IV. Project Summary

Project Title Determination of Aquitard and Crystalline Bedrock Depth Using Time Domain Electromagnetics

Project Number R/UW-HDG-006

Investigators

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Background/Need

As groundwater needs and concerns have increased, larger and more complex groundwater flow models have been developed to address the problems associated with the exploitation of this precious resource. One of the first steps in creating a useful groundwater flow simulation for the Wisconsin region is the development of a conceptual model that includes hydrostratigraphic units, e.g., shale aquitards, sandstone aquifers, and streambed deposits in tills. The depth, thickness, and extent of these units are usually determined from geologic logs, but in locations where the logs are sparse or nonexistent, the modeler is left with the difficult choice of deciding stratigraphic placement at depth. Time domain electromagnetics is a geophysical tool that showed promise in filling in the gaps in the geologic record so that better flow models and understanding of geology can be realized. However, this tool needed further analysis to determine its accuracy under Wisconsin geologic conditions. Guidelines were needed to set boundaries on what structures the method is capable of resolving.

Objectives

The objective of this study was to provide an assessment of the Time Domain Electromagnetic (TEM) method as a hydrostratigraphic mapping tool and to delineate the shaley facies of the Eau Claire Formation.

Methods

The shaley facies of the Eau Claire Formation, an important regional aquitard in southern and southwestern Wisconsin, served as the test case in this study. We used borehole geophysics to measure the thickness, depth, and resistivity of the Eau Claire shale at four locations. First, those measured values were employed in a forward modeling exercise to determine the theoretical limits of the thickness, depth and resistivity of a shale unit that might be resolved using TEM. Following the forward modeling, we conducted 16 TEM surveys in Dane, Sauk, La Crosse, and Trempealeau counties using a Zonge NT-20 transmitter with a loop size of 100 m. Five TEM surveys were conducted at locations where the Eau Claire shale is constrained by well

logs and in areas where the method was challenged due to the shale being thin and/or deep. Multiple surveys were conducted at Pheasant Branch Conservatory, the location where the method was pushed to its limit of resolution with the shale depth and thickness. These surveys allowed us to calibrate and test the method. Finally, 11 additional surveys were conducted at locations where the presence of the Eau Claire shale was unknown. The data collected in the field surveys were analyzed using the WinGLink geophysical software package.

Results and Discussion

The method successfully detected the presence of the Eau Claire shale when the unit was thick and/or shallow, but the method did not always correctly delineate the depth and thickness of the shale. At sites where the Eau Claire shale was present along with a second conductor, e.g., conductive lake sediments, or the deep Mount Simon, the inversion results typically indicated the presence of the deeper conductor, the Mount Simon shale, as well as a second conductor that was sometimes too shallow to be the Eau Claire shale.

Conclusions and Implications

By comparing the geologic structure predicted by the TEM surveys with known geologic structure, this study was able to measure how well the TEM survey could reproduce the known geologic structures. The method is useful for determining whether or not a shale is present and can give a general indication of depth and thickness, but should not be used without a geologic control point. The reliability of the method is significantly lessened by the presence of a second conductor at depth. TEM surveys with different loop sizes might possibly reduce this error. A smaller loop could more accurately characterize the shallower conductor. That information could then be incorporated into the analysis of the data from the larger loop.

Related Publications

Anderson, M.L., D.J. Hart, and D.L. Alumbaugh, Use of the Time-Domain Electromagnetic Method for Determining the Presence and Depth of Aquitards, abstract in American Water Resources Association – Wisconsin Section, 27th Annual Meeting, 2003.

Anderson, M.L. Use of the Time-Domain Electromagnetic Method for Determining the Presence and Depth of Aquitards, Master's Thesis, University of Wisconsin, 2003. pp. 143.

Key Words

TEM surveys, electromagnetic, aquitard, Eau Claire shale, inversion, nonuniqueness

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