MULTIBEAM BATHYMETRIC AND SEISMIC SURVEY
LOMALOMA PORT
LOMALOMA, VANUA BALAVU, LAU
FIJI

Robert Smith

Geoscience Division

Pacific Community

Lomaloma Jetty as viewed looking west during this survey in July 2015.

Pacific Community
Communauté du Pacifique

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DISCLAIMER

SUMMARY

This report details the results of a multibeam and single channel seismic survey for Lomaloma an important wharf serving the communities of Vanua Balavu in Lau. The purpose of the survey was to provide bathymetric and interpreted sections from single channel seismic data for assessment of ground and subsurface conditions at the existing port site. Data sets collected include detailed single and multibeam bathymetry side scan imagery of the seafloor within the general vicinity of the port site and single channel seismic data. A grid of single channel seismic lines offshore was collected to assess the subsurface geology and structure. Positioning was by RTK GPS using an SPS 852 licensed to access the Fugro MarineStar service. Tidal corrections are based on 19 days of data collected with a tide gauge installed at the port for that purpose. Vertical control was established and tied to existing bench marks.

Data were collected by the Geoscience Division (GSD) of the Secretariat of the Pacific Community (SPC) during the period from 20th July through to 8th August 2015.

The work planned is as follows:

- Conduct a multibeam bathymetric and side scan survey within the area of the existing port, covering also the seaward approaches to the port.
- Acquisition of single channel seismic data to define bedrock structure and provide geological interpretation of this data.
- Determine Port "Mean Sea Level" and Tidal datums.
- Establish good horizontal and vertical control for three existing or new bench marks as required that link with the Fiji Map Grid
- Provide a survey report.

Deliverables to include both digital data maps; hard copy maps showing the bathymetric, side scan and seismic reflection detail of the substrate of the site. Tidal datum and Mean Sea Level were determined. Mapping coordinates in metres were based on the Fiji Map Grid.

Conclusions

- Multibeam mapping of the Lomaloma Jetty area has delineated well the present morphology of the seabed. Some evidence of scouring caused by shipping traffic at the south end of the jetty face is interpreted from the detailed bathymetry mapping.
- Calculated MSL depth at the jetty head averages 5.5 metres.
- It is evident from the multibeam data that sedimentation is not an issue at present. That said, if sediment continues to accumulate on the south side of the jetty head, at some point it may migrate along the length of the existing structure into deeper water resulting in shoaling beginning at the south end of the jetty.
- Understanding shoreline sediment sources and their migration pathways and sinks is essential to minimising the impact of shore-normal structures such as jetties with solid attachments to land that are constructed and inevitably interrupt shoreline sediment transport processes.

- The seismic data reveals that bedrock is at between 30 m and 35 m depth with respect to the jetty head location. A significant portion of the over-burden appears to be a homogenous sequence of fine sands with bands of high amplitude and continuity visible through the length of the profile.
- Based on the seismic data available, liquefaction would not be considered a significant geological hazard.
- Based on the tide data, and the GNSS levelling survey, 'Mean Sea Level' is calculated to be 1.875 m below the JICA PIN located on the jetty head where height was determined using GNSS.
- Although there is no record of a tsunamigenic event impacting Lomaloma, the events of 1881 where a local *tsunami* event was recorded with a wave height of 1.8 m impacting Labasa; and strong earthquake events impacting Taveuni in 1979 and Koro in 1932, are worth noting.

Recommendations

- Sedimentation may develop into an issue at Lomaloma based on the large accumulation building on the south side of the jetty seen in the Geoeye-1 imagery taken in 2012. With additional shore-normal structures noted, detailed assessment of coastal processes, currents and wave-induced current transport of sediment needs to be completed.
- Location(s) of sites for drilling of boreholes should, where possible, be determined based on the seismic data.
- Consideration be given to conducting occasional high-resolution multibeam surveys to monitor seabed conditions at port and harbour sites where sedimentation is an issue.
- The lack of multi-faceted data sets that look at the long-term impacts of important infrastructure development projects in the nearshore area for rural settings like Lomaloma must be considered a critical gap to their maintenance and further development; and just as critical is the building up of a national database that can be used in the future to better guide similar surveys as this work. Multibeam data sets (for example) once collected in an area can be used for many different applications.

INTRODUCTION AND OBJECTIVES

The primary objective of the survey was to map the geological and geophysical ground conditions at Lomaloma Jetty in Vanua Balavu, Lau Islands group. The location of Lomaloma Jetty is shown in Figure 1.

Objectives

Undertake bathymetric and seismic reflection surveys at the approaches and jetty site for the Lomaloma port in Vanua Balavu, Lau.

The survey works planned at this location included the following:

1) Collect single-channel seismic reflection data to delineate the subsurface structure, sediment thickness and depth to bedrock

2) Collect single-beam and multibeam bathymetric survey of the site and approaches to delineate seabed depth on location and approaches.

3) Derive Mean Sea Level and tidal planes for Lomaloma and provide three GNSS control points for horizontal control with respect to the Fiji Map Grid Datum.

This baseline data will assist with final location and geotechnical conditions to inform engineering design for port infrastructure development.

This report provides an account of the activities and the results of a field survey undertaken from 20th July to 08th August 2015.

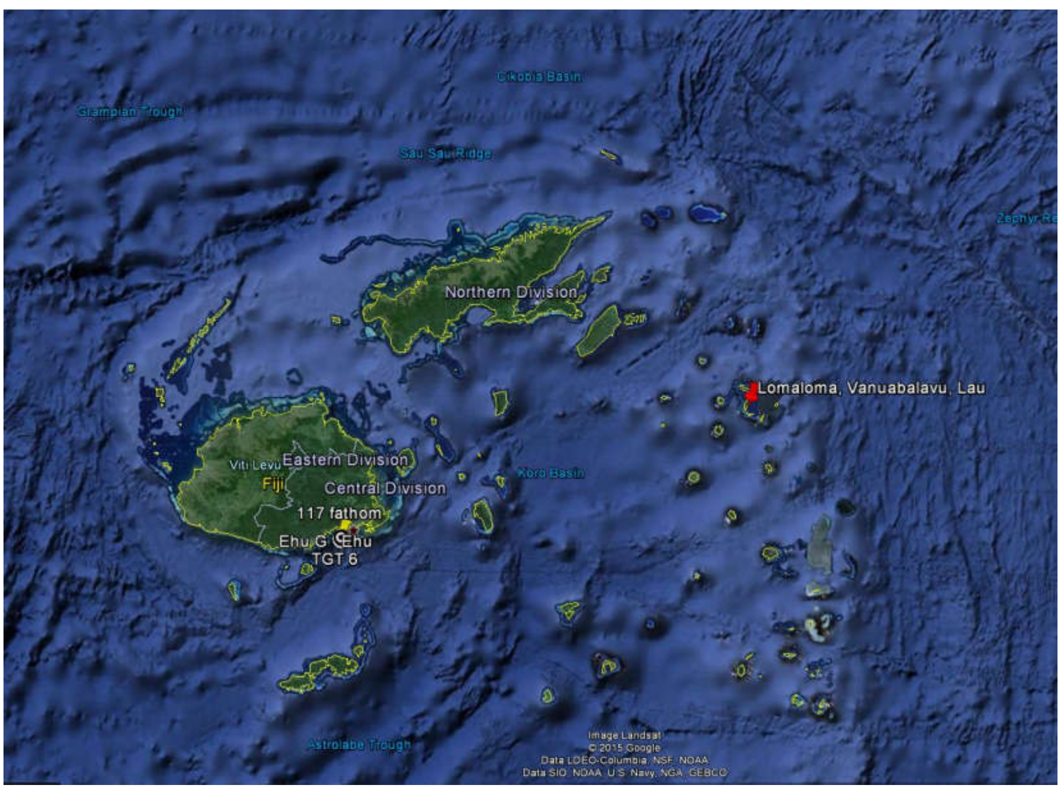

Figure 1: Location sketch showing the location of Lomaloma Jetty on Vanua Balavu Island in the Lau Group captured from Google Earth. Lomaloma is some 180 nm miles from Suva.

EQUIPMENT & METHODS

Navigation Control

Navigation control was accomplished with an Inertial Measurement Unit (IMU) navigation system integrated with the MarineSTAR Fugro correction service for corrected RTK data in realtime (Appendix 1). Map coordinates are based on the Fiji Map Grid projection.

Single Beam Bathymetry

In the shallow areas of the jetty site, namely along the flanks of the jetty head, single-beam profiles were collected at a 10-m line spacing overlapping the multibeam data.

Multibeam Bathymetry

High-resolution swath mapping, using multibeam echosounders, is able to map a complete underwater landscape in a fraction of the time that is currently required by a single-beam echosounder, and with greater accuracy. Computer-processing of swath-mapping data can produce data visualisations that render complex three-dimensional concepts into simple, informative, colour diagrams for the lay observer.

Swath mapping of the sea floor is carried out using sophisticated multibeam echo sounders fitted to a ship or towed at depth. A computer is used to co-ordinate the large amounts of imaging information with the ship's position and attitude at very close time intervals. With further processing, an image can be created that represents, in fine detail, the morphology of the sea floor as well as objects on the sea floor.

Multibeam Configuration

The system used is a R2 Sonic 2024 multibeam system. Details of the system configuration are given in Appendix 2.

Seismic Data Acquisition

High-resolution shallow marine seismic reflection data was collected at the site for subsurface information on the geological structure and sediment thickness. This was done by continuous profiling using a Datasonics Bubble-Pulser SPR 1200 profiling unit on the survey vessel. The seismic source used was a boomer system, mounted on a surfboard sled, operating at 400 Hz that was towed by the vessel. The seismic signal was recorded by a single channel, 7-metre Datasonics BPH-540 Hydrophone Streamer cable with 10 hydrophone elements in oil-filled polyurethane tubing. Band pass filter with low cut frequency of 200 Hz and high cut frequency of 2000 Hz was used. The time variable gain (TVG) setting on the seismic processor was adjusted throughout the survey for best possible signal. The profiles were recorded on an EPC 1048 digital graphic recorder. The seismic profiles collected represent 150 ms two-way travel time (TWT) (11.25 m for 15 ms, assuming interval velocity of ~1.5 km/s).

The seismic profiles are unmigrated. Several acoustic artifacts of non-migrated seismic sections are to be recognised. These are bubble pulse reverberations of prominent seismic reflectors, such as the sea floor, which produce a couplet of reflectors up to 2 milliseconds apart, direct arrivals from source, hyperbolic diffraction patterns and bow-tie effects, and reflection multiples. Individual seismic units can been identified from stratigraphic analysis of seismic profiles on the basis of their geometry, contact relationships, internal structure and reflection characteristics such as amplitude, continuity, frequency and configuration. The seismic profiles also image the near-surface expressions of buried reef sediment thickness and top of bedrock.

Tidal Corrections, Tide Datums and Bench Mark Control

To establish tidal datums and tide levels, a tide gauge was installed at Lomaloma jetty for a period of thirty-five days. The tide gauge and tide pole were tied to MWH local bench marks using high-end Global Navigation Satellite System (GNSS) survey equipment with observation periods of 12 hours on each point. Three such control marks were located in this manner; with the GNSS data post processed using AUSPOST. Notably, a two-week period is required after data is acquired before post processing of the data can be completed. The Top of Tide Pole was then levelled to the control points so that tide datums could then be calculated from the tide data. A 25-hour tide watch was also completed for quality control on the tide data recorded.

Figure 2: Tide gauge installation at Lomaloma Jetty.

For the tide data, two gauges were installed – a Valeport as the primary tide recorder, and a RBR recorder, which is a submerged unit. The locations of the sensors were placed 0.2 m above tide gauge zero of the tide pole. The tide pole had a measured length of 4.05 m.

Figure 3 shows the setup or position of the sensors for the tide gauge.

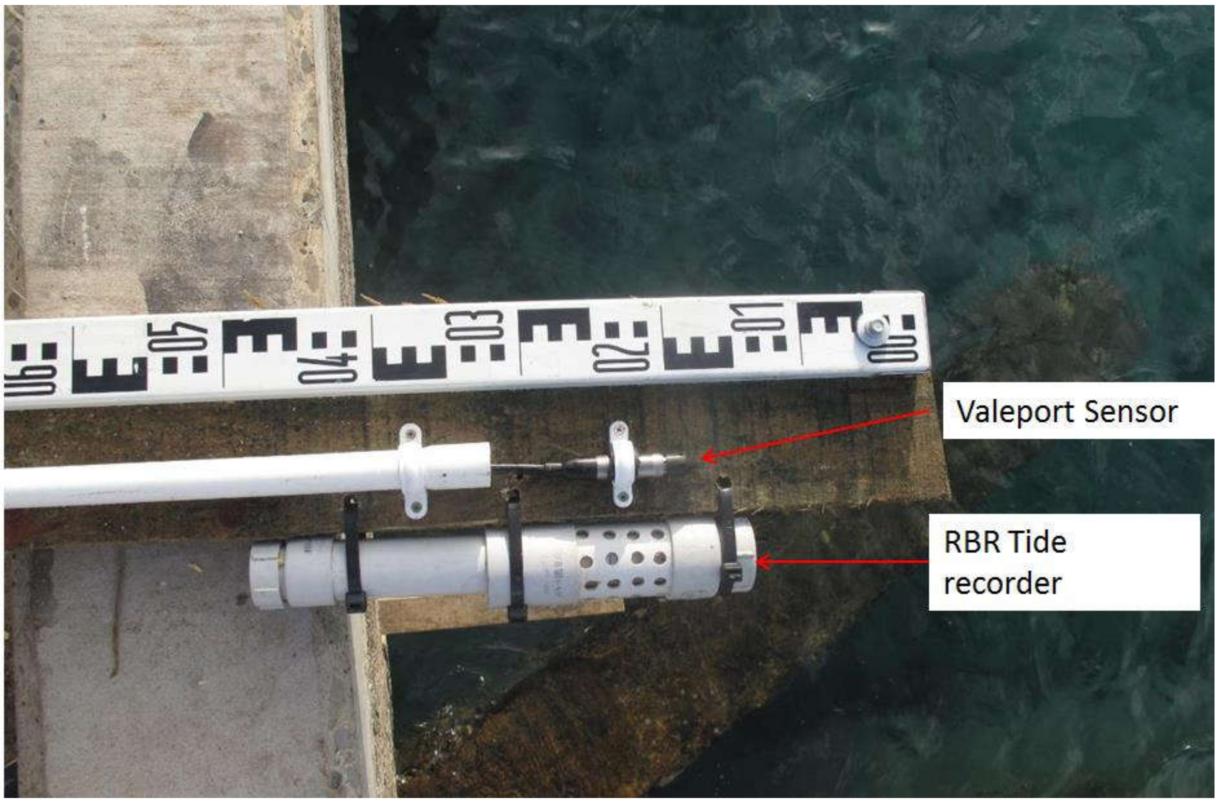

Figure 3: Tide gauge sensor setup showing the actual position of the sensors with respect to the tide pole. Both were placed at 0.2 m above the zero point of the tide pole.

RESULTS

Tides, Vertical and Horizontal Datum Control

Table 1 contains the results of the GNSS data processing with the positions and elevations of the control points and "Top of Tide Pole (ToTP)" heights from which elevations of the tide levels are calculated. Figure 4 are photo diagrams showing the physical locations of the 3 control points surveyed with respect to the jetty position.

Table 1: GNSS survey data results for bench marks and Top of Tide Pole with respect to the Fiji Map Grid.

Point ID	Latitude	Longitude	Easting	Northing	Ellipsoid Height	Elevation m wrt Fiji Map Grid MSL
JICA PIN	-17.29289153	-178.986	2240724	3966173	53.298	2.356
LOM_1	-17.29265219	-178.986	2240673	3966200	53.529	2.588
LOM_2	-17.29255915	-178.986	2240678	3966210	53.586	2.644
ToTP						1.848

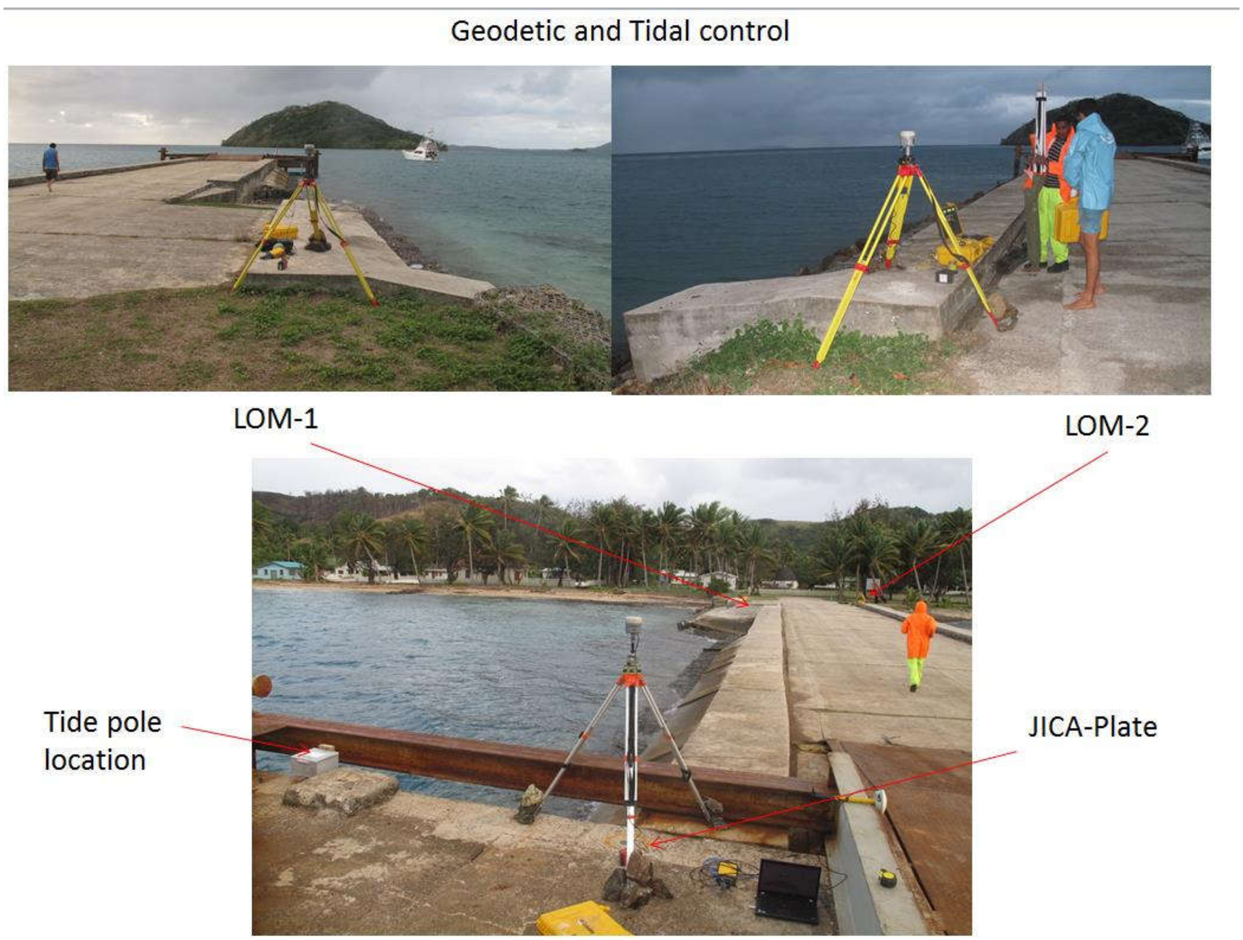

Figure 4. Photo diagrams showing the control points surveyed using GNSS positioning and post processing of data to determine positions and elevations with respect to the Fiji Map Grid. This data are contained in AutoCAD dwg files in the data disc in Appendix 8.

Plate 1: GNSS Net R9 recording on location at the “JICA-PIN” brass plate.

The base drawing initially used to plot the bathymetry and overlay images was the “Lomaloma Jetty Survey.DWG” file provided by MWH; however, following the GNSS survey the common point to both data sets – the JICA-PIN located on the western side of the jetty head – was found to have approximately a 2 m difference in the positions of the JICA-PIN. Using the GNSS position of the JICA-PIN in Table 1, the position of the MWH “Lomaloma-Jetty Survey.DWG” was block shifted to match the new JICA-PIN location, as this was considered more accurate after discussion with the MWH survey team. Post processing results of the positions derived from the GNSS survey are provided in Appendix 6. The new master drawing file is labelled “Lomaloma–Bathymetry-MSL-MWH-shift-2-GSD-points.DWG”.

