United States Department of Agriculture | **Natural Resources Conservation Service** | **100 Matsonford Road, 5 Radnor Corporate Center, Suite 200, Radnor, PA 19087-4585**

Subject: Geophysical Assistance -- **Archaeological** **Date:** 4 January 1999

To: Mary T. Kollstedt
State Conservationist
USDA-NRCS,
4405 Bland Road, Suite 205
Raleigh, North Carolina 27609

Purpose:
To provide ground-penetrating radar (GPR) field assistance to the Deep Creek Watershed Project, Yadkinville, North Carolina.

Participants:
B. J. Cook, District Conservationist, USDA-NRCS, Yadkinville, NC
J. Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
J. Errante, Archaeologist, USDA-NRCS, Columbia, SC
K. Kroeger, Geologist, USDA-NRCS, Raleigh, NC
P. Sheets, District Technician, Yadkin SWCD, Yadkinville, NC
J. Walker, District Project Coordinator, Yadkin SWCD, Yadkinville, NC
R. Williams, Engineer, USDA-NRCS, Raleigh, NC

Activities:
All field activities were completed on 18 December 1998.

Equipment:
The ground-penetrating radar (GPR) unit used in this study was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc.[1] The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. A 12-volt battery powered the system. Morey (1974), Doolittle (1987), Daniels and others (1988), and Conyers and Goodman (1997) have discussed the use and operation of GPR. The antenna used was the model 5103 (400 mHz). A scanning time of 40 ns (nanoseconds) was used in this study.

The radar profile included in this report has been processed through the WINRAD software package.[1] Post-acquisition computer processing was limited to signal stacking, horizontal scaling, and color transforms and table customizing. Color transformation and table customization were used to reduce signal amplitudes and background noise.

To help summarize the results of this study, the SURFER for Windows software program developed by Golden Software Inc. [1], was used to construct two-dimensional simulations. Grids were created using kriging methods.

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[1] Trade names have been used in this report to provide specific information. Their use does not constitute endorsement.

Study Site:
The study site is in an idle field located along South Deep Creek about 0.75-mile northeast of Branon, North Carolina. The site is in a delineated area of Congaree fine sandy loam (Curle, 1962). Congaree soil is a member of the fine-loamy, mixed, active, nonacid, thermic Typic Udifluvents family. This deep, well drained and moderately well drained soil forms in alluvium on floodplains.

Field Procedures:
A 10 by 85-meter survey grid was laid out across the study site. The grid intervals were 2.5 meters between rows and 5.0 meters along each row. Survey flags were inserted in the ground at each grid intersection and served as reference points. This procedure resulted in 90 reference points. Following calibration, the 400 mHz antenna was pulled along each of the five, 85-meter grid lines.

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 (e.g., soil horizon, stratigraphic layer, buried artifact) and back. To convert the travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector must be known. The relationships among depth (d), two-way, pulse travel time (t), and velocity of propagation (v) are described in the following equation (Morey, 1974):

$$v = 2d/t$$

The velocity of propagation is principally affected by the dielectric permittivity (e) of the profiled material(s) according to the equation:

$$e = (c/v)^2$$

Where c is the velocity of propagation in a vacuum (0.2998 m/ns). The amount and physical state (temperature dependent) of water have the greatest effect on dielectric permittivity.

Velocities of propagation and depth scales were calculated at the calibration site. A metallic reflector was buried at a depth of about 20 inches. Based on the round-trip travel time to the buried reflector, the averaged velocity of propagation through the upper part of the soil profile was determined and used to depth scale the radar record. The velocity of propagation was 0.09974 m/ns; the dielectric permittivity was 9.05. With a scanning time of 40 ns, the maximum depth of observation was about 1.99 m.

