Continuous Acquisition of Time Domain Electromagnetic Data to Map Hydrostratigraphy Under a Large Water Body

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Summary

To understand the interaction between groundwater and surface water underlying a water body it is important to understand the geologic setting. Obtaining such information beneath water bodies can be challenging. We present a methodology to fill this data gap and provide a map of aquifer and aquitard layering beneath a water body up to approximately 60m depth. To accomplish this, we use the time domain electromagnetic (TDEM) method which maps changes in electrical properties of the sub surface. Commonly used as a land method, we have adapted a Geonics G-TEM system for marine acquisition. This system is towed behind a boat and acquires data automatically and continuously. We field tested this system and were able to collect approximately 15 Km of data per day. In this presentation we will describe this system in detail and will be presenting results from the pilot survey showing successful mapping of a clay till layer at approximately 15 – 20m depth.

Theory / Method

The TEM sounding method is a time domain technique that resolves the resistivity of the earth's subsurface at pre-determined time (depth) increments. Instrumentation consists of a transmitter to impart current into a single or multi-turn loop of wire laid on the ground surface, and a receiver coil and module to measure and record the resulting magnetic field shown in Figure 1.

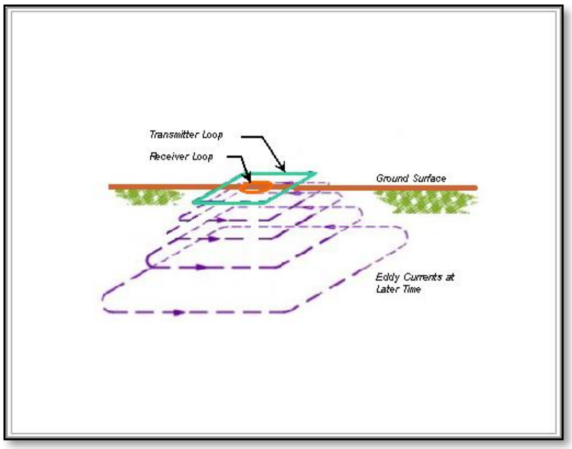

Figure 1. Centre loop TEM sounding configuration

However, this project was not conducted on land but rather on the water and thus the setup of the acquisition equipment had to be slightly different than with typical land-based surveys. For this project, the general setup was a boat that would carry the receiver module while towing a small boat/dinghy with the receiver coil in it while towing a multi-turn transmitter loop that was mounted to a pontoon style raft further back (Figure 2).

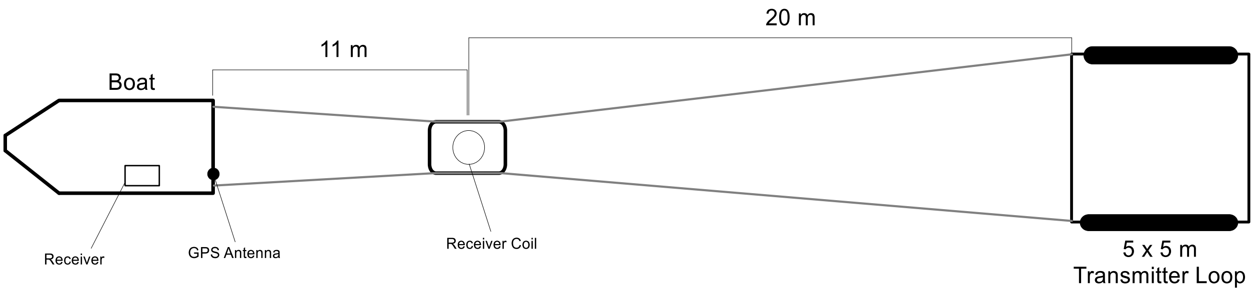

Figure 2. Marine TEM array schematic

The transmitter loop is energized by successive current pulses. While the current is constant, the magnetic field is invariant. The process of abruptly reducing the transmitter current to zero induces, in accordance with Faraday's law, a short duration pulse in the ground, causing a loop of current to flow in the immediate vicinity of the transmitter loop wire. Ground resistivity is such that the amplitude of the resulting current decays with time, thereby inducing a secondary magnetic field at an increasing depth from the source current.

The secondary magnetic field, as measured at water surface at incremental time gates, is dependent upon the electrical properties of the subsurface. In this manner, vertical variations in electrical properties may be resolved. Lateral resistivity variations are determined by moving the TEM instrument configuration along the water surface and acquiring measurements at discrete intervals. The success of the TEM sounding method to delineate subsurface strata is dependent on the degree of contrast in the electrical properties of successive lithologies, target thickness and depth of occurrence.

To achieve lateral variation resolution on a water body, we required a data collection system that could acquire data continuously. On this project, the G-Tem system by Geonics was used. The G-TEM is a time domain electromagnetic instrument that is capable of continuous data acquisition. With this system, data can be monitored in real time. If there were any concerns with the data, crews could easily resample the area without downloading data first. TEM and GPS data could be collected continuously and simultaneously.