Tide Data

After setting up the tide gauge, a 25-hour tide watch was completed as a check against the recorded data. A plot of the results is shown in Figure 5. The full data set file is “Lomaloma-Pole to Gauge 25hr comparison.xls” as provided in Appendix 8 for the tide data files (see also Appendix 5).

Lomaloma TIDE GAUGE DEPLOYMENT OBSERVATIONS

HI No:		UKHO REF	
HI Title:		Page No.:	
Tide Gauge Type (&S/N):			
Tide Gauge Location:	Lomaloma		
Tide Pole Zero Relative to Sounding Datum (SD) (+ above and - below) :	0.000	Tide Gauge Zero Relative to SD (+ above and - below) :	0.000
Uncorrected Tide Gauge Multiplication Factor from Scatter Plot Graph (Gradient) :	0.988	Raw Tide Gauge Constant from Scatter Plot Graph (Intercept) :	0.0327

Date and Time dd/mm/yyyy hh:mm	Time	Uncorrected observed Tide Pole	Observed Tide Pole Reduced to SD ie TGZ	Uncorrected recorded Tide Gauge	Tide Pole Red. to SD **minus** uncorrected recorded Gauge	Gauge reduced to SD using value in cell K6 (mean diff. Tide Pole reduced to SD **minus** uncorrected gauge reading).	Recorded Tide Gauge x Scale Error Formula & Reduced to SD	Tide Gauge Direct Red. to SD **minus** Tide Gauge x Scale Error & Red. to SD	Predicted Tide (Above CD)
20/07/2015 2:12	2:12	2.15	2.145	2.14	0.005	2.14	2.146	-0.006	
20/07/2015 2:18	2:18	2.155	2.155	2.136	0.019	2.136	2.142	-0.006	
20/07/2015 2:24	2:24	2.16	2.160	2.125	0.035	2.125	2.131	-0.006	
20/07/2015 2:30	2:30	2.14	2.135	2.12	0.015	2.12	2.126	-0.006	
20/07/2015 2:36	2:36	2.12	2.120	2.114	0.006	2.114	2.120	-0.006	
20/07/2015 2:42	2:42	2.10	2.095	2.102	-0.007	2.102	2.109	-0.007	
20/07/2015 2:48	2:48	2.09	2.085	2.088	-0.003	2.088	2.095	-0.007	
20/07/2015 2:54	2:54	2.06	2.060	2.077	-0.017	2.077	2.084	-0.007	
20/07/2015 3:00	3:00	2.06	2.060	2.063	-0.003	2.063	2.070	-0.007	
20/07/2015 3:06	3:06	2.06	2.060	2.062	-0.002	2.062	2.069	-0.007	
20/07/2015 3:12	3:12	2.06	2.060	2.057	0.003	2.057	2.064	-0.007	
20/07/2015 3:18	3:18	2.07	2.065	2.071	-0.006	2.071	2.078	-0.007	
20/07/2015 3:24	3:24	2.08	2.075	2.077	-0.002	2.077	2.084	-0.007	
20/07/2015 3:30	3:30	2.08	2.075	2.074	0.001	2.074	2.081	-0.007	
20/07/2015 3:36	3:36	2.08	2.080	2.084	-0.004	2.084	2.091	-0.007	
20/07/2015 3:42	3:42	2.10	2.100	2.096	0.004	2.096	2.103	-0.007	
20/07/2015 3:48	3:48	2.12	2.115	2.103	0.012	2.103	2.110	-0.007	
20/07/2015 3:54	3:54	2.13	2.130	2.1	0.030	2.1	2.107	-0.007	
20/07/2015 4:00	4:00	2.13	2.125	2.105	0.020	2.105	2.112	-0.007	
20/07/2015 4:06	4:06	2.15	2.145	2.114	0.031	2.114	2.120	-0.006	
20/07/2015 4:12	4:12	2.16	2.155	2.133	0.022	2.133	2.139	-0.006	
20/07/2015 4:18	4:18	2.17	2.165	2.138	0.027	2.138	2.144	-0.006	
20/07/2015 4:24	4:24	2.17	2.170	2.156	0.014	2.156	2.162	-0.006	
20/07/2015 4:30	4:30	2.19	2.185	2.179	0.006	2.179	2.185	-0.006	
20/07/2015 4:36	4:36	2.21	2.205	2.193	0.012	2.193	2.199	-0.006	
20/07/2015 4:42	4:42	2.23	2.225	2.216	0.009	2.216	2.221	-0.005	
20/07/2015 4:48	4:48	2.25	2.245	2.231	0.014	2.231	2.236	-0.005	
20/07/2015 4:54	4:54	2.27	2.265	2.247	0.018	2.247	2.252	-0.005	
20/07/2015 5:00	5:00	2.29	2.285	2.259	0.026	2.259	2.264	-0.005	
20/07/2015 5:06	5:06	2.31	2.305	2.277	0.028	2.277	2.281	-0.004	
20/07/2015 5:12	5:12	2.33	2.325	2.3	0.025	2.3	2.304	-0.004	
20/07/2015 5:18	5:18	2.35	2.345	2.317	0.028	2.317	2.321	-0.004	
20/07/2015 5:24	5:24	2.37	2.365	2.344	0.021	2.344	2.348	-0.004	
20/07/2015 5:30	5:30	2.39	2.385	2.369	0.016	2.369	2.372	-0.003	
20/07/2015 5:36	5:36	2.41	2.413	2.391	0.022	2.391	2.394	-0.003	
20/07/2015 5:42	5:42	2.44	2.441	2.429	0.012	2.429	2.432	-0.003	
20/07/2015 5:48	5:48	2.47	2.469	2.453	0.016	2.453	2.455	-0.002	
20/07/2015 5:54	5:54	2.50	2.497	2.488	0.009	2.488	2.490	-0.002	
20/07/2015 6:00	6:00	2.53	2.525	2.511	0.014	2.511	2.513	-0.002	

H143 Cover | Observations Table | Tide Curves | Formulae Used | Weather and Remarks

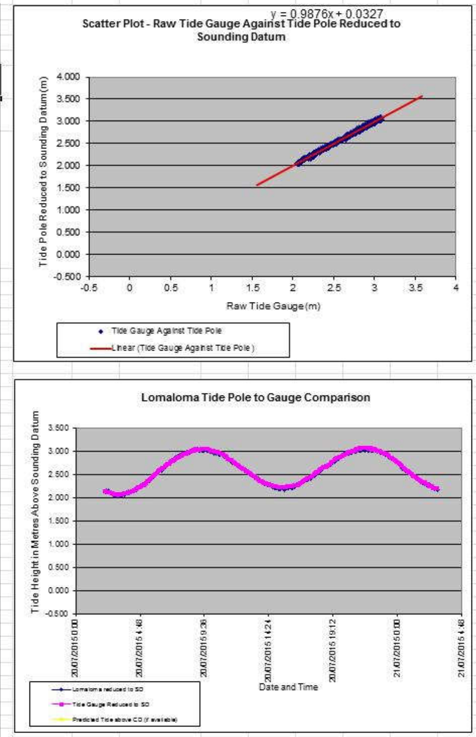

Figure 5: Plot of the 25-hour tide watch for Lomaloma.

Tide gauge data from 20th July through to 7th August 2015, representing 18 days of continuous data, were used to calculate the tide datums. The primary Valeport gauge failed before the 35-day period was reached and the secondary gauge, the RBR tide recorder failed to start logging. Based on the 18 days of data collected, the tide levels were then kindly calculated for this report by Paul Davill of the Tide Unit of the Bureau of Meteorology of Australia. The resulting levels calculated for Lomaloma are illustrated in Figure 6.

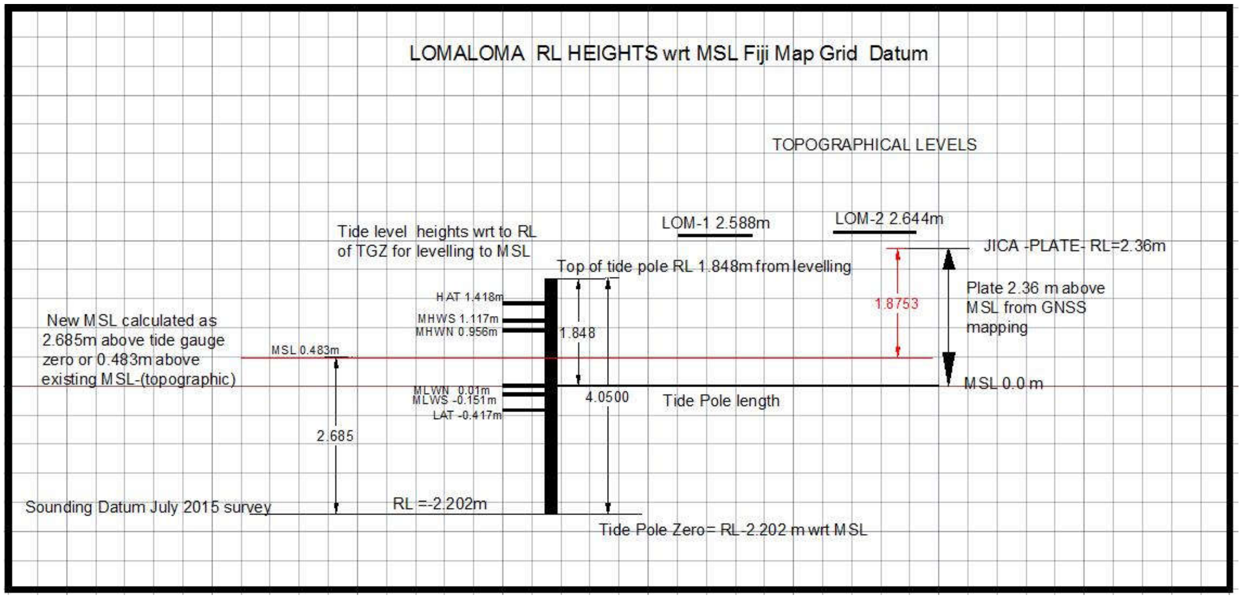

Figure 6: AutoCAD schematic depicting the relationship between the heights of the various Tide Datums, Mean Sea Level (MSL) and the control bench marks.

The working file for this data is named “Datum-levels-Lomaloma.dwg” (see Appendix 8).

Table 2 shows the levels calculated with respect to “Tide Gauge Zero”. Final levels where then calculated based on the levelling results for the height of the tide pole with respect to MSL for the Fiji Map Grid. Based on the tide data collected during this survey, the MSL is calculated to be 1.87 m below the JICA-PIN Brass Plate located on the jetty head. From the tide data recorded during this survey, the MSL has been calculated to be actually 0.48 m higher than the assumed MSL for topographic map reference, which has been calculated to be 2.36 m below the JICA-PIN. Tide gauge zero was set lower than normal as it was not clear where lowest tide would fall so a more conservative depth was set to ensure that the gauge zero point did not become exposed at low tide.

Table 2: Calculated Tide Datums for Lomaloma with respect to (wrt) Tide Gauge Zero.

Tide Datum		Height in metres wrt to Tide Gauge Zero	RL's in metres based on TGZ RL of -2.202(Ref MSL FMG)
HAT	Highest Astronomical tide	3.62	1.418
MHWS	Mean high Water Spring	3.319	1.117
MHWN	Mean High Water Neap	3.158	0.956
MSL	Mean Sea Level	2.685	0.483
MLWN	Mean Low water Neap	2.212	0.01
MLWS	Mean Low Water Spring	2.051	-0.151
LAT	Lowest Astronomical Tide	1.785	-0.417

Data Processing – Multibeam and Single Beam Data

The multibeam data were processed using HYSWEEP software from HYPACK Inc. Sound-velocity profiles were generated from conductivity, temperature, pressure profiles that were taken during the course of the survey. Accurate sound-velocity profiles are required to correct swath data for refraction-path travel times. Detail on the data-processing process is provided in Appendix 2.

XYZ Files Generation and Contour Plots

Using the multibeam processing software MAPPER xyz, files for surface modelling were extracted based on a cell matrix size of 1.0 m. Further details of this process are given in Appendix 2. A series of maps at scale 1:5000 showing the bathymetric contours have been drawn using AutoCAD MAP 2012. The contour plot of the bathymetry was generated using QuickSurf working inside AutoCAD for final plotting. Final file with "x,y,z" data points used for the generation of contour plots is "Lomaloma Bathymetry-MSL-5msort.xyz". This final data has been referenced to MSL based on tide data measured for this project. The map sheet showing the final bathymetric contours (Sheet 1) at a scale of 1:2500 with a contour interval of 0.5 m is provided in Appendix 3.

Multibeam Bathymetry

Processing of the multibeam data from Lomaloma follows along the lines as described in Appendix 2 Processing files used are identified in the multibeam log (Appendix 7). Based on the three days of survey for Lomaloma area, the xyz data set was extracted from the edited file logs based on a cell matrix size of 1x1 m. The sounding matrix used was Lomaloma port. The extent of this is shown in Figure 7. The colour map represents multibeam data and the single straight lines represent single beam data collected on top of the reef at high tide.

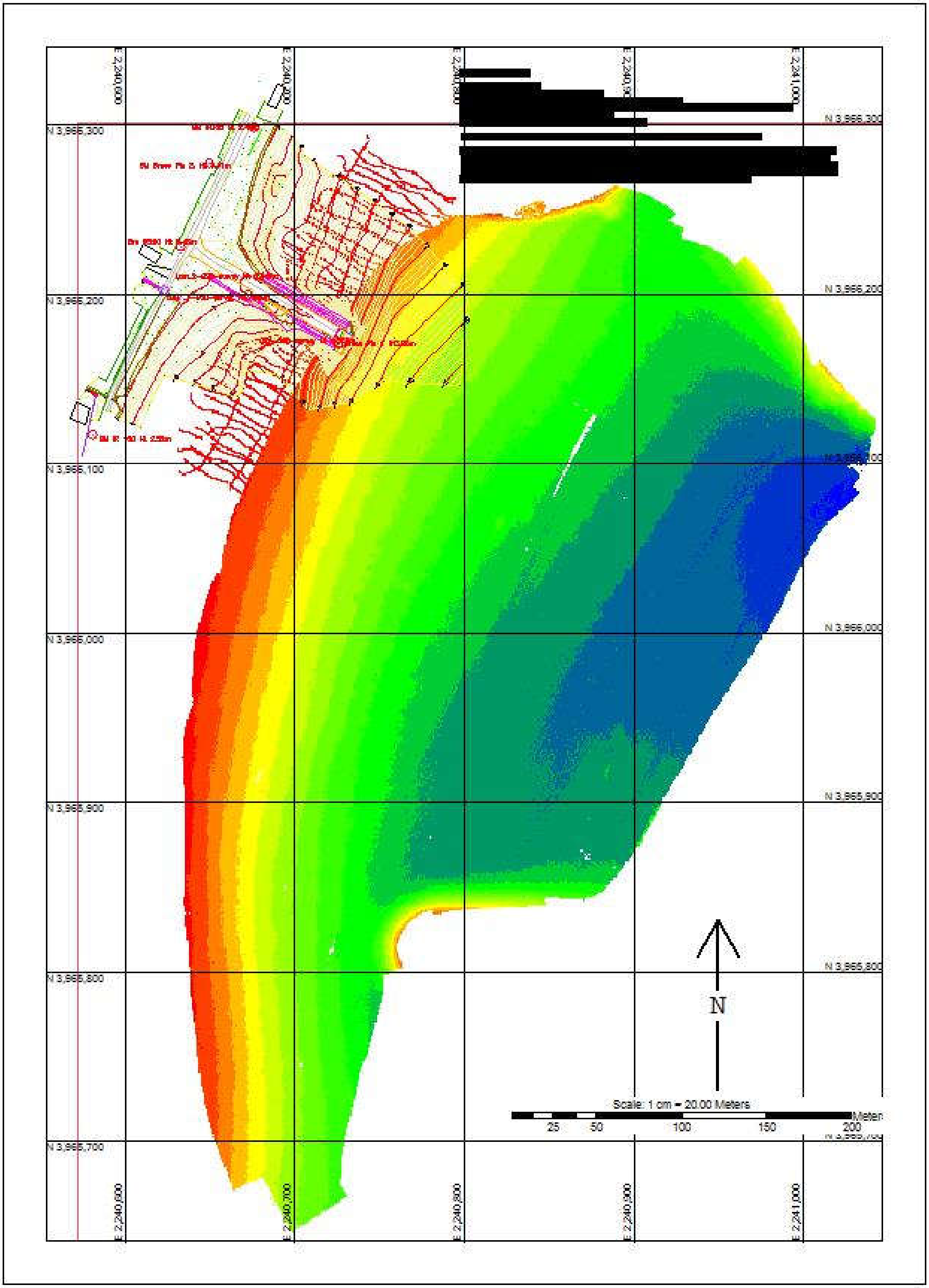

Figure 7: Map showing multibeam coverage and single beam tracks (red lines) for Lomaloma.

Figure 8 is a contour map of the bathymetry of the immediate area and approaches to the Lomaloma Jetty.

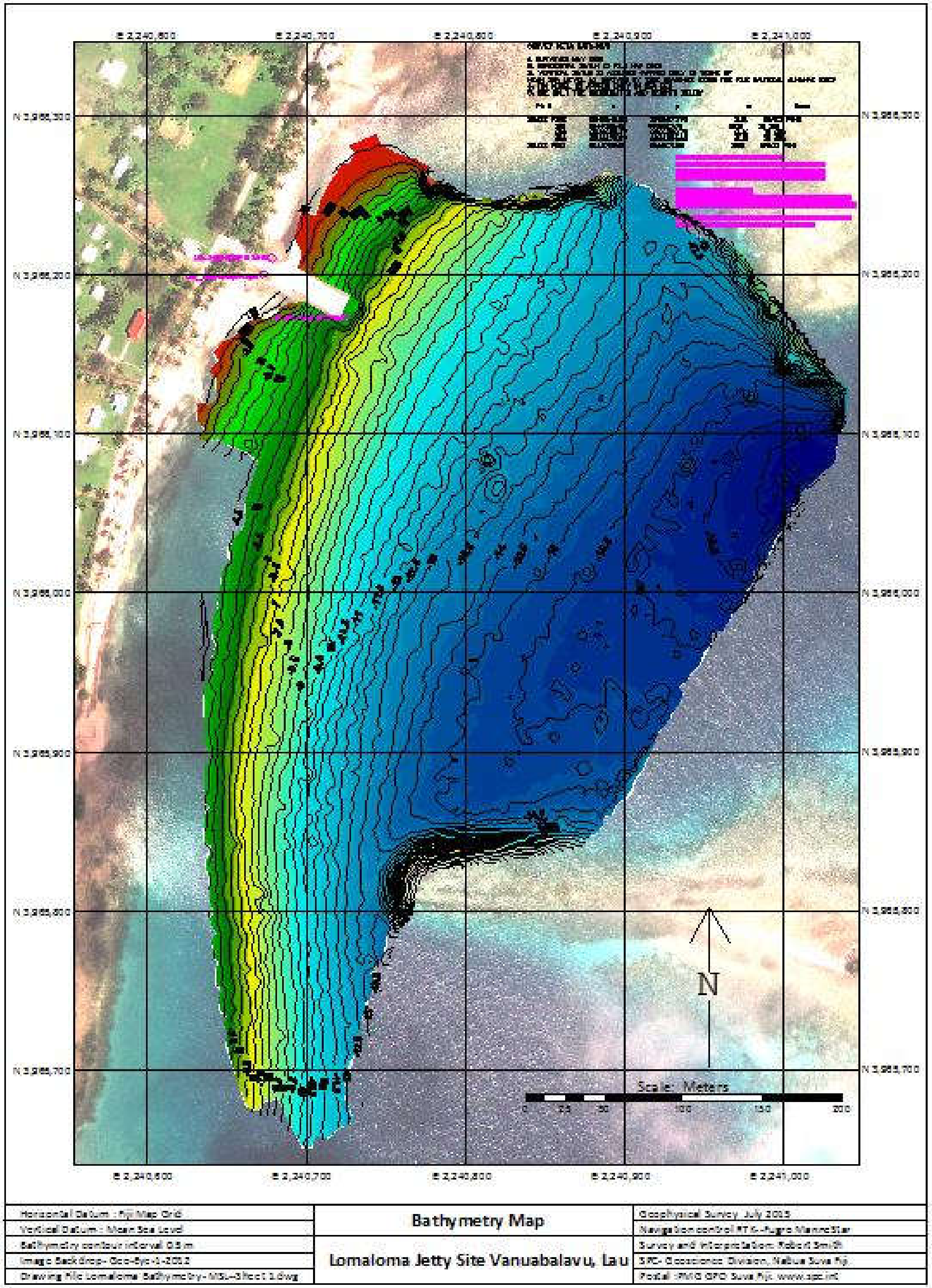

Figure 8: Detail of the bathymetry around Lomaloma Jetty. Contours interval is 0.5 m. The bathymetry reflects a very uniform slope and curvature setting. Minor scouring can be interpreted from the contours close to the southern end of the jetty. This is probably due to the fact that vessels prefer approaching from the south to dock at the wharf.

