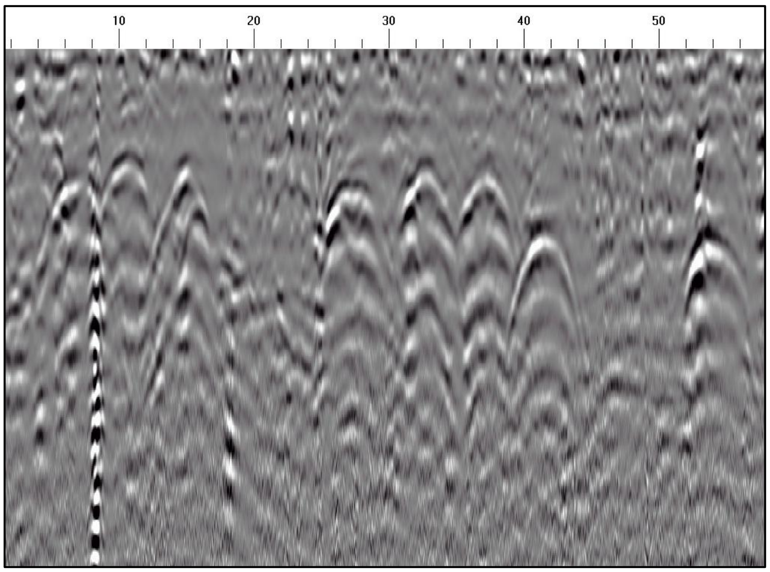
TECHNICAL REPORT APRIL 2025

A Ground Penetrating Radar Survey of a Portion of the Newtown Cemetery Harrisonburg, Virginia



PREPARED FOR:

DR. CAROLE NASH

701 CARRIER DRIVE

HARRISONBURG, VIRGINIA 22807

PREPARED BY:

TERRASEARCH GEOPHYSICAL

2090 Jolly Pond Road

WILLIAMSBURG, VIRGINIA, 23188

TECHNICAL REPORT APRIL 2024

A GROUND PENETRATING RADAR SURVEY OF A PORTION OF THE NEWTOWN CEMETERY HARRISONBURG, VIRGINIA

PREPARED FOR:

DR. CAROLE NASH

701 CARRIER DRIVE

HARRISONBURG, VIRGINIA 22807

PREPARED BY:

TERRASEARCH GEOPHYSICAL

2090 JOLLY POND ROAD

WILLIAMSBURG, VIRGINIA, 23188

ABSTRACT

This report presents the results of a geophysical survey of a portion of the historic Newtown African American Cemetery, an approximately 4-acre lot located in the center of the Newtown neighborhood in Harrisonburg, Virginia. The historic cemetery is bounded on the west side by Sterling Street, north by Kelly Street, east by Hill Street, and south by East Gay Street. The approximate center of the property is bisected by a single-lane asphalt road, an extension of Effinger Street emanating from the west. An impromptu and unpaved alleyway is located on the southern margin of the cemetery, is an active byway for community members, and is used by houses on the north side of East Gay Street.

The aim was to identify potential unmarked burials through a noninvasive geophysical survey, with the express intent of delineating the boundaries based on the results. TerraSearch employed geophysical methodologies that entailed a systematic, gridded ground-penetrating radar (GPR) survey of the enclosed lot and followed best practices for cemetery surveys using non-invasive geophysical techniques. Before conducting geophysical work, the team conducted an extensive pedestrian survey of the site to evaluate the existing evidence of potential burials, including stone grave markers, areas of grave subsidence, and invasive memorial vegetation.

The survey area is a portion of the historic 19^{th}-century (ca. 1869) cemetery that is listed on the Virginia Landmarks Register (VLR # 115-5129) and the National Register of Historic Places (NRHP # 15000014). The Newtown Cemetery Board of Trustees maintains the property and is an active burial location and memorialization space. The grassy areas inside and on the margin (alley) of the cemetery were well-groomed and had few impediments. No extant grave markers or forensic evidence of graves (i.e., subsidence) were noted within the alleyway survey area. The portion of Sterling Street surveyed was relatively free of impediments save for a few parked cars.

TerraSearch, under contract with the Newtown Cemetery Board of Trustees, conducted a noninvasive geophysical survey on March 27, 2025, of approximately 0.46 acres of the cemetery, an alley to the south, a portion of Effinger Street, and a portion of Sterling Street that front the western side of the property. The survey included meticulous documentation, mapping, and a comprehensive geophysical study of the lot.

The GPR survey results and subsequent analyses identified three potential unmarked graves in the cemetery. Although all of the burials found were unmarked, the geophysical features identified throughout the cemetery displayed forensic evidence consistent with human interments and appeared unrelated to any other indication of burial, such as fieldstone or grave markers. While every effort has been made to identify features of interest through GPR, these methods are not foolproof and should be ground-truthed to verify the interpretations.

TABLE OF CONTENTS

List of Figures

Chapter 1 Figures:

Chapter 2 Figures:

Chapter 4 Figures:

CHAPTER 7 FIGURES (APPENDIX):

CHAPTER I: INTRODUCTION

Introduction

TerraSearch, under contract with the Newtown Cemetery Board of Trustees, completed a comprehensive ground-penetrating radar (GPR) survey of portions of the lot, specifically an alleyway north of East Gay Street and approximately 375 linear feet of Sterling Street west of the cemetery. The survey was conducted to determine if there were any unmarked burials beneath the street and alleyway, both of which were constructed and implemented after the graveyard property was set aside for memorialization and interments (Figures 1.1 & 1.2).

The site, located on property managed by the Newtown Board of Trustees, is relatively open aside from memorial plantings (trees), an ancillary support shed, and extant grave markers. Much of the lot features a well-manicured lawn and does not exhibit signs of interments.

The project objectives and methods were determined in consultation with Dr. Carole Nash, a Newtown Cemetery Trustee member, both before the project began and onsite during the survey. The work aimed to investigate and delineate any potential unmarked burials associated with the lot using non-invasive methods to survey portions of the property. The GPR (Figure 1.3) surveys totaled approximately 1.2 acres.

Scope of Work

The non-invasive geophysical work at the Newtown Cemetery included the following tasks:

- Task 1: Background research and a detailed review of available sources and aerial photographs of the property to be surveyed;

- Task 2: Establishing a systematic grid or grids within the project area: the beginning and end points of each grid were recorded by a global positioning system (GPS) to provide accurate control points for the survey;

- Task 3: A non-invasive GPR prospection survey of the study area. No ground disturbance or ground-truthing of anomalies was undertaken as part of the project;

- Task 4: Review the GPR, background, and imagery data to assess the survey area for soil anomalies systematically and to make informed decisions about the nature of these anomalies (i.e., grave shafts, landscaping, utilities, etc.);

- Task 5: Produce a comprehensive technical report, including detailed summaries of all facets of research, methodology, survey results, and recommendations.

Project Personnel

Mr. David M. Givens, M.A., RPA, served as Principal Investigator and supervised all aspects of this project. Mr. Givens performed data analysis and prepared the graphics for this report.

Organization of the Report

Chapter I contains the introduction. Chapter II discusses the methods used to complete this investigation. Chapter III presents the region's natural setting encompassing the Project Area and includes a brief overview of the region's geology, hydrology, and soils. Chapter IV provides the results of the geophysical survey of the cemetery. Finally, Chapter V contains a summary and conclusion of the data collected for this report. A bibliography (Chapter VI) is followed by referenced images, which, if not included in the body of the report, are located in the appendix (Chapter VII).

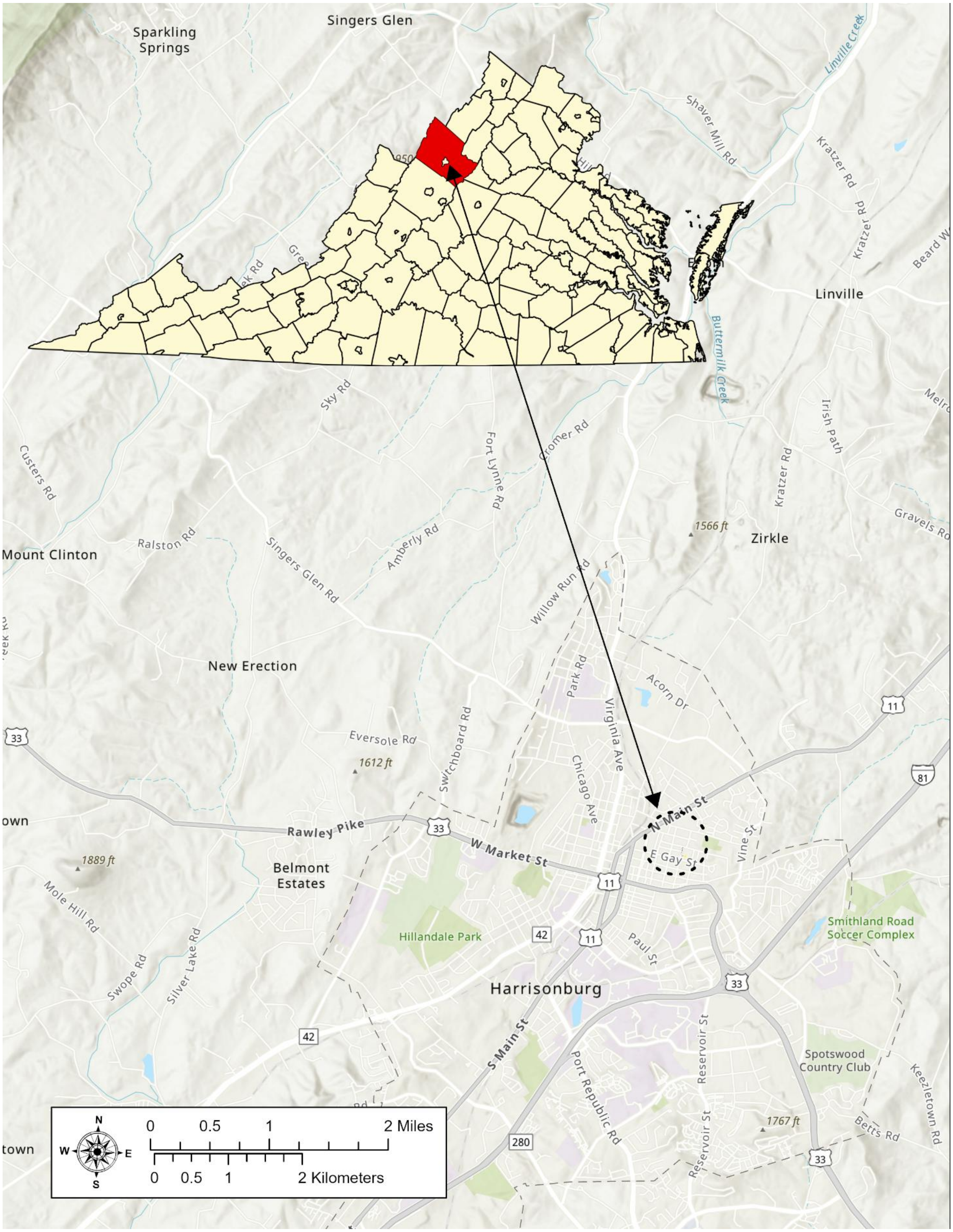


Figure 1.1. Location of the Project Area, City of Harrisonburg, Rockingham County, Virginia.

