COASTAL PROCESSES AND THE ROTUMA WHARF FIJI

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SUMMARY

The wharf basin at Oinafa, Rotuma, has shoaled with sand so that the supply ship now has difficulty mooring at the wharf. The objective of this report is to investigate the cause of shoaling and possible solutions including alternative wharf sites to fullfil SOPAC Work Programme Task92.FJ.19f: Assessment of the Rotuma Island Jetty.

The first part of this study was a perusal of available information on Rotuma (wind, waves, geology maps, charts and air photos). The second part was a detailed site inspection of the existing wharf, the possible alternative wharf sites and all the adjacent shorelines.

Before the wharf was constructed in the mid 70's, the Oinafa site had a sand spit which was rounded and symmetrical. This spit was built by the dominant littoral drift from the east and kept in dynamic equilibrium by both refracted and wind waves from the west. The wharf access causeway was built with a small bridge which let sand into the wharf basin where it became trapped and could not be redistributed eastward to keep the spit in equilibrium. The trapped sand has shoaled the wharf basin and caused accretion on the basin shore while resulting in erosion on the east of the spit.

It is recommended that the bridge be filled in to make a continuous causeway. The existing wharf can be rehabilitated or a new wharf can be built in deeper water as an extension to the existing wharf and causeway. If the existing wharf is rebuilt, the wharf basin will have to be dredged, but if a new wharf is built in deeper water the dredging can be avoided. If the wharf basin is dredged tie sand should be dumped east of Oinafa as beach nourishment. Some dredged sand could be stockpiled for construction purposes.

ACKNOWLEDGEMENTS

This work was supported by the Canadian Government and the Government of Fiji.

Acknowledgement is made of the assistance of Rupeni Mua of the Fiji Ministry of Works, Viliame Baleivanualala of the Fiji Ministry of Lands and Mineral Resources, and the people of Rotuma who assisted with the coastal inspections, especially : Charlie Uafoou, Epeli Fiu and Gagaj Poar and his family.

Acknowledgement is also made to Mr Stan Brown, Retired Fiji Navy Commander, for his helpful comments on sailing and shiphandling in Rotuma waters.

OBJECTIVES

The Rotuma Island Jetty is the only wharf on Rotuma and the basin has been shoaling with sand so that :he supply ship has difficulty mooring at the wharf. The work carried out for this report is to fulfill the requirements of SOPAC Work Programme, Task 92.FJ.19f: Assessment of the Rotuma Island Jetty. The specific objectives are: to ascertain why shoaling has occurred and suggest possible solutions, to inspect other alternative sites for a wharf, and to study the general coastal processes near these sites. All these objectives were met and are discussed in this report.

INTRODUCTION

Rotuma (latitude 12' 30'S, Longitude 177' E) is located about 600km north of Nadi. The main island (14km by 4.5km) is composed of two parts joined by an isthmus or tombolo near the western end (Figure 1). It is surrounded by several smaller islands and a fringing coral reef. It is believed that the Rotuma volcanic group is of late Pleistocene age and some volcanic cones are less than 15,000 years old. Although the average annual rainfall is 3550mm, there is little surface drainage and only a few small streams (Woodhall 1987).

There are only two sites in Rotuma with a reef gap near shore suitable for ships to anchor: Oinafa Bay and Hopmafau Bay. In the 1970's a wharf and access causeway were constructed at Oinafa (Figure 2). The causeway was built west from the sand spit at Oinafa and has a small bridge part way along its length. The wharf basin has now shoaled such that the supply ship has difficulty mooring at the wharf.

Since the Oinafa Wharf is an essential transportation facility for Rotuma, SOPAC was requested by the Government of Fiji to assist with an assessment of the problem (Task 92.FJ.19f), including the cause of the shoaling and whether the present wharf and basin should be rehabilitated or a new wharf built at another site.

Subsequently the writer carried out a detailed site inspection and discussed the coastal processes and possible alternative solutions with the Fiji Ministry of Works. This report describes that site inspection, and discusses the coastal processes involved and some solutions and alternatives to the wharf problem.

