CRC for Coastal Zone Estuary and Waterway Management

In cooperation with

Centre for Marine Science and Technology
Curtin University of Technology

FIELD REPORT:
Toolkit Version

MULTIBEAM AND SINGLE BEAM BACKSCATTER DATA ANALYSIS, AND VIDEO IMAGERY FROM MORETON BAY AND KEPPEL BAY

MILESTONE CA6.01

By:

Paulus J.W. Siwabessy

Centre for Marine Science and Technology (CMST), Curtin University, GPO Box U 1987
Perth 6845, WA

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Introduction

As part of the Coastal Water Habitat Mapping Project of the Coastal CRC, surveys using various sensors were conducted in Moreton Bay, Brisbane between 29 August and 5 September 2004 and in Keppel Bay, Rockhampton between 19 and 26 September 2004. This report provides a brief overview of the objectives of the surveys, the work undertaken and field data that were collected. Moreton Bay spans a section of the eastern coast of Queensland, between longitude 153°05'E and 153°30'E, around latitude 27°20'S and Keppel Bay spans a section of the north-eastern coast of Queensland, between longitude 150°45'E and 151°20'E, around latitude 23°20'S. The study area in Keppel Bay is situated in the Capricorn section of the Great Barrier Reef Marine Park, in the vicinity of the town of Rockhampton.

Fieldwork was undertaken by CWHM project personnel from Curtin University of Technology (Curtin), the Defence Science and Technology Organisation (DSTO), and Geoscience Australia (GA). The survey work was undertaken on *FVR Tom Marshal* and on *MV Rum Rambler*. CASI coverage in Moreton Bay was provided by CSIRO and the University of Queensland.

The field equipment used in the survey included Reson 8125 multibeam, SIMRAD EQ60 single beam and Klein 5500 sidescan sonar systems, and underwater video system (described below).

Personnel

One personnel from Geoscience Australia, five from Curtin University, 2 from Defence Science and Technology Organisation were involved at various stages of the work, together with 4 boat crew members.

Itinerary

<u>Moreton Bay, Brisbane</u>

26 Aug	MP, YT departed from Perth, arrived and met with IP, BT in Brisbane, and checked in and stayed at Foreshore Cottages.
27 Aug	Visit Stuart Phinn at UQ and visit DPI to look at the vessel *FRV Tom Marshall*.
28 Aug	Mobilise all field gear aboard *FRV Tom Marshall*.
29 Aug-5 Sep	MP, IP, YT, BT ran the survey in Moreton Bay.
31 Aug	YT departed from Brisbane to Perth.
5-6 Sep	Demobilise all field gear, freight RESON 8125 system to Perth, drop off other field gear and store at DPI depot.
7 Sep	MP departed from Brisbane to Perth.

<u>Keppel Bay, Rockhampton</u>

16 Sep	JS departed from Perth to Rockhampton.
17 Sep	JS, TW (from Sydney) arrived in Rockhampton, MP, IP, LH drove to Rockhampton and arrived in the evening, checked in and stayed 2 nights at Cambridge Motel in Rockhampton.
18 Sep	Mobilise all field gear aboard the vessel *MV Rum Rambler*.
19-26 Sep	MP, IP, JS, LS, TW, DR ran the survey.
27 Sep	Demobilise all field gear off the vessel *MV Rum Rambler*, consign freight to Sydney, drive to Brisbane, check in and stay overnight at Pegasus Motor Inn, Brisbane.
28 Sep	MP, IP, JS, LS departed from Brisbane to Sydney.

Vessel

Figure 1 shows boats used in the survey. Data collection in Moreton Bay took place on *FVR Tom Marshall* owned Department of Primary and in Keppel Bay from aboard *MV Rum Rambler*, a commercial vessel owned and operated by Kirrod 'Slim' Broadhurst.

FVR Tom Marshall

MV Rum Rambler

Figure 1. Photographs of vessel used in Moreton Bay and Keppel Bay.

Trip Objectives

Moreton Bay, Brisbane

Overall:

1. To demonstrate the scale of operation of different tools to assess the coastal tropical seabed.
2. To obtain an integrated data set of CASI, multibeam, drop-down video and other sensors, platforms and ground-truth information.
3. To incorporate links with other CRC research projects.

Swath-specific:

1. To record as much swath over as many different habitats as possible. In particular, to:
    a. To get full coverage of benthos beneath the optical depth of the sensors used in airborne and satellite hyperspectral surveys.
    b. To differentiate between seagrass and other sedimentary habitats. To trial hydroacoustics to identify Lyngbya blooms on the benthos
    c. To get coverage of hard coral cover
2. To get some good swath for PR

Keppel Bay, Rockhampton

Overall:

1. To showcase CWHM techniques and interpretation, noting the importance of costs and outputs.
2. To maximise the range of sensor types and modalities used, and to facilitate intercomparison and correlation of their outputs within cost and logistics constraints.
3. To seek an opportunity to operate in a normally turbid estuarine environment. Specifically, for the Fitzroy Estuary; to give attention to effects of sediment dynamics.

Methods

Gear

Table 1 lists all field gear deployed in the survey. Not all field gear was deployed in each survey. Table 1 also indicates what and where the particular gear was in operation.

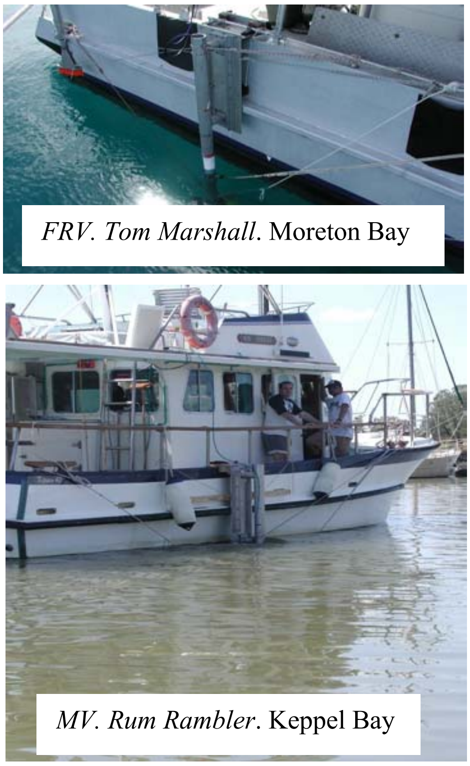
Table 1. List of all equipment used in Moreton Bay and Keppel Bay.

Equipment	Survey Area	
	Moreton Bay	Keppel Bay
RESON 8125 multibeam sonar	√	√
SIMRAD EQ60 single beam sonar	√	
Klein 5500 sidescan sonar		√
FUGRO Starfix DGPS	√	√
UWA underwater video camera	√	√
CTD	√	√
Secchi disk		√
Hydro Bios Grab		√
CASI	√	

Mounting

<u>Sonar heads</u>

<u>Moreton Bay, Brisbane</u>. The RESON 8125 side mounted pole was used to mount the head of the RESON 8125 multibeam sonar. Heads of the RESON 8125 multibeam sonar and the SIMRAD EQ60 single beam sonar were installed in the starboard of *FVR Tom Marshall*. The head of the single beam sonar was located some distance behind the head of the mutlibeam sonar (see Figure 2).



FRV. Tom Marshall. Moreton Bay

MV. Rum Rambler. Keppel Bay

Figure 2. Photographs showing the sonar head side-mounted on the boat used in the survey.

<u>Keppel Bay, Rockhampton</u>. Like in Moreton Bay, Brisbane, the RESON 8125 side mounted pole was deployed. Together with the RESON 8125 side mounted pole, the head was placed in the starboard of *MV Rum Rambler* (see Figure 2).

<u>DMS05 motion sensor and Meridian Surveyor gyrocompass</u>

The DMS05 motion sensor was installed in vicinity of the centre of gravity of the vessel and the Meridian Surveyor gyrocompass parallel to the centre line of the vessel.

Prior to the survey in all areas, the motion sensor was calibrated using the software provided while the vessel was anchored at the jetty.

<u>FUGRO Starfix GPS</u>

The GPS antenna was fitted in a selected location with a full 360 field of view at the roof of the wheelhouse.

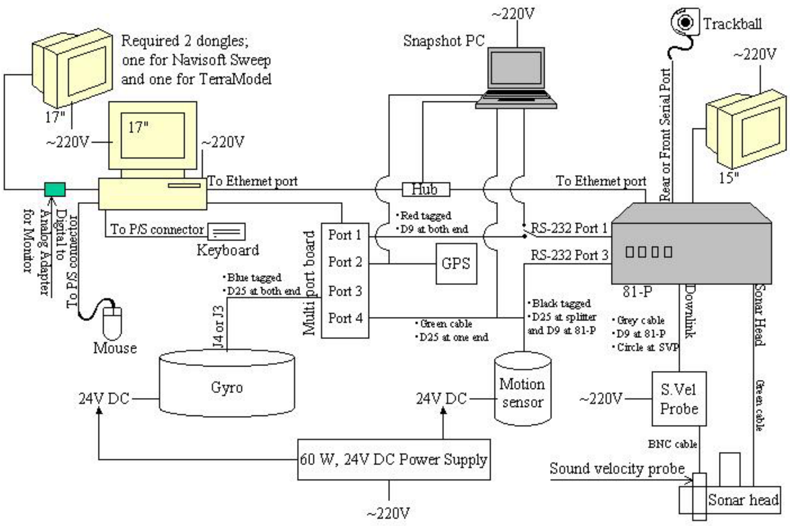


Figure 3. Schematic diagram of the multibeam system for normal and snapshot operations.

