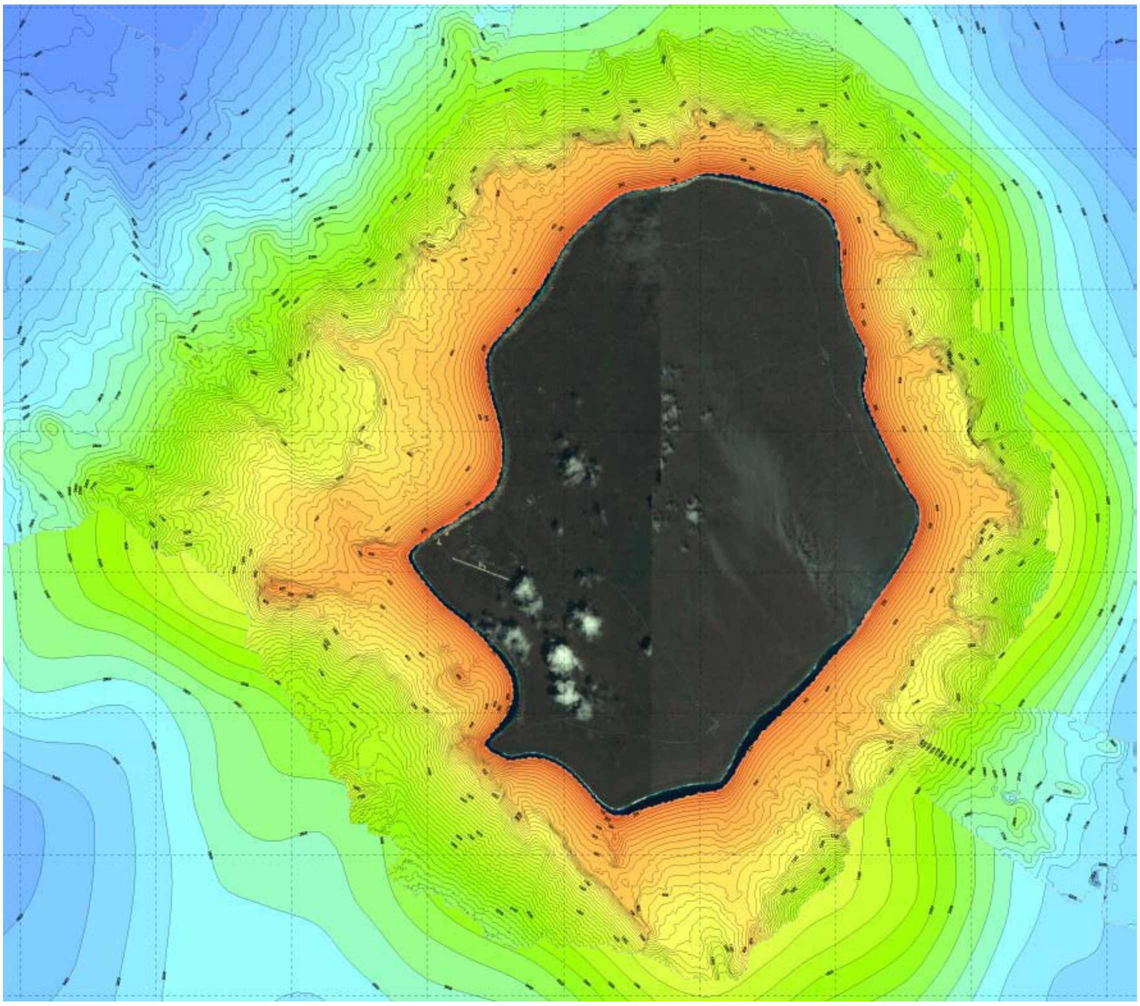
EU EDF 8/9 – SOPAC Project Report 49
Reducing Vulnerability of Pacific ACP States

NIUE TECHNICAL REPORT
HIGH-RESOLUTION BATHYMETRY SURVEY OF NIUE
Fieldwork undertaken from 29 April to 20 May 2005

2008



Bathymetry compilation for Niue Island.

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Important Notice

This report has been produced with the financial assistance of the European Community; however, the views expressed herein must never be taken to reflect the official opinion of the European Community.

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1 Niue, Bathymetry	1 : 50 000	ER049.1
2 Niue, Alofi Bay, Bathymetry	1 : 10 000	ER049.2

Acronyms used and their meaning

ACP	African, Carribean, and Pacific
ADV	Acoustic Doppler Velocimeter
ARGO	Array for real-time geostrophic oceanography
ASCII	American Standard Code for Information Interchange
BP	Before present
CD	Chart datum
CTD	conductivity – temperature – depth
EEZ	Exclusive economic zone
EU	European Union
GDEM	Generalised Digital Environmental Model
GEBCO	General Bathymetry Chart of the Oceans
GPS	Global positioning system
LAT	Lowest astronomical tide
MBES	Multibeam echosounder
MRU	Motion reference unit
MSL	Mean sea level
NOAA	National Oceanic and Atmospheric Administration
PI-GOOS	Pacific Islands Global Ocean Observing System
RTK	Real Time Kinematic
S2004	Global bathymetry grid merging GEBCO and predicted depths from satellite altimeter measurements
SOPAC	Pacific Islands Applied Geoscience Commission
TAO	Tropical atmosphere ocean array
UTC	Universal Time Co-ordinated (Greenwich Meridian Time, GMT)
UTM	Universal transverse Mercator
WGS	World geodetic system

EXECUTIVE SUMMARY

Krüger, J. 2008. High-Resolution Bathymetric Survey of Niue. *EU EDF 8 – SOPAC Project Report 49*. Pacific Islands Applied Geoscience Commission: Suva, Fiji. 44 p. + 2 charts.

This report describes a high-resolution bathymetric mapping survey of the seabed surrounding the island of Niue. The survey was carried out over a period of six days in May 2005, resulting in the acquisition of over 550 km of multibeam echosounder (MBES) data. A temporary tide gauge was also installed at the Alofi Wharf for the duration of the survey.

The survey achieved 100 % coverage of the seafloor from approximately 50 m depth in the nearshore area to an average offshore distance of 5 km, reaching water depths of some 2000 m. The seafloor terrain was found to be highly irregular with an average slope of 22º. A review of external sources of available bathymetry was also undertaken, and the survey data was supplemented with publicly available data for Niue's EEZ. The resultant data compilation was used to produce bathymetry charts of Niue at a scale of 1:50 000, and a more detailed chart of Alofi Bay at a scale of 1:10 000. These new bathymetric maps give a descriptive picture of the ocean bottom terrain, vividly revealing the size, shape and distribution of underwater features, and serve as the basic tool for scientific, engineering, marine geophysical and environmental studies, as well as marine and coastal resource management.

The compiled bathymetry dataset was used to support the possible location of 13 seamounts within Niue's EEZ, as well as map some of the main morphological features of the seabed surrounding the island. The morphological interpretation shows a fault-bound graben structure to the north of Niue, which has developed due to Niue's position on the bulge of the outer rise crest of the Tonga Trench. The faults are trench parallel (generally N-S), and in the order of 100 km in length with scarp heights of 500 m. This bending-induced faulting is believed to have caused the failure of the island flank to the southwest of Tepa Point, where an 18 km-long linear scarp dominates the seabed morphology in 1000 m water depth.

Recommendations arising from this report are as follows:

- The water level gauge located at Alofi Wharf, operated by the Pacific Tsunami Warning Centre, should be levelled into existing bench marks, namely Tomb Point. Referenced against a known vertical datum, the measurements can be useful to determine the effect of ocean water levels on Niue's fresh water lens, and provide a link to the South Pacific Sea Level and Climate Monitoring Project.
- This report has highlighted the value of publicly available bathymetric data. It is recommended that future transiting oceanographic vessels are requested to map seafloor at the location of seamounts listed in this report, as well as improve coverage of the seabed immediately to the southwest of Niue, in order to confirm the shape and size of the presumed mass flow deposit.

2 INTRODUCTION

2.1 Background

This report describes a multibeam bathymetry survey of the seabed surrounding the island of Niue. This work was initiated by the SOPAC/EU project ‘Reducing Vulnerability of Pacific ACP States’. The purpose of this project is to provide a comprehensive GIS database containing information relating to three sectors of interests: aggregates for construction, water and sanitation, and risks and hazards. Seabed maps are of potential use for all three sectors, and consequently are a major activity within the project. With this in mind, the objective of the marine survey was to produce maps of the seafloor topography around the island of Niue using a multibeam echosounder (MBES).

In addition to the bathymetric maps presented in this report and their relevance to the SOPAC/EU project, it is envisaged that data from the survey will be used to support activities in fisheries, mineral exploration, coastal management, and geo-hazard studies.

2.2 Geographic situation

The island of Niue is in a relatively remote location in the South Pacific Ocean (Figure 1). Selected geographic facts about Niue are listed in the table below.

Geography of Niue	
Location	19°03’S and 169°52’W. Approximately 430 km east of Vava’u, Tonga, and 520 km southeast of American Samoa.
Population	Approximately 2000 (CIA, 2006). More than 18 000 (some 90%) Niueans lived in New Zealand in 1996 (Gibson, 2004).
Land area	Approximately 21.5 km long (N-S) by 14.5 km wide (E-W), with a maximum elevation of 68 m, and an area of approximately 263 km^2.
Coastline	78 km of predominantly steep limestone cliffs representing the reef rim of a former atoll. A dry valley south of Alofi, 42 m above present sea level, is interpreted as a former tidal passage (Forbes, 1996). The island is enclosed by a fringing rock platform and reef complex up to 150 m wide.
Tides	Tides are semi-diurnal with a spring and neap range of 0.7 m and 0.5 m, respectively (Nautical chart NZ845).
Climate	Light to fresh (3-5 m s^{-1}) southeast tradewinds dominate during the dry winter season from May to October. A wet summer season prevails from November to April, with winds from the north through west. The mean annual precipitation is 2009 mm, with temperatures around 25ºC (Kreft, 1986). In January 2004 cyclone Heta led to wide-spread destruction and wave overtopping on the west coast of Niue.
Exclusive economic zone, EEZ	Approximately 310 000 km^2 (Figure 4).

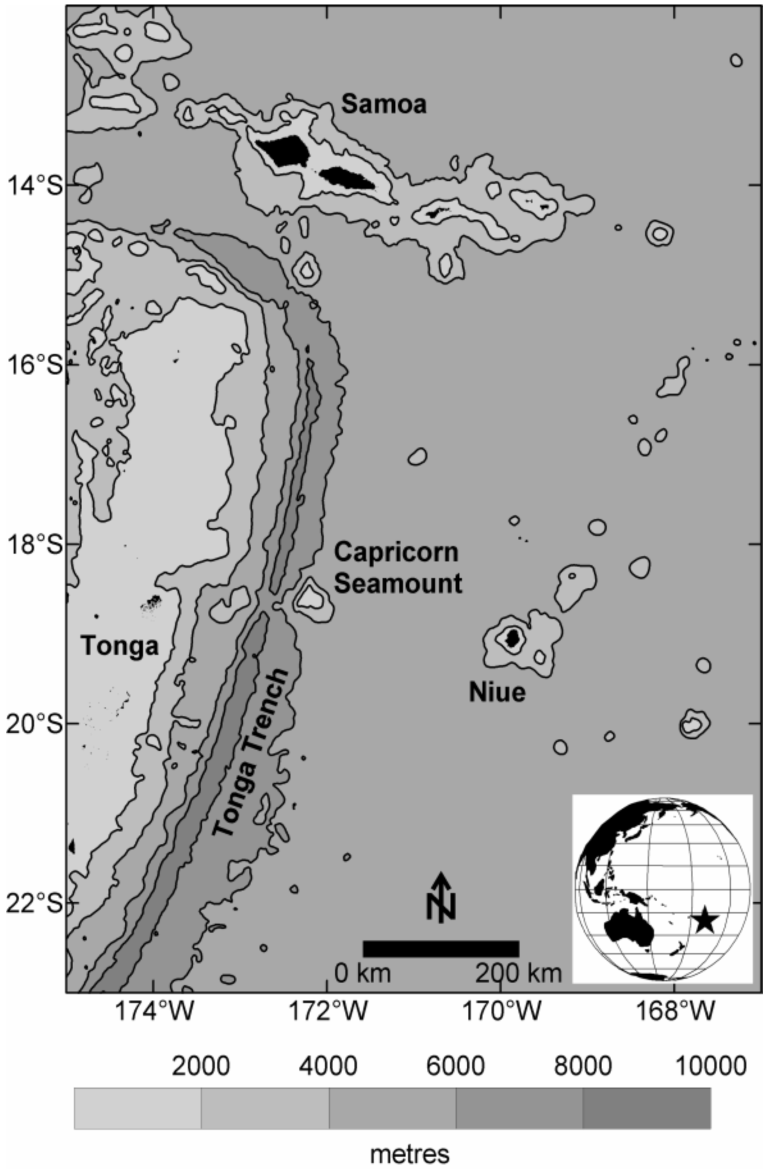


Figure 1. Map showing the regional setting of Niue, east of the Tonga Trench and southeast of Samoa. Bathymetry is S2004 data (Marks and Smith, 2006) shown with 2000 m contour intervals.

2.3 Geological setting

The modern island of Niue is a carbonate platform capping a submarine volcanic cone that rises more than 4000 m from the surrounding seafloor. It is situated on the Pacific Plate, approximately 300 km east of the Tonga Trench (Figure 1). Niue's westward movement toward the Tongan subduction zone has carried it onto a lithospheric bulge, subaerially exposing the previously subsiding atoll in the late Plio-Pleistocene, some 2 million years ago (Wheeler and Aharon, 1991). The carbonate sedimentary rocks occur to a depth of 300-400 m (Hill, 1996). The uppermost 300 m of the carbonate facies have been reported to be middle to late Miocene, or 7 to 12 million years old (Wheeler and Aharon, 1997).

2.4 Previous bathymetry compilations

Bathymetric maps are topographic maps of the sea floor, giving a descriptive picture of the ocean bottom terrain. With an EEZ of approximately 310 000 km^2, the available bathymetric data is limited, and the exact nature of the seafloor is poorly known. Most bathymetric data originates from sparse single beam soundings from oceanographic cruises, and, since the early 1990's, from MBES systems as well as satellite-derived predicted depth. A list of researchers which have assembled depth data for Niue is collated below.