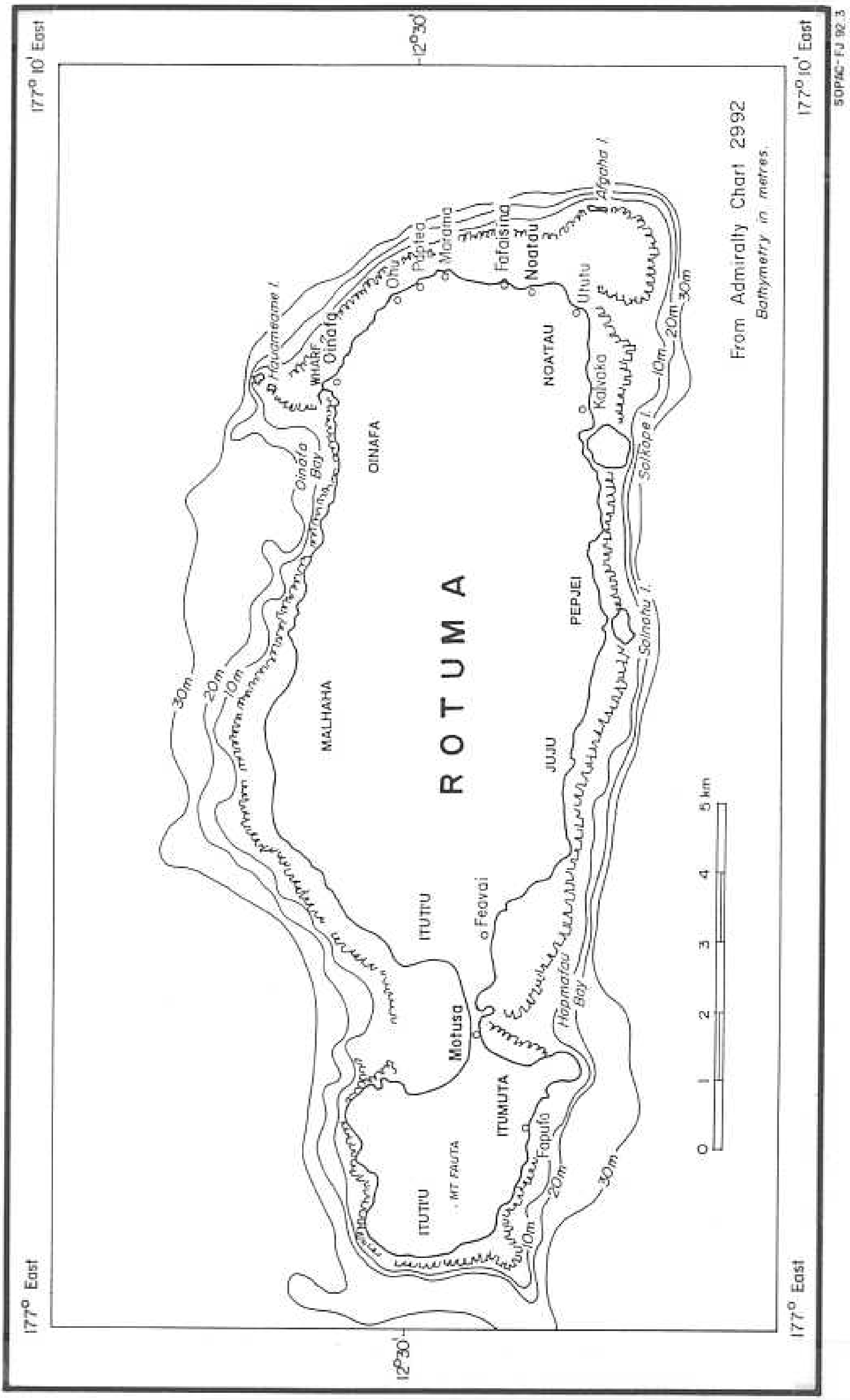

Figure 1. Rotuma site and bathymetric map.

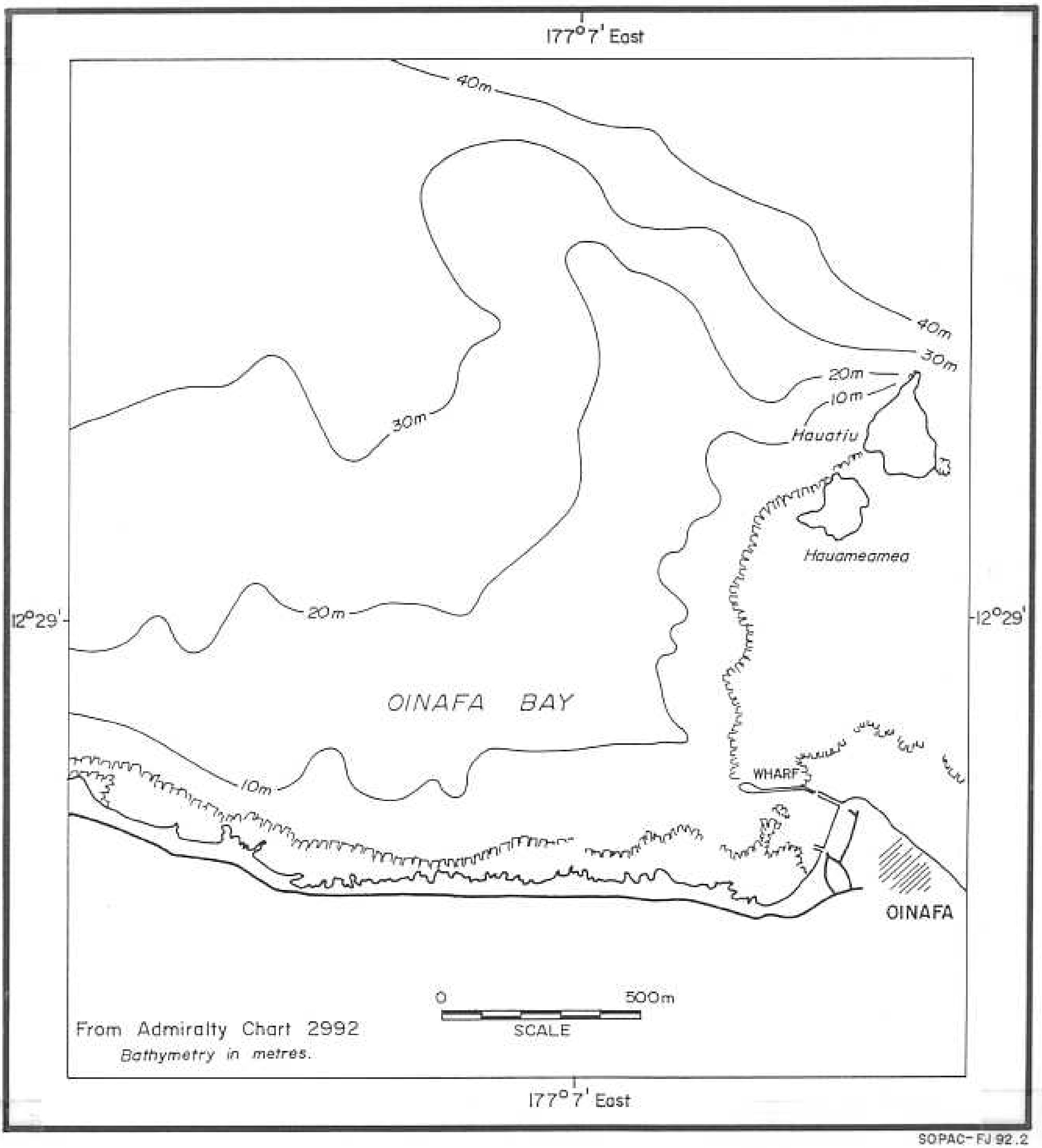

Figure 2. Oinafa Wharf.

METHODS

The first part of this study was a search for any relevant existing information on Rotuma. Information was sought on wind, waves, geology, old maps, navigation charts, and all available air photography. The aim of this part of the study is to get a clear understanding of the geomorphology a i d natural coastal processes that existed before the wharf was built. This understanding is essential to assess the interaction of the wharf with the natural beach processes and to understand the shoaling problem.

