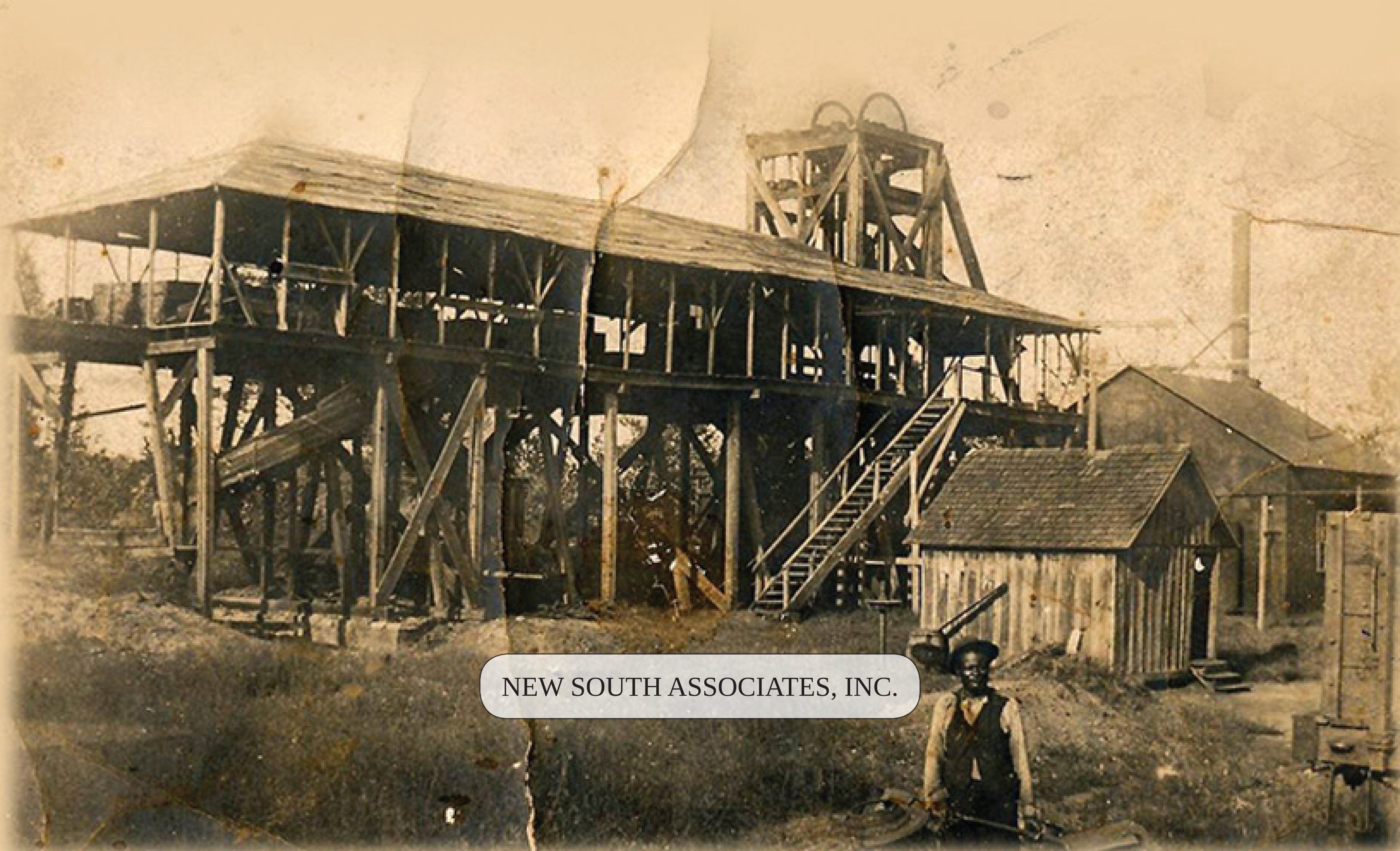
Ground-Penetrating Radar (GPR) Survey to Prospect for Mass Graves Resulting from Mine Explosions in the Bethany Church Cemetery

Chatham County, North Carolina



NEW SOUTH ASSOCIATES, INC.

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Chatham County, North Carolina

Report submitted to:

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ABSTRACT

New South Associates, Inc. (New South) conducted a ground penetrating radar (GPR) survey of a 0.06-acre section of the Bethany Church Cemetery in Gulf, North Carolina. The area selected for survey is suspected to have an unmarked mass grave. The survey, conducted by Sarah Lowry and Maeve Herrick on January 30, 2018, located 34 probable individual graves and one area of disturbed soil with many graves. Based on the available marker data, 15 of the probable graves have associated markers. New South recommends that the 35 GPR anomalies identified as probable graves should be treated as such and avoided when future ground disturbance is planned.

ACKNOWLEDGEMENTS

New South thanks Forest Hazel for his research and work at the Bethany Church Cemetery. Additionally, thank you to the members of the Bethany Church for their engagement and assistance with this survey.

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I. INTRODUCTION

New South Associates, Inc. (New South) conducted a ground-penetrating radar (GPR) survey over a small section of the eastern portion of the Bethany Church Cemetery in Chatham County, North Carolina (Figure 1). The purpose of the survey was to identify unmarked graves in the surveyed area, including a possible mass grave that may have been placed in the cemetery following an explosion at the nearby Egypt mine (Forest Hazel, personal communication, January 30, 2018) (Figure 2). Oral histories indicate that this tragedy resulted in the mass burial of miners in this section of the Bethany Church Cemetery (Forest Hazel, personal communication, January 30, 2018). The marked graves within this cemetery date to the nineteenth and twentieth century. Sarah Lowry and Maeve Herrick conducted fieldwork on January 30, 2018.

The interpreted results of the GPR survey identified 34 probable individual graves and one area of disturbed soils where many probable graves are present, but individual graves could not be separately identified with confidence. New South recommends that the 35 GPR anomalies identified as probable graves should be treated as such.