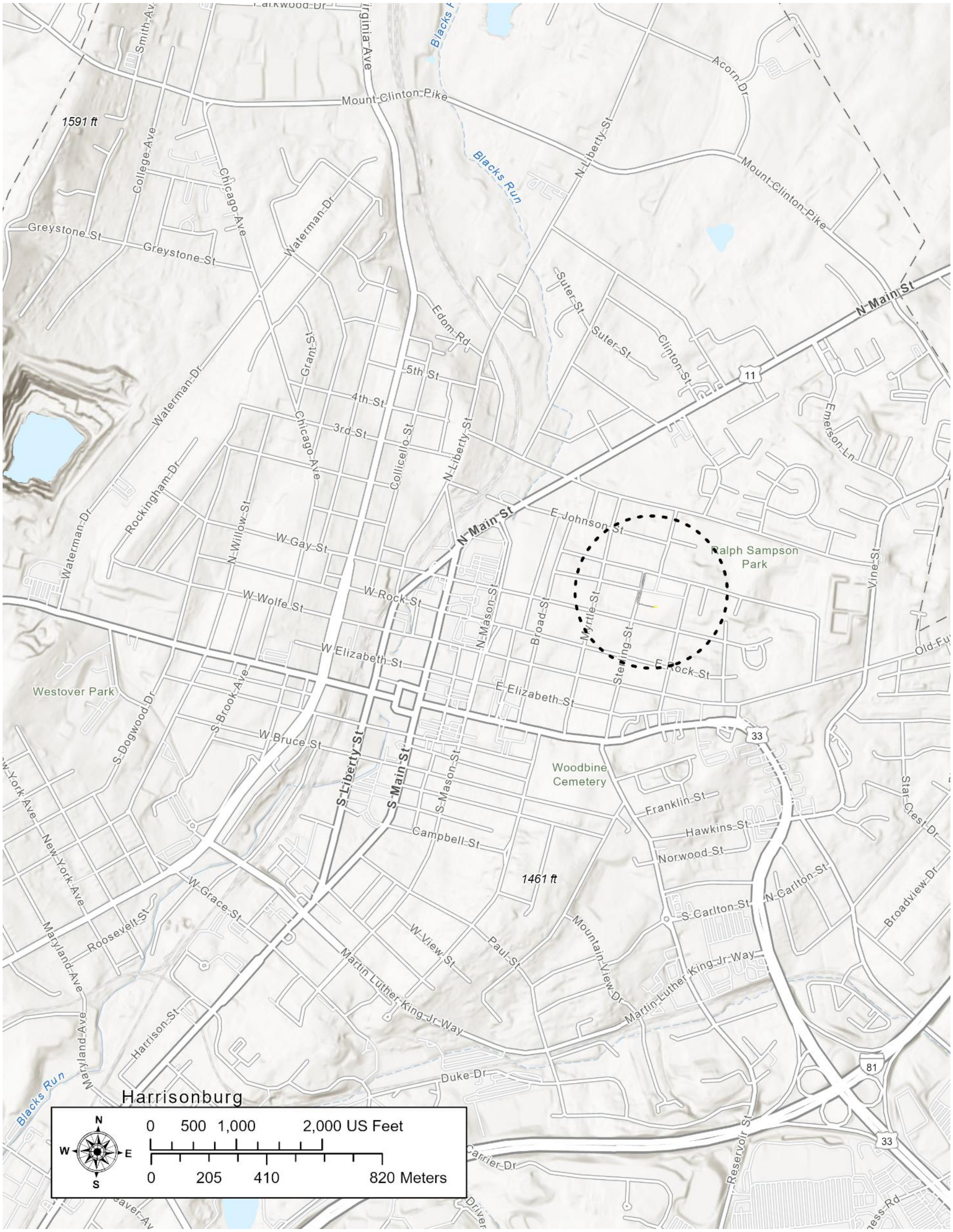


Figure 1.2. Location of the Newtown Cemetery GPR survey, City of Harrisonburg, Rockingham County, Virginia.

Figure 1.3. Aerial perspective of the Newtown Cemetery, City of Harrisonburg, Virginia.

CHAPTER II: METHODS

Introduction

This chapter describes the research design and field methods employed to conduct the geophysical survey of portions of the Newtown Cemetery, including Ground Penetrating Radar (GPR), mapping, and documentation. Additionally, the location and point of contact for the facility where all geophysical data, drawings, maps, photographs, and field notes generated during the survey will be curated are provided below.

The investigation's fieldwork was comprehensive, and planning utilized the information provided by the client before and during the undertaking (both virtually and on-site). The following sections provide an overview of the methods employed to conduct a comprehensive geophysical and documentary survey of the site. All work for this project was performed in accordance with and by TerraSearch staff who meet or exceed the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation (48 FR 44716).

Prospection and Recording Surficial-Related Features

Before any formal gridded geophysical data collection, a walkover of the entire site and surrounding area was conducted. The close inspection of the site was twofold: to identify contextual information that could aid in understanding the context of the site (e.g., the presence of grave makers, subsidence areas, age of markers, ground cover, and vegetation) and, if present, to determine the best way to conduct a gridded and multi-channel array survey of the site (e.g., orientation of subsided grave shafts and burial markers).

Survey and Mapping Methods

After the walkover, TerraSearch implemented two differing geophysical methodologies and survey techniques. For the alleyway, a portion of Effinger Street (in the cemetery) was surveyed, and for Sterling Street, a MALÅ Mira HDR multi-channel array survey was conducted. The MALÅ HDR used a GPS NTRIP-enabled EMLID base and rover configuration, providing dynamic, centimeter-accurate real-time kinematic (RTK) positioning.

To confirm he results of the alleyway survey, a GSSI UtilityScan 350MHz HS antenna was used after establishing a single survey grid within an area defined by the preliminary walkover and consultation with Dr. Nash. The grid included two baselines, approximately perpendicular to observed graves within the cemetery and parallel to the long axis of the alley (W-E). These baselines were used to establish reference points for all geophysical data collected and to accurately map all surficial features and vegetation potentially associated with the cemetery. All geophysical work utilizing the UtilityScan was collected using fiberglass tapes and steel chaining pins, thereby minimizing errors in locating features identified through geophysical testing. Field observations and maps were digitized to create a permanent record of the GPR and survey areas and related surficial information, observed field data, and landforms.

Digital Photography Methods

Digital photography of the survey in progress and from each corner of the survey area was conducted to document and digitally preserve the grid's location. All above-ground features were sufficiently well-lit such that photographs captured as much of the subject and relief of inscriptions as possible (see appendix).

Ground-Penetrating Radar Methods

GPR is an active, non-invasive geophysical method that records contrasts in the dielectric properties of subsurface materials (Heimmer and De Vore 1995; Clark 2001; Bristow and Jol 2003; Conyers 2004, 2006; Daniels 2004). A pulse of transmitted electromagnetic energy emitted from the GPR antenna is reflected or absorbed by such contrasts, and the resulting reflections are recorded to produce a vertical profile. Most reflections are generated at interfaces between materials of differing relative dielectric permittivity, i.e., at the boundary between different stratigraphic layers, where changes in velocity occur (Figure 2.1). A two-dimensional GPR profile represents vertical and horizontal stratigraphy consisting of individual traces resulting from a single pulse of energy and the resulting reflections at a given location that are stitched together to produce an image of dielectric contrasts. In this sense, GPR does not provide a stratigraphic profile; rather, it represents local dielectric contrasts that provide a proxy for subsurface stratigraphic changes.

GPR is an established prospecting method for human graves and archaeological features, such as wells, privies, shafts, buried building foundations, trenches, and other forms of cultural stratigraphy. These features are visible with GPR due to dielectric contrasts between the feature fill and surrounding homogeneous soils, often visible truncation of internal "natural" stratigraphic layers, or as reflections from high-amplitude surfaces, compacted surfaces, or constructed floors made of bricks or stones.

Geophysical survey for human burials is a common and viable GPR application due to the above forensic characteristics. A grave shaft is a vertical cut into potentially intact stratigraphy, recognizable in reflectance profiles as a discrete incision into soil profiles. Observed grave fill will often display evidence of subsidence manifested as slumping stratigraphic layers within the shaft. Grave fill should and frequently does contain internal characteristics derived from disturbance or discombobulation of soil layers that contrast sharply with the surrounding undisturbed subsoil (Figure 2.2) (Bevan 1991). Unmarked graves in disturbed soil contexts may be more difficult to discern.

Well-preserved coffins, along with brick or concrete vaults, provide ideal point-source objects to generate characteristic hyperbolic reflectors in the GPR data. A high-amplitude reflector can also be mapped horizontally in three-dimensional time slices or amplitude maps. Profiles are generally collected across marked graves (i.e., headstones and footstones) as comparative data sets.

