United States	**Natural Resources**	**11 Campus Boulevard**
Department of	**Conservation**	**Suite 200**
Agriculture	**Service**	**Newtown Square, PA 19073**

Subject: Soils – Geophysical Field Assistance **Date:** 9 January 2004

To: Richard Vigil
Acting State Conservationist
USDA-Natural Resources Conservation Service
Dover, Delaware

Purpose:
The purpose of this investigation was to evaluate the use of ground-penetrating radar (GPR) to locate and size areas of buried construction debris in urban subdivisions.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Newtown Square, PA
Brian Felicia, Conservation Planner, New Castle Conservation District, Newark, DE
Richard Kelley, Debris Consultant, Delaware Natural Resource and Environmental Control Division, Newark, DE
Phillip King, Soil Scientist, USDA-NRCS, Georgetown, DE

Activities:
All activities were completed on 6 January 2004.

Results:

1. GPR distinguished different fill materials. GPR can be used to locate and size the extent of different fill materials.

2. With experience and fieldwork supported by soil borings, areas of disturbed and non-disturbed soils can be confidently distinguish on radar records by the radar operator.

3. GPR results are highly site specific. In New Castle County, better results were obtained over coarser-textured Coastal Plain deposits that over finer textured and more attenuating to radar, Piedmont deposits.

It was my pleasure to work in Delaware. The help and skills of Phillip King were greatly appreciated.

With kind regards,

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Equipment:
The radar unit is the TerraSIRch SIR (Subsurface Interface Radar) 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, color SVGA video screen, and connector panel. A 10.8-volt Lithium-Ion rechargeable battery powers the system. This unit is backpack portable and, with an antenna, requires two people to operate. The antennas used in this study have center frequencies of 200 and 400 MHz. However, the 400 MHz provided the best balance of penetration depth and resolution and was the preferred antenna.

The RADAN for Windows (version 5.0) software program was used to process the radar records (Geophysical Survey Systems, Inc, 2003).[1] Processing included color transformation, time-zero adjustment, marker editing, distance normalization, and range gain adjustments.

Background:
With a ban on burning, between 1960 and 1988, over 15000 permits were issued to bury stumps, tree limbs, and construction debris at sites in Newcastle County, Delaware. Since burial, these materials have decomposed resulting in soil subsidence and structural damage to many homes and buildings in Newcastle County. The use of ground-penetrating radar to locate and size areas of buried constructional debris in residential subdivisions was evaluated during this brief investigation.

Ground-penetrating radar has been used in to distinguish features within landfills (Bowders and Koerner, 1982) and locate the boundaries of landfill sites (Lawton et al. 1994). Ground-penetrating radar is noninvasive. Compared with traditional methods, GPR is faster and provides a greater number of observations per unit time. Therefore, GPR is more efficient and can provide more comprehensive site coverage than tradition soil borings.

Study Sites:
All sites were located in residential areas in northern Newcastle County. Sites 1 and 2 were located in the Northern Coastal Plain major land resource area (MLRA) near the town of Brookside. Site 1 was in a residential area best characterized as Fallsington soil. The very deep, poorly drained Fallsington soil forms on loamy marine and old alluvial sediments on flats and depressions within the coastal plain. Fallsington is a member of the fine-loamy, mixed, active, mesic Typic Endoaquults family. Site 2 was in a residential area best characterized as Sassafras soil. The very deep well drained Sassafras soil forms in sandy marine and old alluvial sediments on coastal plains. Sassafras is a member of the fine-loamy, siliceous, semiactive, mesic Typic Hapludults family. Site 3 was located in the Northern Piedmont MLRA near the town of Elsmere. Site 3 was in a residential area best characterized as Montalto soil. The very deep, well drained Montalto soil formed in residuum from basic igneous rocks on the Piedmont. The Montalto soil is a member of the fine, mixed, active, mesic Ultic Hapludalfs family.

Results:
Traverses were completed at each site with GPR. Figure 1 is a portion of the radar record from Site 1. A scale (in meters) is located along the left-hand side of the radar record. This scale represents the two-way travel time of the radar pulse. For the upper part of the soil profile, with the 200 MHz antenna, the velocity of propagation was estimated to be about 0.07 m/ns. Based on this velocity of propagation, a two-way travel time of 120 ns provides a maximum penetration depth of about 4.2-m. However, the maximum depth of clear and consistent imagery is less

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

than 3 m in these soil materials.   The segmented vertical lines at the top of the radar record represent equally spaced (about 5 paces) reference marks.

A vertical green line in Figure 1 approximates a boundary separating contrasting subsurface materials. To the left of this line, the soil surface was noticeably wetter and less firm. In this portion of the radar record, the subsurface is plagued with higher levels of low frequency noise and steeply inclined hyperbolas making interpretations difficult. To the right of the green line, background noise is more suppressed and high amplitude subsurface reflectors are not only detectable but are more continuous and planar. Though the break in subsurface materials is easily identified and the extent of each deposit may be readily determined with GPR, a small number of auger observations is required to confirm the identity of these materials.   The seemingly segmented planar reflectors to the right of the green line may represent layers of fill material or undisturbed coastal plain deposits.   With experience, GPR operators should be able to confidently identity subsurface materials based on the uniqueness of their graphic signatures on radar records.