Previous bathymetry compilations	
Brodie (1966)	Provisional bathymetry of Niue Island at 1:200 000.
Hydrographic chart NZ845	Publication of hydrographic surveys conducted by HMNZS Lachlan (1955) and by HMNZS Monowai (1994). Chart published at 1:150 000, with insets of Alofi Anchorage at 1:6 000, and Alofi Landing at 1:600. Copies of original fair sheets are held at SOPAC.
SOPAC Bathymetric Series Map 11 (1995)	Bathymetric map drawn from GEBCO 5th edition data. Map available at 1:2 500 000 (Woodward and Naibitakele, 1995). Map in pdf format available from the SOPAC virtual library, www.sopac.org.
Seafloor Imaging (1995)	Satellite bathymetry survey of the Niue EEZ with a grid size of 5 km. Map published at 1:1 800 000.
Hill (1996)	Bathymetry based on a geophysical cruise by the HMNZS Tui (1986), and various other sources dating back to 1962. Published map shows Niue island and the Endeavour and Lachlan seamounts with contour intervals at 500 m, covering an area of approx. 100 x 70 km.
Forbes (1996)	Total station surveys of selected coastal areas including Alofi Wharf. Elevations reported relative to 1955 MSL established by HMNZS Lachlan. Report and survey data available from the SOPAC virtual library, www.sopac.org.
S2004 (Smith, unpublished)	Global 1-minute (~2 km) bathymetry grid. S2004 merges the satellite altimeter derived Smith and Sandwell (1997) grid with GEBCO over shallow depths (Marks and Smith, 2006). S2004 is available via ftp from ftp://falcon.grdl.noaa.gov/pub/walter/Gebco_SandS_blend.bi2.

A comprehensive list and ship tracks detailing 20 cruises with predominantly single beam soundings within the Niue EEZ from 1962 to 1991 is given by Seafloor Imaging (1995). The present report includes an updated version of the EEZ bathymetry, which is presented below.

3 RESULTS & DISCUSSION

3.1 Multibeam bathymetry

The MBES bathymetry acquired during this study is shown on Chart 1 at a scale of 1:50 000 and contoured at intervals of 50 m. Chart 1 also shows multibeam bathymetry from other oceanographic surveys, and depths from the global S2004 grid. Chart 2 shows the bathymetry of Alofi Bay at a scale of 1:10 000, at contour intervals of 10 m. The charts also include smaller scale insets of three-dimensional perspective images.

The surveyed area extends from the coast to approximately 5 km offshore, and up to a maximum of 12 km off Alofi, to the west of the island (see coverage map in Appendix B). Water depths within the surveyed area ranged from 6 to 2600 m. Minimum water depths were measured near the coast on the outer slope of the fringing reef with depths becoming deeper in a general seaward direction at a mean slope angle of 22° toward the offshore limits of the survey area. Locally, the seabed is expected to be quite irregular with slope angles expected to be highly variable, ranging from 0 to 83° (Figure 2 and Figure 3).

The nearshore areas were generally mapped to minimum depths of 50-100 m. Nearshore coverage was best along the west coast, particularly between Halagigie Point and Alofi wharf. In this area, the vessel surveyed to within 50 m of the fringing reef, measuring depths of 15-30 m. Nearshore areas to the southeast, between Mata Point and Togo, could only be mapped to minimum depths of approximately 210 m. This was due to large incident swell waves from the southeast, which restricted vessel movement close to the reef edge.

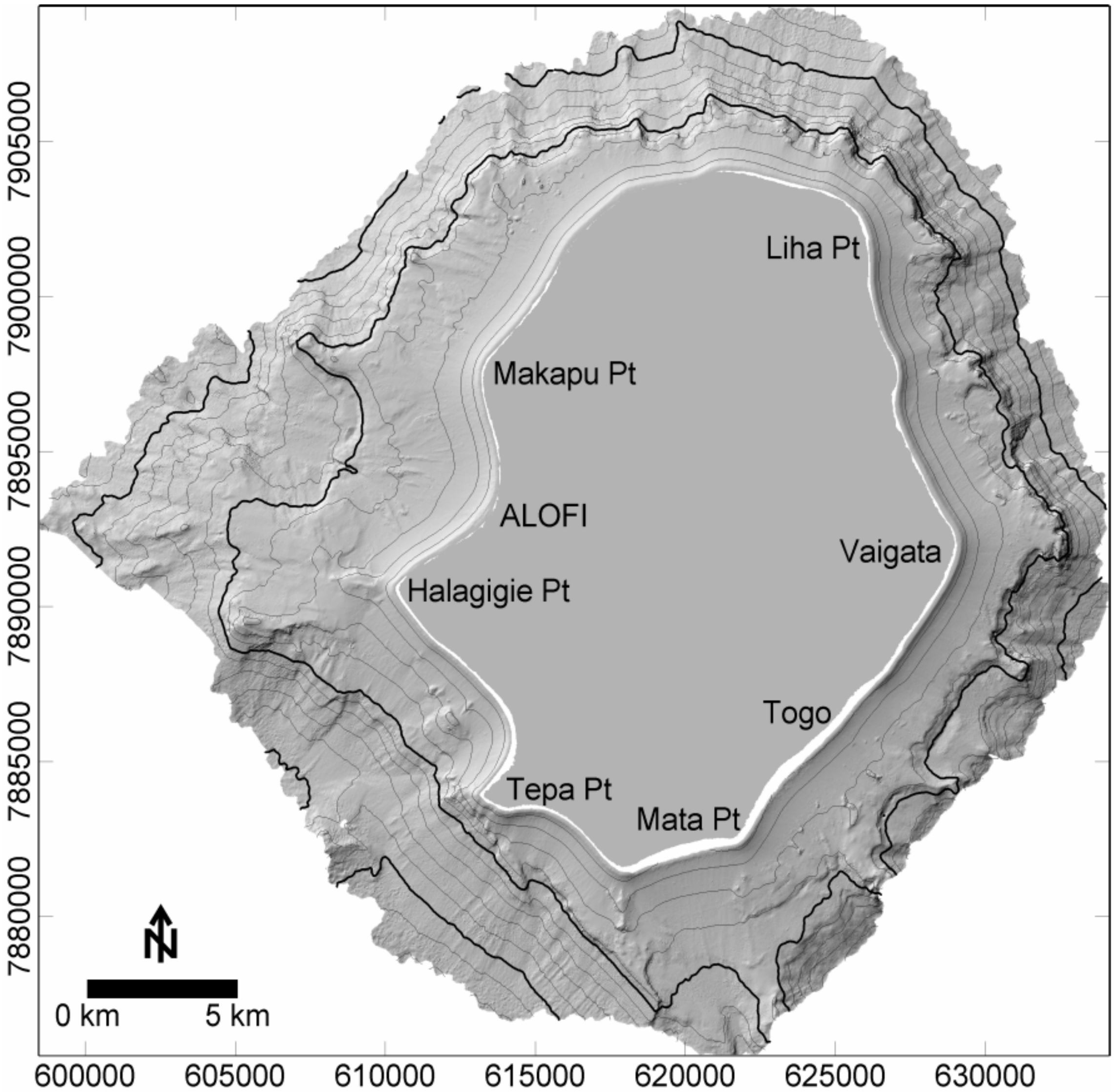


Figure 2. Shaded relief map of Niue's nearshore bathymetry. Illumination is from the northwest. Overlain are contours at 200 m intervals. The 1000 m and 2000 m isobaths are shown in bold.

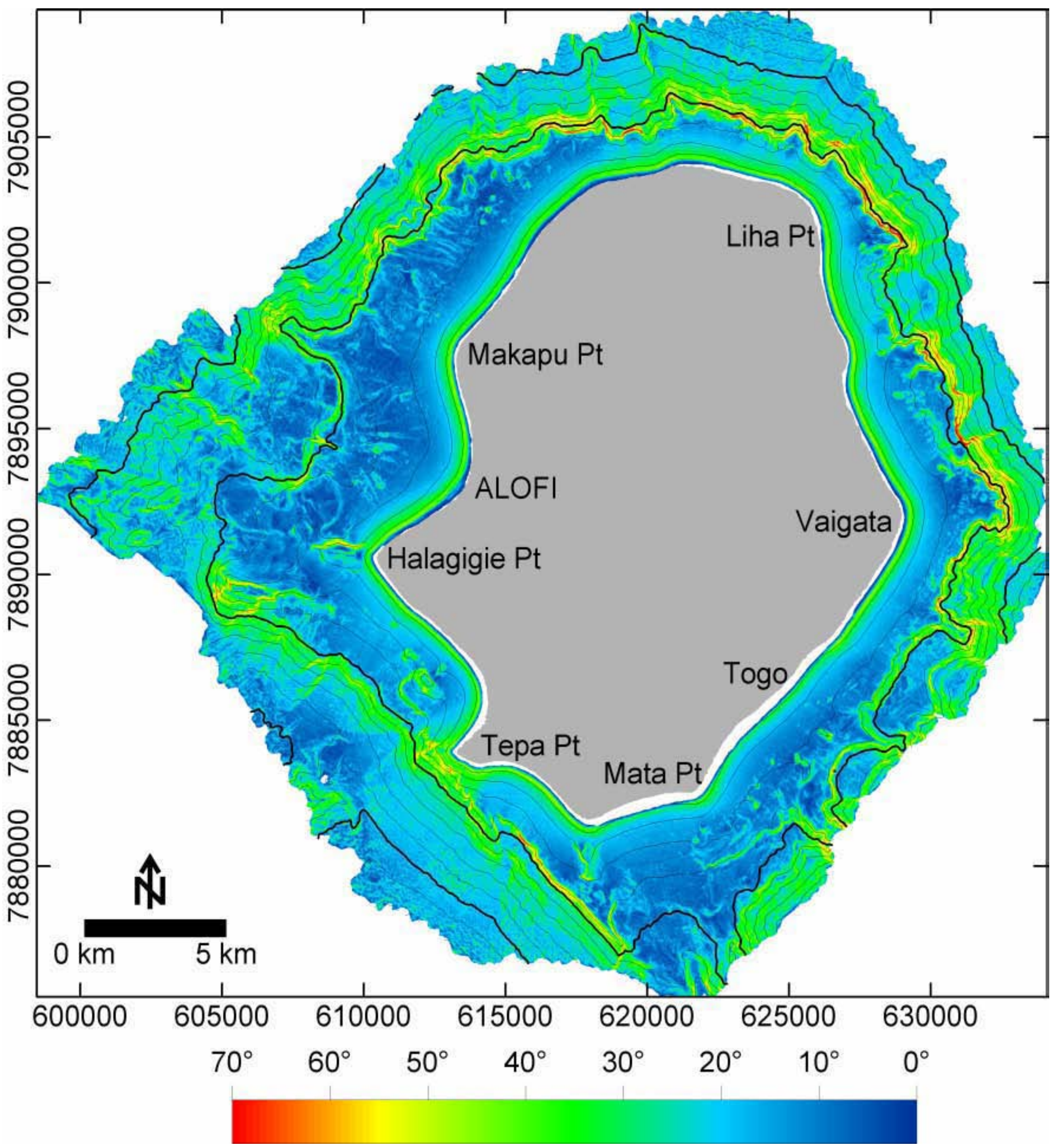


Figure 3. Slope map generated from 20 m gridded MBES bathymetry. Horizontal to steep from blue to red, respectively. Overlain are contours at 200 m intervals. The 1000 m and 2000 m isobaths are shown in bold.

3.2 Exclusive economic zone bathymetry

Public sources of bathymetric data were consulted in order to compile an EEZ bathymetric map for Niue. Data from recent multibeam surveys (1991-2003) were downloaded from the NOAA's National Geophysical Data Centre (http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html, accessed 05/01/2007), and merged with satellite altimeter-derived depths. The bathymetry from space used was the global topography S2004 data described in Marks and Smith (2006). Thus, the data sources used to compile the bathymetry in Figure 4 are listed below.

Survey Name	Ship	Institution	Instrument	Year
EW9106	Ewing	LAMONT (LDEO)	Atlas Hydrosweep DS	1991
WEST05MV	Melville	SCRIPPS	SeaBeam 2000	1994
WEST06MV	Melville	SCRIPPS	SeaBeam 2000	1994

WEST12MV	Melville	SCRIPPS	SeaBeam 2000	1995
BMRG09MV	Melville	SCRIPPS	SeaBeam 2000	1996
KIWI05RR	Roger Revelle	SCRIPPS	SeaBeam 2000	1997
NBP0304	Nathaniel Palmer	US NSF	Simrad EK500	2003
NIUE	Summer Spirit	SOPAC/EU	Reson SeaBat 8160	2005

