| United States Department of Agriculture | Natural Resources Conservation Service | 100 Campus Boulevard Suite 200 Newtown Square, PA 19087-4585 |
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**Subject:** Archaeology -- Geophysical Assistance **Date:** 6 June 2006

**To:** Margo L. Wallace
State Conservationist
USDA-NRCS,
344 Merrow Road, Suite A
Tolland, CT 06084-3917

Dr. Nicholas F. Bellantoni
Connecticut State Archaeologist
Connecticut Archaeology Center
2019 Hillside Road, U-1023
University of Connecticut
Storrs, CT 06269-1023

**Purpose:**
At the request of the Connecticut State Archaeologist and local historians, ground-penetrating radar (GPR) surveys were conducted near the former site of the Bissell Ferry in South Windsor. In addition, exploratory GPR surveys were conducted at the Evergreen Cemetery in Westport, and near the approaches to Exit 28 of the Merritt Parkway in Greenwich.

**Principal Participants:**
Nicholas Bellantoni, Connecticut State Archaeologist, Connecticut Archaeology Center, Univ. of Connecticut, Storrs, CT
Elwood Butts, Evergreen Cemetery, Westport, CT
Robert Cless, Engineer, Connecticut DOT, Hartford CT
Dave Cooke, Archaeologist, FOSA/ABAS, Rocky Hill, CT
June Cooke, Archaeologist, FOSA/ABAS, Rocky Hill, CT
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Leigh Grant, Greenwich Historical Society, Greenwich, CT
Richard LaRose, Archaeologist, FOSA/ABAS, Glastonbury, CT
Shawn McVey, Assistant State Soil Scientist, USDA-NRCS, Tolland, CT
Donald Parizek, Soil Scientist, USDA-NRCS, Windsor, CT
Cece Saunders, Evergreen Cemetery, Westport, CT
Paul Scannell, Archaeologist, FOSA/ABAS, East Windsor, CT
John Spalding, Archaeologist, FOSA/ABAS, Glastonbury, CT
David Strackbein, Greenwich Historical Society, Greenwich, CT
Debbie Surabian, Soil Scientist, USDA-NRCS, Tolland, CT

**Activities:**
All field activities were completed during the period of 25 and 29 July 2005.

**Summary:**

1. An exploratory radar survey at the Evergreen Cemetery in Westport failed to adequately identify unmarked graves. While areas of disturbed soils were identified, conclusive identification of subsurface anomalies as burials was not possible without ground-truth observations.

2. An exploratory GPR survey along Exit 28 of the Merritt Parkway failed to detect two buried time capsules. Two time capsules had been buried near Exit 28 at the opening of the Merritt Parkway in 1937. Radar surveys in the grassed and wooded areas near the north-bound and south-bound exit ramps failed to detect the time capsules.

3. Although the radar worked well at the Evergreen Cemetery and Exit 28 of the Merritt Parkway sites, providing adequate penetration depths and resolution of subsurface features, interpretations were plagued by undesired clutter. The level of clutter and the absence of clearly defined and specific targets fostered ambiguities and weaken confidence in interpretations.

4. Evidence of two former structures and a buried well were detected with GPR near the site of the former Bissell Ferry in South Windsor.

It was my pleasure to work in Connecticut and to be of assistance to you.

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
K. Kolesinskas, State Soil Scientist, USDA-NRCS, 344 Merrow Road, Suite A, Tolland, CT 06084-3917
M. Golden, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250
D. Hammer, National Leader, Soil Investigation Staff, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152, 100 Centennial Mall North, Lincoln, NE 68508-3866
B. Thompson, MO Staff Leader, USDA-NRCS, 451 West Street, Amherst, MA 01002-2934
W. Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, P.O. Box 974, Federal Building, Room G08, 207 West Main Street, Wilkesboro, NC 28697

**Bissell Ferry Site, South Windsor:**
An historic ferry once crossed the Connecticut River in South Windsor. Early documents show that in 1648, the town of Windsor contracted John Bissell to operate a ferry that crossed the Connecticut River. In 1655, the east side landing of the ferry was relocated to a site just south of the mouth of the Scantic River (www.southwindsor.org/history). This ferry provided the early inhabitants of this region with one of the few crossings of the Connecticut River. From 1642 until its end in 1917, this was the longest running ferry services in the United States. Buried remnants of former structures related to the ferry are believed to be located in a cultivated field that presently borders a wooded area near the river (see blocked area in Figure 1). Extensive and detailed GPR grid surveys were carried out in this area in an attempt to find evidence of these former structures and out-buildings.

