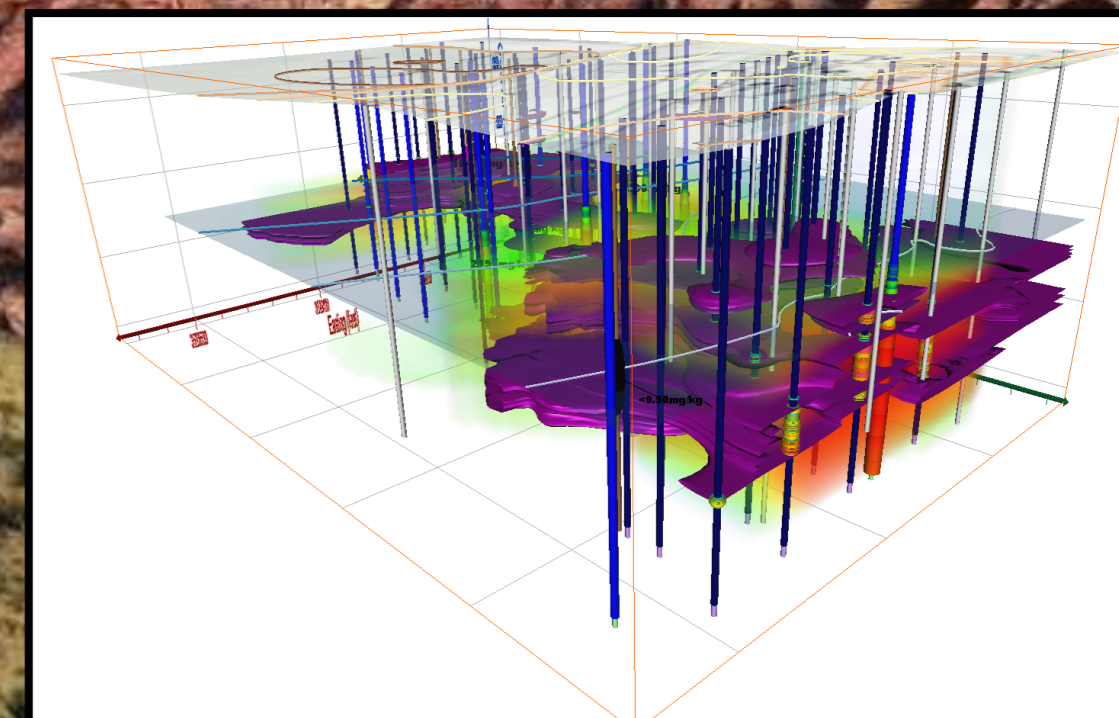


Interpretation of 2D and 3D Images of Ultra-Violet Optical Image Profiler (OiHPT-UV), Hydraulic Profiling, and Electrical Conductivity (HPT/EC) Log Data at Complex LNAPL Sites

John Fontana, CPG, CWD, President/CEO, Vista GeoScience

JFontana@VistaGeoScience.com

BATTELLE 2023 Sixth International Symposium on Bioremediation and Sustainable Environmental Technologies May 8-11, 2023 | Austin, Texas



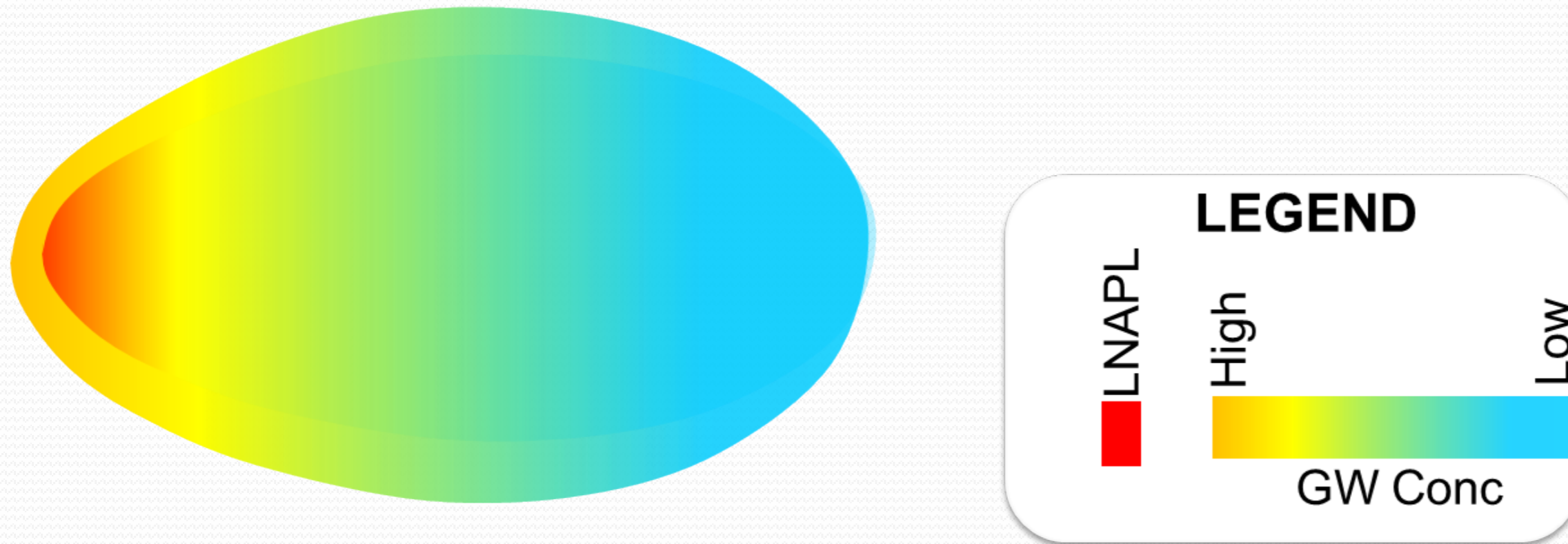
OUTLINE:

- Available Tools and Configurations
- How the UV Optical Image Profiler Works
- Integration with Hydraulic Profiler and Elec. Conductivity
- Data Collected and Analyzed by the System.
- Case Studies: Complex LNAPL Patterns Revealed
- Key Points & Summary



LNAPL Trivia: Dissolved Phase Persistence

If There Is a Persistent Groundwater Plume....



.....there is an LNAPL source

.....it may/may not flow into a well

2018 ITRC LNAPL
Short Course, Part 1

• Optical Image Profilers (OIP)

- For Logging Petroleum LNAPL or DNAPLs
- **OIP-UV:** Ultra-Violet Source for Fuels, Lighter Oils, etc.
- **OIP-G:** Green Laser Source for Heavy Crude, Creosote, Coal Tar, etc.
- **OIP-UVR:** Same as OIP-UV with added photometer for detecting emissions in the UV range (Kerosene, Jet Fuels)



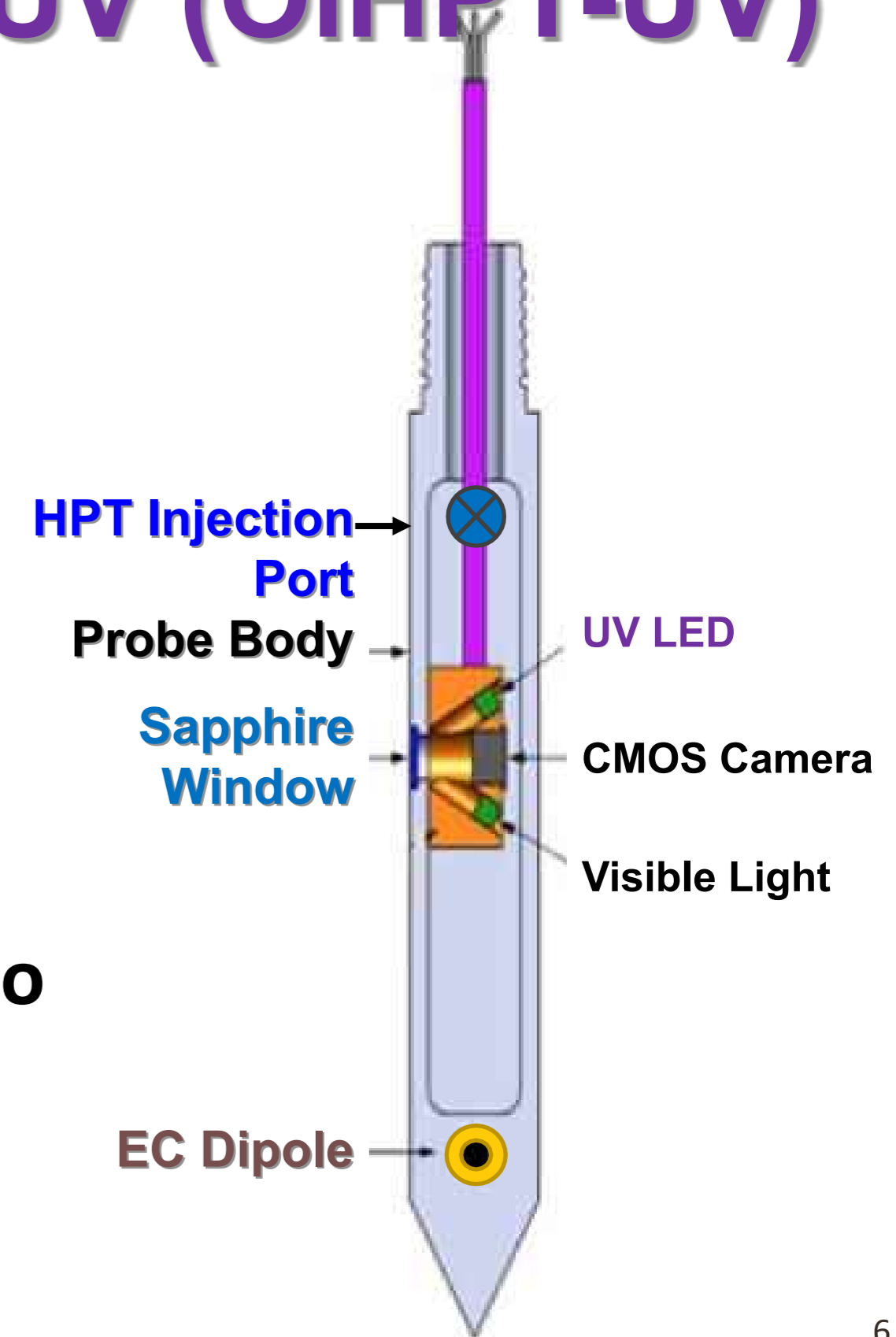
Direct-Push Deployment Systems



4WD- ATV or Van Mounted Subsurface Imaging Systems & Geoprobe Configurations

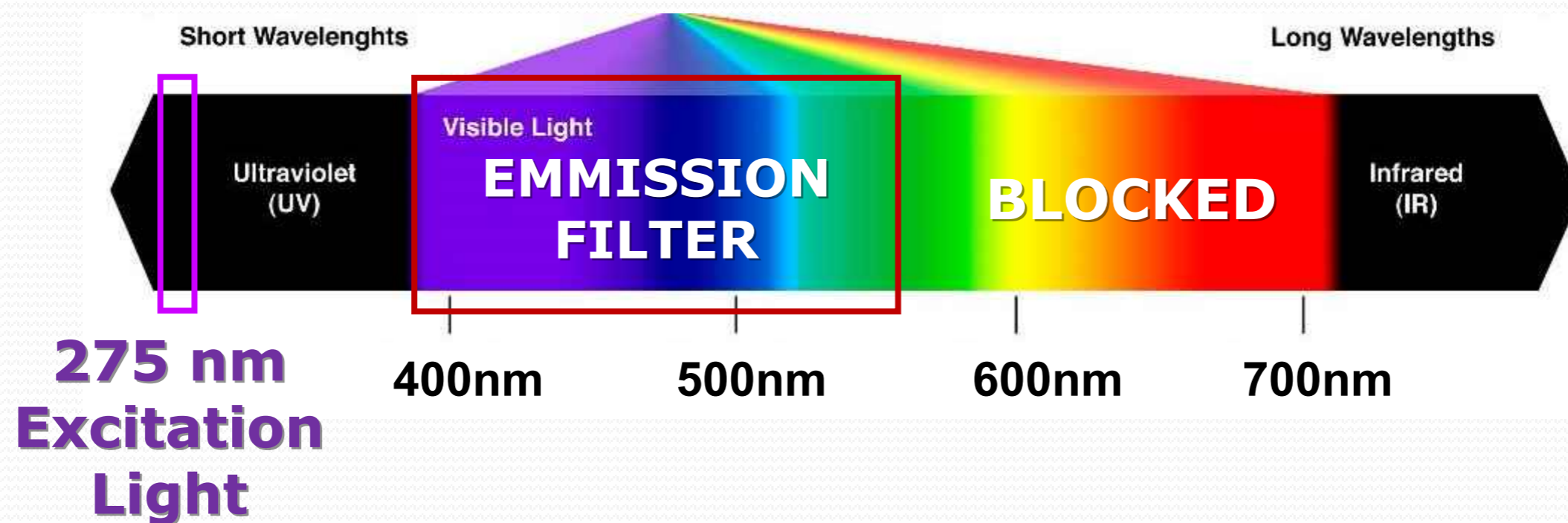
UV Optical Image Profiler: OIP-UV (OiHPT-UV)

- **Ultra-Violet LED Light Source for Fuels, Lighter Oils**
 - Similar Response as LIF/UVOST
- **Detects PAH Fluorescence in Petroleum NAPLs**
- **CMOS Camera Captures Induced Fluorescence**
- **White Light for Capturing of Images of Soil**
- **Geoprobe DI Viewer Software**
- **Combined with Hydraulic Profile Tool (HPT) & Electrical Conductivity (EC), now called OiHPT-UV to measure lithology and permeability**