From the bathymetry shown in Figure 8, the jetty head has an average depth of about 5 m for MSL. The bathymetric isobars reflect a very uniform slope and curvature that follows the general shape of the coastline and fringing reef. The site is nestled in between coral reef patches and Yanuyanu Island to the east as seen in a bird's eye view of the area using Geoeye-1 satellite data from 2012. It should be noted that geo-rectification of the image is best around the wharf area and but degrades as you move away due to the lack of good control points away from the jetty. During the survey period it was found that the site is very exposed to south and southeast winds which can pin vessels to the jetty head, making it difficult for them to pull off.

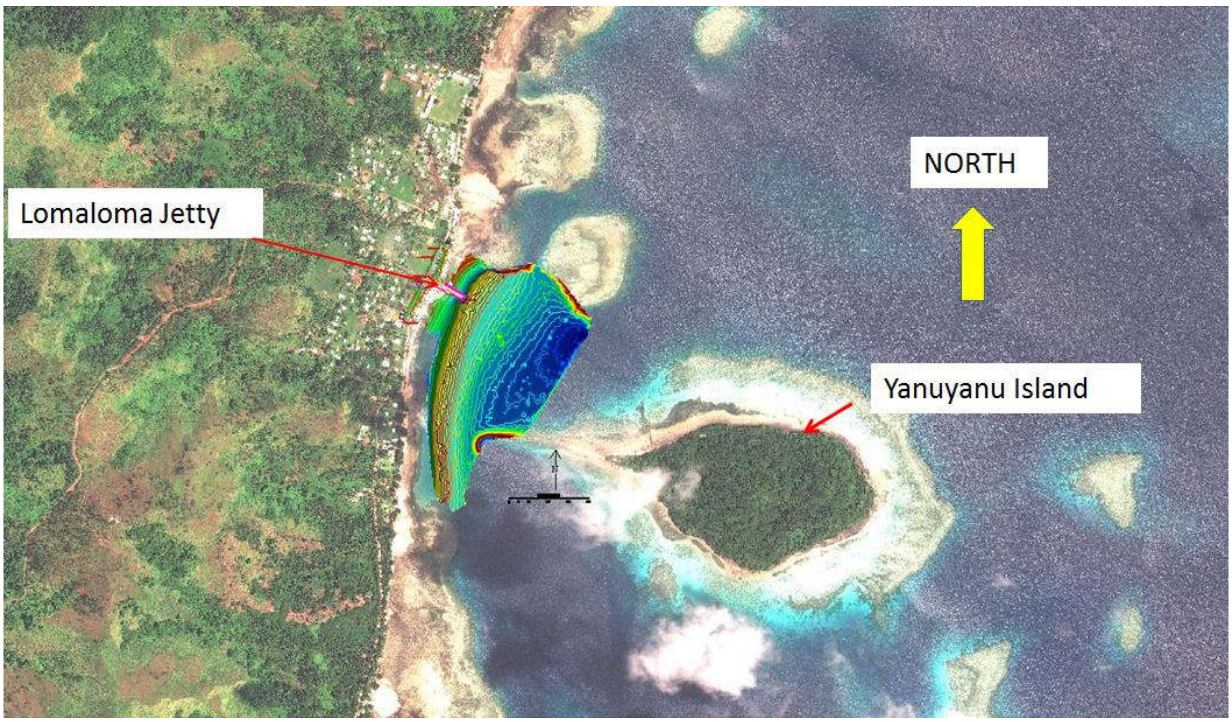

Figure 9: Bird's eye view of Lomaloma Jetty illustrating the setting with Yanuyanu Island to the east.

Although assessment of the suitability of the site is not a requirement of this study, Lomaloma Jetty appears to be sited in an area that would have an energetic hydrodynamic regime with narrow channels to the north and south and a single larger navigable channel to the north east that would be of consideration for vessel maneuverers in this area. Yanuyanu Island to the east actually affords little protection to the jetty site from the dominant wind directions east and southeast, based on the experience of this survey. The potential for vessels to be pinned to the wharf by strong easterlies and southeast winds is a known fact at Lomaloma (Figure 10).

Figure 10: The M.V. Vunilagi *docked at Lomaloma during the survey. Wind speeds were 15 - 20 knots from the east during this period. The vessel is moored with the bow north.*

Sidescan Mosaic Data and Interpretation

The digital sidescan data for the area surveyed has been compiled into a mosaic at a scale of 1:2500 with a resolution of 0.18 m (Appendix 4). The AutoCAD file "Lomaloma-Sidescan-Mosaic-Sheet-3.dwg" and a pdf file "Lomaloma-Sidescan-Mosaic-Sheet-3.pdf" versions of this plot (Figure 11) are provided in Appendix 8.

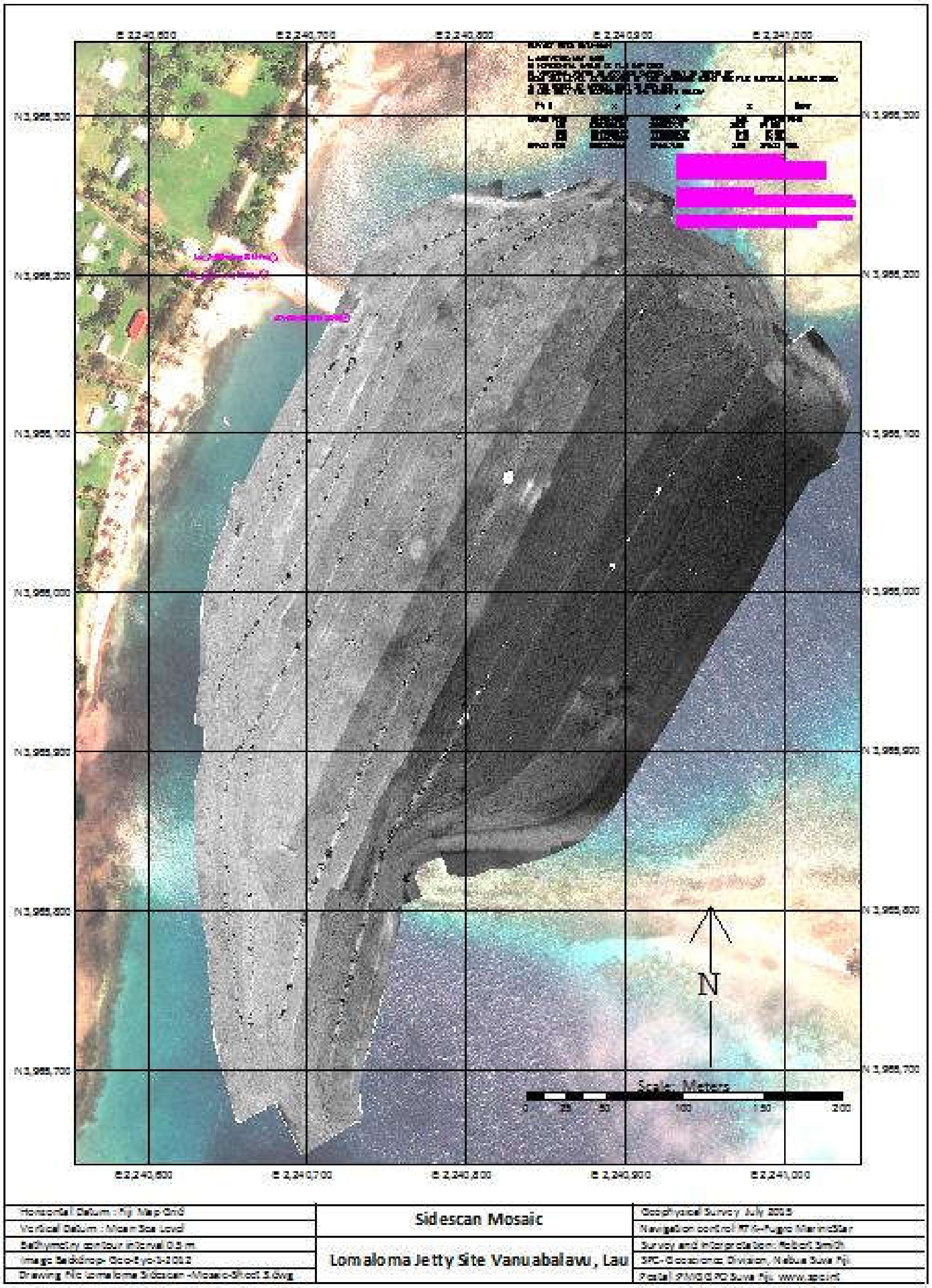

Figure 11: Sidescan mosaic compiled from the multibeam data. Reef structures are clearly identifiable from the sediments of the basin and offshore areas. Different shades of grey in the sediments represent different sediment types and some artefacts of gain control during acquisition.

Reef substrate is mostly present where patch reefs occur and on the slopes of the fringing reefs of Vanuabalavu and Yanuyanu islands. Much of the seabed appears to be a sandy substrate with an occasional coral. No notable bathymetric features occur that could be considered hazardous to navigation with respect to the approaches and jetty head. In the deeper water there are two patches which occur offshore from the jetty head both approximately 1 m above the seabed with a shoal depth of 12.1 m and 11.1 m, respectively. The lighter grey areas indicate coral detritus with higher reflectance clearly visible where the coral patches occur. The rather dark areas are where changeover in receiver gain settings occurred during acquisition; and also a reflection of increased water depth. The mosaic was generated using Geocoder.

Lomaloma Geology and Coastal Geomorphology

The geology of Lomaloma is described in MRD Bulletin No.9, with Map Sheet 2 covering the geology of Vanua Balavu (WoodHall 1984). The Lau Volcanic Group crops out extensively on southern and northern Vanua Balavu and the islands of Namalata, Susui, Munia, Cikobia-i-Lau and Avea. For the Lau Volcanics, a number of different volcanic centres have been described to represent this group based on the fact that although there are similarities in the rock lithology for the islands in the group, there exist quite distinct structural differences. These are the Koroniuvi Volcanic, which dominate southern Vanua Balavu, Naosedabila Volcanics of northern Vanua Balavu, Munia andesite and Cikobia-i-Lau andesite. The Koroniuvi Volcanics of Late Miocene age consists of volcaniclastic rocks with associated lava and minor intrusions forming the 10 km long and 2 km wide southern part of Vanua Balavu. The overall structure of the Koroniuvi Volcanics is that of strata and lava flow units dipping northwest to west and southwest on southern Vanua Balavu.

The detailed geology is presented in Figure 12.

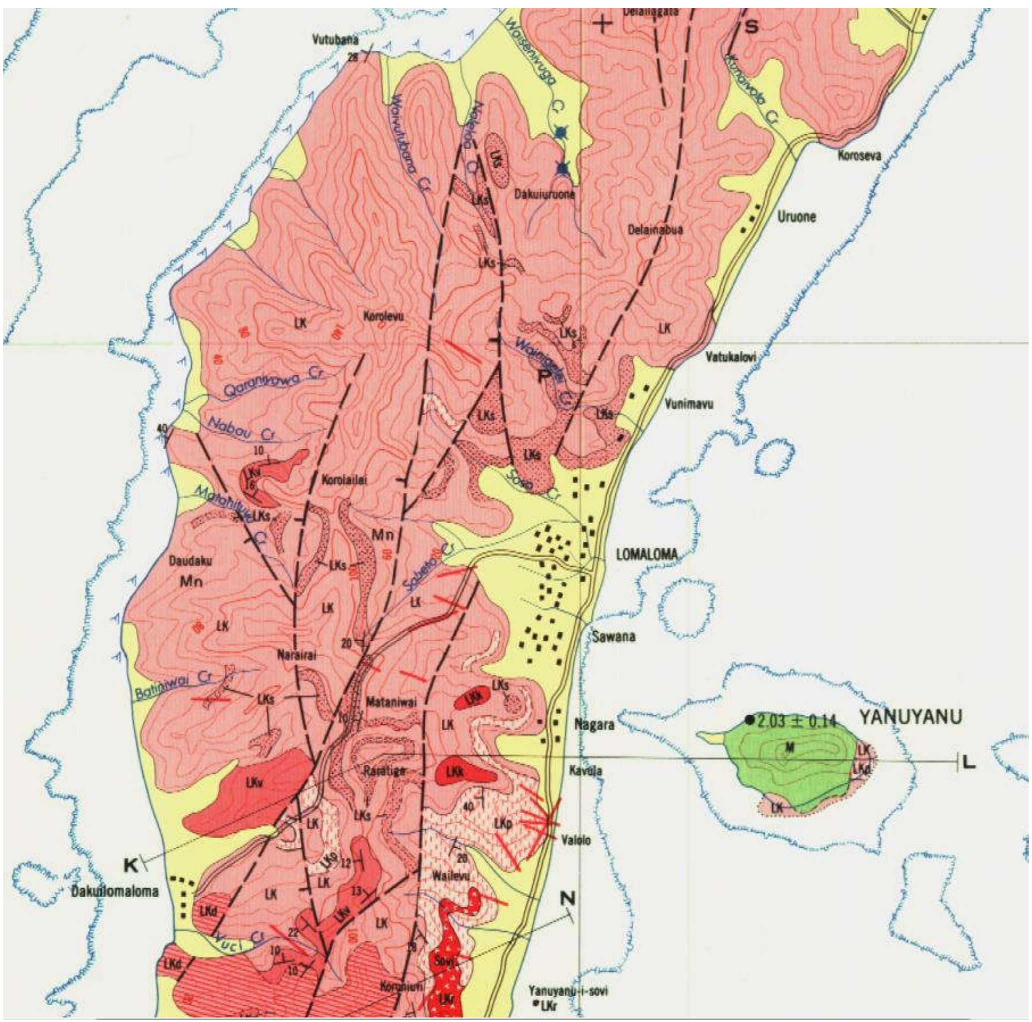

Figure 12: Geological map of Lomaloma (after WoodHall 1984). Main structural and morphological features are illustrated. Vanua Balavu geology is complex. Much of the inferred faulting runs north-south with the down side of the faults to the west. Swarms of intrusive dykes are indicated to exist by red lines visible near Valolo. Lomaloma is dominated by sands of alluvium and colluvium deposits. A number of streams are mapped which would be the source of the paleochannels seen in the seismic data of line 001and shown in Figure 15. A hot spring is located near Dakuiuruone top centre.

Basement or bedrock in the Lomaloma area is interpreted to be andesitic flows and lavas of the Koroniuvi Volcanic Group**.**

To the west of Lomaloma is Yanuyanu Island, an outcrop of the Mago Volcanic Group; a product of Quaternary volcanism that followed after uplift and faulting. Most of the island consists of a thick flow of basaltic lava that overlies an eroded surface of the Lau Volcanic Group rocks. The radiometric dates indicate a Pliocene age later than the Korobasaga Volcanic Group and geochemical and petrographic analyses indicate that the Yanuyanu lava is compositionally distinct. Geochemical analyses indicate alkali olivine basalt, transitional to hawaiite, and in thin sections the lava is non-prophyritic, but coarsely textured with abundant plagioclase laths (70%), olivine (20%) and magnetite (7%). Hawaiite is a volcanic rock that resembles basalt but is generally a lighter grey in colour in contrast to that of basalt which is often black or dark grey. The descriptive term described from Hawaii volcanics. Laminar flow planes in the lava, exposed in the eastern cliffs of the island have a westerly dip suggesting that the vent was located east of Yanuyanu in what is now the lagoon.

Faults affect the Lau and Korobasaga Volcanic Groups; and the Tokelau Limestone Group on all the main islands, but there are few exposed fault planes. Most of the exposed faults trend either north-northeast or north-northwest. Small fault effects are apparent in the exposures along the Lomaloma-Dakuilomaloma road of the Narairai Epiclastic member of the Koroniuvi Volcanic Formation. Overall the configuration of the Exploring Isles reef system is indicative of fault control. It is possible that there is an element of structural control for the fringing reef at Lomaloma, due to the fact that it is rather linear and considerably narrower with respect to the fringing reefs north and south of Lomaloma.

Superficial Deposits

Carbonate sand and gravel, mostly unconsolidated and composed of skeletal organic material derived from adjacent lagoons and reef form the outer part of the coastal plains associated with the volcanic topography associated on Vanua Balavu. The most extensive coastal planes on Vanua Balavu are where the villages Mualevu, Mavana, Malaka, Boitaci and Lomaloma have been established. Consolidated carbonates in the form of beach rock are commonly exposed along parts of the coast of most of the villages.

The reef system that encloses the Exploring Isles is the site of present-day carbonate deposition. Fringing reef extends around most parts of the islands. In Lomaloma where the present jetty is located the fringing reef is noticeably narrower to the south of the jetty indicative of bedrock as interpreted from the seismic data as being deeper in this area. From the image, the seaward side of the fringing reef south of the jetty appears very linear indicative of some structural control – either by control of the bedrock in the subsurface or that it is fault controlled. As a result, to the south of the jetty, the reef affords little protection to the shoreline from wave attack resulting in significant erosion that is most noticeable along this part of the foreshore as shown in Figure 13.

The inclusion of shore-normal structures is obviously having an impact on the coastal processes in this location. The significant sand accumulation against the south side of the jetty implies that the jetty structure is restricting the northward transport of sand, as seen in this Geoeye-1 image of 2012; and significant cuspate erosional scars has exposed possible beach rock or reef in the nearshore. A further smaller shore-normal structure, south of the jetty, is also apparently compounding the issues of shore transport of sand from source to sink. Also apparent in the photo image of the shoreline in Figure 13, is present an additional shore normal structure that would be impacting on the long drift of sand to the north.

Figure 13: Shoreline erosion south of the jetty head. In the Geoeye-1 image of 2012 there is more sand accumulated on the south side of the jetty (North is page up) indicative of northward transport system. Large cuspate erosion scars are also apparent with underlying reef (beachrock?) exposed.

A number of hot springs are reported to exist on Vanua Balavu and have been mapped and sampled (Rodda 1979). Of these springs are Dakuiuruone, located northwest of Lomaloma; Udu and Raralevu, south of Lomaloma, on the east coast.

Seismic Data and Interpretation

Interpretation of the subsurface geology and structure with depth to bedrock is based on single channel seismic data collected offshore adjacent to the site at middle point. Five seismic lines were completed. Individual seismic units can be identified from stratigraphic analysis of seismic profiles on the basis of their geometry, contact relationships, internal structure and reflection characteristics such as amplitude, continuity, frequency and configuration. The seismic profiles also image the near-surface expressions of buried reefs, sediment thickness and top of bedrock. A grid of lines was run across the area and these lines are shown in a track plot in Figure 14, referenced to the wharf site. File reference is “Lomaloma-seismic-profile-location-map-Sheet4.dwg” and pdf (on Appendix 8, and large plot provided in Appendix 4).