The survey area is located in a cultivated field on a low terrace to the Connecticut River in South Windsor, Connecticut. The field is located just south of the junction of the Scantic River with the Connecticut River (see Figure 1). Trees border the west side of the field and cover a lower, more flood-prone terrace. The GPR surveys were conducted on a higher-lying terrace and in an area of Occum fine sandy loam (map unit 101). The very deep, well drained Occum soils form in alluvial sediments on flood plains that are subject to flooding. Occum is a member of the coarse-loamy, mixed, superactive, mesic Fluventic Dystrudepts family. The clay content of Occum soil is low ranging from 2 to 12% in the loamy surface layers and from 0 to 5% in the sandy substratum (http://soildatamart.nrcs.usda.gov). Occum soil is well suited to deep, high-resolution profiling with GPR.

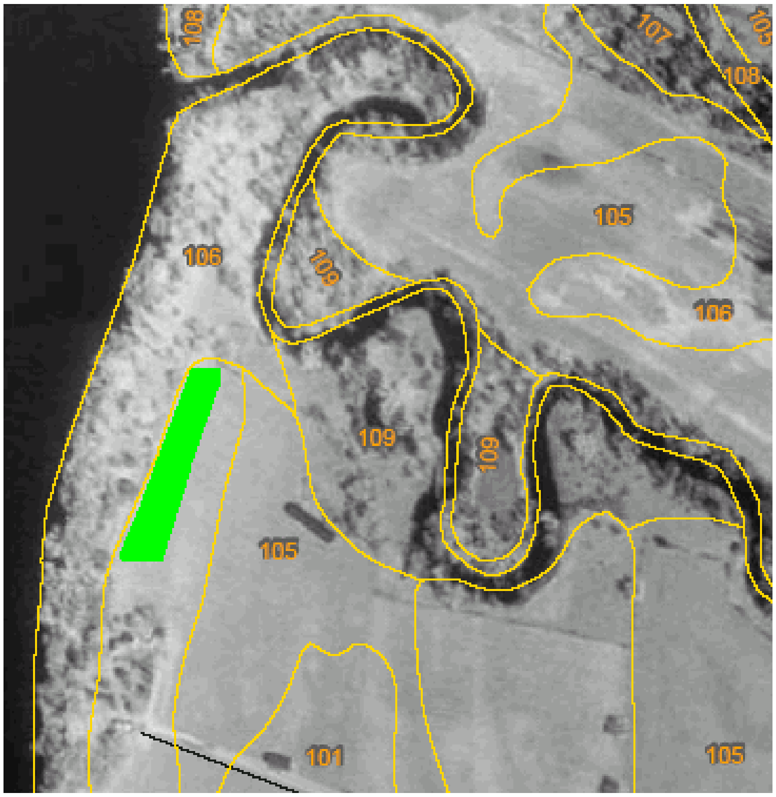


*Figure 1. The general location of GPR survey area (solid green-colored area) has been identified on this soil map.*

**Equipment:**
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000, manufactured by Geophysical Survey Systems, Inc. (North Salem, New Hampshire).[1] The SIR System-3000 weighs about 9 lbs and is backpack portable. With an antenna, this system requires two people to operate. A relatively high frequency 400 MHz antenna was used in this investigation. In this area of Occum soil, the 400 MHz antenna provided an appropriate balance of penetration depth and resolution, and was deemed suitable for this investigation.

Radar records contained in this report were processed with the RADAN for Windows (version 5.0) software program (Geophysical Survey Systems, Inc).[1] Each radar record was submitted to the flowing processing procedures: setting the initial pulse to time zero, color transformation, marker editing, distance normalization, horizontal stacking, and background removal. For each grid site, the processed radar records were combined into a three-dimensional image using the 3D QuickDraw for RADAN Windows NT software (Geophysical Survey Systems, Inc). [1] The processed radar image was migrated and the gain adjusted for display purposes. Once processed, arbitrary cross sections and time slices were viewed and selected images attached to this report.

**Survey Procedures:**
Prior to the arrival of the GPR, wooden stacks had been inserted in the ground at intervals of 60-m along the western boundary of the field. Using these stacks as reference points, three grids were established on the extreme western portion of the field (see green-colored area in Figure 1). Grids were numbered from south to north: grids 1, 2, and 3. The dimensions of the grids were: Grid 1, 55 by 25 m; Grid 2, 55 by 23 m; Grid 3, 45 by 20 m.

Three aligned wooden stacks that were spaced at 60 m intervals along the western boundary of the field provided the baseline for the grids. For each grid, the baseline (Y = 0 m) terminated one meter from the stack located in the grids southwest corner. For each grid, the origin (X = 0, Y = 0) was located in the northwest corner. For Grids 1, 2, and 3, the origin was located 56, 56, and 46 m north of first, second, and third stacks, respectively.

