CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Foreign trip report for attending a 3-day short course entitled "The Principles, Practice and Processing of Ground Penetrating Radar". Administrative Item 20.06002.01.011.015

DATE/PLACE: July 7–9, 2004
Sensors & Software, Inc.
Mississauga, Ontario, Canada

AUTHOR: Sarah Gonzalez

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SENSITIVITY

Not applicable.

BACKGROUND/PURPOSE

The company Sensors & Software Inc. was formed in 1988. It designs, develops, manufactures, and sells ground penetrating radar (GPR) instrumentation and software. I traveled to Ontario, Canada to attend a three-day course on ground penetrating radar offered by Sensors & Software Inc. The course covered GPR theory, field survey training and practice, and data processing techniques.

ABSTRACT

The course covered the fundamentals of GPR. The first day of the short course was comprised of a series of lectures covering GPR concepts and history, basic electromagnetic (EM) theory (including physical properties and EM wave properties) relevant to GPR, and GPR instrumentation and survey design. The second day was a field day held at Borden test site. The Borden test site was developed by the Environmental Geophysics Facility at the University of Waterloo to aid in characterizing and quantifying the GPR response for specific buried target types. The purpose of this field day was to gain "hands on" experience using Sensors & Software's suite of GPR units (including equipment assembly, survey design and data collection). The group of attendees was divided into four groups and each group spent a period of time at each of four field stations. Each field station involved the use of a different GPR unit including water table mapping using the pulseEKKO 100 and buried object mapping using the pulseEkko 1000 and the Noggin^{Plus} and Noggin smart carts. The third and final day of the short course focused on GPR data processing techniques and interpretation using software programs developed by Sensors & Software. Attendees were divided into groups of two. Each pair was assigned a PC workstation in order to perform a series of assignments involving data plotting, processing, and interpretation.

DISCUSSION

The short course spanned three days. Each day was devoted to a particular aspect of GPR. A summary of the main activities performed on each day is provided below.

Day 1: GPR Theory

The first day of the short course consisted of a series of lectures covering GPR concepts and history, basic EM theory (including physical properties and EM wave properties) relevant to GPR, and GPR instrumentation and survey design.. GPR is a relatively young geophysical technique. This technique was developed in the 1950's, but commercial development of GPR instruments did not begin until the 1980's. The method essentially involves emission of an electromagnetic (EM) pulse into the ground. The signal travels through the material and is scattered and/or reflected by structures and changes in material properties (Annan, 2003).

The strength of a GPR signal depends on the physical properties of the transmitting material. In lossy, dielectric materials, EM fields can penetrate to a limited depth before being absorbed (Annan, 2003). Physical properties most critical to GPR include dielectric permittivity, electrical conductivity, and magnetic permeability. GPR is extremely useful for detecting and mapping areas of groundwater contamination because contaminants produce changes in the physical properties of groundwater. For example, a GPR signal disappears (or is absorbed) when water becomes enriched in chloride ions. EM wave properties, including phase velocity, attenuation, and electromagnetic impedance, are functions of the physical properties mentioned above.

The success of a particular GPR survey depends on the appropriate selection of GPR instrumentation and survey design factors. The most important factors to consider when designing a survey are related to target geometry, physical properties of both target and host, and characteristics of the survey environment. Data resolution is controlled by the frequency content of the GPR pulse, velocity, and target depth. Thus, the selection of the recording time window, temporal and spatial sampling interval, and antenna frequency is important.

Day 1 ended with GPR case studies where a broad range of applications of GPR were discussed. The water table is one of the strongest reflecting horizons because of the large impedance contrast between dry and saturated materials, which makes GPR a useful technique for groundwater studies, including groundwater contaminant mapping. GPR has also been used successfully for fracture mapping at potential underground nuclear waste storage sites.

Day 2: GPR Field Demonstrations

The second day was a field day held at Borden test site where we participated in GPR experiments at four field stations using different GPR units.

At the first field station we collected grid data using a Noggin^{Plus} 500 Smart cart, which is designed for applications requiring high-resolution (500 MHz) subsurface imaging. We collected data in a three-dimensional grid using a Noggin^{Plus} Smart Cart in three-dimensional reflection mode to locate buried objects within sandy soil deposits.

The second field station also involved mapping buried objects. In this case the mapping was performed using a pulseEKKO 1000. The pulseEKKO 1000 is designed for high-resolution subsurface mapping surveys with a range of shielded antenna frequencies of 110 to 1200 MHz. This station involved using this instrument in reflection mode to locate buried objects within sandy soil deposits. The responses from several frequencies were compared (including 500 MHz).

The third field station involved reconnaissance mapping using the Noggin Smart Cart. This station involved using a Noggin Smart Cart in reflection mode to locate buried objects within sandy soil using a frequency of 250 MHz.

The fourth field station involved water table mapping using the pulseEKKO 100. The pulseEKKO 100 is designed for deep sounding geologic surveys (including mapping depth to bedrock, groundwater studies, water table mapping) with a range of antenna frequncies of 12.5 to 200 MHz. We performed reflection profiling using the pulseEKKO 100 on a hill site to delineate the depth to the water table and detect a possible perched water table (or possible sense presence of landfill leachable contaminants, using 100 MHz frequency antennas. In addition, a common midpoint (CMP) reflection survey was performed in order to extract an estimate of velocity versus depth to facilitate conversion of reflection profile times to depth.

Day 3: GPR Data Processing

The third day primarily focused on GPR data processing techniques and interpretation using several different software programs developed by Sensors & Software. In addition, a demonstration was performed with the Conquest GPR unit. This instrument is typically used for non-destructive evaluation of concrete structures. Several Conquest GPR instruments (which is a Nogging^{Plus} 1000 unit) were set up at the Sensors & Software training facility site and then used to map rebar in the concrete floor.

The first part of the GPR data processing day described how to download Noggin Data from DVL or Digital Video Logger to a PC. This was then followed by a discussion and an assignment which focused on plotting Noggin data using the program Win_SpiView, plotting Noggin^{plus} and pulseEKKO data using the program EKKO_View.

The next session covered data editing techniques including gain selection, temporal and spatial filtering, topographic corrections, velocity extraction using hyperbola fitting, as well as CMP analysis and migration. This discussion was followed by series of assignments addressing the topics mentioned above using EKKO_View Deluxe software.

Next, a discussion was given describing factors which may affect data interpretation such as air wave reflections, and how air wave reflections may be interpreted. Various GPR images (from a number of different applications) were assigned and interpretations of these images were made based on velocity calculations, signal polarity, and reflectivity strength.

The last part of the GPR data processing day focused on the imaging of data collected in a two dimensional and three dimensional grid using the software EKKO Mapper, and the different types of image plots this software produces.

This GPR course was extremely beneficial. I became more familiar with this geophysical technique including potential applications, equipment use, data processing techniques, and interpretation. This geophysical method is extremely versatile and has many applications relevant to the NRC, including water table mapping (including the corresponding stratigraphy that controls ground water flow) and the evaluation of rock quality.

PENDING ACTIONS/PLANNED NEXT STEPS FOR NRC

None.

POINTS FOR COMMISSION CONSIDERATION/ITEMS OF INTEREST

None.

ATTACHMENTS

None.

"ON THE MARGINS"

None.

REFERENCES

Annan, A.P. "Ground Penetrating Radar Principles, Procedures and Applications". Sensors & Software Inc. Mississauga, Ontario, Canada. 2003.

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