United States Department of Agriculture

Natural Resources Conservation Service

11 Campus Boulevard
Suite 200
Newtown Square, PA 19073
Phone 610-557-4233; FAX 610-557-4136

Subject: Archaeology -- Geophysical Assistance **Date:** 22 August 2003

To: Richard W. Sims
State Conservationist
9173 West Barnes Drive
Suite C
Boise, ID 83709

Purpose:
Ground-penetrating radar (GPR) was used to help students at Jennifer Junior High School in Lewiston, Idaho, locate unmarked burials within the Normal Hill Cemetery.

Participants:
Sreve Branting, Lewis and Clark Rediscovery Project, Lewiston, ID
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Newtown Square, PA
Nate Ebel, Student, Jennifer Junior High School, Lewiston ID
Chris Wagner, Student, Jennifer Junior High School, Lewiston ID

Activities:
All field activities were completed on July 19, 2003.

Equipment:
The radar unit is the Subsurface Interface Radar (SIR) System-2000, 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-2000 consists of a digital control unit (DC-2000) with keypad, VGA video screen, and connector panel. A 12-volt battery powers the system. This unit is backpack portable and, with an antenna, requires two people to operate. The antenna used in this study has a center frequency of 400 MHz. Hard copies of the radar data were printed in the field on a model T-104 printer.

The RADAN NT (version 3.0) software program developed by Geophysical Survey Systems, Inc., was used to process the radar records.[1] Radar records contained in this report were converted into bitmap images using the Radan to Bitmap Conversion Utility (version 1.4) developed by Geophysical Survey Systems, Inc.[1] Radar records were processed into three-dimensional images using the 3D QuickDraw for RADAN Windows NT software developed by Geophysical Survey Systems, Inc.[1] Once processed, arbitrary cross-sections and time slices were viewed and selected images saved to files.

Background:
In 1889, faced with expansion, the city of Lewiston exhumed graves at the city's overcrowded cemetery and reinterred them at a new cemetery on the edge of town, the Normal Hill Cemetery. Gifted students at the Jennifer Junior High School in Lewiston have geo-referenced every gravesite within the Normal Hill Cemetery. However,

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

some burials are unmarked and it is therefore unclear how many individuals were buried or whether some were reinterred in a mass grave.

GPR:

Ground-penetrating radar is a non-invasive, high-resolution geophysical tool that has been used extensively for archaeological investigations. GPR has been proven to be a useful for locating burials (Bevan, 1991; Gracia et al., 2000; King et al., 1993; and Vaughan, 1986). However, results vary with soil conditions. In some soils, rates of signal attenuation are so severe that GPR cannot profile to required depths. In other soils, complex soil horizons, rock fragments, animal burrows, and/or tree roots mask the presence of burials. Even with favorable site conditions (i.e. dry, coarse-textured soils) the detection of a burial is never guaranteed with GPR. The detection of burials is affected by (i) the electromagnetic gradient that exists between the buried feature and the soil, (ii) the size and shape of the buried feature, and (iii) the presence of scattering bodies within the soil (Vickers et al., 1976).

The amount of energy reflected back to an antenna by a buried object is a function of the dielectric gradient existing between the object and the surrounding soil. The greater or more abrupt the difference in dielectric properties, the greater the amount of energy that is reflected back to the antenna, and the more intense will be the amplitude of reflections on the radar record. At first, most buried objects contrast with the surrounding soil matrix. However, with the passage of time, buried objects decay or weather and become less electrically contrasting with the surrounding soil matrix. For burials, the rate of decay or weathering varies with the materials used to contain the corpse. Corpses may be buried in sacks, body bags, or in wooden, fiberglass, composite, or metal caskets. If a coffin is partially intact, an air-filled void may exist, which is generally detectable with GPR.

