PORIRUA HARBOUR SURVEY
REPORT OF SURVEY

Contract No. P31657

Report Prepared for Porirua City Council

PORIRUA
CITY COUNCIL

Surveyed by Discovery Marine Ltd.

DML
HYDROGRAPHIC & COASTAL MANAGEMENT SERVICES

Discovery Marine Ltd
PO Box 4048
Mount Maunganui
BAY OF PLENTY

Email: discoverymarine@xtra.co.nz
Website: www.dmlsurveys.co.nz

Report Date: 25 June 2009

PORIRUA HARBOUR SURVEY
REPORT OF SURVEY

Contract No. P31657

CONTENTS

ENCLOSURES:

1. Selection of 2D depth contoured images

ACCOMPANYING DATA:

- A1 Sounding Sheet Series at 1:5,000 scale
- CD containing Digital Data

DML 1000-WLG

25 June 2009

Keith Calder
Porirua Harbour Strategy Coordinator
Porirua City Council
PO Box 50-218
PORIRUA

PORIRUA HARBOUR SURVEY – REPORT OF SURVEY

SECTION 1 LIST OF ABBREVIATIONS

1.1 Abbreviated terms which may be used in this document are as follows:

BM	Bench Mark
CD	Chart Datum
DML	Discovery Marine Ltd
GPS	Global Positioning System
GWRC	Greater Wellington (Regional Council)
HAT	Highest Astronomical Tide
IHO	International Hydrographic Organisation
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
LAT	Lowest Astronomical Tide
LINZ	Land Information NZ
PCC	Porirua City Council
PDOP	Positional Dilution of Precision (A figure of merit denoting horizontal positioning accuracy)
RL	Reduced Level
RNZN	Royal New Zealand Navy
RTCM	Radio Transmitted Correction Message (corrections providing higher position accuracy).
RTK	Real Time Kinematic (GPS Positioning Method/System)
SBES	Single Beam Echo Sounder
SD	Sounding Datum
TS	Total Station Survey Instrument
TX	Transducer (Echo Sounder Transducer)
UHF	Ultra High Frequency (Radio signal)
WVD	Wellington Vertical Datum

Relevant Document References:

A. Chart NZ 4632 – Approaches to Porirua Harbour
B. LINZ 1:50,000 Topographic Maps 260-R26 and R27

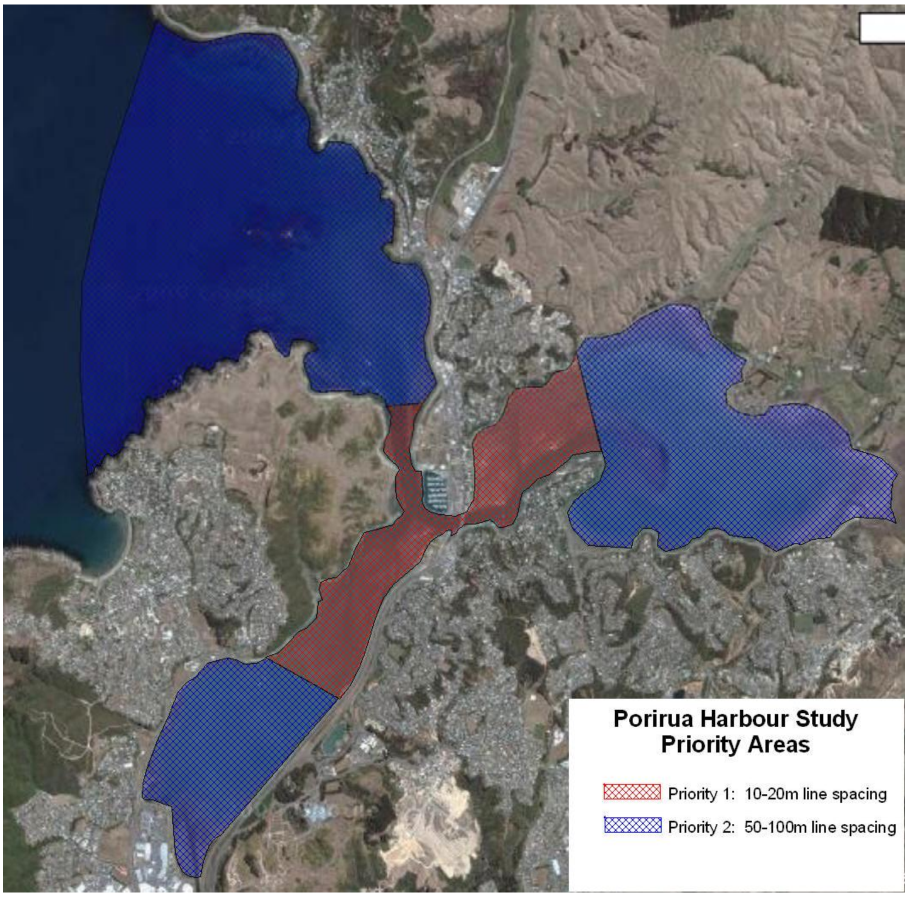
SECTION 2 INTRODUCTION

2.1 Discovery Marine Ltd (DML) was contracted by Porirua City Council (PCC) to undertake a hydrographic survey of Porirua Harbour as part of a wider Harbour Study involving the development of a hydrodynamic model and assessment of historic sediment transportation trends. Whilst the core focus of this survey was not aimed at deriving data for pure hydrographic or charting needs, all work has been undertaken to accepted industry standards in order that the data may be used for the updating of existing charts and nautical information where relevant.

Survey Area

2.2 The area surveyed incorporated all waterways east of a curved line between Te Rewarewa Point on the northern headland at the entrance to Porirua Harbour, to the headland (Te Paokapo) north of Titahi Bay. This is shown in the image below. Encompassing the shallow Pauatahanui and Onepoto Arms, survey coverage over all inter-tidal regions up to the MHWS level was required. The fieldwork therefore necessitated a combination of hydrographic and topographic techniques.

2.3 Based on information supplied by consultants to PCC, the survey area was afforded two distinct density level areas, which ultimately determined the sounding density. The red areas, being more critical to the modelling requirements required 10-20m line spacing whilst the blue areas identified regions that required less density (50-100m line spacing). The two areas were assigned ‘Priority 1’ and ‘Priority 2’ respectively.



2.4 Preparations for the survey were commenced early in February 2009 and fieldwork was commenced on 16 March. The boat sounding effort was completed on 11 April and remaining topographic fieldwork was completed on 22 April 2009.

2.5 The survey was completed by a team of 2-3 surveyors. All work was supervised by an IHO Cat A hydrographic surveyor. The team was accommodated at Mana during the survey with boat operations based from Mana Marina.

2.6 Work Achieved. The project area has been fully surveyed to Client requirements. Overall, a greater level of sounding density than demanded has been achieved in all regions. Being the first major survey of the harbour for many years and the first survey in history to encompass the entire harbour environment and approaches, particular care was taken to ensure all significant seabed features, navigational waterways and channel confluences were fully surveyed.

2.6.1 A summary of the fieldwork effort is tabled below:

Total days on task	20 days
Number of days boat sounding	12 days
Days lost due to weather/equipment	2 days
Total line miles surveyed (boat)	602km
Total boat hours	61hrs
Total number of soundings recorded	1,863,290 soundings

2.7 Environmental Conditions. Varied and changeable weather conditions were experienced throughout the survey period ranging from calm fine periods to gale force frontal systems. As anticipated, prevailing winds were from the southerly sector which did not adversely affect operations, with the exception of the northern part of Pauatahanui Arm where strong S winds created a 0.2m surface chop. Lengthy periods of S winds created a SW swell up the coast and across the entrance to the harbour, but sounding was not undertaken in swell conditions of over 0.5m. During the period 7-8 April, a strong frontal system brought gale force northerly winds which funnelled down the harbour entrance to Mana creating heavy seas with waves breaking right across the bar entrance area. Work was constrained within the Arms during this period.

2.7.1 Sounding was designed to work around the weather and sea conditions and fortunately options were usually available to work within sheltered areas. The most constraining aspect of this survey was the relatively small tide range whereby inlet areas could only be sounded over the top of the tide.

2.8 Difficulties. No significant difficulties were encountered during the survey. Apart from minor weather delays and tidal constraints, the fieldwork phase of the survey was completed on schedule.

SECTION 3 GEODETIC CONTROL

3.1 The survey was undertaken in terms of New Zealand Transverse Mercator coordinate system in accordance with current industry standards. Details are as follows:

Coordinate System:
- Name: NZ Transverse Mercator (NZTM)
- Group: New Zealand GD2000

Ellipsoid: Geodetic Ref System 1980

Projection: Transverse Mercator

Parameters:

Central Latitude:	0°00.0000'N
Central Longitude:	173°00.0000'E
False Northing:	10000000.00 m
False Easting:	1600000.00 m
Scale Factor:	0.9996

Geoid Model: EGM96 (Global)

3.2 Significant research was undertaken prior to the survey to gain an understanding as to the nature and accuracy of local geodetic and bench marks. On arrival, several LINZ survey marks were located and used in a minor network designed to extend horizontal and vertical control along the coast between Mana and Karehana Bay, thereby providing a link between historic tide station locations.

3.3 Two new temporary survey marks were installed, consisting of buried 1.5" iron tubes, for use as RTK Base Stations. The two marks (DML1 and DML2) are located in vicinity of the Mana Marina and Ngatitoa Domain foreshore respectively. These marks were used in the local network.

