

Proposed Geophysics Request, Part 1: Acquisition of Electromagnetic Tool Box

Geophysical methods can be used to obtain high-resolution images of subsurface properties and processes. For hydrologic applications, the most useful methods, in general, are those that measure electrical or electromagnetic (EM) properties, as these properties are sensitive to variation in both lithology and fluid content. The approach to subsurface characterization, advocated by HMF-Geophysics, is a unified approach where a number of complementary electrical/EM geophysical techniques are used to image the subsurface structure and identify flow paths. This approach allows data collection with methods that have different scales of measurement, but which are all governed by the same underlying physics (Maxwell's equations). This allows us to develop a framework for weaving the data sets together into a seamless 3-D geophysical image of the subsurface. We propose to acquire, for use by HMF-Geophysics, an electromagnetic "tool box", containing the electrical/EM equipment that has been successfully used for a range of hydrologic applications. This tool box will include the hardware and software required for the following forms of measurement:

- 1) ground penetrating radar
- 2) electromagnetic induction
- 3) electrical resistivity imaging.

The brief review of these systems given below is taken, with minor modification, from the CUAHSI report: *A Vision for Geophysics Instrumentation in Watershed Hydrological Research* by David Robinson and others.

Ground Penetrating Radar (GPR) is a high-resolution geophysical technique that utilizes the transmission and reflection of high frequency (1 MHz to 1GHz) EM waves. There exist a number of commercial systems that can be used to acquire data from the surface or between boreholes. In all cases, the acquired GPR 'image' maps out subsurface spatial and temporal variation in dielectric properties, which are linked to variation in water content. It is this sensitivity of GPR data to water content, or water-filled porosity, that is the basis for many of the hydrologic applications of GPR. GPR can be used to image the structure of the subsurface over a large area (kilometers or more) or at a specific test site (a few meters in lateral extent). GPR data can be used to image specific features or boundaries such as the water table, depth to bedrock, and fractures. GPR images also contain information about the subsurface variation in lithologic units or lithofacies, and about the sedimentary structure within lithofacies. For small-scale site-specific experiments GPR can be used to monitor the movement of water into and through the subsurface. Time-lapse or 4D GPR imaging has been used to capture the movement of water and other fluids into the subsurface during controlled experiments.

Electromagnetic Induction (EMI) is a highly adaptable non-invasive geophysical technique, originally developed for borehole logging. An EMI instrument consists of a receiver and transmitter loop spaced 1m or greater apart that are used to measure the bulk electrical conductivity of the ground. The nominal depth of penetration for these tools is 0.75 times the transmitter-receiver loop spacing for a horizontal electromagnetic dipole configuration, and 1.5 times the spacing for a vertical dipole. The maps of electrical conductivity obtained from EMI data can be calibrated to provide information about parameters such as clay content, water content and salinity. A number of types of EMI instruments are available with various loop separations to obtain varying penetration depths. The instruments are robust, relatively simple to use and can be linked to a field computer and GPS to provide real time mapping

Electrical resistivity imaging (ERI) is a direct-current (or low-frequency alternating-current) resistivity method that requires the emplacement of electrodes at the surface, or in boreholes, in order to obtain measurements. After data inversion, ERI can provide a series of two- or three-dimensional tomograms, where each tomogram shows the distribution of electrical resistivity in the subsurface. Electrical imaging is possible at the sub-meter- to 10s-of-meters scale in the field, and can be used to reveal static properties such as subsurface structure and hydraulic pathways as well as temporal properties associated with changes in moisture and/or water quality. ERI has been used to determine the extent of conductive contaminant plumes or saltwater intrusion, and for locating voids, such as fractures, mine shafts, and karst terrain. Because ERI is sensitive to changes in fluid electrical conductivity and water content, it has been used for monitoring time-varying processes, such as changes in moisture in the vadose zone and the transport of conductive tracers in groundwater. Several ERI multi-electrode instruments are available, a number of which have multi-channel capability.

HMF-Geophysics proposes to acquire an EM toolbox, giving us a range of geophysical instruments that can be used in an integrated approach to subsurface characterization. The strength of these techniques lies not in the individual instruments but in utilizing them together to construct a seamless 3-D image of the subsurface.