# COASTAL EROSION PROBLEMS IN THE GILBERT ISLANDS GROUP, REPUBLIC OF KIRIBATI
## Phase II

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Personnel participating in the field work included:

**Week One** (Abaiang, Marakei, Makin, Butaritari)

| | |
|---|---|
| Rick Gillie | Coastal Geologist, Axys Environmental Consulting Ltd., Canada (under contract to SOPAC) |
| Naomi Biribo | Minerals Officer, MENRD |
| Amberoti Nikora | Surveyor, Lands and Survey Division |
| Tererei Abete | Environment Officer, MENRD |
| Tiaon Kabauci | Assistant Engineer, Public Works Division |

**Week Two** (Tamana, Arorae, Beru, Nikunau, Aranuka)

Team same as for Week One with a change in PWD representative:
Tapetulu Merang Engineer, Public Works Division

Mr Allan Gee, a UN funded consultant to the Ministry of Finance and Economic Planning also travelled with the team during week two and conducted independent work unrelated to the coastal survey.

Assistance was provided by the ground staff, island agents and pilots of Air Tungaru Limited. The cost of the aircraft charter was the responsibility of SOPAC.
Ground transport was provided by island council trucks where available. The cost of the ground transport was the responsibility MENRD.

Assistance while working on the outer islands was provided by the presidents and clerks of the relevant island councils and the village elders who gave a much needed historical perspective on the local situation. Their co-operation and interest in the survey work is much appreciated.

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## SUMMARY

At the request of the Government of the Republic of Kiribati a reconnaissance survey of coastal erosion sites was conducted on islands in the Gilbert Group (Figure 1) from 29 March - 11 April 1993. This was phase II of a survey started in August 1992. The results of the earlier survey are reported in Gillie (1992c; 1993a).

The survey team was lead by the Minerals Officer from the Ministry of Environment and Natural Resources Development (MENRD). Other personnel on the team included a coastal geologist working as a consultant under contract with SOPAC, a Surveyor from the Lands and Survey Division and an Engineer from the Public Works Division (PWD). The Environment Officer from MENRD also travelled with the team and carried out an independent survey on environmental concerns and the development of the National Environment Management Strategies (NEMS) for Kiribati.

The primary objective of the survey was to define the extent and severity of coastal erosion at predetermined sites in the Gilbert Islands. During 12 days of field survey work nine islands were visited (Abaiang, Marakei, Makin, Butaritari, Tamana, Arorae, Beru, Nikunau and Aranuka) and 21 sites with a history of coastal erosion problems were surveyed. Survey methods included the use of existing maps (1 :25 000), vertical air photos from 1969 and 1984, a physical assessment of the local site, establishment of a beach profile and interviews of local people to determine historical information on the site, the amenities affected and what action or assistance is requested. In the case of four islands (Abaiang, Marakei, Beru, Nikunau) a vertical air photo survey of the erosion sites was also conducted. Ground and oblique air photographs were also obtained and a literature search for any previous, coastal studies on the islands was also made.

As with the previous phase of the survey (Gillie 1992c; 1993a) the preliminary findings of this survey indicate that at the sites visited where coastal erosion is a problem, the causes of the erosion fall into two main categories: natural and man-made. In addition, previous attempts at management of coastal erosion problems using foreshore protection (engineering structures) as the exclusive response have been largely unsuccessful. In most cases the relatively expensive engineering structures have either failed or may have accelerated the erosion of beaches.

**Without fundamental changes in shoreline management practices in Kiribati, coastal erosion problems will increase in frequency and severity and the loss of beaches is expected to accelerate. This is primarily due to the trend of intensive shoreline occupation and development, ineffective coastal zone planning procedures and the practice of seawall construction as the usual response to coastal erosion problems. Other response**

**strategies to coastal erosion problems such as accommodation (land use planning) and retreat (relocation and set-back guidelines) need to be given higher priority**. In this regard, it is noteworthy that on islands where villages are presently exposed to open ocean waves (Tamana and Arorae, for example) the response to storm inundation and flooding includes a traditional buffer zone and set-back of 20-30 m from the active beach ridge.

It is also important to note that this reconnaissance survey of known sites of coastal erosion has been useful in determining the nature and extent of coastal erosion where it is presently a problem. However, generalizations regarding the overall extent and severity of coastal erosion, accretion and stability in the islands of the Gilbert Group should not be made from this study alone. It is recommended that a much broader coastal survey and mapping project needs to be undertaken to define the overall shoreline characteristics, stability and vulnerability of the islands to coastal erosion.

## INTRODUCTION

One of the problems facing the small, narrow and low lying coral atoll islands of Kiribati is coastal erosion. This problem is worst in South Tarawa where high population densities and scarce land have resulted in over crowding and over exploitation of the physical resources of the coastal zone.

Coastal erosion problems are also common to a lesser extent on all of the less densely populated islands in the Gilbert Group (Figure 1). Coastal erosion in some cases has resulted in the loss of houses, roads, coconut trees and highly valued land. In many cases foreshore protection projects to stop the erosion have been of little value and most seawalls do not last long enough to justify their cost of construction. In recent years, during the session of Parliament, it was made clear that the problem of coastal erosion was affecting all islands in the Gilbert Group and that people were demanding assistance to curb the destruction of erosion to their shoreline and villages (T. Iuta, written comm. 1991).

As a result of the concern in Kiribati, SOPAC was approached to undertake a study of coastal erosion of all the islands in the Gilbert Group. SOPAC was directed to look into the causes of erosion on an island by island basis and then to recommend actions to remedy the problem. SOPAC was also asked to look into cheaper and more practical methods of controlling coastal erosion than the expensive construction of seawalls. Possible methods include reopening channels closed by causeways, relocation of roads and planting mangroves to stabilize the tidal flat area. All of this work was deemed necessary before embarking on further attempts to control the problem.

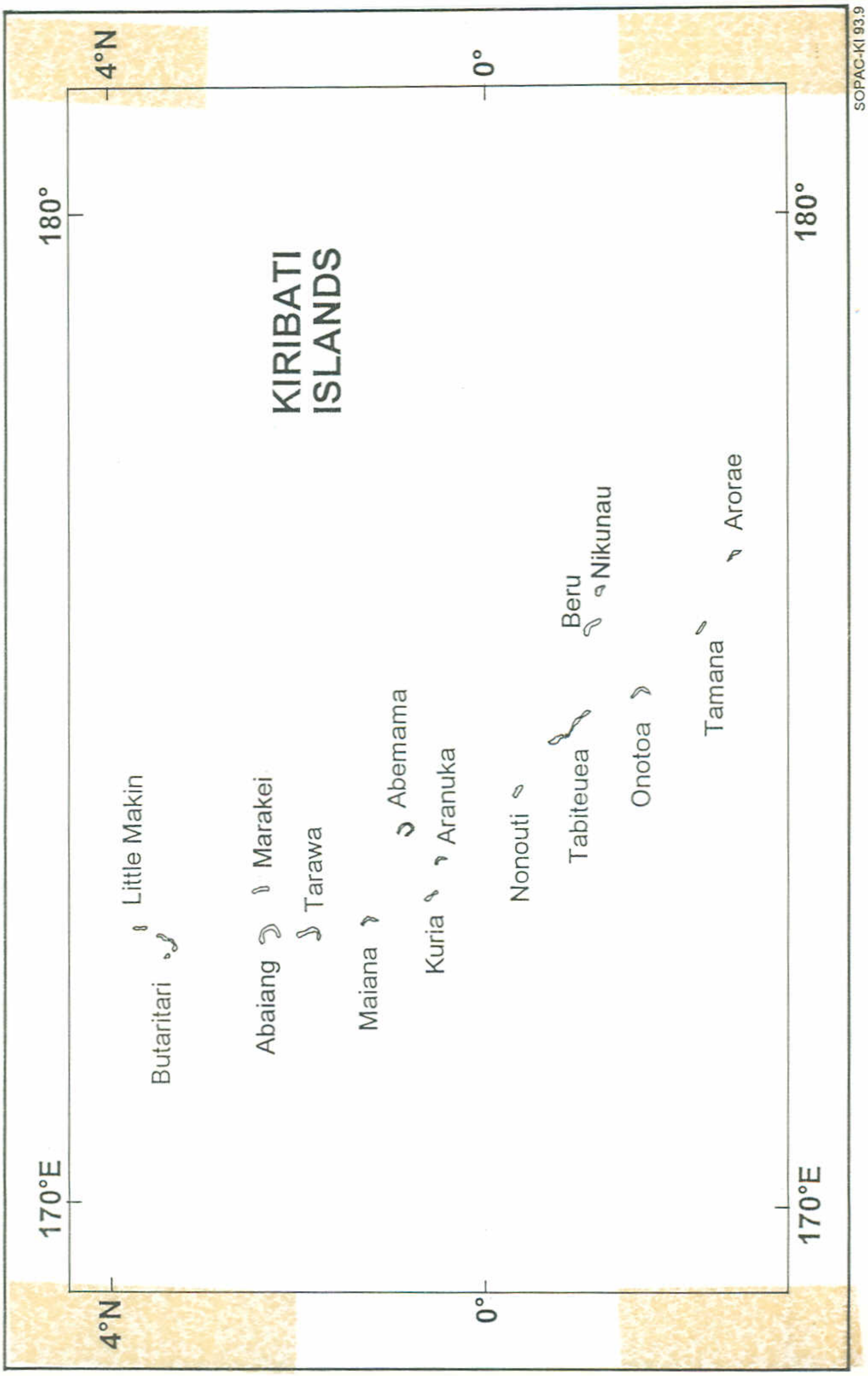


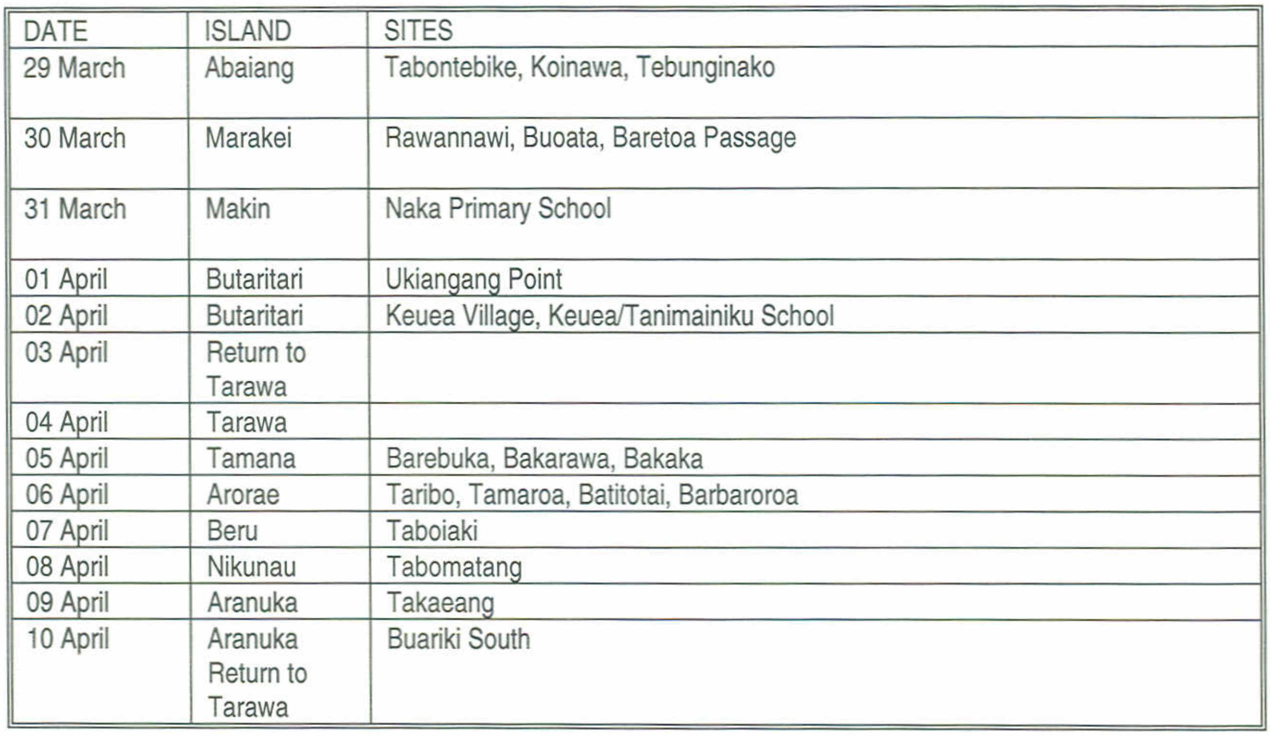
Figure 1. Islands visited in the Gilbert Group included Abaiang, Marakei, Makin, Butaritari, Tamana, Arorae, Beru, Nikunau and Aranuka.

Because of the large amount of time and personnel resources that would be required to undertake a study of coastal erosion of all the islands in the Gilbert Group, it was decided to conduct a reconnaissance survey of sites on the outer islands where erosion has been recognised as a problem. Again, because of personnel commitments, the study was commenced with an initial survey of five islands in August 1992 (Gillie 1992c; 1993a). During this study (Phase II) a further nine islands were visited in March/April 1993. The only islands not included in the survey were Tarawa (the capital island) and Maiana. The sites to be visited were selected by the Public Works Division of the Ministry of Works and Energy, Kiribati. The sites were known to have a history of erosion and in many cases had received government assistance for foreshore protection projects in the past. While conducting the survey the team was also directed to additional sites on the islands where erosion had taken place in the recent past.

The present survey was conducted from 29 March - 11 April 1993. A schedule of field work is presented in Table 1. A detailed log of field activities is presented in the SO PAC Preliminary Report (Gillie 1993b).

The project was conducted as part of the Coastal Program for Kiribati: Project K1.13. Data collected during the field survey is archived at SOPAC as Survey No. KI.93.02. The beach profile data is archived at the Lands and Survey Division, Tarawa as Survey Report No. 37/93.

**Table 1**. Schedule of field survey work (29 March - 11 April, 1993).



| DATE | ISLAND | SITES |
|---|---|---|
| 29 March | Abaiang | Tabontebike, Koinawa, Tebunginako |
| 30 March | Marakei | Rawannawi, Buoata, Baretoa Passage |
| 31 March | Makin | Naka Primary School |
| 01 April | Butaritari | Ukiangang Point |
| 02 April | Butaritari | Keuea Village, Keuea/Tanimainiku School |
| 03 April | Return to Tarawa | |
| 04 April | Tarawa | |
| 05 April | Tamana | Barebuka, Bakarawa, Bakaka |
| 06 April | Arorae | Taribo, Tamaroa, Batitotai, Barbaroroa |
| 07 April | Beru | Taboiaki |
| 08 April | Nikunau | Tabomatang |
| 09 April | Aranuka | Takaeang |
| 10 April | Aranuka<br>Return to Tarawa | Buariki South |

## OBJECTIVES

Very little information was available on the coastal erosion sites prior to the visit to Kiribati. Previous site specific coastal erosion studies had been conducted on Abaiang (Harper 1989; Holden 1992) and reconnaissance geology surveys on other outer islands (Richmond 1991). General reviews of coastal processes in the Gilbert Group are included in McLean (1989) and Woodroffe and McLean (1992)

The objectives of Phase II of the reconnaissance survey of coastal erosion sites in the Gilbert Island Group were defined by SOPAC in their written correspondence of 3 March 1993 as follows:

1. define the extent, severity and causes of coastal erosion at various sites in the islands;

2. determine the relative amount of erosion of each site in terms of its severity and the amenities affected;

3. acquire vertical air photos of sites investigated;

4. recommend actions and options to be undertaken in order to deal with erosion problems found.

As in the first phase of the survey (Gillie 1993a) the plan of work called for a coastal scientist, with the assistance of Kiribati government staff, to visit islands in the Gilbert Group and examine localities where erosion has been identified as a problem.

## REVIEW OF LITERATURE

A search of the literature on the Gilbert Island Group with respect to published and unpublished research on geology, coastal evolution and coastal processes was conducted during Phase I of the study (Gillie 1993a). The results of the literature review are presented again in this report for Phase II of the study. The literature search uncovered a number of relevant studies from which the significant results are summarized below. In general the studies can be classified under the following major themes:

1. Geologic origin and tectonics.

2. Reef growth and atoll evolution in the last 100 000 years.

3. Islet formation and evolution on atoll rims from the late-Holocene (4 000 years BP) to the present.

4. Coastal processes, coastal erosion and coastal engineering studies conducted in the recent past. A majority of these have been conducted by SO PAC on South Tarawa.

5. Climatology, meteorology and oceanography.

6. Climate change, sea level rise and the possible impacts on atolls.

### Geologic Origin and Tectonics

The 16 islands of the Gilbert Group are composed of 11 atoll reefs and five table reefs. The atoll islands comprise an annular ring of coral reef with a central lagoon which is open to the ocean via passages and or submerged reef. The extent of lagoon enclosure varies from almost total enclosure of the lagoon as at Marakei Atoll, to no constriction as at Nonouti and Tabiteuea. The table reef islands do not have lagoons or the lagoons have been filled so that most of the reef platform is covered with land with a fringing reef.

The islands of the Gilbert Group have developed on a northwest trending series of slowly subsiding, mid-oceanic volcanoes on the western edge of the Central Pacific Basin. Based upon magnetic anomalies, the age of the oceanic crust is Early Cretaceous (126 mal near Tabiteuea and Beru and Late Jurassic (139 mal further northwest near Butaritari (Circum-Pacific Tectonic Map of the Pacific, in prep). Subsequent to crustal formation and ocean floor spreading, volcanoes formed on the seabed. No atolls in Kiribati have been drilled to determine the depth or age of their volcanic cores. However, the nearest atolls to Tarawa that have been drilled are Funafuti in Tuvalu, where the drill hole was still in limestone at a depth of 330 m (Hinde 1904), and Eniwetok in the Marshall Islands, where basalt was reached after penetrating 1300 m of limestone (Ladd et al1953). The period of volcanic activity in Kiribati is believed to have occurred between 50 and 10 ma (L. Kroenke, pers. comm. 1992).

Concepts regarding the present tectonic situation in the Gilbert Group are under review. An earthquake swarm in 1981-1983 near Arorae was identified by Lay and Okal (1983). This and other seismicity and seafloor information in the Western Pacific was compiled as evidence to postulate the formation of a new trench in the Western Pacific which runs just southwest of the southern Gilbert Group (Kroenke and Walker 1986). What effect this is presently having on rates of subsidence or uplift within the group is not known.

Long term rates of subsidence for the Gilbert Group can be estimated from other mid-ocean atolls. Subsidence rates range between 0.03 and 0.06 mlka for Bikini, Eniwetok and Midway (Paulay and McEdward, 1990). In the central Pacific during the Cenozoic the average rate of sinking has been about 0.02 mlka with a possible increase to about twice this value in the last five million years (Schofield, 1977a). Therefore, the rate of subsidence in the Gilbert Group is probably in the order of 0.05 m/ka or 0.05 mm/a. By comparison, the rate of global sea level rise is estimated to be 1-2 mm/a (Wyrtki 1990) or 20 times greater than the rate of subsidence. Therefore, on this basis the islands of the Gilbert Group can be considered as relatively stable.

## Atoll Evolution and Reef Growth

The coral islands of the Gilbert Group have formed and evolved over millions of years on gradually subsiding volcanic basements. Over the same period the atolls have been affected by large changes in sea level, in particular those associated with glaciations during the Quaternary Era (the Ice Ages of the last 2 mal. The atolls would have been emerged above the sea and eroded by solution during low sea levels of glacial periods. Conversely, during the high sea levels of interglacials, reef growth would have re-established on the atoll surface. Approximately 120 000 years ago, during the last interglacial, sea level was near the present level. In the intervening glacial period sea level fell more than 100 m, and the atolls were exposed as limestone islands and would have appeared much the same as Banaba Island and Nauru Island are today. The limestone underwent solution which lowered its surface elevation, and along with gradual subsidence, combined to create a total lowering of the surface by 10-20 m (Woodroffe and McLean 1992).

Beginning about 15 000 years ago, global sea level rose rapidly from more than 100 m below present. Drill cores to a depth of 30 m have been obtained from Tarawa (Marshall and Jacobsen 1985). In general the drill holes passed down through similar lithological sequences from (i) surfical conglomerate rock and/or (ii) unconsolidated sediments, to (iii) corals, to (iv) leached limestone. The upper three lithologies were all dated as less than 8 000 years old (Holocene) while the leached limestone was 125 000 years old, indicating that the foundation of the Holocene reef deposits are carbonates of the last inter-glacial. Approximately 20 samples from depths of 4-14 m were radiocarbon dated between 8 000 and 6 000 years BP and it is therefore evident that Holocene reef growth on Tarawa began about 8 000 years before present. Vertical rates of reef accretion derived from this study were 5-8 m/ka.

Based on this data and other studies McLean (1989) proposes a three stage model for the Holocene evolution of the atolls. The first phase from about 8 000 to 6 000 BP was a phase of rapid vertical reef grow1h as the reefs strived to "catch up" with a rapidly rising sea level. The second phase from abut 6 000 to 3 500 years BP was a phase of reef flat formation as reefs caught up with sea level and consolidated. The third phase, perhaps starting around 3 500 years ago and continuing to the present is a phase of reef islet formation. Therefore, the atoll rim islets which form the inhabited land area in the Gilbert Group are geologically very young.

## Islet Formation and Evolution

According to McLean (1992), there is considerable evidence that the sea stood 1-2 m above its present level with respect to many of the coral atolls of the Pacific and Indian Oceans about 4 000-3 000 years ago and that in the last few thousand years sea level has fallen relative to those islands. In this respect, cemented coral conglomerates (cay rock or conglomerate) on the reef flats and islands of atolls, and above the present limit to coral grow1h, have been radiometrically dated on many atoll islands, including Kiribati and Tuvalu (Schofield 1977a, 1977b).

According to Richmond (1992) two necessary conditions for the formation of atoll islets are (i) a reef platform near present sea level and (i1) the accumulation of material above the high water level. The conglomerate rock formations at elevations of less than 2 m above present sea level represent the initial stage or nuclei of islet formation. Once formed, the higher level conglomerate deposits provided the foundation of islets. These probably resulted from storms depositing material above the normal high tide. Falling sea levels in the last 4 000 years may have also assisted their formation. Richmond (1992) further distinguishes at least four major types of islets, based upon morphology, sediment and rock characteristics, and position on the atoll rim. These types are summarised in Table 2.

## Contemporary Coastal Processes and Engineering

According to Woodroffe and McLean (1992) "There is almost no information on the natural dynamics of the shorelines of atolls. Kiribati lies in a part of the Pacific affected by EI Nino, which accounts for major variations in climatic factors and water levels. There is no information on rates of sediment production, patterns of sediment movement, or rates of sediment deposition". This statement largely ignores the large amount of valuable research which has been conducted by SOPAC on coastal processes in Kiribati, mostly on South Tarawa in the last ten years.

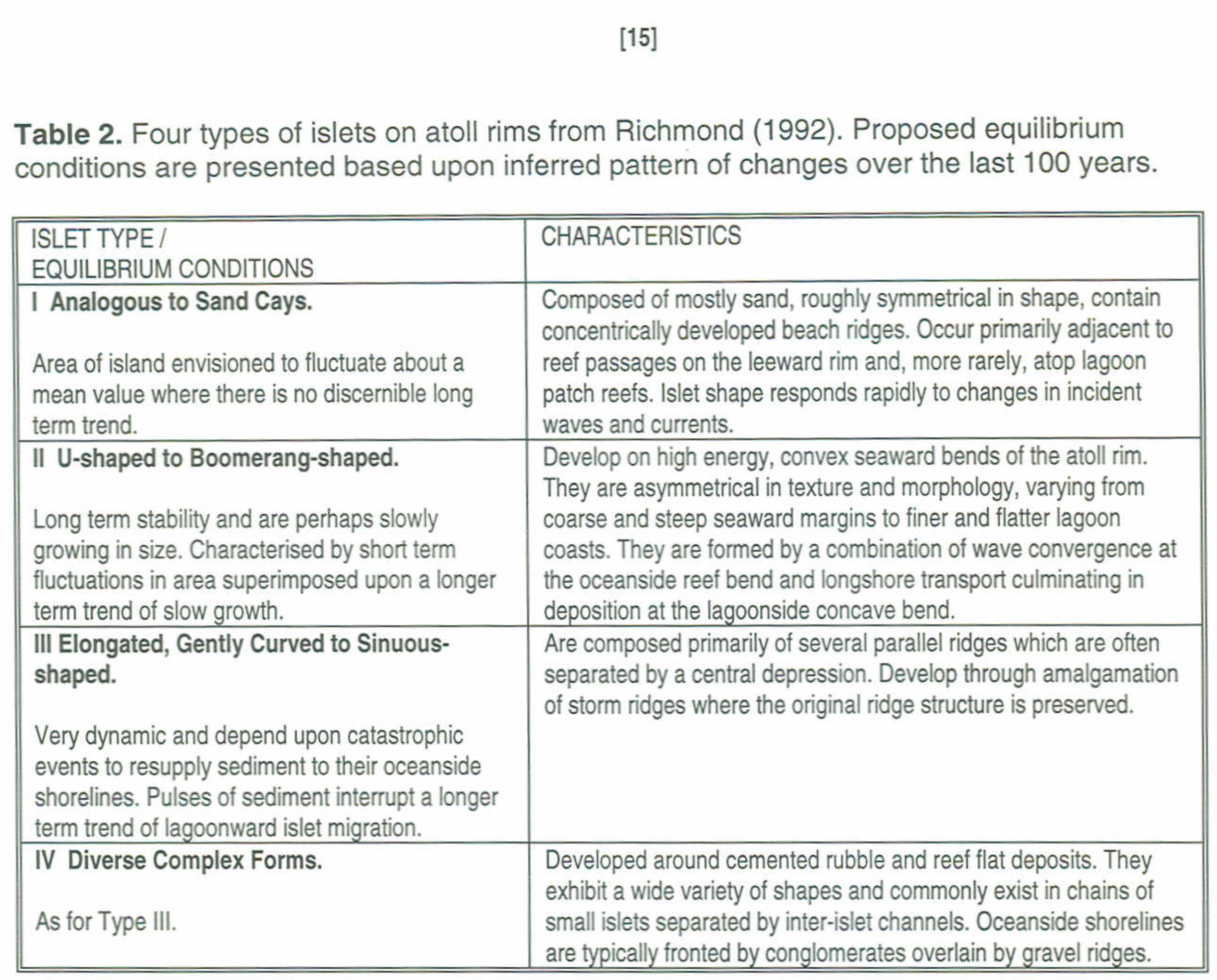


**Table 2.** Four types of islets on atoll rims from Richmond (1992). Proposed equilibrium conditions are presented based upon inferred pattern of changes over the last 100 years.

| ISLET TYPE / EQUILIBRIUM CONDITIONS | CHARACTERISTICS |
|---|---|
| **I Analogous to Sand Cays.**<br>Area of island envisioned to fluctuate about a mean value where there is no discernible long term trend. | Composed of mostly sand, roughly symmetrical in shape, contain concentrically developed beach ridges. Occur primarily adjacent to reef passages on the leeward rim and, more rarely, atop lagoon patch reefs. Islet shape responds rapidly to changes in incident waves and currents. |
| **II U-shaped to Boomerang-shaped.**<br>Long term stability and are perhaps slowly growing in size. Characterised by short term fluctuations in area superimposed upon a longer term trend of slow growth. | Develop on high energy, convex seaward bends of the atoll rim. They are asymmetrical in texture and morphology, varying from coarse and steep seaward margins to finer and flatter lagoon coasts. They are formed by a combination of wave convergence at the oceanside reef bend and longshore transport culminating in deposition at the lagoonside concave bend. |
| **III Elongated, Gently Curved to Sinuous-shaped.**<br>Very dynamic and depend upon catastrophic events to resupply sediment to their oceanside shorelines. Pulses of sediment interrupt a longer term trend of lagoonward islet migration. | Are composed primarily of several parallel ridges which are often separated by a central depression. Develop through amalgamation of storm ridges where the original ridge structure is preserved. |
| **IV Diverse Complex Forms.**<br>As for Type III. | Developed around cemented rubble and reef flat deposits. They exhibit a wide variety of shapes and commonly exist in chains of small islets separated by inter-islet channels. Oceanside shorelines are typically fronted by conglomerates overlain by gravel ridges. |

SOPAC has produced over 20 reports on coastal studies in South Tarawa which have identified sources and amounts of sediment production, historical shoreline changes, beach dynamics through profile monitoring, the effect of engineering structures on coastal processes, coastal mapping and coastal management: Burne (1983), Byrne (1991), Carter (1983), Gauss (1982), Gillie (1991, 1992a, 1992b, 1992c), Gillie and Woodward (1992), Harper (1987, 1988, 1989a, 1989b), Howorth (1982, 1983a, 1983b, 1985, 1991), Howorth, Cowan and Carter (1986), Howorth and Radke (1991), Howorth and Richmond (1988), Richmond (1990), Sherwood et al (1992). In addition, SO PAC has also conducted a limited amount of work on coastal processes in the outer islands of the Gilbert Group (Harper 1989; Holden 1991, Holden 1992; Richmond 1990, 1991).

Major reviews of coastal protection, causeway construction practices and the effect on natural coastal processes in Gilbert Islands have been reported in AIDAB (1988), Colman (1989), Gilmour and Colman (1990), Holmes (1979), Hydraulics Research Station (1976). One of the major conclusions of these reviews is that many coastal protection projects have not only failed to resolve the particular problem that prompted the works but have also led to a deterioration of the situation and undesirable secondary effects. There has been a relatively high rate of failure of previous coastal projects.

In this regard, it is clear that a more comprehensive approach to coastal management strategies is warranted. The aim of a more comprehensive approach is to provide a greater understanding and prediction of the natural processes of sediment and water movement and the impact of engineering works on the coastal zone. There has also been a growing appreciation of alternatives to seawall construction as a first resort or response to coastal erosion. Alternatives include relocation away from the shoreline and improved land use planning and management to avoid potential problem areas (see Appendix 5).

## Climatology, Meteorology and Oceanography

The most recent and complete description of the climate and weather of the Gilbert Group is contained in Burgess (1987). Although the Gilbert Group has a maritime equatorial climate with little variation in temperature throughout the year, there are marked seasonal (inter-annual) and year to year (intra-annual) variations in rainfall, wind speed and direction, wave climate and sea level which have implications for coastal processes.

There are two seasons, namely wet and dry. The former is well known in Kiribati as "Te Au Meang" and the latter as "Te Au Maiaki" (Tebano 1985). Te Au Meang refers to a prevailing north to northeast wind which normally brings a lot of rain and unsettled weather over the period November-April. Te Au Maiaki refers to south to southeast winds which are characterised by fine and settled weather.

### *Winds*

In general, moderate winds between the northeast and southeast prevail throughout the year. Winds are usually light to moderate and gales are rare. However, on most of the islands 60-80 percent of strong winds or greater (over 21 knots) are between northwest and southwest. Westerly winds are also usually associated with squally showery conditions. Tropical cyclones rarely form within 5 degrees of the equator as the Coriolis force is close to zero. For this reason there are no records of tropical cyclones having occurred in Kiribati, apart from an event recorded in late 1927 or 1928 when a "cyclone" is reported to have done considerable damage to the two most northern islands of Butaritari and Makin (Sachet 1957). Gale force west to northwest winds also occur when cyclonic systems are developing beyond 5 degrees to the north or south of the equator. Thus, although winds from an easterly quarter prevail, winds from a westerly quarter probably playa significant role in coastal processes within the lagoon environment, since westerly winds are onshore with respect to most lagoon beaches on atoll islets.

### *El Nino/Southern Oscillation*

Perhaps the most significant feature of the climate and weather of the Gilbert Group is the El Nino / Southern Oscillation (ENSO) phenomena which varies in period and intensity every few years. Because of the annual wet and dry season cycle described above, there are no local names in the Gilbert Islands for ENSO phenomena, which are considered to be more prolonged or extreme variations of the annual cycle. The terms "El Nino and La Nina" are used in the following as globally recognised terms for the two alternating extremes in ENSO phenomena. During "El Nino" episodes the Gilbert Group experiences a greater variation of wind patterns, the trade winds are diminished and there are periods of strong westerlies. There is also heavier than normal rainfall. Conversely, the climatic phase between El Nino, known as "La Nina", is characterised by persistent easterly winds and much lower than normal rainfall, sometimes resulting in severe drought. For example, Onotoa Atoll has an average annual rainfall of 1250 mm (50 inches). During El Nino periods the annual rainfall can reach 3000 mm. Conversely, during 1950 when a strong El Nina event occurred, Onotoa Atoll received only 150 mm of rainfall, with no rainfall over the first six months (Cloud 1952).

There were ENSO events in 1972 (moderate), 1977/78 (moderate), 1982/83 (strong), 1987 (moderate) and in 1991/92 (moderate). The terms moderate and strong refer to the values of the Southern Oscillation Index (SOl). Actual EN SO characteristics such as wind strength and direction, rainfall, sea surface temperatures and sea level deviations can vary within similar SOl values. Pacific atmospheric and oceanic conditions indicate that the 1991/92 El Nino was essentially over by July 1992 (NIWAR 1992).

### *Tides and Sea Level*

Tidal variation is reported for the reference station at Tarawa. Mean sea level is 1.00 m above chart datum. The mean neap tide range is 1.2 m and the mean spring tide range is 1.8 m (Hydrographer of the Navy, UK 1992). The maximum recorded levels vary from -0.3 to +2.45 m (Hydraulic Research Station 1976), but it is not known what these extreme levels were associated with.

There are also large fluctuations in sea level from year to year. All tide stations in Kiribati show a strong seasonal cycle in water level of the order of 10-20 cm related to the location and strength of the trade wind system (McLean 1989). There is also a strong fluctuation in water level associated with the ENSO phenomena. During the 1982/83 ENSO event the monthly mean sea level was 28 cm above the long term mean in 1982, but 21 cm below mean in late 1983. With the passage of the most recent, moderate ENSO event (1991/92) the mean monthly sea level has varied from +27 cm to -10 cm relative to the mean value (IGOSS 1992).

### *Waves*

High seas in this region are very rare, as winds seldom exceed gale force. Most waves in the open sea come from directions between northeast and southeast in association with the trade winds. However, the situation is not this simple. Cloud (1952) reported that during a extended survey (late June, July and August) on Onotoa in 1951 there was a "marked swell from the south which produced strong surf on exposed lee reefs that face the south". Similar conditions were also observed during the Phase I period of this study (August 1992). Persistent southerly swell was observed on the south and west sides of the atolls. Conversely, seas on the windward side of the atolls were composed of very low, locally generated seas. Thus, swell waves from more distant sources, such as the South and North Pacific mid-latitude storm belts, may also reach the area. It is also very likely that waves from cyclones passing to the north (Marshall Islands) and south (between the Solomon Islands and Tuvalu) will cause large swell waves to reach the area.

Within the lagoon of each atoll the wave climate varies considerably. The effect of the leeward reef rim on swell waves passing over it is essentially that of a submerged breakwater. This effect varies with water depth over the reef. Within the lagoon wave refraction is significant. During the survey, long period, low amplitude ocean swell was observed on lagoon beaches. However, of more importance to lagoon beach changes are waves generated by strong westerly winds within the lagoon. Again, the effect of this will vary considerably from site to site, since fetch lengths are so variable. Waves generated within the lagoon would be short period, but because of oblique angles of approach to the shoreline may cause greater longshore sediment transport and predominantly determine patterns of coastal erosion and accretion. In this respect, the strong westerly winds and higher than normal sea levels which characterise the early phase of El Nino events have been associated with periods of coastal erosion on the lagoon beaches of South Tarawa (Howorth 1991).

## Climate Change, Sea Level Rise and Impacts

Accelerated sea-level rise associated with global climate change is a recognized concern in Pacific Island countries, especially those with significant areas of low elevation such as atoll islets deltas and other lowland areas. It has been estimated that sea-level will rise by 18 cm by the year 2030 and 66 cm by the year 2100. Thus, over the next century the average rate of sea-level rise is projected to increase to 6 mm/year which is three to four times faster than the present rate. For the purpose of assessing coastal vulnerability to accelerated sea-level rise by the year 2100, a lower estimate of 0.3 m and a higher estimate of 1.0 m have been adopted as a guide for policy decision makers as reported by the Response Strategies Working Group, Coastal Zone Management Subgroup (IPCC 1992).

There have been a series of assessments of the physical vulnerability of low lying coral atoll nations to sea level rise. These have tended to be based on extremely limited empirical evidence of shoreline response to sea level rise. However for coral atolls it is critical to recognize that the balance between reef growth, island accumulation and sea-level rise will be important and will ultimately determine the habitability of the atoll islets. There have been several studies of the impact of climate change and sea level rise in Kiribati (Nunn 1988; McLean 1989; Sullivan and Gibson 1991; Woodroffe and McLean 1992). In particular, the following points are made in the executive summary of the report by Woodroffe and McLean (1992):

(i) Pacific Ocean water level trends reconstructed from tide gauges, and from large intertidal corals (microatolls) in Kiribati, do not indicate a trend of rising sea level as rapid as the global average, and do not yet show any identifiable acceleration;

(ii) there are pronounced seasonal and inter-annual variations in mean sea level in Kiribati related in particular to EI Nino, suggesting that the islands have a certain resilience to changes in water level, but also making determination of net change more difficult

(iii) the majority of the islands of Kiribati are probably subsiding at an imperceptibly slow rate (<0.2 mm/yr). (This report suggests that subsidence is about 0.05 mm/yr).

(iv) the reef islands of Kiribati are geologically very young, and appear to have developed in the last 3,000-4,000 years during a period when relative sea level has fallen from a level around 1 metre above present;

(v) there are a range of coastal types, representing various sediment sizes, morphology and states of lithification. each of which exhibits a different degree of vulnerability both to present erosional and accretional forces and to accelerated sea level rise;

(vi) coastal vegetation communities, particularly mangroves, offer a protection to the coast, and decrease shoreline erodibility;

(vii) the shorelines of reef islands (islets) in Kiribati are naturally dynamic; sediment is continuing to be produced; beaches both accrete and erode; and there are seasonal and year to year shifts in the patterns of sediment movement. There are also important coastal rock types, conglomerate and beach rock.

In addition to the above, there is still much uncertainty about the potential for accelerated sea level rise and its effects on shorelines. In order to evaluate the impact of sea-level changes on shorelines in the Gilbert Islands two general questions need to be addressed: (1) How have shorelines responded to sea-level changes in the past; and (2) How will shorelines respond in the future?

Considering that it is difficult to obtain consensus among the scientific community as to what presently constitutes evidence of coastal erosion associated with sea-level rise, and that future relationships can not be explicitly predicted, a cautious policy on development programs should be implemented. While a rise of sea level would obviously be a problem for many Pacific Island countries, there are more immediate coastal problems that need attention now. A hasty response of building seawalls to prevent overtopping by a higher sea level would be futile as the structures would not last long enough to be effective.

## FIELD ACTIVITIES AND METHODS

### Aircraft Charter

A Britten-Norman Tri-Islander was chartered from Air Tungaru for two six day periods for the outer island surveys (29 March - 3 April and 5 - 10 April). It was necessary to charter because of limited passenger service to the remote outer islands. The charter, although expensive. allowed the survey team to visit the greatest number of islands in the least amount of time.

The only constraint to the use of the aircraft was fuel limitations. For example during the first week's charter it was necessary to return to Tarawa to refuel after visiting Abaiang and Marakei before continuing further north to Makin and Butaritari. Similarly, in the second week a return to Tabiteuea North was necessary after visiting Tamana and Arorae, before continuing back south to Beru and Nikunau. Fuel considerations also severely limited air photo survey time to 20-30 minutes additional time between islands.

## Air Photo Surveys

An attempt was made to conduct air photo surveys of the study sites using the SOPAC air photo camera which had been developed for this purpose (Gillie 1992a). The camera has been used previously in Kiribati in May 1992 to conduct air photo surveys of selected areas along South Tarawa (Gillie 1992b).

Use of the camera was hampered by three factors. First, the weather was often rainy with very low cloud cover and dark light conditions. This was the case in the far north (Makin and Butaritari) and during the visit to the far south (Tamana and Arorae). Therefore no vertical air photography was conducted over these islands. The additional flying time required to conduct the air photos survey was also limited by aircraft fuel supply. In this regard it would have been impossible to conduct survey photography over Tamana and Arorae even if the weather had been good.

Using the allowable time, successful air photo surveys were conducted while transiting between Abaiang-Marakei and Beru-Nikunau. The additional charter time required to conduct the air photo surveys amounted to approximately 30 minutes between Abaiang-Marakei and 20 minutes between Beru-Nikunau. However in the case of the later, there was only enough time to run one line at low altitude over each site. Low clouds necessitated flying at 1,500 feet. The results of the air photo survey are reported separately (Gillie and Woodward, 1993). Only the area coverage is included here as Appendix 2.