RTK Base Station at BM DML1- Entrance to Mana Marina

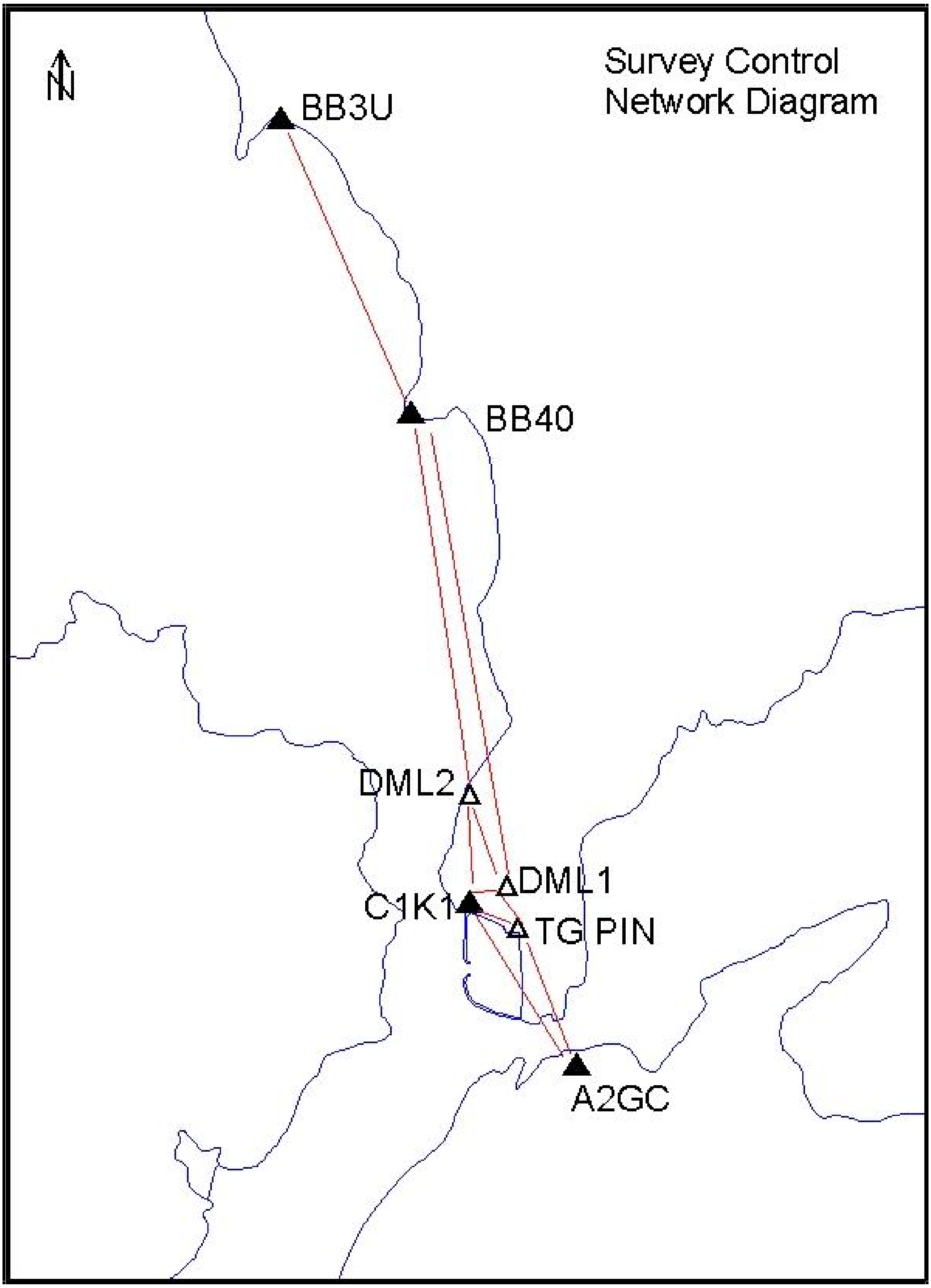
3.3.1 A list of survey marks used in the geodetic network is tabled below:

Name Code	**Northing (m)**	**Easting (m)**	**Height**	**Comments**
Mana Marina C1K1	5448512.31	1756787.10	2.55m CD	LINZ mark, with coordinates updated using observations to L14.
DML1	5448534.14	1756824.56	3.209 CD	Temporary SM. Buried IT near entrance to Marina.
DML2	5448867.02	1756671.29	6.642 CD	Temporary SM. Buried IT located in Ngatitoa Domain.
TG Bolt (Terrier Bolt)	5448475.94	1756821.30	2.538 CD	SS hexagonal bolt cemented into top of seawall next to tide gauge – NE corner of Mana Marina.
L14 A2GC	5448015.21	1757034.98	5.688 CD 4.8376 WVD	LINZ SM. 1st Order Vertical Mark (WVD). Located near Mana Road Bridge.
RM VIII BB40	5450365.04	1756514.07	2.945 CD 2.176 WVD 2.04 MSL	LINZ 2^{nd} order vertical (WVD) located at Plimmerton.
RM III BB3U	5451410.41	1756012.14	2.97 CD 2.249 WVD 2.02 MSL	LINZ 2^{nd} order vertical (WVD) located near Plimmerton Boating Club, Karehana Bay.

3.4 It should be noted that maximum RTK positioning was used for majority of the topographic work, being the survey of the MHWS mark around critical areas and also for areas not accessible by boat. No observations for Geoid-Ellipsoid separation (slope error) were undertaken as distances between the RTK Base Station to the survey team were generally kept within 2km.

3.5 Other coastline details and the MHWS mark were also positioned from the boat using laser binoculars. Such observations were checked against a MHW coastline supplied by LINZ and also a coastline provided by PCC. A good agreement was achieved across all data sets. A final MHWS coastline has been derived from all sources which are depicted on the accompanying sounding sheets.

3.6 Refer to Section 4 below relating to vertical measurements.


Survey Control
Network Diagram
N
BB3U
BB40
DML2
DML1
C1K1
TG PIN
A2GC

4 VERTICAL CONTROL

4.1 Research prior to the survey indicated that three different vertical datum's have been used in the region. This includes Chart Datum for historic charting surveys, MSL and Wellington Vertical Datum (WVD 1953) for local geodetic and topographic work. RTK work at the start of the survey was aimed at confirming the relationships between all three datum's since previous hydrographic surveys of the harbour have been based on at least two of these reference systems.

4.2 Discussions with LINZ confirmed that a rather limited knowledge of vertical datum relationships in the region existed, mainly due to the fact that there has never been any long-term tide observations undertaken within the harbour. Whilst Chart Datum at Mana had been established during the early navy surveys, the CD to MSL and WVD relationship at Mana has not been accurately understood. Furthermore, historic BM's at Mana and Plimmerton Boating Club have long been destroyed, meaning that a direct link between historic work based on CD and more recent surveys using marks in terms of MSL could not be readily achieved without additional geodetic effort.

4.3 Prior to DML's arrival, GWRC installed a tide gauge network in support of the survey. This consisted of a new permanent tide gauge located in the NE corner of the Mana Marina and three temporary tide gauges. The temporary gauges were located at the Plimmerton Boating Club at Karehana Bay, the southern end of Onepoto Arm at the floating pontoon and south coast of Pauatahanui Inlet, east of Brady's Bay. Locations were discussed and agreed by all parties prior to the survey to ensure a suitable spread of sites to gain a full understanding of the tidal regime throughout the harbour environment.

4.4 The survey is referenced to LINZ mark C1KI (Mana Marina), which according to LINZ records, was levelled to the original RNZN BM at the Mana Cruising Club. Coarse levelling was originally carried out using RTK GPS, but was later improved by precise levelling using a dumpy level. Precise Levelling was undertaken between C1K1 and a stainless steel terrier bolt located on top of the wall in the NE corner of the marina. This is adjacent to the GWRC tide gauge. Mark DML1 was also included in the levelling run. RTK GPS was used for the network encompassing a series of marks between Man and Karehana Bay. This included the nearby LINZ 1st Order vertical (WVD) mark L14, thereby confirming a relationship between CD and WVD at Mana.

4.4.1 From network observations, an agreement of 2cm was achieved through the traverse between Mana and Karehana Bay. Reciprocal baseline observations between C1K1 and L14 produced an agreement of better than 1cm. These results are within the accuracy tolerance of the RTK system for the relative baseline distances and taking into account local geoid/spheroid separation. However it's important to note that since L14 is a first order survey mark established in November 1958, it can be assumed with reasonable confidence that there has been no significant topography movement for the Mana region.

4.5 <u>Bench Mark Listing</u>

A table listing final heights is provided below:

Mark	Height/Origin	Observed Height (above CD)	Comments
C1K1	2.55m above CD (LINZ)	LINZ height adopted	CD Value requires investigation based on recent analysis.
SS Terrier Bolt	Origin not known. Possibly 1991 survey.	2.538m	Mana Marina Tide Gauge. Levelled from C1K1
Zero of tide staff	Origin not known	0.054m above CD	This staff is not aligned with CD
BM DML1	New Mark	3.210m	Levelled from C1K1
BM DML2	New Mark	6.642m	From RTK network
L14 (Code A2GC)	4.8376m WVD (1^{st} Order Vertical)	5.688m	From RTK network
BB40	2.176m WVD (2V) 2.04m MSL (4V)	2.945m	RTK Traverse Plimmerton Beach Location
BB3U	2.249m WVD (2V) 2.02m MSL (4V) 2.99m CD (LINZ)	2.97m	RTK Traverse Located at Karehana Bay. Agreement of 2cm with RTK

4.5.1 From the above observations, together with known tide level information, the following has been deduced:

Mana

- MSL is 0.80m above CD (LINZ)
- WVD is 0.85m above CD
- WVD is therefore 0.05m above MSL

Plimmerton Boating Club (Karehana Bay)

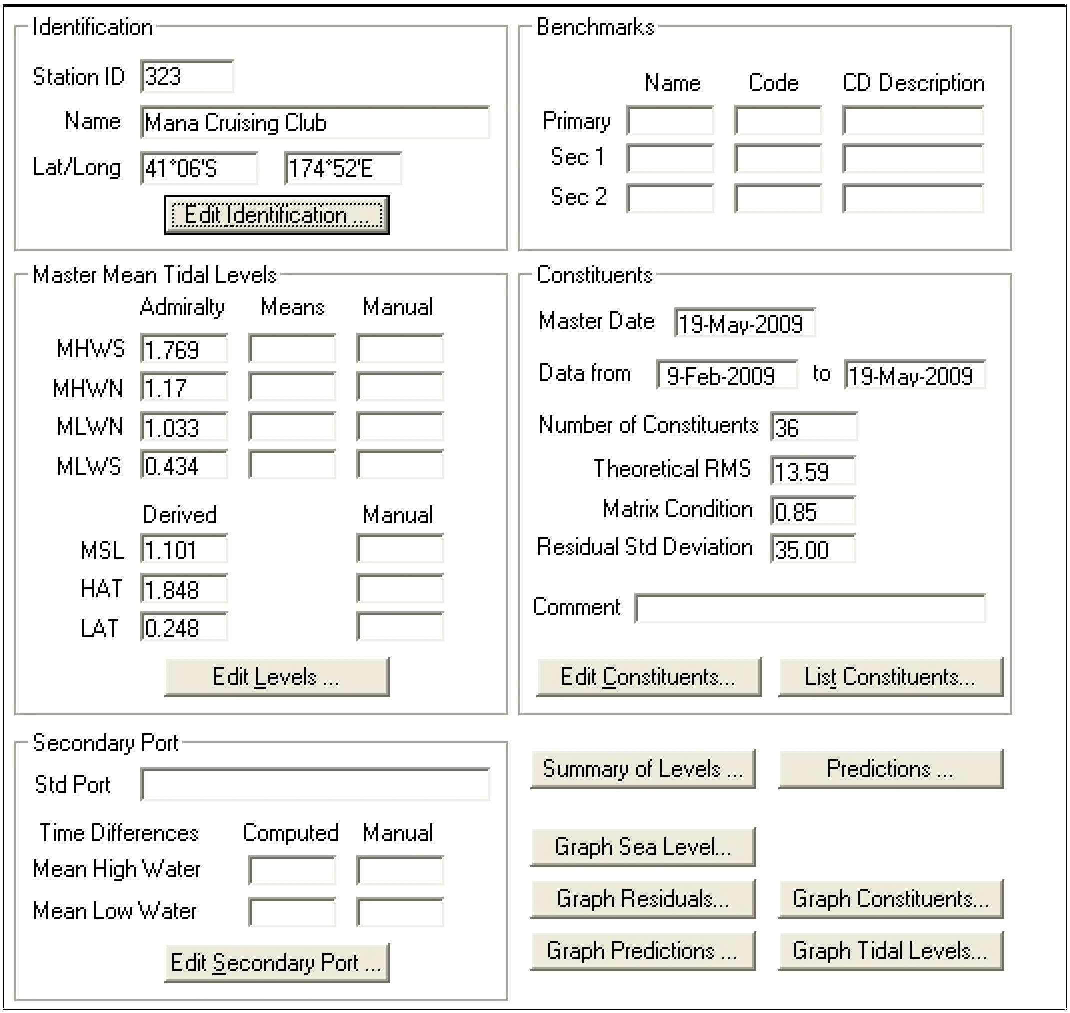
- WVD is 0.741m above CD
- MSL is approximately 0.75m above CD

RTK Fixing of BM at Mana Tide Gauge Site

4.6 Occasional water level readings were taken at the Mana gauge site, which were later compared with downloaded digital tide readings supplied by GWRC. An agreement of +/-1cm or better was achieved providing confidence that the permanent gauge had been correctly referenced to C1K1 by GWRC staff. No physical checks were undertaken at the three temporary sites and it is not known whether these gauges were levelled to any marks ashore, but they were only installed for the purpose of determining time and range relationships to Mana.

