REPORT:

GROUND PENETRATING RADAR GEOPHYSICAL INVESTIGATION TO IDENTIFY POTENTIAL UNMARKED BURIALS ON WADJEMUP (ROTTNEST ISLAND), WESTERN AUSTRALIA.

Date: 22/10/2024

MNG Ref: 106616

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Document Information

Details

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ACKNOWLEDGMENT OF COUNTRY

McMullen Nolan Group (MNG) acknowledges the Traditional Owners and Custodians of the land on which these proposed works are situated—the Whadjuk Noongar People. MNG pays respects to their Elders, both past and present, as well as those emerging.

MNG understand the cultural sensitivity of Wadjemup (Rottnest Island), with its complex and dark history as an Aboriginal prison. The known Wadjemup Aboriginal Burial Ground is of exceptional significance to not only the Whadjuk Noongar People, but many more Aboriginal nations across what is now known as Western Australia. This burial ground is a unique place that serves as the final resting place of many Aboriginal leaders and highly respected individuals who were forcibly removed from their lands and imprisoned on Wadjemup.

Through these works, MNG is dedicated to taking a significant step towards recognition, reconciliation, and healing for Aboriginal people.

CONTENTS

1. INTRODUCTION

The Wadjemup Project, led by the Rottnest Island Authority (RIA) engaged MNG SubSpatial (MNG) to execute a comprehensive geophysical investigation across three (3) designated areas; 8 and 10 Bovell Way, 12 Bovell Way and 10 Boreham Way. These areas (yellow polygons) are illustrated on Figure 1 overleaf and are adjacent to the recognised extents of the Wadjemup Aboriginal Burial Ground, the areas marked in green were previously scanned by MNG using GPR to identify potential unmarked burials **(MNG Ref: 106233, August 2024)**. These areas were subject to demolition to remove on site buildings. The primary objectives of this investigation were to locate potential unmarked burials within the proposed areas. No burial-like anomalies were identified within the data collected for this report. A small number of identified features of interest were identified, however these have not been interpreted as burials.

The geophysical investigation utilised the state-of-the-art technology, specifically the 3D multi-channel Ground Penetrating Radar (GPR) system known as IDS GeoRadar Stream DP and the Leica Total Station to accurately relocate the acquired GPR data. This advanced GPR system demonstrates capabilities in accurately and efficiently detecting anomalies associated with unmarked burials.

The acquired GPR data yielded 2D radar-grams (cross-sections) and 3D depth slices of the subsurface, providing insights to a maximum uncalibrated depth of 6 meters below ground level (BGL). This report aims to present the findings of the survey and offer recommendations in the investigation summary.

2. SITE HISTORY

Wadjemup (Rottnest Island) was used as an Aboriginal prison between 1838 and 1903 (excluding a brief period of closure between 1849-1855) and a forced labour camp for both Aboriginal and non-Aboriginal prisoners until 1931. State records indicate that 4,000 Aboriginal men and boys from Australia were imprisoned on the island. At least 373 of these prisoners died in custody and were buried on Wadjemup.

The boundary for the Wadjemup Aboriginal Burial Ground has been mapped over multiple decades through collaboration between Aboriginal representatives, state government agencies and professional heritage practitioners (including anthropologists, historians, and scientists). The extents are based on evidence derived from historic records, GPR surveys and consultation with the Aboriginal community.

After the prison's closure, the island transformed into a holiday resort, including an area that became a budget camping ground (Tentland), which was built on the Wadjemup Aboriginal Burial Ground. After several occasions of human bones being exhumed, in 1985 the grounds gained official recognition under the Aboriginal Heritage Act.

The Quod building is perhaps the most recognisable symbol of the Island’s prison era history. The Quod was erected between 1863 and 1864 and served as the main prison building on the Island during the penal era. In 2007, Tentland closed, and in 2018, the Quod, closed its doors, marking a significant step toward recognition, reconciliation, and healing for Aboriginal people.

3. GEOPHYSICAL INVESTIGATION SITE

The extent of geophysical data capture across the three (3) investigation areas encompassing a total area of approximately ~1,344 m^2 are outlined below in Figure 1, greater detail of this is provided in *Drawings 106616-01 Site Plan* located in **Appendix A** of this report. The investigation was undertaken by a two-person team from MNG, comprising a Geophysicist and a qualified Surveyor.

Figure 1: The extent of the three investigations areas are outlined in yellow, with the previously scanned areas in green on Wadjemup (Rottnest Island), WA.

