2025

GSWA WA Array Phase 2
Long Period MT Survey Report

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1 Summary

M-Geo Pty Ltd TA Moombarriga Geoscience (Moombarriga) were contracted by Department of Mines, Industry Regulation and Safety (DMIRS) (Client) acquire and process long period (10 - 10,000 s) magnetotelluric (MT) data at 78 locations between Kalgoorlie, Laverton and Geraldton, Western Australia. The WA Array project aims to provide electrical conductivity models of the lithopshere for the whole of Western Australia. These models will provide new and novel information about the geological evolution of Australia, with important implications for natural resource exploration and development, in particular, mineral exploration.

Moombarriga acquired soundings from sites within the Phase 2 polygon over a period of six months. Site locations were moved to the most accessible and appropriate locations within a defined buffer for each site (100m or 4km). Eleven (11) sites were deployed via helicopter. There are sites within Phase 2 that are yet to be recorded, or require re-recording, detailed in Table 1. Final site locations, and the overall project location is shown in Figure 1. Specific site location files can be found in Appendix I. MT impedance tensor (Z) and tipper (Tz) are resolved for the period range 10s – 50,000s.

Table 1: Phase 2 sites outstanding

Site ID	Status
MBI21 MBJ21 MBL08 MBN08 MBN09 MBP19 MBP26 MBK22	The Data quality from the sounding is not suitable, and the site has been flagged to be repeated. When deployed and complete, the details and data will be included in an addendum to this report.
MBK05 MBK10 MBJ11 MBJ05 MBJ06 MBL19 MBL26 MBM16 MBM25 MBO26	These sites have not been deployed to date. When deployed and complete, the details and data will be included in an addendum to this report.

2 Safety

Moombarriga is fully committed to maintaining a safe work environment for all employees and persons involved or affected by its day-to-day activities. All new and casual employees are given an on-boarding general induction, onsite inductions and training for vehicles and equipment they use in their roles. Senior and experienced staff provide on the job training, supervision, and instruction to mentor employees. Working in rural and remote areas poses several safety challenges which can increase risk or complicate team coordination and response to emergencies. Key challenges are communication; driving; environmental conditions and exposure; and flora and fauna.

Reliable communications are essential in maintaining a safe working environment during regional and remote surveys. To ensure communication is maintained throughout the survey Moombarriga uses several independent systems to provide multiple levels of communication redundancy. InReach devices provide near real-time location information for the field crews, which can be remotely monitored by Moombarriga staff and the client. InReach systems provide a means of sending text messages between devices that does not rely on cellular networks and is generally much more reliable than satellite phone systems.

