AUS SEABED

Australian Multibeam

GUIDELINES

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Marine Biodiversity Hub

Australian Multibeam Guidelines

AusSeabed

GEOSCIENCE AUSTRALIA
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Lead Authors: K. Picard[1], A. Leplastrier[1], K. Austine[2], N. Bergersen[3], R. Cullen[4], N. Dando[1], D. Donohue[5], S. Edwards[6], T. Ingleton[7], A. Jordan[8], V. Lucieer[9], I. Parnum[10], J. Siwabessy[1], M. Spinoccia[1], R. Talbot-Smith[11], C. Waterson[4]

Contributing Authors: N. Barrett[9], R. Beaman[12], D. Bergersen[3], M. Boyd[6], B. Brace[4], B. Brooke[1], O. Cantrill[13], M. Case[14], J. Daniell[12], S. Dunne[4], M. Fellows[1], U. Harris[15], D. Ierodiaconou[16], E. Johnstone[5], P. Kennedy[17], A. Lewis[1], S. Lytton[4], K. Mackay[18], S. McLennan[1], C. Mitchell[1], S. Nichol[1], A. Post[1], A. Price[19], R. Przeslawski[1], L. Pugsley[20], N. Quadros[21], J. Smith[1], W. Stewart[4], J. Sullivan[22], M. Tran[1], T. Whiteway[1]

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[1]Geoscience Australia, [2]EGS Survey, [3]Acoustic Imaging, [4]Australian Hydrographic Office, [5]IXSurvey, [6]Commonwealth Scientific and Industrial Research Organisation Marine National Facility, [7]NSW Office of Environment and Heritage, [8]NSW Department of Primary Industries, [9]University of Tasmania, [10]Curtin University, [11]Department of Transport Western Australia, [12]James Cook University, [13]Queensland Department of Transport and Main Roads, [14]Australian Institute of Marine Science, [15]Australian Antarctic Division, [16]Deakin University, [17]Fugro, [18]National Institute of Water and Atmospheric Research, [19]Land Information New Zealand, [20]Australian Maritime Safety Authority, [21]FrontierSI, [22]Department of Infrastructure, Regional Development and Cities.

Department of Industry, Innovation and Science
Minister for Resources, Water and Northern Australia: the Hon Keith Pitt
Secretary: Dr Heather Smith PSM

Geoscience Australia
Chief Executive Officer: Dr James Johnson
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Record of changes

Version	Date	Change	Authority
Version 1.1	4 June 2018	Version 1.1 Published	Kim Picard
Version 2.0	27 May2020	General updates to most sections reflecting evolution of data processes and community protocols. Requirements for MBES surveys in for Marine monitoring included as a final chapter.	Aero Leplastrier

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1 Introduction

High-resolution seafloor mapping has developed into a significant component of the marine surveying industry in the past few decades, with a rapid growth in demand for this fundamental marine geospatial data. There is a large and increasing number of drivers and applications for this data, including:

- Navigation and safety of life at sea
- Environmental assets management (including Fisheries management)
- Ocean and climate modelling
- Hydrodynamic modelling
- Coastal and nearshore sediment mapping
- Resource development
- Aquaculture planning
- Oil and gas subsea assets integrity
- Telecommunication cable deployment
- Renewable energy assessments
- Marine spatial planning
- Territorial claims
- Demonstration of Antarctic presence
- Underwater cultural heritage management
- Artificial reef development

These applications have resulted in seafloor mapping in locations from the upper reaches of estuaries to the abyssal plains from the tropics as far north as Papua New Guinea to the Southern Ocean to the waters of the Australian Antarctic Territory.

In Australia, apart from port and harbour surveying, much of the focus has been on mapping areas of the continental shelf and slope at varying levels of coverage and resolution, which reflect the drivers for mapping, vessel and gear availability, and the combination of targeted and opportunistic data collection. However, despite a significant increase in survey coverage in the past decade, less than 25% of the seafloor in Australia's maritime jurisdiction has been mapped to a relatively high-resolution.

Since only the narrow coastal margin of the seafloor can be detected by airborne or satellite sensors (e.g. lasers; multi-spectral scanners), swath acoustic mapping systems, principally multibeam echosounders (MBES) and bathymetric sidescan sonars (interferometric sonar), are used to map Australia's seafloor. These systems measure water depth, seabed backscatter (commonly known as seabed hardness), and in some cases with MBES, water-column backscatter. Multibeam sonar data is acquired by a wide range of organisations, however, to better realise the value of the data collaboration is needed to build broad regional and national seabed data sets and data needs to be acquired to a common standards. This data needs to be openly available, and easily accessible for reuse to benefit the wider community (Table 1).

The primary objective of this guideline is thus to establish common approaches to the acquisition and processing of MBES data. Use of these guidelines will improve consistency in the collection and description of the data, enhancing its quality and utility.

To achieve this objective, AusSeabed was formed, a national seabed mapping coordination program run by a consortium of representatives from Commonwealth and State governments, universities and industry. AusSeabed's role is to encourage and facilitate the acquisition of seabed mapping data and make it available for use by all stakeholders. As such, the program runs a series of coordinated initiatives, including:

- the production of maps identifying priority areas for Commonwealth and State Government agencies
- maintenance of the **Australian Multibeam Guidelines** (this document)
- the AusSeabed website hosting various resources, survey planning and data management tools, including a data portal.

Table 1 Key stakeholders benefiting from better coordination and availability of seabed mapping data and the type of data they preferentially use (note the list is not exhaustive, but intended to give examples)

Stakeholder	Preferred data type	
	Source data (raw or processed files)	Products (e.g. maps of seabed depths, habitat, morphology)
Department of Defence (e.g. Hydrography, Mine warfare)	X	X
Marine parks (Australia or States Marine Parks)		X
Department of Industry, Innovation and Science (e.g. NOPSIMA)		X
Industry (Oil & Gas; Infrastructure)	X	X
State coastal planning and management groups		X
Maritime Jurisdiction (Geoscience Australia)	X	
Australian Tsunami Advisory group		X
State and Commonwealth research institutions (e.g. CSIRO, Geoscience Australia, State environment and fisheries agencies)	X	X
Universities	X	X

Overall these initiatives aim to achieve a number of specific objectives, including:

- collation of a historically sorted dataset at an identified level of quality available to all stakeholders within Australia and beyond
- identification of areas where new data is needed most
- enabling stakeholders to better leverage Australia's seabed mapping expertise and capabilities

- providing tools to allow efficient and consistent pre-survey planning
- promoting collaboration and innovation with stakeholders
- utilising national resources and efforts to map Australia's seabed
- providing clear guidelines that aim to improve data acquisition methods and compliance with recognised standards
- increasing data availability for stakeholders
- ensuring better informed management of Australian waters through easy access to a larger set of standards-compliant seabed data

1.1 Scope

The Australian Multibeam Guidelines were established by the AusSeabed consortium. The guidelines provide recommended procedures for survey planning, data acquisition and submission, from the pre-survey planning phase to the data submission phase. They are designed for a range of audiences, from those experienced in seafloor mapping using multibeam sonar systems, non-experts who are developing mapping capabilities, and those contracting seafloor mapping surveys using swath systems.

These guidelines aim to improve interoperability, discoverability and accessibility of MBES system data, and encourage improved acquisition standards to better meet end-user requirements. We acknowledge that to achieve such an aim, adaptation of the project might be necessary and could impact time and cost. However, in most cases, the inconvenience of varying parameters will be outweighed by the increased utility of the data to a wider user base.

These guidelines provide a minimum set of requirements for seafloor mapping activities conducted in Australian waters. They are designed to complement the purpose-based requirements and associated documentation related to specific survey requirements (e.g., hydrographic surveys; seabed infrastructure planning or installation) (Figure 1).

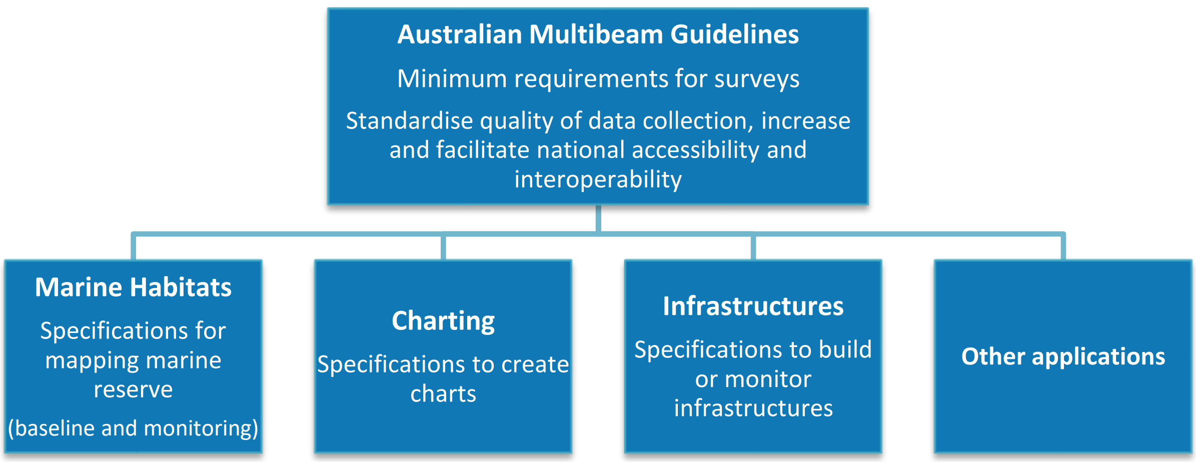


Figure 1 Anticipated key areas of relevance for the Australian Multibeam Guidelines.

The guidelines include a broad examination of data processing and guidance for data submission (Figure 2) with recommendations for all three types of swath acoustic data (bathymetry, backscatter and water column backscatter) relevant across all water depths and adopt international guidelines where appropriate. They do not include instrument preparation activities such as bench/workshop tests, personnel requirements, or provide survey costing information (see section 5.3.4 of Przeslawski et al. 2018a for MBES Costing). This revision of the Australian Multibeam Guidelines (version 2) contains information previously published in the *Seafloor Mapping Field Manual for Multibeam Sonar* (Lucieer et al., 2018) as chapter 8 (*Multibeam acoustics for marine monitoring*) and, as such, will also succeed the *Seafloor Mapping Field Manual for Multibeam Sonar* as chapter 3 in the second release of the National Environmental Science Program (NESP) *Field manuals for Marine Sampling to Monitor Australian Waters* (Przeslawski and Foster, 2018). The decision to make this extension to the guidelines and inclusion in the NESP suite of Field Manuals was made by AusSeabed and the NESP to allow both initiatives to continue with a single reference document to inform seabed mapping and eliminate the complications and community confusion associated with the maintenance of two reference documents with extensive overlap.

1.2 How to use guidelines

To help navigate these guidelines, Table 2 identifies sections that are more relevant to various user-groups. Glossaries of abbreviations and terms are included in appendices A and B, and a variety of tools and resources available are included in Table 3. Some tools are still under development and will be shared through the AusSeabed website.

These guidelines do not include a full and comprehensive technical description of MBES systems, but rather, provide a list of pertinent references, such as Hughes-Clarke (2017a). They also refer to related guidelines where relevant.

Table 2 Relevance to the various user groups by document section number. However, all stakeholders will find useful information in all sections

Section	Non-expert groups	Expert groups
1 Introduction	All	All
2 Pre-survey planning	All	2.1; 2.2; 2.4; 2.5; 2.6
3 Mobilisation, Calibration & Validation	3.1; 3.9	All
4 Acquisition	4.1; 4.6	All
5 Processing and Rendering	5.3	All
6 Reports	All	All

1.3 Related standards and publications

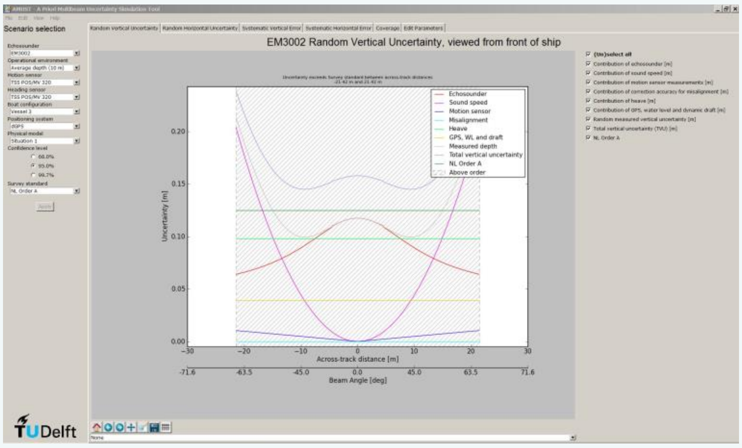
The following publications provide information to underpin the collection of geospatial data and augment these guidelines. The complete references can be found in section 9, but the most recent published versions of key documents are:

1. AHO, 2017. Hydroscheme Industry Partnership Program - Statement of requirements
2. AHO. Hydrographic Note, Australian Hydrographic Office
3. AHO. Seafarer's Handbook for Australian Water (AHP20)
4. CHS, 2013. Hydrographic survey management guidelines
5. Mills J. and Dodd D., 2014. Ellipsoidally Referenced Surveying for Hydrography. FIG Publication No. 62
6. GeoHab Backscatter Working Group, 2015. Backscatter measurements by seafloor-mapping sonars: Guidelines and Recommendations.
7. Godin, A., 1998. The Calibration of Shallow Water Multibeam Echo-Sounding Systems, Technical Report No. 190.
8. Hughes-Clarke, J.E., 2003. A reassessment of vessel coordinate systems: what is it that we are really aligning?
9. ICSM, 2018. Geocentric Datum of Australia Technical Manual.
10. ICSM, 2004. Australian Tides Manual (SP9).
11. ICSM, 2014a. Guidelines for Control Surveys by GNSS (SP1).
12. ICSM, 2014b. Guidelines for Control Surveys by Differential Levelling (SP1).
13. ICSM, 2014c. Standard for the Australian Survey Control Network (SP1).
14. IHO, 2008. IHO Standards for Hydrographic Survey, (S-44)
15. IHO, 2013. Manual on Hydrography (C-13).
16. IHO, 2015. INT1 Symbols, Abbreviations and Terms used on Charts.
17. IOGP, 2018. Seabed Survey Data Model (SSDM)
18. Lamarche G. and Lurton X., 2017. Recommendations for improved and coherent acquisition and processing of backscatter data from seafloor-mapping sonars.
19. LINZ, 2016, Contract Survey Specifications for Hydrographic Surveys, Vers. 1.3
20. Lucieer V. et al., 2017. Seamap Australia
21. Przeslawski R. et al., 2018. NESP field Manual for grab and box core sampling

2 Pre-survey planning

The acquisition of data is the most expensive element of a seabed mapping project. Therefore it is essential that this phase of a survey is optimised by undertaking adequate pre-survey planning. This section of the guidelines identifies key aspects of the planning phase that can be improved for more efficient and effective surveys. They also present tools and resources available that can help (Table 3). These resources are also hosted on the AusSeabed website, and we encourage using the website to discover the full breath of available resources and future updates. The IHO C-13 Manual on Hydrography also provides an appendix on planning considerations and how to best calculate survey timings.