The geophysical investigation benefited from favourable ground conditions, with each area consisting of relatively flat surface topography, with ground cover consisting of either grass, mulch, or coastal sand. In all three areas surveyed, the surface was mostly cleared of any obstructions.

The natural ground conditions on Wadjemup (Rottnest Island) are mostly coastal sands overlying Tamala Limestone. However, the GPR data post demolition suggests that a fill was used in place of the footings of the buildings. This is most likely to be clay or crushed limestone rock, as the signal experienced a large amount of attenuation, resulting in a reduced penetration of data within the building footprints. Site photos of the typical site conditions are displayed in Figure 2.

Figure 2: Photographs illustrating the typical site conditions for the geophysical investigation.

4. GEOPHYSICAL METHOD

Ground Penetrating Radar (GPR) is a non-destructive and non-invasive geophysical technique for rapidly imaging the shallow subsurface and producing high-resolution colour sections in real time. The method works by transmitting electromagnetic energy into the material being tested, most usually the ground.

The transmitted electromagnetic energy propagates through the subsurface as a function of the subsurface material's electrical properties, which are in turn dependent on its physical and chemical properties. Reflection of radar energy occurs at boundaries between differing stratigraphic layers or inclusions which have contrasting electrical properties. Conversely, no reflections occur from a homogenous material where there are no internal reflectors. The reflections are detected by the receiving antenna placed adjacent to the transmitter. The depth to the target is proportional to the time (in nanoseconds) taken for the signal to travel from the transmitting antenna at the surface to the target and back to the receiver – Figure 3.

The achievable depth of penetration depends on the frequency of the antenna used and is also influenced by the local subsurface conditions. GPR is generally effective in clean sands, which provide an optimal medium for radar waves to propagate through, enabling successful subsurface imaging and analysis.

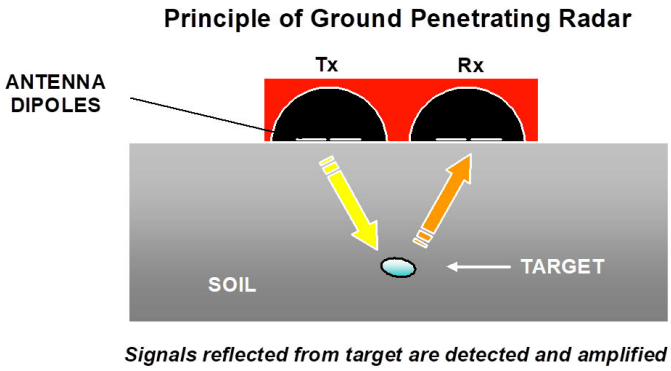


Figure 3: Schematic illustration of the principle behind ground penetrating radar.

Limitations: The quality of the acquired data may be compromised over certain surfaces which are directly related to the GPR method. These limitations are inherent to the geophysics of the technique and are listed below:

- Reduction of penetration is experienced in areas with high clay and/or water content. This is with reference to the dielectric properties of the materials which may result in a significantly higher absorption of radar wave energy.
- Soil with pools of water, soil after heavy rain, high salinity soil, and high mineral containing soil with iron ore.
- A requirement for good coupling between the antenna and the ground. GPR data cannot be collected where surface obstructions are present, including but not limited to infrastructure and vegetation.
- GPR collected over reinforced concrete slabs, or some paving materials may adversely affect the data, and hence the reliability of the information obtained may be compromised in such situations.

5. GEOPHYSICAL DATA ACQUISITION

5.1 INVESTIGATION LOGISTICS

The 8 and 10 Bovell Way and the 10 Boreham Way – 12 Bovell Way investigations were conducted on the 30th September and the 14th of October 2024, respectively. During the investigation 220 GPR swathes were acquired across all three areas, each swathe comprises of 19 channels in-line with direction of movement (VV), which totals 4,180 individual GPR radar-grams (cross-sections). 58 swathes were re-scanned over the areas where the GPR signal was attenuated.

5.2 GROUND PENETRATING RADAR – STREAMDP

GPR data was acquired using an IDS GeoRadar Stream DP system, employing a ground-coupled antenna with a centre frequency of 600MHz. Table 1 provides the acquisition parameters.

The GPR data acquisition involved manually pushing the unit at a deliberate and consistent pace along parallel profiles spaced at 0.5m intervals. Distances along these profiles was logged using a calibrated distance measuring device (odometer wheel) attached to the system.

