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HRD DOG AND GPR INVESTIGATIONS AT KETTLE CREEK BATTLEFIELD, WASHINGTON, GA

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INTRODUCTION

The Kettle Creek Battlefield Association ("the Association") contacted Bigman Geophysical in 2015 to investigate the Kettle Creek Battlefield site in Washington, GA in hopes of locating fallen soldiers dating to the revolutionary war battle that took place at the site. A preliminary human remains detection (HRD) dog survey and a follow up study conducting ground penetrating radar (GPR) survey showed promise as a dual method approach to investigating a large, wooded, and topographically varied landscape containing small potential targets. The Association contracted Bigman Geophysical to expand the study following the initial success of the preliminary investigations (See Figure 1 for an outline of the entire area investigated during the 2017 survey). Mimicking the strategy from the preliminary investigations, this stage of the project began with large scale landscape coverage using trained HRD dogs and an experienced dog handler to narrow down locations with possible graves. Then GPR survey was conducted in these areas as systematically as the ground cover and topography would allow. Since specific locations of dog alerts during the preliminary examination rarely correlated with GPR reflection events in the exact same location, the project collected GPR data over a geographic area often ranging over 5 m from the dog alert. The HRD dogs alerted to 12 distinct locations during the current phase of investigation. The GPR recorded reflection events indicative of possible graves in 6 of these locations, some with multiple GPR reflections of interest. This report summarizes the methods and results of these investigations and provides processed GPR data from each potential unmarked grave in Appendix A.

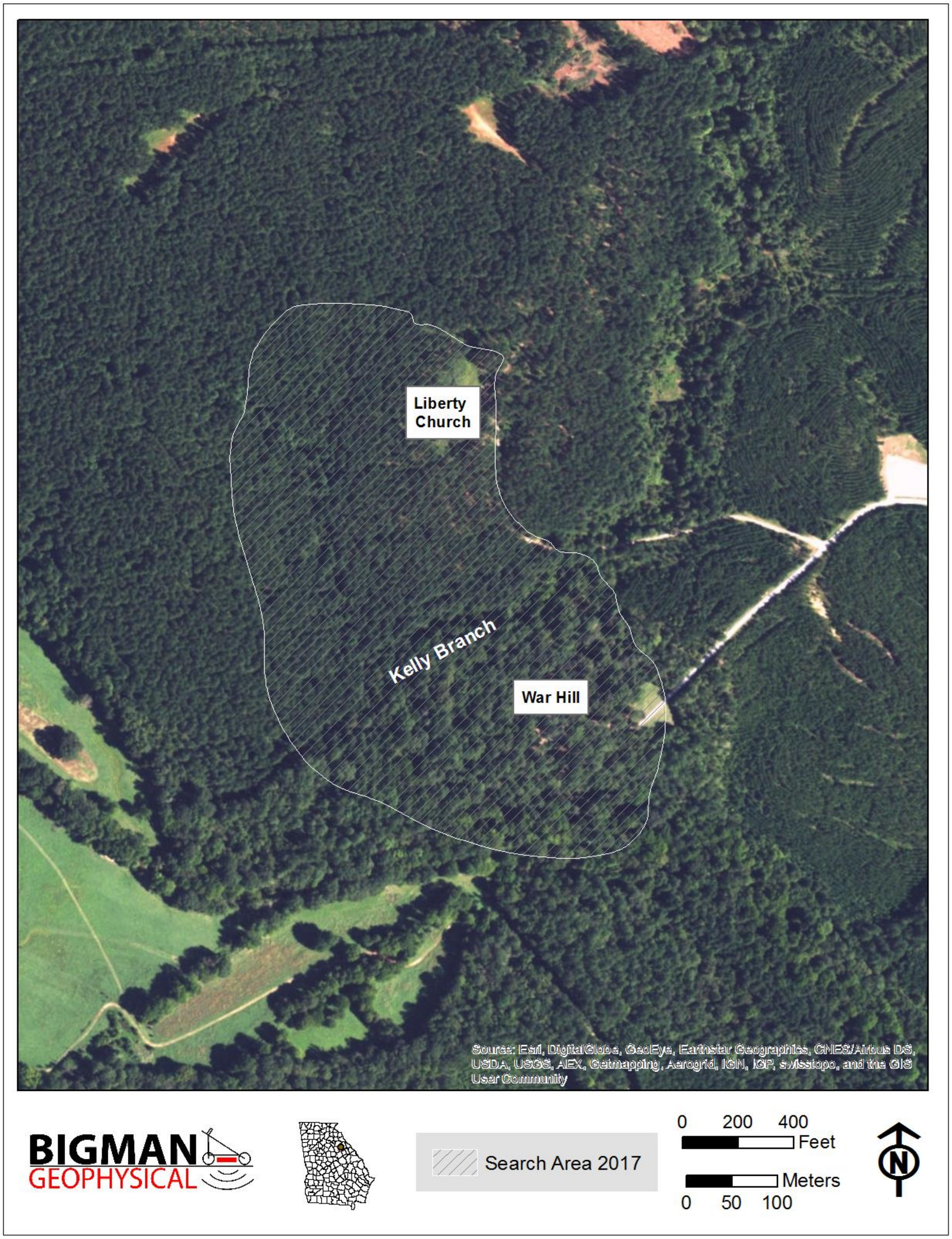

Figure 1. Aerial photo depicting boundaries of study area.

METHODS

Human Remains Detection Dogs

Human Remains Detection (HRD) dogs (sometimes referred to as cadaver dogs) are trained to identify human remains scent from decomposed human bodies using olfactory cues. Decomposed bodies change the physical and chemical properties of the soil they interact with through the release of nutrients and energy (Carter et al. 2007). This interaction can possibly alter soil pH, electrical conductivity, and nutrient levels (Pringle et al. 2015; Stokes et al. 2013) which produce an odor that is detectable by properly trained HRD dogs. The odor can remain in the soil or on the surface long after the remains have completely decomposed and no bone is left (Alexander et al. 2015). Furthermore, multiple studies indicate that HRD dogs can distinguish between decomposing human cadavers and those of other animals (Cablk et al. 2012; Stokes et al. 2013) since each animal cadaver is composed of a unique set of volatile organic compounds (VOCs) that produce a unique odor. There is some overlap in the VOCs found in different animal cadavers, but each species has a unique set. Pigs are often considered the best proxy for decomposition studies (Schultz et al. 2006; Schultz 2008), but pigs and humans only share seven compounds of the 30 that human cadavers contain (Cablk et al. 2012). Despite the abundance of research showing the capability of dogs to locate human remains, it is still unclear exactly which compounds HRD dogs are using (Alexander et al. 2015). Thus, the qualifications of the dog handler remains an important factor in determining the success of any search (Riezzo et al. 2014). Bigman Geophysical hired Tracy Sargent of K9 Search & Rescue Specialists, Inc. to carry out this portion of discovery. She has over 20 years of experience, including experience locating graves at Revolutionary War battle sites.