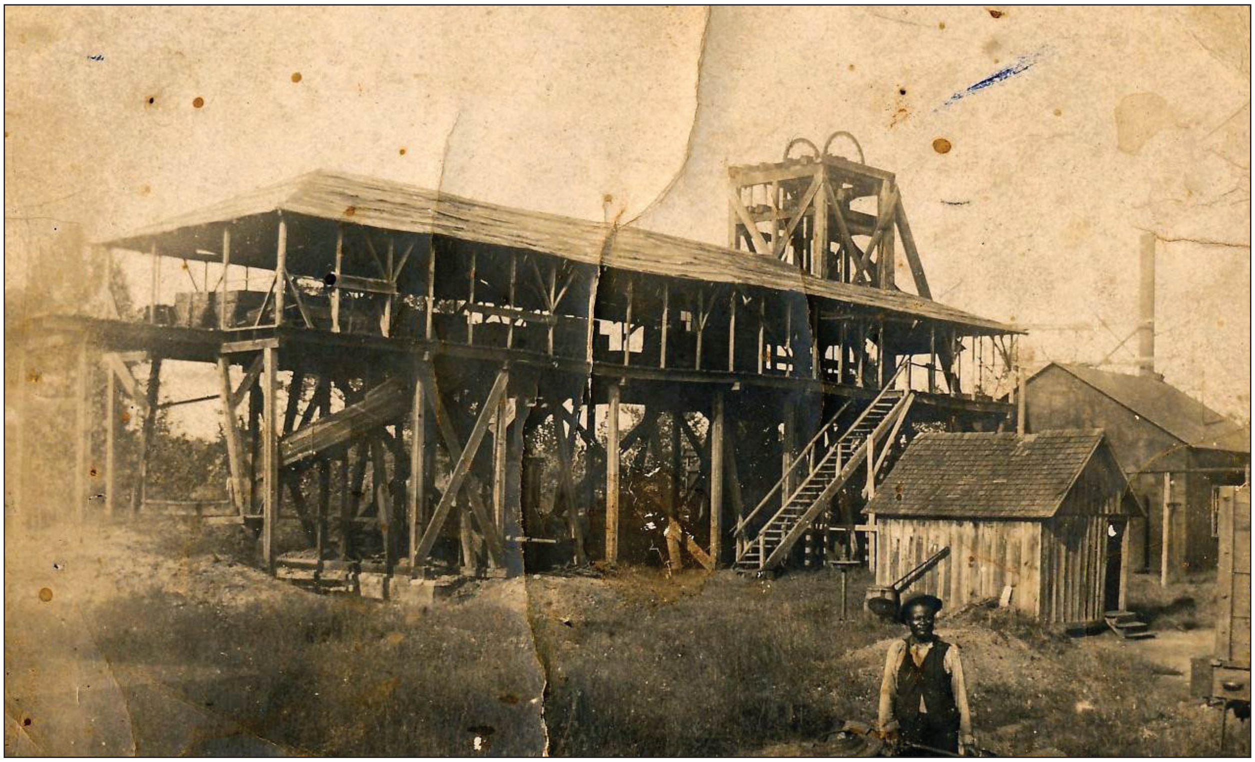
The cemetery soils were Carbonton-Brickhaven complex, two to six percent slopes (Hayes 2006:53–58). These soils are somewhat poorly to moderately well-drained silty and silty clay loams (Hayes 2006:54). Data quality was excellent.

This report is divided into three chapters. Chapter I introduces the investigation and describes the project setting. Chapter II outlines the methods employed during the field investigations, and Chapter III discusses the field investigation results and recommendations.

Figure 1.
Location of GPR Survey

Image source: USDA NAIP 2016

Figure 2.
Circa 1900 Photograph of Cumnock Mine (Previously Named Egypt Mine)



Courtesy of Forest Hazel

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II. METHODS

SURVEY GRID

Prior to data collection, it was necessary to establish a grid, which was accomplished using metric measuring tapes. The grid was placed to cover the area believed, in consultation with Forest Hazel, to contain an unmarked mass grave. Survey flags were used to mark each grid corner, which were mapped using a Trimble RTK GPS unit with R10 antenna with an approximately one- to two-centimeter accuracy.

All spatial data were downloaded from the Trimble RTK GPS unit and then imported into ArcMap 10, ESRI's geographic information system (GIS) program. Separate shapefiles were then created for the geophysical interpretations, markers, and grids. Grave markers were correlated with the geophysical interpretations.

GROUND-PENETRATING RADAR (GPR)

GPR is a remote sensing technique frequently used by archaeologists to investigate a wide range of research questions. In archaeological applications, GPR is used to prospect for potential subsurface features. Because GPR is a remote sensing technique, it is non-invasive, nondestructive, relatively quick, efficient, and highly accurate when used in appropriate situations.

In cemeteries, GPR is commonly used to identify anomalies consistent with the expectations for human graves (Jones 2008; King et al. 1993). The use of GPR for identifying potential historic graves is based on the concept of contrast, which may include differences in physical, electrical, or chemical properties between an object or feature and its surrounding matrix (Conyers 2004a). For graves, the body itself is generally not detected; it is typically the coffin or casket, burial shaft, or bottom of the grave that causes the reflection (Jones 2008; King et al. 1993). Not surprisingly, greater contrast generally equates to better detection and resolution. For example, a metal casket in a concrete vault is much easier to see with GPR than a body buried in a wooden coffin only.

GPR data are acquired by transmitting pulses of radar energy into the ground from a surface antenna, reflecting the energy off buried objects, features, or bedding contacts, and then detecting the reflected waves back at the ground surface with a receiving antenna (Conyers 2004a:1). When collecting radar reflection data, surface radar antennas are moved along the ground in transects, typically within a surveyed grid, and a large number of subsurface reflections are collected along each line. As radar energy moves through various materials, the velocity of the waves will change depending on the physical and chemical properties of the material through which they are traveling (Conyers and Lucius 1996). The greater the contrast in electrical and magnetic properties between two materials at an interface, the stronger the reflected signal, and, therefore, the greater the amplitude of reflected waves (Conyers 2004b).

When travel times of energy pulses are measured, and their velocity through the ground is known, distance (or depth in the ground) can be accurately measured (Conyers and Lucius 1996). Each time a radar pulse traverses a material with a different composition or water saturation, the velocity will change and a portion of the radar energy will reflect back to the surface and be recorded. The remaining energy will continue to pass into the ground to be further reflected, until it finally dissipates with depth.

