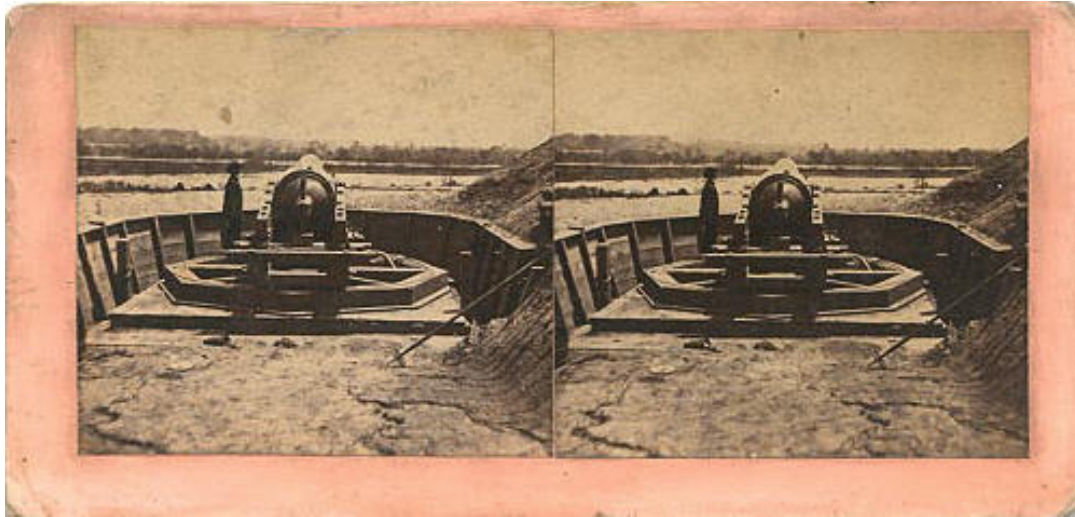


# Ground Penetrating Radar Survey on Portions of Battery Brooke, Chesterfield County, Virginia

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# Ground Penetrating Radar Survey on Portions of Battery Brooke, Chesterfield County, Virginia

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## Introduction

This report presents the findings of a Ground Penetrating Radar (GPR) survey on four portions of Battery Brooke, a Confederate artillery emplacement on the James River in Chesterfield County, Virginia (Figure 1). This research was a demonstration project by the LAMAR Institute to explore the potential for applying this technology to Civil War fortifications in a heavily wooded environment in Virginia. The work was done in conjunction with a metal detector survey of a large property tract

that is currently being examined for potential industrial development. The metal detector survey was conducted by Cypress Cultural Consultants, LLC for TRC, Inc. Only minor portions of the fortifications were surveyed using the GPR equipment. The results indicate that this technology is useful for mapping subsurface features and deposits on military earthworks. The information generated by GPR survey should aid in targeting important components on these types of sites, which would greatly reduce the amount of archaeological excavation required to locate these components.



**Figure 1. Battery Brooke Study Area, Chesterfield County, Virginia (Mapper.acme.com 2008).**

## Methods

Ground Penetrating Radar, or GPR, uses high frequency electromagnetic waves to acquire subsurface data. The device uses a transmitter antenna and closely spaced receiver antenna to detect changes in electromagnetic properties beneath them.

The antennas are suspended just above the ground surface and the antennas are shielded to eliminate interference from sources other than directly beneath the device. The transmitting antenna emits a series of electromagnetic waves, which are distorted by differences in soil conductivity, dielectric permittivity, and magnetic permeability. The receiving antenna records the reflected waves for a

specified length of time (in nanoseconds, or ns). The approximate depth of an object can be estimated with GPR, by adjusting for electromagnetic propagation conditions.

The GPR sample blocks in this study area were composed of a series of parallel transects, or traverses, which yielded a two-dimensional cross-section or profile of the radar data. These samples are termed radargrams. This two-dimensional image is constructed from a sequence of thousands of individual radar traces. A succession of radar traces bouncing off a large buried object will produce a hyperbola, when viewed graphically in profile. Multiple large objects that are in close proximity may produce multiple, overlapping hyperbolas, which are more difficult to interpret. For example, an isolated historic grave may produce a clear signal, represented by a well-defined hyperbola. A cluster of graves, however, may produce a more garbled signal that is less apparent.

The GPR signals that are captured by the receiving antenna are recorded as an array of numerals, which can be converted to gray scale (or color) pixel values. The radargrams are essentially a vertical map of the radar reflection off objects and other soil anomalies. It is not an actual map of the objects. The radargram is produced in real time and is viewable on a computer monitor, mounted on the GPR cart.

GPR has been successfully used for archaeological and forensic anthropological applications to locate relatively shallow features, although the technique also can probe deeply into the ground. The machine is adjusted to best

probe to the depth of interest by the use of different frequency range antennas. Higher frequency antennas are more useful at shallow depths, which is most often the case in archaeology. Also, the longer the receiving antenna is set to receive GPR signals (measured in nanoseconds, or ns), the deeper the search.

The effectiveness of GPR in various environments on the North American continent is widely variable and depends on solid conductivity, metallic content, and other pedo-chemical factors.