Each grid was constructed using two equal length and parallel lines, which formed the opposing sides of a rectangular area. These two parallel lines were orientated in and east-west direction and defined a grid area. Survey flags were inserted in the ground at intervals of 50-cm along each of these two lines. For positional accuracy, GPR traverses were completed along a reference line, which was stretched and sequentially moved between corresponding flags on the two parallel grid lines. Pulling the 400 MHz antenna along the reference line completed a GPR traverse. Along the reference line, marks were spaced at intervals of 1 m. As the antenna was towed passed each reference point, a vertical mark was impressed on the radar record. Walking, in a back and forth manner, along the reference line, which was moved sequentially between similarly numbered flags on the two parallel survey lines, completed a GPR survey.

Based on the depth to a shallowly (50 cm) buried metallic reflector, the relative dielectric permittivity ($E_r$) through the upper part of the Occum soil was estimated to be 9.65. This $E_r$ results in a propagation velocity of 0.096 m/ns. In this study, using this velocity of propagation and a scanning time of 50 ns, the maximum depth of penetration was about 2.4 m. However, the velocity of propagation is spatial variable and generally decreased with increasing depth. Therefore all depths provided in this report must be considered as estimates.

**Interpretations:**
The size and depth of a buried feature affect detection. Large objects reflect more energy and are easier to detect with GPR than small objects. The reflective power of a buried feature decreases with the fourth power of the distance to the feature (Bevan and Kenyon, 1975). In this study, numerous subsurface reflectors were evident on radar records obtained within the grid areas. Some of these reflectors undoubtedly represented buried cultural features. However, without intensive exploratory digging the identities of these smaller objects can not be made clear. As the focus of this study was to ascertain the presence and general locations of larger structural features hidden below the grid areas, the interpretations of smaller anomalies detected with GPR beneath the grid areas have been ignored.

On radar records, the depth, shape, size, and location of subsurface features have been used to identify buried structures. In the past, subsurface reflections were identified and correlated on two-dimensional (2D) radar records alone. Today, three-dimensional (3D) imaging techniques can be used to distinguish and identify potential targets and to reduce interpretation uncertainties (Pipan et al., 1999). Three-dimensional interpretations of GPR data have been used to identify buried structures (Conyers and Goodman, 1997; Pipan et al., 1999; Shaaban and Shaaban, 2001; Whiting et. al, 2001; Goodman et al., 2004; Miller et al., 2005; Leucci and Negri, 2006).

**Results:**
<u>Grid Area 1:</u>
Grid Area 1 represents the southern-most grid area. Figure 2 is a 3D cube display of this grid area. A 45 by 17 m section has been cutout of the cube to a depth of about 70 cm. A buried structure appears as an irregular patch of high-amplitude (black) reflections in the near foreground between the 20 and 25 m distance marks. This feature extends 5 to 7 m along the X axis and about 3.5 m into the grid area (along Y axis). As this structure appears on the Y = 0 m line, it is believed to

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

extend outside the grid area and into the woods to the west; the area that adjoins the terrace break. Also evident in the cutout section of this cube display is a linear pattern that is located to the south and southwest of the presumed buried structure. This linear feature extends in an east-west direction and may represent a buried field drain. Though variable in signal amplitudes, subsurface strata of alluvial deposits are evident in the lower part of the 3D cube display. These reflectors represent strata with different grain-size distributions and moisture contents.