The depths to which radar energy can penetrate, and the amount of resolution that can be expected in the subsurface, are partially controlled by the frequency (and, therefore, the wavelength) of the radar energy transmitted Standard GPR antennas propagate radar energy that varies in frequency from about 10 megahertz (MHz) to 1000 MHz. Low-frequency antennas (10-120 MHz) generate long wavelength radar energy that can penetrate up to 50 meters in certain conditions, but are capable of resolving only very large buried features. In contrast, the maximum depth of penetration of a 900 MHz antenna is about one meter or less in typical materials, but its generated reflections can resolve features with a maximum dimension of a few centimeters. A trade-off, therefore, exists between depth of penetration and subsurface resolution.

The success of GPR surveys in archaeology is largely dependent on soil and sediment mineralogy, ground moisture, subsurface material moisture retention, the depth of buried features, and surface topography and vegetation. Electrically conductive or highly magnetic materials will quickly attenuate radar energy and prevent its transmission to depth. Depth penetration varies considerably depending on local conditions. Subsurface materials that absorb and retain large amounts of water can affect GPR depth penetration because of their low relative dielectric permittivity (RDP). In practical applications, this generally results in shallower-than-normal depth penetration because the radar signal is absorbed (attenuated) by the materials regardless of antenna frequency (Conyers 2004a, 2012; Conyers and Lucius 1996). Differential water retention can also positively affect data when a material of interest, such as a burial, retains more water than the surrounding soils and, therefore, presents a greater contrast.

The basic configuration for a GPR survey consists of an antenna (with both a transmitter and receiver), a harness or cart, and a wheel for calibrating distance. The operator then pulls or pushes the antenna across the ground surface systematically (a grid) collecting data along transects. These data are then stored by the receiver and available for later processing. The “time window” within which data were gathered was 50 nanoseconds (ns), which is the time during which the system is "listening" for returning reflections from within the ground. The greater the time window, the deeper the system can potentially record reflections. To convert time in nanoseconds to depth, it is necessary to determine the elapsed time it takes the radar energy to be transmitted, reflected, and recorded back at the surface by doing a velocity test.

Hyperbolas were found on reflection profiles and measured to yield a relative dielectric permittivity (RDP), which is a way to calculate velocity. The shape of hyperbolas generated in programs is a function of the speed at which electromagnetic energy moves in the ground and can, therefore, be used to calculate velocity (Conyers and Lucius 1996). The RDP for soils in the survey area was approximately 25.63, which, when converted to one-way travel time (the time it takes the energy to reach a reflection source), is approximately 5.9 centimeters/ns. All profiles and processed maps were converted from time in ns to depth in centimeters using this average velocity.

FIELD METHODS

The first step was to calibrate the antenna to local conditions by walking the survey area and adjusting the instrument's gain settings. This method allows the user to obtain an average set of readings based on subtle changes in the RDP (Conyers 2004b). Field calibration was repeated as necessary to account for changes in soil and/or moisture conditions (Conyers 2004a). Effective depth penetration was approximately 120 centimeters (3.9 feet), with very slight signal attenuation occurring at the bottom of the profile. This is adequate depth penetration for a 400 MHz antenna.

The field survey was conducted using a GSSI SIR-3000 with a 400 MHz antenna over the entire project area. The survey area was defined to cover an approximately 0.06-acre area of the cemetery identified by the cemetery committee as high priority (Figure 3). It is generally standard practice to orient transects perpendicular to the long axis of suspected features. In this case, data were collected roughly north to south, as Christian burials are generally oriented east to west. Transect spacing was 50 centimeters, an interval that has been demonstrated to generate the best resolution while maintaining field efficiency (Pomfret 2005). Transects were collected in a zig-zag pattern, alternating starting direction, along the y-axis (north-south).

DATA PROCESSING

All data were downloaded from the control unit to a computer for post-processing. Radar signals are initially recorded by their strength and the elapsed time between their transmission and receipt by the antenna. Therefore, the first task in the data processing was to set "time zero," which tells the software where the true ground surface was in the profile. This is critical to getting accurate

Figure 3.
GPR Survey Grid

Image source: USDA NAIP 2016

results when elapsed time is converted to target depth. A background filter was applied to the data, which removes the horizontal banding that can result from antenna energy "ringing" and outside frequencies, such as cell phones and radio towers. Background noise can make it difficult to visually interpret reflections. Range gains were also applied to the data to make reflections more visible. Finally, a Finite Impulse Response (FIR) filter was applied to the data to reduce any additional ringing or noise that may have been present in the data.

The next step in data processing involved the generation of amplitude slice-maps (Conyers 2004b). Amplitude slice-maps are a three-dimensional tool for viewing differences in reflected amplitudes across a given surface at various depths. Reflected radar amplitudes are of interest because they measure the degree of physical and chemical differences in the buried materials. Strong, or high amplitude reflections often indicate denser (or different) buried materials. Such reflections can be generated at pockets of air, such as within collapsed graves, or from slumping sediments. Amplitude slice-maps are generated through comparison of reflected amplitudes between the reflections recorded in vertical profiles. Amplitude variations, recorded as digital values, are analyzed at each location in a grid of many profiles where there is a reflection recorded. The amplitudes of all reflection traces are compared to the amplitudes of all nearby traces along each profile. This database can then be "sliced" horizontally and displayed to show the variation in reflection amplitudes at a sequence of depths in the ground. The result is a map that shows amplitudes in plan view, but also with depth.

Slicing of the data was done using the mapping program Surfer 8. Slice maps are a series of x, y, z values, with x (east) and y (north) representing the horizontal location on the surface within each grid and z representing the amplitude of the reflected waves. All data were interpolated using the Inverse Distance to a Power method, and image maps were then generated from the resulting files.

From the original raw reflection data (.dzt files), a series of image files was created for cross-referencing to the amplitude slice maps that were produced. Two-dimensional reflection profiles were also analyzed to determine the nature of the features identified on the amplitude slice maps. The reflection profiles show the geometry of the reflections, which can lend insight into whether the radar energy is reflecting from a flat layer (seen as a distinct band on profile) or a single object (seen as a hyperbola in profile). Hyperbolic reflections are generated from the way the radar energy reflects off point targets. In cemeteries, graves are often visible as hyperbolic reflections. Individual profile analysis was used in conjunction with amplitude slice maps to provide stronger interpretations about probable graves.