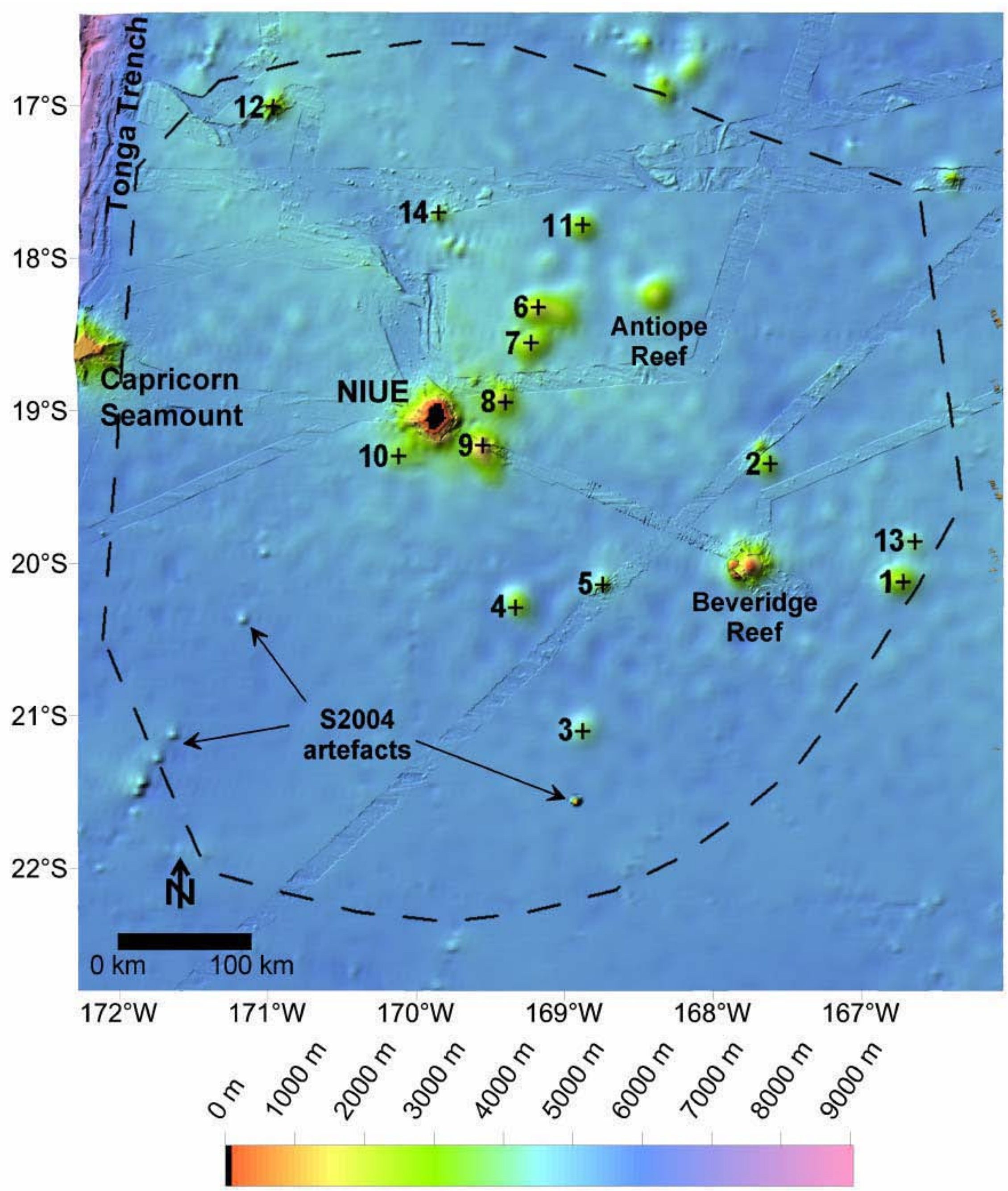


Figure 4. New depth compilation for Niue. The approximate position of the exclusive economic zone is shown as a dashed line. Seamount locations are shown as crosses. See text for details.

The higher resolution areas covered by the MBES swaths (100 m grid spacing) are in clear contrast to the predicted depth (~2 km DTM) shown elsewhere. Artefacts are caused by the local deviation between the MBES and the altimeter data and, to a lesser extend, between overlapping MBES swaths.

3.3 Seamounts

A seamount is generally defined as an independent feature that rises at least 1000 metres above the surrounding seafloor, with those that reach to within 200 m of the sea surface (the euphotic zone) classed as most relevant to fisheries and pelagic ecology (Allain et al., 2006). The Seafloor Imaging (1995) report on Niue's EEZ bathymetry includes a list of ten seamounts with summit depths of less than 3000 m. These have been reproduced and numbered one to ten in the table below. The bathymetry compiled for this report (Figure 4) shows additional seamounts listed under seamount numbers 11-14. The seamount locations listed below are also mapped in Figure 4.

Seamount	Latitude	Longitude	Notes
1	S 20º 07'	E 166º 45'	
2	S 19º 21'	E 167º 38'	
3	S 21º 05'	E 168º 53'	
4	S 20º 17'	E 169º 20'	
5	S 20º 08'	E 168º 45'	
6	S 18º 20'	E 169º 05'	S2004 data shows summit at S 18º 20', E 169º 11'.
7	S 18º 35'	E 169º 07'	S2004 data shows summit at S 18º 34', E 169º 14'.
8	S 18º 57'	E 169º 24'	Endeavour seamount
9	S 19º 14'	E 169º 33'	Lachlan seamount
10	S 19º 18'	E 170º 07'	Presumed mass flow deposit downslope from submarine landslide.
11	S 17º 48'	E 168º 53'	Unreported. Approx. depth 2720 m (source: S2004 data).
12	S 17º 02'	E 170º 57'	Unreported. Approx. depth 1240 m (source: cruise BMRG09MV).
13	S 19º 51'	E 166º 40'	Unreported. Approx. depth 3980 m (source: S2004 data).
14	S 17º 43'	E 169º 51'	Unreported. Approx. depth 3040 m (source: cruise WEST12MV).

Seamounts 11-14 were not reported by Seafloor Imaging (1995), but have been listed by Kitchingman and Lai (2004), who used the Global Digital Elevations Model (Etopo2) grid to identify potential locations of seamounts. The Etopo2 grid is miss-registered however, and locations reported by Kitchingman and Lai (2004) are generally 5-6 km northeast of the positions given in the table above.

3.4 Morphological features

The general morphological trend of the seabed around Niue is summarised in the table below.

Summary of seabed morphology	
~0 m	Modern fringing reef and rock platform, up to 150 m wide.
~13 m	Submarine terrace, 150 m wide
~34 m	Submarine terrace, 80 m wide
34-250 m	Seaward sloping seabed, slope angles 30-40°

Summary of seabed morphology	
250-800 m	Seaward sloping seabed, slope angles 0-20°. Occasional large blocks.
800-1400 m	Numerous seaward convex scarps, slope angles 30-60°, exceeding 60° to the north and northeast.
1400 m to max. survey depths	Variable relief including numerous arcuate scarps, sidewalls, canyons, and flats. Slope angles 0-40°

The nearshore bathymetry at Alofi shows two terraces below the fringing reef platform. The first is a 150 m-wide terrace at an average water depth of 13 m. The lower terrace is 80 m wide at an average depth of 34 m. These submarine terraces have previously been described by Schofield (1959). Below these terraces, the seabed slopes at angles of 30-40° to depths of approximately 250 m. Depths to 800 m are characterised by much gentler slopes of 0-20°. Occasional large blocks several 100 m in length and with a relief of ~50 m occur in water depths of 400-600 m, especially in the southern half of the survey area. Depths of 800-1400 m are characterised by maximum slopes of 30-60°, exceeding 60° to the north and northeast of the island. Depths exceeding 1400 m are characterised by seabed that shows numerous escarpments, sidewalls and minor canyons.

In addition to the broad description given above, the high resolution MBES data was also used to classify the marine habitat in geomorphic terms as shown in Figure 5. This was done through the interpretation of bathymetric derivatives such as those given in Figure 2 and Figure 3, and describing the observed features according to the terms and nomenclature endorsed by the International Hydrographic Organisation (IHO, 2001) as defined in the table below.

Geomorphic feature	Definition
Apron	A gently dipping featureless surface, underlain primarily by sediment, at the base of any steeper slope.
Canyon	A relatively narrow, deep depression with steep sides, the bottom of which generally has a continuous slope, developed characteristically on some continental slopes.
Escarpment	An elongated and comparatively steep slope separating gently sloping areas.
Knoll/Hill/Peak	A small isolated elevation
Pinnacle	Any high tower or spire-shaped pillar or rock or coral, alone or cresting a summit. It may extend above the surface of the water. It may or may not be a hazard to navigation.
Reef	Rock/Coral lying at or near the sea surface that may constitute a hazard to surface navigation.
Ridge	A long, narrow elevation with steep sides.
Shelf	Zone around an island extending from the low water line to a depth at which there is usually a marked increase of slope towards oceanic depths.

Slope	Slope seaward from the shelf edge to the upper edge of a continental rise or the point where there is a general reduction in slope.

The EEZ-wide MBES compilation shown in Figure 4 is spatially limited, in comparison to the high resolution MBES data in the nearshore area that allows for a relatively detailed geomorphic interpretation on the flanks of the Niue edifice. However, Figure 4 reveals mesoscale features, and permits a partial interpretation of the seabed morphology as shown in Figure 6. The seafloor around Niue comprises numerous mounds and NNW-ESE trending ridges, giving the seabed a rough and hummocky bathymetric fabric. The lineations are interpreted abyssal hills that are approximately 50-250 m high and up to 50 km long. The abyssal hills were formed by constructional processes, such as faulting and volcanism, which were active when the Pacific plate was first generated by seafloor spreading, and are thus remnant mid-ocean ridge-parallel lineaments (Goff et al., 2004; Smith and Sandwell, 2004). The numerous minor mounds (1-4 km wide and 50-400 m high) are believed to be volcanoes and lava flows. The prominent feature shown by the multibeam bathymetry is a fault-bound graben structure to the north of Niue. The graben is constrained by distinct NNW-SSE trending sub-parallel faults that are in the order of 100 km in length. The fault scarp heights are significant, resulting in an average graben depth of 5200 m, approximately 500 m lower than the surrounding seafloor, as shown by the profile in Figure 6. Individual abyssal hills can be traced across fault scarps without significant horizontal offsets, indicating that the mapped faults are new bending-induced faults which have broken the seafloor as Niue moved onto the outer rise crest of the Tonga Trench. This is believed to be similar to the trench-parallel faulting observed on the outer slopes of the Tonga Trench by Wright et al. (2000), where fault scarp heights of nearly 1 km have been reported (Mofjeld et al., 2004).

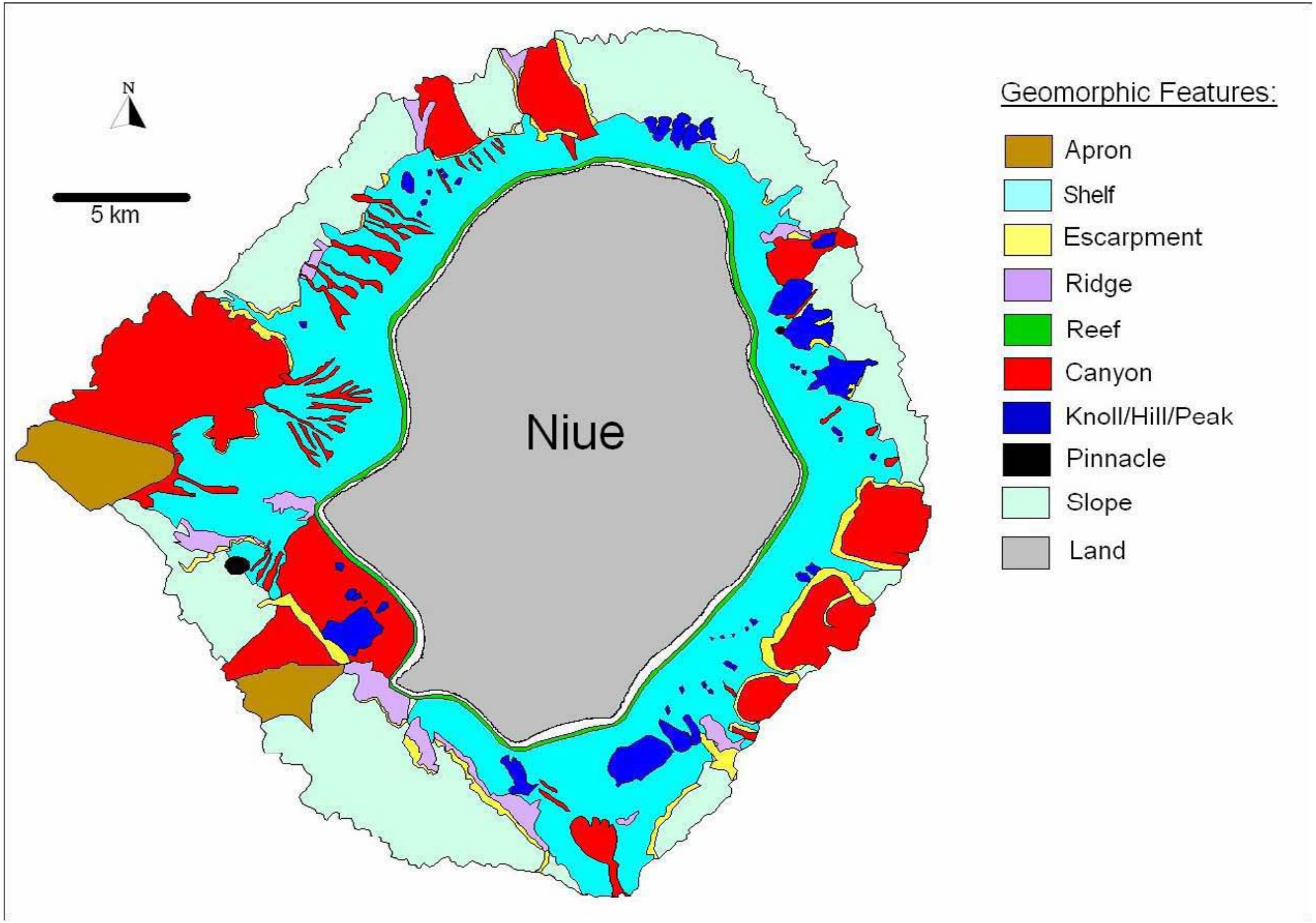


Figure 5. Map of principal morphological features of the seabed surrounding Niue.