4.7 Tide data from all sites were received from GWRC and this was imported into the Sea Level Information Management System (SLIM's) software for analysis and calculation of tide levels. Results are attached:

<u>MANA:</u>



KAREHANA:

Identification

Station ID: 99999
Name: Karehana
Lat/Long: 41°04.3'S 174°51.2'S
Edit Identification ...

Benchmarks

	Name	Code	CD Description
Primary			
Sec 1			
Sec 2			

Master Mean Tidal Levels

	Admiralty	Means	Manual
MHWS	1.693		
MHWN	1.142		
MLWN	0.918		
MLWS	0.366		

	Derived	Manual
MSL	1.03	
HAT	1.863	
LAT	0.273	

Edit Levels ...

Constituents

Master Date: 6-May-2009
Data from: 16-Feb-2009 to 6-May-2009
Number of Constituents: 36
Theoretical RMS: 11.61
Matrix Condition: 0.82
Residual Std Deviation: 34.80
Comment:

Edit Constituents... | List Constituents...

Secondary Port

Std Port: Mana Cruising Club

Time Differences	Computed	Manual
Mean High Water	-00:20	
Mean Low Water	-00:17	

Edit Secondary Port ...

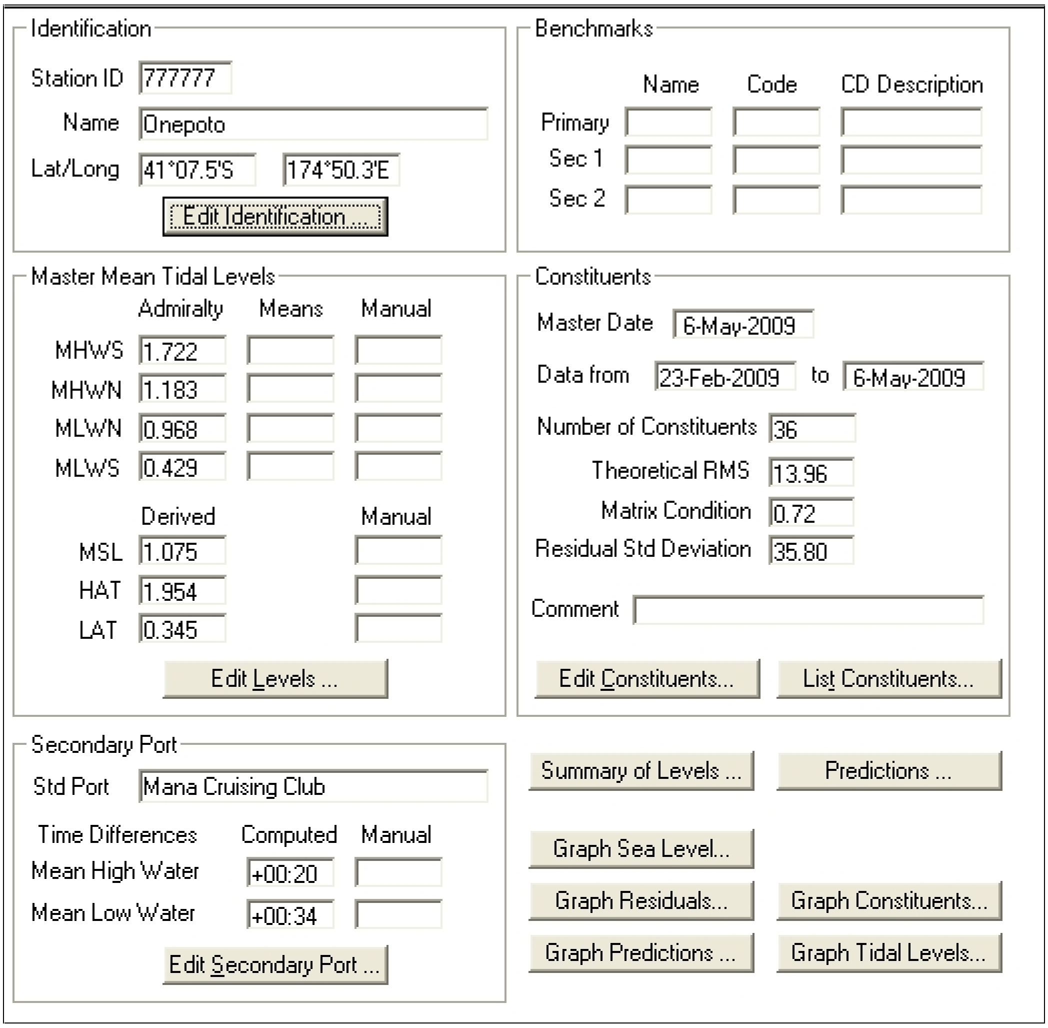
Summary of Levels ... | Predictions ...

Graph Sea Level...

Graph Residuals... | Graph Constituents...

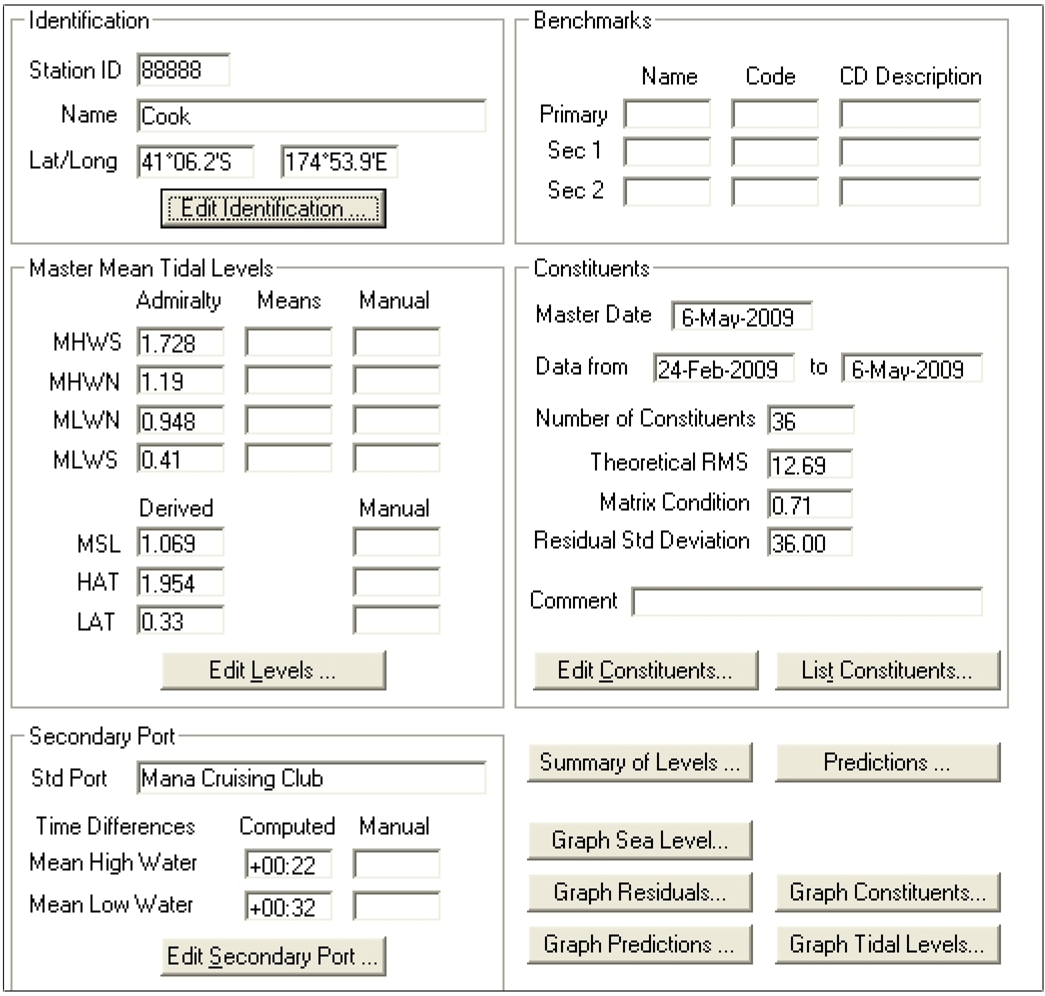
Graph Predictions ... | Graph Tidal Levels...

ONEPOTO:



Identification
Station ID 777777
Name Onepoto
Lat/Long 41°07.5'S 174°50.3'E
Edit Identification ...
Benchmarks
Name Code CD Description
Primary
Sec 1
Sec 2
Master Mean Tidal Levels
Admiralty Means Manual
MHWS 1.722
MHWN 1.183
MLWN 0.968
MLWS 0.429
Derived Manual
MSL 1.075
HAT 1.954
LAT 0.345
Edit Levels ...
Constituents
Master Date 6-May-2009
Data from 23-Feb-2009 to 6-May-2009
Number of Constituents 36
Theoretical RMS 13.96
Matrix Condition 0.72
Residual Std Deviation 35.80
Comment
Edit Constituents...
List Constituents...
Secondary Port
Std Port Mana Cruising Club
Time Differences Computed Manual
Mean High Water +00:20
Mean Low Water +00:34
Edit Secondary Port ...
Summary of Levels ...
Predictions ...
Graph Sea Level...
Graph Residuals...
Graph Constituents...
Graph Predictions ...
Graph Tidal Levels...