Table 3 Summary list of pre-survey planning tools proposed in the section

Tool or Resource	Description
Upcoming Survey Register	Register the survey to encourage collaboration and contribute to national coverage
National Coverage	Coverage of MBES dataset by various agencies.
Seabed Survey Data Model	The SSDM is a GIS model that has been developed since 2010 by the International Association of Oil & Gas Producers (IOGP) to facilitate management, integration and sharing of survey data at all levels, i.e. international, national, local, etc. (IOGP, 2017).
A priori tools	These tools help to determine expected uncertainties for a system.
1) Amust	Amust link points to a registration page on the Rijkswaterstaat (Dutch Hydrographic Service) website. See also Appendix E for a list of possible errors to take into account. 
2) Hydrobib	Hydrobib provides integrated utilities for survey planning. It is more specific to R2Sonic echosounder, but can be adopted for other echosounders.
Datum tools **1) VDatum** **2) AusCoastVDT**	 1) Designed to vertically transform geospatial data among a variety of tidal, orthometric and ellipsoidal vertical datums. 2) A vertical datum transformation tool for the Australian coast.
Line planning tool	Most survey acquisition software packages (QPS, EIVA, HYPACK) have line planning capability built into them. See also **Hydrobib** above

2.1 National coverage consultation and upcoming survey register

AusSeabed is currently developing a suite of pre-survey to view the current extent of national bathymetry data holdings, consult a map of national seabed mapping priority areas, and utilise a survey coordination tool to register and query upcoming surveys. These tools are aimed at providing seabed mappers with information to promote collaboration in areas of common interest and eliminate repeat collection. This initiative is likely to benefit all parties by reducing overall costs and facilitating more efficient collection efforts in Australian waters.

Seamap Australia is a complementary mapping and analysis service that provides information about the Australian shelf (e.g. seafloor imagery, habitat classification) that may also inform proposed mapping areas (Lucieer et al., 2017).

2.1.1 Existing Data coverage

Before planning a survey we recommend consulting the Bathymetry coverage layer hosted on the AusSeabed website to avoid the collection of duplicate data. The identify tool in this portal provides metadata information for each coverage polygon submitted to AusSeabed. This ensures that users are able to attain data custodian and contact details for surveys already conducted that might meet some or all of their needs. The layer contains the spatial extents and metadata of all surveys submitted to Geoscience Australia (GA) by AusSeabed collaborators and external third-parties. It is being continually developed to display national data coverage, with input from an increasing number of organisations.

The GA MARS database contains information on seabed sediment samples collected in Australian waters, analysed, and provided to GA. Links to other data samples collected by different entities is acknowledged as an item for future development..

2.1.2 National Bathymetry priorities

The AusSeabed website also hosts an interactive map of national bathymetry priorities that describes areas that are considered important to government in terms of safety of life at sea, conservation, and environmental monitoring. It is recommended that this tool be consulted in the early stages of survey planning to see if the voyage will be covering any areas of government interest.

2.1.3 AusSeabed Coordination Tool

It is also highly recommended that the upcoming survey layer is consulted on the AusSeabed portal in the early stages of survey planning to look for collaboration opportunities should there be other organisations planning to carry out work in areas of close proximity. Upcoming survey plans can be registered using the AusSeabed Coordination Tool to enable further collaboration and future tracking of new data. The tool allows users to display the planned extent and details of an upcoming survey and collects a set of metadata that are considered a minimum for any seabed mapping activity (section 2.3.1.3) that can be utilised for the survey report and data submission following the survey. If desired, a more detailed planning document can also be attached. To request a user log in for access to the survey coordination tool email ausseabed@ga.gov.au.

2.2 Research and survey permits

Various permissions are required to undertake research in Commonwealth, State and Territory waters. Due to the complexity of laws and intersecting jurisdiction's, information on this page should be treated as a guide only and information from the relevant governing bodies should be consulted to ascertain that the correct permissions have been acquired prior to any research undertaking.

Operators should contact and inform relevant national and local authorities well in advance of any intended survey work ashore and afloat. These include the local harbour authority that should be consulted at all stages of the planning and execution of any harbour surveys, marine reserves, etc. Be mindful that approvals and permits (e.g. Environment Protection and Biodiversity Conservation, Environmental Plan, local marine parks permits, etc.) may be needed before undertaking a survey. Legislation for approvals is slightly different in each state. More information regarding legislation and permitting can be found on the AusSeabed website. Appendix C provides a list of Authorities that may need to be consulted and some links to general research permits for state waters.

2.3 Seabed mapping data collection considerations

The **objectives** of MBES surveys conducted by mapping programs are to collect seafloor data to identify, delineate and map biogenic, anthropogenic and geological features. This objective requires particular data to be collected that can a) chart the water depths creating a high resolution bathymetric map at an appropriate resolution in regards to the target habitat or feature and b) be able to differentiate boundaries between different substrate and/or habitat types.

This national guideline provides the minimum requirements for all seabed mapping activities to enable national coordination and compilation. It is thus designed as an overarching document that can be complemented by more specific requirements of some surveys. If data collection is for charting purposes, consult the Australian Hydrographic Office. The application of these guidelines to marine monitoring has been included as a case study in chapter 8 that outlines the mandated best practice data and metadata requirements, QA/QC and data submission practices for baseline surveying or more targeted feature monitoring. The chapter 8 information supersedes the information previously published as part of Chapter 3 of the NESP MBES field Manual (Lucieer et al., 2018) and should be consulted prior to any work being done in Australian Marine Parks or protected areas. Appendix D provides some approximate planning timeframes as a guide for the various activities related to seabed mapping surveys.

2.3.1 Data type, formats, and metadata

In 2019, AusSeabed held a workshop on data formats and metadata attributes to establish an agreed set of preferences for the delivery and acquisition of seabed data. The outcomes of that workshop underpin the information presented in the following sections, as a set of best practice policies to maximise the utility of collected open data.

2.3.1.1 Data type

The types of data derived from a MBES survey are:

- bathymetry: essential
- seabed backscatter: essential
- water column backscatter: encouraged

The minimum essential requirements of any seafloor mapping survey are the bathymetric data and seabed backscatter data (the collection of which may require manual activation). Water column backscatter data acquisition is encouraged if the system can collect it. In addition to scientific applications, water column data is a common method used to confirm least depth over features and to identify bathymetric artefacts. It is both used in terms of 3D visualisation of the seabed and in observing oceanographic turbulence, such as internal waves, which may result in bathymetric artefacts (Hughes-Clarke, 2017b).

2.3.1.2 Data levels and file formats

Consistent definitions of data levels allow the community to reduce ambiguity when discussing, delivering, processing or describing data. The AusSeabed definitions of data levels has been modelled on those prescribed by NASA for Earth Observations data products. The following definitions were discussed, refined and agreed to at the 2019 AusSeabed metadata and standards workshop (Table 6).

Table 4 AusSeabed Data Level Definitions

Level	Definition	Examples			
		MBES	Delayed Heave/ Ellipsoid/Nav	SVP	Tide
L0	**Unprocessed instrument data** Unprocessed/raw instrument data at full resolution as received from the sensor. Includes MBES and ancillary files as well as any and all artefacts.	Observed by sensor *.all	Observed by sensor *.000	Observed *.raw	Observed, proprietary formats
L1	**Data merged with ancillary information** Reconstructed L0 MBES data undergoes correction with ancillary information either from within the L0 data itself or the separately calculated ancillary files collected by the ancillary system (e.g., delayed heave and svp). This level may include radiometric and geometric correction and calibration, but not cleaning.	Processed depth Integration of L1 ancillary information (uncleaned and unfiltered)	N/A: Data proceeds straight to L2		
L2	**Derived geophysical/georeferenced variables** L1 data undergoes cleaning and filtering to create the first 'usable' multibeam data.	Bathymetry product Cleaned & filtered	Processed to SBET	Processed to *.txt	Processed to *.txt
L3	**Variables mapped on a grid** L2 data undergoes additional processing/value-adding to create L3 products. Variables mapped on uniform grid scales, with some consistency to produce charts/gridded products etc. L3 products cannot be backwards engineered into L2.	Additional value added, or data sampled (e.g. chart, slope map, geomorphology)	N/A: L2 is the final 'product' for ancillary data types, and not all ancillary data have an L1 form. For the majority of commercial software available, backscatter data is progressed automatically through the L1 and L2 stages and saved directly as an L3 final product.		

A set of data formats has been recommended for each of the data levels and types described above based on community consultation. Delivering processed data outputs in as many of the preferred formats as possible ensures that data can be utilised easily by the wider community, increasing the net benefit of the data. It should be noted that, when available, open source formats are always preferred over proprietary formats, for any sensor, at any data level.

Table 5 Preferred data formats by data type and level.

Level	Notes	Preferred Formats			
		Bathymetry	Backscatter	Navigation	Ancillary Data
L0	L0 data is native format, as recorded by the sensor. It should include all necessary datagrams required for a comprehensive bathymetry and backscatter processing, including raw backscatter per beam (BA) and raw backscatter in time series (TS), and all required ancillary data. Water column data is recommended and if possible should be stored in a separate file. *Navigation data currently has no open source format options. Also for nav/attitude data time zone should be in UTC and projection should be WGS84, ITRF, or GDA2020 with an ellipsoidal height datum.	**Priority 1** • .all (.mb56, .mb58), .s7k (.mb88), .kmall (.mb261), .xse (.mb94) **Priority 2** • .gsf (might be only format possible for R2sonic **Priority 3** • XTF	**Priority 1** • Same as for bathymetry and also other proprietary formats that solely collect backscatter/ sidescan.	**Priority 1*** • Any proprietary formats that contain navigation and attitude (for example .000).	**Priority 1** • ASCII (txt, csv) of raw observations including georeferencing and time. **Priority 2** • Proprietary formats
L1	L1 should also include all raw data as required in L0 that allow for processing at any stages if required. Header information and sign convention are required to accompany ASCII point cloud.	**Priority 1** • .gsf, .las/.laz **Priority 2** • Any proprietary data formats **Priority 3** • ASCII point cloud	**Priority 1** • .gsf **Priority 2** • Proprietary formats	**N/A**	**N/A**
L2	If you are going to provide L2 data you should also include all raw data (including auxiliary data) in L0 format that allow for processing at any stages if required. L2 should contain data that is of L3 reproducible product.	Identical to L1 as L2 is mostly done within L1 producing software	Identical to L1 as L2 is mostly done within L1 producing software	SBET data + RMS (for generation of TPU)	**Priority 1** • Text files: (ASCII .txt, NetCDF, .csv) **Priority 2** • Proprietary

L3	L3 should include sounding density and uncertainty. Header information, sign convention, and horizontal and vertical datum are required to accompany any ASCII formats. Separate .asc files for respective sounding density and uncertainty need to accompany the main depth .asc file. This also applies to any data types that are restricted to a single layer/band. Specifications needed for ASCII xyz include metadata for xyz, header information in metadata, positive/negative depth field, and vertical datum.	**Priority 1** • BAG (v1.6.4) • 32-bit floating point GeoTIFF (.tiff) **Priority 2** • ASCII XYZ • .las/.laz	**Priority 1** • 32-bit floating point GeoTIFF (.tiff)	**Priority 1** • ASCII XYZ and sensor trackline shape file (GeoJSON)	**N/A**

2.3.1.3 Metadata

Metadata consistency is an essential aspect of data management and a key step in the move to coordinate a comprehensive national repository of seabed data in the Australian marine estate. The following list of metadata outlines the minimum set to meet ISO 19115.3 standards. The AusSeabed community propose that best efforts are made by collecting and processing institutions to utilise these fields. Appending organisation specific fields is acceptable but such fields should not be used in place of the fields below (Table 6). An example template with descriptions of the metadata fields to assist organisations in "mapping" metadata information is included in appendix H.2.

Table 6 Overview of required metadata.

Metadata Category	General	Citation	Survey	Technical
Metadata Fields	• Survey Title • Survey ID • Abstract • Lineage	• Data Owner • Custodian • Country (data ownership) • Collecting Entity • Attribution Licence • Legal Constraints • Access Constraints • Use Constraints	• Survey Area (general) • Bounding Box • Coordinate reference system-bounding Box • Coordinate reference system–Survey Data • Geodetic Datum of the survey • Horizontal datum • Vertical datum	• Instrument type • Sensor type • Sensor Frequency • Platform type • Platform name

This set of metadata is not exhaustive, and a large number of specific survey, calibration and acquisition parameters need to be recorded in addition to the above information to ensure complete documentation of the survey process. These are categorised and detailed in the section 6.1 which outlines the Mobilisation, Calibration and Validation reports.

2.3.2 Survey area characterization

Operational requirements, gear availability and technical capacity will determine the most appropriate type of MBES system to use (see Bathyswath for general system type information). The characteristics of the survey area and mapping requirements are also key issues to consider, including:

- survey duration and size of the area
- depth range as this will affect line planning (section 2.5.5) and acquisition parameter settings (section 4.3)
- wind and wave conditions and seasonal weather changes
- tidal regime and tidal infrastructure
- feature detection and sounding density requirements; reflected in required pulse repetition (ping rates), swath width and survey speed
- the nature of the seabed, which is important for seabed backscatter data acquisition (section 4.3.2). If one of the objectives of the mapping is to understand the nature of the seabed and to predict it over the area of interest, seabed sediment sampling/imaging needs to be considered (section 2.6).
- water column anomalies and feature anomalies, which may benefit from recording seabed water column backscatter (section 4.3.2)
- the time of year and relevance to whale migrations for low frequency instruments
- potential interactions with surface fishing gear

2.3.3 Data representation (seafloor coverage and resolution)

Data representation, with respect to seafloor coverage, depends primarily on the MBES system utilised. For MBES systems, data representation will be dependent on the beam width of the system and the associated footprint on the seafloor (Table 4). It is important to consider that the data representation of the final output has to be greater or equal to the beam footprint. For bathymetric sidescan, however, the sounding interval on the seafloor is constant. For more details on the two systems, refer to Bathyswath.

Horizontal and vertical accuracy are two key factors of resolution that should also be taken into consideration when choosing the right equipment or designing a survey plan (sections 3.3 and 3.4). These can be assessed by listing all sources of error and calculate interactively the total propagated uncertainties of a sounding (TPU; section 5.2). The Total Vertical Uncertainty (TVU) must not exceed the depth accuracy, and total horizontal accuracy (THU) actually refers to the accuracy of the position of sounding on the seafloor and not the accuracy of the GPS [GNSS] position of the survey vessel alone. Survey speed can also affect the data representation and accuracy (Hughes-Clarke, 2017b).

If data representation is not the primary driver in the choice of the system to use, it is recommended that data be collected at the best resolution achievable by the system.

Table 7 MBES footprint (m) at nadir and beam width (deg). The beam footprint for a MBES increases in the outer beams.

		Beam Width (deg)					
DEPTH (m)		**0.5**	**0.7**	**1**	**2**	**3**	**4**
	10	0.09	0.12	0.17	0.35	0.52	0.70
	25	0.22	0.31	0.44	0.87	1.31	1.74
	50	0.44	0.61	0.87	1.74	2.62	3.49
	75	0.65	0.92	1.31	2.62	3.92	5.23
	100	0.87	1.22	1.75	3.49	5.23	6.97
	250	2.18	3.05	4.36	8.72	13.08	
	500	4.36	6.11	8.73	17.45		
	1000	8.73	12.22	17.45			
	1500	13.09	18.33				
	2500	21.82					

It is important to highlight that identification of features of specific sizes rely on a combination of parameters. It is generally accepted that when using side scan sonar as the feature detection tool, that a minimum of five boresight hits are made on the feature target. When using MBES as the feature detection tool, the common requirement is to achieve a minimum 3 along track hits and 3 across track hits on the feature target. The above requirements are to be considered conservative and in line with accepted sampling theory. Refer to section 7.5 from AHO (2018) for further information.

The general formula to calculate the depth at which five pulses should ensonify a target of a given size at different speed is (GBHD, 1996):

$$D = \frac{\left(Sx\left(\frac{1852}{3600}\right)x\left(\frac{5}{prr}\right)\right) - t}{2\tan\left(\frac{\phi}{2}\right)}$$

Where:

D = least depth of detection (metres below transducers)

S = speed in knots

t = along track dimension of target to be detected (metres)

ф= echo sounder's beam width (fore and aft) in degrees.

prr = pulse repetition rate (pulses per second (Hz))

2.3.4 Quality assessment / uncertainty scheme

The International Hydrographic Organisation (IHO) publishes a document for hydrographic standards – IHO Special Publication (SP-44). Appendix G of this publication details a range of survey standards for varying purposes. By surveying and providing data to these minimum standards, a collaborative approach to providing safe maritime navigation in future surveying areas can be assured in areas where there may be a future need to conduct operations.

