United States Department of Agriculture	**Natural Resources Conservation Service Service**	**344 Merrow Road Suite A Tolland, CT 06084**

SUBJECT: Archaeology – Geophysical Field Assistance April 30, 2019

To: Brian D. Jones, PhD
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Purpose:
A ground-penetrating radar (GPR) survey was conducted at Central Cemetery in Brookfield, Connecticut, to locate marked and unmarked graves within the Sherman family plot. A second GPR survey was conducted in Kent, Connecticut to locate "God's Acre" a former graveyard of the Moravian Church. These investigations were completed in fulfillment with USDA NRCS's commitment to protect and enhance our nation's historical properties.

Principal Investigators:
Scott Brady, Volunteer, Friends of the Office of State Archaeology
Dr. Brian Jones, State Archaeologist, Office of State Archaeology, University of Connecticut, Storrs, CT
Abbie Cadman, Resource Conservationist, USDA NRCS, Tolland, CT
Debbie Surabian, State Soil Scientist CT/RI, USDA NRCS, Tolland, CT

Activities:
Activities were completed 19 April 2019.

Summary:
1. The use of ground-penetrating radar provided added insight into subsurface conditions and the presence of buried features. All results, however, are interpretative.

2. At Central Cemetery, a GPR grid survey was conducted to confirm marked and locate unmarked graves within the Sherman family plot. In addition, several "wildcat" or random GPR transects were completed around several isolated graves. Locations having no anomalous reflection patterns were identified as areas most likely open and available for future burials.

3. In Kent, several "wildcat" or random GPR transects were conducted in areas thought to be associated with the location of God's Acre due to local research. Further investigations using aerial imagery and Lidar were discussed to narrow down the location.

Regards,

DEBORAH SURABIAN Digitally signed by DEBORAH SURABIAN
Date: 2019.04.30 08:09:28 -04'00'

Deborah Surabian
State Soil Scientist CT/RI

cc:
Thomas Morgart, State Conservationist, USDA NRCS, Tolland, CT
Abbie Cadman, Resource Conservationist and Cultural Resources Liaison, USDA NRCS, Tolland, CT

Equipment:

The radar unit used is the SIR (Subsurface Interface Radar) 4000; a ground-penetrating radar data acquisition system manufactured by Geophysical Survey Systems, Inc. (GSSI) that is designed to operate with both analog and digital antennas.[1] The unit consists of a digital control unit with keypad, SVGA video screen, and connector panel. A 10.8-volt lithium-ion rechargeable battery powers the approximately 9 lb. (4.1 kg) portable system. An analog 400 MHz antenna attached to a survey cart was used to collect the radar data. The RADAN for Windows (version 7) software program, developed by GSSI, was used to process the radar profiles.[1] Processing included setting the initial pulse to time zero as well as color table, background removal, and transformation selections.

Ground-Penetrating Radar:

GPR is a non-invasive geophysical method that uses the reflection of electromagnetic energy to produce images of the subsurface. Results are highly site-specific as GPR does not work equally well in all soils. Soils having high electrical conductivity rapidly attenuate radar energy, restrict penetration depths, and limit the effectiveness of GPR. The electrical conductivity of soils increases with an increase in water, clay, and/or soluble salt contents. Excessively drained and well drained, sandy soils are considered well-suited to high resolution, deep profiling with GPR. Conversely, poorly drained and very poorly drained, clayey soils are considered poorly-suited to GPR.

A favorable feature of GPR is its ability to noninvasively produce high-resolution images of the subsurface and detect points or areas that have different reflection patterns than neighboring areas. An area or point having a contrasting spatial reflection pattern is often referred to as an "anomaly" because of the uncertainty attached to it in the absence of ground-truth confirmation. An anomaly simply indicates there is something different in the subsurface. In an archaeological context, an anomaly may indicate an area of disturbance or an artifact buried in the soil. However, even under favorable site conditions (i.e. dry, coarse-textured soils) the detection of an anomaly is never assured with GPR. The detection of an anomaly is affected by (1) the electromagnetic gradient existing between the feature and the soil, (2) the size, depth, and shape of the buried feature, and (3) the presence of scattering bodies within the soil.

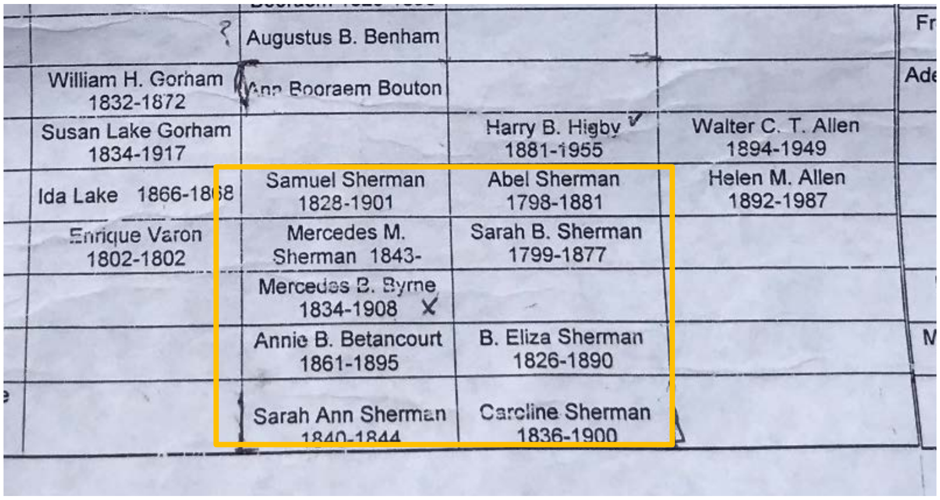
The amount of energy that is reflected to a GPR antenna is dependent on the contrast in dielectric permittivity that exists across subsurface boundaries or interfaces. Dielectric permittivity quantifies how easily a material becomes polarized in the presence of an electric field. The greater and more abrupt the contrast in dielectric permittivity between an anomaly (e.g., buried archaeological feature) and the surrounding soil, the greater the amount of energy reflected to the antenna, and the more intense and conspicuous the reflected signal appearing on the radar profile.