Ground Penetrating Radar (GPR)

This survey utilized GPR to image the subsurface and evaluate the presence or absence of possible unmarked historic graves. GPR sends electromagnetic pulses to a transmitting antenna at the ground surface which produces a radio wave that travels through the subsurface (Koppenjan 2009). Wave speed depends on the ability of a given medium to transfer energy (Annan 2009, Conyers 2004). When an approaching wave encounters a discontinuity in the physical properties of the soil and the wave's speed changes, some of the wave front's energy is reflected back toward the ground surface (Annan 2009). The two-way travel time (usually recorded in nanoseconds) and the amplitude of the reflection are recorded at the surface by a receiver antenna. Each traverse with the GPR provides a two-dimensional profile of the subsurface.

GPR is a popular and often successful technique for mapping cemeteries and locating unmarked burials. Numerous cemetery case studies document the success of the technique in historic contexts (Bevan 1991; Bigman 2014; Conyers 2006; Davenport 2001; Dionne et al. 2010; Fiedler et al. 2009; Gleason et al. 2011; Honerkamp and Crook 2012; Hunter 2012; Jones 2008; Shaaban et al. 2009; Sjostrom et al. 2009; Tarver and Bigman 2013; Torgashov and Anderson 2012). Several researchers developed accurate expectations of various burial anomalies by dragging antennas over wood caskets, metal caskets, and grave shafts (Conyers

2006; Fiedler et al. 2009; Sutton and Conyers 2013). While wood and metal caskets create a clear high-amplitude reflective signature; burial pits, grave shafts, or deteriorated wooden caskets are more difficult to detect. Grave shafts or burial pits can produce lower amplitude reflections at the ground surface since the top of the grave shaft is less compact than the surrounding, undisturbed ground surface (Bigman 2014). However, under conditions where the ground surface has been systematically unconsolidated, such as through plowing or in a flood plain where all of the soil is unconsolidated, it is difficult to identify graves in this manner. The bottom of burial pits or grave shafts may still contrast with the soil matrix at depth, but historic burials often homogenize with the soil matrix through time. Thus the signature for identifying historic burial pits can be limited to low amplitude hyperbolic reflections from the bottom of the pit where there is a higher density of organic remains or differentially more water saturation.

Detection Strategy

The investigations began with large scale dog search to pinpoint locations to examine more intensively with GPR. Two dogs were used during this phase of investigation. Each dog "hunted" separately so neither dog influenced the other and alerts could be viewed as independent. Dog searches began near the presumed location of Liberty Church on the bluff top adjacent to War Hill. Searches eventually covered areas north, west, and south of Liberty Church (Figure 1). Finally, War Hill was covered in areas not previously search by the dogs during the 2015 pilot study. If the two dogs alerted (See Figure 2 for a photo of a dog alerting to human remains scent) within approximately 2 m of each other, those alerts were considered as coming from the same potential target (Figure 3). If the two dogs alerted further than 2 m away, then these were considered separate potential targets and each was investigated separately with the GPR (Figure 4). Marking flags were placed at each dog alert.

Following the dog searches, GPR was used to collect data at each location where the dogs alerted to a possible grave to identify a correlated geophysical signature indicative of a possible historic burial. This survey employed a SIR-4000 GPR unit with a 400 MHz antenna manufactured by GSSI (Figure 5). Each location was surveyed as systematically as the ground cover and topography would allow. However, the variability in these conditions between locations made data collection in some areas highly systematic, while in other areas only a few transects at randomly selected angles could be collected. Potential targets of interest were flagged on site during data collection. Two-dimensional GPR profiles were processed using software. A time-zero correction, background filter, gain adjustment, and velocity estimate were conducted on each profile. Time-slice renderings for data collected near the potential site of the Liberty Church Cemetery were produced with RADAN v.7 software.

Figure 2. HRD dog alerting to human remains scent.

Figure 3. Two dog alerts located within 2 m of each other. Dog alerts are indicated by white crosses. Marking flags represent the locations of subsequent targets identified with GPR.

Figure 4. Photo on north side of War Hill showing HRD dog alert locations more than 2 m from each other. Dog alert locations are indicated with white crosses.

Figure 5. Photo of GPR survey in progress near HRD dog locate 7.

RESULTS

The HRD dogs alerted at 12 separate locations (Figure 6) across the Kettle Creek Battlefield site during the 2017 investigations. Four of these were located on the north side of War Hill, two were located on the north side of Kelly Branch near locations detected in 2015, four alerts were located north of Liberty Church, and two to the west and southwest of Liberty church.

GPR investigations were conducted at each of these locations and reflection geometries indicative of possible graves were recorded with the GPR near dog alerts 3, 4, 7, 8, 10, and 12 (Figure 7). Locations 3, 7, and 8 contained one possible grave each, locations 10 and 12 contained two possible graves each, and location 4 contained 3 possible graves. Depths of each GPR target varied (Table 1) as well as the confidence that the signature represents and actual burial. Figure 8 shows a GPR profile collected near dog alert 7 indicating a possible grave and Figure 9 shows a time-slice image generated near dog alert 12 showing interpretations of two possible burials.

Table 1. Depths of GPR reflections interpreted as possible unmarked graves.

Target No.	Figure No.	Target Depth (m)
GPR 3	A.1	1
GPR 4A	A.2	.4
GPR 4B	A.3	.4
GPR 4C	A.4	.32
GPR 7	A.5	.6
GPR 8	A.6	.45
GPR 10A	A.7	.2
GPR 10B	A.8	.6
GPR 12A	A.9	.35
GPR 12B	A.10	.47

