United States Department of Agriculture

Natural Resources Conservation Service

11 Campus Boulevard
Suite 200
Newtown Square, PA 19073

Subject: Soils – Geophysical Field Assistance

Date: 6 February 2004

To: Margo Wallace
State Conservationist
USDA-NRCS
344 Merrow Road, Suite A (Rte 195)
Tolland, CT 0684-3917

Purpose:
A brief reconnaissance survey using ground-penetrating radar (GPR) and electromagnetic induction (EMI) was conducted in an attempt to identify buried utility lines near a culvert which is scheduled for repair as part of a tidal restoration project. The actual location of these lines is uncertain and it is possible that they do not occur near the roadbed.

Participants:
Nels Barrett, Ecologist, USDA-NRCS, Tolland, CT
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Ben Smith, Student Trainee Hydrologist, USDA-NRCS, Tolland, CT
Jim Turenne, Assistant State Soil Scientist, USDA-NRCS, Warwick, RI
Roger Wolfe, Connecticut DEP, Hartford, CT
Harry Yamalis, Connecticut DEP, Hartford, CT
Joe Zoubek, Connecticut DEP, Hartford, CT

Activities:
All activities were completed on the morning of 26 January 2004.

Equipment:
The electromagnetic induction meter used in this study was the EM38DD, manufactured by Geonics Limited.[1] Operating procedures are described by Geonics Limited (2000). The EM38DD meter is portable and requires only one person to operate. No ground contact is required with this meter. The EM38DD operates at a frequency of 14,600 Hz. It has effective penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively. The EM38DD meter consists of two EM38 meters bolted together and electronically coupled. One meter acts as a master unit (meter that is positioned in the vertical dipole orientation and having both transmitter and receiver activated) and one meter acts as a slave unit (meter that is positioned in the horizontal dipole orientation with only the receiver switched on).

The Geonics DAS70 Data Acquisition System was used to record and store both EMI and global positioning system (GPS) data.[1] The acquisition system consists of the EM38DD meter, an Allegro field computer, and a Trimble AG114 GPS receiver.[1] With the logging system, the EM38DD meter is keypad operated and measurements can either be automatically or manually triggered.

To help summarize the results of this study, the SURFER for Windows, version 8.0, developed by Golden Software, Inc., was used to construct a two-dimensional simulation.[1] The grid was created using kriging methods with an octant search.

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[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR System-3000), manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. The SIR System-3000 consists of a digital control unit (DC-3000) with keypad, SVGA video screen, and connector panel. A 10.8-volt lithium-ion rechargeable battery powers the system. The SIR System-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. With an antenna, this system requires two people to operate. A 400 MHz antenna was used in this study.

The RADAN for Windows (version 5.0) software program was used to process the radar record (Geophysical Survey Systems, Inc, 2003).[2] Processing included setting the initial pulse to time zero, color transformation, marker editing, distance and surface normalization, and range gain adjustments. Radar records were processed into a three-dimensional image using the 3D QuickDraw for RADAN Windows NT software developed by Geophysical Survey Systems, Inc.[2] Once processed, arbitrary time slices were viewed and selected images attached to this report.

Study Site

Both GPR and EMI were used to investigate a portion of a roadbed within Camp Harkness, Waterford, Connecticut. The roadbed borders a tidal wetland and a culvert is to be repaired or replaced as part of a proposed tidal wetlands restoration project. Geophysical methods were used to search for unidentified buried utilities beneath and/or adjacent to the roadbed.

Survey Procedures:

A *random walk* or *wildcat* survey was conducted with the EM38DD meter. Basically the operator walked randomly across the site with the meter. However, the search was centered on the roadbed where more observations were concentrated. The EM38DD meter was operated in the continuous mode with measurements recorded at 1-sec intervals. Each EMI measurement was simultaneously geo-referenced with the DAS70 Data Acquisition System. The EM38DD was held about 3 inches above the ground surface with its long axis parallel to the direction of traverse. Walking at a fairly brisk and uniform pace, in a random back and forth pattern along the roadbed and across adjoining areas, the EM38DD meter recorded 402 geo-referenced measurements.

A small grid, with dimensions of 10 by 12 m, was established across a portion of the roadbed that included the buried culvert pipe. The origin of the grid was in the northwest corner. Radar traverses were conducted orthogonal to the road. Pulling the 400 MHz antenna along thirteen equally spaced (100 cm) north-south trending grid lines in a back and forth manner completed the GPR survey. Each grid line was 10 m long. Reference points were spaced at 1-m intervals along each line. Along each line, as the antenna was towed passed a reference point, a vertical mark was impressed on the radar record.

The depth to the buried culvert was used to estimate the velocity of radar pulse propagation. The velocity of propagation and the dielectric permittivity is moisture dependent and varies with antenna frequency. At the time of the survey the surface was snow covered, and soils were frozen in the surface layers and saturated below. For the upper part of the soil, with the 400 MHz antenna, the estimated velocity of propagation was about 0.06 m/ns and the dielectric permittivity was about 24. These estimates were based on the approximated depth to the buried culvert. Later, based on a hyperbola-matching program in RADAN Windows NT, the velocity of propagation was also estimated to be 0.06 m/ns. Using these parameters, a scanning time of 30 ns provided a penetration depth of about 2 m.