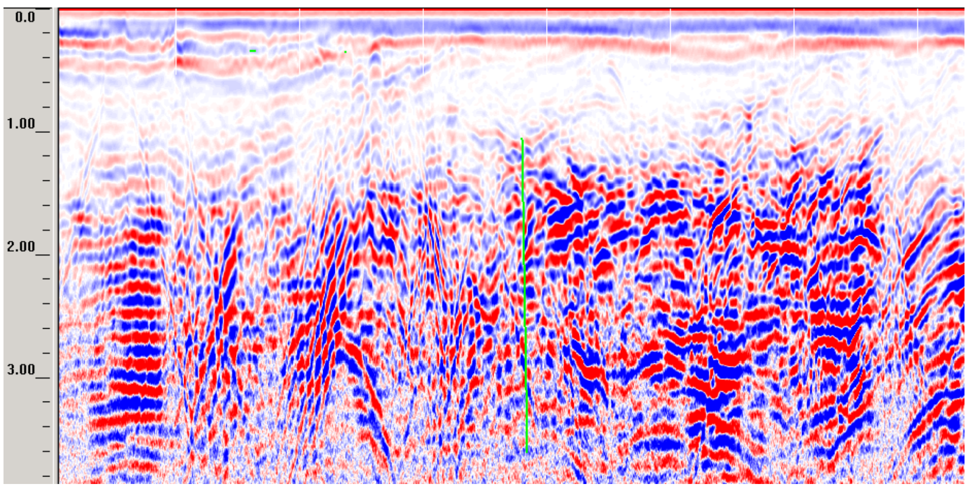

Figure 1. A portion of the radar record from Debris Site 1.

Figure 2 is a portion of the radar record from Site 2.   A scale (in meters) is located along the left-hand side of the radar record. This scale represents the two-way travel time of the radar pulse. For the upper part of the soil profile, with the 400 MHz antenna, the velocity of propagation was estimated to be about 0.07 m/ns. Based on this velocity of propagation, a two-way travel time of 80 ns provides a maximum penetration depth of about 2.9-m. The segmented vertical lines at the top of the radar record represent equally spaced (about 5 paces) reference marks.

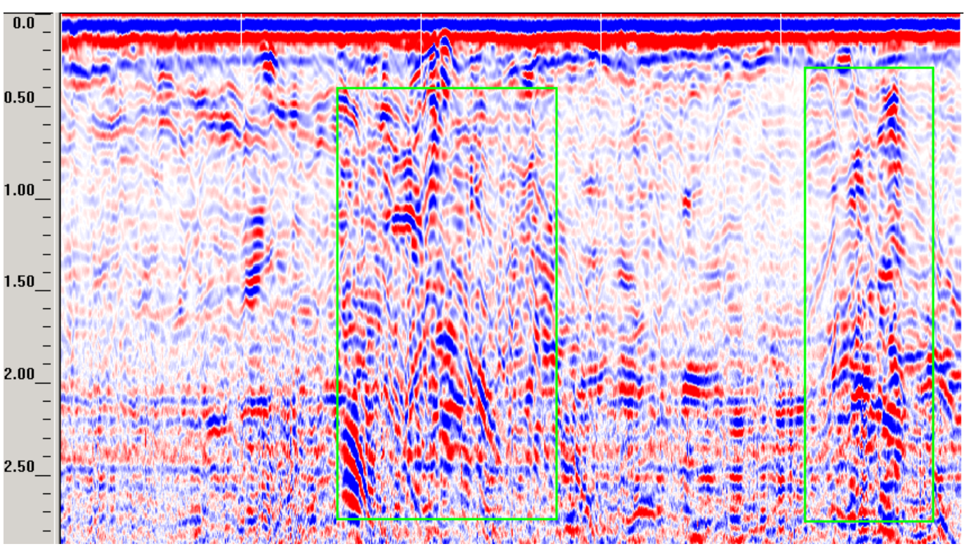

Figure 2. A portion of the radar record from Debris Site 2.

In Figure 2, two green rectangles identify areas of disturbed soil materials that contain an abundance of tree stumps, limbs, and debris. These interpretations were confirmed by auger observations made at the time of the survey. Because of subsidence, the soil surface was also observed to be uneven over these areas. The hyperbolic reflections evident in these outline areas represent contrasting point objects suspected to be tree stumps and limbs. The areas around and between the green squares are presumed to consist of either undisturbed soil materials, or fill materials that contain little woody debris. Greater experience is required to confidently identify and possibly differentiate these areas. Conducting radar surveys over non-disturbed ground and identifying radar signatures from natural soil profiles can increase operator confidence. Coastal Plain and alluvial sediments are stratified. These strata produce subsurface planar reflections of varying signal amplitudes. However, layers of fill material over disturbed sites can produce similar reflections. It is anticipated that with a little additional fieldwork and some ground-truth auger borings, the graphic signatures from disturbed and non-disturbed sites can be confidently distinguish by the radar operator.

