

Geological and geophysical techniques for crime scene investigations in Canada

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Outline

- Introduction to Ground-Penetrating Radar (GPR)
- Church of the Holy Spirit Cemetery Search
- Brecourt Manor
- Indigenous Considerations
- Conclusions

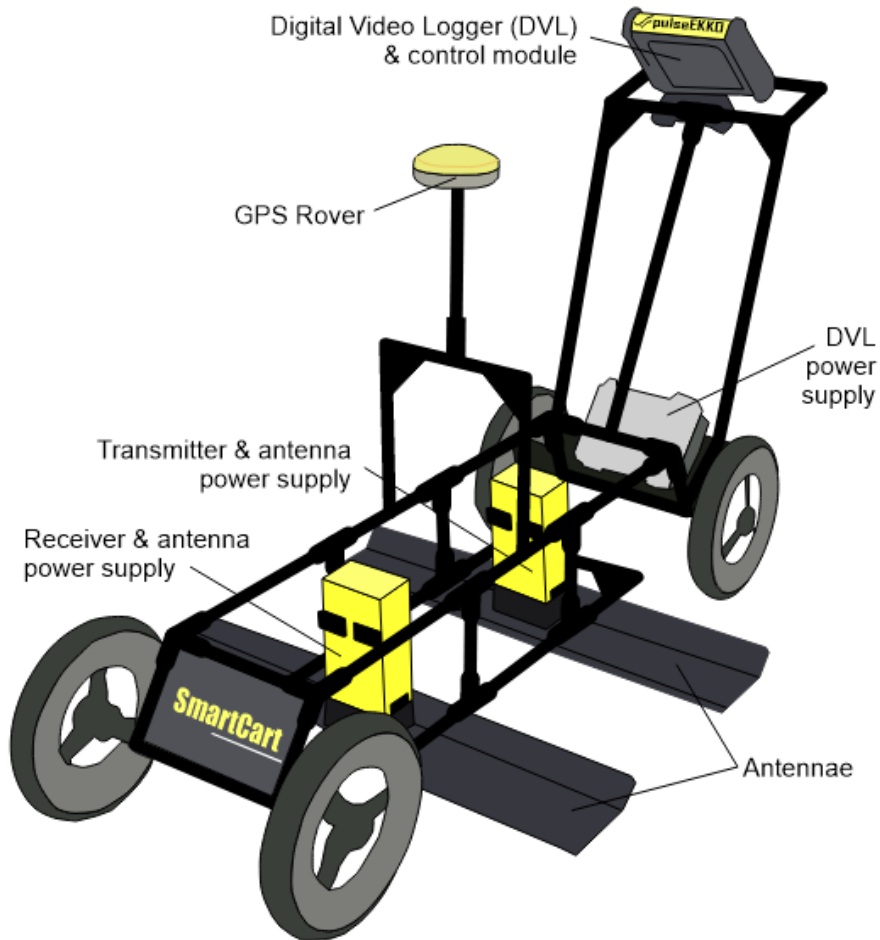
Acknowledgements

- International Union of Geological Sciences (IUGS) Initiative on Forensic Geology (EFG)
- Dr. Alastair Ruffell, Queen's University, Belfast
- Dr. Laurance Donnelly, expert advisor in Forensic Geology
- Dr. Shari Forbes, Canada 150 Research Chair in Forensic Thanatology



Ground-Penetrating Radar (GPR)

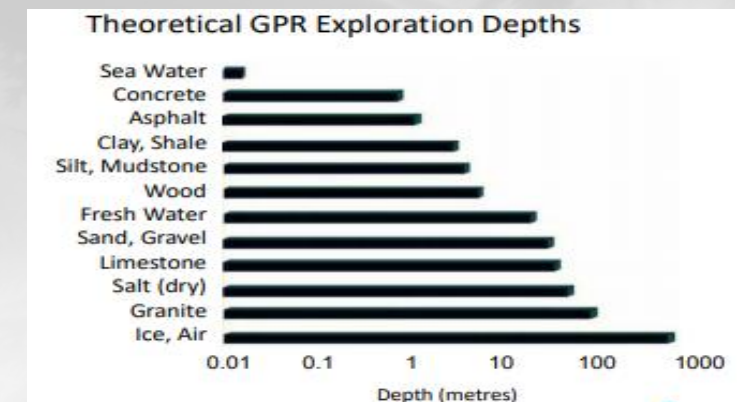
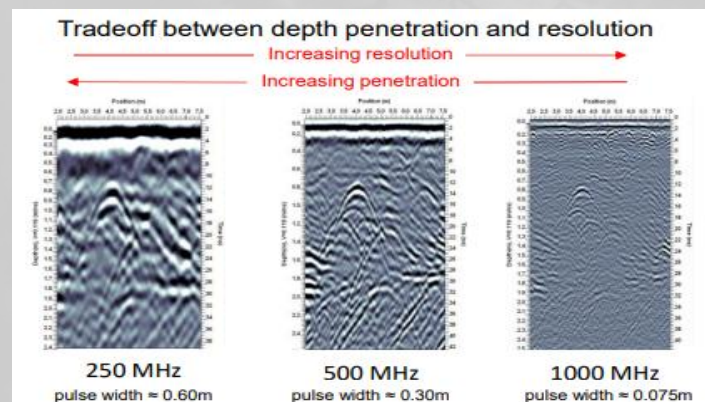
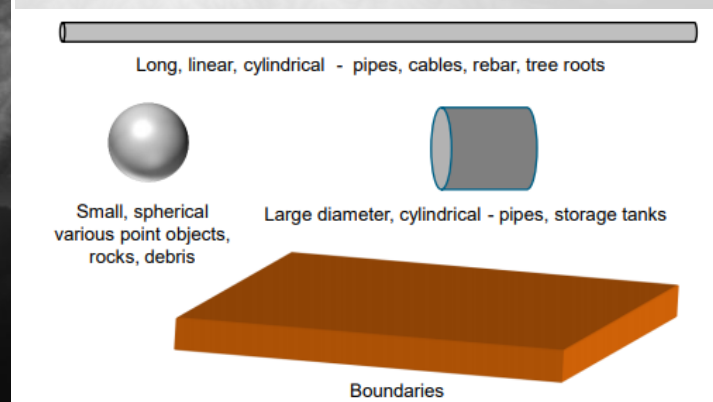
Ground-Penetrating Radar (GPR)



- GPR images the subsurface by detecting electrical discontinuities at shallow depths ($<50\text{m}$) by generating pulses of high-frequency electromagnetic energy and detecting the ensuing reflections
- Electrical discontinuities are directly related to water saturation, salinity, porosity, and mineralogical variations
- 2D GPR allows for detection of objects and their approximate depth. 3D GPR takes it further and allows for interpretations of lateral extent and shape of objects

Limitations

WHAT GPR CAN DO	WHAT GPR CANNOT DO
Detect large targets at depth	Detect small targets at depth
Identify contrasts in subsurface materials	Distinguish between materials with similar velocities
Achieve great depth of imagery through ice	Achieve any depths of imagery through salt water
Reach deeper depths with lower frequency antennae	Maintain resolution of image with lower frequency antennae
Gather 3D imagery through a grid system	Gather 3D imagery through a single line
Identify presence of a target with a single line	Define shape of a target with a single line