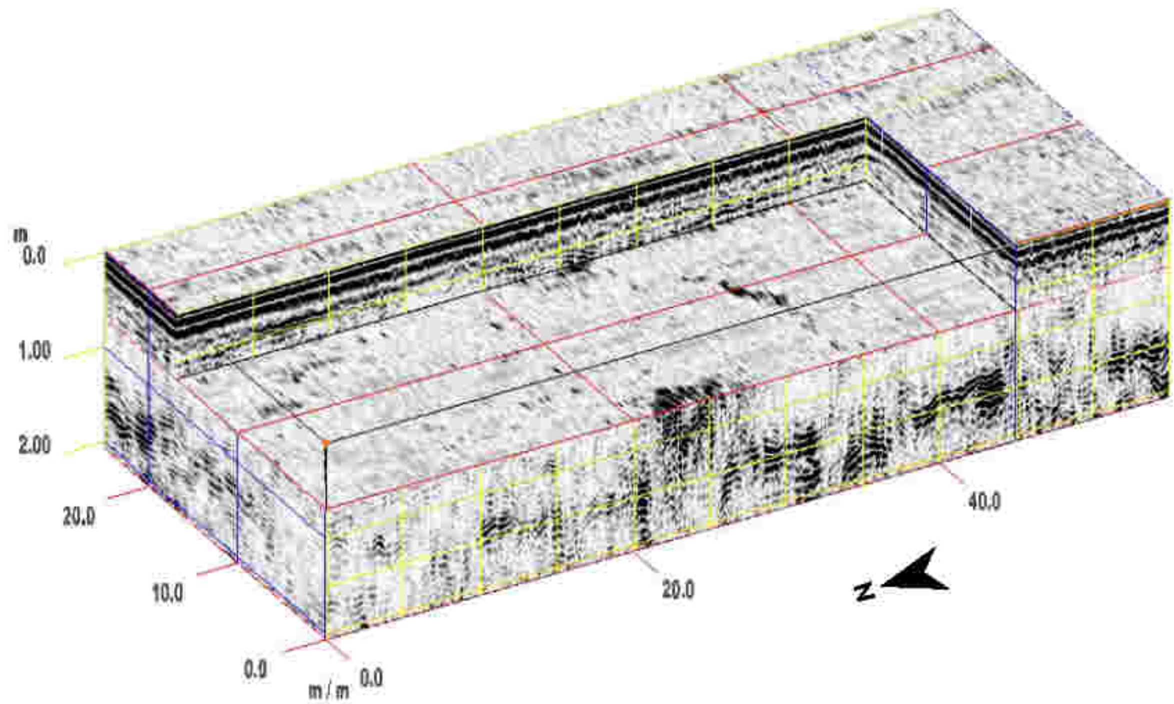


*Figure 2. A three-dimensional cube display of Grid Area 1. A 45 by 17 m inset has been removed to a depth of about 70 cm. The location of a buried structure is evident in the near foreground between the 20 and 25-m distance marks on the X-axis.*

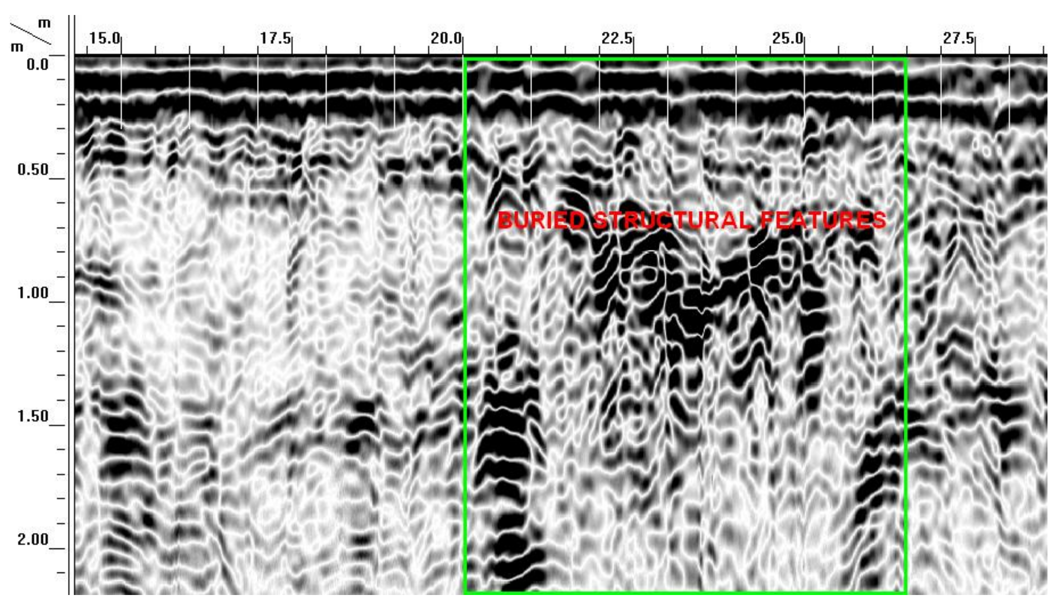


*Figure 3. A two-dimensional radar record from traverse line Y = 0 m. The green-colored lines highlight the area with the buried structure.*

Figure 3 is a 2D radar record from the Y = 0 m traverse line. This record provides a more detailed view of the area containing the suspected buried structure. The area enclosed by the green-colored lines contains imagery suggestive of a buried structure. Within this delineated area, subsurface reflections are considered anomalous and not representative of undisturbed soil. Abrupt, high-amplitude reflectors and reverberated signals bound the disturbed area and suggest the presence of foundation or cellar walls. The high-amplitude reflections at depths of 50 to 100 cm within this disturbed area are believed to represent structural debris.