RESON 8125 multibeam sonar

The connection for the multibeam system is shown in Figure 3. The normal multibeam mode was partly operated when the snapshot mode was in operation. In this case, the normal multibeam mode was used only for navigation purposes.

<u>Patch Test</u>

The patch test is an independent measurement required to allow for "data alignment". The objective is to derive four other offsets i.e. latency, roll, pitch and yaw. For the latency, data were collected with the vessel traveling in the same direction, but at two significantly different speeds over a well-defined feature on the same line. It is required that one speed be at least double the other. Two independent sets of data for the roll offset were collected on reciprocal headings from one to another on the same line over a flat seafloor. Using the same line as was used for the latency, two sets of data for the pitch offset were collected with the vessel traveling at same speed, but in opposite directions on the same line. For the yaw offset, data were collected over a well-defined feature on two different parallel lines. The line spacing was set to allow the outer beams of one line to overlap the track for the other line (approximately 2 times water depth).

The patch test data were collected in each survey area prior to the actual survey.

<u>Survey planning</u>

The following discussion includes comments on a variety of survey planning, data acquisition and processing software packages. These include Navisoft Survey and Navisoft Planning and Presentation, descriptions of which appear in the previous report[1].

[1] Siwabessy, P.J.W. 2003. "RESON Training and Data Collection using SeaBat 8125 Multibeam System in Sydney Harbour." CMST Report 2003-24 for the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management. Centre for Marine Science and Technology, Curtin University of Technology.

As far as bathymetry is concerned, a common practice in a single beam survey is to run survey lines normal to the contour in order to obtain the best definition of the slope. This is however not the case for a multibeam survey. A rule of thumb in a multibeam survey is to run survey lines parallel to the contour. The idea is to get the maximum swath coverage in a short time. The objectives of the survey, navigational requirements and weather conditions may however rule out this multibeam survey requirement. For instance, the objective is to look at changes in seabed habitat type along the track and if it happens that the changes are depth dependent, it is more appropriate to run survey lines normal to the contour.

Irrespectively however, a 100% overlap between adjacent lines is required to avoid gap between lines due to, among others, roll. Survey lines were created in consultation with the skipper on the arrival at the particular area to be surveyed.

<u>Grid setup</u>

The objective here was to divide the survey area into grids/bins. This is a requirement when using the Navisoft package for data acquisition, but is not necessarily the case for other processing packages including FUGRO's Starfix and Caris.

<u>Initial setup and data collection</u>

The software used for data collection was Navisoft Survey. Using this software, the project file created using the Navisoft Planning and Presentation software was loaded and all available offsets were entered. Communication lines between PC and all sensors were checked. Data logging configuration was also checked, making sure that the folder and the filename were correctly specified and the GRD file (grid file) was selected.

Mainly, data were recorded in survey lines and in travelling tracks as necessary. Some additional tracks allowing for filling the gap and setting the boundary close to the shore were required. Each file was created to store the data for each line or track.

<u>Multibeam data processing</u>

The technique adopted was described in Gavrilov *et al* (2005)[2] and has been used to process all other multibeam data collected within the CWHM project[3,4,5]. The analysis can be broken down into three main steps:

1. Estimate of surface scattering coefficient

Estimates of the surface backscatter coefficient[6] were calculated from the snippet data and corrected for spreading loss, absorption loss and footprint size.

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[2] Gavrilov, A.N., Siwabessy, P.J.W. and Parnum, I.M. (2005). "Multibeam echo sounder backscatter analysis: Theory review, methods and application to Sydney Harbour swath data." CRC Milestone Report CA3.03. CMST Report 2005-03 for the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management. Centre for Marine Science and Technology, Curtin University of Technology.

[3] Gavrilov, A.N., Siwabessy, P.J.W. and Bickers, A. (2005). "Multibeam echo sounder backscatter analysis: Analysis of swath backscatter data collected in the region of Recherche Archipelago." CRC Milestone Report CA4.06. CMST Report 2005-08 for the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management. Centre for Marine Science and Technology, Curtin University of Technology.

[4] Siwabessy, P.J.W., Gavrilov, A.N. and Parnum, I.M. (2005). "Swath system deployed in Cockburn Sound for follow up trials of using snippets to classify seabed/benthos." CRC Milestone Report CA4.02. CMST Report 2005-07 for the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management. Centre for Marine Science and Technology, Curtin University of Technology.

[5] Gavrilov, A.N, Duncan, A.J., McCauley, R.D., Parnum, I. M., Penrose, J. D., Siwabessy, P. J. W., Woods, A. J. and Tseng, Y-T. (2005). "Characterization of the seafloor in Australia's coastal zone using acoustic techniques." *Proceedings of Underwater Acoustic Measurements Conference*, Heraklion, Crete, Greece, June 2005.

[6] Medwin, H. and Clay, C.S. (1998). *Fundamentals of acoustical oceanography. Applications of modern acoustics*. R. Stern and M. Levy (Editors). Academic Press.

2. Correcting for angular dependence
To correct for angular dependence of backscatter an empirical method was used, which calculates the average angular response for backscatter intensity level within a spatial window (here 100 pings) that slides along the swath line with a 50 per cent overlap. The average angular dependence was subtracted from the backscatter intensity level within each section of the swath line that spans the central half of the averaging window. Then the absolute level of backscatter was reconstructed by adding the average level measured within the interval of 30±2 degrees.

3. Gridding
A median technique was used to grid the all the data, which calculates the median within equal spaced cells. Using this method data were gridded to a 1m cell size.

For the bathymetry, the Navisoft Calculate module within the Navisoft software was used.

RESON 8125 Snapshot

Snapshot data were collected using the RESON SnapSaver software. This software only permits the acquirsition the acoustic data coming from the RESON 8125 multibeam sonar. Attitude and position data were collected separately using the hyperterminal package in Windows 2000. The RESON Snapsaver version released in 2005 does permit both acoustic and attitude and position data to be acquired together.

SIMRAD EQ60 single beam sonar

The SIMRAD EQ60 single beam sonar was only deployed in Moreton Bay, Brisbane. The single beam sonar and the UWA underwater video camera were deployed simultaneously in selected areas. While these two systems were in operation, the RESON 8125 multibeam sonar was switched off.

Single beam data processing

A RoxAnn-like analytical technique was adopted and has been used at CMST, Curtin University of Technology to discriminate seabed types. Following the procedure described in Siwabessy (2001)[7] and Siwabessy *et al* (2000)[8], E1 and E2 parameters were derived from recorded acoustic waveforms using Echo*view* software. E1 is the energy of the tail of the first acoustic bottom echo, often related to the roughness of the sediment whereas E2 is the energy of the whole of the second acoustic bottom echo, often related to the hardness of the sediment. The technique has been used for single beam data collected with the CWHM in Cockburn Sound[9]. A cluster analysis (CA) was applied to the parameters E1 and E2. The iterative relocation technique with Bayesian distance for clustering was adopted.

UWA underwater video camera

The connection for the UWA underwater video camera system is shown in Figure 4. The system was operated by at least 2 persons; one holding the umbilical and the other watching the screen. The person holding the umbilical operated the camera from the stern of the boat. This person was guided to bring the camera up/down by the person watching the screen. The speed of the vessel was maintained, typically at 1 knot.

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[7] Siwabessy, P.J.W. (2001). "An investigation of the relationship between seabed type and benthic and bentho-pelagic biota using acoustic techniques." PhD Thesis, Curtin University of Technology, Perth, Western Australia.

[8] Siwabessy, P.J.W., Penrose, J.D, Fox, D.R. and Kloser, R.J. (2000). "Bottom Classification in the Continental Shelf: A Case Study for the North-west and South-east Shelf of Australia." *Proceedings of Acoustics 2000*, Australian Acoustical Society, 15-17 November 2000, Joondalup, Perth, Western Australia, 265-270.

[9] Siwabessy, P.J.W., Tseng, Y-T., and Gavrilov, A.N. (2004). "Seabed habitat mapping in coastal waters using a normal incident acoustic technique." *Proceedings of Acoustics 2004*, Australian Acoustical Society, 3-5 November 2004, Gold Coast, Australia, 187-192.

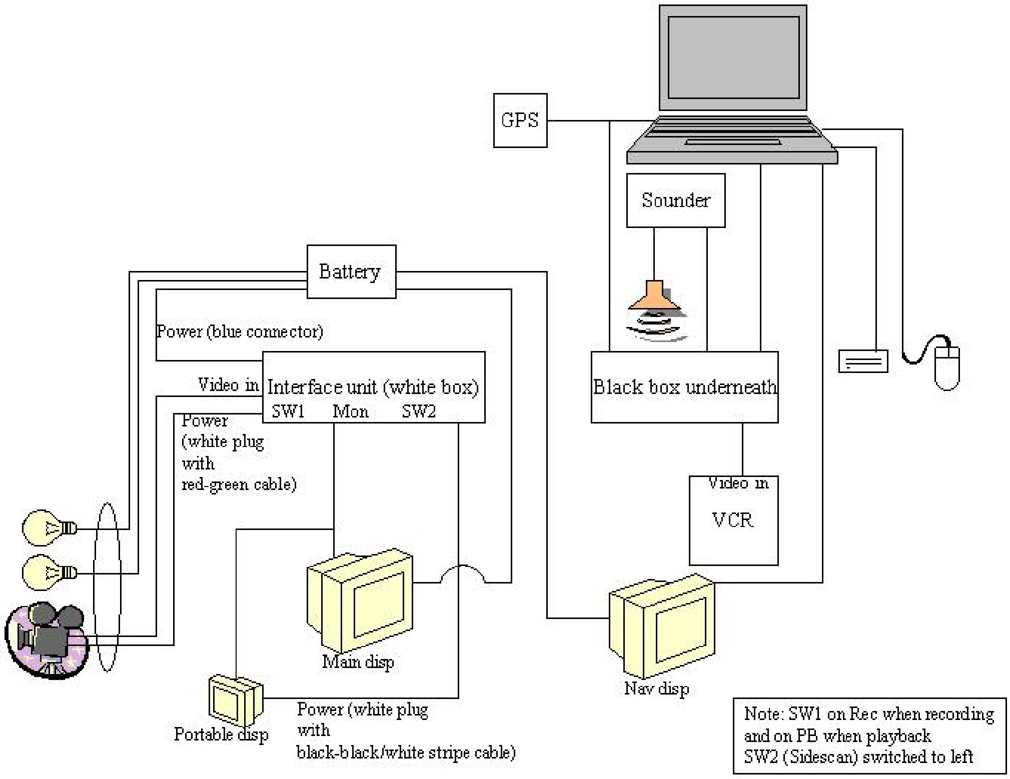

Figure 4. Schematic diagram of the UWA underwater video camera system.