PAUATAHANUI:



4.7.1 The tidal analysis results are summarised below:

A. Existing Tide Levels from NZ Nautical Almanac (LINZ)

PORT	Mean Time Differences		Mean Spring, Neap and Sea Level Heights (metres)				
	HW	LW	MHWS	MHWN	MLWN	MLWS	MSL
Mana	0000	0000	1.40	1.00	0.60	0.20	0.80
Karehana Bay	-0013	-0022	1.50	0.90	0.80	0.20	0.80

B. Refined Tide Levels for Mana (provided by LINZ prior to survey):

PORT	Mean Time Differences		Mean Spring, Neap and Sea Level Heights (metres)				
	HW	LW	MHWS	MHWN	MLWN	MLWS	MSL
Mana	0000	0000	1.43	1.01	0.63	0.13	0.80

C. Porirua Harbour Tide Levels (derived from 2009 Survey):

PORT	Mean Time Differences		Mean Spring, Neap and Sea Level Heights (metres)				
	HW	LW	MHWS	MHWN	MLWN	MLWS	MSL
Mana	0000	0000	1.769	1.170	1.033	0.434	1.101
Karehana Bay	-0020	-0017	1.693	1.142	0.918	0.366	1.030
Onepoto Arm	+0020	+0034	1.722	1.183	0.968	0.429	1.075
Pauatahanui	+0022	+0032	1.728	1.190	0.948	0.410	1.069

D. Additional Levels:

Port	Highest Astronomical Tide (HAT)	Lowest Astronomical Tide (LAT)
Mana	1.848	0.248
Karehana Bay	1.863	0.273
Onepoto Arm	1.954	0.345
Pauatahanui	1.954	0.330

4.8 Results from the harmonic tidal analysis (Tables C and D above) indicate that Chart Datum (which closely equates to LAT) should be adjusted by approximately 0.24m to better reflect current tide levels. A transfer of Sounding Datum (using the Admiralty Semi-diurnal transfer method) referred to predicted tides at Port Taranaki resulted in a Sounding Datum value of 0.26m above the gauge zero.

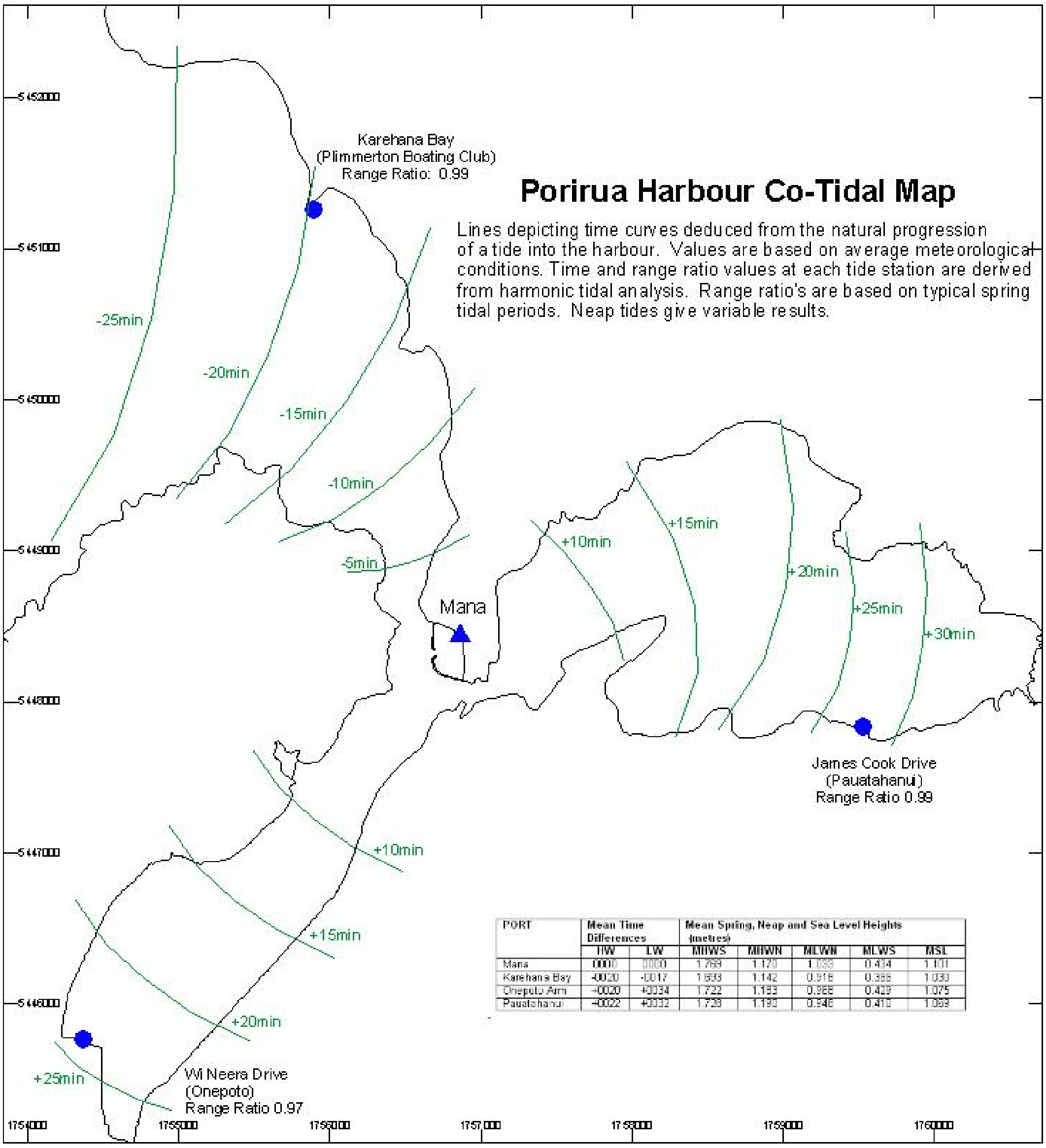
4.9 The SD issue has been raised with LINZ and is being looked into. It is our belief that the value of 2.55m above C1K1 is not accurate for the following reasons:

- The original value was probably based on relatively short-term tide observations
- A lack of subsequent tidal data has precluded the update/revision of this value
- Annual sea level rise (approximately 1.6mm per annum) since CD was first established at Mana has had an effect on tide levels

4.10 Two depth datasets have been derived from the survey. For comparisons with historic data, a dataset comprising depths reduced for tide using the Mana tide gauge observations has been developed. This was to mirror past reduction techniques, where we know that all historic survey were reduced for tide observed in vicinity of Mana.

4.11 Whilst there is a datum issue to be addressed, the final dataset which accompanies this report is currently reduced for tide, using a co-tidal model referenced to Mana, adopting the existing LINZ value for CD (Mana). The co-tidal model applies a geographical weighting to depth reduction, whereby raw depths are reduced for tide based on specific areas selected for each tide station. This has improved the final accuracy of soundings as without the co-tidal model, depths reduced for tide based on Mana tide readings only result in vertical errors of up to 0.25m. The error was quite noticeable at the head of Onepoto Arm and Pauatahanui Inlet which is expected due to typical constriction effects which results in considerable tide time delays.

4.12 A simplified co-tidal diagram, illustrating the time differences throughout the harbour are shown overleaf:



PORT	Mean Time Differences		Mean Spring, Neap and Sea Level Heights (metres)				
	HW	LW	MHWS	MHWN	MLWN	MLWS	MSL
Mana	0000	0000	1.769	1.170	1.033	0.434	1.101
Karehana Bay	-0020	-0017	1.693	1.142	0.916	0.366	1.030
Onepoto Arm	+0020	+0034	1.722	1.183	0.966	0.429	1.075
Pauatahanui	+0022	+0032	1.728	1.190	0.946	0.410	1.069

5 SURVEY SYSTEMS

5.1 DML's 7m Senator inshore survey boat '*Discovery*' was used for all boat sounding. Being a pontoon design, she is a very stable platform for inshore hydrographic surveys. With a shallow draught of 0.4m, she was also an ideal vessel for working the shallow inlet areas and sounding could be undertaken with less than 30cm of clearance under the keel.

5.2 The boat was fitted with a full and modern survey outfit comprising DGPS positioning system and high frequency digital sounder logging directly into a hydrographic software package running on a laptop computer. A motion sensor was also fitted to the boat, which recorded all vessel movement such as heave effects from swell and surface chop. This provided improved sounding accuracy for areas exposed to wind and swell. Data from all devices was logged continuously during sounding operations.

SMB Discovery at Mana

5.3 Details of key equipment used are listed below:

<u>Boat System:</u>

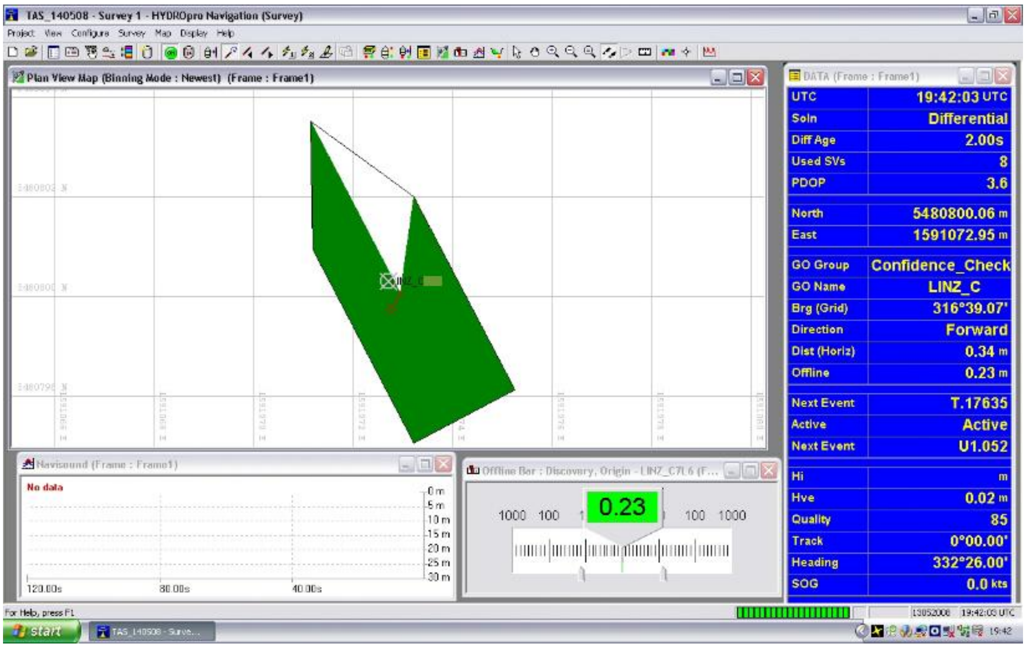
Echo Sounder:	Type:	Navisound 210
	Depth Acquisition:	8-10 soundings per second
	Frequency:	210 kHz
	Beam width:	SBES - 9°
	Rated Accuracy: +/-1cm	
Positioning System:	Trimble DSM212H onboard 12 channel receiver with RTCM corrections provided via local DGPS Base Station and/or Seastar WADGPS system.	
	Positional Accuracy:	Better than +/- 1.5m
Motion Sensor:	TSS DMS H Motion Sensor aided with GPS and Compass Heading for improved settling	
Software Package	Trimble HYDROPro Version 2.3 (2005) Depth and positional data logged directly into Navigation Module. Data Editing & Processing Modules Trimble Terramodel Processing Package	

Topographic Surveying:

Positioning System:	Trimble 5800 Base Station Trimble 5700 Rover TSC 2 Controller
Corrections from Base Station received via UHF Radio Link	
Accuracy of system –	Horizontal: 10mm + 1ppm Vertical: 20mm + 1ppm

Sokkia Total Station and Level

5.4 All equipment was checked, calibrated and operated in accordance with accepted industry procedures. The echo sounder was calibrated daily for vessel draught and sound velocity using the bar check method and verified with a Sound Velocity Probe (SVP). The accuracy of the vessel positioning system was also checked daily by undertaking a static position check against the survey mark (Terrier Bolt) within the Mana Marina. These checks confirmed a horizontal positioning accuracy of better than +/-1.2m at the 95% (2-sigma) confidence level.