Grid Area 2:

Grid Area 2 represents the middle grid area. Figure 4 is a 3D cube display of this grid area. A 50 by 20 m section has been cutout of the cube to a depth of about 60 cm. Across most of the grid area, radar reflections are generally of low signal amplitudes and spatial patterns are nondescript. However, one distinct and persistent radar reflection pattern was observed on adjoining radar records (see Figure 5). The reflection pattern suggests an anomalous feature that has dimensions of about 2 x 2 m. Based on previous experiences, this pattern suggests a buried well. With the exception of this lone feature, the remainder of the grid area was unremarkable. As evident in Figures 4 and 5, multiple subsurface strata of alluvial deposits are evident in the lower part of radar records. These reflectors represent strata with different grain size distributions and moisture contents.

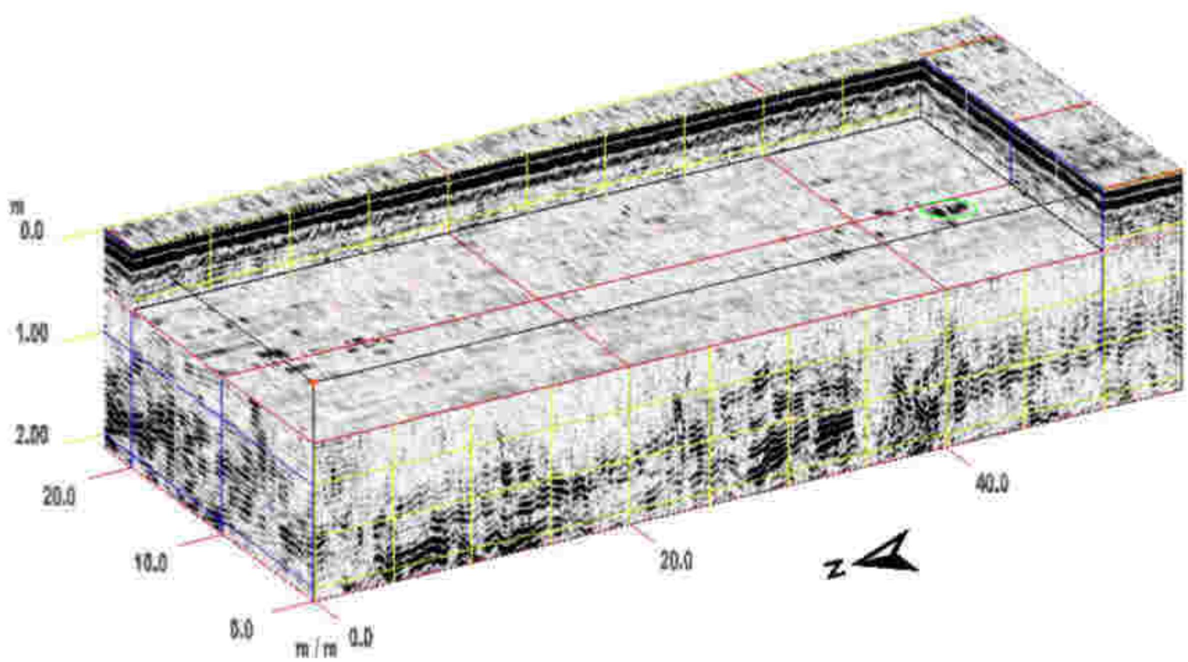


*Figure 4 A 3D cube display of Grid Area 2. A 50 by 20 m inset has been removed to a depth of about 60 cm. An anomalous pattern of radar reflections has been highlighted with a green-colored ellipse.*

Grid Area 3:

Grid Area 3 represents the northern-most grid area. This was the smallest grid area surveyed. This grid area is located nearest to the Scantic River and is suspected to have once contained a structure related to the former ferry. Figure 6 is a 3D cube display of this grid area. A 30 by 15 m section has been cutout of this cube to a depth of about 90 cm. An anomalous zone of high-amplitude point reflectors appears in the near foreground between the 7 and 25 m distance marks on the X-axis. This zone is irregularly shaped and appears to extend about 10 m into the grid area (along Y axis). This zone contains a large number of east-west orientated, linear reflectors. The number, alignment, and general appearance of these reflectors appear unnatural.

Figure 7 is a 15 m section of the radar record that was collected along grid line Y = 0. This record was taken in the western-most area of the grid and nearest to the woods and the terrace break. A noticeable subsurface reflection pattern is evident between the 10 and 24 m distance mark. The irregular pattern of point reflectors suggests a layer of debris and the possible location of a former structure. This pattern appears more segmented and consists of lower amplitude reflectors than appeared in the structure believed to be present in Grid Area 1.