The RADAN NT (version 3.1) software program was used to process the radar records. Processing included color transformation, marker editing, distance normalization, and range gain adjustments.

Interpretations:

<u>EMI Survey:</u>

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Figure 1 is a choropleth map that shows the spatial distribution of apparent conductivity (EC_a) obtained with the EM38DD meter. Apparent conductivity is expressed in millisiemen per meter, or mS/m. In Figure 1, color variations have been used to help show the distribution of EC_a. The color interval is 5 mS/m. To reduce spurious measurements and lines, the grid node editor of Surfer 8 was used to make slight changes (0.1 to 0.2 mS/m) to some of the measurements. The locations of the radar traverse line and observation points are shown in this figure. Also shown are the approximate locations of the road and the road culvert. The tidal wetland is located to the southeast.

In general, EC_a increases towards the southeast and this trend is associated with increased ionic concentrations in the brackish soil water as Long Island Sound is approached. The area of noticeably lower (< 20 mS/m) EC_a along the western boundary of the site represents a higher-lying, better-drained upland area with some exposed ledges of bedrock. The ends of the culvert have produced identifiable and anomalously high EC_a. No spatial patterns that indisputably suggest the present of buried utility lines are evident in this plot. However, in the central portion of the site, immediately adjacent to the north side of the roadbed and to the east of the road culvert, three aligned, anomalous polygons suggest the presence of a linear feature that parallels the roadbed. These polygons could represent the contact between the elevated roadbed materials with the surrounding soils or a shallow roadside ditch. While inferences can be made, results of the EMI survey are inconclusive. A more comprehensive EMI survey of the site could possibly improve the definition of the seemingly aligned anomalous features and clarify their identity. To improve the definition of any feature that parallels the roadbed, EMI traverses should be conducted orthogonal (north-south direction) to the roadbed.

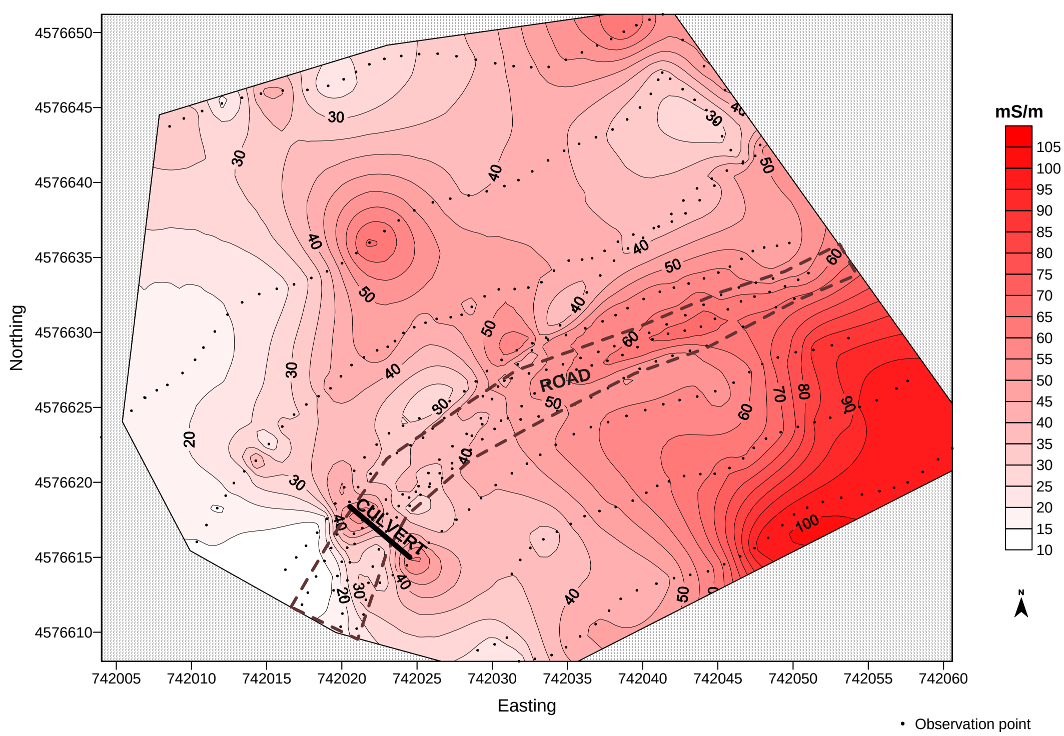

Figure 1. Plot of apparent conductivity collected with the EM38DD meter in the deeper-sensing (0-1.5 m) vertical dipole orientation. Distances are expressed in meters.