The size and depth of a burial affect detection. Large objects reflect more energy and are easier to detect than small objects. In addition, the reflective power of an object decreases proportional to the fourth power of the distance to the object (Bevan and Kenyon, 1975). Most bones are too small and generally indistinguishable with GPR (Bevan, 1991; Killam, 1990). Bevan (1991) noted that it is more likely that GPR will detect the disturbed soil within a grave shaft, a partially or totally intact coffin, or the chemically altered soil materials, which directly surrounds a burial rather than the bones themselves. However, in soils that lack contrasting horizons or geologic strata, the detection of a grave shaft is improbable. In addition, with the passage of time, natural soil-forming processes will erase the signs of disturbances.

Burials are difficult to distinguish in soils having numerous rock fragments, tree roots, animal burrows or stratified or segmented soil layers. These scattering bodies produce undesired subsurface reflections, which complicate radar records and mask the presence of burials. Under such conditions, burials may be indistinguishable from the background clutter.

Survey Procedures:

Multiple grids were established across designated cemetery rows. Most grids had dimensions of 10 by 2 m with their long axes aligned in a north-south direction. Two grids had dimensions of 8 by 1.5 meters. The addendum to this report lists the location, direction of travel, and GPR file number for each traverse. The origin of each grid was in the northwest corner. While burial practices change with time, it was assumed that coffins would be orientated with their long axis orientated in an east-west direction and buried at a depth of 1 to 2 m. Radar traverses were conducted orthogonal to the assumed orientation of the graves. For most grids, pulling the 400 MHz antenna along five equally spaced (50 cm) north-south trending grid lines in a back and forth manner completed a GPR survey. 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 scanning time was set to 30 ns. The soil was generally dry at the time of this investigation. Based on a hyperbola-matching program in RADAN Windows NT, the velocity of propagation was estimated to be 0.13 m/ns. The dielectric permittivity was estimated to be 5, which corresponds to tabled values for dry, sandy soil.

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:
Figure 1 is a representative radar record from the cemetery. The short, white, vertical lines at the top of the radar record represent the equally spaced (1 m) reference points along the radar traverse. The vertical scale along the left-hand margin of this figure is a depth scale that is based on a velocity of pulse propagation of 0.13 m/ns. Note that the depth scale in Figure 1 is exaggerated relative to the horizontal scale by a factor of about 2.5.

In the left-hand portion of Figure 1, the low amplitude, hyperbolic reflector at a depth of about 1 m is believed to represent a burial. During the course of several grid surveys, additional hyperbolic reflectors were identified. Generally, these reflectors were aligned in an east-west orientation and occurred at a similar depth. This repeated pattern suggested burials. Most were at an estimated depth of about 1 m. Some corresponded with headstones, others were unmarked. These hyperbolic reflectors, while prominent, did vary in size, shape, and amplitude. Some larger reflectors appeared to consist of two or more, superimposed reflectors, which suggested multiple, closely spaced burials. While most radar records contained hyperbolic reflectors, no indications of grave shafts were evident above these reflectors. The absence of a noticeable grave shaft was attributed to homogenous soil properties.

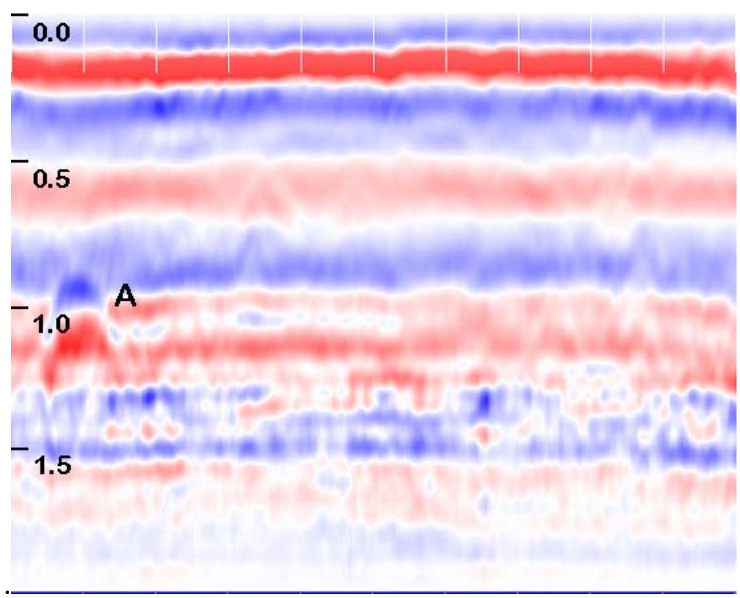


Figure 1. A representative radar record from the Normal Hill Cemetery.

