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April 27, 2018

Central Sands Lake Study – All interested parties

Re: Brief description of the project, field methods employed, and uses of field data collected

Dear interested party,

The Wisconsin Geological and Natural History Survey (WGNHS) has been contracted by the Wisconsin Department of Natural Resources (WDNR) to assist them in their 3-year study to evaluate and model the hydrology of Long and Plainfield Lakes in Waushara County and Pleasant Lake, along the Waushara-Marquette County border. Specifically, in your area, we will be doing a variety of fieldwork and this letter outlines those activities. WDNR is the lead agency for this study and the WGNHS is one of several collaborators including WDNR staff, the University of Wisconsin-Stevens Point, and the U.S. Geological Survey.

This project was initiated following passage of 2017 Wisconsin Act 10, requiring the WDNR to conduct the Central Sands Lake Study (**see WDNR Fact Sheet**). The primary objectives for the WGNHS are to map the geology with an emphasis on the areas surrounding the three above-mentioned lakes. In addition, the WGNHS will install monitoring wells and measure groundwater levels and fluxes (flow) in areas surrounding the three lakes.

To fulfill these objectives, the WGNHS plans to perform the following fieldwork activities near and on Long, Plainfield, and Pleasant Lakes and other areas as necessary within the study area:

- Conduct lake water and lakebed surveys to better characterize groundwater-surface water interactions,
- Collect cores of sediments and bedrock to determine the geology and inform interpretations about groundwater flow,
- Install monitoring wells and piezometers to measure groundwater levels and flows and better characterize groundwater-surface water interactions,
- Conduct surface geophysical surveys to determine the depth to bedrock and identify sediments, which may influence groundwater flow.

The bulk of these field activities will be performed in spring, summer, and fall of 2018; however, some fieldwork may continue into 2019. Taken together, these field activities will help us characterize the geology and better understand the groundwater connection to Long, Plainfield, and Pleasant Lakes.

The following sections provide further information about each field method planned for use by the WGNHS and summarize how data will be used and made available.

Lake surveys

To measure where and how much groundwater is entering or leaving the lakes, several techniques will be used to survey the lake water and lakebed on Long, Plainfield, and Pleasant Lakes. Using a canoe outfitted with measurement equipment, WGNHS staff will collect profiles of lake water around each lake and will use seepage meters and lake piezometers to gather estimates of water flow into and out of the lakebed. The following paragraphs provide an overview of each profiling technique.

Canoe profiles

WGNHS staff will use a standard canoe, outfitted with a water pump, GPS, and measurement probes to navigate each lake and obtain profiles of basic lake water properties (i.e., temperature, conductivity, pH, and dissolved oxygen). As the canoe moves through the water, a small pump will continuously feed lake water through a flow chamber. Water moving through the flow chamber will be analyzed for basic chemistry, a GPS location will be assigned to each measurement, and the water will be returned to the lake. These profiles are intended to provide insights about areas in the lake where groundwater may be preferentially seeping into the lakebed. Staff will access lakes at public access points and circumnavigate each lake as needed. Most work will take place in shallow water (<5 feet depth), along the perimeter of each lake, but some transects may extend out into deeper water. Photos of the canoe and instrumentation set-up are included below as **Photos 1 and 2**.

Photos 1 and 2 - Canoe profile performed on a lake (left) and a view showing equipment mounted on the canoe.

Seepage meter measurements

Seepage meters directly measure the flow of water between groundwater and a surface water feature, such as a lake. Seepage meters consist of an open-bottomed cylindrical drum with a hole and plastic bag on the top. The drum is pushed into the lake sediment and the bag placed over the hole in the top of the drum. As groundwater flows out of the lakebed into the drum, it fills the bag. The time it takes for the bag to fill with water gives a measure of the amount of groundwater flow. To conduct these tests, staff will wade out into 1-4 feet of water and install the seepage meter directly into the lakebed sediment. The seepage meter will likely need to be left in place for 24 hours, generally the time needed for the bag to fill, before being removed and repositioned at the next measurement point. A small handful of sediment may also be collected to determine the type of material (e.g., gravel, sand, silt, clay, organic muck) present at the measurement point. Staff will access the lake at public access points but move around the lake by walking or with a small canoe or boat to help access distant locations and carry equipment. A conceptual illustration of a seepage meter installation is shown in **Figure 1** and a photo is included as **Photo 3**.

