Using the Combined UV Optical Image Profiler and Hydraulic Profile Tool with Modeling Tools to Visualize Complex Petroleum LNAPL Migration

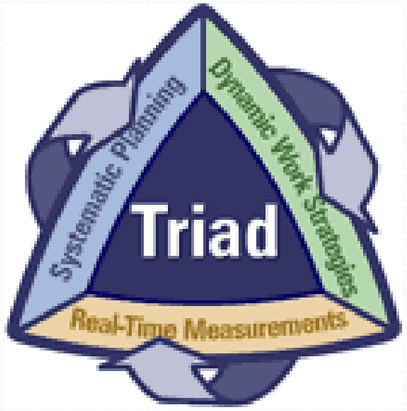
John Fontana

CPG, CWD, President/CEO, *Vista GeoScience*

Vista GeoScience

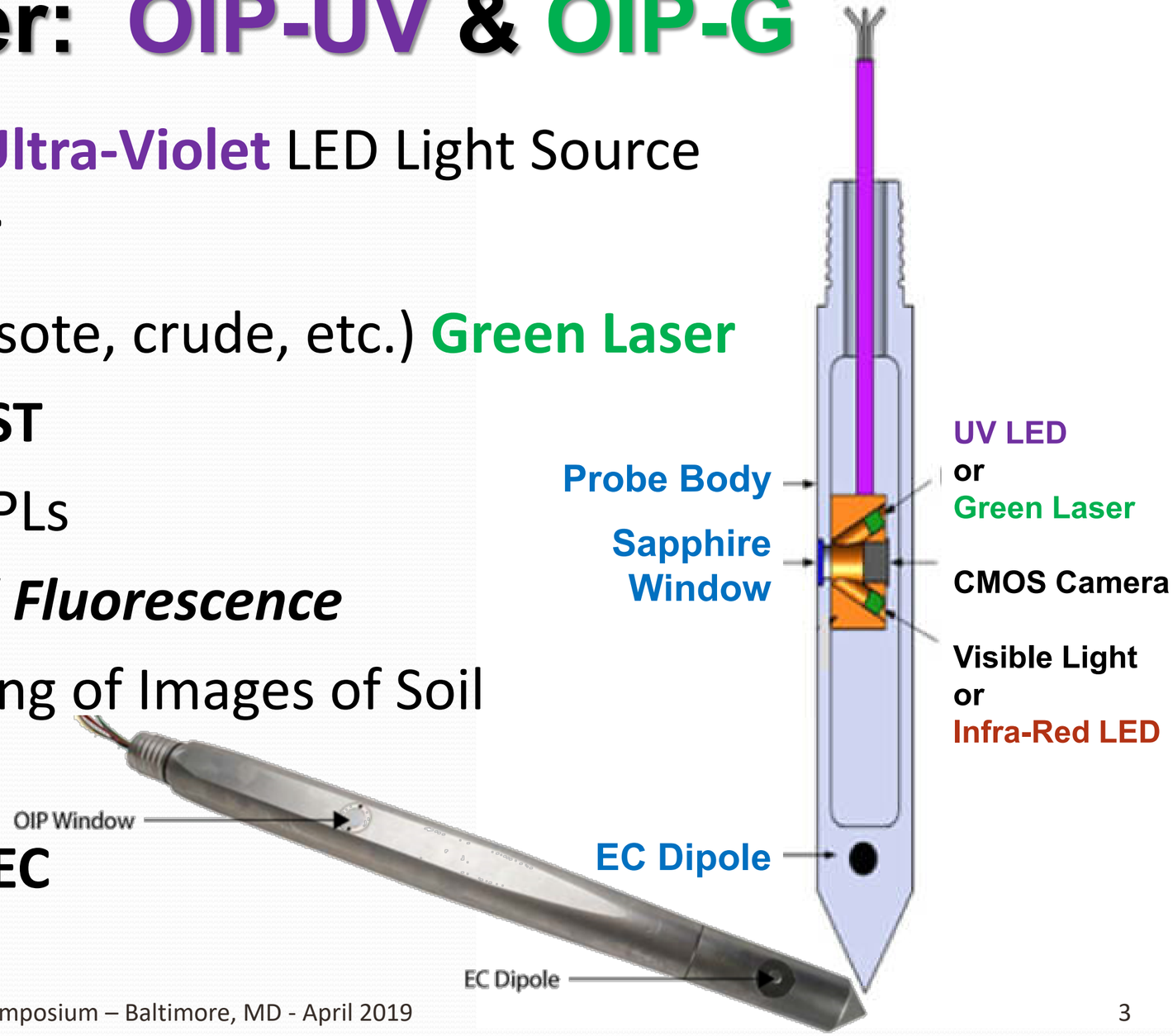
OUTLINE:

- How the Optical Image Profiler Works
- Advantages of Reviewing Images
- Integrated HRSC Combined Tools (OIP+HPT+EC)
- Quality Control
- Case Studies: 2D & 3D Visualization of Complex LNAPL Patterns
- Summary



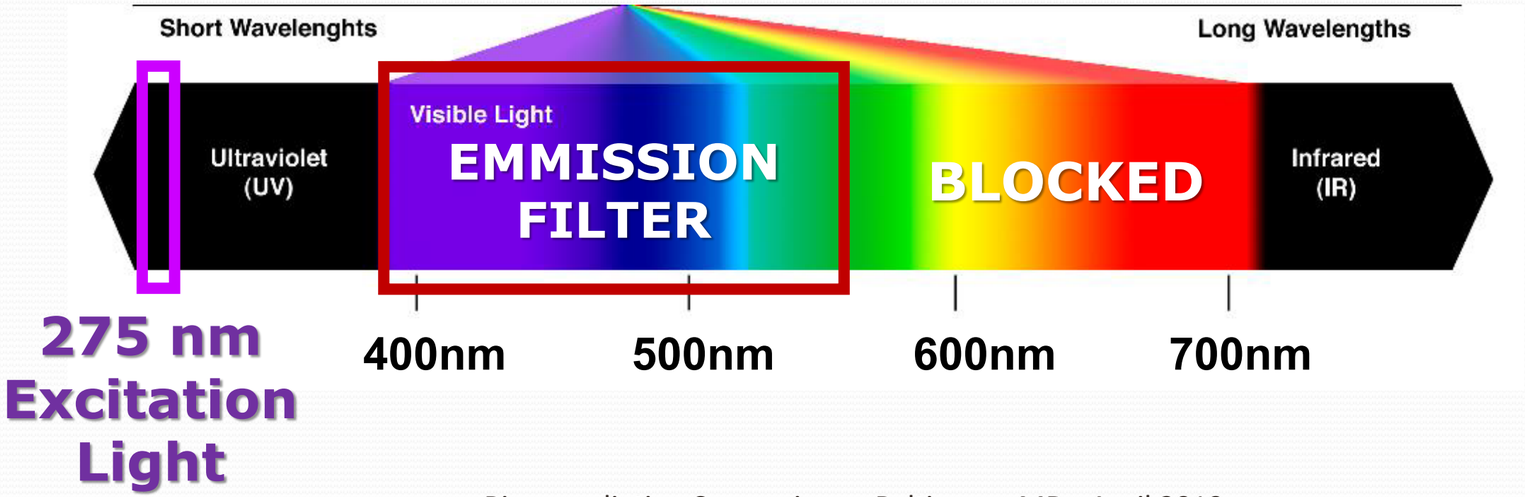
Optical Image Profiler: OIP-UV & OIP-G

- **OIP-UV for Fuels, Lighter Oils: Ultra-Violet** LED Light Source
  - Similar Response as **LIF/UVOST**
- **OIP-G for Heavy PAHs:** (tar, creosote, crude, etc.) **Green Laser**
  - Similar Response as **LIF/TarGOST**
- **PAHs Fluoresce** in Petroleum NAPLs
- **CMOS Camera *Captures Induced Fluorescence***
- **White Light or IR LED** for Capturing of Images of Soil
- **Geoprobe DI Viewer Software**
- **Tools are combined with HPT & EC**



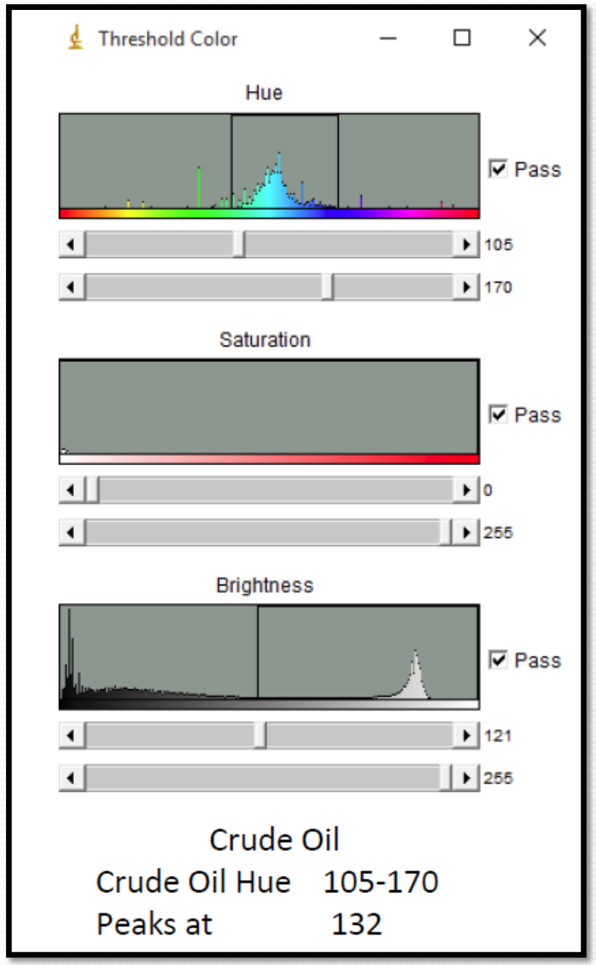
OIP-UV Analysis of Fluorescence

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



Analysis of Fluorescence (Digital Photography)