The second part of this study was a detailed site inspection of the relevant areas. The site inspection involved walking the shoreline, making notes and photographing significant natural features and coastal structures (see Appendix A). The sites inspected were the Oinafa Wharf, the shoreline around the east end of the island, and the possible alternative sites (Solkope Island, Hopmafau Bay, and Motusa) and their adjacent shorelines. These site inspections were necessary to check and confirm the nature of the shore processes as inferred from the wind data and maps.

RESULTS

Wind

Wind data were collected in Rotuma by the New Zealand Meteorological Service from July **1978** to December **1985** (see Appendix B). Although this is a short period of record, these data confirm that Rotuma is in the trade wind zone and the winds are predominantly easterly. These easterly winds are very strongly dominant from April to December and particularly in August. Although the easterlies are still dominant during the cyclone months of January to March, they are much less frequent. During these months, the wind comes from all directions and westerlies are nearly as frequent as easterlies and can be of greater strength (Appendix B).

Cyclones cannot occur at the equator and rarely occur within 5' of it, because of negligible coriolis force. Cyclones commonly originate between 10' S and 15' S, but they are not likely to reach hurricane force until they are south of Rotuma. Cyclones usually become strongest between latitudes 15'S and 20'S (Crane 1988). During the cyclone season, wind can be expected from any direction and strong westerly to southwesterly winds can be expected from cyclones centered to the south or southwest of Rotuma. Although these winds are not the most frequent, they are probably the strongest. Also during El Nino years, (1982-83, 1987, 1991), westerly winds may possibly be more frequent, as is the case in Kiribati (Burgess 1987), but there are no Rotuma data to support this possibility.

Littoral Drift

Although swell waves can come from any direction at Rotuma, the dominant easterly winds mean that the dominant wave direction is westward. Waves moving westward will hit the east end of Rotuma and move littoral (beach) material westward along both the north and south shores of the island. Littoral material will continue moving westward until it gathers in a sheltered area or is pushed offshore into deep water. The less frequent wind and waves from the west will tend to reverse the direction of littoral drift and move beach material eastward. Although the westerly wind and waves are not frequent, they can be more severe and could move a considerable amount of beach material eastward in a short time.

Maps and Air Photos

The geological map of Rotuma (Figure 3) indicates that the island is mostly basalt lava and scoria, except for some depositional areas near the coast (Woodall 1987). The shore around the east end of the island, from Oinafa to Kalvaka (Figure 3), is a coastal plain with only a small section of lava near the shore at Fafaisina. There are also substantial coastal plains in Pepjei and Juju districts on the south coast and at the Motusa isthmus (Figure 1). These coastal plain areas and the smaller beaches are composed of carbonate sand and gravel derived from the reef (Woodhall 1987, page 21).

Air photographs of the Oinafa Wharf area were acquired for 1958, 1979, 1980, and 1984. The 1958 photo (Figure 4) shows the natural shoreline of the Oinafa area before construction of the wharf in the 1970s. The 1979 and 1984 photos (Figures 5, 6) show gradual changes in the shape of the beach after construction of the wharf. A brief comparison of these airphotos shows some obvious changes to the shoreline since the wharf construction.

The 1958 photo (Figure 4) shows Oinafa Point as a symmetrical, rounded spit on the reef flat opposite Hauameamea and Hautiu Islands. The symmetrical rounded (rather than pointed) tip of the spit indicates that waves are refracting around the tip of the spit and impacting the shore from both east and west. The post-construction photos (Figures 5, 6) show a gradual shifting of