GPR signals cannot penetrate large metal objects and the signals are also significantly affected by the presence of salt water. Although radar does not penetrate metal objects, it does generate a distinctive signal that is usually recognizable, particularly for larger metal objects, such as a cast iron cannon or man-hole cover. The signal beneath these objects is often canceled out, which results in a pattern of horizontal lines on the radargram. For smaller objects, such as a scatter of nails, the signal may ricochet from the objects and produce a confusing signal. Rebar-reinforced concrete, as another example, generates an unmistakable radar pattern of rippled lines on the radargram. Larry Conyers notes:

*Ground-penetrating radar works best in sandy and silty soils and sediments that are not saturated with water. The method does not work at all in areas where soils are saturated with salt water because this media is electrically conductive and 'conducts away' the radar energy before it can be reflected in the ground (Conyers 2002).*

Using the same RAMAC X3M GPR system as that used in the present study, Elliott has conducted several GPR



studies of 18<sup>th</sup> and 19<sup>th</sup> century archaeological sites in coastal Georgia and South Carolina (Elliott 2003a-c; 2004; 2006a-c; 2008; Rita Elliott et al. 2002; Battle and Battle 2004). GPR has proven effective in examining military ditch work and fortifications at several Revolutionary War period sites in Georgia. It was also used to define a buried road trace on a Civil War battlefield near Lovejoy, Georgia. Bevan (1979) used GPR technology to map other Civil War military defenses near Petersburg, Virginia with success.

The equipment used for this study consisted of a RAMAC/X3M Integrated Radar Control Unit, mounted on a wheeled-cart and linked to a RAMAC XV11 Monitor (Firmware, Version 3.2.36). A 500 megahertz (MHz) shielded antenna was used for the data gathering. MALÅ GeoScience's *Ground Vision* (Version 1.4.5) software was used to acquire and record the radar data (MALÅ GeoScience USA 2006a). Figure 2 shows the GPR equipment and operator in the field. The radar information was displayed as a series of radargrams. *Easy 3D* software (Version 1.3.3), which was developed by MALÅ GeoScience (2006b), was used in post-processing the radar data and 3-D imaging. This entailed merging the data from the series of radargrams for each block. Once this was accomplished, horizontal slices of the data were examined for important anomalies and patterns of anomalies, which were likely of cultural relevance. These data were displayed as aerial plan maps of the sample areas at varying depths below ground surface. These horizontal views, or time-slices, display the radar information at a set time depth in nanoseconds. Time-depth can be

roughly equated to depth below ground. This equivalency relationship can be calculated using a mathematical formula.



**Figure 2. GPR Survey in Progress, Battery Brooke.**

Output from the survey was viewed using the *GroundVision*, which provided preliminary information about the suitability of GPR survey in the area and the effective operation of the equipment.

The GPR data from the present study was further processed with more robust imaging software, which was developed by Dean Goodman and called *GPR-Slice* (Version 5.0). Goodman's *GPR-Slice* program is recognized as the world leader in GPR imaging (Goodman 2006). The output from his software, which is superior to that generated by *Easy 3D*, forms the results presented in this report.

Various adjustments to the GPR equipment were made in the field during the data collection phase. The time window that was selected allowed data



gathering to focus on the upper 2 meters of soil, which was the zone most likely to yield archaeological deposits. Additional filters were used to refine the radar information during post-processing. These include adjustments to the gain. These alterations to the data are reversible, however, and do not affect the original data that was collected. This same combination of GPR equipment and radar imaging software was used previously in coastal Georgia with very satisfactory results

Upon arrival at the site, the RAMAC X3M Radar Unit was set up for the operation and calibrated. Several trial runs were made on parts of the site to test the machine's effectiveness in the site's soils. Machinery settings and other pertinent logistical attributes included the following:

**Machine Settings**

Time Window: 94.6 ns  
Number of Stacks: 4  
Number of Samples: 736  
Antenna: 500 MHz shielded  
Sampling Frequency: 7462.12 MHz  
Antenna Separation: 0.18 m  
Radargram Spacing: 50 cm

GPR Block A measured 15 m North-South by 8 m East-West. Thirteen radargrams were collected in this block. Radargrams were collected from South to North and progress was from East to West. The Datum for GPR Block B was located in its southeastern corner (0,0) with these UTM Coordinates: Zone 18, Easting 287701, Northing 4140401. This sample was placed within a level area between the primary berm of Battery Brook and a cannon emplacement berm.

GPR B measured 27 m East-West by 6 m North-South. Seventeen radargrams were collected in this block. Radargrams

were collected from East to West and progress was from South to North. The Datum for GPR Block B was located in its southeastern corner (0,0) with these UTM Coordinates: Zone 18, Easting 287714, Northing 4140388. This sample was placed within a narrow, elongated space between the primary berm of Battery Brooke and a cannon emplacement berm. It included portions of the lower slope of both berms on its northern and southern sides.

GPR Block C measured 12 m East-West by 3 m North-South Seven radargrams were collected in this block. Radargrams were collected from East to West and progress was from North to South. The Datum for GPR Block A was located in its southeastern corner (0,0) with these UTM Coordinates: Zone 18, Easting 287699, Northing 4140393. This sample was placed within a cannon emplacement berm. It included portions of the lower slopes of the berm on its northern and southern sides.

