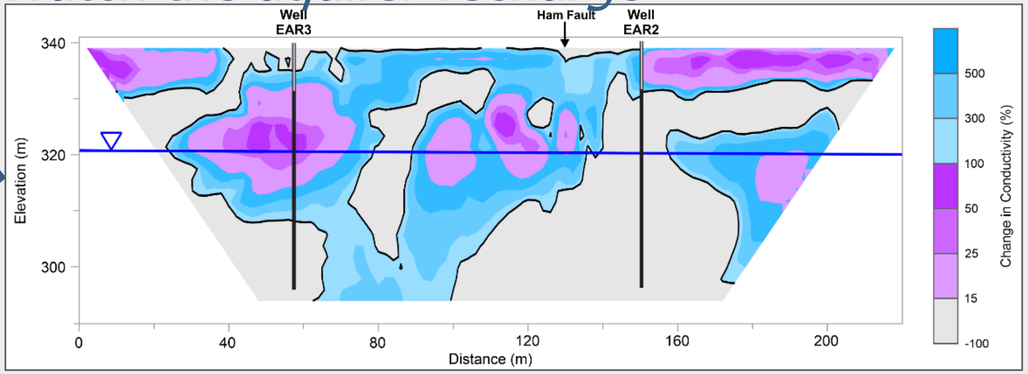
Or

Monitor a Plane
(~220 m of subsurface sampled)

Watch the aquifer dry



Watch the aquifer recharge

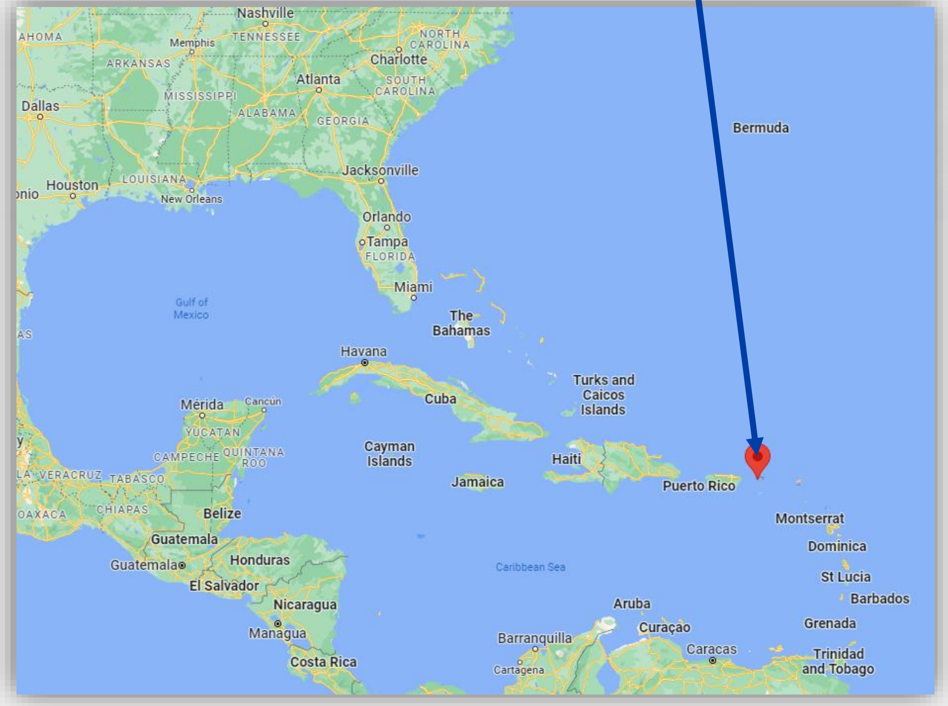


Temporal electrical resistivity images (TERI)

EPA Superfund Site, Tutu Wellfield

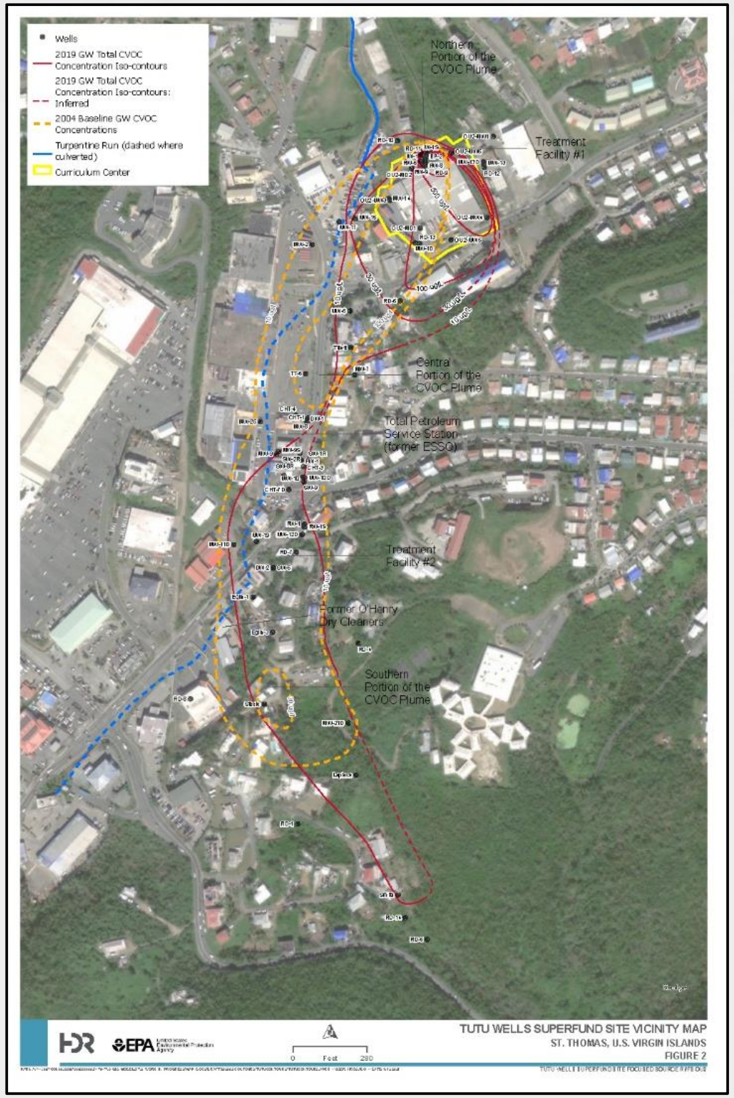
- Location: St. Thomas, US VI
- Geology: fractured, volcanic bedrock
- Source: PCE (manufacturing plant/dry cleaner)
- Problem: source zone still not fully delineated

Tutu Wellfield
Superfund Site



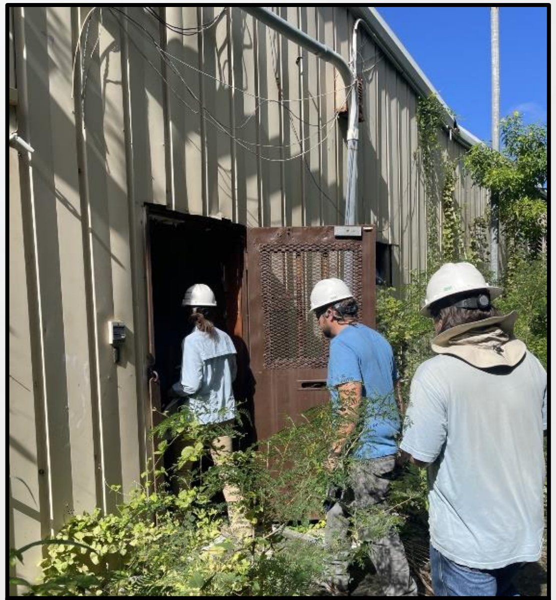
Site History

- Multiple investigations at the source area since 1987; <u>no DNAPL located</u>
- GW impacted with CVOCs as deep as ~140′ BGS
- Fractured igneous bedrock site
- GW flow to southwest
- SVE & groundwater extraction and treatment system began in 2004