Crude Oil

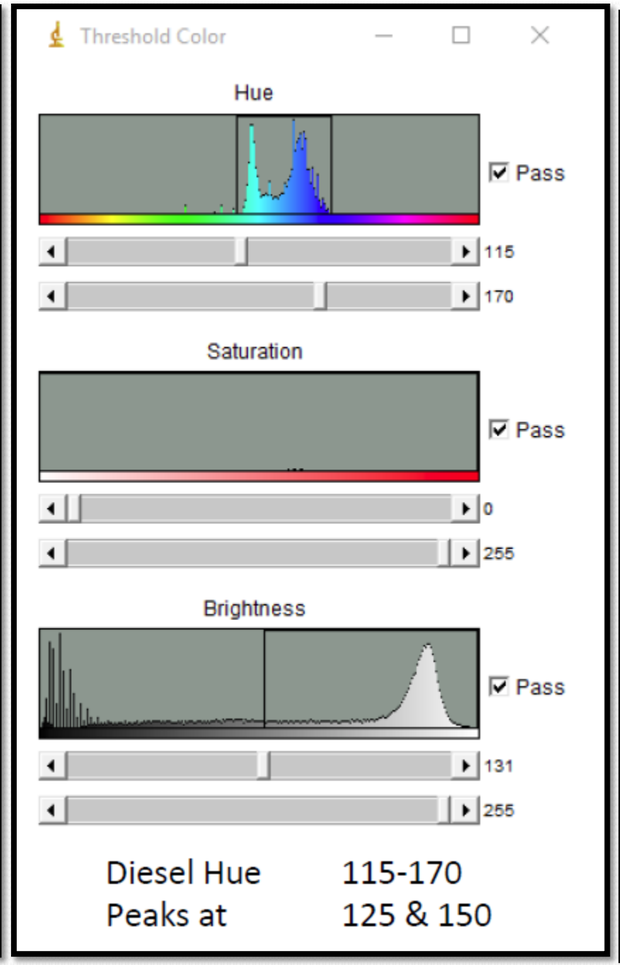


Crude Oil

Crude Oil Hue 105-170

Peaks at 132

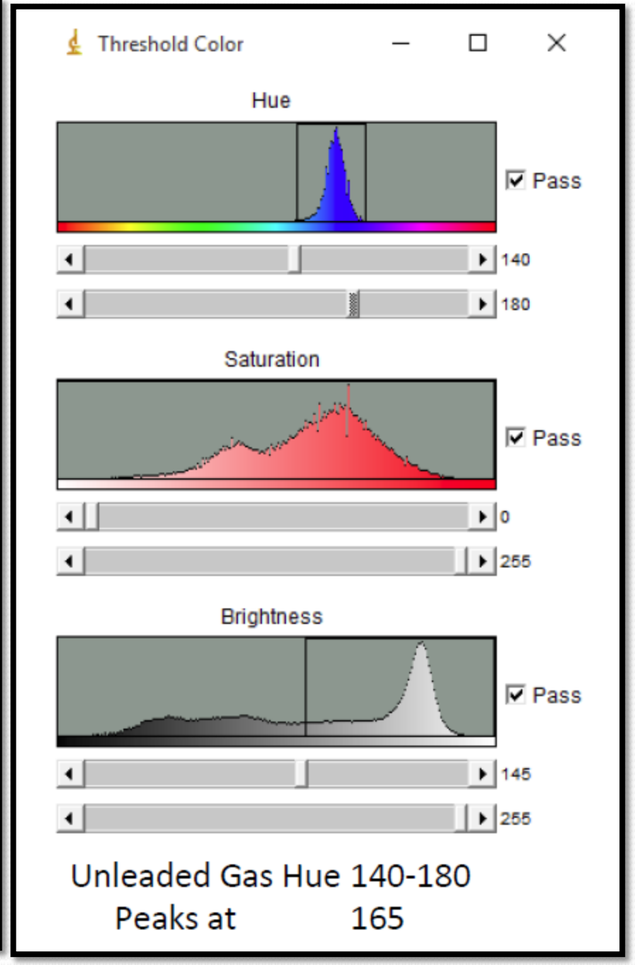
Diesel



Diesel Hue 115-170

Peaks at 125 & 150

Gasoline



Unleaded Gas Hue 140-180

Peaks at 165

Hue

Saturation

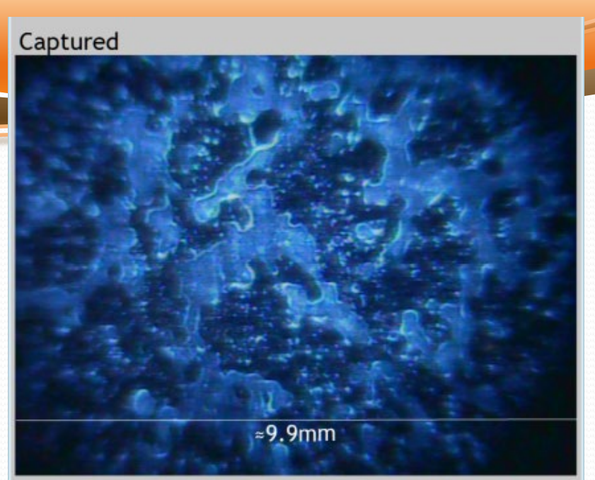
Value

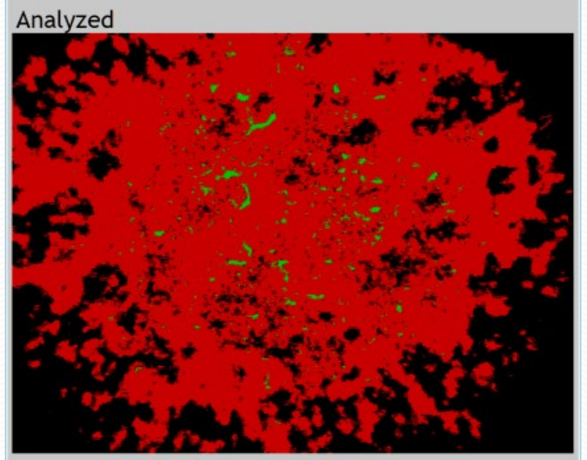
OIP-UV Images

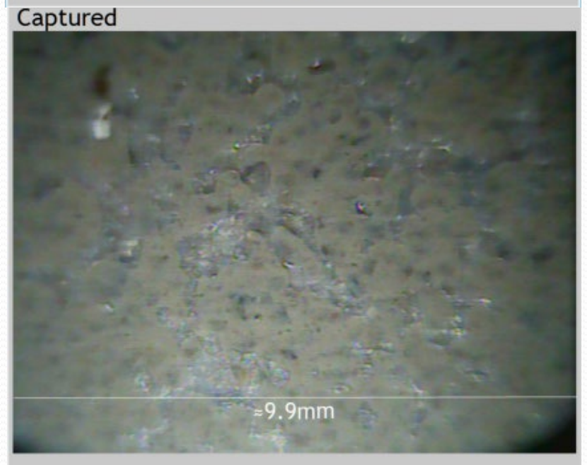
- Captured Fluorescence Image under 275nm UV LED Light

- Software Analysis of % Area Fluorescence (22.3% %AF)

