ABSTRACT

Title of Thesis:	READING BETWEEN THE LINES: EVALUATING GPR TRANSECT SPACING INTERVALS EMPLOYED TO IDENTIFY HISTORIC ARCHAEOLOGICAL FEATURES AT THE WILLIAM HARRIS HOMESTEAD SITE, 9WN168, WALTON COUNTY, GEORGIA
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This thesis examines the variable distance between transect/line spacing when using ground-penetrating radar (GPR) as a method for the identification of historic subsurface features associated with enslaved African American features at the William Harris Homestead site, 9WN168, in Walton County, Georgia. The fieldwork for this thesis sought to identify and interpret nineteenth-century subsurface features associated with the enslaved African American individuals who lived on the homestead utilizing 0.25 meter (m) transect spacing with a single channel 400 MHz antenna. This thesis sought to evaluate whether the collection of transects at 0.25 m intervals compared to wider spacing such at 0.5 m or 1 m intervals not only allows for greater resolution in the data but also whether tighter intervals locate subsurface features not identified at wider intervals. How does GPR interval spacing affect the quality and accuracy of

the reflection data collected at an archaeological site using a single channel 400 MHz antenna under similar soil conditions, and does smaller interval transect line spacing support better interpretation of GPR results? The importance of line spacing intervals used for identifying subsurface features at archaeological sites has been emphasized in the literature (Conyers 2012:28; Goodman and Piro 2013:74), however, there have been very few evaluations of the difference of clarity or accuracy that closer interval line spacing provides when compared to wider intervals (Pomfret 2006).

The reflection data examined by this thesis were gathered at the William Harris Homestead, a nineteenth-century farmstead in Walton County, Georgia. The GPR investigations sought to identify the burials of the enslaved African American people who worked at the homestead and any features associated with their living quarters. The methods for gathering the GPR reflection data involved testing gridded areas at 0.25 m interval transect spacing. The data were then processed at 0.25 m, 0.5 m, and 1 m intervals to compare resolution and the features identified by the three data sets. The results indicate that while the resolution of the imagery created from the 0.25 m interval spacing is superior to the imagery created at 0.5 m or 1 m intervals, there were no additional potential features identified. Overall, this appears to be correlated to the size of the subsurface features identified, since almost all were found at the widest interval. However, the potential size of some smaller burials and their orientation; along with the size of potential structural features targeted at the site could be determining factors for the utility of 0.25 m interval transect spacing. When evaluating the usefulness of a closer interval GPR transect strategy for single channel 400MHz frequency antennas in cultural resource management, it should be utilized for projects where there are fewer time and budget constraints along with prime environmental conditions.

READING BETWEEN THE LINES: EVALUATING GPR TRANSECT SPACING INTERVALS EMPLOYED TO IDENTIFY HISTORIC ARCHAEOLOGICAL FEATURES AT THE WILLIAM HARRIS HOMESTEAD SITE, 9WN168, WALTON COUNTY, GEORGIA

by

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Foreword

My work in this thesis is the culmination of the ground-penetrating radar (GPR) surveys I have conducted over the years and my fieldwork efforts at the William Harris Homestead site, 9WN168, which began in early 2023. Two field deployments of GPR investigations were conducted at the William Harris Homestead. The first investigation was conducted on February 25, 2023, by Edwards-Pitman, Inc. under contract with the Georgia Gwinnett College under the direction of Dr. Kathryn Deeley (Moss 2023:1). I, along with several students, assisted the lead GPR professional on this project, Richard Moss, with the fieldwork for this investigation. The first field deployment was discussed in gray literature by Richard Moss through a letter report sent to Dr. Kathryn Deeley. These findings were used in the results section of this thesis, highlighting the initial processing and anomaly identification performed by Richard Moss. The data gathered in Grid 1 of that initial deployment was then processed by me to test the research questions outlined in the thesis.

In the summer of 2023, I participated in an internship at Edwards-Pitman, Inc. that centered around improving GPR knowledge and expertise. It was during this time that I learned to process GPR data using both RADAN and GPR-Slice. I also completed a GPR Basics course through the website Learn GPR hosted and taught by Daniel Bigman. Near the end of the summer, a second field deployment was voluntarily conducted by me at site 9WN168 on September 9, 2023. I completed this investigation with the help of Richard Moss, Dr. Katherine Deeley, my coworkers Samuel Plent and William Frye IV, and Georgia Gwinnett College students. With

Edwards-Pitman's approval, I was able to use their GPR equipment to complete the survey. The results of this survey will be ground-truthed during the Spring of 2024. I am thankful to have had the chance to participate in the ongoing archaeological work being conducted at the homestead, as it hopes to bring to light the lives of the enslaved individuals who resided there so the public will learn more about their experience.

Acknowledgements

I am extremely grateful for my thesis advisor, Dr. Matthew Palus, who provided invaluable feedback and guidance throughout this entire process. This endeavor would have been impossible without my colleague, member of my thesis committee, and GPR specialist Richard Moss who has always been an excellent friend and mentor. Many thanks to Dr. Katherine Deeley for inviting us out for the initial GPR investigation near the Harris Family cemetery and for all the background information she provided about site 9WN168. Special thanks to the Harris Homestead Foundation and Dotty Zarworsky for providing access to the William Harris Homestead from where I gathered all the data used for my thesis.

I am also grateful for all the feedback and helpful commentary from my fellow cohort members who were along for the ride with me during our Winter to Spring 2024 thesis workshop. I would also like to recognize Dr. Daniel Bigman for his GPR Basics course which assisted me on my journey to understanding and using GPR as an archaeological field method. I would like to acknowledge all my friends and family who supported me through my thesis writing process. Lastly, I would like to thank my kind and loving partner Stephanie Fitzpatrick, who has consistently provided me with tons of emotional support and kept my spirits high.

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Chapter 1: Introduction

Over the past several decades, ground-penetrating radar (GPR) has been increasingly used as a less invasive archaeological survey technique in cultural resource management (CRM). It is employed in all types of environments to locate subsurface features, such as buried structural remnants, precontact storage pits, or even streetcar lines found under pavement in urban settings. However, it is predominantly used for its ability to detect graves associated with known or potential cemeteries. In CRM GPR investigations, single-channel antennas are often utilized, typically pulled along by a single survey wheel or pushed by a three-wheel cart. These types of antennas tend to be less costly for CRM firms and are potentially less destructive than multi-channel antennas, which are often pulled by off-road vehicles through a site. The data sets resulting from the investigations are often referred to as GPR reflection data. These data are gathered within grids, collected along equally spaced lines or transects. While the spacing of these transects is discussed as an important aspect in the accuracy of the identification of targets using GPR in the field (e.g. Conyers 2012; Goodman and Piro 2013), there have been very few evaluations of the difference of clarity or accuracy that closer interval line spacing provides when compared to wider intervals in CRM (e.g. Pomfret 2006).

This thesis, through qualitative assessment, examines how varying the distance between transect or line spacing impacts efficacy when using GPR as a method for the identification of potential cultural features. The GPR reflection data assessed were gathered at the William Harris Homestead site, 9WN168, in Walton

County, Georgia, near the Barrow County line (Figure 1.1). Two GPR investigations were conducted at the site seeking to identify and interpret subsurface features associated with the enslaved African American individuals who lived on the homestead utilizing 0.25-meter (m) transect spacing with a single channel 400-megahertz (MHz) antenna. The main research question addressed by this thesis asks: how does GPR interval spacing affect the quality and accuracy of the reflection data collected at an archaeological site using a single channel 400 MHz antenna under similar soil conditions, and does smaller interval transect line spacing support better interpretation of GPR results? As sites across the United States can vary in complexity and content, this thesis also considers the regional aspects of GPR's use in CRM. Should there be a minimum quality standard for GPR testing intervals, when using a single channel 400 MHz antenna, in an agricultural landscape, within the Piedmont physiographic region of Georgia? If so, what should that standard be?

GPR Investigation for Burials of Enslaved Individuals at Site 9WN168

The Harris Homestead Foundation currently provides a historical interpretation of site 9WN168 through background provided on the foundation's website and through in-person visits to the site. The foundation's goals are to present an interpretation of "what life was like on the farm for the Harris family and their descendants in the 19th century" (Deeley 2018:2). However, not much is known about the enslaved individuals who lived at site 9WN168. In partnership with the Harris Homestead Foundation, Dr. Katherine Deeley of Georgia Gwinnett College has been

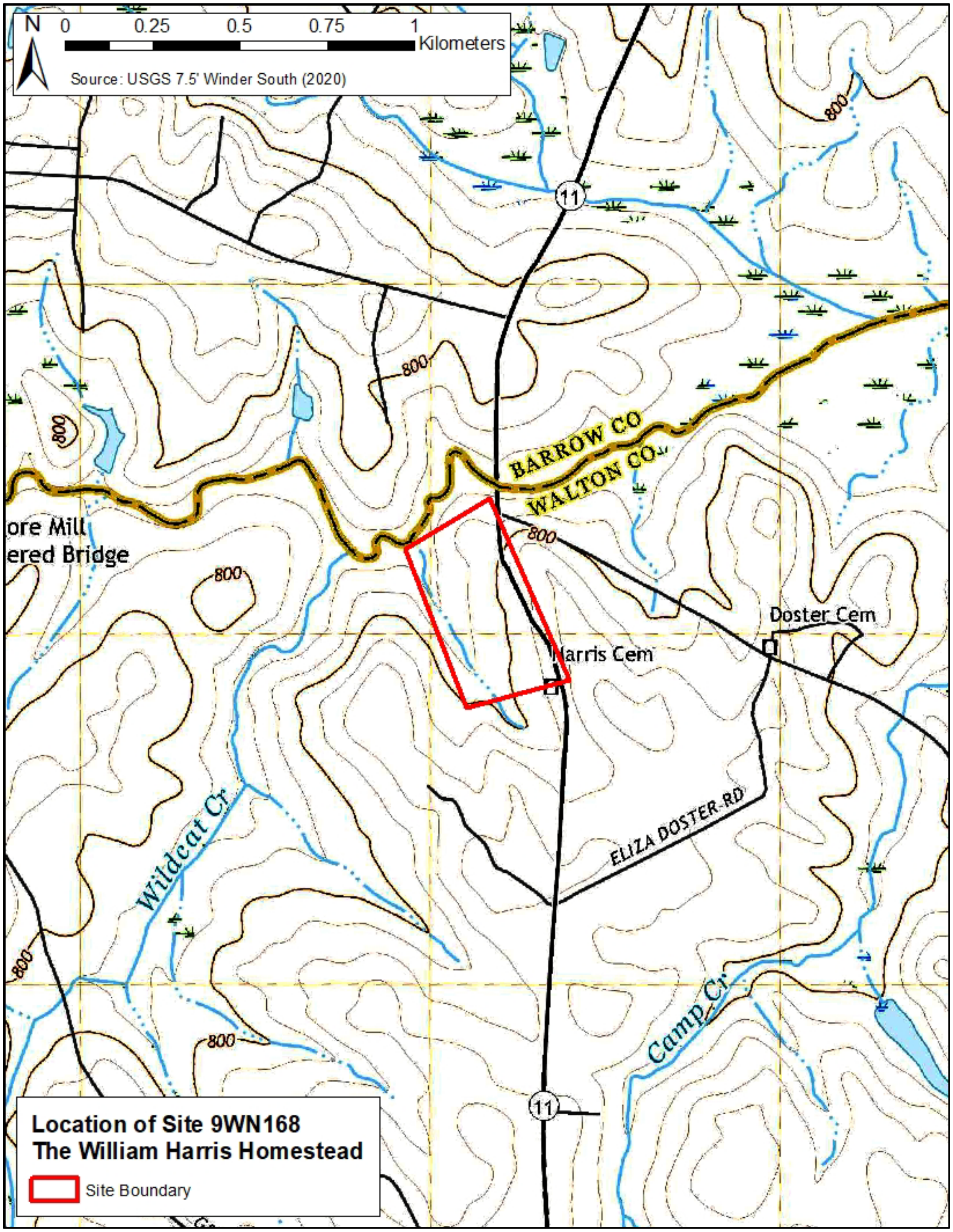


Figure 1.1. Location of site 9WN168, the William Harris Homestead, in Walton County, Georgia.

conducting archaeological investigations to gain a better understanding of the lifeways for the enslaved individuals residing at the homestead (Deeley 2018:3). An initial GPR investigation was conducted in February 2023, in the area surrounding the enclosed historic Harris Family Cemetery at site 9WN168 as part of the ongoing archaeological investigations being conducted at the William Harris Homestead (Figure 1.2). The intention behind the survey was to identify potential burials of the enslaved individuals who lived at the William Harris Homestead (Moss 2023).

Edwards-Pitman, Inc., an Atlanta-based CRM firm, conducted the GPR investigation of the cemetery under the direction of Dr. Deeley. The main objective of this initial GPR investigation was to potentially identify the burials of the enslaved individuals nearby the enclosed portion of the cemetery. The area investigated is currently in use as a modern cemetery by the descendants of William Harris. This portion of the family cemetery is assumed to continue to grow as additional grave sites are added. Therefore, the GPR investigation in this area was intended to provide significant data that would assist future descendants avoid the "placement of any new graves in locations where the risk that they may encroach upon unmarked historic graves" (Moss 2023:2) and aid the ongoing archaeological research at the site.

Coinciding with providing the location of potential burials to be protected from future earth-moving activities associated with future burials, additional GPR testing utilizing non-grid two-dimensional profiles was conducted within the enclosed historic family cemetery to potentially identify additional unmarked graves of Harris family members (Moss 2023:2). This additional testing was conducted as a request from a Harris family descendant, Dotty Zazworsky of the Harris Homestead

Foundation. While the additional profiles provided helpful information for descendants and the Harris Homestead Foundation, the profiles gathered in the enclosed historic Harris family cemetery will not be analyzed further for the purposes of this thesis. However, it is important to discuss that when working with a descendant community, GPR has become an especially important method for identifying unmarked or previously marked burials within a burial ground. The GPR investigation at the enclosed historic Harris family cemetery is just one good example of how these types of non-invasive surveys are used in collaboration with a descendant community.

Figure 1.2. View of enclosed historic Harris Family Cemetery, facing northeast (Moss 2023:3)

Researching cemeteries provides a great way to get a community more involved in the archaeological process. As such, GPR has the potential to be a tool for civic or community engagement and any data gathered from a GPR survey could be used in a reciprocal fashion as it has potential to empower a community using the cemetery as heritage (Little 2007:7). For both parties, archaeological researchers and stakeholders, a collaborative approach could be most beneficial as it allows researchers the opportunity to listen to an affected descendant community and develop goals for a cemetery project together (Colwell 2016:117). Information would flow freely between the stakeholders and the investigators allowing for better insights into GPR results (Colwell 2016:117). As a non-invasive survey technique, it can provide useful data for both researchers and community members who have an interest in a historic cemetery without impacting its integrity. In fact, GPR is often the most culturally appropriate method for the identification of ancestral graves in aboriginal and descendent communities.

A GPR survey conducted at the Mapoon Mission Cemetery, in Queensland, Australia, mapped unmarked burials using the geophysical method as it is a non-invasive approach that was "valued by Mapoon Elders" as they do not wish to damage or "disturb the remains of their ancestors" (Sutton et al. 2013:793). The survey was able to identify precontact and "mission time" burials at the cemetery which allowed the community to be able to preserve and protect an important burial ground of their ancestors (Sutton et al. 2013:803). A similar GPR survey was conducted at a historic African American cemetery in the Gullah-Geechee Community of Sapelo Island in the state of Georgia (Honerkamp and Crook 2012).

The residents of Sapelo Island were concerned about potential disturbances to unmarked graves at Behavior Cemetery, so the study developed goals for the research conducted at Behavior Cemetery through consultation with the local descendant population (Honerkamp and Crook:2012:103). Two goals sought to make an accessible inventory of known extant grave markers and find locations where modern burials could occur "without disturbing existing graves" using GPR (Honerkamp and Crook 2012:103). The GPR study of the Harris family cemetery serves as another good example of archaeological investigations working with a descendant and local community to assist in the protection and preservation of the individuals buried there However, as of yet, no descendants of the enslaved individuals who resided at the homestead have been identified.

GPR Investigation for Living Quarters of Enslaved Individuals at Site 9WN168

The second GPR investigation performed at the William Harris Homestead was conducted in September 2023, west of the extant structures at the site (Figure 1.3). The goal of this investigation was to identify the potential location of the living quarters for enslaved individuals at the William Harris Homestead site. Identifying this type of feature is one of the main components of the ongoing archaeological research at site 9WN168 (Deeley 2018). These living quarters would have served as a cultural hub for the enslaved individuals living at the William Harris Homestead. Living quarters are more thoroughly defined as important cultural features for enslaved residents by Patricia Samford in her book *Subfloor Pits and the Archaeology of Slavery in Colonial Virginia* (2007). She states that "at the grouped dwellings, known as quarters, the bonds of family and community were strengthened and reinforced as children were born and grew, men and women fell in and out of love, and the sick and elderly were nursed… these quarters are visible now only to archaeologists, who carefully record and excavate soils stains and brick foundations and preserve the thousands of artifacts revealed by their digging" (2007:2-3).

Figure 1.3. Conducting the second GPR investigation at site 9WN168 (Photo courtesy of Georgia Gwinnett College).

Since 2017, archaeological investigations at site 9WN168, conducted by Dr. Kathryn Deeley, have hoped to identify the living quarters of the enslaved individuals who resided at the homestead. These investigations, involving metal detecting and shovel testing, have so far been unsuccessful in identifying the living quarters (Deeley 2018; personal communication 2023). GPR was used to attempt to locate the living quarters because it has the potential to locate subsurface structural features. However, the success of the additional GPR investigation hinged on the location of the survey grids deployed within this portion of the site. With the aid of a hand-drawn map and Dr. Deeley's research of nineteenth-century plantations, the second GPR survey was conducted within a portion of the site likely to yield evidence of slave quarters in the form of anomalous reflection results (Deeley 2018:3,5). The results of the GPR investigation will hopefully aid with excavations at the site in Spring of 2024.

Summary of Following Chapters

The subsequent chapters will take a closer look at the methodological approach of GPR survey at the William Harris Homestead site, analyzing the results of the two investigations, and addressing the research questions about GPR transect spacing intervals posed by this thesis. Chapter 2 focuses on the science of GPR to gain an understanding of how the equipment works and how it is applied to archaeology. The chapter also discusses the methodological approach of GPR in archaeology and how it is applied. At the end of Chapter 2, case studies are summarized involving different line spacing strategies and how they affected the results of those investigations. The author also discusses at least one previous case study that partially sought to answer the GPR transect interval question. Chapter 3 focuses on an environmental and historic context for the William Harris Homestead, site 9WN168. The types of soils found at the site are discussed as well as how particular soil types affect the transmission of radio waves from the GPR equipment. This chapter provides a brief history of the William Harris Homestead and characterizes the regional context of slavery at the time of the site's occupation.

