



November 16, 2021

Ms. Kara O'Donnell
City of Shaker Heights, Ohio
15600 Chagrin Boulevard
Shaker Heights, Ohio 44120

Re: Ground Penetrating Radar Survey Report – Warrensville West Cemetery, Shaker Heights, Ohio

Dear Ms. O'Donnell:

The Mannik & Smith Group, Inc. (MSG) was retained by the City of Shaker Heights to perform a Ground Penetrating Radar (GPR) investigation for the Warrensville West Cemetery located in Shaker Heights, Ohio (Site). This project is part of the Historic Preservation Master Plan project for the Warrensville West Cemetery.

The Warrensville West Cemetery is located on the east side of Lee Road, approximately 250 feet north of the intersection of Lee Road and Chagrin Boulevard, Shaker Heights, Ohio. The purpose of the investigation described herein was to provide GPR services focused on the identification of potential buried human remains located within the Warrensville West Cemetery. Since buried human remains are not always marked with a monument or aligned with their respective monument, GPR was chosen as the preferred method of determining buried human remains on the Site. The GPR Survey Area is illustrated on the attached *Figure 1, GPR Survey Results Map*. The GPR survey was conducted within the marked boundaries of the Warrensville West Cemetery, bounded by a building structure and metal fence to the north, a concrete retaining wall to the east, and shrubs and a concrete retaining wall to the south and west.

PROCEDURES

GPR operates by transmitting electromagnetic impulses (radio waves) into the subsurface and measuring the time for a reflected signal to return to the receiving antenna. A two-dimensional cross-section representing the subsurface response is generated in real-time as the GPR broadband dipole antenna is moved across the ground surface. Electromagnetic waves transmitted from the GPR propagate downward through the subsurface, reflect off subsurface boundaries and return to the receiver antenna. GPR signals reflect back toward the ground surface depending on the contrast in the electrical properties of subsurface materials.

Important limitations to GPR performance are detecting small or deeply buried targets, as well as penetrating dense or conductive materials (i.e. moist clay, silty clay, weathered shale, slag, concrete, foundry sand, etc.), which cause signal attenuation (absorption). The recommended survey methodologies and equipment were selected to meet the project objectives; however, data interpretation is subjective and constrained by instrument limitations and site conditions, and therefore, is not guaranteed to be 100% accurate. Horizontal accuracy of the location of subsurface anomalies is approximately +/- 1 feet and the vertical accuracy is +/- 0.25 feet per foot of burial depth.

MSG conducted a GPR survey at the Site using a Geophysical Survey Systems, Inc. 4-wheel GPR system, from September 28 through September 30, 2021. The GPR system included a 400 megahertz (MHz) antenna was used in conjunction with a SIR-3000 field computer for locating subsurface anomalies within the GPR survey area. Since a majority of the burials at the Site are oriented east-west in accordance with traditional Christian burial methods, the GPR survey grid was oriented approximately in the east-west and north-south directions, which are approximately



perpendicular and parallel to the alignment of these burials. A two-foot survey grid was established over the 210 foot by 206 foot GPR survey area and the GPR was operated in a series of parallel lines (x,y-grid) over the GPR survey area, except for sections of the GPR survey area where additional detail was necessary and a one-foot survey grid was used. Portions of the cemetery were blocked by surface obstructions (trees, shrubs, burial monuments, fences, etc.) and GPR was not performed in these obstructed areas. GPR survey areas, detected anomalies and reference surface features were surveyed with a Trimble Geo7X centimeter edition Global Navigation Survey System (GNSS) unit including a Zephy3 antenna. The survey grid was established using a measuring tape and distance recorded along the survey lines with the GPR odometer (+/- 0.1 feet). The GPR antenna was moved over the ground surface using the 4-wheel cart GPR system that acquired data at approximately 18 traces per foot. The depth of measurement was estimated using an approximate dielectric constant for clay soil (8.0). The interpretable depth of the GPR signal (signal floor) was limited to approximately six feet due to signal attenuation within the soils at the Site.