However, these standards may not fit the purpose of the survey or be flexible enough (Figure 1). Therefore, it is recommended that each parameter be evaluated separately when planning a survey. Consideration should be given to other user specifications or requirements, such as Port Authorities and Marine Parks, as these could also be met with little additional time, effort or cost (e.g. PPA, 2017, Lucieer et al., 2018). The data would then benefit more users and contribute to the National Seabed Mapping effort.

Regardless of the standards used, it is important to provide quality and uncertainty statements based upon calibration and validation evidence to ensure consistency. These should be quantitative statements where numerical analysis is conducted e.g. TVU = +/-0.1m, THU = +/-1.0m.

2.3.5 Platforms & Systems

Seabed mapping can be conducted from a variety of platforms, including ships, which can have hull or pole-mounted systems, towed-platform or automated underwater and remotely operated vehicles (AUV and ROV respectively). While this guideline provides information that applies to any platform, this section only provides general information on the various platforms and does not address the specific requirements of each. Refer to the material referenced for more information.

2.3.5.1 Hull or pole-mounted systems

A hull-mounted system refers to a system fixed to the vessel, and is the most robust way to mount a transducer. However, due consideration must be given to the effects of acoustic interference and bubble sweep down over the face of the MBES transmit and receive arrays.

A pole-mounted system refers to a system fixed to the end of a pole, which is commonly mounted to the side or the bow of the vessel. They are commonly used for smaller installations, allowing for permanent or deployable mounting. Rigidity and minimisation of the vibration of the pole are key to acquiring good quality data. It is also recommended that where possible, the motion reference unit (MRU) be installed and 'tightly coupled' on the pole at the transducer.

For deployable pole-mounted systems, it is important to consider that every time the system is deployed, there should be assurance that the system returns to exactly the same position in order to negate the requirement for another patch test. An operating check, which is less robust than a patch test but verifies the mount is returned to the correct position, should be conducted if the pole is reset. This may be as simple as performing cross perpendicular lines over a significant feature and analysing for incorrect alignments.

Regardless of which method is used to deploy the swath system, it is important to understand the negative impact of vessel hull, machinery noise and bubble sweep down on the system. Care should be taken to install the transducers as far away from acoustic noise sources as possible and to ensure a smooth flow of water over the sonar(s) when the vessel is underway at the planned survey speed. Clients should be made aware that it is rarely possible to guarantee an acoustically silent installation on any vessel being used for the first time. Unfortunately, it is often a case of undertaking the installation and subsequently testing, before the suitability of the vessel and installation can be known.

This website provides additional information on various possible mounts and considerations. Note that the working group is not endorsing the company that this information is taken from.

2.3.6 Dimension control of sensor offsets

Dimensional control, otherwise known as a sensor offset survey, is essential to any seafloor mapping survey and needs to be reported (see section 3.2).

2.4 Project team

The project team should include personnel with relevant and adequate experience in swath acoustic instrumentation and survey requirements. These may consist of qualified people from various backgrounds, such as geophysicists, geologists, engineers, and hydrographic surveyors, but also increasingly includes marine ecologists and spatial analysts that manage seafloor mapping programs.

It is recommended that for all survey reports each team member should be identified. This provides traceability for decisions and the data acquired. It is also highly recommended that a member of the team has completed professional training in the principles and operation of swath systems and provides evidence of recent field experience with swath acoustic systems.

2.5 Field survey instructions

2.5.1 Geodetic control and Horizontal Datum

Seabed mapping surveys conducted within the Australian EEZ shall be referenced to a geodetic reference frame based on the International Terrestrial Reference System (ITRS), e.g. ITRF 2014 (GRS80 Spheroid) during collection.

Data should be processed on the Geocentric Datum of Australia 2020 (Figure 2; GDA2020) which is being implemented to modernise the geodetic positioning, based on 1994 models (ICSM, 2018). Stage 1 of GDA2020 will be fixed to the epoch 2020.0 and Stage 2 (anticipated in 2020) will transition to a time dependent reference frame and will be known as the Australian Terrestrial Reference Frame (ATRF). Specific information regarding GDA2020 can also be found on GA's website.

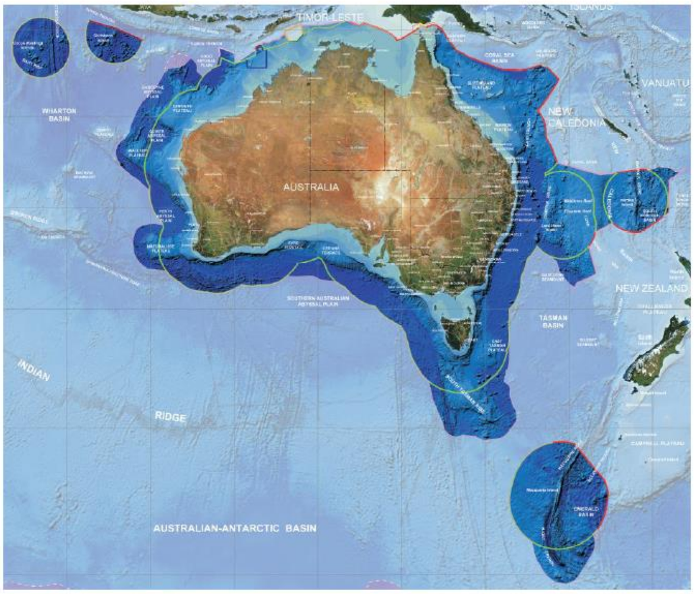


Figure 2 Extent of GDA2020 on the Australian continental shelf (Geoscience Australia)

Proposed Horizontal control should be reviewed for accuracy and if local control such as RTK base stations are to be used, then sites for local positioning systems should be determined. To establish shore-based geodetic control, refer to the procedures described in Intergovernmental Committee on Surveying and Mapping (ICSM, 2014a-c).

Grid positions shall be referenced to the Universal Transverse Mercator (UTM) Grid.

2.5.2 Tidal or ellipsoidal datum

The datum to which depths are to be reduced is fundamental to any seafloor mapping survey. Many datums can be used (Figure 3), but the common datums are the ellipsoidal or tidal chart datums (sections 2.5.2.1 and 2.5.2.2). While mapping however, the sounding datum should be used.

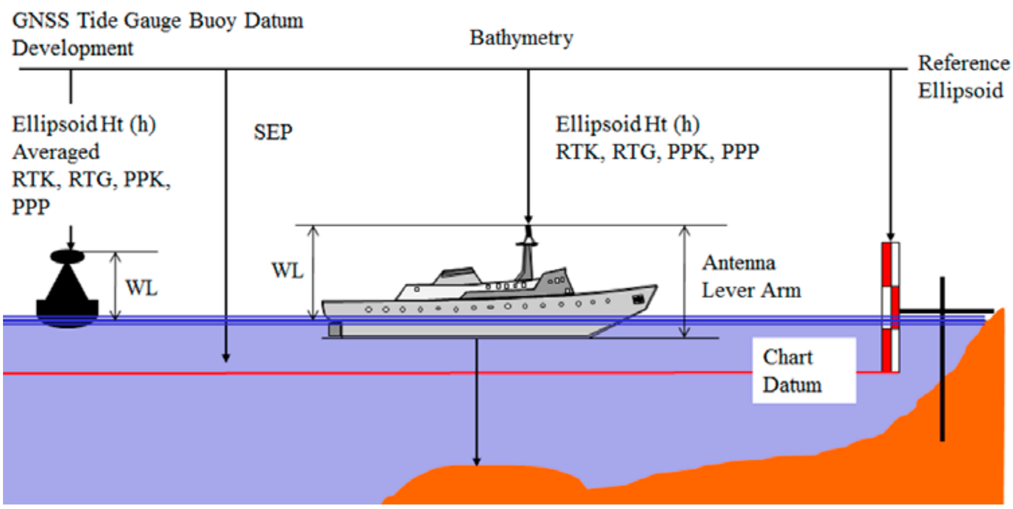


Figure 3 Schematic of datum and associated reduction information (Mills & Dodd, 2014)

Regardless of the datum used for the final products, the following points need to be considered:

- direct tide from the GNSS (GPS tide) should be recorded
- all data should be acquired and processed in WGS84 or ITRF if available
- all raw GNSS observations should be kept to allow post-processing
- all efforts should be made to improve positions to the highest accuracy possible, and post-processing will usually also improve horizontal positioning and minimise heave artefacts.

Typically, post-processing would involve:

- offshore: Precise Point Positioning (PPP) corrections using the final International GNSS Service (IGS) products
- coastal regions: kinematic post processing against land based fixed GNSS base stations, either permanent or deployed.

Transformation to the required 'publication datum' can be made after this process but retains the benefits of being connected to the global datum. These transformations can be done using AusCoastVDT, which is a free software tool with a blanket accuracy of ± 0.5 m for MSL to LAT reductions. AusCoastVDT was developed by the Intergovernmental Committee on Surveying and Mapping, a collaboration between the Australian states, defence force and New Zealand.

2.5.2.1 Ellipsoidal Datum

With the advancement of modern GNSS positioning systems and post-processing methods, ellipsoidal datum connections can be employed as an alternative to the Lowest Astronomical Tide (LAT) or chart datum (CD) connections. The GRS80 ellipsoid vertical reference surface has benefits to scientific and environmental disciplines with a consistent surface separation of seafloor features globally.

When used in conjunction with GNSS connected/levelled tide gauge data, connections to CD/LAT can be estimated where required. For details on the issues of this method see “Ellipsoidally Referenced Surveying for Hydrography” (FIG, 2014).

2.5.2.2 Tidal Datum

When surveying for the purposes of nautical charting, it is essential to have knowledge of local tides. In many areas around Australia, the tidal network infrastructure is sparse and additional temporary tidal infrastructure will be required. To acquire ‘observed tide’ from a tide gauge, a number of tide gauges will need to be installed depending on the tidal complexity of the environment, albeit it is desirable to have at least one gauge installed.

For specific advice regarding recommended tidal infrastructure for your survey area, please contact the Australian Hydrographic Office (tides.support@defence.gov.au).

2.5.3 Sound velocity profiling

Sound Velocity Profiling (SVP) of the water column is essential to the acquisition of swath mapping data, and is used for ray tracing through the water column. SVP influences directly the accuracy and uncertainty of both the horizontal and vertical position of each sounding and its impact is greatest towards the outer beams of the swath (farthest sounding).

Physical processes such as fresh water influx, solar warming of the upper water column, presence of mesoscale currents, and storm mixing can affect the temperature and salinity profile, and hence the SVP. These changes can occur at various spatial and temporal scales and can sometimes be observed in the water column backscatter data.

Acquisition of SVPs must be planned to identify the relevant number and distribution of profiles, and monitored carefully during the survey. It is recommended to commence a survey area with frequent SVPs until the behaviour of the water column is understood and then reduce the time and spatial interval as required to maintain best quality depth data. It is recommended that SVPs are conducted with a minimum interval of 6 hours. If sounding is restricted to the daytime only then SVPs should be conducted at the beginning and end of the day as the absolute minimum, but this is not recommended. The SVP can be determined using one of the following methods:

1. direct observation via deployment of a SVP measuring device
2. calculation of the SVP through deployment of an expendable bathy thermograph (XBT)
3. bar check
4. calculation of the SVP using CTD (Conductivity/Temperature/Depth) data and applying the UNESCO formula

5. calculation of the SVP from sea surface temperature and climatology using SVP builder software (Sinquin et al. 2016).

2.5.4 Time and date

All digital data, field notebooks (logs) and samples should be set and recorded using the Coordinated Universal Time (UTC) and associated date.

For descriptive text used in reporting, the time zone should be clearly specified (AWST, ACST, and AEST).

2.5.5 Line planning

Survey line planning will vary based on the seafloor mapping objectives. However, the following minimum recommendations have to be taken into consideration:

1. Seabed topography: lines should be designed parallel to the general direction of seabed contours as much as possible for swath systems.

2. Depth range: the depth of the survey area changes the swath width and consequently the line spacing. Large areas should be divided into similar depth ranges so that the requirement to run in-fill lines is reduced.

3. Swath width (angle): depends on what type of swath system is used for the project (e.g. dual versus single-head MBES system), and hence the line spacing will differ. It is nearly always necessary to operate the swath system at less than published 'maximum' swath angles in order to improve the quality of the data collected and to improve the sounding density of the data collected.

4. Overlap: for full (100%) seabed mapping coverage, a minimum of 10% overlap of the good data swath (data meeting the 95% uncertainty level) is recommended. This will enable validation by comparison of the data acquired at the edge of each swath. For partial coverage, where possible, it is recommended to use line spacing that will enable a subsequent in-fill mapping effort to complete the mapping of the area.

5. Other requirements: acquisition of other sonar data, seabed and water column backscatter data (see below), etc. may dictate a different line spacing.

6. Regular checks: where there is an object of interest on the seabed detected in the survey, additional lines should be run to better delineate the feature and overall area.

7. Crosslines: crosslines are essential quality indicators, especially for data uncertainty management, and hence it is **highly recommended** to plan multiple crosslines.

   As a minimum, one cross line per "block" of data mapped should be acquired. Crossline(s) should normally be run last so that the cross line can be run perpendicularly across the whole extent of the data block collected.

8. Turn data: consists of data that is recorded during a vessel turning from one survey line to the next. While data quality may not be at its best during turns due to poor MRU stabilisation, this data nevertheless provides new information that can be useful for some users.

   It is thus strongly recommended to record turns as a separate file (i.e. stop recording before the turn, record the turn, and start recording new line.).

9. <u>Transit data</u>: consists of data generally acquired between port and the primary survey area and is used as "discovery" data. Data from transit or passage sounding, contributes significantly to the national good by increasing knowledge of our seabed, and oceanography.

   Transit data should be:

   a. logged whenever possible unless the sea conditions are deemed too bad

   b. collected over new ground, i.e. not where previously mapped

   c. recorded and identified as a separate file to the primary survey lines

10. <u>File length</u>: depending on the system used, the rate of data acquisition and data type being collected, the size of the digital file recorded will vary. To avoid data loss and facilitate data management, it is recommended that file size be managed and data collected as smaller files in preference to large continuous files.

Where **seabed backscatter data is the primary objective** of the survey, the same recommendations as above apply with the following exceptions:

11. <u>Incidence angles</u>: overlap should be as the swath coverage but limited to incidence angles between 20 and 60 degrees (Figure 4; Lamarche and Lurton, 2017). This angle requirement is needed in order to compensate for the high variability of individual backscatter intensities (Gavrilov and Parnum, 2010; Kloser, 2017).

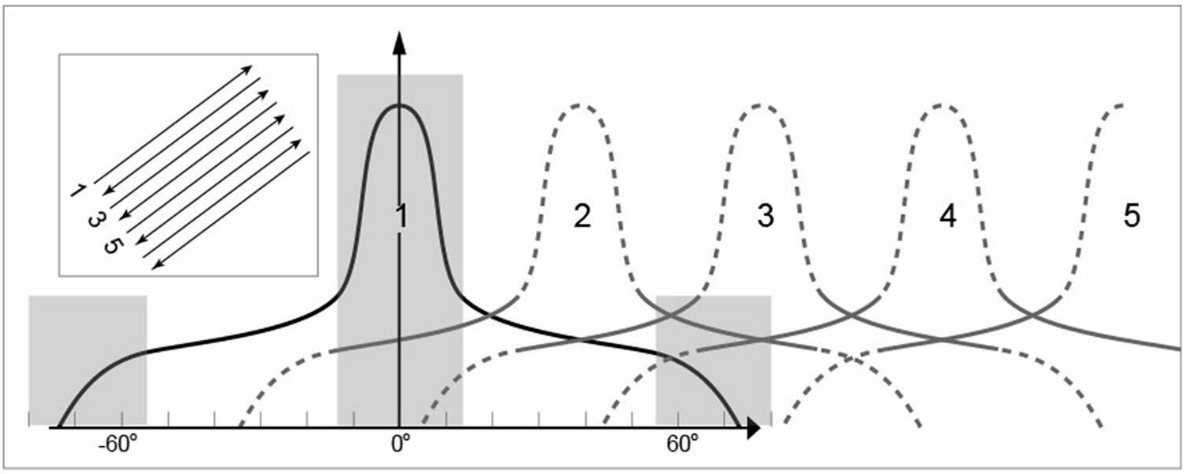


Figure 4 Diagram of ideal swath overlap (After Lamarche and Lurton, 2017).