The final step in the data processing is to integrate the depth slices with other spatial data. This was done using ArcGIS 10, which can display and manipulate all forms of spatial data created for this project, including GPR results, GPS data, marker inventory data, and base graphics such as aerial photography and topographic maps. The resulting interpretations were digitized as individual features.

GPR IN CEMETERIES

Most Judeo-Christian cemeteries share common characteristics with respect to burial of the dead. In general, bodies are oriented east-west, with the head facing east to face the rising sun on Judgment Day. Depths vary, but are typically between two and six feet, depending on local conditions and customs. Shapes tend to oblong and rectangular to accommodate the use of coffins and caskets and burial-in-prone positions. Sizes can vary considerably, particularly between adults and infants, with most adults in the range of approximately six feet long by two feet wide (Patch 2009).

Several factors influence the overall effectiveness of GPR for detecting anomalies consistent with individual graves. Contrast between the remains, grave shaft, coffin, or casket and the surrounding soils is the most important variable. Remains that have a chemical or physical contrast from the subsurface materials surrounding them will cause reflections of electromagnetic energy. Age of the graves is critical to this contrast: older graves typically have less contrast and are more difficult to detect because they have had more time to decompose and are less likely to have intact coffins or caskets (if these were present to begin with).

The burial “container” that the physical remains may have been placed in is also important and includes simple linen or cloth shrouds, pine boxes or wooden coffins, lead or other metal caskets, and burial vaults. In certain cases, hardware such as nails, hinges, and handles may be present, but not necessarily all the time. Although there is a high degree of variation in specific container types among different geographical regions, each of these tends to have been used at certain times throughout history and correlates with the presumed age of the grave. For example, burial shrouds were common throughout the seventeenth and early eighteenth centuries before being replaced by wooden coffins. It must also be noted that cultural trends and patterns tended to persist much longer in rural and/or economically depressed areas than in urban centers.

In this case, oral histories suggest that there is the potential for a mass grave in the survey area. When a mass grave is excavated, a large amount of soil is removed and then used for reburial. This excavation and reburial will be visible in the data as a large pit filled with disturbed soil. If burial containers were used, they may produce point-source reflections within the pit.

III. RESULTS AND RECOMMENDATIONS

The primary purpose of this survey was to identify geophysical anomalies consistent with the expected signature for graves, including the potential mass grave hypothesized to be present in this area of the cemetery. GPR results were based on analysis of the 400MHz data, including individual reflection profiles and amplitude slice maps. The identified graves represent a distinct contrast with their surrounding soils and were identifiable in both plan and profile view (Figure 4).

Of the 34 probable individual graves identified, 15 are associated with markers and 19 are unmarked (Table 1, Figures 5-9, Appendix A). In addition to the individual graves, there is a large area of disturbed soils with many graves that are in close proximity to each other (Anomaly 35). It is not possible to discern the number of individual graves buried in this area, but there is evidence for numerous unmarked graves.

Anomaly 35 is most likely an area with several individual graves in close proximity. Because it does not appear that one excavation was used for all of the individuals, Anomaly 35 cannot be conclusively interpreted as a mass grave. It does appear that the multiple graves in this area were interred within a short period of time, and there is a large area of disturbed soil. There is no evidence that the probable graves in Anomaly 35 represent burials conducted over a long period of time, and the level of disturbance suggests that many of the grave shafts may have been open and reburied at the same time. In the section of the cemetery surveyed, there were four corner markers placed by the cemetery to indicate the location of the mass grave (see Figure 9). Interestingly, these corner markers seem to mark both the extent of unmarked individual graves and Anomaly 35, marking an area much larger than that of Anomaly 35.

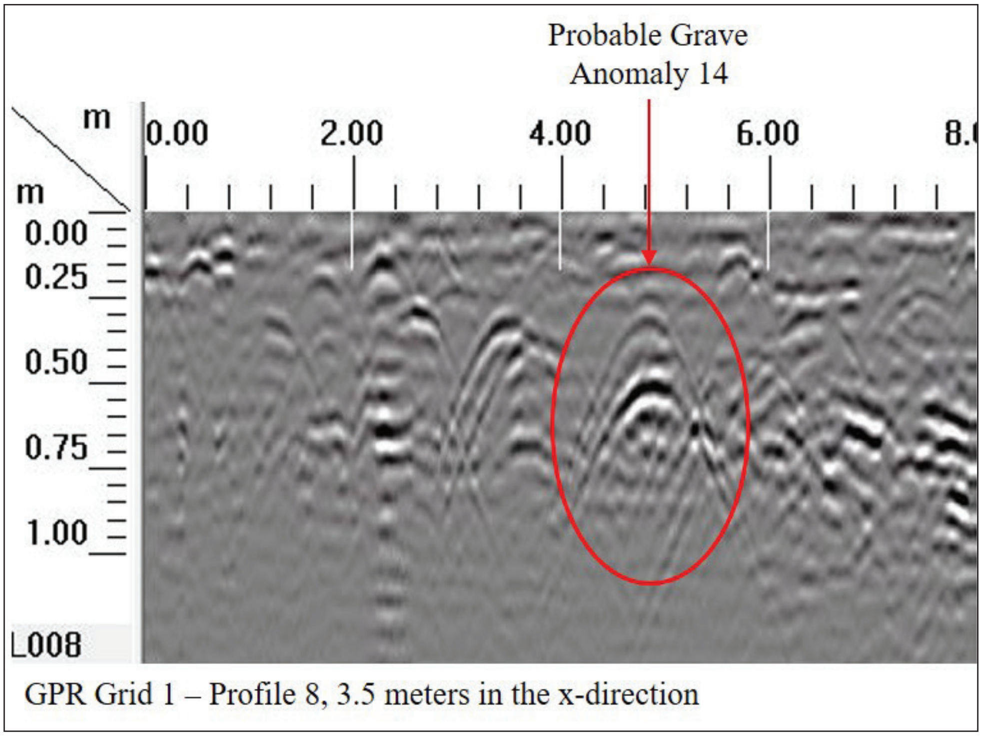
Table 1. GPR Anomalies

Anomaly Number	Label	Depth (cmbs)	Marked
1	Probable Grave	25-60	No
2	Probable Grave	20-90	No
3	Probable Grave	20-60	Yes
4	Probable Grave	35-60	No
5	Probable Grave	100-120	Yes
6	Probable Grave	35-55	No
7	Probable Grave	45-60	No
8	Probable Grave	25-45	Yes