Relocation referencing of the GPR data was achieved through a Global Positioning System (GPS) with live coordinates fed to the GPR control unit, ensuring accurate relocation along each GPR profile.

The StreamDP possess a multichannel 3D antenna with 30 channels in double polarization (19 channels in the vertical plane and 11 channels in the horizontal plane). The system essentially “paints” the floor in a swathe sense acquiring data both inline and orthogonal to the direction of movement.

The StreamDP also features Equalized scrambled Technology - EsT a new Patented Technology by IDS GeoRadar, that overturns the traditional definition of GPR. EsT brings out the deepest signal at the same level as shallow targets through noise rejection, both the clarity of shallow targets and high penetration depth are achieved. After equalization, the data is 'scrambled' together into a single radar trace, providing an extended depth range and an ultra-high resolution.

The StreamDP was released in July 2022 and represents the pinnacle of GPR technology in the industry at this current time.

Figure 4: StreamDP GPR data acquisition using the StreamDP on 30/09/2024.

Table 1 – Stream DP GPR Acquisition Parameters

Acquisition Parameter	Specification
Antenna centre frequency	600MHz
Sampling step	0.0397m
Sampling time	0.125ns
Polarization	Vertical and Horizontal
Uncalibrated radar wave velocity	0.1m/ns
Maximum apparent depth	6m

5.4 LOCATING AND POSITIONING

The StreamDP GPR system relies on an external GPS device, the Leica Zeno FLX100 Smart Antenna with SmartNet RTK technology was used for precise positioning. This GPS device is paired with a Wi-Fi-enabled tablet for data acquisition. The integration of Pulse-per-second (PPS) into the antenna ensures accurate synchronisation with the external GPS, facilitating precise positioning.

In areas with substantial tree canopy or near buildings, where the StreamDP's external GPS was hindered, a Total Station with multiple base station setups was employed to maintain enhanced accuracy in relocating the GPR data, with projected accuracies of:

- ±100mm Horizontally Accuracy, and
- ±200mm Vertically Accuracy

The requested datums from RIA used for this project are:

a) Horizontal: Perth Costal Grid 2020 (PCG 2020)
b) Vertical: Australian Height Datum (AHD)

6. GEOPHYSICAL DATA PROCESSING

The acquired geophysical datasets were processed and analysed with current industry standard software by qualified geophysicists using MNG standard processing routines.

6.1 GROUND PENETRATING RADAR - STREAMDP

The acquired GPR data was processed and interpretated using two industry standard software, Geolitix and IQMaps (IDS Software). Geolitix is a cloud computing GPR processing software and IQMaps seamlessly integrates StreamDP data, where both were utilised for this project. Each software provides post-processing application data analysis and allows 3D immersive visualisation. The following processing routine was used:

1. Correct Max Phase – Set GPR zero time to the first crossing of the reflection wavelet.
2. Manual Gain – Apply a gain curve function in the y-direction to account for GPR signal attenuation with depth.
3. 1D Bandpass Filtering – High-cut and low-cut frequency filter to improve signal to noise ratio.
4. Dewow – Removes low frequency ‘wow’ effects caused by inherent antenna characteristics.

5. 2D Filtering – Background removal and running average filters to suppress horizontally coherent energy, effectively emphasising signals which vary laterally.

The following steps were then applied to enable the generation of 3D time slices.

1. Kirchoff Migration – Sums the amplitude of a hyperbola into a focused point at its apex, removing the tails
2. Hilbert Transform – Calculate the overall reflectivity strength for each trace by using adding a phase shift and eliminating negative frequency components.
3. Time Slicing – Amplitude is calculated for each trace in each swath at a specific travel time and then gridded to generate a map image of radar reflectivity, this is repeated for all travel times in a specified range.

Following the application of the above processing flow, the GPR data was predominately observed to be of high quality, with strong signal to noise ratio and expected penetration depth for the antenna frequency used. The processed GPR data was analysed to delineate interpreted subsurface features including high amplitude features. Analysis of the GPR data consisted of viewing and digitising the profiles sequentially with consideration to the:

- **Signal travel time** which, combined with the material radar-wave velocity, defines the depth of the target [1]
- **Amplitude and phase of the signal** which defines the dielectric contrast between different materials [2]
- **Continuity of the signal** which shows the general dimension, condition, and shape of the target

[1] With the GPR method, the depth to a given subsurface target is obtained by measuring the two-way travel time of the radar pulse from the antenna to that target and by multiplying this time by the radar wave velocity within the overlying layers. For this investigation, a bulk radar wave velocity of 0.1m/ns was used.