Chapter 3 also explores the previous archaeological investigations performed at site 9WN168 leading up to the two GPR survey deployments.

Chapter 4 discusses the methods used to gather the reflection data at site 9WN168 and how they were processed for analysis. This chapter includes a discussion of the two GPR fieldwork deployments at the William Harris Homestead, the placement of each grid, their dimensions, and the transect/line spacing interval utilized per grid. Chapter 4 also summarizes the post-processing steps that were used to examine the reflection data gathered at the site and how the grids were processed at the tested intervals for further analysis. Chapter 5 examines the results of each GPR investigation conducted at site 9WN168. The results include each anomalous reflection identified within the grids post-processing and some initial interpretations of them. Chapter 5 includes these results in both graphic and tabular format to help with mapping these anomalies for future archaeological research and to avoid impacting potential burials in the in-use cemetery presently surrounding the historic enclosed Harris family cemetery.

In Chapter 6, the author further analyzes the interpretations of anomalous reflections identified at site 9WN168. The chapter discusses what types of characteristics are sought after when interpreting an anomaly as a potential burial feature. Three anomalous reflections corresponding to known marked burials were used as a comparison of how those characteristics are presented in the data. This assists with the discussion of how other anomalies of the first GPR investigation of the cemetery were interpreted. Also in Chapter 6, the interpretations for anomalies identified during the second GPR investigation conducted looking for the living quarters of the enslaved individuals that once resided at the William Harris Homestead are further analyzed and discussed in relation to future archaeological work to be conducted at site 9WN168. The results of the qualitative GPR transect spacing study are examined and discussed at the end of Chapter 6. The discussion relates to how the data appeared at different intervals and what these findings could mean for future GPR studies at similar sites within the region. Finally, Chapter 7 concludes the thesis by summarizing the GPR-related work conducted at site 9WN168 for this thesis and its findings. Chapter 7 also addresses the research questions posed by the author based on the qualitative analysis of the results, as well as the limitations and future applications of the methodological experiment conducted for the thesis.

Chapter 2: GPR Theory and Application to Archaeology

Introduction

All types of remote sensing techniques have been applied to archaeological research. These include but are not limited to different types of geospatial analysis using Geographic Information Systems (GIS) and geophysical survey methods such as resistivity, magnetometry, and GPR (Johnson 2006). These are considered active geophysical methods as they “transmit energy into the ground and then measure how that energy is affected by cultural, geological, or environmental changes in the ground” (Conyers 2004:3). GPR is one of the most well-known geophysical survey techniques and it is also one of the more complex geophysical instruments in relation to processing its electromagnetic reflection data (Johnson 2006:8). GPR has a wide array of uses outside of archaeology, such as utility detection, mining, forensics, structural engineering, and the detection of unexploded ordinances and essentially can be applied to “anything buried beneath another surface” (Utsi 2017:117). GPR as a geophysical technique has increased in use in archaeology over the last few decades as a non-destructive method for investigating archaeological sites, especially in its use as a tool for identifying historic structural features and burials (Utsi 2017:126).

GPR and Archaeology

Early geophysical techniques were attempted at archaeological sites in the 1920s and 1930s in North America and Europe (Conyers 2004:4). These early surveys utilized tools that were created for “mining and petroleum exploration” and resulted in the recording of geological features rather than cultural ones (Conyers 2004:4). The first recorded use of GPR survey in an archaeological context was in the

1970s where it was used to map wall locations in Chaco Canyon (Conyers and Cameron 1998:418). These early GPR surveys involved the use of "analog equipment" that recorded raw data upon magnetic tape or printed them out on paper (Conyers and Cameron 1998:418). Investigators had to manually look through these paper records for any data that might indicate subsurface features (Conyers and Cameron 1998:418; Conyers 2012:47). In the 1980s, the use of digital GPR equipment paired with computer processing software became available to GPR practitioners, which allowed them to examine multiple data sets at once to create three-dimensional maps of the areas they investigated (Conyers and Cameron1998:418).

The Science Behind GPR

Lawrence B. Conyers, an established archaeological geophysical practitioner, defines GPR as a near-surface geophysical technique that archaeologists use to locate and plot cultural features and geological units buried beneath the ground surface (Conyers 2022:1). GPR works by gathering data from under the surface, transmitting radar waves into the ground to reflect off buried features or objects which are then detected by a receiving antenna (Conyers 2022:2). The electromagnetic pulses are sent through a transmitter that transfers the electromagnetic energy into the "survey medium", which is typically sediment but could consist of other materials such as concrete along paved surfaces (Utsi 2017:4). GPR retrieves this data by moving the antennae along survey lines or transects where constant reflections are being recorded over a certain distance. Conyers (2022:2) notes that "hundreds or even thousands of reflections are recorded every meter". These constant reflections are often referred to as the sampling interval, trace increment, or read distance (Utsi 2017:76). These reflections are recorded and digitized on a computer as the GPR is moved across the ground (Conyers 2022:2). The distance the GPR is pushed is measured by a survey or odometer/encoder wheel (Utsi 2017:3) which helps inform the length of a two-dimensional profile created by reflection data gathered over a transect (Conyers 2022:2). Figure 2.1 illustrates how the GPR antenna is pushed along the ground with a three-wheel cart with one encoder or survey wheel that measures horizontal distance along its route.

Figure 2.1. GPR setup with receiving antenna pushed along the ground by a three-wheel cart with an attached survey wheel (Photo courtesy of Georgia Gwinnett College).

GPR generates accurate measurements created from the time, in nanoseconds, that it takes for a radar wave to reflect from a buried object or feature back to the receiving antennae. These time measurements equate to depths that in combination with the horizontal surface, the GPR equipment traverses generate a "complex three-dimensional data set" (Conyers 2012:17). The process of creating these three-dimensional diagrams or maps of cultural and geological features buried in the ground, works by combining multiple two-dimensional profiles gathered across a surveyed area (Conyers 2022:15). However, these three-dimensional models, are more accurately described as 2.5-dimensional as they are based on simulated three-dimensional maps of arranged two-dimensional profiles (Zhao et al. 2013:107).

Another means of explaining how GPR operates in three dimensions is to start with the initial vertical transfer of energy into the ground and the reflection of that energy back to the receiving antenna, this process creates a one-dimensional "amplitude trace" also referred to as an "A-scan" (Martin and Everett 2023:5). The GPR survey equipment will transmit hundreds if not thousands of these A-scans over a single transect, which are combined to form the two-dimensional profile image also referred to as a "B-scan" (Martin and Everett 2023:5). The B-scans or profiles collected by GPR are often referred to as radargrams as well. Finally, after recording data along transects across an entire surveyed area, combing two-dimensional B-scans to form a two-dimensional time-slice map which is also called a "C-scan" (Martin and Everett 2023:5). Since the two-dimensional profiles, or B-scans, record the vertical distance of across a surveyed area, this creates that pseudo three-dimensional model discussed above, allowing a GPR practitioner to examine the reflection data gathered both vertically and horizontally.

The radar waves or electromagnetic energy transmitted from the GPR is often affected by multiple factors below the ground surface. In order to correctly interpret GPR reflection data, practitioners "must think geologically, biologically, geophysically, and archaeologically, often at the same time" (Conyers 2012:17). Some of the things a GPR practitioner needs to consider are the types of soils, stratigraphy, the behavior of the radar energy below the surface, types and distribution of archaeological features that may be identified, the hydrology of the area, biological features like roots and burrows, and of course an understanding of the GPR equipment itself. The speed of electromagnetic waves can differ contingent on the chemical makeup of the material they are traveling through (Conyers 2012:25; Conyers 2022:2).

Electromagnetic or radio waves are also not being transmitted at a constant velocity and the material of the medium can determine the speed of the energy transferred as well as the environment's electrical or magnetic properties (Utsi 2017:39). GPR practitioners must evaluate a medium's "relative permittivity" or dielectric constant as it is a measurement of a material's electromagnetic response (Utsi 2017:39-40). Most notably, the dielectric constant of both air and water has the ability to affect the speed of the electromagnetic waves transmitted by GPR (Utsi 2017:39). This is why soil conditions matter at a site where GPR is being used as dry soil conditions allow for good signal transference (Conyers 2022:4), but soils that have been saturated with water could reduce the effectiveness of the signal and not penetrate as deeply into the ground as the signal will attenuate much more quickly than dry soils (Johnson 2006:308; Utsi 2017:40).

Methodology

GPR equipment samples reflection data in two ways. The first way in which GPR collects data at a site was described previously when the sampling interval or trace increment was first defined (Utsi 2017:76). Sampling intervals are the A-scans and are typically measured in scans per meter. The second way GPR collects a sample is along transects spaced at definitive intervals within a "rectangular" grid (Conyers 2012:28, Conyers 2022:3). The GPR grid is generally based on a cartesian coordinate system so that the grid can be easily mapped using a GPS device (Conyers 2012:28). This is the most common type of GPR methodology used in archaeological investigations, it is referred to as "common-offset reflection" as the receiver and transmitter "have fixed spacing" and move through a "fixed offset" on the surface (Manatki et al 2015:15). It is important to have "accurate data positioning" when conducting a GPR survey, so this requires precise measurements when establishing GPR grids (Novo 2013:171). GPR transects are the B-scans that make up the horizontal area of a C-scan, which is the surveyed grid (Martin and Everett 2023:315). This involves "transect spacing" which can vary depending on the GPR application (Utsi 2017:77). In the context of archaeological investigations, line spacing is generally "tens of cm" between transects, generally one m or less (Martin and Everett 2023:315-316). According to Goodman and Piro, GPR transect spacing should at a minimum be half or "smaller" than the width and length of a potential subsurface target (Goodman and Piro 2013:74). It also noted that shallower GPR targets are much more likely to be identified at closer intervals, as deeper targets are likely to be picked up by overlapping radio waves that spread out wider as they penetrate deeper into the soil (Goodman and Piro 2013:75). For a single channel GSSI SIR-4000 it is recommended to have no "more than 0.5 m between adjacent survey lines" (Martin and Everett 2023:316).

Transect spacing is often determined by the frequency at which the radar waves are being transmitted. Conyers posits that higher frequency antennas usually necessitate closer transect spacing than those of lower frequencies (2012:28). GPR antennas used for archaeological purposes vary in frequency ranging from 10 MHz to 2GHz (Manataki et al 2017:13), but the most common frequency for archaeological uses is 250, 400, or 500 MHz (Utsi 2017:127). 400 MHz antennas are considered excellent for archaeological purposes as "they generate a well-focused transmission beam of radar energy, are well shielded, can resolve features of about 20 cm or so in dimension, and can often transmit energy to 2 m or more in depth" (Conyers 2012:27). Regardless of the frequency, the line spacing interval between GPR transects works best as a "fixed value" appropriately set for the shape and size of the targeted feature (Manataki 2017:15).

Interpretation

GPR is made up of radar reflections and displays what is truthfully below the surface, it is an operator's interpretation of it that can be incorrect (Utsi 2017:1). One issue that is often associated with GPR as a tool for archaeological interpretation is that it can differ depending on the GPR practitioner (Conyers 2012:17). The goal of GPR is to identify subsurface features initially classified as "anomalies". Anomalies can be defined as something out of the ordinary or "different from the norm" (Conyers 2012:29). Anomalies represent the buried cultural and geological features that archaeologists are hoping to interpret and examine at a site. In order to identify and interpret an anomaly, a practitioner must first know how to read the reflection data displayed gathered by GPR equipment.

One important thing to note is that the image displayed by the GPR does not resemble the actual object under the ground (Utsi 2017:5). The reflections from the GPR electromagnetic signal are created when the "electromagnetic properties of the subsurface materials change" and the "signal amplitude" is the strength of this reflection (Utsi 2017:5-6). The primary shape created by the radar reflection signals are "hyperbolas" and it is important to note that these hyperbolas do not mean the object identified by the GPR is round or "cylindrical" (Utsi 2017:6). The hyperbola reflection is created due to the nature of the electromagnetic energy making contact with the object in the ground. As the radar nears the target the edge of the electromagnetic energy will begin to detect it and give an "apparent depth" (Utsi 2017:6). The radar energy will continue to move, shortening the apparent depth of the object until it is directly above the feature at which point it is at the "minimum" depth of the object and will continue to increase in apparent depth as the radar energy gets further away from the object, resulting in the hyperbola shape along the two-dimensional profile (Utsi 2017:6). When interpreting GPR targets, smaller subsurface objects are generally referred to as "point" targets, or "point-source" targets and wider more expansive objects, such as floors or defined soil horizons, are more generally referred to as "planar" targets (Conyers 2022:7).

For a complete analysis and interpretation of the features identified, a GPR practitioner uses at least three distinct types of imaging created by GPR data:

reflection profiles, amplitude maps, and isosurface renderings (Conyers 2012:25). Reflection profiles are created from the two-dimensional B-scans collected along one transect and amplitude maps, as well as isosurface renderings are created from "multiple profiles in a grid" (Conyers 2012:17), or the C-scan. When analyzing and interpreting GPR data imaging distinction of solid objects or "void spaces" is possible (Conyers 2022:5). A solid GPR signal could be interpreted as a compacted living space floor or hearth feature, but void spaces under the surface could range from tunnels to burials or even tombs (Conyers 2022:5, 12). The void space in the case of a burial in a cemetery would actually be the backfill within the grave shaft when it was filled in, post-interment (Conyers 2006:66). This distinction could be important to the understanding of the determination of feature type, its context, and research importance to the overall site.

Applying GPR: Looking for Subsurface Features

GPR can be used to locate and define structural remains at archaeological sites from any time period, however, sites with major structural elements, such as those at a classical Roman site, are much easier to define than some cultural features since they are easily apparent in the reflection data (Conyers 2012:20). A recent example of mapping structural features at a site was performed in the Ancient Macedonian and Greek city of Demetrias in Volos, Greece (Manataki et al. 2015:17). The survey resulted in clearly distinguishable imaging exhibiting an arrangement of houses with gardens in a "dense collection of buildings" along two roads (Manataki 2015:18). The investigators could also identify rooms within the structures mapped by their two GPR systems (Manataki et al. 2015:19). While GPR is a useful tool for investigating archaeological remains constructed of stone, it can also be applied to features that are made of compacted soil, such as mound sites.

GPR was once used to interpret the mound building process at the Lake Jackson Mound Site (8LE1) in Tallahassee, Florida (Seinfeld et al. 2015). They found the use of GPR to be more practical than more destructive excavation methods as the method allows them to visualize the "depth and extent of buried cultural deposits" within the mound structure (Seinfeld et al. 2015:222). By comparing previous excavation data at the mounds with the GPR data they gathered, the investigators were able to identify different construction periods at the mounds through the identification of "successive mound summits" (Seinfeld et al. 2015:227). These GPR studies demonstrate what GPR is capable of as a non-invasive archaeological technique.

GPR is generally the most often used geophysical method in cemetery contexts (Moffat 2017:46). It can be utilized to determine several attributes associated with burials at historic cemeteries. These attributes include depth, size, and orientation of the burial, as well as the casket type and the "distribution of graves" at a cemetery (Conyers 2006:64). There are also four physical features of interments that could be potentially identified and mapped with GPR which include: the naturally occurring sediments surrounding a grave shaft, the burial or coffin and its associated cultural items, backfill that filled the grave shaft post-interment, and the surface sediments that have accumulated on top of the grave post-interment (Conyers 2006:66).

When using GPR for the detection of graves, the recommended methodology dictates that the investigator should move the GPR system along transects that are at least 10 m in length and "with reflection profile transects spaced between 25 cm and 1 m apart" (Conyers 2006:69). The reflection profiles within a grid are typically oriented in one direction, i.e., north to south, east to west, etc. GPR transect orientation often depends on the type of feature an archaeologist is looking for. For example, transects are often oriented north-south to locate burials that are oriented east-west, typical of a traditional Christian cemetery in the United States. To further assist with interpretation, GPR results could also be compared with historical maps to assess whether anomalies line up with suspected grave locations (Conyers 2006:72). It can be a useful tool for guiding the next steps when studying a cemetery. Most often investigators would probably like to leave human remains undisturbed, but in some cases, such as in development work that may affect the remains, it may be pertinent to ground truth the results and potentially relocate identified human remains.

It is possible for investigators to miss a cultural or geological feature with a GPR system. Objects are only displayed in the reflection data if the electromagnetic reflections are recorded by the receiving antenna, so if a buried object or feature is situated in a position where the reflected energy is directed away from the antenna, the object is essentially "invisible" to the GPR system (Conyers 2012:25). Burials, in particular, have the potential to be missed if a feature is too small or due to collapsing of material within a grave shaft (Horsley 2021:9). Therefore, it is especially important to practice good GPR survey methodology when trying to identify unmarked burials, so that interments are not missed and left unprotected. The transect spacing used can vary across different archaeological sites, depending on the different types of GPR frequencies used and the soil conditions at a site.

For example, a GPR survey conducted within the Georgia Piedmont physiographic region at the Wadsworth Cemetery in Lamar County, Georgia, attempted to identify unmarked Wadsworth family graves from the nineteenth century and a potential "mass grave of confederate soldiers" (Elliot 2017:1). The survey utilized a 500 MHz antenna with transect spacing at 0.5 m intervals (Elliot 2017:4-5). 0.5 m interval is often the standard practice for GPR surveys within cemeteries and elsewhere in Georgia, but this spacing does not often account for the potential of missing smaller child graves from lack of overall ground coverage. These lapses in coverage are sometimes the result of immovable objects within the grid that the GPR must be steered around, thereby widening the line spacing interval in some portions of the grid. The survey at the Wadsworth Cemetery resulted in the identification of 103 potential interments, but there were potentially more not detected by the GPR system (Elliot 2017:13).

In contrast, a survey conducted on the Sarah Lee Family Cemetery at Calverton-Galloway Park in Montgomery County, Maryland involved closer GPR transect spacing (Horsley 2021). The geophysical survey was performed within the Sarah Lee Family Cemetery dating to the nineteenth century (Horsley 2021:5). The GPR system that was used for the study utilized one 350 MHz antennae moved along GPR transects spaced at .25 m intervals within the fenced-in cemetery, scanned twice over at "two different orientations" crisscrossing the survey grid (Horsley 2021:8). This methodology was used to try and solve the invisible anomaly problem. The results of the GPR survey at the Sarah Lee Family Cemetery identified 19 “probable burials”, well-defined burial-shaped anomalies, within a fenced-off portion of the cemetery, and 11 “possible burials” that were the result of a weaker radar reflection (Horsley 2021:13).

