SUBSURFACE IMAGING SYSTEMS

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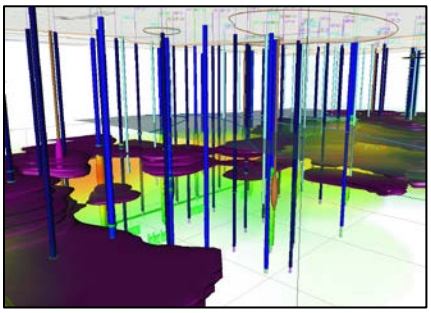

Advanced Site Characterization & Optimized In-Situ Remediation Support Services

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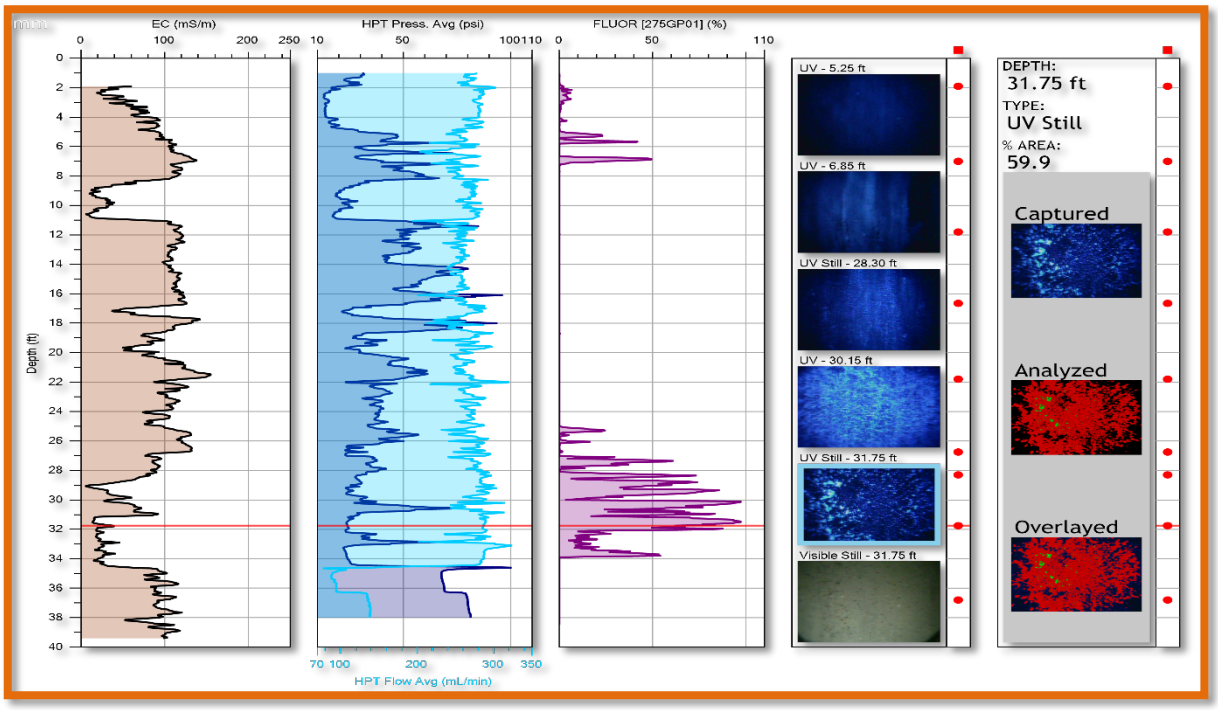


1 Membrane Interface Probe (MIP, MiHPT)

The MIP is used for field screening and rapidly mapping sorbed and dissolved phase VOCs, typically petroleum and chlorinated solvent contamination. The MIP will quickly delineate both the horizontal and vertical extent of contamination and identify relative concentrations down to ppm levels, or ppb levels using the Low-Level MIP option. The MIP systems are combined with the Hydraulic Profile Tool (HPT) and Electrical Conductivity (EC), known as the MiHPT.

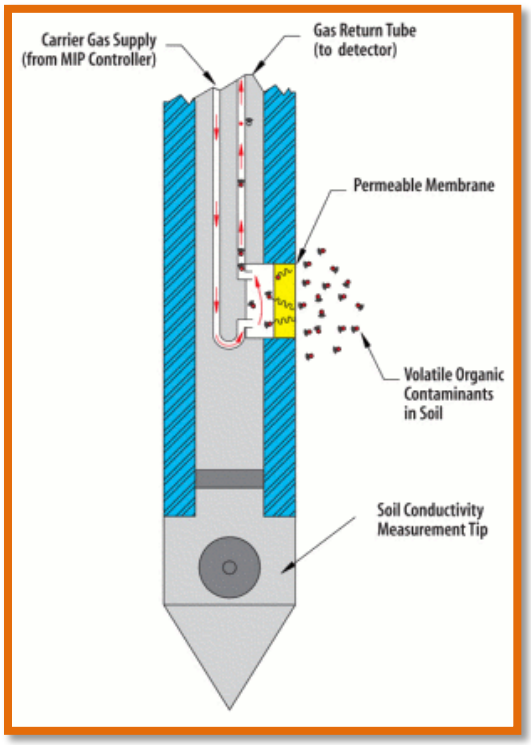
The MIP is driven by direct-push technology (DPT) and continuously logs volatile organic compounds (VOCs) as it is pushed through the soil at a constant rate. It heats the soil and water to increase the vapor pressure of the contaminants. The VOCs pass across a semi-permeable membrane and are carried to the surface by an inert gas via small diameter tubing. At the surface, the VOC mass is passed across through selective chemical detectors to provide a continuous correlation between contaminant detection and the depth of the probe at the point of detection. Vista's standard MIP sensor detection system utilizes three laboratory grade detectors in its sensor detection system that have been built into a ruggedized instrument. The detectors utilized include:

- **Photo Ionization Detector (PID)**
- **Flame Ionization Detector (FID)**
- **Halogen Specific Detector (XSD)**

Operated in Standard Mode, the MIP system can detect common VOCs at levels ranging from 0.2 to 2.0 ppm. If lower detection limits are required, the MIP system can be operated in Low Level mode (LL-MIP) with the addition of a controller that increases sensitivity by at least 10x, reaching low ppb levels.

The MIP tool is integrated with an Electrical Conductivity (EC) Dipole and Hydraulic Pressure (HPT) Injection port to gather hydrogeologic and permeability data.

The probe is typically pushed at an average rate of about 2cm per inch, or 15 seconds per foot, or slightly slower in Low-Level mode.



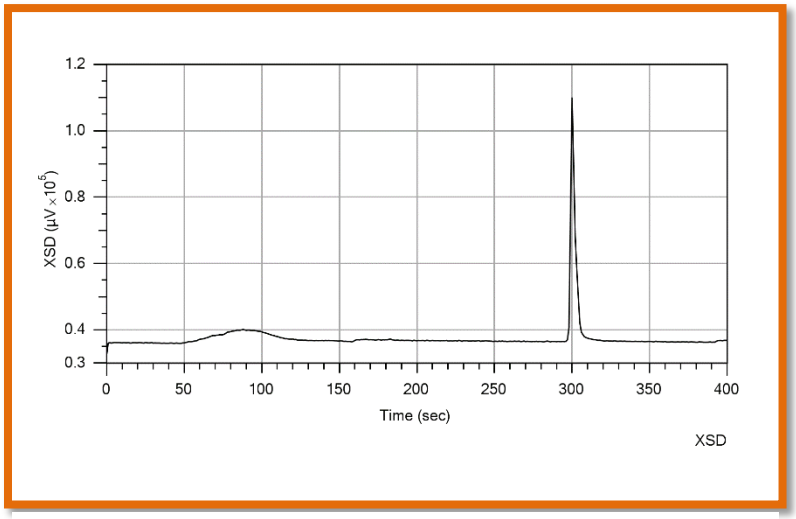
Schematic of MIP probe tool showing carrier gas flow and VOC capture through the membrane.

Detector instrumentation for MIP system housing PID, FID and XSD selective detector suite.

Quality Control: All instruments are continuously monitored by the software and the operator is notified of out of spec conditions. A response test using a standard (PCE, TCE, benzene, etc. in water) is run at the before and after each borehole log run by exposing the membrane to the standard. This helps demonstrate instrument sensitivity and condition of the replaceable membrane. The results of the test are recorded in the digital log files with each log run.

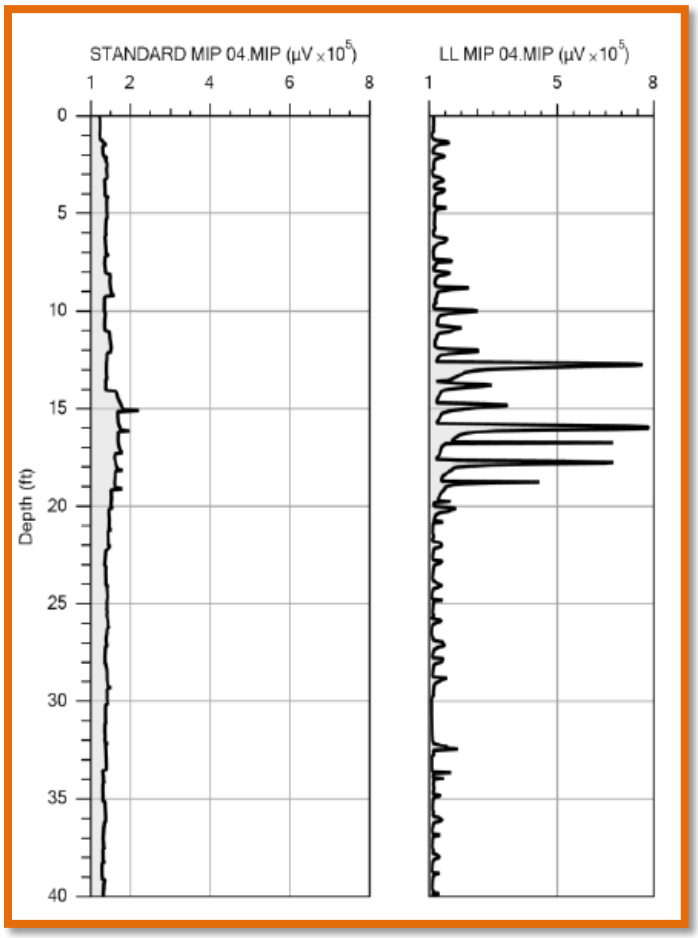
2 Low-Level MIP (LL-MiP, LL-MiHPT)