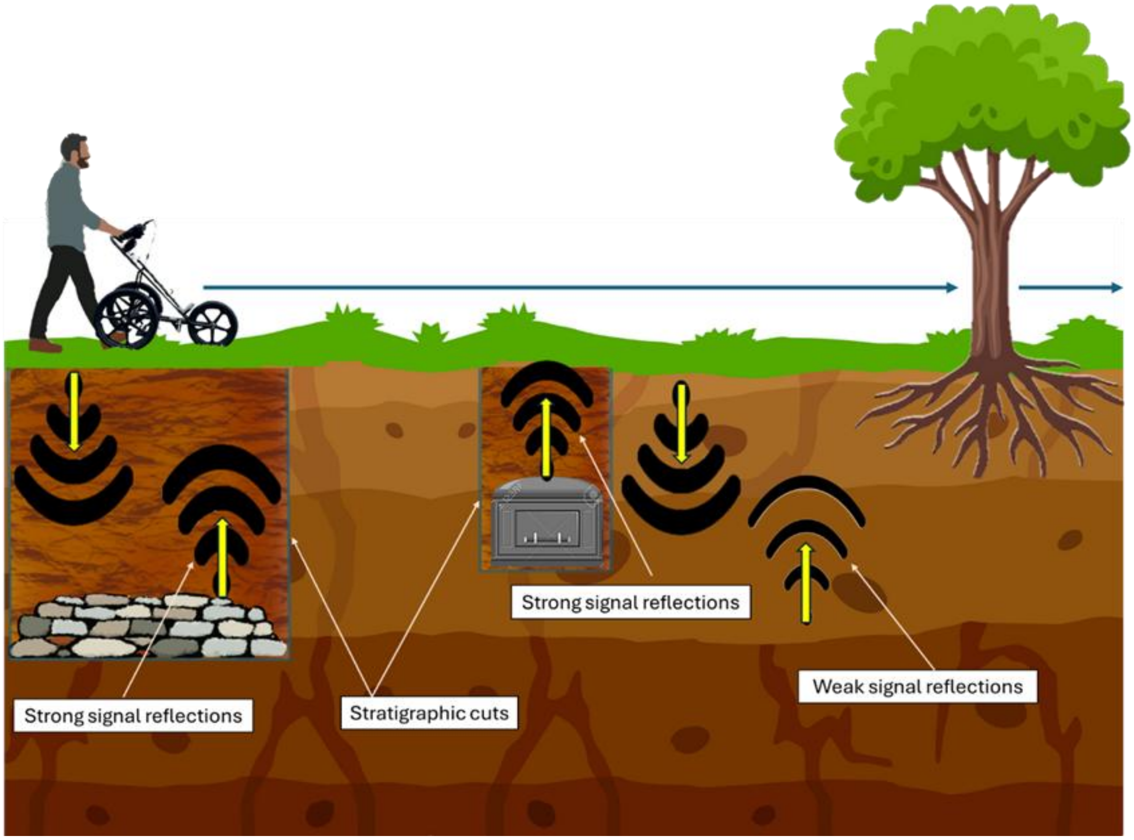


Figure 2.1. Idealized strong and weak reflectors from objects and soils via GPR.

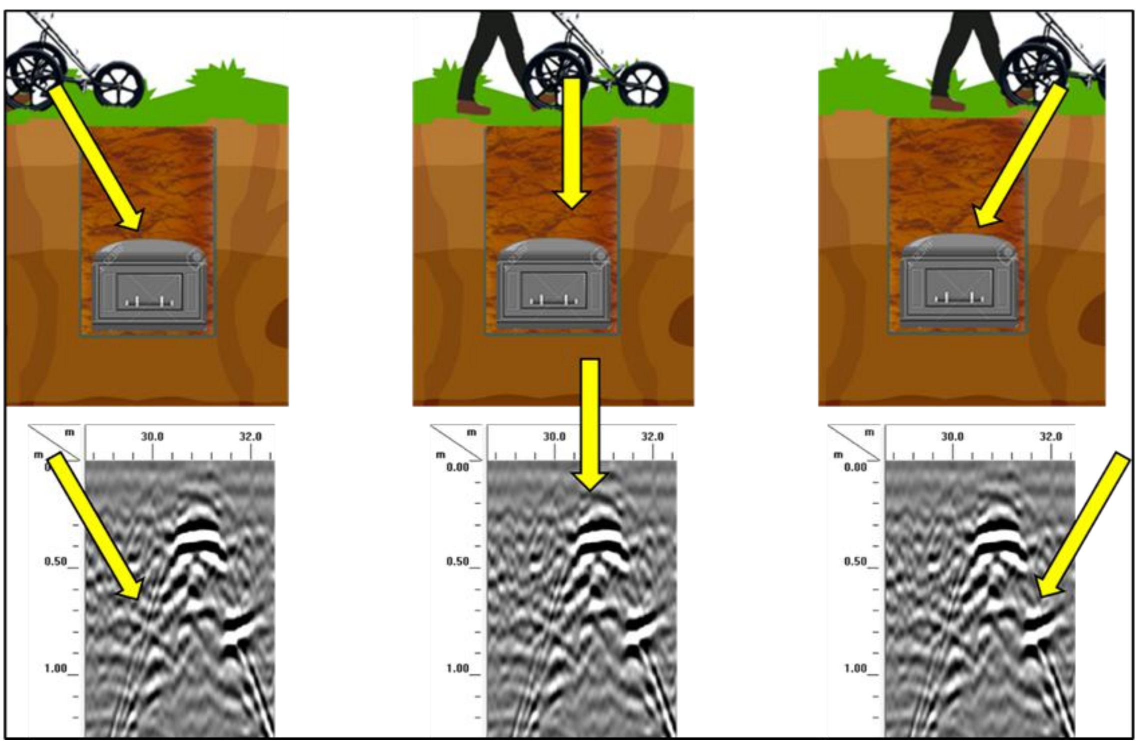


Figure 2.2. Idealized radar reflections from a coffin produce faint hyperbolic tails on either side of the coffin as the antenna approaches, moves over, and then passes the target. The result is a dense, bright parabolic reflector representing the top of the coffin.

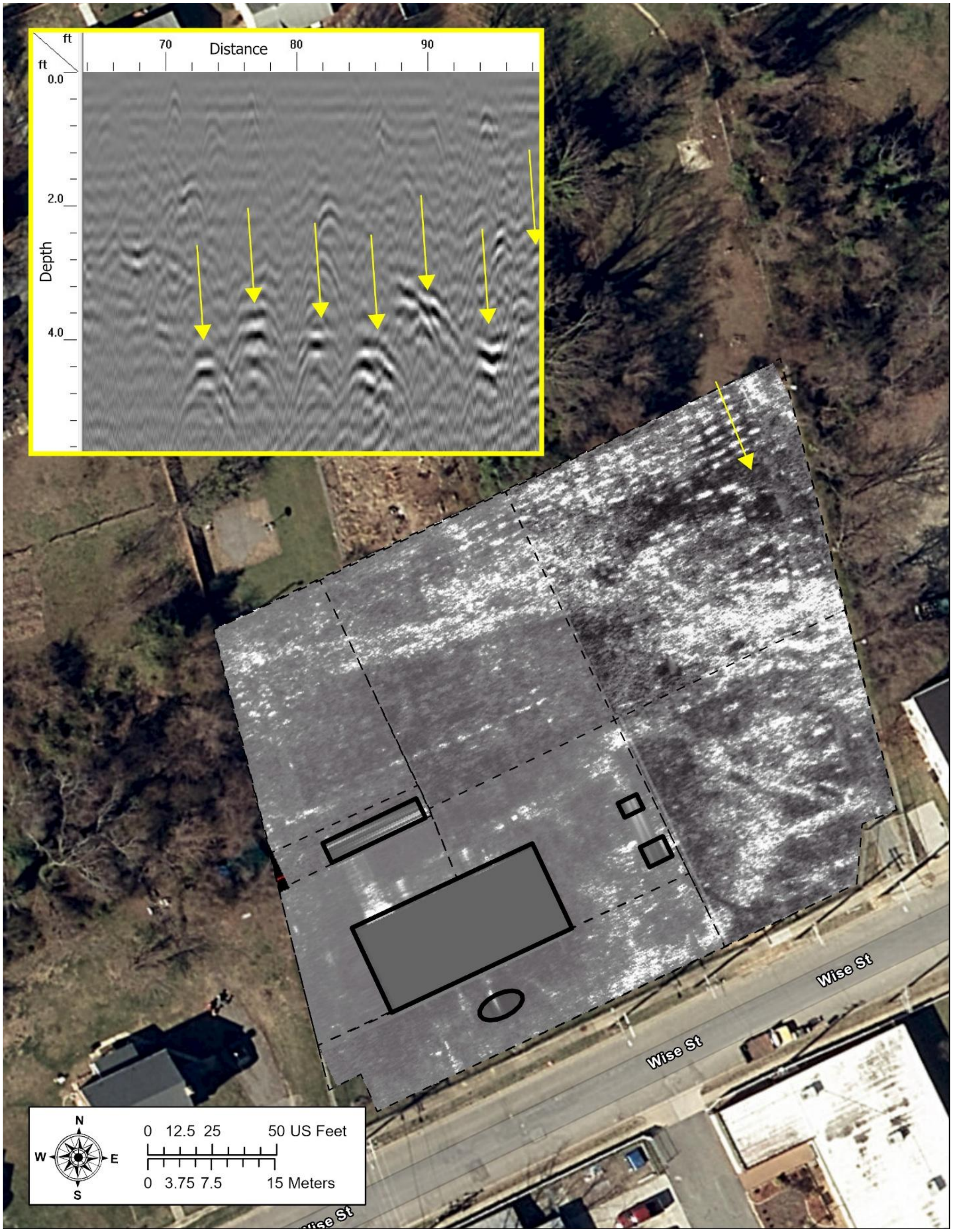


Figure 2.3. An example of a 19th-century cemetery associated with the Weisinger-Carroll Hospital, City of Richmond, Virginia. The inset shows the high-amplitude targets representing probable coffins (yellow arrows).

GPR prospection for historical period features yields differing characteristics and morphologies of the geophysical signatures. Structural cellars (stone- or brick-lined), foundations, postholes, and middens result in notably distinctive diagnostic GPR profiles. As many of these features entail a vertical cut through subsurface stratigraphy, the buried target often contrasts sharply with the surrounding undisturbed subsoil. Internal characteristics of these types of domestic features frequently contain a variety of point-source reflectors. Walls provide high-amplitude vertical surfaces with unique GPR signatures, characterized by “single tail” and often variegated hyperbolae as the survey unit passes over the target. The resulting three-dimensional maps frequently yield ideal representations of buried structures. An example of an ideal amplitude map and profile transect displaying burials in a 19th-century cemetery in Richmond, Virginia, is shown in Figure 2.3.

