Technical Report

INSTALLATION OF WAVERIDER BUOY
OFFSHORE TONGATAPU
21° 13.26’ S
175° 12.90’W

Kingdom of Tonga

by

Ralf Carter

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Prepared For:
Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC)
Work Program CCSP/TG.7

As a Contribution by:
United Nations Development Project RAS/86/125 Mineral Resources Potential of South Pacific
INSTALLATION OF WAVERIDER BUOY
OFFSHORE TONGATAPU, 21° 13.26'S 175° 12.90' W

Investigation of Oceanographic Conditions at Tongatapu for Assessment of Power from Wave Energy

23 March to 6 April 1987
Cruise TG-87-1

INTRODUCTION AND BACKGROUND

This cruise was undertaken as a part of the CCOP/SOPAC Work Programme CCSP/TG.7 “Investigation of Oceanographic Conditions at Tongatapu for Assessment of Power from Wave Energy”.

The Government of Norway is funding a wave energy study program in the South Pacific and has supplied CCOP/SOPAC with two Waverider Buoys for installation in both Tonga and Rarotonga. A third buoy is to be supplied for installation in Western Samoa.

During November of 1986 bathymetric surveys were made at two sites in Tongatapu. These sites proved to be unsatisfactory and a third site, one at Makeke near the Experimental Farm, was selected in consultation with Norway. This site was surveyed and the Waverider Buoy was installed during March and April of 1987. The following reports discussed the mooring design and details of the installation.

STUDY OBJECTIVES

The objective of this report is to document details of the site selection, description of the anchor system, method of buoy installation, and conditions during installation of the Waverider buoy in Tonga for future reference. The wave observations that will be made by the buoy are for input into the wave energy program. Some of the initial wave data resulting from the Waverider buoy are presented in the report.

The primary objective of the wave energy programme is to develop wave statistics for the southern exposure to Tongatapu Island for use in the design of a wave powered electrical energy generating plant to be located onshore and just east of the Waverider location. The major wave energy is expected to result from swell originating from winter storms located far south of Tonga waters. A second objective is to record both seas and swell produced by tropical cyclones that occur during the hurricane season and may pass nearby Tonga. These wave data will find application in the design of harbour and coastal protection facilities not only in Tonga but at other nearby island groups at the same latitude.
PERSONNEL PARTICIPATING

The design and preparation of the mooring facility, selection of the final location employed, and the installation of the Waverider Buoy was done under the direction of Ralf Carter, Marine Scientist/Engineer from CCOP/SOPAC. He had the support and assistance of the Ministry of Lands, Surveys and Natural Resources, and Mr. Arne Lothe, an engineer provided by the Government of Norway to assist in the operation and confirm the transmission of data by the buoy after its installation. Individuals assisting in the project included:

Mr. Sione L. Tongilava, Permanent Secretary  
Ministry of Lands, Surveys, and Natural Resources  
Mr. Arne Lothe, Engineer provided by Norway  
Mr. Saimone Helu, Geologist  
Mr. Dave Tappin, Geologist  
Mr. Siua Finau, Captain of Ekiaki  
Mr. Sione Soakai, Trainee  
Mr. Tavita Malolo, Surveyor

Others contributing include Director of Fisheries, Crew of the Ekiaki, Survey Department, and Maintenance Department.

EQUIPMENT, FACILITIES, AND METHODS

The following equipment was provided by CCOP/SOPAC:

- Sextant and Charts
- Hand Compass
- Hand Tools
- Danfort Anchor with Chain
- Miscellaneous Supplies
- Lines and Buoys
- Calibrated Sounding Lines
- Waverider (Supplied by Norway Aid)
- Anchor Lines (Supplied by Norway Aid)
- Blocks and Falls

The facilities and equipment supplied by the Government of Tonga included the following:

- F/V Ekiaki and Crew
- Scrap Iron for Anchor
- Land Transportation
- Wharf Facilities
- Battery
- Survey Instruments and Crew
- Lumber for Launch Ramp
- Anchor Chain

The operation was conducted in three stages. The first stage was to survey the site, establish a depth profile, locate a spot where the reflected waves from the steep shore would not
affect the wave data. A spot about 600 metres west of the Makeke tip site which is about 200 metres or so west of the proposed wave power plant site and 1150 metres offshore was located by radar ranging. The depth was estimated to be 152 metres (500 ft) in depth. The anchor lines were then measured, cut and prepared for launch (see photos attached).

During the above operation the Waverider buoy was made ready for deployment. The batteries were changed and the systems activated. Receipt of the signal and its transmission to Norway was confirmed.