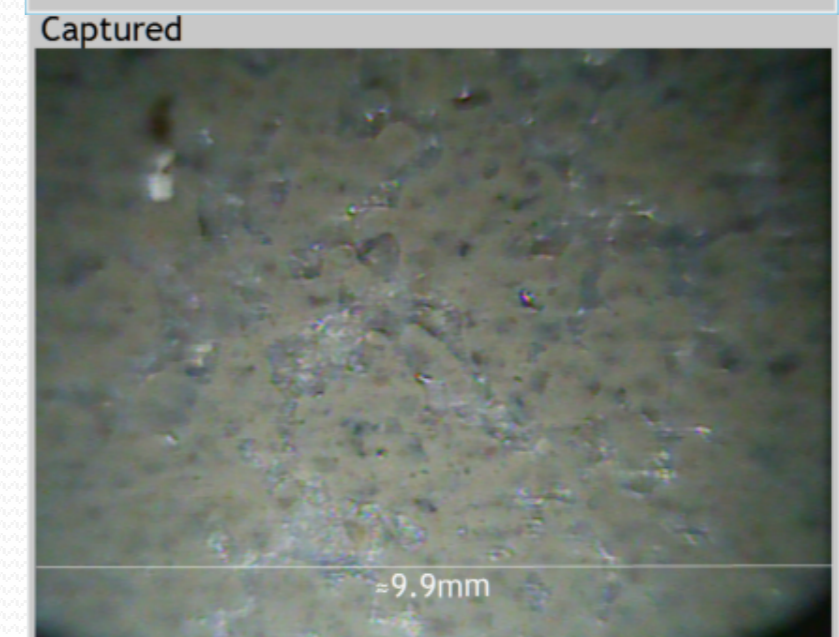
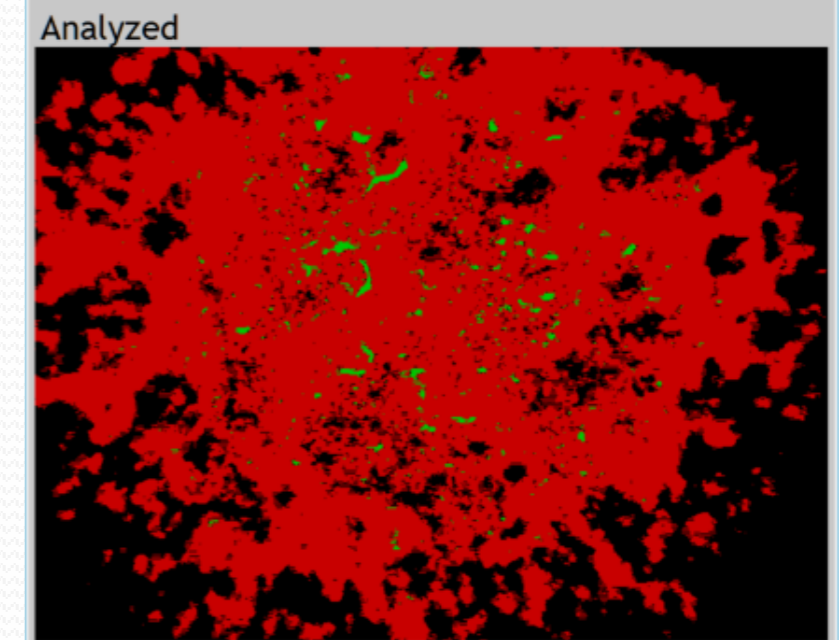
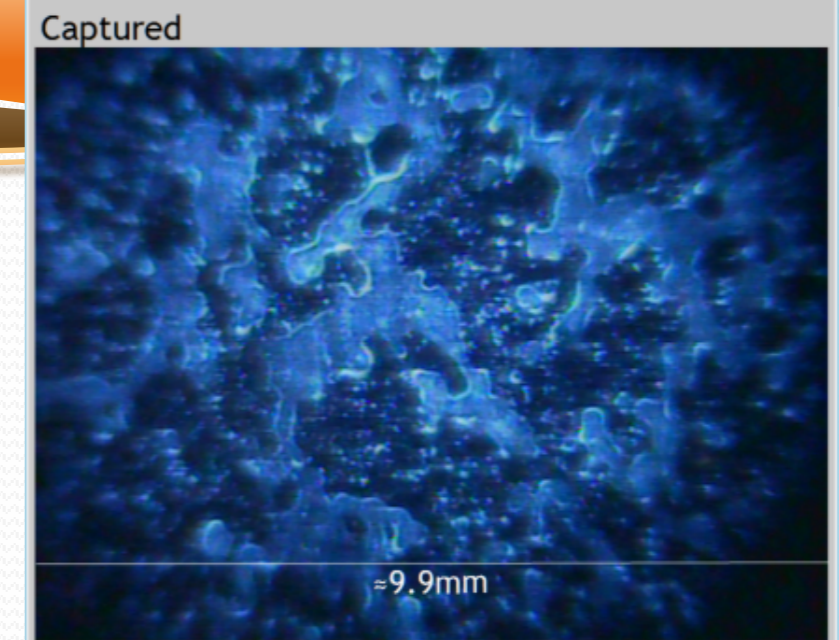
OIP-UV Analysis of Fluorescence

- Excitation (LED) Light – 275nm (UV)
- Emission Light Filter – 400-550nm (purple, blue, green)
- Records Data Like your digital camera!
 - HSV - Hue, Saturation, & Value (Brightness)



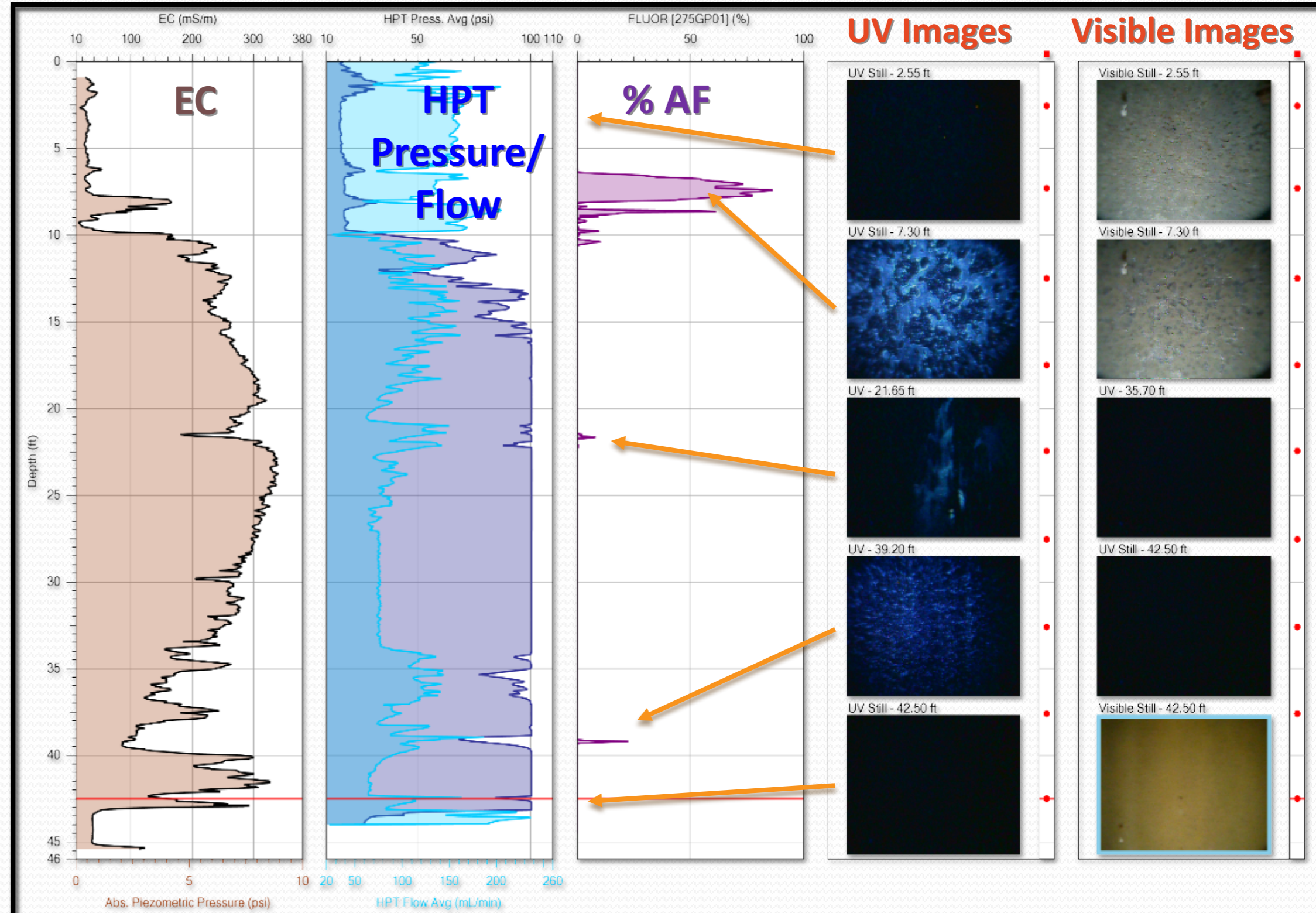
OIP-UV Images

- Captured Fluorescence Image under 275nm UV LED Light
 - Software Analysis of % Area Fluorescence (%AF)
- Captured Soil Image under Visible (White) LED Light

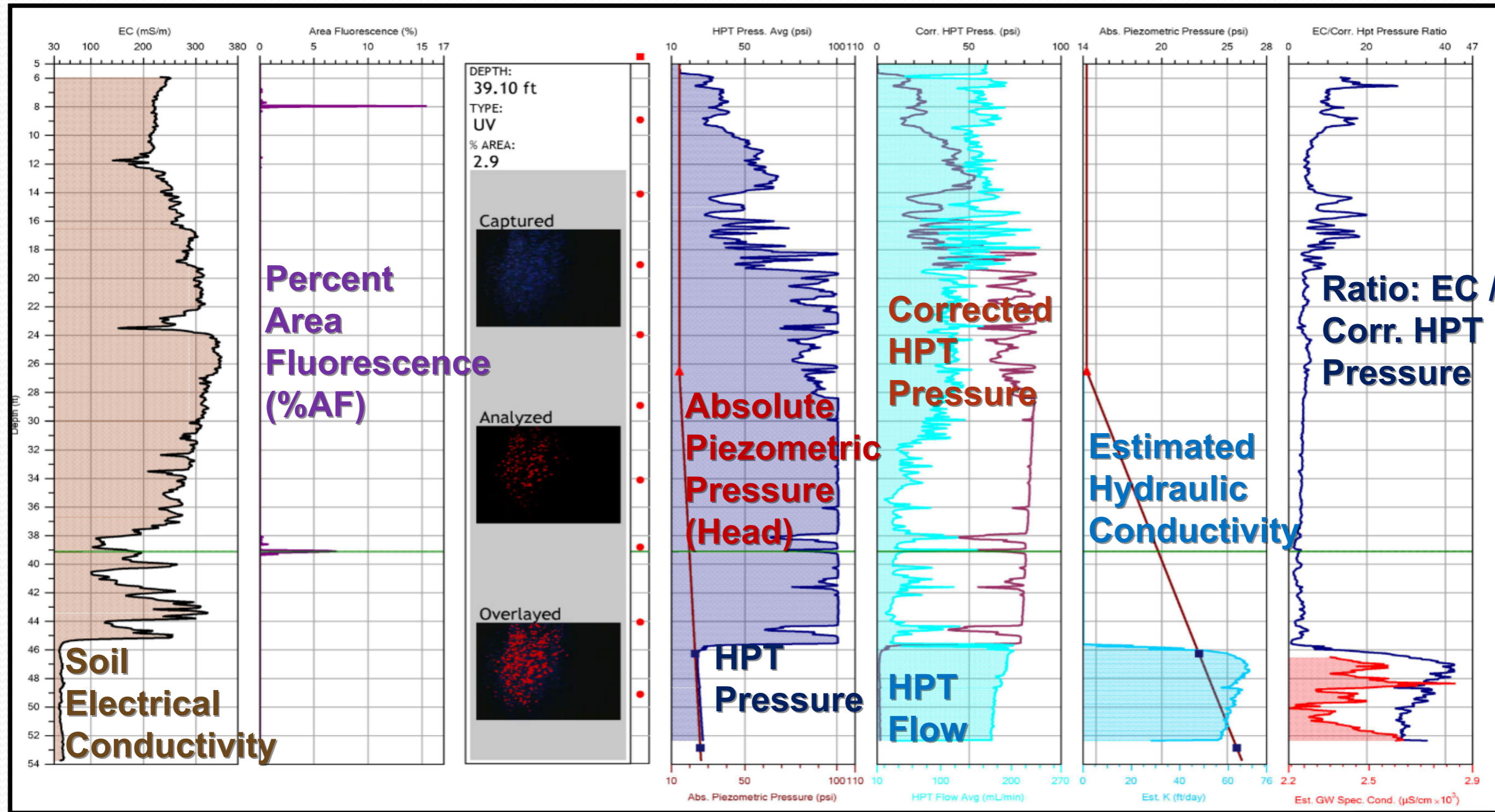


Typical OiHPT-UV Log

- Electrical Conductivity
- HPT Injection Pressure & Flow
- % Area Fluorescence
- UV Images
- Visible Light Images
- Moving vs. Still Images



Additional Post Processed Data (K, SEC, etc.)



CSM Case History:

Gasoline Plume Migrating Opposite of Groundwater Gradient

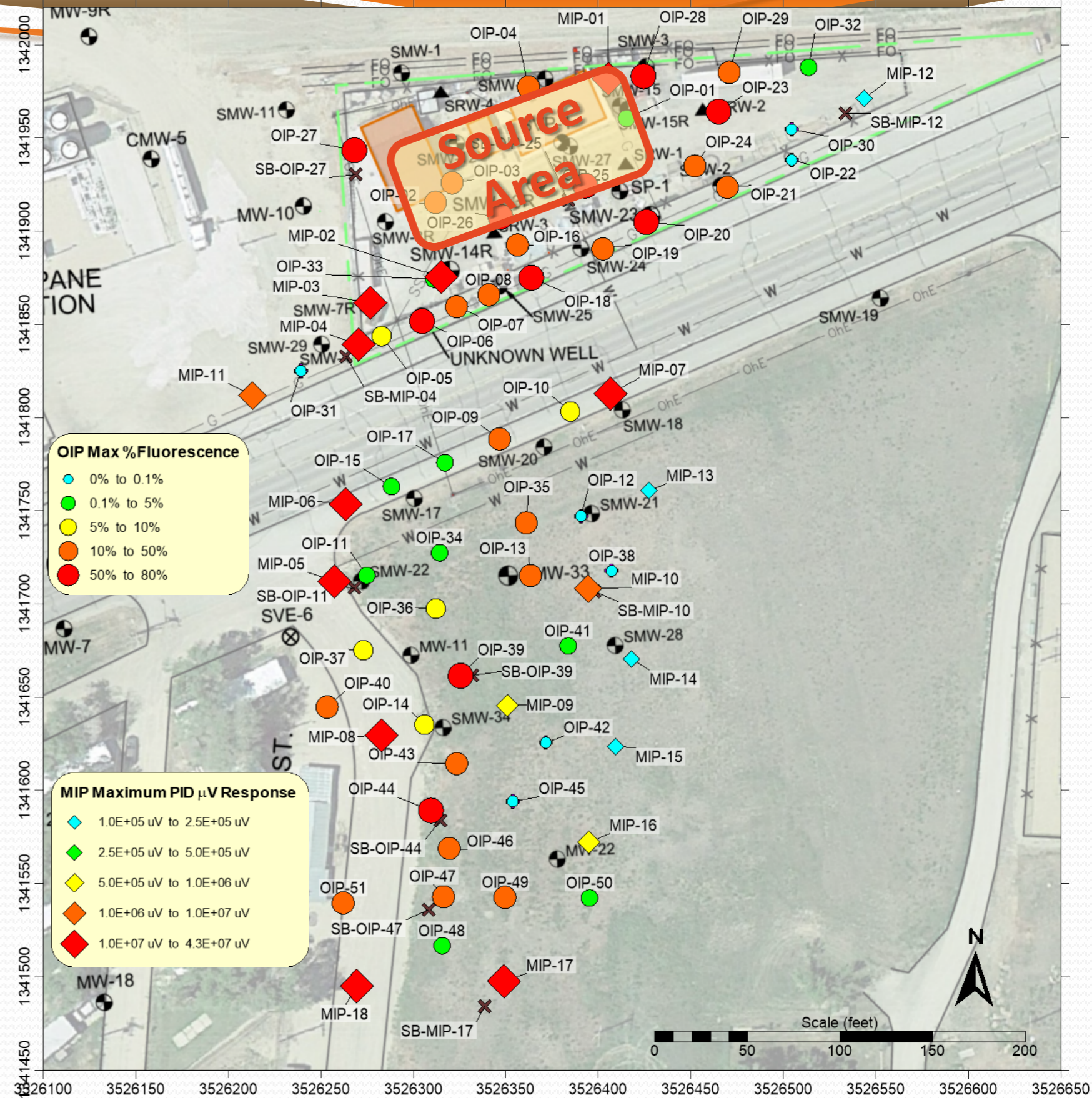
- OIP-UV (51 borings) and MiHpt (18 borings)
- Confirmation Cores (10 borings)
- Eastern Colorado Plains
- Identified Migration of LNAPL Plume moving opposite of ground water gradient

Courtesy CGRS Inc.