CTD

CTD was deployed by hand. At least one CTD cast was collected in each area where the multibeam data were collected. Normally two casts were collected before and after collecting the multibeam data in an area of interest.

Klein 5500 sidescan sonar

The transducer of the Klein 5500 sidescan sonar was operated only in Keppel Bay, Rockhampton. The RESON 8125 side mounted pole was used to hold the transducer. The sidescan data were collected while steaming seaward along the Fitzroy River.

Secchi disk

The Secchi disk was designed and made by Mal Perry of CMST. It was made of wooden board and was white painted.

Hydro Bios Grab

Grab samples were collected only in Keppel Bay, Rockhampton using the Hydro Bios Grab. It was operated by hand in selected areas around the Centre Banks.

Sensor offsets

All the measurements were made using a metal tape. A spirit level and a plumb bob were used to allow for accurate measurements.

Results

Offsets

The offset of all sensors deployed in every survey was measured. Table 2, however, provides only the summary of all offsets required for the multibeam survey in all areas.

Table 2. Summary of sensor offsets measured for the multibeam system.

Survey	Sensor	Offset [m]		
		dX	dY	dZ
Moreton Bay, Brisbane	DGPS	1.76	-0.845	3.86
	Sonar head	2.87	-5.47	-1.41
	Motion sensor	0	0	0.72
Keppel Bay, Rockhampton	DGPS	-0.58	1.38	4.39
	Sonar head	2.13	-2.16	-1.28
	Motion sensor	-0.1	0	0.59

Table 3 provides the summary of the patch test offsets required for further multibeam analysis. The offsets were derived on the field using the Navisoft Patch Test software. Further analysis is required as the variability of the latency is considerable despite the fact the same GPS system was used throughout.

Table 3. Summary of the patch test offsets.

Survey	Parameter			
	Latency [ms]	Roll [ ]	Pitch [ ]	Yaw [ ]
Moreton Bay, Brisbane	200	0.50	2.50	2.00
Keppel Bay, Rockhampton	-340	1.40	3.70	-2.80

Data collection

Table 4 summarises the multibeam data available from the two survey areas. The multibeam data were collected from 7 different areas within 7 days in Moreton Bay and from 4 different areas within 7 days in Keppel Bay. Including travelling tracks, the total length surveyed was 197 km in Moreton Bay and 343 km in Keppel Bay.

Table 4. Summary of RESON 8125 multibeam data operated in normal mode. *including traveling tracks.

Survey	Date	Area	Data		
			Number of lines*	Size [Gb]	Location (Format)
Moreton Bay	29/08/04	Port Development area	24	5.02	CMST (RAW, XTF)
	31/08/04	North Peel Is.	11	3.83	
	01/09/04	North Peel Is., Rous Channel	39	6.39	
	02/09/04	Rous Channel, North Peel Is.	17	2.44	
	03/09/04	Moreton Banks	28	3.86	
	04/09/04	Moreton Banks	14	2.61	
	05/09/04	Flinders Reef	3	0.33	
Keppel Bay	20/09/04	Centre Banks	16	3.74	CMST (RAW, XTF)
	21/09/04	Port Alma	13	1.45	
	22/09/04	Centre Banks	32	6.28	
	23/09/04	Centre Banks	82	8.97	
	24/09/04	Arch Rock	59	8.08	
	25/09/04	Centre Banks	39	6.58	
	26/09/04	Arch Rock	17	3.03	

RESON 8125 snapshot data are also available and are summarised in Table 5. The snapshot data were only collected in selected areas within each survey area.

Table 5. Summary of RESON 8125 snapshot data.

Survey	Date	Area	Data		
			Number of lines	Size [Gb]	Location (Format)
Moreton Bay	01/09/04	North Peel Is., Rous Channel	2	1.30	
	02/09/04	Rous Channel, North Peel Is.	2	1.50	
Keppel Bay	26/09/04	Arch Rock	4	1.95	

The single beam sonar was in operation in Moreton Bay only and the sidescan sonar was operated only along the Fitzroy River in Keppel Bay. The summary of the single beam and the sidescan sonar is given in Table 6. The single beam data were collected along the total length of 33 km in 6 different areas in Moreton Bay.

Table 6. Summary of other acoustic data. Simrad=SIMRAD EQ60 Single beam sonar. Klein= Klein 5500 sidescan sonar.

Survey	Device	Date	Area	Data		
				Number of lines	Size [Gb]	Location (Format)
Moreton Bay	Simrad	29/08/04	Port Development area	2	0.10	CMST (RAW)
		01/09/04	North Peel Is., Rous Channel	1	0.45	
		02/09/04	Rous Channel, North Peel Is.	3	0.70	
		04/09/04	Moreton Banks	2	0.56	
Keppel Bay	Klein	19/09/04	Fitzroy River	35	6.41	DSTO (XTF), CMST (XTF)

The areas where video footages were taken were similar to the area where single beam data were collected in Moreton Bay. The towed video and the single beam sonar were operated simultaneously. Due to poor visibility of the water around Keppel Bay, video footages were only taken once in the Arch Rock area. Table 7 provides the summary of the video footages taken from the two survey areas.

Table 7. Summary of video data.

Survey	Date	Area	Data		
			Number of lines	Size [Hr]	Location (Format)
Moreton Bay	29/08/04	Port Development area	1	1.00	CMST (DV)
	01/09/04	North Peel Is.	1	1.75	
	02/09/04	Rous Channel, North Peel Is.	2	2.75	
	04/09/04	Moreton Banks	2	2.00	
Keppel Bay	26/09/04	Arch Rock	1	1.00	CMST (DV)

In general, two CTD measurements per surveyed area per day were conducted (see Table 8). Table 8 summarises all CTD measurements available from both survey areas.

The grab samples were collected with Hydro Bios Grab. The grab sample data were collected only in Keppel Bay. A general description of the grab sample data is provided in Table 9. In general, only mud and sand were observed in all surveyed areas in Keppel Bay.

Water visibility was measured with the Sechhi disc. A summary of the measurements is given in Table 10. As seen in Table 10, the Secchi depth is as low as 0.5 m around Port Alma.

Table 8. Summary of CTD data.

Survey	Date	Area	Data	
			Number of deployment	Location (Format)
Moreton Bay	29/08/04	Port Development area	1	CMST (ASCII)
	31/08/04	North Peel Is.	2	
	01/09/04	North Peel Is., Rous Channel	2	
	02/09/04	Rous Channel, North Peel Is.	2	
	03/09/04	Moreton Banks	1	
	04/09/04	Moreton Banks	2	
	05/09/04	Flinders Reef	1	
Keppel Bay	20/09/04	Centre Banks	2	CMST (ASCII)
	21/09/04	Port Alma	2	
	22/09/04	Centre Banks	2	
	23/09/04	Centre Banks	2	
	24/09/04	Arch Rock	1	
	25/09/04	Centre Banks	2	
	26/09/04	Arch Rock	1	

Table 9. General description of grab samples collected using Hydro Bios Grab in Keppel Bay.

Sample ID	Easting	Northing	Date	Time	Depth (m)	Photo available	Description
HB01	293730.768	7399986.678	24/09/2004	18:20	-	No	Very soft, watery, jelly mud with some soft lumps
HB02	295923.319	7409496.502	25/09/2004	07:31	16	Yes	(Sandy) gritty shelly mud - small sample
HB03	296262.857	7411557.268	25/09/2004	10:30	12	Yes	Mud with shell and gravel
HB04	296235.150	7411347.320	25/09/2004	11:25	-	Yes	Muddy sand with shell and gravel
HB05	296020.39	7411399.38	25/09/2004	11:35	-	Yes	Slightly muddy, sand and shell debris
HB06	295696.06	7411414.11	25/09/2004	11:44	8	Yes	Sand and shell
HB07	295424.44	7411415.81	25/09/2004	-	10	Yes	Slightly muddy, sand and shell debris
HB08	295179.42	7411244.51	25/09/2004	12:00	8	Yes	Course sand
HB09	294812.8	7411405.03	25/09/2004	12:20	10	Yes	Slightly muddy sand, with shell & mud lumps
HB10	294627.66	7411317.46	25/09/2004	-	8	No	Slightly muddy sand
HB11	294226.6	7411037.83	25/09/2004	12:50	9	No	Muddy fine sand
HB12	293863.86	7411158.2	25/09/2004	-	11	No	Muddy fine sand
HB13	293922.59	7411104.23	25/09/2004	-	11	No	Muddy fine sand
HB14	293563.76	7411184.78	25/09/2004	-	11.5	No	Black mud
HB15	293434.64	7411148.81	25/09/2004	-	-	No	
HB16	293486.49	7411122.375	25/09/2004	-	-	No	
HB17	293538.34	7411095.94	25/09/2004	-	-	No	
HB19	293348.45	7410984.49	25/09/2004	-	-	No	Muddy sand
HB20	293757.49	7411213.08	25/09/2004	-	-	No	Muddy sand
HB30	289931.220	7413851.240	27/09/2004	-	-	No	Shell debris and sand
HB31B	287072.110	7412266.210	27/09/2004	-	-	No	Mud very cohesive
HB32D	287188.570	7412389.850	27/09/2004	-	-	No	Muddy sand and shell with pebbles
HB33A	287316.240	7412376.980	27/09/2004	-	-	No	Slightly sandy mud with shell
HB34a	287346.930	7412406.870	27/09/2004	-	-	No	Mud with shell
HB35	287812.670	7412528.550	27/09/2004	-	-	No	Sandy mud soft and sloppy (no shell)

Table 10. Summary of Secchi data collected in Keppel Bay.