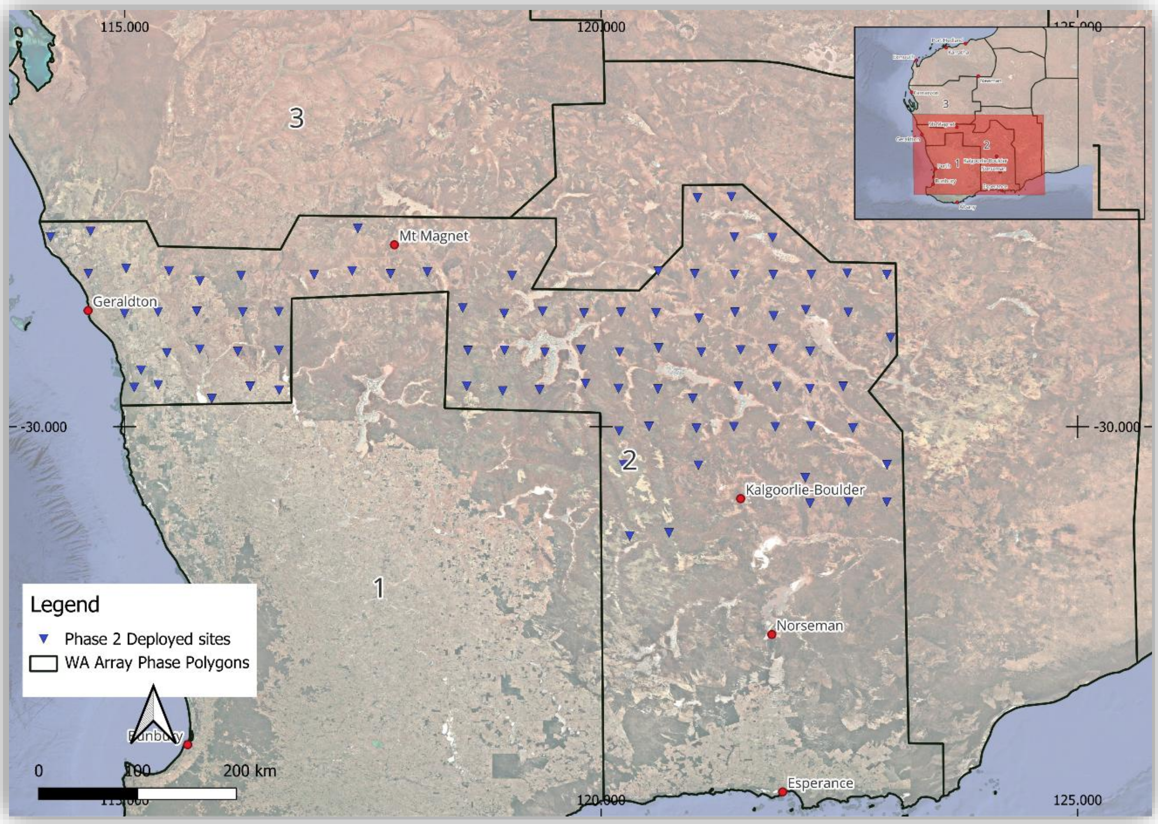

Figure 1: Location of AusLAMP Phase 2 2024-2025 - Final LPMT locations.

InReaches also provide alert and SOS PLB (Personal Locator Beacon) capabilities in case of emergencies. All vehicles are equipped with UHF radios and satellite phones, ensuring field crews can communicate with each other and with the Moombarriga office. Field crews make a scheduled call back to the Moombarriga office on return to base camp at the end of each day to confirm all staff are back to camp safely.

Driving is the highest risk task undertaken by Moombarriga field teams. Remoteness, navigation, road condition, journey length, vehicle type and load are all factors which must be managed to mitigate this risk. All Moombarriga team members complete 4WD training at the start of their employment to provide them tools to tackle more challenging road conditions. Moombarriga safety policies require driving to be conducted during daylight hours, unless under extenuating circumstances, to a) ensure best visibility b) to minimise fatigue c) reduce likelihood of interaction with animals on the road and d) reduce the risk of vehicle-vehicle interactions. Driver fatigue is also managed by ensuring travel is carefully planned to minimise fatigue, e.g. drive on bitumen as much as possible and ensuring good accommodation is available for the crews overnight. Where possible, drivers are rotated, and frequent rest periods are taken to ensure drivers remain alert. Journey plans also require teams to check in at predetermined intervals so progress can be monitored.

Moombarriga vehicles carry: two spare tyres; recovery equipment, e.g. snatch straps, traction boards; tyre changing equipment; first-aid kits; satellite phones; InReaches; emergency water; and UHF radios, to ensure the crew have the tools to undertake recoveries, repairs and to communicate in the case of emergencies. Moombarriga field crew on the survey hold the *'HLTAID011: Provide first aid'* qualification.

Four minor incidents and one near miss were reported during the data acquisition. Two were first aid treated injuries; one from a gate latch and fence flicking back into the employee and injuring their hand (LTI), one from a dog bite at a tyre yard when dropping off tyres for repair. Two were vehicle/trailer related, with a toolbox drawer opening uncontrolled and another having a trailer axle slightly bent. The near miss was from gas hose connection loosening over time and gas leak noticed on camp cooking setup. Details of the incidents identified are provided in Appendix IV: Incidents and Near Miss Reports.

