Subsurface Electrical Imaging of a Permeable Reactive Barrier Undergoing Bioremediation of DNAPL Contaminated Groundwater

David Correll & Robert Reynolds

Overview:

Electrical Resistivity Imaging (ERI) in addition to traditional site characterization methods can prove to be an effective, non-invasive monitoring technique in permeable reactive barrier remediation. Permeable reactive barriers or "biowalls" are subsurface trench-like structures created to intercept and treat contaminated groundwater. The traditional method to test a biowall's effectiveness is to install monitoring wells and examine the contaminate concentrations entering and leaving the biowall. If the biowall is successful, the down gradient concentration would be significantly less than the up gradient concentration. The installation of the traditional monitoring well method is an invasive as well as an expensive process. ERI technology has been used as an effective approach in the characterization of sites undergoing in situ remediation. It has the capability to display how chemical contaminates such as DNAPL's (dense nonaqueous phase liquids) and the biowall are interacting, ultimately determining the biowall's remediation ability in a less invasive, less time consuming and more cost-effective manner.

Through this research it is envisioned that ERI technology will enhance the site characterization ability of a scientist whose aim is to remediate sites with subsurface environmental contamination. The long term goal of this investigation is to advance the science of environmental remediation techniques. The specific objective goal of this project is to test the ability of ERI technology as an effective tool in characterizing a site that is undergoing in situ remediation of DNAPL's with a permeable reactive barrier. It is hypothesized that an ERI survey conducted over such a barrier will show that the biowall is creating conditions for bioremediation which can be described electrically as having resistive conditions for untreated subsurface zones and highly conductive zones where microbial degradation is taking place. The two PI's on the project have used ERI technology on their thesis work, and also work with a professor who specializes in site contaminated site characterization using ERI methods. Due to the physical properties of DNAPLs, the contaminants migrate downward rapidly and become increasingly difficult to recover as time progresses. There is a critical need to address the effectiveness of biowalls, which in turn can allow for the confirmation that an installed biowall is performing effectively, or that it has failed and other remediation techniques need to be employed. The specific aims of for this proposal are to:

Specific Aim #1: Create a new application of ERI technology to study the effectiveness of a biowall on a DNAPL contaminated site at the OU-1 biowall in Altus, OK.

Specific Aim #2: Determine if ERI technology in the study of biowalls can reduce or replace the traditional invasive and costly monitoring well techniques currently in use for DNAPL sites.

This research is novel because its goal is to test the effectiveness of a biowall at a DNAPL site where monitoring wells are already in place. It is hypothesized that ERI technology will be able to detect the migration of DNAPL more effectively than the monitoring wells. If successful, this research will lead to the development and implementation of a new application of ERI which meets a need to confirm the effectiveness of an already installed biowall. This new knowledge will lead to decreased costs in remediation techniques in that it can determine if a specific technique such as a biowall is successful or unsuccessful, thereby saving time and money when it has been determined that the technique has failed. This research will ultimately contribute to the knowledge of the effectiveness of biowalls on DNAPL sites, and will lead to the proliferation of the use of ERI technology at other biowall sites.

Significance

By completing this research, scientists will be provided with a vital tool to properly characterize sites with contaminated soil and groundwater. Upon completion of this research, a manuscript will be written and submitted for publication in The Journal of Contaminate Hydrology. ERI has been used as an effective method to aid in characterization of sites undergoing other types of in situ remediation but this research would be the first ERI survey at a site with a permeable reactive barrier. This work is significant because it is imperative to properly asses if a groundwater remediation technology is working as it was designed; if it shown that the remediation is not working as designed, then it is of vital importance to know this as soon as possible for obvious reasons. The capability of ERI has the potential to make the task of assessing remediation projects such as biowalls much quicker, cheaper and more thorough. Successful completion of this project will not only further the application of ERI technology, but will also lessen the cost and improve the overall effectiveness of the known biowall remediation technology.