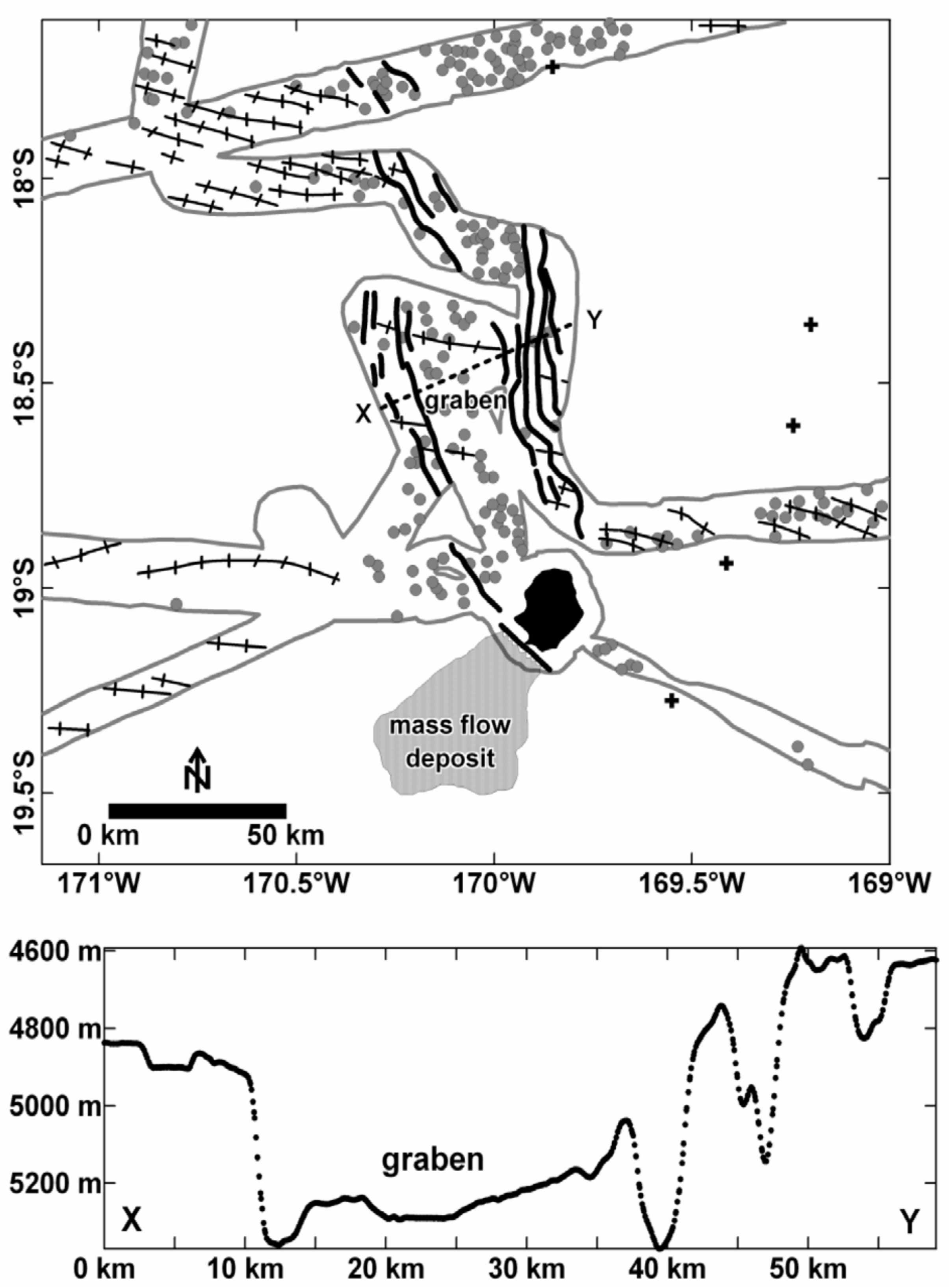


Figure 6. Map of principal morphological features based on the interpretation of compiled multibeam bathymetry data shown in Figure 4. Lines with cross-hatching are abyssal hills. Solid lines indicate mapped fault scarps. Circles mark locations of volcanoes. The shaded area to the southwest of Niue delineates a presumed mass flow deposit. Crosses show locations of seamounts. Grey heavy lines delineate areas of available multibeam bathymetry. The profile (lower panel) location is shown by the dashed line in the upper panel.

The bathymetric high immediately to the southwest of Niue has previously been mapped as a seamount (Seafloor Imaging, 1995). Only altimeter-derived depths are available in this location, the shape however appears less peaked and much broader compared to other seamounts within Niue's EEZ (Figure 4). Dredge sampling in this area at depths of 2500 m and 3500 m, approximately 10 km and 15 km south of Tepa Point, respectively, recovered altered Tuff, vesicular Basalt, coral fragments, Pumice, and limestone rubble (Hill, 1996).

Land-based gravity and magnetic surveys of Niue Island have indicated that the volcanic substructure consists of a roughly flat-topped volcanic core that is centred in the southwest of the island at a depth of 300-400 m below sea level (Hill, 1983). An asymmetric skew of the volcanic core to the southwest was confirmed by a sparse marine geophysical survey that acquired echo sounder, gravity, magnetic and seismic reflection measurements (Hill, 1996). This suggests that the island collapsed near the end of the volcanic phase of island formation (Hill, 1996; Nunn, 2004). A cataclysmic event or caldera collapse (Hill, 1996), or caldera collapse after the resumption of lava eruptions following a hydro-explosive period (Nunn, 2004), are processes that are expected to result in arcuate escarpment features.

Hill (1996) noted that the isobaths on the southwest flank have distinct NW-SE trend, and suggested that a major structural zone intersects this area. The multibeam bathymetry in this area indeed shows a NW-SE orientated 18 km-long sub-linear scarp along the 1000 m isobath, with small canyons cutting the lower slopes but not reaching the break-in-slope of the headscarp. A fault line (see Figure 6, and de terminates below 1000 m isobath in Alofi Bay, and continues in the form of a linear scarp along Niue's southwest flank, again in close proximity to the 1000 m depth contour. The linearity of this scarp is in definite contrast to other collapse features observed on the bathymetric data, which are convex seaward and separated by terminal points that radially protrude perpendicular to the coastline (Figure 2). The morphology to the southwest of Niue is therefore interpreted to be a mass flow deposit generated by downslope movement of debris from a fault-induced submarine landslide. This concept is illustrated in Figure 7. The submarine landslide is therefore presumed to have occurred near the end of the atoll stage, triggered by the growth of an incipient bending-induced normal fault, cutting across the southwest flank of the Niue edifice.

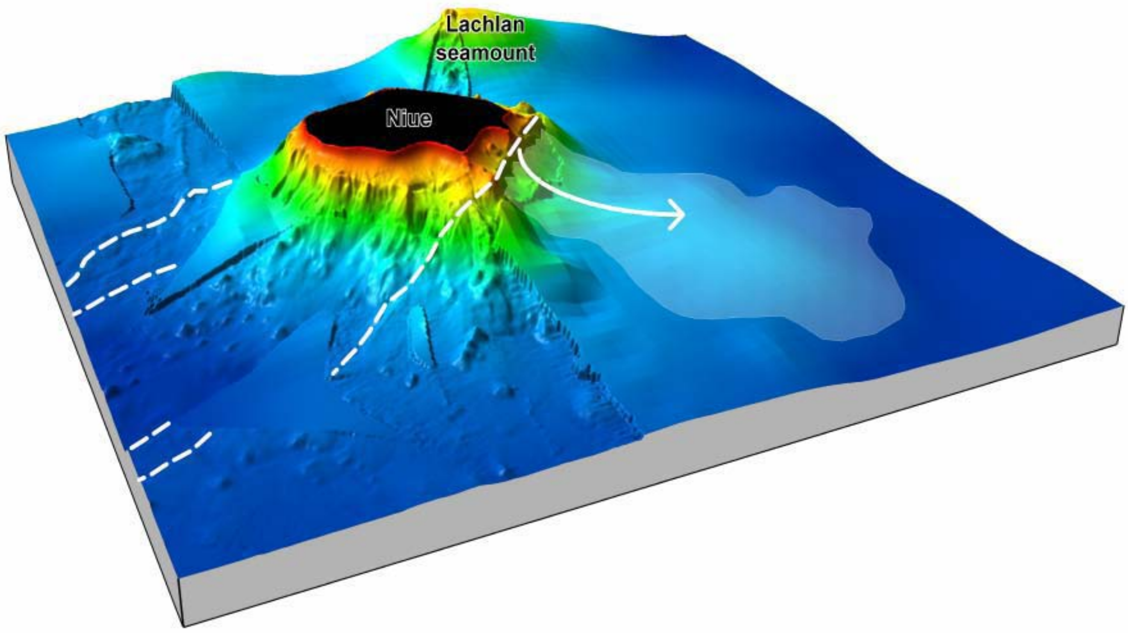


Figure 7. Three-dimensional perspective view of Niue, looking southeast, illustrating mapped fault scarps (white dashed lines) and the interpreted mass flow deposit downslope from the linear flank failure (shaded area). Note the significant vertical offset between S2004 data and the available multibeam bathymetry.

4 DATA ACQUISITION AND PROCESSING

4.1 Fieldwork summary

Survey Particulars	
Survey vessel	R.V. Summer Spirit
Fieldwork dates	08/05/2005 to 13/05/2005
Equipment Used	Reson Seabat 8160 MBES Sontek Triton ADV
Survey programme (line km)	555.6 km

All dates and times in this report are given in the local Niue time zone (UTC -11hrs). The coverage of the MBES survey is shown in Appendix B.

4.2 Field personnel

SOPAC	
Jens Kruger	Physical Oceanographer
Kalisi Fa'anunu	Technical Officer
Peni Musunamasi	Electronics Engineer

Vessel	
Brian Hennings	Master
Gordon Elliot	Officer
Nelson Tafilangi	Engineer
Elias Mckay	Cook

Observer	
Jay Talangi	Department of Fisheries

4.3 Geodetic reference system

The survey results were mapped in terms of the following geodetic reference system:

Geodetic datum	WGS84	
Ellipsoid	WGS84	
	semi-major axis (a)	6378137.000
	semi-major axis (b)	6356752.314
	inverse flattening (1/f)	298.257223563
	eccentricity sq. (e^2)	0.0066943800
Projection	UTM Zone 2S	
	projection type	Transverse Mercator
	origin latitude	00° 00' 00.000" North
	origin longitude	177° 00' 00.000" East
	origin false easting	500 000.000
	origin false northing	10 000 000.000
	Scale factor	0.9996000000
	grid unit	Metres
Geodetic transformation	from WGS84 (GPS satellite datum) to UTM 2S	
	source coordinate system	WGS84
	target coordinate system	UTM 2S
	transformation parameters	
	dX	0.00
	dY	0.00
	dZ	0.00
	rX	0.00000
	rY	0.00000
	rZ	0.00000
	scale	0.00000

4.4 Vessel description and static offsets

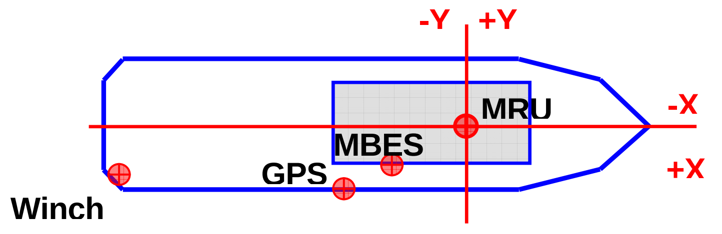
Sensor	X (m)	Y (m)	Z (m)
Reference point at water level	0.00	0.00	0.00
Motion Reference Unit (MRU)	0.00	0.00	1.82
Positioning Antenna (GPS)	2.17	-6.92	-6.29
Multibeam Echo Sounder (MBES)	0.86	-3.96	0.80
Magnetometer tow point	N/A		
Winch	1.92	-14.25	4.00

Vessel

Name	RV Summer Spirit
Length overall	25 m
Breadth (mid)	6.6 m
Draft (mid)	1.8 m
Displacement	65 t
Port of registry	Brisbane
Official No.	IQ115Q

A photo of the vessel is shown in Figure 8

Not to scale



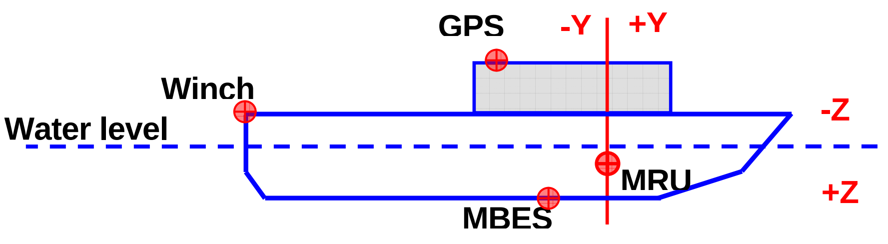


Figure 8. The chartered survey vessel RV Summer Spirit.

4.5 Positioning control

The vessel's reference point (X=0, Y=0, Z=0) was the motion reference unit (MRU) position at the waterline. Positioning was by stand-alone GPS, using an Ashtech Aquarius dual-frequency P-code receiver. A good satellite constellation status was observed throughout the survey. The pre-survey patch test was conducted in Suva, Fiji (see details below).

4.6 Survey computer

The survey computer was a Windows 2000 PC running Hypack 4.3. This computer was used for continuous on-line data logging and computation of positioning and digital bathymetry. The package also provided a line control display for the helm. The on-line operator continuously monitored a range of quality control parameters.

An off-line Hypack 4.3A package was used in the office for replaying and post-processing of track data and bathymetry. An A0 plotter was available for the production of charts.

4.7 Multibeam echo sounder

A Reson SeaBat 8160 multibeam echo sounder was installed on RV Summer Spirit, and was used to provide swathe bathymetry data.

The main instrumental and auxiliary operating parameters are listed below.

Instrumentation	
Multibeam echo sounder	Reson SeaBat 8160
Transducer mount	Starboard side hull
Motion reference unit	TSS DMS 2-05 Dynamic Motion Sensor
Gyro	SG Brown Meridian Surveyor Gyro Compass
Sound velocity probe	Sea-Bird SBE19+ / Argo / GDEM.

Operating Parameters	
Transducer Frequency	50 kHz

Operating Parameters	
Velocity Sensor at Transducer	Measured by Sound Velocity Probe.
General water depth	10 – 2500 m
Average ship's speed	6 knots (3 m s^{-1})
Transmit Power	Variable 1-16
Pulse length	Variable 0.5 - 8.0 ms
Horizontal coverage	Approx. 0.8 - 2.0 $\times$ water depth
No of beams	126
Ping rate	Maximum 2 Hz

Calibration	22/04/2005
Roll correction	-0.70
Pitch correction	-1.00
Yaw correction	-1.00
GPS Latency correction	0.7
Gyro correction	Not determined
Draft correction	0.8 m

The dynamic calibration offsets for the MBES were determined during a pre-survey patch test conducted in Suva, Fiji, using autonomous GPS as no other system was available at the time. The patch test and bar check were performed in accordance with procedures contained in USACE (2002).

4.8 Multibeam echo sounder data processing

On return to SOPAC's office, Hypack 4.3A software was used for the post-processing of the MBES survey data. The production of contour maps was done using Surfer 8.05 software. The processing and gridding sequences are listed below.

Post-processing Sequence	
Phase 1	Tidal and sound velocity corrections. Navigation checked for poor GPS positioning.
Phase 2	Removed poor quality beams (quality<3) and outliers from individual survey lines.
Phase 3	Applied 4th standard deviation filter to remove outliers from median depth. Further manual cleaning of outliers.
Output	ASCII XYZ file using actual positions of median sounding depths in the project coordinate system.

