BCI DMPA4-Mardie Salt Bathymetric Field Survey

Hydrographic Survey Report

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Version Register

Version	Status	Author	Reviewer	Approver	Date
Rev A	Draft	Emil Sottopietra			
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Transmission Register

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Changes from Previous Versions

Changes beyond amendment of typographical and formatting errors, or adjustment of text for clarity are listed below.

Section	Change
N/A	Original

Acronyms and Abbreviations

Acronyms & Abbreviations	Definitions
AHD	Australian Height Datum
BSA	BlueSpatial Australia
CRP	Central Reference Point (Origin of Vessel Coordinate System)
GDA	Geocentric Datum of Australia
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IMU	Inertial Measurement Unit
kHz	Kilohertz
LAT	Lowest Astronomical Tide
MBES	Multibeam Echo Sounder
MGA	Map Grid of Australia
O2Me	O2 Metocean
POS MV	Position and Orientation System Marine Vessel
PPP	Precise Point Positioning
Qinsy	Quality Integrated Navigation System
RTK	Real Time Kinematic
SVP	Sound Velocity Profiler
SVS	Sound Velocity Sensor
THU	Total Horizontal Uncertainty
TVU	Total Vertical Uncertainty
UTM	Universal Transverse Mercator
WA	Western Australia
WGS84	World Geodetic System of 1984

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1. Introduction

O2 Metocean (O2Me) was contracted by BCI Mineral Ltd to acquire bathymetric data for environmental mapping purposes, to facilitate the environmental assessment at the designated spoil-ground area known as DMPA4.

This report covers the methodology, checks and calibrations that were carried out for this survey. Note this survey is not for navigation purposes or engineering design and therefore are not to any defined survey order as it does not meet the requirements for a classification.

1.1. Project Summary

O2Me mobilised a high-resolution integrated wideband multibeam echo sounder survey system onto *"Geelong"* vessel contracted from O2 Marine.

The survey was conducted over three days including time taken for mobilization, demobilization, survey checks and survey calibration. An experienced surveyor was on the vessel for the duration of the project.

A summary of the survey operations is provided in Table 1.

Table 1 Project Timeline.

Date	Operations
20/09/2024	• O2Me Personnel arrived in Dampier, survey equipment was delayed due to airline delay with luggage. • Preparation of the boat, and launch to avoid tidal restrictions for boat launching. • Collection of survey equipment in the late afternoon.
21/09/2024	• Mobilisation of survey equipment on the vessel. • Survey checks and calibration within Hampton Harbour boundaries. • Patch test. • Transiting via sea to Mardie.
22/09/2024	• Weather and BCI camp road closure stand by
23/09/2024	• Weather condition not suitable for MBES operations, drop camera scope was prioritised.
24/09/2024	• MBES data acquisition at DMPA4.
25/09/2024	• Data assessment and transit via boat back to Dampier. • Post survey checks.
26/09/2024	• Equipment demobilisation and O2M personnel back to Perth.

Prior to mobilisation a Health, Safety, and Environment (HSE) plan was submitted to BCI which included a detailed Job Hazard Analysis (JHA) of the work proposed considering the remote nature of the site.

The JHA was addressed in the morning by the field team before work, to assess whether there were any changes required to ensure the job was completed in a safe and effective matter. The project was completed with zero injuries to personnel, or incidents to the environment, and equipment.

2. Equipment

2.1. Vessel Specifications

2.1.1. O2 Marine - *Geelong*

Contracted vessel *Geelong* (Figure 1) was used as the survey vessel for the MBES portion of the project.

- Length 8.5 m
- Width 3.0 m
- Draft 0.6 m
- MBES Mounting Side Mounted Pole
- IMU Mounting MBES Integrated

Figure 1 Survey Vessel *Geelong.*

2.2. Survey Vessel Equipment

2.2.1. Multibeam equipment

The Norbit iWBMS Multibeam Echosounder (MBES) adopted in this study offers a tightly integrated bathymetric mapping solution by combining all sensors required to carry-out a high-grade bathymetric survey in a single unit. Hence, the sonar measurement and inertia measurement unit (IMU) centres are known and fixed, thus predefined within the system setup during factory integration.