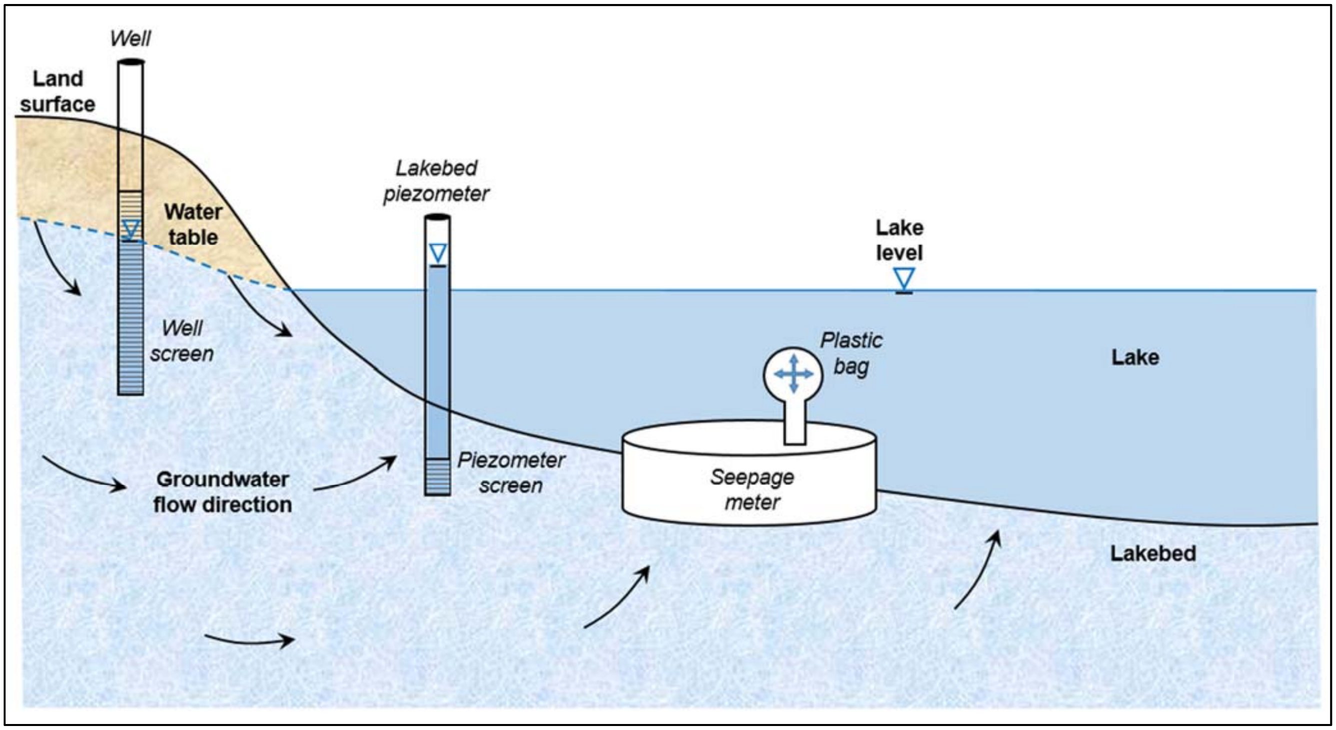


Figure 1 - Illustration of a monitoring well, lakebed piezometer, and seepage meter deployed at a lake. Groundwater is shown moving towards, and discharging to, the lake. In this example, where groundwater discharges to the lake, the water level in the lakebed piezometer rises above the lake level and the plastic bag on the seepage meter inflates. If conditions reversed, and lake water seeped into the groundwater system, the water level in the lakebed piezometer would drop below lake level and the plastic bag would deflate.

Photo 3 - Seepage meter installed in a lakebed. Clear plastic bag is visible, extending upwards from the top of the yellow cylindrical drum (Rosenberry and LaBaugh, 2008).

