EnergyCo

Central-West Orana Renewable Energy Zone Transmission project

Amendment Report

Appendix M: Ground Penetrating Radar Report

March 2024

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Central West Orana Renewable Energy Zone

Ground Penetrating Radar Interpretation

Prepared for Prepared for WSP Australia Pty Ltd on behalf of the Energy Corporation of NSW

February 2024

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Executive Summary

EMM Consulting Pty Limited (EMM) has been engaged by WSP Australia Pty Ltd (WSP) to review Ground Penetrating Radar (GPR) data collected by Beveridge Williams Subsurface Investigation Department (BWSID) from three sites in Tallawang: CWO-22-HH08 Spir Road Cottage (lot 27 DP750764); CWO-22-HH09b Tallawang Union Church (lot 120 DP750764);CWO-22-HH09c Tallawang Catholic Churches (lot 103 DP750764) as part of the Central-West Orana Renewable Energy Zone Transmission Project. The purpose was to interpret the data from an archaeological perspective to identify unmarked graves and buried architecture.

The GPR investigation, conducted on July 8, 2023, utilised advanced technology including the IDS Stream DP device with 30 active antennae, allowing for detailed tomographic imaging up to 2.5 m below the surface. Despite challenges posed by recent rainfall and clay soil composition, the survey aimed to visualise subsurface features and assess the presence of human burials and other underground elements.

GPR technology provides a non-destructive approach widely employed in archaeological investigations for locating unmarked graves while minimising disturbance. Although valuable, GPR technology has limitations in demonstrating all nuances related to burial practices and archaeological features. Interpretation of the GPR data involved expert analysis to recognise subtle anomalies indicative of graves, coffin outlines, or soil disturbances aligning with burial practices.

Interpretation of the GPR data involved the analysis of each subsurface anomaly identified during the GPR survey, following established historic conventions related to nineteenth-century graves. This encompassed factors such as the placement, orientation, dimensions, and depth of each anomaly. Subsequently, each interpreted anomaly was graded for confidence, categorised as high, moderate, or low, based on the level of certainty derived from the interpretation process. This confidence grading procedure was implemented to ensure the accuracy and reliability of the assessment. While many anomalies received moderate confidence gradings, indicating potential graves, careful consideration of soil conditions and historical contexts was necessary. Anomalies clustered near potential church buildings aligned with typical burial orientations, supporting the interpretation.

Despite limitations, radargrams graded with moderate or high confidence were considered potential graves, while those with low confidence signified significant subsurface anomalies. It is recommended to regard radargrams graded with moderate or high confidence as potential graves and to treat even subtle indications with caution.

The GPR survey suggests the presence of graves and buried architecture on the church lots. Therefore, designated areas within the church lots should be made restricted zones to avoid unexpected finds that may delay construction. Additionally, construction activities, lay downs, heavy plant, and traffic in the footprint of the Tallawang Catholic churches and the Tallawang Union Church should be avoided to protect potential archaeological features identified in the GPR interpretation.

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1 Overview

1.1 Introduction

EMM Consulting Pty Limited (EMM) has been engaged by WSP Australia Pty Ltd (WSP) to review Ground Penetrating Radar (GPR) data collected by Beveridge Williams Subsurface Investigation Department (BWSID) and provide an interpretation that considers the data from an archaeological perspective.

Beveridge Williams Subsurface Investigation Department was enlisted by WSP Australia to conduct a GPR investigation aimed at detecting unmarked graves at three sites in Tallawang on 8 July 2023 (Plate 1.1) The three sites were identified in the *Central-West Orana Renewable Energy Zone Transmission Project: Non-Aboriginal heritage assessment* report prepared by EMM (September 2023) for WSP on behalf of Energy Corporation of NSW (EnergyCo):

1. CWO-22-HH08 Spir Road Cottage (lot 27 DP750764)
2. CWO-22-HH09b Tallawang Union Church (lot 120 DP750764)
3. CWO-22-HH09c Tallawang Catholic Churches (lot 103 DP750764)

The survey locations are shown in Plate 1.1 which employed GPR technology to visualise subsurface features and assess the presence of subsurface features such as human burials and other underground elements of interest.

Data collection was carried out by Beveridge Williams using an IDS Stream DP device, equipped with 30 active antennae, each operating at a central bandwidth size of 600 MHz. The close antenna spacing and high-frequency capabilities, with antennae oriented in both cross-polarised directions, enabled the generation of detailed tomographic images.

This equipment was selected for its ability to produce high-resolution subsurface imagery at the site, reaching depths of approximately 2.5 m below the surface. However, it is worth noting that recent rainfall prior to the survey, and the clay soil composition on site having poor soil velocity properties, likely posed challenges to GPR penetration. To process the GPR field data, IQ Maps software was used, specifically designed for processing and interpreting data from IDS Stream DP Unit.

Consultation with Beveridge Williams was undertaken to procure additional data, including two-way travel time (depth) and distance, particularly for transects exhibiting clear subsurface anomalies indicative of potential graves. This ensured access to information required for interpretation.

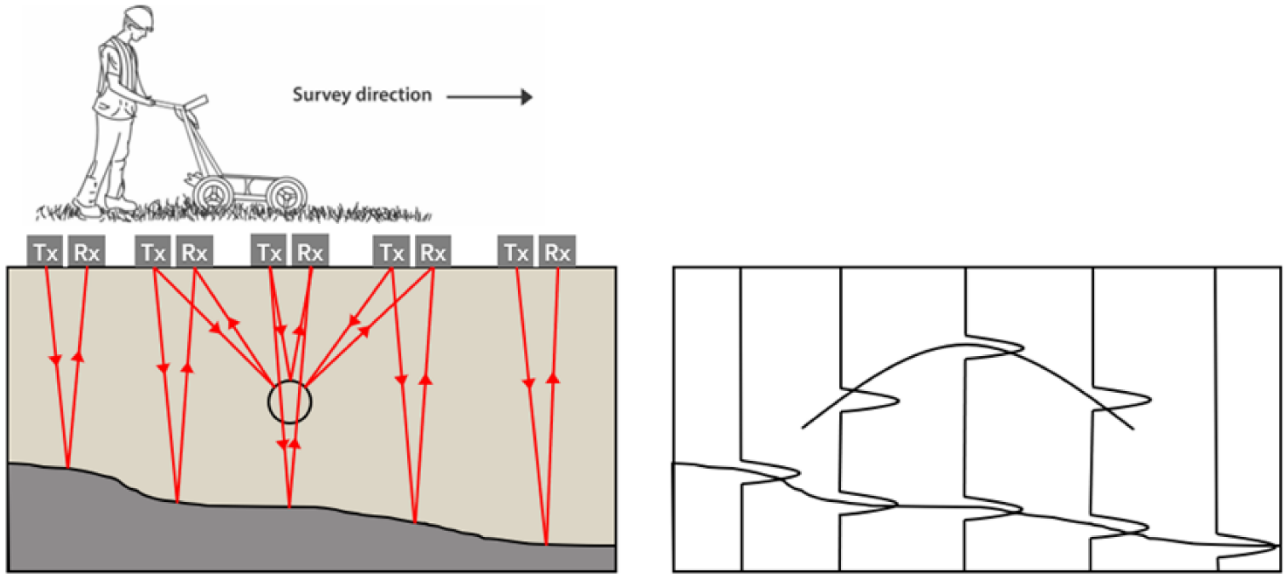
Plate 1.1 **Aerial Image of the investigation locations – Spir Cottage, Tallwang Union Church and Tallwang Catholic Church**

1.2 Ground penetrating radar in theory

GPR is widely utilised across various disciplines for subsurface imaging, offering a non-destructive approach with significant applicability. In archaeological and forensic contexts, GPR has emerged as a tool for locating unmarked or clandestine burials while minimising disturbance, owing to its non-invasive nature.

The utility of GPR in archaeological investigations arises from its capacity to survey sensitive sites and materials without causing harm, contributing to its widespread use (Goodman and Piro, 2013). Continuous advancements in theory, technique, and technology have propelled GPR into a rapidly evolving field (Zhao *et al.*, 2015). Operating on the principle of electromagnetic signal penetration, GPR is highly versatile and non-destructive (Dougherty, Choi and Dosseto, 2016). By emitting high-frequency radio waves, GPR generates high-resolution data in real-time, facilitated by the fixed velocity of electromagnetic waves, which is determined by subsurface material properties such as permittivity, conductivity, and permeability (Goodman and Piro, 2013).

The emission pattern of radar energy from the GPR antenna is conical, resulting in varying two-way travel times along the cone's edge compared to the immediate vicinity beneath the antenna (Zhao *et al.*, 2015) (Plate 1.2). This contrast in travel times leads to target reflections at different depths along the profile, with targets appearing as hyperbolas in the data (Jol, 2008). The distance between the antenna and the target diminishes as the antenna approaches the target, reaching peak amplitude when directly over it, and increases as the antenna moves away, resulting in observable hyperbolic patterns (Hansen, Pringle and Goodwin, 2014) (Plate 1.2).Due to its accuracy, versatility, and effectiveness, GPR methodology continues to gain traction across diverse fields, enhancing its applicability and validity (Conyers, 2016).



Source: Scantech Geoscience, 2017

Plate 1.2 **Schematic diagram of the GPR method, point and planar GPR reflections and simplified radargram**

2 Interpretation methods

While the initial interpretations of the GPR data adhered to best practices, it is essential to recognise the inherent limitations of GPR technology and the interpretation of the data, which could impact the thoroughness of the investigation. WSP engaged EMM to review the data from an archaeological perspective. This approach aims to consider archaeological factors in assessing the presence or absence of human burials and other underground features of interest.

Employing an archaeological approach to interpret geophysical data is recommended when investigating potential historic graves. GPR technology, while valuable, cannot demonstrate all nuances related to burial practices and archaeological features. An archaeologist can bring expertise in recognising subtle anomalies indicative of grave shafts, coffin outlines, or soil disturbances that align with burial practices. Moreover, archaeological expertise ensures that interpretations go beyond a purely geophysical approach. An archaeologist will consider historical and cultural contexts, burial traditions, and site-specific factors that may influence the detection of graves. This approach provides a deeper insight into the significance of detected anomalies and assists with differentiating between potential archaeological features and natural phenomena.

Interpretation and analysis were then conducted to determine the depth and distance of subsurface anomalies. This process involved adhering to typical historic conventions associated with nineteenth century graves, encompassing factors such as placement, orientation, dimensions, and depth. Standard grave conventions established by the International Cemetery, Cremation, and Funeral Association were applied, taking into account dimensions of 2.5’ x 8’ (76 cm x 244 cm) for graves and a standard burial depth of 6’ (183 cm). Environmental factors such as soil composition, moisture levels, and vegetation were considered to assess their potential impact on burial depth. The consistency of these anomalies in terms of depth and size was evaluated, as uniform anomalies are more likely to represent graves.

Each interpreted anomaly was assigned a grading of confidence (high, moderate, or low) based on the level of certainty derived from the interpretation process. This confidence grading was applied to ensure accuracy and reliability in the assessment. The spatial distribution of the graves and their confidence grading was mapped out in Figure 4.1, Figure 4.2and Figure 4.3 to visually depict their distribution across each site. This exercise facilitated the examination of any structured patterns formed by confident graves, offering insights into the potential existence of a graveyard, particularly in the context of a rural church setting, where such features are expected.

Error! Reference source not found. presents the matrix utilised for assessing the confidence of an anomaly being a grave, delineating clear definitions to aid in the interpretation of confidence levels assigned to anomalies identified through GPR surveys. High confidence signifies a strong likelihood of the anomaly representing a grave, while moderate and low confidence levels indicate varying degrees of uncertainty necessitating further evaluation or validation.

Table 2.1 Confidence grading matrix

Confidence Grading	Definition
High	Anomaly demonstrates consistent characteristics of a grave based on depth, size, and shape, aligning closely with typical burial patterns and historical conventions. There is high confidence that the anomaly represents a grave.
Moderate	Anomaly exhibits some characteristics suggestive of a grave, but inconsistencies or uncertainties in depth, size, or shape may exist. Further investigation or corroboration is needed to confirm its classification as a grave.
Low	Anomaly shows minimal resemblance to typical grave characteristics or presents significant uncertainties, making its classification as a grave uncertain. Additional data or field verification is required to assess its significance.

3 Limitations

Acknowledgment of the following limitations ensures transparency and rigor in the assessment process, offering a nuanced understanding of uncertainties when interpreting subsurface anomalies and identifying potential graves at the Tallawang site:

- Data quality and coverage: Accuracy hinges on the quality and coverage of GPR survey data, varying across transects and areas, affecting the consistency of findings.
- Interpretation subjectivity: Interpreting subsurface anomalies involves some subjectivity, influenced by environmental conditions, operator expertise, and criteria, leading to potential result variations.
- Depth penetration and resolution: GPR's effectiveness depends on soil composition, moisture, and antenna frequency, with limited penetration or resolution possibly causing underrepresentation or misinterpretation.
- Assumptions and generalisations: Applying standard grave conventions may introduce generalisations not reflecting the site's specific historical and cultural context, potentially leading to misinterpretations.
- Environmental and site-specific factors: Environmental factors like disturbances, erosion, vegetation, and human activities can obscure or alter subsurface features over time, complicating interpretation. Site conditions such as topography and geology may also pose challenges.
- Confidence grading variability: Assigning confidence grades involves judgment, varying among interpreters, resulting in inconsistencies, affecting overall assessment reliability.
- Temporal and spatial constraints: Time constraints may preclude comprehensive data interpretation or necessitate prioritisation of certain areas over others, potentially limiting the scope of the assessment

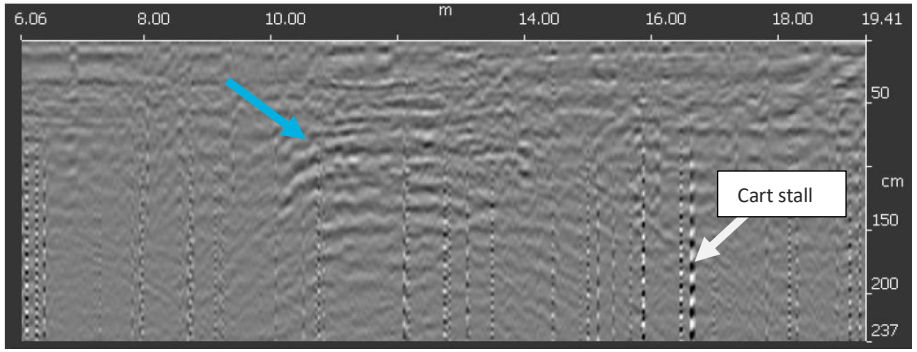
4 Interpretation of results

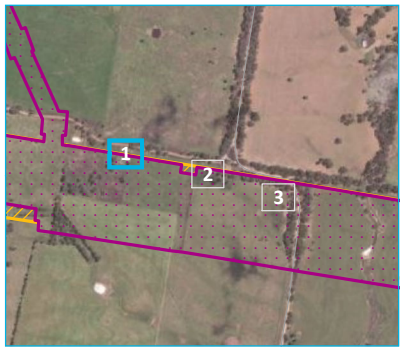
The interpretation of the GPR data is presented separately for each surveyed site: Spir Cottage (Table 4.1), Tallawang Catholic Church (Table 4.2), and Tallawang Union Church (Table 4.3). Each table depicts the corresponding 2D profile indicating identified anomalies, their interpretation, and the assigned confidence grading for each anomaly being a grave. To locate the specific radargrams corresponding to each site, please refer to Figure 4.1, Figure 4.2 and Figure 4.3f or spatial references. Chapter 5 draws conclusions from the observations made below.