RESULTS AND CONCLUSIONS

GPR is an effective means of characterizing the subsurface and the detection of buried anomalies and can provide a significant amount of detail about what is underground. GPR identification of burials at cemeteries typically involves the detection of the top of buried coffins or vaults, however over time, graves deteriorate and become difficult to detect. Additional GPR anomalies that are used in detection of burials are soil disturbances, including burial shafts and excavation areas. Other observable physical evidence is also considered along with the GPR data in the detection of burials, including surface disturbances and ground subsidence. However, GPR data can contain many additional unwanted components in the data, or noise, which originate from the use of the GPR, soil conditions or additional subsurface materials (tree roots, rocks, and other forms excavation, not related to burials).

Based on the GPR survey data, all significant detected anomalies, including burials located at the Warrensville West Cemetery, are depicted on *Figure 1, GPR Survey Results Map*. Photos of field activities are located in Figure 2 through Figure 4. Multiple select examples of noise and anomalies detected during the GPR survey at the Warrensville West Cemetery are depicted in Figure 5 through Figure 15, including:

1. Figure 5 illustrates an example of a typical GPR radiogram collected during the GPR survey at the Site, which is representative of the clayey till soils and soil layers present across the Site.
2. Figure 6 illustrates multiple linear anomalies detected indicative of suspected tree roots and are an example of one of the sources of noise detected at the Site.
3. Figure 7 illustrates the hyperbolic response of a linear anomaly indicative of a subsurface utility located in the northeast portion of the cemetery leading to the east towards the east cemetery boundary as indicated on *Figure 1*. A GPR radiogram from a profile collected across the linear GPR anomaly indicative of the suspected utility is illustrated in *Figure 4* below.
4. Figure 8 illustrates a GPR radiogram of typical noise encountered of suspected fill material from previous excavation activities at the Site, not directly related to burials. Noise from fill material was encountered along the east cemetery retaining wall and north drainage area within the cemetery.
5. Figure 9 illustrates a GPR radiogram of a linear anomaly indicative of a suspected burial vault located within the Warrensville West Cemetery. The wider hyperbolic response of a suspected burial vault illustrated in Figure 9 is different than that of the hyperbolic response of a cylindrical utility structure illustrated in Figure 7.
6. Figure 10 illustrates a GPR radiogram of a linear anomaly indicative of a suspected burial vault located within the Warrensville West Cemetery. Note how the longer "flat topped" response of a suspected burial vault across the length of the vault is different than that of the hyperbolic response across the width of a burial illustrated in Figure 9.
7. Figure 11 illustrates a GPR radiogram of a linear "flat topped" anomaly indicative of a suspected burial coffin located within the Warrensville West Cemetery. This burial is characteristic of multiple other

burials detected within the northeastern portion of Warrensville West Cemetery, which were without burial markers or monuments.

8. Figure 12 illustrates a GPR radiogram of a linear anomaly indicative of a burial shaft located within the Warrensville West Cemetery.
9. Figure 13 illustrates a GPR radiogram of multiple linear anomalies indicative of burials located within the Warrensville West Cemetery. These particular burials had markers or monuments located adjacent at the surface.
10. Figure 14 illustrates a GPR radiogram of two linear anomalies detected indicative of suspected burial vaults and an anomaly indicative of a suspected excavation. This excavation lies adjacent to the granite marker and memorial plaque indicating the final resting place of the Shakers of the North Union Society located within the Warrensville West Cemetery.
11. Figure 15 illustrates a GPR radiogram of an anomaly indicative of a suspected excavation, which is sloped from approximately one to five feet below ground surface. This excavation lies adjacent to the granite marker and memorial plaque indicating the final resting place of the Shakers of the North Union Society located within the Warrensville West Cemetery.

The conclusions in this report are based on MSG's interpretation of the field data obtained during the geophysical investigation, our understanding of the project and our experience during previous work with similar sites and subsurface conditions.

MSG appreciates the opportunity to provide GPR services to the City of Shaker Heights. If you have any questions concerning this GPR survey report, please feel free to contact the undersigned at 734-397-3100.