12. <u>Repeated seabed backscatter survey</u>: For survey using the same swath system, it is recommended that the survey strategies, such as survey direction and orientations, and the system settings are kept identical. Frequency should also not be changed.

See section 4.2 which provides information regarding the project structure and nomenclature

2.5.6 Seabed samples

Seabed samples are often acquired during a seafloor mapping survey for various purposes, including seabed characterisation and seafloor backscatter data calibration. It is thus recommended that procedures outlined in the relevant chapters of the ‘Field manuals for marine sampling to monitor Australian waters’ (Przeslawski and Foster 2018) are followed.

This manual recommends sending the samples to Geoscience Australia for analyses, such as grain-size, carbonate content, and results will be delivered in MARS public database. This analysis of samples contributes significantly to the knowledge of our seabed.

2.6 Submission of plan, data and notifications

See sections 2.1.3, 7 and 4.6.

3 Mobilisation, Calibration and Validation

Mobilisation refers to the process of combining multiple equipment sets (echo sounder, positioning system, motion reference unit & sound velocity instrumentation) into a single functioning high precision and accurate system. Calibration refers to the measurement and removal of systematic errors in all installed sensors. For most installations, errors mainly consist of small offsets and rotations between system components. Validation refers to testing calibrated systems against known controls by conducting multiple observations in order to provide an analysis of the repeatability, precision and accuracy of an individual or combined system.

3.1 Overview

Mobilisation must be done with care since compromise to any part of the integrated equipment set will increase the risk of degrading the whole system and can result in no capacity to correct or post-process the problem. Calibration and validation are vital to assess the performance of the installed system against survey specifications, particularly TVU, TPU and datum control, as elaborated throughout this section.

The mobilisation, calibration and validation process will vary between vessels. For example, a 'vessel of opportunity' commonly involves significantly more planning and setup time than permanently configured survey vessels. The steps below generalise the detailed processes outlined in the hardware and software manufacturer's instructions for the deployed equipment. Specific information on some of the steps of the mobilisation, calibration and validation are included as a brief glossary in the following subsections.

Generalised steps for mobilising a vessel of opportunity:

1. During the pre-survey planning phase, attempt to source previous mobilisation reports for the planned survey vessel and equipment (even if from another vessel). This information will assist in understanding any engineering requirements or complications, thus saving downtime during mobilisation.

2. Ensure adequate resources are assigned for mobilisation of the swath acoustic system on the vessel of opportunity, which typically requires days (2-3 days), not hours.

3. Confirm the vessel reference frame to be used along with offsets and keep records and diagrams by either organising a survey of the vessel or re-use the results of a recent one. This establishes the spatial layout of equipment and sensors relative to each other. The responsible seabed mapper should conduct QC on any offset report received from a third party or conducted by the team.

4. Make equipment structures as rigid as possible to ensure stable geometry. E.g. moon-pool, and/or over the side rigid mounts should return to exactly the same location when deployed.

5. Take care with the physical installation, particularly cable runs and joins, and account for vessel vibrations, vessel traffic, water ingress, power-stability (pure sine wave for inverters, earthing), etc. Consider under-keel and overhead clearances.

6. Minimise acoustic and vibration noise sources to acoustic sensors, IMU and electronics.

7. Check vessel sounder or engine vibration and noise over engine revolution range. Test a range of survey speeds for noise changes. Where possible check the swath systems performance at desired survey speed and sea state.

8. Check sky view of observed GNSS satellites in positioning system and minimise radio interference on GNSS antennas. Lost GNSS observations cannot be recovered.

9. Perform all manufacturer's self-tests and calibrations (positioning system, swath sonar, sound velocity instruments) to ensure validity of entire system. This includes a patch test (section 3.5)

10. Record all sign conventions and calibrated geometries of installed sensors (screen captures and reports; section 6.1).

11. Backup system and parameter files on a separate location. This is also important for rolling back configurations when accidental, unknown system changes are made.

12. Preferably complete mobilisation and testing before leaving port for the survey area.

13. Check tidal observation equipment for connections to local tidal datum if required.

14. Double check all geodetic parameter settings in positioning and acquisition systems for consistency. Ensure no undesired/undocumented transformations are taking place.

15. Consider processing capability on the vessel for near real-time assessment of acquired data.

16. Confirm on-board vessel storage has enough capacity to capture all required raw data, including backup strategy.

17. Discuss planned survey lines with vessel master, survey ground sea-states, forecast weather and implication for survey plan. Communication strategies between MBES system operator and helm (including installing swath system helm display).

18. Describe the equipment and actions undertaken on the vessel before, during and after the survey to form part of a 'mobilisation and calibration' report to be submitted along with the data (section 6.1).

3.2 Dimensional control

This is the process of establishing the spatial relationships of the mounted equipment locations on the vessel. This includes the physical vessel offsets (section 3.2.1) and angular rotational offsets (section 3.2.2) of the installed equipment, and the integration of them into the complete swath acoustic system. All recommended calibration and alignment procedures specified in the manufacturer's equipment manuals should be carried out. These measurements are validated and refined during the patch test process.

3.2.1 Physical offset survey

Establish the physical offsets of the installed equipment to permanent locations or marks on the vessel (Figure 5). This is achieved by adding equipment specific offsets to the previously carried out static (slipped) vessel system offsets survey or via surveyed measurements to the installed equipment. Preferably offsets should be known with centimetre level uncertainties, or better, to establish spatial relationships between soundings and external earth reference frames (WGS84, ITRF) via the GNSS equipment installed on the vessel.

It is important to note that the systematic errors and uncertainties associated with this control will feed directly into the overall quality of the data and will greatly increase with water depth. Acquiring accurate data ensures the long term benefits that accompany the "collect once, use many times" mantra. For more information, refer to Hughes-Clarke (2003).

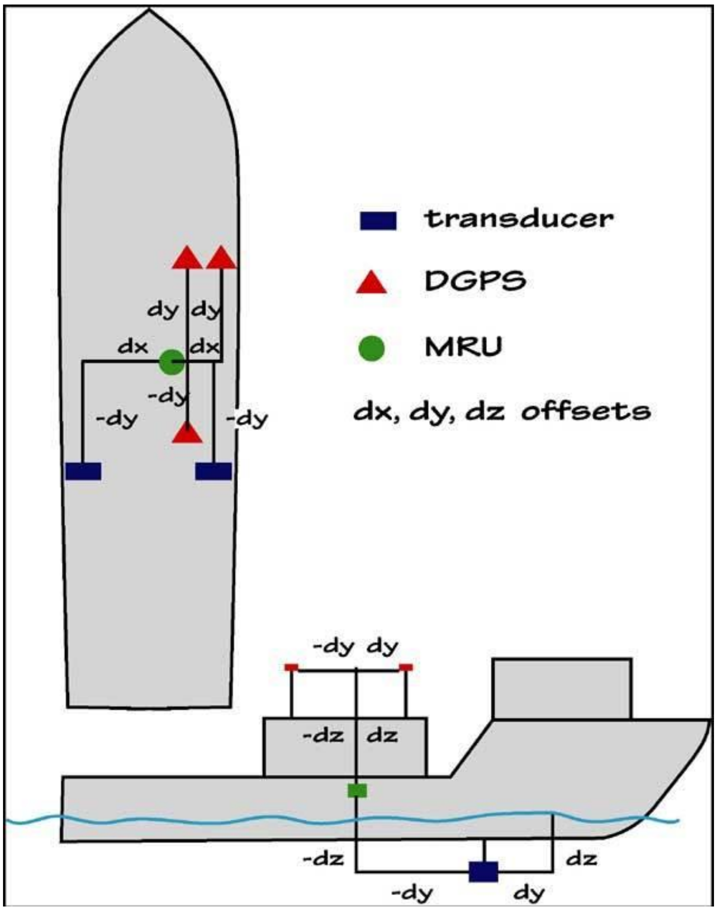


Figure 5 Diagram of dimensional control for MBES system (After Gardner et al., 2002)

3.2.2 Rotation offset survey

A rotation offset survey checks the alignment of individual equipment relative to the vessel's reference frame.

Establish all known rotations (angular offsets between the vessel and the reference frames of the installed equipment) for each equipment set. The offsets between rotational frame conventions (if any) of each equipment set should be accounted for as part of this process and recorded in the mobilisation, calibration and validation report (section 6.1). If equipment rotations (physical measurement) are known separately to calibrated rotations (patch test) and applied as such in the acquisition software, these details should also be included in the report.

Rotation offset survey is normally associated with permanently-installed systems.

3.3 Horizontal positioning

It is recommended to use a tightly coupled GNSS-Inertial system consisting of dual GNSS antennae and IMU integrated system that is tested. The GNSS-Inertial system has to be calibrated and validated prior to the commencement of the survey as this is critical to detect and correct setup errors, and estimate uncertainties. This process involves both static and dynamic validation if possible:

Static validation of GNSS positioning equipment involves verifying the performance of the system against a known reference position. This should be preferably done using land survey methods, however should a known reference point not exist near the point of mobilisation, points may be established and should be in accordance with ICSM (2014a-c).

Dynamic validation or confidence checks involves carrying out dynamic comparisons between positioning systems (where more than one system is mobilised). These dynamic calibrations should be performed regularly and whenever any component or changes to the vessel positioning systems or setup are made.

Validations may include:

- alongside checks using baseline and offset measurements to vessel datum points while logging on the acquisition system.
- check of independent positioning system mounted on vessel with known offset to transducer and on-board primary positioning system. Vessel records of all systems while conducting a box, then perform comparative analysis between logged system data and the independent positioning system. The least preferred method is to conduct this while static, but this may be the only operational option.

Setting up positioning systems to transmit data to the swath system topside at a frequency of 1 Hz is adequate for most scenarios.

3.4 Vertical positioning

3.4.1 Depth validation

Depth validation should be done once the patch test (section 3.5) has been performed. The system should be used to run a series of parallel and perpendicular sounding lines over a reference bottom surface where the depths have been previously determined and verified with an independent system of known accuracy.

If none of these comparative methods are available, then a “bar check” can be undertaken understanding that the results will not be as accurate as the precedent methods. The results obtained by any of the methods should compare favourably and be within the accuracy requirements of the survey.

Prior to sailing, a lead line observation may also be conducted.

3.4.2 Settlement and squat

Settlement occurs once the vessel is in a constant transit and is a vertical displacement which is constant at a given speed through water. Squat is a relationship between depth of water and speed through water.

All vessels are subject to settlement and squat, and measurements of these parameters should be made wherever practically possible by the most appropriate validation method. Ideally tests should be performed at various vessel speeds over a flat bottom using RTK GNSS or orthometric levelling heights at the transducer location. The heights should be measured at rest and then in increments of vessel speed with RPM noted, and then used to derive an appropriate squat/settlement table. A squat table is not necessary when using ellipsoidal reduction methods, however, should you need to revert to sounding reduction by tide, a table is best practice.

3.4.3 Vessel draft

Vessel draft may be difficult to measure. However, it is possible to approximate distance from arbitrary reference points to the waterline before and after a survey as this is likely to change with fuel consumption. For validation, the vessel draft should be derived using quantitative measurement methods as for section 3.4.2 (Settlement and squat).

3.4.4 Sound velocity

To ensure proper calibrated sound velocity reading, at least one probe (SVS or SVP) needs to be independently calibrated. Use a comparative method to validate other sensors (SVS at head and SVP). Assess speed of sound at the swath sonar head against SVP at same depth below surface. Where possible, compare SVP readings with external sensors (e.g. derived sound velocity from CTD).

3.4.5 Tidal station

For shallow inshore work (<30m), water level tidal observations, including local environmental effects, should be conducted for a minimum period of 35 days. If this is not possible, predictions based on tidal constituents may be used and in this instance tidal stations should be installed and calibrated as directed by ICSM (2004).

3.5 Patch test

The patch test confirms timing and alignment of the MBES sensor, vessel and IMU reference frames. It is essential to execute the standard patch test method as appropriate for sensor type (single or dual- head) and vessel (Appendix F). A patch test should be conducted at the beginning of the field season or whenever a piece of equipment is replaced or repaired and has to be undertaken once the calibration for the GNSS inertial system is complete (section 3.3). The results of the patch test should be reported in the Mobilisation and Calibration Report (Appendix H).

3.6 Seafloor backscatter calibration

Lamarche and Lurton (2017) provide a comprehensive review of seafloor backscatter from data acquisition to processing. Calibrated seafloor backscatter is essential to enable comparison of data acquired by various systems. There are two types of calibrated backscatter: absolute and relative backscatter.

Calibration is executed through the use of reference areas of known seabed types (preferably flat, smooth, and geologically and acoustically homogeneous areas). Use roll lines of the patch test (no need to rerun for backscatter) and list overlap (for backscatter quality survey). For systems with multiple transmitting sectors it is recommended that the average backscatter level be consistent across all sectors and for different modes.

It is also recommended that sediment samples and/or imagery samples be taken from the area to ground truth and calibrate backscatter data. As part of a sea-acceptance test practice, an overall calibration must be performed once the sonar system has been installed on the vessel. This involves both the customer's technical team and operators.

3.7 Water column backscatter calibration

Calibration of water column data is desirable into the future and is best acquired if available on system. The same procedure for seabed backscatter calibration should be applicable for the water column backscatter calibration. While it is not practical to use the sphere calibration technique, inter-calibration with a calibrated fisheries single-beam echo sounder through the use of reference areas (Demer et al. 2015; Foote et al. 1987) may be employed. This at least provides assurance of self-consistency.

3.8 Built-in systems test

Built-in tests, such as built-in systems test (BIST) or built-in test environment (BITE) are a test of sonar head communication with software controllers and are useful for the validation of communication between systems. They becomes integral when troubleshooting and should be logged. It is recommended that, at a minimum, a BIST be done at the start and end of the mapping. The results should be reported in a Mobilisation and Calibration Report (section 6.1).

3.9 Final acceptance test

A final check should be performed to ensure that all the equipment is working properly and that the logging systems are operating correctly. Care should be taken to ensure depth, position and if necessary water level values are being logged correctly. The positioning system should be checked for operation and periodically throughout the survey.

4 Acquisition

4.1 Survey plan

Acquisition of the MBES data should follow the pre-survey plan discussed in section 2, unless the on-board seabed mapping lead decides otherwise based on the environmental situation and new information at-hand, which are difficult to account for in the planning stage. It is recommended that any changes to the acquisition plan are captured in the Report of Survey (section 6.2.2). Wherever possible, nearing the conclusion of data acquisition, a review of data coverage is highly recommended and infill lines conducted to ensure there are no gaps in the bathymetry, as this impacts the suitability of the data for end use. Additional lines over significant shoal features are also recommended to ensure good density of soundings and determination of least depth. For efficiency, such lines may be conducted concurrently to other activities such as during transits or seabed sampling. Emphasis here is put on the system settings and other specifics that were not recommended in section 2, especially section 2.5.