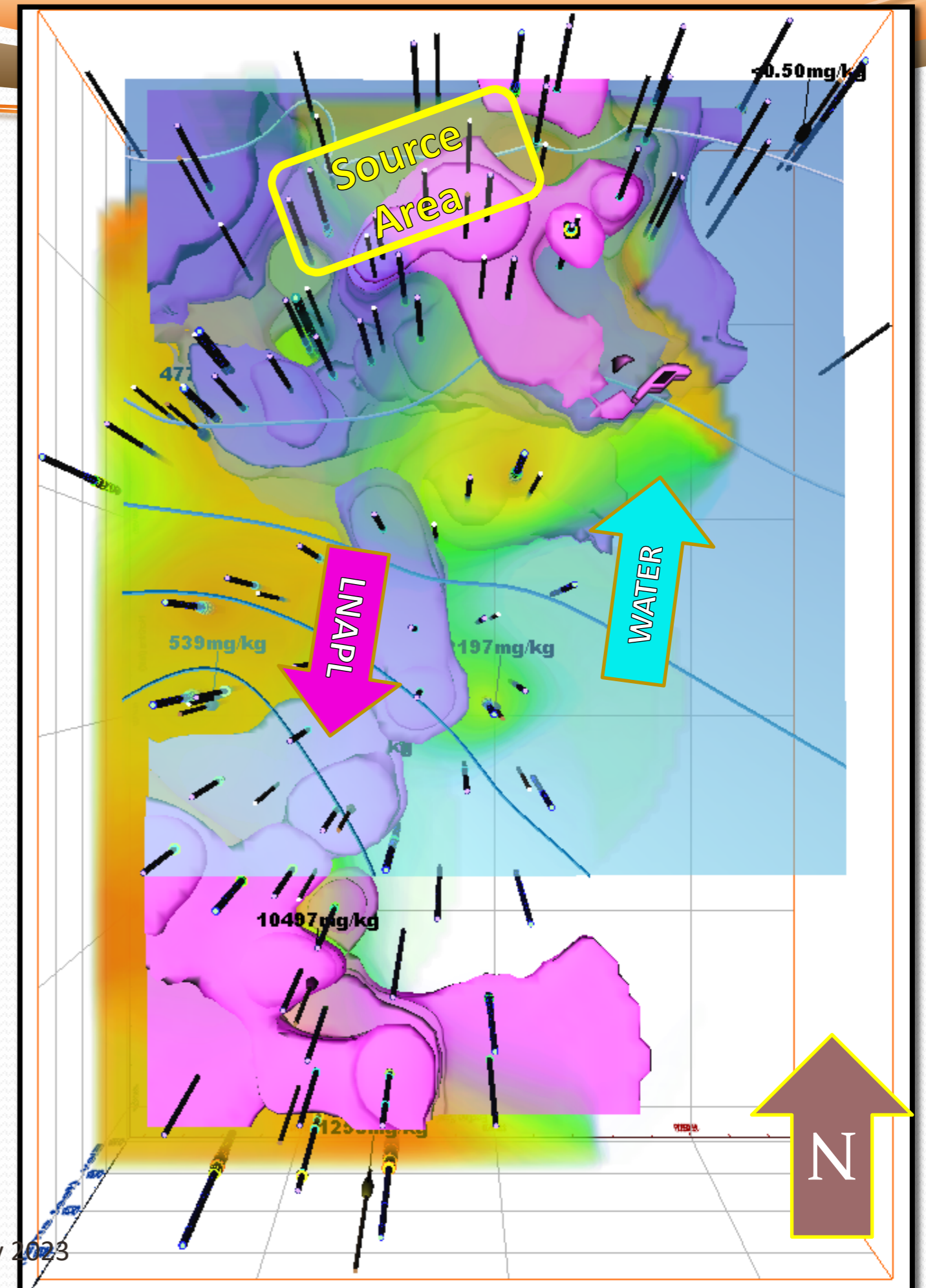
2D MiHpt & OIP-UV Survey Map

- Classic 2D Bubble Map used to display maximum values at each log boring.
- Max. OIP-UV % Area Fluorescence
- Max. MIP-PID (micro volts)
- Source Area: AST & dispenser releases in the site on the north side of the highway.

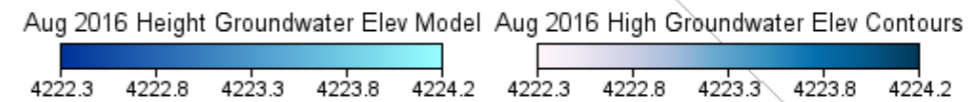
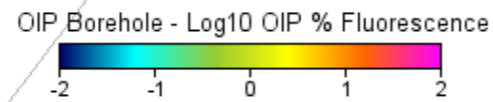
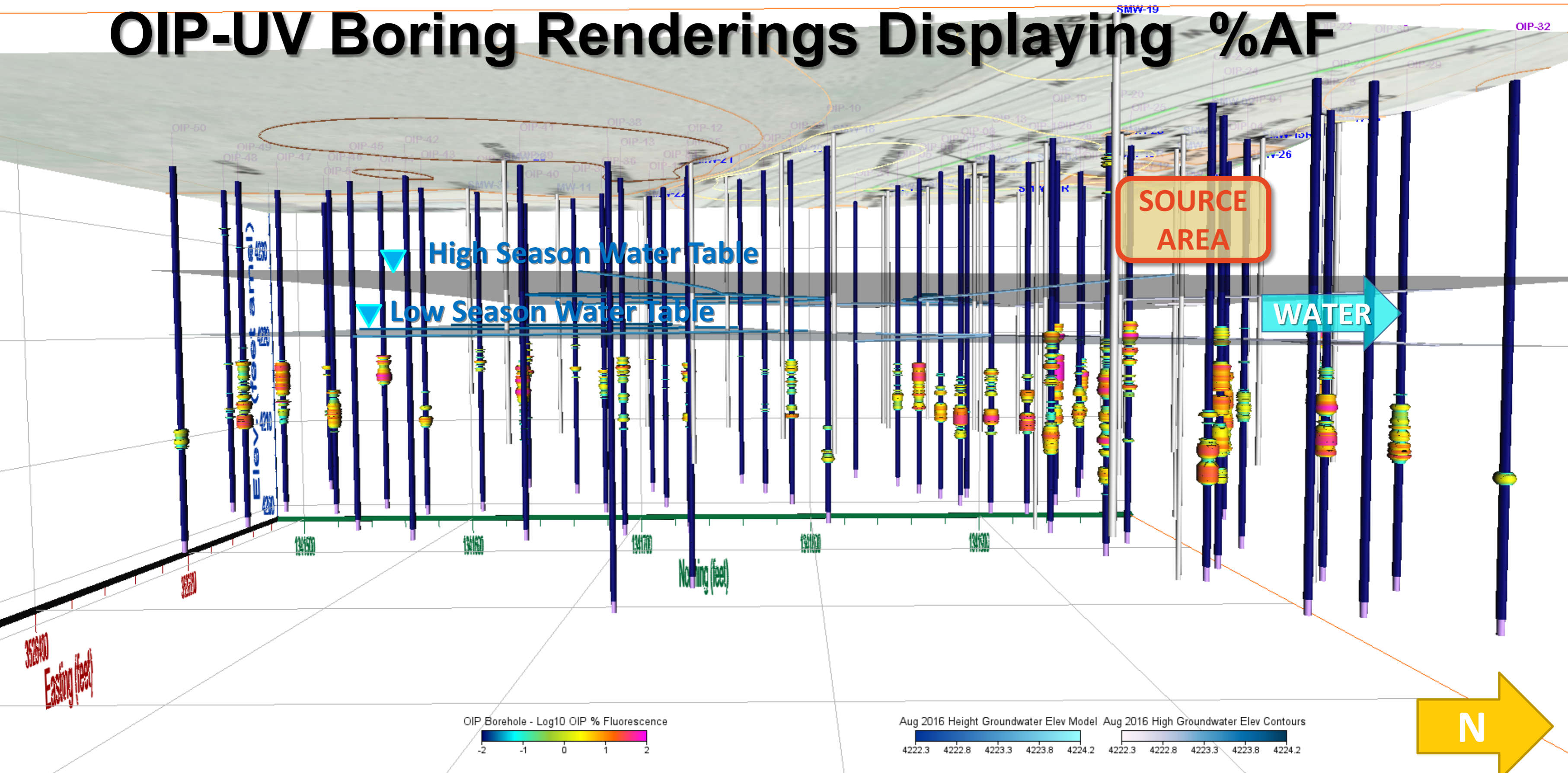


LNAPL Plume & Low Ground Water Table

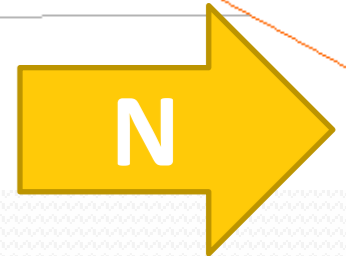
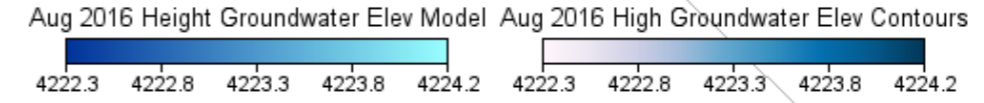
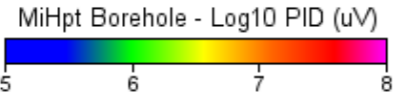
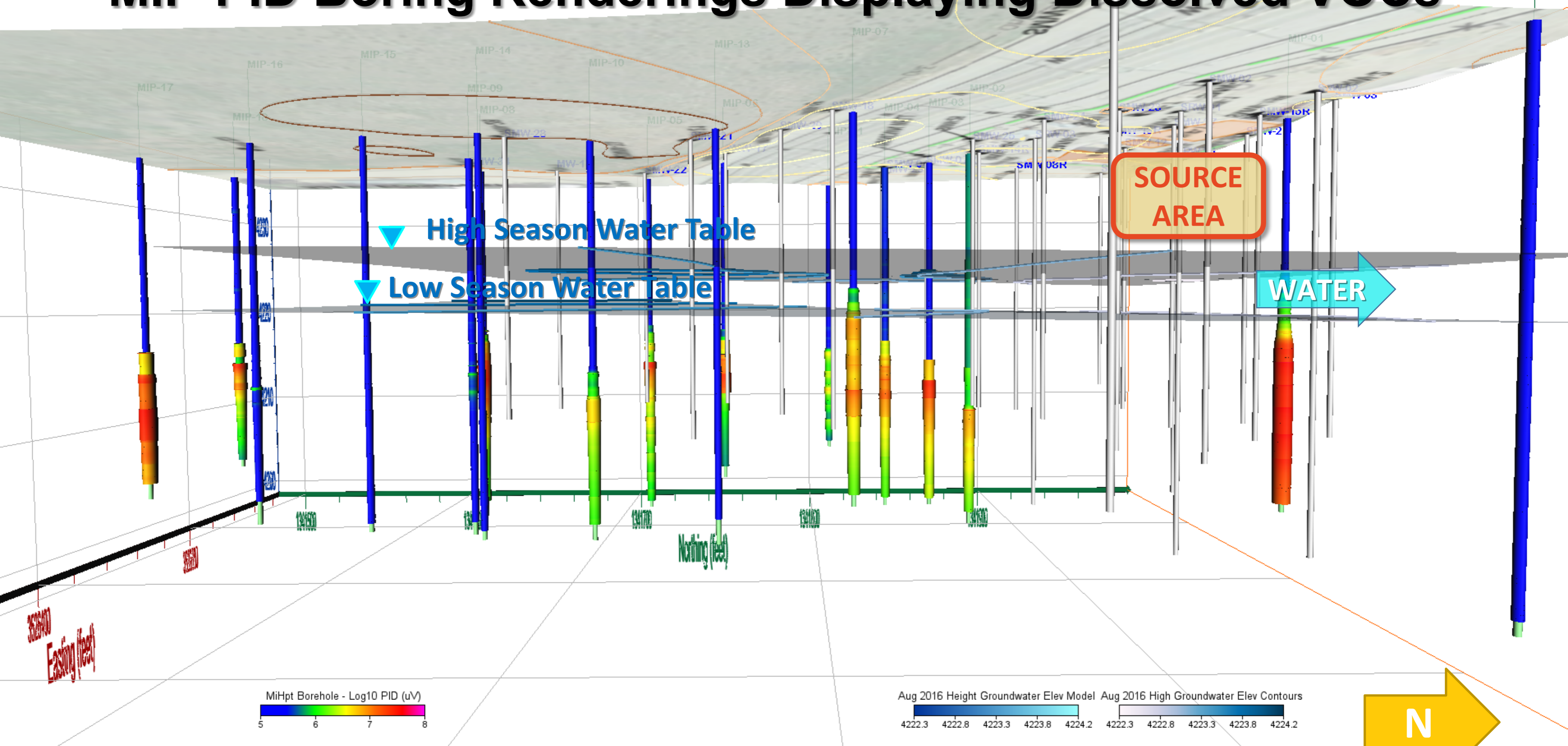
- Groundwater Moving North – Both High and Low Seasons
- LNAPL Plume Migrated South >300 feet from Source Area
- Notice Narrow Channel in Center Area
- Most LNAPL Confined Below Water Table