Broad parallel bands of noise plague the radar records (see Figure 1). Meaningful information is generally restricted to depths of less than 1.25 to 1.5 m. Several small, weakly expressed point anomalies, identified by their hyperbolic patterns, were evident in the upper part (< 0.3 m) of radar records. These features may represent buried artifacts, burrows, and/or roots.

In general, the more recent burials produced higher amplitude subsurface reflections than older burials. This suggests variations in burial procedures, coffin materials, and/or the effects of weathering. Several unmarked graves were detected with GPR. In general, these displayed lower signal amplitude, which suggested older burials. It is probable that some burials were not detected with GPR. At the Normal Hill Cemetery, some burials were not detected with GPR over known, marked gravesites. It was assumed that these corpses had been buried in more easily weathered materials and lacked sufficient contrast and/or size to be detected with the 400 MHz antenna. Though highly speculative, another possibility is that several of these marked graves lack buried corpses. No evidence supporting a mass grave was observed on the radar records.

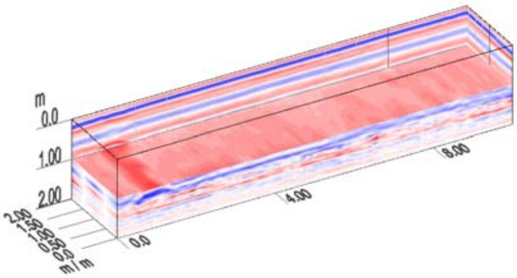
3D Time sliced image:

Three-dimensional interpretations of GPR data have been used to identify burials, middens, and other cultural features (Conyers and Goodman, 1997, Whiting et. al, 2000). In the past, the use of 3-D images has been restricted because of the time required to conduct fieldwork over limited areas and the lack of satisfactory signal-processing software. The recent development of sophisticated signal-processing software has enabled signal enhancement and improved pattern- recognition on radar records.

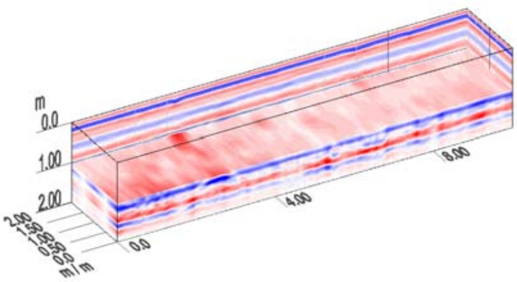
Figure 2 contains 3D block diagram of each 10 x 2 m grid area. All units of measurement are expressed in meters. The origin is located in the northwest corner of each grid. A horizontal "time slice" was made across each cube at a depth of about 1 m, the anticipated depth of burials. This depth was based on an assumed signal propagation velocity of 0.013m/ns through the soil. At this depth, several hyperbolic reflectors are aligned on adjoining radar records and form linear patterns of high amplitudes (dark red colors) that suggest burials (burials are longer in one direction than the other).

Burials generally are inferred when hyperbolic reflections are aligned and occur at a uniform depth on three or more radar traverses (Bevan, 1991). At Normal Hill Cemetery, multiple radar traverses in front of headstones often indicated the presence of a series of reflectors that form a linear pattern at a uniform depth and orientated in an east to west direction. These reflectors were assumed to be burial.