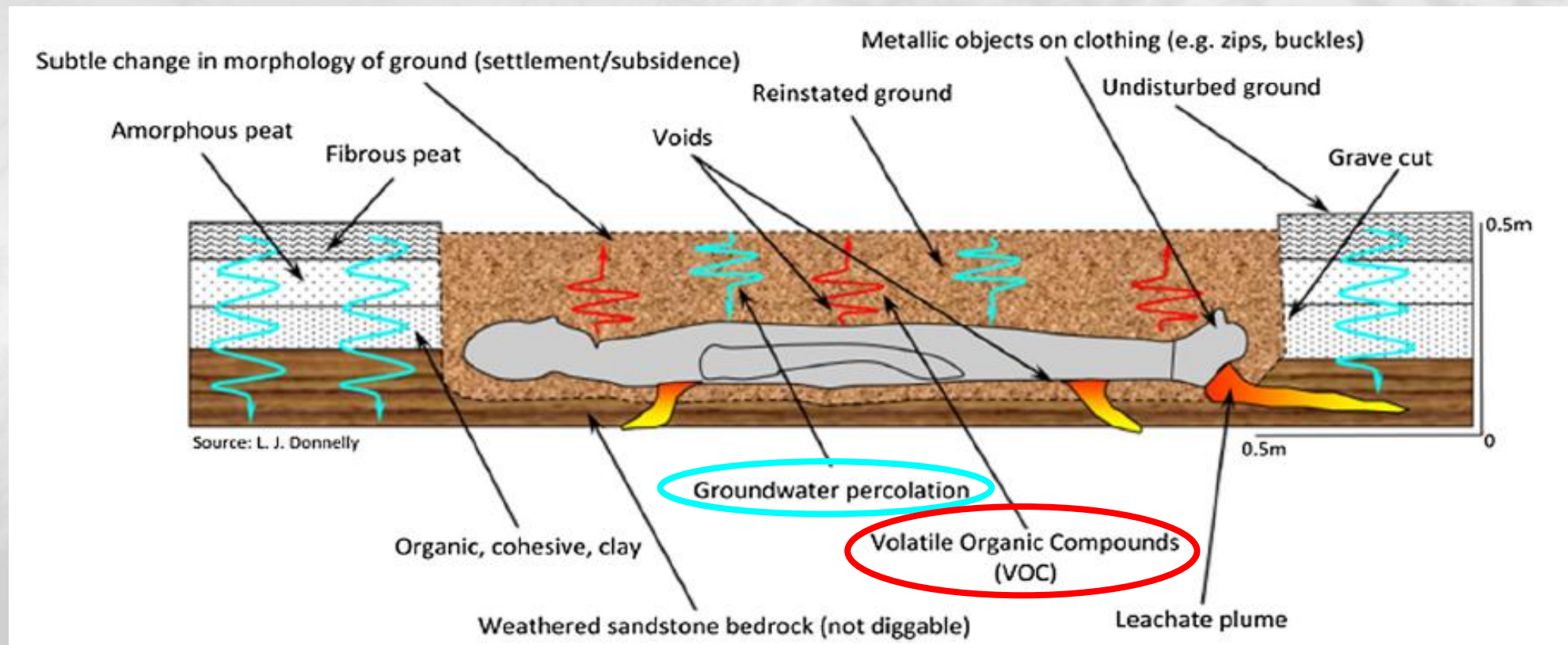


GPR: Forensic Applications

- So, since GPR detects the changes in subsurface through electrical discontinuities, in theory it can detect buried objects, including bodies
- Geologically, GPR can detect disturbances in soil morphology, which can be interpreted as areas of recent burial
- In terms of buried objects, GPR can detect a difference in material from say surrounding soil and something like a barrel or a gun
- In terms of bodies, other than soil disturbance, the main thing to look out for is the presence of water – considering we are comprised of up to 60% water

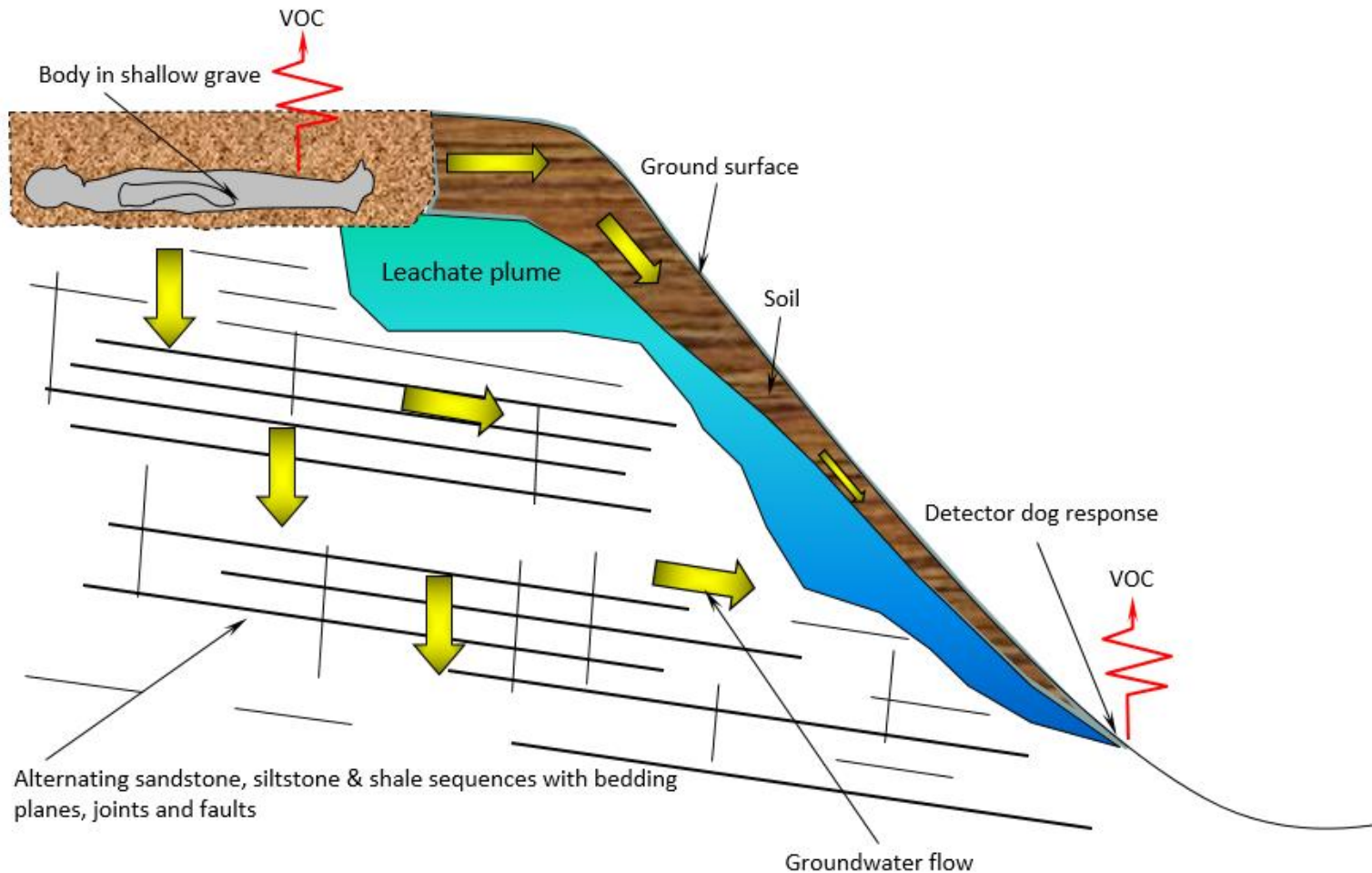
GPR: Forensic Applications

Conceptual Geological Model for a shallow, unmarked, grave



(source: Dr Laurance Donnelly)

GPR: Forensic Applications



Leachate plume
and VOC
generation from
human
decomposition
(conceptual
model)

(source: Dr Laurance Donnelly)



Church of the Holy Spirit

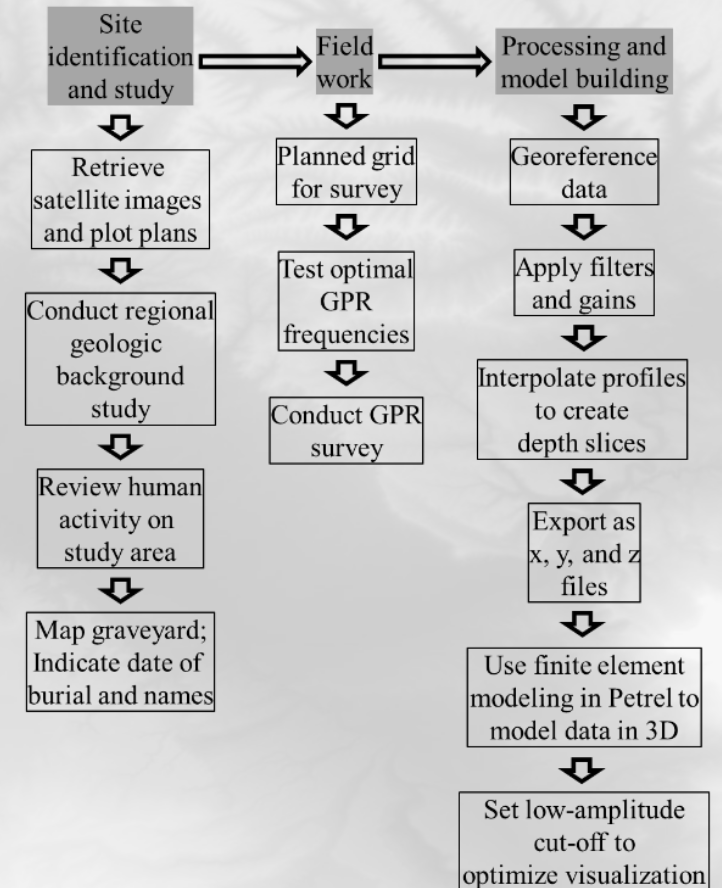
Identifying marked and unmarked grave sites

Church of the Holy Spirit Cemetery

- The Church of the Holy Spirit in Lakelands, NS reached out requesting a GPR survey of the property
- They had ongoing wet ground conditions, and were interested in adding a proper drainage system to the property
- As this cemetery has been in place for decades, and the church did not have complete burial records for the grounds, they wanted to confirm the presence of any unmarked graves before digging began for the drainage system

