United States Department of Agriculture | **Natural Resources Conservation Service** | **100 Campus Boulevard Suite 200 Newtown Square, PA 19087-4585**

Subject: Archaeology -- Geophysical Assistance **Date:** 29 March 2004

To: Margo L. Wallace
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Purpose:
At the request of the Connecticut State Archaeologist and local historians, ground-penetrating radar (GPR) surveys were conducted at the East Street Cemetery (Plainville) and the Merwin Brook Cemetery (Brookfield) in an attempt to locate unmarked burials. In addition, GPR and electromagnetic induction (EMI) were used at the Glebe House (Woodbury) in an attempt to locate possible outbuildings.

Participants:
Nicholas Bellantoni, Connecticut State Archaeologist, Connecticut Archaeology Center, Univ. of Connecticut, Storrs, CT
Robert Brown, Brookfield Museum & Historical Society, Brookfield, CT
Marjorie Carmody, Conservation Commission, Brookfield, CT
Dave Cooke, Archaeologist, FOSA/ABAS, Rocky Hill, CT
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Kenneth Hedman, President, Plainville Cemetery Association, Plainville, CT
Judy Heise, Selectman, Brookfield, CT
Ruth Hummel, Plainville Historian, Plainville, CT
Shawn McVey, Asst. State Soil Scientist, USDA-NRCS, Storrs, CT
Donald Parizek, Soil Scientist, USDA-NRCS, Windsor, CT
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Activities:
All field activities were completed on 9 and 10 March 2004.

Findings:

1. Interpretations contained in this report are considered preliminary estimates of site conditions. These interpretations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. Interpretations should be verified by ground-truth observations.

2. At all sites, a 400 MHz antenna provided satisfactory penetration depths and resolution. Radar records collected with the 400 MHz antenna were of good interpretative quality. However, if present, burials were difficult to distinguish with GPR, because of their age, the effects of weathering and decay, and the presence of numerous scattering bodies in the soils.

3. Ground-penetrating radar and advance signal processing techniques failed to confidently identify unmarked gravesites within an open area at the East Street Cemetery in Plainville. If present, failure to

detect gravesites is related to the high levels of background noise in Merrimac soil. This clutter is related to the large number of coarse fragments in the soil. While GPR detected subsurface features, without ground-truth verification, the identity of these features is unclear and highly interpretative.

4. At the Merwin Brook Cemetery in Brookfield, GPR located several buried headstones and helped to confirm the extent of the cemetery. The cemetery extends to a berm on the west and to an old apple tree on the north end of the site. A scarp on the east defines the eastern boundary of the cemetery. Within the Merwin Brook Cemetery, soils lacked strongly contrasting layers and contained a large number of coarse fragments, which hindered the possible identification of gravesites.

5. Both GPR and EMI identified anomalous areas to the immediate south of the Glebe House. In addition, GPR identified a high amplitude linear feature that is believed to be a former road.

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

With kind regards,

James A. Doolittle
Research Soil Scientist
National Soil Survey Center

cc:
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Equipment:
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR System-3000), manufactured by Geophysical Survey Systems, Inc.[1] The SIR System-3000 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 System-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. With an antenna, this system requires two people to operate. A 400 MHz antenna was used in the studies described in this report. The use and operation of GPR are discussed by Morey (1974), Doolittle (1987), and Daniels (1996).

The RADAN for Windows (version 5.0) 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, marker editing, distance normalization, and range gain adjustments. In addition all radar records were migrated to remove hyperbola diffractions and to correct the geometry of steeply dipping layers. 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 time slices were viewed and selected images attached to this report.

The electromagnetic induction meter used at the Glebe House was the EM38DD, manufactured by Geonics Limited.[1] Operating procedures are described by Geonics Limited (2000). The EM38DD meter is portable and requires only one person to operate. No ground contact is required with this meter. The EM38DD operates at a frequency of 14,600 Hz. It has effective penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively. The EM38DD meter consists of two EM38 meters bolted together and electronically coupled. One meter acts as a master unit (meter that is positioned in the vertical dipole orientation and having both transmitter and receiver activated) and one meter acts as a slave unit (meter that is positioned in the horizontal dipole orientation with only the receiver switched on).

The Geonics DAS70 Data Acquisition System, developed by Geonics Limited, was used to record and store both EMI and GPS data.[1] The acquisition system consists of the EM38DD meter, an Allegro field computer, and a Trimble AG114 GPS receiver.[1] With the logging system, the EM38DD meter is keypad operated and measurements are automatically triggered.

To help summarize the results of the EMI survey at the Glebe House, the SURFER for Windows, version 8.0, developed by Golden Software, Inc., was used to construct a two-dimensional simulation.[1] The grid was created using kriging methods with an octant search.

GPR:
A favorable feature of GPR for archaeological investigations is its ability to detect disturbances and the intrusion of foreign materials in soils. In many soils, GPR is a useful tool for locating burials (Bevan, 1991; Gracia et al., 2000; King et al., 1993; and Vaughan, 1986). However, results vary with soil conditions. In some soils, rates of signal attenuation are so severe that GPR cannot profile to the required depths.

Even with favorable site conditions (i.e. dry, coarse-textured soils) the detection of a burial is never assured with GPR. The detection of burials is affected by (i) the electromagnetic gradient existing between the feature and the soil, (ii) the size and shape of the buried feature, and (iii) the presence of scattering bodies within the soil (Vickers et al., 1976).

The amount of energy reflected back to an antenna by a buried object is a function of the contrast in dielectric properties that exists between an object and the surrounding soil matrix. 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. At first, most buried objects

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

generally contrast with the surrounding soil matrix. However, with the passage of time, buried objects decay or weather and become less electrically contrasting with the soil matrix. For burials, the rate of decay or weathering varies with the materials used to contain the corpse. Corpses may be buried in sacks, body bags, or in wooden, fiberglass, composite, or metal caskets. If a coffin is partially intact, an air-filled void may exist, which is generally detectable with GPR.

