United States Department of Agriculture

Natural Resources Conservation Service Service

344 Merrow Road Suite A Tolland, CT 06084

SUBJECT: Archaeology – Geophysical Field Assistance

November 2, 2010

TO: Dr. Nicholas F. Bellantoni
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Purpose:
At the request of the Connecticut State Archaeologist, GPR surveys were conducted at historical sites located in Ridgefield, Wethersfield, and Bolton, Connecticut.

Principal Participants:
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Debbie Surabian, MLRA Soil Survey Office 12-6 Leader, USDA-NRCS, Tolland, CT

Activities:
All activities were completed during the period of 25 to 26 October 2010.

Summary:

1. At most sites, the use of geophysical techniques provided archaeologists with added insight into subsurface conditions and the presence of archaeological features. All results, however, are interpretative and must be confirmed with ground-truth excavations.

2. At the first and second meeting house location in Ridgefield, GPR did not provide a clear indication as to the location of the former structures. An analysis of both 2D radar records and 3D pseudo-images revealed no subsurface reflectors or spatial patterns that could be unequivocally associated with remnants of these former structures Anomalous features present in the survey area were attributed to a water main pipe and soil compaction or disturbances adjacent to the sidewalk, and though were not verified by excavation.

3. At the Ye Burying Yard in Ridgefield, an analysis of both 2D radar records and 3D pseudo-images revealed no subsurface reflectors or spatial patterns that could be associated with graves. If present at this site, gravesites were not clearly detected with the GPR system.

4. At the Battle of Ridgefield site in Ridgefield, remnants of graves or a mass grave, if present at this site, were not clearly detected with the GPR system and procedures used.

5. At the Village Cemetery in Wethersfield, GPR appears to have detected fill materials over the original soil surface, a stone lined crypt, and anomalous features that may be deemed worthy of further on-site investigations.

6. At the Heritage Farm in Bolton, GPR revealed no subsurface reflectors or spatial patterns that could be unequivocally associated with remnants of a former structure. One anomalous feature was detected with this geophysical technique that may be deemed worthy of further attention by archaeologists.

Regards,

Deborah Surabian
Soil Scientist

cc:
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Equipment:
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (SIR-3000); manufactured by Geophysical Survey Systems, Inc.[1] The SIR-3000 consists of a digital control unit (DC-3000) with keypad, SVGA video screen, and connector panel. One 10.8-volt lithium-ion rechargeable battery powers the system. The SIR-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. A 400 MHz antenna was used in the study described in this report. Scanning rates of 64 scans/sec and a scanning time of 50 ns was used. With a scanning time of 50 ns, the maximum penetration depth is about 3 m.

The RADAN for Windows (version 6.6) software program developed by Geophysical Survey Systems, Inc, was used to process the radar records.[1] Processing included setting the initial pulse to time zero, color table and transformation selection, and marker editing. For this site, radar records were processed into a three-dimensional image using the 3D QuickDraw for RADAN Windows NT software developed by Geophysical Survey Systems, Inc.[1] Once processed, arbitrary cross sections and three-dimensional images were viewed and attached to this report.

Ground-Penetrating Radar and Archaeological Investigations:
A favorable feature of GPR for archaeological investigations is its ability to detect disturbances and the intrusion of foreign materials in soils. Even under favorable site conditions (i.e. dry, coarse-textured soils) the detection of a burial is never assured with GPR (Doolittle, 2004). The detection of burials is affected by (1) the electromagnetic gradient existing between the feature and the soil, (2) the size, depth, and shape of the buried feature, and (3) 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 contrast in dielectric properties that exists between an object and the surrounding soil. The greater and more abrupt the difference in dielectric properties, the greater the amount of energy that is reflected back to an antenna, and the more intense will be the amplitude of the reflected signals on the radar record. The reflection coefficient of a subsurface interface is dependent on the difference in dielectric permittivity (E_r) that exists between the two materials. As the E_r of a material is strongly dependent upon its moisture content, the amount of energy reflected back from an interface is dependent on the abruptness and contrast in moisture contents of the materials (Doolittle, 2004).

On radar records, the depth, shape, size, and location of subsurface features may be used as clues to infer buried cultural features. In the past, reflections were identified and correlated on two-dimensional radar records. Today, three-dimensional imaging techniques can be used to distinguish coherent noise components, reduce interpretation uncertainties, and aid identification of potential targets (Pipan et al., 1999). The recent development of sophisticated signal-processing software has enabled signal enhancement and improved pattern-recognition on some radar records (Doolittle, 2004).

Survey Procedures:
In order to calibrate the GPR and assess site conditions, random GPR traverses were conducted across selected sites. To collect the data required for the construction of 3D GPR pseudo-images, small survey grids were established across selected areas. The sizes and dimensions of the grids varied and are listed in Table 1. For each grid, two parallel lines were established across the selected sites. Along each of these parallel lines, survey flags were inserted into the ground at a spacing of 50 or 100 cm. A reference line was extended between matching survey flags on opposing sides of the grid using a distance-graduated rope. GPR traverses were conducted along the distance-graduated rope. For each grid, the 400 MHz antenna was towed along the graduated rope, and as it passed each 100-cm graduations, a mark was impressed on the radar record. Following data collection, the reference line was sequentially moved to the next pair of survey flags to repeat the process.