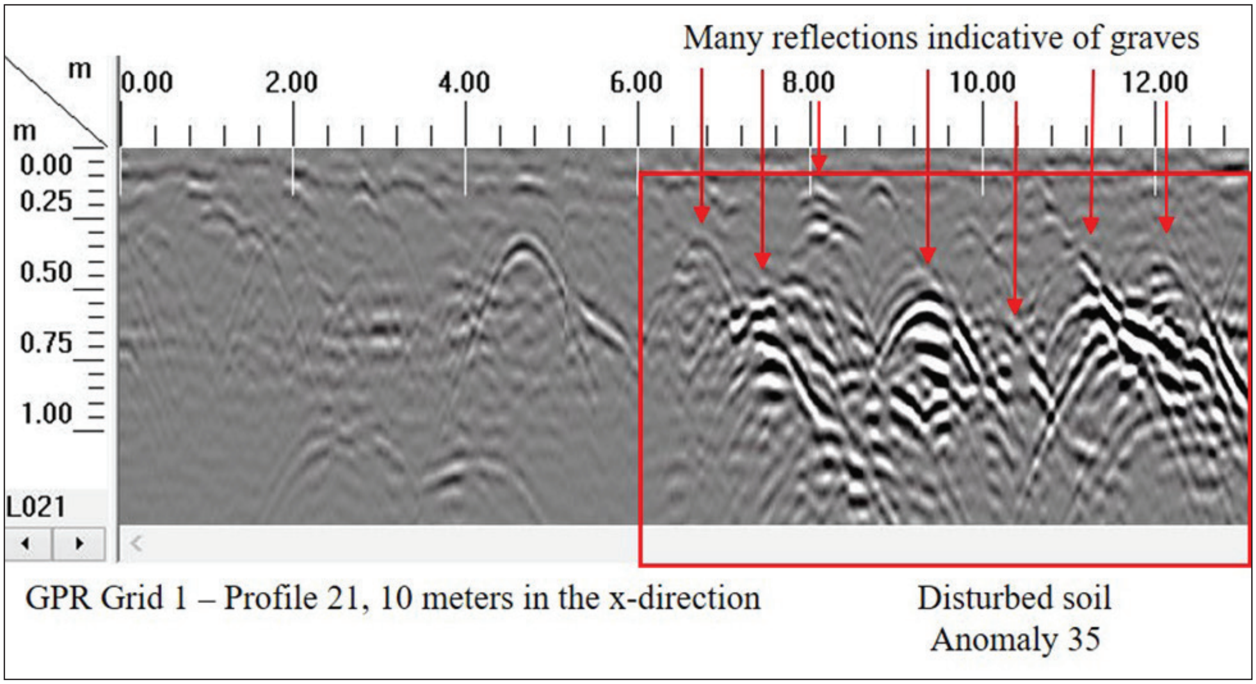
Table 1. GPR Anomalies

Anomaly Number	Label	Depth (cmbs)	Marked
9	Probable Grave	55-70	Yes
10	Probable Grave	35-60	No
11	Probable Grave	40-55	Yes
12	Probable Grave	30-60	Yes
13	Probable Grave	25-60	No
14	Probable Grave	25-50	No
15	Probable Grave	50-60	No
16	Probable Grave	20-40	No
17	Probable Grave	35-45	No
18	Probable Grave	100-120	Yes
19	Probable Grave	100-120	Yes
20	Probable Grave	90-120	Yes
21	Probable Grave	90-105	No
22	Probable Grave	100-120	Yes
23	Probable Grave	85-100	Yes
24	Probable Grave	60-90	Yes
25	Probable Grave	60-90	Yes
26	Probable Grave	90-120	Yes
27	Probable Grave	90-120	No
28	Probable Grave	100-120	No
29	Probable Grave	40-60	No
30	Probable Grave	65-90	Yes
31	Probable Grave	40-70	No
32	Probable Grave	40-70	No
33	Probable Grave	40-70	No
34	Probable Grave	90-110	No
35	Area of Disturbed Soils with Many Graves	10-70	No

Figure 4.
Profile Examples



A. Individual Grave, Grid 1 - Profile 8, 3.5 Meters in the x-direction



B. Area with Disturbed Soil and Many Graves, Grid 1 - Profile 21, 10 Meters in the x-direction

Figure 5.
Amplitude Slice Map from 0-30 Centimeters Below Surface (cmbs)