Moombarriga personnel held daily toolbox meeting prior to work commencing each day. These meetings provide a forum for team members to discuss the work plan, report any incidents, near-misses or hazards identified, discuss upcoming changes or factors which may affect work, eg changing weather, access issues etc assess existing controls and implement new controls if necessary. Copies of the Daily Toolbox Meetings can be found in Appendix III: Daily Toolbox Meetings.

Table 2: Safety Record

Reported Incidents	Loss Time Injury (LTI)	Medically Treated Injury (MTI)	Near Misses
4	1	0	**1**

3 Data Acquisition

Specifics of the data acquisition activities can be found in Appendix II: Daily Field Activity Notes and the site descriptions and layout notes in Appendix V: Layout Sheets.

3.1 Equipment

Table 3 summarises the equipment used during the survey. Moombarriga used the long period magnetotelluric instruments LEMI-424 and Moombarriga's proprietary non-polarising electrodes which do not require maintenance, making them safer to the operators and are more stable, providing better results in low signal/high resistance environments. Technical specifications of the MT equipment used are located in Appendix VII: Technical Specifications.

Table 3. Equipment used for data acquisition.

Data Logger	LEMI – 424	42
Magnetometer	3 component flux-gate magnetometer	42
Electric Field Sensors	Nonpolarising electrodes $Pb/PbCl_2$ (Moombarriga proprietary)	70
Magnetometer Cables	LEMI	32
Wire	2.5mm	~ 6000m cumulative length
Power Supply	Rechargeable batteries 12V 55Ah-80Ah	32
	Solar panels with regulators	32

Ancillary Equipment

- BRUNTON Compass (x1)
- Compass Tripod (x1)
- Measuring Tape; 60 metre metric/imperial (x3)
- Field laptop (x1)
- Field Tablet with Database App
- Multimeter (x2)
- Battery Charger (x1)
- 2x Inreach devices
- Iridium Satellite Phone (x2)
- Mobile phones
- First Aid kits (x2)
- Batteries, electrical tape, duct tape, rope etc.
- 2 x Toyota Landcruiser 70 series

3.2 Method

3.2.1 Site Selection and Equipment Layout

The Client provided proposed locations to be surveyed. Moombarriga field crew adjusted positions as required due to accessibility and appropriateness of the site. Factors affecting the final site location included road access, vegetation clearance and land access approvals. Final site locations are shown in Figure 1.

Figure 2 is a schematic of the standard deployment of MT equipment during sounding acquisition.

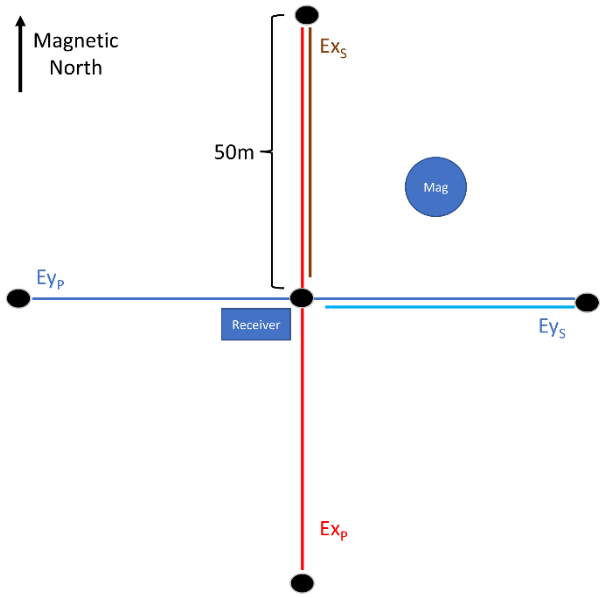

Figure 2. Schematic of MT site layout.

A single, 3 component flux-gate magnetometer and two horizontal components of the electric field (E_x, E_y) are the primary measurements from each site.

A single, 3 component flux-gate magnetometer was positioned nominally to north and then accurately aligned ensuring a By > +/- 200nT and the magnetometer cable buried to minimise noise and/or damage or interference from animals.