Table 1. Basic features of the GPR Grid Sites

Site	Grid Dimensions	Line Spacing
First Meeting House, Ridgefield	12 x 8 m	50 cm
Second Meeting House, Ridgefield	12 x 10 m	50 cm
Ye Old Cemetery, Ridgefield	6 x 12 m	50 cm
Village Cemetery, Wethersfield; Grid 1	28 x 5 m	50 cm
Village Cemetery, Wethersfield; Grid 2	7 x 14 m	50 cm
Heritage Farm , Bolton	14 x 24 m	100 cm

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

Results:

<u>First and Second Meeting House, Ridgefield</u>

The site is located in the front yard of the First Congregational Church of Ridgefield. Historical records indicate that the first meeting house was built on the green in 1713. After the first meeting house fell in disrepair, the town decided to replace it in 1800 with a second meeting house on the green adjacent to the first meeting house. The second meeting house was used until 1888. Ground-penetrating radar surveys were completed in this area in an attempt to locate buried foundation remnants of these two former structures.

Figure 1. The first meeting house shown in the far right-hand corner of this photo was built in 1713 on the green. (Photograph courtesy of HMdb.org, taken by Michael Herrick).

The soil in this area is mapped as Paxton and Montauk fine sandy loam, 3 to 8 percent slopes. The Paxton and Montauk soils are formed in glacial till, more specifically, lodgement till derived mostly from schist, gneiss, and granite. Glacial till is material that has been transported and deposited directly by ice. Till typically has unsorted sediments varying in texture, mineralogy, and degree of consolidation. Material carried in different parts of the glacier produces till with different characteristics. Lodgement till is compact and contains a greater amount of fine-grained sediment. Paxton soils formed in a loamy mantle underlain by loamy dense till and are classified as coarse-loamy, mixed, active, mesic Oxyaquic Dystrudepts. Montauk soils formed in a loamy mantle underlain by sandy dense till and are classified as a coarse-loamy, mixed, subactive, mesic Oxyaquic Dystrudepts. Paxton and Montauk soils are considered well suited to GPR applications.

Figure 2. The first and second meeting house site location in the front lawn of the First Congregational Church of Ridgefield.

A grid was established across a portion of the front lawn of the First Congregational Church of Ridgefield that was suspected to contain the remnants of the first and second meeting house foundations. Using the 400 MHz antenna, parallel radar traverses were conducted across the grid area in essentially a south-north direction. Each traverse line was 12-m long. The distance between each traverse line was 50 cm. The grid was then split into two survey areas to remove the sidewalk in the middle of the grid. The traverse lines were used to construct a 3D pseudo-image of the grid site.

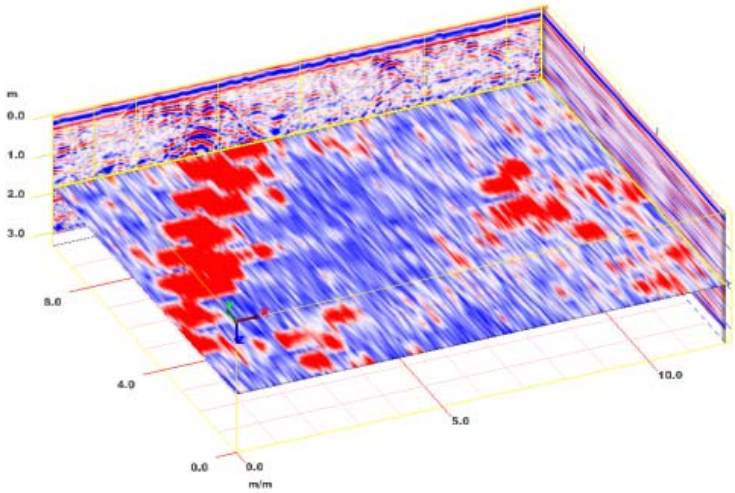

Figure 3. A three-dimensional image at 200 cm below the soil surface of the first and second meeting house GPR grid site. Spatial patterns (colored red) may indicate a buried water main pipe going to the church.

A three-dimensional image of the grid site is shown in Figures 3 and 4. In Figure 3, high-amplitude reflections (colored red) show a linear pattern across the left-hand portion of the record from southeast to northwest towards the church. Based on oral knowledge of the area, the water main line for the church extends into this area. In Figure 4, high-amplitude reflections (colored red) show a linear pattern across the lower portion of the radar record which is directly adjacent to the sidewalk. This pattern may be associated with a compacted soil surface and/or different base materials used to level the sidewalk for construction. The three-dimensional images revealed no subsurface reflectors or spatial patterns that could be unequivocally associated with remnants of these former structures.