Both case studies above were performed within a similar physiographic environment, the Piedmont province, creating similar soil and environmental conditions (National Park Service 2023). Each GPR system utilized different frequencies, 350 MHz and 500 MHz antennas, but were not far off from the typical 400 MHz used for most archaeological contexts. The main difference between the two surveys was the interval spacing used between the GPR transects, supporting the idea that closer intervals produce higher quality reflection data, but did it reveal anomalies that may have been missed at wider intervals? The survey conducted at the Sarah Lee Family Cemetery not only used closer intervals between transects but surveyed the same GPR grid twice in a crisscross fashion, theoretically increasing the odds of burial identification (Horsley 2021:8). However, the investigation was not able to make any determinations about an increase in accuracy at closer intervals, as it was not compared to wider interval data collected within the same grid unit nor did it consider if the crisscross pattern increased the accuracy of the GPR survey.

Another study conducted by James Pomfret in 2006, questioned whether there would be greater resolution of features in a grid collected at intervals from 0.5 m to 0.25 m or for a grid collected along both the x and y axes (Pomfret 2006), in a crisscross fashion like the survey method performed by Horsley the Sarah Lee Family Cemetery (Horsely 2021). The study was conducted within the Coastal Plain of

Georgia, which is of a different physiographic region than the previous two surveys, but still provides insight into GPR survey methodology in the region. The survey examined one linear feature type, a privy, and found that the resolution improved in both scenarios, however, each method only tested one grid examining one specific feature type and there was no mention of any additional features that were identified in the grids by either method (Pomfret 2006).

The discussion of the three scenarios evokes interesting questions about GPR methodology in cemetery settings and how interval spacing and placement might increase the accuracy of the electromagnetic reflection data. Some structural features have the potential to be quite small and shallow (i.e., posts or foundational piers) and may not be missed completely by GPR. This can also be true of small grave or interment features (i.e., urn or children's interments). Would a wider GPR transect interval like 0.5 m be less likely to identify smaller subsurface features than the closer 0.25 m interval due to the lack of resolution in the reflection data imagery? This thesis considers these ideas as it evaluates the use of close interval GPR transect spacing of 0.25 m at the William Harris Homestead site.

Chapter 3: Environmental and Historic Context of the William Harris Homestead

Introduction

This chapter discusses the specific environmental context, as well as the historic and cultural context of site 9WN168, the William Harris Homestead. The environmental and cultural context of the site informs the type of features that may be identified and the material factors that played a role in their identification by GPR reflection data. As described in Chapter 2 of this thesis, the transference, reflection, and velocity of GPR waves are affected by the mediums or materials through which they pass through; therefore, it is important to consider the environmental factors at an archaeological site such as the physiographic conditions, soil types, hydrology, and the effects of bioturbation (Conyers 2012:17). This means that at different sites around the United States, GPR operators must consider the physical properties of the landscape they are working in. This chapter will also discuss the historic context of site 9WN168 and the previous archaeological investigations at the site in more detail.

Physiography and Geography of 9WN168, the William Harris Homestead

Georgia is divided into six main physiographic provinces including the Appalachian or Cumberland Plateau, the Ridge and Valley, the Blue Ridge, the Piedmont, the Upper Coastal Plain, and the Southern Coastal Plain (Clark and Zisa 1976). Site 9WN168 is located within the Piedmont province. The physiographic province received its name from early settlers who thought it to be similar to the "foothill sections of Southern Europe," so they named the region after the Italian "Piemonte" meaning "foot of the mountains" (Godfrey 2012:11). The Piedmont is a region that extends from Southern New York to Alabama (NPS 2023) and consists of the "transitional area" between the relatively level, low elevation Coastal Plain and the more mountainous regions to the northwest (Griffith et al. 2001). The Piedmont is a "complex mosaic of Precambrian and Paleozoic metamorphic and igneous rocks with granite outcrops spread across the province (Griffith et al. 2001). The province is geologically referred to as a "peneplain" which is "a plain not yet worn entirely smooth by the ineluctable agents of erosion" (Godfrey 2012:12). The Piedmont province is more thoroughly divided into two subsections, the Upland Georgia subsection and the Midland Georgia subsection, and then even further into nine physiographic districts. Site 9WN168 is located within the Winder Slope physiographic district within the Midland Georgia subsection (Clark and Zisa 1976). The Winder Slope district consists of "gently rolling topography" with elevations ranging from 700 to 1000 ft above sea mean level (asml) (Clark and Zisa 1976).

Soils at Site 9WN168

To fully evaluate the environmental conditions at the site, it is important to understand the types of soils the GPR equipment operates within. Soils are generally the main medium through which GPR transmits and receives reflected radio waves and their properties affect the travel time and overall depth in which reflected frequencies are received. Soils within the Piedmont are noted to be finer in texture than soils found within the Coastal Plain of Georgia, generally higher in clay with a smaller proportion of sand (Griffith et al. 2001). Historically, this is due to most of the topsoil in the Piedmont region of Georgia being heavily eroded from intensive agricultural processes across the state (Hodder and Schretter 1986). GPR frequencies attenuate or dissipate at a faster rate in clayey soils, which can lead to a decrease in the depth of GPR data recovery. The relative dielectric permittivity (RDP), or dielectric constant of the clay generally ranges from 5 to 40 RDP with a velocity of 0.05 meters per nanosecond (m/ns) (Bigman 2023). A higher dielectric constant means that electromagnetic waves will move more slowly through a material and the higher the conductivity of the material leads to faster attenuation of signal. Air has the lowest RDP of any material, 1, and water has the highest, 81 (Bigman 2023). Therefore, clay with a higher water content, for instance soil after a heavy rain, has a greater RDP than clayey soil that is completely dry. Therefore, the energy of the wave is then lost at a greater rate which leads to it dissipating much more quickly, reaching a shallower depth.

According to the soil survey staff (SSS) at the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA), there are at least three majority soil types within the 9WN168 site area: Cecil coarse sandy loam (CdB2), Cecil sandy clay loam (CZD3), and Lloyd clay loam (LeB3) (SSS, NRCS, USDA 2023). Derived from igneous and high-grade metamorphic rocks, Cecil soils are observed within the uplands of the Piedmont. They are generally located on side slopes and ridges, consisting of a shallow sandy loam from 0 to 8 inches (in.) underlain by clay subsoil (USDA 2007). Much like Cecil soils, the Lloyd soil series is observed within the uplands of the Southern Piedmont and formed from igneous and high-grade metamorphic rocks. Lloyd soils consist of a shallow loam from 0 to 9 in. over subsoil made up of clay loam underlain by clay (USDA 2006). Both soil series comprise a form of saprolite, Cecil soils from

50 to 80 in. and Lloyd soils from 56 to 72 in., before contacting bedrock (USDA 2006; 2007). The soils are similar enough across site 9WN168 that the GPR signal would likely reach similar depths. Therefore, the main factor affecting the overall recorded depth of the GPR signal during fieldwork would be the soil's water content during the investigations.

A Brief History of the William Harris Homestead

The land where the William Harris Homestead is located today, consisting of 367 acres (ac.) of farmland (Cloues 1982:1), was first settled by Euro-Americans in the early 1820s. Present-day Walton County, consisting of 394 square miles (sq mi.) was purchased by the state of Georgia from the Muscogee (Creek) in 1818 for $120,000 (William Harris Foundation 2023). The William Harris Homestead property initially consisted of two distinct land lots, Lot 122 and Lot 149 (Deeley 2018:1). The lots were originally awarded to Barbary Wilson and James Gardner, but both had been acquired by William Carr by 1823 (William Harris Foundation 2023; Deeley 2018:1). In 1836, William Carr sold the property to Willis Kilgore and John D. Harris, the brother-in-law and brother of William Harris respectively, but within months, the property would be owned by the mother of William Harris, named Milley Price (Deeley 2018:2). William Harris, most likely the youngest of the Harris siblings (William Harris Foundation 2023), would eventually own the land in 1840, living there with his wife Harriet Davenport until his death in 1879 (Deeley 2018:2). In 1888, William Harris's two sons acquired the land, which has been passed down through the family for generations since (Deeley 2018:2; Cloues 1982).

The original nineteenth-century log farmhouse, likely built by William Carr between 1821 and 1823, is still extant within the site (Deeley 2018; Cloues 1982:1). The house is constructed from oak timbers made with one and half stories consistent with early Virginia architecture "plantation plain type" (William Harris Foundation 2023). Several of the original outbuildings are also still standing within the property, these include a smokehouse constructed of fieldstone and hand-made brick, a corn crib, a barn, a wagon shed, and a shop (William Harris Foundation 2023). A half-acre family cemetery is also located within the property, approximately 37.5 meters (m) southwest of the house. William Harris and his wife Harriet are buried in the family cemetery, and it is still in use by their descendants (William Harris Foundation 2023). The original homestead, outbuildings, and family cemetery represent a living legacy that tells the story of the homestead and what life in frontier Georgia was like for early Euro-American settlers. However, like many historic agricultural-based sites in the southeast, the Harris family was not the only group of people who lived on the property; like many landowners at the time, they possessed enslaved African American individuals.

From 1751 until the start of the Civil War in 1861, plantation systems in Georgia heavily relied upon the use of enslaved labor. The Georgia Coastal Plain in particular involved large, enslaved workforces to farm cash crops such as rice and indigo (Coleman 1991:55). Inland farmsteads, much like the William Harris Homestead, utilized fewer enslaved individuals to farm tobacco, cotton, wheat, or corn (Coleman 1991:119). In nearby Gwinnett County, located northwest of Walton County, a minority of households owned enslaved individuals, roughly estimated around 20% (Gagnon 2017:5). Up until recently, not much information has been ascertained or published about the lives of the enslaved residents of the William Harris Homestead. Due to this void in the known history of the site, recent archaeological investigations at the site have aimed to rediscover and interpret the lives of the enslaved African American people who were an integral part of the nineteenth-century history of site 9WN168 and other smaller farmsteads throughout the Midland Subsection of the Georgia Piedmont.

From 1850 to 1860, it has been reported in the United States Census Slave Schedules (USCSS) that William Harris owned 18 enslaved individuals in 1850 and 10 in 1860 (Ancestry.com 2024b; 2024c). The records differ from the Georgia Property Tax Digests from 1850 to 1859 which indicate “between 7 to 10” enslaved individuals were living on the William Harris Homestead property (Deeley 2018:3; Ancestry.com 2024a). Unfortunately, the names of the enslaved individuals were not included on the USCSS records, however, in 1850 their ages were listed as ranging from 2 to 50 years old (Ancestry.com 2024b), and in 1860 their ages ranged from 2 to 22 years old (Ancestry.com 2024c). No additional information regarding the enslaved individuals living at site 9WN168 is found in available family records, which could indicate this information was never recorded in government documentation or that this information was somehow lost.

However, it should be noted that the father of William Harris, John Harris, did leave his property to his wife Milly Harris when he died in 1821. The list of names of the 12 enslaved individuals that he owned were included in this will which were given in first name only: “Pompey, Easter, Liah, Lilley, Sam, Peggy, Aron, George, Mary, Mariah, Sarah, and Jerry…" (Ancestry.com 2024d). It is unclear whether any of these individuals were brought to the William Harris Homestead by Milley before she gifted the property to William in 1840. Kathryn Deeley of Georgia Gwinnett College speculates that Milly gave all her property to one of her older sons before moving to the homestead in Walton County, but there is no additional documentation for what became of the enslaved individuals once owned by John Harris (personal communication 2024).

Archaeological Investigations at Site 9WN168

The USCSS records from 1860 indicate that there were two living quarters for enslaved individuals on the property (Ancestry.com 2024c). However, a hand-drawn map of the William Harris Homestead (Figure 3.1), provided by Dr. Katherine Deeley from the Harris family's initial NRHP application, depicts three squares drawn near the bottom left which were labeled as potential "site of slave cabins" (Deeley 2018:3). Unfortunately, these structures were razed, which is often the fate of these types of structures (Samford 2007), well before the map was drawn by family member Hubert Harris (Deeley 2018:3) and their location on the map is approximate, based on memory, with the limited scale provided. The Harris map also labels an area the "slave cemetery site" (see Figure 3.1), noting that enslaved individuals were not necessarily buried within the main family cemetery but within its vicinity. Spatially, if the enslaved individuals were buried near the family cemetery, this might indicate that they were treated with a greater respect by the Harris family than typical of the time period (Bigman 2013:17). However, if burials for enslaved individuals are "isolated," or "distributed in an unsystematic way" across the landscape of a site, could imply a poorer relationship between the enslaved individuals and the family that owned them (Bigman 2013:17).

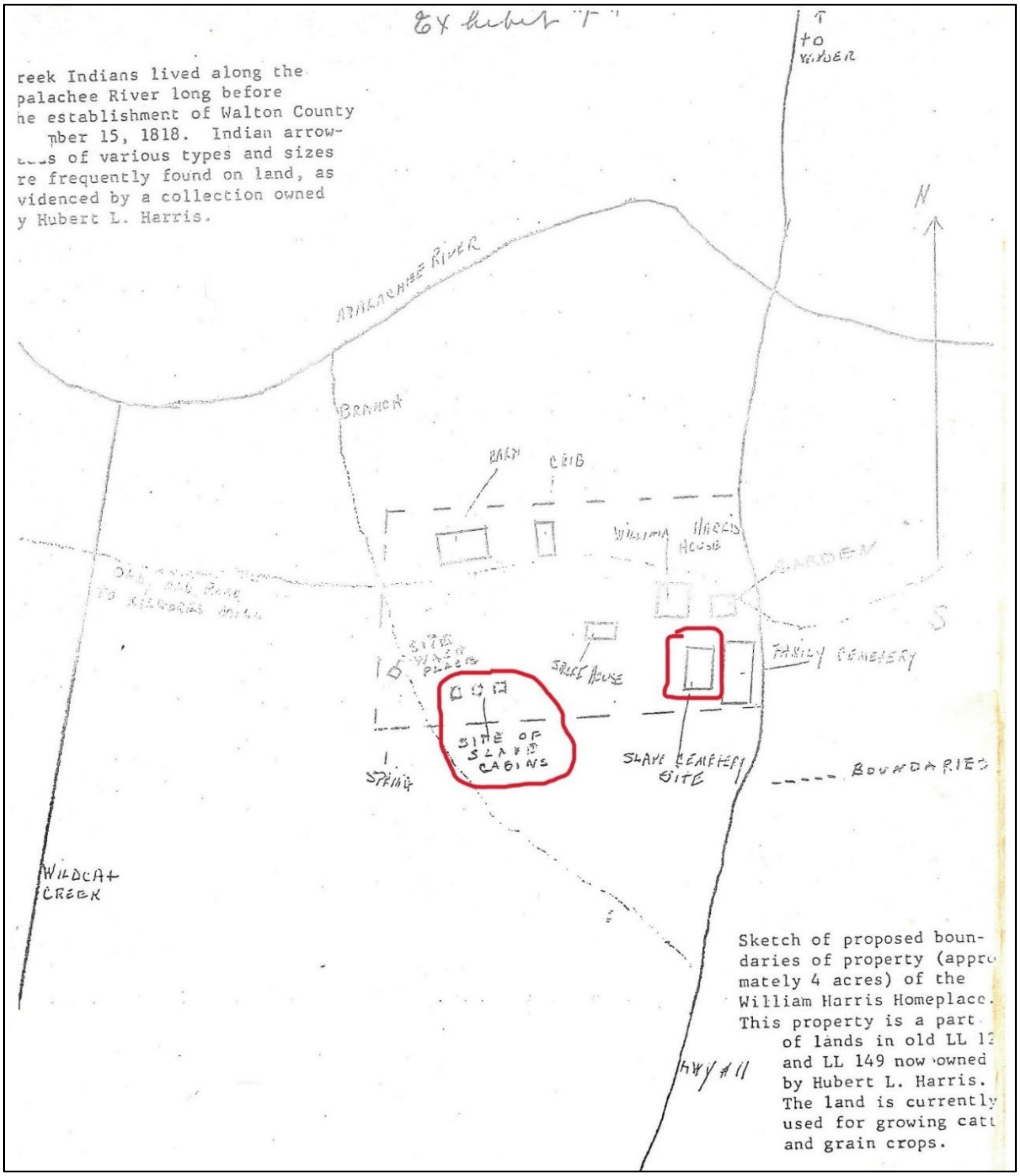


Figure 3.1. Hand-drawn map of the WWH, drafted by Hubert Harris, proposed areas for cemetery and quarters circled in red (Provided by Dr. K. Deeley 2023, “Exhibit F” from the William Harris Homestead NRHP application).

Based on her research of nineteenth-century plantations, Dr. Katherine Deeley surmises that the living quarters for the enslaved residents of the William Harris Homestead would be located within the "farm core" of the property, which is the area within line of sight of the log house near the outbuildings (Deeley 2018:5). Dell Upton, a well-known architectural historian, has noted that slave quarters for a farm or plantation are often visible from the main house and were arranged in a row or "street" (1984:63). This would also be in concurrence with the family's hand-drawn map of the homestead site, showing the slave quarters are not far from the other outbuildings and in view of the main house (see Figure 3.1). Since the structures were razed, there is nothing on the surface that would suggest the exact location of the quarters for the enslaved population at the William Harris Homestead.

However, some structural features may be identifiable through subsurface archaeological investigation. For instance, the outbuilding structures at site 9WN168, such as the corn crib (Figure 3.2), are constructed with stacked stone piers, partially buried into the ground, elevating the structure above the surface. The historic outbuilding's construction method may indicate how the quarters for the enslaved individuals on the property were built. Other identifiable features might include the remains of a chimney, root cellars, or "cuddy holes" used for storage (Upton 1984:61). In fact, sub-floor pits, similar to the types of storage pits identified at precontact Native American sites, are commonly associated with the households of enslaved individuals in Virginia (Samford 2007:6). If no subsurface architectural features are identifiable, material evidence such as nails, brick, mortar, etc. may reveal the location of the quarters for the enslaved individuals at the site. These smaller materials could be interpreted if there are multiple small hyperbolic single point-source reflections in the recovered data.

Figure 3.2. View of corn crib at 9WN168 and the stacked stone piers that support it, facing west (photo taken and edited by the author).