## Topographic Maps

Topographic maps at a scale of 1:25.000 (1 :12,500 for Marakei) are available for all islands in the Gilbert Group. These were published in 1979-1980 and are based on 1: 10,000 aerial photography flown in 1968/1969. Maps for the islands to be surveyed were purchased from Lands and Survey Division on arriving in Kiribati. These were examined for pertinent information and taken into the field.

## Aerial Photographs

Aerial photographs of the Gilbert Islands are housed with the National Archives of Kiribati. All of the Gilbert Group was photographed at a scale of 1: 1 0,000 in 1968/1969 by the Department of Lands and Survey, Fiji. The negatives and track lines for this survey are now housed with the Ordnance Survey International in the United Kingdom. A more recent survey of portions of the islands was conducted at a similar scale in 1984 by the Australian Department of Defence. A search was made for photographs on file at the National Archives of Kiribati, the survey sites were examined and in some cases 35 mm photos were taken of the original air photos.

Since these photographs are the only copies that Kiribati has available they may not be taken from the Archives office. The cost of obtaining copies from the UK is very expensive (approximately AUD 70.00 for each print). In principle, analysis of coastal changes between 1969 and 1984 is possible from the older sets of air photos and comparison is possible with the new photos obtained during this survey. In some cases WWII photography may also be available from the US Navy. However, it is expected to be some time before these air photos can be procured and analysed by SOPAC and it has not been possible to carry out this part of the study.

## Field Survey Methods

The study of each site visited included the following survey components:

### *(a) Site Description*

Notes were made of the physical characteristics of the site including the nature and extent of the erosion, physical shoreline characteristics, sediments and morphology, shoreline protection structures present and amenities affected by the erosion;

### *(b) Interview of Local Sources*

Background information was obtained from representatives of the local community on observed coastal changes in the past, dates when shore protection was emplaced and the source of shore protection materials. A standard set of interview questions was used to obtain this information. Possible response options to the erosion problem were reviewed and discussed (see Appendix 4). The interviews were made by Naomi Biribo, MENRD.

### *(c) Survey of Shoreline Profile*

A typical profile of the shoreline was obtained using standard level, tape and survey staff equipment. Beach profile data was referenced to a relative bench mark. Documentation of the beach profile locations and sketches of the location of the bench marks were made by Amberoti Nikora, Lands and Survey Division. The originals of this information are archived with the Lands and Survey Division, Tarawa as Survey Report No. 37/93.

### *(d) Ground Photography Documentation*

Photos along and across the shoreline were taken. Oblique aerial photos were also obtained were possible.

### *(e) Aerial Photography Documentation*

As described above, aerial photos were taken of sites on four islands (Abaiang, Marakei, Beru, Nikunau). Surveys were flown at a height of 1 500 feet. The photos will be used to illustrate conditions of the site at the time of the survey and to compare to earlier survey photography, when it becomes available.

### *(f) Public Works Division Information*

PWD was asked to provide information (date, type, length, cost, etc.) on any previous coastal protection construction at the survey study sites (Appendix 3).

## RESULTS

The results of Phase II of the reconnaissance survey of coastal erosion sites on outer islands in the Gilbert Group are presented below. During 12 days of field survey work nine islands were visited (Abaiang, Marakei, Makin, Butaritari, Tamana, Arorae, Beru, Nikunau and Aranuka) and 21 sites with a history of coastal erosion problems were surveyed.

Each coastal erosion site is defined in terms of its location, a description of the site characteristics and the nature of the coastal erosion problem. Recommended action to be taken for each site is then presented. A summary of map sheet and site coordinate data is presented in Appendix 1. The coverage obtained during the air photo portion of the survey is presented in Appendix 2. Appendix 3 contains information provided on each site by a representative from the Public Works Division. Appendix 4 contains information provided from interviews conducted with local representatives. Appendices 5 and 6 contain, respectively, beach profile data and descriptions of beach profile bench marks.

## Abaiang: Tabontebike

### *Site Description and Erosion Problem*

The coastal erosion site is located at the southernmost tip of the island of Abaiang. The name Tabontebike means "end of the sand". The exact location is shown in Figure 2 and comprises most of the west facing beach in a shallow bay immediately north of Bolton Point. The area of concern is fronted by a reef flat covered with a variable veneer of coral cobbles and boulders. The inner portion of the reef flat has extensive areas of conglomerate platform which is breaking up into slabs. At the time of observation the tide was low and the reef flat was exposed (Figure 4). Although a swell of 1-2 m was breaking on the exposed east side of the island, only refracted waves of <0.3 m reached the reef directly off the study site. This indicates the site is sheltered from the prevailing easterly swell. However, it is directly exposed to westerly wind waves.

Moderate erosion of 5-10 m has occurred along 200-300 m of the sheltered ocean shoreline. The amenities affected include loss of coconut trees and swampy babai growing areas affected by salt water intrusion. Ownership of the affected areas is distributed as plots amongst many families.

Shoreline flooding was occasionally a problem in the 1950s when high spring tides and strong westerlies caused sea water to inundate the low lying babai swamp. A ridge was constructed (Figure 3) in the 1970s using earth moving equipment available on the island during the airfield construction. Subsequently a rock seawall of traditional design was constructed in the 1980s. Material for the ridge was obtained by loader/truck from the reef flat and the seawall was built with coral boulders/slabs collected from the reef.

The erosion is probably due to natural causes but was also made worse by removing large amounts of material from the reef flat. This effectively deepened the water over a portion of the reef and left a pool of water visible at low tide. The deeper water allows larger waves to directly approach the beach. The ability of the reef flat to protect the shoreline has been reduced by the removal of material and increase in the water depth.

### *Recommendations*

The concern at the Tebontebike site is that the beach crest will be breached and flooding of the backshore will result. A previous study of this site (Harper, 1989) recommended that no action be taken. This recommendation was based upon the assessment that although occasional wave

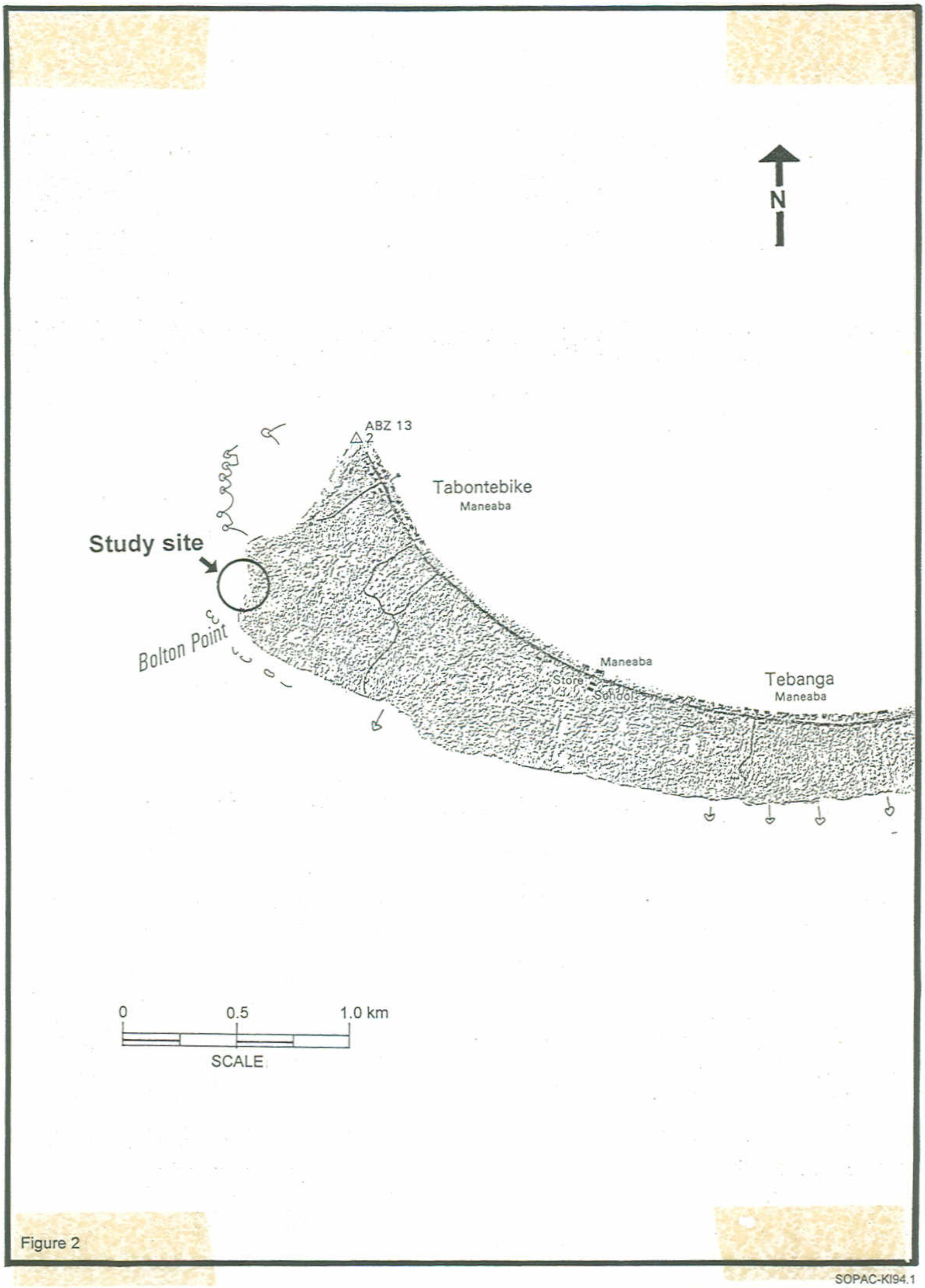


Figure 2. Map showing location of beach erosion study site at Tabontebike on southwest tip of Abaiang. Site is located in the shallow bay adjacent to Bolton Point.

Figure 3. Tabontebike, Abaiang. View of man-made ridge between beach (out of view to the left) and the low lying, swampy ground (to the right of truck).

Figure 4. Tabontebike, Abaiang. View north along section of eroding shoreline immediately north of Bolton Point.

overtopping of the berm crest may occur, given the close proximity of the backshore swampy area to the ocean it was not thought that this would lead to any significant change in groundwater salinity. The priority for any action at this site is not urgent nor is the magnitude of the natural physical hazard and the amenities which would be potentially affected large. Therefore, no immediate action is recommended for this site.

### Abaiang: Koinawa

#### *Site Description and Erosion Problem*

The study site is near the maneaba at Koinawa on the lagoon shoreline (Figure 5). Moderate erosion of 5-10 m has occurred along 150 m of the lagoon shoreline. The road adjacent to the shoreline at this location is subject to undermining if the erosion continues (Figure 6). Previously placed shore protection (a coral rubble mound seawall) along the threatened section of the road has collapsed. North of the site a well maintained seawall enclosing an area of reclaimed land projects 40 m into the lagoon. The owner of this land said that he had to continuously maintain his seawall. In this regard, he was critical of other residents in the vicinity who had not maintained seawalls.

#### *Recommendations*

Because of the position of the maneaba and the road, relocation of the road is not feasible. A previous study of this site (Harper 1989) recommended renewing the older shore protection over the 100-200 m of threatened road. Except for the previously placed shore protection materials (now collapsed), rubble material for any new shore protection should not be taken from the immediate site since this would aggravate the current erosion problem. Also, since the seawalls constructed in the past have been made of relatively small material and have failed it is expected continuous maintenance will be required unless larger material is used or concrete is employed to strengthen the seawall. In this regard, the use of a concrete strengthened coral boulder seawall is recommended rather than gab ion baskets.

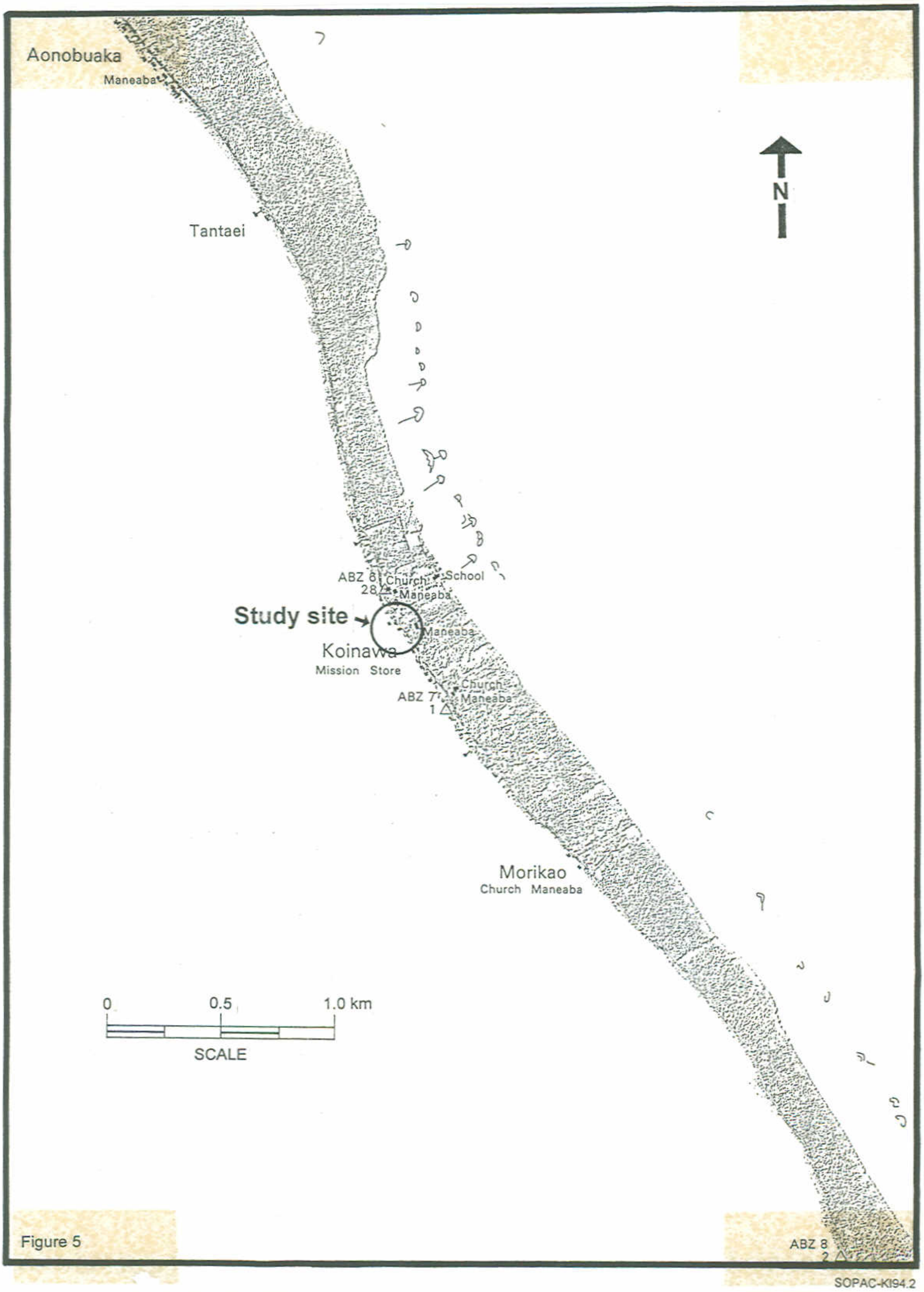


Figure 5. Map showing location of beach erosion study site along lagoon shoreline at Koinawa, Abaiang.

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Figure 6. Koinawa, Abaiang. View north along lagoon shoreline showing remains of previous rubble mound seawall on beach. The main island road is located immediately behind the beach.

## Abaiang: Tebunginako

### *Site Description and Erosion Problem*

This site is located along the lagoon shore on an old recurved spit complex (Figure 7). The length of shoreline being eroded extends over 500 m of which the southern-most 200 m is the most affected (Figure 8). Shoreline erosion has affected a large number of traditional house structures and two maneabas. The southern-most maneaba is now floored with sand washed in by waves. The foundations (coral rock pillars in the sand) are all that remain of a number of other traditional design buildings (Figure 9).

According to local information (Appendix 4) a village existed here at least 80 years ago. Over the last 60 years the number of people living in the village has increased. At least 50 years ago shoreline erosion was apparent. From 10 to 30 m of erosion may have taken place.

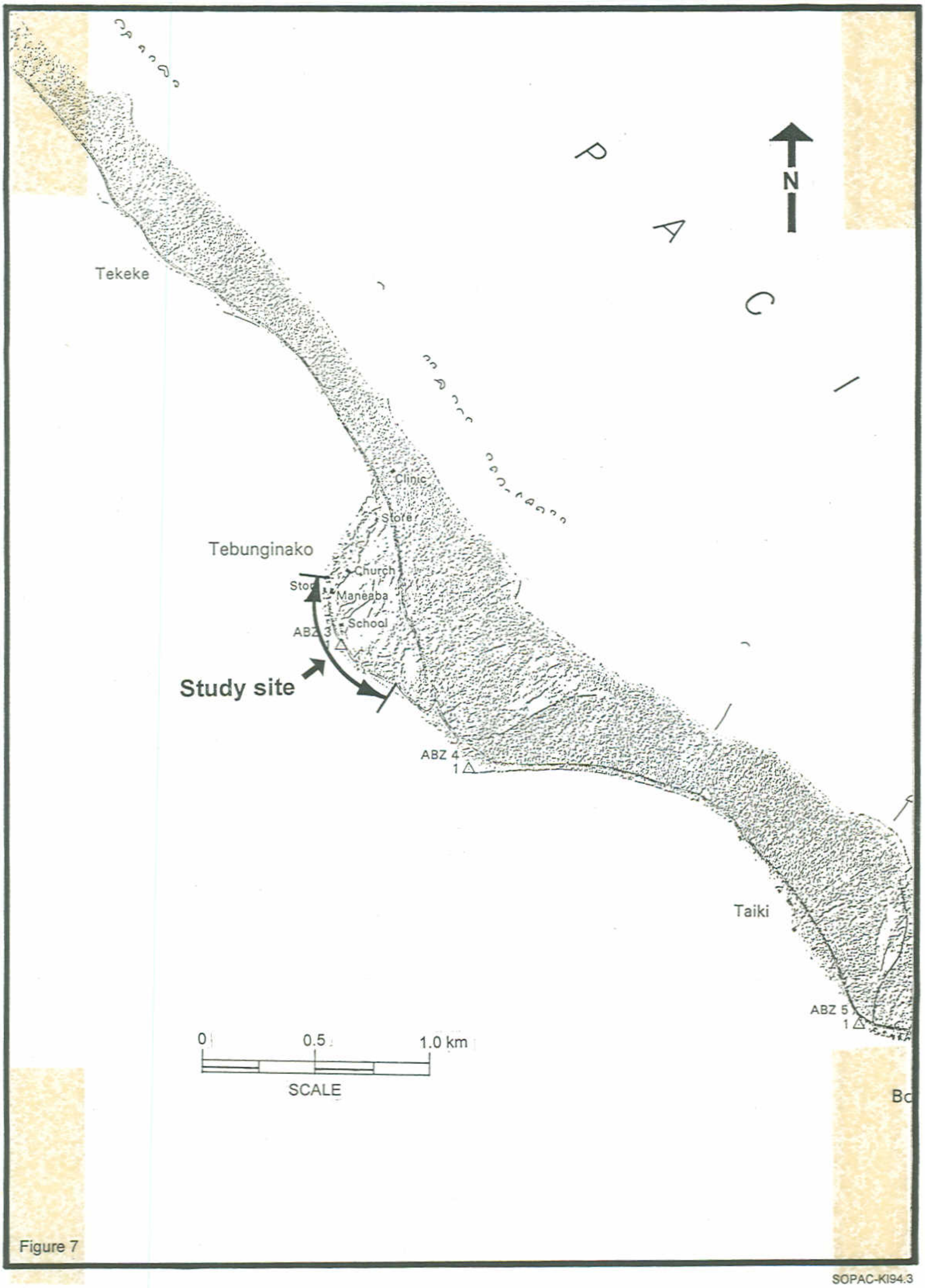

Figure 7. Map showing location of beach erosion along lagoon shoreline at Tebunginako, Abaiang.

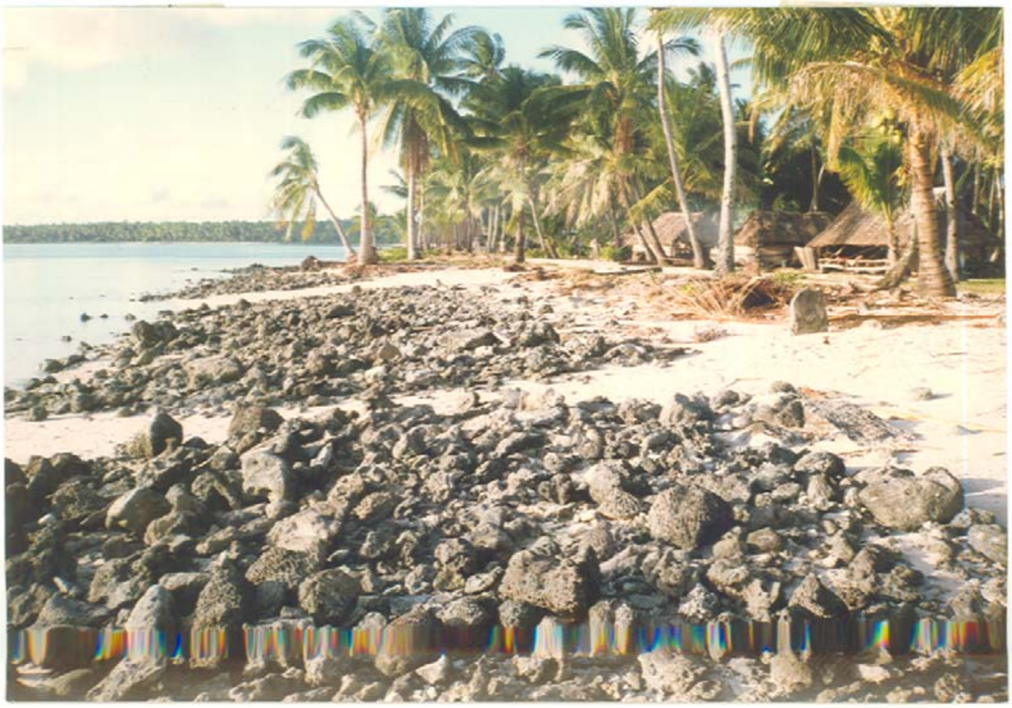

Figure 8. Tebunginako, Abaiang. View northwest along lagoon shoreline towards village, showing extensive remains of previous attempts at seawall construction. Pathways have been cleared through the seawall rubble to create boat launching sites.

Figure 9. Tebunginako, Abaiang. View northwest showing erosion extending beneath maneaba. The maneaba is no longer used because the floor is flooded during westerly seas and high tides. The remaining foundation blocks of an abandoned building are visible in the foreground at the level of normal high water.

Public Works Division (PWD) records indicate that two previous attempts at coastal protection have been made at Tebunginako (Appendix 3). In 1978 a gabion seawall (wire baskets filled with coral boulders) was construction along 500 m of shoreline and in 1980 a "dyke" of 60 m length was constructed. Both of these structures have failed to control the erosion and now litter the beach (Figure 8).

Erosion is thought to be due to natural causes as a result of spit migration northward along the lagoon shoreline. The north end of the village shoreline has accreted by 20-40 m, which is to be expected if the recurved spit complex on which Tebunginako is built is migrating northward. It is expected that erosion will continue, especially at the southern end of the village. Recent El Nino events in 1987 and 1991-1993 which have produced higher than normal sea levels and westerly winds rnay have aggravated the effects of the longer term shoreline erosion.

*Recommendations*

The initial study of this site by SOPAC (Harper 1989) recommended that a coastal engineer should conduct a comprehensive protection plan and that the long-term objective should be to relocate buildings to an area less sensitive to shoreline changes. The subsequent study by a SO PAC coastal engineer (Holden 1992) determined that existing attempts at coastal protection had been largely ineffective. Several coastal protection alternatives were discussed; however, the limitations of local construction made most of these impractical.

It was recommended by Holden (1992) that future buildings be setback 15 m from the natural boundary of the sea. In addition, a coastal protection alternative was provided for expensive buildings (maneaba or concrete buildings) which could not be relocated. A grout filled sand bag seawall of a sloping design was recommended and a design drawing was presented as Figure 11 in Holden (1992). It is recommended that action be taken on this design to protect expensive buildings and that less expensive buildings be relocated.

## Marakei: Rawannawi

*Site Description and Erosion Problem*

The site of coastal erosion is located on the northwest corner of Marakei as shown on Figure 10. The village of Rawannawi is iocated adjacent to a natural pass on the edge of the fringing reef which was enlarged and extended towards the shore by blasting over 10 years ago. According to

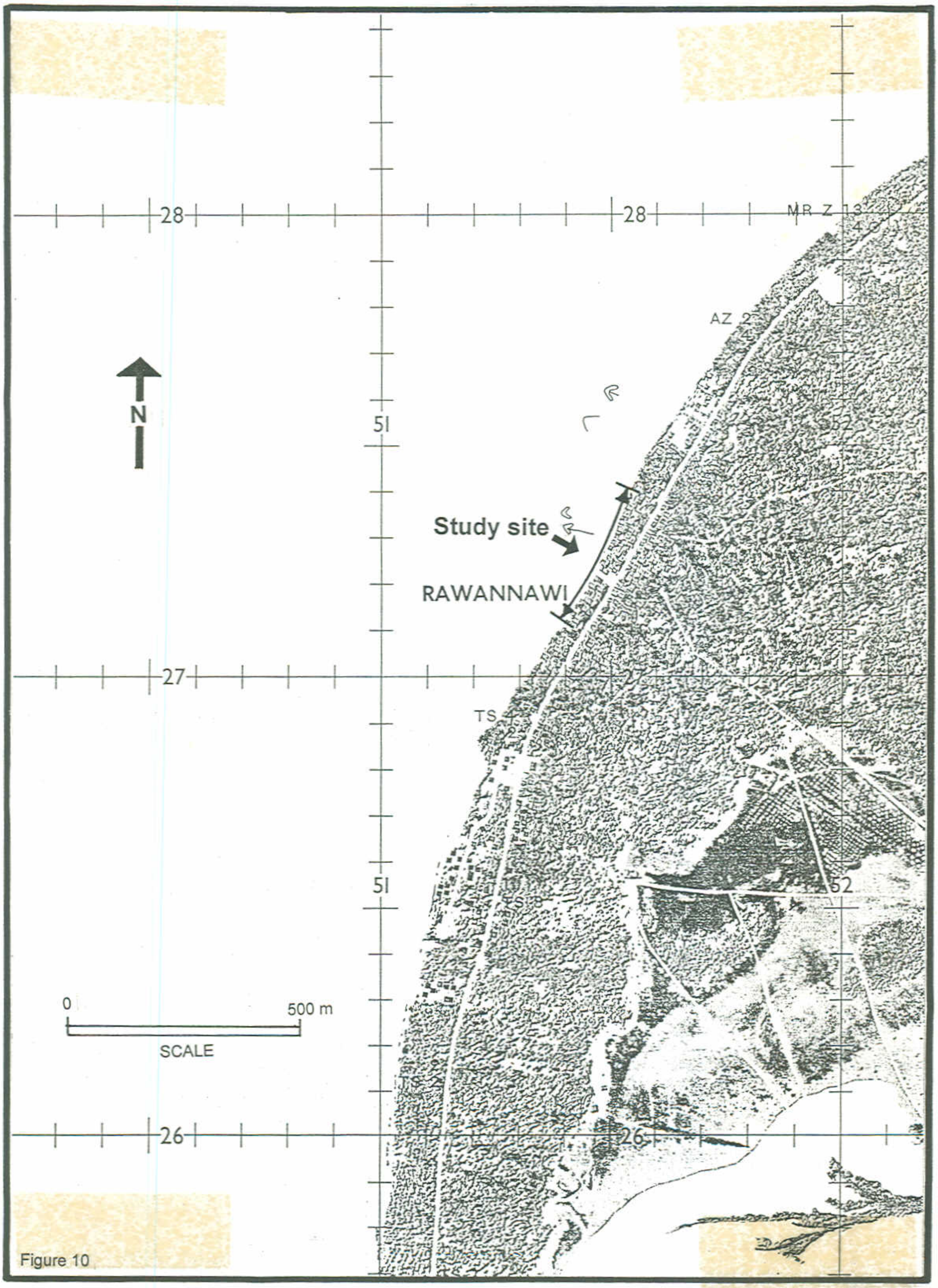

Figure 10

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Figure 10. Map showing location of beach erosion study site along ocean shoreline at Rawannawi, Marakei.

local sources (Appendix 4), there was some beach erosion before the channel was blasted, but there has been much more since then. The area of eroding beach concern extends about 400 m both north and south of the channel.

Evidence of erosion is visible as a lowered beach level near the channel as compared to areas further away (Figure 11). Vertical seawalls from 2-3 m high back the beach where the loss of beach has been greatest (Figure 12). Steep eroding cliffs (as indicated by land washed from under the roots of large trees) of 1-2 m in height are also present to the north and south. To the north the remains of a concrete foundation of a house was being undermined. We were told the foundation was over 40 years old.

We were also told that sand was removed from the beach on occasions and used for construction purposes. This appears to be a common practice and is not regulated.

There have been a number of local initiatives at coastal protection. There is a near vertical seawall 2-3 m in height immediately landward of the boat passage. The seawall is comprised of coral plates stacked and packed with their long axis in the vertical. On the day of the visit a group of three local land owners were rebuilding a seawalls which had fallen down in recent times. It was apparent that the work was very difficult and that a lot of labor goes into building and maintaining the seawalls. Further to the north, some groynes have been built on the lower foreshore/reef flat, but these have a very low profile and appear to be ineffectual in trapping sand.

On the day of the site visit (30 March 1993) a northerly swell was refracting onto the shore and into the boat passage with breaking wave heights of about 0.5-1.0 m on the edge of the reef. Under conditions of strong westerly winds or westerly swell this site would be exposed to higher energy conditions.

*Recommendations*

The location of villages at the location of natural passes in the fringing reef is common on atolls of the Gilbert Islands which do not have a deep lagoon and large leeward reef passes. Prior to European contact the natural passes met the needs of the small canoes the time. However, after European contact there developed a desire and need to move larger amounts of cargo and fishing boats to and from the shoreline. As a result, the enlargement and shoreward extension of natural channels has taken place. Unfortunately, this had resulted in increased transport of

Figure 11. Rawannawi, Marakei. View north (at location of reef passage) along shoreline showing protection response with locally constructed, near vertical seawalls.

Figure 12. Rawannawi, Marakei. View of near vertical seawall constructed of tabular coral and beachrock slabs. The wall is over two metres high.

beach sediment into the channel and larger waves being able to travel up the channel to the shoreline, both of which have contributed to shoreline erosion.

Therefore, any coastal protection structure would have to be of sufficient strength to withstand relatively brief but high energy conditions. This would require the extensive use of concrete.

## Marakei: Buoata

### *Site Description and Erosion Problem*

The village and district of Buoata is located about half way along the west side of the island. The reef fringing the shoreline at this location is relatively narrows (Figure 13). Shoreline erosion was visible as small scarps (0.5 m high) undercutting the shore and road and some wash over of beach material onto the road for a distance of about 0.5 km north and 1-2 km south of the village. According to local sources sections of the road have had to be relocated inland two or three times over the last 10 years. However, the distance of relocation could not be determined.

It was also observed that there were extensive deposits of coral boulders landward of the shore road. The boulders were 20-30 cm in diameter and indicated that on certain occasions (probably under conditions of westerly gales or storm force winds) it is possible for large waves to wash over the surface of the road. The time when the boulders were deposited could not be determined and may represent a very rare event (perhaps once in a hundred years on average).

### *Recommendations*

Where possible the road should be relocated inland in order to avoid future impact from coastal erosion.

## Marakei: Baretoa Passage

### *Site Description and Erosion Problem*

Baretoa Passage is located on the west side of Marakei Atoll towards the southern end (Figure 13). The site is not presently experiencing coastal erosion. However, because there has been a significant change in the shoreline at this location it is worthy of discussion. According to local

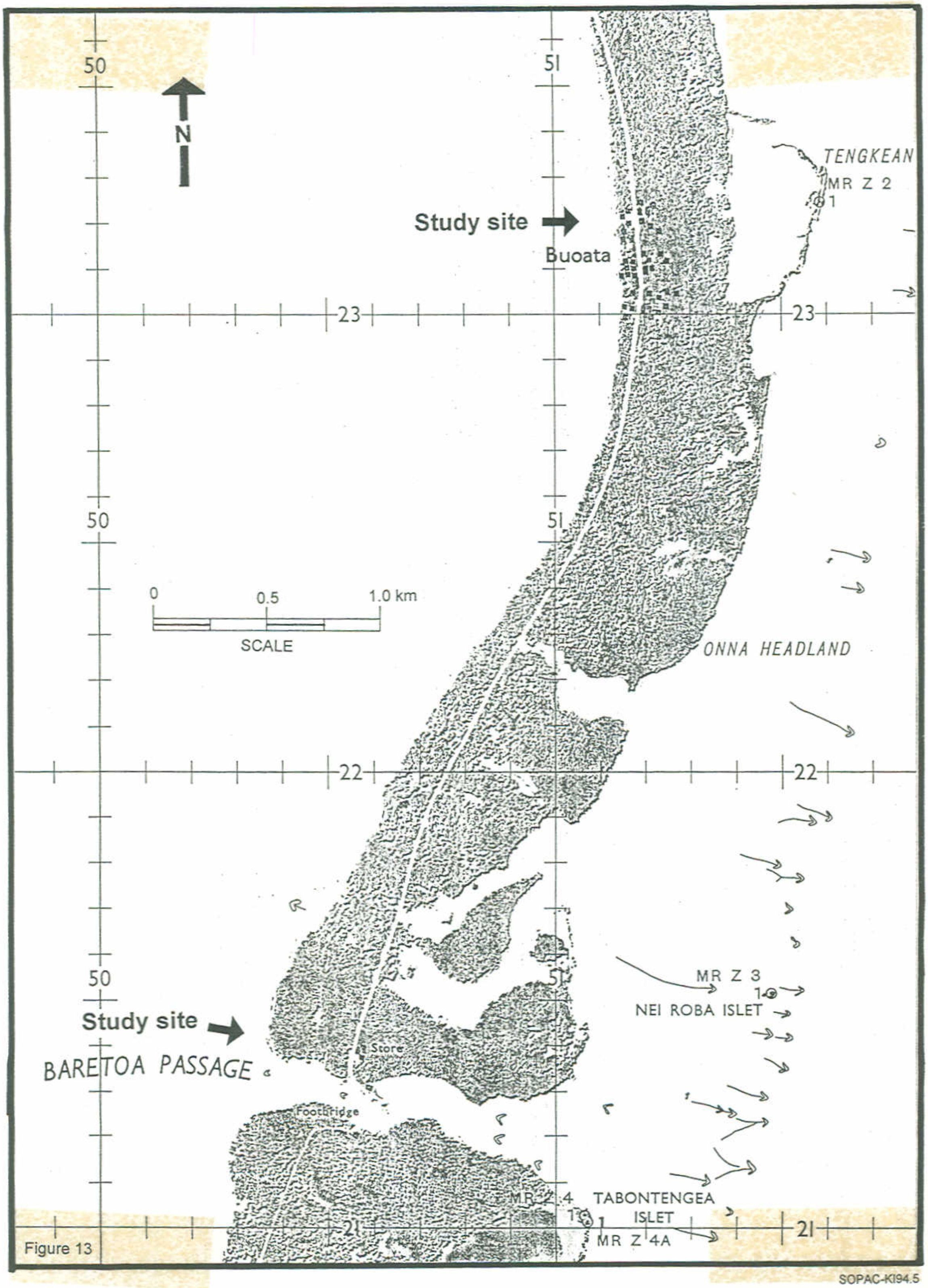

Figure 13

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Figure 13. Map showing location of erosion study sites along ocean shoreline at Buoata and Baretoa Passage, Marakei.

sources the passage was closed about 10-12 years ago (approximately 1982) by the accumulation of a large bar or ridge across the seaward end of the passage. Since then the ridge has grown by accumulation of more beach sediments. It is now about 30-40 m in width and reaches about 1 m above the normal high tide (Figure 15). The closure of Baretoa Passage is significant since the lagoon on Marakei is now entirely enclosed except for the one remaining passage on the east side of the lagoon.

Midway along the passage a causeway bridge was constructed about six years before (1976?) the passage was closed. The bridge over the centre of the passage provided an unobstructed channel about 10m wide. Since closure of the passage the original channel has shoaled (Figure 14). The local people claim a degradation in fishing in the lagoon as a result of the closure and they want the channel re-opened in the hope that fishing will improve. Apparently, an attempt was made to re-open the channel, but this action was stopped by a court order from the adjacent landowner who made claim to the accretion by right of traditional land tenure.

The island council wants to see the channel re-opened for the common good of the island and to restore the natural circulation of the former channel and lagoon, now degraded by the blockage of the passage. Apparently, the land owner adjacent to the beach ridge/bar has claimed the land as his own. However, he has since lost an appeal in the lower court and is not appealing to the higher court. In the meantime, the causeway\bridge has been partially dismantled by the local people, presumably for other uses.

### *Recommendations*

It is recommended that the passage be re-opened. This would require two actions: dredging of the channel to allow lagoon water to reach the beach ridge and breaching of the beach ridge to allow water to flow through. It is likely that once the beach ridge is breached, oceanward flowing water from the lagoon will maintain the channel open. However, it may also become closed at some later date. The causeway and bridge will also need to be rebuilt for their intended use.

## Makin: Naka Primary School

### *Site Description and Erosion Problem*

The site of the primary school is located on a broad point of land on the west side of the island (Figure 16). The school includes classes 1-7 with some 250 students. The amenities affected by

Figure 14. Baretoa Passage, Marakei. View east through passage past abandoned causeway and towards lagoon. Since closure of the passage the causeway has been partially removed in an attempt to restore the natural flow and re-open the passage.

Figure 15. Baretoa Passage, Marakei. View south along the crest of the large beach ridge which has closed off the western entrance to the passage.

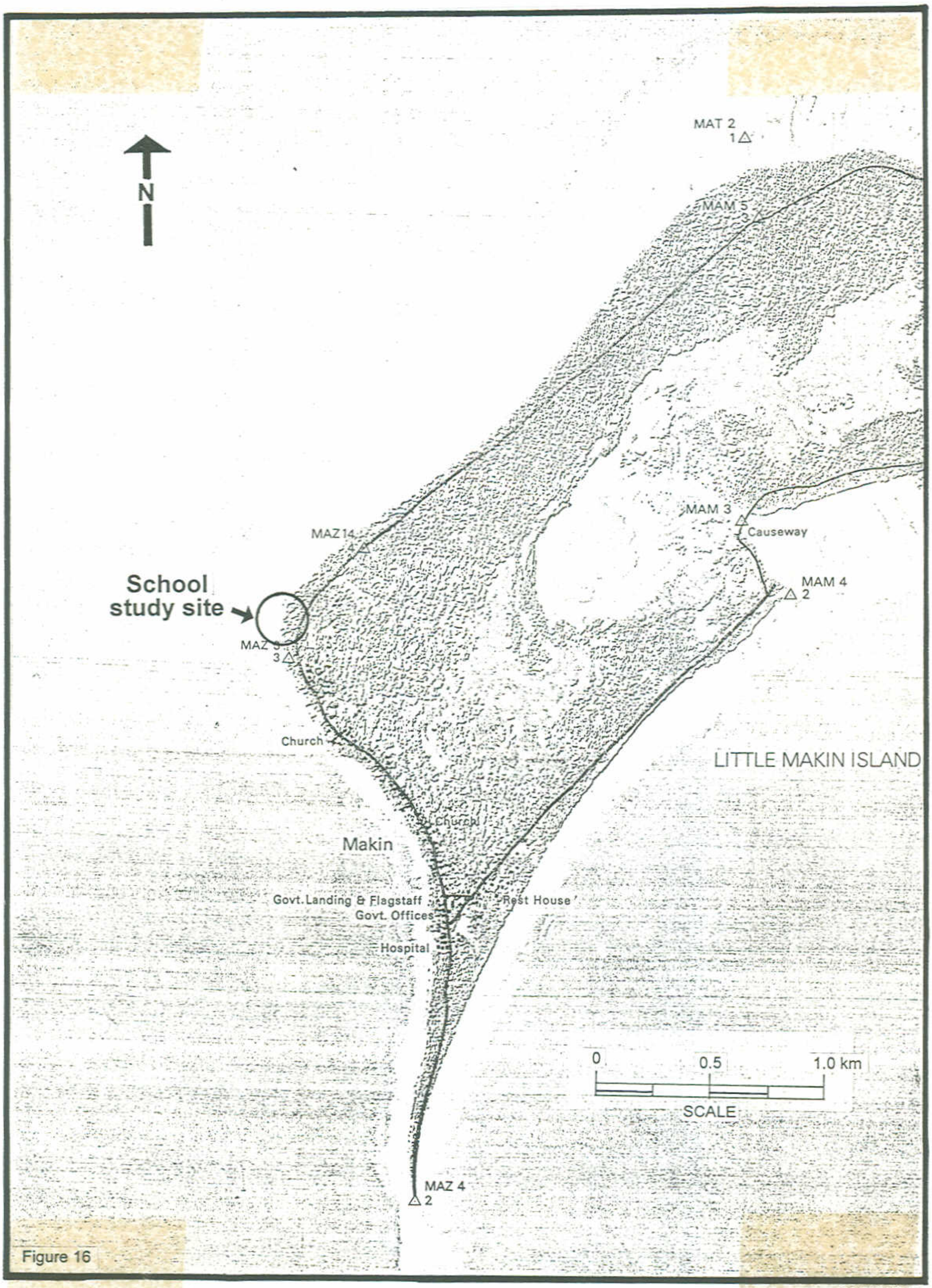

Figure 16

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Figure 16. Map showing location of erosion study site at Naka Primary School on western ocean shoreline of Makin.

the erosion include the school which is constructed of modern materials (concrete floor, block walls and iron roofing); a playing field extending for 120 m to the south and family property to the north and south.

