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Hydrographic Survey of the Boags Commonwealth Marine Reserve in Southwestern Bass Strait

Project: BF2018_v01

Compiled By: Philippe Vandenbossche & Craig Davey (GSM Group)

Compiled for: For Institute for Marine and Antarctic Studies (University of Tasmania) / Parks Australia

Report No: BF2018_v01a

Revision History:

Revision	Description of change	Author	Date
0	First Issue	P. Vandenbossche / C. Davey	06-08-2018

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1 Executive summary

The CSIRO's Oceans & Atmosphere Shallow Survey Internal Facility (SSIF) was contracted by the Institute for Marine and Antarctic Studies (IMAS) of the University of Tasmania (UTAS) in collaboration with Parks Australia, to undertake a hydrographic survey of the Boags Commonwealth Marine Reserve in the southwestern Bass Strait. This site was surveyed in conjunction with other smaller sites for Petuna Aquaculture, as part of a broader survey campaign. All of the sites covered in this campaign are located in the vicinity of the Hunter Group of Islands, off the north-western coast of Tasmania.

The Boags Marine Reserve is located ~8 km to the north of Three Hummock Island and measures ~27.7 km x 19.4 km (covering an area of 537.4 km^2). The Petuna Aquaculture sites (designed as Hope Channel and SE Hummock) are significantly smaller in size and are located within the Hunter Group of Islands.

A two person CSIRO complement from the Geophysical Survey and Mapping (GSM) team, took over the operation of a pre-mobilised Kongsberg EM2040c Multibeam Bathymetry Echosounder (MBES) system on-board the *MV Bluefin* in Stanley (NW Tasmania), from the 27th June until the 4th July 2018. The vessel had been previously mobilised by Geoscience Australia (GA) for survey work in the Beagle Marine Reserve of the Bass Strait. Following the handover from the GA personnel, the vessel transited to the Boags Marine Reserve and commenced survey operations on the 27th June 2018.

The objective of the survey was to measure seabed depths and map the seafloor topography within the marine reserve, using a high resolution bathymetry system.

Unfortunately due to budgetary & time constraints, as well as adverse weather conditions encountered in the last few days of the survey campaign, operations at the Boags Marine Reserve had to be suspended, leaving the site incomplete.

It should be noted that due to the presence of large subaqueous dunes (some >10 m in height) within the Boags Marine Reserve area, survey line spacing had to be considerably reduced from an expected 220 m - 240 m, to between 150 m and 175 m. This unfortunately impacted the expected coverage and constrained the time allocation for the site.

During the survey, the data were mapped to Lowest Astronomical Tide (LAT), but for the final survey products, the soundings and map products have been reduced to the Australian Height Datum (AHD).

The entire CSIRO survey campaign covered approximately 2,361 line kilometres (or 1,275 nautical miles), including transits. Of this total, 1,595 line km were surveyed in the Boags Marine Reserve and 627 line km were surveyed across the Petuna Aquaculture sites. A summary of the survey details, data acquired and results are presented in Tables 1 to 4 below.

1.1 Summary of the Survey Details

CATEGORY	DETAILS
Survey Area(s)	Boags Marine Reserve (Parks Australia), Hope Channel & SE Hummock (Petuna)
Survey Dates	27 June 2018 to 4 July 2018
Survey Vessel	MV Bluefin
Survey Personnel	Neville Barrett (IMAS), Craig Davey (CSIRO), Philippe Vandenbossche (CSIRO)
MBES System	Kongsberg EM2040c (single head)
Positioning System	POS MV V5 (aided with Fugro G2 Marinestar signal). *Accuracy: 0.10 m (Horizontal) & 0.15 m (Vertical) @ 95%.*
Motion & Gyro System	POS MV V5 *Accuracy: 0.02° (Heading), 0.02° (Roll/Pitch), 5 cm or 5% (Heave) & 2 cm or 2% (TrueHeave)*
Sound Velocity	Valeport MiniSVS (Head) & MiniSVP (Water Column)
Horizontal Datum & Projection (Processed)	WGS84, UTM Zone 55 (South)
Reduced Vertical Datum (Processed)	AHD (Australian Height Datum) using AUSGeoid09
Survey Standard (Processed)	IHO Order 1a or better

Table 1: Summary of the survey details

1.2 Summary of the Data Acquired

INSTRUMENT	DATA TYPE	RAW DATA SIZE	NUMBER OF FILES
EM2040C	Multibeam Echosounder Bathymetry & Backscatter (.ALL)	173 Gb	708
EM2040C	Multibeam Echosounder Water Column Data	1.78 Tb	683
POS MV	RAW GNSS & IMU (000 file)	31 Gb	249
SVP Casts	Sound Velocity Profile	288 Kb	16

Table 2: Raw data collected by instrument

1.3 Summary of Bathymetry Results

SITE	MINIMUM DEPTH	MAXIMUM DEPTH	COMMENTS
Boags Marine Reserve	32.90 m	59.00 m	Extensive occurrence of large subaqueous dunes, N-S aligned (>10 m high in cases). No obvious rock outcrop but possibly presence of lithified sediments in the west.

Table 3: Bathymetry results

1.4 Summary of Backscatter Results

SITE	NOTEABLE ROCK OUTCROP	SIGNIFICANT FEATURES
Boags Marine Reserve	No evidence of any significant rock/reef outcrop	➢ Extensive occurrence of large subaqueous dunes, N-S aligned (>10 m high in cases) ➢ Arcuate lineations perhaps analogous with sand ribbons on a harder, sediment starved, seafloor.