The living quarters and burials of the enslaved individuals who lived at the homestead are two key nineteenth-century features that recent archaeological investigations at the site hope to identify. The search for the living quarters of the enslaved individuals at site 9WN168 began in the summer of 2017 with a metal detector survey conducted within the southern portion of the property (Deeley 2018:4). Unfortunately, the results of the metal detector survey were inconclusive and did not reveal the potential location of the nineteenth-century structures. In early 2018, a shovel test survey was conducted along the western edge of the property

(Deeley 2018:5). The shovel test survey was also unable to identify the quarters. The shovel tests excavated recovered a historic hoe blade and no other historic artifacts were identified; however, a large amount of late 19th and early 20th century artifacts were recovered from a midden exposed by tree fall (Deeley 2018:6). Since that time, several field seasons have been conducted in the Fall of 2019, Spring of 2022, and Spring of 2023 within the western edge of the property, continuing the shovel test survey that began in 2018 (Katherine Deeley, personal communication, 2023).

The current archaeological investigations have also begun to try and locate the enslaved individuals buried at the William Harris Homestead. As noted in Chapter 2, GPR survey is particularly useful for identifying historic burial features, especially if they are otherwise unmarked or not well-maintained. The GPR investigation conducted in February 2023 by EP, sought to identify the potential burials of enslaved individuals near the family cemetery, as identified on Harris' hand-drawn map of the property (Moss 2023). GPR also can identify architectural features beneath the surface. The second GPR investigation was employed in September 2023 within the core area of the site, just west of the extant outbuildings and within view of the main house. This GPR investigation sought to try and identify remnants of the quarters for the enslaved individuals of site 9WN168, as they have yet to be identified by previous survey efforts. The results of both GPR surveys are discussed in depth in Chapters 5 and 6 as both features, the potential quarters and enslaved African American burials, are the two archaeological feature types that the GPR close transect interval methodological approach for this thesis attempted to identify.

Chapter 4: Methods for Data Collection and Processing GPR Reflection Data Gathered at Site 9WN168

Introduction

The methodological use of GPR has been discussed in Chapter 2, but the specific GPR data collection methods and processing steps used at site 9WN168, the William Harris Homestead, will be discussed in greater detail in this chapter. The field methodology used at site 9WN168, an important component of the experiment of this thesis, is outlined in this chapter along with the reflection data processing steps taken, and the different software used. Processing is of tantamount importance to the understanding of the GPR data collected as it will assist in answering the research questions posed by this thesis. The research design for the thesis employs the use of 0.25 m interval GPR transect spacing in a selected grid for two field deployments of GPR investigation at site 9WN168. Once these data sets have been initially processed, the author will reprocess the reflection data at both 0.5 m and 1 m intervals for comparison to the closer intervals and determine if GPR transect spacing interval affects the interpretation of the results of the GPR investigations. This experiment also hopes to determine if there should be a standard interval for the identification and interpretation of historic subsurface features in an agricultural landscape within the Piedmont province of the state of Georgia.

GPR Field Methodology at Site 9WN168

The GPR investigations conducted at site 9WN168 utilized a GSSI SIR 4000 equipped with a single channel 400 MHz antenna. The GPR reflection data were collected from the William Harris Homestead site over two field deployments. The purpose of the initial field deployment was to identify potential burials of enslaved individuals interred near the historic fenced-in portion of the Harris family cemetery, to keep from disturbing these grave sites during future family burials. Three rectangular GPR survey grids, Grids 1, 2, and 3, were utilized to identify potential unmarked burials of enslaved individuals surrounding the enclosed portion of the cemetery (Moss 2023:6). Known graves with grave markers were mapped in using a Juniper Geode Real-time Sub-meter GPS device to compare the anomalous reflections created by these features with potential unmarked grave features in the reflection data. Individual reflection profiles, or "B-scans" (Martin and Everett 2023:315), were also collected within the enclosed historic family cemetery at the behest of Dotty Zazworsky, a descendant of the Harris family and part of the William Harris Homestead Foundation, to look for potential unmarked graves of family members buried there (Moss 2023:1-2).

The focus of the second deployment was to identify the living quarters for the enslaved individuals who lived at the William Harris Homestead. This deployment involved the utilization of two more GPR grids, Grids 4 and 5, within the western portion of the property near the historic outbuildings but within view of the historic house, the "farm core" of the property (Deeley 2018:5; see Figure 4.1). While Grid 5 is a rectangular grid like the others used at site 9WN168, Grid 4 is a different shape than the other four grids, as it consists of two rectangular grids appended together (11 x 10 m grid combined with a 6 x 20 m grid), forming a backwards "L" shape. This was done to avoid a wooden platform, which would have served as a significant obstacle in the middle of one larger rectangular grid.

Each grid was placed based on information provided by the descendant family members of the William Harris Homestead, personal communication with Dr. Deeley, and the hand-drawn map discussed in the previous chapter (Figure 4.1). Grids were created using fiberglass metric measuring tapes with corners first marked by chaining pins and then eventually more permanently demarcated by wooden stakes. A handheld Juniper Geode GPS unit recorded the staked corners of each grid to establish its location within the site. With the GPS data, the results of each grid were georeferenced during post-processing to better establish each anomalous reflection's geographical location within site 9WN168. Each grid's dimensions, the data collection interval, and the orientation and direction of data collection are included in Table 4.1.

The reflection profiles of each grid were collected along the y-axis of the grid, north to south. Grids 1 through 3 were oriented this way to better identify graves oriented east to west, as is the "historic Christian tradition" (Moss 2023:6). The grids were collected in alternate directions starting from the southwestern corner of each grid. Figure 4.2 demonstrates the employment of alternate directions described above used in Grid 1. The green point represents the start of each line or reflection profile, while the red point represents the end of each line. Also, the transect lines starting from the southern end are green in color and those starting from the northern end are red (see Figure 4.2). Unfortunately, there were restraints to the amount of time for fieldwork, therefore, the goal of the methodological experiment was to test at least one grid at 0.25 m transect spacing intervals during each deployment. Profiles for Grids 1 and 4 were gathered along GPR transects spaced 0.25 m apart.

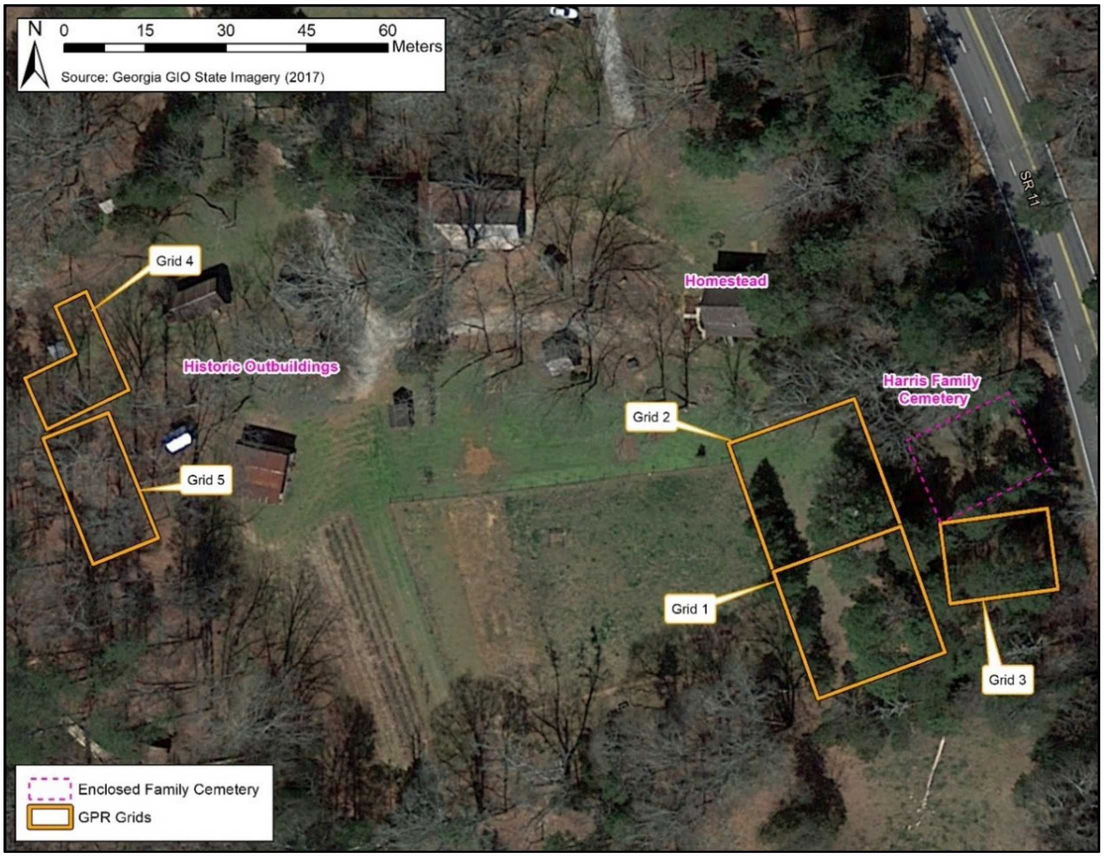


Figure 4.1. Location of GPR grids at site 9WN168.

Table 4.1. GPR Grid Attributes at Site 9WN168 (Adapted and Updated Data from Table 1 in Moss 2023:7).

Grid	Dimensions	Interval Collected	Orientation and Direction Collected
1	25 x 25 m	0.25-m Interval	North to South, Collected in Alternating Directions.
2	25 x 25 m	0.5-m Interval	North to South, Collected in Alternating Directions.
3	15 x 20 m	0.5-m Interval	North to South, Collected in Alternating Directions.
4	17 x 10-20 m	0.25-m Interval	North to South, Collected in Alternating Directions. From 10 m to 20 m along Y-Axis East to West, Collected in Alternating Directions.
5	13 x 25 m	0.5-m Interval	North to South, Collected in Alternating Directions.

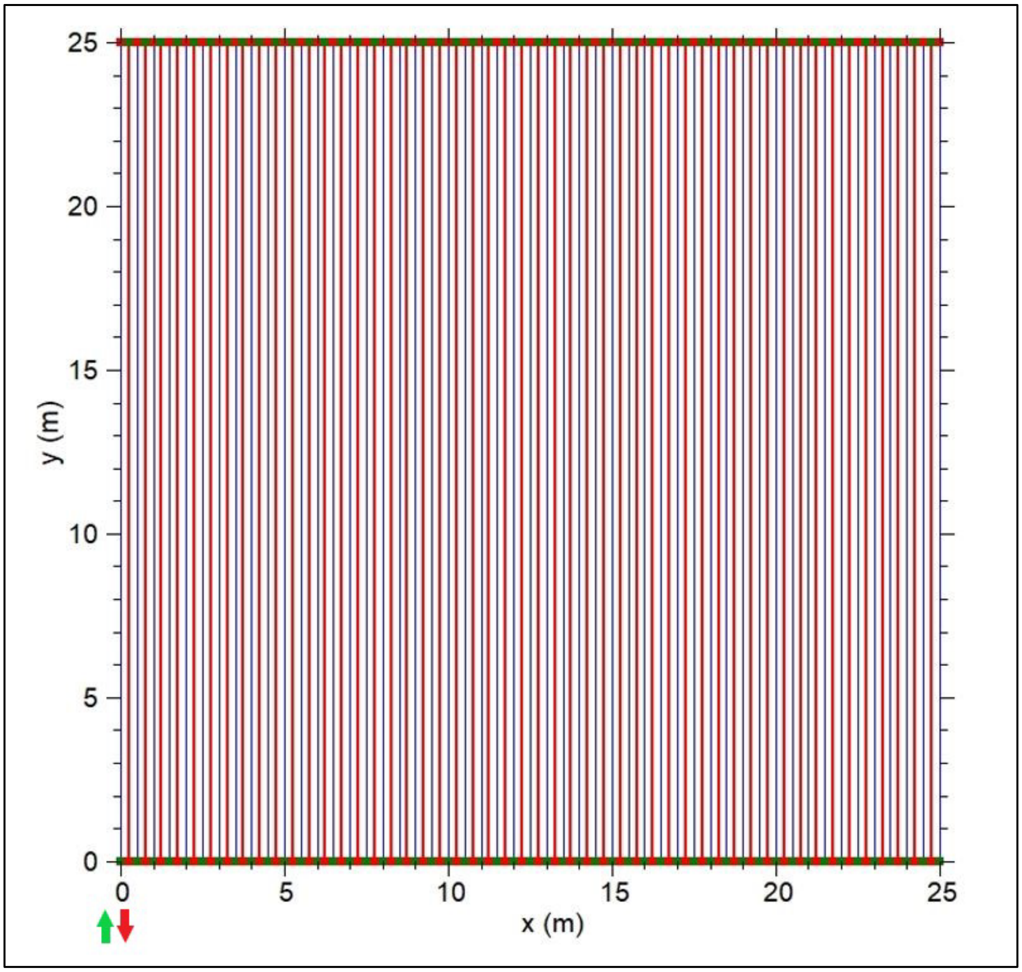


Figure 4.2. Sketch map of the orientation and direction of each GPR transect line in Grid 1.

Data sets from both Grid 1 and Grid 4 will be useful for answering the research questions proposed in this thesis, as they represent two different types of archaeological features which will provide better information in the overall usefulness of the closer interval methodological approach. The remainder of the grids were collected at 0.5-m interval, an interval typically used by Edwards-Pitman for GPR studies and is consistently used the most often in Georgia as mentioned in Chapter 2 (Elliot 2017). The grids collected at 0.5 m interval still provide useful information for the identification and interpretation of the different anomalies found at the William Harris Homestead site but cannot assist in answering the research questions this thesis presents. Additionally, to further evaluate identified targets within an area, a grid could be tested by transects that are oriented in alternate directions, such as north to south and then east to west. By examining both orientations, the GPR practitioner could potentially have two anomalous shapes to discern and evaluate, potentially providing a better interpretation. This was applied within the northwestern portion of Grid 4, which initially was covered by GPR transects from north to south, with reflection profiles additionally collected from east to west to further define anomalous reflections identified while in the field (Figure 4.3).

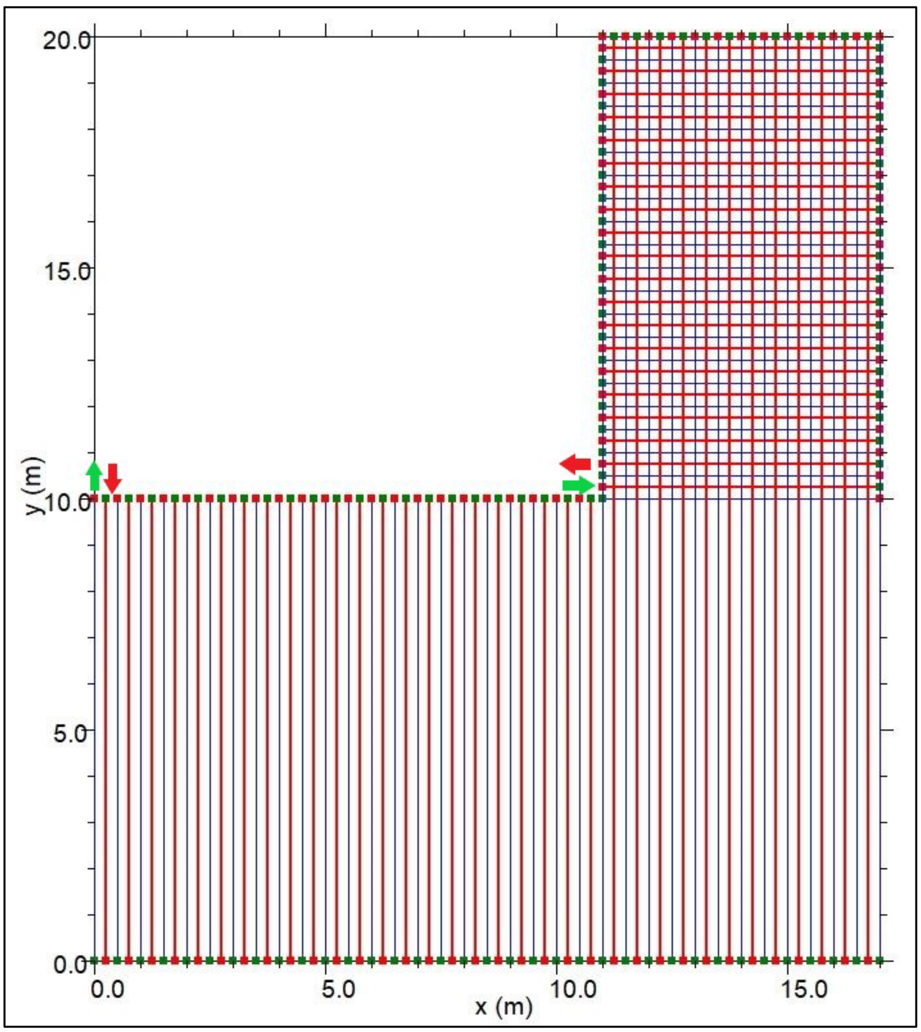


Figure 4.3. Sketch map of the orientation and direction of each GPR transect line in Grid 4.

Weather is an important consideration, both for the day of and the days preceding a field deployment. The relative dielectric permittivity (RDP) of a medium is the determining factor for the expected depth of the radar energy. The higher the water content and conductivity of the soil, the higher the RDP. Therefore, soil saturation from rain will affect the dielectric properties of the soil which would affect the depth at which the GPR signal would reach. The depth for which the data are collected is determined by the time range window in nanoseconds (ns). The time range must be adjusted on the equipment to exceed the expected depth to ensure the identification of all the desired targets (Bigman 2023). The time range of the antenna was adjusted in the field to ensure that the GPR equipment recorded data at the maximum depth possible, so the time range window was extended so that some attenuation or degradation of the signal was observed at the bottom of the scan trace, or "A-scan" (Martin and Everett 2023:315). Additionally, the survey wheel was calibrated appropriately to measure the distance the antenna has been pushed along the ground creating the reflection profile. Finally, it is important to adjust the "gains" along certain points in each scan trace to better visualize potential targets in the field (Bigman 2023).

Post-Processing

To generate a reflection profile, that lends itself to interpretation, it is often a good idea to run the raw reflection data through basic processing steps that do not generally modify or erase any reflection data collected in the field (Conyers 2012:40). The steps for processing data are "time-zero adjustments, profile axis calibrations for depth (using a calculated velocity) and horizontal distance, regaining to highlight or enhance certain amplitudes, and use of basic background removal and frequency filters" (Conyers 2012:40). These processing steps are all that are generally needed for most GPR data sets, but "more complicated processing and filtering methods" can be conducted only after the initial processing has been done (Conyers 2012:40). Removing unwanted "noise" is one of the most important elements of processing GPR data as the main aim in processing the data is to "highlight the reflections related to the target(s)" (Manataki et al. 2015:16).