LL-MIP is a technology developed by Geoprobe Systems® that greatly increases the sensitivity (and therefore utility) of the MIP logging tool. The primary feature of LL-MIP technology is that the carrier gas stream that sweeps the internal surface of the MIP membrane is pulsed, or paused at selected intervals. This results in an increase in the concentration of VOC contaminant delivered to the MIP detectors and a 10x or better increase in sensitivity. LL-MIP can be performed with standard MIP probes, or combined MiHpt probes.



Comparison of 500ppb TCE standard response tests performed by standard MIP and LL MIP methods.

In standard MIP operation, the carrier gas continually sweeps across the membrane transporting contaminates to the detectors at the surface. In the LL-MIP method, the trunkline sweep flow is temporarily stopped when the MIP probe is brought to rest at a discrete depth in the soil. Stopping the sweep gas flow allows the contaminant concentration to build behind the membrane. This results in a larger and narrower contaminant response peak at the detectors (see figure above, and left) for a given chemical concentration. A switching valve creates separate flow paths for the MIP trunkline and detectors; trunkline flow can be stopped and restarted without impacting detector baseline or stability. When the trunkline flow is restarted the contaminant mass (peak) is quickly swept to the surface and is routed to the detectors giving a 10x or better magnified response to any VOCs present. Low Level mode takes about 40% longer to run than standard mode, so a decrease in daily footage rate must be accounted for.



Comparison of PID response in standard (left) and low level (right) modes.

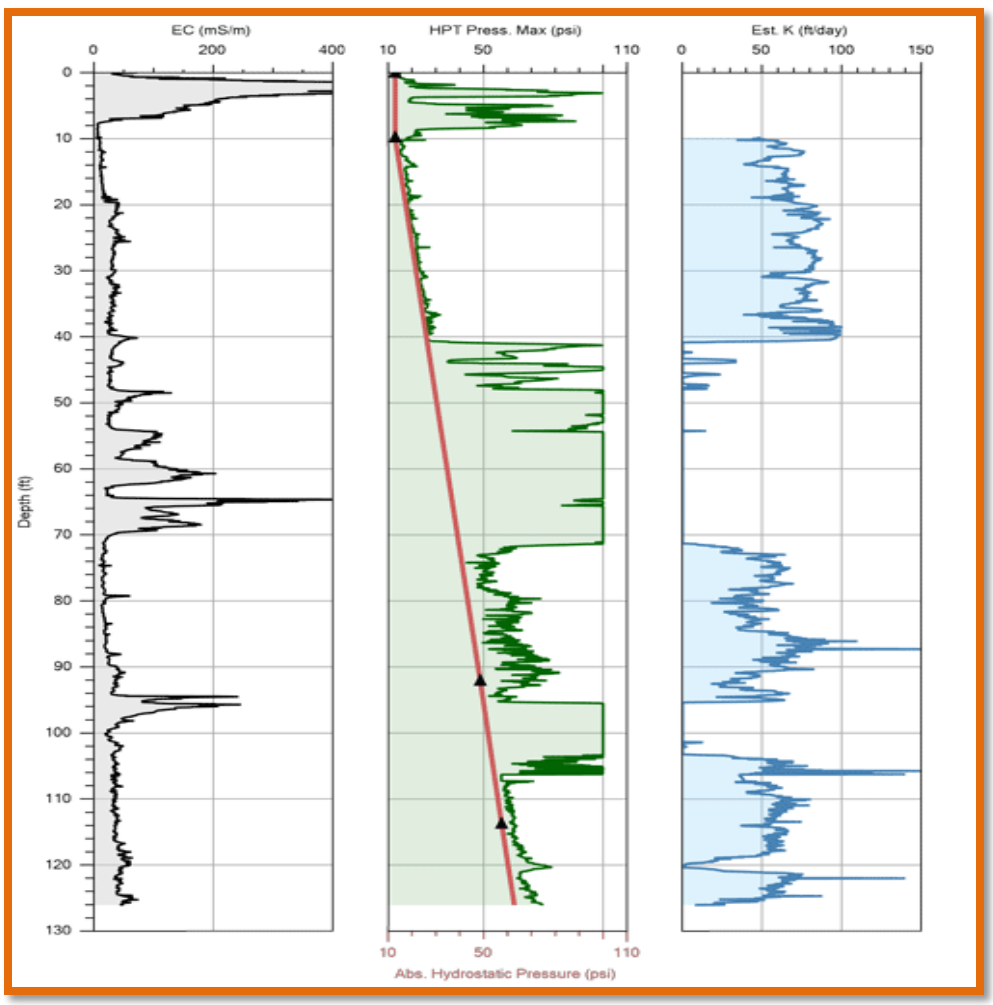
3 Hydraulic Profiling Tool (HPT) with EC