Table 4: Backscatter features noted

2 Site Location

2.1 Site Location Overview

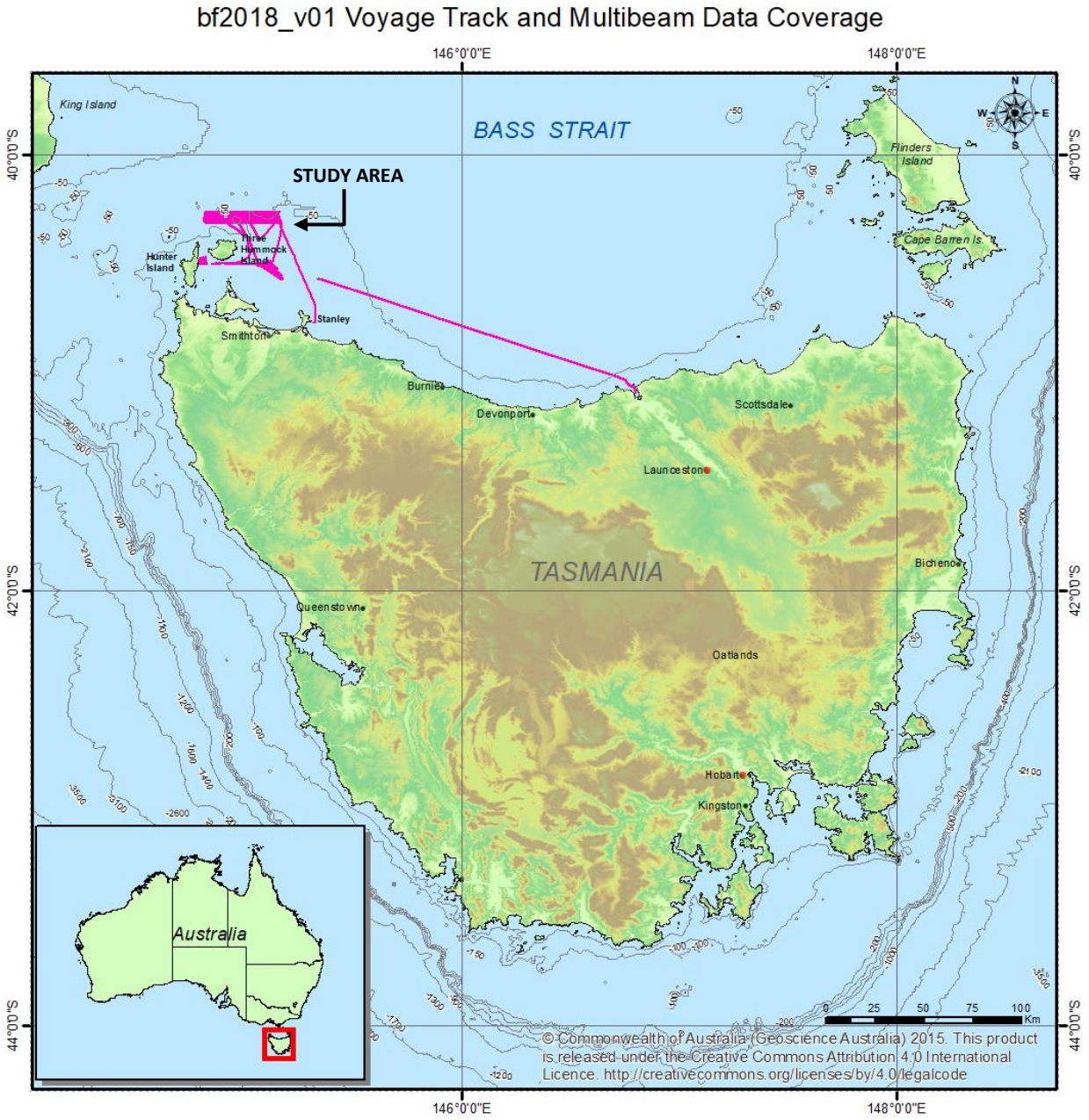

Figure 1: General site locality map & voyage tracks for the survey campaign

2.2 Site Specific Location

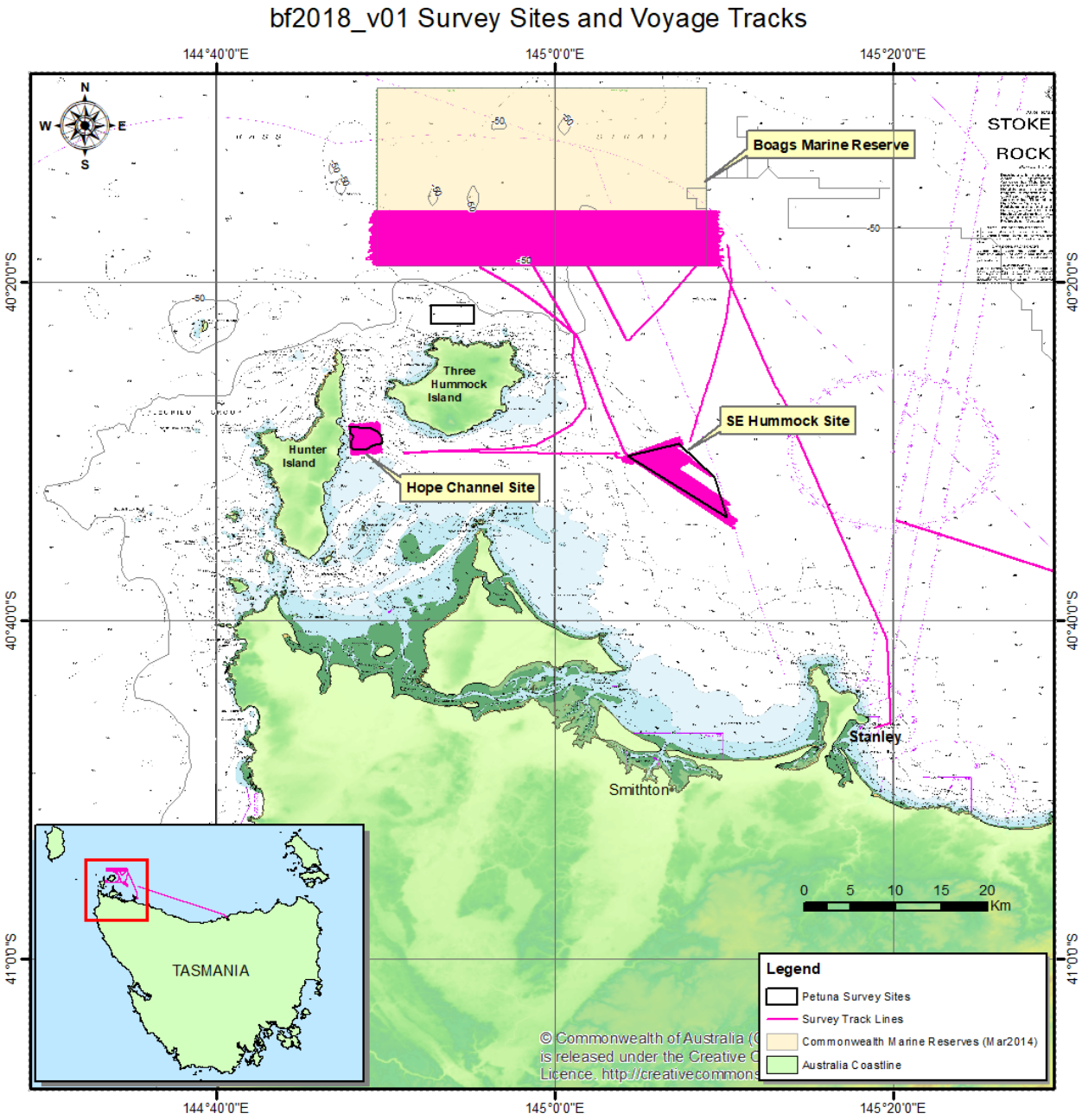

Figure 2. Site specific locality map & survey tracks

3 Results

The bathymetry and backscatter data is presented together brief description/interpretation for the site in the following sections of the report. The data provided is presented in the WGS84, UTM55 (South) projected horizontal datum, and the vertical datum is referenced to the Australian Height Datum (AHD).

Backscatter data is derived from the amplitude strength of the returning sound from the MBES, and is useful in that it can give an indication of seafloor characterisation. Greyscale mosaics have been produced from the backscatter data and are presented, along with the bathymetry, in the sections below. It should be noted that the greyscale imagery of the mosaics has been displayed in a manner that highlights finer sediments with a darker tonal range, while coarser sediments present as lighter tones in the maps shown.

The data presented at a 1 m resolution, adequately highlights both larger scale seafloor features (such as large sand waves) as well as more subtle, smaller-scale geomorphology. Many of the subtle tonal changes from the backscatter data (inferring different sediment classifications), when combined with the bathymetry, can provide a good indication of both the overall seafloor geomorphology and its composition.

3.1 Boags Commonwealth Marine Reserve

The bathymetry and backscatter data for the surveyed section of the Boags Marine Reserve is presented in Figures 3 & 4.

The Bathymetry within the mapped area (i.e. the southern portion) of the Boags Marine Reserve varies in depth from 32.9 m to 59.0 m with an average depth of 51.6 m (AHD). The most prominent and striking features in the area include an extensive presence of large two- and three-dimensional sediment bedforms (subaqueous dunes) that propagate throughout much of the area (for at least 27 km) from east to west. A number of these dunes have heights in excess of 10 m and wavelengths of the order of 400 m to 600 m. The majority of the subaqueous dunes have an N-S to NNW-SSE alignment, suggesting an E-W (or vice versa) sediment transport direction across the site.

The eastern half of the site generally has a shallower bathymetry (averaging of ~45 m) and is occupied by a NW-SE trending broad bathymetric high or ridge (that is ~12-14m in height), on top of which the large dunes have been superposed (Figure 5, top). In this area the dunes appear to be mostly asymmetrical inferring a predominant current flow from west to east. In contrast to this, the western half of the site is deeper (averaging ~55 m), but continues to highlight the presence of large dunes. Although there is a slight asymmetry to the dune morphology in the west (again inferring a dominant easterly transport direction), many of the deeper dunes have a more symmetrical appearance that might suggest a bi-directional current flow regime. The bathymetry also highlights the presence of “washed-out” dunes, inferring strong currents in the area.