Two different types of processing software were utilized to interpret and produce imagery revealing patterns within the GPR reflection data gathered from the site. Radan, the proprietary software of GSSI, was utilized for the initial processing and interpretation as it works well with the reflection data downloaded from the GSSI SIR 4000. GPR-Slice was also utilized to further evaluate and interpret the GPR reflection data gathered at site 9WN168. GPR-Slice also produces high-quality imagery which was used for graphics in this thesis. Imaging in GPR-Slice is particularly useful as it allows you to view GPR reflection data within a three-dimensional model through defined depth ranges. Specific processing steps were followed for each grid to highlight the anomalous reflections identified during the GPR investigations of site 9WN168.

The initial step involves defining the location of each individual reflection profile within a grid using the notes taken about each file while in the field. Then operators would run a time zero correction process which determines the actual start of the ground surface from where the data were collected. Next, background filtering was conducted which removes any horizontal "noise" or banding within the data set

(Moss 2023:7). Gain removal on a data set was then applied and followed by automatic gain correction. Bandpass filtering was used next to remove excess high and low frequency interference. Finally, a Hilbert transformation was utilized to determine the absolute values and create a packet or envelope of amplitudes within the data set (Moss 2023:7). To estimate the actual average soil RDP and wave velocity within the grids, hyperbola curve fitting was utilized on point-source hyperbolic reflections. This practice enhances the accuracy of the approximate depth ranges generated from the two-way reflection time. Once this was done, a series of time/depth slices were made and interpolated using an inverse distance weighting and then subsequently smoothed by lowpass filtering (Moss 2023:7). This creates the pseudo-three-dimensional data set, an amplitude map or "C-scan" (Martin and Everett 2023:315) that is viewable from its x, y, and z axis.

The reflection data were first processed for each GPR grid at the original interval in which it was gathered to identify any anomalous reflections. The anomalous reflections identified in the amplitude maps of each grid were further analyzed and compared with the two-dimensional reflection profiles that form it. These initial results will highlight each anomaly and interpretation can begin. Results along with initial interpretations will be discussed further in Chapter 5. The reflection profiles in Grids 1 and 4 were processed at three distinct line spacing intervals: 0.25 m, 0.5 m, and 1 m. This was done by only processing files located at those specific intervals within the defined coordinate system of Grids 1 and 4. This practice was done to further analyze and address the research questions posed by this thesis. Discussion and further interpretation of the results along with the additional processing and analysis of the reflection profiles and amplitude maps of Grids 1 and 4 will be analyzed and examined in Chapter 6.

Chapter 5: Results of the GPR Investigation at Site 9WN168

Introduction

The previous chapter introduced the collection methods for gathering GPR data at site 9WN168, the William Harris Homestead. This chapter will provide the results of those GPR investigations after the initial recovery and post-processing. Preliminary results of the GPR investigation conducted surrounding the enclosed Harris family cemetery were previously reported in Moss 2023, all other results related to the potential structural features associated with the living quarters for the enslaved individuals stemmed from a second GPR investigation not previously reported. In total, 28 anomalies were identified in the five grids by the GPR investigations conducted at 9WN168 (Table 5.1). These anomalies and preliminary interpretations will be discussed in further detail below.

Table 5.1. Results of the GPR Investigations at Site 9WN168 (Adapted and Updated Data from Table 1 in Moss 2023:7).

Grid	Dimensions (X-axis x Y-axis)	Time Range (nanoseconds [ns])	Radargrams/Files Collected	Total No. of Anomalies Identified
1	25 x 25 m	62.63	2-43, 45-67, 69-104 (101 Total)	8
2	25 x 25 m	62.63	105-155 (51 Total)	9
3	20 x 15 m	62.63	157-170, 172-198 (31 Total)	5
4	17 x 10-20 m	61.28	13-34, 36-49, 51-124 (110 Total)	5
5	13 x 25 m	61.28	129-133, 135-156 (27)	2

GPR Investigation to Locate Burials of Enslaved Individual at Site 9WN168

Three GPR grids were established surrounding the enclosed family cemetery. Grids 1 and 2 were placed adjacent to one another, west of the enclosed portion of the family cemetery where known marked interments are located. Grid 3 was placed to the south of the enclosed portion of the cemetery in an area with no known or marked burials (see Figure 4.1). The dimensions of each grid are included in the overall results table above (see Table 5.1). Vegetation within Grids 1 and 2 consisted of manicured grasses with planted trees (Figure 5.1) and Grid 3 consisted of a small copse of mixed hardwoods (Figure 5.2). The southwestern corner of each grid served as the starting point for recording reflection profiles or Radargrams.

Figure 5.1. Overview of Grids 1 and 2 from the southeastern corner of Grid 1, facing northeast (photograph taken by the author).

Figure 5.2. Overview of Grid 3 from the southeastern corner, facing northeast (photograph courtesy of Edwards-Pitman, Inc.).

Grids 1, 2, and 3 were surveyed in alternating directions at consistent GPR line intervals. Grid 1 was surveyed in the field in 0.25 m intervals and Grids 2 and 3 were surveyed in 0.5 m intervals. The soil was considered to be of average condition and the original dielectric constant for the unit was set at 14, fairly typical of soils with a high clay content. The maximum depth range was set at 2.25 m with a two-way travel time or time range of 62.4 ns (see Table 5.1). Manual gain was applied along the scan trace or "A-scan" (Martin and Everett 2023:315) along seven points. Finally, the investigators calibrated the survey wheel for the distance of 25 m, the length of one reflection profile along the Y-axis of Grids 1 and 2.

The results of the first deployment depict anomalous reflections in a georeferenced plan view or amplitude map, however, it should be asserted that the location of the mapped anomalies is approximate. The method of the georeferencing imagery in ArcMap is not fully precise, therefore, the location of anomalies may be up to a meter or two off in some cases. The measurements of each anomaly's size and dimensions are, therefore, also approximate. The only confirmed way to determine the nature of each anomaly is through ground truthing. These depictions illustrate the anomalous reflections mapped across each grid based on their depth (Moss 2023:9). Regarding the anomalous reflections identified at depths ranging from 0 to 30 cmbs, the original letter report states that “these depth slices produced a cacophony of reflections interpreted as primarily roots or other shallow disturbances, and therefore no anomalies were mapped in this data set” (Moss 2023:9), referring to shallow-depth anomalies. Essentially, the roots and potential loss of antenna contact with the ground caused disruptions in the data creating “noise” in the shallower depths of the data set. All of the anomalies identified with the first field deployment were identified at depths from 50 to 110 cmbs (Figure 5.3).

In total, 21 anomalous reflections were identified and interpreted during the first deployment. Some of these anomalous reflections were considered the result of several natural and artificial disturbances within the gridded areas, such as tree roots and buried waterline utilities. Others were the result of known burial features that were marked by headstones (see Figure 5.3). All anomalies identified and their initial interpretations are detailed in Table 5.2 (adapted and from Moss 2023:9). The table

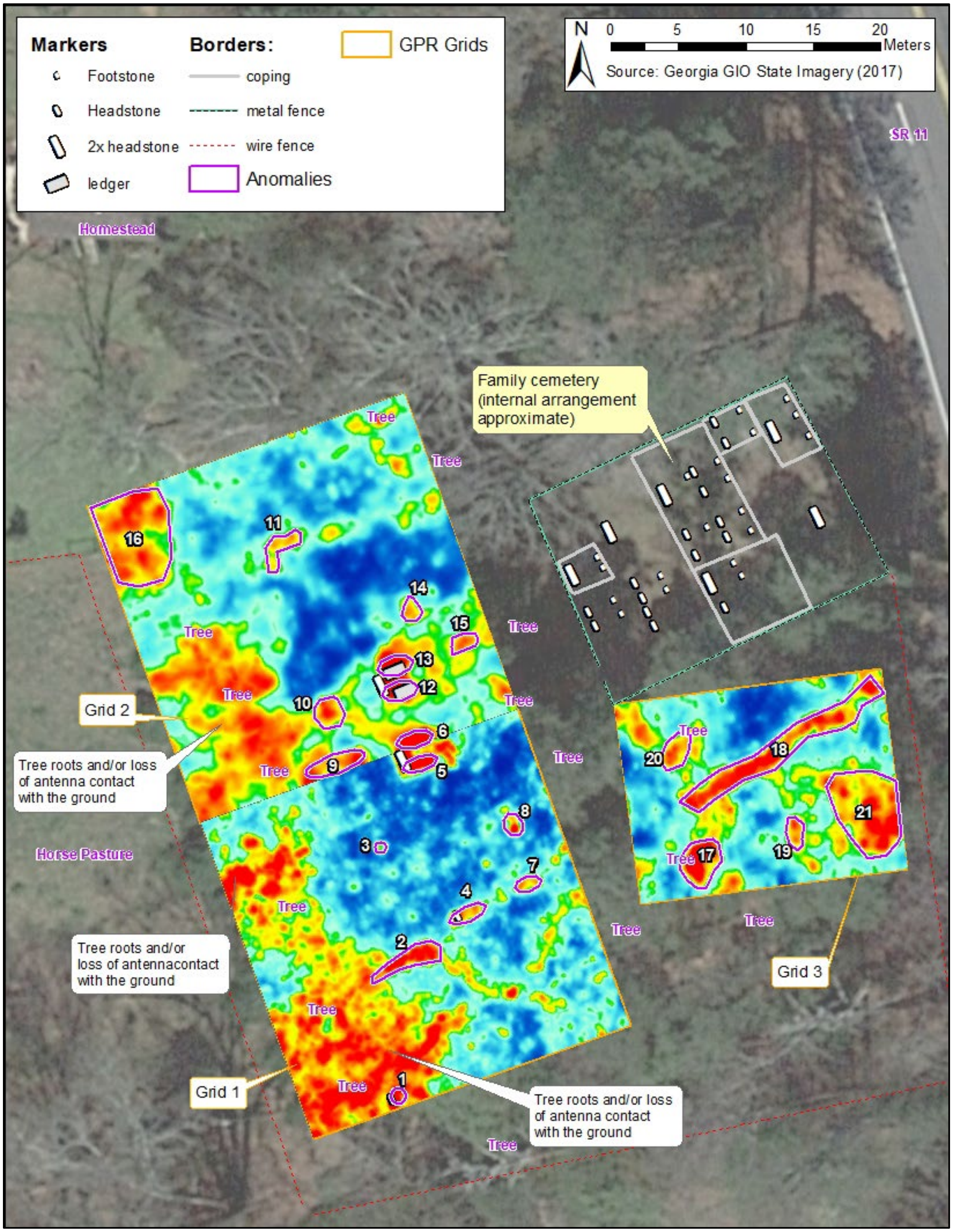


Figure 5.3. Grids 1 through 3 results from 50 to 100 cmbs (Adapted and Updated from Figure 7 in Moss 2023:11).

Table 5.2. Summary of Anomalies Identified in Grids 1 through 3 (Data and Findings Adapted from Table 2 in Moss 2023:9).

Anomaly	Local X, Y Coordinate (Approximate Position in m)	Z Coordinate (Approximate Depth in cm)	Approximate Dimensions (m)	Interpretation
Grid 1				
1	6.5, 1	35-100	1 x 0.75	Known Marked Urn Burial
2	11.75, 10	80	4 x 2	Potentially a Water Line
3	11.75, 18	75	0.25 x 0.25	Faint/Unknown
4	16.5, 12	40-60	2.5 x 1.5	Known Marked Grave
5	16.5, 24	40-100	3 x 1.5	Known Marked Grave
6	16.5, 25	40-100	3 x 1.5	Known Marked Grave
7	21.75, 13	80	2 x 1	Unknown
8	21.75, 16.5	105	1 x 2	Unknown
Grid 2				
9	11.5, 1	35	5 x 1	Likely Roots/Unknown
10	11.5, 5	75-90	2 x 2	Likely Roots/Unknown
11	12.5, 18	66	3 x 1	Likely Roots/Unknown
12	17, 4	0-100	2.5 x 1.5	Known Marked Grave
13	17, 6	0-100	2.5 x 1.5	Known Marked Grave
14	20, 10	45	2 x 2	Likely Roots/Unknown
15	22.5, 5.2	40	2 x 1.5	Likely Roots/Unknown
16	1, 20	95-100	5 x 6	Irregular Reflections- Potentially Former Tree/ and/or Privy?
Grid 3				
17	4.5, 2.5	50-100	3.5 x 3	Unknown Large Disturbance (Potentially a Tree)
18	4.5, 15; 12, 10; 20, 7	50-80	16 x 1-1.5	Long Linear Feature (Potential Water Line)
19	15, 5	75	1 x 3	Potentially Rocks/Unknown
20	4, 10.5	70	4 x 2	Likely Roots/ Unknown
21	18, 4	N/A	4 x 5.5	Probable Interference from Telephone Pole Wire or Fence

provides a detailed summary of each anomaly identified within Grids 1 through 3. The X-coordinate is the starting point of each reflection profile along the Y-axis. The local Y-coordinate is the approximate location on the reflection profiles that form the horizontal plan view of the three-dimensional time-slice or amplitude map. The Z-coordinate is the approximate depth each anomaly was found, which was calculated by determining the appropriate RDP of the gridded area measuring the two-travel time of the radio wave. Unknown reflections identified are likely associated with roots, but other possibilities could be likely (Moss 2023:15). No potential unmarked graves were identified during this GPR investigation.

GPR Investigation to Locate the Living Quarters of the Enslaved Individuals at Site 9WN168

On September 9, 2023, a GPR investigation was conducted to search for the living quarters of the enslaved individuals of the William Harris Homestead. Two GPR grids were established to the west of extent outbuildings on the western portion of the William Harris homestead property (see Figure 4.1). The dimensions of each grid were previously discussed in Chapter 4 but are included in the results table found in the introduction of this chapter (Table 5.1). Vegetation within Grid 4 consisted of manicured grasses north of the tree line of a copse of hardwood forest (Figure 5.4) and Grid 5 consisted of a light density of hardwoods (Figure 5.5). A wooden platform was located within the northwestern portion of Grid 4, resulting in the backwards "L" shape discussed in Chapter 4 (see Figure 5.4). The southwestern corner of each grid served as the starting point for recording each reflection profile, however, a portion of the profiles were collected along the x-axis in Grid 4, starting on the western side of the grid along the Y-axis at 10 m (see Figure 4.3).

Figure 5.4. Overview of Grid 4 from the southeastern corner of Grid 4, facing northeast (photograph taken by the author).

Grids 4 and 5 were surveyed in alternating directions at consistent GPR line intervals. Grid 4 was surveyed in the field in 0.25 m intervals and Grid 5 was surveyed in 0.5 m intervals. The soils retained a higher moisture content than soils in the first deployment due to a recent rain, so the dielectric constant for the unit was set at 20 during fieldwork. The maximum depth range was set at 1.85 m with a two-way travel time or time range of 61.28 ns (see Table 5.1). Manual gain was applied along the A-scan along seven points. Finally, the investigators calibrated the survey wheel for the distance of 10 m, the length of one reflection profile along the Y-axis of Grid

4 and then again for a distance of 25 m, the length of one reflection profile along the Y-axis of Grid 5.

Figure 5.5. Overview of Grid 5 from the southwestern corner of Grid 5, facing northwest (photograph taken by the author).

Grids 4 and 5 were surveyed in alternating directions at consistent GPR line intervals. Grid 4 was surveyed in the field in 0.25 m intervals and Grid 5 was surveyed in 0.5 m intervals. The soils retained a higher moisture content than soils in the first deployment due to a recent rain, so the dielectric constant for the unit was set at 20 during fieldwork. The maximum depth range was set at 1.85 m with a two-way travel time or time range of 61.28 ns (see Table 5.1). Manual gain was applied along the A-scan along seven points. Finally, the investigators calibrated the survey wheel for the distance of 10 m, the length of one reflection profile along the Y-axis of Grid

4 and then again for a distance of 25 m, the length of one reflection profile along the Y-axis of Grid 5.

The results of the second deployment are represented by anomalous reflections in a georeferenced amplitude map. It should once again be noted that the location and dimensions of the mapped anomalies are entirely approximate since the time-slice imagery has been georeferenced, which involves manually placing imagery into a map placing points of reference. Ground-truthing is the most accurate way to confirm the true nature of anomalous reflection identified by GPR. Anomalies were identified within Grid 4 at depths of 30-65 cmbs and two anomalous reflections in Grid 5 from 0-35 cmbs (Figure 5.6). At times, the roots and potential loss of antenna contact with the ground caused disruptions in the data creating “noise” in the data set which were not considered to be anomalous reflections. In total, 7 anomalous reflections were identified and interpreted. All anomalies identified and their initial interpretations are detailed in Table 5.3. The table provides a detailed summary of each anomaly identified within Grids 4 and 5. This GPR investigation identified four to five potential structural features in Grid 4. However, the results of this GPR investigation are not conclusive regarding whether these marked anomalies represent actual structural features. A more thorough discussion of the interpretation of these anomalous reflections identified during both field deployments of the William Harris Homestead site is presented in Chapter 6 along with representative radargrams of these anomalies denoting a profile view of potential features identified. Chapter 6 also analyzes and evaluates the tested GPR transect intervals in Grids 1 and 4 as previously discussed in Chapter 4.