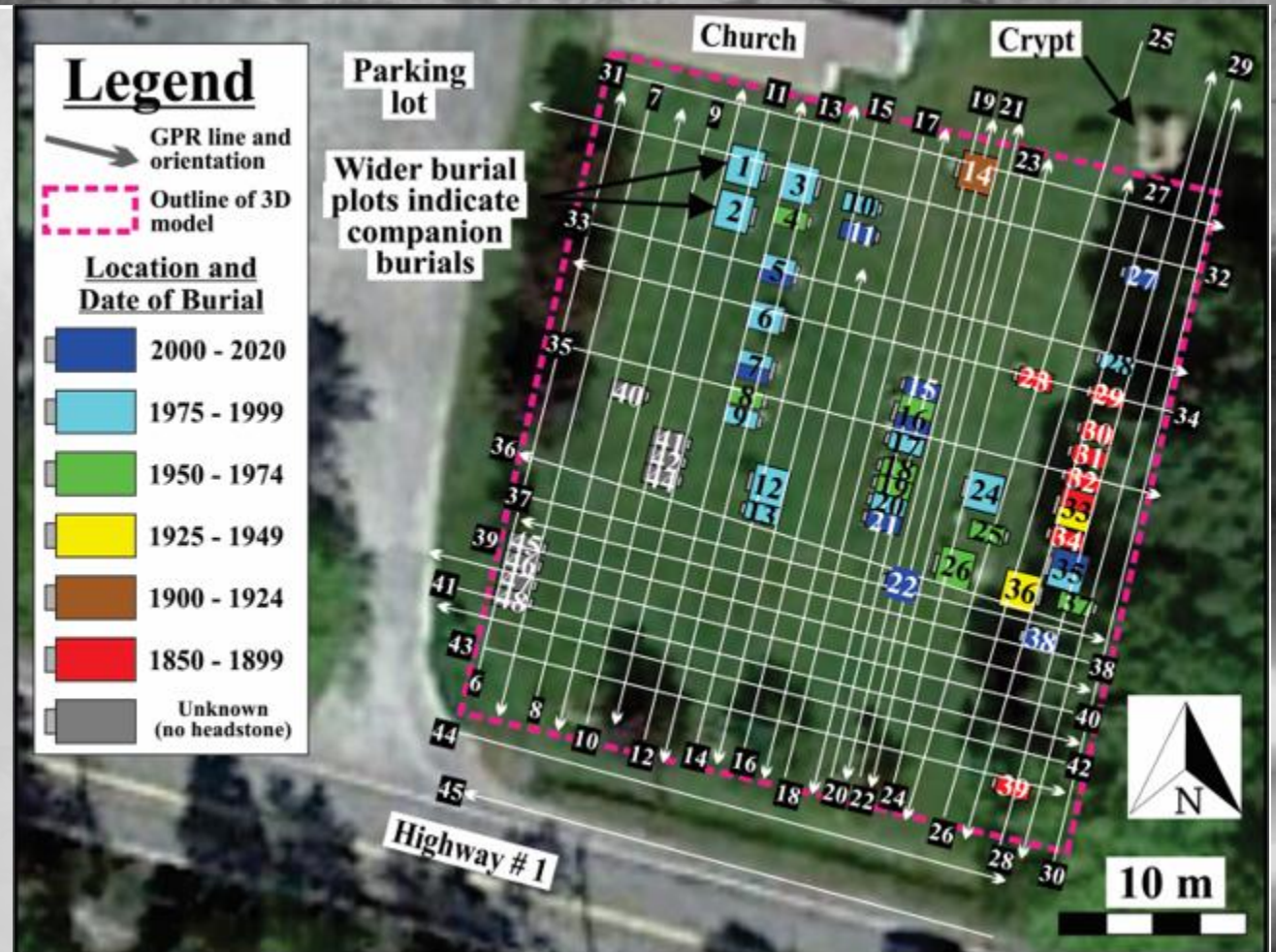
GPR Survey Workflow

- This site provided a unique opportunity to demonstrate a unique workflow to optimally visualize data in 3D
- This involves:
 - Study of the site, geologic background, and church documents
 - Completion of the survey on site
 - Data processing and final image creation



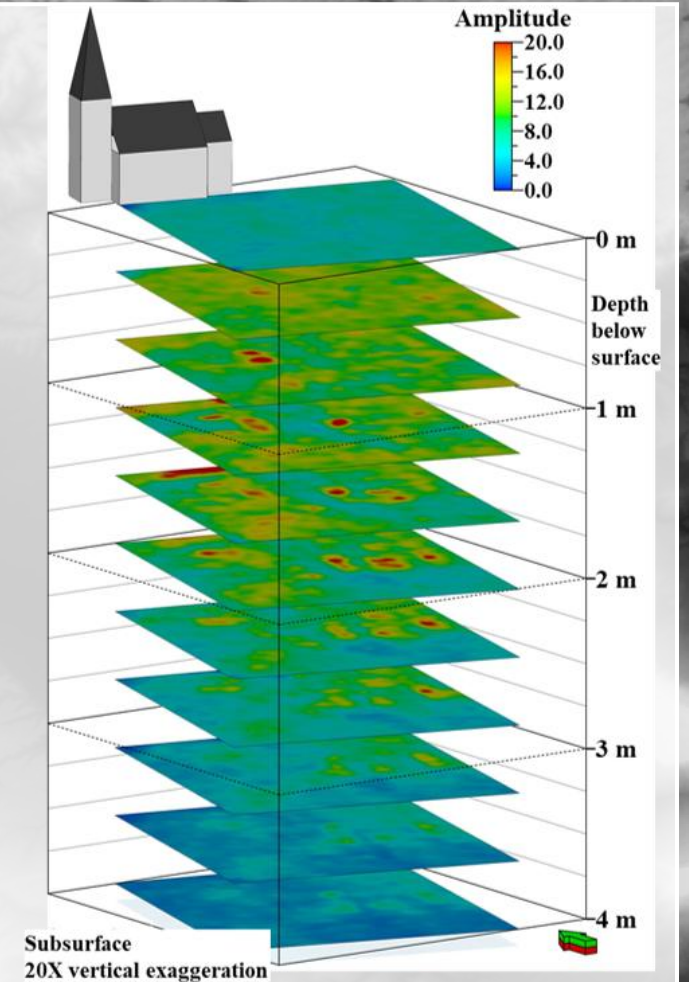
3D Grid Setup

- Based on the site conditions, the following GPR grid was mapped out
- The study area covers a 30x40m section of the cemetery
- Total of 40 separate radargrams (vertical slices) taken around 1m apart



Depth Slices

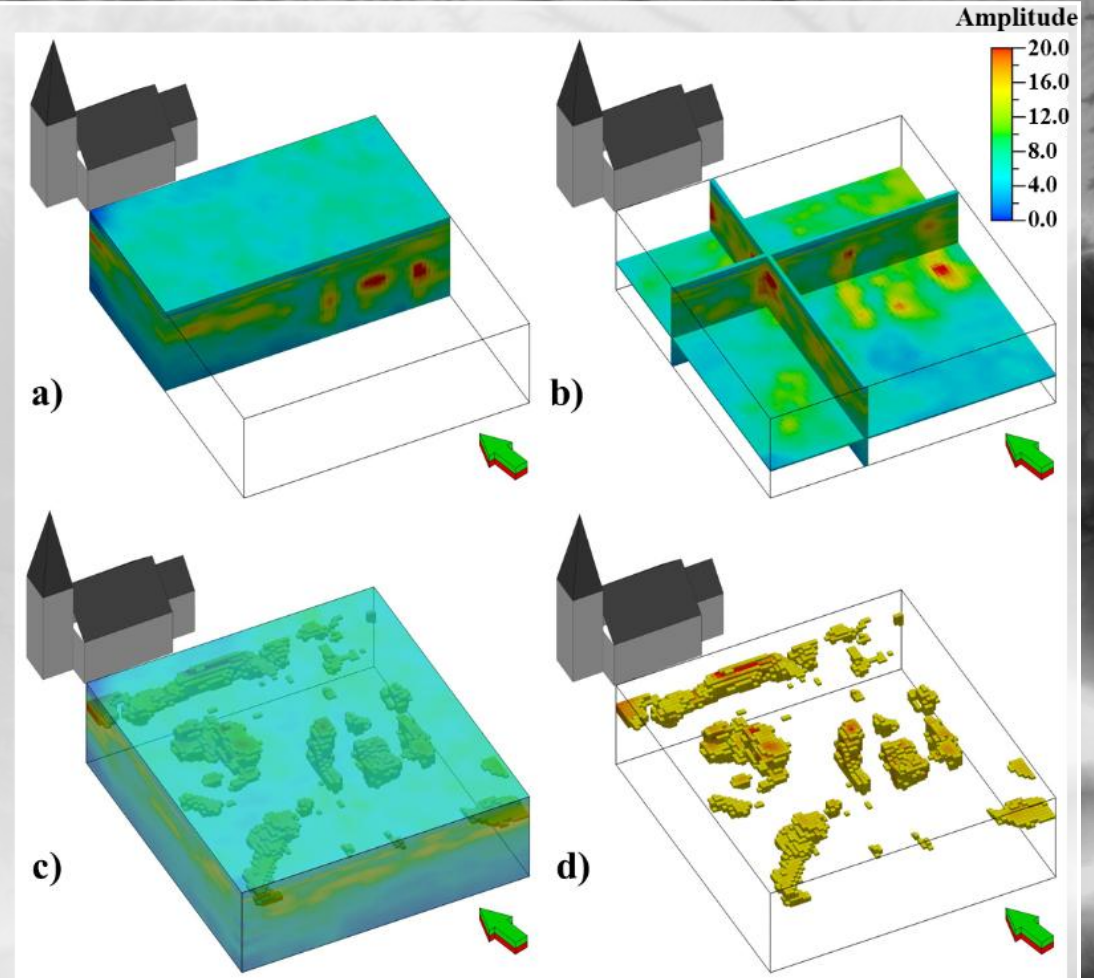
- With the grid pattern used, 2D depth slices could be rendered
- And with the combination of the radargrams and associated depth slices, a 3D model was created



