United States Department of Agriculture

Natural Resources Conservation Service

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Subject: SOI - Ground-penetrating radar assistance

Date: 30 June 1999

To: Janet Oertly
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Purpose:
The purpose of this study was to evaluate the suitability of ground-penetrating radar for charting the depth and expression of fragipans. This information is needed by researchers to better understand and model overland and subsurface flow patterns.

Participating Agencies:
USDA-ARS
USDA-NRCS

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
Peter Kleinman, Research Associate, USDA-ARS, University Park, PA
Brian Needelman, Graduate Student, PSU, University Park, PA

Activities:
All field activities were on 28 June 1999.

USDA-ARS Pasture Systems & Watershed Management Research Laboratory, Klingerstown, PA:
The study site is located in a cultivated field. The site is in an area of Watson soil. The very deep, well drained Watson soil is a member of the fine-loamy, mixed, mesic Typic Fragiudults family. Depth to fragipan ranges from 18 to 32 inches. Included soils are Berks and Buchanan. The moderately deep, well drained Berks soil is a member of the loamy-skeletal, mixed, mesic Typic Dystrochrepts family. The very deep, moderately well drained Buchanan soil is a member of the fine-loamy, mixed, semiactive, mesic Aquic Fragiudults family.

Equipment:
The radar unit used in this study was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc. The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. A 200 mHz and a 400 mHz antenna were used in this evaluation. A 12-volt battery powered the system.

Calibration:
Ground-penetrating radar is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (i.e., soil horizon, stratigraphic layer) and back. The relationships among depth (d), two-way, pulse travel time (t) and velocity of propagation (v), are described in the following equation:

$$d = vt/2 \qquad [1]$$

The velocity of propagation is inversely related to the bulk dielectric permittivity of the profiled material according to the equation:

$$e = (c/v)^2 \qquad [2]$$

where e is the bulk dielectric permittivity and c is the velocity of propagation in a vacuum (0.3 m/ns).

A metallic reflector was buried at a depth of about 38 cm (15 inches). The depth to this reflector was used to verify radar interpretations, estimate pulse propagation velocities, and establishes a crude depth scale for the radar profiles. Based on the round-trip travel time to this reflector, the averaged velocity of propagation through the upper part of the soil profile was estimated to be 0.1086 meters per nanoseconds (m/ns). Based on these velocities, a scanning time of 35 ns provided a maximum observation depth of about 1.9 m. The dielectric permittivity was estimated to be 7.6.

Interpretation:
Based on calibration trials, both antennas provided observation depths of about 2 m. However, signal attenuation limited the reliable profiling depth to about 0.75 m. The 400 mHz antenna provided greater resolution of subsurface features, similar profiling depths, and more interpretable results than from the 200 mHz antenna. Neither the argillic horizon nor the fragipan provided recognizable reflections. These horizons were closely spaced and apparently lacked sufficient contrast to be detectable with either antenna. The large number of rock fragments in these soils further weakens the expression of these diagnostic soil horizons. High levels of background noise partially masked and complicated the detection of desired reflections. Even with signal processing that removed this background noise, major soil horizons could not be detected with confidence. Some large size rock fragments were discernible to depths of about 1.5 meters on profiles collected with both the 200 and 400 mHz antennas.

Recommendation:

1. Results were too ambiguous to warrant further use of GPR in this study.

2. Several rock and tile drains cross the study area. I would be interested in returning to this site and evaluate the potential of electromagnetic induction (EMI) to detect and map buried drainage systems. In many states, soil scientists tasked with wetland determinations need to know if soils are drained or not. In many instances, only oral accounts exist concerning the presence of buried drains. Electromagnetic induction could help soil scientist verify the presence of buried field drains and facilitate wetland determinations.

3. A complete record of the radar profiles has been turned over to Dr. Peter Kleinman.

With kind regards,

James A. Doolittle

James A. Doolittle
Research Soil Scientist

cc:
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