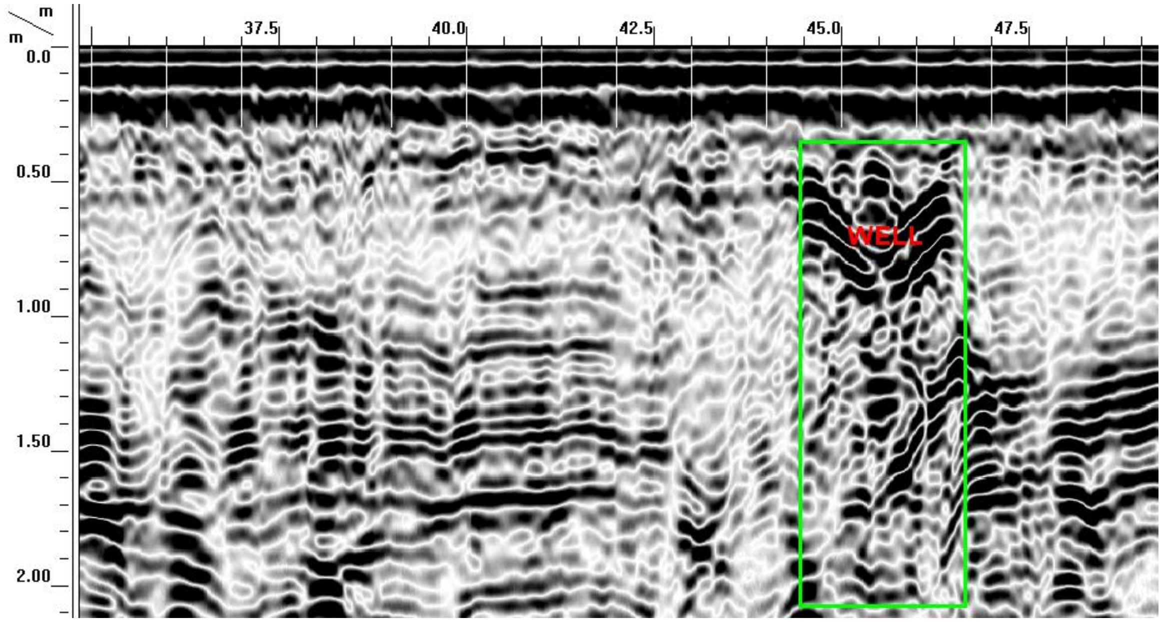


*Figure 5. A 2D radar record from Grid Area 2, traverse line Y = 9 m. The green-colored lines highlight the suspected well.*