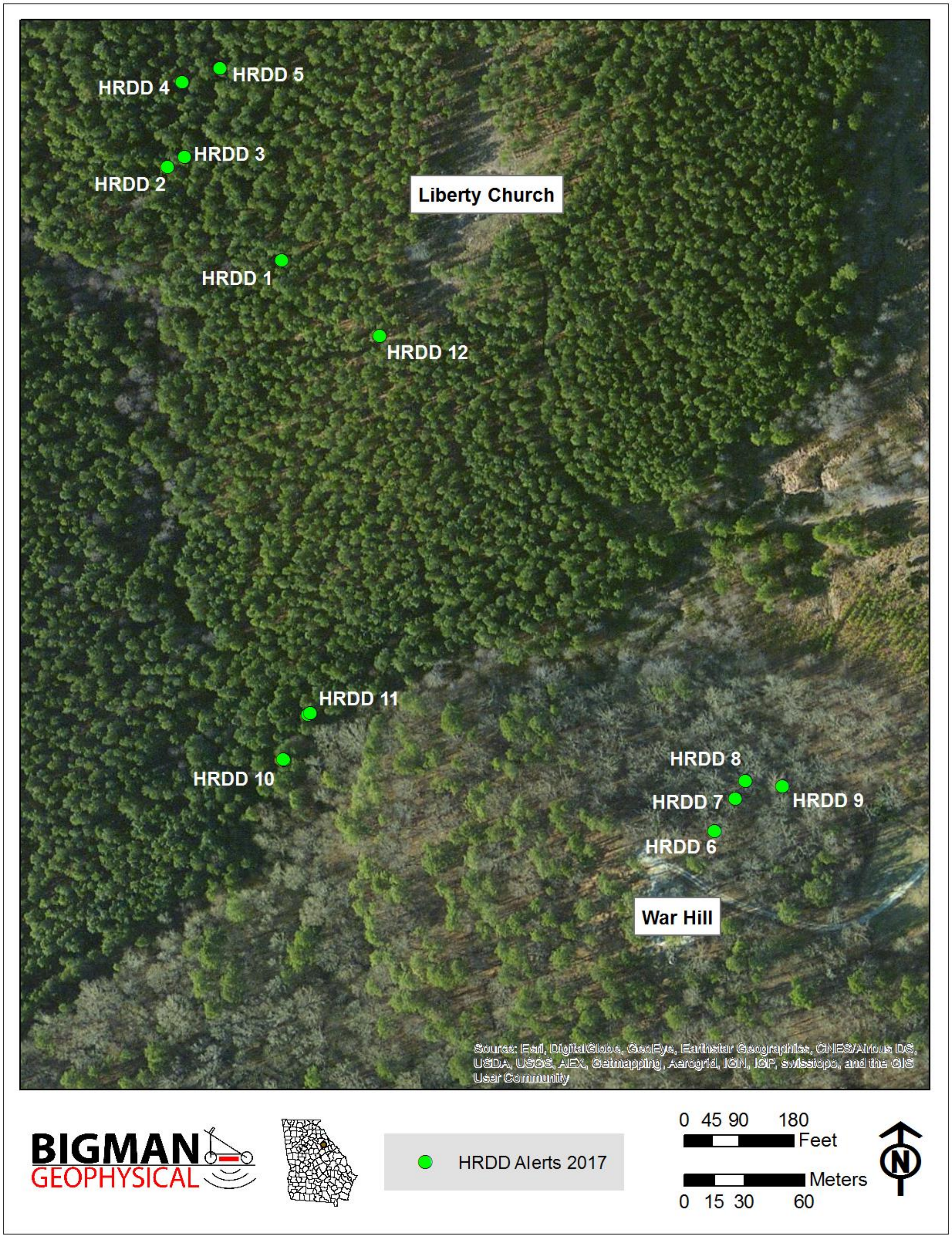

Figure 6. Locations of HRD dog alerts from 2017 search.

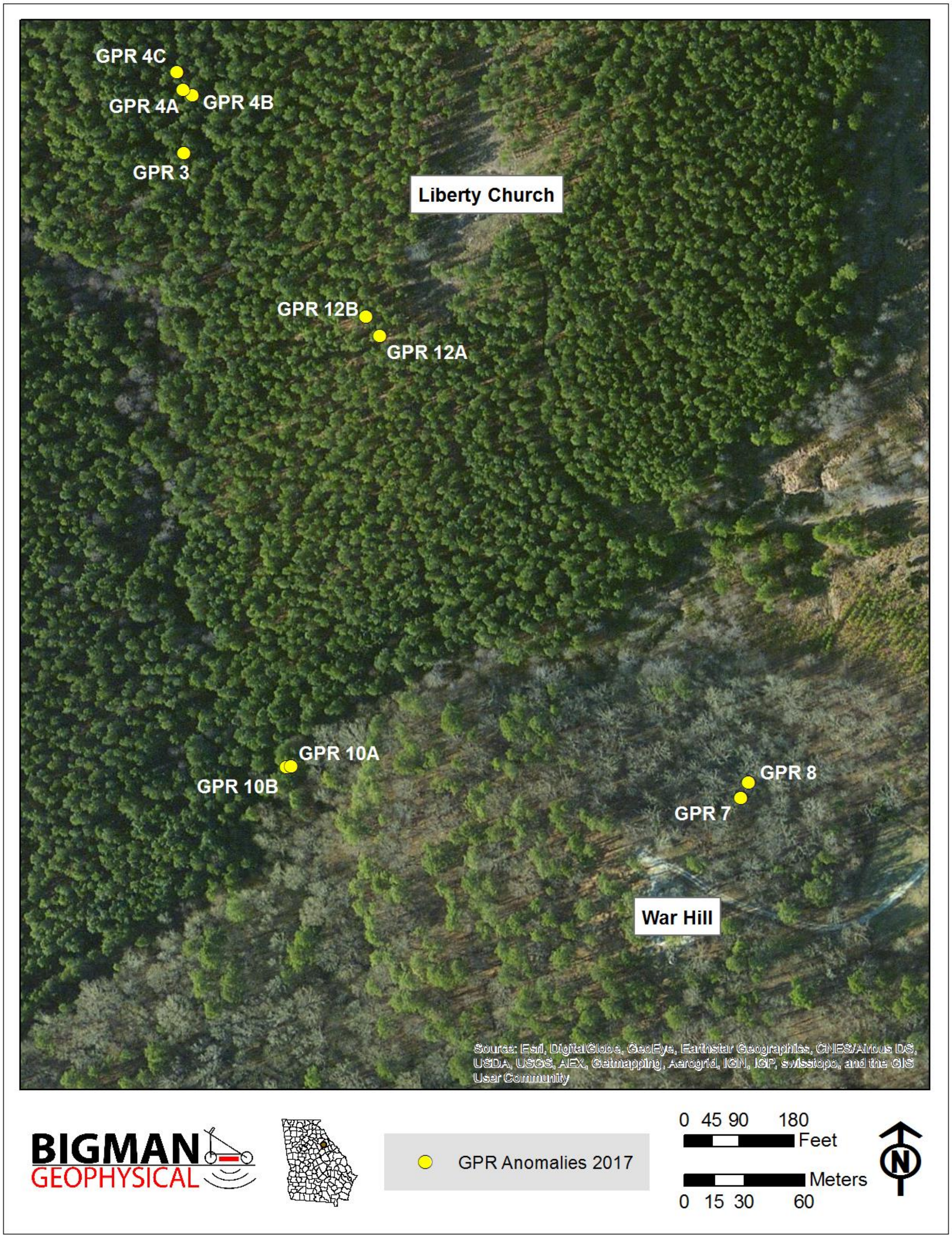

Figure 7. Locations and possible unmarked graves identified with GPR in 2017.

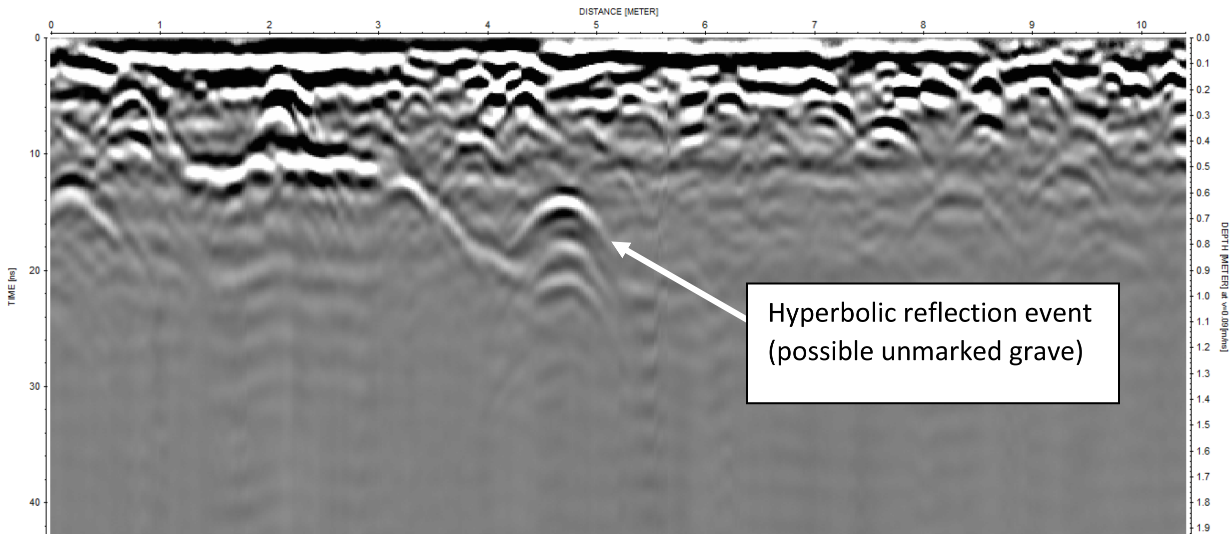

Figure 8. GPR profile collected near HRD dog alert 7 indicating a possible unmarked grave.

