

S2C2 Direct-Sensing Options

Electrical Conductivity (EC)

Traditionally EC logging has been used to determine variations in subsurface lithology, such as defining permeable sand zones and impermeable clay confining layers to help with locating groundwater sampling. The electrical conductivity of unconsolidated materials is a function of the moisture content of the material and the conducting properties of the pore fluids and sediments (Schon1996). In the saturated zone, where variations in moisture content are small, fluid and matrix properties are the major factors. In formations where variations in ground water chemistry are small, differences in sediment size and type are the dominant control on electrical conductivity (Keys 1990). The electrical conductivity associated with sedimentary materials varies with particle size and mineral species. Silt and sand-sized particles of covalently bonded minerals, such as quartz, mica, and feldspar, are generally nonconductive. For this reason, electrical conductivity in sand and gravel aquifers primarily reflects variations in concentrations of dissolved constituents. Clay-sized particles, such as phyllosilicates, humic substances, and iron and manganese oxides and oxyhydroxides, tend to be highly conductive due to their extremely small size, relatively high surface area per unit volume, and charge characteristics (Langmuir 1997). Thus, in formations where clay-sized particles are present, both lateral and vertical variations in lithology may be assessed using EC logs.

In direct-push EC logging, a sensor attached to the end of a steel rod is driven into the subsurface using a percussion hammer. The sensor configuration is typically a four-electrode Wenner array with an inner-electrode spacing of 0.02 m (Figure 1). As the EC probe is advanced, a current is applied to the two outer electrodes and voltage is measured across the two inner electrodes. Given the applied current and the measured voltage, electrical conductivity is calculated to produce a log of electrical conductivity versus depth. The small electrode spacing allows the sensor to resolve thin units and sample a small lateral radius (5 to 10 cm; Beck et al. 2000). Data are collected every at a rate of 20 readings per second and a potentiometer mounted on the mast of the direct-push unit tracks the depth and speed of advancement of the probe.

S₂C₂'s experience in pushing EC probes in urban areas has also led them to use the EC probe to determine the presence of historic fill/ash layers in the subsurface. Typically EC results range from 0.1 to 10mS/m for sands and gravels and 10 to 400 for clays. Results greater than 400 with specific patterns indicate potential fill material. Due to the inherent difficulty of soil sampling in fill material, performing conductivity logging provides the most accurate way of locating and determining extent of the fill material in the subsurface. Upon completion of EC logging, soil sampling can be targeted to the identified zones of potential impact, thereby reducing the number of samples to be collected and insuring an accurate sample. S₂C₂ has been able to conduct up to 400' of logging in a day. The EC can be affected by mineralogy and pore water chemistry (brines, pH and contaminants).

Electrical Conductivity (EC) Diagram

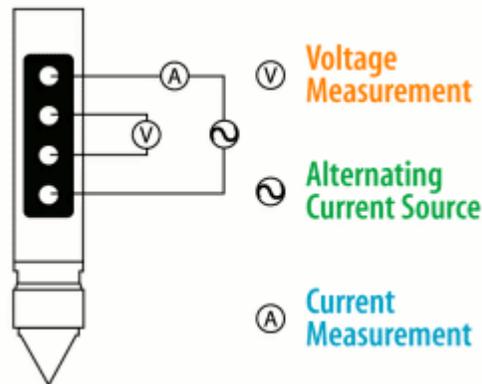


Figure 1: Array for Conductivity Measurements

The EC probes come in two different configurations, Dipole Array and Wenner Array, with the same theory of operation. A current is sent through the formation between two probe contacts. This current is measured along with the voltage that results (Figure 1). The conductivity is a ratio of current to voltage times a constant. The resulting reading is in milli-Siemens per meter (mS/m).

