ENERGY

CROWN AGENTS

1980.

THE RESULTS OF A RECONNAISSANCE SURVEY INTO THE POTENTIAL AND DEVELOPMENT OF WAVE ENERGY ALONG THE CORAL COAST FIJI

IMR THE INSTITUTE OF MARINE RESOURCES, THE UNIVERSITY OF THE SO

UNIVERSITY OF THE SOUTH PACIFIC

MARINE RESOURCES RESEARCH DEPARTMENT

THE RESULTS OF A RECONNAISSANCE SURVEY INTO THE POTENTIAL AND DEVELOPMENT OF WAVE ENERGY ALONG THE CORAL COAST FIJI

Development Services
Crown Agents for Oversea
Governments & Administration
4 Millbank
Westminster
LONDON SW1P 3JD

The Results of a Reconnaissance Survey with the Potential and Development of Wave Energy along the Coral Coast, Fiji.

Section	Contents	Page
Section	Contents	Page

<u>List of Appendices to the Crown Agents Survey</u>

A OS Map X552 Fiji (1: 250,000) showing potential wave energy sites along Coral Coast area.

B OS Map Sheets 15, 16, 17 (Fiji) showing potential wave energy sites along Coral Coast area, but on a 1: 50,000 (reduced photographically) scale.

C Extracts from Map Sheets 15, 16, 17 (Fiji) showing Sites A, B, C, D, E, F, G and H, to an actual scale of 1: 50,000.

D Equivalent Tidal levels.

E Assessment and Ranking of Potential Sites, Coral Coast.

F Basic Data on the selected areas along the Coral Coast, including notes of General Observations.

G Document produced by Mr A S P Green, Senior Geologist, of Wave Heights and Periodicity of typical sites on the Coral Coast of Viti Levu.

Results of a Reconnaissance Survey into the Potential and Possible Development of Wave Energy along the Coral Coast, Fiji

1.0 Introduction

1.1 The Coral Coast, Fiji, was one of the areas included in a South Pacific Marine Resources Energy Programme commissioned by the Marine Resource Department of the University of the South Pacific. This present survey formed part of an overall exercise embracing similar work in Tonga and West Samoa, and the period spent in Fiji covered March 22nd to April 11th.

1.2 Unfortunately the time set aside for the field work on the Coral Coast coincided with the occurrence of the successive cyclones which severely hampered operations, as can be indicated by the fact that the local survey team which had left the site for the Easter holiday period was unable to return owing to blocked roads and destroyed bridge. One result of the situation was that apart from one site, Malevu, the investigation of reservoir sites had to be abandoned. Also the wave measuring programme was considerably reduced.

2.0 Reconnaissance Programme and Objectives

2.1 In the Crown Agents Pre-feasibility Desk Report dated November 1979, eight possible sites were identified as being worthy of an air and ground reconnaissance, these being identified in a west to east sequence as shown on the maps at Appendices A and B, with enlarged scale at Appendix C, and as follows:

Site A	Naindiri
Site B	Naevuevu
Site C	Malevu (West) and Malevu (East)
Site D	Namandu
Site E	Nakavaleka
Site F	Komave

/Site G

Site G Navatulevu
Site H Vunaniu

2.2 The Pre-feasibility Desk Report stated that there were good grounds for mounting a reconnaissance exercise with a view to implementing Stages (I) , (II) and (III) mentioned in the Report; these stages are as set out in sections 13.1, 13.2 and 13.3 of the Report, and are reproduced below;

Stage I Elimination of manifestly impractical sites
Stage II Wave and Tidal measurements of the remaining sites
Stage III Selection of three sites for later further investigation

3.0 Elimination of Manifestly Impractical Sites - Stage (I)

3.1 It was found that the following three sites could be eliminated as being impractical;

Site B Naevuevu
Site E Nakavaleka
Site H Vunaniu

In the cases of both sites B and E, it was decided that the reef formation was too broken and tortuous, presenting unacceptable civil engineering problems. In the case of H, it was found that about 7 kms of access road would be required, and this together with long lengths of bund walls that would be needed, meant that it should be eliminated because of high civil works costs.

3.2 Accordingly, the remaining five sites could be subjected to a more detailed reconnaissance, and are considered in the following sections 4.0 and 5.0.

4.0 Wave and Tidal Measurements of Remaining Sites A, C, D, F and G - Stage II

4.1 General Introduction

It must be pointed out that no equipment was available

/during

the survey for precision measurement and recording of wave heights, and wave lengths. Equipment such as a Wave-rider Buoy is required, which transmits information by a radio signal to a nearby shore based station. However with such expensive equipment, it is necessary that about eighteen months' results are obtained to properly assess the merits of a potential project. An immediate alternative is by beach sighting, and Appendix G contains details of the methodology used by the local Ministry of Mineral Resources survey team. At best, this method provides only a rough indication of wave climate and the cyclone conditions already mentioned in this report prevented any check measurements between the various sites for final grading; it is also possible that the wave climate of the sea south of Fiji could have been affected prior to the actual impact on the island by the cyclones.

4.2 Wave Heights

4.2.1 The assessment of long term wave heights is, at this time, very much a matter of personal judgement together with the consideration of reliable local opinion, for the reasons mentioned in section 4.1 above.

4.2.2 No instrument measurements by the local survey team were made in respect of Naindiri, because of the reasons mentioned, but a visual assessment by field glasses left little doubt that this site A was the most active of the reefs A to F. Access difficulties precluded examination of sites E and H, but as stated in section 3.1, both have been abandoned for other reasons. In view of the near impossibility of carrying out any reliable analysis, Site A has been taken as representing the value 100% for wave activity, and after considering all available evidence, the remaining sites are shown below in ranking order on a percentage basis;

Site A	Naindiri	100%
Site C	Malevu West	80%

Site C	Malevu East	80%
Site D	Namanda	90%
Site F	Komave	70%
Site G	Navutulavu	70%

4.3 Wave Frequency

4.3.1 As in the case of wave heights, the few sites sampled, i.e. site C Malevu, site D Namanda and site F Komave, and the lack of correlation with tidal levels, makes it difficult to draw any reliable inferences. If, however, the results shown at figure I of Appendix G are representative of the Coral Coast as a whole, as would be expected, then it would appear that the majority of wave frequencies be between 6 and 12 seconds, and with the most common frequency being 10 seconds. As wave frequency is closely related to the sea bed approach profile, this may explain the long wave periods shown of 8 to 22 seconds for Site F Komave. Any firm deductions and calculations would have to be deferred until it is possible to use a measuring technique such as the Wave-rider Buoy.

4.3.2 Under the previously mentioned circumstances, it is prudent to interpret such information that is available, very conservatively, and this has been done. Even so, the basis for assessment is very uncertain. In effect the final assessments constitute the intelligent consideration and integration of information derived from many diverse sources such as including personal observations of sea waves, and those of fishermen and others.

4.4 Tidal Variation

4.4.1 The figure shown in Appendix D is taken from the Nautical Almanac 1980, issued by the Fiji Marine Department, and is entitled "Equivalent Tidal Levels". The gauge on which the Monthly Tables are based is installed at Suva Harbour, and is the only one on the island. The figure indicates tide levels at the main points in the tide cycle, the coastal configuration around Suva Harbour is such as to suggest that a funneling effect takes place which would tend to increase the 'flow' tide. It will be noted that the maximum variation between the Highest Astronomical Tide (H.A.T.) and the Mean Sea Level (M.S.L.) is 1.05 metres, and that between the lowest Astronomical Tide (L.A.T.) and the Mean Sea Level (M.S.L) is 1.07 metres, to give a total variation of 1.05 + 1.07 = 2.12 metres. Astronomical tide levels are, however, of infrequent occurence and can be ignored for our purpose. Indeed, so far as power output is concerned, the meaningful range would be the mean of M.H.W.S. and M.H.W.N. (Spring and Neep) tides, and semi early with the mean of M.L.W.S. and M.L.W.N. (Spring and Neep) tides. This results in an average Mean High Water level above Mean Sea Level of $\frac{1.90 + 1.70}{2} + 1.1 = 0.7$ metres

and a corresponding average Mean Low Water level below Mean Sea Level of $1.1 - \frac{0.06 + 0.60}{2} = 0.4$ metres

These values give a total range of 1.10 metres, and is a figure normally expected in 'open sea' location, not an in-shore area around Fiji. A confirmed similar range in Mauritius, for example, is as low as 0.37 metres. Bearing this in mind, and also the possible Suva Harbour effect, one may well be justified in assuming an effective range of say 1.0 metre with Mean High Water 0.65 metres above Mean Sea Level and an average Mean Low Water 0.35 metres below Mean Sea Level.

4.4.2 In considering the implications of tidal range on the power output of a wave energy scheme, two important factors should be considered, namely;

(i) the hydraulic 'head' on the turbo generator plant is determined by the vertical distance between the crest of the wave-impounding wall and sea level. Thus at high water the 'head'

/would

would be reduced by 0.65 metres and at low water increased by 0.35 metres, thereby resulting in an apparent power loss;

(ii) the surface of the sea at any moment is, in effect, the platform upon which the waves develop and break.

The crest level of a wave impounding wall is fixed absolutely in relation to the M.S.L., from which it follows that tidal range alters the effective heights of a wave wall in relation to wall crest level.

As an example, it may be assumed that a 2.0 metre wave, at M.H.W.L., the effective wave height becomes 2.65 metres, whereas at M.L.W.L. it becomes 1.65 metres. However, wave overspill, and therefore energy delivery is usually reckoned as being proportional to the cube of the wave height above M.S.L., so that the comparative energy content of the foregoing case is as 2.65 to 1.65 (proportional), i.e. 2.65^3 to 1.65 = 18.6 to 4.48
i.e. a positive energy gain of 18.6 - 4.48
= 14.12 units of energy

The formation of a wave and its point of breaking is determined by water depth from which it follows that at high tide, waves break closer to the sea wall, thus giving a greatly enhanced overspill. Conversely at low tide, the overspill is less. No figures can be given for this, but it seems clear that the increase would outweigh the decrease. The smoothing out of those diurnal variations is one of the advantages of reservoir storage.

It is obvious that there is a limit to which tidal variations can be harnessed as a bonus; a point could be reached at which there would be no wave overspill at all, at low tide. The exact effects will never be known until a wave energy scheme is in operation, but it is interesting and significant that a wave energy project may also automatically embody tidal energy, without incurring additional capital expenditure.

5.0 Selection of Three Sites for Further Investigation - Stage (III)

5.1 The evaluation under this stage consists of the consideration of the five sites being regarded as possible for development, and the selection of three of these for futher and more detailed investigation. The five thus considered are as follows:

Site A	Naindiri
Site C	Malevu West and Malevu East
Site D	Namanda
Site F	Komave
Site G	Navatulevu

To evaluate these sites, it is necessary to grade each one with the attributes and quantities essential to a successful project, both technically and economically, these being listed below in general sequence of importance;

(a) Suitability of reef structure with respect to good alignment, absence of openings, distance from shoreline.

(b) Wave activity in terms of wave height, frequency and tidal range.

(c) Estimated output of overall project, in terms of kW and kWh.

(d) Flooding of coastal areas including highways, hotels and other properties.

(e) Availability and proximity of potential reservoir sites.

(f) Interference with fishing rights, land tenure etc.

(g) Distance from electricity load centres.

(h) Any perceptible civil engineering/capital cost problems.

/This

This evaluation is therefore essentially a comparative exercise in which each unit embraces a number of the above mentioned attributes and qualities.

