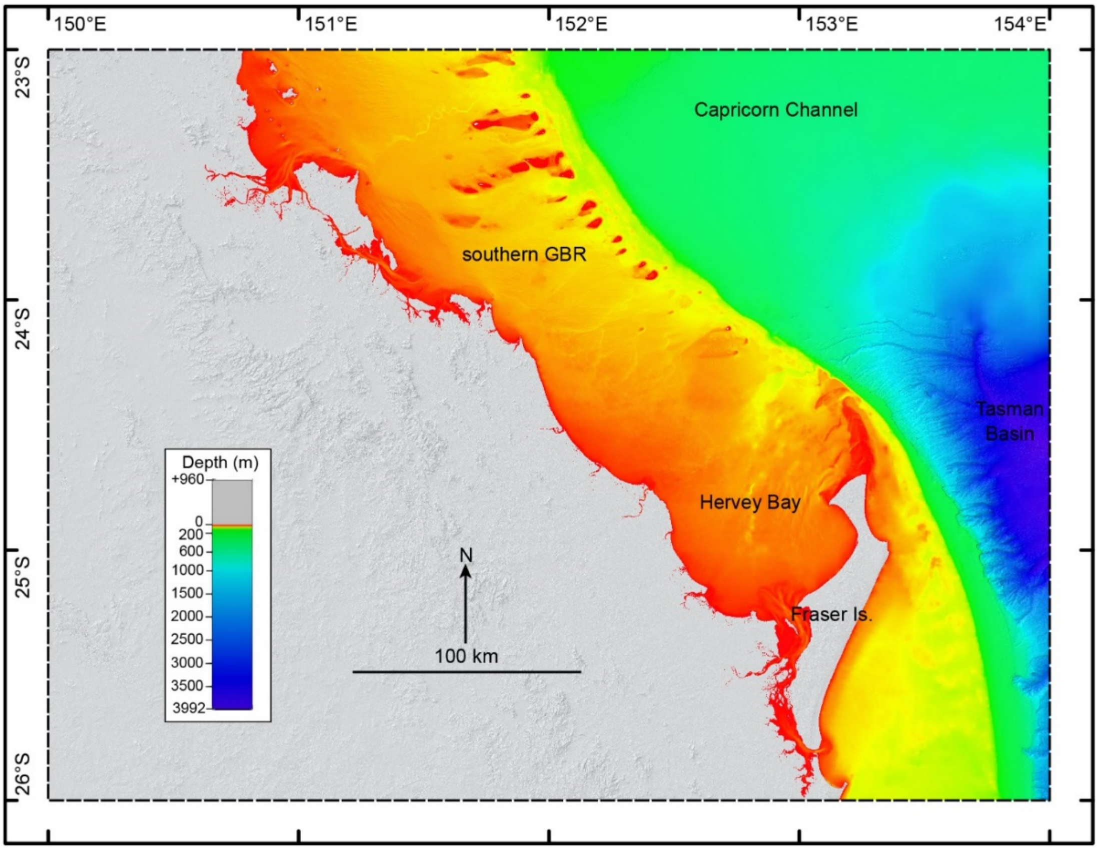
Development of the ceq30 bathymetry grid

Intertidal and Subtidal Habitat Mapping and Conservation Values Assessment for Central Queensland State Waters Project



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Queensland Government

Queensland Wetlands Program

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Contents

List of figures

List of tables

Acronyms and Abbreviations

AGD66	Australian Geodetic Datum 1966
AHD	Australian Height Datum
AHS	Australian Hydrographic Service
ALB	airborne lidar bathymetry
AusBathyTopo	Australian Bathymetry and Topography Grid
AusCoastVDT	Australian Vertical Datum Transformation Tool
CRCSI	Cooperative Research Centre for Spatial Information
DEM	Digital Elevation Model
DSM	Digital Surface Model
ECDIS	Electronic Chart Display and Information System
ENC	Electronic Navigational Chart
EOMAP	Satellite aquatic information company
ESRI	Environmental Systems Research Institute Company
GA	Geoscience Australia
GBR	Great Barrier Reef
GBRDEM	Great Barrier Reef Depth and Elevation Model
GDA94	Geocentric Datum of Australia 1994
GIS	Geographic Information System
GMT	Generic Mapping Tools
HAT	highest astronomical tide
HTF	Hydrographic Transfer Format
IHO	International Hydrographic Organization
ITEM	Intertidal Extents Model
LADS	Laser Airborne Depth Sounder
LAT	lowest astronomical tide
MGA	Map Grid of Australia
MHWS	mean high water springs
MIP	EOMAP’s Modular and Inversion Processor
MLWS	mean low water springs
MSL	mean sea level
MSQ	Maritime Safety Queensland
NDVI	Normalised Difference Water Index
netCDF	network Common Data Form
QPS	Quality Positioning Services company
RAN	Royal Australian Navy
RTK	Real Time Kinematic
SDB	satellite derived bathymetry
SRTM	Shuttle Radar Topographic Mission
THU	Total Horizontal Uncertainty
TVU	Total Vertical Uncertainty
USGS	United States Geological Survey
WGS84	World Geodetic System 1984

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- Department of Environment and Science (Queensland)
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- EOMAP Australia Pty Ltd (Australia)

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GEOSCIENCE AUSTRALIA NOTICE: This ceq30 bathymetry grid incorporates data which are © Commonwealth of Australia (Geoscience Australia) 2009-2017. The Commonwealth gives no warranty regarding the data's accuracy, completeness, currency or suitability for any particular purpose. This dataset has been compiled from a wide range of data sources of varying resolution and accuracy.

QUEENSLAND GOVERNMENT NATURAL RESOURCES AND MINES: This ceq30 bathymetry grid incorporates vector data sourced from Geographic features - Queensland series, licensed under Creative Commons Attribution 3.0 sourced on 22 June 2017.

1 Summary

The ceq30 bathymetry grid was developed for the Intertidal and Subtidal Habitat Mapping and Conservation Values Assessment for Central Queensland State Waters Project. High-resolution bathymetry data are fundamental to underpin marine habitat mapping and are an essential attribute for use in the 'Interim Queensland intertidal and subtidal ecosystem classification scheme'.

The ceq30 grid is a compilation of new and existing source bathymetry data, including multibeam and singlebeam echosounder data, Electronic Navigational Chart (ENC) spot depths, airborne lidar bathymetry (ALB) data, Intertidal Extents Model (ITEM v1.0) Digital Elevation Model (DEM) data, satellite derived bathymetry (SDB) and coastline data. Source data are current to 22 June 2017. Shuttle Radar Topographic Mission (SRTM) Digital Surface Model (DSM) data were used as land elevation source data.

The source bathymetry data Total Vertical Uncertainty (TVU) is a measure of maximum allowable vertical uncertainty at the 95% confidence level. The TVU for the source bathymetry data varies from International Hydrographic Organisation (IHO) S44 Order 1a to 2. Alternatively, uncertainty calculations are provided where the TVU for source data falls outside of the standard IHO S44 categories.

All source bathymetry data were subjected to extensive pre-processing as 3D point clouds in order to remove any noise and data spikes. All source data were adjusted to a consistent WGS84 horizontal datum, and wherever possible, to approximate the mean sea level (MSL) vertical datum prior to the grid interpolation process.

The new ceq30 bathymetry grid has a grid pixel resolution of 0.0003° (~30 m), and spans an area latitude 23° to 26° South, longitude 150° to 154° East. The grid has a version date of 12 June 2017. The new grid uses a horizontal datum of WGS84 and a vertical datum approximating MSL. An accompanying TVU grid at the same 0.0003° grid pixel resolution provides the maximum allowable vertical uncertainty at the 95% confidence level, based upon the processed TVU of the underlying source data.

The additional source data and extensive pre-processing effort to remove data spikes and noise have significantly improved the level of detail of seabed geomorphic features seen in the new grid. The bathymetry grid data are recommended for use as a base for mapping or modelling other biophysical attributes for the 'Interim Queensland intertidal and subtidal ecosystem classification scheme', such as morphology, sediment grain size and wave energy.

2 Introduction

The ‘Interim Queensland intertidal and subtidal ecosystem classification scheme’ was developed as part of the Queensland Wetlands Program to provide a structured framework for classifying intertidal and subtidal ecosystems using independent biophysical attributes. The scheme is an attribute-based classification, providing a strong integrating framework for multiple disciplines e.g. ecology, oceanography, water quality etc., and forms the basis for the classification scheme and the mapping of components of these ecosystems.

Bathymetry data are essential and fundamental to underpin marine mapping as these provide the core data to which other datasets relate. For example, bathymetry data can be used as a base for mapping or modelling other biophysical attributes including seafloor morphology, sediment grain size, wave and tidal energy, and structural macrobenthos distribution. Beyond habitat mapping, bathymetry data can also be used for providing routes for safe shipping, marine jurisdiction planning, natural hazard risk assessment, to plan and build offshore infrastructure, benefit tourism and fishing industries, and for sea-level rise planning.

Given the fundamental importance of bathymetry data to the scheme, a major challenge is to provide bathymetry data that are as up-to-date as possible, i.e. using all currently available source survey datasets, and in file formats and at resolutions that allow further useful development of other biophysical attributes, e.g. morphology. Typically, such bathymetry data are provided as interpolated raster (grid) files or Digital Elevation Models (DEMs), where the grid pixel size represents the smallest feature able to be resolved within a DEM, and with spatial reference properties of a particular horizontal and vertical datum.

Within the Central Queensland State Waters project area, between the Fitzroy River in the north and Fraser Island in the south (Figure 1), there have been previous efforts to aggregate and interpolate source bathymetry data. These efforts have resulted in DEMs covering wider geographic areas but at coarse grid pixel resolutions that preclude useful modelling of other attributes within the project area. The Great Barrier Reef Depth and Elevation Model or ‘GBRDEM’ (Lewis, 2001) for the entire Queensland coast and shelf, uses a grid pixel size of 250 m and a horizontal datum Zone 55 of the Australian Geodetic Datum 1966 (AGD66). The vertical datum is mean sea level (MSL).

Another DEM is the widely-used Australian Bathymetry and Topography Grid covering the entire Australian continent and offshore marine jurisdiction (Whiteway, 2009). Geoscience Australia (GA) developed the ‘AusBathyTopo’ grid as a 0.0025° (~250 m) bathymetric grid including a large range of new source datasets not previously available to the GBRDEM and therefore current up to 2009. The grid uses a horizontal datum of WGS84 but the wide variation of source datasets collected at differing vertical datums meant that many of these datasets had not been adjusted to a consistent vertical datum, e.g. MSL.

A more recent bathymetry model called the ‘gbr100’ grid, is a 0.001 (~100 m) grid pixel dataset covers an area from the southern Torres Strait to northern New South Wales, and easterly into the offshore Coral Sea (Beaman, 2010). Initially funded by a Qld Smart Futures Fellowship in 2009, this grid has been improved and revised on a near-yearly basis to incorporate the latest source survey data. This grid uses a horizontal datum of WGS84 with a vertical datum approximating MSL, as all source bathymetry data are vertically adjusted to approximate MSL prior to the interpolation process of the gbr100 grid.

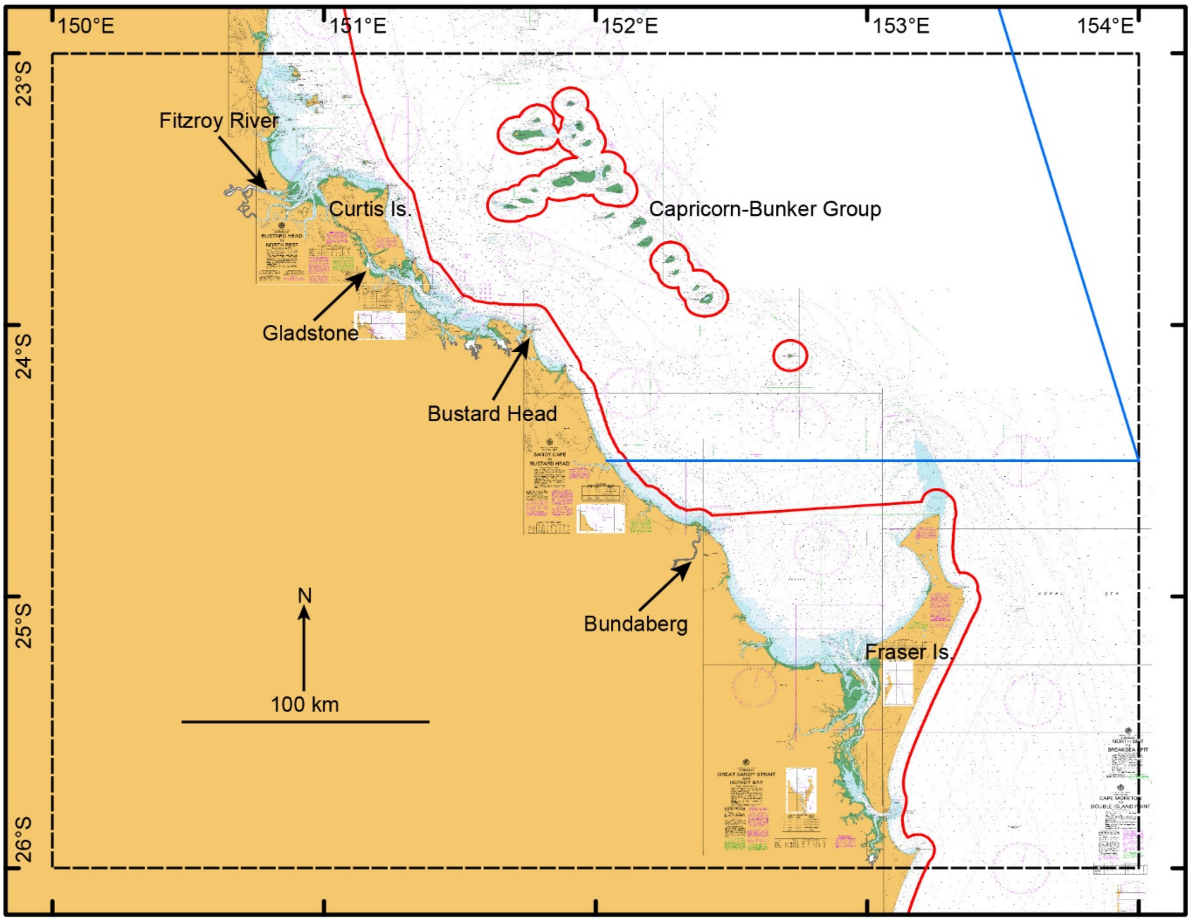

Figure 1 Overview map of the central Queensland study area using AusCharts 815, 816, 817, 818, 819 and 820. Dashed line is the ceq30 grid boundary limits. Red line is the Qld coastal waters limit. Blue line is the Great Barrier Reef World Heritage Area outer limit.

Then in 2014, the aquatic earth observation services company EOMAP was commissioned by the Qld Wetlands Program to supply a 15 m resolution satellite derived bathymetry (SDB) dataset to support the Qld Estuarine and Marine Habitat Classification Project. This dataset stretched from north of Curtis Island to south of Bustard Head in depths to about 20 m, thus providing valuable source bathymetry data for the nearshore around the Central Queensland area that otherwise lacked dense data coverage.

And in 2017, the topography of Australia's intertidal zone became available through the development of the Intertidal Extents Model (ITEM v1.0) as part of the Digital Earth Australia program (Sagar et al., 2017). Using a dense time series of Landsat data, a research team from the National Earth and Marine Observation Branch of Geoscience Australia created a continent-wide intertidal zone extent model for the whole of mainland Australia and Tasmania. The 25 m resolution DEM of the intertidal zone derived from this model therefore provided a further solution to the lack of nearshore source data along the Queensland coast.

With the availability of these new source datasets and the fundamental requirement of an up-to-date bathymetry grid for the Project, a new DEM was commissioned called the 'ceq30' grid, where 30 represents a 0.0003° grid pixel size (~30 m). This resolution was considered optimal based on the similar grid pixel size of the SRTM land elevation data available for the Australian mainland (Tickle et al., 2010). At ~30 m resolution, the grid would be able to help ‘capture’ the morphological detail required to derive the other biophysical attributes used in the ‘Interim Queensland intertidal and subtidal ecosystem classification scheme’.

This report describes the development of the new ceq30 grid for the Intertidal and Subtidal Habitat Mapping and Conservation Values Assessment for Central Queensland State Waters Project. The ceq30 grid spans an area from latitude 23° to 26° South and longitude 150° to 154° East. The new grid utilised the latest source data from multibeam and singlebeam surveys, airborne lidar bathymetry surveys, Electronic Nautical Chart spot depths, satellite derived bathymetry and ITEM DEM data. Information is presented on the datums used, survey uncertainty, descriptions of the source data types, processing methodology, and results of the new ceq30 grid.

The ‘Interim Queensland intertidal and subtidal ecosystem classification scheme’ uses independent biophysical attributes for classifying intertidal and subtidal ecosystems.

Bathymetry data are essential and fundamental to underpin marine mapping, providing the core data to which other datasets relate.