Map Production Sequence	
Input	XYZ output data from Hypack reduced to 1 mm at charting scale (e.g. 50 m-grid size for a chart at 1:50 000).

Surface Model	XYZ data were gridded using the Kriging method in Surfer 8.05. Data gaps were interpolated using three times the grid spacing.
Output	DXF contours, PDF chart, backdrop images, and DTM model in the project coordinate system.

Various levels of smoothing were applied to the contours and DTM, which gave a realistic impression of the seabed without removing any real features from the data set.

4.9 Multibeam backscatter

The MBES records echo strength data (reflected energy) that can be presented as seabed backscatter maps, similar to sidescan sonar. A sidescan sonar mosaic, or backscatter image, shows information on the composition of the seafloor. The backscatter signal recorded along with the MBES data was of very poor quality and was therefore not processed or interpreted.

The backscatter intensity is largely a function of the properties of the superficial seafloor material, particularly the physical shape of individual components, and the angle of incidence of the sonar beam as it encounters a reflective surface. The surveyed area consisted of generally steep seafloor with an average slope of 22º from the horizontal. It was found that the quality of the sounding data was best while circumnavigating the island with shore-parallel track lines. However, the steep nature of the seafloor resulted in very high incidence angles of the sonar beam, with swath width dropping to less than one times the water depth. MBES settings such as pulse length, range, and transmit power were continuously modified in order to maintain optimum quality and maximum coverage of depth soundings. The overall quality of backscatter was therefore very poor, with data showing very high amplitude returns on the channel facing the island flank, whilst the channel facing offshore and downslope contained little or no returns. Good quality bathymetry data was therefore acquired at the expense of the backscatter data.

4.10 Tidal information

A Sontek Triton acoustic Doppler velocimeter (ADV) was used as a temporary tide gauge during the survey. The ADV was installed at the southern end of Alofi Wharf a distance less than 15 m from BM2 on 4 May 2005, and levelled to BM2 using a theodelite with an approximate accuracy of 4 mm (Hubert Kalauni, pers. comm., 4 May 2005). The pressure port opening of the ADV was then referenced to the sounding datum, and the recorded water levels were used to reduce the measured water depths to the HMNZS Monowai 1994 sounding datum as defined in Robbins (1994). The distance of 4 cm between the pressure port opening and the position of the pressure sensing element (the zero point) within the ADV was not accounted for and introduced an index error and linear offset. No additional tide pole was established or direct comparison to a secondary physical marker was undertaken. The recorded pressure is shown in Figure 9 below.

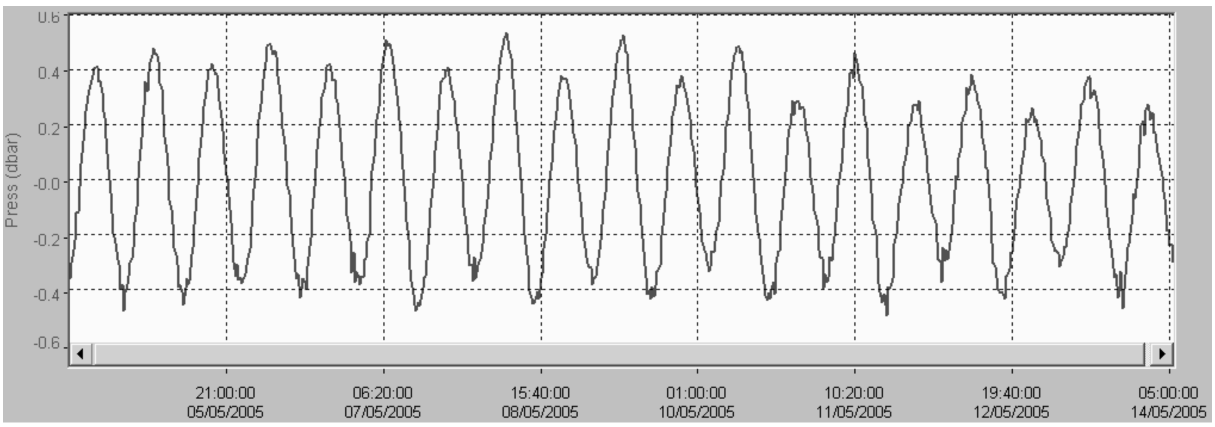


Figure 9. Record of the pressure (decibar) as recorded by the ADV. Mean removal applied.

Sounding Datum	
5.573 m below BM1, also known as MWBM 178 94/1	RNZN Brass Benchmark plate cemented into the northern corner of Alofi Wharf.
3.165 m below BM2, also known as MWBM 178 94/1	Stainless steel terrier bolt recessed in concrete steps to the east of the boat ramp at Alofi Wharf.
19.174 m below Tomb Point	Niue Fundamental Station N001.

The hydrographic chart NZ845 refers to this datum with the following tidal levels at Alofi Wharf.

Tidal Heights	
MHWS	1.1 m
MHWN	1.0 m
MLWN	0.5 m
MLWS	0.4 m
MSL (derived)	0.75 m

The sounding datum deduced by HMNZS Monawai in 1994 is approximately 0.30 m lower than the MSL deduced by HMNZS Lachlan in 1955 (Figure 10). The stand pipe referenced to the HMNZS Lachlan 1955 datum is no longer available (Hubert Kalauni, pers. comm., 4 May 2005).

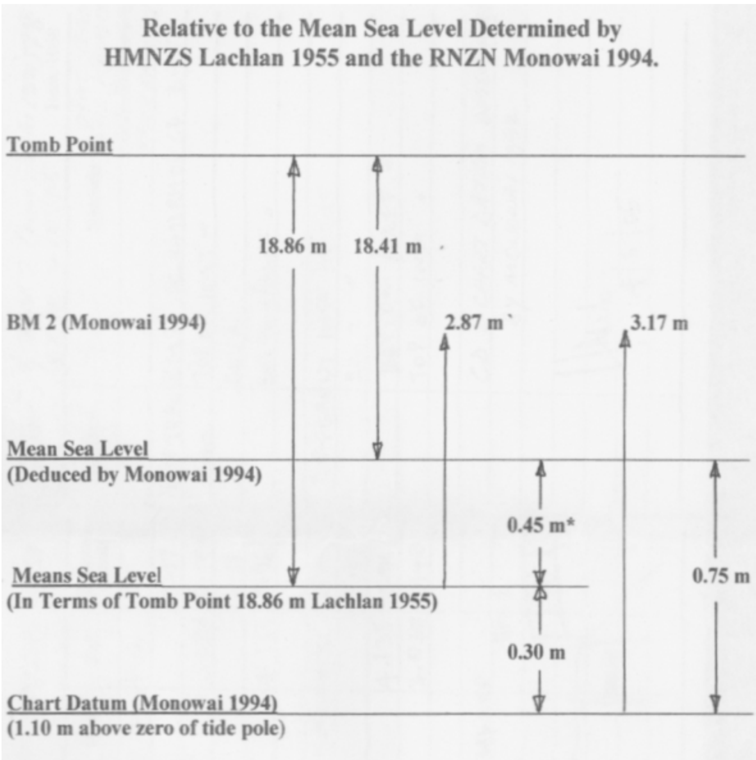


Figure 10. Diagram showing the tidal levels at Alofi Wharf, Niue. Drawn by H.M. Kaulani (23 August 1994).

The Pacific Tsunami Warning Centre has a water level gauge located at the Alofi Wharf, which was established in October 2004. The gauge consists of two Druck pressure sensors that take 2 s samples which are averaged over a 2 minute period. Data are transmitted via the GEOS satellite to NOAA's National Environmental Satellite, Data and Information Service every hour

(Richard Nygard, pers. comm., 15 April 2005). Unfortunately, the gauge is not levelled into existing bench marks as the installation is not part of the South Pacific Sea Level and Climate Monitoring Project.

4.11 Sound velocity profiling

The accuracy of the depth soundings depends in part on the variation of the speed of sound with water depth. Sound velocity profiles are therefore required in order find the correct depth and location of water depth soundings. The speed of sound in seawater varies with temperature, salinity and depth, and was determined by measuring the conductivity, temperature and depth (CTD) through the water column. The main instrumental, operational, and processing parameters are listed below.

CTD Instrumentation	
Make	SeaBird Electronics
Model	SeaCat 19+ (self-powered, self-contained)
Serial number	4716
Calibration	11/01/2005
Depth rating	3000 m

Operating Parameters	
Sample rate	1 scan every 0.5 s
Data recorded	Profiles of conductivity, temperature, and pressure
Maximum depth	400 m (limited by on-board wire rope length)

Data Processing	
Positioning	The profile position was taken at the GPS attenna near the start of the downcast. Vessel drift may have been significant (~500 m) over the duration of the profile.
Data conversion	Converted raw data (.hex) to a .cnv file. The following values are output from the recorded data: Pressure, dbar Depth, m (derived using salt water at local latitude) Temperature, deg C (ITS-90) Salinity, psu (derived) Density, kg m^{-3} (derived) Sound velocity, m s^{-1} (derived using Chen and Millero, 1977)
Bin average	Averaged data into 1 m depth bins. No filtering was applied.
Output	Processed data was saved in ASCII text format with the file name *date_location*_bin.cnv.

CTD profiles are listed below. A summary of the CTD profile data in graphical form are shown in Appendix D. Locations are shown in Figure 11.

Open Water Profile	Date	Time	Easting	Northing	Water Depth
Alofi Bay	08/05/2005	17:40	610529	7893242	753m

Open Water Profile	Date	Time	Easting	Northing	Water Depth
Alofi Bay	11/05/2005	05:32	611557	7895179	723m

The on-board CTD probe could only be operated to a maximum depth of 400 m due to restrictions on the wire rope length. The ship-based profile data were complemented with external sources of sound velocity data, in order to ensure corrections for depth soundings exceeding 400 m. These sources consisted of measured temperature and salinity profile data from an Argo float and a predicted sound velocity profile from the Generalised Digital Enviornmental Model (GDEM). The Argo data were collected and made freely available by the International Argo Project and the national programmes that contribute to it (www.argo.ucsd.edu and argo.jcommops.org). Argo is a pilot programme of the Pacific Islands Global Ocean Observing System (PI-GOOS). The GDEM is a global climatology model developed by the U.S. Naval Oceanographic Office and provides monthly temperature, salinity, and sound velocity profiles on a global ¼ degree grid (https://128.160.23.42/gdemv/gdemv.html). Parameters of these sources are given below.

Argo float	
Profile ID	CO_5900624_20070102_033817
Date	24/06/2005
Latitude	19 07.50ºS
Longitude	169 27.36ºW
Easting	662400 E
Northing	7884624 N
Available data	Pressure, salinity, temperature
Bin size	From 5-50 m, steps increasing with depth
Maximum Depth	981 m

Generalised Digital Environmental Model Data (GDEM)	
Data file version	3.0
Date	Monthly average for April
Latitude	19.00ºS
Longitude	169.75ºW
Easting	631571 E
Northing	7898705 N
Available data	Depth, temperature, salinity, sound velocity
Bin size	From 2-200 m, steps increasing with depth
Maximum Depth	2800 m

The Argo profile data were used to calculate the speed of sound utilising the Chen-Millero equation (Chen and Millero, 1977). This is the same method used by the SeaBird CTD software. The GDEM model provided a monthly mean of sound velocity.

The final sound velocity profiles used to correct MBES data were therefore a construction from three sources as summarised in the table below. Figure 11 shows the location of the profiles and a plot of the sound velocity data of the various sources is shown in Figure 12.

Sound Velocity Data Source	Water Depth

Sound Velocity Data Source	Water Depth
CTD casts	1 m to a maximum of 393 m
Argo floats	400 m to 981 m
GDEM model	1000 m to 2800 m

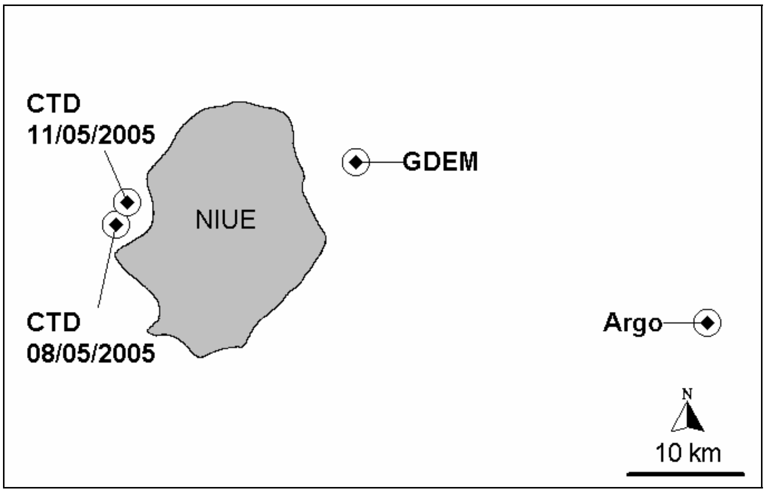


Figure 11. Map showing the location of CTD casts and Argo and GDEM profile locations.

