GROUNDWATER RESOURCES OF NGALO (LOMLOM) ISLAND REEF ISLANDS, TEMOTU PROVINCE

by

R. J. CURRY

S. 123

MEMORANDUM

TO: Provincial Secretary,
Temotu Province.

Attn: Mr R Natowan

NO: Glld 1
DATE: 2/7/85
Tel. No.

Your ref: c.c. Permanent Secretary/MEP
Attn: Messrs Kitchener & Patterson, PDU.

c.c. Permanent Secretary/MHA&PG
c.c. High Commissioner, Australian High Commission
Attn: Mr G Brooke.

GROUNDWATER RESOURCES OF NGALO ISLAND

As promised,please find attached a copy of the report entitled 'Groundwater Resources of Ngalo (Lomlom) Island, Reef Islands, Temotu Province,as prepared by the undersigned.

The report details the study carried out on Ngalo Island from 5-9 June and considers the groundwater resource in relation to your proposed Water Supply Scheme requirements.

As can be seen from the report,sufficient groundwater exists on Ngalo Island to meet your Scheme requirements,although changes to the source of water for some villages are recommended.

Potential groundwater pollution problems have been identified and remedial or alternative actions are also outlined in the recommendations.

As mentioned in the acknowledgements,I would like to convey my thanks to the members of your Province involved in ensuring the smooth and well organised running of the entire trip.

Trusting this report now allows you proceed with the design of the scheme.

(R J CURRY)
Snr Water Resources Officer,
for Permanent Secretary/MNR
rr

att.

GROUNDWATER RESOURCES OF
NGALO (LOMLOM) ISLAND
REEF ISLANDS, TEMOTU PROVINCE

by

R J CURRY

Water Resources Section

Geology Division

Ministry of Natural Resources

GROUNDWATER RESOURCES

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June 1985

Distribution: Provincial Secretary, Temotu Province
Permanent Secretary, Ministry of Economic Planning
Permanent Secretary, Ministry of Health & Medical Services
High Commissioner, Australian High Commission
High Commissioner, New Zealand High Commission

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R J Curry *

1. INTRODUCTION:

The Reef Islands are a small group of low-lying reefs and terraces located 48km north-east of Nendo, the main island of the Santa Cruz group. (Fig.1) The main islands are Ngalo (Lomlom), Ngawa and Fenualoa (Fig 2), the remaining islands consisting of smaller, outlying islands. In 1983 the total population for the Reef Islands was estimated at 4200 persons.

As with the other islands in the Reefs, Ngalo Island (14.02km^2) is devoid of any significant topography and so lacks natural surface water resources and scope for surface reservoir development (Fig 3b). Consequently water supplies are drawn by hand from several natural deep groundwater wells and a few shallow hand dug wells which are very sparsely located around the Island. More recently some villages have turned to roof catchment supplies for drinking water particularly where groundwater salinity is high, however these are both expensive and limited in capacity. As with many other islands Ngalo is experiencing an increase in population and a growing demand for water.

As part of the 1984 Provincial Rolling Plan, the Temotu Provincial Executive approved in principle the construction of a rural Water Supply project to serve 1600 persons on Ngalo Island. The project proposes that fresh water be pumped from natural wells at Nimoa (Balipa'a School) and Laro by solar power to elevated storage tanks and then distributed by gravity to surrounding villages (Fig. 4). Total project costs were estimated at $85,000 to be shared by the Province, local community, and a yet to be identified overseas aid source.

Before such a scheme can proceed an assessment of the extent of the groundwater resource must be undertaken in order to ensure that adequate water is available and that the extraction of same will not cause salt-water intrusion and thus contaminate the resource.