5.2 The sites under consideration actually number six of the Site C Malevu is split into the sections namely West and East, and the evaluation is carried out accordingly.

The methodology used is to identify what may be regarded as a comparability grading for each site, and to award points, which, when added up for each site, will provide an order of merit. The maximum number of points awarded for each of the attributes and qualities mentioned under (a) to (h) inclusive (see section 5.1) is 10.

The result of such a process is shown in Appendix E, from which the following order emerges.

Grade I	Site 'A' Naindiri
Grade II	Site 'C' Malevu East
Grade III	Site 'C' Malevu West
Grade IV	Site 'D' Namanda
Grade V	Site 'F' Komave
Grade VI	Site 'G' Navutulavu

5.3 In arriving at the results mentioned in section 5.2 the following comments are pertinent and should be taken into account.

1 Owing to weather conditions and time limitation, direct inspection of reef alignment was impossible either on the lagoon or the seaward side of the reef edges. This work would require to be done at low water neep tides and in a quiet weather period. All deductions have therefore been made from aerial photographs with a scale of 1/5000.

2 For similar reasons to those mentioned above, it was only possible to make a partial site inspection of one reservoir at Site 'C' Malevu, and again, deductions have been based upon maps with a scale of 1/50,000.

3 The results of the shore based instrument measuring process of wave heights are not regarded as reliable and more credence has been placed upon visual assessment by eye and measurements of wave periodicity.

4 As a consequence of para. 3 above, estimates of energy output must be regarded as very approximate although probably of the right order.

5 In the absence of a complete survey of the coastal and timberland levels, the matter of flooding is by visual assessment.

6 An item has been included for any social/ commercial problems arising from interference with fishing rights, land tenure, etc. Arising from discussions with the local lands and surveys Department and with the Native Lands and Fisheries Commission, it is clear that virtually the whole of the Coral Coast is allocated in Freehold Land, Nature Reserves and Crown Land. It is understood that coastal fishing rights were granted to coastal inhabitants under the Act of Cession. It would appear therefore that this would be a common problem except at Naindiri where about 50% of the coastal strip is Crown Land.

/5.4 As

5.4 As will be seen, the final ranking order for the selected three sites is as follows:

First	Site 'A' Naindiri	59 Points
Second	Site 'C' Malevu East	54 Points
Third	Site 'C' Malevu West	43 Points

5.5 Basic data on the selected areas along the Coral Coast is shown in Appendix F, which also includes notes on General Observations of the sites.

6.0 Summary and Conclusions

6.1 The timing of the reconnaissance work unfortunately coincided with the most disastrous floods and local damage, within living memory. The high winds and heavy seas therefore caused freak wave conditions, and the resulting small amount of survey work that was possible has not provided any very reliable indications of wave heights and therefore energy input.

Wave frequency, however, was not so likely to be affected, and did provide some guide to wave conditions.

Most of the wave height measuring was done by eye, using field glasses; this has provided sufficiently close information for the present exercise, although more precise information obtained by instruments would have been very valuable.

6.2 Five of the eight reefs included in the Crown Agents Data Report dated November 1979 were considered worthy of close study, and of these the top four in ranking order are as follows:

1 Site 'A'	Naindiri	59 Points
2 Site 'B'	Malevu East	54 Points
3 Site 'C'	Malevu West	48 Points
4 Site 'D'	Namanda	46 Points

There appears to be good reservoir sites, but the importance of reservoir storage in relation to the total operation capacity would be a matter for the F.E.A. to decide, should the project be implemented.

6.3 As stated in the Crown Agents Desk Report dated November 1979, Stage IV of the investigation assumed that the reconnaissance operation would be able to identify the three most promising sites for proceeding to that stage, which provides for individual detailed study with a view to selecting the preferred site. This site would then receive concentrated investigation to establish technical feasibility and to prepare outline design together with estimated capital costs.

For reasons already given, the ranking order cannot be regarded as absolute, as too much reliance has had to be placed on intuition and improved information.

The three selected sites, and perhaps a fourth site, all require further investigation, most of which would consist of survey work to establish the following:

a Levels of all coastlines where flooding would be likely.
b Detailed survey of all properties within flood lines.
c Preliminary survey of potential reservoir sites.
d More accurate wave measurements and installation of a Wave-rider Buoy.
e Installation of a tide gauge at mid-point of all sites, along the coast.
f Further discussions with Government regarding Fishing Rights, Land Tenure etc.

It is estimated that to carry out the above survey work adequately, would require the services of a competent supervisor and survey team for a period of two or three months; this could no doubt be done most economically by local government staff.

6.4 The general deficiency in the reconnaissance results could be made up by further work under stage III of the programme, or by linking it directly with stage IV. This stage IV would normally be the point at which consultants would be brought in, and it would therefore be very much cheaper if this work, which is virtually confined to surveying, could be done by a Fiji Government Team under the direction of a competent supervisor. The work on the selected sites would be mainly as follows:

a Further and more extensive wave tests by one or more methods shown at Appendix G.

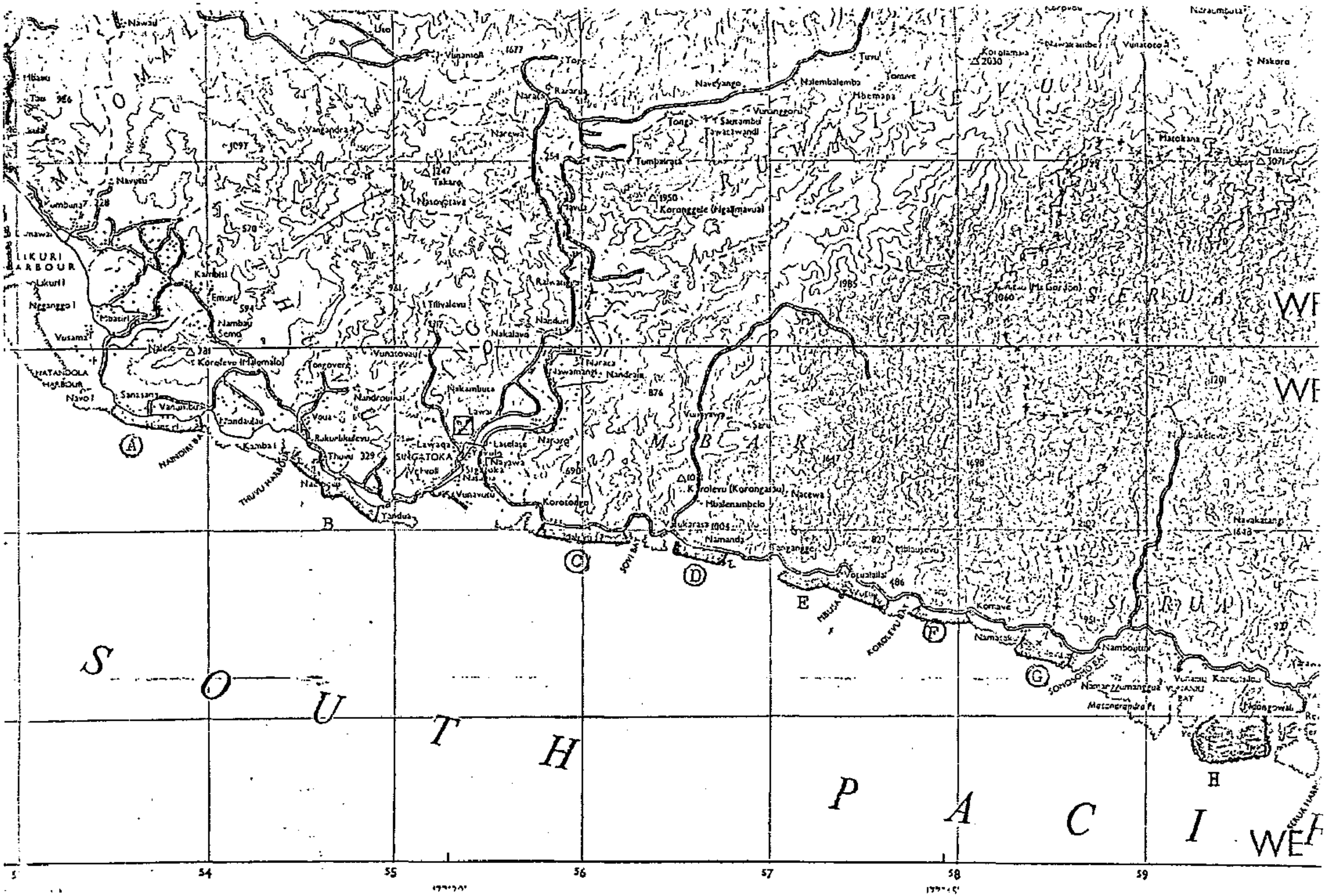
b Setting up a tide gauge midway along the Coral Coast and logging daily readings for a complete month.

c Survey of reservoir facilities with a view to identifying a suitable dam site, and extent of storage at various levels.

d Establishment of flood lines along the coast lines of selected sites, allowing 4 metres clear from low water.

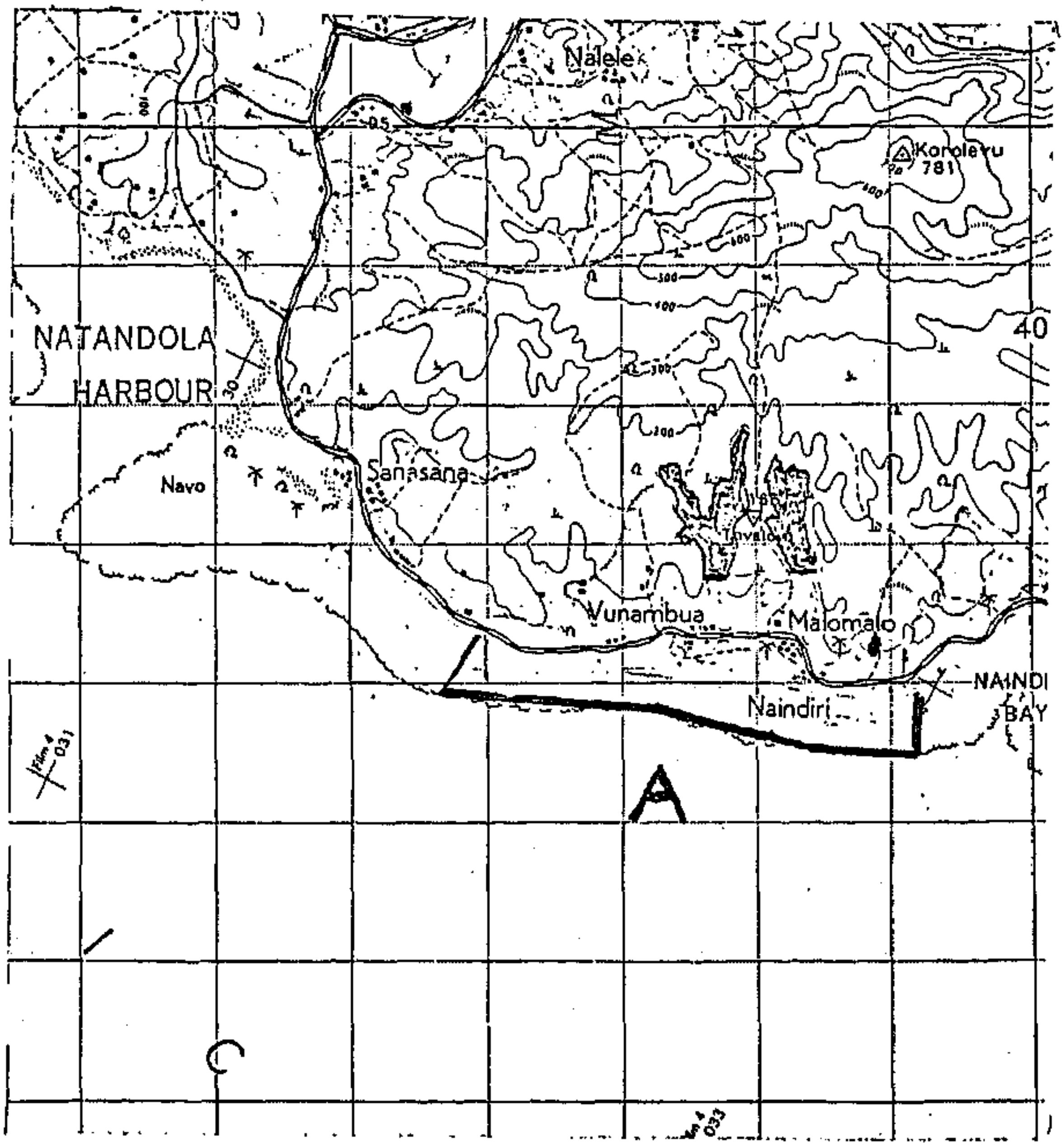
e Survey of roads, property and usable land that may be affected.