An additional regional feature noted in the bathymetry, and well pronounced in the backscatter data, are the presence of linear, arcuate features or striations (Figure 5, bottom). These have a slightly positive micro-topography (with a relief of ~0.2 m), and are most notable in the deeper, western region that is devoid of sand waves. The exact nature and formation of these is unclear from this cursory data review, but they could represent strong current-induced sediment ribbons (of a coarser sediment composition), as many seem to overprint the dunes, especially in the northwest. Those along the southern boundary could also have some paleo-formation context, but a further more detailed investigation would be required to determine this.

Although there is no clear evidence to suggest the presence of obvious and significant reef/rock outcrop, both the bathymetry and backscatter data suggest that the seafloor to the west along the southern boundary, appears to be largely sediment-starved, and displays a more competent (or consolidated) bottom type appearance (Figure 6). This is evidenced by the lack of sand waves and a more planar, hummocky topography in that area.

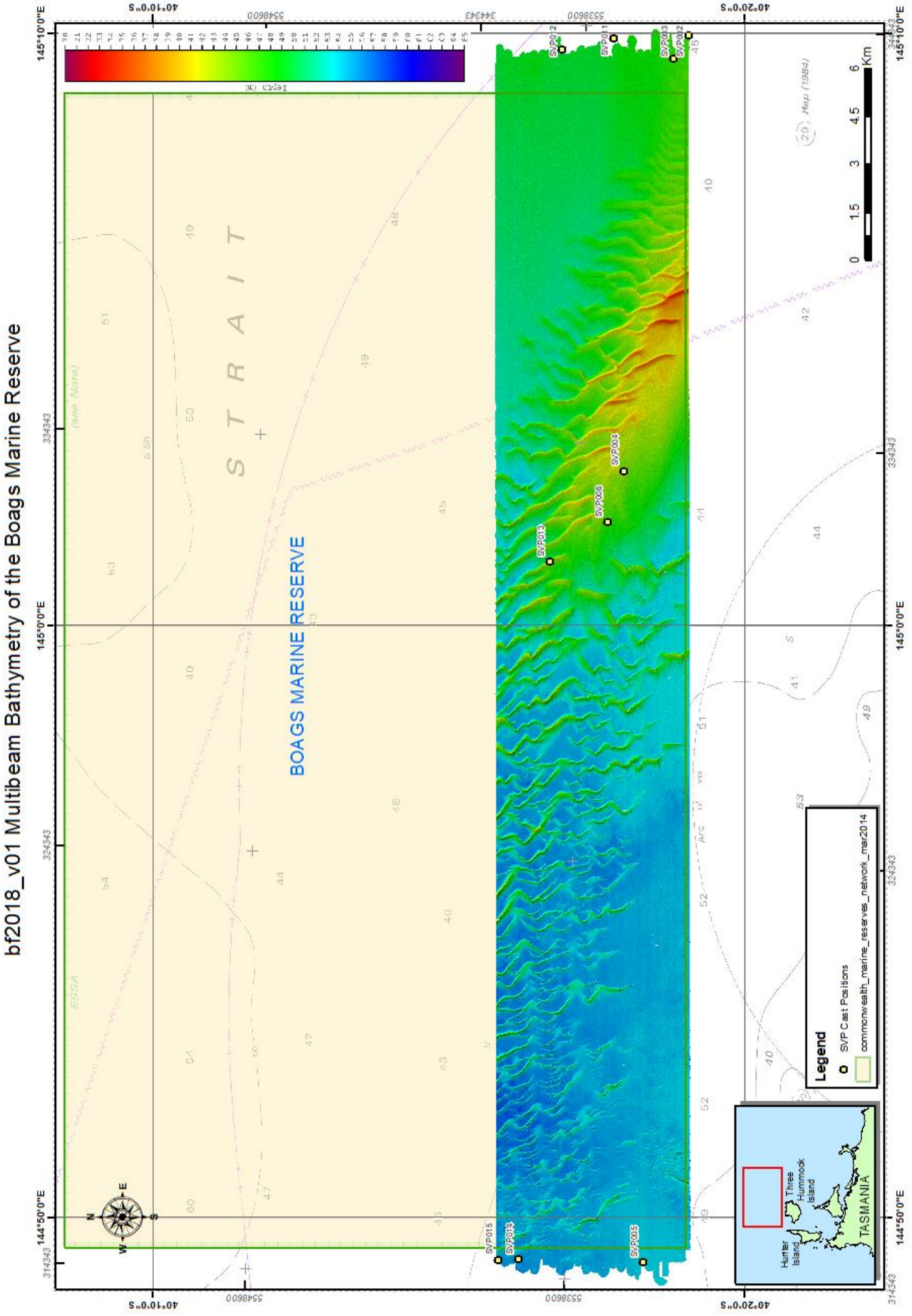

Figure 3. Bathymetry of the Boags Marine Reserve

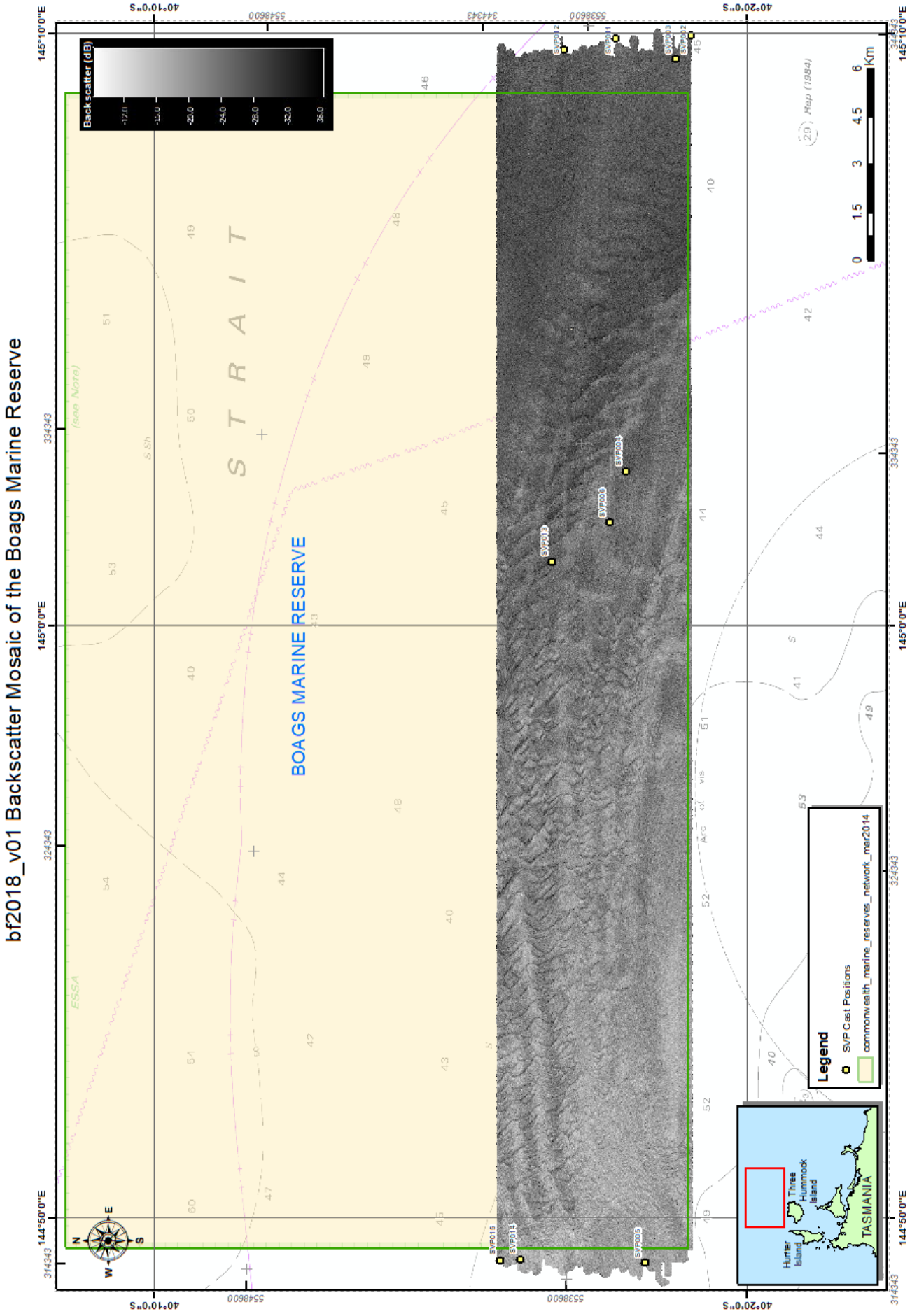

Figure 4. Backscatter mosaic of the Boags Marine Reserve

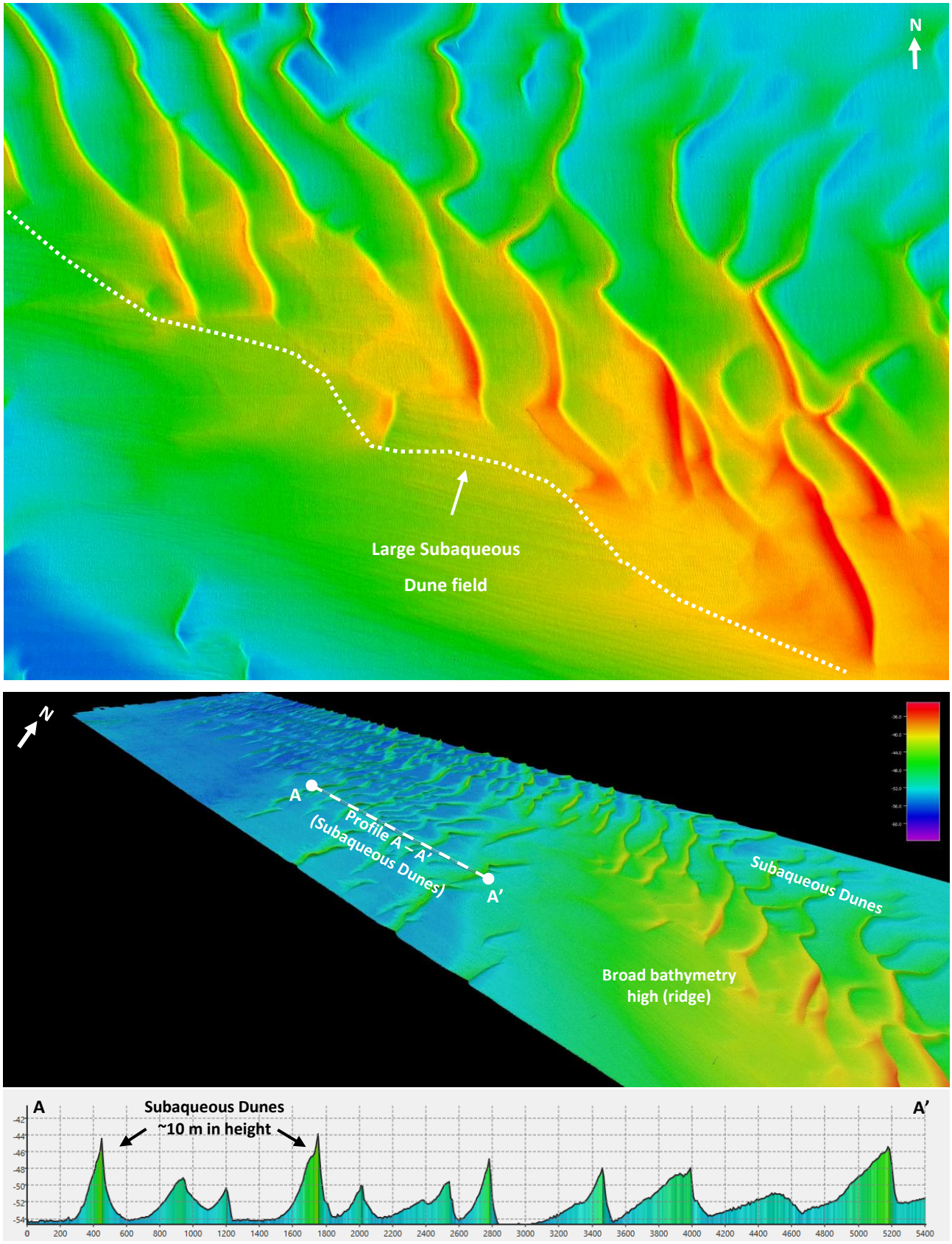

Figure 5. Bathymetry data examples showing a large subaqueous dune field (top, scale ~5.2 km across), and a representative bathymetric profile across dunes in the west with 50x exaggeration (bottom)