Electric dipoles (E_x and E_y) were aligned perpendicularly, north-south and east-west. Non-polarising electrodes grounded the dipoles at each end and were aligned using a Brunton compass mounted on a tripod located in the centre of each station. Nominal dipole lengths of 100m were measured between electrodes using surveyors measuring tapes. For some sites, final dipole lengths varied depending on terrain and accessibility, however every effort was made to achieve 100m dipole lengths. Final dipole lengths were recorded in both field notes and in the data record files.

General practice uses an element of redundancy by creating 4 dipoles at 50m with two central electrodes (Figure 3). This method was used to try and minimise repeating sites due to failure of one electrode (interference from animals being the primary cause).

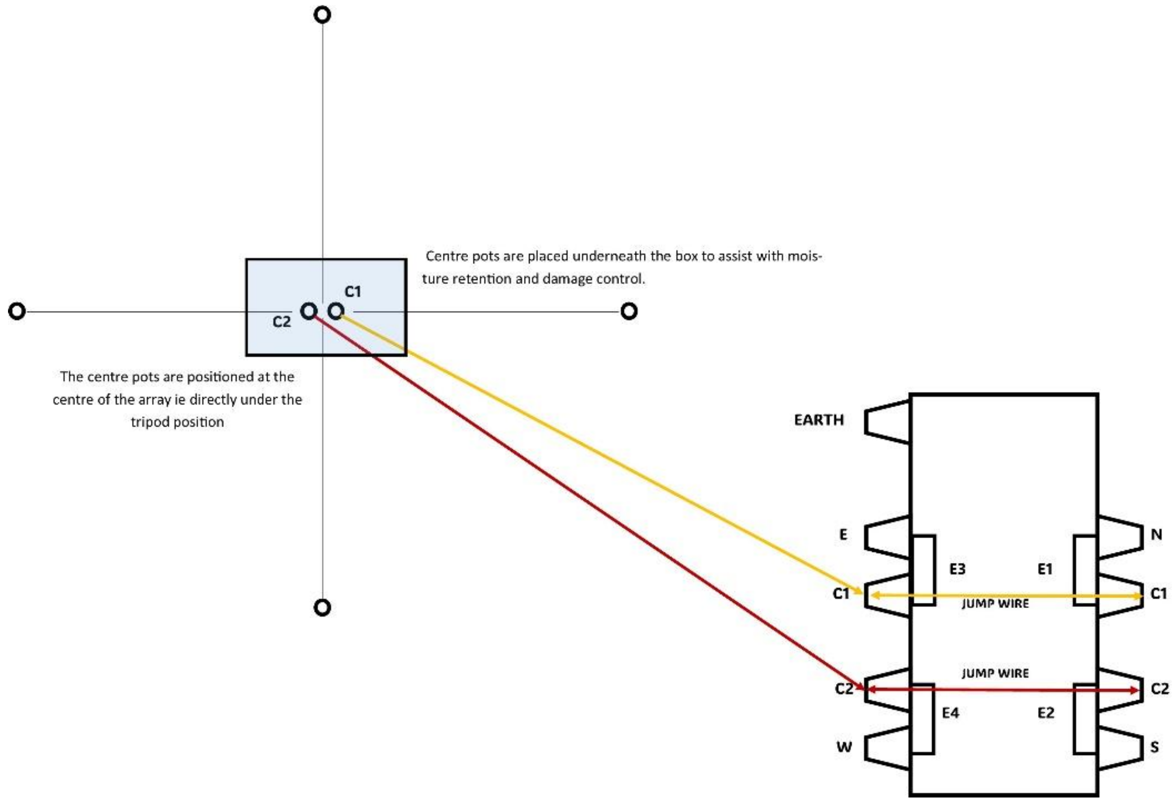

Figure 3: Recorder configuration to use enable E-field redundancy.

Prior to initiating acquisition, DC voltage and resistance were measured and recorded for each dipole to ensure satisfactorily low contact resistances, which ensured good ground contact.