4.2 Project structure and nomenclature

Although the project structure and nomenclature is specific to the project, it is recommended that the following conventions be considered to facilitate data submission and interoperability:

- project structure:
    a. reports
    b. tides
    c. QA DataPack
    d. products
    e. raw data (see 2.3.1)
    f. processed data
    g. backscatter
    h. WC data
- file naming convention should be sequential, include timestamp and system type, e.g. nnnn_yyyymmdd_hhmmss_system, where: nnnn is the sequential number; yyyymmdd is the date; hhmmss is the time

4.3 Systems settings

System settings should depend on the purpose of the seafloor mapping and the data types that are being recorded.

4.3.1 Bathymetry

While acquiring data, the power, pulse width and gain need to be monitored and adjusted during the course of the survey to ensure good bathymetry. For high resolution/high frequency operations a short pulse width is desirable. As water depth increases, longer pulse widths will become necessary.

4.3.2 Backscatter

If the MBES system is capable, it is required that you ensure backscatter data (both the Beam Average Backscatter and the Time Series “Snippets” Backscatter data) are being logged and stored with the bathymetry data files. It is imperative that the Range (R), intensity (I), angle (ϴ) information are all recorded. Collecting these data may require custom settings to be applied during the initial set up of the acquisition software.

When acquiring data, it is essential that a log is kept of all settings and changes made to settings during acquisition (section 6.2.1). Do NOT run the MBES system on auto mode as this will make it very difficult to normalise the backscatter data due to the dynamic changes in the pulse length. Changes to the pulse length and pulse type should be avoided if possible, and if not, kept to a minimum. If you are required to change either of these settings please stop logging at the end of the line and apply new settings before starting to log the next line and detail in the log accordingly. Efforts should also be made to minimise constant saturation of the seabed backscatter signal.

At the end of a survey, an **additional backscatter calibration test is essential** if you have used pulse lengths that differ from your original patch test and backscatter calibration**.** This calibration test is made up by running the same line once for each pulse length that was used during the survey. It is important that enough space is given for the turn so that the line can be intersected straight on because the calibration requires the lines to directly overlap for at least 500 m. Please record which pulse length coincides with which line number for each calibration run.

4.3.3 Transit data

It is recommended that the system settings during transit data acquisition be set to maximise data quality by considering the overall characteristics of the transit rather than maximise data coverage or swath width. Refer also to section 2.5.5.

Unless a deep water CTD or XBT cast is available throughout the transit and when water depth is greater than 200m, a generic SVP tool, such as the Hydroffice Sound Speed Manager tool can be used to improve profiles. Should no SVP option be available, the sound velocity should be set to 1500m/sec.

4.4 Ancillary systems

4.4.1 Sound velocity Profile

It is recommended that:

- for shelf waters (< 200m water depth), at least one SVP be conducted every 24 hours. However, every 6 hours would better align with Bureau of Meteorology (BOM) weather reporting requirements
- for “off the shelf” surveys (> 200 m), SVP may not be necessary daily, but monitoring of the SVP is still recommended as per point below.

- SV be constantly monitored and SVP be collected if visual changes are observed in the acquired swath (e.g. frown or smiles), or the SV vessel probe indicate greater changes than 2 or 3 m/s at the sonar head for a consistent period of time.

Note that SVP for all depths are also highly valued by other types of users, such as oceanographers and ecologists. To further accommodate such users it is recommended that SVPs are also collected during deployment and retrieval of deep-tow systems, ROVs and AUV.

4.4.2 Tides

During a survey, acquisition of GNSS tide (ellipsoidal height of the vessel minus the geoid model at the same location) can be monitored; however, it is difficult to monitor tide gauges unless regular download of the data is undertaken. Therefore, for GNSS tides acquisition, it is recommended to:

- ensure that all the bathymetry files include GNSS height, otherwise GNSS tides will be computed to less than 10 cm vertical accuracy.
- use an updated Geoid model (e.g. AUSGeoid2020) keeping in mind that this model is unsuitable offshore.
- acquire the delayed heave from the MRU without gaps and ensure that the bathymetry data has a complete delayed heave coverage applied.
- compute GNSS tide for all the files.

During the survey, data QC should be done using predicted tides from the Bureau of Meteorology (BOM) for standard ports or AusTides for secondary ports. Refer also to section 2.5.2.

4.5 Monitoring, QA/QC & Data backup

During a survey the following information should be constantly monitored, including:

- depth
- vessel draft
- GNSS (see section 4.5.1) or subsea positioning for sub-sea platform
- motion sensor
- sound velocity
- backscatter consistency and saturation
- overlap
- data density

To ensure safe data transport it is recommended that multiple copies of the data be made and transported separately in the time between data collection and submission (section 7).

4.5.1 GNSS positioning

Most seafloor mapping and GNSS software provide real-time monitoring capabilities. The quality of the GNSS data should be monitored while mapping to ensure that the horizontal positioning falls within the seafloor mapping specification. Any deviations outside of the survey specification should be noted and included within the Report of Survey (section 6.2). Maintaining a minimum QC requirement will provide data that is interoperable with many providers and uses. This integrity information includes (LINZ, 2016):

- Sigma values or semi-major axis of the positional error ellipse are not to exceed 3.5m at the 95% confidence level.
- The DGNSS correction age is not to exceed 10 secs.
- PDOP is not to exceed 6 for recording and continued sounding. If PDOP is greater than 7 then surveying is to be halted until it improves.
- The minimum number of observable healthy satellites being tracked during survey operations is to be 5.
- The minimum elevation for SVs is to be 10° above the horizon.

4.6 Mandatory notifications

4.6.1 Dangers found – hydrographic notes

It is **imperative** that any feature found, which may be a potential navigational hazard to vessels, **is reported to the AHO** by hydrographic note (AHO, AH102) and if an immediate danger exists, **the Joint Rescue Coordination Centre (JRCC) Australia (AMSA)**. Once danger is reported and received by these agencies, the agencies noted assume responsibility for further reporting to mariners. Should reports not be lodged and an incident occurs, liability may be passed on to operators who failed to notify dangers during operational activities.

4.6.2 Underwater cultural heritage notification

Thousands of historic ship and plane wrecks are known to exist within Australian waters, although the locations of many of these remain unknown. Information about known shipwrecks can be found using the Australian National Shipwreck Database. Notifying relevant State and Commonwealth management agencies, when underwater cultural heritage sites are discovered, will greatly assist these organisations to manage fragile and irreplaceable resources (Table 8). Notification of underwater cultural heritage finds is also a legal requirement under the *Historic Shipwrecks Act 1976* (Cth) (HSA) and state heritage protection legislation (see section 17 (1) of the Act).

A notification report should include a snapshot of the scan image, coordinates, water depth and a brief description of the site giving dimensions of the object.

Table 8 Contact details of management agencies to notify for wrecks

Commonwealth: Historic Heritage Section Department of the Environment and Energy GPO Box 787 CANBERRA ACT 2601 Tel: (02) 6274 2116 Website: www.environment.gov.au/heritage/historic-shipwrecks	**Northern Territory**: Heritage Branch Department of Lands, Planning and the Environment GPO Box 1680 DARWIN NT 0801 Tel: (08) 8999 5039 Email: heritage@nt.gov.au Website: www.dlp.nt.gov.au/heritage/maritime-heritage
Commonwealth: Great Barrier Reef Marine Park Authority Heritage, International and Governance Project Manager, Maritime Cultural Heritage GPO Box 1379 TOWNSVILLE QLD Tel: (07) 4750 0618 Email: info@gbrmpa.gov.au Website: www.gbrmpa.gov.au/	**South Australia:** State Heritage Unit Department for Environment, Water and Natural Resources GPO Box 1047 ADELAIDE SA 5001 Tel: 08) 8124 4960 Email: DEWNRheritage@sa.gov.au Website: www.environment.sa.gov.au/our-places/cultural-heritage/Maritime_heritage
Queensland: Heritage Branch Department of Environment and Heritage Protection GPO Box 2454 BRISBANE QLD 4001 Tel: 13 74 68 Email: info@ehp.qld.gov.au Website: www.qld.gov.au/environment/land/heritage/archaeology/maritime/	**Tasmania:** Historic Heritage Parks and Wildlife Service GPO Box 1751 HOBART TAS 7001 Tel: 1300 827 727 Email: mike.nash@parks.tas.gov.au Website: www.parks.tas.gov.au/index.aspx?base=1729
New South Wales: Heritage Division Office of Environment and Heritage Locked Bag 5020 PARRAMATTA NSW 2124 Tel: (02) 9873 8500 Email: heritage@heritage.nsw.gov.au Website: www.environment.nsw.gov.au/maritimeheritageapp/WebsiteSearch.aspx	**Victoria:** Heritage Victoria Department of Planning and Community Development GPO Box 2392 MELBOURNE VIC 3001 Tel: (03) 9938 6894 Email: heritage.victoria@delwp.vic.gov.au Website: www.dtpli.vic.gov.au/heritage/shipwrecks-and-maritime
Norfolk Island: Norfolk Island Museum Kingston NORFOLK ISLAND 2899 Tel: (0011) 672 323 788 Email: admin@museums.gov.nf Website: http://norfolkislandmuseum.com.au/exhibitions/hms-sirius/	**Western Australia:** Western Australian Museum Maritime Archaeology Department 45-47 Cliff Street FREMANTLE WA 6160 Tel: (01) 300 134 081 Email: reception@museum.wa.gov.au Website: http://museum.wa.gov.au/research/research-areas/maritime-archaeology

5 Data Processing

5.1 Data processing considerations

5.1.1 During survey

Processing during a survey should at a minimum be done to QC the data, both bathymetry and backscatter data. QC includes:

- checking for artefacts
- consistency of seabed backscatter
- meeting the required specifications, e.g. data density

A processing log should be kept.

5.1.2 Post-survey

Post-survey processing should include:

- reduction of soundings to appropriate vertical datum (observed or post-processed GNSS tides).
- application of SVPs and refraction correction applied (where allowed).
- data cleaning, which may vary depending on the purpose of the survey.
- data QA using crosslines (if collected). If specific crosslines are not collected, consider using transit lines that cross main survey lines (e.g. data acquired while going to a sampling location).
- TPU calculation for each sounding (section 5.2).

See also section 10 of AHO, 2018 for more information on processing.

5.1.3 Backscatter processing requirements

Please keep a processing log that records what processing software and settings are used to prepare the backscatter mosaic. When you process, it is important to specify the imagery type (Beam Average/Time Series); Beam Pattern Correction (yes/no); and Anti-aliasing (yes/no) selection.

Mandatory information to record for the backscatter data processing is:

- the AVG window size
- AVG method
- beam Pattern Correction (yes/no – if yes, please provide the beam pattern file)
- the imagery type (Beam Average/Time Series)
- gain (yes/no)

- time varying gain (yes/no)

Other image processing information that is useful but not mandatory:

- the speckle option (to remove noise)
- anti-aliasing (yes/no)

Further details about best-practice for backscatter data acquisition can be found in Lamarche and Lurton (2017).

Acquisition and processing logs should be delivered alongside all raw data (including calibration test) and processed mosaics in accordance with Section 7.

5.2 Total propagated uncertainties (TPU)

The total propagated uncertainty (TPU) for each sounding should be computed and included in the data submission (Section 7).

The TPU is the combination of the total horizontal uncertainties (THU) and the total vertical uncertainties (TVU) of that sounding (Appendix E). THU is a 2-dimensional quantity in the horizontal plane and is assessed only after the GNSS-Inertial system has been calibrated. TVU is a 1-dimensional quantity in the vertical dimension. TPU is not a linear addition of uncertainties in each system's component. It is a propagated combination of uncertainties for the non-linear set of equations comprising the integrated swath acoustic-GNSS Inertial system.

Uncertainty calculation is best addressed using most internationally accepted statistical models for determination of TPU, which are derived from Hare et al. (1995). Current international best-practice statistical model for resolving the system of equations is the Combined Uncertainty Bathymetric Estimator (CUBE). The average horizontal and vertical TPU estimates determined by the software for a range of water depths is provided with respect to the IHO S-44 standard for position and depth accuracy in Table 6.

Table 9 Example Sounding Accuracy - TPU (calculated at 1σ, but most software computes at 2σ)

Depth band (m)	0-5	5-20	20-50	50-100	100-200
Position Accuracy (m)					
IHO Standard	5.25	5.50	6.00	6.50	7.25
TPU Estimate	0.27	0.27	0.30	0.34	0.42
Depth Accuracy (m)					
IHO Standard	0.38	0.39	0.44	0.50	0.63
TPU Estimate	0.27	0.27	0.28	0.31	0.35

6 Reports

In order to ensure consistent documentation of all aspects of survey planning, mobilisation, calibration and acquisition, all information (reports and logs) should be recorded throughout the process. At a minimum, metadata (section 2.3.1.3), records for Mobilisation, Calibration and Validation (section 6.1), and the records proposed in section 6.2 are recommended. The proposed templates for these reporting requirements can all be found in Appendix H.

6.1 Mobilisation, calibration and validation records

Methodology and results of the mobilisation and calibration should be outlined in the mobilisation and calibration report, and the associated records created using templates provided in Appendix H.

6.1.1 Logs

Mobilisation and calibration logs should include:

- tests survey lines, including patch test and final acceptance test
- SVP deployments (filename, time, lat, long, depth, SV sonar head reading (used for comparison)
- squat and draft tables

6.1.2 Report

Mobilisation and calibration report should document the integrated survey system, methodology, raw results and processed results, i.e. once the calibration is accepted. At a minimum, it is recommended to include the following (modified from AHO, 2018) and if needed, Appendix H provides a template:

Report Heading:

- seabed mapping survey title and associated reference number
- mapped by (agency/company/etc. and Seabed mapping lead)
- dates of mapping
- mobilisation, calibration and validation report
- version
- date of the report

Introduction: includes an overview of the procedures conducted for the installation and calibration of equipment that comprise the seabed mapping system (SMS).

- Background and outline of events: a narrative giving an overview and timeline for the set-to-work of the survey platform(s).
- Platforms: a description of, and justification for, the survey platforms chosen to undertake the survey.

- Geodetic controls: geodetic parameters for the control survey, station diagrams and descriptions outlining the geodetic control utilised for the survey.

Equipment: summary of equipment that forms the SMS as installed on the survey platforms, including all relevant offsets and calibrations.

- Hardware: summary of the hardware relating to data acquisition including manufacturer, model and serial number is to be tabulated.
- Software: summary of the acquisition and processing software, including version numbers is to be tabulated.
- Sensor mounting systems: a description of the mounting system utilised for data acquisition is to be provided, e.g. pole mount, gondola, moon pool etc.
- Sensor offsets: the measurement method and results for the dimension control that determine the relationship between the measurement sensors and the platform CRP are to be provided. Sensor offsets may be annexed to the report.
- MRU heading checks.
- Built-in test results (e.g., BIST, BITE).

Underway calibration: outline the checks and calibrations of platform when underway. These may include:

- acoustic sensor bar checks
- draft, settlement and squat
- primary and secondary positioning
- patch test; the method undertaken, and results of the patch test for the pitch, roll and heading bias are to be calculated and rendered
- reference surface (if performed): difference statistics between manoeuvring lines and the reference surface are to include; beam number; mean, maximum and minimum differences and standard deviation
- target detection (if performed): the ability of the SMS to meet the target detection criteria of the specified order are to be demonstrated
- acoustic interference check (if performed): results of the pre-survey acoustic interference check are to be rendered

6.2 Record Keeping

This section includes logs that should be used during acquisition of data as well as information required in the Report of Survey provided at the end of the survey. This section also points to legal notification requirements in regards to Dangers found (section 4.6.1) and Underwater Cultural Heritage (section 4.6.2). Templates of the reports and logs can be found in Appendix H for a summary of minimum requirements and in the IHO M-13 Manual on Hydrographic Surveying for a comprehensive report.