Bathymetry data were captured with the following instrumentation and software:

- 1 x Norbit iWBMS Multibeam with integrated Applanix POS MV WaveMaster II

- 1 x Acquisition laptop
- 1 x Valeport SWiFT SVP
- 1 x Emlid RS3 GNSS and RTK receiver

2.2.1.1. RTK Correction Source

PPP corrections (G2+, G4) were used as positioning correction, provided by subscription with Fugro Marinestar. Corrections quoted to provide a vertical accuracy of ± 10 cm.

The Port of Dampier RTK correction casted via NTRIP was utilised to run the checks and calibration to ensure a higher accuracy.

2.2.1.2. Software

Details of the software and version number in use during the survey are:

- BeamworX NavAQ — Version 2024.1.1.3
- BeamworX AutoClean — Version 2023.3.1.0
- Valeport Datalog X2 — Version 1.0.7

3. Survey Area

The survey area was located approximately 40 km Southwest of Cape Preston and 100 km Northeast of Onslow in the Pilbara region of Western Australia (WA).

The survey scope included a square area of 800 m x 1,300 m located approximately 25 km offshore from Powdar Creek mouth where to collect bathymetric data (Figure 2).

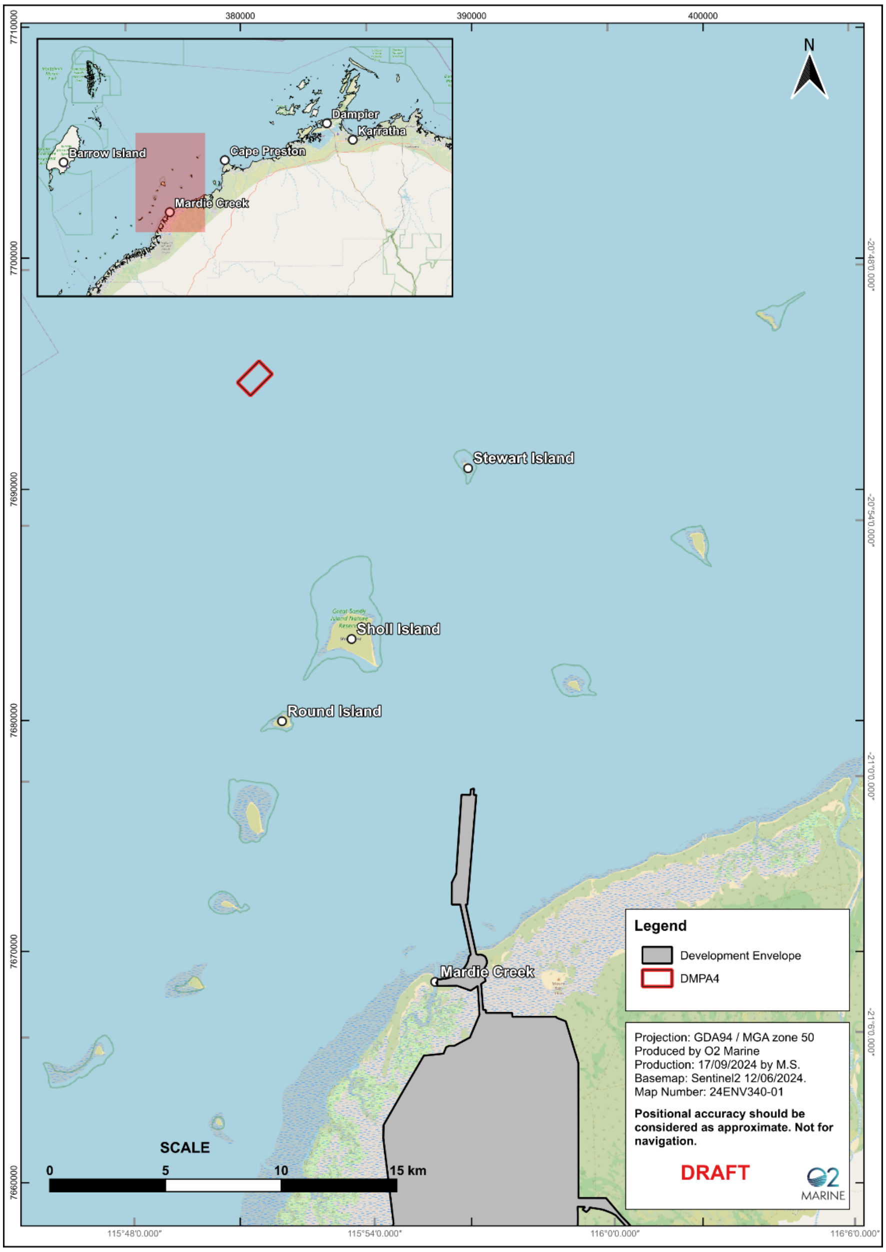

Figure 2 BCI DMPA4 proposed survey area.

4. Datum and Control

This project was to be defined with final coordinates in MGA2020 GDAZ50S / AHD.

4.1. Horizontal Datum

The horizontal datum used for this survey is Map Grid of Australia 2020 Zone 50 (MGA2020 Zone 50), based on the Geocentric Datum of Australia 2020 (GDA2020). See Table 2 for the details of the MGA2020 Zone 50 grid coordinate system.

Table 2 MGA2020 Parameters.

Parameter	Value
Coordinate System	MGA2020 Zone 50
Datum	GDA2020
Spheroid	GRS 1980
Projection	UTM Zone 50 South
Latitude of Origin	0° N