4.1 Spir Road Cottage

The GPR survey conducted at Spir Road Cottage revealed a singular subsurface anomaly that warranted further analysis:

Table 4.1 Spir Cottage

2D radargram	Interpretation	Confidence
	A single hyperbolic reflection was observed, exhibiting a depth of approximately 0.9 m and a length of around 4 m. However, the interpretation of the data was complicated by the presence of cart stalls throughout the profile, manifesting as abrupt breaks or discontinuities in the hyperbolic reflections. Cart stalls, commonly observed in GPR data, result from irregularities or interruptions in the movement of the GPR cart during data collection. These disruptions can obscure the interpretation of subsurface features, posing challenges in accurately identifying anomalies. In the context of Spir Road Cottage, the cart stalls likely stem from surface irregularities, such as tree roots, which interfere with the smooth progression of the GPR cart along the transect lines. The characteristics of the hyperbolic reflections within the profile provide additional insights into the nature of the subsurface anomaly. The shallow depths and irregular dimensions of the reflections are inconsistent with those typically associated with graves. Instead, they suggest the presence of other underground features, such as mature tree roots or structural remains, which may have penetrated the subsurface. Considering these factors, it is plausible that the identified anomaly at Spir Road Cottage is not indicative of a grave but rather represents a natural or archaeological feature obscured by surface disruptions	low



KEY

- Amended construction area
- Exhibited construction area

Subsurface anomaly confidence

- Low

Existing environment

- Minor road
- Cadastral boundary

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Source: EMM (2024); EnergyCo (2024); WSP (2024); DCSSS (2023); ESRI (2024); GA (2009)

0 10 20 m

GDA2020 MGA Zone 55

N

Assigned confidence levels - Spir Road Cottage

Central West Orana Renewable Energy Zone transmission
Historical Heritage
Figure 4.1

EMM creating opportunities

4.2 Tallawang Catholic Church

The GPR survey at the Tallawang Catholic Church identified 14 anomalies requiring interpretation:

Table 4.2 Tallawang Catholic Church

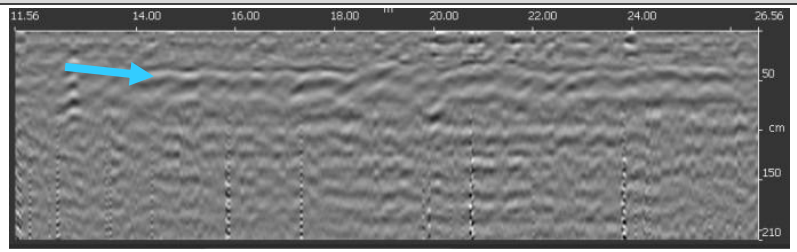
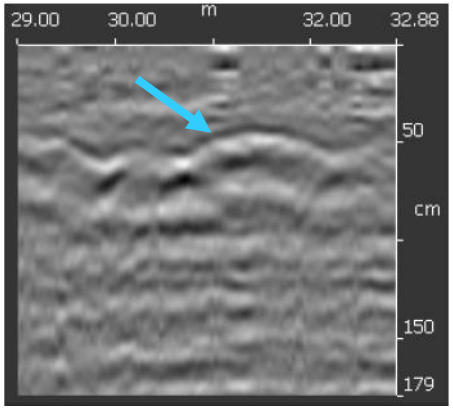
Reference	2D radargram	Interpretation	Confidence
1		A large, flat ground disturbance is evident at a depth of approximately 0.5 m, extending over a distance of more than 10 m. This subsurface anomaly is consistent with the presence of structural remains, possibly indicative of a concrete or brick footing related to the church's construction. Given its elongated dimensions and relatively shallow depth, it is unlikely to represent a grave site.	low
2		A prominent hyperbolic reflector stands out at a depth of around 0.5 m and extends over approximately 2 m. While the length of the anomaly aligns with typical grave dimensions, the depth of 0.5 meters is considered too shallow for a conventional burial. However, in the context of burial practices, it is plausible that this reflection represents the grave shaft, with the actual burial occurring at a deeper level. Alternatively, it could indicate the presence of a burial vault, which would generate a reflection at a shallower depth.	moderate

Table 4.2 Tallawang Catholic Church

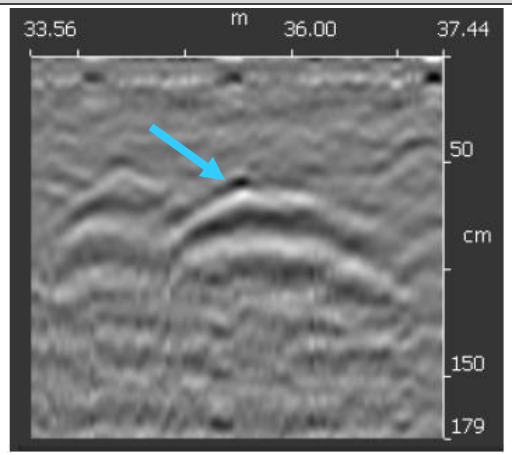
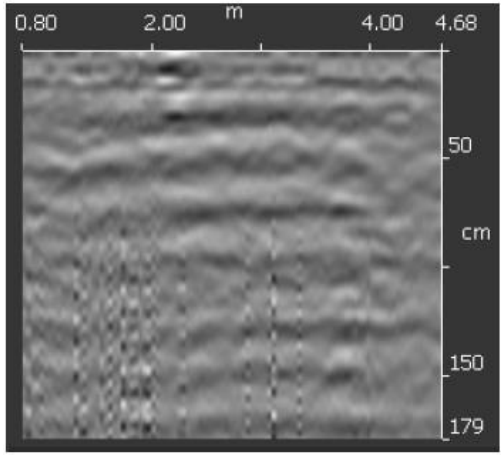
Reference	2D radargram	Interpretation	Confidence
3		A prominent hyperbolic reflection stands out at a depth of around 0.6 m and extends over approximately 2 m in length. Again, while the length of the anomaly aligns with typical grave dimensions, a depth that does not exceed 1 m is considered too shallow for a conventional burial, however, this can be attributed to other factors associated with a burial.	moderate
4		There is an absence of hyperbolic reflectors in this radargram. Instead, there is an increasing presence of noise as the depth within the profile increases. This phenomenon is commonly associated with signal attenuation, where the radar signal weakens or dissipates as it penetrates deeper into the subsurface.	low

Table 4.2 Tallawang Catholic Church

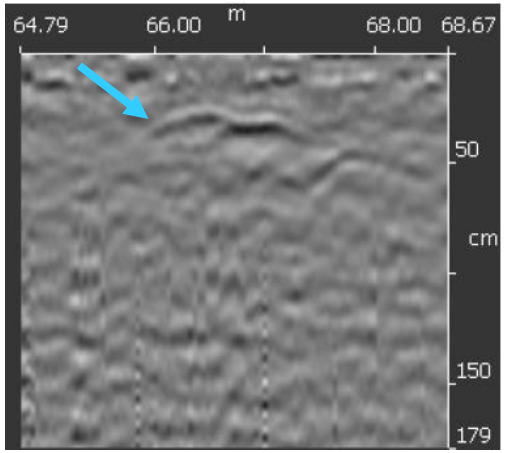
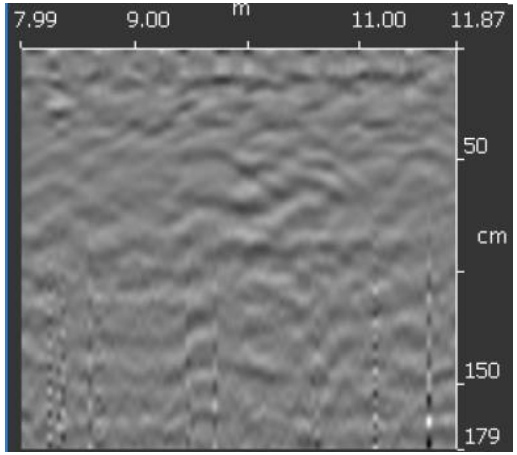
Reference	2D radargram	Interpretation	Confidence
5		A weak reflection is discernible at a depth above 0.5 m, extending approximately 1 m. Given its shallow depth and inconsistent dimensions with typical grave features, this reflection is more likely attributed to tree roots or soil voids rather than a burial site.	low
6		There is an absence of strong reflectors in this radargram. Noise can be seen as the depth increases in the profile, likely signal attenuation.	low

Table 4.2 Tallawang Catholic Church

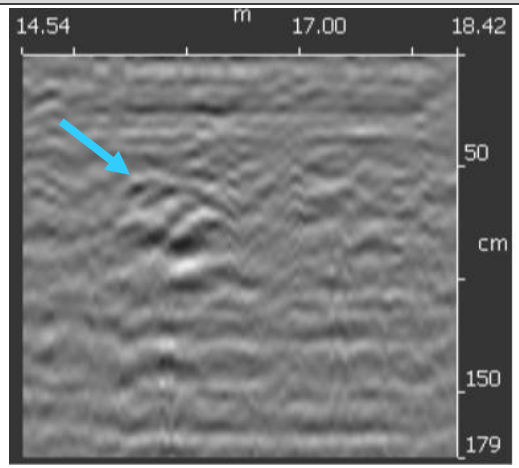
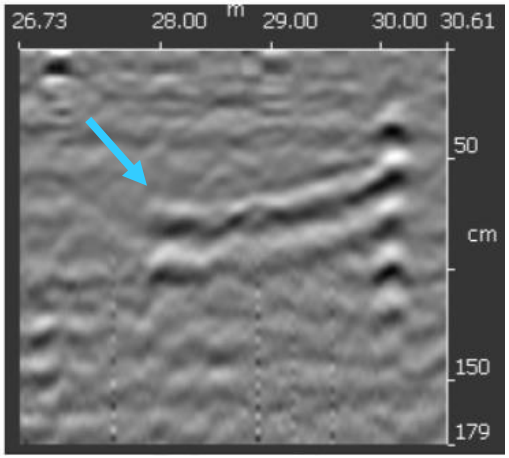
Reference	2D radargram	Interpretation	Confidence
7		A subtle hyperbolic reflector is observable at a depth of around 0.6 m, extending over a distance of 1 m. Although the dimensions and depth do not conform to conventional grave standards, this could be attributed to other factors associated with the potential grave.	moderate
8		A strong reflector is evident at a depth of 0.5 m, spanning a distance of 2 m. While the depth may seem shallow for a conventional grave, the strength and size of the reflector raise the possibility of it being associated with a burial.	moderate

Table 4.2 Tallawang Catholic Church

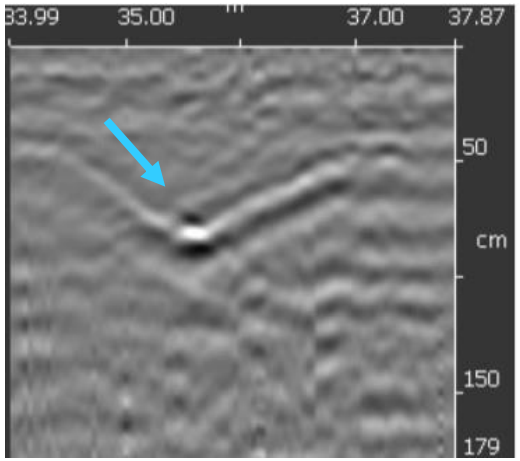
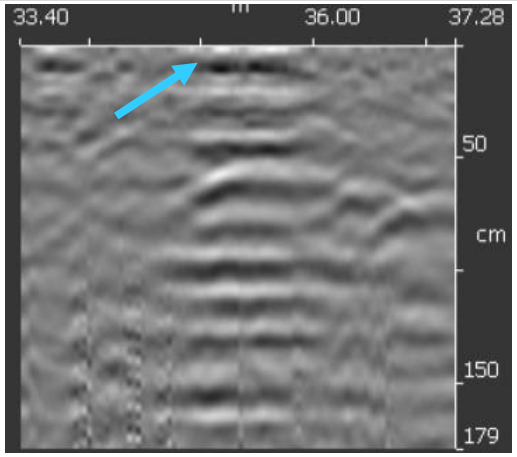
Reference	2D radargram	Interpretation	Confidence
9		A disturbance in the subsurface is observed at a depth of approximately 0.8 m, extending over a distance of approximately 2 m. While it could potentially indicate a void, the strength and size of the reflector suggest the possibility of it being associated with a grave.	moderate
10		A disturbance is evident beginning at 35 m, originating at the surface level. Such a manifestation could suggest a void or a shift in soil composition, but it is not indicative of a grave.	low

Table 4.2 Tallawang Catholic Church

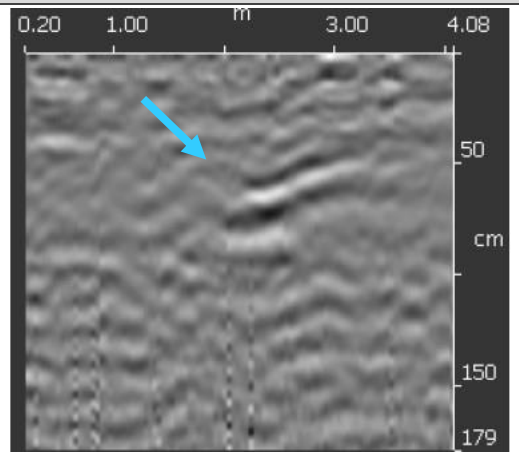
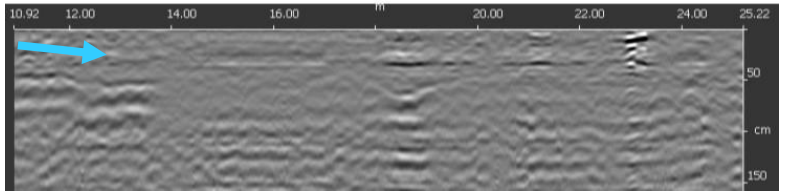
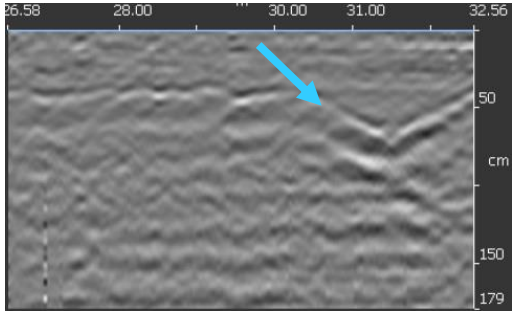
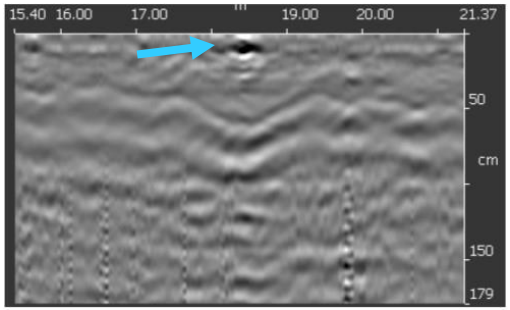
Reference	2D radargram	Interpretation	Confidence
11		A weak reflector is discernible at a depth above 0.5 m, extending approximately 1 m. Given its shallow depth and inconsistent dimensions with typical grave features, this reflector is more likely attributed to tree roots or soil voids rather than a grave site.	low
12		A large, flat reflector is evident at a depth of approximately 0.4 m, extending over a distance of more than 10 m. This is consistent with the presence of structural remains, possibly indicative of a concrete or brick footing related to the church's construction. Given its elongated dimensions and relatively shallow depth, it is unlikely to represent a grave site.	low
13		A large ground disturbance is observed at a depth of 0.5 m, tapering downwards towards the end of the transect around 31.5 m along the profile. This suggests a possible change in stratigraphy, where soil collapse or shifting may have occurred, leading to the dip observed in the profile.	low

