United States Department of Agriculture

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**SUBJECT**: MGT – Trip Report - Geophysical Assistance 18 September 2014

**TO**: Lisa R. Coverdale File Code: 330-20-7
State Conservationist
USDA, Natural Resources Conservation Service
344 Merrow Road, Suite A
Tolland, CT 06084-3917

**Purpose**:

To complete ground-penetrating radar (GPR) and electromagnetic induction (EMI) surveys were conducted across 8 historical sites in Connecticut.

**Principal Participants:**

Nicholas Bellantoni, Connecticut State Archaeologist (retired), Connecticut Archaeology Center, Univ. of Connecticut, Storrs, CT
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Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Brian Jones, Connecticut State Archaeologist, Connecticut Archaeology Center, Univ. of Connecticut, Storrs, CT
Debbie Surabian, State Soil Scientist, USDA-NRCS, Tolland, CT
Jim Trocchi, Volunteer, Friends of the Connecticut State Archaeologist, Storrs, CT

**Activities:**

All activities were completed during the period of 25 to 28 August 2014.

**Summary:**

At the request of the Connecticut State Archaeologists, and in cooperation with the University of Connecticut, and several local historic groups, ground-penetrating radar (GPR) and electromagnetic induction (EMI) surveys were completed across eight historical sites in Connecticut. These studies deepened our partnership with these groups and demonstrated NRCS's commitment to the identification, assessment, preservation, and protection our Nation's cultural resources in compliance with the National Historic Preservation Act. As documented in the National Cultural Resources Procedures Handbook, NRCS is mandated to provide technical assistance for the assessment, preservation and protection of both federally and non-federally owned historic properties. Moreover, NRCS is directed to provide technical assistance in the fields where it has considerable expertise, such as ground-penetrating radar and electromagnetic induction, for the study and/or preservation of our cultural resources.

It was the pleasure of Jim Doolittle and the National Soil Survey Center to work in Connecticut and be of assistance to you, your staff, and your cooperators.

JONATHAN W. HEMPEL
Director
National Soil Survey Center

Attachment (Technical Report)

cc:
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**Technical Report**

**Jim Doolittle**

**Background:**
At the request of the Connecticut State Archaeologists, and in cooperation with the University of Connecticut, and several local historic groups, ground-penetrating radar (GPR) and electromagnetic induction (EMI) surveys were conducted across 8 historical sites in Connecticut. These studies deepened our partnership with these groups and demonstrated NRCS's commitment to the identification, assessment, preservation, and protection our Nation's cultural resources in compliance with the National Historic Preservation Act. As stipulated in the National Cultural Resources Procedures Handbook, NRCS is mandated to provide technical assistance for the assessment, preservation and protection of both federally and non-federally owned historic properties. Moreover, NRCS is directed to provide technical assistance in the fields where it has considerable expertise, such as ground-penetrating radar and electromagnetic induction, for the study and/or preservation of our cultural resources.

**Equipment:**
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000, manufactured by Geophysical Survey Systems, Inc. (GSSI; Salem, NH).[1] The SIR-3000 system consists of a digital control unit (DC-3000) with keypad, SVGA video screen, and connector panel. A 10.8-volt lithium-ion rechargeable battery powers the system. The SIR-3000 weighs about 4.1 kg (9 lbs.) and is backpack portable. With an antenna, the SIR-3000 system requires two people to operate (Figure 1). Operating procedures for the SIR-3000 are described by Geophysical Survey Systems, Inc. (2004). Jol (2009) and Daniels (2004) discuss the use of GPR. A relatively high frequency, 400 MHz antenna was used in the investigations. This antenna provided satisfactory investigation depths and resolution of subsurface features in the profiled soils. The RADAN for Windows (version 7.0) software program (developed by GSSI) was used to process the radar records and to improve pattern recognition.[1]

The electromagnetic induction meter is the Profiler EMP-400 sensor (here after referred to as the Profiler), which is manufactured by Geophysical Survey Systems, Inc. (Salem, NH).[1] The Profiler has a 1.22 m (4.0 ft) intercoil spacing and operates at frequencies ranging from 1 to 16 kHz. It weighs about 4.5 kg (9.9 lbs.). The Profiler is a multifrequency EMI meter that can simultaneously collect data in as many as three different frequencies. For each frequency, inphase and quadrature phase data are recorded. The calibration of the Profiler is optimized for 15 kHz and, therefore, apparent conductivity ($EC_a$) is most accurately measured at this frequency. Operating procedures for the Profiler are described by Geophysical Survey Systems, Inc. (2008).

The Profiler needs only one person to operate and requires no ground contact (Figure 2). Lateral resolution is approximately equal to the intercoil spacing of the instrument. In the studies described in this report, data were recorded at both 15000 and 5000 MHz. The sensor was held in the deeper sensing vertical dipole orientation (VDO) (Figure 2). The sensor's electronics are controlled via Bluetooth communications with a Trimble TDS RECON-400 Personal Data Assistant (PDA).[1] The MagMap 2000 software (developed by Geometric, Inc., San Jose, CA) was used to post- process the survey measurements.[1] To help summarize the results of the EMI survey, SURFER for Windows (version 10.0) software (Golden Software, Inc., Golden, CO) was used to construct the simulations shown in this report.[1] Grids of $EC_a$ data shown in this report were created using kriging methods with an octant search.

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

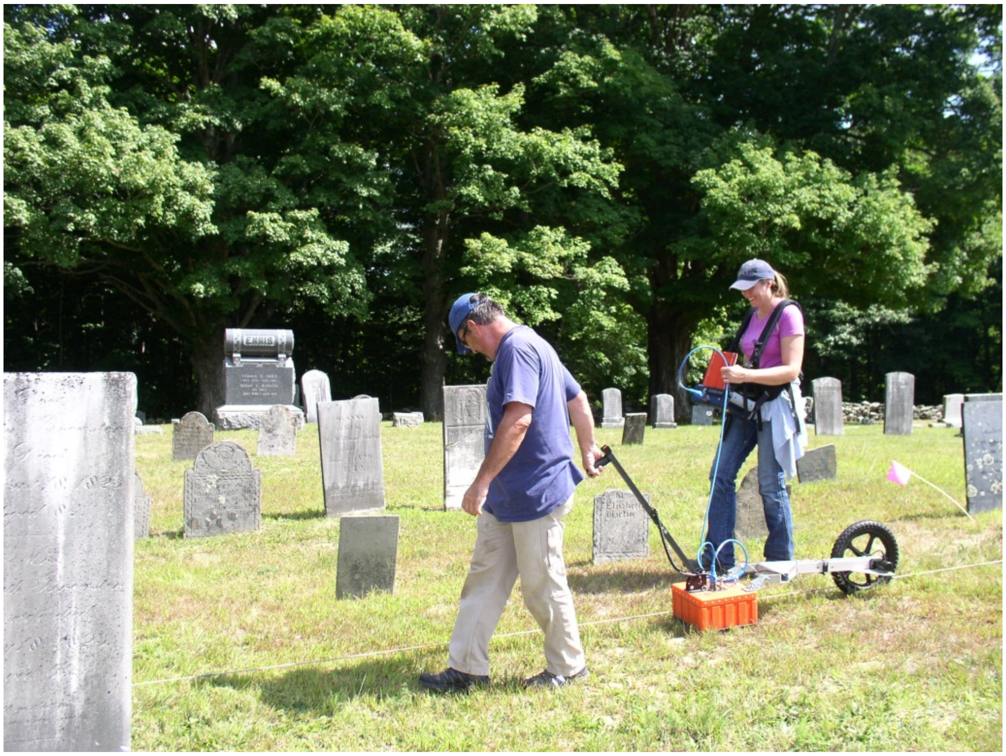

**Figure 1. Ground-penetrating radar is used to investigate an open area within a historic cemetery for unmarked graves.**

**Figure 2. A Profiler EMP-400 sensor is used as a rapid reconnaissance tool to expand survey areas and locate subsurface anomalies that may be of interest to archaeologists.**

**Three-dimensional GPR:**

The effective visualization of radar data is the key to current GPR interpretations. An emerging approach in GPR is the analysis of subsurface structures, distributions, and geometries from a three-dimensional

(3D) perspective. This approach relies on programs and analysis techniques that were developed for processing seismic data. Three-dimensional GPR allows the rapid processing and visualization of data volumes from different perspectives and cross-sections (Beres et al., 1999). This can assist (i) the identification, (ii) outline the structure and geometry, and (iii) improve the interpretation of subsurface features. In areas of electrically resistive materials, Grasmueck and Green (1996) noted that, compared with two-dimensional (2D) GPR, 3D GPR can provide unrivaled resolution and detail of subsurface features. Beres et al. (1999) observed that 3D GPR improves the definition of subsurface structural trends and results in more complete and less ambiguous interpretations than traditional 2D GPR.

The acquisition of 3D GPR data does require greater expenditures of time and labor than 2D GPR. However, the additional expenditures of resources needed to collect, process, and visualize 3D GPR data are often compensated by the more comprehensive spatial coverage and the higher resolution of subsurface structural information (Grasmueck and Green, 1996). To construct a 3D pseudo-image of the subsurface, a relatively small area (typically, 1 to 2500 $m^2$) is intensively surveyed with multiple, closely-spaced (typically, 0.1 to 1.0 m), parallel GPR traverse lines. This relatively dense set of grid lines is necessary to resolve the geometry and size of different subsurface features and to prevent spatially aliasing the data (Grasmueck and Green, 1996). Once the radar data are processed into a 3D pseudo-image of a grid site, arbitrary cross-sections, insets, and time slices can be extracted from the 3D data set. Interactive software packages enable the 3D pseudo-image to be viewed from nearly any perspective (Junck and Jol, 2000). In addition, animated imaging allows users to travel through the entire data volume (Grasmueck, 1996). Lehmann and Green (1999) discuss the concerns that are important for conducting 3D GPR surveys.

One advanced signal processing method that is commonly used in archaeological investigations is amplitude slice analysis (Conyers, 2004). This analysis technique explores differences in signal amplitudes within the 3D pseudo-image in "time-slices" (or depth-slices). In each time-sliced image, the reflected radar energy is averaged horizontally among adjacent, parallel radar traverses and in specified time (or depth) windows. Each depth-sliced image displays changes in signal amplitudes within specific depth intervals of the soil (Conyers, 2004). Each amplitude time-slice image shows the distribution of reflected signal amplitudes, which can indicate changes in soil properties or the presence of buried structural features and burials. In many instances, amplitude time-slice images have been used to distinguish or identify buried archaeological features and to reduce interpretation uncertainties. Although the terms “time-slice” and “depth-slice” are used interchangeably, only the term “depth-slice” will be used in this report.

**Investigation Sites:**

Monroe Congregational Church:

The purpose of this investigation was to detect subsurface features relating to the original Monroe Congregational Church, which was erected in 1762 and later torn down in 1847. This former structure had dimensions of 52 by 36 feet, and probably did not have a basement. The present church structure is located at the intersection of Monroe Turnpike and Church Street. The areas of investigation are located on the grassy lawn that is between the church and the parsonage (41.3329 $^o$ N latitude, 73.2072 $^o$ W longitude), and immediately across Church Street on the Monroe Green. These sites are located in an area of Woodbridge fine sandy loam, 2 to 8 percent slopes, very stony (46B). The well-drained Woodbridge series soils are very deep (> 150 cm) to bedrock and moderately deep (50 to 100 cm) to dense lodgement till. The Woodbridge soil is well drained and has low clay and soluble salt contents. As a consequence, Woodbridge soils are considered well suited to GPR.

Farmington Station:

The planned Farmington Canal Heritage Greenway project in the Town of Farmington will feature a 12 foot wide bituminous multi-use trail that will be approximately 2.4 miles long and constructed along a former railroad bed, which is currently owned by the Connecticut Department of Transportation. The proposed Greenway project will also include parking facility, interpretive signs, landscaping and benches. The purpose of the geophysical investigation is to identify remnant of the former *Farmington Station*, as well as several other former rail support facilities (e.g., water tower and platforms) located within the project's potential area of impact.

Based on historical records, maps, and aerial photographs, the area of investigation is located in the general vicinity of the former *Farmington Station*. The investigation area is located in the grassy area south of the intersection of Meadow Road and New Britain Avenue in Farmington, Connecticut (41.7200 $^{o}$ N latitude, 72.8629 $^{o}$ W longitude). The area of investigation is located in a delineation of Merrimac sandy loam, 0 to 3 percent slopes (34A). The very deep, somewhat excessively drained Merrimac soils formed in sandy outwash and are considered well suited to GPR.

<u>Berlin Farmstead:</u>
The purpose of this geophysical investigation was to identify former outbuildings that are related to a historical farmstead (circa 1770). The farmstead is located on Kensington Road in Berlin, Connecticut (41.6029 $^{o}$ N latitude, 72.7787 $^{o}$ W longitude). The investigation area is located in a delineation of Branford silt loam, 0 to 3 percent slopes (30A). The very deep, well drained Branford soils formed in loamy over sandy and gravelly outwash materials that are derived mostly from red sedimentary rocks and basalt. Branford soils are considered well suited to GPR.

<u>Hampton Cemetery:</u>
A relatively open area within the Brewster plot of the Hampton Cemetery is suspected to contain unmarked graves. The purpose of this investigation was to use GPR to confirm the presence or absence of burials within this portion of the cemetery. The plot dates back to the early 1800's. Lines of existing headstones and footstones are intermixed suggesting their repositioning to accommodate mowing operations. The Hampton Cemetery is located near the intersection of Cemetery and Pudding Hill Roads in Hampton, Connecticut (41.76615 $^{o}$ N latitude, 72.0577 $^{o}$ W longitude). The cemetery and the investigation area are in a delineation of Canton and Charlton soils, 3 to 8 percent slopes, very stony (61B). The very deep, well drained Canton and Charlton soils formed in a loamy mantle underlain by sandy till and loamy till, respectively. These soils are considered well suited to GPR.

<u>Coogan Farm:</u>
The purpose of this ground-penetrating radar investigation was to identify former outbuildings related to a historical farmstead. The Coogan Farm dates back to the 17th-century when Captain John Gallup received a 500-acre land grant from Governor John Winthrop, Jr. for his efforts in the Pequot War. The land was farmed for over 350 years. Some (45 acres) of the original land is presently part of the *Nature and Heritage Center* operated by the Denison Pequotsepos Nature Center and the Trust for Public Land. The Coogan Farm Nature and Heritage Center is located off of Greenmanville Avenue in Southington, Connecticut (41.3678 $^{o}$ N latitude, 71.9606 $^{o}$ W longitude). The selected investigated area has been heavily disturbed over the years. This area is in a delineation of Charlton-Chatfield complex, 3 to 15 percent slopes, very rocky (73C). The well drained and somewhat excessively drained, moderately deep Chatfield soils formed in till. These soils are considered well suited to GPR, but large numbers of rock fragments impeded radar surveys and likely masked the presence of some artifacts.

<u>Salem Community Park:</u>
Salem Community Park is located off of Norwich Road in Salem, Connecticut (41.4836 $^{o}$ N latitude, 72.2547 $^{o}$ W longitude). The Salem Historical Society is searching for the burial site of Samuel and Hannah Dolbeare (circa 1832 and 1811, respectively). Dolbeare was the owner of the Dolbeare Tavern and a wealthy and respected citizen of Salem. It is understood that the burial site for the Dolbeare family is located within the Salem Community Park. The survey area is located in a delineation of Paxton and

Montauk fine sandy loams, 3 to 8 percent slopes (84B). The well drained Paxton and Montauk soils are very deep to bedrock and moderately deep to lodgement till. In addition, Montauk soils have sandy substrata. These soils are considered well suited to GPR, but the large numbers of rock fragments in the till are easily confused with, and obstruct the GPR interpretations of burials. These soils are considered well suited to GPR.

Milford Cemetery:
The purpose of this GPR study was to examine the relative detectability of known graves from different periods of time. The Milford Cemetery is one of the oldest, continuously active burying grounds in Connecticut. Milford Cemetery is located between Plymouth and Gulf Streets in Milford, Connecticut (41.2248 $^{o}$ N latitude, 73.0537 $^{o}$ W longitude). The cemetery is located in a delineation of Haven-Urban land complex, 0 to 8 percent slopes (232B). The very deep, well drained Haven soils formed in loamy over sandy and gravelly outwash. Haven soils are considered well suited to GPR.

The taxonomic classifications of the named soils are listed in Table 1.