GPR Block D measured 20 m North-Northeast-South-Southwest by 10 m East-Northeast to West-Southwest. Forty-one radargrams were collected in this block. Radargrams were collected from West-Southwest to East-Northeast (Magnetic bearing of 70 degrees) and progress was from South-Southwest to North-Northeast. The Datum for GPR Block D was located in its southeastern corner (0,0) with these UTM Coordinates: Zone 18, Easting 287608, Northing 4140353. This sample was located in a level area and approximately one-half of the primary berm of Battery Brooke. The initial radargram on this sample began on the crest of the berm.

## Results and Interpretation

The GPR survey of all four areas of Battery Brooke yielded very good GPR data. Signal strength was favorable for successful penetration and mapping to depths greater than 3 meters.

### *GPR Block A*

This sample was placed within a level area between the primary berm of Battery Brook and a cannon emplacement berm. Figure 3 shows a radargram near the center of Block A.

Several radar reflections are apparent in this view. Two or more of these are likely large metal objects. The radar reflections as evidenced by the radargrams in Block A do not suggest any major structure or construction within this area. The numerous metal items, which are best viewed in the radargram profiles, may prove to be interesting metal artifacts relating to the defenses, or shrapnel or bombs from incoming fire.

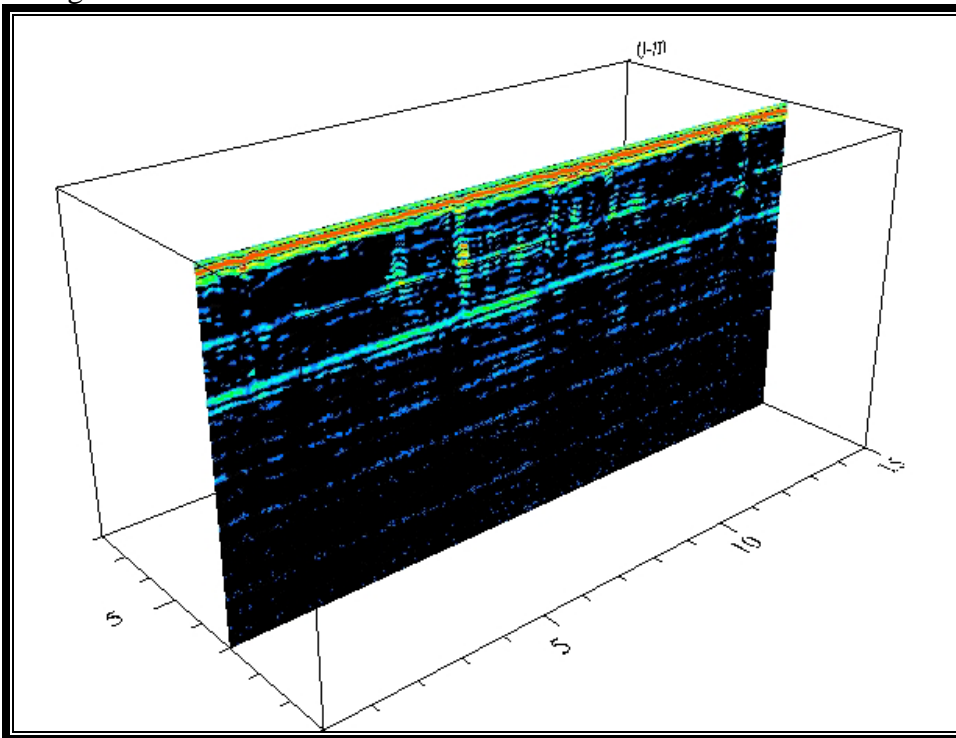


Figure 3. Radargram Example from GPR Block A.

Figure 4 is a plan view of Block A at approximately 1 m depth. This image indicates a linear radar anomaly, which is oriented North-South and is located just west of the center of the GPR block. Several less well-defined perpendicular anomalies are located near the center of this image.

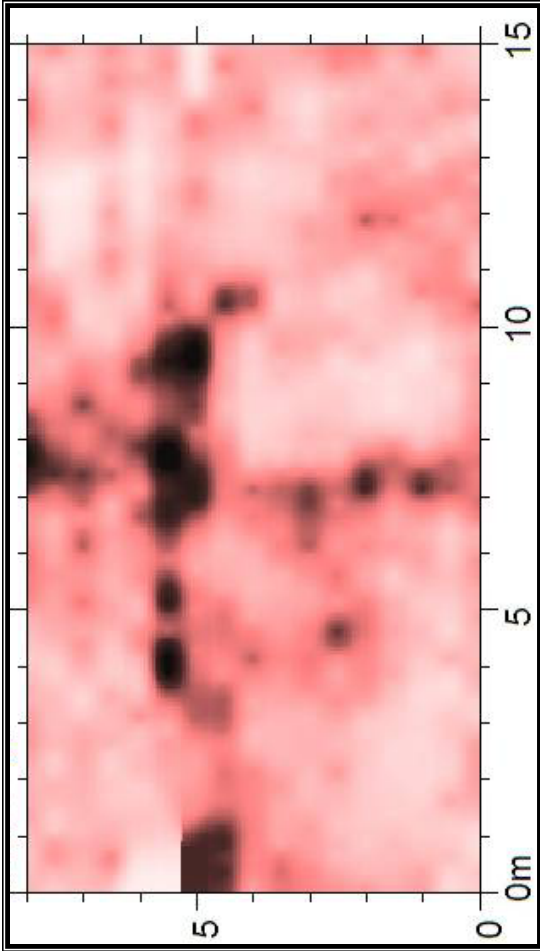


Figure 4. Plan of GPR Block A, 1 m Depth.