The size, orientation, and depth to an artifact affect GPR interpretations. Large objects reflect more energy and are easier to detect than small objects. Small artifacts, unless buried directly beneath the path of the radar antenna may be missed. In addition, with increasing soil depth, small artifacts are more difficult to discern on radar profiles. Strongly stratified soil horizons, stones and cobbles, tree roots, animal burrows, modern cultural features or disturbed soil conditions can produce undesired reflections that complicate the radar imagery and mask the presence of buried artifacts or burials.

Central Cemetery:

Central Cemetery is located on 490 Federal Road in Brookfield, CT, and is managed by the Central Cemetery Association. The cemetery started in 1777 when Abigail Starr, wife of John Starr, was buried here. Notable burials in this cemetery include Dr. Amos Williams (for whom Williams Park in Brookfield is named) and Sarah Jane Campbell Pishon (who was exhibited by P.T. Barnum in the Great American Museum) (Central Cemetery, 2019). The Association is in search of open spaces within the Sherman family plot for future burials. Figure 1 lists the burials that are known to be located within the Sherman Family plot. Figure 2 is a rough sketch showing the marked burials surrounding the monument within the Sherman family plot.

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



?	Augustus B. Benham			Fr
William H. Gorham 1832-1872	Ann Booraem Bouton			Ade
Susan Lake Gorham 1834-1917		Harry B. Higby 1881-1955	Walter C. T. Allen 1894-1949	
Ida Lake 1866-1868	Samuel Sherman 1828-1901	Abel Sherman 1798-1881	Helen M. Allen 1892-1987	
Enrique Varon 1802-1802	Mercedes M. Sherman 1843-	Sarah B. Sherman 1799-1877		
	Mercedes B. Byrne 1834-1908			
	Annie B. Betancourt 1861-1895	B. Eliza Sherman 1826-1890		M
	Sarah Ann Sherman 1840-1844	Caroline Sherman 1836-1900		

Figure 1. An image of known burials marked around the Sherman monument.

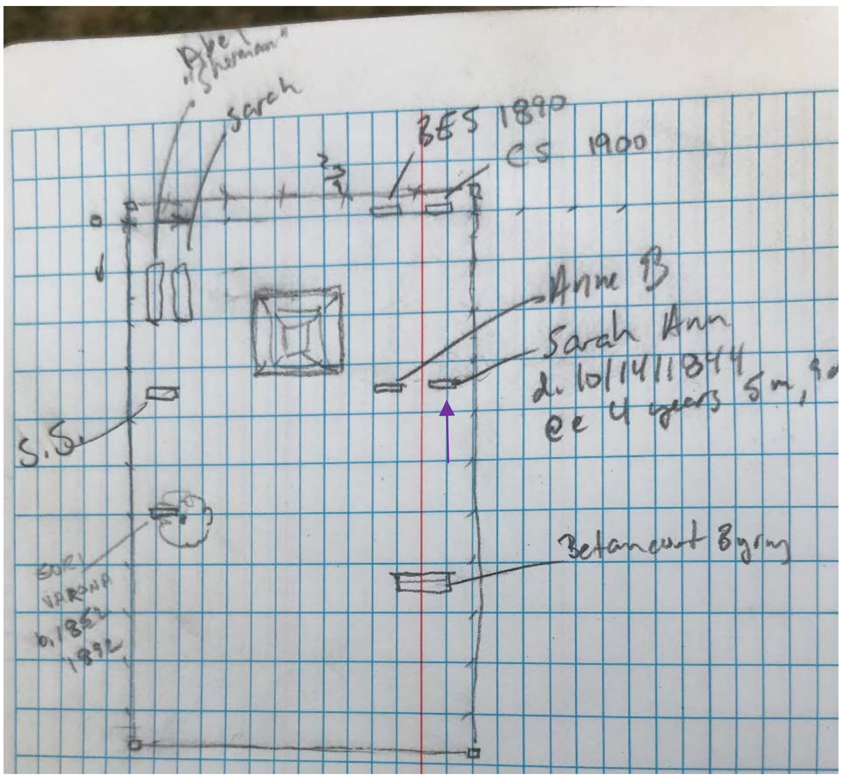


Figure 2. A sketch from Brian Jones's field book showing the locations of the marked burials within the Sherman family plot. The large rectangular feature in the center of this sketch is the monument.

God's Acre:

God's Acre is the traditional name given to burial grounds by congregations of the Moravian Church. These congregations typically laid out their burial grounds on hilltops. The name comes from the belief that the bodies of the dead are "sown as seed" in God's Acre, as in a field, so that they can rise again when Jesus Christ returns to the world (God's Acre, 2019). Moravians believe strongly in equality, even in death, so every stone in a God's Acre is of the same size and material so that the gravestone of no one person stands out among the others. In addition, the deceased are buried by choir, which means being separated by gender, there are also sections for people of different age and marital status. God's Acre is not exactly one acre in size; many are larger or smaller (God's Acre, 2019). Figures 3 and 4 show the locations of two areas that have been identified for investigations (highlighted by yellow-colored polygons) on the 1951 and 2018 imagery.