[2] The amplitude of the radar wave reflection signal is a function of the contrast in dielectric properties of the subsurface material. Near zero amplitude reflections occur where there is no or minimal change in the dielectric properties indicative of a homogeneous material. High amplitude reflections (either positive or negative) occur where there is a significant change in dielectric properties for example within an inhomogeneous material with multiple inclusions such as buried utilities or the interface between differing geological layers.

7. RESULTS

The results of the geophysical investigation carried out across three (3) investigation areas on Wadjemup (Rottnest Island), Western Australia are provided in both digital and PDF format.

7.1 DRAWINGS

PDF drawings of the results are provided in the following Appendices of this report:

APPENDIX A – GEOPHYSICAL INVESTIGATION SITE PLAN

- ***106616-02 SITE PLAN GPR DATA ACQUISITION 01***: Site overview of GPR data acquisition of portions 8 and 10 Bovell Way, 12 Bovell Way and 10 Boreham Way investigation areas.

- ***106616-02 SITE PLAN GPR DATA ACQUISITION 02***: Site overview of GPR data acquisition of portions 8 and 10 Bovell Way, 12 Bovell Way and 10 Boreham Way investigation areas, included with data previously acquired in previous reports (MNG Ref: 106233, August 2024).

APPENDIX B – GROUND PENETRATING RADAR IDENTIFIED FEATURES OF INTEREST

- ***106616-04 IDENTIFIED GPR FEATURES OF INTEREST:*** Identified features of interest across 8 and 10 Bovell Way, 12 Bovell Way and 10 Boreham Way investigation areas, these anomalies are not interpreted as burials.

7.2 DIGITAL DATA

All features of interest identified were exported to AutoCAD (Autodesk) and generated as an AutoCAD DWG file, titled:

- *106616-001_Identified GPR Features of Interest*

8. GROUND PENETRATING RADAR INTERPRETATION

Interpreting GPR data involves the analysis of radar signals reflecting from subsurface features to deduce details about the subsurface composition and geometry. The expertise of a qualified Geophysicist with a background in GPR investigations is crucial for accurate interpretation.

8.1 POTENTIAL UNMARKED BURIALS

When interpreting GPR data (radar-grams) for unmarked burials the following parameters need to be considered:

1. Vertical Discontinuities in Soil/Strata Profile: More pronounced for new burials, less evident in older burials.
2. Depressions in Soil Layers Above the Grave.
3. Mottled GPR Signal Above the Grave: Result of the unconsolidated nature of the fill material.
4. Typical Depth Extent: 1.5 to 3.0 meters below ground level.
5. Consistent Amplitude and Phase Across Multiple Parallel Profiles with a clear start and end.

These considerations are crucial when employing GPR for the identification of unmarked burials. Understanding these parameters enhances the accuracy of the analysis and increases the reliability of the results. **No features were identified in this report that met all the criteria to be considered a burial-like anomaly.**

However, there were several features that met some of the above criteria that have been presented as features of interest, MNG Subspatial does not believe these represent likely burial sites. GPR profiles in these areas have been consistent with irregular shallow limestone rock, it is likely that these features are due to boulders of limestone, or naturally occurring fractures of limestone rock. Additionally, activities related to the construction and demolition of buildings on this site are likely to have left remnant debris and disturbances in the ground which would be seen on radargrams.

A list of data examples has been provided between Figures 5 to 8, to illustrate some of the identified features of interest interpreted across the 8 and 10 Bovell Way, 12 Bovell Way and 10 Boreham Way investigation areas.

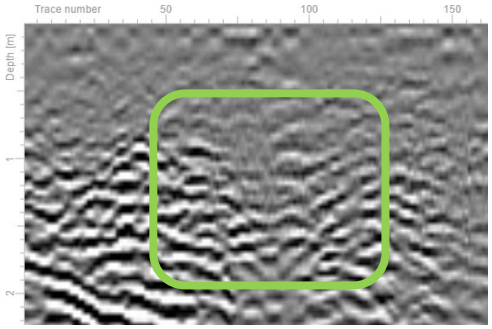


Figure 5: Identified feature of interest, this has been interpreted to be a natural depression within surrounding limestone rock.