Longitude of Origin	117° 0' 0" E
False Easting	50,000.000 m
False Northing	10,000,000.000 m
Scale Factor	0.9996

4.2. Vertical Datum

Vertical control for the survey was AHD using the Ausgeoid2020 on the GDA2020 ellipsoid.

5. Mobilisation

The vessel *Geelong* was mobilised on 21/09/2024. A Norbit iWMBS multibeam echo sounder was mounted on a purposely designed fixed pole on the vessel side gunnel.

Figure 2 MBES side-mounted survey pole with integrated GNSS antenna supports.

The lever arms were measured using a tape measure and checked with the POS MV auto calibration. Table 3 summarises the measured lever arms.

Table 3: Lever Arm Offsets for *Geelong*.

Vessel Node	X (+ Starboard)	Y (+ Bow)	Z (+ Up)
CRP (iWMBS Measure Point)	0.000 m	0.000 m	0.000 m
POS MV Prim. GNSS Antenna phase centre	0.000 m	1.046 m	-2.887 m
POS MV IMU	0.000 m	0.076 m	-0.149 m
Norbit iWMBS SRP (Sonar Ref Point)	0.000 m	-0.172 m	-0.070 m
Draft Check Reference Node	0.000 m	0.000 m	0.550 m

6. Survey Checks and Calibrations

To validate the onboard survey systems an independent Emlid Reach RS3 GNSS receiver is used to identify any systematic or random errors.

6.1. GAMS Calibration

A GNSS Azimuth Measurement Subsystem (GAMS) calibration involves conducting a series of figure eight and turning manoeuvres which calculates the baseline between the two POS MV GNSS antennas. Once the baseline between the two antennas is known, the POS MV can then use carrier phase observations to provide an accurate vessel heading rather than a traditional gyro-compass method. This calibration was carried out prior to the start of survey. The measured offset between the antennas was compared with the GAMS calibration values to verify the calibration was successful.