Figure 5 is a plan view of Block A at approximately 2.75 m depth. In this view, the North-South linear anomaly observed at about 1 m is still present and more pronounced. An arcing “tail” now appears on its northern end, which forms a “C” shape facing east. This C-arc is a curious feature, which may be cultural in origin. Possible explanations include a bomb crater or a privy feature.

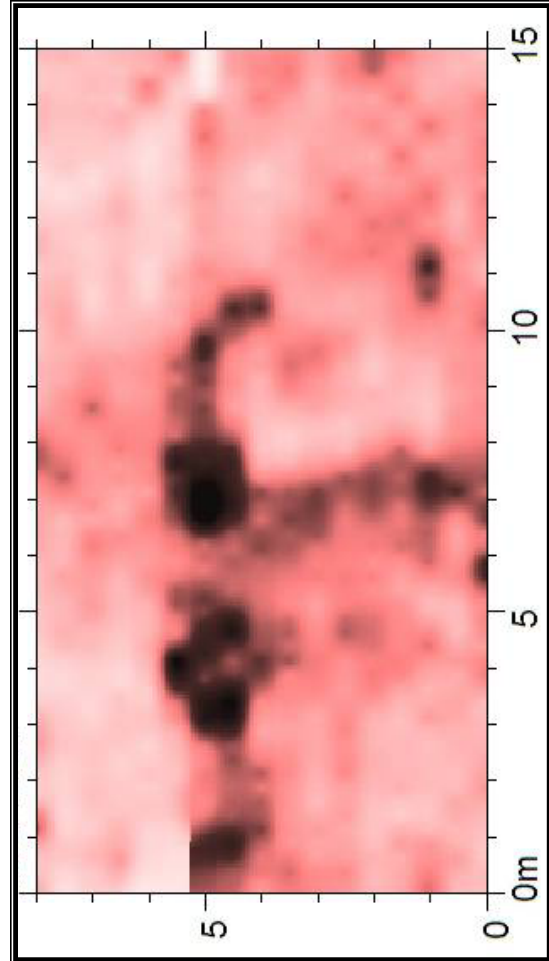


Figure 5. Plan of GPR Block A, 2.75 m Depth.

### ***GPR Block B***

This sample was placed within a narrow, elongated space between the primary berm of Battery Brooke and a cannon emplacement berm. The GPR data from Block B shows several areas of interest. Figure 6 is a radargram in GPR Block B. This image reveals a strong zone of radar reflections on the central and northern end of the block.