Sincerely,



Michael J. Friedhoff, CPG
Senior Geophysicist / Project Manager

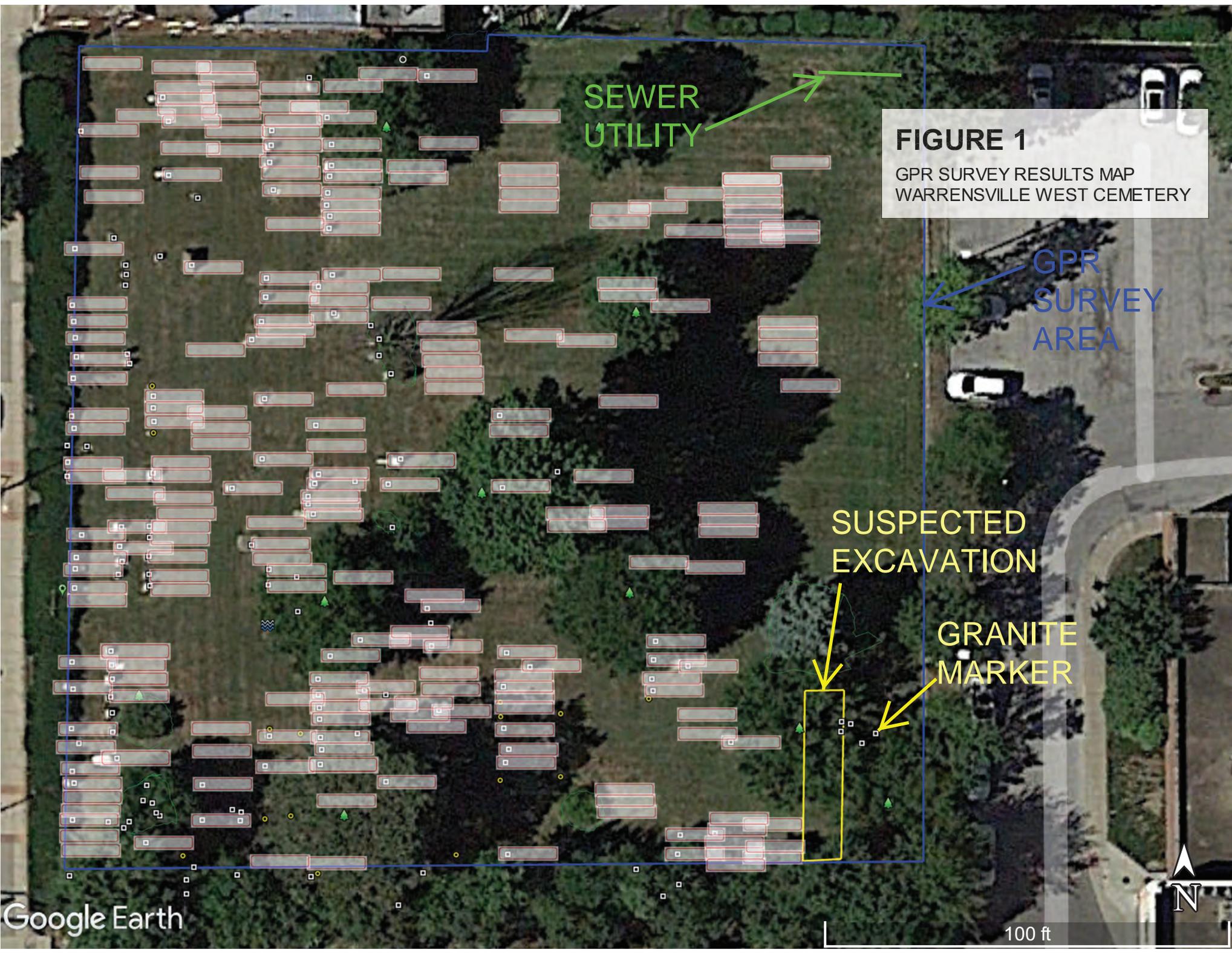


FIGURE 1

GPR SURVEY RESULTS MAP
WARRENSVILLE WEST CEMETERY

SEWER
UTILITY

GPR
SURVEY
AREA

SUSPECTED
EXCAVATION

GRANITE
MARKER





Figure 2 (left): View of the GPR survey grid flagging at the Warrensville West Cemetery, facing southwest.

Figure 3 (right): View of the GPR survey activities at the Warrensville West Cemetery, facing southeast.



Figure 4 (left): View of burial marker and GPR anomaly field marking of suspected burial (marked in pink) at the Warrensville West Cemetery, facing south.