Site	Date	Time	Easting	Northing	Approximate Depth (m)	Sechhi Disc Depth (m)	Water Colour
Centre Banks - Patch Test	20/09/04	13:00	295880.7758	7408734.655	21	2.1m @ 0	Pastel Green
Centre Banks - Patch Test	20/09/04	15:15	296116.7616	7408713.001	18	3.2m @ 50	Pastel Green
Channel in to Port Alma	21/09/04	13:30	288472.6538	7396005.887	5	0.55m @ 0	Khaki/Light Brown
Port Alma	22/09/04	11:35	281757.6252	7389780.623	N/A	0.5m @ 45	Khaki/Light Brown
Centre Banks	22/09/04	15:32	296626.2894	7411358.896	14	5.5m @ 0	Sea Green
Centre Banks	22/09/04	17:01	296631.7832	7411104.811	14	5.5m @ 0d	Sea Green
Centre Banks	23/09/04	07:13	296138.7837	7408824.694	16	3.3m @ 0	Pastel Green - ie slightly milky
Centre Banks	23/09/04	14:45	293438.0413	7411293.639	13.5	4.5m @ 0	Pastel Green - ie slightly milky
Arch Rock	24/09/04	8:06	289979.5331	7413669.854	24	3.5m @ 0	Pastel Green
Arch Rock	24/09/04	16:41	290592.2489	7412650.190	N/A	3.75m @ 0	Pastel Green
Centre Banks	25/09/04	07:31	295923.2761	7409499.579	16	3.5m @ 0	Pastel Green/Slightly Brown shaded
Centre Banks	25/09/04	15:52	293758.0053	7411281.811	13	1m @ 0	Pastel Green/Slightly Brown shaded
Arch Rock	26/09/04	10:08	289883.1382	7413856.186	23	3.5m @ 0	Green

Survey Narrative

Moreton Bay

Figure 5 shows the survey area in Moreton Bay, Brisbane. Swath coverage, single beam, snapshot and video tracks, and position of CTD stations are shown in Figure 5.

The survey started on 29 August 2004. The patch test data were collected first in the so-called Port Development area along 12 survey lines. After collecting the patch test data, the actual multibeam survey started in the area. 12 lines of multibeam data were produced. Only one CTD cast was made in this area. The single beam sonar and the underwater video were operated simultaneously along a single line in this area.

The survey went on in the North Peel Island on 31 August 2004. Multibeam data collected along 11 survey lines were attained. Two CTD casts, before and after the survey, were made in this study area.

On 01 September 2004, the survey continued in the North Peel Island and then moved to the Rous Channel. Two CTD casts were made; one before the survey and the other one after the survey. Multibeam data were obtained along 2 survey lines in the North Peel Island. Before moving to the Rous Channel, the snapshot data, the single beam data and the underwater footage were taken in the North Peel Island. In the Rous channel, multibeam data were taken along 33 survey lines. The single beam data and the snapshot data were also collected.

On 02 September 2004, the single beam data and the underwater footage were taken simultaneously in the Rous Channel. The same line was used also to collect the snapshot data. The multibeam survey resumed afterwards. 11 survey lines of multibeam data were produced in the Rous Channel. The multibeam survey continued in the North Peel Island running from shallow to deep water in a direction perpendicular to the previous swath in the area. Multibeam data along total of 6 lines were acquired. The single beam data and the underwater footage were taken simultaneously along a single line. The snapshot data were gathered along the same line.

Data were collected in the Moreton Banks on 03 September 2004. Total of 28 survey lines were produced from the Moreton Banks. Only one CTD cast was made in this area.

The multibeam survey in the Moreton Banks resumed on 04 September 2004. Multibeam data along 14 survey lines were collected. Two lines in two different sub-areas were setup for the single beam and the video. The single beam data and the underwater footage were gathered simultaneously.

The survey in the Flinders Reef was conducted on 05 September 2004. Multibeam data were collected along 3 lines. The survey in the Flinders Reef was prematurely terminated because of the accident happening to the pole of the RESON 8125 multibeam sonar.

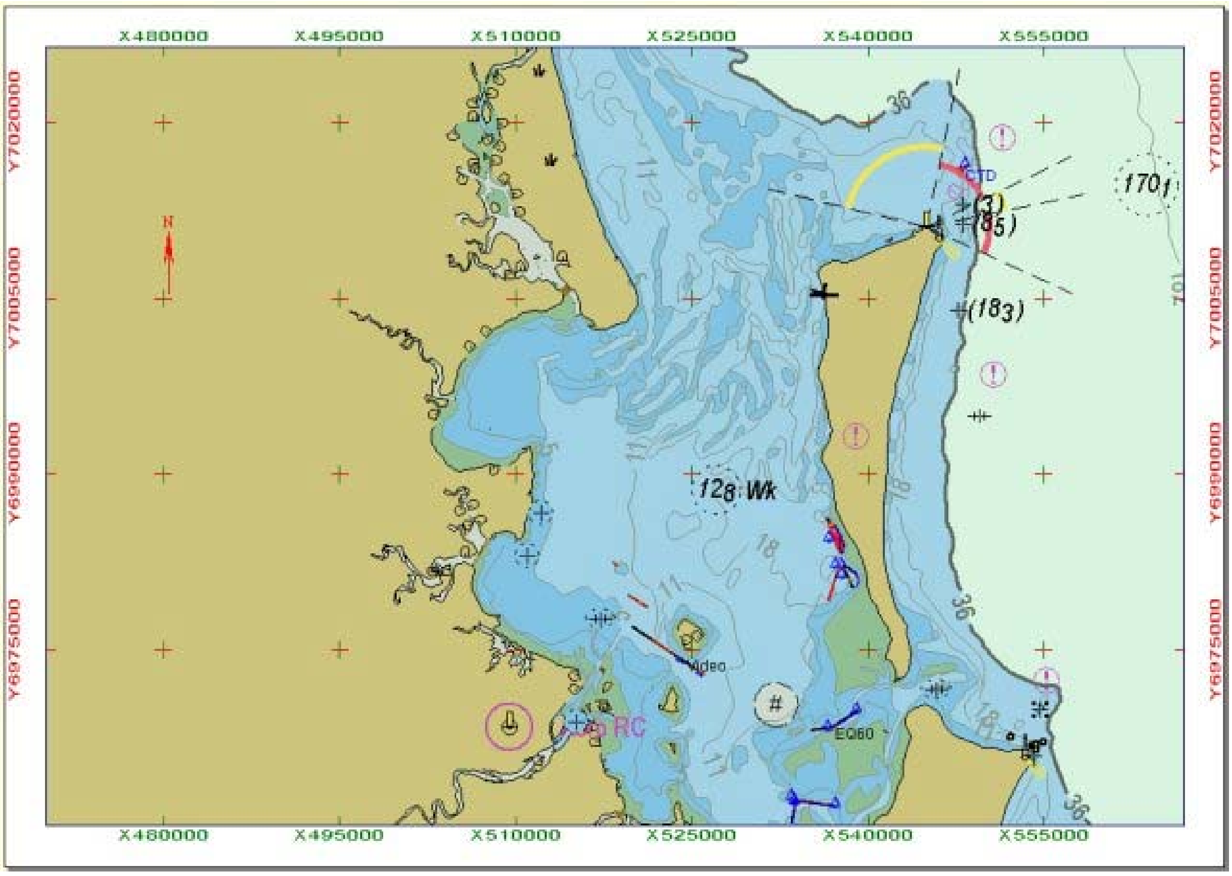

Figure 5. C-MAP chart of the survey area in Moreton Bay, Brisbane.

Keppel Bay

A summary of all data collected in Keppel Bay, Rockhampton is visualised together with the C-MAP chart in Figure 6. Figure 6 shows also positions of V-core samples and CHIRP data collected separately by GeoScience Australia before this survey.

Right after the mobilisation and the installation of the field gear aboard *MV Rum Rambler* on 19 September 2004, the survey in Keppel Bay, Rockhampton began. While the boat steamed off seawards from Rockhampton, the sidescan data were collected along the Fitzroy River using the Klein 5500 sidescan sonar. In late afternoon, the accident happened in shallow banks when approaching the Centre Banks. The head of the Klein 5500 sidescan sonar was sunk underwater after a collision between the head and the seabed. After the accident, some concentrated on the rescue plan, others started assembling the head of the RESON 8125 multibeam sonar on the pole.