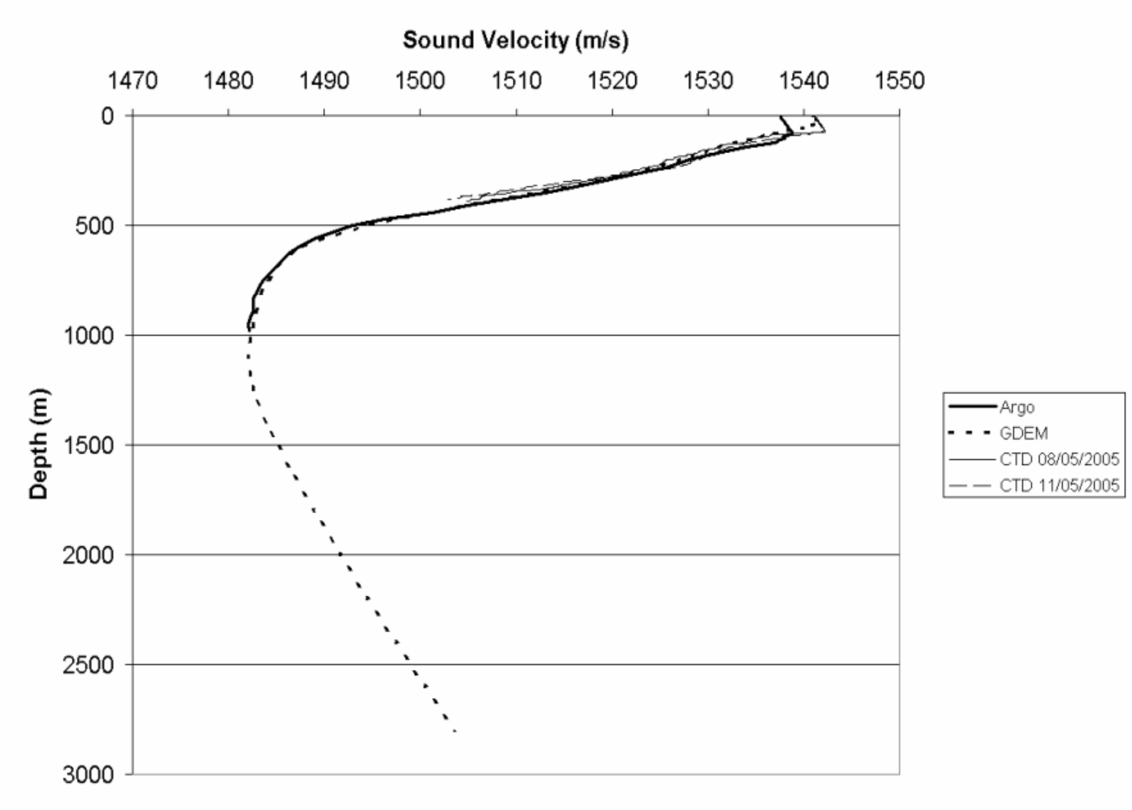


Figure 12. Plot showing the sound velocity profiles used for MBES data correction.

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6 APPENDIX A - STATEMENT OF ACCURACY AND SUITABILITY FOR CHARTING

Bathymetric maps are topographic maps of the sea floor. The bathymetric map serves as the basic tool for performing scientific, engineering, marine geophysical and environmental studies. The information presented in this report and enclosed charts are intended to assist persons and authorities engaged in recreation, tourism, marine resource related industries, hydrographic mapping, coastal development, trade and commerce, sovereignty and security, and environmental management. It is consequently important that users be informed of the uncertainties associated with the data and with products constructed from it. The following is an outline of the survey equipment used and the operating principles, including limitations and estimates regarding the data accuracy.

6.1 Horizontal positioning

The methods used to acquire survey data will affect the final product accuracy. The global positioning system, GPS, uses radio signals from satellites that orbit the earth to calculate the position of the GPS receiver. Stand alone GPS has an estimated accuracy as good as approximately 10 m, depending on satellite configuration and atmospheric conditions. In addition to this, equipment and measurement errors also need to be considered.

A general rule of thumb is that surveys should be conducted with a positioning accuracy of 1 mm at the scale of the chart. Therefore, at a chart scale of 1:10 000, the survey would be required to be accurate to 10 m.

The present S-44 4th Edition Standard of the International Hydrographic Office (IHO) includes a depth-dependent factor that takes into account the added uncertainty of the positions of soundings from multibeam echo sounder systems as water depth increases. The relevant survey orders are listed below, with multibeam surveys conducted by SOPAC generally falling into orders 2 or 3.

Survey order	Application	Recommended horizontal accuracy
Order 1	Harbours and navigation channels	5 m + 5% of depth
Order 2	Depths < 200 m	20 m + 5% of depth
Order 3	Depths > 200 m	150 m + 5% of depth

For the purpose of this survey, it was assumed that the use of stand-alone GPS provided adequate precision in terms of horizontal position. Therefore, it is not recommended to interpret nearshore data at scales larger than 1:10 000, or a grid size smaller than 10 m. For areas with water depths greater than 200 m, a charting scale of at least 1:50 000 is recommended.

6.2 Depth measurements

Bathymetric maps provide information about the depth of water from the water surface to the seabed. Through the use of detailed depth contours and full use of bathymetric data, the size, shape and distribution of underwater features are clearly revealed. The depth is measured using a ship-mounted multibeam echo sounder (MBES). The MBES transducer produces an acoustic pulse designed as a fan that is wide in the across-track and narrow in the along-track direction (Figure 13). The swath of seabed covered by this transmit beam is typically more than twice the water depth. The pulse of sound emitted from the MBES travels through the water column and is reflected back as an echo and received as numerous narrow beams by the receiving elements of the MBES. The measurements are time based, and by using the speed of sound in seawater each time is converted first to a range and then, knowing the beam angle, to a depth. The distance to the seabed is then combined with the movement of the vessel to stabilise it into a real-world framework. This framework is then positioned to provide XYZ soundings for each beam's interaction with the seabed. A series of these swaths are then combined to produce a three-dimensional representation of the seafloor topography.

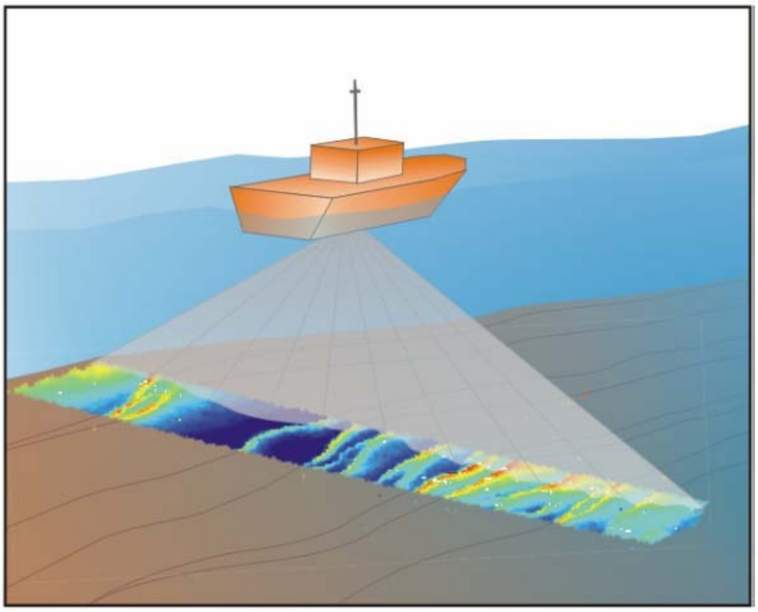


Figure 13. Conceptual illustration of bathymetric data acquisition with a multibeam echosounder, MBES (source: http://www.rcom.marum.de, accessed 10/01/2007).

The accuracy of the MBES system is critically dependent on the corrections applied for vessel motion (heave, pitch, roll, yaw, and heading). However, the absolute accuracy of single beam and multibeam bathymetry depends on several factors that are not easy to determine. For single beam data, probably the principal errors that may be introduced are due to topographic features falling between survey lines. Multibeam systems give far better coverage.

The S-44 4th Edition Standard of the IHO lists values "a" and "b", which should be introduced into the following equation to calculate the error limits for depth accuracy:

$\pm\sqrt{a^2 + (b \times d)^2}$, where d = depth.

Survey order	Application	Constants
Order 1	Harbours and navigation channels	a = 0.5 m, b = 0.013
Order 2	Depths < 200 m	a = 1.0 m, b = 0.023
Order 3	Depths > 200 m	a = 1.0 m, b = 0.023

For example, the IHO recommends that a near-shore coastal survey (Order 2) in water depths of 20 m should have a maximum depth error of ±1.1 m.

A MBES has, as any other measuring instrument, an inherent limit in its achievable accuracy. The total measurement accuracy, *i.e.* the uncertainty in the depth and location of the soundings, also depends upon the errors of the auxiliary instruments such as the motion reference unit, the gyro compass, and the measurements of the speed of sound through the water column. The sea state at the time of the survey also contributes significantly to the quality of the data. The possible accuracy of the measured depths may be estimated by considering the following main error sources.

Error budget analysis for measured depths	
Measurement	The nadir-beam bottom detection range resolution of the multibeam system has a maximum limit of 0.1 m (Reson, 2002). However, multibeam systems are particulary susceptible to errors in the far range (outer beams), and detection is estimated at ±0.3 m plus 0.5 % of the depth. Errors also include the detection of the sea floor due to local variations of depth within the beam footprint, especially in the outer beams, and a varying density of the bottom material. This may be significant if a relatively low frequency transducer is used on soft marine muds in shallow water.
Transducer draft	The transducer depth below the water line may be determined to ± 0.1 m. However, the draft of the vessel due to the variability in vessel loading, *e.g.* fuel and fresh water storage, was not determined. It is estimated that this introduced a water depth independent error of up to ± 0.2 m. Dynamic draft errors, *e.g.* vessel squat, may also be significant.
Sound velocity	The sound velocity profiles measured by the conductivity-temperature-depth sensor (CTD) probe did not reach full survey depths in waters exceeding 400 m water depths. An inaccurate sound path from the transducer to the bottom and back will affect not only the observed depth of water, but also the apparent position of the observed sounding. This error is presumed to exceed 0.5% of the water depth beyond the direct CTD measurements. In order to minimise this error, ARGO and GDEM data may be used to supplement the CTD data.
Heave	This error is directly dependent on the sea state, the sensitivity of the motion sensor and installation parameters. The MRU installation did not account for the offset distance between MRU, the centre of gravity, and the MBES transducer mount. However, the software was able to perform lever arm calculations and heave compensation during post-processing, and the vertical error is assumed to be significant only in heavy seas.
Tide/water level	Errors due to tides may be significant, especially where predicted tides some distance from the survey area are used. Perhaps ± 0.3 m for uncertainty in tidal datum need to be considered.

From the table above, it is estimated that the measured depths in 20 m are typically accurate to about ± 1.1 m. However, the complete bathymetric model, or digital terrain model (DTM), is based on some form of interpolation between the sampled depths from several survey lines. Consequently, the total uncertainty associated with a bathymetric model will include uncertainties due to horizontal positioning, and uncertainties introduced by the interpolation process, and will therefore be larger than the depth sounding uncertainty.

6.3 Multibeam echosounder data density

The density of data used to construct a bathymetric grid is an important factor in its resolution – the denser the data, the higher the resolution that can be achieved. Sounding density is critical in terms of seabed feature detection and delineation. The two main factors that control the potential bathymetric target resolution capability of a multibeam echosounder are the distance between individual soundings (both in the cross-track and along-track dimensions), and the footprint size. The footprint is the area on the seabed covered by the sound pulse. Footprint size is a function of range, beam angle, and receiver and transmitter beam widths. A high sounding density and small footprint will result in higher resolution data. Conversely, the target detection capability is going to decay as a result of a growing projected beam footprint and decreasing data density.

The along-track spacing is controlled by the ping rate, which in turn is limited by the two-way travel time from the source to the seafloor. The maximum across-track spacing depends again primarily on the range, but also on the equiangular beam spacing. The size of the beams received by the MBES system is between one and one and a half degrees. This means that a system mounted on a ship will have an increasing projected footprint size with increasing water depth. The footprint will also be larger at the outer beams than at the centre of the swath, as the range and incident angles increase with distance from the nadir beam. It is possible to have local variations of depth within the beam footprint, causing vertical error and affecting amplitude detection.

The table below shows a summary of the projected beam footprint size under varying water depths for the two MBES systems currently in use by SOPAC. It should be noted that the higher frequency system (SeaBat 8101) is not appropriate for applications in waters deeper than 200 m. Due to the constant beam width; the sounded area varies according to the depth and slope, which results in a variable data density in the survey area.

Water depth	**SeaBat 8160 (deep water) 50 kHz, 126 beams at 1.5 °**		**SeaBat 8101 (shallow water) 240 kHz, 101 beams at 1.5 °**	
(m)	Inner footprint, nadir (m)	Outer footprint (m)	Inner footprint, nadir (m)	Outer footprint (m)
20	0.4	5.8	0.5	3.5
50	1.0	14.4	1.3	17.6
100	2.1	28.8	2.6	35.3
200	4.2	57.6	5.2	70.6
500	10.5	143.9	N/A	N/A
1000	20.9	287.9	N/A	N/A
1500	31.4	431.8	N/A	N/A

The table above assumes a horizontal seabed, and shows the variation in across-track footprint size with water depth and beam angle. The sounding density and swath width will also vary when surveying steep slopes, or highly incised margins, as the footprint size varies strongly with topography. Therefore, deeper sections have larger projected footprints and fewer data point. This has the effect that a bathymetric feature whose lateral dimensions are less than the beam footprint size will not be resolved.

It should also be noted that the along-track resolution usually exceeds the across-track resolution due to ping rates, especially in deep water. Since ping rates are limited by the two-way travel time. Rates for water depths of 20 m and 1500 m are 12.9 and 0.2 pings per second, respectively. Using maximum ping rates, or when surveying in deep water, it is possible that the same area may be measured with the outer beams for several pings, which may give inconsistent sounding data due to the poor repeatability on uneven seabed.

In order to take into account depth-dependent point density, it is generally accepted to grid bathymetric data at a resolution that is on the order of the average beam footprint size, typically 10% of the water depth.