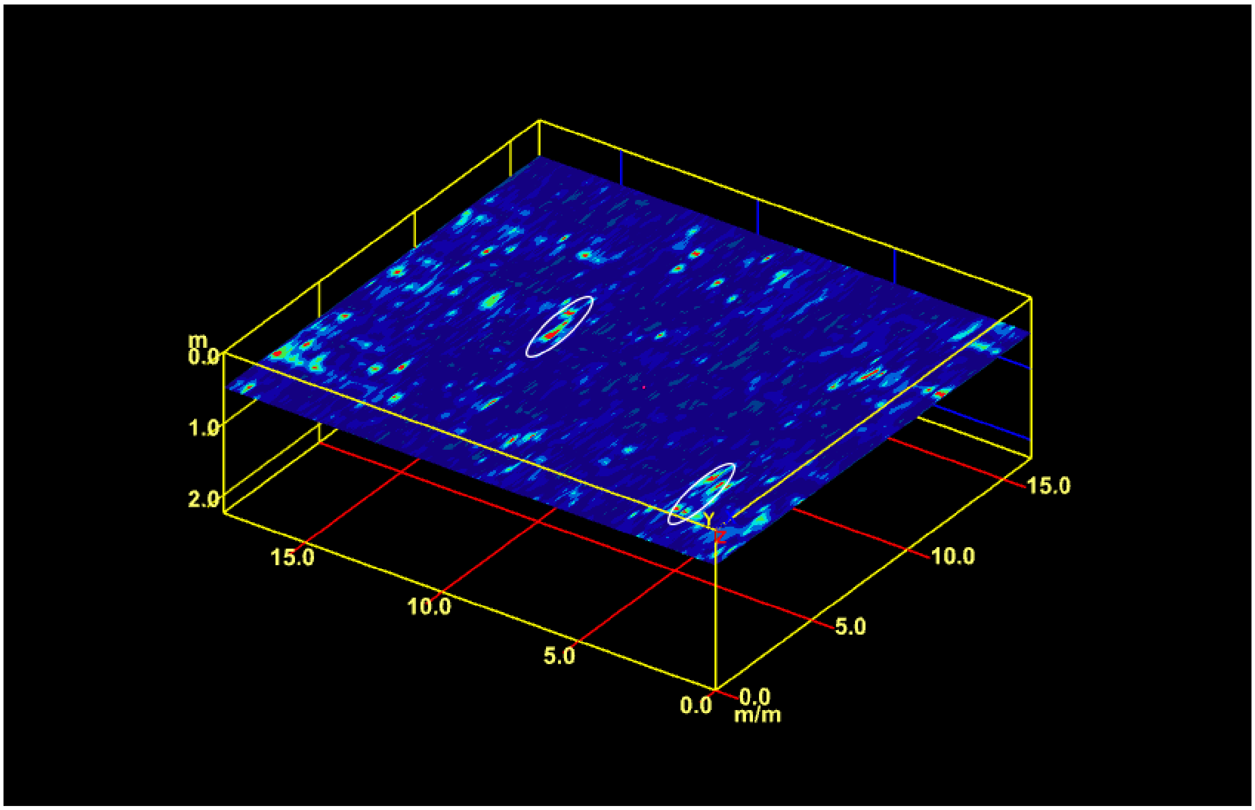

Figure 9. Time-slice collected near HRD dog alert 12 showing a horizontal plan view of two high-amplitude reflection events indicating possible unmarked graves.

CONCLUSION

This strategy showed great promise as a multi-stage method to locating fallen revolutionary war soldiers on large battlefield sites. This study indicates that HRD dogs can detect human remains scent of decomposed bodies that died over two centuries ago. Our study also found however, that dog alerts are rarely precise to the exact location of a grave. This is to be expected since residue will travel through the subsurface and in our context there is an active creek and topographic variability which would impact the decomposed human residue through post-depositional processes such as ground water movement. Furthermore, the conditions at the site were non-ideal for GPR survey, and some of the geophysical signatures interpreted as possible unmarked graves may be reflections from other subsurface variation such as burrows, large tree roots, voids, buried rocks, etc. Despite these limiting factors, the dog search and subsequent GPR survey ultimately narrowed an 80 acre area down to 11 locations of possible graves (See Figure 10 for a compilation of HRD dog alerts and GPR anomalies from all phases of the project). The combination of the current results with those from the pilot study provide a series of potential sites to examine through limited excavation in an attempt to verify some of these targets as actual graves and to further test the validity of the approach.