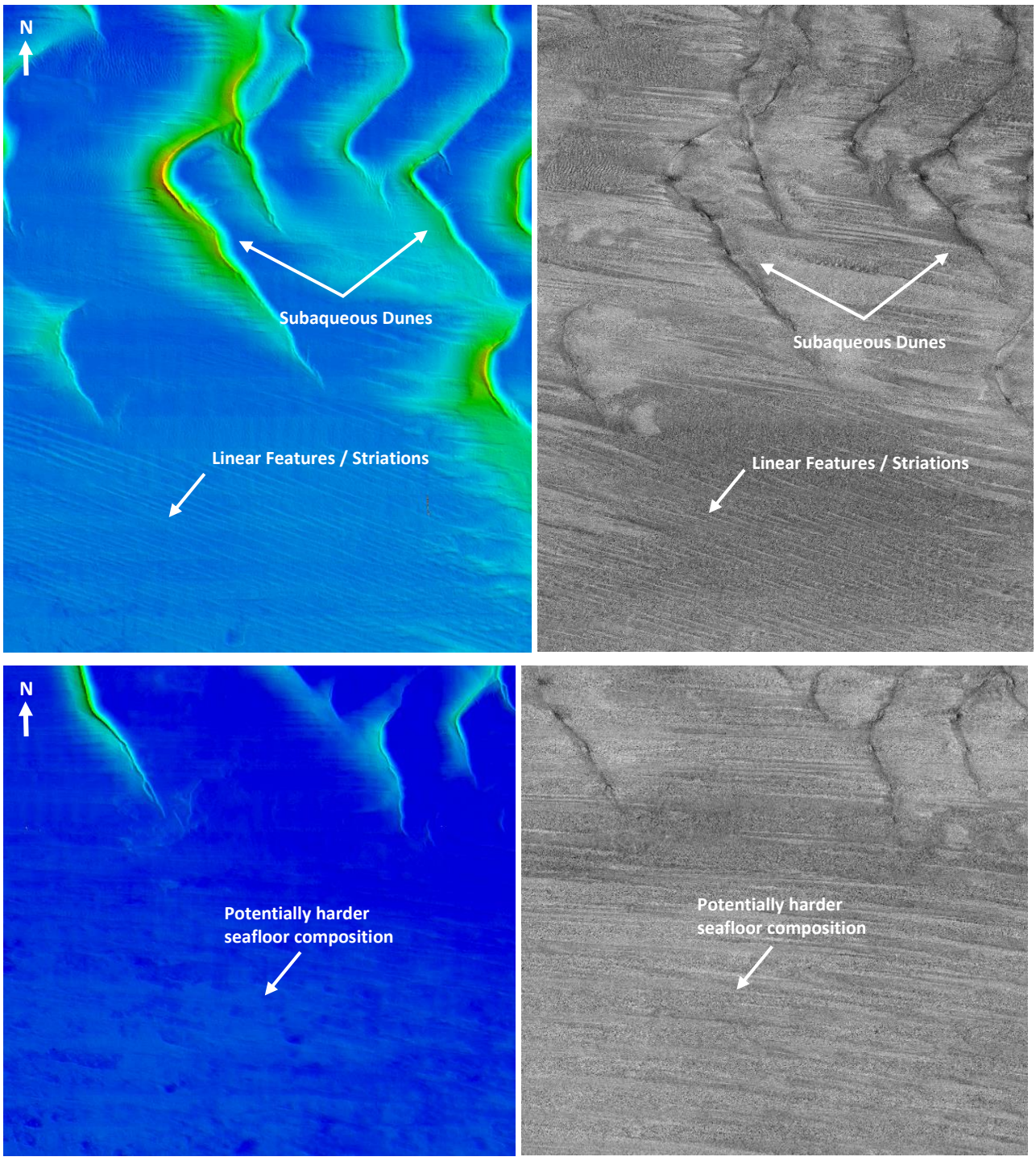

Figure 6. Bathymetry & backscatter data examples. (Top) subaqueous dunes and arcuate linear features (scale ~145 m across), and (Bottom) potentially harder seafloor to the west (scale ~1650 m across)

4 Survey & Processing Details

4.1 Vessel & Equipment

4.1.1 Vessel

The 35 m AMC (Australian Maritime Collage) operated training vessel, *MV Bluefin,* was used for the survey operations.

Figure 7: MV Bluefin

4.1.2 Survey Hardware

The following survey equipment, owned and installed by GA, was used for the survey operations.

ITEM	MANUFACTURER	MODEL	SERIAL NO.
Acquisition Computer	Custom built	Workstation HWS window 7	No. 2
Ancillary Computer	Toshiba (SVP)	Tecra A50-A	4E056637H
MBES (Processing Unit – PU	Kongsberg (Norway)	EM2040C slim PU	127
MBES Transducer	Kongsberg (Norway)	EM2040C dual-swath	1338
Motion Reference System	Applanix	POS MV V5	5810
Motion Reference Unit (MRU)	Applanix	IMU7	2383
SV Sensor (MBES Tx)	Valeport UK	miniSVS	42869
SV Sensor - Profiler	Valeport UK	miniSVS	34826
SV Sensor – Profiler (spare)	Valeport UK	Midas SVX2	44514

Table 5: Survey equipment (Source: GA)

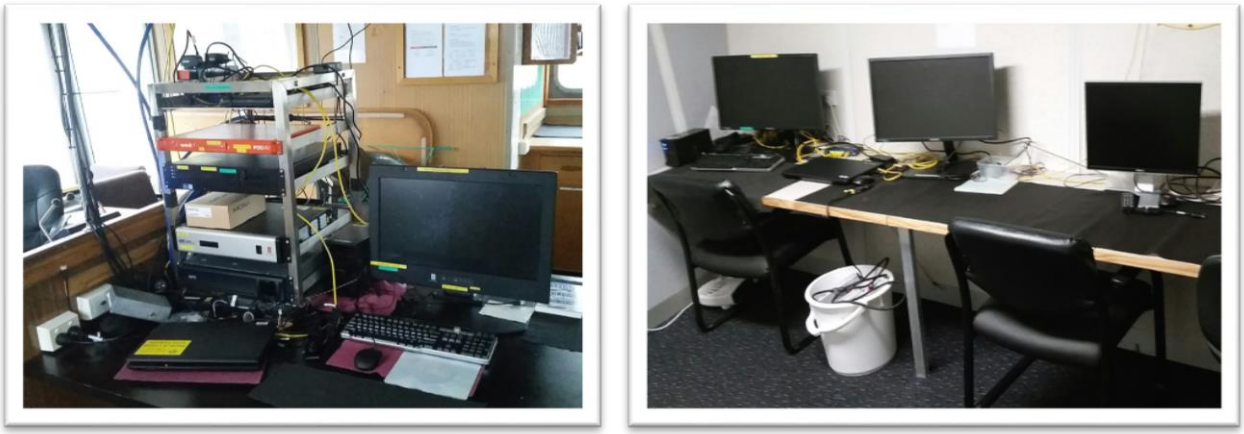

Figure 8: Photographs showing the survey station (left) and processing station (right)

4.1.3 Survey Software

The following GA survey and CSIRO processing software was used on board the vessel.

ITEM	MANUFACTURER/VENDOR	MODEL	VERSION
Data Acquisition	Kongsberg	SIS	4.3.2
Motion Reference Unit	Applanix	POS MV FW	9.29
Sound Velocity	Valeport UK	Data Log Express	G11
MBES Data Processing	CARIS	HIPS & SIPS	10.4
Backscatter Data Processing	QPS	QPS FMGT	7.7.9

Table 6: Survey software (Source: GA & CSIRO)

4.2 Acquisition

4.2.1 General Data Acquisition Information

Survey acquisition was undertaken according to the following criteria:

- A Kongsberg EM2040C single head MBES (with a 1.3° x 1.3° beamwidth) was used to acquire all data. Auxiliary sensors included an Applanix POS MV for position and motion information (aided with a Fugro Marinestar GNSS G2 subscription signal), a Valeport MiniSVS for sound velocity at the transducer and a Valeport MiniSVP (S/N 34826) for water column sound velocity profiles.
- The MBES system was pre-installed and calibrated by GA and provided to the CSIRO as a fully calibrated and operational system.
- The bathymetry data were acquiring using Kongsberg's SIS (Seafloor Information System) software.
- Dual Swath mode (dynamic setting) was utilised throughout the survey to increase the along track resolution.
- A sonar frequency of 300 kHz was selected.
- A long CW pulse was used in the deeper water areas (Boags) and a Medium CW was used in the shallower water sites (Hope Channel & SE Hummock).

- A sector coverage of 63° (Port) and 65° (Starboard) were applied.
- Angular coverage mode was set to Auto and Beam Spacing was set to HD EQDST.
- Vessel speed was typically kept between 8 and 10 knots for the majority of the survey, and reduced to 4 - 6 knots in poor weather conditions.
- Sixteen sound velocity profiles were taken throughout the CSIRO survey campaign.
- Survey cross/check lines were performed at each site for data QC.

4.2.2 Surface Positioning

An Applanix POS MV was used to provide real time surface positioning aided with a Fugro Marinestar GNSS G2 correction signal. The POS MV combines the Inertial Measurement Unit (IMU) and Global Navigation Satellite System (GNSS) data into an integrated navigation solution.

Real time position information was output to the EM2040C processing unit (PU) via RS232 at a frequency of 100 Hertz. Offsets entered into the Applanix POSMV were done to reduce the position information to an arbitrary location (RP) on the vessel.

4.2.3 Heading and Motion Data

An Applanix POS MV was used to provide heading and motion data in real time. Motion and heading was output to transceiver unit via RS232 at a frequency of 100 Hertz. Applanix TrueHeave was recorded for application in post processing.

4.2.4 Multibeam Bathymetry

Multibeam bathymetry was acquired using a Kongsberg EM2040C single head echosounder.

Position data was input directly to the transceiver unit via a NMEA GGA string at 1 Hertz. Time information was input directly to the transceiver unit via a NMEA ZDA sting in conjunction with a 1PPS input via RS232 from the POS MV. Velocity information was input directly via an Ethernet real time output packet at 100 Hertz. Motion and heading data was input directly to the transceiver unit via an EM3000 string at 100 Hertz.

Sound velocity at the transducer was interfaced to the EM2040C acquisition computer at 1 Hertz.