The ceq30 bathymetry grid is a raster DEM with a grid pixel size representing ~30 m, using the WGS84 horizontal datum and approximating the MSL vertical datum.

3 Methods

3.1 Datums

The ceq30 grid uses a horizontal datum of WGS84. This datum was selected as WGS84 is typically the datum used by bathymetry collection agencies. Prior to the interpolation process, all source xyz (longitude, latitude, depth) data were checked to ensure the position used the WGS84 datum. For example, some older National Mapping singlebeam surveys across the Great Barrier Reef (GBR) shelf had used the AGD66 horizontal datum. These xyz files were converted to the WGS84 datum prior to interpolation. Similarly, several surveys were provided as projected xyz (easting, northing, depth) data using the MGA56 GDA94 datum. These xyz files were converted to unprojected WGS84 prior to interpolation.

The ceq30 has a vertical datum that approximates MSL, i.e. a height of 0 m approximates MSL (Figure 2). This datum was chosen as MSL is equivalent to the Australian Height Datum (AHD). Thus if source data were vertically adjusted to approximate MSL prior to interpolation, this should result in a bathymetry grid with depths that relate to the similar AHD land survey datum typically used for elevation data. Using MSL as the vertical datum thus provides the best chance to obtain a ‘seamless’ land/ocean interface, when also combined with the SRTM elevation data which has a vertical datum that approximates AHD.

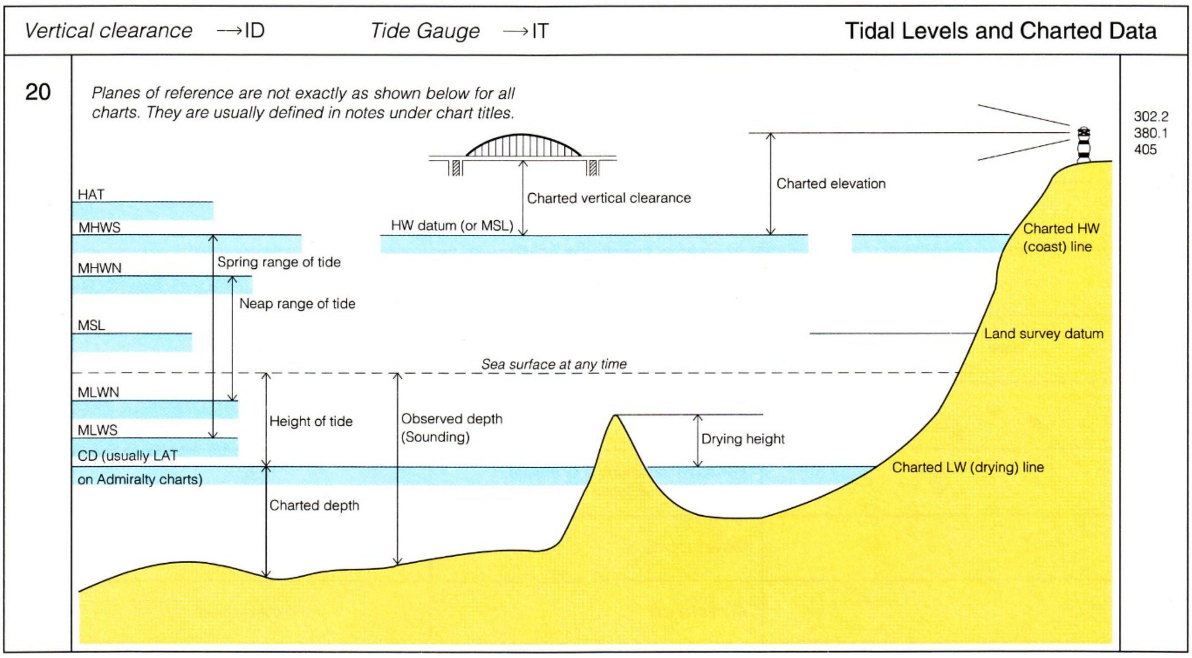

Figure 2 Tide levels and charted data for charts, adapted from UKHO (1998). The ceq30 bathymetry grid approximates mean sea level (MSL).

In practice, however, consistent vertical adjustment of source bathymetry data to a MSL datum is challenging, because source data were provided in a variety of vertical datums. For example, the Australian Hydrographic Service (AHS)-supplied data used the lowest astronomical tide (LAT) vertical datum, typically based upon a local tidal adjustment to the raw data and generated from a co-tidal model across the survey area. Therefore, these source data required a LAT-MSL vertical adjustment. The AusCoastVDT - Australian Vertical Datum Transformation Tool (http://www.crcsi.com.au/research/commissioned-research/auscoast-vdt/) was used to adjust these LAT depth values to MSL prior to the gridding interpolation process.

Other source data were supplied with no tidal adjustment applied at all. For raw singlebeam and multibeam data with no tidal adjustment, Caris HIPS/SIPS software was used to apply a MSL tidal adjustment using predicted tides generated from AusTides software (http://www.hydro.gov.au/prodserv/publications/ausTides/tides.htm). Other source data from the shelf (<200 m) but with no tidal information supplied, would be viewed within a 3D point cloud, together with other source datasets with a higher level of datum confidence (e.g. AHS-supplied), to make a visual comparison and then a datum shift applied accordingly. Source data beyond the shelf (e.g. >200 m) would typically not have any tidal adjustment applied.

> The WGS84 horizontal datum was selected because it is the most widely used datum for hydrographic surveys in Australian waters.
>
> The mean sea level (MSL) vertical datum was selected to obtain the best chance of a 'seamless' land/ocean interface.
>
> The AusCoastVDT – Australian Vertical Datum Transformation Tool was used to adjust source bathymetry data to MSL prior to grid interpolation.

3.2 Survey uncertainty

The ceq30 grid has an accompanying Total Vertical Uncertainty (TVU) grid. As background on the horizontal and vertical uncertainties used in hydrographic surveying practice, it is important to understand that bathymetric data vertical and horizontal accuracies are usually classified according to the International Hydrographic Organization Standards for Hydrographic Surveys Special Publication 44 (IHO, 2008). Source bathymetry data can be classified into four categories of uncertainty: Special Order, Order 1a, Order 1b and Order 2 (Table 1).

Table 1 Minimum standards for hydrographic surveys, adapted. THU = Total Horizontal Uncertainty. TVU = Total Vertical Uncertainty.

Order	Special	1a	1b	2
Maximum allowable THU 95% Confidence level	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
[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

[1]Recognising that there are both constant and depth dependent uncertainties that affect the uncertainty of the depths, the formula below is used to compute, at the 95% confidence level, the maximum allowable TVU: $\pm\sqrt{(a^2 + (b \times d)^2)}$

Where:

a represents that portion of the uncertainty that does not vary with depth.

b coefficient which represents the portion of the uncertainty varying with depth.

d is the depth.

b x d represents that portion of the uncertainty that varies with depth.

THU calculations would thus generate the following Table 2 for depths 0-30 m:

Table 2 THU calculations for surveyed depths 0-30 m.

Depth	THU (IHO S44 Special)	THU (IHO S44 1a)	THU (IHO S44 1b)	THU (IHO S44 2)
0	2.00	5.00	5.00	20.00
5	2.00	5.25	5.25	20.50
10	2.00	5.50	5.50	21.00
15	2.00	5.75	5.75	21.50
20	2.00	6.00	6.00	22.00
25	2.00	6.25	6.25	22.50
30	2.00	6.50	6.50	23.00

TVU calculations would generate the following Table 3 for depths 0-30 m:

Table 3 TVU calculations for surveyed depths 0-30 m

Depth	TVU (IHO S44 Special)	TVU (IHO S44 1a)	TVU (IHO S44 1b)	TVU (IHO S44 2)
0	0.250	0.500	0.500	1.000
5	0.253	0.504	0.504	1.007
10	0.261	0.517	0.517	1.026
15	0.274	0.537	0.537	1.058
20	0.292	0.564	0.564	1.101
25	0.313	0.596	0.596	1.154
30	0.336	0.634	0.634	1.215

For example, the AHS-supplied airborne lidar bathymetry (ALB) surveys conform to IHO S44 1b. There is no real difference in the calculations between 1a and 1b, except that for surveys conforming to 1b allow that not all subsurface features have been detected, as would be the case for dense singlebeam/sidescan surveys or full 100% coverage multibeam surveys. For this Project, the TVU calculations were applied to every depth point prior to interpolation of the TVU grid (see 3.12 Total Vertical Uncertainty grid development).

Satellite derived bathymetry (SDB) data are relatively new and the uncertainty values calculated do not conform to these established IHO S44 categories. Hence, much work is occurring worldwide into validating SDB data against observed lidar and sonar bathymetry data. The EOMAP-supplied SDB data using Landsat8 imagery quotes the vertical uncertainty of pixels as within an absolute error of 0.5 m, plus a relative (i.e. depth dependent) error of 15%. These uncertainty results are considered typical for SDB data using similar satellite imagery over tropical waters. For this Project, the TVU calculations were applied to every depth point prior to interpolation of the TVU grid.

TVU calculations for SDB data would generate the following Table 4 for depths 0-30 m:

Table 4 TVU calculations for SDB data against true depths 0-30 m.

Depth	TVU
0	0.5
5	1.25
10	2.00
15	2.75
20	3.50
25	4.25
30	5.00

Regarding Total Horizontal Uncertainty (THU), the majority of source bathymetry data used modern dGPS positioning systems (position errors <10 m; IHO S44 1a/b), or if derived from imagery, were accurately positioned, meaning position errors were considered to be less than half pixel width (position errors <15 m; between IHO S44 1a/b and 2). With such small positioning errors overall, it was considered that there was little value in developing an accompanying THU grid for the Project, and therefore THU is not considered any further within this report.

Total Vertical Uncertainty (TVU) is based upon International Hydrographic Organization Standards for Hydrographic Surveys Special Publication 44.

TVU is the maximum allowable vertical uncertainty at the 95% confidence level (i.e. worst-case uncertainty) for bathymetry surveys.

TVU calculations were were applied to every source depth point prior to interpolation of the accompanying TVU grid.

3.3 Multibeam source data

Australian Hydrographic Service (AHS)-supplied multibeam data were provided as Hydrographic Transfer Format (HTF) files, named according to HI (Hydrographic Instruction) number or SRAT number (Survey Requested and Action Taken) and the location of the survey, e.g. HI295_LadyElliotIs. The Royal Australian Navy (RAN) Hydrographic Survey Fleet are typically focussed on safety of navigation on the shelf, and so coverage is typically restricted to depths <200 m. The point spacing for these HTF files are between 6-12.5 m. TVU is considered to be IHO S44 1b. Large surveyed areas have been conducted in the southern Capricorn-Bunker Group and on the approaches to Gladstone (Figure 3).

The xyz data from the HTF files were first extracted using HTF Builder software (http://www.hydro.gov.au/prodserv/data/htf/htf.htm), then imported to QPS Fledermaus (http://www.qps.nl/display/main/home) for viewing as a 3D point cloud. Any noise were removed and the accepted soundings exported, prior to LAT-MSL vertical adjustment using AusCoastVDT (http://www.crcsi.com.au/research/commissioned-research/auscoast-vdt/).

Geoscience Australia (GA)-supplied multibeam data were provided as individual Teledyne Caris (http://www.caris.com/) HIPS&SIPS projects. Surveys were usually named by vessel, survey number, year, geographic location, e.g. SS072012_TasmantidSeamounts for RV *Southern Surveyor*, 07th survey of 2012 to the Tasmantid Seamounts. Surveys were mainly restricted to transits through the Project area or concentrated on the outer shelf and offshore areas in the vicinity of Fraser Island. Depths ranged 20-4000 m, with point spacing varying between 1-30 m. TVU is considered to be IHO S44 1b.

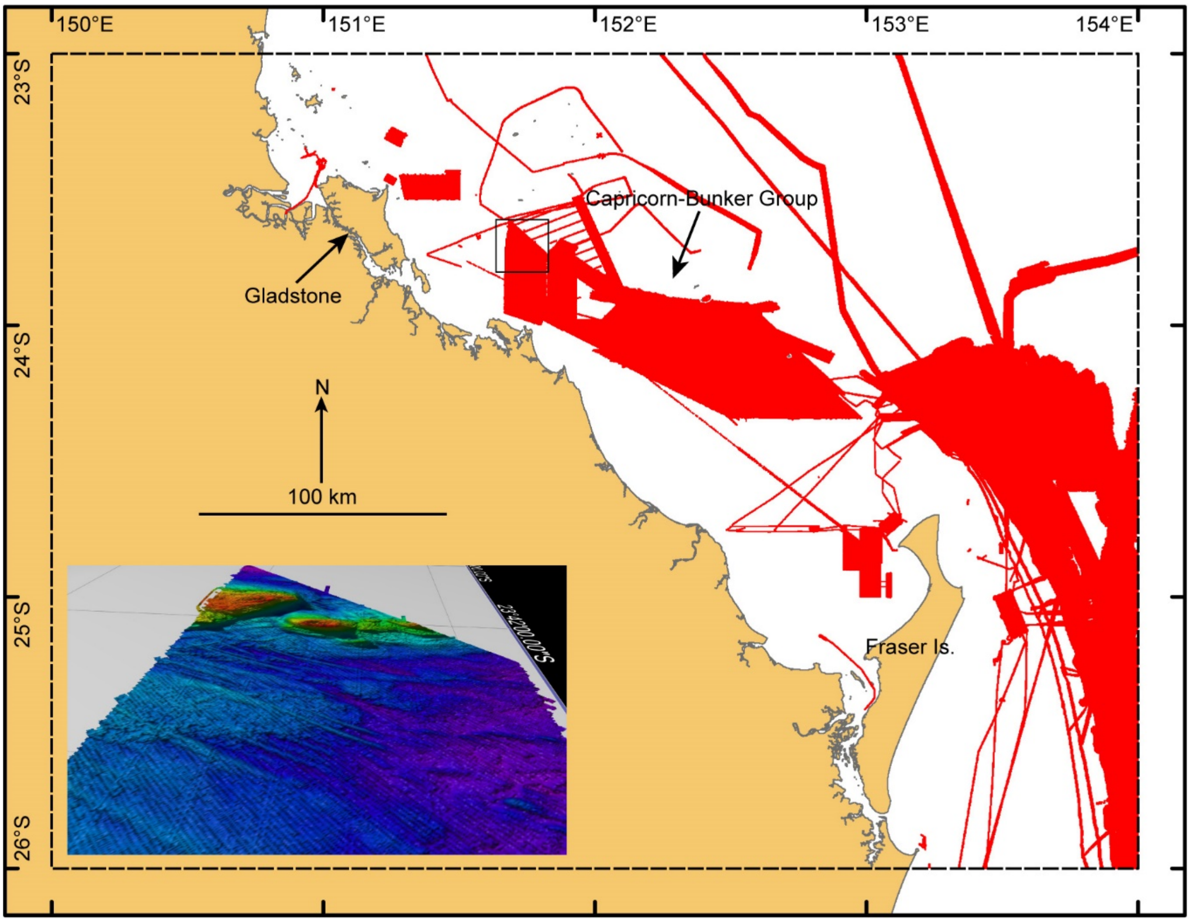

Figure 3 Multibeam echosounder source data coverage. Inset shows typical AHS-supplied HI442_ApproachesToGladstone survey as oblique view in Fledermaus software.

The HIPS&SIPS multibeam projects allowed a detailed view of the raw multibeam sounding data from each survey, with advanced tools provided to conduct fine-scale editing of any noise viewed within 3D point clouds, or refraction editing if sound velocity profiles were in error, and finally MSL tide adjustment if data were acquired over the shelf (<200 m). The accepted soundings were then exported as xyz data prior to the grid interpolation process.

Other multibeam data were supplied by Maritime Safety Queensland (MSQ) as xyz text files, named as MSQ and survey area, e.g. MSQ_UranganFairway. These data were generated from dense fairsheet data collected from within the Hervey Bay region and for the MV *Shen Neng* anchorages. Depths were generally <60 m with point spacing of ~30 m. TVU is IHO S44 1b. The xyz data were imported to Fledermaus software for viewing as a 3D point cloud, then accepted soundings exported and LAT-MSL adjustment using AusCoastVDT software.

The Australian Hydrographic Service (AHS)-supplied the majority of multibeam source data for the Project area, conducted mostly for safety of navigation purposes.

Geoscience Australia (GA) provided other extensive multibeam source data, primarily along the continental slope near Fraser Island.

Extensive editing on source bathymetry data were conducted using a 3D point clouds in QPS Fledermaus and Caris HIPS&SIPS software.

3.4 Singlebeam source data

AHS-supplied singlebeam source data were provided as HTF files and named similar to AHS-supplied multibeam data, e.g. HI302_Z_WhitsundayIs. The point spacing of the HTF files were 6-12.5 m, covering a large area of the shelf in depths <200 m. There is particularly dense coverage east and north of Curtis Island (Figure 4). TVU is considered to be IHO S44 1b. HTF Builder software was used to extract xyz data from the HTF files, and then imported to Fledermaus software for editing in a 3D point cloud. Accepted soundings had LAT-MSL adjustment using AusCoastVDT prior to interpolation of the grid.