2019 CVOC Groundwater Plume Map by HDR

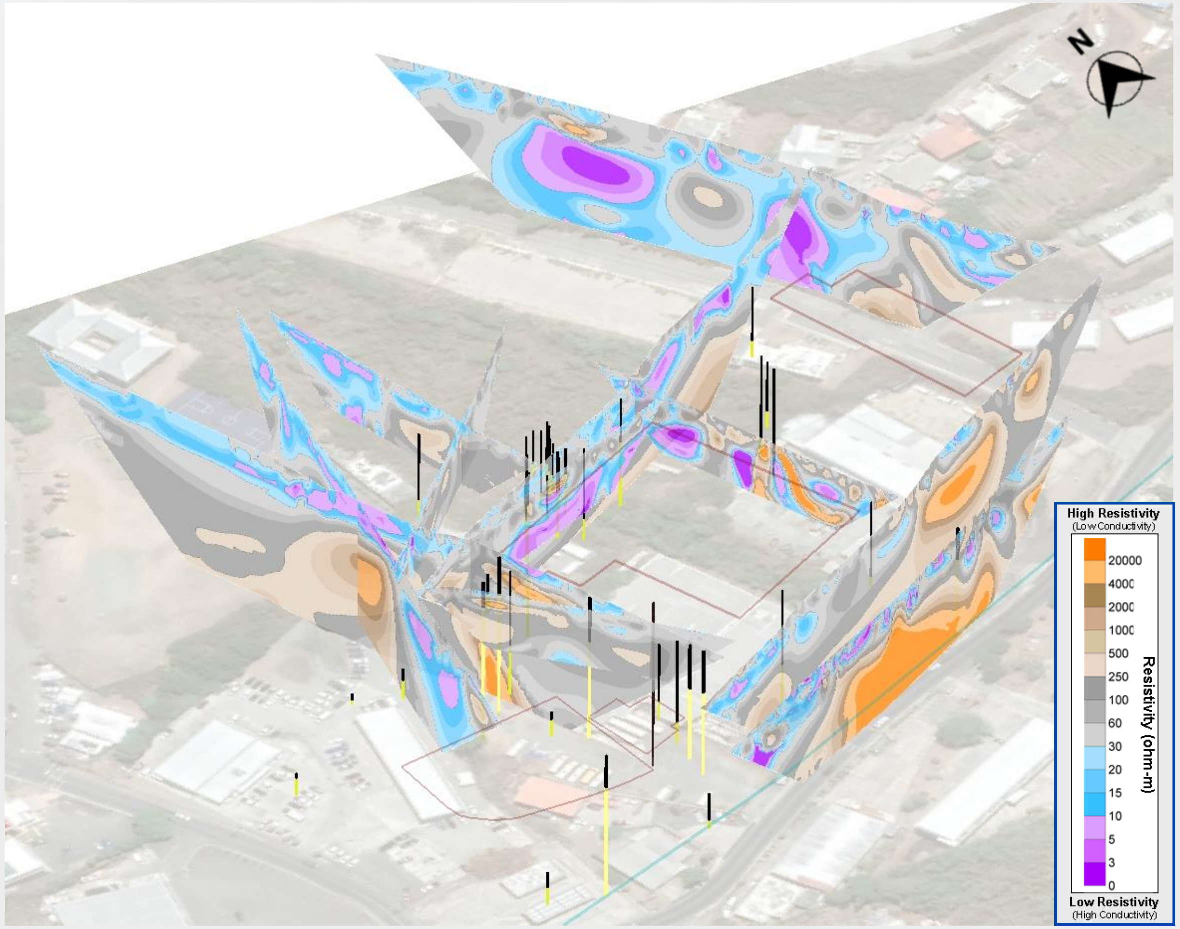
Island Site Logistics



Post Field Work Data Integration

2D/3D integration of historical data and new electrical images:

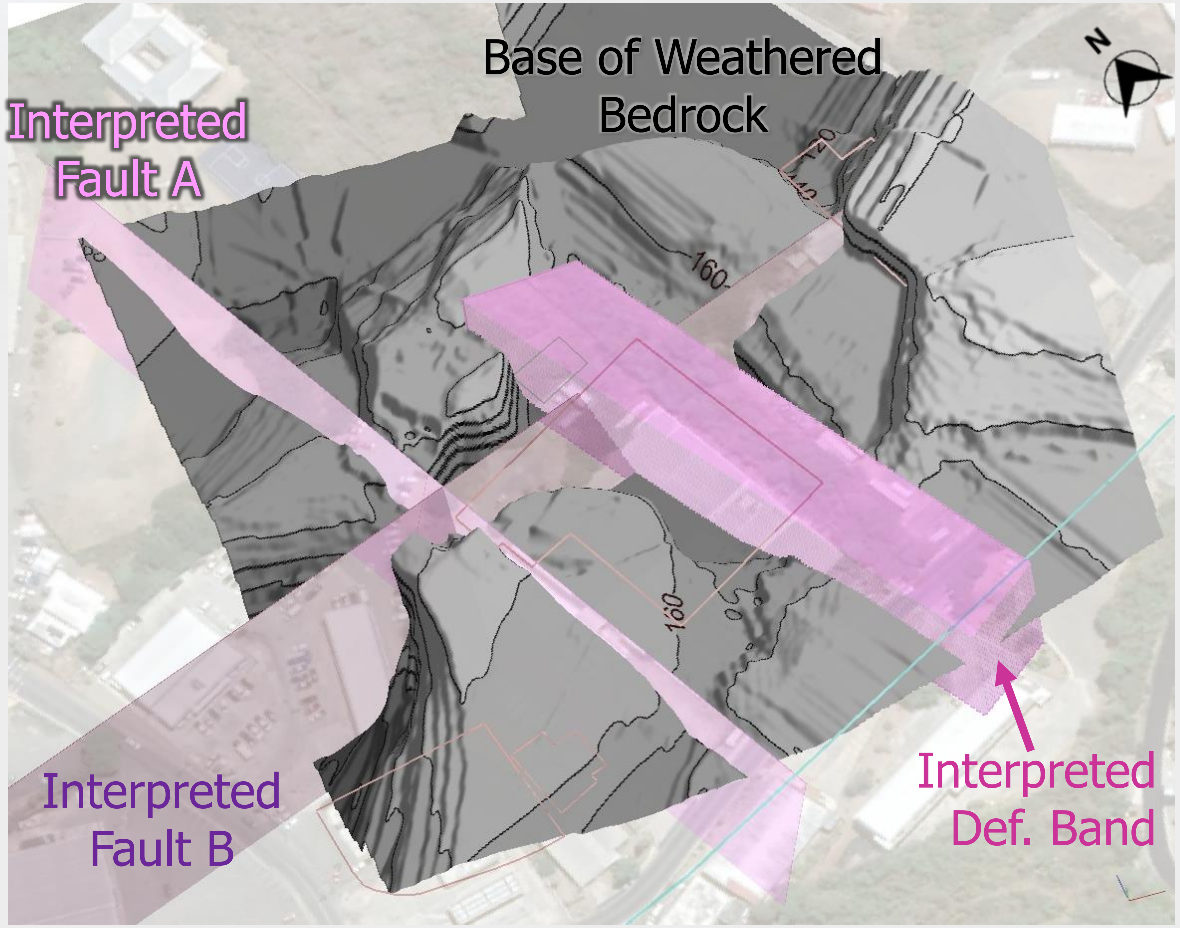
- Existing boring/well data
- GeoTrax Survey™ 2D Imagery
- Honor multiple lines of evidence approach



Newly Developed CSM Components

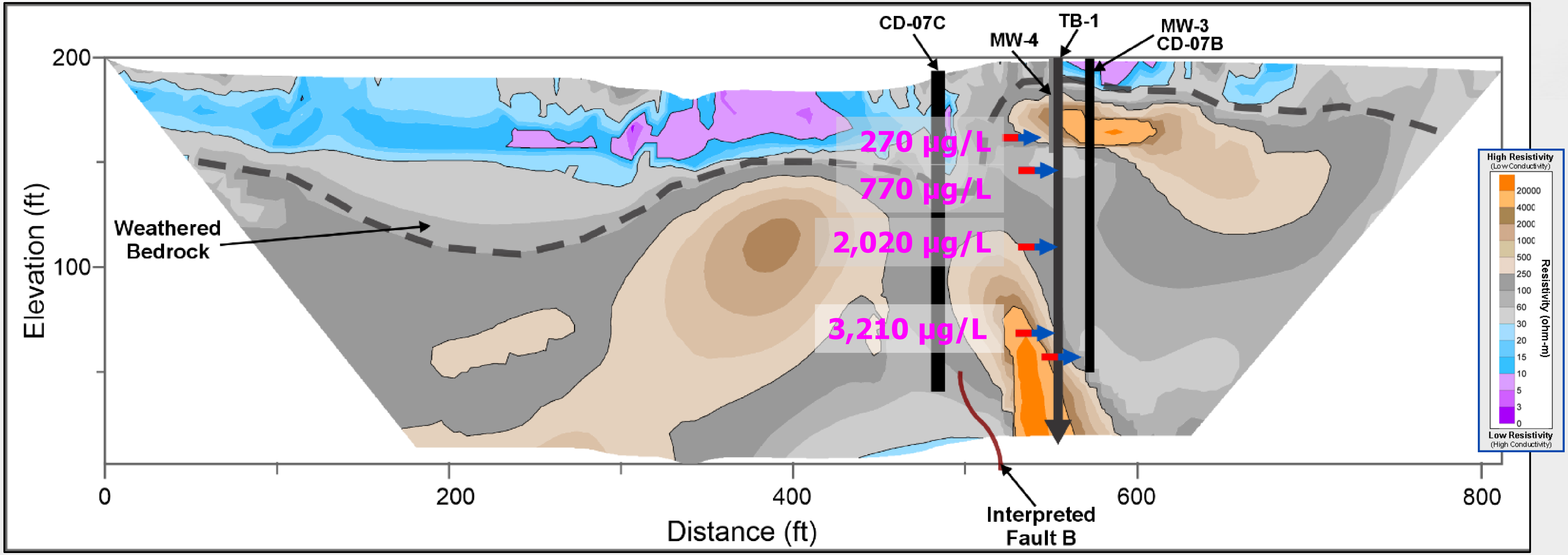
Delineating preferential flowpaths via electrical hydrogeology:

- Team of "electrical interpreters"
- Identified fault zones and potential deformation band; controls GW flow and contaminant migration
- Developed modeled bedrock surface based on electrical imagery to inform migration



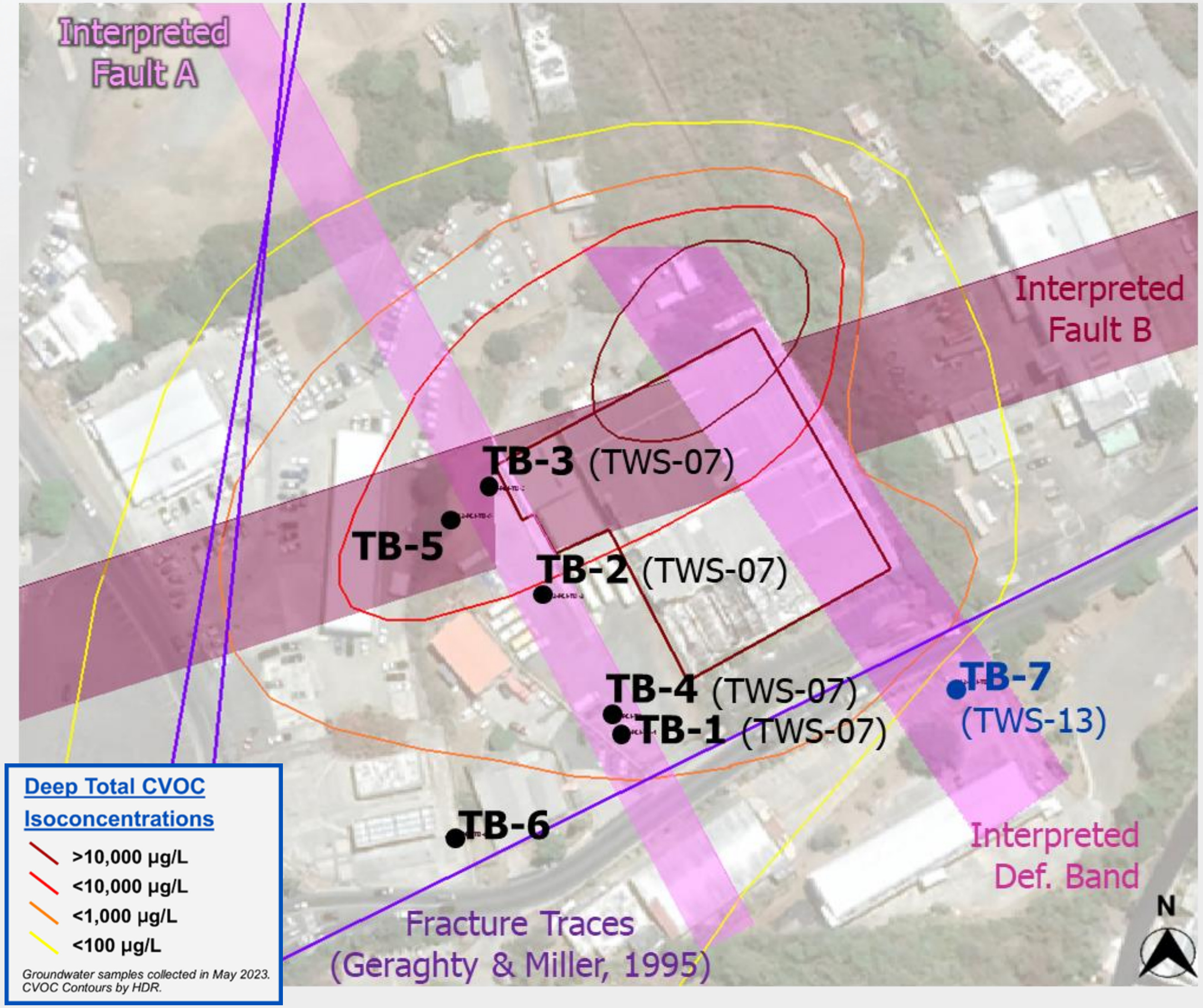
Confirmed Impacts in Geologic Features

- Precise integration of electrical data with well data provides valuable insights to CSM
- Continuous data dense 2D imagery provides more context to well data