*Snr Water Resources Officer
Water Resources Section
Geology Division
Ministry of Natural Resources
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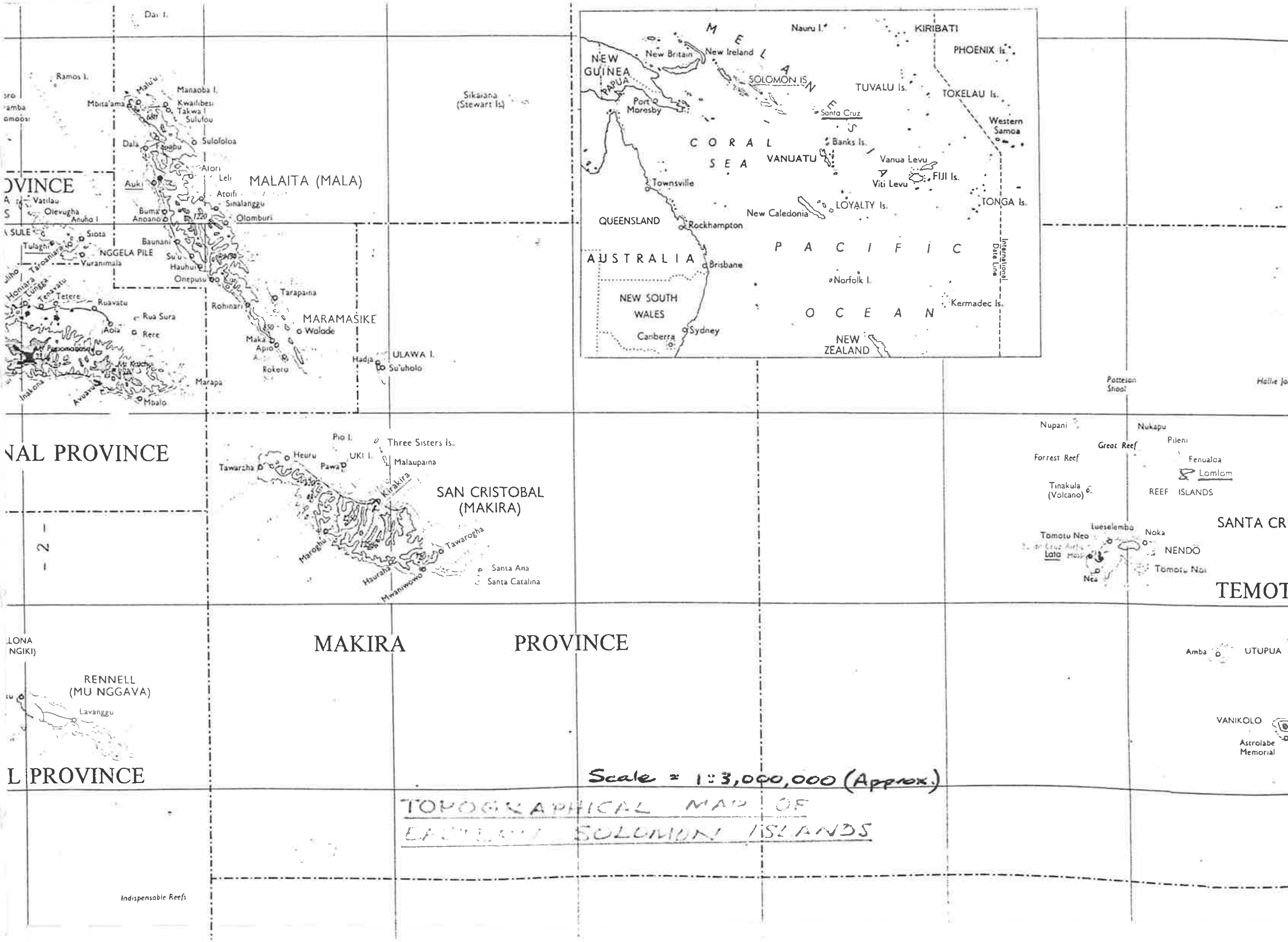

TOPOGRAPHICAL MAP OF EASTERN SOLOMON ISLANDS

FIG. 1

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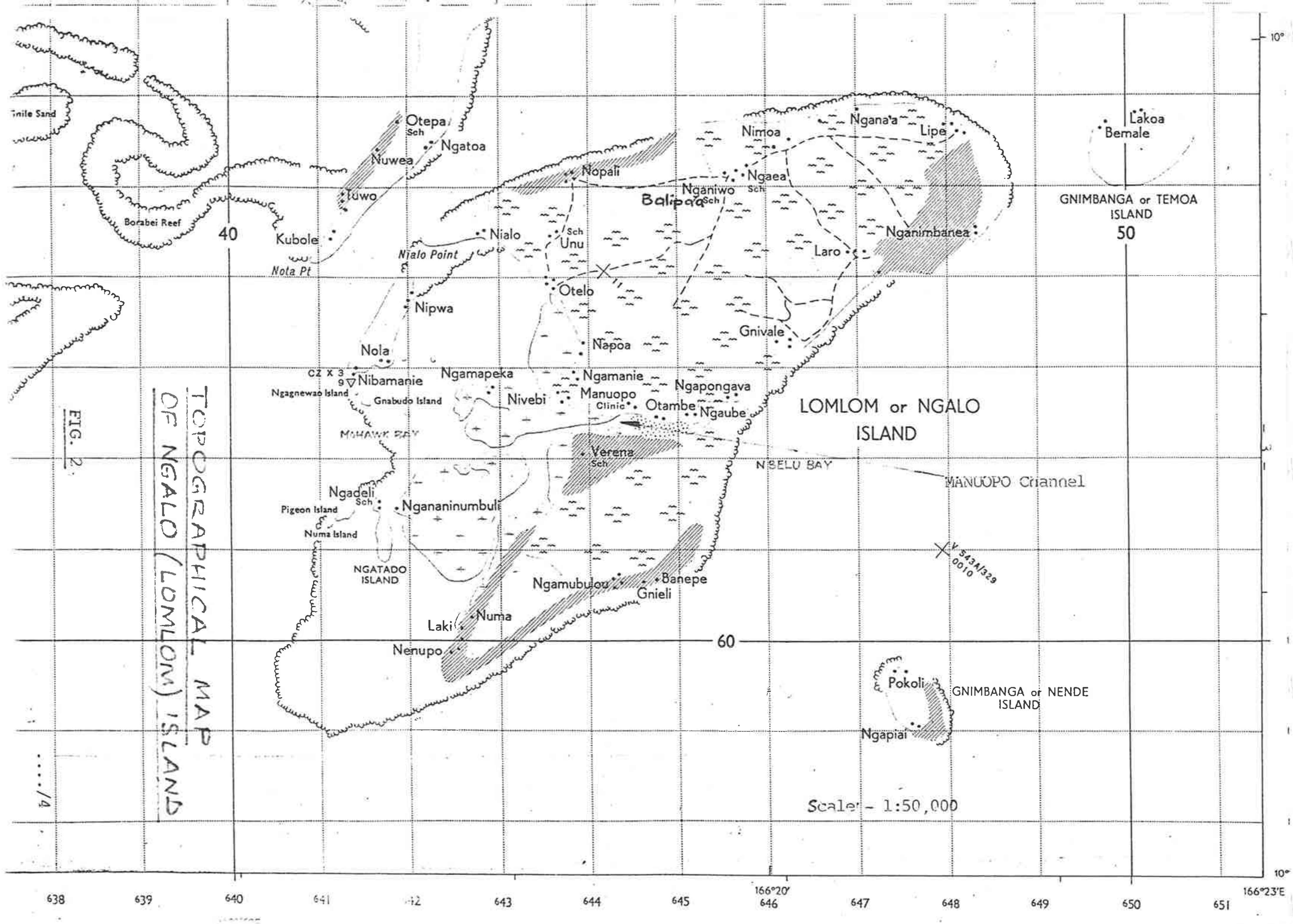