**Table 1. Taxonomic Classifications of the Soils that were profiled with GPR.**

| Soil Series | Taxonomic Classification |
|---|---|
| Branford | Coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Typic Dystrudepts |
| Canton | Coarse-loamy over sandy or sandy-skeletal, mixed, semiactive, mesic Typic Dystrudepts |
| Charlton | Coarse-loamy, mixed, active, mesic Typic Dystrudepts |
| Chatfield | Coarse-loamy, mixed, superactive, mesic Typic Dystrudepts |
| Haven | Coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Typic Dystrudepts |
| Merrimac | Sandy, mixed, mesic Typic Dystrudepts |
| Montauk | Coarse-loamy, mixed, subactive, mesic Oxyaquic Dystrudepts |
| Paxton | Coarse-loamy, mixed, active, mesic Oxyaquic Dystrudepts |
| Woodbridge | Coarse-loamy, mixed, active, mesic Aquic Dystrudepts |

**Results:**
Monroe Congregational Church
Survey grids were established on both sides of Church Street in the town of Monroe. The dimensions of the northern grid (on the grassy area between parsonage and present church) were 17 (east-west) by 16 (north-south) meters. Thirty-five GPR traverses were completed in north-south directions at 50 cm intervals across this grid area.

The dimensions of the southern grid (on the grassy area of Monroe Green that bordered Church Street) were 17 (east-west) by 13 (north-south) meters. However, because of trees, the grid was divided into two sections. The western section was 5.5 (east-west) by 13 (north-south) meters. Thirty-five GPR traverses were completed in north-south directions at 50 cm intervals across this grid area.

*Grid 1:*
Figure 3 is a representative radar record from the northern grid area. This traverse was collected along line X = 4 meters and trends from south (along Church Street) to north (near parsonage). All scales on this radar record are expressed in meters. A relatively shallow (20 to 40 cm) layer of suspected fill materials has been highlighted with a white-colored segmented line between distance marks 0 and 9 meters. This feature is believed to be related to the adjoining roadway. What is believed to be the top of an underling layer of dense lodgement till has been highlighted with a yellow-colored segmented line. Other than these features, this and other two-dimensional radar records were nondescript with no clear subsurface reflection patterns that would support the presence of the former structure.

Figure 4 is a 3D, solid-cube, pseudo-image of the northern grid area. To construct this 3D pseudo-image, radar traverses were conducted parallel to the Y axis (left foreground) of the grid. Because data was continuously recorded in this direction, greater detail is evident along the Y axis of the pseudo-image than along the X axis (right foreground) where data were collected at 50 cm intervals (traverse line spacing). Data shown along the X axis is spatial aliased, notably "smeared", and poorer in detail. The smearing problem can be remedied by reducing the interval between traverse lines. On the surface of the 3D pseudo-image, several linear features, which parallel the Y axis, are evident. These features are false and caused by slight errors in the positioning of the *time-zero offset* correction during signal processing. A cluster of higher-amplitude reflections appear on the cube's surface in the northwest corner of the grid area. This area bordered a large tree and some of these higher amplitude reflections probably represent tree roots.

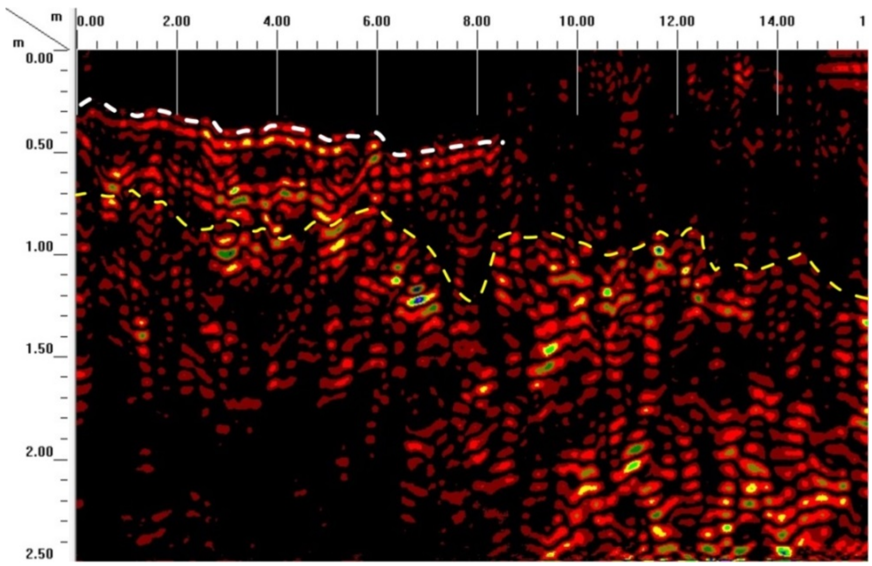


**Figure 3. This two-dimensional radar record was collected along line X = 4 meters on the northern grid area at the Monroe Congregational Church. White and yellow segmented lines highlight interfaces believed to be related to the adjoining roadway and an underling layer of dense lodgement till, respectively.**

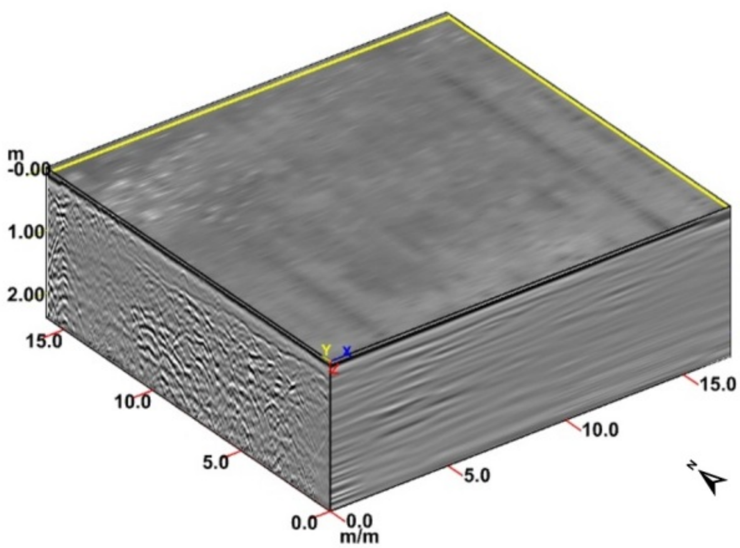


**Figure 4. This solid, 3D pseudo-image is of the northern grid area at the Monroe Congregational Church. Church Street parallels the lower-right boundary of this pseudo-image.**

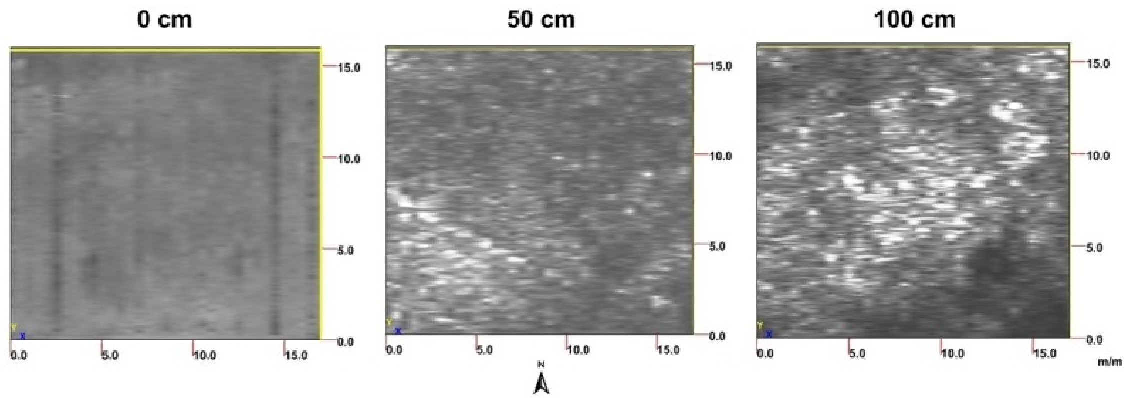


**Figure 5. These three depth-sliced pseudo-images show the reflection patterns for the 0-, 50-, and 100-cm depth intervals of the northern grid at the Monroe Church Site..**

Figure 5 contains three depth-sliced images of the northern grid area. The depth-sliced images shown in Figure 5 are from the 3D pseudo-image shown in Figure 4. In each of these depth-sliced images, the survey area is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and in a specified depth interval (20 cm) window.

In Figure 5, other than the artificial lines produced by processing errors and a cluster of random, higher amplitude reflections in the northwest corner of the grid, the 0 cm depth-sliced image is unremarkable. In the 50-cm depth-sliced image, a linear feature, composed of high-amplitude (colored white) reflections, extends in a northwest to southeast direction across the southwest corner of the grid. This feature could represent an utility line or be related to the former position of the roadway. With increasing depth, the number of high-amplitude reflections increase. While it is very likely that these reflections are caused by larger rock fragments in the underlying till, with some imagination, a rectangular area with a high concentration of high-amplitude reflections can be visualized in the 100 cm depth-sliced image. However, because of the large number of chaotically arranged point reflectors, many of which are presumed to represent rock fragments in the underlying till, the radar survey did not provide any clear indications of a former church structure within this grid area.

*Grid 2:*
Figure 6 contains two solid-cube, 3D pseudo-images from the southern grid area. Because of obstruction by trees, a 3.5 m section between these two pseudo-images was not surveyed. To construct the 3D pseudo-images shown in Figure 6, radar traverses were conducted parallel to the Y axes of each grid (left foreground). Once again, linear patterns on the surface of these 3D pseudo-images that parallel the Y axes are artifacts caused by slight positioning errors in the setting of the *time-zero offset* correction during signal processing. On the surface of the western pseudo-image, a linear pattern of higher amplitude reflections is evident. This lineation cuts diagonally across the grid area. In addition, randomly distributed clusters of higher amplitude reflections occur across the surface of the eastern grid area. Without some ground-truth cores or excavations, no further comment or conclusion can be made concerning these features.

Figure 7 contains three depth-sliced images of the western grid area. In each of these depth-sliced images, the survey area is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and in a specified depth interval (20 cm). On the 0-cm depth-sliced image, a segmented line has been used to help identify a linear feature that cuts diagonally across the lower central portion of the grid area. Without some ground-truth excavations, no further comments on this feature and its identity can be made. It is apparent on the depth-sliced images shown in Figure 7 that the number and amplitude of reflectors increase with increasing depth (compare 0, 50, and 100 cm depth slice images). While some of the reflectors appear aligned, no obvious structural trend that would suggest the presence of a former building is apparent on these depth-sliced images.

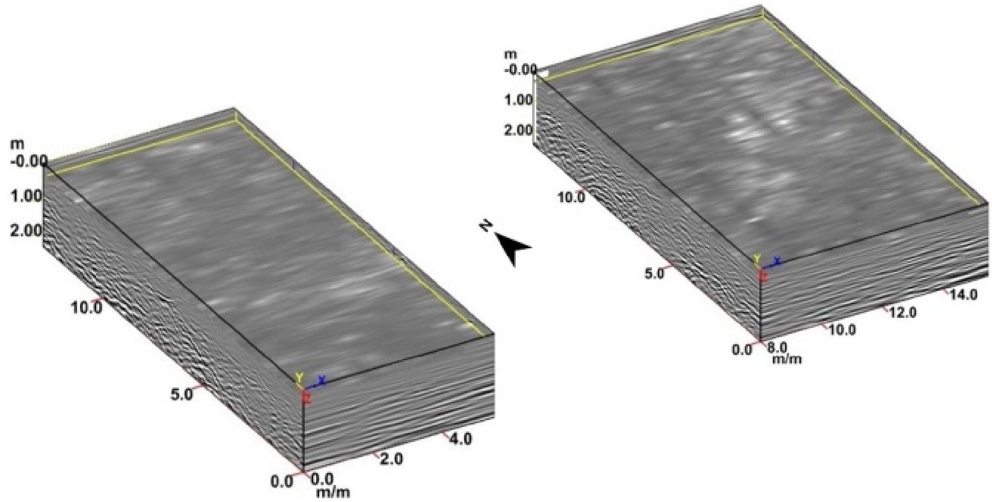


**Figure 6. These solid 3D pseudo-images are from the southern grid area at the Monroe Congregational Church. Church Street parallels the upper-left boundary of these pseudo-images.**

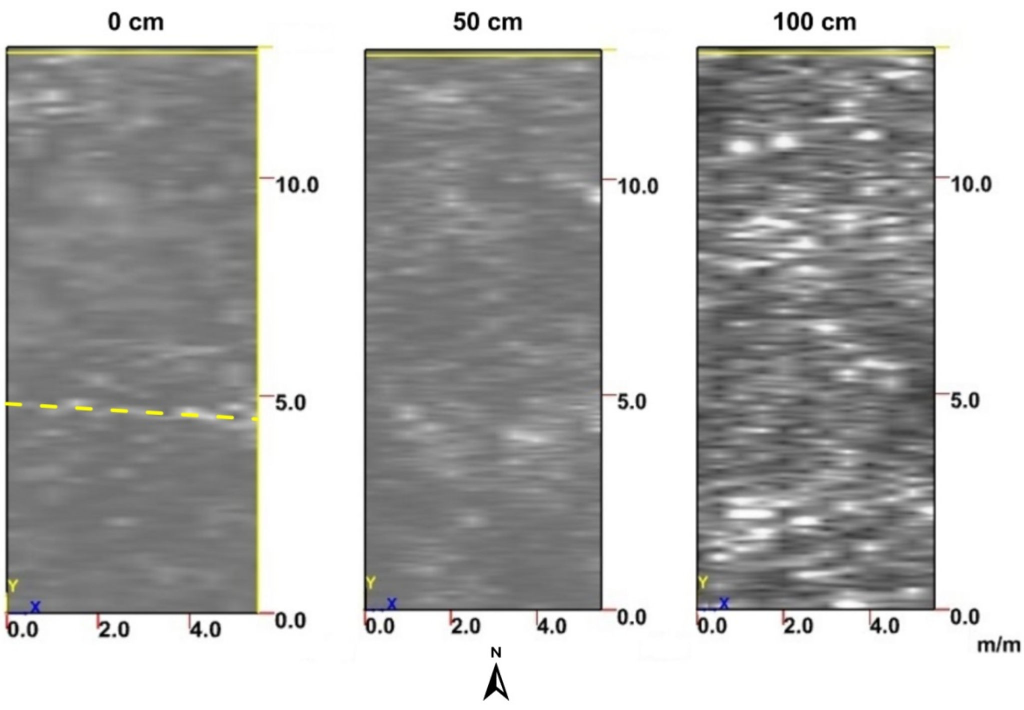


**Figure 7. These three depth-sliced pseudo-images show the reflection patterns for the 0-, 50-, and 100-cm depth intervals of the western grid constructed on the northern edge of the Monroe Green.**

Figure 8 contains three depth-sliced images of the eastern grid area. In each of these depth-sliced images, the survey area is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and in a specified depth interval (20 cm). On the 0-cm depth-sliced image, the two darker, north-south trending linear patterns are artifacts caused by slight positioning errors in the setting of the *time-zero offset* correction during processing (this is also evident on the 50-cm depth-sliced image, but to a lesser degree). As was observed on images from the western grid area, the number and amplitude of reflectors increase with increasing depth (compare 0, 50, and 100 cm depth slice images in Figure 8). Many of these reflectors are assumed to represent rock fragments in the underlying lodgement till of Woodbridge soils. With some inventiveness, two linear patterns have been identified in the 50- and 100-cm depth-sliced images in Figure 8. However, these patterns provide no recognizable trends that suggest subsurface remnants to a former structure.