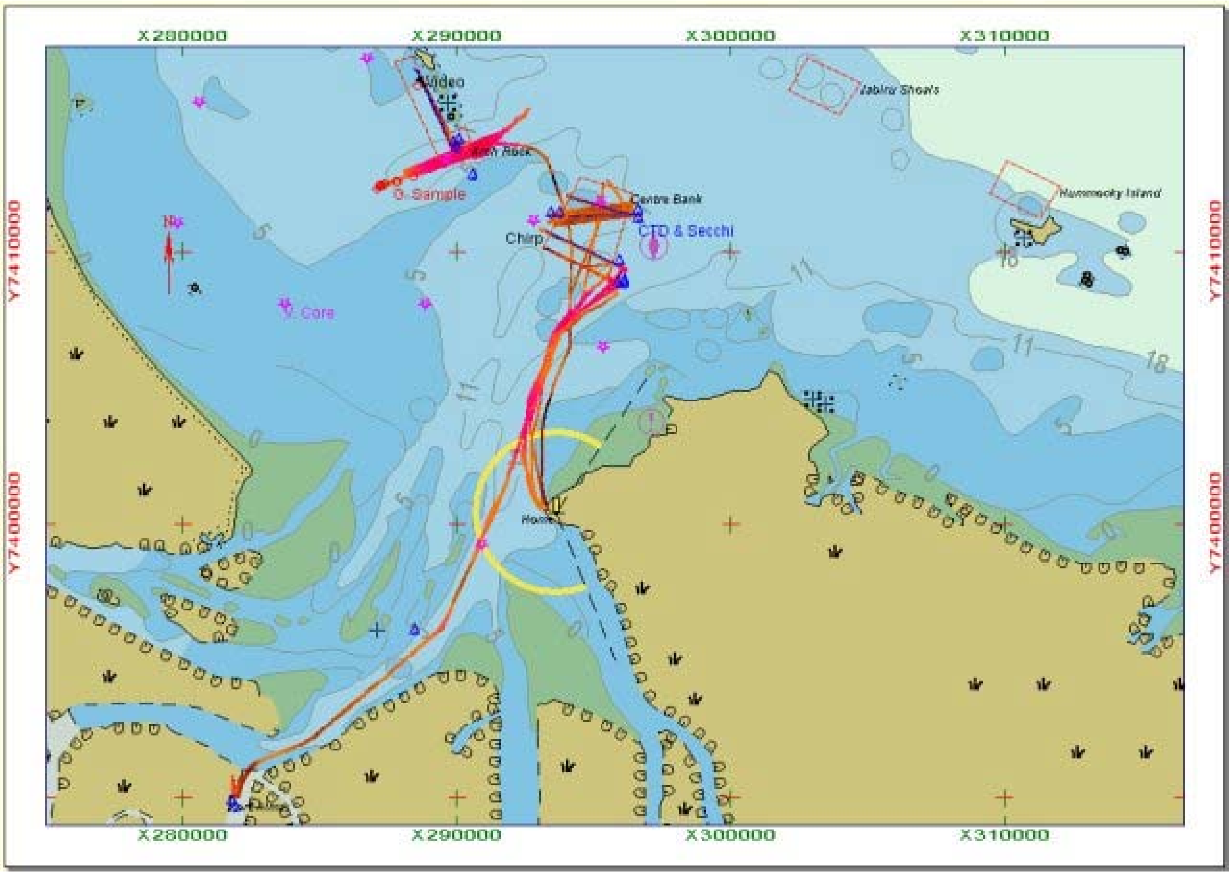

Figure 6. C-MAP chart of the survey area in Keppel Bay, Rockhampton.

The multibeam survey started on 20 September 2004 in the afternoon after an unsuccessful rescue attempt finding the sidescan head. CTD and Secchi disk were deployed around the survey area in the Centre Banks before collecting any other data. Patch test data were collected along 7 lines. The multibeam data were also collected along travelling tracks from and to Port Alma.

Hunt for the sidescan head continued on 21 September 2004. A commercial diver was hired to search for the sidescan head. After two searching attempt, the head was finally found. While traveling from and to Port Alma on the rescue operation, the multibeam data were collected. On the way back to Port Alma, multibeam bathymetry data around Port Alma were collected before calling off the day. In total, multibeam data along 21 lines including traveling tracks were obtained. CTD and Secchi disk were deployed before and after the survey in Port Alma.

The boat left from Port Alma for the Centre Banks on 22 September 2004. The multibeam data were collected along the traveling track from Port Alma to the Centre Banks. On the arrival in the Centre Banks, CTD and Secchi disk were deployed. Multibeam data were collected in the Centre Banks along GA CHRIP lines. In total, multibeam data were collected along 32 survey lines. CTD and Secchi disk were deployed in the Centre Banks right after the survey before heading off to the anchorage.

The survey went on in the Centre Banks on 23 September 2004. While traveling to the Centre Banks from the anchorage, multibeam data were collected along the way. CTD and Secchi disk was deployed before starting the survey in the Centre Banks. Multibeam data from 82 lines including traveling tracks were taken. After the survey, CTD data and Secchi data were taken.

On 24 September 2004, the survey carried on in the Arch Rock. Multibeam data were collected along 59 lines including traveling tracks to and from the Arch Rock. Only one CTD cast and one Secchi measurement were made in the Arch Rock.

The survey returned to the Centre Banks on 25 September 2004. This time, multibeam data from 39 lines including traveling tracks were obtained. Two CTD casts and two Secchi measurements were made before and after the survey, respectively. Total of 45 grab samples were collected using the Hydro Bios Grab.

On 26 September, the survey continued in the Arch Rock. This time, CTD and Secchi disk were deployed only once in the Arch Rock. Multibeam data were collected along 17 lines including traveling tracks. The snapshot data and the underwater footage were taken simultaneously in a single line. 10 grab samples were collected in the Arch Rock.

Bathymetry and backscatter

Moreton Bay

Figure 7 shows the bathymetry image of the main area around Moreton Banks in Moreton Bay derived from the RESON 8125 multibeam bathymetry data. Accurate navigation and correction for motion allow for stitching together swath lines and suppressing motion artefacts. The coastal slope is observed in the eastern part of the bathymetry image. Shallow waters appear in the northern side of the bathymetry image. Deeper waters start from the central part and expand to the coastal slope in the eastern and southern sides of the area.

Also shown in Figure 7 is the backscatter strength image of the Moreton Banks. High backscatter strength values (light yellow) appear in the shallow waters in the northern side and in the southern and southwestern sides. The lowest backscatter strength value (dark greyish yellow) seems to coincide with the deepest part of the area.

In Figure 8, bathymetry and backscatter images around North Peel Island are presented. Results from the single beam data are overlaid in the bathymetry and backscatter images for comparison. Results from the single beam data show three distinct seabed types given as C1 (black) in the south, C2 (blue) in the centre and C3 (green) in the north. C3 coincides with the multibeam high backscatter strength values in the northern side of the area whereas C1 and C2 coincide with the multibeam low backscatter strength values starting from the central to the southern part of the area. Video recordings reveal that the single beam C3 and the multibeam high backscatter strength value are due sparse-medium seagrass on coarse muddy sand. Although single beam C1 and C2 that correspond to the multibeam low backscatter strength value are similar in terms of the sediment, video recordings and the multibeam bathymetry suggest that very big undulated/bioturbated feature of the seabed make C2 different from C1. The difference between C1 and C2 is also observed in the probability density function (PDF) shown in Table 11. In general, the PDF of E1 and that of the multibeam backscatter strength are in good agreement. This may suggest that the correlation between the E1 parameter and the multibeam backscatter strength exists[10].

As mentioned earlier, the multibeam backscatter intensity data are corrected for the angular dependence of backscatter strength. The angular dependence of backscatter strength itself holds physical and morphological characteristics of the seabed and hence can be used for seabed classification. Figure 9 shows the angular dependence of backscatter strength of the three classes presented in Figure 8.

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[10] Collier, J.S. and Brown, C.J. (2005). "Correlation of sidescan backscatter with grain size distribution of surficial seabed sediments." *Marine Geology* 214: 431-449.