3D Model

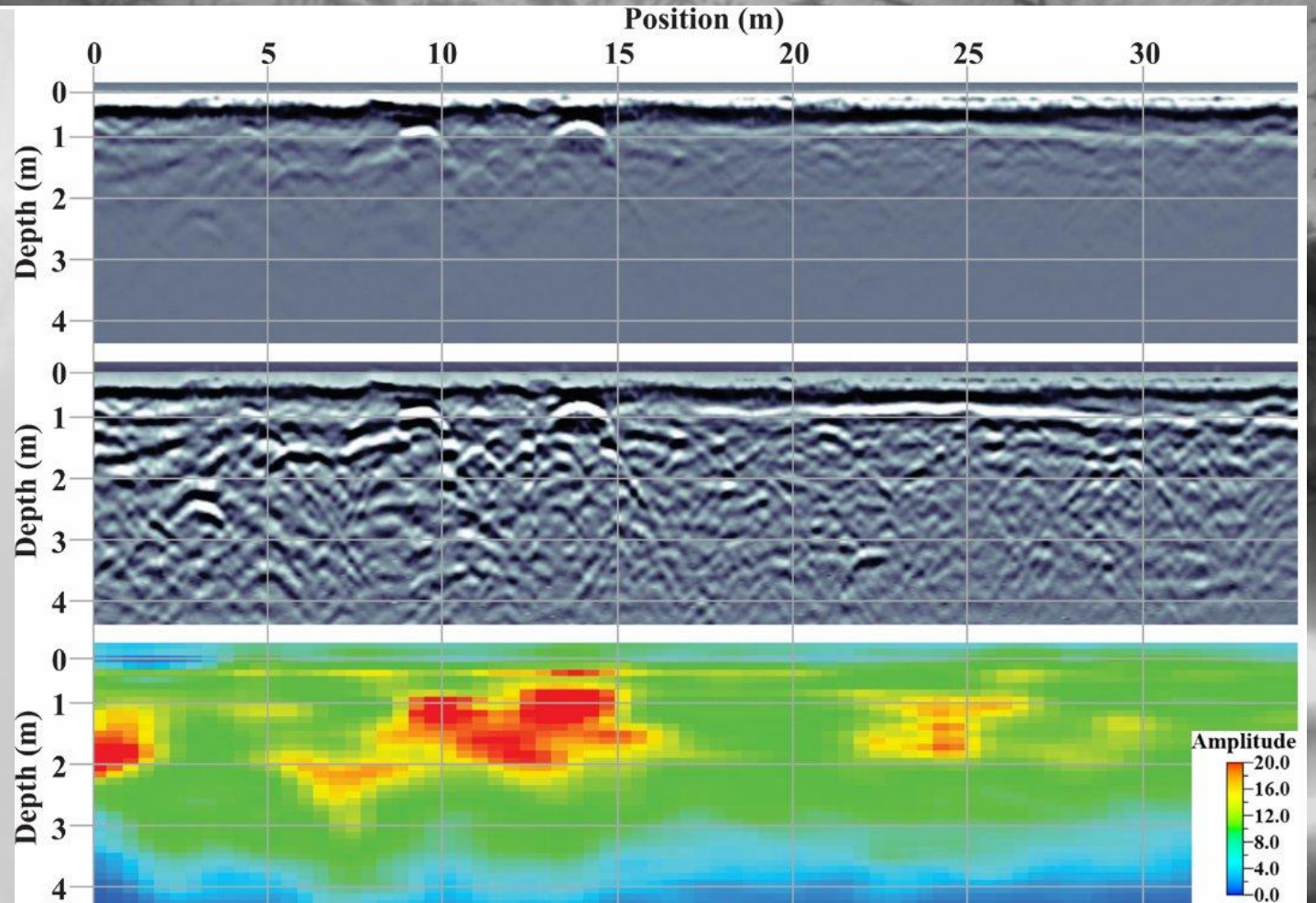
Various ways previous 3D models have been displayed in the GPR literature and the issues with each type of display:

- a) **Slicing the 3D model in a single plane** (impossible to see the 3D shape and spatial relationship of the subsurface objects).
- b) **Slicing the 3D model in each of the three model planes** (only provides partial understanding of shape and spatial relationships of subsurface objects).
- c) Using a **partial transparency filter** on the low amplitude reflection signals (difficult to understand the depth of objects relative to one another).
- d) **Using a complete transparency filter** on the low amplitude reflection signals (difficult to understand the depth of objects relative to one another).



Benefits of Processing

- **Top:** Unprocessed radargram of line 13 showing pronounced hyperbolic tops at ~ 9 m and ~ 14 m.
- **Middle:** Processed radargram of line 13 showing clearer and **more abundant hyperbolas** between position ~ 4 m and ~ 16 m, which corresponds to the locations of burials 3 to 9.
- **Bottom:** Cross-section through the 3D model at the approximate location of line 13. **Three zones of high amplitude** are visible within this cross-section.



Church of the Holy Spirit Cemetery

With this method and associated workflow, we were able to accurately map out the area of the cemetery, produce a 3D display of assumed gravesites, and advise the owners on appropriate pathways for their drainage system





Brecourt Manor

Locating WWII Armaments

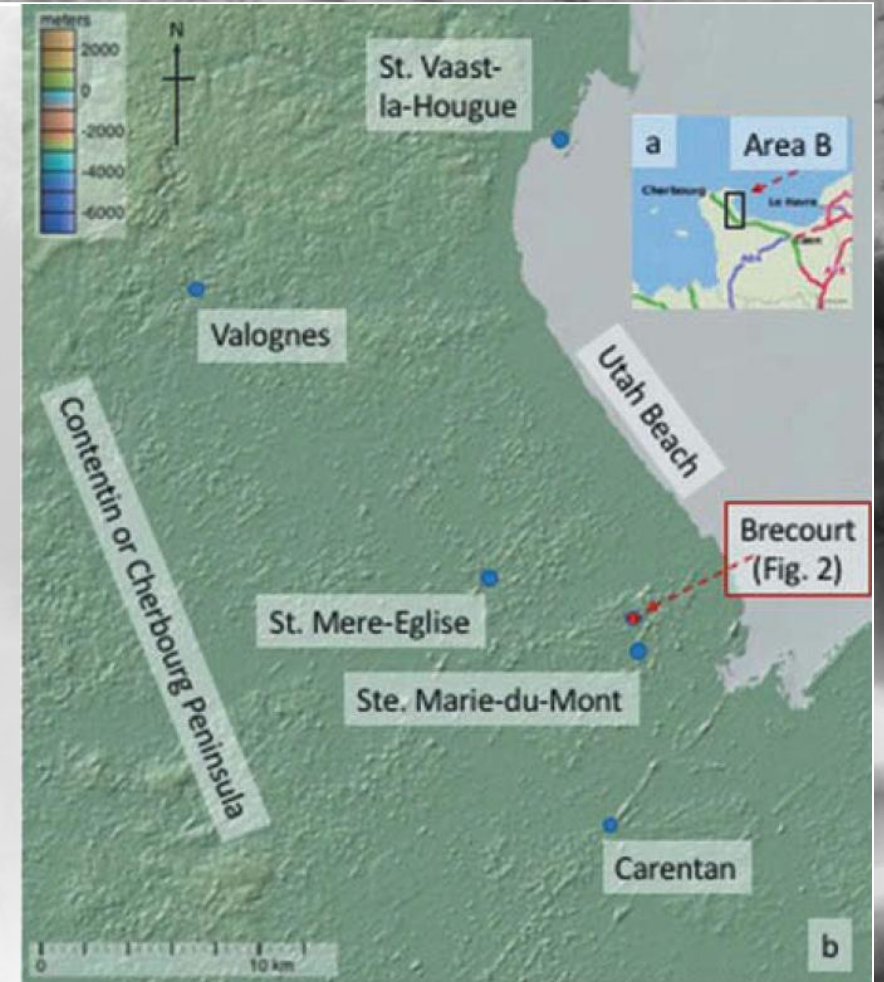
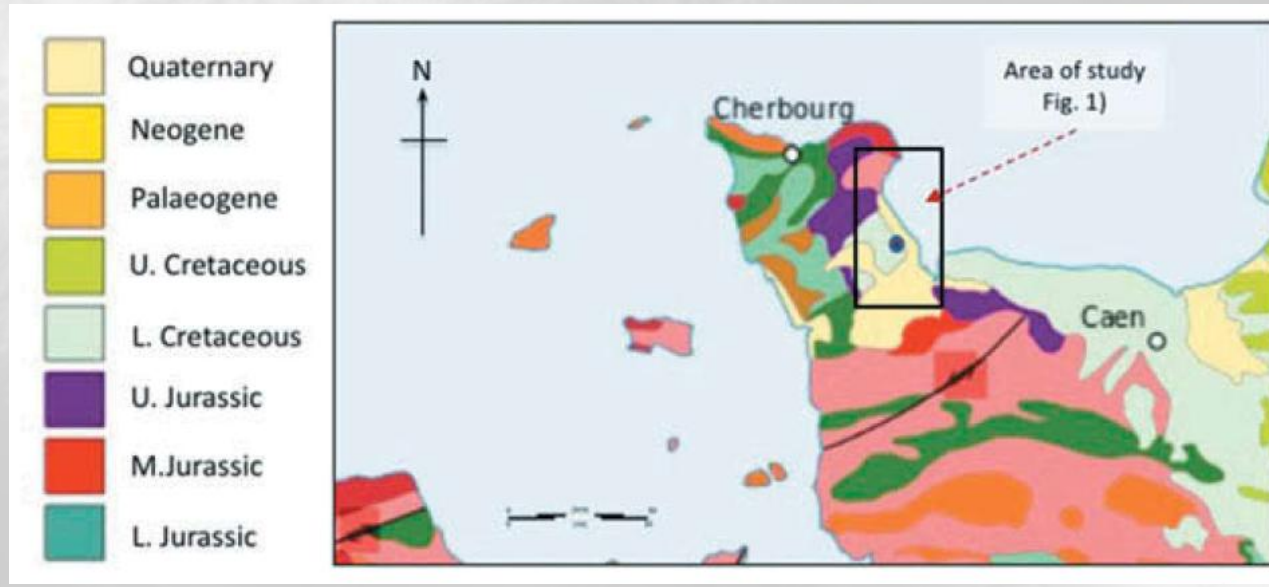
Brecourt Manor