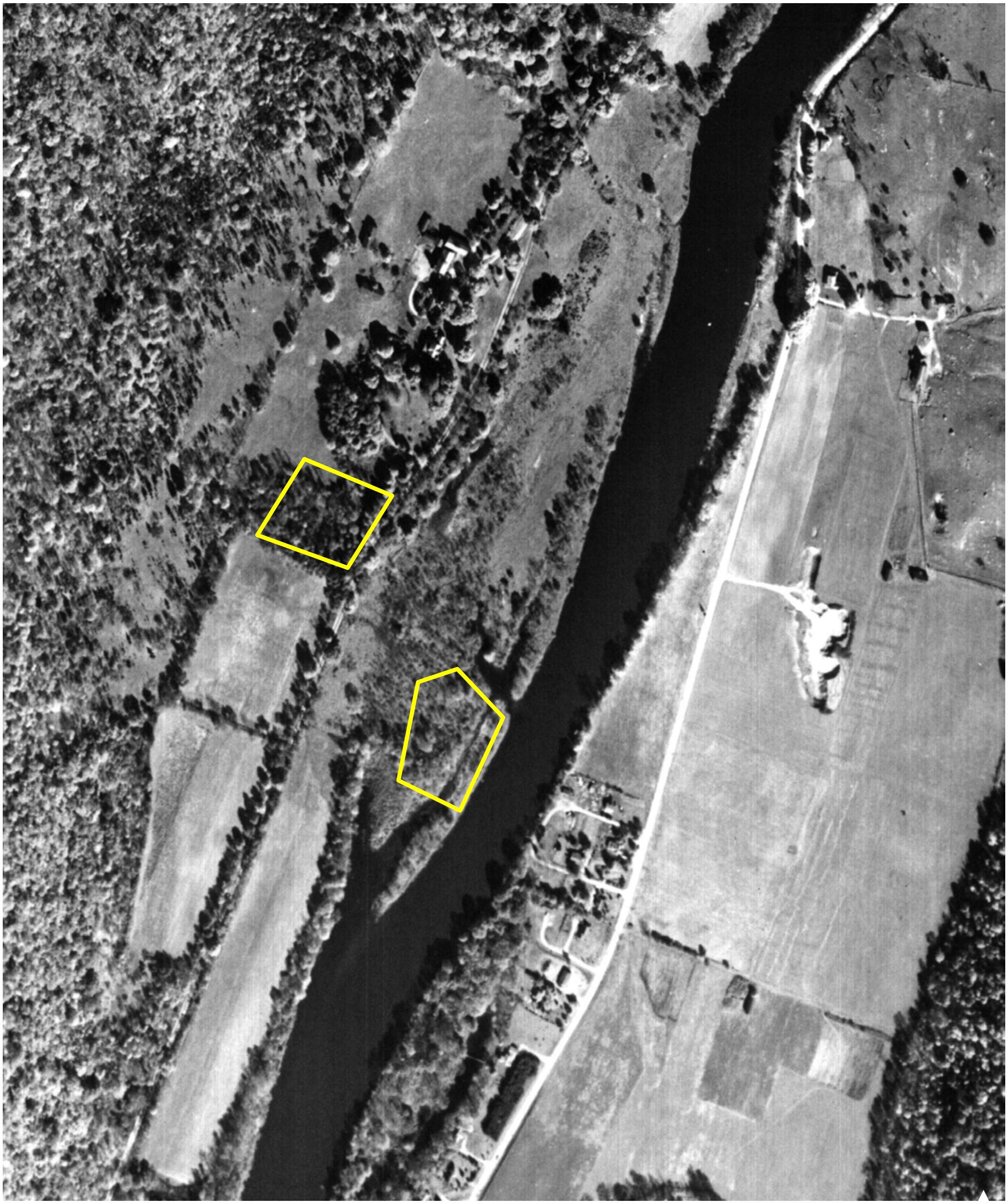


Figure 3. A 1951 aerial showing the approximate areas of investigation in Kent, CT.

Figure 4. A 2018 aerial showing the approximate areas of investigation in Kent, CT.

GPR Survey Procedures:

A 10 by 6 meter (m) survey grid was constructed across Sherman's family plot. To facilitate the construction of this grid, two parallel survey lines were laid out on opposite sides of the plot (see Figure 5). Along these two parallel lines, survey flags were inserted into the ground at a spacing of 50 centimeters (cm). A rope was stretched between matching survey flags located on opposing sides of the grid area, and the survey cart was moved along the rope for guidance. Following data collection along the line, the rope was sequentially moved 50 cm to the next pair of survey flags to repeat the process, with the GPR moving in the same direction. The survey flag in the southwest corner of this grid served as the grid's origin (0, 0 m) and is highlighted by a yellow-colored star in Figure 6. Random GPR transects were also completed in selected areas.

Figure 5. A GPR grid survey, conducted around he Sherman Family monument, was laid out using orange-colored flags (photo courtesy of Chris Randall).

Soils:

A Google Map image with a superimposed soil map from the Soil Survey of the State of Connecticut is shown in Figure 6. In the inset to Figure 6, the red-colored box identifies the approximate location of the GPR survey in Central Cemetery which is located within a soil delineation of Agawam fine sandy loam, 8 to 15 percent slopes that is labeled 29C. Agawam soils are very deep, well drained soils formed in sandy, water deposited materials. In Figure 9, a soil core that was extracted from an undisturbed area within the plot confirms the identity of the soil as Agawam. Because of its low clay, water and soluble salt contents, Agawam soil is considered well suited for GPR investigation work.

Figure 6. This Google Map image has soil lines and symbols that were imported from the Soil Survey of the State of Connecticut. The red-colored box indicates the approximate location where GPR survey was completed. The yellow-colored star indicates the starting location of the GRP grid survey (0,0) and the yellow-colored arrow indicates the direction of the transects. The soils are mapped as 29C Agawam fine sandy loam, 8 to 15 percent slopes.

Figure 7. An undisturbed Agawam soil is verified by the State Soil Scientist and State Archaeologist (photo courtesy of Chris Randall).