The size and depth of a burial affect detection. Large objects reflect more energy and are easier to detect than small objects. In addition, the reflective power of a buried object decreases with the fourth power of the distance to the object (Bevan and Kenyon, 1975). Most bones are too small to be distinguished with GPR (Bevan, 1991; Killam, 1990). Bevan (1991) noted that it is more likely that GPR will detect the disturbed soil within a grave shaft, a partially or totally intact coffin, or the chemically altered soil materials that directly surrounds a burial rather than the bones themselves. However, in soils that lack contrasting horizons or geologic strata, the detection of soil disturbances or grave shafts is more difficult. In addition, with the passage of time, natural soil-forming processes will erase the signs of disturbances. At the East Street and Merwin Brook cemeteries, grave shafts were not detected with a 400 MHz antenna.

Burials are difficult to distinguish in soils having numerous rock fragments, tree roots, animal burrows, modern cultural features, or highly stratified or segmented soil layers. These scattering bodies produce undesired subsurface reflections that complicate radar records and mask the presence of buried cultural features. Under such conditions, “desired” cultural features can be indistinguishable from the background clutter. In soils having numerous scattering bodies, GPR often provide little meaningful information to supplement traditional sampling methods (Bruzewicz et al., 1986). The identification of buried cultural features was complicated by scattering bodies in radar surveys conducted by Bevan (1991), Dolphin and Yetter (1985), Doolittle (1988), and Vaughan (1986).

On radar records, the depth, shape, size, and location of subsurface features are used to identify buried cultural features. In the past, reflections were identified and correlated on two-dimensional radar records. Often, in soils with complex stratigraphy or high amounts of background noise, cultural features that produced reflections of low or moderate amplitudes are difficult to detect on a series of closely-spaced, parallel radar records. Three-dimensional imaging techniques can be used to augment radar records, distinguish coherent noise components, reduce interpretation uncertainties, and aid identification of potential targets (Pipan et al., 1999). Three-dimensional interpretations of GPR data have being used to identify burials, middens, and other cultural features (Conyers and Goodman, 1997; Whiting et. al, 2000; Goodman et al., 2004). In the past, the use of 3-D images was restricted because of the lack of satisfactory signal-processing software. The recent development of sophisticated signal-processing software has enabled signal enhancement and improved pattern-recognition on radar records.

In recent years, a sophisticated type of GPR data manipulation has been used in archaeological investigations. Known as *amplitude slice-map analysis* (Conyers and Goodman, 1997), horizontal maps of reflected wave amplitude differences can be created from a set of closely spaced radar records. A 3-D image of a study site is derived from computer analysis of a series of closely-spaced, two-dimensional radar records (Conyers and Goodman, 1997). In order to be interpreted, amplitude differences within the 3-D image are analyzed in "time-slices" that examine only changes within specific depths in the ground (Conyers and Goodman, 1997). Time slice data were created using spatially averaged amplitudes of return reflections. The reflected energy was averaged horizontally between each set of parallel radar records and in 3.2 ns time windows to create a time slice. Each amplitude time-slice shows the spatial distribution of reflected wave amplitudes, which are indicative of these changes in sediments, soils and buried features.

East Street Cemetery, Plainville:

A GPR survey was conducted to ascertain whether unmarked graves, possibly belonging to African American, occur beneath an open area that is located in the southeast corner of the East Street Cemetery. The East Street Cemetery is located in Plainville, Connecticut, along the west side of Highway 10 and immediately across from the Plainville High School. The cemetery is located in an area that has been mapped as Merrimac sandy loam, 0

to 3 percent slopes (Shearin and Hill, 1962). The very deep, somewhat excessively drained Merrimac soil formed in glacial outwash on outwash plains and terraces. Merrimac is a member of the sandy, mixed, mesic Typic Dystrudepts family.

Survey Procedures:
A grid, consisting of 37, 25-m survey lines, was laid out across the open area in the southeast portion of the cemetery. The dimensions of the grid were 25- by 19-m. The origin of the grid was located 4-m west and 3-m north of the cemetery's southeast fence corner (about 0677954 East and 4614783 North). The x-axis extended north-south and paralleled Highway 10. Survey lines were 25-m long, orientated in a north-south direction, and spaced 50 cm apart. Along each line reference marks were spaced at 5-m intervals. Pulling the 400 MHz antenna, in a back and forth manner, along the 37 equally spaced (50-cm) survey lines completed the GPR survey. Along each line, as the antenna was towed passed a reference point, a vertical mark was impressed on the radar record.

While burial practices change with time, it was assumed that burials, if present, would be orientated with their long axis orientated in an east-west direction and buried at depths of about 1- to 2-m. Radar traverses were conducted orthogonal to the assumed orientation of the graves.

At the East Street Cemetery, calibration trials were conducted with 400 MHz antenna. The radar's scanning time was set to 40 nanoseconds (ns). The soil was moist at the time of this investigation. A frost layer occurred at a depth of about 30 cm. Based on hyperbola-matching processing techniques (the shape of a hyperbole is dependent on signal velocity), the velocity of propagation decreased with depth, but over the scanned depth averaged about 0.09 m/ns (dielectric permittivity (E_r) of 11). With a scanning time of 40 ns, the maximum penetration depth was about 1.8 m.

Results:
Figure 1 is a representative radar record from the cemetery. This record was obtained along line Y = 7-m. The short, white, vertical lines at the top of the radar record represent equally spaced (5-m) reference points along the radar traverse. The vertical scale along the left-hand margin is a depth scale that is based on a velocity of pulse propagation of 0.09 m/ns. Note that the depth scale in Figure 1 is exaggerated. In Figure 1, south is to the left and north is to the right.

In Figure 1, the high amplitude (black), wavy, subsurface planar reflector that occurs at depths of about 20 to 35 cm represents the frost line. The substratum of Merrimac soil consists of stratified deposits of coarse sand, sand, gravel, and cobbles. In Figure 1, the low amplitude (gray), segmented, subsurface planar reflectors are from layers with materials having closely similar dielectric properties. In Merrimac soil, subsurface strata contain 25 to 55 percent gravel and 5 to 15 percent cobbles. A majority of the hyperbolic reflectors evident in this radar record undoubtedly represent cobbles. An exceptional large and conspicuous hyperbolic reflector, which has been enclosed in a green oval, is believed to represent a larger boulder or cobble.