APPENDIX A OS Map X552 Fiji (1:250,000) showing potential wave-energy sites along Coral Coast area.

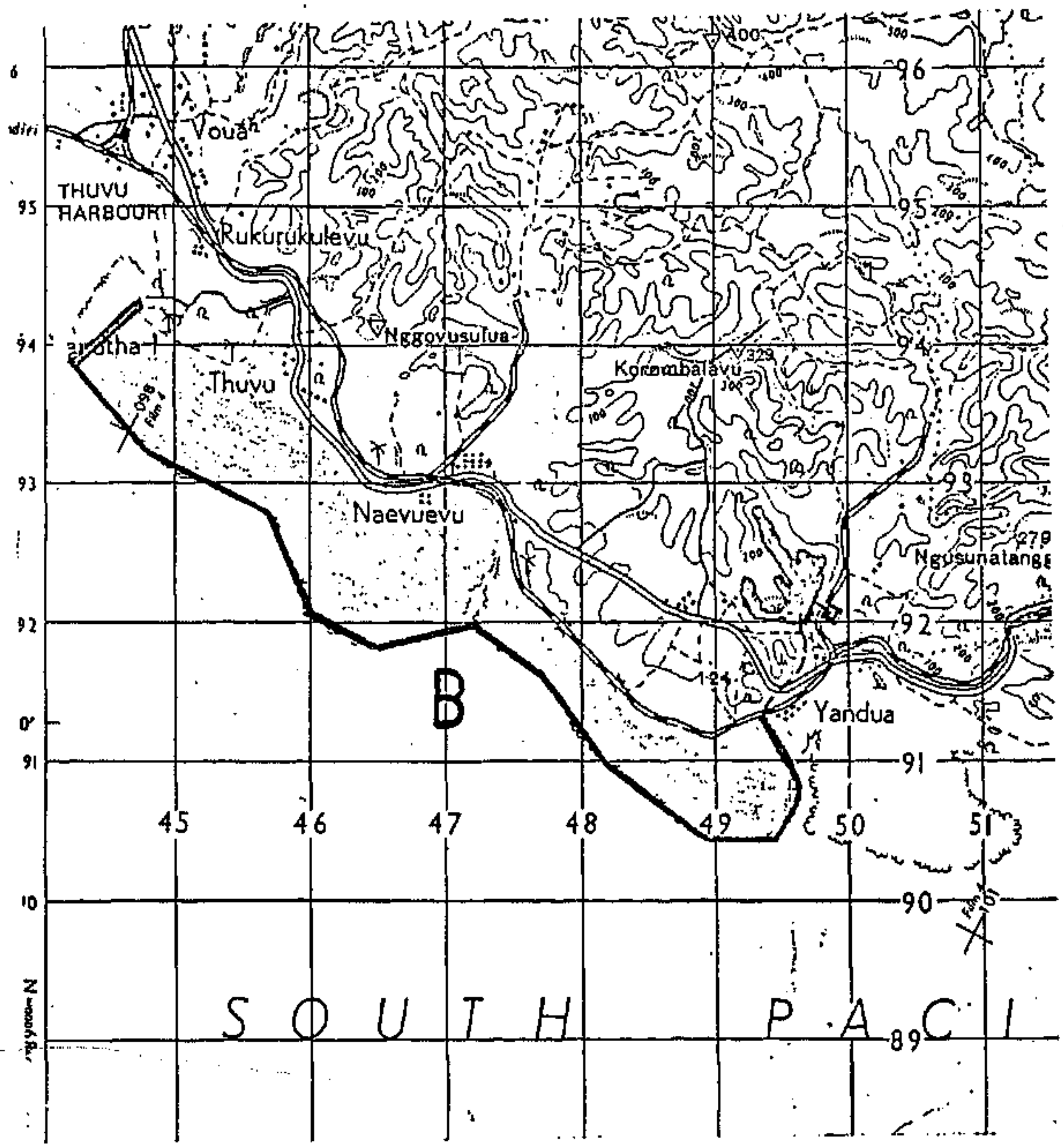

SOUTH PACIFIC
SIGATOKA
NANDIRI BAY
THUVU HARBOUR
SOVI BAY
KOROLEVU BAY
NATANDOLA HARBOUR
Korolevu (Korongatsu)
Korolevu (Halomalo)
Koronggele (Ngaliimavua)
Namboutini
Komave
Namanda
Nakambuta
Vunatovau
Nandroumai
Vunavutu
Tonggovere
Nakalavo
Tilivalevu
Takaro
Tumpairata
Naveyango
Navutu
A
B
C
D
E
F
G
H
54
55
56
57
58
59

APPENDIX B OS Maps Sheets 15, 16, 17 (Fiji) showing above information on 1:50,000 reduced scale.

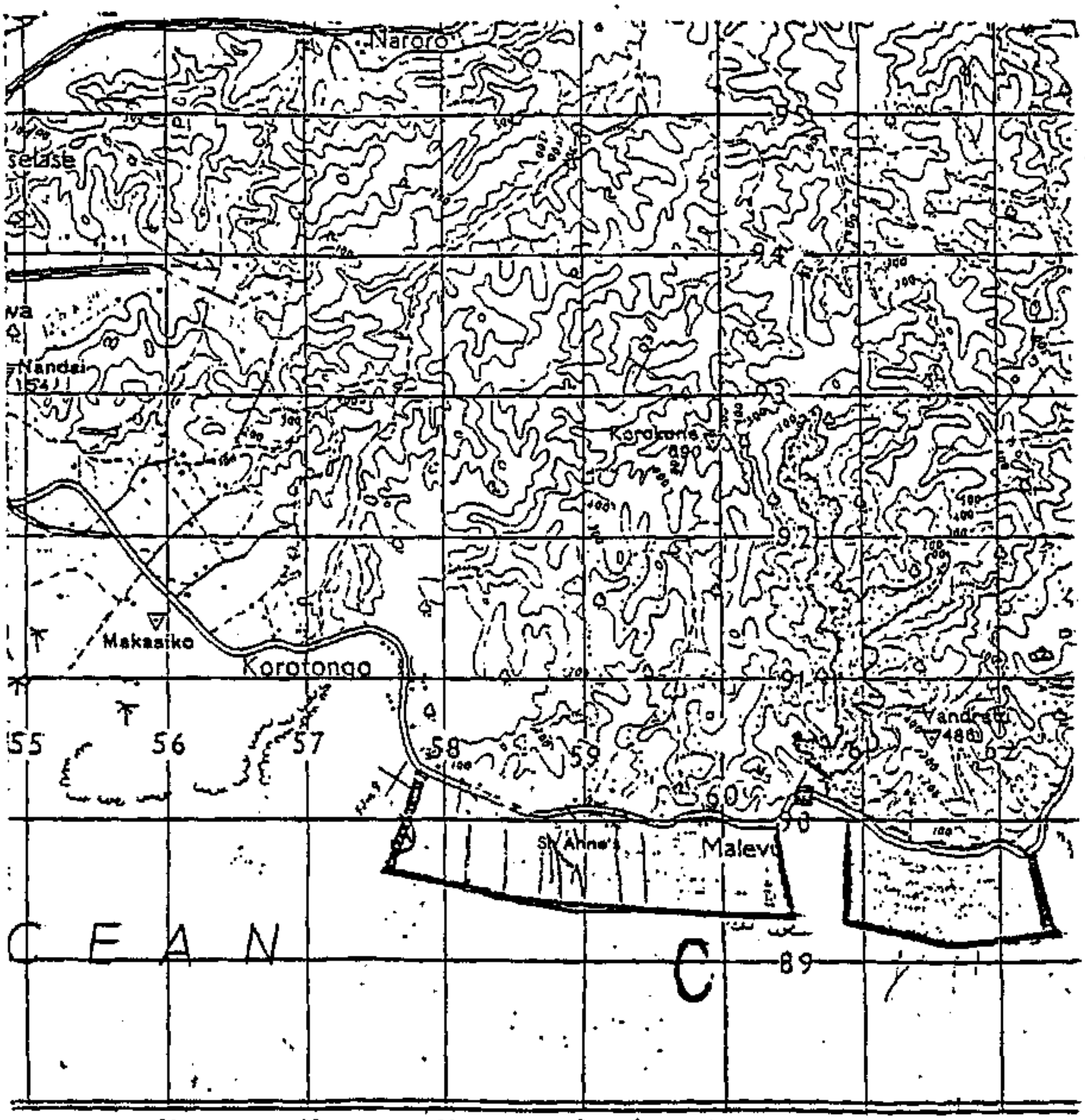
APPENDIX C Extracts from Map Sheets 15, 16 and 17 (Fiji) showing Sites A, B, C, D, E, F, G and H, to an actual scale of 1:50,000.