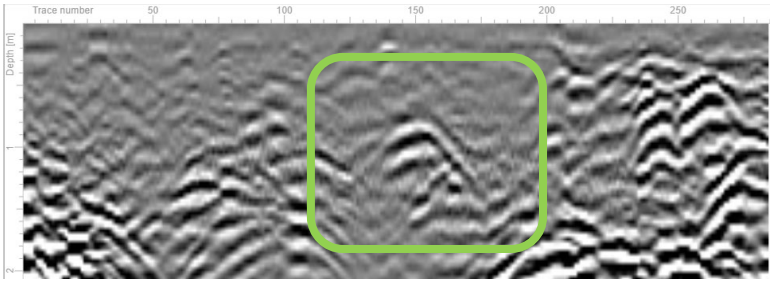


Figure 6: Identified feature of interest, this has been interpreted to be a naturally occurring limestone boulder, noting evidence of shallow limestone either side of this feature

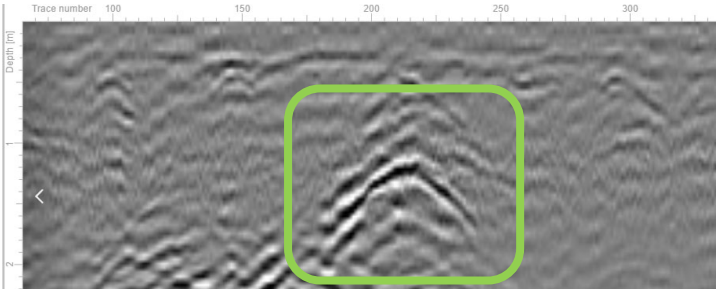


Figure 7: Identified feature of interest, the intensity of this feature is most consistent with remnant debris from building and demolition activities at this site.

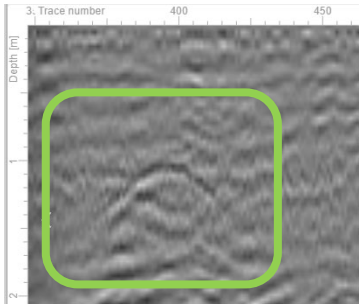


Figure 8: Identified feature of interest, this feature has a low amplitude and was only observed over a limited number of radar profiles.

9. INVESTIGATION SUMMARY

As part of the Wadjemup Project led by the Rottnest Island Authority (RIA), MNG SubSpatial (MNG) conducted a comprehensive geophysical investigation across three (3) designated areas adjacent to the known Wadjemup Aboriginal Burial Ground (WABG). These areas previously contained buildings that have recently been demolished. The investigation employed advanced 3D multi-channel Ground Penetrating Radar (GPR). The purpose of the geophysical investigation was to identify any potential unmarked burials within the specified areas. This report should be read in addition to the report and results from previous work on the WABG (MNG ref: 106233).

During the geophysical investigation conducted on 30th September and 14th of October 2024, a total of 280 GPR swathes were acquired across the three areas. This resulted in 8,400 individual GPR profiles or transects (cross-sections) of the subsurface, reaching a maximum uncalibrated depth of 6 meters below ground level (BGL).

Throughout the investigation, no features were identified that were considered to be consistent with burial-like anomalies. However a number of features of interest were identified, that met some, but not all the criteria to be considered a burial-like anomaly.

The results of the investigation have been supplied in both digital and PDF drawings, which should be used in conjunction with this report. A digital AutoCAD DWG file and drawings provided in the appendices of this report:

- *106616-003B_Identified Features of Interest_RIA*

The methods used during the investigation are geophysical and as such the results are based on indirect measurements and the processing and interpretation of electrical signals. The findings in this report represent the professional opinions of the authors, based on experience gained during previous similar surveys and with correlation to known and assumed subsurface ground conditions at the site.

We trust that this report and the attached drawings provide you with the information required. If you require clarification on any points arising from this geophysical investigation, please do not hesitate to contact the undersigned on (03) 7002 2207.