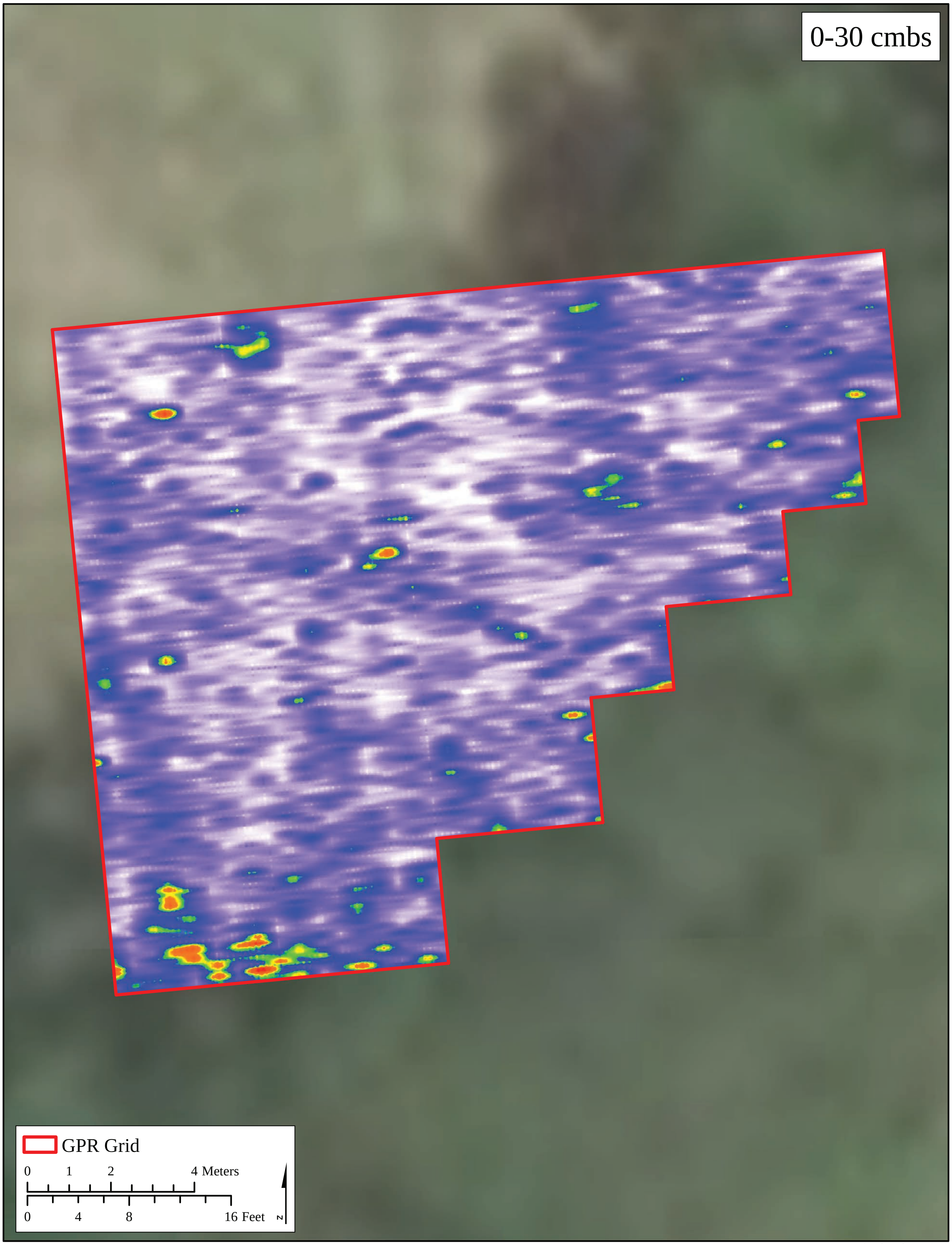


Image source: USDA NAIP 2016

Figure 6.
Amplitude Slice Map from 30-60 cmbs

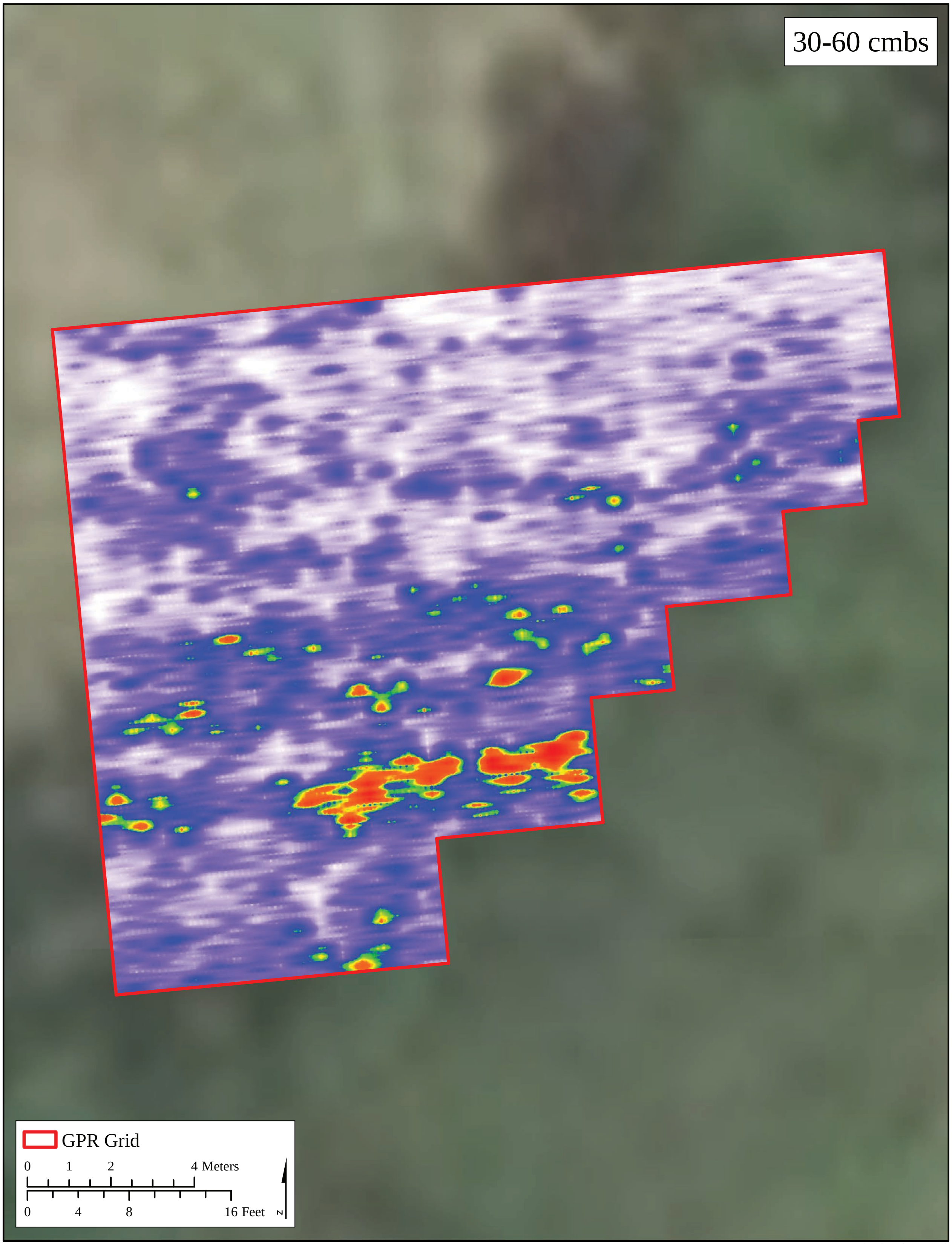


Image source: USDA NAIP 2016

Figure 7.
Amplitude Slice Map from 60-90 cmbs

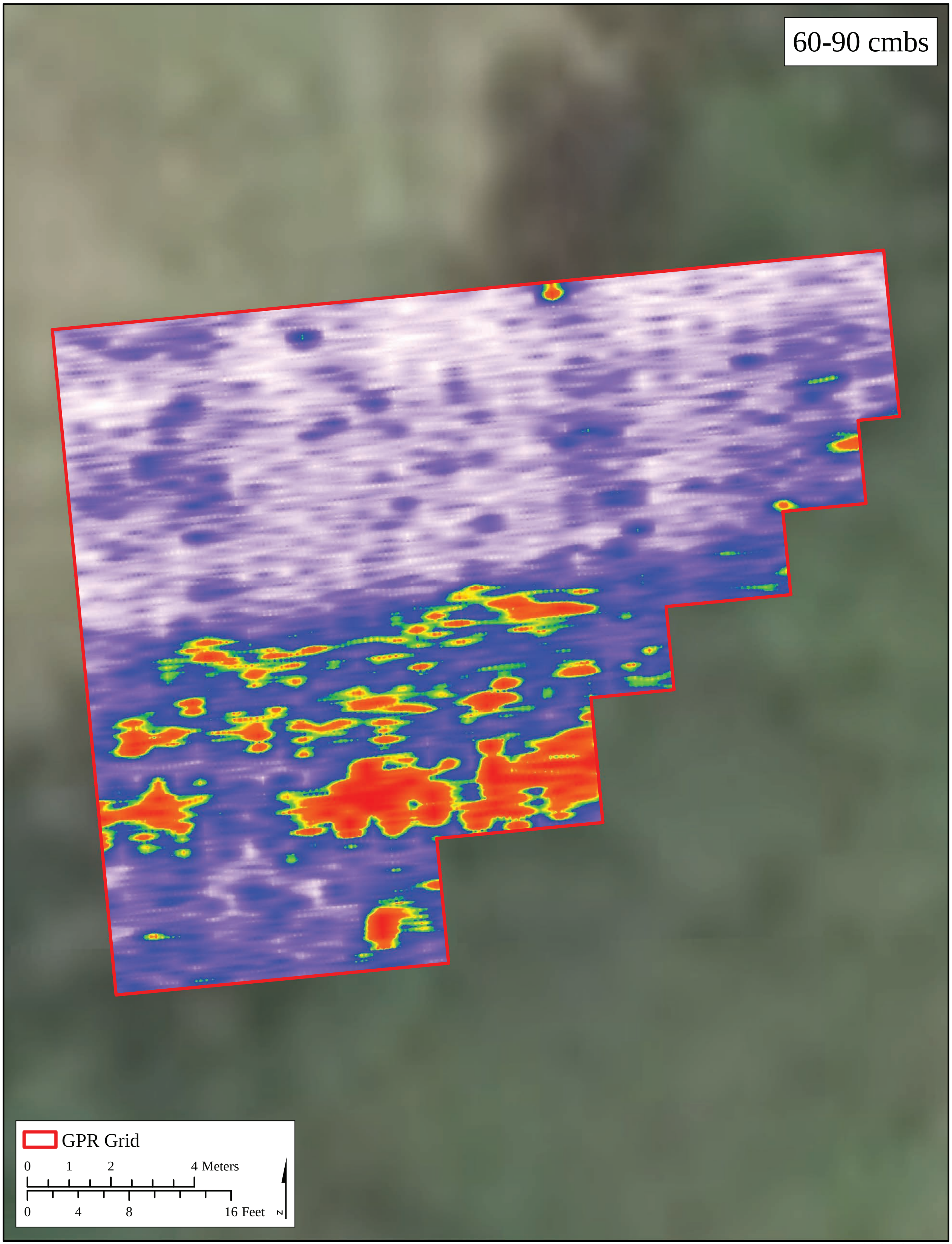


Image source: USDA NAIP 2016

Figure 8.
Amplitude Slice Map from 90-120 cmbs

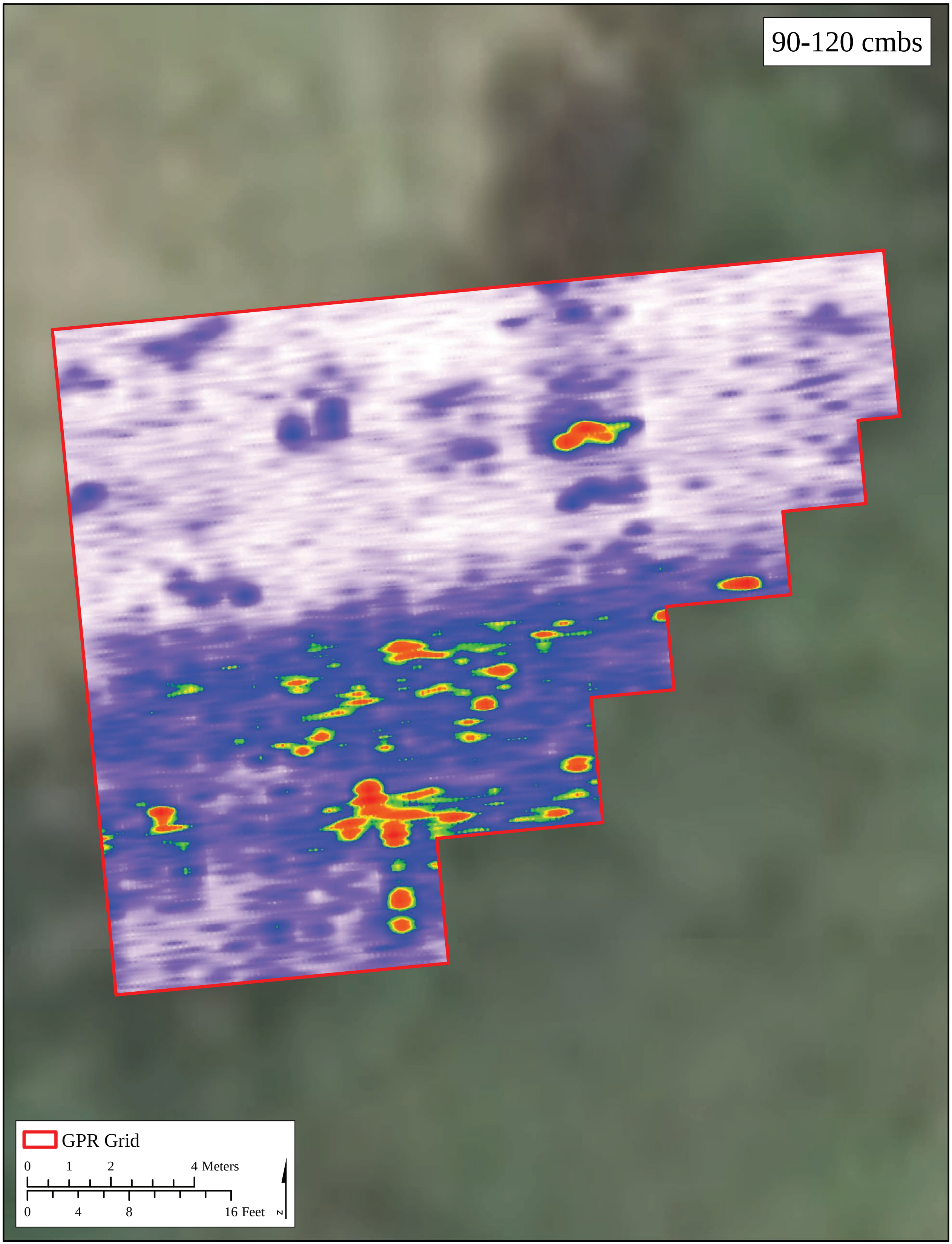


Image source: USDA NAIP 2016

Figure 9.
Map of Surveyed Area Showing Identified Probable Graves

New South takes a conservative approach to the identification of graves based on GPR data. The probable graves in the surveyed area were identified based on their size, shape, depth, orientation, and overall reflective characteristics in both plan and profile. Many factors influence the overall effectiveness of GPR for detecting anomalies consistent with graves, including soil type and acidity, moisture and precipitation, age of probable graves, likely grave depth, and burial container (e.g., shroud, wood coffin, metal casket, concrete vault). In general, if the anomaly has any of the characteristics of a grave, it is marked as a potential grave.

New South recommends that the 35 GPR anomalies identified as probable graves and disturbed soils with many graves should be treated as such. Additionally, if any ground is to be disturbed within the cemetery, care should be taken to avoid damaging any graves that might be present, but were not detected