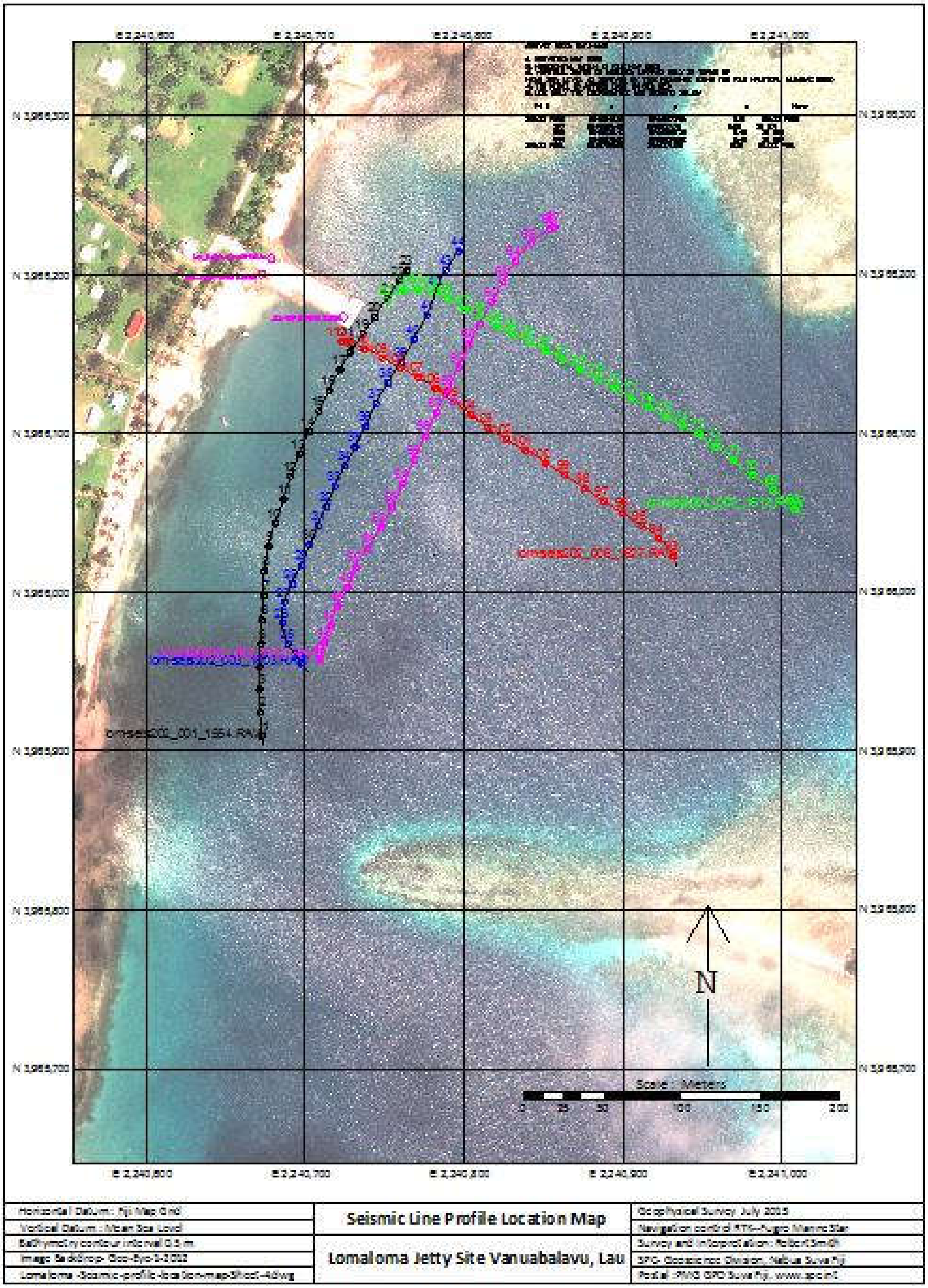

Figure 14: Seismic line track plot with respect to Lomaloma Jetty.

The author is not aware of any existing borehole data for Lomaloma Jetty, to assist with interpretation of the seismic profiles collected; however, three horizons are delineated in the seismic data with mapping of the interpretation of depth to bedrock compiled. Two seismic profiles are provided to illustrate the subsurface geology interpretation at Lomaloma. Figure 15 is the seismic profile “LOM-seis_202-001_1554.raw”, which crosses the face of the wharf from south to north and Figure 16 is a seismic profile from the jetty head towards Yanuyanu Island.

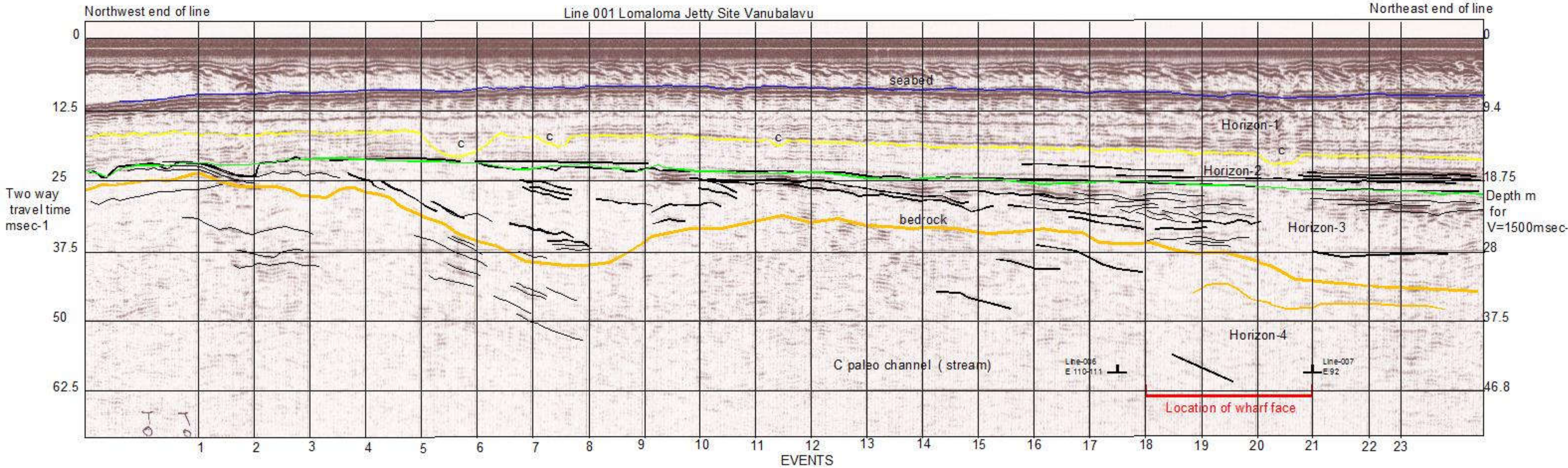

Figure 15: Interpretation of single channel seismic profile Line LOM_seis_202_001.15554.raw

In Figure 15, the location of seismic profile 1 with respect to the jetty head and boreholes is illustrated; and the position of the jetty head (wharf face) is indicated to be located between events 18 through 21. Up to four horizons have been interpreted based on the seismic reflection patterns seen in the cross sections. Each horizon is delineated by a colour boundary line separating seismic reflection patterns sequences. Continuity of horizons across sections is based on line intersections. A geological interpretation of the horizon is made based on the seismic reflection characteristics. The first is seabed and is depicted by the blue line. Horizon-1 shows a thickening of sediment from south to north. Internally the reflectors show good continuity, are parallel with good amplitude in terms of reflectance. The thicker sediments to the north imply sedimentation is coming from this direction. The second horizon, coloured yellow, marks the base of Horizon-1 and the top of Horizon-2. Horizon-2 appears to represent a hiatus in deposition with the presence of paleo channels delineated at events 5-6, 7-8, 11-12 and 20-21, associated with a possible erosional phase during a possible sea level hiatus. Reflection characteristics of Horizon-2 are low amplitude with faint continuity indicative of sediments that are relatively homogenous and weakly stratified, most likely a sequence of silts and fine sand. Horizon-3 is seismic facies representing the initial phase of deposition on bedrock. Reflections appear hummocky and chaotic possibly representative of a fan complex, with some cross bedding, which indicates deposition in a higher energy environment; and infilling of depressions in the erosional surface of the bedrock. From the south, in places, they appear as foreset beds prograding into shallow waters and infilling depressions within the bedrock. Top of bedrock is a little more difficult to delineate across the sections. Where reflections are visible, they show strata dipping north. Bedrock is interpreted to be andesitic lava flows, breccia and occasional basalts and andesitic basalts are present. It is worth noting that outcrops indicate epic clastic sandstone and conglomerate with some calcareous sandstone and impure in the south of the area. Yanuyanu Island is interesting with basalt lava with basal hyaloclastite formation of younger age intrusive. Hyaloclastite formations are best described as basalt lava flowing into the water and building up volcanic deltas that resemble foreset beds. Figure 16 is a detailed section of the seismic data across the existing wharf face. Full profile interpretation is contained in file “Seismic profile–line1-Lomaloma-Jetty.pdf” in Appendix 4 and digital copies in Appendix 8.

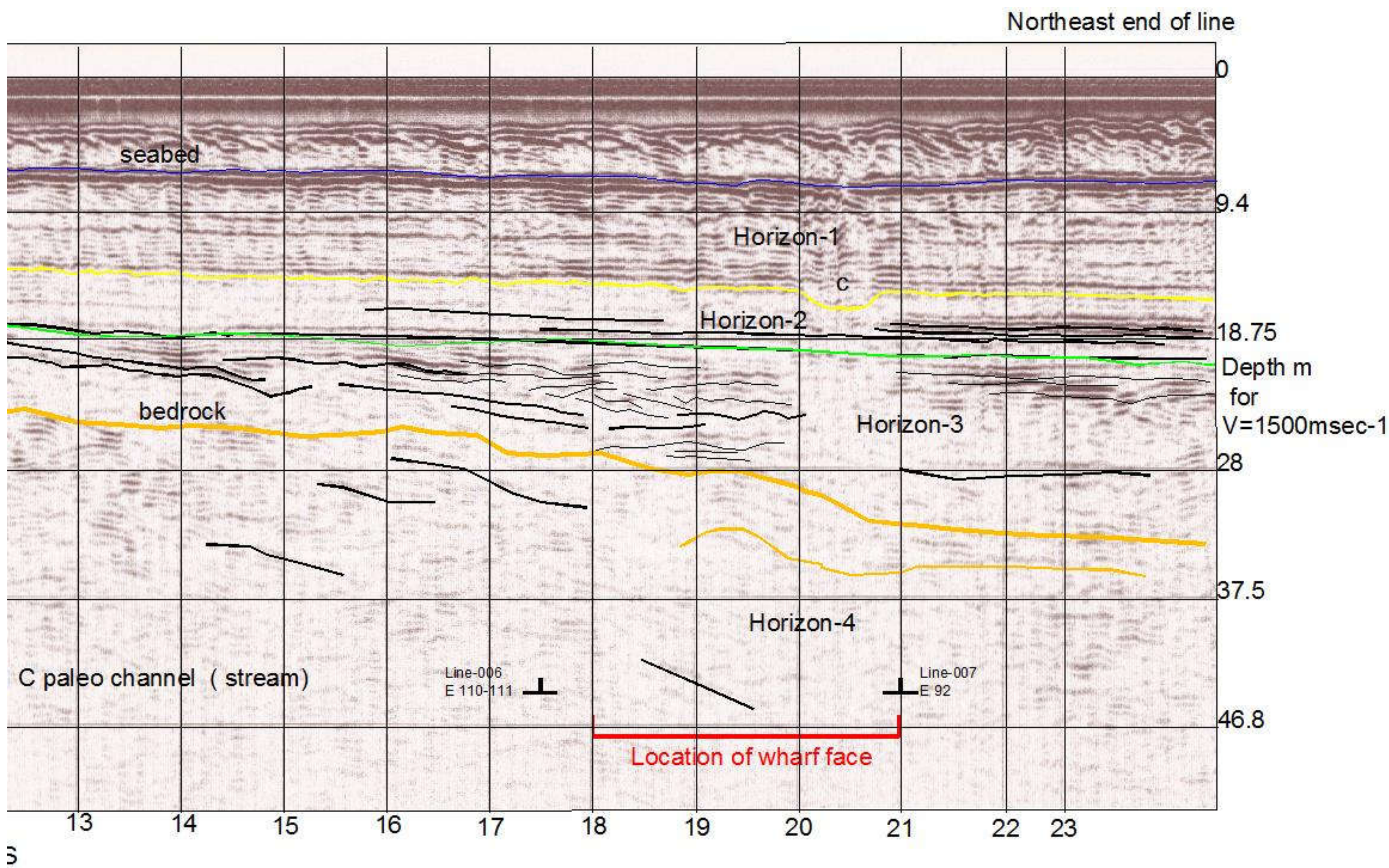

Figure 16: Detail of the seismic reflection patterns in the cross section at the wharf face.

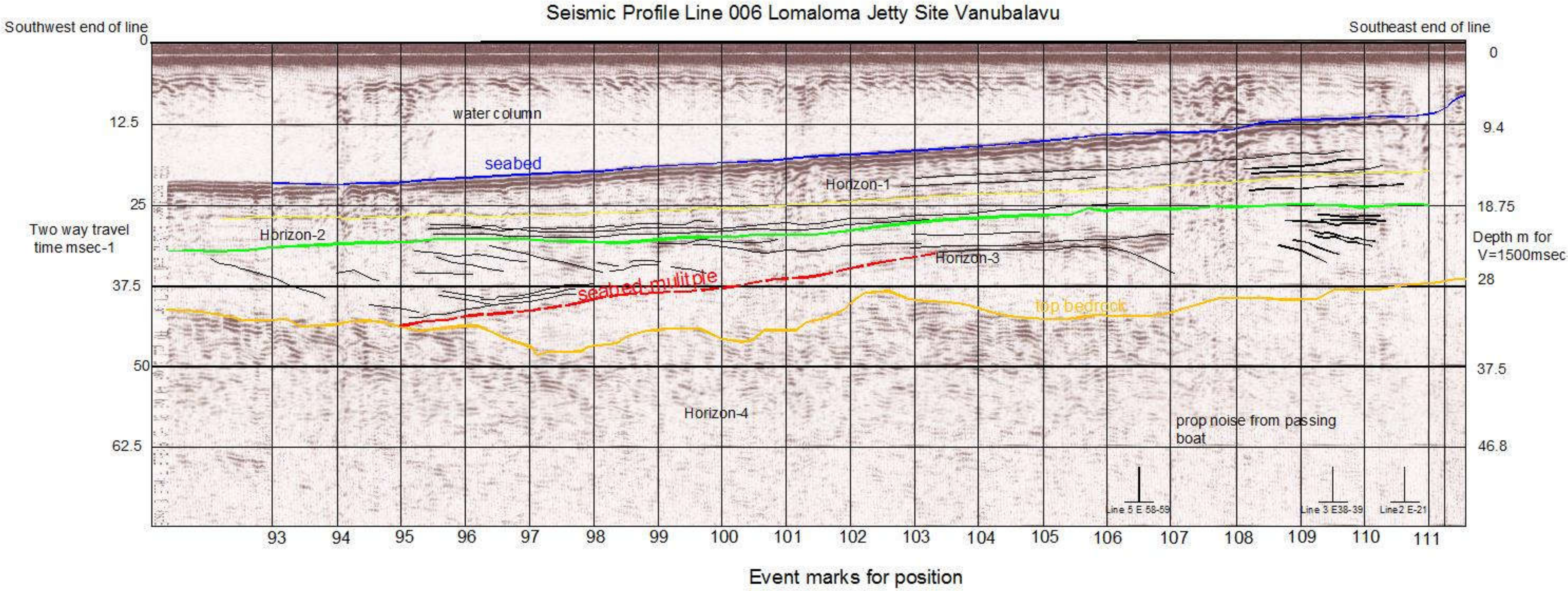

Figure 17: Interpreted seismic profile for Line 006.

Seismic profile for line 006, which traverses from offshore towards the southern end of the jetty head (wharf face), terminating on the south side. Bedrock is delineated by the orange line. It appears bedrock is relatively flat, lying with erosional irregularities in its surface. Near the jetty head the interpreted depth to bedrock is about 28 m at the south end. Immediately above bedrock, Horizon-3 displays the same chaotic pattern with variations in dip suggestive of some cross bedding. Full profile interpretation is contained in pdf file “Seismic Profile-line6-Lomaloma-Jetty.pdf” in Appendix 4 (with digital copy in Appendix 8).

Based on the seismic interpretation, a depth to bedrock map has been generated. A snapshot is shown in Figure 18. A large scale plot is provided for in Appendix 4.

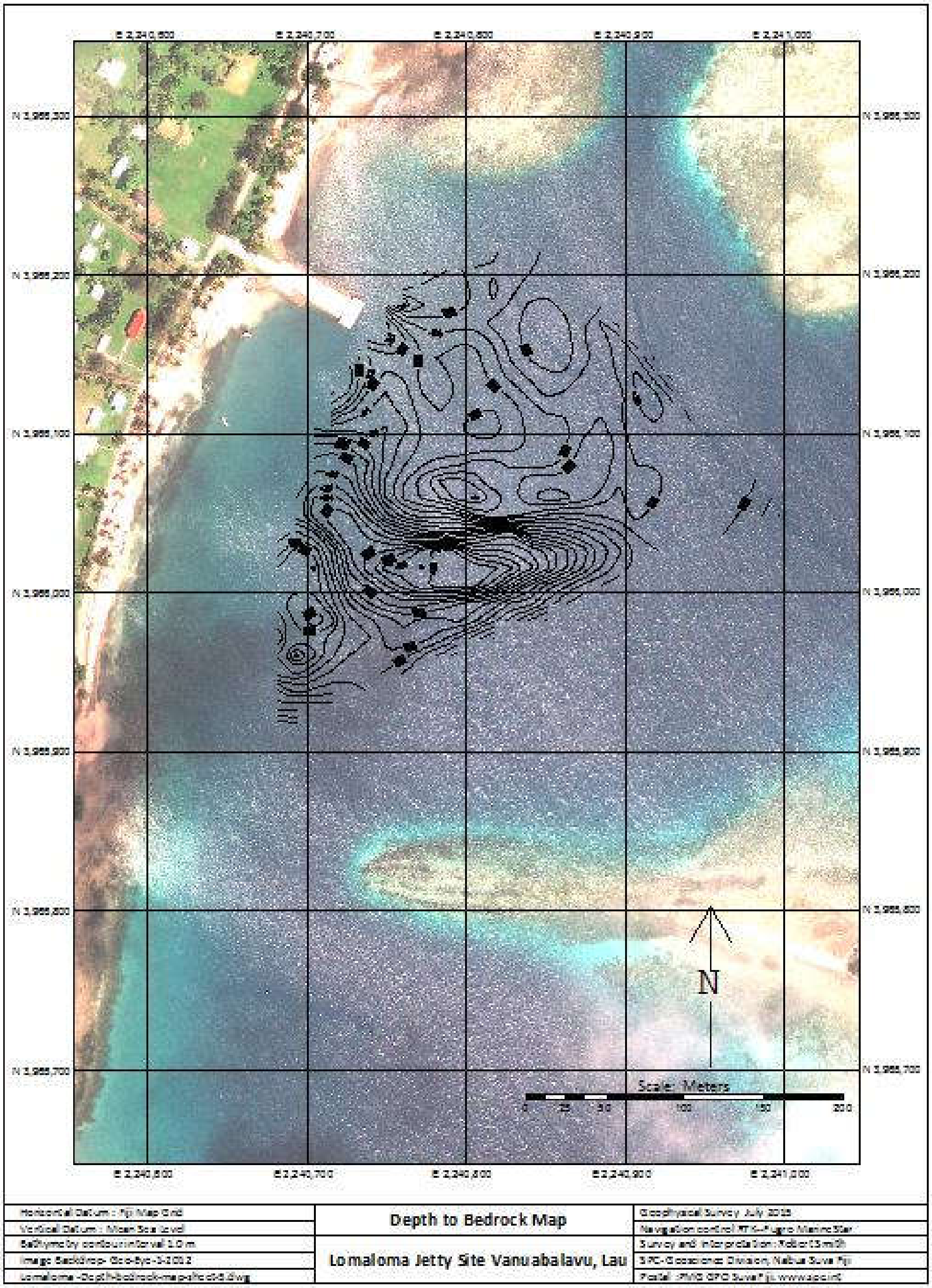

Figure 18: Top of bedrock as interpreted from the seismic data. The contours are referenced to MSL with a contour interval of 1.0 m.

Based on the seismic interpretation, bedrock is about 30 m below MSL with respect to the location of the present jetty head. To the south and offshore, an interpreted high appears in the bedrock rising to 19 m with respect to MSL. The nature of this structure appears to parallel the westward extension of Yanuyanu Island suggesting the bedrock here is a subsurface extension of the basalt lava flows of Yanuyanu Island.

Geological Hazards – Liquefaction, Earthquakes, Tsunami and Sedimentation

In terms of geological hazards, sedimentation and liquefaction are existing issues for two of Fiji's major ports – Suva and Lautoka.

Liquefaction

Liquefaction is a process by which water-saturated sediment temporarily loses strength and acts as a fluid during an earthquake. A consequence of this process is that ground damage may occur and impact surface infrastructure. There are a number of factors required for liquefaction to occur. Foremost is ground shaking and duration of the motion. Other factors are underlying sediment properties – grain size and type; and levels of saturation with respect to the water table.

A scale used to measure ground shaking force in the context of liquefaction is the Modified Mercalli Intensity. The scale has a range from 1 to 10; and while it measures the strength of ground shaking at a particular location; it is not the same as measuring the 'magnitude' of an earthquake. On the Modified Mercalli Intensity scale, liquefaction can begin to occur at MM7. Physically speaking, at MM7, it is difficult to stand, furniture moves around and unreinforced structures like chimneys will break, roofing tiles and water intakes as well will suffer damage. At Lomaloma, the seismic data shows a very significant section of fine silt and clays forming a thick layer over bedrock.