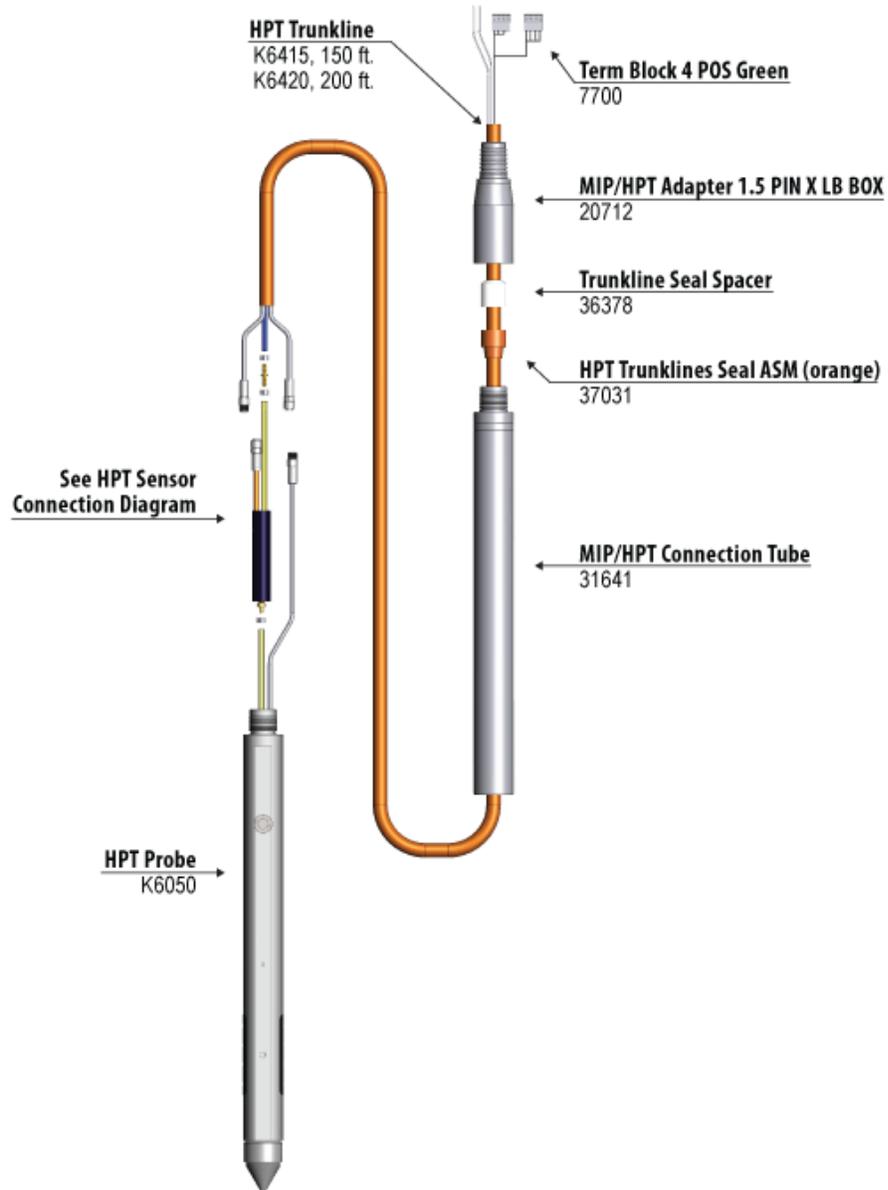
Hydraulic Profiling Tool (HPT) Equipment

The HPT system is designed to evaluate the hydraulic behavior of unconsolidated materials. As the probe is pushed or hammered at 2 cm/s, clean water is pumped through a screen on the side of the HPT probe at a low flow rate, approximately 300 mL/min. Injection pressure, which is monitored and plotted with depth, is an indication of the hydraulic properties of the soil. That is, a relatively low pressure response would indicate a relatively large grain size, and the ability to easily transmit water. A relatively high pressure response, however, would indicate a relatively small grain size and the lack of ability to transmit water.

A Wenner, conductivity, array is also integrated into the HPT probe. This allows the collection of soil electrical conductivity (EC) data for lithologic interpretation. In general, the higher the electrical conductivity value, the smaller the grain size, and vice versa. However, other factors can affect EC, such as mineralogy and pore water chemistry (brines, extreme pH, contaminants). Conversely, the HPT pressure response is independent of these chemical and mineralogical factors.

In addition to the above real-time information collected with the HPT, post-processing of the log data with Geoprobe®'s DI Viewer software allows for estimates of hydraulic conductivity (K) and water table elevation. See below for a graphical depiction of the MiHPT.