- Captured Soil Image under Visible (White) LED Light

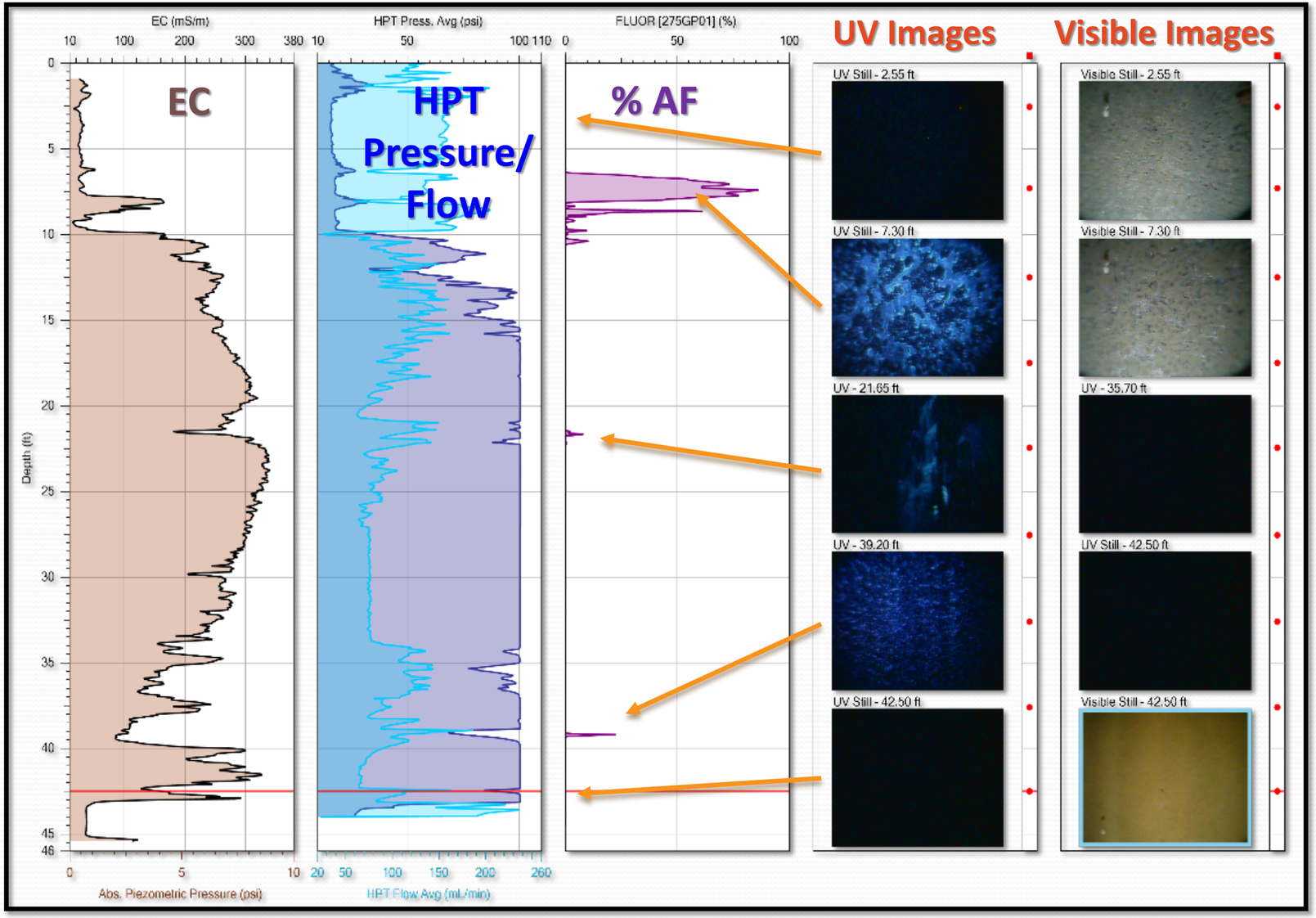




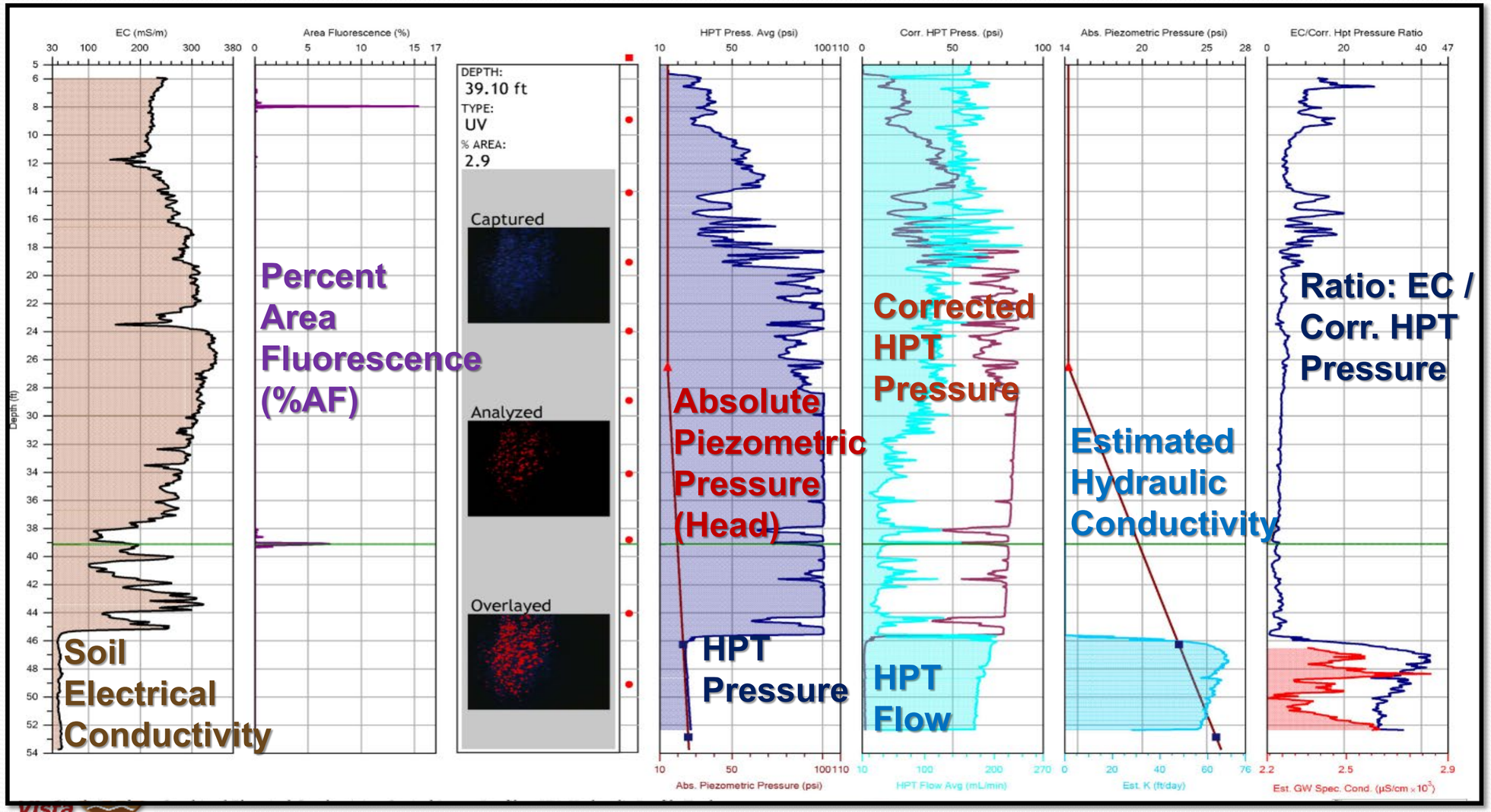


Typical OiHPT-UV Log

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



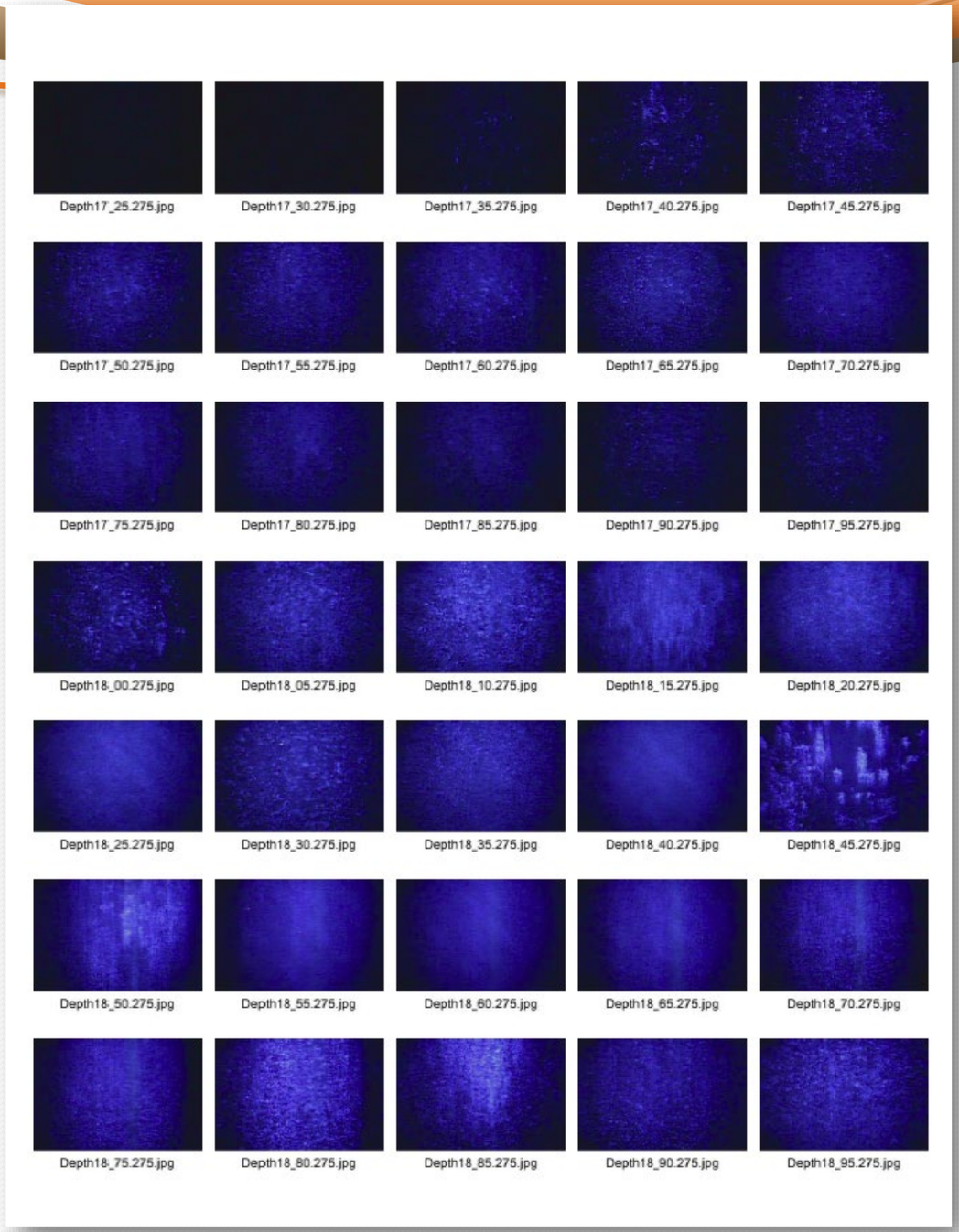
Additional Post Processed Data (K, SEC, etc.)



Groundwater Specific Electrical Conductance

View of Continuous Captured UV Images

- Imaged is captured every 1/20th of a foot.
- Can be viewed in DI Viewer software.
- Can be printed to a contact sheet.



Quality Control

.nfo File Records *ALL THIS DATA for Later Review:*

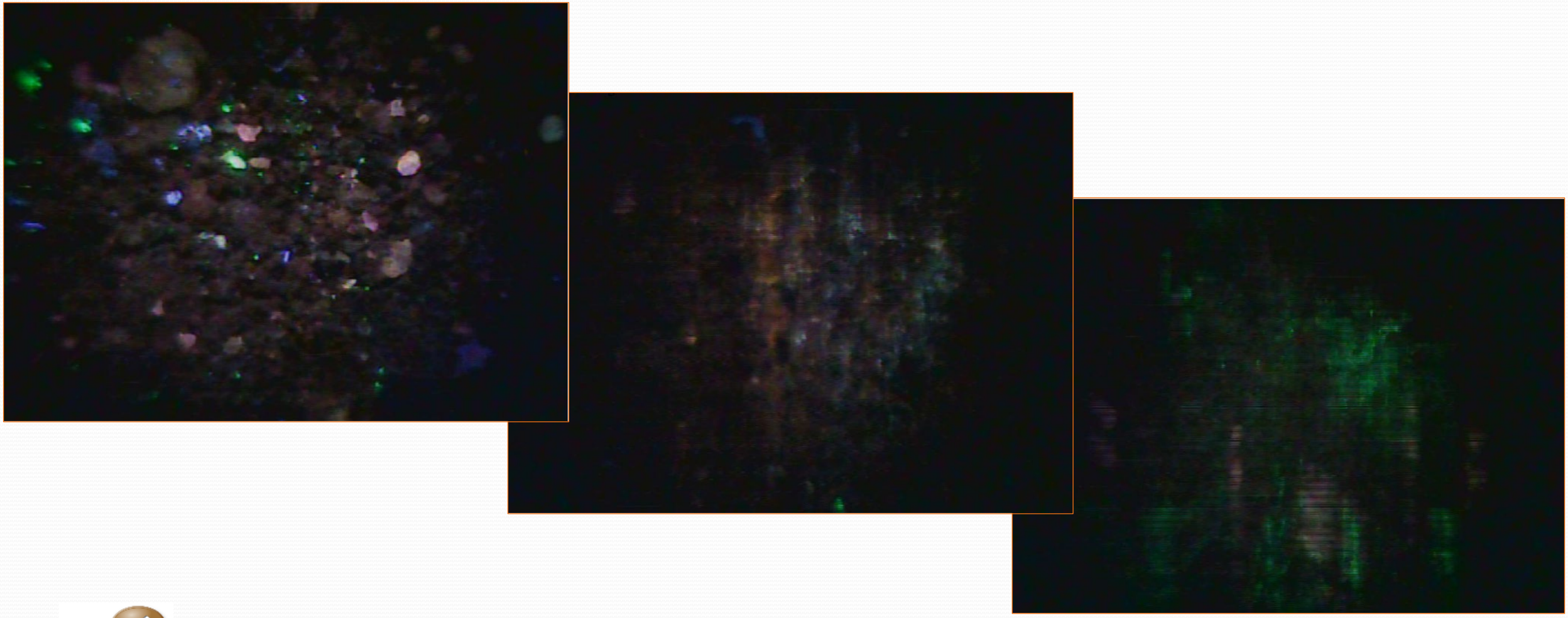
- **Logging Parameters - Alarms:**
  - Power, Voltage - Indicate Camera & LED Health
- **Sensor Response Tests** (Every Log Run!)
  - OIP Fluorescence Standards Responses
    - Actual Gasoline, Diesel, and Oil Standards
  - HPT Pressure Sensor Response
  - Electrical Conductivity Response
- **Confirmation Borings** (Soil & GW)

- ***ASK FOR THE RAW DATA FILES FOR YOUR RECORDS!!***

```
M-01a.zip
SITE INFORMATION -- DIRECT IMAGE MIP+HPT PROBE
Geoprobe DI Acquisition Software for Windows
Version: 3.0   Build: 17007

EC PRE-LOG TESTS BYPASSED

COMPANY: Vista GeoScience
OPERATOR: DF
PROJECT ID: 17151.01
CLIENT: AECOM
UNITS: ENGLISH
PROBE AND ARRAY: MH6530/6532 MiHPT Probe with Top Dipole
LOCATION: Paris TX
100 INCH STRING POT USED
ROD LENGTH: 5 feet

MIP PRE-LOG RESPONSE TEST
FILENAME: M-01a.pre.tim
COMPOUND: Benz, TCE
CONCENTRATION: 10, 10 ppm
FLOW: 36.1 mL/min
RESPONSE TEST START TIME: Thu Sep 28 2017 09:52:40
RESPONSE TEST ATTENUATION CHANGES
   TIME         DET1    DET2    DET3    DET4
     0            1       1       1       1

TRIP TIME: 45 sec
Gas Used: nitrogen

PRE-LOG HPT REFERENCE TEST VALUES
PRE TEST TIME: Thu Sep 28 2017 10:04:40
        TEST            HPT PRESSURE (psi)      FLOW (mL/min)   HPT PRESSURE (kPa)
TOP with FLOW=0          15.502                   0.0            106.880
TOP with FLOW>0          15.889                   304.3          109.550
BOTTOM with FLOW=0       15.299                   0.0            105.480
BOTTOM with FLOW>0       15.677                   302.6          108.090

EXPECTED FLOW=0 HPT DIFF.: 0.22 psi (1.5 kPa) +/- 10%
  ACTUAL FLOW=0 HPT DIFF.: 0.20 psi (1.4 kPa)

TRANSDUCER TEST PASSED

DETECTOR NAME: PID FID XSD None
HPT IDEAL COEFFS:       2.2696e1,-2.2356
HPT SENSOR CAL NUMBERS: XD30850A,0.0000,0.0000,0.0000,0.0000,9.9460e-1,-1.1500

Temperature out of range (42.0 deg C) at 0.00 ft (0.000 m)
Temperature out of range (38.8 deg C) at 0.00 ft (0.000 m)

LOG START TIME: Thu Sep 28 2017 10:06:30
```

Examples of Mineral Fluorescence in OIP-UV Images

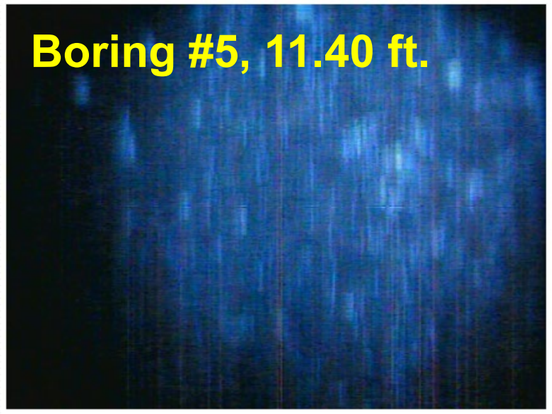
These colors were all filtered out and not reported as %AF

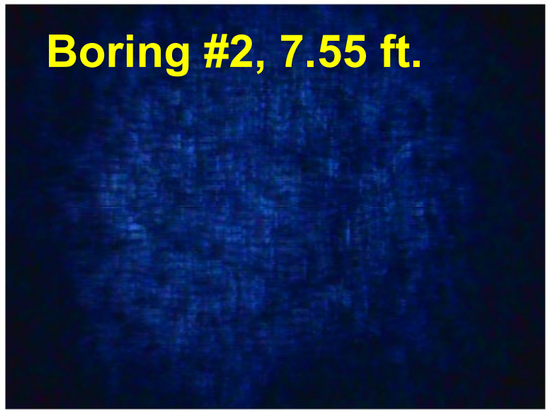


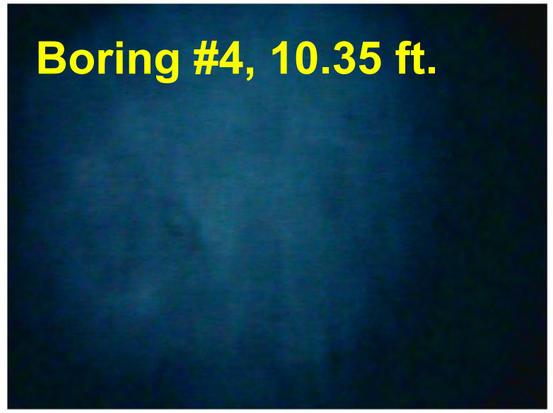
Fresh or Weathered Fluorescence?