Example of Positioning Check against a known survey mark

6 METHODOLOGY

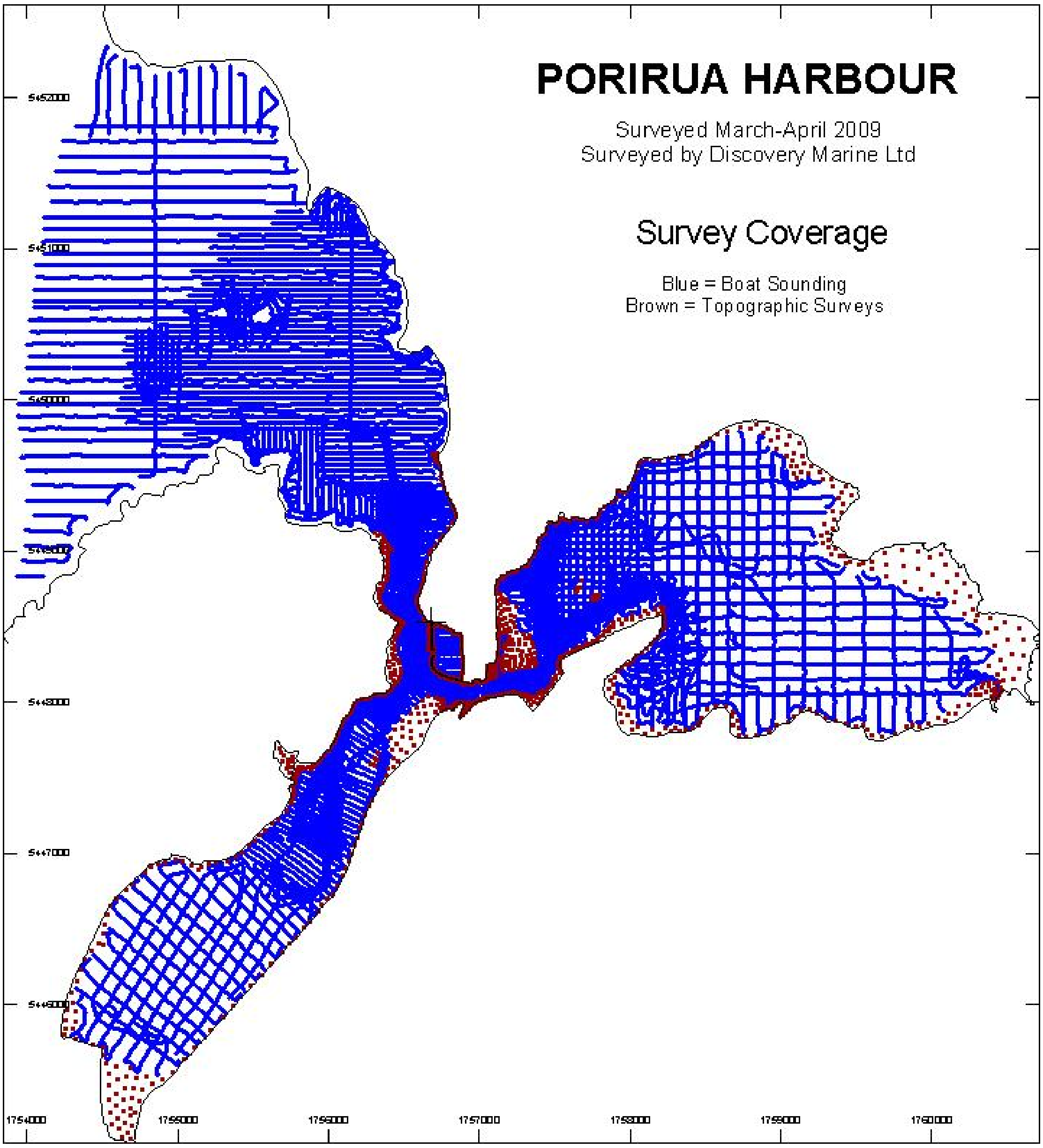
6.1 Sounding operations were undertaken using standard hydrographic principles. Where possible, conventional lines of sounding were run perpendicular to the general seabed contours in order to accurately delineate gradient changes. Cross lines or check lines were sounded to provide overlaps in data for internal checking and QA requirements.

6.2 The Priority 1 area was sounded at between 10-20m intervals, comprising conventional grid patterns as well as lines of opportunity and random lines, in order to achieve greater density in channel areas. Often, zigzag patterns were utilised as a means of initially determining the extents of channels and runnels.

6.2 For Priority 2 areas, line spacing was gradually extended at distance away from the primary focus area at the Mana confluence with line spacing of 30-40m, increasing to 50m and greater over the more benign seabed areas, being the deeper offshore waters and also the headwaters of both inlets. Whilst conventional lines of sounding were utilised in the majority of the offshore approaches, the Pauatahanui and Onepoto Arms were best sounded using a grid pattern to maximise time and provide sufficient coverage for modelling requirements.

6.3 Areas not accessible by boat were surveyed during low water periods using RTK GPS. A surveyor with the RTK rover unit walked across drying areas taking spot fixes at regular intervals to fill gaps in data coverage. This topographic work was mainly undertaken throughout the Priority 1 area, but some work was also completed in the headwater regions of the two inlets. Elsewhere, the position of the MHW coastline was determined by laser binocular fixes from the boat to the visible HW mark and then compared to the LINZ digital shoreline; the PCC supplied coastline as well as the existing Chart.

6.4 The final survey coverage is depicted in the image below:



SECTION 7 DATA EDITING AND PROCESSING

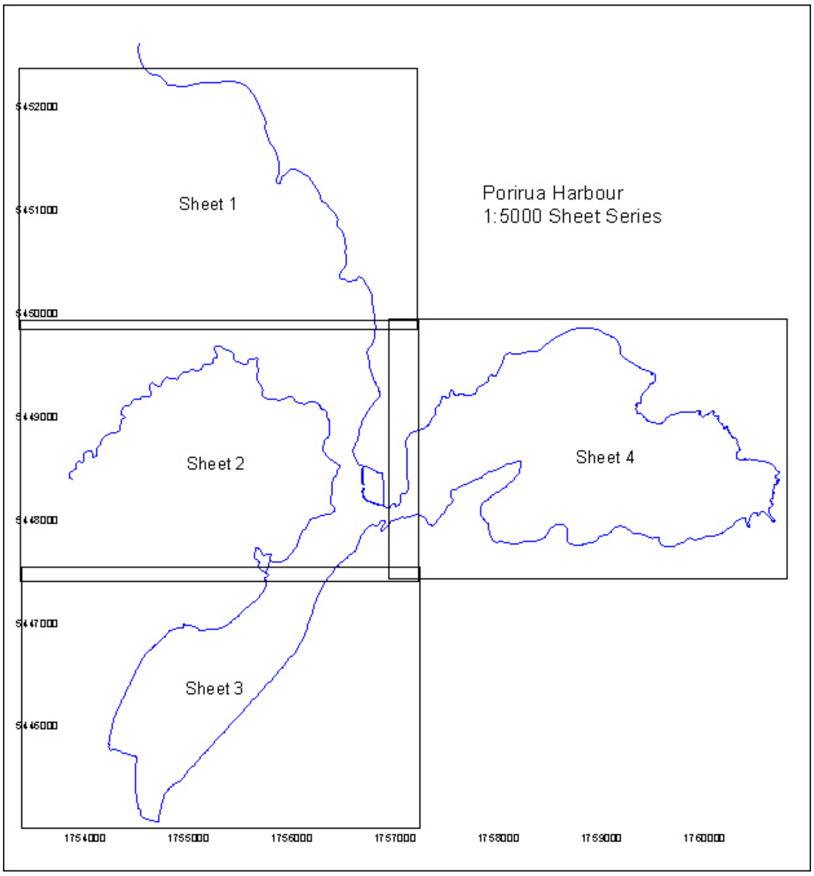
7.1 All sounding data was edited and processed using the Trimble HYDROPro Edit and Processing software suite. Obvious depth spikes (outliers) were removed via automatic filtering and manually checked for each survey line. Many spikes were caused by weed cover over rocks, mainly in the coastal areas seaward of Mana. Generally, the data recorded within the two Arms was 'clean', comprising compacted sands and silts and required very little editing.

7.2 The edited data was then exported into Terramodel processing package where data was checked for coverage and consistency. Individual surveys (separate days or distinct areas) were imported as separate layers in order that overlaps of data could be easily inspected. Topographic data was imported and merged with the depth layers.

7.3 From the final merged dataset, a digital depth layer, consisting of depths thinned to 1m intervals was exported in ASCII XYZ format. This dataset was then used for the creation of the accompanying 2D Images, which were produced using Surfer8 surface modelling software. Data was gridded using a 'nearest neighbour' technique to derive depth contour images.

7.4 Within Terramodel, the final depth layer was thinned to approximately 15m intervals to create a 1:5000 sounding sheet series. A 'shoal bias' was used in the thinning process ensuring that shallows are correctly depicted. However, minor channels and runnels are less conspicuous, although the accompanying 2D images do provide the best 'picture' of general seabed topography. The A1 sounding sheets accompany this report.

7.5 The 1:5000 sheet series is illustrated below:



SECTION 8 RESULTS AND ACCURACIES

8.1 Rigorous checks have been undertaken of the survey data. Based on daily positioning checks, the horizontal accuracy of soundings is estimated to be better than +/-1.5m. The accuracy of depth data (reduced suing the co-tidal model) has been checked digitally via inspection of overlapping soundings. Overall, excellent results have been achieved in most areas with close agreements in cross line comparisons, despite overlapping survey data being gathered on different days and in varying sea conditions. Spot checks throughout the final database indicate general cross line agreements of better than +/-0.1m.