Preliminary Data:

Recent developments in ERI technology have been utilized to help characterize sites that have undergone remediation for NAPL contaminates. In Jackson, TN, a dry-cleaner site with DNAPL contamination was characterized with ERI after several rounds of injection-type remediation had already been applied (Halihan et al, 2012). Through their research they discovered areas of

high resistivity located in the phreatic zone which are interpreted as DNAPL contamination and areas of high conductivity located in the vadose zone which were interpreted as remediated DNAPL as a result of biological activity potentially induced by the remediation efforts. After completion and evaluation of the ERI survey, soil borings were collected to confirm the presence of DNAPL at the site post remediation. This research describes the ability to more accurately and efficiently evaluate a remediation technique at a particular site. The research has thus been successful at better characterizing a DNAPL contaminated site that has undergone an injection type of remedial effort, while the proposed research expects similar success at evaluating a site with a permeable reactive barrier type of remediation technique.

Narrative:

An Electrical Resistivity Imaging survey is to be conducted at the OU-1 permeable reactive barrier site in Altus, OK. This is intended to be done to test if ERI technology can aid in better assessment of a permeable reactive barrier's effectiveness in remediating groundwater. It is expected that the unremediated DNAPL groundwater zones up gradient of the biowall will be imaged as an area of high resistance measured in Ohm-Meters, while zones inside and down gradient from the biowall will display highly conductive properties indicative of biodegradation of DNAPL, which parallels the findings in the (Halihan et al. 2012) research. To complete the proposed research a list will be completed as follows:

1. An ERI line will be installed orthogonal to the biowall. This includes installing 56 electrodes into the soil and connecting the cable to the electrodes. The electrode spacing will be 1 meter giving the line an overall length of 55 meters which will give the system a 0.5 meter resolution at a total depth of approximately 10 meters.
2. The ERI line will connect to an Advanced Geosciences Inc. *R8 SuperSting* with an OSU proprietary command file which will allow the *SuperSting* to make the proper subsurface electrical measurements.
3. The data will be collected.
4. All electrodes will be surveyed using a *Topcon* differential GPS system to gain spatial data and altitude data. This data will be used to make accurate site view maps and also terrain files which aid in image accuracy.
5. The data collected will then be processed used OSU proprietary technology to produce a 2-D image of the electrical properties of the subsurface at the biowall site.
6. The image will be analyzed to determine if the suspected outcomes have been met.

The field work portion of the research will require about two days of research with the help of four students per day (not including the P.I's). Data processing will require about one week of work while writing will require another week's worth of work. It is expected that the field work will be done by mid-October and that the data processing will be done by the beginning of November and the final manuscript will be completed for review by the end of the same month.

Budget:

Travel with ¾ ton truck at $0.75 per mile at 450 miles =$337.50

¾ ton truck daily rental $75.00 per day = $150.00

2 Hotel rooms at $75.00 per night for 2 nights = $300

Total = $787.50

N/A -$

AGI *SuperSting R8*

AGI 56 Electrode Cable

56 Stainless Steel Electrodes

Two 12-volt deep cycle batteries

12V battery charger

Honda Generator

Two Black Smith Hammers

AGI EarthImager 2D software license

David Correll

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Summary

- Groundwater Hydrologist with Oklahoma Water Resources Board, Oklahoma City, Oklahoma
- Internship with U.S EPA, Groundwater and Ecosystem Restoration Division, Ada, Oklahoma
- Research Assistant with Biosystems and Agricultural Engineering, OSU, Stillwater, Oklahoma
- Environmental Science M.S Student at Oklahoma State University
- Thesis Topic: "Transient Electrical Resistivity Imaging Evaluation of Salt and Phosphorous Through Gravel Alluvium"
- OSHA 40 Hour Hazwoper Certified

Education

Oklahoma State University – Stillwater, Oklahoma

M.S in Environmental Science, Expected Graduation: May 2013

East Central University – Ada, Oklahoma
B.S in Environmental Health Science: December 2010

Experience,

Groundwater Hydrologist, Oklahoma Water Resources Board, Planning & Management Division

