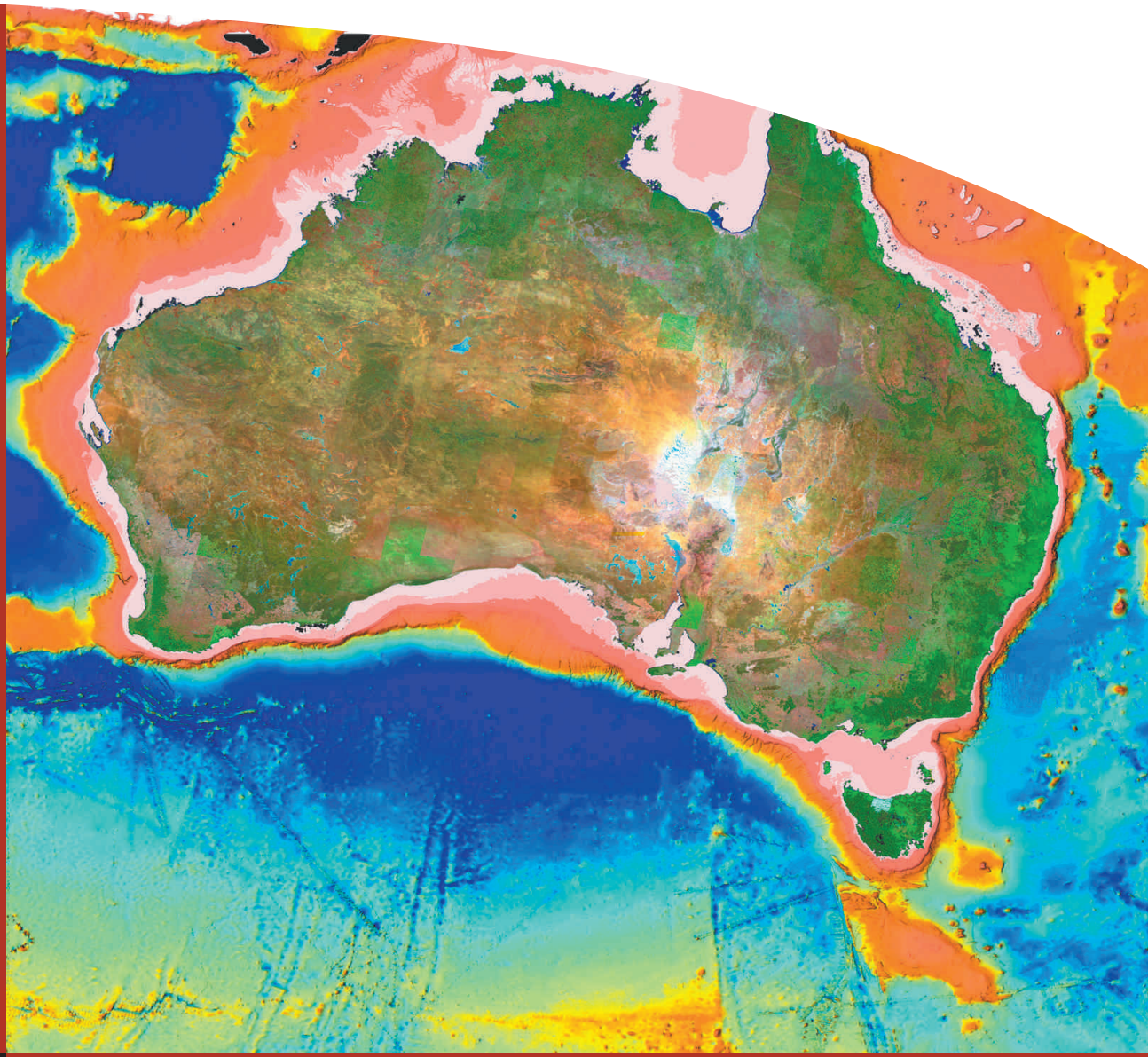
Australian Government
Geoscience Australia

Australian Bathymetry and Topography Grid

JUNE 2005

Record
2005/12



Australian Bathymetry and Topography Grid, June 2005

Geoscience Australia
Record 2005/12

by

M.A. Webster, P. Petkovic.

Australian Government
Geoscience Australia

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Abstract

Geoscience Australia and the National Oceans Office carried out a joint venture project to produce a consistent, high-quality 9 arc second (0.0025° or ~250m at the equator) bathymetric data grid of those parts of the Australian water column jurisdiction lying between 92˚ E – 172˚ E and 8˚ S – 60˚ S. As well as the waters adjacent to the continent of Australia and Tasmania, the area selected also covers the area of water column jurisdiction surrounding Macquarie Island, and the Australian Territories of Norfolk Island, Christmas Island, and Cocos (Keeling) Islands. The area selected does not include Australia's marine jurisdiction off of the Territory of Heard and McDonald Islands and the Australian Antarctic Territory.

This report provides a list of the datasets and procedures used to produce a grid of 9 arc second cell dimensions. The underlying data from which this grid is derived can only support this resolution in areas where direct bathymetric observations are sufficiently dense (eg. where swath bathymetry data or digitised chart data exist). In areas where only track-line data exist, the grid resolution is high along-line but low perpendicular to lines. In areas where no sounding data are available, the grid is based on interpolated or indirectly observed bathymetry, and these data can only support a resolution of 2 arc minutes (2 nautical miles or ~3.7 km).

The grid covers an area of approximately 41 million square kilometres. Its dimensions are 32003 x 20803 cells resulting in a file size slightly in excess of 1.3 Gb of 2-bytes integer numbers representing the bathymetric values. The grid synthesises approximately 1.7 billion observed data points.

This grid is not suitable for use as an aid to navigation, or to replace any products produced by the Australian Hydrographic Service.

Introduction

Geoscience Australia (GA, formerly the Australian Geological Survey Organisation and the Bureau of Mineral Resources) has been collecting bathymetry data routinely from seismic and sampling surveys around the Australian margin since 1963. More recently GA has taken on a role of national custodian for all bathymetry data holdings within the Australian Maritime Jurisdiction. GA's bathymetry data holdings consist of ship-track bathymetry, swath bathymetry, digitised soundings from hydrographic charts, laser airborne depth sounder (LADS) data and other associated ship-track geophysical measurements. Approximately 10% of these surveys were acquired by GA. The remainder of GA's data holdings are from other scientific institutions, oil exploration companies and academic organisations. Some of this data has been sourced indirectly through the National Geophysical Data Centre (USA) to which various institutions have contributed.

GA has a diverse range of data from a variety of systems with differing data densities and levels of accuracy. In the geographic extents 34°N - 79°S, 90°E - 180°E, GA holds approximately 1400 surveys that collected bathymetric data. For ship-track data the typical spacing of point data along track is 25-200m, the two-dimensional spacing of points covered by swath surveys is of similar order. The coverage of ship-track surveys is widely variable, such that some points covered by grid lines are many tens of kilometres apart, whereas for swath bathymetry surveys, the areas of coverage are at relatively high density, but of very limited coverage.

This report documents the procedures used to construct the bathymetric grid and their associated displays. The extents used for this grid are 92˚ E – 172˚ E and 8˚ S – 60˚ S, see Figure 1. The input data were derived from a number of sources, were of variable vintages and quality. A number of approaches were required to process, check and edit the data. The availability of data also varied considerably throughout the region, effectively restricting the maximum useful resolution of the grid in areas where no soundings exist, to that of the satellite predicted bathymetry that was used as infill.

These data, together with predicted bathymetry from satellite altimetry, have been brought together into a single data and processing system to allow the routine creation of grids with a range of specifications, from which images as illustrated in Figure 2 can be created.