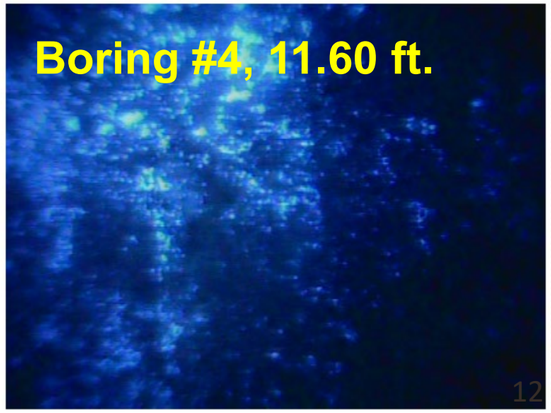
(New spill bucket release at old site)

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









Other Potential Applications Beyond NAPL

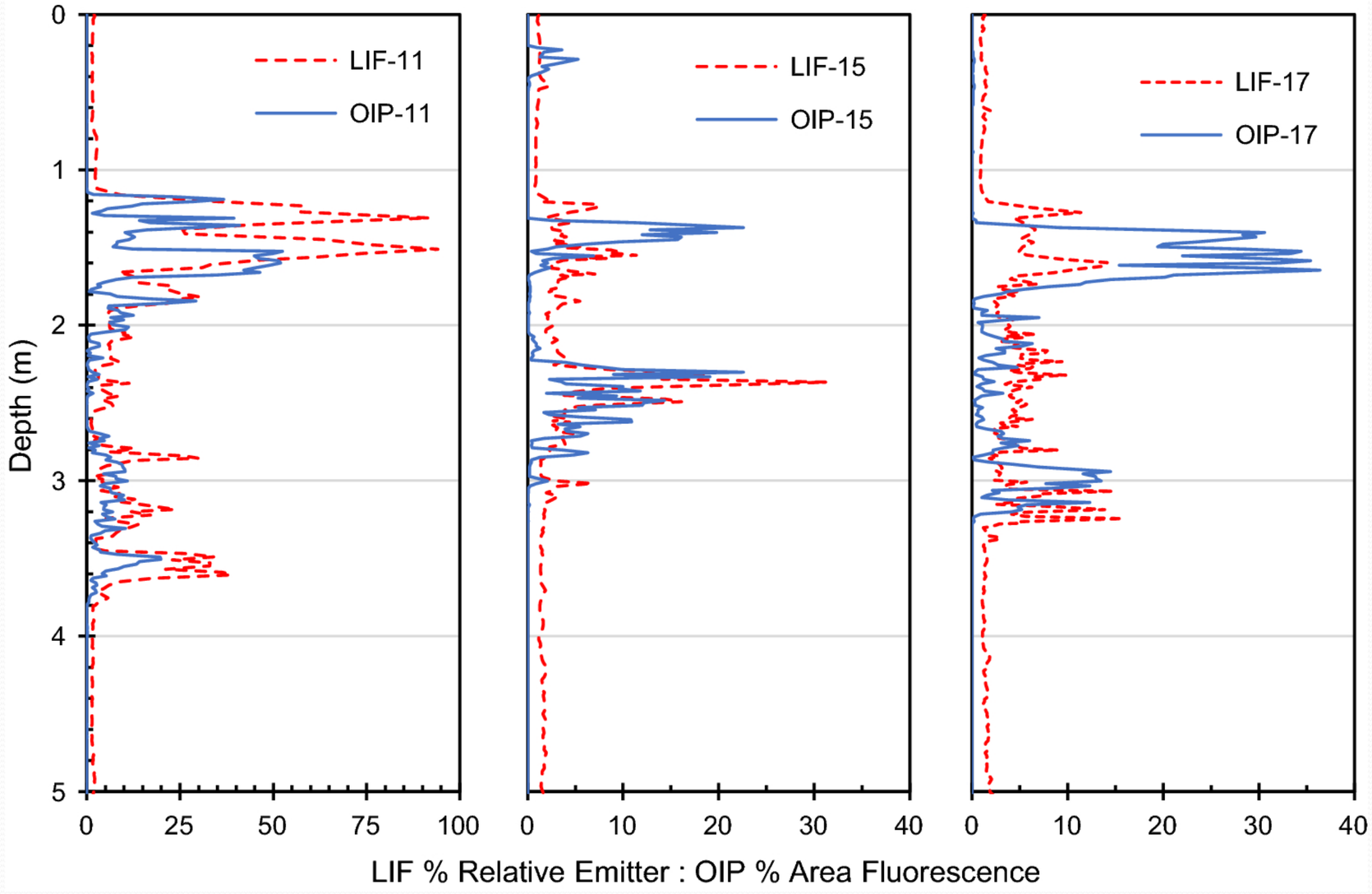
Use Visible Light or UV to Find Injected Fluids or Slurries

- **Visible Light Image Located RPI BOS-200® Carbon**
- **Tracer Dyes**
- **EVO, ORC, etc.**
- **Sand Fracture Placement**
- **Reagents with Color (e.g. Permanganate)**

Image of RPI BOS-200 seam under visible light

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

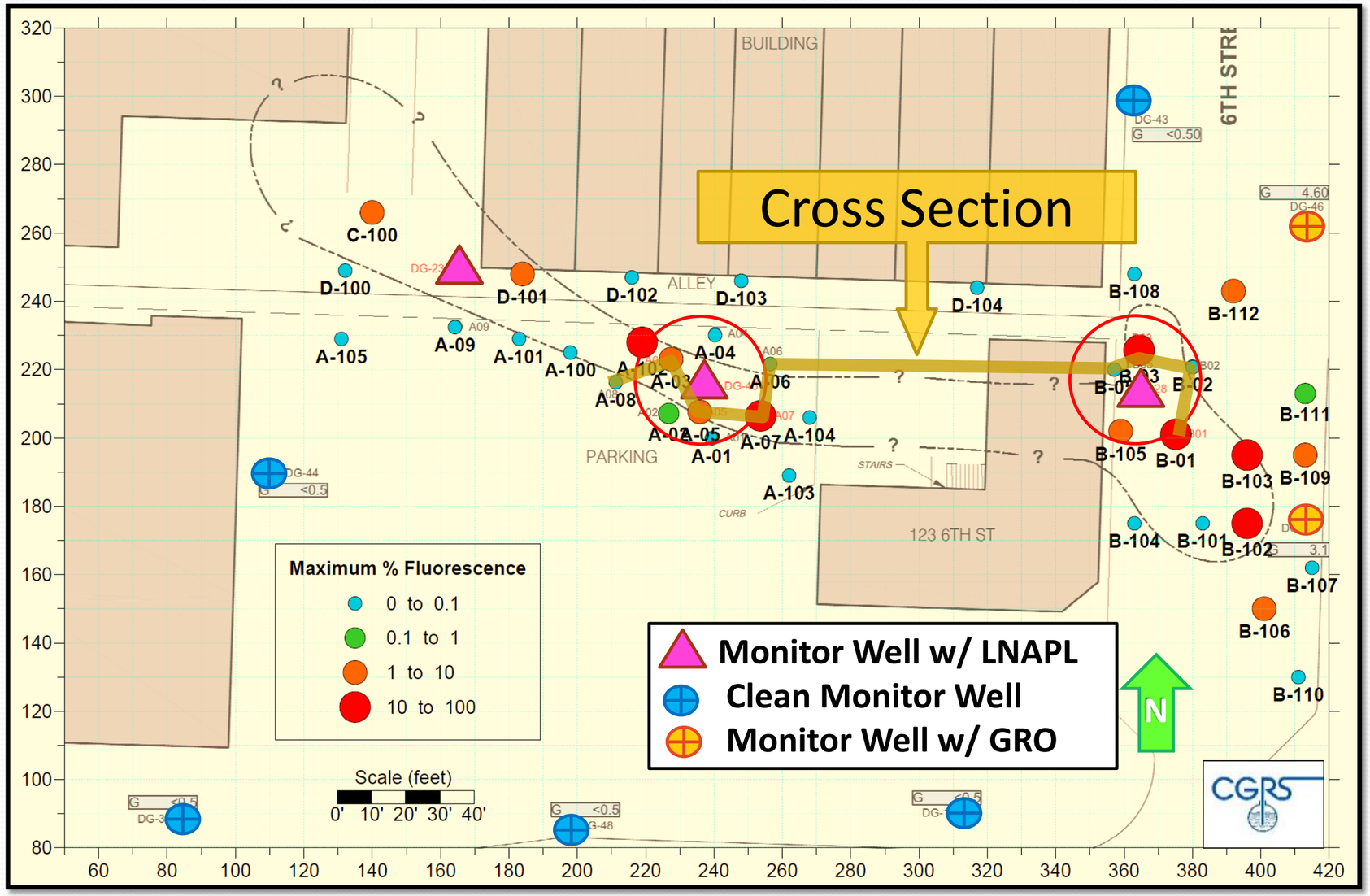


Case History:
Confined and UnConfined Gasoline LNAPL

- **OIP-UV / EC**
- **Grand Junction, CO**
- **Unidentified Historic Gasoline Source**
- **Identified Confining Conditions that Presented False Thickness of LNAPL in Some Monitor Wells**

Courtesy CGRS Inc.

LNAPL Investigation Area - OIP-UV



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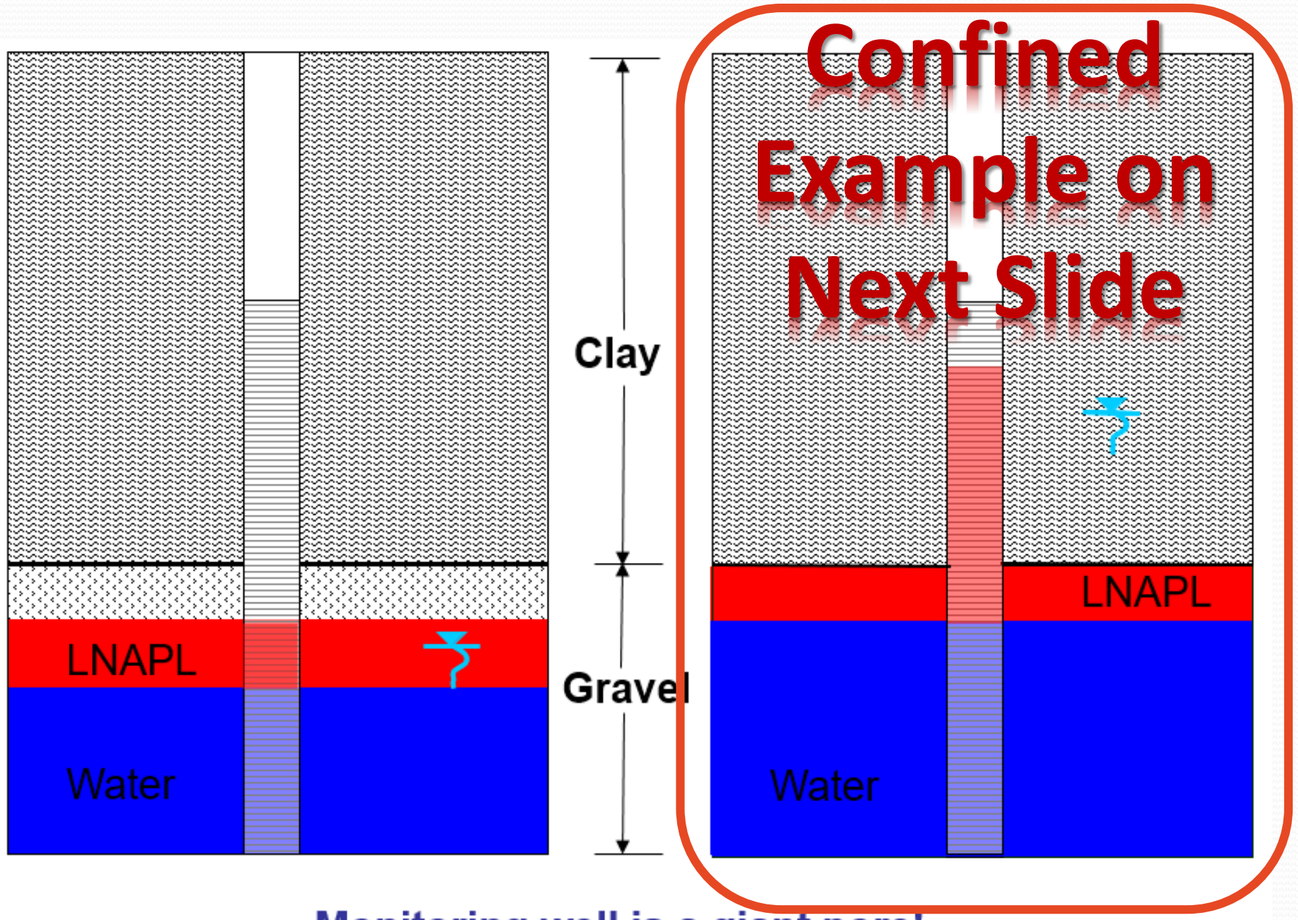
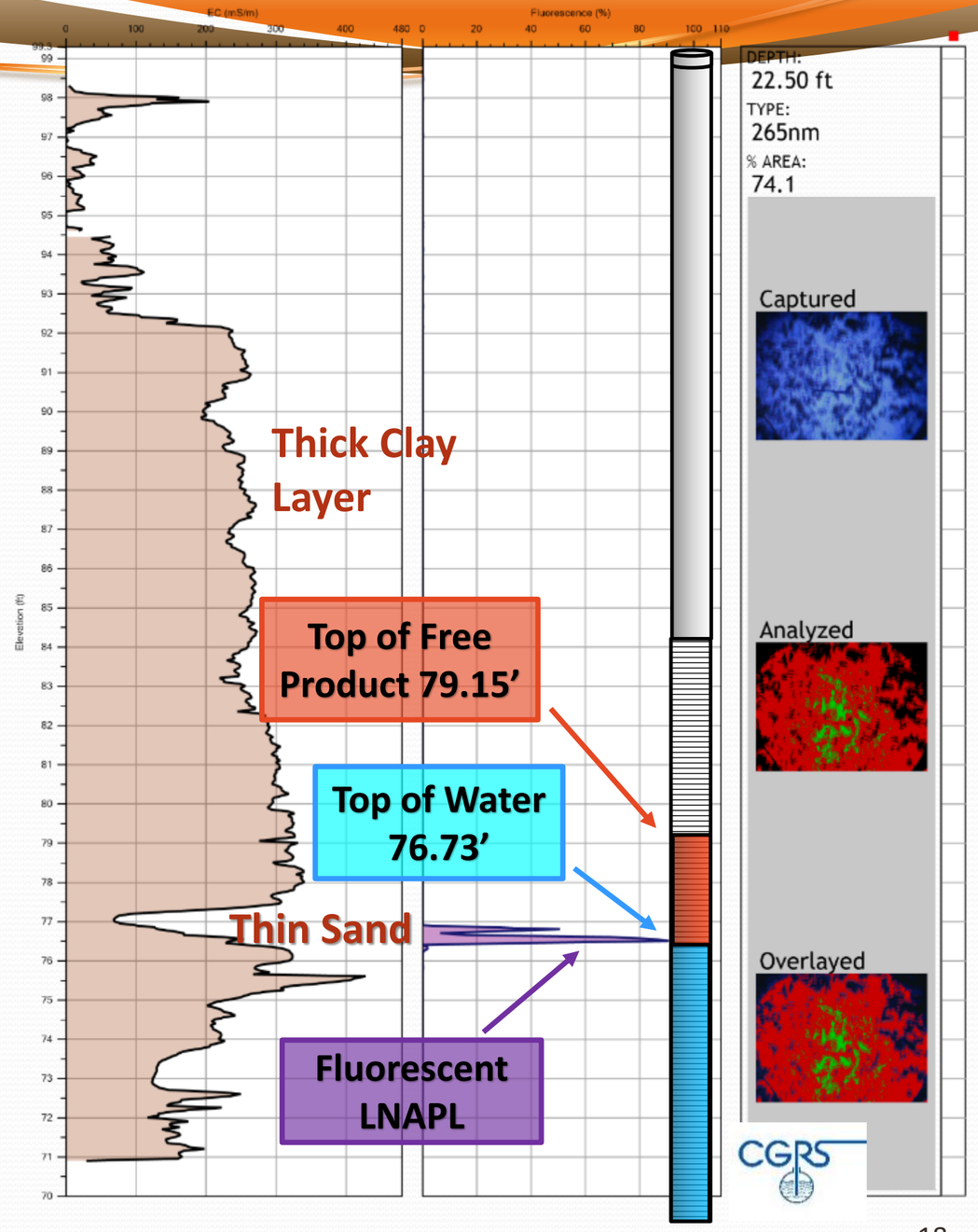
ITRC LNAPL Short Course Example