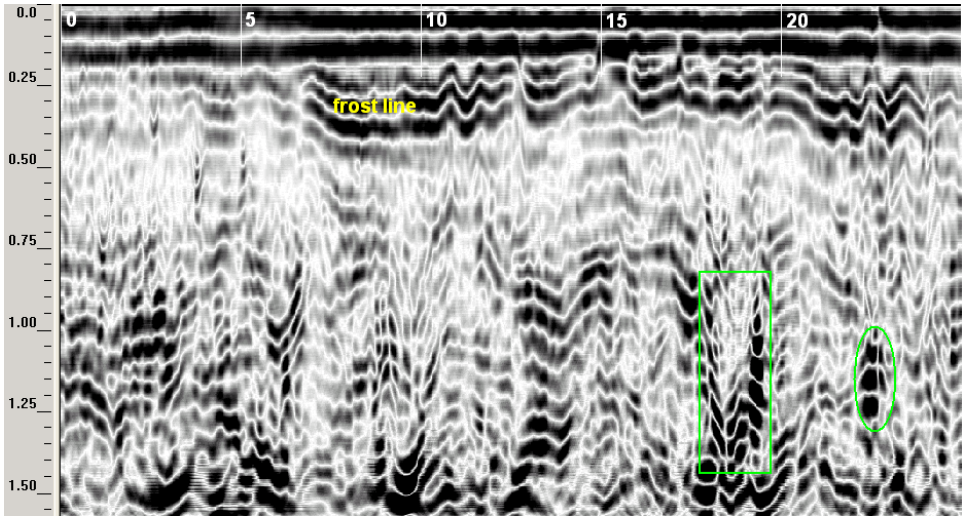
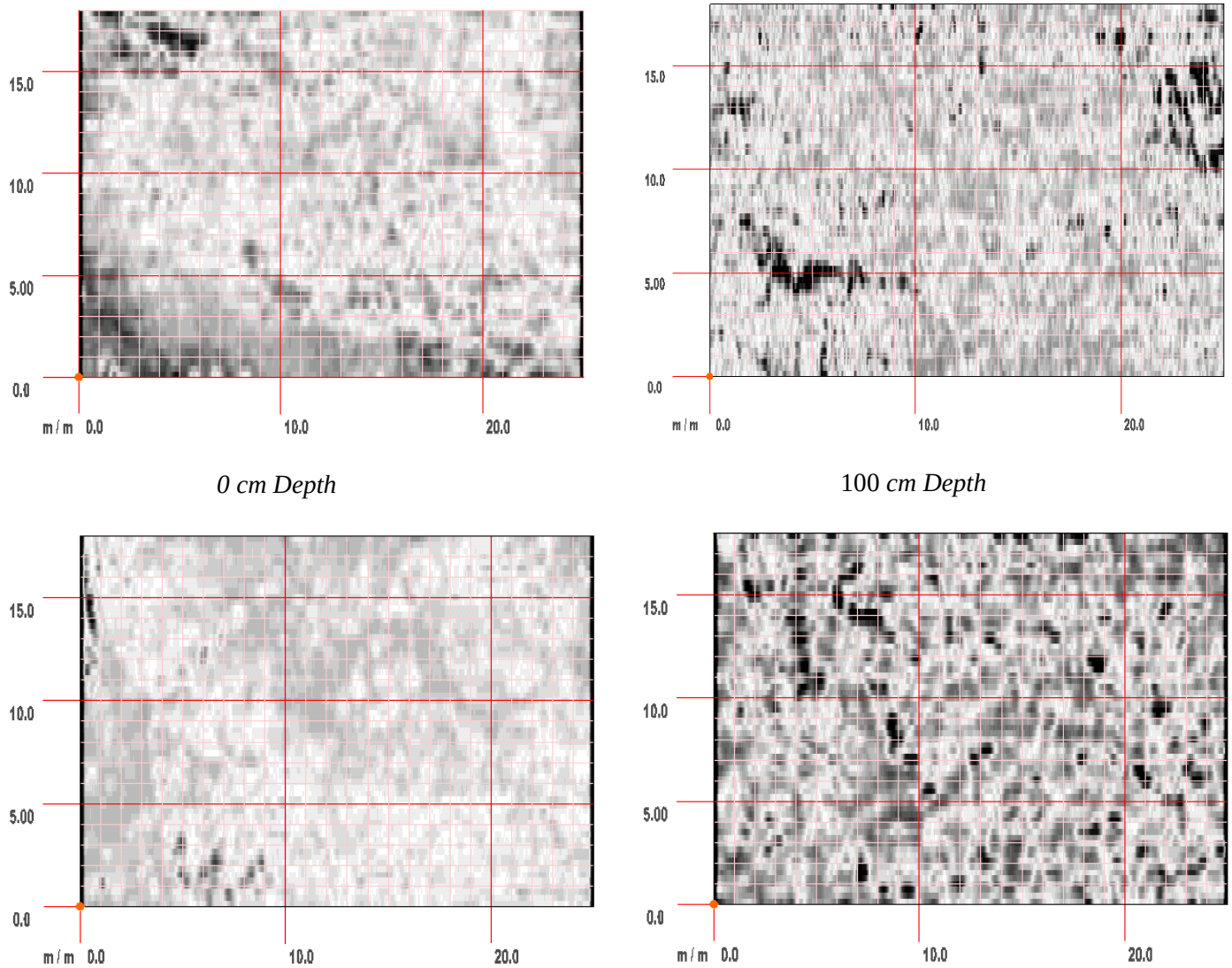


Figure 1. Representative radar record collected with the 400 MHz antenna at the East Street Cemetery.