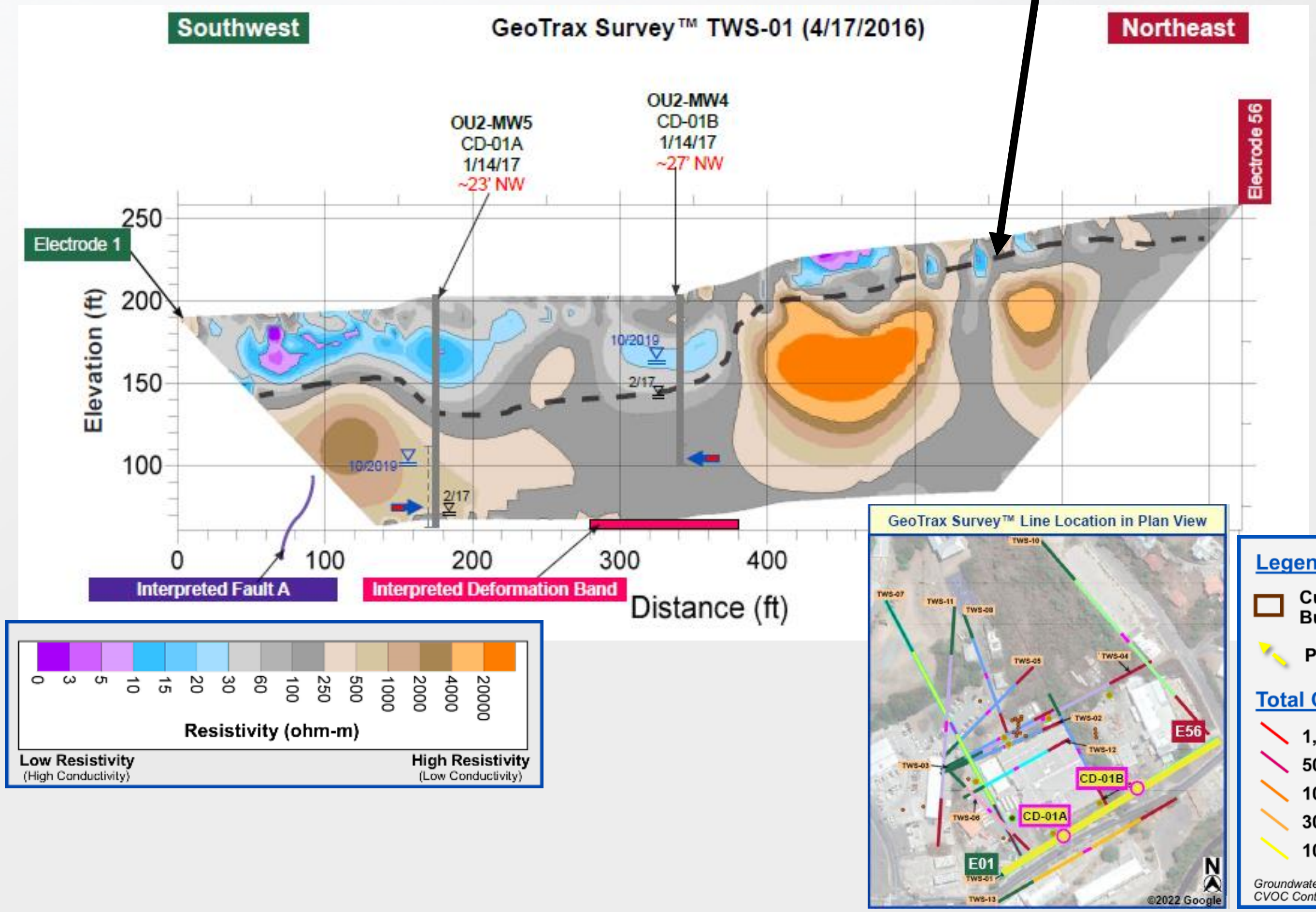
Plume Geometry Controlled by Geology

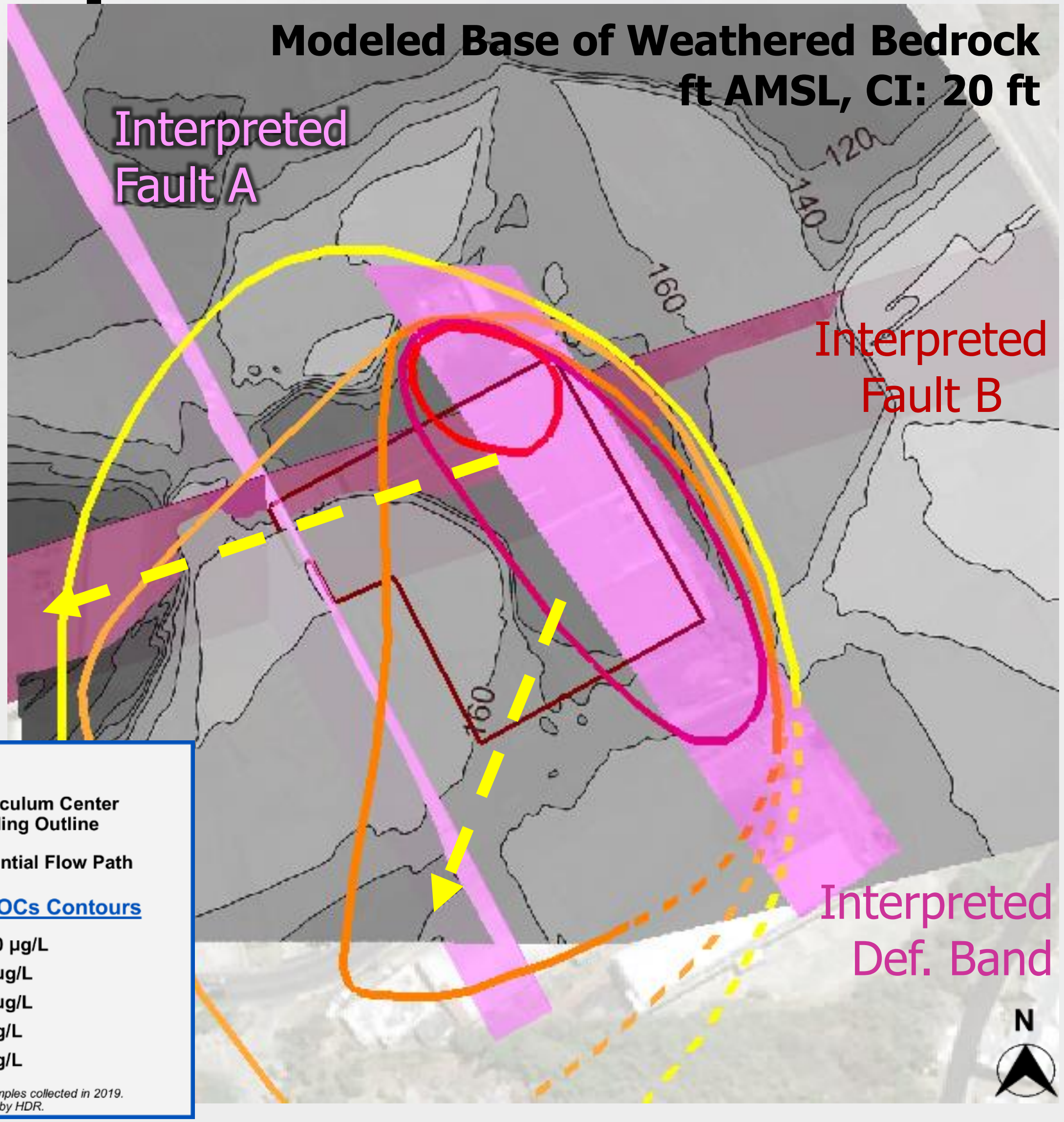
- Data dense imagery enables discovery of key geologic features
- Delineating these features informs contaminant distribution/migration
- Culmination of 2D analysis in 3D provides basis for robust CSM



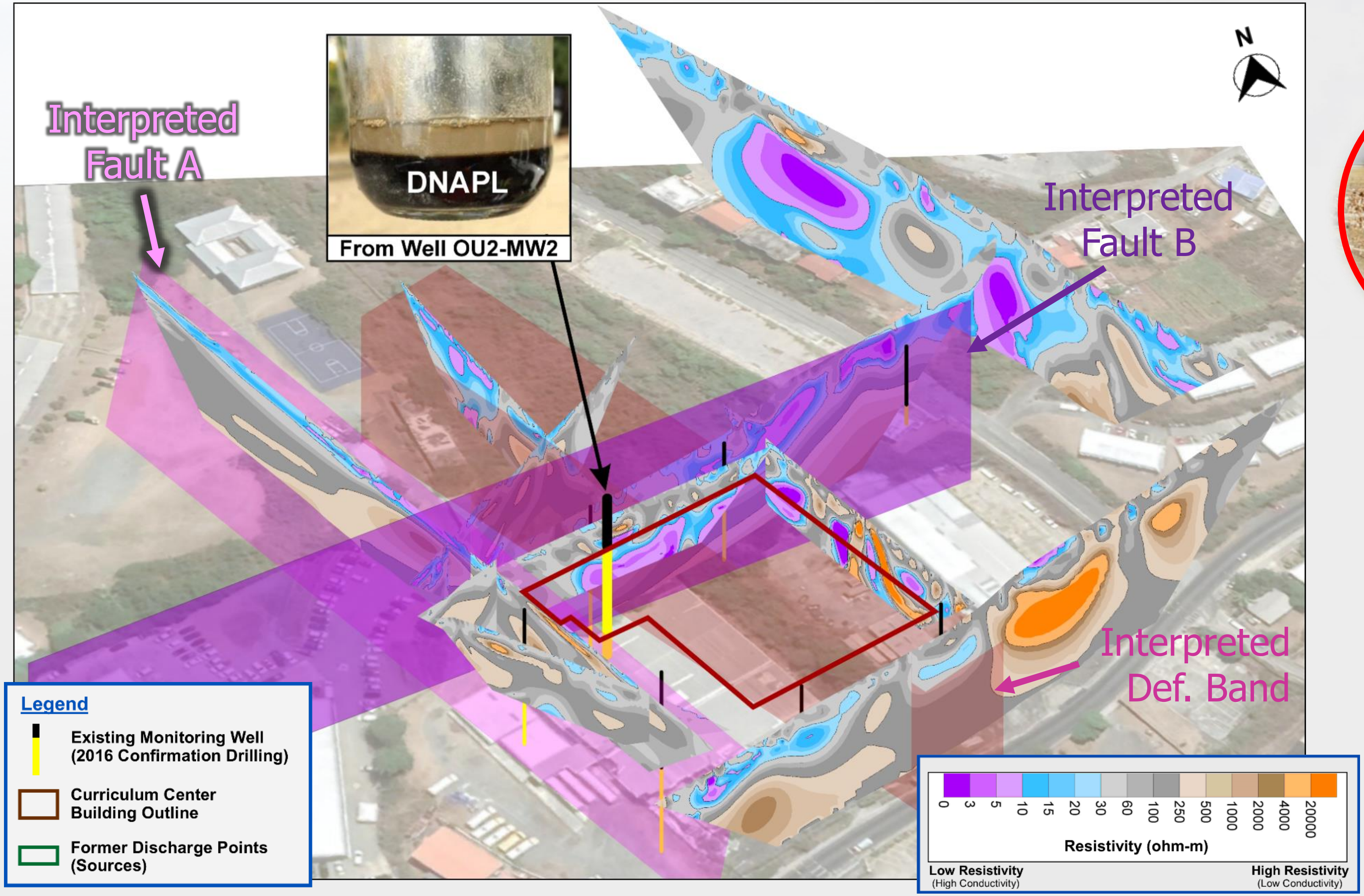
Interpreted Bedrock Surface Impacts Flow Direction

Interpreted Base of Weathered Bedrock
(100 ohm-m contact)



