State of the Practice in Geophysical Site Characterization and Monitoring

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Background/Objectives. Geophysical methods are increasingly used for site characterization in support of environmental management. Conventional hydrologic measurements are commonly invasive, expensive, and sparse, and provide information that is local to boreholes, whereas geophysical surveys are minimally invasive or non-invasive, relatively inexpensive, and provide spatially dense information over large areas. Modern geophysical site characterization involves a strategic selection of a synergistic combination of methods designed to (1) address information needs for a given site; (2) work under site-specific geologic or infrastructure conditions and other practical constraints (e.g., cost); and (3) reduce interpretation uncertainty associated with an individual method, which may be sensitive to multiple biogeochemical and (or) geologic properties. The modern 'geophysical toolbox' comprises a diverse array of methods including electrical, electromagnetic, magnetic, seismic, thermal, radar, gravity and other methods. Where repeat surveys or long-term geophysical installations are possible, geophysical monitoring can provide insights into temporal changes in subsurface biogeochemical conditions associated with amendment emplacement and distribution, bioremediation, and natural attenuation. We stress, however, that there is no geophysical 'silver bullet,' and geophysical methods should be used in concert with conventional approaches for calibration and (or) ground truth.

Approach/Activities. We (1) review the state of the practice for geophysical approaches to complement conventional site characterization; (2) present examples demonstrating the successes and failures of geophysical technologies; and (3) showcase tools to support the selection and rejection of geophysical methods based on site conditions, study objectives, and the cost of data collection and analysis. We discuss electrical, electromagnetic, and thermal methods in the context of case studies involving amendment emplacement; characterization and remediation of contaminated fractured rock; mapping groundwater/surface-water exchange; and monitoring natural attenuation. We demonstrate the U.S. Geological Survey's software packages SEER (Scenario Evaluator for Electrical Resistivity) and FRGT-MST (Fractured Rock Geophysical Toolbox Method Selection Tool) for selecting geophysical methods and understanding their limitations and likelihood of their success. The FRGT-MST identifies methods likely to achieve user goals and succeed under site-specific geologic and engineering conditions. SEER performs desktop feasibility studies for electrical resistivity surveys, allowing the user to predict survey results given a user-specified target (e.g., plume), survey design, and geologic conditions.

Results/Lessons Learned. Geophysical technologies have advanced rapidly over the last decade, with the state-of-the-practice now capitalizing on cellular data transmission for remote operation and monitoring, global positioning systems for georeferencing, new batteries for long-term deployments, and expanding computer power for three-dimensional imaging. Perhaps the foremost impediment to advancing the state-of-the-practice in geophysical site characterization is the slow adoption of tools for desktop feasibility studies, which are common practice within the academic and research communities. "Pre modeling" involves use of software tools to predict survey results prior to field campaigns based on hypothetical targets and site conditions. In the absence of pre-modeling, overselling of geophysical solutions and unrealistic expectations are possible, and anecdotal failures of geophysics are more frequent than necessary. Pre-modeling with tools such as SEER can help guide method selection and rejection based on site-specific goals and conditions, thus reducing the chance of failure and associated cost.