In Figure 1, evidence of soil disturbance, grave shafts, and coffins are difficult to unambiguous identify. While many patterns that appear on the radar record may suggest these features, no clear and unmistakable manifestation or pattern is available to reliably identify the occurrence of either grave shafts or coffins. A prominent trough shaped features has been highlighted with a green-colored rectangle in Figure 1. The feature consists of prominent reflectors and multiples that bound a lower-lying point reflector. The arrangement of these reflectors suggests a potential gravesite. However, as the cemetery represents a sacred or sensitive area, ground-truth verifications of interpretations were not carried out at the time of the survey. Interpretations are therefore constrained.

Figure 2 contains four time-slice images of the area surveyed within the East Street Cemetery. In Figure 2, all distance units are expressed in meters. The origin is located in the southeast corner (lower left) of each slice. The four horizontal "time-slices" represent depths of about 0, 50, 100, and 150 cm. These depths were based on an assumed constant signal propagation velocity of 0.09 m/ns through the soil. The width of the time-slice is about 20 cm. The shallowest (0.0 cm) slice reveals patterns related principally to differences in soil moisture content and soil density. Changes in these properties are reflected in signals of low and moderate amplitudes. The identity of the large area of high amplitudes in the southwest (upper left) portion of the grid is unknown. In the 50 cm slice, two conspicuous high amplitude (black) features can be identified. A shallow linear anomaly, which is about 7-m long, is evident in the extreme southwest (upper left) corner of the grid. This feature is suspected to be a drainage tile. The cluster of high amplitude reflections in the southeast (lower left) portion of the 50 cm slice represents larger roots from a nearby tree (located just outside the grid). In the 100 cm slice, a cluster of high amplitude linear reflections is apparent in the northwest (upper right) portion of the grid. This area of the grid contained several headstones. The locations of these headstones were not referenced at the time of the survey, and therefore, no positive association can be made. Also in the 100 cm slice, a band of high amplitude reflections is apparent in the southeast (lower left) portion of the grid. This band appears to trend mostly in a general north-south direction. This direction is orthogonal with the presumed orientation of the graves. Neither the conspicuous band nor cluster evident in the 100 cm slice is expressed in the 150 cm slice. The higher amplitude reflections evident in the 150 cm slice are believed to represent cobbles and dissimilar stratigraphic features in the underlying outwash deposits.



0 cm Depth

100 *cm Depth*

50 cm Depth

150 cm Depth

Figure 2. 3D time-slice radar images of the East Street Cemetery.

Ground-penetrating radar and advance signal processing techniques failed to unambiguously identify unmarked gravesites within an open area at the East Street Cemetery. If present, failure to detect gravesites is related to the high levels of background noise in Merrimac soil. This clutter is related to the large number of coarse fragments in the soil. While GPR detected subsurface features, without ground-truth verification, the identity of most features is unclear and highly interpretative.

Merwin Brook Cemetery, Brookfield:

Around 1900, a former landowner of the property that contains the Merwin Brook Cemetery overturned the headstones and buried them beneath a thin layer of sod. This was done in an attempt to facilitate the sale of this property. Today, several of the headstones that were buried and border the escarpment to Merwin Brook are partially exposed. Other headstones are believed to be shallowly buried beneath the site. A GPR survey was conducted to ascertain the locations of buried headstones and the extent of the colonial cemetery (graves date from the late 1780's to 1806).

The Merwin Brook Cemetery is located in Brookfield, along the north side of Highway 133, on a bluff along the west side of Merwin Brook. The cemetery is located in an area that has been mapped as Sutton fine sandy loam, 3 to 8 percent slopes (Wolf, 1981). The very deep, moderately well drained Sutton soil formed in supraglacial till on till plains, low ridges, and hills. Sutton is a member of the coarse-loamy, mixed, active, mesic Aquic Dystrudepts family.

Survey Procedures:

A grid, consisting of 26, 15-m survey lines was laid out across the suspected area of the cemetery. The dimensions of the grid were 15- by 13-m. The origin of the grid was located at 635153 East and 4591935 North, the presumed southeast corner of the cemetery. The x-axis extended north-south and away from Highway 133. Survey lines were 15-m long, orientated in a north-south direction, and spaced 50 cm apart. Along each line, reference marks were spaced at 5-m intervals. Pulling the 400 MHz antenna in a back and forth manner along the 26 equally spaced (50-cm) survey lines completed the GPR survey. Along each line, as the antenna passed a reference point, a vertical mark was impressed on the radar record.

Once again it was assumed that burials, if present, would be orientated with their long axis orientated in an east-west direction and buried at depths of about 1- to 2-m. Radar traverses were conducted orthogonal to the assumed orientation of the graves.

At the Merwin Brook Cemetery, calibration trials were conducted with 400 MHz antenna. The radar's scanning time was set to 40 nanoseconds (ns). The soil was moist at the time of this investigation. A frost layer occurred at a depth of about 30 cm. Based on hyperbola matching techniques, the velocity of propagation decreased with depth, but over the scanned depth averaged an estimated 0.09 m/ns (dielectric permittivity (E_r) of 11). With a scanning time of 40 ns, the maximum penetration depth was about 1.8 m.

Results:

Figure 3 is a representative radar profile from the Merwin Brook Cemetery. This radar record is from line Y = 8.5 m. In Figure 3, the vertical scale is a depth scale (in meters). The white vertical lines at the top of the radar record represent the equally-spaced (5-m) reference points along the traverse line. In Figure 3, south is to the left and north is to the right.