7 APPENDIX B - SHIP TRACK AND DATA COVERAGE

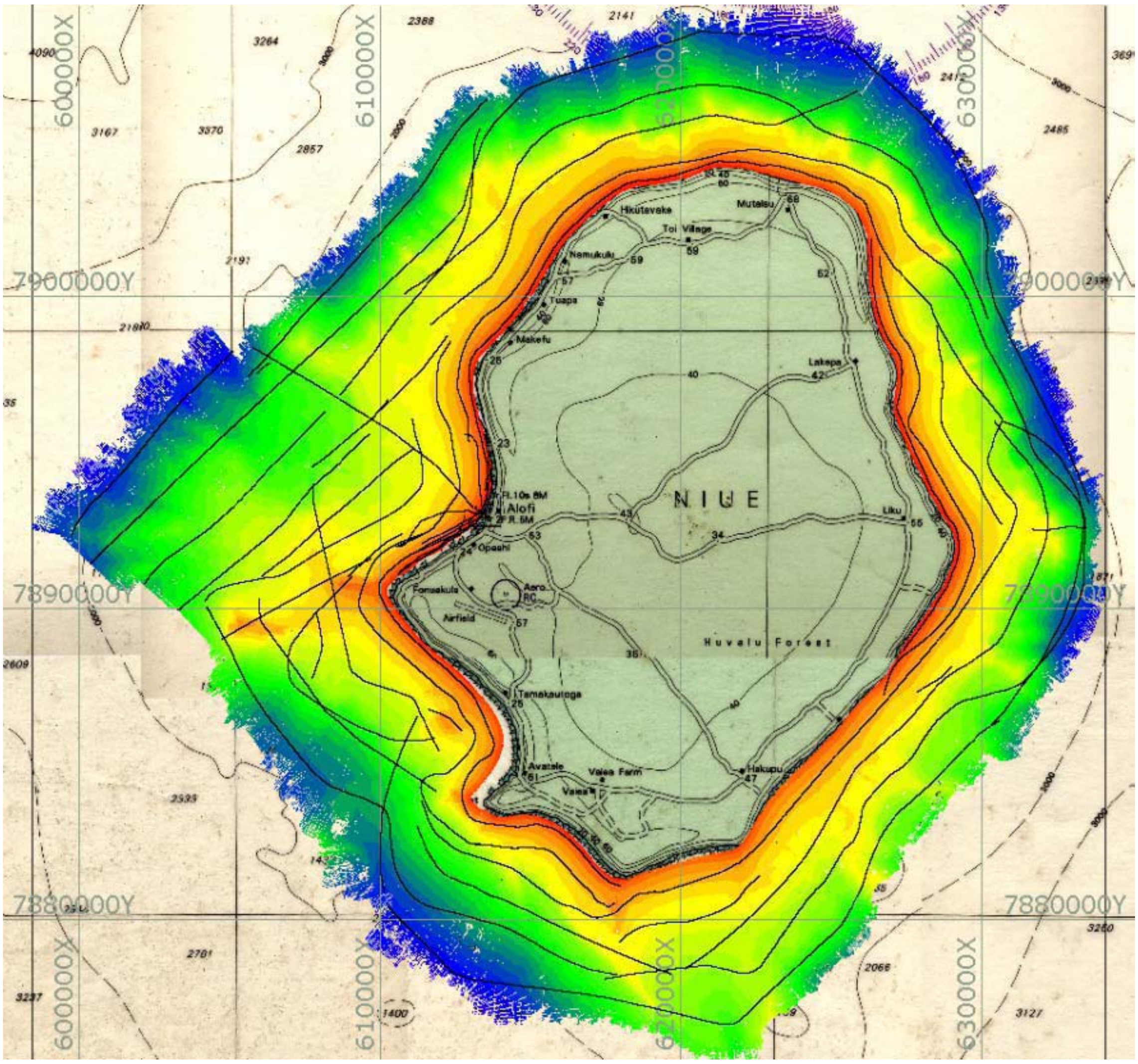


Figure 14. Completed 2006 bathymetry coverage, shown as 10 m-gridded sounding points. Shallow to deep from red to blue. Ship track lines are shown in black. Backdrop image is hydrographic chart NZ845.

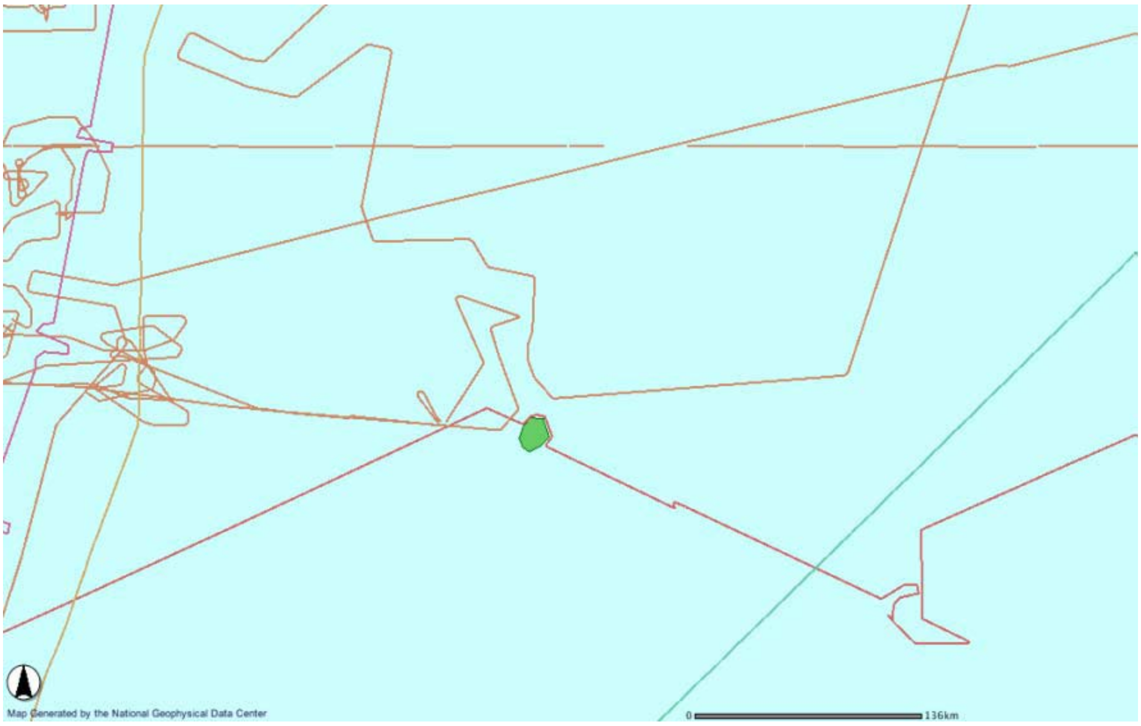


Figure 15. Ship track lines for multibeam data available from NOAA's National Geophysical Data Centre in the region around Niue (http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html, accessed 05/01/2007).

8 APPENDIX C - DATA ARCHIVE

Submitted data and documentation are stored on a companion DVD-ROM. The data archive is structured with subdirectories and contents as listed in the table below. This technical report is contained in the Documents subdirectory.

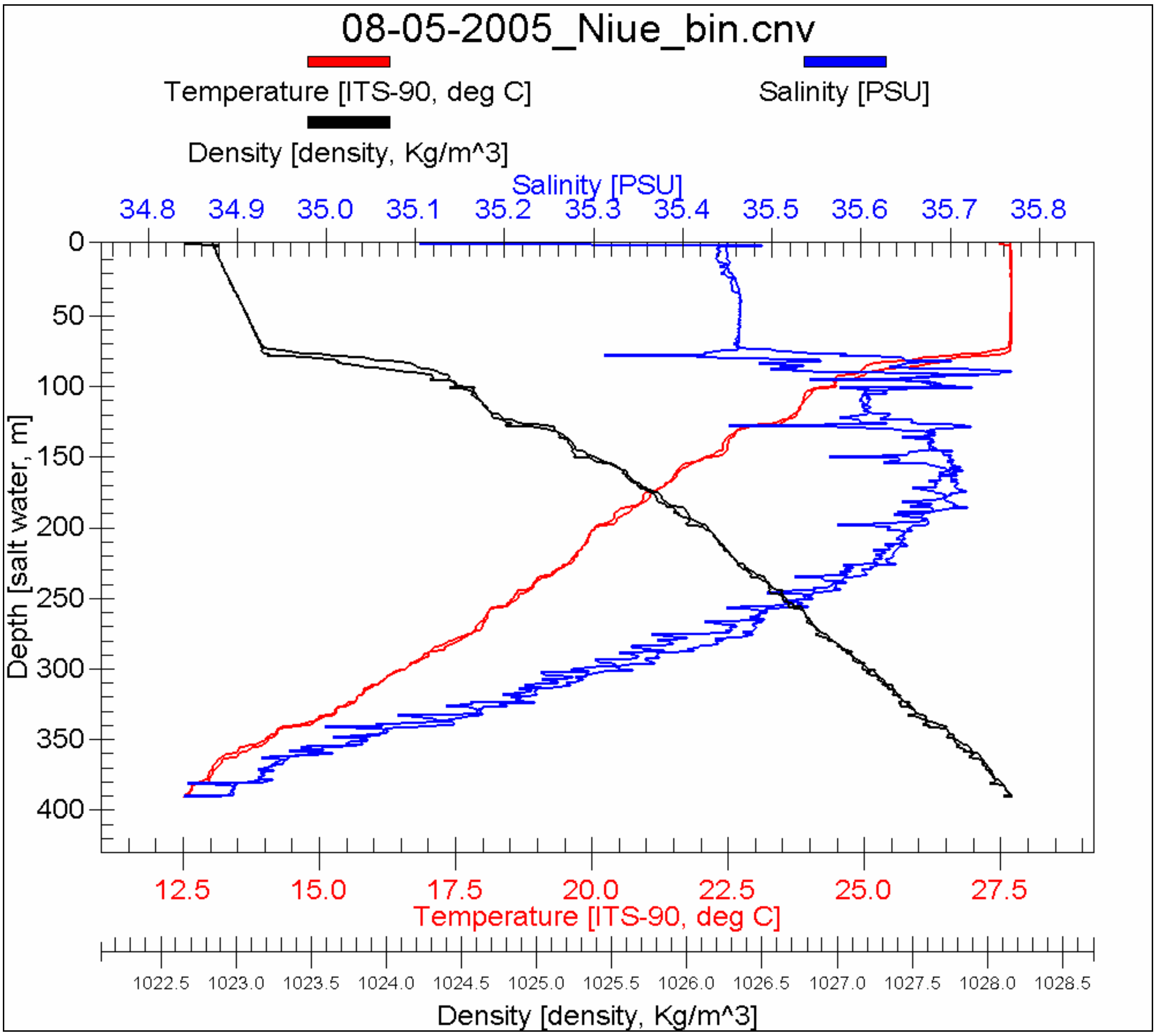
Raw data	
CTD	SeaBird CTD profiles in HEX format.
ADV	Sontek Triton files in binary (.tri) and ASCII format.
Argo	Argo profiles in ASCII format.
GDEM	GDEM profiles in ASCII format.

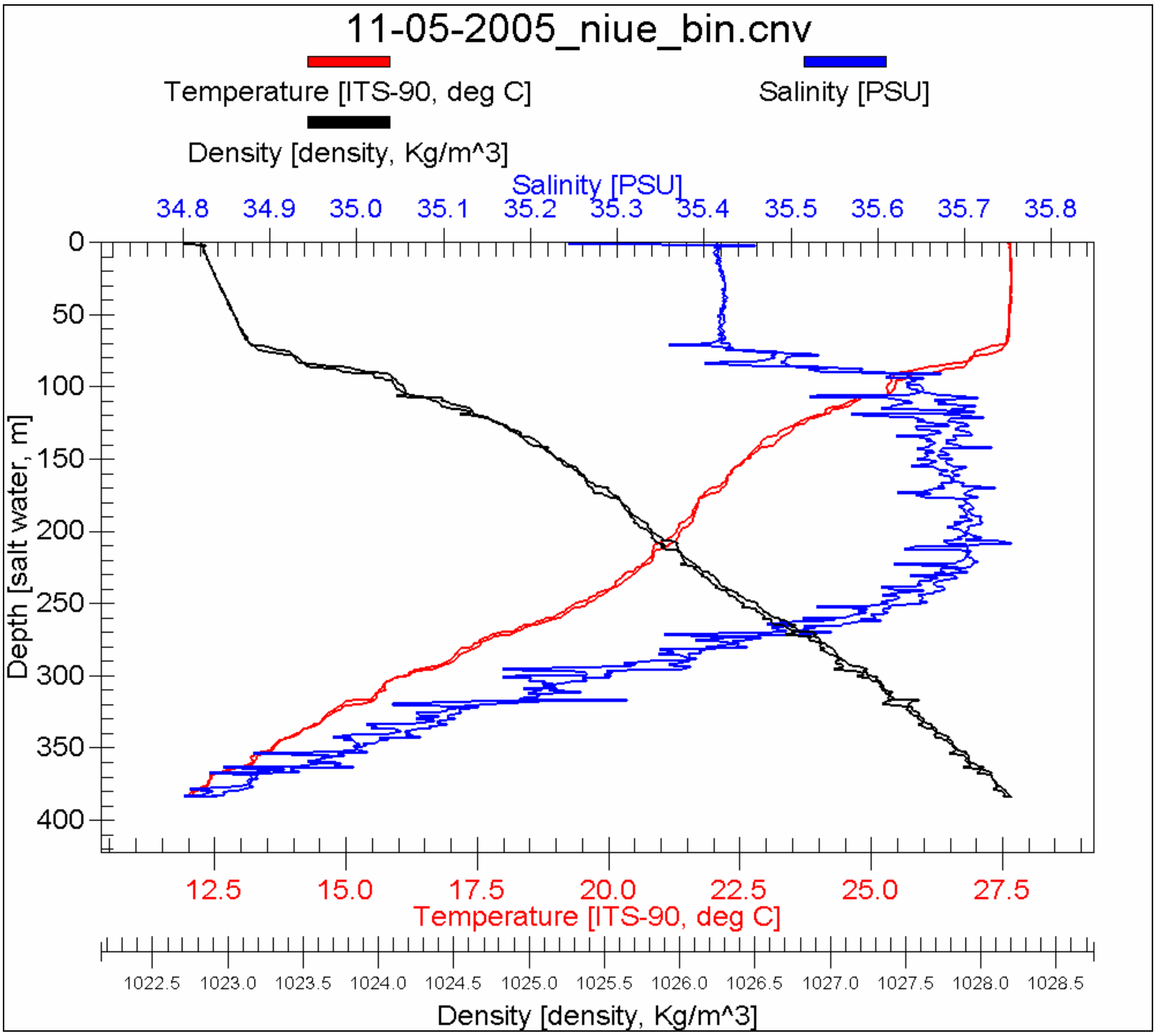
Processed data	
MBES	Gridded XYZ soundings and 'all pings processed' data in ASCII format.
CTD	Converted and binned CTD profiles in ASCII format.
Tides	Water levels in ASCII format.

Documentation	
Reports	This report in PDF format
Logs	Online and post-processing quality control logs. Spreadsheet in XLS format
Instruments	Manufacturer specifications in PDF format

Drawings	
Charts	Bathymetry charts in PDF format.
Contours	Contours with Z values in DXF format
Images	Charts and figures in TIFF format with associated TFW files.