The erosion is worst at the apex of the point and extends for about 0.5 km north and south away from the point. Erosion of the shoreline is visible as a low cliff about 1-2 m high and fallen coconut trees (Figure 17). The beach profile surveyed at the site (Appendix 5) indicates that the wall of the school was X m away from the shoreline. Local sources stated that there had been about 7 meters of erosion since the late 1970s.

The beach sediment comprises coarse sand on the upper beach, mixed sand/gravel on the mid foreshore and coral boulders on the lower beach. There is a sharp transition to the reef flat which has very little sediment cover. There were about six micro-atolls on the reef flat around the seaward end of the beach profile.
On the day of the site visit (01/04/93) the swell height on the east side of the island was 1-2 m. The swell waves were refracting around the north end of the island and off Naka were only 0.3 m high. At the school site, with about 0.2 m of water covering the reef flat, there was a southward directed current of about 0.1-0.2 m/sec.

Previous attempts at shore protection at the site include a locally built seawall comprised of coral plates stacked vertically which was now virtually destroyed. There is also a small groyne on the beach about 120 m south of the school which has trapped sand on the north side, indicating southward directed transport (Figure 18). However, local sources indicated that accretion along the sides of the groyne shifts from one side to the other.

*Recommendations*

The erosion may have reached its maximum and beach erosion may stop. However, the erosion is close to affecting the school building and some form of protection is warranted considering the economic value of the assets to be protected. However, if the erosion observed in March 1993 has stopped and accretion has taken place since then there may be no need for coastal protection. In this regard, it should be recognized in Kiribati that (1) valuable buildings should not be built close to the shoreline where they are at potential threat from the normal changes which occur in the shoreline; and (2) valuable buildings should not be built adjacent to shorelines which have been determined to have a long term or chronic erosion problem.

Figure 17. Naka Primary School, Makin. View north along beach scarp. Local estimates of erosion have amounted to 7 metres since the late 1970's.

Figure 18. Naka Primary School, Makin. View of locally constructed small groyne located approximately 200 m south of school site. The greater volume of sand on the left (north side) of the groyne indicates that the most recent predominant direction of longshore transport has been from the left (north).

If the erosion has continued and the school buildings are threatened, then some form of protection may be required, such as an inclined seawall constructed of grout filled sand bags.

## Butaritari: Ukiangang Point

### *Site Description and Erosion Problem*

The study site is located on the ocean shoreline of Ukiangang Point which is the most southern point of Butaritari (Figure 19). Although there is evidence for shoreline erosion (Figure 20) the main concern at the site is inundation of low lying backshore areas which comprise a lake, parts of which are used for growing babai (Figure 21). According to local sources overwash of ocean water into the lake occurs annually in association with westerly gales.

The study area is presently reached via a road which circles the point (Figure 19). The road was originally built by American forces in 1943/44. According to map notes made by Bruce Richmond in 1985, a new road was placed around the point to replace one washed away in June/July 1985. Local sources also confirmed that the road was relocated eight years ago (1985) and a artificial bank placed on the seaward side.

The ocean shoreline is relatively exposed to wave action and primarily consists of coral cobbles with little sand.

### *Recommendations*

The village council at Ukiangang consider the area of babai pits a valuable resource. They want to have the pits protected from further inundation by salty water. However, it would be costly and difficult to build protection along the entire length of shoreline and it is recommended that no shoreline protection be considered. Rather, it is recommended that inland alternatives for the protection of marginal babai growing areas be investigated.

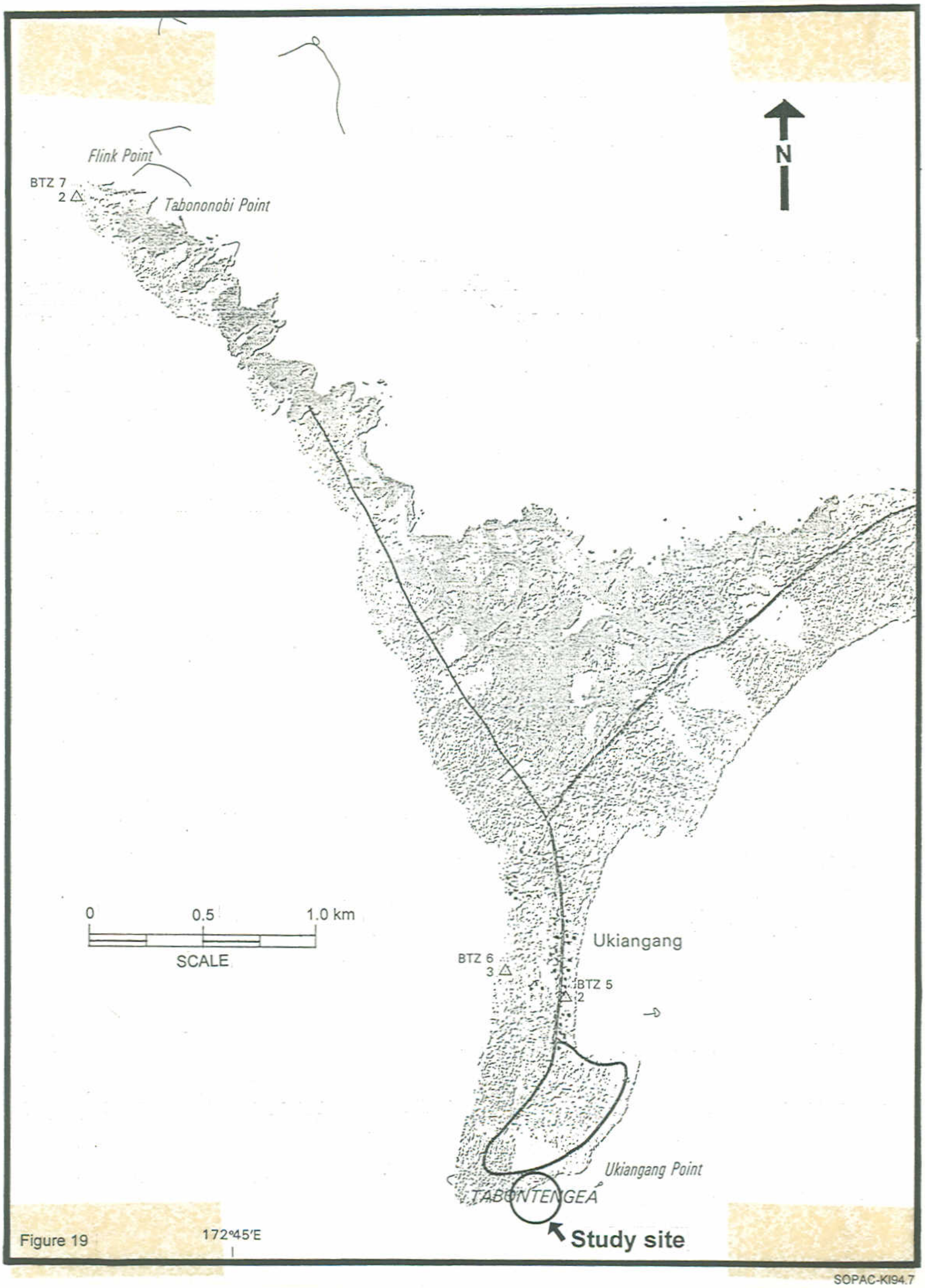

Figure 19. Map showing location of erosion study site southwest of Ukiangang Point on the ocean shoreline of the most southerly point of Butaritari.

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Figure 20. Ukiangang Point, Butaritari. View southwest along eroding section of beach. Waves occasionally overwash beach and cause salt water intrusion into backshore swamp areas.

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Figure 21. Ukiangang Point, Butaritari. View of backshore swamp area immediately behind beach road. Swampy sites further inland, which are less salty, are used for growing babai.

## Butaritari: Keuea Village

### *Site Description and Erosion Problem*

Keuea Village is located on the northeast side of the atoll rim of Butaritari (Figure 22). The village is located on the lagoon and central part of the reef islet. The ocean shoreline adjacent to the village faces southeast and is undergoing moderate erosion and is subject to periodic sea water inundation associated with wave overtopping the shoreline ridge. Two sites were studied along the ocean shoreline (Figure 22). At the more northern of the two the major problem is sea water inundation (Figure 23, 24) and at the more southern the major problem is shoreline erosion (Figure 25).

At the northern site, episodes of sea water inundation occur every 3-4 years on average. During each of the events the sea water washes over the shoreline ridge and flows down to the babai pit about 40 m inland (Figure 24). The locals described the event as a "rush of water" and note that it happens with spring tides and large waves. The saltwater causes the young babai plants to die and they have to be pulled out and new ones planted. They also noted that this problem had occurred for some time (as long as they could remember) and had not just started recently.

The beach is coarse coral gravel and boulders with minor sand and conglomerate coral rock. The backshore is surfaced by coral rubble, covered with vegetation (young and older coconut trees). There was no evidence of recent overwash in the form of sand lobes or cobble banks.

At the southern site erosion is visible as a low cliff (about 1 m high, see Figure 25). According to local sources the amount of lateral erosion has amounted to 3-5 m. The shoreline is similar to the northern site. However, overwash and saltwater inundation were not identified as a problems.

### *Recommendations*

The infrequent saltwater inundation of marginal babai pits and minor coastal erosion do not justify foreshore protection.

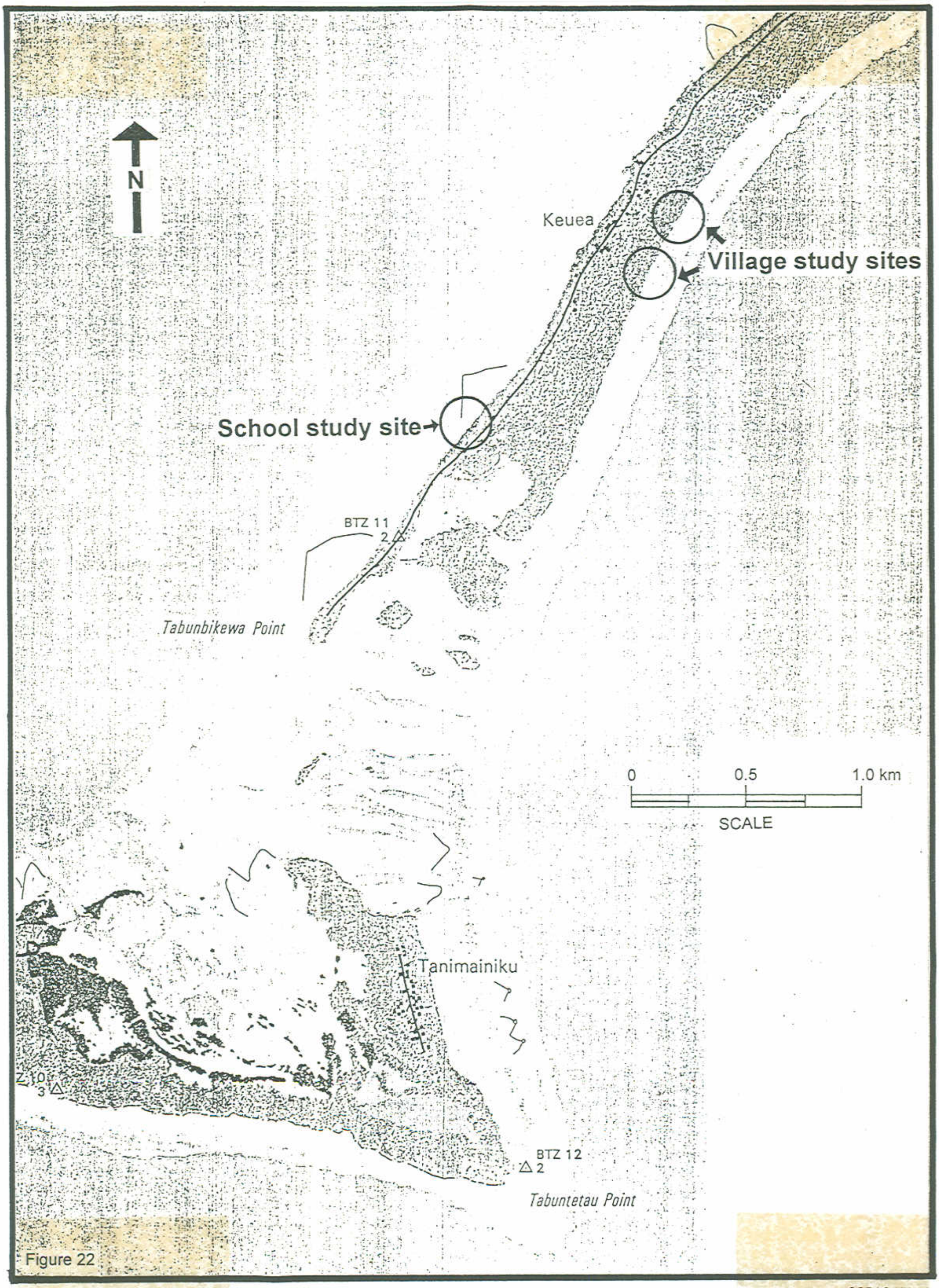

Figure 22. Map showing location of erosion study sites at Keuea Village and Keuea/Tanimainiku School on lagoon shoreline of Butaritari.

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Figure 23. Keuea Village, Butaritari. View southwest along ocean shoreline east of Keuea Village. The beach at this location is composed of a very narrow zone of coral boulders with minor sand.

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Figure 24. Keuea Village, Butaritari. View seaward along line of beach profile. Note the greater height of the most seaward point (on the beach ridge). Information provided by local sources indicates that waves sometimes wash salt water over the ridge and into babai growing pits immediately landward of this location.

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Figure 25. Keuea Village, Butaritari. View of scarp eroding into beach ridge along ocean shoreline.

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Figure 26. Keuea/Tanimainiku School, Butaritari. View north along narrow sandy beach on lagoon shoreline.

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Figure 27. Keuea/Tanimainiku School, Butaritari. Aerial view southwest showing sandspit and causeway. The study site is located in the middle of the spit along the lagoon shoreline.

The study site at Barebuka is located on the shoreline at the west end of the airfield runway (Figure 28). The site was visited on 5 April 1993 and the survey party team was accompanied by the Island Council President. Shoreline erosion was visible as an erosion scarp or low cliff. Large slabs of broken beach rock lay on the lower foreshore. According to local information, the beach rock slabs are not normally exposed, but have become extensively exposed since the westerly seas of early January 1993 (Figure 29). Naomi Biribo and Tererei Abete were sent by the Kiribati Government to visit Tamana in January 1993 to examine the erosion caused by gale force westerly winds and large waves. According to local information, damage caused by large waves occurred on 4 January 1993 and was regarded as "an unusual event".

In addition to the shoreline at the end of the runway the entire shoreline around the north end of the island as far as the east end of the airfield (Figure 28) was walked to examine the nature of the beach. Within 100 m north of the erosion on the west end of the runway the shoreline character changed from one of erosion to a wide beach with a berm about a 10 m wide. This

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Figure 28. Map showing location of erosion study sites at Barebuke (west end of airfield runway), Bakarawa and Bakaka on western ocean shoreline Tamana.

Figure 29. West end of airfield runway, north of Barebuke, Tamana. View south showing erosion scarp at left and scattered slabs of broken beachrock.

shoreline gradually changes around the north end of the island becoming narrower with less sand and more cobbles, and finally becomes a narrow cobble beach overgrown by shoreline scrub. The entire backshore was covered by scrub and coconut trees only grew about 20 m back from the shoreline. Once the east end of the runway is reached, the beach sediment character again changes to sand with minor erosion. Local information provided at the time indicates that about 2-3 m of erosion had occurred at the east end of the runway, but that this amount was variable and the shoreline fluctuated between phases of erosion and accretion.

It would appear that sand accumulation probably shifts around the northern end of the island depending upon sea and swell wave directions. The resulting nearshore currents cause cycles or reversing patterns of erosion and accretion. It is clear that the most recent events have been dominated by seas from a westerly direction which has eroded sand from the northwestern end of the island and transported it alongshore to the north resulting in a wide beach berm. The backshore zone of coastal scrub, some 10-20 m in width, indicates the width of the zone of beach fluctuation over cycles of erosion and accretion.

*Recommendations*

The erosion recently experienced at the west end of the runway is not considered to be a chronic or long term problem. Rather it is considered to be cyclical in nature and the recent phase of erosion should be replaced by accretion in the near future. No engineering construction activity is recommended.

## Tamana: Bakarawa

### *Site Description and Erosion Problem*

Prior to viewing the Bakarawa site the shoreline around the south end of the island was examined. It was noted that freshly broken pieces of branching coral had accumulated as a recently formed beach ridge along the southwest shoreline. This most likely represents the effects of the early January 1993 gales. According to local sources, westerly gales persisted for about 10 days. On the southeast facing shoreline a cuspate foreland of sand about 20 m wide and over 200 m long had also been deposited during and subsequent to the January gales. Both of these shoreline deposits are consistent with recent higher energy wave conditions from the west.

Returning north along the west coast of Tamana, minor erosion\accretion features characterised the shoreline which was predominantly composed of cobble size material.

The shoreline erosion site at Bakarawa is actually located south of main village and about 300 m north of a shipwreck (Figure 28). The shipwreck occurred in 1978/79 and lay on the edge of the reef until this year when it was broken apart and driven unto the shoreline during the 4 January event.

According to local sources of information, there has been progressive erosion over the last 10 years. The shoreline was composed of beachrock alternating with coral sand and cobbles. Again, according to local sources, the exposure of the beachrock was relatively recent and it was normally covered by sand. Some erosion and backshore overwash was visible, but was not severe. Some coconut trees had been undermined and fallen onto the beach. From the visible evidence it was estimated that the shoreline had retreated about 5 m in the recent past.

*Recommendations*

The moderate erosion experienced recently (1993) at this site appears to have stopped and it is expected that the shoreline will not erode further and will probably recover with shoreline accretion. Therefore, it is recommended that no action be taken. In this regard the shoreline is presently at least 20 m from the nearest buildings of traditional construction and no major assets are at risk. The traditional practise of building well-back from the ocean shoreline on the west coast of Tamana should be continued and encouraged since this leaves a wide "buffer zone" between the active shoreline and local habitations.

### Tamana: Bakaka

*Site Description and Erosion Problem*

Bakaka is the main village on Tamana and site of a large church, island council offices and the guest house (Figure 28). All of these major buildings are set well-back from the shoreline and presently are not at risk (Figure 30).

An older vertical seawall of concrete construction marks the landward limit of higher sea levels. In general it is in good condition and only needs minor repairs. The fact that is set above and back from the normal high tide means that it does interfere with normal beach processes and does not induce erosion, which would be the case if it had been placed further down on the beach.

*Recommendations*

It is recommended that no action be taken at this site and that any repairs to seawalls should only be made to the existing seawall. The seawall should not be extended onto or along the beach.

Arorae: Taribo

*Site Description and Erosion Problem*

Arorae is a relatively long and narrow table reef island with no lagoon. All villages and the main road are located on the western shoreline which is the leeward side of the island in relation to the

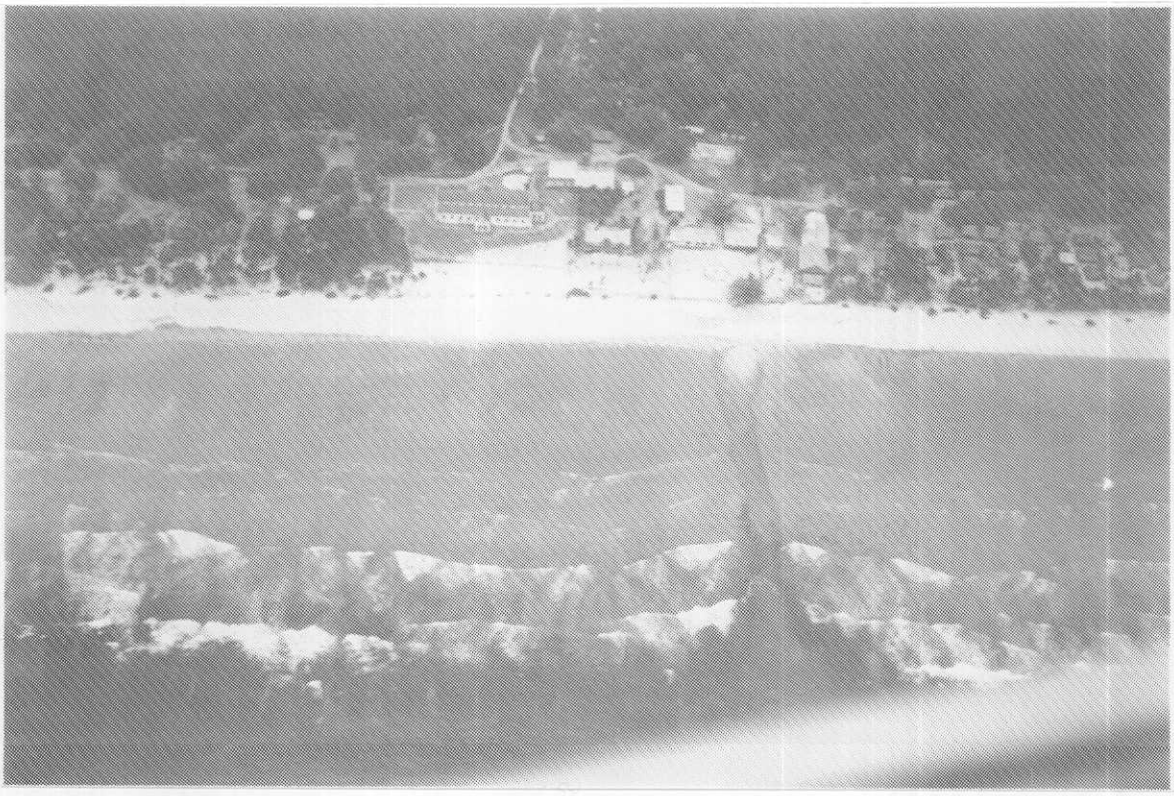

Figure 30. Bakaka, Tamana. Oblique aerial view showing man-made boat channel across reef and shoreline fronting large church and government buildings. Note that the permanent buildings are set well back from the shoreline.

predominantly easterly winds (Figure 31). Four sites on the north and south ends and the central west side of the island were examined. It was noted from the aircraft while approaching the airfield at Arorae that the effects of the westerly gales and seas of early January 1993 appeared to have been much greater here than on Tamana. In particular, a storm surge appears to have overwashed the shoreline and carried beach material up to 50 m inland along the west coast (Figure 33).

The length of shoreline examined at Taribo was approximately 50 m south of the school and 100 m south of the man-made boat channel (Figure 32). A beach profile was surveyed from a point inland across the backshore and onto the reef flat (Appendix 5).

According to local sources, between the two and six am on Monday 4 January 1993 at least three large "tidal waves" (properly called a storm surge) washed over the beach ridge and onto the island behind of the shoreline. Waves breaking on the edge of the reef were estimated to have heights of 4-6 metres. As a result of the storm surge waves, sand and cobble debris were carried up to 50 m inland of the normal high tide beach ridge (Figure 33). Local sources also

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Figure 32. Taribo, Arorae. View northwest along exposed shoreline approximately 100 m south of man-made boat channel.

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Figure 33. Taribo, Arorae. View south through backshore showing storm surge overwash deposits (approximately 0.5 m deep) extending 40-50 m landward of beach ridge shown in Figure 32.

indicated that coral boulders on the reef flat were moved landward, but that no new boulders were ripped from the reef front.

Seawalls which had been in place for over 10 years at 15-20 m behind of the active beach shoreline, were overtopped by the storm surge and either demolished or buried by the storm washed debris. One 56 year-old lifetime resident of the island said that the storm surge of 4 January had been the greatest he could remember and that there had also been many lesser events in the past.

### *Recommendations*

It should be emphasised that there was very little damage that occurred from the storm surge event, apart from the destruction of some pig pens and traditionally constructed cook houses which are placed shoreward of the main houses. The accumulation of storm surge debris is actually beneficial in that it builds the island up which is a normal process. This should not be interfered with by seawall construction. The traditional local practise of leaving a wide buffer zone between the shoreline and living quarters should be encouraged as this reduces damage from extreme events.

## Arorae: Tamaroa

### *Site Description and Erosion Problem*

The study site at Tamaroa is located seaward of the large LMS church which has existed at the site for close to 70 years (Figure 31). Unlike the adjacent shoreline which is vegetated with coconut trees, the shoreline and backshore in front of the church has been cleared of vegetation (Figure 34). This may have contributed to the relatively greater impact of the January storm surge at this location.

At the time of the survey, a relict erosion scarp was observed at the back of the beach which is presumed to have been caused by the January 1993 event. This is fronted by an actively accreting beach ridge which is now some 5-8 m wide. This is normal for a beach to recover or show accretion after a major storm.

While travelling the road north of Tamaroa it was also noticed that there is generally a distance of some 100 m between the road and the shoreline on the west side of the island. Most houses are built 50 back from the shoreline on older and slightly higher ground than the most recent backshore areas which are subject to storm surge overwash as happened in January 1993.

*Recommendations*

It is recommended that no seawall or shoreline structure be constructed at this site. It is recommended that the existing buffer zone between the shoreline and the church be maintained and no construction take place in this zone. It is recommended that coconut trees be planted along the shoreline to assist with its stabilization.

### Arorae: Batitotai

*Site Description and Erosion Problem*

The study site examined is located at the southwest corner of the island, west of the abandoned viliage site of Batitotai (Figure 31). The remains of the viii age consist of house foundations, a concrete lined well and the grave of a giant man, reported to have been 4-5 m in height.

The shoreline adjacent to the abandoned village is comprised of coral rubble on the west (Figure 35) which gradualiy changes to a wide sand beach on the south. The western shoreline shows the effects of erosion\accretion cycles and at the time of the survey appeared to have recently eroded landward.

Information provided local sources indicates that the village was not a permanent site. It was used as a weekend retreat as part of the LMS church. Apparently, there used to be three rows of houses when the camp was first built in the 1940s, but now there is just two indicating the erosion of about 5 m of shoreline. This could not be confirmed from observations of the ground at the site. We were also told that the site was originally a low area, sometimes flooded with a pond and bordered by mangroves. In order to make it habitable it was raised by fill composed of coral cobbles. Where the fill material came from could not be established. However, it is likely that it was obtained from the adjacent beaches which may have ultimately contributed to the erosion problem.

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Figure 34. Tamaroa, Arorae. View southeast at location in front of large LMS church. The beach ridge is composed of coral rubble and is presently accreting in front of an erosion scarp created during the early January storm surge.

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Figure 35. Batitotai, Arorae. View southeast along narrow beach ridge composed of coral rubble. The beach ridge has recently migrated landward as indicated by small tree on beach and burial of backshore vegetation.

### *Recommendations*

There appears to have been a minor amount of erosion at the site. The present economic assets such as they are (an abandoned, temporary village site) do not justify the need for coastal protection.

## **Arorae: Barbaroroa**

### *Site Description and Erosion Problem*

The study site at Barbaroroa is located on the northwest corner of Arorae (Figure 31). As shown in Figures 36 and 37, shoreline erosion is apparent as a high erosion scarp of about 1.5-2.5 m and exposure of large slabs of beach rock at the base of the beach. The extent of severely eroded shoreline covers about 200-300 m. The site is relatively exposed to high energy waves because of the focusing effect that the curved fringing reef and shoals have on waves at this location.

Some qualitative indication of the amount of erosion that has occurred is evident from a United States Air Force (USAF) survey monument installed in 1965 (Figure 37). Although there is a relatively high beach ridge at this site, there was also evidence for this having been recently overtopped by waves: small slabs of beach rock weighing 20-40 kg have been carried up to 10 m landward of the erosion scarp.

Also of note is the low level of the ground behind the beach ridge. On the day of the survey (6 April 1994), a high tide peaking about 16:30 - 17:00 hours resulted in salt water infiltrating into the low lying ground behind the beach ridge.

### *Recommendations*

Presently, apart from some survey markers and the land itself, there are no assets at risk. The land is not being utilized for subsistence food supply and supports a salt tolerant scrub bush. The site of the Arorae Navigation Stones is about 200 m inland of the study site and is not deemed to be at risk. Therefore, it is recommended that no action be taken at the site.

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Figure 36. Barbaroroa, Arorae. View north showing erosion scarp associated with early January storm surge and subsequent strong westerly winds and waves.

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Figure 37. Barbaroroa, Arorae. View southeast along crest of erosion scarp. Information on concrete monument indicates installation by USAF survey in 1965.

## Beru: Taboiaki

### *Site Description and Erosion Problem*

The study site at Taboiaki is located on the southwest facing shoreline of the island of Beru (Figure 38). The site of the beach profile is towards the southern end of the village of Taboiaki and the road which runs along the shoreline. Nearer Taboiaki, seawall construction has been quite extensive, especially when the road comes close to the shoreline and the land between the road and shoreline is densely populated. There is virtually continuous erosion between the main part of Taboiaki and the site examined in detail (Figures 38-40).

It is clear that the southwest facing shoreline near Taboiaki has recently experienced erosion. In this regard, the shoreline is exposed to the open ocean and waves reach the shoreline over the adjacent reef. It would appear that under the influence of westerly waves which has recently characterised the wave climate of the island, sediment is transported away from the study site towards both the northwest and the southeast.

The profile measured at the site (Appendix 5) is significant in that the area between the lagoon and the road is comprised of a series of beach ridges (at least four major ridges and many smaller ridges). This indicates that in the geological past this section of shoreline was experiencing progradation.

### *Recommendations*

Protection of the existing shoreline erosion scarp (Figures 39, 40) would require a substantial structure because of the exposure to relatively high wave energy conditions and the length of the shoreline. Where the land is not under intensive development the assets at risk do not justify the cost and the implementation of set-back guidelines is appropriate. Where the land is occupied, the re-location of existing land uses is recommended when and if required.

## Nikunau: Tabomatang

### *Site Description and Erosion Problem*

Tabomatang is located on the southwest facing shoreline of the southern end of Nikunau, a table

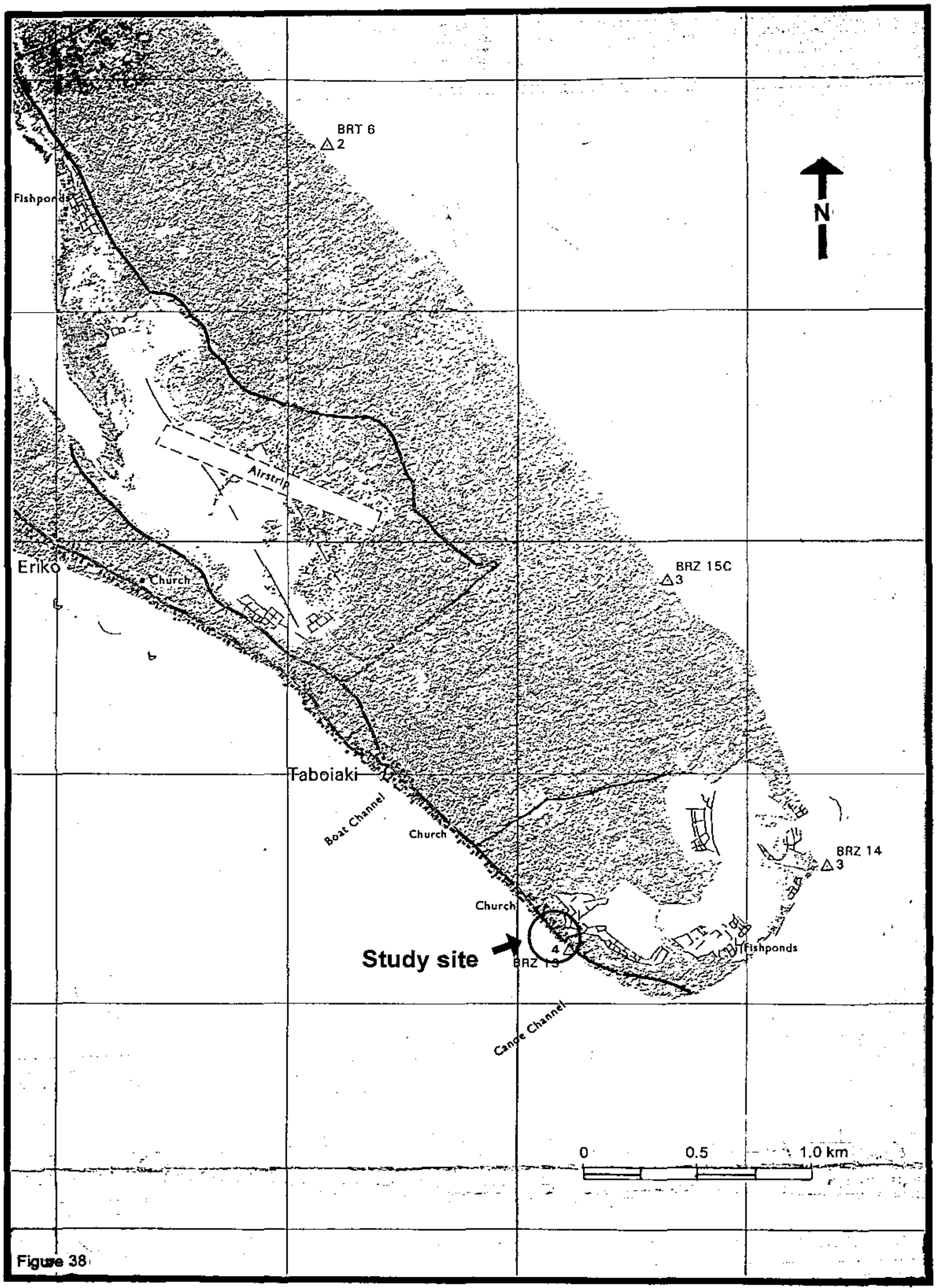

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Figure 38. Map showing location of erosion study site on southwest ocean shoreline at Taboiaki, Beru.

Figure 39. Taboiaki, Beru. View northwest showing erosion scarp along shoreline at beach profile site south of village.

Figure 40. Taboiaki, Beru. View southeast at beach profile site showing erosion scarp, beachrock on lower foreshore and end portion of privately constructed seawall.

reef island with no lagoon (Figure 41). The study site is at the south end of the village near the large church.

It was noted travelling south from the guest house at the north end of Nikunau that in general the shoreline on the west side of the island consists of wide mixed sand and gravel beaches. However, at Tabomatang there is a concentration of seawalls that extends over 300 m along the shoreline of the village. Some of the seawalls are very massive being 2-3 m high and 0.5 m thick with extensive use of concrete in the lower portions and foundations of the seawalls (Figure 43).

The particular location of interest to the village council was the site of a maneaba just north of the church. A seawall had been built at the site in the late 1970s in order to reclaim some land along the shoreline (Figure 42). Apparently the seawall was paid for by the Public Works Department. Subsequently most of the seawall collapsed and the maneaba site has been abandoned for some 6-8 years.

The site is relatively exposed to ocean waves passing over the leeward fringing reef. A seawall of approximately 40 m in length would be required to allow re-development of the site. Only 15-20 m of the original seawall remains intact.

### *Recommendations*

Re-establishment of the site for its former use would require building a new seawall and reclaiming some of the beach. This is not recommended because the seawall extends onto the natural beach by some 5-10 m (see Figure 42; and Appendix 5). In addition, where other seawalls have been built in the area, they are quite large so that the cost would be relatively high per unit metre of beach. It is recommended that no action be taken at the site.

## Aranuka:Takaeang

### *Site Description and Erosion Problem*

Takaeang is a large islet on the atoll rim at the western corner of Aranuka Atoll. It is separated from the main islet of Buariki by a wide shallow lagoon. A large canoe was hired to take the survey party to Takaeang. The actual study site was located on the southeast corner of Takaeang (Figure 44) where a school and housing for teachers has been built in the last twenty years.

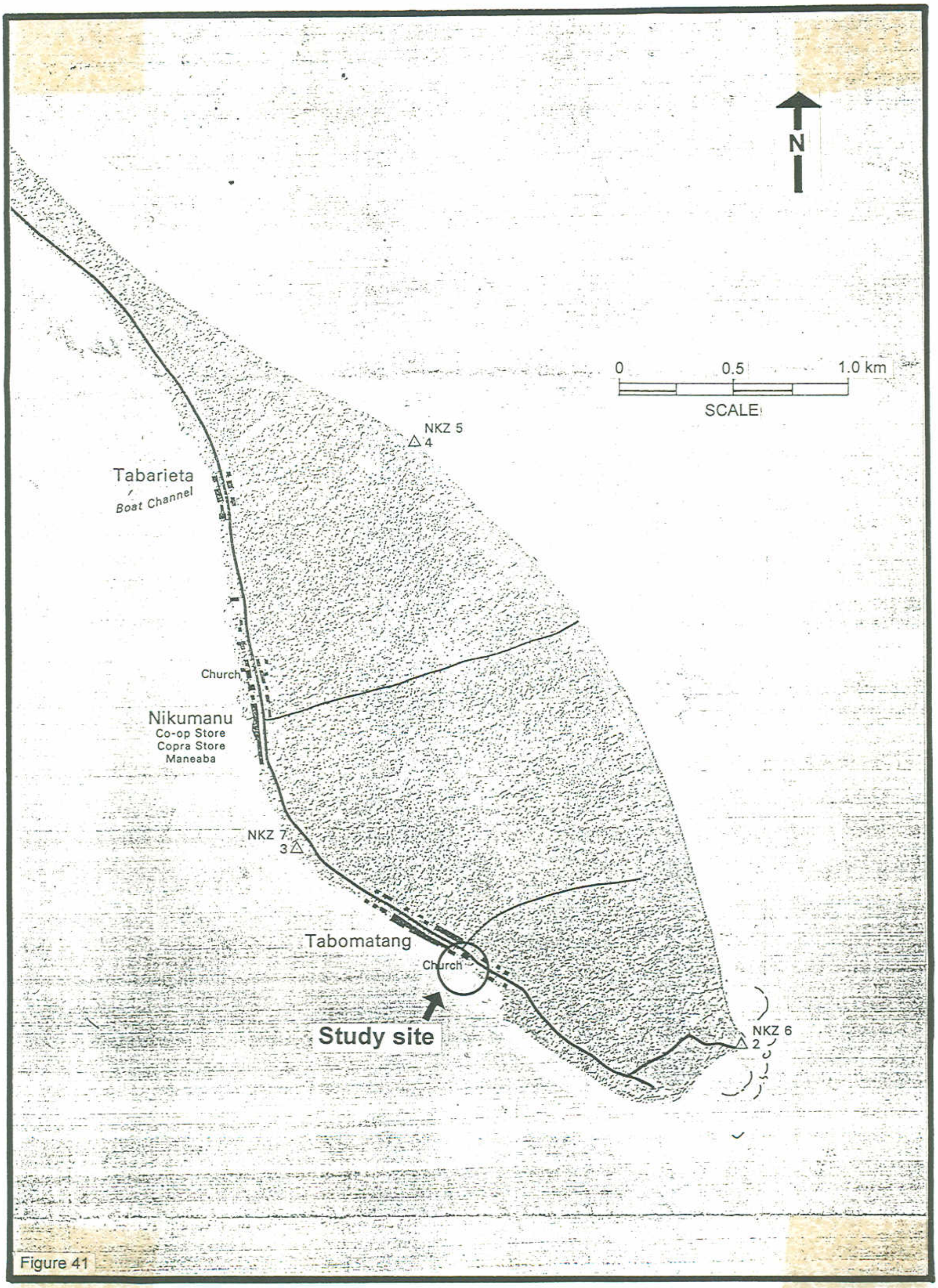

Figure 41. Map showing location of study site on the southwest ocean shoreline at Tabomatang, Nikunau. Main area of shoreline erosion concern is immediately north and south of church.