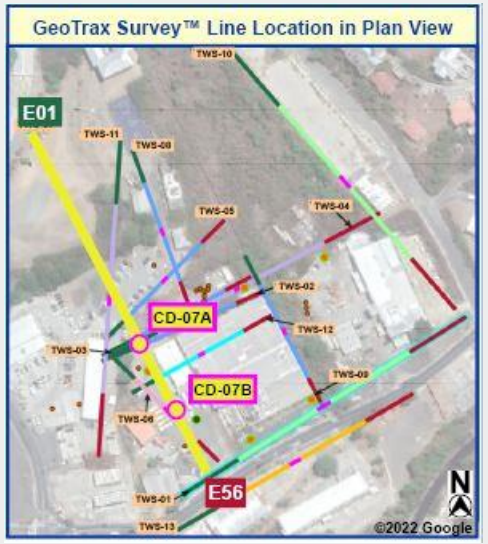


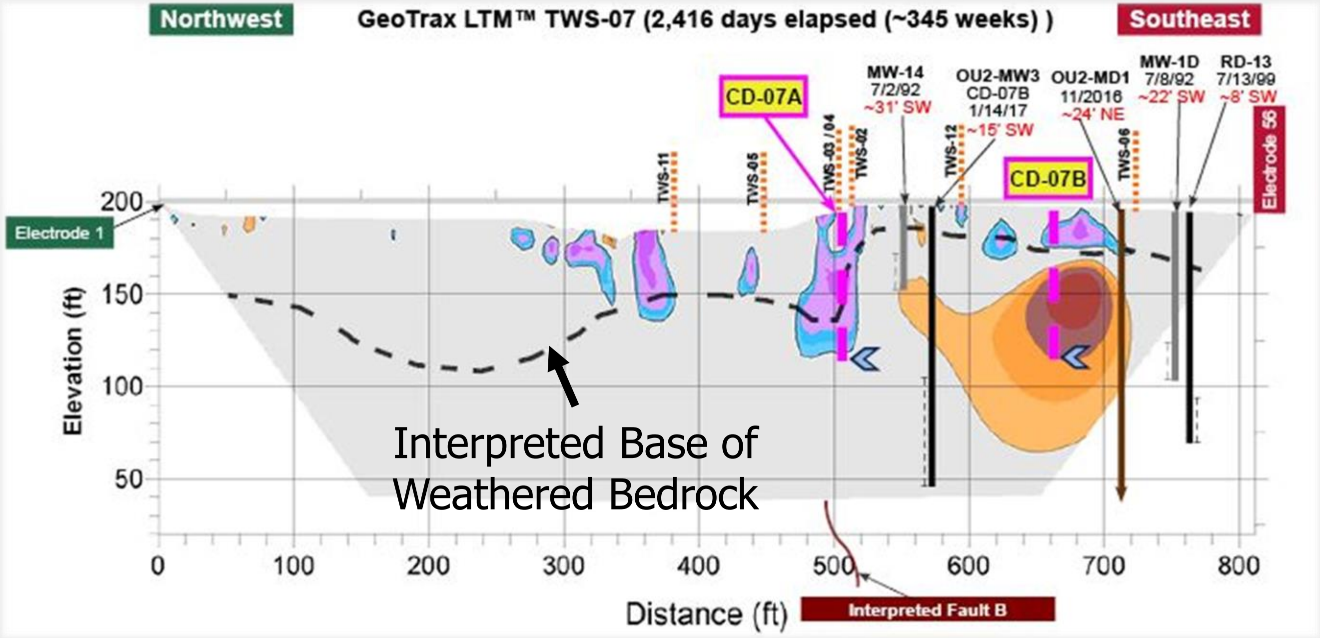
Targeted Drilling Locates DNAPL Source Zone

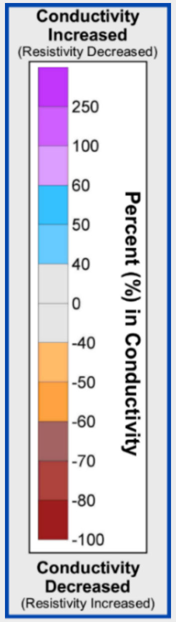


Benefits of Temporal Imaging

- Assessment of changes above/below weathered bedrock surface (how is fault functioning?)
- Changes above weathered bedrock indicate where flux occurring
- Provided valuable insights for remediation team

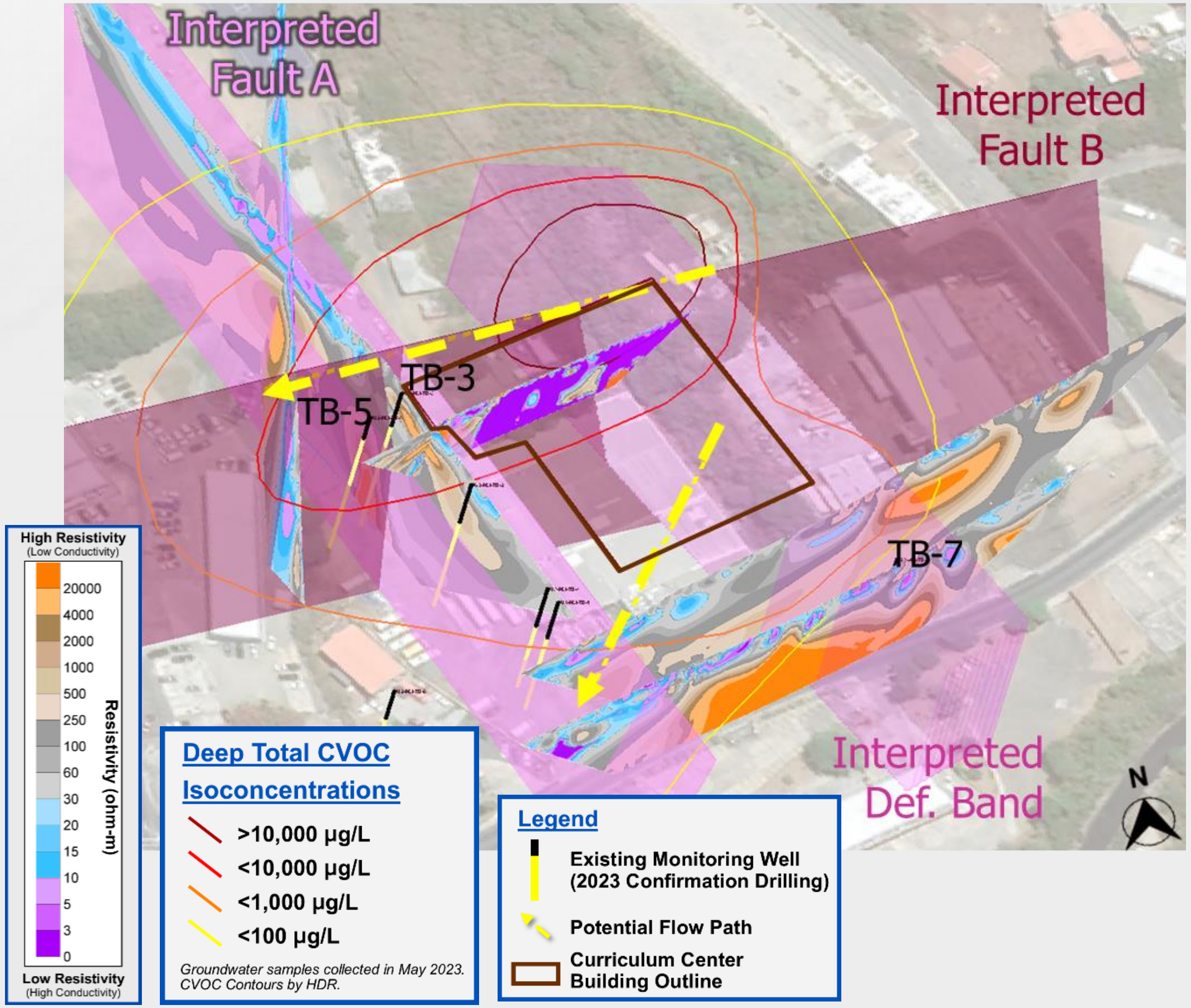






Building CSMs via Electrical Hydrogeology

- CSM built on field data, not extensive interpolation
- Up-leveling your data density at any stage adds significant value
- Does not rely solely on vertical tools
  - Borings/wells are ineffective
  - Base of site often undefined
- Temporal monitoring (2D planes) of subsurface changes informs remediation efforts



***Goal:** Focused remediation in less time at lower cost*

Advantages to Utilizing Electrical Hydrogeology

- ✓ Targeted drilling located previously unknown DNAPL source zones
- ✓ GeoTrax Survey™ effectively imaged key geologic structures
- ✓ Preferential contaminant migration pathways delineated
- ✓ CSM based on electrical hydrogeology process was used for remedial design

HDR Project Manager:

Without Aestus' GeoTrax CSM+™ process and integral subsurface imaging data, we would not have been able to fully characterize the fractures, faults, and deformation zone where most of the groundwater flow and contaminant migration is occurring on our site. These results allowed us to target monitoring and extraction wells in the high-flow pathways so that remediation can be more effective.