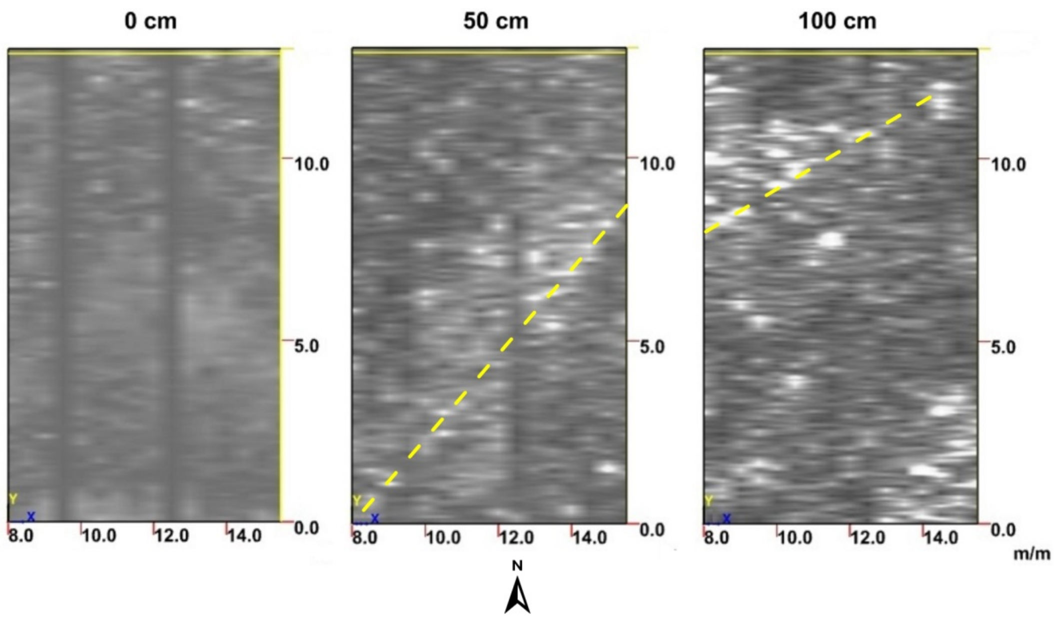


**Figure 8. These three depth-sliced pseudo- images show the reflection patterns for the 0-, 50-, and 100-cm depth intervals of the eastern grid constructed on the northern edge of the Monroe Green.**

An electromagnetic induction survey was conducted across the northern grid area with the Profiler. The same grid lines (lines spaced 50-cm apart) used by the GPR were used by the Profiler. In Figure 9, the spatial distributions of apparent conductivity (upper plot) and inphase response (lower plot) across this grid area are shown. In general, $EC_a$ increases from northwest to southeast across this grid area. The higher $EC_a$ values along the southern edge of the grid area may be the result of an accumulation of road salts that were spread along Church Street, or proximity to utility lines buried along this roadway. In general, spatial $EC_a$ patterns are relatively dispersed and provide no evidence supporting the presence of a former structure. Two notice anomalies (labeled “A” and “B”) do occur on the plots of $EC_a$ shown in Figure 9. The negative $EC_a$ values of these anomalies suggest buried metallic artifacts. One of these anomalies (“A”) is also manifested on the lower plot in Figure 9. As noted by McNeill (1983), the detection of large metal objects is greatly enhanced by measuring the inphase component of the induced magnetic field. Other than these features, no noteworthy spatial patterns are apparent on these plots.

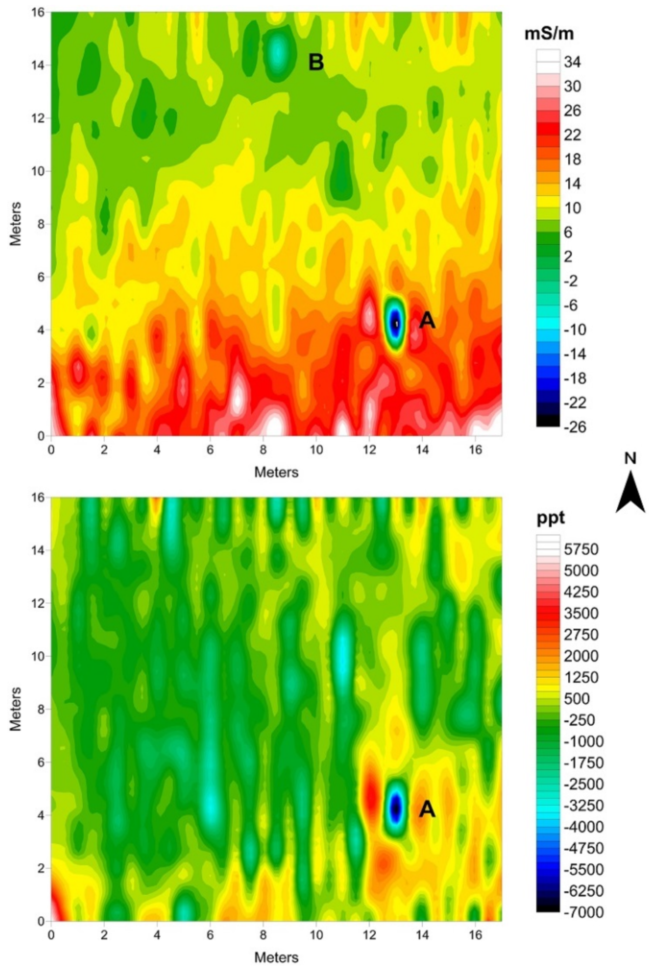


**Figure 9. These 2D plots show the spatial distribution of apparent conductivity (upper) and inphase (lower) responses that were measured with the *Profiler* across the northern grid area in Monroe.**

Farmington Station:

The purpose of this geophysical investigation is to identify remnant of the former *Farmington Station*, as well as other former rail support facilities (e.g., water tower and platforms), that are located along the projected Farmington Canal Heritage Greenway in Farmington, Connecticut.

A survey grid was established on a grassy area to the west of New Britain Avenue and south of Meadow Road Church Street. This grid was situated over an area that is believed to approximate the location of a former railroad station and the railway line. The dimensions of the grid were 15 (east-west) by 86 (north-south) meters. Sixteen traverses were completed in a back-and-forth manner (in alternating north-south directions) at 100-cm intervals across this grid area with both GPR unit and an EMI sensor.

Figure 10 contains two radar records, each from line Y = 0 meters. This is the westernmost, north-south trending grid line and the furthest from New Britain Avenue. In Figure 10, the upper radar record shows the entire traverse line, while the lower radar record shows only the first 22 meters of this traverse line (northernmost portion of line). A noteworthy feature on these radar records is the continuous line of seemingly equally-spaced point reflectors at a depth of about 45 cm. These reflectors are assumed to represent relicts of the former railway line; railroad crossties used to support the rails. These features were laid perpendicular to the rails, and served to transfer loads to the track ballast and hold the rails erect. These lines of point reflectors were only evident on the three western-most traverse lines (2 meter width).

Also evident on the radar records shown in Figure 10, are planar reflectors representing contrasting (most probably in terms of grain size distributions) stratifications in the underlying glacial outwash.

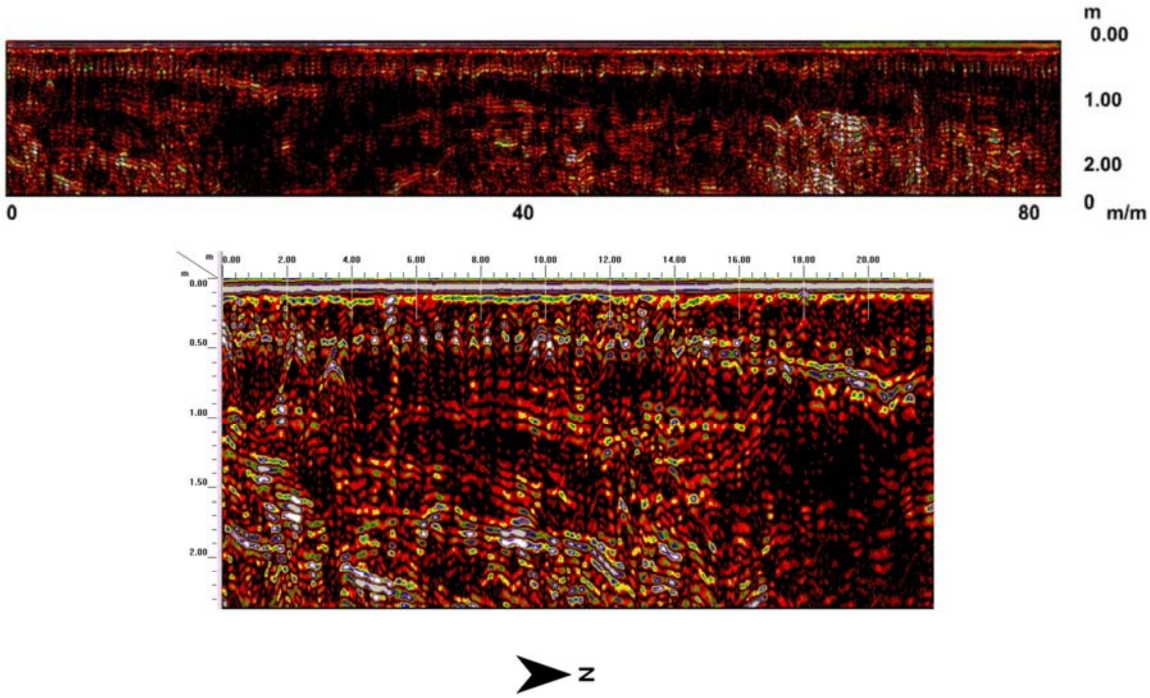


**Figure 10.These two radar records are from the Farmington grid, line Y = 0 meters. The upper record shows the entire traverse line, while the lower radar record provides a close-up view of the first 22 meters of this traverse line. All scales are expressed in meters.**

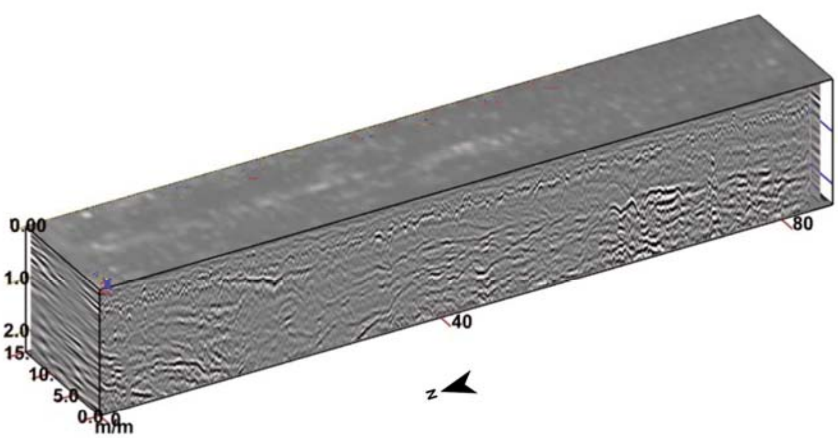


**Figure 11. This solid 3D pseudo-image represents the Farmington grid area. New Britain Avenue parallels the upper-left boundary of this pseudo-image. All scales are expressed in meters.**

Figure 11 is a 3D pseudo-image of the Farmington grid area. To construct this 3D pseudo-image, radar traverses were conducted in a back and forth manner across the grid and parallel to the X axis (right foreground). Later, during processing, the individual data files were assemble together to create a 3D grid file and pseudo-image. Because data was continuously recorded in a north-south direction, greater detail is evident along the X axis of the 3D pseudo-image than along the Y axis (left foreground) where data were collected at 100 cm intervals (traverse line spacing). Data shown along the Y axis is spatial aliased, “smeared”, and poorer in detail.

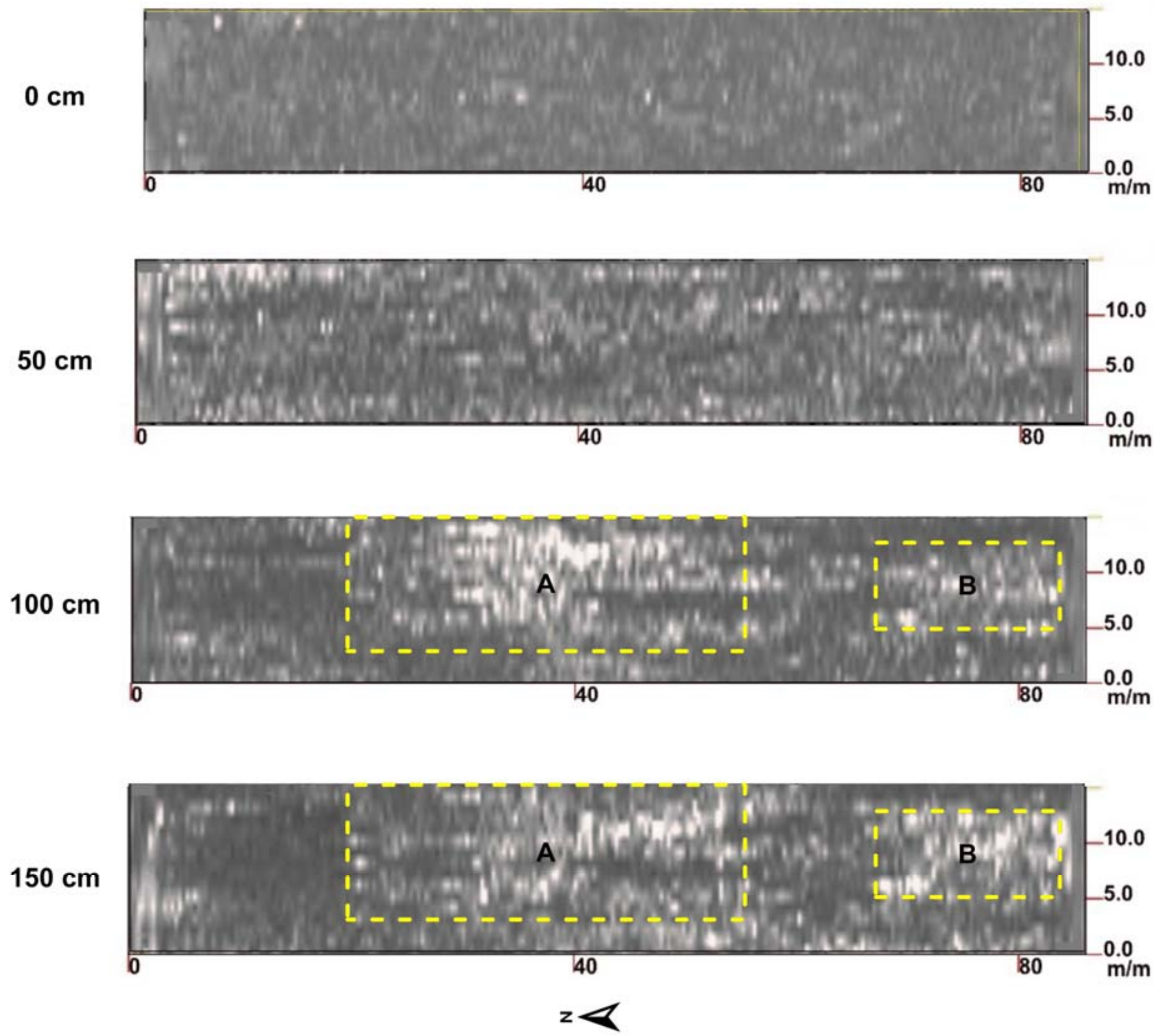


**Figure 12. These four images represent slices taken from the 3D pseudo-image shown in Figure 10 at different depth intervals (i.e., 0, 50, 100, and 150 cm).**

Figure 12 contains four depth-sliced images from the 3D pseudo-image shown in Figure 11. In each of these depth-sliced images, the survey area is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and vertically in a 15-cm depth window. The 0-cm depth-sliced image is unremarkable. However, in the 50-cm depth-sliced image, faint indications of the former rail line are evident as higher-amplitude (whiter) reflections along the upper (western) boundary of the grid area. In the 100- and 150-cm depth-sliced images, two clusters (A & B) of higher amplitude (colored white) reflectors are evident and have been enclosed by segmented, yellow-colored lines. While generally ill-defined and unclear, these clusters do suggest the presence of linear reflectors, which are more likely to represent artificial rather than natural features. It is also very likely that some of these reflections represent larger rock fragments in the underlying glacial outwash. Based on radar reflection patterns, the area identified by "A" in the 50- and 100-cm depth sliced images shown in Figure 12 is considered the most probable location of the former train station. In order to verify this interpretation, a small number of borings or shallow excavations by a qualified archaeologist is recommended.