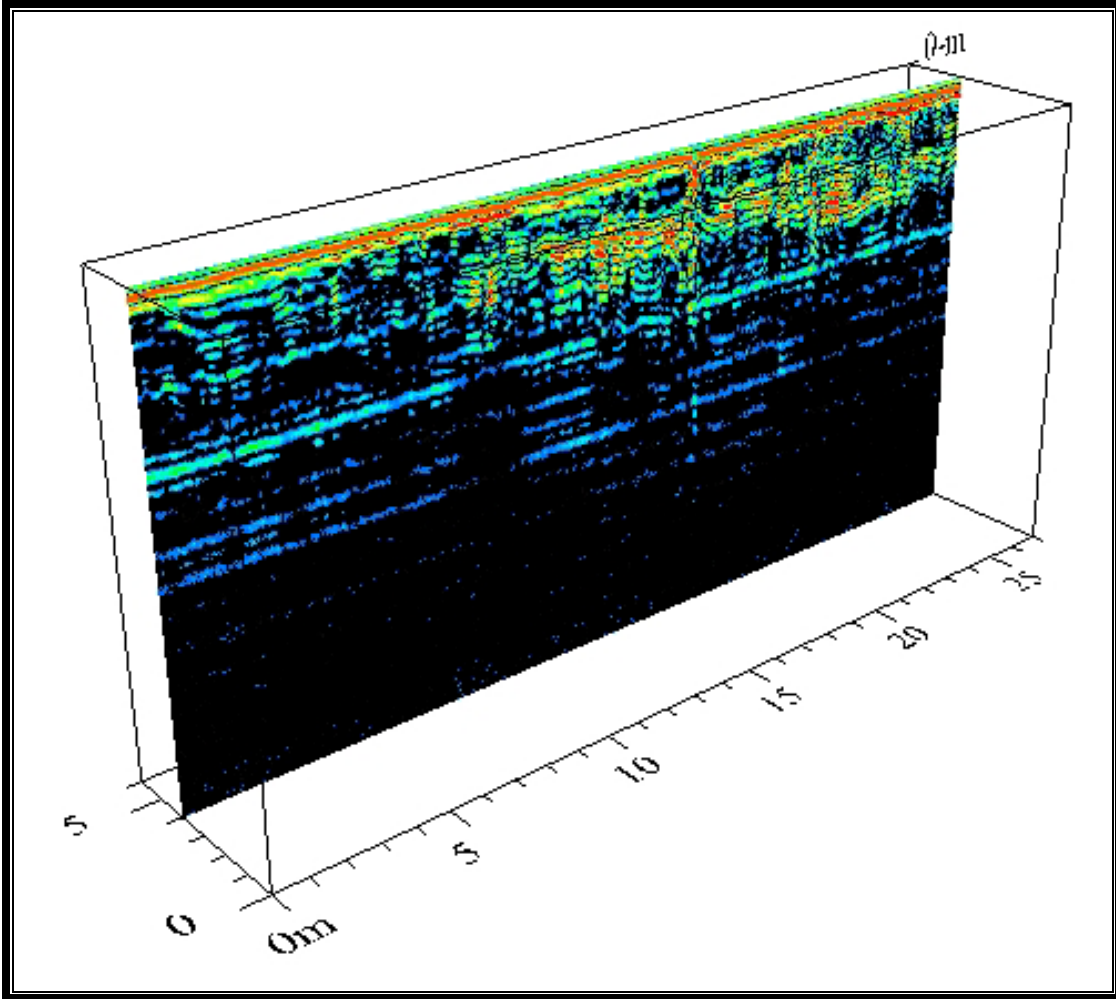


Figure 6. Radargram from GPR Block B.

Figure 7 is a plan of GPR Block B at approximately 50 cm depth. In this image strong radar reflections are concentrated in an East-West alignment and are more pronounced on the eastern end of the block. We suspect that this is

possibly the result of differential soil compaction resulting from frequent foot traffic along the central valley of the battery. It may indicate the presence of palisade posts or other features associated with the defenses.

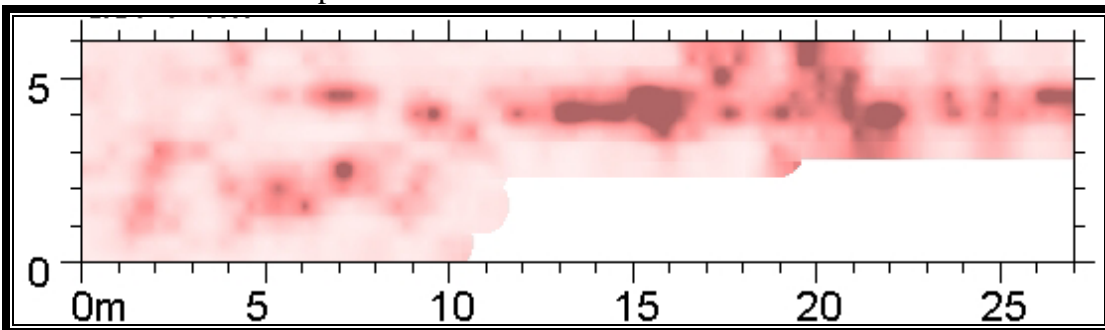


Figure 7. Plan of GPR Block B, 50 cm Depth.

Figure 8 is a plan of GPR Block B at approximately 1 m depth. In this view

the linear anomalies on the eastern end of the block are no longer visible. Instead, three areas with strong

anomalies appear on the western 1/3 of the block. The largest of these is slightly arcing, facing north.

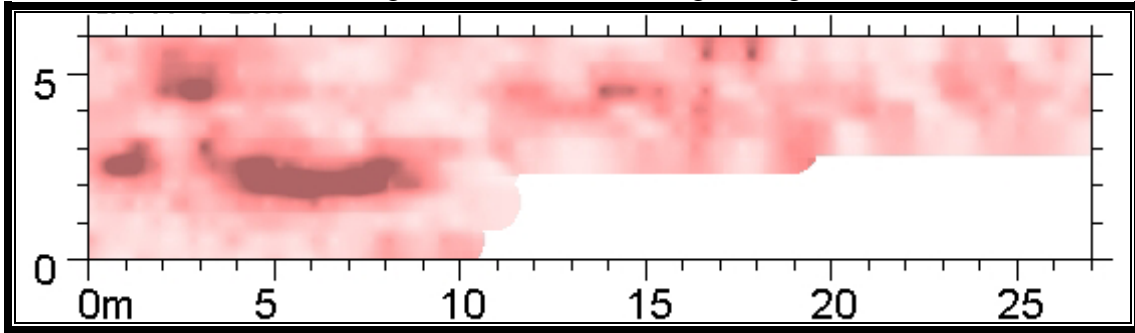


Figure 8. Plan of GPR Block B, 1 m Depth.

### ***GPR Block C***

This sample was placed within a cannon emplacement berm. Figure 9 is a radargram of GPR Block C, which contains a very interesting radar anomaly. A steeply sloping radar reflection, extending more than 6 m East-West, is located near the center of

the block. This prominent buried feature is less apparent on the radargrams immediately north and south of the one shown here. This suggests that the feature is about than 1 m wide and 6 m in length and extends more than 1 m below ground. Its function is undetermined, but it is certainly a GPR target worthy of test excavation.