9 APPENDIX D - CTD PROFILES



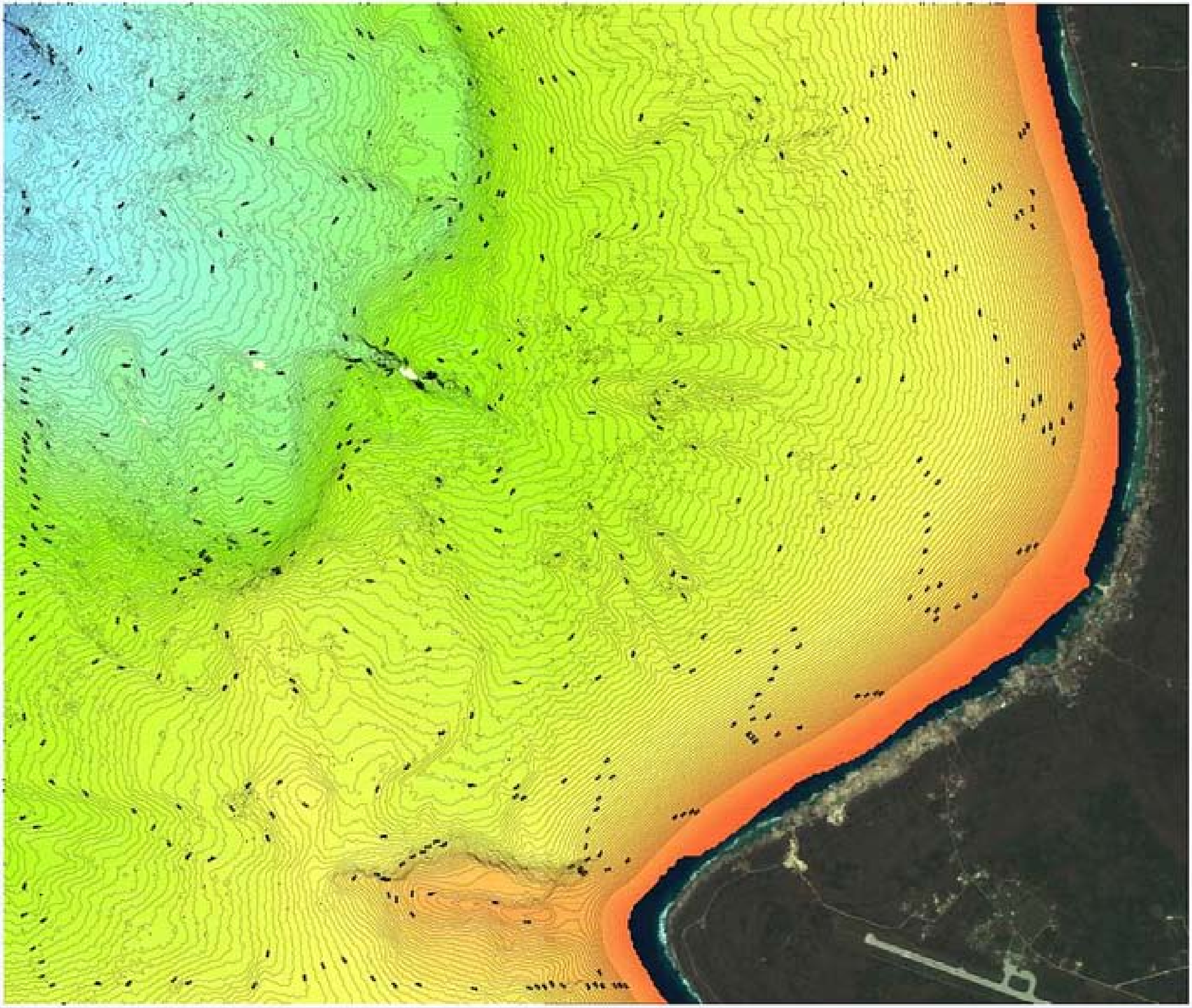

11-05-2005_niue_bin.cnv
Temperature [ITS-90, deg C]
Salinity [PSU]
Density [density, Kg/m^3]
Salinity [PSU]
34.8 34.9 35.0 35.1 35.2 35.3 35.4 35.5 35.6 35.7 35.8
Depth [salt water, m]
0 50 100 150 200 250 300 350 400
12.5 15.0 17.5 20.0 22.5 25.0 27.5
Temperature [ITS-90, deg C]
1022.5 1023.0 1023.5 1024.0 1024.5 1025.0 1025.5 1026.0 1026.5 1027.0 1027.5 1028.0 1028.5
Density [density, Kg/m^3]

10 APPENDIX E - LINE LOGS

Date	Location	Line No.	Time		Fix		HD G	SPD	Filename (.HSX)	Log File (.LOG)	Line QC	Comments / Online changes
			SOL	EOL	SOL	EOL						
8/05/2005	Niue		1317		1				000_1317		DNP	test logging
			1340	1533	3	193	195	5.8	000_1340	HSX_0508	kf	max depth chopped off til F28. Turned on TVG at F47. Changed gain to TVG with autogain at F134. Changed to fixed gain at F156. Back to TVG at F165
			1540	1727	194	395	313	6.2	000_1540	HSX_0508	kf	power failure F393
			1803	1806	396	403			000_1803		DNP	power failure. Today=40km
9/05/2005	Niue		636		405	605	8.3	5.9	000_0636	HSX_0509	kf	
			836	10:24	606	801	113	5	000_0836	HSX_0509	jk	
			10:24	1237	802	1001	222	5.95	000_1024	HSX_0509	kf	
					1002	1003					DNP	
			1311	14:08	1004	1108	330	5.9	000_1311	HSX_0509	jk	power failure near EOL F1107
			14:21	14:40	1109	1143	61	5.8	000_1421	HSX_0509	jk	power failure near EOL
			14:55	1513	1144	1177	49	5.75	000_1455	HSX_0509	kf	
			1517	15:58	1178	1258	148	6.3	000_1517	HSX_0509	kf	noticed that GPS not logging at EOL
			1605	1636	1259	1315	242	5.9	000_1605	HSX_0509	kf	
			1649	1746	1317	1422	65	6.1	000_1649	HSX_0509	kf	Today=101.7km
10/05/2005	Niue		05:32	05:49	1425	1455	301	5.8	000A0532		DNP	no position data
			05:51	006:04	1456	1479	6	5.7	000_0551	HSX_0510	jk	
			06:13	06:24	1480	1504	48	6.4	000_0613	HSX_0510	jk	logging while transiting to wharf
			06:34	06:50	1505	1538	78	6.7	000_0634	HSX_0510	jk	transit to wharf. Marginal wx
			07:49	08:25	1539	1605	225	6	000_0749	HSX_0510	jk	marginal wx NW 20kn
			08:29		1606		177	6	000_0829	HSX_0510	kf	logging suspended. Resumed to start new line
			08:34	09:17		1697	145	6.6	000_0834	HSX_0510	kf	marginal wx. Poor data F1659
			09:30	10:24	1698	1799	165	6	000_0930	HSX_0510	kf	
			10:27	12:42	1800	2031	52	6.1	000_1027	HSX_0510	kf	
			12:45	14:55	2032	2257	108	6.4	000_1245	HSX_0510	jk	

			14:55	15:33	2258	2320	217	5.4	000A1455	HSX_0510	jk	
			15:43	16:12	2321	2375	62	6.1	000_1543	HSX_0510	kf	
			16:54	18:40	2376	2571	272	5.5	000_1654	HSX_0510	kf/jk	Today=114.6km
11/05/2005	Niue		06:10	09:06	2572	2895	342	5.7	000_0610	HSX_0511	jk	
			09:06	09:51	2586	2979	150	6	000_0906	HSX_0511	jk	
			10:13	11:29	2980	3126	35	6.5	000_1013	HSX_0511	jk	nearshore line
			11:35	1304	3127	3289	178	5.8	000_1135	HSX_0511	kf	
			13:11	13:19	3290	3305	60	5.9	000A1311	HSX_0511	kf	
			13:34	15:29	3306	3505	237	5.8	000_1334	HSX_0511	kf/jk	
			15:29	16:03	3506	3567	277	5.1	000_1529	HSX_0511	jk	
			16:06	16:35	3568	3628	352	6.5	000_1606	HSX_0511	jk	gap filling
			16:38	16:46	3629	3643	107	5.9	000_1638	HSX_0511	jk	gap filling
			16:55	17:46	3644	3739	260	4.9	000_1655	HSX_0511	kf	gaption. Today=116.7km
12/05/2005	Niue		06:18	07:52	3740	3913	239	6	000_0618	HSX_0512	kf	
			08:01	09:45	3914	4106	49	5.7	000_0801	HSX_0512	kf	
			09:45	10:21	4107	4173	121	6.2	000_0945	HSX_0512	kf	
			10:31	11:10	4174	4245	170	6.3	000_1031	HSX_0512	kf	gap filling
			11:15	11:25	4246	4265	91	6.1	000_1115	HSX_0512	jk	
			11:29	13:01	4266	4426	335	8.9	000_1129	HSX_0512	jk	Hdop 1.3 at F4356
			13:01	13:56	4427	4528	312	6	000_1301	HSX_0512	jk	
			13:56	16:03	4529	4765	256	5.8	000_1356	HSX_0512	jk	
			16:11	16:45	4766	4847	17	6	000_1611	HSX_0512	kf/jk	
			16:58	17:41	4848	4939	119	7.1	000_1658	HSX_0512	kf	
			17:42	18:01	4940	4946	16	0.5	000_1742	HSX_0513		line while docking at wharf. Sometimes stationary. Today=120.6km
13/15/2005	Niue		06:40	06:53	4947	4972	223	5.9	000_0640	HSX_0513	kf	
			06:57	07:13	4973	5005	60	6.2	000_0657	HSX_0513	kf	F4987 Hdop 1.7/1.8. Fishermen.
			07:36	08:21	5006	5092	241	6.5	000_0736	HSX_0513	jk	
			08:30	09:15	5093	5176	42	6	004_0830	HSX_0513	jk	

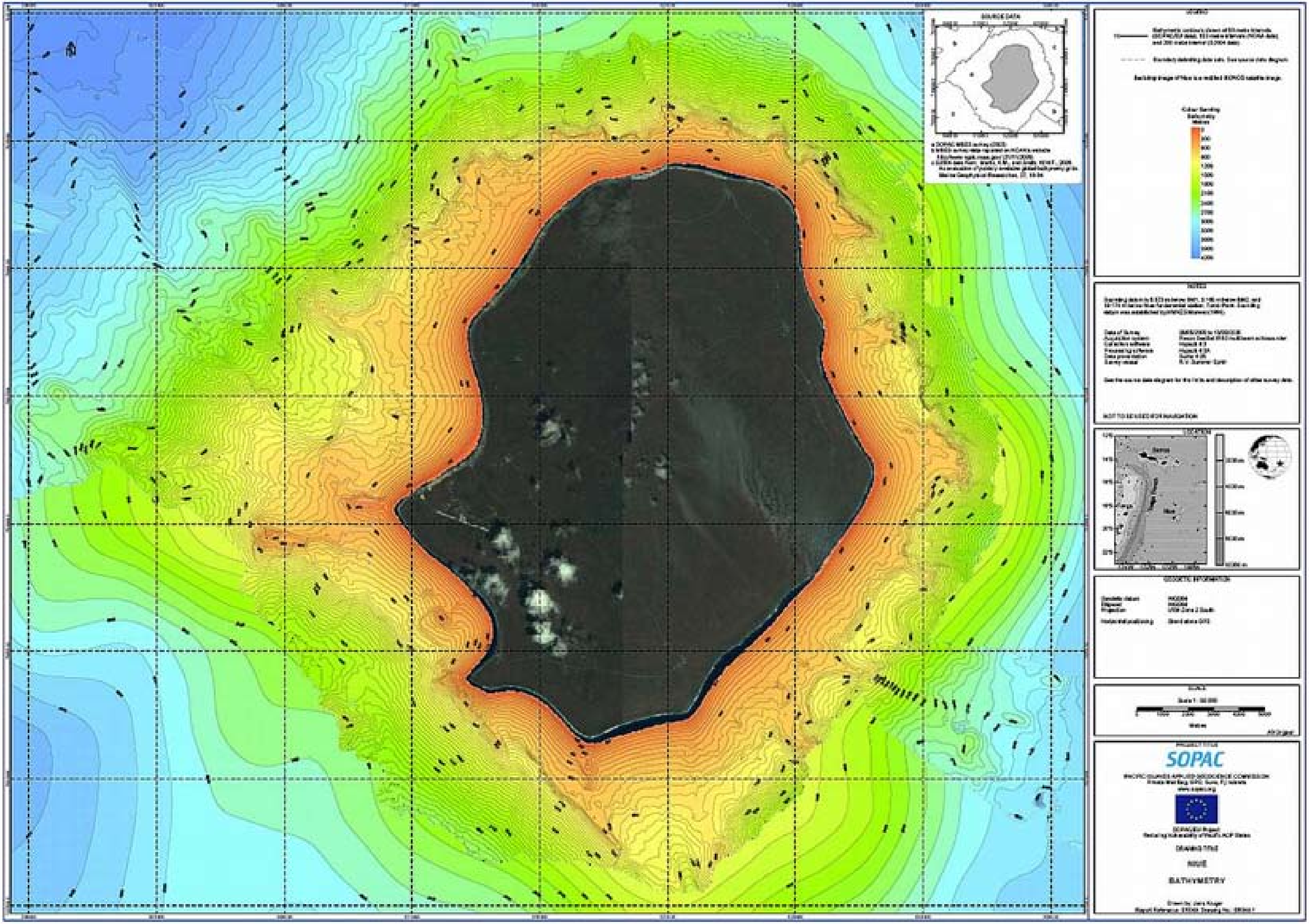
			09:39	09:53	5177	5203	107	6	000_0939	HSX_0513	jk	
			09:56	10:11	5204	5232	50	6.2	000_0956	HSX_0513	kf	nearshore line
			10:16	10:51	5233	5300	144	5.9	000_1016	HSX_0513	jk	nearshore line. 2p/s
			10:54	11:12	5301	5336	66	6	000_1054	HSX_0513	kf	
			17:50		5337	5343	47	5.9	000_1750	HSX_0513	DNP	
			18:07	19:11	5344	5465	38	5.7	000_1807	HSX_0513	kf	
			19:22	20:17	5466	5567	195	6	000_1922	HSX_0513	jk	Todays total=62km



SOPAC

NIUE
ALOFI BAY

BATHYMETRY


SOPAC
BATHYMETRY