Earthquakes

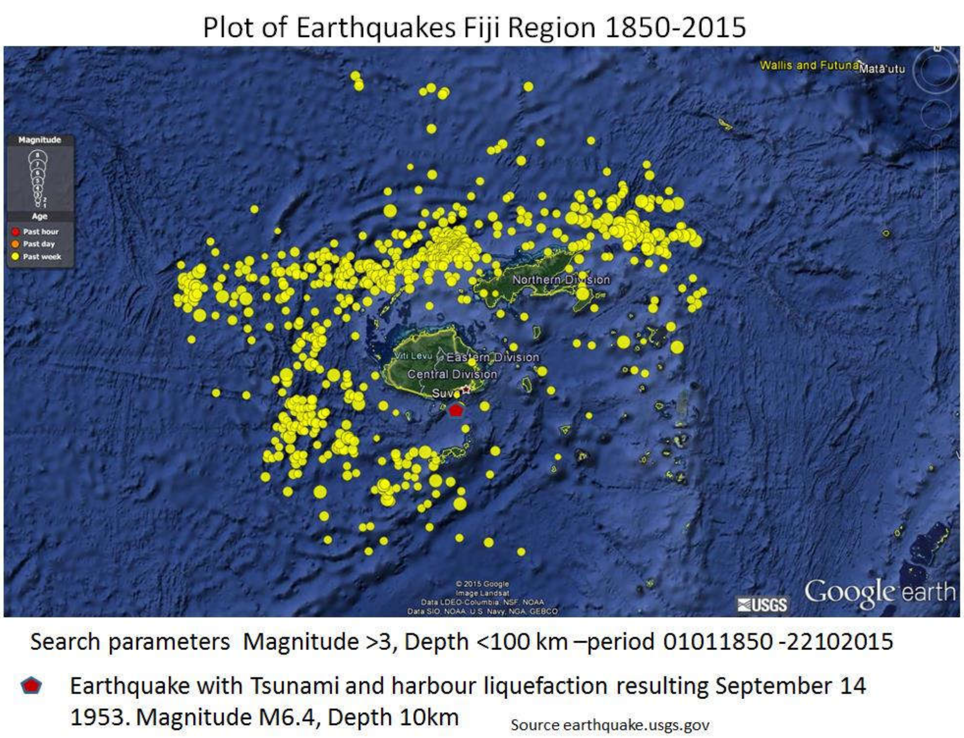

Figure 19: Earthquake epicentre map for Fiji, from 1850 to 2015 that have similar parameters to the earthquake that generated both liquefaction and a tsunami that damaged the Suva Port in 1953. Vanua Balavu appears to be in a seismically quiet zone, at least for shallow damaging earthquakes.

Table 3 is a listing of strong earthquakes from Everingham (1983) taken from a table prepared by the Pacific Disaster Centre.

Table 3: Strong earthquakes felt in Fiji from 1850 to 2001 (Everingham 1983).

Date of Occurrence		Magnitude	Lat/Long	Location	Intensity (Modified Mercalli)	Death/Injuries
About 1850		6.5?	19.0S 178.0E	Kadavu	VIII	30-40 deaths
1869	Oct 2	5-6	17.8S 178.3E	Upper Rewa River	VII	None reported
1884	Jan (?)	6.8?	16S 179E	Naduri, (Macuata)	VII	None reported
1902	Aug 3	6.8?	16.7S 177.2E	Yasawas, Ba	VII	None reported
1919	Oct 3	6.9	16.4S 180.0	Rabi, Tunuloa	VIII	None reported
1921	Sep 30	6.7	17.0S 176.5E	Lautoka, Nadarivatu	V	None reported
1928	Jun 21	7.0	17.0S 179.5W	Taveuni	VI	None reported
1932	Feb 17	6.6	16.2S 179.7W	Rabi, Tunuloa	VII	None reported
1932	Mar 9	6.5	17.5S 179.6E	Koro, Ovalau, Savusavu, Rabi, and northern Taveuni	VII	None reported
1950	Feb 13	6.5	18.9S 177.8E	Kadavu	VI	None reported
1953	Sep 14	6.8	18.25S 178.25E	Suva, Navua	VII	8 deaths (5 due to *tsunami*)
1957	Jan 3	5.0	16.7S 179.8E	Taveuni	VI	None reported
1979	Nov 17	6.9	16.5S 179.75W	Taveuni	VIII	None reported
1983	Jul 19	4.8	19.06S 177.77E	Kadavu	VI	None reported
1984	Oct 13	6.1	16.79S 177.3E	Yasawas	VI	None reported
1998	Nov 2	6.0	19.4S 177.5E	Kadavu	VII	None reported
2001	Feb 14	5.8	19.0S 177.4E	Kadavu	VI	None reported
2001	Sep 3	6.0	16.2S 178.3E	Bua, Labasa, Yasawa, Suva	VI	None reported

Closer to home (Lomaloma) a local earthquake event on March 9, 1932 – a 6.5 Magnitude earthquake centred just southeast of the island of Koro triggered a significant landslide that washed part of a village into the sea, and damaged a reef lighthouse. Many other buildings were severely damaged, including a stone church at Napuka. Mud volcanoes[4] and changes to natural water supplies were also reported. The earthquake was felt in Koro, Ovalau, Savusavu, Rabi, and northern Taveuni (Everingham 1983).

With respect to documentation on earthquake hazards and design input for Fiji, foremost is a report by Trevor Jones (1997) titled 'Probabilistic earthquake Hazard Assessment for Fiji.' In this report, Jones (1997) produced a spectral acceleration map for a 450 year return period (see Figure 20), as the basis for the Zone Factor map in the National Building Code for Fiji. This replaced the 'Preliminary Earthquake Risk Map' produced in the 1990 draft National Building Code for Fiji. The 450-year spectral accelerations are equivalent to values of the Zone Factor referred to in the National Building Code, subject to the following caution: **This national hazard assessment does not take into account the different ground conditions which may exist in urban areas and at critical facilities. The site specific hazard may be strongly dependent on local ground conditions and the hazard assessments of this study should be augmented by detailed urban zonation studies and site-dependent risk studies for lifelines and important infrastructure where appropriate (Jones 1997).**

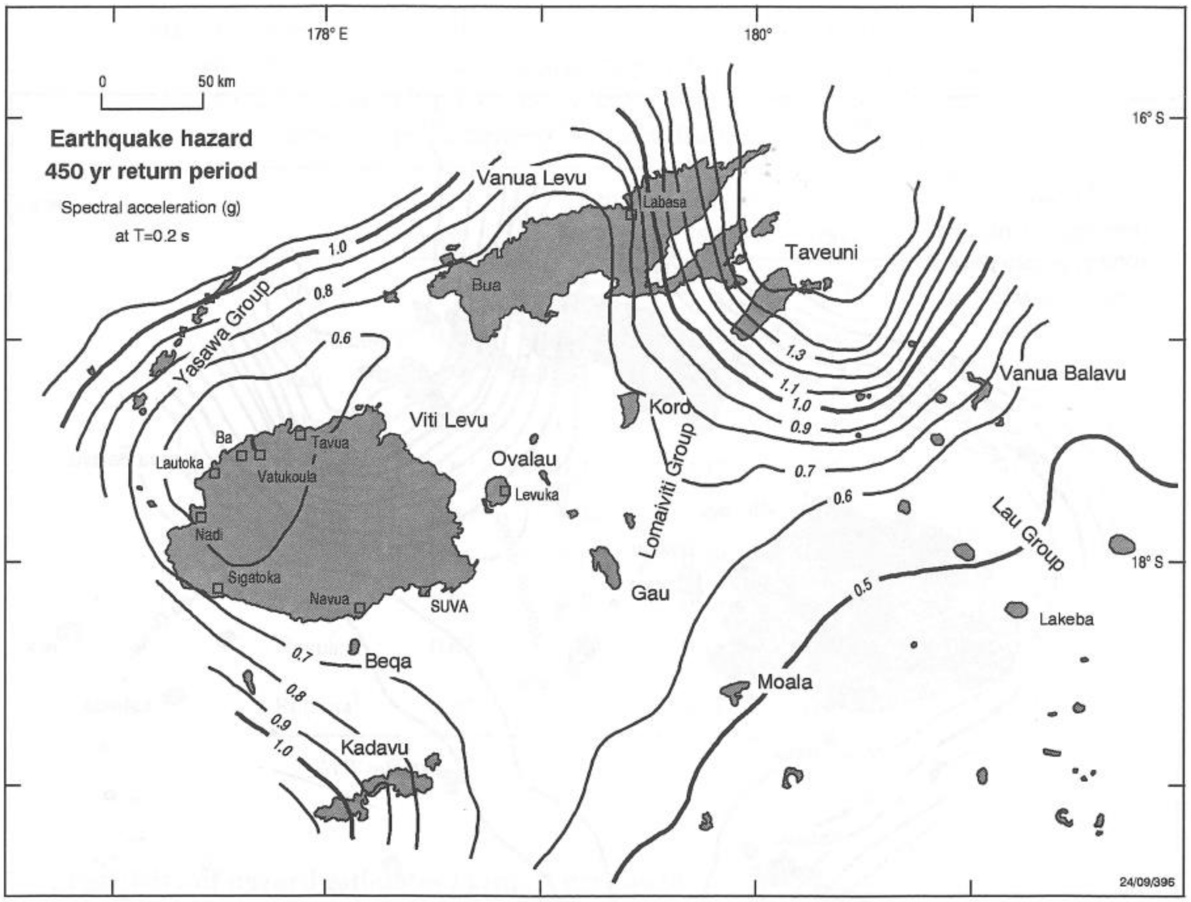

Figure 20: Earthquake hazard map for Fiji, for a return period of 450 years. Contours are shown for values of elastic, 5% damped, horizontal response spectral acceleration (in units of the acceleration due to gravity, g), Katayama ground condition Type 3, at a period of T = 0.2 s. The acceleration contours over marine areas indicate the general pattern of the hazard but cannot be used for the design of marine or submarine structures. This map was recommended as the Zone Factor Map for the National Building Code for Fiji (from Jones 1997).

Tsunami

Fiji experienced 17 *tsunami* events between 1877 and 2004. Of these, four had recorded wave heights ranging between 0.5 and 5.0 meters. The 1953 event triggered the largest wave heights, measuring 1.5 to 5.0 metres above Mean Sea Level (MSL). Three other significant events were caused by earthquakes that occurred off the island of Vanua Levu in 1881, and off the coast of Chile in South America in both1877 and 1960. A list of tsunami events between 1870 and 2004 are presented in Table 4 (based on Everingham 1984), some of which are described in more detail below. It should be noted that these examples are categorized as either local, regional or distant *tsunami*, depending on Fiji's proximity to the source region or point of origination. A ' *tsunami* is defined as one originating from a source within 200 kilometres of a given location – where destructive effects are confined to coasts *within 100 kilometres of the source*. A 'regional' *tsunami* is defined as one where destructive effects are confined *to within 1000 kilometres from the source*. Finally, a 'distant' *tsunami* (also referred to as 'Pacific-wide' or 'tele-*tsunami*') *originates from a source greater than 1000 kilometres away*.

Table 4: Tsunami *recorded in Fiji from 1877 to 2004 (based on Everingham 1984).*

Date of Occurrence		Location	Lat/Long	Magnitude	Category	Location	Wave Height (m)
1877	May 10	Chile	21.5S 71.0W	MS 8.3	Distant (D)	Savusavu	2.0
(1881)	Jul 12	Fiji (Vanua Levu)	16.9S 179.0E	MS 6.8	Local (L)	Labasa Levuka	1.8 0.4
1953	Sep 14	Fiji – Suva	18.2S 178.3E	MS 6.8	L	Nakaseleka Makuluva Suva Beqa Koro	4.3 3.4 1.8 1.4 1.4
1960	May 23	Chile	41.0S 73.5W	MS 8.4	D	Suva	0.5
1967	Jan 01	Vanuatu	11.3S 166.0E	No magnitude listed	Regional (R)	Suva	<0.10
1968	Jul 25	Kermadec	30.8S 178.4W	MS 7.2	R	Suva	0.10
1975	Dec 17	Fiji (Kadavu)	18.5S 178.6E	MS 5.2	L	Suva Ono	(0.2) (0.2)
1975	Dec 27	Tonga	16.2S 172.5W	MS 7.8	R	Suva	0.08
1976	Jan 15	Kermadec	29.0S 177.4W	MS 8.0	R	Suva	0.22
1977	Jun 23	Tonga	16.8S 172.0W	MS 7.2	R	Suva	0.16
1977	Oct 10	Kermadec	26.1S 175.3W	MS 6.9	R	Suva	0.02
1995	May 16	Loyalty Islands	23.0S 169.9E	MS 7.7	R	Lautoka Suva	0.06 0.05
1995	Jul 30	Chile	23.3S 70.3W	MW 8.0	D	Lautoka	0.10
1997	Apr 21	Santa Cruz Islands	12.6S 166.7E	MW 7.7	R	Suva	<0.10
1999	Nov 26	Vanuatu	16.4S 168.4E	MS 7.5	R	Lautoka	0.13
2001	Jun 23	Peru	16.1S 73.4W	MW 8.4	D	Suva Lautoka	0.10 0.10
2004	Dec 26	Sumatra	3.29N 95.98E	MW 9.0	D	Suva	0.11

Lomaloma appears to not have any significant *tsunami* risk based on existing data.

Sedimentation

Sedimentation affects many ports, which over time reduces berthing depth so dredging becomes a maintenance requirement. This occurs in Suva as well as Lautoka. Based on the seismic and multibeam data, sedimentation is interpreted to not be an issue at Lomaloma at present. Nevertheless, based on the Geoeye-1 imagery, the evidence for coastal erosion and build up of sediment along the southern edge of the jetty structure may result in shoaling issues at the present jetty location in future. A similar situation has occurred with the wharf at Rotuma.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- Multibeam mapping of the Lomaloma Jetty area has delineated well the present morphology of the seabed. Some evidence of scouring caused by shipping traffic at the south end of the jetty face is interpreted from the detailed bathymetry mapping.

- Calculated MSL depth at the jetty head averages 5.5 metres.

- It is evident from the multibeam data that sedimentation is not an issue at present. That said, if sediment continues to accumulate on the south side of the jetty head, at some point it may migrate along the length of the existing structure into deeper water resulting in shoaling beginning at the south end of the jetty.

- Understanding shoreline sediment sources and their migration pathways and sinks is essential to minimising the impact of shore-normal structures such as jetties with solid attachments to land that are constructed and inevitably interrupt shoreline sediment transport processes.

- The seismic data reveals that bedrock is at between 30 m and 35 m depth with respect to the jetty head location. A significant portion of the over-burden appears to be a homogenous sequence of fine sands with bands of high amplitude and continuity visible through the length of the profile.

- Based on the seismic data available, liquefaction would not be considered a significant geological hazard.

- Based on the tide data, and the GNSS levelling survey, 'Mean Sea Level' is calculated to be 1.875 m below the JICA PIN located on the jetty head.

- Although there is no record of a tsunamigenic event impacting Lomaloma, the events of 1881 where a local *tsunami* event was recorded with a wave height of 1.8 m impacting Labasa; and strong earthquake events impacting Taveuni in 1979 and Koro in 1932.

Recommendations

- Sedimentation may develop into an issue at Lomaloma based on the large accumulation building on the south side of the jetty seen in the Geoeye-1 imagery taken in 2012. With additional shore-normal structures noted, detailed assessment of coastal processes, currents and wave-induced current transport of sediment needs to be completed.

- Location(s) of sites for drilling of boreholes should, where possible, be determined based on the seismic data.

- Consideration be given to conducting occasional high-resolution multibeam surveys to monitor seabed conditions at port and harbour sites where sedimentation is an issue.

- The lack of multi-faceted data sets that look at the long-term impacts of important infrastructure development projects in the nearshore area for rural settings like Lomaloma must be considered critical to their maintenance and further development; and just as critical is the building up of a national database that can be used in the future to better guide similar surveys as this work.

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APPENDIX 1

Fugro MarineSTAR Signal Service Data Sheet

General Description

Fugro MarineSTAR provides consistent and highly reliable DGNSS corrections signal for both the American Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS) for marine survey and positioning. DGNSS corrections are broadcast on dedicated communication satellite channels in all four INMARSAT ocean regions and in addition to high power satellite SPOT beams including Oceania (OC-Sat) and Eastern Pacific (AM-Sat).

Technical benefits :

- The world's first composite GPS/GLONASS orbit and clock solution (G2) to cope with the effect of the forecast increase in solar activity and interference [ref. Appendix B]
- The G2 service increases the number of satellites available by accessing the GLONASS satellite constellation in addition to the GPS constellation. More satellites mean less likelihood of shadowing when operating close to steep shorelines, mangroves and other obstructions ; "more is better"
- Integrated L-band corrections demodulator, GNSS positioning and heading sensor in a single rugged enclosure combined with two antennas for ease of configuration and mobilisation.
- With seamless coverage, approximately 100 reference stations, 14 satellite uplinks and 2 global network control centres, Fugro MarineSTAR provides consistent and highly reliable positioning services worldwide, 24 hours a day, 365 days a year.
- Fugro Satellite Positioning offers three totally independent decimeter level DGPS augmentation services that provide High Accuracy positioning for the marine user:

  Orbit/Clock Carrier Phase Based GPS Service (XP)
  Orbit/Clock Carrier Phase Based GPS/GLONASS Service (G2)
  Wide Area Network Carrier Phase Based Service (HP)

MarineSTAR DGNSS Signal Services

VBS
– Single frequency DGPS Service,
– Accuracy: 1 m, 2dRMS within 1000 km of a reference station

XP
– Dual frequency DGPS Service,
– XP positioning is based on satellite 'orbits and clocks' data based on the JPL reference station network.
– Accuracy: 20 cm, 2dRMS world-wide

HP
– Dual frequency DGPS Service,
– Based on the Fugro 100 + reference station network.
– Accuracy: 10 cm, 2dRMS within 1000 km of a reference station

G2
– Dual frequency DGPS Service,
– Based on precise 'orbits & clocks' technology for both GPS and Glonass using the Fugro~ESA G2 reference station network.
– Accuracy: 15 - 20 cm, 2dRMS world-wide

Modular GPS Receiver
Receiver Name SPS852 Modular GPS Receiver

Configuration Option
Base and Rover interchangeability Yes
Rover position update rate 1 Hz, 2 Hz, 5 Hz, 10 Hz, 20 Hz
Rover maximum range from base radio Unrestricted, typical range 2–5 km (1.2–3 miles) without radio repeater
Rover operation within a VRS™ network Yes
Heading and Moving Base operation Yes7
Factory options See Receiver Upgrades below
General

Keyboard and display Vacuum Fluorescent display 16 characters by 2 rows. Invertable
On/Off key for one-button startup

Escape and Enter keys for menu navigation
4 arrow keys (up, down, left, right) for option scrolls and data entry
Dimensions (L × W × D) 24 cm × 12 cm × 5 cm (9.4 in x 4.7 in x 1.9 in) including connectors
Weight 1.65 kg (3.64 lb) receiver with internal battery and radio
1.55 kg (3.42 lb) receiver with internal battery and no radio

Antenna Options
GA510 L1/L2/L2C GPS, SBAS, and OmniSTAR
GA530 L1/L2/L2C GPS, SBAS, and OmniSTAR
GA810 GPS, Glonass, OmniSTAR, SBAS, Galileo (optimized for OmniSTAR)

L1/Beacon, DSM 232 Not Supported
Zephyr™ Model 2 L1/L2/L2C/L5 GPS, Glonass, OmniSTAR, SBAS, Galileo
Zephyr Geodetic™ Model 2 L1/L2/L2C/L5 GPS, Glonass, OmniSTAR, SBAS, Galileo
Zephyr Model 2 Rugged L1/L2/L2C/L5 GPS, Glonass, OmniSTAR, SBAS, Galileo
Zephyr, Zephyr Geodetic, Z-Plus, Micro-Centered™ Refer to Antenna specification

Temperature
Operating1 -40 °C to +65 °C (-40 °F to +149 °F)
Storage -40 °C to +80 °C (-40 °F to +176 °F)
Humidity MIL-STD 810F, Method 507.4
Waterproof IP67 for submersion to depth of 1 m (3.3 ft), dustproof

Shock and Vibration
Pole drop Designed to survive a 1 m (3.3 ft) pole drop onto a hard surface
Shock – Non-operating To 75 g, 6 ms
Shock – Operating To 40 g, 10 ms, saw-tooth
Vibration Tested to Trimble ATV profile (4.5 g RMS): 10 Hz to 300 Hz: 0.04 g/Hz2
300 Hz to 1,000 Hz; –6 dB/octave

APPENDIX 2

Equipment Specifications

Multibeam Configuration, Calibration and Processing

The system used was R2Sonic 2024 multibeam system configured with a POSmV Wave master for heave pitch and roll and a Trimble R10 GNSS system with dual antenna arrangement providing heading. A Universal Sonar Mount system was used to mount the complete system in a repeatable reference frame.