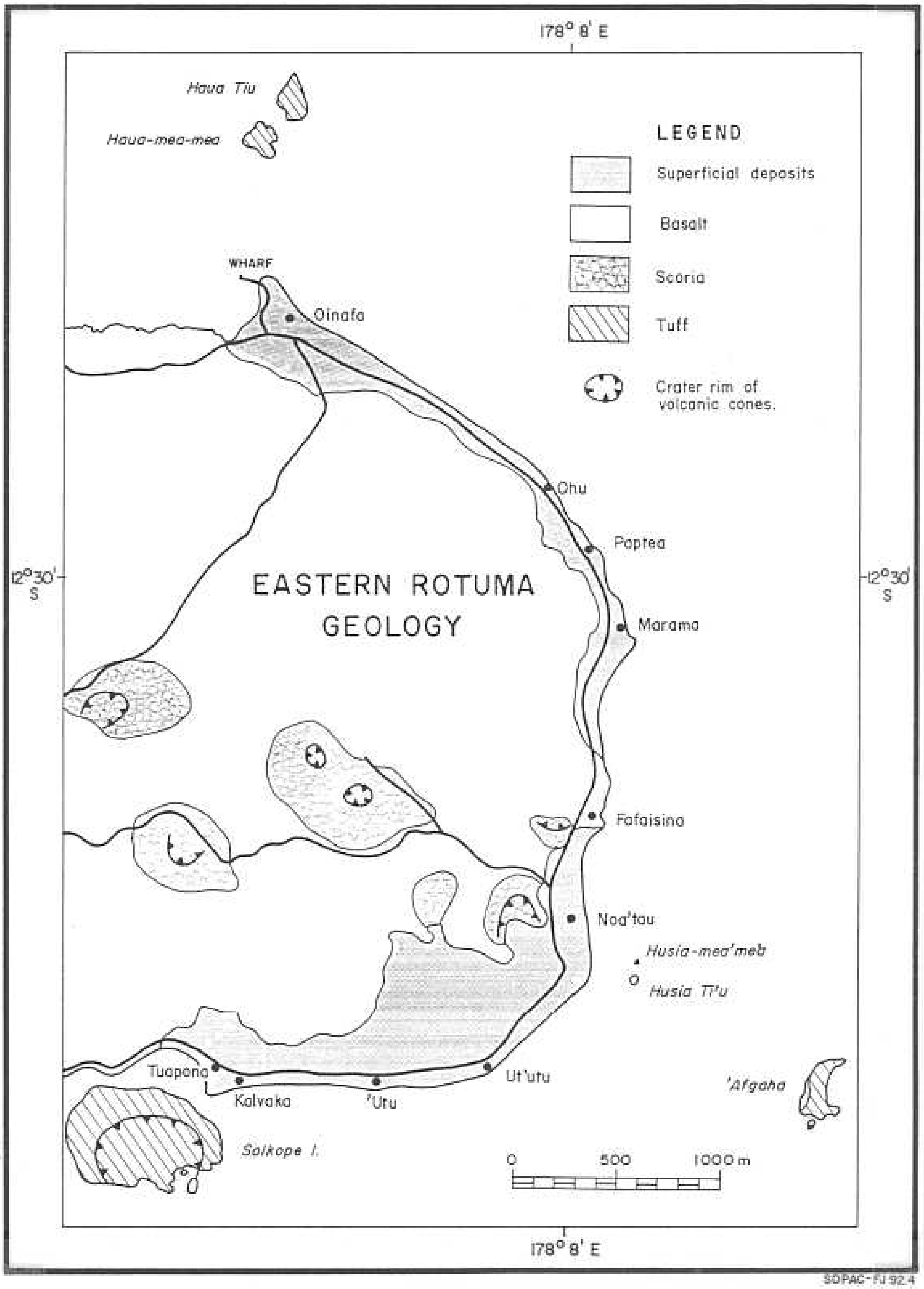

Figure 3. Geological map of eastern Rotuma.

Figure 4. Oinafa 1958 air photo.

Figure 5. Oinafa 1979 air photo.

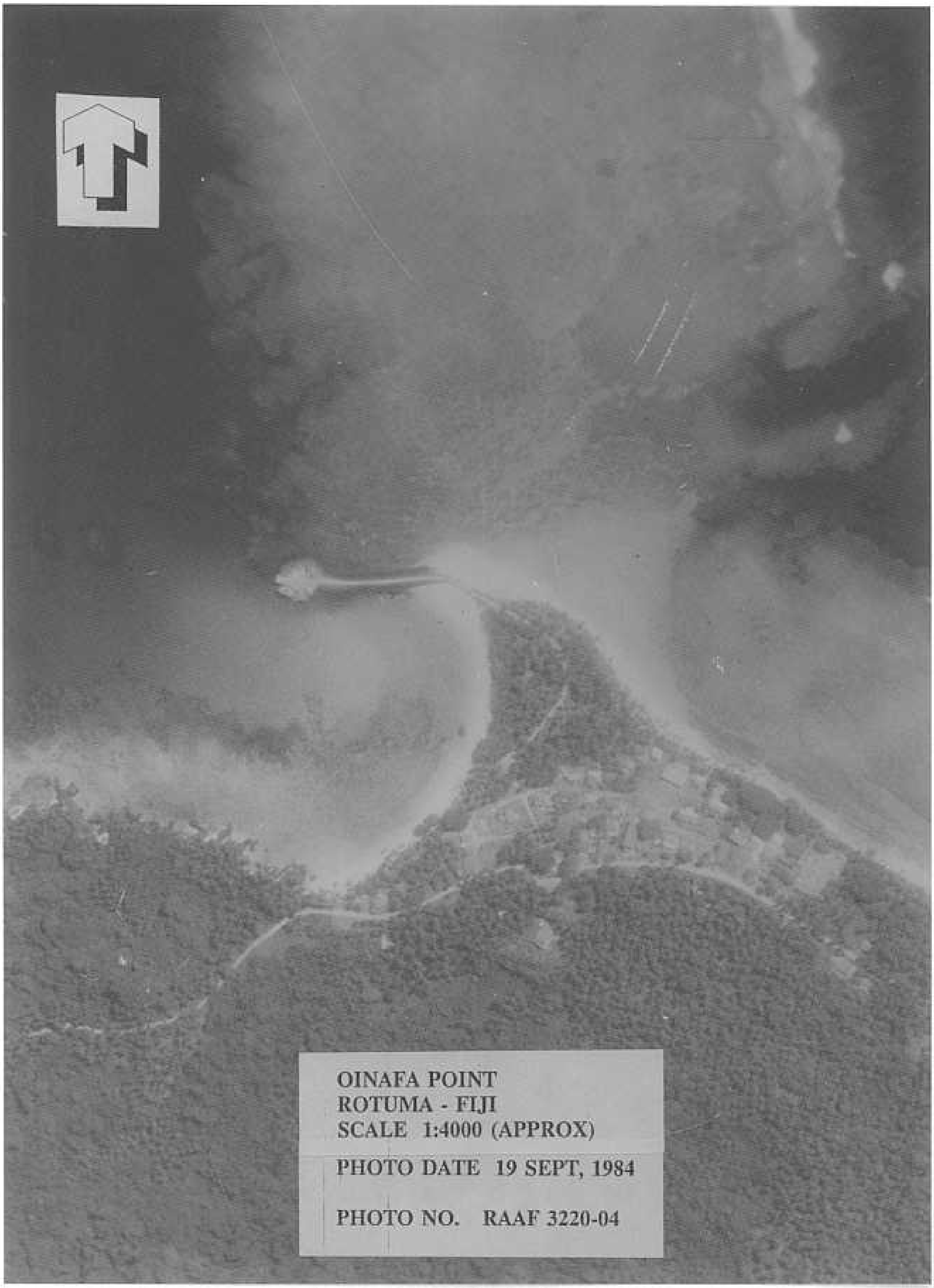

Figure 6. Oinafa 1984 air photo.

the spit so that it has become skewed westward toward the wharf. The beach on the west side of the spit has accreted since the wharf construction. A current airphoto and a detailed and accurate comparison of all these photos would be required to determine the exact changes to the shoreline.

Site Inspections

Oinafa Bay

The wharf was constructed by building a causeway west from Oinafa Point. There is a small bridge in the causeway about 100m west of the original shoreline and the causeway extends about another 200m west to the wharf (Figures 7, 8). The north side of the causeway is armoured with rock and the smaller rocks have been moved by the waves. At the side of the causeway the 0.4m armour stones are stable at a 2/3 side slope. At the tip of the causeway the 0.6m armour stones are stable at a 2/3 side slope. Both the bridge and the wharf are concrete structures which have deteriorated and need to be rehabilitated or replaced.