FIG. 2

TOPOGRAPHICAL MAP OF NGALO (LOMLOM) ISLAND

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GEOLOGY MAP OF NGALO (LOMLOM) ISLAND.

FIG. 3

Fig. 3a

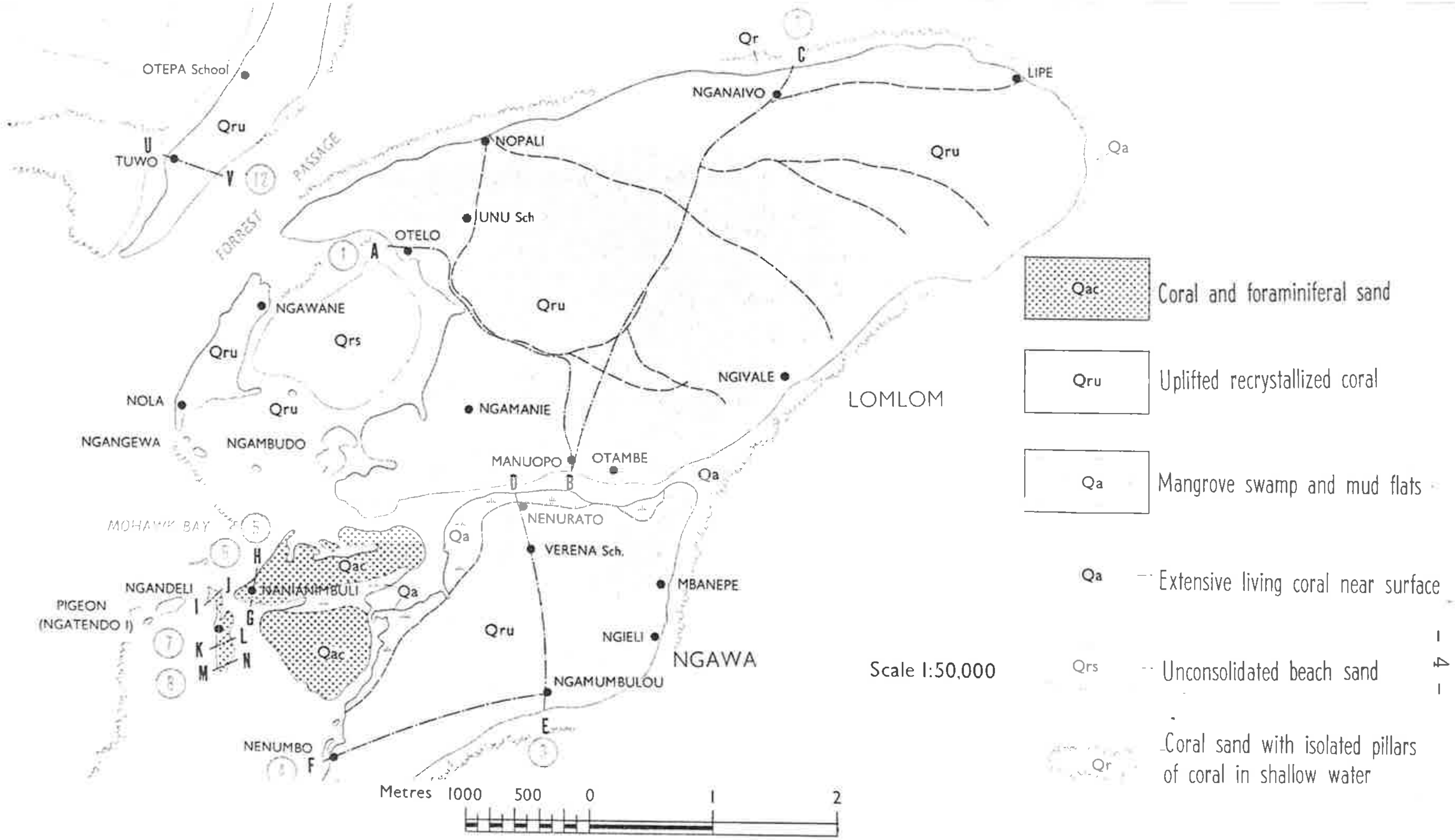

Fig. 3b

SECTIONS ACROSS NAMED ISLAND GROUP, OBTAINED FROM LEVELLING TRAVERSES. HORIZONTAL SCALE NOT CONSTANT, BUT APPROXIMATELY 6 INCHES TO 1 MILE.