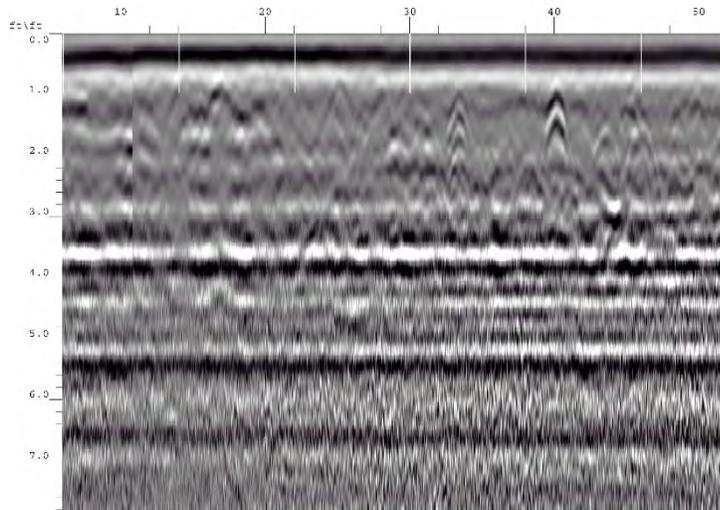


Figure 5 (left): GPR radiogram illustrating the representative signature of the clayey till soils and soil layers present across the Warrensville West Cemetery.

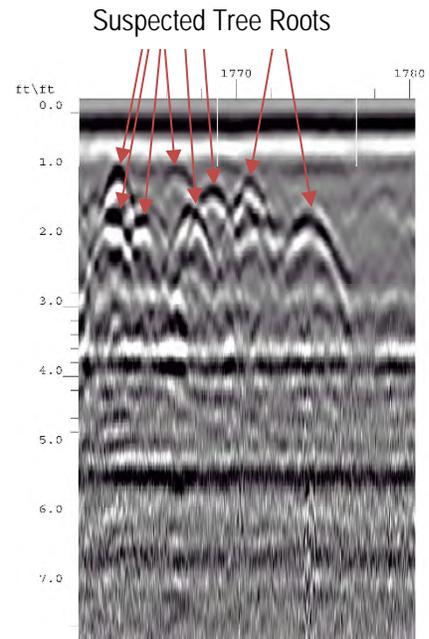


Figure 6 (right): GPR radiogram illustrating the hyperbolic response of multiple linear anomalies indicative of suspected tree roots encountered at the Warrensville west Cemetery..

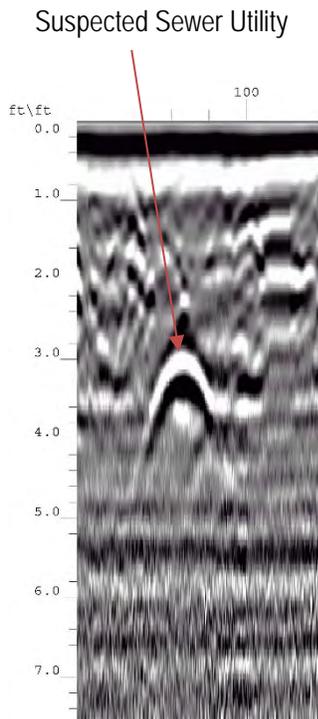
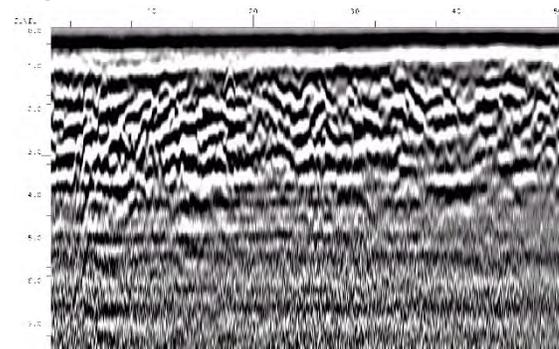


Figure 7 (left): GPR radiogram illustrating the hyperbolic response of a linear anomaly indicative of a subsurface utility that was detected from the sewer catch basin located in the northeast portion of the cemetery leading to the east towards the east cemetery boundary.

Figure 8 (below): GPR radiogram of suspected fill material from previous excavation activities at the Site located along the east retaining wall and north drainage area within the cemetery. While fill material can be a source of interference to detection of burials during a GPR survey, only a small portion of the cemetery appears to contain fill material that interferes with burial detection.