Lakebed piezometer measurements

A piezometer is a monitoring well designed to measure water levels at a specific depth. For this study, our goal is to measure the water level 1-3 feet below the lakebed and determine if groundwater (water below lake bottom) is moving upward or downward in relation to the lake. Water levels above the lake level indicate that groundwater is discharging to the lake, while water levels below the lake level indicate that lake water is seeping down into the groundwater system. To conduct these tests, staff will wade out into 1-4 feet of water and install a piezometer 1-3 feet down into the soft lakebed sediment. The piezometer will be in place only long enough to take a pressure reading (sometime between 5 minutes to 2 hours), before being removed and repositioned at the next measurement point. A small handful of sediment may also be collected to determine the type of material (e.g., gravel, sand, silt, clay, organic muck) present at the measurement point. Staff will access the lake at public access points but move around the lake by walking or with a small canoe or boat to help access and carry equipment to more remote portions of the lakes. Occasionally, piezometers will be left in place for longer periods of time (2-5 days) to collect lakebed temperature measurements. These piezometers will be equipped with a red or orange box, placed in areas with minimal boat traffic, and flagged with markings so that the equipment is visible to boaters and others recreating on the lake. A conceptual illustration of a lakebed piezometer is shown in **Figure 1** and a photo is included as **Photo 4**.

Photo 4 - Example of a lakebed piezometer nest. While a single temporary piezometer will typically be installed, multiple piezometers may be used to evaluate vertical gradients beneath the lakebed.

Exploratory drilling

Exploratory drilling and coring will be performed in the immediate vicinity of Long, Plainfield, and Pleasant Lakes as well as other locations within the study area to better characterize the subsurface geology and hydrogeology. The following sections describe each drilling method.

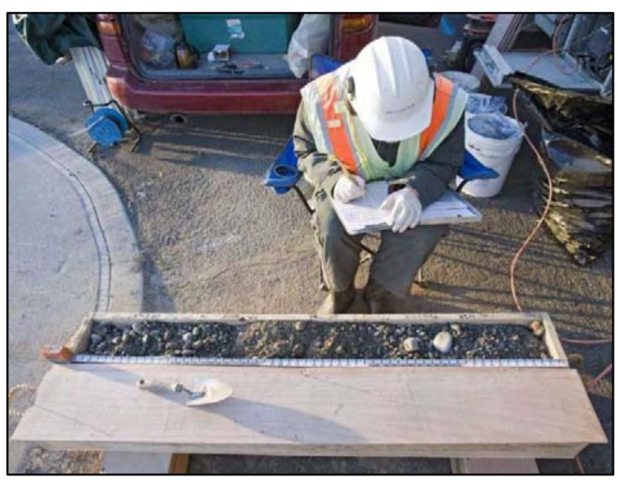
Geoprobe drilling

Geoprobe utilizes the direct-push method, which drives a small 1-2-inch diameter drill string into the ground using a percussion hammering motion. Examples of the Geoprobe equipment and samples collected from Geoprobe drilling are included in **Photos 5 and 6**. Subsurface samples can be collected from the the unconsolidated soils and sediments to a maximum depth of 80 feet or until refusal of the drill tip on bedrock or large stones/boulders. This method is ideal for obtaining subsurface samples in unconsolidated materials and will provide a quick and relatively inexpensive way to obtain a detailed profile of the geology and install piezometers. Samples will be described by WGNHS geologists and documented for future reference. Geoprobe drilling will most likely be performed on both public and private lands. Landowners will be contacted for permission to access their property and Diggers Hotline will be notified prior to drilling. Boreholes drilled only for subsurface sample collection will be immediately filled and sealed according to WDNR standards.

Photos 5 and 6 - Track-mounted Geoprobe drilling rig (left) and subsurface samples collected from Geoprobe drilling (right).

Rotosonic drilling

Rotosonic drilling utilizes a high-frequency vibration technique to liquify soils and rapidly drill to great depth, through unlithified sediments, boulders, and bedrock. Examples of a rotosonic drilling rig is included in **Photos 7 and 8**. Subsurface samples can be collected to hundreds of feet deep allowing for full determination of subsurface materials. This technique will be deployed in areas along the moraine where the depth to bedrock can approach 300 feet. Drilling samples will be described by WGNHS geologists and documented for future reference. Rotosonic drilling will most likely be performed on both public and private lands. Landowners will be contacted for permission to access their property and Diggers Hotline will be notified prior to drilling. Boreholes drilled only for subsurface sample collection will be immediately filled and sealed according to WDNR standards.