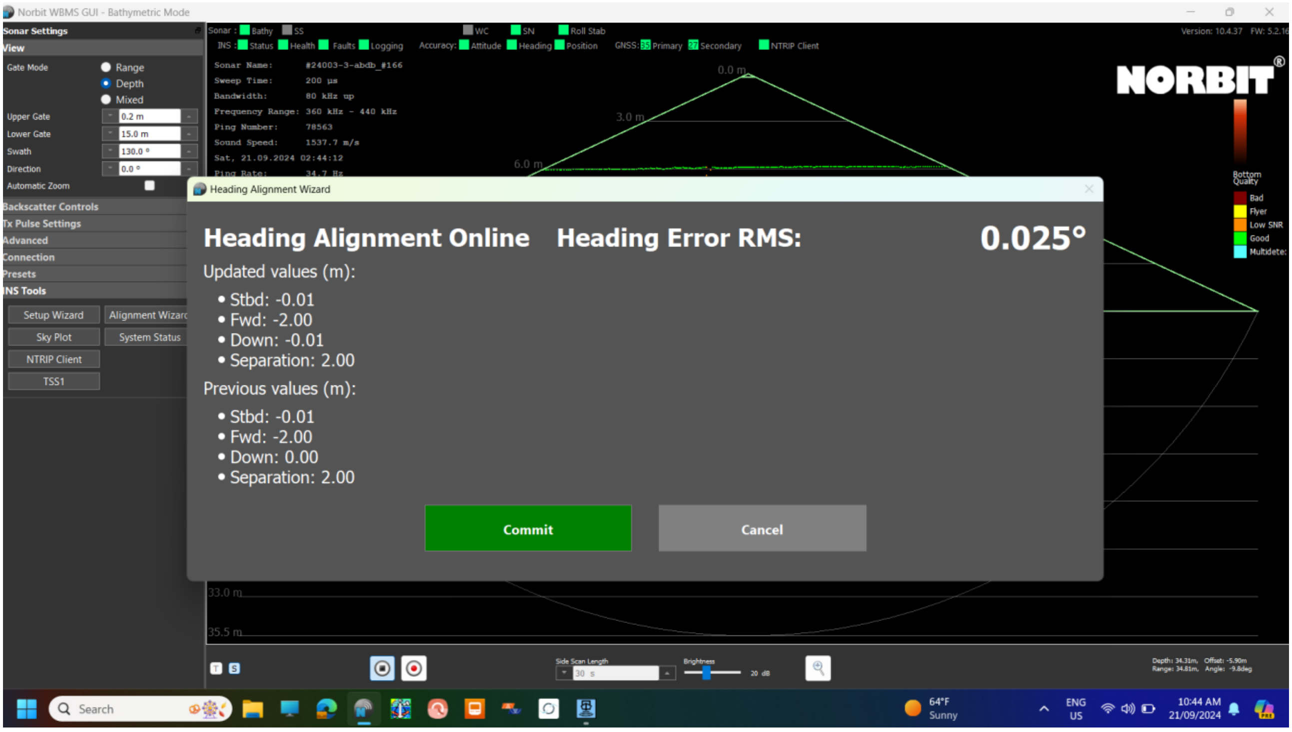

Figure 3 GAMS calibration results and calibrated heading RMS error.

Table 4: GAMS Calibration result.

Baseline Vector	X (+ Starboard)	Y (+ Bow)	Z (+ Up)
Measured	0.00 m	-2.00 m	0.000 m
Calibrated	-0.01 m	-2.00 m	-0.01 m

6.2. Vessel Position Check

Using the validated independent GNSS rover, a check of the vessel position was conducted by comparing the GNSS RTK rover with the POS MV system. The GNSS rover was placed on a dedicated node with a known offset in the vessel reference frame system established in the navigation software. The two systems were simultaneously logging for a period of one minute. The two sets of observations were time-synchronised before differences were computed for each epoch (every second). The average difference was calculated, and observations graphed to identify any trends or errors. See Table 5 for a summary of the results.

Table 5: Vessel Position Check Results.

Date	Easting Difference [m]	Northing Difference [m]	Height Difference [m]
21/09/2024	0.012	0.006	0.078

The above results indicate that the position computed through the NavAQ system compared within expectation with the GNSS RTK rover, validating the lever arms offset measurements.