East of the causeway the beach is fine sand and littoral drift is westward. About 300m east of the bridge, there are fallen trees and the shoreline shows evidence of erosion. Just east of the bridge there is a borrow pit of a small sand mining operation (Figure 9). The sandy beach extends only to the bridge and the sand is then pushed under the bridge into the wharf basin. The shoreline and basin east of the wharf is accreting and the wharf basin is now too shallow to moor the supply ship. From the different heights of the coconut trees, it is estimated that the shoreline inside the wharf basin has accreted about 100m since the causeway was constructed in the 1970s. Small coconut trees have recently been planted along the edge of the beach to stabilise and claim the recent accretion.

East Coast

The shoreline around the east end of Rotuma, from Oinafa to Kalvaka, is characterised by fine carbonate sand, black rock outcrops and beachrock slabs. Littoral drift is northwestward from Marama, to Oinafa and southward and westward from south of Marama to Kalvaka (Figure 3). Along this shore there are several locations where black rock outcrops, perpendicular to the shore or slightly offshore, act as groynes and pocket the fine sand. Fronting Paptea village the groyne

Figure 7. Oinafa Wharf: north side of causeway showing armour stone sizes.

Figure 8. Oinafa Wharf: south side of causeway showing bridge at landward end of causeway.

Figure 9. Oinafa Point: sand mining site showing author standing in borrow pit.

Figure 10. Paptea Village: fine sand beaches between black rock outcrops that act as groynes.

effect of these rock outcrops has formed a very good sandy beach (Figure **10**). At several locations there are black rock boulders partially embedded in the beachrock slabs. An example of this beach type with small patches of sand is near Marama (Figure **11**). From Marama to Noatau there is a scarcity of sand, some coarse material and some signs of erosion. Littoral drift may be alternately moving sand north and south from this area. Near Noatau there are old concrete foundation blocks on the beach and south of Noatau there are exposed tree roots. There is a large accumulation of fine sand off Ututu and a sand spit at Kalvaka at the entrance passage behind Solkope Isand.

Motusa

At Motusa on the north side of the isthmus, there is an extensive reef flat with a deeper water lagoon area toward the western side. This area is sheltered by the fringing reef but does not have a suitable entrance channel. The water depth in the lagoon is not known.

Hopmafau Bay

At Hopmafau Bay on the south side of the isthmus, the fringing reef follows close to the western shore and has a gap near the isthmus. This gap allows ocean waves to approach almost to the isthmus shore. It is reported by locals that this reef gap is completely natural and was never blasted or dredged. There are large exposed beachrock slabs near shore and some evidence of erosion. It is reported that there was a Brown & Joske building on the shore here in the 1950s and the site has now eroded. Just east of the reef gap, there is a large sand spit extending out from the shore, (Figure 12) which local residents say accumulated only in recent years. This spit location and shape is somewhat atypical but is believed formed by the ocean waves coming in through the reef gap, refracting to the east and pushing sand onto the sandspit. It is difficult to understand why this spit would only have formed recently, unless the reef gap had been widened or altered in some way. Public Works Department has a sand mining operation on the tip of this spit and from which it is hauling sand to repair the island roads (Figures **13, 14**).

Figure 11. Marama: black rocks embedded (melted) into the beach rock and thin patches of sand.

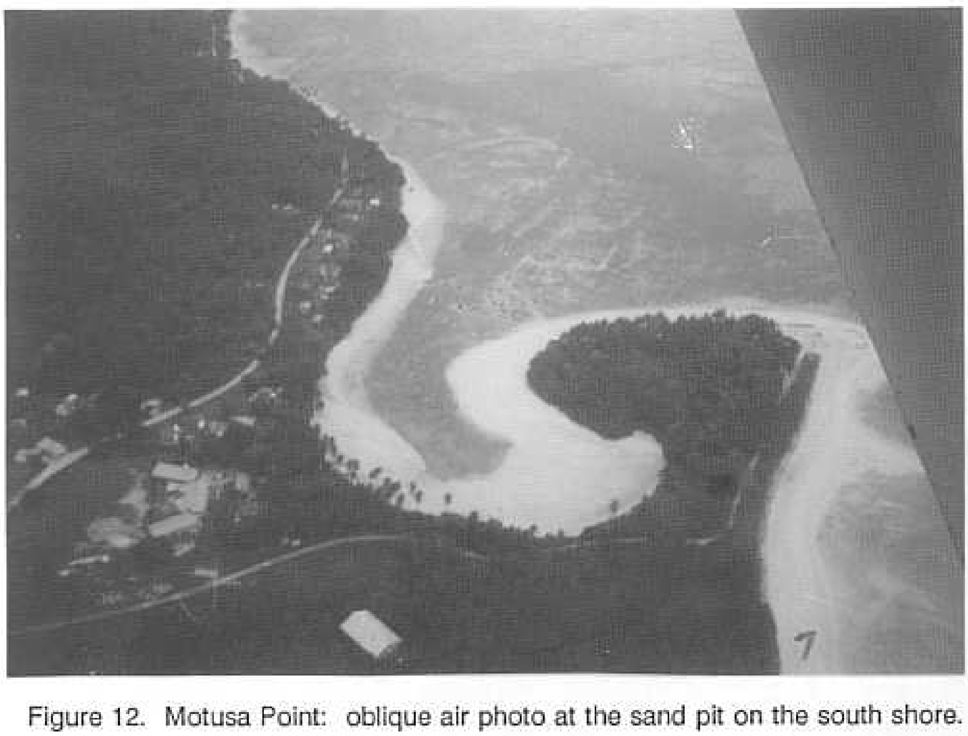

Figure 12. Motusa Point: oblique air photo at the sand pit on the south shore.

Figure 13. Motusa Point: sand mining of the tip of the spit.

Figure 14. Motusa Point: sand mining at the tip of the spit.