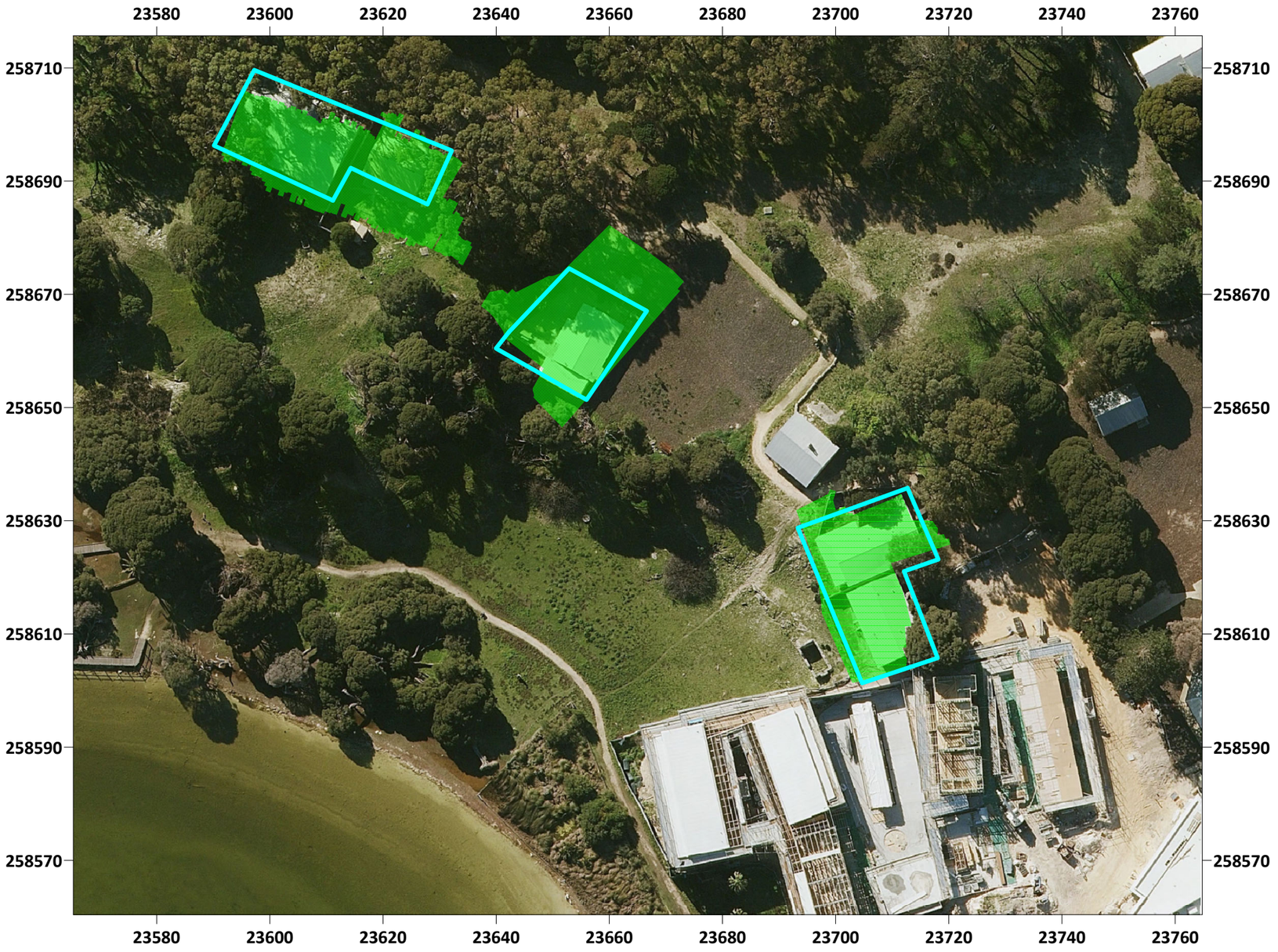
For and on behalf of
MNG SubSpatial

TAVIS LAVELL
Manager, MNG SubSpatial / Senior Geophysicist

APPENDIX A – GROUND PENETRATING RADAR SITE PLAN

GEOPHYSICAL INVESTIGATION - WADJEMUP

SITE PLAN



LEGEND:

Extent of GPR Transects
(Acquired in Sep-Oct 2024, by MNG)

RIA Survey Extent
(Sep-Oct 2024)

The contents of this drawing are current and correct as of the date stated within the revision panel. All consultants and persons wishing to utilise this data should ensure this is the most up to date version, by contacting McMullen Nolan Group.