LNAPL Thickness Variation in Monitor Wells

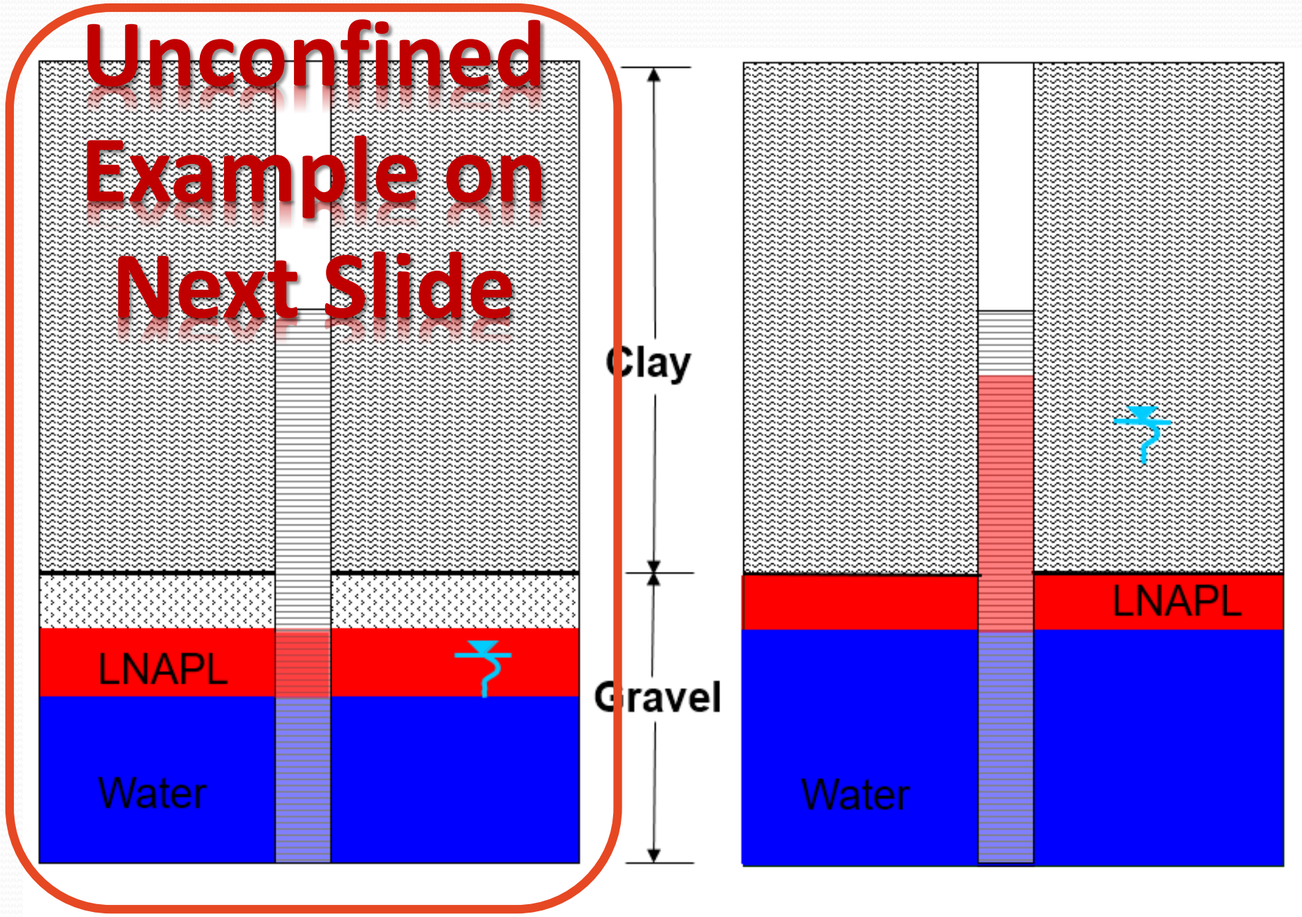


OIP-A07 Shows LNAPL Not as Bad as it Looks in Well!

- Well 20’ from OIP Boring
- Thick Low Perm Clay
- **LNAPL in thin sand stringer *confined* below water table**
- LNAPL displays ***false*** thickness in well.



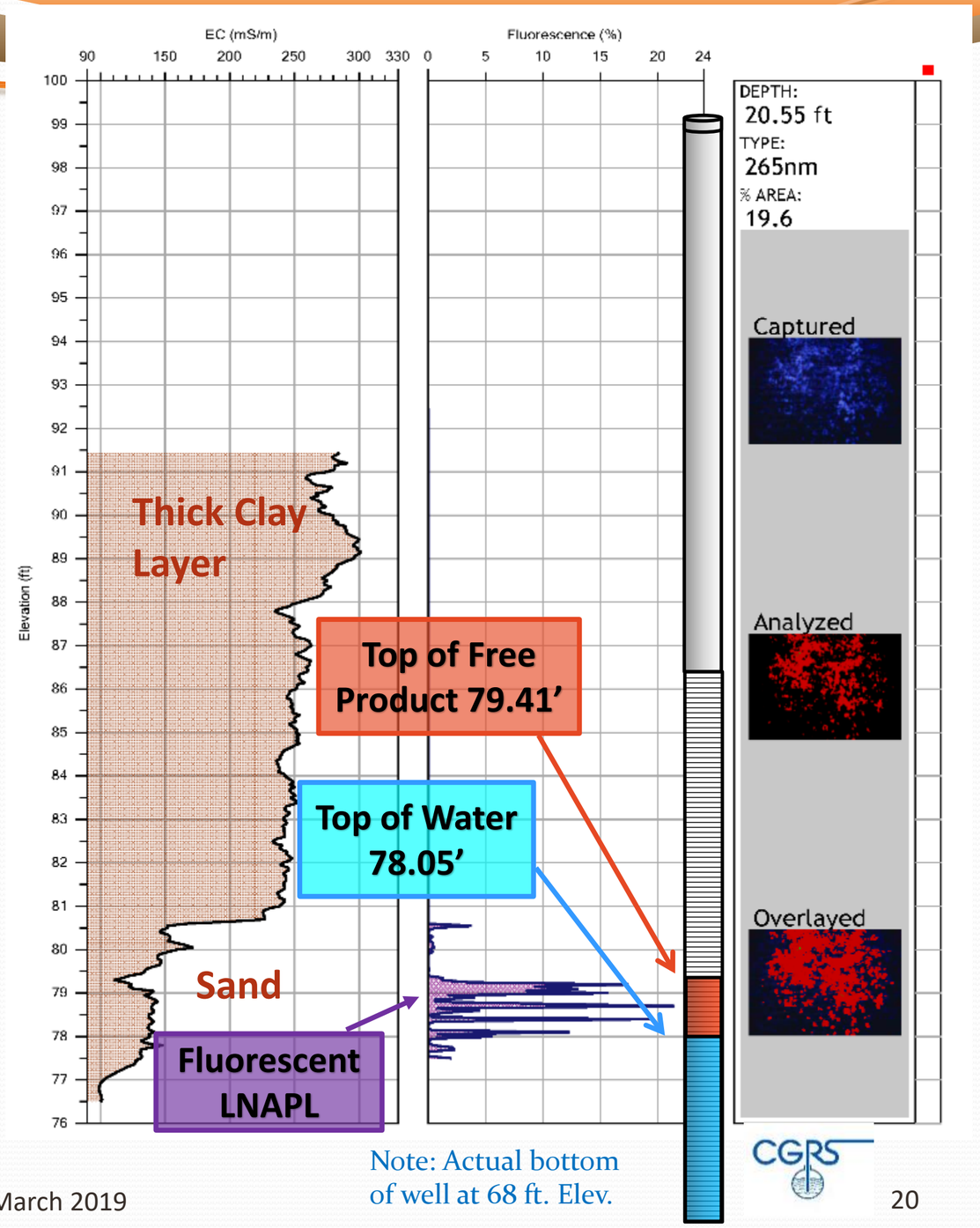
ITRC LNAPL Short Course Example



Monitoring well is a giant pore!

OIP-B03 Shows LNAPL *is* as Bad as it Looks in Well!

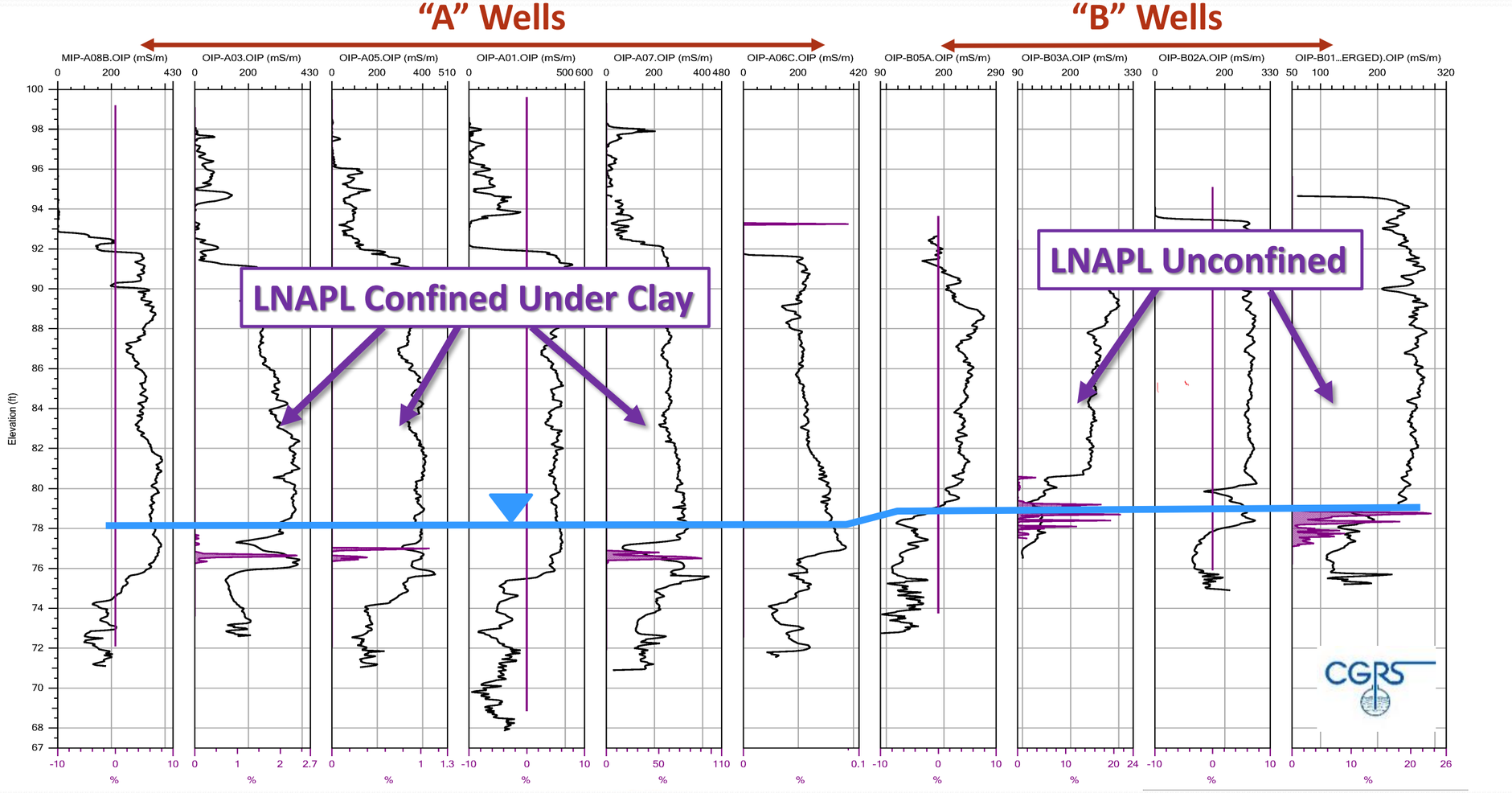
- Well 10’ from OIP Boring
- Thick Low Perm Clay
- LNAPL in main ***unconfined*** sand body.
- LNAPL displays ***actual*** thickness in well.