8.2 The estimated accuracy of soundings has been calculated via a Sounding Error Budget, taking into consideration all sources of error. A SEB for the approaches to Porirua and the inner harbour areas has been produced at the 95% (2-sigma) confidence level:

Sounding Error Budget – Inshore Area (Mana, Onepoto and Pauatahanui)

Source of Error	**Depth Independent Error**	**Depth Dependent Error**	**Note**	**Depth 2m**	**Depth 5m**	**Depth 10m**
Vessel Draught Setting	0.01		A	0.01	0.01	0.01
Variation of Vessel Draught	0.00		B	0.00	0.00	0.00
Vessel Settlement & Squat	0.03		C	0.03	0.03	0.03
Echo Sounder Instrument Accuracy	0.01	+/- 0.20% d	D	0.01	0.02	0.03
Roll Error		0.000 d	E	0.00	0.00	0.00
Heave Error	0.01		F	0.01	0.01	0.01
Sound Velocity Measurement		0.0007 d	G	0.00	0.00	0.01
SV Spatial Variation		0.0006 d	H	0.00	0.00	0.01
SV Temporal Variation		0.0025 d	I	0.01	0.01	0.02
Tide Readings	0.01		J	0.01	0.01	0.01
Application of Tides (Co-tidal Model)	0.08		K	0.08	0.08	0.08
Combined Total	**$\sqrt{a^2 + b^2 + c^2 \ldots}$**			**0.088**	**0.090**	**0.095**

Notes:

A Set by daily bar check
B Minimal – due to nil significant changes in fuel state during period of each survey
C Minor squat in shallow water – minimised by operating at slow speeds
D Manufacturer rated accuracy
E No vessel roll encountered
F Nil significant heave effects experienced inside the Mana ‘throat’ region
G SV determined by daily bar check and verified with SVP
H Sounding kept to small distinct survey areas each day. Negligible fresh water effects
I Surveys undertaken during high water periods – minimal time delays from SV observations
J Accuracy of tide gauge readings as proven via pole/gauge comparison
K Worst case accuracy of co-tidal model for maximum distance from tidal site

Sounding Error Budget – Approaches to Mana (Karehana Bay, Plimmerton)

Source of Error	**Depth Independent Error**	**Depth Dependent Error**	**Note**	**Depth 2m**	**Depth 5m**	**Depth 10m**
Vessel Draught Setting	0.02		A	0.01	0.01	0.01
Variation of Vessel Draught	0.01		B	0.01	0.01	0.01
Vessel Settlement & Squat	0.02		C	0.02	0.02	0.02
Echo Sounder Instrument Accuracy	0.01	+/- 0.20% d	D	0.01	0.02	0.03
Roll Error		0.000 d	E	0.00	0.00	0.00
Heave Error	0.15		F	0.15	0.15	0.15
Sound Velocity Measurement		0.0007 d	G	0.00	0.00	0.01
SV Spatial Variation		0.0006 d	H	0.00	0.00	0.01
SV Temporal Variation		0.0050 d	I	0.01	0.02	0.05
Tide Readings	0.01		J	0.01	0.01	0.01
Application of Tides (Co-tidal model)	0.10		K	0.10	0.10	0.10
Combined Total	**$\sqrt{a^2 + b^2 + c^2 \ldots}$**			**0.183**	**0.184**	**0.192**

Notes:

A Set by daily bar check
B Minimal – due to nil significant changes in fuel state during period of each survey
C Minor squat in shallow water – minimised by operating at slow speeds
D Manufacturer rated accuracy
E No vessel roll encountered
F Residual heave, using motion sensor in outer areas
G SV determined by daily bar check and verified with SVP
H Sounding kept to small distinct survey areas each day. Negligible fresh water effects
I Surveys undertaken during high water periods – minimal time delays from SV observations
J Accuracy of tide gauge readings as proven via pole/gauge comparison
K Worst case accuracy of co-tidal model for maximum distance from tidal site

8.3 Overall, excellent results have been achieved. A high level of depth accuracy has been accomplished and the density of coverage exceeds the project requirements.

SECTION 9 ANCILLARY OBSERVATIONS

9.1 Comparisons with Existing Chart (NZ 4632)

9.1.1 The current chart does not encompass the entire harbour environment. It is also based on a number of historic navy surveys, mainly from 1966-1967. It has been more recently updated with survey data from a PCC initiated survey undertaken by a land survey company in 1991. This 1991 survey was referred to MSL and the data was converted to CD for charting requirements. Advice from LINZ indicates that a conversion factor of 1.0m was used to convert MSL depths to CD.

9.1.2 Visual comparisons between the current chart and 2009 data show a reasonable agreement with the latest survey results. In the approaches to Mana, an agreement in depths of +/-0.2m is evident and the charted least depth over the bar entrance (off Plimmerton Beach) agrees to within +/-0.1m.

9.1.3 Unfortunately, no direct comparisons with Pauatahanui Inlet or the southern portion of Onepoto Arm could be made due to the limits of the chart and also due to some erroneous data in historic survey datasets. It is known that these inlets are shoaling at a steady rate due to sediment deposition from tide transported sediments as well as stream runoff.

9.1.4 Comprehensive checks of the charted coastline have not been undertaken, although a geo-referenced raster image of the Chart was loaded into the acquisition software as a background image for sounding operations. There were indications that some distortion in the coastline was evident, particularly along the western side of the approaches to Mana. It is recommended that should results of this survey be used by LINZ for updating the current chart, then the most recent coastline imagery/data be used to confirm the position of the MHWS coastline as there may be positional errors in the current chart.

9.1.5 It is understood that the limits of the current chart do not encompass the full extent of Onepoto Arm and Pauatahanui Inlets due to the minimal amount of sea traffic. However, it is apparent that a large number of recreational vessels do use the western areas of Pauatahanui Inlet, as can be seen by the number of vessels moored alongside boatsheds on both the northern and southern shorelines. In future, should a re-scheme of NZ4632 be possible, the chart should encompass the Pauatahanui Inlet as far as Moorehouse Point (1.25km east of the Paremata Road Bridge). Similarly, whilst Onepoto Arm is used mainly by small boats and sailing vessels, chart coverage further towards the head at the south of the inlet would be useful.

9.2 Navigation Aids, Lights and Coastline Features

9.2.1 Confirmation of coastline features, verification of navigational aids etc was not a core requirement of this survey. However, the location and characteristics of a number of navigation marks were positioned from the boat during the survey. These are tabled below:

Feature	Northing	Easting	Comments
Goat Point Leading Lights (Bearing 100^0 04') Light No. 4066.3	N/A	N/A	Lights not positioned, but sounding was completed along the leads and an offset of approx 5m was noted when comparing the vessel position on raster image of chart.
Starboard Beacon Fl G 2s Light No. 4066.8	5449016	1756441	Positioned from boat. Light operating correctly. Lat/Long in NZNA is incorrect.
Starboard Beacon Fl(4)G 6s Light No. 4066.5	5448520	1756503	Positioned from boat. Light operating correctly. Lat/Long in NZNA is incorrect.
Paremata Leading Lights (Bearing 171^0 25') Light No. 4066.4	N/A	N/A	Lights not positioned, but sounding was completed along the leads and good agreement with vessel position on raster image of chart.
Mana Marina Breakwater Lights Light No. 4066.6 and 4066.7	N/A	N/A	Port and Starboard entrance lights. Lights confirmed as operating correctly. Not positioned.
Starboard Channel Marker Morehouse Point, Pauatahanui	5448685	1758202	Not charted due to limits of chart. Green Δ topmark. Positioned from boat.
Starboard Channel Marker Pauatahanui Inlet	5448514	1757516	White post with small cone, orange stripes. Not Charted due to limits of chart. Positioned from boat.
Starboard Channel Marker Pauatahanui Inlet	5448646	1757473	White post with small cone, orange stripes. Not charted due to limits of chart. Positioned from boat.
Starboard Channel Marker Pauatahanui Inlet	5448784	1757491	White post with small cone, orange stripes. Not charted due to limits of chart. Positioned from boat.
Starboard Channel Marker Onepoto Arm	5447509	1756015	Charted. Green Δ topmark. Positioned from boat.
Port Channel Marker Onepoto Arm	5447234	1756004	Charted. Red □ topmark. Positioned from boat.
Starboard Channel Marker Onepoto Arm	5446840	1755962	Charted. Green Δ topmark. Positioned from boat.
Starboard Channel Marker Onepoto Arm	5446761	1755917	Charted. Green Δ topmark. Positioned from boat.
Starboard Channel Marker Onepoto Arm	5446800	1755701	Charted. Green Δ topmark. Positioned from boat.

9.3 Tidal Streams & Circulation

- Strongest flood and ebb tidal streams were observed in vicinity of the Mana rail and road bridges. Streams in excess of 3 knots are common during spring tide periods.
- The direction and flows of flood and ebb streams in Onepoto Arm appear to be rather uniform with no significant deflections due to topography.
- Tidal flows within Pauatahanui Inlet appear to be more complex with streams being 'moulded' and directed by the shallow banks and coastline. Deflections occur and are varied, constantly changing according to the state of tide. Some areas of back eddies were observed. The main flow of the flood tide entering Pauatahanui appears to circulate in a clockwise direction.

- The true nature of the tidal streams in this complex environment can only be verified through appropriate tidal stream measurement and analysis, via ADCP, drogue tracking or dye tracking.

9.4 Sediment transportation

- Whilst sediment sampling was not required in this survey, general observations were undertaken in the field whilst boat sounding and coast lining.
- There did not appear to be any significant variances in the sediment throughout the inner and upper harbour areas. Sediments were typically sandy or light grey coloured fine silts and sands.
- During calm weather periods, the flood tide entering the two arms consisted of clean, clear water, indicating very little suspended sediment. The seabed over the bar entrance could be viewed from the boat on some days. Small sand ripples could be seen.
- The main drying banks in Onepoto and Pauatahanui Arms consisted of compacted sediments with only a very fine layer of mobile sediment on top.
- Whilst the drying banks immediately inside the entrance to Pauatahanui Arm (east of the Mana spit) have been the subject of much debate, there doesn't appear to be any significant concentrations of 'clean' sand, indicating that deposition in this location may not be occurring as rapidly as in previous years.
- East of this spit, the area of drying banks and shallows on the northern side of the main channel (north of Moorehouse Point) is a complex undulating area and drying banks contain large concentrations of cockle shell. North of these shallows is a region of soft silts and suspended sediment was often observed during windy periods.
- The large shallow crescent shaped bank that lies east of Moorehouse Point that extends south towards Browns Bay appears to contain larger concentrations of fine silts and sediment. It is most likely that this suspended sediment gravitates to this location, possibly originating from upper harbour areas through stream run-off etc. It was observed that strong southerlies funnelling up Pauatahanui Arm stir the upper harbour muddy sediments which are then transported clockwise around to this vicinity.

SECTION 10 SUMMARY & RECOMMENDATIONS

10.1 Summary

10.1.1 The survey of Porirua Harbour is considered complete in all respects. The primary aim of acquiring up-to-date accurate data for hydrodynamic modelling has been achieved. The final data set will be most useful as a baseline survey for any future harbour monitoring programmes. It will also prove useful should LINZ decide to improve/update the current chart.