Photos 7 and 8 - Rotosonic drilling rig (left) (Boart Longyear) and examples of subsurface samples collected from Rotosonic drilling (right) (GeoDesign, Inc).

Monitoring well and piezometer installation

Monitoring wells and piezometers will be installed near Long, Plainfield, and Pleasant Lakes as well as other locations within the study area. Wells and piezometers serve as “windows” into the groundwater system and help to refine our understanding of groundwater levels and groundwater flow directions. Examples of monitoring wells are included in **Photos 9 and 10**. Data collected from monitoring wells and piezometers will help inform our conceptual model of the study area and serve as calibration data for groundwater model development.

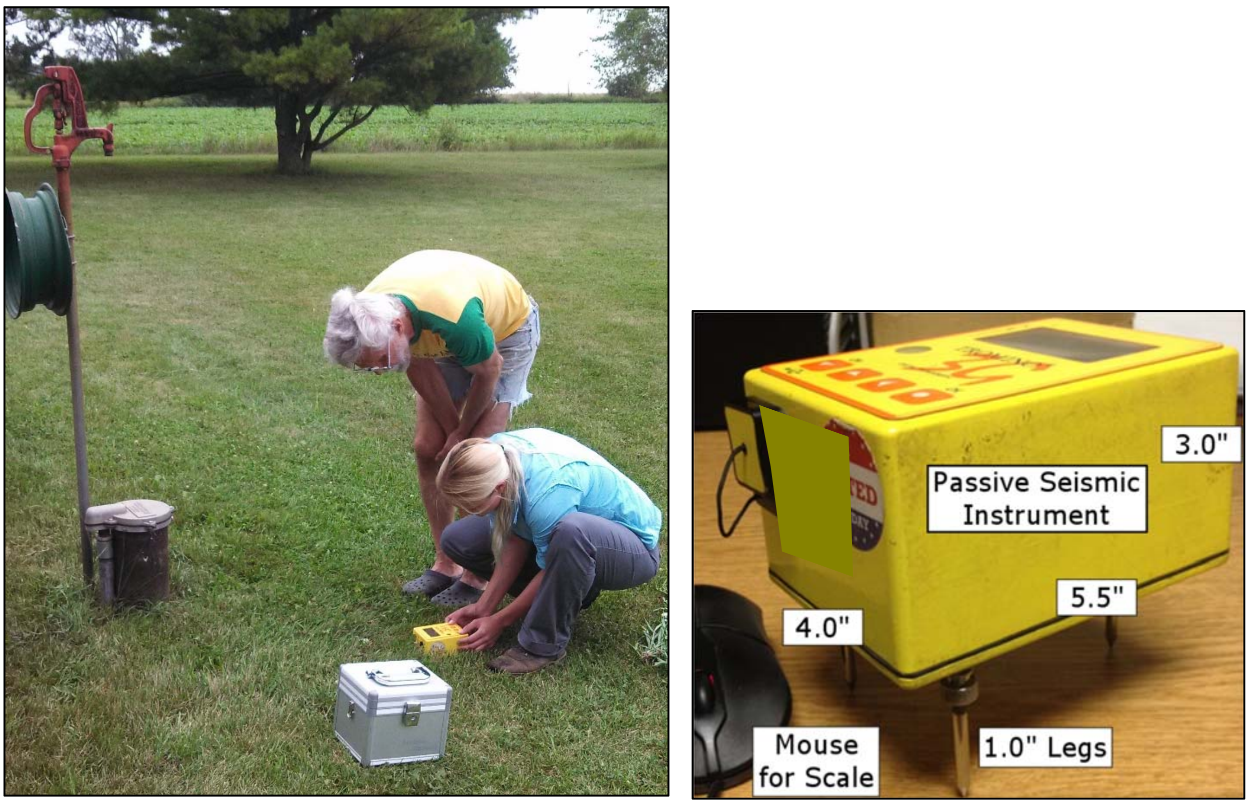
Monitoring wells and piezometers will be installed directly into boreholes drilled by Geoprobe, Rotosonic, or other drilling methods (see section: Exploratory Drilling). Monitoring wells installed close to the three lakes will provide a means for comparing lake levels to groundwater levels. Similar to the lakebed piezometer measurements (see section: Lakebed piezometer measurements), monitoring wells and piezometers will allow us to determine if water is flowing into or seeping out of lakes. By monitoring several wells and piezometers around each lake, we plan to develop a better understanding of surface water-groundwater interactions.