Demetrios Klerides, P.E., BCEE, Senior Project Manager / Professional Associate at HDR, Inc

When Should You Scan First?

- On bedrock sites
- Where flow paths are highly preferential and difficult to target with borings
- Traditional methods cannot be used (e.g. through buildings or rugged terrain/environments)
- Multiple remedies have been attempted in the past and regulatory goals are still not being met
- Thermal remediation being considered

Acknowledgements

- EPA Region 2
- HDR, Inc.

- Aestus' Field Team
- Aestus' 3D visualization and interpretation team

QUESTIONS?

Thank you for your time!

<u>Please contact Us to Learn More:</u>

Kyle Spears kws@aestusllc.com

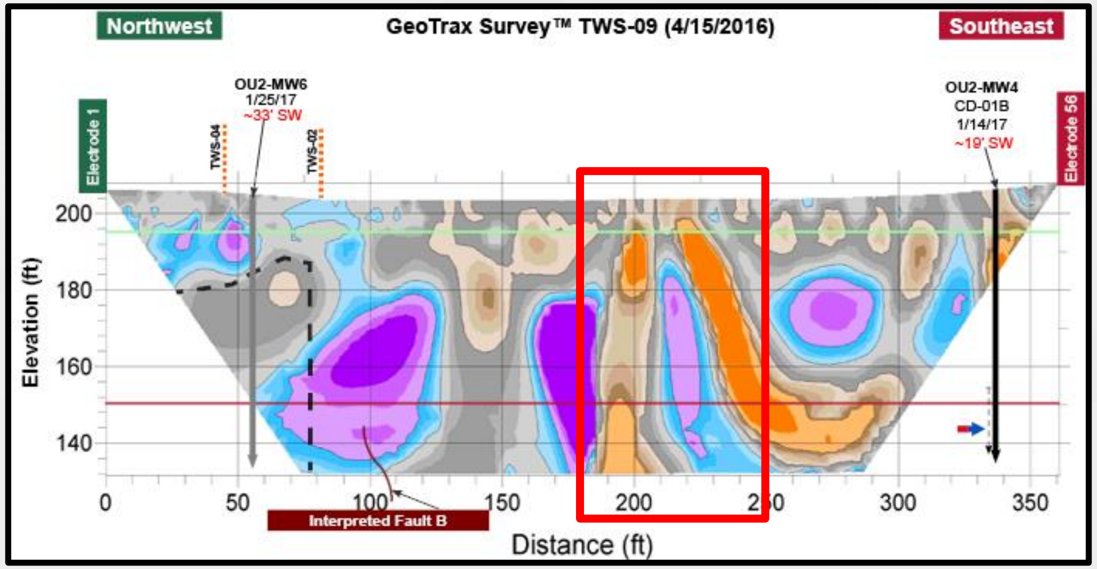
Stuart McDonald swm@aestusllc.com

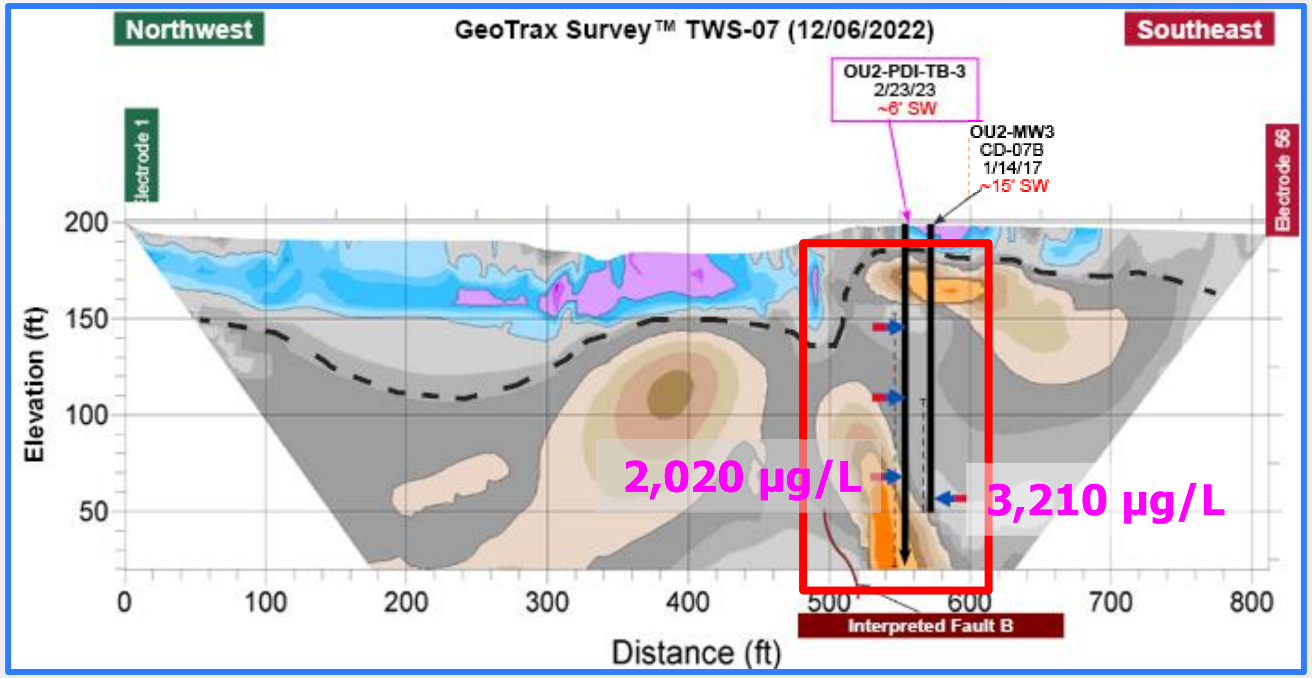
Samantha Frandsen smf@aestusllc.com

Aestus

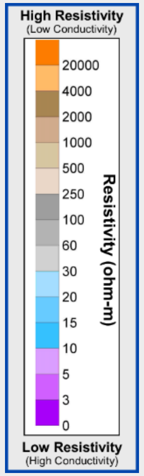
III. Case Study: DNAPL in Igneous Bedrock
Confirmed Geologic Features

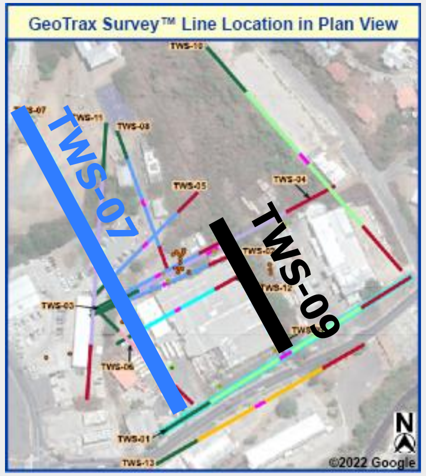
Impacted target on TWS-07 (2022) similar to electrical resistors on TWS-09 (2016)