6.3. Multibeam Patch Test

A multibeam patch test is conducted to determine the angular offsets between the alignment of the MBES transducer and the POS MV coordinate frame. The test consists of surveying a series of parallel lines over a small object or slope, then processing these lines using BeamworX AutoPatch to calculate the angular offsets. A patch test can also be used to calculate any latency in the positioning system on the vessel, however on occasions where a pulse-per-second (PPS) time pulse is used such as this, it is deemed unnecessary as the remaining latency is negligible.

Table 6: Patch Test Results.

Date	Roll	Pitch	Heading
Initial Offsets	0.000°	0.000°	0.000°
21/09/24	-0.017°	-0.160°	0.170°

These angular measurements are in line with what is expected from an integrated MBES system. The deviation in pitch can be contributed to the sea conditions during the patch test.

6.4. Lead-Line Check

A lead-line check is conducted to ensure the correct operation of the MBES, and as a check to verify the MBES is correctly measuring depths. The results of the lead line checks are presented in Table 8 below.

Table 7: Lead-Line Check Summary.

Date & Time	Instrument Draft + Sonar reference (m)	MBES depth (m)	Led Line (m)	MBES + draft (m)	Difference (m)
25/09/2024 13:13	0.55 + 0.07	5.30	5.86	5.92	0.06
25/09/2024 13:42	0.55 + 0.07	2.61	3.26	3.23	0.03
25/09/2024 13:48	0.55 + 0.07	2.64	3.27	3.26	0.01

The Lead Line check result indicates the correct operation of the echo sounder.

7. Multibeam data Acquisition

Hydrographic survey data acquisition took place on 24/09/2024. The MBES lines were planned to achieve a representative coverage of the study areas with crosslines conducted as a check.

During the survey, the quality of the data was continuously monitored through NavAQ to ensure the acquired data met the survey specifications:

- The POS MV positioning accuracy was monitored, and where PPP dropouts occurred the survey line was re-run with PPP.
- Sound velocity profiles were collected at the start in the middle and at the end of the survey checking that the SVS / SVP comparison was greater than 2 m/s to correct the data from the ray bending effect caused by salinity and temperature stratification/changes across the water column.
- The MBES data was monitored online to ensure optimal coverage.

The following multibeam settings were used throughout the project:

- Frequency 400 kHz
- Pulse length 15 µs
- Maximum angular coverage 120°
- Bottom Sampling Equidistant (beams per ping)

8. Multibeam data Processing

Processing of the survey data was conducted using BeamworX AutoClean data processing software. The following processes were conducted on the data to obtain a high standard of data quality and to ensure that objects were not missed or deleted.

8.1. 95% Confidence Assessment

The 95% confidence from the data was analysed as an overall check on the quality of the data and particularly the quality of the GNSS leveling. Any areas that fell outside the 0.3 m threshold for the 95% standard deviation were analysed, corrected, or removed if necessary.

8.2. Multibeam Data Cleaning

An experienced surveyor analysed the data in detail and removed erroneous data manually using the BeamworX AutoClean processing software.

8.3. Spot Soundings

Spot soundings were used to ensure the exact shallowest depth of any small object near the design depth was retained and not affected by the statistical surface creation process detailed below in Section 8.4. These spot soundings were manually selected by an experienced hydrographic surveyor and carried through to the final products.

8.4. Surface Generation and ASCII data sets

The final ASCII XYZ data sets were created as per the below processes:

1. Spot soundings
   Manually selected as per Section 8.3.
2. Processed 0.5 m mean depth gridded
   All soundings within a 0.5 m bin size are averaged to create one mean depth sounding per 0.5 m bin.

Generated surface is presented in Figure 4.