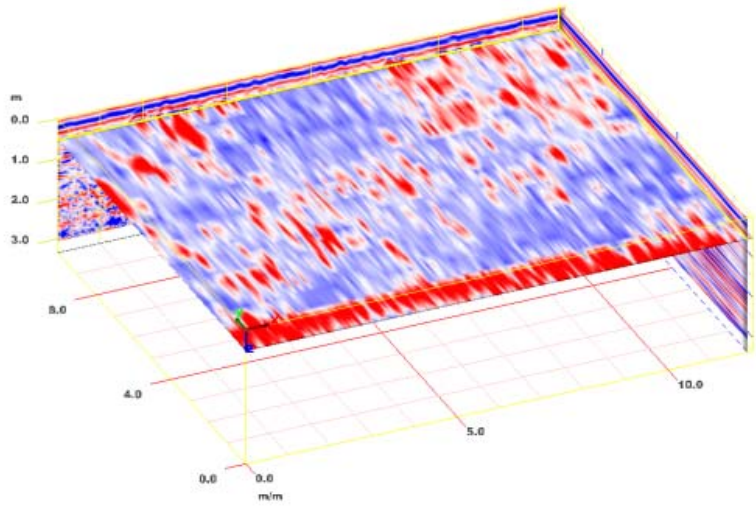

Figure 4. A three-dimensional image at 50 cm below the soil surface of the first and second meeting house GPR grid site. The red linear line of high-amplitude reflections may be associated with a compacted soil surface and/or different base materials used to level the sidewalk for construction.

Ye Burying Yard, Ridgefield

With no original standing headstones, Ye Burying Yard is marked only by a white sign and constructed monument on top of a forested knoll. The monument is engraved with 40 people who were buried in this cemetery between 1708 and 1760. Behind the monument is the only remaining broken headstone belonging to Capt. Matthew Benedict. Sam Carlson, an intern researcher, investigated this plot of land and was told that many of the remains and headstones may have been moved sometime around 1850. A ground-penetrating radar survey was completed in this area in an attempt to locate unmarked graves and buried headstones.

The site is mapped as Paxton and Montauk fine sandy loams, 8 to 15 percent slopes. The Paxton and Montauk soils are formed in glacial till, more specifically, lodgement till derived mostly from schist, gneiss, and granite. Glacial till is material that has been transported and deposited directly by ice and typically has unsorted sediments varying in texture, mineralogy, and degree of consolidation. Lodgement till is compact and contains a greater amount of fine-grained sediment. Paxton and Montauk soils are considered well suited to GPR applications.

Because of large trees surrounding the monument, a small grid was laid out in front of the monument for the GPR survey. Using the 400 MHz antenna, parallel radar traverses were conducted across the grid in essentially a north-south direction. Traversing in a north-south direction with the radar in this cemetery is important in establishing patterns of unmarked graves since most early New England cemeteries are orientated in an east-west direction. This traditional Christian method of positioning bodies face up and facing east in the direction of the rising sun was to allow the dead to see the Second Coming of Jesus.

Figure 5. Photographs of the marker and monument at the Ye Burying Yard.

Figure 6 shows a 3D image at a depth of 50 cm from the soil surface with scattered high-amplitude reflectors (colored red) that form no coherent geometric pattern of unmarked grave sites. One of the high-amplitude reflectors was probed only to reveal a large root from the surrounding trees. These random high-amplitude reflectors are difficult to identify as buried headstones and though by using a push probe one could discern if they are roots or stones.

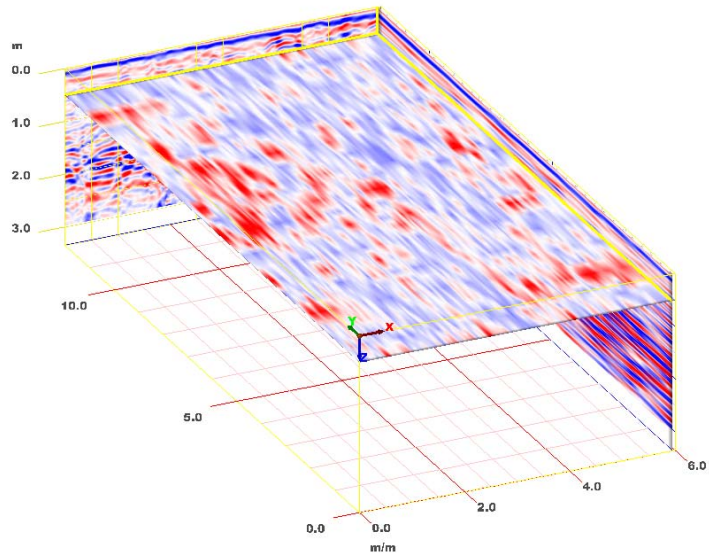

Figure 6. A three-dimensional image at 50 cm below the soil surface at the Ye Burying Yard. No identifiable spatial patterns can be seen on this three-dimensional image that would suggest the locations of unmarked graves or buried headstones.

<u>The Battle of Ridgefield, Ridgefield</u>

The site is located on town property near Casagmo and may contain the graves of eight Patriots and sixteen British soldiers. The monument shown in Figure 7 indicates the Battle of Ridgefield took place in 1877 and that 24 people were laid in these grounds. The site is located in an area of Paxton soils that are suitable for GPR investigations; however, the wooded nature of this site limited the use of the radar and formation of a grid. Several GPR traverses were conducted across the site with no conclusive evidence of a mass grave or individual gravesites. Based on our incomplete survey with the GPR, other geophysical techniques may be better suited for this area such as EMI or different investigative methods such as probing for areas of disturbance with a hand auger.