The geophysical work utilized a GSSI Utility Scan GPR system with a 350 MHz HyperStacking antenna to conduct the GPR survey. The antenna and UtilityScan are mounted on a custom-built carriage by GSSI and utilize an encoder-triggered collection of 50 traces per meter (one reading every 0.8 in). All GPR data were collected at 25 cm intervals in four unidirectional transect grids. In areas where obstructions were encountered that prevented completion of the survey transect, such as a headstone, fence, tree, etc., an additional or continuation transect was collected, beginning at the opposite end of the obstacle. Before starting the continuation, the position of the GPR machine was carefully recorded manually to ensure that no data was lost during the survey.

In addition to the GSSI antenna, the TerraSearch team utilized a MALÅ MIRA (Miracle) HDR (High Dynamic Range) GPR unit specifically to image a portion of the alley and Sterling Street. This addressed suppositions about potential interments in the street and provided additional forensic evidence for probable graves identified within the alleyway. The MALÅ HDR array utilizes 11 antennae, each with a 500 MHz center frequency and 12 receivers.

For the Newtown Cemetery survey, the system was configured to collect data as a multi-channel array, simultaneously collecting data from 22 different frequencies. This allowed for data collection from any transmitter-receiver combination within the array. Each antenna is 6.5 cm apart, permitting precise, high-resolution data that excels in complex contexts like Sterling Street.

<u>GPR Data Analysis</u>

All GPR profiles were interpreted and analyzed using GSSI RADAN and MALÅ Vision software and industry-standard techniques (i.e., Conyers 2006; Leach 2019; 2021). These techniques include the following RADAN software adjustments to the raw data collected in the field: Time Zero, Range Gain, Background Removal, Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) Filters, Migration, as well as three-dimensional and two-dimensional exploratory data analysis.[1] Each of these techniques is described in more detail below.

Time Zero is a position correction of the ground surface relative to the radar pulse transmitted from the machine, measured in nanoseconds. For the Utility Scan, the position correction is generally minimal, approximately 1 to 3 nanoseconds. Range Gain is a critical analytical technique because it enables the user to adjust the radar signal relative to the depth of the recording device. As the signal travels farther from the machine, it becomes weaker, and vice versa. The dataset must be normalized to compensate for this

[1] These techniques are applied generally to a dataset to “ground” the analysis. There is no “cookie cutter” approach to GPR analysis. Each survey presents unique environmental and soil conditions that require informed choices in both the analysis and the collection of data.

and correctly interpret the entire target depth for the GPR analysis. TerraSearch personnel utilized an exponential Range Gain to analyze the data, as this technique most closely approximates the loss of signal with depth relative to the machine.

Background Removal is another normalization technique that removes horizontal “noise” from the dataset, or those targets that extend the entire length of a GPR transect and are thus not relevant for an archaeological analysis (but may be applicable for geological analyses); noise interference from radio frequencies (cell towers, WIFI, radio towers, etc.) are also removed using the Background Removal function. FIR and IIR filters are generally applied as a custom background removal of frequencies that appear spurious after an exploratory analysis. Migration is a transformation that flattens the appearance of a conical shape associated with hyperbolic reflectors, which are visible at depth and, thus, farther away from the machine in horizontal space.

The MALÅ vision software was used to process, filter, and interpolate the data for the MALÅ HDR-collected profile lines. As with the RADAN processing, similar filtering techniques were used, including time zero and DC drift positioning, signal gain (ACG, Exponential, or Smart), background removal, envelope, and migration. Unlike the RADAN processing, the MALÅ Vision software is somewhat automated and only offers an inverse distance weighting (IDW) for interpolating the two-dimensional data to create a three-dimensional map.

Finally, while three-dimensional viewing of the GPR dataset presents a powerful way to interpret geometric patterns, it is merely an algorithmic approach to viewing two-dimensional data. All GPR transects were analyzed as amplitude profiles (two-dimensional) and in post-processed formats; these data were then compared with three-dimensional geometric targets to interpret geologic and anthropogenic features.

Curation

After completing and accepting the Final Report of Investigations, TerraSearch will curate all drawings, maps, photographs, field notes, and GPR data.

Report Preparation

The data gathered during the survey are synthesized and presented in this report. While TerraSearch understands that this work is being conducted solely for planning and preservation purposes, all work complied with the Secretary of the Interior’s *Standards and Guidelines for Archeology and Historic Preservation* (48 FR 44716).

UtilityScan 350MHz HS GPR Grid Layout

One GPR grid was collected in the alleyway of the Newtown Cemetery (Figures 2.4 & 2.6). The GPR grid (Grid 1) was designed and surveyed to encompass what was believed to be the cemetery's southern-most margin. The survey area's origin point (started in the northwest corner and surveyed southward) began at the intersection of the alleyway and Sterling Street. The transects were conducted from west to east and ran as much as 17 ft as the landscape and impediments allowed.

Figure 2.4. The approximate location of the Newtown GPR survey areas (terrain model).

Figure 2.5. The approximate location of the Newtown GPR survey areas (aerial image).

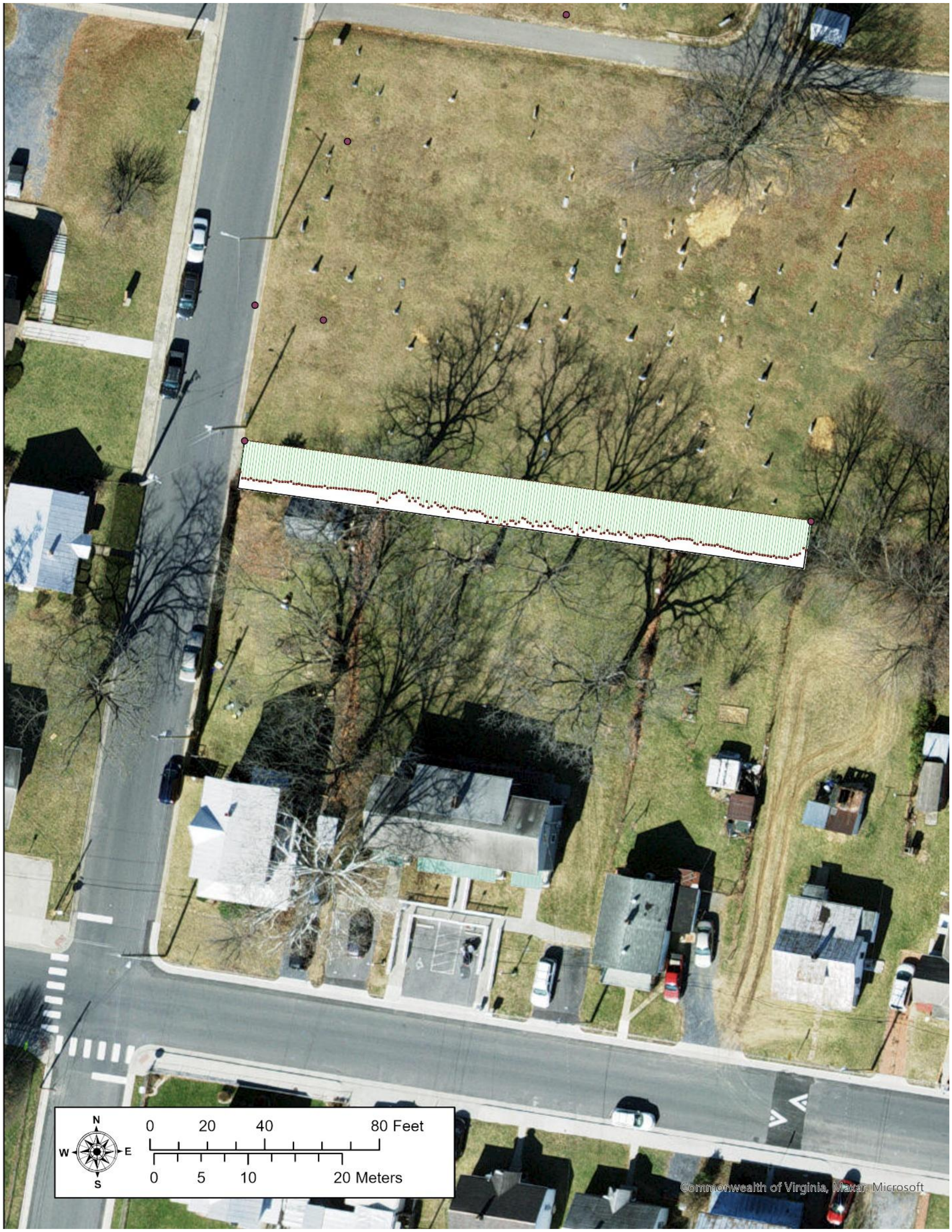


Figure 2.6. UtilityScan 350 MHz HS survey lines in the alleyway of the Newtown GPR survey (north of East Gay Street).

CHAPTER III: NATURAL SETTING

Introduction
This chapter briefly overviews the region's natural setting, including the study area associated with the Angel Visit Baptist Church Cemetery GPR Survey Area. It includes general ecological conditions and types of freshwater sources, soils, and slopes. The remainder of this section provides a brief overview of the ecology, hydrological resources, and soils near the study area and the larger region.

Ecoregion and Hydrology of the Study Region
The project area is part of the Appalachian Ridge and Valley ecoregion (67a), as defined by the United States Environmental Protection Agency (US EPA) in 1996. The ecoregion extends northeast through West Virginia and Maryland and terminates in the south in Alabama and to the north in New York State. The region continues westward into West Virginia, bounded by the Northern Piedmont Region to the east. Elevations typically range from 950 to 1,570 ft, and local relief is approximately 1,400 ft (+/- 30 ft).

The region can be humid with moderate precipitation throughout the four distinctive seasons. Recent precipitation has been lacking, resulting in severe drought for the region and the study area. The region tends to have more significant relief, elevation, and channel gradients than the Northern Piedmont to the east, generally resulting in better drainage. The region is characterized by "underlying bedrock is mostly the soluble and calcium-rich limestone and dolomite, but there is also some shale" (Virginia Division of Mineral Resources, 1993).

Streams and rivers of this region are primarily perennial and of low to moderate gradients and locally drain westerly into the Blacks Run, which subsequently runs southwest where it drains into the North River. The North River runs southeast, intersecting the South River in Port Republic. The confluence of the two rivers forms the South Fork of the Shenandoah River, which flows northeast to the intersection of the North Fork of the Shenandoah at Port Royal. The union of the two rivers forms the Shenandoah River, which runs northeast and empties into the Potomac River at Harpers Ferry. The Potomac flows southeasterly, eventually emptying into the Chesapeake Bay.