Hydraulic Profiling Tool (HPT) Diagram



Membrane Interface Probe (MIP) Equipment

The [MIP](#) coupled with an electrical conductivity sensor will provide continuous stratigraphic information of the soil as well as semi-quantitative concentrations of volatile organic compounds (VOCs). The MIP can be used in both saturated and unsaturated materials to detect VOCs in the gaseous, sorbed, dissolved or free phases. The “Membrane” acts as an interface between the VOCs in the subsurface and gas phase detectors at the surface. The membrane is semi-permeable and is comprised of a thin film polymer impregnated into a stainless steel screen for support. The membrane is approximately 6.35mm in diameter and may be easily replaced if damaged. The membrane is placed in a heated block attached to the probe. This block is heated to approximately 120 degrees C and is raised at the leading edge to help protect the membrane from damage when being pushed through the geologic matrix. Heating the block helps accelerate diffusion of the VOCs through the membrane. Diffusion occurs due to a concentration gradient between the impacted soil and the clean carrier gas behind the membrane. A constant gas flow of 35-45 mL/min sweeps behind the membrane and carries the diffused VOCs to the gas phase detectors at the surface. Travel time from the membrane interface to the detector(s) is approximately 60-75 seconds (depending on the length of trunkline, flow rate, and ambient air temperature). S2C2 will be using a MP 6520 or equivalent MIP probe, FI 6000 Field Instrument, MP 6500 MIP controller, coupled with a HP GC. S2C2 will use a combination of the three following detectors: PID/FID/XSD. THE XSD detector is a halogen (chlorinated) specific detector, which is similar to an ECD but has a larger working range. Detection limits for typical MIP configurations are generally between 1ppm and 150ppb or less, depending upon contaminant concentrations and soil matrix.

Heated Trunkline MIP

In addition to the standard MIP setup, S2C2 can run a system that uses a heated trunkline. Unlike traditional MIP setups where the MIP probe is the only portion of the system that is heated, Geoprobe’s HTL will be used to heat the entire trunkline to approximately 100 degrees C along its entire length. The heated trunkline moves the contaminant through the trunkline quicker than a traditional trunkline. This reduces the typical slurred baseline drop seen when dealing with high concentrations of contaminants.

Membrane Interface Probe (MIP) Diagram

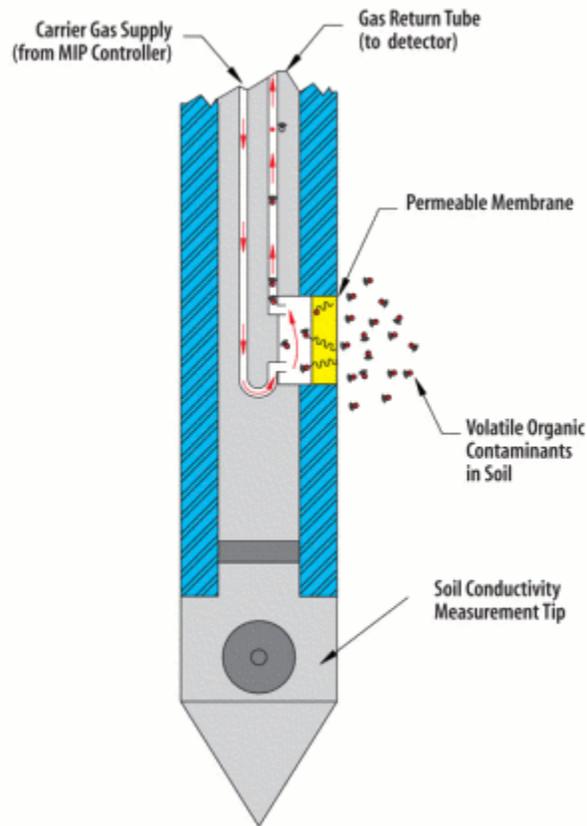
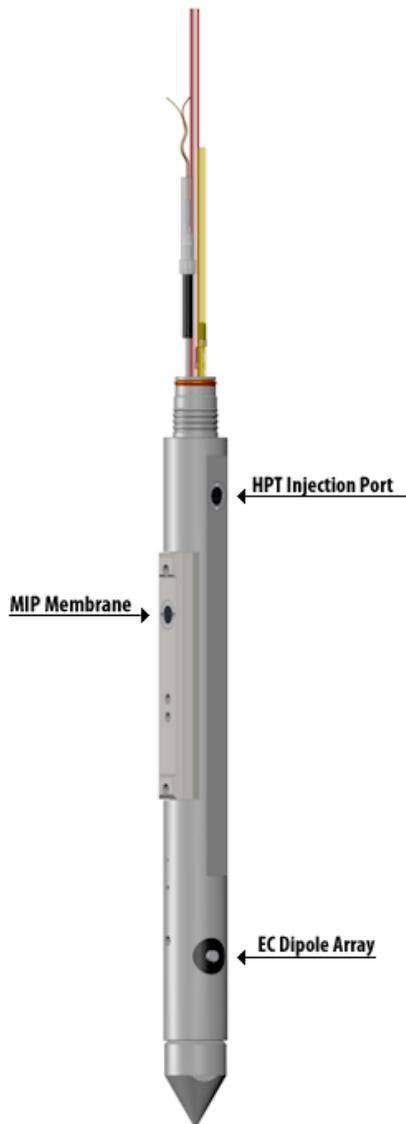