10.1.2 Comparisons with historic survey data have been made and reported on separately. The results of this clearly indicate that the Onepoto Arm and Pauatahanui Inlets are suffering from ongoing sediment deposition, whilst some of the coastal areas (Plimmerton Beach and Karehana Bay) are suffering from beach erosion.

10.2 Recommendations

10.2.1 It is recommended that a copy of this report, sounding sheets and digital depth data be forwarded to LINZ. Particular reference to Sections 9.1 and 9.2 above should be made with respect to possible charting action.

10.2.2 Should PCC require future surveys for monitoring requirements, then specific areas of interest should be surveyed at regular intervals, rather than full harbour surveys. This will save time and cost. It is most important that repeat surveys be undertaken at regular intervals (at least annually for a period of 2-3 years) to enable accurate assessments of sedimentation rates. Surveys also need to be undertaken to a set of specific standards in order that tangible results can be gleaned from data comparisons. DML can provide outline specifications as well as recommendations for areas to be surveyed for future monitoring requirements if required.

10.2.3 DML wishes to thank PCC for the opportunity to undertake the survey. Assistance provided by Keith Calder (PCC), Mana Marina Management and the Mana Cruising Club is greatly appreciated. In addition Jon Marks from GWRC has been most helpful with coordinating the tide gauge network effort and in providing tidal data.

Greg Cox.

G.J. COX
Managing Director
Discovery Marine Ltd

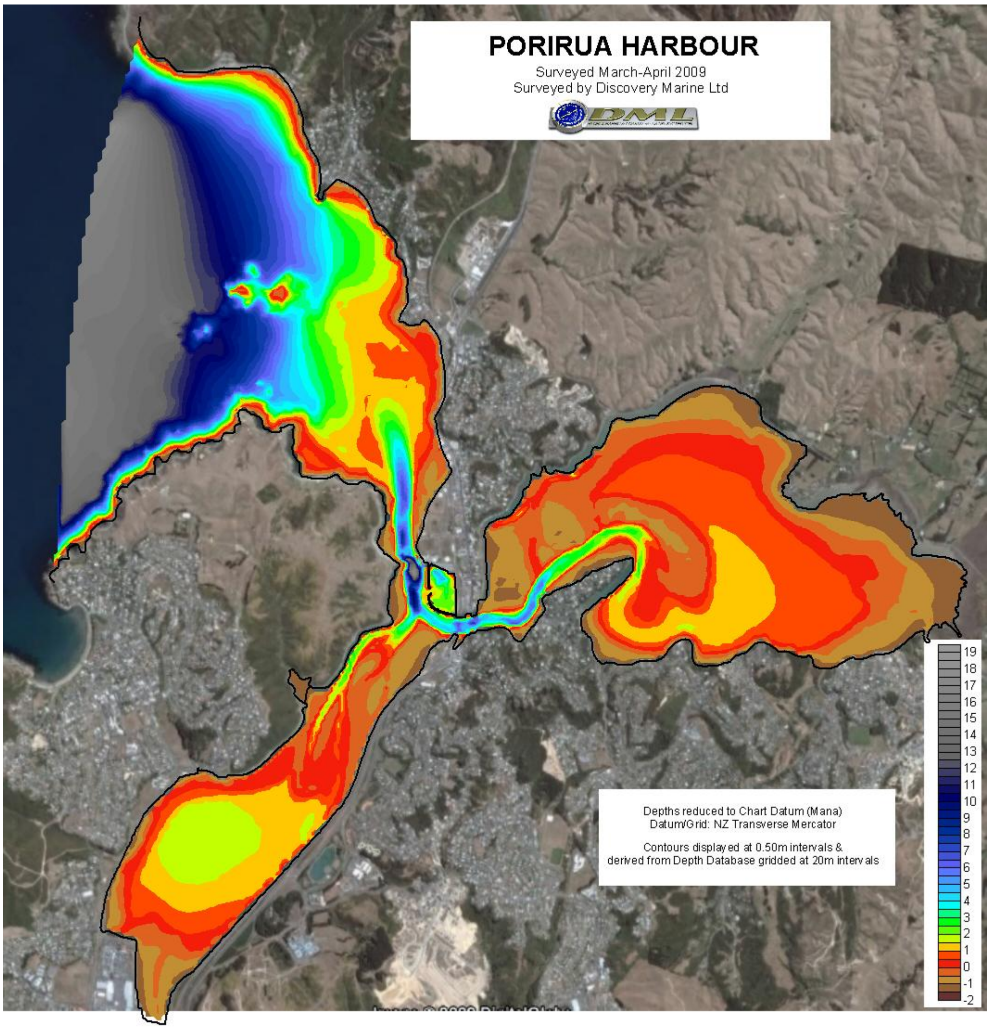
Enclosures:

1. Selection of 2D depth contoured images

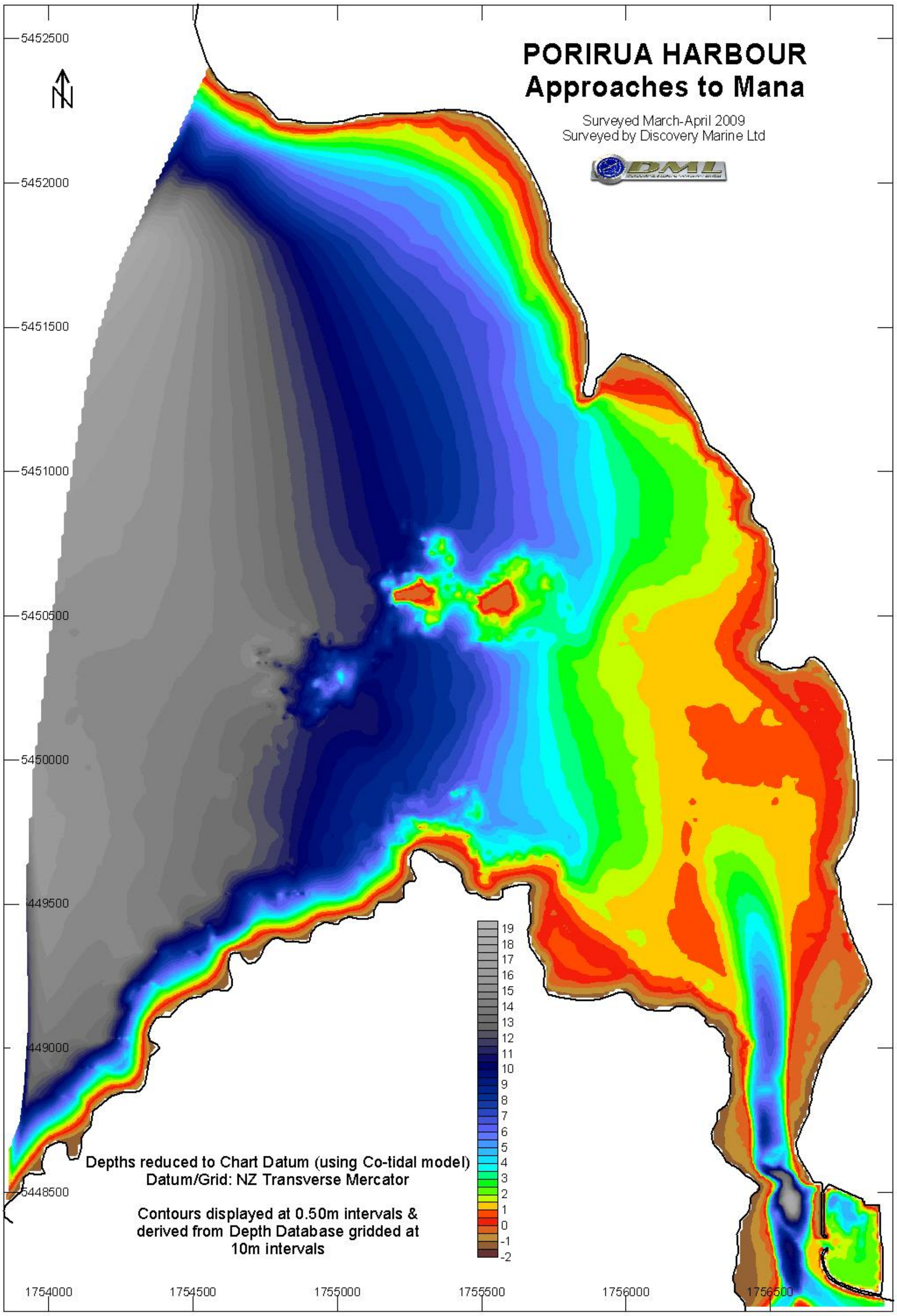
Accompanying Data:

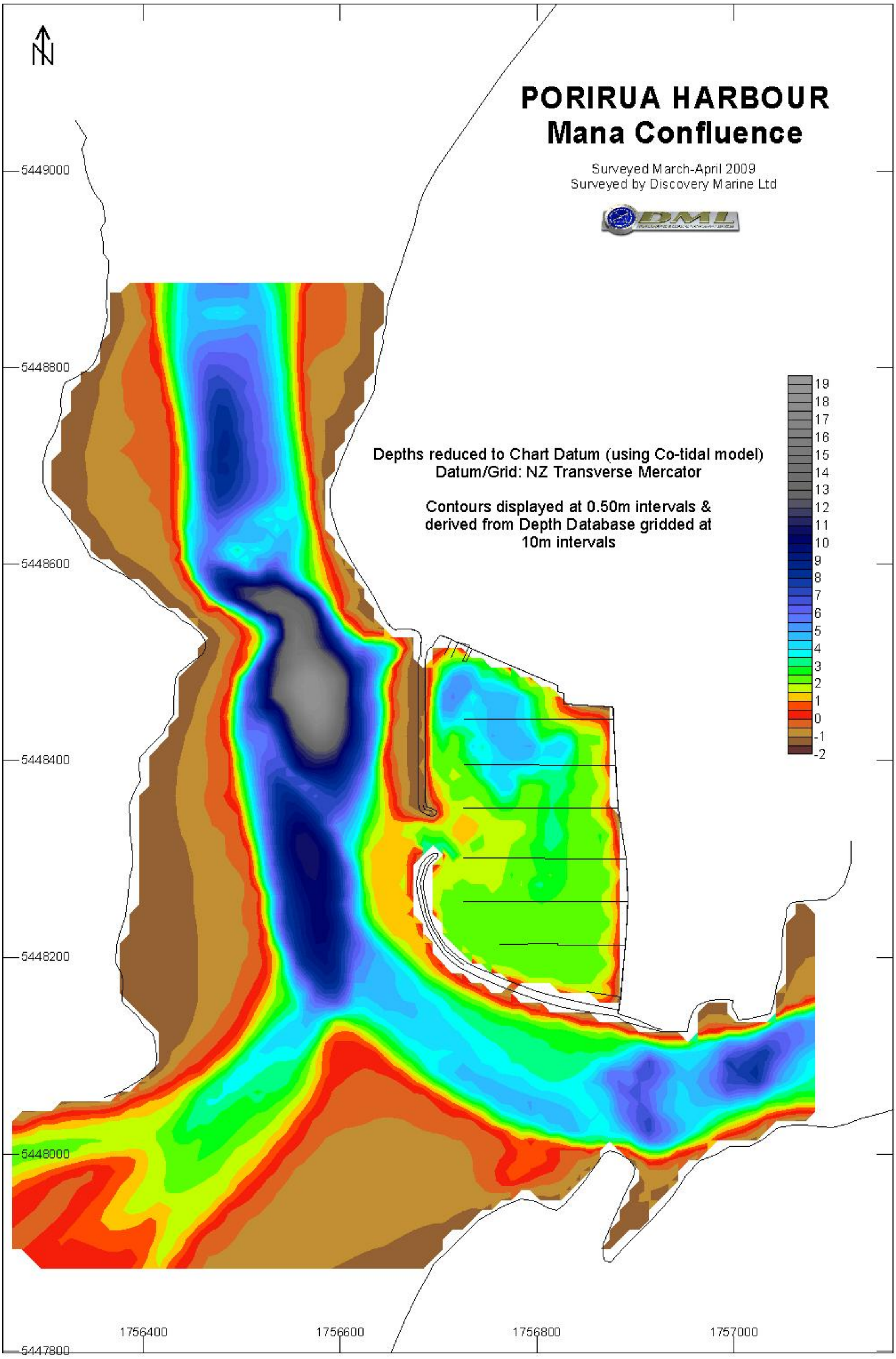
- A1 Sounding Sheet Series at 1:5,000 scale
- CD containing Digital Data