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A	Initial Issue	JDG	01/10/24	NWH

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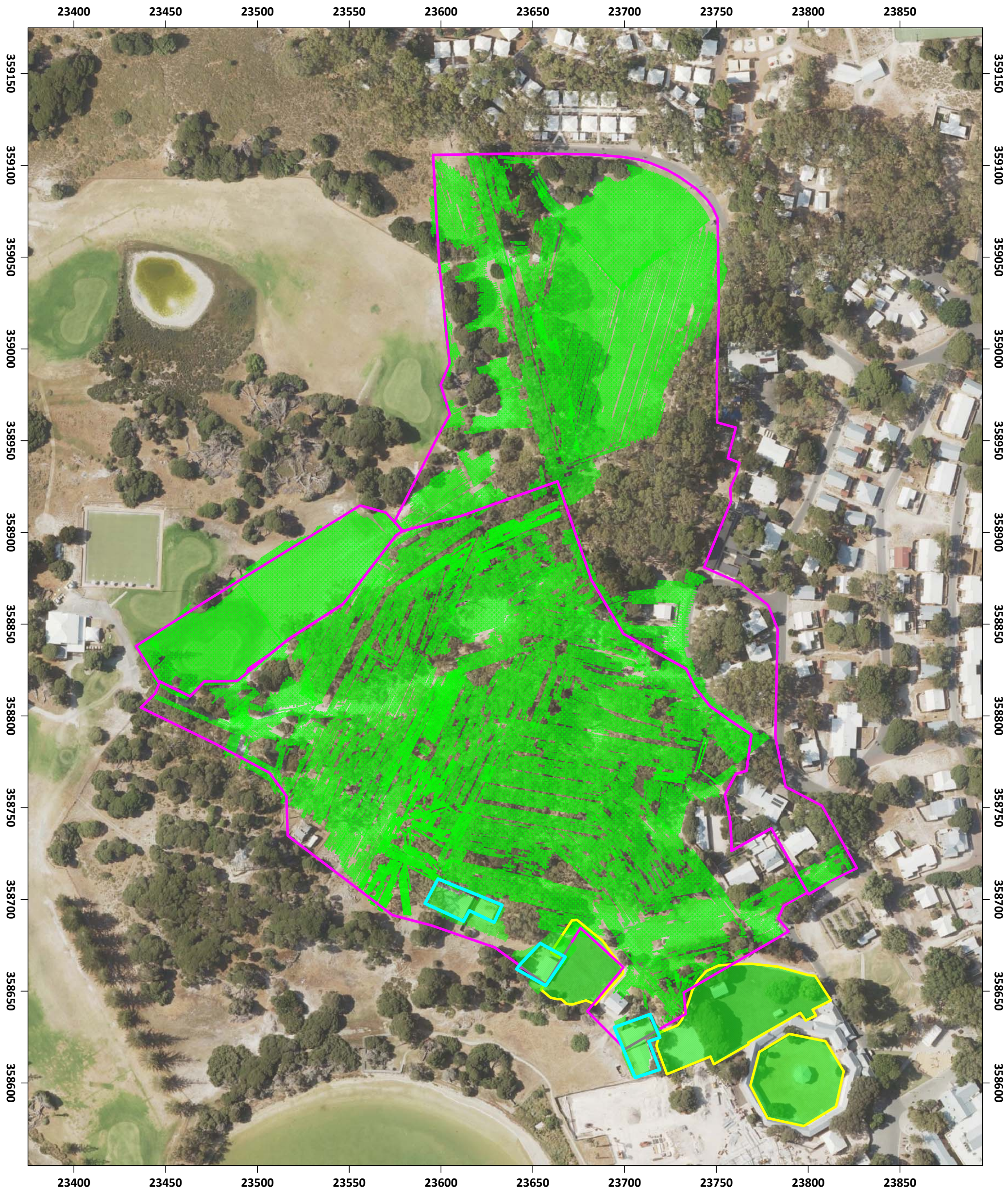
Client: ROTTNEST ISLAND AUTHORITY

Proj. Mngr.	TLA	Datum	MGA2020 / AHD

Drawing: 106616-01

GEOPHYSICAL INVESTIGATION - WADJEMUP

OVERALL SITE PLAN - GPR DATA ACQUISITION



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LEGEND:

- **GPR Data Coverage** (Acquired by MNG, Jan 2023, Mar-July 2024 and Sep-Oct 2024)
- **RIA Survey Extent** (Mar-July 2024)
- **RIA Survey Extent** (Sep-Oct 2024)
- **RIA Survey Extent** (Jan 2024)

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Client: ROTTNEST ISLAND AUTHORITY