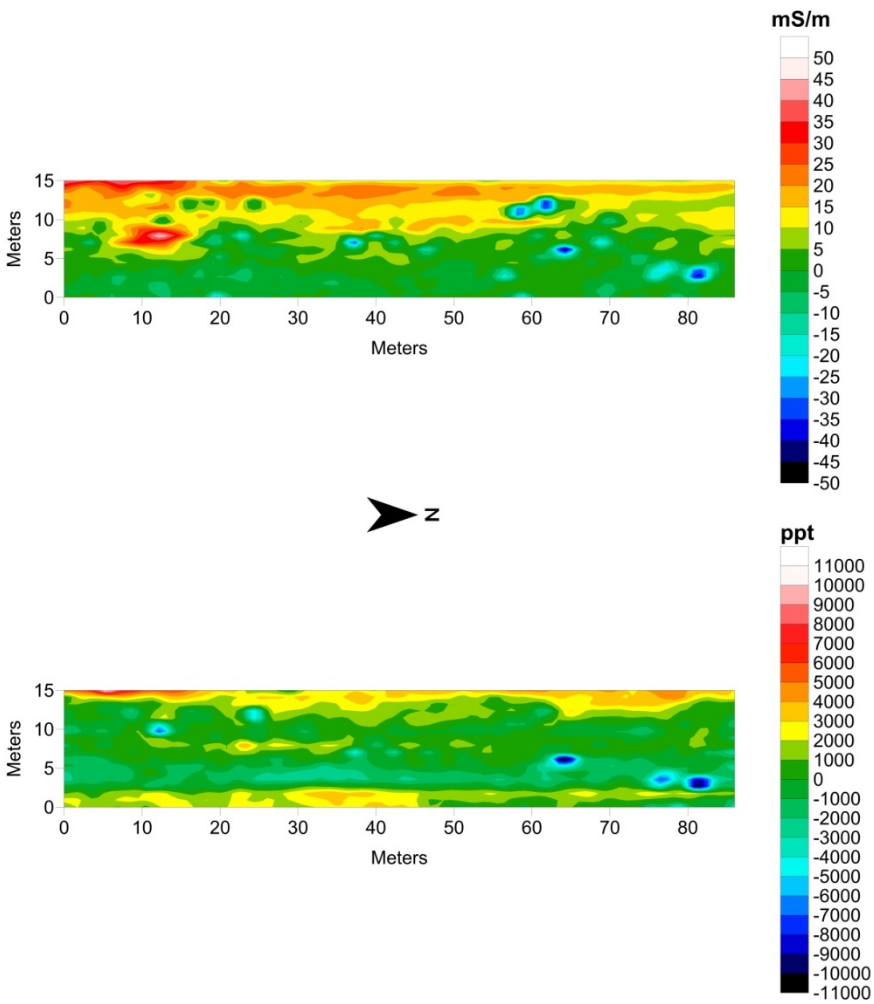


**Figure 13. These plots of apparent conductivity (upper plot) and inphase (lower plot) data were collected across the Farmington grid site with a Profiler EMP-400 sensor.**

Figure 13 contains two simulations based on data collected with the Profiler. The upper plot shows the distribution of apparent conductivity ($EC_a$) while the lower plot shows the distribution of inphase data. The data in both plots were collected at a frequency of 15000 kHz. The inphase response is more sensitive to metallic objects. In both plots, higher values are evident along the western boundary (upper margin) of the grid; the likely location of the former rail line. A relatively broad area of higher $EC_a$ (> 10 mS/m) extends across the entire grid site from north to south along the western boundary. Knowing the history of this site, these relatively high spatial $EC_a$ patterns are believed to represent the presence of artifacts associate with the former railroad line. A conspicuous area of high $EC_a$ (> 30 mS/m) can be observed in the southern portion of the grid area, near X = 12, Y = 8 meters. This area also has a negative inphase response, suggesting the presence of buried metallic artifacts.

On the lower plot in Figure 13, parallel bands of higher and lower inphase data occur along the grid's eastern boundary and parallel with New Britain Avenue. The location and orientation of these anomalous patterns suggests the presence of buried utility line(s).

Berlin Farmstead:

The purpose of this GPR investigation was to identify former outbuildings related to a historical farmstead. Two survey grids were established across mowed areas located to the southwest and west of the present farmhouse structure. The dimensions of the smaller grid located to the southwest of the farmhouse were 9 (east-west) by 8 (north-south) meters. Ten GPR traverses were completed in north-south directions at 100-cm intervals across this grid area. The X-axis was the eastern-most, north-south trending line. The dimensions of the larger grid were 17 (east-west) by 35 (north-south) meters. Eighteen GPR traverses were completed in north-south directions at 100-cm intervals across this larger grid area. The X axis was the eastern-most, north-south trending line.

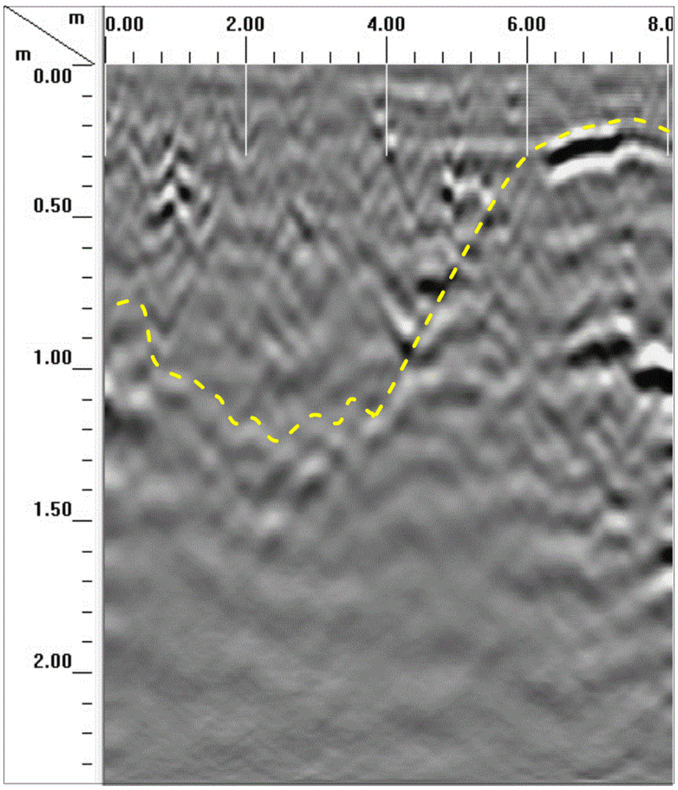


**Figure 14. This two-dimensional radar record was collected along line Y = 2 meters on the smaller grid area at the Berlin Farm Site. The outline of a highly interpretive, trough-like feature has been highlighted with the yellow, segmented line.**

Figure 14 is a representative radar record from the smaller grid area. This radar record was collected along line Y = 2 m, which trended from south to north. All scales on this radar record are expressed in meters. Several higher-amplitude (represented in shades of bright white and black) point reflectors are evident on this radar record. Each reflection consists of both positive (colored white) and negative (colored black) polarity reflections. These features may represent larger rock fragments, tree roots, or buried artifacts. Though unclear and highly interpretive, a large trough-like subsurface feature appears to extend across the first 6 meters of this radar record. This feature has been highlighted by a yellow-colored, segmented line in Figure 14. This feature appears to be about 1.2 m at its deepest point. While the identity of this feature is unknown and its boundary only approximated, it may be worthy of future investigations by a qualified archaeologist.

Figure 15 contains four depth-sliced images of the smaller grid area at the Berlin farm site. These images of the grid area have been made at depths of 0-, 50-, 100- and 150-cm. In each of these depth-sliced images, the survey area is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and in a specified depth (20-cm) window.

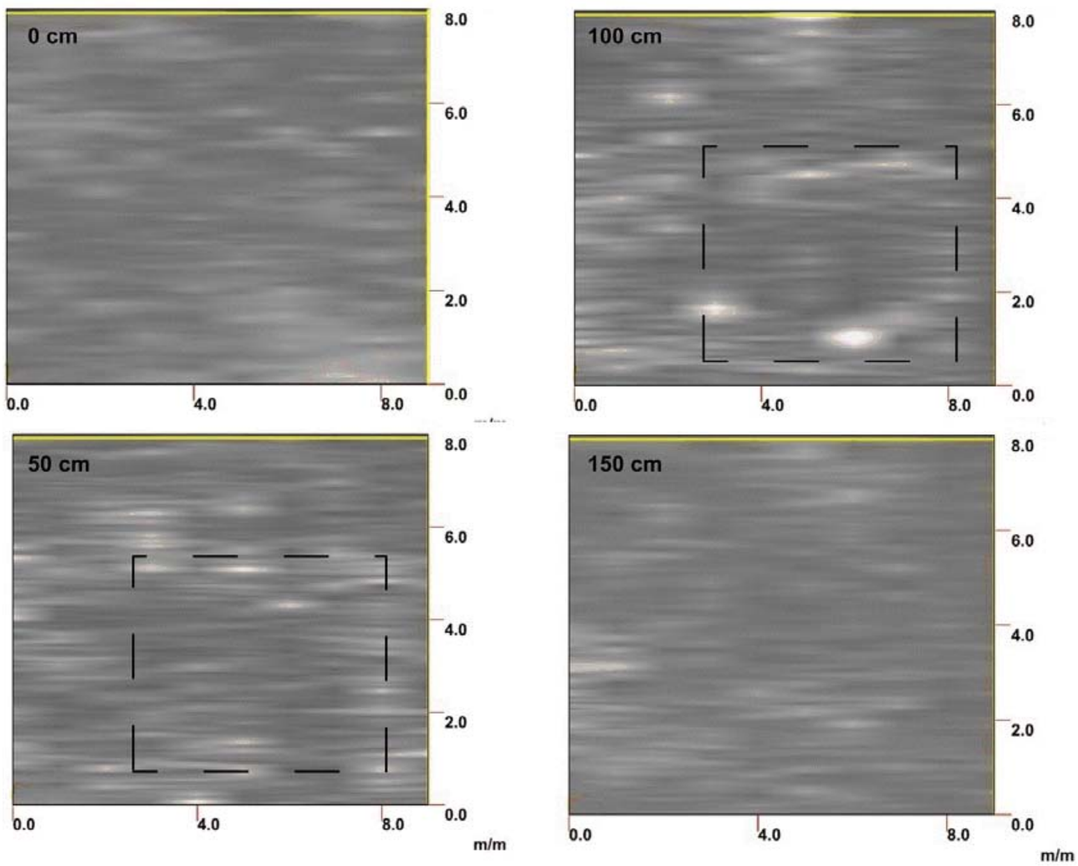


**Figure 15. These four images represent slices taken across the smaller grid area at the Berlin Farm site at different depth intervals (i.e., 0-, 50-, 100-, and 150-cm).**

In general, the depth-sliced images shown in Figure 15 are unremarkable and lack subsurface reflections that suggest a buried artificial structure. However, in the 50- and 100-cm depth-sliced images, an area of relatively no reflections that is surrounded by higher amplitude reflections is indistinctly evident. This area has been approximated by segmented, black colored lines on these two depth-sliced images. While considered highly speculative, this area, based on the radar imagery, would be considered the most recommendable if further studies by archaeologists are desired.

Figure 16 is a representative radar record from the larger grid area at the Berlin site. This traverse was collected along line Y = 13 meters, which trended from south to north. All scales on this radar record are expressed in meters. There are some indications of an orderly arrangement of reflections in alternating layers, each presumably having different particle size distributions and moisture contents, on this radar record. Such stratification is considered characteristic of Branford soils, which formed in loamy over sandy and gravelly glacial outwash. Several high-amplitude point reflectors (identified by hyperbolic patterns) are evident on this radar record. Each reflection consists of both positive (colored white) and negative (colored black) polarity reflections. These point reflectors probably represent larger rock fragments and/or tree roots, but some may represent buried cultural features. Unfortunately, while GPR locates subsurface features, it does not identify these features.

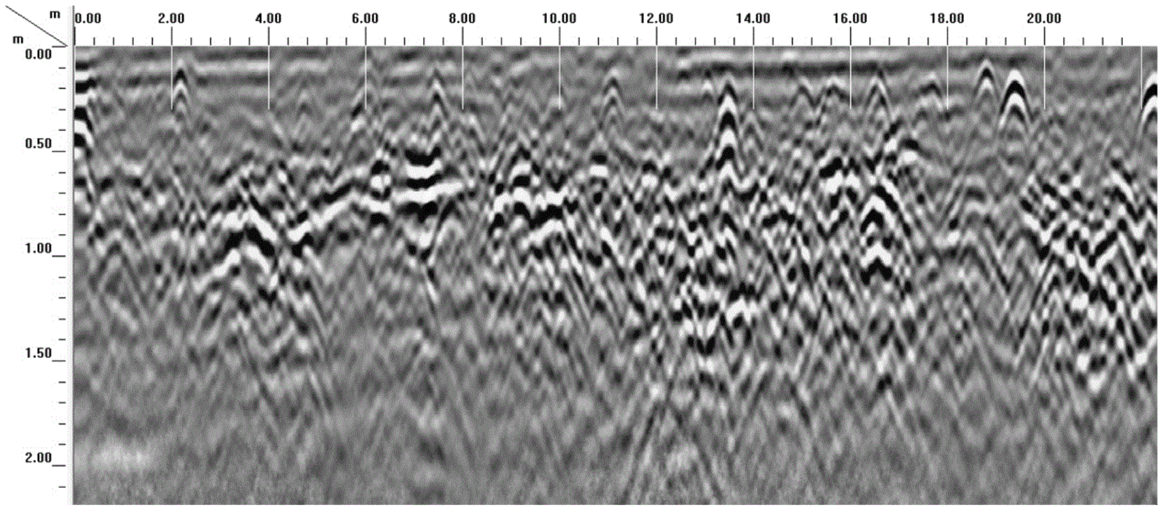


Figure 16. This two-dimensional radar record was collected along line Y = 13 meters of the larger grid area at the Berlin Farm Site

Figure 17 contains four depth-sliced images of the larger grid area at the Berlin farm site. These slices of the grid area have been made at depths of 0-, 25-, 50-, and 75-cm. Each depth-sliced image is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and in a 20 cm depth window.

On each depth-sliced image shown in Figure 17, multiple, randomly distributed, high-amplitude (colored white), point reflectors are evident. These reflectors appear most numerous on the 25- and 50-cm depth-sliced images and in the northern and northwestern portions of the grid area. In general, as no orderly arrangement for these reflectors is apparent, the features that caused these reflectors are assumed to be natural. An exception may be found in the southeast (lower right) corner of the grid where a cluster of high-amplitude reflections on the 50- and 100-cm depth-slices produces what seems to be a rectangular pattern.

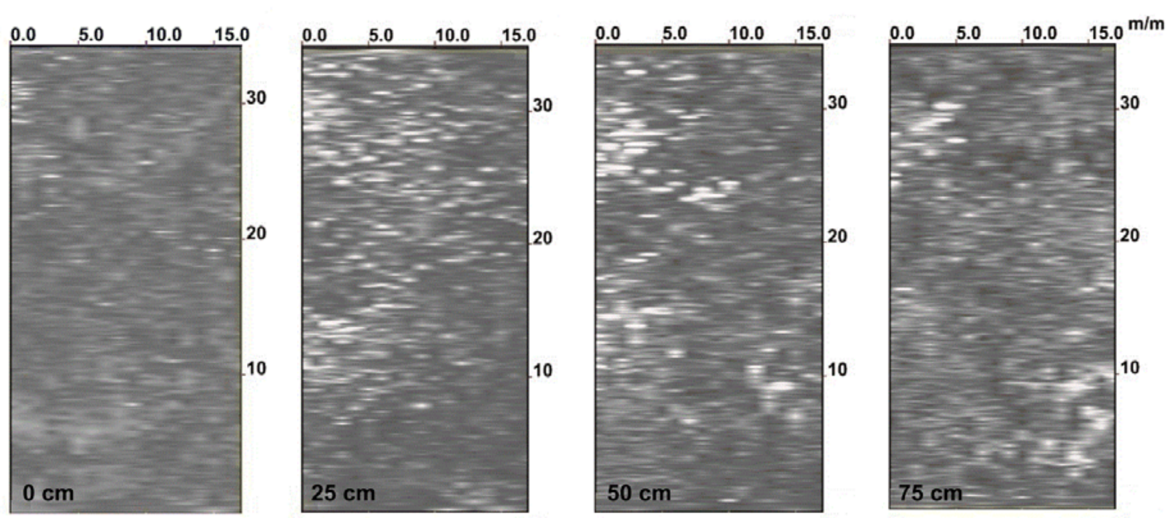


Figure 17. These four images represent slices taken from the larger grid area at the Berlin Farm site at different depth intervals (i.e., 0, 25, 50, and 75 cm).

Hampton Cemetery:

The purpose of this GPR investigation was to identify unmarked graves in a relatively open area within the Brewster plot of the Hampton Cemetery. A grid with dimensions 4 (east-west) by 11 (north-south) meters was established across this open area. Nine GPR traverses, each 11 meters long were completed in north-south directions at 50 cm intervals across this grid area.