The second step was to reoccupy the station, confirm the depth with a sounding line, and place the anchor with an extra length of line attached to a large marker buoy for recovery of the anchor line.

The third step was to bring the end of the anchor line onboard, replace the marker buoy system with the rubber snubber, attach the waverider buoy, and place it into the sea. The buoy's signal was received and found to indicate a wave height and period that was then present, 1.3 metres at 4.5 seconds. The location of the buoy was determined from shore stations by triangulations. Receipt of the signal and its transmission to Norway was confirmed after return to port.

SURVEY OF WAVERIDER SITES

A site at Mui Hopohoponga Point (Figure 1), the west end of Tongatapu was surveyed 11/11/86 (Figure 2). The bottom was on a slope of 1.33 to 1 at the depth where the anchor might be placed. The site is in the lee of 'Eua Island for south east swell, and would be exposed only to the east. The ocean bottom is quite deep just to the north of the site.

A site near Vaotuu, the Blow Hole Site was also surveyed 11/11/86 (Figure 3). The site was more of a south west exposure then desired.

The Makeke Site (Figure 4) used for the Waverider Buoy was east of the Blow Hole Site. and it has a more southerly exposure to the seas than the other two sites. The ocean bottom where the anchor is located has a north/south slope on the order of 9 to 1. The east/west slope appears to be steeper. The depth of water where the anchor was placed was estimated to be 505 ft or 154 metres. The depth was determined using three methods. The ships' fathometer indicated 154 metres. A 60 kg test mono-filament fishing line with a 3 kg lead weight was used to sound the bottom, and the freeboard on the anchor line were also employed to estimate the depth. The current on the anchor line made it difficult to estimate its length due to stretch in the line. The sounding line appeared to be the more accurate method. Its length was marked as the weight reached the bottom, and its length was measured on land while stretched with 3 kg tension. The
fathometer measures to the nearest reflector that is not necessarily directly under the ship.

**PREPARATION OF ANCHOR LINE**

The following materials were available for making up the anchor system:

- Anchor: four pieces of cast iron weighing 950 kg
- 3/8" chain: 30 metres of zinc coated chain
- 1/4" chain: 30 metres
- Anchor: 135 Danforth Anchor
- 1/2" line: 30 metres polypropylene rope
- 28 cm float: 10 each submergible buoys, net buoyancy 97 kg
- 1" line: 45 metres of float line
- 5/8" line: 258 metres of Kelevar
- 3/8" line: 26 metres of polypropylene rope
- Rubber: 17 metres of 36 mm diam rubber snubber
- Shackles: Several 1/4" and 1/2" shackles with safety wire
- Tape: Several rolls of electrical tape

The four pieces of cast iron were strung together using the 3/8" chain. The 1/4" chain was used to hold the clump together. A 6 metre length of the 3/8" chain was used as part of the anchor line. A 5 metre length of the 1/4" chain was used to attach the Danforth anchor as a safety against lateral drag of the clump anchor.

**SOUNDING SITE AND ANCHOR DROP**

A 3 kg lead weight attached to a mono-filament line was allowed to free fall from a hand fishing spool. The line was pulled tight and marked at the waterline as the weight touched bottom before the current could cause a bight to form in the line. The line had been calibrated with 3 kg tension so to compensate for stretch in the line. A small marker float was attached to the line to mark the location while the large clump anchor was made ready to cast over (see attached photos).

A 0.8 meter diameter inflatable buoy was attached to a 30 metre length of 12 mm diameter line that was bent onto the upper end of the float rope. The entire anchor string with the 10 submergible floats was strung out abeam the work vessel, and the clump anchor, safety chain and small danforth anchor were heaved over the side.

The fathometer record was lost as bubbles from the plunging anchor intercepted the signal. The signal returned a moment later and indicated that the drop depth was about 154 metres (505 ft). The mono-filament line was recovered and was measured again to confirm this depth. The 0.8 metre buoy was brought aboard and the 30 metre line was hauled aboard. Only a few metres of the float rope could be pulled aboard by three men. The pull was estimated to be on the order of 1330 N, (300 lbs). The line appeared to be
held by the current as the lead was not vertical. The anchor was placed at 1110 hrs local time on 1 April 1987. The wind was less than 5 knots from an easterly direction and the surface current had a slight set to the west. The tide was about 2 hours into the ebb at 1.2 metre (tide datum).

**LAUNCH OF WAVE RIDER BUOY**

Prior to attachment of the rubber snubber the 0.8 metre buoy was hauled aboard along with the 30 metre pendant. Tension was taken in the anchor line about the anchor capstan. The clump anchored was a weight and the string was carried ashore a short distance to reset the anchor slightly closer to shore. Any change in its depth was not determined. The amount of line brought aboard was about 7 metres thus leaving about 163 metres in the water. The line was not vertical at the time of this observation. There would be considerable stretch in the line when the clump anchor was lifted free of the bottom.