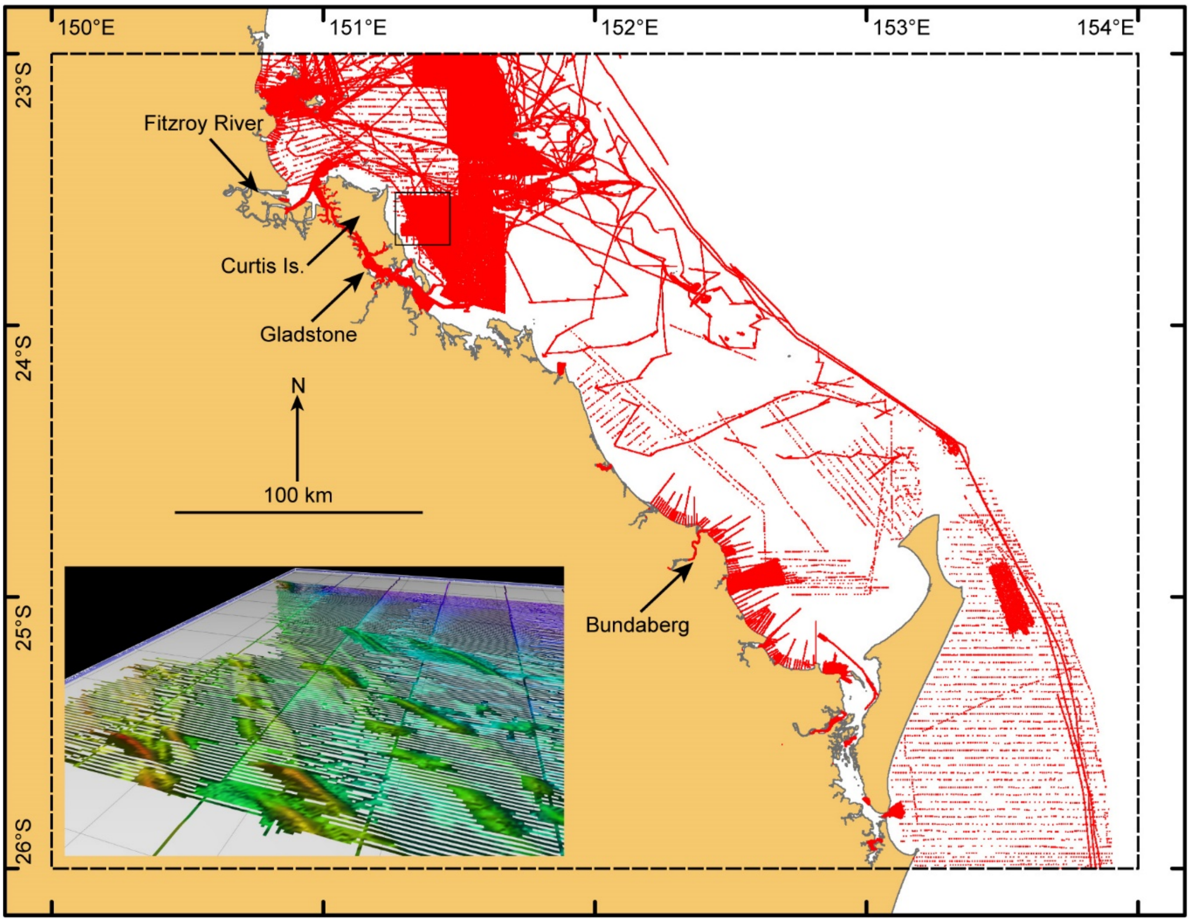

Figure 4 Singlebeam echosounder source data coverage. Inset shows typical AHS-supplied HI282_Gladstone survey as oblique view in Fledermaus software.

MSQ-supplied singlebeam data were provided as ASCII text files, named by series along the Queensland coast. For example, the MSQ_Fseries file were surveys collected over a time series within the vicinity of Bundaberg, Gladstone and Fitzroy River area. The latest survey data collected in Bundaberg was July 2013, in Gladstone harbour was December 2013, and for the Fitzroy River area was March 2013. Point spacing was 10-30 m and TVU considered to be IHO S44 1b. Data were imported to Fledermaus for viewing as 3D point clouds, with accepted soundings exported then LAT-MSL adjustment using AusCoastVDT.

Extensive AHS-supplied singlebeam surveys have been conducted around Curtis Island and the adjacent continental shelf.

Maritime Safety Queensland (MSQ)-supplied singlebeam data were collected in the Bundaberg, Gladstone and Fitzroy River area.

3.5 Electronic Navigational Chart source data

The Electronic Navigational Chart (ENC) spot depths were generated from S-57 files provided by the AHS (Figure 5). These S-57 files are adjacent tiles viewed at the 1:25,000 scale in an Electronic Chart Display and Information System (ECDIS). The spot depths fully cover the shelf and upper slope of the project area (<300 m), with point spacing varying between 100 m to 3 km. TVU is considered to be IHO S44 1b. Spot depths were extracted from the S-57 files using an ESRI file geodatabase and the xyz data imported to Fledermaus software for examining as a 3D point cloud. Accepted soundings were then exported and then LAT-MSL adjustment conducted with AusCoastVDT prior to interpolation of the grid.

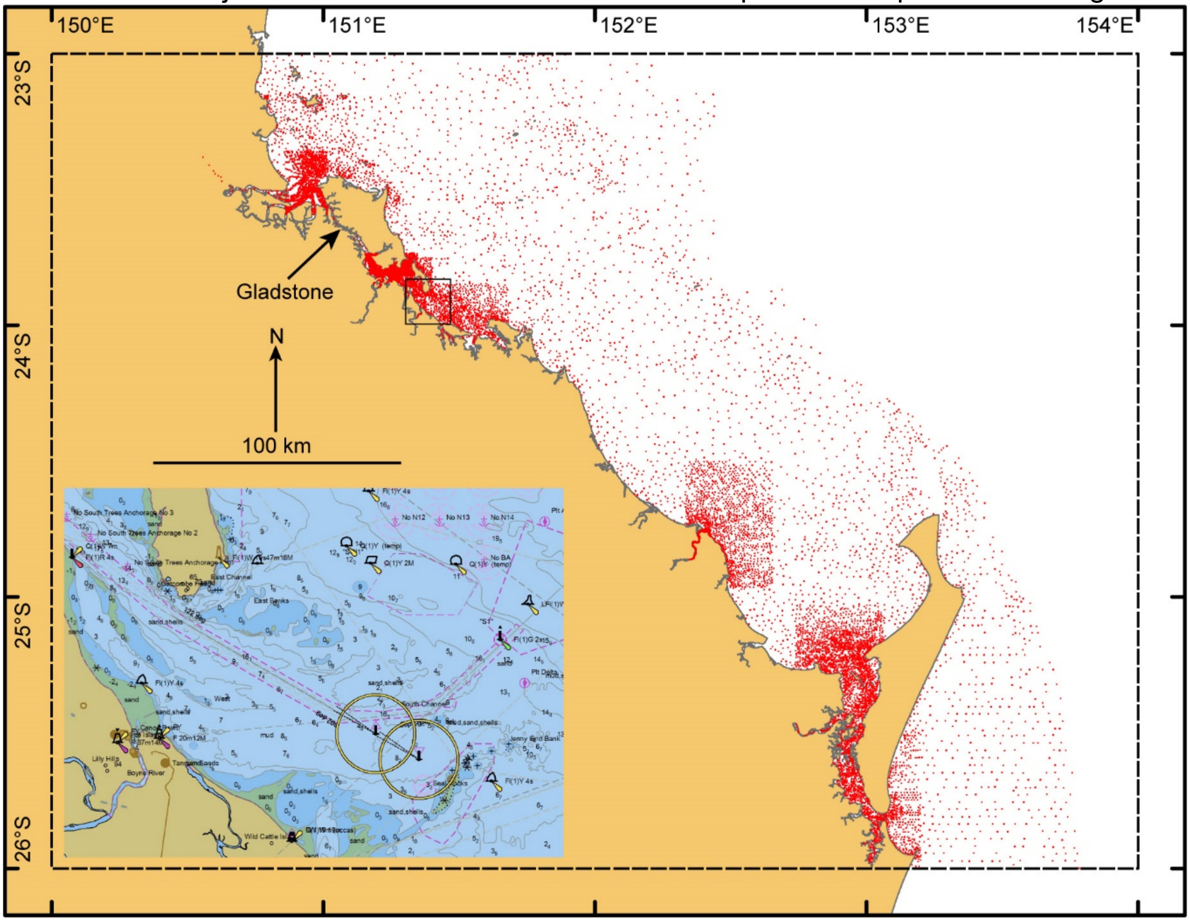

Figure 5 ENC spot depth source data coverage. Inset shows typical ENC S-57 tile AU424151_KeppelIsles near Gladstone Harbour using the ESRI S-57 viewer in ArcMap.

> Electronic Navigational Chart (ENC) bathymetry source data were spot depths extracted from S-57 files.
>
> The spot depths can be widely-spaced but have a broad coverage across the entire continental shelf within the Project area.

3.6 Airborne lidar bathymetry source data

AHS-supplied airborne lidar bathymetry (ALB) data are primarily from the RAN Laser Airborne Sounder (LADS) safety of navigation surveys over reefs where vessel-mounted sonar surveys would be hazardous. HTF file naming is similar to AHS-supplied multibeam surveys, e.g. HI505_KeppelBay. LADS data are mainly around the Capricorn-Bunker Group and the shelf to the west (Figure 6). Depths are restricted to shallower than ~40 m due to the limitations of turbidity on the laser scanning. Point spacing is 6-12.5 m and TVU is IHO S44 1b. HTF Builder software was used to extract xyz data from the HTF files, then imported to Fledermaus software for noise editing in a 3D point cloud. Accepted soundings then had LAT-MSL adjustment with AusCoastVDT prior to interpolation of the grid.

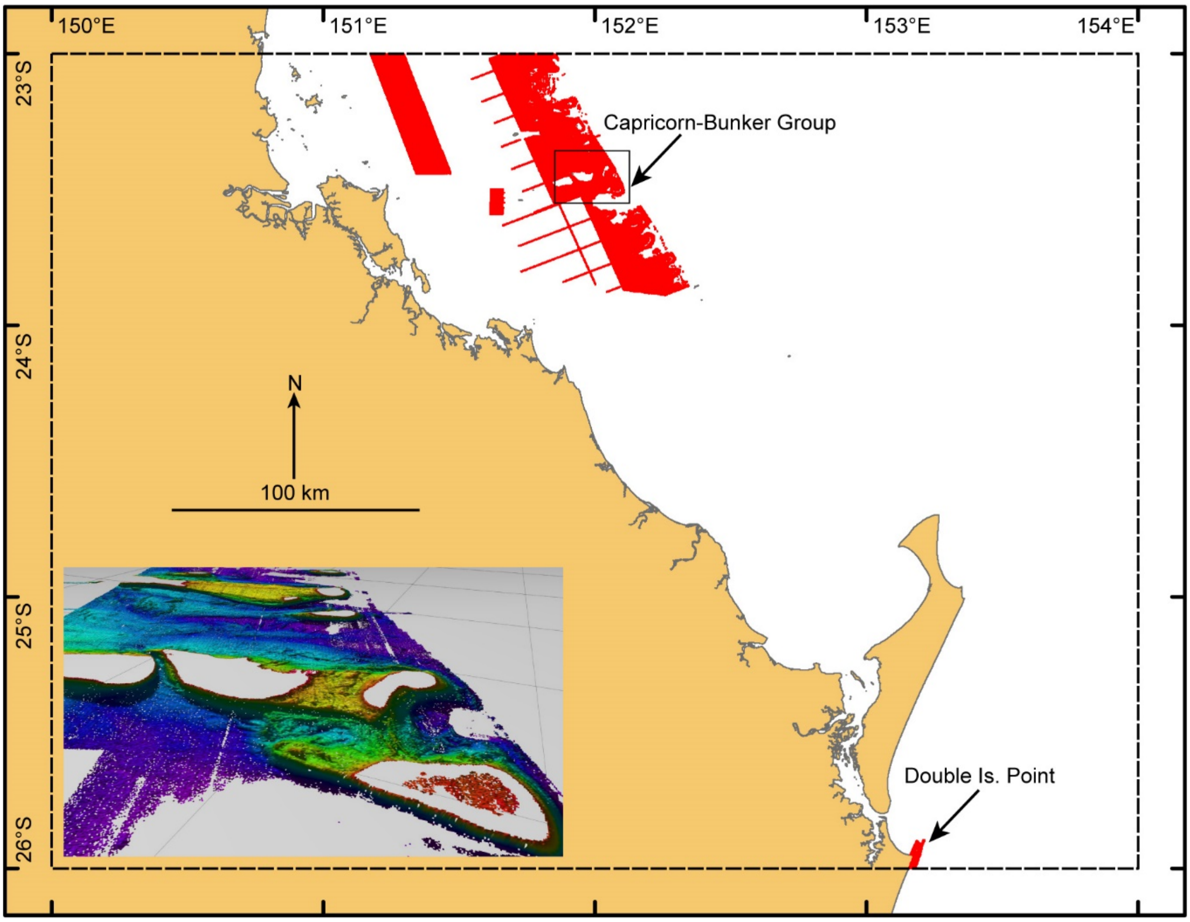

Figure 6 Airborne lidar bathymetry source data coverage. Inset shows typical AHS-supplied HI199_CapricornGroup LADS survey as oblique view in Fledermaus software.

Another ALB survey is the Cooperative Research Centre for Spatial Information (CRCSI)-supplied LADS survey conducted for the Qld Climate Change Centre of Excellence. Stretching along the Sunshine Coast, across the exposed beach and nearshore seabed, this is one of the few ALB surveys conducted in Queensland across this difficult to survey zone. The northern part of the survey crosses into the Project area near Double Island Point. Point spacing is 5 m and TVU is IHO S44 1b. The xyz data were imported to Fledermaus software for editing of noise in a 3D point cloud then accepted depths exported as xyz files. No LAT-MSL adjustment was required as data used the AHD vertical datum.

Airborne lidar bathymetry (ALB) data are mainly from AHS-suppled Laser Airborne Depth Sounder (LADS) surveys undertaken over the Capricorn-Bunker Group.

Other ALB data are from the Sunshine Coast for the Qld Climate Change Centre of Excellence. ALB depths are typically limited to ~40 m.

3.7 Intertidal Extents Model DEM source data

The GA-supplied ITEM DEM data were derived from the Intertidal Extents Model (ITEM v1.0) product as part of the Digital Earth Australia program (http://www.ga.gov.au/about/projects/geographic/digital-earth-australia). The ITEM v1.0 product is a national-scale gridded dataset characterising the spatial extents of the exposed intertidal zone (http://www.ga.gov.au/metadata-gateway/metadata/record/100600). The current version utilises a full 28 year time series of Landsat observations for the Australian coastal region. The DEM data derived from the ITEM product are the result of a continental-scale tidal model, combined with a median pixel compositing of Normalised Difference Water Index (NDWI) stacks, to estimate the tidal extent and elevation profile across the observed tidal range (Sagar et al., 2017).

The ITEM DEM data provides a possible solution to the lack of source elevation data across the full intertidal zone, thus providing as seamless a DEM as possible at the land/ocean interface (Figure 7). However, much work continues by GA to fine-tune the continent-scale tidal model that would, in-turn, improve the accuracy of elevation profiles. Note the highest and lowest observed tides from the Landsat time series are not highest astronomical tide (HAT) and lowest astronomical tide (LAT), respectively, but are likely to be roughly equivalent to mean high water springs (MHWS) and mean low water springs (MLWS) (see Figure 2). However, caution is advised against strictly tying the ITEM DEM data to particular tidal levels for the Project area.