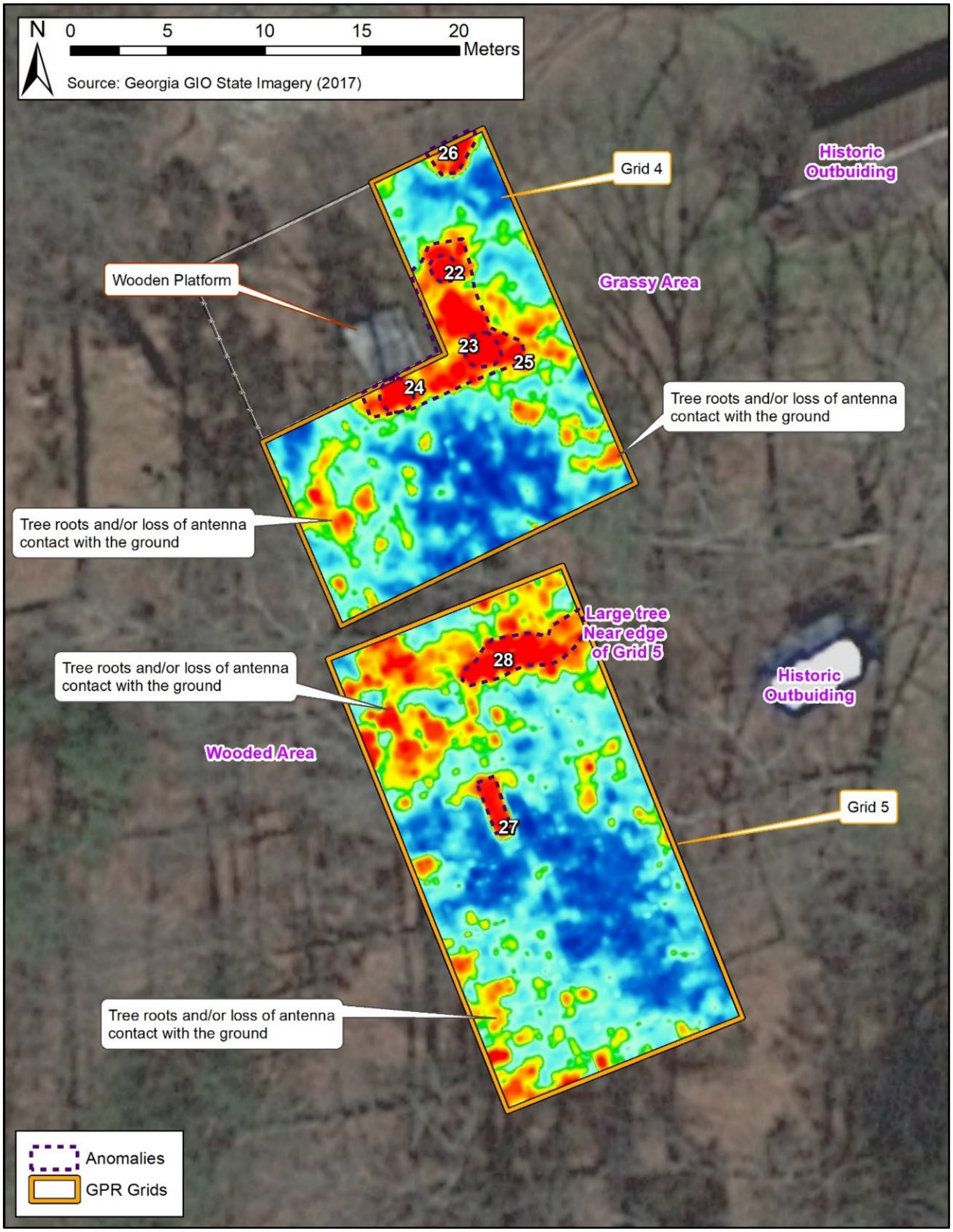


Figure 5.6. Grid 4 results from 30 to 65 cmbs and Grid 5 results from 0-35 cmbs (Figure created by the author).

Table 5.3. Summary of Anomalies Identified in Grids 4 and 5 (Table Created by the Author).

Anomaly	Local X, Y Coordinate (Approximate Position in m)	Z Coordinate (Approximate Depth in cm)	Approximate Dimensions (m)	Interpretation
Grid 4				
22	12.25, 14	30-55	1 x 1.5	Potential Structural Feature
23	11.75, 9.5	35-55	1.5 x 2	Potential Structural Feature
24	7.5, 9	35-90	1 x 1	Potential Structural Feature
25	6.25-14.5	20-65	7 x 8	Potential Compacted Surface
26	15, 9	35-60	2 x 4	Potential Compacted Surface, Corner of Something Larger
Grid 5				
27	5, 15	0-15	4 x 1	Known Raised Garden Bed
28	9.5, 21	25-110	5 x 3	Unknown Large Disturbance, Likely Large Tree Root

Chapter 6. Analysis of Interpreted Anomalies at the William Harris Homestead Site and Evaluation of the GPR Transect Spacing Intervals in Grids 1 and 4

Introduction

The previous chapter discussed the results of the two GPR investigations at the William Harris Homestead. The results included the number of anomalies identified for each investigation and a brief interpretation of each anomalous reflection. This chapter will begin by discussing specific anomalies in more detail and providing further interpretation of what they potentially represent. As discussed in Chapter 5, no anomalous reflections that appeared to pertain to unmarked burials of the enslaved residents of site 9WN168 were identified during the GPR investigation near the family cemetery in Grids 1 through 3. However, this chapter will discuss what characteristics were evaluated and compared to existing known burials represented in the reflection data and attempt to interpret one unknown anomalous reflection identified based on these characteristics. The second GPR investigation identified anomalous reflections of potential structural features in Grid 4. Their interpretation will be discussed in greater detail, as well as implications for future archaeological excavation at site 9WN168. Finally, using the reflection data gathered from Grids 1 and 4, the author will compare the different time-slice or amplitude maps generated by the GPR transect intervals spaced at 0.25, 0.5, and 1 m apart and evaluate each tested interval's use when interpreting results at site 9WN168.

Interpretation of Results for the Cemetery Investigation

The grave shaft is often the most discernable feature for GPR to identify. The grave shaft is created by the initial excavation and backfilling of the interment (Conyers 2006:66). The differences in the soil stratigraphy and natural characteristics of the surrounding “undisturbed soil” can be visible in the reflection data of GPR (Moffat 2017:47). The backfill returned to the grave with its stratigraphy disturbed by the excavation process, the backfilled sediment begins to “settle” often creating a depression on the surface, but “also producing settling structures within the shaft that can be distinctive” (Conyers 2006:66). These distinctive structures in a burial shaft are the result of differences in compaction of the soils and moisture content (Damiata et al 2013:269).

Investigators can make interpretations about the burials within a cemetery based on the type of reflection signal received by the GPR system. For instance, metal and lead-lined caskets create “hyperbolic reflections” and “distinct stacked reflections” in a sequence underneath the peak of the hyperbola (Conyers 2006:70). “Narrow hyperbolas” are usually the result of caskets constructed from wood or are the “void spaces” from caskets that have buckled, and “smaller” hyperbolas are generally the result of child interments (Conyers 2006:70). In graves where there are no caskets or the wooden caskets have deteriorated, no obvious hyperbolas are made in the reflection data which results in the “truncation of the undisturbed joining material”, resulting in a pillar-like “slump” in the soils near the surface (Conyers 2006:70). GPR may even be able to detect skeletal remains of graves without a casket due the “contrast between bone and backfill materials” (Dimiata et al 2013:269).

Examples of what grave-like anomalies look like in GPR data are represented in Grid 1. Anomalies 4, 5, and 6 each were identified in Grid 1 where known modern graves existed outside of the enclosed historic Harris family cemetery (Figure 6.1). All three are depicted in the reflection profile of the radargram from file 073 along X-Coordinate 17.25 m (Figure 6.2). Anomalies 5 and 6 appear to represent burials with metal caskets as not only the top and bottom of the reflections are visible, but the "distinct stacked reflections" (Conyers 2006:70) are evident. These reflections stacked on top of each other close together is also known as a "ringing" effect which results from the electromagnetic wave hitting a metal object effectively making it another "antenna" emitting its own waves back up to the receiving antenna of the GPR (Bigman 2023). Anomaly 4 represents a potential deteriorated wooden casket (see Figure 6.2). The top and the bottom of each anomaly are evident for each, which likely highlights the top and bottom of the caskets at the known burial locations.

As noted in the original letter report, the GPR investigation surrounding the enclosed Harris family cemetery resulted in the identification of no potential unmarked burials of enslaved individuals, "however, this does not prove their absence" (Moss 2023:15). The population of enslaved individuals at the William Harris Homestead was not as large as some populations found at bigger farmsteads or plantations and it is also unclear how many of those individuals passed away while living at the homestead (Moss 2023:15). Since there were so few individuals, burials may not have been performed in distinctive rows or patterns similar to the rest of the known burials surrounding the enclosed cemetery. Depending on the age of a burial or those buried without caskets, the amplitude of the reflections may not "contrast as strongly as the modern graves in the same grids" (Moss 2023:15).

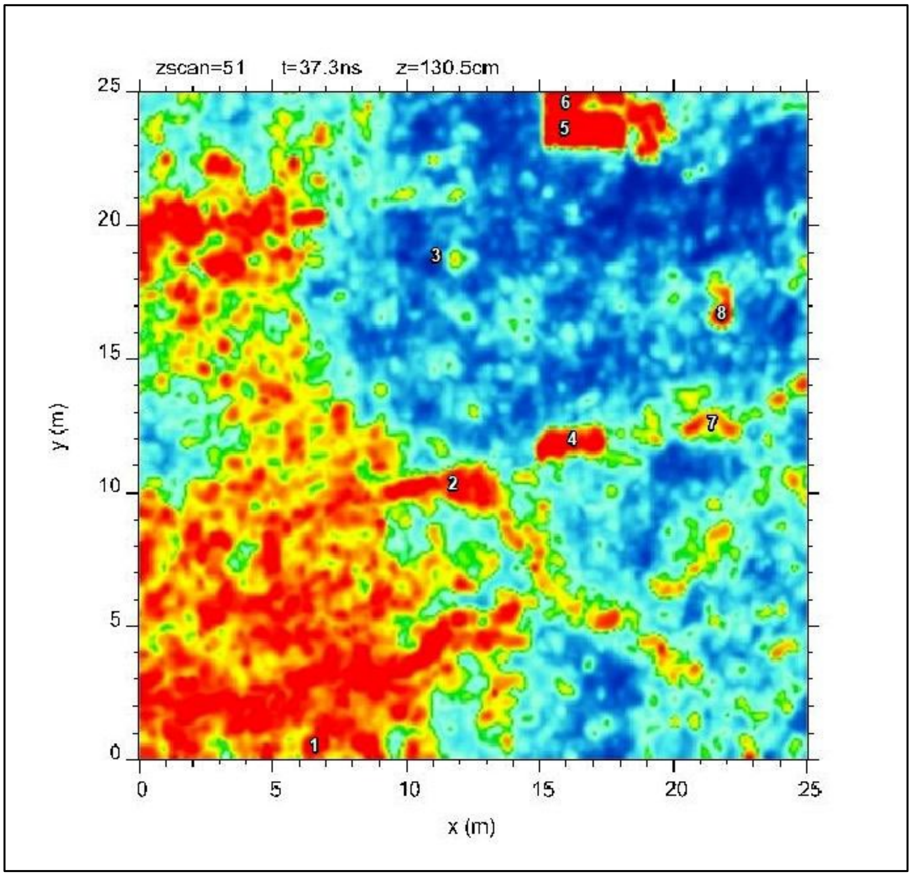


Figure 6.1. Amplitude map of Grid 1 illustrating anomalies identified from 55 to 150 cmbs.

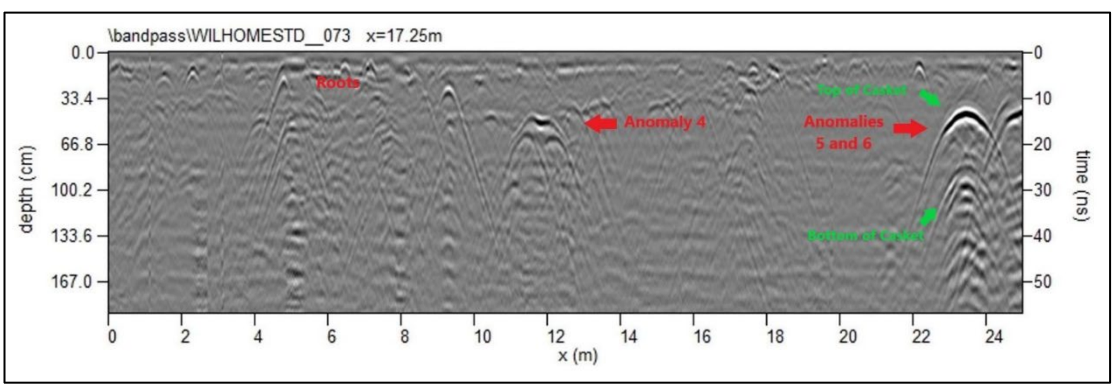


Figure 6.2 Radargram illustrating Anomalies 4, 5, and 6 in Grid 1.

One of the more interesting anomalies marked as "unknown" in the original letter report (Moss 2023:9) consists of something smaller than a grave that was buried approximately 100 cmbs. Anomaly 8 was identified to the southeast of Anomalies 5 and 6. This anomaly is depicted best in the reflection profile of the radargram from file 091 approximately 17 m along the transect of X-coordinate 21.75 m (Figure 6.3). The anomaly measures approximately 2 m north to south and 1 m east to west, which is smaller than the known graves. However, based on the amplitude map (see Figure 6.1), the buried anomalous reflection is oriented north to south, unlike burials of the Christian tradition. This does not completely rule it out as being a potential interment, however, other characteristics would suggest that this interpretation is unlikely.

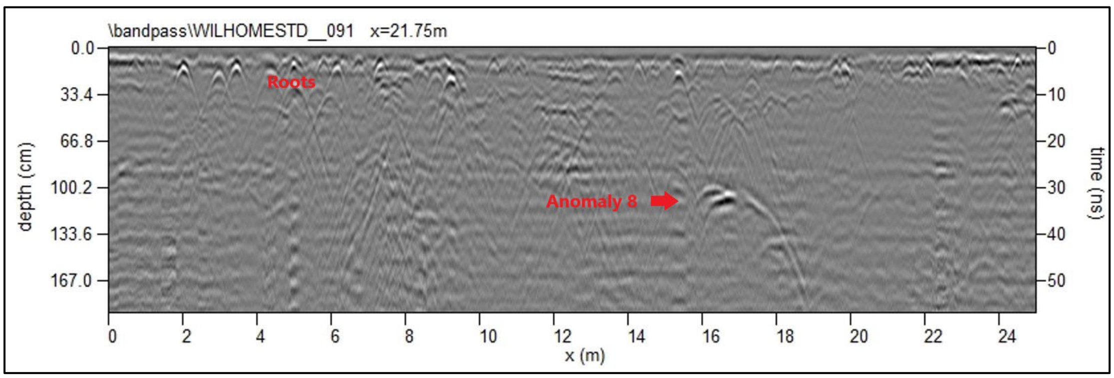


Figure 6.3. Radargram illustrating Anomaly 8 within Grid 1.

While there is an obvious hyperbola highlighting Anomaly 8 (see Figure 6.3), there is no additional hyperbola underneath to indicate the bottom of a potential casket. If this were a burial with no casket, there is none of the expected "truncation" (Conyers 2006:70) in the surrounding medium of the soil matrix. Coinciding with the existence of the point-source reflection makes this buried anomaly much less likely to be the location of an unmarked grave. All in all, this anomalous reflection is peculiar, but interpretations of what it could be are inconclusive. It could be the result of any type of potential buried object, natural or man-made. Ground-truthing the anomaly would be the only approach to truly determine what the buried anomalous reflection represents. Future users of this portion of the property would be wise to exercise caution if conducting any ground-disturbing activities in this area.

Interpretation of Results for the Potential Living Quarters GPR Investigation

Anomalies potentially associated with structural features could range in variation of size, orientation, and type. As noted in Chapter 3, potential structural features identified by GPR might have been partially buried in the ground, such as foundational piers or chimneys. There also could be the potential for sub-floor storage pits that would have been located under the structure (Samford 2007). Since structural features vary in size, they have the potential to be much smaller than the burials that the previous investigation hoped to identify, but they also could be the largest. Since their size, shape, and type often vary more than targeted burial features, anomalies with a potential association to structural features provide an interesting variable to assess regarding the GPR transect spacing intervals.

Five anomalous reflections identified in Grid 4 have the potential to be related to structural features in association with the razed living quarters for the enslaved individuals at site 9WN168 (Figure 6.4). Three of the anomalous reflections in Grid 4, Anomalies 22, 23, and 25, provide the best example of these types of features. These anomalies are depicted in the reflection profile of the radargram from file 064 along the transect of X-coordinate 12.25 m (Figure 6.5). The amplitude map of Grid 4 shows that from a depth of 30 to 65 m, Anomaly 25, a rectilinear layer-like or planar anomalous reflection, measuring about 7 x 8 m is apparent in the data (see Figure 6.4). This anomaly is partially obscured by the area under the platform where no reflection data were gathered. This anomaly is most discernable in the profile between the other two distinct anomalous reflections (see Figure 6.5). Anomaly 25 could represent an original ground surface beneath a structure raised on piers, which was compacted with gravel or clay under the construction of a small building. Compaction is just a supposition but could explain the resulting higher amplitude reflection within the surrounding soil matrix. A similar anomalous reflection was identified in the northeastern portion of Grid 4, Anomaly 26. However, this appears to be only the corner of something bigger as the rest of the buried anomalous reflection appears to fall outside of the limits of Grid 4.