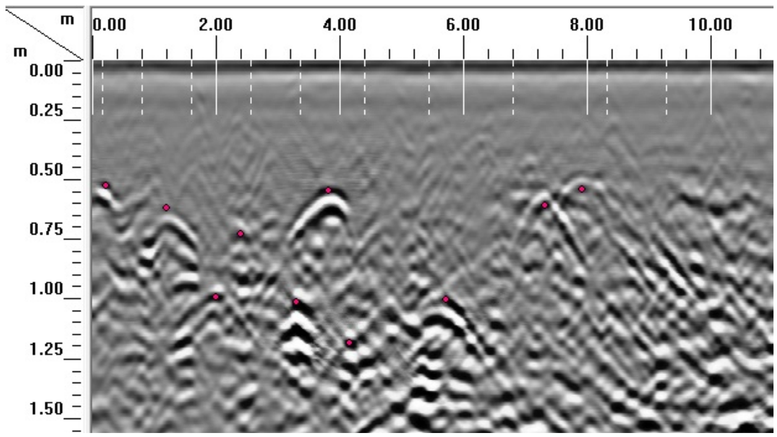


**Figure 18. This two-dimensional radar record was collected along line X = 50 cm within the Brewster plot of the Hampton Cemetery. The white colored, segmented, vertical lines at the top of this record mark the center of nearby headstones that date from 1772 to 1823. Red dots mark the tops of point reflectors.**

Figure 18 is a representative 2D radar record from the Brewster plot grid. This traverse was collected along line X = 50 cm, which trends in a general south to north direction across the grid. All scales on this radar record are expressed in meters. The white-colored, vertical, segmented lines at the top of the radar record mark the approximate centers of nearby headstones and footstones. These marks were impressed on the radar record as the antenna was pulled passed these features. Headstones and footstones within this cemetery have been moved and mingled in rows to facilitate mowing operations. It is uncertain whether the line of headstones is presently aligned with graves. A quick scan of the radar record in Figure 18 reveals that the most prominent reflection hyperbola occurs at a distance of about Y = 3.9 meters and at a depth of about 50 cm. The peaks of several additional hyperbolas have been marked on Figure 18 with red dots. While several of these features may represent burials, there is no way to distinguish graves from other natural features (e.g., rocks, roots, animal borrows) that occurs in these soils. There is no accessory evidence supporting burials, such as the truncation of soil horizons or admixed fill materials caused by grave shafts, on the 2D radar records from this site.

Figure 19 contains four depth-sliced images from the Brewster plot within the Hampton Cemetery. These depth-sliced images are for depths of 0-, 50-, 75-and 150- cm. In each depth-sliced image, the survey area is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and within a 30 cm depth window. A nearby row of headstones and footstones is located to immediate east (left) of these plots. The strong reflection hyperbola noted on the radar record in Figure 18 (at Y = 3.9 meters) appears as a prominent rectangular shaped anomaly on the 50-cm depth-sliced image. This feature’s shallow depth and dimensions suggest a possible buried headstone. The number of high amplitude (colored white) reflections increases with increasing soil depth. Most are believed to represent larger rock fragments in the underlying till. However, on the 100- and 150-cm depth sliced images, several linear patterns of higher amplitude reflection are noticeable and some have an east to west orientation that is characteristic of early gravesites. No conclusions can be made at this time in the absence of ground-truth core observations.

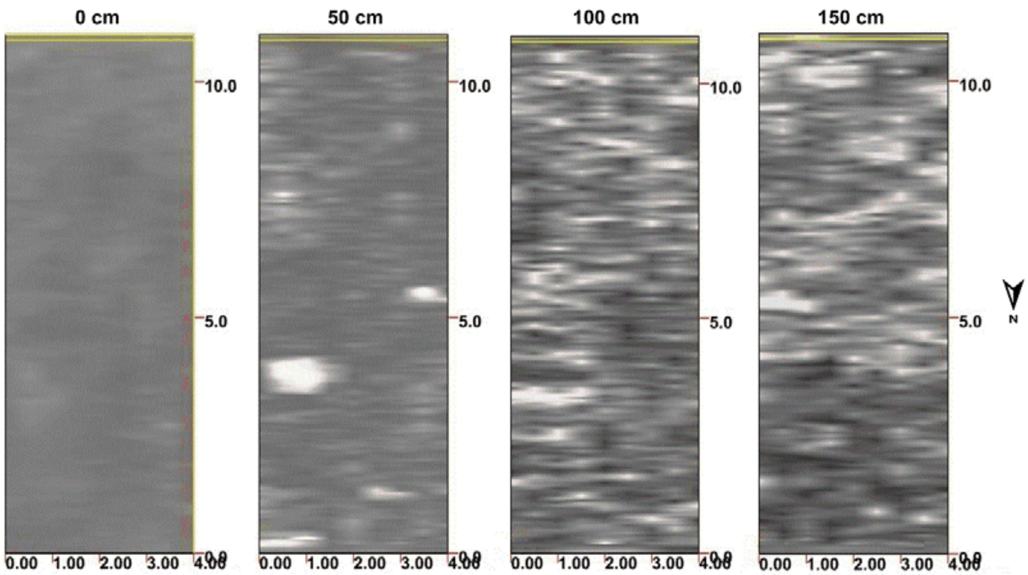


**Figure 19. These four depth-sliced images represent slices taken from Hampton Cemetery site at different depth intervals (i.e., 0- , 50-, 75- , and 150- cm).**

<u>Coogan Farm:</u>
Several "wildcat" or randomly located exploratory GPR surveys were completed across different portions of the Coogan Farm in a futile attempt to locate remnants of structures related to this historical farm. The area is large (45 acres), rocky and partially forested, and the existence and locations of former structures are unknown. It was decided to concentrate GPR survey efforts on a grid, which was established within an animal enclosure. This enclosure was bounded by impressive walls construct from large fieldstones.

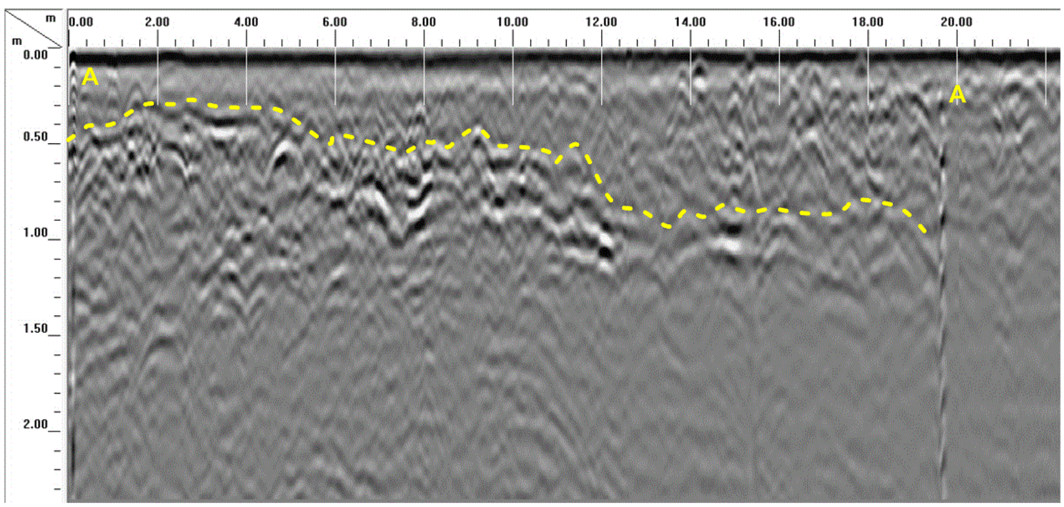


**Figure 20. This two-dimensional radar record was collected along line X = 2.0 meters within the enclosure at the Coogan Farm in Southington.**

Figure 20 is a representative 2D radar record from the interior of this enclosure. This traverse was collected along line X = 2.0 m, which trended in a general south to north direction. All scales on this radar record are expressed in meters. Two metallic objects ("A") buried in the soil produced reflected signals that reverberated down the radar record. An undisclosed subsurface interface has been traced with a segmented yellow-colored line across the radar record shown in Figure 20. This irregular interface may represent the underlying soil/bedrock interface. However, no borings have been presently made to confirm this interpretation. Many of the hyperbolic reflections evident in the soil profile on this radar record are presumed to represent rock fragments.

Figure 21 contains four depth-sliced images of the interior of a historical animal enclosure at the Coogan Farm. Depth-sliced images are for depths of 0-, 25-, 50-, and 75-cm. In each of these depth-sliced images, the survey area is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and across a 20-cm depth window. On each depth-sliced image, multiple, randomly distributed, high-amplitude (colored white), point reflectors are evident. However, these reflectors appear to become more numerous with increasing soil depth. These reflectors are believed to represent rock fragments. In the extreme northern part of the grid area, a persistent pattern of reflectors occurs on each depth-slice image (see "A" on plots in Figure 21). These reflectors represent the metallic reflector that was identified on the radar record shown in Figure 20 near the 19 meter distance mark. On the depth-sliced images shown in Figure 21, these reflectors appear to form a line stretching from east to west across the northern part of the grid area. They may represent a buried fence line or stand of barbed wire. Other than this and the general haphazardness of the many point reflectors that occurs on these images, no other spatial pattern is discernible.

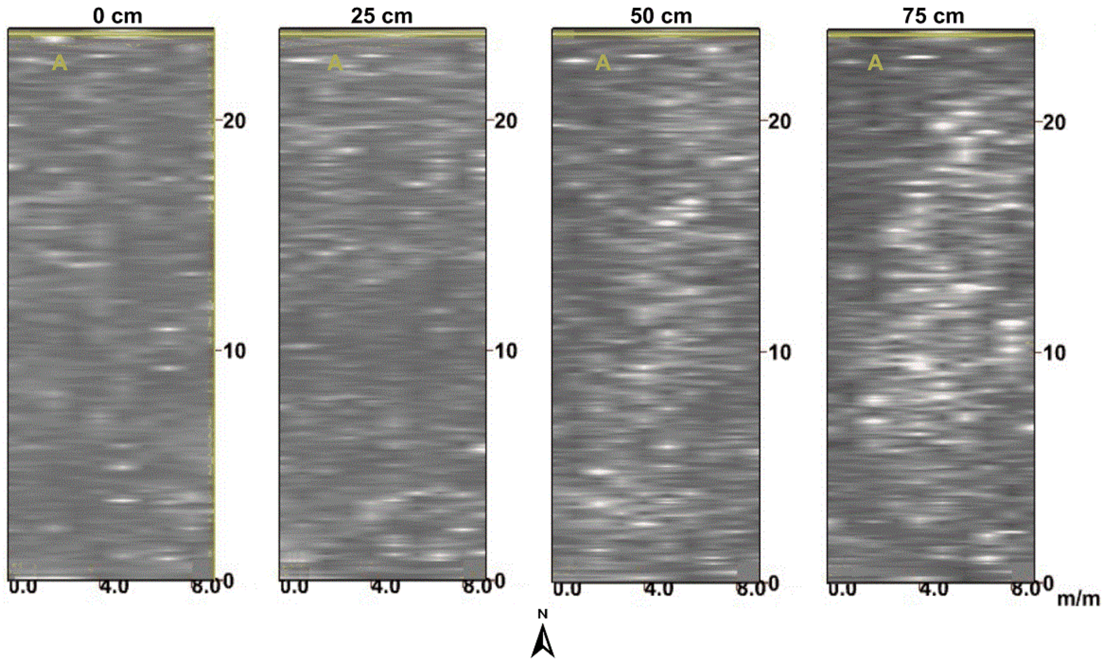


**Figure 21. These four depth-sliced images represent slices taken from the grid within the Coogan Farm enclosure at different depth intervals (i.e., 0-, 25-, 50-, and 75- cm).**

<u>Salem Community Park:</u>
Ground-penetrating radar and electromagnetic induction were used to search Salem Community Park for an unmarked burial site belonging to Samuel and Hannah Dolbeare (circa 1832 and 1811, respectively). Local historians identified an area of higher ground near the entrance to the park where they suspected the grave site may be located. A grid, with dimensions 16 (east-west) by 13 (north-south) meters, was established across this open, grassy area. Thirty-three GPR traverses, each 13-meters long were completed in a general north to south direction across the grid area. The distance between adjoining grid lines was 50-cm.

Figure 22 is a representative radar record from the grid area. This radar traverse was collected along line X = 6.0 meters. All scales on this radar record are expressed in meters. This radar record contains many hyperbolic reflections. Some of the higher-amplitude and better expressed hyperbola within the upper 1 meter of the soil profile have been identified with white-colored arrows. The hyperbolas are produced by reflections from point objects located within the soil. As the mapped Paxton and Montauk soils formed in glacial till, the point reflectors are assumed to represent larger rock fragments. No discernable feature other than these point reflectors is immediately evident on this radar record. Two, deeper, higher-amplitude point reflectors are possibly worthy of note. One is located at a depth of about 130 cm beneath the 3 meters distance mark. This "anomaly" has been circled in Figure 22. The other interesting reflector is located at a depth of about 80 cm beneath the 9 meters distance mark. This "anomaly" has been indicated with a white-colored arrow in Figure 22. Other than their high amplitudes, these features are unremarkable and seem undeserving of further attention.

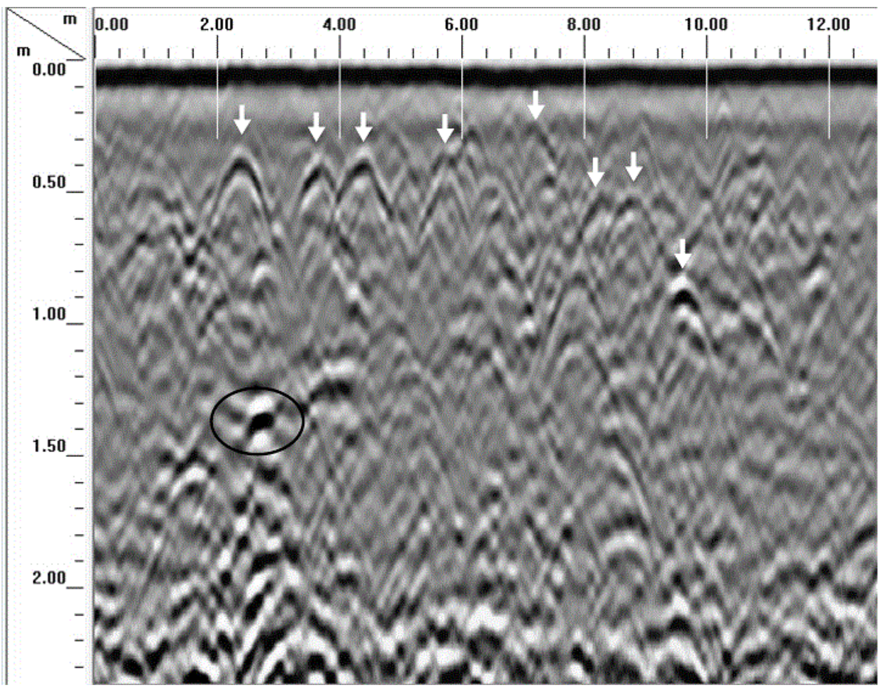


**Figure 22. This two-dimensional radar record was collected along line X = 6.0 meters of the grid that was established over a portion of Salem Community Park.**

Figure 23 contains four depth-sliced images from the Salem Community Park grid area. These images are for soil depths of 0-, 50-, 100-, and 150-cm. In each of these depth-sliced images, the survey area is viewed from directly overhead. In each depth-sliced image, the reflected radar energy has been averaged horizontally among adjacent, parallel radar traverses and in a 20-cm depth window.

In general, the depth-sliced images shown in Figure 23 are nondescript. Each depth-sliced image contains numerous higher-amplitude point reflectors, which are randomly dispersed across the grid area. However, on the 100 cm depth-sliced image a series of these point reflectors appear to form a straight line that cuts diagonally across the survey area from northwest to southeast. This line of point reflectors has been highlighted with a black-colored, segmented line in Figure 23 (see 100-cm depth-slice image). On the 150-cm depth-sliced image in Figure 23, two high-amplitude linear reflectors have been circled. One of these reflectors represents the reflector that was identified and circled on the 2D radar record shown in Figure 22. Because of their shape or geometry, both features may be noteworthy and warrant future attention.