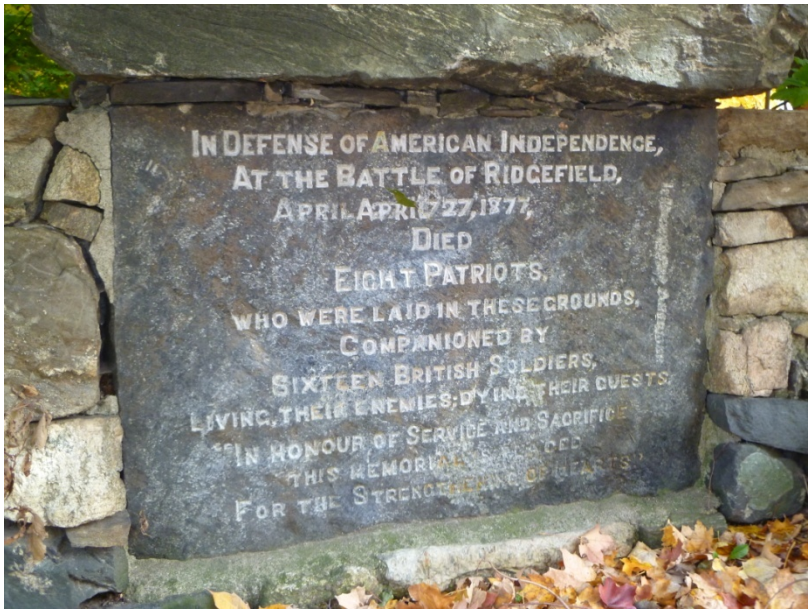

Figure 7. Vegetation at the Battle of Ridgefield site limited the use of GPR.

Village Cemetery, Wethersfield

The site is located in Village Cemetery, which is located in Wethersfield. In a small portion of the cemetery there is a relatively open lawn area. Cemetery officials wish to confirm whether this open area contains unmarked graves. If not, this open area can be used for additional burials.

Based on the location of marked graves, several grids were constructed within the open area of the cemetery. Using the 400 MHz antenna, parallel radar traverses were conducted across the grid area in essentially a north-south direction. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of the grid site.

Figure 8. Photograph of the GPR survey at Village Cemetery in Wethersfield, CT. (Photograph courtesy of Rachel Quish).

Figure 9 contains a three-dimensional image of the first grid completed at the Village Cemetery Site. In the image, high-amplitude (red colored) reflections having an unusual pattern within the original soil surface were identified with a green cylinder. The identities of these reflectors are unknown; some may represent graves or headstones while others may be soil discontinuities.

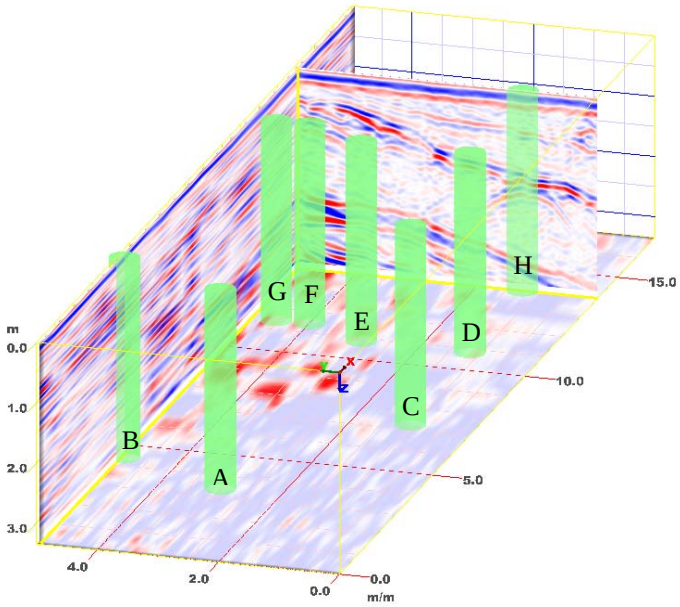

Figure 9. A three-dimensional image showing the eight points of interest in the first grid completed at Village Cemetery in Wethersfield, CT. The 0, 0 origin is in the southwest corner of the grid.

Anomalous areas have been identified in Figures 10 through 16. Figures 10 through 15 are from grid one and Figure 16 is from grid two. Because of their size, prominence and location within the original soil material, these subsurface features may be deemed worthy of further attention by archaeologists.

The site is located in an area of Hinckley soils. Hinckley soils are composed of stratified deposits of sands and gravels. These stratifications are manifested in planar reflections of different amplitudes (black arrow) on radar records as shown in Figure 10. The mixed materials (orange arrow) used to fill and level the area in the 1970s is seemingly apparent in the upper 1 to 1.5 meters on the radar record in Figure 10. Below the fill material is the natural soil material that would be more likely to contain graves prior to the 1970s. The original soil surface is marked with a green arrow in Figure 10.