The instrument buoy #68234-9 transmitter #3871 was connected to the anchor line and placed into the water at 1052 hr local time on 2 April 1987 during low high water at about one hour into ebb tide. The message "FKTOKAGE FAKAMAMA'O MEI HENI" or "Notice, Keep Away From Here" was painted on the buoy before release. The transmitter had been reset on 1 April 1987 (see attached photos).

A pass was made by the buoy to check the depth on the fathometer, and it was again found to be 154 metre. The buoy's transmission was received on board with a special instrument that indicated a 1.3 meter wave at 4.5 seconds. The transmission could he received only when the buoy was alongside.

The survey team located on the shore at the site determined angles to the buoy from two shore stations, and they reported that the location of the buoy was:

7 652 315.49 N  
685 234.79 E

This location scales 1050 metre offshore at 21 degrees 12.58 minutes S and 175 degrees 13.46 minutes W. The anchor line had about 37 metres (120 ft) of scope depending upon tide level and stretch in the system. The location reported by the satellite had not been received for this report.

**DRAG ON ANCHOR LINE**

The current drag on the anchor line and submerged buoys was estimated using constants etc., found in handbooks (Myers, Holm and Mcallister; Berteaux; and Brater and King). Assuming that the current acted over the entire length of line then the current required to produce a force of 1334 N (300 lbs) would be on the order of 0.7 knots (0.373 metre per second).
WAVE OBSERVATIONS

The Waverider instrument collects and stores three sets of three hours of wave data. This data is later processed to determine the significant wave height over the three hours the energy flux period, and eight energy flux density values for the 4-6, 6-8, 8-10, 10-12, 12-14, 14-16, 16-20, and >20 second cycle periods. Three sets of data are stored in a total of 32 sensors. The last data is stored in S01 to S10. S11 to S20 contains a three hours older set of data etc. All three sets are transmitted to the Argos Satellites as they pass over at a favourable angle. Wave data can be transmitted by Telex from the Argos channels, and the values are transmitted for the individual sensors and printed out in the following pattern:

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A data set from sensors S01 through S10 have been plotted in a graph of energy flux density vs frequency in Figure 5. A frequency of 0.068 cycles per second or a period of about 14.7 seconds would have the higher energy concentration in the wave spectra shown in the figure.

The first set of wave date received from the Waverider was sent by mail on floppy disk for PC manipulation. It contained 244 three hour sets of data. The data for each three hour set is filed as an 80 character string.

The file received by mail could contain approximately one month of observations: however, it is not yet confirmed if they are consecutive sets, and the starting time and date for this data is to be determined.

CONCLUSIONS

The conclusions given are based upon observations made during the deployment of this buoy system, and experience elsewhere in the ocean environment.

1. The placement of a clump anchor in 150 metre (500 ft) depth water by free fall with the anchor line floating extended in a straight line from the drop location does not affect the final location significantly.
2. The sounding of the depth by means of a mono-filament line using a 3 kg weight at 150 metres is possible; however, it is difficult to determine when the bottom is reached. A heavier weight should be used.

3. The 950 kg (2090 lbs) clump anchor can be handled safely using the 19 metre (62 ft) F/V 'EKIAKI' in 1.3 metre seas. The running tackle aboard this vessel can lift the anchor off the bottom, and shift its location.

4. It would be desirable to make a bathymetry chart of the general area where the buoy is deployed in order to better select the anchor location. Note: The equipment necessary to make this survey were not available to the project at the time of deployment.

5. Tapping of the line connections should extend the lift of the anchor system significantly. Likewise the elimination of connections by employing fewer but longer lines should also extend the life of the anchor system.

6. It would be desirable to conduct a current study at a proposed buoy location prior to deployment in order to select the times of minimum current at the location for working with the anchor system.

7. Facility to place the vessel at a known station and to maintain that location during actual launch is critical to the success of the deployment operation. In the case of the Tonga location a few meters drift would result in significant change in water depth.

8. The receipt of the wave data in the format used for the TONGA.CHR file for the May 1987 data appears to be a satisfactory method of transmission from Norway back to the South Pacific.
REFERENCES


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1. The views expressed in this report are those of the Author and do not necessarily reflect those of the United Nations.

2. Mention of any firm or licences process does not imply endorsement by the United Nations.
Figure 2

Mui Hapohoponga

Slope 1/1.33
Figure 3
Blow Holes Site
Figure 5 - Wave Energy Spectrum, kW/m