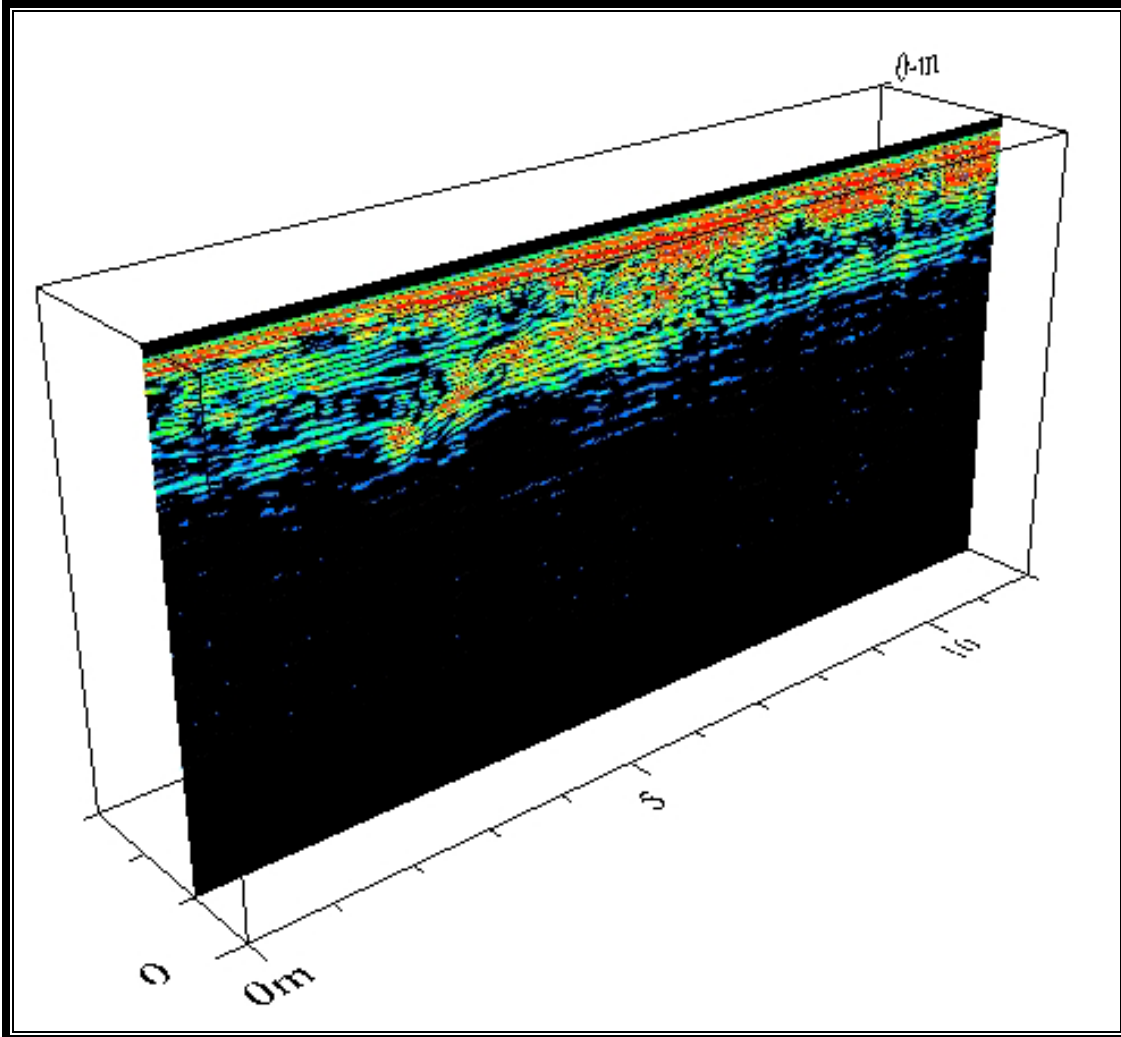


Figure 9. Radargram of GPR Block C.

Figure 10 is a plan of GPR Block C at approximately 1 cm depth. The strong anomaly depicted previously in the

radargram is not readily apparent in plan view. Several strong anomalies are visible in this view, at the eastern end and near the center.

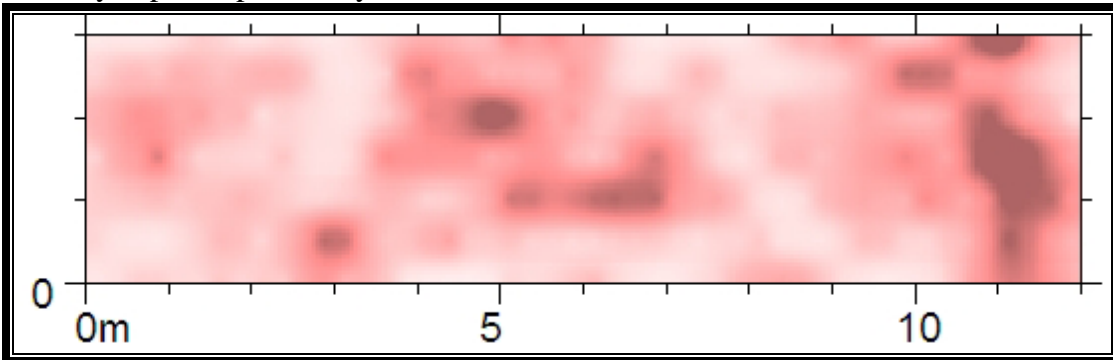


Figure 10. Plan of GPR Block C, 1 m Depth.