6.2.1 Logs

Survey logs should include:

- relevant information on survey lines, including data types recorded and daily events. Minimum parameter requirements found in Appendix H.

- system parameters relevant to backscatter data acquisition include:

  - environmental parameters controlling sound speed and absorption within the water column
  - weather and sea conditions
  - backscatter intensity
  - source level
  - pulse length
  - transmit beam patterns
  - receive beam patterns
  - receiver time varying gain functions
  - path length attenuation characteristics (spherical spreading and absorption coefficient)
  - seabed grazing angle

- SVP deployments (filename, time, lat, long, depth, SV sonar head reading (used for comparison)

- log for additional data collected, such as seabed samples (section 2.6)

6.2.2 Report of Survey

The Report of Survey (ROS) should give a comprehensive account of how the seabed mapping survey was carried out, the results achieved, and any difficulties encountered. A template can be found in Appendix H, but at a minimum, it is recommended to include the following (modified from AHO, 2018):

Report heading:

- seabed mapping survey title and associated reference number

- mapped by (agency/company/etc. and seabed mapping lead)

- dates of mapping

- report of seabed mapping

- version

- date of the report

Introduction:

- dates: give start and end dates with activities that took place during the survey, especially where swath acoustic data was acquired while executing other activity (transit and sampling)

- map: give general map of where the data was collected, including coordinates of coverage

- setting conditions: general statement on weather and sea conditions as these are essential to understand data quality. Provide also information on oceanographic conditions which explain SVP frequency

- completion: comment on completeness of the survey, including opinion in regards to coverage and line spacing, and MBES data type recorded

Standards:

- local datum epoch and transformation parameters: provide a table with the relevant information that was used within the acquisition software. In addition, all software used on the survey must contain the correct datum parameters and this should be checked independently and evidenced here.
- horizontal and vertical accuracy: the following section confirms that the horizontal and vertical accuracy of soundings acquired during the *Survey Name* seabed mapping survey are compliant/non-compliant with the (IHO/LINZ/Other) standard for position and depth accuracy
- TPU: comment on TPU in reporting relative to various industry standards and provide a Table (see example Table 5 from section 5.2) with a detailed analysis of the TPU estimates for the relevant depth bands mapped for the project, using *name of software*

Seabed sampling:

- method: describe method used and problems with equipment or recovery of the samples, state sampling interval and any particular samples obtained from interesting features, state the number, plan for analysis and submission of samples

Tides and sounding datum (see section 13.4.1.9 in AHO, 2018)

Wrecks and danger found:

- Provide a table with any notifications made in accordance with legislation (section 4.6)

7 Data Release

The AusSeabed Data Hub is the national repository for all seabed mapping data collected within the legal boundaries of the Australian Continental Shelf and the Australian Charting Area and any data that lies outside this region but is considered of value to the Australian marine community or was commissioned by Australian entities. Data submitted to this repository will be made publicly visible and available through the AusSeabed Marine Data Portal under a Creative Commons Attribution 4.0 International licence unless that data is subject to embargos or confidentiality agreements. Data delivered through the AusSeabed Marine Data Portal is done so under the proviso that it is not used for navigational purposes. To submit data to the AusSeabed Data Hub first check that it complies with section 6.1.1 Final QA/QC checklist and then follow the steps outlined in section 6.1.2 Data Submission to AusSeabed.

7.1 Final QA/QC

The final QA/QC checklist for data acceptance includes:

- Vessel configuration file for the survey is updated with the latest information received from the survey acquisition report. Ensure to not apply the calibration values twice, i.e. in the acquisition and processing software.
- AusSeabed's policy and preference is for data to be reduced using GNSS heights to the ellipsoid. However, if appropriate, accurate tide files should be contained within data being submitted.
- All ancillary systems, SVP, true heave, etc., are applied and if not, these have been noted in the survey report or logs.
- SV artefacts were applied where necessary and noted in the processing report.
- Any other surface artefacts, e.g. resulting from calibration errors have been addressed and parameters that have been applied have been noted in a processing report.
- Random errors (ambient noise) have been removed using Filters/CUBE or manual techniques and have been noted in the processing report.

7.2 Data Submission to AusSeabed

In the future, a data submission portal will be integrated with the Survey Coordination Tool and the QC Tools suite currently being developed by AusSeabed. This will make the provision of data to the AusSeabed repository a seamless and efficient user experience, utilising metadata captured during earlier stages of the surveying process and providing automated quality assurance of collected data. In the interim, data can be transferred to AusSeabed using any one of a number of secure online data transfer mechanisms (Google Drive, One Drive, Cloudstor, Drop Box, directly through the National Computing Infrastructure, by sharing permissions to Amazon S3, etc.) or if no online data transfer method is possible by sending through a hard drive to Geoscience Australia. Please follow the steps outlined below to ensure efficient delivery of data and contact ausseabed@ga.gov.au if unsure during any stage of the process.

1. Ensure that data meet the Final QA/QC requirements above (section 7.1.1) and that all files outlined in Table 9 have been gathered or prepared for submission.
2. Contact AusSeabed (ausseabed@ga.gov.au) and AHO (datacentre@hydro.gov.au) to inform of the intention to submit data. This communication with AusSeabed can be used to determine the most convenient method for file transfer. If hard drives are used, they will be returned to sender within 2 weeks after being received.
3. Send data and associated files to AusSeabed.
4. Publish metadata record(s) to the Australian Ocean Data Network (AODN) catalogue as soon as possible after metadata has been quality controlled. This can be done in one of two ways:
   - If metadata from your agency is regularly harvested by the AODN, follow agency-specific protocols for metadata and data release.
   - Otherwise, metadata records can be created and submitted via the AODN Data Submission Tool. Note that user registration is required, but this is free and immediate.

Table 10 Data required for submission to AusSeabed

Deliverable item	Information
L0 data (unprocessed instrument data)	**Description**: The following L0 data are required: • raw multibeam • raw navigation and attitude (e.g. posmv, Terrapos, or Fugro Starfix) It is required that raw multibeam data include SV profile, attitude, navigation, heading, raw bathymetry, raw backscatter per beam and, if available, raw backscatter in time series i.e. the equivalent seabed image or snippet style. Water column data, recorded as (separate files) are only required when the data files have been requested specifically during survey planning. For more info see section 2.3.1.2 **Data format**: native format as produced by the acquisition system (see table 5 for formats) **Datagram (multibeam echosounder only)**: logged automatically for Kongsberg EM series. However, for Reson SeaBat, datagrams with the following IDs are required: 1003, 1012, 1013, 7000, 7001, 7002, 7004, 7006, 7005, 7007, 7012, 7018, 7022, 7028, 7200, and 7504.
Coverage shape file	**Description**: Shape file showing the coverage of the collected data. **Data format**: GeoJSON (compulsory)
L2 data (Derived geophysical/georeferenced variables)	**Description**Processed multibeam bathymetry data, including processed multibeam backscatter data (if collected), also include all SVP (and SVP log) as well as, if used, tide data. **Data format**: .GSF (compulsory for multibeam and backscatter), text file compulsory for SVP and tide.
L3 data (Variables mapped to a grid)	**Description**: Processed multibeam bathymetry surface grid (for BAG the TPU is a compulsory inclusion) **Data format**: 32-bit floating point GeoTIFF and BAG (both compulsory)
Visual Imagery	**Description:** Two visual images of the bathymetric surface one with sun illumination from two orthogonal directions and the other with five time's vertical exaggeration. These images are for quick manual inspection of the data quality. **Data Format:** 8-bit or 24-bit RGB GeoTIFF
Processed backscatter mosaic	**Description:** Processed multibeam time-series generated backscatter mosaic **Data format**: 32-bit floating point GeoTIFF (values have to be provided in dB).

Sound velocity profile	**Description:** Sound velocity casts used in SIS or equivalent acquisition system together **Data format:** ASCII *.csv, *.asvp, *.svp
Log file (SVP cast)	**Description:** SVP cast info (date, time, depth of cast and seafloor, location and line applied to) **Data format:** ASCII text
Records (Report and log)	As per section 6 of the Australian Multibeam Guidelines
Metadata	**Description:** Metadata should as a minimum conform to the list of attributes outlined in section 2.3.1.3 and described in detail in appendix H.2 **Data format:** .xml (preferred) txt file or spreadsheet also accepted

8 Multibeam acoustics for marine monitoring

There are two particular needs for mapping and surveying when considering multibeam acoustics for marine monitoring, these can be defined as either baseline surveys or monitoring surveys. MBES can be used for both survey types, however, they have different acquisition and post-processing standards. A decision tree to help you decide on which set of specifications apply to the work you are carrying out is provided in Figure 6. A baseline survey is for exploratory purposes and data will be collected in a 'single pass operation'. These data are used to map the distribution of marine benthic habitats at a particular spatial scale, and provide information necessary for more targeted field surveys using such tools as towed video, AUVs and stereo baited remote underwater video stations (BRUVs) (Lucieer et al. 2013, Monk et al. 2016). In contrast, a monitoring survey may have already identified target habitats or features (such as rocky outcrops) from previous broad scale or other hydrographic data that are to be monitored to assess change in distribution and extent (Rattray et al. 2009, McGonigle et al. 2010). This type of survey will require MBES data to be collected at a higher resolution and with a greater degree of positional accuracy. The survey specifications and requirements needed to meet the aims of each survey type are presented in Table 11.

The principles developed in the preceding chapters of these guidelines should still inform and influence the planning through to acquisition phases of MBES work and the requirements detailed in this section should be seen as a complementary lens used to refine efforts so that data is fit for purpose for work carried out for marine monitoring or within state or commonwealth marine parks.

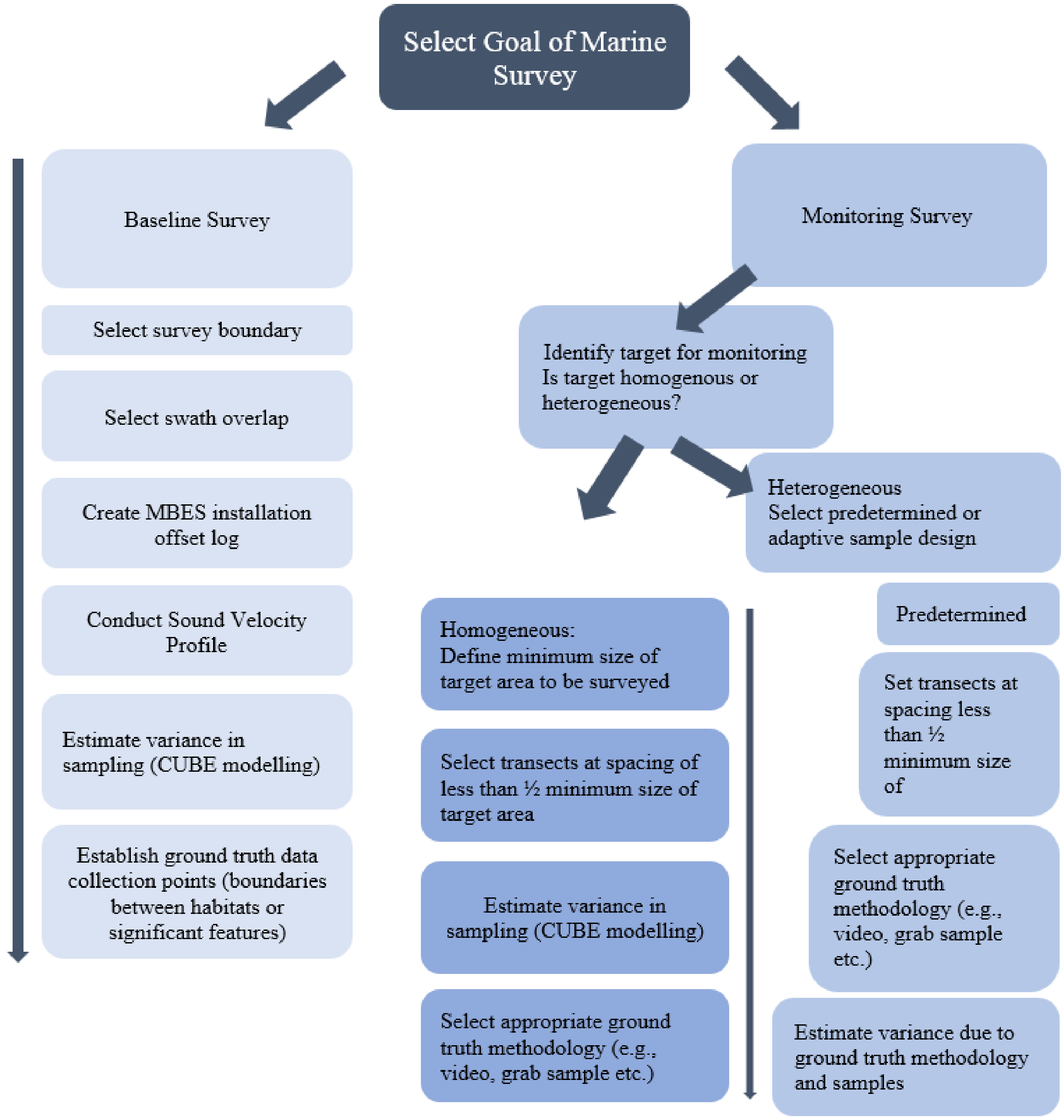


Figure 6 . Decision tree for seabed classification survey design (adapted from Anderson et al. (2007)).

Table 11 Standard Operating Procedures for MBES surveys according to survey purpose: Baseline or Monitoring

Specification	NESP Baseline	NESP Monitoring
Purpose	• Used to identify seafloor habitats and potential biodiversity hotspots. • Used for discovery purposes in regions that have had no baseline mapping conducted.	• Used to ensure spatio-temporal assessment of the seabed and habitat. The survey accuracy standard is very high to ensure reproducibility over time. • Used for repeat mapping and for targeting key habitats for monitoring purposes.
Pre survey preparation	• The coverage of the area to be surveyed (bounding box) with the datum and coordinate system clearly identified. • Apply for appropriate permits • Establishment of line spacing • Register upcoming survey with the AusSeabed Survey Coordination Tool (section 2.1.3) • Determination of the system offsets and calibration area (patch test) area to be conducted as soon as practical and after the system is completely set up ready for survey. • The location and scheduling of the Sound Velocity Profiles	• In addition to baseline survey specifications: • Synthesis of all pre-existing survey data into survey region database • Identification of locations of seafloor targets to be monitored
Installation Offsets	• Provide Mobilisation Calibration Reports and logs (section 6.1)	
Data Logging	• Bathy: Mandated • Seabed Backscatter: Mandated • Water column backscatter: Recommended (if available)	
Acquisition setting	• Mode: Equidistant mode where system allows • Minimise setting changes to optimise backscatter (avoid running system on auto mode) section 4.3.2	
Sound Velocity Profiles (SVP)	• Min of 1 per day, but should be monitored. • If sound speed at the transducer varies by > 2m/s another SVP should be collected	• Min of 2 per day (beginning and end of survey), but should be monitored. • If sound speed at the transducer varies by > 1m/s another SVP should be collected
Geodetic Parameters	• GDA2020. Horizontal accuracy: 5m + 5% of water depth. Vertical accuracy: 1% water depth	• GDA2020 -– Horizontal accuracy: absolute positioning to be < 2 m. Vertical accuracy: < 0.5 m
Survey Speed	• at survey speed appropriate to capture resolution required (typically 5 knots or less)	
Mapping Coverage & Overlap	• 100% Coverage with 30% overlap between survey lines of data with an 80% confidence level.	• 100% coverage with 60% overlap between survey lines of data with an 80% confidence level.
Resolution	• 1 m resolution in < 50m depth ; 5% of depth beyond 50 m	• 1 m resolution
Tides and GPS Tide	• Record GPS tides. All soundings shall be reduced to the ellipsoid.	
Point data attribution	• All data should be attributed with its uncertainty estimate at the 80% confidence level for both position and, if relevant, depth.	• All data should be attributed with its uncertainty estimate at the 95% confidence level for both position and, if relevant, depth.