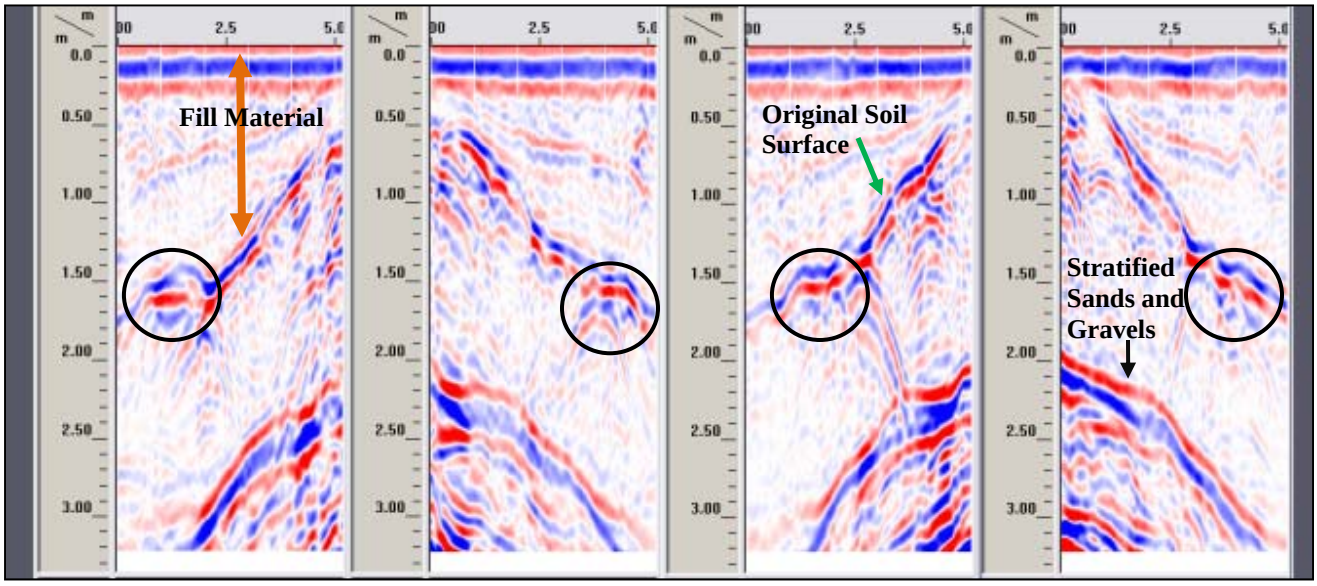

Figure 10. The four radar records show point H (circled in black) approximately 1.5 m below the soil surface within the original soil material. Fill material (marked with an orange arrow) placed in the 1970s covers the original soil surface (marked with a green arrow). Planar reflections of different amplitudes (marked with a black arrow) indicate the stratified sand and gravel layers of the natural soil. Point H is located 14 m east and between 1 and 1.5 m north from the 0, 0 origins.

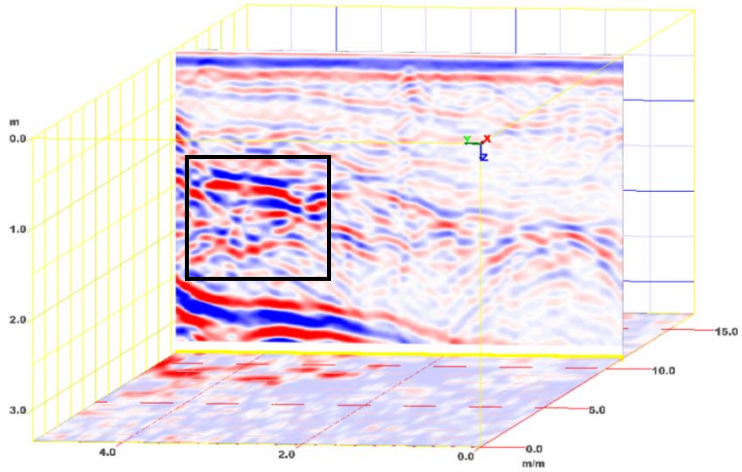

Figure 11. The radar record shows points F and G (marked with a black rectangle) that are 11 meters west and between 4 to 5 meters north from the 0, 0 origins; and approximately 1.5 meters below the soil surface.

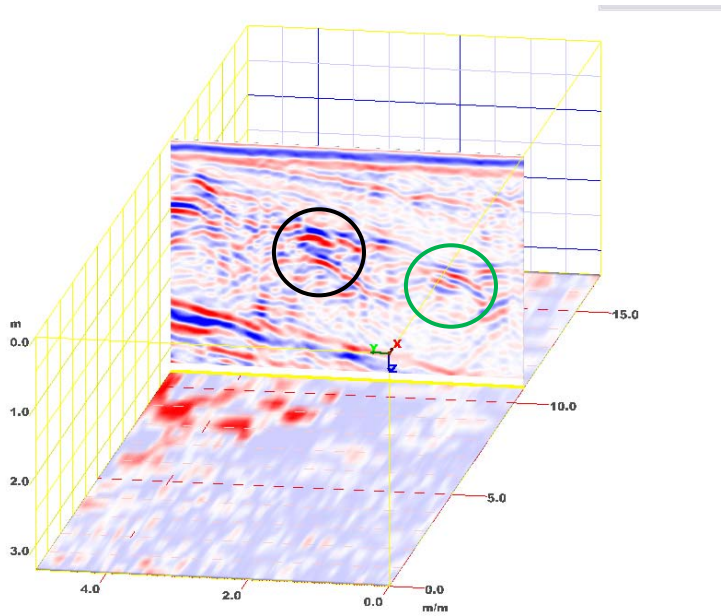

Figure 12. The radar record shows point E (circled in black) located 10.5 m east and 3 m north from the 0, 0 origins, and between 1.0 and 1.5 m below the soil surface. There is a similar anomaly (point D) circled in green. It is located 10.5 m east and between 1.0 to 1.5 m north from the 0, 0 origins; and between 1.5 to 2 m below the soil surface.