Multibeam bathymetry was corrected for position, motion and sound velocity in real time and recorded in Kongsberg's standard datagram format with the .all extension.

Multibeam bathymetry data was monitored for quality throughout the survey through the Seafloor Information System (SIS) software provided by Kongsberg.

4.3 Processing

4.3.1 Multibeam Bathymetry Data

Multibeam data was logged in the Kongsberg's proprietary *.all format and was converted to be processed within Caris HIPS and SIPS version 10.4. Converted data had sound velocity profiles reapplied using the nearest profile in distance where necessary.

During the merge process in CARIS, predicted tides obtained from AusTide 2018 for Three Hummock Island (referenced to LAT) were applied for initial processing in CARIS on board the vessel. Total Propagated uncertainty was computed, and gridded Combined Uncertainty and Bathymetric Estimator (CUBE) surfaces were created at a 1m resolution for the survey site.

Final post processing of the data undertaken in the office in Hobart, involved additional swath and surface editing of the bathymetry in CARIS HIPS and SIPS to visually remove any remaining outliers, as well the application of True Heave and POSPac derived SBETs (Smooth Best Estimate of Trajectory) files. Applanix's POSPac MMS 8 aided-inertial post-processing software was used to generate these SBET files. POSPac is a post-processing tool that incorporates raw position and orientation measurements, precise clock & ephemeris data (satellite) as well as private (if required) and publically available GNSS base station correction data, to provide, (a) QC of the MBES/GNSS-INS installation biases, and (b) improved vertical and horizontal positional accuracy of the data.

The remote location of the survey areas meant that the only available form of post-processing in POSPac MMS, was the stand-alone "Primary Marinestar Nav" mode (as no appropriately close-by base stations could be used).

Final cleaned CUBE surfaces, referenced to the WGS84 UTM Zone 55 (South) horizontal datum, and reduced vertically to the Australian Height Datum (using the AusGeoid09 model), were generated at 1 m resolution for the survey area.

4.3.2 Navigation, Motion and Time Data

The real-time position and attitude solution was not used for the majority of this dataset and instead the raw logged ranges and azimuths (from GNSS antennas) and angular rates and accelerations (from IMU) were reprocessed. Reprocessing was conducted within the Applanix POSPac MMS 8 software (as described above) using the Marinestar (satellite based) mode to compute a new solution for time, latitude, longitude, height, roll and pitch. From the new solution, new lever arms and angles of the antennas, with respect to the IMU and the RP of the mounting pole, were derived and applied.

The reprocessed dataset (SBET files) were used to overwrite the attitude and motion data that was logged in real time, and were applied to the entire dataset within CARIS HIPS & SIPS.

4.3.3 Backscatter Data

Backscatter information was extracted from the raw .all files using QPS's FMGT (Fledermaus Geocoder Toolbox) software and processed. FMGT performs a number of processing routines on the data such as a correction for gain, angle varying gain, absorption etc. After these corrections were performed, some adjustments were made to achieve the most visually balanced result and thereafter a final 1 m resolution Beam Time Series (BTS) backscatter mosaic was produced for each of the survey sites and exported as GeoTiff images.

Two GeoTiff output options have been provided, the first has a linear greyscale colourmap output and the second is an inverted linear greyscale image. The linear greyscale image displays data with a lower reflectivity (e.g. finer sediments) as a darker appearance, and data with a higher reflectivity (e.g. coarser sediments or rock) as a lighter appearance. The inverted linear option swaps this relationship around. The former is sometimes better for visualisation purposes, but this is largely a personal preference.

In addition to these images, Floating Point Backscatter TIFF files have also been provided, as these maintain the raw backscatter intensity values (captured in the .all file) in their geospatial reference frame.

4.3.4 Water Column Data

Water column data (.wcd format) was acquired for the survey site as an additional dataset. The processing and reporting of these datasets is beyond the scope of this report, and a separate project request would be required to process these data and provide associated products.

4.3.5 Sound Velocity Correction

Sixteen sound velocity profiles were conducted during the survey operations and are shown in Figure 9. The first sound velocity profile (SVP001) was taken in Sawyer Bay near Stanley, prior to the initial transit. For the majority of the time the sound velocity was very consistent per site, and these data suggest that the water column was predominantly well-mixed throughout (as evidenced by the vertically homogeneous profiles).

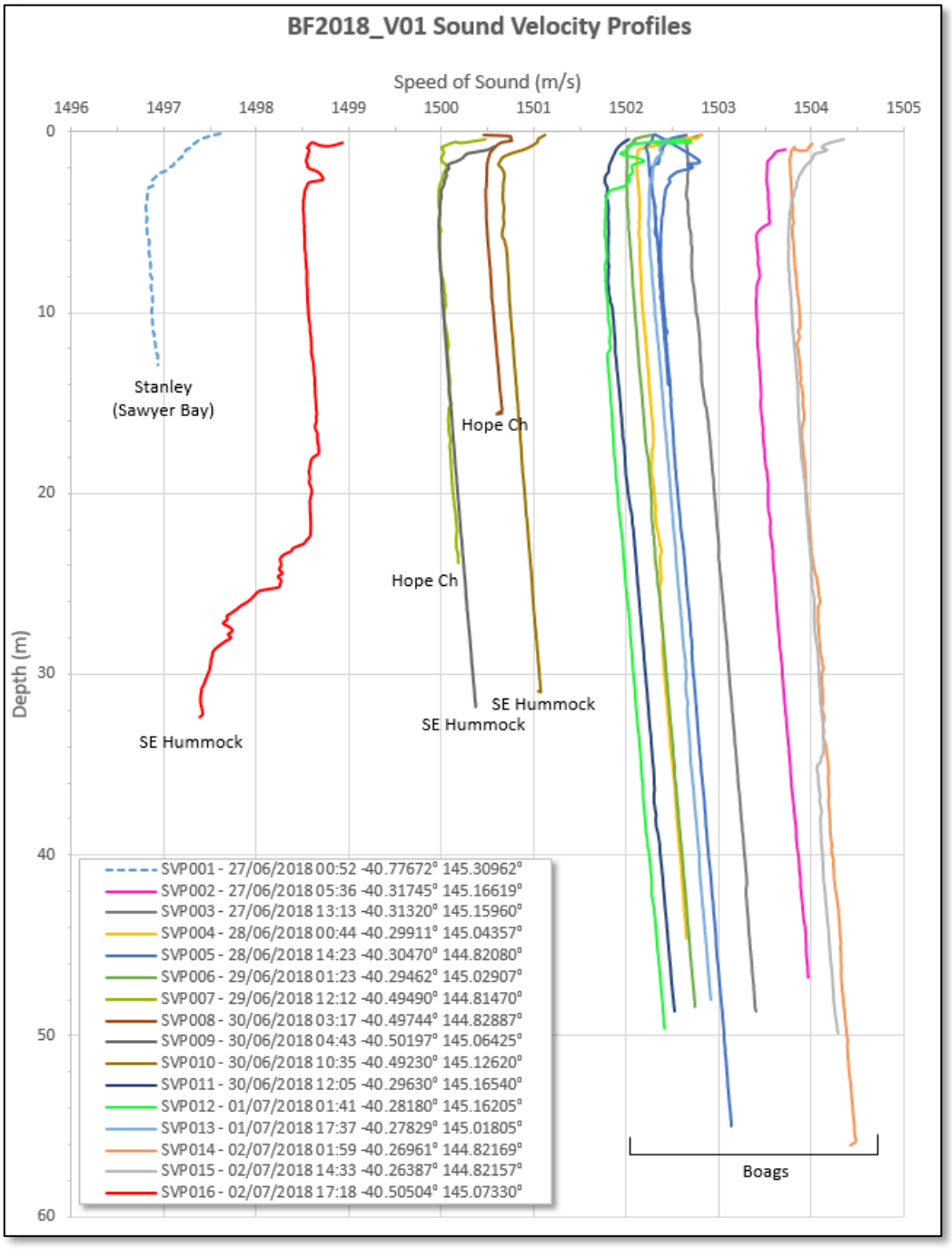

Figure 9: Sound Velocity Casts

4.3.6 Tidal Data Processing

Tidal reduction of the acquired soundings was performed to LAT (Lowest Astronomical Tide) during preliminary processing onboard the vessel (using AusTides2018 for the secondary port of Three Hummock Island, Figure 10).