The HPT is a logging tool that measures the pressure required to inject a flow of water into the soil as the probe is advanced into the subsurface. This injection pressure log is an excellent indicator of formation permeability. In addition to measurement of injection pressure, the HPT can also be used to measure hydrostatic pressure under the zero flow condition. This allows the development of a hydrostatic pressure graph for the log and prediction of the position of the water table.

Formation hydraulic conductivity can be estimated from HPT logs using empirical relationships developed for the tool. These estimations can be made automatically using the DI-Viewer software. A graph of hydraulic conductivity estimated from an HPT log is shown in the figure below. Data from this estimate is readily transferable to groundwater flow models.

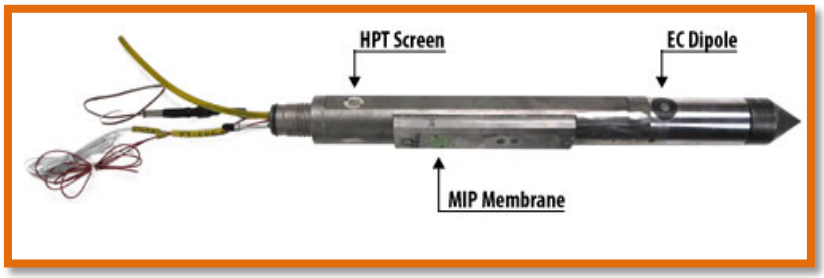
The rate of advancement of the probe is targeted at no more than 4ft (1.22m) per minute. Therefore, an average daily production of 200'-300' per day can be expected.

Quality Control: Before and after each log run, the pressure sensor in the HPT tool is tested by measuring differential head pressure in a short water column at the surface. The results of the test are recorded in the log file.



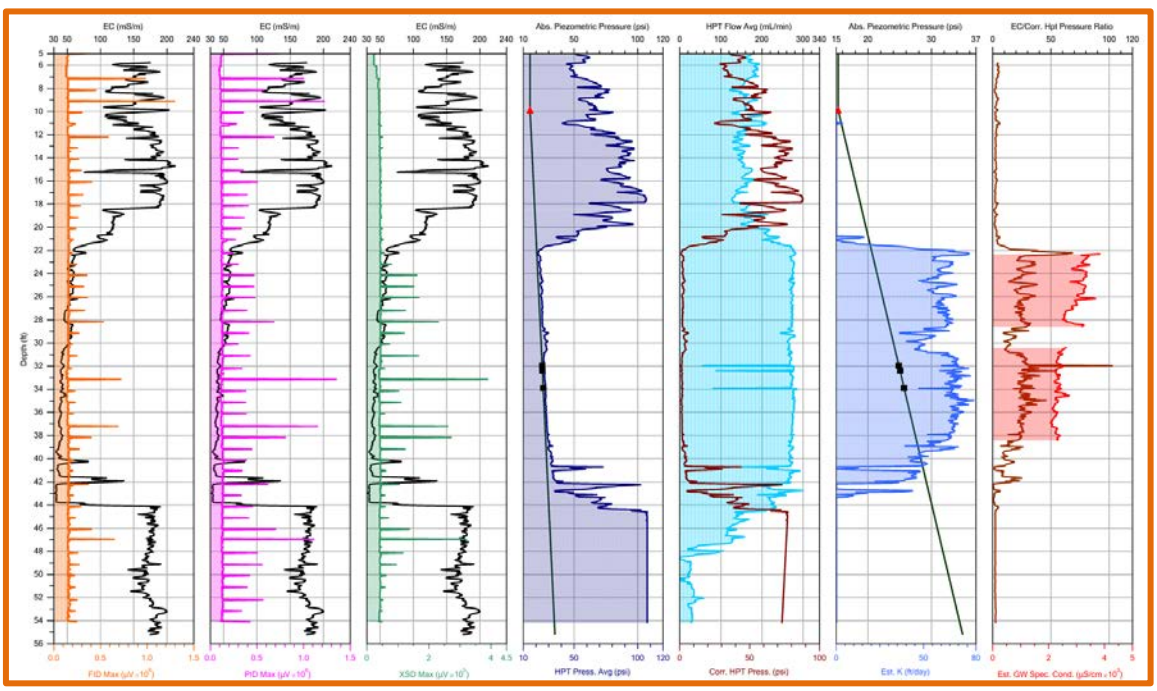
HPT log showing EC, HPT pressure, hydrostatic head with tdepth, dissapation test results, and estimated K values.