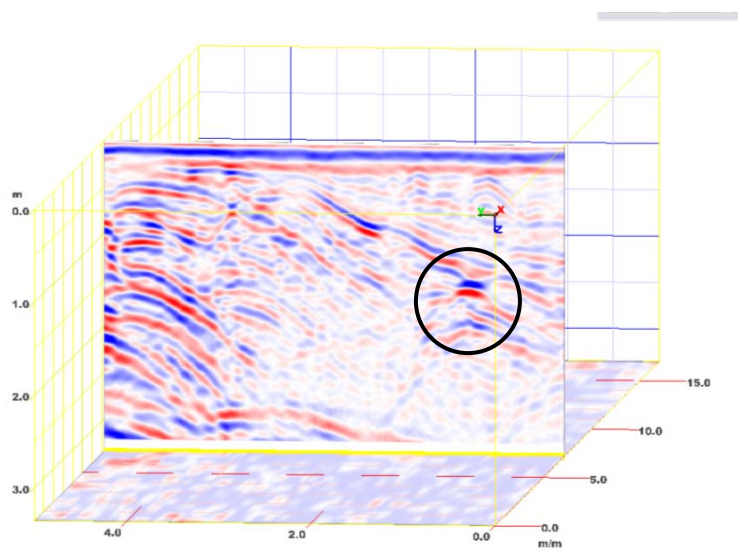

Figure 13. This radar record shows the anomaly referenced as point C circled in black. Point C is located 7 m east and 1 m north from the 0, 0 origins; and approximately 1.5 m below the soil surface.

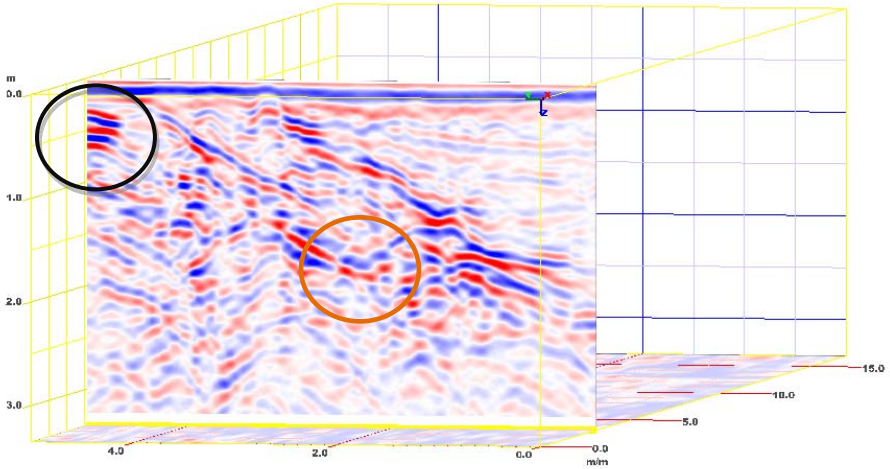

Figure 14. This radar record shows the anomalies referenced as point A circled in orange and point B circled in black. Point A is located 4 m east and 3 m north from the 0, 0 origins, and is approximately 1 m below the soil surface. Point B is located between 4 and 5 m east and 5 m north from the 0, 0 origins; and just over 0.5 m below the soil surface. Point B was investigated further using a push probe and was assumed to be an unmarked stone lined crypt.

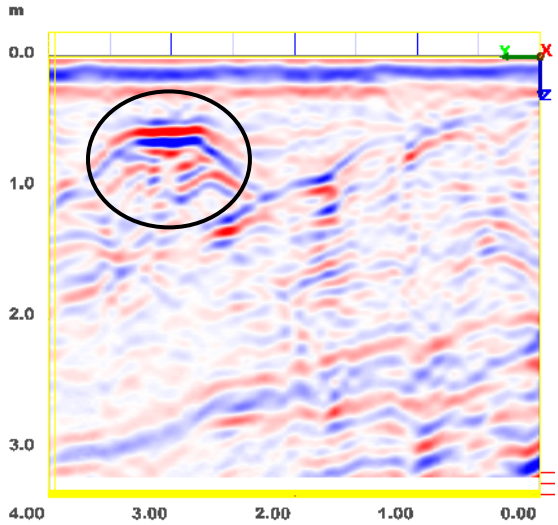

Figure 15. This radar record shows an anomaly circled in black. It is located 17.5 m east and 3 m north from the 0, 0 origins of grid one; and approximately .5 m below the soil surface.