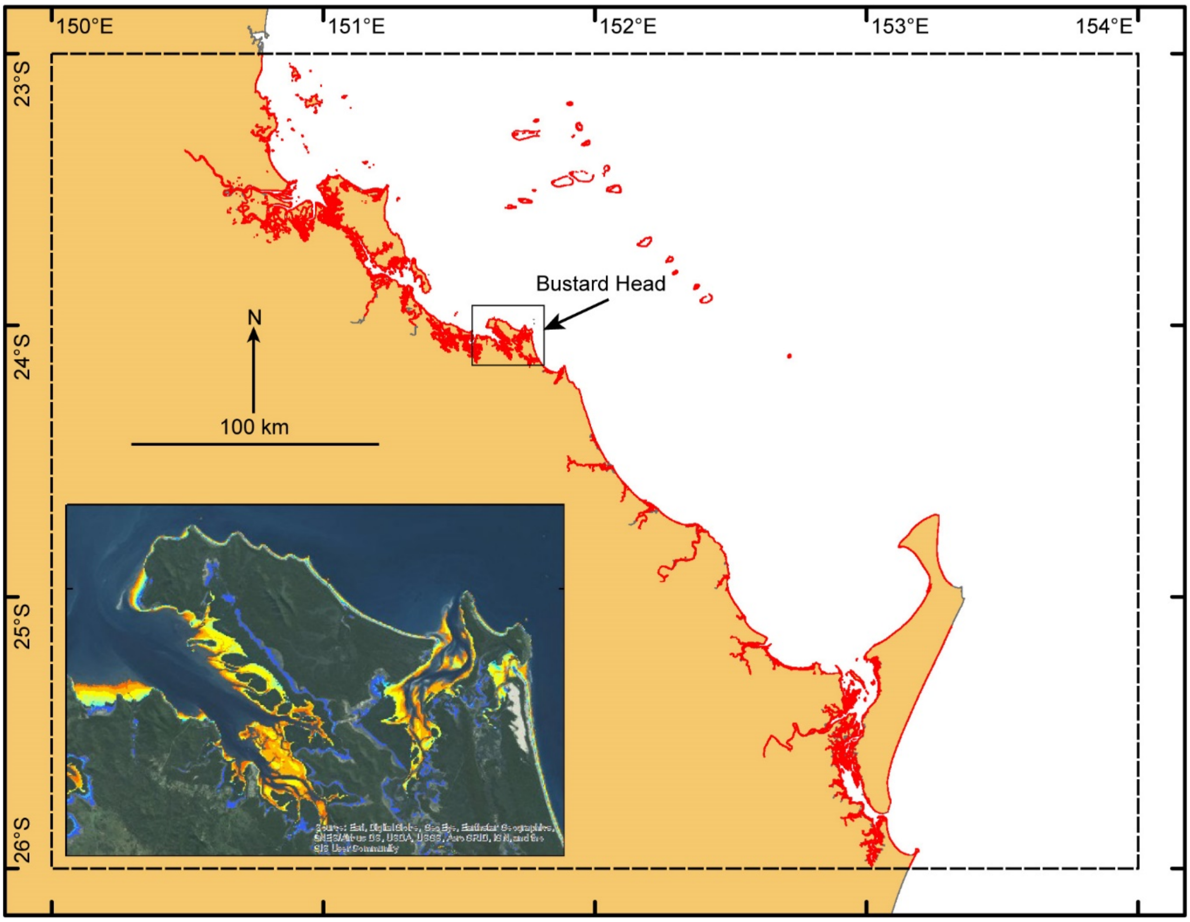

Figure 7 ITEM DEM source data coverage. Inset shows typical GA-supplied ITEM_DEM_e151s25 data for the Bustard Head area overlaid on ESRI World Imagery in ArcMap.

An ephemeral layer based upon the ITEM v1.0 confidence layer (http://www.ga.gov.au/metadata-gateway/metadata/record/100464) set to a value of >250, was used to mask out the ITEM DEM for these pixels. Data were provided as raw (unedited) 1° x 1° tiles as 0.00025° (~25 m) 32-bit floating point geotiffs using the WGS84 horizontal datum and MSL vertical datum. The ESRI ArcToolbox > Spatial Analyst Tools > Map Algebra was used to setnull on anomalous pixels over water and on high land, leaving only the remaining intertidal zone. The clean geotiffs were then imported to Fledermaus and the pixel values extracted as xyz files. Height values ranged from +2.29 to -1.27 m. Discussions with GA on the vertical uncertainty of ITEM DEM data point to validation tests conducted in Moreton Bay with Real Time Kinematic (RTK) transect elevation data (Sagar et al., 2017). TVU is considered to be a constant 0.5 m.

The ITEM DEM data are derived from the Intertidal Extents Model (ITEM v1.0), a national-scale gridded dataset characterising the spatial extents of the exposed intertidal zone.

ITEM DEM data estimate the tidal extent and elevation profile across the observed tidal range, based upon a full 28 year time series of Landsat observations.

ITEM DEM data have 25 m point spacing and range between highest and lowest observed tides over the 28 years, possibly representing MHWS and MLWS, respectively.

3.8 Satellite derived bathymetry source data

Satellite derived bathymetry (SDB) data utilise optical imagery and are limited to optically shallow waters where sunlight penetrates through to the seafloor. Two approaches are generally used for deriving bathymetry from multispectral imagery: physics-based optimisation and empirical approaches (Hamylton et al., 2015). In 2014, EOMAP was commissioned to provide the Qld Wetlands Program with Landsat8 SDB data for the nearshore between the northern Curtis Island and south to Bustard Head (Figure 8). The image was processed using EOMAP's Modular and Inversion Processor (MIP) designed for physics-based assessment of parameters such as water quality, bathymetry and seafloor properties.

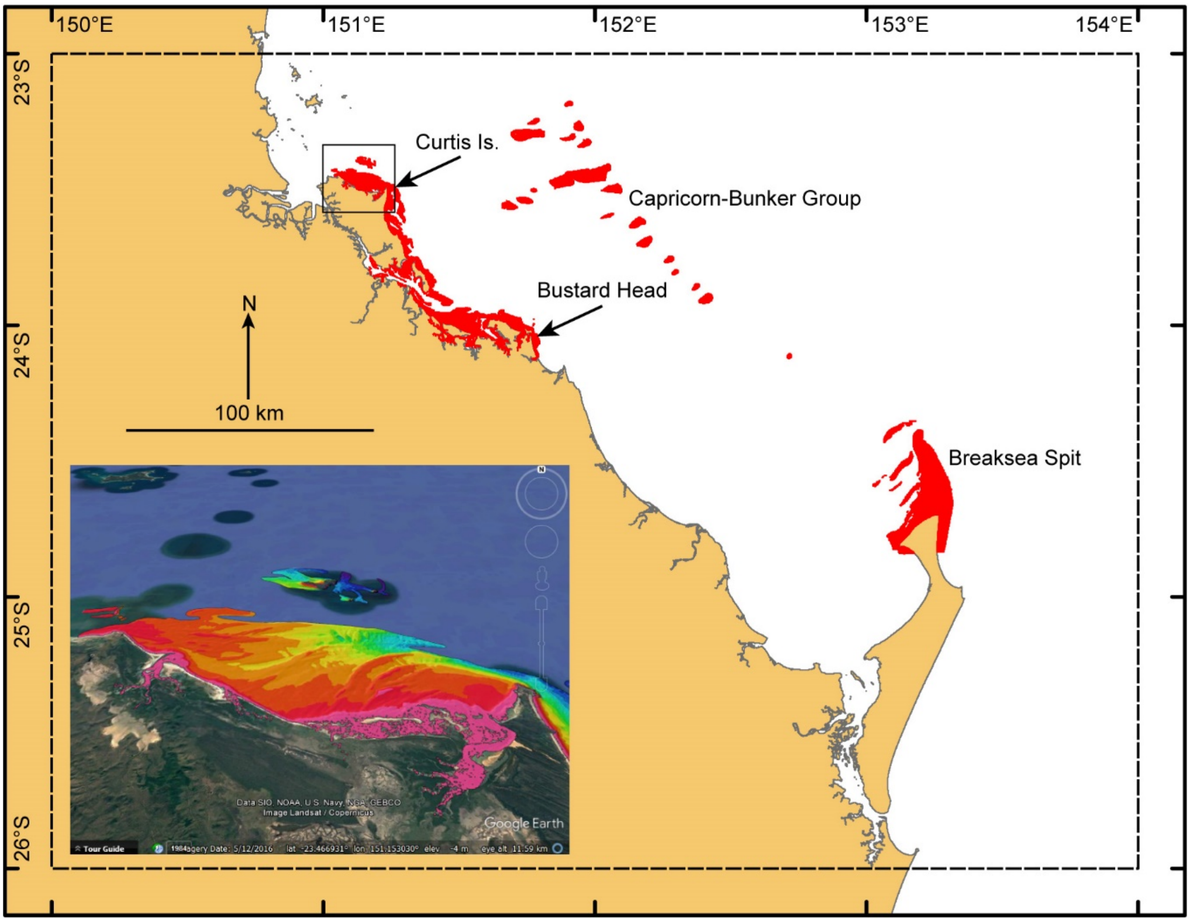

Figure 8 Satellite derived bathymetry (SDB) source data coverage. Inset shows typical EOMAP-supplied SDB data for Curtis Island area as oblique view in Google Earth.

The data were provided as a 15 m 32 bit floating point geotiff using the WGS84 UTM56S horizontal datum and LAT vertical datum. The ESRI ArcToolbox > Spatial Analyst Tools > Map Algebra was used to setnull for no data values, resulting in useful depth values of +1.63 to -22.5 m. An ephemeral layer based upon the ITEM v1.0 confidence layer (http://www.ga.gov.au/metadata-gateway/metadata/record/100464) set to a value of >250, was used to mask out SDB data for these pixels. ITEM DEM data were also used to mask out any overlapping SDB data, as ITEM DEM data were considered the priority. The geotiff was imported to Fledermaus and pixel values extracted as a xyz file using the WGS84 horizontal datum. These data then had LAT-MSL adjustment applied using AusCoastVDT software. TVU is 15% of depth + 0.5 m.

Other SDB datasets included empirical-derived data using Landsat7 imagery over the Capricorn-Bunker Group and Breaksea Spit. These areas were optically clear and had sufficient ALB and singlebeam data and ENC spot depths to provide an empirical relationship between the (MSL-adjusted) observed and Landsat derived depths (Stumpf et al., 2003). Landsat7 images were obtained from the USGS EarthExplorer site (https://earthexplorer.usgs.gov/) as 30 m 32-bit floating point geotiffs using the WGS84 UTM56S horizontal datum. Raw images were imported to ENVI and the Spectral Processing Exploitation and Analysis Resource (SPEAR) tools used to generate derived depths. R^2 values were in the range 0.6-0.75. Geotiffs were then imported to Fledermaus and pixels extracted as xyz files with the WGS84 horizontal datum. TVU is 15% of depth + 0.5 m.

Satellite derived bathymetry (SDB) data utilise optical imagery and rely on physics-based or empirical methods to derive bathymetry data for optically-shallow waters.

EOMAP-supplied SDB data using Landsat8 imagery were provided for the nearshore around Curtis Island, southward towards Bustard Head.

Other Landsat7 SDB data were generated for the Capricorn-Bunker Group and Breaksea Spit. SDB depths are typically limited to ~20 m.

3.9 Coastline source data

The coastline source data are an important input to the interpolation process. Prior to the ITEM DEM becoming available and with the overall lack of nearshore source data along much of the Queensland coast, a dataset representing the most accurate coastline available was used to help 'pin' the interpolated grid at the coastline. The aim was to prevent 'bleeding' of the land into the water during the grid interpolation process, or alternatively, producing anomalously deep areas against the coast. However, the ITEM DEM data are the priority and so the only coastline data required within the Project area is for the eastern side of Fraser Island and several small islands off Bustard Head, which lack ITEM DEM data (Figure 9).

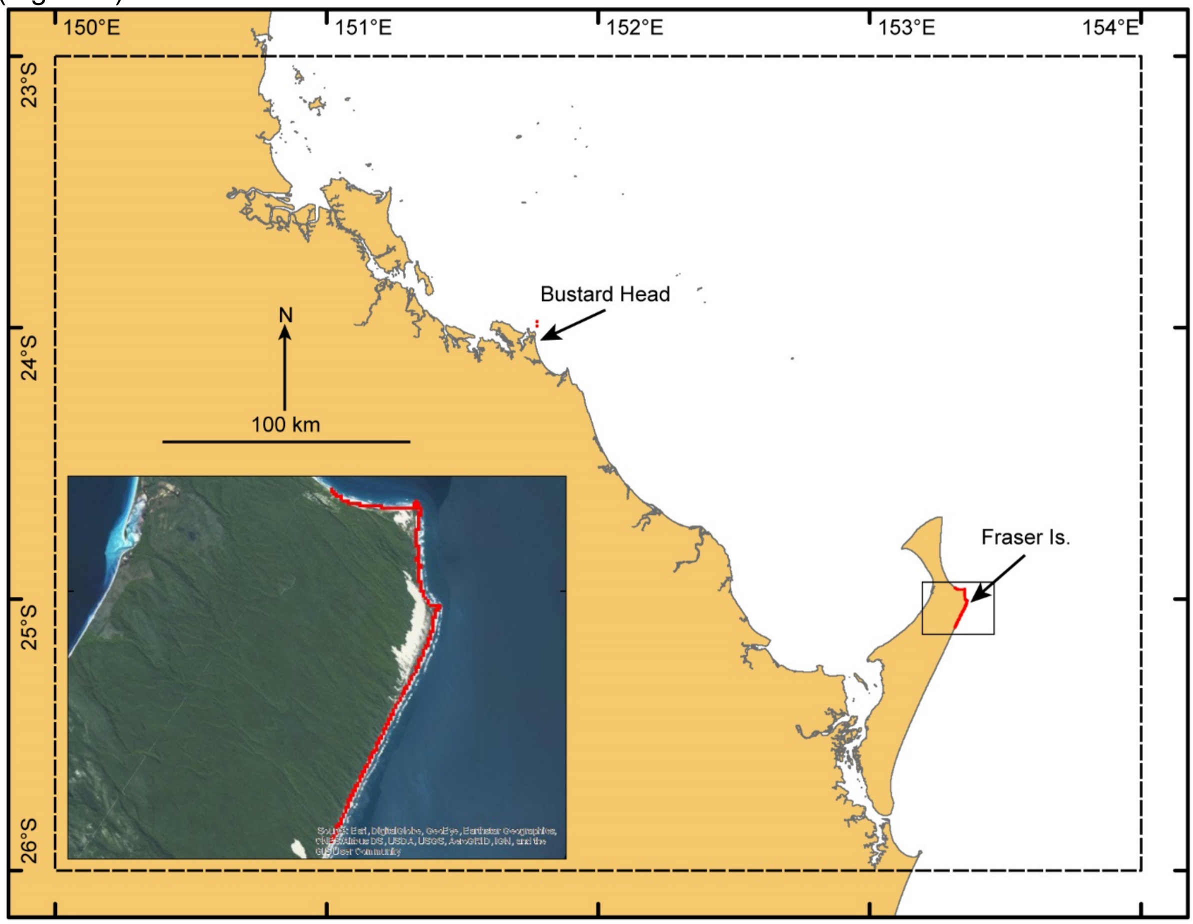

Figure 9 Coastline source data coverage. Inset shows typical Qld Government-supplied coastline data for Fraser Island overlaid on ESRI World Imagery in ArcMap.

The Mainland and Marine islands layers were obtained from the Geographic Features - Qld site (https://data.qld.gov.au/dataset/geographic-features-queensland-series). These were shapefiles using the GDA94 horizontal datum and representing MHWS. Datasets were merged and projected to the WGS84 datum, and then ITEM DEM coverage used to exclude the coastline areas lying within these tiles. Only a section of the Fraser Island and several small islands off Bustard Head remained, which were converted to a WGS84 datum 0.00025° (~25 m) raster grid. The xyz data were extracted and given height values of 0 m. As the original vector layers represent MHWS, then AusCoastVDT was used to apply a MSL-MHWS adjustment for those areas. The TVU is considered to be 0.5 m.

> Coastline source data are used to ‘pin’ the bathymetry grid at the coastline in order to prevent ‘bleeding’ of land into the water during the interpolation process.
>
> Only a small section of coastline source data were required on Fraser Island where the higher priority ITEM DEM data are absent.
>
> The Qld Government-supplied coastline data were adjusted to MHWS using AusCoastVDT tool.

3.10 Shuttle Radar Topographic Mission source data

Shuttle Radar Topographic Mission (SRTM) land elevation data (Farr et al., 2007) were obtained for the entire Queensland mainland and offshore islands at a spatial resolution of 0.00027 ° (~27 m) and using the WGS84 horizontal datum (Figure 10). For this Project, the raw SRTM Digital Surface Model (DSM) data were used to best represent the topography of the land, but also includes vegetation features. Tests with other smoothed and hydrologically enforced SRTM Digital Elevation Models (DEMs), available at the Foundation Spatial Data Framework site (http://link.fsdf.org.au/dataset/5670), revealed artefacts at the coast and so were not suitable for use.