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Figure 42. Tabomatang, Nikunau. View northwest at location of beach profile site showing remains of seawall on upper foreshore.

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Figure 43. Tabomatang, Nikunau. View northwest at location approximately 100 m north of beach profile site (Figure 42) showing area of extensive seawall construction.

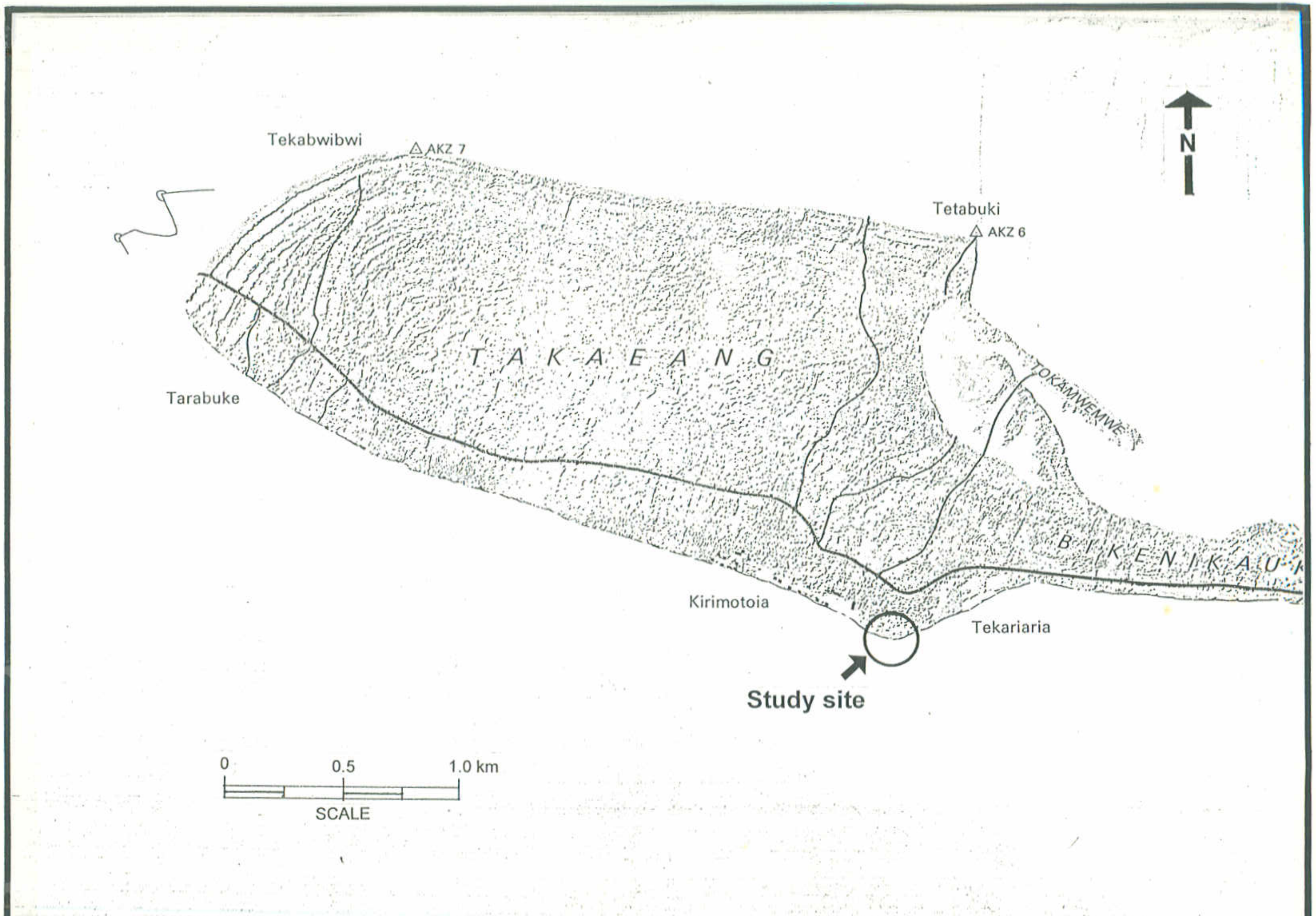

Figure 44

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Figure 44. Map of Takaeang Island, Aranuka showing location of study site on southeast corner of island.

In general, there is abundant evidence for the rapid growth of the shoreline of Takaeang and adjacent lagoon islets in recent times. This is recognised by the local inhabitants. Most of the inland and recent backshore areas of the islet consist of recent beach ridges which indicate active shoreline progradation. The is also active beach spit growth on the northeast side of the islet (Figure 44). In addition, based on the comparison of shorelines on older maps. air photos and existing conditions a small islet to the east of Takaeang appears to be growing very rapidly. Considerable consolidation of sediments and growth of terrestrial vegetation appears to have occurred where previously there were intertidal areas.

At the study site. a previous rock filled gabion wire basket seawall has mostly failed and only small sections of the original seawall exist. In fact only about 5 m of the original 1 00 m exists (Figure 45. 46). Apparently the seawall was constructed about 1985 and had started to fail within two to three years. Requests to have the seawall repaired were initially made to Home Affairs about 1988. The representative from the village that acted as a local source of information was pleased to see us but chided us for our tardiness. Local sources also provided information on the longer term changes on the southeast corner of the island. Apparently some 60-70 years ago shoreline erosion became a problem at Tekariaria and the village was moved to the new site at Kirimotoia (Figure 44).

Wave energy reaching the site must pass over a wide reef. At the time of the survey the tide was rising and a strong flood tide current was running along the beach from west to east. The strength and direction of this current probably exerts some control on the stability of the shoreline at the point as well as currents generated by waves.

The were limited assets at risk during the time of the visit. The school itself is some 30 m back from the shoreline. However, traditional huts to house the school teachers are on the edge of the beach and therefore at immediate risk.

### *Recommendations*

A possible solution was discussed with the villagers whereby the teachers quarters could be relocated back 5-10 m from the shoreline. It is not recommended that a seawall along the shoreline be re-built.

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Figure 45. Takaeang, Aranuka. View of remaining gabion basket seawall in front of teacher's quarters near school.

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Figure 46. Takaeang, Aranuka. View northeast of gabion basket seawall remains to east of school site.

## Aranuka: Buariki South

*Site Description and Erosion Problem*

Buariki South is located south of the main village of Buariki on the lagoon shoreline of Buariki Islet, which is located on the eastern side of the atoll rim (Figure 47).

Prior to viewing the erosion study site, the survey team travelled along the ocean shoreline road to the southern end of Buariki and then returned via the lagoon road to Buariki South. This afforded an opportunity to view a number of shoreline conditions around the islet. A large boat channel had been constructed across the ocean reef on the eastern side of the islet. However, it was not used under most conditions by boats because the water current running off the reef and out through the channel caused waves to steepen and break which results in hazardous conditions.

Most of the ocean shoreline is uninhabited and is fronted by a wide beach. The ocean beaches appeared to be either stable or actively prograding. The effects of longshore sand transport resulting from predominantly westerly wave conditions in recent times were evident as large areas of accretion on the western sides of natural rock platform groynes. Actively prograding beaches some 200 m long were also observed at the heads of two wide shoreline re-entrants or bays on the southeast side of the island. In general, no erosion problems were observed along the lagoon shoreline until the area of concern at South Buariki was reached.

The lagoon shoreline at Buariki South is fronted by exposed beachrock extending over about 500 m along the shoreline (Figures 48, 49). According to local sources the amount of erosion has amounted to about 10 metres over the last 50 years. This would appear to be consistent with a similar width of exposed beachrock. Both the map and airphoto shows an exposure of beachrock which indicates it has been so for some time. The study site and beach profile were also just north of the foundations remaining of a trader store (Langley) which was now very close to the shoreline. The store had been operated at the site for some time in the past. However, the original position of the shoreline relative to the store could not be determined.

Most of the study site shoreline is composed of a locally constructed seawall made from pieces of beachrock. This includes large blocks up to 200-300 kg which have been cut or split from the beachrock formation.

There was no apparent reason for the erosion at this site. A sand veneer covered the beachrock to the north and south and information provided from local sources indicated that some sand

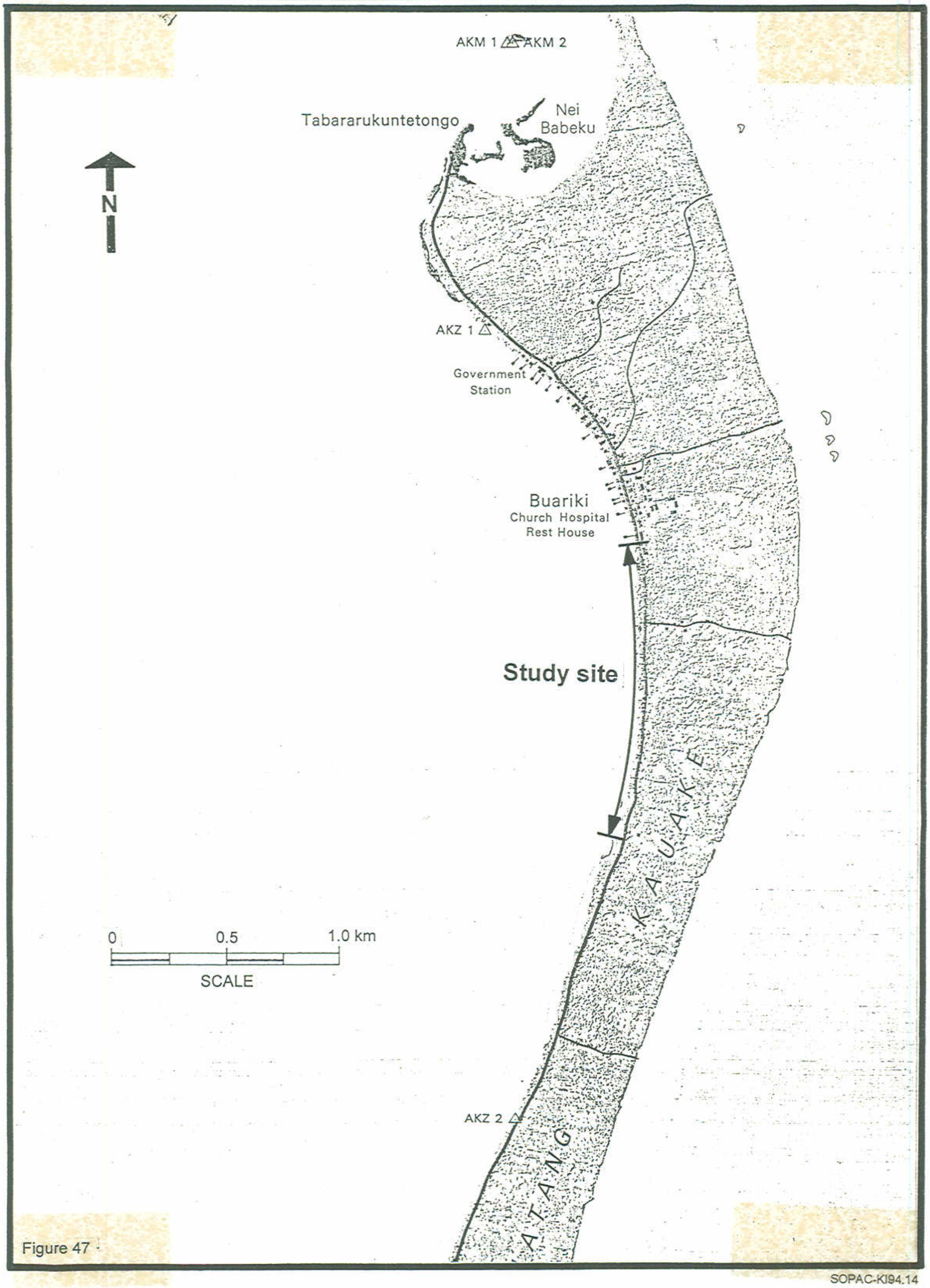

Figure 47. Map of Buariki Island, Aranuka showing location of study site on lagoon shoreline south of village of Buariki.

Figure 48. Buariki South, Aranuka. View north at beach profile site showing exposed beachrock in front of seawall constructed of beachrock slabs quarried from the lower foreshore. Note absence of any beach sediment on upper foreshore.

Figure 49. Buariki South, Aranuka. View south of beach profile site showing extensive area of exposed beach rock and natural shoreline with narrow beach.

reappears from time to time for brief periods. It is possible that a gradual evolution and re-alignment of the lagoon shoreline of Buariki islet is taking place. This appears to be taking the form of progradation of north and south lagoon ends of the islet while the central part has eroded.

*Recommendations*

The erosion appears to be long term and not related to short term cycles of weather and beach erosion\accretion. It is recommended that the local island and national authorities take this into consideration for future development decisions and long term planning needs on Buariki.
In the short term a limited amount of seawall construction could be assisted by the use of concrete. In this regard, the foundation conditions at the site (i.e. extensive beachrock) are suitable. However, it must be emphasised that seawall construction on the shoreline will significantly reduce the likelihood of a beach becoming re-established at the site.

## DISCUSSION

The primary objective of Phase II of the reconnaissance survey in the Gilbert Island Group was to define the extent, severity and causes of coastal erosion at various sites in the outer islands. During twelve days of survey work nine islands were visited (Abaiang, Marakei, Makin, Butaritari, Tamana, Arorae, Beru, Nikunau and Aranuka) and 21 sites with a history of coastal erosion problems were surveyed. The relative amount of erosion of each site and the amenities impacted at each site were also determined. The survey results are briefly summarised in Table 3 along with recommendation actions.

A vertical air photo survey was conducted over shoreline erosion sites on four (Abaiang, Marakei, Beru, Nikunau) of the nine islands. Poor weather conditions and aircraft fuel limitations prevented air photo survey operations on the rest of the islands. Beach profile surveys were conducted at each study site.

As was the case with Phase I of the survey (Gillie 1992c; 1993a) the preliminary findings indicate that at the sites visited where coastal erosion is a problem, the causes of the erosion fall into two main categories: natural and man-made causes.

## Natural Causes of Erosion

Natural causes of erosion include locations with a high variability of shoreline position such as depositional spit complexes along lagoon shorelines and beaches near inter-islet channels, reef passages and at the ends of table reef islands such as Tamana, Arorae, Nikunau and Makin.

Shorelines exposed to winds and waves from a westerly quarter also experience a high degree of natural variability in position. Periods of time with higher than average sea levels and strong to gale force westerly winds can result in episodes of erosion on an otherwise stable shoreline. In this regard atmospheric and oceanic conditions during the last six months continue to reflect the persisting, mature phase of the already prolonged 1990-1992 EI Nino Southern Oscillation (ENSO) event (NIWAR 1993). In particular, coastal processes in the Gilbert Group in the last 2-3 years have been affected by higher than average sea levels, and more persistent and stronger westerly winds and associated waves. In early January 1993 gale force westerly winds caused a storm surge in the southern islands of the Gilbert Group. The islands of Arorae and Tamana were the most affected.

Episodes of salt water incursion/inundation into or adjacent to babai growing areas (taro pits) were also identified as a coastal stability problem at two locations.

## Man-made Causes of Erosion

Man-made causes of coastal erosion include the undesirable effects of causeway construction across inter-islet channels, boat channel construction across the ocean reef which acts as a pathway for sand loss from the beach, removal of beach sediments and beachrock for on-land construction activities and the impact of seawall and revetment construction.

Previous attempts at foreshore protection have been mostly unsuccessful. Most seawalls have failed to halt or prevent erosion because of a combination of financial and management shortcomings including: severe project funding limitations, inappropriate or under-engineered designs and poor control of on-site construction methods.

It was also clear from the discussions with local island representatives that seawall construction is regarded as their preferred response to coastal erosion problems. However, this is not the only response which should be under consideration. Seawalls are relatively expensive engineering structures. In most cases in the past, they have either failed to protect the shoreline or may have accelerated the erosion of beaches. Other response strategies to coastal erosion problems such as accommodation (land use planning) and retreat (relocation and set-back guidelines) need to be given higher priority. In this regard, it is noteworthy that on islands where villages are presently exposed to open ocean waves (Tamana and Arorae, for example) the response to repeated storm inundation and flooding presently includes a natural set-back of 20-30 m from the beach ridge. Similar set-back guidelines should be considered for other islands.

Without fundamental changes in shoreline management practises in Kiribati, coastal erosion problems will probably increase in frequency and severity and the impact of coastal erosion and loss of beaches is expected to accelerate in the future. This is primarily due to the practice of intensive shoreline occupation and development and the limited infrastructure in Kiribati to manage coastal resources and development.

It is also important to note that this reconnaissance survey of known sites of coastal erosion has been useful in determining the nature and extent of coastal erosion where it is presently a problem. However, generalisations regarding the overall extent and severity of coastal erosion, accretion and stability in the islands of the Gilbert Group should not be made from this study alone. It is recommended that a much broader coastal survey and mapping project needs to be undertaken to define the overall shoreline characteristics, stability and vulnerability of the islands to coastal erosion.

**Table 3.** List of islands visited, sites surveyed, summary of coastal erosion problems and recommended action to be taken. See text of report for further explanation of summary of erosion problem and consideration of recommended action.

| ISLAND SITE/VILLAGE | SUMMARY OF COASTAL EROSION PROBLEM | RECOMMENDED ACTION |
|---|---|---|
| **ABAIANG** | | |
| Tabontebike | Moderate erosion of 5-10 m along 200-300 m of sheltered ocean shoreline. Amenities affected include loss of coconut trees and salt water intrusion into babai pits. Erosion appears due to natural causes. | No immediate action is recommended for this site. The priority for any action at the site is not urgent. Nor is the magnitude of the natural physical hazard and the amenities which would be potentially affected large. |
| Koinawa | Moderate erosion of 5-10 m along 150 m of lagoon shoreline. Potential effects on road if erosion continues. | A previous study of this site (Harper 1989) recommended renewing the older shore protection over 100-200 m of the threatened road. In this regard, the use of concrete strengthened coral boulder seawall or grout filled sandbags is recommended over gabion baskets. |
| Tebunginako | Severe erosion of greater than 10 along more than 500 m of lagoon shoreline. Site previously surveyed by Harper (1989) and Holden (1992). Southern (older) maneaba now inundated by sand overwash. Many other traditional buildings have been removed or are threatened by further erosion. Erosion due to natural causes of spit migration along lagoon shoreline. | It was recommended by Holden (1992) that future buildings be setback 15 metres from the natural boundary of the sea. For existing expensive buildings at risk, a grout filled sloping sandbag seawall was recommended (see Figure 11 in Holden 1992). |
| **MARAKEI** | | |
| Rawannawi | Severe erosion of ocean shoreline along village fronted by natural pass in reef which has been modified (boat channel near shore). Erosion extends 400 m north and south of reef pass. Cause of erosion appears to be loss of beach sands to the boat channel, reef pass and beyond the reef. | Any proposed shoreline protection structure at this site would have to be relatively large because of the height of the existing shoreline wall and the high energy wave conditions. This would require the extensive use of concrete. |
| Buoata | Moderate erosion along ocean shoreline for 0.5 km north and 1-2 km south of Buoata village. Affected amenities includes village, coconut trees and road. Shoreline subject to storm overwash. | Where possible, the road should be relocated well inland in order to avoid future impact from coastal erosion. |

| | | |
|---|---|---|
| Baretoa Passage | Natural inter-islet channel closed by accretion of large sand ridge on ocean side entrance approximately 10 years ago. Channel closure probably related to causeway construction across channel some 15 years ago. Severe local impact on lagoon fisheries since channel is one of only two channels on Marakei allowing flow between ocean and lagoon waters. | It is recommended that the passage be re-opened and the previous causeway and bridge be re-built. |
| **MAKIN** | | |
| Naka Primary School | Moderate erosion along ocean shoreline for about 0.5 km north and south of school located on point. Besides school, other amenities affected include village houses. Erosion occurs with strong westerly winds and waves. | Some form of shoreline protection is warranted considering the economic value of the asset at risk. |
| **BUTARITARI** | | |
| Ukiangang Point | Moderate erosion (5-10 m) of ocean shoreline adjacent to road threatens babai growing areas adjacent to slightly brackish pond. Salt water inundation into the pond occurs with storms. Main concern is security of food supply (babai pits). Salt water inundation difficult to prevent with coastal protection alone. | It would be costly and difficult to build protection along the entire length of shoreline and it is recommended that no shoreline protection be considered. Rather, it is recommended that inland alternatives for the protection of marginal babai growing areas be investigated. |
| Keuea Village | Minor coastal erosion (< 5 m) with some erosion scarps along the ocean shoreline away from the village on the lagoon shoreline. Main concern is episodic inundation of saltwater into babai pits. Approximately every 3-4 years storm-driven saltwater overtops the coastal ridge and flows inland about 40 m to babai pits causing young plants to die off. | The infrequent saltwater inundation of marginal babai pits and minor coastal erosion do not justify foreshore protection. |
| Keuea/Tanimaini-ku School | Moderate erosion (5-10 m) along lagoon shoreline north of causeway under construction for nine years (1975-1983). School built in 1980 now some 30 m from shoreline. Some erosion beside road to north of school as well. | Minor erosion is expected to continue because of the effects of the causeway construction. However, because the school is still 30 m from the shoreline no protection is warranted at this time. |

| | | |
|---|---|---|
| **TAMANA** | | |
| Barebuka | Site at west end of airport runway on north end of island. Erosion at end of runway with vertical scarp changing to cobble beach and then sand beach accretion on extreme north end of island. Erosion associated with westerly winds and waves, especially storm surge in early January 1993. | No coastal engineering protection is recommended. |
| Bakarawa | Survey site approximately 300 m north of shipwreck. Shoreline comprises alternating beach rock and sand with some erosion and evidence of wave overwash into backshore. Progressive erosion over 10 years of about 5-10 m. However, shoreline still at least 20 m from traditional houses. | It is recommended that no action needs to be taken because no major assets are at risk. The traditional practise of building well back from the shoreline on the west coast of Tamana should be encouraged elsewhere in Kiribati. |
| Bakaka | Site fronts government office, guest house and large KPC church. Shoreline protection includes existing and destroyed seawalls. However, all buildings are set well back from the shore and are not in danger. | It is recommended that minor repairs be made to the existing seawall, but that it should not be extended onto the beach. |
| **ARORAE** | | |
| Taribo | Erosion site approximately 100 m south of boat channel. Storm surge event in early January caused overtopping of the beach ridge and destruction of portions of locally constructed seawalls. Overwash deposits up to 0.5 m thick and 40-50 m back of beach ridge. | The natural process of accumulation of backshore deposits from storm surge events should not be interfered with by the construction of seawalls. The traditional local practise of leaving a wide storm buffer zone should be encouraged. |
| Tamaroa | Minor erosion at large LMS church north of town. The beach is accreting seaward in front of erosion scarp from early January storm surge. No buildings in immediate danger. | It is recommended that the existing storm buffer zone between the shoreline and the church be maintained and no construction take place in this zone. It is also recommended that coconut trees be planted along the shoreline to assist with shoreline stabilisation. |
| Batitotai | Erosion of west side of southern end of island over a 50 year period. Site comprises abandoned village site and no permanent buildings are in danger. | There has only been a minor amount of erosion at the site and the value of the present assets at risk do not justify the need for coastal protection. |

| | | |
|---|---|---|
| Barbaroroa | Erosion of west side of northern end of island. Erosion scarp associated with early January storm surge and subsequent strong westerly winds and waves. Shoreline approximately 200 north and 100 m west of Navigation Stones culture heritage site. | The site of the Arorae Navigation Stones is about 200 m inland of the study site and they are not presently at risk. Therefore, it is recommended that no action be taken. |
| **BERU** | | |
| Taboiaki | Moderate erosion predominantly south of village. Erosion extends over 1.5 km along shore. Overcrowding forcing local people to live on the shoreline. Extensive length of existing seawall construction. | Protection of the existing shoreline would require a costly and substantial structure. Where the land is not under intensive development the assets at risk do not justify the cost and the implementation of set-back guidelines is appropriate. Where the land is occupied, the re-location of existing land use activities when and if required is recommended. |
| **NIKUNAU** | | |
| Tabomatang | Main area of concern north and south of church. Extensive length of shoreline with seawalls north of church. Longer term erosion in the order of 10-20 m according to local sources. | Re-establishing the site for its former use (a maneaba) would require building a new seawall and reclaiming some of the beach foreshore. This is not recommended. |
| **ARANUKA** | | |
| Takaeang | Minor erosion near school on point along south coast of island. Strong tidal currents flow past this point in both directions (flood to the east and ebb to the west). Initial gabion basket seawall placed in 1985 and came apart 2-3 years later. School presently 30 m back of beach and not in immediate danger. | A possible solution was discussed with the villagers whereby the teachers quarters could be relocated back 5-10 m from the shoreline. Otherwise no action should be taken and the construction of a seawall is not recommended. |
| Buariki South | Erosion of low lagoon shoreline over 500 m along Buariki South village area. Moderate erosion of 10 m over approximately 50 years. Beach rock exposed along shoreline and broken pieces have been used extensively for seawall construction. | Erosion at this site appears to be long term. It is recommended that the local and national authorities take this into consideration for future development needs and long term planning needs on Buariki. In the short term seawall construction could be assisted by the use of concrete. |

## GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The primary objective of the survey was to define the extent and severity of coastal erosion in the outer islands of the Gilbert Group. During 12 days of field survey work, nine islands were visited (Abaiang, Marakei, Makin, Butaritari, Tamana, Arorae, Beru, Nikunau and Aranuka) and 21 sites with a history of coastal erosion problems were surveyed. The survey results are summarized in Table 3 which provides a list of islands visited, sites surveyed, summary of coastal erosion problem and the recommended action to be taken.

2. The results of the survey indicate that at the sites visited where coastal erosion is a problem, the causes of the erosion fall into two main categories: natural and man-made or man-induced causes.

3. Natural causes include locations with a high variability of shoreline position such as depositional spit complexes at the south end of atolls, along lagoon shorelines and at the sides of inter-islet channels. Periods of time with higher than average sea level and westerly winds caused by seasonal and inter-annual variations in climatic and oceanographic factors can also result in cycles of erosion and/or accretion on an otherwise stable lagoon shoreline. Basically, these cycles of erosion and accretion are times when the shoreline is re-aligned in response to varying coastal processes.

4. Man-made causes include the deleterious effects of causeway construction across inter-islet channels. This effectively cuts off the supply of sand from the ocean reef to the lagoon and causes the re-alignment of the adjacent lagoon shoreline. Other man-made causes of coastal erosion include the disruption of sediment transport budgets (local erosion and accretion changes). Sediment transport budgets are disrupted by harbour and associated mole construction, dredging of lagoon sediments and the creation of borrow pits near to the shore, and land reclamation activities.

5. The majority of the erosion sites that were visited in Phase I was located on the lagoon shoreline of atolls. This is probably a reflection of two factors. First, it has been established on South Tarawa that lagoon beaches tend to be more dynamic than ocean beaches (Harper 1989b). This is because lagoon beaches experience a greater temporal variation in the I magnitude and direction of waves than ocean beaches. Second, the settlement pattern on most atolls tends to be concentrated along the lagoon shorelines. These settlements are ultimately impacted by the dynamic lagoon shoreline.

In this, Phase II of the study, a number of ocean shoreline sites were examined, particularly those on table reef Islands with no lagoons (Arorae, Tamana, Nikunau, Makin, southern Beru).

The extremities of these islands are subject to natural shoreline instability as a result of variable sea conditions.

6. It is clear that previous attempts at foreshore protection have been largely unsuccessful. Most coastal erosion sites visited have had one or two generations of seawalls which had failed totally. Failed seawall types included traditional loose coral boulders stacked as a vertical wall, cemented coral boulders as a vertical wall, rock fill gabion wire baskets and grout filled sandbags. Earlier work in South Tarawa by SOPAC and overseas researchers from the UK and Australia have made similar conclusions. It is therefore recommended that a complete review of the policy, design and construction of foreshore protection be undertaken. In this regard, the issues and problems relating to coastal protection within the region are presently being addressed, as reported in SOPAC (1993) and SPREP (in prep).

7. Shore protection on outer islands is relatively costly in terms of other development need. It is clear from the history of previous foreshore protection projects on outer islands that this provides only a temporary solution to erosion problems. This is either because the nature of the erosion is long term and chronic or the locally designed and built foreshore protection experiences structural failure soon after completion. As discussed in Appendix 5, more consideration needs to be given to the cost effectiveness and advantages of setback and/ or relocation as a viable alternative to coastal protection. This will require education, government regulations and enforcement.

8. Related to 7, the possible risk of coastal erosion at all sites visited in the Gilbert Islands needs to be taken into consideration in the future planning and siting of villages, permanent buildings and other valuable land use activities.

9. The reconnaissance survey of known sites of erosion has been useful in determining the nature and extent of coastal erosion where it has presently become a problem. However, generalizations regarding the overall extent and severity of coastal erosion in the atoll islands of the Gilbert Group cannot be made from this study.

Therefore, it is recommended that a wider ranging geographic study of coastal erosion and mapping be conducted in the Gilbert Islands. To implement this recommendation the techniques which would need to employed to conduct this type of study would include: analysis of aerial photographs for historical shoreline changes, use of contemporary aerial photography an low angle aerial video surveys and detailed ground surveys.

Analysis of historical air photos (from WWII, 1969, 1984, and the most recent photo obtained during this survey) is required to document the longer term nature and rates of shoreline change.

10. An attempt should be made to continue monitoring the beach profiles established during this survey in order to document the present rate of erosion. Beach profiles should be resurveyed once a year if possible. It would be desirable, but not absolutely necessary, to conduct the resurvey during the same season each year.

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# APPENDIX 1

## SUMMARY OF MAP SHEET AND COORDINATE DATA FOR EACH SURVEY SITE

Table A1. Summary of map sheet and coordinate data.

| ISLAND / SHEET | SITE / VILLAGE | COORDINATES |
|---|---|---|
| ABAIANG-3<br>(Edition 1 - DOS 1980) | Tabontebike | 27900 E<br>190600 N |
| ABAIANG-2<br>(Edition 1 - DOS 1980) | Koinawa | 28400 E<br>206300 N |
| | Tebunginako | 23500 E<br>211800 N |
| MARAKEI<br>(Edition 1 - DOS 1972) | Rawannawi | 9300 E<br>227200 N |
| | Buota | 9000 E<br>223700 N |
| | Baretoa Passage | 8200 E<br>221300 N |
| MAKIN<br>(Edition 2 - DOS 1977) | Naka Primary School | 71900 E<br>373400 N |
| BUTARITARI-2<br>(Edition 1 - DOS 1977) | Ukiangang Point | 12300 E<br>335600 N |
| BUTARITARI-3<br>(Edition 1 - DOS 1977) | Keuea Village | 28100 E<br>345500 N |
| | Keuea/Tanimainiku School | 26700 E<br>343900 N |
| TAMANA<br>(TAMANA & ARORAE)<br>(Edition 2 - DOS 1979) | Barebuka (Airfield) | 384800 E<br>9725100 N |
| | Bakarawa | 387200 E<br>9722500 N |
| | Bakaka | 386500 E<br>9723400 N |
| ARORAE<br>(TAMANA & ARORAE)<br>(Edition 2 - DOS 1979) | Taribo | 480600 E<br>9707500 N |
| | Tamaroa | 480000 E<br>9708500 N |
| | Batitotai | 482800 E<br>9704700 N |
| | Barbaroroa | 476700 E<br>9711100 N |
| BERU<br>(Edition 2 - DOS 1977) | Taboiaki | 390100 E<br>9848300 N |
| NIKUNAU<br>(Edition 1 - DOS 1977) | Tabomatang | 13700 E<br>145700 N |
| ARANUKA<br>(Edition 1 - DOS 1980) | Takaeang | 34000 E<br>118700 N |
| | Buariki South | 42200 E<br>118000 N |

## APPENDIX 2

### AIR PHOTO SURVEY COVERAGE

| ISLAND / Location | Line | Contact Print Numbers, Comments | Contact Prints To be Enlarged | No. |
|---|---|---|---|---|
| *ABAIANG* | | | | |
| Tebontebike | 1 | 1-4, over water | | |
| | 2 | 5-11, on target | 6-11 | 6 |
| Tebunginako | 1 | 12-18, on target | 15-18 | 4 |
| | 2 | 19-25, over water | | |
| *MARAKEI* | | | | |
| Rawannawi | 1 | 26-33, over reef | | |
| *BERU* | | | | |
| Taboiaki | 1 | 1-6, over reef | | |
| | | 7-16, on target | 7-16 | 10 |
| *NIKUNAU* | | | | |
| Tabomatang | 1 | 17-22, over water/reef | | |
| | | 23-37, over target | 23-37 | 15 |

Total number of contact prints to be enlarged = 35

35 Prints for SOPAC

35 Prints for Kiribati

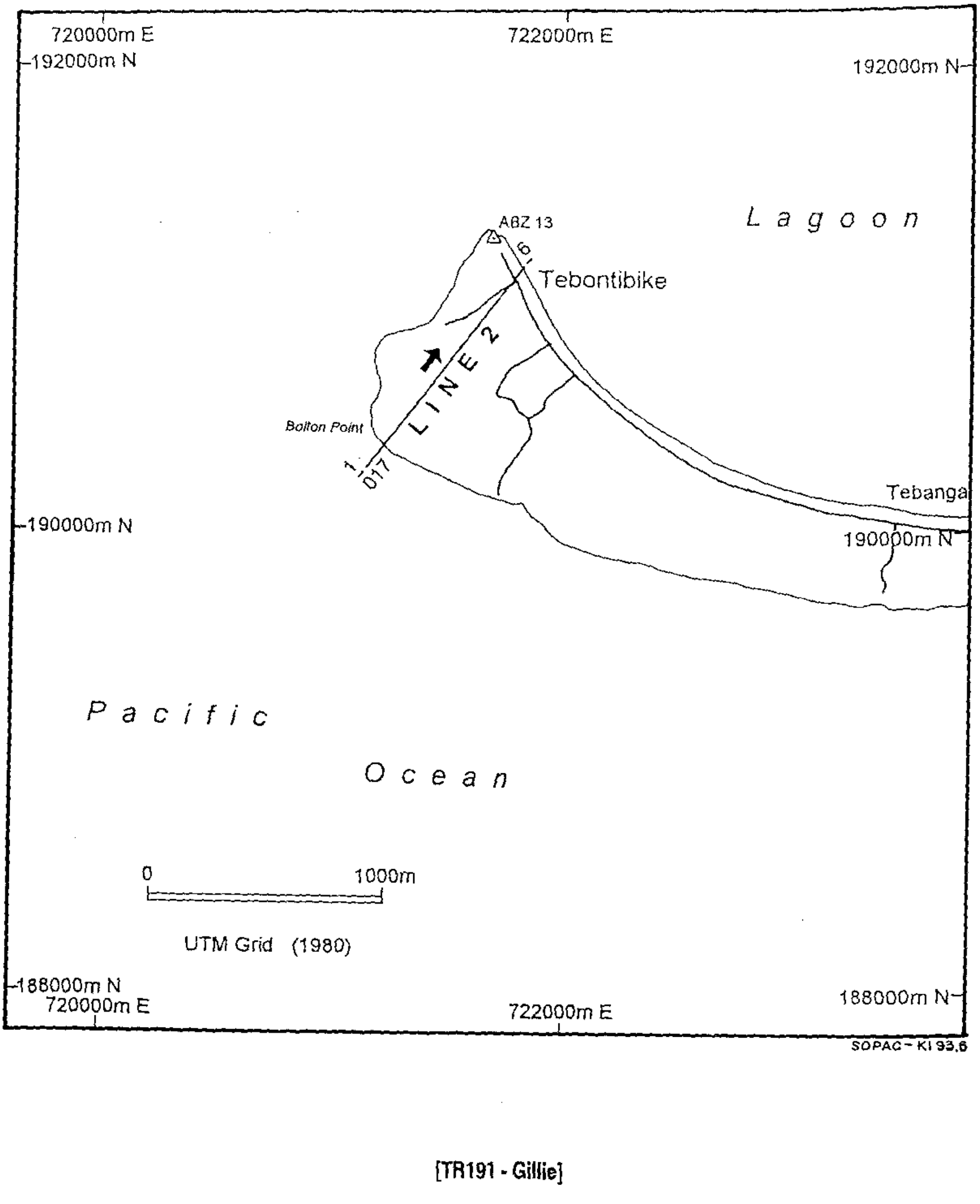
## SOPAC AIR PHOTO SURVEY

KIRIBATI

ABAIANG - TEBONTEBIKE

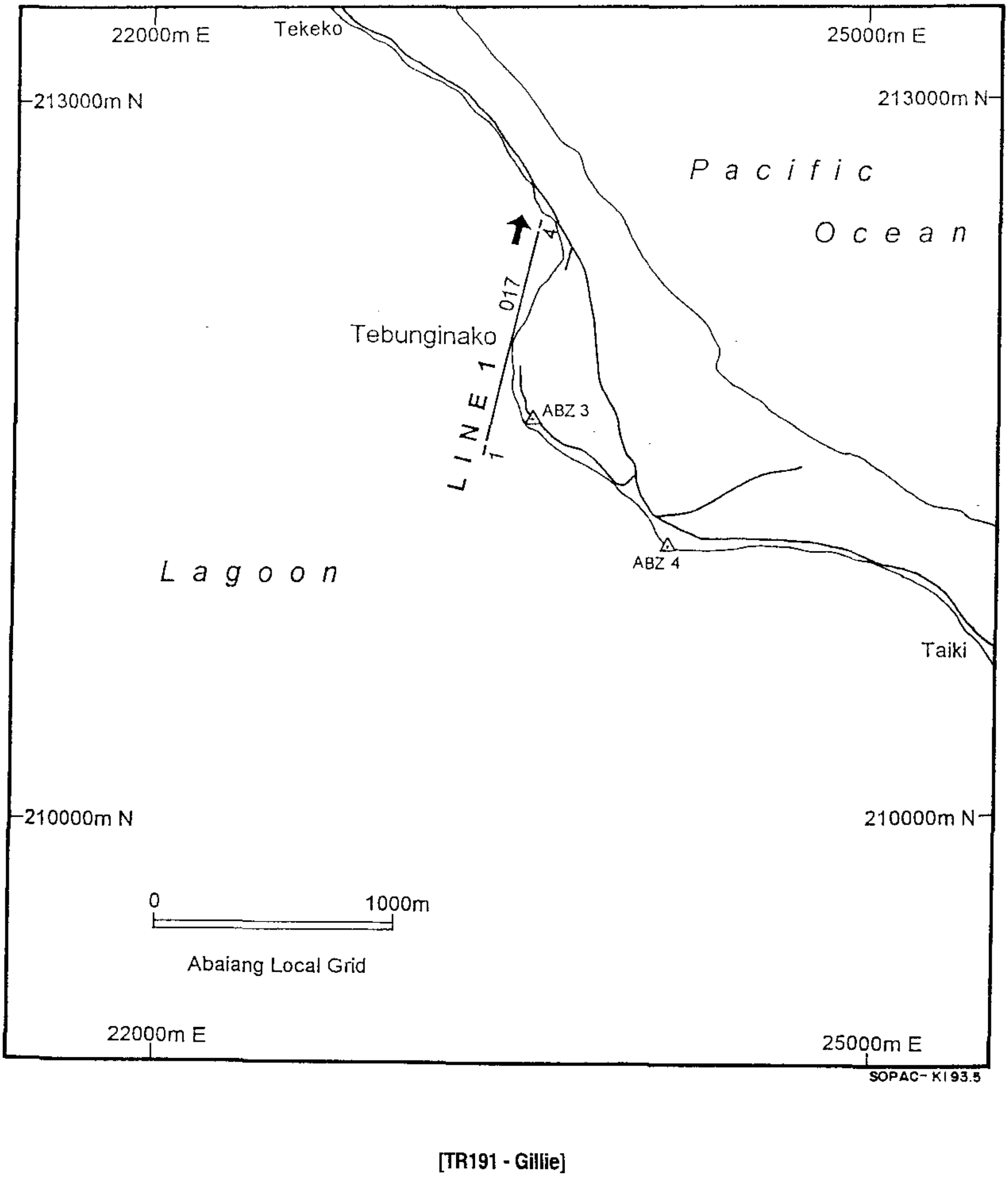
SURVEY DATE: 30 March, 1993 PRINT SCALE: 1 : 1300

| FILM S/N | LINE # | FRAME # | TOTAL |
|---|---|---|---|
| 017 | 2 | 1 - 6 | 6 |
| | | | |
| | | | |
| | | | |
| | | | |