Photos 9 and 10 - Dedicated monitoring well measured to determine the water level (left). Nest of piezometers installed to monitor water levels associated with distinct horizons in the subsurface (right). Multiple piezometers are typically installed when low-permeability layers such as clay, separate two distinct aquifer units.

Surface geophysical methods

Surface geophysical methods will be used to estimate depth-to-bedrock and identify other subsurface features, which may influence groundwater flow. Geophysical measurements are particularly effective because they are non-invasive (no drilling or disturbance to ground), low-cost, and quickly provide an estimate of depth to bedrock. We plan to use passive seismic, ground penetrating radar, electrical resistivity imaging, and active seismic methods. Each method has unique applications depending on field conditions (sandy vs clayey/loamy surface materials; dry vs saturated surface materials) and the ability to image specific features (depth to bedrock, subsurface clay layers). Taken together, this suite of surface geophysical methods provides a robust tool for mapping geological features, which can constrain and influence groundwater flow.

The method which will be used most often for this study is the Horizontal-to-Vertical Spectral Ratio Passive Seismic Method (HVSR Passive Seismic). The HVSR Passive Seismic instrument has three 1-inch metal legs that are pushed into the ground on a level surface (see **Photos 11 and 12**). Data collection takes about 10-20 minutes, depending on ambient ground vibrations and the type of sediment or rock at depth. To prevent non-ambient vibration noise, such as footsteps, everyone should remain at least 20 feet away from the instrument during the measurement. Landowners do not need to be present while the data is collected, but are welcome to stay and observe. When performed on private property, landowners will be asked for permission prior to performing GPR transects on their land. The WGNHS anticipates taking tens to hundreds of HVSR Passive Seismic measurements to improve our understanding of the top-of-bedrock surface. Many of these will be performed along transects radiating away from Long, Plainfield, and Pleasant Lakes as well as other geologic features such as bedrock outcrops or tunnel channel features, which may influence groundwater flow. Measurements will also be taken in areas of known depth-to-bedrock, such as at existing wells or borings, to validate the accuracy of HVSR Passive Seismic.



Photos 11 and 12 - The HVSR Passive Seismic instrument shown in the field (left) and up close (right). The three 1-inch metal legs are inserted into the ground to record ambient ground vibrations for bedrock depth data collection. A computer mouse is shown for scale in the photo on the right. Ambient ground vibrations occur due to movement of objects at the ground surface penetrating down into the earth, such as the vibrating roots of a tree blowing in the wind.

Another geophysical method that will be used to estimate depth to bedrock is Ground Penetrating Radar (GPR) Examples of GPR equipment are included in **Photos 13, 14, and 15**. While the HVSR Passive Seismic method collects a single data point at each location, GPR can provide a two-dimensional profile image of the ground. The GPR instrument is an antenna that sends radio waves into the ground through a transmitter, which is either slowly towed behind a truck (about 5 mph) or pulled by hand. The radio waves sent down from the antenna, reflect off subsurface materials (e.g., sediments and rock) at depth and return to the antenna's receiver. The travel time of the radio waves from the transmitter back to the receiver provides an estimate of depth to specific subsurface features, such as the top of bedrock. The larger 80 MHz antenna can be towed by truck or pulled by hand on lightly travelled public roads, dirt roads, open fields, or grasslands. The smaller 500 MHz antenna is only pulled by hand but provides access to harder to access areas such as near buildings or in fields between rows of corn. When performed on private property, landowners will be asked for permission prior to performing GPR transects on their land. The WGNHS anticipates taking tens to hundreds of GPR measurements to improve our understanding of bedrock features such as the top of bedrock or clay layers, which may influence groundwater flow. GPR can be used to obtain two-dimensional subsurface profiles in areas where subsurface features of interest, such as the sediment-bedrock contact, are too deep for electrical resistivity imaging or too shallow for HVSR Passive Seismic.