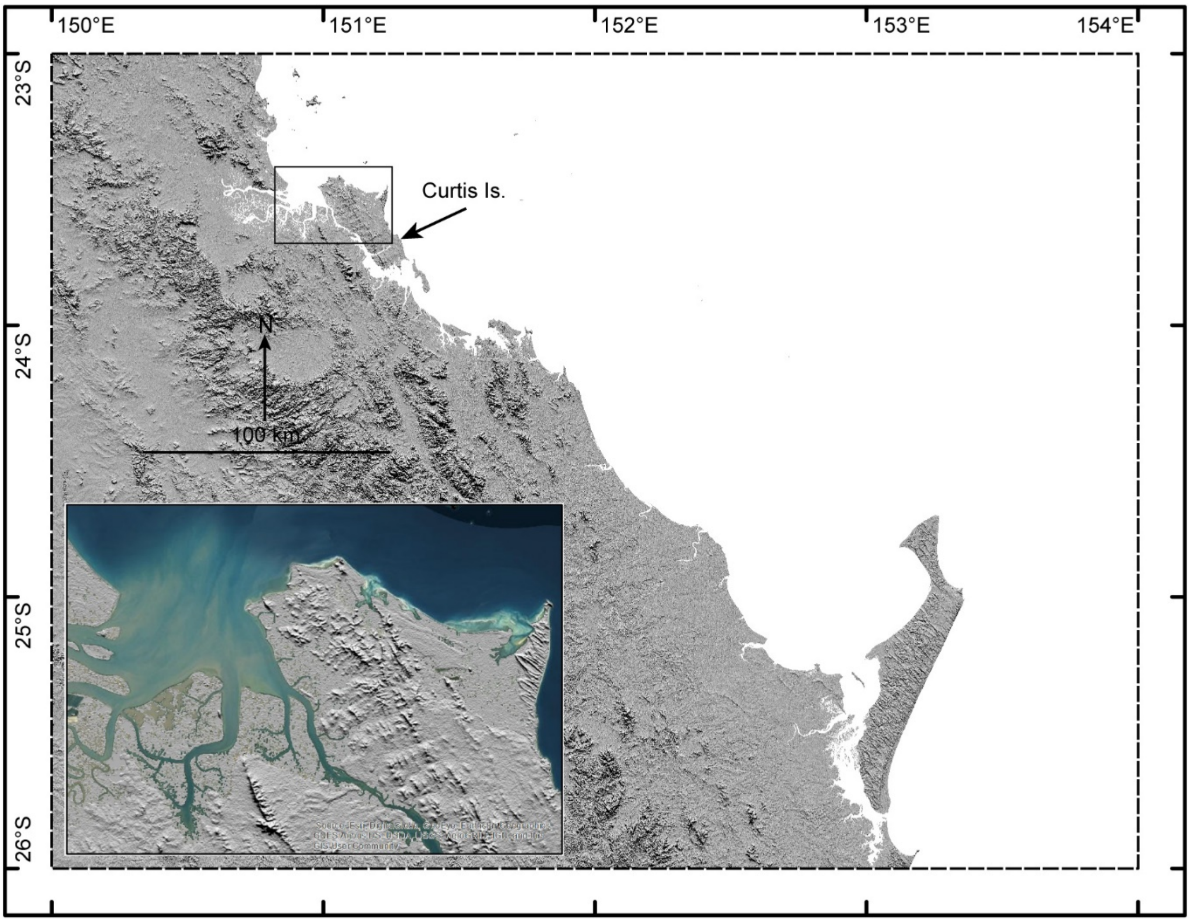

Figure 10 SRTM land elevation data coverage. Inset shows a close-up of grey hillshaded SRTM data near Curtis Island overlaid on ESRI World Imagery in ArcMap.

The aim during the grid development process was to merge the SRTM land elevation data with the interpolated grid output to produce a final ceq30 grid, correct for both land topography (albeit with vegetation features) and the available bathymetry data. The SRTM

> The Shuttle Radar Topographic Mission (SRTM) - Digital Surface Model (DSM) data were used as land elevation data for the ceq30 grid.
>
> The DSM data best represents the topography of the land across the entire Project area, but also includes vegetation features.

data were resampled to 0.0003° (~30 m) to match the pixel size of the interpolated bathymetry grid. The vertical uncertainty of the SRTM data were not considered further, as the development of the accompanying TVU grid applies only for the intertidal and subtidal areas.

3.11 Bathymetry grid development

Following the pre-processing and data cleaning phase for the source data, the next grid development phase was conducted using Generic Mapping Tools (GMT) software (Wessel and Smith, 1991), following the methodology used in Becker et al. (2009). GMT is a Unix-based gridding and plotting software package that can deal with large datasets. This grid development phase is a 'repair and replace' method that is widely used for aggregating source bathymetry data for regional-scale and global-scale grids, e.g. SRTM30_PLUS (http://topex.ucsd.edu/WWW_html/srtm30_plus.html), and also used in Google Earth topography.

The cleaned xyz source data files from each of the multibeam, singlebeam, ENCs, ALB, ITEM DEM, SDB and coastline datasets were first decimated using GMT blockmedian into individual xyz data files representing single node points at 0.00015° (~15 m) resolution (Figure 11). The decimated data files were then concatenated into one large xyz file. Next, GMT blockmedian was conducted on the single large file to decimate the combined data to 0.0003° (~30 m) resolution in order to produce one valid depth point for each pixel location to be used in the interpolated bathymetry grid at that same 0.0003° resolution.

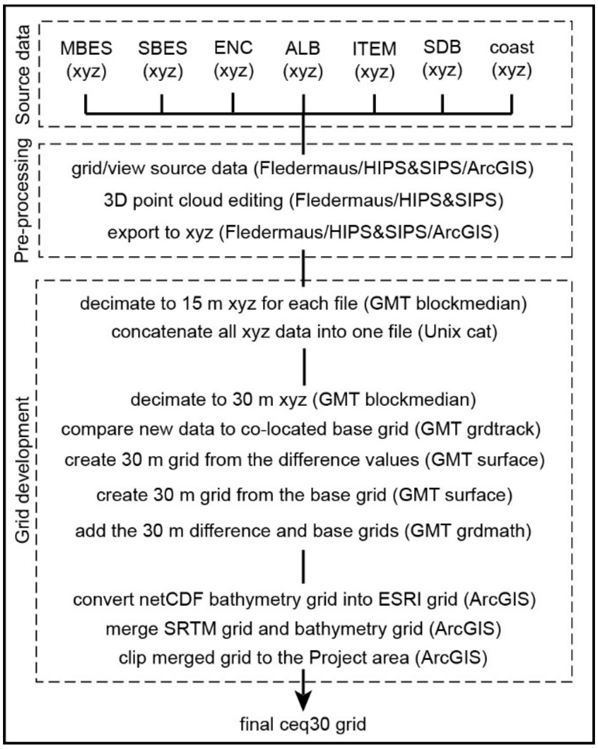

Figure 11 Processing scheme used to develop the ceq30 bathymetry grid.

The 0.0003° blockmedian values from the combined file were then compared with the co-located depths from an underlying base grid, in this case the AusBathyTopo grid (Whiteway, 2009). This base grid has a pixel size of 0.0025° (~250 m). The purpose of using the base grid was firstly as a comparison to flag any new source data that may be greatly in error and thus be rejected, and secondly to provide underlying bathymetry data for grid pixels that lack coverage by the new source bathymetry data. The ‘repair and replace’ method is effectively repairing the AusBathyTopo base grid and replacing pixels with newer, higher-resolution data. GMT grdtrack was used to find the comparative depth differences between the co-located new data and the underlying base data.

A grid surface was made with GMT surface using those difference values between the co-located new data and the base data. GMT surface was also used to resample the AusBathyTopo base grid at the higher-resolution of 0.0003°. The difference grid and the resampled base grid were then added together with GMT grdmath. The output of this process was a network Common Data Form (netCDF) file that was converted into an ESRI raster grid using ArcGIS, which represents the ~30 m gridded bathymetry data. Next, the 0.0003° SRTM land elevation grid was merged with the bathymetry grid using ArcGIS, and lastly clipped to the Project area to produce the final ceq30 grid.

> Grid development used Generic Mapping Tools (GMT) as a ‘repair and replace’ method to aggregate source data and interpolate the ceq30 grid.
>
> The Geoscience Australia-supplied AusBathyTopo grid was used as the base grid for ‘repair and replace’ with the new source data.
>
> The SRTM land elevation grid was merged with the interpolated bathymetry grid, then clipped to the Project area to produce the final ceq30 grid.

3.12 Total Vertical Uncertainty grid development

The accompanying Total Vertical Uncertainty (TVU) grid is useful to show the maximum allowable uncertainty at the 95% confidence level and with a similar 0.0003° pixel size. Users can thus identify the calculated TVU in metres for co-located bathymetry values on the new ceq30 grid, which have taken into account the TVUs of the source data. The TVU grid development follows closely the steps taken for the bathymetry grid development but with an extra process (Figure 12). GMT gmtmath recalculates source xyz data files using the TVU IHO S44 categories or other calculations stated for each source data type prior to TVU grid development, i.e. z bathymetry values of the xyz files were recalculated as TVU values.

The TVU source data were decimated using GMT blockmedian into individual xyz data files representing single node points at 0.00015° resolution. The decimated data files were then concatenated into one large xyz file. GMT blockmedian was conducted on the single large file to decimate the combined data to 0.0003° resolution, producing one valid TVU point for each pixel to be used in the interpolated TVU grid. The process required a TVU base grid to compare with the new TVU source data; hence, the AusBathyTopo grid was recalculated as a TVU grid equivalent to IHO S44 Order 2. In effect, the process repairs and replaces the AusBathyTopo TVU grid with TVU values from the newer, high-resolution source data.

GMT grdtrack was used to find the comparative differences between the co-located new TVU data and the underlying TVU base grid. A grid surface was made with GMT surface using those difference values between the co-located new data and the base data. GMT surface was used to resample the TVU base grid at a higher-resolution of 0.0003°. The difference grid and the resampled TVU base grid were added together with GMT grdmath. The netCDF TVU output was then converted into an ESRI raster grid using ArcGIS. The

SRTM land elevation grid was used to mask out any land areas from this grid and then clipped to the Project area to produce the final TVU grid.

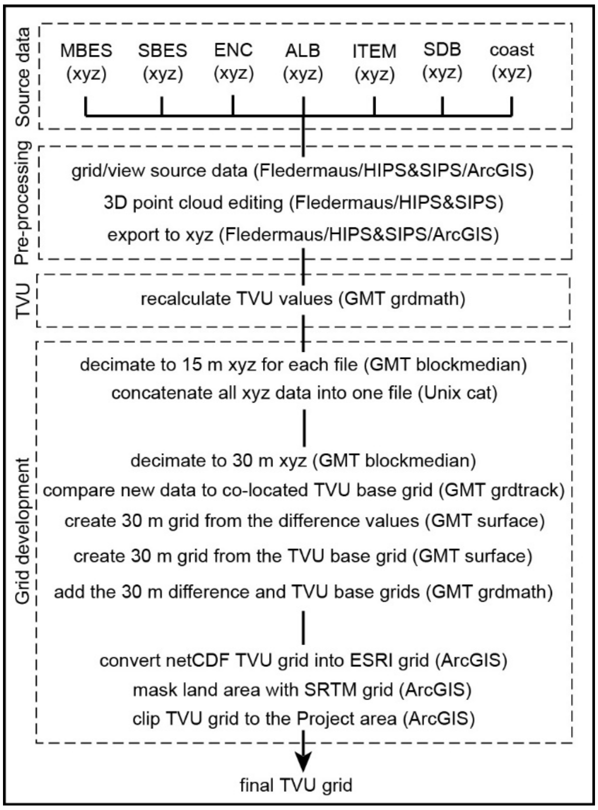

Figure 12 Processing scheme used to develop the TVU grid.

> The Total Vertical Uncertainty (TVU) grid is useful to show the maximum allowable uncertainty based upon the TVUs of the source data.
>
> The TVU grid development uses a similar 'repair and replace' method as the bathymetry grid development.
>
> The AusBathyTopo grid is used as the base grid for the 'repair and 'replace' method, after first recalculating TVU values as IHO S44 Order 2.

4 Results

4.1 ceq30 bathymetry grid

The new ceq30 bathymetry grid spans latitude 23° to 26° South, longitude 150° to 154° East over the Central Queensland mainland and adjacent islands, southern Great Barrier Reef shelf, Capricorn Channel, Hervey Bay, Fraser Island shelf and slope, and the deep Tasman Basin (Figure 13). The grid has a version date of 12 June 2017. The ceq30 grid has an area of 134,672 km^2 and a full elevation range from +960 to -3992 m. The new grid has a 0.0003° (~30 m) grid pixel size with a WGS84 horizontal datum and approximates the MSL vertical datum. The new source data available, and the substantial pre-processing effort on these source data, have significantly improved the level of detail of seabed geomorphic features shown in the ceq30 bathymetry grid.

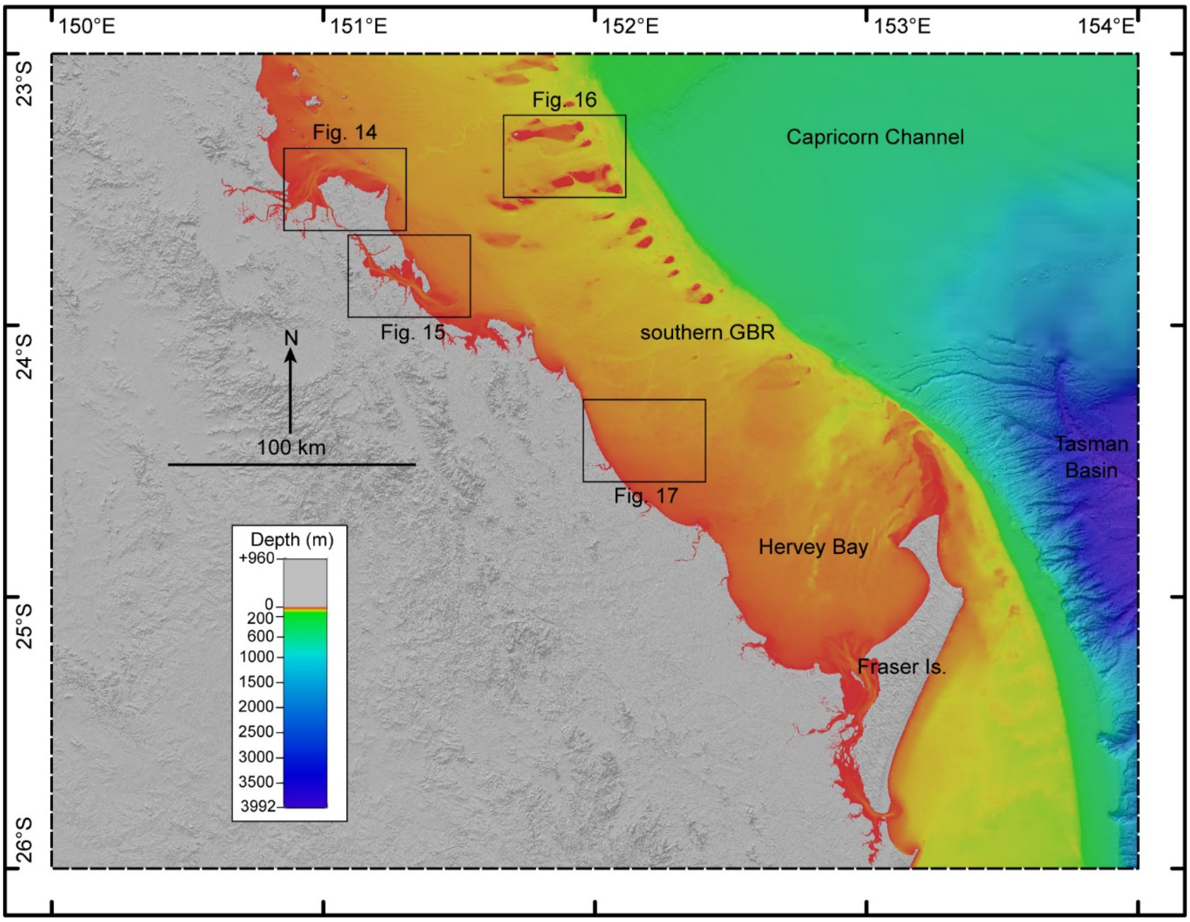

Figure 13 Coloured hillshade view of the ceq30 bathymetry grid, shown with vertical exaggeration x6, sun azimuth 315°, and sun angle 51°. Boxes show locations of Figs. 14-17.

Figure 14 shows a grey hillshade comparison between the ceq30 and AusBathyTopo (Whiteway, 2009) grids near the Fitzroy River. The main trunk of the Fitzroy River channel is clearly observed about 600 m wide and with depths dropping from a shallow ~4 m either side of the channel down to 14 m. Several other palaeo-channels are seen running parallel to the main channel, following around the northern end of Curtis Island. Between Hummocky Island and Curtis Island, is a broad 7 km wide platform stretching out from Curtis Island to a depth of ~10 m. This platform has superimposed curvilinear dunes, over 6 km long about 2 m crest to trough, together with shorter dunes up to 1 m high. The new EOMAP-supplied SDB source data are largely responsible for observing these dune features

Figure 15 shows a grey hillshade comparison between the ceq30 and AusBathyTopo grids near Gladstone. The dredged Gladstone channel is about 400 m wide dropping from ~10 m either side of the channel to ~19 m. The dredge spoil area can also be seen as a slightly raised area in about 14 m near the dredge channel entrance, and covering an area ~2.4 x 2.6 km. Narrow channels can be seen meandering through the shallow flats between Curtis and Facing islands towards Gladstone harbour. Seaward of Facing Island are numerous curvilinear dunes lying in a NW-SE direction, presumably shaped by the prevailing SE winds. Depths drop to ~24 m across this dune field, with crest-to-crest distances of between 200 m to 1 km apart, and peak to trough heights of up to 3 m. Again, the new EOMAP-supplied SDB data are responsible for much of the geomorphic detail along the nearshore area.