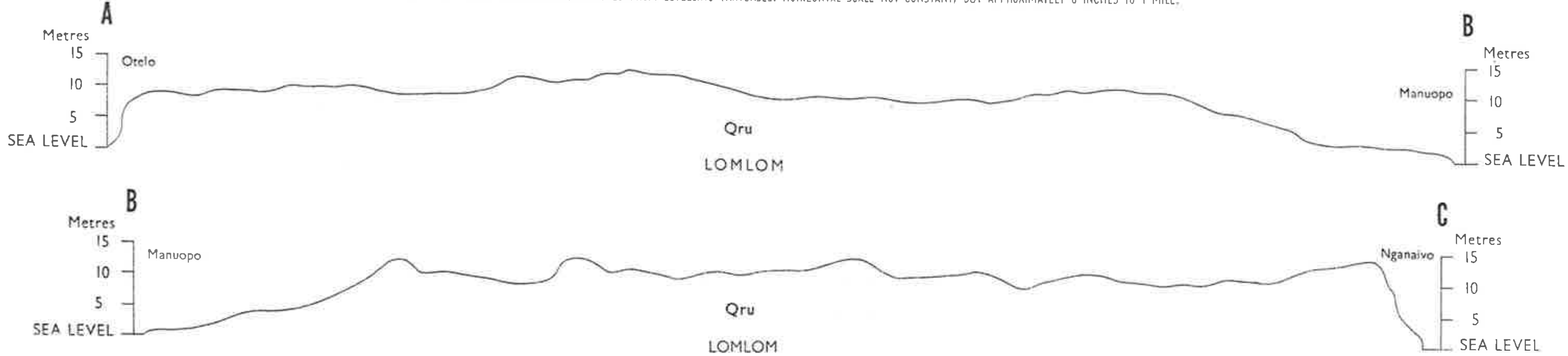

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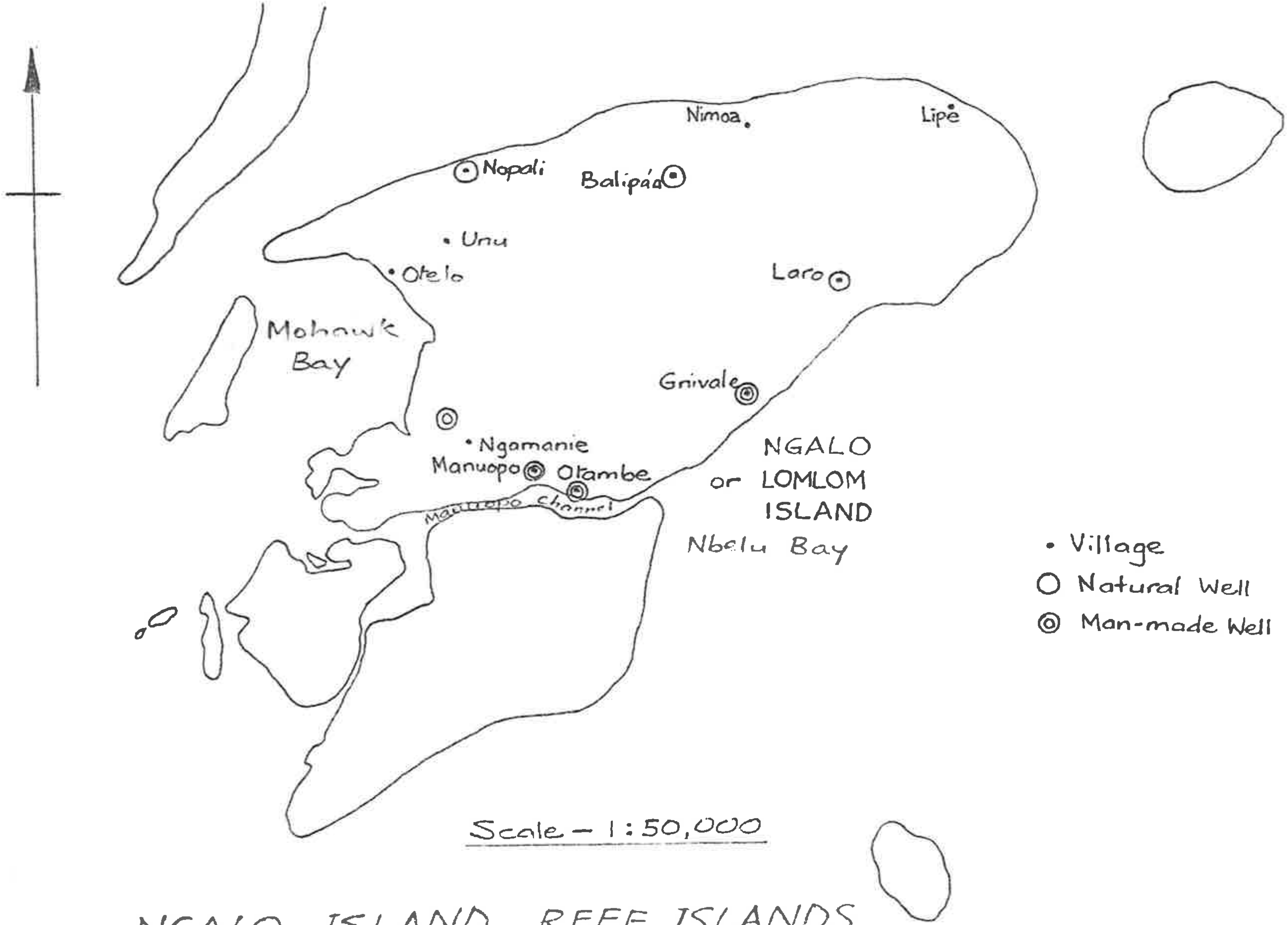
FIG. 4.



NGALO ISLAND, REEF ISLANDS

SHOWING VILLAGE AND WELL LOCATIONS.

Considerable difficulties exist in assessing the groundwater on islands such as Ngalo ,with its comparitively small area and very low topographical relief (limiting groundwater lens development), together with the complete lack of hydro-geological data. In order to obtain a good understanding of the underground water resources of such an island, many months of well logging, levelling and geophysical testing would normally be necessary, however due to its extreme isolation neither time, nor manpower and financial resources were available for such a survey.

A water-resources survey team comprising Messrs Pule, Tickell and Curry spent 5 days on the island (5 - 9 June 1985) and during this time sufficient data were collected to allow predictions to be made on the maximum sustainable yields from the various wells studied.

2. GEOLOGY

A knowledge of the geology is essential to the understanding of the possible extent of the groundwater resource.

Ngalo Island is entirely composed of biogenic limestone and forms part of an extensive east-west aligned oval area based upon a discountinuous submarine ridge capped with living coral. The maximum altitude of the island is 31 metres above LWM, this being attained at the south-east end of the island. There is no surface drainage, the water supply being confined to several natural limestone solution channels and sinkholes, and coastal hand dug wells.