## SOPAC AIR PHOTO SURVEY

| | | | |
|---|---|---|---|
| KIRIBATI | | | |
| ABAIANG - TEBUNGINAKO | | | |
| SURVEY DATE: 30 March, 1993 | | PRINT SCALE: 1 : 1300 | |
| FILM S/N | LINE # | FRAME # | TOTAL |
| 017 | 1 | 1 - 4 | 4 |
| | | | |
| | | | |
| | | | |
| | | | |



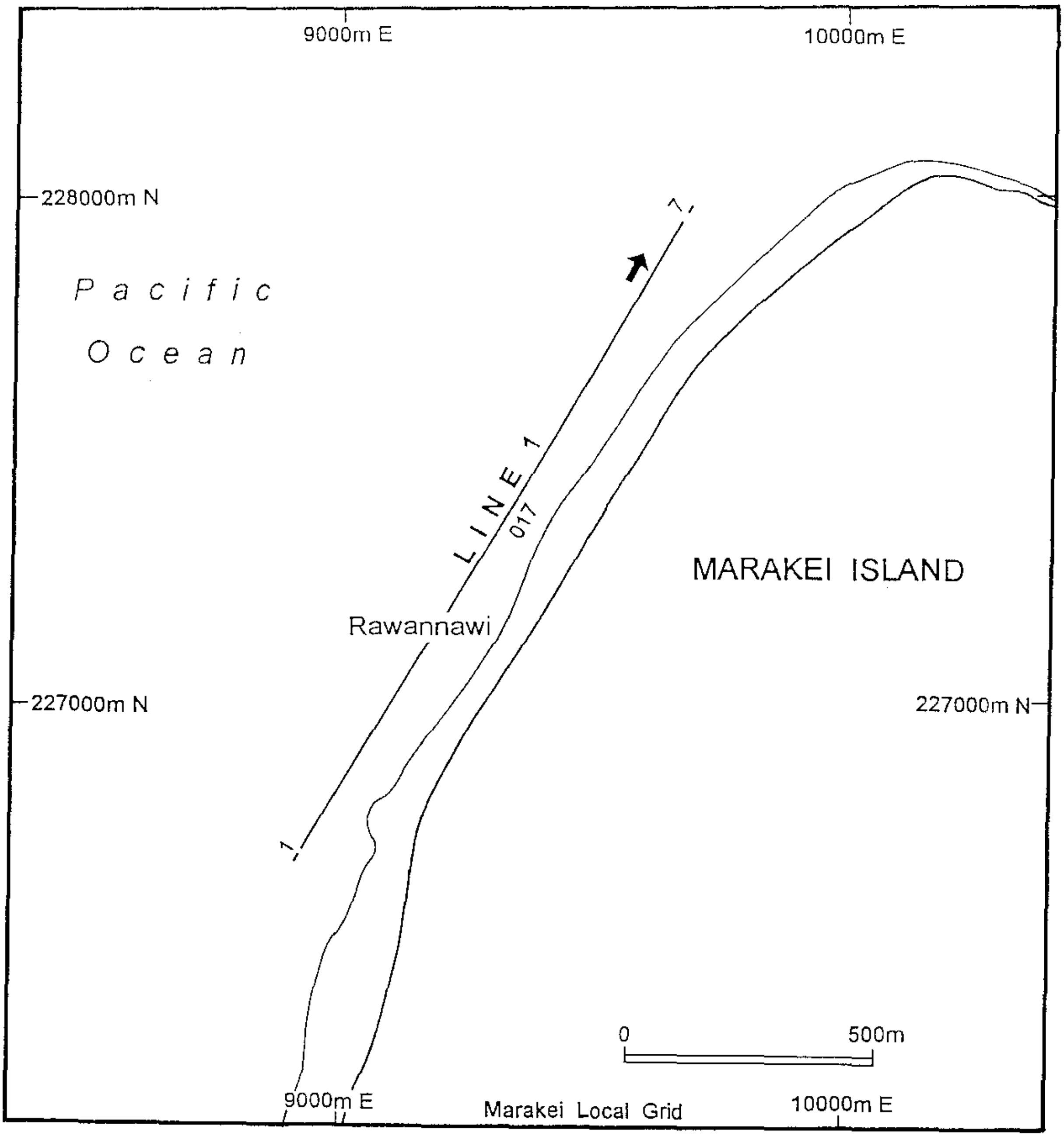
## SOPAC AIR PHOTO SURVEY

KIRIBATI

MARAKEI - RAWANNAWI

SURVEY DATE: 30 March, 1993 PRINT SCALE: 1 : 1300

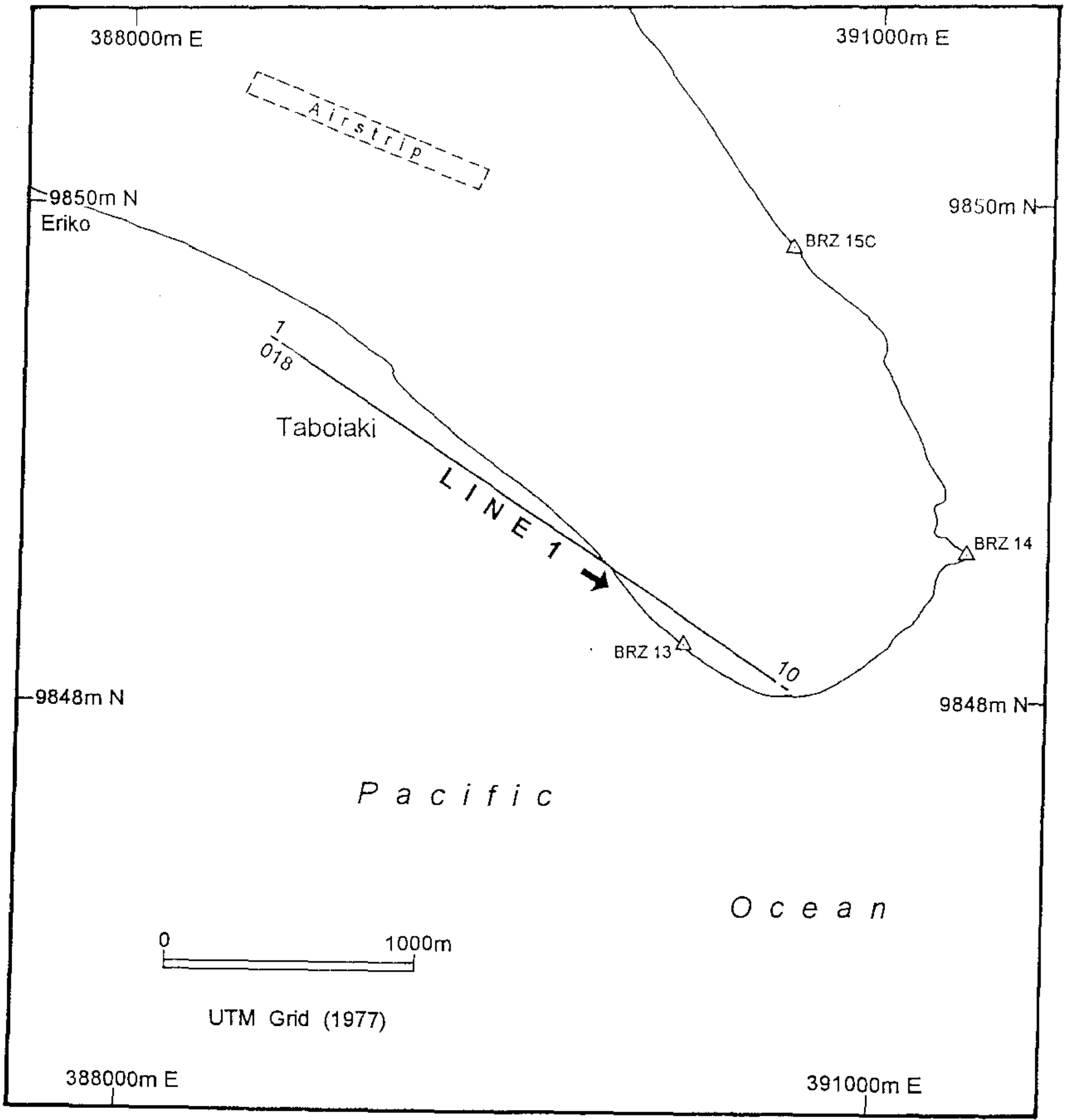
| FILM S/N | LINE # | FRAME # | TOTAL |
|---|---|---|---|
| 017 | 1 | 1 - 7 | 7 |
| | | | |
| | | | |
| | | | |
| | | | |



SOPAC-KI 93.3

## SOPAC AIR PHOTO SURVEY

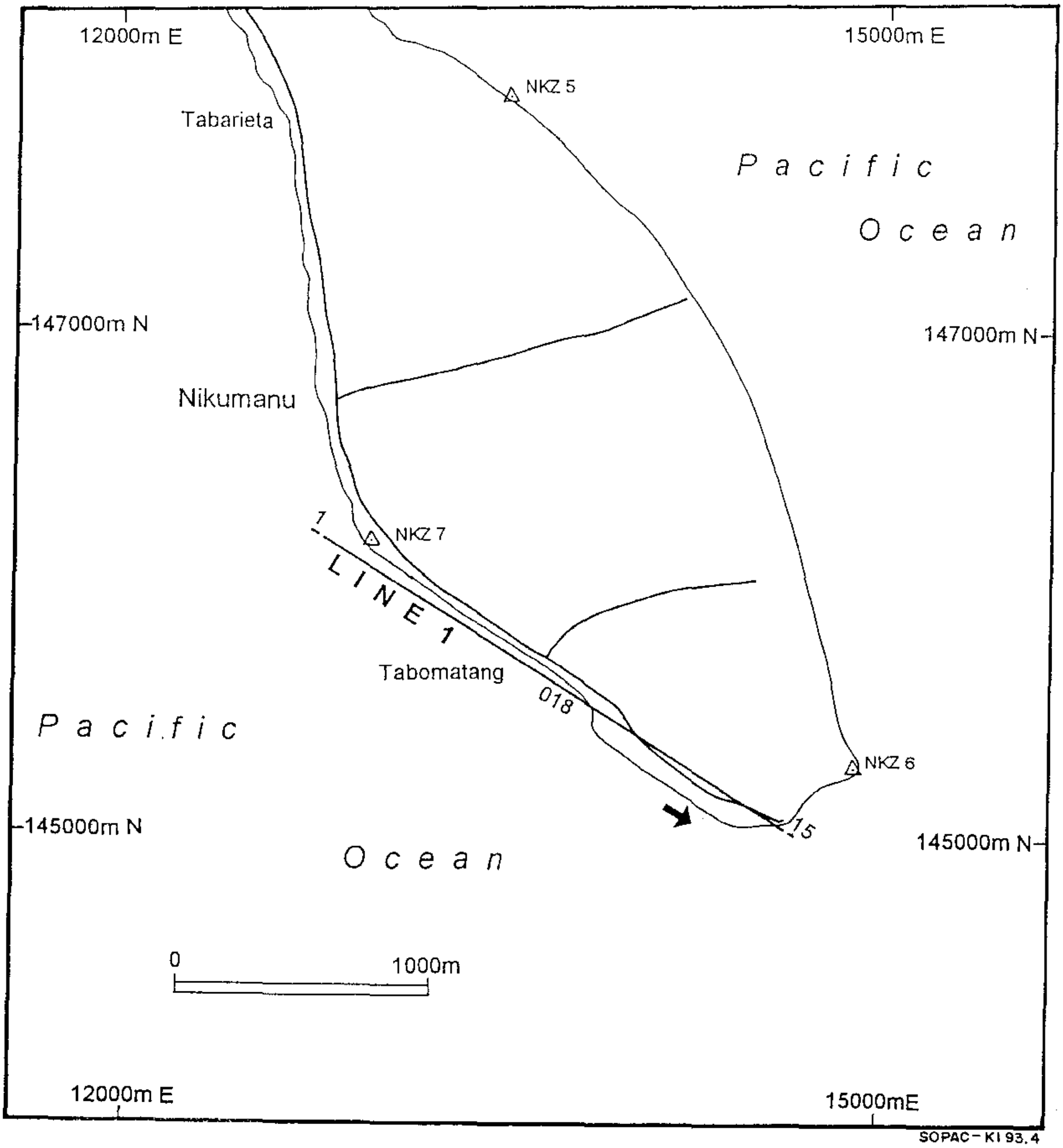
| | | | |
|---|---|---|---|
| KIRIBATI | | | |
| BERU - TABOIAKI | | | |
| SURVEY DATE: 30 March, 1993 | | PRINT SCALE: 1 : 1300 | |
| FILM S/N | LINE # | FRAME # | TOTAL |
| 018 | 1 | 1 - 10 | 10 |
| | | | |
| | | | |
| | | | |
| | | | |



SOPAC-KI 93.7

# SOPAC AIR PHOTO SURVEY

| | | | |
|---|---|---|---|
| KIRIBATI | | | |
| NIKUNAU - TABOMATANG | | | |
| SURVEY DATE: 30 March, 1993 | | PRINT SCALE: 1 : 1300 | |
| FILM S/N | LINE # | FRAME # | TOTAL |
| 018 | 1 | 1 - 15 | 15 |
| | | | |
| | | | |
| | | | |
| | | | |



SOPAC-KI 93.4

## APPENDIX 3

### PUBLIC WORKS DIVISION INFORMATION

INFORMATION REQUESTED FOR EACH SITE:

1. Date of construction: initial, re-built, repairs?
2. Type of construction.
3. Length of seawall.
4. PWD Assistance: design, materials, labour ?
5. Local initiative: design, materials, labour ?
6. Total cost.
7. Advise received from I-Matang or overseas advice?

SEAWALL AT TABOIAKI - BERU

Date of Construction - April 1993.

Length - 10 metres.

Type of Seawall - Stone wall vertical face.

PWD Assistance - Nil.

Local Initiative - The seawall was built by one man to protect his property and still in progress but only 10 metres now completed.

Total Cost - $1,500.00.

Advise - Nil.

SEAWALL AT TABOMATANG - NIKUNAU

Date of Construction - 1973.

Length - 40 metres on completion and 15 metres collapsed.

Type of Seawall - Sandbag slanting face.

PWD Assistance - The seawall was designed and supervised by PWD. Island labour were engaged to construct the wall Materials sandbag fill with concrete laid and motored with sand/cement motor.

Advice - PWD.

Total Cost - $5,500.00

## SEAWALL AT TAKAEANG ARANUKA

Date of Construction - 1975.

Type - Cabion Basket.

Length - 70 metres completed but only 10 metres left and the remaining seawall need repair work immediately.

PWD Assistance - Nil.

Local Initiative - The island council is directly supervising and provide labour for the job,Cabion basket from Supplies.

Total Cost - $6,000.00.

Advise - There is a standard specification for this type of seawall and this are obtainable from PWD free of charge to island councils. During the inspection of the seawall I found out that the standard procedure to construct this type of seawall were not used on this seawall.

## SEAWALL AT BUARIKI - ARANUKA

Date of Construction - 1975.

Type - Stone wall vertical face.

Length - 25 metres.

PWD Assistance - Nil.

Local Initiative - The island council is directly supervising and provide labour for the job. The materials used to construct the wall are natural rocks from the island.

Total Cost - $3.000.00.

Advise - Nil.

3: BUTARITARI.

A:KEUEA.

| | |
|---|---|
| DATE OF CONSTRUCTION. | JUNE 1981 |
| TYPE: | CAUSEWAY |
| LENGTH: | 2km |
| PWD ASSISTANCE: | PLANT AND MACHINERY. |
| LOCAL INITITIVE: | DESIGNED/MATERIALS AND LABO |
| TOTAL COST: | NIL. |
| ADVICE RECEIVED- ON DESIGN. /CONST'N- FROM OVERSEAS. | NIL |

B: KEUEA PRIMARY SCHOOL

| | |
|---|---|
| DATE OF CONSTRUCTION.' | NIL |
| TYPE: | NIL. |
| LENGTH: | 200m |
| PWD ASSISTANCE: | NIL. |
| LOCAL INITITIVE. | NIL. |
| TOTAL COST. | NIL. |
| ADVICE RECEIVED- ON DESIGN. /CONST'N- FROM OVERSEAS. | NIL. |

4:MAKIN

NAAKA PRIMARY SCHOOL

| | |
|---|---|
| DATE OF CONSTRUCTION. | NIL |
| TYPE: | NIL. |
| LENGTH: | 500m |
| PWD ASSISTANCE: | NIL. |
| LOCAL INITITIVE: | NIL. |
| TOTAL COST. | NIL. |
| ADVICE RECEIVED- ON DESIGN. /CONST'N- FROM OVERSEAS. | NIL. |

## 1: ABAIANG.

### A: TEBUNGINAKO.

| | |
|---|---|
| DATE OF CONSTRUCTION: | 1980 |
| TYPE: | DYKE. |
| LENGTH: | 60M. |
| PWD ASSISTANCE: | PLANTS AND MACHINERY. |
| LOCAL INITITIVE. | LABOUR AND MATERIAL. |
| TOTAL COST | NIL. |
| ADVICE RECEIVED– ON DESIGN /CONST'N– FROM OVERSEAS. | NIL |

### B:TEBUNGINAKO.

| | |
|---|---|
| DATE OF CONSTRUCTION: | 1978 |
| TYPE: | SEAWALL (GABION) |
| LENGTH: | 500m |
| PWD ASSISTANCE | SUPERVISION. |
| LOCAL INITITIVE. | MATERIALS AND LABOUR. |
| TOTAL COST | $10000 |
| ADVICE RECEIVED – ON DESIGN /CONST'N. FROM OVERSEAS. | NIL |

## 2: MARAKEI

### A: RAWANAWI.

| | |
|---|---|
| DATE OF CONSTRUCTION: | NIL. |
| TYPE: | SEAWALL ( STONE WALL) |
| LENGTH: | 500m |
| PWD ASSISTANCE: | NIL. |
| LOCAL INITITIVE: | DESIGNED/MATERIALS AND LABO |
| TOTAL COST. | NIL. |
| ADVICE RECEIVED– ON DESIGN /CONST'N FROM OVERSEAS. | NIL. |

### B:BARATOA.

| | |
|---|---|
| DATE OF CONSTRUCTION. | 1977 |
| TYPE: | CAUSEWAY BRIDGE. |
| LENGTH: | 150m |
| PWD ASSISTANCE: | SUPERVISION. |
| LOCAL INITITIVE: | LABOUR AND MATERIALS. |
| TOTAL COST. | $22500.00 |
| ADVICE RECEIVED – ON DESIGN /CONST'N– FROM OVERSEAS. | NIL. |

## APPENDIX 4

INTERVIEW OF LOCAL SOURCES OF INFORMATION

### Information Requested from each Local Source

1. How many years have you lived on the island and/or in the village site under study?

2. How may years has the village, building, harbour, or otherwise been here?

3. In what year was the coastal erosion first noticed? When is the erosion bad? How high or how far inland does flooding/inundation occur during storms?

4. What do you think is the cause of the erosion?

5. Do you think the sea level is rising? Do you think that the climate is changing? How? Is now more wet or dry. Is the wind more east or west?

6. Was there a coastal erosion problem in the old days? How did the people rive in the old days before the resident commissioner? Where did the people live? Are there more people on the island now than in the old days?

7. How much erosion has occurred? Where did the shoreline used to be?

8. When was the seawall or harbour built? Was it built all at once or in phases or upgrades? How many stages?

9. Who designed/built the seawall (local, PWD, I-Matang)?

10. In your own words what amenities are affected by the erosion.

11. Did a beach once exist here? What did it look like?

12. Where were the materials to build the seawall taken from?

13. How many years did it take to build the structure? What was used: manual labour, trucks, etc. 14.

14. Have others come to look at the erosion (I-Kiribati, PWD, I-Matang)?

### Response Option Considered

1. Is the land being impacted by the erosion owned by an individual, a family, a clan group, the village, the community or by the government?

2. What are the alternative responses to the local situation:

- do nothing
- retreat, relocate
- accommodate (limit land use, planning)
- protection What do the local people want to have done?

4. What priority do you give to coastal protection in comparison to other needs such as food, health and education?

   Would you accept another form of development assistance (such as education, health, etc.) in lieu of a seawall as compensation for the loss of land or a road, etc.?

5. What type of seawall would you like to have built? What do you think of the various types of seawalls (traditional coral boulder, cemented coral boulder, gabion baskets, grout filled sandbags either vertical or sloping, or other such as solid concrete)?

6. What assistance would the village or island like to receive from the government? Expertise, materials, labour, money for materials and labour?

ABAIANG - Tabontebike (29 March 1993)

1. 29 years.

2. Ridge built in 1970's, when the airfield was built. Seawall in 1980's, councils initiative/project, $100.00 spent on it.

3. 1950's in the south. High Spring Tide and Westerlies. Goes Inland to where the swamp is and destroys the babai 25 meters.

4. Winds, high spring tides and westerlies.

5. Sea Level: little bit of change ~ increase. Climate: Rain - increase. Wind - increase - creates greater westerlies, Le. more westerlies occurring.

6. Flooding was common in those days, but no erosion was obvious.

7. About 10 metres or so.

8. Ridge was built when the airfield was done, it was built at one stage as well as the seawall. No upgrading on both.

9. Ridge - built by PWD, Matang Kamatie - local. Seawall - Councils initiative and hired local contractors.

10 The only amenities affected are the coconut trees and babai pit.

11 There was a beach. No description.

12. Reef material for the ridge was collected from the site. Seawall - coral boulders/slabs collected from the reef as well at site.

13. About a month to build the ridge - used heavy machinery (loaders etc.). Seawall - about 2 months used manual labor.

14. PWD, I-Matang.

NO REVIEW OF RESPONSE OPTIONS

ABAIANG - Tebunginako (29 March 1993)

1. 60 yrs old.

2. Village established about 80+yrs.

3. About 50 yrs ago. Worse in westerlies. 30 metres of flooding.

4. Westerlies, high spring tide. If there was any coastal protection there could have been lesser erosion.

5. Sea level is increasing, evident in higher spring tides. Rainfall greater. Sunshine quite stable.

6. No, coastal erosion evident before. People used to cut toddy in other villages as the water was too salty and also breadfruit was unable to grow. Pinanisen (Commissioner). People used to live here. More people living here than before.

7. Erosion occurred is about 20 metres.

8. Seawall built by government 3 times, it has broken down. Built in one stage. It was going to be maintained but the Government then wanted another structure protecting the shoreline. No, it was not upgraded.

9. I-matang Civil Engineer, with some locals.

10. Maneaba, land, houses, coconuts, store.

11. Beach was there, kind of scarp type where ships couid come in and dock.

12. a) Coral rocks in a groyne, (b) Gabion baskets in a vertical position. (a) was more favourable because it gained more sand deposit.

13. Just north of Tebunginako, machinery used were ones used in the airfield construction.

14. Government machinery, trucks, loaders. 15. Kiribati, PWD, I-matang.

REVIEW OF RESPONSE OPTIONS

1. Individuals
2. Protection
3. Protection but in groyne style as it would gain sand.
4. Can not answer this as would require a community answer.

MARAKEI - Rawannawi (30 March 1993)

1. 68 yrs.

2. Two generations village has been occupied.

3. About 10 yrs. About 6 yrs ago erosion was experienced to be getting worse. Flooding does not occur inland.

4. Cause of erosion is the closing of the passage at Baretoa and the deepening of the Rawanuea (reef passage).

5. A bit of sea level rise. Climate is changing. It is becoming hotter and becoming drier.

6. Coastal erosion was not a problem, just experienced shifting of sand. People used to live in clans, when the resident commissioner arrived they moved into villages. Increase in people.

7. Shoreline was about 20 metres - erosion.

8. Channel was a natural one, it was deepened and made to be close to the shore in the 1980's. It was upgraded.

9. By government - locals.

10. Land, coconut trees, houses.

11. Yes.

12. Seawall - materials from the Aobuto sites.

13. Took about 3-4 weeks, local manual with use of trucks. Had to collect more materials as the ones used were not sufficient.

14. Locals - Minister T. Awira, PWD.

REVIEW OF RESPONSE OPTIONS

1. Individuals

2. Protection

3. Protection, as it seems that the sand is eroding and depositing into the channel which shows that there is no way replenishment would occur. Require protection which will assist to lessen further erosion.

4. Sandbags (vertical sloping) better than the horizontal one because it allows the waves to flow properly and lessens its strength.

5. No answer, require Community answer.

MAKIN - Naka Primary School (31 March 1993)

1. 23+ yrs.

2. Naka Primary School - 60's, 64.

3. Late 70's. Westerlies, high spring tides. Waves come into the playing field about 15m from beach.

4. Different current goes to the west nowadays and this is probably the cause. Causeway as well, "Tanginteaira".

5. Increase in sea level. Increase in rain and wind. A bit colder. Westerl'18s are becoming dominant, i.e. goes beyond its season.

6. No. It seems that after 60's there was accretion on the south side and erosion on the sites where Naka Primary school. Sites where the hospital is, have experienced accretion. Increase in number of people.

7. About 5 metres.

8. First seawall was built in the 70's. Seawall was upgraded in 84. First seawall was completed in one stage because there was machinery for making the road, trucks, loaders. PWD. This seawall was upgraded, in 84 - locals. Another seawall was built in 1992 by Council assistance, but it collapsed as well. Locals.

10. School, pandanus trees, coconut trees, houses.

11. Yes. Large sloping beach with no stones evident.

12. Materials - from Tabon Makin, Naka's place.

13. 1st seawall - 1 month
2nd seawall - 1 week (community work)
Local 3rd s/wall - 2 days (community work)

14. Locals (PWD) - 1992.

REVIEW OF RESPONSE OPTIONS

1. Families, Council leased land.
2. Protection. Also can retreat the affected classrooms to other side of the road.
3. Protection, road, seawall, to be built just for the school area not for family land.
4. Require one which will lessen erosion and one which will not require upgrading in future.
5. Locals will require assistance in the form of aid~money to supply cements to strengthen the seawall and expertise. Locals can provide the labour without being paid.

BUTARITARI- Ukiangang (1 April 1993)

1. 67 yrs.
2. 5+ yrs (5-10)
3. About 5-10 yrs ago. The erosion was on the southern side, from the surveyed site. After this was protected by a barrier (ridge) in which was made by fhe Island Council, the surveyed site started to experience flooding. Recent about in February 1993. The erosion started about times when Funatuti was struck by cyclone/hurricane? The flooding goes about 30 metres inland.

4. The cause is due to increase in sea and turbulence (Le. current is strong).

5. Increase in sea level, even when there is no westerlies. Increase in rain.

6. No. Families used to live on their own land. Peopie used to live on the lagoon side before the present site tor the village.

7. About 4.5 metres? 3 te nga.

8. Ridge was built 1985. It was only built in one stage.No.

9. Ridge was built by locals.

10. Babai pits, coconut trees.

11. There was a beach, with piles of slabs, gravel.

12. Taken from inland, from site which is at present a babai pit.

13. Trucks.

14. Don't know.

REVIEW OF RESPONSE OPTIONS

1. Family

2. Barrier to prevent flooding.

3. They want a barrier to stop tlooding into the babai pit, as the same as the ridge built. The area visited which separates the 2 baba; pits, there should be a wide barrier to stop the sea water flooding into the babai pits. There is another site in the north which experiences the same situation (site where the bomb crater is). Sea water comes into the area and floods into the babai pit.

4. (a) Seawall to help babai pits survive because this is where you get tood.
   (b) Hospital (because there is already a hospital present).

5. Require assistance from Government in forms of aid, expertise, materials, labour money. If this assistance takes time to provide due to monetary problems, they would accept expertise, materials and they would provide local labour in order to speed up the project.

BUTARITARI - Keuea Village (2 April 1993)

1. 51 yrs.

3. The flooding has occurred when he was about 11 yrs of age. The flooding is worse when it is high spring tides with storms (south east wind). This occurs 3-4 years interval. The flooding goes about 20 metres inland.

4. The cause is the high spring tides and storms.

5. Increase in sea level. Increase in rainfall.

6. No coastal erosion problem. People lived in the village in families. Increase in number of people.

8. There is a barrier to protect the babai pits from the flooding. Can not recall when this was actually made. It is made from slabs of rocks.

14. First time this has ever been attended to.

REVIEW OF RESPONSE OPTIONS

1. The whole village people own it.

2. Protection.

3. A barrier to prevent the flooding or if possible to level the land off, i.e. to be the same level as the ridge.

4. No, as this provides us with food source, which is quite hard to grow. Also the project takes a while to do, and other development projects can be raised by the Council. It is quite rare to get this done, to build something to prevent the flooding.

5. All the ones listed, expertise, materials, labour, money.

BUTARITARI - Keuea School Site (2 April 1993)

1. 20+ years.

2. School village - 79-80. Causeway - 1993.

3. Coastal Erosion was experienced, little effect when the causeway construction started, greater erosion experienced when it was completed.

4. Cause of erosion is the causeway.

5. Increase in sea level. Rainfall is fluctuating, increase at certain times, decrease in other times.

6. No. People lived in Keuea village only lived in this site when the school was completed. Increase - only in the school teachers number as this is their living site.

7. About 3 metres. The shoreline used to be 3 metres away from present shoreline.

8. The causeway was built for 9 years. It was built in stages. It has been upgraded several times. 9.

9. First time built, was by the locals, (Nariketa), built by Council and locals.

10. Teachers living quarters, school buildings, coconut trees, pandanus trees.

11. There was a beach before, thick one.

12. Materials collected from the ocean and lagoon sides just near the present causeway site.

13. 9 yrs. Local labour, trucks, tractors were used at the later stage.

14. Can not remember.

REVIEW OF RESPONSE OPTIONS

1. T eababa with family (individual)

2. Protection

3. They want something just to lessen or stop the erosion occurring at this site.

4. Also require upgrading of school, that includes the building of school seawall so as to prevent further erosion, so that do not relocate school again.

5. Sandbags because site is easier to get sand and also the vertical sloping will Jessen the erosion and also stable structure.

6. Expertise, machinery.

TAMANA - Barebuka- Airport (5 April 1993)

1. 73yrs.

2. Airport built in 70's to 80's.

3. Te au maiaki - brings sand
Te au meang - carries away the sand causing erosion.

4. Erosion is due to the shifting of sand at times in the year.

5. Sea level is rising. No difference in climate/wind. It is getting wetter, evidence is in the increase in food crops Le. breadfruit, coconut trees.

6. Yes, erosion was also evident, same process. People used to live here before airport was made. Before construction of airport, people moved back to the viliages. More people living on Tamana.

7. Erosion is the same as it is. When the sand gets shifted back, the shoreline is about 10 yards from present shoreline.

8. No seawall built.

10. Coconut trees, pandanus trees.

REVIEW OF RESPONSE OPTIONS

1. Individually owned. Airport - council leased area.

2. Do nothing - accommodate.

4. Education, health before coastal protection as erosion not really a problem in the site visited.

5. Whatever seawall government proposes they would accept.

6. Up to the Council to decide.

TAMANA - Bakarawa (5 April 1993)

1. 60 yrs.

2. Village built in 1981. Used to live in the other villages before the extension of Bakarawa village was made.

3. 70's. The worst of was when the 3 strong waves splashed onto Tamana in January. Last January it came in about 2 metres from the present high tide level.

4. Waves action.

5. Increase in rain.

6. There was erosion but just a little not a problem as it is. Increase in popuiation.

7. About 3 yards in erosion has occurred.

8. There was a seawall, in 80's (81) built by the local. It buBt in many stages, 6 months in total. No upgrades. 9. The local guy (Ebara Karemeru) built it and designed il himself.

10. Coconut trees, pandanus trees, local houses but gradually.

11. Yes, a thick beach which covered the reef platform which is now exposed.

12. Materials are from the oceanside just beside the local's piece of land.

13. Manual labour, 6 months. The seawall was about 15 metres long.

14. Nobody.

NO REVIEW OF RESPONSE OPTIONS

ARORAE - Taribo (6 April 1993)

1. 53 yrs.

2. School- 1915.

3. About 20 yrs+ gradual erosion of site, greatest when the waves hit the island in January 1993. About 45m inland the fiooding occurred.

4. Blamed the strong waves which made the erosion obvious.

5. Te ang-maeao is prolonged. Te au-meang is getting stronger in terms of wind strength. Hotter. In times of sunshine, it is very hot. In times of rain, it is very cold. Increase in sea level when wind is strong.

6. Coastal erosion was not a problem in those days. In those days, the village was like this but occupied by missionaries before government/council occupied it. Increase in people.

7. About 12 metres. Shorelinelbeach was sloping as it iooks now, covering the reef platform now exposed.

8. Seawall was built 1976. Built by locals under council supervision. Built in a month. The seawall was built to prevent the waves from knocking down the local houses.

9. Locals.

10. Coconut trees, houses (cooking) pandanus trees.

12. Materials collected from the ocean side beach.

13. Tractors, manual labour mainly. 14. I-Kiribati.

REVIEW OF RESPONSE OPTIONS

1. Council leased lands.

2. Accommodate/retreat.

3. Barrier to protect the fiooding strengthen present seawall.

4. (a) Rest-house (upgrading)
   (b) Coastal protection
   (c) Terminal upgrading

5. Any suitable seawall which is recommended. It should be strong enough to withstand these strong waves. Waves which cause flooding are usually ones which occur during te au-meang in every year.

6. Cash - to buy cement (materials) and wages for labour. Expertise and machinery to assist with the work.

ARORAE - Batitotai ( 6 AprH 1993)

1. 53yrs.

2. 1939 - village - camping site for the LMS

3. 1949/50 which led to the people leaving the site.

4. Natural phenomena - waves winds etc.

5. Some notable only when the winds are strong/……

6. People used to come here just for camping, leisure. Place is now deserted.

7. About nearly 15 - 20 metres. Shoreline used to be about 20 metres turther away trom present beach crest

10. Shrubs, betore houses used to be affected but not now as site is evacuated. Tomb

11. No beach, only boulders was present on beach.

14. Nobody.

REVIEW OF RESPONSE OPTIONS

1. Individuals.

2. Accommodate.

3. Something to help lessen erosion. It was taboo/forbidden to collect stones, boulders from the area in the 50's after the erosion, but still erosion is occurring.

5. Don't know, depends upon recommendafions from experienced people as the area is a high energy place.

6. Money, expertise, materials and council to provide labour which they would pay iabour charge out of aid funds.

ARORAE - Babaroroa (6 April 1993)

1. 53 yrs.

2. Village - camping site was started 11 September 1947. It was for women's group for camping. Left the village/camp site in the year 1952.

3. Erosion started about 60's. It was quite a gradual erosion, but after the January event, the erosion was so great that an erosion scarp occurred.

4. Don't know, but could be due to increase in sea level rise.

7. About a 100+ metres of erosion has occurred. The sand used to be shifting, but the cast 5-6 yrs, the sand has not returned.

10. Coconut trees, shrubs.

REVIEW OF RESPONSE OPTIONS

1. Council owns the land.

2. Accommodate.

3/5. Anything what the government can do to assist lessening/preventing this erosion.

6. Assistance will be in form of money, materials.

Note: The land is only owned up to the site where the navigation rocks are because the rest up to present site is where the accretion has occurred. From this site, there has been up to about 100m. People standing on present shoreline, were not able to recognize person fishing at end of beach (past shoreline).

BERU - Taboiaki - Taborengerenge (7 April 1993)

1. 56yrs.

2. The village has been here since the 1940's.

3. Quite a long time, about in the 40's-50's. The erosion is worse during high spring tides with the north westerlies. The flooding gets to the road which is about 20+ metres.

4. Waves during the high spring tides with the north westerlies have caused great erosion.

5. There is a sea level rise definitely. Getting hotter. Only when there are north westerlies are there rain, and other times, it is hot.

6. There was a coastal problem but not as great as nowadays. People used to live here when there was a resident commissioner and left due to the erosion problem. They returned again when there was limited living space in the other nearby villages. There is an increase of people about 4 times greater.

7. About 15 meters has been eroded. There used to be rocks and te baa on the shoreline. Rocks from this area were taken to build the causeway further north.

8. Seawall was once built in the 40's but damaged several times. It was rebuilt again but collapsed again. The guy kept on restrengthening his seawall every time a north westerly occurred.

9. The local owning plot of land where each protile was done designed it.

10. Houses, coconuts, land, as living space is limited.

11. Not really, as it is not permanent, what was left was actually te baa.

12. From the boulders and rocks from the oceanside.

13. Manual labour. 14. I-Kiribati.

REVIEW OF RESPONSE OPTIONS

1. Family lands.
2. Protection.
3. A seawall which should have cement to strengthen it.
4. Prioritise the coastal protection and education, because as living space is limited this is quite a need.

5. Any type but one which is strong enough to withstand strong wind and currents.

6. Expertise, materials, money for materials and labour.

NIKUNAU - Tabomatang (8 April 1993)

1. 70yrs.

2. Village : long time ago,
Maneaba - (Te baire) : early 18th
Teraranimatang : Century

3. 1970's or 68, strong waves hit the area and brought up boulders onto the land. The second time it was when the cyclone Bebe hit Funafuti, it also hit here. The flooding came to about 20 metres.

4. Erosion is the result of the wave/sea action.

5. 1932-1939 there was a drought at time. Now everything is the same only. Hotter nowadays. Sea level is the same.

6. No. People used to live in this area before the resident commissioner, as it is family land. Increase in number of people nowadays.

7. About 2 metres from edge of land or where the present seawall ruin is. Erosion is about 2 metres.

8. Seawall was built in the 1970's. It was built in one stage.

9. PWD (Teratabu Tira) - with the Rural Unit Home Affairs, to supervise the work. Local person designed the seawall.

10. Church, coconuts, pandanus trees, maneaba and Pastor's house.

11. Beach used to be thicker, but as time passed the sand has been moving and so the beach was thinned out.

12. It was built at once, but upgraded as the seawall started to fail in after a few months (about 11 months to be exact).

13. Materials obtained from where the canoe passage. 14. PWD - locals.

REVIEW OF RESPONSE OPTIONS

1. Tabomatang maneaba owned by village. Individuals own the other adjacent lands.

2. Protection.

3. Another upgrading of the seawall, with the use at concrete to strengthen the seawall.

4. Coastal protection is seen as high priority as development project for individuals are hard to obtain - to seek funds. This is seen as a priority as land is eroding and land space is hard to find for the people living on the ocean side.

5. Don't want filled sandbags as this has failed. Want a sloping seawall in a step fashion with no filled sandbags used.

6. Expertise, materials, labour, money for materials and labour (allowance).

ARANUKA - Takaeang (9 April 1993)

1. 60+ yrs.

2. 1971 's the school was here. Boat passage was built (deepened) in 88, 89.

3. Erosion began in 60 yrs ago. Erosion great in times of the high spring tides and north westerlies 3 metres of flooding in land.

4. Current and waves. At high spring tides - the waves greater in size.

5. Increase in sea level rise. Increase in rain.

6. There was a problem as that was the time this erosion started. People used to live at site further south, which has eroded now. Increase in number of people. The old village Takariaria, was abandoned 60 yrs ago as it started eroding. They moved to another site for living.

7. The tip of beach used to be about 2-3 yards further away from present site.

8. It was built in the late 80's (85). The seawall is about 100m in length.

9. The council/locals built the seawall. It was built in different stages as different groups had different portions to build. It seems like the PWD designed it.

10. Houses, (school), coconut trees, playing field, pandanus trees.

11. Materials (rocks) were collected from the reef.

12. The structure took 2 months to build this gab ion basket seawall. Manual labour. 13. Home Affairs (I-Kiribati) PWD (Teunaia)

REVIEW OF RESPONSE OPTIONS

1. KPC (Kiribati Protestant Church) owns this land and the Council leased it.

2. Protection.

3. Coastal protection for the school village and playing fieid.

4. In terms of rating the prioritises the seawall (coastal protection) first, then the improvement of the school and then the hospital.

5. Want one with cement, sloping one, as it will lessen wave energy.

6. Money for labour and materials, expertise, labour provided by village.

ARANUKA - Buariki (10 April 1993)

1. 32 yrs.

2. Village has been here for since the 1930's.

3. Coastal erosion occurred in the 70's. During westeriies, the erosion is great. 1972 flooding occurred into main road. That is about 30m. It also happens when there is high spring tide and westerlies.

4. Do not really know.

5. There is a sea level rise and also get higher spring tides. Greater heat/experienced in the past. Now experience wet conditions and it is getting cooler.

6. Coastai erosion was not a problem in those days. Betore there used to be a track for bicycles, near the beach beside present road, but this has eroded away. People used to live here on present village site. Increase in population.

7. Erosion has occurred about 10 metres from present bottom of beach to previous bottom of beach.

8. Seawall was built in 1985 by councillors with the help of local labours. With the funds from Home Affairs. It was built at one stage.