During post-processing, a final reduction of the data from the ITRF ellipsoid to AHD was performed using the Ausgeoid09 model. According to AusCoastVDT, LAT averages approximately 1.38 m below AHD for the surveyed portion of the Boags Marine Reserve (with a separation of 1.33 m in the west and 1.43 m in the east).

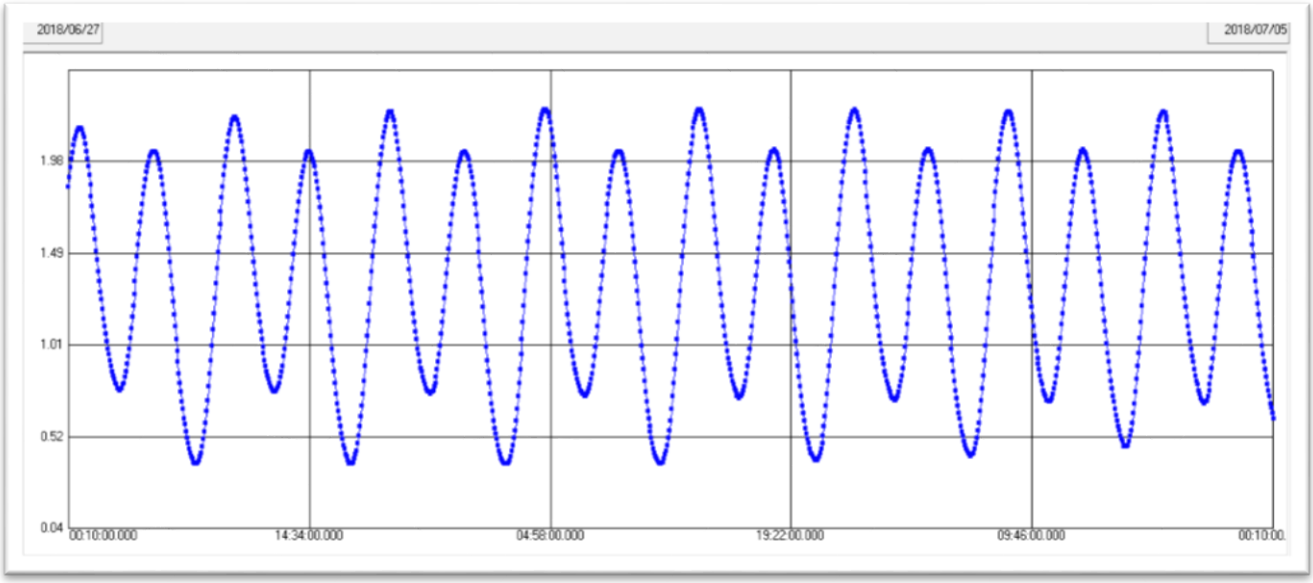

Figure 10: Tidal data (referenced to LAT) for Three Hummock Island from 27 June to 5 July 2018

4.3.7 Waterline

The recording of accurate daily waterline measurements was not possible at sea, and since the vessel did not return to port during the survey campaign, these measurements were not taken. Instead the vessel's draft was noted at the start of the initial voyage (by GA), and a final draft value was recorded (by CSIRO) at the end of the voyage in Beauty Point. These measurements are summarised in Table 7 below.

DATE/TIME (UTC)	FORWARD DRAFT (M)	AFT DRAFT (M)	MEAN DRAFT (M)
17/06/2018	3.10	4.00	3.55
4/07/2018 05:30	2.6	3.95	3.275

Table 7: Waterline/Draft Measurements

The overall average change in draft was 0.275 m over the full duration of the vessel's charter, from 17/06/2018 (for the initial survey with the GA team members) to 04/07/2018 (CSIRO charter). The final waterline measurement used with reference to the sonar setup, was determined by GA to be **-4.186 m**.

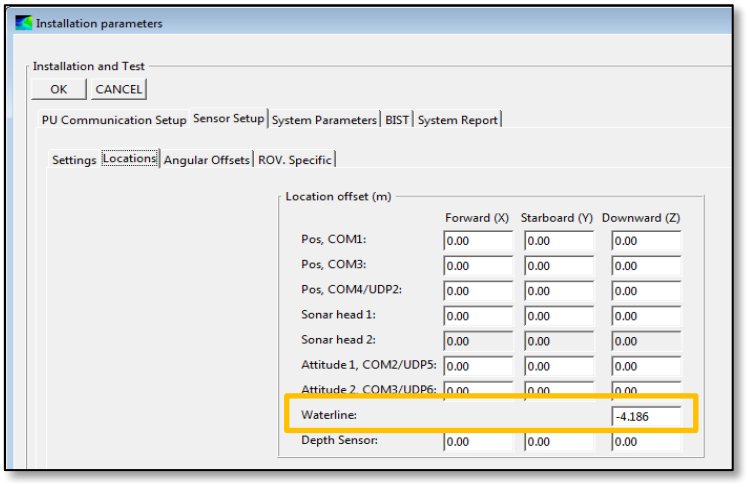

Figure 11: Waterline offset applied in SIS

5 Vessel Configuration

5.1 Sensor Offsets

Sensor offsets on-board the MV Bluefin were provided by GA and are summarised in Table 8, and a screen-capture of the offsets as entered into the POS MV are shown in Figure 12.

SENSOR	X OFFSET FORWARD +VE (M)	Y OFFSET STARBOARD +VE (M)	Z OFFSET +VE DOWN (M)
Sonar Head 1 – EM2040c (Ref)	0.000	0.000	0.000
***Ref to IMU**	-8.340	0.005	-6.455
***Port GNSS Antennae (Pri)**	-8.280	-1.241	-14.493
***Ref to Centre of Rotation**	-7.995	0.542	-4.186
Waterline			-4.186

Table 8: Sensor Offsets (as per POS MV sign convention)

**Please note that the offsets between the Ref, IMU and the GNSS antennae's are reduced by the POS MV before being sent to the EM2040C PU. Offsets between the Ref and the EM2040C Transducer were entered into the SIS acquisition software. As such all data within the .all raw files is reduced to the EM2040C Transducer. They are listed here for information purposes. This is the reason that the vessel file used to post process this data contains mostly zero's.*