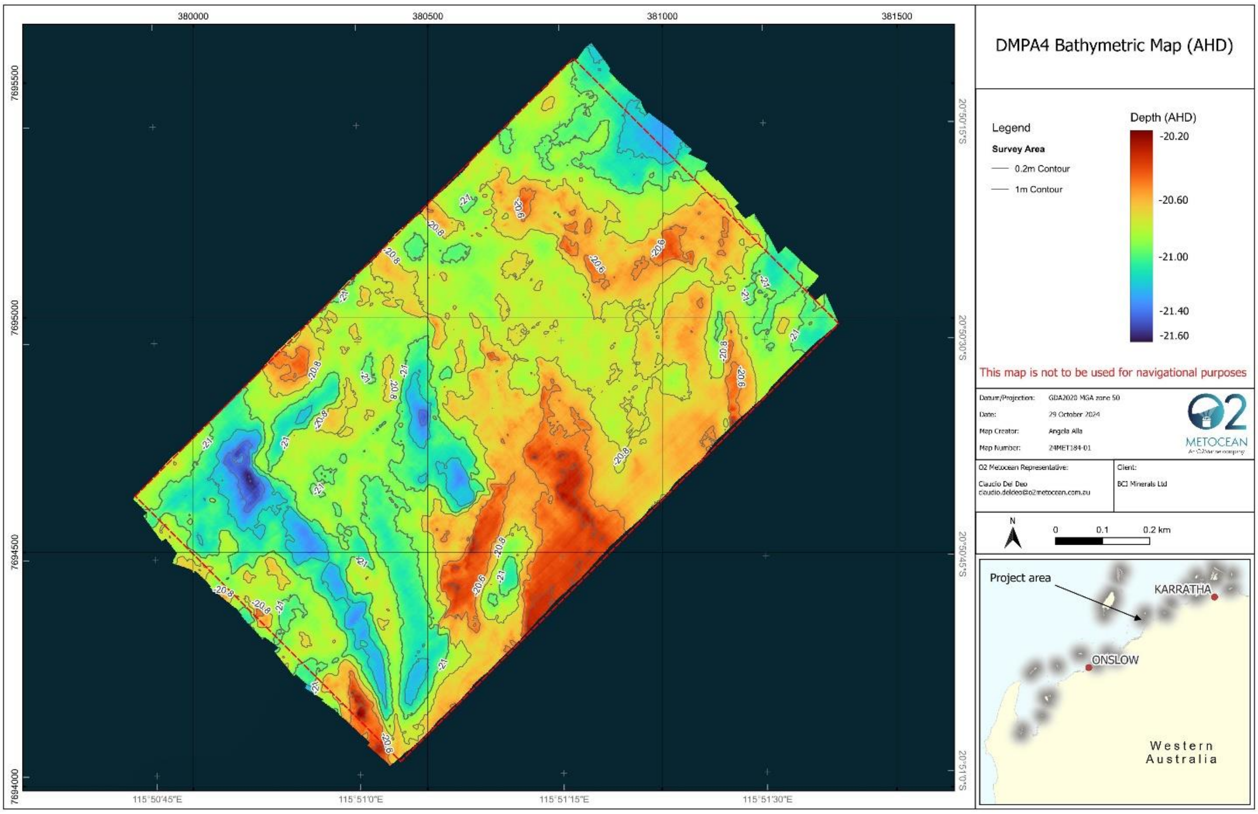

Figure 4 Bathymetric Survey AHD map.

8.5. Multibeam data Quality Control

The above processes were conducted by an experienced hydrographic surveyor to ensure the seabed had been properly and accurately represented.

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9. Theoretical Uncertainty

An assessment of the total vertical and horizontal uncertainty (THU & TVU) can be determined by combining the errors due to the survey systems and tidal reduction methodology. The errors associated with this survey have been assessed as follows.