The Profiler was used to reconnoiter a larger area about the GPR grid in an attempt to locate additional subsurface features that may be associated with an unmarked gravesite or the history of the site. Across much of the reconnoitered area, the apparent conductivity and inphase responses were non-descript and rather uniform (see Figure 24). However, several clusters of anomalous values were evident especially near the western boundary of the survey area. This area bordered the access road to the park and a line of utilities. Some of these anomalous spatial patterns and values are associated with these cultural features. On the simulations shown in Figure 24, the anomaly near "B" is in close proximity to a utility pole and may have been caused by this feature.

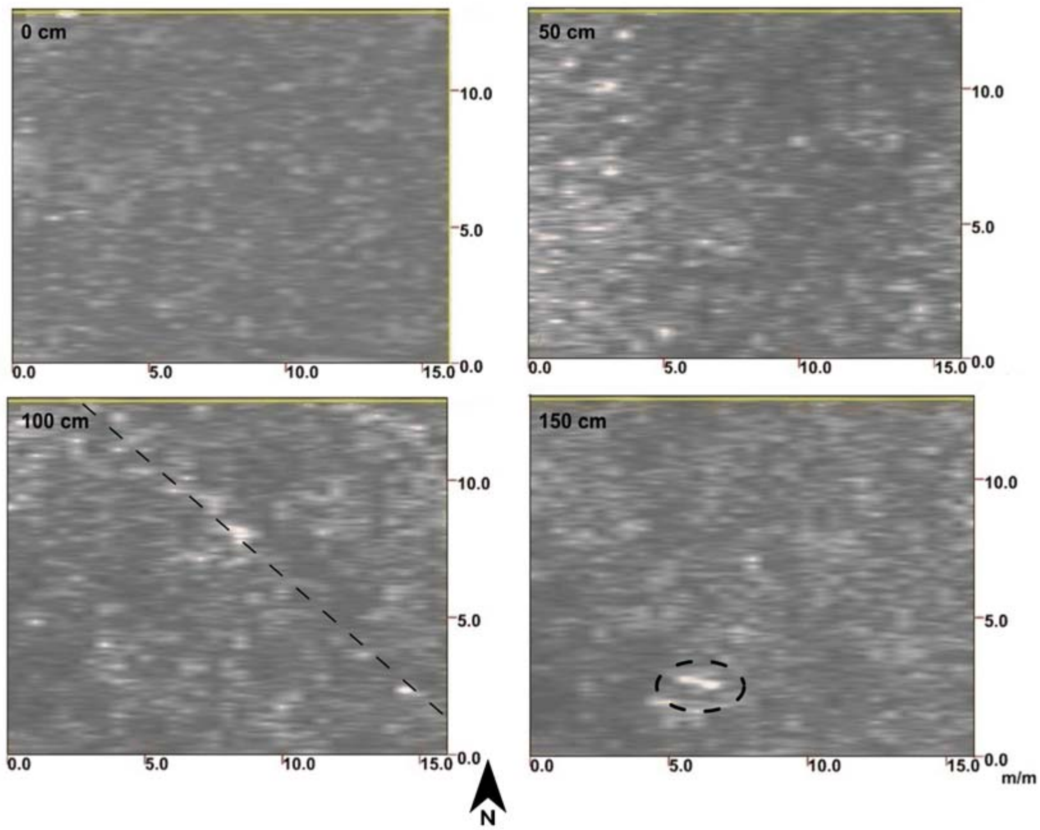


**Figure 23. These four depth-sliced images are from the grid that was established across a portion of Salem Community Park. Slices have been made at different soil depths (i.e., 0-, 50-, 100-, and 150-cm).**

During this field investigation, attention was focused on an EMI anomaly that was rather remote from the GPR grid area. In Figure 24, this anomaly is faintly evident to the left of "A". The EMI responses suggested a buried metallic feature. The feature causing the atypical responses could not be associated with any known cultural feature and was therefore of interest. Several GPR traverses were made across this anomalous area. Figure 25 is a representative radar record from this area. A high-amplitude, hyperbolic reflection that is at a depth of about 70 cm has been highlighted with a circled in Figure 25. This feature is believed to have caused the anomalous response. A hasty, preliminary excavation was made over the suspected site, but results were inconclusive. This site may be revisited at a later time by local historians and archaeologist in order to make a more comprehensive examination of this anomaly and site.

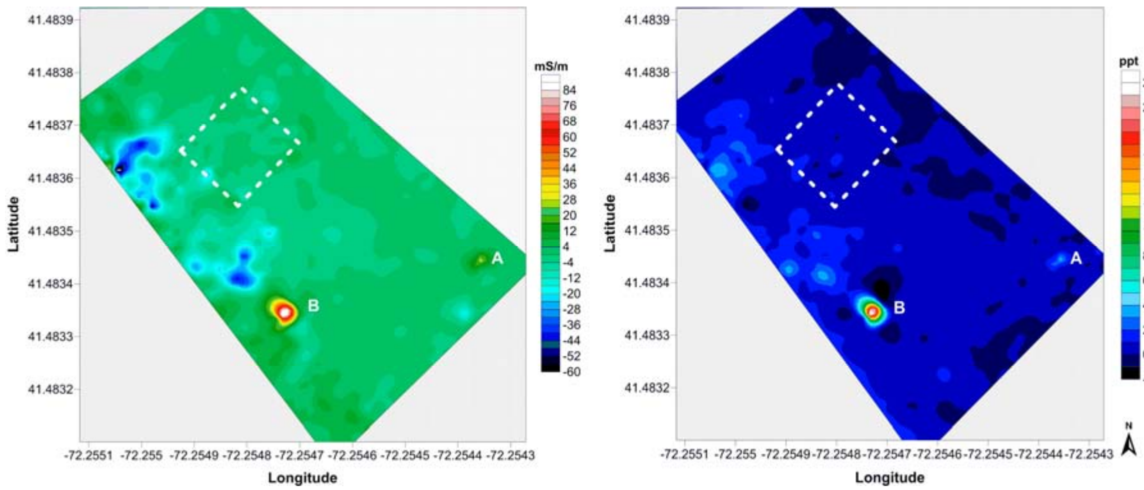


**Figure 24. These simulations of a portion of Salem Community Park were prepared from apparent conductivity (left) and inphase (right) data collected with the Profiler. In each plot, white-colored segmented lines have been used to show the relative location of the GPR grid area.**

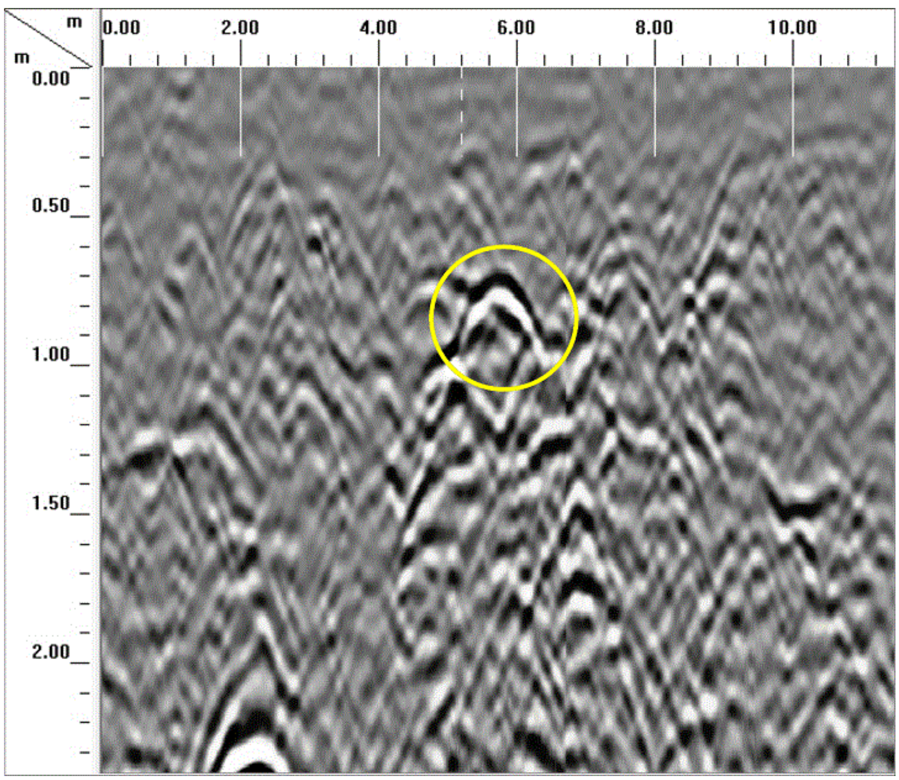


**Figure 25. This two-dimensional radar record was collected across the anomalous area "A" that is identified in Figure 24. The feature believed to have caused an anomalous EMI response has been circled.**

<u>Milford Cemetery:</u>
The purpose of this study was to examine the relative detectability with GPR of known graves from different periods of time. The study was conducted in the Milford Cemetery; one of the oldest, continuously active burying grounds in Connecticut.

As noted by Henderson (1987) ''burials exist in an environment in which a complex interaction occurs between a wide range of variables.'' This partially explains differences that have been observed in the state of burial preservations and detection with GPR within the same cemetery. The detection of burials with GPR often depends upon the materials used to contain the bodies. Within a given cemetery, materials used to enclose corpses can consist of shrouds, body bags, wooden caskets, stone or concrete vaults, and/or fiberglass, composite or metal coffins. Early settlers often buried their dead wrapped in shrouds and placed in coffins made of wood (Owsley and Compton,1997). Wood coffins were the most commonly used burial receptacle until the mid- to late-19th century (Haberstein and Lamers, 1981). Metallic or lead coffins and concrete burial vaults provided relatively large, long-lasting, and more contrasting interfaces that produce high amplitude, recognizable radar reflections. Metallic coffins were first patented in the 1848, but were not common until the 1860s after mass production had begun (circa 1858) (Owsley and Compton, 1997).

In general the preservation of early burials and their identification with GPR depends on soil conditions, but is generally poor (Owsley and Compton, 1997). Milford Cemetery is located in relatively level area of Haven-Urban land complex, 0 to 8 percent slopes (232B). The very deep, well drained Haven soils formed in loamy over sandy and gravelly glacial outwash. Because of their low clay and soluble salt contents, Haven soils are considered well suited to GPR investigations. In addition, Haven soils are considered to have medium potential for the preservation of bones (Surabian, 2012). However, the acidic pH of Haven soils may create conditions that are not favorable for the preservation of bones. Also, within a cemetery, such as Milford Cemetery, burials will produce different GPR responses not only because of differences in states of preservation and spatial variations in soil properties, but changes in burial practices over time.

In this study a 400 MHz antenna was used along closely-spaced traverse lines within structured grids. Grids were representative of burials spanning a 300 year time period from the early 1700s to the early 2000s. These rather small grids were established between rows of headstones and foot stones. The spacing between grid lines was 25 cm. All radar traverses were conducted along grid lines that were orientated in a general north-south direction. It was assumed that burials are orientated in a traditional west to east direction in order for the deceased to face the rising sun. Crossing orthogonally across a burial with a GPR antenna will produce a hyperbolic reflection pattern. This facilitates the identification of burials. On radar records, a subsurface anomaly that is narrow (about twice the width of a body) and linear (about 100 to 200 cm long) can suggest a probable burial. Multiple, similarly aligned, elongated subsurface anomalies occurring at a common depth on radar records suggest probable burials.

All radar records were similarly processed. Processing consisted of time-zero adjustment, background removal and migration. All accompanying presentations are displayed with the same color table and color transform, and use the maximum signal amplitude option. The display gains were varied slightly in order to bring out subtle signal amplitudes on some presentations.

*Burials dated to the early 2000s*:
The dimensions of this grid were 9 by 2 meters. Nine, 9-meters long, parallel radar traverses, which were spaced 25-cm apart, were made across this grid. The grid was located between a row of footstones and headstones. There are six recorded burials within the grid area that are dated between the years of 2003 and 2007. Figure 26 contains four depth-sliced images from this grid site. Each image is viewed from directly overhead looking downwards into the grid. These depth slices average the reflection amplitudes within a 30-cm vertical interval at depths of 0-, 50-, 100-, and 150-cm.

Other than the 50 cm depth-sliced image, the images shown in Figure 26 are nondescript. The 50-cm depth-sliced image shows five and possibly a six planar reflectors that are elongated in an east-west direction. On this depth-sliced image, the reflector nearest the 1.5 meters horizontal distance mark may be composed of two very closely spaced and overlapping reflectors. All of these reflectors represent burials. It is surprising that these burials, which were most likely placed in shallow concrete vaults, are only visible on the 50 cm depth sliced images, and variable in expression. This is much shallower than the "six feet deep" often referenced for burials in western movies. Based on local jurisdictions, burial depth can vary from 1.5 to greater than 12 feet. Historians believe the "six feet " phrase dates to the Great Plague (circa 1665), when officials required graves to be at least six feet deep in order to limit the spread of the outbreak.

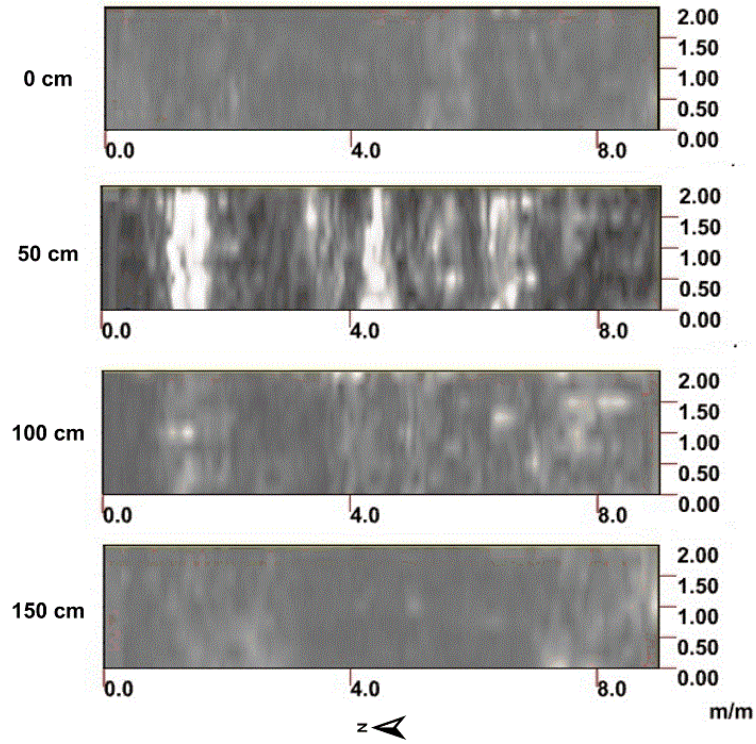


**Figure 26. These depth-sliced images are from burials dated in the early 2000s at the Milford Cemetery.**

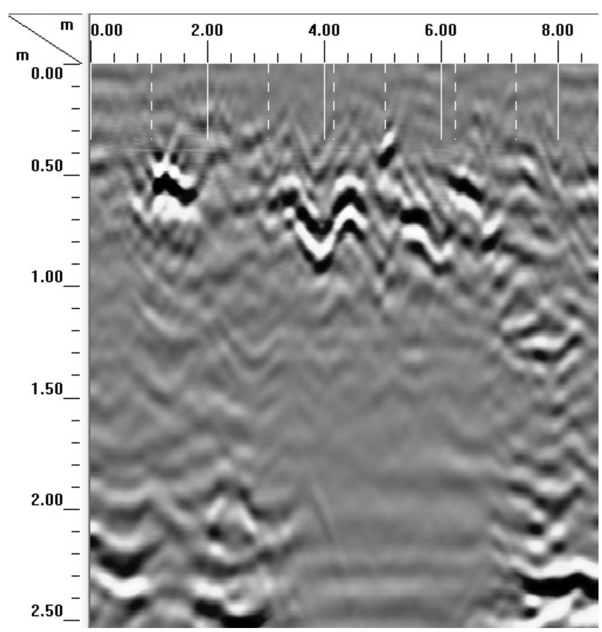


**Figure 27. This 2D radar record was made along line Y = 75 cm of the grid constructed over recent burials in Milford Cemetery. The white, vertical, segmented lines at the top of this record indicate the center of adjoining headstones.**

Figure 27 is a 2D radar record from line Y = 75 cm of this grid. The traverse was conducted from north to south. All scales on this radar record are expressed in meters. The white, vertical, segmented lines at the top of this record indicate the centers of nearby headstones which were arranged in a row to the immediate west of the grid. Six point reflectors, between depths of 30 and 65 cm, having different dimensions and signal amplitudes can be associated with these vertical marks. All are removed from the centers of the headstones.