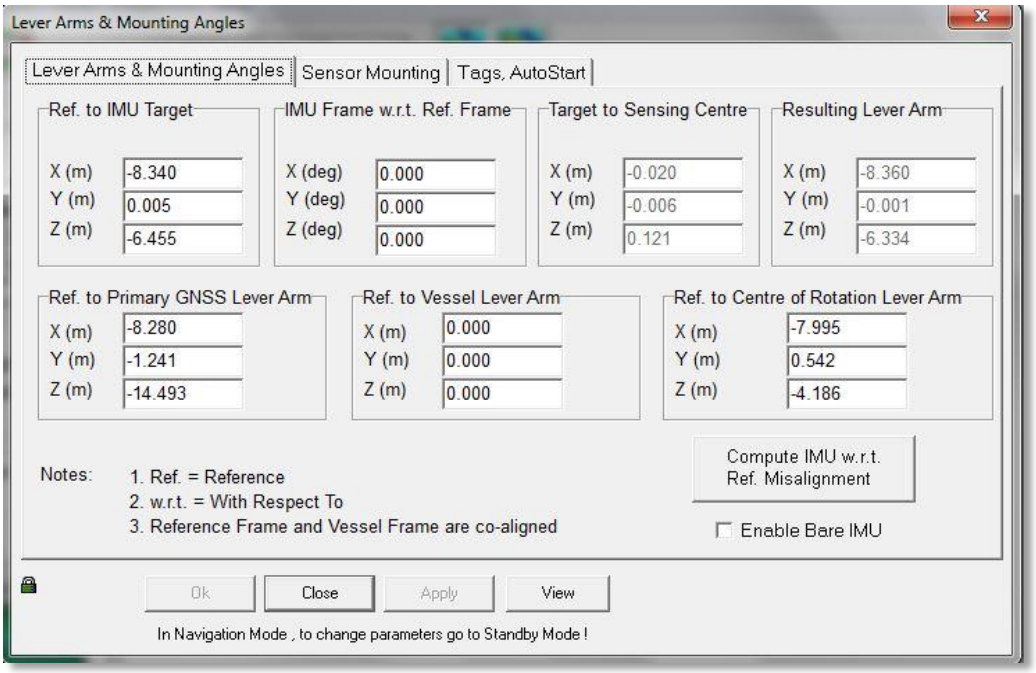

Figure 12: POS MV Lever Arms

6 Calibrations and Checks

6.1 Pre Survey Calibrations

6.1.1 POS MV

The POS MV was calibrated by GA on the 17th June 2017. The calibration, called a GAMS calibration, required manoeuvring of the vessel to induce velocities in the IMU. As such figure of eight style manoeuvres were conducted by the vessel while logging data. The calibration converged in real time and produced a final baseline vector between the primary and secondary antennas as shown in Table 9.

CALIBRATION	X VECTOR (M)	Y VECTOR (M)	Z VECTOR (M)
GAMS (Pri to Sec GNSS)	-0.049	3.648	-0.037

Table 9: POS MV GAMS Calibration Values

6.1.2 Patch Test Calibration

The patch test calibration of the EM2040C was conducted by GA on the 17th June 2018 and the values obtained are summarised in the Table 10 and Figure 13 below.

SENSOR	PITCH (°)	ROLL (°)	YAW (°)
EM2040C Transducer	1.710	-1.180	0.000

Table 10: Patch Test Calibration Values

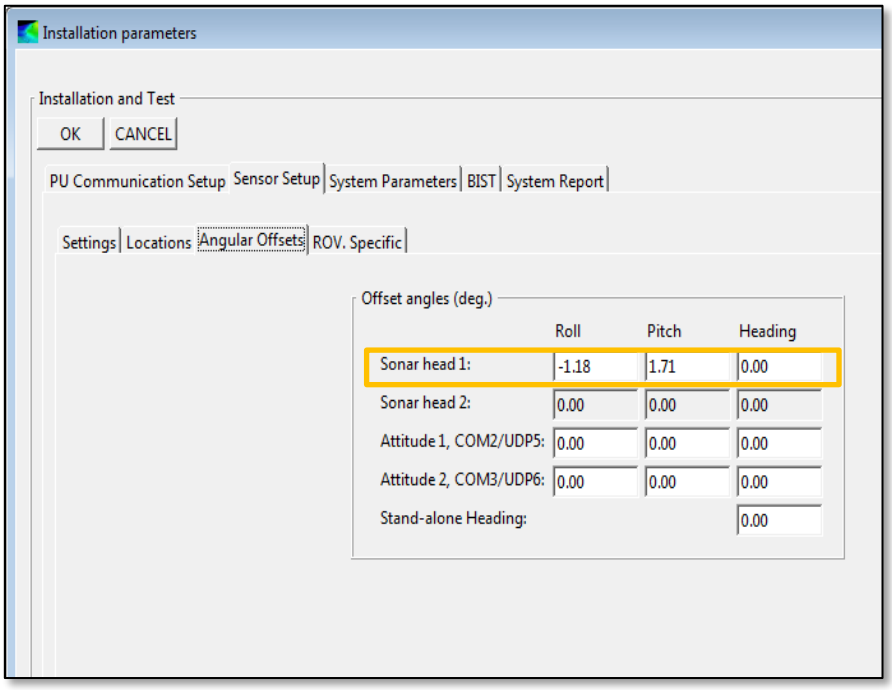

Figure 13: Angular offsets (patch test values) in SIS

6.2 Post Survey Checks

6.2.1 POSPac Adjusted Offsets

After post processing the POS MV "000" data in POSPac MMS 8, it was determined that a lever arm bias was present in the REF to Primary GNSS antenna measurement and in the measurement between the Primary and Secondary GNSS antennae. A series of convergence iterations were run within POSPac until suitable values were obtained. The post processed offsets are presented in Tables 11 & 12.

SENSOR	X OFFSET FORWARD +VE (M)	Y OFFSET STARBOARD +VE (M)	Z OFFSET +VE DOWN (M)
***Port GNSS Antennae (Pri)**	-8.41	-1.35	-14.45

Table 11: POSPac adjusted Offsets

CALIBRATION	X VECTOR (M)	Y VECTOR (M)	Z VECTOR (M)
GAMS (Pri to Sec GNSS)	-0.039	3.648	-0.037

Table 12: POSPac adjusted Heading Vector

6.2.2 Data Check Line Verification

Line QC (or check lines) were performed for the site using lines run perpendicular to, or at an angle across the main survey lines. This was done to verify that the data were meeting the desired survey criteria and standard. From the results obtained, the survey standard was confirmed to conform to IHO Order 1a or better (results presented below).

Checkline 0228_Boags

Beam Angle	**Count**	**Max (+)**	**Min (-)**	**Mean**	**Std Dev**	**Order 1a (%)**
-65.0 - 0.0	1,639,435	3.584	2.982	-0.122	0.132	99.954
0.0 - 65.0	1,630,844	6.293	2.020	-0.029	0.123	99.976

Checkline_0539_Boags

Beam Angle	Count	Max (+)	Min (-)	Mean	Std Dev	**Order 1a (%)**
-65.0 - 0.0	1,775,001	2.592	1.576	0.018	0.132	99.920
0.0 - 65.0	1,809,238	1.736	1.437	0.095	0.129	99.953

Checkline_0714_Boags

Beam Angle	Count	Max (+)	Min (-)	Mean	Std Dev	**Order 1a (%)**
-65.0 - 0.0	2,087,271	2.945	3.481	0.069	0.133	99.939
0.0 - 65.0	1,998,392	3.922	3.326	0.140	0.130	99.964

7 Geodetic Parameters

Positions derived from the POS MV aided with a Fugro Marinestar G2 solution are referenced to the International Terrestrial Reference Frame (ITRF2014). The relevant datum and projection information is summarised in Table 13 below.

7.1 ITRF2014 Datum and Projection

DATUM DESCRIPTION	
Datum	ITRF2014
Ellipsoid	Geodetic Reference System 1980 (GRS80)
Semi-major Axis (a)	6 378 137.000m
Semi-minor Axis (b)	6 356 752.314m
Eccentricity Squared (e^2)	0.006694380
Flattening ($1/f$)	298.257222101
Projection Type	Universal Transverse Mercator (UTM)
UTM Zone	55 S
Central Meridian	147° East
Scale Factor at CM	0.9996
False Easting	500 000m
False Northing	10 000 000m
Latitude of Origin	0° (Equator)

Table 13: ITRF2014 Datum Description

CONTACT US

t 1300 363 400
+61 3 9545 2176
e csiroenquiries@csiro.au
w www.csiro.au

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FOR FURTHER INFORMATION

Oceans and Atmosphere
Stuart Edwards (GSM Team Leader)
t +61 3 6232 5440
e stuart.edwards@csiro.au
w www.csiro.au/en/Research/OandA