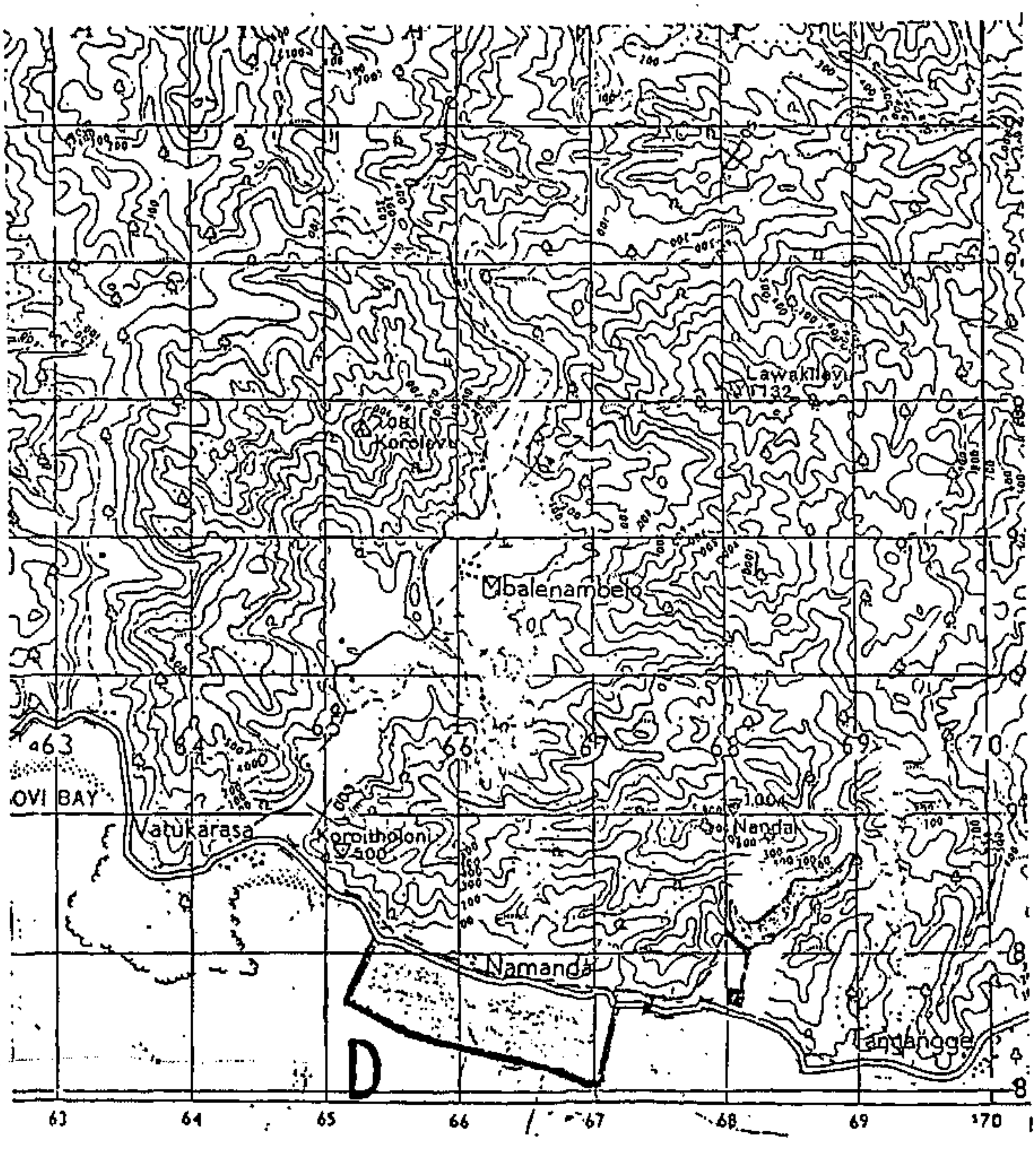
SITE A NAINDIRU



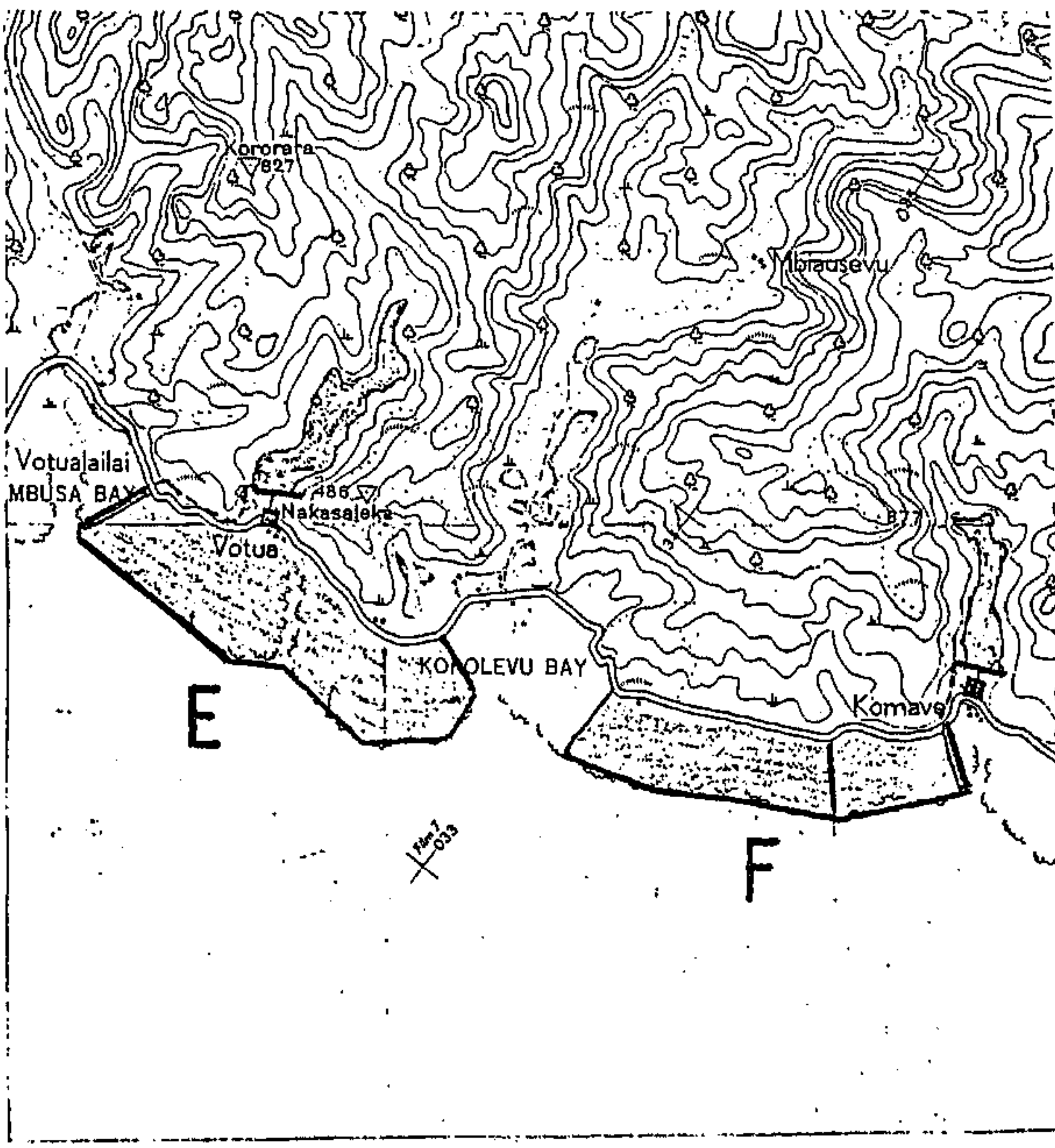
SITE B NAEVUEVU



SITE C
MALEVU (WEST)
MALEVU (EAST)