Metadata and Reports	• Metadata should conform to the schema outlined in section 2.3.1.3, Mobilisation, Calibration, and validation reports, as well as the Report of Survey should conform with section 6. • Templates are provided in Appendix H that contain more detail.
Data Release	• Refer to section 7 for instructions on submitting data and metadata to AusSeabed and AODN for archiving.
Notification	• After the data has been successfully received by AusSeabed and AODN please contact marineparks@awe.gov.au to confirm delivery of data.

9 References

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Appendices

Appendix A – Abbreviations

Table A1 Abbreviations used in this document.

AHO	Australian Hydrographic Office
AUV	Autonomous underwater vehicle
BIST	Built-in Systems Test (Kongsberg specific)
BITE	Built-in test environment (Reson specific)
BM	Benchmark
CD	Chart Datum
CTD	Conductivity / Temperature / Depth
CRP	Common Reference Point
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
DOP	Dilution of Precision
GA	Geoscience Australia
GNSS	Global Navigation Satellite System
GPS	Global positioning system
HAT	Highest Astronomical Tide
ICSM	Inter-Governmental Committee on Surveying and Mapping
IHO	International Hydrographic Organisation
IMU	Inertial motion unit
ITRF	International Terrestrial Reference Frame
LAT	Lowest Astronomical Tide
LINZ	Land Information New Zealand
MBES	Multibeam Echo Sounder (inclusive of interferometric bathymetric swath systems)
MHHW	Mean High Water
MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
M	International Nautical Mile
MRU	Motion Reference Unit
MSL	Mean Sea Level
PPK	Post Processed Kinematic
PPS	Pulse Per Second
QA	Quality Assurance
QC	Quality Control
ROS	Report of Survey
ROV	Remotely operated vehicle
RTK	Real Time Kinematic
SD	Sounding Datum

SIC	Seabed mapper in Charge
SMS	Seabed Mapping System
SO	Special Order
SV	Sound Velocity
SVP	Sound Velocity Probe or Sound Velocity Profile
SVS	Sound velocity sensor
THU	Total Horizontal Uncertainty
TPU	Total Propagated Uncertainty
TVU	Total Vertical Uncertainty
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WGS-84	World Geodetic System 1984
XBT	Expendable Bathythermograph

Appendix B – Glossary

Below are some of the terms used in this guideline. However, more terms and definitions can be found in Table 2.1.2 of AHO, 2008.

% Overlap: refer to the amount of overlap between adjacent swaths. 0% overlap means that the ship tracks are run so that the outer beams of the swath meet the outer beam of the adjacent swath (Figure B.1). 100% overlap means that the adjacent ship track is run along the outer beam edge (meeting the required specification) of the previous swath (Figure B.2). Refer to section 7.4 of AHO, 2018 for more details

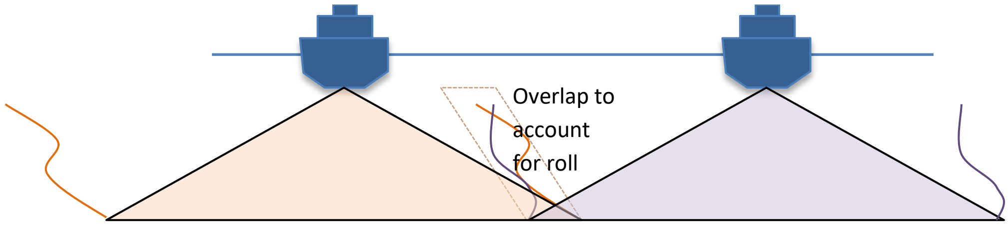

Figure B1   100% swath coverage with 0% or barely any overlap to cover ship roll (AHO, 2018)

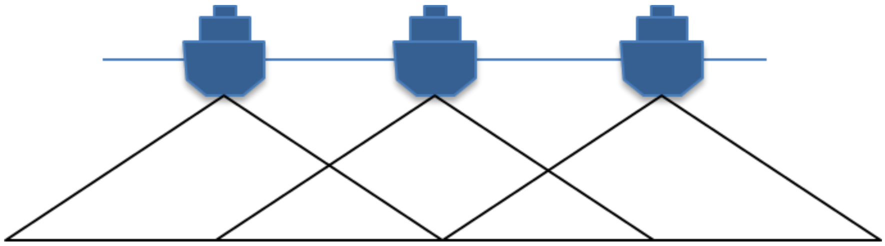

Figure B2   200% swath coverage with 100% overlap (AHO, 2018)

Blunders: See Error, gross.

Checkline: Sounding lines that are run perpendicular to the main survey lines and used to QA the soundings.

Coverage: portion of the seabed cover by the multibeam swath. 100% coverage refers to 100% of the seabed covered by the swath without any overlap (Figure B.1), while 200% coverage refers to 100 % overlap (Figure B.2). Partial coverage refers to a seabed coverage that is less than 100%.

Crossline: also known as checkline

Depth: Depth is a vertical distance from a given vertical datum. Depths are derived by MBES from measurements of angles and ranges corrected for environmental factors. Horizontal Position is provided to derived depth by GNSS-Inertial system thus providing an xyz value. GNSS Inertial system derived vertical position from measurements of angular rates and acceleration.

Dimension control: consists of determining the relationship between the measurement sensor and the platform Common Reference Point.

Error: The difference between an observed or computed value of a quantity and the ideal or true value of that quantity.

Error, gross: The result of carelessness or a mistake; may be detected through repetition of the measurement. Also called *blunder.*

Error, random: remaining uncorrelated noise in the system, or noise, also known as accidental error.

Patch test: A Patch test is a specific survey performed prior to principal survey to allow adjustments of the MBES data for parameters such as transducer error (pitch, roll and yaw), and navigation latency. This test is done since the MBES has no reference to external fixed frame of reference (satellite constellation isn't visible underwater), the MBES receives its “frame” from GNSS-Inertial system. These adjustments are entered in the acquisition software.

Seabed backscatter: Defined as the amount of acoustic energy being received by the sonar after a complex interaction with the seabed. Measured as the ratio between the intensity of the acoustic pulse scattered back by the seafloor and the incident intensity, this information can be used to determine bottom type, knowing that the different bottom types “scatter” sound energy differently. The intensity of the backscatter received at the transducer depends on the transmitted source level, the transmission loss (absorption in the water column and geometrical spreading), and the target strength. Many multibeam sonar systems offer two types of seabed backscatter data namely “one-per-beam” backscatter (either beam average or max intensity) and “time series” backscatter. For further information on backscatter refer to Lamarche and Lurton, 2017

Sounding datum: This datum is used while mapping. It is a low-water plane to which soundings are reduced and above which drying heights are given on the Standard Sheet and in other survey records. However, for chart datum, tidal reduction is essential (Figure 5).

Swath system: Current swath sounding systems utilize two differing technologies to achieve bathymetry measurements across a “swath” of the sea floor: 1) Beam forming (multibeam echo sounders), and 2) interferometric or phase discrimination sonars, also known as bathymetric sidescan. Both of these techniques have their merits; however, the same end results are achieved.

Systematic error: see error.

Transit data: Transit data include any data collected outside the survey specific area, e.g. data collected between port and survey area or between sampling sites. In hydrographic terms, this is referred to as passage soundings.

Water Column backscatter: Recently developed multibeam sonars have the capability to record the sonar time series for each beam, which maps the water column in addition to the seafloor. Water column data could be used for direct mapping of fish and marine mammals, the mapping of plumes and vents, the location of mid-water targets, and a wide range of physical oceanographic processes.

Appendix C – Legislation and permitting

Table C1 List of documents relevant to multibeam activities in the Commonwealth waters (defined as 3 nautical miles seaward to the outer boundary of the EEZ, 200 nautical miles). Extracted from Marine Sampling Field Manuals (Przeslawski and Foster, 2018). Similar issues should be considered when working in coastal waters of States and the Northern Territory.

Activity	Activity Type	Jurisdiction	Responsible Agency	Legislation/Treaty/ Documents	Requirements for approval	Link
Research and monitoring	All activities	Australian Marine Parks	Department of Agriculture, Water and Environment (DAWE)	*Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (EPBC Act)	Authorisation is required for all zones	https://parksaustralia.gov.au/marine/contact/
	Activities with potentially significant impact on a matter of national environmental significance	EEZ 3 – 200nm	DAWE	Australian Marine Park Management Plans EPBC Act	EPBC Act referral Public consultation, including indigenous stakeholders	http://www.environment.gov.au/protection/environment-assessments/ http://www.environment.gov.au/epbc/what-is-protected
	All activities	Heard Island and McDonald Islands	DAWE	Environment Protection and Management Ordinance 1987 (HIMI) EPBC Regulations 2000	Permit required	*https://www.antarctica.gov.au/living-and-working/travel-and-logistics/cargo-and-freight/types-of-cargo/scientific-samples/environmental-approvals/*
	All activities	Antarctica (south of 60°S)	DAWE	Antarctic Treaty (Environment Protection) Act 1980 *Antarctic Marine Living Resources Conservation (AMLRC) Act 1981*	Authorisation ***and*** permit required *AMLRC Act permit required if carrying out research with respect to marine living organisms in the CCAMLR Convention Area*	*https://www.antarctica.gov.au/environment/environmental-impact-assessment-approvals-and-permits//*

Interactions with Cetaceans	Acoustic equipment with received exposure level 160dB re 1 µPa2.s for 95% of shot at 1km range (seismic)	EEZ 3 – 200nm	DAWE	EPBC Act Policy Statement 2.1	EPBC Referral and comply with Policy Statement 2.1	http://www.environment.gov.au/resource/epbc-act-policy-statement-21-interaction-between-offshore-seismic-exploration-and-whales
	Vessel interaction	EEZ 3 – 200nm	DAWE	*EPBC Act. Regulations 2000* (Cth) (EPBC Regulations) part 8	Report death, injury, stranding or entanglement of whales and dolphins to DoEE. Specific requirements for vessels	https://www.legislation.gov.au/Details/F2016C00914
Interaction with Heritage	Historic Ship wrecks	Continental shelf waters (incl. some areas > 200 nm)	DAWE	*Historic Shipwrecks Act 1976 (Cth)*	Ship wrecks and relics older than 75 years and lying within protected zones.	http://www.environment.gov.au/heritage/historic-shipwrecks
Restricted vessel movement and moored scientific equipment that create navigation hazards			Australian Hydrographic Service AHS Australian Marine Safety AMSA		Notice to mariners 2-3 weeks prior to survey commences. Vessel to RCC to update NAVAREA X alerts	https://www.amsa.gov.au/safety-navigation/navigation-systems/maritime-safety-information-database datacentre@hydro.gov.au rccaus@amsa.gov.au
Research in the Great Barrier Reef Marine Park GBRMP	Research, except for limited impact research.	GBRMP	Great Barrier Reef Marine Park Authority GBRMPA	*Great Barrier Reef Marine Park Act 1975 (Cth)* *EPBC Act*	Limited impact research may be conducted under a letter of authority issued by an accredited educational or research institutions All other research requires permission	http://www.gbrmpa.gov.au/zoning-permits-and-plans/permits http://www.gbrmpa.gov.au/zoning-permits-and-plans/permits/research-permissions
Research around petroleum and other infrastructure		3nm seaward to EEZ or outer limits of the continental shelf		*Sea Installations Act 1987*	Vessels prohibited to go within a safety zone of 500m	http://www.environment.gov.au/topics/marine/marine-pollution/sea-dumping/sea-installations

Laws and regulations regarding multibeam sonar acquisition in State and Territory waters (less than 3 nm from the coast) vary slightly across jurisdictions, but they are generally not restricted or subject to permit requirements, with the exception of:

- Survey undertaken in Marine Protected Areas (for guidance see Marine Protected Areas section above).

- Survey carrying out extractive work (marine biota) or work that could be considered destructive to marine habitats.
- Surveys undertaken across areas with access restrictions (e.g., naval waters, commercial ports, or shipping channels).
- Surveys carried out In New South Wales for the purposes of resource exploration (permission through NSW Resources and Energy - Environment and Planning).

Table C.2 Web links to States and Territory permits

VIC Research	SA Research	NSW Research	NT Research	TAS Research	QLD Research	WA Research

Appendix D – Guideline on timeframe for actions

Table D1 Estimated time frame required to perform some of the swath system related tasks. These estimates are to assist in survey planning, but note that they can vary considerably depending on the difficulty or the issues arising from the task performed.

Action	Timeline to be expected
Authorisation/permits from authority	Months
Mobilisation, calibration, validation (does not include time to manufacture mounts to fit the system)	3-5 days
Patch test	2 hrs to 0.5 day
Self-system test	2-5 minutes
SVP cast (depends on water depth and device)	20 min plus deployment time of the SVP, which depends on water depth (based on SVP not XBT device)
Crossline	0.5 day (depends on survey area)
Acquisition vs Processing ratio (depends on the quality of the input data and the level of cleaning)	1:1 to 1:3

Appendix E – Total Propagated Uncertainties

Table E12Sounding Accuracy - Example MBES Total Propagated Uncertainty Estimates

Uncertainty Source	Value	Reference to Accuracy Value for Total Propagated Uncertainty Computation
Heading (degrees)	0.05	(Make/Model) – Manufacturer Accuracy Value
Smart Heave (Amplitude %) Real-Time Heave (Amplitude %)	2.5 5.0	(Make/Model) – Manufacturer Accuracy Value
Smart Heave (m) Real-Time Heave (m)	0.025 0.05	(Make/Model) – Manufacturer Accuracy Value
Roll (degrees)	0.01	(Make/Model) – Manufacturer Accuracy Value
Pitch (degrees)	0.01	(Make/Model) – Manufacturer Accuracy Value
Navigation (m)	0.10	(Make/Model) – Manufacturer Accuracy Value
Transducer Timing (s)	0.001	Estimated – 1PPS (Make/Model)
Navigation Timing (s)	0.001	Estimated – 1PPS (Make/Model)
Heading Timing (s)	0.001	Estimated – 1PPS (Make/Model)
Heave Timing (s)	0.001	Estimated – 1PPS (Make/Model)
Pitch Timing (s)	0.001	Estimated – 1PPS (Make/Model)
Roll Timing (s)	0.001	Estimated – 1PPS (Make/Model)
Offset X (m)	0.02	Estimated – (Description of Dimensional Control method)
Offset Y (m)	0.02	Estimated - (Description of Dimensional Control method)
Offset Z (m)	0.02	Estimated - (Description of Dimensional Control method)
Speed (knots)	0.10	Not Applicable
Loading (m)	0.02	Estimated
Draft (m)	0.05	Estimated – (Description of measurement)
Delta Draft (m)	0.02	Estimated - Vessel Dynamic Draft (Squat/Settlement) Calibration
MRU Heading Alignment (degrees)	0.05	Estimated - Multi-beam Patch Test Calibration
MRU Pitch/Roll Alignment (degrees)	0.05	Estimated - Multi-beam Patch Test Calibration
Tidal Measurements (m)	0.02 0.02 0.03 0.05	(Make/Model) TG – Manufacturer Accuracy Value (Make/Model) Barometer – Manufacturer Accuracy Value Estimated - GNSS Buoy TG calibration Estimated – Accounting for above Contributions
Tidal Zoning (m)	0.10	Estimated - Co-Tidal Model
SVP Profile Measurement (m/s)	0.02 0.50	(Make/Model) – Manufacturer Accuracy Value Estimated - Temporal and Spatial Variation
SVP Surface Measurement (m/s)	0.017	Make/Model) - Manufacturer Accuracy Value
Sonar Measurement		MBES Device Models File

Appendix F – Patch test

The figure below shows the pattern to use for the patch test of a MBES system with one or two sonar heads configuration.