Solkope Island

The area behind Solkope Island has a rock shoreline and is well sheltered from waves from any direction. The fringing reef runs along the outside of the island and has no gap. This area is very shallow and appears suitable only for small canoes. It would be required to deepen the basin and excavate an entrance channel and it is not known if the area behind Solkope Island is reef flat or a sand deposit.

DISCUSSION

In addition to the present wharf site at Oinafa, three alternative wharf sites have been suggested and were also inspected; Motusa, Hopmafau Bay, and Solkope Island. The following is a discussion of some special features, advantages and disadvantages of each site.

Oinafa Bay

The prevailing wind and waves move beach sand from the east end of Rotuma to Oinafa Point. Because the westerly (cyclone) winds are much stronger than the easterlies and the reef gap allows westerly waves to hit the shore directly, the west side of Oinafa Point is subjected to bigger but shorter duration waves than the east side. From April to December littoral drift would be strongly westward with the prevailing easterlies. From January to March, littoral drift would reverse with the increased frequency of westerlies. There are also swell waves from the north to east sector which refract around the Hautiu Island reef and impact Oinafa Point from the west. The combined effect o the bigger westerly waves and the refracted swell waves move beach sand back around Oinafa Point and balance the smaller but prevailing easterly waves.

This balance of littoral wave energy at Oinafa Point had kept the spit rounded, symmetrical, and in equlibrium as a partial tombolo on the shoreline before construction of the wharf (Figure 4). The excess sand spilled out through the reef gap and was lost to deeper water where it could not be picked up by the waves.

After the wharf was constructed, the sand continued to move westward outside the causeway until it reached the bridge. The prevailing easterly waves pushed sand westward and under the bridge into the wharf basin. The westerly waves then pushed this sand back onto the beach inside the wharf basin. The westerly waves could not push the sand back around Oinafa Point because of he causeway between the bridge and the original shoreline. If a longer open pile bridge had been built instead of this causeway. the sand would be able to move back around the point. Thus the beach has accreted out to the bridge on the west side and there is erosion on the east side of Oinafa Point. The excess sand has also filled in the wharf basin. Essentially the shoreline section of the causeway and short bridge have caused the wharf basin to become a sand trap and Oinafa Point to be skewed westward with an area of erosion on the east side and accretion on the west side (Figure 6).

One solution to the problem is to restore the natural movement of sand around Oinafa Point. If a longer open bridge was built from the original Oinafa Point shoreline (instead of a causeway) then the sand should be able to move back and forth around Oinafa Point as it did before construction of the causeway. The bridge need not extend the full length to the wharf but should be sufficiently long and open to allow westerly waves to push sand back around the point. There would likely still be some realignment of the shoreline from the pre-construction profile but it would not be as bad as at present.

Another opossible solution is to attempt to artificially balance the movement of sand around Oinafa Point. If the bridge was filled in, making a solid causeway to the wharf, then the sand could not enter the wharf basin and would move westward on the outside of the causeway. At the end of the causeway the excess sand would spill off the reef edge into deeper water and some sand may be pushed into the wharf basin by westerly waves. From January to March the sand outside the causeway could then be pushed back around Oinafa Point by the westerly wind and waves. Waves which refract around the Hautiu Island reef and hit the causeway from the west would also push sand back around Oinafa Point. This would lessen the skewed effect on the point and would delay or at least slow the rate of infilling of the wharf basin.

The Oinafa Bay site is sheltered from most waves but is exposed to the westerly waves, which are more likely to be cyclone generated. This site is reported to be the best anchorage in Rotuma (Brown 1992). In the event of unacceptable westerly waves, a ship can easily find shelter to the east of Rotuma.

The present wharf basin needs extensive dredging and the sand should be returned to the littoral system by clumping it east of Oinafa Point. Some dredged sand could be stockpiled for construction uses. This wharf basin is expandable at a future date by dredging the beach at the east end of the basin. Both the wharf and bridge at Oinafa are reported by the Public Works

Engineer to be unsound and need to be rehabilitated. A new longer bridge built out from the original shoreline would be expensive but would hopefully enable Oinafa Point to return to near its original natural shape. Filling in the existing bridge to make a solid causeway would be considerably cheaper and should stop or at least slow the rate of infilling of the basin and reduce the need for future maintenance dredging. Either of these causeway options would require initial dredging of the basin if the present wharf site is to be used.

If the causeway was extended and a new wharf built on piles northeast of the present wharf (Brown 1992), there would be no need to dredge the present wharf basin. An open - piled structure does not significantly affect littoral processes so the sand movement would be essentially the same as if the present solid wharf was rehabilitated. Although a deep water wharf on piles is expensive, it would avoid the need to dredge the wharf basin. If the wharf basin is not dredged, there would be no readily available supply of sand to artificially nourish the east side of Oinafa Point. In this case Oinafa Point would be left to stabilise naturally, by the supply of sand coming from the east. The existing bridge would still need to be filled in or replaced with a new longer bridge.

The Oinafa site would not require new land acquisition and the existing road transport to the co-op warehouses at Oinafa and Noatau would remain adequate. The costs at this site would be dredging the basin, building or rebuilding a wharf and possibly a new longer bridge. Rehabilitating the Oinafa site by one of the above means is recommended rather than developing another site.

Motusa

A wharf site at Motusa on the north side of the isthmus could possibly use the lagoon inside the fringing reef as a wharf basin. If a suitable entrance channel can be excavated, this site looks like a potential all weather anchorage. The entrance channel through the reef must be carefully chosen to minimise the effect of ocean waves entering the wharf basin. Excessive wave action in the wharf basin would cause havoc with ship mooring and may cause shoreline erosion at Motusa. Since t i e depth of this basin is not known, no comment can be made on its suitability for a supply ship. f dredging is feasible then this basin could be expanded in the future. A new wharf and causeway access road would also have to be constructed. This site would require additional land acquisition and significantly increase the road transport distance to the co-op warehouses on the east end of the island. The cost at this site would be land acquisition, construction of a new wharf, access road, and entrance channel and possibly some dredging. This alternative is very expensive and merits consideration only if it can offer an all weather anchorage.