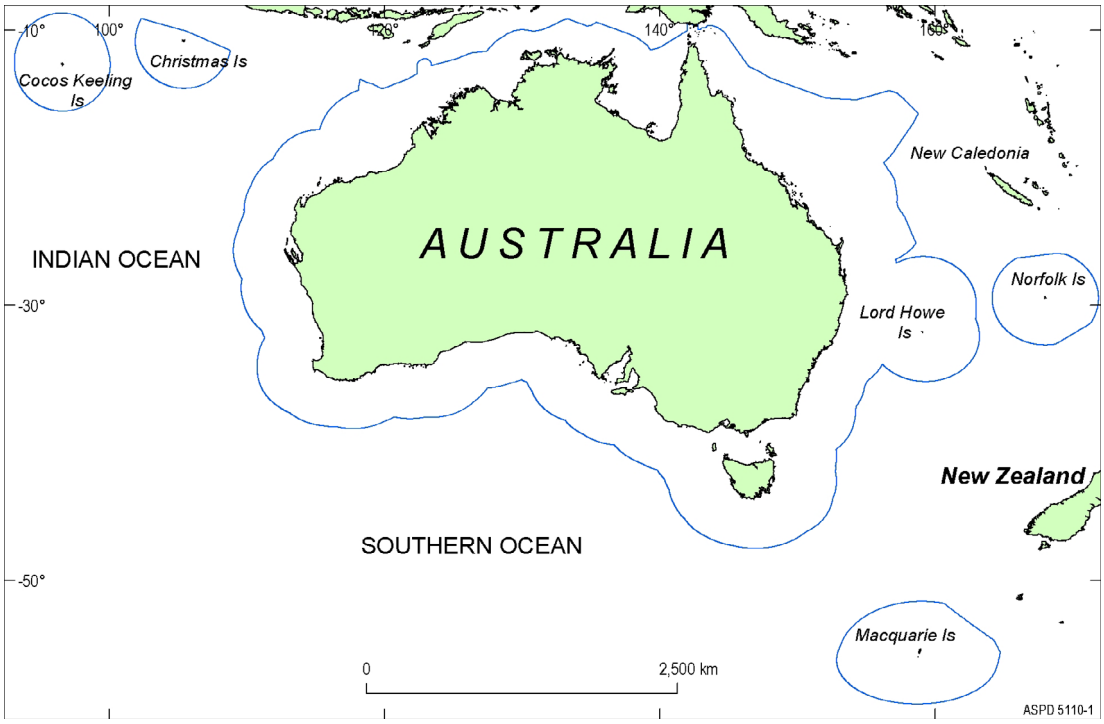

Figure 1 Location Map of area covered

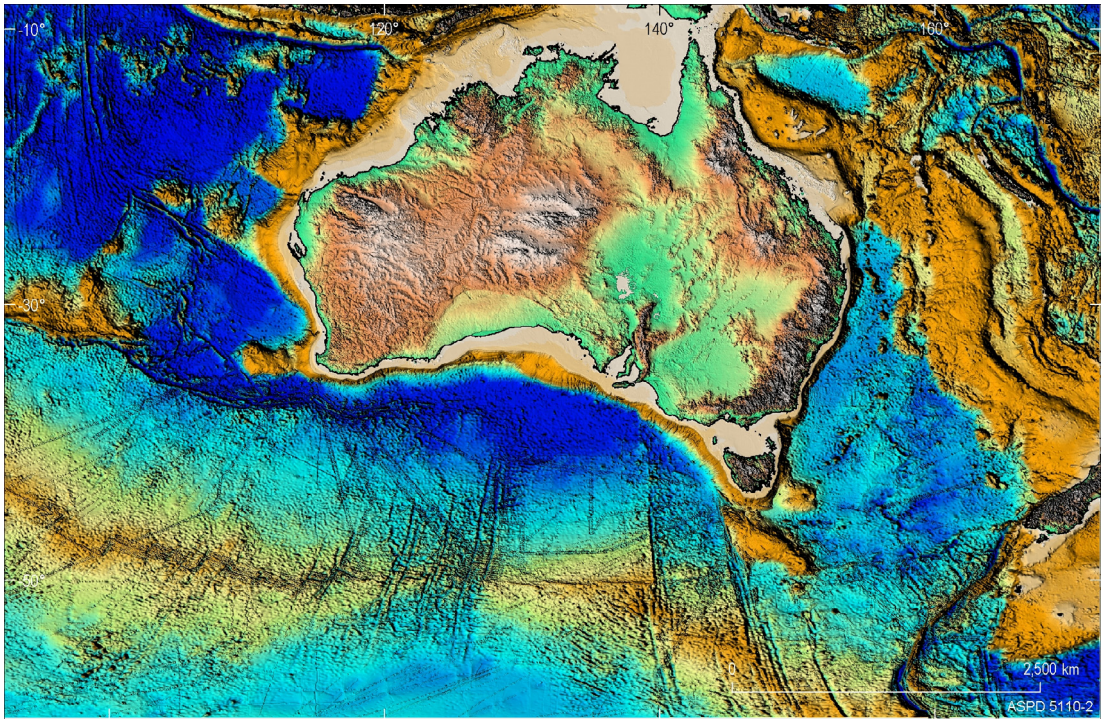

Figure 2 Final Grid Image

Earlier Work

Geoscience Australia's first comprehensive compilation of the Australian bathymetric dataset into a digital grid was completed by Buchanan (1998). This grid covers 9°S - 45°S, 108°E - 160°E, and is produced at a 30 arc second (approx. 1km) cell size.

The 2005 version of the bathymetry and topography grid is an update from the previous version by Petkovic and Buchanan (2002), for which documentation is included in the DVD that accompanies this report.

While much of the original data and the processes used to create the grid are similar to those used in the 2002 grid, the new grid described in this document is of higher resolution and contains more multi-beam data.

Principal Datasets

GA holds separately compiled database systems consisting of track line bathymetry values, multi-beam swath bathymetry and digitised charts which can be used for creating a bathymetric grid of Australia's margins.

In order to build the grid, data from these various systems were exported and centralised into a set of 120 Intrepid™ databases. Intrepid[1] is used widely in Geoscience Australia as a geophysical data processing tool.

The following describes the categories of data loaded into the Intrepid™ databases and from which the grid was computed.

SHIP-TRACK DATABASE

This included surveys from Australian and foreign institutions, surveys from the National Geophysical Data Centre (NGDC) in the USA, and oil exploration surveys obtained under the Petroleum Submerged Lands Act (Figure 3). Bathymetry data from 650 of the surveys were used for this grid.

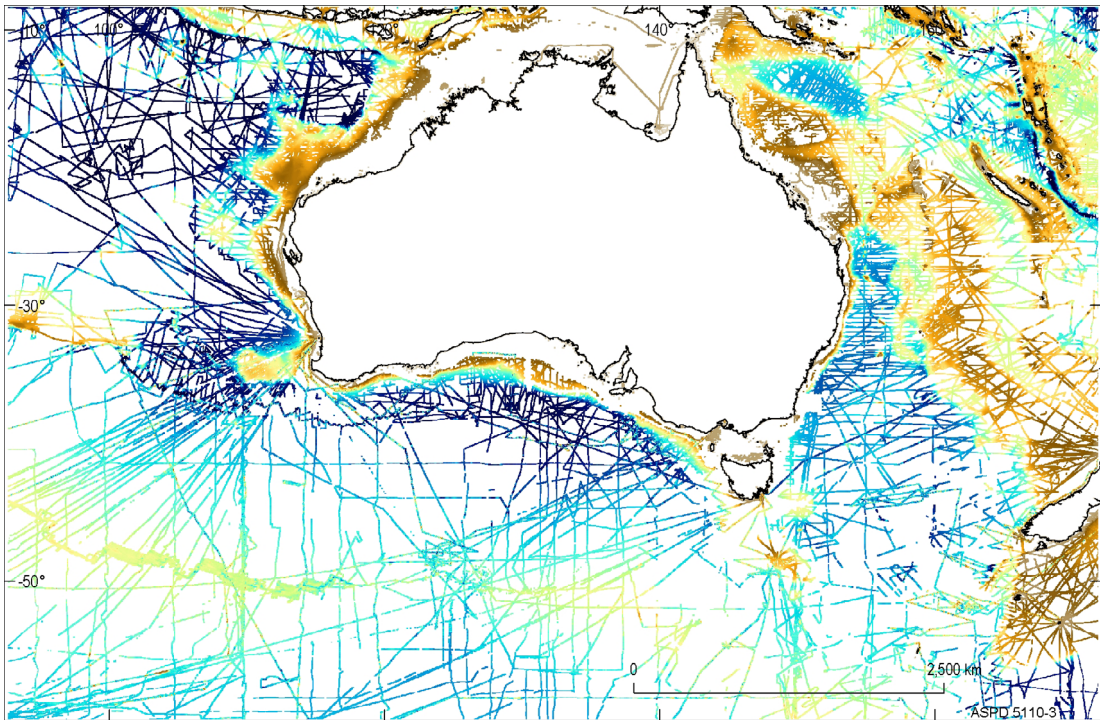

Figure 3 - GA ship-track database.

There are many uncertainties associated with the creation of gridded compilations of data from the wide range of vintages and sources of data used to produce this grid. In particular, the technology used to navigate vessels has improved dramatically in the last 40 years. In the early 1960s, before the advent of satellite navigation, the vessel's position may have been known to within 10km if it was operating offshore.

[1] Intrepid Geophysics website is: http://www.intrepid-geophysics.com/

Now, with the advent of GPS, and its associated technologies a vessels position can be determined to within less than 10m. Thus, the earliest of the surveys used in this compilation, collected in 1963 in the Bonaparte Gulf, would have been collected using visual survey techniques and could have uncertainties of position measured in kilometres. This is in contrast to the most recent survey, collected in the last year, using differential GPS which may have a positional uncertainty of 10m or less. Added to this, for many surveys little or no metadata exists regarding the survey techniques used or processing applied since. This has its most significant consequence in the reduction of the individual bathymetric values as the speed of sound in water used to process the data may not be recorded. Lack of velocity information may give rise to an uncertainty in the depth measured of a few percent of the water depth at that point. In cases where no water velocity is recorded a velocity of 1500m/s is assumed.