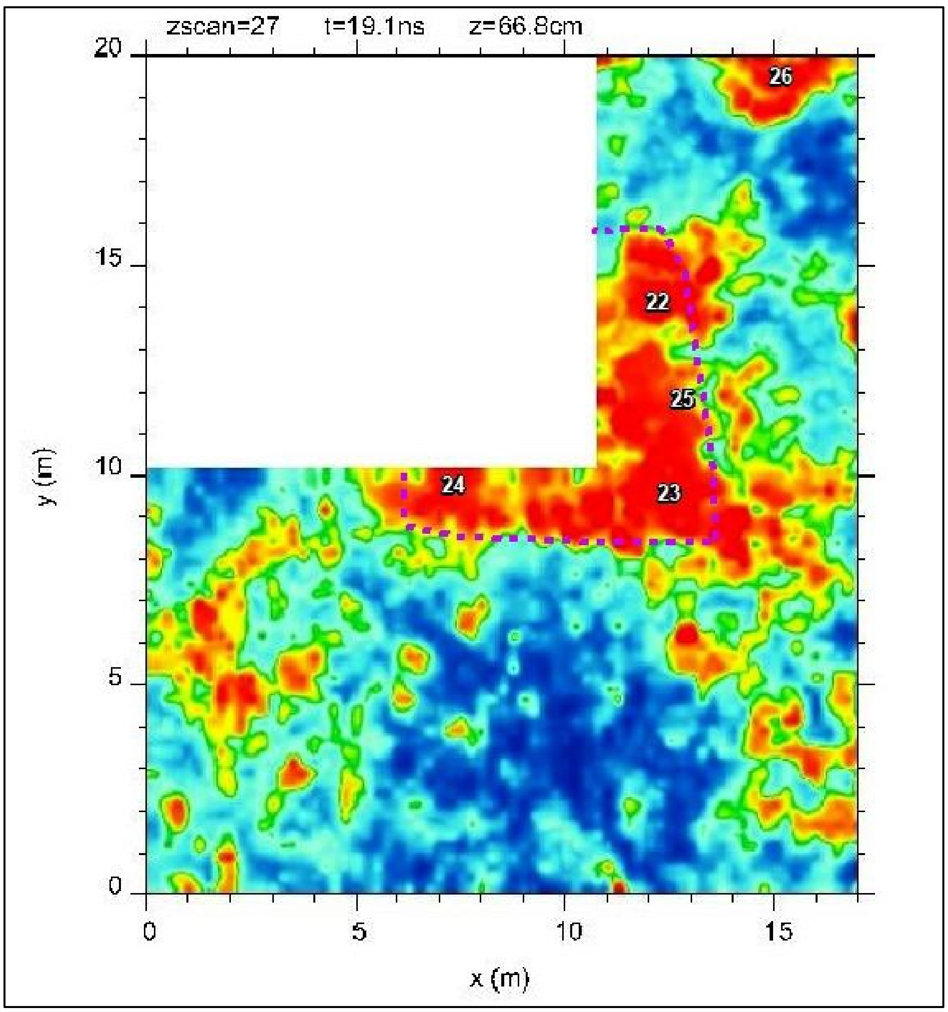


Figure 6.4. Amplitude map of Grid 4 illustrating anomalies identified from 30-65 cmbs**.**

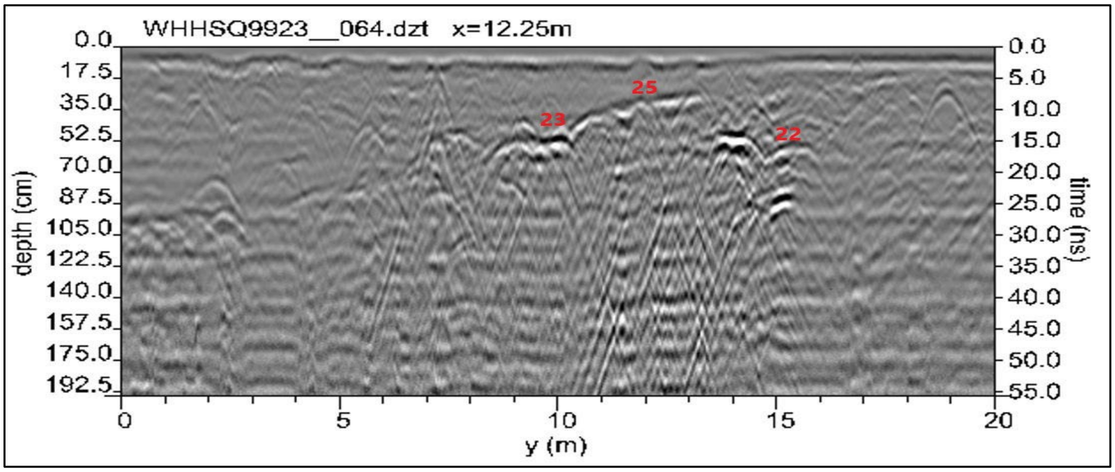


Figure 6.5. Radargram illustrating Anomalies 22, 23, and 25 within Grid 4.

Within Anomaly 25 are a couple more discrete anomalies that potentially could relate to structural features. Two somewhat circular anomalous reflections appear to straddle the edges of the compacted planar reflection designated as Anomaly 25 (see Figure 6.5). In the depicted amplitude map of Grid 4, these two anomalous reflections both register at higher amplitudes than Anomaly 25. They each present several smaller hyperbolic reflections within a well-defined planar reflection (Anomaly 25). Anomaly 22 presents as a hyperbola with the highest amplitude and is the most well-defined in the amplitude map (see Figure 6.4). Possible interpretations of the anomalies would be their resemblance to potential remnants of stone-stacked foundational piers along outer walls, chimney features, or even storage pits. In this same profile (see Figure 6.5), other shallow point-source reflections from discrete objects are present. If the interpretation is correct that the anomalies identified in Grid 4 are potentially related to structural features, these discrete reflectors could be related to building materials, such as bricks, rocks, or nails. Similar discrete reflectors show what could be potentially a few isolated bricks or stones in the reflection profile of the radargram from file 066 along X-coordinate 12.75 m (Figure 6.6). Additionally, the reflection profile for file 077 shows a particularly strong shallow reflection that could represent a metallic object, as there is an evident "ringing" effect occurring as described in the previous section (Figure 6.7). This profile also highlights the start of Anomaly 26 as well as a point-source reflection potentially buried under fill.

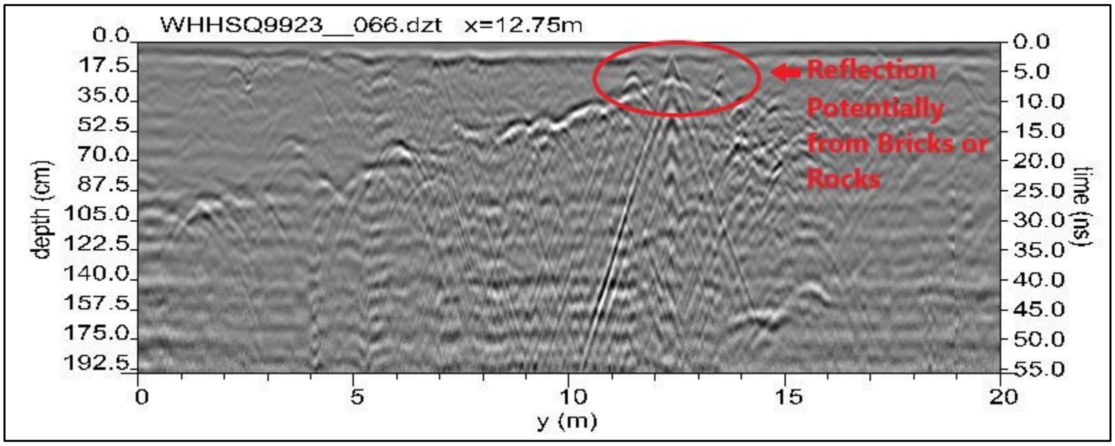


Figure 6.6. Radargram illustrating potential stones or bricks used as building materials.

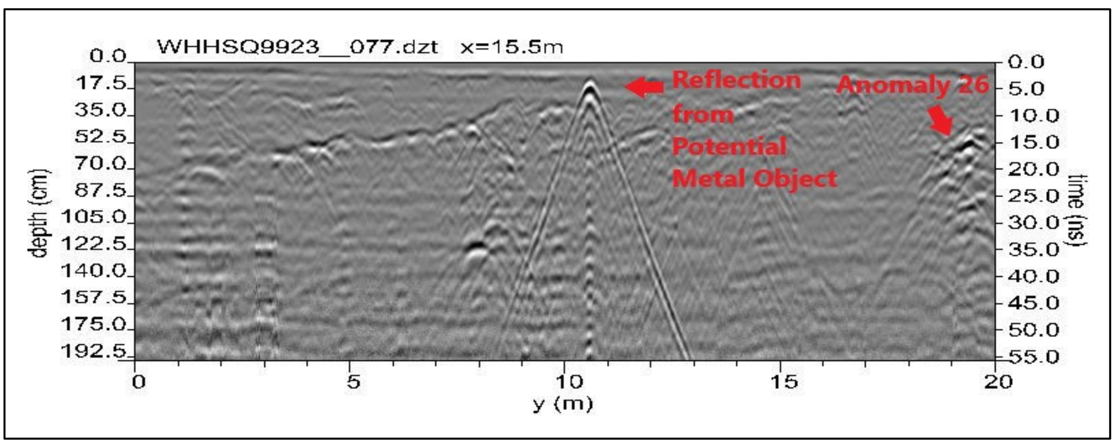


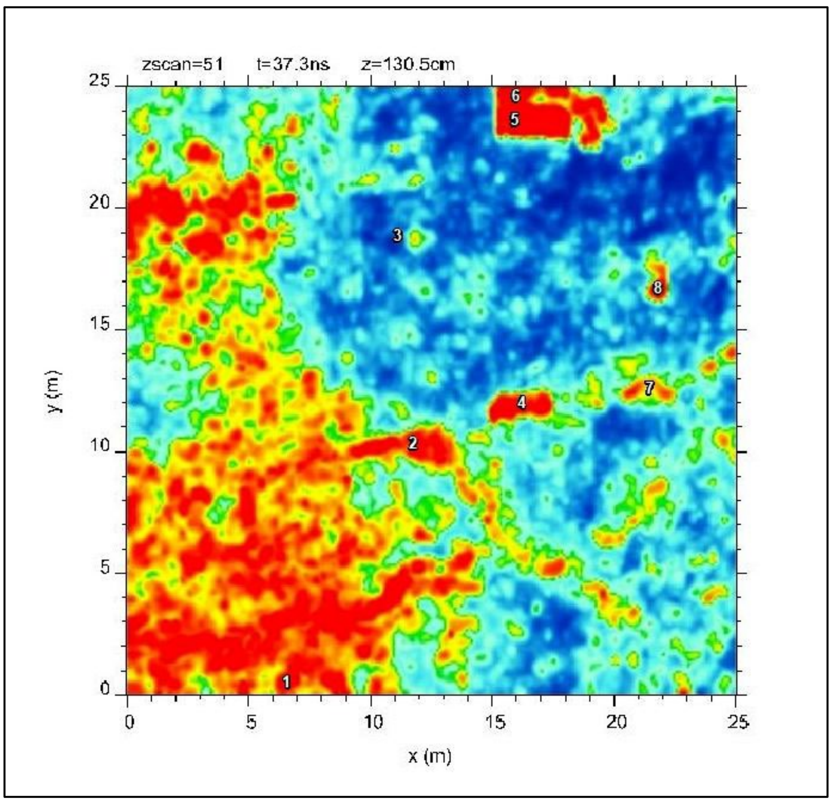
Figure 6.7. Radargram illustrating a potential metal object used as building materials and Anomaly 26.

Upcoming archaeological investigations at the site in the Spring of 2024, to be led by Katheryn Deeley of Georgia Gwinnett College, intend to ground-truth Anomaly 22 and the small portion of Anomaly 25 surrounding it. Anomaly 22 is particularly well-defined in both the reflection profiles and amplitude map of Grid 4. This author would argue that Anomaly 22 is the anomalous reflection with the greatest potential to yield an archaeological feature, possibly related to the living quarters for the enslaved individuals at the William Harris Homestead. However, this ground-truth examination does not change the results of the methodological experiment performed at site 9WN168, which sought to understand potential differences in the clarity and accuracy of the reflection data gathered at the William Harris Homestead and whether this ultimately affects the interpretation of the results. This is especially true regarding Grid 1, which resulted in anomalous reflections associated with known marked burials.

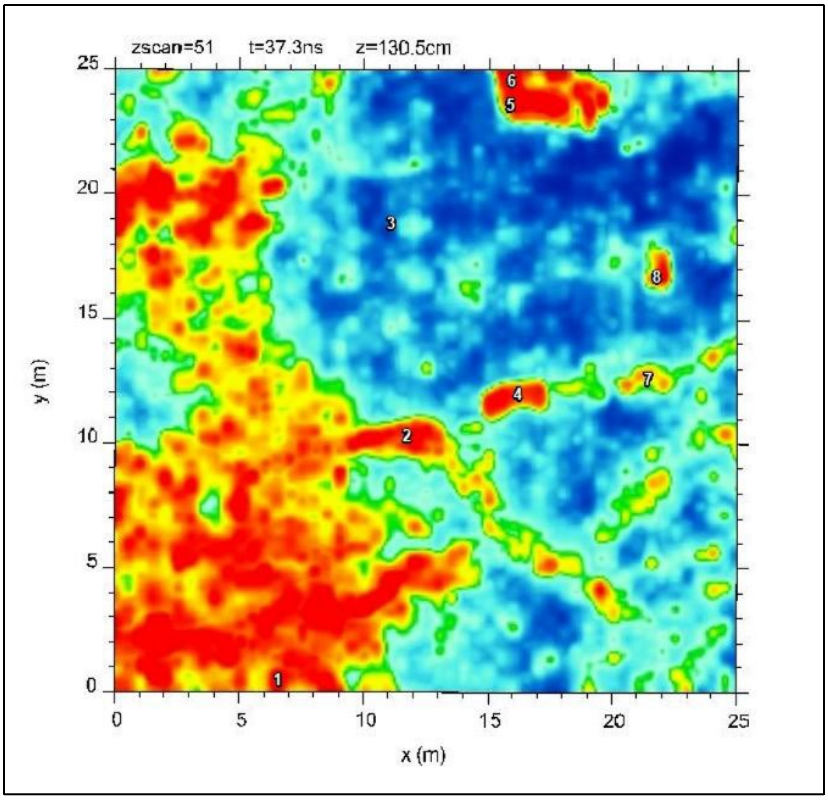
Evaluating GPR Transect Interval Spacing at the William Harris Homestead

This discussion is best opened with a comparison of Grid 1's and Grid 4's results at the different proposed GPR transect intervals of 0.25, 0.5, and 1 m. Figures 6.8 and 6.9 consist of amplitude maps from both Grid 1 and Grid 4 illustrating the depths at which important anomalies were identified at the tested GPR transect line intervals. Starting with Grid 1 (Figure 6.8) it is evident that the resolution of the data is highest at 0.25 m interval and lowest at 1 m interval. This lower resolution at 1 m results in a rounding-off of the identified anomalous reflections as they appear more ovular and less angular than the same anomalous reflections identified at 0.25 or 0.5 m intervals (see Figure 6.8). Every identified anomaly is visible at all selected intervals except for

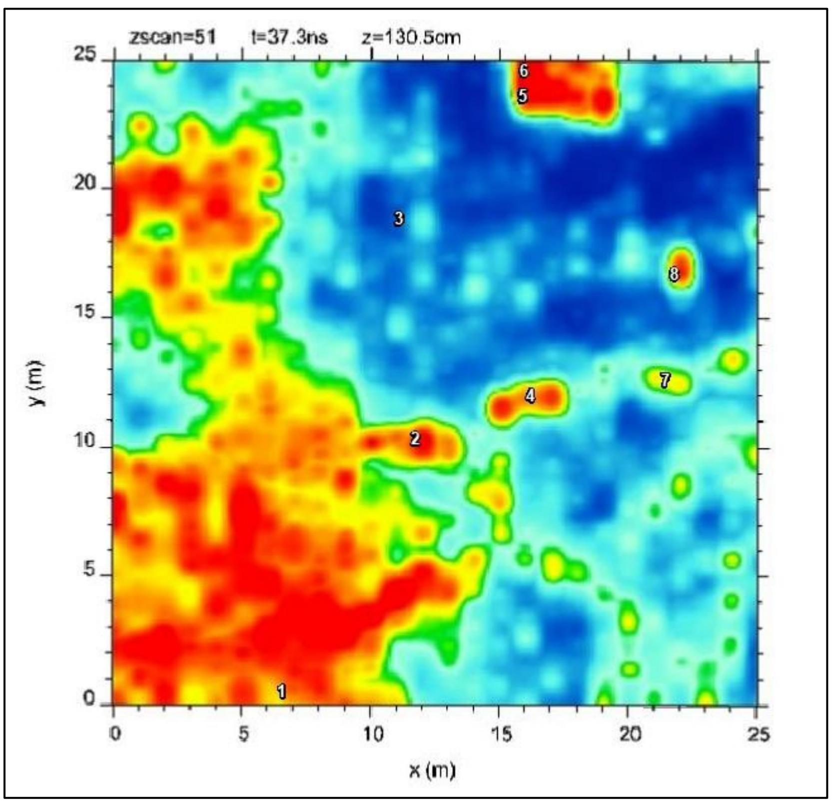
Anomalies 3 and 7, which are less apparent at the wider intervals appearing at a lower amplitude than other identified anomalous reflections (see Figure 6.8). Anomalies 3 and 7 were not suspected to be features related to the burial of enslaved individuals living at the homestead, but their lack of visibility at wider intervals could be a problem if no additional care were applied to these locations or regarded as devoid of any possibility for burials. However, only Anomaly 3 could have potentially gone unnoticed at wider intervals as it was already reading as low amplitude at 0.25 m interval.



(A)



(B)

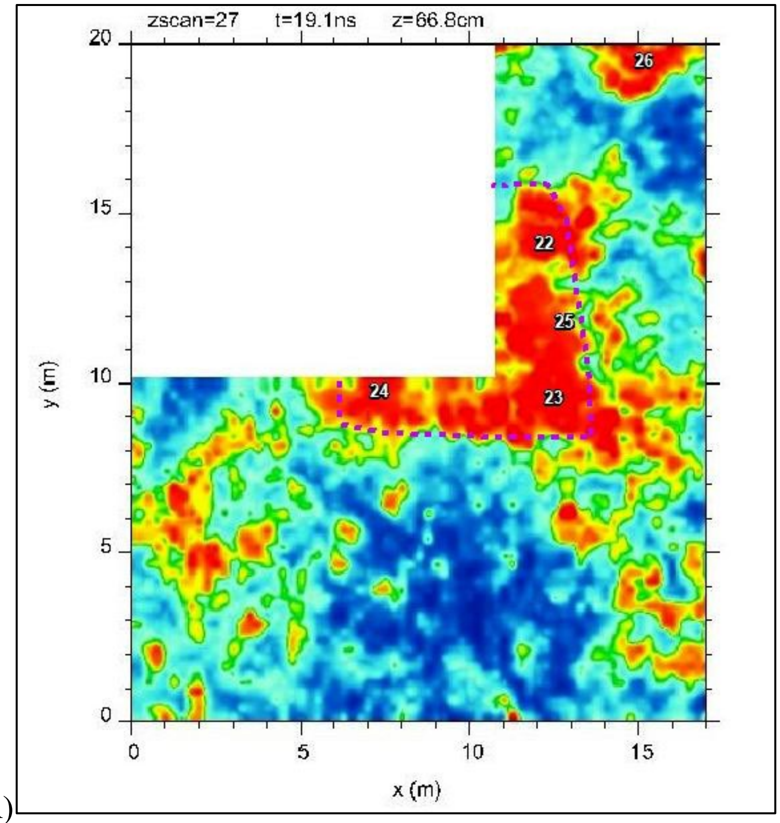


(C)

Figure 6.8. GPR results in the amplitude map of Grid 1 from 55-130 cmbs at 0.25 m interval (A), 0.5 m interval (B), and 1 m interval (C).