3.3 System Retrieval

Upon system retrieval, the data was copied from the data loggers to a field laptop. Data was imported into LEMIgraph and field processed to EDI to ensure data quality was sufficient. Resistance and DC voltage were measured for both electric dipoles to ensure good contact was maintained during acquisition. If QAQC steps indicated satisfactory data recovery, MT equipment was dismantled for transport to the next site. Rehabilitation of the site involved back filling of all holes dug for the magnetic sensor and porous pots as well as collecting any used tape or other rubbish.

3.4 Data QAQC

Each night two copies of the raw data were created: one on a processing laptop and a second on an external hard drive. All data tables were checked against the field notes to ensure correct metadata were recorded, e. g. site number, dipole length. The time-series for all data were checked for internal consistency. Processed results were sent to Moombarriga's Perth office for final QA/QC, editing and export of final data product (EDI).

4 Processing

Processing of MT data uses the measured time-series data to calculate the MT response function (Z) for a range of periods. Z describes the relationship between the magnetic (H) and electric (E) fields according to the generalised relationship:

$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \begin{pmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{pmatrix} \begin{pmatrix} H_x \\ H_y \end{pmatrix}$$

Equation 1: The generalised equation for the MT impedance tensor

Note the subscript x and y refer to the orientation of the measurement, with x being north and y east, see Figure 2.

The data are decomposed into variations at different periods. This is achieved using Fourier transforms. Due to the skin-depth effect, the longer period variations penetrate deeper into the sub-surface, so by comparing data from different periods, vertical variations can be inferred. By combining data recorded at different locations, electrical properties of the sub-surface can be mapped in 2D (data acquired as transects) and/or 3D (data acquired as a grid or on adjacent transects). Note that directly equating a given period to a specific depth is very difficult because the depth of penetration for a given period also depends on the local electrical resistivity structure. Less resistive conditions equate to less depth penetration for a given period.

From the MT response function (Zxx etc in Equation 1), more readily interpretable properties can be calculated, e.g, apparent resistivity (ρ_A) and phase (ϕ), and inverse modelling can be conducted to map the distribution of resistivity as a function of location in the subsurface, allowing geologically meaningful interpretations. For example, the procedure for apparent resistivity is to square the ratio of a set of orthogonal E and H components at a certain period and then multiply by the appropriate constant.

The time-series data acquired during this survey were processed using Ohmega Geosciences GmbH (Ohmega). Ohmega use proprietary software called MAnTiS. The software expands on the eigenvalue decomposition method originally presented to the academic community by Egbert (1997), and its strength comprises two unique workflows:

Firstly, it includes a robust estimation of the spectral density and the noise covariance matrices. The multivariate approach accounts for the statistical dependence between regression residuals related to the data channels at a single site (Advanced Noise Model, ANM) and therefore significantly reduces the impact from locally coherent noise signals.

Secondly, the software provides an algorithm that analyses the number of source-field processes in the multivariate data space. Here, an eigenvalue criterion that identifies time segments (within the complete time-series) that exhibit high MT signal-to-noise ratio and simultaneously reduces the influence of regional coherent noise signals is calculated for each single time window. Ideally, noise-free MT data will have two dominant eigenvalues associated with the two statistically independent polarisations of the natural magnetic source field. Coherent noise between the observed local field components will result in further eigenvalues and are categorized by an eigenvalue index (Hering, 2019).

The final transfer function is calculated as a weighted stack of cross-spectra between the channels of each time interval. Here, the software offers different ranking criteria based on eigenvalue indices and/or partial coherences, which are combined with robust data selection- and weighting schemes. Data Analysis

4.1 Data quality

Figure 4 illustrates the typical range of data quality for WA Array Phase 2 survey. The data quality is generally very good with robust impedance estimate past 10,000 seconds at most sites.