Motion Sensor

MAXIMIZE YOUR ROI WITH POS MV 320

POS MV 320 is a user-friendly, turnkey system designed and built to provide accurate attitude, heading, heave, position, and velocity data of your marine vessel and onboard sensors. POS MV is proven in all conditions, and is the georeferencing and motion compensation solution of choice for the hydrographic professional.

POS MV blends GNSS data with angular rate and acceleration data from an IMU and heading from the GPS Azimuth Measurement System (GAMS) to produce a robust and accurate full six degrees-of-freedom position and orientation solution.

PERFORMANCE SUMMARY - POS MV 320 ACCURACY[1]

POS MV 320	DGPS	Fugro Marinestar*	IARTK	POSPac MMS PPP	POSPac MMS IAPPK	Accuracy During GNSS Outage (60 s total)
Position	0.5 - 2 m[2]	Horizontal: 10 cm 95% Vertical: 15 cm 95%	Horizontal: +/- (8 mm + 1 ppm x baseline length)[2] Vertical: +/- (15 mm + 1 ppm x baseline length)[2]	Horizontal: < 0.1 m Vertical: < 0.2 m	Horizontal: +/- (8 mm + 1 ppm x baseline length)[2] Vertical: +/- (15 mm + 1 ppm x baseline length)[2]	~6 m (DGPS) ~3 m (RTK) ~2 m (PPDGNSS) ~1 m (IAPPK)
Roll & Pitch	0.02°	0.01°	0.01°	<0.01°	0.008°	0.03°
Heading	0.01° (4 m baseline) 0.02° (2 m baseline)	0.01° (4 m baseline) 0.02° (2 m baseline)	0.01° (4 m baseline) 0.02° (2 m baseline)	0.01° (4 m baseline) 0.02° (2 m baseline)	0.01° (4 m baseline) 0.02° (2 m baseline)	1° per hour degradation (negligible for outages <60 s)
Heave TrueHeave™	5 cm or 5%[4] 2 cm or 2%[5]	5 cm or 5%[4] 2 cm or 2%[5]	5 cm or 5%[4] 2 cm or 2%[5]	-	-	5 cm or 5%[4] 2 cm or 2%[5]

PCS OPTIONS

COMPONENT	DIMENSIONS	WEIGHT	TEMPERATURE	HUMIDITY	POWER
Rack Mount PCS	L = 442mm, W = 356mm, H = 46mm	3.9 kg	-20 °C to +70 °C	10 - 80% RH	AC 120/230 V, 50/60 Hz, auto-switching 40 W
Small Form Factor PCS	L = 167mm, W = 185mm, H = 68mm	2.5 kg	-20 °C to +60 °C	0- 100% RH	DC 10-34 V, 35 W (peak)

INERTIAL MEASUREMENT UNIT (IMU)

ENCLOSURE	DIMENSIONS	WEIGHT	TEMPERATURE	IP RATING
Between Decks	L = 158 mm, W = 158 mm, H = 124 mm	2.5 kg	-40 °C to +60 °C	IP65
Between Decks	L = 150 mm, W = 130 mm, H = 148 mm	2.8 kg	-40 °C to +60 °C	IP65
Submersible	Ø172 mm X 206 mm (base plate Ø209 mm)	3.9 kg	-40 °C to +60 °C	IP68

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

COMPONENT	DIMENSIONS	WEIGHT	TEMPERATURE	HUMIDITY
GNSS Antenna	Ø178 mm, W = 73 mm	0.45 kg	-50 °C to +70 °C	0-100% RH

[1] 1 sigma unless otherwise stated
[2] Depending on quality of differential corrections
[3] Assumes 1 m IMU-GNSS antenna offset
[4] Whichever is greater, for periods of 20 seconds or less
[5] Whichever is greater, for periods of 35 seconds or less

1. ETHERNET INPUT OUTPUT

Ethernet	(10/100 base-T)
Parameters	Time tag, status, position, attitude, heave, velocity, track and speed, dynamics, performance metrics, raw IMU data, raw GNSS data
Display Port	Low rate (1 Hz) UDP protocol output
Control Port	TCP/IP input for system commands
Primary Port	Real-time (up to 200 Hz) UDP protocol output
Secondary Port	Buffered TCP/IP protocol output for data logging to external device

2. SERIAL RS232 INPUT OUTPUT

5 COM Ports	User assignable to: NMEA output (0-5), Binary output (0-5), Auxiliary GNSS input (0-2), Base GNSS correction input (0-2)

3. NMEA ASCII OUTPUT

Parameters	NMEA Standard ASCII messages: Position ($INGGA), Heading ($INHDT), Track and Speed ($INVTG), Statistics ($INGST), Attitude ($PASHR, $PRDID), Time and Date ($INZDA, $UTC)
Rate	Up to 50 Hz (user selectable)
Configuration	Output selections and rate individually configurable on each assigned com port

4. HIGH RATE ATTITUDE OUTPUT

Parameters	User selectable binary messages: attitude, heading, speed
Rate	Up to 200 Hz (user selectable)
Configuration	Output selections and rate individually configurable on each assigned com port

5. AUXILIARY GNSS INPUTS

Parameters	NMEA Standard ASCII messages: $GPGGA, $GPGST, $GPGSA, $GPGSV Uses Aux input with best quality
Rate	1 Hz

6. BASE GNSS CORRECTION INPUTS

Parameters	RTCM V2.x, RTCM V3.x, CMR and CMR+, CMRx input formats accepted. Combined with raw GNSS observables in navigation solution
Rate	1 Hz

7. DIGITAL I/O

1PPS	1 pulse-per-second Time Sync output, normally high, active low pulse
Event Input (2)	Time mark of external events. TTL pulses > 1 msec width, rising or falling edge, max rate 200 Hz

8. USER SUPPLIED EQUIPMENT

- PC for POSView Software (Required for configuration): Pentium 90 processor (minimum), 16 MB RAM, 1 MB free disk space, Ethernet adapter (RJ45 100 base T), Windows 98/2000/NT/XP/Windows 7
- PC for POSPac MMS Post-processing Software: Pentium III 800Mhz or equivalent (minimum), 512 MB RAM, 400 MB free disk space, USB Port (For Security Key), Windows XP or Windows 7

Scan the QR Code on your mobile device to access information on POS MV

Headquarters: 85 Leek Crescent Richmond Hill, ON Canada L4B 3B3 T +1.905.709.4600 F +1.905.709.6027
United Kingdom: Forester's House, Old Racecourse Oswestry UK SY10 7PW T +44 1691 659359 F +44 1691 659299
USA: 17461 Village Green Drive, Houston TX USA 77040 T +1.713.896.9900 F +1.713.896.9919
marine@applanix.com
www.applanix.com

applanix
A TRIMBLE COMPANY

capture everything. precisely.

Universal Multibeam Side mount

Universal Sonar Mount

designed by sonar technicians for sonar technicians

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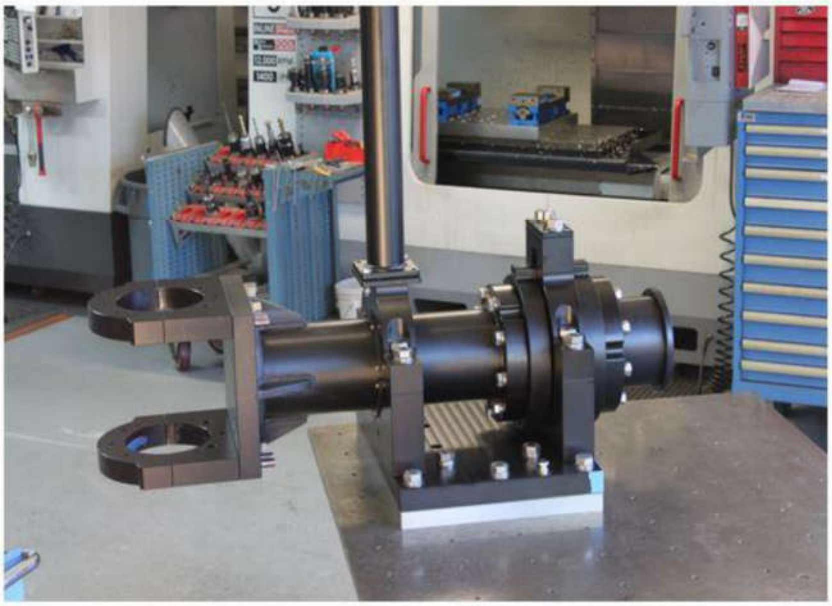
USM XL

XL USM Package: 500-9001-01



We have just finished our newest product in the USM lineup: The XL version of our standard mount. This version is designed to be used on larger vessels requiring Z pole lengths in the range of 10-20 feet; Z pole lengths come in 5'and 10'sections. We have scaled our standard mount up to meet the demands of large vessels that require a side mount application. We have also Incorporated all of the same repeatability and indexing of our standard products saving valuable time in setup and operation while maintaining vessel and sonar safety.

- Universal fixed plate can be bolted, or welded to the vessel.
- Shear block design, allows the Z-pole to release if hit while vessel is underway, keeps vessel, crew and sonar safe.
- Repeatable hydrographic pole; no need to re-calibrate when raising and lowering the Z-pole.
- Designed for easy and accurate setup with built-in adjustability for sonar position and orientation.
- Z pole design allows for any sonar to be bolted on and off with USM flange kits.
- 1 spare shear block for breakaway action
- Z-pole (Standard 60". Can be customized)
- X-pole (Standard 23". Can be customized)

Multibeam Specifications

R2 SONIC

Technical Specifications

Feature	Sonic 2024	Sonic 2022	Sonic 2020
Frequency	200 to 400kHz Over 20 frequency selections User selectable in real-time	200 to 400kHz Over 20 frequency selections User selectable in real-time	200 to 400kHz Over 20 frequency selections User selectable in real-time
Bandwidth	60 kHz, all frequency selections	60 kHz, all frequency selections	60 kHz, all frequency selections
Beamwidth	0.3° x 0.6° at 700kHz (optional) 0.5°x1° at 400kHz 1°x 2° at 200kHz	0.6° x 0.6° at 700kHz (optional) 1°x 1° at 400kHz 2°x 2° at 200kHz	2° x 2° at 400kHz 4° x 4° at 200kHz
Swath Sector	10° to 160° All frequency selections User selectable in real-time	10° to 160° All frequency selections User selectable in real-time	10° to 130° All frequency selections User selectable in real-time
Sounding Depth*	400m+	400m+	75m+
Ping Rate	60 Hz	60 Hz	60 Hz
Range Resolution	1.25cm	1.25cm	1.25cm
Pulse Length	15μsec–1000μsec	15μsec–1000μsec	15μsec–1000μsec
Number of Beams	256	256	256
Near-field Focusing	Yes, all beams, over entire swath	Yes, all beams, over entire swath	Yes, all beams, over entire swath
Equiangular or Equidistant beams	Yes	Yes	Yes
Roll Stabilization	Yes	Yes	Yes
Rotate Sector	Yes	Yes	Yes
Automated Operation	Yes	Yes	Yes
Depth Rating	100m, 3000m optional	100m, 3000m optional	500m, 3000m optional
Operating Temp.	-10°C to 50°C	-10°C to 50°C	-10°C to 50°C
Storage Temp.	-20°C to 55°C	-20°C to 55°C	-20°C to 55°C
Mains	90-260 VAC, 45-65Hz	90-260 VAC, 45-65Hz	90-260 VAC, 45-65Hz
Power Consumption	50W	35W	20W
Uplink/Downlink	10/100/1000Base-T Ethernet	10/100/1000Base-T Ethernet	10/100/1000Base-T Ethernet
Deck Cable Length	15m, optional 25m, 50m	15m, optional 25m, 50m	15m, optional 25m, 50m
Receiver Dim (LWD)	480 x 109 x 190mm	276 x 109 x 190mm	155 x 140 x 150mm
Receiver Mass	12 kg	7 kg	4 kg
Projector Dim (LWD)	273 x 108 x 86mm	273 x 108 x 86mm	N/A
Projector Mass	3.3 kg	3.3	N/A
SIM (LWD)	280 x 170 x 60mm	280 x 170 x 60mm	280 x 170 x 60mm
SIM Mass	2.4 kg	2.4 kg	2.4 kg

*Depending on environmental conditions

Cover Image: Produced by Sonic 2024/Hypack, edited with IVS Fledermaus software, offshore UK in 8-20m water depths. Image courtesy of Aspect Land & Hydrographic Surveys, UK.

Sonar Options

- Snippets & TruePix™ Backscatter Imagery
- Raw Water Column Data
- Switchable Forward Looking Sonar
- Ultra High Resolution
- Sediment Profiler
- 3000m Immersion Depth Rating
- Integrated Inertial Navigation System (INS)
- Mounting Hardware & Assemblies
- Antifouling Coating Protection

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Fall 2014

Navigation and heading control

DATASHEET

TRIMBLE R10 GNSS SYSTEM

KEY FEATURES

Cutting-edge **Trimble HD-GNSS** processing engine

Precise position capture with **Trimble SurePoint** technology

New **Trimble xFill** technology provides RTK coverage during connection outages

Advanced satellite tracking with **Trimble 360** receiver technology

Sleek ergonomic design for easier handling

A NEW LEVEL OF PRODUCTIVITY

The first of its kind, the new Trimble® R10 System is designed to help surveying professionals work more effectively. With powerful new technologies like Trimble HD-GNSS, Trimble SurePoint™, and Trimble xFill™ integrated into a new sleek design, this powerful system goes beyond comprehensive GNSS support to ensure surveyors have the ability to collect more accurate data faster and easier—no matter what the job or the environment.

TRIMBLE HD-GNSS PROCESSING ENGINE

A new generation of core positioning technology

Integrated into the Trimble R10 is the advanced Trimble HD-GNSS processing engine. This ground-breaking technology transcends traditional fixed/float techniques to provide a more accurate assessment of error estimates than traditional GNSS technology, especially in challenging environments. Markedly reduced convergence times as well as high position and precision reliability enable surveyors to collect measurements with confidence while reducing their occupation time.

TRIMBLE SUREPOINT TECHNOLOGY

Simplifying the survey workflow

Trimble SurePoint technology incorporated into the Trimble R10 system provides users with faster measurements, increased accuracy, and greater quality control.

An Electronic Bubble

The Trimble R10 system employs an electronic bubble that appears on the Trimble controller display. With this new eBubble, all measurement information is displayed in one place and users don't have to switch focus from the controller screen to the pole bubble to check that the pole is plumb.

Rapid, Accurate Measurement

Trimble SurePoint technology displays the eBubble in green when the pole is plumb, clearly indicating that an accurate measurement is possible. The system constantly monitors pole tilt for the user. If a point is measured with pole tilt beyond a user-defined setting, Trimble Access™ software will alert the user and prompt them to accept or discard the point. SurePoint even uses the pole tilt as a controlling input. After a point is measured, tilting the pole causes the system to automatically prepare to measure the next point.

Data Traceability

As insurance that all of your data is traceable, the Trimble R10 can record the pole tilt information for measured points. These records include the pole tilt angle and the distance on the ground represented by that pole tilt angle.

TRIMBLE 360 RECEIVER TECHNOLOGY

Future Proof Your Investment

Powerful Trimble 360 receiver technology in the Trimble R10 supports signals from all existing and planned GNSS constellations and augmentation systems. With two integrated Trimble Maxwell™ 6 chips the Trimble R10 offers an unparalleled 440 GNSS channels. Trimble delivers business confidence with a sound GNSS investment for today and long into the future.

TRIMBLE xFILL TECHNOLOGY

More continuous surveying, less downtime

Continue surveying without interruption when you temporarily lose connection to your base station or Trimble VRS™ network. Leveraging a worldwide network of Trimble GNSS reference stations and satellite datalinks, Trimble xFill works to seamlessly 'fill in' for gaps in your RTK or VRS correction stream.

ERGONOMICALLY DESIGNED

Easier Handling and Operation

As the smallest and lightest integrated receiver in its class, the Trimble R10 system is ergonomically designed to provide the surveyor with effortless handling and operation. Designed for ease of use, the progressive design incorporates a more stable center of mass at the top of the range pole, while its sleeker, taller profile provides the durability and reliability for which Trimble is known.

The Trimble R10 receiver incorporates a quick release adaptor for simple and safe removal of the receiver from the range pole. Additionally, the quick release adaptor ensures a solid, stable connection between the range pole and receiver.

AN INTELLIGENT SOLUTION

Advanced features combined with the powerful technology in the Trimble R10 make this the most intelligent GNSS system on the market today.

Smart GNSS Antenna

Survey with confidence—the Trimble R10 system's GNSS antenna tracks GNSS and SBAS signal bands. Its Trimble Stealth™ Ground Plane mitigates multipath signals by using electrical resistance to keep unwanted signals from reaching the antenna element.

Smart Battery

A smart lithium-ion battery inside the Trimble R10 system delivers extended battery life and more reliable power. A built-in LED display allows the user to quickly check remaining battery life.

Advanced Communication Capabilities

The Trimble R10 system uses the latest mobile phone technology to receive VRS corrections and connect to the Internet from the field. Then, access Trimble Connected Community to send or receive documents while away from the office. Using WiFi, easily connect to the Trimble R10 system using a laptop or smartphone to configure the receiver without a Trimble controller.

The Trimble system of hardware and software that's known and trusted

Bring the power and speed of the Trimble R10 system together with trusted Trimble software solutions, including Trimble Access and Trimble Business Center, to get the most complete, intelligent solution. Trimble Access field software provides specialized and customized workflows to make surveying tasks quicker and easier while enabling teams to communicate vital information between field and office in real-time. Back in the office, users can seamlessly process data with Trimble Business Center office software.

The Trimble R10 GNSS system, a new era of surveying productivity beyond GNSS for professional surveyors.

Trimble.

TRIMBLE R10 GNSS SYSTEM

DATASHEET

PERFORMANCE SPECIFICATIONS

Measurements

- Measuring points sooner, faster and in harsh environments with Trimble HD-GNSS technology
- Increased measurement traceability with Trimble SurePoint electronic plumb detection
- Reduced downtime due to loss of radio signal with xFill technology
- Advanced Trimble Maxwell 6 Custom Survey GNSS chips with 440 channels
- Future-proof your investment with Trimble 360 GNSS tracking
- Satellite signals tracked simultaneously:
  - GPS: L1C/A, L1C, L2C, L2E, L5
  - GLONASS: L1C/A, L1P, L2C/A, L2P, L3
  - SBAS: L1C/A, L5 (For SBAS satellites that support L5)
  - Galileo: GIOVE-A and GIOVE-B, E1, E5a, E5B
  - COMPASS: B1, B2, B3
- OmniSTAR HP, XP, G2, VBS positioning
- QZSS, WAAS, MSAS, EGNOS, GAGAN
- Positioning Rates: 1 Hz, 2 Hz, 5 Hz, 10 Hz, and 20 Hz

POSITIONING PERFORMANCE[1]

Code differential GNSS positioning

Horizontal	0.25 m + 1 ppm RMS
Vertical	0.50 m + 1 ppm RMS
SBAS differential positioning accuracy[2]	typically <5 m 3DRMS

Static GNSS surveying
High-Precision Static

Horizontal	3 mm + 0.1 ppm RMS
Vertical	3.5 mm + 0.4 ppm RMS

Static and Fast Static

Horizontal	3 mm + 0.5 ppm RMS
Vertical	5 mm + 0.5 ppm RMS

Real Time Kinematic surveying
Single Baseline <30 km

Horizontal	8 mm + 1 ppm RMS
Vertical	15 mm + 1 ppm RMS

Network RTK[3]

Horizontal	8 mm + 0.5 ppm RMS
Vertical	15 mm + 0.5 ppm RMS
RTK start-up time for specified precisions[4]	2 to 8 seconds

Trimble xFill[5]

Horizontal	RTK[6] + 10 mm/minute RMS
Vertical	RTK[6] + 20 mm/minute RMS

1 Precision and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. The specifications stated recommend the use of stable mounts in an open sky view, EMI and multipath clean environment, optimal GNSS constellation configurations, along with the use of survey practices that are generally accepted for performing the highest-order surveys for the applicable application including occupation times appropriate for baseline length. Baselines longer than 30 km require precise ephemeris and occupations up to 24 hours may be required to achieve the high precision static specification.
2 Depends on WAAS/EGNOS system performance.
3 Network RTK PPM values are referenced to the closest physical base station.
4 May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.
5 Precisions are dependent on GNSS satellite availability. xFill positioning ends after 5 minutes of radio downtime. When using a single base station, xFill requires the location of the base antenna to be within 1 m of the base coordinate in a known global reference frame such as WGS-84. When establishing a single base station using the "Here" key in Trimble Access software, the required accuracy is usually only achieved when the position is augmented with WAAS or EGNOS. VRS subscribers should check with their network administrator that the network is setup in a known coordinate system.
6 RTK refers to the last reported precision before the correction source was lost and xFill started.
7 Receiver will operate normally to -40 °C, internal batteries are rated to -20 °C.
8 Varies with temperature and wireless data rate. When using a receiver and internal radio in the transmit mode, it is recommended that an external 6 Ah or higher battery is used.
9 Varies with terrain and operating conditions.
10 Bluetooth type approvals are country specific.