Soil moisture is crucial in GPR interpretation, presenting challenges and opportunities. A thorough survey can generally overcome the interpretive difficulties of substantially wet soil. The water content is the most significant factor in determining a material's dielectric constant, and the presence of the water table or increased soil moisture within a survey area can radically alter the geophysical signature of sediments or features. Subtle differences in a soil layer's porosity may mean pockets of water that produce stark dielectric contrasts, generating multiple reflections or potentially scattering energy (Conyers 2013). Conversely, complete saturation of a material may reduce its contrast with neighboring materials, thereby muting some reflections. Finally, soil moisture can also alter the preservation environment of objects found within the soil, another factor to remember when analyzing amplitude reflections from near-surface or buried objects and surfaces.

Soils Comprising the Project Area
Soil formation directly results from the interaction of several variables, including climate, vegetation, parent material, time, and organisms present (Gerrard 1981). Once archaeological deposits are buried within the soil, they undergo many diagenic processes. Different classes of artifacts may be preferentially protected or unaffected by these processes, whereas others may deteriorate rapidly. Cyclical wetting, drying, freezing, thawing, and compression can accelerate the decay processes for animal bones, shells,

lithics, ceramics, and plant remains chemically and mechanically. Lithic and ceramic artifacts are mainly unaffected by soil pH. In contrast, animal bones and shells decay more quickly in acidic soils like those in the current Project area. In contrast, acidic soil enhances the preservation of charred plant remains. Varied soil chemistries affect geophysical signatures in many ways. Differing preservation environments can impact the presentation of an object or feature of archaeological interest (i.e., decayed coffins versus intact coffins). Variations in soil formation can also lead to soils with different electrical conductivity and moisture retention, directly impacting the depth penetration and effective wavelength of GPR signals.

The Newtown Cemetery GPR Survey study area mainly comprises Edom Series Soils, with the remaining defined as simply “urban land.” The Edom series is defined by silty clay loam on low to moderate terraces within the Appalachian valley floor's generally low rolling landscape.

Edom Series

The Edom Series of soils consists of deep (more than 70 in), well-drained loams. These soils are formed from a parent material of eroded limestone bedrock and decayed organic materials. Slopes typically range from 7 to 15 percent but can range from 0 to 50 percent, although slopes within the survey area did not exceed slopes of 15 percent. A typical profile associated with Turbeville soils is as follows: **H1** - 0 to 6 inches; silty clay loam, **H2** - 6 to 34 inches; clay, and **H3** -34 to 70 inches; channery silty clay loam.

Summary

A review of mapping, geological data, ecological conditions, soils, slopes, and proximity to water can inform geophysical data analysis of the Newtown Cemetery dataset. The soils featured therein generally have well-drained properties, making them ideal for GPR surveys performed with the GSSI 350MHz antenna and the MALÅ MIRA HDR multi-channel array. No saturation or inundation was observed during the survey, and overall, the site, terrain, and underlying geology appeared favorable for a geophysical study.

Chapter IV: GPR Results

Introduction

The following results are based on the comprehensive geophysical survey of a portion of the Newtown Cemetery lot in Harrisonburg, Virginia. Before the formal gridded GPR survey of the site was undertaken, an intensive walkover of the survey area was conducted, and all surficial information related to the cemetery and cultural context (e.g., grave markers, extant and buried vaults, grave subsidence areas, orientation of the graves, and vegetation) of the site were noted.

After the pedestrian survey, the TerraSearch team conducted a prospection GPR survey of the observed potential graves to confirm that the orientation of the buried interments matched the potential grave slumping (see below). The synthesis of the collected data provided the necessary information for the team to formulate a comprehensive set of GPR grids for systematic geophysical data collection.

As described in Chapter II, a single GPR grid was collected using the UtilityScan 350 MHz HS antenna during the fieldwork effort (see Figures 2.4 – 2.6). The GPR grid was triangulated using cloth tapes to encompass the suspected boundaries of the prescribed survey area in the alleyway along the south margin of the Newtown Cemetery. The grid was designed to be contiguous and comprehensive and was surveyed up to the backyards of the houses located on the north side of East Gay Street.

In addition to the gridded GPR survey, several multi-channel array GPR surveys (using the MALÅ MIRA HDR) were conducted outside the cemetery on Sterling Street, on a portion of Effinger Street (within the cemetery bounds), and in the alleyway on the southern margin of the property. The Sterling Street survey was conducted parallel to the western boundary (N-S) of Newtown Cemetery and was free from impediments. However, several parked vehicles blocked portions of the thoroughfare, resulting in only a partial survey (see below). The HDR data collected in the alleyway was slightly larger than the gridded survey area and was meant to supplement the data collected by the UtilityScan 350 MHZ HS antenna.

Initial Prospection and Walkover

The preliminary site walkover within the cemetery's boundaries revealed several depressions or potential "grave slumps" features that can, and often do, result from settling grave shaft fill, coffin collapse, subsidence, or a combination of these factors. The walkover of the alleyway revealed no obvious *in-situ* grave markers or subsidence features; however, several grave markers were noted within only a few feet of the grass alleyway (Figure 4.1).

After performing an antenna calibration to maximize data collection within the local geologic settings, three initial prospecting survey lines were conducted across and perpendicular to the marked graves and subsided grave shafts, all appearing to be oriented approximately east to west. The results of the geophysical prospection indicated clear indications of grave shaft incision, high- and low-amplitude reflectors of probable coffins, and depth to potential interments (Figure 4.2). Generally, the grave depths observed in the prospection transects ranged from just over 1 ft to just over 3.5 ft.

Similarly, a prospecting transect was conducted using the MALÅ MIRA HDR across a small portion of the cemetery where gravestones were spaced farther apart, allowing the four-foot HDR antenna to traverse. Grave shaft incisions and high-amplitude features (probable coffins) were observed in the two-dimensional reflectance profiles. Similar depths for the probable coffins were also observed (Figure 4.3).

Near-Field Data

The near-field perspective, or surficial GPR readings, revealed natural and anthropogenic features. During the survey, an intense scatter of shallow, high-amplitude targets was visible in the zone directly beneath the antenna and within a few inches of the ground. Subsequently, data interpolation and filtering rendered the targets into two separate natural phenomena. Firstly, a network of articulated roots emanating from the vegetation, primarily trees, is located in the backyards south of the survey area. In addition to the roots, a single, high-amplitude linear target was situated along the alleyway in the southern-most limits of the gridded survey. This feature is likely a communication line (i.e., phone or cable) serving one of the houses on the north side of East Gay Street (Figure 4.4).

Figure 4.1. Grave markers in proximity to the Newtown Cemetery alleyway GPR survey area (dashed yellow line).

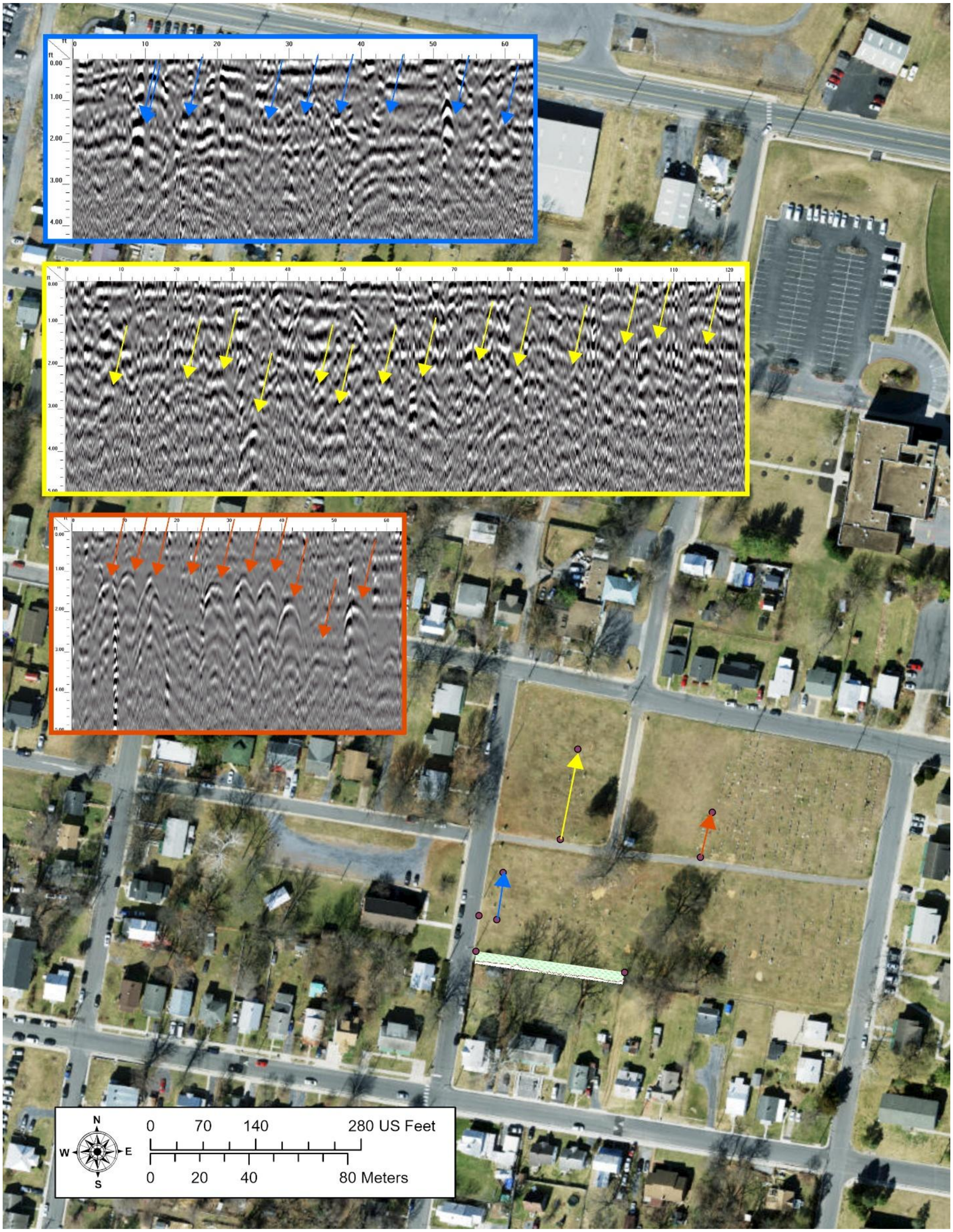


Figure 4.2. Locations of the three GPR prospecting transects (blue, yellow, and red arrows) and the corresponding profiles (S-N). Probable interments are marked by the arrows in the reflectance profiles (inset). The y-axis of each profile represents depth, and the x-axis is distance.