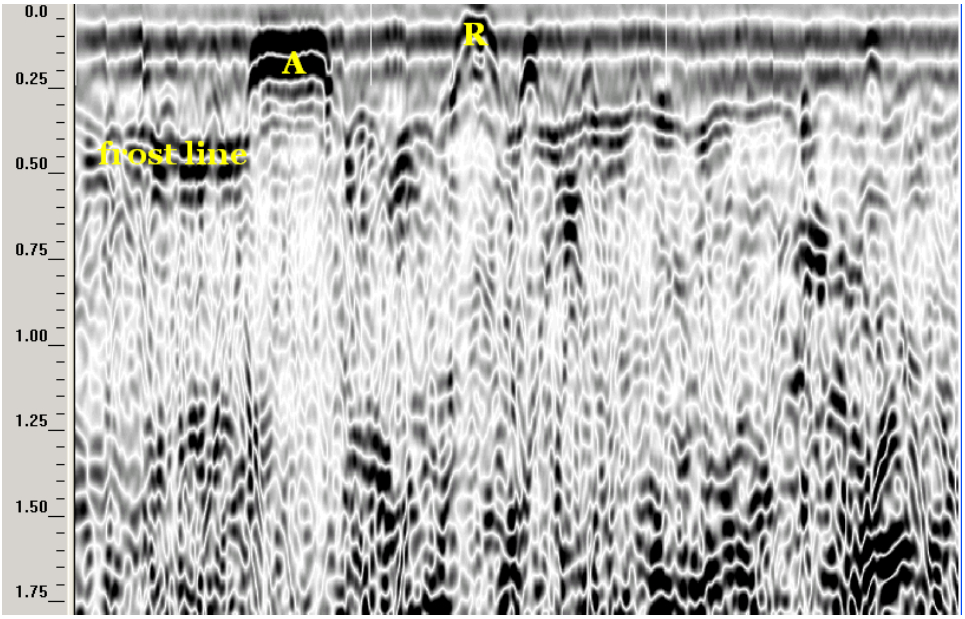


Figure 3. Representative radar record collected with the 400 MHz antenna at the Merwin Brook Cemetery.

In Figure 3, the frost line provides a continuous planar reflector of variable signal amplitudes at a depth of about 30 to 35 cm. Rock fragments are conspicuous features of the till and form distinct hyperbolic patterns on the radar record. In Figure 3, the reflector at "A" has a noticeably flat and comparatively extensive upper surface. A distinct *shadow zone* is produced beneath this reflector. This reflector was later exhumed and verified to represent a very shallowly buried headstone. The point reflector at "R" forms a more pointed hyperbola and was confirmed to be a large rock fragment. Other smaller hyperbolas, which are presumed to represent rock fragments, are evident throughout the radar record.

Figure 4 is time-slice image of the area surveyed at the Merwin Brook Cemetery. In this diagram, north is to the right. All measurements are in meters. The vertical width of the time-slice is about 20 cm. The horizontal slice has been made at a depth of about 25 cm. In this diagram, prominent, high amplitude (black), reflections from known buried headstones have been highlighted in green. These known reflectors occur principally along the eastern (lower) boundary of the grid in a line that is adjacent to a scarp into Merwin Brook. Here, two headstones were partially exposed. The headstone shown in the preceding radar record (Figure 3) is outlined in green in the upper left-hand (southwest) portion of the survey area. All of the headstones enclosed by green-colored rectangles were exhumed by the Connecticut State Archaeologist. These headstones were remarkably well-preserved and dated from the mid-1780 to about 1806.

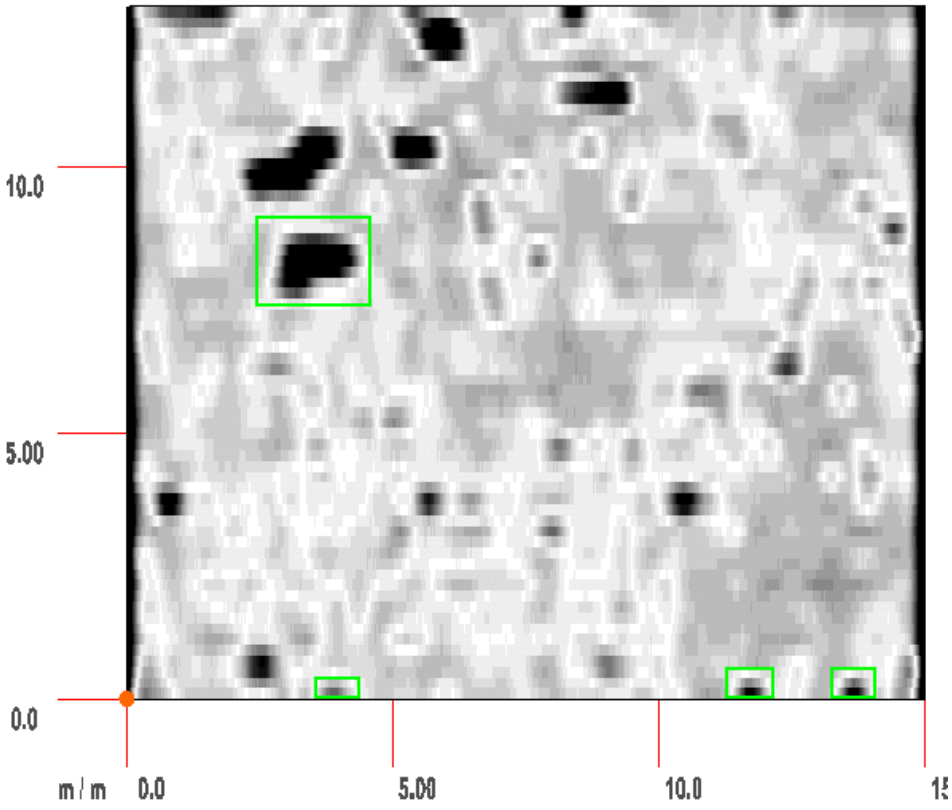


Figure 4. A time-slice image of the 25-cm depth layer at the Merwin Cemetery, Brookfield, Connecticut.

Many of the higher amplitude reflections evident in this time-slice image represent reflections from larger rock fragments. However, several reflectors, mostly located in the upper left-hand (southwest) portion of the survey area, are larger, more conspicuous, and appear to be linear. Some of these reflectors may represent additional headstones. In addition, the alignment of three, smaller point reflectors along line Y = 4-m, suggest potential

footstones.

A random *wild-cat* survey of the area surrounding the grid site helped to confirm the extent of the cemetery. The cemetery appears to extend to a berm on the west with no significant subsurface anomalies that suggested additional headstones or burials found beyond the berm. A headstone was detected with the GPR near an old apple tree to the north of the grid site. This probably represents the northern-most extent of the cemetery. A scarp on the east defines the eastern boundary of the cemetery.