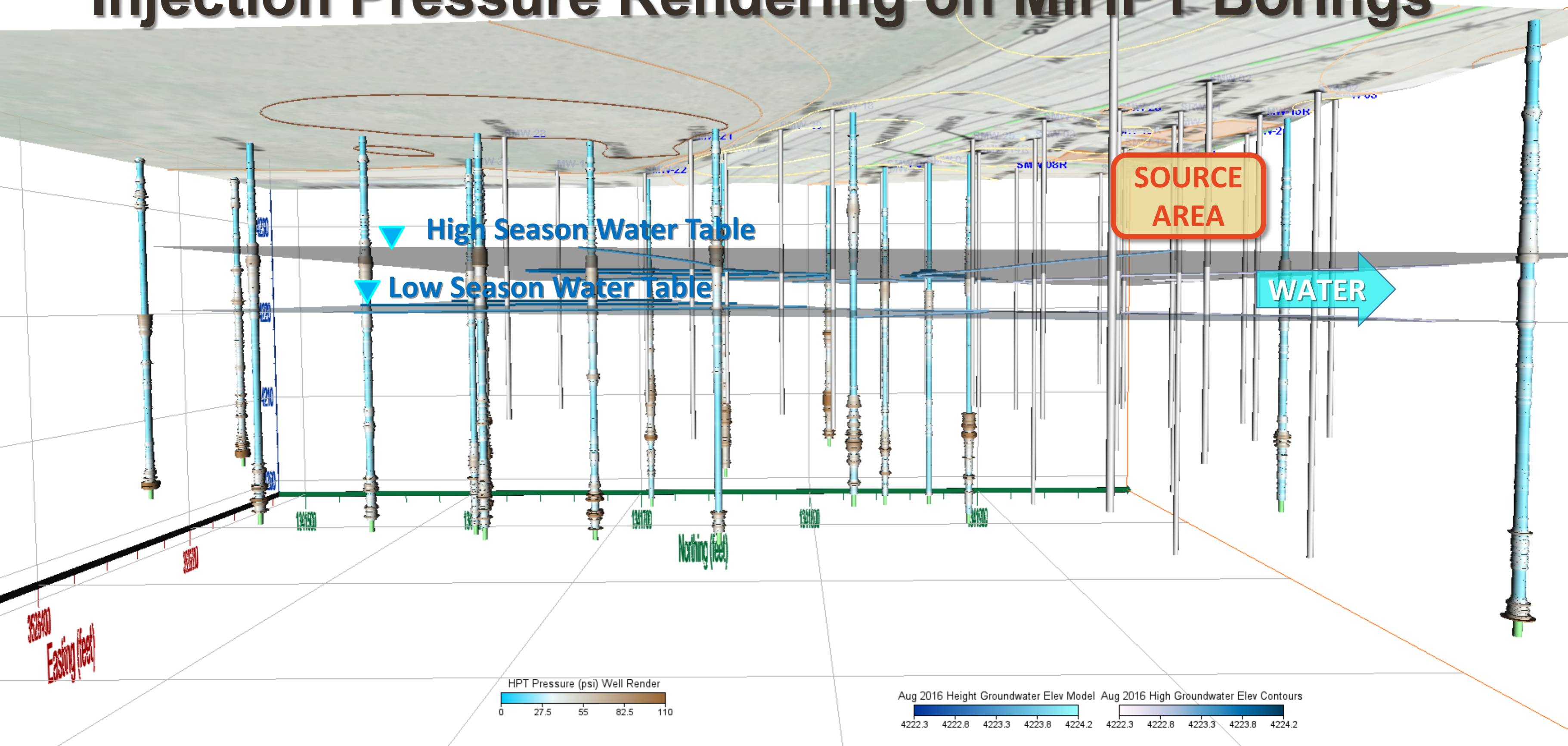
OIP-UV Boring Renderings Displaying %AF



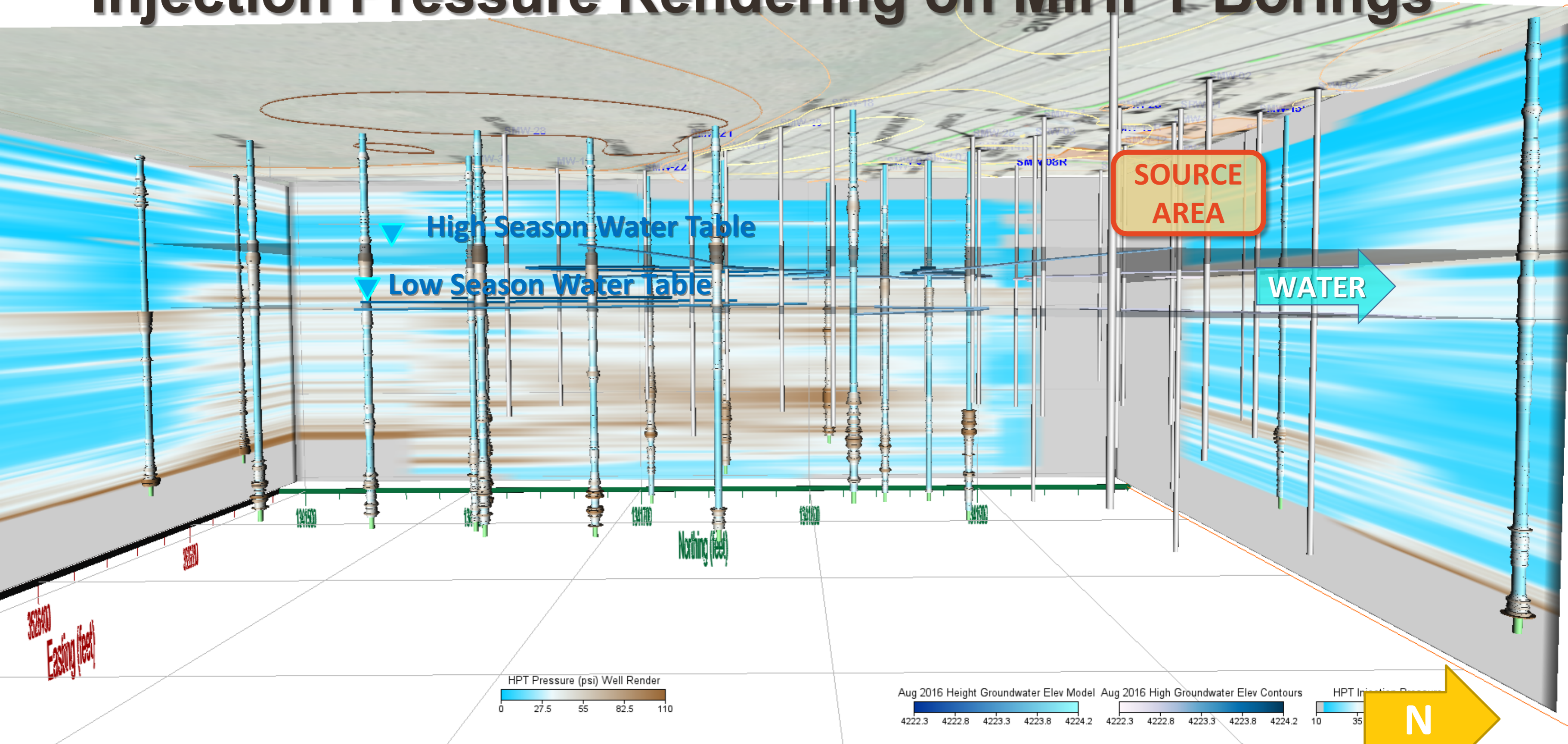
MIP-PID Boring Renderings Displaying Dissolved VOCs



Injection Pressure Rendering on MiHPT Borings



Injection Pressure Rendering on MiHPT Borings



382500
Easting (feet)

384500

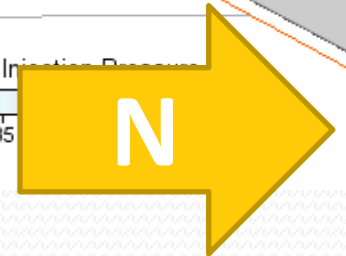
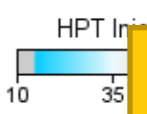
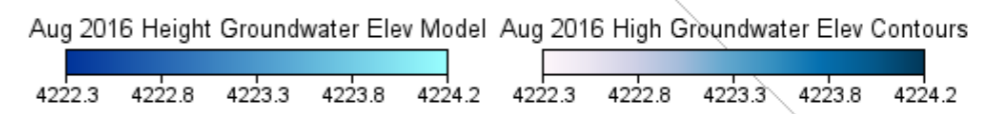
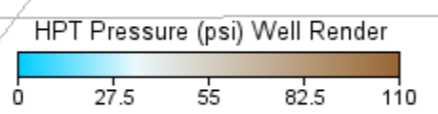
386500

388500

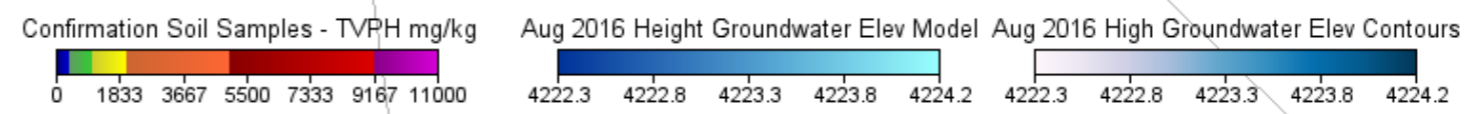
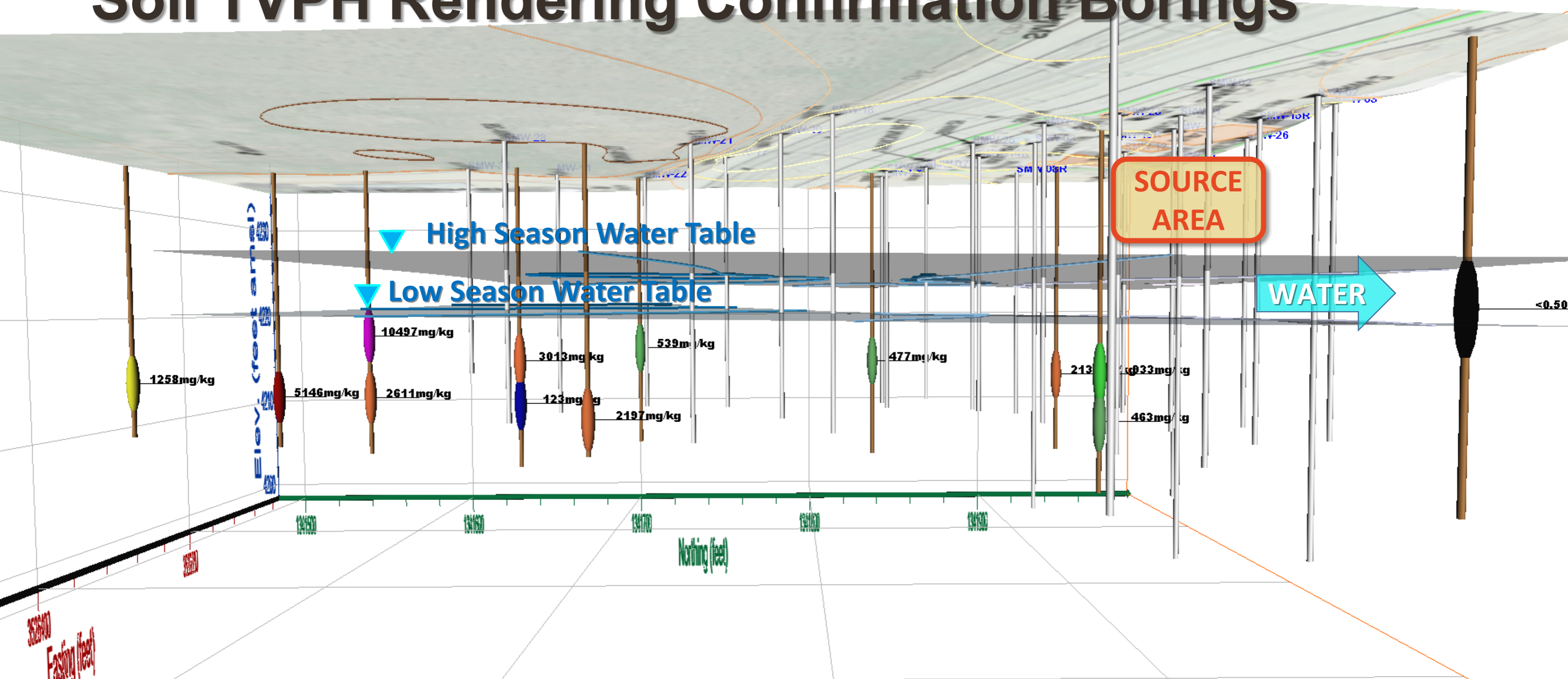
Northing (feet)

390500

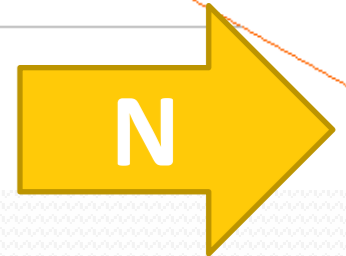
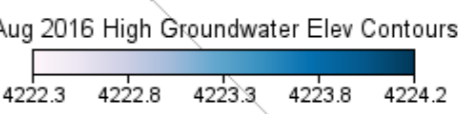
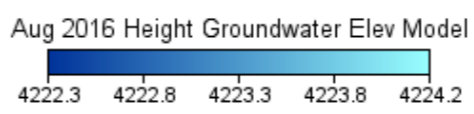
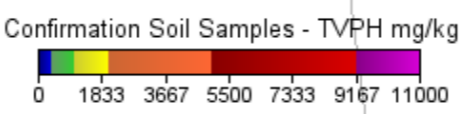
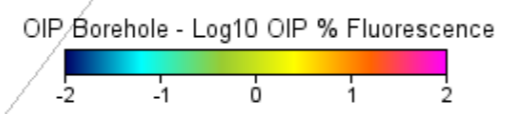
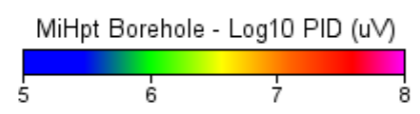
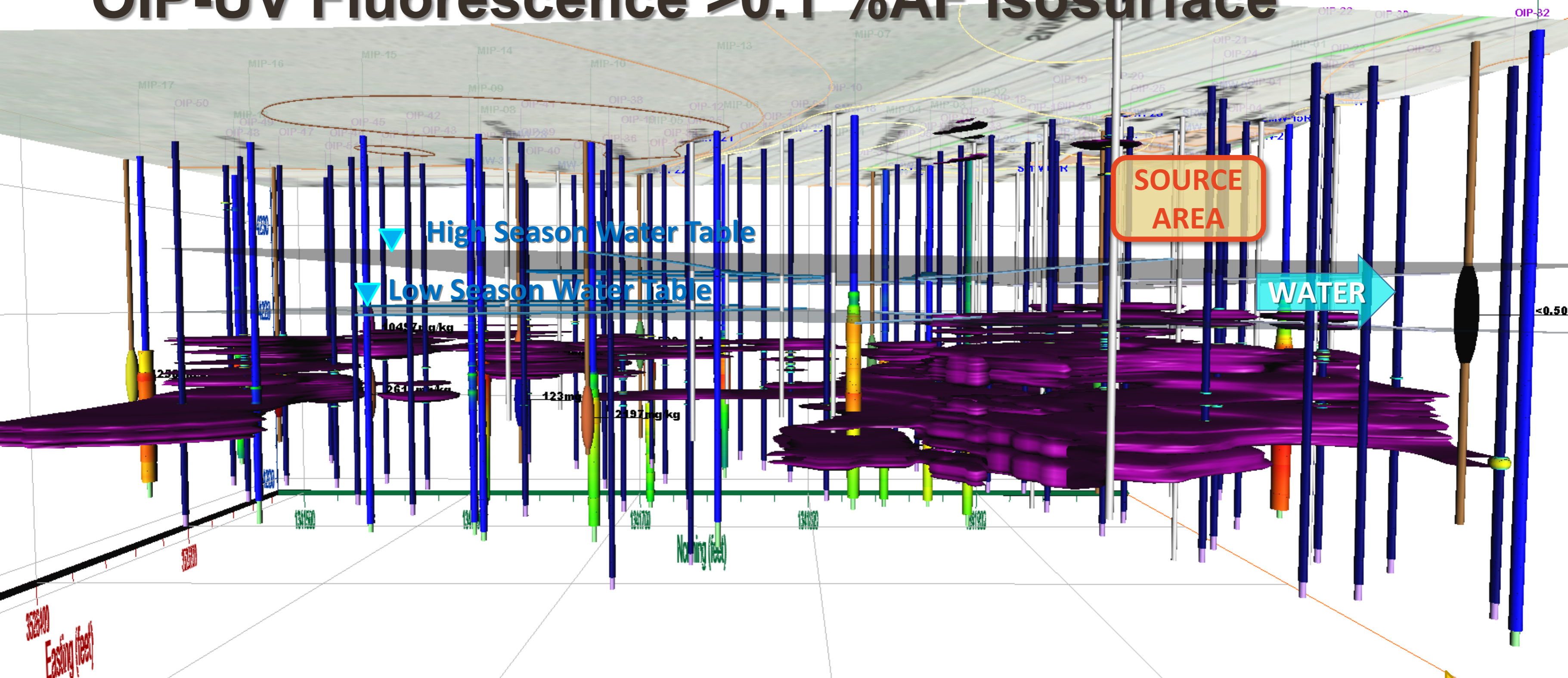
392500