Figure 2: The MIP Principle of Operation. The downhole, permeable membrane serves as an interface to a detector at the surface. Volatiles in the subsurface diffuse across the membrane and partition into a stream of carrier gas where they can be swept to the detector. The membrane is heated so that travel by VOCs across this thin film is almost instantaneous. MIP acquisition software logs detector signal with depth.

Membrane Interface Probe with HPT (MiHPT)

The MiHPT is the combination of the MIP with the HPT. The new probe detects volatile contaminants with the MIP, measures soil electrical conductivity with a standard (MIP) dipole array, and measures HPT injection pressure using the same down-hole transducer as the Geoprobe[®] stand-alone HPT system. In post-processing the log data with Geoprobe[®] DI Viewer software, the user is able to estimate hydraulic conductivity (K) and water table elevation, as well as prepare graphical outputs of the log data.



Low Level MIP

Low Level MIP (LL MIP) is a technology developed by Geoprobe Systems® that greatly increases the sensitivity 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. This results in an increase in the concentration of VOC contaminant delivered to the MIP detectors.

Low Level MIP can be performed with standard MIP probes or MiHPT probes. The addition of the LL MIP to the system is simple and requires only the rearrangement of gas line connections. This controller can then be easily removed from the system to return to standard MIP logging. Switching between methods requires only a few minutes of time.



Figure1: MP9000 Pulse flow controller (patent pending)

General Operation:

In standard MIP operation, the carrier gas continually sweeps across the membrane transporting contaminants 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 (Fig. 2 and 3) for a given chemical concentration. Switching valves located inside the MP9000 create 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 with a trunkline flow rate of approximately 60ml/min. and is routed to the detectors via a sample loop located in the MP9000.

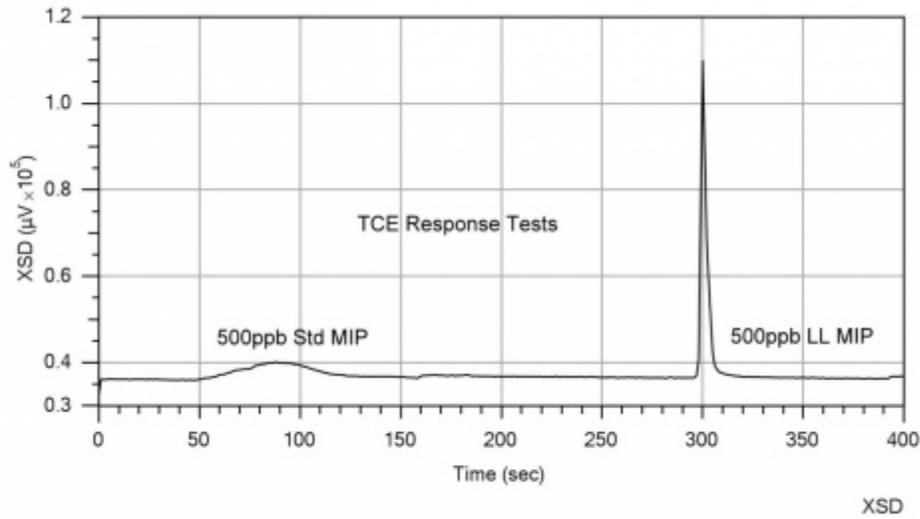


Figure 2: Comparison of 0.5ppm TCE response between standard (50-100s) and Low level (300s) MIP methods