Table 4.2 Tallawang Catholic Church

Reference	2D radargram	Interpretation	Confidence
14		A reflector is evident at around 18.5 m along the profile, positioned just below the surface. This reflection is likely caused by the presence of a large stone or similar object, which creates a contrast within the subsurface that is detectable by the GPR.	low

KEY

- Amended construction area
- Exhibited construction area

Subsurface anomaly confidence

- Moderate
- Low

Existing environment

- Minor road
- Cadastral boundary

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Source: EMM (2024); EnergyCo (2024); WSP (2024); DCSSS (2023); ESRI (2024); GA (2009)

0 10 20 m

GDA2020 MGA Zone 55

N

Assigned confidence levels - Tallawang Catholic Church

Central West Orana Renewable Energy Zone transmission
Historical Heritage
Figure 4.2

EMM
creating opportunities

4.3 Tallawang Union Church

The GPR survey at the Tallawang Union Church identified 22 anomalies requiring interpretation:

Table 4.3 Tallawang Union Church

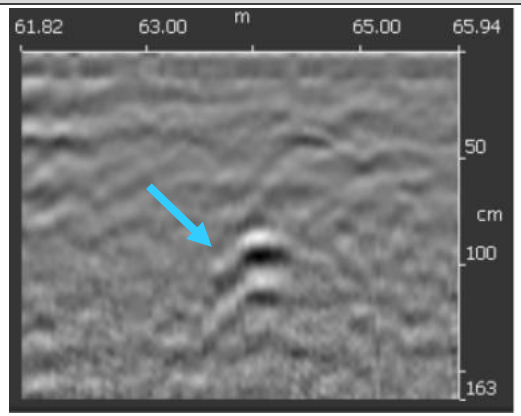
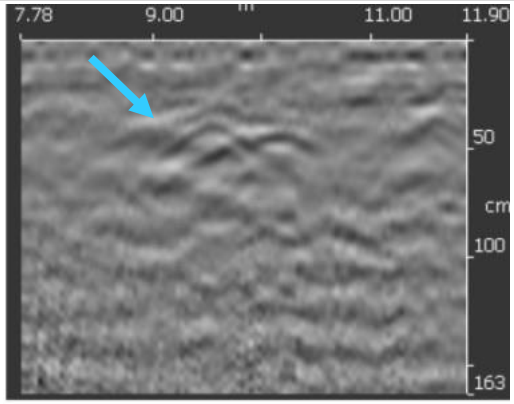
Reference	2D radargram	Interpretation	Confidence
1		A strong hyperbolic reflector appears at approximately 1 m depth, spanning about 1.5 m. While shallower than typical graves, it aligns with possible burial practices in this area, accommodating the clay soil. It could represent a coffin, burial vault, or backfill, contributing to the reflector's depth and size, fitting grave dimensions.	high
2		Two moderate hyperbolic reflectors, around 0.5 m deep and spanning 2 m, overlap each other. Individually, they're small for graves, and are possibly mature tree roots. Depth inconsistencies and the reflectors' size suggest roots rather than graves.	low

Table 4.3 Tallawang Union Church

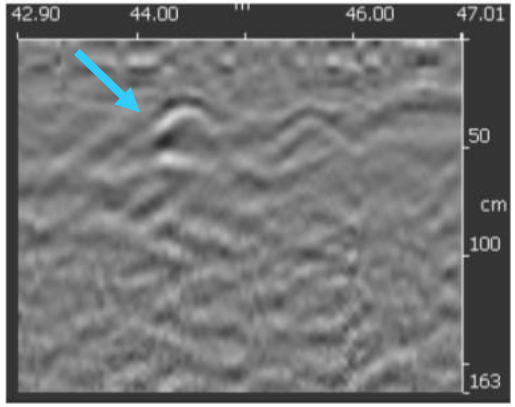
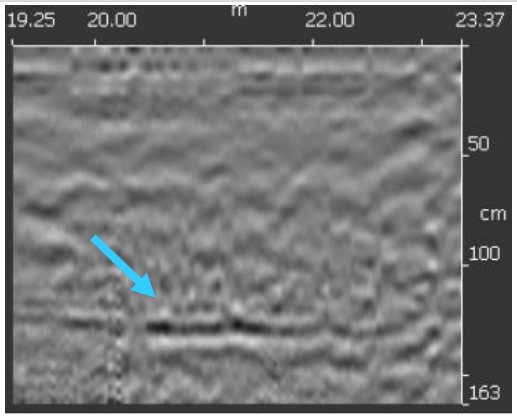
Reference	2D radargram	Interpretation	Confidence
3		While a strong hyperbolic reflector is visible, its size and depth do not match grave conventions. Its depth <0.5 m and span <1 m makes it unlikely to be a grave.	low
4		A strong horizontal reflector at 1.5 m depth, spanning 2 m, conforms to grave dimensions. However, its flatness can suggest stratigraphic changes, bedrock, or water intrusion, rather than a traditional grave.	moderate

Table 4.3 Tallawang Union Church

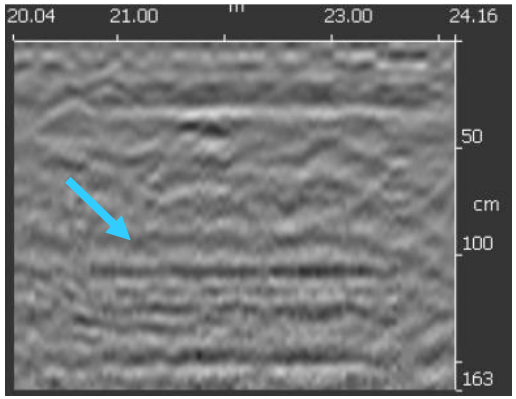
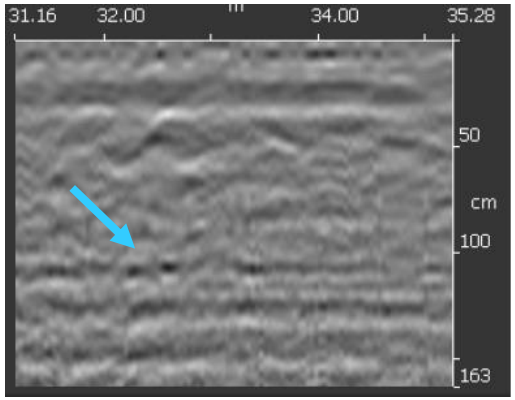
Reference	2D radargram	Interpretation	Confidence
5		Two strong horizontal reflectors parallel at 1 m and 1.6 m depth, spanning 2 m+, match grave conventions. But their flatness can suggest stratigraphic or water-related factors rather than graves.	moderate
6		Although horizontal reflectors are present, their inconsistent placement suggests stratigraphic, bedrock, or water-related origins rather than graves.	low

Table 4.3 Tallawang Union Church

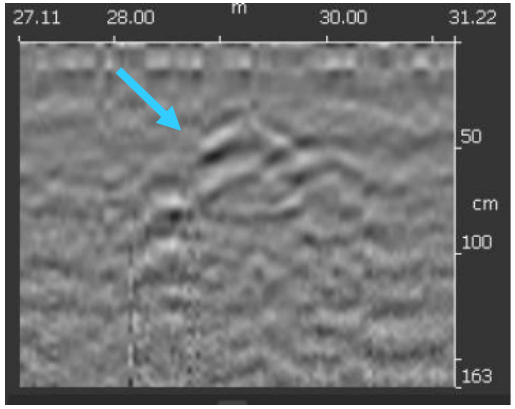
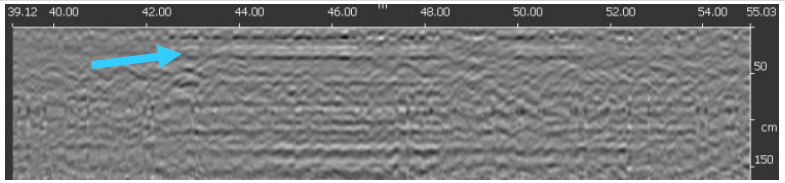
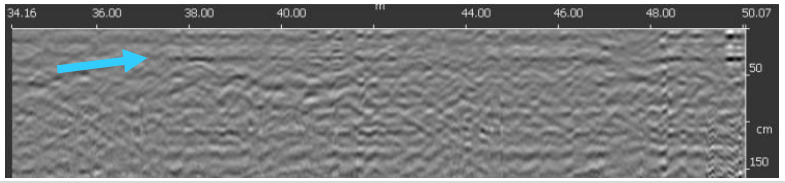
Reference	2D radargram	Interpretation	Confidence
7		A strong hyperbolic reflector at 0.5 m depth, spanning 2 m, aligns with grave conventions. Shallow depth could stem from additional factors, indicating a possible burial site.	moderate
8		A large, flat reflector at 0.4 m depth, over 10 m, suggests structural remains, not graves, due to its elongation and shallowness.	low
9		As above.	low

Table 4.3 Tallawang Union Church

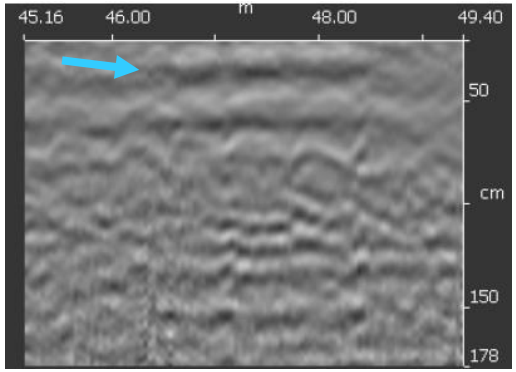
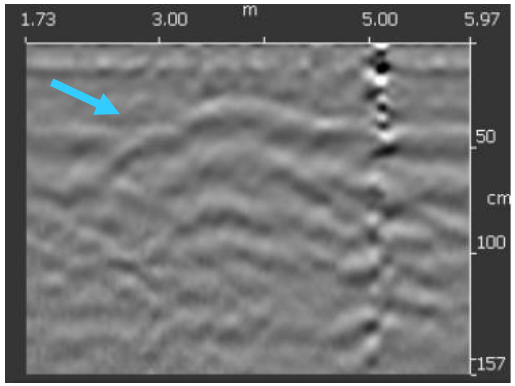
Reference	2D radargram	Interpretation	Confidence
10		Two flat horizontal reflectors below the surface likely denote concrete footings or water intrusion.	low
11		A large sloping reflector at 0.4 m depth, spanning 4 m, suggests water intrusion due to its gradient, size, and shallowness.	low

Table 4.3 Tallawang Union Church

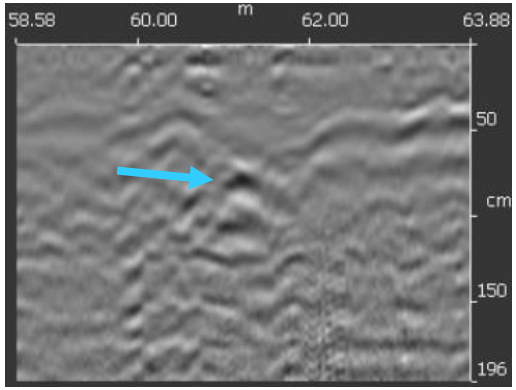
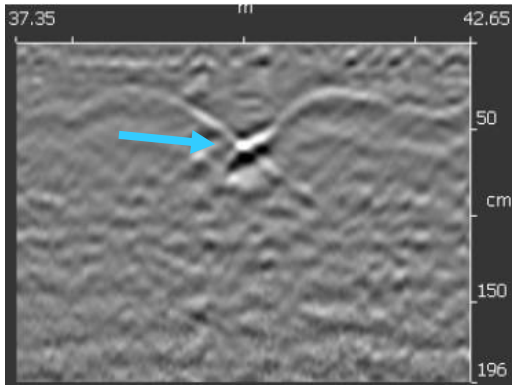
Reference	2D radargram	Interpretation	Confidence
12		A hyperbolic reflector at 0.75 m depth, spanning 1.5 m, aligns with grave conventions despite being shallow, possibly indicating a burial-related feature.	moderate
13		A strong small reflector at 0.5 m depth, 39 m along the profile, may signify a void or stone rather than a grave due to its size and location.	low

Table 4.3 Tallawang Union Church

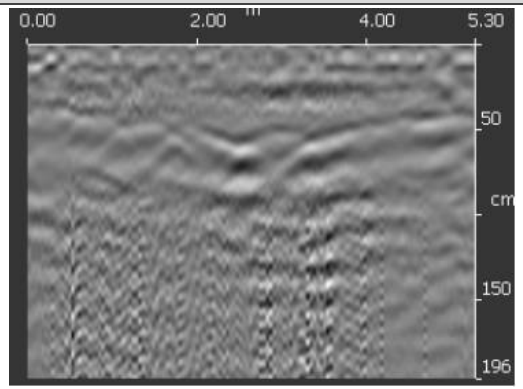
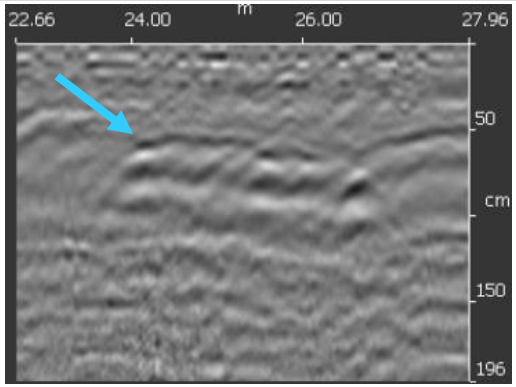
Reference	2D radargram	Interpretation	Confidence
14		Absence of strong reflectors indicates signal attenuation with depth, typical in certain soil conditions	low
15		A large, weak hyperbolic reflector at 0.5 m depth, spanning approximately 2 m in length may represent non-grave features due to its depth and size.	low