Although GPR detected several buried headstones, soil conditions proved to be too inhospitable for the detection of gravesites at the Merwin Brook Cemetery. As at the East Street Cemetery in Plainville, the failure of GPR to unequivocally detect gravesites is related to the large number of coarse fragments in the soil.

Glebe House, Woodbury:
Ground-penetrating radar and electromagnetic induction surveys were conducted in an area to the south of the Glebe House in an attempt to find subsurface evidence of outbuildings. The Glebe House is located in historic Woodbury, Connecticut. The house was built around 1750 and occupied by several Episcopalian priests. The house was the home to Samuel Seabury, the first American bishop of the Episcopal Church. The study site is located in an area that has been mapped as Belgrade silt loam, 0 to 3 percent slopes (Shearin and Hill, 1962). The very deep, moderately well drained Belgrade soil formed in glaciolacustrine material on terraces. Belgrade is a member of the coarse-silty, mixed, active, mesic Aquic Dystric Eutrudepts family. With the updating of soil surveys in Connecticut, areas of Belgrade silt loam, 0 to 3 percent slopes, are being recorrelated as map unit 21A, Ninigret and Tisbury soils, 0 to 5 percent slopes (Donald Parizek, personal communication). The very deep, moderately well drained Ninigret soils formed in loamy over sandy and gravelly outwash. Ninigret is a member of the coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Aquic Dystrudepts family. The very deep, moderately well drained Tisbury soils formed in silty eolian deposits overlying outwash. Tisbury is a member of the coarse-silty over sandy or sandy-skeletal, mixed, active, mesic Aquic Dystrudepts family.

Survey Procedures:
A grid, consisting of 18, 50-m survey lines, was laid out across the relatively open area to the south and southeast of the Glebe House. The dimensions of this grid were 50- by 34-m. The origin of the grid was located in the extreme southeast corner of the property. The x-axis extended north-south and paralleled a township road. Survey lines were 50-m long, orientated in a north-south direction, and spaced 2 m apart (stakes had been inserted in the ground to locate the traverse lines). Along each line, reference marks were spaced at 5-m intervals. Pulling the 400 MHz antenna in a back and forth manner along the 18 equally spaced (2-m) survey lines completed the GPR survey. Along each line, as the antenna passed a reference point, a vertical mark was impressed on the radar record.

Calibration trials were not conducted with 400 MHz antenna. The radar's scanning time was set to 40 nanoseconds (ns). The soil was moist at the time of this investigation. Based on hyperbola matching techniques, the velocity of propagation decreased with depth, but over the scanned depth averaged an estimated 0.099 m/ns (dielectric permittivity (E_r) of 9.1). With a scanning time of 40 ns, the maximum penetration depth was about 2-m.

The EM38DD meter was operated in the continuous mode with measurements recorded at 1-sec intervals. The EM38DD was held about 3 inches above the ground surface with its long axis parallel to the direction of traverse. Walking at a fairly brisk and uniform pace, in a random back and forth pattern across the field, the EM38DD meter recorded 896 geo-referenced measurements. The area surveyed with the EM38DD meter was larger than the area surveyed with the GPR.

Results:
Figure 5 contains two time-slice images of the surveyed area at the Glebe House. In each diagram, north is to the right. All measurements are in meters. In each diagram, the vertical width of the slice is about 30 cm. The dark vertical lines along the south (left) and north (right) boundaries of each time-slice image are artifacts of the

processing techniques used. The diagram on the left is a time-slice image of the surface (upper 30 cm). In this diagram, a prominent linear band of high amplitude signals, which extends in a north-to-south direction, has been highlighted in green. The linearity of this pattern suggests an artificial feature of potential archaeological interest. As it parallel a present roadway (off and parallel with the lower boundary of this diagram), this feature may represent a former roadbed that contains slightly more compacted and higher density soil materials.

In Figure 5, the diagram on the right is a time-slice image of the radar data at a depth of 50 cm. In this diagram, a comparatively large (24- by 24-m) area of high amplitude reflections has been highlighted in green. This area of higher amplitude reflections adjoins the Glebe House and a parking area. Another high amplitude reflector has been highlighted with a green oval in the southwest (upper left-hand) portion of the grid. The more irregular, less linear, low and moderate amplitude signals are believed to represent changes in soil properties.

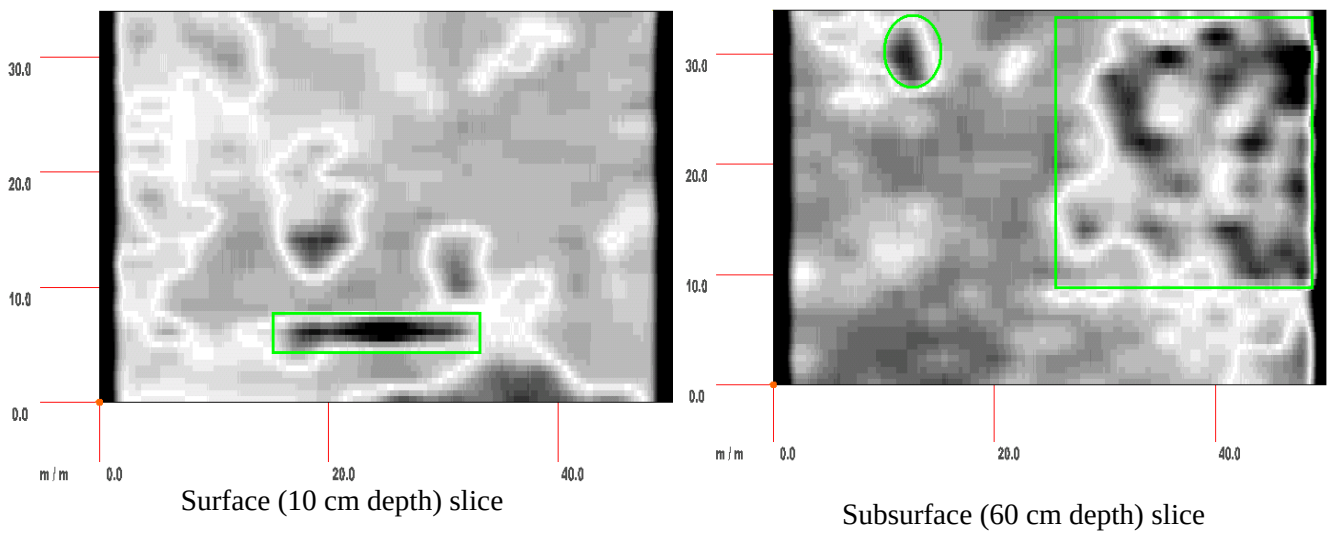


Figure 5. Time-slice images of the 50 by 34 m GPR survey area to the immediate south and southeast of the Glebe House, Woodbury, Connecticut.