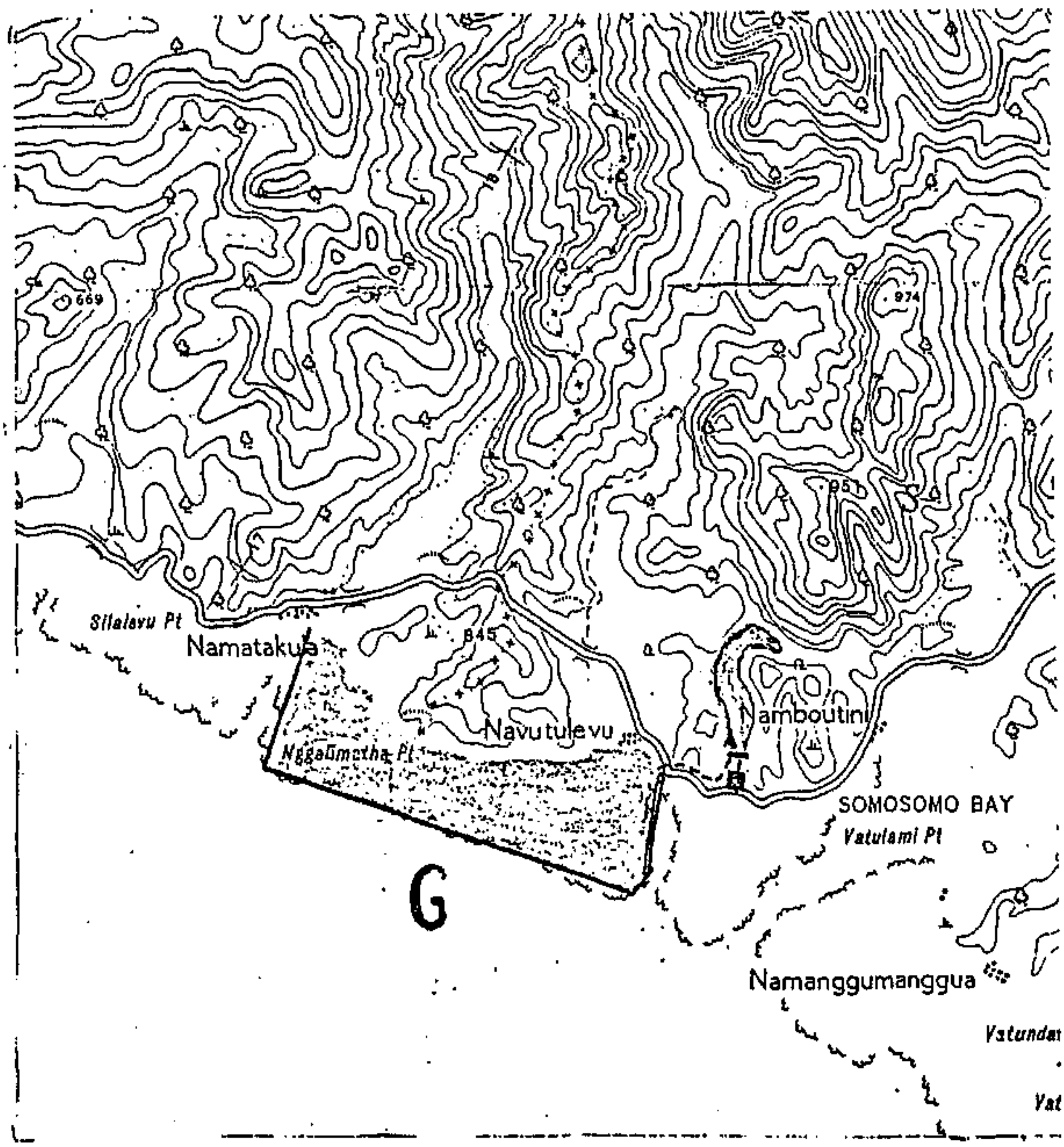


SITE D NAMANDA

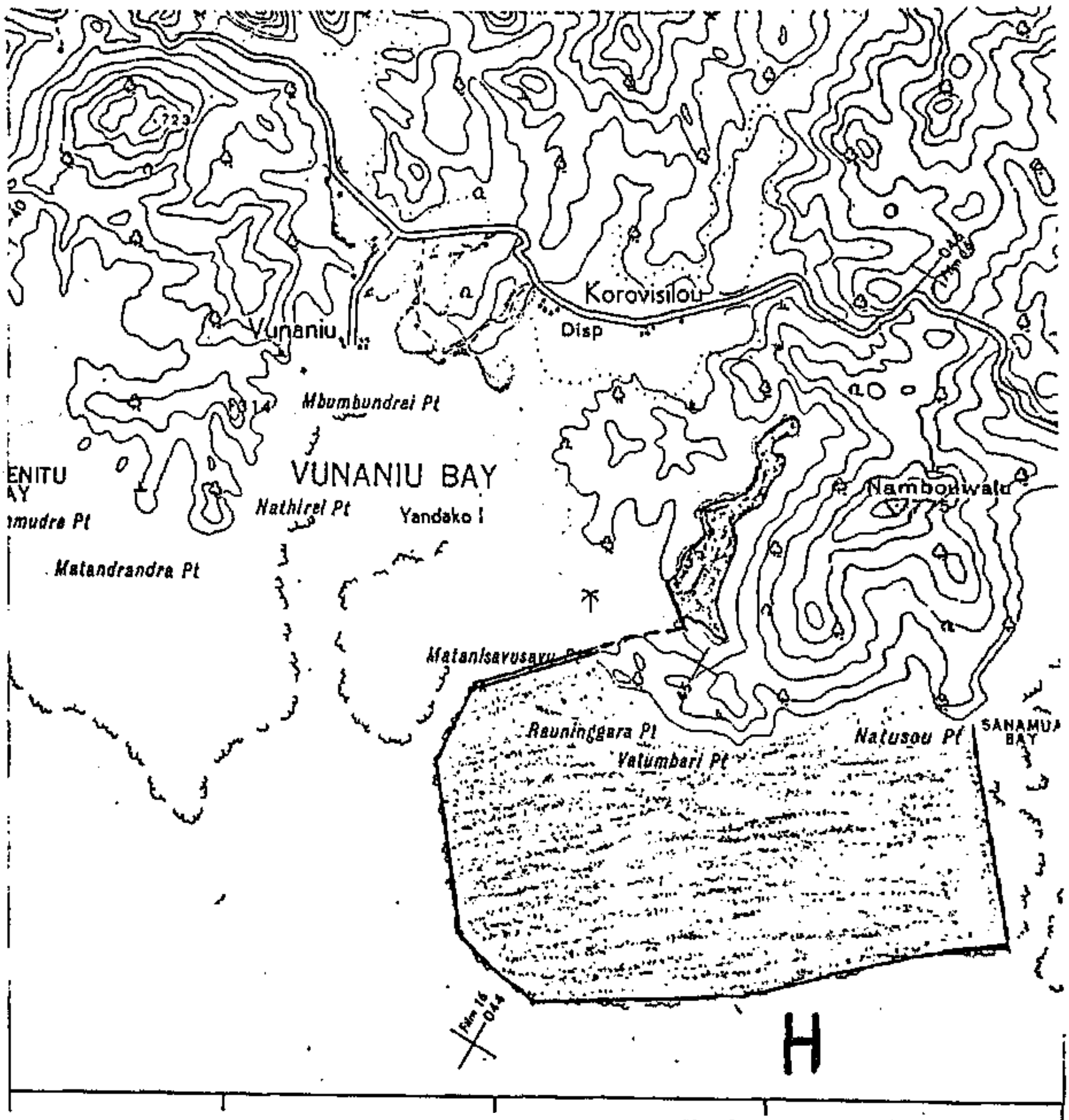


SITE E NAKASALEKA

SITE F KOMAVE



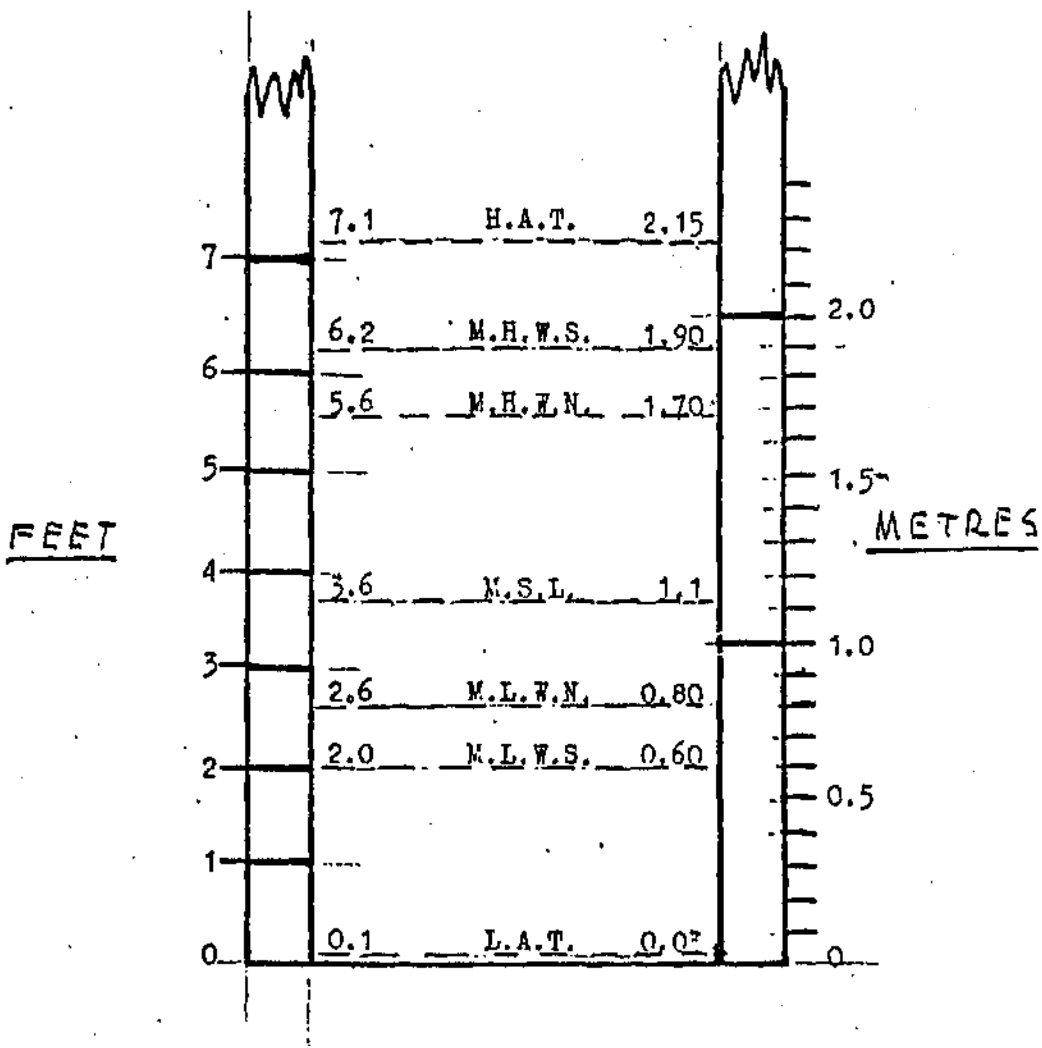
SITE G NAVUTUIEVU



SITE H VUNANIU

APPENDIX D Equivalent Tidal Levels extracted from the Nautical Almanac 1980, issued by the Fiji Marine Department.

Equivalent Tidal Levels



1 Foot = 0.3048 Metres
1 Metre = 3.2808 Feet

KEY TO ABBREVIATIONS -

H.A.T.	-	Highest Astronomical Tide.
L.A.T.	-	Lowest " "
M.H.W.S.	-	Mean High Water Springs.
M.L.W.S.	-	" Low " "
M.H.W.N.	-	" High " Neeps.
M.L.W.N.	-	" Low " "
M.S.L.	-	Mean Sea Level.

APPENDIX E Assessment and Ranking of Potential Sites, Coral Coast.

ASSESSMENT AND RA... NG OF POTENTIAL SITES CORAL (EAST *'A', 'C'(WEST), 'C'(EAST), 'D', 'F', 'G

(see footnotes)

Site Ref.	Names accorded to potential sites	ITEMS SELECTED FOR GRADING								TOTALS PER SITE	OVERALL GRADING FOR EACH SITE
		Structure of Reef	Wave activity	Power output (Note 1	Coastal flooding	Reservoir facil- -ities	Civil (ii) Enginning problems	Proximity to load centres (iii)	Fishing Rights, Land (iv)		
(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(xi)	(xii)	(xiii)
A	NAINDIRI	7	10	10	7	10	7	8	-	59	I
C(W)	MALEVU (WEST)	8	8	5	2	9	8	8	-	48	III
C(E)	MALEVU (EAST)	9	8	5	7	9	8	8	-	54	II
D	NAMANDA	8	9	5	6	4	7	7	-	46	IV
F	KOMAVE	8	7	3	5	7	5	6	-	41	V
G	NAVATULEVU	6	7	4	9	8		5	-	39	VI

Notes

(i) Based on on an estimated 7KW per metre wave front and a Load Factor of 70% over the year

(ii) This includes for expenditure on access roads

(iii) This assessment is based on the relative line losses. It is understood that the F.E.A. will will be constructing a 33KV coastal line interconnecting Suva and Nandi.

(iv) No assessment of these matters has yet been made but if problems exist they would appear to be common to all sites but least of all at Naindiri.

APPENDIX F Basic Data on the selected areas along the Coral Coast, including notes on General Observations.

BASIC DATA ON SELECTED COASTAL AREAS ALONG CORAL COAST

SITE LETTER	SITE DESCRIPTION	LAGOON DATA LENGTH	WIDTH	AREA	WAVE HEIGHTS	kW OUTPUT	kWh OUT @ 7 L.F
A	NAINDIRI (OR VANAMBUA)	4.5km	380m	1.71M	1.75 - 2.5	22.5	138 GWh
C	MALEVU (EAST)	1.7	500	0.85	1.5 - 2.0	8.5	52
C	MALEVU (WEST)	3.5	500	1.75	1.5 - 2.0	17.5	107
D	NAMANDA	2.4	500	1.20	1.75 - 2.0	12	73
F	KOMAVE (OR KOROLEVU)	2.7	450	1.21	1.25 - 1.75	13.5	83
;	NAVUTULAVU	3.0	700	2.10	1.5 - 2.0	15	92

GENERAL OBSERVATION (See Note 1)

; A (i) Relatively straight reef edge with only slight curves and one only lagoon exit openings. It is believed that all reefs reach back to the shoreline (See Note 3)

(ii) Very strong and constant wave action (See Note 2)

(iii) Shoreline rises quite steeply at eastern end probably giving the required 4 metre freeboard above M.S.L. - western end not inspected.

(iv) At 100m contour it appears that two sizeable reservoir sites could be developed.

(v) Secondary road access exists along whole length of site connecti with the primary Suva-Singatoka-Nandi roads. Extensive system of Sugar Estate narrow gauge railways connects site with Nandi and Natandula Barbour some 2kms from site. Sand and aggregates available within short distances, and cement works at Nandi.

(vi) This site is nearest to the west coast load centres.

;e C (i) Relatively straight reef edge with no lagoon openings.

(ii) Good and constant wave activity.

(iii) Low shoreline providing insufficient freeboard; considerable problems may exist as this is a popular holiday coast with many hotels.

(iv) At 100m contour it would appear that a very sizeable reservoir would be available.

(v) Direct access to Suva-Nandi primary road. The Malevu (West) reef is separated from the Malevu (East) reef by wide gap opposite the Waiweswes Riv in the valley of which the above reservoir site exists.

---

te C (i) Relatively straight reef edge with only slight curves and one only reef opening.

(ii) Good and constant wave activity.

(iii) Low shoreline providing insufficient freeboard; problems involving some hotels and other properties - also primary roadway.

(iv) The potential reservoir site for Malevu (West) would also serve for Malevu (East).

(v) Direct access to Suva-Mandi primary road.

---

te D (i) Longest reef but only western section of 2.4kms considered suitable. This has a good straight reef edge with only one slight concave curve and no lagoon openings.

(ii) Good moderate wave activity.

(iii) Low shorelines involving road. No hotels or other properties greatly affected but Namanda Village would present a problem.

(iv) There is an apparent and modes reservoir site within 1 km.

(v) Direct access to the Suva-Nandi primary road.