Hopmafau Bay

On the south side of the isthmus, the fringing reef comes close to the shore and there is an anchorage but no wharf or loading facility. This anchorage is protected from northeasterly to westerly waves bit is exposed directly to waves from the south, which include hurricane waves. The prevailing easterly waves also refract into this anchorage. In the event of unacceptable waves from the south, shelter would have to be found on the north side of the island. Considerable excavation and/or a breakwater may be required to develop a wharf basin that is protected against waves from the south. If dredging is feasible, then this basin could also be expanded in the future. A new wharf and access road would need to be constructed at this site. This site would require additional and acquisition and significantly increase the road transport distance to the co-op warehouses or the east end of the island. The costs at this site would be land acquisition, construction of a new wharf, an access road and possibly some dredging or excavation. This alternative is not recommended because it is exposed to cyclone wind and waves from the south and would require considerable protection works.

Solkope Island

The area behind the island near Kalvaka is well sheltered from all directions but it is very small and shallow. Both an entrance channel and a wharf basin would have to be excavated to facilitate a supply ship. This area has no expansion potential. A new wharf and access road would have to be constructed at this site. The costs at this site would be land acquisition, a new wharf, an access road and excavation of a basin and an entrance channel. This alternative is not recommended because it involves considerable work and is too small.

CONCLUSIONS

1. As the low cost solution, the Oinafa Wharf causeway could be modified by filling the existing bridge. This would stop sand from entering the wharf basin via the bridge, and enable this sand to be pushed back eastward by natural processes to stabilise Oinafa Point. The sooner the bridge is filled in the sooner the basin shoaling should cease or be lessened.

2. As a higher cost ideal solution, the Oinafa Wharf causeway could be partially replaced by a bridge starting back at the original shoreline of Oinafa Point. This arrangement should prevent accumulation of sand in the wharf basin and let the Oinafa Point shoreline return to near its original shape and location. Initial dredging will be required but future maintenance dredging should be minimal.

3. A new wharf could be built as an open pile structure to the northwest of the existing wharf. This would provide a deep water wharf without dredging the existing basin. This would not change the erosion on the east side of Oinafa Point or the accretion to the west side.

4. The existing wharf could be rebuilt but this would necessitate dredging of the present basin and maintenance dredging may be required in the future depending on modifications made to the access causeway.

5. If the Motusa site lagoon is deep enough or can be easily dredged and a suitable reef gap entrance channel can be excavated, this site warrants further consideration.

6. The Hopmafau Bay site is not deemed suitable because it is exposed to cyclone wind and waves from the south and would require considerable protection works.

7. The Solkope Island site is not feasible because it is too small and requires too much work.

RECOMMENDATIONS

1. That the Oinafa Wharf causeway be rehabilitated by filling in the present bridge to make a continuous causeway. This should be done as soon as possible to reduce shoaling of the wharf bas n and enable the sand to help stabilise Oinafa Point.

2. That the choice between:
   (a) rebuilding the existing wharf and dredging the basin or
   (b) building a new wharf on piles in deeper water to the northwest, be based on an economic comparison.

3. That, if the existing wharf basin is dredged, the dredged sand be dumped east of Oinafa Point to nourish and hasten the re-adjustment of the shoreline. Some dredged sand could be stockpiled for construction use.

4. That sand mining not be permitted from any beaches except at the terminal end of spits or where sand is being lost to deep water offshore.

REFERENCES

Brown, S.B., 1992. Retired Fiji Navy Commander, Oral communication.

Burgess, S.M.,1987. The Climate and Weather of Western Kiribati. New Zealand Meteorological Service. Miscellaneous Publication 188 (7).

Crane, E., 1988. Tropical Cyclones. Octopus Publishing Group (NZ) Ltd, 39 Rawene Road, Birkenhead, Auckland. ISBN 0 86863 476X.

Woodhall, D., 1987. Geology of Rotuma. Mineral Resources Department, Ministry of Lands Energy & Mineral Resources, Government of Fiji. Bulletin No.8

APPENDIX A

FIELD WORK LOG
ROTUMA, FIJI
28/04/92 - 2/05/92

Brendan Holden
SOPAC Technical Secretariat

Rupeni Mua
Fiji Ministry of Works

Field Work Log

Task92.FJ.19f
Rotuma Island, Fiji

Tuesday/28/April/1 992

Arrived Rotuma airport about noon, met the District Officer, and went to Gagaj Poar's house for official welcome as first time visitor to Rotuma. Inspected the beach and shore just east of Oinafa Wharf. Sand is moving westward and under bridge into wharf basin where bottom is shoaling and beach accreting.

Wednesday/29/April/1992

General overview inspection of Rotuma Island coastline to view possible alternative wharf sites and sand mining sites. The alternative wharf sites were north and south sides of the Motusa tombolo (isthmus) and behind Solkope Island near Kalvaka.

Thursday/30/April/1992

AM — Detailed inspection of entire east shoreline of Rotuma by walking from Oinafa around to Kalvaka. Important beach features were noted and photographed. At Paptea there are black rock outcrops with plenty of sand trapped on the beach indicating littoral drift to be northwestward. North of Marama, littoral drift is northwestward. From Marama to Noatau, there is a scarcity of sand on shore and littoral drift is southward or less well defined. South of Noatau, littoral drift is south and south west. There are large accumulations of sand just west of Ututu and at Kalvaka.

PM — Detailed inspection of Oinafa Wharf area. Size of stable armour stone at head of wharf is 0.6m and along seaward side of wharf is 0.4m. There appears to be about 100m accretion to the bay beach since the wharf was built. Accretion seems to be limited by flushing under the bridge.

Night — Attended community meeting at next village and showed video on "waves" but "beaches" video jammed.

Friday/1/May/1992

Went to west end of Rotuma for detailed inspection of alternative sites near Motusa tombolo, visited volcanic caves (tubes) near shore at Fapufa and on top of Mount Fauta. The Motusa Point sand spit is reported to have started building only recently, but there are no recollection of any man made alterations to the shore or the reef. Some erosion is reported on the shore west of Motusa Point where the reef gap comes close to shore.