because of poor preservation. Caution should also be used when disturbances are planned adjacent to the cemetery boundary, outside of the surveyed areas where there may be additional unmarked graves. If avoidance of graves is not probable, then additional steps should be taken to relocate the graves in compliance with the relevant North Carolina statutes. It is New South’s understanding that no disturbances are currently planned within the cemetery, but that the cemetery is still being actively used for burials. Care should be taken when new burials are planned, as there are a number of unmarked graves in the area surveyed.

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APPENDIX A: GRAVE ANOMALY TABLE

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Appendix A:
Grave Anomaly Table

Anomaly Number	Label	Depth	Marked	Easting	Northing
1	Probable Grave	25-60 cmbs	No	654844.6594	3936392.991
2	Probable Grave	20-90 cmbs	No	654841.0541	3936396.597
3	Probable Grave	20-60 cmbs	Yes	654836.6108	3936385.044
4	Probable Grave	35-60 cmbs	No	654830.6909	3936384.58
5	Probable Grave	100-120 cmbs	Yes	654836.5024	3936387.457
6	Probable Grave	35-55 cmbs	No	654846.995	3936396.329
7	Probable Grave	45-60 cmbs	No	654846.2466	3936394.906
8	Probable Grave	25-45 cmbs	Yes	654840.1878	3936398.801
9	Probable Grave	55-70 cmbs	Yes	654840.1261	3936400.017
10	Probable Grave	35-60 cmbs	No	654830.1075	3936387.437
11	Probable Grave	40-55 cmbs	Yes	654832.7575	3936387.707