Norbit iWMBS Performance Summary
Geelong

Rate of Seafloor Coverage	0.44	km^2/hr
(within the seafloor coverage limitations described below)		

Below is a summary of complex calculations based on all assessed error sources associated with this survey

Environment	
Parameter	**Value**
Maximum Water Depth	23 m
Maximum Sea State	1 m
Maximum Vessel Roll	0 °
Maximum Observed Vessel Pitch	4 °
Seafloor Slope	0 °
Sound Speed	1535 m/s
Maximum Sound Speed Uncertainty	1 m/s

Coverage Summary	
Parameter	**Value**
Sounding Speed	5 knots
Average Swath Width	100 °
Swath Overlap	25%
Total Seafloor Coverage	125%
Minimum Ping Rate	20.5 Hz
Maximum Swath Coverage	54 m
Maximum Distance between Pings Alongtrack	0.13 m

Depth Position Uncertainty Summary	
Parameter	**Values (95%)**
Positioning System Error	0.273 m
Beam Footprint Error	0.329 m
Refraction Error	0.010 m
Roll Error	0.022 m
Pitch Error	0.079 m
Heading Error	0.097 m
Gridding Error	0.180 m
Total Propagated Horizontal Uncertainty	**0.481 m**
Number of Beams meeting Special Order	256 / 256
Number of Beams meeting Order 1	256 / 256

Depth Uncertainty Summary	
Parameter	**Values (95%)**
Sounder Error	0.025 m
Refraction Error	0.008 m
Roll Error	0.026 m
Pitch Error	0.006 m
Induced Heave Error	0.001 m
Vertical Positioning System Error (incl. heave)	0.227 m
Vertical Offset Measurement Error	0.020 m
Total Propagated Vertical Uncertainty	**0.231 m**
Number of Beams meeting Special Order	256 / 256
Number of Beams meeting Order 1	256 / 256

Figure 5: Theoretical Uncertainty - 100%.

Note: Error sources are a combination of manufacturer specification and environmental conditions calculated for the most outer beam of the multibeam system operating at 400kHz using a maximum angular coverage of 100° and a signal pulse length of 15 µs.

10. Deliverables

- Bathymetric Report (pdf)
- ASCII XYZ Bathymetric Data (0.5 and 1 m mean grid in .pts format)
  - BSA_2414-O2M_Mardie_SpoilGround_GDA2020_AHD_0.5m_MG.pts
  - BSA_2414-O2M_Mardie_SpoilGround_GDA2020_AHD_1m_SB.pts
  - BSA_2414-O2M_Mardie_SpoilGround_GDA2020_AHD_1m_SG.pts
  - BSA_2414-O2M_Mardie_SpoilGround_GDA2020_AHD_SS.pts

- Imagery (GeoTIFF and KML)
  - BSA_2414-O2M_Mardie_SpoilGround_GDA2020_AHD_0.5m_Backscatter.tif
  - BSA_2414-O2M_Mardie_SpoilGround_GDA2020_AHD_0.5m_Backscatter.kml
  - BSA_2414-O2M_Mardie_SpoilGround_GDA2020_AHD_0.5m_MG.kml

- Digital elevation Model (3D) (0.25 m mean grid in .Tiff format:
  - BSA_2414-O2M_Mardie_SpoilGround_GDA2020_AHD_0.5m_MG.tif
- Contour charts 0.25 m and 1 m:
  - 24MET-0168-01_MultibeamAHD.png
  - 24MET-0168-02_MultibeamAHD-1mContoursOnly .png
  - 24met168_GDA2020_AHD_0.2m_MG_contour
  - 24met168_GDA2020_AHD_1m_MG_contour

Note:

- MG – Mean Grid – average depth calculated from all the sounding within the 0.25m cell.
- SS – Spot Sounding- Least depth within the cell of the 0.5 m mean grid.
- SG- Shallowest Grid- average depth calculated from all the sounding within 1m cell
- SB – Shallowest Bin within the SG.

11. Approval

This report and the accompanying survey plans have been closely reviewed and are considered complete and adequate as per the job specification.

Survey and report produced by:

Emil Sottopietra

O2 Metocean

QC of data and review of this report by:

Neville Benson, BSurv, MGCA

Certified Professional Hydrographic Surveyor Level 1