Figure 3 is a portion of the radar record from Site 3. A scale (in meters) is located along the left-hand side of the radar record. This scale represents the two-way travel time of the radar pulse. For the upper part of the soil profile, with the 400 MHz antenna, the velocity of propagation was estimated to be about 0.10 m/ns. This estimate was based on the depth to a known reflector (140 cm). Based on this velocity of propagation, a two-way travel time of 80 ns provides a maximum penetration depth of about 4.2-m. The segmented vertical lines at the top of the radar record represent equally spaced (about 5 paces) reference marks.

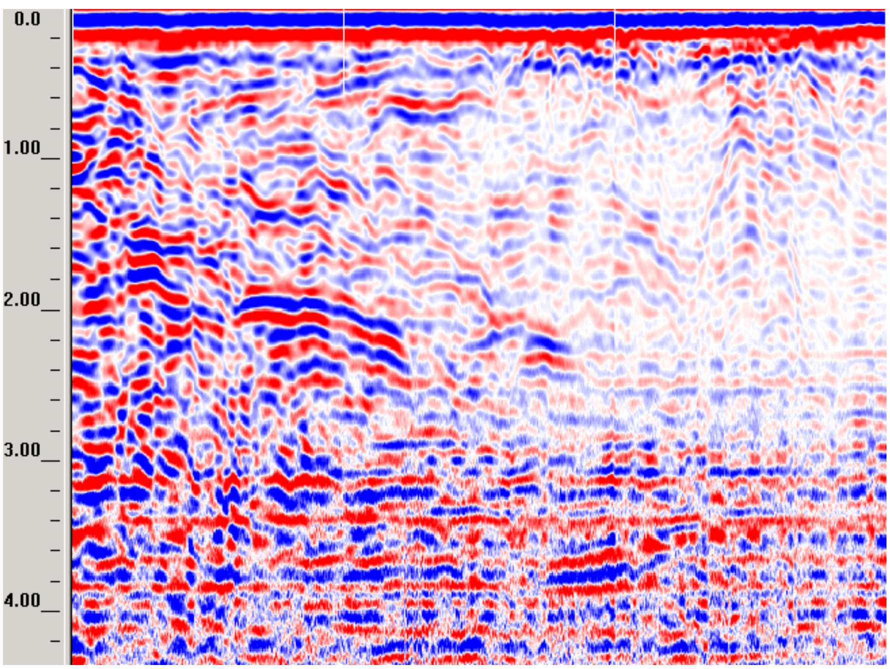

Figure 3. A portion of the radar record from Debris Site 3.

Coarser textured fill materials and stones underlie the left hand portion of Figure 3. Disturbed, finer-textured soil materials underlie the right hand portion of Figure 3. Because of the lower electrical conductivity of the coarser-textured materials, the radar energy is less rapidly attenuated and the depth to penetration is greater in this portion of the radar record. Because of the higher clay content of the fill material in the right-hand portion of this record, the radar energy has been more rapidly attenuated and the penetration depth is less. GPR distinguished the two different types of fill. However, if buried woody debris underlies layers of fine-textured fill material, because of signal attenuation and depth restrictions, it would not be detected with GPR.

References:

Bowders, J. J. and R. K. Koerner 1982. Buried Container detection using ground-probing radar. Journal of Hazardous Materials 7:1-17.

Daniels, D. J. 1996. Surface-Penetrating Radar. The Institute of Electrical Engineers, London, United Kingdom. 300 p.

Doolittle, J. A. 1987. Using ground-penetrating radar to increase the quality and efficiency of soil surveys. 11-32 pp. In: Reybold, W. U. and G. W. Peterson (eds.) Soil Survey Techniques, Soil Science Society of America. Special Publication No. 20.

Geophysical Survey Systems, Inc, 2003. RADAN for Windows Version 5.0; User’s Manual. Manual MN43-162 Rev A. Geophysical Survey Systems, Inc., North Salem, New Hampshire.

Lawton, D. C., H. M. Jol, and D. G. Smith. 1994. Ground penetrating radar for near-surface characterization: Example from the Canada Creosote Site, Calgary. p. 1275-1282. IN: GPR '94. Proceedings of the Fifth International Conference on Ground-Penetrating Radar. 12 to 16 June 1994. Kitchner, Ontario, Canada. Waterloo Centre for Groundwater Research and Canadian Geotechnical Society.

Morey, R. M. 1974. Continuous subsurface profiling by impulse radar. p. 212-232. IN: Proceedings, ASCE Engineering Foundation Conference on Subsurface Exploration for Underground Excavations and Heavy Construction, held at Henniker, New Hampshire. Aug. 11-16, 1974.