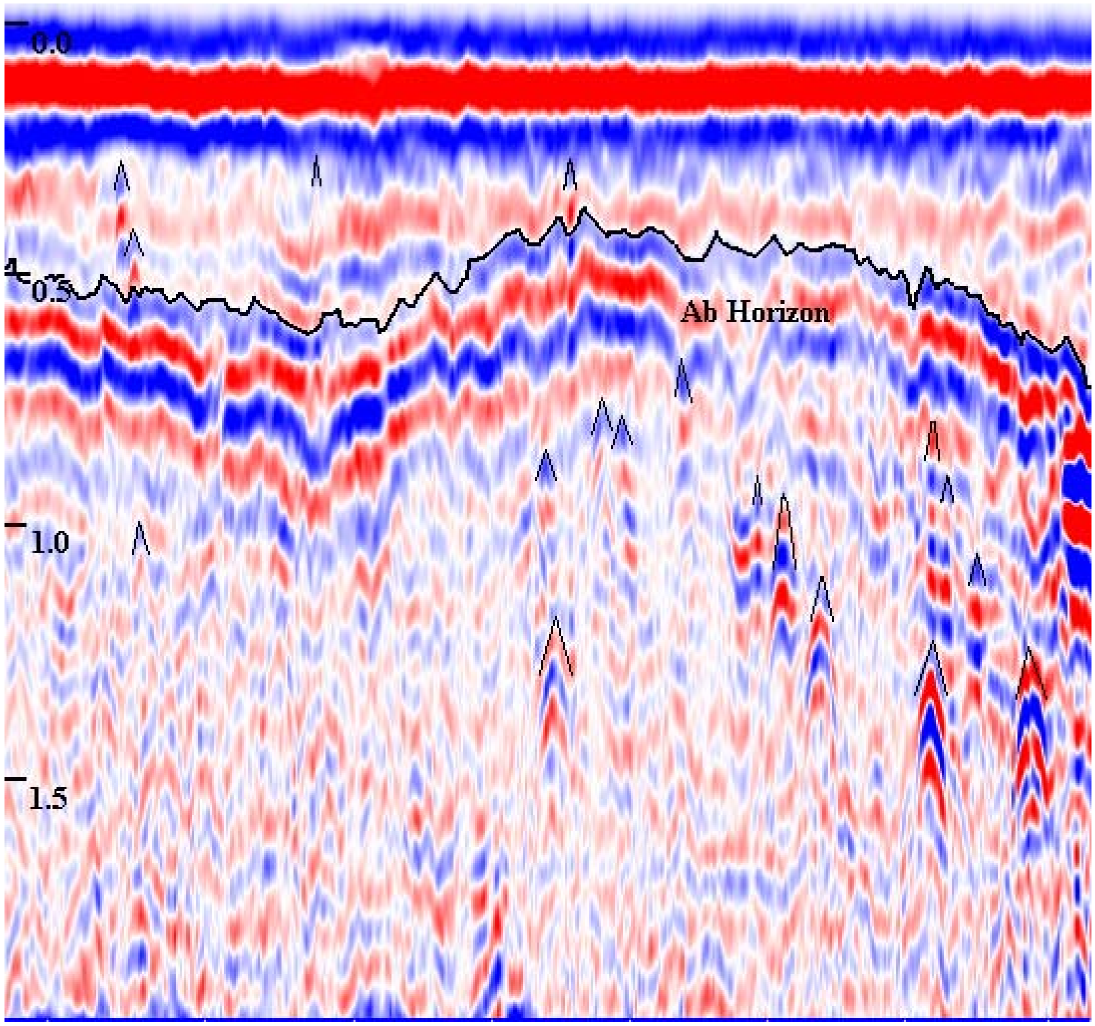
Interpretations:
In the search for buried cultural features with GPR, success is never guaranteed. Even under ideal site and soil conditions, some buried cultural features will be missed with GPR. The usefulness of GPR depends on the amount of uncertainty or omission that is acceptable to archaeologists.

Ground-penetrating radar provided satisfactory observation depths and high resolution of subsurface feature. Radar profiles were interpretable and contained an abundance of subsurface information. Figure 1 is a representative radar profile from the study site. In Figure 1, the depth (vertical) scale is in meters. The horizontal scale (distance) is about 35 m. Compared with the horizontal scale, the vertical scale is exaggerated.

In Figure 1, the series of blue and red parallel lines at the top of the radar profile represents reflections from the soil surface. Below the surface reflections, reflections from a conspicuous subsurface interface (highlighted with a dark line) can be traced across the radar profile. In Figure 1, this interface varies in depth from about 48 to 62 cm. This interface is believed to represent the boundary separating the C from the Ab horizon. However, this interpretation is unconfirmed as no soil probing or descriptions were made at the time of the radar survey.

In Yadkin County, the typical profile of Congaree soil has a surface layer of fine sandy loam overlying strata (C horizon) of loamy fine sand (Curle, 1962). Exploratory test pits within the study area have revealed a well defined, loamy, buried A horizon (Ab) at depths of about 45 cm. The C and Ab horizons have strongly contrasting clay and moisture contents. In Figure 1, the high amplitude of reflected signals from the subsurface interface is believed to be caused by contrast in clay and moisture contents across the C / Ab interface. The amount of energy reflected back to an antenna by an interface is a function of the dielectric gradient existing across an interface. The greater and more abrupt the difference in electromagnetic properties, the greater the amount of energy reflected back to the antenna, and the more intense will be the amplitude of the recorded image.

In Figure 1, the "Ab horizon", though continuous, is variable in expression. Reflections from this interface are more pronounced in the extreme right-hand portion of Figure 1. High amplitude reflections imply a more abrupt boundary, a greater contrast in the electrical properties of the bounding soil layers, or both. Differences in clay, organic matter, and water contents can cause the electrical properties to vary between these layers. In Figure 1, reflections from the "Ab horizon" have lower amplitudes and appear faint immediately above the layer's label. Here the boundary is presumed to be more gradual, the contrast in electrical properties less, or both.