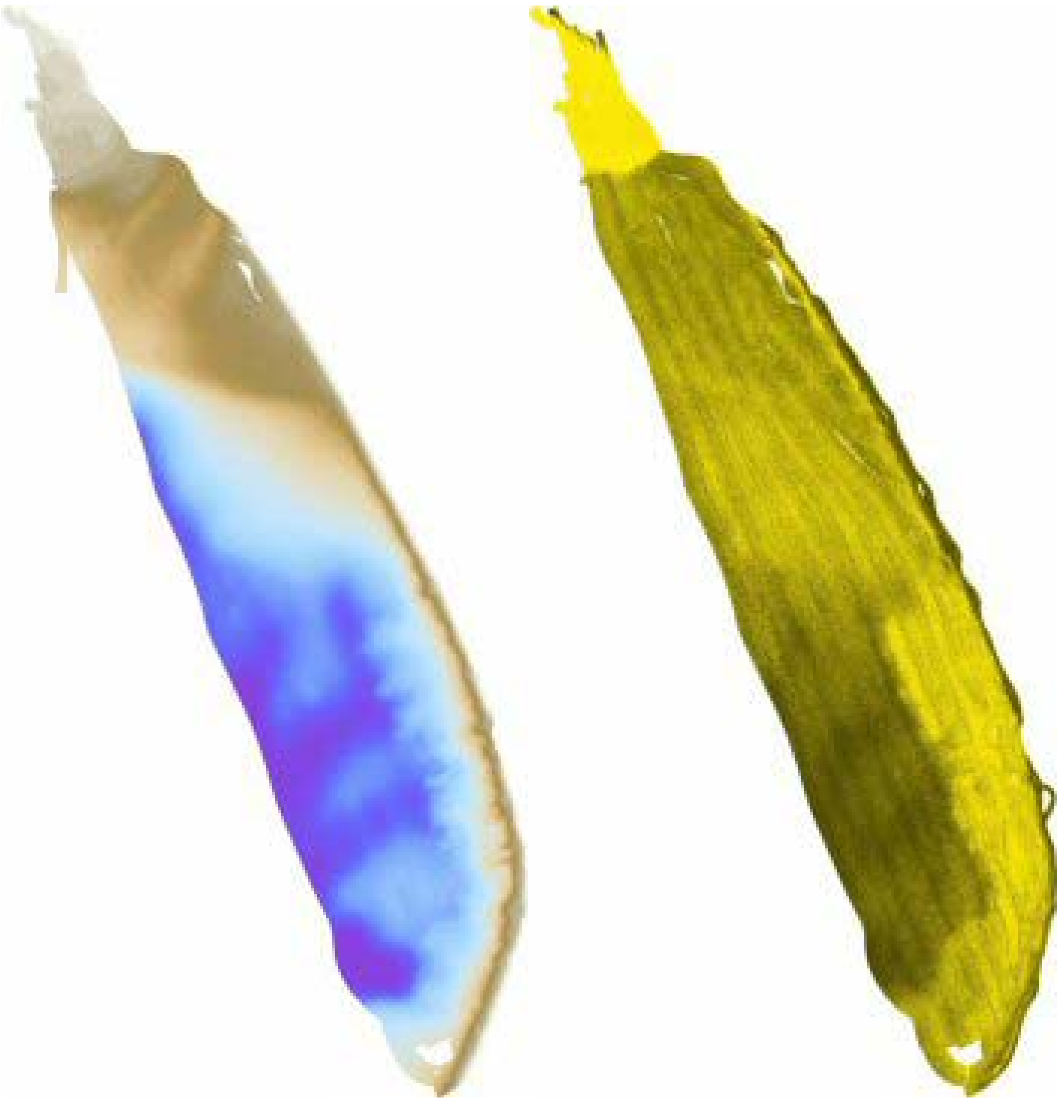


Figure 7. Bathymetry and backscatter images of Moreton Banks A.

Multibeam and single beam systems, and video footages are also compared for data collected from an area called hereinafter Moreton Banks B, south off Moreton Banks presented in Figure 7. Four different seabed classes derived from the single beam data are found in this area (Figure 10). Medium seagrass (C3+) appear in the northern side of the area shown as dark green in Figure 10. Video recordings reveal that the density of the seagrass in this part of the area is higher than that presented in Figure 8. Low multibeam backscatter strength values that appear in the southern side of the area are due to the mud as revealed from the video recordings. The poor visibility in this particular however makes it difficult to further reveal the morphological characteristic of the seabed. Strong, long first bottom returns and weak second bottom returns in this particular area as shown in the echogram in Figure 10 however suggest that the seabed is rough and soft. This may indicate the undulation/bioturbation of the seabed. Coarse sand seabed shown as gray color in Figure 10 is found in areas before and after the undulated/bioturbated mud seabed. A mixture of medium seagrass and algae on coarse sand seabed is evident in the southern part of the area.

Bathymetry and backscatter images of all other areas in Moreton Bay are presented for completeness in Table 12.

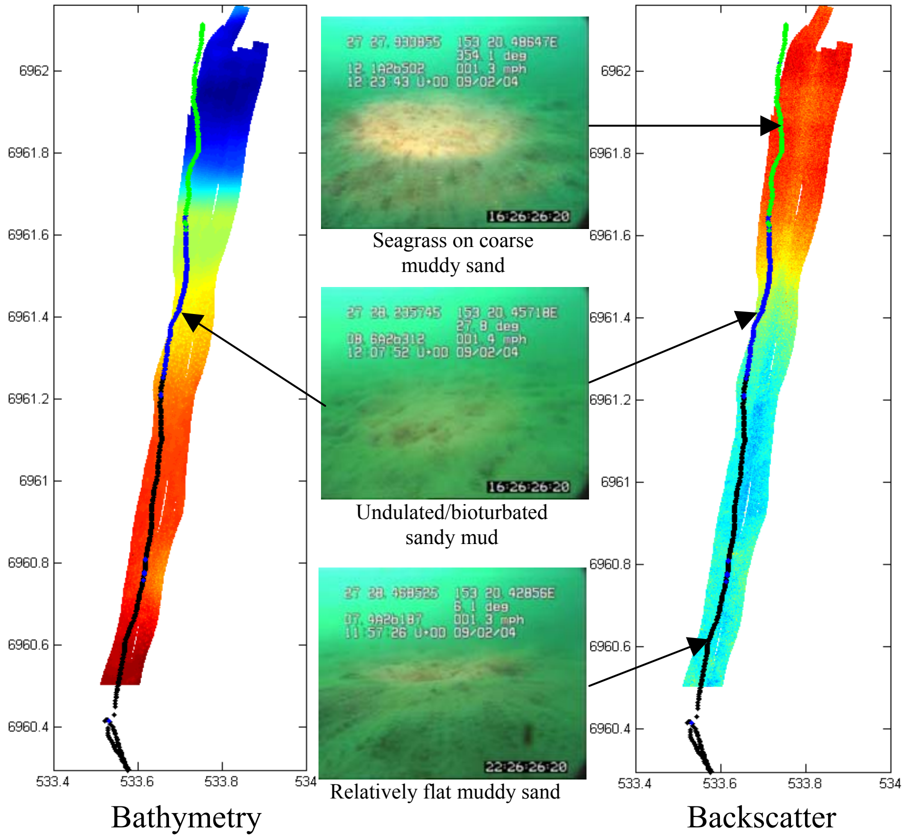
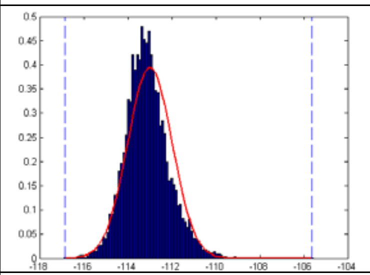
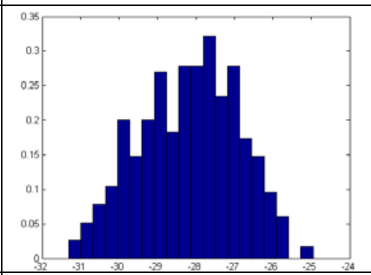
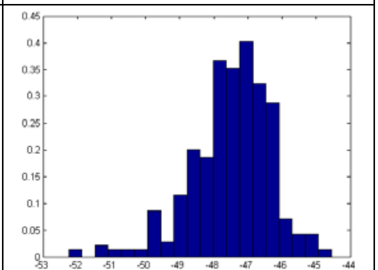
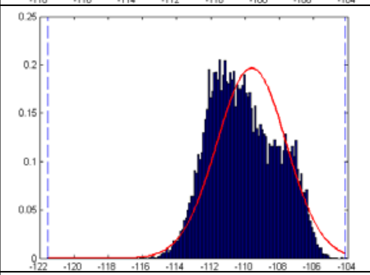
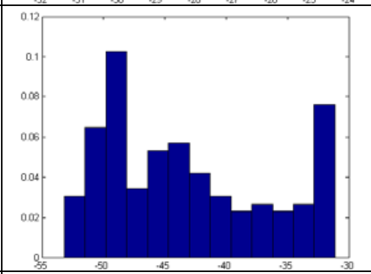
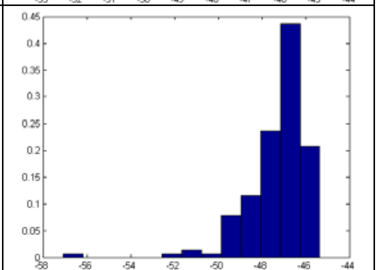
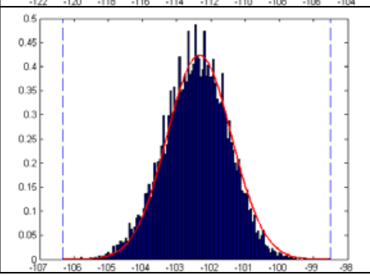
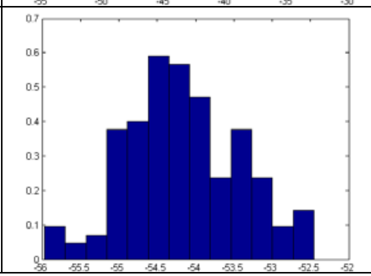
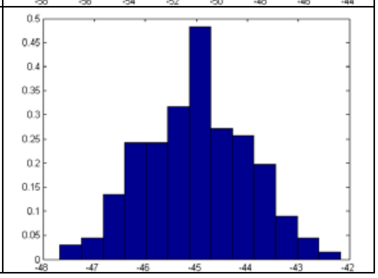


Figure 8. Comparison of multibeam and single beam data of the North Peel Island B. Seabed classes derived using single beam data (E1 and E2). Black (C1) = Relatively smoother muddy sand; Blue (C2) = Very rough/undulated sandy mud; Light Green (C3) = coarse muddy sand covered with sparse-medium seagrass/algae.

Table 11. PDF of classes derived from single beam and multibeam backscatter data from North Peel Island B.