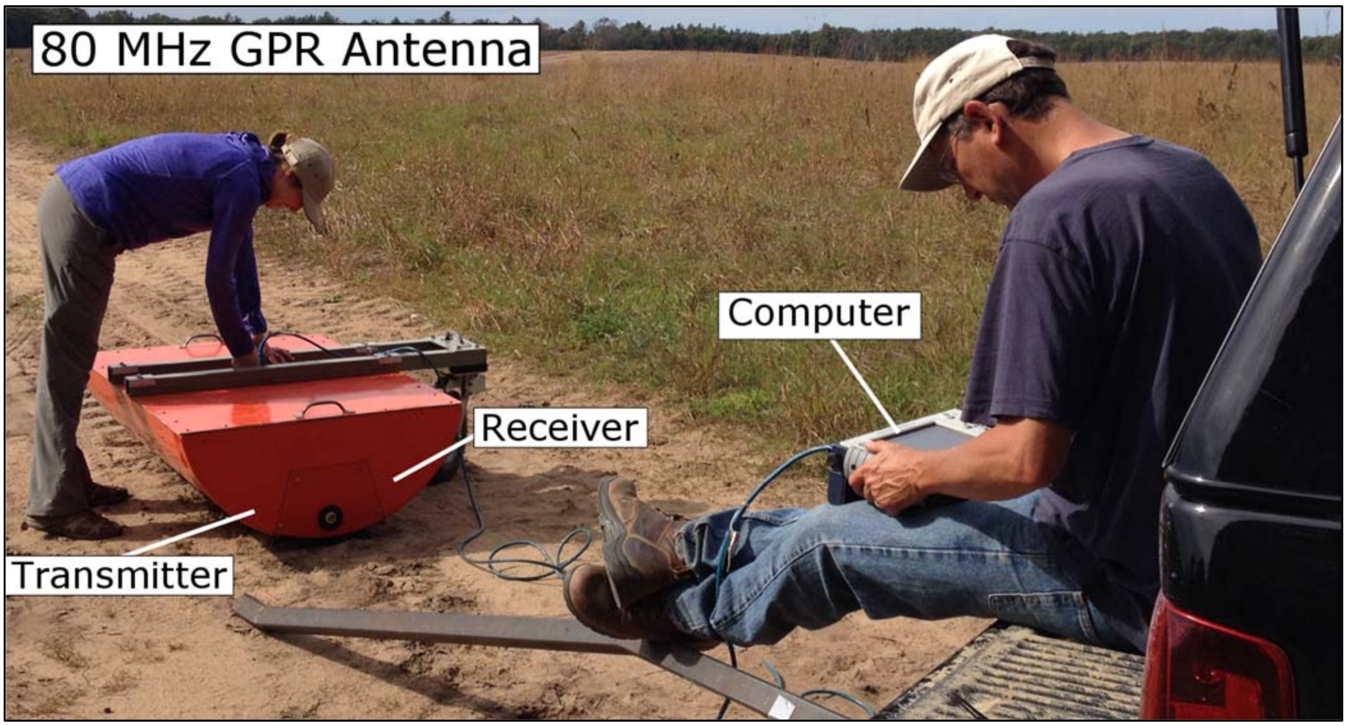


Photo 13 - The 80 MHz Ground Penetrating Radar (GPR) equipment during set-up onto the back of a pickup truck.

Photo 14 - The 80 MHz Ground Penetrating Radar (GPR) in action on the road. This unit is typically pulled behind a pickup truck along roads or open fields at slow speeds (about 5 mph).