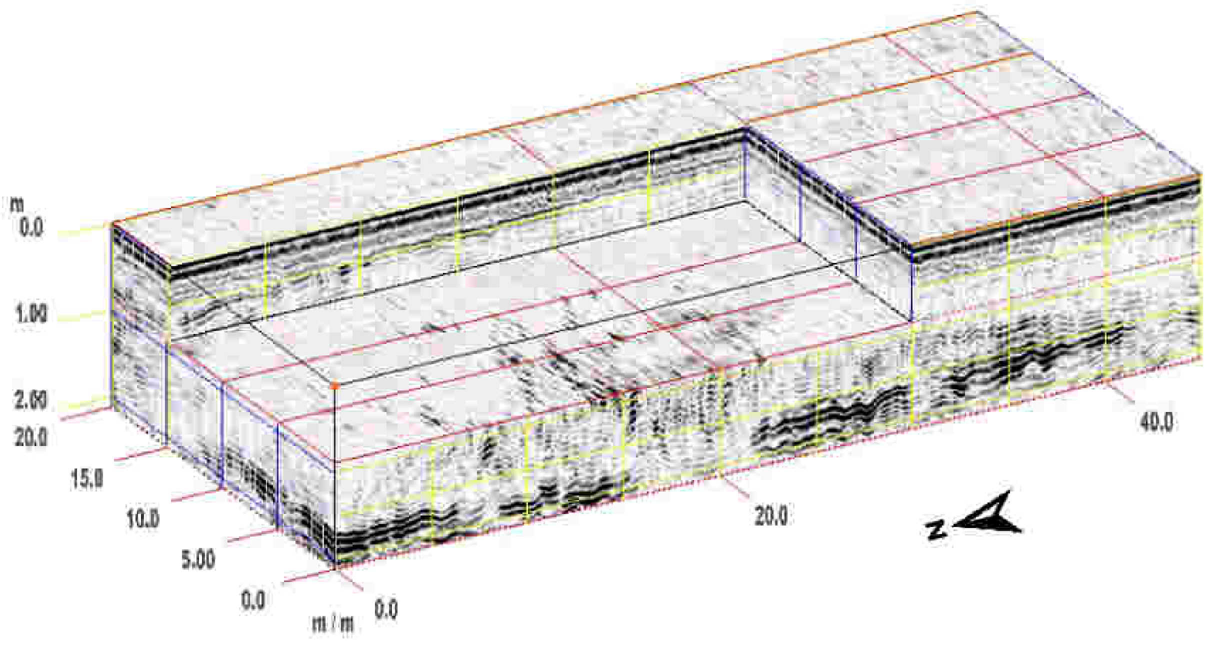


*Figure 6 A 3D cube display of Grid Area 3. A 30 by 15 m inset has been removed to a depth of 90 cm.*

Figure 8 provides a closer view of the anomalous zone that is located in the northwest corner of Grid 3. Linear features confound interpretations of a buried structure. Though highly interpretive, the lengths and orientations of these linear reflectors suggest possible graves. However, the general arrangement of these linear reflectors appears too random for graves.

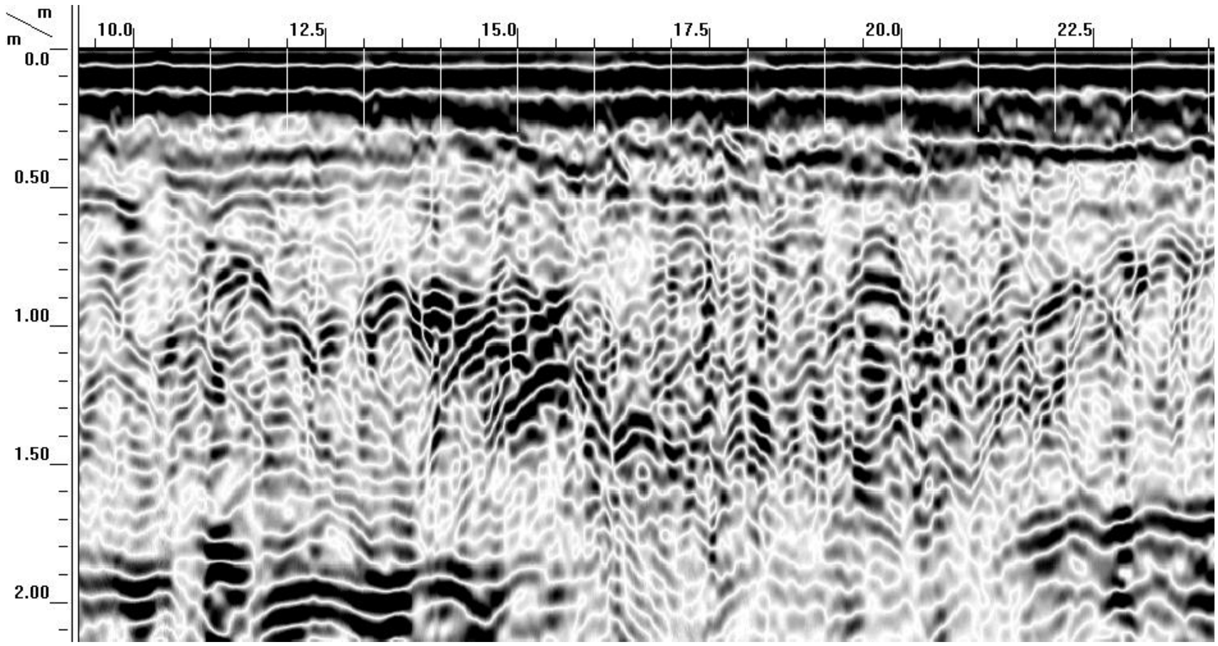


*Figure 7. A 2D radar record from Grid Area 3, traverse line Y = 0 m. The green-colored lines highlight the suspected well.*