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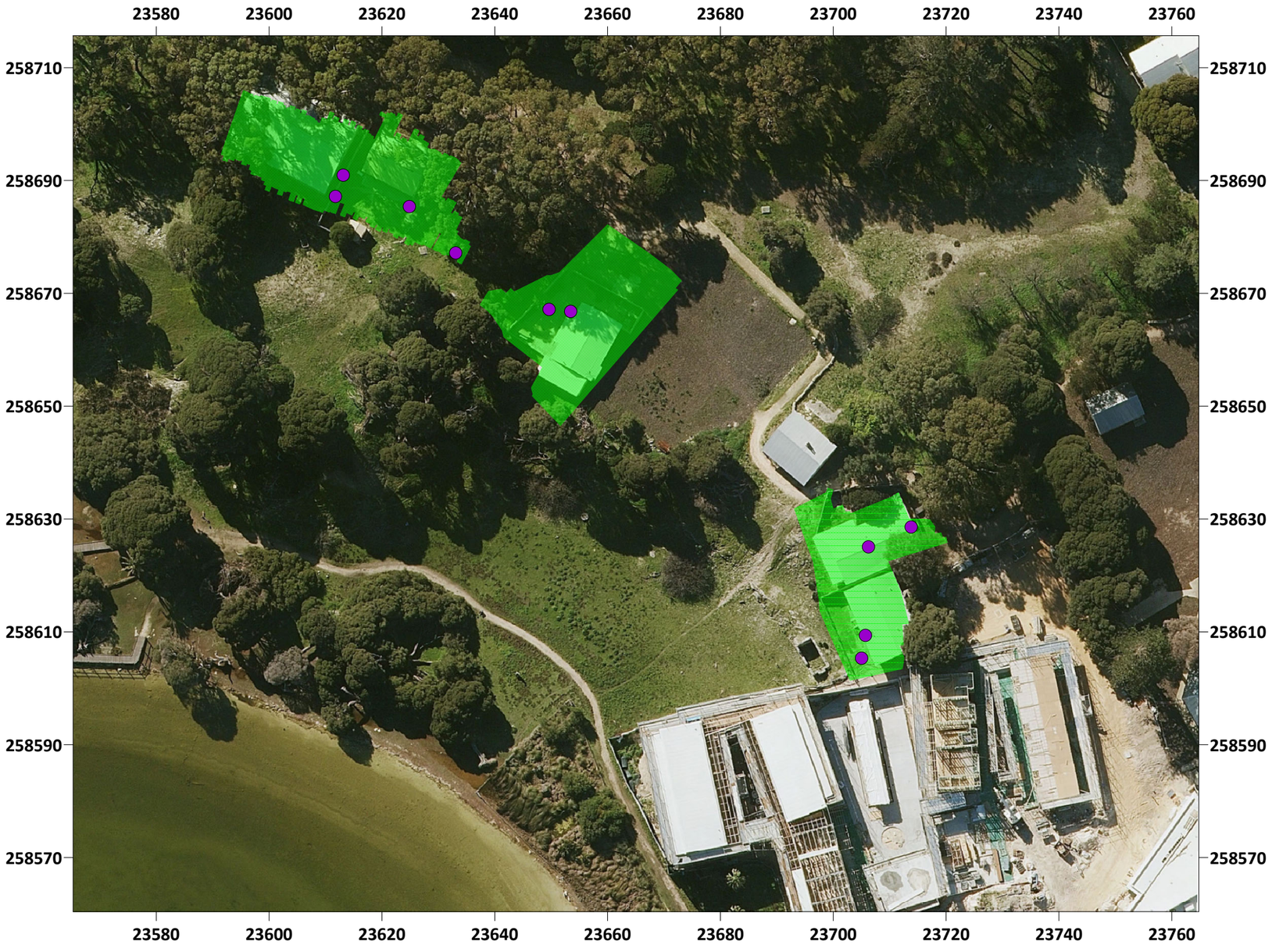
Drawing: 106616-02

APPENDIX B – GROUND PENETRATING RADAR FEATURES OF INTEREST

GEOPHYSICAL INVESTIGATION - WADJEMUP

IDENTIFIED FEATURES OF INTEREST



LEGEND:

Extent of GPR Transects
(Acquired in Sep-Oct 2024, by MNG)

Identified Features of Interest
(Not Considered to be Unmarked Burials)
(2.2m in diameter)

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A	Initial Issue	JDG	22/10/24	NWH

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