Using a geoforensic search strategy, we were able to locate a WW2 Howitzer Battery in Brecourt (Normandy, France)



Study Location

Assault on the German Howitzer Battery at Brecourt, Normandy, by Easy Company of the 101st Airborne Corps, US Army took place on June 6, 1944 as part of Operation Neptune (D-Day)

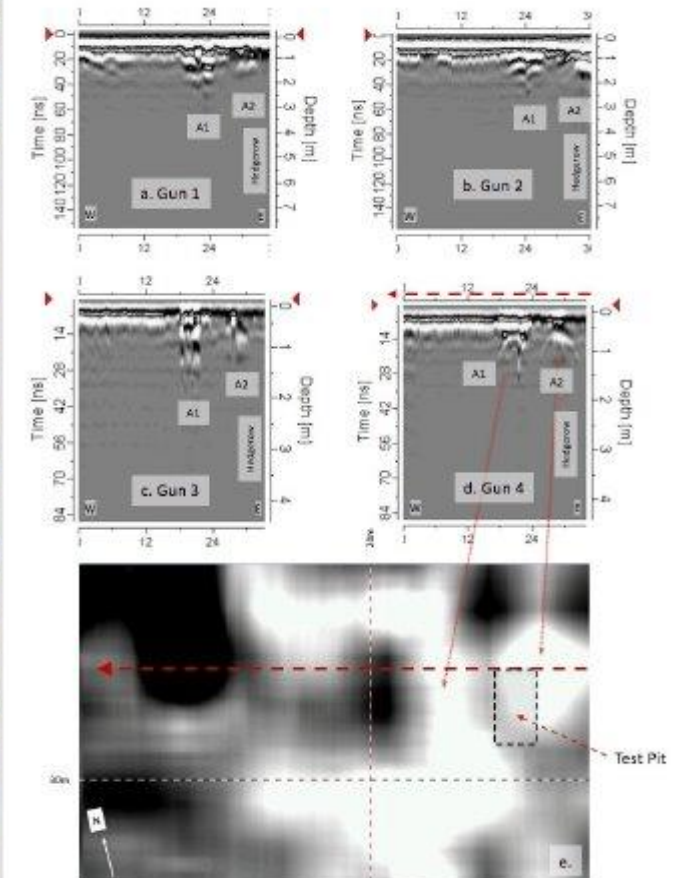
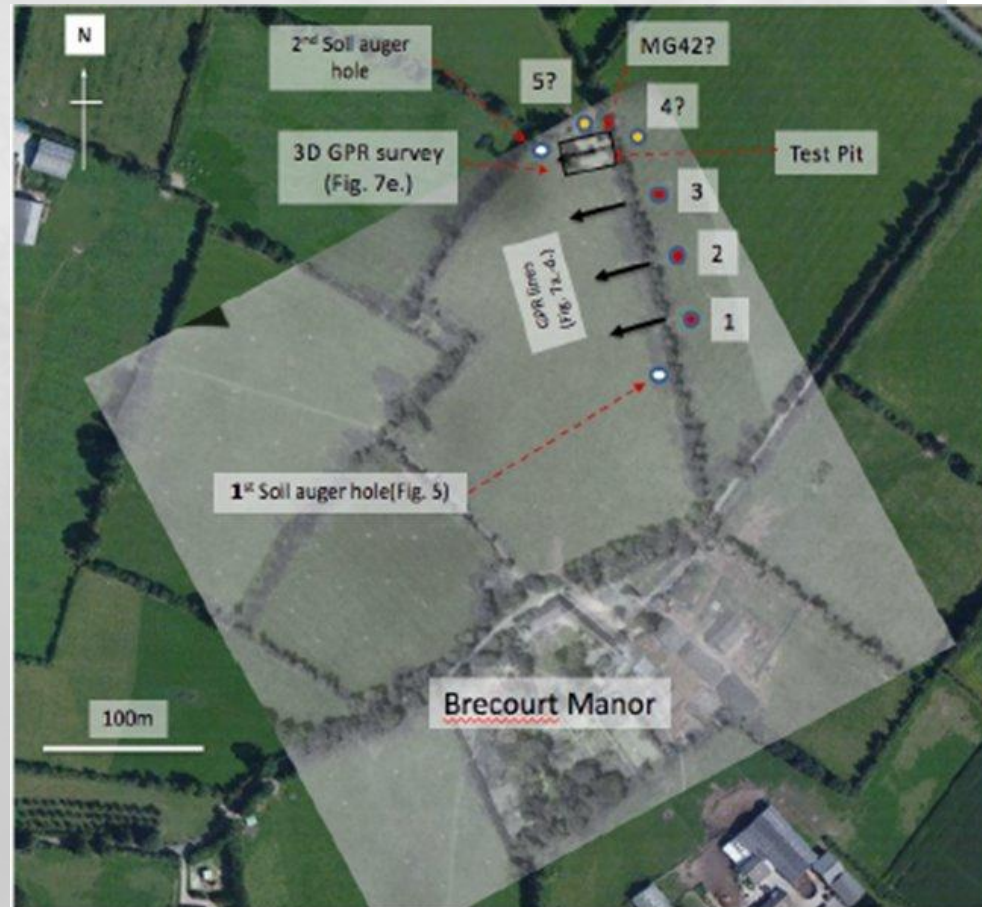