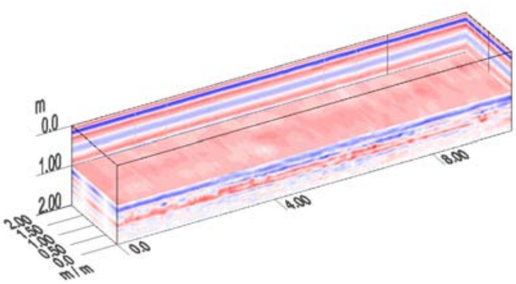
With the exception of Grid #3, conspicuous linear patterns suggesting probable burials were evident in all grids. In all grids, additional, less pronounced linear reflectors were evident at differing depths, but these features were too ambiguous to be identified as burials. In Grid #1, distinct hyperbolic reflections and a prominent linear pattern extends in an east-west direction at X = 1 m. In Grid #2, distinct, but segmented, hyperbolic reflections occur at X = 3 to 3.5 m. These reflectors form a linear pattern that extends in an east-west direction. In Grid #4, distinct hyperbolic reflections and prominent linear patterns extend in an east-west direction at X = 6.5 to 7, and 9 to 10 m. These patterns suggest multiple, closely spaced burials. In Grid #5, distinct, closely spaced, hyperbolic reflections and prominent linear patterns, which extend in an east-west direction, suggest two sets of multiple burials at X = 7 to 7.6 and 8 to 9 m. In Grid #5, a weaker set of reflectors is also evident at X = 2. Grid #6 contains several very faint and ambiguous reflectors that form narrow linear patterns. A broad reflector near X =10 provides the best choice for a possible burial. In Grid #7, a small, distinct, hyperbolic reflector is evident near X=10. As reverberations are evident, this reflector is presumed to represent a buried metallic object. In Grid #9, a broad hyperbolic reflection produces a conspicuous, linear band that extend in an east-west direction at X = 8 to 9 m. The breath of this reflector suggests multiple, closely spaced burials. In addition, a unique, more scattered pattern of short, segmented reflectors between X = 1 and 3 m suggests possible burials.



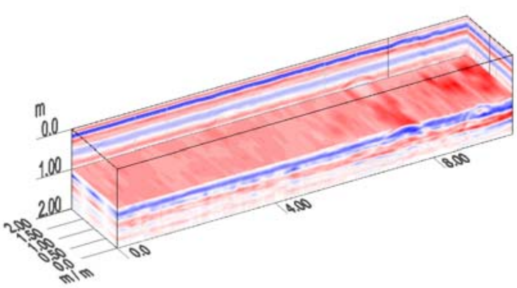
Grid #1



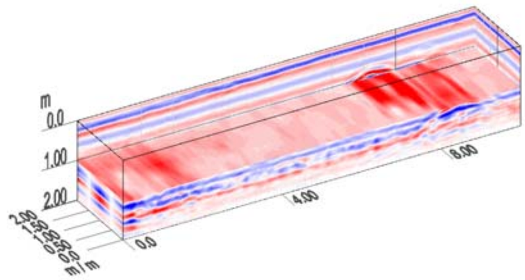
Grid #2



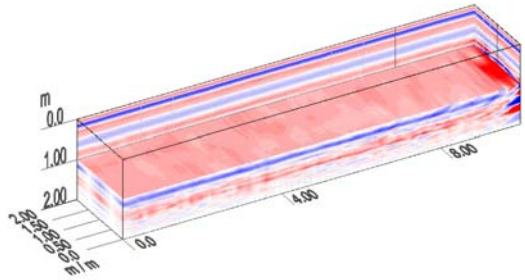
Grid #3



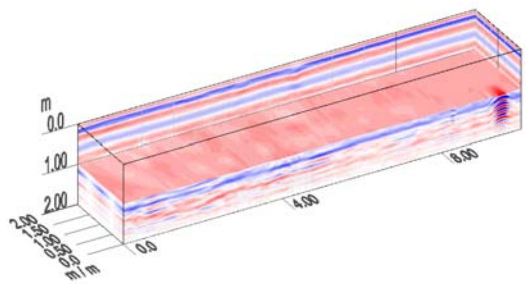
Grid #4



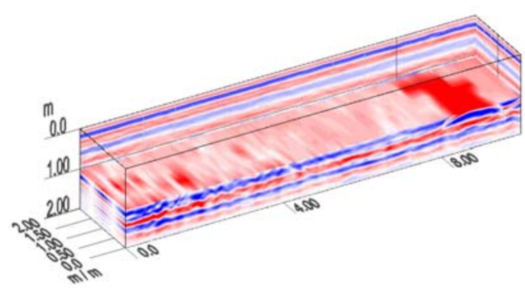
Grid #5



Grid #6



Grid #7



Grid #9

Figure 2. 3D time-sliced images of grid areas within the Normal Hill Cemetery.