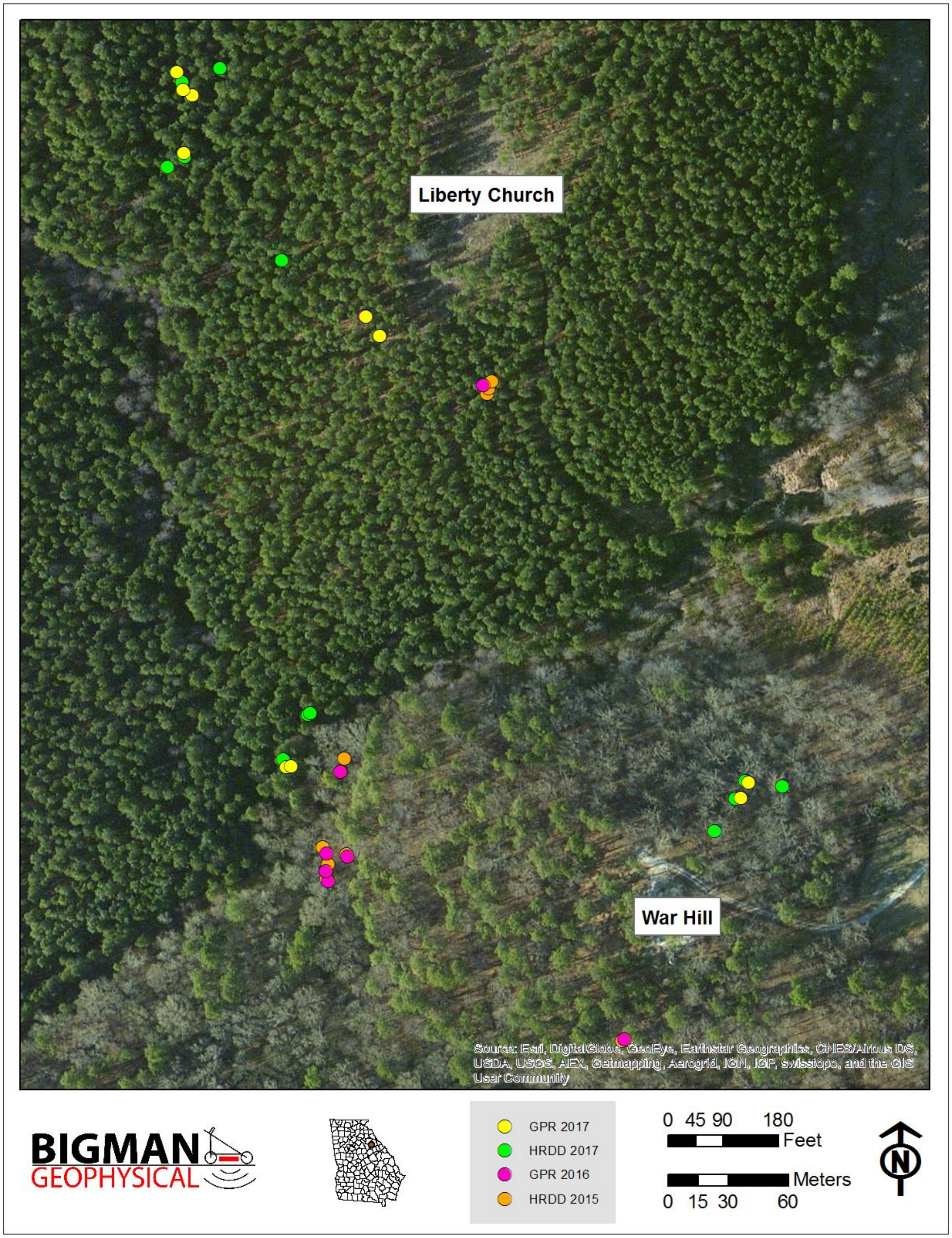

Figure 10. Locations of all HRD dog alerts and GPR reflections of possible unmarked graves throughout the Kettle Creek Battlefield investigation.

REFERENCES

Alexander, Michael B., Theresa K. Hodges, Joan Bytheway, and Jacqueline A. Aitkenhead-Peterson (2015) Application of Soil in Forensic Science: Residual Odor and HRD Dogs. *Forensic Science International* 249:304-313.

Annan AP (2009) Electromagnetic Principles of Ground Penetrating Radar. In: Jol HM (ed) Ground Penetrating Radar: Theory and Applications, Elsevier, Amsterdam, pp 3-40

Bevan BW (1991) The search for graves. Geophmeysics 56:1310–1319

Bigman DP (2014) Mapping Social Relationships: Geophysical Survey of a 19th Century American Slave Cemetery. Archaeological and Anthropological Sciences 6:17-30

Bigman DP (2015) Cadaver Dog Search for Unmarked Burials at Kettle Creek Battlefield, Washington, GA. Report submitted to the Kettle Creek Battlefield Association, Inc.

Cablk, Mary E., Erin E. Szelagowski, and John C. Sagebiel (2012) Characterization of Volatile Organic Compounds Present in the Headspace of Decomposing Animal Remain, and Compared with Human Remains. *Forensic Science International* 220:118-125.

Carter, David O., David Yellowlees, and Mark Tibbett (2007) Cadaver Decomposition in Terrestrial Ecosystems. *Naturwissenschaften* 94:12-24.

Conyers LB (2004) Ground-Penetrating Radar for Archaeology. Alta Mira Press, Lanham.

Conyers LB (2006) Ground-penetrating Radar Techniques to Discover and Map Historic Graves. Historical Archaeology 40:64-73

Davenport GC (2001) Remote Sensing Applications in Forensic Investigations. Historical Archaeology 35:87-100

Dionne CA, Wardlaw DK, Schultz JJ (2010) Delineation and Resolution of Cemetery Graves Using a Conductivity Meter and Ground-Penetrating Radar. Technical Briefs in Historical Archaeology 5:20-30

Fiedler S, Illich B, Berger J, Graw M (2009) The Effectiveness of Ground-Penetrating Radar Surveys in the Location of Unmarked Burial Sites in Modern Cemeteries. Journal of Applied Geophysics 68:380-385

Gleason P, Smith L, Goffinet C, White N, Harrivel G, Hinga B (2011) Detecting Graves in a Lime Marl Environment: A Comparison of Soil Resistivity and Ground Penetrating Radar Methods. Symposium on the Application of Geophysics to Engineering and Environmental Problems 2011:226

Honerkamp N, Crook R (2012) Archaeology in a Geechee Graveyard. Southeastern Archaeology 31:103-114

Hunter D (2012) The Mala MIRA at the Wallaga Lake Aboriginal Cemetery. ISAP News. 31:2-4

Jones G (2008) Geophysical Mapping of Historic Cemeteries. Technical Briefs in Historical Archaeology 3:25-38

Koppenjan S (2009) Ground Penetrating Radar Systems and Designs. In: Jol HM (ed) Ground Penetrating Radar: Theory and Applications, Elsevier, Amsterdam, pp 73-97

Pringle, Jamie K., John P. Cassella, John R. Jervis, Anna Williams, Peter Cross, and Nigel J. Cassidy (2015) Soilwater Conductivity Analysis to Date and Locate Clandestine Graves of Homicide Victims. *Journal of Forensic Sciences* 60: 1052-1060.

Riezzo, Irene, Margherita Neri, Marcello Rendine, Alessandro Bellifemina, Santina Cantatore, Carmela Fiore, and Emanuela Turillazzi (2015) Cadaver Dogs: Unscientific Myth or Reliable Biological Devices?. *Forensic Science International* 244:213-221.

Schultz, JJ (2008) Sequential monitoring of burials containing small pig cadavers using ground-penetrating radar. *Journal of Forensic Sciences* 53:279–287.

Schultz, JJ, ME Collins, AB Falsetti (2006) Sequential monitoring of burials containing large pig cadavers using ground-penetrating radar. *Journal of Forensic Sciences* 51:607–616.

Shaaban FA, Abbas AM, Atya MA, Hafez MA (2009) Ground-penetrating Radar Exploration for Ancient Monuments in the Valley of Mummies –Kilo 6, Bahariya Oasis, Egypt. Journal of Applied Geophysics 68:194-202

Sjostrom K, Ryerson K, Watson J, Bock D, Rush D (2009) Geophysical Mapping of an Entire Municipal Cemetery. Symposium on the Application of Geophysics to Engineering and Environmental Problems 2009:1032-1041

Stokes, Kathryn L., Shari L. Forbes, and Mark Tibbett (2013) Human Versus Animal: Contrasting Decomposition Dynamics of Mammalian Analogues in Experimental Taphonomy. *Journal of Forensic Sciences* 58:583-591.