Because there is uncertainty in the position and absolute depth of bathymetry values used to produce the grid, artefacts are produced in the grid. These are caused by the depth measured on different surveys at the same position being different. This is called a mistie or crossover error. To reduce this problem, a process caused levelling is undertaken. A subset of the GA ship-track data holdings has been levelled to reduce these crossover errors. Levelled data are available within the polygon defined by the following longitude, latitude pairs: (106°, -8°), (106°, -46°), (140°, -46°), (140°, -52°), (156°, -52°), (156°, -39°), (172°, -39°), (172°, -25°), (160°, -25°). Data in areas outside of this region have not been levelled.

The levelling of ship-track data is described by Petkovic and Buchanan (2002). In brief, high resolution surveys and digitised charts are used as reference datasets. Other track-line data is then tied to these and adjusted with respect to each other to minimise the effect of misties. No additional levelling of ship-track data than that performed for the 2002 grid has been done for the production of the present grid.

MULTI-BEAM SWATH BATHYMETRY

GA holds data from multi-beam surveys acquired by government organisations (including GA), academic and foreign institutions. Appendix 1 lists the 106 swath surveys used for this grid. These data comprise a very important component of the bathymetry holdings because of the very high resolution coverage, speed of sound control, and modern navigation systems employed. The quality of the metadata supplied for these surveys is highly variable.

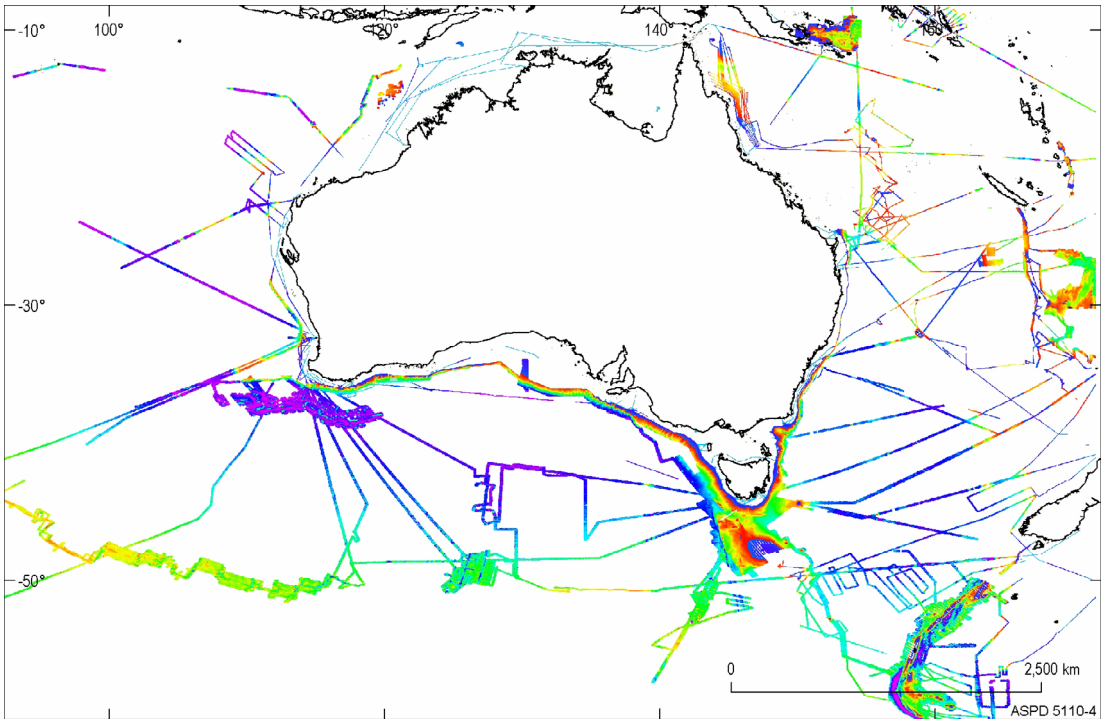

Figure 4 – Map showing swath surveys only.

DIGITAL BATHYMETRY FROM NATMAP 1:250,000 SERIES AND AHS FAIRSHEETS

In 1994, GA received a set of charts from the Australian Hydrographic Service, Royal Australian Navy (AHS), sourced from the NATMAP 1:250,000 bathymetric series. These charts included contours on the face of the map and soundings as spot depths on the back. The spot depths for a subset of the charts, mainly for the NW Shelf and Gulf of Carpentaria, were captured digitally by the AHS, and these data were provided to GA. The digitisation of the remainder of the charts was continued by GA and completed in 2001.

At the request of GA, the AHS provided an additional set of charts as scanned images for the shelf in selected regions. These 'fairsheets' displayed hand-written spot depths for surveys completed over various periods of time. To save costs the fairsheets were digitised selectively, leaving out near coastal data points, and, as a general rule, digitising lines to a minimum spacing of 2 nautical miles (~3.7 km). Some charts of high interest to clients were digitised in entirety. There are 1049 charts in the collection, refer to figure 5.

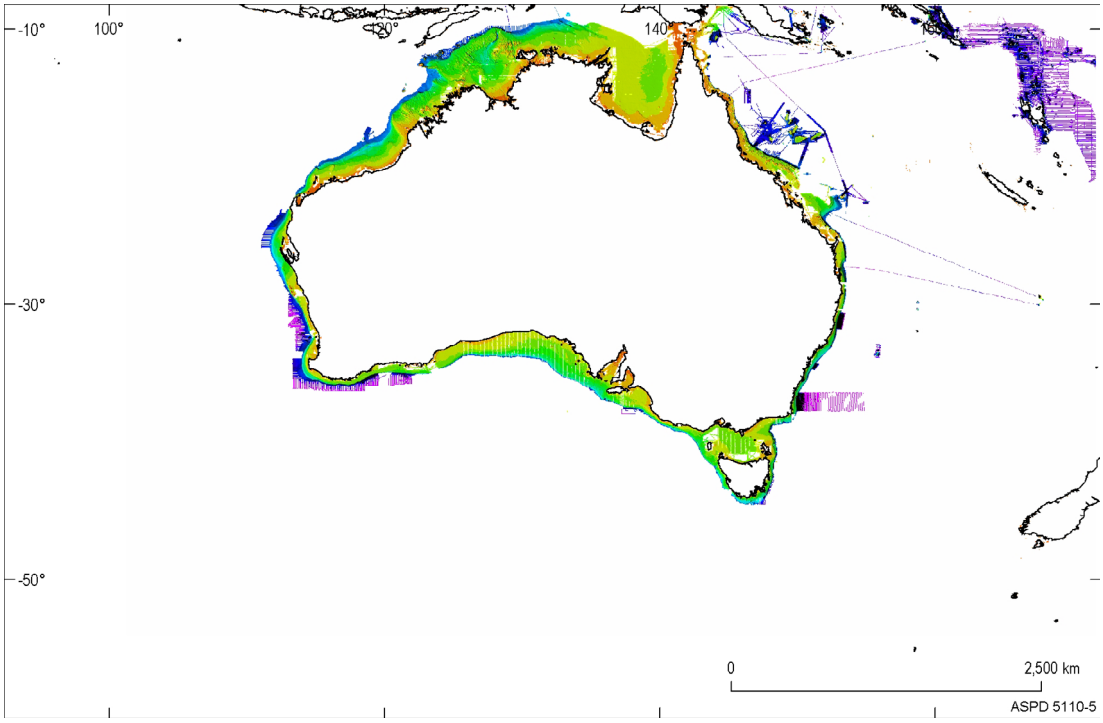

Figure 5 – Image of fair sheets only

LASER AIRBORNE DEPTH SOUNDER

The AHS has been operating its Laser Airborne Depth Sounder (LADS) systems since 1993. The system uses red and green laser light emitted from a stabilised platform inside a fixed wing aircraft. The light pulses reflected from the sea surface (red) and sea floor (green) are separately detected, and the time difference between the sea surface and sea floor returns allows calculation of the water depth.

Data are typically acquired at a rate of 900 soundings in a 240 m wide x 5 m long swath per second. The system works best in clean water of the pristine coral reefs of the Coral Sea down to 70m depth. Shallower maximum depths are achieved in other areas, such as Great Barrier Reef, Bass Strait, Timor Sea (40-50m), South Australia (30-35m), Torres Strait (15-25m), and anywhere waters are not clear.

AHS provided GA with LADS data recorded in Queensland waters for inclusion in the bathymetry grid (Figure 6). The coverage is very small on the regional scales of interest to GA; however the data form a very valuable subset of the bathymetric database.