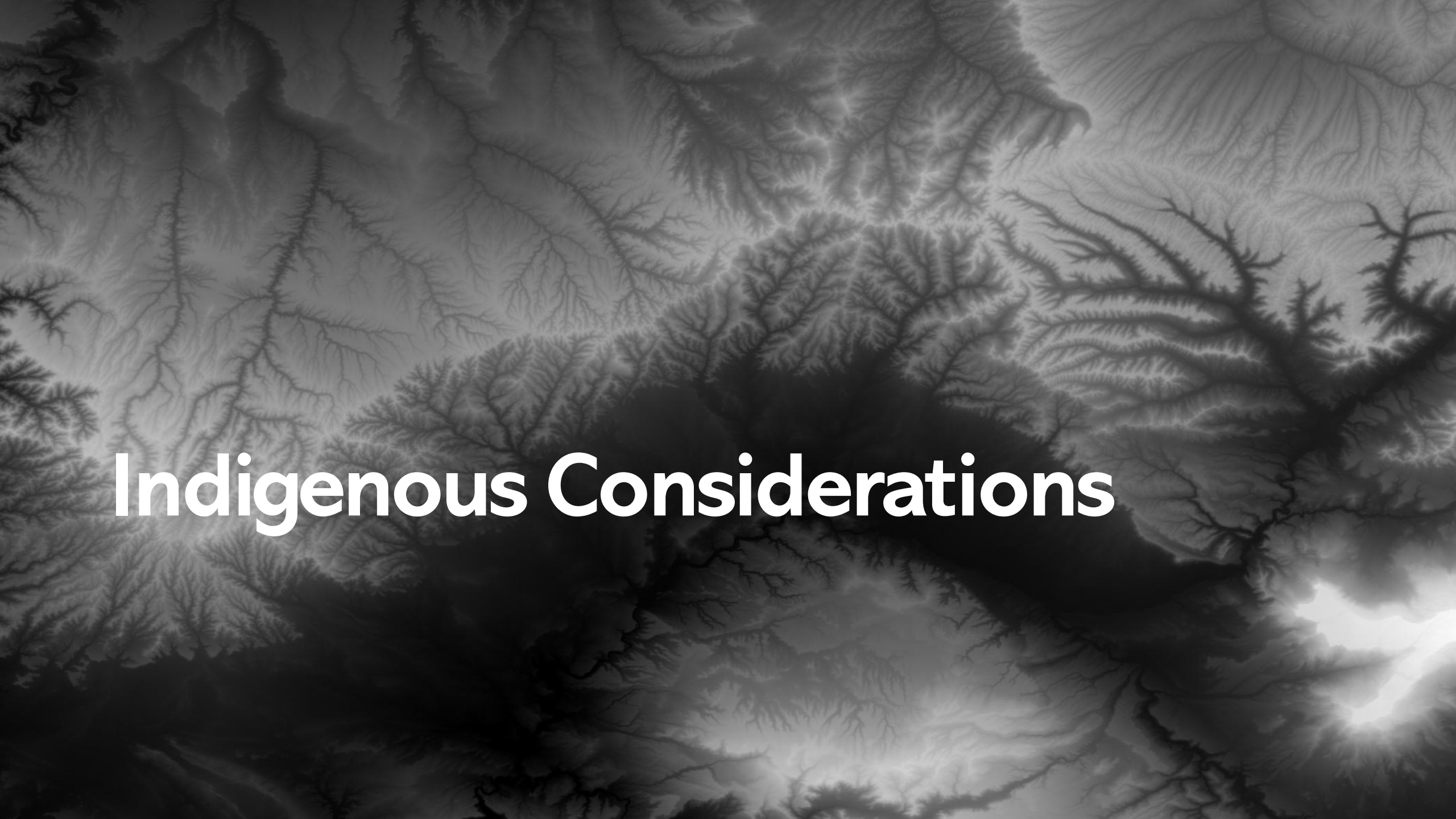
Finding the Fourth Howitzer

- Knowing the exact locations of the different howitzers at this site helps to understand the firefight and disablement of the guns during the battle
 - 3 of the 4 howitzer positions are known, with the fourth being the subject of this study
 - The debated location of the fourth howitzer is due to 2 differing accounts
- Investigation shows strong evidence for the likely position of the final gun, and hypothesizes that the location of this gun was moved from its original site in the days leading up to D-Day

Geoforensic Investigation

- Aerial images from 1947 were used in collaboration with modern satellite imagery to estimate general location
- GPR and soil probing were then used to further identify the location of the gun



A black and white photograph of a dense evergreen forest. The trees are tall and their branches are covered in needles, creating a complex, textured canopy. Sunlight filters through the trees, creating bright, glowing patches and long, dark shadows. The overall mood is serene and natural.

Indigenous Considerations

Indigenous Considerations



- In recent years, geoforensics and GPR especially, has been used in searches at former Residential School sites in Canada
- Similarly to the Church of the Holy Spirit survey, GPR methods are implemented for the identification of unmarked graves

Residential School GPR Investigations



Dr. Kisha Supernant at the University of Alberta has been at the forefront of these investigations, providing logistical information about GPR forensic searching and trying to stop the spread of misinformation regarding searches at these sites

Indigenous Considerations

If conducting an investigation on current Indigenous reserve land, or an area known as a previous settlement site, the appropriate communities and organizations (like KMK and the Assembly of NS Mi'kmaw Chiefs) should be consulted and included in any work



Artwork by Dozay Christmas (Membertou FN)

Indigenous Considerations

And as the histories and truths about the Residential Schools continue to come to the forefront of Canadian politics and media, be sure to exhibit extra care when dealing with a case associated with the local First Nations communities or Residential School sites



Only when “you” and “me” becomes “us” and “we” can there be any reconciliation – Kevin Takahide Lee

A dramatic black and white photograph of a dense evergreen forest. Sunlight filters through the canopy, creating a high-contrast scene with bright highlights and deep shadows. The word "Conclusions" is overlaid in white text on the left side.

Conclusions

Conclusions

- Geoforensics can be a useful addition in criminal investigations – from the location of potential buried objects, to linking of evidence to a particular location
- GPR in particular is gaining popularity, particularly in the identification of unmarked graves at residential school sites
 - But there is a lack of qualified and experienced individuals to aid in these investigations, and this technique may not be as widespread or common as it has the potential for
- As police forces continue to expand their methods, geoforensics may be considered and roles created for their contributions



Thank you!

Questions?



Collaboration with Local Police

Investigation assistance in active cases

NS Law Enforcement Investigation #1

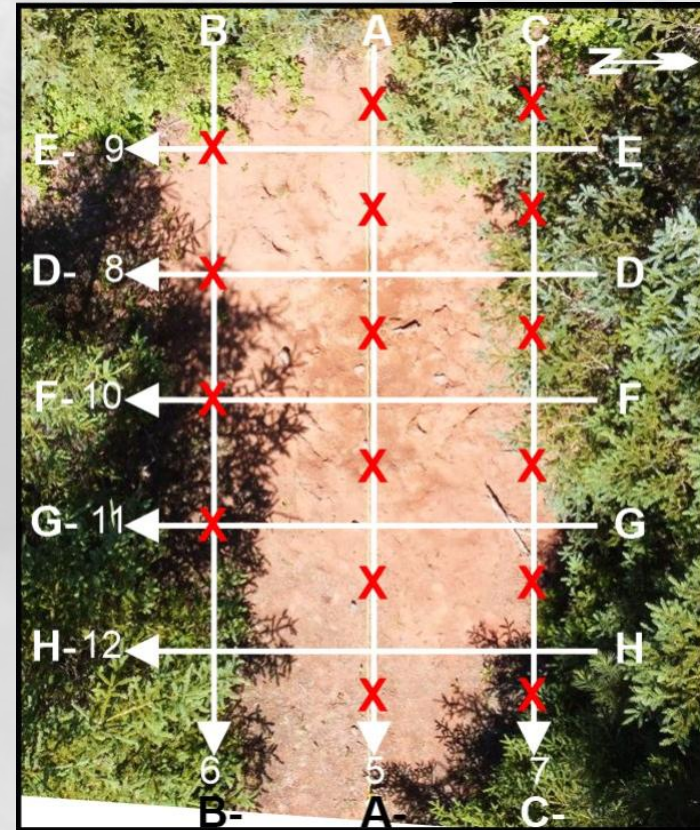
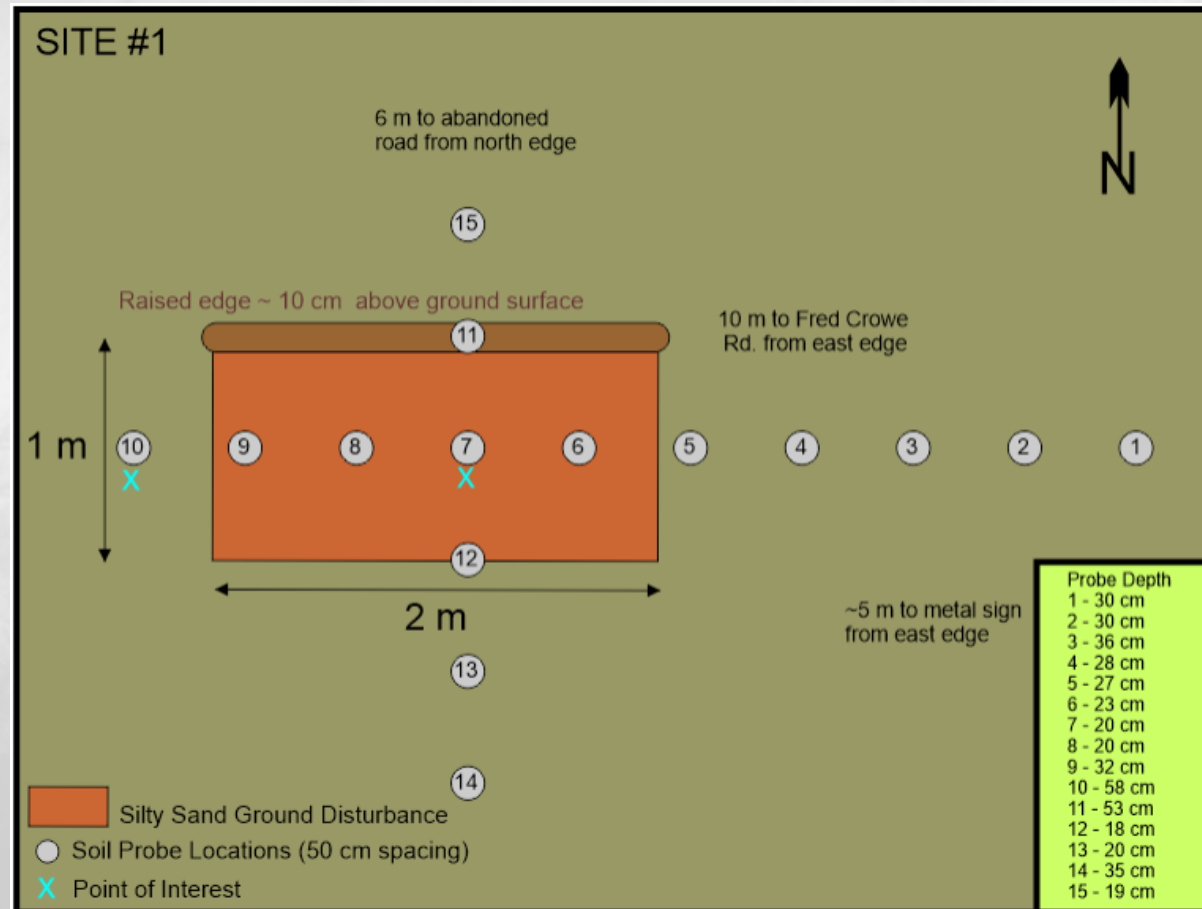
- In 2021, work was requested by the RCMP to survey a suspicious-looking area, originally reported by a concerned member of the public
- This work included:
 - Initial site assessment of conditions & GPR survey
 - Lab processing of radar profiles acquired in the field
 - Calibration of radar profiles with aerial and ground photography
 - Incorporation of soil probe data
 - Incorporation of metal detection data
 - Incorporation of scintillometer data