Table 4.3 Tallawang Union Church

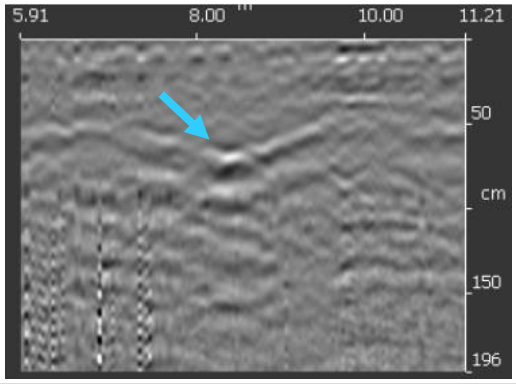
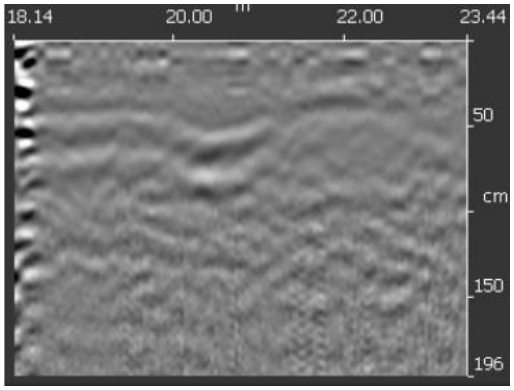
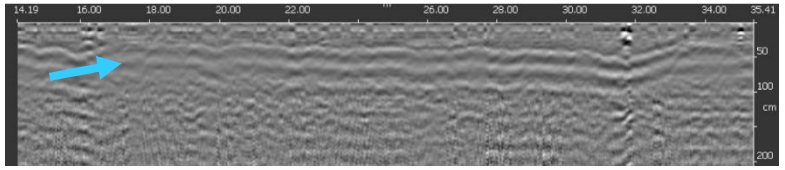
Reference	2D radargram	Interpretation	Confidence
16		A small hyperbolic reflector at 0.6 m depth, 8 m along the profile, could be a grave, despite its size, given its isolated nature.	moderate
17		Cart stall can be seen at the beginning of the profile. A weak reflector at 0.5 m, 20 m along the profile spans at a distance of 1 m. This suggests intrusive water being reflected rather than a grave due to its size and weak reflection strength.	low
18		A large, flat reflector at 0.4 m depth over 10 m in length suggests structural remains, not graves.	low

Table 4.3 Tallawang Union Church

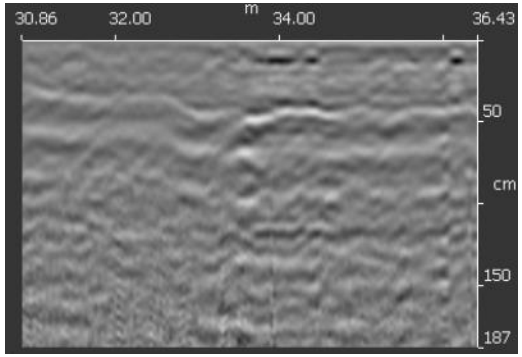
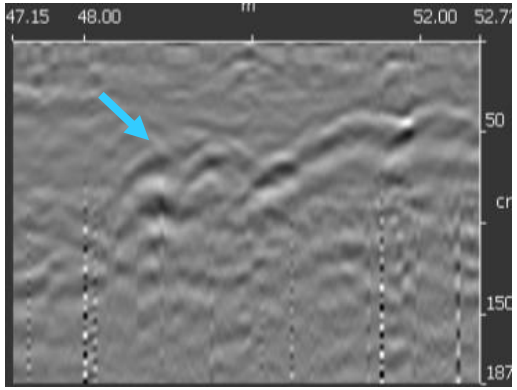
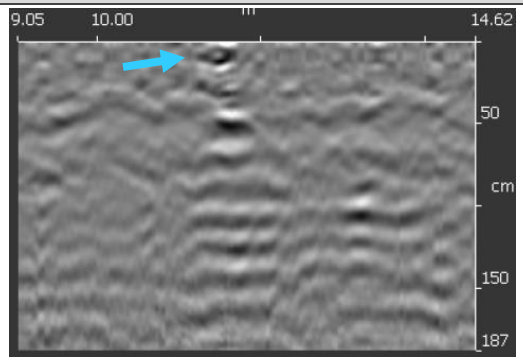
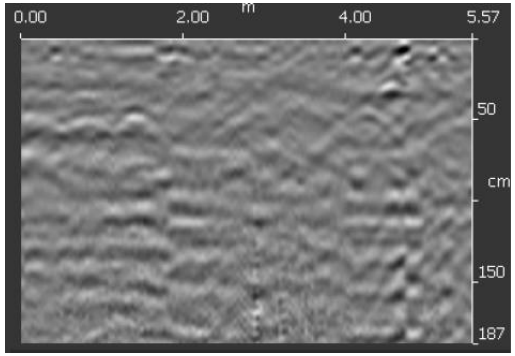
Reference	2D radargram	Interpretation	Confidence
19		Absence of strong reflectors with ringing suggests noise interference or signal attenuation.	low
20		A large, staggering reflector at 0.5 m depth spanning to the edge of the profile may indicate water, voids, or bedrock.	low

Table 4.3 Tallawang Union Church

Reference	2D radargram	Interpretation	Confidence
21		The reflector just below the surface around 12 m appears to be a large stone reflecting back into the GPR antenna. Below this, there is ringing in the profile, which happens when the radar signal produces unwanted echoes or reverberations, typically after a strong reflection.	low
22		There is an absence of strong reflectors in this radargram.	low

KEY

- Amended construction area
- Exhibited construction area

Subsurface anomaly confidence

- High
- Moderate
- Low

Existing environment

- Major road
- Cadastral boundary

Source: EMM (2024); EnergyCo (2024); WSP (2024); DCSSS (2023); ESRI (2024); GA (2009)

0 10 20 m

GDA2020 MGA Zone 55

N

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Assigned confidence levels - Tallawang Union Church

Central West Orana Renewable Energy Zone transmission
Historical Heritage
Figure 4.3

EMM creating opportunities

5 Conclusion

5.1 The potential graves

The GPR survey conducted at Spir Road Cottage, Tallawang Catholic Church, and Tallawang Union Church yielded 29 potential graves, with 18 identified at the Catholic Church and 11 at the Union Church site. The re-evaluation of the data, led by an archaeologist with a geophysics background aimed to refine interpretation of these anomalies to understand if graves are likely to be present. Key factors such as reflector size and depth were compared against conventional grave dimensions outlined by the International Cemetery, Cremation, and Funeral Association.

In general, strong isolated hyperbolic reflectors were assigned a *moderate* confidence grading, despite occasionally shallow depths. While the average depth of these reflections fell within the 0.5 m–0.6 m range, typically too shallow for a grave, several factors were considered. Firstly, the clay soil prevalent in the area could have made digging deeper graves challenging, leading to shallower burials. Additionally, the reflections could represent grave shafts, coffins, backfill, burial vaults, or child graves, all of which could appear shallower than the actual grave (McKillop, 1995).

Only one radargram received a *high* confidence grading, located near Tucklan Road adjacent to the Union Church. Local consultation indicated that the graves at these sites were located near Tucklan Road, aligning with this high, albeit circumstantial, confidence grading. Radargrams graded *low,* either lacked strong reflector strength, displayed incorrect sizes, and depths inconsistent with typical graves. Many of these anomalies, spanning lengths of 10 m, likely represented footings or foundations for the church. Smaller, isolated finds rated low sometimes aligned with larger footings, suggesting isolated sections of these structural remains.

The clustering of moderate confidence graves near Tucklan Road and the traditional orientation of Catholic churches east to west with graveyards typically to the back of the church, further supported interpretation (Swensen and Brendalsmo, 2018). The potential footings identified with the GPR revealed that the church was oriented east to west, aligning with the typical orientation of Catholic churches (Adeboye, 2016). Additionally, the graves for the Catholic church were located west, as the front of churches usually faces east. Thus, the clustering of moderate gradings near the western side of the church is consistent with this orientation. Furthermore, the GPR also recorded a large footing within the Union Church, also appearing to be orientated east to west, with the potential graves located to the north, with a few to the west noting that Union churches may not strictly adhere to conventions, and graveyard placement can vary based on local customs, available space, and congregational preferences (Stewart, 1924).

Soil conditions proved a significant factor affecting data interpretation, particularly with the predominantly clay soils in the area. Heavy rainfall prior to the survey compounded this issue, increasing soil conductivity and moisture content. Clay soils, with their smaller particle size and high moisture retention, likely hindered GPR signal transmission and strength, leading to the overall quality of the data to be impacted.

Ultimately, it is recommended to regard radargrams graded with *moderate* or *high* confidence as potential graves. While excavation remains the only definitive method for confirmation, it is advisable to treat even subtle indications with caution.

Radargrams graded with low confidence, though less likely to be graves, signify significant subsurface anomalies. These anomalies could be attributed to subsurface structural elements or natural phenomena, capable of causing reflections in GPR data. Thus, they should also be factored into any future development plans.

5.2 The Tallawang building group

The outcomes of the GPR survey at the Tallawang Union Church (CWO-22-HH09b) and the Tallawang Catholic churches (CWO-22-HH09c) suggests that footings of the building survive archaeologically and *in situ.* Table 4.2 and Table 4.3 describes possible structural remains such as footings or large stones on the site of the Tallawang Catholic churches in referenced numbers 1, 12 and 14, and at the Tallawang Union Church in referenced numbers 8, 9, 10, 13 and 18.

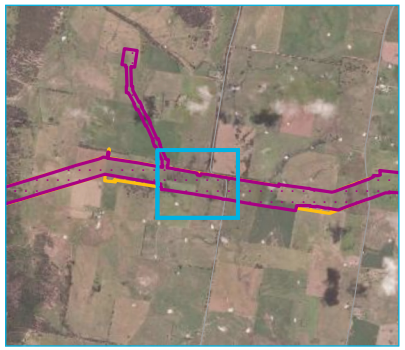
5.3 Recommendations

The GPR survey suggests the presence of graves and buried architecture predominantly within specific areas of the Tallawang Catholic Church lots. Therefore, it is advised to designate only those specific areas as restricted zones to prevent any unexpected finds that could potentially delay construction. To implement this recommendation effectively:

1. Heavy traffic should adhere to the designated routes outlined in Figure 5.1.

2. Restricted zones should be enforced exclusively in the identified areas of the church lots, as illustrated in Figure 5.2.

3. Construction, lay downs and heavy plant in the footprint of the Tallawang Catholic churches and the Tallawang Union Church is avoided to protect what appears in the GPR interpretation to be footings and graves.



KEY

- Amended construction area
- Exhibited construction area

Traffic management

- No vehicle access
- Light vehicle access
- No vehicle restriction

Subsurface anomaly confidence

- High
- Moderate
- Low

Existing environment

- Major road
- Minor road
- Cadastral boundary

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Source: EMM (2024); EnergyCo (2024); WSP (2024); DCSSS (2023); ESRI (2024); GA (2009)

0 100 200 m

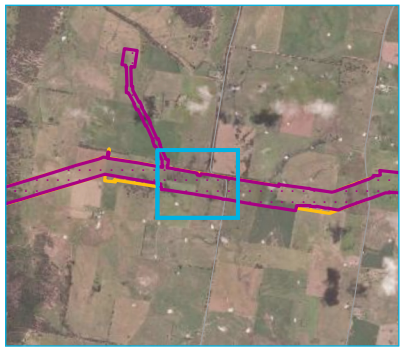
GDA2020 MGA Zone 55

N

Traffic management route

Central West Orana Renewable Energy Zone transmission
Historical Heritage
Figure 5.1

EMM
creating opportunities



KEY

Amended construction area
Exhibited construction area

Traffic management

Restricted zone
No vehicle access
Light vehicle access
No vehicle restriction

Existing environment

Major road
Minor road
Cadastral boundary

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Source: EMM (2024); EnergyCo (2024); WSP (2024); DCSSS (2023); ESRI (2024); GA (2009)

0 100 200 m

GDA2020 MGA Zone 55

N

Restricted Zones

Central West Orana Renewable Energy Zone transmission
Historical Heritage
Figure 5.2

EMM
creating opportunities

6 References

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Appendix A

Beveridge Williams GPR report

EMM
creating opportunities

3D Array GPR - Tallawang Grave Investigations

Spir Road, Tallawang

Client
WSP Australia

Issued
21/07/2023

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Beveridge Williams

Client	WSP Australia
Representative	Alistair Hitchon
Phone number	0457 521 391
Issued	21/07/2023
Site Date	08/07/2023
Technician	Minhtam Tong
Checked by	Paul Wallis
Project Number	2300879

INTRODUCTION

Beveridge Williams Subsurface Investigation Department was engaged by WSP Australia to perform an investigation targeting unmarked graves at Tallawang using Ground-Penetrating Radar (GPR). The area investigation is highlighted below (Figure 1).

Figure 1: Aerial Image of the investigation locations – Spir Cottage, Tallwang Union Church and Tallwang Catholic Church

METHODS

Ground Penetrating Radar

This survey utilised GPR to image the subsurface and evaluate the presence or absence of human burial and other underground features of interest. GPR sends electromagnetic pulses to a transmitting antenna at the ground surface which produces a radio wave that travels through the subsurface. Wave speed depends on the ability of a given medium to transfer energy.

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. According to classic works, the amount of energy that will be reflected when an approaching wave encounters a contrast in dielectric permittivity will vary based on how different the two materials are on either side of the interface.
A large difference in dielectric permittivity will result in a large amount of energy reflected off the interface whereas a small difference on either side of the boundary will result in a small amount of energy being reflected.

The two-way travel time (usually recorded in nanoseconds) and the amplitude of the reflection is recorded at the surface by a receiver antenna. Each traverse with the GPR provides a two-dimensional profile of the subsurface. When traverses are collected adjacent to each other, then data can be resampled to create pseudo-3D visuals called time-slices.

GPR is a popular and often successful technique for identifying utilities and other manmade subsurface features, However, there are limits to the resolution of any non-destructive testing and the physical properties of subsurface materials, surface conditions at a site, and the complexity or orientation of targets that can impact the overall quality of results from a GPR survey.

DATA COLLECTION AND POST PROCESSING

Data collection was performed by Beveridge Williams using an IDS Stream DP (Figure 2), a multichannel device with 30 active antennas, all with 600 MHz as their central bandwidth size. The tight antenna spacing and high frequency of the antennas, which are oriented in both directions of travel (cross-polarized) allow the creation of highly detailed tomography.

This equipment was chosen for its quality of output, to allow for the highest resolution of subsurface features at the site location, to a depth of approximately 2.5m below the surface. We were advised it had rained within the last week which may affect GPR penetration. Farmer on-site also advised that ground material is clay which has poor soil velocity properties – potentially hindering GPR penetration.