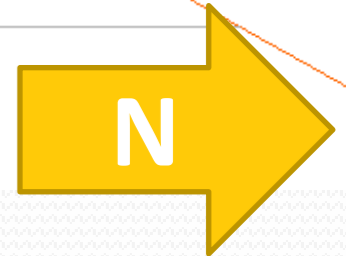
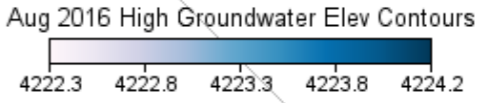
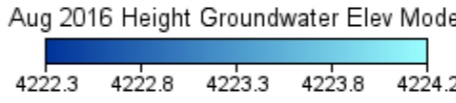
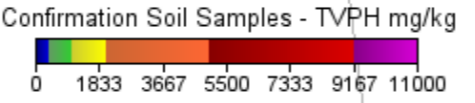
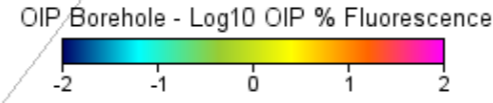
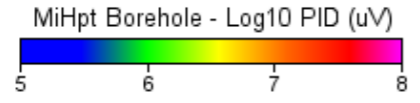
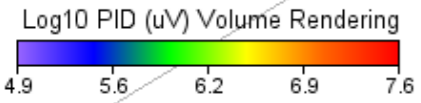
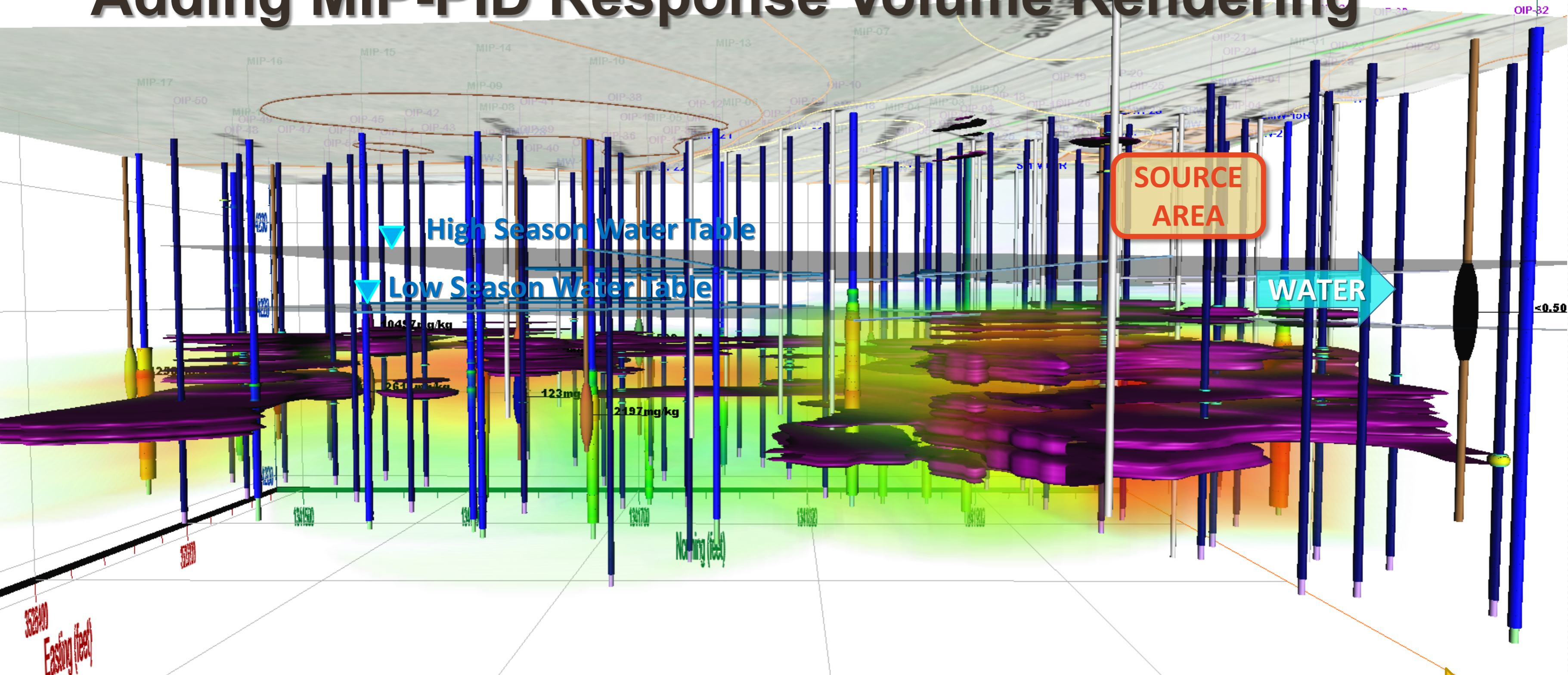
Soil TVPH Rendering Confirmation Borings



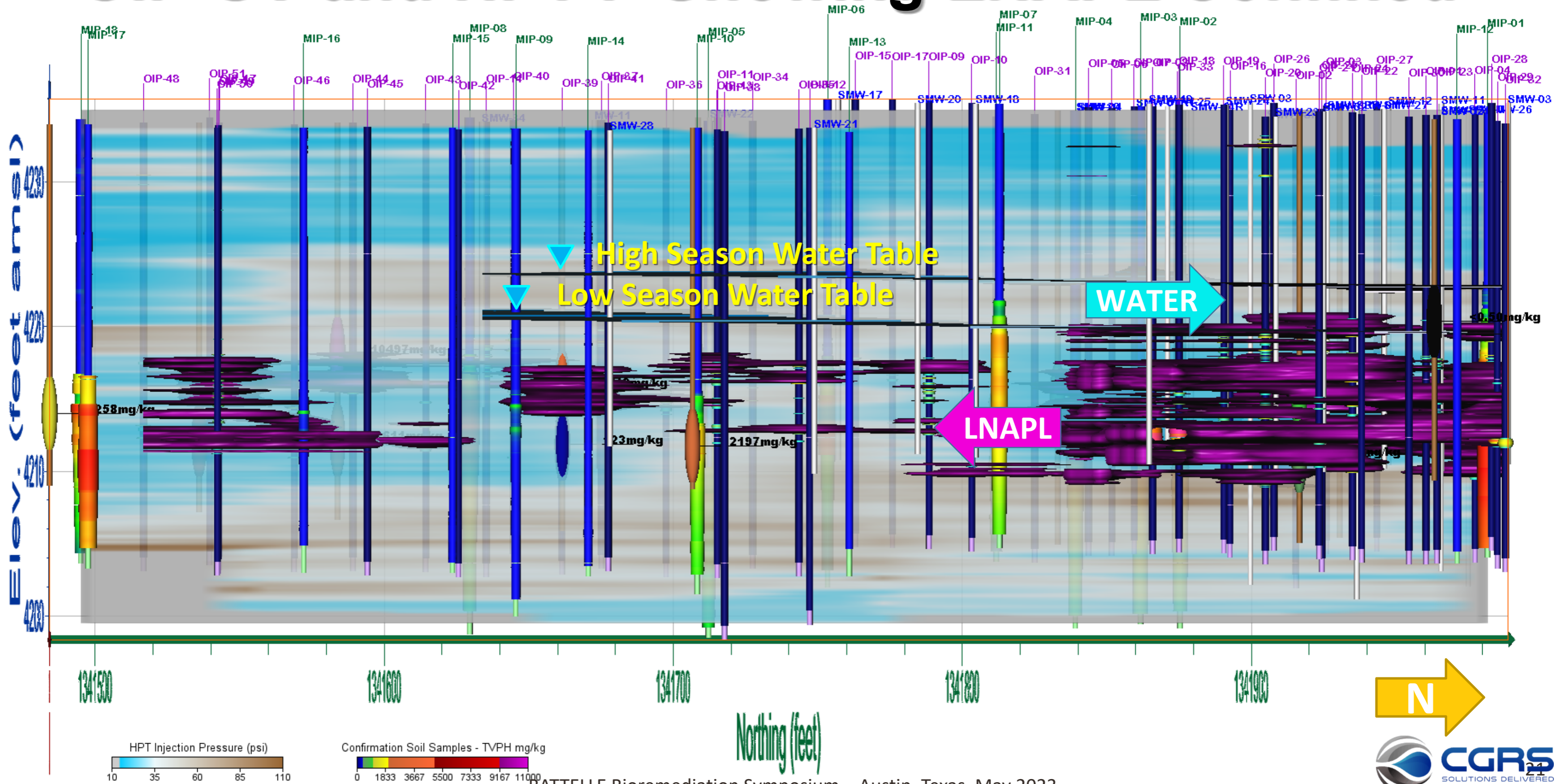
OIP-UV Fluorescence >0.1 %AF Isosurface



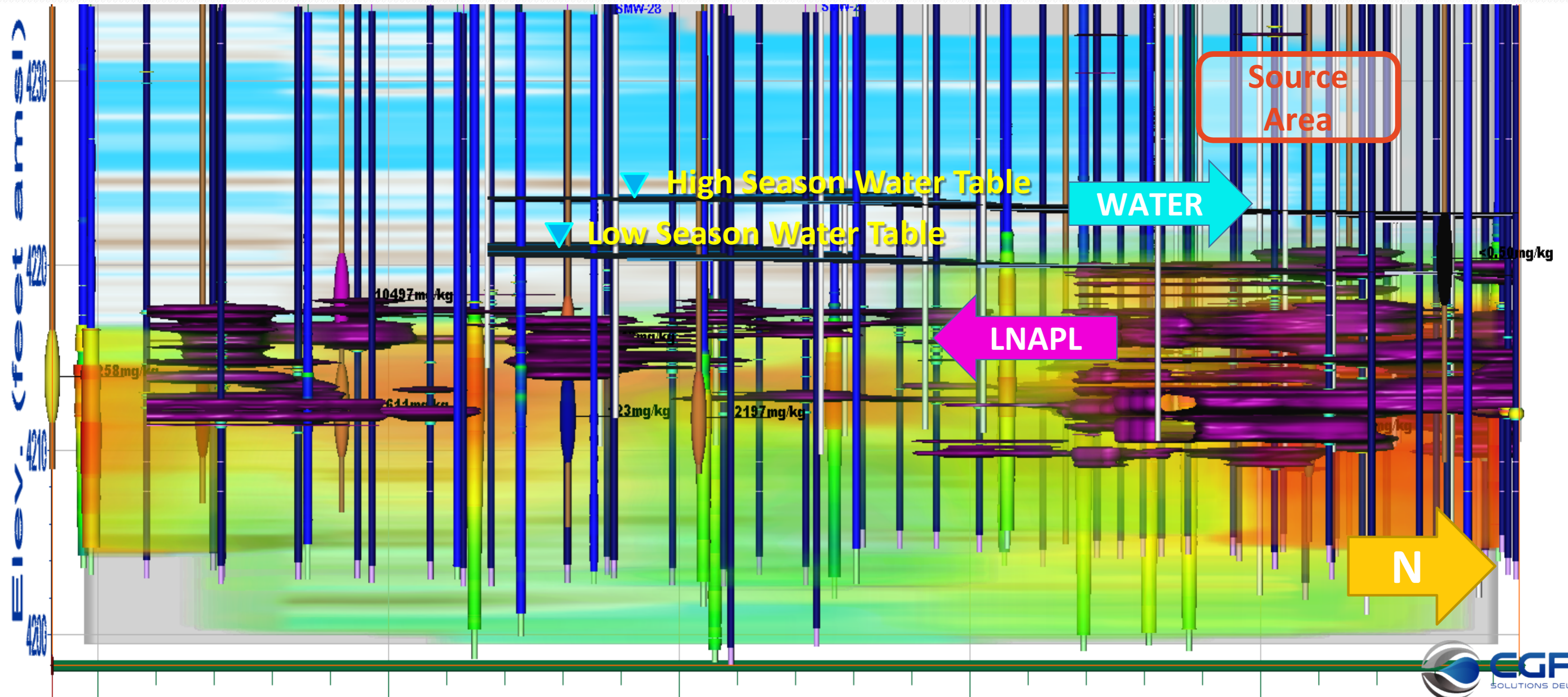
Adding MIP-PID Response Volume Rendering



OIP-UV and HPT-P Showing LNAPL Confined



Cross Section View: LNAPL from OIP-UV & MIP-PID Migration and HPT Pressure >45 psi Isosurface



CSM Case History:

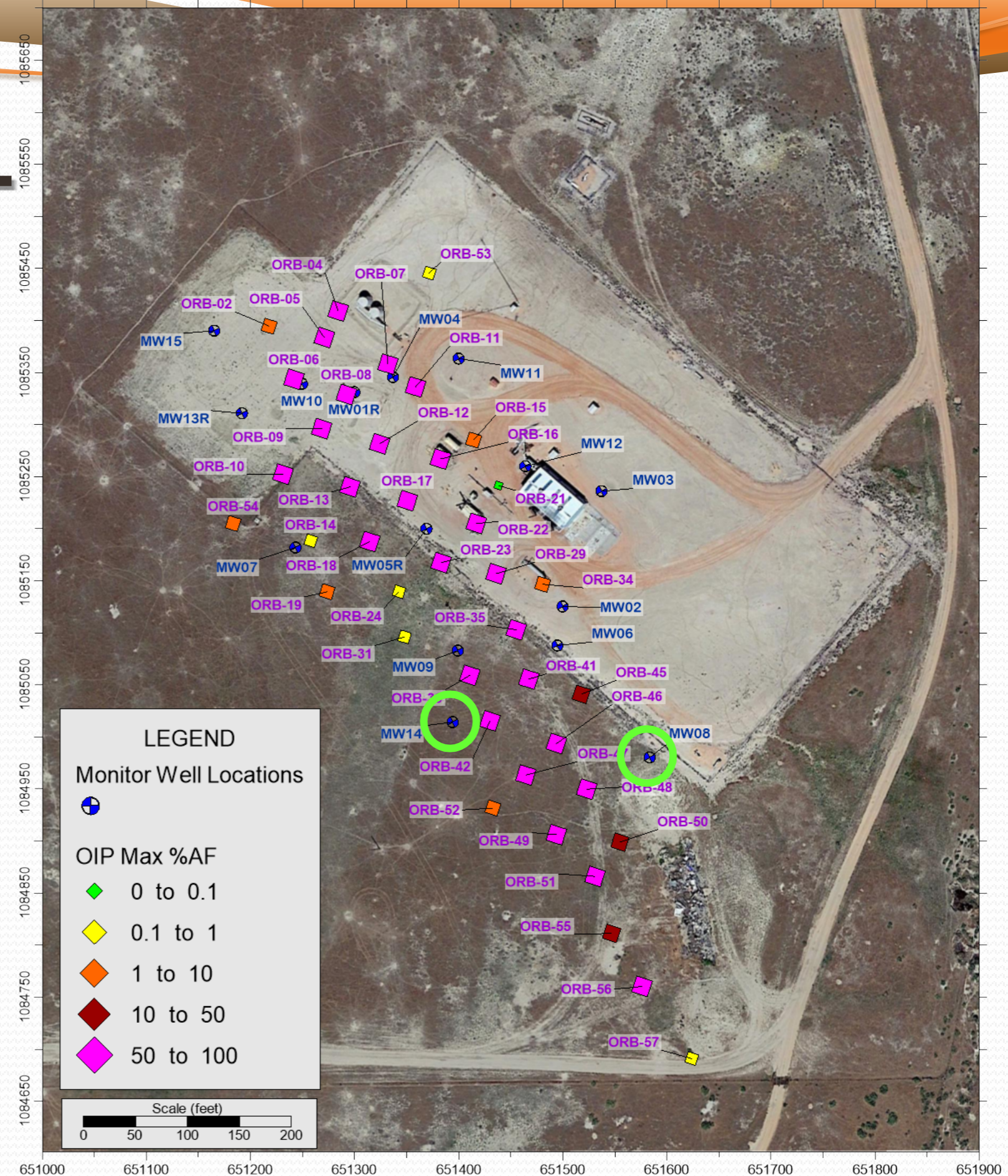
Condensate Pit Release: Plume Migrated Past “Clean” Monitor Wells

- Wyoming Oil Field Pumping Station
- Mapped path of LNAPL in Vadose Zone from Pit to Groundwater.
- Narrow Plume Snuck Between Monitor Wells.
- Changed Remedy from Injection to AS/SVE