Sutton MJ, Conyers LB (2013) Understanding Cultural History Using Ground-Penetrating Radar Mapping of Unmarked Graves in the Mapoon Mission Cemetery, Western Cape York, Queensland, Australia. International Journal of Historic Archaeology 17:782-805

Tarver G, Bigman DP (2013) Preservation of McVicker Family Cemetery, Jonesboro, Georgia. Early Georgia 41:211-241

APPENDIX A: GPR DATA

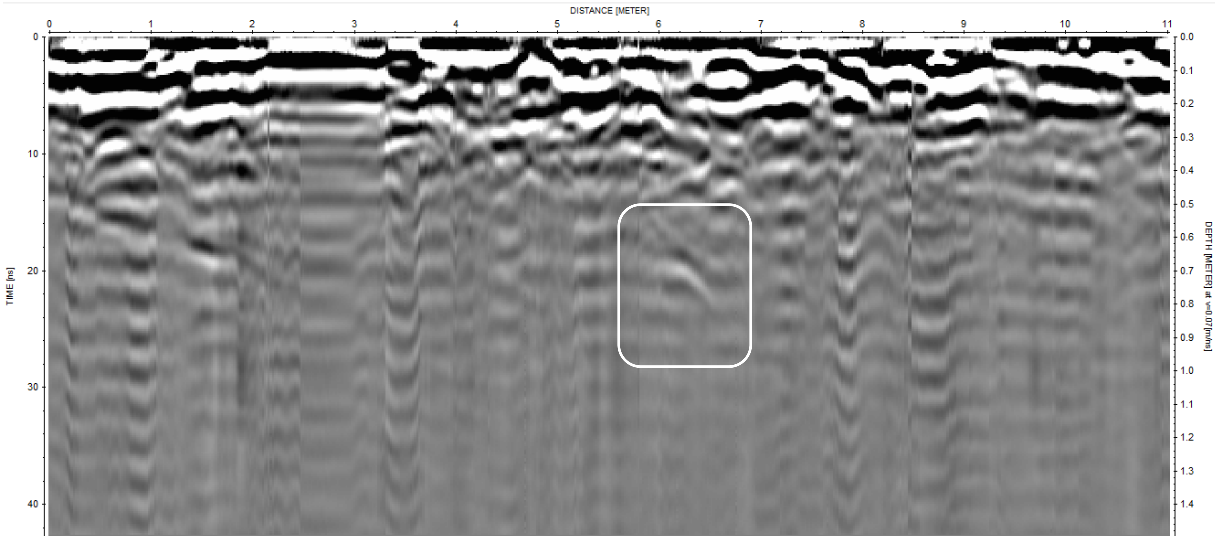

Figure A.1. GPR target 3

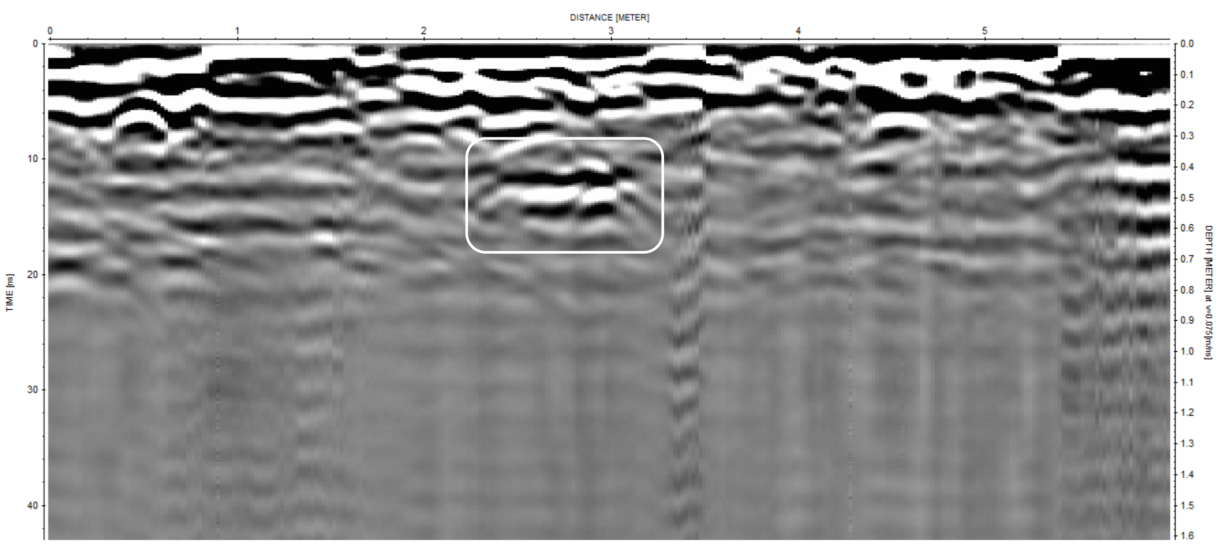

Figure A.2. GPR target 4A

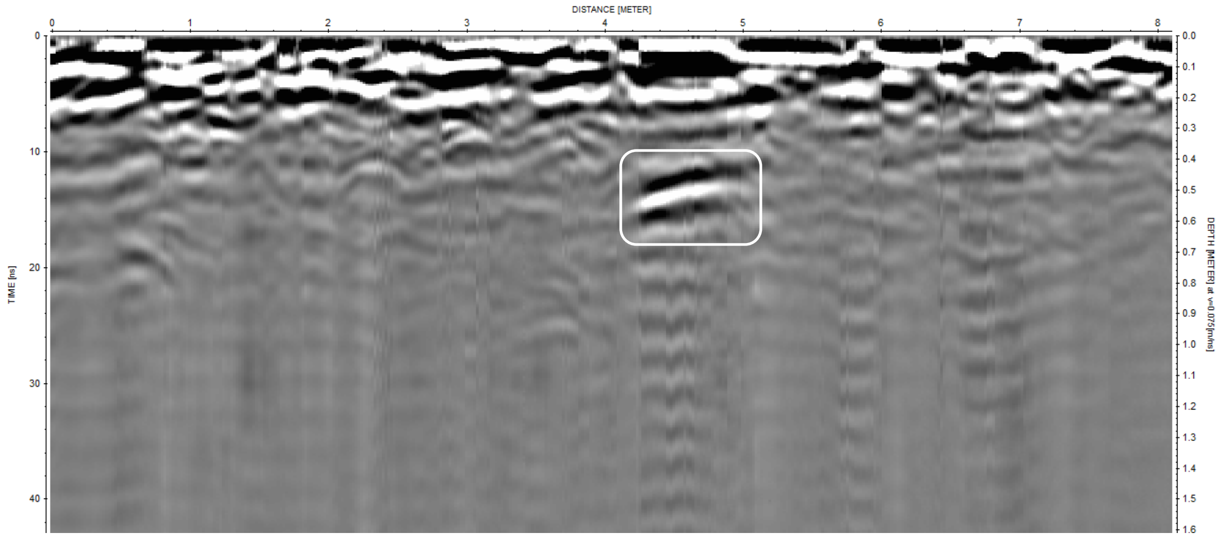

Figure A.3. GPR target 4B

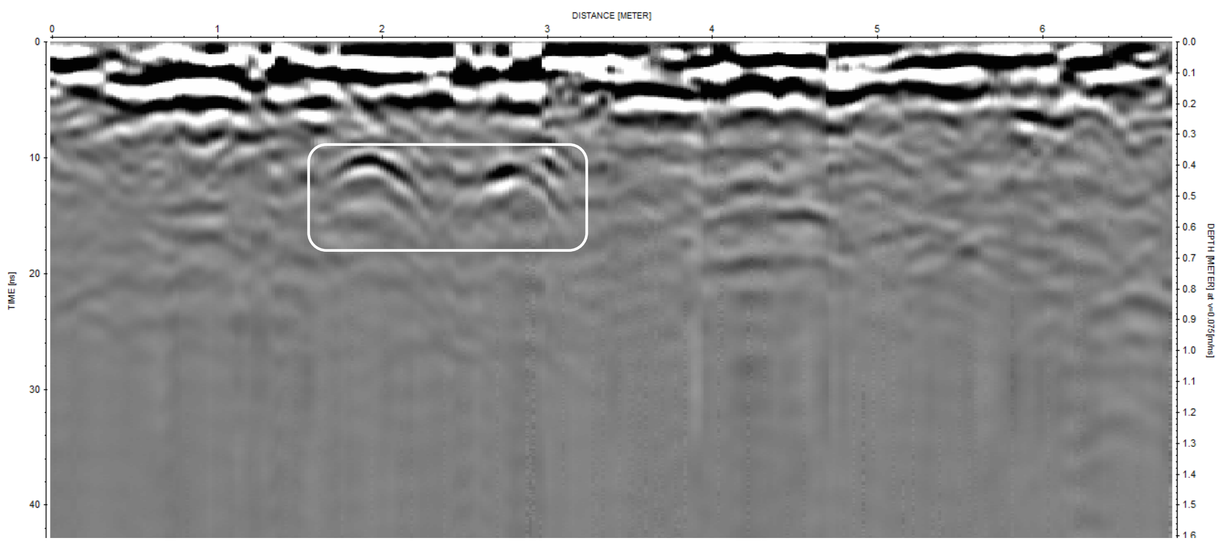

Figure A.4. GPR target 4C

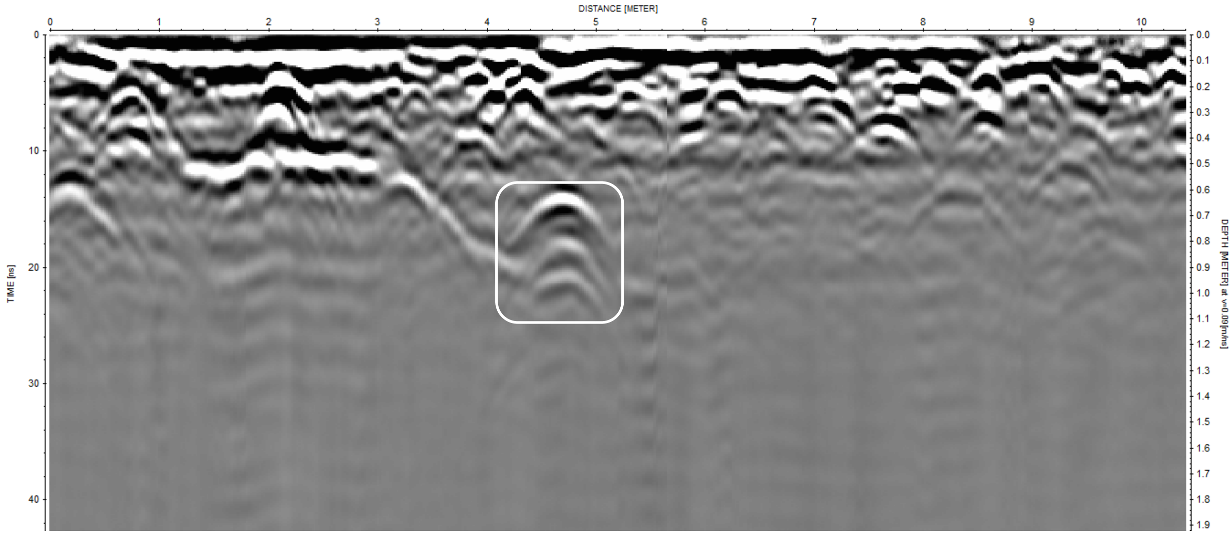

Figure A.5. GPR target 7

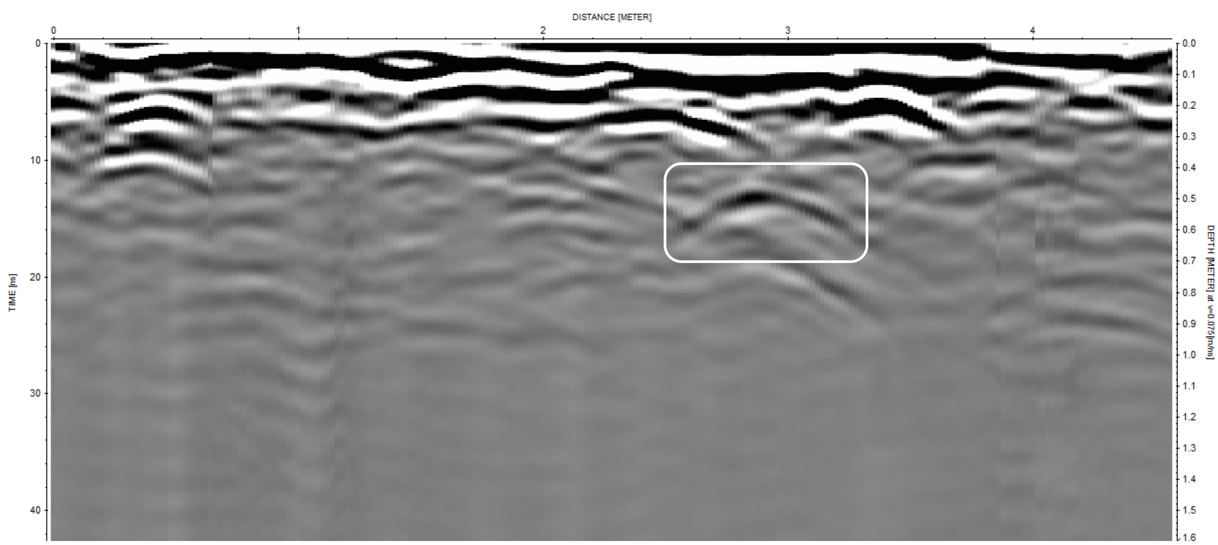