Figure 16 shows a grey hillshade comparison between the ceq30 and AusBathyTopo grids near Heron Island. The outlines of the shallow reefs are clearly observed and the geomorphic detail of reef walls dropping to the adjacent deeper seafloor in ~35 m depth. Heron Island and Sykes reefs are near-sea-surface reefs connected by a larger submerged bank around 12-14 m depth (Harris et al., 2013). Similarly, North West Island and Broomfield reefs are part of a much larger submerged bank 10-13 m deep. The seafloor between these two large banks drops to a maximum of 46 m and has scattered curvilinear and barchan dunes up to 10 m in height and 2 km in length. Between One Tree Island and Sykes reefs are numerous submerged reefs as a series of ridges and dropping from 25-50 m to seawards, before flattening at 65 m towards the outer-shelf.

Figure 17 shows a grey hillshade comparison between the ceq30 and AusBathyTopo grids near Baffle Creek. This area has relatively poor source data coverage and so is useful to see what improvement the ceq30 grid has made compared to the AusBathyTopo grid. The seafloor generally deepens gradually to depths of around 30 m towards the north-east. The inner-shelf has no apparent topographic high features, which also reflects the lack of features in the nautical charts from this area. A slight stepping effect can be observed across the ceq30 grid, which is likely due to the lack of source data making any repair/replacement on the underlying AusBathyTopo grid. However at the north-east corner, new multibeam source data reveals subtle sandwaves. But despite the lack of source data over this area, the ceq30 grid has reduced some of the more obvious artefacts shown in the AusBathyTopo grid, e.g. N-S oriented artefact at the south.

The ceq30 bathymetry grid spans latitude 23° to 26° S, longitude 150° to 154° E, across the Central Queensland mainland, shelf and offshore area.

The grid has a full elevation range +960 to -3992 m, 0.0003° (~30 m) grid pixel size, WGS84 horizontal datum and approximates the MSL vertical datum.

The new source data and processing methodology have significantly improved the level of geomorphic detail observed in the new grid.

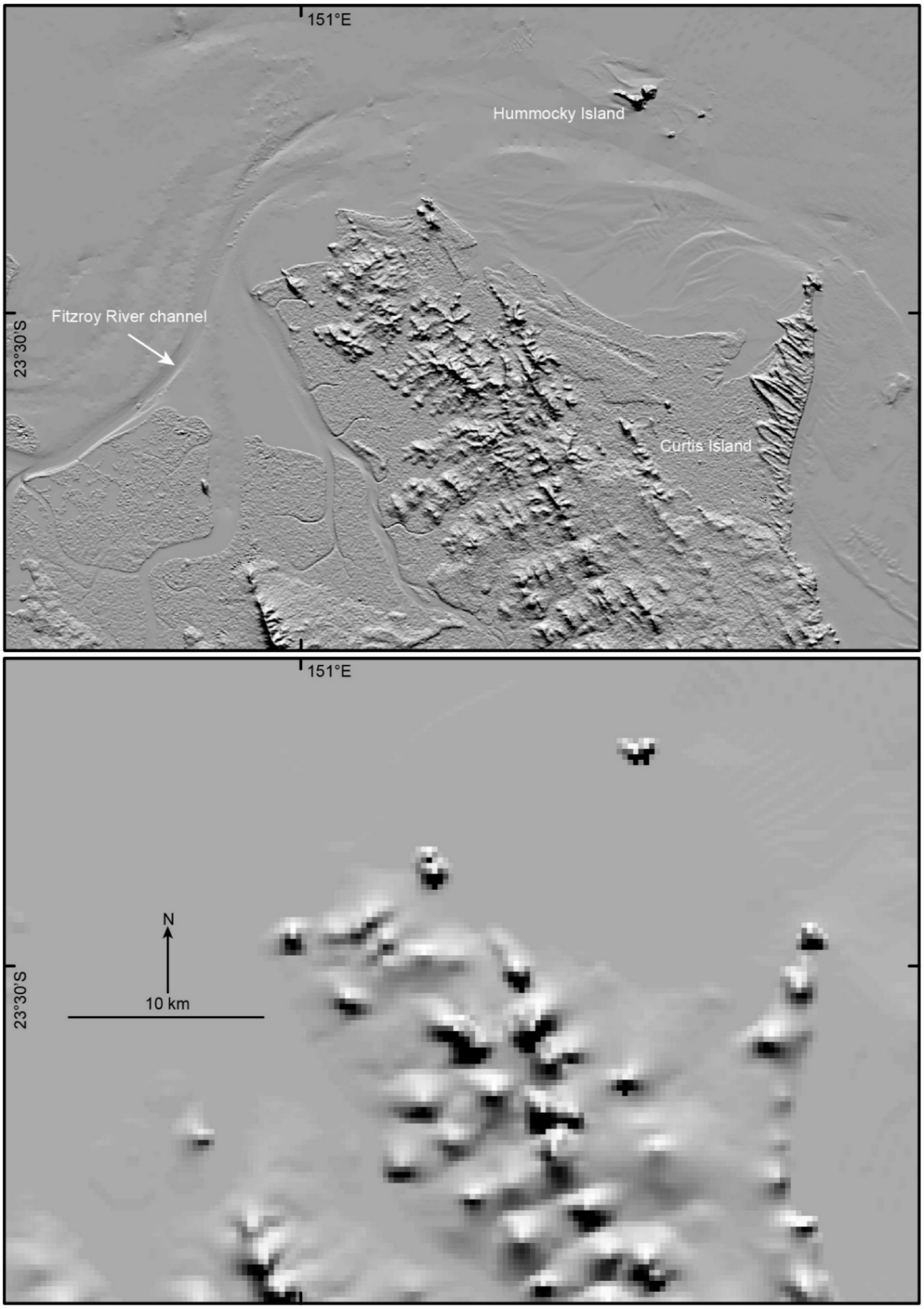

Figure 14 Comparison between the ceq30 and AusBathyTopo grids near the Fitzroy River, shown with vertical exaggeration x1, sun azimuth 001°, and sun angle 50°. Location in Fig. 13.

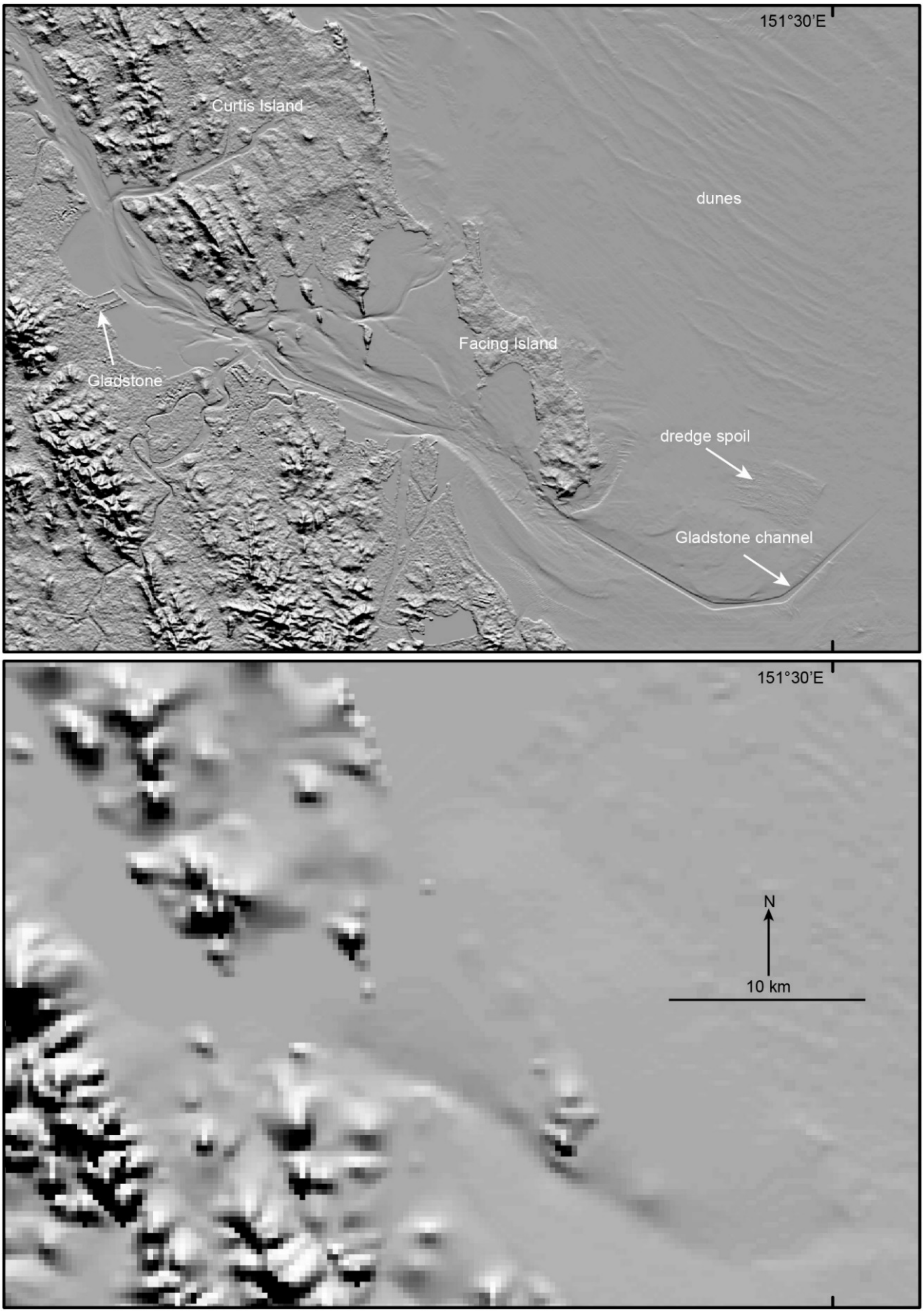

Figure 15 Comparison between the ceq30 and AusBathyTopo grids near Gladstone, shown with vertical exaggeration x1, sun azimuth 001°, and sun angle 50°. Location in Fig. 13.

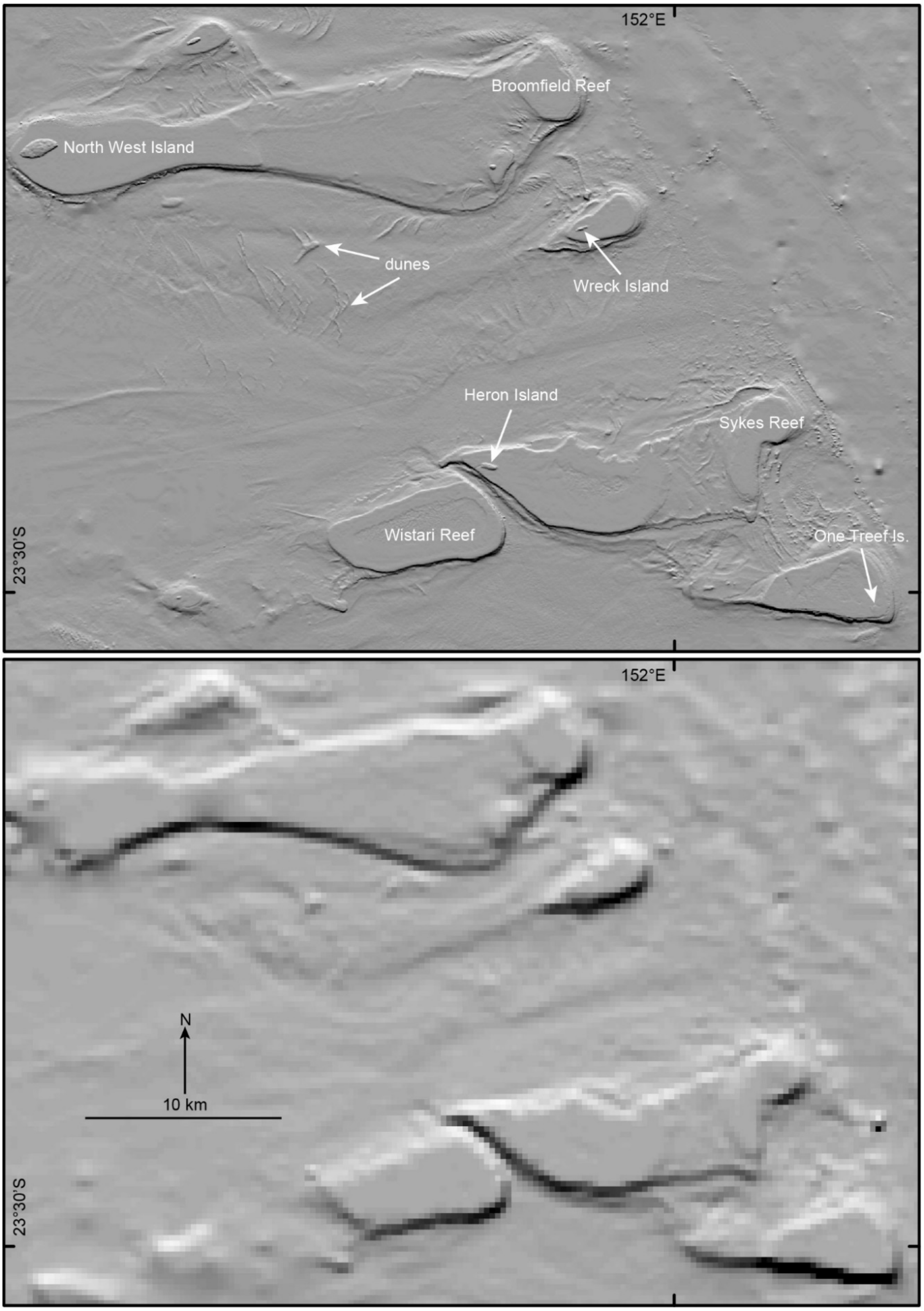

Figure 166 Comparison between the ceq30 and AusBathyTopo grids near Heron Island, shown with vertical exaggeration x1, sun azimuth 001°, and sun angle 50°. Location in Fig. 13.

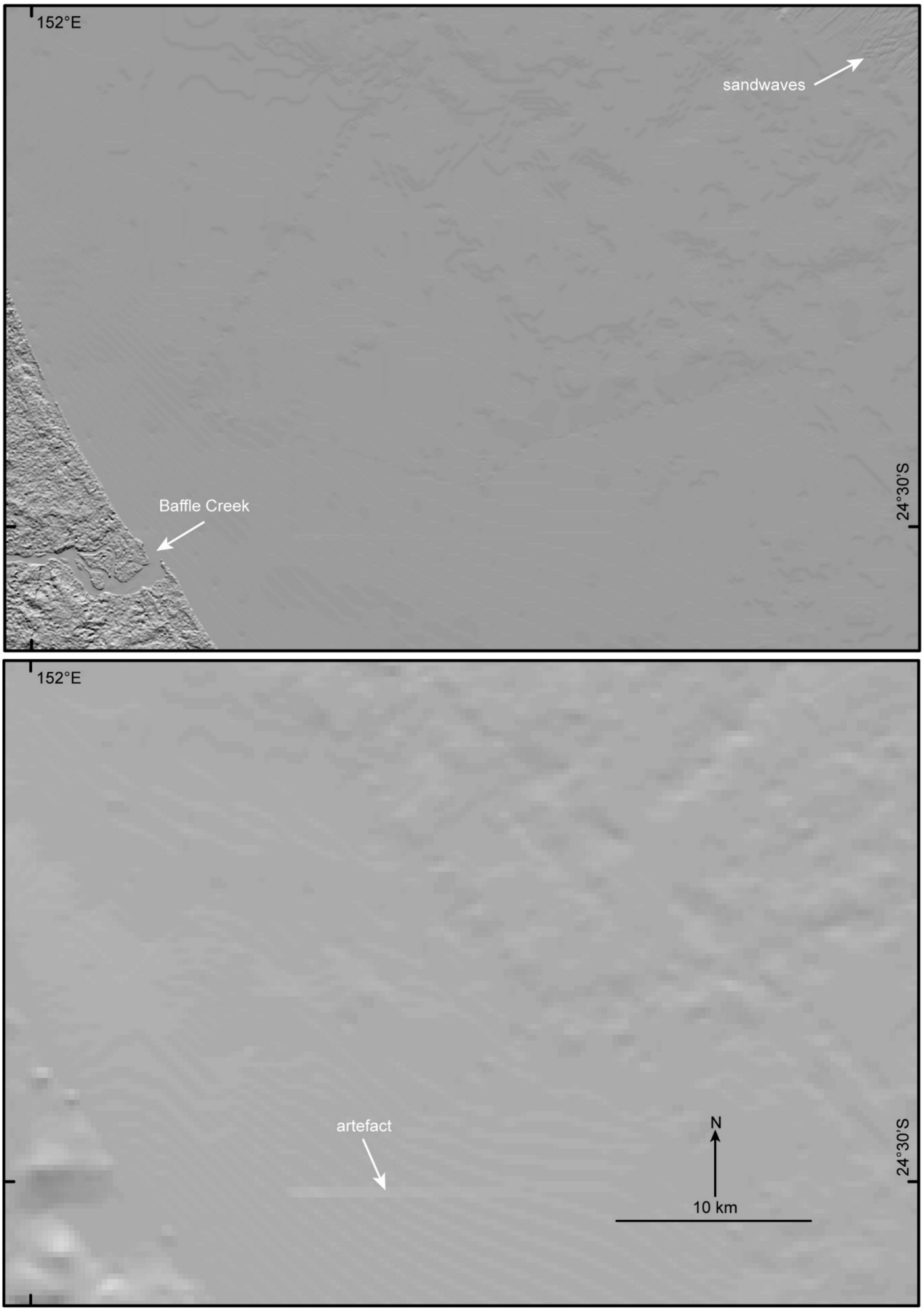

Figure 177 Comparison between the ceq30 and AusBathyTopo grids near Baffle Creek, shown with vertical exaggeration x1, sun azimuth 001°, and sun angle 50°. Location in Fig. 13.