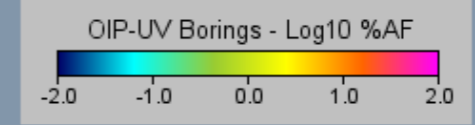
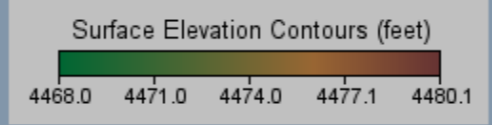
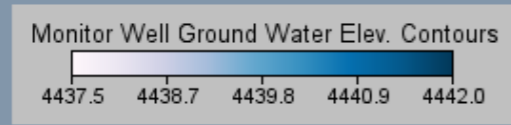
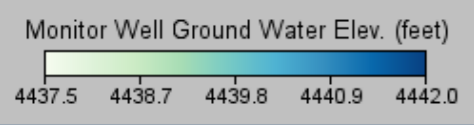
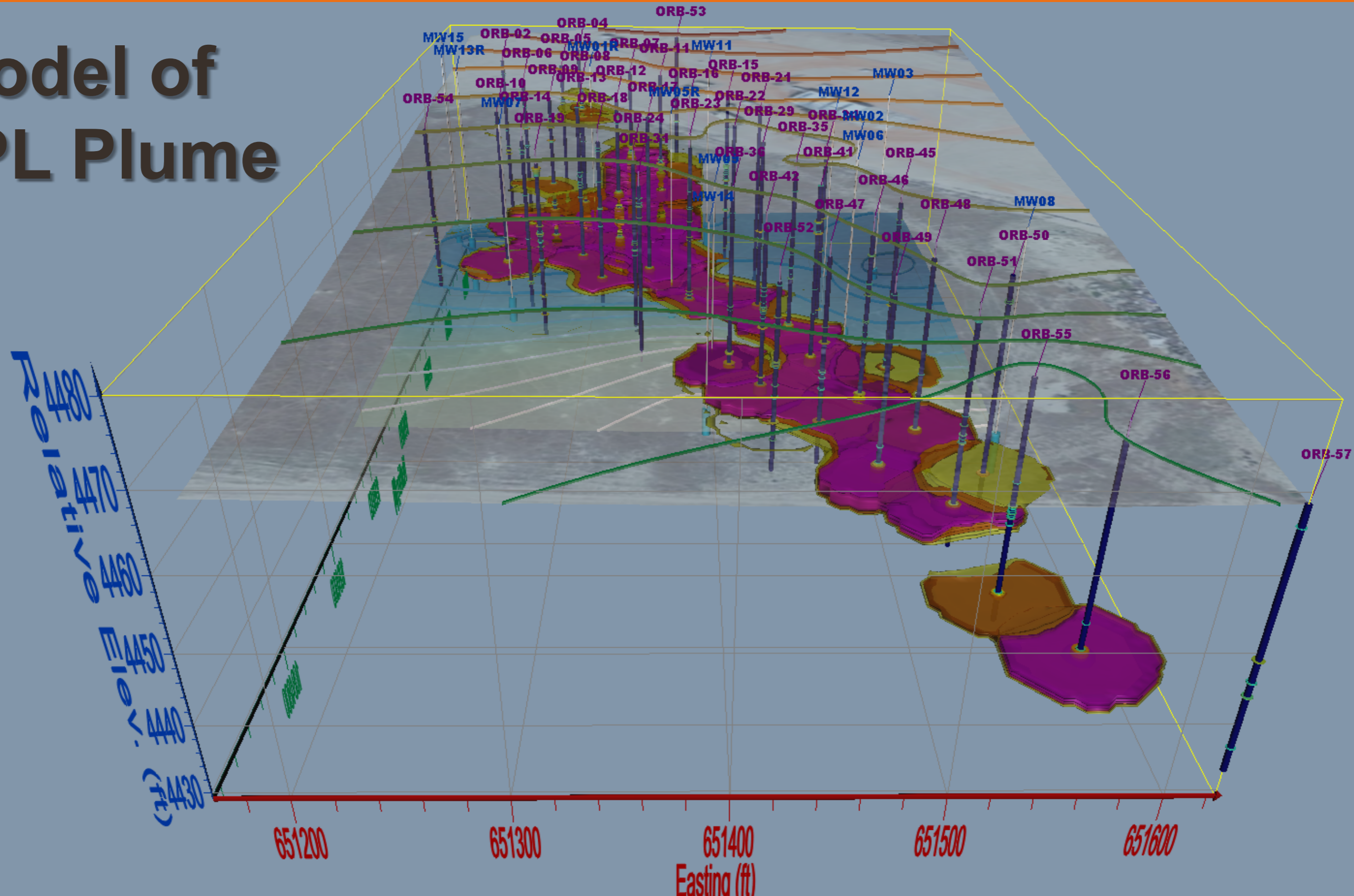


2D Top View of LNAPL Plume Migration Path

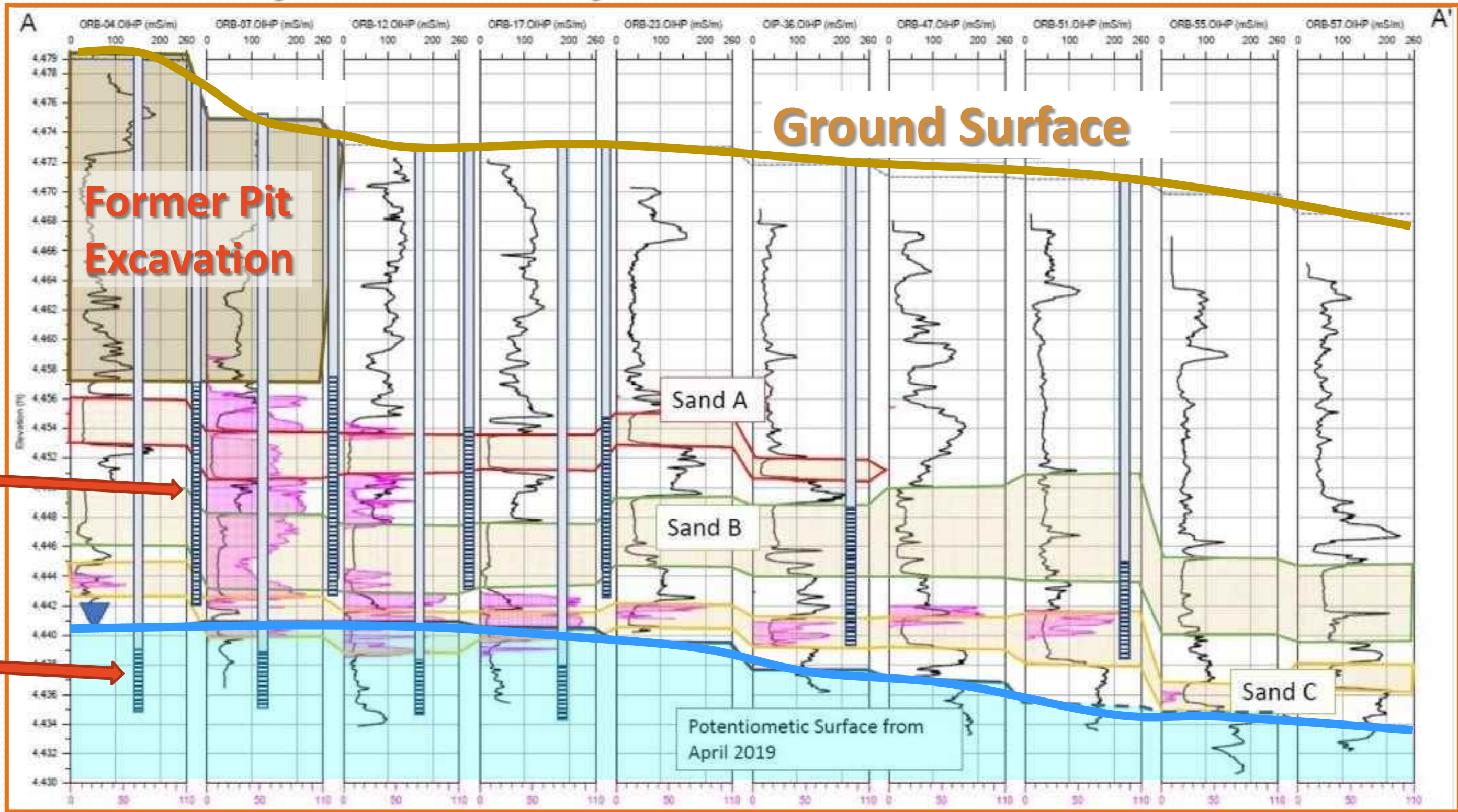
- Condensate in Pit, Excavated
- Long narrow LNAPL plume
- LNAPL Sneaked Between ○ Existing “Clean” Monitor Wells



3D Model of LNAPL Plume



Condensate at Compressor Station in Vadose Zone - SVE/AS vs. Injection Remedy Determined Based on 3D Visualization



Soil Vapor Extraction

Air Sparge

Ground Surface

Former Pit Excavation

Sand A

Sand B

Sand C

Potentiometric Surface from April 2019

CSM Case History:

Perched and Confined Gasoline LNAPL

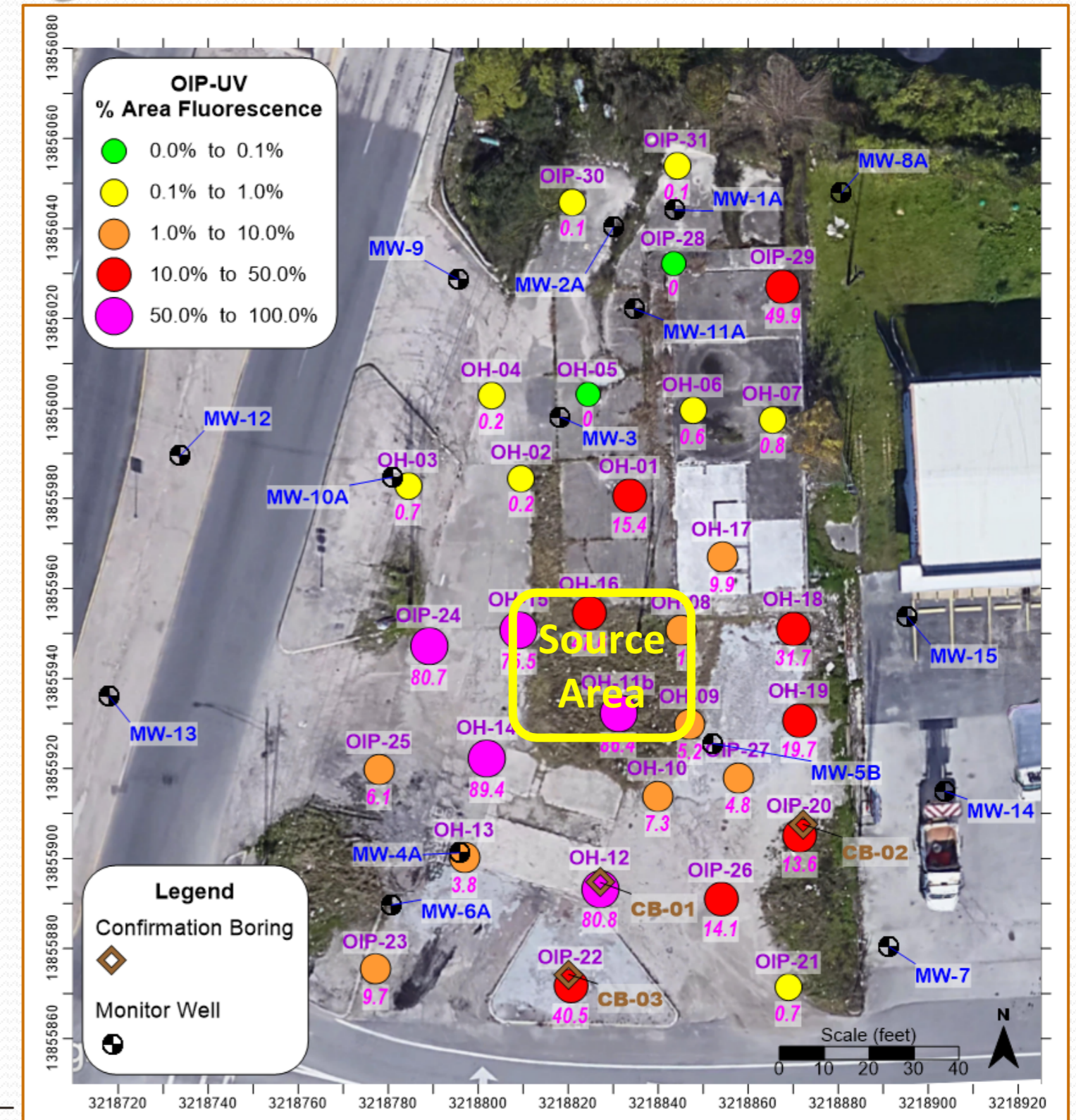
- Abandoned Service Station, Baytown, Texas
- HPT Identified thick confining clay
- OIP Identified LNAPL in perched water table, and confined in deeper aquifer
- Monitor Well Screens May be a Problem!

Courtesy GeoStrata Environmental Consultants

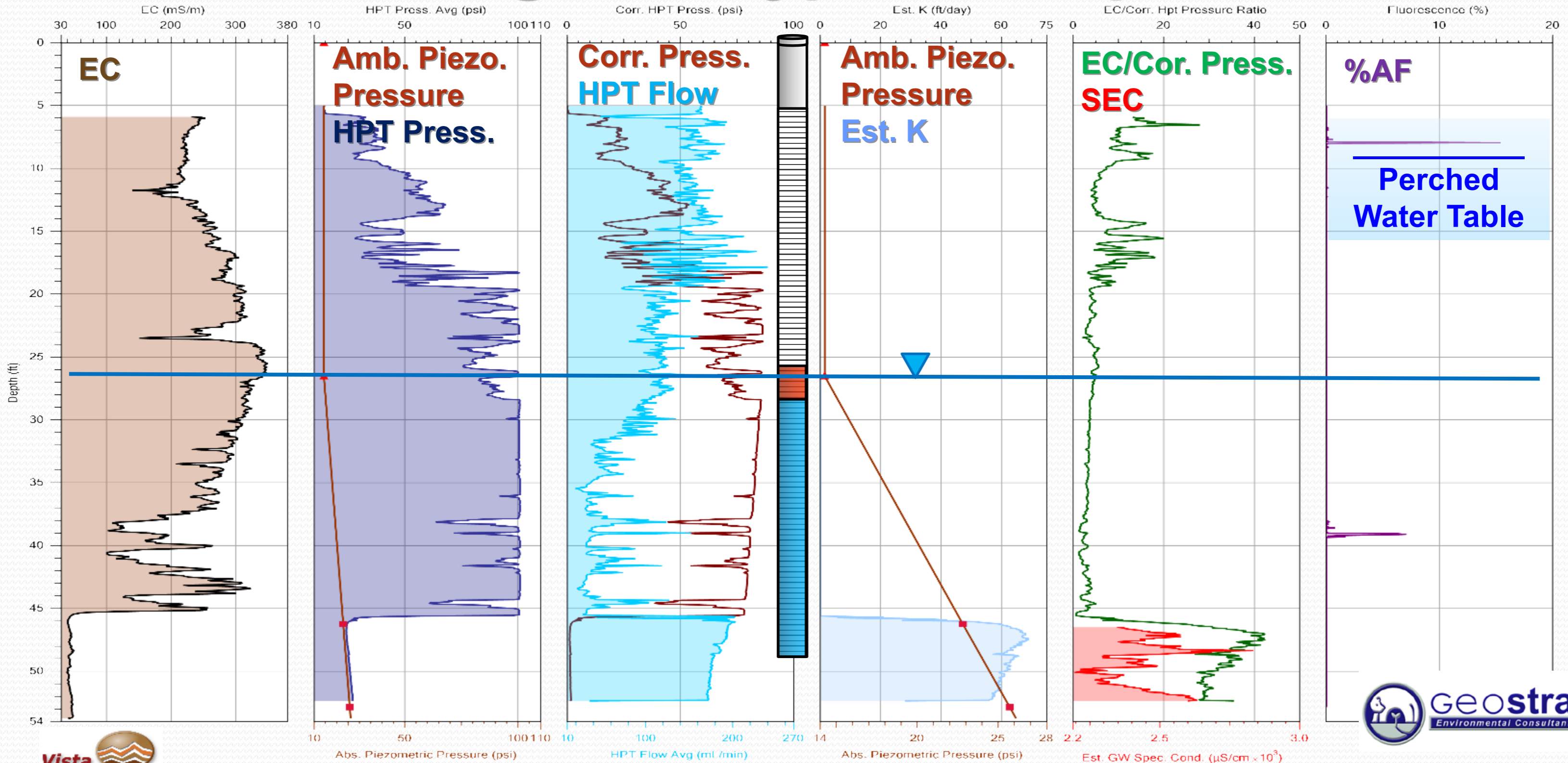


Abandoned Gas Station, Baytown, TX

- Tanks removed long ago
- LNAPL in scattered wells
- Original Investigation, 1997
- 31 OIHPT-UV Borings
- 3 Confirmation Soil Cores
- Groundwater Table Modeled from MWs