A Google Map image with a superimposed soil map from the Soil Survey of the State of Connecticut for the Kent site is shown in Figure 8. In Figure 8, the colored circles identify the approximate locations of GPR transects. These transects are located within soil delineations of Limerick and Lim soils (labeled as 107) and Raypol silt loam (labeled as 12). Limerick and Lim soils consist of very deep, poorly drained soils formed in loamy alluvial sediments. They are on nearly level flood plains and are subject to frequent flooding. Raypol soils are very deep, poorly drained soils formed in loamy over sandy and gravelly outwash. They are on nearly level to gently sloping drainageways and lower-lying positions on terraces and plains. Because of their high water table, these soils are not considered well suited for GPR investigation work.

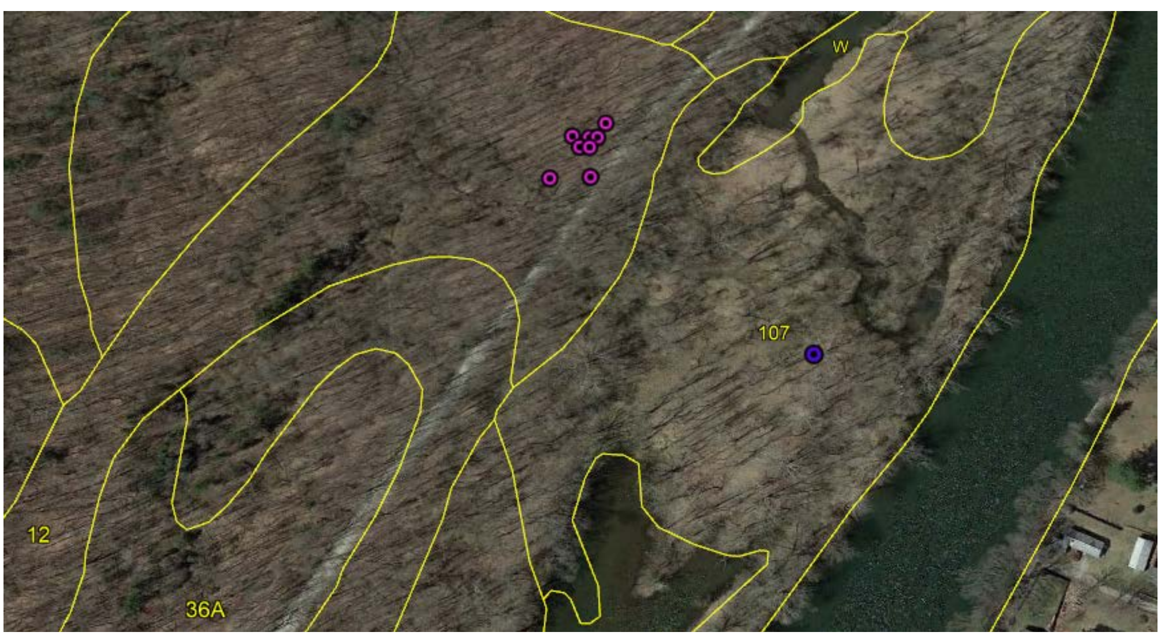


Figure 8. This Google Map image has soil lines and symbols (colored yellow) that were imported from the Soil Survey of the State of Connecticut. The purple and blue dots indicate the approximate locations where wildcat GPR transects were completed. The soils are mapped as 107 Limerick and Lim soils and 12 Raypol silt loam.

Sherman Family Plot GPR Survey:
The results of the GPR surveys are displayed as two-dimensional (2D) radar profiles. In addition, for the grid survey that was conducted at the Sherman family plot, selected depth-sliced images are shown in Figure 9. These depth-sliced images were generated from a three-dimensional (3D) data cube that was constructed from the multiple, closely-spaced, parallel 2D radar profiles collected at this site. In each of the illustrated depth-sliced images, the reflected radar energy was averaged horizontally between adjacent, parallel radar traverses and in a specific time or depth window. For display purposes, each depth-sliced image is viewed from directly overhead looking downwards into the grid.

Figure 9 shows two depth-sliced images of the GPR grid at soil depths of 70 and 140. The narrow, high amplitude, linear reflection pattern that parallels the western boundary (left-hand side of images) of the grid site may represent interference from the metallic border fence. On these depth-sliced images, some of the medium and high-amplitude reflectors appear to be elongated in an east to west orientation and could be interpreted as the disturbed soil materials overlying marked and unmarked graves. However, most of these reflectors are believed to be too closely-spaced and of limited linear dimensions to represent individual graves. The areas highlighted within the black-colored dashed boxes are presumed to contain graves (see Figure 2). Several small areas outside of these boxes have no major reflection patterns indicative of burials and may be suitable for additional burials. However, before any such use, these limited areas should be explored by a certified archaeologist. Figure 9 shows four labeled red-colored arrows that are associated with the 2D radar profiles in Figures 10 through 13.

Figure 10 shows two 2D radar records taken on the west side of the monument. Four medium to high-amplitude hyperbola reflections (highlighted by blue-colored circles) appear between the 0 and 2 meter and the 3.5 to 5.5 meter distance markers. These anomalies coincide with the known burials marked (from left to right) with headstones identified as Abel, Sarah, B. Elisa, and Caroline, respectively. The average depths of these burials are between 90 to 125 cm from the soil surface. Highlighted in the green-colored boxes are the two burials (Abel and Sarah) that have marked stones that lay flat and flushed with the ground surface.

Figure 11 shows two 2D radar records taken on the east side of the monument. Five medium to high-amplitude reflection hyperbolas appearing between the 0 and 5.5 meter distance markers are highlighted by blue-colored circles. These reflections likely coincide with three burials marked with headstones (labeled Samuel, Anne, and Sarah Ann) and two unmarked burials in the middle (possibly Mercedes M. Sherman and Mercedes B. Byme). The depths of the burials are between approximately 70 to 90 cm from the soil surface.