4 Combined Membrane Interface and Hydraulic Profiling Tool (MIP+HPT = MiHpt)



Sensor placement on the MiHpt probing tool body also showing water, gas and electrical connections.

This combined probe tool offers a powerful combination of the same logging tools described above. It is a revolutionary addition to the HRSC toolbox capable of collecting six log parameters all at one time. It is able to detect volatile compounds with the MIP, measure hydrostratigraphy with the HPT, and soil conductivity with the EC dipole array. The combined tool generates a tremendous data set by simultaneously generating a log of VOCs with three selective detectors (FID, PID, XSD), HPT pressure, flow and K_{est}, and electrical conductivity (EC), all in single borehole push, cutting your acquisition time in half! Quality control checks are performed the same as in the above previous tool package descriptions.



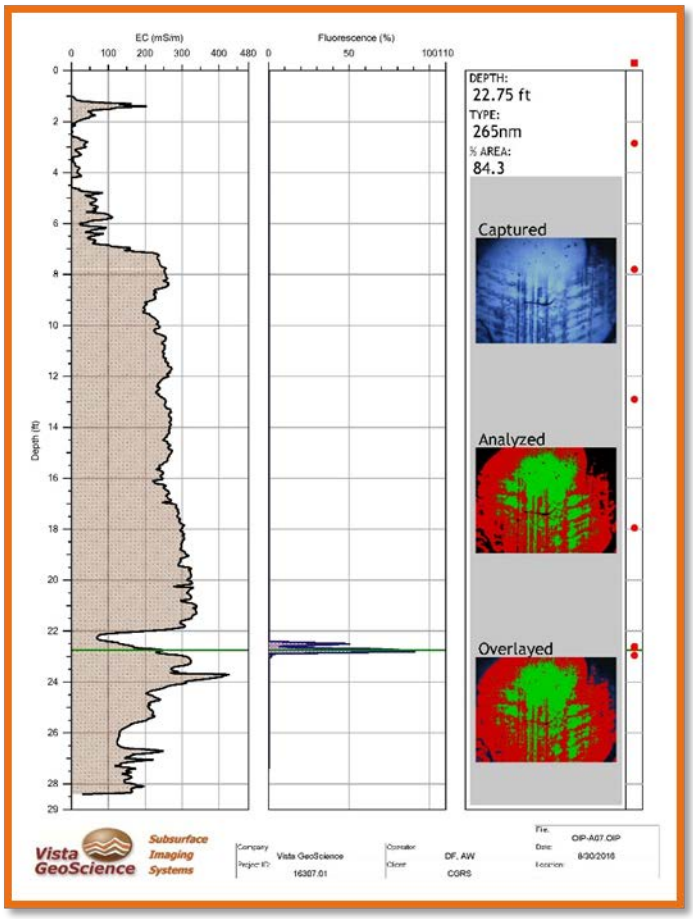
Sample MiHPT log run in Low-Level mode showing the chemical sensors (FID, PID, XSD) along with Electrical Conductivity, Injection Pressure & Flow, Corrected Pressure, Absolute Piezometric Pressure, Estimate Hydraulic Conductivity (K), and groundwater Specific Electrical Conductance (SEC).

5 Optical Imaging Profiler (OiHPT-UV, OiHPT-G) for NAPL

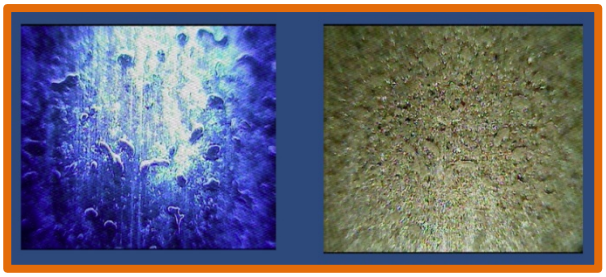
This **OiHPT-UV** tool is new and was released in 2016. Previous to its development, the only other tools for measuring petroleum NAPL was the laser induced fluorescence (LIF) system. This tool provides very similar data and response characteristics to the LIF/UVOST system. Instead of a laser source, this tools uses a LED light source, both ultraviolet and visible.

The OIP was developed for the detection of NAPL level fuels which will fluoresce when exposed to a UV light source. During the advancement of the probe images of the soil are taken through a sapphire window in the probe using an onboard camera. The image color is then analyzed by the software for presence of fluorescing light consistent with that of known fuels. The fluorescence is then measured as an amount of fluorescence within the area of the image.