HARDWARE

Physical

Dimensions (W×H)	11.9 cm x 13.6 cm (4.6 in x 5.4 in)
Weight	1.12 kg (2.49 lb) with internal battery, internal radio with UHF antenna, 3.57 kg (7.86 lb) items above plus range pole, controller & bracket
Temperature[7]	
Operating	-40 °C to +65 °C (-40 °F to +149 °F)
Storage	-40 °C to +75 °C (-40 °F to +167 °F)
Humidity	100%, condensing
Ingress Protection	IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)
Shock and vibration	Tested and meets the following environmental standards:
Shock	Non-operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth
Vibration	MIL-STD-810F, FIG.514.5C-1

Electrical

- Power 11 to 24 V DC external power input with over-voltage protection on Port 1 and Port 2 (7-pin Lemo)
- Rechargeable, removable 7.4 V, 3.7 Ah Lithium-ion smart battery with LED status indicators.
- Power consumption is 5.1 W in RTK rover mode with internal radio.
- Operating times on internal battery[8]:
  - 450 MHz receive only option .... 5.5 hours
  - 450 MHz receive/transmit option (0.5 W) .... 4.5 hours
  - 450 MHz receive/transmit option (2.0 W) .... 3.7 hours
  - Cellular receive option .... 5.0 hours

COMMUNICATIONS AND DATA STORAGE

- Serial: 3-wire serial (7-pin Lemo)
- USB: supports data download and high speed communications
- Radio Modem: fully integrated, sealed 450 MHz wide band receiver/transmitter with frequency range of 410 MHz to 470 MHz:
  - Transmit power: 2 W
  - Range: 3–5 km typical / 10 km optimal[9]
- Cellular: integrated, 3.5 G modem, HSDPA 7.2 Mbps (download), GPRS multi-slot class 12, EDGE multi-slot class 12, UMTS/HSDPA (WCDMA/FDD) 850/1900/2100MHz, Quad-band EGSM 850/900/1800/1900 MHz, GSM CSD, 3GPP LTE
- Bluetooth: fully integrated, fully sealed 2.4 GHz communications port (Bluetooth®)[10]
- WiFi: 802.11 b,g, access point and client mode, WEP64/WEP128 encryption
- External communication devices for corrections supported on – Serial, USB, Ethernet, and Bluetooth ports
- Data storage: 4 GB internal memory; over three years of raw observables (approx. 1.4 MB /day), based on recording every 15 seconds from an average of 14 satellites
- CMR+, CMRx, RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1 input and output
- 24 NMEA outputs, GSOF, RT17 and RT27 outputs

WebUI

- Offers simple configuration, operation, status, and data transfer
- Accessible via WiFi , Serial, USB, and Bluetooth

CERTIFICATIONS

FCC Part 15 (Class B device), 22, 24; R&TTE CE Mark; C-Tick, A-Tick; PTCRB; WFA

Contact your local Trimble Authorized Distribution Partner for more information.

Specifications subject to change without notice.

TRIMBLE AUTHORIZED DISTRIBUTION PARTNER

NORTH AMERICA
Trimble Navigation Limited
10355 Westmoor Dr
Westminster CO 80021
USA

EUROPE
Trimble Germany GmbH
Am Prime Parc 11
65479 Raunheim
GERMANY

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Trimble Navigation
Singapore Pty Limited
80 Marine Parade Road
#22-06, Parkway Parade
Singapore 449269
SINGAPORE

Table detailing sensor offsets

Horizontal Offsets with respect to IMU Vertical Reference is Water Line

SENSOR	X (Port /Starboard)	Y(Forward, Aft)	Z WRT Water line
GPS-Primary Antenna	0.248 m	1.1985 m	-3.265 m
MRU	0	0	0.5403 m
R2Sonic	0	0.3803 m	1.3152 m

Sound-Velocity Profiler: Sound-velocity measurements in the water column are required to correct for beam refraction as the sound passes through the water column. Sound-velocity profiles in the survey area are measured using a Valeport mini sound velocity profiler. Sound velocity corrections applied during the processing and editing phase.

VALEPORT

miniSVS Sound Velocity Sensor

Our unique digital time of flight technology gives unmatched performance figures, with signal noise an order of magnitude better than any other sensor. The miniSVS is available in a selection of configurations and with optional pressure or temperature sensors. There are a variety of sizes to suit many applications.

miniSVS - still the most accurate sound velocity sensor in the world. Nothing else comes close.

Sound Velocity Measurement

Each sound velocity measurement is made using a single pulse of sound travelling over a known distance, so is independent of the inherent calculation errors present in all CTDs. Our unique digital signal processing technique virtually eliminates signal noise, and gives almost instantaneous response; the digital measurement is also entirely linear, giving predictable performance under all conditions.

Range:	1375 - 1900m/s	
Resolution:	0.001m/s	
Accuracy:	Dependent on sensor size	
100mm	Random noise (point to point)	±0.002m/s
	Max systematic calibration error	±0.013m/s
	Max systematic clock error	±0.002m/s
	Total max theoretical error	**±0.017m/s**
50mm	Total max theoretical error	±0.019m/s
25mm	Total max theoretical error	±0.020m/s

Acoustic Frequency: 2.5MHz

Sample Rate: Selectable, dependent on configuration

Rate	SV	SV+P	SV+T
Single Sample	•	•	•
1Hz	•	•	•
2Hz	•	•	•
4Hz	•	•	•
8Hz	•	•	•
16Hz	•	•	•
32Hz	•	•	
60Hz	•		

Optional Sensors

The miniSVS may be optionally supplied with either a pressure or temperature sensor (but not both). Data is sampled at the rates shown above

Sensor	Pressure	Temperature
Type	Strain Gauge	PRT
Range	5, 10, 50, 100 or 600 Bar	-5°C to +35°C
Resolution	0.001% range	0.001°C
Accuracy	±0.05% range	±0.01°C

Data Output

Unit has RS232 & RS485 output, selected by command code. RS232 data may be taken directly into a PC over cables up to 200m long, whereas RS485 is suitable for longer cables (up to 1000m) and allows for multiple addressed units on a single cable.

Baud Rate: 2400 - 115200 (NB. Low baud rates may limit data rate)
Protocol: 8 data bits, 1 stop bit, No parity, No flow control

Electrical

Voltage: 8 - 30vDC
Power: 0.25W (SV only), 0.35W (SV + Pressure)
Connector: Subconn MCBH6F (alternatives on request)

Data Format

Examples of data formats are:
<space>{sound_velocity}<cr><lf>
<space>{pressure}<space>{sound_velocity}<cr><lf>
<space>{temperature}<space>{sound_velocity}<cr><lf>

SV: Choose from mm/s (1510123), m/s to 3 decimal places (1510.123), or m/s to 2 decimal places (1510.12)

Pressure: If fitted, pressure is always output in dBar with 5 digits, with a decimal point, including leading zeroes if necessary. Position of the point is dependent on sensor range, e.g.

50dBar	47.123
100dBar	047.12
1000dBar	0047.1

Temperature: If fitted, temperature is output as a 5 digit number with 3 decimal places and leading zeroes, signed if negative, e.g. 21.456
02.298
-03.174

Physical

Please refer to factory for detailed dimensions if required.

Depth Rating: 6000m (Titanium), 500m (acetal)
Weight: 1kg (housed type)
Housing & Bulkhead: Titanium or acetal, as selected
Transducer Window: Polycarbonate
Sensor Legs: Carbon Composite
Reflector Plate: Titanium.

Ordering

All systems supplied with operating manual and carry case. OEM units come with a test lead, housed units with a 0.5m pigtail.

Configuration	100mm	50mm	25mm
Titanium Housed	0652004	0652005	0652006
Acetal Housed	0652045	0652046	0652047
Bulkhead OEM	0652001	0652002	0652003
Remote OEM	0652007	0652008	0652009
Titanium + Pressure	0652004-P	0652005-P	0652006-P
Titanium +Temperature	0652004-T	0652005-T	0652006-T

Datasheet Reference: miniSVS version 2b, June 2013

Multibeam Bathymetry Data Editor: Multibeam data, once collected, require editing and cleaning before presentation of data can be considered. This is accomplished using HYSWEEP software from HYPACK Inc.

Tidal reductions: All bathymetric data acquired during the survey are reduced to Tide Gauge Zero based on tidal data recorded by a Valeport and/or a RBR tide recorder on site over a of period 35 days. Calculations of tidal planes were done by Paul Davill of the National Tidal Facility (Australian BOM); also using data from the South Pacific Sea Level and Climate Monitoring Project and SOPAC from the Kings Wharf tide gauge maintained by the SPSLCM Project. These corrections are applied during the editing and cleaning of the data.

VALEPORT

TideMaster

TideMaster has been designed to provide an accurate, versatile and easily deployed tide gauge for use in short or long term survey operations. Optional control/display panel, Bluetooth, SD card memory and optional weather sensor provide unrivalled functionality. Low power consumption and user selectable sampling regime allow for up to a year of autonomous operation, whilst optional telemetry packages extend the capabilities for real time operations. TideMaster is compatible with a wide range of hydrographic software and tools.

Pressure Transducer

Type:	Vented strain gauge, with stainless steel mounting bracket.
Range:	Standard 10dBar (approx 10m), with 20m cable. Other ranges and lengths available.
Accuracy:	±0.1% Full Scale.
Calibration:	Held within logging unit.
Dimensions:	18mm diameter x 80mm.

Weather Sensor Options

Windsonic Ultrasonic Anemometer

Wind Speed:	0-60m/s
Wind Direction:	0-359°
Calibration:	Held within sensor.
Dimensions:	142mm x 160mm.

MetPak II ™ Weather Station

Wind Speed:	0-60m/s
Wind Direction:	0-359°
Air Temperature:	-35°C to +70°C
Relative Humidity:	0 – 100% RH
Barometric Press:	600 – 1100hPa/mbar
Dew Point:	As per temperature range
Calibration:	Held within sensor.
Dimensions:	142mm x 274mm.

Logging Unit

Housing:	Injection moulded housing rated to IP67, with injection moulded mounting bracket.
Display:	Optional control/display (128x64 OLED) panel for system configuration and data display.
Power:	4 "C" cells within separate sealed compartment. Tool-less battery change. Alkaline cells provide power for up to a year of autonomous sampling
Memory:	512 MB SD card memory allowing for effectively unlimited data storage.
Sampling:	Raw data sampled at 8Hz, mean and standard deviation of burst samples is logged. 5 pre-programmed burst modes + custom sampling mode. Continuous Sampling Mode (1Hz)
Switching:	Power switch on unit.
Resolution:	Data logged to 1mm resolution.
Comms:	Integral Bluetooth for short range wireless communication RS232/RS485 for cabled communication
Dimensions:	Housing 52 mm x 144.5 mm x 197 mm. Bracket 35 mm x 210 mm x 159 mm. Mounted 61.5mm x 210 mm x 197 mm
Weight:	1.1 kg (approx) including batteries.

Radio Telemetry

Frequency:	Selectable frequency UHF synthesized radio transceiver, operating in UK licence exempt band (458.5 - 458.9 MHz).
Power output:	Supplied as nominal 100mW peak output.
RS232 output:	4800 baud, 8,1,N.
Aerials	
Transmitter:	¼ wave 'rubber duck' (standard, ~2km). 3dB omni-directional (option, ~10km)
Receiver:	3dB omni-directional.
Power input	
Transmitter:	External 12vDC supply.
Current:	0.04mA sleep, 120mA receive, 410mA transmit.
Receiver:	External 12vDC input
Current:	120mA receive, 410mA transmit.
Transmitter Physical	
Materials:	IP67 Black anodised aluminium box.
Size:	200mm x 200mm x 70mm.
Connectors:	To antenna, TideMaster & external power supply.
Receiver Physical	
Materials:	Desktop style anodised aluminium box.
Size:	200mm x 180mm x 70mm.
Connectors:	To antenna, 12vDC input & RS232 output.

GSM/GPRS/Bluetooth Telemetry

Please contact Valeport to discuss GSM/GPRS/Bluetooth telemetry requirements.

Software

System is supplied with TideMaster Express Windows based PC software, for instrument setup, data extraction and display. Tidemaster Express is licence free.

Ordering

0741001	TideMaster portable water level recorder. c/w wall mounting bracket and electronics/logger (**with display**) in rugged injection moulded housing with batteries. Supplied with Windows based TideMaster Express software and operating manual. (*Transducer option below required*)
0741002	TideMaster portable water level recorder c/w wall mounting bracket, electronics/logger (**without display**) in rugged injection moulded housing with batteries. Supplied with Windows based TideMaster Express software and operating manual. (*Transducer option below required*)
0741PT1D20	1 bar transducer c/w 20m cable and connector.

Datasheet Reference: TideMaster version 2A, Feb 2011

As part of our policy of continuing development, we reserve the right to alter at any time, without notice, all specifications, designs, prices and conditions of supply of all equipment

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Multibeam Data – Presentation Software: Commercially available software that accepts X, Y, Z points can be used. Once the datasets have been cleaned and reduced, presentation of the data can be accomplished in software packages such as AutoCAD using QuickSURF, MapINFO using Vertical Mapper, or Surfer for that matter.

PATCH TEST CALIBRATION

The patch test is a multibeam calibration procedure that is completed after installation and setup to calculate sonar roll, pitch, yaw and GPS latency errors in the multibeam data. Data for the patch test are collected over specific bottom terrain in a specific order. The roll-angle test is done in an area where the bottom terrain is smooth and flat, running the same line in different directions at survey speed. Latency test follows running a line twice in the same direction up a slope once at survey speed and once as slowly as possible. The pitch test is done running reciprocal lines with a slope at normal survey speed. The yaw test is done last by running offset lines in the same direction, approximately 2 to 4 times water depth apart. The roll test is by far the most important, because it is misalignment in the roll direction that leads to the greatest survey errors.

The Patch test utility in HYSWEEP was used to calculate the patch test calibrations parameters.

Patch Test calibration completed in the vicinity of Natovi Wharf on the 11 July6th 2015.

For processing the patch files, the following were used in the final analysis.

Table showing patch test processing and results.

Patch test	Files	Results
LATENCY	Natovi192_003_0503	0.10 secs
	Natovi192_003_0454	
ROLL	Natovi192_001_0426-	-0.25 degrees
	Natovi192_001_432	
PITCH	Natovi192_003_0503	12.0 degrees
	Natovi192_003_0509	
YAW	Natovi192_003_0503	-2.0 Degrees
	Natovi192_004_0513	

MULTIBEAM DATA PROCESSING

Multibeam Data Files

A log of all the files for the multibeam data is provided in Appendix 7. The original data files have the file extension *.**hsx** and are archived on DVD (Appendix 8). For processing, the raw *.hsx files are processed with HYSWEEP and saved as Edited HYSWEEP files *.hs2. During the editing process the raw files are first imported into the sweep editor along with a tidal-correction file and sound-velocity file. Tidal and sound-velocity-profile correction files have been archived along with the raw data files. The graphical representation of all collected data, position, heave, heading and soundings, makes it easier to separate good points from bad.

Once satisfied with the graphs, the Sweep Editor will convert the raw survey data into X, Y, Z points and redisplay them, again in a graphical format. In multibeam surveys, data spikes in the dataset occur due to fish, bubbles, hull turbulence, etc.

Sounding Reductions

Multibeam surveys produce a lot more data than are actually required, particularly for presentation. Sounding reductions of a multibeam data set are done using the Mapper program in HYSWEEP. This program will load an entire survey and reduce the data to the desired density. This data reduction is accomplished through gridding. A grid is created from a matrix with rectangular cells of any size, and the soundings are loaded and reduced to one per cell.

APPENDIX 3

Lomaloma Bathymetric Map Sheets

Lomaloma Jetty Bathymetry-MSL- Map Sheet 1
Files: Lomaloma-Jetty Bathymetry-MSL Sheet 1.pdf
Lomaloma-Jetty Bathymetry-MSL Sheet 1.dwg

Lomaloma Jetty Soundings-MSL- Map Sheet 2.dwg
File:Lomaloma Jetty Soundings-MSL- Map Sheet 2.pdf

Lomaloma Side Scan Mosaic- Map Sheet 3.dwg
File:Lomaloma Side Scan Mosaic Map Sheet 3.pdf

Lomaloma-Datum-Levels.dwg

APPENDIX 4

Lomaloma – Seismic Data

LOMALOMA-seismic-profile-location-map-Sheet-4
File: LOMALOMA-seismic-profile-location-map-Sheet-4.pdf
LOMALOMA-seismic-profile-location-map-Sheet-4.dwg

LOMALOMA- Depth-Bedrock-map-Sheet-5
Files: LOMALOMA- Depth-Bedrock-map-Sheet-5.pdf
LOMALOMA- Depth-Bedrock-map-Sheet-5.dwg

Scanned Seismic line profile sections -

Lomaloma_sol_7.tif
Lomaloma_sol_6.tif
Lomaloma_line_5tif
Lomaloma_line_1.tif
Lomaloma_line_3.tif
Lomaloma_line_2.tif

Seismic-profile-line-1-Lomaloma-Jetty.dwg
Seismic-profile-line-6-Lomaloma-Jetty.dwg
Seismic-profile-line-1-Lomaloma-Jetty.pdf
Seismic-profile-line-6-Lomaloma-Jetty.pdf

APPENDIX 5

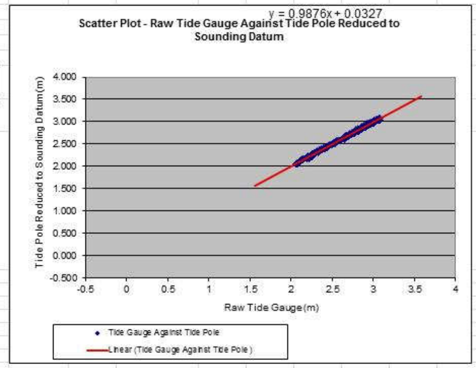
Tide Data and Analysis

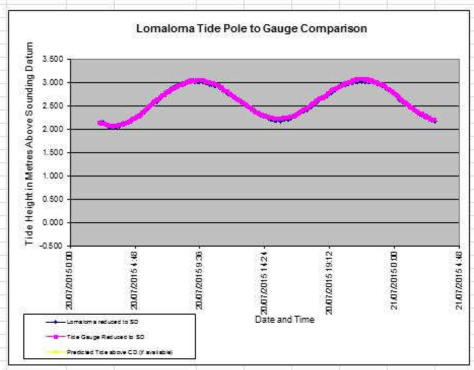
Lomaloma Tide pole 25 hour tide watch Comparison to recorded data.