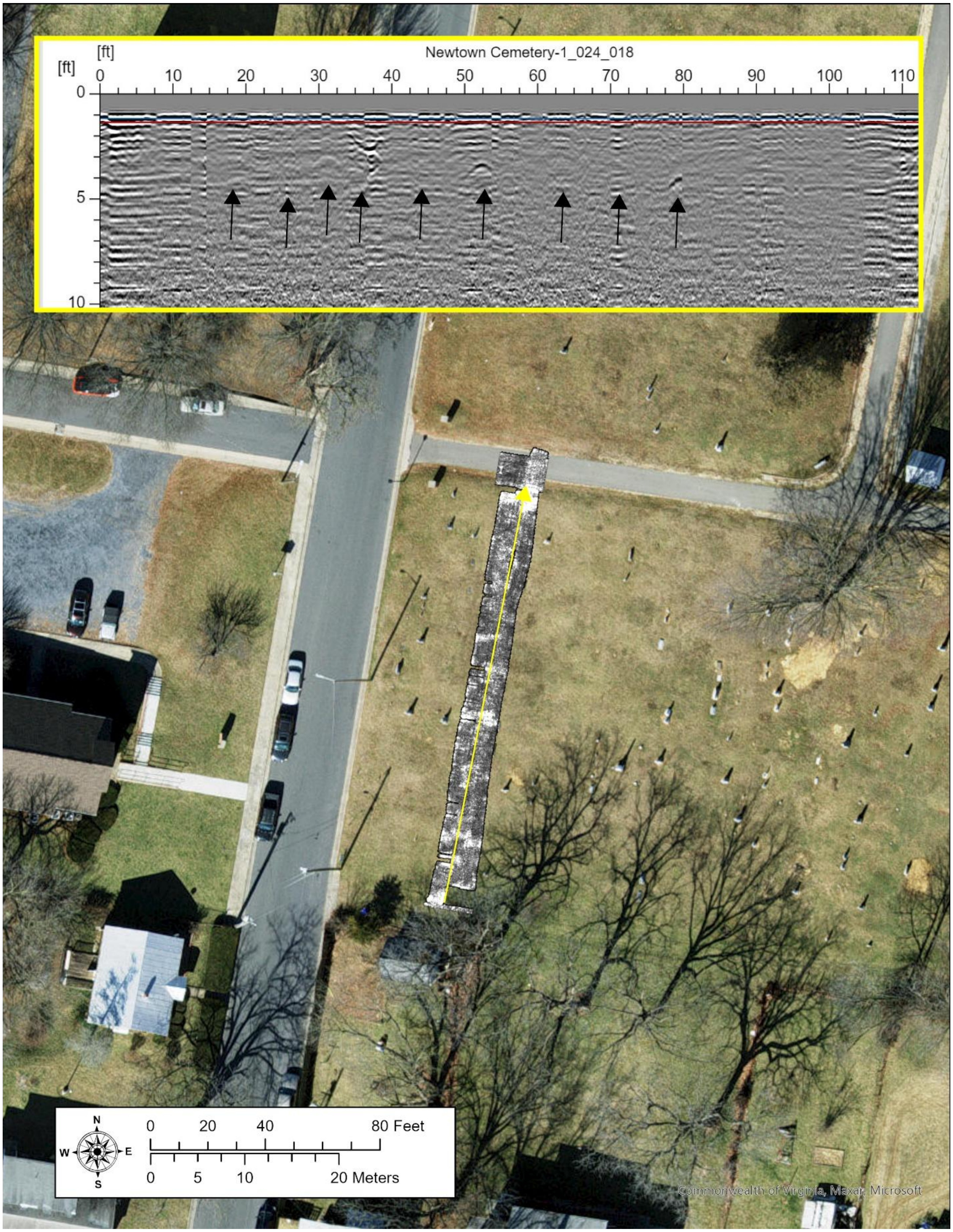


Figure 3.3. Prospection line (yellow arrow) and corresponding reflectance profile (inset) from the MALA MIRA HDR multi-channel array. The black arrows indicate probable coffins (inset).

Figure 4.4. Shallow, high-amplitude linear target (black arrows) located in the alleyway gridded survey area. The profile of the feature, likely a communication line (i.e., cable, fiber, or phone), is shown in the inset (black arrow).

UtilityScan 350MHz HS Gridded GPR Survey of the Alleyway

During the analysis, anomalies representing marked or unmarked graves were identified as "probable" or "possible" interments. In this report, probable burial indicates greater certainty in identifying interments than the latter.

Assigning the term **probable** to an interment involves evaluating multiple lines of evidence and geophysical analysis. Surficial observations (e.g., grave markers, slumping of grave shafts, and ground cover) are closely compared with the GPR reflectance profiles and three-dimensional interpolations. Two-dimensional profiles may reveal forensic evidence of grave shaft incision, slumping stratigraphy, and depth to the coffin or remains. Rendered amplitude maps can also provide spatial patterning indicating rows of individual burials, vaults, coffins, or casket remnants.

Assigning the term **possible** to a burial means that one or more pieces of forensic evidence are missing. Possible unmarked burials may also involve interments within severely decayed coffins or those buried within a shroud, resulting in poorly reflective targets or surfaces. Anomalies marked as possible burials may also represent other features, such as a tree throw, rodent dens, or a buried, faintly reflective geologic object. Disinterments are also common in cemeteries, and the geophysical signatures of these events cannot always be distinguished from those of burials in which coffins have degraded significantly. Potential disinterments can sometimes be identified when historical documentation of the event is compared with survey data, as surrounding graves exhibit features such as minimal disturbances and well-preserved coffins.

The gridded GPR survey collection began in the northwest corner of the alleyway, and individual lines extended no more than 17 ft to the south. Field conditions for the survey were relatively free from obstructions save for fences, trees, and brush associated with the houses to the south. The two-dimensional reflectance profiles and three-dimensional interpolation from the UtilityScan 350 MHz HS survey suggest that **one possible burial** may be located within the alleyway (Figure 4.5). Located on the eastern side of the study area, the reflectance profiles indicated an incision and a potential collapse coffin with a weak amplitude target in the center of the incision.

Multi-Channel Array GPR Survey of the Alleyway, Sterling Street, and Effinger Street

The MALÅ MIRA HDR array survey was conducted in four main areas: Sterling Street, the alleyway, and a portion of Effinger Street located within the Newtown Cemetery. The Sterling Street survey consisted of eleven transects over 350 ft long and approximately 29 ft wide (W-E). It was conducted in a bidirectional manner and was designed to be contiguous with the alleyway as it intersected with Sterling Street. **No potential graves or forensic evidence of interments** were found in the multi-channel survey of Sterling Street. It was noted that the elevation of the Newtown Cemetery was several feet higher than the road's surface. Additionally, the construction of Sterling Street would likely have required several feet of grading before installing asphalt, which may preclude the survival of any potential burials beneath the road (Figure 4.6).

A small section (145 ft) of Effinger Street within the cemetery's boundaries was surveyed with the MALÅ HDR to calibrate the antenna for the Sterling Street survey. The survey consisted of three bidirectional transects within the road's footprint and was approximately 13 ft wide (Figure 4.7). This portion of Effinger Street was located on a slope, and construction of the road appears to have involved a cut episode on the hill's south side. **No potential interments or forensic evidence of burials** were found in this section of the geophysical survey.

The last area surveyed with the MALÅ MIRA HDR was a portion of the alleyway. The GPR survey focused on the alleyway's eastern half, consisting of five transects, approximately 223 ft in length (W-E) and approximately 14 ft wide (N-S). **Two probable and one possible graves** were found on the east end of the alleyway survey (Figure 4.8). Each high-amplitude target was at a depth (approximately 2.4 ft) consistent with the observed depths imaged in the prospection phase of the geophysical survey, and each measured approximately 2.5 ft (N-S) by 5.8 ft (W-E) in plan. The possible grave found with the HDR array appears to be the same high-amplitude target imaged with the UtilityScan 350 MHz HS antenna (see above).