Class	Multibeam	Single beam	
	BSE	E1	E2
C1			
C2			
C3			

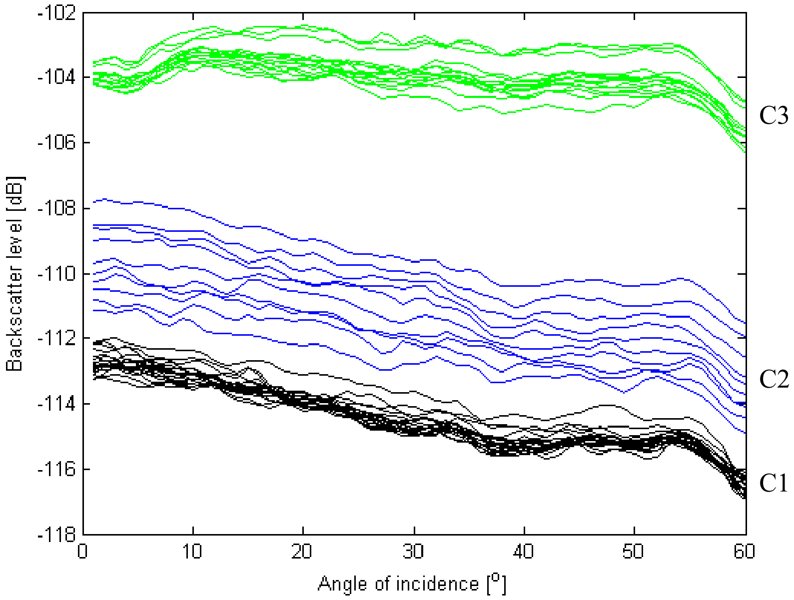


Figure 9. Angular dependence of backscatter intensity level of the three classes.

Keppel Bay

Severe motion artefacts were observed from data collected from all areas in Keppel Bay except those from Port Alma. It was found later that these artefacts were due to the misalignment in timestamp. Extra latency was required to align the bathymetry and attitude data. The top image presented in Figure 11 shows these artefacts from data collected in Centre Banks. A Matlab code was developed to estimate the extra latency for each effected swath line. The code cross-correlates the roll data and bathymetry data from moderate beam angle. The result after correction is shown in the bottom image presented in Figure 11.

The water in Keppel Bay in general was very turbid. For instance, the visibility around Port Alma was only 0.55 m and was 3.57 m around Centre Banks. Complete bathymetry and backscatter images of the area are presented in Figure 12. The presence of big dunes in Centre Banks area is evident from both images. Several prominent features are also observed in the backscatter image. High backscatter strengths shown as light yellow are prominent in the eastern Centre Banks and lower ones indicated as dark greyish yellow appear in the west. It is also interesting to note that features in light greyish yellow appear between sandbanks. Grab samples suggest that the low backscatter strength values correspond to muddy fine sand seabed and high ones correspond to sandy shell debris seabed. In addition, medium backscatter strength values appeared between sandbanks correspond to muddy, sandy shell debris seabed. The difference between seabed types is also observed from the PDF provided in Figure 12.

Bathymetry and backscatter images of all other areas in Keppel Bay are presented for completeness in Table 13.

It was found that a small proportion of the snippets data from the Arch Rock was saturated. The percentage was however low and negligible.

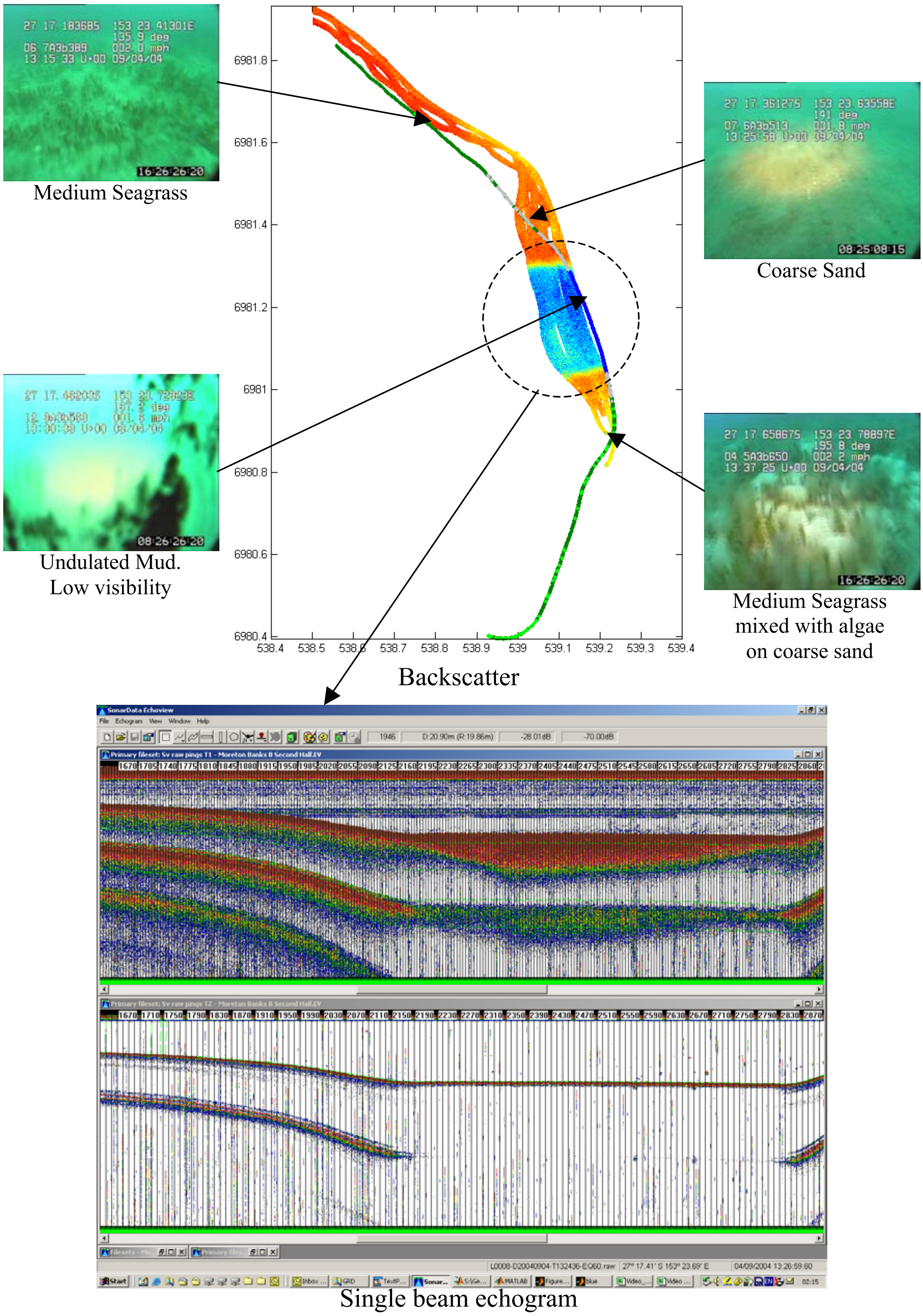
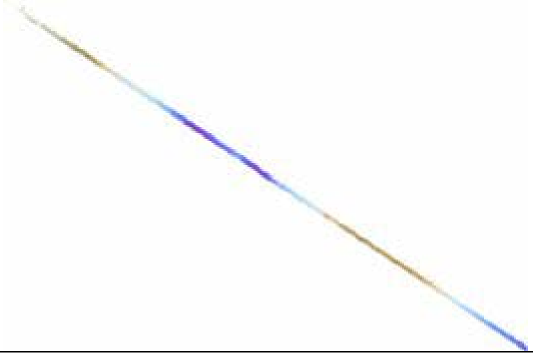
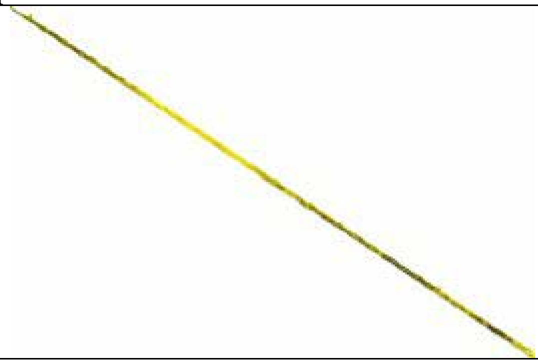
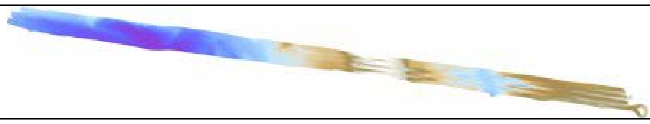
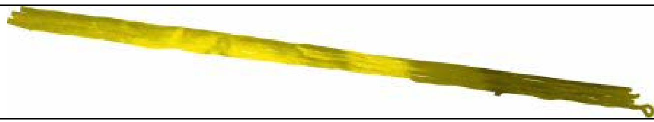
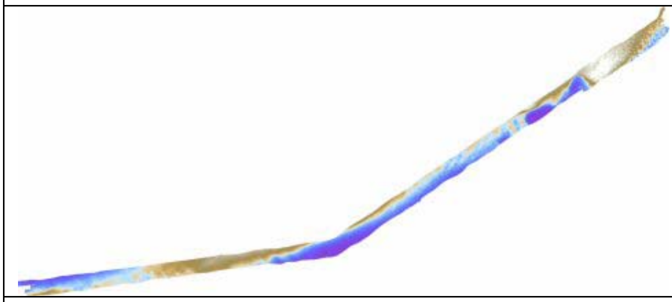
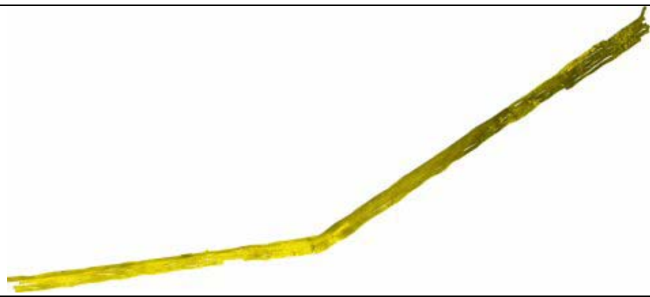
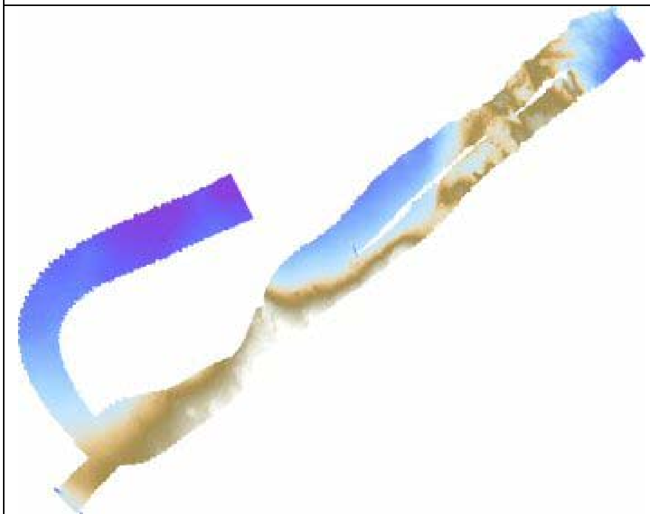
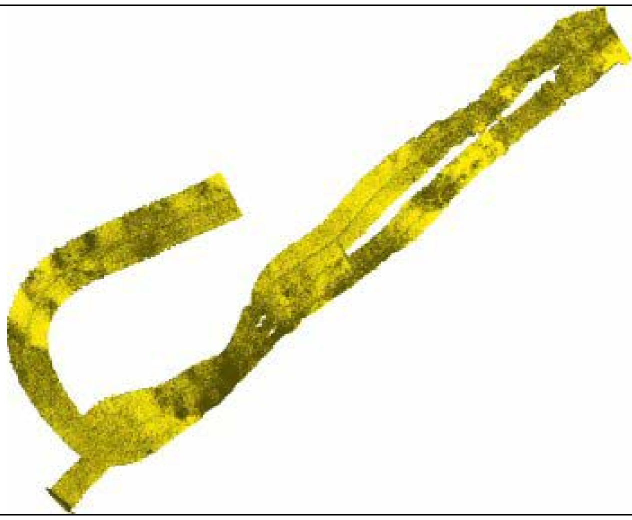
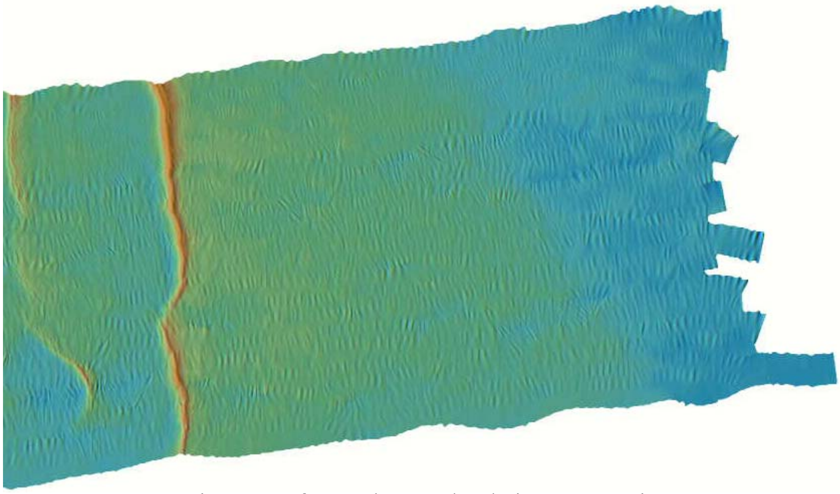