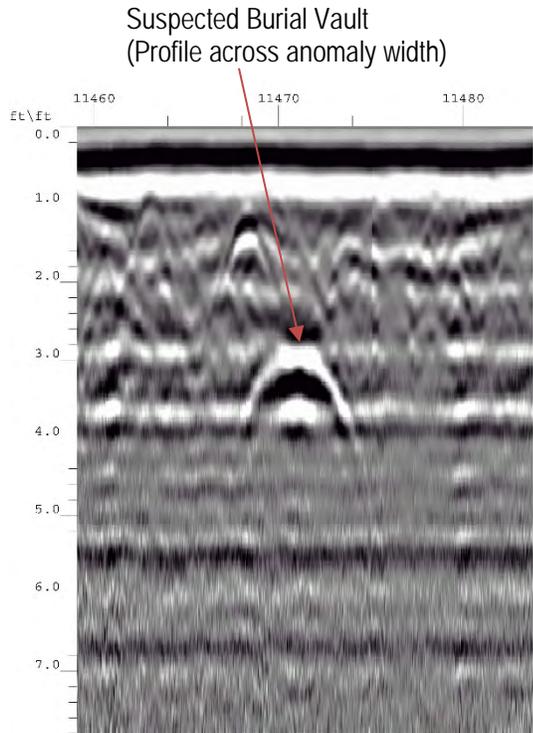


Figure 9 (left): GPR radiogram of a linear anomaly indicative of a suspected burial vault located within the Warrensville West Cemetery. Note how the wider hyperbolic response of a suspected burial vault (across the width of the vault) is different than that of the hyperbolic response of a cylindrical utility structure in Figure 7.

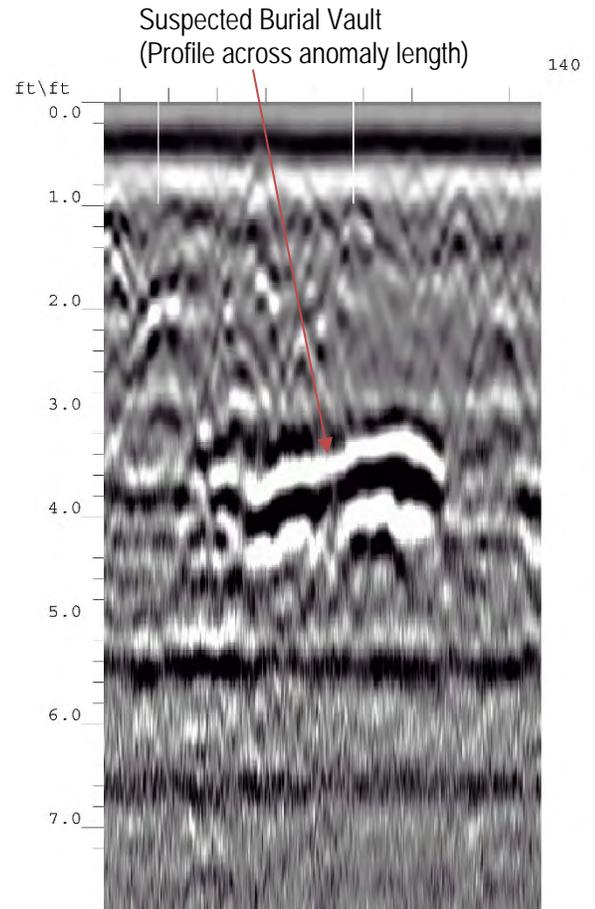


Figure 10 (right): GPR radiogram of a linear anomaly indicative of a suspected burial vault located within the Warrensville West Cemetery. Note how the longer “flat topped” response of a suspected burial vault (across the length of the vault) is different than that of the hyperbolic response across the width of a burial in Figure 9.