Ngalo Island consists entirely of uplifted recrystallised coralline limestone (Fig.3) bordered to the west by a deep steep sided linear passage (Forrest Passage) and to the east by steep cliffs and living coral platforms. The thickness of the coral reef limestone is unknown though it is believed to be exceedingly thick. Drilling on Bikini and Funafuti atolls indicate thicknesses of 760m and 335m respectively in similar limestones. (Kirk & Grundy 1961). Traverses and cliff height measurements indicate that the Ngalo Island surface dips towards the west and suggests that some regional tilting has occurred which may have been synchronous with the main period of uplift (Hughes et al 1981). Raised beaches, ranging from 2 - 4 metres above LWM surround the north and east of the island, provide evidence of regional physical instability and fresh water springs discharging water of varying salinities are common around the coast below HWM.

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The lower lying land to the south of the island, adjacent to the Manuopo Channel, is largely a mixture of fragmented coral and sands overlying the uplifted coralline limestone,however the depth of this pourous layer is not known.

Soils are generally shallow but do exhibit a three fold zcnation viz dark brown humic top soil, a transition zone and a carbonate-sand layer.

3. GROUNDWATER POTENTIAL

The potential for there to be a groundwater resource on Ngalo Island is dependent on sufficient effective rainfall, adequate infiltration and a suitable degree of permeability within the underlying strata.

Adequate infiltration is evident with a thin soil layer overlying numerous cracks, and sinkholes synonymous with limestone strata. Permeability is likely to be highly variable, due to the fractured rock and solution tunnels, thus requiring site specific investigations to determine actual water yields.