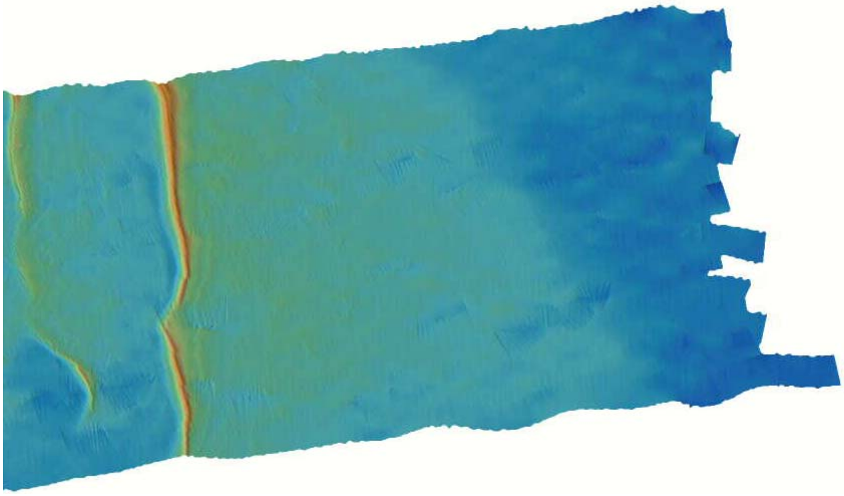
Figure 10. Comparison of multibeam and single beam data of the Moreton Banks B. Seabed classes derived using single beam data (E1 and E2). Blue (C2) = undulated mud (big holes but) visibility low; Light Green (C3) = Medium macro algae (mixed sparse seagrass); Gray (C4) = Coarse sand, relatively flat; Dark Green (C3+) = Medium seagrass on coarse sand. Moreton Banks B.

Table 12. Bathymetry and backscatter images of other areas in Moreton Bay.

Bathymetry	**Backscatter**
Port development area	
	
North Peel Island A	
	
Rous Channel	
	
Flinders Reef	
	



Motion artefacts due to bad timestamping



After correction for timestamping

Figure 11. Example of motion artefacts due to timestamping misalignment.

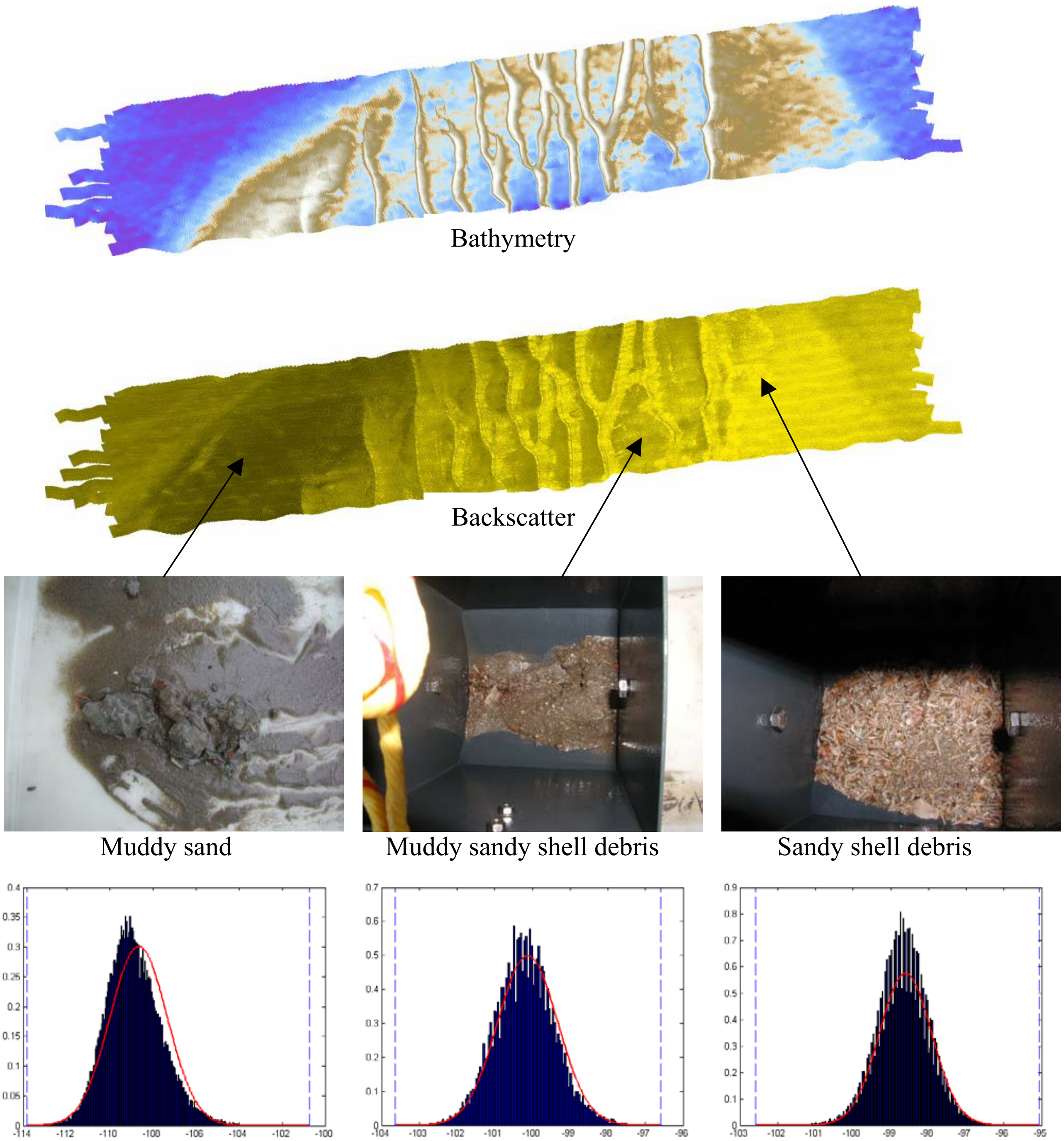


Figure 12. Bathymetry and backscatter images of Centre Banks.

Table 13. Bathymetry and backscatter images of other areas in Keppel Bay.

Bathymetry	Backscatter
Port Alma	
	
Arch Rock	
	
Arch Rock Hole