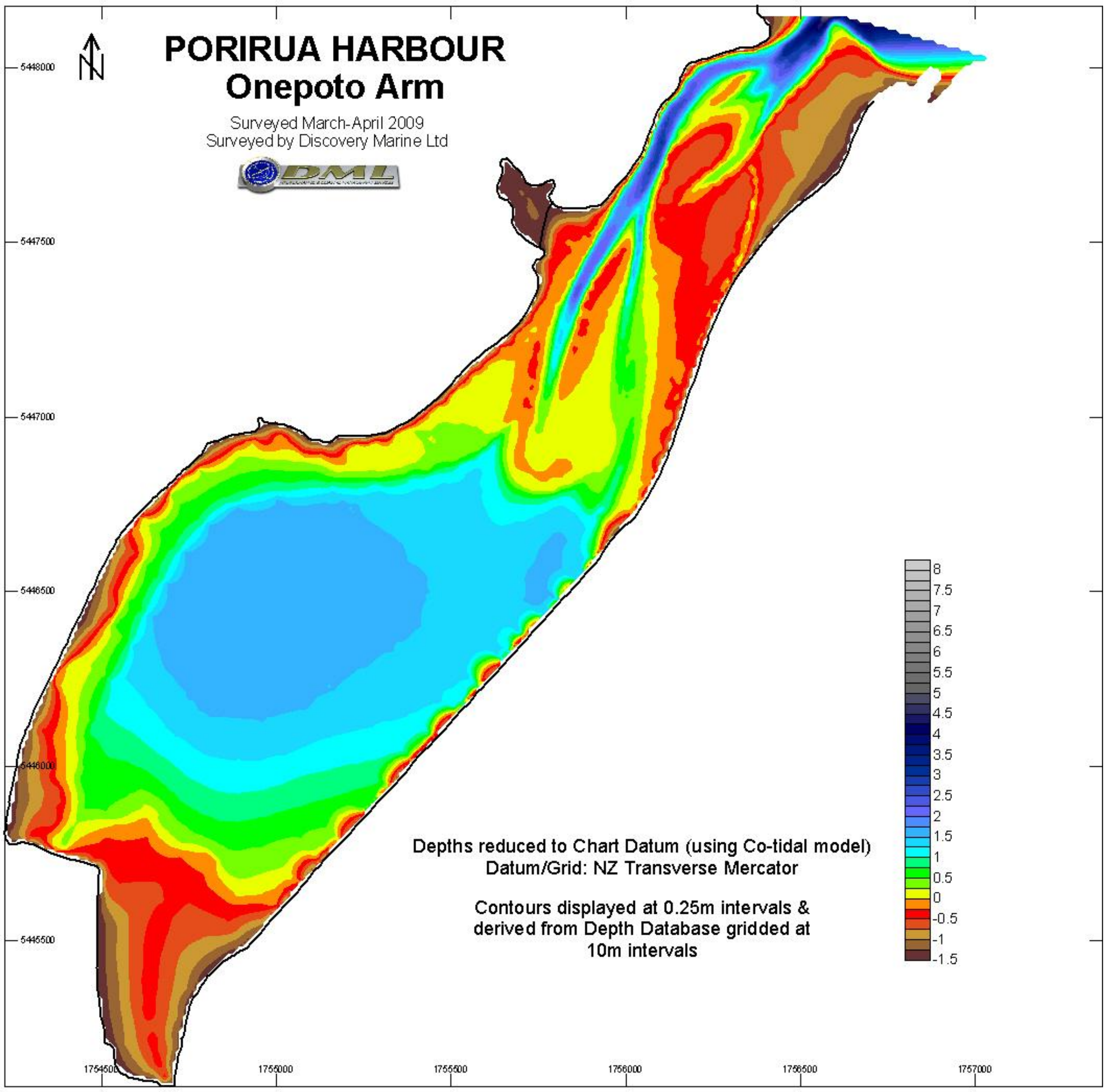
Enclosure 1 - Depth Contour Images

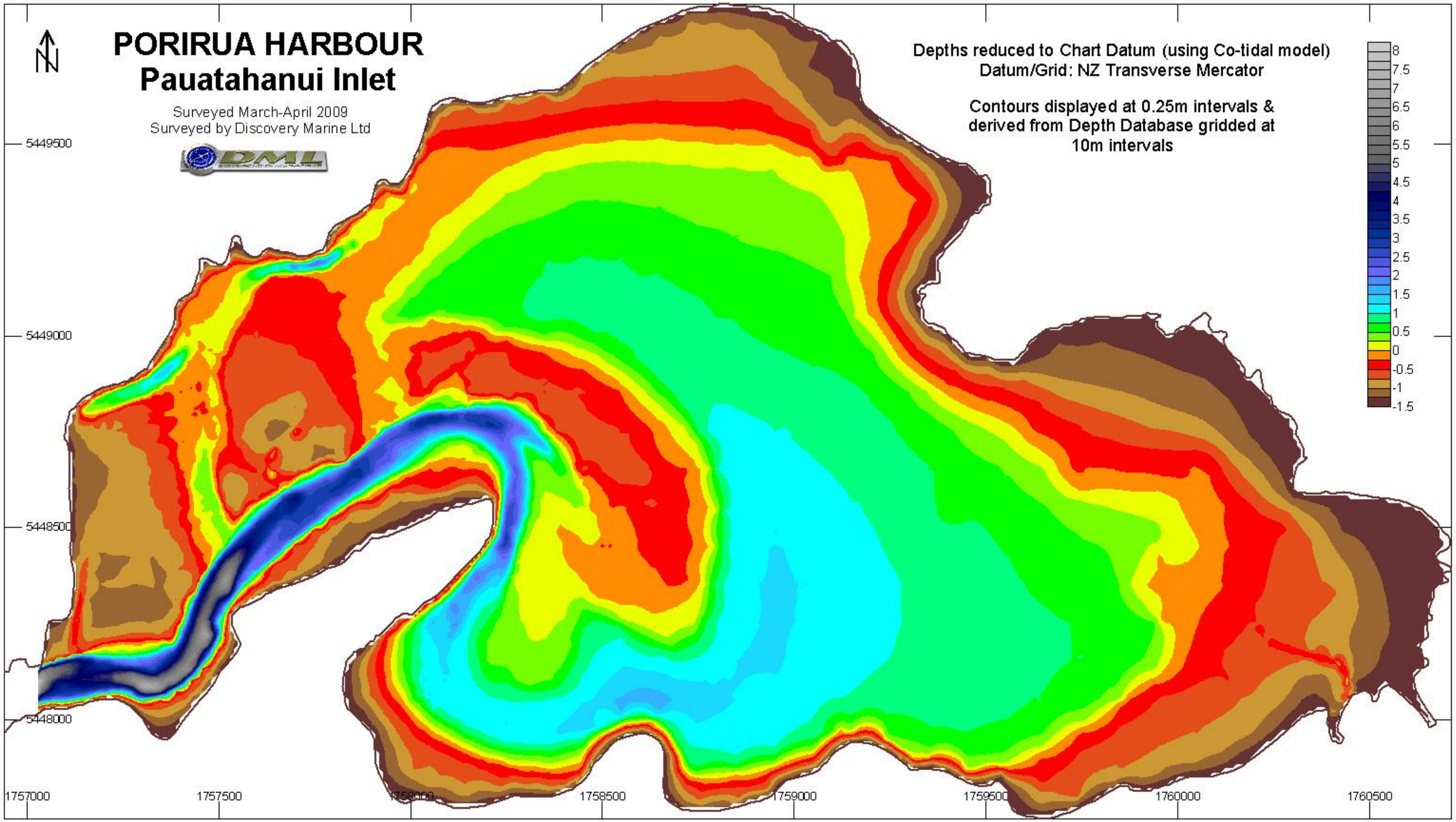


2D Colour Image of Area Surveyed


PORIRUA HARBOUR
Approaches to Mana
Surveyed March-April 2009
Surveyed by Discovery Marine Ltd
5452500
5452000
5451500
5451000
5450500
5450000
5449500
5449000
5448500
1754000
1754500
1755000
1755500
1756000
1756500
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
Depths reduced to Chart Datum (using Co-tidal model)
Datum/Grid: NZ Transverse Mercator
Contours displayed at 0.50m intervals &
derived from Depth Database gridded at
10m intervals


PORIRUA HARBOUR
Mana Confluence
Surveyed March-April 2009
Surveyed by Discovery Marine Ltd
Depths reduced to Chart Datum (using Co-tidal model)
Datum/Grid: NZ Transverse Mercator
Contours displayed at 0.50m intervals & derived from Depth Database gridded at 10m intervals
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
5449000
5448800
5448600
5448400
5448200
5448000
5447800
1756400
1756600
1756800
1757000


PORIRUA HARBOUR
Onepoto Arm
Surveyed March-April 2009
Surveyed by Discovery Marine Ltd
Depths reduced to Chart Datum (using Co-tidal model)
Datum/Grid: NZ Transverse Mercator
Contours displayed at 0.25m intervals &
derived from Depth Database gridded at
10m intervals
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5



PORIRUA HARBOUR
Pauatahanui Inlet
Surveyed March-April 2009
Surveyed by Discovery Marine Ltd
Depths reduced to Chart Datum (using Co-tidal model)
Datum/Grid: NZ Transverse Mercator
Contours displayed at 0.25m intervals &
derived from Depth Database gridded at
10m intervals
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
5449500
5449000
5448500
5448000
1757000
1757500
1758000
1758500
1759000
1759500
1760000
1760500