4.2 Total Vertical Uncertainty grid

The accompanying TVU grid is useful to understand the maximum allowable vertical uncertainty at the 95% confidence level. The TVU grid has a 0.0003° (~30 m) grid pixel size with a WGS84 horizontal datum and positive uncertainty values representing the processed TVU of the underlying source data (Figure 18). Users can thus identify the uncertainty values in metres, for co-located bathymetry values on the ceq30 grid. The TVU grid has an uncertainty range from ~0 to 64 m, with the larger TVU values representing the deeper parts of the ceq30 grid, e.g. 3992 m (ceq30) +/- 64 m (TVU), or an uncertainty range of 3928 to 4056 m at 95% confidence level. Conversely, shallower parts of the ceq30 grid will have correspondingly smaller uncertainty values, e.g. 10 m (ceq30) +/- 0.5 m (TVU), or an uncertainty range of 9.5 to 10.5 m at 95% confidence level.

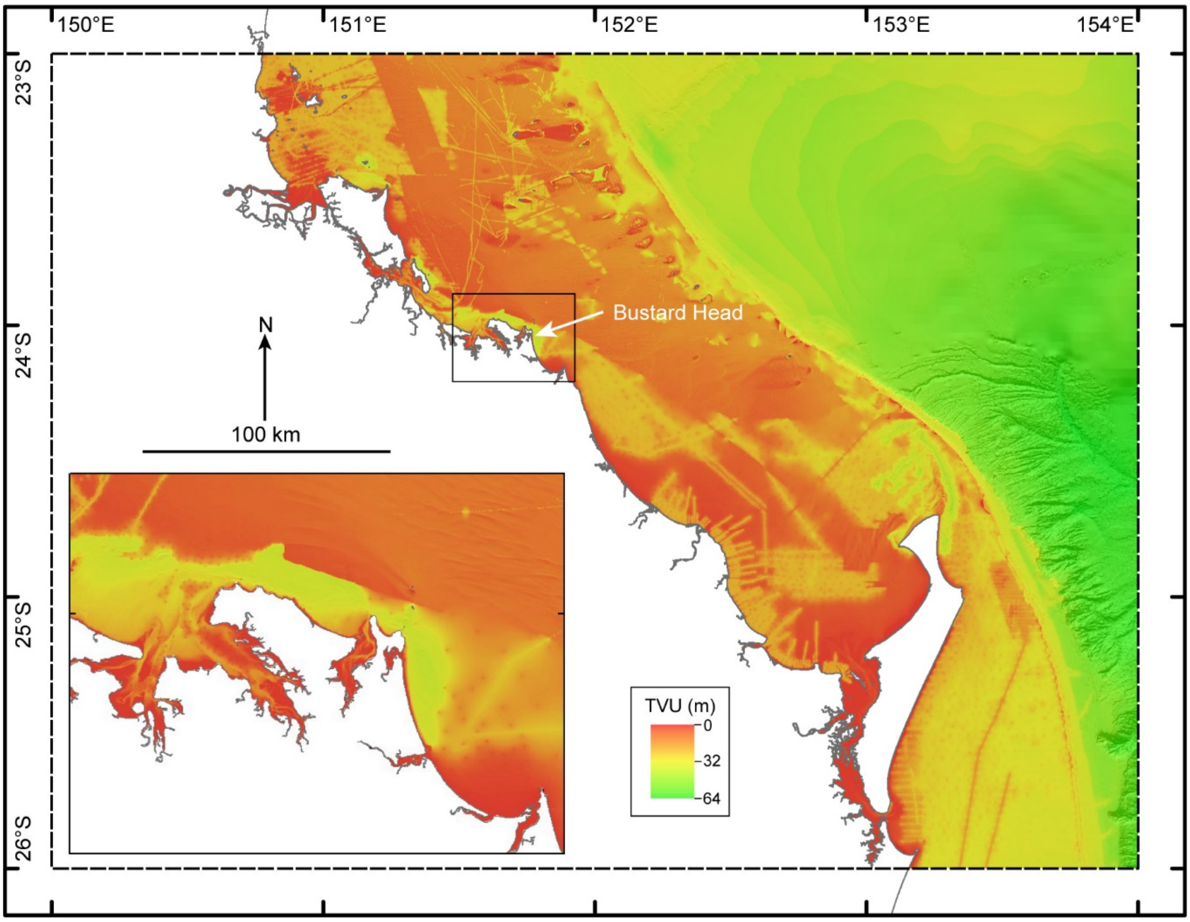

Figure 188 Histogram-stretched view of the Total Vertical Uncertainty grid. The inset shows the Bustard Head area and the relatively larger TVU values for the EOMAP SDB source data.

The TVU grid is also useful to compare the relative differences in uncertainty across localised areas that were processed from different source data types. For example, in areas of the ceq30 grid that only used SDB data (Figure 18 inset), the TVU grid shows the relatively larger uncertainty values from these SDB source data (e.g. TVU = 15% + 0.5 m), compared to adjacent areas sourced from the higher quality singlebeam or multibeam data that have smaller uncertainty values (e.g. TVU = IHO S44 Order 1a/b or 2).

The TVU grid allows users to identify the uncertainty values for co-located bathymetry values on the ceq30 grid.

The TVU grid has an uncertainty range from ~0 to 64 m, with the larger values corresponding to the deeper areas of the ceq30 grid.

Localised areas can be compared for relative differences in uncertainty based upon the TVU of the underlying source data types.

5 Recommendations

An important consideration for use of the new ceq30 bathymetry grid is that even though much source data relied on hydrographic survey data collected by the AHS for safety of navigation purposes, the ceq30 grid is not a hydrographic product. The ceq30 bathymetry grid should not be used for navigation. The use of the ceq30 bathymetry grid is limited for the purposes of the Intertidal and Subtidal Habitat Mapping and Conservation Values Assessment for Central Queensland State Waters Project. For example, to use the grid for mapping or modelling other biophysical attributes within the Project area, including seafloor morphology, sediment grain size, wave and tidal energy, and macrobenthos distribution.

In mapping geomorphic features from the ceq30 grid, users need to be aware that the available source data do not cover 100% of the entire seafloor. Consequently there are gaps in the spatial coverage of seabed features, i.e. not all features can be resolved (observed) in the ceq30 grid because of the lack of detailed bathymetry data over those features. Further, residual artefacts may still be present in those areas lacking source data. The white areas shown in Figure 19 reveal the lack of source digital data available for this Project. But these white areas can also be used to highlight priority areas for future surveys. For example, the source data coverage for the nearshore Baffle Creek area mostly used bathymetry data from widely-spaced singlebeam surveys. The general depths in this area are likely to be correct but will lack geomorphic detail (see also Figure 17).

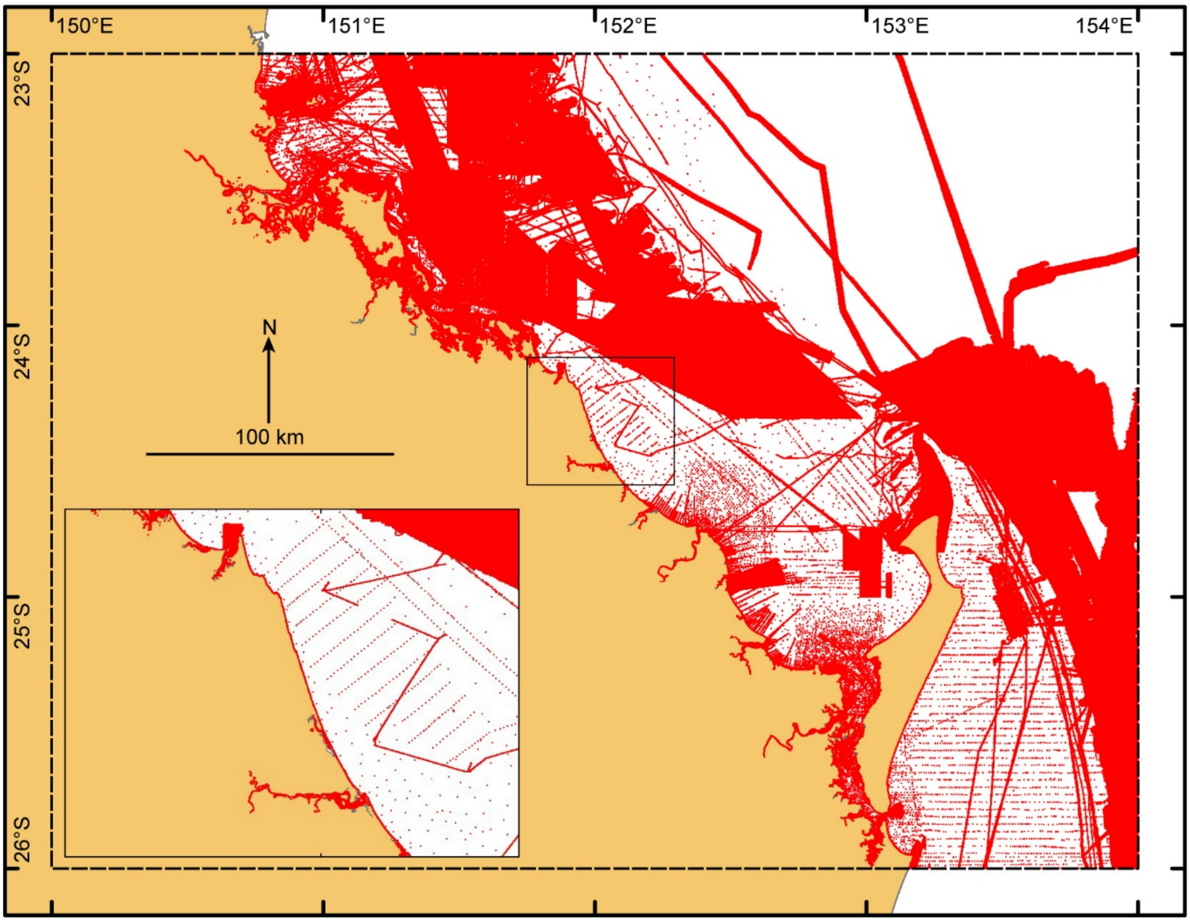

Figure 199 All source data coverage. The white areas indicate the lack of source digital data. Inset shows close-up of source data coverage near Baffle Creek. Also see Fig. 17.

Future surveys could target these source data-poor areas to provide more dense bathymetric data coverage, should these areas be considered priorities for more detailed habitat mapping or modelling climate change impacts. ALB surveys would provide the best quality bathymetry data for the nearshore and in depths shallower than ~20 m. Modern ALB surveys can simultaneously acquire both land elevation data and bathymetry data using multiple frequency lasers, in addition to co-located aerial imagery, to generate seamless DEMs across the land/ocean interface and through the surf zone. For depths deeper than about 20 m, multibeam surveys mounted on surface vessels or AUVs provide the best quality bathymetry data with dense coverage over seabed features.

Another limitation of the ceq30 grid is that while the grid approximates MSL, caution is advised against using fine-scale tidal level slicing of the depth model for mapping inundation areas within the intertidal zone, understanding that the ITEM DEM source data for the intertidal zone has a point spacing of 25 m, TVU of 0.5 m, and likely ranges from MHWS to MLWS (not HAT to LAT). The Queensland Government has been conducting sub-5 m point spacing airborne lidar elevation surveys along the coast, which in places, extend across the intertidal zone. During the period of development of the ceq30 grid, these terrestrial lidar data (ideally water-masked) were not available for inclusion in the grid development process. Where the ceq30 grid and terrestrial lidar data overlap, the latter may be more suitable for fine-scale tidal level slicing for mapping the inundation areas.

The raw SRTM Digital Surface Model (DSM) data used as the land elevation data for the ceq30 grid are also not ideal, as the elevation data also includes vegetation heights. However for the entire Project area, the SRTM data are still the only nationally consistent elevation dataset available at no cost and area relatively easy to obtain. The new Queensland Government terrestrial lidar data could (in the future) be an alternative to the SRTM data. But because these terrestrial lidar datasets were not available as land-only (i.e. water-masked) DEMs for inclusion in the grid development process, the SRTM data were the elevation data used in the ceq30 grid. Again, where the ceq30 grid and terrestrial lidar data overlap, the latter may be more useful for coastal zone modelling.

The ceq30 grid is therefore recommended mainly for use as MSL subtidal depths where overlapping with terrestrial lidar data within the intertidal zone, and for use only as MSL intertidal (with caution) and subtidal depths where there is no overlap with terrestrial lidar data. Users wanting to study the intertidal zone will need to ascertain for themselves where the ceq30 grid and terrestrial lidar data overlap through the intertidal zone, as these terrestrial lidar datasets become publically released in the future. The ceq30 bathymetry grid is best used for MSL depths deeper than 0 m (i.e. negative depth values).

In summary, the new source data and substantial pre-processing effort on the source data have significantly improved the level of detail of seabed geomorphic features observed in the ceq30 bathymetry grid. The ceq30 bathymetry grid is recommended for use as a fundamental dataset for mapping or modelling other biophysical attributes for the ‘Interim Queensland intertidal and subtidal ecosystem classification scheme’, such as morphology, sediment grain size, wave and tidal energy, and structural macrobenthos distribution.

The ceq30 bathymetry grid is not a hydrographic product and should not be used for navigation.

Bathymetry data gaps for priority areas can be addressed using ALB surveys for the nearshore (less than ~20 m) or using multibeam surveys in deeper waters.

Caution is advised in using the ceq30 grid for mapping inundation areas within the intertidal zone. Overlapping terrestrial lidar data are preferable for inundation mapping.

Terrestrial lidar data (when publically released) could be more suitable for coastal zone modelling where overlapping with the ceq30 grid.

The ceq30 bathymetry grid is best used for MSL depths deeper than 0 m (i.e. negative depth values).

The ceq30 grid is recommended for mapping or modelling other biophysical attributes for the 'Interim Queensland intertidal and subtidal ecosystem classification scheme'.

6 Conclusion

The ceq30 bathymetry grid was developed for the Intertidal and Subtidal Habitat Mapping and Conservation Values Assessment for Central Queensland State Waters Project. The grid has a version date of 12 June 2017. The ceq30 grid spans from latitude 23° to 26° South, longitude 150° to 154° East, and has an area of 134,672 km^2 and an elevation range from +960 to -3992 m. The grid has a pixel size of 0.0003° (~30 m) with a horizontal datum of WGS84 and a vertical datum approximating MSL. The new grid utilised the latest multibeam and singlebeam bathymetry source data, ENC spot depths, airborne lidar bathymetry, satellite derived bathymetry, and coastline datasets provided by Federal and State Government agencies, Universities and commercial companies.

The large increase in source bathymetry data and the extensive pre-processing of the source datasets have significantly improved the level of geomorphic detail compared with earlier bathymetry grids. The ceq30 bathymetry grid provides new insights into the detailed geomorphic shapes and spatial relationships between adjacent seabed features. An accompanying Total Vertical Uncertainty grid provides maximum allowable vertical uncertainty values for co-located bathymetry data, based upon the TVUs of the underlying source data. In conclusion, the higher level of detail of features revealed by the ceq30 grid demonstrate the value of regional-scale bathymetry compilations in helping to understand the seafloor environment.