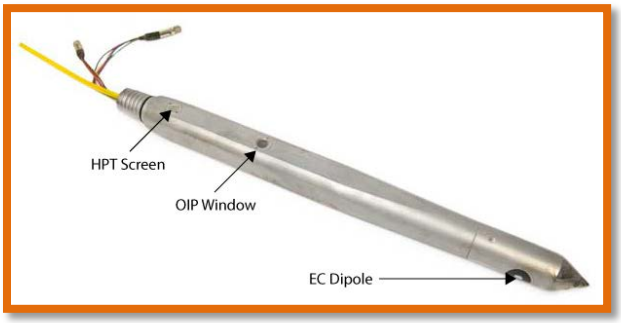
OIP logging is performed using an OIP probe attached to 1.75in diameter probe rods. The probe tool is equipped with an onboard camera to collect soil images through a sapphire window produced by both UV (275 nm) and visible light sources. As with all the other Direct Imaging tools, simultaneous measurements of soil electrical conductivity (EC) are collected using a dipole array built into the tool.



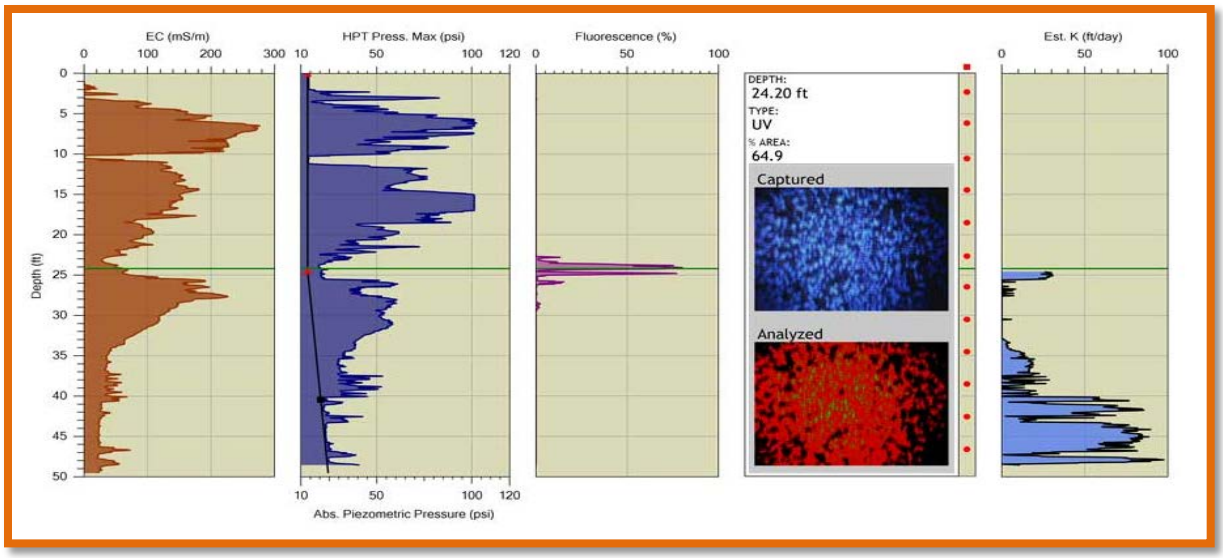
OIP-UV Log showing a thin layer of LNAPL trapped in a low EC zone at 23', just below a massive clay layer. Captured and analyzed images shown on right side of log.



Captured image of soil fluorescence (left) and soil under visible light (right) at the same depth.



At selected depths, the operator can stop the probe and capture still images using visible light and UV light. The rate of advancement of the probe is targeted at no more than 4ft (1.22m) per minute. Therefore, an average daily production of 200'-300' per day can be expected.



Graphs left to right: Soil EC, HPT pressure (formation permeability) along with absolute piezometric pressure (secondary axis), UV percent area Fluorescence, saved UV image from 24.20ft, and estimate hydraulic conductivity (estimated K).

The new **OiHPT-G** Green Laser system is designed for identifying the fluorescence of heavier PAHs, such as creosote or coal tar, was also just released in 2018. Since heavier PAHs adsorb the shorter wavelength UV light, a longer wavelength excitation light is required, which causes stronger fluorescence of the PAHs in the yellow to red light wavelengths. An optical filter in the probe removes the shorter wavelengths interference, including the green light. This allows us to see these heavier NAPLS that can even be found as solids petroleum compounds (often DNAPLS). Soil texture can also be viewed by switching to the Infra-Red (IR) light source.