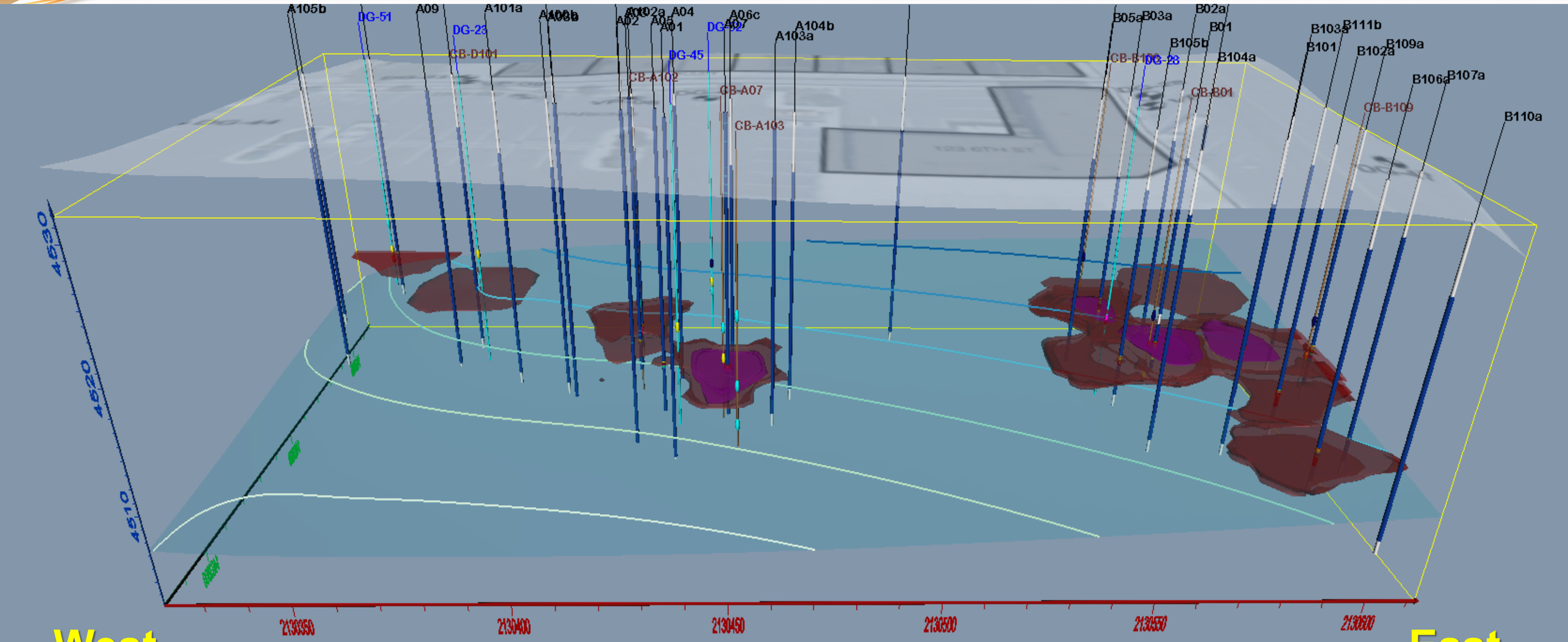
Note: Actual bottom of well at 68 ft. Elev.

West to East Cross-Section (%AF & EC)

A wells demonstrate confined LNAPL conditions. B wells base of clay is higher, LNAPL is unconfined. *Could the LNAPL migrate up dip under the confined clay?*



3D Model of LNAPL and Groundwater



Vista GeoScience Project No.16307.02
MODEL DRAFTED: July 24, 2017
OIP DATA ACQUIRED: Aug/Sep 2016 & Apr 2017
GROUND WATER ELEV. DATA: Feb & Apr 2017
Z- Elevation Above Mean Sea Level (feet)
X-Y Coordinates: Colorado Central State Plane (feet), NAD83

OIP % Fluorescence Borehole Rendering
0 18.2 36.4 54.6 72.8 91

Confirmation Soil TVPH mg/kg (spheres)
0 1100 2200 3300 4400 5500

Groundwater Elevation
4507 4510 4513

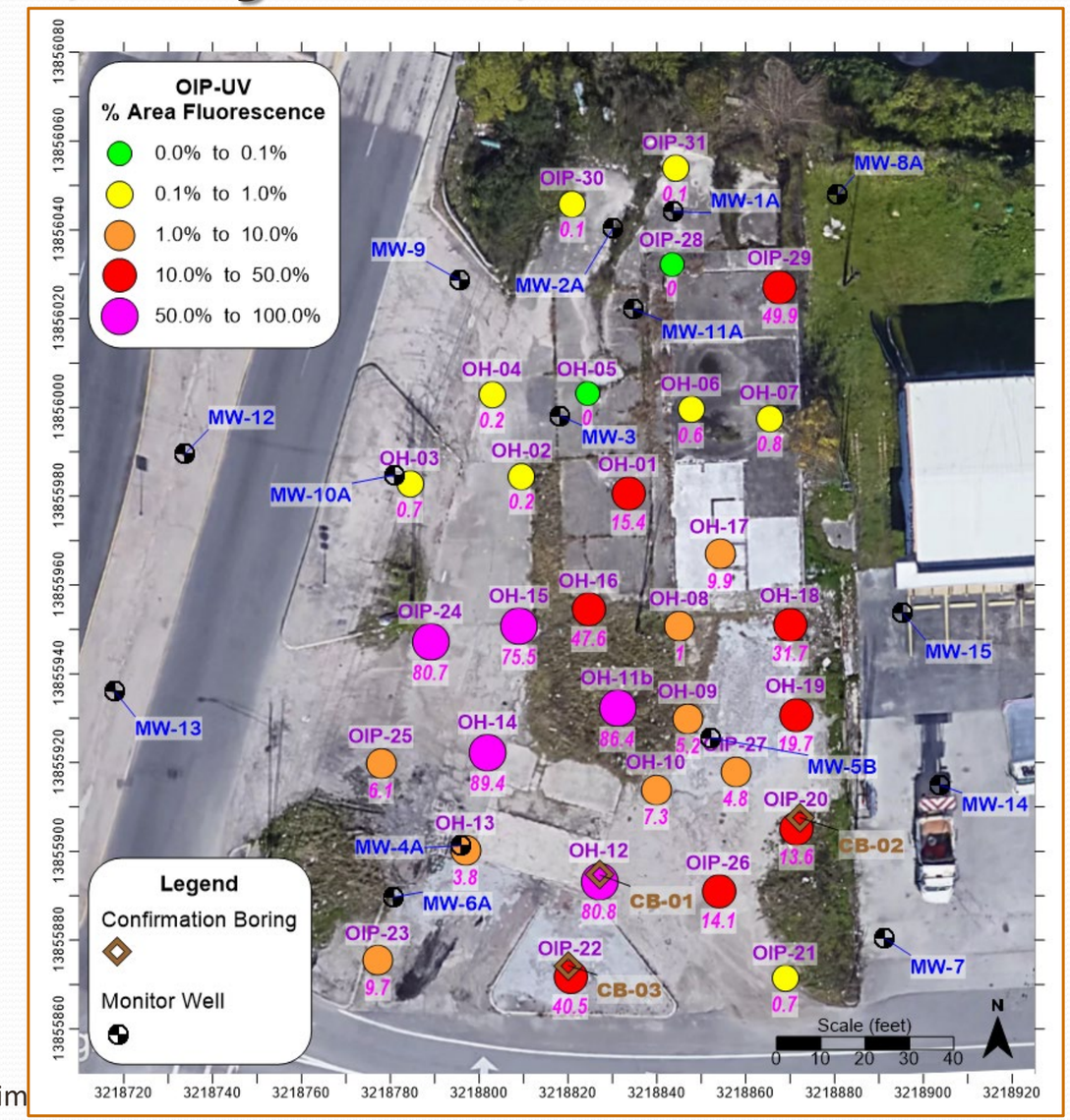
HRSC CSM Case History: Perched and Confined Gasoline LNAPL

- **OiHPT**
- **Baytown, Texas**
- **HPT Identified thick confining clay**
- **OIP Identified LNAPL in perched water table, and confined in deeper aquifer**

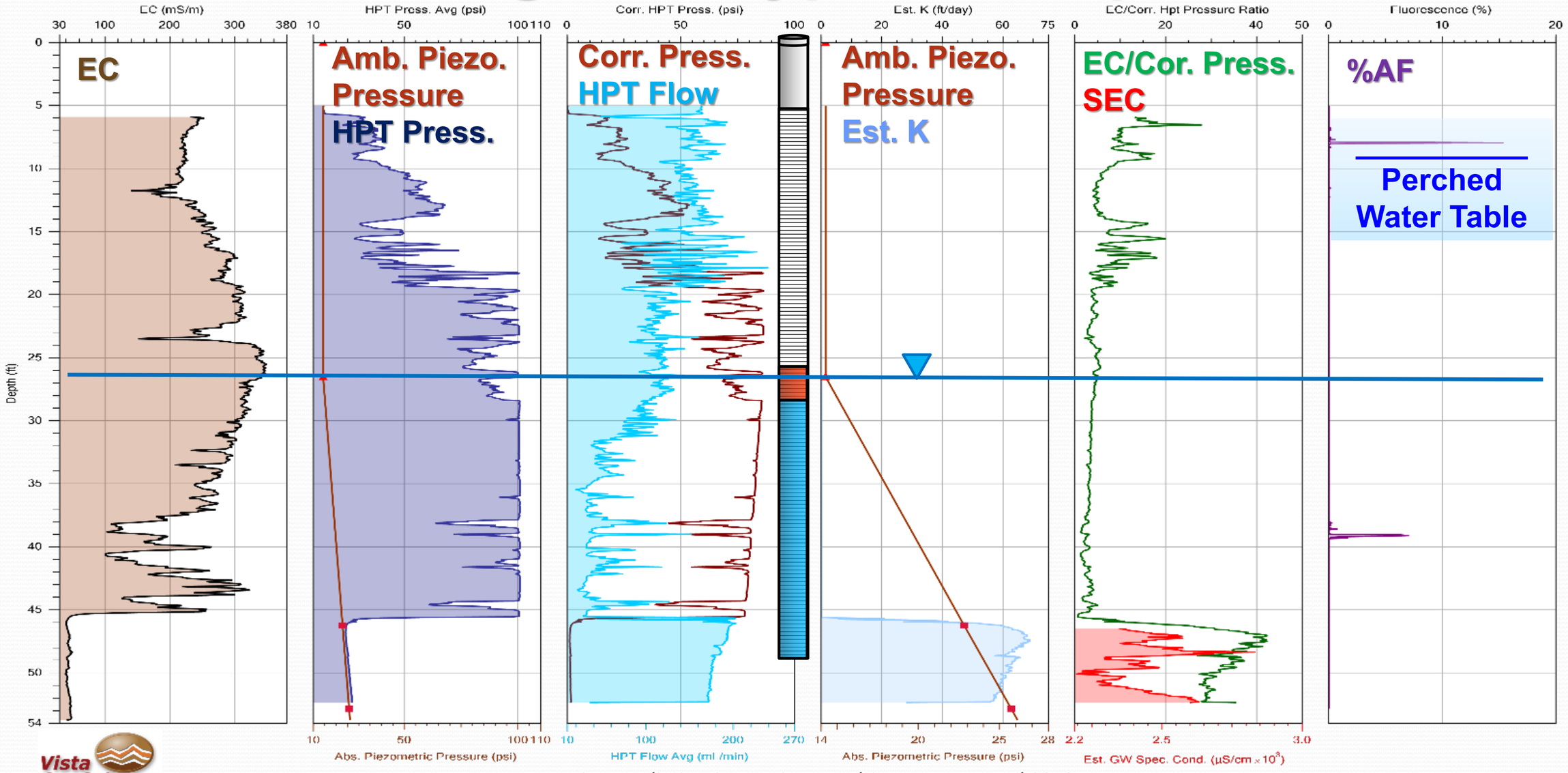
Courtesy GeoStrata Environmental Consultants