---

te F (i) Relatively straight reef edge with a long slightly concave section in the centre. There is no reef opening.

(ii) There is a rising shoreline over most of lagoon but the closure of several low-level sections may be necessary at several points. In particular the foreshore of a high class hotel may be affected.

(iii) Good and constant wave activity.

(iv) There is an apparently good reservoir site on the Naithomobothombo Riv. about 1 km distant.

(v) Direct road access along full length of lagoon on to Suva-Nandi primary road.

G (i) The reef edge is relatively straight and uniform but has a fairly prominent convex curve about the centre.

(ii) Coastline not inspected as no proper land access exists but according to maps and aerial photos there are no observable buildings or developments and no serious flooding problems should exist.

(iii) No inspection made as no road access available for coastal approach and weather conditions ruled out inspection from the sea.

(iv) There appears to be a modest reservoir site about 1 km from lagoon.

(v) The nearest access points are the villages of Namatukua and Navutevu at the two extremities of the lagoon and which connect with the Suva-Nandi primary road but 3/4 kms of secondary road would require to be constructed to provide adequate construction access to this site.

Notes

(1) All reef observations are based on examination of greatly enlarged low level aerial photographs.

(2) Naindiri reef is taken as the most active and for comparative purposes is therefore ranked as 100%.

(3) It is believed that all reefs stretch from wave-plunge line to beach and have a level flat surface over which vehicles with large rubber tyres could travel: also that all lagoons virtually empty between tides. The lagoon areas are therefore 'dead' both as regards coral and fish.

(4) Site C (West) spans one of the most popular beach resort areas in Fiji and besides many private houses includes the following hotels - Tubukula, Corotogu Club, Reef Hotel, Sea Loung, Waratah, Wakaviti, Crows Nest.

APPENDIX G. Document produced by Mr A S P Green, Senior Geologist, of Wave Heights and Periodicity of typical sites on the Coral Coast of Viti Levu.

BP 20/12

WAVE HEIGHT AND PERIODICITY

MEASUREMENTS ON THE CORAL COAST OF VITI LEVU

A S P GREEN

APRIL 1980

INTRODUCTION

A passive wave energy scheme has been suggested as a suitable means of generating electricity in Fiji. The method is discribed in several other places so will not be gone into here. (Bott, Hailey and Hunter 1978, New Civil Engineer 1979, Development Services 1979).

The purpose of this report is to relate the results of attempts to measure the wave heights and periodicity at several promising locations on the coral coast. Some measurements were carried out in December 1979. (A Green BP 20/9). The conclusion of the report was that with the equipment available, a wild T16 theodolite, staff and measuring tape, it was not possible, to make measurements to the required accuracy. A Crown Agents' consultant on this project, Mr N Walton-Bott, commented on this report and in addition requested that further attempts be made prior to, and during, his visit to Fiji (BX5 20:2:80).

To carry out this second survey it was decided to approach the acting Principal Survey of the Control Section, Ministry of Lands, Mr A Kumar. He agreed to help and released Mr V Seniloli and their Wild T2 theodolite. This is more accurate that M.R.D.'s T16. The measurements were all taken between the 27 February and 3 April.

METHOD

Wave Height Measurements

The method employed for these measurements was very similar to that used in December 1979, with some minor modification.

The distance from the theodolite to the reefs was taken from the aerial photographs. At three locations accurate measurement were taken by sending someone out on the reef and using a distomat. These were compared with the data taken from the aerial photograph. An error of no more than 5% was observed.

/The

The wave heights were determined by measuring the zenith angle of the wave crest as it broke on the reef. Two types of measurement were taken; the maximum wave and the average wave. The maximum wave was the average of the five biggest waves observed in a 10 minute period. The average wave was the average of 5 medium sized waves observed in the same period.

The final measurements taken were to a datum to which the height of the wave could be referred to. These proved the most problematic. Three different datums were used. The first two involved measuring the zenith angles to the horizon and to the front of the reef. The third, and ultimately most successful, uwas to use the theodolite as a level and site to a staff placed at the water's edge. All these measurements were designed to give a value for the height of the theodolite above some meaningful datum, however all had errors in them. This will be discussed in the next section.

At each site location two or three measurements were taken. In order to be able to locate the same points on the reef the following procedure was adopted. The theodolite site was always marked either by a large boulder, markings on a rock or a post in the sand. The theodolite was levelled and sited on an easily recognisable point along the beach, often a coconut tree. The observation points were then taken as so many degrees from this point. Usually 60°, 90° and 120°.

All the calculations involved are shown in appendix I.

<u>Periodicity Measurements</u>
These were taken by an observer with binoculars, calling out each time a wave crashed on the reef, and a recorder with a stop-watch noting the time. The observer would also make the rather subjective comment as to whether the wave was large, medium or small. Waves breaking on the reef straight out from the observation point on the beach were counted.

DISCUSSION

Wave Height Measurements

The first measurements of wave heights were carried out using the horizon and reef as a datum. For measurements to different parts of the reef from one shore station, the height of the theodolite above the datum should be the same. It is appreciated that the height of the reef may change along its length but for a short section of reef it was assumed that this would be small. However differences of as much as 1.5 metres and 2 metres were noted when observing the horizon and reef respectively. No satisfactory explanation for the errors could be advanced. The surveyors felt their measurements should have easily been able to produce a smaller error. However if these values were accepted and wave heights calculated, on some occasions negative values were obtained.

It was then decided to relate the theodolite height to the water level in the lagoon. This could easily be achieved to an accuracy of 1cm. The only doubt here is whether the water level in the lagoon is equivalent to sea level outside. At low tide it is known that impounding effects cause it to be higher. So measurements were taken at high tide when possible. Using this datum acceptable values for the wave heights are obtained.

It was hoped to be able to take measurements at all the sites using the new datum and thus be able to adjust all the old data. Unfortunately heavy rain made measurements extremely difficult. This same rain has now put the road out of action and it will not be possible to relocate the sites for some time.

Results we have so far for maximum and average waves are listed in Tables 1 and 2. It is difficult to come to any meaningful conclusion from the data. For instance, Namada seems to be a promising site with many recordings over 1.8 metres. However one soon realises that maximum reading of 2.05 metres made at site 1 was made at the same time as the lowest reading at site 3 only a few hundred metres along the coast.

The mean and standard deviation of the results on table 1 are 1.18 and 0.54. For table 2, the average wave, they are: 0.68 and 0.46. This is for all sites. It is not realistic to be able to compare different sites on the basis of these few measurements, many of which were done at different times under different conditions.

Wave Periodicity Measurements

The results in fig. 1 show that waves of period 8 to 12 seconds are most common. Where peaks in the graphs occur at 16, 18 or 22 seconds it is felt that these are likely to be caused by low waves that were not observed, and thus the time actually refers to two wave periods.

Fig. 2 shown the percentage of waves classified as small, medium or large in a five minute observation spell. The Namanda and Malevu data were observed by V Seniloli who also took the wave height measurements. The large and medium approximate to his maximum and average in a very rough sense. The Komave measurements were the first taken and are almost certainly too heavily weighted towards the small. These results show then that approximately 1/3 of the waves are small, medium or large. This leads us to the conclusion that the maximum wave heights refer to the "Significant Waves". That is, the height of the largest one third.

CONCLUSION

The conclusion differs little from that of Green 1980 BP 20/9.

"...... waves of heights from 1-2 metres regularly break acrosss the fringing reef on south-west Viti Levu".

A little more can be added in that we can say that about 1/3 of all waves exceed 1 metre and the predominant wave period lies between 8 and 12 seconds.

Further work needs to be performed with automatic recording equipment so that spectral analysis can be performed on the data by computers.

/REFERENCES

REFERENCES

Bott, Hailey and Hunter	1978	The Mauritius wave energy project research results and proposed outline design. Int. Symp. on Wave and Tidal Energy. September 22-29 1978 University of Kent England.
Development Services Crown Agents - London	1979	The Government of Fiji Seawave Energy Development. Vol. 1 and 2. Pre-feasibility Desk Report to the Government of Fiji.
Green A S P	1980	Wave height measurements on the south-west coast of Viti Levu. M R D Report BP 20/9.

A S P Green

Senior Geologist

1/5/80

Maximum Wave Heights in Metres

DATE	THEODOLITE SITES											
	N A M A N D A			K O M A V E			M A L E V U			N A V U T U L E V U		
	1	2	3	1	2	3	1	2	3	1	2	3
5:3	-	-	-	-	0.65	-	-	-	-	-	-	-
7:3	-	-	-	0.85	-	0.78	-	-	-	-	-	-
13:3	1.86	0.68	0.10	-	-	-	-	-	-	-	-	-
20:3	2.05	1.69	0.03	1.56	1.47	1.61	-	-	-	-	-	-
27:3	-	-	-	0.98	1.77	1.25	-	-	-	-	-	-
28:3	1.92	1.92	1.30	-	-	-	-	1.08	1.06	-	-	-
31:3	-	-	-	1.39	0.79	1.54	0.67	-	0.60	0.73	0.99	
1:4	1.84	1.10	-	-	-	-	-	-	-	-	-	-

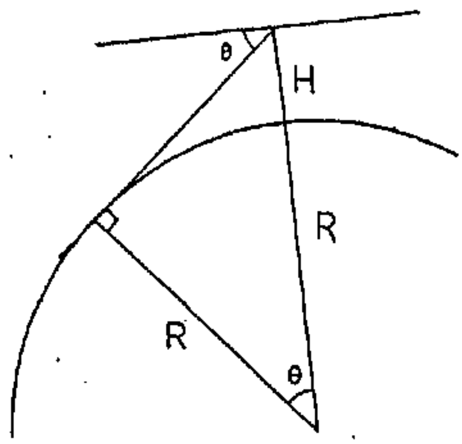
Average Wave Heights in Metres

DATE	N A M A N D A			K O M A V E			M A L E V U			N A V U T U L E V		
	1	2	3	1	2	3	1	2	3	1	2	3
5:3	-	-	-	-	0.17	-	-	-	-	-	-	
7:3	-	-	-	0.20	-	0.48	-	-	-	-	-	
13:3	1.42	0.35	0.00	-	-	-	-	-	-	-	-	
20:3	1.52	0.60	0.27	0.74	1.01	1.02	-	-	-	-	-	
27:3	-	-	-	0.43	0.69	0.79	-	-	-	--	-	
28:3	1.37	1.06	0.25	-	-	-	-	0.71	0.53	-	-	
31:3	-	-	-	0.70	0.50	1.366	-	-	-	0.44	0.61	
1:4	1:44	0:89	-	-	-	-	0.34	-	0.26	-	-	