Saturday/2/May/1992

Return to Suva

APPENDIX B

ROTUMA WIND DATA

from

JOHN REVFEIM
FIJI METEOROLOGICAL SERVICE
PRIVATE BAG, NADI, FIJI

FAX (679) 790 430/790 190

NZ METEOROLOGICAL SERVICE

WIND ROSE DATA - FREQUENCIES PER THOUSAND OBSERVATIONS
NOTE: 0 INDICATES OCCURRENCES < 0.5, A BLANK INDICATES NO OCCURRENCES

J65000 ROTUMA   HT ABOVE MSL 26M   LAT 12 30S LONG 177 3E   GRID REF

DATA PERIOD JUL 1976 - DEC 1985   OBSERVATIONS HOURLY 0000-2300 HR

JULY

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	2	4	4	3			15
NE	4	14	15	4			37
E	124	169	159	51	5		508
SE	10	37	60	60	12	6	186
S	0	5	19	20	2	1	39
SW	1	1	1				3
W						1	1
NW				1			1
						CALM	211
TOTAL	143	231	250	140	19	7	
TOTAL OBSERVATIONS USED							1501

AUGUST

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N		3					3
NE	4	17	12				33
E	154	162	187	68	1		572
SE	8	49	79	51	5	2	192
S	4	7	21	18	7	4	61
SW							
W			1				1
NW							
						CALM	138
TOTAL	170	237	301	136	13	6	
TOTAL OBSERVATIONS USED							1403

SEPTEMBER

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	1	3	3	2	7		11
NE	7	9	2	1	0		20
E	135	175	166	64	1	1	542
SE	16	43	87	58	12		216
S	5	12	17	12	2		48
SW			1				1
W			2				2
NW			1				1
						CALM	160
TOTAL	164	244	278	136	16	1	
TOTAL OBSERVATIONS USED							1466

OCTOBER

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N		2	3	1			5
NE	4	16	11	5	0	0	36
E	76	178	161	50	1	0	466
SE	12	56	80	42	7	2	199
S	4	27	25	7	2	3	69
SW		1	1	0	0		2
W		0		1	0		2
NW		0		1	1		2
						CALM	220
TOTAL	96	280	280	107	11	6	
TOTAL OBSERVATIONS USED							1580

NOVEMBER

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	3	6	3	2			13
NE	6	23	19	8	1		56
E	92	143	136	33	1	1	405
SE	15	45	43	38	5	1	146
S	5	5	11	3	1		26
SW	0	3	1				5
W	1	10	3	0			15
NW		2	2	0			4
						CALM	330
TOTAL	122	236	218	84	8	1	
TOTAL OBSERVATIONS USED							1599

DECEMBER

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	4	6	11	3	5		30
NE	11	21	16	9	3	2	62
E	46	118	80	18	1		263
SE	24	57	51	12	3		148
S	11	29	17	4	2	0	63
SW	4	15	9	3	1	2	34
W	3	16	12	9	2	2	44
NW	1	2	3	1	2		8
						CALM	348
TOTAL	105	264	200	59	19	6	
TOTAL OBSERVATIONS USED							1809

NZ METEOROLOGICAL SERVICE

WIND ROSE DATA - FREQUENCIES PER THOUSAND OBSERVATIONS
NOTE: 0 INDICATES OCCURRENCES < 0.5, A BLANK INDICATES NO OCCURRENCES

J65600 ROTUMA HT ABOVE MSL 26M LAT 12 30S LONG 177 3E GRID REF

DATA PERIOD JUL 1978 - DEC 1985 OBSERVATIONS HOURLY 0000-2300 HR

JANUARY

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	9	19	27	23	11	4	93
NE	9	33	16	13	2	0	72
E	35	69	19	6	1	1	131
SE	12	45	21	1			79
S	7	18	6	2			32
SW	7	9	13	3	2	1	35
W	15	20	20	30	8	2	96
NW	6	16	22	20	2	1	67
						CALM	395
TOTAL	99	229	143	98	26	10	

TOTAL OBSERVATIONS USED 1514

FEBRUARY

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	6	17	29	24	10	3	89
NE	17	19	16	8	2		62
E	53	64	42	8	1		169
SE	5	21	18	4			46
S	10	24	14	4			52
SW	8	12	5	6	1		31
W	19	29	27	22	2	1	101
NW	5	14	14	10	1		44
						CALM	403
TOTAL	124	199	166	86	17	5	

TOTAL OBSERVATIONS USED 1455

MARCH

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	12	33	33	25	6	9	118
NE	15	41	43	13	1		112
E	17	68	37	3	1		126
SE	6	27	16	1			51
S	4	17	12	7			39
SW	5	17	16	14	1		54
W	6	26	25	20	3	1	80
NW	3	17	17	17	2	2	58
						CALM	362
TOTAL	68	245	199	101	13	11	

TOTAL OBSERVATIONS USED 1559

APRIL

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	5	21	16	4			46
NE	7	17	7	2			33
E	104	134	58	14	1		311
SE	7	38	29	13	6	1	93
S	3	11	1				15
SW	0	10	3	1	2	1	16
W	5	14	12	10	4	2	48
NW	5	5	6	4	1	0	22
						CALM	418
TOTAL	136	249	133	47	14	3	

TOTAL OBSERVATIONS USED 1451

MAY

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	3	2	0	1	2	2	12
NE	6	10	5	1	1	0	23
E	129	152	93	19	1	1	395
SE	26	67	89	22	4		208
S	4	24	10	1	1		39
SW		3	3	0			6
W		4	7	3	1		16
NW	1	2	6	2	0		13
						CALM	287
TOTAL	169	264	216	49	10	3	

TOTAL OBSERVATIONS USED 1539

JUNE

SPEED(KT) DIR	1-3	4-6	7-10	11-16	17-21	22-99	TOTAL
N	2	2	5	1		1	11
NE	4	16	11	6	0		32
E	111	203	160	32	5		511
SE	31	43	75	36	14	3	202
S	1	10	8	4			24
SW		1		1			2
W	1	3	1	1			5
NW		1	0				1
						CALM	212
TOTAL	150	280	260	76	19	4	

TOTAL OBSERVATIONS USED 1506