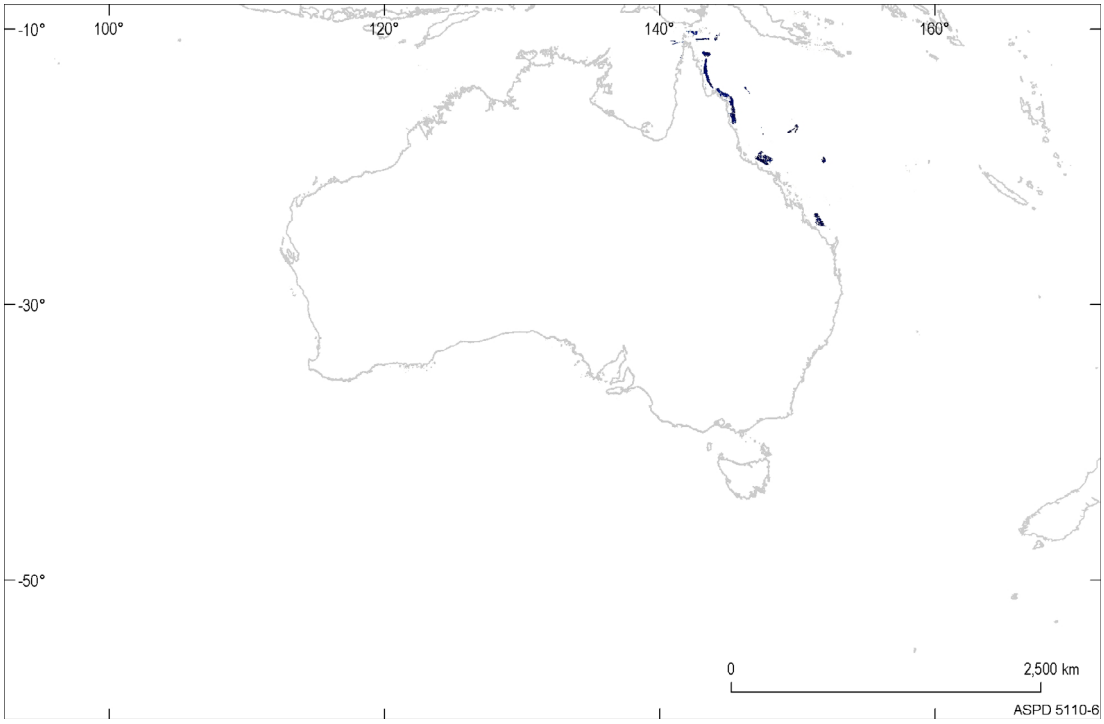

Figure 6 – Image of LADS data only

SATELLITE MEASUREMENTS

In deep-water areas where there are no ship-track depth measurements, the 2 arc minute ETOPO2 data based on predicted bathymetry from satellite altimetry (Smith and Sandwell, 1997) was used to give some regional continuity to the grid.

This predicted bathymetry (figure 7) was only included in areas where the high-resolution data (swath and digitised charts) were not available. The satellite data were excluded from areas shallower than 300m water depth, where the predicted depths are unreliable. The predicted depths were also excluded from all areas within 20 km of measured depths, whether ship-track or swath. In some areas, this exclusion process left thin 'slivers' of predicted depths which gave rise to misleading artefacts in the grid. These remnants were excluded from the grid where possible. The predicted bathymetry contributes the characteristic artefact of rippled noise which has a wavelength of about 25km and amplitude of about 200m in the deep water.

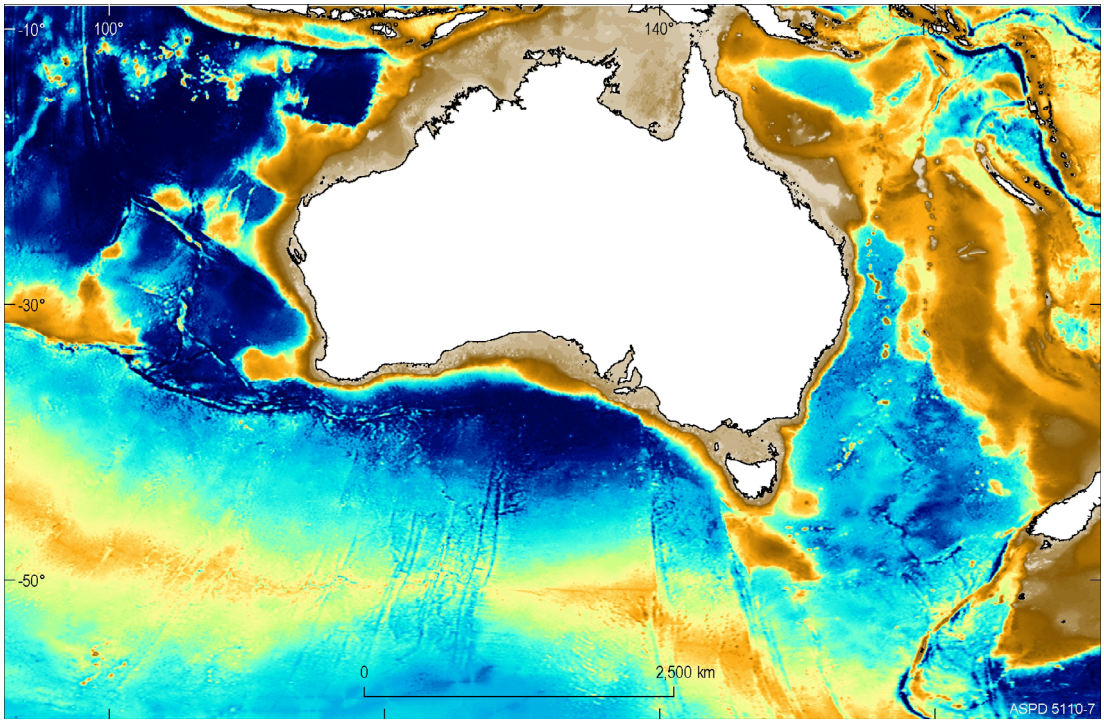

Figure 7 - Predicted bathymetry from satellite altimetry (Smith & Sandwell, 1997), version 8.2.

Other Datasets

TOPOGRAPHY

For continuity across the coastline, the database 'AusTopo' was utilised. It contains data from GA's 2nd edition DEM (formerly AUSLIG's 9" DEM, Carrol (1996)). For areas outside the Australian landmass, the dataset 'Gtopo30' was used (USGS, http://edcwww.cr.usgs.gov/landdaac/gtopo30/gtopo30.html).

OFFSHORE RESOURCE MAP SERIES CONTOURS

The Offshore Resource Map Series (ORMS, 1990-1997) are a set of contour maps for which digital contour strings are available. They were produced by machine contouring followed by manual modification according to an interpretation of the seafloor morphology. They have been included in the database in selected localised areas where it is judged that they give a reasonable form to canyons and other narrow structural features, and where ship-track data are not sufficient to produce an acceptable result using computer gridding alone.

GRID AND CONTOUR DATASETS

In some cases, where the original sounding data were not available, it was necessary to use portions of other grids or digital contour strings. To the north of Australia, contours from the Grim and Edgar (1998) map of the Gulf of Carpentaria and Arafura Sea were used. GEBCO (Jones et al, 1997) contours were used north of the Timor Trough to better define the morphology there. A grid from a SOEST swath survey in the Woodlark Basin is used due to the unavailability of the original

sounding data. Small portions of the grid by Buchanan (1998) were used in NW Australian coastal regions, where the original soundings used to make the grid have been lost.

POLYGON DATASETS

To define the zero iso-bath, a coastline polygon was used. A reef polygon file obtained from the Great Barrier Reef Marine Park Authority was also used with -2m as the depth value.

The Process

The process used to develop the grid is summarised in Table 1, which defines an eight step sequence to allow the grid to be updated by making corrections and additions at the level of the fundamental data.

Table 1 - Summary of process used to create the grid.

1	Collect, process and prepare data from various databases systems
2	Import data into Intrepid databases
3	Create a high resolution 'level 1' grid
4	Create a low resolution 'level 2' grid
5	Merge the two grids, placing level 1 grid as the top layer
6	Identify and delete cells containing spurious values
7	Smoothly fill the holes created by deleting spurious values
8	Final merge to create a 250m grid

Future revisions of the grid will omit step 7. This will be replaced by a process to identify the fundamental datasets contributing to spurious values, and will loop back to step 1.

STEP 1 - COLLECT, PROCESS AND PREPARE DATA

An audit of GA bathymetry data holdings identified 1.7 billion data points within 92˚ E – 172˚ E and 8˚ S – 60˚ S, belonging to current ship-track, swath and fair sheets data, and these formed the primary datasets upon which to base the grid. Internal QC processes on all surveys were completed to a standard suitable for the purpose of creating a grid at such high resolution.

STEP 2 - IMPORT DATA

Each survey and/or database was then exported into ASCII format and then imported into 120 Intrepid™ databases. Intrepid was chosen because it is widely used within GA as a geophysical processing tool, and the gridding tool allows considerable flexibility of parameter control, grid masking, and auxiliary operations such as stitching, merging and editing (Billings and Fitzgerald, 1998).

These 120 Intrepid™ databases, containing approximately 1.7 billion points, were the basis to the whole grid and comprised the largest number of points ever used to make a bathymetry grid within GA.

STEP 3 – CREATION OF A HIGH RESOLUTION GRID

The final grid is a merge of a high resolution grid (9 arc second cell size, level 1) overprinting a low resolution grid (108 arc second cell size, level 2). The level 1 grid is based only on the high resolution swath data and digitised charts, and was tightly clipped to minimise extrapolation. This level 1 grid covers the only areas where the 9 arc second resolution of the grid is supported by the underlying data (Figure 8).