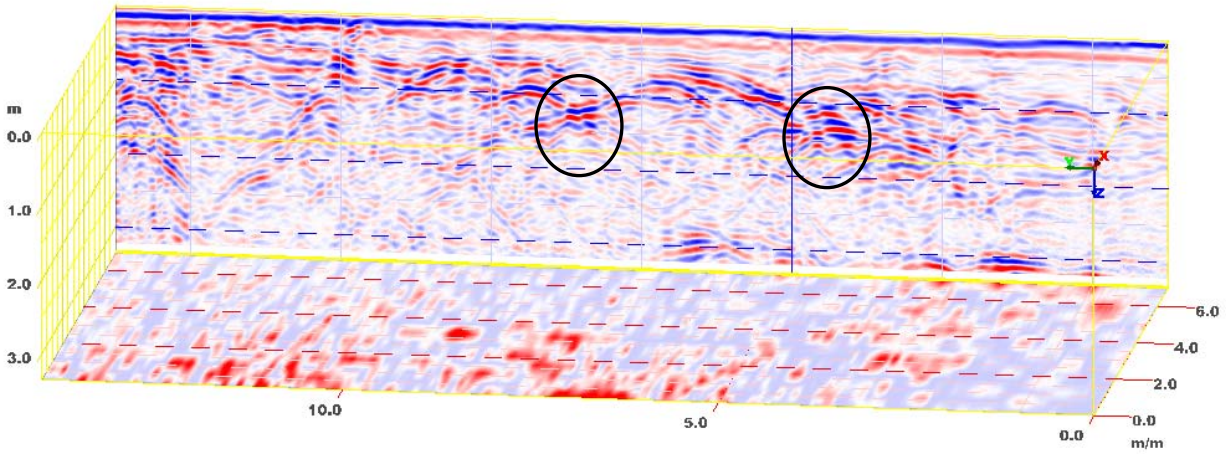

Figure 16. This radar record is from grid two completed at Village Cemetery near the woods. It shows two anomalies circled in black. The right-hand circle is a known gravesite marked with a headstone. The left-hand circle is an anomaly of interest having similar radar reflections as the nearby known gravesite.

A wildcat GPR survey was then completed to determine if a burial was located in front of or back of a replaced headstone. A high amplitude reflector was recorded on the side facing the headstone. Further investigation to identify the anomaly by cemetery staff revealed the base of the original headstone.

Figure 17. Photographs from the Village Cemetery in Wethersfield, CT. Further investigation to identify the anomaly by cemetery staff revealed the base of the original headstone. (Photograph courtesy of Rachel Quish).

Heritage Farm, Bolton

The site is located on the grounds of Heritage Farm (103 acres) in an area of Paxton-Montauk soils. The Heritage Farm House, shown in Figure 15, was built in 1725 and visited by Washington, Hamilton, Rochambeau, Lafayette, and many other famous people. In 2001, the hill to the east of the house and barn was examined where remnants of old fire pits from French General Rochambeau's Army's fifth camp site during June 1781 were found. The French General with 5,500 troops camped in this vicinity for four nights while traveling to Yorktown to help the Americans defeat the British. Other artifacts recovered from the area are regimental buttons, .66 caliber musket balls, period coins and a lead bar (Clouette and Harper, 2001). The 13 acre site is listed on the National Register of Historic Places and the Washington-Rochambeau Revolutionary Route is a National Historic Trail.

It is believed that an earlier home once stood to the west of the Heritage Farm House. In this area, a GPR survey grid was established and conducted in an attempt to locate buried structural remnants, which could be associated with a former residence.

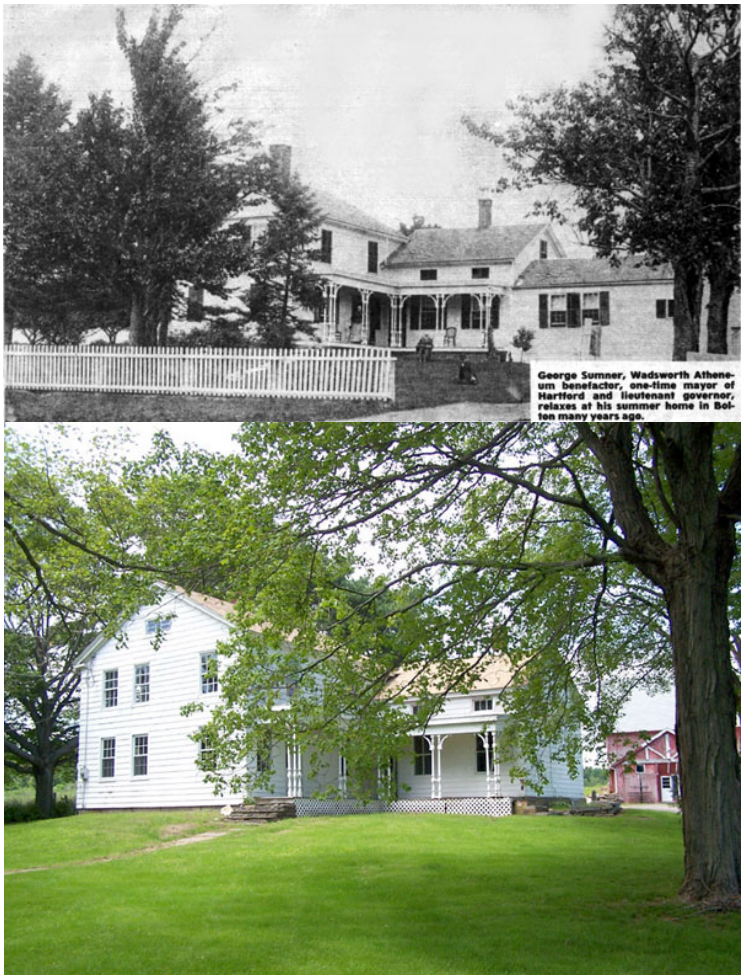

Figure 18. Photographs of the Heritage Farm House. (Photograph courtesy of the Bolton Historical Society website http://boltoncthistory.org/heritagefarmhouse.html)

Using the 400 MHz antenna, parallel radar traverses were conducted across a grid, in essentially a north-south direction. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of each grid site. The three-dimensional image showed no coherent geometric pattern that would suggest remnants of a former structure in this area. One unusual bowl shaped feature shown in Figure 19 may be deemed worthy of further attention by archaeologists. The radar record shows widely dispersed and chaotic patterns of high-amplitude reflections that are typically associated with the underlying till soil.