12	Probable Grave	30-60 cmbs	Yes	654836.5889	3936386.079
13	Probable Grave	25-60 cmbs	No	654833.61	3936398.818
14	Probable Grave	25-50 cmbs	No	654844.5399	3936395.896
15	Probable Grave	50-60 cmbs	No	654844.6601	3936393.808
16	Probable Grave	20-40 cmbs	No	654844.8648	3936396.971
17	Probable Grave	35-45 cmbs	No	654832.9793	3936393.611
18	Probable Grave	100-120 cmbs	Yes	654828.7301	3936397.953
19	Probable Grave	100-120 cmbs	Yes	654828.9523	3936395.189
20	Probable Grave	90-120 cmbs	Yes	654831.543	3936398.844
21	Probable Grave	90-105 cmbs	No	654841.2614	3936395.192
22	Probable Grave	100-120 cmbs	Yes	654840.4694	3936399.422
23	Probable Grave	85-100 cmbs	Yes	654846.7827	3936399.37
24	Probable Grave	60-90 cmbs	Yes	654829.5849	3936389.36
25	Probable Grave	60-90 cmbs	Yes	654829.4946	3936390.752
26	Probable Grave	90-120 cmbs	Yes	654840.7471	3936398.003
27	Probable Grave	90-120 cmbs	No	654837.6651	3936397.438
28	Probable Grave	100-120 cmbs	No	654837.8086	3936396.104
29	Probable Grave	40-60 cmbs	No	654834.3637	3936396.875
30	Probable Grave	65-90 cmbs	Yes	654846.6053	3936397.909
31	Probable Grave	40-70 cmbs	No	654831.2119	3936397.041
32	Probable Grave	40-70 cmbs	No	654831.1547	3936395.849
33	Probable Grave	40-70 cmbs	No	654831.7146	3936394.792
34	Probable Grave	90-110 cmbs	No	654831.9925	3936392.795
35	Area of Disturbed Soils with Many Graves	10-70 cmbs	No	654837.0618	3936390.355

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