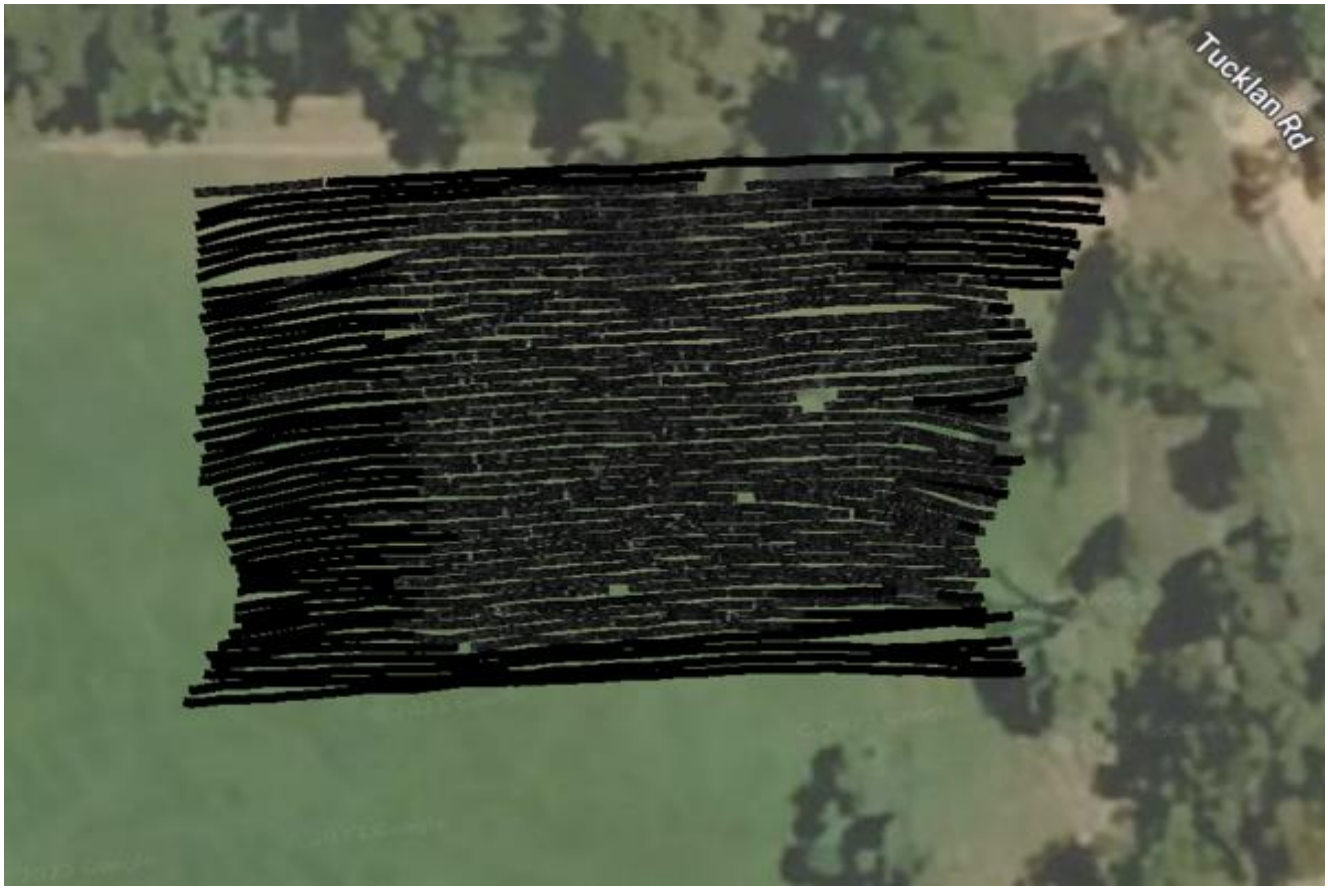
The software program used to process the GPR field data was IQ Maps a software package designed specifically for processing and interpretation of data from IDS Stream DP Unit.
Data was interpreted using the best practice approach. Alternative interpretations are possible and the limitations of the GPR may affect the completeness of the investigation.

Swaths (coverage) using the Ground Penetrating Radar within each of the sites are shown below in Figure (3).

Figure 2: Ground Penetrating Radar used onsite.

Figure 3: Spir Cottage Swaths

Tallawang Catholic Church



Tallawang Union Church

RESULTS

The GPR recorded signatures with shape, size, and depth characteristic of those typically generated from burials throughout the area of investigation.

These were identified and annotated using two-dimensional profiles in IQ Maps software. In profile view each signature that had characteristics of a potential burial was flagged and highlighted red , the approximate size and orientation of features could then be estimated. An aerial map of the approximate locations and distribution of features for each of the investigation locations are shown below.

At the Union and Catholic Church locations longer linear features highlighted green were interpreted as potential footings while unknown ground disturbance highlighted in purple were unable to be categorised it as a potential grave or footing due to its inconsistency.

Legend

Green – Potential Footing - Green depicts larger, consistent, and noticeably flat ground disturbance over a large area – potential footings.
Red – Potential Grave - Red depicts potential graves. Determined due to the size of the area of soil disturbance.
Purple – Unknown Ground Disturbance - Purple depicts areas of unknown ground disturbance. Unable to categorise.

Image Above: Spir Road Cottage Features Detected

Image Above: Tallawang Catholic Church Features Detected

Image Above: Tallawang Union Church Features Detected

Reduced B-Scan Examples

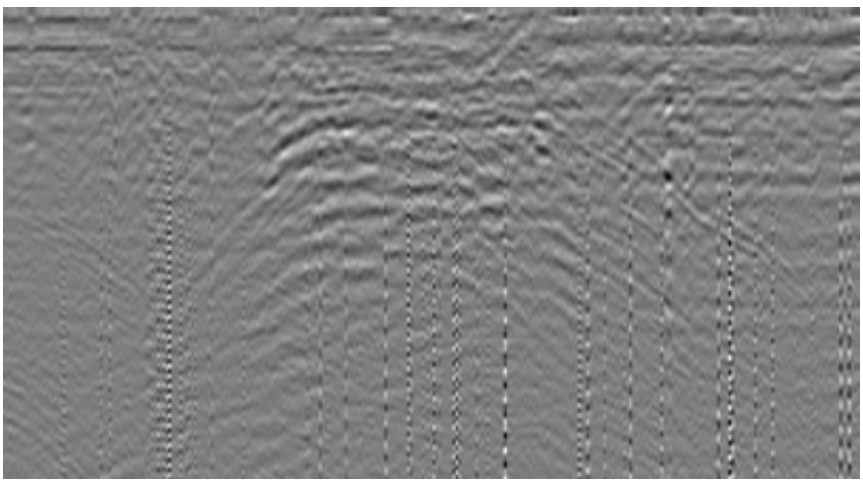
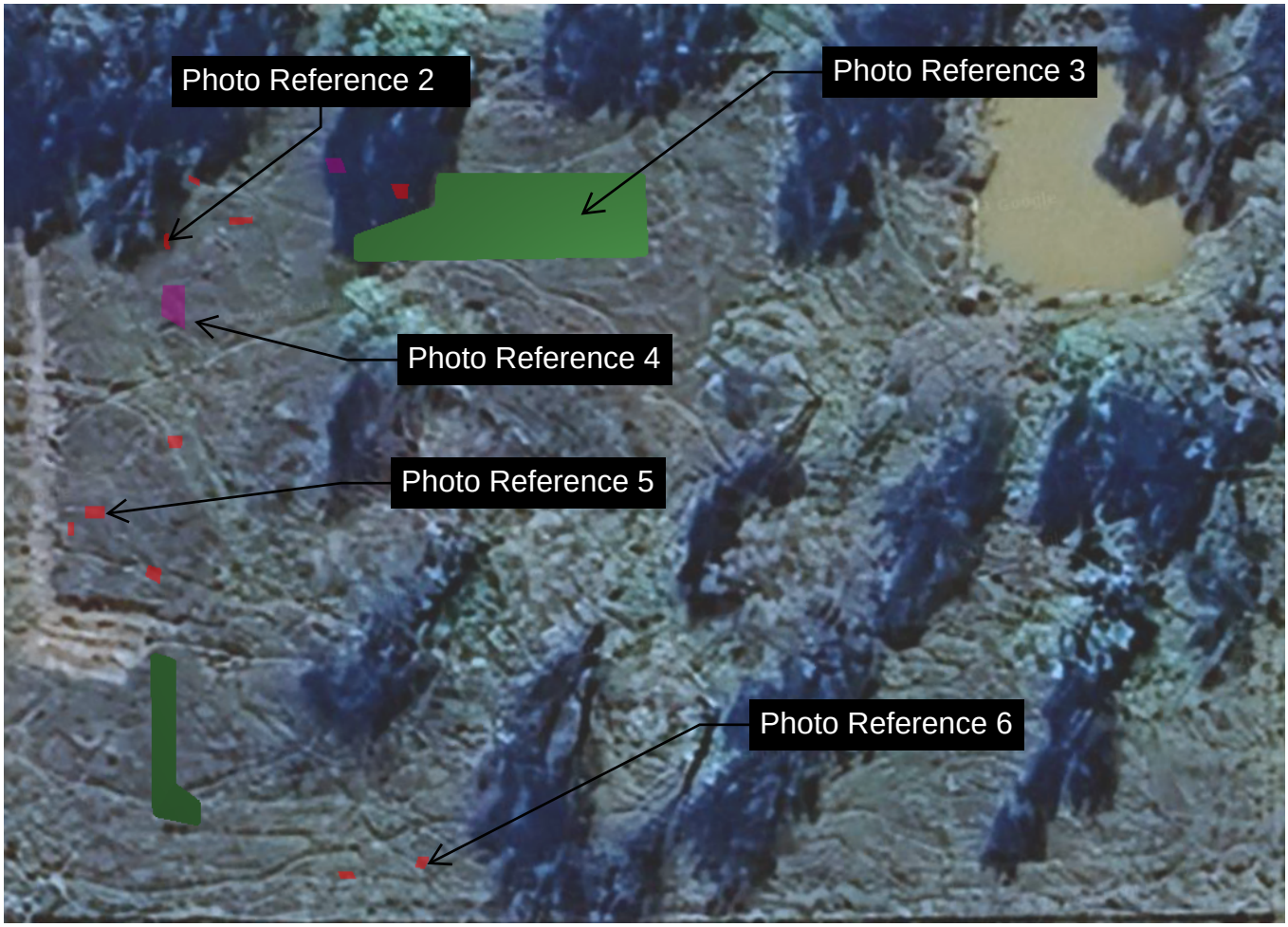
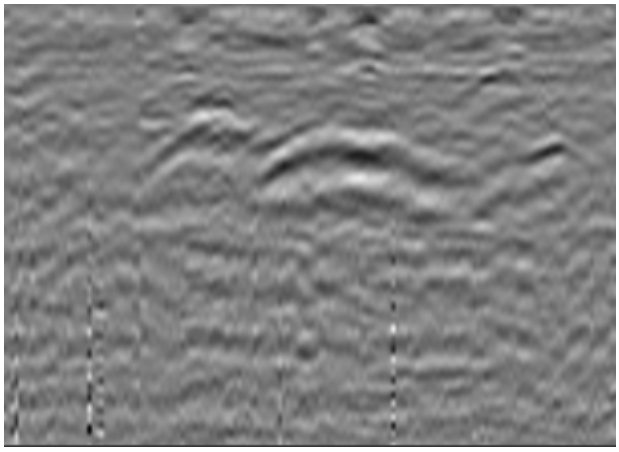


Photo Reference 1





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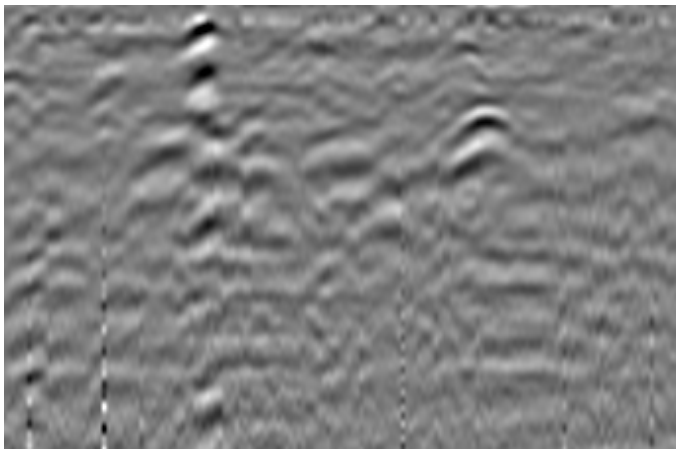


Photo Reference 4

Photo Reference 3

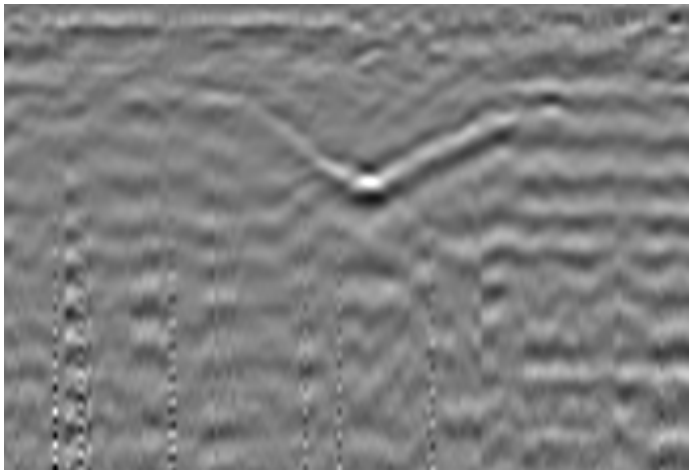


Photo Reference 5

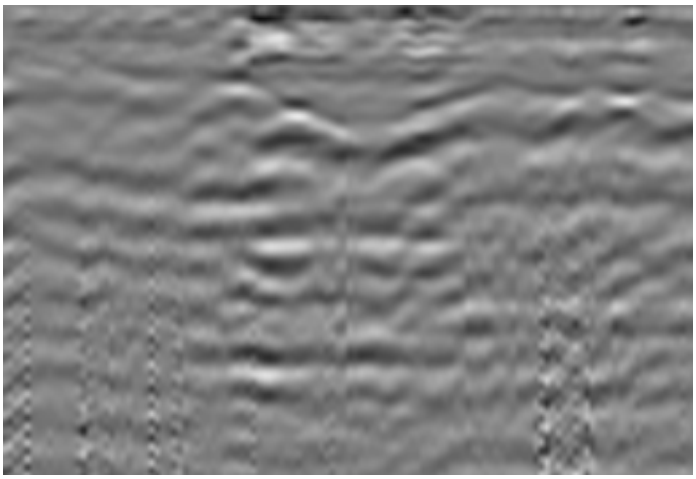
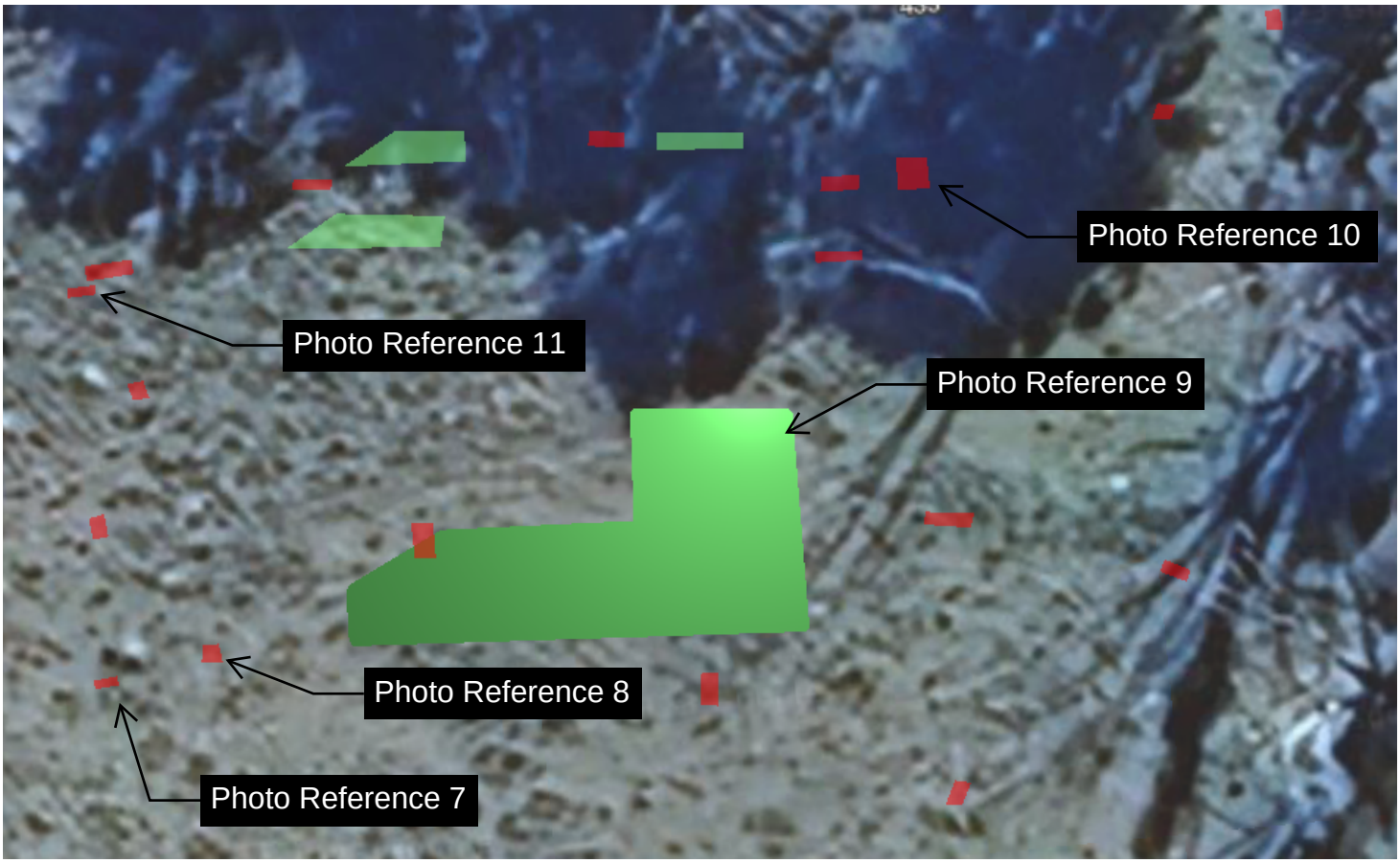