Figures 12 and 13 show two 2D radar records taken on the east side of the monument. Medium to high-amplitude reflection hyperbolas that occur either within the black-colored dashed outlined boxes (Figure 12)or as blue-colored circles (Figure 13) may be associated with marked and unmarked graves. On many radar profiles, the identification of burials is aided by accessory features, such as truncated soil interfaces (from soil excavations) or vertical zones of contrasting reflection patterns (from the mixed soil materials in the refilled grave shafts). On the depth-sliced images in Figure 11, a majority of the observable reflectors appear to be elongated in an east to west orientation in these areas, supporting the interpretation of disturbed soil materials due to burials. If they are burials, the depths are between approximately 50 to 75 cm from the soil surface.

Figure 14 shows a random 2D radar profile that was collected parallel to the headstone of Sarah Ann Sherman, a 4 year old child who died in 1844. Medium to high-amplitude hyperbola reflections between 50 to 95 cm below the soil surface (highlighted by a black-colored box) may be associated with the marked burial.

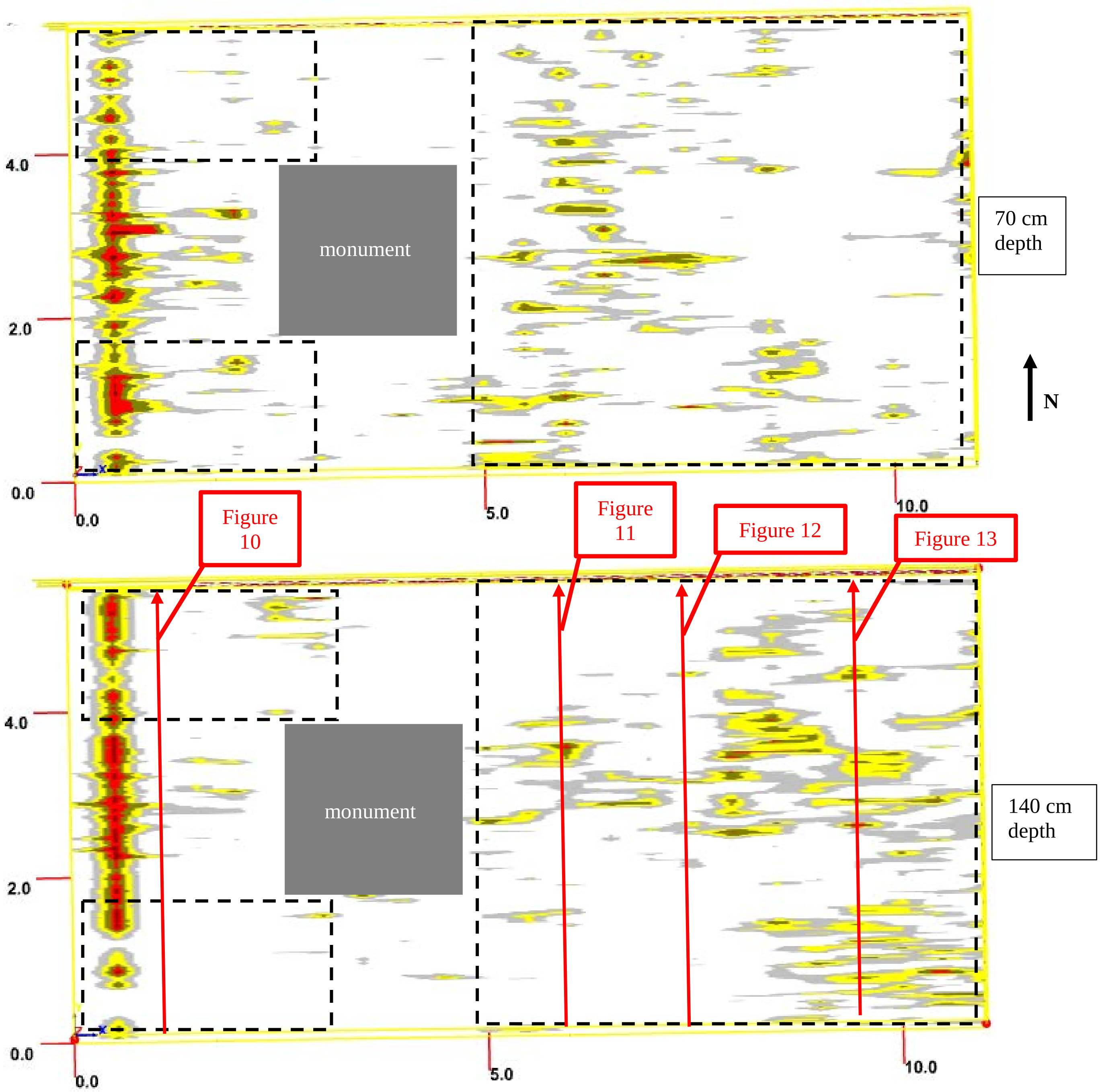


Figure 9. Depth-sliced images of the GPR grid at soil depths of 70 and 140 centimeters.