GPR Survey:

Figure 2 contains 3D time-sliced images of a 10 x 12 m grid area that was established across the roadbed. A portion of the grid area overlies the road culvert, which parallels the shorter (10-m) x-axis. Three-dimensional displays permit the viewing of all collected radar data at one time. Three-dimensional displays have proven useful in studies that require the identification of linear features. In order to generate a 3D display, data between the radar traverse lines are interpolated to produce a solid cube. In general, the quality and level of detail improves as the number of traverse lines increase and the spacing between these parallel lines decrease.

In Figure 2, the origin is located in the northwest corner of the grid site, and the X-axis (in foreground) extends in a north-south direction across the roadbed. The y-axis generally conforms to the long axis of the roadbed. In Figure 2, all units of measurement are expressed in meters. In Figure 2, horizontal "time slices" have been made across the 3D cube at intervals of 50 cm. These depth intervals were based on an estimated propagation velocity of 0.06m/ns through the soil. The amplitude anomaly slices shown in Figure 2 are useful for recognizing and plotting subsurface features that are difficult to distinguish on individual radar profiles.

In Figure 2, the road culvert provides high amplitude, dark green reflections that parallel that x-axis in the foreground of the display. The road culvert is best expressed at a depth of 1 m, but disturbed soil and reverberated signals are evident in the 0.5 and 1.5 m depths slices. At a depth of 50 cm, several short, segmented, linear anomalies that parallel the roadbed are evident. As these linear anomalies are all equally expressed and dispersed across the roadbed, no uniqueness can be attached to anyone.

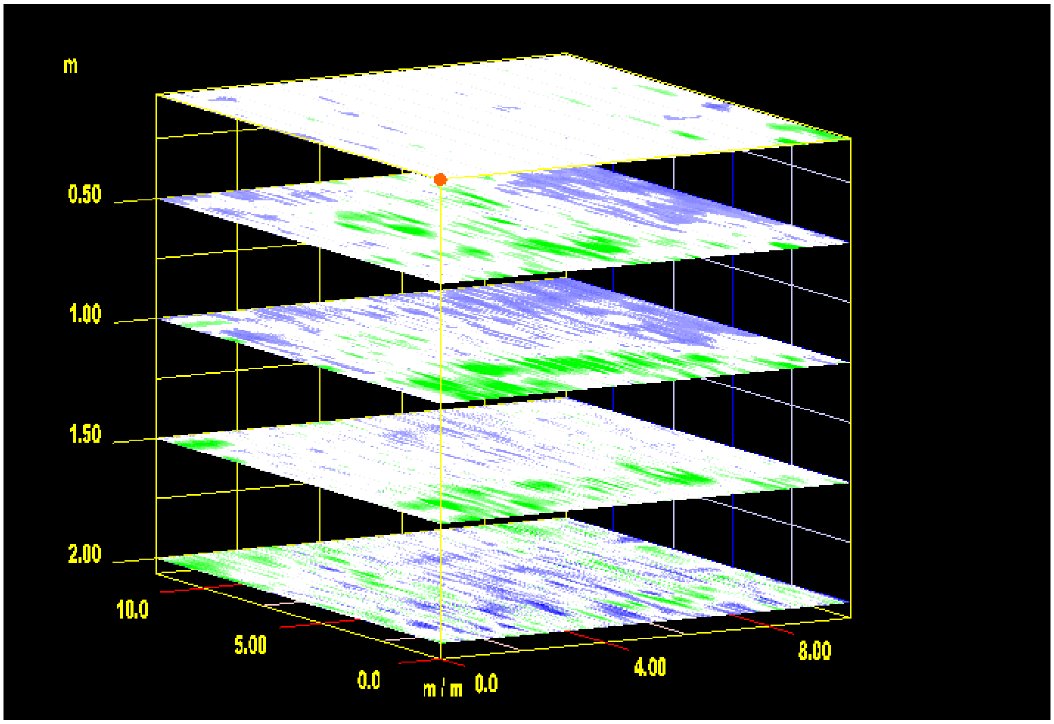

Figure 2. Three-dimensional time sliced radar imagery of a portion of the roadbed that is underlain by a buried culvert. Roadbed parallels the y-axis; culvert parallels the x-axis.

Other than the known road culvert, GPR did not provide indisputable evidence supporting the presence of buried utility lines underlying the roadbed.

It was my pleasure to work in Connecticut and with members of your fine staff.

With kind regards,

James A. Doolittle
Research Soil Scientist
National Soil Survey Center

cc:
B. Ahrens, Director, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
C. Olson, National Leader, Soil Investigation Staff, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
M. Golden, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250
K. Kolesinskas, State Soil Scientist USDA-NRCS, 16 Professional Park Road, Storrs, CT 06268-1299
N. Barrett, Ecologist, USDA-NRCS, 344 Merrow Road, Suite A (Rte 195), Tolland, CT 0684-3917
W. Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, P.O. Box 974, Federal Building, Room 206, 207 West Main Street, Wilkesboro, NC 28697

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