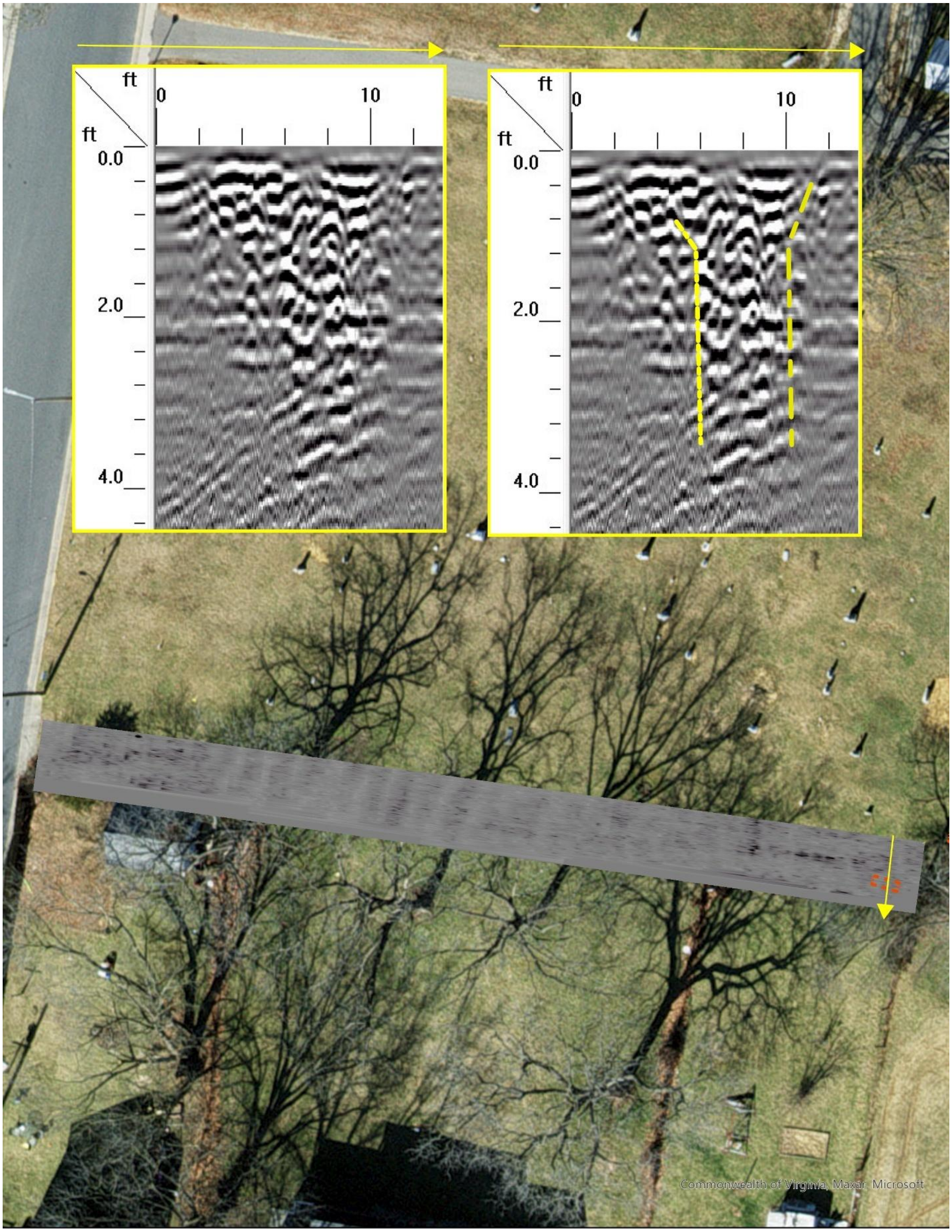


Figure 4.5. The UtilityScan 350 MHz HS gridded survey and the possible grave (red dashed outline). The yellow arrow represents the reflectance profile (insets). The profile shows evidence of incision (annotated on the right).

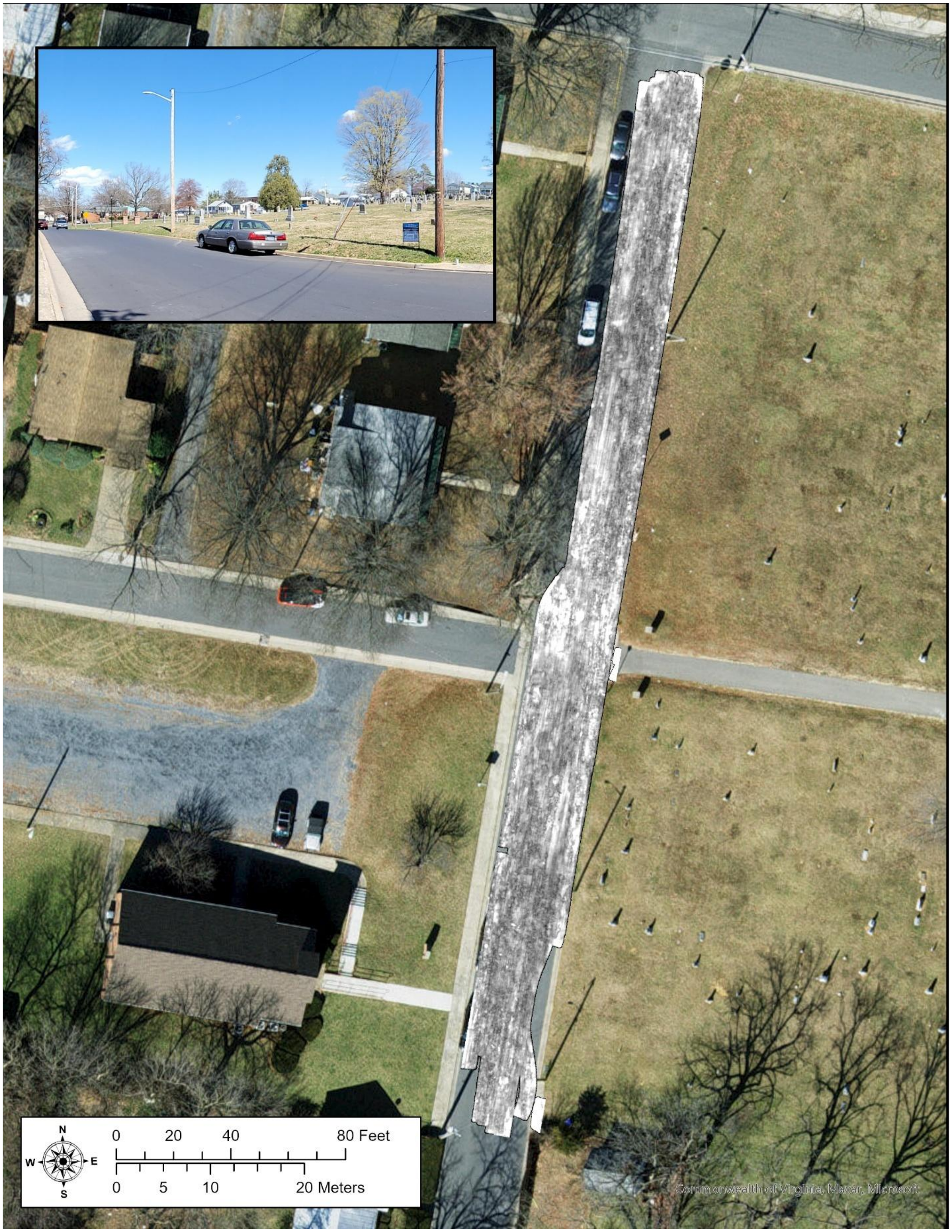


Figure 4.6. The Sterling Street multi-channel array survey and perspective of the transition of the cemetery to the street (inset), looking northeast.

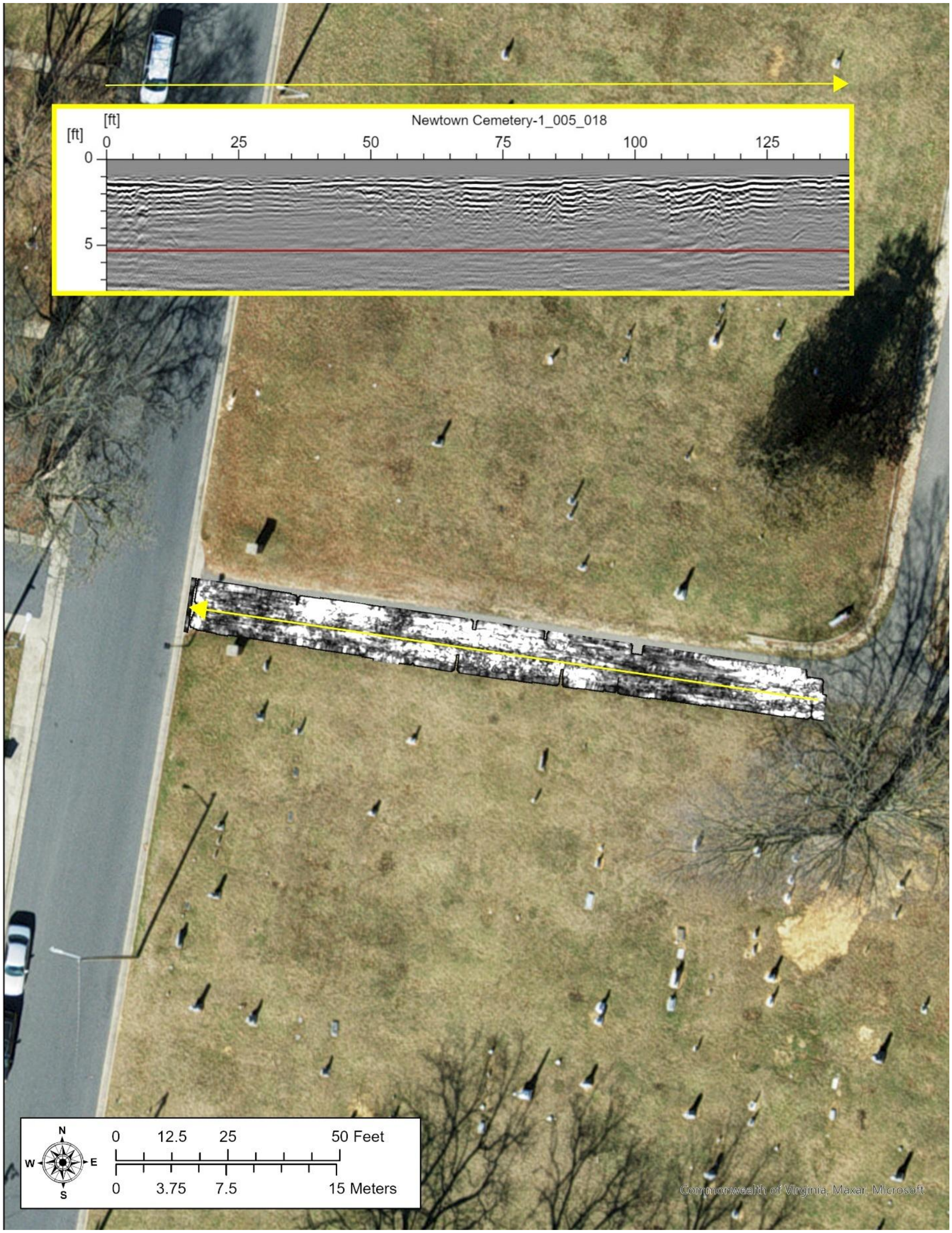
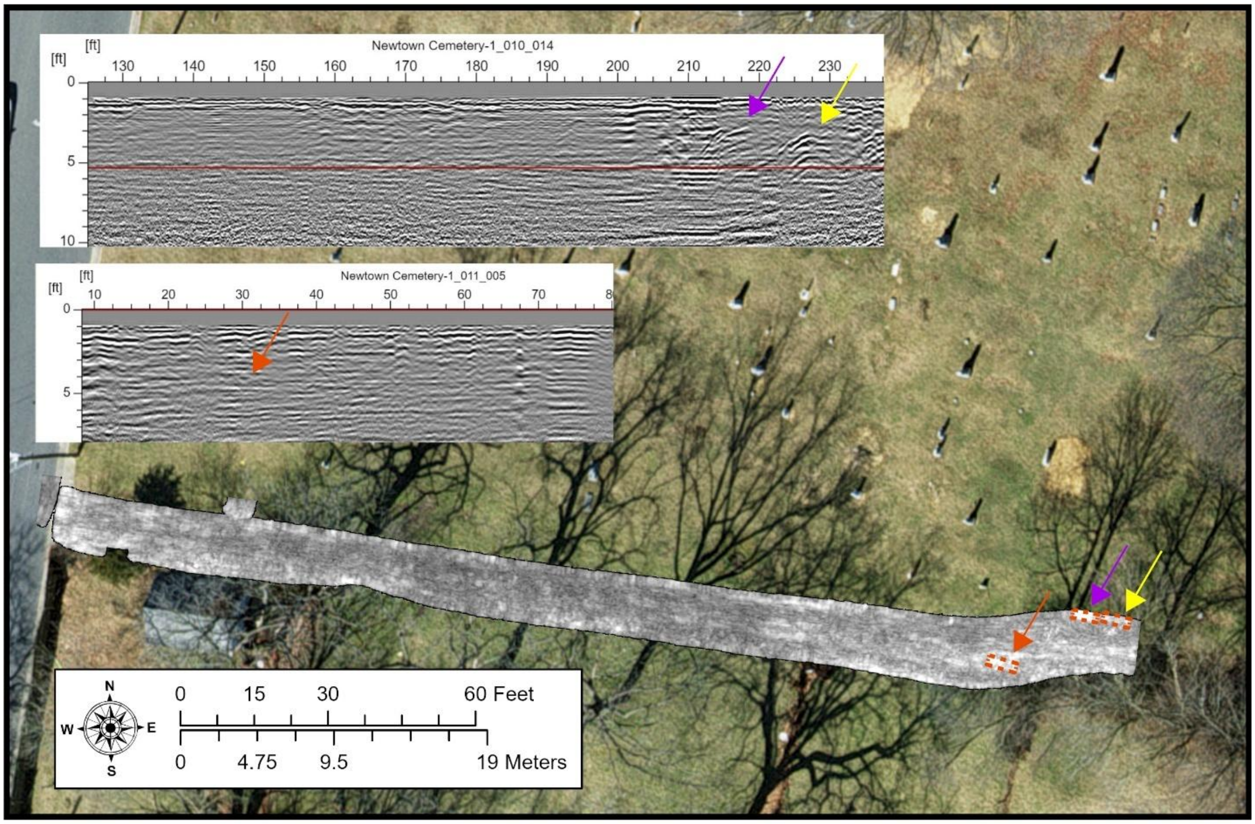