Study Area

- This is the general study area
- Note that study of the initial site is imperative to final results – heavy vegetation, particularly tree roots, along with animal disturbances can affect imaging
- The reported surficial and bedrock geology in the area did not appear to be a concern

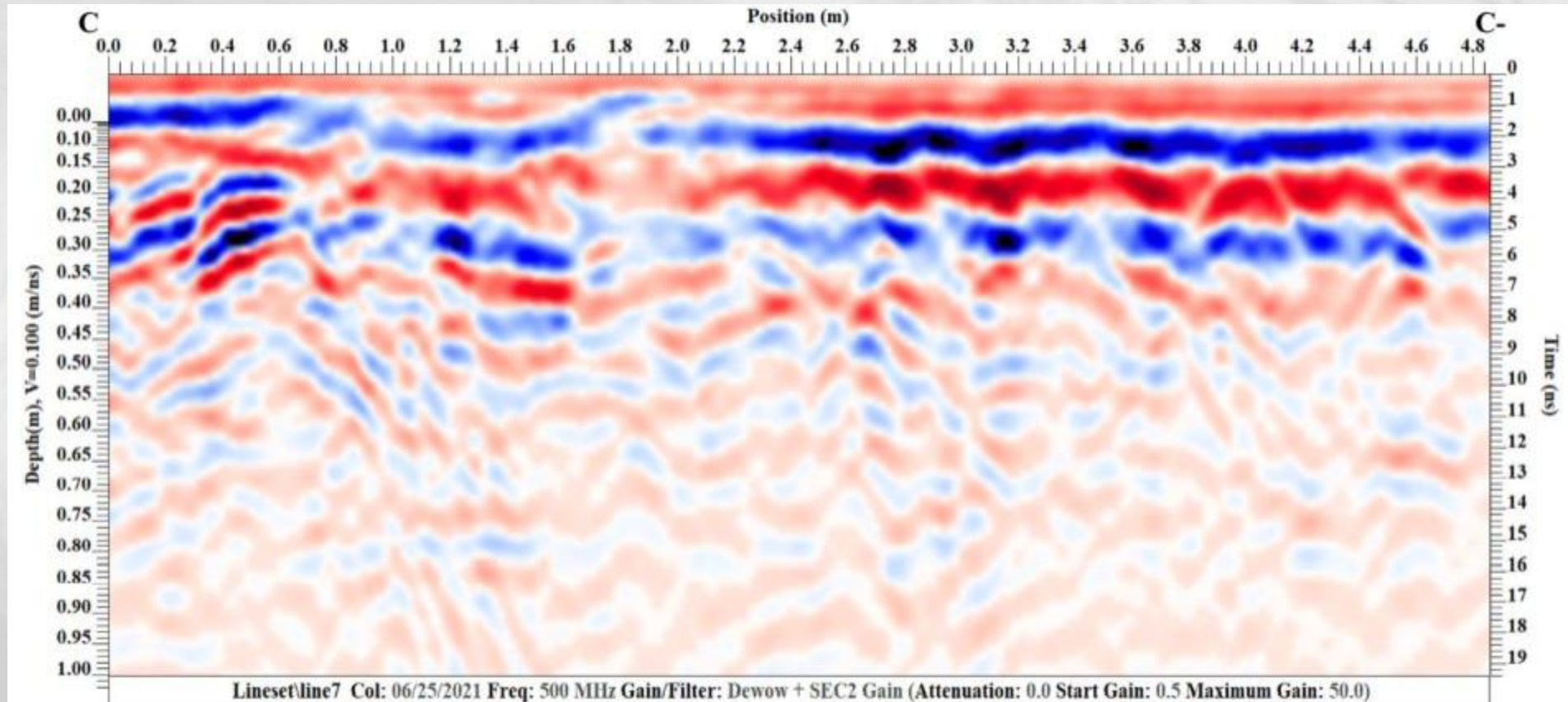


Site #1 – Soil Probe & GPR



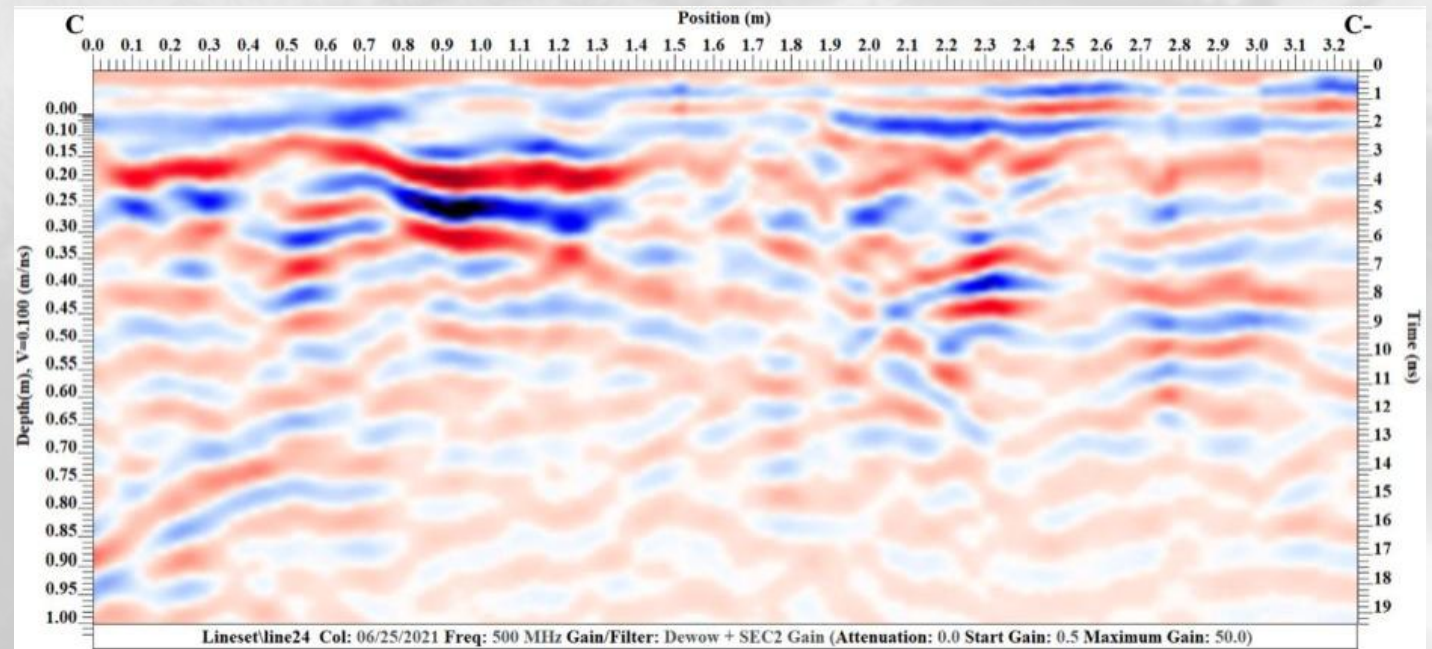
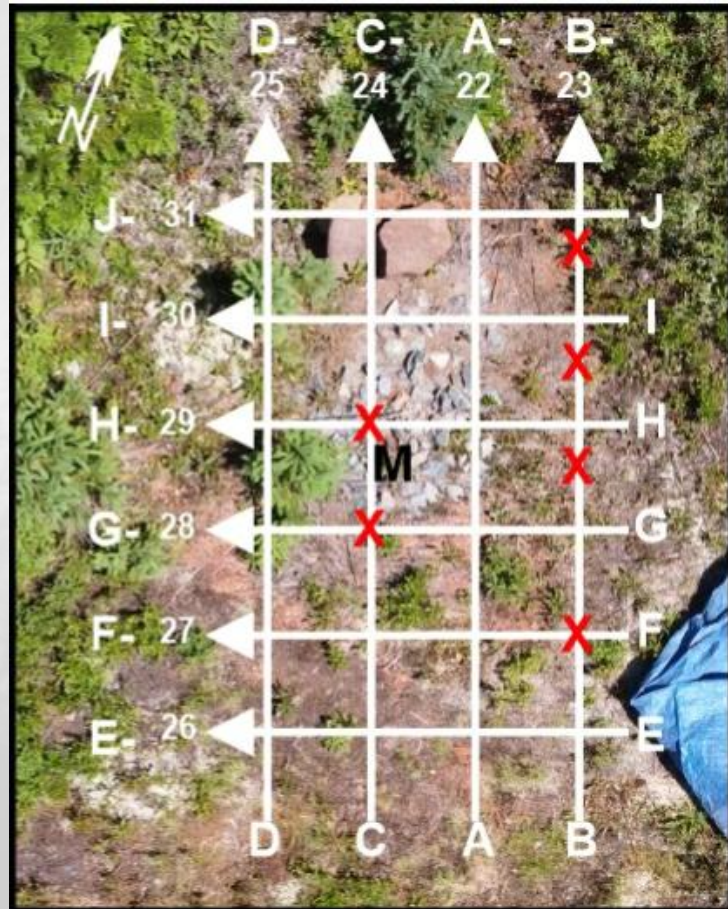
Red X's denote areas of potential disturbance in the GPR images