*Burials dated to the mid-1900s:*
The dimensions of this grid were 9 by 2 meters. Nine, 9-meters long, parallel radar traverses, which were spaced 25-cm apart, were made across this grid. The grid was located in front of a row of headstones. There are seven recorded burials within the grid area that are dated mostly between the years of 1958 and 1986. However, one headstone has a record burial year of 2008. There are only five headstones. Figure 28 contains four depth-sliced images from this grid site. Each image is viewed from directly overhead looking downwards into the grid. These depth slices average the reflection amplitudes within a 30-cm vertical interval at depths of 0-, 50-, 100-, and 150-cm.

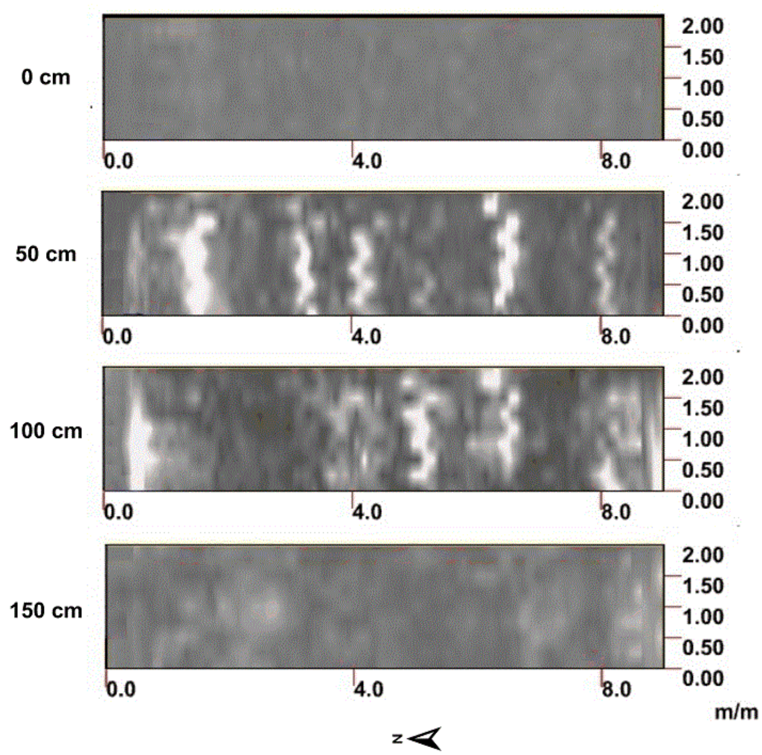


**Figure 28. These depth-sliced images are from burials dated in the mid-1900s at the Milford Cemetery.**

In Figure 28, the 0 and 150 cm depth-sliced images are relatively nondescript. The 50- and 100-cm depth-sliced images show several planar reflectors that are elongated in an east-west direction. On the 50-cm depth-sliced image, there appears to be seven planar reflectors of variable signal amplitudes and dimensions. On the 100-cm depth-sliced image, only five planar reflectors are evident and some of these appear to be shifted from the reflectors evident in the 50-cm depth-sliced image. These reflections may represent the sides rather than the top of concrete vaults used to enclose the coffins.

Figure 29 is a 2D radar record from line Y = 75 cm of this grid. The traverse was conducted from north to south. All scales on this radar record are expressed in meters. The white, vertical, segmented lines at the top of this record indicate the center of five neighboring headstones. Eight point reflectors, all between depths of about 25 to 50 cm, are associated with the seven burials record for this grid area. If there are only seven burials, one of these reflection hyperbolas represents another feature in the soil. Five of the point reflectors are removed from the centers of the headstones. Three of these reflectors appear to be aligned with the centers of the headstones. A closer look at the radar record in Figure 29 reveals additional, less well-expressed point reflectors evident between depths ranging from 20 to 80 cm. The features causing these reflectors are unknown, but are not questioned as reflections from burials have been identified. In this example, only the most prominent reflectors occurring within a restricted depth interval were associated with the burials.

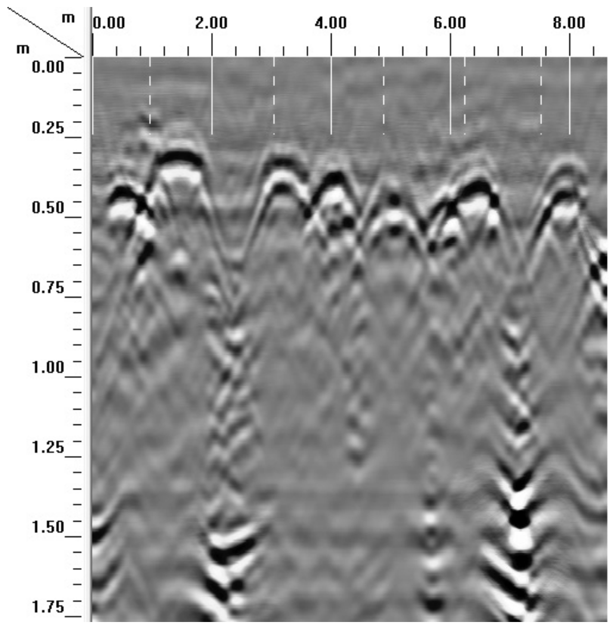


**Figure 29. This 2D radar record was made along line Y = 75 cm of the grid constructed over mid-1900 burials in Milford Cemetery. The white, vertical, segmented lines at the top of this record indicate the center of four adjoining headstones.**

*Burials dated from the late 1800s to the early 1900s:*

The dimensions of this grid were 7 by 1.75 meters. Eight, 7-meters long, parallel radar traverses, spaced 25-cm apart were conducted across this grid. The grid area was located in front of a row of six headstones. There are six recorded burials within the grid that are dated mostly between 1874 and 1921. However, one headstone has a burial date of 1865. Figure 30 contains four depth-sliced images from this grid. Each image is viewed from directly overhead looking downwards into the grid. These depth slices average the reflection amplitudes within a 30-cm vertical interval at depths of 0-, 50-, 100-, and 150-cm.

The 0- and 50-cm depth-sliced images in Figure 30 are comparatively unremarkable. However, several clusters of high-amplitude reflections are apparent on the 50-cm depth-sliced image. None of these clusters have the size or geometry that would suggest a burial. The 100- and 150-cm depth-sliced images show several planar reflectors that are elongated in an east-west direction. These planar reflectors have variable signal amplitudes and dimensions. These anomalous reflections are indicative of burials. On the 100-cm depth-sliced image, with some contemplation and creativity, two high-amplitude and four faint and almost indistinguishable planar reflectors can be seen and associated with the six recorded burials.

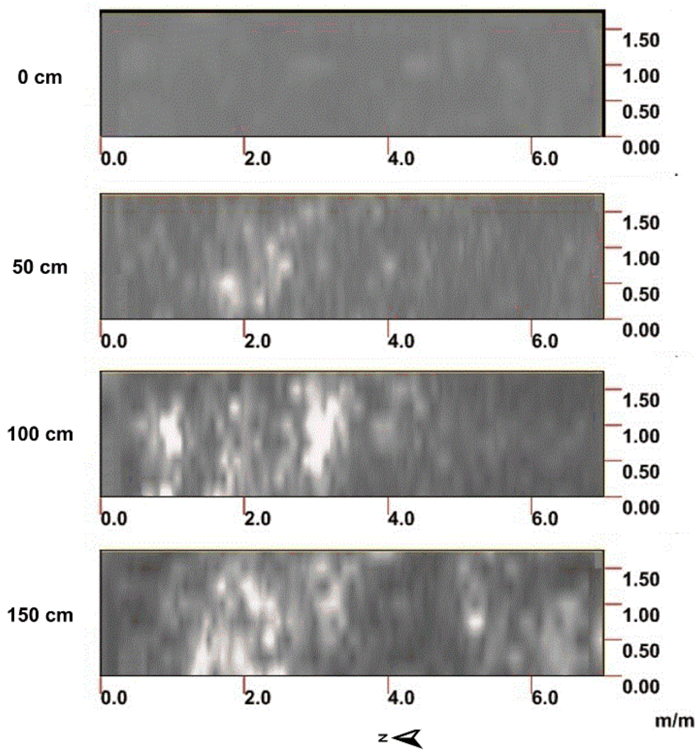


**Figure 30. These depth-sliced images are from burials dated from the late 1800s to the early 1900s at the Milford Cemetery.**

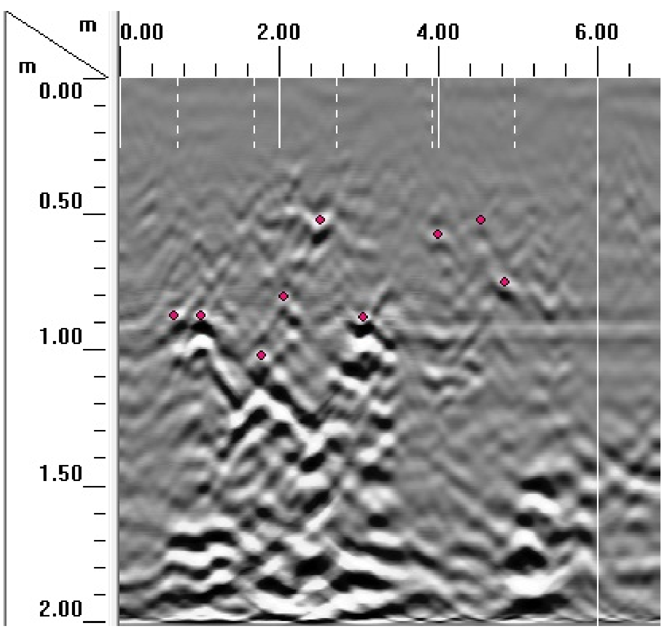


**Figure 31. This 2D radar record was made along line Y = 75 cm of the grid constructed over the site of the late-1800s to the early 1900s burials in Milford Cemetery. The white, vertical, segmented lines at the top of this record indicate the center of four adjoining headstones.**

Figure 29 is a 2D radar record from line Y = 75 cm of this grid. The traverse is measured from north to south. All scales on this radar record are expressed in meters. The white, vertical, segmented lines at the top of this record indicate the center of five adjacent headstones. Also on this radar record, the white, vertical, solid line indicates the center of another headstone. On this migrated radar record, clusters of high amplitude point reflectors, largely between depths of 85 to 110 cm, dominate the first 4 meters of this radar traverse. In addition, three point reflectors are evident between depths of about 50 to 75 cm. In Figure 31, these point reflectors have been identified with red dots. Undoubtedly, because of their locations, some of these features represent burials. However, on this 2D radar record, other than several larger and higher-amplitude point reflectors, the selection is unclear.

A comparison of the 2D radar records appearing in Figures 27, 29, and 31, reveals larger, more easily identified point reflectors for the mid-1900 to early-2000 burials, and smaller, less easily identifiable reflectors for the late-1800 to early-1900 burials. This may reflect a change in burial practices and the use of concrete vaults to enclose caskets. According to Wikipedia, "by the early part of the 20th century, concrete (and, later, reinforced concrete) vaults became more common).[2] Concrete burial vaults were first used to deter grave robbers and latter to prevent the ground from settling over graves.

*Burials dated to the mid-1800s:*
The dimensions of this grid were 6 by 2.0 meters. Nine, 6-meters long, parallel radar traverses, spaced 25 cm apart were conducted across this grid. The grid was located in front of a row of five headstones. There are five recorded burials with dates ranging from 1836 and 1878. Figure 32 contains four depth-sliced images from this grid site. Each image is viewed from directly overhead looking downwards into the grid. These depth slices average the reflection amplitudes within a 30-cm vertical window at depths of 0-, 50-, 100-, and 150-cm. The five headstones are located directly below the grid area (to the west).

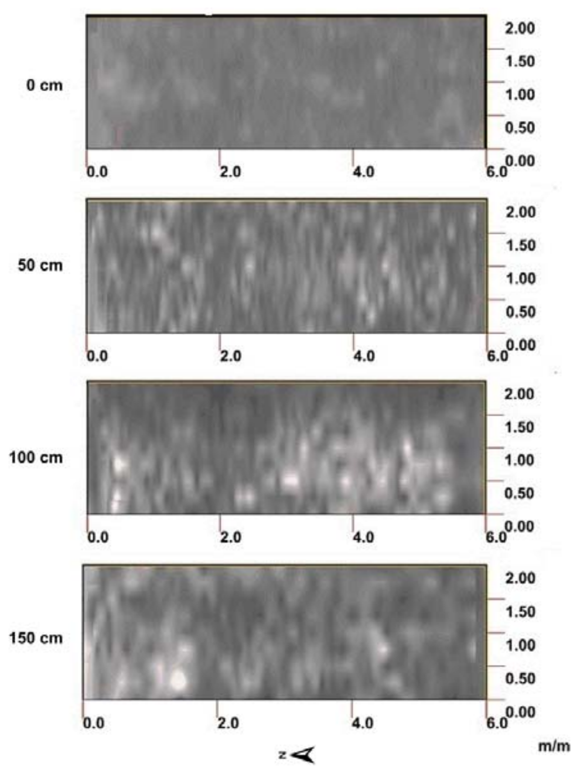


**Figure 32. These depth-sliced images are from burials dated from the mid-1800s at the Milford Cemetery**

In Figure 32, the 0-cm depth-sliced image is comparatively nondescript. The 50-cm depth-sliced image contains several very faint, blurred, and indistinct planar reflectors, with most seeming to have an east to west orientation that is characteristic of historical graves. However, they are not suspected to represent

[2] "Burial vault (enclosure)" assessed thru Wikipedia on 17 September 2014.

caskets or human bodies. It is more likely that these reflections represent ground disturbances caused by the excavation and refilling of grave shafts. The 100- and 150-cm depth-sliced images show several blurred, seemingly segmented, planar reflectors that appear elongated in an east-west direction. These segmented, planar reflectors have varying signal amplitudes and dimensions. These reflectors suggest potential burials. On the 100-cm depth-sliced image, with much contemplation and some creativity, five planar reflectors can be envisioned and associated with the five known burials.

Figure 33 is a 2D radar record from line Y = 75 cm of this grid. The traverse is measured from north to south. All scales on this radar record are expressed in meters. The white, vertical, segmented lines at the top of this record indicate the center of five adjoining headstones. On this migrated radar record, while point reflectors occur throughout, several conspicuously higher amplitude point reflectors occur at depths slightly greater than 100 cm. These reflectors have been identified with red dots in Figure 33. These reflectors are interpreted to represent the five burials.

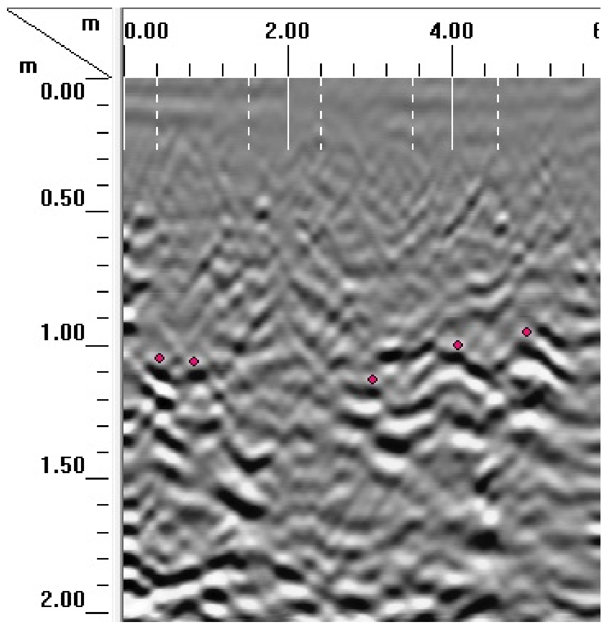


**Figure 33. This 2D radar record was made along line Y = 75 cm of the grid constructed over the mid-1800s burials in Milford Cemetery. The white, vertical, segmented lines at the top of this record indicate the center of five adjoining headstones.**

*Burials dated to the late 1700s and early 1800s:*

The dimensions of this grid were 8 by 1.5 meters. Seven, 8-meters long, parallel radar traverses, spaced 25 cm apart were conducted across this grid. The grid was located between a row of five headstones and three footstones. There are five recorded burials within this grid with dates ranging from 1791 and 1807. Figure 34 contains four depth-sliced images from this grid site. Each image is viewed from directly overhead looking downwards into the grid. These depth slices average the reflection amplitudes within a 30-cm vertical window at depths of 0-, 50-, 100-, and 150- cm. The five headstones are located directly below the grid area (to the west).