7 References

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8 Appendix 1 - Data sources for the ceq30 bathymetry grid

SURV_CODE	SURVEY_NAME	DATA_TYPE	VESSEL	START_DATE	END_DATE	START_PORT	END_PORT	DATA_OWNER	SYSTEM	TVU
CRC012004	FitzroyRiver	multibeam	Rum Rambler	20/09/2004	26/09/2004	Gladstone	Gladstone	Coastal CRC	Reson 8125 (455 kHz)	IHO S44 1b
HI295	LadyElliotIs	multibeam	HMAS Leeuwin	26/06/2000	1/12/2000	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI318	LadyElliotIs	multibeam	HMAS Melville	3/07/2000	18/07/2000	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI325_1	CapricornGroup	multibeam	HMAS Leeuwin	2/04/2001	22/05/2001	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI325_B	CapricornGroup	multibeam	HMAS Melville	16/07/2001	10/08/2001	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI369	HeraldPatches	multibeam	HMAS Leeuwin	23/06/2003	27/08/2003	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI369	HerveyBay	multibeam	HMAS Leeuwin	23/06/2003	27/08/2003	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI370	HeraldPatches	multibeam	HMAS Melville	22/04/2003	26/04/2003	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI370_B	LadyMusgravels	multibeam	HMAS Melville	3/07/2003	6/07/2003	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI371	GladstoneShoals	multibeam	HMAS Melville	unknown	11/09/2003	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI412	Gladstone	multibeam	HMAS Melville	unknown	26/09/2006	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI412_B	FVAltheniaIIWreck	multibeam	HMAS Melville	unknown	24/10/2005	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI412_C	FVBonnieEllenWreck	multibeam	HMAS Melville	unknown	4/11/2005	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI412_D	MystiqueWreck	multibeam	HMAS Melville	unknown	20/09/2005	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI412_H	SandyCapeBrisbane	multibeam	HMAS Melville	unknown	2/11/2005	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI412_K	SandyCapeBrisbane	multibeam	HMAS Melville	unknown	1/08/2006	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI421	HerveyBay	multibeam	HMAS Melville	16/06/2006	4/08/2006	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI442	Gladstone	multibeam	HMAS Melville	unknown	28/05/2007	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI442	ApproachesGladstone	multibeam	HMAS Melville	23/05/2007	2/08/2007	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI442_C	GladstoneWreck	multibeam	HMAS Melville	unknown	28/05/2007	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI442_D	GladstoneWreck	multibeam	HMAS Melville	unknown	27/07/2007	Cairns	Cairns	AHS	Atlas Fansweep20 (100 kHz)	IHO S44 1a
HI464	GladstoneApproaches	multibeam	HMAS Mermaid	unknown	18/09/2009	Cairns	Cairns	AHS	Reson Seabat7125 (400 kHz)	IHO S44 1a
HI464_A	Gladstone	multibeam	HMAS Paluma	unknown	12/11/2009	Cairns	Cairns	AHS	Reson Seabat7125 (400 kHz)	IHO S44 1a
HI464_B	GladstoneApproaches	multibeam	HMAS Mermaid/Paluma	unknown	8/03/2010	Cairns	Cairns	AHS	Reson Seabat7125 (400 kHz)	IHO S44 1a
HI464_C	Gladstone	multibeam	HMAS Paluma	unknown	10/04/2010	Cairns	Cairns	AHS	Reson Seabat7125 (400 kHz)	IHO S44 1a
HI518	BustardHead	multibeam	HMAS Mermaid/Paluma	unknown	27/04/2012	Cairns	Cairns	AHS	Reson Seabat7125 (400 kHz)	IHO S44 1a
KM0702	BrisbaneTownsville	multibeam	RV Kilo Moana	11/03/2007	13/03/2007	Brisbane	Townsville	SOEST	Simrad EM1002 (95 kHz)	IHO S44 1b
MR03K03L2	TropOceanClimate	multibeam	RV Mirai	1/07/2003	30/07/2003	Nakagusuku	Brisbane	JAMSTEC	Seabeam 2112 (12 kHz)	IHO S44 1b

MR0901Leg2	PapeeteBrisbane	multibeam	RV Mirai	21/05/2009	19/06/2009	Papeete	Brisbane	JAMSTEC	Seabeam 2112 (12 kHz)	IHO S44 1b
MR0901Leg3	BrisbaneMoji	multibeam	RV Mirai	20/06/2009	2/07/2009	Brisbane	Moji	JAMSTEC	Seabeam 2112 (12 kHz)	IHO S44 1b
MSQ	UranganFairway	multibeam	QG Norfolk	23/01/2015	23/01/2015	Brisbane	Brisbane	MSQ	Kongsberg EM3002D (300 kHz)	IHO S44 1b
MSQ	GladstoneHerveyBay	multibeam	QG Norfolk	12/05/2010	12/05/2010	Brisbane	Brisbane	MSQ	Kongsberg EM3002D (300 kHz)	IHO S44 1b
MSQ	ShenNengHerveyBay	multibeam	QG Norfolk	5/05/2010	5/05/2010	Brisbane	Brisbane	MSQ	Kongsberg EM3002D (300 kHz)	IHO S44 1b
MSQ	ShenNengBarrenIsland	multibeam	QG Norfolk	5/05/2010	5/05/2010	Brisbane	Brisbane	MSQ	Kongsberg EM3002D (300 kHz)	IHO S44 1b
SS012005	FraserIsland2	multibeam	RV Southern Surveyor	7/01/2005	23/01/1900	Brisbane	Bundaberg	UNewcastle	Simrad EM300 (30 kHz)	IHO S44 1b
SS012013	BrisbaneBrisbane	multibeam	RV Southern Surveyor	18/01/2013	3/02/2013	Brisbane	Brisbane	Usydney	Simrad EM300 (30 kHz)	IHO S44 1b
SS022005	MellishRise	multibeam	RV Southern Surveyor	25/01/2005	20/02/2005	Bundaberg	Cairns	GA	Simrad EM300 (30 kHz)	IHO S44 1b
SS032003	FraserIsland1geog	multibeam	RV Southern Surveyor	12/04/2003	26/04/2003	Brisbane	Cairns	Uni of Newcastle	Reson 8101 (240 kHz)	IHO S44 1a
SS032003	FraserIsland1grid	multibeam	RV Southern Surveyor	12/04/2003	26/04/2003	Brisbane	Cairns	Uni of Newcastle	Reson 8101 (240 kHz)	IHO S44 1a
SS072012	TasmantidSeamounts	multibeam	RV Southern Surveyor	18/12/2012	18/12/2012	Brisbane	Brisbane	UQ	Simrad EM300 (30 kHz)	IHO S44 1b
SS092008	GBRCO2	multibeam	RV Southern Surveyor	24/07/2008	11/08/2008	Cairns	Gladstone	CSIRO-BOM	Simrad EM300 (30 kHz)	IHO S44 1b
SST022012	BrisbaneLautoka	multibeam	RV Southern Surveyor	2/05/2012	9/05/2012	Brisbane	Lautoka	JCU	Simrad EM300 (30 kHz)	IHO S44 1b
SST032008	NextWave	multibeam	RV Southern Surveyor	12/08/2008	16/08/2008	Gladstone	Sydney	UTS/UNSW	Simrad EM300 (30 kHz)	IHO S44 1b
SST032013	BroomeBrisbane	multibeam	RV Southern Surveyor	27/08/2013	10/09/2013	Broome	Brisbane	JCU	Simrad EM300 (30 kHz)	IHO S44 1b
SST062007	MackayNewcastle	multibeam	RV Southern Surveyor	16/10/2007	21/10/2007	Mackay	Newcastle	CMAR	Simrad EM300 (30 kHz)	IHO S44 1b
TM2014V01	FraserCoast	multibeam	RV Tom Marshall	26/05/2014	5/06/2014	Brisbane	Brisbane	CSIRO	Simrad EM2040C (300 kHz)	IHO S44 1b
WEST05MV	PapeeteBrisbane	multibeam	RV Melville	19/05/1994	25/06/1994	Papeete	Brisbane	SIO	Seabeam 2000 (12 kHz)	IHO S44 1b
AIMS2008-2014	GBR	singlebeam	RV Cape Ferguson	30/09/2008	19/02/2014	Cape Ferguson	Cape Ferguson	AIMS	Furuno FCV-1200L (200 kHz)	IHO S44 2
AMSA96_1	OuterGBRRoute	singlebeam	MV Cape Grafton	28/11/1996	26/01/1997	unknown	unknown	AHS	Atlas DESO 25 (15 kHz)	IHO S44 1b
AUSLIG	ErskineReef	singlebeam	unknown	unknown	unknown	unknown	unknown	GA	unknown	IHO S44 2
AUSLIG	FairfaxIsReef	singlebeam	unknown	unknown	unknown	unknown	unknown	GA	unknown	IHO S44 2
AUSLIG	IrvingReef	singlebeam	unknown	unknown	unknown	unknown	unknown	GA	unknown	IHO S44 2
AUSLIG	LadyMusgraveIsReef	singlebeam	unknown	unknown	unknown	unknown	unknown	GA	unknown	IHO S44 2
AUSLIG	MastHeadIsReef	singlebeam	unknown	unknown	unknown	unknown	unknown	GA	unknown	IHO S44 2
AUSLIG	NorthWestIsReef	singlebeam	unknown	unknown	unknown	unknown	unknown	GA	unknown	IHO S44 2
DERM	Queensland	singlebeam	various	unknown	unknown	unknown	unknown	DERM	unknown	IHO S44 2
GBRSeabed	Biodiversity	singlebeam	RV Lady Basten	17/09/2003	28/11/2005	Townsville	Townsville	CSIRO	Simrad EY500 (120 kHz)	IHO S44 2

HI173	NorthWestIs	singlebeam	HMAS Paluma/Mermaid	22/02/1992	4/05/1992	Cairns	Cairns	AHS	unknown	IHO S44 1b
HI190	KeppelIsles	singlebeam	HMAS Shepparton/Benalla	28/02/1994	24/03/1994	Cairns	Cairns	AHS	Atlas DESO 35 (210 kHz)	IHO S44 1b
HI198	Benchmarks	singlebeam	HMAS Shepparton/Benalla	unknown	2/12/1994	Cairns	Cairns	AHS	unknown	IHO S44 1b
HI230	FraserIs	singlebeam	HMAS Flinders	15/08/1995	24/09/1995	Cairns	Cairns	AHS	unknown	IHO S44 1b
HI230	Gladstone	singlebeam	HMAS Flinders	30/07/1995	9/11/1995	Cairns	Cairns	AHS	unknown	IHO S44 1b
HI259_B	GardnerBanks	singlebeam	HMAS Flinders	6/08/1997	15/08/1997	Cairns	Cairns	AHS	Atlas DESO 20 (33-210 kHz)	IHO S44 1b
HI282	Gladstone	singlebeam	HMAS Benalla/Shepparton	2/02/1999	23/04/1999	Cairns	Cairns	AHS	Atlas DESO 35 (210 kHz)	IHO S44 1b
HI302_Z	WhitsundayIs	singlebeam	HMAS Benalla/Shepparton	20/09/1999	20/09/1999	Cairns	Cairns	AHS	Atlas DESO 35 (210 kHz)	IHO S44 1b
HI325_A	GreatKeppelIs	singlebeam	HMAS Leeuwin SMB	5/04/2001	20/05/2001	Cairns	Cairns	AHS	Atlas DESO 25 (210 kHz)	IHO S44 1b
HI355	Gladstone	singlebeam	HMAS Paluma/Mermaid	20/05/2002	1/07/2002	Cairns	Cairns	AHS	Atlas DESO 35 (210 kHz)	IHO S44 1b
HI355_B	CapeCapricorn	singlebeam	HMAS Paluma/Mermaid	8/06/2002	8/06/2002	Cairns	Cairns	AHS	Atlas DESO 35 (210 kHz)	IHO S44 1b
HI371	Gladstone	singlebeam	HMAS Melville	10/09/2003	11/09/2003	Cairns	Cairns	AHS	Atlas DESO 25 (210 kHz)	IHO S44 1b
HI397	GoodwinShoal	singlebeam	HMAS Benalla/Shepparton	unknown	6/07/2005	Cairns	Cairns	AHS	unknown	IHO S44 1b
HI456_B	QldPassage	singlebeam	HMAS Leeuwin	unknown	5/11/2008	Cairns	Cairns	AHS	unknown	IHO S44 1b
MSQ	Eseries	singlebeam	unknown	unknown	unknown	unknown	unknown	MSQ	unknown	IHO S44 1b
MSQ	Fseries	singlebeam	unknown	unknown	unknown	unknown	unknown	MSQ	unknown	IHO S44 1b
MSQ	Gseries	singlebeam	unknown	unknown	unknown	unknown	unknown	MSQ	unknown	IHO S44 1b
SD100006328	Rockhampton	singlebeam	unknown	unknown	20/05/1982	unknown	unknown	AHS	unknown	IHO S44 2
SD100006329	Rockhampton	singlebeam	unknown	unknown	20/05/1982	unknown	unknown	AHS	unknown	IHO S44 2
SD100011744	WideBay	singlebeam	unknown	1/11/1971	4/12/1971	unknown	unknown	AHS	unknown	IHO S44 2
SD100012326	WideBay	singlebeam	unknown	1/11/1971	4/12/1971	unknown	unknown	AHS	unknown	IHO S44 2
SD100012327	WideBay	singlebeam	unknown	1/11/1971	4/12/1971	unknown	unknown	AHS	unknown	IHO S44 2
SD100012328	WideBay	singlebeam	unknown	1/11/1971	4/12/1971	unknown	unknown	AHS	unknown	IHO S44 2
SD100012329	BarwonBank	singlebeam	unknown	3/08/1971	18/10/1971	unknown	unknown	AHS	unknown	IHO S44 2
SD100012332	Caloundra	singlebeam	unknown	3/08/1971	18/10/1971	unknown	unknown	AHS	unknown	IHO S44 2
SD100017148	PortClinton	singlebeam	unknown	unknown	11/09/1984	unknown	unknown	AHS	unknown	IHO S44 2
SD100017154	Bundaberg	singlebeam	unknown	unknown	20/05/1986	unknown	unknown	AHS	unknown	IHO S44 2
SD100021007	SandyCape	singlebeam	unknown	unknown	unknown	unknown	unknown	AHS	unknown	IHO S44 2
SRATA130	GreatKeppelIsland	singlebeam	LUB Alert	unknown	18/06/2007	Cairns	Cairns	AHS	unknown	IHO S44 1b

USC	BaffleCreek	singlebeam	USC Tinny	22/01/2018	6/02/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	BoyneRiver	singlebeam	USC Tinny	16/01/2018	16/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	BurnettRiver	singlebeam	USC Tinny	6/01/2018	8/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	Burrum	singlebeam	USC Tinny	21/02/2018	23/02/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	CalliopeRiver	singlebeam	USC Tinny	17/01/2018	17/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	CawarralCreek	singlebeam	USC Tinny	31/01/2018	3/02/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	ElliotRiver	singlebeam	USC Tinny	5/01/2018	5/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	EurimbulaCreek	singlebeam	USC Tinny	4/02/2018	4/02/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	KolanRiver	singlebeam	USC Tinny	7/01/2018	7/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	MaryRiver	singlebeam	USC Tinny	17/02/2018	20/02/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	MiddleCreek	singlebeam	USC Tinny	5/02/2018	5/02/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	MulambinCreek	singlebeam	USC Tinny	2/02/2018	2/02/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	RossCreek	singlebeam	USC Tinny	31/01/2018	31/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	RoundHillCreek	singlebeam	USC Tinny	19/01/2018	21/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	TheNarrows	singlebeam	USC Tinny	18/01/2018	18/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
USC	TheodoliteCreek	singlebeam	USC Tinny	8/01/2018	8/01/2018	Sippy Downs	Sippy Downs	USunshineCoast	Lowance HDS-7 Gen3 (200 kHz)	IHO S44 1b
AU323151	MoresbyBank	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU323152	CapricornChannel	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU324152	Capricorn	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU325153	FraserIsland	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU423150	ShoalwaterBay	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU424150	KeppelBay	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU424151	KeppelIsles	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU425151	BustardHead	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU425152	CurtisChannel	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU426152	HerveyBay	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU426153	DoubleIsland	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU427153	NthMoretonBay	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU5242P0	Bundaberg	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU5244X5	Gladstone	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b

AU5247P2	RosslynBay	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
AU5265P0	PortAlma	ENC	na	na	na	na	na	AHS	S57 soundings from ENC tiles	IHO S44 1b
CRCSI2011	Sunshine	ALB	LADS	29/10/2011	11/11/2011	Marcoola	Marcoola	CRCSI	LADS3	IHO S44 1b
HI199	CapricornGroup	ALB	LADS	24/01/1994	31/03/1994	Cairns	Cairns	AHS	LADS1	IHO S44 1b
HI505	KeppelBay	ALB	LADS	unknown	unknown	Cairns	Cairns	AHS	LADS2	IHO S44 1b
SRATA0203	PolmaiseReef	ALB	LADS	unknown	unknown	Cairns	Cairns	AHS	LADS2	IHO S44 1b
ITEM_DEM	e150s23	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e150s24	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e151s24	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e151s25	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e152s24	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e152s25	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e152s26	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e153s25	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e153s26	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
ITEM_DEM	e153s27	ITEM v1.0	Digital Earth Australia	na	na	na	na	GA	ITEMv10	0.5
Landsat	BreakseaSpit	SDB	Landsat7	na	na	na	na	JCU	empirical	15% + 0.5
Landsat	Capricorn	SDB	Landsat7	na	na	na	na	JCU	empirical	15% + 0.5
Landsat	Gladstone	SDB	Landsat8	na	na	na	na	EOMAP	physics	15% + 0.5
AUST	COAST	coastline	na	na	na	na	na	Qld Govt	na	2.0