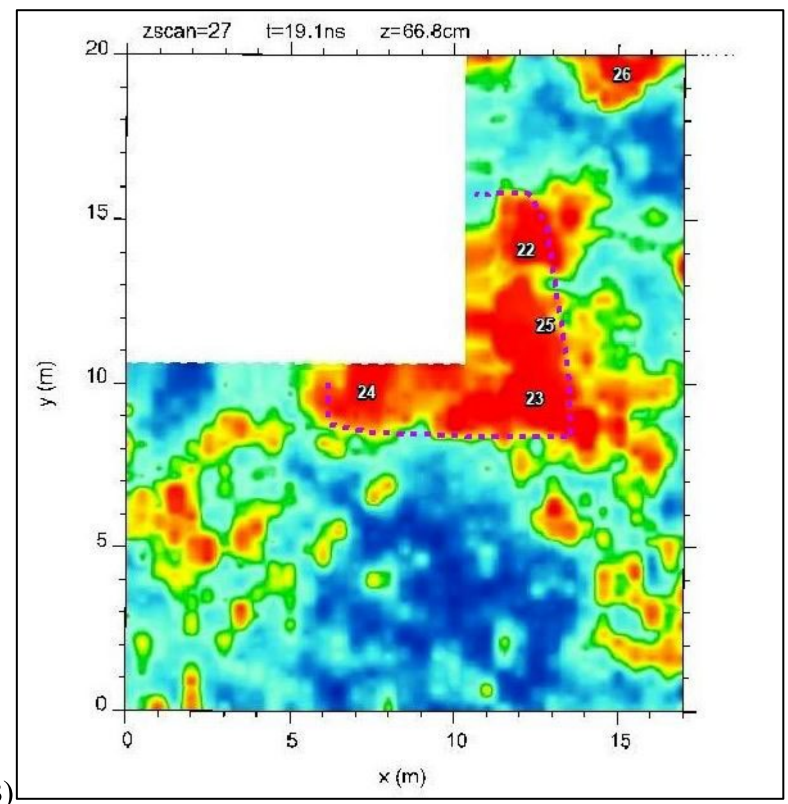
Grid 4 demonstrates similar results as Grid 1 (Figure 6.9). The resolution appears to get worse as the interval gets wider. This leads to the same rounding appearance of the anomalous reflections as with Grid 1. The identified anomalies look almost globular compared to the more angular or square shapes presented at 0.25 m interval. This globular appearance could weaken the interpretation of some potential features, that are naturally more rectangular in shape. However, unlike Grid 1, all anomalies are visible at all selected intervals, however, the amplitude or strength of each appears to weaken as the interval widens. Anomalies 22, 23, and 24 are seemingly smaller than a potential grave-like anomaly that the first GPR investigation around the family cemetery had hoped to identify. These anomalous reflections in Grid 4 were arguably the smallest to be identified, but as they spanned at least 1 m in diameter they were detected at all GPR transect intervals tested. These anomalous reflections, if only surveyed at 1 m interval, might have been missed at the slightest misstep or if the GPR unit veered minorly off course during collection.

There seems to be less use for 1 m interval as the overall data quality is better at 0.25 m and 0.5 m intervals. The surplus of data is remarkably useful based on the sheer number of reflection profiles to examine and compare when using 0.25 m interval, nearly double as many profiles to view than at 0.5 m intervals and quadruple the number of profiles generated the 1 m intervals. Due to the size of most of the anomalies identified, the same anomalous reflections would likely have been identified at the widest interval as most of these anomalous reflections appear in the radargrams at 1 m intervals. However, the faintest of targets within Grid 1, Anomaly 3, would not have been identified as it is not easily discernable within the reflection



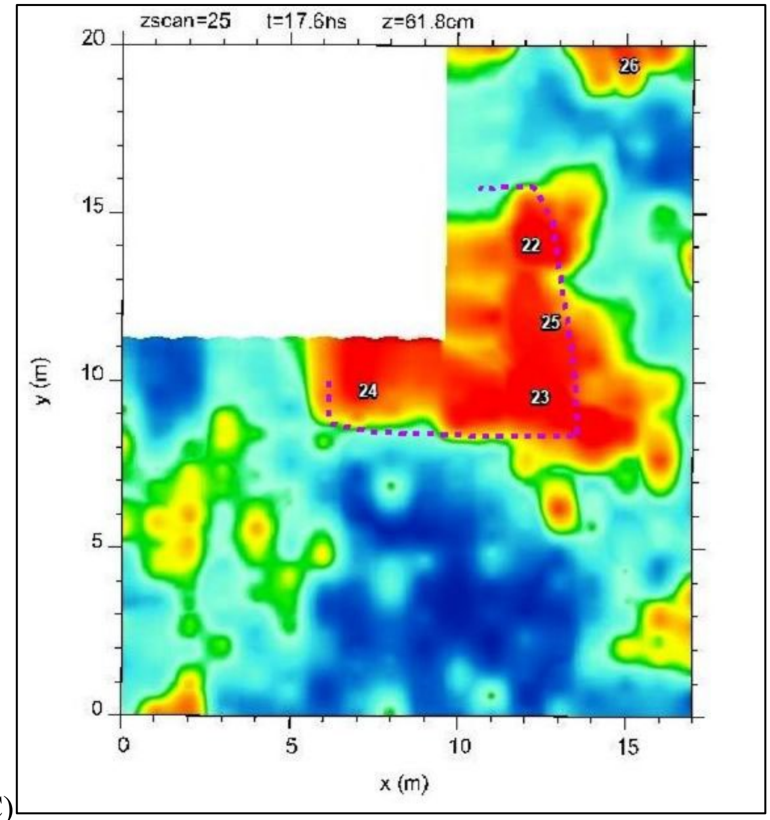
zscan=27 t=19.1ns z=66.8cm
y (m)
x (m)
20
15
10
5
0
0
5
10
15
22
23
24
25
26

(A)



zscan=27 t=19.1ns z=66.8cm
y (m)
x (m)
20
15
10
5
0
0
5
10
15
22
23
24
25
26

(B)



(C)

Figure 6.9. GPR results in the amplitude map of Grid 4 from 55-130 cmbs at 0.25 m interval (A), 0.5 m interval (B), and 1 m interval (C).

profiles gathered. The advantage of examining more radargrams could quickly become a hindrance, however, if time or budget is a factor for a GPR investigation. Operating the GPR unit down GPR transect lines spaced at 0.25 m takes time, 2 to 3 hours, essentially more than twice as long than at 0.5 m intervals. The time it would take to test a GPR grid at 1 m was not learned during this study, but based on the time it took to test a grid at 0.5 m interval, it is likely that it would take an incredibly short time compared to 0.25 m interval as much fewer profiles would need to be gathered. The time to conduct fieldwork would take even longer if there were any errors as the slimmer intervals could easily waver from the original transect line as operators would need to evade objects on the surface twice as often. However, the crisp and more precise data generated allows for the identified anomalous reflection to be more well-defined which assists with interpretation.

Alternating GPR transect lines, oriented east-to-west and north-to-south, were utilized to potentially highlight and further define anomalies in the northeastern portion of Grid 4. After examining both the results together and separately, it became clear that there was no additional advantage to running alternate transects, except for further solidifying the approximate location of Anomalies 22, 23, 25, and 26. Another noteworthy factor related to the tested GPR transect intervals was the small drift in the location of the anomalous reflections as the interval widened (see Figures 6.8 and 6.9). This drift is hardly discernable from 0.25 to 0.5 m, however, a small portion of the anomalous reflections in both tested grids, appear to shift approximately 0.2 to 0.3 m at the 1 m interval compared to their location at the 0.25 m interval. Based on this observation, it appears that the accuracy of the location of each identified anomalous reflection, while still not exact, was improved at closer and closer intervals. This improved location accuracy could assist in the determination of additional archaeological testing when ground-truthing anomalies potentially related to subsurface features at a site.

Examining each amplitude map at the different tested intervals (see Figures 6.8 and 6.9), the reliance on the number of reflection profiles used plays a large role in their formation. When an amplitude map lacks specific reflection profiles at smaller intervals, the software relies more heavily on interpolation from the GPR software used, forming less complete, globular, or blurry shapes in the amplitude maps. If more reflection profiles are provided the shapes are created using the extra raw data. This could be advantageous when trying to interpret the shape of something more precisely, however, if the goal is to simply locate a specific buried feature wider intervals still work, but smaller or less defined anomalies might be harder to discern in the data. Simply put, closer interval GPR transect lines appear to improve the overall quality and accuracy of the data and interpretation when viewed in an amplitude map, however, sifting through the larger number of reflection profiles can take additional time to make those interpretations.

Additionally, closer interval seems more practical when attempting to find point source anomalies that are smaller and could be missed at wider intervals, however, it appears that surface-like reflections that take up more space (i.e. Anomaly 25) could still be identified and interpreted at even the widest tested interval of 1 m. This discussion included an explanation of the findings uncovered as a result of the examination of the close-interval GPR transect interval methodology tested for this thesis. The findings of this experiment, as discussed in this chapter, will lend to the final discussions of this evaluation in Chapter 7 of this thesis, the author's conclusions. The conclusion chapter will also provide a summary of the GPR investigations performed at the William Harris Homestead, site 9WN168, discuss the limitations of the methodological experiment, and attempt to answer the research questions proposed by this thesis based on the evidence provided in this chapter.

Chapter 7: Conclusion

Introduction

The previous chapters of this thesis discussed the two GPR investigations conducted at site 9WN168, the William Harris Homestead, in Walton County, Georgia (see Figure 1.1). The results of both investigations are detailed in Chapter 5. The interpretation of these results is discussed in Chapter 6 along with the implications of the reflection data results for the ongoing archaeological research at the site. This chapter presents the information examined in this analysis and aims to answer the main research question proposed in this thesis: how does GPR interval spacing affect the quality and accuracy of the reflection data collected at an archaeological site using a single channel 400 MHz antenna under similar soil conditions, and does smaller interval transect line spacing support better interpretation of GPR results?

The primary objective of the thesis was to examine different GPR transect intervals utilized within Grids 1 (cemetery investigation) and 4 (living quarters investigation) to determine how the width of the different intervals affected the quality and interpretation of the reflection data gathered at the site. The end of Chapter 6 analyzed the results of the examination by comparing the different time-slices or amplitude maps of both Grid 1 and Grid 4 at the tested transect intervals: 0.25 m, 0.5 m, and 1 m. The limitations of the methodological experiment conducted at site 9WN168 are discussed in this chapter followed by future directions. Finally, with all the information gathered, the author attempts to answer a secondary research question proposed by this thesis and determine how the data acquired from this experiment might assist in future GPR investigations within the region.

Answering the Question

Based on the information gathered during this study using a GSSI 4000 with a 400 MHz antenna, 0.25 m transect intervals yielded the clearest and most accurate results, but the use of wider intervals may still be suitable in some environmental or time-restricted scenarios. It should be noted that the greater accuracy comes from one representation of the data, the time-slices or amplitude maps, which creates a two-dimensional plan view of gridded areas that can be viewed at different depths. While almost every anomaly was identified within the evaluated amplitude maps or time slices at all intervals, the closer intervals provide better clarity and accuracy for the anomalous reflections in both Grid 1 and Grid 4 (see Figures 6.8 and 6.9).

As previously noted, the anomalous reflections registered more angular and squarer at 0.25 m when compared to the grids at 1 m intervals, which were rounder or more globular in appearance within the time slices. The definition a GPR operator gains at the closest interval assisted in the overall interpretation of the anomaly. The locational accuracy, while still not determined through ground-truthing, appears to have decreased slightly as the interval widened. The anomalies in both Grids 1 and 4 appear to have shifted approximately 0.2 to 0.3 m compared to their locations at 0.25 m interval. The anomalous reflections also appear to register as slightly larger at wider intervals than at 0.25 m interval. This is likely due to the increase in reliance on interpolation from the GPR software used, in both RADAN and GPR Slice.

As noted in Chapter 6, smaller anomalous reflections or anomalies that read at lower amplitudes have the potential to be missed as the transect interval widens. Anomaly 3 in Grid 1 is the best example of this as it is nearly imperceptible at both 0.5 and 1 m intervals. This instance exemplifies why it is important to choose the appropriate GPR transect interval based on the size of the targeted archaeological feature, which should be approximately half or "smaller" than the width and length of the potential target (Goodman and Piro 2013:75). However, it is important to consider every factor involved in collecting reflection profiles in the field. How close should these intervals really be and is there such thing as too close when considering time and budget constraints that coincide with archaeological fieldwork in CRM?

Collecting reflection profiles at 0.25 m took more than double the time in the field than those collected at 0.5 m interval. The environment of an investigation would also play a factor in the difficulty of the use of 0.25 m interval. Slimmer intervals would potentially increase the amount of "repeat" lines that resulted from errors in the field. These errors were generally due to wavering from the original line placement or major loss of antenna contact with the ground surface due to obstacles along a transect line. Some of the larger obstacles encountered within Grids 1 and 4 included known grave markers, planted trees, and a wooden platform. These obstacles were encountered twice as often at the closer 0.25 m intervals than at 0.5 m intervals. Processing also took a longer time at 0.25 m intervals. While the software can produce amplitude maps at pretty much the same speed, regardless of the difference in the interval, it took more time to review each individual radargram produced at the closest tested interval. GPR transects spaced at 0.25 m interval produced nearly twice the amount of radargrams than at 0.5 m interval and quadruple the amount than at 1 m interval. 101 radargrams were processed at Grid 1 at 0.25 m interval compared to 51 when processed at 0.5 m interval and 26 when processed at 1 m interval.

In summary, when considering the question of the use of 0.25 m interval at archaeological sites compared to wider intervals using a single channel 400 MHz, the closer interval allows for a clearer three-dimensional examination of the GPR reflection data. The closer intervals allow GPR processing software, such as GPR-Slice, to produce amplitude maps with higher resolution, better locational accuracy, and rely less on interpolation from the software itself to make connections between the profiles collected. All of these factors allow for a better interpretation of GPR results, which indicates that 0.25 m interval is superior to both 0.5 m and 1 m intervals in terms of the quality of reflection data collected. However, due to the additional time it takes to collect the GPR reflection data at 0.25 m intervals, as compared to the wider intervals, other factors such as environment and size of the targeted feature should be considered. While all the data gathered for this thesis are applicable to the research questions posed, there are potential future directions for this study that could involve the gathering of reflection data at the site and processing the data.

Future Considerations

Limitations encountered during the study conducted at the William Harris Homestead site should be considered for future directions of experiments conducted in a similar manner. While it benefited the GPR investigations to identify anomalous reflections that were the potentially targeted archaeological features at site 9WN168, the processing stage of both investigations began with the closest interval of 0.25 m utilized for the survey of Grids 1 and 4. The processing was originally conducted this way for Grid 1 out of necessity to obtain the results of the initial GPR investigation at the family cemetery promptly. The processing of Grid 4 was also conducted the same way due to an initial desire to know and understand the results. However, this may have led to an implicit confirmation bias, or anchoring bias, by learning where each anomalous reflection was located before comparing it to the wider transect spacing intervals.

One future direction of this investigation might involve starting with the widest interval of 1 m. Beginning the processing stage at 1 m interval instead of 0.25 m interval could have avoided the potential bias that comes with anticipating the locations for all of the anomalous reflections. However, it should be noted that it was only after processing the radargrams that correlated only to the 1 m intervals in Grid 4 that anomaly 24 was identified. Likely due to the number of files examined, this anomaly may have been "lost" in the shuffle as it appeared on very few reflection profiles. It only became apparent when sifting through a few radargrams at a time. Additional controls established to assist in the evaluation of the GPR reflection data would also be beneficial to prevent anchoring bias when comparing the GPR results at the different tested intervals. Looking towards other disciplines outside of archaeology and geology, the types of equipment radiologists use also operate using electromagnetic energy like GPR and produce similar types of imagery. Furthermore, it may be pertinent for a future study to review literature concerning radiological test results and how medical researchers control implicit confirmation or anchoring bias when reviewing CT scan imagery.

An additional future direction would involve gathering more data. If the time to conduct the study had allowed for it, each GPR grid for the two investigations at site 9WN168 might have been tested. A future GPR transect spacing experiment using a single channel 400 MHz antenna at the same site or even at a different site with similar environmental conditions could assist in answering the research question posed by this thesis. This future GPR transect experiment might also take a more quantitative approach. The results of the examination discussed in this thesis were qualitative, but a more quantitative evaluation of GPR transect spacing intervals using a single channel 400 MHz antenna might consist of overlaying the different interval results maps to better measure the displacement of anomalies from closer to wider intervals. However, this type of quantitative analysis may require a GPR unit that comes equipped with GPS for greater locational accuracy.

Standardizing GPR Methodological Practices in CRM?

Since graves can undergo so many natural and cultural processes that conceal them, it makes it more difficult to identify them through visual observation. Using geophysical survey methods allows investigators to identify burial features that may be missed from other types of archaeological survey methods utilized in cemeteries. Considering GPR's use in locating potential unmarked burials within and surrounding historic cemeteries it might be worth considering a standardization of the methodological practices used in GPR fieldwork in CRM. An additional research question asked by this study is whether there should be a minimum quality standard for GPR testing intervals, when using a single channel 400 MHz antenna, in an agricultural landscape, within the Piedmont physiographic region of Georgia. If so, what should that standard be? Depending on the budgetary constraints involved in a CRM archaeological investigation, the time and effort that 0.25 m interval takes to produce data both in the field and during processing should be considered. An interval even closer than 0.25 m interval would, of course, take even more time with the GSSI 4000 equipment used and may not be worth the effort in the field or during processing for most CRM investigations unless the targeted subsurface feature is expected to be smaller than 0.5 m in both width and length.

As noted previously, other factors should be contemplated alongside the budgetary concerns of a given CRM project. The environment in which the GPR investigation will be performed is a very important factor to consider. Unfortunately, not all GPR surveys are located on a manicured lawn. Consider a densely forested area. This type of environment could prove to be a major challenge at 0.25 m interval, as it would be very difficult to move the GPR equipment around at such a close interval unless the area is first cleared. Even clearing, however, may not entirely improve the environment as stumps and roots protruding from the ground could still make tricky obstacles to avoid with GPR equipment. Also, the ground disturbance from clearing might potentially impact the archaeological features the investigation is hoping to identify. Wider intervals, up to 1 m interval, while not ideal could potentially perform better during fieldwork in environments that present a lot of obstacles.

This thesis demonstrates that 0.25 m intervals used in Grids 1 and 4 of the GPR investigations performed at site 9WN168 produced higher quality reflection data allowing for better interpretation of the GPR results. However, based on the analysis of this methodological experiment, many factors affect its utility for CRM-related fieldwork. These factors mainly include budgetary concerns of a given project and environmental conditions at an archaeological site. Therefore, it could be said that there is no secret recipe or "proper" GPR transect spacing methodology that could be applied to every archaeological site investigated within the Georgia Piedmont when utilizing a single channel 400 MHz antenna. However, given the budgetary opportunity, it should be considered best practice to use a close GPR transect interval, such as 0.25 m, within a grid to collect the clearest and potentially most accurate GPR reflection data at an archaeological site.

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