Fluorescence image of creosote

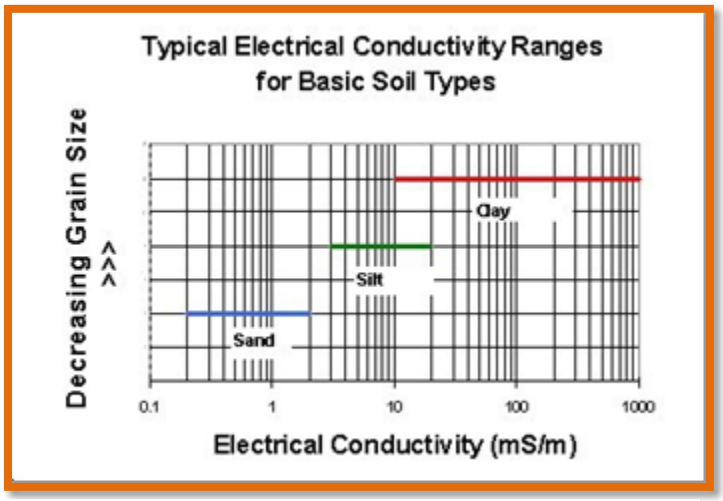
IR image

The new combination **OiHpt** tools captures LNAPL UV fluorescence (%AF) and visible light images, HPT injection pressure/flow, estimated K, and EC soil measurements. Previously, to map the permeability pathways that LNAPL could migrate within required offsetting the OIP borehole with the HPT tool to obtain the hydraulic conductivity data. Now, these tools are combined in one tool and also include electrical conductivity (EC), cutting acquisition time, and cost, in half.

Quality Control: The response of the tool is checked using liquid petroleum standards in a quartz cuvette placed up against the sapphire window before and after each log run. The response results are recorded in the log file.

6 Soil Electrical Conductivity (EC)

The EC is integrated into all of the above subsurface imaging tools to measure soil conductivity. This is the original direct push sensing tools made by Geoprobe®. Soil conductivity and resistivity (the inverse of conductivity) have long been used as tools to classify soils or rock formations in borehole logging tools. The power of this tool stems from the fact that, in general, silts and clays exhibit higher electrical conductivity readings than sands and gravels. As with any of the Direct Image® logging tools, the collection of a few confirmation soil samples, either from discrete depths or a continuous core, should be used to verify the lithology represented by electrical conductivity values at a site. The electrical logs are then correlated across the site to show changes in thickness or elevation of lithologic units of interest. Soil conductivity logging continues to increase in usage because conductivity logging can be efficiently performed with highly mobile and cost-effective percussion probing equipment.



Soil conductivity relative to grain size.

Soil conductivity, in general, varies with grain size. Finer grained soils, such as silts or clays, tend to produce higher EC signals than coarser grained sand and gravels. The figure above shows that while specific values cannot be assigned to each soil type, each soil type should provide a different response on a specific site. The coarser grained sediments will allow the migration of contaminants and the finer grained sediments will trap and store contaminants. The EC gives the investigator real-time, on-screen logs allowing onsite decisions. When used in conjunction with HPT data, relative permeability of the soils is also identified adding powerful information to the soil characterization task.

Quality Control: The continuity of the dipole array and response is checked before and after each log run. The test response information is recorded in each log file verifying the check was done.

7 Slimline Natural Gamma Ray Logging Tool

Originally manufactured exclusively for Vista, we own a unique Slimline Natural Gamma Ray tool. While this tool cannot be driven with DPT percussion rigs, it can be lowered by conventional wireline down any existing monitoring well or in a borehole with temporary 1" ID PVC. It's 0.75" OD body can even be run in steel probe rod and obtain a slightly attenuated signal.

It can be used to measure natural gamma from uranium, potash, and base metals. The GR identifies lithology based on potassium content and stratigraphic correlations in boreholes (case or uncased), liquid or air filled.

8 High Resolution Soil and Groundwater Sampling

While the above subsurface imaging tools provide millions of data points across a site, the tools still only provide qualitative and relative numbers. Often, more quantitative data is needed for things like remediation design to determine treatment reagent dosing. Once the above tools have identified highly focused areas of interest, high resolution soil and ground water sampling can be done to collect this additional information.

8.1 Continuous Soil Core Collection

For confirmation sampling, continuous soil core sampling can be completed using a Geoprobe® DT32 or DT22 Dual-Tube sampling system. The advantages of dual-tube sampling are a continuous outer casing while collecting soil cores. There is no tripping in and out of the bore hole, smeared slough and cross contamination from pushing contaminants to deeper intervals as when using conventional core tubes. The outer casing may also be outfitted with an expendable cutting shoe to allow for small diameter PVC well, or pre-packed well screen, installation after continuous coring is complete. Pressure grouting is also possible with the dual tube system since the outer casing is in place the entire duration of the coring process.

Collecting discrete samples from 40 feet of continuous soil core.

8.2 Discrete Groundwater Sampling

Discrete groundwater samples can be collected economically at specific depths using retractable Screen Point (SP-16, SP-22) samplers, or by nesting temporary tubing implants with short screened intervals in DPT core holes. The temp wells can be completed through the dual-tube allowing proper nested grouting intervals. The HPT tools described above can point to the permeable flow zones and aquitards for selecting screen intervals.

Screen Point Samplers with screen extended.