In Figure 34, the 0-cm depth-sliced image is comparatively nondescript. On the 50-cm depth-sliced image, at about the 7.0 m distance mark, a very prominent high-amplitude, continuous, planar reflector stretches in a slightly offset east to west direction across the grid. This reflector was evident on each of the eight radar traverses from this site. However, this reflector is considered too shallow, too long, and too exceptional to represent a burial. The 100-cm depth-sliced image shows six faint, moderate-amplitude, planar reflectors that appear equally spaced and elongated in an east-west direction. These reflectors are rather broad and have varying signal amplitudes and dimensions. On the 100-cm depth-sliced image, segmented, red-colored vertical lines identify these reflection patterns. These reflectors suggest potential burials. The broad, high amplitude reflection in the southwest corner of the 150-cm depth-sliced image is believed to represent a contrasting stratigraphic layer in the sandy and gravelly glacial outwash deposits of the Haven soils.

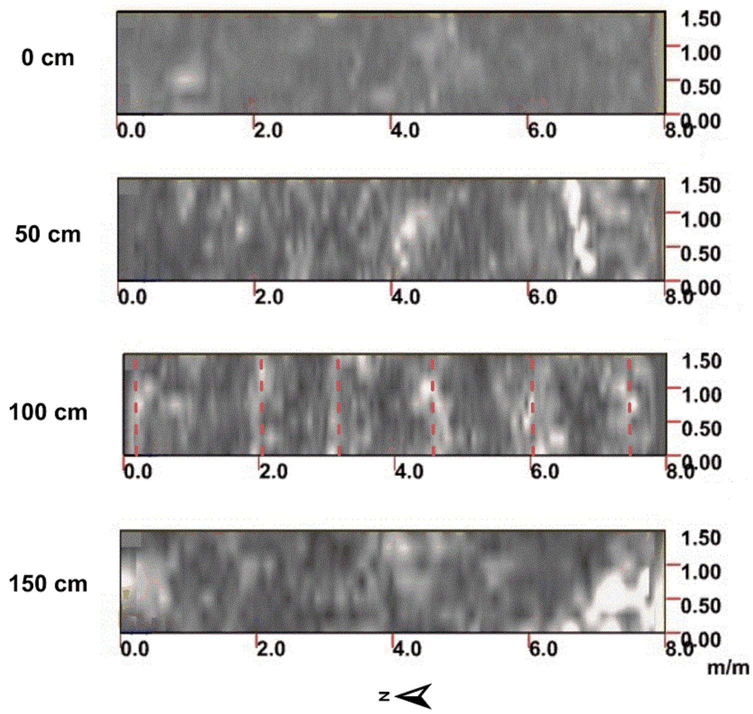


**Figure 34. These four depth-sliced images are from burials dated from the late 1700s to early 1800s at the Milford Cemetery.**

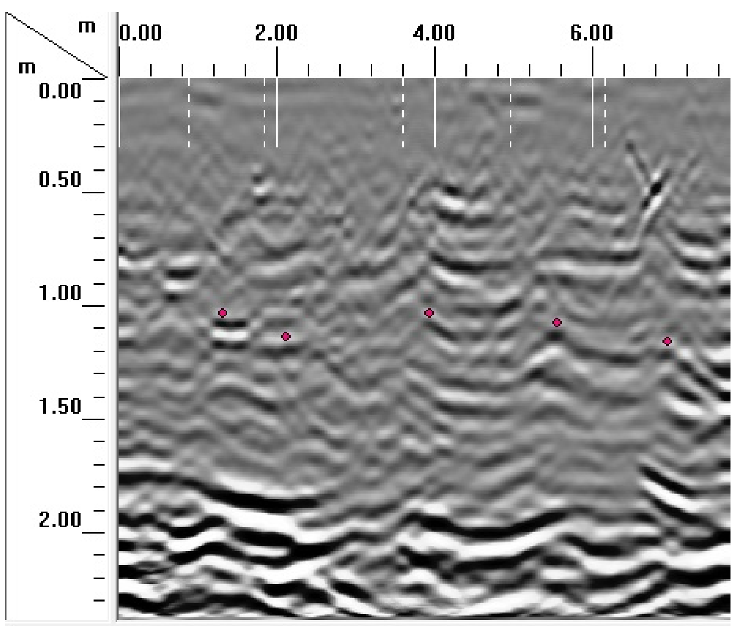


**Figure 35. This 2D radar record was made along line Y = 75 cm of the grid constructed over the site of late-1700 and early-1800s burials in Milford Cemetery. The white, vertical, segmented lines at the top of this record indicate the center of four adjoining headstones.**

Figure 35 is a 2D radar record from line Y = 75 cm of this grid. The traverse is measured from north to south. All scales on this radar record are expressed in meters. The white, vertical, segmented lines at the top of this record indicate the center of five adjoining headstones. Several suspected layers of contrasting outwash materials are believed to form the subtle reflection bands that cross this radar record at depths of approximately 70-, 120-, and 190-cm. On this migrated radar record, it is difficult to ascribe point reflectors to burials. However, at a depth of slightly greater than 100 cm, five of the more prominent point reflectors have been identified with red dots. These reflectors are considered the most likely candidates for potential graves.

*Burials dated to the mid-1700s:*

The dimensions of this grid were 7 by 1.25 meters. Six, 7-meters long, parallel radar traverses, spaced 25 cm apart were conducted across this grid. The grid was located between a row of five footstones and a row composed of four headstones and three footstones. These features have been undoubtedly mixed and moved over the years to accommodate maintenance and mowing operations. It is therefore unclear whether the headstones mark the original gravesites. There are four recorded burials have dates ranging from 1749 and 1787. Figure 36 contains four depth-sliced images from this grid site. Each image is viewed from directly overhead looking downwards into the grid. These depth slices average the reflection amplitudes within a 30-cm vertical window at depths of 0-, 50-, 100-, and 150-cm. The row of four headstones and three footstones is located directly below the grid area (to the west).

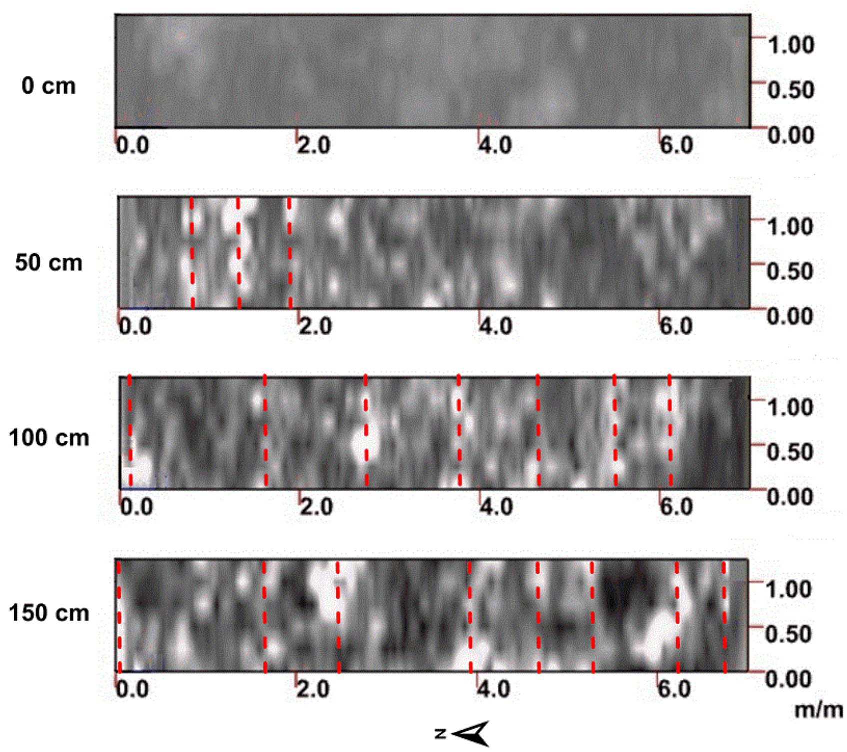


**Figure 36. These four depth-sliced images are from burials dated from the mid- 1700s at the Milford Cemetery.**

In Figure 36, the surface, or 0-cm depth-sliced image, is once again comparatively nondescript. On the 50-cm depth-sliced image, three high-amplitude, segmented, planar reflectors have been highlighted by red-colored, dashed lines. Other similar but lower amplitude reflection patterns can also be found with a little imagination on this depth-sliced image. Such linear features suggest artificial features and that is all that will be said at this time about these reflectors. They are assumed to be too shallow to represent colonial gravesites, but this could be a false assumption. On the 100-cm depth-sliced image, seven additional high-amplitude segmented planar reflectors have been identified. On the 150-cm depth-sliced image, eight seeming linear, high amplitude spatial patterns have been similarly identified. A majority of the identified spatial patterns on the 100- and 150-cm depth-sliced images appear to be spatially aligned. While it is probable that GPR with depth slice-imaging procedures have identified some early 1700s gravesites that are orientated in a characteristic east to west orientation, ground-truth verifications by a qualified archaeologists is required to accept these interpretations.

Figure 37 is a 2D radar record from line Y = 75 cm of this grid. The traverse is measured from north to south. All scales on this radar record are expressed in meters. The white, vertical, segmented lines at the top of this record indicate the centers of four adjoining headstones and three footstones. Several suspected layers of contrasting outwash materials are believed to form the subtle reflection bands that cross this radar record at depths of approximately 70-, 120-, and 190-cm. On this migrated radar record, it is difficult to ascribe point reflectors to burials. However, at a common depth of about 110- to 120-cm, seven point reflectors have been identified with red dots in Figure 37. These reflectors are considered potential contenders for graves.

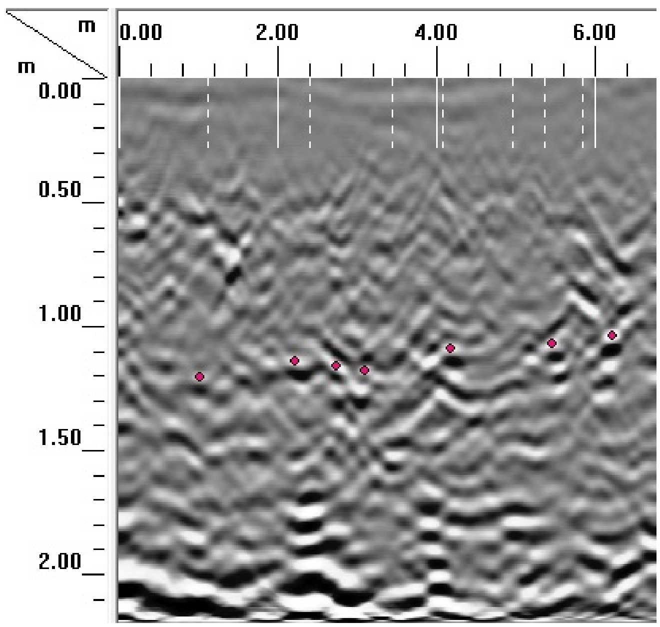


**Figure 37. This 2D radar record was made along line Y = 75 cm of the grid constructed over mid-1700s burials in Milford Cemetery. The white, vertical, segmented lines at the top of this record indicate the center of four adjoining headstones.**

<u>*Burials dated to the early 1700s:*</u>
The dimensions of this grid were 7 by 1.5 meters. Seven, 7-meters long, parallel radar traverses, spaced 25 cm apart were conducted across this grid. The grid was located between a row of four footstones and a row composed of three headstones and three footstones. The intermixing of headstones and footstone in a common row indicates that these features have been moved over the years to accommodate maintenance and mowing operations. It is unclear whether the headstones mark the original gravesites. There are three recorded burials within this grid site all with dates in 1705.

Figure 39 contains four depth-sliced images from this grid site. Each image is viewed from directly overhead looking downwards into the grid. These depth slices average reflection amplitudes within a 30-cm vertical window at depths of 0-, 50-, 100-, and 150-cm. The row of three headstones and three footstones is located directly below the grid area (to the west).

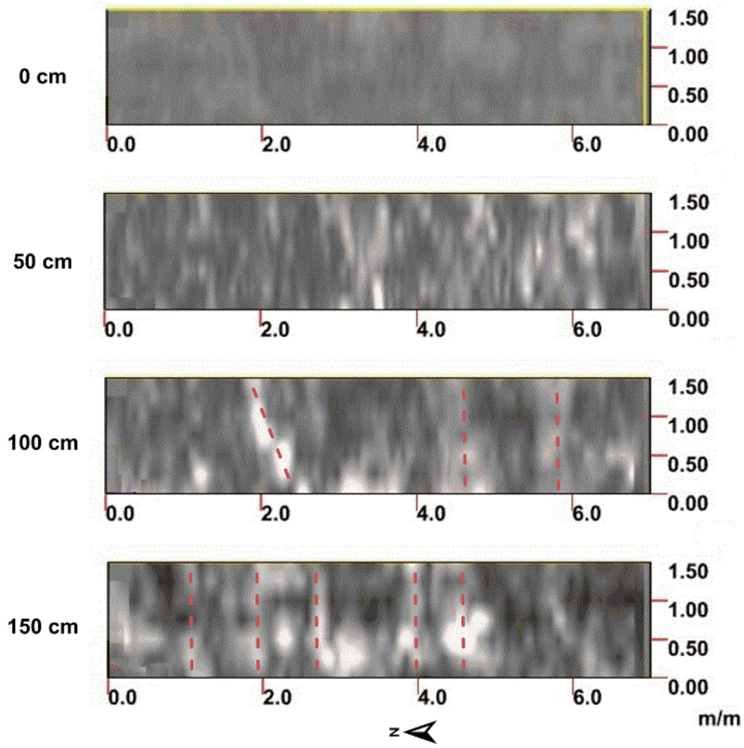


**Figure 38. These four depth-sliced images are from burials dated from the early- 1700s at the Milford Cemetery.**

In Figure 38, the 0-cm depth-sliced image is nondescript. On the 50-cm depth-sliced image, several higher amplitude planar reflectors cross the grid, but are believed to represent disturbed or altered soil materials. On the 100-cm depth-sliced image, three segmented, planar reflectors have been highlighted by red-colored, dashed lines. The northern-most of these reflectors is conspicuously higher in signal amplitude and more continuous. It is not suspected to represent a colonial era grave. On the 150-cm depth-sliced image, five seeming linear, diffuse and segmented, higher amplitude spatial patterns have been identified by red-colored, dashed lines. These patterns appear to be aligned in an east to west direction. Based on their appearance, geometry, and orientation, they are suspected to represent colonial era grave. However, once again, ground-truth verifications by a qualified archaeologist are required to accept these interpretations.

Figure 39 is a 2D radar record from line Y = 75 cm of this grid. The traverse is measured from north to south. All scales on this radar record are expressed in meters. The six white, vertical, segmented lines at the top of this record indicate the center of the adjoining three headstones and three footstones. Spatially, there is a noticeable, layered, undulating pattern in the reflectors. This pattern reflects the structure of the underlying coarse-textured glacial outwash materials. These patterns will obscure reflections from burials. Because of the inherent complexity of the underlying soil and outwash materials, no interpretation identifying probable burials can be advanced with any degree of confidence.

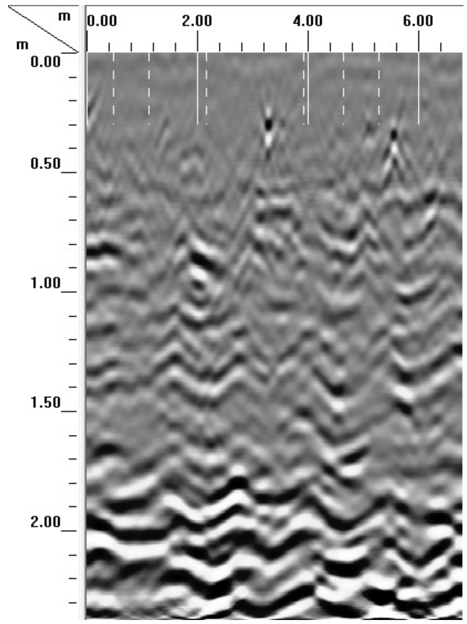


**Figure 39. This 2D radar record was made along line Y = 75 cm of the grid constructed over early-1700s burials in Milford Cemetery. The white, vertical, segmented lines at the top of this record indicate the center of four adjoining headstones.**

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