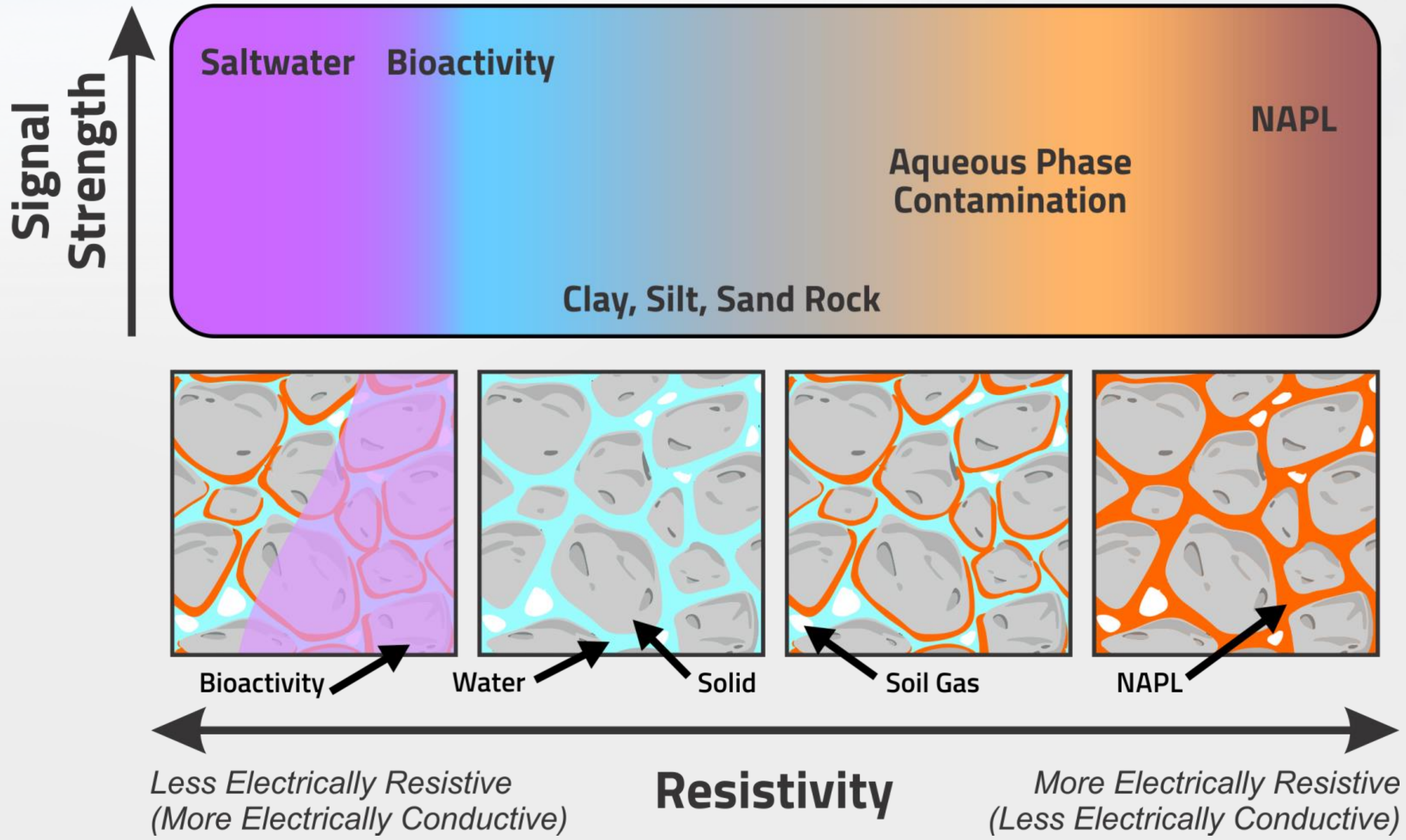


PCE
(May 2023)

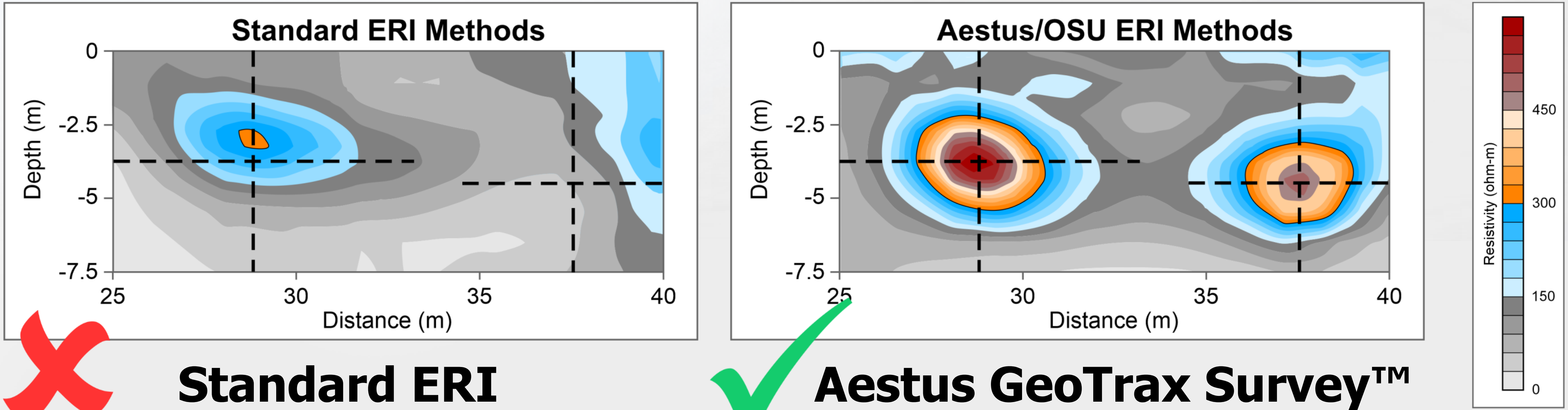




Typical Electrical Properties
Environmental Sites



Picture This:
Traditional ERI vs GeoTrax Survey™



Standard ERI

Aestus GeoTrax Survey™

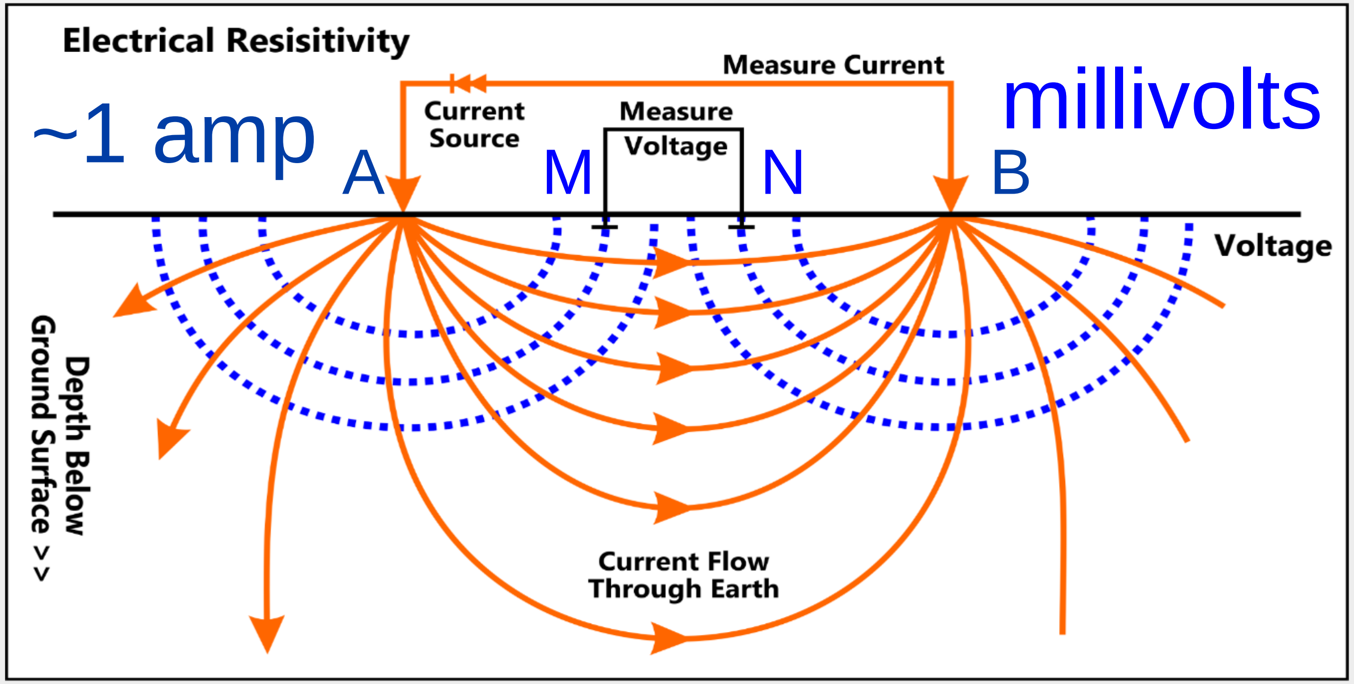
Confirmed by EPA Ada Lab
Drillable Image
Halihan et al, 2005