APPENDIX I

Three methods of measuring the height of the theodolite above datum

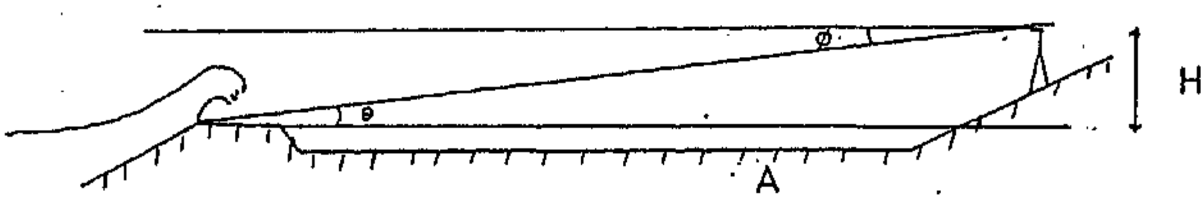
(1) Siting to the horizon



$$\cos\theta = \frac{R}{R+H}$$

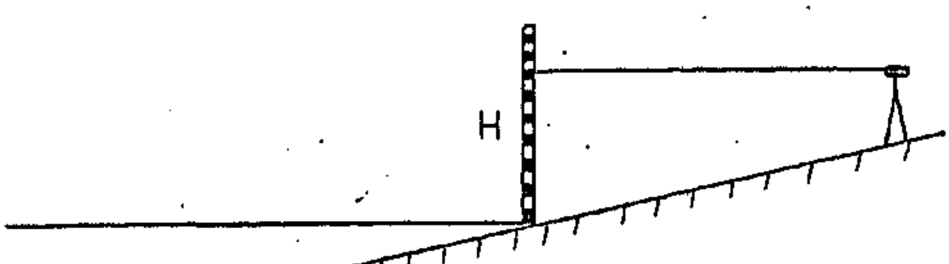
$$H = R\left(\frac{1}{\cos\theta} - 1\right)$$

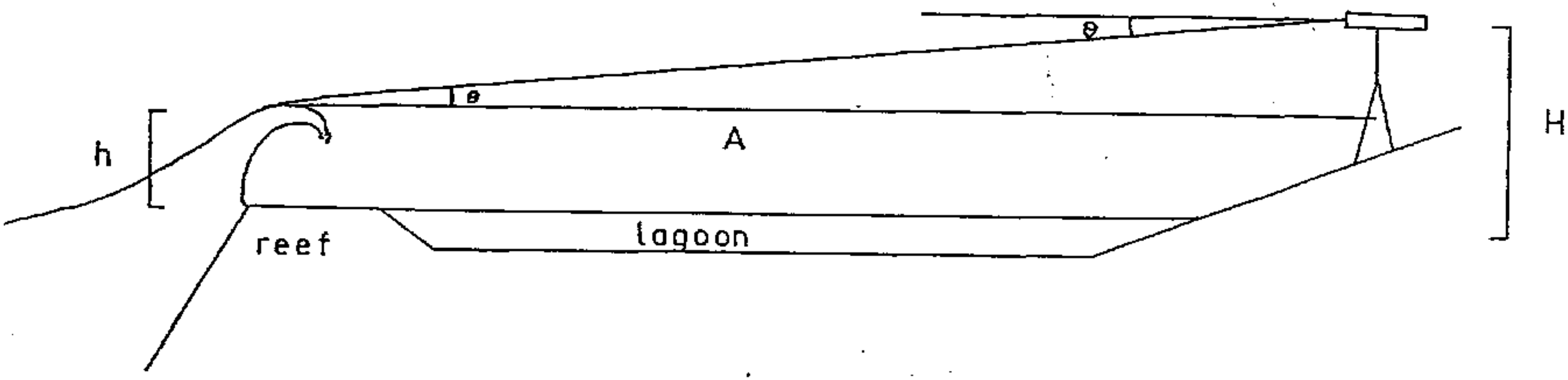
(2) Siting to the reef.



$$H = A \times \tan Ø$$

(3) Levelling to the water level in the lagoon.





$$\tan\theta = \frac{H - h}{A}$$

$$\underline{\underline{h = H - A \times \tan\theta}}$$

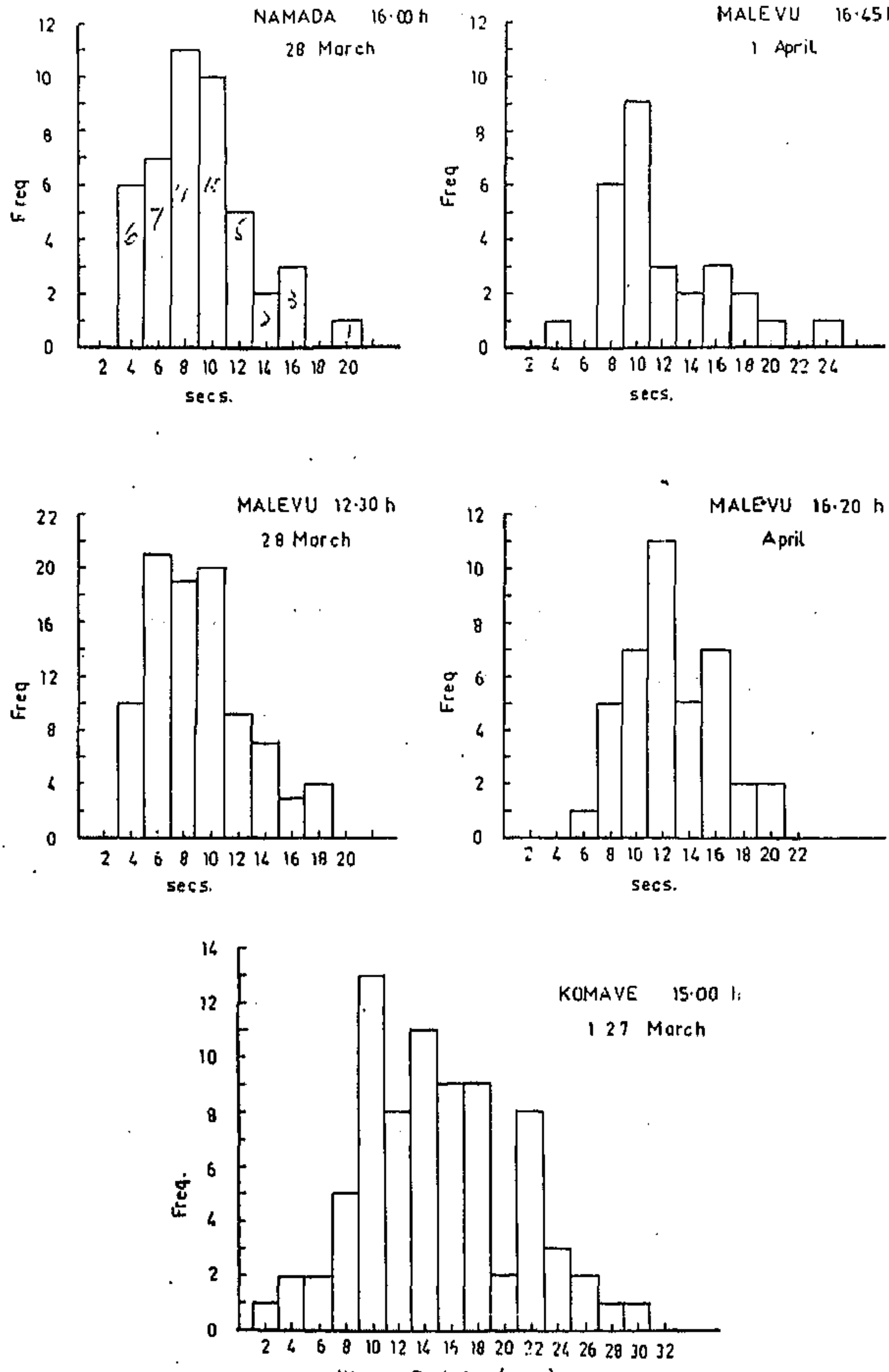


Fig 1 WAVE PERIODICITY MEASUREMENTS

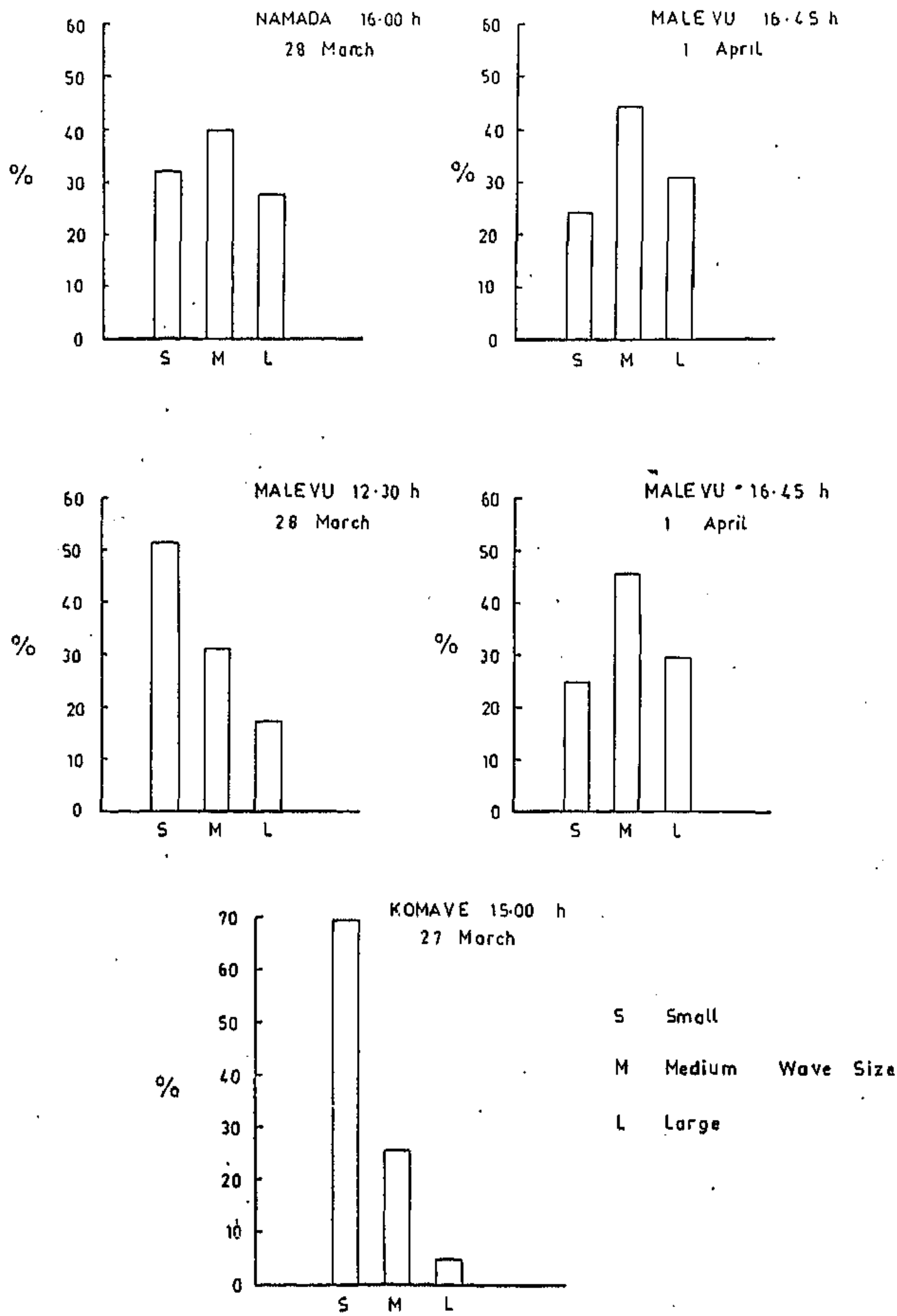
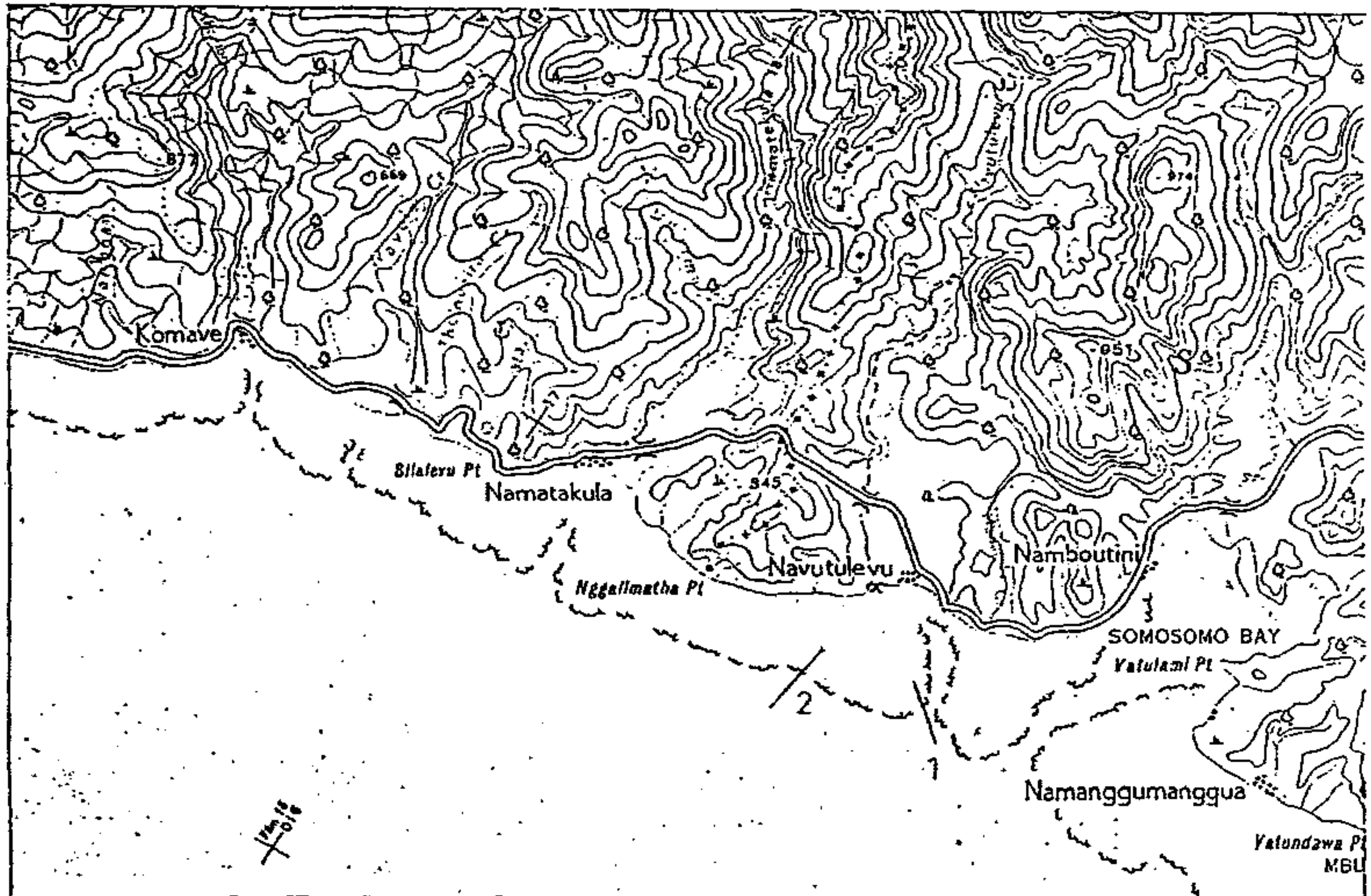