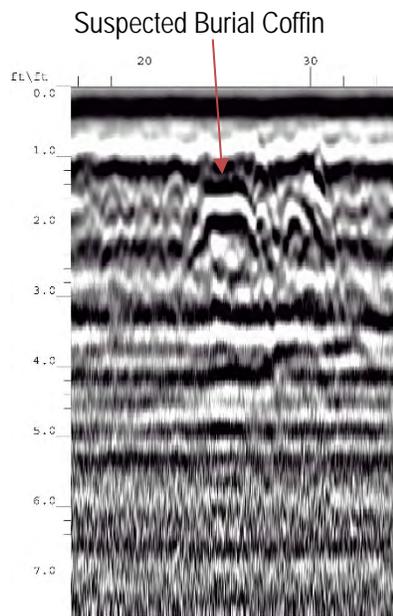


Figure 11 (left): GPR radiogram of a linear “flat topped” anomaly indicative of a suspected burial coffin located within the Warrensville West Cemetery. This burial is characteristic of multiple other burials detected within the northeastern portion of Warrensville West Cemetery, which were without burial markers or monuments.

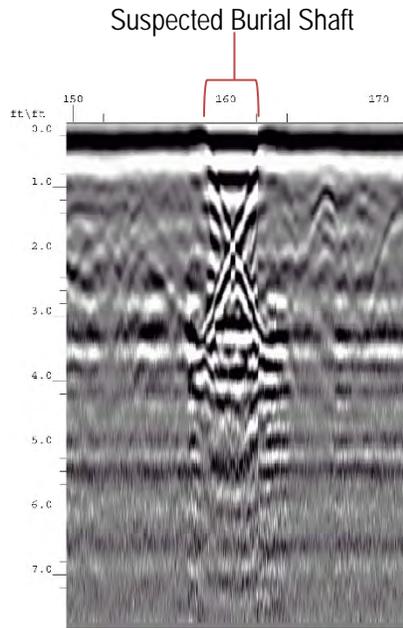


Figure 12 (left): GPR radiogram of a linear anomaly indicative of a burial shaft located within the Warrensville West Cemetery.

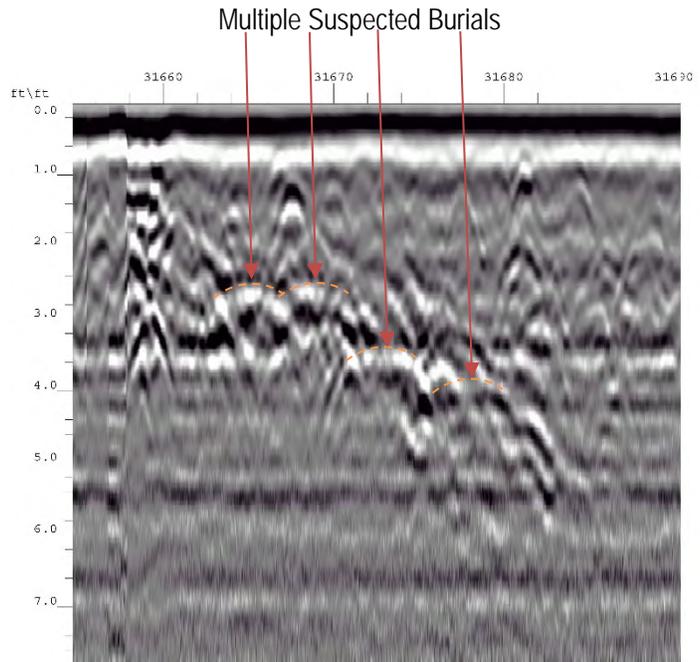


Figure 13 (right): GPR radiogram of multiple linear anomalies indicative of burials located within the Warrensville West Cemetery. These particular burials had burial markers or monuments located adjacent at the surface.