Same equipment

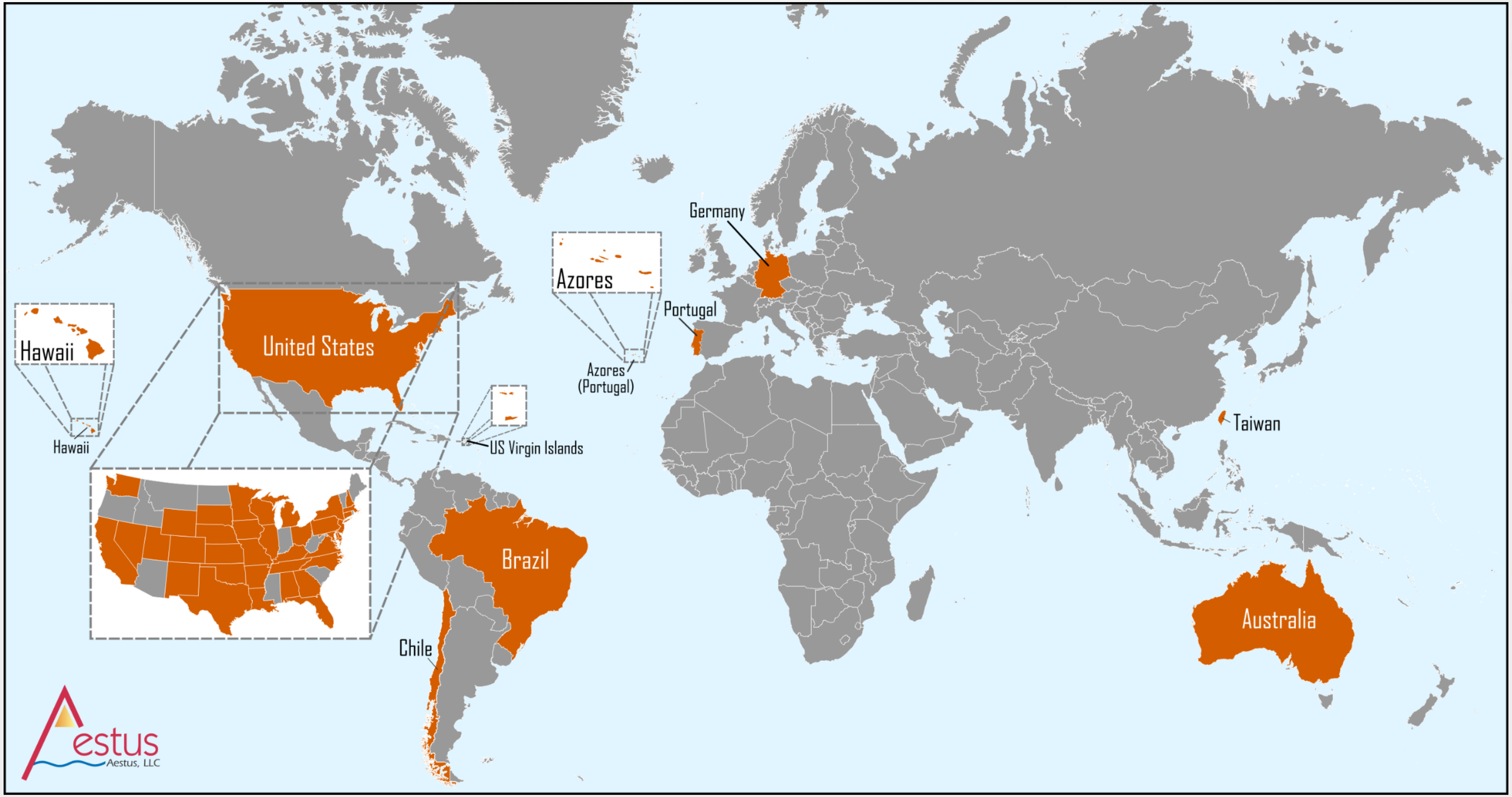
Same transect line

Electrical Resistivity Imaging (ERI) Measurements

- Measurement: electrical potential from applied current
- 4 electrodes yield 1 data point "pixel"
- Result: electrical resistivity distribution



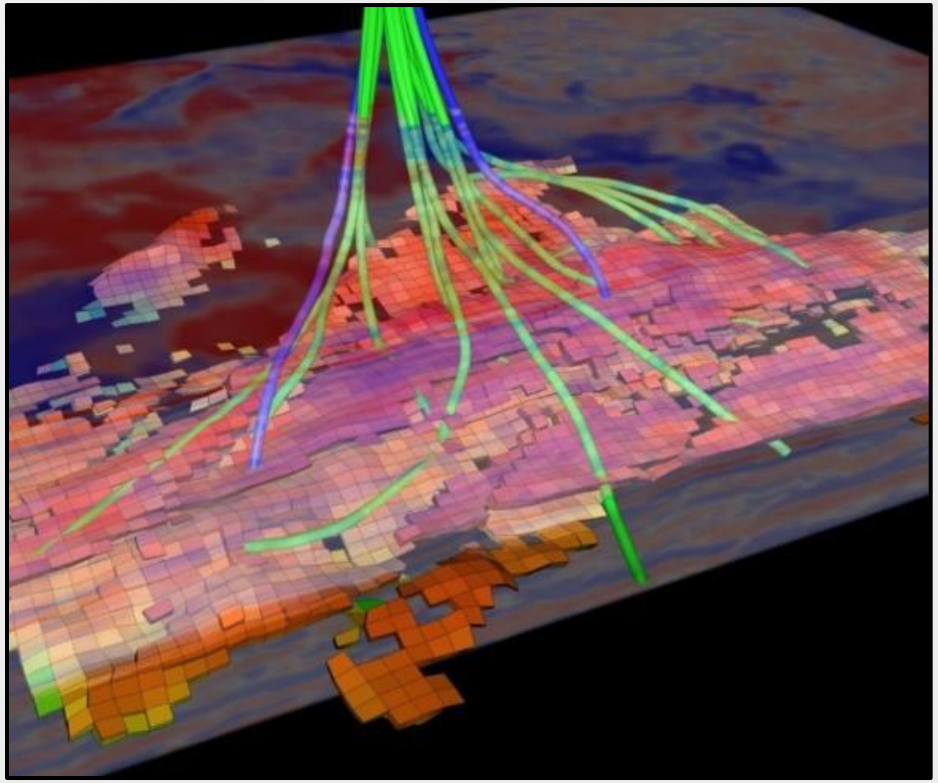
Where in the World is Aestus?



Scan and Target Approach: Aligning with Other Industries

X-ray of Skull

nydailynews.com

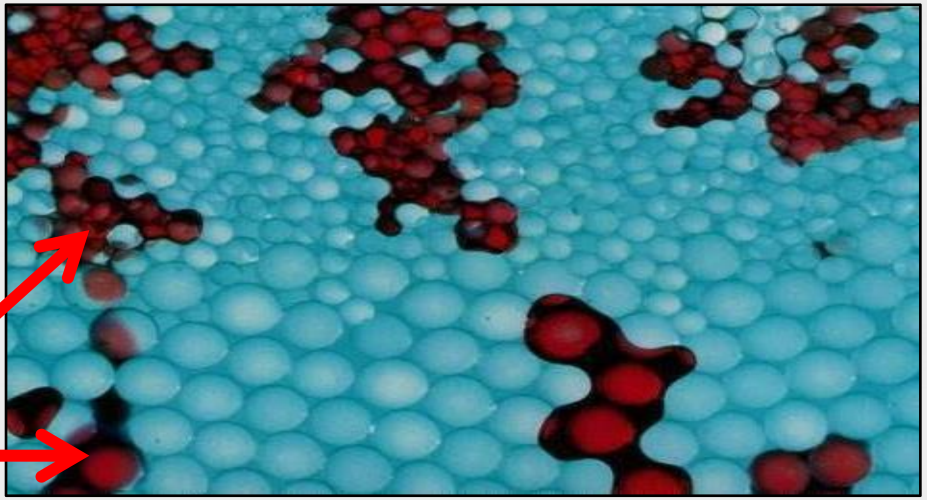


3-D Seismic North Sea

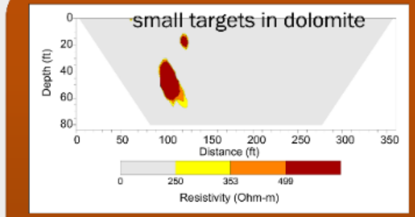
dgi.com

Unweathered NAPL Impacts

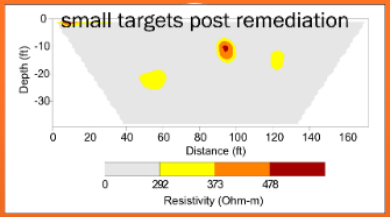
Resistive signatures of NAPLs (liquid resistors) dependent on NAPL composition and solubility



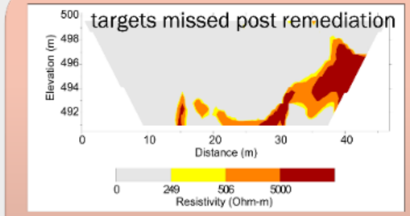
NAPL in pore space



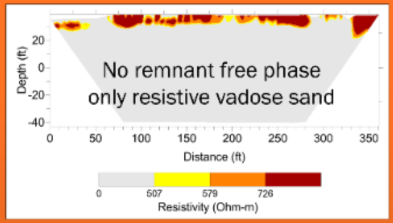
PAHs in Dolomite



Gasoline in Silty Clay



PCE In Silty Sand



TCE in Sand

Relative Solubility

PAHs in Dolomite	Gasoline in Silty Clay	PCE In Silty Sand	TCE in Sand
1	7.5	8	54
Solubility: 20 mg/l	150 mg/l	160 mg/l	1070 mg/l

Reason for Bioactivity Detection

"Nanowires"

(Electron Microscopy)