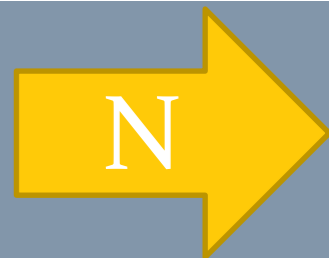
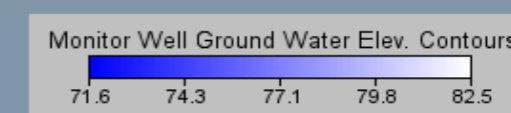
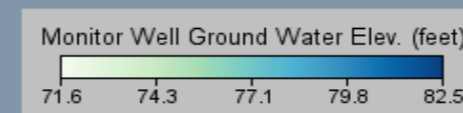
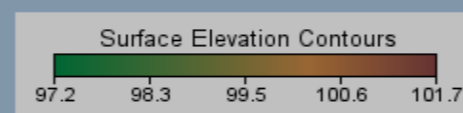
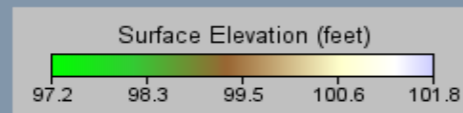
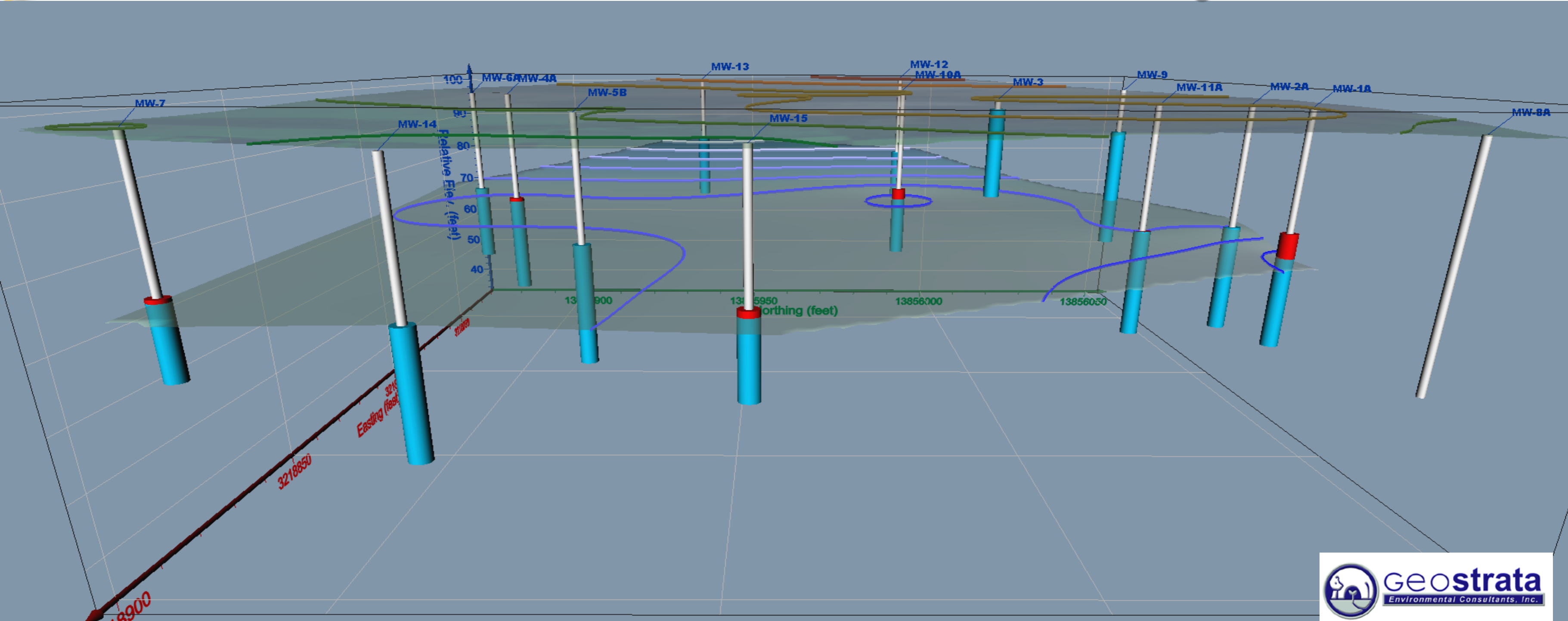


OiHPT-UV Log with Typical Responses at Site



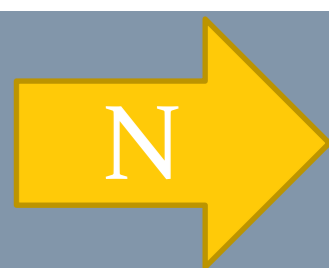
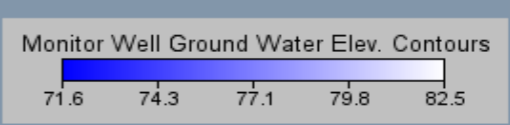
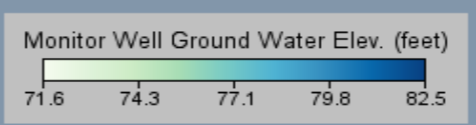
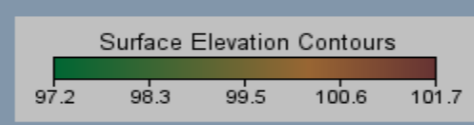
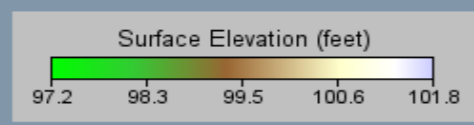
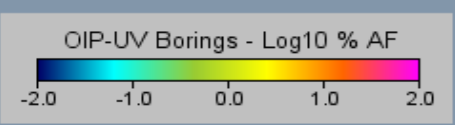
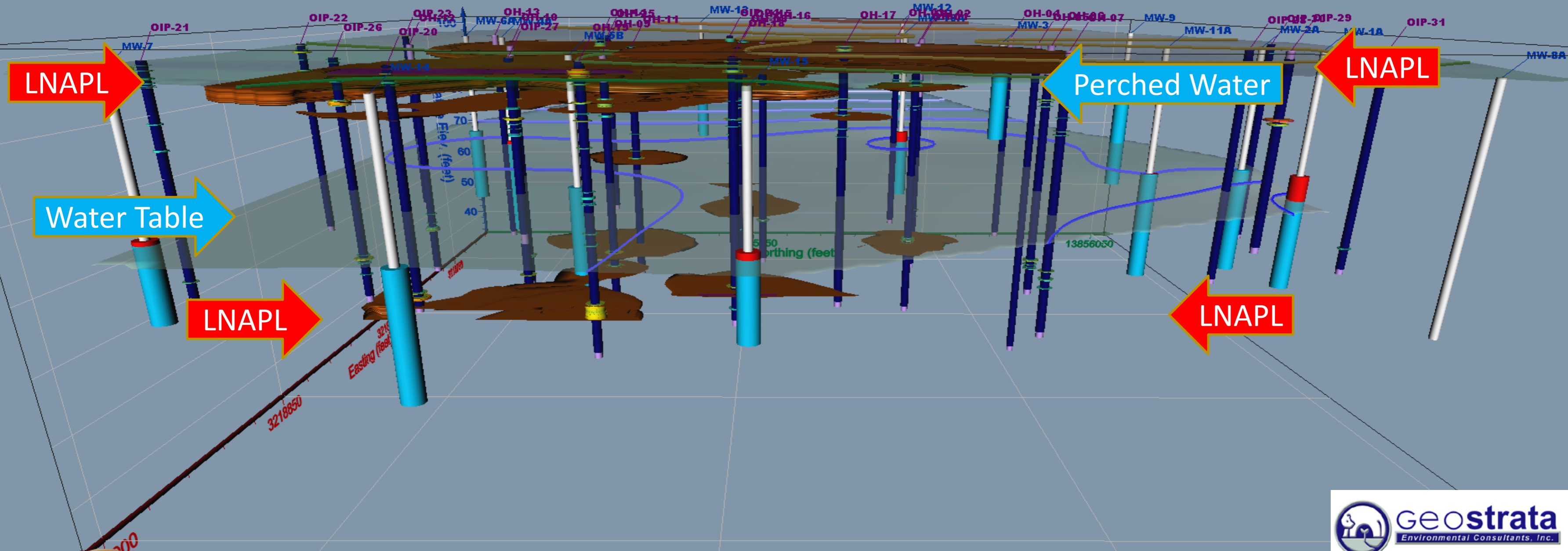
Ground water Elevation Model

Monitor Wells with **Water** and **LNAPL** Column - View Looking West

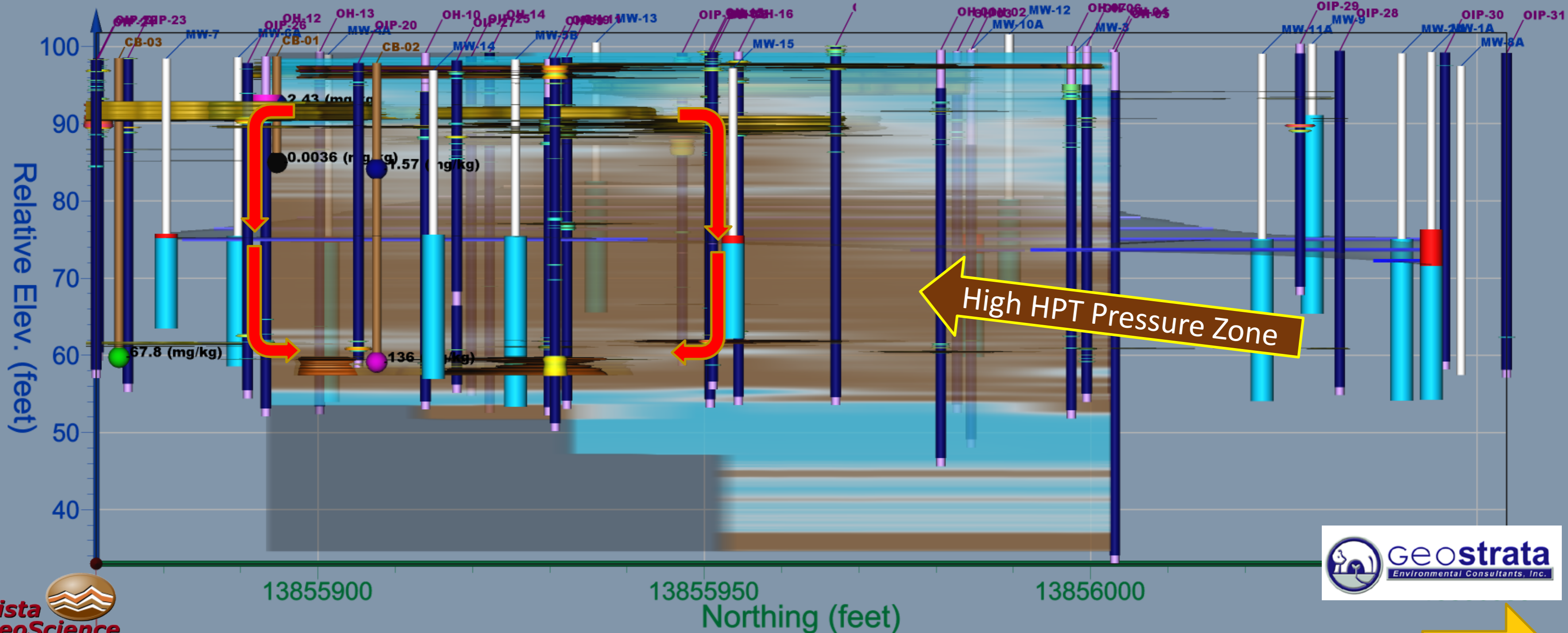


LNAPL Plume > 1% Area Fluorescence (%AF)

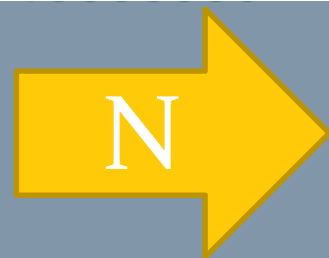
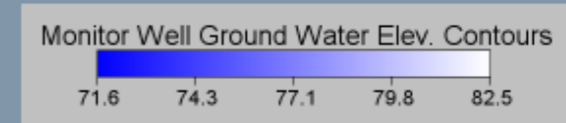
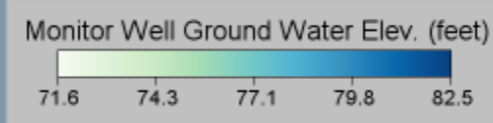
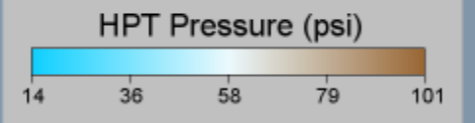
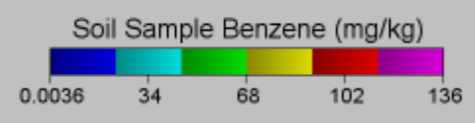
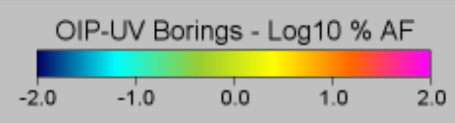
LNAPL in perched zone above water table, and confined 15' below water piezometric head.



Cross Sectional (Orthographic) View of HPT Pressure Showing Massive Clay Layer



High HPT Pressure Zone



Key Points & Summary



- **OiHPT-UV** is able to vertically resolve thin residual and thick mobile LNAPL Fluorescence down to 0.05 foot resolution.
- **The integrated HPT and EC data** reveal hydrostratigraphic information and helps to understand the confining lithologies and migration pathways.
- **LNAPL in confining conditions** can result in erratic and false thickness in monitor wells which does not represent the location of LNAPL in the soil, and LNAPL migration can move counter to groundwater flow.
- **3D modeling of OiHPT-UV data** quickly condense the tens of thousands of data points and clearly show where contaminant mass is present, moving, and where it is trapped in confining layers for a significantly improved CSM.
- **By pinpointing where the bulk of contaminant (LNAPL) resides**, this data helps design targeted and more effective remediation solutions, and quicker site closure.

Thanks!

Questions?