Photo Reference 6



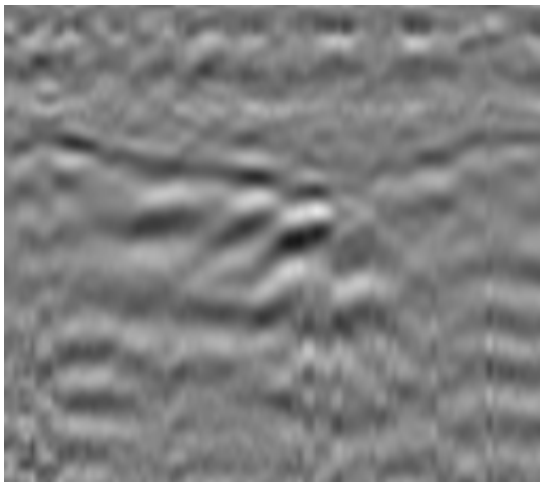


Photo Reference 7

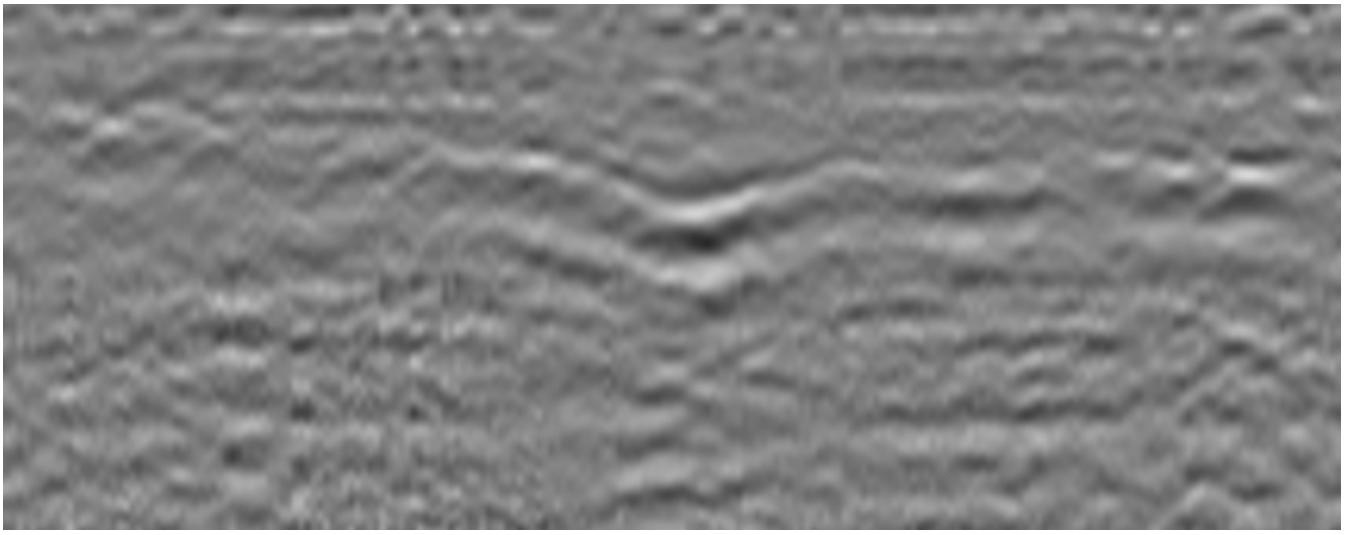
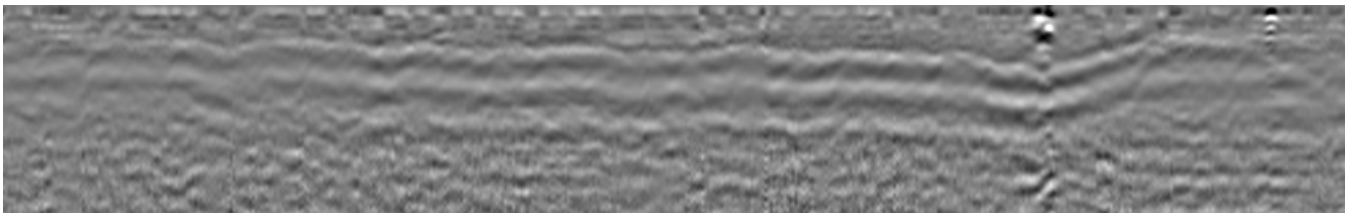


Photo Reference 8



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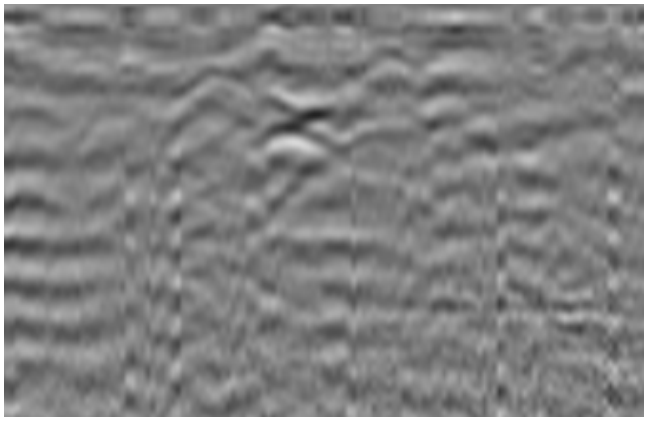

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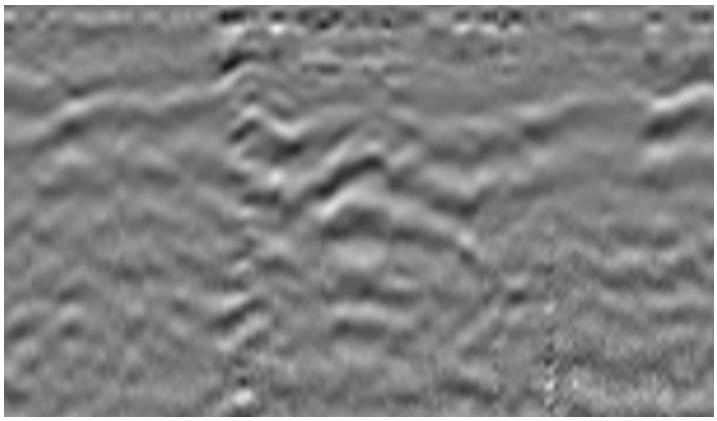

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CONCLUSION

The GPR recorded evidence of potential unmarked graves throughout the Union Church and Catholic Church sites . The total number of features flagged as potential graves came to 29, 18 within the Catholic Church and 11 at the Union Church site.
A reflection may be generated by an intact casket, by the disturbed soil which was used to back-fill the burial shaft, by the walls of the gravel shaft, or by a void space that exists where remains are no longer present, but a pocket of open space remains.

It is possible that a number of unmarked graves were not resolved by the GPR, which can occur for a number of reasons. Graves may be mistaken for, or obstructed by tree roots in GPR data, and degradation of older burials may result in failure to present identifiable responses. Furthermore, some of the graves indicated could be "false positives" caused by natural disturbances such as tree roots, root balls or void spaces from uprooted trees, and disturbances from burrowing animals. For these reasons, counts and distributions of burials should be seen as approximations, and conspicuous areas in which no burials were indicated in the investigation
may still contain buried individuals which were not resolved by the GPR. Extreme caution should be taken when disturbing soils within a historic cemetery for any reason, and Beveridge Williams strongly recommends having an archaeological monitor on site during any construction or alteration of soils.

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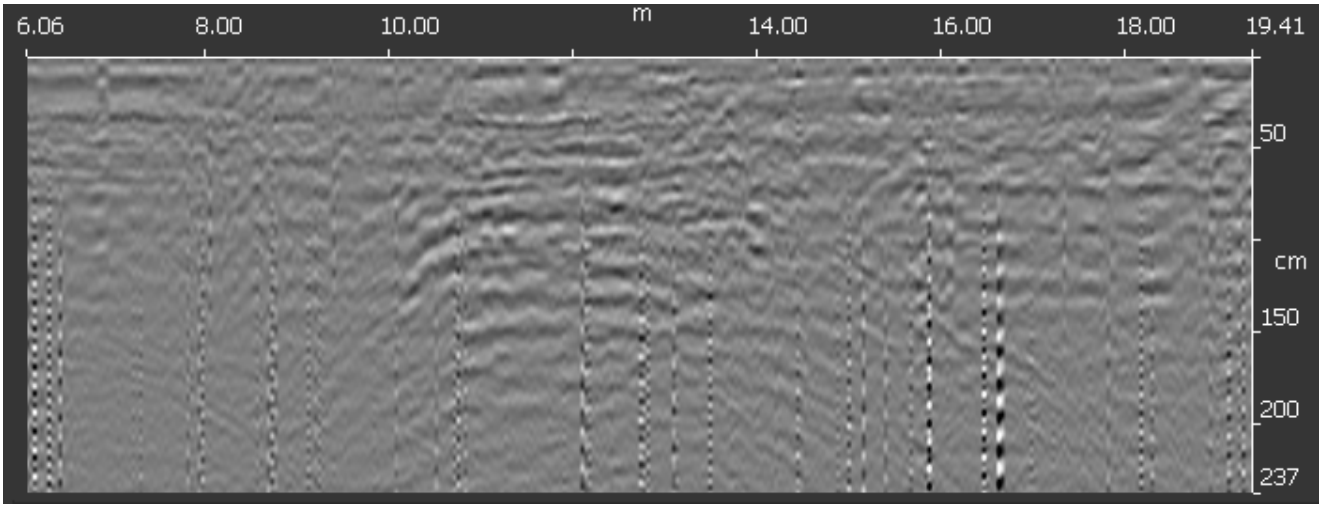
PIT REFERENCE	DATE	SURVEYOR/TECHNICIAN	PROJECT REFERENCE
2300879	14/02/2024	M.T.	Tallawang Grave Investigation

LOCATION
Spir Road Cottage



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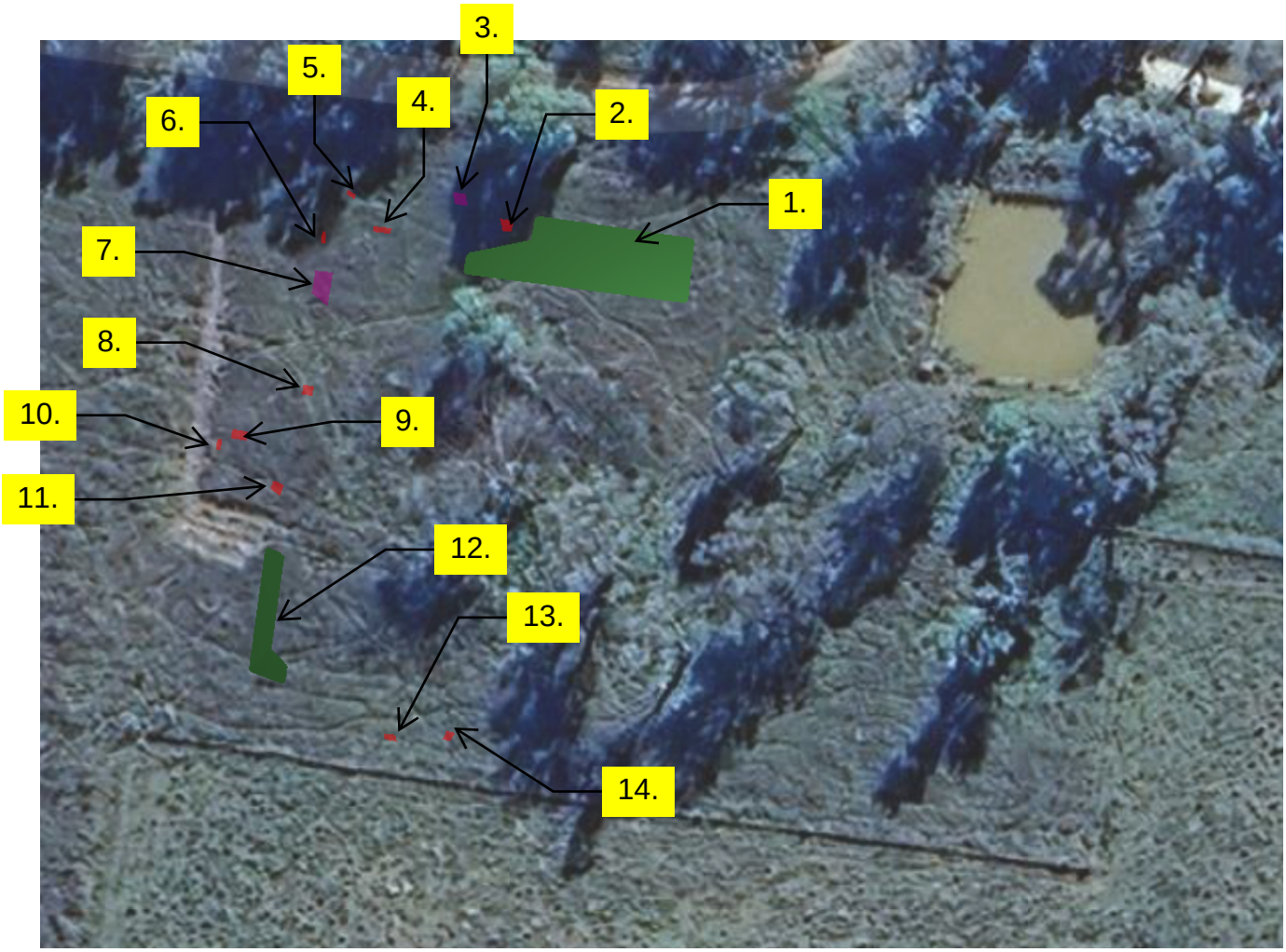
PIT REFERENCE	**DATE**	**SURVEYOR/TECHNICIAN**	**PROJECT REFERENCE**
2300879	14/02/2024	M.T.	Tallawang Grave Investigation
LOCATION			
Tallawang Catholic Church			