Results & Observations

The results from the TEM survey show lateral resistivity variations in subsurface to an approximate depth of 60 m as shown in Figure 3 and Figure 4. Resistivities are shown from 10 ohm-m to 100 ohm-m for the purpose of this investigation. The TEM data showed a well-defined continuous low resistivity layer with resistivities in the range of 10-20 ohm-m (blue/purple) at an approximate depth of 20 m. This layer was interpreted as a clay till aquitard, this was further confirmed through borehole data.

Shown in the data, the clay till aquitard exhibited little variation in thickness over the survey area. There were areas where the geologic section sloped down (Figure 4), but thickness was not affected. Within the clay till aquitard, areas of higher resistivities are visible in the range of 30-40 ohm-m. These regions of higher resistivity, shown circled in Figure 3 and Figure 4 may represent weaknesses within the aquifer allowing hydrogeological pathways. Any faulting present within the aquitard will also have potential to affect hydrogeological flow. Additional surveys may be completed in the future with acoustic sub-bottom profiling to investigate these anomalies further.

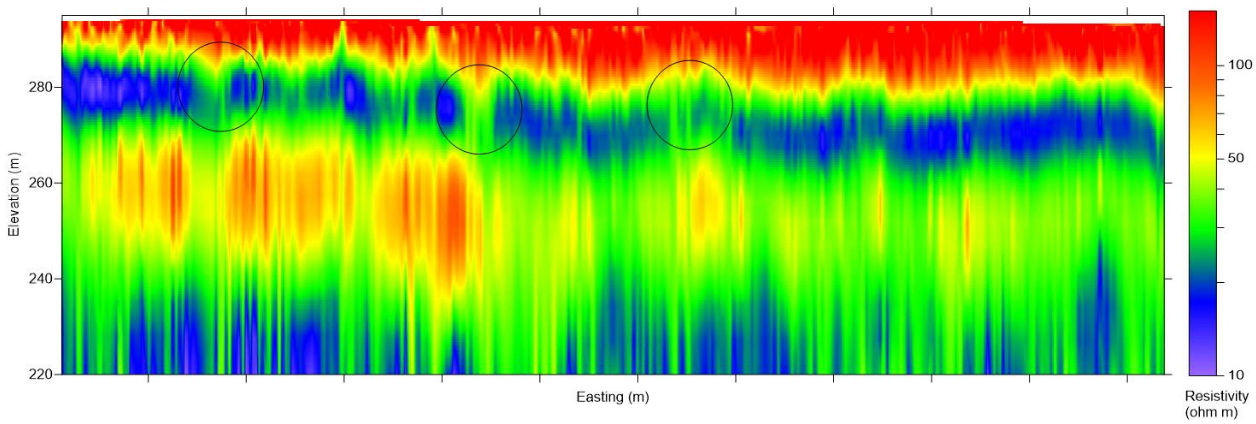

Figure 3. Cross section of TEM data moving east. Areas circled indicate zones of interest for possible hydrogeological pathways.

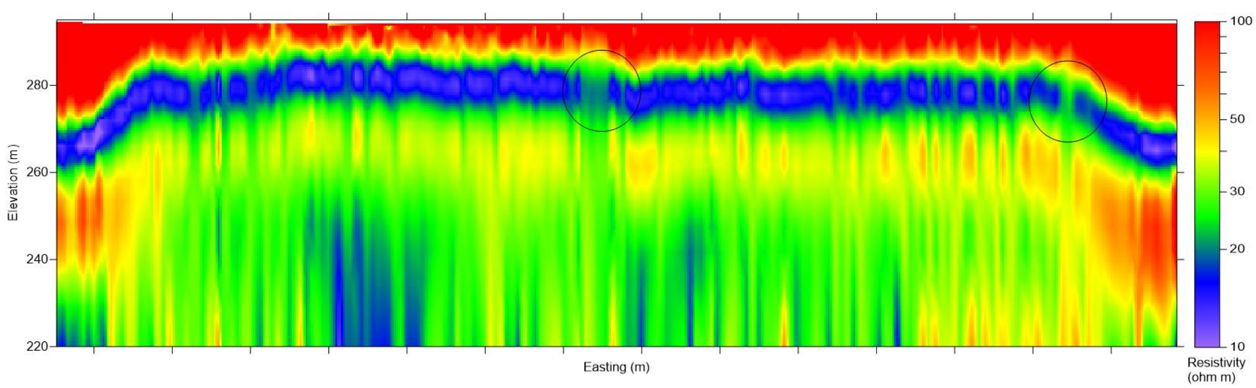

Figure 4. Cross section of TEM data moving east. Eastern and western edges of the section are shown sloping down.

Conclusions

Overall, the TEM survey was successful in mapping a clay aquitard under a body of water. Identification of these more resistive regions within a low resistivity clay till aquitard is important as these regions may indicate zones of interest that can affect hydraulic flow. Like most geophysical methods, further acquisition with another method may be beneficial to enhance the results.

Acknowledgements

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