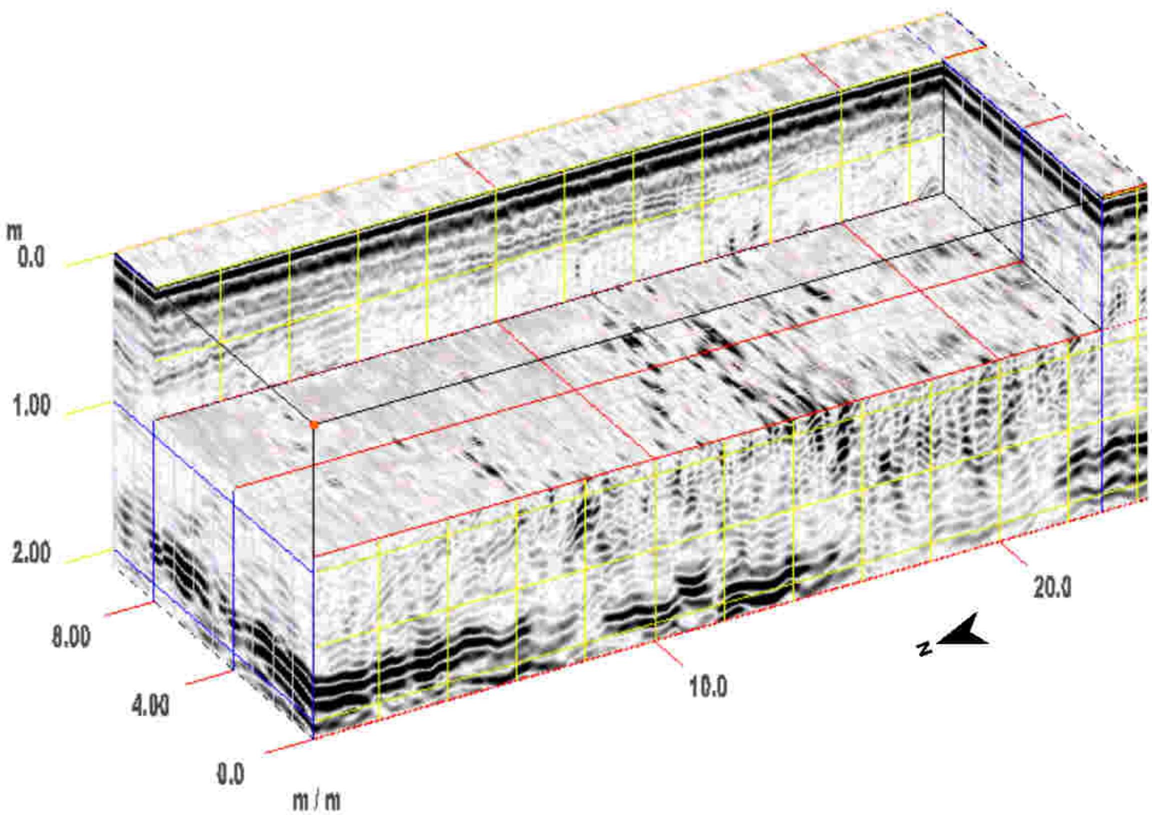


*Figure 8 A 3D cube display of the northwest portion of Grid Area 3. An 8 by 24.5 m inset has been cutout of the cube display to a depth of about 90 cm.*

**References**

Bevan, B. and J. Kenyon. 1975. Ground-probing radar for historical archaeology. MASCA (Museum Applied Science Center for Archaeology) University of Pennsylvania, Philadelphia. Newsletter 11(2): 2-7.

Conyers, L. B., and D. Goodman. 1997. Ground-penetrating Radar; an introduction for archaeologists. AltaMira Press, Walnut Creek, CA.

Goodman, D., S. Piro, Y. Nishimura, H. Patterson. 2004. Discovery of a 1st century AD Roman amphitheater and other structures at the Forum Novum by GPR. Journal of Environmental & Engineering Geophysics 9(1): 35-41.

Leucci, G., and S. Negri. 2006. Use of ground penetrating radar to map subsurface archaeological features in an urban area. Journal of Archaeological Science 33: 502-512.

Miller, C. R., A. L. Allen, M. A. Speece, A-K. El-Werr and C. A. Link. 2005. Land streamer aided studies at Saqqara, Egypt. Journal of Environmental & Engineering Geophysics 10(4): 371-380.

Pipan, M., L. Baradello, E. Forte, A. Prizzon, and I. Finetti. 1999. 2-D and 3-D processing and interpretation of multi-fold ground penetrating radar data: a case history from an archaeological site. Journal of Applied Geophysics 41: 271-292.

Shaaban, F. F. and F. A. Shaaban. 2001. Use of two-dimensional electric resistivity and ground penetrating radar for archaeological prospecting at the ancient capital of Egypt. African Earth Science 33: 661-671.

Whiting, B. M. D., McFarland. D. P., S. Hackenberger. 2001. Preliminary results of three-dimensional GPR-based study of a prehistoric site in Barbados, West Indies. 260-267 pp. IN: (Noon, D. ed.) Proceedings Eight International Conference on Ground-Penetrating Radar. May 23 to 26, 2000, Goldcoast, Queensland, Australia. The University of Queensland.