Basic statistic for the apparent conductivity (EC_a) data recorded with the EM38DD meter at the Glebe House is listed in Table 1. In general apparent conductivity increased and became slightly less variable with increasing soil depth. Apparent conductivity averaged about 1.8 and 7.3 mS/m for measurements obtained in the shallower-sensing, horizontal and in the deeper-sensing, vertical dipole orientations, respectively. Apparent conductivity ranged from about -10.2 to 92.4 mS/m with a standard deviation of about 4.1 mS/m in the horizontal dipole orientation. Apparent conductivity ranged from about -53.7 to 33.3 mS/m with a standard deviation of about 3.4 mS/m in the vertical dipole orientation. The more anomalous values represent cultural features.

Figure 6 is a choropleth map that shows the spatial distribution of EC_a collected with the EM38DD meter in the vertical dipole orientation. Color variations have been used to show the distribution of EC_a. The color interval is 4 mS/m. To reduce spurious measurements and lines, the *grid node editor* of Surfer 8 was used to remove or make slight changes (0.1 to 0.2 mS/m) to some of the measurements. The general location of the Glebe house is shown in this plot

Table 1. Apparent Conductivity Data collected with the EM38DD meter at the Glebe House.
All values are in mS/m

	Horizontal	Vertical
Average	1.84	7.26
Standard Deviation	4.12	3.37
Minimum	-10.2	-53.7
Maximum	92.4	33.3
25% Quartile	0.53	7.21
75% Quartile	2.59	8.35

In Figure 6, patterns of apparent conductivity reflect the homogeneity of soils and soil properties and the presence of dissimilar cultural features. Patterns of anomalously high (red) and low (blue) EC_a are believed to represent interference from and the presence of cultural features. A conspicuous zone of higher EC_a extends outwards from the southern side of the Glebe House. This zone is flanked by two conspicuous anomalies of negative EC_a. Negative values generally indicate the presence of metallic features. The negative EC_a anomaly in the west-central part of the survey area is associated with a metallic cone-shaped frame feature in a garden.

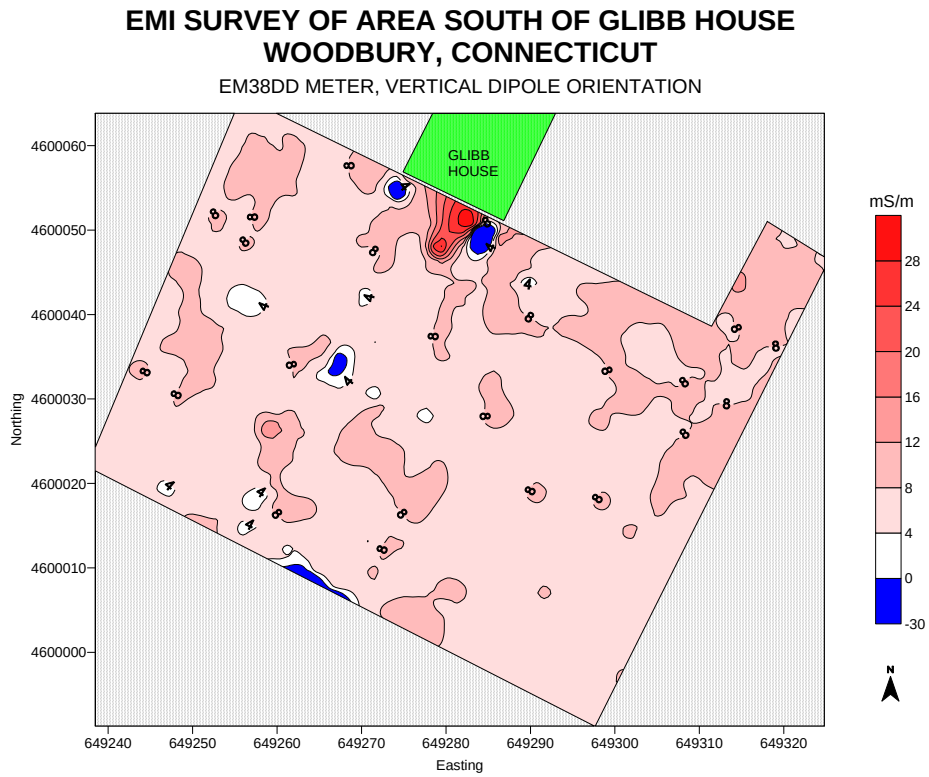


Figure 6. Plot of EC_a collected with the EM38DD meter at the Glebe House.

References:

Bevan, Bruce W. 1991. The search for graves. Geophysics 56(9):1310-1319.

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

Bruzewicz, A. J., C. R. Smith, D. E. Berwick, and J. E. Underwood. 1986. The use of ground-penetrating radar in cultural resource management. Technical Papers 1986 ACSM-ASPRS Annual Convention Vol. 5: 233-242.

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

Daniels, D. J. 1996. Surface-Penetrating Radar. The Institute of Electrical Engineers, London, United Kingdom.

Dolphin, L. and T. J. Yetter. 1985. Geophysical survey at Third Mission Site, Santa Clara University. SRI Project 8745. SRI International, Menlo Park, California. p. 56.