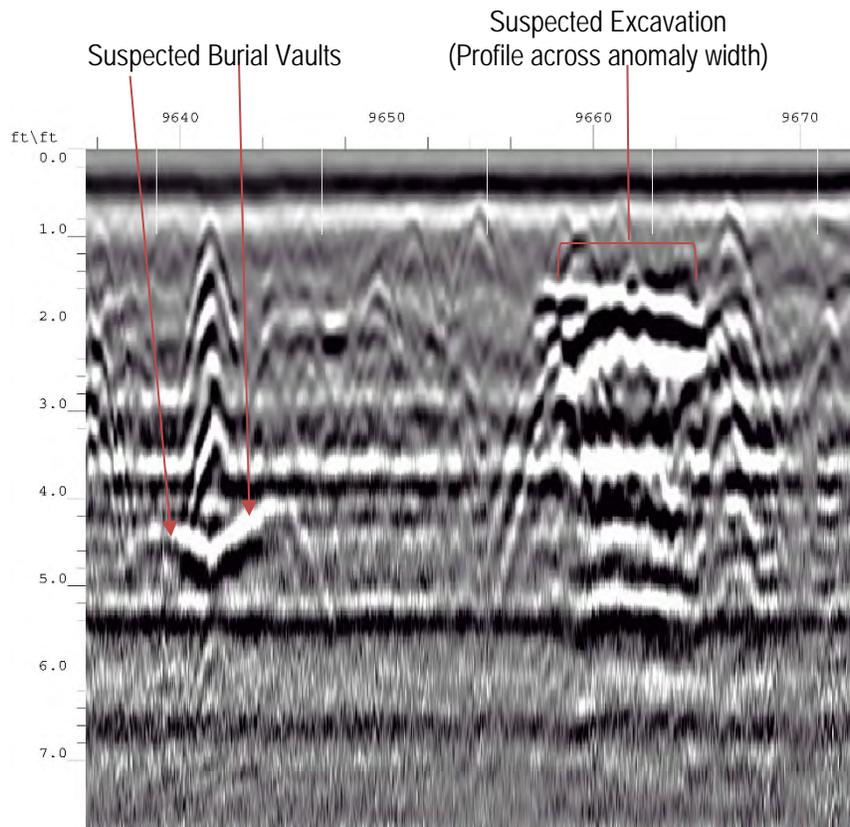


Figure 14 (left): GPR radiogram of two linear anomalies indicative of suspected burial vaults and an anomaly indicative of a suspected excavation. This excavation lies adjacent to the granite marker and memorial plaque indicating the final resting place of the Shakers of the North Union Society located within the Warrensville West Cemetery.

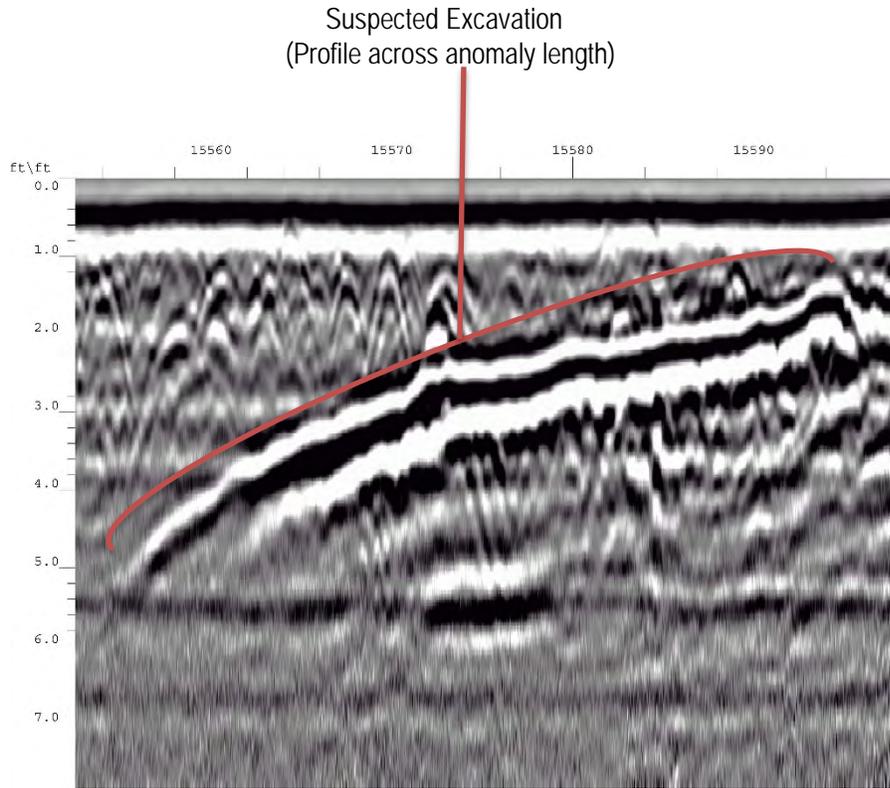


Figure 15 (left): GPR radiogram of an anomaly indicative of a suspected excavation, which is sloped from approximately one to five feet below ground surface. This excavation lies adjacent to the granite marker and memorial plaque indicating the final resting place of the Shakers of the North Union Society located within the Warrensville West Cemetery.