Due to memory limitations on computers running the Intrepid software, the task of computing the level 1 grid was broken down into 16 sub-grids, each requiring 2-5 hours of computing time on a Pentium 4 computer. To reduce the computing time to an over-night process, a Condor[2] distributed computing system was employed for the task. Furthermore, because of the large number of data points that were held within the Intrepid databases, sub-processed were designed to limit the number of points read during each of the 16 gridding runs, such that surveys outside the area of interest were ignored.

A HTML interface to a CGI process was devised to manage the creation of the large number of Condor and Intrepid control files. This browser-based process reduces the task of preparing a complex set of instructions to create any number of grids to a few entries on a single form.

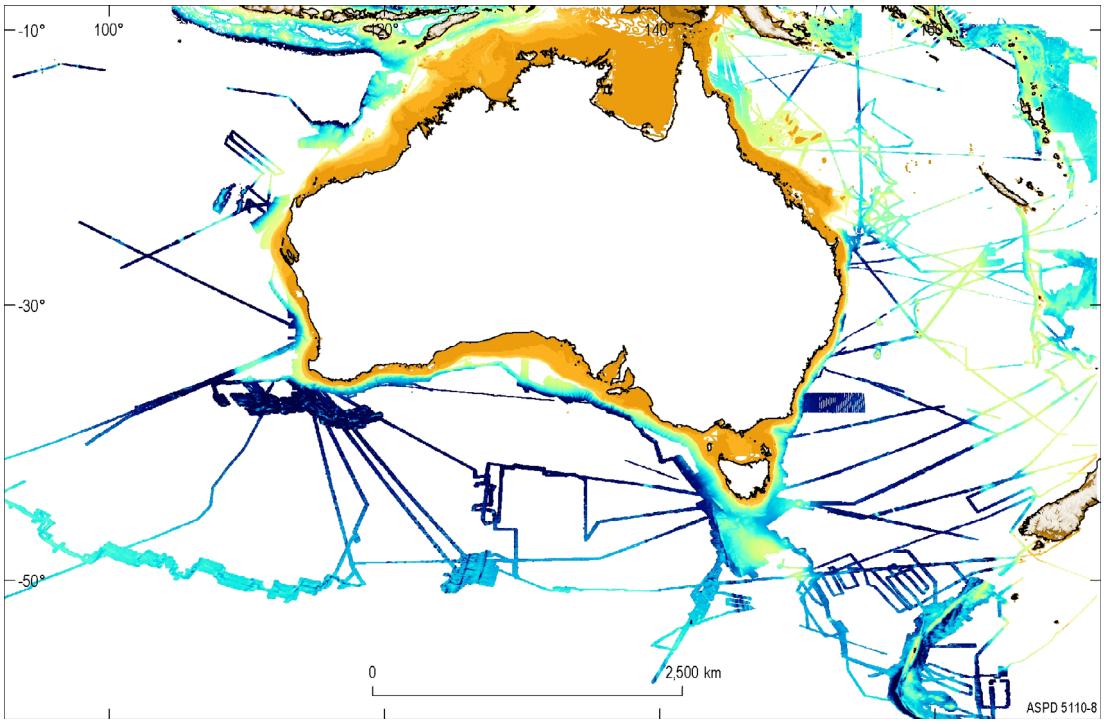

Figure 8 – High resolution data. Level 1 grid.

STEP 4 – CREATION OF A LOW RESOLUTION GRID

A coarser resolution grid at 108 arc second cell size (~3 km) was then created, to fill gaps in the level 1 grid. This 'level 2' grid was created using all datasets, including the high-resolution datasets used for the level 1 grid. The cell size was chosen to be comparable to that of the satellite predicted bathymetry.

In order to avoid interference between the satellite-predicted bathymetry and data sourced from actual water depth measurements, the satellite-derived points were removed if they were within 20 km of an actual sounding. Furthermore, they were excluded for depths shallower than 300 m. This was achieved by gridding the

[2] http://www.cs.wisc.edu/condor/

soundings data with extrapolation to 20 km, and then using this grid to mask out the satellite-derived points. Therefore, the satellite-predicted bathymetry is only represented in those areas where substantial holes occur in the coverage by soundings. These areas are common in deep water and are easily recognised by the characteristic bumpy effect which is a noise artefact.

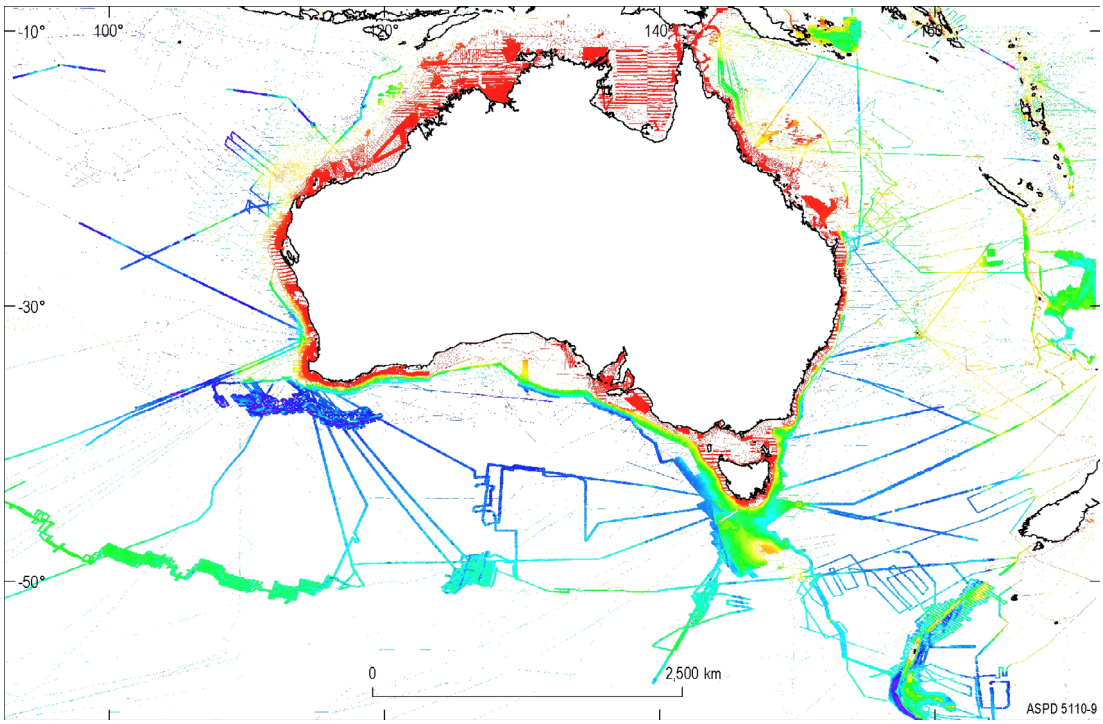

Figure 9 – Data Density Image

STEP 5 – MERGING OF THE TWO GRIDS

The high-resolution level 1 grid was then superimposed over the lower resolution level 2 grid (figure 10b). The resulting grid is therefore a level 1 grid in which holes are filled by the level 2 grid. The edges are feathered so transition effects are minimal. This formed the 9" 'base' grid for the next phase (figure 10c).