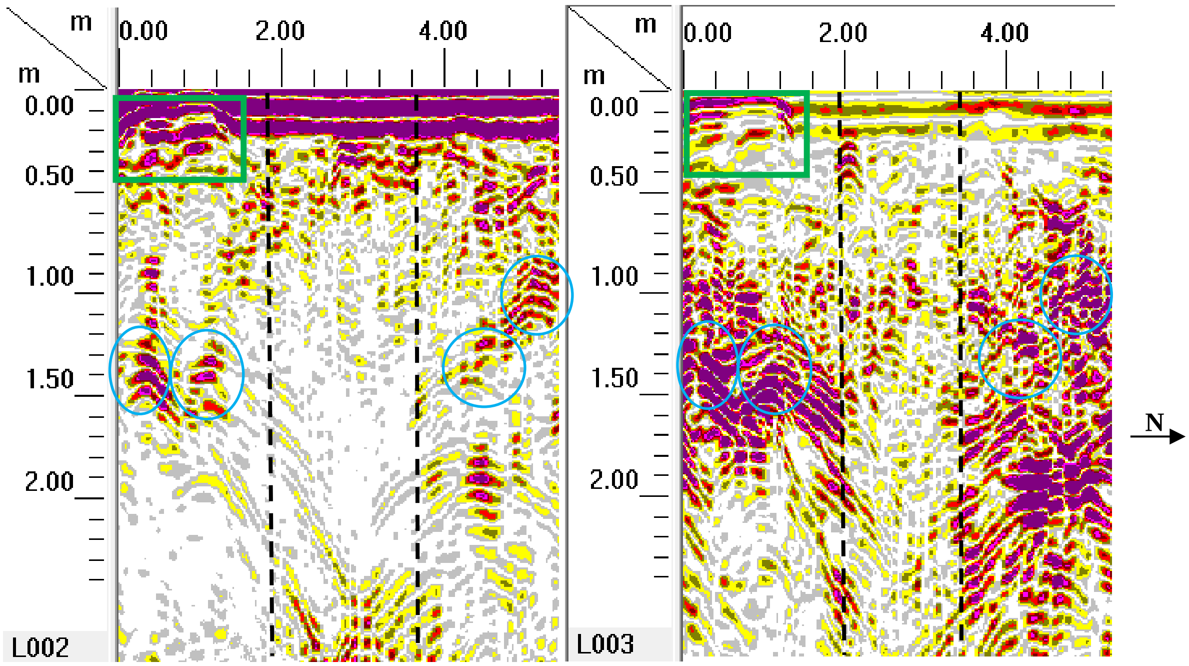


Figure 10. A set of two 2D radar profiles from the GPR grid taken on the west side of the monument.

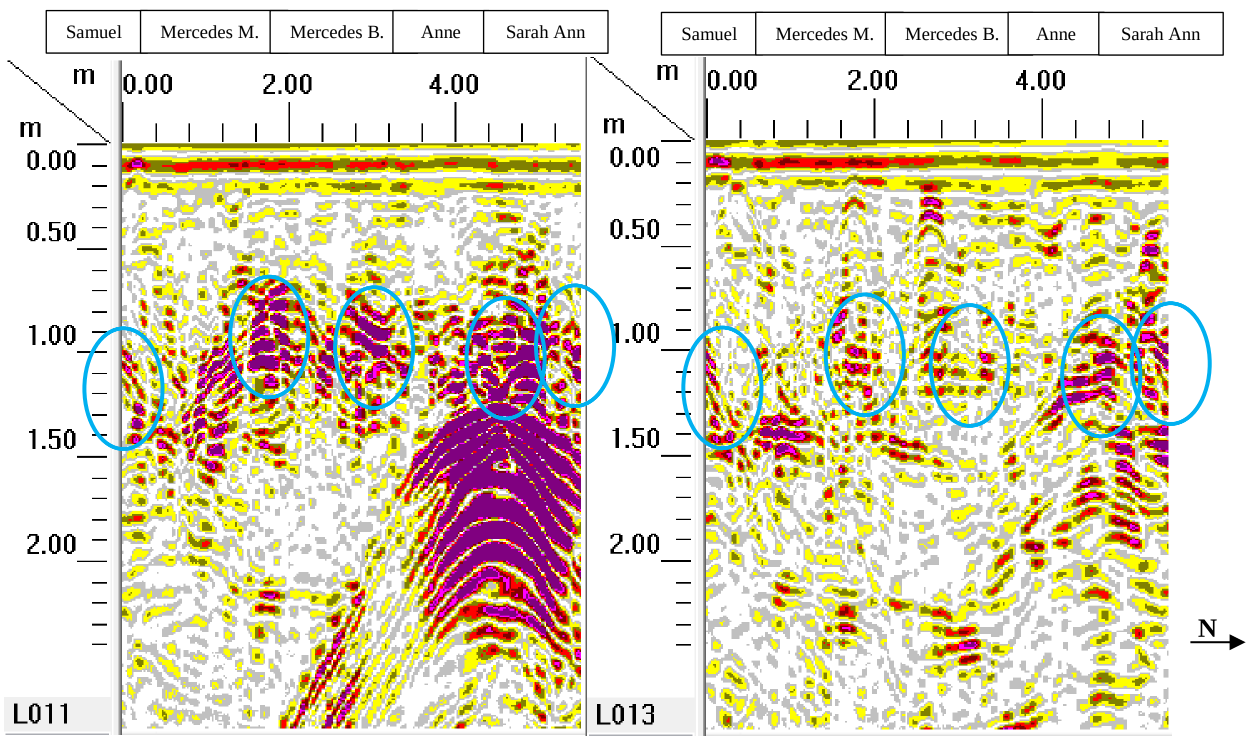


Figure 11. Two 2D radar profiles from the east side of the monument.