9. Locals designed the seawall.

10. Houses, coconut trees, pandanus. A house made of local and concrete material has collapsed due to this erosion, owned by a Langley guy in the 40'sll

11. Beach was a sloping one which covered the now exposed beach rock.

12. Materials were collected from the ocean side further south of the village.

13. Manual labour, it took about 2 months to build.

14. I-Kiribati - PWD?
    Home Affairs?

REVIEW OF RESPONSE OPTIONS

1. Individual

2. Protection

3. Want a coastal protection.

4. Educafion first, coastal protection second, thirdly health.

5. Sloping seawall reinforced with cement.

6. Money for materials and labour. Council will provide labour. Expertise to supervise work.

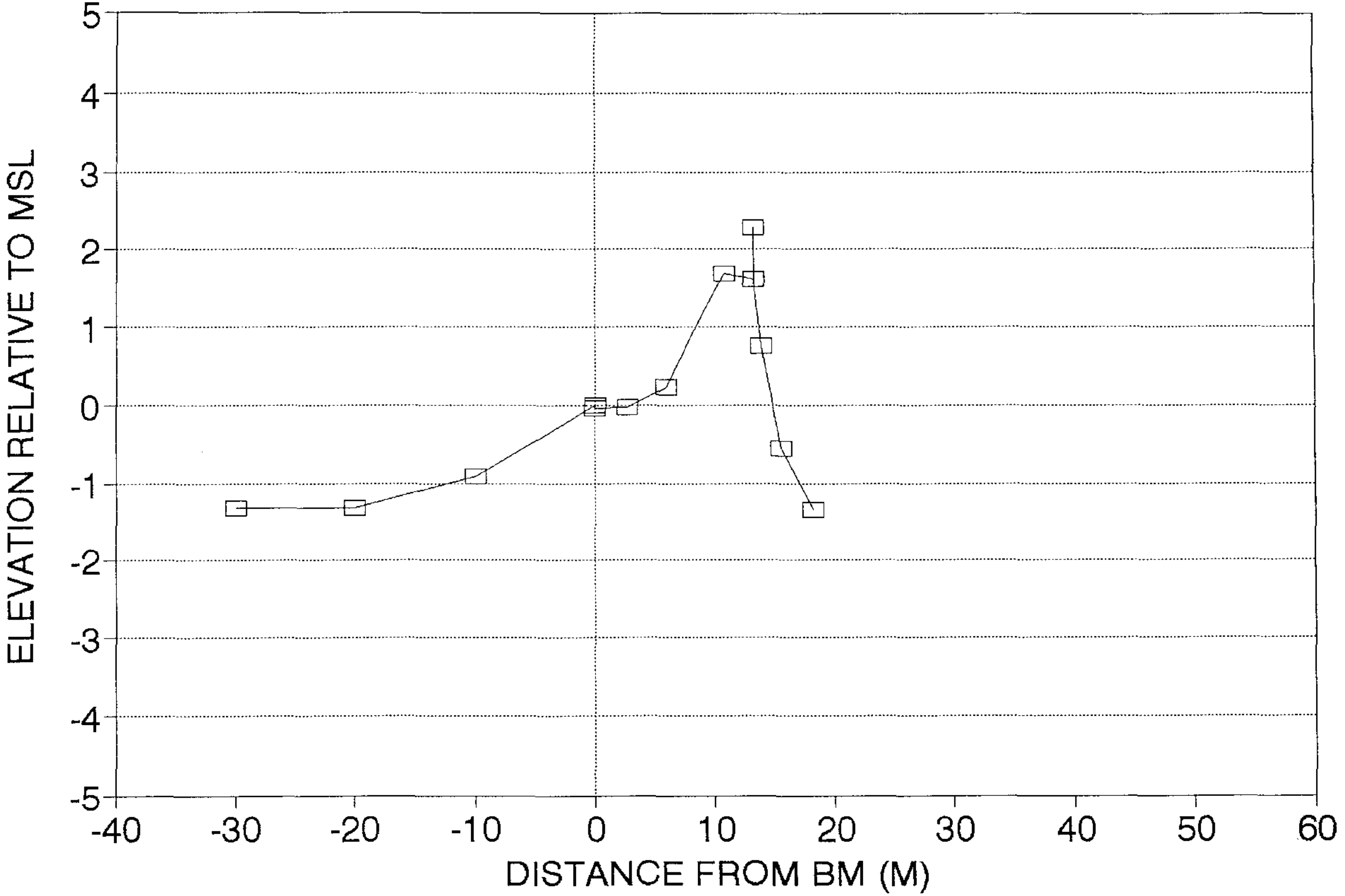
# APPENDIX 5

## BEACH PROFILE DATA

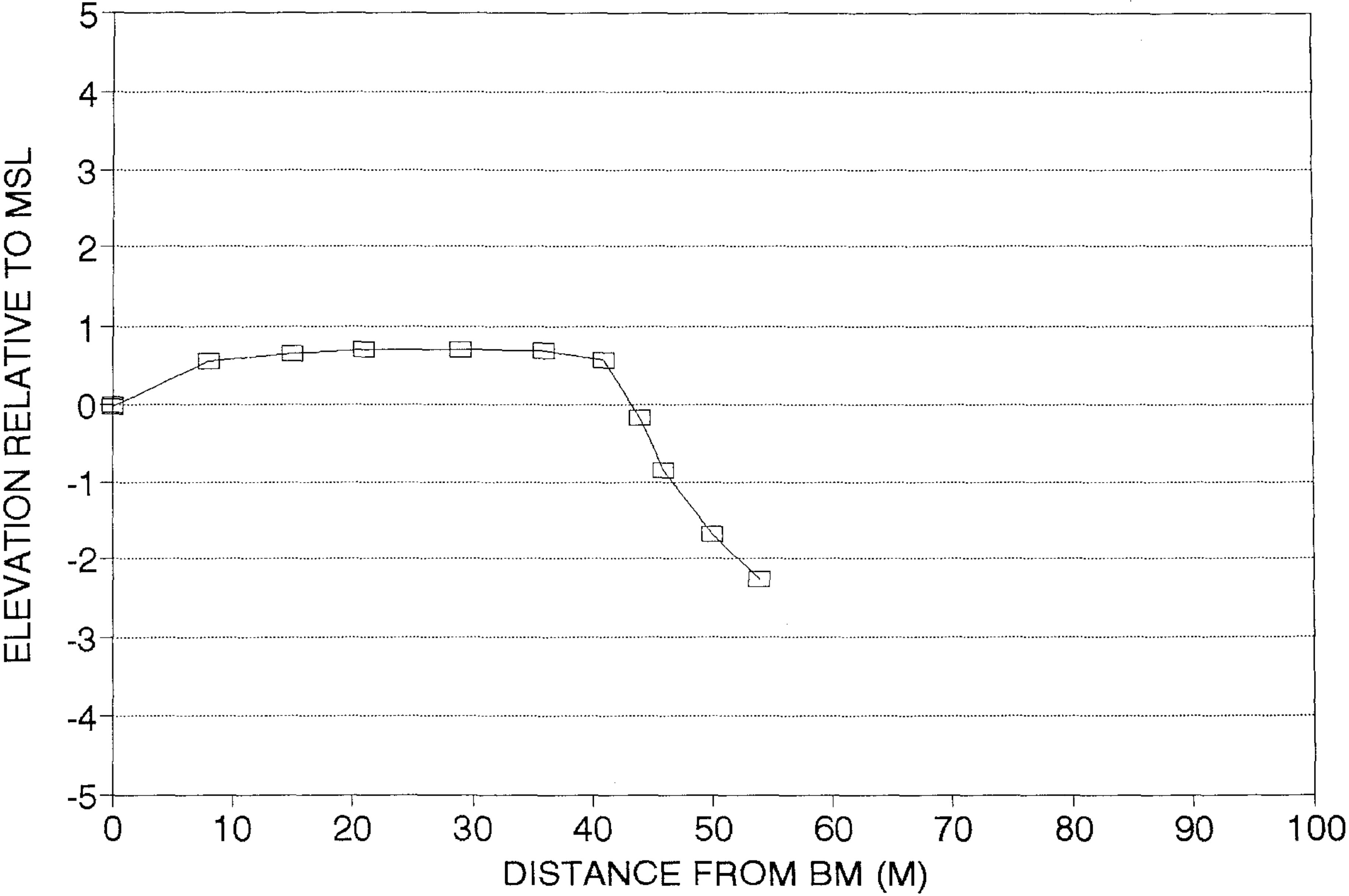
**Table A2.** List of beach profile sites.

| ISLAND | SITE/VILLAGE | PROFILE NAME | DATE |
|---|---|---|---|
| Abaiang | Tebontebike<br>Tebunginako | Tebontebike<br>Tebunginako | 29/03/93<br>29/03/93 |
| Marakei | Rawannawi | Rawannawi | 30/03/93 |
| Makin | Naka Primary School | Naka | 31/03/93 |
| Butaritari | Ukiangang<br>Keuea Village<br>Bikewa Primary School | Ukiangang<br>Keuea Village<br>Bikewa | 01/04/93<br>02/04/93<br>02/04/93 |
| Tamana | Barebuka (Airfield) | Barebuka | 05/04/93 |
| Arorae | Taribo<br>Babaroroa | Taribo<br>Babaroroa | 06/04/93<br>06/04/93 |
| Beru | Taboiaki Village | Taboiaki | 07/04/93 |
| Nikunau | Tabomatang Village | Tabomatang | 08/04/93 |
| Aranuka | Takaeang School<br>Buariki South | Takaeang<br>Buariki | 09/04/93<br>10/04/93 |