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Figure A.6. GPR target 8

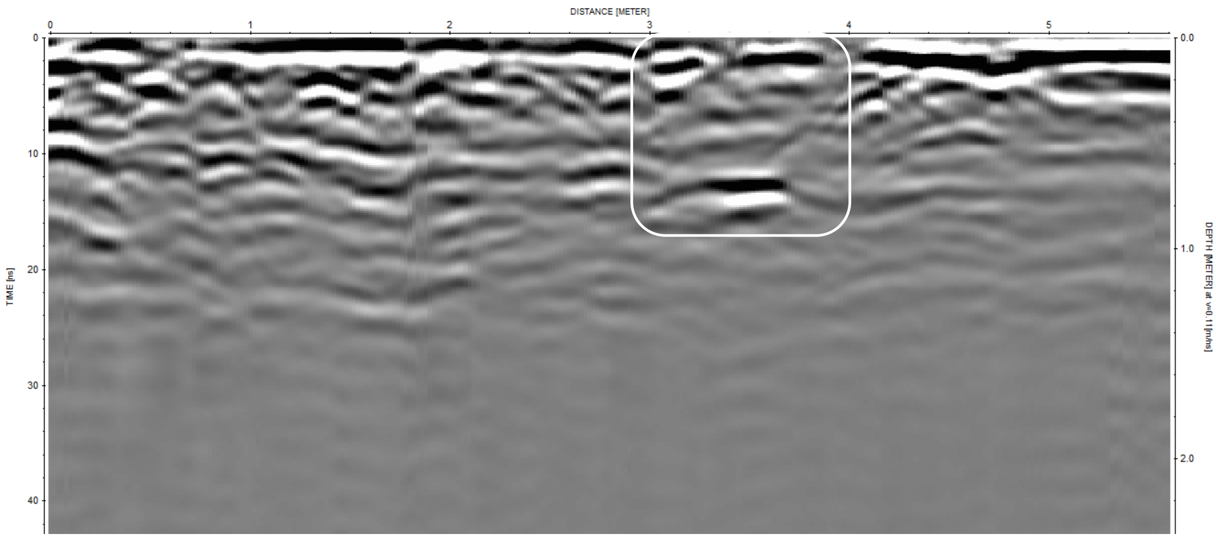

Figure A.7. GPR target 10A

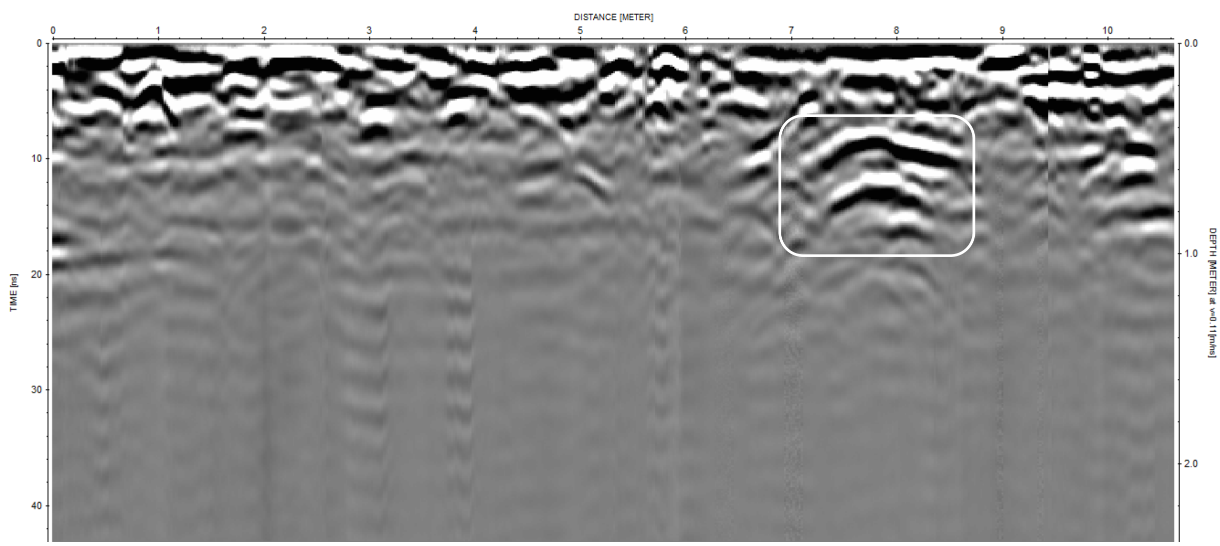

Figure A.8. GPR target 10B

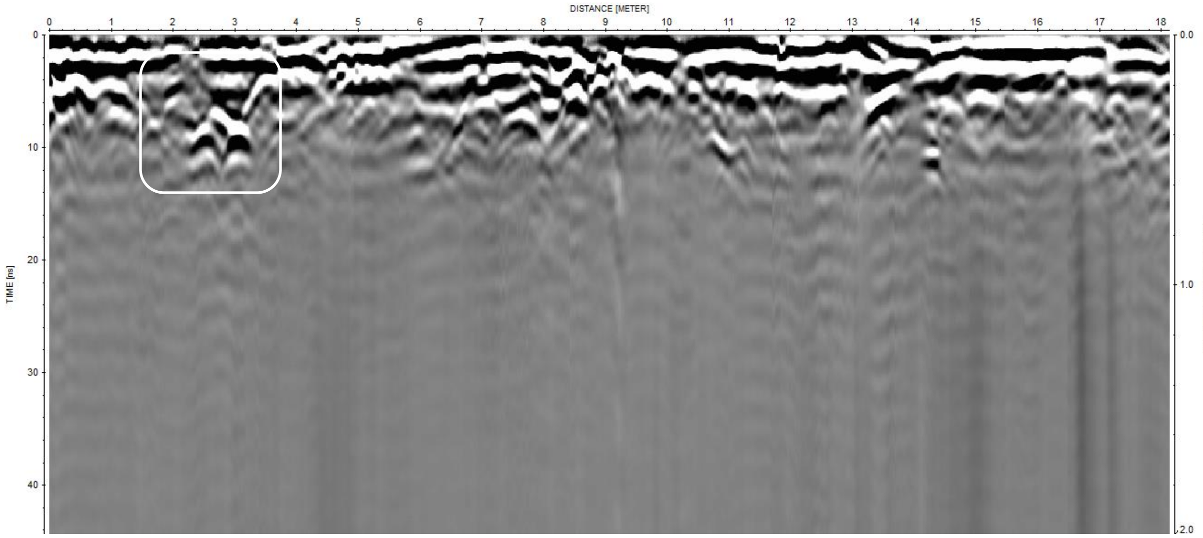

Figure A.9. GPR target 12A

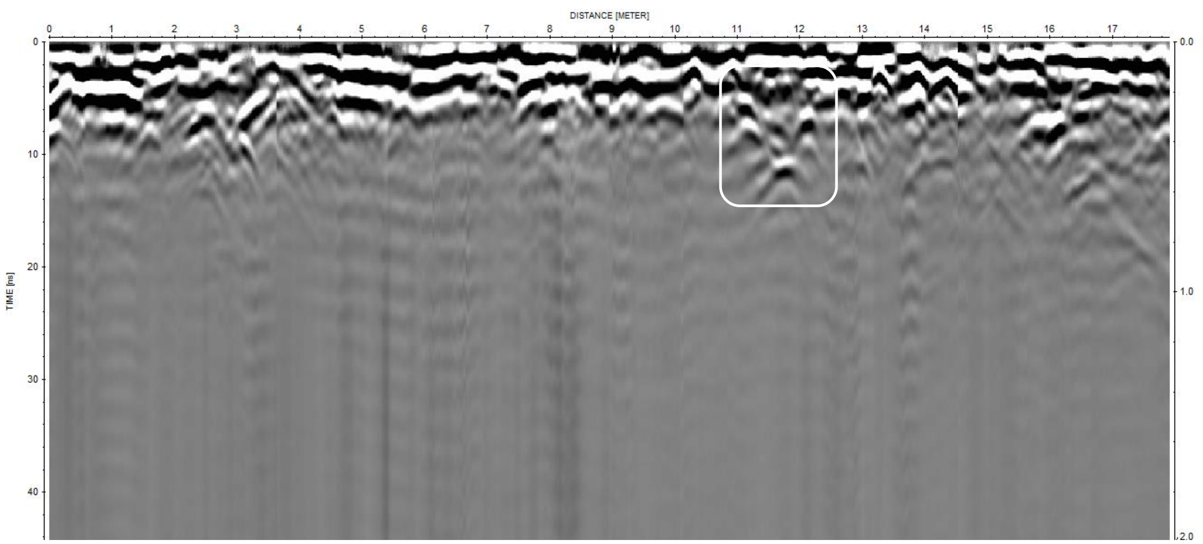

Figure A.10. GPR target 12B