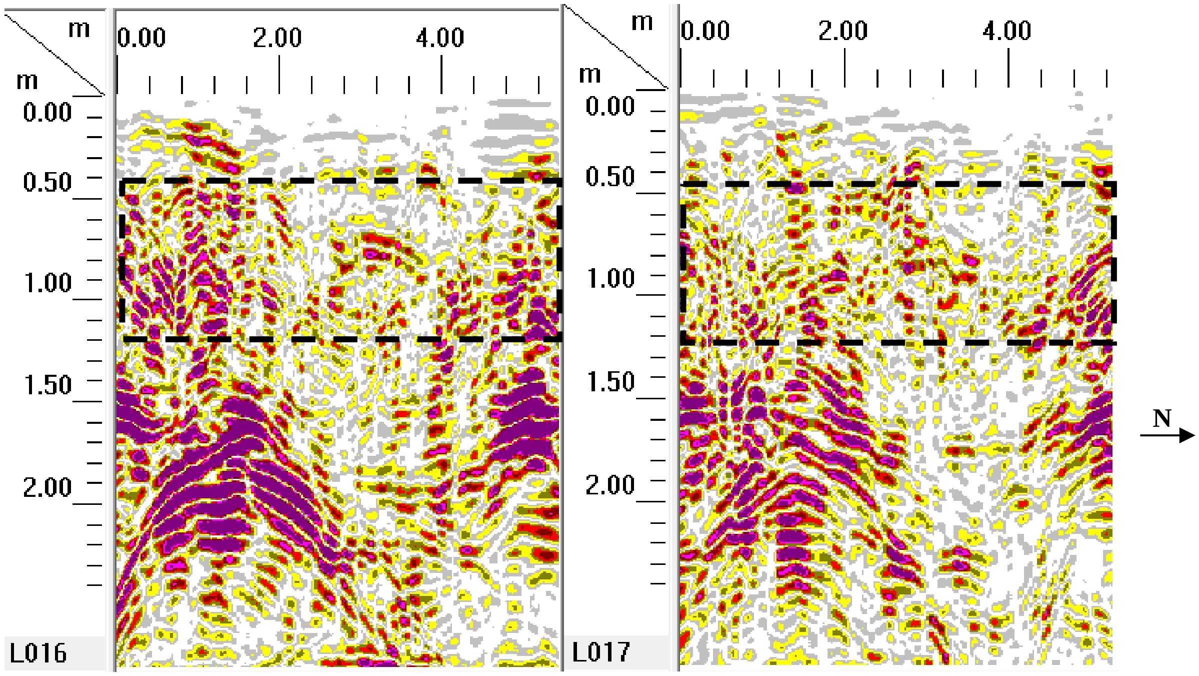


Figure 12. Two 2D radar profiles from the east side of the monument.

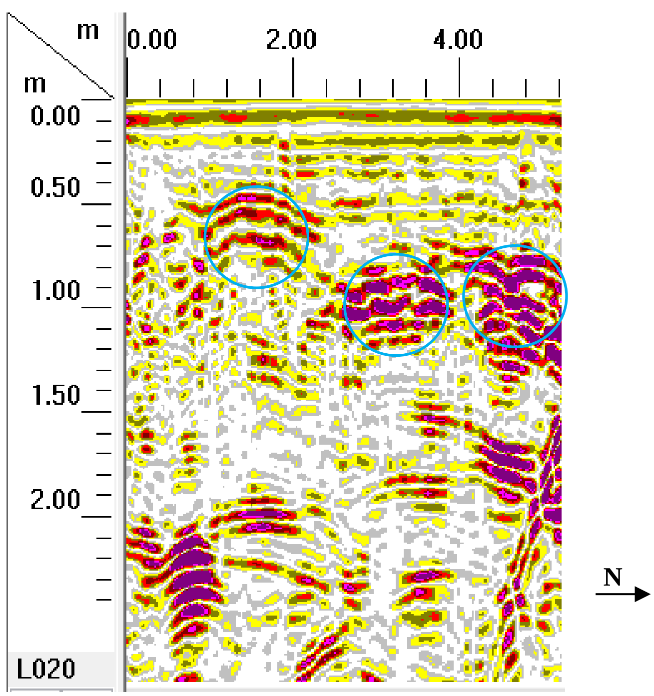


Figure 13. A radar profile from the east side of the monument.

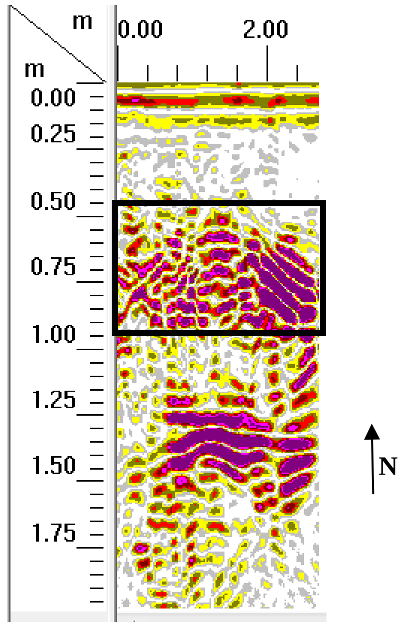


Figure 14. A random 2D radar profile taken parallel to the headstone of Sarah Ann Sherman.

Kent GPR Surveys:
Figure 15 shows a 2D radar profile taken on the east side of the road close to the river in Kent, CT. The transect was taken in a west to east direction moving towards a large Sycamore tree (shown as the blue-colored dot in Figure 4). There appears to be no indication of burials, such as truncated soil interfaces (from soil excavations) or vertical zones of contrasting reflection patterns (from the mixed soil materials in the refilled grave shafts) on the radar profile. The soil horizons appear mostly horizontal and linear across the entire transect with little disturbance which is indicative of a natural floodplain soil where like materials are laid down during flooding events.

Figure 16 shows a set of 2D radar profiles taken on the west side of the road in Kent, CT (shown in Figure 10 as the purple-colored dots). There appears to be some indication of truncated soil interfaces or rock fragments where there are associated high-amplitude reflectors and hyperbolas. Overall, the radar profiles show no patterns of burials.