For **backscatter calibration**, run the line schema for various modes. Alternatively, change the settings along a line where the seafloor is expected to be homogeneous.

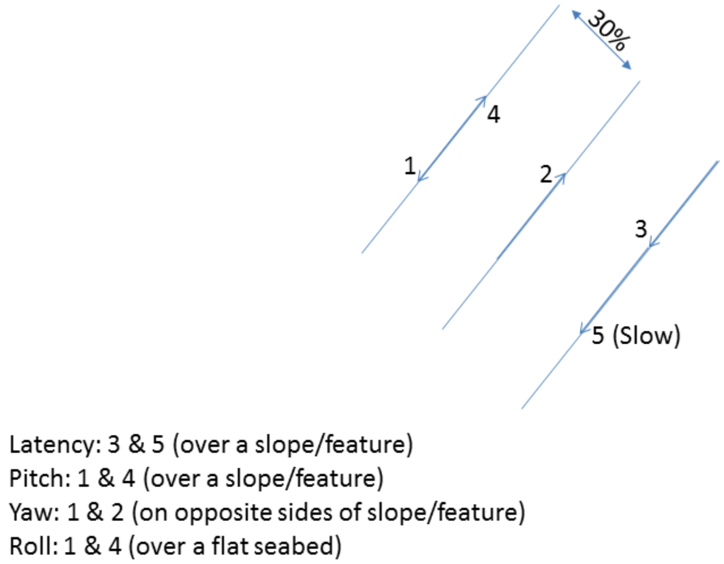

Figure F9 Proposed line pattern for single head sonar patch test

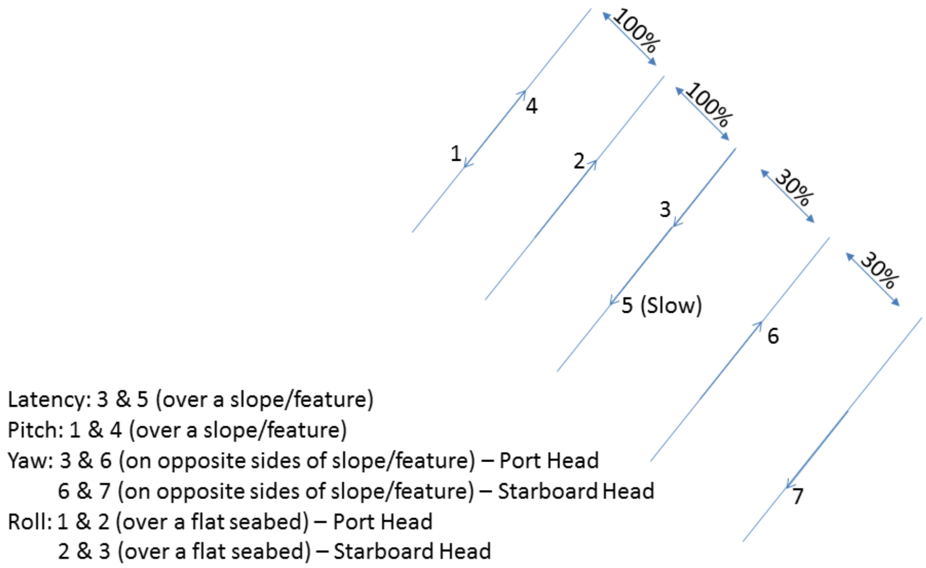

Figure F2. Proposed line pattern for ***dual-head*** *sonar patch test*

Appendix G – IHO Standards

Table G13 IHO standards for hydrographic surveys (S-44). Read in conjunction with document (IHO, 2008). These are presently in review by the IHO.

Reference	Order	Special	1a	1b	2
Chapter 1	**Description of areas.**	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	**Maximum allowable THU 95% *Confidence level***	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	**Maximum allowable TVU 95% *Confidence level***	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	***Full Sea floor Search***	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	***Feature Detection***	Cubic *features* > 1 metre	Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	**Recommended maximum Line Spacing**	Not defined as *full sea floor search* is required	Not defined as *full sea floor search* is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	**Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)**	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	**Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)**	10 metres	20 metres	20 metres	20 metres
Chapter 2 and note 5	**Mean position of floating aids to navigation (95% *Confidence level*)**	10 metres	10 metres	10 metres	20 metres

Table G2 HIPP standards for hydrographic surveys (AHO, 2018)

HIPP ORDER		HIPP - Precise	IHO – Special	IHO - 1a	IHO - 1b	HIPP - 2	IHO - 2	HIPP-Passage
TOTAL HORIZONTAL UNCERTAINITY (THU)								
TOTAL HORIZONTAL UNCERTAINITY (95% Confidence Level)		1m	2m	5m + 5% of depth	5m + 5% of depth	5m + 1% of depth	20m + 10% of depth	5m +5% of depth
SEAFLOOR SEARCH REQUIREMENTS (COVERAGE)								
Swath Systems [(1)]		Full Seafloor Coverage (FSC)	Full Seafloor Coverage	Full Bathymetric Coverage (FBC) (LIDAR – 200% Coverage)[(2)]	Full Seafloor Ensonification (FSE)	Full Bathymetric Coverage	Not Required	Offset tracklines (if applicable)[(3)]
FEATURE DETECTION								
Water Depth <40m	Swath	50cm	1m	2m	As Specified	As Specified	Not Applicable	4m
Water Depth >40m	Swath	1m	2.5% of depth	5% of depth	As Specified	2% of depth	Not Applicable	10% of depth
TOTAL VERTICAL UNCERTAINITY (TVU) [(4)]								
TOTAL VERTICAL UNCERTAINITY (95% Confidence Level)		a = 0.15m b = 0.0075	a = 0.25m b = 0.0075	a = 0.5m b = 0.013	a = 0.5m b = 0.013	a = 0.6m b = 0.0085	a = 1.0m b = 0.023	a = 0.5m b = 0.023

Appendix H – Records templates

The following appendix provides suggested templates for Records that should be produced during a seabed mapping survey. These templates can also be downloaded on the AusSeabed website (with the exception of the AusSeabed required metadata table.

H.1 Mobilisation, calibration and validation report

The following link provides you with the template.

H.2 AusSeabed minimum required metadata

Below is a table with specific field definitions and examples for each metadata field expected to accompany data submitted to AusSeabed. The fields specified are considered a minimum set that can be appended to, but not deviated from, replaced, or altered. Note that on submission it is only required to provide the Field column and the associated survey metadata the other columns in the table are provided for illustrative purposes only.

Table H14 Required Metadata for data submitted to AusSeabed

Category	Definition	Fields	Specific Field Definitions	Example Data
General	Basic information about the data package being submitted.	Survey title (full)	A short phrase or sentence describing the dataset. In many discovery systems, the title will be displayed in the results list from a search, and therefore should be human readable and reasonable to display in a list of such names.	*MH370 Phase 1 150m Bathymetry datasets*
		Survey ID	The ID assigned to the survey, relevant especially when an ID may be how the survey is more widely referenced.	*GA-4421, GA-4422, GA-4430*
		Abstract	A paragraph describing the dataset, analogous to an abstract for a paper.	*"On behalf of Australia, the Australian Transport Safety Bureau (ATSB) is leading search operations for missing Malaysian airlines flight MH370 in the Southern Indian Ocean. Geoscience Australia provided advice, expertise and support to the ATSB to facilitate bathymetric surveys …* [for full abstract visit http://pid.geoscience.gov.au/dataset/100315]

Category	Definition	Fields	Specific Field Definitions	Example Data
		Lineage	Information about the events or source data used in constructing the data specified by the scope or lack of knowledge about lineage. Lineage can be complex to record, so can be actively linked within a metadata record either to a file within the dataset being submitted or to a hosted location where the lineage statement may be found. If neither of these options are preferred, a full narrative may also be provided.	*"link-to-lineage-statement"_OR Full text: "The MH370 Search bathymetry Surveys, GA-4421 GP1483 was acquired by the Australian Government through ATSB/GA on-board the MV Fugro Equator from the 05th of June to the 30th of July 2016, GA-4422 through the Chinese Navy Vessel Zhu Kezhen 872 from the 3rd June to 31 August 2014 and from the 5th January to the 30 April 2015 for the MV Fugro Supporter………"*
Contact for the Data	Information that is related to contacts for the data	Data Owner	. The person and/or organisation that owns the submitted data for the purpose of empowering AusSeabed to act as a custodian	*Commonwealth of Australia*
		Custodian	The person and/or organisation that accepts, archives and disseminates the data	*Commonwealth of Australia*
		Point of Contact	The person and/or contact details for initiating contact regarding the data	*Commonwealth of Australia (Geoscience Australia) clientservices@ga.gov.au (Manager Client Services) Cnr Jerrabomberra Ave and Hindmarsh Dr GPO Box 378, Canberra, ACT, 2601, Australia Call 1800 800 173,02 6249 9960*
		Collecting Entity	The organisation that was responsible for collecting the data being described.	*Australian Transport Safety Bureau (ATSB)*
Citation	Information that is collected to ensure appropriate credit is assigned for the data being provided, and ensuring the data's intended use of the data is clear.	Attribution Licence (citation)	Statement of attribution that must be included whenever the data being provided is distributed/redistributed or used by another organisation.	*2017. MH370 Phase 1 150m Bathymetry datasets (GA-4421, GA-4422 & GA-4430). Geoscience Australia, Canberra. http://pid.geoscience.gov.au/dataset/100315*
		Legal Constraints	Restrictions and legal prerequisites for accessing and using the resource or metadata	*Creative Commons Attribution 4.0 International Licence http://creativecommons.org/licenses/*
		Access Constraints	Details of any constraints that are not determined under the licence constraints regarding the access to the information being provided. Access constraints are applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata	*As per licence*
		Use Constraints	Details of any constraints that are not determined under the licence constraints regarding the use of the information being provided.	*As per licence*

Category	Definition	Fields	Specific Field Definitions	Example Data
		Country (of data ownership)	Country of the owner of the data.	*Australia*
Survey Positioning Data	The information provided in the positioning data provides for both an overview of the survey's coverage, and the primary coordination reference system that was used to collect/prepare the survey data.	Survey area (general)	Plain English description of the location of the survey.	*Indian ocean approximately 1100nm off the coast of Perth Australia.*
		Survey bounding box coordinates	The detailed coordinates of the survey. This may be provided in a variety of formats, however full positioning information is required.	*78.00, -42.00, 116.00, -12.00* *"WGS 84 / UTM zone 44S (EPSG:32744)","WGS 84 / UTM zone 46S (EPSG:32746)","WGS 84 / UTM zone 47S (EPSG:32747)","WGS 84 / UTM zone 48S (EPSG:32748)","WGS 84 / UTM zone 49S (EPSG:32749)","WGS 84 / UTM zone 50S (EPSG:32750)"*
		Coordinate reference system - Bounding Box	The coordinate reference system used to define the survey bounding box.	
		Coordinate reference system - Survey Data	The coordinate reference system used for data collection.	*"WGS 84 / UTM zone 44S (EPSG:32744)","WGS 84 / UTM zone 46S (EPSG:32746)","WGS 84 / UTM zone 47S (EPSG:32747)","WGS 84 / UTM zone 48S (EPSG:32748)","WGS 84 / UTM zone 49S (EPSG:32749)","WGS 84 / UTM zone 50S (EPSG:32750)"*
Reference System	The finer details of the reference system used for data collection.	Geodetic datum of the survey	The reference datum of the data collected	*WGS 84*
		Horizontal Datum	The horizontal reference datum for data collection	*UTM*
		Vertical Datum	The vertical reference datum for data collection	*MSL*
Survey Configuration	The configuration of the survey as it ran.	Instrument type	The type of instrument used to capture the data. Suggested values are: - Multi-beam - Single-Beam - Bathy LiDAR - Airborne Imagery - Satellite - Side-Scan - Sub-Bottom profiler	*Multi-beam Sonar*
		Sensor type	The type of sensor used to collect the data being provided.	*EM2040*
		Sensor Frequency	Frequency at which the survey was conducted. This may be provided as multiple values based on the sensor's capabilities.	*200-400kHz*
		Platform type	The platform hosting the instruments and sensors used to collect the data.	*Ship, AUV*
		Platform Name	The name of the platform used to collect submitted data	*RV Investigator*

H.3 Survey log sheet templates

MBES LOG SHEET				
SURVEY NAME:	VESSEL:	JULIAN DAY:	UTC OFFSET:	PAGE:

OPERATOR		GENERAL DESCRIPTION:
Name:	Signed:	

WEATHER:

Local Time		Line Name	Heading	Speed	Event (e.g. settings, SVP, Transit, Turn, etc.)	Comments (e.g. mode, frequency, pulse length, etc)
Start	Stop					

SVP LOG SHEET

SURVEY NAME:	VESSEL:	LOCAL DATE:	UTC OFFSET:	PAGE:

OPERATOR		GENERAL DESCRIPTION:
Name:	Signed:	

Local Time	Position		Water Depth	Surface SV (SVS)	Weather			Comments
	Deploy	Recover			Wind speed	Direction	Sea state	

H.4 Report of Survey template

The following template has been modified from AHO Survey Summary Template, which can be found in full here. Guidance on Confidence Levels and Error Ellipse scaling is contained in ICSM (2014a), uncertainties from IHO publication S-44 or by contacting the Bathymetric Data Assessment Section at the Australian Hydrographic Office on 02 4223 6500.

Introduction

Survey Title and ID	Locality
Survey Authority	**Survey Sponsor/Custodian**
Surveyor in Charge and qualification	**Date this Survey Summary was completed**
Start Date of Survey	**End Date of Survey**
Survey Platform/Vessel Name	**Survey Platform/Vessel Name**
Purpose of the Survey	

Horizontal Control

Soundings are on the following datum (WGS84 preferred but not essential)	
Datum	
Spheroid	
Projection and Zone	
Was the positioning system validated?	
Were laybacks applied?	

Estimated horizontal accuracy of soundings at 2 Sigma (95%) confidence level (Calculations can be included as an attachment. Don't know? Enter "Not Known")	

Vertical Control

Tides Applied	
Soundings Datum	
Tide Station 1 Details	
Benchmark (BM) used and Datum connection	
Geoid details if using GPS tides	
Tide Station 2 Details	
Benchmark (BM) used and Datum connection	
Geoid details if using GPS tides	
Tide Station 3 Details	
Benchmark (BM) used and Datum connection	
Geoid details if using GPS tides	
Tide Model comments (if applicable)	

Were soundings corrected for draught?	
Were the soundings corrected for sound velocity?	

Estimated vertical accuracy of soundings at 1.96 Sigma (95%) confidence level (Calculations can be included as an attachment. Don't know? Enter "Not Known")	

The following positioning systems were used:		
Positioning System 1		
Positioning System 2		
Base station (If applicable)		
The following sounding systems were used:		
Model / System Details	**Frequency (kHz)**	
Echosounder 1		
Echosounder 2		
Logging and Processing Systems used, and Versions:		
Logging		
Processing		
Was the survey systematically controlled with planned survey lines or methods?		
Was full feature detection achieved as defined in IHO publication S-44, Edition 5, February 2008?		
If feature detection was achieved, what Order of features is applicable?		
Feature detection comments (if applicable)		

Were all shoal depths systematically investigated and their least depths determined?	
Has data been thinned from that collected?	
If thinned, what thinning method and bin size was used?	
Remarks (If applicable)	

Shoals and Dangers

This section seeks comments on any features that may be dangerous to surface navigation. (Comments as required. General location and depth references, pictures, screen dumps, etc. will assist. Has a Hydrographic Note or Danger to Navigation Report been submitted?)

Wrecks

This section seeks comments on any wrecks detected during the course of survey. (Comments as required. General location and depth references, pictures, screen dumps, etc. will assist.)