Lomaloma TIDE GAUGE DEPLOYMENT OBSERVATIONS

HI No:		UKHO REF	
HI Title:		Page No.:	
Tide Gauge Type (&S/N):			
Tide Gauge Location:	Lomaloma		
Tide Pole Zero Relative to Sounding Datum (SD) (+ above and - below) :	0.000	Tide Gauge Zero Relative to SD (+ above and - below) :	0.000
Uncorrected Tide Gauge Multiplication Factor from Scatter Plot Graph (Gradient) :	0.988	Raw Tide Gauge Constant from Scatter Plot Graph (Intercept) :	0.0327

Date and Time dd/mm/yyyy hh:mm	Time	Uncorrected observed Tide Pole	Observed Tide Pole Reduced to SD ie TGZ	Uncorrected recorded Tide Gauge	Tide Pole Red. to SD **minus** uncorrected recorded Gauge	Gauge reduced to SD using value in cell K6 (mean diff. Tide Pole reduced to SD **minus** uncorrected gauge reading).	Recorded Tide Gauge x Scale Error Formula & Reduced to SD	Tide Gauge Direct Red. to SD **minus** Tide Gauge x Scale Error & Red. to SD	Predicted Tide (Above CD)
20/07/2015 2:12	2:12	2.15	2.145	2.14	0.005	2.14	2.146	-0.006	
20/07/2015 2:18	2:18	2.155	2.155	2.136	0.019	2.136	2.142	-0.006	
20/07/2015 2:24	2:24	2.16	2.160	2.125	0.035	2.125	2.131	-0.006	
20/07/2015 2:30	2:30	2.14	2.135	2.12	0.015	2.12	2.126	-0.006	
20/07/2015 2:36	2:36	2.12	2.120	2.114	0.006	2.114	2.120	-0.006	
20/07/2015 2:42	2:42	2.10	2.095	2.102	-0.007	2.102	2.109	-0.007	
20/07/2015 2:48	2:48	2.09	2.085	2.088	-0.003	2.088	2.095	-0.007	
20/07/2015 2:54	2:54	2.06	2.060	2.077	-0.017	2.077	2.084	-0.007	
20/07/2015 3:00	3:00	2.06	2.060	2.063	-0.003	2.063	2.070	-0.007	
20/07/2015 3:06	3:06	2.06	2.060	2.062	-0.002	2.062	2.069	-0.007	
20/07/2015 3:12	3:12	2.06	2.060	2.057	0.003	2.057	2.064	-0.007	
20/07/2015 3:18	3:18	2.07	2.065	2.071	-0.006	2.071	2.078	-0.007	
20/07/2015 3:24	3:24	2.08	2.075	2.077	-0.002	2.077	2.084	-0.007	
20/07/2015 3:30	3:30	2.08	2.075	2.074	0.001	2.074	2.081	-0.007	
20/07/2015 3:36	3:36	2.08	2.080	2.084	-0.004	2.084	2.091	-0.007	
20/07/2015 3:42	3:42	2.10	2.100	2.096	0.004	2.096	2.103	-0.007	
20/07/2015 3:48	3:48	2.12	2.115	2.103	0.012	2.103	2.110	-0.007	
20/07/2015 3:54	3:54	2.13	2.130	2.1	0.030	2.1	2.107	-0.007	
20/07/2015 4:00	4:00	2.13	2.125	2.105	0.020	2.105	2.112	-0.007	
20/07/2015 4:06	4:06	2.15	2.145	2.114	0.031	2.114	2.120	-0.006	
20/07/2015 4:12	4:12	2.16	2.155	2.133	0.022	2.133	2.139	-0.006	
20/07/2015 4:18	4:18	2.17	2.165	2.138	0.027	2.138	2.144	-0.006	
20/07/2015 4:24	4:24	2.17	2.170	2.156	0.014	2.156	2.162	-0.006	
20/07/2015 4:30	4:30	2.19	2.185	2.179	0.006	2.179	2.185	-0.006	
20/07/2015 4:36	4:36	2.21	2.205	2.193	0.012	2.193	2.199	-0.006	
20/07/2015 4:42	4:42	2.23	2.225	2.216	0.009	2.216	2.221	-0.005	
20/07/2015 4:48	4:48	2.25	2.245	2.231	0.014	2.231	2.236	-0.005	
20/07/2015 4:54	4:54	2.27	2.265	2.247	0.018	2.247	2.252	-0.005	
20/07/2015 5:00	5:00	2.29	2.285	2.259	0.026	2.259	2.264	-0.005	
20/07/2015 5:06	5:06	2.31	2.305	2.277	0.028	2.277	2.281	-0.004	
20/07/2015 5:12	5:12	2.33	2.325	2.3	0.025	2.3	2.304	-0.004	
20/07/2015 5:18	5:18	2.35	2.345	2.317	0.028	2.317	2.321	-0.004	
20/07/2015 5:24	5:24	2.37	2.365	2.344	0.021	2.344	2.348	-0.004	
20/07/2015 5:30	5:30	2.39	2.385	2.369	0.016	2.369	2.372	-0.003	
20/07/2015 5:36	5:36	2.41	2.413	2.391	0.022	2.391	2.394	-0.003	
20/07/2015 5:42	5:42	2.44	2.441	2.429	0.012	2.429	2.432	-0.003	
20/07/2015 5:48	5:48	2.47	2.469	2.453	0.016	2.453	2.455	-0.002	
20/07/2015 5:54	5:54	2.50	2.497	2.488	0.009	2.488	2.490	-0.002	
20/07/2015 6:00	6:00	2.53	2.525	2.511	0.014	2.511	2.513	-0.002	

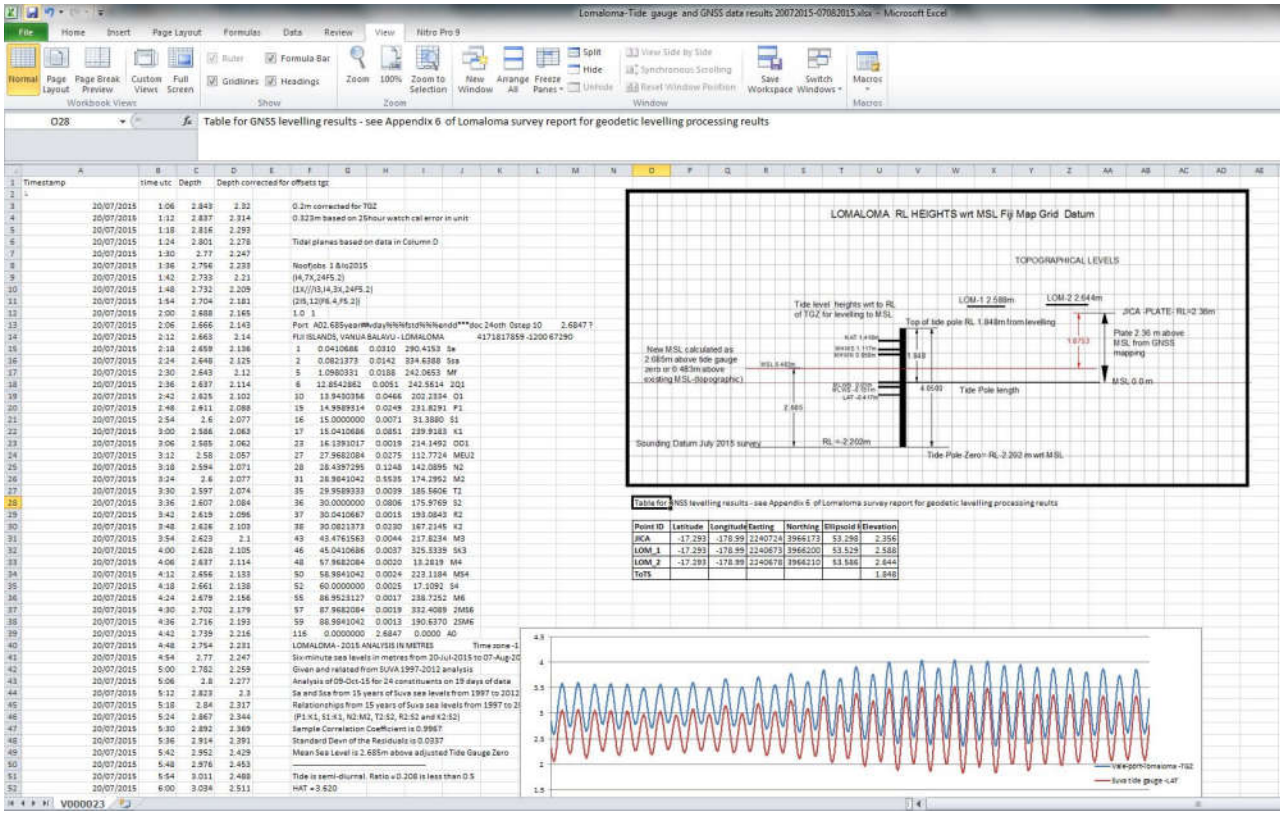




H143 Cover | Observations Table | Tide Curves | Formulae Used | Weather and Remarks

Data File Lomaloma Pole –Gauge-25hr Comparison.xls

Data File Lomaloma-Tide gauge and GNSS levelling results.xls



Tide analysis report from Paul Davill

Normally we compute the tidal analysis with at least 30 days of data. Below is an analysis on the 19 days of data from the ***Lomaloma-adj-ML*** column of your ***Lomaloma-Suva-TL-comparison.xlsx*** spreadsheet.

ort A02.685year##vday%%%fstd%%%endd***doc 24oth 0step 10 2.6847 ?
FIJI ISLANDS, VANUA BALAVU - LOMALOMA 4171817859 -1200 67290

1	0.0410686	0.0310	290.4153	Sa
2	0.0821373	0.0142	334.6388	Ssa
5	1.0980331	0.0188	242.0653	Mf
6	12.8542862	0.0051	242.5614	2Q1
10	13.9430356	0.0466	202.2334	O1
15	14.9589314	0.0249	231.8291	P1
16	15.0000000	0.0071	31.3880	S1
17	15.0410686	0.0851	239.9183	K1
23	16.1391017	0.0019	214.1492	OO1
27	27.9682084	0.0275	112.7724	MEU2
28	28.4397295	0.1248	142.0895	N2
31	28.9841042	0.5535	174.2952	M2
35	29.9589333	0.0039	185.5606	T2
36	30.0000000	0.0806	175.9769	S2
37	30.0410667	0.0015	193.0843	R2
38	30.0821373	0.0230	167.2145	K2
43	43.4761563	0.0044	217.8234	M3
46	45.0410686	0.0037	325.3339	SK3
48	57.9682084	0.0020	13.2819	M4
50	58.9841042	0.0024	223.1184	MS4
52	60.0000000	0.0025	17.1092	S4
55	86.9523127	0.0017	238.7252	M6
57	87.9682084	0.0019	332.4089	2MS6

59	88.9841042	0.0013	190.6370	2SM6
116	0.0000000	2.6847	0.0000	A0

LOMALOMA - 2015 ANALYSIS IN METRES Time zone -1200
Six-minute sea levels in metres from 20-Jul-2015 to 07-Aug-2015. No gaps
Given and related from SUVA 1997-2012 analysis
Analysis of 09-Oct-15 for 24 constituents on 19 days of data
Sa and Ssa from 15 years of Suva sea levels from 1997 to 2012 Analysis
Relationships from 15 years of Suva sea levels from 1997 to 2012 Analysis
(P1:K1, S1:K1, N2:M2, T2:S2, R2:S2 and K2:S2)
Sample Correlation Coefficient is 0.9967
Standard Devn of the Residuals is 0.0337
Mean Sea Level is 2.685m above adjusted Tide Gauge Zero

Tide is semi-diurnal. Ratio = 0.208 is less than 0.5
HAT = 3.620
MHWS = 3.319
MHWN = 3.158
MSL = 2.685
MLWN = 2.212
MLWS = 2.051
ISLW = 1.919
LAT = 1.785

APPENDIX 6

GNSS Station Results and Data Processing

Baseline Processing Report

Project file data		Coordinate System	
Name:	C:\Users\andrickl\Documents\My Work Andrick\Vanuabalavu\Lomaloma V3 FMG.vce	Name:	Fiji 2012
		Datum:	ITRF2005@2008.0 to FMG1986
Size:	568 KB	Zone:	FMG1986
Modified:	3/11/2015 3:37:36 PM (UTC:13)	Geoid:	EGM2008-25
Time zone:	Fiji Standard Time	Vertical datum:	
Reference number:			
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LOM_1 --- JICA (B1715)	LOM_1	JICA	Fixed	0.001	0.001	117°06'42"	58.125	-0.232
LOM_1 --- LOM_2 (B1717)	LOM_1	LOM_2	Fixed	0.001	0.001	28°21'03"	11.700	0.057
JICA --- LOM_2 (B1716)	JICA	LOM_2	Fixed	0.001	0.001	308°32'20"	59.042	0.289
LAUT --- JICA (B1719)	LAUT	JICA	Fixed	0.004	0.008	85°15'57"	380579.593	-37.176
LAUT --- LOM_2 (B1718)	LAUT	LOM_2	Fixed	0.004	0.008	85°15'34"	380537.365	-36.916
LAUT --- LOM_1 (B1720)	LAUT	LOM_1	Fixed	0.005	0.008	85°15'40"	380530.805	-36.970

Acceptance Summary

Processed	Passed	Flag	Fail
6	6	0	0

Project File Data		Coordinate System	
Name:	C:\Users\andrickl\Documents\My Work Andrick\Vanuabalavu\Lomaloma V3 FMG.vce	Name:	Fiji 2012
		Datum:	ITRF2005@2008.0 to FMG1986
Size:	568 KB	Zone:	FMG1986
Modified:	3/11/2015 3:37:36 PM (UTC:13)	Geoid:	EGM2008-25
Time zone:	Fiji Standard Time	Vertical datum:	
Reference number:			
Description:			

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna:	0.000 m
Centering Error:	0.000 m

Covariance Display

Horizontal:

Propagated Linear Error [E]:	U.S.
Constant Term [C]:	0.000 m
Scale on Linear Error [S]:	1.960

Three-Dimensional

Propagated Linear Error [E]:	U.S.
Constant Term [C]:	0.000 m
Scale on Linear Error [S]:	1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment:	3
Network Reference Factor:	1.00
Chi Square Test (95%):	Passed
Precision Confidence Level:	95%
Degrees of Freedom:	9

Post Processed Vector Statistics

Reference Factor:	1.00
Redundancy Number:	9.00
A Priori Scalar:	2.35

Control Coordinate Comparisons

Values shown are control coordinates minus adjusted coordinates.

Point ID	ΔEasting (Meter)	ΔNorthing (Meter)	ΔElevation (Meter)	ΔHeight (Meter)
LAUT	?	?	?	-0.004

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LAUT	Grid				Fixed
LAUT	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
JICA	2240724.098	0.005	3966173.138	0.001	2.356	0.011	
LAUT	1861654.664	?	3932152.848	?	31.251	?	LLe
LOM_1	2240672.645	0.005	3966200.248	0.002	2.588	0.011	
LOM_2	2240678.325	0.005	3966210.485	0.001	2.644	0.011	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
JICA	S17°17'34.498347855"	W178°59'09.568884126"	54.271	0.011	
LAUT	S17°36'31.788061595"	E177°26'47.151058953"	91.466	?	LLe
LOM_1	S17°17'33.636703000"	W178°59'11.320750736"	54.503	0.011	
LOM_2	S17°17'33.301757795"	W178°59'11.132621137"	54.560	0.011	

Adjusted ECEF Coordinates

Point ID	X (Meter)	X Error (Met)	Y (Meter)	Y Error (Met)	Z (Meter)	Z Error (Meter)	3D Error (Meter)	Constraint
JICA	-6090729.041	0.011	-107819.076	0.005	-1883823.087	0.004	0.012	
LAUT	-6075194.207	?	270923.786	?	-1917189.056	?	?	LLe
LOM_1	-6090738.050	0.011	-107767.489	0.005	-1883797.865	0.004	0.012	
LOM_2	-6090741.066	0.011	-107773.099	0.005	-1883788.050	0.004	0.012	

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
JICA	0.006	0.002	89°
LOM_1	0.006	0.002	89°
LOM_2	0.006	0.002	89°

Adjusted GNSS Observations

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
LAUT --> JICA (PV1719)	**Az.**	85°15'56"	0.001 sec	0.000 sec	0.607
	ΔHt.	-35.918 m	0.011 m	-0.018 m	-2.279
	Ellip Dist.	380579.146 m	0.005 m	-0.001 m	-0.435
LAUT --> LOM_2 (PV1718)	**Az.**	85°15'34"	0.001 sec	0.000 sec	-0.122
	ΔHt.	-35.630 m	0.011 m	0.011 m	1.318
	Ellip Dist.	380536.923 m	0.005 m	0.004 m	1.346
LAUT --> LOM_1 (PV1720)	**Az.**	85°15'39"	0.001 sec	-0.001 sec	-0.892
	ΔHt.	-35.687 m	0.011 m	0.007 m	0.870
	Ellip Dist.	380530.354 m	0.005 m	-0.005 m	-1.256
LOM_1 --> JICA (PV1715)	**Az.**	117°06'42"	3.380 sec	0.062 sec	0.043
	ΔHt.	-0.231 m	0.002 m	0.000 m	0.364
	Ellip Dist.	58.125 m	0.002 m	0.000 m	-0.321
JICA --> LOM_2 (PV1716)	**Az.**	308°32'19"	3.496 sec	-0.355 sec	-0.352
	ΔHt.	0.288 m	0.002 m	0.000 m	-0.057
	Ellip Dist.	59.042 m	0.001 m	0.000 m	0.267
LOM_1 --> LOM_2 (PV1717)	**Az.**	28°21'01"	28.525 sec	-1.903 sec	-0.163
	ΔHt.	0.057 m	0.002 m	0.000 m	-0.175
	Ellip Dist.	11.700 m	0.001 m	0.000 m	-0.212

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
JICA	LAUT	**Az.**	264°11'44"	0.001 sec	1 : 82256626	1 : 82321674
		ΔHt.	37.194 m	0.011 m		
		ΔElev.	28.895 m	0.011 m		
		Ellip Dist.	380579.592 m	0.005 m		
JICA	LOM_2	**Az.**	308°32'20"	3.530 sec	1 : 48044	1 : 47690
		ΔHt.	0.289 m	0.002 m		
		ΔElev.	0.288 m	0.002 m		
		Ellip Dist.	59.042 m	0.001 m		
LOM_1	JICA	**Az.**	117°06'42"	3.429 sec	1 : 35202	1 : 35021

		ΔHt.	-0.232 m	0.002 m		
		ΔElev.	-0.231 m	0.002 m		
		Ellip Dist.	58.125 m	0.002 m		
LOM_1	LAUT	**Az.**	264°11'27"	0.001 sec	1 : 80609583	1 : 80675427
		ΔHt.	36.963 m	0.011 m		
		ΔElev.	28.663 m	0.011 m		
		Ellip Dist.	380530.799 m	0.005 m		
LOM_1	LOM_2	**Az.**	28°21'01"	28.335 sec	1 : 11991	1 : 12164
		ΔHt.	0.057 m	0.002 m		
		ΔElev.	0.057 m	0.002 m		
		Ellip Dist.	11.700 m	0.001 m		
LOM_2	LAUT	**Az.**	264°11'22"	0.001 sec	1 : 82436039	1 : 82500562
		ΔHt.	36.906 m	0.011 m		
		ΔElev.	28.607 m	0.011 m		
		Ellip Dist.	380537.369 m	0.005 m		

APPENDIX 7

Lomaloma Jetty – Multibeam Survey Log

APPENDIX 8

Lomaloma Jetty – Digital Data Files

Lomaloma-survey report.pdf

Appendix 3 – Bathymetry Files

Sheet 1 Lomaloma Jetty Bathymetry-MSL.DWG
Sheet 2 Lomaloma Jetty Soundings –MSL.DWG

Sheet 1 Lomaloma Jetty Bathymetry-MSL.PDF
Sheet 2 Lomaloma Jetty Soundings –MSL.PDF

Sheet 1 Lomaloma Jetty Sidescan.PDF
Sheet 2 Lomaloma Jetty Sidescan.PDF

Lomaloma Jetty- Bathymetry –MSL.XYZ

Appendix 4 – Seismic Data

LOMALOMA-seismic-profile-location-map-Sheet-4
File: LOMALOMA-seismic-profile-location-map-Sheet-4.pdf

LOMALOMA- Depth-Bedrock-map-Sheet-5
File: LOMALOMA- Depth-Bedrock-map-Sheet-5.pdf

Scanned Seismic line profile sections -
Lomaloma_sol_7.tif
Lomaloma_sol_6.tif
Lomaloma_line_5tif
Lomaloma_line_1.tif
Lomaloma_line_3.tif
Lomaloma_line_2.tif

Seismic-profile-line-1-Lomaloma-Jetty.dwg
Seismic-profile-line-6-Lomaloma-Jetty.dwg
Seismic-profile-line-1-Lomaloma-Jetty.pdf
Seismic-profile-line-6-Lomaloma-Jetty.pdf

Appendix 5 – Tide Data files

Datum-levels-Lomaloma.dwg
Lomaloma Pole to Gauge 25Hr Comparison.xls
Lomaloma-Suva-TL-Comparison.xls