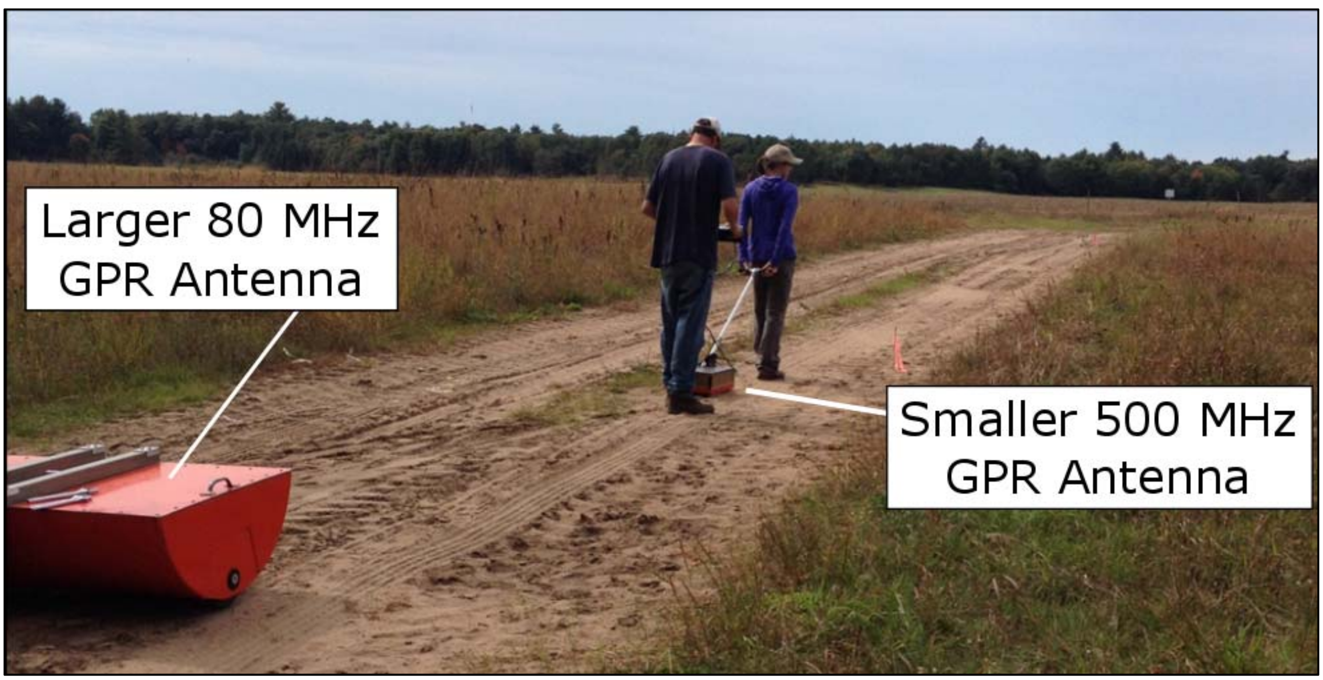


Photo 15 - The smaller 500 MHz Ground Penetrating Radar (GPR) antenna can be used wherever the larger 80 MHz antenna can be used; however, it is smaller and can easily maneuverable in tight areas, such as in a field between rows of corn. The 80 MHz might temporarily flatten taller standing grasses and weeds, but they usually recover after a day. If the 80 MHz were being towed by truck, the minimal damage would be a result of the truck tire tracks.

In the Electrical Resistivity Imaging (ERI) method, stainless steel electrodes are placed in a line in the ground and a small current is run through them. As the current travels through the earth, it is affected by the ambient resistivity levels of different sediments and rock units and the resulting current is then collected at the surface. These voltage changes are used to build an apparent resistivity profile of the subsurface. After apparent resistivity values are collected in the field, the data file is processed using inversion software to create a two-dimensional resistivity profile with depth of the subsurface. Subsurface sediment and rock type can be inferred from the resistivity values in the image. More competent units, like bedrock, consistently have higher resistivity values than less competent units in the overlying sediment. Dryer and/or harder subsurface units almost always have a higher resistivity than wetter and/or less competent subsurface units. The WGNHS anticipates taking tens to hundreds of ERI measurements to improve our understanding of bedrock features such as the top of bedrock or clay layers, which may influence groundwater flow. Photos of the ERI method are included in **Figure 2**.

Figure 2 - ERI survey line set-up. A) The survey line is a straight transect. B) The ERI instrument sends a current into the ground through electrodes. C) Electrodes are spaced evenly along the survey line. Two electrodes send the current into the ground, and two electrodes receive the current after it has gone through the subsurface.

The last method, active seismic, uses a hammer attached to a truck hitch to strike the ground and create a seismic wave. Geophones laid out in a line can measure the wave as it passes to help image the subsurface. The WGNHS anticipates taking tens to hundreds of GPR measurements to improve our understanding of bedrock features such as the top of bedrock or clay layers, which may influence groundwater flow.

Data/sample collection and data availability

All data and samples collected by the WGNHS as part of this study will be processed, compiled, and maintained by the WGNHS. As part of UW-Extension and the University of Wisconsin System, this data is part of the public record and will become publically available at the completion of the study. WGNHS data sets will be published as appendices or incorporated into a final project report prepared by the WDNR following the study.

Feel free to contact us directly should you have any further questions about the WGNHS' fieldwork effort.

Sincerely,

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