Soils represent complex layered systems. In Figure 1, weaker, less contrasting layers can be observed on the radar profiles. These reflections were caused principally by variations in moisture and clay contents, compaction, and porosity.

Numerous point reflectors or anomalies were observable on radar profiles. Point anomalies appear on radar profiles as hyperbolas. Because of the wide angle (90^{o} fore and aft) of the transmitted radar beam, the antenna "sees" the point anomaly prior to being directly over it. As the antenna passes over and past an anomaly, it continues to "see" the feature. The resulting radar reflection is a hyperbola. In Figure 1, eighteen point anomalies have been highlighted with dark ∧-shaped lines. Some of these point anomalies may represent buried cultural features. The detection of these buried features is affected by the electromagnetic gradient existing between the feature and the surrounding soil matrix; the size, shape, and orientation of the buried cultural feature; and the presence of scattering bodies within the soil (Vickers et al., 1976). Buried cultural features with electromagnetic properties similar to the surrounding soil matrix are poor reflectors of electromagnetic energy and are difficult to detect on radar profiles (Doolittle, 1988; Gibson, 1989; Vaughan, 1986).

The size, orientation, and depth to a buried cultural feature affect detection. Large, electrically contrasting features reflect more energy and are easier to detect than small, less contrasting features. Small, shallowly buried features will be missed, unless located directly beneath the aperture of the radar's antenna. With GPR surveys covering extensive areas and using large grid intervals, the detection of small cultural features is considered fortuitous. The reflective power of a buried feature decreases proportional to the fourth power of the distance to the object (Bevan and Kenyon, 1975). As a consequence, small, deeply buried cultural features are difficult to discern on radar profiles.

Cultural features are difficult to distinguish in soils having numerous rock fragments, roots, animal burrows, modern cultural features, and debris or fill layers. These scattering bodies produce undesired subsurface reflections that complicate radar imagery and can mask reflections from buried cultural features. Frequently, "desired" cultural features are indistinguishable from background clutter.

Results:
Radar profiles were interpretable and contained an abundance of subsurface information. Depth of observation, while unconfirmed, was estimated to be about 2.0 m. A review of the radar profiles revealed a conspicuous subsurface interface believed to be the Ab horizon. Figure 2 is a two-dimensional plot summarizing the interpreted depth to this interface. In Figure 2, the contour interval is 0.10 m. The "Ab horizon" was more deeply buried and prominent (higher amplitude signals) in the lower (eastern) portion of this plot. In the upper (western) portion of this plot, this interface was more shallowly buried and was either not observed or more weakly expressed. Several additional subsurface interfaces were detected in the lower (eastern) portion of the study area (not shown in Figure 2).

Within the study site, the average depth to the "Ab horizon" is 52 cm with a range of 35 to 77 cm. One half of the observations had depths to this interface between 47 and 60.5 m. This interface was not detected at four reference points.

Also shown in Figure 2, are eighty prominent point anomalies detected within the upper 70-cm of the soil surface. These point reflectors occur above or within the buried Ab horizon. Some of these prominent point reflectors may represent buried cultural features. However, many may represent rock fragments, roots, or other buried features. The radar records contain an abundance of additional, less well-expressed or more deeply buried point reflectors. However, because of their poor expression or greater depth of burial, these point anomalies are neither identified nor plotted in Figure 2.

Summary:

1. Interpretations contained in this report are considered preliminary estimates of site conditions. These interpretations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. Interpretations should be verified by ground-truth observations.

2. Radar profiles were interpretable and contained an abundance of subsurface information. A major

subsurface interface believed to be the Ab horizon was identified on radar profiles. The depth to this interface as well as a large number of buried point reflectors was plotted in Figure 2. The point reflectors plotted in Figure 2 occur within the upper 70 cm of the soil profile.

3. Two radar traverses were conducted along the centerline of the proposed dam. For these traverses, the radar's observation depth was increased. These profiles charted the relative depths to several major subsurface strata. These radar profiles were turned over to Kim Kroger.

4. Copies of the radar profiles have been turned over to Jim Errante for use and further interpretations

It was my pleasure to be of some assistance to you and your staff.

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:
J. Culver, Acting Director, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
J. Errante, Archaeologist, USDA-NRCS, 1835 Assembly Street, Room 950, Columbia, South Carolina 29201
C. Olson, National Leader, Soil Survey Investigations, USDA- NRCS, National Soil Survey Center, Federal Building, Room 152, 100 Centennial Mall North, Lincoln, NE 68508-3866.
H. Smith, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250
G. Stem, ASTC-Water Resources, USDA-NRCS, 4405 Bland Street, Suite 205, Raleigh, NC 27609

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