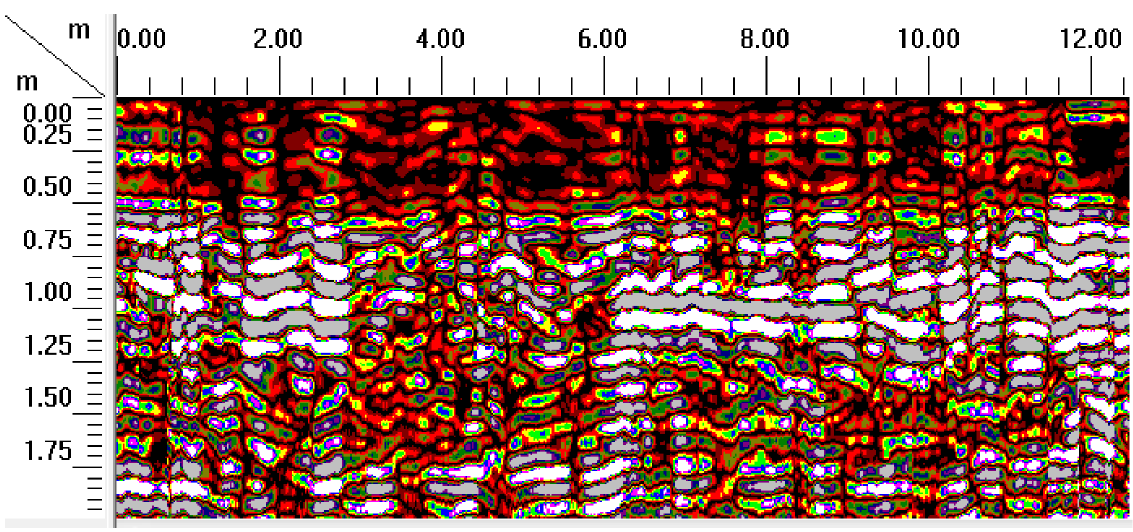


Figure 15. A 2D radar profile taken on the east side of the road close to the river in Kent, CT. The transect was taken in a west to east direction moving towards a large Sycamore tree (the blue-colored dot in Figure 10).

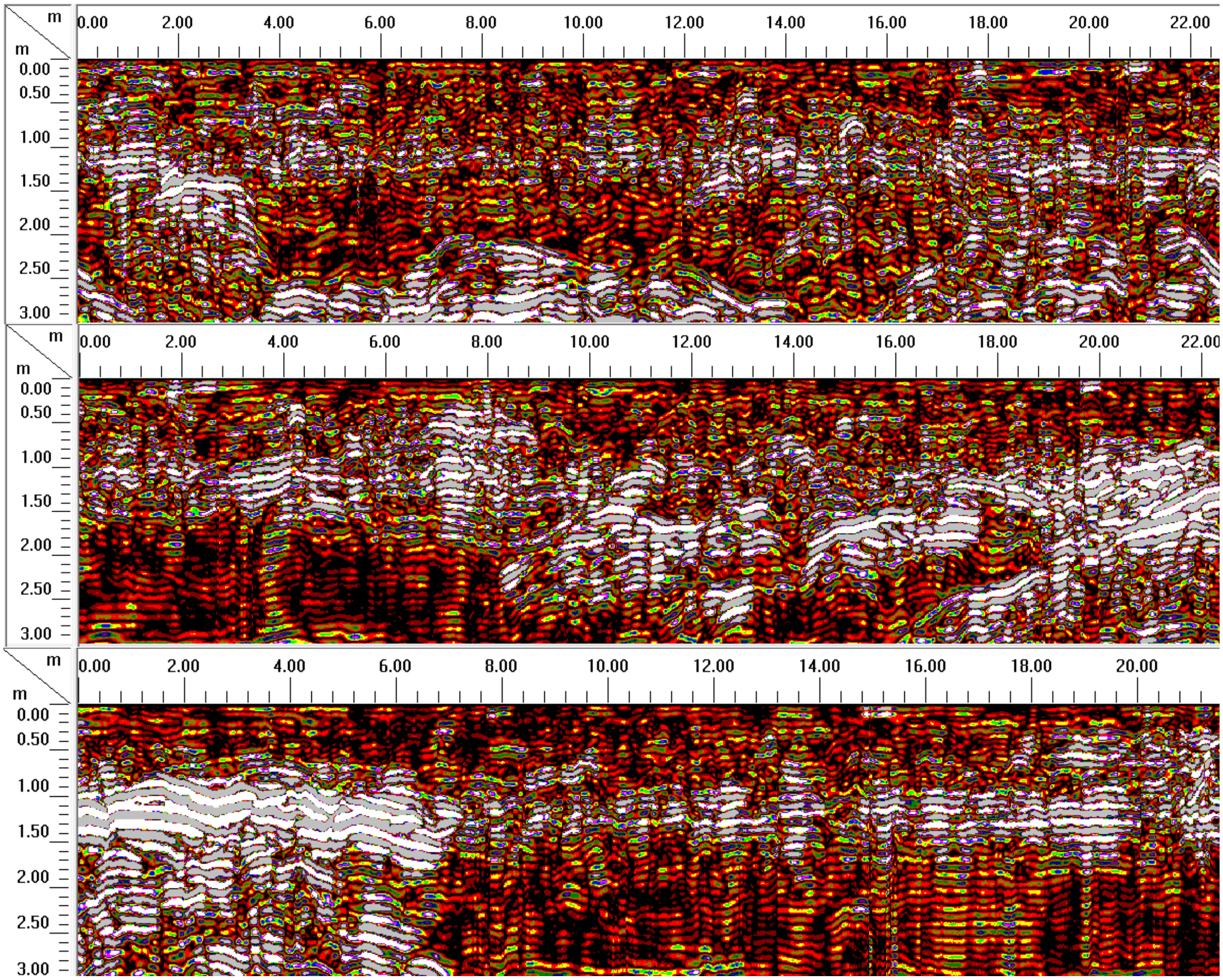


Figure 16. A set of 2D radar profiles taken on the west side of the road in Kent, CT.

References:

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