Fig 2 WAVE HEIGHT MEASUREMENTS



× Observation site

1 Site No.

Fig 3 LOCATION OF MEASUREMENTS AT NAVUTULEVU

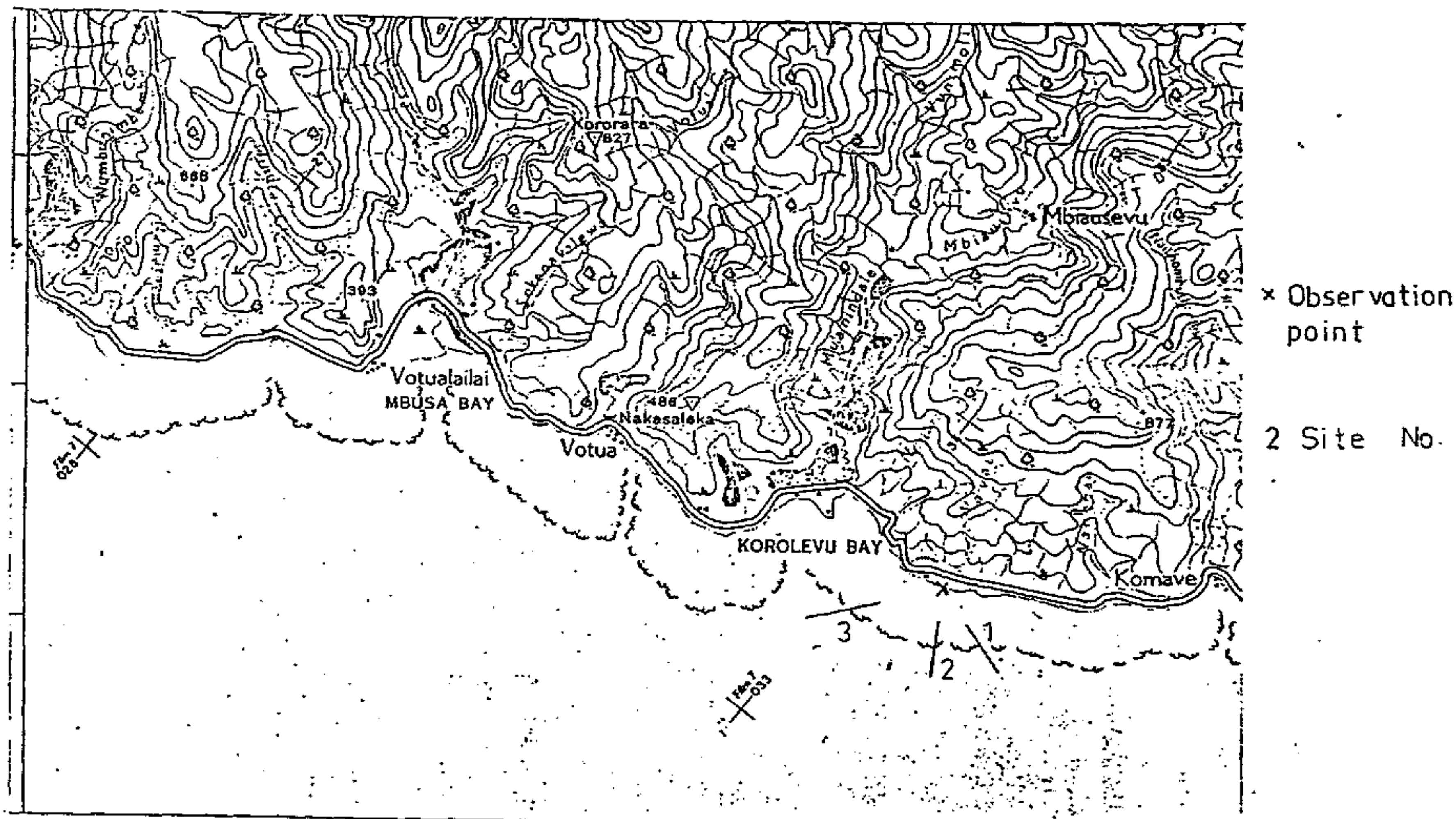


Fig 4 LOCATION OF MEASUREMENTS AT KOMAVE

Observation site

Site No.

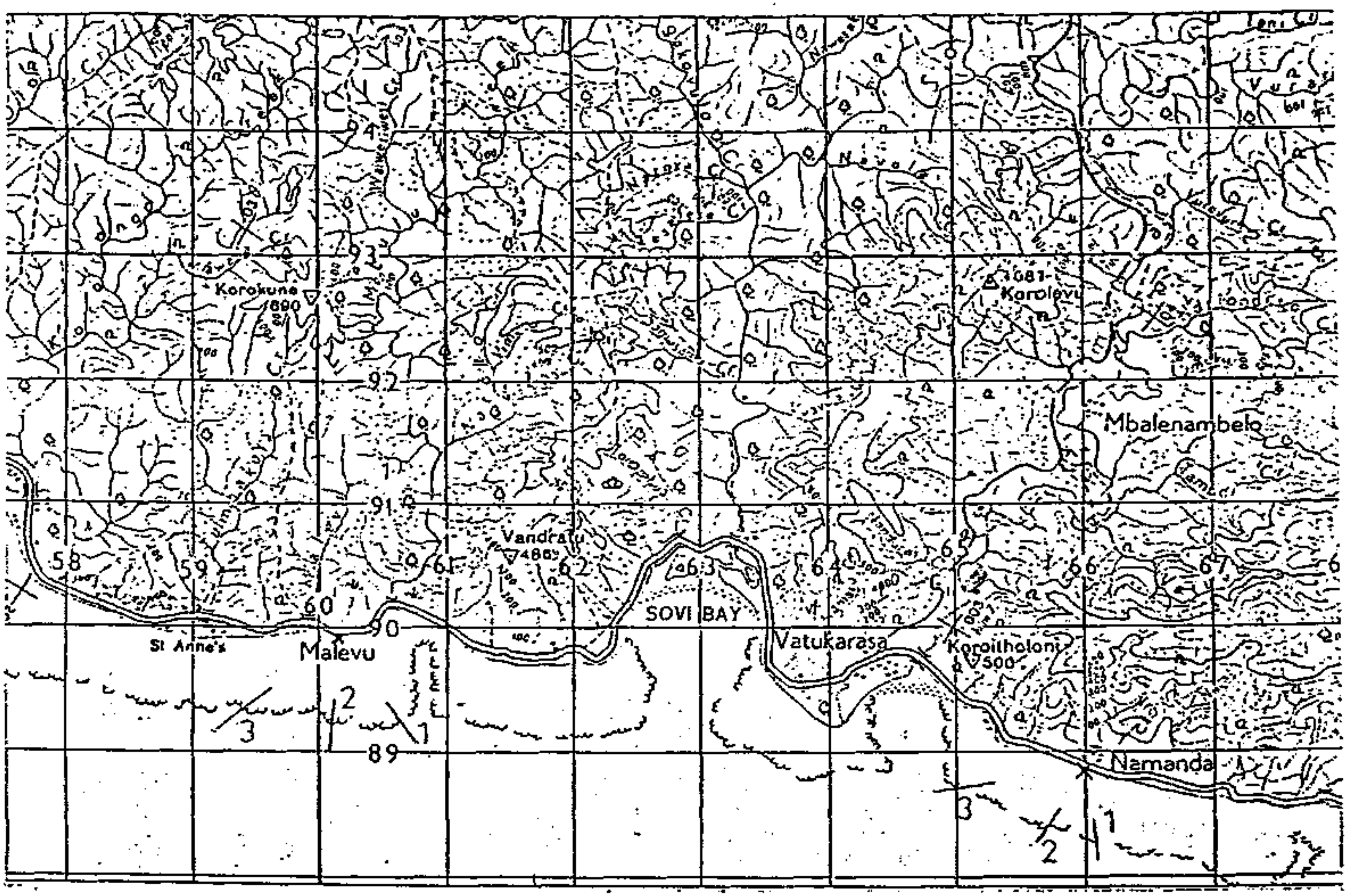


Fig 5 LOCATION OF MEASUREMENTS AT NAMADA & MALEVU