GeoConvention 2016
Calgary • Canada • March 7-11
OPTIMIZING RESOURCES

Environmental Geophysics: Using Non-Invasive Methods to Improve Conceptual Site Models

Brent Forrest & Josh Brown
Matrix Solutions Inc.

Summary

Shallow surface geophysical methods can be useful tools for environmental site assessments. Geophysical methods can be used in conjunction with invasive sampling techniques, but can also be used to gather information that simply can't be determined by conventional methods. Electromagnetic (EM) surveys are one of the more common geophysical method employed in environmental assessments; however, other methods including electrical resistivity tomography (ERT) and siesmic refraction can be invaluable for obtaining a greater understanding of subsurface site characteristics. Two case study sites are provided to demonstrate the use of these methods to fill data gaps required to further develop conceptual site models (CSM).

At the first case study site, an extensive geophysical assessment program including EM31, EM38, ERT and shallow seismic refraction surveys was completed to delineate of salinity impacts associated with a former flare pit area, as well as obtain information on the depth of bedrock underlying the site. At the second site, ERT and shallow seismic refraction surveys were completed to address data gaps in the understanding of subsurface contaminant transport off-site where conventional investigation methods were restricted due to terrain limitations. In both cases, non-invasive geophysical methods were utilized to further understanding of subsurface conditions and the strategy for further targeted intrusive sampling could then be streamlined with a significant program scope and cost reduction.

Introduction

Shallow surface geophysical methods can be useful tools for environmental site assessments, specifically where produced water is a contaminant of concern. Geophysical methods can be used in conjunction with invasive sampling techniques, but can also be used to gather information that simply can't be determined by conventional methods. Electromagnetic (EM) surveys are the most common geophysical method employed in environmental assessments; however, other methods including electrical resistivity tomography (ERT) and shallow seismic refraction can be invaluable for obtaining a greater understanding of subsurface site characteristics. Two case study sites are provided to demonstrate the use of these methods to fill data gaps required to further develop conceptual site models (CSM).

Theory and/or Method

EM surveying techniques are used to investigate a wide variety of environmental and geotechnical problems. EM instruments generate a secondary magnetic field in the subsurface by alternating current in a transmitter coil. The strength of the induced current - as well as that of the secondary magnetic field produced as a result - is directly proportionate to the conductivity of the subsurface material. The measured subsurface conductance may be attributed to a number of parameters including soil composition, pore volume and contents, permeability, relative water saturation, and buried or overhead conductive objects such as fences, pipe and wire. In the oil and gas industry, large volumes of brines are typically produced with hydrocarbons. Brine-impacted soils and groundwater (resulting from brine/hydrocarbon spills and leaks) will generally exhibit elevated conductivity measurements. As such, subtle changes in ground conductivity are used to delineate areas of possible salinity impact.

Electrical Resistivity Tomography (ERT) surveys collect measurements of the electrical resistance of the ground by setting up a direct circuit using a power source and two current electrodes. The difference in electrical potential between two other potential electrodes, while this current is on, allows for a measurement of apparent ground resistivity (the resistivity of a homogenous earth that would lead to the observed result). A large dataset of measurements can be acquired along a line or over a grid by collecting many apparent resistivity measurements using a multi channel ERT system that has a multi core cable connected to a switching box. A model of the true electrical resistivity, or its reciprocal electrical conductivity, on a 2D cross section under a line of electrodes or a 3D volume under a grid of electrodes can be estimated through a tomographic inversion. The inversion procedure fits the numerically simulated response of a modeled subsurface electrical resistivity distribution to the observed data. The resulting best fit model can be interpreted as an image of the subsurface electrical resistivity distribution. A large dataset collected with a multi core cable contains information about the subsurface; however, even with a large and noise free dataset the inversion is non unique. Constraints of smoothness are added to the inversion to produce an image. These constraints and non uniqueness can cause the inversion to produce unreliable results in the presence of sharp contrasts in electrical resistivity such as metallic infrastructure.

Seismic refraction surveys are commonly used to determine depth to bedrock, characterize features on the bedrock surface and determine the thickness of overburden. At the survey location, an array of geophones is placed on the ground at specified intervals. The survey is completed by generating a mechanical shock at the ground surface, for example, hitting a steel plate with a sledgehammer. This energy travels through the ground at the seismic velocity of the material it is passing through. The travel time and magnitude of arrivals of this energy are recorded at each individual geophone. Under typical geological conditions, the seismic velocity increases with depth. At a certain offset from the source, the first arrival at the geophones will be from a wave that has traveled deeper into the subsurface and through faster material. Due to the first arrival travel times being influenced by the velocity of deeper features, these first arrivals can be used to constrain an inversion that produces a model of the seismic velocity of the subsurface that best fits the observed travel times. Each stratigraphic material has a characteristic range of velocities; and therefore, using values from literature and borehole data, it is possible to make predictions about the lithology based on the seismic velocity model estimated through the inversion process.

Examples

At the first site, an extensive geophysical assessment program was completed to address several of the data gaps identified in the CSM. Several intrusive soil and groundwater sampling programs had been completed at the site; however, several data gaps in the understanding of the site were still present. These data gaps included a lack of horizontal and vertical delineation of salinity impacted groundwater and soil associated with a former flare pit area, as well as a lack of information on the depth of the bedrock underlying the site. Instead of completing an extensive invasive characterization and sampling program, it was determined that using a combination of geophysical methods including EM31, EM38, ERT and shallow seismic refraction surveys would provide further insight on subsurface conditions underlying the site and help address the CSM data gaps.

At the second site, a geophysical assessment program was completed to address data gaps in the understanding of subsurface contaminant transport off-site where full usage of conventional investigation methods was restricted due to terrain limitations. Groundwater monitoring had indicated groundwater flow was predominantly to the north-northeast; however, groundwater quality results indicated that saline groundwater impacts were migrating north-northwest. An ERT survey was completed to evaluate the relative vertical extent of salinity impacted soils and groundwater, and a shallow seismic refraction survey was completed to evaluate the depth of bedrock and profile of the bedrock surface.

Conclusions

Surface geophysical methods can be useful for environmental site assessments, in conjunction with invasive sampling techniques. Electromagnetic (EM) surveys are one of the more common geophysical methods employed in environmental assessments, but other methods such as resistivity tomography (ERT) and shallow seismic refraction can be invaluable for fully developing a conceptual site model. Specifically, in the two provided case studies the use of geophysical assessments provided a higher degree of certainty pertaining to subsurface conditions controlling contaminant migration and proved an effective means to reduce the scope and cost of further intrusive investigations.

References

References will be provided in presentation.