Old Abandoned Gas Station, Baytown, TX

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

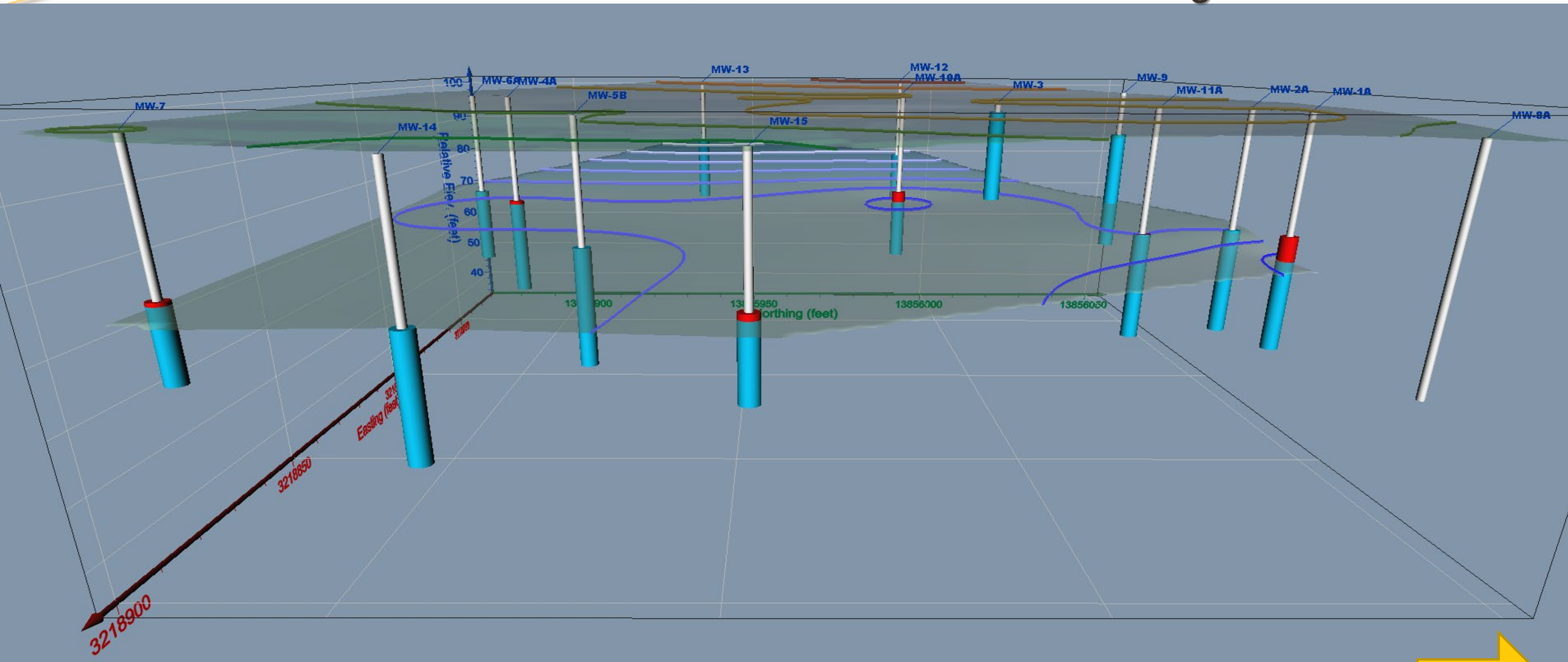


OiHPT-UV Log with Typical Responses at Site



Ground water Elevation Model

Monitor Wells with Water and LNAPL Column - View Looking West



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Surface Elevation (feet)
97.2 98.3 99.5 100.6 101.8

Surface Elevation Contours
97.2 98.3 99.5 100.6 101.7

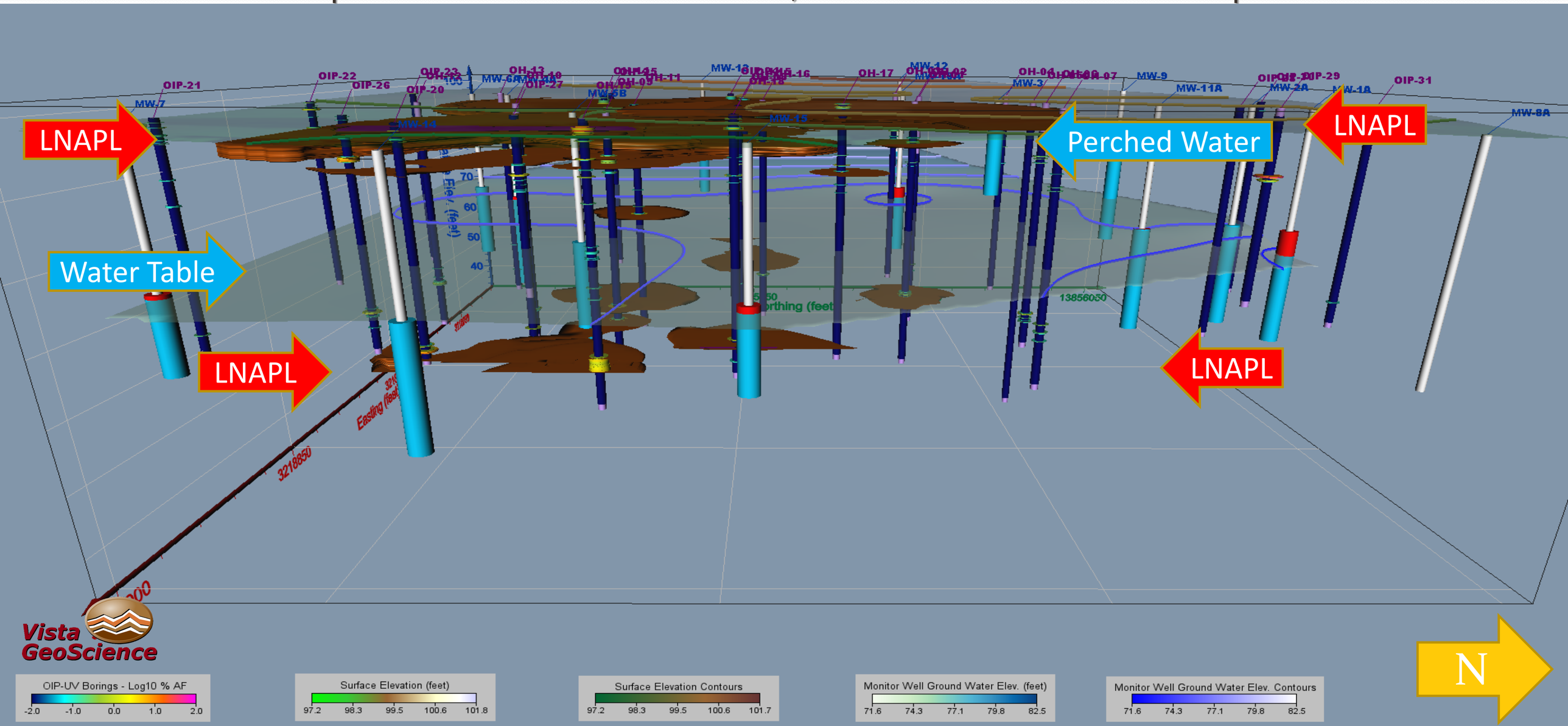
Monitor Well Ground Water Elev. (feet)
71.6 74.3 77.1 79.8 82.5

Monitor Well Ground Water Elev. Contours
71.6 74.3 77.1 79.8 82.5

N

LNAPL Plume > 1% Area Fluorescence (%AF)

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



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OIP-UV Borings - Log10 % AF
-2.0 -1.0 0.0 1.0 2.0

Surface Elevation (feet)
97.2 98.3 99.5 100.6 101.8

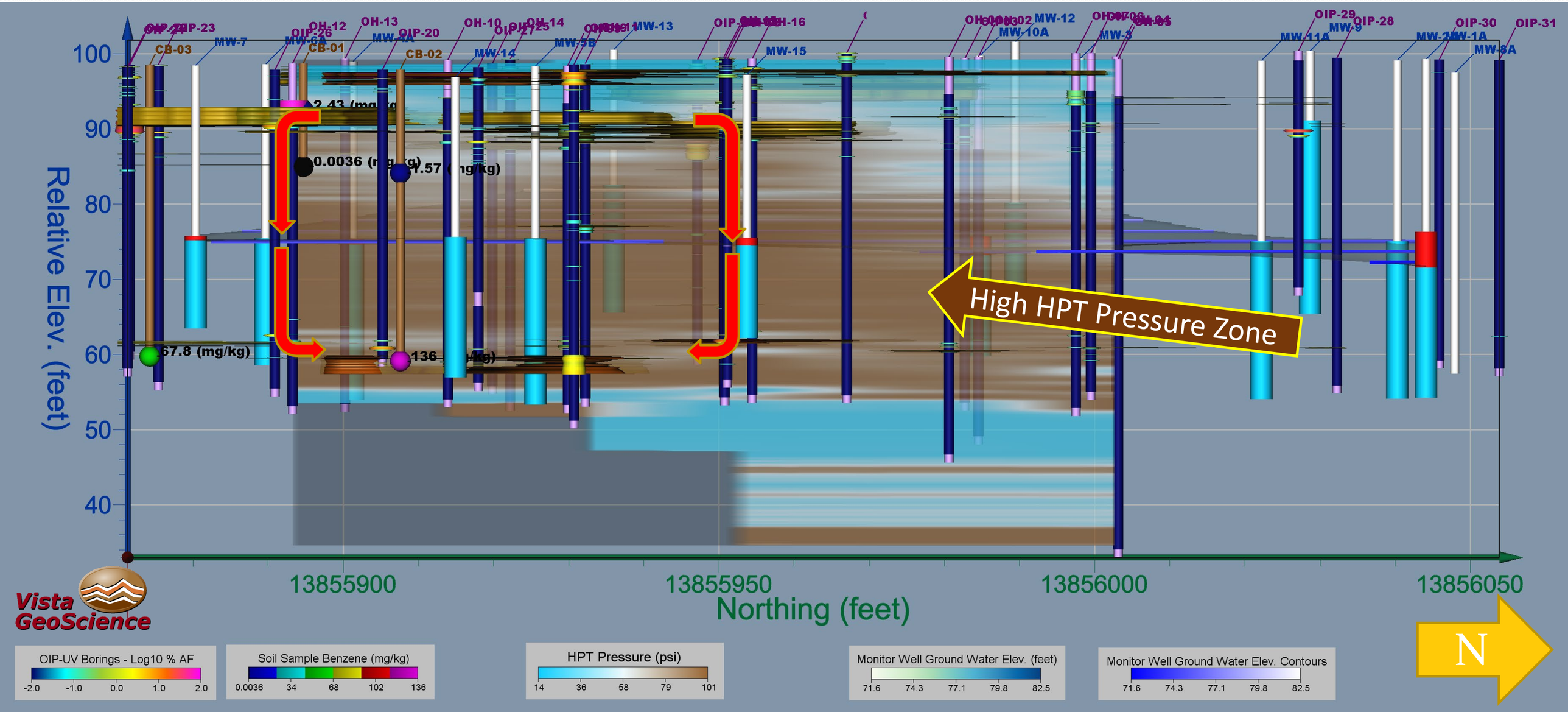
Surface Elevation Contours
97.2 98.3 99.5 100.6 101.7