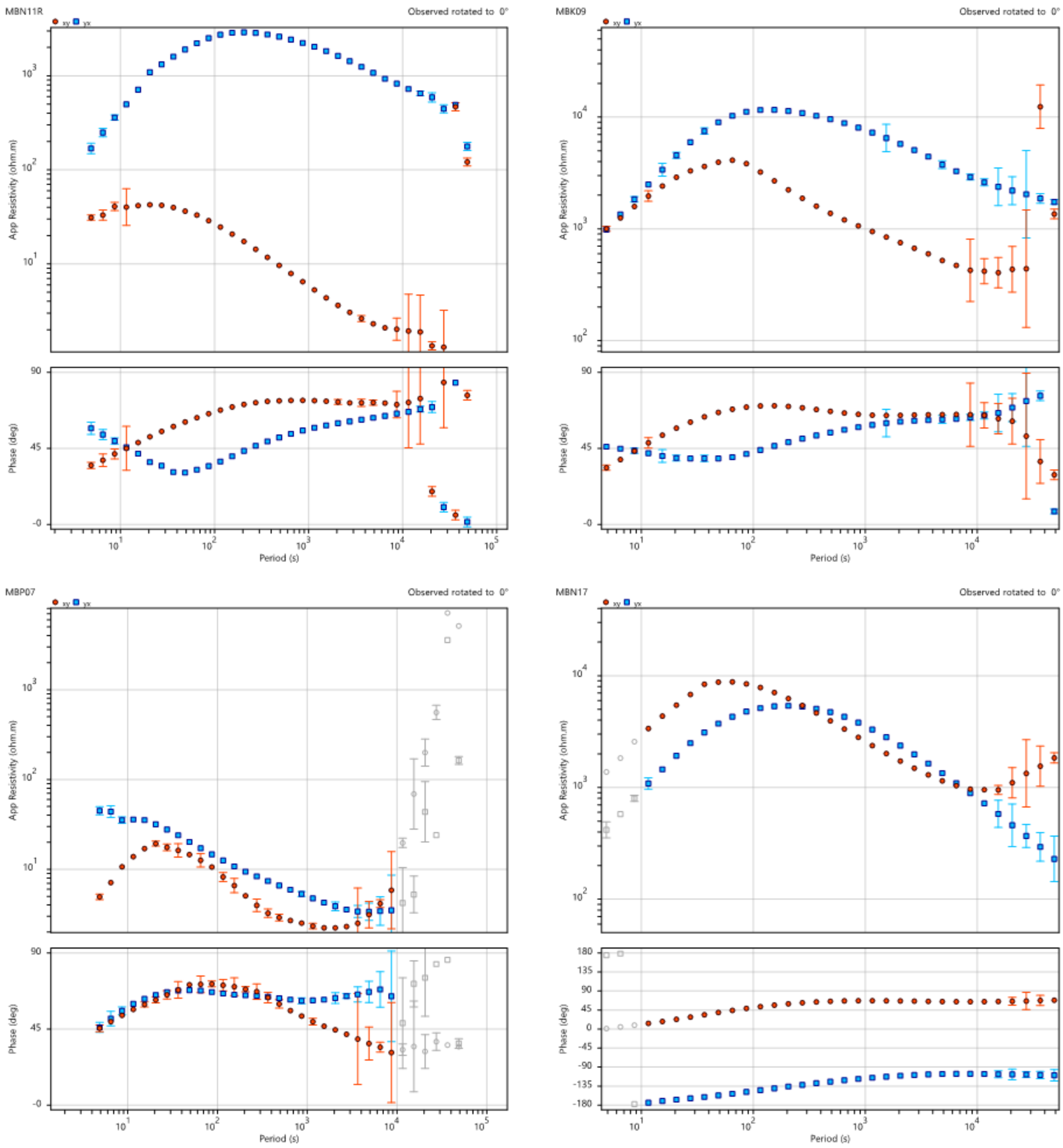

Figure 4: Example MT sounding curves.

5 Results and Final Deliverables

- This report
- All processed data in EDI format MT data are included in Appendix VI: Final Data along with images of all the processed data.
- Raw time series data.

6 References:

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