Firstly, however there is a need to determine the amount of rainfall available for recharge in order to assess the groundwater resource potential.

3.1. Recharge Capability

The simple water balance equation used is as follows:

$$P = I + Ep + Re + RO + Qab + Qs + Si$$

where P = precipitation
I = intercepted rainfall
Ep = evapotranspiration
Re = recharge
RO = surface runoff
Qab = groundwater abstraction
Qs = groundwater flow to sea
& Si = incremental groundwater storage change

To determine recharge or the potential input to the system the above equation can read:

$$Re = P - I - Ep$$

Output parameters or losses RO, Qab and Si are insignificant compared with Qs which is unable to be quantified due to the number of sub marine and semi submarine outflows, only some of which were observed during low tide.

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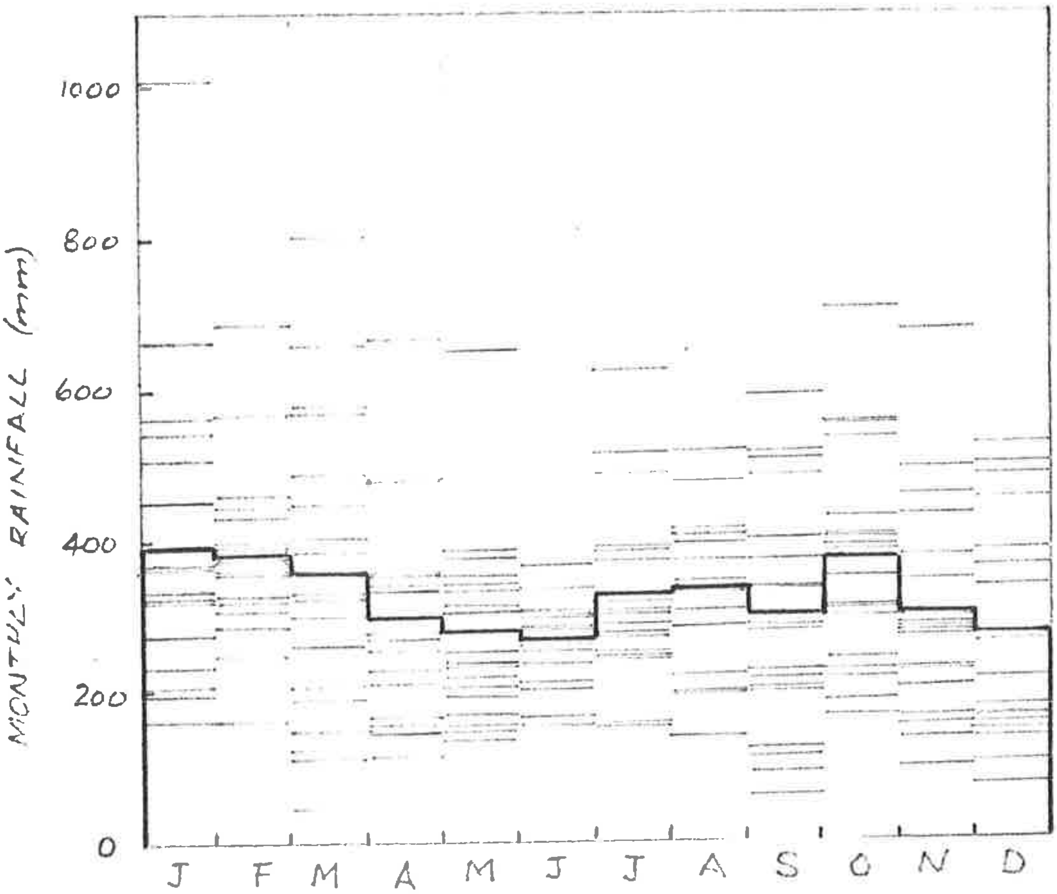
If the groundwater resource is assumed to be relatively stable from year to year then the recharge will approximately equal the flow to the sea and so an estimate of the magnitude of the throughput or water balance can be obtained.

Long term rainfall data for the period 1969 - 85 was available for Mohawk Bay (Fig.4), the monthly totals and long term monthly and annual falls being given in Table 1.



MONTHLY AND MEAN MONTHLY RAINFALL FOR MOHAWK BAY (REEF ISLANDS)