Figure 11 is a plan of GPR Block C at approximately 1.5 m depth. Five areas of

strong radar reflection are apparent in this view in the eastern ½ of the block.

These appear to form a semi-circular, facing south.

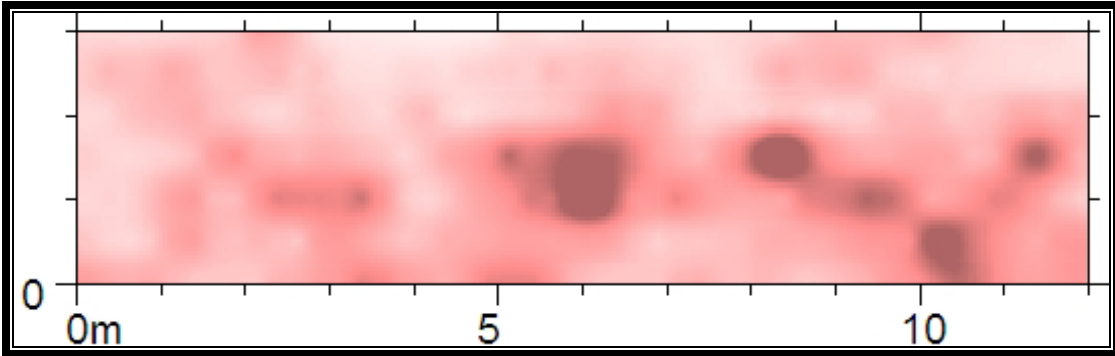


Figure 11. Plan of GPR Block C, 1.5 m Depth.

### ***GPR Block D***

This sample was located in a level area and approximately one-half of the primary berm of Battery Brooke. Figure 12 is a radargram in GPR Block D.

Strong radar reflections are visible across nearly the entire radargram on its south side. The plan views for Block D, however, do not indicate any substantial radar anomalies in this vicinity.

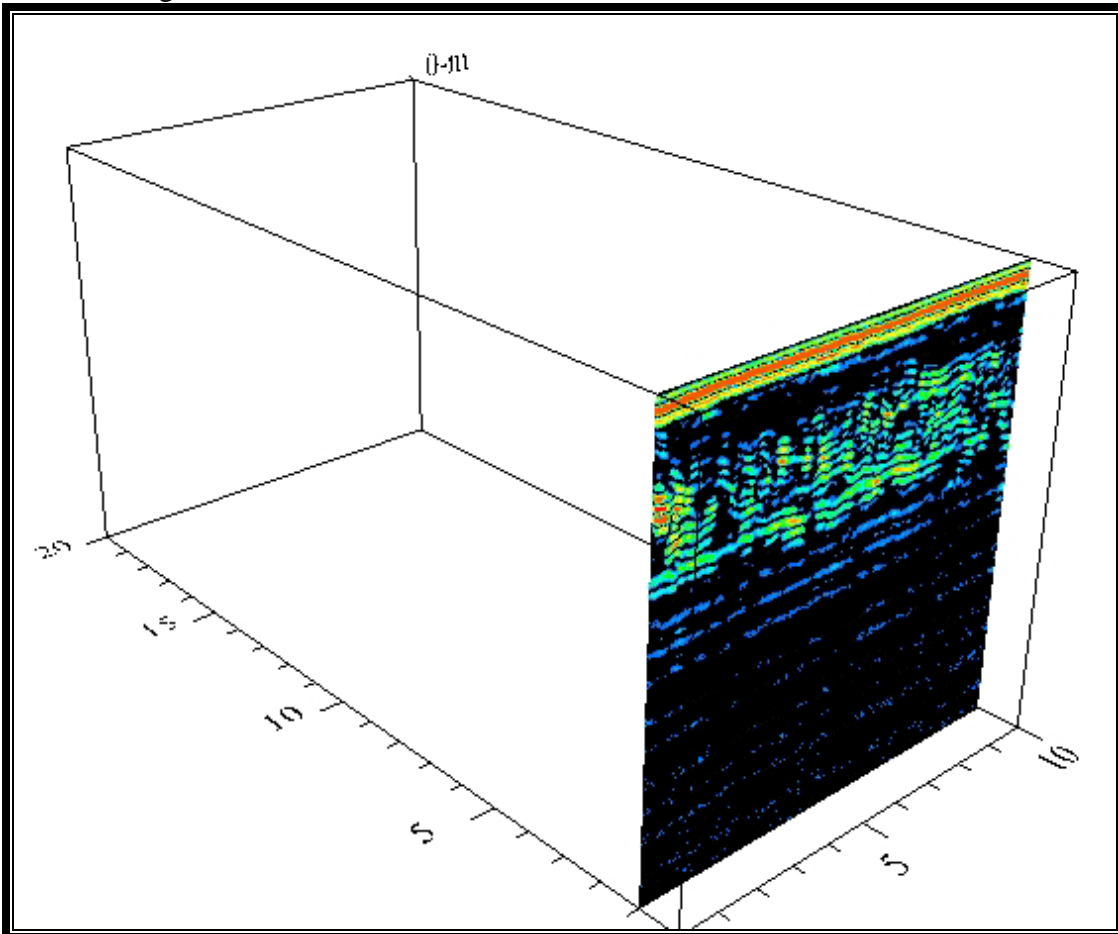


Figure 12. Radargram in GPR Block D.