Doolittle, J. A. 1987. Using ground-penetrating radar to increase the quality and efficiency of soil surveys. pp. 11-32. In: Reybold, W. U. and G. W. Peterson (eds.) Soil Survey Techniques, Soil Science Society of America. Special Publication No. 20.

Doolittle, J. A. 1988. Ground-penetrating radar (GPR) survey at Tell Halif, Israel. pp. 180-213. In: Technical Proceedings of the Second International Symposium on Geotechnical Applications of Ground-Penetrating Radar. Gainesville, Florida. March 6-10 1988.

Geonics Limited. 2000. EM38DD ground conductivity meter: Dual dipole version operating manual. Geonics Ltd., Mississauga, Ontario.

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

Gracia, V. P., J. A. Canas, L. G. Pujades, J. Clapes, O. Caselles, F. Garcia, and R. Osorio. 2000. GPR survey to confirm the location of ancient structures under Valencian Cathedral (Spain). Journal of Applied Geophysics 43: 167-174.

Killam, E. W. 1990. The detection of human remains. Charles C. Thomas Publisher, Springfield, Illinois.

King, J. A., B. W. Bevan, and R. J. Hurry. 1993. The reliability of geophysical surveys at historic-period cemeteries: An example from plains Cemetery, Mechanicsville, Maryland. 1993. Historical Archaeology 27(3): 4-16.

Morey, R. M. 1974. Continuous subsurface profiling by impulse radar. 212-232 pp. IN: Proceedings, ASCE Engineering Foundation Conference on Subsurface Exploration for Underground Excavations and Heavy Construction, held at Henniker, New Hampshire. Aug. 11-16, 1974.

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

Shearin, A. E., and D. E. Hill. 1962. Soil Survey of Hartford County, Connecticut. USDA – Soil Conservation Service in cooperation with the Connecticut Agricultural Experiment Station and Storrs Agricultural Experiment Station. US Government Printing Office, Washington, DC.

Vaughan, C. J. 1986. Ground-penetrating radar surveys in archaeological investigations. Geophysics 51(3): 595-604.

Vickers, R., L. Dolphin, and D. Johnson. 1976. Archaeological investigations at Chaco Canyon using subsurface radar. 81-101 pp. IN: Remote Sensing Experiments in Cultural Resource Studies, assembled by Thomas R. Lyons, Chaco Center, USDI-NPS and University of New Mexico.

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

Wolf, B. L. 1981. Soil Survey of Fairfield County, Connecticut. USDA – Soil Conservation Service in cooperation with the Connecticut Agricultural Experiment Station and Storrs Agricultural Experiment Station. US Government Printing Office, Washington, DC.

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TOWN NEWS

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KATHY HANLEY / THE HARTFORD COURANT

FOLLOWING up on a request by Plainville's Historical Society to look into what may be a section of the East Street Cemetery for unmarked graves where black residents may have been buried in the late 19th century, scientists surveyed the grounds Tuesday. At left are, Shawn McVey, assistant state soil scientist with the Natural Resources Conservation Service in Tolland; John Spaulding, with the state archeology office; and Jim Doolittle, a research soil scientist, with the Conservation's Philadelphia office.

LOOKING FOR CLUES OF THE DEPARTED

Possible Burial Grounds Of Blacks Surveyed

By HILDA MUÑOZ
COURANT STAFF WRITER

PLAINVILLE – It's no secret that African Americans, Native Americans and anyone too poor to afford a lasting headstone, were usually buried separately from wealthy whites years ago.

"It was segregation. Even in death it was segregation," said Town Historian Ruth Hummel, who suspects that sort

PLAINVILLE

of discrimination happened in Plainville's historic burying grounds on East Street.

Except for a 100-year-old African American woman who in the 1970s pointed Hummel to an empty corner at the East Street Cemetery, there are no records of where Plainville's early black families are buried.

"It's surprising that somebody could disappear," said Hummel Tuesday morning as snow blanketed the cemetery. "It seems in Plainville if there were records we don't have 'em."

Acting on the 100-year-old woman's hint, Hummel last year asked state archeologist Nicholas Bellantoni to conduct a ground-penetrating radar scan last summer, hoping the information might fill the void in the records of Plainville's oldest dead.

TOWN HISTORIAN, Ruth Hummel, watches the scientists work as Frank Robinson Jr., left, a local documentary filmmaker and Chris Cadrain videotape.

So, Bellantoni arrived Tuesday morning with a team from the state's Natural Resources Conservation Service, to see what they could find.

"Just because we see an empty space there doesn't mean nobody is buried there," said Bellantoni, pointing to the cemetery's southern corner, the only bald spot in a plot of thin, brittle-looking gravestones.

The crew surveyed an area of 18 by 30 meters with what looked like a small, red lawn mower. Results from the scan won't be ready for at least three weeks.

"This is great they may be able to establish some more history in Plainville," said Kenneth Hedman, president of the Plainville Cemetery Association.

Old graveyards are hard to keep a track of because they become overgrown with weeds and are often forgotten. Headstones are weathered by the years.

Black cemeteries can be more of a challenge because the people buried in them couldn't afford tombstones and written records are sometimes hard to find, said Ruth Shapleigh-Brown, president of the Connecticut Gravestone Network in Manchester.

"It seems that records involved people who were part of the community," Shapleigh-Brown said in a phone interview. "If you weren't paying taxes no one had a need to keep a track of who you were."

Shapleigh-Brown noted that there are exceptions and mentioned four headstones in South Windsor that mark the resting places of African Americans and Native Americans.

The radar study can only suggest a person is buried underground and doesn't determine a person's ethnicity, said Bellantoni.

"It's not going to say yes, this is a burial ground, yes, this is where African Americans are buried," said Bellantoni. "The radar will hopefully give us a hit and if there's a pattern we might be able to delineate a row."

And the row might mean graves exist below ground.

Article from the Hartford Courant that covers the field studies conducted with the GPR in Plainville, Connecticut. Special thanks to Tammy Umholtz of the National Soil Survey Center in Lincoln, NE, for scanning this newspaper column.