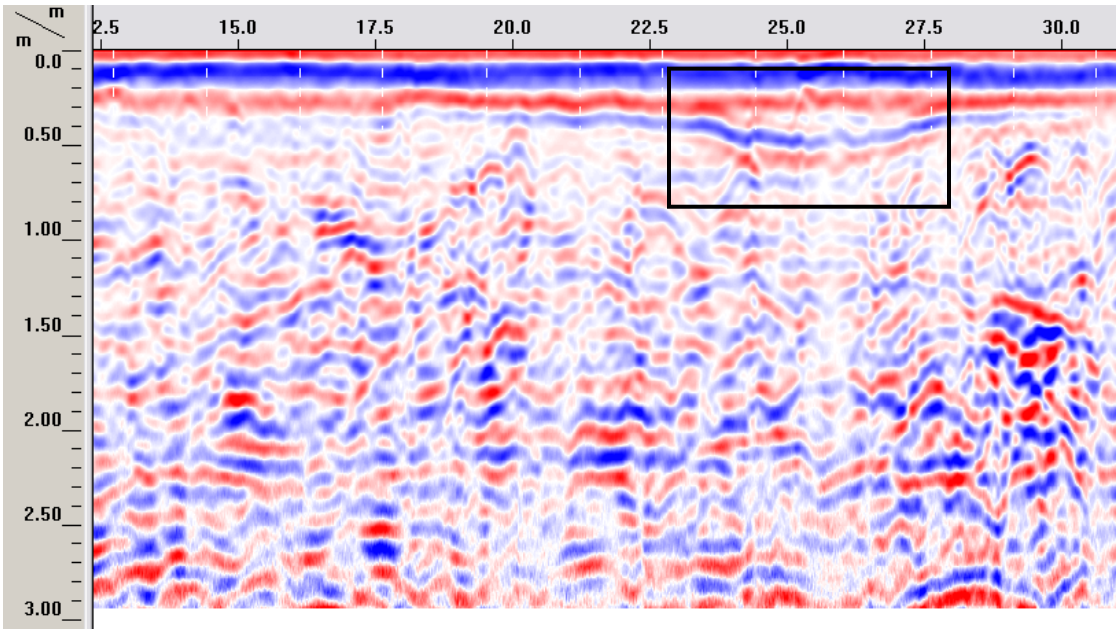

Figure 19. This radar record shows an anomaly (within the black box) that may be worthy of further attention by archaeologists. The anomaly is approximately 4 m wide and expands into the adjacent radar records that are 1 m apart. The center of the anomaly lies 11 m west from the 0,0 origin (southwest corner of the survey grid) and between 23.5 and 27.5 m north.

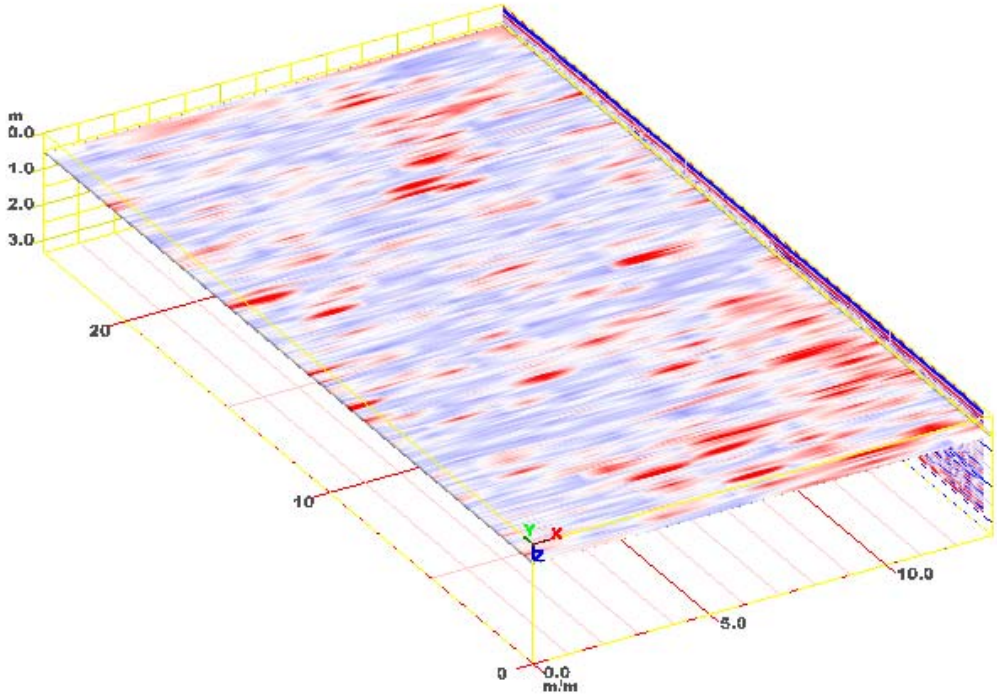

Figure 20. A three-dimensional image showing no coherent geometric pattern that would suggest remnants of a former structure in this area

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