FIG. 5

TABLE 1

MOHAWK BAY (REEF ISLANDS)
RAINFALL RECORDS

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOT.
1967	451.9	689.4	404.6	481.3	387.4	369.1	278.6	518.9	280.2	404.6	279.7	179.3	4725
1968	368.3	353.3	260.9	255.3	170.4	169.4	513.8	395.5	508.3	704.6	379.0	499.1	4570.2
1969	281.2	372.4	111.0	666.0	204.0	284.7	627.1	n/a	92.5	551.2	136.4	524.3	-
1970	196.0	377.5	333.0	475.6	377.0	307.2	382.5	309.8	204.1	536.4	297.4	451.7	4002.5
1971	507.2	430.4	568.1	352.1	157.7	264.4	248.4	477.8	335.1	229.7	281.4	385.8	4223.5
1972	562.2	308.2	324.5	277.8	651.7	307.9	245.9	285.4	400.5	169.1	226.9	339.7	4107.2
1973	323.6	329.3	448.4	358.4	305.0	213.2	271.0	332.6	287.9	297.1	278.3	275.0	3719.1
1974	274.8	390.4	361.0	336.5	148.4	281.6	288.6	403.6	219.2	401.6	460.0	156.6	3722.2
1975	664.8	286.6	382.6	269.4	231.0	236.1	373.6	346.4	487.0	309.2	495.8	215.0	4297.5
1976	1008.2	569.6	656.6	340.8	218.6	269.0	390.4	332.6	333.6	350.8	431.4	484.4	5436.0
1977	540.0	396.0	801.6	207.2	333.4	337.2	487.4	406.8	373.4	429.2	168.2	163.4	4643.8
1978	233.8	460.0	300.6	324.0	235.0	153.5	150.5	199.0	123.5	189.0	156.5	165.0	2690
1979	326.0	162.0	149.0	228.0	252.0	202.0	253.5	197.0	197.5	219.0	238.0	265.0	2688
1980	203.5	249.5	577.5	114.0	138.0	255.5	309.0	221.0	593.0	242.0	678.0	73.0	3654
1981	366.0	370.0	48.0	351.5	191.0	266.0	319.0	374.0	115.0	313.5	273.0	364.5	3351
1982	372.5	389.2	124.2	145.0	322.0	295.5	300.5	414.0	228.0	383.0	99.0	104.0	3175
1983	323.6	387.5	184.0	150.2	342.1	300.2	169.0	137.0	519.0	392.1	204.2	136.2	3244
1984	329.7	398.2	204.5	158.2	352.6	306.9	301.0	337.5	61.5	552.5	345.5	147.5	3496
1985	156.0	322.0	488.5	167.5									
AVERAGE	394	381	354	298	279	268	328	334	298	371	302	274	3694

provided by: Meteorology Division,
Ministry of Transport & Communications

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Fig 5 shows the variability within each month and the relative uniformity of the average monthly falls throughout the year. The month of the survey (June) was noted as having the lowest long term average rainfall and the least variability and so was the best month to do the survey.

Normally potential evapotranspiration (Ep) is calculated using the Penman (1948) techniques but unfortunately adequate data are unavailable in Temotu even with the modifying corrections adopted for smaller islands by Lloyd, et al. (1977). As temperature is a standard measurement in any climate station irrespective of its function it would appear that the Thornthwaite (1948) evaporation estimation provides the only viable means of assessing this parameter despite its obvious shortcomings (Ward, 1971). In the Ngalo Is study this method was therefore used with temperature data for Lata. In view of the lack of data it is not possible to comment on the accuracy of evaporation calculated for Ngalo Is using Thornthwaite in comparison to the more sophisticated Penman method. However, where such work has been carried out elsewhere the Thornthwaite calculations have been found to be most in error where very variable climate conditions appertain so that gross errors would not appear to be likely in the calculations made for Ngalo Island.

Although precipitation is the controlling parameter for recharge input, on the Pacific atolls a significant proportion of the precipitation does not reach the ground and have the opportunity to support the vegetation cover through evapo-transpiration. Broad coconut fronds for example intercept precipitation which is subsequently evaporated; this loss is obviously important and may be considered to amount up to 15 percent of the total precipitation for islands such as Ngalo (Penman, 1963; West and Arnell, 1975).

To account for recharge reaching the water table the concept of a soil moisture balance as described by Penman (1950) and Lloyd, et al. (1966), was adopted using the effective precipitation as the total precipitation (P) minus the intercepted rainfall (I). The balance was established on a running monthly basis with the relationship between effective rainfall, evaporation and actual recharge to a lens subsequently controlled by two parameters 'C' and 'D'. Although it is appreciated that probably a daily balance (or at least a 10-day balance) may provide more accurate estimates (Howard and Lloyd, 1979) the accuracy of the rest of the ground water data on Ngalo does not justify such accuracy.

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The soil moisture parameter 'C' may be defined as the moisture level in the soil (in mm) which has to be satisfied before water can infiltrate as recharge below the root zone. The parameter is therefore a function of 'field capacity' and rooting depth. The parameter 'D' (mm) is the limiting moisture content in the root zone at which effective evapotranspiration ceases and plants start to wilt. In the balance evapotranspiration is considered to occur at the potential rate when soil moisture values are within the 'C' range. When values fall between the 'C' and 'D' limits the evapotranspiration is constrained and for Ngalo Is has been assessed to operate at 10 percent of the potential value (Penman and Schofield, 1964).

Values of 50mm and 120mm were adopted for "C" & "D" respectively. (Lloyd et al 1980).