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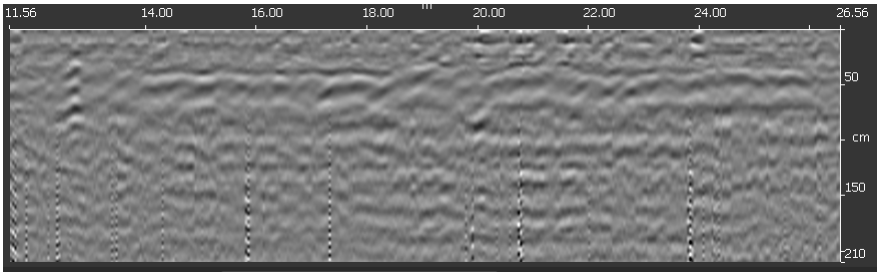

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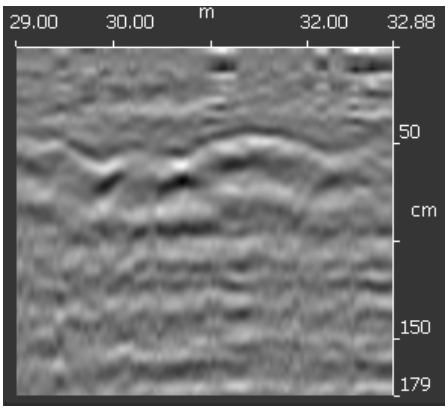

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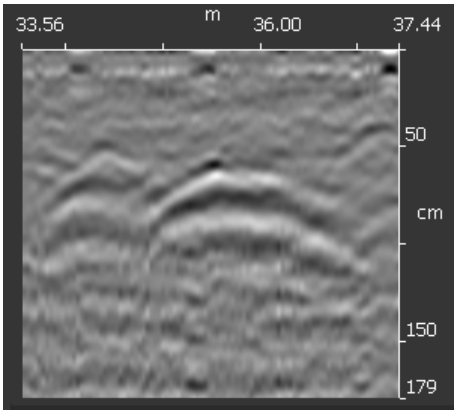

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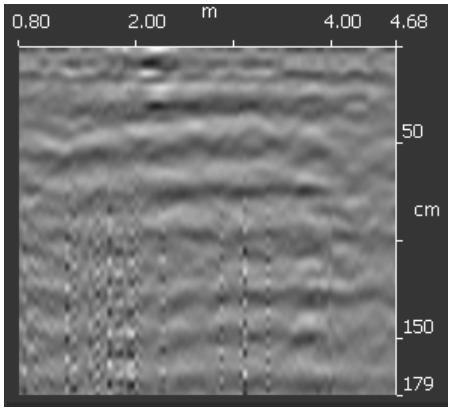

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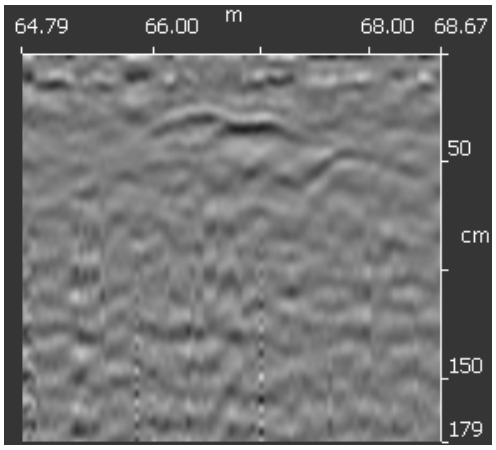
2300879	14/02/2024	M.T.	Tallawang Grave Investigation
LOCATION			
Tallawang Catholic Church			

Reference 5.



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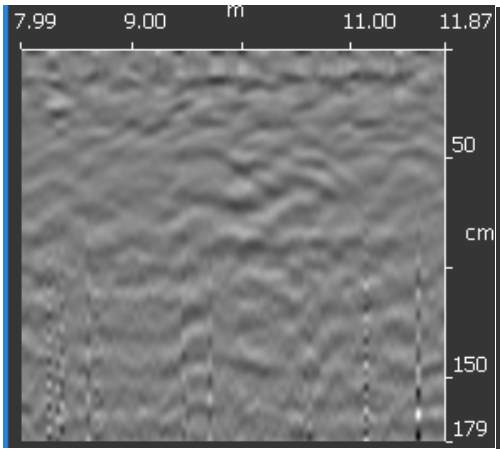

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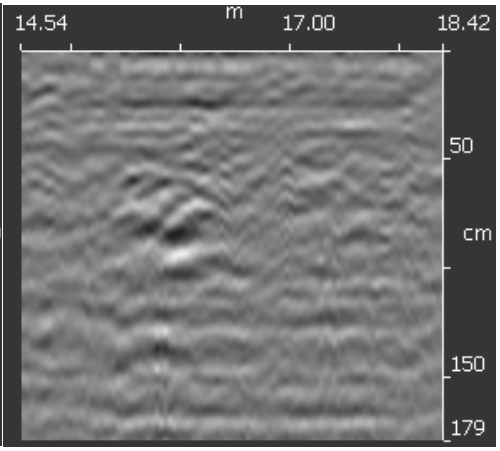

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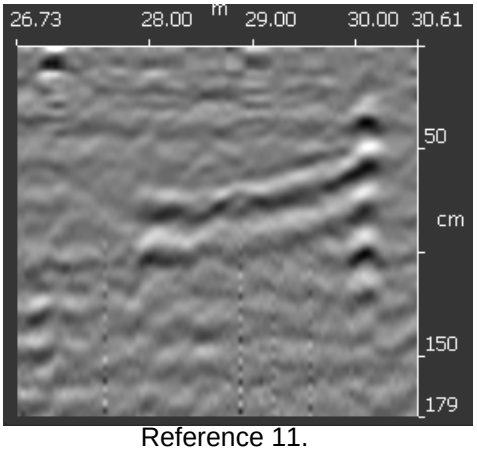

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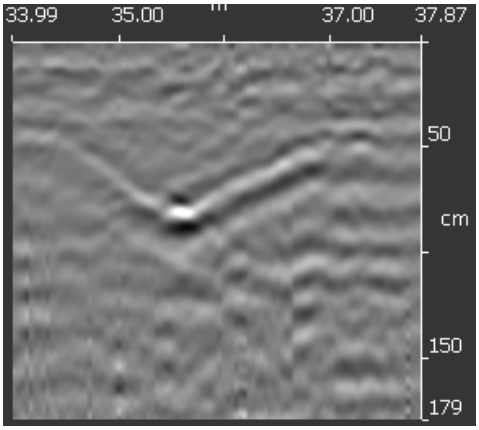

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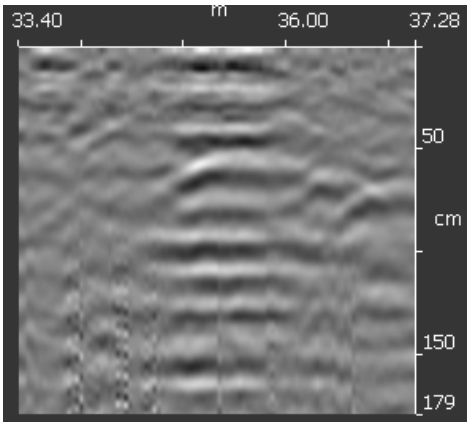

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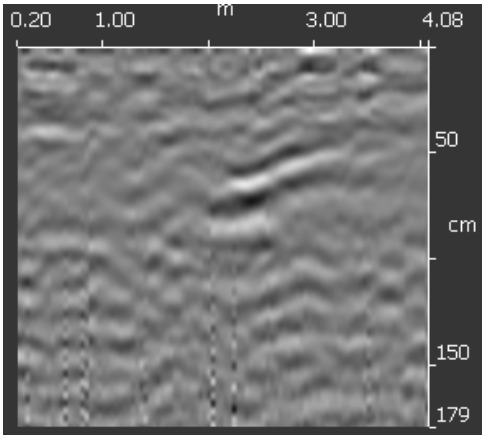

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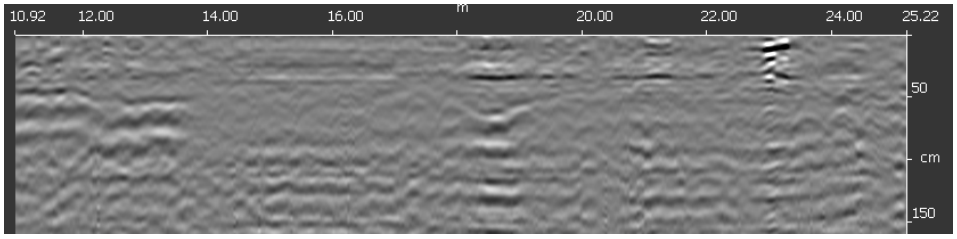

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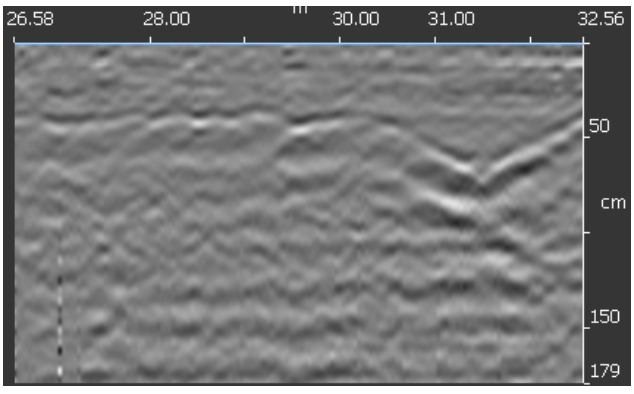

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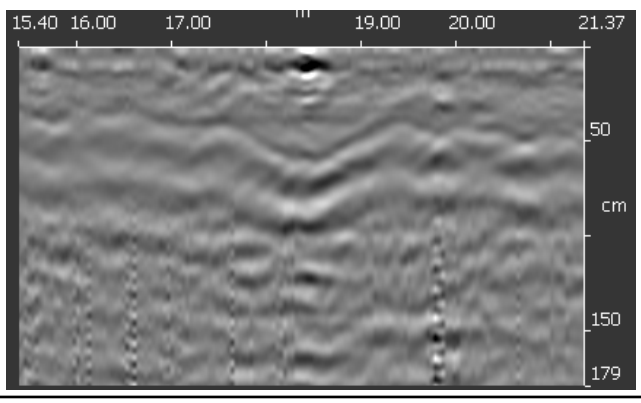

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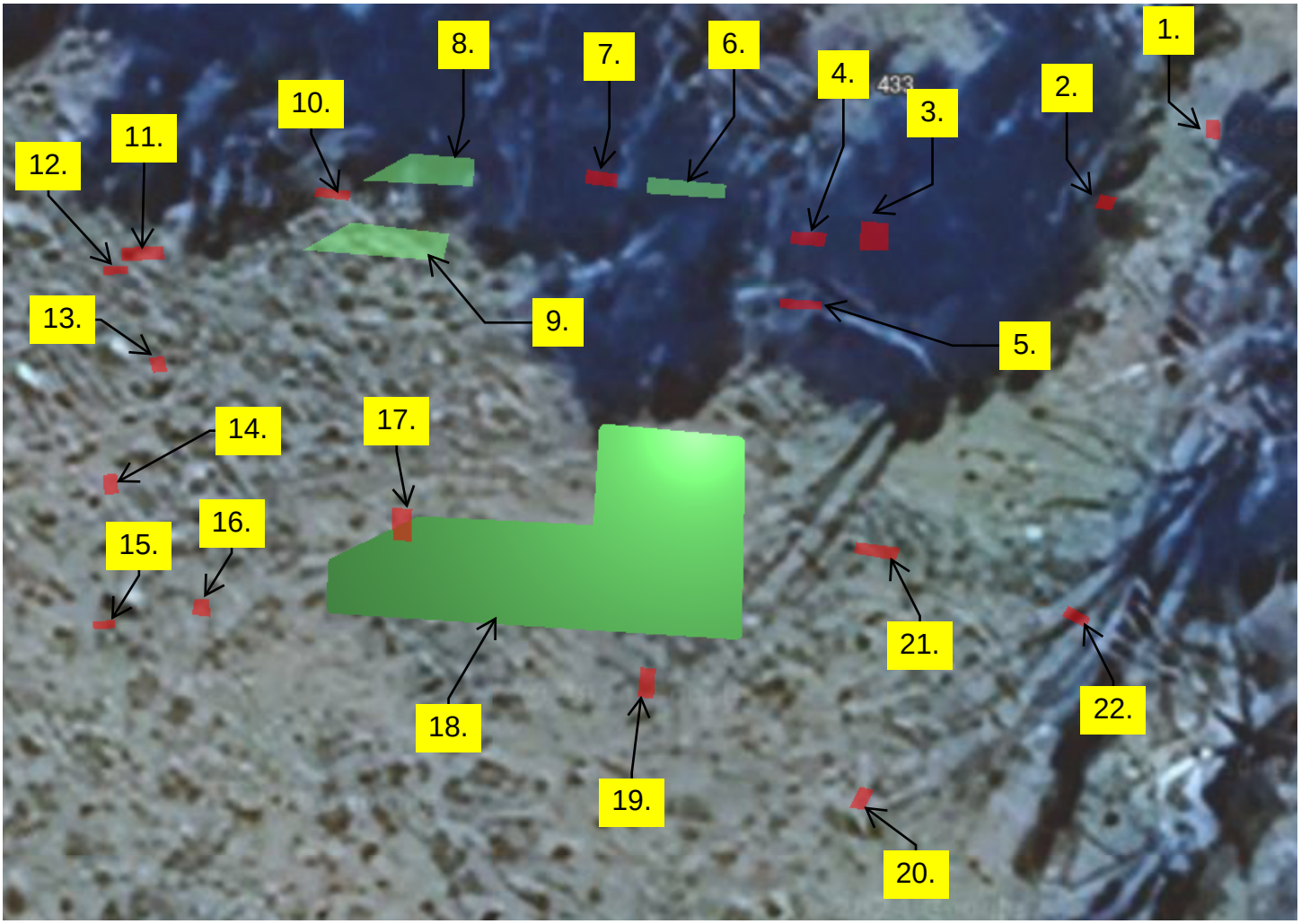
PIT REFERENCE	**DATE**	**SURVEYOR/TECHNICIAN**	**PROJECT REFERENCE**
2300879	14/02/2024	M.T.	Tallawang Grave Investigation
LOCATION			
Tallawang Union Church			