Findings:

1. Geophysical interpretations are considered preliminary estimates of site conditions. The results of geophysical site investigations are interpretive and do not substitute for direct ground-truth observations. The use of geophysical methods can reduce the number of coring observations, direct their placement, and supplement their interpretations.

2. In a brief period, ground-penetrating radar was used to locate several unmarked graves within a portion of the Normal Hill Cemetery. The number of detected gravesites does not agree with the number of burials that were supposedly reinterred in this cemetery from the city's overcrowded cemetery in 1889. No evidence supporting a mass grave was detected. Knowledge of the presence and locations of these burials will assist students unravel this segment of the Lewiston's history and may lead to the location of additional burials.

3. Bitmap images of all radar records and selected 3D time sliced images of the grids have been mailed to Steve Branting under a separate cover letter. Students may use these images to document their work and findings.

It was my pleasure to assist Steve Branting and his students in this project.

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
S. Branting, Gifted & Innovated Program, Independent School District1, 1213 16th Street, Lewiston, ID 83501
D. Hoover, State Soil Scientist, USDA-NRCS, 9173 West Barnes Drive, Suite C, Boise, ID 83709-1574
W. Maresch, Acting Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250
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
W. Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, P.O. Box 974, Federal Building, Room G08, 207 West Main Street, Wilkesboro, NC 28697

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Addendum

Cemetery Row 75

Grid 1

Line 1	North to South	File 1
Line 2	South to North	File 2
Line 3	North to South	File 3
Line 4	South to North	File 4
Line 5	North to South	File 5

Grid 2

Line 1	North to South	File 6
Line 2	South to North	File 7
Line 3	North to South	File 8
Line 4	South to North	File 9
Line 5	North to South	File 10

Grid 3

Line 1	North to South	File 11
Line 2	South to North	File 12
Line 3	North to South	File 13
Line 4	South to North	File 14
Line 5	North to South	File 15

Grid 4

Line 1	North to South	File 16
Line 2	South to North	File 17
Line 3	North to South	File 18
Line 4	South to North	File 19
Line 5	North to South	File 20

Grid 5

Line 1	North to South	File 21
Line 2	South to North	File 22
Line 3	North to South	File 23
Line 4	South to North	File 24
Line 5	North to South	File 25

Cemetery Row 74

Grid 6

Line 1	North to South	File 26
Line 2	South to North	File 27
Line 3	North to South	File 28
Line 4	South to North	File 29
Line 5	North to South	File 30

Cemetery Row 72

Grid 7

Line 1	North to South	File 31
Line 2	South to North	File 32
Line 3	North to South	File 33
Line 4	South to North	File 34
Line 5	North to South	File 35

Cemetery Row 51

Grid 8

Line 1	North to South	File 36
Line 2	South to North	File 37
Line 3	North to South	File 38
Line 4	South to North	File 39

Cemetery Row 52

Grid 9

Line 1	North to South	File 41
Line 2	South to North	File 42
Line 3	North to South	File 43
Line 4	South to North	File 44
Line 5	North to South	File 45

Cemetery Row 53

Grid 10

Line 1	North to South	File 46
Line 2	South to North	File 47
Line 3	North to South	File 48
Line 4	South to North	File 49

Notes:

1. The origin of grid 1 was located 50 cm east of the southern headstone with Chinese inscriptions in cemetery row 75. All other grids (2-5) were located sequentially to the south of grid 1. Adjoining grids shared common boundaries.

2. The southwest corner of grid 6 was located about 1 m to the east of the Endicott headstone in cemetery row 74.

3. The southwest corner of grid 7 was located about 1 m to the east of the Wall headstone in cemetery row 72.

4. The southwest corner of grid 8 was located about 1 m to the east of the Martin headstone in cemetery row 51.

5. The origin of grid 9 was located at the intersection of cemetery row 52 and the cemetery road.

6. The origin of grid 10 was located at the intersection of cemetery row 53 and the cemetery road.