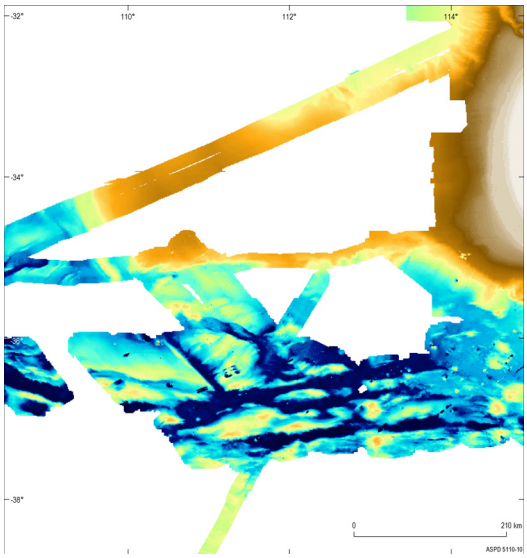

Figure 10a – High resolution grid

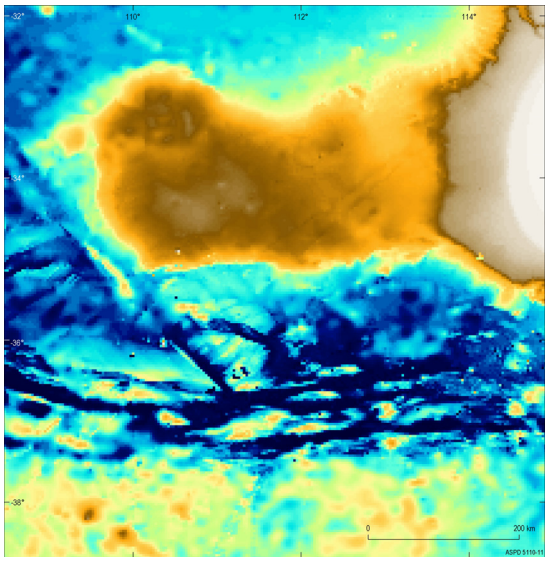

Figure 10b – Low Resolution grid

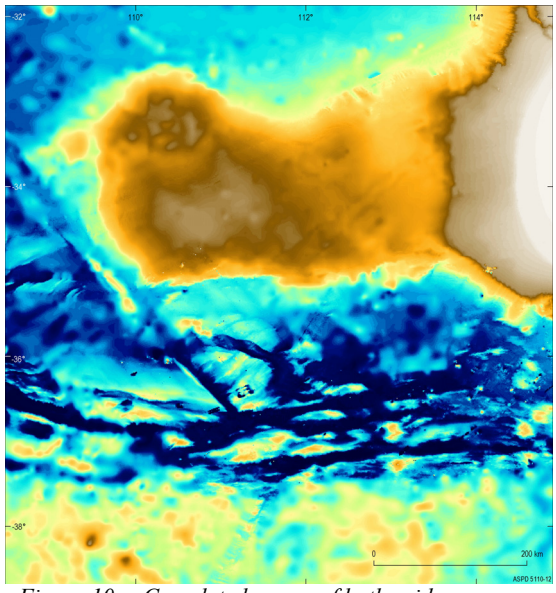

Figure 10c –Completed merge of both grids

STEP 6 - IDENTIFY AND DELETE SPURIOUS VALUES.

The merged 'base' grid was visually inspected and 39 areas were identified where obvious artefacts existed (Figure 11).

To check or remove these artefacts, the future strategy will be to return to Step 1, apply corrections to the fundamental databases if required, and re-generate the grid using the tile-and-merge approach described in step 3 onwards. By such an iterative approach the grid will always be a true representation of data at the fundamental level. In addition, the grid can be reproduced from the data according to an openly defined process, and grids of any resolution can be generated for any area.

Due to time constraints a decision was made not to apply a second iteration as described in the above paragraph. Instead, the following process was applied directly to the grid, and in such a way that it could be reproduced if necessary.

Within the 38 problem areas a total of 92 polygons were manually digitised while inspecting the grid on screen, to define the boundaries of the suspected anomalies more precisely. To quantify the amplitude of the anomaly within each polygon, we computed the difference between the merged base grid and that of the grid by Petkovic and Buchanan (2002). Then, cells in the merged base grid were deleted if the computed difference exceeded an arbitrary threshold of 100m. Values in cells of the merged base grid were deleted if and only if they fell within the polygon boundaries previously identified by visual inspection (figure 12c). The threshold was chosen at 100m to give what could be judged a reasonable result, and not introduce excessive new artefacts.

After deleting cells affected by the 100m difference threshold, there remained suspected artefacts which were not treated to any correction process, as they were deemed of secondary significance.

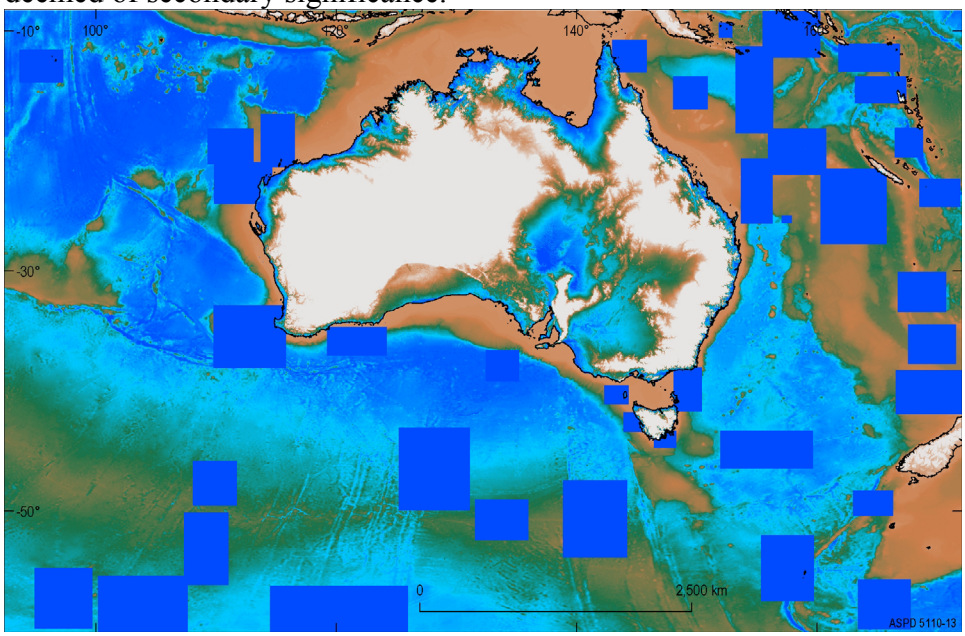

Figure 11 – Image showing identified areas that had major errors within the grid.

STEP 7 - SMOOTH FILL THE SPURIOUS VALUES

The holes left in the merged base grid after step 6 were filled by minimum curvature regridding process through ERmapper™ which left extant surrounding cells intact. Again, because of the limitations in ERmapper™ to handle the regridding of large grids, the task required segmenting the grid (figure 12d).

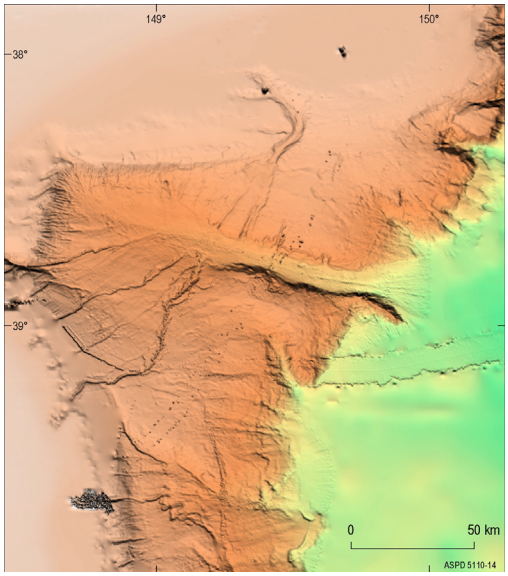

Figure 12a – Identified Errors

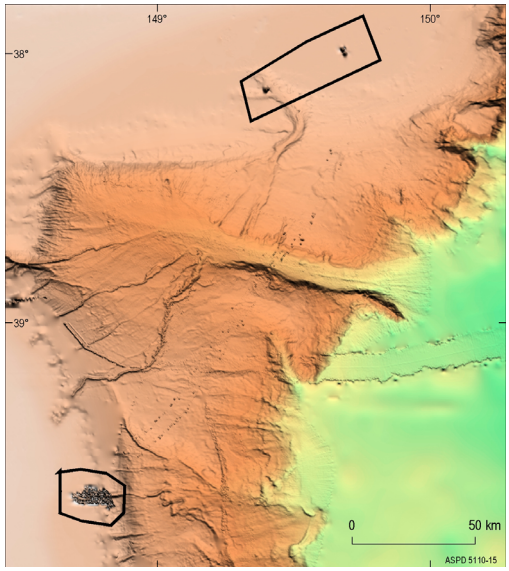

Figure 12b – Digitised Regions

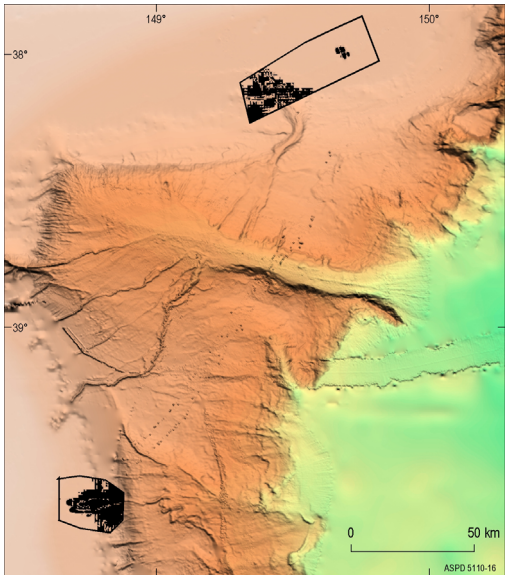

Figure 12c – Errors replaced with NULLS

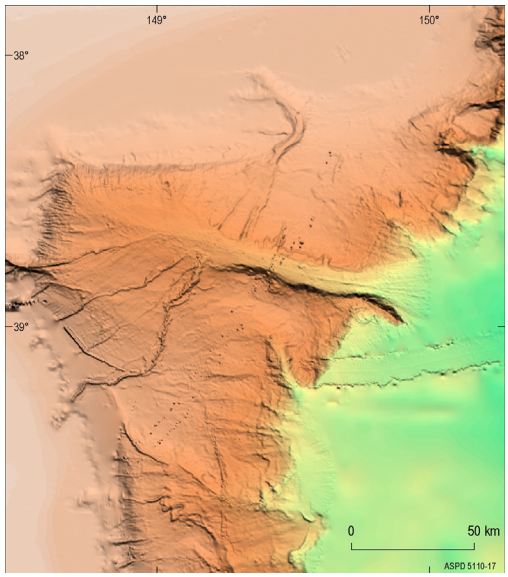

Figure 12d – Error regions removed

In five specific cases the differencing of the two grids identified errors within the 2002 grid. In these cases the satellite-predicted bathymetry grid was used for comparison (again at 100m) instead of the 2002 grid. These cells were set to null then filled over using the minimum curvature process as described above.