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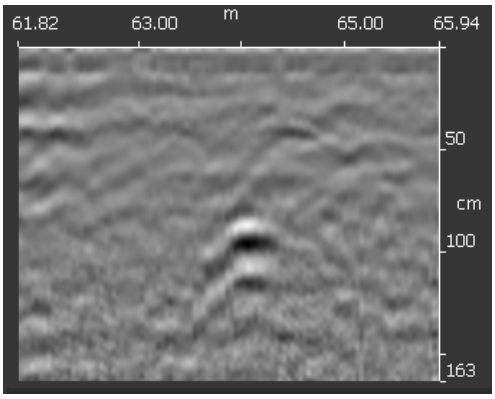

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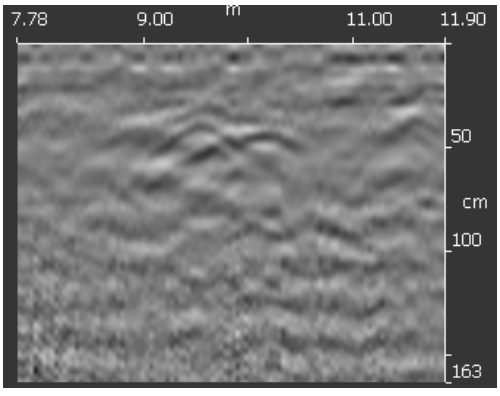

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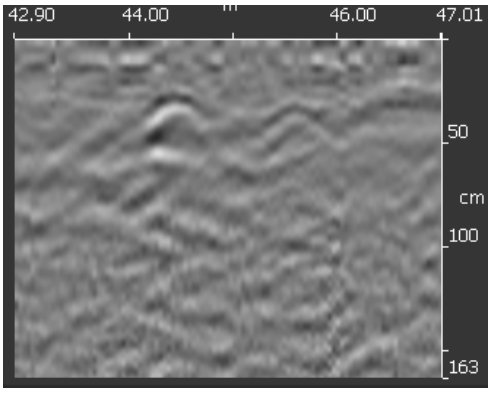

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LOCATION			
Tallawang Union Church			

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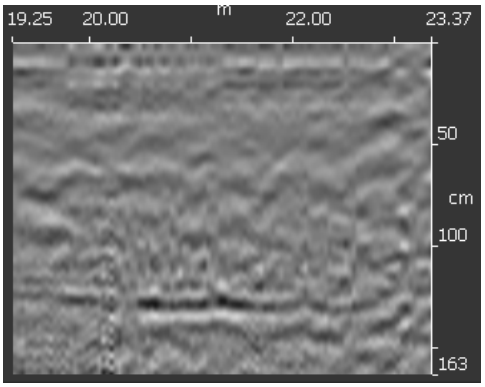

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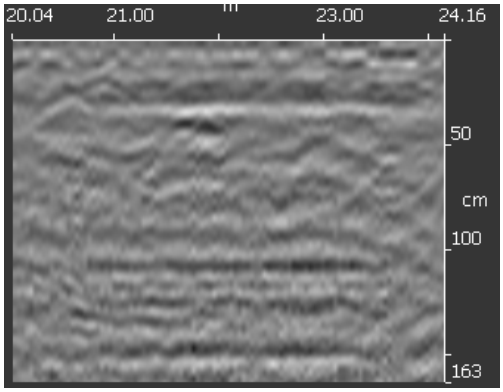

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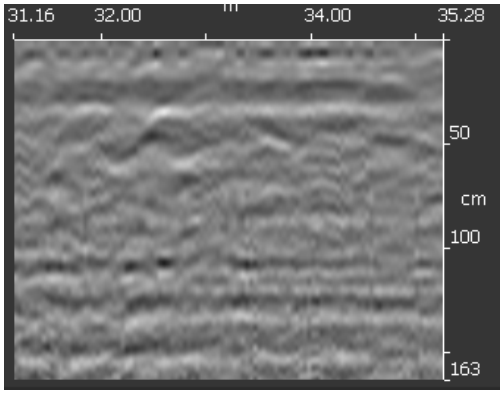

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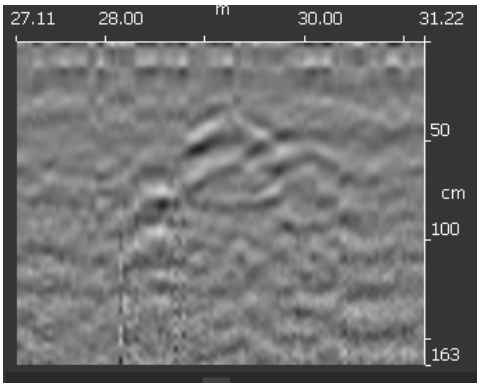

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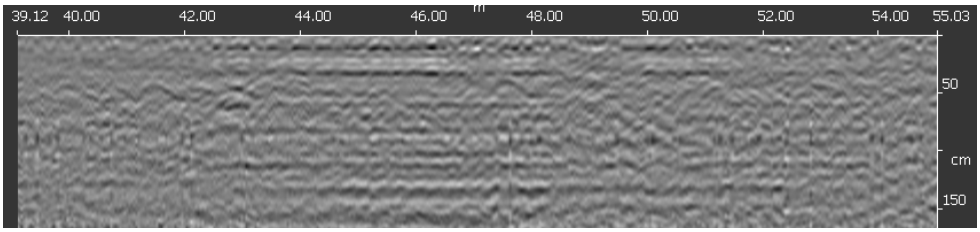

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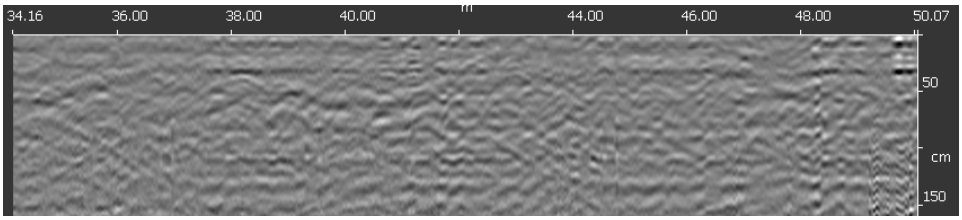

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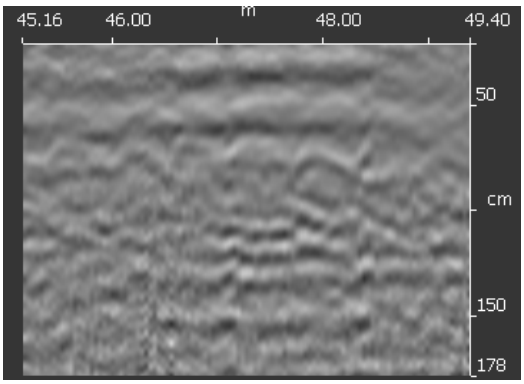

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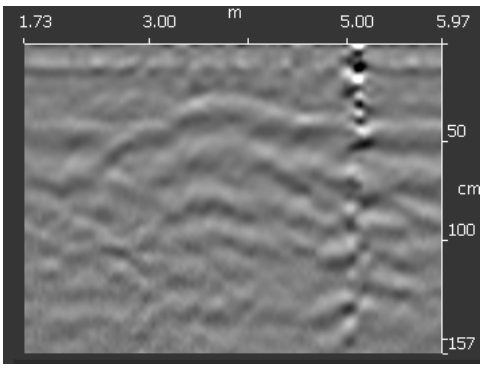

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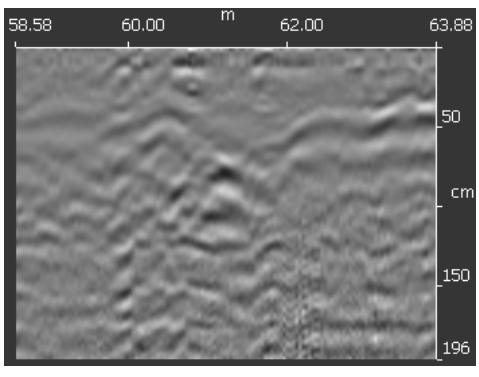

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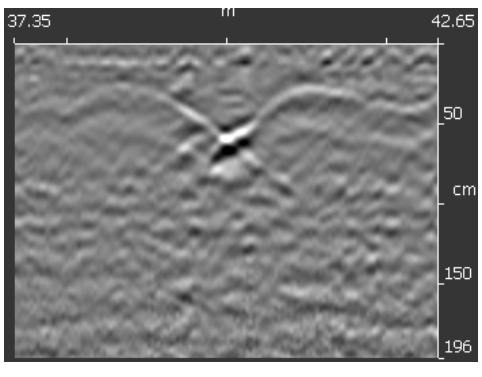

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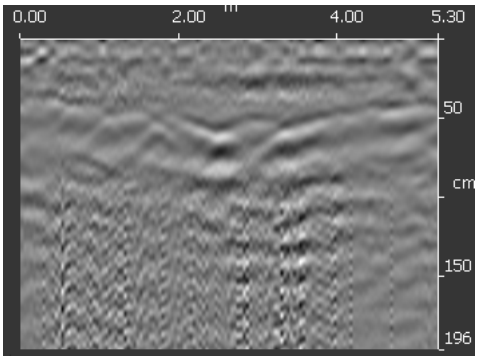
2300879	14/02/2024	M.T.	Tallawang Grave Investigation

LOCATION
Tallawang Union Church

Reference 14.



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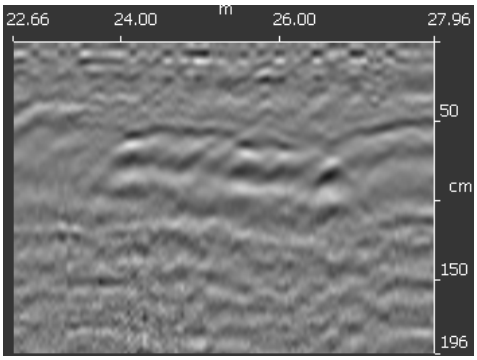

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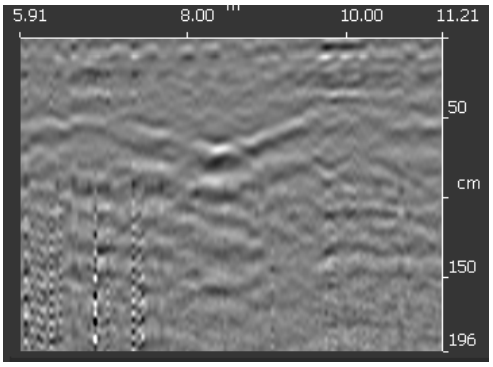

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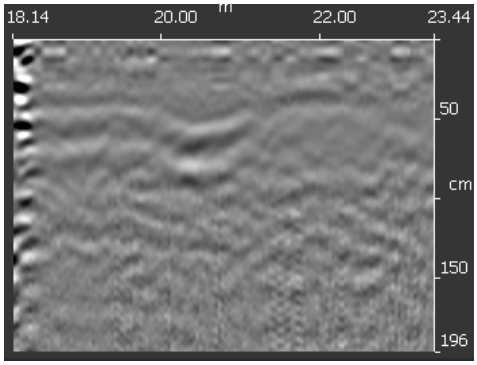

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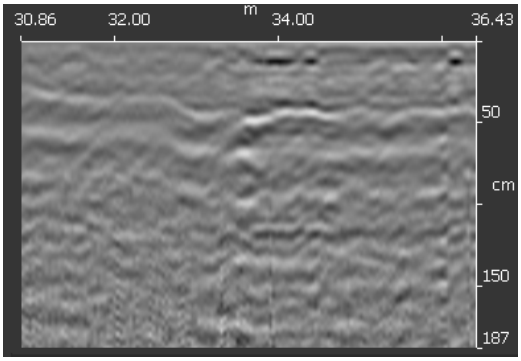

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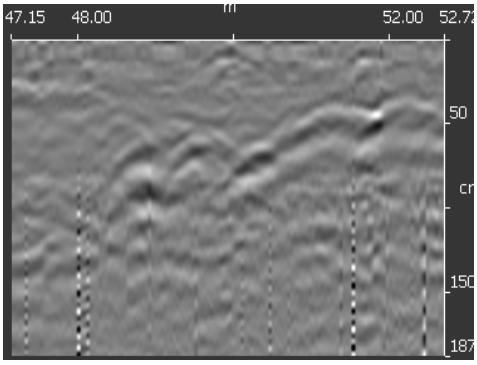

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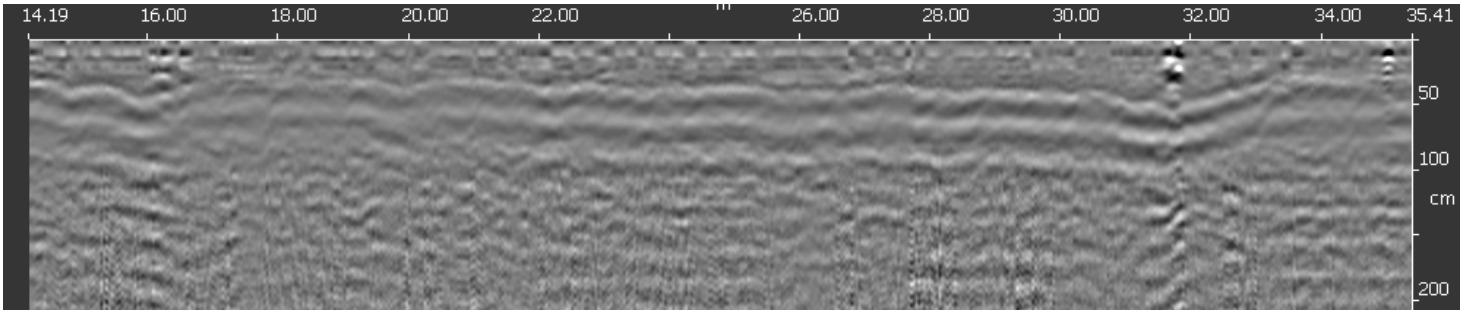

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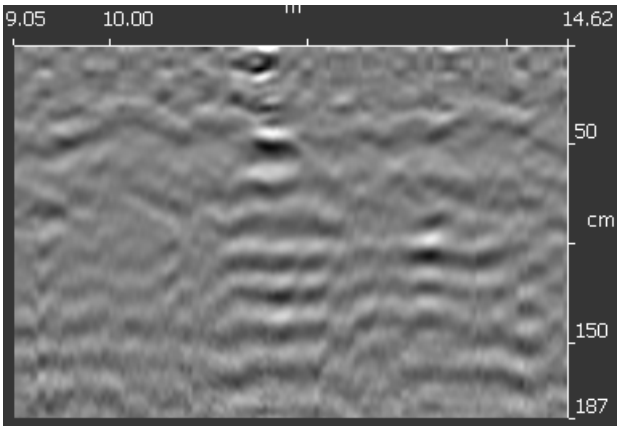

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