9 Subsurface Imaging Reports

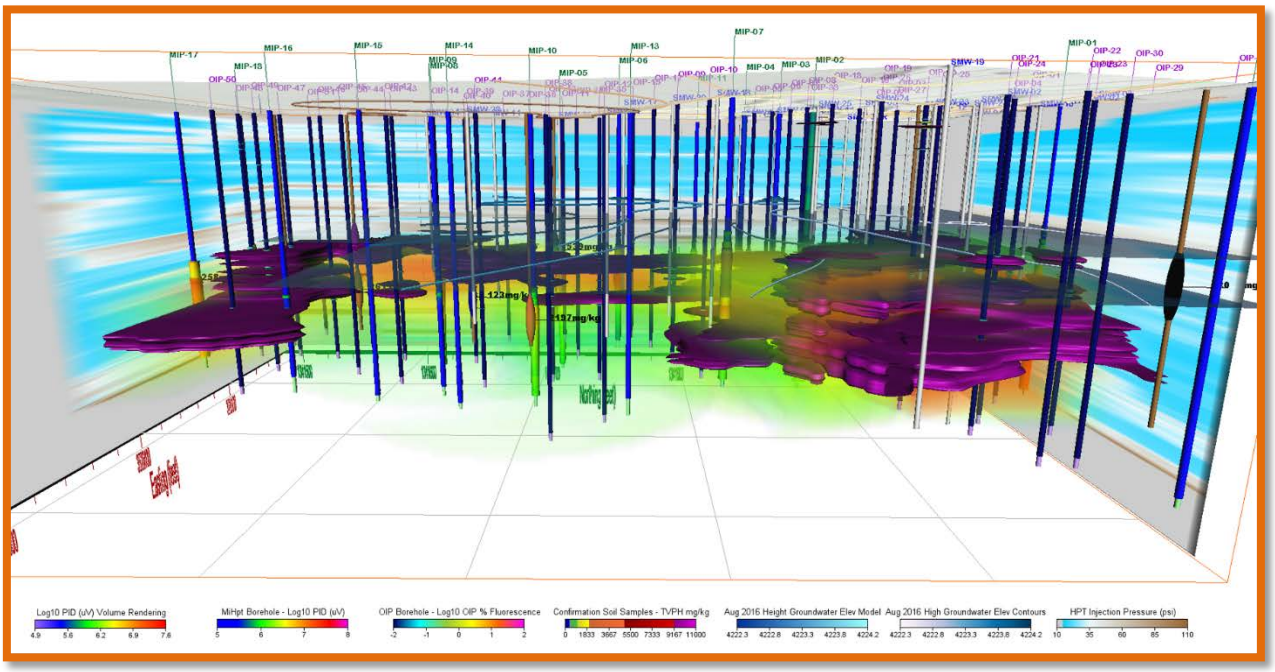
REAL TIME DATA REVIEW: A Google Earth field map of the locations is maintained on site. Draft Field Logs can be printed on site, viewed on a computer, tablet device, or phone. A site map and PDF log file prints are uploaded real time to a SharePoint website for remote viewing on your computer, tablet, or phone at your office or home.

POST PROCESSING AND BASIC REPORTS: A post project Basic Final Report will include the following:

- Written summary of field activities.
- Log-run Summary Table.
- QA/QC, Response Test Methods and Review.
- Color Graphic Logs printed in two scaling formats, with all sensors.
- Final edits of post-processed logs will include estimated K and SEC values were applicable.
- Optionally - Excel or ASCII export files of the data, or DI Viewer files.

ADVANCED INTERPRETIVE & 3D CSM VISUALZATION REPORTS: An optional Advanced Report includes:

- Scaled Log plots in cross-section of selected sensor responses, corrected to elevation.
- Fence diagrams of selected sensor responses and hydrostratigraphy.
- Power Point Report of 3-D Model diagrams of selected sensor responses (isosurface) and hydrostratigraphy plots.
- Integration and plotting of laboratory results with the above information.
- Advanced QA/QC Data Review



3D visualization and conceptual site model (CSM) showing confined petroleum LNAPL, VOC plume, hydrostratigraphy, surface elevation model, groundwater elevation model, OiHPT and MiHPT borings, monitor wells, and confirmation soil core borings.

Vista GeoScience

Specialty Services

- Membrane Interface Probe (MiHPT & LL-MIP)
- Optical Image Profiler (OiHPT-UV & OiHPT-G)
- Hydraulic Profile Tool (HPT) & Electrical Conductivity (EC) for estimated K & SEC)
- HPT with Groundwater Profiling (HPT-GWP)
- 3D Data Modeling, Visualization & CSM Reports
- Optimized In-Situ Remediation Applications
- Specialized Clean-Inject Remediation Systems
- Bedrock Fracture Enhanced Reagent Placement
- Geoprobe Dual-Technology Drill Rigs (DPT & HSA)
- Continuous Soil Coring & Sampling Systems
- Discrete Groundwater Sampling Tooling
- Groundwater and Soil Gas Monitor Wells
- Active & Passive Gas Soil Sampling
- Landfill Tier-2 NMOC Surveys
- Stray Gas Migration Mapping & Forensics
- Injection & CO_2 Sequestration Monitoring