In another five cases, the 100m threshold was too large to identify errors in the merged grid. For these regions a threshold difference of 10m allowed successful removal of anomalies from the grid.

STEP 8 – FINAL MERGE

The modifications were applied to the component sub-grids, and were then written back into the final grid.

Following this, the 9” digital elevation model was written onto the final grid, so that the topography as it appears in the final grid is not subject to our re-gridding process (figure 13).

This final 9” grid was then used to produce the final formats needed for most GIS and gridding applications: ERmapper, BIL, ESRI grid and ASCII XYZ.

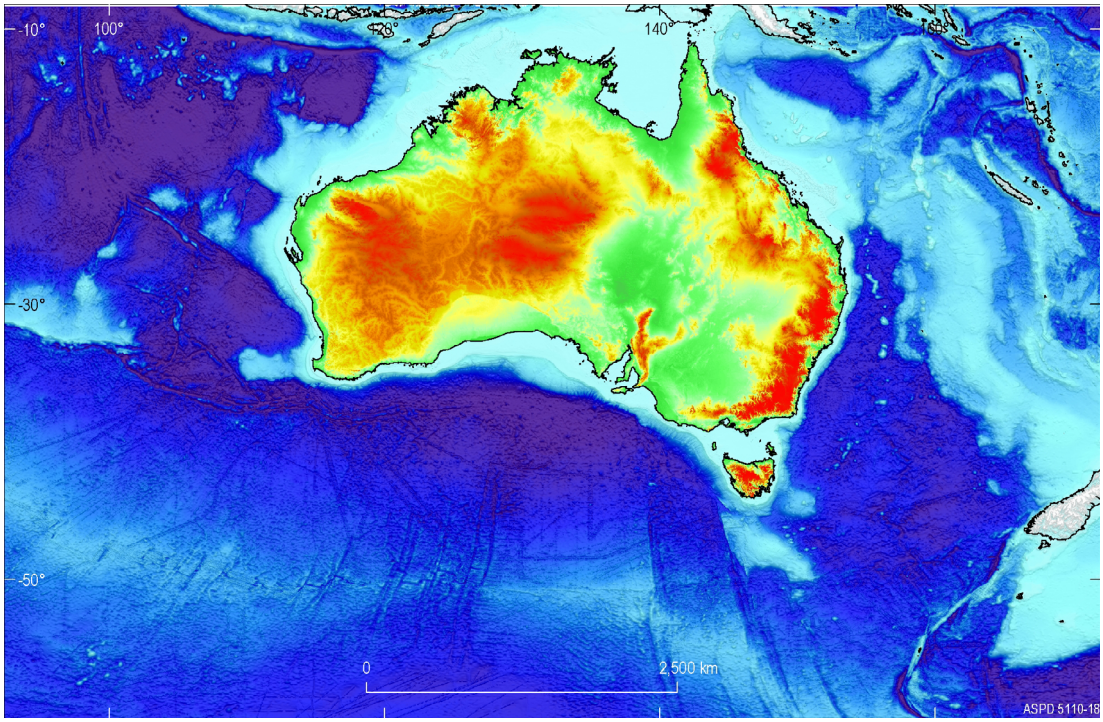

Figure 13 – Final grid image

Gridding

The grid was computed using Intrepid software, which requires data to be present in an Intrepid database or set of databases. Intrepid was chosen because of its ease of use with large datasets, its combination of GUI and batch operation, fine control over parameter setting, large user base within the organisation, associated grid manipulation utilities, and mature version history. To create the present grid Intrepid was used in batch mode accessing several databases sequentially. These same databases can be updated as the need requires, and grids of any specification can be created from them.

Intrepid was originally designed to deal with potential field data, and uses the minimum curvature algorithm which is not well suited to topography. Other software such as that of Hutchinson (1989) deals effectively with stream-lines and roughness, for example, but doesn't allow masking, which is essential to the present task.

In order to simulate the roughness of topographic character in Intrepid, the minimum curvature tension parameter was set to mid-way between pure minimum curvature and pure minimum potential. This avoids some of the over-shoot that results from minimum curvature surface fitting in areas of poor control, while at the same time doesn't produce severe cusps at data points. Inspection of test grids indicates that this compromise setting gives sufficiently smooth results yet retains some of the characteristic roughness of topographic data.

Billings and Fitzgerald (1998) discuss some of Intrepid's gridding options and its limitations. The main gridding parameters are given in the table below.

Table 4 - Gridding parameter settings for Intrepid, where grid 1 refers to the 'level 1' grid of high-resolution data and grid 2 refers to the low-resolution 'level 2' grid. The two grids were joined together with preference given to grid 1 values where they existed.

Parameter	Value
Latitude range	8° S – 60° S
Longitude range	92° E – 172° E
Cell size – grid 1	0.0025° (9")
Cell size – grid 2	0.03° (108")
Minimum curvature tension	0.5
Maximum iterations	100
Maximum residual	1.0 m
Extrapolation for grid 1	5 cells (~1.25 km)
Setting no-data areas to null – grid 1	Yes
Setting no-data areas to null – grid 2	No
Additional Smoothing	No
Initial cell assignment	nearest neighbour
Output precision	Signed 16 Bit Integer

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Appendix 1 – Multibeam Surveys

Vessel	Year	Institution	Area
Unknown	Various	BHP	NW Shelf & Otwaty Basin
HMAS Cook	1986	AHS-RAN	Townsville Trough
HMAS Cook	1986	AHS-RAN	Offshore Syney
HMAS Cook	1986	AHS-RAN	Kangaroo Island, Great Australian Bight
HMAS Cook	1986	AHS-RAN	Albany
HMAS Cook	1986	AHS-RAN	SW Western Australia, Perth Canyon
R/V Ewing	2001	LDEO	Exmouth Plateau
R/V Ewing	1992	LDEO	Tasman Sea
R/V Ewing	1992	LDEO	Woodlark Basin
R/V Ewing	1995	LDEO	Southern Ocean/Macquarie Island
R/V Ewing	2001	LDEO	Southern Ocean/Australian-Antactic Ridge
R/V Ewing	2002	LDEO	Transit: Hobart-Guam
R/V Ewing	1995	LDEO	Solomon Islands, Fiji
R/V Ewing	1995	LDEO	Fiji - New Zealand
R/V Ewing	1999	LDEO	Woodlark Basin, Coral Sea
R/V Ewing	1999	LDEO	Northern Australia
R/V Ewing	1999	LDEO	Townsville - Fiji - Christchurch
R/V Ewing	2000	LDEO	Fiji - New Zealand
R/V Ewing	1999	LDEO	Woodlark Basin - Guam
R/V Ewing	2001	LDEO	Indian Ocean - Fremantle
R/V Franklin	2002	GA/CSIRO	Torres Strait
HMAS Melville	2001	AHS-RAN	Vic/NSW Border (Bass Strait)
HMAS Melville	2001	AHS-RAN	Transit: Sydney - Woolongong
R/V James Kirby	2004	GA	Torres Strait
R/V James Kirby	2004	GA	Torres Strait
R/V Knorr	1994	WHOI	Perth Canyon
R/V Knorr	1995	WHOI	Wombat Plateau
N/O L'Atalante	1993	IFREMER	Norfolk Ridge
N/O L'Atalante	1994	GA/IFREMER	South Tasman Rise
N/O L'Atalante	1994	GA/IFREMER	South/West/Northwest Margin
N/O L'Atalante	1999	GA/IFREMER	Fairway Basin
N/O L'Atalante	1999	GA/IFREMER	Norfolk Ridge
N/O L'Atalante	2000	GA/IFREMER	Lord Howe Island , Southeast Margin
N/O L'Atalante	2000	GA/IFREMER	South Tasman Rise, Macquarie Ridge
N/O L'Atalante	2000	IFREMER	Norfolk Ridge/Three Kings Ridge
HMAS Leeuwin	2002	AHS-RAN	Ashmore Reef
N/O Marion Dufresne	1998	GA/IPEV	Diamantina Fracture Zone
N/O Marion Dufresne	2003	GA/IPEV	Southern Margin/ South Tasman Rise
N/O Marion Dufresne	2003	GA/IPEV	Southern Margin/ South Tasman Rise
N/O Marion Dufresne	2003	IPEV	Southern Ocean/Antarctica
R/V Melville	1997	GA/SIO	Bass Canyon/Eastern Tasmania - Hobart
R/V Melville	2003	GA/SIO	Cairns - Gulf of Papua - Port Moresby
R/V Melville	1994	SIO	Tasman Sea - Lord Howe Rise
R/V Melville	1994	SIO	Pacific Ocean: Tonga -Brisbane
R/V Melville	1995	SIO	Christchurch - Australian Antarctic Ridge - Fremantle