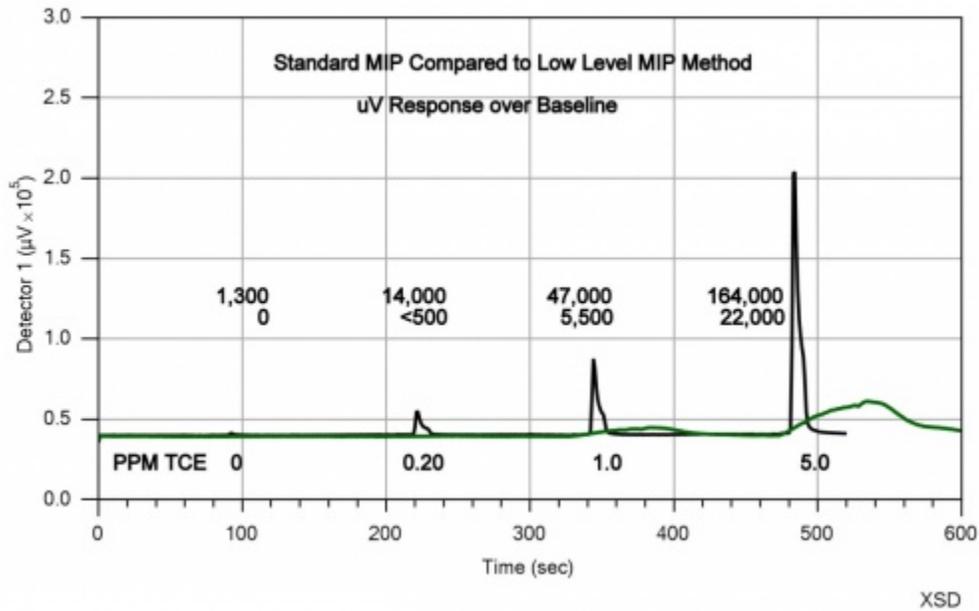


Figure 3: Comparison of standard and LL MIP method 0, 0.20, 1.0 & 5.0ppm TCE

The Low Level MIP operation requires the use of a specific purpose edition of DI Acquisition software to control the timed cycling of the MP9000 controller. This software also includes a subroutine for automatic triggering of LL MIP cycling at preset depth intervals during the MIP logging process.

Low level MIP will not replace standard MIP logging, but will expand MIP capabilities. LL MIP is most useful when low contaminant concentrations are present. Figure 4 shows a comparison of closely spaced standard MIP and LL MIP logs at a location of low concentration chlorinated VOC's. While it is difficult or even impossible to discern the presence of VOC contamination based on the standard MIP log at this location, the LL MIP log exhibits robust signal to noise and the presence and location of contamination is easily defined. Projects with contaminant concentrations too low to proceed with traditional MIP methods may be good candidates for investigation using the LL MIP method. This technology will provide operators with the ability to track and map contaminant plumes down to concentrations at or below the 100ppb range for some contaminants.

The LL MIP method will greatly increase the sensitivity of a MIP system but the resulting detection limits are dependent on the sensitivity of the detectors. To achieve the lowest possible detection limits the probe and trunkline need to be new or verified clean with a system blank. The detectors also need to be fully current within their maintenance program and sensitivity should be tested prior to mobilization. Equipment that has been used to map high level contaminants will result in false positive results due to contaminant desorption from the membrane and return carrier gas line.

Fuel Fluorescent Detector (FFD) The FFD probe collects hydrocarbon impact information in real-time by detecting the fluorescence produced by aromatic hydrocarbons when excited by an ultraviolet (UV) light source. S2C2 will use an FFD made by Vertek, a division of Applied Research Associates, Inc. of Randolph, Vermont. The FFD technology is based on the science of fluorescence, whereby certain substances, when exposed to ultraviolet (UV) light, will radiate light at different discrete wavelengths. The FFD sensor module contains a mercury vapor UV lamp that emits a continuous light source through a sapphire window in the side of the module. The light is absorbed by the subsurface material in direct contact with the outside of the window. If compounds that fluoresce (e.g. organic compounds with aromatic ring structures) are present in the matrix, a portion of the UV lamp energy absorbed will be re-radiated at wavelengths specific to that compound. Two photomultiplier tubes (PMTs) collect and detect the re-radiated fluorescence. The PMTs produce a voltage signal proportional to the amplitude of the re-radiated light. Optical filters in front of the PMTs isolate fluorescence emission wavelengths corresponding to the heavier (HFFD response; wavelengths >450 nm) and lighter hydrocarbons (LFFD response; wavelengths 280-450 nm) and allow for differentiation of hydrocarbon fuel types (e.g., diesel, jet fuel, gasoline, etc.).

The FFD only picks up free and residual product – not dissolved phase.