Interpretation of 2D and 3D Images of Ultra-Violet Optical Image Profiler (OiHPT-UV), Hydraulic Profiling, and Electrical Conductivity (HPT/EC) Log Data at Complex LNAPL Sites

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JFontana@VistaGeoScience.com

BATTELLE 2023 Sixth International Symposium on Bioremediation and Sustainable Environmental Technologies May 8-11, 2023 | Austin, Texas



Vista
GeoScience
Advanced Site Characterization
& Optimized In-Situ Remediation

Thanks to our clients for use of their data:



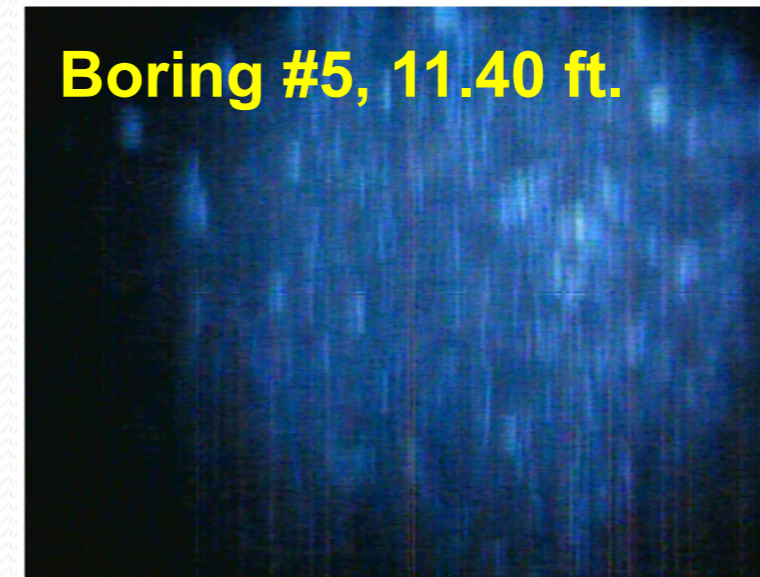
Extra Slides for Potential Questions

Fresh or Weathered Fluorescence?

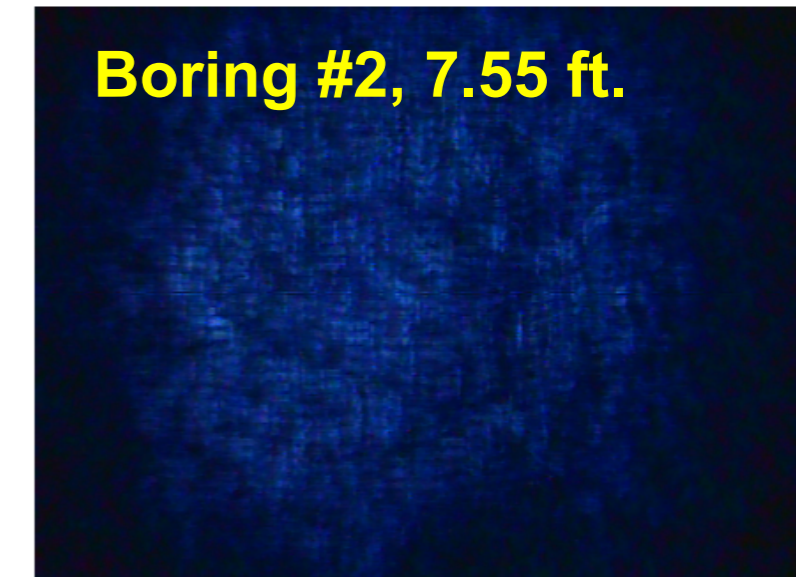
(New spill bucket release at old site)

- Fresh fluorescence near new 2018 release
- Dull fluorescence from old previous 1997 release
- Boring with both types at different depths

Boring #5, 11.40 ft.



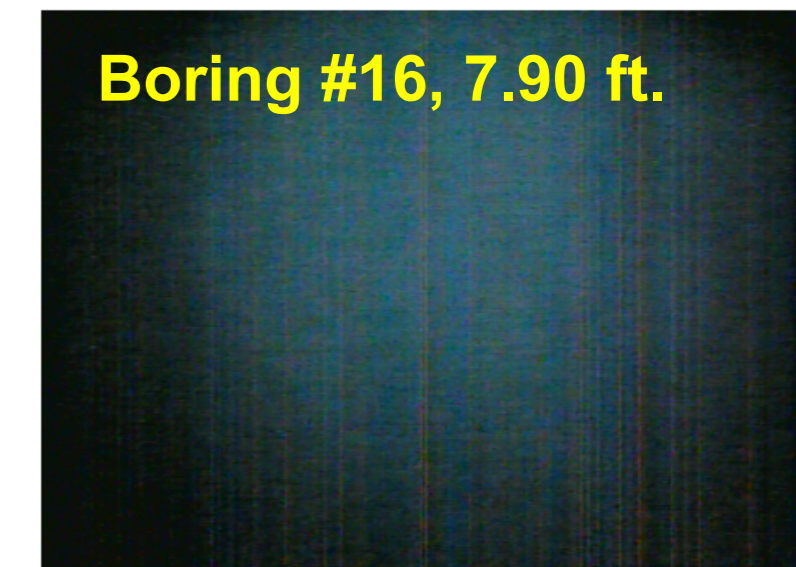
Boring #2, 7.55 ft.



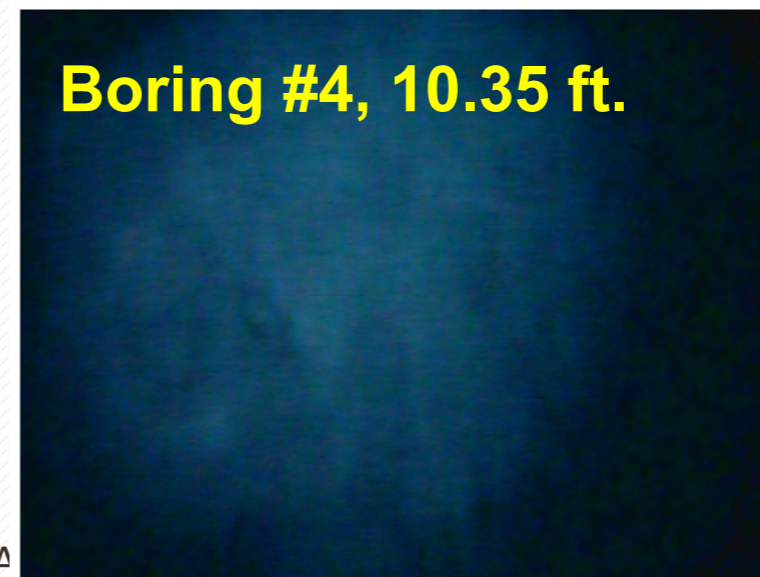
Boring #9, 10.60 ft.



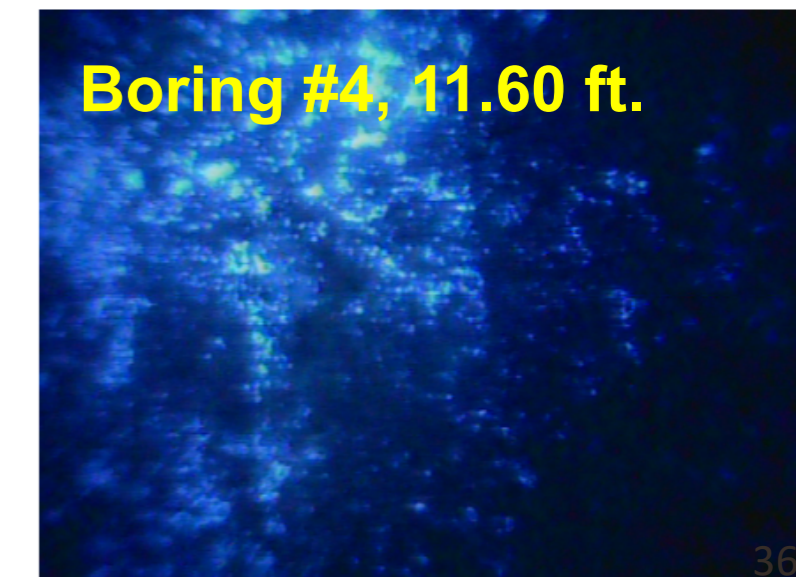
Boring #16, 7.90 ft.



Boring #4, 10.35 ft.

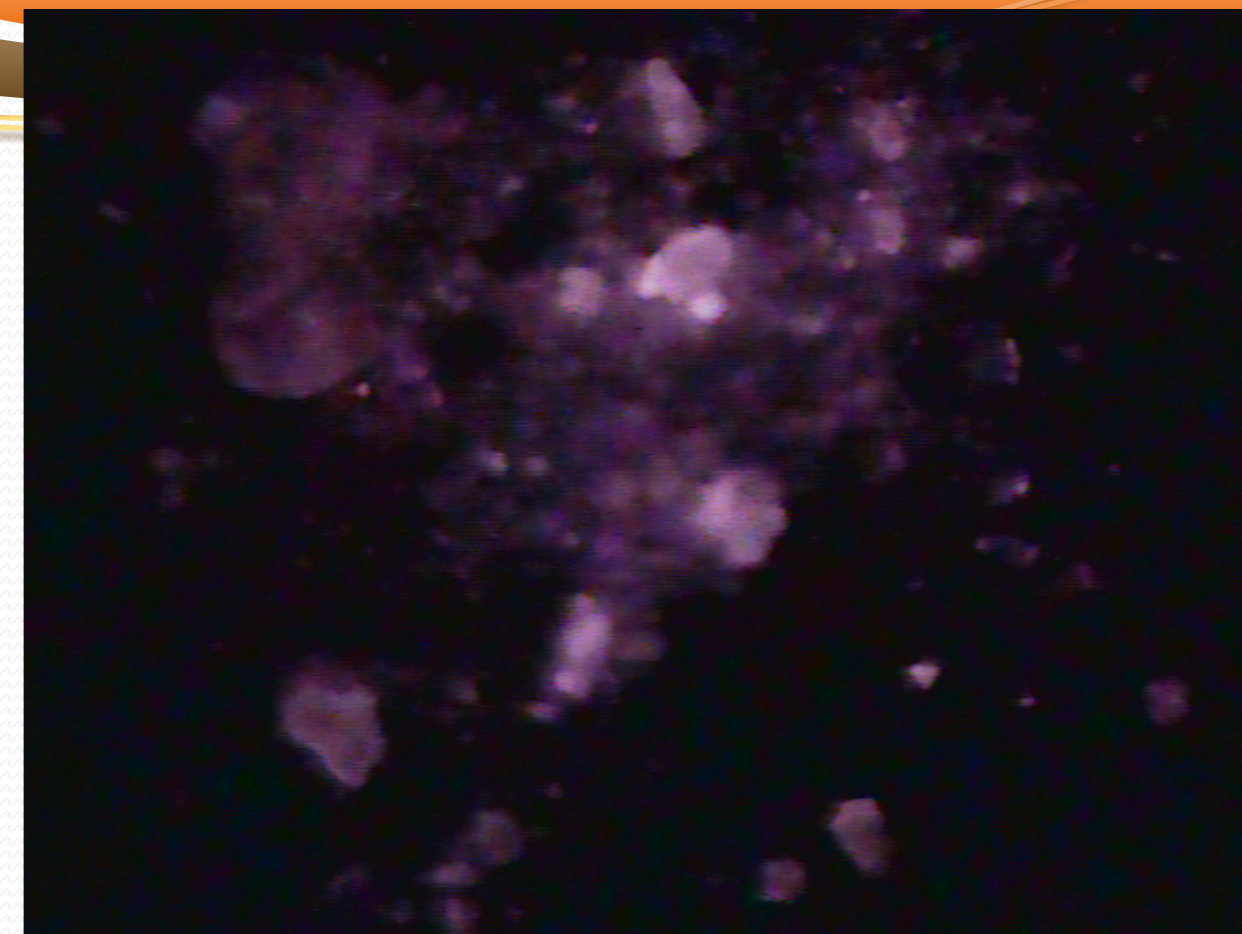


Boring #4, 11.60 ft.



Mineral Fluorescence

(Possible Interference)



Comparison of OIP-UV and LIF/UVOST

- Michigan UST Site
- Comparison Study with 40 offset borings
- OIP-UV & LIF/UVOST in Relative Response
- Intervals were Identical
- Similar Relative Response

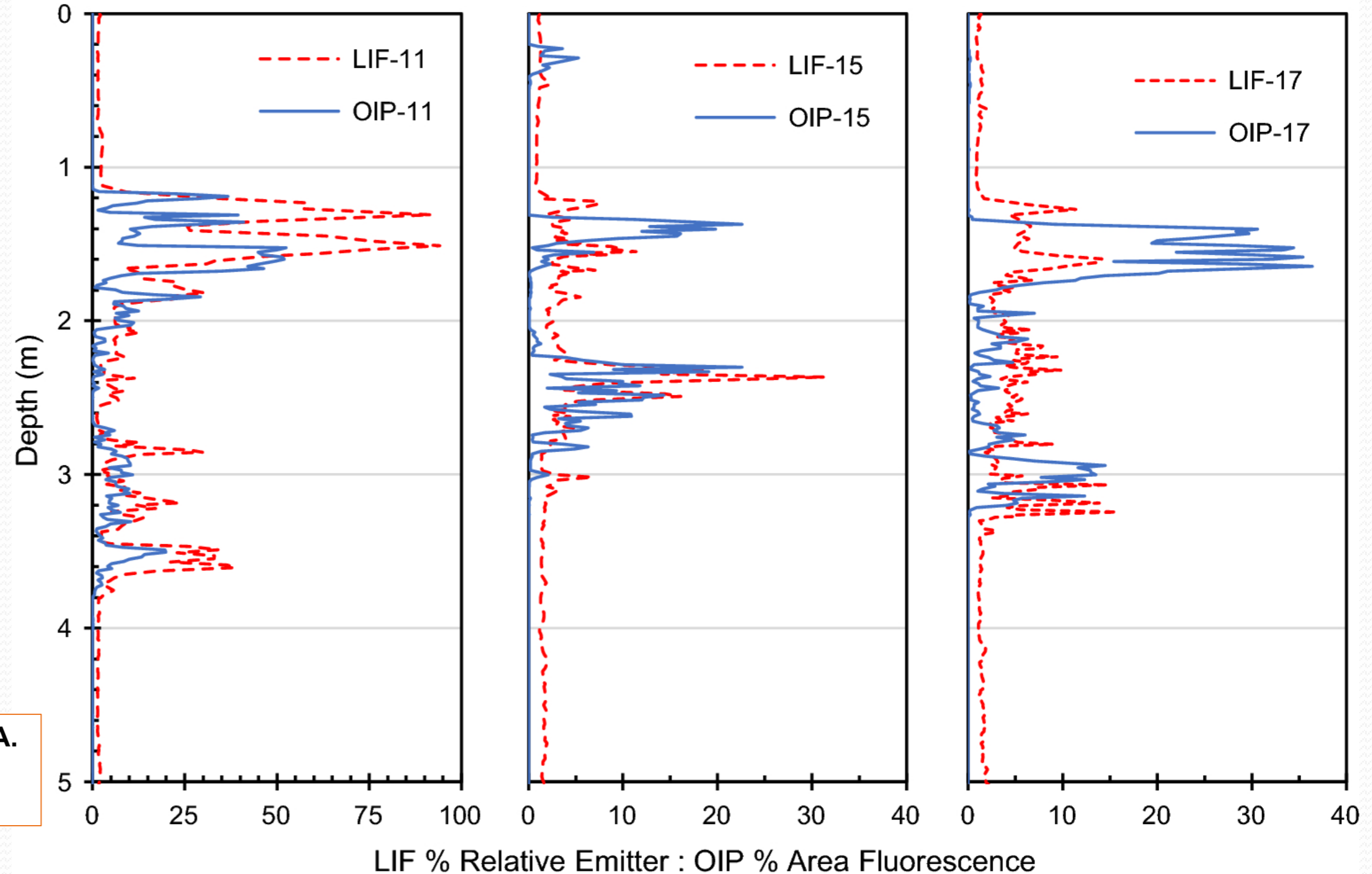


FIGURE: McCall, W., Christy, T.M., Pipp, D.A. et al. Environ Earth Sci (2018) 77: 374.

<https://doi.org/10.1007/s12665-018-7442-2>