In order to ascertain the magnitude of the annual average recharge, the water balance was calculated for the year 1984 (approximates mean annual rainfall and incorporates typical monthly variations). Monthly rainfall totals from the Mohawk Bay Station and mean monthly temperatures from the Lata climate station (Fig 1) for 1984 were used, the latter to calculate the monthly potential evapotranspiration (Table 2).

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CALCULATION OF POTENTIAL EVAPOTRANSPIRATION
FOR REEF ISLANDS (SANTA CRUZ) USING THE
THORNTHWAITE METHOD

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean* Monthly Temp. (°C)	28.4	28.6	27.8	28.4	28.5	27.6	27.2	27.8	27.9	28.2	28.4	29.1	28.2
Heat Index I	13.87	14.01	13.43	13.87	13.89	13.28	12.99	13.43	13.50	13.72	13.87	14.39	(Ia) 164.25
Uncorrec-ted PE (cm)	13.89	14.28	12.77	13.89	14.08	12.41	11.71	12.77	12.95	13.51	13.89	15.29	
PE correct-ions for 10°S (after Criddle)	1.06	1.08	1.07	1.02	1.02	0.98	0.99	1.00	0.91	1.03	1.03	1.08	
PE (mm)	147	154	137	142	144	122	116	128	118	139	143	165	1655

Heat Index I $= (t/5)^{1.514}$ where t is the mean monthly temp in °C.

e.g. For Jan. I $= \left(\frac{28.4}{5}\right)^{1.514} = 13.87$

Uncorrected PE (30days of 12 hrs) $= 1.6 \left(\frac{10\ t}{I\ a}\right)^x$

where $x = 6.75 \times 10^{-7}(I_a)^3 - 7.71 \times 10^{-5} (I_a)^2 + 1.792 \times 10^{-2}\ Ia, + 4.9239 \times 10^{-1}$

$= 2.9910 - 2.0800 + 2.9434 + 0.49239$

$= 3.9468$

e.g. For Jan U.P.E. $= 1.6 \left(\frac{10 \times 28.4}{164.25}\right)^{3.9468} = 13.89$ cm

* Provided by Meteorology Division, Ministry of Transport & Communications

TABLE 2

The potential recharge calculation for 1984 is given in Table 3 and shows that 1371 mm or 42% of the 1984 annual rainfall of 3244 mm is available for recharge.

As the areal extent of Ngalo Island is 14.02 km the average annual volume of water available for recharge is 1.9×10^7 m^3 which approximately equates to an average annual flow rate of 600 $l\ s^{-1}$. A flow rate of this magnitude can quite conceivably be accounted for from the numerous springs apparent around the coastline.

The water balance showed that adequate potential exists for there to be a good ground water system.

4. GROUNDWATER EVALUATION

As already noted the permeability in the limestone formations is likely to be highly variable and as such would not promote the Ghyben-Herzburg hydrostatic development and lens formation between fresh ground water and sea water as described by Wentworth C.K., 1947.

Nevertheless some local hydrostatic developments could exist within the highly permeable caverns and certainly in the pourous unconsolidated coastal coral and sand, accentuating the possibility of salt-water intrusion.

Prior to the Water Resources Teams visit to Ngalo Is., the Province was requested to take water samples from all the wells in use. Table 4 details the water quality analyses of these samples and the total dissolved solids (TDS) and chloride measurements made during the subsequent visit. The groundwater from all the wells tested was seen to be fit for human consumption, all being well within the World Health Organisation (WHO) maximum allowable standards. However, some parameters tested were a little over or very close to WHO maximum acceptable recommendations. These were Manuopo well with a high alkalime content (pH=8.6) and Ngivale with a TDS concentration of 500 $mg\,l^{-1}$.

Having recorded these baseline quality levels, detailed well testing was carried out on all the wells except Ngivale as it was assumed that, with pumping, the Ngivale TDS was likely to rise and become even less acceptable.

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TYPICAL SOIL MOISTURE - RECHARGE CALCULATION

FOR YEAR 1984

MONTH	MOHAWK BAY RAINFALL LESS INTERCEPTION (mm)	SANTA CRUZ POTENTIAL EVAPORATION (mm)	EFFECTIVE RAINFALL (mm)	SOIL MOISTURE DEFICIT (mm)	RECHARGE (mm)
Jan	280	147	133	0	133
Feb	338	154	184	0	184
March	174	137	37	0	37
April	134	142	-8	-8	0
May	300	144	156	0	148
June	261	122	139	0	139
July	256	116	140	0	140
Aug	287	128	159	0	159
Sept	52	118	-66	-51	0
Oct	470	139	331	0	280
Nov	294	143	151	0	151
Dec	125	165	-40	-40	0
					1371

Annual Recharge for 1984 = 1371 mm (42% of annual rainfall of 3244 mm)

Area of Lomlom Island = 14.02 km^2

Therefore total volume of water available for recharge
= 1.9×10^7 m^3 p.a. or 600 $l\ s^{-1}$.

TABLE 3

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