Figure 13 is a plan of GPR Block D at approximately 1 m depth. This view shows several areas of strong radar reflection near the center of the block.

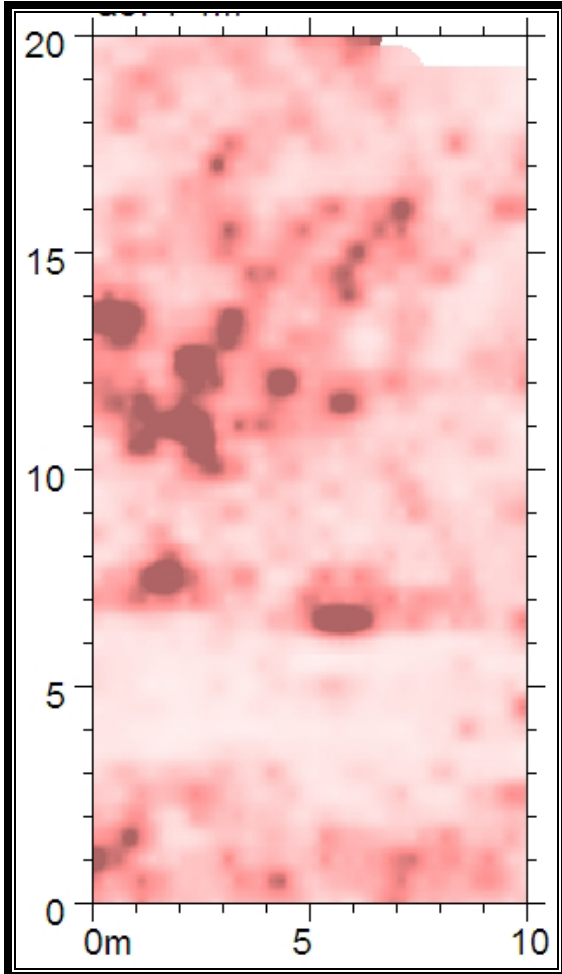


Figure 13. Plan of GPR Block D, 1 m Depth.

Figure 14 is a plan of GPR Block D at approximately 1.5 m depth. The northwestern corner of this block exhibits a concentration of strong radar reflections at this depth. A smaller oval area of reflections is visible near the center of the block (12, 4). These are areas where the ground has been significantly disturbed, although the cause of this disturbance is undetermined. It is probably to massive

to represent biological disturbances, such as a large tree root system.

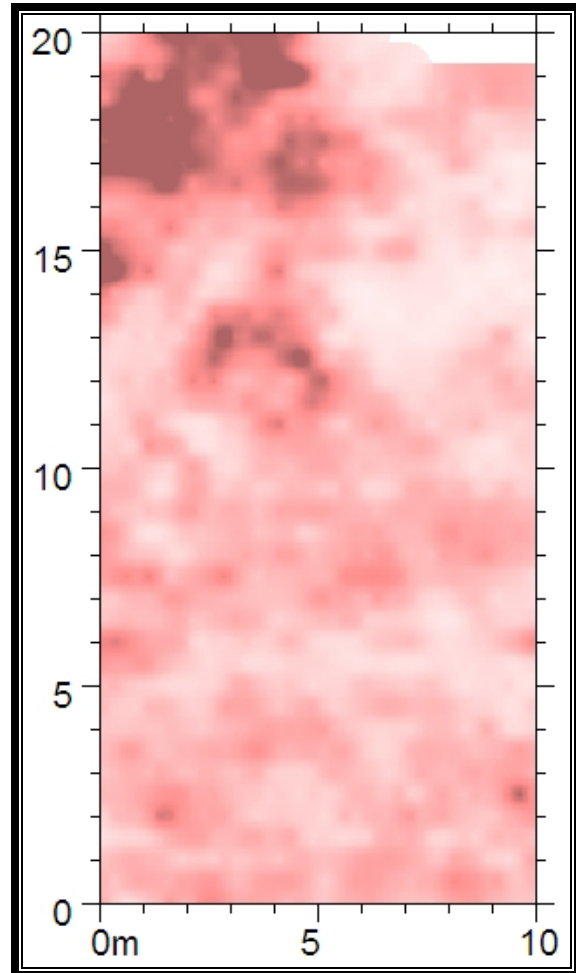


Figure 14. Plan of GPR Block D, 1.5 m Depth.

## Summary

Ground Penetrating Radar (GPR) was employed by the LAMAR Institute team on four portions of Battery Brooke, a Confederate artillery battery along the James River bottoms in Chesterfield County, Virginia. This research contributes to a larger cultural resources investigation of a potential development tract.

The four areas selected for GPR survey were along sections of the artillery battery and one cannon emplacement

that was behind the primary battery berm. Survey of these areas yielded very good GPR data and many profile and plan view images were generated after the data was downloaded. Selected images were shown in this report. Additional images are in digital format in Appendix I, which includes a series of GPR-Slice animations for each GPR block. These four small samples of a large Confederate defensive battery demonstrate that important information may be recovered by GPR survey. Ground truthing of several of the more curious radar anomalies is recommended to better assess the value of this remote sensing technique in this environment.

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