Oklahoma City, Oklahoma, November-Present

- Instrumental in beginning major aquifer study
- Evaluate Hydrogeologic data
- Create maps for publications
- Assisted public with groundwater and geology related issues
- Collect water quality field data
- Conducted field operations for technical studies section
- Evaluate borehole geophysical logs
- Evaluate drillers lithologic descriptions
- Compiled historic water quality data
- Collect and manage GPS data in a geodatabase
- Manage aquifer information database
- Review historic aquifer study literature
- Received software training (ArcGIS), (MS Access)
- Entered water well completion reports for aquifer study database
- Maintained and repair field equipment

Research Assistant, Oklahoma State University, Biosystems and Agricultural Engineering

Stillwater, Oklahoma, June 2011-August 2011

- Research Assistant on Scale Dependent Phosphorous Leaching onto Alluvial Floodplains project.
- Collection and analysis of soil cores using Geoprobe direct push drilling equipment.
- Installation of monitoring wells using Geoprobe equipment.
- Instructed colleges on proper geoprobe drilling techniques
- Execution of Phosphorous leaching experiment by introducing water with salt tracer and visual tracer on the land surface and monitoring for tracers in the subsurface.
- Utilization of Advanced Geoscience electrical resistivity imaging equipment.
- Processing electrical resistivity imaging data with Earth Imager 2D.
- Installation and recovery of borehole transducers.
- Site surveying using a laser level and differential GPS equipment.

Internship, U.S EPA, Groundwater and Ecosystem Restoration Division.

Ada, Oklahoma March-December, 2010

- Laboratory Technician in the general parameters laboratory analyzing water samples using EPA approved standard operating procedures.
- Dense Non-Aqueous Phase Liquid contaminate plume data modeling regarding mass discharge of contaminate across a defined cross sectional area over time.
- Field sampling of groundwater monitoring wells around underground storage tanks with known leaks for vapor intrusion study.
- Utilization of experimental soil gas sampling equipment developed by EPA Office of Research and Development.
- Assisted in analyzing Freeze cores from permeable reactive barriers.
- Experience with Geoprobe direct push drilling equipment and custom fabrication of tooling for Geoprobe drilling equipment.
- Maintenance of laboratory equipment in accordance with quality assurance/quality control protocols.

Other Experience

- Proficient in Microsoft Excel, ArcGIS and Earth Imager.
- Soil sampling for Sewell Environmental Company.
- Experience with welding and machining equipment.
- Assisted in electrical resistivity investigation of mound springs in New Mexico.

Robert B. Reynolds Jr.

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Summary

- Research Assistant with Geology Department, OSU, Stillwater, Oklahoma
- Environmental Science M. S. Student at Oklahoma State University
- Thesis Topic: "Field Evaluation of Groundwater Convection in the Nacimiento Fault"

Education

Oklahoma State University - Stillwater, Oklahoma

M.S. in Environmental Science, Expected Graduation: May 2013

University of Colorado - Colorado Springs, Colorado

B.A. in Psychology and Fine Arts Studio: December 2001

Experience

Groundwater Hydrologist, Thornhill Group Inc.

Austin, Texas, May 15th – May 22nd 2012

- Week long aquifer test using e-meters contracted through OG&E at the Lake Overholser Power Plant in Oklahoma City, Oklahoma.

Research Assistant, Oklahoma State University, Geology Department

Stillwater, Oklahoma, June 2012 – present

- Research Assistant with contracted job from Colorado State University on "ERI Resistivity Survey on a Sand Tank DNAPL Experiment".

Other Experience

- Proficient in Microsoft Excel, Microsoft Word, EarthImager 2D, RockWorks and Surfer8.

- ERI experiment with a dye test and water sampling done N.E. of Talequah, OK, off the Baron Fork River, June 2012.

- GSA Research Grant for $1,300.00 received February 2012 for thesis field work.

- PSO Environmental Science Graduate Program Research Assistantship for $1,000.00 received February 2012 to fund transportation for thesis work to be done in New Mexico.

- Thesis work done 55 miles N.W. of Albuquerque, New Mexico in June 2012. Working together with UNM and NMT, an ERI grid was plotted and performed using a total of ten ERI lines each having a length of 550 meters. Data was later processed using AGI *EarthImager 2D*, *Surfer8* and *RockWorks* in August 2012.