R/V Melville	1996	SIO	Fremantle -Southeast Indian Ridge - Port Hedland
R/V Melville	1994	SIO	Fremantle - Southeast Indian Ridge - Fremanle
R/V Melville	1996	SIO	Transit: Dunedin - Hobart
R/V Melville	1996	SIO	Hobart - Australian Antarctic Ridge - Fremantle
R/V Melville	1997	SIO	Hobart - Southern Ocean - Fremantle
R/V Melville	1997	SIO	Transit: Bass Strait - North of New Zealand
R/V Melville	1995	SIO	Australian Antarctic Ridge
R/V Melville	1995	SIO	Tasman Sea: Hobart - North of New Zealand
R/V Melville	1996	SIO	Port Hedland - Northern Australia - Fiji
R/V Melville	1995	SIO	Fremantle - Australian Antarctic Ridge - Hobart
R/V Melville	1997	SIO	Indian Ocean - Fremantle
R/V Melville	1997	SIO	Hobart - Southern Ocean - Hobart
R/V Melville	2003	SIO	Indian Ocean -Port Hedland
R/V Melville	2003	SIO	NW Shelf - Darwin
R/V Melville	2003	SIO	Northern Australia
R/V Melville	2003	SIO	Fly River Delta
R/V Melville	2004	SIO	Cairns - Fly River Delta - Port Moresby
R/V Melville	2004	SIO	Fly River Delta
R/V Melville	2004	SIO	Port Moresby - Fly River Delta - Cairns
R/V Melville	2004	SIO	Cairns - Gulf of Papua - Port Moresby
R/V Melville	2004	SIO	Port Moresby - Gulf of Papua - Cairns
R/V Melville	2004	SIO	Cairns - Fly River Delta - Port Moresby
R/V Melville	2004	SIO	Fly River Delta
R/V Melville	2004	SIO	Port Moresby - Fly River Delta - Cairns
R/V Melville	2004	SIO	Transit: Cairns - Yokohama
R/V Melville	2003	SIO	Fly River Delta
R/V Melville	2004	SIO	Fly River Delta
R/V Melville	2004	SIO	Fly River Delta
R/V Melville	2004	SIO	Gulf of Papua
R/V Melville	2004	SIO	Fly River Delta
R/V Mirai	2004	JAMSTEC	Southern Indian Ocean
R/V Moanna Wave	1992	UCSC/HMRG	Solomon Sea
R/V Moanna Wave	1993	HMRG	Woodlark Basin
R/V Nathaniel B Palmer	1997	RPSC/NSF	South of New Zealand
R/V Nathaniel B Palmer	1998	RPSC/NSF	McMurdo Sound
R/V Nathaniel B Palmer	1996	RPSC/NSF	Transit: Hobart -New Zealand
R/V Nathaniel B Palmer	2000	RPSC/NSF	Hobart - Antarctic Margin
R/V Nathaniel B Palmer	2002	RPSC/NSF	East Macquarie Island
R/V Nathaniel B Palmer	2001	RPSC/NSF	Antarctic Margin
R/V Parmelia K	2004	GA	Yampi Shelf
R/V Rig Seismic	1994	UTIG/HMRG	Macquarie Ridge
R/V Roger Revelle	1998	SIO	Norfolk Ridge
FS Sonne	1998	GA/GEOMAR	Southern Ocean/NZ - Macquarie Island/Tasmania
FS Sonne	2002	GEOMAR	Tasman Sea
FR/V Southern Surveyor	2004	GA/CSIRO	Gulf of Carpentaria

FR/V Southern Surveyor	2004	GA/CSIRO	Bremer Basin
FR/V Southern Surveyor	2004	GA/CSIRO	Kenn Plateau
FR/V Southern Surveyor	2005	GA/CSIRO	Mellish Rise
FR/V Southern Surveyor	2005	GA/CSIRO	Gulf of Carpentaria
FR/V Southern Surveyor	2005	GA/CSIRO	Gulf of Carpentaria
FR/V Southern Surveyor	2005	Uni Newcastle/ CSIRO	North of Fraser Island
FR/V Southern Surveyor	2003	CSIRO	Perth Canyon
FR/V Southern Surveyor	2004	CSIRO	West Tasmania - King Island - Sydney
FR/V Southern Surveyor	2004	CSIRO	Transit: Sydney - Hobart
FR/V Southern Surveyor	2004	ANU/CSIRO	New Hebrides
FR/V Southern Surveyor	2004	CSIRO	Southwest margin Tasmania
FR/V Southern Surveyor	2004	ANU/CSIRO	Tonga
FR/V Southern Surveyor	2004	ANU/CSIRO	Tonga
FR/V Southern Surveyor	2004	CSIRO	Moreton Bay/North Stradbroke Island
FR/V Southern Surveyor	2004	CSIRO	Tasman Sea/ Britannia Seamount
R/V Tangaroa	2003	NOO/CSIRO/MFISH/NIWA	Tasman Sea

Appendix 2 - Contributing Organisations

The following organisations conducted surveys in the region covered by this compilation and contributed bathymetric data, or were a source of bathymetric data from their own databases.

Abbreviation	Name
AHS	Australian Hydrographic Service, Royal Australian Navy
AMPOL	Ampol Exploration Ltd
AMPOLEX	Ampolex Ltd
AQUITAINE	Elf-Aquitaine
ARCO	Atlantic Richfield Company
ASA	Antarctic Support Associates
AUSLIG	Australian Surveying and Land Information Group
BGR	Bundesanstalt fur Geowissenschaften und Rohstoffe
BHP	BHP Billiton
BODC	British Oceanographic Data Centre
BP	British Petroleum
BRS	Bureau of Resource Sciences (Australia)
CANYON	Canyon Oil
CARNARVON	Carnarvon Petroleum Pty Ltd
CHEVRON	Chevron Corporation
CNW	Canada Northwest Oil (Australia) Pty. Ltd.
CONOCO	Conoco Inc.
CRES	Centre for Resource and Environmental Studies
CSIRO	Commonwealth Scientific & Industrial Research Organisation
CULTUS	Cultus Petroleum NL
DSIR	Dept. Science, Industry and Resources (NZ)
ENTERPRISE	Enterprise Oil Exploration Pty. Ltd.
ESSO	Esso Australia Ltd
FLINDERS U	Flinders University
GA	Geoscience Australia
GBRMPA	Great Barrier Reef Marine Park Authority (Australia)
GETTY OIL	Getty Oil
GLOBEX	Globex Resources Ltd
GSI	Geophysical Services International
GULF	Gulf Oil
HADSON	Hadson Oil
HGSI	Haliburton Geophysical Services International
HUDBAY	Hudbay Oil & Gas
IFREMER	Institut Francais de Recherche pour l'Exploitation de la Mer
IFRTP	French Institute for Polar Research and Technology
IPR	Institute for Polar Research (Japan)
JNOC	Japan National Oil Corporation
JODC	Japan Oceanographic Data Centre
KUFPEC	Kuwait Foreign Petroleum Exploration Company
LASMO	LASMO Plc
LDGO	Lamont Doherty Geophysical Observatory
MARATHON	Marathon Oil
MESA	Minerals & Energy South Australia
MIMPEX	Mimpex Ltd
MINORA	Minora Resources NL

MOBIL	Mobil Corporation
NATMAP	Division of National Mapping (Australia)
NERC	National Environmental Research Council (UK)
NGDC	National Geophysical Data Centre (USA)
NORCEN	Norcen Energy Resources Ltd.
OCCIDENTAL	Canadian Occidental Petroleum Ltd
ODP	Ocean Drilling Program
OOVM	l'Observatoire Oceanologique de Villefranche-sur-Mer
ORSTOM	Institut de Recherche pour le Developpement
OUTBACK	Outback Oil N.L.
PETROFINA	Petrofina Exploration
PGS/NOPEC	Nopec International
PHILLIPS	Phillips Oil Company Australia
PIRSA	Primary Industries and Resources South Australia
RSRIG	All-Russian Scientific and Research Institute for Geophysics
SADME	South Australia Department of Mines & Energy
SAGASCO	Sagasco Resources Ltd
SEAFIELD	Seafield Resources Plc.
SHELL	Shell Development (Australia) Pty. Ltd.
SIO	Scripps Institution of Oceanography, U California
SOEST	School of Ocean and Earth Science & Technology
STIRLING	Stirling Petroleum
STRATA	Strata Oil
TAMU	Texas A & M University
TARGET	Target Oil
UADELAIDE	University of Adelaide
UKIOS	Institute of Oceanographic Sciences, UK
ULTRAMAR	Ultramar Australia Inc.
USGS	United States Geological Survey
USNAVY	US Navy
UTOKYO	University of Tokyo
WAINOCO	Wainoco International
WAPET	West Australian Petroleum Pty. Ltd.
WESTERN	Western Geophysical
WHOI	Woods Hole Oceanographic Institution
WMC	Western Mining Corporation
WOODSIDE	Woodside Offshore Petroleum Pty. Ltd.