Site #1 – GPR Results



Site #1 – Line #7

Site #2 – GPR Results



Site #2 – Line #24

NS Law Enforcement Investigation #1



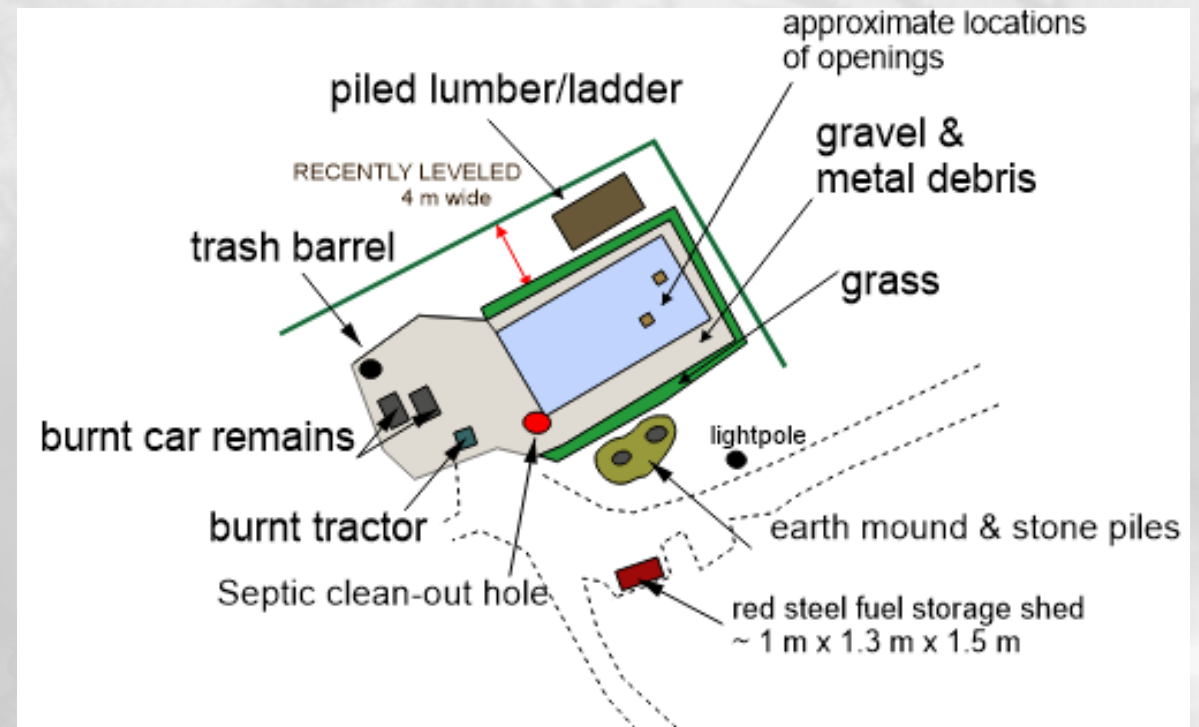
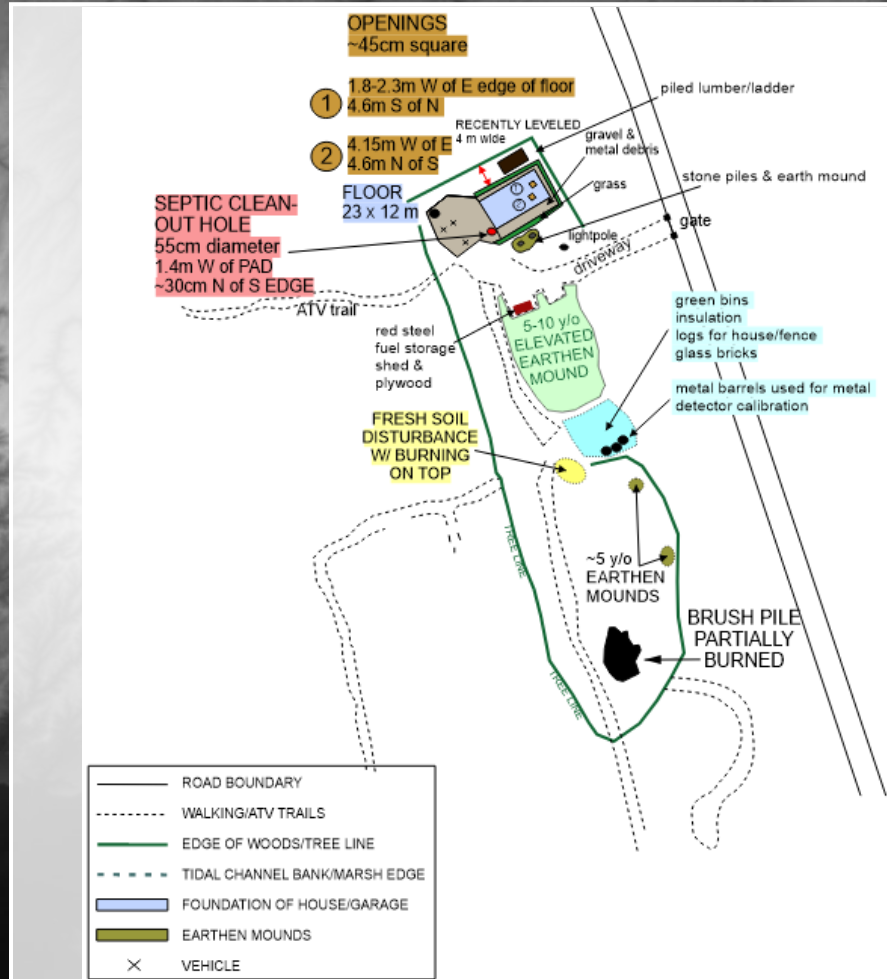
- Using the results from both the GPR survey and soil probe results, we were able to suggest specific spots for the different sites where there could be potential for burial or other disturbance
 - After continued investigation, we were notified that no human remains were recovered from the site



NS Law Enforcement Investigation #2

- Similarly to the first case, this investigation began with research into the study area, comprising of surficial and bedrock geology, general site conditions, and setting out mapping parameters
- For this site, RCMP were looking to determine if there was any evidence to support an ongoing investigation

Site Sketches



Depiction of site conditions and areas of interest

NS Law Enforcement Investigation #2

Through the 30 radargrams acquired across multiple sites of interest, nothing of significance was located in the images or through subsequent investigation