Figure 4.7. The Effinger Street MALA HDR survey and representative reflectance profile (inset).



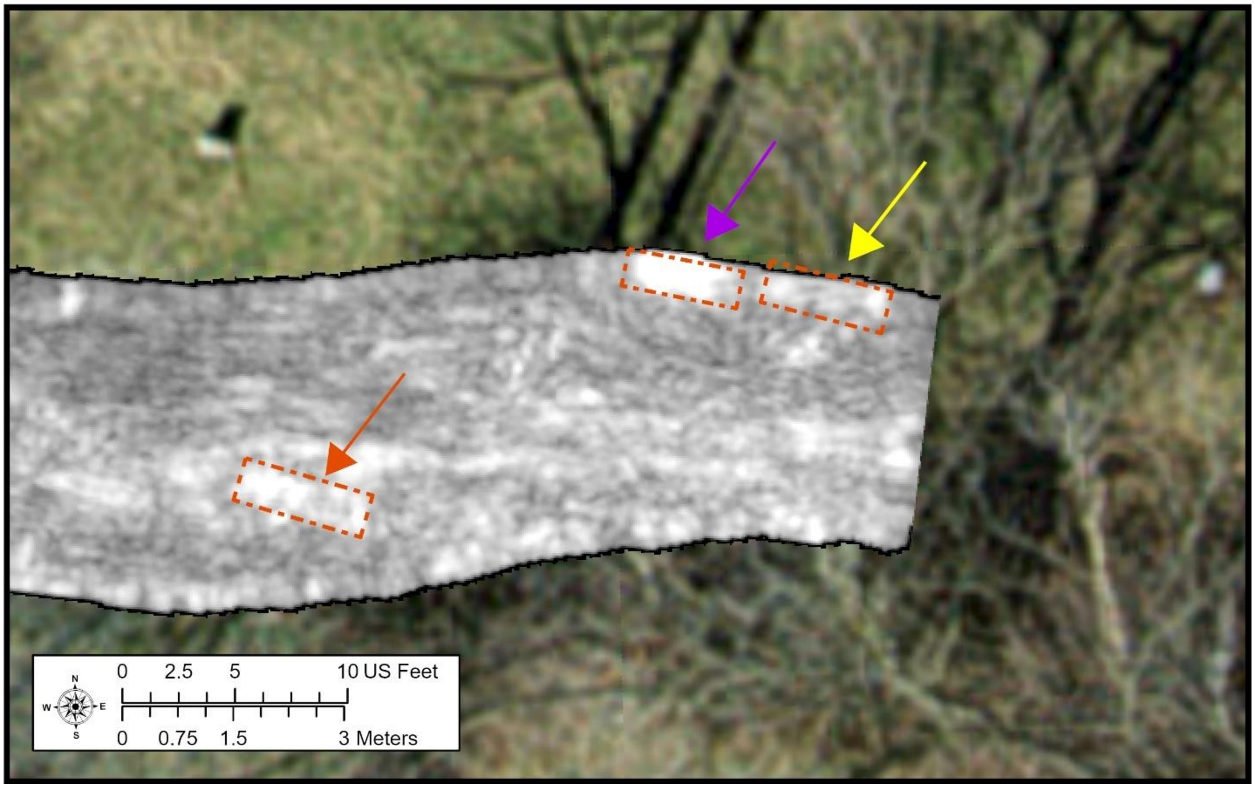


Figure 4.8. The Effinger Street MALA HDR survey (top) and representative reflectance profiles for the probable and possible graves located in the alleyway (insets). A magnified view of the two probable (yellow and blue arrows) and possible (red arrow) interments.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

TerraSearch Geophysical, LLC (TerraSearch) conducted a ground-penetrating radar (GPR) survey of approximately 0.46 acres of the Newtown Cemetery, located in Harrisonburg, Virginia (-78.8589584°W, 38.4529721°N), in March 2025. The survey included geophysical prospecting, documentation, mapping of the cemetery, and a comprehensive GPR survey utilizing single- and multi-channel antennae.

Four portions or areas in and around the Newtown Cemetery were surveyed, each suspected of containing interments. Each area differed in size and survey methodology. A GSSI UtilityScan 350 MHz HS, single-channel antenna was used in a gridded survey in the alleyway south of the cemetery's margin. One possible grave was found at the eastern end of the survey area.

The MALÅ MIRA HDR multi-channel array was utilized for a portion of Sterling Street, Effinger Street, the alleyway, and a prospection survey with a marked cemetery (extant gravestones) area. While compelling evidence of graves was found in the prospection survey, no indication of burials was found beneath Effinger or Sterling Streets. A supplementary study of the alleyway revealed two probable graves in addition to the one found in the gridded survey.

While comprehensive, the ground-penetrating radar survey summarized in this report represents only a small portion of the Newtown Cemetery, demonstrating the value of non-invasive geophysical methodologies in locating unmarked burials. For this GPR survey, every effort has been made to identify features of interest through geophysics and the analysis of the collected data. As with any geophysical survey, these methods are not foolproof and should be ground-truthed to verify the interpretations.

CHAPTER VI: BIBLIOGRAPHY

Bevan, Bruce W.

1991 The Search for Graves. *Geophysics* 56(9): 1310-1319.

Bristow, C. S. and Jol, H. M., eds.

2003 *Ground Penetrating Radar in Sediments*. Geol. Soc., London, Special Pub. 211.

Clark, Anthony

2001 *Seeing Beneath the Soil: Prospecting Methods in Archaeology*. Oxon: Routledge.

Conyers, Lawrence B.

2004 *Ground-Penetrating Radar for Archaeology*. Lanham, MD: Altamira Press.

2006 Ground-Penetrating Radar. In *Remote Sensing in Archaeology: An Explicitly North American Perspective*. Jay K. Johnson, Editor. Pp. 131 – 160. Tuscaloosa, AL: The Univ. of Alabama Press.

Daniels, David J.

2004 *Ground Penetrating Radar* – 2nd Edition. London, UK: The Institute of Electrical Engineers.

Gerrard, A.J.

1981 Soils and landforms. An integration of geomorphology and pedology. London: George Allen and Unwin. xviii + 219 pp. £15.00 cloth, £7.95 paper. Progress in Physical Geography: Earth and Environment, 7(3), 439-440.

Heimmer, Don H., and Steven L. De Vore

1995 *Near-surface, High-resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations*, Denver, Co: U.S. Department of the Interior.

Leach, Peter

2019 *RADAN 7 for Archaeology, Forensics, and Cemeteries.* Nashua, NH: Geophysical Survey Systems, Inc. Nashua, NH.

2021 *A Theory Primer and Field Guide for Archaeological, Cemetery, and Forensic Surveys with Ground Penetrating Radar.* Nashua, NH: Geophysical Survey Systems, Inc.

Porter, S.T., Roussel, M. and Soressi, M.,

2016 A simple photogrammetry rig for the reliable creation of 3D artifact models in the field: lithic examples from the Early Upper Paleolithic sequence of Les Cottés (France). *Advances in Archaeological Practice*, 4(1):71-86.

Virginia Division of Mineral Resources.

1993 *Geologic map of Virginia: Commonwealth of Virginia, Department of Mines, Minerals, and Energy, Virginia Division of Mineral Resources, scale 1:500,000*

Woods, A.J, Omernik, J.M., Brown, D.D.
1999 *Level III and IV Ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia, U.S.* Environmental Protection Agency: National Health and Environmental Effects Research Laboratory, Corvallis, OR.

CHAPTER VII: APPENDIX

Figure 7.1. Origin point (top) for the UtilityScan 350 MHz HS gridded survey (looking southeast). The terminal line for the gridded survey (bottom) is demarcated by the white flag in the foreground.

Figure 7.2. A view of the alleyway survey area looking southeast (top). Perspective of prospection transect A looking north (bottom).

Figure 5.3. A view of GPR transect B from the margin of Effinger Street (top). Perspective of prospection transect C looking north (bottom). Transect C was located in the 20th-century portion of Newtown Cemetery.