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

Subject: Archaeology—Geophysical Assistance **Date:** 30 July 1998

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Purpose:
Ground-penetrating radar (GPR) was used to help locate buried cultural features within the *Spicebush Site*, Bards College, Annadale, New York. The buried cultural features related to the Lenni-Lenape Indians.

Participating Agencies:
Bard College
USDA-Natural Resources Conservation Service

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
Chris Linder, Professor, Bard College, Annadale, NY
Ed Stein, Resource Soil Scientist, USDA-NRCS, Cooperstown, NY

Activities:
All field activities were completed on 17 July 1998.

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 model 5103 (400 mHz) antenna was used in the investigation. The system was powered by a 12-volt battery. The use and operation of GPR have been discussed by Morey (1974), Doolittle (1987), and Daniels and others (1988).

Study Site:
The Spicebush site is located near the Hudson River and on the grounds of Bard College.

Survey Procedures*:*
Two survey lines were established across a comparatively open area within the site. These lines extend from near the river inland. The lines were 20 meters in length. Survey flags were inserted in the ground at 1 meter intervals along these lines. A third survey line was established orthogonal to the other two. This line was 15 m in length. Along this line, two survey flags were inserted in the ground at intervals of about 1 meter. A 4 by 4 meter grid was established and tied into the three survey lines. Figure 1 shows the location of the survey lines and grid.

The radar survey was completed by towing the 400 mHz antenna along each survey line and each east-west trending grid line. The radar antenna was pulled along either the north or east side of each survey or grid line. An additional radar traverse was conducted midway between the two, north-south survey lines. The file number, location, and direction of each radar traverse are also shown in Figure 1. Table 1 summarizes the radar traverses. The table shows the file number, traverse length and direction.

Table 1

File #	Length	Direction
1	20	south to north
2	20	south to north
3	20	south to north
4	15	east to west
5	4	east to west
6	4	east to west
7	4	east to west
8	4	east to west
9	4	east to west

Results:

Calibration of GPR:

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., buried artifact, soil horizon, stratigraphic layer, bedrock surface) 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 earthen material(s) according to the equation:

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

Where c is the velocity of propagation in a vacuum (1 m/nanosecond). Velocity is expressed in meters per nanosecond (ns). A nanosecond is one billionth of a second. The amount and physical state of water (temperature dependent) have the greatest effect on the dielectric permittivity of earthen materials.

Calibration trials were carried out near the site. The upper part of the soil profile was moist and moderately fine textured. A reflector was buried at a depth of 25 cm. The averaged velocity of propagation through the upper part of the soil profile was determined to be 0.069 m/ns. The dielectric permittivity was estimated to be 18.9. Based on an average velocity of propagation of 0.069 m/ns, a scanning time of 30 ns provided a maximum observation depth of about 1 meter. However, because of the high clay content and rates of signal attenuation, observation depths were less than 0.5 m.

Interpretations:

The 400 mHz antenna provided continuous, detailed images of the subsurface. In this brief survey, the radar provided about 95 meters of continuous subsurface information (to a depth of about 0.5 m).

The radar provided highly resolved images of feature occurring with the upper 0.5 m of the soil profile. Because of the high rates of signal attenuation, little information was gathered below a depth of 0.5 m with the 400 mHz antenna. Because the antenna often passed too close to many of the survey flags, dark, reverberated reflections from the flags were pickup at many observation points (dashed vertical lines on radar profiles). The lower part of radar profiles contains broad parallel bands of noise. This noise was produced by the high gain settings used to amplify weaker subsurface reflections.

No major subsurface feature was evident on radar profiles. Sixty-five point reflectors were identified on radar profiles. These reflectors varied in depth, size, signal amplitude, and appearance. The locations of these point reflectors are plotted in Figure 2. While the radar detects subsurface reflectors, it does not identify these features. The greatest concentrations of point reflectors occur in the southeast portion of the grid and between observation points 8 and 16 m on the north-south survey lines. As the site was located in a forest area, many of the point anomalies are believed to represent tree roots. Some represent rock fragments, animal burrows, or buried cultural features.

Conclusions:

1. Interpretations are considered preliminary estimates of site conditions. The results of geophysical site investigations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. All interpretations should be verified by ground-truth observations.

2. Dr. Linder will use the radar profiles to direct exploratory excavations in the area by students. This will provide verification of radar interpretations. Copies of these radar profiles have been mailed to Ed Stein for delivery to Dr. Linder.

It was my pleasure to work with and to be of assistance to members of your fine staff.

With kind regards,

James A. Doolittle
Research Soil Scientist

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References

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