Monitor Well Ground Water Elev. (feet)
71.6 74.3 77.1 79.8 82.5

Monitor Well Ground Water Elev. Contours
71.6 74.3 77.1 79.8 82.5

N

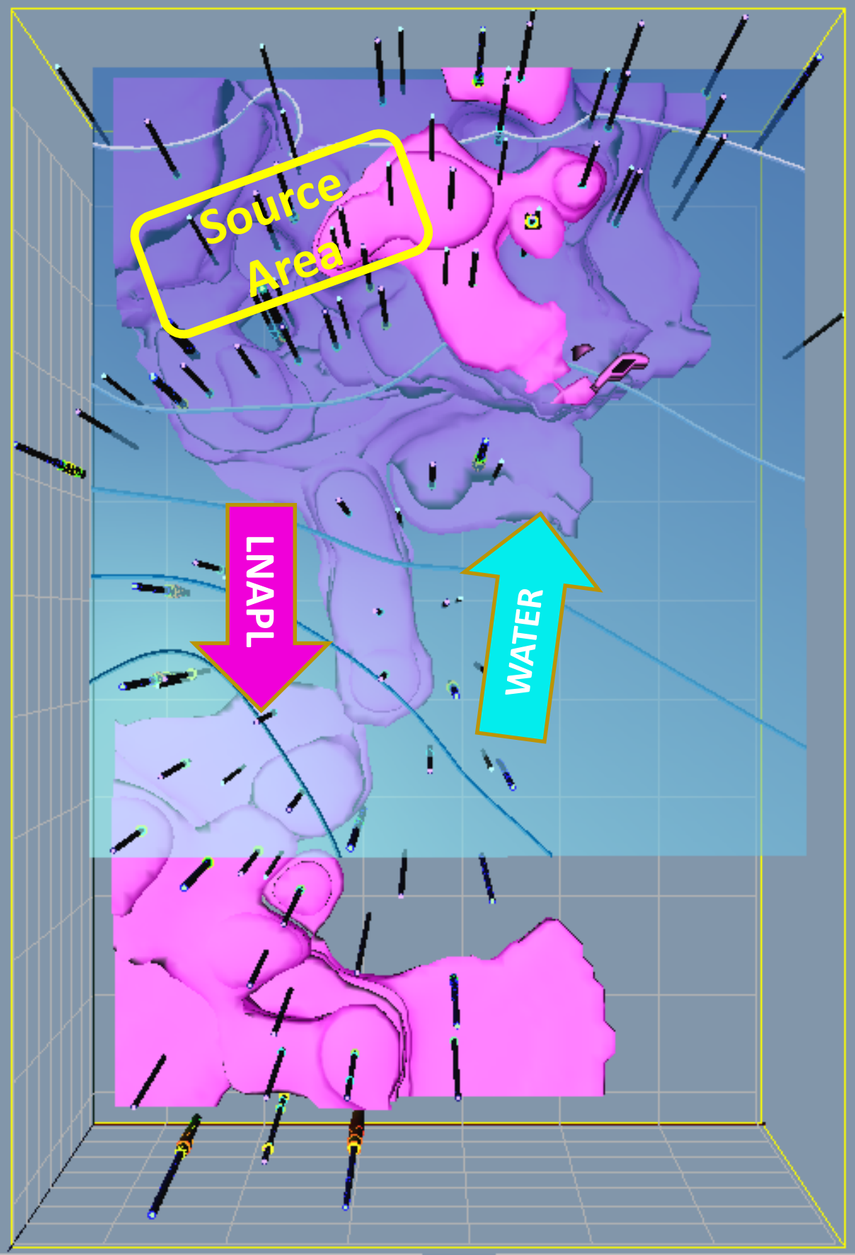
Cross Sectional View of HPT Pressure Showing Massive Clay Layer



CSM Case History: Gasoline Plume Migrating Opposite of Groundwater Gradient

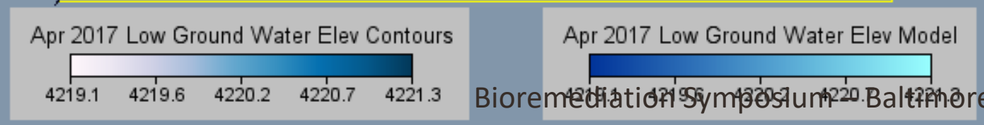
- **OIP-UV (51 borings) and MiHpt (18 borings)**
- **Eastern Colorado Plains**
- **Identified Migration of LNAPL Plume moving opposite of ground water gradient**

Courtesy CGRS Inc.

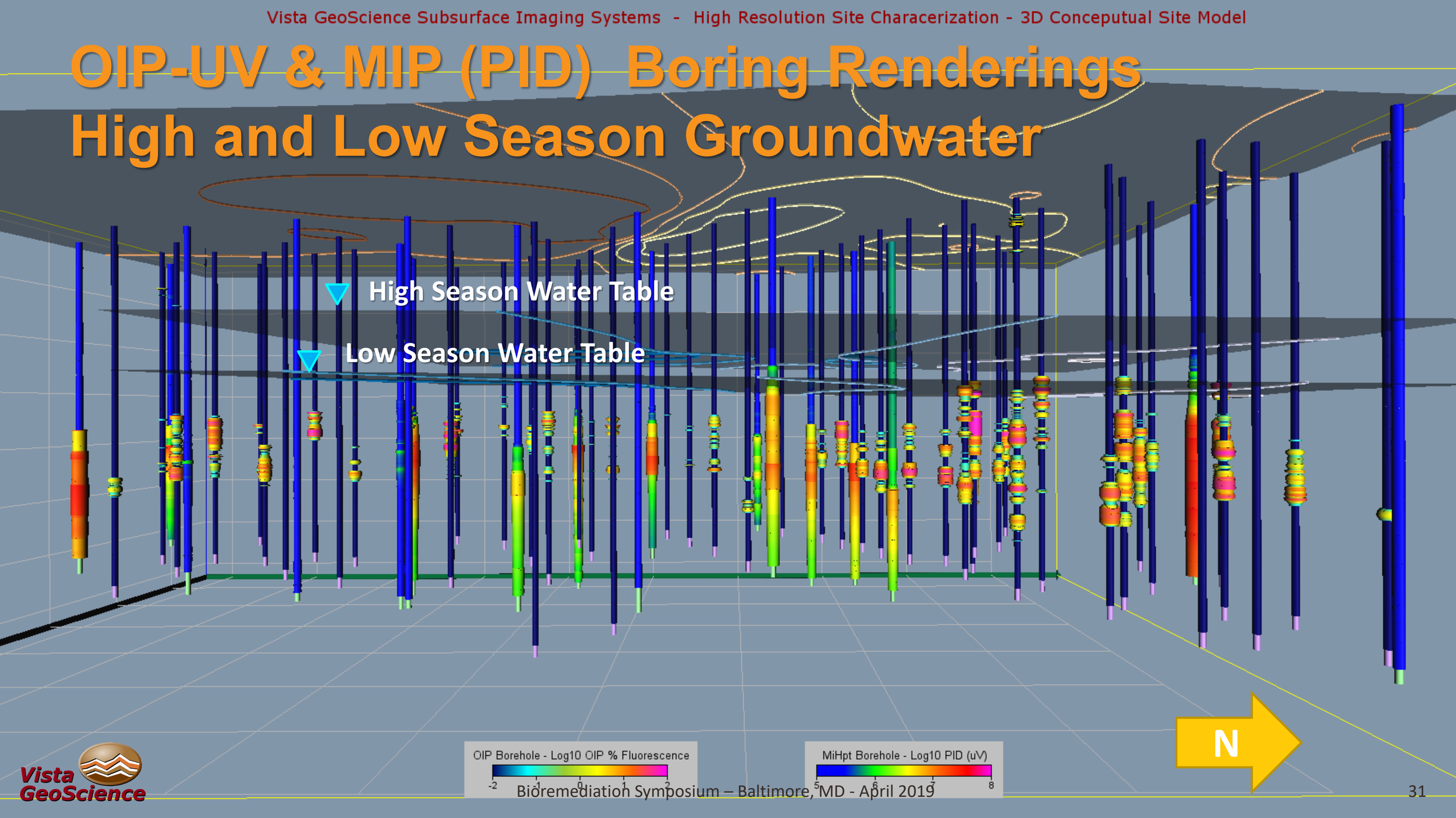


LNAPL Plume & Low Ground Water Table

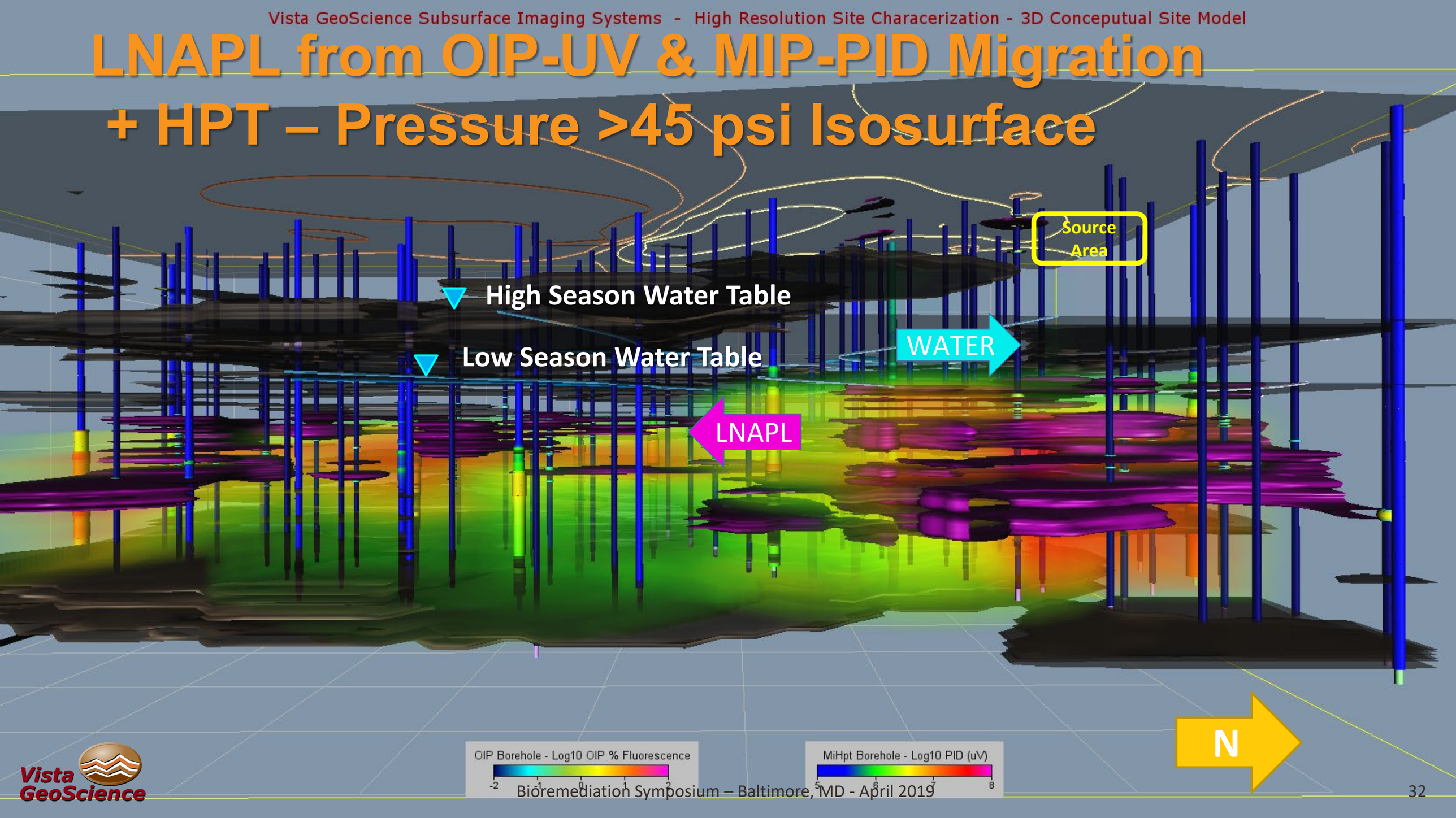
- Groundwater Moving North – Both High and Low Seasons
- LNAPL Plume Migrated South >300 feet from Source Area
- Notice Narrow Channel
- Most LNAPL Confined Below Water Table



OIP-UV & MIP (PID) Boring Renderings
High and Low Season Groundwater



LNAPL from OIP-UV & MIP-PID Migration + HPT – Pressure >45 psi Isosurface



Questions?

Using the Combined UV Optical Image Profiler and Hydraulic Profile Tool with Modeling Tools to Visualize Complex Petroleum LNAPL Migration

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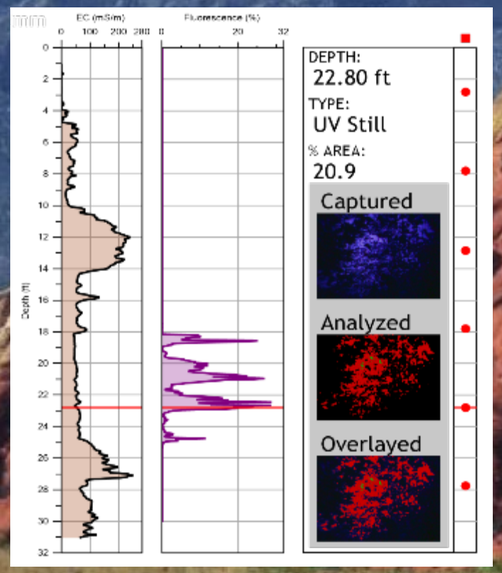

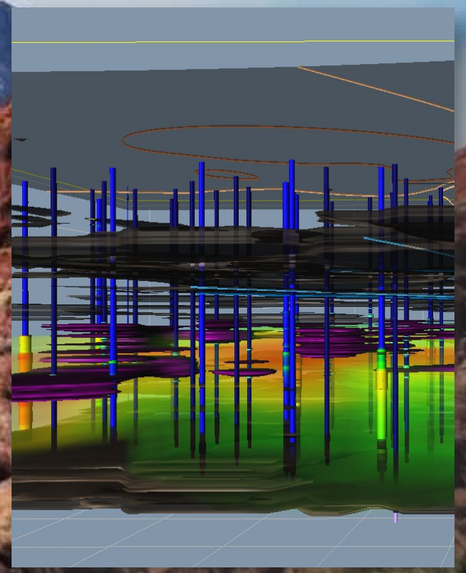

Acknowledgements for use of their site data:

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