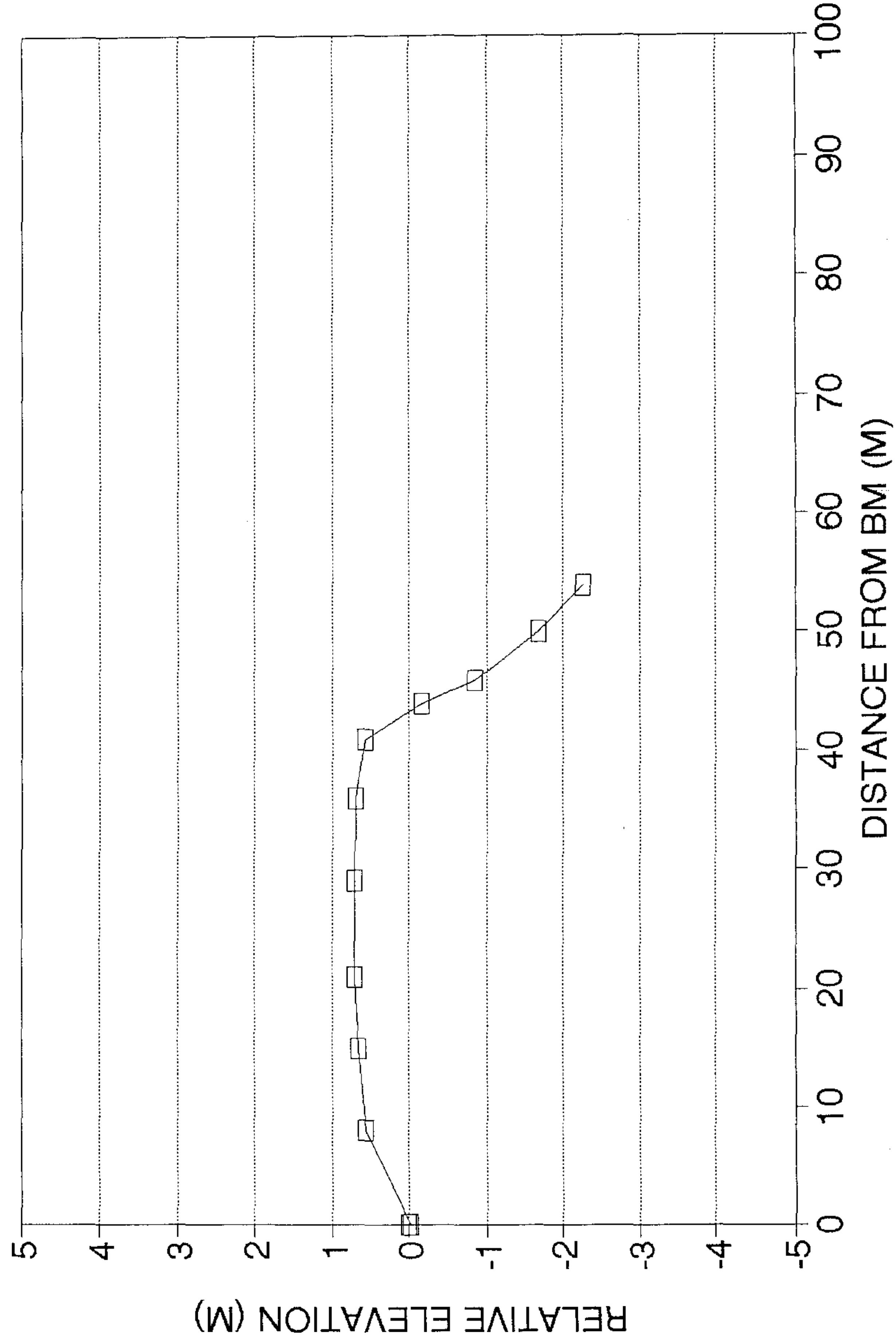
# BABAROROA, ARORAE



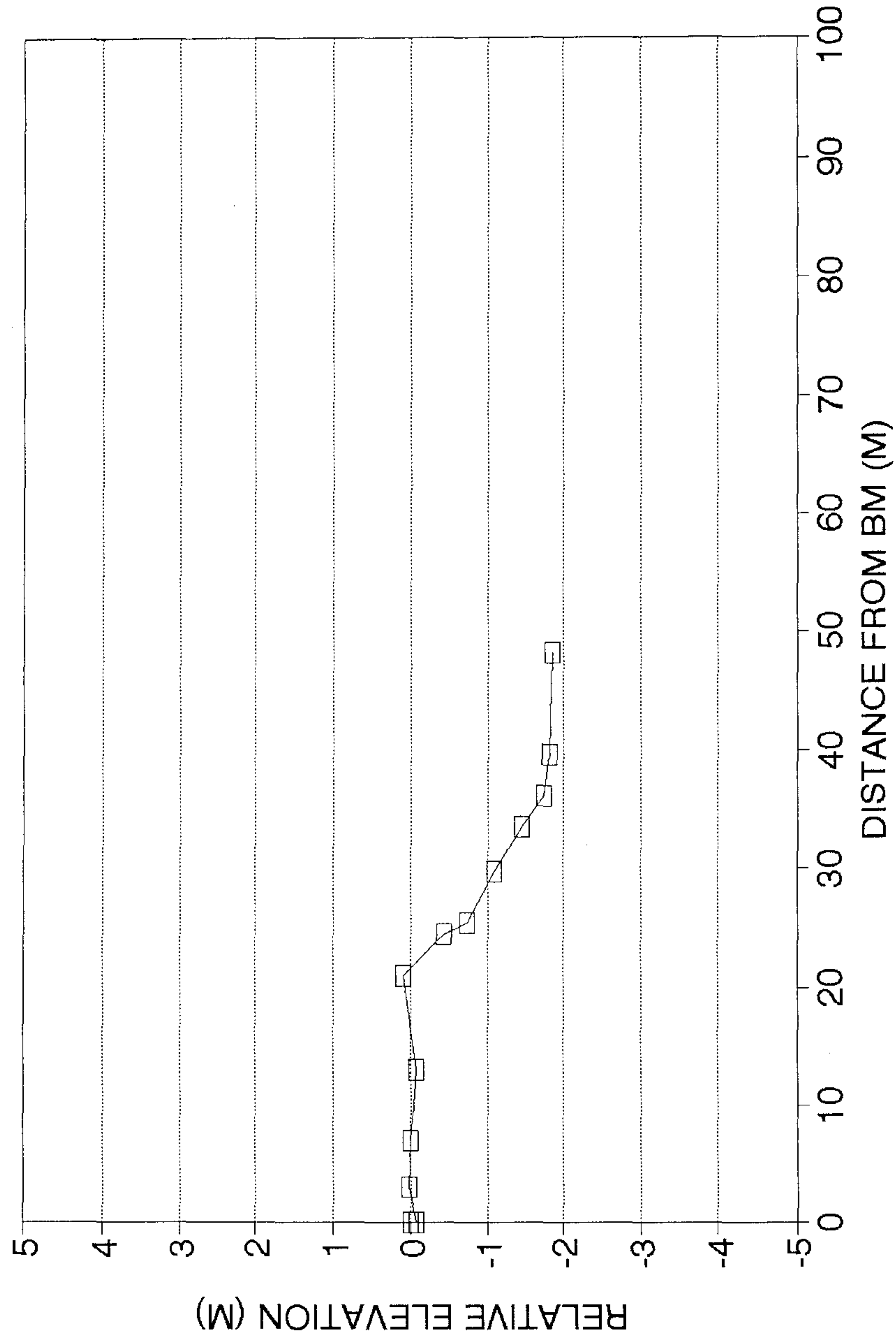
# BAREBAKA, TAMANA



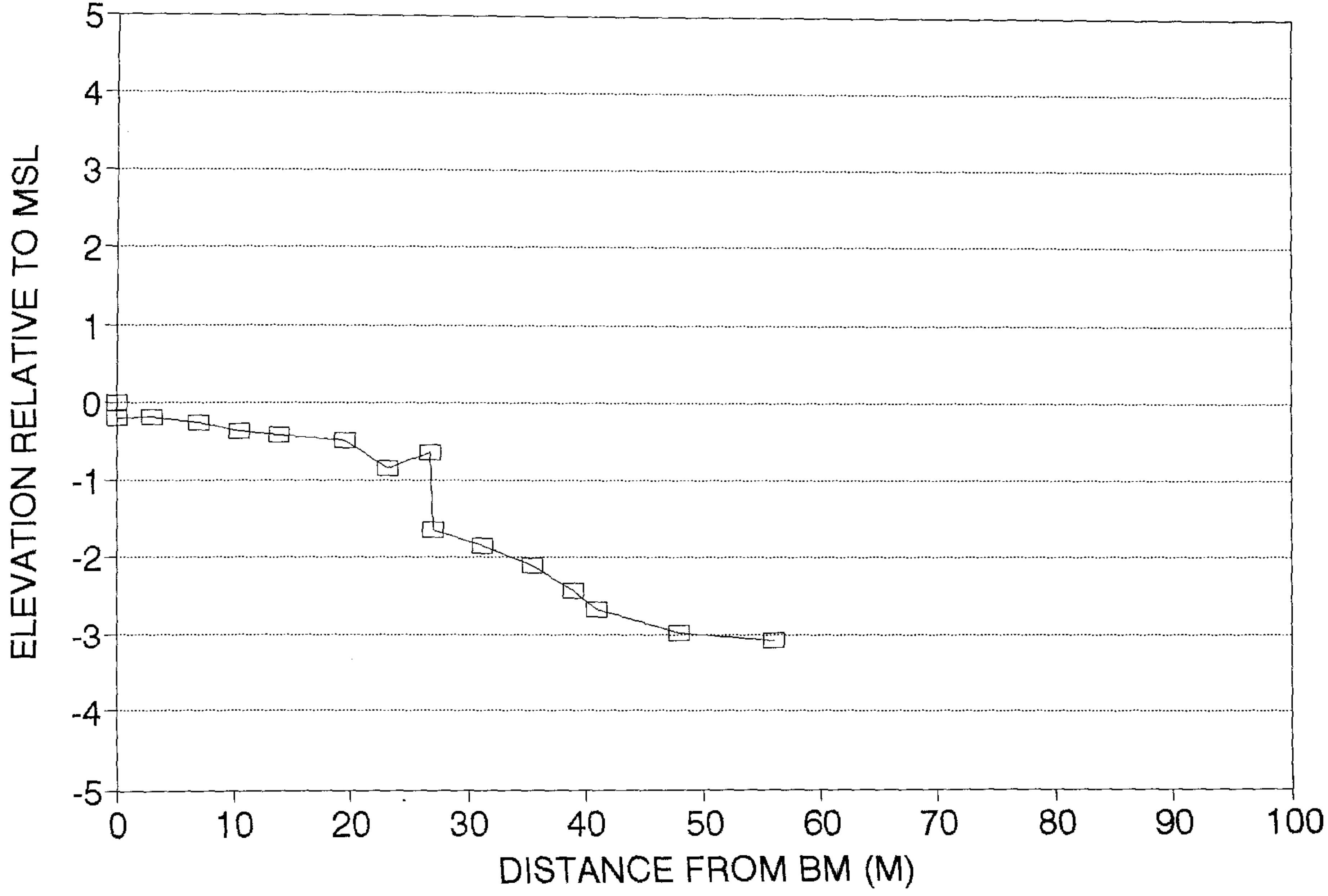
# BAREBUKA, TAMANA



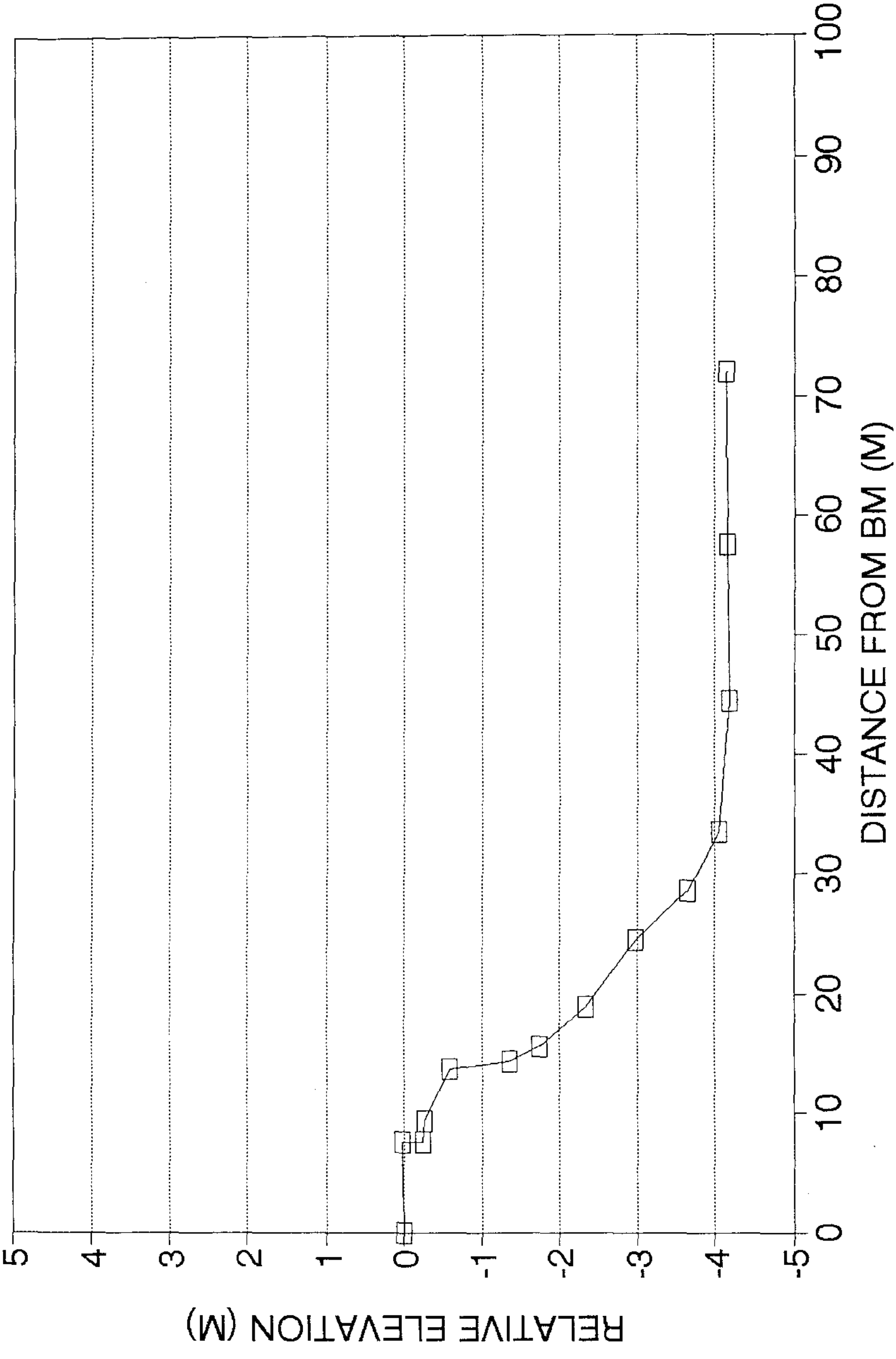
# BIKEWA, BUTARITARI



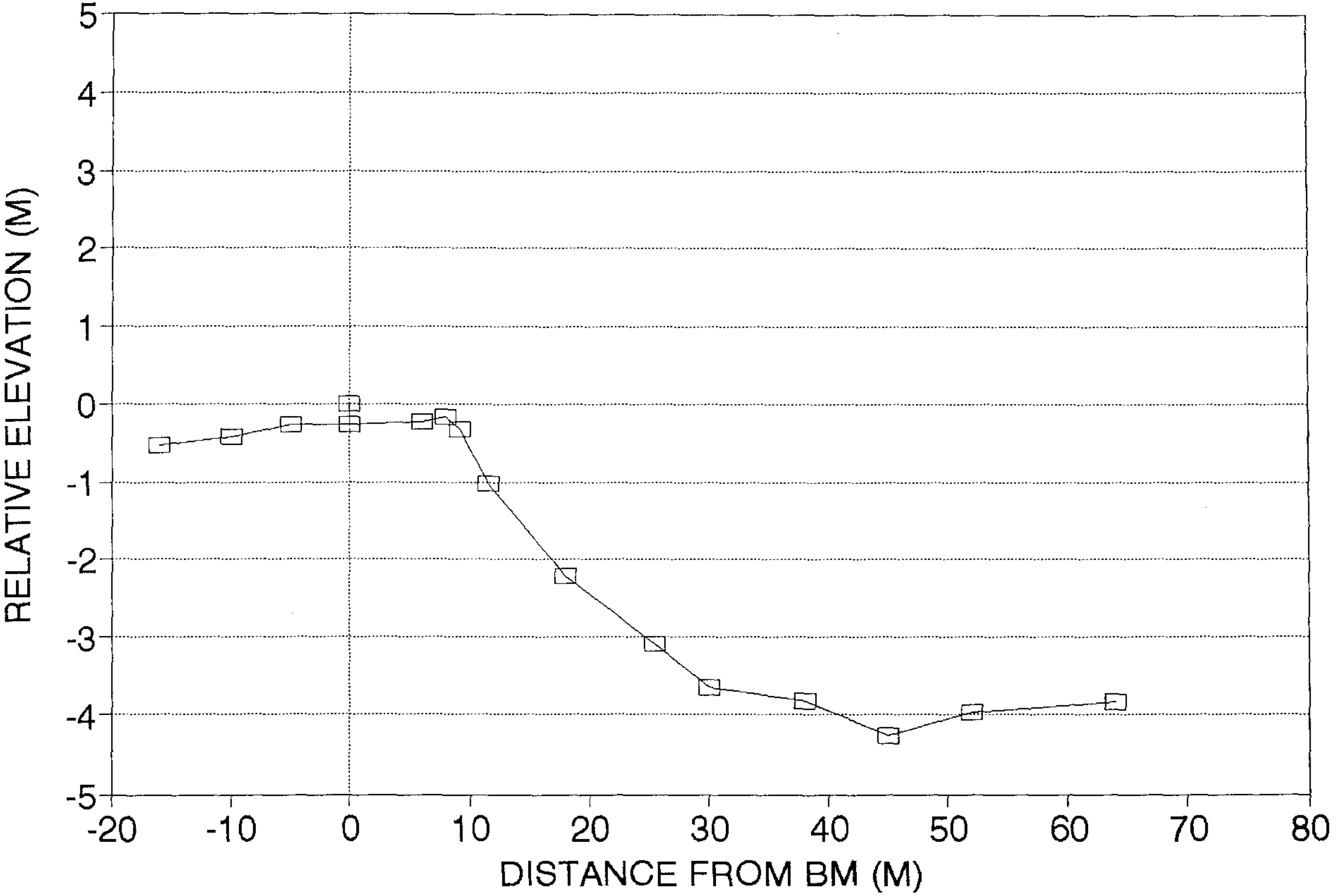
# BUARIKI, ARANUKA



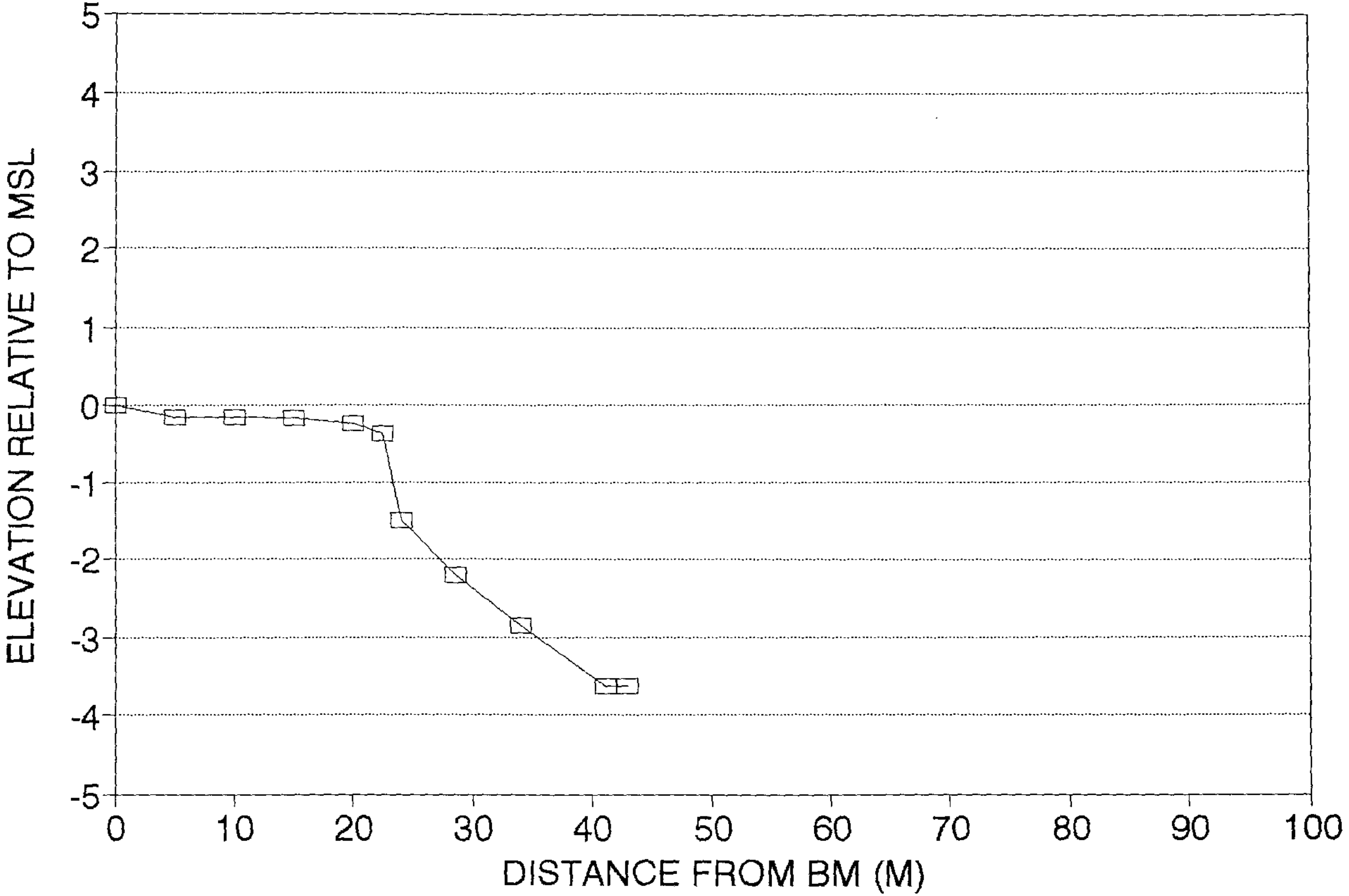
# NAKA, MAKIN


RELATIVE ELEVATION (M)
5
4
3
2
1
0
-1
-2
-3
-4
-5
DISTANCE FROM BM (M)
0
10
20
30
40
50
60
70
80
90
100

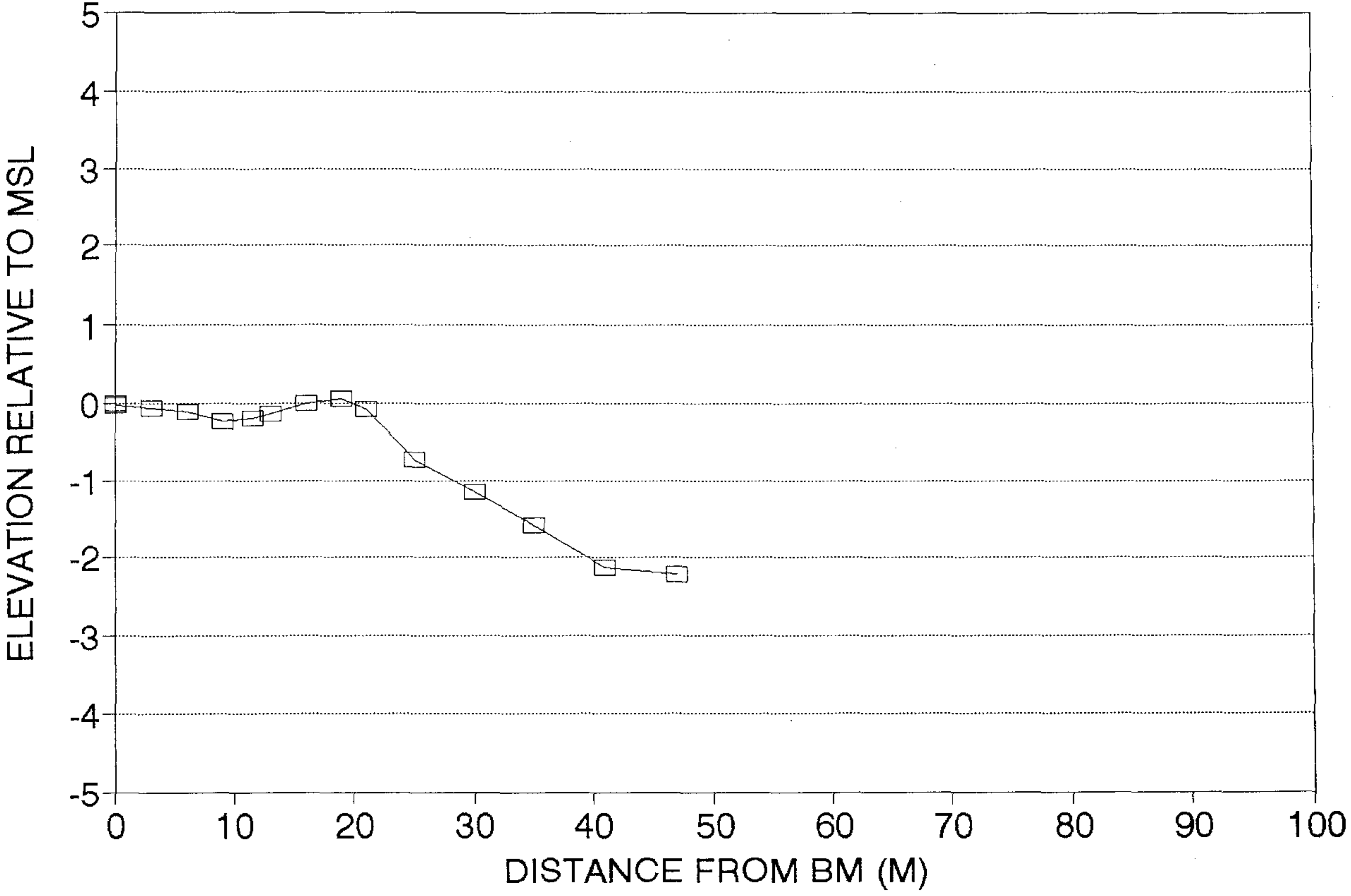
# RAWANNAWI, MARAKEI



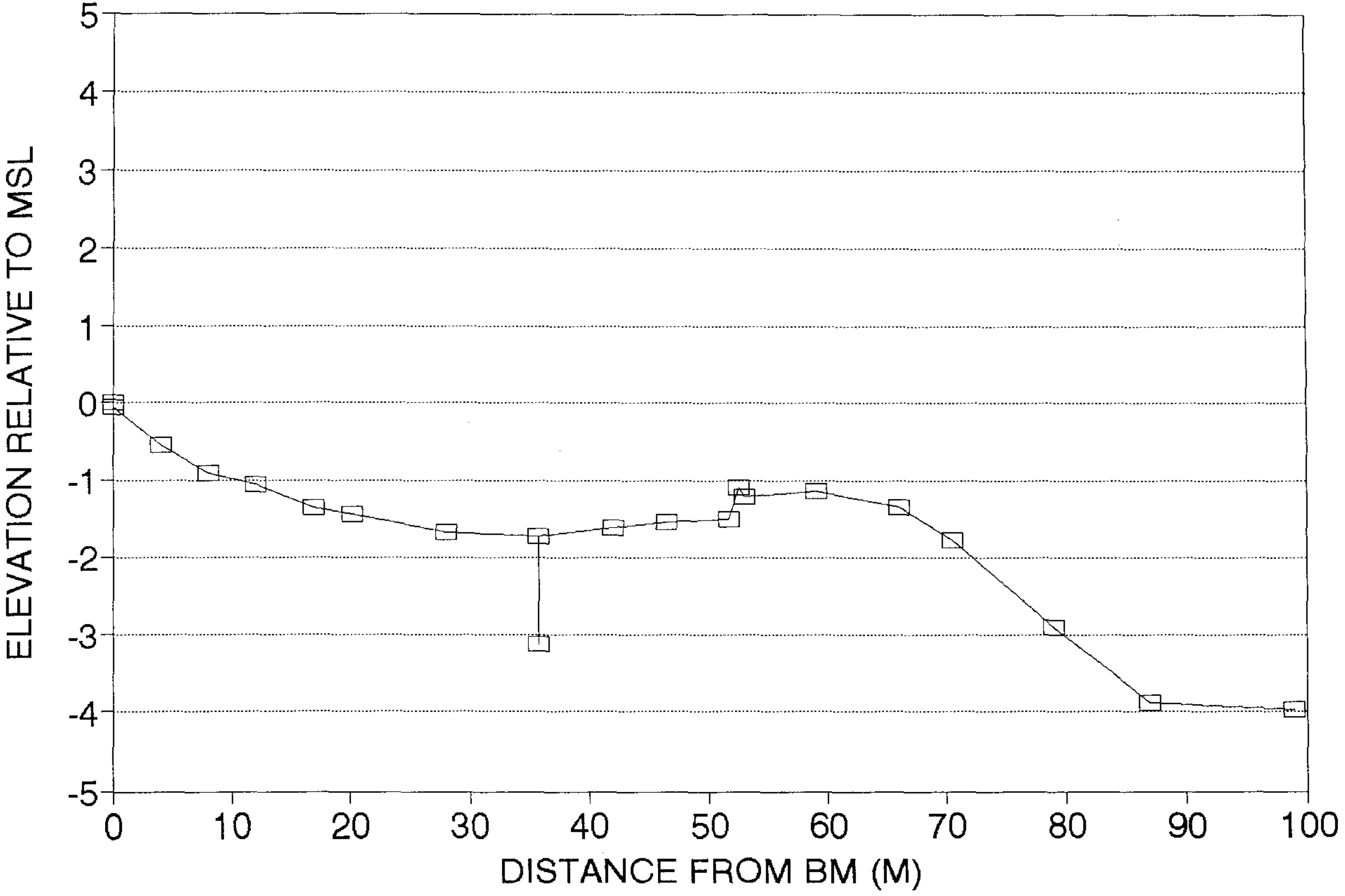
# TABOMATANG, NIKUNAU

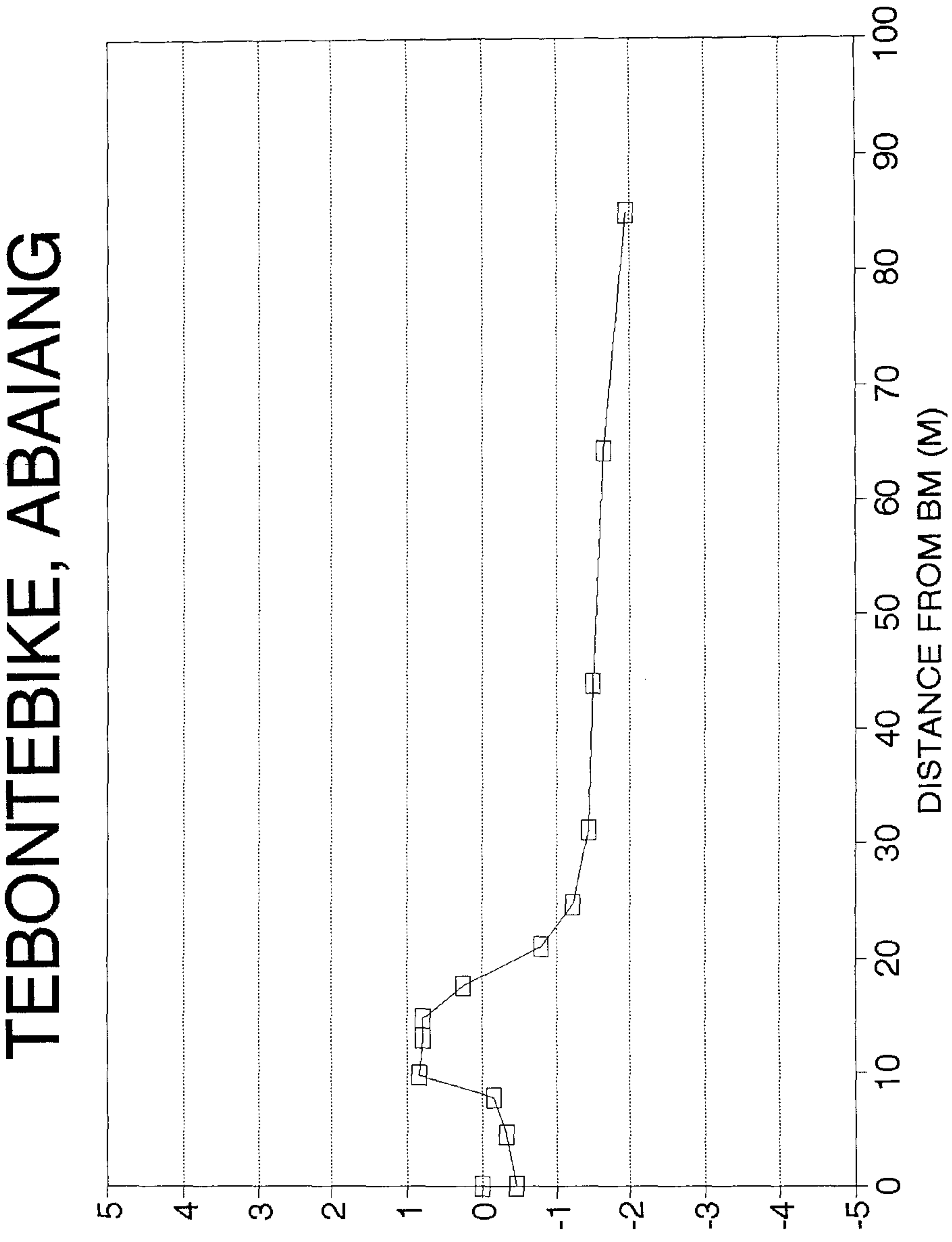


# TAKAEANG, ARANUKA

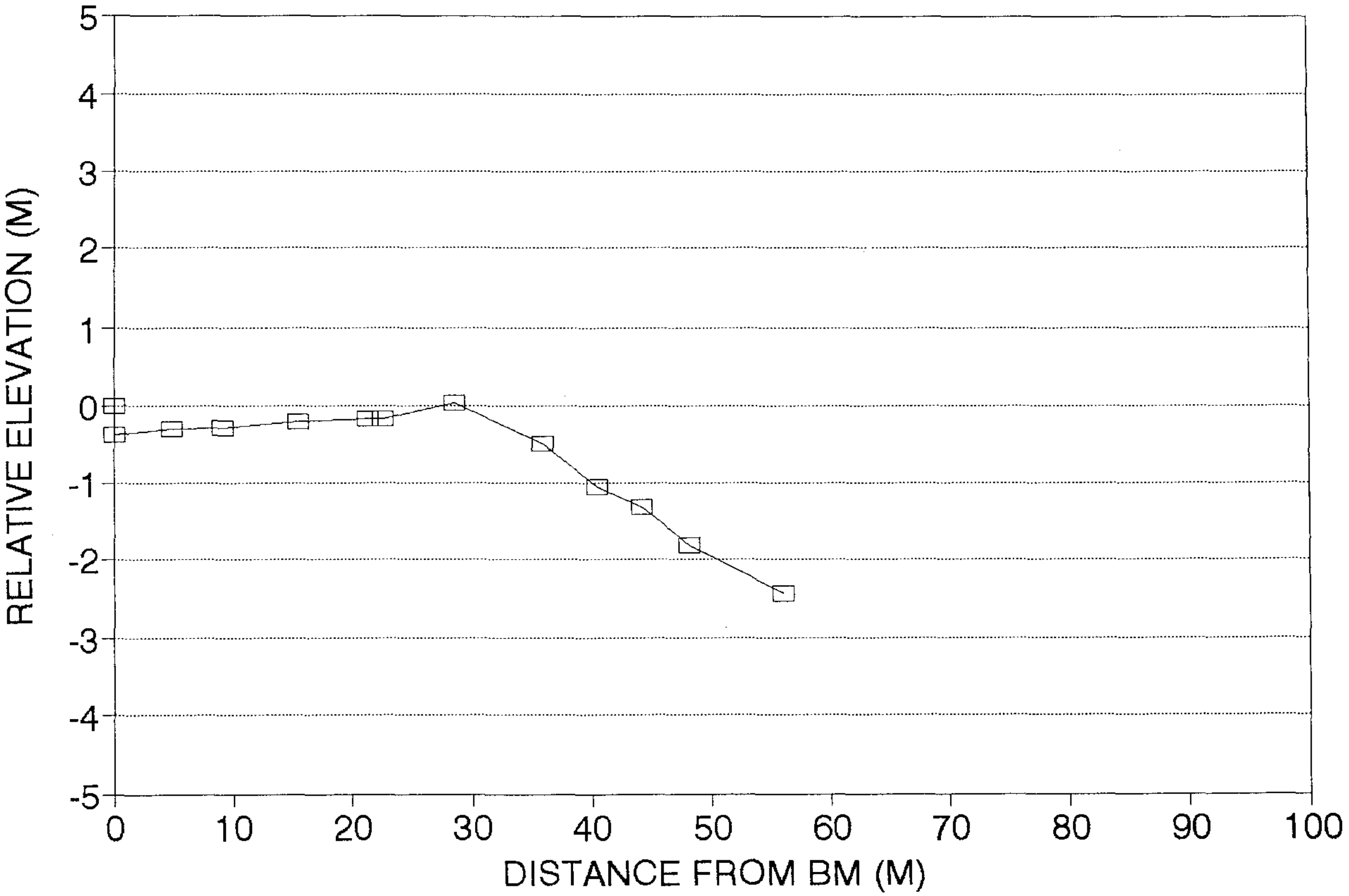


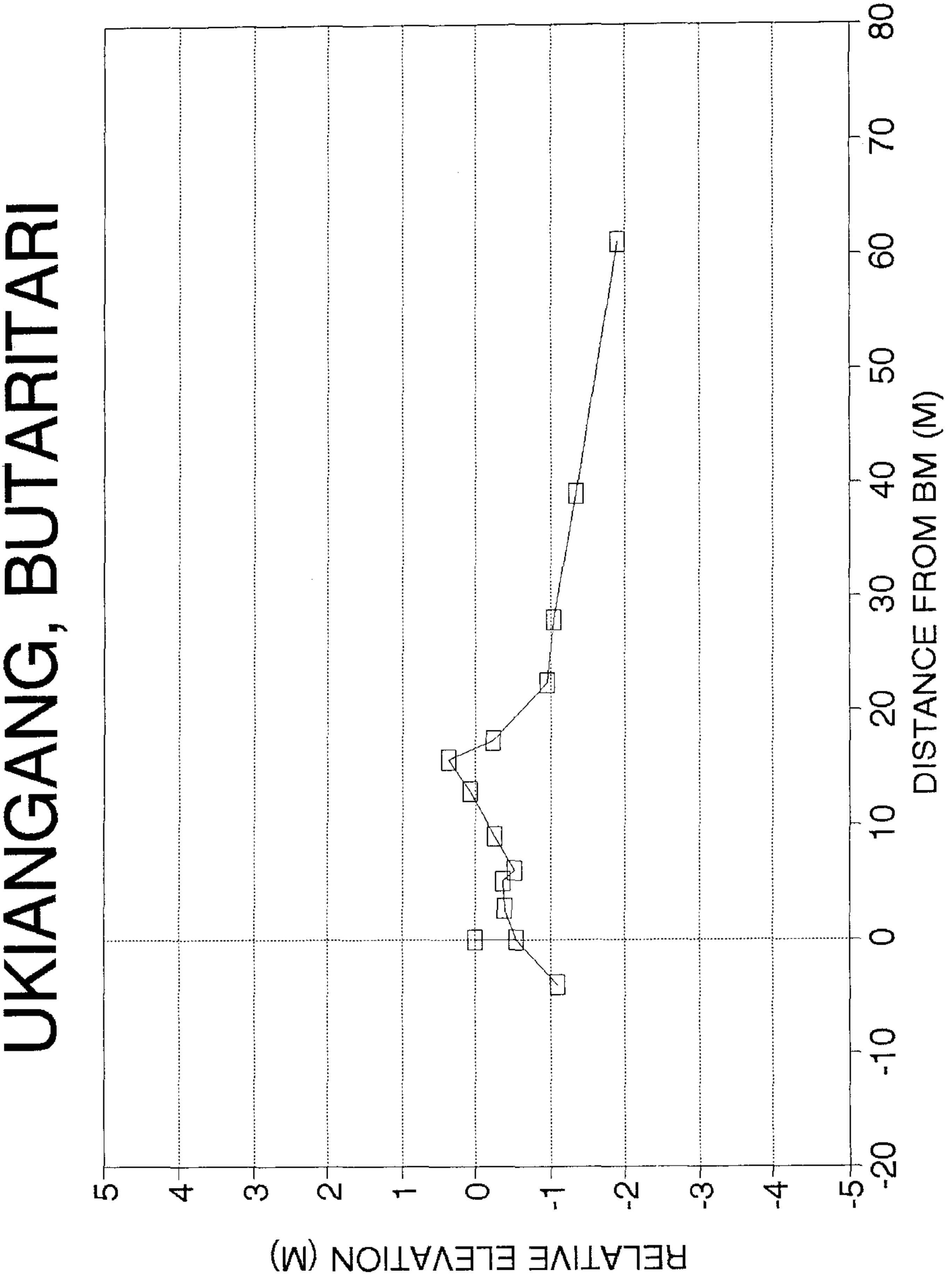
# TARIBO, ARORAE




TEBONTEBIKE, ABAIANG
RELATIVE ELEVATION (M)
5
4
3
2
1
0
-1
-2
-3
-4
-5
DISTANCE FROM BM (M)
0
10
20
30
40
50
60
70
80
90
100

# TEBUNGINAKO, ABAIANG

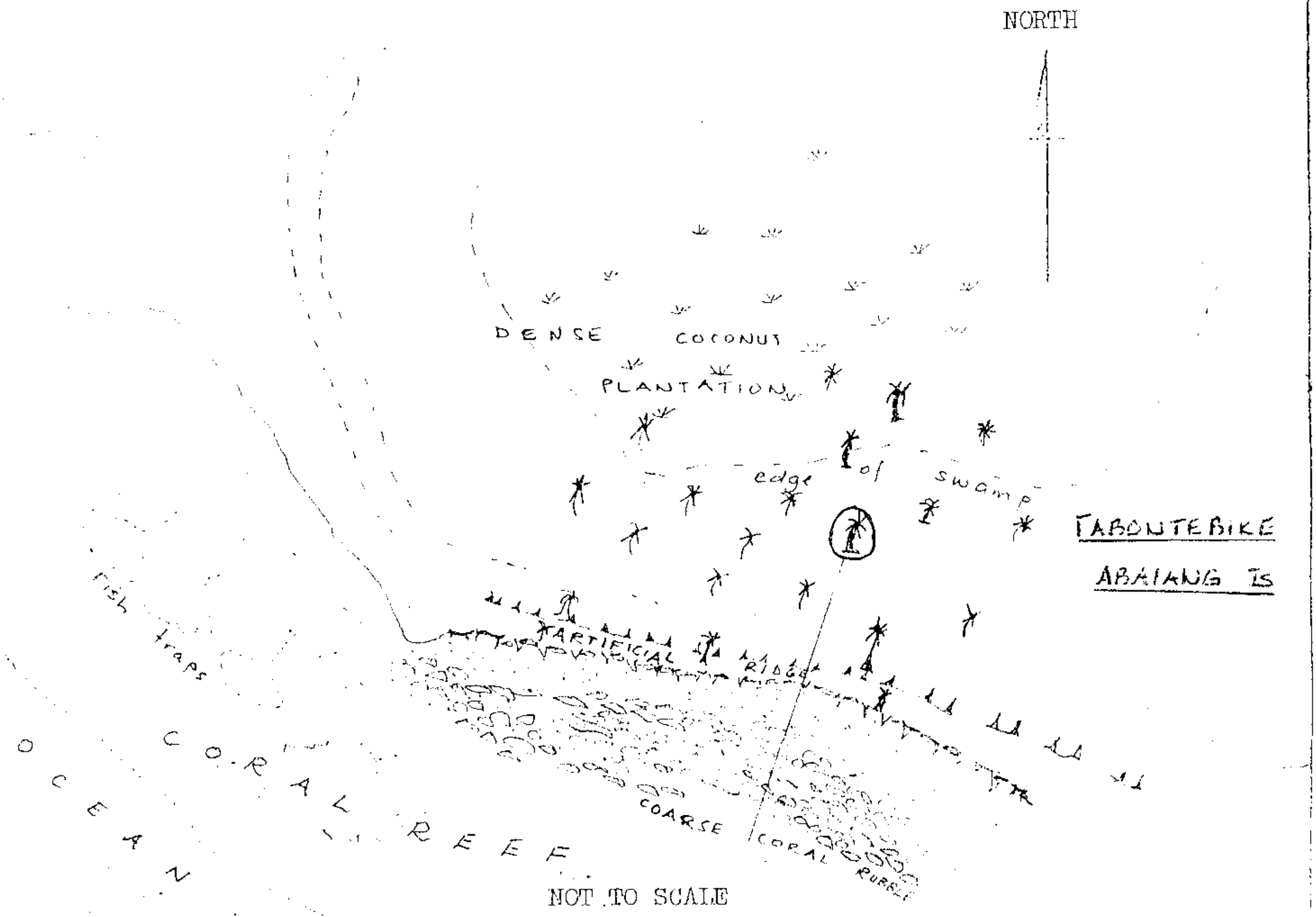



UKIANGANG, BUTARITARI
RELATIVE ELEVATION (M)
5
4
3
2
1
0
-1
-2
-3
-4
-5
DISTANCE FROM BM (M)
-20
-10
0
10
20
30
40
50
60
70
80

# APPENDIX 6

## BENCH MARK DESCRIPTIONS

## LOCATION DIAGRAM



NOT TO SCALE

## NOTES:

CONTROL MARK NO: TABONTEBIKE

LOCATION : Most ~~western~~ southern point of Abaiang Is

DESCRIPTION: Galv. Nail on SW of coconut tree (as above) about an foot above ground level. On the edge of abandoned babai bit on swampy land.

REFERENCES:

S.R. NO: 37/93

SHEET NO: TEMPORARILY

HEIGHT: REFERENCED.

CO-ORDINATES: (E): — (N): —

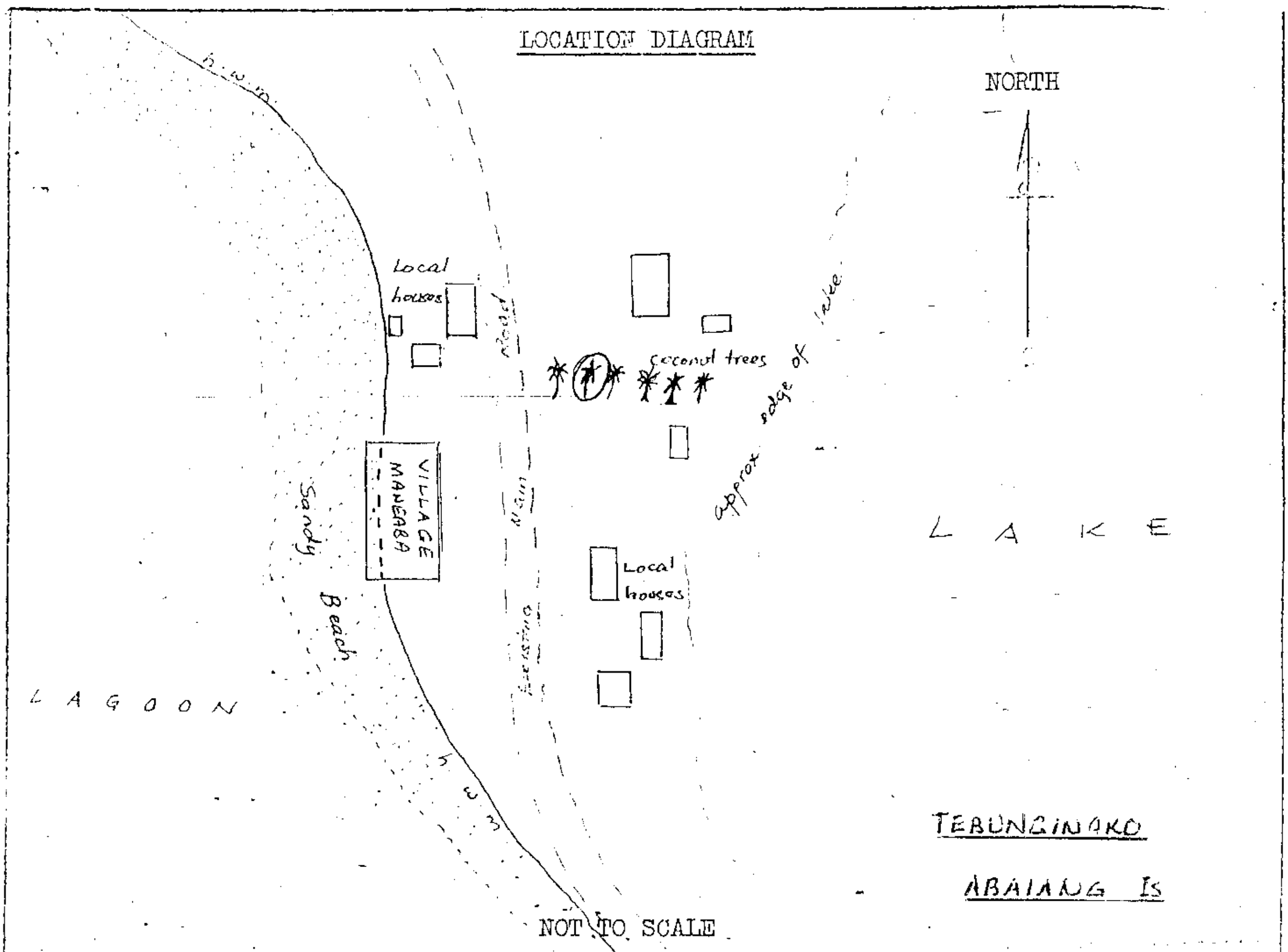
ESTABLISHED BY: AMBEROTI 29 - 05 - 93 DATE

REPLACED BY: DATE

GENERAL INFO:

OFFICE SURVEYOR

LOCATION DIAGRAM



NOTES:

CONTROL MARK NO: TEBUNGINAKO

LOCATION : Vicinity of Main Village Maneaba of Tebunginako

DESCRIPTION: Galv. nail at tree trunk approx. a foot above ground level (see above). Line of trees gives alignment of profile.

REFERENCES:

S.R. NO: 37/93

SHEET NO: —

HEIGHT: —

CO-ORDINATES: (E): — (N): —

ESTABLISHED BY: AMBEROTI 29 - 03 - 93
DATE

REPLACED BY:
DATE

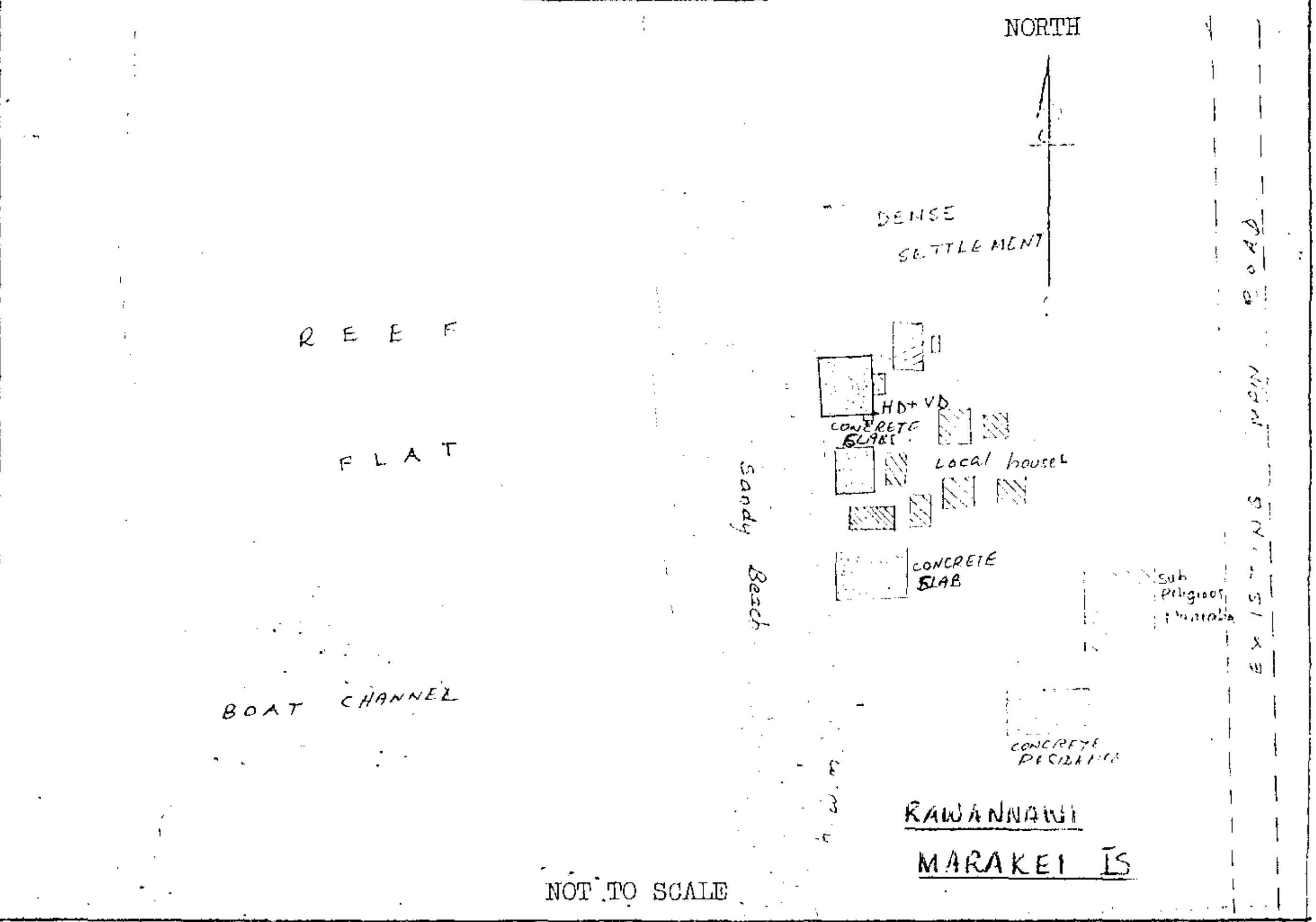
GENERAL INFO:

LANDS AND SURVEY
Ministry of
HOME AFFAIRS
BAIRIKI

OFFICE

SURVEYOR

## LOCATION DIAGRAM



## NOTES:

CONTROL MARK NO: RAWANNAWI

LOCATION : SE corner of remain concrete floor.

DESCRIPTION: Approx. 100m ~~from~~ NW of Sub Religious Maneaba and approx. 200m North of Main Channel. Alignment of profile is line of south wall of concrete slab.

REFERENCES:

S.R. NO: 37/93

SHEET NO: —

HEIGHT: —

CO-ORDINATES: (E): — (N): —

ESTABLISHED BY: Amberoti 30-03-93
DATE

REPLACED BY:
DATE

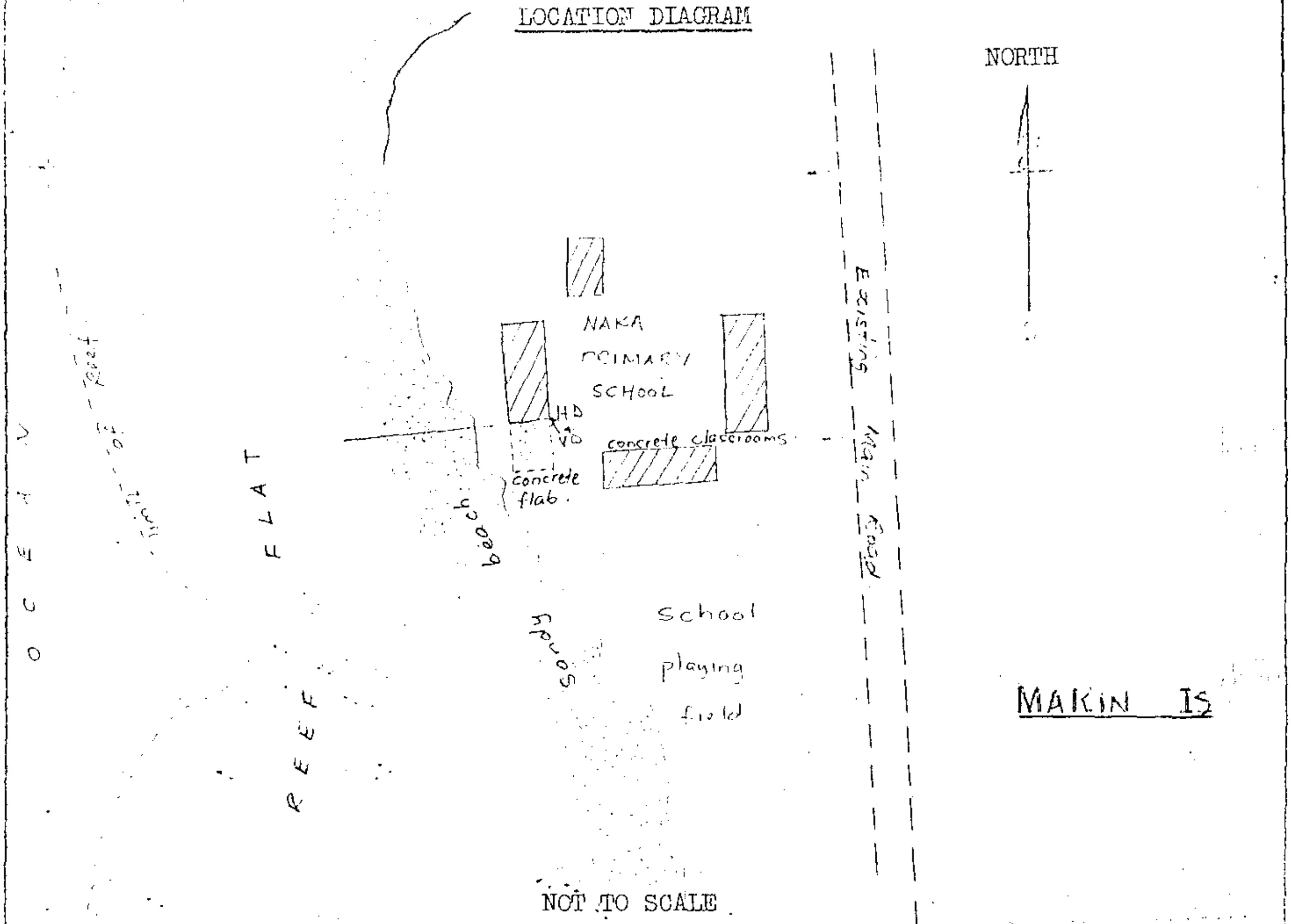
GENERAL INFO:

LANDS AND SURVEY
Ministry of
AFFAIRS

OFFICE

SURVEYOR

## LOCATION DIAGRAM



NOT TO SCALE

NOTES:

CONTROL MARK NO: NAKA PRIMARY SCHOOL (MAKIN IS)

LOCATION : S.E. corner of building inside Primary School Compound

DESCRIPTION: At top of intersection of South East corner of building and concrete flab at end of building: Alignment is along line of south wall of most western building.

REFERENCES:

S.R. NO: 37/93

SHEET NO: –

HEIGHT: –

CO-ORDINATES:(E): – (N): –

ESTABLISHED BY: Amberati Nikora 31-03-93
DATE

REPLACED BY: ...................... ..........
DATE

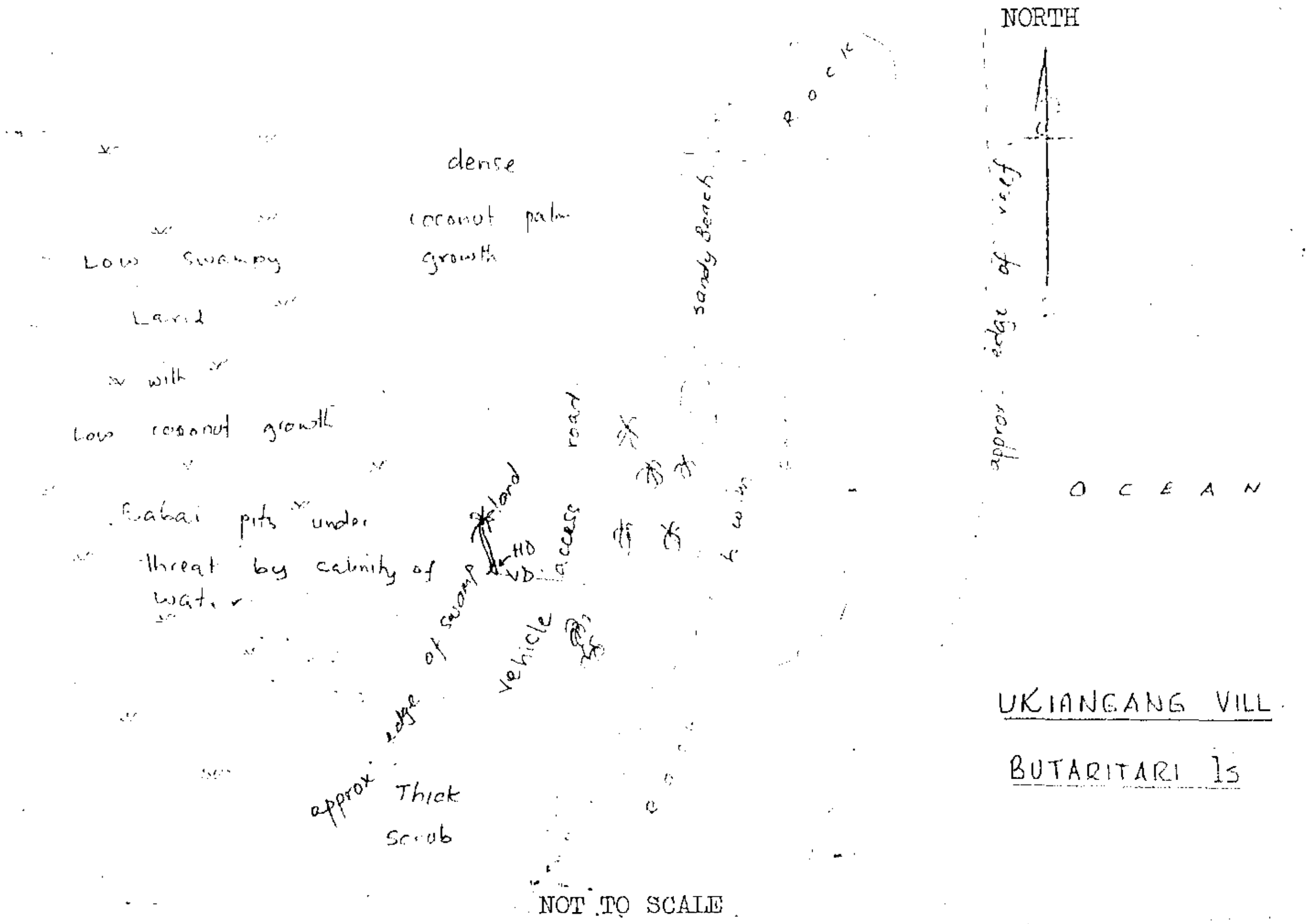
GENERAL INFO:

LANDS AND SUR[illegible] Ministry of [illegible]

Lands & Survey.
OFFICE

SURVEYOR

## LOCATION DIAGRAM



## NOTES:

CONTROL MARK NO: UKIANGANG

LOCATION : SW. tip corner of Ukiangang village

DESCRIPTION: A deep cut on a coconut tree approx. 3m from main road and about 20m from h.w.m. The cut is approx. 1 foot above ground level. Alignment of profile is 141° M Bearing

REFERENCES:

S.R. NO: 37/93

SHEET NO: —

HEIGHT: —

CO-ORDINATES: (E): — (N): —

ESTABLISHED BY: Amberoti Nikora 01/04/93
DATE

REPLACED BY:
DATE

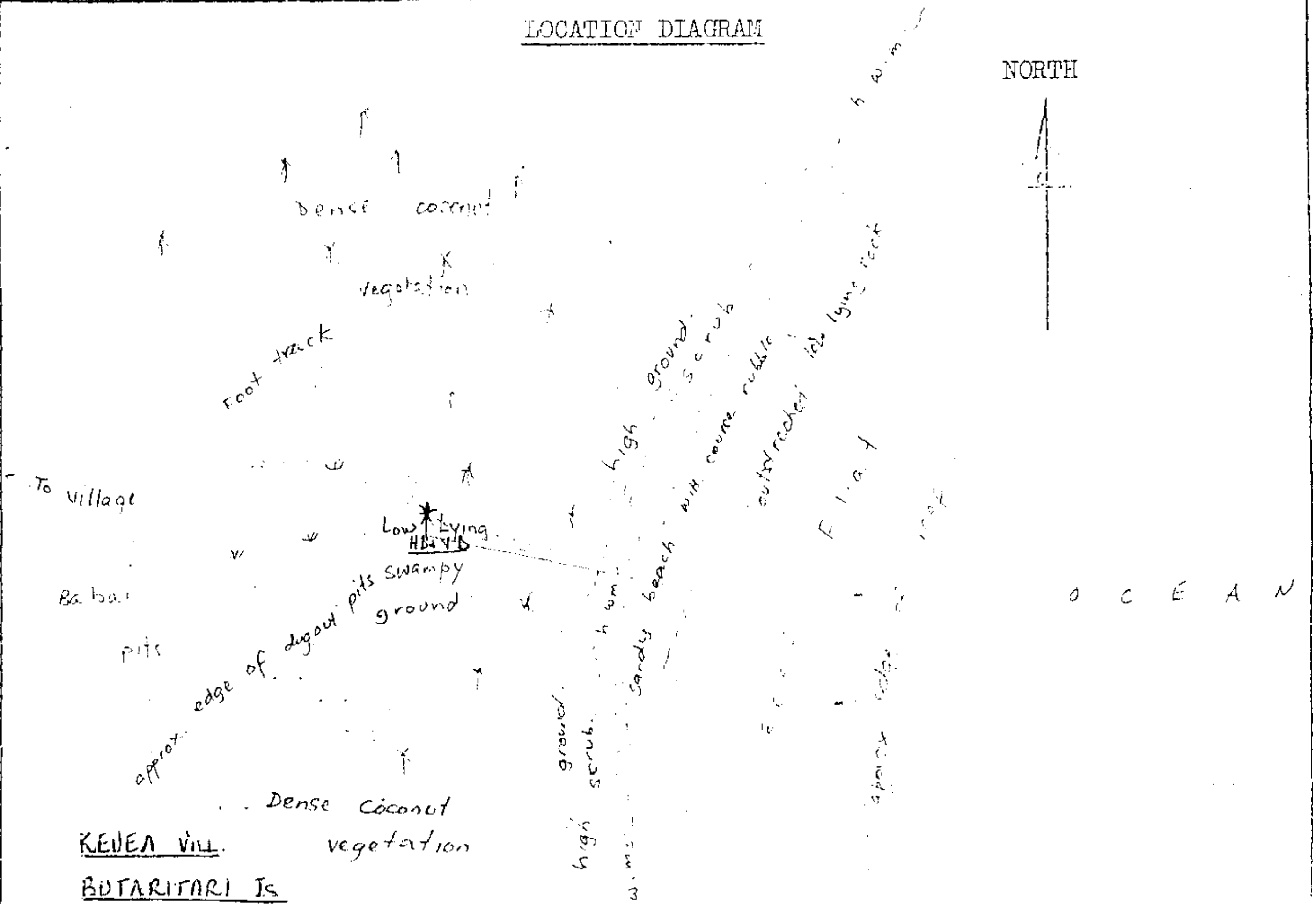
GENERAL INFO:

LANDS AND SURVEY
Ministry of
HOME AFFAIRS
KIRIBATI

OFFICE

SURVEYOR

## LOCATION DIAGRAM



NOT TO SCALE

NOTES:

CONTROL MARK NO: KEUEA VILLAGE (ocean side)

LOCATION : Ocean side of village close to babai pit with foot track

DESCRIPTION: Galv. nail on North side of coconut tree approx 4 foot above ground level. Alignment of profile is 121° MAG BRG

REFERENCES:

S.R. NO: 37/93

SHEET NO: –

HEIGHT: –

CO-ORDINATES:(E): – (N): –

ESTABLISHED BY: AMBEROTI NIKORA 02-04-93
DATE

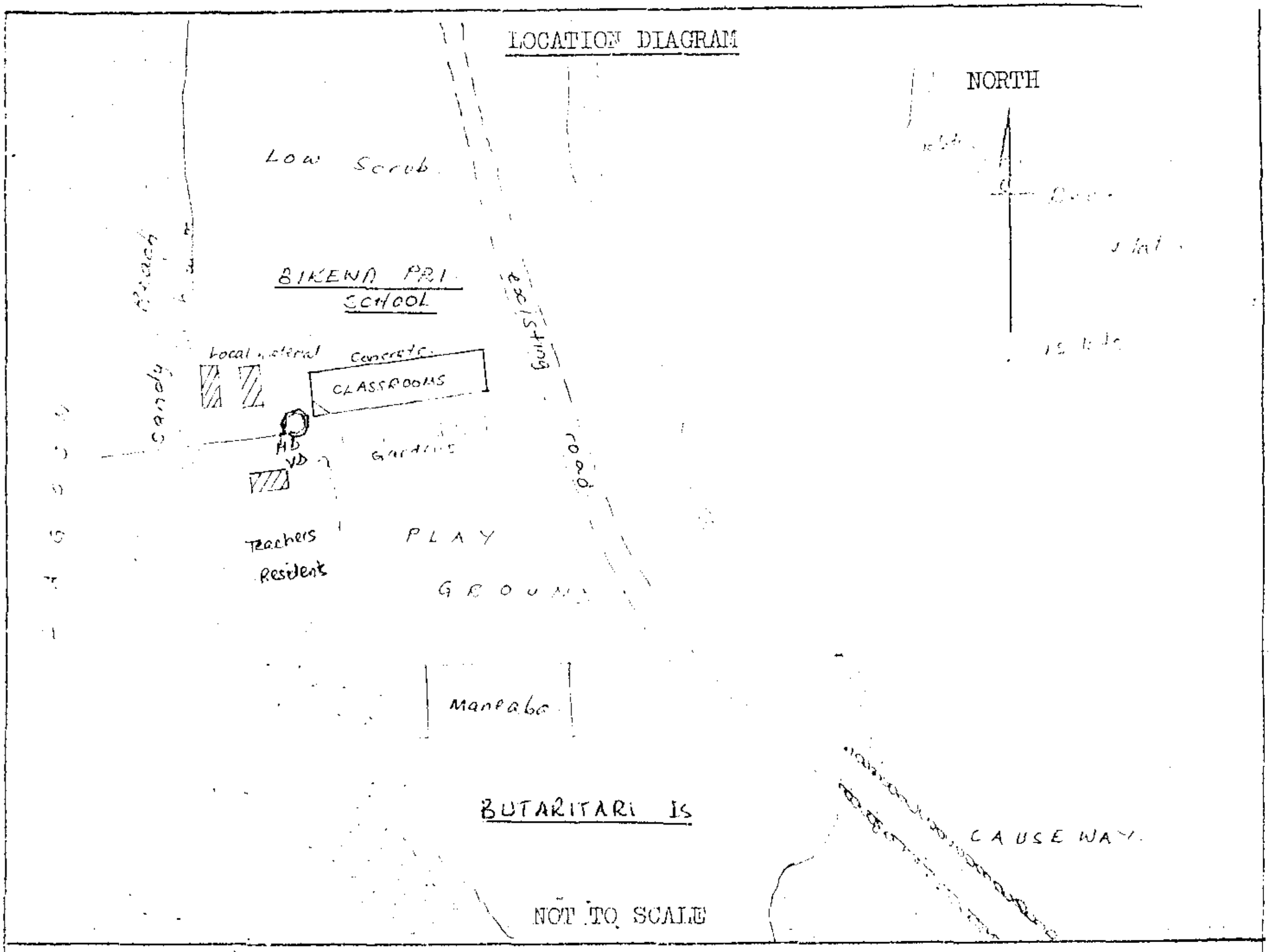
REPLACED BY:
DATE

GENERAL INFO:

LANDS AND SURVEY
Ministry of
HOME AFFAIRS

OFFICE

SURVEYOR



NOTES:

CONTROL MARK NO: BIKEWA PRIMARY SCHOOL

LOCATION : corner point of tank stand foundation

DESCRIPTION: Top of base of concrete water tank at SW corner of tank. (Alignment of profile is 297° MAG. BRG. (Basement of tank is octagonal in shape)

REFERENCES:

S.R. NO: 37/93

SHEET NO: –

HEIGHT: –

CO-ORDINATES:(E): – (N): –

ESTABLISHED BY: Amberoti Nikora 2 - 04 - 93
DATE

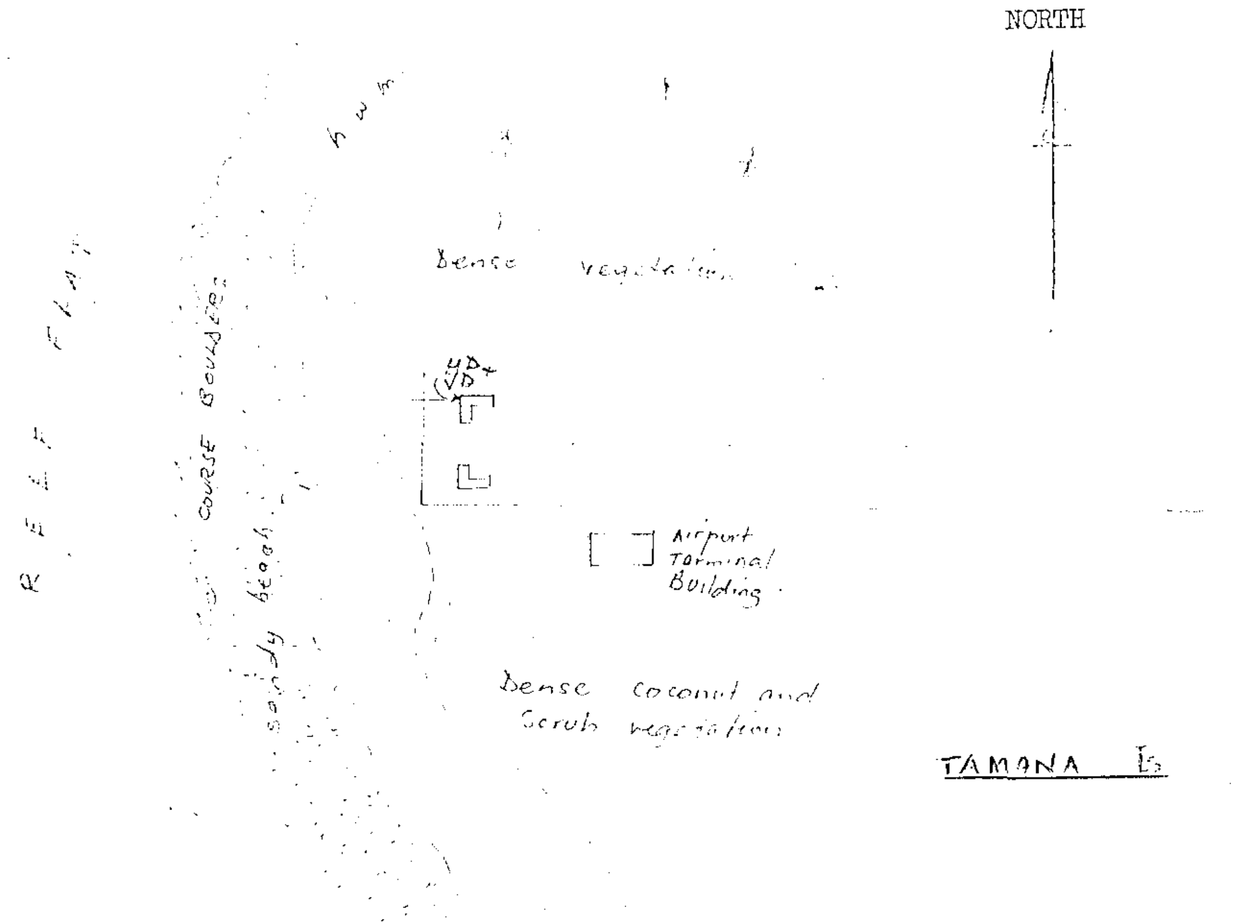
REPLACED BY: ……
DATE

GENERAL INFO: ……

OFFICE

SURVEYOR

## LOCATION DIAGRAM



NOT TO SCALE

## NOTES:

CONTROL MARK NO: BAREBUKA (Airport Site)

LOCATION : At NW corner of Tamana Airstrip

DESCRIPTION: Top of corner of concrete airstrip marking block

Alignment is 255° MAG

REFERENCES:

S.R. NO: 37/93

SHEET NO: —

HEIGHT: —

CO-ORDINATES: (E): — (N): —

ESTABLISHED BY: AMBEROTI NIKORA 5 - 04 - 92

DATE

REPLACED BY:

DATE

GENERAL INFO:

OFFICE

SURVEYOR

## LOCATION DIAGRAM

NOT TO SCALE

TARIBO NOTES:

CONTROL MARK NO: TIONA (Primary School Site)

LOCATION : West of School Compound close to Maneaba

DESCRIPTION: 16m from ~~top of~~ SW Corner of outside concrete slab of concrete foundation immediately south of School Maneaba. Alignment of profile is ~~235°~~ 229° MAG

REFERENCES:

S.R. NO: 37/93

SHEET NO: —

HEIGHT: —

CO-ORDINATES:(E): — (N): —

ESTABLISHED BY: Amberoti Nikora 06-04-93
DATE

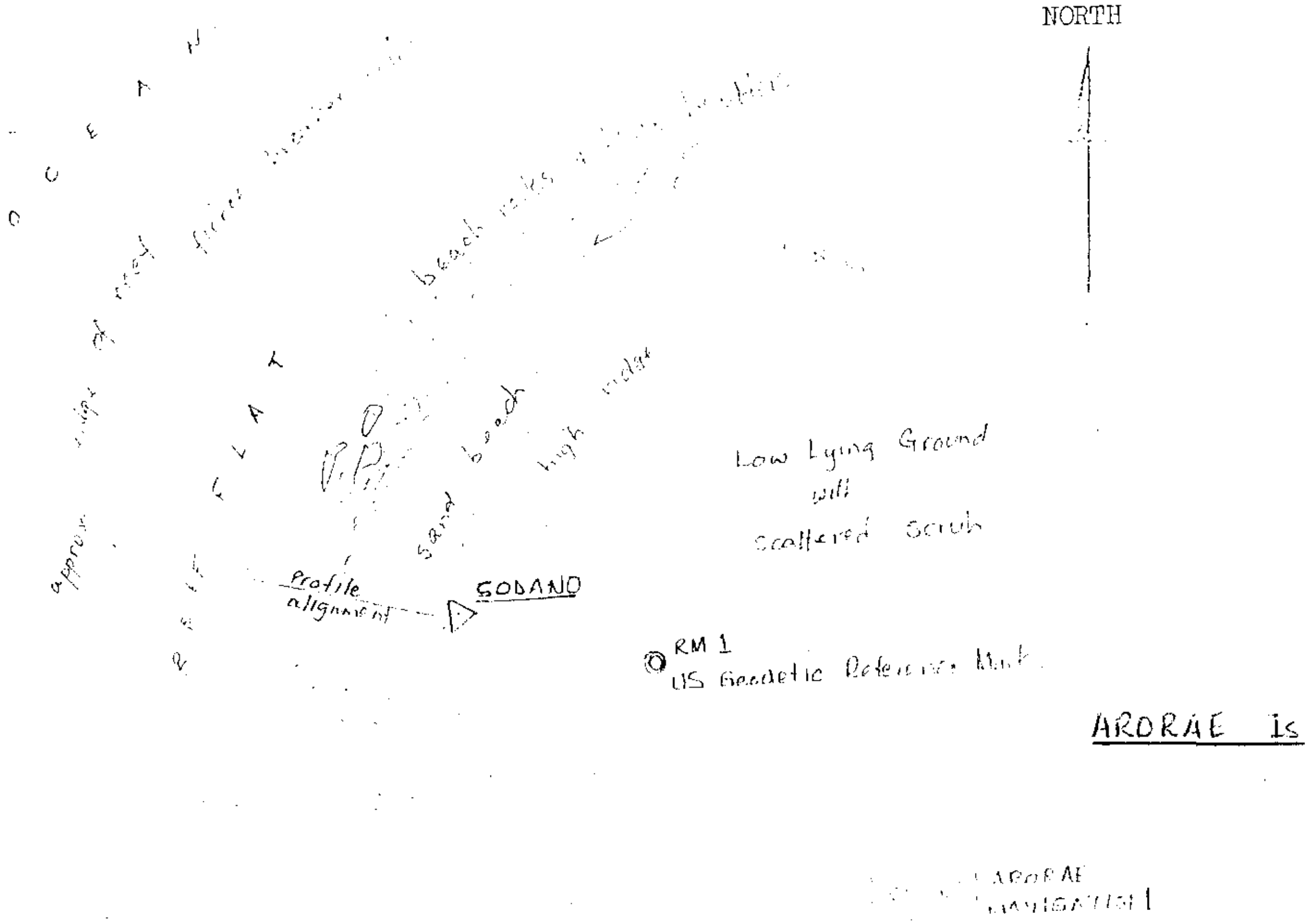
REPLACED BY:
DATE

GENERAL INFO:

OFFICE

SURVEYOR

## LOCATION DIAGRAM



NOT TO SCALE

## NOTES:

CONTROL MARK NO: RM 1 (US Geodetic Reference Mark)

LOCATION : NW tip of Arorae Island

DESCRIPTION: Brass plaque set in concrete approx 10m SE of SODANO Trig Stn

Alignment of profile 232° MAG

REFERENCES:

S.R. NO: 37/93

SHEET NO: –

HEIGHT: –

CO-ORDINATES: (E): – (N):

ESTABLISHED BY: AMMSRE (1965) (Amberati Nikora) (06 - 04 - 93)
DATE

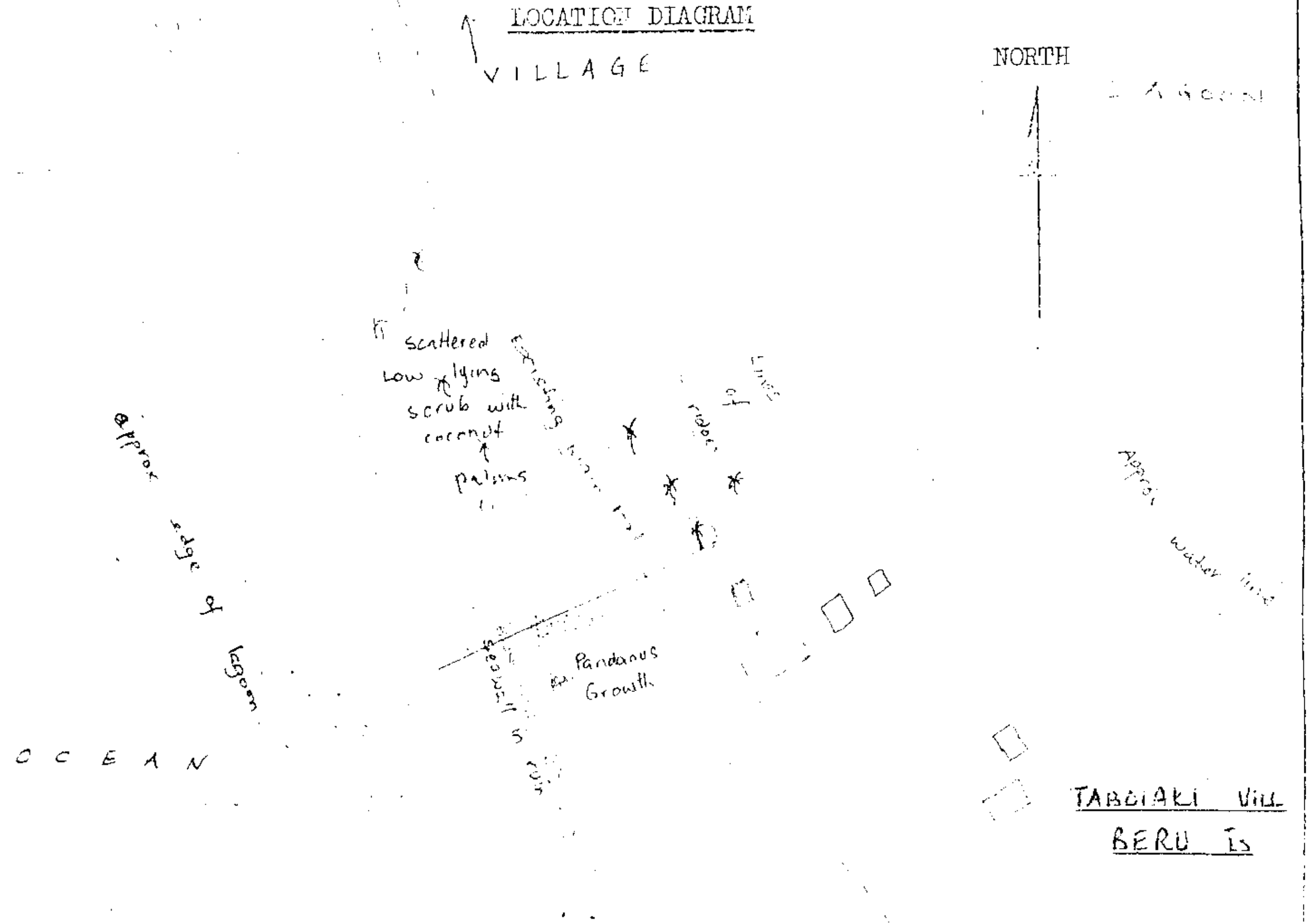
REPLACED BY:
DATE

GENERAL INFO:

OFFICE

SURVEYOR

## LOCATION DIAGRAM



NOT TO SCALE

## NOTES:

CONTROL MARK NO: TABOIAKI (Taborengrenge)

LOCATION : Southern end of main village of Taboiaki

DESCRIPTION: On Nth side of coconut tree penetrated galv. nail about a foot above ground level. Alignment of profile is not taken.

REFERENCES:

S.R. NO: 37/93

SHEET NO: –

HEIGHT: –

CO-ORDINATES: (E): – (N): –

ESTABLISHED BY: AMBEROTI NIKORA 07 - 04 - 93
DATE

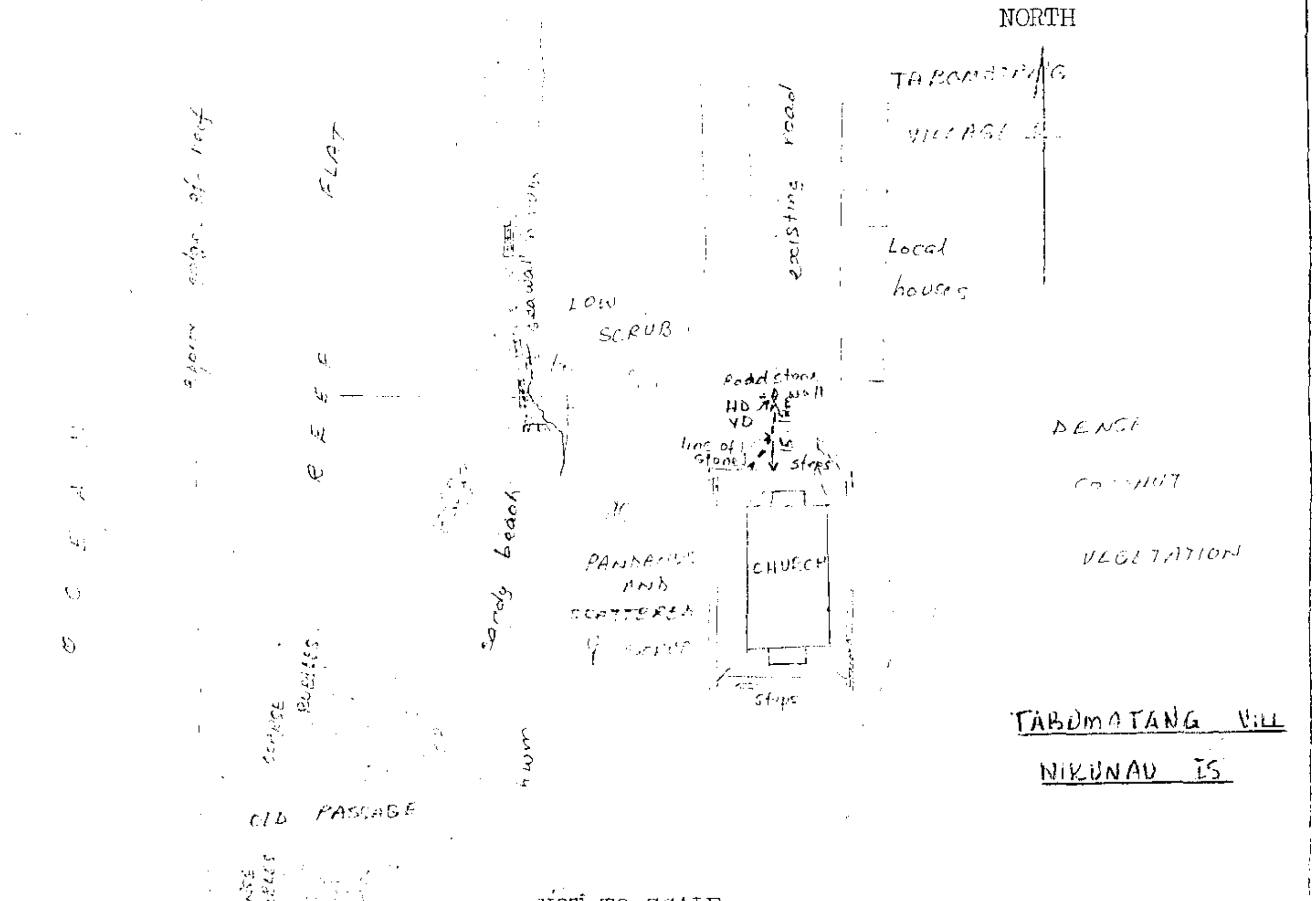
REPLACED BY:
DATE

GENERAL INFO:

OFFICE

SURVEYOR

## LOCATION DIAGRAM



TABOMATANG Vill

NIKUNAU IS

NOT TO SCALE

## NOTES:

CONTROL MARK NO: TABOMATANG (NIKUNAU IS)

LOCATION : 15.10m North of bottom step to church.

DESCRIPTION: Top of stone wall of road at above distance flush with ground level. BM lies on seaward line of stones. Alignment of profile is 207° MAG

REFERENCES:

S.R. NO: 37/93

SHEET NO: –

HEIGHT: –

CO-ORDINATES: (E): – (N): –

ESTABLISHED BY: AMBEROTI NIKORA 8-04-93
DATE

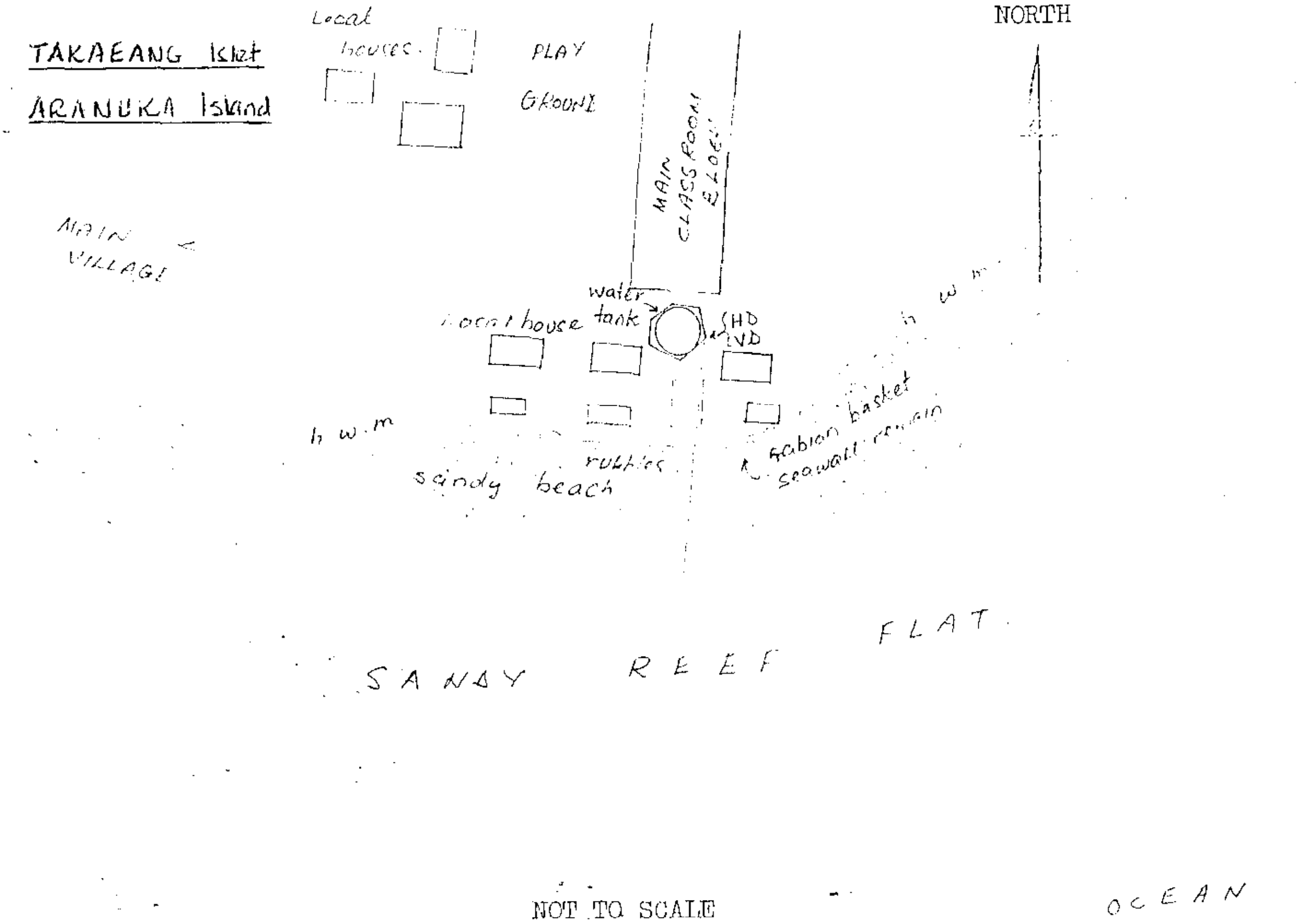
REPLACED BY:
DATE

GENERAL INFO:

OFFICE

SURVEYOR

## LOCATION DIAGRAM



NOT TO SCALE

NOTES:

CONTROL MARK NO: TAKAEANG (school Site).

LOCATION : Water Tank } At South end of main classroom block.

DESCRIPTION: Top of corner of water tank basement on line with eastern wall of classroom Alignment is forgotten.

REFERENCES:

S.R. NO: 37/93

SHEET NO: —

HEIGHT: —

CO-ORDINATES: (E): — (N): —

ESTABLISHED BY: BAREROTI NIKORA 09-4-93

DATE

REPLACED BY:

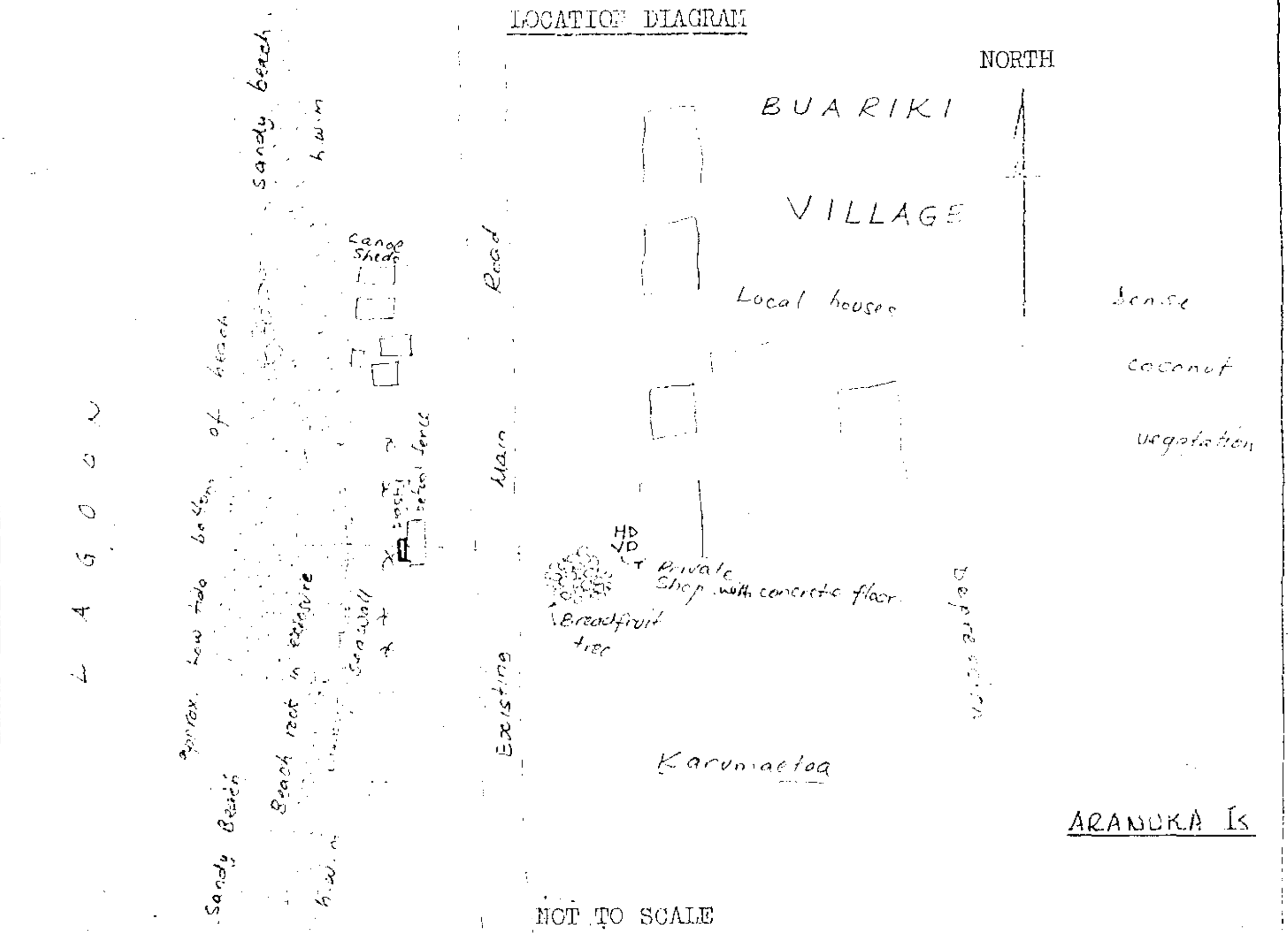
DATE

GENERAL INFO:

OFFICE

SURVEYOR

## LOCATION DIAGRAM



NOT TO SCALE

NOTES:

CONTROL MARK NO: BUARIKI SITE (ARANUKA Is)

LOCATION : Southern End of Buariki Village in the resettlement of Karumaetoa

DESCRIPTION: Top of SW corner of concrete sho foundation of privately run shop. The shop has corrugated roofing with local wall material. Alignment of profile is

REFERENCES:

S.R. NO: 37/93

SHEET NO: –

HEIGHT: –

CO-ORDINATES: (E): – (N): –

ESTABLISHED BY: Amberati Nikora 10 - 4 - 93
DATE

REPLACED BY:
DATE

GENERAL INFO:

LANDS AND SURVEY

OFFICE SURVEYOR

# APPENDIX 7

## APPROXIMATE COSTS FOR FORESHORE PROTECTION ALTERNATIVES IN KIRIBATI

**Table A7.** Approximate costs of foreshore response options.

| COSTS (per linear m or km) | TYPE OF RESPONSE OR FORESHORE PROTECTION, COMMENTS |
|---|---|
| Approx. $ 5,000/km | Relocation of road back from shoreline.<br>Does not included land use cost (see note 3 below). |
| Approx. $ 5-10/metre | No action. No construction or maintenance costs.<br>For a site with long term erosion rate of 0.5m/yr, resulting land and tree losses would be valued at about $5-10 per linear metre of beach lost. This does not consider value of lost buildings which will vary from site to site. |
| Needs to be determined. | Relocation of buildings which can be easily moved or reconstructed.<br>Does not include land use cost (see note 3 below). |
| $100-200/metre | **Low Cost Protection**<br>Coral rock seawall, vertical (stone packed), no concrete used. *Unsuitable for exposed sites. High maintenance costs for labour.*<br>Coral rock seawall, vertical or steeply sloping, with concrete. *Marginally better than above, depending upon amount of concrete used. Moderate maintenance costs.* |
| $200-400/metre | **Medium Cost Protection**<br>Sandbag seawall, vertical, cement/sand grout filled bags. *Stability varies with site exposure and foundation preparation. Low maintenance cost for sites with restricted wave action (for example, protected harbours and causeways at narrow inlets.*<br>Gabion rock basket, 1 x 1 metre section, coral rock filled. *Life of structure usually limited to 3-5 years by corrosion of wire. Not suitable for exposed locations. Maintenance difficult and usually requires replacement of failed section.* |
| $400-600/metre | **High Cost Protection**<br>Sandbag seawall, gently sloping, cement/sand grout filled bags.<br>*Recommended only for protection of very valuable property. Costs may be 50% greater, depending upon thickness, height and concrete percentage used. Generally low maintenance.* |

Notes:

1. Sources: AIDAB (1988), Holden (1992), and Woodroffe and McLean (1992).

2. Road costs are assumed to be formed of approximately 0.4 m of reef material, compacted and graded. It is also assumed that some compensation will be necessary for lost land and coconut trees.

3. Land use values: It is important to distinguish between urban land, which is only found in South Tarawa and non-urban land, upon which subsistence is practised. An approximate figure which can be used for the value of land on the outer islands is $1000/acre (approx. $2500/ha). In this respect, all land in the Line and Phoenix Islands is owned by Government, which bought the remaining land that it did not own only a few years ago at this rate. Another approach towards calculating the value of land is to value it in terms of the coconuts it supports (one of the main cash crops). The value put on an individual coconut tree, should compensation be paid for development projects is $25. Coconut tree densities are typically 80-150/ha, representing land values of $2000-3750/ha. This assigns no capital value to other plants or resources on the land, despite their role in subsistence economy (Woodroffe and McLean, 1992).

# APPENDIX 8

## COASTAL PROTECTION ALTERNATIVES

**Note**: The material in this Appendix is based upon the SOPAC Technical Report by Holden (1992) on coastal protection for Tebunginako Village, Abaiang Atoll. It has been modified to represent general conditions for the outer islands of the Gilbert Group.

## COASTAL PROTECTION ALTERNATIVES

Several of the most common alternatives for beach protection are discussed below with respect to their advantages and disadvantages, their labour, equipment and materials requirements, and their maintenance problems. Some design specifications are given for each alternative and comments are made on their feasibility for the outer islands in the Gilbert Group. This discussion provides a comparative summary of some shore protection alternatives and indicates those appropriate for outer islands in the Gilbert Group. A summary of these coastal alternatives is presented in Table A8 for ease of reference.

### Groynes

A groyne is a structure placed approximately perpendicular to the shoreline on a beach. The groyne acts as a dam to the littoral drill process and accumulates material on the updrill side. The build up of the beach on the up drift side is an immediately apparent benefit, which makes the groyne initially look attractive. The major disadvantage is that while accretion is occurring on one side of the groyne, erosion is occurring on the down drift side of the groyne. Since groynes cause erosion on the down drill side, the net benefit is questionable unless the groyne is filled artificially when it is constructed. Groynes do not reduce the wave energy striking the shore. Groynes may also force littoral drill to move offshore around the groyne and thus beach material may be lost to the coastal system.

To mitigate the down-drift erosion, groynes must be filled artificially at the time of construction. Earth moving equipment (loader & truck) would have to be brought to fill the groynes with a sufficient quantity of material. Material to fill the groynes would need to be hauled from an alternate area with suitable sand. A well constructed groyne which is artificially filled at the time of construction should not require maintenance.

Groynes can be built with manual labour from locally available material such as rocks or logs fixed perpendicular to the shoreline. A rock mound groyne must have the heaviest available stones placed on top to protect against wave action. Log groynes require some anchoring method to hold the logs in place.

Because of the down drift erosion effects and the possibility that they will force material offshore, in general groynes are not recommended.

### Offshore Breakwater

An offshore breakwater is a breakwater structure which is located parallel to the shoreline a short distance offshore. An offshore breakwater causes the area behind the breakwater to be sheltered from wave action resulting in a build-up of beach material like a tom bolo. An offshore breakwater will trap littoral drift and will also cause erosion on its downdrift side, like a groyne. Unlike a groyne, an offshore breakwater does reduce the wave energy striking the shore and will not force beach material offshore into deep water.

An offshore breakwater should also be artificially filled with beach material at a time of construction to avoid downdrill erosion. If an offshore breakwater is properly constructed and artificially filled at the time of construction, it should require no further maintenance.

An offshore breakwater must be built from heavy rock which can withstand the design wave forces. Since an offshore breakwater requires armour stone weights of several hundred kilograms, and construction offshore in deeper water, it cannot be constructed by manual labour. Heavy equipment is required to move and place the large quantities of heavy rock and to fill behind the breakwater.

An offshore breakwater is a very expensive structure for which neither the rock nor the heavy equipment is not generally available on outer islands in the Gilbert Group. Therefore, it is not feasible.

### Artificial Nourishment

Artificial nourishment refers to the dumping of sand on an eroding beach. This artificially supplied beach material will gradually move along the eroded area and will continue to move down-drift with the littoral process. The principal advantage of artificial nourishment is that it does not create an obstruction on the beach and it leaves the beach with a natural appearance. The principal disadvantage is that artificial nourishment is not maintenance free and it must be repeated from time to time as the material moves downdrift from the erosion area.

Artificial nourishment requires heavy machinery to transport and dump large amounts of beach material. The large amounts of material which must be transported cannot be handled by manual labour. There must be a readily available and suitable source of beach material. Material could only be borrowed and hauled from an area of coastal accretion or land based borrow pits. In general, reef flat materials do not make suitable material for beach nourishment since it is composed of a high percentage of angular, coarse material. Attempts to reclaim or put buildings on the artificially nourished area is not recommended and could only worsen an existing problem.

Since artificial nourishment needs heavy equipment and will need to be repeated periodically it is not practical on outer islands in the Gilbert Group.

### Seawalls

A seawall is a structure built along the land-sea boundary which only protects against erosion of land and does not attempt to protect or save the beach. Seawalls are constructed when valuable land or buildings have been built too close to the natural boundary of the sea, and are **only advantageous when land or buildings are more valuable than the cost of the seawall.** A disadvantage of seawalls is that they often cause erosion in front of the wall. The amount of maintenance required for a seawall depends inversely on how well the wall has been built.

The most durable seawalls are rubble mound structures with armour stone rock sizes of several hundred kilograms and appropriate filter layers. A properly constructed rubble mound seawall can absorb wave energy and minimise wave reflection. A vertical concrete seawall, on the other hand, reflects wave energy and is susceptible to cracking and concrete failure.

Heavy equipment would be required to move and place the large quantities of heavy rock and armour stone. As with the offshore breakwater, this is an very expensive structure for which neither the rock nor the equipment is available on outer islands. Therefore, it is not feasible.

Some possible alternatives to rubble mound or vertical seawalls are stepped seawalls or sandbag seawalls, which may offer reasonable temporary protection against land erosion. **Gabions (or rock-filled wire baskets) are another alternative form of seawall which are not long lasting and must be regarded as short term (2-4 years) structures only.**

The only material which is abundantly available on outer islands is sand and some rock from previous attempts at protection. A reasonable armouring could be made by filling sand bags with a cement and sand mix (grout). A seawall cross section using these grout filled sand bags was proposed by Holden (1992).

The grout bags are a compromise alternative for armour stone and are not as durable as the rubble mound seawall. Because the grout bags are much smaller than the normal armour stone sizes, certain precautions are necessary for the seawall to be viable. The grout mix must be rich enough to give good bonding between individual bags and the two layers of bags must be carefully placed to insure 50% overlap in both horizontal directions to make a solid unit. The solid unit effect should compensate for the small size of the grout bags.

A seawall must be built on land or as close to the land as possible so it does not extend into the water any more than necessary for the following reasons:

(i) The toe of the seawall must extend below the beach level and construction would be difficult under water.

(ii) If the structure is in water, it will likely cause some beach erosion in front of the seawall.

(iii) Any protrusion into the water will cause the build-up and erosion effects of a groyne.

The ends of the seawall must be rounded and the wall tied back into the land to avoid end scour. The closer the seawall is built into the land the better are its chances of survival.

**A seawall should be built only to protect property which is valuable to the community and cannot be moved back from the seashore.**

### Setbacks

Setback is the distance a building is built back from the natural boundary of the sea. By building permanent buildings at a safe setback distance, the beach and shoreline can be allowed to fluctuate and the buildings will not be lost or endangered. An advantage of setback of building is that the beach is left in its natural state and allowed to fluctuate naturally with no expensive structures being necessary to protect either the beach or the land. A disadvantage is that setbacks require government regulations and enforcement of these regulations. Some land owners perceive a disadvantage in being any distance from the shoreline with respect to loading and unloading of boats or fishing equipment.

The natural boundary is the high water "mark". It is not the high water level because it also includes the effects of common and normal storms and wave runup. The natural boundary is the natural mark of the ocean on the land, made by the normal high tide plus the wave runup. Since the natural boundary represents the combined effect of both high tides and wave runup, and is easily seen on the soil and vegetation, it is the best mark from which to measure setback distances or elevations of coastal structures.

Considerable work has been done by Coastal Zone Management agencies to determine appropriate setback distances. The setback distance is usually chosen to save a building or other amenity from loss for a specific period of time. The time period is often based on one of the following: the estimated life of the structure (variable from less than 10 to 50 years) or an estimate of the 100 yr erosion limit, the 200 yr storm event, etc. Thus when considering setbacks in the outer islands of the Gilbert Group shoreline stability and/or rates of shoreline erosion need to be taken into consideration.

The setback distance should be appropriate to the cost and the intended life of the building. A setback of about 10-15 m from the natural boundary would be appropriate for low cost and/or short term buildings for the lagoon shoreline of outer islands in the Gilbert Group. Buildings intended for long term use, such as churches, stores, government offices and meeting houses (maneaba) should be set back further (20-30 m) from the shoreline.

**Table A8.** Summary of Coastal Protection Alternatives

| STRUCTURE | ADVANTAGE | DISADVANTAGES | APPROPRIATENESS FOR OUTER ISLANDS |
|---|---|---|---|
| **Groynes** | Immediate buildup on updrift side.<br>Depending upon design may be easy to construct from local materials. | Immediate erosion on downdrift side.<br>Beach obstruction.<br>Movement of drift off shoreline. | Generally not recommend because of effects of disadvantages. |
| **Offshore Breakwater** | Buildup of material inside the breakwater.<br>No beach obstruction | Erosion downdrift of the structure.<br>Requires heavy equipment and construction supervision. | Large boulders and heavy equipment generally not available. Not feasible. |
| **Seawall** | Protects land area only.<br>Depending upon design can be built on land by manual labour. | May cause beach erosion.<br>Requires proper design and construction supervision. | To be used only where threatened property and buildings are valuable and cannot be relocated. |
| **Artificial Nourishment** | Preserves the natural beach.<br>Does not disrupt natural processes. | Requires periodic replenishment.<br>Requires heavy equipment and a supply of sand. | Problem with equipment being available.<br>Not feasible for small projects. |
| **Setback/Relocation** | Preserves the natural beach.<br>Avoids future coastal erosion problems. | Requires government regulation and enforcement.<br>Requires compensation for land and trees.<br>Offers no protection for existing shoreline. | Can be implemented by enforcement of regulations.<br>Recommended. |

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